Chapter 1

Introduction

1.1. BACKGROUND

Section 7(a) of Public Law 97-414 directs the Secretary of Health and Human Services to "(1) conduct scientific research and prepare analyses necessary to develop valid and credible assessments of the risks of thyroid cancer that are associated with thyroid doses of Iodine 131; (2) conduct scientific research and prepare analyses necessary to develop valid and credible methods to estimate the thyroid doses of Iodine 131 that are received by individuals from nuclear bomb fallout; and (3) conduct scientific research and prepare analyses necessary to develop valid and credible assessments of the exposure to Iodine 131 that the American people received from the Nevada atmospheric nuclear bomb tests; ..."

The National Cancer Institute (NCI) was requested to respond to this mandate. This report describes the data, methodologies, and analyses that were used to address parts (2) and (3) of the mandate. The report does not address the issue of the risk of thyroid cancer associated with thyroid doses of iodine-131. Efforts to estimate this risk have been and continue to be the objective of a number of past and ongoing studies of persons exposed to iodine-131 from diagnostic procedures or from environmental contamination in Utah, in the Hanford, Washington area, in Sweden, Slovenia and Israel, and in Belarus, the Russian Federation and Ukraine.

A task group, established to assist the NCI in this effort, suggested that it might be possible to estimate, for each atmospheric nuclear weapons test, the iodine-131 (^{131}I or I-131) exposures from fallout for representative individuals and for the populations of each county of the contiguous U.S. In this report, "Nevada atmospheric bomb tests" is interpreted as meaning "tests conducted at the Nevada Test Site that released radioactive materials into the atmosphere," thus including also cratering tests and underground tests which vented, or released radioactive materials into the atmosphere, as well as the tests that were part of a peaceful applications program. All such tests were considered.

The most significant atmospheric weapons tests with respect to fallout occurred in the 1950s, during which time most of the monitoring of environmental radioactivity consisted of gross beta measurements. Because the radioactive half-life of ^{131}I is about 8 days, the activity of ^{131}I present in the samples collected more than 35 years ago has completely decayed and cannot be measured retrospectively. Therefore, the estimation of ^{131}I exposures dating back to the 1950s must essentially be derived either from the original measurements of gross beta activity, from current or past measurements of radionuclides other than ^{131}I, or from mathematical models.

1.2. METHODOLOGY

Previous studies have suggested that once ^{131}I from fallout has been deposited on vegetation the main exposure route to man is, for individuals who drink milk, the ^{131}I transported from the vegetation to cows consuming the vegetation to the milk produced by the cows to man via the consumption of milk, i.e., via the pasture-cow-milk food chain (Bergström 1967; Eisenbud and Wrenn 1963; Garner and Russell 1966; UNSCEAR 1972). This is due to a combination of factors: (a) cows graze over large areas of ground, (b) the population regularly consumes substantial amounts of fresh cows' milk, and (c) there is a short delay time between the production and consumption of milk.

However, exposures resulting from inhalation of contaminated air or the ingestion of foodstuffs other than cows' milk may be more important than those resulting from ingestion of cows' milk for people who drink little or no cows' milk or for people who drink milk from cows that were not on pasture. This report will focus on the assessment of doses of radiation to the thyroid of people resulting from the consumption of milk produced by cows grazing on pasture contaminated with ^{131}I from fallout and will discuss inhalation of contaminated air and the ingestion of foodstuffs other than cows' milk in much less detail. *Figure 1.1* illustrates the various steps involved in the dose assessment.

When absorbed into the body, ^{131}I concentrates in the thyroid to such an extent that the radiation absorbed doses in other organs and tissues are negligible in comparison. For a given intake of ^{131}I, the radiation absorbed doses in the thyroid of people vary as a function of age, the highest doses being received by infants. In this report, thyroid doses are calculated for various age categories (i.e., fetus, infant, child, adult male and female).

For each atmospheric test, radiation absorbed doses to the thyroids of people have been estimated for the population of each county subdivided by age and sex, assuming average, high, and low exposure to ^{131}I. Collective thyroid doses also have been calculated for the entire population of each county *(Figure 1.2)* and for the entire population of the contiguous United

Figure 1.1. Steps involved in the assessment of the exposure to I-131 that the American people received from the atmospheric bomb tests (simplified diagram).

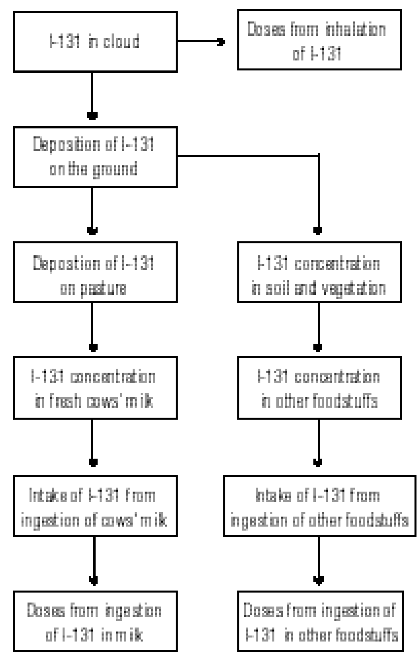
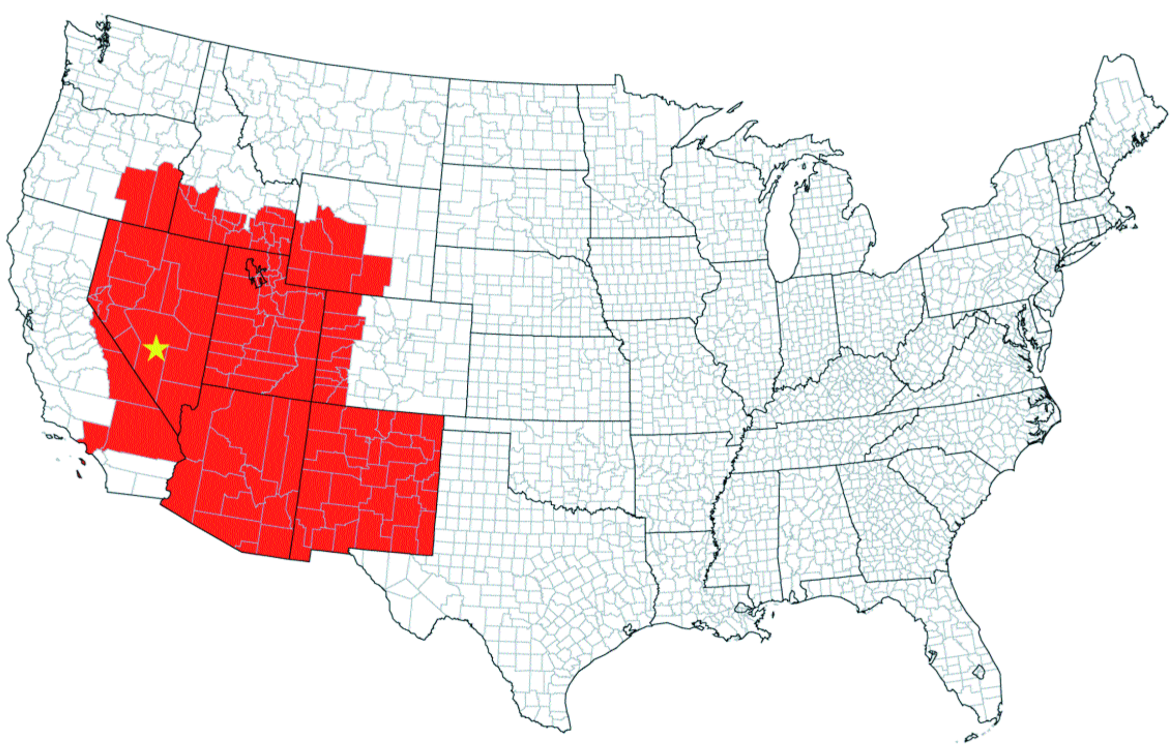


Figure 1.2. County boundaries of the contiguous United States. The area in red represents the geographical coverage of the Offsite Radiation Exposure Review Project (ORERP) study. The location of the Nevada test site is marked with a yellow star within the area in red.



States following each test. Appendices and Annexes to the report present results in sufficient detail so that an individual can estimate his/her own thyroid dose given his/her residential history and dietary habits. Estimates of the uncertainties associated with the dose values and with the principal parameters entering into the dose calculations also are provided.

In addition to the present study, two other studies address the exposure of more specific populations to ^{131}I from fallout. The Offsite Radiation Exposure Review Project (ORERP) of the Department of Energy (Church et al. 1990) estimated exposures of downwind residents of several states to fallout *(Figure 1.2)* with special emphasis on the residents of four counties in Nevada (Clark, Esmeralda, Lincoln, and Nye) and of Washington County in Utah. The University of Utah reported on an epidemiological study of thyroid disease among identified populations of Utah and Nevada, together with retrospective estimates of individual thyroid doses due to ^{131}I in fallout (Kerber et al. 1993; Lloyd et al. 1990; Till et al. 1995).

The environmental transfer models used in the three studies to estimate the extent to which individuals or populations were exposed to ^{131}I are similar. There are some differences that distinguish this study from the other two, however, because of its larger geographic scope. The data and parameter values (e.g., dietary patterns, lifestyle) used in this study represent averages and are not specific to individuals or to limited population groups as in the other two studies. Also, because most of the deposition of radioactive materials on the ground in the eastern part of the country was associated with precipitation (i.e., "wet" deposition), whereas "dry" deposition (i.e., deposition of radioactive materials on the ground that was not associated with precipitation) was predominant in the western part of the country (Beck et al. 1990), the effect of precipitation on the fallout has received a greater emphasis in this study than was required for the other two studies.

It is important to note that the internal radiation absorbed doses in the thyroid of people from ^{131}I in NTS fallout that are calculated in this report constitute only one component of the thyroid doses that the American people received in the 1950s. Internal irradiation of the thyroid resulted also from the intake of ^{131}I from other sources (e.g., nuclear weapons testing at sites other than the NTS, whether by the United States or by other countries, atmospheric discharges from weapons producing facilities such as nuclear reactors and fuel reprocessing plants, medical uses of ^{131}I and, to a lesser extent, from the intake of radionuclides other than ^{131}I (e.g., ^{133}I or ^{132}I)). In addition, thyroid doses were also received as a result of external irradiation from the Nevada Test Site (NTS) fallout and from other sources, including natural background. A rough indication of the relative magnitude of the contributions to the thyroid dose from all those sources is provided in the report.

1.3. ORGANIZATION OF THE REPORT

This report includes:

- The history of nuclear weapons testing at the Nevada Test Site **(Chapter 2).**
- The deposition of ^{131}I on the ground **(Chapter 3).**
- The transfer of ^{131}I from deposition on the ground to fresh cows' milk **(Chapter 4).**
- The production, utilization, distribution, and consumption of milk across the continental U.S. **(Chapter 5).**
- The methods and data used to calculate radiation absorbed doses in the thyroids of people resulting from the ingestion of fresh cows' milk **(Chapter 6).**
- The methods and data used to calculate radiation absorbed doses in the thyroids of people resulting from exposure routes to people other than the ingestion of fresh cows' milk **(Chapter 7).**
- The results, expressed in terms or per capita of collective radiation absorbed doses in the thyroids of people **(Chapter 8).**
- How to calculate an individual's thyroid absorbed dose **(Chapter 9).**
- Model validation and the uncertainties attached to the estimates of radiation absorbed dose in the thyroids of people **(Chapter 10).**

The main body of the text is supplemented with Appendices and Annexes. The Appendices present detailed information on some aspects of the methodology used and general data that are not related to any specific nuclear test:

- The meteorological dispersion and deposition model that was used to predict estimates of ^{131}I deposition per unit area of ground when environmental radiation data were not available **(Appendix 1)**.
- The structural characteristics of the methodology used in the dose assessment, as well as the origin and content of the databases **(Appendix 2)**. Special consideration is given to the data related to the counties close to the Nevada Test Site because of the complexity of fallout deposition patterns in that area.

- Information on pasture practices **(Appendix 3).**

- The estimated volumes of milk annually produced, available for fluid use and consumed in each county of the contiguous United States in 1954 **(Appendix 4).**

- Information on regional milk distribution **(Appendix 5).**

- A review of the metabolism and dosimetry of ^{131}I **(Appendix 6).**

- The influence on the resulting thyroid doses of the distribution of physico-chemical forms of ^{131}I in fallout **(Appendix 7).**

- The initial retention of fallout ^{131}I by vegetation according to distance from the NTS and to daily rainfall **(Appendix 8).**

- Information on the main computer codes used in the dose assessment **(Appendix 9).**

The basic information and the main results obtained for each nuclear test that is taken into consideration in the dose assessment are presented as Annexes and as Sub-annexes.

The Annex for a given nuclear test includes:

- A description of the test along with a presentation of the environmental data, specific for that test, that have been used in the dose assessment.

- A color-coded map showing estimates of ^{131}I depositions per unit area of ground for all counties of the contiguous United States.

- Tabulated estimates of ^{131}I concentrations in fresh cows' milk resulting from the test for each county of the contiguous United States.

- Tabulated estimates of ^{131}I concentrations in ground-level air and in foodstuffs other than fresh cows' milk, resulting from the test, for each county of the contiguous United States.

- A color-coded map showing estimated thyroid-dose ranges for all counties of the contiguous United States.

In addition, results are summarized in the Annexes for each test series (corresponding, in many cases, to one year of testing) either in the form of tables or of maps. The tabulated results, in particular, enable an individual to obtain an approximate estimate of her (or his) own individual thyroid dose, provided that the individual considered knows, among other factors, her (or his) consumption rate of milk and the geographical origin of that milk during the time period of the test series. The results provided in the Annexes for each test series and for each county of the contiguous United States are:

- Tabulated estimates of ^{131}I concentrations in fresh cows' milk.

- Tabulated estimates of ^{131}I concentrations in ground-level air and in foodstuffs other than fresh cows' milk.

- Tabulated estimates of radiation absorbed doses in the thyroid of people to several categories of people in each age class that are expected to represent a reasonable spectrum of the population.

- Maps presenting estimates of ^{131}I depositions per unit area of ground and of "per capita" radiation absorbed doses in the thyroids of people resulting from the test series.

There is a Sub-annex for each nuclear weapons test. Each Sub-annex consists of:

- Tables showing the estimated daily ^{131}I depositions per unit area of ground for each county of the U.S. following each test.

- Tables presenting, for each county following each test:

  Estimates of the collective thyroid dose and the per capita thyroid dose to the county population.

  Estimates of the thyroid doses to each age group (and gender for the adult population) for each of the four milk consumption scenarios considered.

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Chapter 2

History of the Nevada Test Site and Nuclear Testing Background

Contents: The Nevada Test Site (NTS) and the types of nuclear tests conducted there from 1951 to date are described, and resulting off-site contamination, especially with respect to ^{131}I, is discussed.

2.1. NEVADA TEST SITE LOCATION AND SIZE

The Nevada Test Site (NTS) is located in Nye County in southern Nevada; the southernmost point of the NTS is about 65 miles (105 kilometers) northwest of Las Vegas. The site contains 1,350 square miles (3,500 square kilometers) of federally owned land with restricted access, and varies from 28-35 miles (45-56 kilometers) in width (east-west) and from 40-55 miles (64-88 kilometers) in length (north-south).

The Nevada Test Site is bordered on three sides by 4,120 square miles (10,700 square kilometers) of land comprising the Nellis Air Force Range, another federally owned, restricted area (*Figure 2.1*). This restricted area provides a buffer zone to the north and east between the test area and land that is open to the public, and varies in width from 15-65 miles (24-105 kilometers). A northwestern portion of the Nellis Air Force Range is occupied by the Tonopah Test Range, an area of 624 square miles (1,620 square kilometers), which is operated for the U.S. Department of Energy (DOE) by the Sandia Laboratories primarily for airdrop tests of ballistic shapes. The combination of the Tonopah Test Range, the Nellis Air Force Range, and the Nevada Test Site is one of the largest unpopulated land areas in the United States, comprising some 5,470 square miles (14,200 square kilometers).

Figure 2.1. Location of the Nevada Test Site.

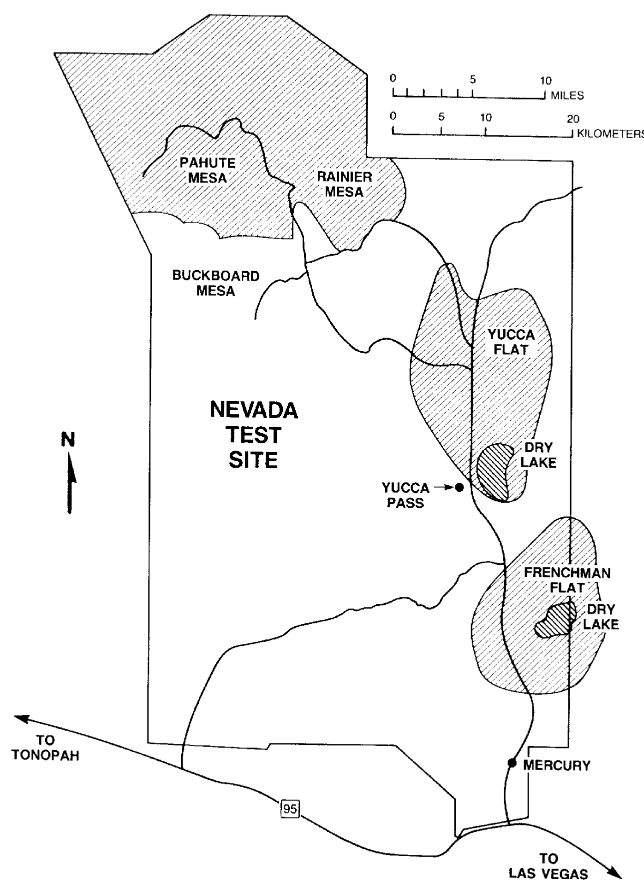


Figure 2.2 Details of the Nevada Test Site. Areas used for nuclear testing are shaded.

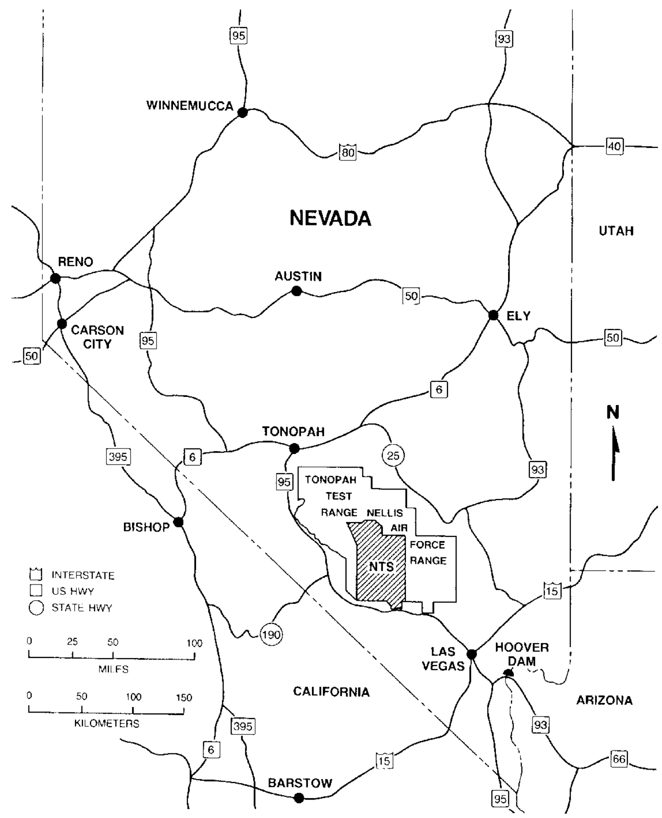


Figure 2.2 shows the general layout of the Nevada Test Site, and identifies some of the areas within the site referred to in this report.

2.2. HISTORICAL BACKGROUND OF THE NEVADA TEST SITE

From the end of World War II until 1951, five U.S. nuclear weapons tests were conducted at distant islands in the Pacific Ocean: two at Bikini atoll and three at Enewetak atoll (U.S. Department of Energy 1994). Testing at those sites required an extensive logistic effort and an inordinate amount of time. When the decision to accelerate the development of nuclear weapons was made in the late 1940s in response to the national defense policy, it became apparent that weapons development lead times would be reduced and considerably less expense incurred if nuclear weapons, especially the lower yield weapons, could be tested safely within the continental boundaries (Anders et al. 1983). Accordingly, a number of sites throughout the continental United States, including Alaska, were considered on the basis of low population density, safety, favorable year-round weather conditions, security, available labor sources, reasonable accessibility including transportation routes, and favorable geology. After review of known information about fallout, thermal, and blast effects, it was determined that an area within what is now the Nellis Air Force Range could be used for relatively low-yield nuclear detonations. Although the NTS originally was selected to meet criteria for atmospheric tests, it subsequently also was used for underground tests.

Public Land Order 805 dated February 19, 1952, identified 680 square miles (1,800 square kilometers) for nuclear testing purposes from an area used by the Air Force as a bombing and gunnery range; this area now comprises approximately the eastern half of the present Nevada Test Site. The predominant geological features of this area are the closed drainage basins of Frenchman Flat and Yucca Flat where the early atmospheric tests were conducted. The main Control Point has remained on the crest of Yucca Pass between these two basins (*Figure 2.2*). Additional land was added to the site in 1958, 1961, 1964, and 1967, thereby enlarging the site to its present size of about 1,350 square miles (3,500 square kilometers).

2.3. NUCLEAR TESTING PROGRAM AT THE NEVADA TEST SITE

Nuclear testing at the NTS has been conducted in two distinct eras (Friesen 1985): the atmospheric testing era (January 1951 through October 1958) and the underground testing era (1961 to the present). On October 31, 1958, the United States and the Soviet Union entered into voluntary test moratoria which lasted until the U.S.S.R. resumed testing on September 1, 1961. The United States responded with renewed testing on September 15, 1961. A few surface, near surface, and cratering tests were conducted from 1961 to 1968, but all other nuclear weapons tests have been carried out underground since 1961. The United States and the Soviet Union signed the Limited Test Ban Treaty on August 5, 1963, which effectively banned these countries from testing nuclear weapons in the atmosphere, in outer space and underwater. Six of the eight cratering tests conducted between 1962 and 1968 were part of a peaceful applications program.

2.3.1. Atmospheric Testing Era (1951-1958)

The United States conducted 119 nuclear tests at the NTS from the start of testing in January 1951 through October 1958 (U.S. Department of Energy 1988; U.S. Department of Energy 1994). Most of those nuclear tests were carried out in the atmosphere. Some tests were positioned for firing by airdrop, but metal towers were used for many Nevada tests at heights ranging from 100 to 700 feet (30-200 meters) above the ground surface. In 1957 and 1958, helium-filled balloons, tethered to precise heights and locations 340 to 1,500 feet (105 to 500 meters) above ground, provided a simpler, quicker, and less expensive method for the testing of many experimental devices. The tests of the atmospheric era took place in Yucca and Frenchman Flats *(Figure 2.2). Table 2.1* gives the characteristics of the 119 nuclear tests that were conducted at the NTS during the atmospheric testing era (1951-1958); they consist of 97 nuclear tests conducted in the atmosphere, of two cratering tests, detonated at depths less than 100 feet (30 meters), and of 20 underground tests. In *Table 2.1,* "type" refers to the type of deployment of the nuclear device at time of detonation (Friesen 1985):

Table 2.1. List of nuclear detonations at the Nevada Test Site during the atmospheric testing era (1951-1958) (Hicks 1981; U.S. Weather Bureau 1964; U.S. Department of Energy 1988).

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
RANGER:						
ABLE	01/27/51	1345	1	Airdrop	320	140
BAKER	01/28/51	1352	8	Airdrop	330	1300
EASY	02/01/51	1347	1	Airdrop	330	100
BAKER-2	02/02/51	1340	8	Airdrop	335	1300
FOX	02/06/51	1347	22	Airdrop	340	3200
BUSTER-JANGLE:						
ABLE [b]	10/22/51	1400	<0.1	Tower	100	N.D.
BAKER	10/28/51	1520	3.5	Airdrop	340	600
CHARLIE	10/30/51	1500	14	Airdrop	345	2000
DOG	11/01/51	1530	21	Airdrop	430	3100
EASY	11/05/51	1630	31	Airdrop	400	4500
SUGAR	11/19/51	1700	1.2	Surface	1	170
UNCLE	11/29/51	2000	1.2	Crater	-5	170
TUMBLER-SNAPPER:						
ABLE	04/01/52	1700	1	Airdrop	240	140
BAKER	04/15/52	1730	1	Airdrop	320	140
CHARLIE	04/22/52	1730	31	Airdrop	1050	4600
DOG	05/01/52	1630	19	Airdrop	320	2900
EASY	05/07/52	1215	12	Tower	90	1800
FOX	05/25/52	1200	11	Tower	90	1600
GEORGE	06/01/52	1155	15	Tower	90	2200
HOW	06/05/52	1155	14	Tower	90	2100

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Activity detected on-site only.
N.D. = not detectable.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
UPSHOT-KNOTHOLE:						
ANNIE	03/17/53	1320	16	Tower	90	2400
NANCY	03/24/53	1310	24	Tower	90	3500
RUTH	03/31/53	1300	0.2	Tower	90	28
DIXIE	04/06/53	1530	11	Airdrop	1835	1700
RAY	04/11/53	1245	0.2	Tower	30	28
BADGER	04/18/53	1235	23	Tower	90	3500
SIMON	04/25/53	1230	43	Tower	90	6300
ENCORE	05/08/53	1530	27	Airdrop	740	3900
HARRY	05/19/53	1205	32	Tower	90	4600
GRABLE [b]	05/25/53	1530	15	Airburst	160	2100
CLIMAX	06/04/53	1115	61	Airdrop	400	8600
TEAPOT:						
WASP	02/18/55	2000	1	Airdrop	230	160
MOTH	02/22/55	1345	2	Tower	90	320
TESLA	03/01/55	1330	7	Tower	90	1200
TURK	03/07/55	1320	43	Tower	150	6400
HORNET	03/12/55	1320	4	Tower	90	620
BEE	03/22/55	1305	8	Tower	150	1200
ESS	03/23/55	2030	1	Crater	-20	140
APPLE-I	03/29/55	1255	14	Tower	150	2000
WASP PRIME	03/29/55	1800	3	Airdrop	225	450
HA	04/06/55	1800	3	Airdrop	11160	450
POST	04/09/55	1230	2	Tower	90	340
MET	04/15/55	1915	22	Tower	120	3100
APPLE-II	05/05/55	1210	29	Tower	150	4100
ZUCCHINI	05/15/55	1200	28	Tower	150	4000

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Fired from 280-mm gun.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
PROJECT 56:						
No. 1 [b]	11/01/55	2210	0	Surface	0	N.D.
No. 2 [b]	11/03/55	2115	0	Surface	0	N.D.
No. 3 [b]	11/05/55	1955	No Yld.	Surface	0	N.D.
No. 4 [b]	01/18/56	2130	Slight	Surface	0	N.D.
PLUMBBOB:						
BOLTZMANN	05/28/57	1155	12	Tower	150	1900
FRANKLIN	06/02/57	1155	0.14	Tower	90	19
LASSEN [c]	06/05/57	1145	0.0005	Balloon	150	0.1
WILSON	06/18/57	1145	10	Balloon	150	1500
PRISCILLA	06/24/57	1330	37	Balloon	210	5800
COULOMB-A	07/01/57	N.A.	0	Surface	0	N.D.
HOOD	07/05/57	1140	74	Balloon	460	11000
DIABLO	07/15/57	1130	17	Tower	150	2500
JOHN [d]	07/19/57	1400	About 2	Rocket	6100	6100
KEPLER	07/24/57	1150	10	Tower	150	1700
OWENS	07/25/57	1330	10	Balloon	150	1700
PASCAL-A	07/26/57	800	Slight	Shaft	N.A.	10
STOKES	08/07/57	1225	19	Balloon	460	2800
SATURN	08/10/57	N.A.	0	Tunnel	N.A.	N.D.
SHASTA	08/18/57	1200	17	Tower	150	2500
DOPPLER	08/23/57	1240	11	Balloon	460	1700

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Safety experiment.
[c] Activity detected on-site only.
[d] Air-to-air missile.
N.D. = not detectable.
N.A. = not available.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
PLUMBBOB (cont'd):						
PASCAL-B	08/27/57	N.A.	N.A.	Shaft	N.A.	N.D.
FRANKLIN P.	08/30/57	1240	4.7	Balloon	230	690
SMOKY	08/31/57	1230	44	Tower	210	6400
GALILEO	09/02/57	1240	11	Tower	150	1900
WHEELER	09/06/57	1245	0.2	Balloon	150	27
COULOMB-B	09/06/57	2005	0.3	Surface	N.A.	42
LAPLACE	09/08/57	1300	1	Balloon	230	140
FIZEAU	09/14/57	1645	11	Tower	150	1700
NEWTON	09/16/57	1250	12	Balloon	460	2100
RAINIER [b]	09/19/57	1700	1.7	Tunnel	-240	0
WHITNEY	09/23/57	1230	19	Tower	150	2900
CHARLESTON	09/28/57	1300	12	Balloon	460	1800
MORGAN	10/07/57	1300	8	Balloon	460	1200
PROJECT 58:						
PASCAL-C [c]	12/06/57	2015	Slight	Shaft	N.A.	N.D.
COULOMB-C [c]	12/09/57	2000	0.5	Surface	N.A.	69
PROJECT 58 A:						
VENUS [c]	02/22/58	N.A.	<0.001	Tunnel	N.A.	N.D.
URANUS [c]	03/14/58	N.A.	<0.001	Tunnel	N.A.	N.D.
HARDTACK-PHASE II:						
OTERO [c]	09/12/58	2000	0.038	Shaft	-150	6
BERNALILLO [c]	09/17/58	1930	0.015	Shaft	-140	N.D.
EDDY	09/19/58	1400	0.083	Balloon	150	12
LUNA [c]	09/21/58	1900	0.0015	Shaft	-150	N.D.

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Contained underground.
[c] Safety Experiment.
N.D. = not detectable.
N.A. = not available.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT)[a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
HARDTACK-PHASE II (cont'd):						
MERCURY[b]	09/23/58	N.A.	Slight	Tunnel	N.A.	N.D.
VALENCIA[b]	09/26/58	2000	0.002	Shaft	-150	N.D.
MARS[b]	09/28/58	0	0.013	Tunnel	N.A.	N.D.
MORA	09/29/58	1405	2	Balloon	460	340
HIDALGO	10/05/58	1410	0.077	Balloon	100	11
COLFAX[b]	10/05/58	1615	0.0055	Shaft	-110	N.D.
TAMALPAIS	10/08/58	2200	0.072	Tunnel	-100	N.D.
QUAY	10/10/58	1430	0.079	Tower	30	11
LEA	10/13/58	1320	1.4	Balloon	460	240
NEPTUNE	10/14/58	1800	0.115	Tunnel	-30	N.D.
HAMILTON	10/15/58	1600	0.0012	Tower	15	0.2
LOGAN	10/16/58	600	5	Tunnel	-250	N.D.
DONA ANA	10/16/58	1420	0.037	Balloon	140	6
VESTA	10/17/58	2300	0.024	Surface	0	4
RIO ARRIBA	10/18/58	1425	0.09	Tower	22	120
SAN JUAN[b]	10/20/58	N.A.	0	Shaft	N.A.	N.D.
SOCORRO	10/22/58	1330	6	Balloon	440	1000
WRANGELL	10/22/58	1650	0.115	Balloon	460	17
RUSHMORE	10/22/58	2340	0.188	Balloon	150	17
OBERON[b]	10/22/58	N.A.	0	Tower	N.A.	N.D.
CATRON	10/24/58	1500	0.021	Tower	22	4
JUNO	10/24/58	1601	0.0017	Surface	0	N.D.
CERES	10/26/58	400	0.0007	Tower	10	N.D.
SANFORD	10/26/58	1020	4.9	Balloon	460	750
DE BACA	10/26/58	1600	2.2	Balloon	460	380
CHAVEZ	10/27/58	1430	0.0006	Tower	15	0.1
EVANS	10/29/58	0	0.055	Tunnel	-260	N.D.
HUMBOLDT	10/29/58	1445	0.0078	Tower	10	1
MAZAMA	10/29/58	N.A.	0	Tower	N.A.	N.D.
SANTA FE	10/30/58	300	1.3	Balloon	460	220
TITANIA	10/30/58	2034	0.0002	Tower	10	0.03
BLANCA	10/30/58	1500	22	Tunnel	-250	0.51
GANYMEDE[b]	10/30/58	N.A.	0	Surface	N.A.	N.D.

[a] GMT = Greenwich Mean Time, Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Safety Experiment.
N.D. = not detectable.
N.A. = not available.

airburst: fired from a cannon,
airdrop: dropped from an aircraft,
balloon: suspended from a tethered balloon,
rocket: launched by rocket,
tower: mounted at top of a metal or wooden tower,
surface: placed on or close to the earth's surface,
crater: placed shallow enough underground to produce a throw-out of the earth when exploded,
shaft: exploded at the end of a drilled or mined vertical hole,
tunnel: exploded at the end of a long horizontal hole mined into a mountain or mesa in a way that places the burst point deep within the earth.

The yields presented in *Table 2.1* are a measure of the total energy released during the explosion; they are expressed in terms of the equivalent mass of TNT required to produce the same energy release. The unit commonly used for the yield is the kiloton (kt). Depending on the type of weapon, the yield may include a fusion component in addition to the fission component. It is believed that all the nuclear weapons tested at the NTS during the atmospheric era were only of the fission type, and therefore that their yields were the same as their fission yields.

The yields of the 119 nuclear tests detonated in the atmospheric era ranged from 0 to 74 kt, with 41 tests with yields greater than, or equal to, 10 kt, 23 tests with yields between 1 and 10 kt, and 55 tests with yields less than or equal to 1 kt. The arithmetic average yield was 8.6 kt. Among the tests with yields lower than 1 kt are included all safety experiments, in which atomic bombs were destroyed by conventional explosives in order to determine the spread of the fissionnable material so that the consequences of transportation accidents involving warheads could be evaluated. The yields of the safety experiments that were reported as “slight,” “not available,” or “no yield” were taken to be equal to zero.

2.3.2. Underground Testing Era (1961 to 1992)

In 1962, before the onset of the Limited Test Ban Treaty, the United States conducted, in addition to its underground tests, two small surface tests, one tower test and two cratering tests as part of the nuclear weapons testing program. Six nuclear cratering tests were conducted from 1962 through 1968 as part of the peaceful applications (Plowshare) program. The overwhelming majority of the 809 tests that took place at the NTS from 1961 through September 1992 were conducted underground either in shafts or in tunnels that were designed for containment of the

Table 2.2. List of atmospheric and cratering events at the Nevada Test Site from 1961 through September 1992 (Hardy et al. 1964; Hicks 1981; Schoengold et al. 1990; U.S. Department of Energy 1994).

Test	Date (mo/d/y)	Time (GMT)[a]	Yield (kt)	Type	Height (m)	Cloud Height (km MSL)	Atmospheric release of ^{131}I (kCi)
DANNY BOY	03/05/62	1815	0.43	Crater	-30	N.A.	73
SEDAN[b,c]	07/06/62	1700	104	Crater	-200	3.7	880
LITTLE FELLER 2	07/07/62	1900	<20	Surface		2.4	N.A.
JOHNNY BOY	07/11/62	1645	0.5	Crater	-1	3.4	70
SMALL BOY	07/14/62	1830	<20	Tower		4.6	270
LITTLE FELLER 1	07/17/62	1700	<20	Surface		3	3
SULKY[c]	12/18/64	1935	0.092	Crater	-30	N.A.	13
PALANQUIN[c]	04/14/65	1314	4.3	Crater	-85	N.A.	910
CABRIOLET[c]	01/26/68	1600	2.3	Crater	-20	N.A.	6
BUGGY[c]	03/12/68	1704	5.4	Crater	-40	N.A.	40
SCHOONER[c]	12/08/68	1600	30	Crater	-100	N.A.	15

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Less than 30 kt fission yield.
[c] Tests conducted as a part of the “Plowshare” program.
N.A.= not available

Table 2.3. List of underground events at the Nevada Test Site during the underground testing era (from 1961 through September 1992) that resulted in the detection of radioactive materials off-site[a] (Hardy et al. 1964; Hicks 1981; U.S. Department of Energy 1988; Schoengold et al. 1990).

Test	Date (mo/d/y)	Time (GMT)[b]	Yield (kt)	Type	Atmospheric release of ^{131}I (kCi)
ANTLER	09/15/61	1600	2.6	Tunnel	0.0042
FEATHER	12/22/61	1730	Low	Tunnel	0.00114
PAMPAS	03/01/62	2010	Low	Shaft	0.000012
PLATTE	04/14/62	1900	1.85	Tunnel	0.0114
EEL	05/19/62	1700	Low	Shaft	0.0114
DES MOINES	06/13/62	2200	Low	Tunnel	33
BANDICOOT	10/19/62	1900	Low	Shaft	9
YUBA	06/05/63	1800	Low	Tunnel	0.000022
EAGLE	12/12/63	1702	Low	Shaft	0.00228
OCONTO	01/12/64	N.A.	less than 20	Shaft	0.001
PIKE	03/13/64	1702	less than 20	Shaft	0.36
ALVA	08/19/64	1700	less than 20	Shaft	0.000037
DRILL	12/05/64	2215	3.4	Shaft	0.0122
PARROT	12/16/64	2100	1.3	Shaft	0.0046
ALPACA	02/12/65	1610	less than 20	Shaft	0.000024
TEE	05/07/65	1647	less than 20	Shaft	0.0016
DILUTED WATERS	06/16/65	1730	less than 20	Shaft	0.0177
RED HOT	03/05/66	1915	less than 20	Tunnel	0.2
FENTON	04/23/66	N.A.	less than 20	Shaft	N.A.
PIN STRIPE	04/25/66	1938	less than 20	Shaft	0.2
DOUBLE PLAY	06/15/66	1800	less than 20	Tunnel	0.12
DERRINGER	09/12/66	1630	less than 20	Shaft	0.00024
NASH	01/19/67	1745	20 to 200	Shaft	0.0138
MIDI MIST	06/26/67	1700	less than 20	Tunnel	0.00026
UMBER	06/29/67	1225	less than 20	Shaft	0.00052
DOOR MIST	08/31/67	1730	less than 20	Tunnel	0.008
HUPMOBILE	01/18/68	1730	10	Shaft	0.12
TYG	12/12/68	N.A.	less than 20	Shaft	Undetected
POD	10/29/69	2100	20 to 200	Shaft	0.000078
SCUTTLE	11/13/69	1515	less than 20	Shaft	0.000004
SNUBBER	04/21/70	1530	less than 20	Shaft	0.0055
MINT LEAF	05/05/70	1630	less than 20	Tunnel	0.08
BANEBERRY	12/18/70	1630	10	Shaft	80
DIAGONAL LINE	11/24/71	2015	less than 20	Shaft	0.00136
RIOLA	09/25/80	826	less than 20	Shaft	0.00058
MISTY RAIN	04/06/85	N.A.	less than 20	Tunnel	Undetected
GLENCOE	03/22/86	N.A.	20 to 150	Shaft	0.000000009
MIGHTY OAK	04/10/86	N.A.	less than 20	Tunnel	0.0024

[a] There were in addition more than 500 underground events that did not result in detection off-site.
[b] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
N.A. = not available.

radioactive debris (U.S. Department of Energy 1993; U.S. Department of Energy 1994). Most underground tests were conducted under Yucca Flat but a few underground and cratering tests took place under Buckboard, Pahute, and Rainier Mesas in the northern part of the Nevada Test Site *(Figure 2.2)*.

Table 2.2 presents the characteristics of the 11 atmospheric and cratering tests conducted since 1961 while *Table 2.3* gives the characteristics of the 38 underground events detonated through September 1992 that have released volatile radioactive materials (particulate or gaseous), which resulted in detection off-site (Hicks 1981; Schoengold et al. 1990; U.S. Department of Energy 1994).

The remainder of the 809 tests that took place at the NTS between 1961 and 1992 were either completely contained underground or resulted in releases of radioactive materials that were only detected onsite. *Table 2.4* presents the characteristics of the 299 events that resulted in releases of radioactive materials that were detected onsite only (Schoengold et al. 1990; U.S. Department of Energy 1993; U.S. Department of Energy 1994). When quantified, those releases are extremely small in comparison to those from atmospheric and cratering tests.

All United States nuclear tests have been publicly announced; the total number of nuclear weapons tests that were conducted at the Nevada Test Site up to September 1992 is 928—100 which were atmospheric, and the other 828 underground (U.S. Department of Energy 1993; 1994).

On October 2, 1992, the United States entered into another unilateral moratorium on nuclear weapons testing announced by President Bush. President Clinton extended this moratorium in July 1993, and again in March 1994 until September 1995 (U.S. Department of Energy 1994).

2.4. NUCLEAR TESTING BY THE U.S. AT SITES OTHER THAN THE NEVADA TEST SITE

Although the scope of this report is limited to the estimation of the radiation exposures resulting from nuclear tests that took place at the NTS, other sites also were used by the U.S. to conduct nuclear tests.

The first test of a nuclear weapon was in the atmosphere on July 16, 1945, in a remote part of New Mexico on what was

Figure 2.3. Location and number of nuclear tests conducted from July 1945 to September 1992 in the continental U.S.

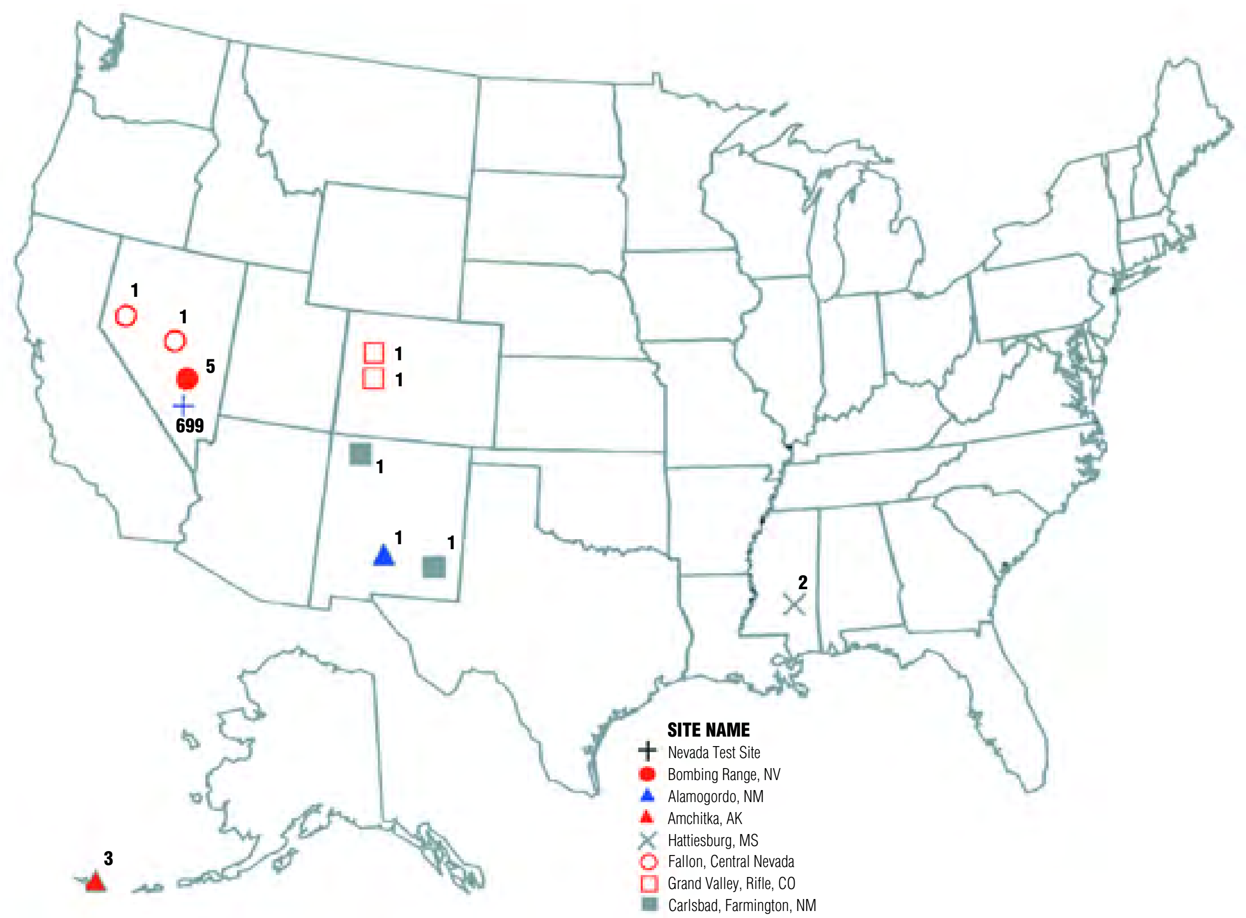


Table 2.4. List of nuclear detonations at the Nevada Test Site during the underground testing era (from 1961 through September 1992) that resulted in the detection of radioactive materials onsite but not offsite (Schoengold et al. 1990; U.S. Department of Energy 1993; U.S. Department of Energy 1994). The release of ^{131}I, when available, is presented in the last column. When the release of ^{131}I is not available, the reported amount for the release of all radioactive materials is provided for most of the tests. Footnotes are at the end of the Table.

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
SHREW	09/16/61	Weapons related	<20	Shaft	^{131}I not detected
BOOMER	10/01/61	Weapons related	<20	Shaft	^{131}I not detected
CHENA	10/10/61	Weapons related	<20	Tunnel	^{131}I not detected
MINK	10/29/61	Weapons related	<20	Shaft	All: 500
FISHER	12/03/61	Weapons related	13.4	Shaft	^{131}I not detected
MAD	12/13/61	Weapons related	0.5	Shaft	^{131}I not detected
RINGTAIL	12/17/61	Weapons related	<20	Shaft	^{131}I not detected
STOAT	01/09/62	Weapons related	5.1	Shaft	^{131}I not detected
DORMOUSE	01/30/62	Weapons related	<20	Shaft	^{131}I not detected
STILLWATER	02/08/62	Weapons related	3.07	Shaft	^{131}I not detected
ARMADILLO	02/09/62	Weapons related	7.1	Shaft	^{131}I not detected
HARD HAT	02/15/62	Weapons effects	5.7	Shaft	^{131}I not detected
CHINCHILLA	02/19/62	Weapons related	1.9	Shaft	^{131}I not detected
CODSAW	02/19/62	Weapons related	<20	Shaft	All: <1,000
CIMARRON	02/23/62	Weapons related	11.9	Shaft	^{131}I not detected
PLATYPUS	02/24/62	Weapons related	<20	Shaft	^{131}I not detected
ERMINE	03/06/62	Weapons related	<20	Shaft	^{131}I not detected
BRAZOS	03/08/62	Weapons related	8.4	Shaft	^{131}I not detected
HOGNOSE	03/15/62	Weapons related	<20	Shaft	^{131}I not detected
HOOSIC	03/28/62	Weapons related	3.4	Shaft	^{131}I not detected
CHINCHILLA II	03/31/62	Weapons related	<20	Shaft	^{131}I not detected
DORMOUSE PRIME	04/05/62	Weapons related	10.6	Shaft	^{131}I not detected
PASSAIC	04/06/62	Weapons related	<20	Shaft	^{131}I not detected
HUDSON	04/12/62	Weapons related	<20	Shaft	^{131}I not detected
DEAD	04/21/62	Weapons related	<20	Shaft	^{131}I not detected
BLACK	04/27/62	Weapons related	<20	Shaft	^{131}I not detected
PACA	05/07/62	Weapons related	<20	Shaft	^{131}I not detected
ARIKAREE	05/10/62	Weapons related	<20	Shaft	^{131}I not detected
AARDVARK	05/12/62	Weapons related	40	Shaft	^{131}I not detected
WHITE	05/25/62	Weapons related	<20	Shaft	^{131}I not detected
PACKRAT	06/06/62	Weapons related	<20	Shaft	^{131}I not detected
DAMAN I	06/21/62	Weapons related	<20	Shaft	^{131}I not detected
HAYMAKER	06/27/62	Weapons related	67	Shaft	^{131}I not reported[a]
MARSHMALLOW	06/28/62	Weapons effects	<20	Tunnel	^{131}I not detected
SACRAMENTO	06/30/62	Weapons related	<20	Shaft	All: <1,000
LITTLE FELLER II	07/07/62	Weapons effects	<20	Surface	^{131}I not detected
MERRIMAC	07/13/62	Weapons related	20-200	Shaft	^{131}I not detected
WICHITA	07/27/62	Weapons related	<20	Shaft	All: 760
BOBAC	08/24/62	Weapons related	<20	Shaft	^{131}I not detected
YORK	08/24/62	Weapons related	<20	Shaft	^{131}I not detected

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
RARITAN	09/06/62	Weapons related	<20	Shaft	^{131}I not detected
HYRAX	09/14/62	Weapons related	<20	Shaft	^{131}I not detected
ALLEGHENY	09/29/62	Weapons related	<20	Shaft	^{131}I not detected
MISSISSIPPI	10/05/62	Weapons related	115	Shaft	^{131}I not detected
ROANOKE	10/12/62	Weapons related	<20	Shaft	^{131}I not detected
WOLVERINE	10/12/62	Weapons related	<20	Shaft	^{131}I not detected
SANTEE	10/27/62	Weapons related	<20	Shaft	^{131}I not detected
ST.LAWRENCE	11/09/62	Weapons related	<20	Shaft	^{131}I not detected
ANACOSTIA	11/27/62	Plowshare	<20	Shaft	^{131}I not detected
TAUNTON	12/04/62	Weapons related	<20	Shaft	^{131}I not detected
MADISON	12/12/62	Weapons related	<20	Shaft	^{131}I not detected
NUNBAT	12/12/62	Weapons related	<20	Shaft	^{131}I not detected
MANATEE	12/14/62	Weapons related	<20	Shaft	^{131}I not detected
CASSELMAN	02/08/63	Weapons related	<20	Shaft	^{131}I not detected
KAWEAH	02/21/63	Plowshare	<20	Shaft	^{131}I not detected
CARMEL	02/21/63	Weapons related	<20	Shaft	^{131}I not detected
TOYAH	03/15/63	Weapons related	<20	Shaft	^{131}I not detected
CUMBERLAND	04/11/63	Weapons related	<20	Shaft	^{131}I not detected
KOOTANAI	04/24/63	Weapons related	<20	Shaft	^{131}I not reportedb
PAISANO	04/24/63	Weapons related	<20	Shaft	^{131}I not detected
STONES	05/22/63	Weapons related	20-200	Shaft	All: 5,800
PLEASANT	05/29/63	Weapons related	<20	Shaft	All: 20,000
APSHAPA	06/06/63	Weapons related	<20	Shaft	^{131}I not detected
KENNEBEC	06/25/63	Weapons related	<20	Shaft	^{131}I:<30
PEKAN	08/12/63	Weapons related	<20	Shaft	^{131}I: 10
KOHOCTON	08/23/63	Weapons related	<20	Shaft	All: 3,000
AHTANUM	09/13/63	Weapons related	<20	Shaft	^{131}I not detected
BILBY	09/13/63	Weapons related	249	Shaft	Trace
CARP	09/27/63	Weapons related	low	Shaft	All: 570
GRUNION	10/11/63	Weapons related	<20	Shaft	^{131}I: 0.043
TORNILLO	10/11/63	Plowshare	<20	Shaft	^{131}I not detected
CLEARWATER	10/16/63	Weapons related	20-200	Shaft	^{131}I: 0.023
ANCHOVY	11/14/63	Weapons related	low	Shaft	^{131}I: 2.5
MUSTANG	11/15/63	Weapons related	<20	Shaft	Trace
GREYS	11/22/63	Weapons related	20-200	Shaft	All: 460
SARDINE	12/04/63	Weapons related	<20	Shaft	^{131}I:<0.09
EAGLE	12/12/63	Weapons related	<20	Shaft	^{131}I:<0.1
TUNA	12/20/63	Weapons related	low	Shaft	All: 0.12
FORE	01/16/64	Weapons related	20-200	Shaft	^{131}I not detected
CLUB	01/30/64	Weapons related	<20	Shaft	All: 1.2
SOLENDON	02/12/64	Weapons related	<20	Shaft	All: 9.6
BUNKER	02/13/64	Weapons related	<20	Shaft	All: 1.4
KLICKITAT	02/20/64	Plowshare	20-200	Shaft	^{131}I:<0.02
HANDICAP	03/12/64	Weapons related	<20	Shaft	All: 300

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
HOOK	04/14/64	Weapons related	<20	Shaft	^{131}I not detected
STURGEON	04/15/64	Weapons related	<20	Shaft	^{131}I: 0.01
BOGEY	04/17/64	Weapons related	<20	Shaft	All: 6.9
TURF	04/24/64	Weapons related	20-200	Shaft	^{131}I:<2
PIPEFISH	04/29/64	Weapons related	<20	Shaft	^{131}I not detected
DRIVER	05/07/64	Weapons related	<20	Shaft	All: 37
BACKSWING	05/14/64	Weapons related	<20	Shaft	^{131}I:<37
ACE	06/11/64	Plowshare	<20	Shaft	^{131}I:<9.3
FADE	06/25/64	Weapons related	<20	Shaft	^{131}I:<35
DUB	06/30/64	Plowshare	<20	Shaft	^{131}I:<5
BYE	07/16/64	Weapons related	20-200	Shaft	^{131}I:<1
CORMORANT	07/17/64	Joint US-UK	<20	Shaft	^{131}I: 0.014
LINKS	07/23/64	Weapons related	<20	Shaft	All: <6.7
CANVASBACK	08/22/64	Weapons related	<20	Shaft	^{131}I: 0.2
PAR	10/09/64	Plowshare	38	Shaft	^{131}I not detected
BARBEL	10/16/64	Weapons related	<20	Shaft	^{131}I: 0.41
FOREST	10/31/64	Weapons related	<20	Shaft	^{131}I: 0.002
HANDCAR	11/05/64	Plowshare	12	Shaft	^{131}I not detected
CREPE	12/05/64	Weapons related	20-200	Shaft	^{131}I not detected
MUDPACK	12/16/64	Weapons related	2.7	Shaft	^{131}I:<1
WOOL	01/14/65	Weapons related	<20	Shaft	^{131}I not detected
TERN	01/29/65	Weapons related	<20	Shaft	All: 170
CASHMERE	02/04/65	Weapons related	<20	Shaft	^{131}I not detected
MERLIN	02/16/65	Weapons related	10.1	Shaft	^{131}I not detected
WISHBONE	02/18/65	Weapons effects	<20	Shaft	^{131}I: 1.3
SEERSUCKER	02/19/65	Weapons related	<20	Shaft	All: 1.3
WAGTAIL	03/03/65	Weapons related	20-200	Shaft	^{131}I: 0.03
CUP	03/26/65	Weapons related	20-200	Shaft	^{131}I: 1
KESTREL	04/05/65	Weapons related	<20	Shaft	^{131}I: 0.029
GUM DROP	04/21/65	Weapons effects	<20	Tunnel	^{131}I not detected
CHENILLE	04/22/65	Weapons related	<20	Shaft	All: 0.93
TWEED	05/21/65	Weapons related	<20	Shaft	^{131}I: 0.02
TINY TOT	06/17/65	Weapons effects	<20	Tunnel	^{131}I:<7
PONGEE	07/22/65	Weapons related	<20	Shaft	All: 6.4
BRONZE	07/23/65	Weapons related	20-200	Shaft	^{131}I: 0.23
CENTAUR	08/27/65	Weapons related	<20	Shaft	^{131}I: 0.0022
SCREAMER	09/01/65	Weapons effects	<20	Shaft	All: 63,000
ELKHART	09/17/65	Weapons related	<20	Shaft	^{131}I not detected
SEPIA	11/12/65	Weapons related	<20	Shaft	^{131}I: 0.0011
KERMET	11/23/65	Weapons related	<20	Shaft	All: <5.5
CORDUROY	12/03/65	Weapons related	20-200	Shaft	^{131}I not detected
EMERSON	12/16/65	Weapons related	<20	Shaft	^{131}I not detected
MAXWELL	01/13/66	Weapons related	<20	Shaft	^{131}I not detected
REO	01/22/66	Weapons related	<20	Shaft	All: 10

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
PLAID II	02/03/66	Weapons related	<20	Shaft	^{131}I:<1
REX	02/24/66	Weapons related	19	Shaft	^{131}I not detected
FINFOOT	03/07/66	Weapons related	<20	Shaft	^{131}I not detected
CLYMER	03/12/66	Weapons related	<20	Shaft	^{131}I not detected
TEMPLAR	03/24/66	Plowshare	<20	Shaft	^{131}I not detected
STUTZ	04/06/66	Weapons related	<20	Shaft	^{131}I not detected
DURYEA	04/14/66	Weapons related	70	Shaft	^{131}I not detected
TRAVELLER	05/04/66	Weapons related	<20	Shaft	^{131}I not detected
TAPESTRY	05/12/66	Weapons related	<20	Shaft	^{131}I not detected
DUMONT	05/19/66	Weapons related	20-200	Shaft	^{131}I not detected
PILE DRIVER	06/02/66	Weapons effects	62	Tunnel	^{131}I not detected
KANKAKEE	06/15/66	Weapons related	20-200	Shaft	^{131}I not detected
VULCAN	06/25/66	Plowshare	25	Shaft	^{131}I not detected
SAXON	07/28/66	Plowshare	<20	Shaft	^{131}I not detected
ROVENA	08/10/66	Weapons related	<20	Shaft	^{131}I not detected
NEWARK	09/29/66	Weapons related	<20	Shaft	^{131}I not detected
SIMMS	11/05/66	Plowshare	<20	Shaft	^{131}I: 0.009
AJAX	11/11/66	Weapons related	<20	Shaft	^{131}I not detected
CERISE	11/18/66	Weapons related	<20	Shaft	^{131}I not detected
VIGIL	11/22/66	Weapons related	<20	Shaft	All: 0.0014
SIDECAR	12/13/66	Weapons related	<20	Shaft	All: 0.041
NEW POINT	12/13/66	Weapons effects	<20	Shaft	^{131}I not detected
RIVET II	01/26/66	Weapons related	<20	Shaft	All: 0.058
RIVET III	03/02/67	Weapons related	<20	Shaft	Trace
MUSHROOM	03/03/66	Weapons related	<20	Shaft	All: 0.38
HEILMAN	04/06/66	Weapons related	<20	Shaft	All: 0.031
COMMODORE	05/20/67	Weapons related	250	Shaft	Trace
KNICKERBOCKER	05/26/67	Weapons related	76	Shaft	^{131}I not detected
SWITCH	06/22/67	Plowshare	<20	Shaft	Trace
STANLEY	07/27/67	Weapons related	20-200	Shaft	^{131}I not detected
WASHER	08/10/67	Weapons related	<20	Shaft	^{131}I not detected
YARD	09/07/67	Weapons related	20-200	Shaft	^{131}I not detected
MARVEL	09/21/67	Plowshare	2.2	Shaft	^{131}I:<27
LANPHER	10/18/67	Weapons related	20-200	Shaft	^{131}I not detected
COGNAC	10/25/67	Weapons related	<20	Shaft	All: 0.064
SAZERAC	10/25/67	Weapons related	<20	Shaft	^{131}I: 0.0049
STACCATO	01/19/68	Weapons related	20-200	Shaft	^{131}I not detected
BRUSH	01/24/68	Weapons related	<20	Shaft	All: 0.00002
KNOX	02/21/68	Weapons related	20-200	Shaft	^{131}I not detected
RUSSET	03/05/68	Weapons related	<20	Shaft	All: 29
MILK SHAKE	03/25/68	Weapons related	<20	Shaft	^{131}I not detected
NOOR	04/10/68	Weapons related	20-200	Shaft	^{131}I not detected
SHUFFLE	04/18/68	Weapons related	20-200	Shaft	^{131}I not detected
SCROLL	04/23/68	Vela Uniform	<20	Shaft	All: 18,000

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
ADZE	05/28/68	Weapons related	<20	Shaft	All: 0.007
TUB	06/06/68	Weapons related	<20	Shaft	^{131}I not detected
FUNNEL	06/25/68	Weapons related	<20	Shaft	All: 0.00002
SEVILLA	06/25/68	Weapons related	<20	Shaft	All: 0.004
TANYA	07/30/68	Weapons related	20-200	Shaft	^{131}I not detected
IMP	08/09/68	Weapons related	<20	Shaft	All: 4,200
DIANA MOON	08/27/68	Weapons related	<20	Shaft	^{131}I: 0.1
NOGGIN	09/06/68	Weapons related	20-200	Shaft	^{131}I not detected
STODDARD	09/17/68	Plowshare	20-200	Shaft	^{131}I not detected
HULA	10/29/68	Weapons related	<20	Shaft	All: 0.06
TINDERBOX	11/22/68	Weapons related	<20	Shaft	^{131}I not detected
SCISSORS	12/12/68	Weapons related	<20	Shaft	All: 0.00013
PACKARD	01/15/69	Weapons related	10	Shaft	^{131}I not detected
BARSAC	03/20/69	Weapons related	<20	Shaft	^{131}I:<41
COFFER	03/21/69	Weapons related	<100	Shaft	^{131}I not detected
BLENTON	04/30/69	Weapons related	20-200	Shaft	^{131}I not detected
IPECAC	05/27/69	Weapons related	20-200	Shaft	Trace
TAPPER	06/12/69	Weapons related	<20	Shaft	^{131}I not detected
HUTCH	07/16/69	Weapons related	20-200	Shaft	^{131}I not detected
SPIDER	08/14/69	Weapons related	<20	Shaft	^{131}I not detected
PLIERS	08/27/69	Weapons related	<20	Shaft	^{131}I not detected
MINUTE STEAK	09/12/69	Weapons effects	<20	Shaft	^{131}I: 0.05
KYACK	09/20/69	Weapons related	20-200	Shaft	All: 510
SEAWEED	10/01/69	Weapons related	20-200	Shaft	All: 0.00000005
PIPKIN	10/08/69	Weapons related	200-1000	Shaft	^{131}I not detected
SEAWEED B	10/16/69	Weapons related	20-200	Shaft	All: 0.0000002
TUN	12/10/69	Weapons related	20-200	Shaft	All: 72
TERRINE	12/18/69	Weapons related	20-200	Shaft	^{131}I not detected
YANNIGAN	02/26/70	Weapons related	20-200	Shaft	^{131}I not detected
CYATHUS	03/06/70	Weapons related	8.7	Shaft	^{131}I:<1
HOD	05/01/70	Weapons related	<20	Shaft	^{131}I not detected
DIAMOND DUST	05/12/70	Vela Uniform	<20	Tunnel	^{131}I not detected
MANZANAS	05/21/70	Weapons related	<20	Shaft	^{131}I not detected
FLASK	05/26/70	Plowshare	105	Shaft	^{131}I not detected
HUDSON MOON	05/26/70	Weapons effects	<20	Tunnel	^{131}I:<49
PITON A	05/28/70	Weapons related	<20	Shaft	All: 25,000
ARNICA	06/26/70	Weapons related	20-200	Shaft	^{131}I not detected
SCREE	10/13/70	Weapons related	<20	Shaft	All: 11
TRUCHAS	10/28/70	Weapons related	<20	Shaft	All: 3
CREAM	12/16/70	Weapons related	<20	Shaft	^{131}I not detected
CARPETBAG	12/17/70	Weapons related	220	Shaft	^{131}I not detected
HAREBELL	06/24/71	Weapons related	20-200	Shaft	^{131}I not detected
CAMPHOR	06/29/71	Weapons effects	<20	Tunnel	^{131}I not reported[c]
MINAITA	07/08/71	Plowshare	83	Shaft	Trace

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
ZINNIA	05/17/72	Weapons related	<20	Shaft	^{131}I not detected
MIERA	03/08/73	Weapons related	20-200	Shaft	^{131}I not detected
ANGUS	04/25/73	Weapons related	20-200	Shaft	^{131}I: 0.0013
STARWORT	04/26/73	Weapons related	90	Shaft	^{131}I not detected
PORTULACA	06/28/73	Weapons related	20-200	Shaft	^{131}I not detected
BERNAL	11/28/73	Weapons related	<20	Shaft	^{131}I not detected
FALLON	05/23/74	Joint US-UK	20-200	Shaft	^{131}I not detected
ESCABOSA	07/10/74	Weapons related	20-200	Shaft	^{131}I not detected
PUYE	08/14/74	Weapons related	<20	Shaft	^{131}I: 0.000002
HYBLA FAIR	10/28/74	Weapons effects	<20	Tunnel	^{131}I not detected
CABRILLO	03/07/75	Weapons related	20-200	Shaft	^{131}I not detected
ESROM	02/04/76	Weapons related	20-200	Shaft	^{131}I not detected
BILLET	07/27/76	Weapons related	20-150	Shaft	^{131}I not detected
BANON	08/26/76	Joint US-UK	20-150	Shaft	^{131}I not detected
MARSILLY	04/05/77	Weapons effects	20-150	Shaft	^{131}I not detected
COULOMMIERS	09/27/77	Weapons related	20-150	Shaft	^{131}I not detected
BOBSTAY	10/26/77	Weapons related	<20	Shaft	^{131}I: 0.000003
HYBLA GOLD	11/01/77	Weapons effects	<20	Tunnel	^{131}I not detected
FARALLONES	12/14/77	Weapons related	20-150	Shaft	^{131}I not detected
CAMPOS	02/13/78	Weapons related	<20	Shaft	^{131}I: 0.000026
REBLOCHON	02/23/78	Weapons related	20-150	Shaft	^{131}I not detected
QUARGEL	11/18/78	Joint US-UK	20-150	Shaft	^{131}I not detected
KLOSTER	02/15/79	Weapons related	20-150	Shaft	^{131}I not detected
PEPATO	06/11/79	Weapons related	20-150	Shaft	^{131}I not detected
FAJY	06/28/79	Weapons related	20-150	Shaft	^{131}I not detected
TARKO	02/28/80	Weapons related	<20	Shaft	^{131}I not detected
NORBO	03/08/80	Weapons related	<20	Shaft	^{131}I not detected
FLORA	05/22/80	Weapons related	<20	Shaft	^{131}I: 1
VERDELLO	07/31/80	Weapons related	<20	Shaft	^{131}I: 0.007
MINERS IRON	10/31/80	Weapons effects	<20	Tunnel	^{131}I not detected
VIDE	04/30/81	Weapons related	<20	Shaft	^{131}I not detected
NIZA	07/10/81	Weapons related	<20	Shaft	^{131}I not detected
HAVARTI	08/05/81	Weapons related	<20	Shaft	^{131}I not detected
ISLAY	08/27/81	Weapons related	<20	Shaft	^{131}I not detected
TREBBIANO	09/04/81	Weapons related	<20	Shaft	^{131}I: 0.05
CABOC	12/16/81	Weapons related	<20	Shaft	^{131}I not detected
MOLBO	02/12/82	Weapons related	20-150	Shaft	^{131}I not detected
GIBNE	04/25/82	Joint US-UK	20-150	Shaft	^{131}I not detected
BOUSCHET	05/07/82	Weapons realted	20-150	Shaft	^{131}I:<0.0001
MONTEREY	07/29/82	Weapons related	20-150	Shaft	^{131}I not detected
FRISCO	09/23/82	Weapons related	20-150	Shaft	^{131}I not detected
HURON LANDING/ DIAMOND ACE	09/23/82	Weapons effects	<20	Tunnel	^{131}I not detected
MANTECA	12/10/82	Weapons related	20-150	Shaft	^{131}I not detected

Table 2.4. cont'd

Test	Date (mo/d/y)	Time (GMT)[b]	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
CHEEDAM	02/17/83	Weapons related	<20	Shaft	^{131}I not detected
TURQUOISE	04/14/83	Weapons related	<150	Shaft	^{131}I: 0.000003
ARMADA	04/22/83	Joint US-UK	<150	Shaft	^{131}I not detected
CROWDIE	05/05/83	Weapons related	<20	Shaft	^{131}I not detected
MINI JADE	05/26/83	Weapons effects	<20	Tunnel	^{131}I not detected
DANABLU	06/09/83	Weapons related	<20	Shaft	^{131}I not detected
LABAN	08/03/83	Weapons related	<20	Shaft	^{131}I: 0.000011
ROMANO	12/16/83	Weapons related	20-150	Shaft	^{131}I not detected
GORBEA	01/31/84	Weapons related	20-150	Shaft	^{131}I not detected
AGRINI	03/31/84	Weapons related	<20	Shaft	^{131}I not detected
CAPROCK	05/31/84	Weapons related	20-150	Shaft	^{131}I not detected
KAPPELI	07/25/84	Weapons related	20-150	Shaft	^{131}I not detected
BRETON	09/13/84	Weapons related	20-150	Shaft	^{131}I not detected
TIERRA	12/15/84	Weapons related	20-150	Shaft	^{131}I not detected
VAUGHN	03/15/85	Weapons related	20-150	Shaft	^{131}I: 0.006
MISTY RAIN	04/06/85	Weapons effects	<20	Tunnel	^{131}I not detected
SALUT	06/12/85	Weapons related	20-150	Shaft	^{131}I not detected
VILLE	06/12/85	Weapons related	<20	Shaft	^{131}I not detected
MARIBO	06/26/85	Weapons related	<20	Shaft	^{131}I not detected
SERENA	07/25/85	Weapons related	20-150	Shaft	^{131}I not detected
DIAMOND BEECH	10/09/85	Weapons effects	<20	Tunnel	^{131}I not detected
MILL YARD	10/09/85	Weapons effects	<20	Tunnel	^{131}I not detected
GLENCOE	03/22/86	Weapons related	20-150	Shaft	^{131}I: 0.000009
JEFFERSON	04/22/86	Weapons related	20-150	Shaft	^{131}I not detected
PANAMINT	05/21/86	Weapons related	<20	Shaft	^{131}I: 0.001
CYBAR	07/17/86	Weapons related	20-150	Shaft	^{131}I not detected
CORNUCOPIA	07/24/86	Weapons related	<20	Shaft	^{131}I not detected
LABQUARK	09/30/86	Weapons related	20-150	Shaft	^{131}I not detected
BELMONT	10/16/86	Weapons related	20-150	Shaft	^{131}I not detected
GASCON	11/14/86	Weapons related	20-150	Shaft	^{131}I not detected
BODIE	12/13/86	Weapons related	20-150	Shaft	^{131}I not detected
HAZEBROOK	02/03/87	Weapons related	<20	Shaft	^{131}I not detected
HARDEN	04/30/87	Weapons related	20-150	Shaft	^{131}I not detected
MISSION GHOST	06/20/87	Weapons effects	<20	Tunnel	^{131}I not detected
PANCHUELA	06/30/87	Weapons related	<20	Shaft	^{131}I<0.3
LOCKMEY	09/24/87	Weapons related	20-150	Shaft	^{131}I: 0.001
BORATE	10/23/87	Weapons related	20-150	Shaft	^{131}I not detected
SCHELLBOURNE	05/13/88	Weapons related	<150	Shaft	^{131}I: 0.000035
BULLFROG	08/30/88	Weapons related	<150	Shaft	^{131}I not detected
BARNWELL	12/08/89	Joint US-UK	20-150	Shaft	^{131}I not reported[d]

[a] The event produced detectable offsite ^{131}I contamination in milk with a maximum measured concentration of 180 pCi L^{-1} at Austin NVon 30 June. The Department of Energy has nevertheless classified this event as an onsite only release. The release of ^{131}I has not been reported.

[b] The total release of radioactive materials is estimated to be 400 Ci and to consist of xenons and iodines. The fraction of activity due to ^{131}I has not been reported.

[c] A controlled release of radioactive materials of 140 Ci has been estimated. The fraction of activity due to ^{131}I has not been reported.

[d] Information on the release of ^{131}I has not been found.

then the Alamogordo Bombing Range, and is now the White Sands Missile Range. Following this test, nuclear bombs were dropped on Hiroshima and Nagasaki, Japan, in August 1945. These bombs leveled both cities and ended the war in the Pacific. After the war, at various times between June 1946 and November 1962, five underwater and 101 atmospheric tests took place in the Pacific (mainly in the Marshall Islands, Christmas Island, and Johnston Atoll), and three atmospheric tests were conducted over the South Atlantic Ocean. Since July 1962, all nuclear tests conducted by the United States have been underground and most of them have been at the NTS. Five tests were conducted on the Nellis Air Force Bombing Range in the vicinity of the NTS; one in central Nevada; one in northwestern Nevada; three in New Mexico; two in Colorado; two in Mississippi; and three on Amchitka, one of the Aleutian islands off the coast of Alaska (U.S. Department of Energy 1993;1994).

The number and type of tests that were conducted by the U.S. through September 1992 are listed in *Table 2.5* for each location. *Figure 2.3* shows the location and the number of tests that took place in the continental U.S. (U.S. Department of Energy 1994).

2.5. PRODUCTION AND CHARACTERISTICS OF ^{131}I IN FALLOUT

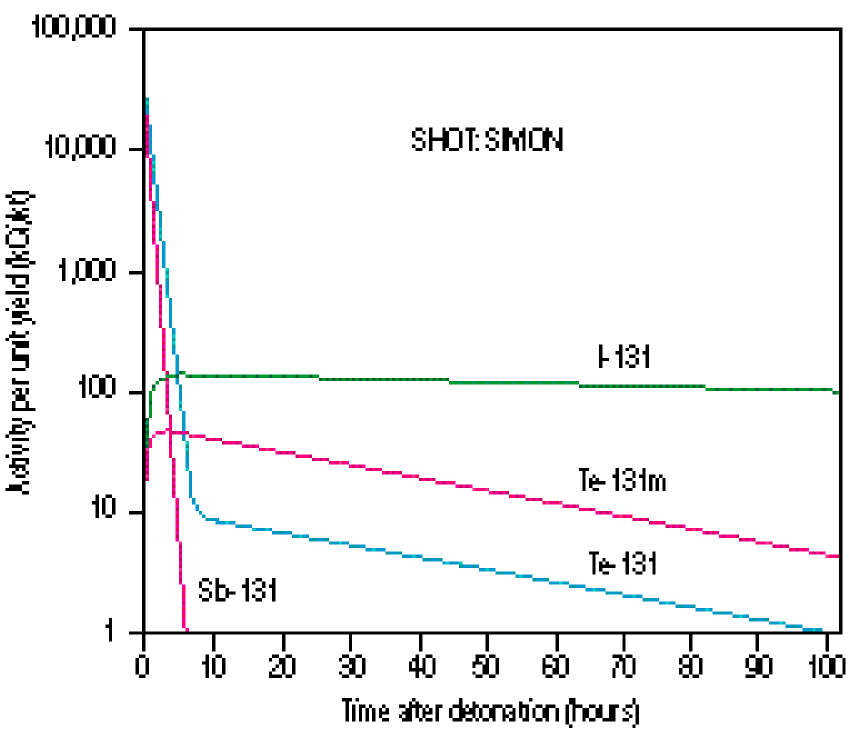
The production of ^{131}I in a nuclear test, its dispersion in the atmosphere and its deposition on the ground are discussed in the following section.

2.5.1. Production of ^{131}I

The detonation of a nuclear device creates hundreds of different kinds of radioactive atoms, or radionuclides. As these radioactive atoms decay, the number of original radionuclides drops while new decay products form. Over a period of time, most of the atoms become stable (non-radioactive), leaving a residue consisting of relatively few radionuclides. The term "half-life" is used to characterize the rate of decay of each radionuclide, i.e., the time it takes for that radionuclide to decay to one half of its initial activity. Radionuclides that decay rapidly have a short half-life, while those that decay more slowly have a longer half-life. For example, the isotope of caesium with a mass number of 137 (^{137}Cs) takes 30.2 years to decay to half of its initial activity, but ^{131}I decays to one half of its initial activity in about eight days.

Most of the activity of ^{131}I resulting from the fission process arises from the decay of short-lived precursors with half-lives ranging from 0.29 second to 30 hours. *Table 2.6* presents the radioactive precursors and decay products of ^{131}I, along with their radioactive half-lives and an example of their fractional independent yields; the latter represent the relative numbers of atoms with a mass number of 131 that are created during the nuclear explosion, expressed as a fraction of the fission-chain yield.[1] The fractional independent yields and the fission-chain yield vary slightly from one test to another; *Table 2.6* presents the values derived from measurements related to the shot Simon, detonated 25 April 1953 (Hicks 1981).

Figure 2.4. Activity of radionuclides of the 131 chain.



[1] The fission-chain yield is the total number of fissions creating atoms with the same mass number (in this case, 131) and is expressed as the percentage of the total number of fissions produced in the explosion.

Table 2.5. United States nuclear tests from July 1945 through September 1992 (Friesen 1985; U.S. Department of Energy 1993; 1994).

	Aboveground	Underground		Underwater	Total
		Cratering	Non-cratering		
Continental U.S.:					
NTS(through 1958)	97	2	20	0	119
NTS(since 1961)	3	8	798[a]	0	809
Other	6	0	11	0	17
Pacific:					
Johnston Island	12	0	0	0	12
Enewetak	41	0	0	2	43
Bikini	22	0	0	1	23
Christmas Island	24	0	0	0	24
Other	2	0	0	2	4
South Atlantic					
	3	0	0	0	3
Total	210	10	829	5	1054

[a] Including 24 tests conducted jointly with the United Kingdom
[b] Totals do not include two combat uses of nuclear weapons, which are not considered “tests”. The first combat detonation was a 15-kt weapon airdropped on August 6, 1945, at Hiroshima, Japan, The second was a 21-kt weapon airdropped on August 9, 1945 at Nagasaki, Japan.

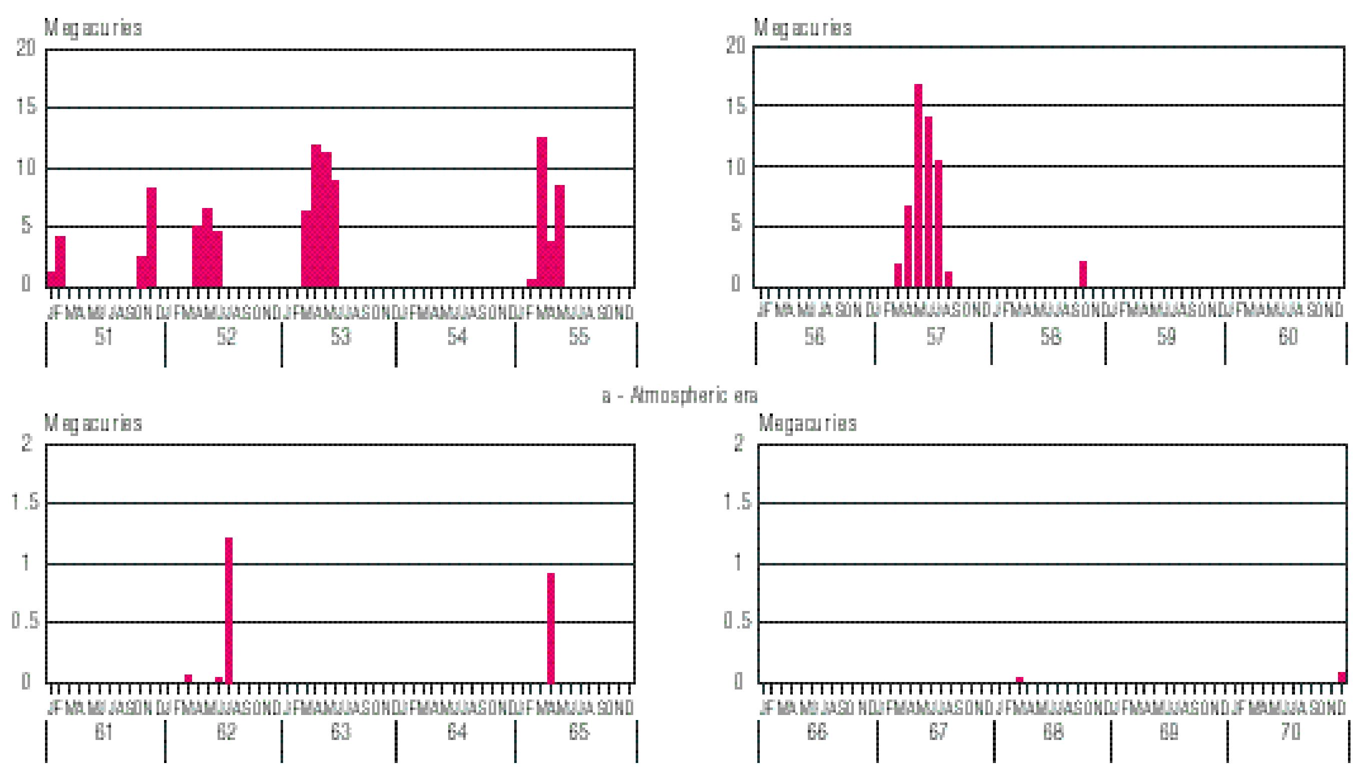
The variation of the activity of important radionuclides of the mass-131 decay chain with time after detonation was calculated using the parameter values given in *Table 2.6.* The results, presented in *Figure 2.4,* are related to the shot Simon but would be very similar for most of the tests conducted at the NTS. The activity of ^{131}I increases rapidly during the first few hours after detonation and then remains relatively constant for several days. About 150,000 curies (Ci) of ^{131}I are produced per kt of energy released. The actual amounts of ^{131}I released into the atmosphere in each nuclear test were calculated on the basis of measurements, as indicated in **Appendix 1.** The total activity of ^{131}I released into the atmosphere by the Nevada atmospheric bomb tests is estimated to be 150 MCi. *Figure 2.5* illustrates the distribution with time of the monthly releases of ^{131}I into the atmosphere. Most of the ^{131}I releases took place in the 1950s, with peaks above 10 MCi in a month in 1953, 1955, and1957. The highest monthly releases in the 1960s were in the neighborhood of 1 MCi. The last substantial monthly release of the monthly releases between 1971 and 1990 (not shown in *Figure 2.5*) are all below 0.0001 MCi.

It is worth noting that there is no practical possibility at the present time to detect the amounts of ^{131}I that were released into the environment in the 1950s. Because of its radioactive half-life of 8.04 days, ^{131}I decays to 2 x 10^{-14} of its initial value after one year, and to 2 x 10^{-479} of its initial value after 35 years. The amounts of ^{131}I still present in the environment are therefore infinitesimally small. Theoretically, ^{127}I and ^{129}I, other isotopes of iodine that are created by the fission process, could be used as tracers for ^{131}I (Holland 1963). Stable ^{127}I, as the end-point of a low-yield fission product decay chain is produced in such small quantities when compared to the natural inventory that it cannot be used as a tracer for ^{131}I. The radioactive ^{129}I has a half-life of 16 million years, so that its activity at the present time is practically the same as it was 35 years ago. Unfortunately, the production of ^{129}I resulting from nuclear tests at the NTS constitutes a small fraction of the total activity of ^{129}I that has been released into the environment as a result of nuclear tests at other sites and of the reprocessing of nuclear fuel. In measurements of ^{129}I/^{127}I ratios in human thyroid tissues from Utah that had been stored in paraffin blocks since the 1940s and 1950s, Wrenn et al. (1992) found no statistical difference between the mean values of ^{129}I/^{127}I ratios prior to and after the start of atmospheric testing at the NTS in 1951.

2.5.2. Characteristics and Dispersion of the Radioactive Cloud

Nuclear tests (also called bursts, shots or events) releasing radioactivity into the air are categorized by the position of the detonation point relative to the earth's surface. This categorization arises from the direct and secondary explosion phenomenology as the explosion interacts with its environment. Whether or not the fireball created by the shot touches the

Figure 2.5. Chronology of atmospheric releases of I-131 resulting from nuclear tests at the NTS.



ground is the separating criterion between types. The typical air shot, of which the high-altitude shot is a special case, explodes at a height where the fireball is in its entirety above the surface of the earth so there is little or no interaction with the surface.

The important difference between an air shot and those involving the surface or sub-surface is that the resulting radioactive cloud from the latter two is very heavily loaded with ground debris. This debris includes the material initially vaporized or melted and the material drawn up into the cloud by the subsequent strong updraft.

The stabilization height, defined as the maximum height reached by the radioactive cloud, depends on the thermal buoyancy generated by the weapons' energy release into the atmosphere and by the ambient atmospheric conditions, primarily the stability of the atmosphere and its moisture content. The greater the heat generated by the explosion and released into the atmosphere, the greater is the thermal buoyancy and the higher the cloud ascends. The cloud from an airburst rises higher than a similar-sized surface or sub-surface event which loses heat in its ground interaction and has reduced thermal buoyancy.

The radioactive cloud that is formed after an atmospheric detonation near the ground surface usually is in the shape of a mushroom with a stem extending from the mushroom cloud base to the ground, and, if of sufficient energy, can penetrate to the highest layers of the troposphere, and occasionally reach into the stratosphere. As an example, *Figure* 2.6 shows a schematic depiction of the mushroom cloud and stem resulting from the test Simon, which took place on 25 April 1953 (List 1954). The top of the radioactive cloud reached an altitude of 13.7 km. Eighty percent of the ^{131}I activity contained in the radioactive cloud was estimated to be between 9.5 km and 13.7 km; 10% was between ground level and 9.5 km, and the remaining 10% was deposited as local fallout.

As the radioactive cloud reaches its stabilization height, ambient meteorological conditions begin to exert their influence on its movement. Winds aloft begin to move the cloud downwind while atmospheric vertical motions and dispersion cause vertical and lateral cloud movement. As exemplified in *Figure* 2.7 in the case of the test Simon, wind speeds and directions usually vary with altitude. These variations result in a substantial spread of the ^{131}I present in the radioactive cloud over large territories. *Figure* 2.7 presents the paths of the trajectories followed by the portions of the radioactive cloud located at four altitudes after the test Simon. The entire radioactive cloud, which spread between those trajectories, covered about half of the continental United States. The meteorological model that

Figure 2.6. Schematic depiction of the mushroom cloud and stem resulting from the test Simon, detonated 25 April 1953.

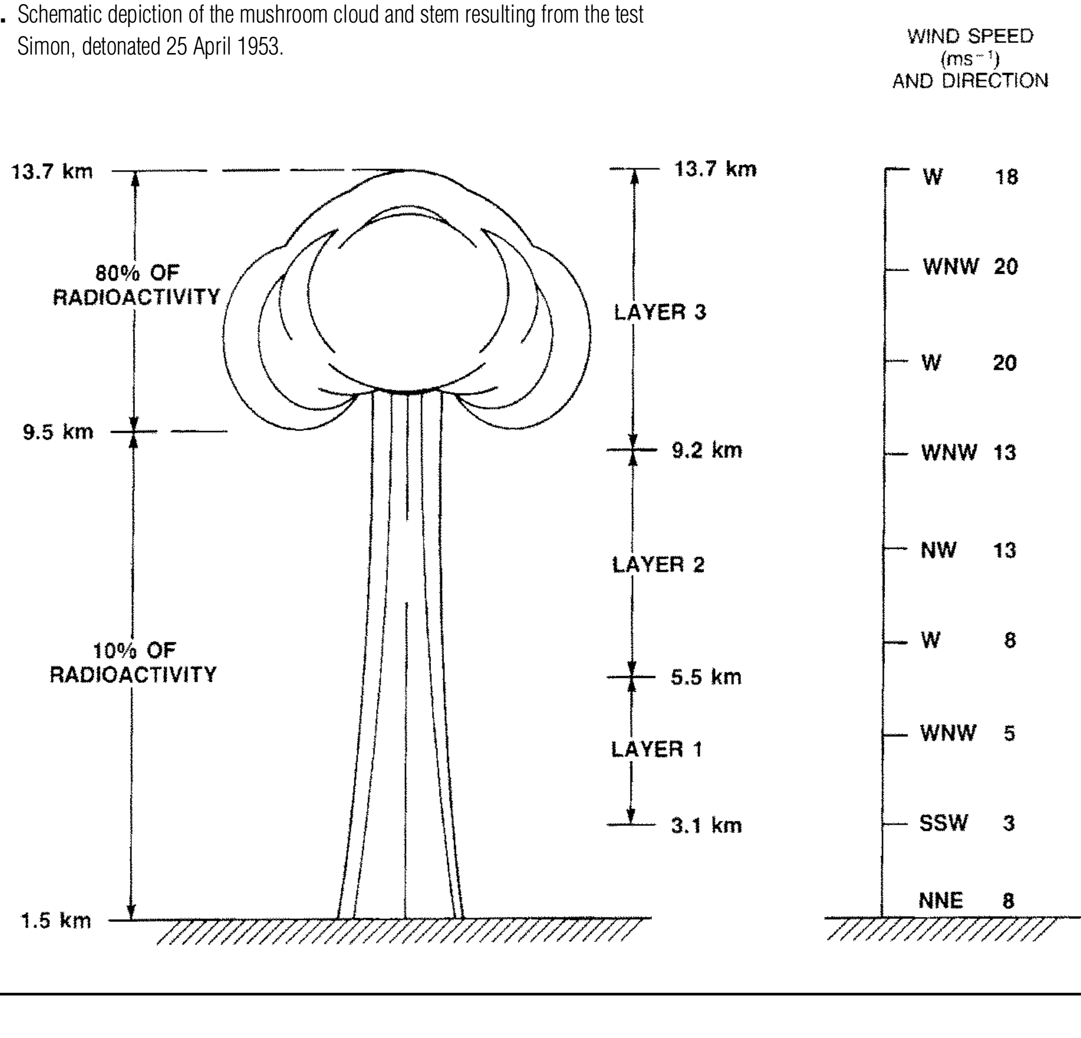


Table 2.6. Nuclear characteristics of the radionuclides of the 131 decay chain.

Name of radionuclide		Radioactive half-life (Lederer 1978)	Fractional independent fission yields (a) (Crouch 1977, Hicks 1981)
Indium-131	(In-131)	0.29 s	0.01
Tin-131	(Sn-131)	63 s	0.27
Antimony-131	(Sb-131)	23.03 min	0.47
Tellurium-131 isomer	(Te-131m)	30 n	0.00002
Tellurium-131	(Te-131)	25 min	0.23
Iodine-131	(I-131)	8.04 d	0.02
Xenon-131 isomer	(Xe-131m)	11.77 d	—
Xenon-131	(Xe-131)	stable	—
Fission-chain yield (a): 3.72%			

(a)Based on measurements related to the shot Simon detonated 25 April 1953; the values vary slightly from shot to shot

was used in this report to estimate the dispersion of the radioactive cloud is described in detail in **Appendix 1.**

2.5.3. Characteristics of ^{131}I in Fallout

A nuclear detonation creates a fireball of extremely high temperature that vaporizes everything in the immediate area. In an atmospheric detonation, as the fireball rises rapidly and begins to cool, some of the vaporized radioactive fission products condense from the gaseous state into droplets. Some of the more volatile elements such as iodine collect on the solid particles (soil and other materials) that have been drawn up into the cloud. In the absence of precipitation, large particles fall back to the earth's surface within a few hours (close-in, or local, fallout), smaller particles are deposited within a few days or weeks (intermediate, or tropospheric, fallout) while very small particles may be carried to high altitudes (in the stratosphere) and fall back to earth over a period of months to years (world-wide or global, fallout). When precipitation occurs, however, particles of any size are scavenged by rain as a result of (a) incorporation of particles in the raindrops as they are formed in the cloud, or (b) attachment of the particles to the raindrops as they fall to the ground.

The chemical and physical form of the ^{131}I is an important factor in estimating the amount of ^{131}I deposited on the ground. Limited measurements, unrelated to weapons testing at Nevada Test Site (NTS), show that ^{131}I from weapons tests is partitioned among three physico-chemical forms: gaseous organic, gaseous inorganic, and particulate (Perkins 1963; Perkins et al. 1965; Voilleque 1979). From measurements taken after a

Figure 2.7. Paths of the trajectories followed by portions of the radioactive cloud at the altitudes of 3.1, 5.5, 9.2, and 12.2 km above mean sea level (MSL) resulting from the test Simon detonated 25 April 1953. The closed dots represent the locations of the trajectories at 00:00 GMT, while the numbers near the closed dots are the day of the month. The open dots represent the locations of the trajectories at 06:00, 12:00 and 18:00 GMT.

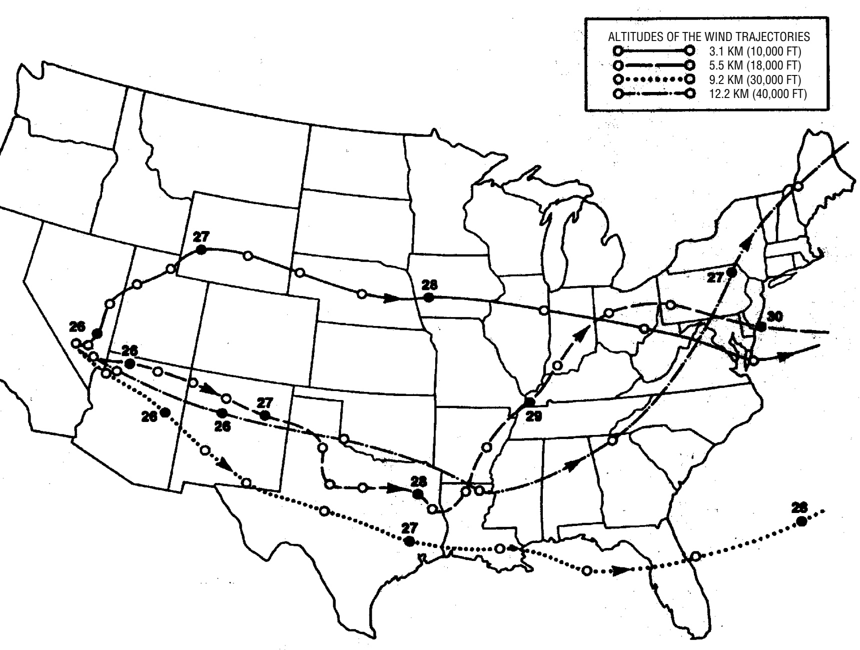
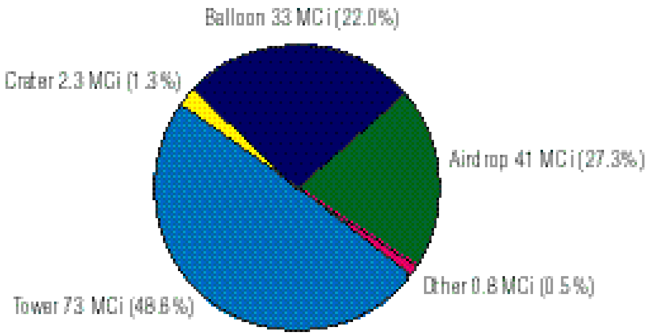


Figure 2.8. Distribution and activity releases of I-131 (MCi) into atmosphere according to type of test.



Chinese nuclear weapons test, the partitioning between these three forms was shown to vary with the time elapsed following the detonation (Voilleque 1979). At the request of the NCI, Voilleque (1986) reviewed the literature and estimated that more than half the ^{131}I from NTS fallout would be associated with particle diameters of less than about 20 m, with the remainder of the ^{131}I presumably in organic and inorganic gaseous forms. Because the behaviour of particles with respect to deposition processes is intermediate between those of gaseous organic and gaseous inorganic iodine, it is assumed for the purpose of the calculations that all of the ^{131}I was associated with particles. It is shown in **Appendix 7** that this assumption does not lead to a substantial bias in the estimates of ^{131}I deposition.

The pattern of local and intermediate fallout from a given nuclear test had unique characteristics determined by the meteorological conditions (e.g., wind speed and direction at all altitudes, atmospheric stability, precipitation) and by the characteristics of the initial radioactive cloud (e.g., physical dimensions, range of particle sizes, distribution of activity within the cloud). In general, tower and surface shots resulted in substantial local and intermediate fallout whereas very little close-in fallout was associated with airdrops or balloon events. *Figure 2.8* shows that about half of the total activity of ^{131}I released into the atmosphere as the result of the Nevada atmospheric bomb tests was due to tower shots, while the other half was contributed by airdrop and balloon events.

2.6. SUMMARY

- The Nevada Test Site (NTS), located in Nye county in southern Nevada, consists of 3,500 square kilometers of federally owned land with restricted access.

- Detonation of a nuclear device creates hundreds of radionuclides, among which are ^{131}I and its precursors, and is accompanied by a tremendous release of energy. The characteristics of the radioactive cloud produced by the explosion depend essentially on the energy released (yield) and on the location of the device in relation to the earth's surface. Above-ground nuclear tests of substantial yield result in radioactive clouds which extend vertically over 10 kilometers and carry radioactive debris that may fall back to earth over a period of months to possibly years.

- Low-yield nuclear tests have been conducted at the NTS since 1951. From January 1951 through October 1958, 119 tests were conducted, most of them above ground. Nuclear testing was interrupted between November 1958 and September 1961, but more than 800 tests were conducted from 1961 until September 1992; the overwhelming majority of those shots were detonated underground, under conditions that were designed for containment of radioactive debris. On October 2, 1992, the United States entered into another unilateral moratorium on nuclear weapons testing announced by President Bush. President Clinton extended this moratorium in July 1993, and again in March 1994 until September 1995 (U.S. Department of Energy 1994).

- The total activity of ^{131}I released into the atmosphere is estimated to have amounted to 150 MCi; most of this activity was released in the 1950s, with peaks in 1953 and in 1957.

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Chapter 3

Deposition of ^{131}I on the Ground

Contents: The data used to estimate the activities of ^{131}I deposited per unit area of ground for each county of the contiguous United States following each nuclear test of interest are described. There are limited data available from the time during which the tests were carried out. In the absence of environmental radiation measurements, a meteorological transport and wet deposition model was used. The estimated amounts of ^{131}I released into the atmosphere by each test are tabulated. The available measurements are described in **Section 3.2.** *Detailed mathematical descriptions of the procedures used to estimate daily depositions of ^{131}I are in* **Section 3.3.** *Comparisons of the results obtained using different procedures are presented in* **Section 3.4.** *In* **Section 3.5***, the nuclear weapons tests are subdivided according to the procedures used to estimate ^{131}I deposition. A detailed listing of all tests considered in this report is provided as is the rationale for selection of those tests.* **Section 3.6** *provides summary estimates of ^{131}I deposition throughout the country from weapons testing in Nevada.*

3.1. INTRODUCTION

The amount of ^{131}I deposited in each county of the contiguous United States[1] for each shot was estimated using one of three methods. The method chosen depended upon the extent and type of environmental measurements available.

The activity of ^{131}I deposited on the ground was not measured directly in the 1950s because most measurements of environmental radioactivity at that time were of gross beta (β) activity; specific measurements of ^{131}I in the environment were not performed to a significant extent before 1960. Since the half-life of ^{131}I is about 8 days, the activity of ^{131}I present in the samples collected more than thirty years ago has now completely decayed, and therefore cannot be analyzed. Because few ^{131}I measurements were made at that time and because ^{131}I present at that time cannot be measured today, the estimation of the amount of ^{131}I deposited on the ground at that time cannot be based on unequivocal measurements of ^{131}I. It is possible, however, to estimate the amounts of ^{131}I deposited on the ground from some of the measurements (e.g., exposure rates, total β activity in air or deposited on sticky surfaces) which were systematically made after most of the tests as part of environmental monitoring programs. Although most of the measurements were made in the vicinity of the Nevada Test Site (NTS), one of the environmental monitoring programs collected samples at up to 95 sites located throughout the United States.

Three procedures are used for the determination of the deposition of ^{131}I in the counties of the contiguous United States for which no monitoring data are available. First, where there are enough measurements of deposition of gross β activity that can be converted to estimates of ^{131}I deposition, these, together with precipitation data, are used to interpolate estimates of ^{131}I deposition for all counties of the contiguous United States. A statistical technique, kriging, described in **Section 3.3.1.3,** is used to make these estimates. Second, where the kriging procedure is unlikely to be satisfactory due to an insufficient number of ^{131}I deposition estimates based on the analysis of gross β activities, a less complex method is employed. For a county without monitoring data, the ^{131}I deposition is estimated using the deposition estimate from the nearest county with monitor-

1 Data on the name, location, area, and population of each county of the contiguous United States are provided in **Appendix 2.**

ing data and the precipitation data for those counties **(see Section 3.3.1.2.4).** Those two procedures constitute what is called the *"historical monitoring data approach"* in this report. Finally, if estimates of surface deposition values of ^{131}I are not available, calculations of the wet deposition of ^{131}I were based upon a meteorological model **(Section 3.3.2 and Appendix 1).** This is called the *"meteorological transport approach"* in this report.

3.2. AVAILABLE MEASUREMENT RESULTS FROM THE TESTING PERIOD

A limited number of environmental radiation measurements are available from the period of testing in the atmosphere at the NTS. They are:

(a) measurements of exposure rates above ground, which were obtained near the NTS after each test using survey meters and are called "close-in measurements of environmental radiation,"

(b) measurements of deposition of fallout on gummed film. This systematic monitoring of fallout deposition was carried out for sites within the contiguous U.S. and also for sites throughout the rest of the world. For the purpose of this report, only the sites within the contiguous U.S. and, occasionally, a few sites in Canada, have been considered. This fallout deposition network is called "national network of deposition measurements,"

(c) measurements of individual radionuclides in the radioactive cloud, allowing the determination of the activity distribution of the radionuclides to be made. These measurements, called "radiochemical data," were necessary to establish the correspondence between the exposure rates above ground, or the fallout depositions, and the ^{131}I depositions per unit area of ground,

(d) measurements of exposure rates aboard aircraft, and

(e) other, less extensive measurement programs in the temporal or spatial dimensions, such as the measurements of ground-level air activity by the Public Health Service (PHS) and by the Naval Research Laboratory (NRL), or the measurements of activity in precipitation by the PHS.

In addition, the spatial and temporal distribution of rainfall vis-à-vis that of the radioactive cloud, which played an important role in the determination of the deposition at the national scale, is available from historical records.

3.2.1. Close-In Measurements of Environmental Radiation

For counties near the NTS, the primary data are exposure-rate measurements using portable survey instruments. An extensive program of exposure rate measurements was carried out in a few counties near the NTS for several days following each test. These exposure-rate measurements, together with other, less extensive, monitoring data, were evaluated and archived by the Offsite Radiation Exposure Review Project (ORERP) of the Department of Energy. From these data, a Town Data Base (Thompson 1990) and a County Data Base (Beck and Anspaugh 1991) were derived:

(a) The Town Data Base (TDB) lists the time of arrival of the radioactive cloud produced by each test and the exposure rate normalized at 12 hours after detonation (H + 12) at 173 stations, representing inhabited locations, in 4 counties of Nevada (Clark, Esmeralda, Lincoln, and Nye) and in Washington County, Utah. In order to provide a uniform basis of comparison, the pertinent literature has used H + 12 as the standard time to report exposure rates; fallout may have been deposited on the ground before or after H + 12.

(b) The County Data Base (CDB) lists the estimated times of initial arrival of the radioactive cloud and the estimated exposure rates normalized at H + 12 in 24 subdivided areas of nine counties in Arizona, California, Nevada, and Utah, along with similar information for 120 additional counties (which were not subdivided) in Arizona, California, Colorado, Idaho, New Mexico, Nevada, Oregon, Utah, and Wyoming.

The geographical areas included in the Town and County Data Bases are shown in *Figures 3.1 and 3.2,* respectively.

3.2.2. National Network of Deposition Measurements

Monitoring of long-range fallout deposition in the United States in the 1950s was carried out primarily by the Health and Safety Laboratory (HASL) of the Atomic Energy Commission in cooperation with the U.S. Weather Bureau (Beck 1984; Harley et al. 1960). The HASL deposition network evolved gradually, beginning in the fall of 1951 with the Buster-Jangle test series. The original monitoring technique consisted of collectors which were trays of water; these were soon replaced by gummed paper for the 1952 Tumbler-Snapper test series. The gummed paper was replaced by an acetate-backed rubber-base cement gummed film in 1953, and this medium was used until the program ended in 1960.

A 1 square foot (0.093 m^2) exposed area of gummed film was positioned horizontally on a stand 3 feet (0.9 meters) above the ground. Usually two replicate films were exposed during a 24-h period beginning at 1230 Greenwich Mean Time (GMT) for the Upshot-Knothole, Teapot, Plumbbob and Hardtack-II series and at 1830 GMT for the Buster-Jangle and Tumbler-Snapper series. Daily high volume air samples also were collected at many of the gummed-film sites.

The number and types of monitoring sites in operation in the United States changed from one test series to another.

Figure 3.1. Geographical coverage of the Town Data Base of the ORERP study of the U.S. Department of Energy: each of the 173 stations is marked with its code number. The approximate center of the Nevada Test Site is marked with a star.

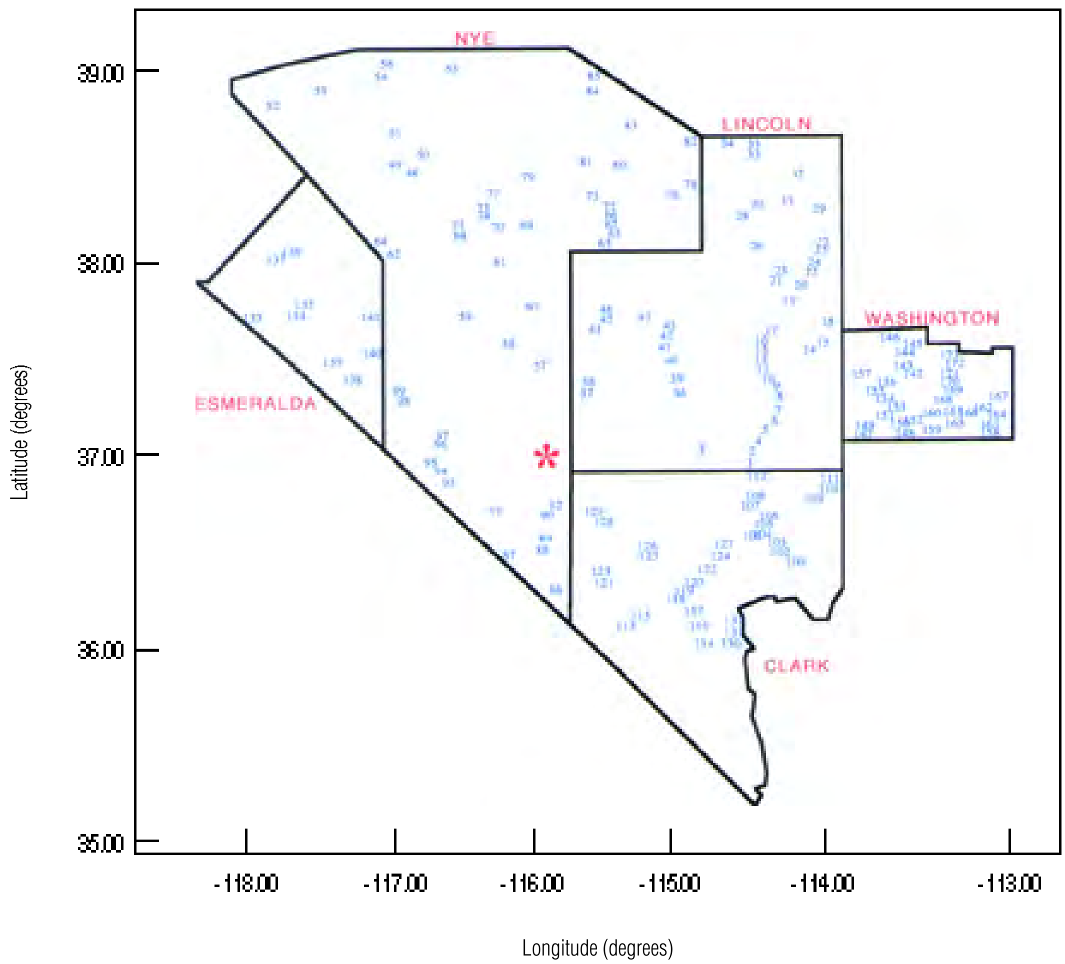


Figure 3.2. Geographical coverage of the County Data Base of the ORERP study of the U.S. Department of Energy: the 9 counties in solid colors are those that were subdivided while the 120 counties hatched in blue were not subdivided. County boundaries for the remainder of the states in which the County Data Base is located also are shown. The approximate center of the Nevada Test Site is marked with a star and the 5 counties covered by the Town Data Base are shown in white.

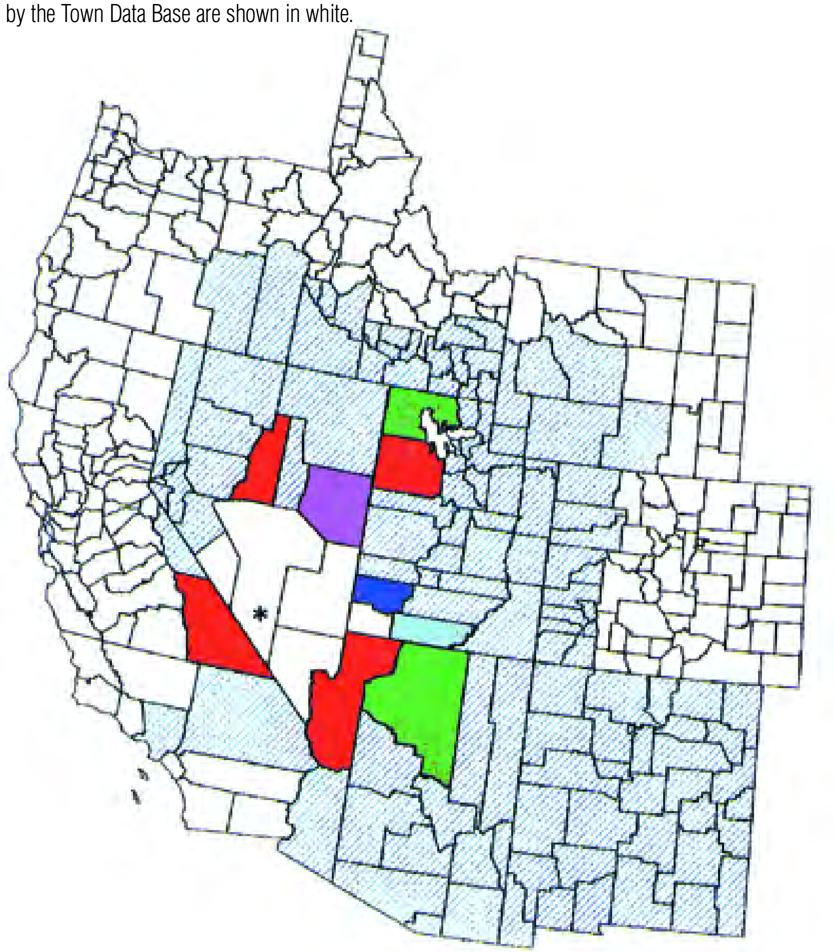


Table 3.1. Number of contiguous U.S. sites of fallout monitoring by HASL, for which data are available, by test series (Beck 1990).

Test Series	Year	Number of sites
BUSTER-JANGLE	1951	51-61[a]
TUMBLER-SNAPPER	1952	93
UPSHOT-KNOTHOLE	1953	95
TEAPOT	1955	89
PLUMBBOB	1957	42[b]
HARDTACK-PHASE II	1958	40

[a] The number of sites of fallout monitoring varied from one test series to another.

[b] Estimates of ^{131}I deposition also were derived from 25 sites at which measurements of β activity in air and in precipitation were carried out by the Public Health Service.

Although only about 40 sites operated continuously throughout the atmospheric testing era, the number generally was increased during the testing periods and reached a maximum of 95 in 1953 (Upshot-Knothole series) (*Table 3.1*).

Figure 3.3 illustrates the geographical coverage of the network during the Upshot-Knothole series. *Figure 3.4* shows the reduced available coverage during 1957, which was the last year of substantial atmospheric testing at the NTS; during that year, however, estimates of ^{131}I deposition also were derived from 25 sites from the PHS network (described in **Section 3.2.5**).

The gummed-film samples were sent to HASL where they were processed and total beta activity counts were made. The measured beta activities were extrapolated to the middle of the sampling day, using the assumption that the total beta activity decreased with time after detonation t, expressed in hours, according to a power function ($t^{-1.2}$). These fallout results, as well as the amount of precipitation recorded at the sampling location that day, were published in joint reports by HASL and the U.S. Weather Bureau (List 1953, 1954, 1956; NYO 1952, 1954).

The HASL network effectively fulfilled its purpose of indicating quickly where and when fallout occurred. Although this network was not designed to derive radiation exposures, it represents the only data set available on a daily basis over the entire United States during most of the atmospheric testing period. Therefore, it was extensively used to derive deposition estimates of ^{131}I (or of any other radionuclide from fallout) at the national scale.

3.2.3. Radiochemical Data

Measurements of individual radionuclides in the radioactive cloud were conducted after many events (Hicks 1981a). These measurements, called "radiochemical data", were used to establish the relative amounts of radionuclides in the radioactive cloud, immediately after detonation.

On the basis of the radiochemical data, the correspondence between external gamma radiation exposure rate and radionuclide ground depositions, as a function of time after detonation, has been published by Hicks (1981a) for all tests that resulted in off-site detection of radioactive materials. The tabulated results include 30 decay times, grouped in three time periods following detonation: 10 decay times between 1 and 21 hours, 10 decay times between 1 to 300 days, and 10 decay times between 1 to 50 years. For each of these times, Hicks calculated: (a) the exposure rate from external gamma radiation, (b) the deposited activity per unit area of ground of specified individual radionuclides (including ^{131}I), and (c) the total deposited activity per unit area of ground of all radionuclides. Thus, given a measurement of the exposure rate, one can derive the ^{131}I and total deposition on the ground. Similarly, if the total deposition is known, the ^{131}I deposition and the exposure rate can be determined.

3.2.4. Aircraft Measurements

Aircraft measurements were used: (1) to track the movement of the radioactive cloud and sample its contents, or (2) to estimate off-site radiation fields .

Aircraft sampling of radioactive clouds was obtained at high altitudes in 1951 (Machta et al. 1957). In general, flights were made along the 80th and 95th meridians, at elevations between 2.5 and 9.2 km. The aircraft were equipped with two filters, which were changed alternately every 15 min, so that each filter was exposed for 30-min periods. After sufficient time for decay of the natural radioactivity, the filter was measured with a Geiger counter. The conversion of the counting rates into activity concentrations in air was not attempted because of inadequate information on the efficiency of the filter, the counting geometry of the Geiger counters, etc. (Machta et al. 1957).

Aerial surveys of off-site radiation fields began in 1953 and continued until 1970 with aircraft flying at altitudes of 50 to 500 ft (Burson 1984). The data from those aerial surveys were used extensively to assist in quickly estimating the fallout radiation patterns. In general, the aerial survey results were used to support the ground data, not vice-versa, since the aerial survey technique was still under development and many uncertainties existed in its application. In many locations, however, ground measurements were not made and the aerial survey results alone were relied on to extend the fallout patterns. This occurred particularly during the Plumbbob test series in 1957 and also in the 1960s when the aerial survey results were more reliable (Burson 1984).

The radioactive clouds from cratering and vented underground tests, beginning in 1960, were tracked by aircraft (usually two) (Anon. 1975, 1976; Crawford 1970; Placak 1962; Thompson 1966). The movements and speed of the radioactive cloud were determined by on-board exposure-rate meters and by visual observations of dust in the cloud. Many such clouds were tracked beyond the test site and a few were tracked into neighboring states to the north and east of NTS. High-volume air samples also were collected in the aircraft, depositing radioactive particles on special filters.

3.2.5. Other Measurement Programs

Other measurement programs, less extensive than those described above, were established in the 1950s with the purpose of monitoring fallout or man-made activity in air or in water (RHD 1960).

The Public Health Service operated several networks, among which:

(a) The Nationwide Radiation Surveillance Network, established in April 1956 consisted of about 40 stations in which sampling operations included: (a) the daily radioassay of beta-emitting suspended particulate matter with relatively long half-lives, collected on a filter from approximately 2,000 cubic meters of air, (b) two (or more) daily determinations of external gamma radiation levels with a portable survey meter, (c) the collection of radioactive fallout with gummed-film devices, (d) the collection of precipitation sam-

Figure 3.3. Geographical coverage of the gummed-film network during the Upshot-Knothole test series. The diamonds represent the gummed-film stations operated by HASL. The approximate center of the Nevada Test Site is marked with a star.

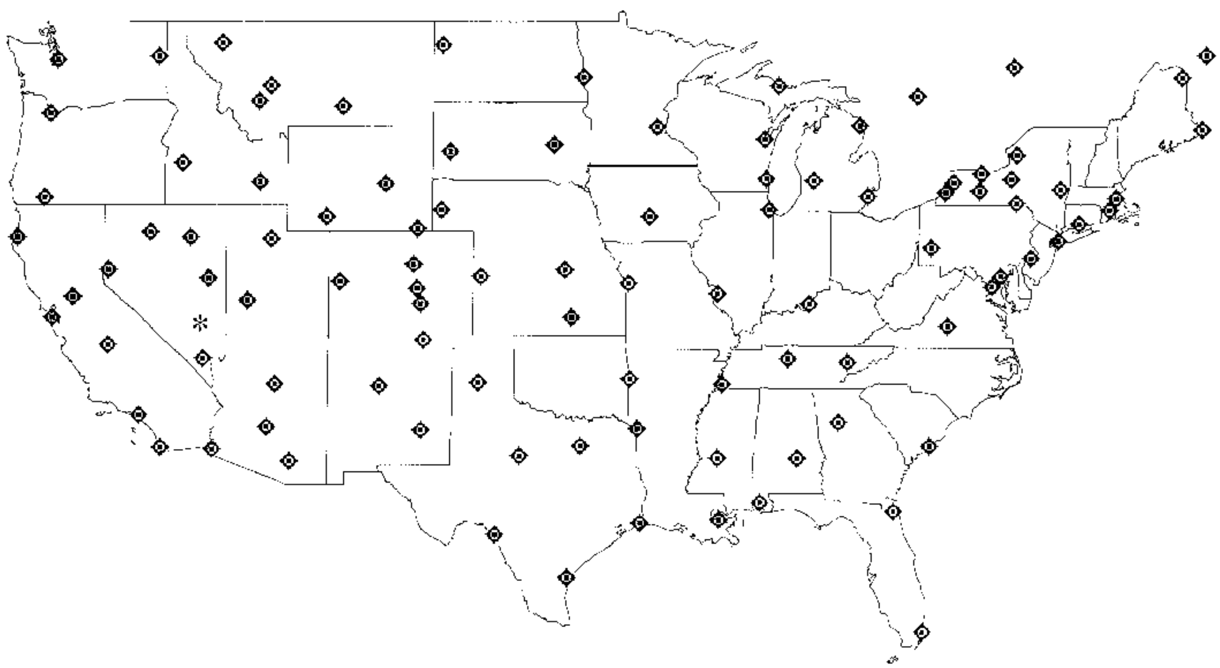
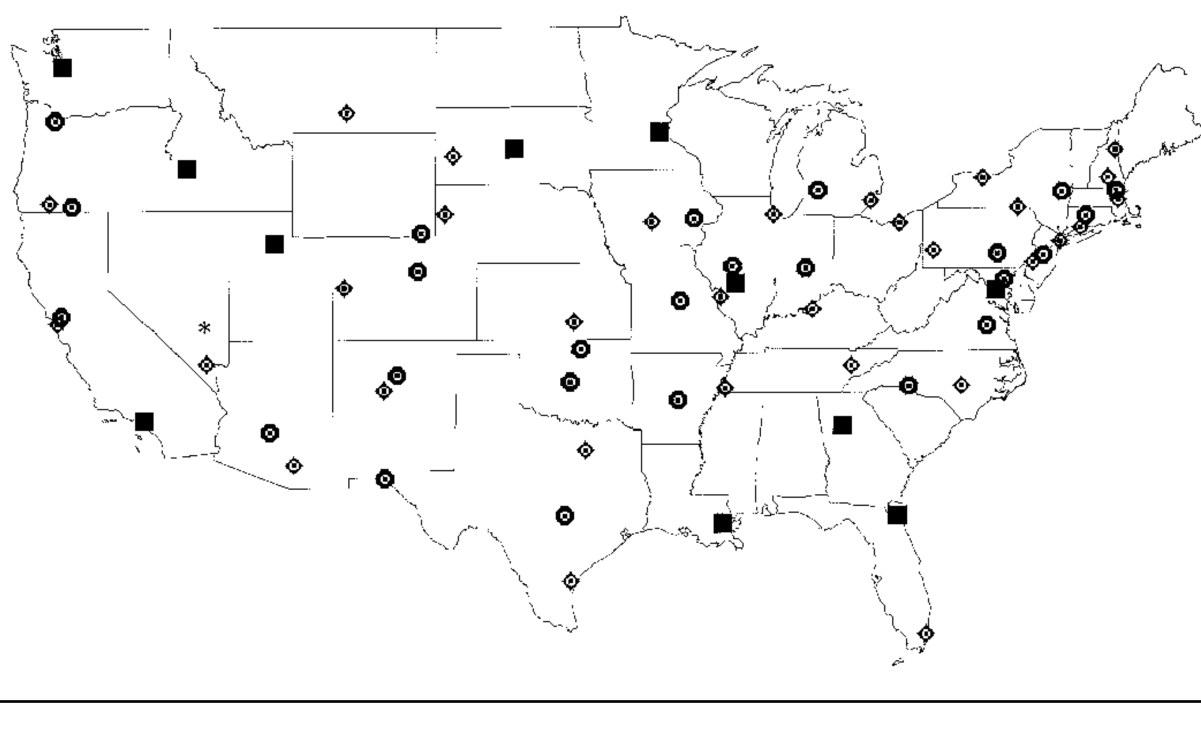


Figure 3.4. Geographical coverage of the deposition network during the Plumbbob test series in 1957. The diamonds represent the gummed-film stations operated by HASL; the circles represent the sites where air and precipitation were collected and analyzed for their activity content by PHS; the squares represent the cities where both HASL and PHS had monitoring stations; the approximate center of the Nevada Test Site is marked with a star.



ples, and (e) the preparation of preliminary reports from which public information might be made available by State and Territorial departments of health (PHS 1957). The results of the Nationwide Radiation Surveillance Network were used in this report to supplement the daily estimates of ^{131}I deposition derived from the HASL gummed-film network.

(b) The National Air Sampling Network, established in 1953, consisted of 17 stations in 1953 and about 200 in 1957. Twenty-four hour samples of suspended particulate matter were collected on filters on a predetermined sampling schedule. Unfortunately, the only results that could be found (PHS 1958) were presented in a statistical manner without indication of the sampling dates. This form of presentation precluded the use of the results for the purpose of reconstructing the fallout patterns after each test.

Beginning in December, 1949, the Naval Research Laboratory operated stations for the detection and collection of both natural radioactivity and radioactive atomic bomb debris (Blifford et al. 1956).There were as many as five stations in the contiguous U.S. (Washington, D.C.; Glenview, IL; San Francisco, CA; San Diego, CA; Bremerton, WA). A filter was used to collect airborne particles for each 24-h period beginning at 1600 local time. At the end of the collection interval the filter was removed from the pumping system and its activity recorded overnight or for approximately 16 hours. The results, reported on a daily basis, constitute the only time series of radioactivity measurements that could be found for the Ranger test series (January - February 1951).

The other measurement programs operated or sponsored by governmental agencies (RHD 1960) were not used because their results were either not found or not suitable for the purposes of this study, usually because the sampling times were too long.

3.2.6. Precipitation Data

Precipitation, hereafter used interchangeably with the words rain or rainfall, efficiently scavenges particles suspended in the atmosphere and can result in much greater deposition than that due to dry processes such as sedimentation, impaction, and diffusion. However, although a substantial fraction of the amount of radioactive materials present in the air may be scavenged by rainfall at particular locations, the fraction of the whole radioactive cloud so removed during one day is small.

Nuclear weapons were detonated when dry weather was predicted so that the deposition of radioactive materials onto the ground in the vicinity of the NTS would be as low as possible. However, because dry conditions were seldom maintained over the entire U.S. for several days after each shot, rainfall represents the primary means by which ^{131}I was deposited east of the Rocky Mountains. Fortunately, there was (and is) a very comprehensive national network of precipitation monitoring stations operated by cooperative observers for the U.S. Weather Bureau, now the National Oceanic and Atmospheric Administration (NOAA). For many years, this network, with rare exceptions, provided at least one measurement location in each of the counties of the contiguous United States. *Figure 3.5* illustrates the location of such stations, together with county boundaries, for one state.

The rainfall amounts represent 24-h accumulations ending usually at 9:00 a.m. local time or within an hour or two of that time. For the purposes of this report, a single precipitation value for each day (the arithmetic average of all readings in the county) was assigned to the entire county. The date to which the precipitation value was assigned was the day that collection of precipitation was begun. Counties without data were rare; such counties were assigned amounts of rainfall based on measurements from locations in the closest adjacent counties. For the purpose of this report, the amounts of rain were categorized on a logarithmic scale by index value as shown in *Table 3.2*.

3.3. DESCRIPTION OF THE METHODS USED TO ESTIMATE DAILY DEPOSITIONS OF ^{131}I PER UNIT AREA OF GROUND

Two approaches were used to estimate daily depositions of ^{131}I per unit area of ground (also called daily deposition densities of ^{131}I):

(a) The historical monitoring data approach: for the tests and counties for which environmental radiation measurements were available that could be used to derive estimates of ^{131}I depositions per unit area of ground, these measurements served as a basis for the assessment of ^{131}I depositions per unit area of ground in the counties and for the days in which the samples or the measurements were taken. For other counties and days in which no environmental radiation measurement was available that could be used to derive estimates of ^{131}I depositions per unit area of ground, the estimates of daily depositions of ^{131}I per unit area of ground were inferred from the closest counties in which daily depositions of ^{131}I per unit area of ground were derived from environmental radiation measurements for the same day, using mathematical techniques that took into account the daily precipitation values.

(b) The meteorological transport approach: for the Ranger series of tests (January-February 1951) and during the underground testing era, useful environmental radiation measurements were not available, either for the entire country or for a large part of it. For those tests, calculations of the deposition of ^{131}I were based upon a meteorological transport model for those counties where precipitation occurred.

Figure 3.5. Network of stations collecting precipitation in New York State. The numbers represent rainfall on April 27, 1953 in hundredths of inches. The solid lines are the county boundaries. The circles show the location of the gummed-film stations.

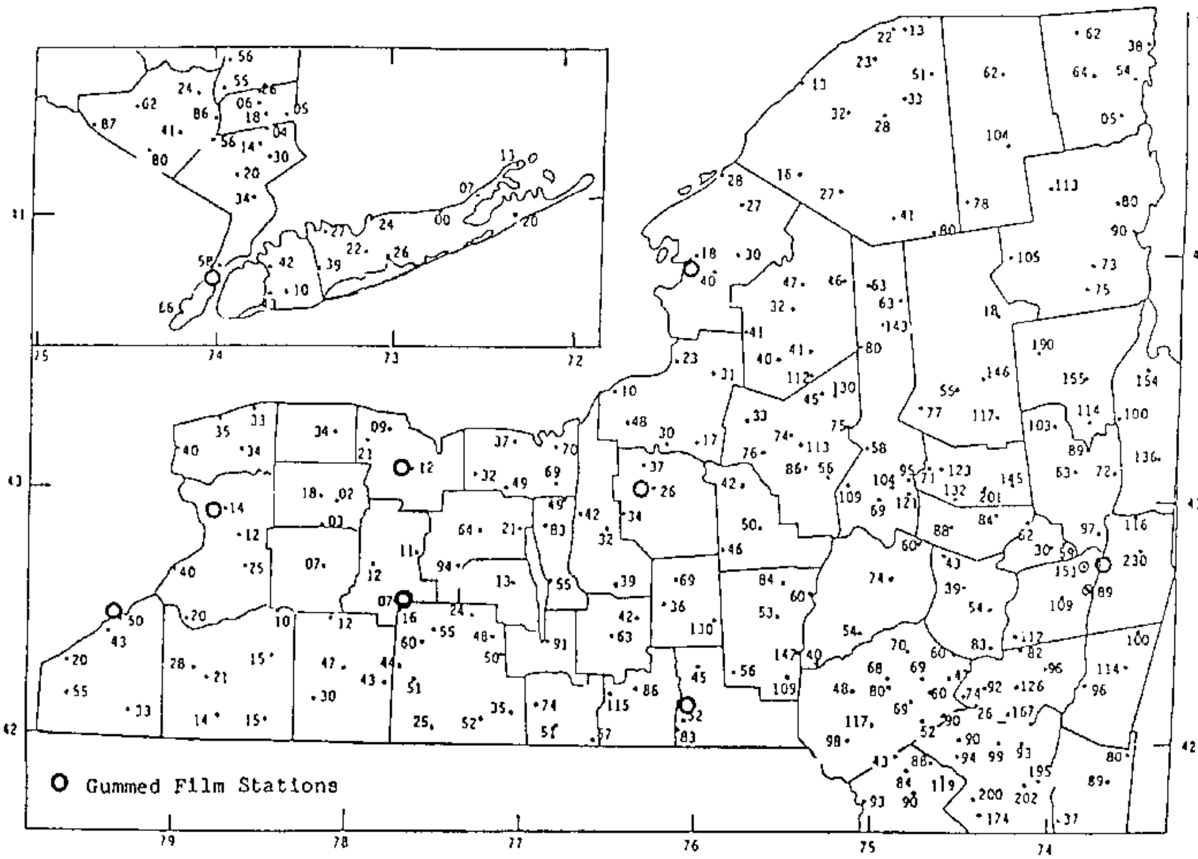


Table 3.2. Relationship between the 24-h precipitation amount and the precipitation index.

Precipitation index number	24-h precipitation amount	
	(inches)	(millimeters)
1	none	none
2	trace	trace
3	0.01-0.03	0.25-0.76
4	0.03-0.10	0.76-2.5
5	0.10-0.30	2.5-7.6
6	0.30-1.00	7.6-25
7	1.00-3.00	25-76
8	3.00-5.00	76-127
9	5.00 or over	127 or over

3.3.1. Historical Monitoring Data Approach

The historical monitoring data approach consists of: (a) processing the historical data available to derive estimates of deposition of ^{131}I per unit area of ground, and (b) using mathematical techniques to interpolate between observed sampling locations using auxiliary information. The main advantage of this method is that it does not require the knowledge of:

(a) the amount of ^{131}I released into the atmosphere,

(b) the mechanisms of transport and diffusion of ^{131}I in the atmosphere, or

(c) parameters for predicting deposition of ^{131}I on the ground.

3.3.1.1. Determination of ^{131}I deposition in counties with monitoring data

3.3.1.1.1. Close-in deposition

The depositions of ^{131}I per unit area of ground after each test were derived for 134 counties near the NTS from the County Data Base and the Town Data Base, which provide estimates for the time of arrival, TOA, of the radioactive cloud and for the exposure rate normalized at 12 hours after detonation, H + 12, for specific localities and areas.

As shown in *Table 2.6* and *Figure 2.4,* the activity of ^{131}I that is found in the radioactive cloud or on the ground after a nuclear test results not only from the production of ^{131}I itself but also from the decay of its precursor radionuclides (^{131m}Te, ^{131}Te, and, to a lesser extent, ^{131}Sb). The activity of ^{131}I calculated 12 hours after a nuclear test does not, therefore, represent the "total" activity of ^{131}I that will be found 1 or 2 days later and which is the quantity of interest of this study. In order to take into account the contribution that these precursors eventually will make to the activity of ^{131}I, the activity of ^{131}I at H + 12 is calculated as if all precursors had already decayed into ^{131}I. The activity obtained, called "total" activity of ^{131}I at H + 12, and denoted as A_{12}, is calculated as:

$$A_{12} = \frac{3{,}600 \times 0.027 \times \ln 2 \times N_{12}}{T_4} \qquad (3.1)$$

where:

N_{12} is the total number of atoms present per square meter of ground of ^{131}Sb, ^{131m}Te, ^{131}Te, and ^{131}I,

T_4 is the radioactive half-life of ^{131}I (hours),

3,600 is the number of seconds per hour, and

0.027 nCi per disintegration s^{-1} is a conversion coefficient.

The value of N_{12} is:

$$N_{12} = \frac{A_1 T_1 + A_2 T_2 + A_3 T_3 + A_4 T_4}{0.027 \times 3{,}600 \times \ln 2} \qquad (3.2)$$

where:

T_1, T_2, and T_3 are the radioactive half-lives of ^{131}Sb, ^{131m}Te, and ^{131}Te, respectively, expressed in hours, and

A_1, A_2, A_3, A_4 are the depositions at H + 12 of ^{131}Sb, ^{131m}Te, ^{131}Te, and ^{131}I obtained using the tabulated quotients, published by Hicks (1981a), of the deposition of ^{131}I per unit area of ground at H + 12 and of the exposure rate at H + 12.

If N_{12} in *equation 3.1* is replaced by its value, one obtains:

$$A_{12} = \frac{A_1 T_1 + A_2 T_2 + A_3 T_3 + A_4 T_4}{T_4} \qquad (3.3)$$

The variation with time of the "total" activity of ^{131}I deposited per unit area of ground is only due to the radioactive decay of ^{131}I. Therefore, the "total" activity of ^{131}I deposited per unit area of ground at the time of arrival, TOA in hours, of the radioactive cloud is estimated as:

$$A_{TOA} = A_{12} \times e^{\frac{-\ln 2}{T_4} \times (TOA - 12)} \qquad (3.4)$$

3.3.1.1.1.1. Estimation of deposition densities of ^{131}I in the Town Data Base area

The values of A_{TOA} derived from the Town Data Base are for 173 inhabited places in five counties (Clark, Esmeralda, Lincoln, and Nye in Nevada, and Washington in Utah). As an example: *Table 3.3* presents the estimates of "total" ^{131}I deposition densities at TOA following the Simon test, detonated April 25, 1953. Results for each of the 173 inhabited locations were derived from the Town Data Base. Results for the other 71 tests for which Town Data Base data are available are provided in the Annexes.

It is to be noted that the estimates of ^{131}I deposition densities (per unit area of ground) that are listed in *Table 3.3* are, in most cases, derived from several measurements of exposure rates and that the values selected are the medians of readings taken within 2.5 km of the inhabited location considered. (The median [or median value] of a distribution is such that, if a number of measurements are taken, half would be greater than the median and half would be less than that value).

In this report, the distribution of the estimates of deposition density is assumed to be log-normal. A log-normal distribution is in *Figure 3.6:* it is characterized by its median value and by its geometric standard deviation, GSD, which describes the dispersion of the values around the median. The arithmetic mean of a log-normal distribution is always greater than the median whereas the mode of the distribution is lower than the median. The relative spread between the mode, the median, and the mean increases with the GSD. The log-normal distribution presented in *Figure 3.6* has a GSD of 2. *Figure 3.7* shows,

Table 3.3. Estimates of median ^{131}I depositions per unit area of ground (nCi m^{-2}) at the Town Data Base sites following the test Simon detonated 4/25/1953.

Site code	State	County	Sub-county (Fig. 3.8)	^{131}I depostion density (A_{TOA}, nCi m^{-2}) Median	GSD	Deposition weight, w (Eq. 3.3 and 3.4)
1	NV	LINCOLN	1	9300	1.4	0.035
2	NV	LINCOLN	1	3900	1.4	0.035
3	NV	LINCOLN	1	16000	1.4	0.0035
4	NV	LINCOLN	1	2900	1.4	0.035
5	NV	LINCOLN	1	2500	1.4	0.035
6	NV	LINCOLN	1	2000	1.4	0.035
7	NV	LINCOLN	1	1800	1.4	0.035
8	NV	LINCOLN	1	1100	1.4	0.035
9	NV	LINCOLN	1	900	1.4	0.035
10	NV	LINCOLN	1	820	1.4	0.035
11	NV	LINCOLN	1	770	1.4	0.035
12	NV	LINCOLN	1	610	1.4	0.035
13	NV	LINCOLN	1	600	1.4	0.035
14	NV	LINCOLN	1	810	1.4	0.035
15	NV	LINCOLN	1	810	1.4	0.035
16	NV	LINCOLN	1	400	1.4	0.035
17	NV	LINCOLN	1	380	1.4	0.035
18	NV	LINCOLN	1	770	1.4	0.035
19	NV	LINCOLN	1	240	1.4	0.035
20	NV	LINCOLN	1	0	1.0	0.035
21	NV	LINCOLN	1	0	1.0	0.035
22	NV	LINCOLN	1	0	1.0	0.035
23	NV	LINCOLN	1	240	1.4	0.035
24	NV	LINCOLN	1	0	1.0	0.035
25	NV	LINCOLN	1	0	1.0	0.035
26	NV	LINCOLN	1	0	1.0	0.0035
27	NV	LINCOLN	1	0	1.0	0.035
28	NV	LINCOLN	1	0	1.0	0.0035
29	NV	LINCOLN	1	0	1.0	0.035
30	NV	LINCOLN	1	0	1.0	0.0035
31	NV	LINCOLN	1	0	1.0	0.035
32	NV	LINCOLN	1	0	1.0	0.035
33	NV	LINCOLN	1	0	1.0	0.0035
34	NV	LINCOLN	1	0	1.0	0.0035
35	NV	LINCOLN	1	0	1.0	0.0035
36	NV	LINCOLN	2	280	1.4	0.15
37	NV	LINCOLN	2	0	1.0	0.015
38	NV	LINCOLN	2	55	1.4	0.015
39	NV	LINCOLN	2	110	1.4	0.15
40	NV	LINCOLN	2	0	1.0	0.15
41	NV	LINCOLN	2	0	1.0	0.15
42	NV	LINCOLN	2	0	1.0	0.15
43	NV	LINCOLN	2	0	1.0	0.15
44	NV	LINCOLN	2	0	1.0	0.015
45	NV	LINCOLN	2	0	1.0	0.015
46	NV	LINCOLN	2	0	1.0	0.015

Table 3.3. cont'd

Site code	State	County	Sub-county (Fig. 3.8)	^{131}I depostion density (A_{TOA}, nCi m^{-2}) Median	GSD	Deposition weight, w (Eq. 3.3 and 3.4)
47	NV	LINCOLN	2	0	1.0	0.015
48	NV	NYE	1	0	1.0	0.14
49	NV	NYE	1	0	1.0	0.14
50	NV	NYE	1	0	1.0	0.14
51	NV	NYE	1	0	1.0	0.14
52	NV	NYE	1	0	1.0	0.014
53	NV	NYE	1	0	1.0	0.014
54	NV	NYE	1	0	1.0	0.14
55	NV	NYE	1	0	1.0	0.14
56	NV	NYE	1	0	1.0	0.14
57	NV	NYE	2	0	1.0	0.0046
58	NV	NYE	2	0	1.0	0.0046
59	NV	NYE	2	0	1.0	0.0046
60	NV	NYE	2	0	1.0	0.0046
61	NV	NYE	2	0	1.0	0.046
62	NV	NYE	2	0	1.0	0.0046
63	NV	NYE	2	0	1.0	0.046
64	NV	NYE	2	0	1.0	0.0046
65	NV	NYE	2	0	1.0	0.046
66	NV	NYE	2	0	1.0	0.046
67	NV	NYE	2	0	1.0	0.046
68	NV	NYE	2	0	1.0	0.046
69	NV	NYE	2	0	1.0	0.046
70	NV	NYE	2	0	1.0	0.046
71	NV	NYE	2	0	1.0	0.046
72	NV	NYE	2	0	1.0	0.046
73	NV	NYE	2	0	1.0	0.046
74	NV	NYE	2	0	1.0	0.046
75	NV	NYE	2	0	1.0	0.046
76	NV	NYE	2	0	1.0	0.046
77	NV	NYE	2	0	1.0	0.046
78	NV	NYE	2	0	1.0	0.046
79	NV	NYE	2	0	1.0	0.0046
80	NV	NYE	2	0	1.0	0.046
81	NV	NYE	2	0	1.0	0.0046
82	NV	NYE	2	0	1.0	0.046
83	NV	NYE	2	0	1.0	0.046
84	NV	NYE	2	0	1.0	0.046
85	NV	NYE	2	0	1.0	0.046
86	NV	NYE	3	0	1.0	0.24
87	NV	NYE	3	0	1.0	0.024
88	NV	NYE	3	0	1.0	0.024
89	NV	NYE	3	0	1.0	0.024
90	NV	NYE	3	0	1.0	0.024
91	NV	NYE	3	84	1.4	0.24
92	NV	NYE	3	83	1.4	0.024
93	NV	NYE	3	0	1.0	0.24
94	NV	NYE	3	0	1.0	0.024

Table 3.3. cont'd

Site code	State	County	Sub-county (Fig. 3.8)	^{131}I depostion density (A_{TOA}, nCi m^{-2})		Deposition weight, w (Eq. 3.3 and 3.4)
				Median	GSD	
95	NV	NYE	3	0	1.0	0.024
96	NV	NYE	3	0	1.0	0.024
97	NV	NYE	3	0	1.0	0.024
98	NV	NYE	3	0	1.0	0.024
99	NV	NYE	3	0	1.0	0.024
100	NV	CLARK	1	0	1.0	0.077
101	NV	CLARK	1	0	1.0	0.077
102	NV	CLARK	1	0	1.0	0.077
103	NV	CLARK	1	0	1.0	0.077
104	NV	CLARK	1	70	1.4	0.077
105	NV	CLARK	1	70	1.4	0.077
106	NV	CLARK	1	0	1.0	0.077
107	NV	CLARK	1	0	1.0	0.077
108	NV	CLARK	1	1200	1.6	0.077
109	NV	CLARK	1	150000	1.4	0.077
110	NV	CLARK	1	80000	1.4	0.077
111	NV	CLARK	1	26000	1.6	0.077
112	NV	CLARK	1	15000	1.4	0.077
113	NV	CLARK	2	0	1.0	0.010
114	NV	CLARK	2	0	1.0	0.10
115	NV	CLARK	2	0	1.0	0.010
116	NV	CLARK	2	0	1.0	0.10
117	NV	CLARK	2	0	1.0	0.10
118	NV	CLARK	2	0	1.0	0.10
119	NV	CLARK	2	0	1.0	0.10
120	NV	CLARK	2	0	1.0	0.10
121	NV	CLARK	2	0	1.0	0.010
122	NV	CLARK	2	0	1.0	0.10
123	NV	CLARK	2	0	1.0	0.010
124	NV	CLARK	2	0	1.0	0.10
125	NV	CLARK	2	0	1.0	0.010
126	NV	CLARK	2	0	1.0	0.010
127	NV	CLARK	2	0	1.0	0.10
128	NV	CLARK	2	0	1.0	0.010
129	NV	CLARK	2	0	1.0	0.010
130	NV	CLARK	3	0	1.0	0.33
131	NV	CLARK	3	0	1.0	0.33
132	NV	CLARK	3	0	1.0	0.33
133	NV	ESMERALDA	1	0	1.0	0.71
134	NV	ESMERALDA	1	0	1.0	0.071
135	NV	ESMERALDA	1	0	1.0	0.071
136	NV	ESMERALDA	1	0	1.0	0.071
137	NV	ESMERALDA	1	0	1.0	0.071
138	NV	ESMERALDA	2	0	1.0	0.25
139	NV	ESMERALDA	2	84	1.0	0.25
140	NV	ESMERALDA	2	83	1.0	0.25
141	NV	ESMERALDA	2	0	1.0	0.25

Table 3.3. cont'd

Site code	State	County	Sub-county (Fig. 3.8)	^{131}I depostion density (A_{TOA},nCi m^{-2}) Median	GSD	Deposition weight, w (Eq. 3.3 and 3.4)
142	UT	WASHINGTON	1	810	1.4	0.24
143	UT	WASHINGTON	1	810	1.4	0.24
144	UT	WASHINGTON	1	810	1.4	0.24
145	UT	WASHINGTON	1	0	1.0	0.24
146	UT	WASHINGTON	1	810	1.4	0.024
147	UT	WASHINGTON	2	1100	1.4	0.018
148	UT	WASHINGTON	2	0	1.0	0.18
149	UT	WASHINGTON	2	1100	1.4	0.018
150	UT	WASHINGTON	2	720	1.4	0.18
151	UT	WASHINGTON	2	810	1.4	0.18
152	UT	WASHINGTON	2	810	1.4	0.18
153	UT	WASHINGTON	2	810	1.4	0.18
154	UT	WASHINGTON	2	810	1.4	0.018
155	UT	WASHINGTON	2	810	1.4	0.018
156	UT	WASHINGTON	2	810	1.4	0.018
157	UT	WASHINGTON	2	810	1.4	0.018
158	UT	WASHINGTON	3	0	1.0	0.062
159	UT	WASHINGTON	3	810	1.4	0.062
160	UT	WASHINGTON	3	810	1.4	0.062
161	UT	WASHINGTON	3	0	1.0	0.062
162	UT	WASHINGTON	3	0	1.0	0.062
163	UT	WASHINGTON	3	0	1.0	0.062
164	UT	WASHINGTON	3	0	1.0	0.062
165	UT	WASHINGTON	3	0	1.0	0.062
166	UT	WASHINGTON	3	0	1.0	0.062
167	UT	WASHINGTON	3	0	1.0	0.062
168	UT	WASHINGTON	3	0	1.0	0.062
169	UT	WASHINGTON	3	0	1.0	0.062
170	UT	WASHINGTON	3	0	1.0	0.062
171	UT	WASHINGTON	3	0	1.0	0.062
172	UT	WASHINGTON	3	0	1.0	0.062
173	UT	WASHINGTON	3	0	1.0	0.062

for a constant median of 1, how the mean of a log-normal distribution increases with the GSD. Also shown in *Figure 3.7* are curves labelled "Median x 1 GSD" and "Median / 1 GSD"; the probability of a value lying between the median and either "Median x 1 GSD" or "Median / 1 GSD" is 0.34.

The GSD values associated with the distributions of the deposition of ^{131}I per unit area of ground at each Town Data Base site for the test Simon are taken from Thompson (1990) and listed in *Table 3.3*.

Many of the ^{131}I depositions per unit area of ground presented in *Table 3.3* are listed as zeros. In fact, those values may be true zeros, where there was no deposition of radioactive materials from the test Simon, or they may be lower than a threshold value of the deposition, inferred from the detection limit of the exposure-rate meter, which was taken to be equal to three times background at the time of measurement (0.06 mR h^{-1} for most tests, 0.15 mR h^{-1} for the test Harry). Since the exposure rate from fallout deposition varies sharply during the first hour after detonation, the threshold value of the deposition therefore depends on the time elapsed after detonation at the point of measurement, and this elapsed time is likely to have varied substantially from location to location and from test to test. The threshold value of the deposition also depends on the conversion coefficient from the exposure rate at H+12 to the "total" ^{131}I deposition, which also varied from test to test. The smallest non-zero ^{131}I depositions per unit area of ground

Figure 3.6. Probability density function of a positive random variable log-normally distributed with a median of 1 and a geometric standard deviation (GSD) of 2.

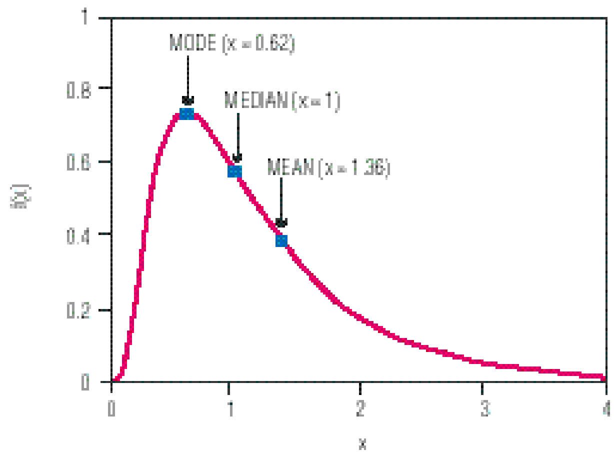
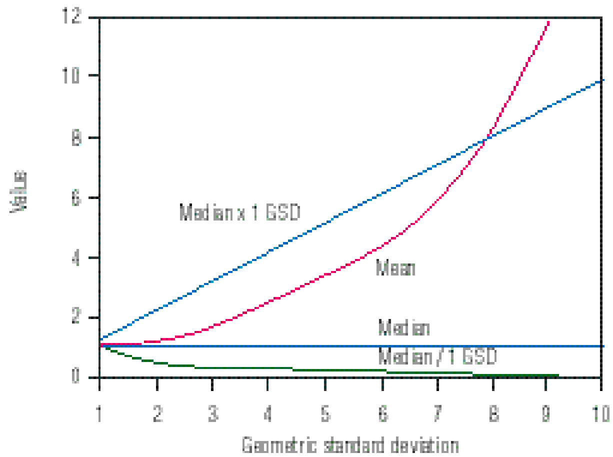


Figure 3.7. Variation of the mean of a log-normal distribution with a median of 1 as a function of the geometric standard deviation (GSD).



that were derived from the Town Data Base varied from test to test: for example, the smallest non-zero ^{131}I depositions obtained for the test Schooner detonated on 8 December 1968 was estimated as 1.8 nCi m^{-2}, while the smallest non-zero ^{131}I deposition obtained for the test Harry detonated on 19 May 1953 was estimated as 360 nCi m^{-2}. For the purpose of this report, it was assumed that there was no ^{131}I deposition in the locations where the exposure rates were below the detection limit.

Because of the substantial variations, within the same county, in the deposition of ^{131}I resulting from some of the tests (see, for example, the range of ^{131}I deposition densities in Lincoln and in Clark counties in *Table 3.3*), it would not be appropriate to select a single deposition value as representative of the ^{131}I deposition per unit area of ground in entire counties of the area covered by the Town Data Base. For that reason, each of those five counties was subdivided into two to three areas, hereafter called "sub-counties", and estimates of ^{131}I deposition were made for each sub-county. The total number of sub-counties in the area covered by the Town Data Base is 13. The variability of ^{131}I deposition estimates in each sub-county was not as large as in entire counties, but still substantial for some tests (see, for example, the range of ^{131}I depositions in sub-county LINCOLN 1 in *Table 3.3*). In determining the estimates of ^{131}I depositions in sub-counties, the fact that the resulting thyroid doses depends to a large extent on the ^{131}I concentrations in milk, and therefore on the ^{131}I contamination of pasture, was taken into account. As explained below, this was done by assigning greater weights to the deposition densities measured at locations near dairy farms than to those measured elsewhere.

The characteristics of each sub-county (location, area, population) are provided in **Appendix 2.** Within these sub-counties, the exposure rates determined in other areas were given a much higher weight than the exposure rates measured near dairy farms or farms with family cows. The location of dairy farms and of farms with family cows was taken from a survey conducted by the Public Health Service in the early 1960s (PHS 1964). The data on locations of farms and numbers of cows are shown in *Figure 3.8*. Deposition estimates for locations in the vicinity of dairy farms or farms with family cows were given a weight, w_{high}, 10 times greater than the weights, w_{low}, given for locations distant from dairy farms or from farms with family cows. In a sub-county, sc, with N_{high} Town Data Base sites with high deposition weights and N_{low} sites with low deposition weights, the relationship:

$$N_{low} \times w_{low} + N_{high} \times w_{high} = 1 \qquad (3.1)$$

holds because the sum of all weighting factors must be one. Since $w_{high} = 10 \times w_{low}$, *equation 3.1* can be written as:

$$w_{low} (N_{low} + 10 \times N_{high}) = 1 \qquad (3.2)$$

and the values of the weights can be computed from the following equations:

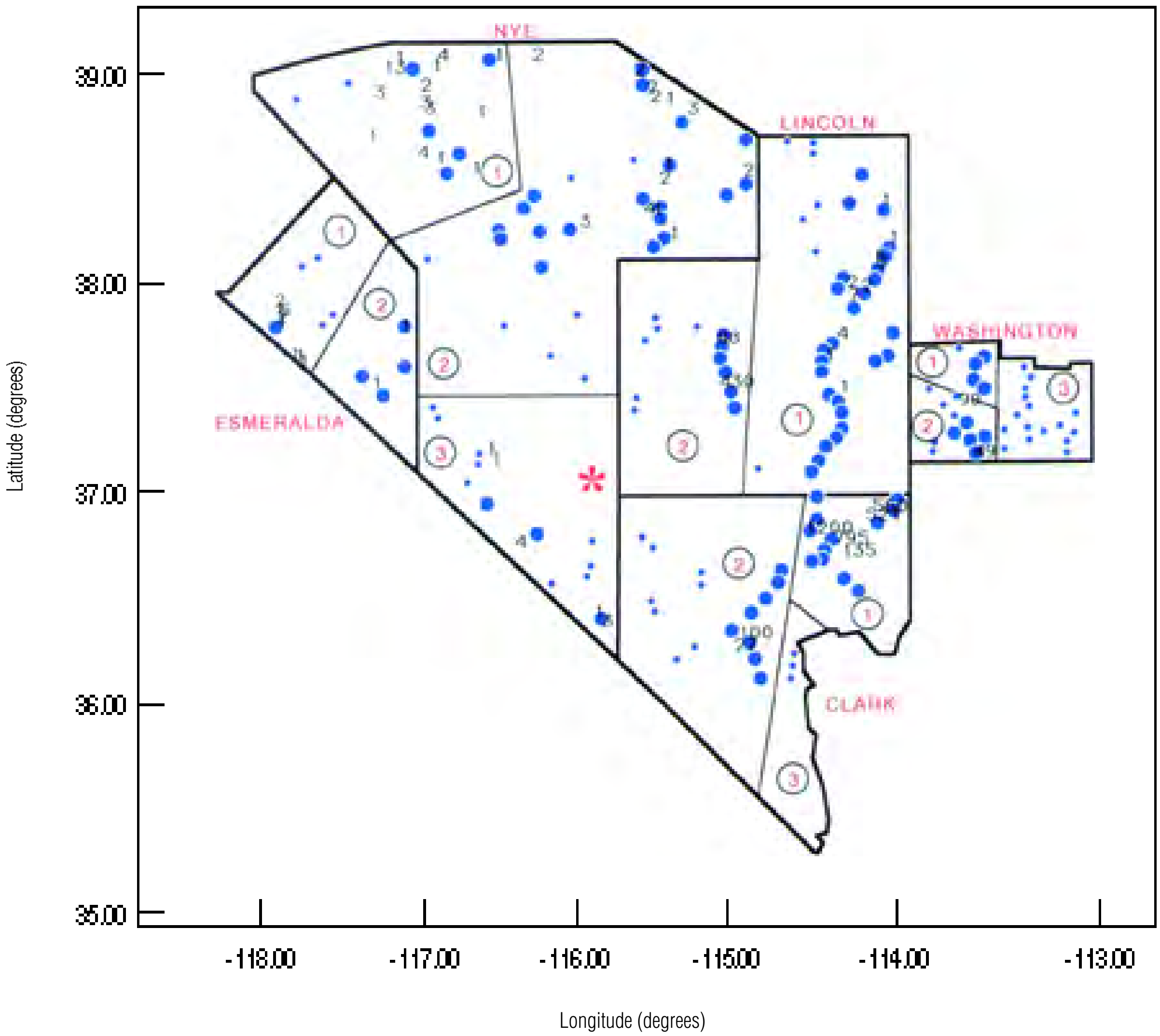
$$w_{low} = 1 / (N_{low} + 10 \times N_{high}) \qquad (3.3)$$

and:

$$w_{high} = 10 / (N_{low} + 10 \times N_{high}) \qquad (3.4)$$

The arithmetic means of the deposition weights for all Town Data Base sites are presented in *Table 3.3*. For the purposes of the uncertainty analysis, it is assumed that the deposition weights are log-normally distributed with a GSD of 1.5.

Figure 3.8. Location of the sites where exposure rates were measured in the Town Data Base area (small circles and large circles) and location of the dairy farms and farms with family cows (numbers indicating the number of cows in those farms). In a given sub-county, the Town Data Base sites that are represented with large circles, located near farms with cows, were given a weight 10 times greater than the Town Data Base sites represented with small circles in the estimation of the median ^{131}I deposition per unit area of ground.



The ^{131}I deposition per unit area of ground, averaged over the sub-county, $A_{TOA}(sc)$, is derived from:

$$A_{TOA}(sc) = \sum_{n=1}^{N} A_{TOA}(n) \times w(n) \qquad (3.5)$$

where:

- n refers to a Town Data Base site in sub-county, sc,
- N is the total number of sites in the sub-county, and
- w(n) is the deposition weight for Town Data Base site, n. The numerical value of w(n) is either the value of w_{low} or that of w_{high} for the sub-county considered *(Table 3.3).*

Since both $A_{TOA}(n)$ and w(n) are assumed to be log-normally distributed, the median value of $A_{TOA}(sc)$ can either be derived numerically from *equation 3.5,* by means of a Monte Carlo procedure, or analytically, using a mathematical procedure with a number of underlying assumptions. Because of the subjective and somewhat arbitrary manner in which the uncertainties on both $A_{TOA}(n)$ and w(n) have been assigned, a relatively simple analytical procedure was deemed to be sufficient for the purposes of the uncertainty analysis in this report. The basis for the simpler procedure and the associated assumptions are described below.

The analytical procedure, called the multiplicative log-normal method, is based on the following theorem (Aitchison and Brown 1969; Crow and Shimizu 1988): [2]

If:

- $X_1, X_2, ..., X_N$ are multivariate log-normal random variables,
- μ_n and σ_n^2 are the mean and variance of $Y_n = \ln X_n$,
- $r_{nn'}$ is the correlation between Y_n and $Y_{n'}$, with $n \neq n'$,

then:

- the product $X = X_1 \times X_2 \times ...X_N$ is log-normally distributed, and
- the function Y = ln X is normally distributed with:
- a mean: $\mu = \mu_1 + \mu_2 + ... \mu_N$ (3.6)

and

- a variance:

$$\sigma^2 = \sum_{n=1}^{N} \sigma^2_n + \sum_{n=1}^{N} \sum_{n'=1}^{N} r_{nn'}\, \sigma_n \sigma_{n'} \qquad (3.7)$$

[2] The assistance of Lynn Anspaugh (University of Utah), Richard Gilbert (Pacific Northwest National Laboratory), Owen Hoffman (SENES Oak Ridge Inc.), and Paul Voillequé (MJP Risk Assessment Inc.) in the development and the implementation of the multiplicative log-normal method in this report is gratefully acknowledged.

If there is no correlation between any of the variables, the variance of Y is simply:

$$\sigma^2 = \sigma_1^2 + \sigma_2^2 + ...\sigma_N^2 \qquad (3.8)$$

It follows from the properties of log-normal distributions that:

- the median of X, denoted as <X>, is equal to: e^{μ}
- the geometric standard deviation of X, denoted as GSD(X), is equal to: e^{σ}
- the arithmetic mean of X, denoted as m(X), is:

$$m(X) = e^{\mu + \sigma^2/2} = \langle X \rangle \times e^{\sigma^2/2} \qquad (3.9)$$

- the variance of X, denoted as $s^2(X)$, is:

$$s^2(X) = m^2(X) \times (e^{\sigma^2} - 1) \qquad (3.10)$$

In the case of summation of variables, as in *equation 3.5,* it is also assumed that the distribution of a sum of log-normally distributed variables is log-normal. This is strictly not true (Crow and Shimizu 1988) but it has been shown that, in the case of independent log-normal variables, the sum of those variables can be approximated reasonably well by a log-normal distribution (Barakat 1976; Fenton 1960; Mitchell 1968). Therefore, if:

- $X_1, X_2, ..., X_N$ are multivariate log-normal random variables,
- m_n and s_n^2 are the mean and variance of X_n,
- $r_{nn'}$ is the correlation between X_n and $X_{n'}$, with $n \neq n'$,

then:

- $X = X_1 + X_2 + ...X_N$ is assumed to be log-normally distributed, with:
- a mean: $m(X) = m_1 + m_2 + ...m_N$ (3.11)

and

- a variance:

$$s^2(X) = \sum_{n=1}^{N} s^2_n + \sum_{n=1}^{N} \sum_{n'=1}^{N} r_{nn'}\, s_n s_{n'} \qquad (3.12)$$

If there is no correlation between any of the variables, the variance of X is simply:

$$s^2(X) = s_1^2 + s_2^2 + ...s_N^2 \qquad (3.13)$$

It follows from the properties of log-normal distributions that:

- the mean of Y = ln(X), denoted as μ, is:

$$\mu = \ln \left[\frac{m(X)}{\left(1 + \frac{s^2(X)}{m^2(X)}\right)^{0.5}} \right] \qquad (3.14)$$

- the standard deviation of Y, denoted as σ, is:

$$\sigma = \left[\ln\left(1 + \frac{s_2(X)}{m_2(X)}\right)\right]^{0.5} \quad (3.15)$$

- the median of X, denoted as <X>, is equal to e^{μ}
- the geometric standard deviation of X, denoted as GSD(X), is equal to e^{σ}.

In summary, two critical assumptions are involved in using the multiplicative log-normal method:

(1) the random variables must be assumed to be log-normally distributed, and

(2) the distribution of a sum of log-normally distributed random variables must be assumed to be log-normal.

The symbols used throughout this report for the parameters of a log-normally distributed variable, X, and of its logarithm, Y, are:

- the median of X is symbolized by <X>
- the geometric standard deviation of X is symbolized by GSD(X)
- the arithmetic mean of X is symbolized by m(X)
- the variance of X is symbolized by $s^2(X)$
- the median and arithmetic mean of Y = ln X is symbolized by μ(X) or the shortened version, μ
- the standard deviation of Y = ln X is symbolized by σ(X) or the shortened version, σ

It is useful to note that *equations 3.9* and *3.10* can be written as:

$$m(X) = \langle X \rangle \times e^{0.5\,\sigma^2(X)} \quad (3.16)$$

$$s^2(X) = m^2(X) \times (e^{\sigma^2(X)} - 1) \quad (3.17)$$

The values for μ (X),<X>, σ (X), and GSD (X) are computed using the following relationships:

$$\mu(X) = \ln\left[\frac{m(X)}{\left(1 + \frac{s^2(X)}{m^2(X)}\right)^{0.5}}\right] \quad (3.18)$$

$$\langle X \rangle = e^{\mu(X)} = \frac{m(X)}{\left(1 + \frac{s^2(X)}{m^2(X)}\right)^{0.5}} \quad (3.19)$$

$$\sigma(X) = \left[\ln\left(1 + \frac{s^2(X)}{m^2(X)}\right)\right]^{0.5} \quad (3.20)$$

$$GSD(X) = e^{\sigma(X)} = e^{\left[\ln\left(1 + \frac{s^2(X)}{m^2(X)}\right)\right]^{0.5}} \quad (3.21)$$

The multiplicative log-normal method has been applied to the variables in *equation 3.5* in order to derive the medians and geometric standard deviations of A_{TOA}(sc). It is assumed that there is no correlation between the variables in *equation 3.5.*

In the first step, the product of A_{TOA}(n) and w(n), denoted as WA_{TOA}(n), called the weighted ^{131}I deposition density for Town Data Base site n, is computed:

$$WA_{TOA}(n) = A_{TOA}(n) \times w(n) \quad (3.22)$$

The median of WA_{TOA}(n) is then calculated using:

$$\langle WA_{TOA}(n) \rangle = \langle A_{TOA}(n) \rangle \times \langle w(n) \rangle \quad (3.23)$$

The values listed in *Table 3.3* are the median of A_{TOA}(n) and the mean of w(n). The median of w(n), as used in *equation 3.23,* is derived from the mean using *equation 3.16:*

$$\langle w(n) \rangle = m(w(n)) \times e^{-0.5\,\sigma^2(X)} \quad (3.24)$$

The geometric standard deviation of WA_{TOA}(n) is calculated using:

$$GSD(WA_{TOA}(n)) = e^{\sigma(WA_{TOA}(n))} \quad (3.25)$$

in which the value of σ ($WA_{TOA}(n)$) is derived from the variance, computed as in *equation 3.8:*

$$\sigma^2 (WA_{TOA}(n)) = \sigma^2 (A_{TOA}(n)) + \sigma^2 (w(n)) \qquad (3.26)$$

In *equation 3.26,* the value of $\sigma^2(A_{TOA}(n))$ is obtained from the value of $GSD(A_{TOA}(n))$ listed in *Table 3.3,* using:

$$\sigma^2 (A_{TOA}(n)) = [\ln (GSD (A_{TOA}(n))]^2 \qquad (3.27)$$

while the value of $\sigma^2(w(n))$ is obtained from the assumption that GSD(w(n)) is equal to 1.5 :

$$\sigma^2 (w(n)) = [\ln (GSD (w (n)))] = [\ln (1.5)]^2 \qquad (3.28)$$

In a second step, the median and geometric standard deviation of the sum of the weighted ^{131}I deposition densities from each of the N Town Data Base sites in the sub-county considered are determined. From *equations 3.5 and 3.22:*

$$A_{TOA} (sc) = \sum_{n=1}^{N} WA_{TOA}(n) \qquad (3.29)$$

The mean of $A_{TOA}(sc)$ is obtained using:

$$m (A_{TOA}(sc)) = \sum_{n=1}^{N} m(WA_{TOA}(n)) \qquad (3.30)$$

where the values of $m(WA_{TOA}(n))$ are calculated from the relationship given in *equation 3.16.*

The variance of $A_{TOA}(sc)$ is obtained using:

$$s^2 (A_{TOA}(sc)) = \sum_{n=1}^{N} s^2 (WA_{TOA}(n)) \qquad (3.31)$$

where the values of $s^2(WA_{TOA}(n))$ are calculated from the relationship given in *equation 3.17.*

The median of $A_{TOA}(sc)$ is obtained from:

$$< A_{TOA}(sc)> = e^{\mu (A_{TOA}(sc))} \qquad (3.32)$$

where the value of μ ($WA_{TOA}(sc)$) is calculated from the relationship given in *equation 3.18.*

The geometric standard deviation of $A_{TOA}(sc)$ is obtained from:

$$GSD (A_{TOA}(sc)) = e^{\sigma (A_{TOA}(sc))} \qquad (3.33)$$

where the value of σ ($WA_{TOA}(sc)$) is calculated from the relationship given in *equation 3.20.*

The median of the A_{TOA} values obtained in each sub-county in this way was taken to represent the median deposition density of ^{131}I on the ground in that sub-county. The complete results (estimates of $<A_{TOA}(sc)>$ and of $GSD(A_{TOA}(sc))$ for each sub-county in the Town Data Base area and for each test are presented in the **Annexes.**

3.3.1.1.1.2. Estimation of deposition densities of ^{131}I in the County Data Base area

The County Data Base provides estimates for the time of arrival of the radioactive cloud and for the exposure rate normalized at 12 hours after detonation (H + 12) for 55 nuclear tests and for areas in 129 counties in Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, Utah, and Wyoming (Beck and Anspaugh 1991). Values of $<A_{TOA}>$ were derived from the County Data Base and from the tabulated quotients, published by Hicks (1981a) for all the tests considered, of the deposition of ^{131}I per unit area of ground at H + 12 and of the exposure rate at H + 12. The calculational procedure involves *equations 3.1* to *3.4*. The variable A_{TOA} is assumed to be log-normally distributed. The largest uncertainty in the determination of A_{TOA} is believed to be due to the estimation of the median exposure rate at H + 12 in the area considered. The geometric standard deviation attached to the distribution of A_{TOA} is assumed to be equal to the geometric standard deviation assigned by Beck and Anspaugh (1991) to the exposure rate at H + 12.

The County Data Base provides data for 120 undivided counties and for nine counties (located in Arizona, California, Nevada, and Utah) subdivided into 22 county segments because of the substantial variations in the exposure rates at H + 12 resulting from some of the tests. In this report, two of those county segments (the division of Kingman in Mohave county in Arizona and the county segment including Bishop, Independence and Lone Pine divisions in Inyo county in California) were further subdivided into two parts in order to account for large differences in the origin of fresh cows' milk supplied in those areas. The total number of geographic divisions (counties or sub-counties) in the area covered by the County Data Base is 144 (see **Appendix 2**).

The median of the ATOA values obtained in each county or sub-county was taken to represent the median deposition density of ^{131}I on the ground in that county or sub-county. As an example, *Table 3.4* presents the results obtained for the shot Simon, detonated April 25, 1953. Complete results for the 55 tests for which County Data Base information is available are presented in the Annexes.

Here again, as was the case for the depositions derived from the Town Data Base, a large number of the ^{131}I depositions per unit area of ground presented in *Table 3.4* are listed as zeros. In fact, those values may be true zeros, where there was no deposition of radioactive materials from the test Simon, or they may be lower than a threshold value of the deposition, as inferred from the detection limit of the instruments or methods that served to determine the exposure rate at H+12 in each par-

Table 3.4. Estimates of median ^{131}I depositions per unit area of ground (nCi m^{-2}) at the County Data Base area following shot Simon detonated 4/25/1953.

Test name	Date (y/mo/d)	State	County	^{131}I deposition density (A_{TOA}, nCi m^{-2})	
				Median	GSD
SIMON	530425	AZ	APACHE	4800	1.7
SIMON	530425	AZ	COCHISE	0	1.0
SIMON	530425	AZ	GILA	0	1.0
SIMON	530425	AZ	GRAHAM	0	1.0
SIMON	530425	AZ	GREENLEE	0	1.0
SIMON	530425	AZ	MARICOPA	0	1.0
SIMON	530425	AZ	NAVAJO	3200	1.7
SIMON	530425	AZ	PIMA	0	1.0
SIMON	530425	AZ	PINAL	0	1.0
SIMON	530425	AZ	SANTA CRUZ	0	1.0
SIMON	530425	AZ	YAVAPAI	0	1.0
SIMON	530425	AZ	YUMA	0	1.0
SIMON	530425	AZ	MOHAVE1*	1400	1.7
SIMON	530425	AZ	MOHAVE2*	1200	1.7
SIMON	530425	AZ	MOHAVE3*	1200	1.9
SIMON	530425	AZ	MOHAVE4*	1200	1.9
SIMON	530425	AZ	COCONINO1*	1400	1.7
SIMON	530425	AZ	COCONINO2*	8100	1.7
SIMON	530425	AZ	COCONINO3*	1600	1.5
SIMON	530425	CA	LOS ANGELES	8	1.7
SIMON	530425	CA	MONO	8	1.7
SIMON	530425	CA	SAN BERNADINO	8	1.7
SIMON	530425	CA	INYO1*	8	1.7
SIMON	530425	CA	INYO2*	8	1.7
SIMON	530425	CA	INYO3*	200	1.9
SIMON	530425	CO	DELTA	740	1.7
SIMON	530425	CO	DOLORES	1500	1.7
SIMON	530425	CO	GARFIELD	500	1.7
SIMON	530425	CO	LA PLATA	1100	1.7
SIMON	530425	CO	MESA	960	1.5
SIMON	530425	CO	MOFFAT	150	1.7
SIMON	530425	CO	MONTEZUMA	1100	1.7
SIMON	530425	CO	MONTROSE	740	1.7
SIMON	530425	CO	OURAY	740	1.7
SIMON	530425	CO	RIO BLANCO	510	1.7
SIMON	530425	CO	SAN JUAN	740	1.7
SIMON	530425	CO	SAN MIGUEL	740	1.7
SIMON	530425	ID	ADA	22	1.7
SIMON	530425	ID	BANNOCK	22	1.7
SIMON	530425	ID	BEAR LAKE	31	1.7
SIMON	530425	ID	BINGHAM	22	1.7
SIMON	530425	ID	BONNEVILLE	15	1.7
SIMON	530425	ID	CANYON	15	1.7
SIMON	530425	ID	CARIBOU	23	1.7
SIMON	530425	ID	CASSIA	30	1.7

* Sub-county identified by the number at the end of the county name.

Table 3.4. cont'd

Test name	Date (y/mo/d)	State	County	^{131}I deposition density (A_{TOA}, nCi m^{-2})	
				Median	GSD
SIMON	530425	ID	ELMORE	22	1.7
SIMON	530425	ID	FRANKLIN	30	1.7
SIMON	530425	ID	GOODING	22	1.7
SIMON	530425	ID	JEROME	22	1.7
SIMON	530425	ID	LINCOLN	22	1.7
SIMON	530425	ID	MINIDOKA	22	1.7
SIMON	530425	ID	ONEIDA	30	1.7
SIMON	530425	ID	OWYHEE	15	1.7
SIMON	530425	ID	POWER	30	1.7
SIMON	530425	ID	TWIN FALLS	22	1.7
SIMON	530425	NV	CHURCHILL	13	1.7
SIMON	530425	NV	DOUGLAS	6	1.7
SIMON	530425	NV	ELKO	13	1.7
SIMON	530425	NV	EUREKA	14	1.7
SIMON	530425	NV	HUMBOLDT	13	1.7
SIMON	530425	NV	LYON	6	1.7
SIMON	530425	NV	MINERAL	6	1.7
SIMON	530425	NV	PERSHING	13	1.7
SIMON	530425	NV	STOREY	6	1.7
SIMON	530425	NV	WASHOE	13	1.7
SIMON	530425	NV	WHITE PINE1*	41	1.7
SIMON	530425	NV	WHITE PINE2*	41	1.7
SIMON	530425	NV	WHITE PINE3*	41	1.7
SIMON	530425	NV	CARSON CITY	13	1.7
SIMON	530425	NV	LANDER1*	14	1.7
SIMON	530425	NV	LANDER2*	14	1.7
SIMON	530425	NM	BERNALILLO	1400	1.5
SIMON	530425	NM	CATRON	380	1.7
SIMON	530425	NM	CHAVES	3700	1.5
SIMON	530425	NM	COLFAX	270	1.5
SIMON	530425	NM	CURRY	2200	1.7
SIMON	530425	NM	DE BACA	2200	1.7
SIMON	530425	NM	DONA ANA	0	1.0
SIMON	530425	NM	EDDY	740	1.7
SIMON	530425	NM	GRANT	0	1.0
SIMON	530425	NM	GUADALUPE	2200	1.7
SIMON	530425	NM	HARDING	740	1.7
SIMON	530425	NM	HIDALGO	0	1.0
SIMON	530425	NM	LEA	740	1.7
SIMON	530425	NM	LINCOLN	3000	1.7
SIMON	530425	NM	LOS ALAMOS	1500	1.7
SIMON	530425	NM	LUNA	0	1.0
SIMON	530425	NM	MCKINLEY	3900	1.7
SIMON	530425	NM	MORA	740	1.7
SIMON	530425	NM	OTERO	0	1.0
SIMON	530425	NM	QUAY	1800	1.7

Table 3.4. cont'd

Test name	Date (y/mo/d)	State	County	^{131}I deposition density (A_{TOA}, nCi m^{-2}) Median	GSD
SIMON	530425	NM	RIO ARRIBA	1500	1.7
SIMON	530425	NM	ROOSEVELT	2200	1.7
SIMON	530425	NM	SANDOVAL	3000	1.7
SIMON	530425	NM	SAN JUAN	1500	1.7
SIMON	530425	NM	SAN MIGUEL	1500	1.7
SIMON	530425	NM	SANTA FE	3000	1.7
SIMON	530425	NM	SIERRA	0	1.0
SIMON	530425	NM	SOCORRO	370	1.7
SIMON	530425	NM	TAOS	740	1.7
SIMON	530425	NM	TORRANCE	2200	1.7
SIMON	530425	NM	UNION	440	1.7
SIMON	530425	NM	VALENCIA	2300	1.7
SIMON	530425	OR	HARNEY	13	1.7
SIMON	530425	OR	MALHEUR	13	1.7
SIMON	530425	UT	BEAVER	880	1.5
SIMON	530425	UT	CACHE	30	1.7
SIMON	530425	UT	CARBON	150	1.7
SIMON	530425	UT	DAGGETT	74	1.7
SIMON	530425	UT	DAVIS	74	1.7
SIMON	530425	UT	DUCHESNE	150	1.7
SIMON	530425	UT	EMERY	380	1.7
SIMON	530425	UT	GARFIELD	390	1.7
SIMON	530425	UT	GRAND	590	1.7
SIMON	530425	UT	JUAB	150	1.7
SIMON	530425	UT	MILLARD	470	1.7
SIMON	530425	UT	MORGAN	74	1.7
SIMON	530425	UT	PIUTE	390	1.7
SIMON	530425	UT	RICH	52	1.7
SIMON	530425	UT	SALT LAKE	100	1.7
SIMON	530425	UT	SAN JUAN	1100	1.7
SIMON	530425	UT	SANPETE	220	1.7
SIMON	530425	UT	SEVIER	390	1.7
SIMON	530425	UT	SUMMIT	74	1.7
SIMON	530425	UT	UINTAH	150	1.7
SIMON	530425	UT	UTAH	110	1.7
SIMON	530425	UT	WASATCH	110	1.7
SIMON	530425	UT	WAYNE	380	1.7
SIMON	530425	UT	WEBER	52	1.7
SIMON	530425	UT	IRON1*	810	1.5
SIMON	530425	UT	IRON2*	400	1.7
SIMON	530425	UT	IRON3*	400	1.7
SIMON	530425	UT	KANE1*	800	1.7
SIMON	530425	UT	KANE2*	800	1.7
SIMON	530425	UT	TOOELE1*	22	1.7
SIMON	530425	UT	TOOELE2*	110	1.7

Table 3.4. cont'd

Test name	Date (y/mo/d)	State	County	^{131}I deposition density (A_{TOA}, nCi m^{-2}) Median	GSD
SIMON	530425	UT	BOX ELDER1*	22	1.7
SIMON	530425	UT	BOX ELDER2*	37	1.7
SIMON	530425	WY	CARBON	150	1.7
SIMON	530425	WY	FREMONT	150	1.7
SIMON	530425	WY	LINCOLN	37	1.7
SIMON	530425	WY	SULETTE	37	1.7
SIMON	530425	WY	SWEETWATER	75	1.5
SIMON	530425	WY	UINTA	75	1.7

ticular county or sub-county. This detection limit is likely to have varied from location to location and from test to test. The threshold value of the deposition also depends on the conversion coefficient from the exposure rate at H+12 to the "total" ^{131}I deposition, which also varied from test to test. The smallest non-zero ^{131}I deposition per unit area of ground that was derived from the County Data Base varied from test to test: for example, the smallest non-zero ^{131}I deposition obtained for the test Schooner detonated on 8 December 1968 was estimated to be 0.3 nCi m^{-2}, while the smallest non-zero ^{131}I deposition obtained for the test Tesla detonated on 1 March 1955 was estimated to be 28 nCi m^{-2}. For the purpose of this report, it was assumed that there was no ^{131}I deposition in the counties and sub-counties for which exposure rates at H+12 were not reported in the County Data Base.

3.3.1.1.2. National monitoring of deposition measurements
The gummed-film network data, when available, are used to derive ^{131}I deposition densities throughout the United States for all the nuclear tests that resulted in significant fallout. The original fallout data have been re-evaluated by Beck (1984), and coworkers, Beck et al. (1990).

Beck (1984) reviewed the methods of analysis and interpretation of gummed-film data reported by Harley et al. (1960) and modified the original analysis of the fallout data in order to derive deposition estimates for ^{137}Cs. The corrections applied to the original fallout data to derive the ^{131}I deposition estimates are based on Beck's (1984) work with ^{137}Cs and are summarized as follows:

1. The collection efficiency of the gummed film was reassessed. Gummed film is an inefficient collector of fallout relative to that actually deposited on the earth's surface. The efficiency of collection was probably affected, among other factors, by humidity, dust loading, washoff by rain, wind, and particle size of the fallout (Rosinski 1957, Rosinski et al. 1959). Estimates of collection efficiency for dry deposition, which were originally thought to be about 60%, are now believed to have been only about 20% for the measured beta activity. This is based on comparisons of estimates of ^{137}Cs deposition derived from exposure rates measured at gummed-film sites near the Nevada Test Site (where dry processes were the predominant mode of deposition) with estimates of ^{137}Cs deposition made from the gummed film. There is also good agreement between the ^{137}Cs estimates based on the corrected efficiency of collection of gummed film and recent ^{137}Cs activity results from soil samples taken at different locations in the western states (see Beck and Krey 1982). The collection efficiency for wet deposition has been estimated from three sets of experimental data: (a) comparison of measurements of the fallout in precipitation carried out by the Public Health Service in the 1950s and of the corresponding gummed-film results obtained at the same time and location; (b) measurements of naturally-occurring radioactive particles deposited by precipitation in 1986 on sticky material that exhibits properties similar to those of the gummed film used in the 1950s; (c) measurements of ^{131}I originating from the Chernobyl accident and deposited by precipitation on the same sticky material. Although the results from each of the 3 sets of data contain large variabilities, the combination of the results clearly indicates that the collection efficiency of gummed film depends on the daily precipitation amount: about 30% for light rain and less than 10% for heavy showers (Beck et al. 1990). These values also are in agreement with measurements carried out under controlled conditions (Hoffman et al. 1989). *Table 3.5* presents the estimated gummed-film collection efficiencies for each precipitation index value used in this report.

Table 3.5. Variation of the estimated collection efficiency of fallout by gummed film as a function of daily rainfall. (Beck et al. 1990).

Precipitation index	Daily rainfall (mm)	Estimated collection efficiency of fallout by gummed film, %
1	0	20
2	< 0.25	30
3	0.25-0.76	30
4	0.76-2.5	25
5	2.5-7.6	15
6	7.6-25	10
7	25-76	6.7
8	76-127	6.7
9	> 127	6.7

2. The efficiencies of radioactivity counting equipment varied from test series to test series according to the counting procedure and the radioactivity standard used. The data are corrected for the appropriate counter efficiency to convert count rate to the proper value of beta activity.

3. As a result of sample preparation at temperatures ranging from 500 to 550 degrees Celsius, it has been assumed that the total beta activity measured on the original samples did not include any of the volatile radionuclides, such as ^{131}I. Although originally no corrections were made for these losses, the total beta activity results have since been corrected for the loss of the volatile radionuclides using the data reported by Hicks (1981a).

4. The total beta activity at the time of sampling was inferred from the total beta activity at the time of counting. To this end, use was made of the calculated decay rates of the total beta activity and of each of the significant radionuclides, including ^{131}I, that were published by Hicks (1981a) for a number of fixed times after detonation, and for each test that resulted in off-site fallout. These results show that the original $t^{-1.2}$ decay rate that previously was used occasionally resulted in occasional substantial errors in reported beta activities. The proper decay rate for each test was used in the evaluation.

5. The ratio of the ^{131}I activity to the total beta activity at the time of sampling is calculated from Hicks' tables (1981a). The product of this ratio and of the total beta activity permit the calculation of the ^{131}I deposition per unit area of ground; the results are expressed in nanocuries per square meter (nCi m^{-2}) at the time of deposition.

6. When data other than gummed-film data were used, further calculations were necessary to estimate the ^{131}I deposition at that location. Details on how these calculations are performed can be found in Beck (1984). For example, when high-volume air sampler data were used, it was assumed that the quotient of the deposition rate and of the air concentration at ground-level (a quantity usually called deposition velocity) was equal to 5 cm s^{-1} (Beck 1984).

Beck (1984) estimated a measurement uncertainty of 40% to all daily estimates of ^{137}Cs deposition from gummed-film data and a measurement uncertainty of 80% when other than gummed-film data were used. In this report, the daily estimates of ^{131}I deposition obtained by means of the analysis described above are taken as the median deposition densities of ^{131}I in the counties in which the gummed-film collectors were located, with associated geometric standard deviations of 1.5. These daily estimates of ^{131}I deposition were rounded to the nearest integer, with the implication that values less than 0.5 nCi m^{-2} are treated as zeros.

One of the difficulties in the re-analyses of monitoring data is that original data may have been either mislabelled or not assigned to the appropriate nuclear weapons test. In an effort to alleviate this potential difficulty, locations of gummed-film monitoring that showed that fallout occurred were systematically compared with the path of fallout cloud as projected by a meteorological model (see **Appendix 1**). When discrepancies between the data and the projected path occurred, professional judgment was applied to each case to decide whether or not to utilize the gummed-film data.

The resulting data set includes daily depositions of ^{131}I at up to 95 locations in the U.S. during most of the atmospheric testing period. Those ^{131}I depositions are associated with information on the precipitation amounts occurring during the same 24-h periods. *Table 3.6* lists, as an example, results obtained for the shot Simon for the first 7 days following detonation. The complete results for all tests for which gummed-film data were analyzed are provided in the Annexes.

3.3.1.2. Determination of ^{131}I deposition in counties without monitoring data

The estimation of ^{131}I deposition in more than 3,000 counties based upon data available from 95 or fewer locations presents a considerable problem in spatial interpolation. A solution was sought that would make the best use of all of the available information known to affect the deposition at a site. For example, the amount of fallout at a particular site is known to be highly dependent on whether or not precipitation occurred during the passage of the cloud, and on the intensity of any such precipitation. This is a systematic relationship in that, given that the cloud is present, it is believed that the deposition generally increases with the intensity of the rain. It also is clear that the amount of fallout in counties that are near one another will be more closely related than those that are farther apart. When the deposition measured in a particular county was high, it is more likely that the deposition in a neighboring county also would be high rather than low. As one moves farther from the original county, however, the strength of this relationship diminishes. This kind of relationship is far less certain than that involving the rainfall. In essence, the data are statistically correlated, and the strength of this correlation depends on the distance between the sites.

3.3.1.2.1. Selection of the interpolation technique

Several methods for spatial interpolation of ^{131}I deposition were investigated. Early analyses using a variety of interpolation techniques showed that kriging results were far more flexible than those obtained with other procedures such as spline curve fitting. Kriging originally was developed to estimate gold reserves in the mining industry, but in recent years it has been used increasingly for the analysis of environmental contamination (e.g., Zirschky 1985), including acid rain (Eynon and Switzer 1983). The technique also was used by ORERP to estimate some of the Town Data Base exposures (Thompson and Hutchinson 1988).

The kriging technique was selected because it has the advantage of being able to accommodate both systematic relationships among the data, such as the amount of rainfall, and statistical correlations among the data, such as the relative proximity of the different gummed-film sites. Kriging also is known to be an exact interpolator, in that the results will always yield the exact value of the original data at a measurement site, whereas some other methods, such as least squares, in general return a somewhat different value depending on the fit to the original data. The particular approach to kriging used in this study is described by Ripley (1981) and Oden (1984), and the reader is referred to those publications for the mathematical details. The computer code used to perform the analyses was provided by Oden (1987) and modified at EML in order to conform to the particular requirements of this study.

3.3.1.2.2. Application of the kriging technique

The data upon which the kriging analysis is based are the ^{131}I depositions inferred from total beta activity at the gummed-film locations in operation on a given day following a nuclear test (Beck et al. 1990). Generally, on the first day or two, detectable deposition was confined to a few stations within several hundred miles (or kilometers) of the Test Site. In order to insure a reasonable level of credibility in the calculated depositions, the kriging analysis was carried out only for those tests that resulted in a sufficient number (usually 20) of positive gummed-film results. When the close-in deposition pattern following a test incorporated only a few locations, the patterns for two consecutive days occasionally would be combined in order to provide an adequate data base for the kriging program. As the fallout cloud traveled (usually) eastward across the U.S., the deposition pattern widened; however, many of the stations still did not indicate any detectable fallout since the radioactive cloud rarely covered the entire country. To avoid unnecessary interpolations of many zero results between the gummed-film stations located outside the deposition pattern, a gummed-film station was not included in the analysis unless there was a measured deposition of one or more of its four closest neighboring stations. Results from Canadian stations located near the U.S. border were considered in this decision process. This procedure was found to provide satisfactory limits for enclosing the boundary of the deposition pattern while focusing the analysis on the important locations with measurable fallout. Any county outside the deposition pattern was assigned a value of zero deposition for that day. On some days, two or more distinct areas of deposition could be defined, e.g., an area of dry deposition in the west distant from an area of wet deposition in the east. In such instances, the two areas were analyzed separately because the rainfall dependences and the strength of the proximity correlations would generally be different in the two areas, and the combination of the two areas would distort these relationships.

The kriging analysis was carried out for each day and for each distinct area of deposition by first converting the data to a logarithmic scale. This was done because the data tend to span a wide range, often several orders of magnitude, with many low values and a few much higher ones. As with most environmental monitoring data, a log transformation brings the data closer to a normal (bell-shaped) distribution. Analyses performed without using this transformation resulted in physically unrealistic fallout patterns compared to those obtained with logarithmic transformed data. The transformed data at each site were fit to the reported precipitation index value for that site on that day; this removed the systematic influence of rainfall. Other system-

Table 3.6. Estimates of ^{131}I daily deposition derived from gummed-film results (DG; unit: nCi m^{-2}) and associated precipitation indices (Pi) for the test Simon detonated 4/25/1953.

Site	State	Month and day													
		4/25		4/26		4/27		4/28		4/29		4/30		5/01	
		DG[a]	Pi[b]	DG	Pi	DG	Pi	DG	Pi	DG	Pi	DG	Pi	DG	Pi
Abilene	TX	0	1	34	1	1	1	13	5	6	1	3	1	1	1
Albany	NY	0	1	11,000	7	120	6	52	2	NA	1	90	7	12	1
Albuquerque	NM	0	1	930	1	240	1	56	4	35	1	19	1	2	1
Alpena	MI	0	1	0	1	0	1	0	1	0	1	12	6	8	6
Amarillo	TX	0	1	340	1	210	1	2	1	8	2	12	1	3	1
Atlanta	GA	0	1	0	1	0	1	0	1	24	7	9	8	0	1
Baltimore	MD	0	1	0	1	0	1	12	3	16	1	18	5	1	1
Billings	MT	0	1	0	1	3	2	90	5	0	1	0	1	0	1
Binghamton	NY	0	1	24	6	0	1	0	1	0	1	8	6	2	5
Boise	ID	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Boston	MA	0	1	0	1	7	4	1	1	3	1	12	6	2	6
Buffalo	NY	0	1	1	5	0	1	1	2	0	1	7	5	8	6
Butte	MT	0	1	0	1	1	1	3	5	0	1	0	1	0	1
Caribou	ME	0	1	0	1	360	6	11	2	20	2	0	1	10	1
Casper	WY	0	1	11	1	200	1	92	4	3	5	0	1	1	5
Charleston	SC	0	1	0	1	0	1	0	1	4	1	0	1	0	1
Cheyenne	WY	0	1	59	1	60	1	30	3	1	1	1	1	0	1
Chicago	IL	NA[c]	1	NA	1	NA	1	NA	1	NA	1	NA	1	NA	1
Colo Springs	CO	0	1	1	1	120	1	110	5	2	2	5	3	1	4
Concordia	KS	0	1	0	1	63	1	85	5	42	6	0	1	0	1
Corpus Chris	TX	NA	1	1	1	1	3	0	1	NA	1	1	1	NA	1
Dallas	TX	0	1	190	1	140	1	60	7	16	2	1	1	3	1
Dansville	NY	0	1	0	1	0	1	0	1	0	1	6	5	2	5
Del Rio	TX	0	1	1	1	0	1	4	1	2	1	0	1	0	1
Denver	CO	0	1	19	1	110	1	78	5	9	1	6	5	1	1
Des Moines	IA	0	1	0	1	1	1	23	1	96	6	10	6	1	2
Detroit	MI	0	1	0	1	0	1	38	5	1	2	7	5	3	5
Dunkirk	NY	NA	1	NA	1	0	1	0	1	0	1	8	2	NA	1
East Port	ME	NA	1	NA	1	140	6	0	1	10	2	NA	1	15	5
Elko	NV	0	1	0	1	1	5	0	1	2	3	0	1	0	1

Table 3.6. cont'd

Site	State	4/25		4/26		4/27		4/28		4/29		4/30		5/01	
		DG[a]	Pi[b]	DG	Pi	DG	Pi	DG	Pi	DG	Pi	DG	Pi	DG	Pi
Ely	NV	12	1	7	1	20	4	1	2	0	1	0	1	0	1
Eureka	CA	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Fargo	ND	0	1	0	1	1	1	14	2	115	5	NA	1	4	6
Flagstaff	AZ	1100	1	150	1	190	6	6	3	0	1	0	1	0	1
Fort Smith	AK	0	1	0	1	150	7	27	7	10	2	1	1	1	1
Fresno	CA	0	1	0	1	2	6	0	1	0	1	0	1	0	1
Goodland	KS	NA	1	NA	1	160	1	82	5	6	6	1	3	0	1
Grand JNC	CO	0	1	870	1	84	3	7	5	6	1	3	2	0	1
Grand Rapids	MI	0	1	0	1	0	1	130	5	10	2	NA	1	6	5
Green Bay	WI	0	1	0	1	0	1	6	3	13	2	10	6	0	1
Helena	MT	0	1	0	1	0	1	2	5	0	1	0	1	0	1
Huron	SD	0	1	0	1	1	1	220	6	90	6	3	7	0	1
Jackson	MS	0	1	0	1	109	1	170	1	190	8	2	1	0	1
Jacksonville	FL	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Kalispell	MT	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Kansas City	MO	0	1	0	1	90	1	40	4	30	7	2	2	10	3
Knoxville	TN	NA	1	0	1	0	1	6	1	12	6	1	5	0	1
Las Vegas	NV	0	1	4	1	7	1	NA	1	0	1	0	1	1	1
Los Angeles	CA	2	2	0	1	2	6	0	1	0	1	0	1	0	1
Louisville	KY	0	1	0	1	73	5	110	1	50	5	3	3	2	1
Lynchburg	VA	0	1	0	1	0	1	36	1	8	1	8	6	0	1
Marquette	MI	0	1	0	1	0	1	0	1	5	2	32	6	1	5
Medford	OR	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Memphis	TN	0	1	0	1	26	1	180	2	27	8	2	1	1	1
Miami	FL	0	1	0	1	42	1	34	1	3	1	1	1	0	1
Milford	UT	320	1	240	1	240	5	6	6	1	2	0	1	0	1
Milwaukee	WI	0	1	0	1	0	1	280	6	4	3	20	6	10	5
Minneapolis	MN	0	1	0	1	0	1	110	3	180	5	18	6	1	5
Mobile	AL	0	1	0	1	0	1	19	1	13	5	0	1	NA	1
Montgomery	AL	0	1	0	1	1	1	38	1	33	7	3	5	0	1
Nashville	TN	0	1	0	1	1	1	42	1	180	7	2	1	0	1
New Haven	CT	0	1	3	5	0	1	0	1	0	1	18	7	0	1
New Orleans	LA	0	1	0	1	150	1	130	1	39	4	6	1	2	1
New York AEC	NY	0	1	0	1	0	1	1	1	NA	1	10	6	0	1
Philadelphia	PA	0	1	0	1	0	1	0	1	1	2	8	6	2	5
Phoenix	AZ	0	1	0	1	1	2	0	1	0	1	0	1	0	1

Month and day columns: 4/25 through 5/01.

Table 3.6. cont'd

Site	State	Month and day													
		4/25		4/26		4/27		4/28		4/29		4/30		5/01	
		DG[a]	Pi[b]	DG	Pi	DG	Pi	DG	Pi	DG	Pi	DG	Pi	DG	Pi
Pittsburgh	PA	0	1	0	1	0	1	4	3	19	1	6	3	5	2
Pocatello	ID	0	1	10	1	6	6	0	1	0	1	0	1	0	1
Port Arthur	TX	0	1	17	1	18	1	28	2	10	6	4	1	0	1
Portland	OR	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Providence	RI	0	1	2	6	0	1	0	1	1	1	75	7	1	5
Pueblo	CO	0	1	0	1	120	1	21	4	8	2	3	1	0	1
Rapid City	SD	0	1	0	1	5	1	250	6	4	6	0	1	0	1
Raton	NM	0	1	10	1	100	1	10	2	17	3	9	2	5	1
Reno	NV	0	1	0	1	0	1	13	1	0	1	0	1	0	1
Rochester	NY	0	1	2	5	0	1	0	1	0	1	16	6	6	6
Rock Springs	WY	0	1	42	2	14	1	1	5	0	1	0	1	0	1
Roswell	NM	25	1	4200	1	710	1	200	3	17	1	11	1	2	1
Sacramento	CA	0	1	2	6	0	1	0	1	0	1	0	1	0	1
Salt Lake	UT	0	1	64	1	37	5	0	1	0	1	0	1	0	1
San Diego	CA	0	1	0	1	0	1	0	1	0	1	0	1	0	1
San Francisco	CA	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Scottsbluff	NB	0	1	1	1	28	1	55	5	0	1	0	1	0	1
Seattle	WA	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Spokane	WA	0	1	0	1	0	1	0	1	0	1	0	1	0	1
St. Louis	MO	0	1	0	1	32	1	98	3	30	3	13	5	5	1
Syracuse	NY	0	1	3	5	1	5	0	1	0	1	0	1	0	1
Texarkana	AK	0	1	0	1	26	1	66	7	7	5	3	1	1	1
Tucson	AZ	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Washington	DC	0	1	0	1	0	1	13	2	26	1	14	6	1	5
Watertown	NY	0	1	0	1	0	1	0	1	3	1	12	6	2	5
Wichita	KS	0	1	0	1	285	1	55	2	33	5	2	2	5	3
Williston	ND	0	1	0	1	1	2	57	4	76	6	4	6	1	5
Winnemucca	NV	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Yuma	AZ	0	1	0	1	0	1	1	1	0	1	1	1	0	1

[a] DG=daily deposition of ^{131}I per unit of area of ground (nCi per m^{-2})
[b] Pi=precipitation index
[c] NA=not available

atic relationships in the data were also explored, including any possible dependence of fallout on the latitude and longitude of the gummed-film station, and the predicted amount of radioactive material in the air column above the gummed-film station as determined from NOAA's meteorological model. In virtually every case, the precipitation index emerged as the single most important parameter in predicting systematic variations in ^{131}I deposition. The calculated air column content was rarely a good predictor of the measured daily deposition. This reflects the relative discrepancy between the calculated position of the radioactive cloud and the observed areas of deposition (especially at long distances from the NTS and several days after detonation) and the uncertain altitude and efficiency of scavenging by rain clouds relative to radioactive clouds. The reasons for this are discussed in **Appendix 1,** which describes the meteorological model.

Statistical correlations among the deposition values at different locations were examined as a function of the relative distance between locations by using one of a number of simple mathematical functions depending on a single parameter. In this study, several such mathematical functions were fit to each data set, and the most appropriate data set for a given day and test was determined by a cross-validation procedure. This procedure consisted of removing one data point from the set and using the other data points to predict its value by kriging. The average error obtained after sucessively removing and predicting each point of the set in sequence is the cross-validation error. The mathematical function with the smallest associated cross-validation error generally was the one used. The magnitude of the improvement in the estimation of the interpolated values which results from the use of statistical correlations was determined by comparing the cross-validation error after kriging, including the effects of statistical correlations, with that obtained after only correcting for the effect of precipitation (and any other significant systematic relationships that were found). This improvement corresponded to a reduction factor in the cross-validation error of about 50% on average.

After the best fit to both systematic and statistical relationships among the data was determined, these relationships were used to calculate the deposition at the geographic center (centroid) of each county that could have received fallout. The average precipitation index for each county, as provided by NOAA, was used to predict the average wet deposition in the county. A map of the U.S. was generated for each day following each test showing the measured deposition at each gummed-film location and the interpolated values at each county cen-

Figure 3.9. Estimates of daily deposition of ^{131}I per unit area of ground for April 27, 1953 (2 days after detonation of the shot Simon). The numbers in large characters represent the ^{131}I deposition derived from the gummed-film results whereas the numbers in small characters are the interpolated results, for each county centroid, obtained by kriging.

Table 3.7. Geometric standard deviations (GSDs) attached to the estimates of ^{131}I deposition, according to the values of the kriging error and of the precipitation index.

Multiplicative kriging error	GSD	
	Precipitation indices 1 to 4	Precipitation indices 5 to 9
1.0-1.5	1.5	2.0
1.5-2.0	2.0	2.5
2.0-2.5	2.5	3.0
2.5-3.0	3.0	3.5
> 3.0	3.5	4.0

troid. An example is shown in *Figure 3.9*. Each map was examined to ensure that the interpolated values were consistent with the measured deposition pattern, the rainfall pattern, and expected atmospheric transport processes.

3.3.1.2.3. Discussion of uncertainties

The success of the interpolation effort can be measured in several ways. The magnitude of the cross-validation errors indicates that the deposition at any given location could be predicted from the ^{131}I depositions derived from gummed-film data at other locations to within about a factor of three. The kriging analysis itself produces an estimate of the interpolation error at each site using the mathematical function describing the statistical correlations. This is called the kriging standard deviation. Most alternative interpolation methods provide no such estimate. While there are a considerable number of assumptions necessary to deduce an interpolation error from the kriging standard deviation, it can be used as a relative indicator of the uncertainty in the results. In general, the closer a county centroid is to actual measurement locations, the smaller the interpolation error. The highest errors occur when values are extrapolated beyond the boundaries of the fallout pattern. Fortunately, this occurred rarely and generally involved low deposition values. The kriging standard deviation indicates that the typical interpolation error is about a factor of two or three. This is in general agreement with that estimated from the cross-validation errors.

The deposition estimate for each day and each county obtained by the kriging analysis is assumed to represent the geometric mean of a log-normal distribution; the geometric standard deviation, GSD, associated with the deposition estimate was taken to be slightly higher than the kriging error in order to account for other possible sources of error such as the uncertainties attached to the estimates of ^{131}I deposition at the gummed-film sites and the precipitation index. The GSDs were assigned as indicated in *Table 3.7*.

The estimate of ^{131}I deposition derived from gummed-film data at each gummed-film site was compared to the interpolated value at the centroid of the county within which it was located in order to assess any potential biases in the interpolated depositions for individual counties. The average difference in these values was only 12%, which is very small compared to the other estimates of interpolation error. This would indicate that the interpolation errors are about as likely to result in an overestimate as in an underestimate at any particular site. The total activity of ^{131}I deposited over the U.S. for each day was calculated by multiplying the interpolated deposition value at each county centroid by the area of the county and summing all of the county depositions. When the total activity of ^{131}I deposited over the entire U.S. is summed for all days on which fallout occurred following a given test, the result can be compared to the total amount of ^{131}I estimated to have been produced by the test. For example, the total ^{131}I deposition across the U.S. from the test Simon was estimated to be 1.8 MCi by the kriging technique, or approximately 30% of the ^{131}I produced by that test. This does not include the deposition in the immediate vicinity of the NTS, for which the spatial resolution of the gummed-film stations is insufficient to provide adequate interpolated values. However, the result is consistent with other estimates, and indicates that the kriging analysis does not result in a significant systematic bias. For other tests, the range of estimated total ^{131}I deposition was 3-70% of that produced, and varies generally in a manner consistent with what is known of relationships between amounts of ^{131}I produced by a test and the fallout associated with that test (Beck et al. 1990). Estimates of the total deposition of ^{131}I is discussed in **Section 3.6.**

In summary, the challenging task of estimating realistic deposition values in over 3,000 U.S. counties from fewer than 100 data points was accomplished for 38 tests by using a combination of statistical analysis together with all available information about the physical deposition process. The method consisted in using an interpolation scheme known as kriging, the

results of which were carefully monitored and inspected though-out the process to ensure that the results were physically reasonable. The predicted values are estimated by a variety of means to be generally accurate within about a factor of three, and do not appear to contain any significant bias in either direction.

3.3.1.2.4. Use of the Area-of-Influence Precipitation-Corrected (AIPC) method

For those tests and days that resulted in a very small number of positive gummed-film results, the determination of the deposition in the counties without monitoring data required a less complex approach. In those cases, the irregular deposition patterns that were generally involved would lead to unreasonable or questionable values if the interpolation were performed by the objective kriging technique. Such cases were treated by a much simpler method than kriging: the deposition in the county of interest was taken to be the same as in the nearest county with a measured gummed-film value if the precipitation indices were the same; if the precipitation indices differed, the estimates of deposition were adjusted using precipitation weights. The values of the precipitation weights, which were derived from the scavenging coefficients used in the meteorological model described in **Appendix 1**, are presented in *Table 3.8*.

This simple technique, denoted as AIPC (acronym for Area-of-Influence, Precipitation Corrected method) was used for the days when the kriging procedure was not applied but positive ^{131}I depositions per unit area of ground had been derived from the gummed-film measurements and precipitation data were available. The AIPC technique was either used for complete tests or for days following a test that had few positive gummed film results. Generally, the tests to which this simpler procedure has been applied released less ^{131}I into the atmosphere than did the tests for which kriging was done.

For the days and tests for which the AIPC method was used, the GSD associated with the depositions obtained with the AIPC method was taken to be 1.5 for counties with gummed-film values and 4.0 for all other counties

3.3.2. Meteorological Transport Approach

The national network of gummed-film monitoring stations was operational from the autumn of 1951 until 1960. The gummed-film network was not operational for the tests of the Ranger series detonated in January and February 1951, or for the tests of the underground testing era (from 1961 to date). No deposition data that can be related to those tests conducted at the NTS are available, except in the close-in area. For these tests, another method for determining the deposition of ^{131}I across the U.S. has been employed, but it is deemed less reliable than either the kriging or the AIPC methods. This alternative method simulates the transport and diffusion of the cloud of radioactive debris across the United States based on observed wind patterns and assumes that the ^{131}I deposits only with precipitation.

The ^{131}I releases from the nine tests evaluated using the meteorological transport model were relatively small; only four of them released more than 1 MCi of ^{131}I and none more than 3.5 MCi. The smaller amounts of ^{131}I produced by the 9 tests in this category should be kept in mind when the associated large uncertainties using this approach are compared to the smaller uncertainties associated with the depositions predicted by the kriging and AIPC methods.

Three of the four larger tests (Baker, Baker-2, and Fox from the Ranger series) were air bursts which helps to justify the use of a model which only predicts deposition by precipitation

Table 3.8. Relationship between the 24-h precipitation values and the precipiation weights used in the AIPC method.

Precipitation Index	24-h precipitation amount		Precipitation weight
	(inches)	(millimeters)	
1	none	none	1
2	trace	trace	1.5
3	0.01-0.03	0.25-0.76	2
4	0.03-0.10	0.76-2.5	2
5	0.10-0.30	2.5-7.6	4
6	0.30-1.00	7.6-25	6
7	1.00-3.00	25-76	10
8	3.00-5.00	76-127	10
9	5.00 or over	127 or over	10

scavenging. The fourth test (Sedan) was a cratering event, which produced airborne dust that deposited quickly. Very little of the radioactive debris was transported much farther than a few hundred kilometers, where it was measured.

There are major uncertainties in each of the steps leading to the predictions of deposited ^{131}I by the meteorological transport model. Rather than quantifying each of these uncertainties, the overall uncertainty was described in the uncertainty of the estimate of the scavenging, or wet removal, coefficient. This coefficient is the ratio of the deposited activity to the activity in the overhead radioactive cloud, and its uncertainties are due to errors in the source term of ^{131}I, in the meteorological transport model, in the assumed dispersion of the clouds and the character of the scavenging process. The scavenging coefficient is estimated from data obtained during the predicted passage of radioactive clouds over gummed-film stations while there was precipitation and thus it contains all the uncertainties of the transport and dispersion model as well as the uncertainties in the scavenging characteristics. It also includes the smaller uncertainties of the gummed-film ^{131}I depositions at monitoring sites, referred to in **Section 3.2.2.2.** The uncertainty in the scavenging coefficient as described above can be applied directly to the uncertainty that is assigned to the deposition of ^{131}I estimated by this method.

It should be emphasized, however, despite the limitations of the meteorological transport method, the relatively small atmospheric releases of ^{131}I from these tests to which it is applied produce small estimated deposition values. The use of the meteorological model to estimate ^{131}I depositions per unit area of ground resulting from a given nuclear weapons test involves the estimation of:

(a) the activity of ^{131}I released into the atmosphere by the test considered,

(b) the initial distribution of ^{131}I in the mushroom cloud produced by the explosion,

(c) the transport and dispersion across the U.S. of the ^{131}I present in the radioactive cloud, and

(d) the deposition of ^{131}I on the ground with falling precipitation.

A detailed description of the meteorological model is provided in **Appendix 1.**

3.4. COMPARISON OF THE ESTIMATES OF DAILY ^{131}I DEPOSITIONS PER UNIT AREA OF GROUND OBTAINED WITH VARIOUS METHODS

There are, all together, 3,094 counties and sub-counties for which ^{131}I deposition densities were estimated:

(a) 5 counties in the Town Data Base, subdivided into 13 counties,

(b) 120 undivided counties and 9 counties sub-divided into 24 sub-counties in the County Data Base, and

(c) 2,937 undivided counties in the remainder of the contiguous United States.

In the area covered by the Town and County Data Bases (157 counties and sub-counties, also called “near-NTS area”), estimates of ^{131}I deposition per unit area of ground could be obtained for the tests for which both exposure rates and gummed-film data are available, using ORERP results, the kriging method, the AIPC method, and the meteorological transport model. The last three methods could also be used to estimate ^{131}I depositions per unit area of ground in the 2,937 counties representing the remainder of the contiguous United States when gummed-film data were available. In order to illustrate the advantages and disadvantages of the various methods, and also in order to show the importance of some of the assumptions used in the calculations, the deposition results obtained with the different methods are compared in the following sections, using several days of deposition following the test Simon detonated April 25, 1953 as examples.

3.4.1. Comparison of the ^{131}I Depositions Per Unit Area of Ground Obtained with Various Methods for the Counties Near the NTS

The estimates of ^{131}I deposition per unit area of ground derived by ORERP using measured exposure rates, as well as those obtained by the kriging and by the AIPC method for the counties in the near-NTS area are presented for the test Simon are presented in *Figures 3.10, 3.11, and 3.12,* respectively. *Figure 3.11* shows, in addition, the ^{131}I depositions per unit area of ground that are calculated from the gummed-film data, expressed in nanocuries per square meter. These values form the basis for the estimation of ^{131}I deposition per unit area of ground for the kriging *(Figure 3.11)* and the AIPC methods *(Figure 3.12)*. An array of supplementary data, some of which is classified, was used by ORERP to produce the results in *Figure 3.10*. The estimates of ^{131}I deposition per unit area of ground that would be obtained with the meteorological transport model have not been calculated since it did not rain in most of the counties considered during the time of deposition of radioactive materials following the test Simon. The results obtained with the meteorological transport model would have been extremely patchy because the meteorological model can only calculate the depositions associated with falling precipitation.

The overall patterns of deposition obtained with the three methods are fairly similar, with the highest values in northern Arizona, southern New Mexico, and southwestern Colorado, and with low values in California, southern Arizona, and western Nevada. There are, however, substantial differences in the deposition levels obtained in some counties: for example, a very high deposition is calculated in Clark county in southeastern Nevada with the ORERP data (*Figure 3.10*) whereas both the kriging and the AIPC methods yield lower values for that county; conversely, the deposition estimates derived from the ORERP data for counties in the southern part of New Mexico are lower than those estimated using either the kriging or the AIPC method. This is undoubtedly due to the fact that the deposition at the widely separated gummed-film sites did not represent adequately the average deposition in those counties for that particular day. The ORERP approach employed more sources of information and a finer resolution in the measurements and produced better estimates of the average deposition. It is also to be noted that the AIPC method, in the absence of rain, yields constant deposition levels over large areas (see, for example, New Mexico in *Figure 3.12*), resulting in areas of either high or low contamination, whereas the transitions of contamination levels between counties are smoother when the other two methods are used.

The overall similarity of the deposition patterns obtained with the three methods is also verified in *Figures 3.13* and *3.14,* where the ratios of the depositions obtained in the same counties with, on the one hand, the kriging or the AIPC method, and, on the other hand, the ORERP data, are plotted as histograms. *Figure 3.13,* which compares the estimates of ^{131}I deposition per unit area of ground obtained with the kriging method to those derived from the ORERP data, shows that, on the average, the kriging method resulted in deposition estimates that were lower than those derived from the ORERP data. The dispersion of the ratios, however, is relatively small, with most of the values in agreement within a factor of 4.

Figure 3.14, which compares the estimates of ^{131}I deposition per unit area of ground obtained with the AIPC method to those derived from the ORERP data, shows, on the contrary, a wider dispersion of the ratios but a larger number of counties in which the AIPC method led to higher deposition estimates than those derived from the ORERP data.

Even though the comparison of the estimates of ^{131}I deposition per unit area of ground obtained with the three methods for the counties in the near-NTS area are limited to a single test, it seems that the overall agreement is relatively good. It is clear that the depositions obtained from the ORERP data are to be preferred to those obtained with the other two methods as the ORERP data are culled from a large array of measurement results, some of which are not available to the general public. Since the spatial variation of the fallout deposition was quite substantial in the area near the NTS, the finer grid of measurement results used by ORERP leads to a better representation of the fallout pattern.

Figure 3.10. Estimates of ^{131}I deposition per unit area from the exposure rates at H + 12 reported by ORERP for the test Simon detonated April 25, 1953 and for the near-NTSarea.

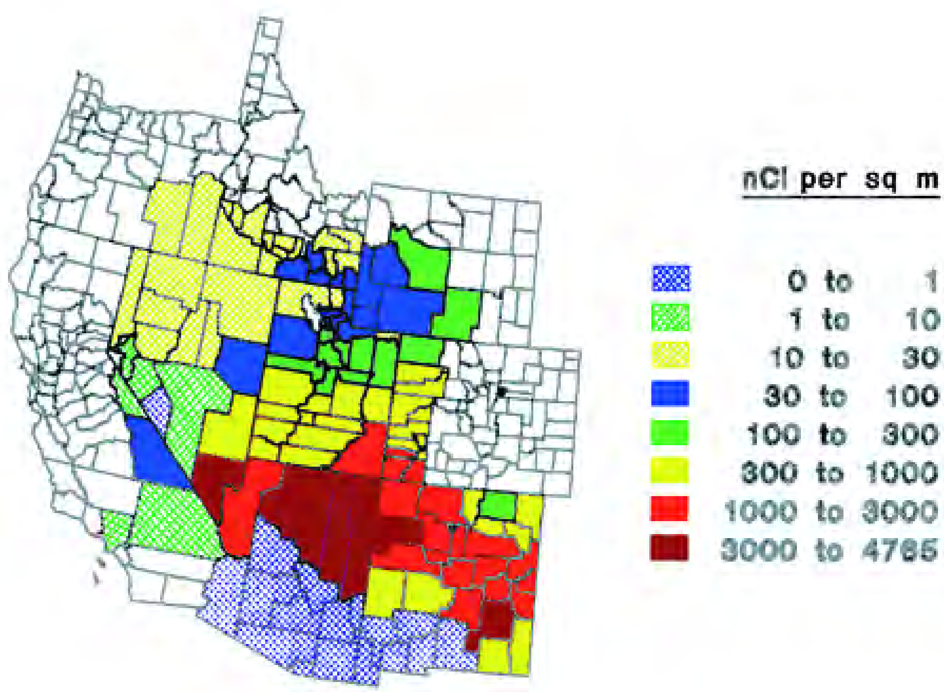


Figure 3.11. Estimates of ^{131}I deposition per unit area of ground derived from the test Simon detonated on April 25, 1953 and for the near-NTS area. The numbers represent the ^{131}I depositions derived from gummed-film measurements at the gummed-film sites.

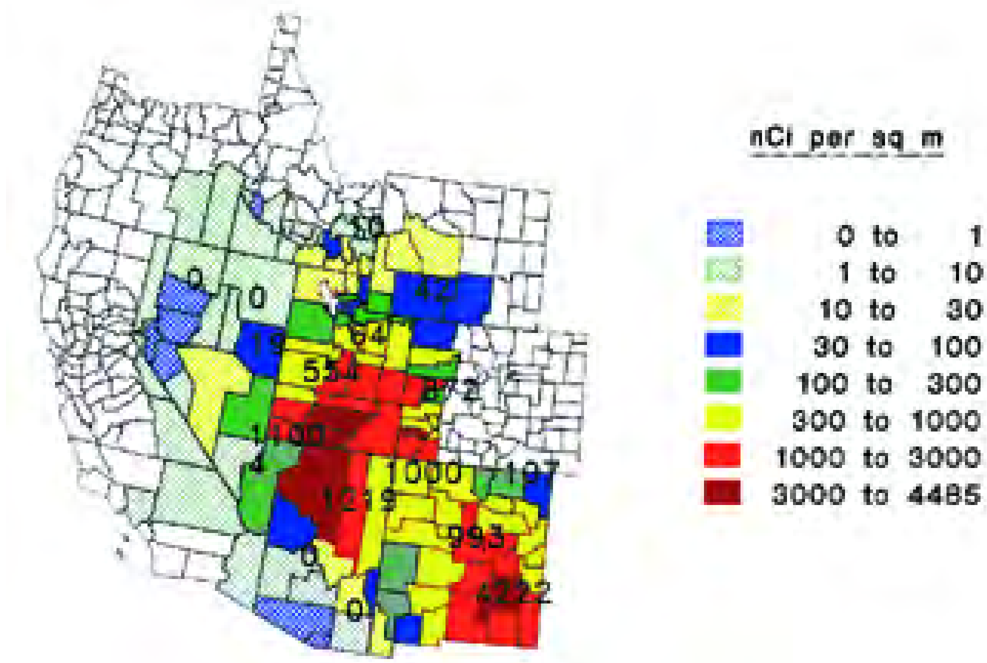


Figure 3.12. Estimates of ^{131}I deposition per unit area of ground derived from the gummed-film measurements by the AIPC method for the test Simon detonated on April 25, 1953 and for the near-NTS area.

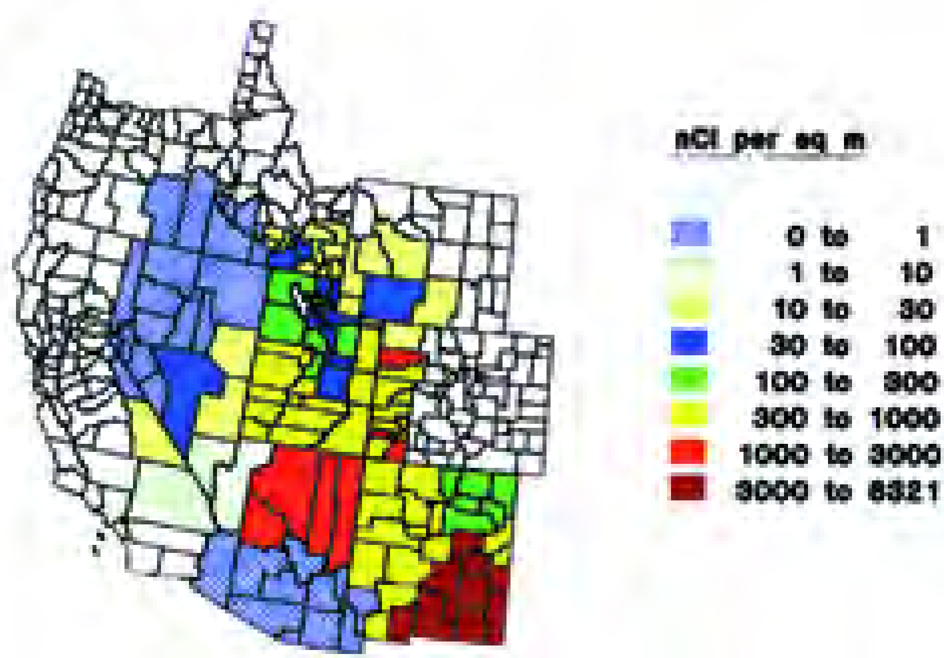


Figure 3.13. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the gummed-film measurements by the kriging method to those derived from the exposure rates at H + 12 reported by ORERP for the test Simon detonated on April 25, 1953 and for the near-NTS area.

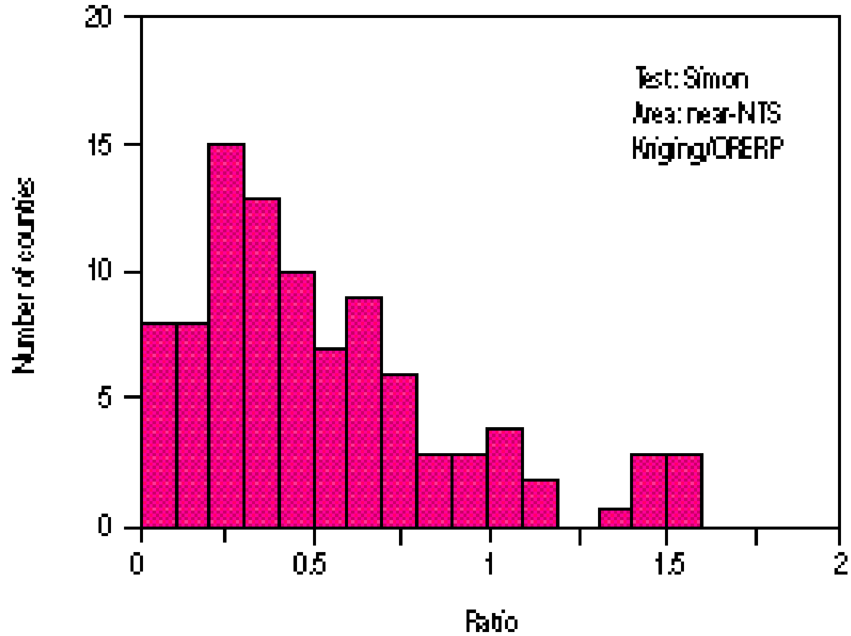
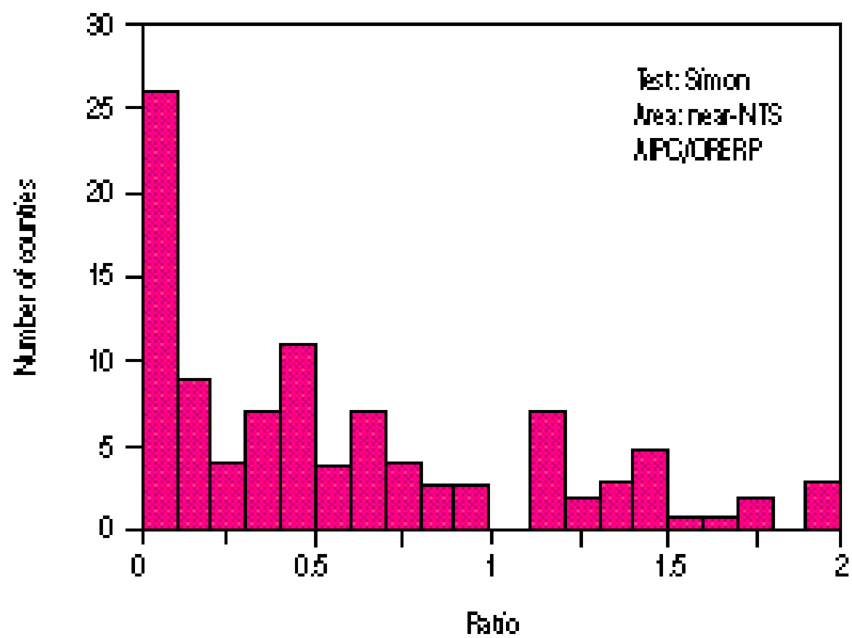


Figure 3.14. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the gummed-film measurements by the AIPC method to those derived from the exposure rates at H + 12 reported by ORERP for the test Simon detonated on April 25, 1953 and for the near-NTS area.



3.4.2. Comparison of the ^{131}I Depositions Per Unit Area of Ground Obtained with Various Methods for the Counties in the Remainder of the Contiguous United States

The sets of deposition estimates that have been obtained with the meteorological model and with the kriging and AIPC methods for the 2,937 counties that are in the remainder of the contiguous United States have been compared for April 28 and 29, 1953, that is, 3 and 4 days after the detonation of the test Simon, at a time when deposition almost had ceased in the near-NTS area but was observed in the eastern part of the country. A third comparison was made for July 8, 1957, three days after detonation of the test Hood. The date was selected because rainfall was widespread and it provided an expanded test of the meteorological transport model.

3.4.2.1. Comparison of the ^{131}I depositions per unit area of ground obtained with various methods for the counties in the remainder of the contiguous United States for April 28, 1953 following test Simon

The estimates of ^{131}I deposition per unit area of ground that were calculated with the kriging method, with the AIPC method, and with the meteorological transport model are presented in *Figures 3.15, 3.16, and 3.17,* respectively. *Figures 3.15 and 3.16,* which are based on the same set of gummed-film measurements, are very similar, and both are notably different from *Figure 3.17*. *Figures 3.15 and 3.16* show the same deposition pattern, with relatively high values in Louisiana, Arkansas, Missouri, Indiana, and South Dakota, and a widespread deposition area extending from Montana to Alabama. In comparison, the deposition pattern obtained with the meteorological transport model is more limited because the predicted location over the entire radioactive cloud, calculated from the airmass trajectories and shown in *Figure 3.18,* is located over the eastern half of the country. Also, there were large areas in the eastern part of the country where it did not rain on April 28, 1953. The meteorological transport model predicts no deposition at those locations.

The overall similarity of the deposition patterns obtained with the kriging and with the AIPC methods is verified in *Figure 3.19,* where the ratios of the depositions estimated in the same counties with the AIPC and with the kriging methods are plotted as a histogram. On the average, the kriging and the AIPC methods resulted in deposition estimates that were within a factor of 2, with about 16% of the counties with no deposition according to the AIPC method and with some deposition according to the kriging method.

Figure 3.20, which compares the estimates of ^{131}I deposition per unit area of ground obtained with the meteorological model and with the kriging method shows, in contrast, that the deposition estimates obtained with the kriging method were in general higher than those calculated with the meteorological model, and that the meteorological model did not predict any deposition in almost 2,000 counties for which estimates of deposition are available with the kriging method.

Figure 3.15. Estimates of ^{131}I deposition per unit area of ground derived from the gummed-film measurements by the kriging method on April 28, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the contiguous United States.

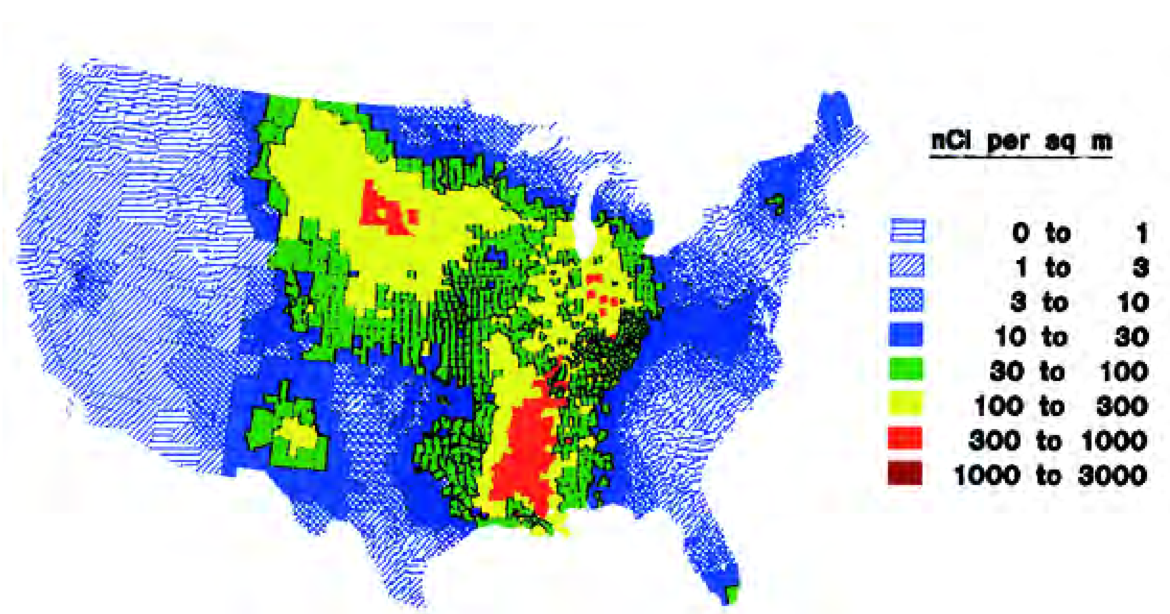


Figure 3.16. Estimates of ^{131}I deposition per unit area of ground derived by the AIPC method on April 28, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the contiguous United States.

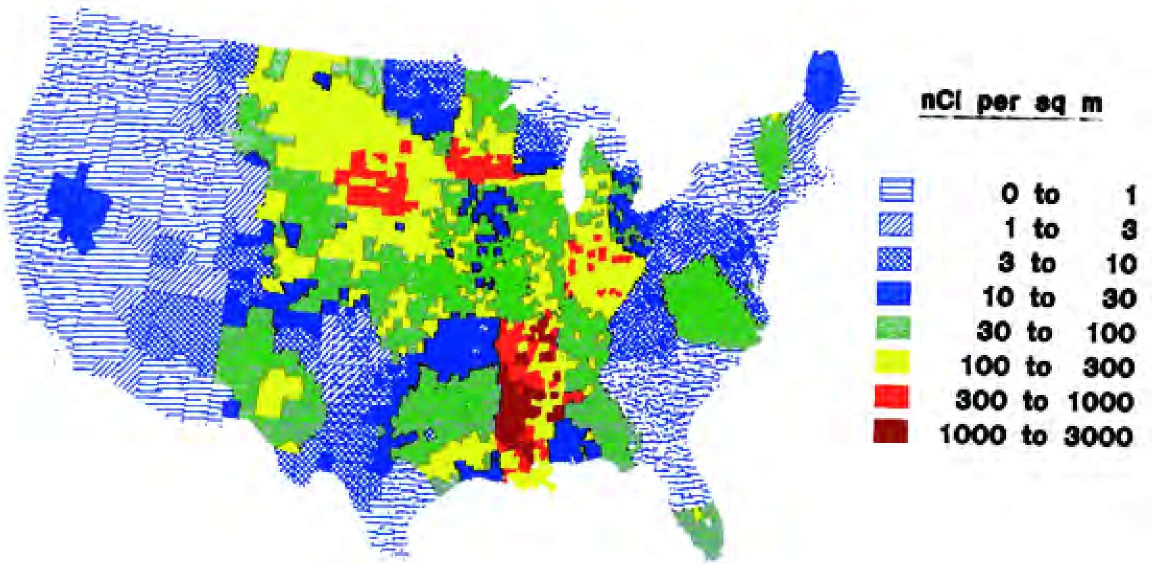


Figure 3.17. Estimates of ^{131}I deposition per unit area of ground obtained using the meteorological transport model on April 28, 1953 following the test Simon detonated on April 25, 1953 for all counties of the contiguous United States in which precipitation was recorded.

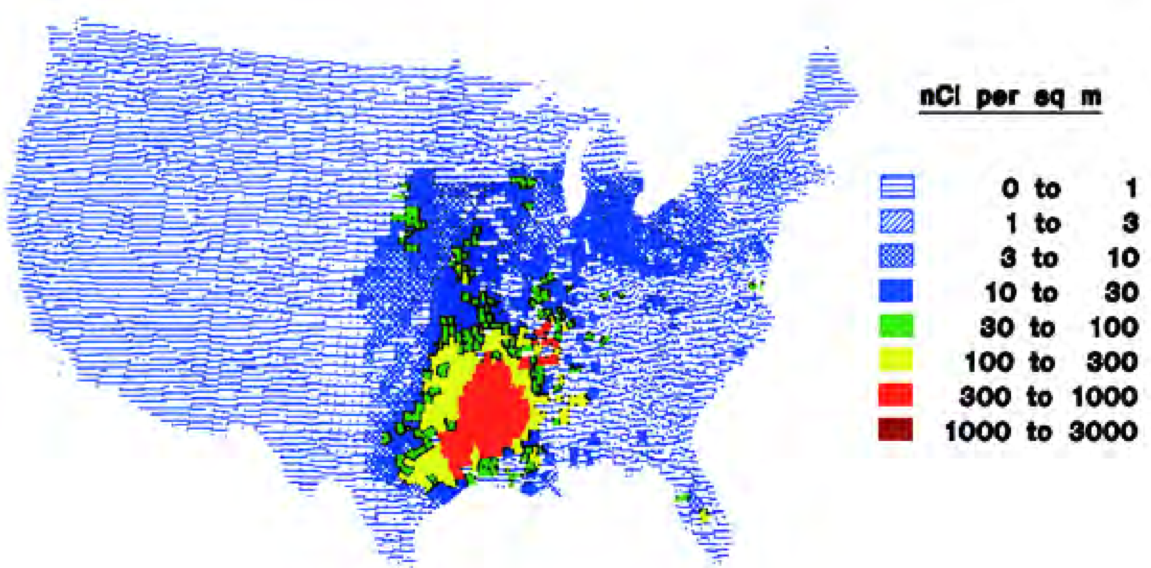


Figure 3.18. Estimates of ^{131}I contained in the radioactive cloud per unit area of ground obtained using the meteorological transport model on April 28, 1953 following the test Simon detonated on April 25, 1953 for all counties of the contiguous United States.

Figure 3.19. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the AIPC method to those derived from the gummed-film measurements by the kriging method for April 28, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the United States with estimated non-zero deposition by the kriging method.

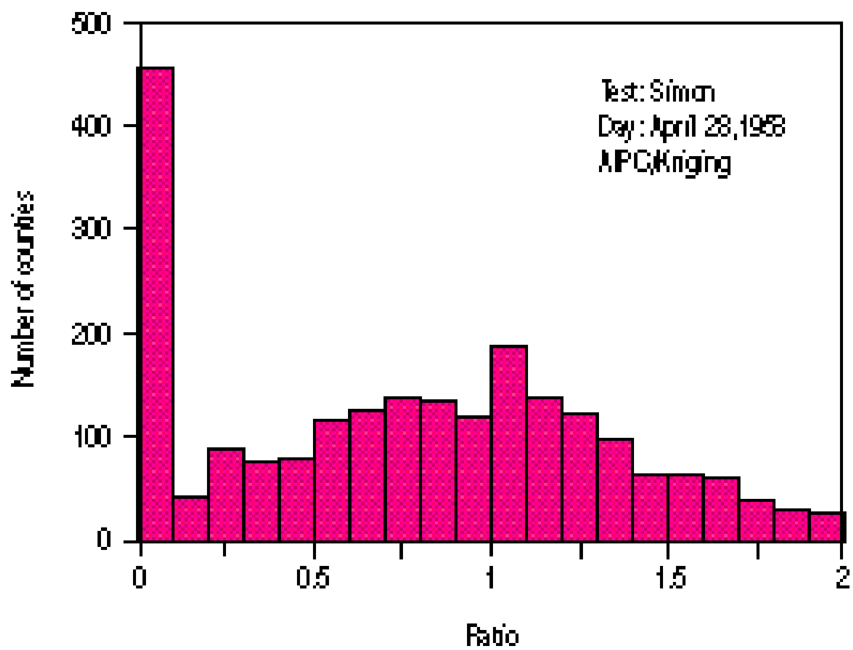
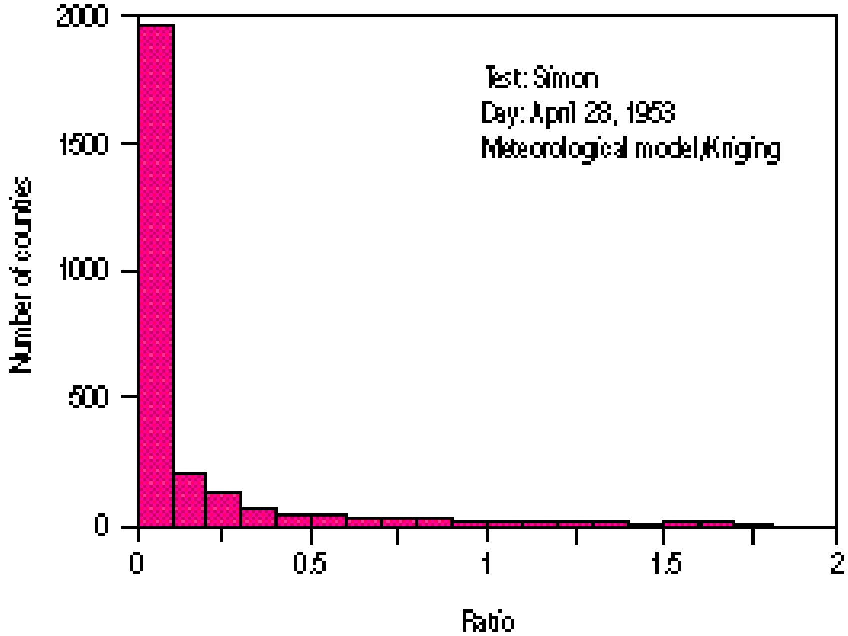


Figure 3.20. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the meteorological model to those derived from the gummed-film measurements by the kriging method for April 28, 1953 resulting from the test Simon detonated on April 25, 1953for all counties of the United States with estimated non-zero deposition by the kriging method.



3.4.2.2. Comparison of the ^{131}I depositions per unit area of ground obtained with various methods for the counties in the remainder of the contiguous United States for April 29, 1953 following test Simon

The general conclusions from comparison of the depositions calculated for April 28, 1953 are also valid for April 29th, 1953. The estimates of ^{131}I deposition per unit area of ground that were calculated for that day with the kriging method, with the AIPC method, and with the meteorological model are presented in *Figures 3.21, 3.22, and 3.23,* respectively. *Figures 3.21 and 3.22,* which are based on the same set of gummed-film measurements, are very similar, and both are notably different from *Figure 3.23. Figures 3.21 and 3.22* show deposition patterns that are similar in size to those of the day before, the absolute deposition levels being, however, substantially lower. In comparison, the deposition area predicted by the meteorological transport model is now limited to an even smaller part of the country (see also *Figure 3.24*).

The overall similarity of the deposition patterns obtained with the kriging and with the AIPC methods is verified in *Figure 3.25,* where the ratios of the depositions obtained in the same counties with the AIPC and with the kriging methods are plotted as an histogram. On the average, the kriging and the AIPC methods resulted in deposition estimates that were within a factor of 2, with about 14% of the counties with no deposition according to the AIPC method and with some deposition according to the kriging method.

Figure 3.26, which compares the estimates of ^{131}I deposition per unit area of ground obtained with the meteorological model and with the kriging method shows, again, that the meteorological model did not predict any deposition in almost 2,000 counties for which estimates of deposition are available with the kriging method. However, in the remaining few counties for which positive deposition values were calculated with both the kriging method and with the meteorological model, there is a relatively good agreement between the two sets of deposition estimates for that day. Most ratios were within the range 0.5-2.

3.4.2.3. Comparison of the ^{131}I depositions per unit area of ground obtained with various methods for the counties in the remainder of the contiguous United States for July 8, 1957 following test Hood.

To further check the general patterns seen from comparisons of ^{131}I deposition estimates following test Simon, the three methods of estimating ^{131}I deposition were also compared for the test Hood, detonated on July 5, 1957. The day selected for comparison was July 8, 1957, because precipitation records indicated that rainfall was widespread on that day. This provided the meteorological model with the possibility of estimating ^{131}I depositions in a large part of the area covered by the radioactive cloud.

The estimates of ^{131}I deposition per unit area of ground that were calculated for July 8, 1957 with the kriging method, with the AIPC method, and with the meteorological model are

Figure 3.21. Estimates of ^{131}I deposition per unit area of ground derived by the kriging method from the gummed-film measurements on April 29, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the contiguous United States.

Figure 3.22. Estimates of ^{131}I deposition per unit area of ground derived by the AIPC method from the gummed-film measurements on April 29, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the contiguous United States.

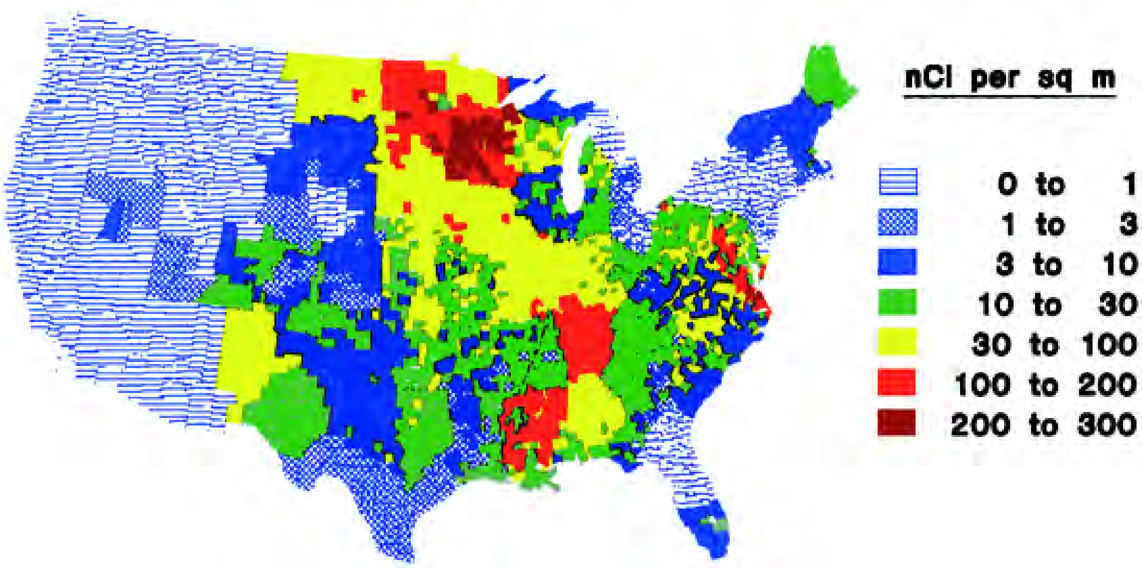


Figure 3.23. Estimates of ^{131}I deposition per unit area of ground obtained using the meteorological transport model for April 29, 1953 following the test Simon detonated on April 25, 1953 for all counties of the contiguous United States in which precipitation was recorded.

Figure 3.24. Estimates of ^{131}I activity in the radioactive cloud per unit area of ground obtained using the meteorological transport model on April 29, 1953 following the test Simon detonated on April 25, 1953 for all counties of the contiguous United States.

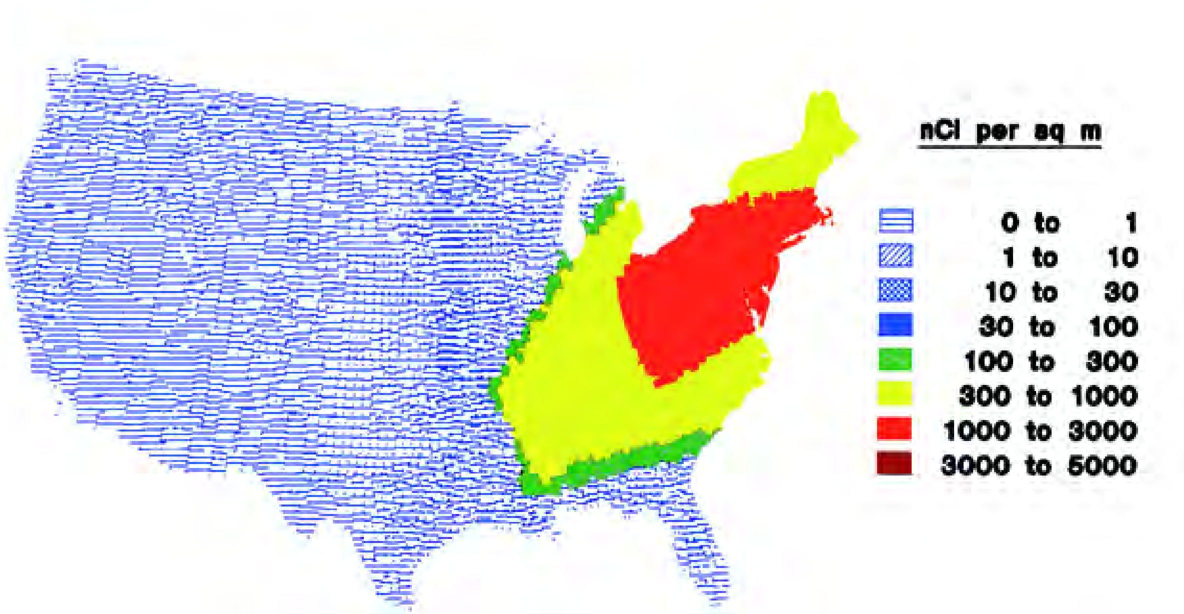


Figure 3.25. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the gummed-film measurements by the AIPC method and by the kriging method for April 29, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the United States with estimated non-zero deposition by the kriging method.

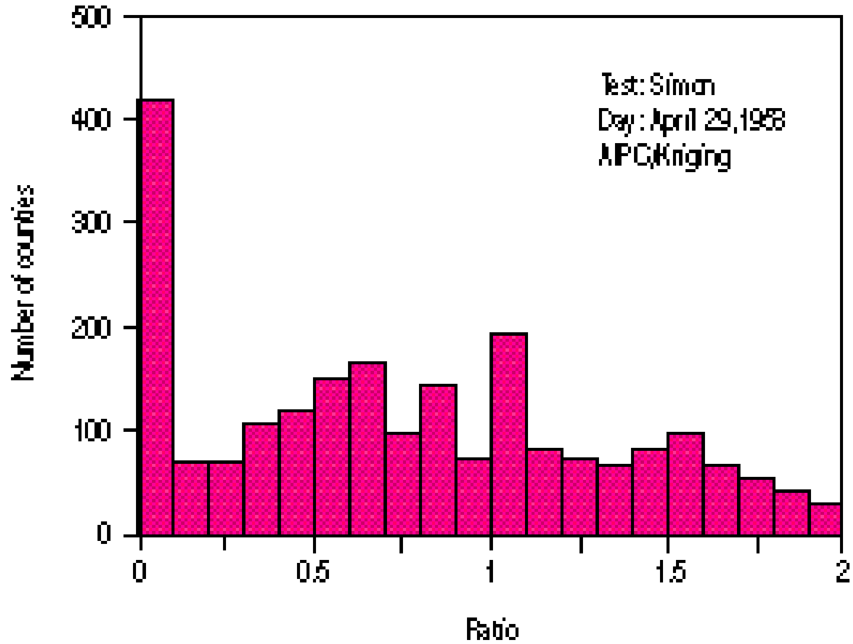


Figure 3.26. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the meteorlogical model and from gummed-film measurements by the kriging method for April 29, 1953 resulting from the test Simon detonated on April 25, 1953 for all counties of the United States with estimated non-zero deposition by the kriging method.

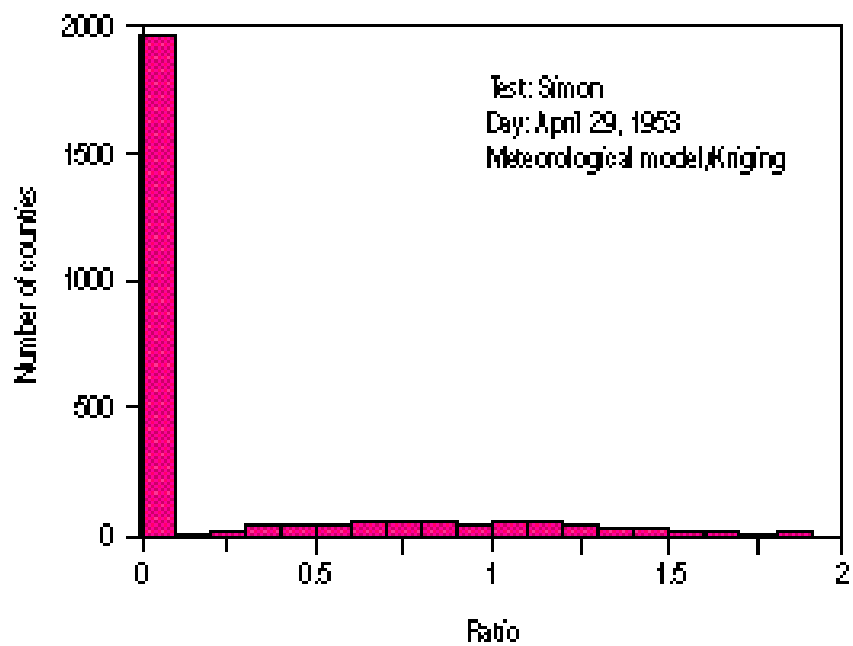


Figure 3.27. Estimates of ^{131}I deposition per unit area of ground derived by the kriging method from the gummed-film measurements for July 8, 1957 following the test Hood detonated on July 5, 1957 for all counties of the contiguous United States.

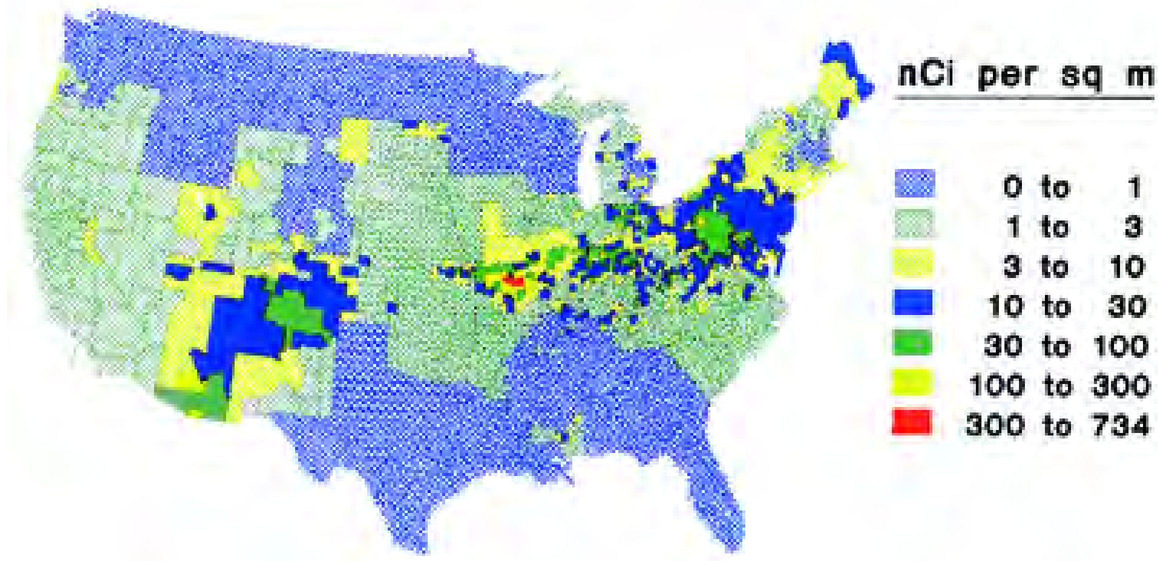


Figure 3.28. Estimates of ^{131}I deposition per unit area of ground derived by the AIPC method from the gummed-film measurements for July 8, 1957 following the test Hood detonated on July 5, 1957 for all counties of the contiguous United States.

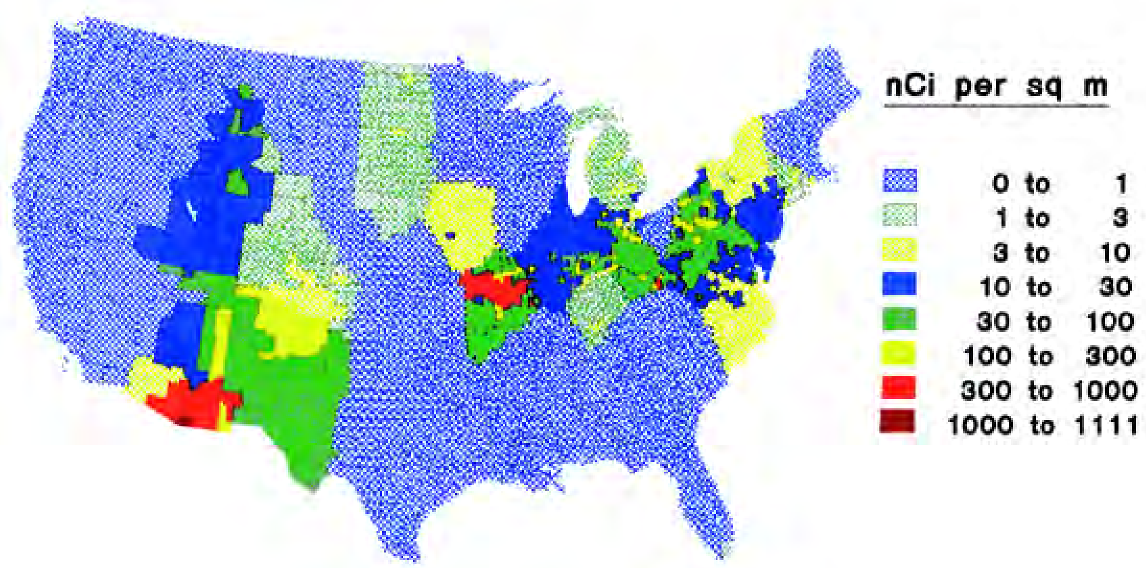
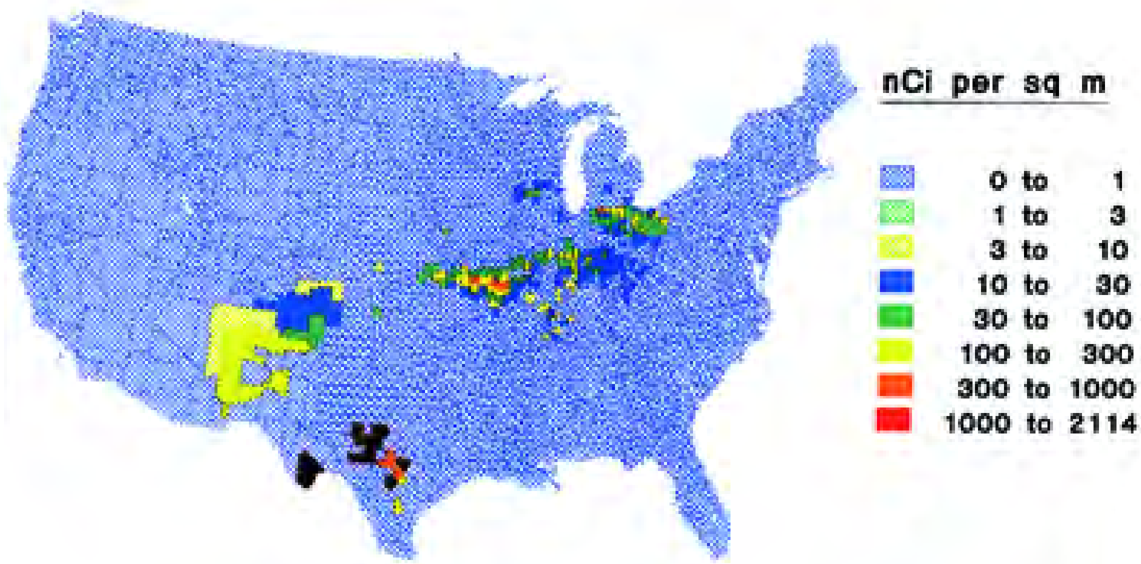


Figure 3.29. Estimates of ^{131}I deposition per unit area of ground obtained using the meteorological transport model on July 8, 1957 following the test Hood detonated on July 5, 1957 for all counties of the contiguous United States, in which precipitation was recorded.



presented in *Figures 3.27, 3.28,* and *3.29,* respectively. *Figures 3.27* and *3.28* are similar and show that both the kriging and the AIPC methods predicted depositions of ^{131}I across the country from the far west to the eastern seaboard; the deposition pattern obtained with the kriging method, however, is more extensive than the one observed with the AIPC method, notably in California, Oregon, Nebraska, Kansas, Oklahoma, and Maine, but the ^{131}I depositions obtained with the kriging method in those States are generally low. The AIPC model predicted some higher depositions in New Mexico and Texas and also over a greater area in west Texas.

In comparison, the deposited area obtained with the meteorological model is limited to a smaller part of the country as the cloud coverage predicted by that model (*Figure 3.30*) is only a diagonal band extending from New Mexico and Texas to Ohio. Some relatively high depositions were predicted for some countries in southwest Texas by the meteorological transport model.

The histogram containing the ratios of the ^{131}I depositions obtained in the same counties using the AIPC and kriging methods (*Figure 3.31*) shows a relatively good agreement between the two methods, with many ratios close to one. In about 700 counties no deposition was predicted by the AIPC method but some deposition was estimated by the kriging method. *Figure 3.32,* comparing the estimates of ^{131}I deposition obtained with the meteorological model and with the kriging method, shows, as was the case for the two other days (**Sections 3.4.2.1** and **3.4.2.2**) for which a similar comparison was made, that the agreement is not as good as between the kriging method and the AIPC method.

3.4.3. Summary

Both the meteorological transport modeling technique and the re-analysis of nationwide historical data have limitations. The calculated position of the radioactive cloud is not always in agreement with the areas of deposition derived from monitoring data, usually because of the simplifying assumptions used to calculate transport and dispersion of the cloud. In particular, measured depositions often occurred over a longer period of time than predicted by the meteorological model. In addition, although the meteorological model has the potential of predicting ^{131}I deposition by wet processes, it can only do so in a crude way for those areas where precipitation occurred during the predicted passage of the radioactive cloud. The meteorological model, however, can be applied to all tests for which there are no historical monitoring data.

The re-analysis of nationwide historical monitoring data, on the other hand, provides the best available estimates of ^{131}I deposition per unit area. However, under the best conditions, measurements were made at only about 100 locations and inter-

polation is needed to estimate deposition at many other places. Finally, nationwide monitoring data have not been reported, or found, for a sizable number of tests. Despite these shortcomings, the deposition estimates based on the analysis of measured environmental radiation data, when available, are thought to be less uncertain than those calculated with the meteorological transport model.

In the near-NTS area, the deposition estimates derived from the vast array of monitoring data processed by ORERP constitutes the preferred method when those monitoring data are available.

The daily depositions of ^{131}I per unit area of ground have been estimated for each of the 3,094 counties and sub-counties of the contiguous United States. In order to estimate the ^{131}I deposition in any given county or sub-county, the following procedure, in which preference is systematically given to the monitoring data, has been applied:

- For the 157 counties or subcounties near the NTS, the deposition densities derived from the exposure rate data bases were adopted without modification when they were available. In the absence of such data, the depositions per unit area were interpolated from the gummed-film results. If no monitoring data were available, the ^{131}I deposition per unit area of ground was calculated using the meteorological model.

- In the remaining 2937 counties, the monitoring data used in this assessment are those of the HASL deposition (gummed-film) network. For those counties, two situations may arise:

  1. if monitoring data for a test are available (for up to about 100 sites), the estimation of the deposition densities at the county centroids was generally obtained by interpolation between the counties with measured data by means of the kriging procedure, using the daily rainfall amounts as a prediction parameter; however, if the gummed-film results are too spotty or very low, the estimation of the deposition density was obtained by using the simple AIPC procedure;

  2. if monitoring data for a test are not available, meteorological modeling was used to estimate deposition densities in the counties where precipitation occurred during the predicted passage of the radioactive cloud. Counties where precipitation did not occur during the predicted passage of the radioactive cloud were assigned a zero deposition.

Figure 3.30. Estimates of ^{131}I contained in the radioactive cloud per unit area of ground derived by the meteorological model for July 8, 1957 resulting from the test Hood detonated on July 5, 1957 for all counties of the contiguous United States.

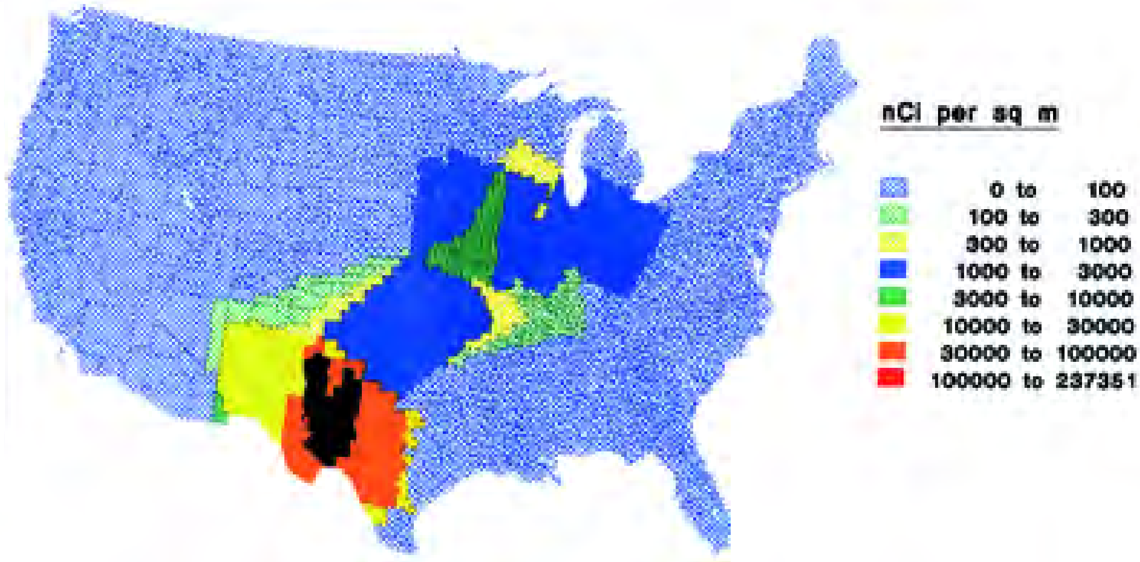


Figure 3.31. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the gummed-film measurements by the AIPC method and by the kriging method for July 8, 1957 following the test Hood detonated on July 5, 1957 for all counties of the United States with estimated non-zero deposition by the kriging method.

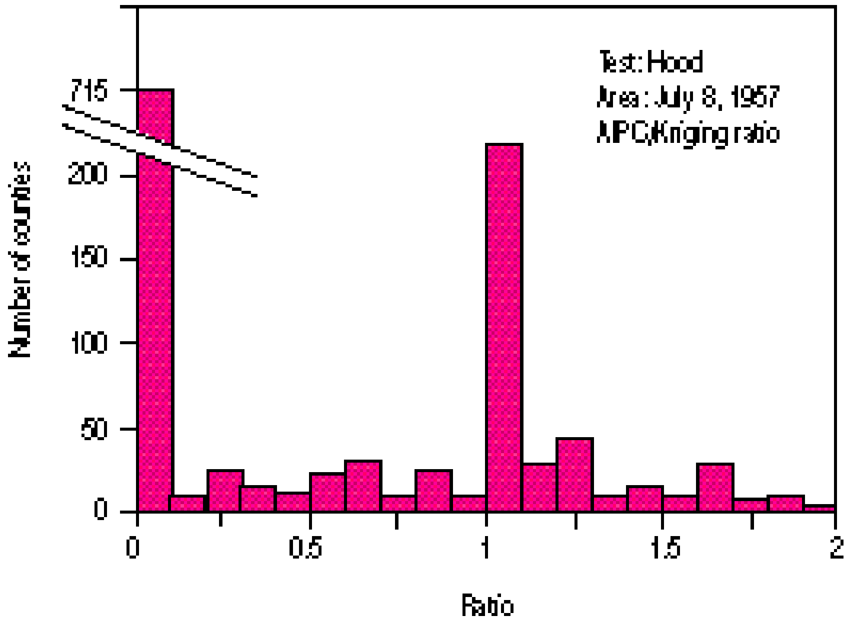
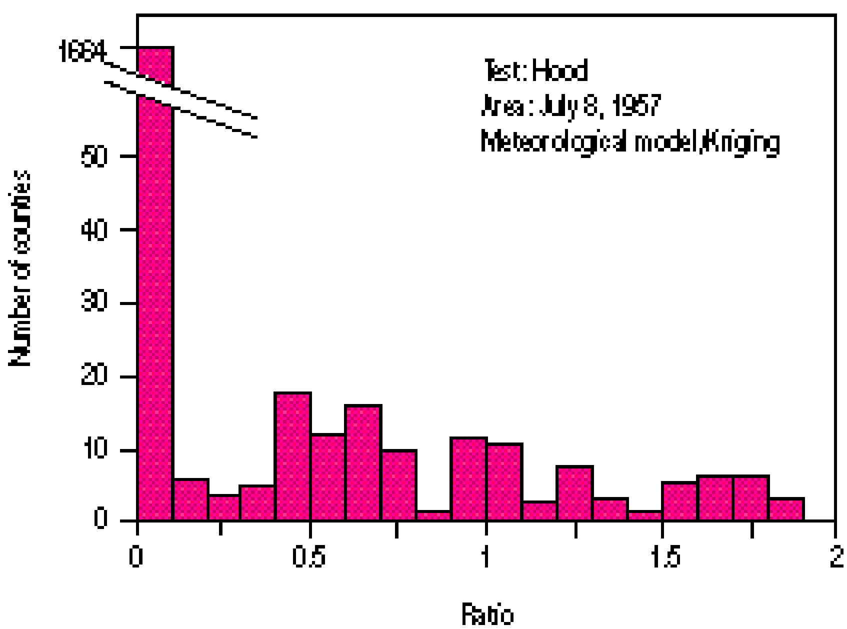


Figure 3.32. Distribution of the ratios of the estimates of ^{131}I deposition per unit area of ground derived from the meteorological transport model and from gummed-film measurements by the kriging method for July 8, 1957 following the test Hood detonated on July 5, 1957 for all counties of the United States with estimated non-zero deposition by the kriging method.



3.5. CLASSIFICATION OF THE NEVADA ATMOSPHERIC BOMB TESTS WITH RESPECT TO THE ESTIMATION OF DAILY ^{131}I DEPOSITIONS PER UNIT AREA OF GROUND

The tests carried out during the atmospheric testing era, from January 1951 through October 1958, are considered separately from those conducted in the underground testing era (1961 to 1992). Tests conducted during these two periods are discussed below.

3.5.1. Atmospheric Testing Era

The number of tests detonated at the NTS before October 31, 1958 was 119. The dates, times, types of test, and yields of these tests are given in *Table 2.1*. Those tests have been classified into 5 categories (*Table 3.9*) on the basis of the availability of monitoring data and the estimated amount of ^{131}I released to the atmosphere.

Category 1 includes the 38 tests which are shown from monitoring data to have led to significant depositions in substantial parts of the country. Most of those tests are tower shots and have yields in excess of 10 kt. The estimated total atmospheric release of ^{131}I from the 38 tests of category 1 amounts to about 100 MCi (about two thirds of the total release). Daily depositions from those tests have been determined by means of the kriging procedure for all counties except those near the NTS. For those counties, daily depositions were inferred from the exposure rates at H+12 and the times of arrival of fallout given for the 157 counties or sub-counties in the County Data Base and/or the Town Data Base provided by the ORERP (Beck and Anspaugh, 1991; Thompson and Hutchinson, 1988).

Category 2 consists of 17 tests for which the available gummed-film data show low and spotty depositions. Most of these tests are airdrop shots detonated at heights above ground in excess of 1000 feet (300 m). The estimated total atmospheric release of ^{131}I from the 17 tests of Category 2 is almost 33 MCi. Daily depositions from those tests for all counties of interest have been determined by means of the AIPC method for all counties except those near the NTS. For those counties, daily depositions were inferred from the exposure rates at H+12 and the times of arrival of fallout given in the County Data Base (Beck and Anspaugh, 1991) and/or the Town Data Base (Thompson and Hutchinson, 1988).

Category 3 includes 15 tests for which non-negligible deposition has been observed only near NTS. The total atmospheric release of ^{131}I from the 15 tests of category 3 is estimated to be about 8 MCi. Daily depositions for those tests were inferred from the exposure rates at H + 12 and the times of arrival of fallout given in the County Data Base (Beck and Anspaugh, 1991) and/or the Town Data Base (Thompson and Hutchinson, 1988).

Category 4 consists of three tests for which monitoring data are not available but which are thought to have possibly led to significant depositions of ^{131}I in the U.S. on the basis of their yield and type. Those tests, which were detonated in the Ranger series in the early part of 1951, have been analyzed using the meteorological model. The estimated total atmospheric release of ^{131}I from the three tests of category 4 amounts to about 6 MCi.

Category 5 consists of the 46 remaining tests that were shown from the measurement of β activity on gummed film to have led to negligible ^{131}I depositions or that are thought to have led to negligible depositions on the basis of their yield (less than 1 kt). The estimated total atmospheric release of ^{131}I from the 46 tests of category 5 is about 2 Mci, slightly more than 1 percent of the total release. Dose assessments have not been carried out for tests in Category 5.

3.5.2. Underground Testing Era

All of the tests performed since 1961, with the exception of Small Boy and of Little Feller I, were detonated underground. A few of these tests resulted in small off-site depositions of ^{131}I due to venting. The gummed-film program had been discontinued in 1960, however, and replaced by the PHS environmental network. The results provided by the PHS network have not been used in this assessment because the ^{131}I depositions due to NTS tests, beyond the local area, were overshadowed by the fallout resulting from much larger tests carried out by the U.S. in the Pacific or by other countries. The only environmental data that can be systematically used for the tests carried out since 1961 are those of the Town and County Data Bases close to the NTS.

The six tests of the underground test era for which dose assessments were carried out by means of the meteorological model are listed in category 6 in *Table 3.10*. They consist of four cratering tests, one low-yield tower test, and one underground test; each of those tests released into the atmosphere an activity of ^{131}I greater than 70 kCi. The total activity of ^{131}I released into the atmosphere by those six tests is about 2 MCi.

Table 3.9. Classification and characteristics of tests of the atmospheric era.

Test name	Date		Type	Atmospheric release of ^{131}I (kCi)	Burst height above ground (m)	Cloud height	
	mo/d/y	hr/min (GMT)				base (km MSL)	top (km MSL)
CATEGORY 1: INTERPOLATION OF GUMMED-FILM DATA BY KRIGING							
CHARLIE	10/30/51	1500	airdrop	2000	345	9.8	12.2
EASY	05/07/52	1215	tower	1800	90	N.A.	10.4
FOX	05/25/52	1200	tower	1600	90	N.A.	12.5
GEORGE	06/01/52	1155	tower	2200	90	N.A.	11.3
HOW	06/05/52	1155	tower	2100	90	N.A.	12.5
ANNIE	03/17/53	1320	tower	2400	90	8.5	12.5
NANCY	03/24/53	^{131}0	tower	3600	90	7.9	12.8
DIXIE	04/06/53	1530	airdrop	1700	1800	10.1	13.1
BADGER	04/18/53	1235	tower	3500	90	7.0	10.7
SIMON	04/25/53	1230	tower	6300	90	9.4	13.7
HARRY	05/19/53	1205	tower	4600	90	8.2	13.1
GRABLE	05/25/53	1530	airburst	2100	160	7.0	11.6
CLIMAX	06/04/53	1115	airdrop	8600	410	10.7	13.1
TESLA	03/01/55	1330	tower	1200	90	5.5	9.1
TURK	03/07/55	1320	tower	6400	150	11.0	13.4
HORNET	03/12/55	1320	tower	620	90	8.2	10.7
APPLE 1(1)	03/29/55	1255	tower	2000	150	6.7	9.8
+ WASP PRIME(1)	03/29/55	1800	airdrop	450	225	N.A.	9.8
POST	04/09/55	1230	tower	340	90	4.0	4.9
MET	04/15/55	1915	tower	3100	120	9.4	12.2
APPLE 2	05/05/55	1210	tower	4100	150	10.4	13.1
ZUCCHINI	05/15/55	1200	tower	4000	150	7.6	10.7
BOLTZMANN(1)	05/28/57	1155	tower	1900	150	7.0	10.1
+ FRANKLIN(1)	06/02/57	1155	tower	19	90	4.3	5.2
+ LASSEN(1)	06/05/57	1145	balloon	0.1	150	N.A.	2.1
WILSON	06/18/57	1145	balloon	1500	150	7.6	10.7
PRISCILLA	06/24/57	1330	balloon	5300	210	7.3	13.1
HOOD	07/05/57	1140	balloon	11000	460	10.7	14.6
DIABLO	07/15/57	1130	tower	2500	150	6.1	9.8
KEPLER(1)	07/24/57	1150	tower	1700	150	6.1	8.5
+ OWENS(1)	07/25/57	1330	balloon	1700	150	6.1	10.7
SHASTA	08/18/57	1200	tower	2500	150	4.9	9.8
GALILEO	09/02/57	1240	tower	1900	150	5.2	11.3
WHEELER	09/06/57	1245	balloon	27	150	4.3	5.2
+ COULOMB B(1)	09/06/57	N.A.	surface	42	N.A.	N.A.	5.5
+ LAPLACE(1)	09/08/57	1300	balloon	140	230	4.3	6.1
WHITNEY	09/23/57	1230	tower	2900	150	5.5	9.1
CHARLESTON	09/28/57	1300	balloon	1800	460	6.1	9.8
Total release (rounded)				100000			

Table 3.9. cont'd

Test name	Date		Type	Atmospheric release of ^{131}I (kCi)	Burst height above ground (m)	Cloud height	
	mo/d/y	hr/min (GMT)				base (km MSL)	top (km MSL)
CATEGORY 2: USE OF THE AIPC METHOD							
BAKER	10/28/51	1520	airdrop	600	340	7.0	8.8
DOG	11/01/51	1530	airdrop	3100	430	8.2	12.2
EASY	11/05/51	1630	airdrop	4500	400	9.4	13.7
SUGAR	11/19/51	1320	surface	170	1	3.4	4.9
ABLE	04/01/52	1700	airdrop	140	240	N.A.	4.9
BAKER	04/15/52	1730	airdrop	140	320	3.0	4.9
CHARLIE	04/22/52	1730	airdrop	4600	1050	9.4	12.8
DOG	05/01/52	1630	airdrop	2900	320	8.5	12.8
RUTH	03/31/53	1300	tower	28	90	3.4	4.3
RAY	04/11/53	1245	tower	28	30	2.4	4.0
ENCORE	05/08/53	1530	airdrop	3900	740	8.8	12.5
BEE(1)	03/22/55	1305	tower	1200	150	8.8	12.2
+ ESS(1)	03/23/55	2030	crater	140	-20	N.A.	3.7
DOPPLER	08/23/57	1240	balloon	1700	460	7.0	11.6
SMOKY	08/31/57	1230	tower	6400	210	6.1	11.6
NEWTON	09/16/57	1250	balloon	2100	460	5.8	9.8
MORGAN	10/07/57	1300	balloon	1200	460	7.9	12.2
Total release (rounded)				33000			
CATEGORY 3: USE OF LOCAL MONITORING ONLY							
UNCLE(2)	11/29/51	1700	crater	170	-5	N.A.	3.4
WASP(2)	02/18/55	2000	airdrop	160	230	4.6	6.7
MOTH(2)	02/22/55	1345	tower	320	90	4.9	7.6
STOKES(2)	08/07/57	1225	balloon	2800	460	8.2	11.3
FRANKLIN P.(2)	08/30/57	1240	balloon	690	230	6.4	9.8
FIZEAU(2)	09/14/57	1645	tower	1700	150	8.2	12.2
EDDY(2)	09/19/58	1400	balloon	12	150	2.3	3.4
HIDALGO(2)	10/05/58	1410	balloon	11	100	2.4	3.7
QUAY(2)	10/10/58	1430	balloon	11	30	2.1	3.0
LEA(2)	10/13/58	1320	balloon	240	460	3.7	5.2
VESTA(2)	10/17/58	2300	surface	4	0	N.A.	3.0
RIO ARRIBA(2)	10/18/58	1425	tower	120	22	3.4	4.1
WRANGELL(2)	10/22/58	1650	balloon	17	460	2.1	3.0
SOCORRO(2)	10/22/58	1330	balloon	1000	440	6.1	7.9
SANFORD(2)	10/26/58	1020	balloon	750	460	3.8	7.9
Total release (rounded)				8000			

Table 3.9. cont'd

Test name	Date		Type	Atmospheric release of ^{131}I (kCi)	Burst height above ground (m)	Cloud height	
	mo/d/y	hr/min (GMT)				base (km MSL)	top (km MSL)
CATEGORY 4: USE OF THE METEOROLOGICAL MODEL							
BAKER	01/28/51	1352	airdrop	1300	330	N.A.	10.7
BAKER-2	02/02/51	1349	airdrop	1300	335	N.A.	11.0
FOX	02/06/51	1347	airdrop	3200	440	N.A.	12.8
Total release (rounded)				5800			
CATEGORY 5: NOT INCLUDED IN THE ASSESSMENT							
ABLE	01/27/51	1345	airdrop	140	320	N.A.	5.2
EASY	02/01/51	1347	airdrop	160	330	N.A.	3.7
ABLE	10/22/51	1400	tower	N.D.	30	2.0	2.4
HA(2)	04/06/55	1800	airdrop	450	11000	N.A.	16.8
PROJECT 56/1	11/01/55	2210	surface	N.P.	0	N.A.	N.A.
PROJECT 56/2	11/03/55	2115	surface	N.P.	0	N.A.	N.A.
PROJECT 56/3	11/05/55	1955	surface	N.P.	0	N.A.	N.A.
PROJECT 56/4	01/18/56	2130	surface	N.P.	0	N.A.	N.A.
COULOMB-A(2)	07/01/57	N.A.	surface	N.D.	0	N.A.	N.A.
JOHN(2)	07/19/57	1400	rocket	250	6100	N.A.	13.4
PASCAL-A(2)	07/26/57	0800	shaft	10	N.A.	N.A.	N.A.
SATURN	08/10/57	N.A.	tunnel	N.D.	N.A.	N.A.	N.A.
PASCAL-B(2)	08/27/57	N.A.	shaft	N.D.	N.A.	N.A.	N.A.
RAINIER	09/19/57	1700	tunnel	N.D.	-240	N.A.	N.A.
PASCAL-C	12/06/57	2015	shaft	N.D.	N.A.	N.A.	N.A.
COULOMB-C(2)	12/09/57	2000	surface	69	N.A.	N.A.	N.A.
VENUS	02/22/58	N.A.	tunnel	N.D.	N.A.	N.A.	N.A.
URANUS	03/14/58	N.A.	tunnel	N.D.	N.A.	N.A.	N.A.
OTERO(2)	09/12/58	2000	shaft	6	-150	N.A.	N.A.
BERNANILLO	09/17/58	1930	shaft	N.D.	-140	N.A.	N.A.
LUNA	09/21/58	1900	shaft	N.D.	-150	N.A.	N.A.
MERCURY	09/23/58	N.A.	tunnel	N.D.	N.A.	N.A.	N.A.
VALENCIA	09/26/58	2000	shaft	N.D.	-150	N.A.	N.A.
MARS	09/28/58	0000	tunnel	N.D.	N.A.	N.A.	N.A.
MORA(2)	09/29/58	1405	balloon	340	460	3.0	5.5
COLFAX	10/05/58	1615	shaft	N.D.	-110	N.A.	N.A.
TAMALPAIS	10/08/58	2200	tunnel	N.D.	-100	N.A.	N.A.
NEPTUNE	10/14/58	1800	tunnel	N.D.	-30	N.A.	N.A.
HAMILTON(2)	10/15/58	1600	tower	0.2	15	1.4	1.8
LOGAN	10/16/58	0600	tunnel	N.D.	-250	N.A.	N.A.
DONA ANA(2)	10/16/58	1420	balloon	6	140	2.0	3.4
SAN JUAN	10/20/58	N.A.	shaft	N.D.	N.A.	N.A.	N.A.
RUSHMORE(2)	10/22/58	2340	balloon	17	150	N.A.	3.4
OBERON	10/22/58	N.A.	tower	N.D.	N.A.	N.A.	N.A.
CATRON(2)	10/24/58	1500	tower	4	22	1.5	2.4
JUNO	10/24/58	1601	surface	N.D.	0	N.A.	1.5
CERES	10/26/58	0400	tower	N.D.	7	N.A.	1.8
DE BACA(2)	10/26/58	1600	balloon	380	460	3.0	5.3

Table 3.9. cont'd

Test name	Date		Type	Atmospheric release of ^{131}I (kCi)	Burst height above ground (m)	Cloud height	
	mo/d/y	hr/min (GMT)				base (km MSL)	top (km MSL)
CATEGORY 5: NOT INCLUDED IN THE ASSESSMENT							
CHAVEZ(2)	10/27/58	1430	tower	0.1	16	N.A.	2.0
EVANS	10/29/58	0000	tunnel	N.D.	-260	N.A.	N.A.
HUMBOLDT(2)	10/29/58	1445	tower	1	7	1.8	2.1
MAZAMA	10/29/58	N.A.	tower	N.D.	N.A.	N.A.	N.A.
SANTA FE(2)	10/30/58	0300	balloon	220	460	4.0	5.5
TITANIA(2)	10/30/58	2034	tower	0.03	7	N.A.	1.8
BLANCA(2)	10/30/58	N.A.	tunnel	0.51	-250	N.A.	N.A.
GANYMEDE	10/30/58	N.A.	surface	N.D.	N.A.	N.A.	N.A.
Total release (rounded)				2100			

(1) these 2 or 3 shots adjacent in time were combined in the analysis because the resulting fallout in most of the country could not be unambiguously attributed to a single shot.
(2) gummed-film data are available but the derived ^{131}I depositions were judged to be negligible.
N.A. = data not available.
N.D. = no off-site detection of radioactive materials; ^{131}I release cannot be estimated but is believed to be quite small.
N.P. = no production of ^{131}I in these "safety shots" because no fission occurred.

There are 11 tests for which the activity of ^{131}I released into the atmosphere was less than 70 kCi but which gave rise to environmental activities detectable by the local monitoring network. They are included in this assessment as Category 7 (see *Table 3.10*). All together, the amount of ^{131}I activity released is about 0.1 MCi.

Table 3.10 also lists, for comparison purposes, the other 25 tests (category 8) that were reported to have released radioactive gases and particles to the atmosphere that resulted in detection off site (U.S. Department of Energy 1988), but that have not been included in the Town Data Base or in the County Data Base. All but one of these tests was underground. Dose assessments have not been carried out for those tests because the ^{131}I atmospheric releases involved were very small (total of 0.004 MCi).

In addition, more than 400 other announced nuclear tests were reported to have resulted in no detection of radioactivity off site (U.S. Department of Energy 1988). Those tests are not listed in *Table 3.10*.

3.5.3. Summary

The nuclear weapons tests that were detonated at the NTS were classified into the following eight categories:

1. Tests detonated during the atmospheric era (1951 to 1958) for which many positive deposition results are available nationwide. The kriging procedure was used throughout the country except for the 157 counties and subcounties near the NTS where the ^{131}I depositions per unit area of ground were derived from the Town and County Data Bases, when available.

2. Tests detonated during the atmospheric era (1951 to 1958) for which only a few positive deposition results are available nationwide. The AIPC procedure was used throughout the country except for the 157 counties and subcounties near the NTS where the ^{131}I depositions per unit area of ground were derived from the Town and County Data Bases, when available.

3. Tests detonated during the atmospheric era (1951 to 1958) for which positive deposition results were obtained only near the NTS. The ^{131}I depositions per unit area of ground were estimated from the Town and County Data Bases monitoring data.

Table 3.10. Classification of tests of the atmospheric era that led to off-site detection of radioactive materials (Hicks 1981b).

Test name	Date		Type	Atmospheric release of ^{131}I (kCi)
	mo/d/y	hr/min (GMT)		
CATEGORY 6: USE OF THE METEOROLOGICAL MODEL				
DANNY BOY	03/05/62	1815	crater	73
SEDAN	07/06/62	1700	crater	880
JOHNIE BOY	07/11/62	1645	crater	70
SMALL BOY	07/14/62	1830	tower	270
PALANQUIN	04/14/65	^{131}4	crater	910
BANEBERRY	12/18/70	1630	shaft	80
Total release (rounded)				2300
CATEGORY 7: USE OF LOCAL MONITORING ONLY				
ANTLER	09/15/61	1600	tunnel	0.0042
PLATTE	04/14/62	1900	tunnel	0.0114
EEL	05/19/62	1700	shaft	0.0114
DES MOINES	06/13/62	2200	tunnel	33
BANDICOOT	10/19/62	1900	shaft	9
PIKE	03/13/64	1702	shaft	0.36
SULKY	12/18/64	1935	crater	13
PIN STRIPE	04/25/66	1938	shaft	0.2
CABRIOLET	01/26/68	1600	crater	6
BUGGY	03/12/68	1704	crater	40
SCHOONER	12/08/68	1600	crater	15
Total release (rounded)				120
CATEGORY 8: NOT INCLUDED IN THE ASSESSMENT				
FEATHER	12/22/61	1730	tunnel	0.00114
PAMPAS	03/01/62	2010	shaft	0.000012
LITTLE FELLER I	07/17/62	1700	surface	3
YUBA	06/05/63	1800	tunnel	0.000022
EAGLE	12/12/63	1702	shaft	0.00228
ALVA	08/19/64	1700	shaft	0.000037
DRILL	12/05/64	2215	shaft	0.0122
PARROT	12/16/64	2100	shaft	0.0046
ALPACA	02/12/65	1610	shaft	0.000024
TEE	05/07/65	1647	shaft	0.0016
DILUTED WATERS	06/16/65	1730	shaft	0.0177
RED HOT	03/05/66	1915	tunnel	0.2
DOUBLE PLAY	06/15/66	1800	tunnel	0.12
DERRINGER	09/12/66	1630	shaft	0.00024
NASH	01/19/67	1745	shaft	0.0138
MIDI MIST	06/26/67	1700	tunnel	0.00026

Table 3.10. cont'd

Test name	Date		Type	Atmospheric release of ^{131}I (kCi)
	mo/d/y	hr/min (GMT)		
CATEGORY 8: NOT INCLUDED IN THE ASSESSMENT				
UMBER	06/29/67	1225	shaft	0.00052
DOOR MIST	08/31/67	1730	tunnel	0.008
HUPMOBILE	01/18/68	1730	shaft	0.12
POD	10/29/69	2100	shaft	0.000078
SCUTTLE	11/13/69	1515	shaft	0.000004
SNUBBER	04/21/70	1530	shaft	0.0055
MINT LEAF	05/05/70	1630	tunnel	0.08
DIAGONAL LINE	11/24/71	2015	shaft	0.00136
RIOLA	09/25/80	0826	shaft	0.00058
Total release (rounded)				4

4. Tests detonated during the atmospheric era (1951 to 1958) for which no environmental radiation data are available but which were thought to have resulted in substantial ^{131}I depositions per unit area of ground on the basis of their yield and type. The meteorological model was used throughout the country.

5. Tests detonated during the atmospheric era (1951 to 1958) for which no environmental radiation data are available and which, on the basis of their yield and type, were thought to have led to negligible ^{131}I depositions per unit area of ground. Deposition estimates are not provided for these tests.

6. Tests detonated during the underground era (1961 to date) for which positive deposition results were available near the NTS and for which the estimated activity release of ^{131}I into the atmosphere per test was greater than 70 kCi. The estimates of ^{131}I depositions per unit area of ground in the 157 counties and subcounties near the NTS were estimated from the Town and County Data Bases monitoring data. The meteorological model was used in the remainder of the country.

7. Tests detonated during the underground era (1961 to date) for which positive deposition results were available near the NTS and for which the individual estimated activity release of ^{131}I into the atmosphere was less than 70 kCi. The estimates of ^{131}I depositions per unit area of ground in the 157 counties and subcounties near the NTS were estimated from the Town and County Data Bases monitoring data. Deposition estimates are not provided for the remainder of the country.

8. Tests detonated during the underground era (1961 to date) for which no environmental radiation data are available and for which the estimated individual activity release of ^{131}I into the atmosphere was less than 70 kCi. Deposition estimates are not provided for these tests.

The distribution of the total atmospheric releases of ^{131}I as a function of the test category is presented as a histogram in *Figure 3.33*. This Figure shows that deposition estimates are calculated for all counties of the contiguous United States for the tests which represent the bulk of the ^{131}I activity released into the atmosphere (Categories 1, 2, and 4). Deposition estimates are only calculated for the 157 counties and sub-counties near the NTS for tests of category 3, which represent a small percentage of the total activity of ^{131}I that was released into the atmosphere. The tests for which no estimates of deposition are provided in this report (categories 5 and 8) represent a very small percentage of the total activity of ^{131}I that was released into the atmosphere.

Figure 3.33. Total atmospheric release of I-131 (MCi) according to test category.

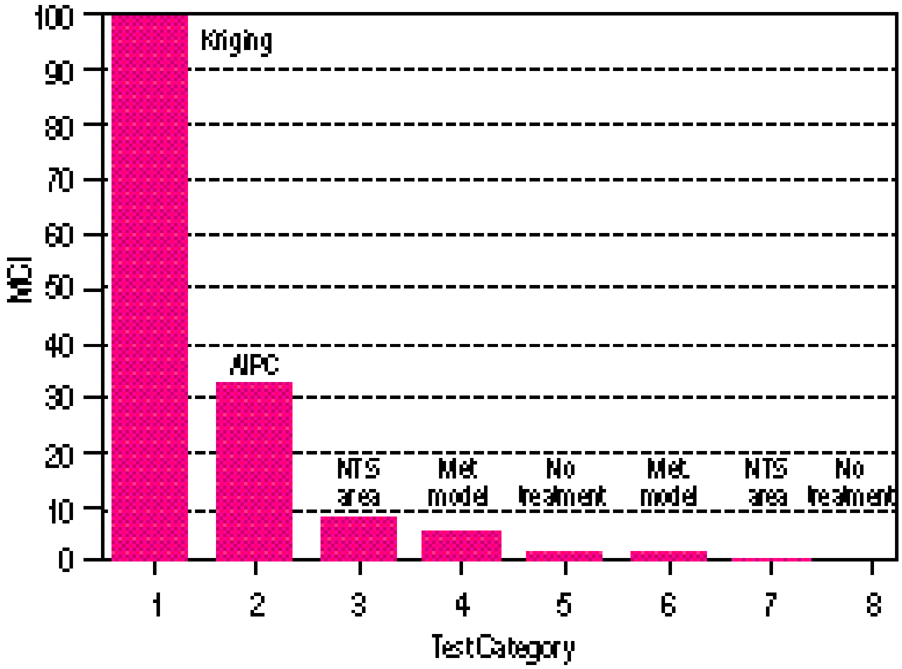
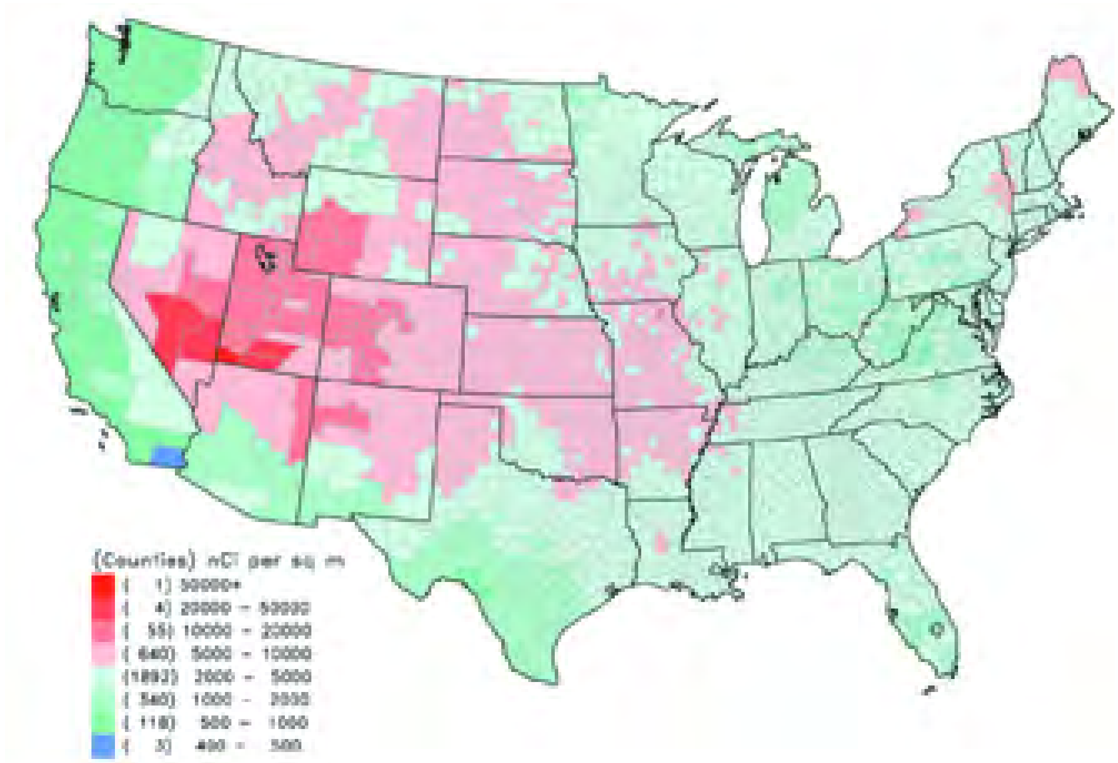


Figure 3.34. Activities of I-131 deposited per unit area of ground: All tests



3.6. ESTIMATES OF ^{131}I DEPOSITION PER UNIT AREA OF GROUND

Daily deposition densities of ^{131}I have been calculated for the 90 tests for which dose assessments have been carried out. The complete results, day by day and county by county for all shots, are presented in the Sub-annexes. This information (daily ^{131}I depositions per unit area of ground together with corresponding precipitation indices) constitutes the primary computer database from which all dose estimates were derived. The total ^{131}I depositions for each test, each test series, and each county are presented in the form of maps in the Annexes.

For illustrative purposes, *Figure 3.34* presents the distribution of the total ^{131}I depositions per unit area of ground, summed over all 90 tests, for all counties of the contiguous United States. The thyroid doses, however, are not directly proportional to the total ^{131}I depositions as intervening factors, such as interception by vegetation or presence of cows on pasture, need to be taken into account.

A summary of the estimates of ^{131}I deposited on the ground in the areas covered by the Town and County Data Bases as well as in the 48 contiguous states is presented in *Table 3.11*. In this summary, deposition estimates for some tests have been combined. This is indicated by one or more "+" in the second column. For example, "Wheeler++" in the Plumbob series includes fallout from the Wheeler, Coulomb B, and LaPlace tests (see *Table 3.9*). The test that is estimated to have led to the greatest amount of ^{131}I deposition in the U.S. is test Harry detonated on 19 May 1953. The total activity of ^{131}I that is estimated to have been deposited on the ground as a result of the tests conducted at the NTS amounts to about 25 % of the total activity of ^{131}I released into the atmosphere.

3.7. SUMMARY

- Best estimates of activities of ^{131}I deposited per unit area of ground (also called depositions or deposition densities) have been produced for 90 shots, out of a total of 115 shots that are reported to have released radioactive gases or ^{131}I to the atmosphere resulting in detection off-site. These 90 shots account for almost 99% of the total activity of ^{131}I that is estimated to have been released into the atmosphere by all shots conducted at the Nevada Test Site.

- For each of these 90 shots, median values of the activities of ^{131}I deposited per unit area of ground have been estimated for the 3,071 counties of the contiguous United States.

- Because of the heterogeneous character of the deposition field in the vicinity of the Nevada Test Site, 14 of the counties located in that area were subdivided into a total of 37 sub-counties; average values of the activities of ^{131}I deposited per unit area of ground have also been estimated for those 37 sub-counties.

- Historical environmental radiation measurements were used whenever possible to derive the best estimates of activities of ^{131}I deposited per unit area of ground. These historical environmental radiation measurements consist essentially of exposure-rate measurements near the Nevada Test Site and of measurements of the total beta activity deposited on stickysurfaces (gummed film) at 40-95 locations in the remainder of the country. Historical environmental radiation data were used for 81 of the shots that were analyzed.

- In the absence of historical environmental radiation data, a meteorological transport model was applied for 9 of the shots that were analyzed.

- The best estimates of the total activities of ^{131}I deposited per unit area of ground vary from county to county by four orders of magnitude. They are highest in the counties of Nevada and Utah that were downwind of the Nevada Test Site during the most important shots and lowest in the northwestern part of the country which was generally upwind of the Nevada Test Site. Some high depositions were obtained in the eastern part of the country where rainfall coincided with the passage of the radioactive cloud.

- The uncertainties attached to the deposition values are expressed in terms of geometric standard deviations, GSDs, around the best estimates. These GSDs, which vary according to a number of parameters (existence or non-existence of historical environmental radiation data in the county, type and quality of the data, method used to derive the deposition estimate in the absence of historical environmental radiation data, etc.), range from 1.5 to about 10 and are usually around 2 to 3.

Table 3.11. Estimates of activities of ^{131}I deposited on the ground in the areas covered by the Town and County Data Base and in the contiguous U.S.

Test I.D.	Name	Date	Type	^{131}I release (kCi)	^{131}I activities deposited (kCi)		
					TDB	CDB	U.S.
RA.1	BAKER	01/28/51	A[a]	1300	0	0	160
RA.2	BAKER-2	02/02/51	A	1300	0	0	36
RA.3	FOX	02/06/51	A	3200	0	0	1
BJ.1	BAKER	10/28/51	A	600	0	0	16
BJ.2	CHARLIE	10/30/51	A	2000	0	10	548
BJ.3	DOG	11/01/51	A	3100	0.3	0	132
BJ.4	EASY	11/05/51	A	4500	0	0	14
BJ.5	SUGAR	11/19/51	S[b]	170	29	125	242
BJ.6	UNCLE	11/29/51	C[c]	170	24	19	43
TS.1	ABLE	04/01/52	A	140	0	18	175
TS.2	BAKER	04/15/52	A	140	0	91	112
TS.3	CHARLIE	04/22/52	A	4600	0	35	228
TS.4	DOG	05/01/52	A	2900	0	20	58
TS.5	EASY	05/07/52	T[d]	1800	52	691	1269
TS.6	FOX	05/25/52	T	1600	112	431	1323
TS.7	GEORGE	06/01/52	T	2200	28	499	2843
TS.8	HOW	06/05/52	T	2100	54	451	2425
UK.1	ANNIE	03/17/53	T	2400	69	71	472
UK.2	NANCY	03/24/53	T	3600	72	590	1474
UK.3	RUTH	03/31/53	T	28	0	33	33
UK.4	DIXIE	04/06/53	A	1700	0	0	60
UK.5	RAY	04/11/53	T	28	0.02	36	70
UK.6	BADGER	04/18/53	T	3500	42	411	717
UK.7	SIMON	04/25/53	T	6300	115	1165	3233
UK.8	ENCORE	05/08/53	A	3900	0	0	171
UK.9	HARRY	05/19/53	T	4600	564	1612	3881
UK.10	GRABLE	05/25/53	A	2100	4	85	396
UK.11	CLIMAX	06/04/53	A	8600	5	98	233
TP.1	WASP	02/18/55	T	160	0	75	75
TP.2	MOTH	02/22/55	T	320	14	0	14
TP.3	TESLA	03/01/55	T	1200	28	45	164
TP.4	TURK	03/07/55	T	6400	82	314	920
TP.5	HORNET	03/12/55	T	620	14	91	287
TP.6	BEE + ESS	03/22/55	T	1300	8	41	121
TP.7	APPLE 1 +	03/29/55	T	2500	8	157	531
TP.8	POST	04/09/55	T	340	6	97	232
TP.9	MET	04/15/55	T	3100	107	279	747
TP.10	APPLE 2	05/05/55	T	4100	70	417	1787
TP.11	ZUCCHINI	05/15/55	T	4000	30	314	1132
PB.1	BOLTZMANN ++	05/28/57	T	1900	287	374	976
PB.2	WILSON	06/18/57	B[e]	1500	5	34	528
PB.3	PRISCILLA	06/24/57	B	5300	13	90	545
PB.4	HOOD	07/05/57	B	11000	2	194	821
PB.5	DIABLO	07/15/57	T	2500	141	139	1048

Table 3.11. cont'd

Test I.D.	Name	Date	Type	^{131}I Release (kCi)	^{131}I Activities deposited (kCi)		
					TDB	CDB	U.S.
PB.6	KEPLER +	07/24/57	T	3400	44	197	1020
PB.7	STOKES	08/07/57	B	2800	0	0	0
PB.8	SHASTA	08/18/57	T	2500	54	222	1073
PB.9	DOPPLER	08/23/57	B	1700	0.7	86	701
PB.10	FRANKLIN P.	08/30/57	B	690	0	0	0
PB.11	SMOKY	08/31/57	T	6400	115	660	1050
PB.12	GALILEO	09/02/57	T	1900	21	92	1014
PB.13	WHEELER ++	09/06/57	B	210	1	86	700
PB.14	FIZEAU	09/14/57	T	1700	4	25	89
PB.15	NEWTON	09/16/57	B	2100	0.4	30	258
PB.16	WHITNEY	09/23/57	T	2900	28	106	459
PB.17	CHARLESTON	09/28/57	B	1800	0	122	551
PB.18	MORGAN	10/07/57	B	1200	1	23	314
HT.1	EDDY	09/19/58	B	12	0.1	0	0.1
HT.2	HIDALGO	10/05/58	B	11	0.3	0	0.3
HT.3	QUAY	10/10/58	B	11	1	0	1
HT.4	LEA	10/13/58	B	240	1	0	1
HT.5	VESTA	10/17/58	S	4	0.007	0	0.007
HT.6	RIO ARRIBA	10/18/58	T	120	1	0	1
HT.7	SOCORRO	10/22/58	B	1000	0.2	0	0.2
HT.8	WRANGELL	10/22/58	B	17	0.02	0	0.02
HT.9	SANFORD	10/26/58	B	750	0.5	0	0.5
UE.1	ANTLER	09/15/61	U[f]	0.004	0.09	0	0.09
UE.2	DANNY BOY	03/05/62	C	73	0.1	0	76
UE.3	PLATTE	04/14/62	U	0.011	0.2	0	0.2
UE.4	EEL	05/19/62	U	0.011	0.02	0.02	0.02
UE.5	DES MOINES	06/13/62	U	33	9	0	9
UE.6	SEDAN	07/06/62	C	880	9	10	41
UE.7	JOHNIE BOY	07/11/62	C	70	2	0	89
UE.8	SMALL BOY	07/14/62	T	270	7	34	108
UE.9	BANDICOOT	10/19/62	U	9	3	0	3
UE.10	PIKE	03/13/64	U	0.4	0.06	0	0.06
UE.11	SULKY	12/18/64	U	13	0.02	0	0.02
UE.12	PALANQUIN	04/14/65	C	910	2	0	2030
UE.13	PIN STRIPE	04/25/66	U	0.2	1	8	9
UE.14	CABRIOLET	01/26/68	C	6	0.2	0	0.2
UE.15	BUGGY	03/12/68	C	40	0.05	0	0.05
UE.16	SCHOONER	12/08/68	C	15	0.4	0.7	1
UE.17	BANEBERRY	12/18/70	U	80	3	2	81
Totals (kCi)				149000	2320	10900	40100

[a] Airdrop [d] Tower
[b] Surface [e] Balloon
[c] Crater [f] Underground

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Chapter 4

Transfer of ^{131}I from Deposition on the Ground to Fresh Cows' Milk

Contents: The parameters used to estimate the transfer of ^{131}I from deposition on the ground to fresh cows' milk via the ingestion of ^{131}I - contaminated pasture, the primary transfer route, are presented and discussed. The importance of all other exposure routes by which cows might be exposed to ^{131}I (ingestion of soil, water, and hay directly contaminated with ^{131}I, ingestion of vegetation contaminated with ^{131}I re-suspended from soil, and inhalation of ^{131}I in the air) is assessed relative to the pasture-cow-milk exposure route. The total time-integrated ^{131}I concentrations in fresh cows' milk from all tests are estimated and illustrated.

The transfer of ^{131}I from deposition on the ground to fresh cows' milk is well documented (e.g., Bergstrom 1967; Black et al. 1976; Dunster et al. 1958; Eisenbud and Wrenn 1963; Garner 1967; Kirchner et al. 1983; Knapp 1963; Ng et al. 1977; Stevens et al. 1992; Till and Meyer 1983; Whicker and Kirchner 1987). The environmental transfer processes resulting in the contamination of fresh cows' milk that usually are considered include: (a) ingestion of ^{131}I contaminated pasture, (b) ingestion of vegetation contaminated with ^{131}I resuspended from soil, (c) ingestion of ^{131}I contaminated soil, (d) ingestion of ^{131}I contaminated water, (e) ingestion of ^{131}I contaminated hay, and (f) inhalation of ^{131}I in the air. The largest contribution to the ^{131}I concentration in fresh cows' milk is usually due to the ingestion of ^{131}I contaminated pasture; this transfer process, often called the "pasture-cow-milk" exposure route, is considered separately.

In the remainder of the report:

- the ground is assumed to consist of soil and pasture grass;
- "fresh cows' milk" and "milk fresh from cow" mean milk collected directly from the cow.

4.1. ESTIMATION OF THE ^{131}I CONCENTRATIONS IN FRESH COWS' MILK RESULTING FROM THE CONSUMPTION OF ^{131}I CONTAMINATED PASTURE

The mechanisms involved in the estimation of the ^{131}I concentrations in fresh cows' milk resulting from the consumption of ^{131}I contaminated pasture are: (a) the interception by pasture grass of the ^{131}I activity that is deposited on the ground, (b) the retention of ^{131}I by pasture grass over a certain time period, (c) the consumption of ^{131}I contaminated pasture by the cow, and (d) the secretion of ^{131}I in the milk. *Figure 4.1* illustrates those mechanisms.

Following a single deposition of ^{131}I on pasture grass, the ^{131}I concentration in fresh cows' milk produced by cows assumed to consume pasture grass in a continuous manner at the same rate reaches a maximum a few hours after the time of deposition of ^{131}I on the ground and thereafter decreases by a factor of two about every five days. The total impact of the contamination of milk with ^{131}I is obtained by summing over time the ^{131}I concentrations in milk until the ^{131}I has decayed completely. The result, called the time-integrated concentration of ^{131}I in milk, is the quantity of interest in this report. The time-integrated concentration of ^{131}I in fresh cows' milk, IMC_p, result-

ing from the consumption of ^{131}I-contaminated pasture (p) in county, i, following deposition of ^{131}I on the ground on day, j, can be expressed as:

$$IMC_p\,(i,j) = \int_0^{\infty} C_p(i,j,t) \times PI(i,j,t) \times f_m \times dt \qquad (4.1)$$

where:

$C_p(i,j,t)$ = average concentration of ^{131}I in pasture grass in county, i, at time, t, after deposition on day, j [nCi kg^{-1} (dry mass)],

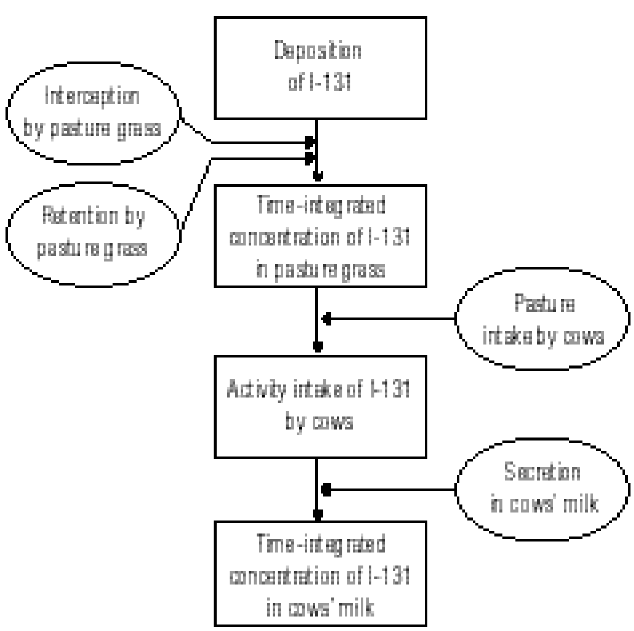
$PI(i,j,t)$ = average amount of pasture consumed daily by the cow (hereafter called pasture intake) in county, i, at time, t, after deposition on day, j [kg (dry mass) d^{-1}],

f_m = average coefficient relating the amount of ^{131}I consumed by the cow per unit of time to the concentration of ^{131}I in milk obtained from the cow under equilibrium conditions (hereafter called intake-to-milk transfer coefficient of ^{131}I in cows and expressed in units of d L^{-1}), and

$IMC_p(i,j)$ = expressed in nCi d L^{-1}.

The mechanisms involved in the pasture-cow-milk exposure route will be discussed in turn.

Figure 4.1. Transfer of I-131 from deposition to fresh cows' milk via the pasture-cow-milk exposure route.



4.1.1. Interception of ^{131}I by Pasture Grass

As illustrated in *Figure 4.2*, the activity of ^{131}I which is deposited per unit area of ground, DG(i,j), is distributed, in vegetated areas, between the activity that is intercepted by vegetation, $A_p(i,j,0)$, and the activity that is deposited on the soil, $A_{sl}(i,j,0)$:

$$DG(i,j) = A_p\,(i,j,0) + A_{sl}\,(i,j,0) \qquad (4.2)$$

The fraction of ^{131}I activity deposited on the ground which is intercepted by vegetation during the time of deposition is called the interception factor, F(i,j):

$$F\,(i,j) = \frac{A_p\,(i,j,0)}{DG\,(i,j)} \qquad (4.3)$$

The value of the interception factor depends, among other factors, on the meteorological conditions, on the type of vegetation, and on the standing crop biomass (mass of vegetation above ground per unit area of ground). Values of interception factors obtained in laboratory or field experiments conducted under dry conditions or using a light water spray (equivalent to very light rain) spiked with radionuclides show a large range of variation between 0.02 and 0.82 (Miller 1980). However, the mass interception factor, F*, defined as the interception factor, F, divided by the standing crop biomass, Y, shows usually a much narrower range of 1 to 4 m^2 kg^{-1} (dry mass) (Miller 1980), and it is the quantity that is usually determined:

$$F^*\,(i,j) = \frac{F\,(i,j)}{Y} \qquad (4.4)$$

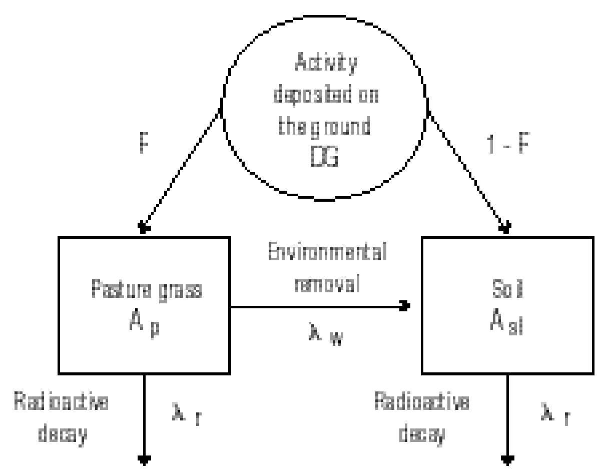
From *equations 4.4 and 4.3*:

$$F^*\,(i,j) = \frac{A_p\,(i,j,0)}{Y \times DG\,(i,j)} = \frac{C_p\,(i,j,0)}{DG\,(i,j)} \qquad (4.5)$$

where:

$C_p(i,j,0)$ represents the concentration (nCi kg^{-1}) of ^{131}I on pasture grass immediately after deposition on day, j.

Figure 4.2. Schematic representation of the distribution of the activity of I-131 deposited on the ground.



The estimation of the mass interception factor is carried out differently according to whether ^{131}I is deposited under dry conditions or as a result of precipitation. To avoid ambiguities, the mass interception factor is denoted, in this section, as F^*_{dry} when ^{131}I is deposited under dry conditions and as F^*_{wet} when ^{131}I is deposited under wet conditions. Also, the indices i and j are not used explicitly to simplify presentation of the equations.

In the remainder of the report, "deposition on the ground" is usually shortened to "deposition" unless further clarification is needed.

4.1.1.1. Estimation of the mass interception factor of ^{131}I by vegetation under dry conditions

On the basis of experiments carried out under dry or light spray conditions, Chamberlain (1970) proposed that F_{dry} and Y can be related by means of the following equation:

$$F_{dry} = 1 - e^{-\alpha Y} \qquad (4.6)$$

where:

F_{dry} = interception factor,

α = the foliar interception constant for elemental iodine and for particles up to 30 µm in diameter, and

Y = standing crop biomass (kg (dry mass) m^{-2}).

From *equation 4.6*, the mass interception factor under dry conditions can be estimated according to *equation 4.7:*

$$F^*_{dry} = \frac{F_{dry}}{Y} = \frac{1 - e^{-\alpha Y}}{Y} \qquad (4.7)$$

This factor, therefore, is influenced by the standing crop biomass, Y, and by the foliar interception constant, α. Although α is called a constant, it will be shown in **Section 4.1.1.2** that in fact it depends on several parameters, including the particle size of the material intercepted by vegetation.

4.1.1.1.1. Influence of the standing crop biomass on the mass interception factor

The value of the standing crop biomass varies, among other factors, with the stage of the growing season and with the type of vegetation. For economic reasons, however, dairy cows are not expected to be put on pasture until the standing crop biomass of the grass is relatively high, thus resulting in a relative uniformity of the standing crop biomass consumed by dairy cows throughout the year and the country.

Baes and Orton (1979), on the basis of a compilation of more than 500 values of standing crop biomasses for forage grasses at harvest time, found a log-normal distribution with a median value of 0.3 kg m^{-2} (dry mass) and a geometric standard deviation of 1.8. Koranda (1965), using data from the U.S. Department of Agriculture, reported average forage crop yields for the U.S. of 0.20 kg m^{-2} for wild hay, 0.26 kg m^{-2} for lespedeza (a legume used for hay in southern states), 0.34 kg m^{-2} for clover and clover-grass mixtures, 0.28 kg m^{-2} for grain hay, 0.29 kg m^{-2} for other hay, 0.40 kg m^{-2} for sorghum forage, and 0.53 kg m^{-2} for alfalfa and alfalfa-grass mixtures. These values are in fairly good agreement with the results obtained by Baes and Orton (1979), which are used in this report for calculation purposes and are assumed to apply to any county of the contiguous United States. It can be shown (*Figure 4.3*) that the mass interception factor is not sensitive to the value of the standing crop biomass for a large range of values of the foliar interception constant. The foliar interception constant, whose value has a greater effect on F*, is discussed next.

4.1.1.1.2. Influence of the foliar interception constant on the mass interception factor

The foliar interception constant is an empirical parameter that includes the influence on the mass interception factor of all factors other than the standing crop biomass (e.g., meteorological conditions, physical and chemical form of ^{131}I, type of vegetation, etc.).

There is evidence that the value of the foliar interception constant, α, decreases as the particle size increases (Anspaugh et al. 1986; Romney et al. 1963; Whicker and Kirchner 1987) and, therefore, that the mass interception factor decreases as the particle size increases. In the case of atmospheric nuclear weapons tests, large-size particles (more than 100 µm in diameter) fall out near the detonation site and smaller particles are deposited as the radioactive cloud moves further away. Simon (1990), on the basis of limited measurements carried out near the NTS, estimated that the variation of the foliar interception constant $\alpha(X)$ for pasture grass, expressed in $m^2\ kg^{-1}$ (dry mass), as a function of the distance, X, from the NTS, expressed in km, can, in the absence of precipitation, be calculated as:

$$\alpha(X) = (7.0 \times 10^{-4}) \times (X^{1.13}) \qquad (4.8)$$

Based upon this equation, the value of $\alpha(X)$ increases with distance from the NTS and is equal to 2.8 $m^2\ kg^{-1}$ (dry mass) for X = 1,540 km (*Figure 4.4*). Beyond that distance, the value of $\alpha(X)$ is taken to remain constant at 2.8 $m^2\ kg^{-1}$ in order to remain consistent with the value proposed by Chamberlain (1970) for elemental iodine and small-sized aerosols (see **Section 4.1.1.1**). The variation of F^*_{dry} as a function of distance can then be calculated:

$$F^*_{dry}(X) = \frac{1 - e^{-\alpha(X)\,Y}}{Y} \qquad (4.9)$$

and is also presented in *Figure 4.4*, using a value of 0.3 kg m^{-2}

Figure 4.3. Variation of the mass interception factor F^*_{dry} as a function of the standing crop biomass Y for several values of the foliar interception constant α expressed in $m^2\ kg^{-1}$ (dry mass).

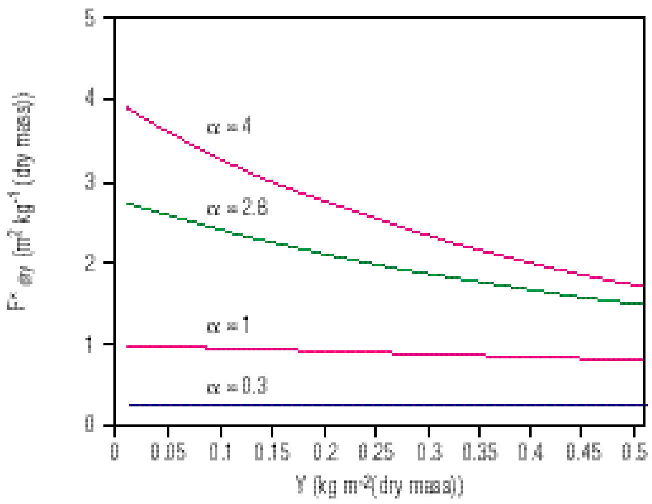
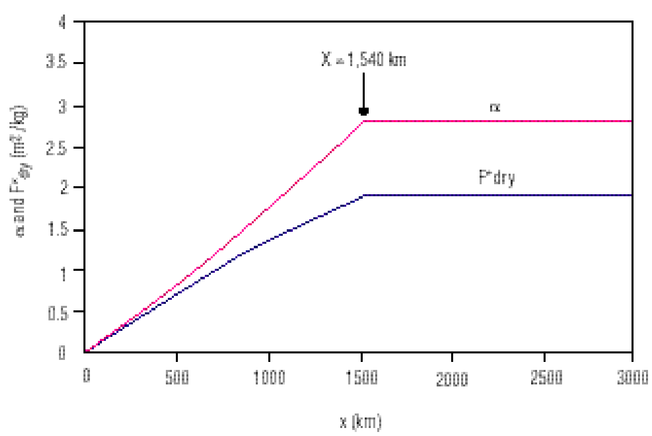


Figure 4.4. Variation of the foliar interception constant α and of the mass interception factor F^*_{dry} under dry meteorological conditions as a function of distance X from the NTS for Y = 0.3 kg m^{-2} (dry weight).



(dry mass) for Y.

Simon (1990) estimated that the GSDs attached to the values of α for distances from the NTS between 130 and 420 km are about 1.8. It is assumed that this value applies for any distance less than 1540 km from the NTS. For distances greater than 1540 km, the GSD for α, based upon the review of Chamberlain (1970), is estimated to be 1.3. Using the distribution of Y (median=0.3 kg m^{-2}, GSD=1.8) found by Baes and Orton (1979), it is found that the values of $F_{*dry}(X)$ can be relatively well approximated by lognormal distributions with GSDs of 1.5 for X smaller than 1540 km and of 1.2 for X greater than 1540 km.

4.1.1.2. Estimation of the mass interception factor of ^{131}I by vegetation in the presence of precipitation

As indicated in **Section 4.1.1**, most of the laboratory and field experiments investigating interception factors were conducted under dry or light spray conditions (Miller 1980) and do not, therefore, provide any information on the values to be expected in moderate or heavy rainfalls. In a limited number of cases, however, ^{131}I was measured in rain and vegetation after atmospheric nuclear weapons tests. The interception factor values derived from those measurements show a large range of variation, from less than 0.09 to about 0.9, with a high scatter for any given rainfall level, but with a tendency to decrease as the rainfall amount increases (Anspaugh 1987; Voillequé 1986 (included as **Appendix 8**)). By adapting an expression originally developed by Horton (1919) for the initial retention of rainwater by vegetation, Voillequúe (1986) proposed that the variation of the mass interception factor as a function of the rainfall amount (mm), denoted as F^*_{wet} and expressed in m^2 per kg (dry mass) of vegetation, can be estimated:

$$F^*_{wet} = EF + \frac{RS}{R} = 1.3 + \frac{16}{R} \qquad (4.10)$$

where:

EF is a constant equal to 1.3 $m^2\ kg^{-1}$ (dry mass),

RS is a constant equal to 16 mm kg^{-1} (dry mass) m^{-2}, and

R is the rainfall amount (mm or L m^{-2}).

In this expression, which describes in mathematical form Horton's model modified by Voillequé (1986), the mass interception factor for wet deposition, F^*_{wet}, is inversely related to the rainfall amount. The values of EF and of RS were obtained by fitting *equation 4.10* to available values of F^*_{wet} for fallout and the assorted precipitation data.

Because of the importance of the mass interception factor in the assessment of the ^{131}I exposures, and because of the limited amount of information on its value under conditions of moderate or heavy rainfall, a research program was designed to investigate the dependence of the mass interception factor on: (a) the physico-chemical form of the radionuclide, (b) the rainfall amount and intensity, and (c) the type and height of vegetation (Hoffman et al. 1989). Field experiments were conducted in which two mechanical rain simulators were used to study the interception by vegetation of radionuclides contained in rain. Rain simulator No. 1 had been designed to deliver rain at rates typical of moderate intensity storms (1 to 4 cm h^{-1}), while rain simulator No. 2 had been designed to reproduce rates common to very high intensity storms (4 to 12 cm h^{-1}). The simulated rain contained three radionuclides (^{141}Ce, ^{95}Nb, and ^{85}Sr) in three size classes (3, 9, and 25 μm, respectively) of insoluble polystyrene microspheres. The microspheres had been annealed at over 400 $^{\circ}C$ to seal the radionuclides inside (Hoffman et al. 1989). The deposition of those insoluble microspheres was taken to be representative of the deposition of ^{131}I attached to particles resulting from NTS tests. Also, the deposition of ^{131}I in

soluble form was simulated by adding ^{131}I to the solution as either iodide or periodate. These materials were applied in simulated rain, in amounts varying from 1 to 30 mm in a given application, to pure stands of white clover and fescue, and to mixed stands of old field vegetation. In a separate experiment, simulated rain also was applied intermittently to fescue with approximately 30 min elapsing between the end of one application of rain and the beginning of another, up to cumulative amounts of 75 mm (Hoffman et al. 1989).

The results of these experiments are compared with those derived from Voillequé (1986) in *Figure 4.5* for particles and in *Figure 4.6* for ^{131}I in soluble form. When ^{131}I is attached to particles, which is the form most likely to have been predominant in fallout, there is good agreement between experimental and predicted values of the mass interception factor (*Figure 4.5*), especially for amounts of rainfall in excess of 10 mm. The initial estimates of EF and RS, however, were multiplied by 0.7 in order to obtain an even better agreement with the experimental values of the mass interception factor obtained by Hoffman et al. (1989) under controlled conditions. The resulting equation, which is used in this assessment, is:

$$F^*_{wet}(R) = EF_{cl} + \frac{RS_{cl}}{R} = 0.9 + \frac{11}{R} \qquad (4.11)$$

where:

$F^*_{wet}(R)$ = mass interception factor [m^2 kg^{-1} (dry mass)],

EF_{cl} = calibrated value of EF = 0.91 m^2 kg^{-1} (dry mass),

RS_{cl} = calibrated value of RS = 11 mm m^2 kg^{-1} (dry mass), and

R = rainfall amount (mm).

Figure 4.5. Variation of the mass interception factor as a function of rainfall amount. The curves represent the estimates derived from Horton's model, as modified by Voillequé (1986) as a dashed line and as further calibration in this report as a solid line. The crosses, points, and squares represent experimental values (to which the model was calibrated for interception) for radionuclides bound in particles by grass from continuous and intermittent applications using rainfall simulators (Hoffman et al. 1989).

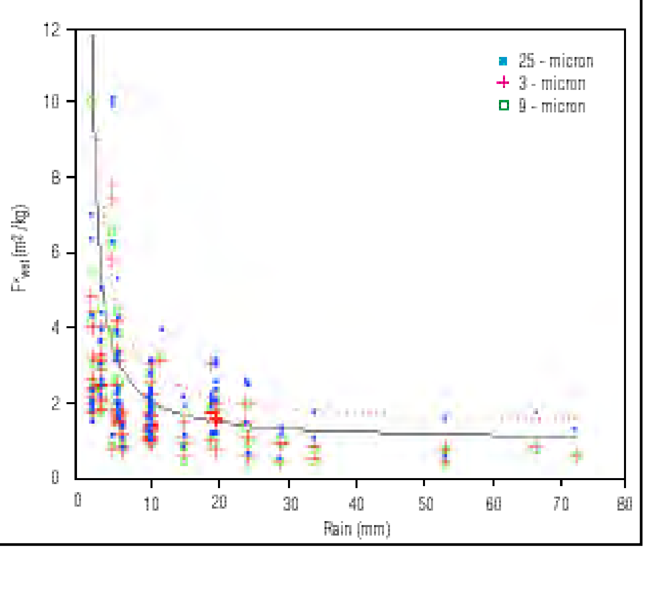
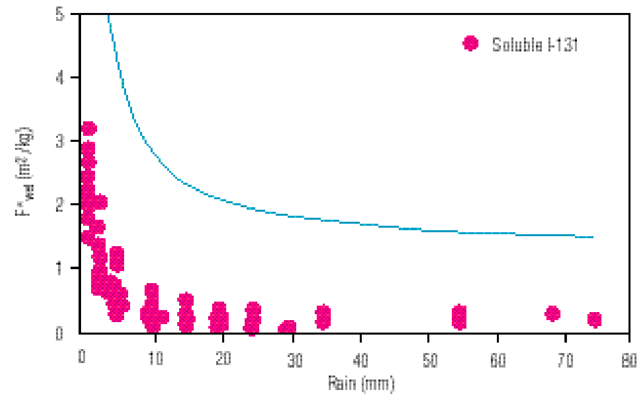


Figure 4.6. Variation of the mass interception factor as a function of rainfall amount. The solid curve represents the estimates derived from Horton's model as modified by Voillequé (1986), while the solid dots represent experimental values for soluble I-131 on grass from continuous and intermittent applications of water supplied by rainfall simulators (Hoffman et al. 1989).



When ^{131}I is in soluble form, the experimental values of the mass interception factor are about 10 times lower than those predicted by the model (*Figure 4.6*). However, ^{131}I is not thought to have been present in soluble form in fallout from the NTS in substantial amounts. It is shown in **Appendix 7** that the deposition of ^{131}I on pasture grass, as well as the resulting concentrations in cows' milk, can be adequately estimated using the assumption that all of ^{131}I in fallout from NTS was attached to particles. This assumption is used throughout the report.

For low rainfall amounts associated with high standing crop biomasses, the use of *equations 4.11* and *4.4* for ^{131}I attached to particles yields values of the interception factor, F, that are greater than one, which physically is impossible. To avoid this inconsistency, *equation 4.11* is only used for daily rainfall amounts that exceed 5 mm (denoted as R_2). On the basis of experimental data (*Figure 4.5* and **Appendix 8**), the values of $F^*_{wet}(R)$ for moderate and heavy rain (R > 5 mm) are considered approximately independent of the size of particles to which fallout ^{131}I is attached. This means that F^*_{wet} does not change with distance from the NTS.

For light rain (R< 5 mm), two rainfall intervals are considered:

- for values of daily rainfall between R_1 = 2.5 mm and R_2 = 5 mm, the mass interception factor is assumed to remain constant, irrespective of the distance from the NTS:

$$F^*_{wet}(R) = F^*_{wet}(R_2) = 3.1 \text{ m}^2 \text{ kg}^{-1} \text{ (dry mass) for } R_1 < R < R_2 \qquad (4.12)$$

- for values of daily rainfall between 0 and R_1 = 2.5 mm, the value of F^*_{wet} for a distance X from the NTS and a daily rainfall amount R is obtained by linear interpolation between the value of the mass interception factor used for dry conditions, $F^*_{dry}(X)$, in *equation 4.9* and the value of the mass interception factor in the presence of a rainfall R_1 of 2.5 mm, $F^*_{wet}(R_1)$:

$$F^*_{wet}(X,R) = F^*_{dry}(X) + [F^*_{wet}(R_1) - F^*_{dry}(X)] \times \frac{R}{R_1} \text{ for } R < R_1 \quad (4.13)$$

where:

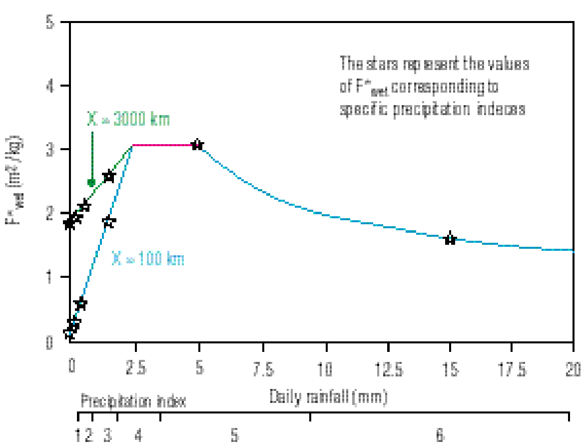
$F^*_{wet}(X,R)$ = mass interception factor at a given distance from the NTS and for less than 2.5 mm of rainfall.

$F^*_{dry}(X)$ = mass interception factor at a given distance from the NTS and no precipitation,

$F^*_{wet}(R_1)$ = mass interception factor for 2.5 mm of rainfall.

The variation of F^*_{wet} as a function of X and of R is illustrated in *Figure 4.7*. For the purposes of the uncertainty analysis, the values of F^*_{wet} are assumed to be log-normally distributed with GSDs of 1.4 and 1.6 for distances from the NTS that are less and greater than 1,540 km, respectively.

Figure 4.7. Variation of the mass interception factor, F^*_{wet}, as a function of daily rainfall, R. The straight solid lines for light daily rainfall (R < 2.5 mm) illustrate results obtained at two distances from NTS using the interpolation procedure adopted.



4.1.1.3. *Discussion*

The values of the mass interception factor F*(i,j) determined as indicated in the preceding **Sub-sections 4.1.1.1** and **4.1.1.2** are combined with the deposition density DG(i,j) to estimate the concentration of ^{131}I in pasture grass immediately after deposition. From *equation 4.5:*

$$C_p(i, j, 0) = DG(i, j) \times F^*(i, j) \quad (4.14)$$

The variation of the concentration of ^{131}I in pasture grass with time, t, after deposition, $C_p(i,j,t)$, is discussed in the following section.

4.1.2. *Retention of ^{131}I by Pasture Grass*

After ^{131}I is deposited on pasture grass, environmental removal processes combine with radioactive decay to reduce the initial amount, $A_p(0)$, on the vegetation surface per unit area of ground. *Figure 4.2* shows schematically the operative processes. The time necessary for one-half of the activity to be removed by environmental processes or diluted by plant growth is referred to as the environmental weathering half-life, T_w (Miller and Hoffman 1979). Literature values of T_w for particulate forms of iodine have a geometric mean of 8.2 d with a geometric standard deviation of 1.8 while those for I_2 vapor have a geometric mean of 6.8 d with a geometric standard deviation of 1.3 (Miller and Hoffman 1983). Within the framework of the research program related to this study, measurements of environmental weathering half-lifes of soluble ^{131}I and of insoluble particulates resulted in values ranging from 7.5 to 17.6 d with a median value of about 11 d (Hoffman et al. 1989). In this report, the mean value of T_w for ^{131}I in NTS fallout is taken to be 10 d, which is consistent with the findings of Miller and Hoffman (1983). This time value, together with that of the radioactive half-life, Tr = 8.04 d, determines the effective half-life of retention on vegetation, Te, according to:

$$T_e = \frac{T_w \times T_r}{T_w + T_r} \quad (4.15)$$

Using *equation 4.15* and the values for T_w and T_r given above, a value of 4.5 d is obtained for T_e.

The rate constants according to which the activity of ^{131}I decreases by environmental removal processes and by radioactive decay are denoted as λ_w and λ_r, respectively, and are related to T_w and to T_r as:

$$\lambda_w = \frac{\ln(2)}{T_w} \quad (4.16)$$

and

$$\lambda_r = \frac{\ln(2)}{T_r} \quad (4.17)$$

In the same way, the effective rate constant, λ_e, which is the sum of λ_w and of λ_r, is related to the effective half-life, T_e as:

$$\lambda_e = \lambda_w + \lambda_r = \frac{ln\,(2)}{T_e} \qquad (4.18)$$

The activity of ^{131}I present on pasture grass per unit area of ground, A_p, decreases exponentially with time after deposition, t, according to:

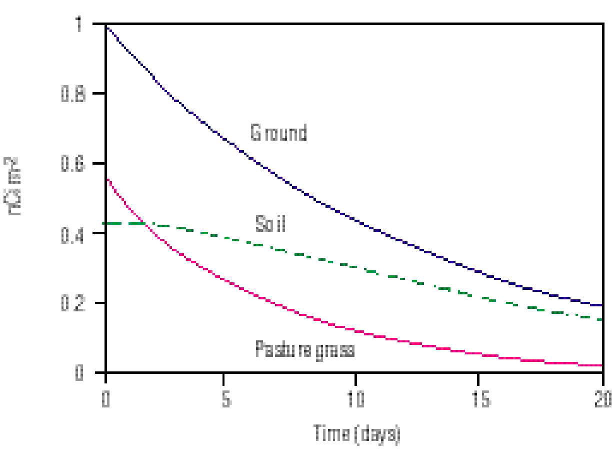
$$A_p\,(t) = A_p\,(0) \times e^{-\lambda_w t} \times e^{-\lambda_r t} \qquad (4.19)$$

Since $A_p(0)$ = DG x F *(equation 4.3)* and $\lambda_e=\lambda_w+\lambda_r$ *(equation 4.18)*, *equation 4.19* can be written as:

$$A_p\,(t) = DG \times F \times e^{-\lambda_e t} \qquad (4.20)$$

The variation of the activity of ^{131}I present in pasture grass per unit area of ground, A_p, as a function of time is presented in *Figure 4.8* for a single deposition, DG, of 1 nCi m^{-2} at time zero and for the value of F* corresponding to dry deposition far away (>1,540 km) from the NTS. The value of A_p decreases exponentially with time; it reaches 1% of its initial value after 5 weeks and 0.1% of its initial value after approximately 2 months. Also shown in *Figure 4.8* are the decreases with time of the activity of ^{131}I deposited on soil and the total ^{131}I activities per unit area of ground. The activity on soil is initially lower than the activity on pasture grass, but it becomes greater after a certain time because the activity removed from pasture grass by environmental processes is transferred to soil.

Figure 4.8. Variation with time of the activities of ^{131}I per unit area in pasture grass and in soil following a deposition of 1 nCi m^{-2} of ^{131}I on the ground (assuming that α=2.8 m^2 kg^{-1} and Y=0.3 kg m^{-2} (dry weight)).



The concentration of ^{131}I in pasture grass, $C_p(t)$, is obtained by dividing the activity $A_p(t)$ by the standing crop biomass, Y:

$$C_p\,(t) = \frac{A_p\,(t)}{Y} = DG \times F^* \times e^{-\lambda_e t} \qquad (4.21)$$

The time-integrated concentration of ^{131}I in pasture grass, IC_p, resulting from a single deposition of ^{131}I on the ground, DG, is obtained by integrating $C_p(t)$ over time until complete decay of ^{131}I:

$$IC_p = \int_0^\infty C_p\,(t) \times dt = DG \times \frac{F^*}{\lambda_e} = DG \times F^* \times \tau_e \qquad (4.22)$$

where:

τ_e, the reciprocal of λ_e, is the effective mean time of residence of ^{131}I on pasture grass.

Measurements carried out within the framework of the research program related to this study to investigate the influence of the physico-chemical form of the material deposited, the effect of plant growth dilution after deposition, and the wash-off effect of uncontaminated rain falling on vegetation showed: (a) no significant differences between the retention by vegetation of ^{131}I and of insoluble microspheres, (b) an effect of growth dilution of minor importance, and (c) unsuccessful attempts to correlate the removal of deposited materials with subsequent uncontaminated rain (Hoffman et al. 1989). If wash-off and growth dilution are not responsible for the reduction of the initial concentration with time, one can only speculate as to what are the important controlling processes. Some of the removal mechanisms may be surface abrasion and leaf bending from wind action, leading to tissue senescence of growing vegetation (Hoffman et al. 1989).

The uncertainties attached to the values of T_e and τ_e can be inferred from the uncertainties related to the environmental weathering half-life, T_w, as the radioactive half-life of ^{131}I, T_r = 8.04 d, can be assumed to be exactly known for the purposes of this report. Given the short radioactive half-life of ^{131}I, the effective half-life T_e is not particularly sensitive to large variations of the environmental weathering half-life T_w. In this assessment, the values of T_w are taken to be log-normally distributed with a geometric mean of 10 d and geometric standard deviation of 1.8 for any county of the contiguous U.S. for any time during the year. The corresponding geometric means of T_e and τ_e are 4.5 and 6.4 days, respectively, with a geometric standard deviation of 1.3.

4.1.3. Pasture Consumption by Dairy Cows and by "Backyard" Cows in the Continental U.S.

Fresh pasture is the portion of the cow's diet that is of primary interest in this report because it is the principal dietary component that was directly exposed to fallout and contaminated to a substantial extent by ^{131}I. Knowledge of the pasture consumption (also called intake) by cows is necessary to determine their ^{131}I activity intake due to the consumption of pasture contaminated following the deposition of ^{131}I resulting from a nuclear test at the NTS. The activity intake of ^{131}I, $AI_p(i,j)$, resulting from deposition on day, j, in county, i, is estimated as:

$$AI_p\,(i,\,j) = \int_0^{\infty} C_p\,(i,\,j,\,t) \times PI\,(i,\,j,\,t) \times dt \qquad (4.23)$$

where:

$C_p(i,j,t)$ is the concentration of ^{131}I in pasture grass in county, i, at time, t, after deposition on day, j (see *equation 4.21*), and PI(i,j,t) is the rate of pasture intake by cows in county, i, at time, t, after deposition on day, j.

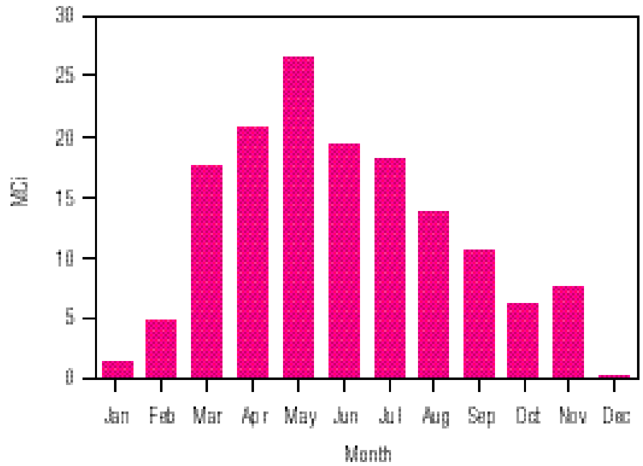
In order to estimate the amount of ^{131}I-contaminated pasture consumed by cows across the country, it is necessary to correlate temporal and spatial characteristics of the fallout patterns following each test with both the pasture intake by cows and the beginning and end of the pasture season for different regions of the U.S. These parameters in turn are influenced by the large climatic and agricultural variations that exist across the country. As shown in *Figure 4.9*, the atmospheric tests analyzed in this study released ^{131}I during each of the 12 months of the year, with maximum releases occurring during the spring.

Since the deposition of ^{131}I following an atmospheric test was usually widespread, the amounts of pasture consumed by cows were estimated for each week of the year and each region of the country.

Since the 1950s, the trends toward larger farms and the greater daily food intake requirements by high-milk-producing cows have reduced the importance of pasture feeding in favor of an increased reliance upon drylot feeding (Koranda 1965; McCullough 1981; Ward and Whicker 1987), which utilizes little or no pasture. Therefore, current dairy practices cannot be used as a surrogate for dairy practices that occurred during the 1950s.

Almost all of the cows' milk consumed in the United States in the 1950s originated from "dairy," or "commercial," cows. However, it was not unusual, during the 1950s, for families living in rural areas to keep one or two cows to provide the milk needed by the family. The diet of these "backyard" cows was not as carefully controlled as the diet of cows in commercial operations. The care of the cows and the pasture practices were more likely to have been motivated by ease of care and by reducing the maintenance costs to the extent practicable. To account for these differences, slightly different assumptions were made for the pasture practices of "backyard" cows.

Figure 4.9. Distribution of atmospheric releases of I-131 from NTS tests analysed in this study.



4.1.3.1. Pasture data available for dairy cows

No federal or state agricultural statistics exist regarding the consumption of pasture by dairy cows. Although occasional reports discuss pasture practices in terms of ideal conditions for cows or pasture, no direct information was found on the actual daily intakes of pasture by cows in the 1950s. Therefore, indirect methods were used to estimate the daily intake of pasture by cows throughout the country. The only nationwide standardized information source for dairy herd diets is the Dairy Herd Improvement Association (DHIA). Since 1905, the DHIA has maintained records to help its members improve the health of dairy cattle, increase milk production and increase efficiency of herd management. Since 1953, the Animal Improvement Program Laboratory of the U.S. Department of Agriculture (USDA) has maintained a national computer database of the DHIA data from the nine relatively independent regional Dairy Records Processing Center offices (DRPC 1987; Voelker 1985).

In 1950, over 1 million cows, about 5% of the number of dairy cows in the U.S., were included in the DHIA program. By 1960 the percentage of cows in the program doubled, and by 1970 about 20% of the cows were included (Voelker 1985). The success of the program is shown by higher average milk production rates of cows in the program, as compared to the average rate of all cows. For example, in 1950, cows in the DHIA program produced 58% more milk than the average U.S. cow. This increased production can be related to improved feeding programs, better herd management and the use of superior breeding stock (Voelker 1985).

The DHIA maintained records on breeding, diet, milk production, health, and operation costs of the cows for the farmers that were members of the association. The data collected included: number of cows in the herd, days-in-milk (number of days the cow produces milk as opposed to being "dry"), number of cows milked 3 times a day instead of twice, weight of the cows, milk and fat production of each cow, and feed costs.

Also, records were kept on estimates of the amount of protein, dry forage, succulent forage and concentrates that were fed to the cows. In addition, the fractions of the total net energy fed from dry forage, succulent forage and concentrates were estimated, as was the number of days the cows were on pasture during the year. A ratio called the feed index was reported as a measure of the amount of energy fed to the cows as compared to the amount of energy required by the animals for maintenance and milk production.

These data were estimated at the time by the farmers and the DHIA field staff and reported as monthly averages to the local DHIA office. Yearly, these data were compiled into annual herd summaries and the records were transferred to the Animal Improvement Laboratory in Beltsville, MD. The annual summaries of the data collected for the herds included in the DHIA program were obtained from the Animal Improvements Programs Laboratory.[1]

In reviewing the more than 270,000 records, some inconsistencies in recording, collecting and/or computational methods became apparent. In some states, the same value was recorded for certain factors for all the herds and all years. In other states, large portions of the data in a given record would be missing. For example, in California there were no data available for the time period of interest. It also appears that over the span of 10 years some of the different DHIA offices calculated estimates of net energy from dry forage, succulent forage and concentrates utilizing the annual herd average data in different ways. The values reported for the number of days on pasture were difficult to interpret in some states. It was not easy to determine if a value of zero indicated that no data were collected or that the herd was on feedlot.

In general, data for the number of cows, the milk and fat production for each cow, the weight of the cows and number of days on pasture are consistently reported. Using these data, the pasture intake by dairy cows has been calculated in two steps: (a) estimation of the total intake of dairy cows, averaged over the years 1953 to 1963, for each of the contiguous states, and (b) estimation of the fraction of total dry matter intake that was provided by pasture. In order to estimate the fraction of diet from pasture, the average cow's total diet was calculated using a method recommended by the National Research Council (NRC) (NRC 1978). The following DHIA annual herd data were utilized to calculate the total diet of dairy cows:

- average number of cows in the herd,
- average weight of the cows,
- average yearly milk production,
- average fat content in the milk, and
- number of days the cows were on pasture.

The estimates of the total daily dry matter intake that can be calculated from the DHIA data reported in the 1950s seem representative of the average cow's dry matter intake because these values are in fair agreement with the diets recommended in the manuals at that time (Morrison 1961). However, the greater milk production rates for DHIA herds suggest that the proportions of feed types (dry forage, succulent forage, and concentrates) in the rations may have differed. Information on the relative importance of the components of the diet in each state were obtained from experts (see list of contacts in **Appendix 3, Part 1**).

The geography, type of grasses, and climatological variation from year to year, as well as the economic climate at any given time, all influence the length of the pasture season as well as the fraction of the cow's diet obtained from pasture at different times of the year. In addition, the traditions followed by individual families can have a profound effect on the pasture practices. This study utilized the data provided by: (1) the DHIA (for the number of days on pasture), (b) interviews with USDA Extension Service experts (**Appendix 3, Part 1**), and (c) published reports to estimate the beginning and end of the pasture season, as well as the fluctuation in the fraction of the cow's diet that was provided by fresh pasture during the season.

A detailed discussion on the methods and results of the estimation of the pasture practices across the U.S. in the 1950s is found in **Sections 4.1.3.2, 4.1.3.3,** and **4.1.3.4.** The estimation of the backyard cow diet is discussed separately in **Section 4.1.3.5.**

4.1.3.2. Total daily consumption of feeds by dairy cows

There is considerable variation in the total daily consumption of feeds by dairy cows depending on the cow's body weight, level of milk production, and quality of the forage feeds. The variation is reduced if the food intake is described in terms of dry weight or "dry matter intake." The ability of cows to digest feed varies on a relatively small scale; however, their appetites, growth rates and milk production rates can vary considerably (NRC 1988). Feeding standards have been established to help farmers in selecting the properly balanced rations for optimum health of their animals and maximum milk production (Morrison 1961; NRC 1978, 1988). Using the National Research Council methodology (NRC 1978), the recommended daily intake, DM, expressed in terms of dry matter (kg d^{-1}), is estimated using:

$$DM = \frac{BWT \times PBWT}{100} \qquad (4.24)$$

where:

DM = daily dry matter intake (kg d^{-1}),

BWT = cow's body weight (kg), and

PBWT = percentage of cow's body weight to be fed to the cow per day.

Using the NRC methodology (NRC 1978), the values of PBWT are estimated as a function of the cow's body weight, BW, and of the daily production of milk normalized to 4% fat content, FCM, as shown in *Table 4.1* for a range of values of BW and of FCM.

[1]Personal communication (1985) with G. Wiggans and C. Ernst, at Animal Improvement Programs Laboratory, Agricultural Research Service-USDA, Building 263, Poultry Road, BARC-East, Beltsville, MD 20705.

Table 4.1. Estimates of percentage of body weight, PBWT, to be fed to dairy cows, as a function of the cow's body weight, BWT, and of the daily production of milk normalized to 4% fat content, FCM (NRC 1978).

Cow's body weight, BWT (kg)	300	400	500	600	700	800	900
FCM (kg d^{-1})							
5	2.4	2.2	2.1	2.0	2.0	2.0	2.0
10	2.7	2.5	2.3	2.2	2.1	2.0	2.0
15	3.0	2.8	2.5	2.4	2.3	2.2	2.1
21	3.3	3.1	2.8	2.7	2.6	2.4	2.2
25	3.5	3.4	3.1	3.0	2.8	2.6	2.4
30	3.9	3.7	3.4	3.2	3.0	2.8	2.6
35	4.0	4.0	3.6	3.4	3.2	3.0	2.8
40	4.0	4.0	3.8	3.6	3.4	3.2	3.0
45	4.0	4.0	4.0	3.8	3.6	3.4	3.2

The 4% fat-corrected daily milk production, FCM, is calculated for each herd average using the following empirical equation recommended in the NRC (1988) methodology:

$$FCM = (0.4 \times MY) + (15 \times FAT) \qquad (4.25)$$

where:

FCM = 4% fat-corrected daily milk production (kg d^{-1}),

MY = milk yield (kg d^{-1}), and

FAT = fat yield (kg d^{-1}).

The annual herd averages for cows' body weight, milk production, and fat production reported to the DHIA from 1955 to 1965 were used to calculate, for each year that data were reported, in order: (1) the daily averages of the milk yield, MY, and of the fat yield, FAT; this was done by dividing the total yearly productions by the average number of days that cows produce milk during the year, 305 days, as cows are allowed an annual 60-day dry period for optimal milk production (DRPC 1987); (2) the 4% fat-corrected daily milk production, FCM, using equation 4.25; (3) the percentage of body weight to be fed to the cow, PBWT, using *Table 4.1;* (4) the average total daily dry matter intake for the herd, DM, using *equation 4.24*. It is assumed that the daily total dry matter intake of the cows remains constant throughout the year for all the cows in the herd.

Table 4.2 presents the arithmetic means of BWT, MY, and FAT for all of the herd data available in each state as well as the resulting values of PBWT and of DM obtained using *equations 4.24* and *4.25* and *Table 4.1.* For example, the average DHIA cow in New York state weighed 517 kg and produced 15.3 kg of milk and 0.58 kg of fat per day. From 3566 herd records in New York state, over a 10-year period, it is estimated that the mean daily dry matter intake for DHIA cows in New York state was 13 kg d^{-1} with a standard deviation of 1.4 kg d^{-1}. The distributions of the daily dry matter intakes in each state are relatively narrow and are fairly well approximated by normal distributions; consequently, the median daily dry matter intake in each state has been assumed to be equal to the mean value.

It is to be noted that the values of DM obtained by this method may be thought to be overestimates for two reasons: the NRC guidelines are intended to provide maximum dry matter intakes and the cows included in the DHIA program may not be representative of all cows because they may weigh more and produce more milk of better quality than those that are not listed in the DHIA program. However, the arithmetic means for the dry matter intake that are presented in *Table 4.2* are consistent with the range of 9 to 17 kg per day that is found in the literature for dairy cows of the 1950s (CES 1979; Koranda 1965; Leaver 1985; Morrison 1961; NRC 1978; Ward and Whicker 1987). The increased milk production represented by cows in the DHIA program may be due both to better nutrient quality of the DHIA recommended diet and to a somewhat greater total dry matter intake.

Table 4.2. Ten-year average state values and standard deviations (1 σ) of DHIA yearly herd data from 1953 to 1963 for the weight of the cows, daily milk and fat yield, and the estimated daily dry matter intake per cow. Each DHIA herd record provided average information on an individual herd for a given year.

	Average weight of cow(BWT)		Milk yield(MY)		Estimated fat yield (FAT)		Dry matter intake (DM)		Number of records
State	(kg)	(1σ)	(kg d^{-1})	(1σ)	(kg d^{-1})	(1σ)	(kg d^{-1})	(1σ)	
Alabama	520	148	10.7	2.7	0.446	0.1	12.1	2.4	1477
Arizona	616	101	14.2	2.5	0.54	0.084	14.4	1.8	1307
Arkansas	536	135	12.6	2.6	0.516	0.102	12.8	2.3	238
California*	700	-	17.4	3.5	0.685	0.103	17.0	1.1	5782
Colorado	704	113	13.8	2.8	0.547	0.089	15.8	2.0	1359
Connecticut	608	130	15.2	3.3	0.61	0.111	14.6	2.3	4557
Delaware	581	114	13.9	3.0	0.558	0.1	13.8	2.1	1037
Florida	500	144	10.8	1.9	0.478	0.092	11.9	2.3	648
Georgia	622	142	12.1	2.9	0.487	0.103	14.0	2.2	1641
Idaho	615	145	14.5	3.2	0.584	0.091	14.5	2.5	5386
Illinois	676	119	15.2	2.9	0.593	0.097	15.7	2.0	15334
Indiana	659	130	14.8	3.2	0.594	0.102	15.3	2.3	10753
Iowa	585	105	15.0	3.2	0.576	0.099	14.1	2.0	15626
Kansas	594	115	14.9	3.0	0.576	0.097	14.2	2.1	4501
Kentucky	604	141	13.1	3.0	0.523	0.096	13.9	2.3	2411
Louisiana	575	163	9.6	2.5	0.422	0.085	12.8	2.6	257
Maine	511	94	14.2	3.1	0.583	0.107	12.8	1.9	5201
Maryland	661	130	14.2	2.9	0.568	0.099	15.2	2.1	7127
Massachusetts	649	134	14.7	3.2	0.597	0.109	15.2	2.2	4794
Michigan	661	129	15.5	3.2	0.598	0.098	15.5	2.2	14556
Minnesota	553	83	15.4	3.0	0.576	0.092	13.6	1.7	27221
Mississippi	537	145	10.3	2.7	0.444	0.105	12.3	2.3	616
Missouri	602	142	13.2	3.1	0.55	0.101	14.0	2.4	2415
Montana	642	113	14.6	2.9	0.55	0.086	14.9	2.0	826
Nebraska	651	124	14.5	3.1	0.561	0.102	15.0	2.2	2789
Nevada	762	59	16.0	2.9	0.635	0.088	17.4	1.3	47
New Hampshire	651	135	14.1	3.0	0.574	0.111	15.0	2.1	2864
New Jersey	648	123	15.3	2.8	0.596	0.094	15.2	2.1	3718
New Mexico	754	68	13.7	2.7	0.551	0.087	16.6	1.3	118
New York	517	56	15.3	2.8	0.582	0.092	13.0	1.4	3566
North Carolina	561	124	13.4	2.9	0.529	0.096	13.3	2.1	4939
North Dakota	569	58	14.2	3.0	0.532	0.106	13.6	1.4	1153
Ohio	690	124	14.9	3.3	0.578	0.099	15.8	2.2	12398
Oklahoma	642	136	13.1	3.1	0.515	0.101	14.5	2.2	1085
Oregon	750	75	12.9	2.4	0.59	0.089	16.6	1.4	2967
Pennsylvania	662	126	15.0	3.0	0.59	0.1	15.4	2.1	38757
Rhode Island	631	128	14.9	3.1	0.593	0.1	14.9	2.2	519
South Carolina	573	142	12.2	2.7	0.501	0.938	13.3	2.3	893
South Dakota	616	108	15.1	3.1	0.553	0.104	14.5	2.0	1320
Tennessee	476	72	12.2	2.9	0.511	0.1	11.8	1.6	2033
Texas	614	147	12.6	3.3	0.512	0.104	14.0	2.4	2164
Utah	533	67	16.1	3.0	0.606	0.1	13.5	1.6	27629
Vermont	605	151	22.4	3.1	0.558	0.11	14.1	2.4	9653
Virginia	528	71	14.5	3.0	0.574	0.103	13.1	1.6	7507
Washington	770	16	14.2	3.2	0.614	0.099	17.2	0.9	3283
West Virginia	506	72	13.3	2.8	0.526	0.093	12.4	1.5	1690
Wisconsin	601	118	14.7	2.9	0.564	0.093	14.3	2.2	13430
Wyoming	665	77	13.7	2.9	0.501	0.085	15.0	1.4	71

* In the absence of data, the weight of California's DHIA cows was assumed to be 700 kg.

4.1.3.3. Fraction of total consumption of dry matter by dairy cows due to pasture

The fraction of the total daily consumption of dry matter by dairy cows that is obtained from pasture, FP, varies from one region of the country to another and from one time of the year to another. The DHIA records provide information on the total number of pasture days in the year and on the yearly averages of the fraction of diet on pasture, but not on the dates corresponding to the beginning and end of the pasture season, or on the variation of the value of FP during the pasture year. In order to reconstruct pasture feeding practices during the 1950s for the contiguous United States, the expert opinions of individual state USDA Extension Specialists throughout the country, and of other knowledgeable persons, were requested. The list of the persons who provided assistance can be found in **Appendix 3 (Part 1).** Most of the information was obtained during telephonic conversations and was based on subjective estimates from the experts. Problems related to spatial and temporal variations of FP were treated as follows:

(a) Spatial variations: Experts were requested to provide values of FP averaged over the entire state with which they were familiar. In some states, however, the environmental conditions and therefore the pasture practices varied considerably across the state. For example, in the southeastern states, the coastal areas are milder and therefore have significantly longer pasture seasons than do the inland sections. For the same reason, there are large intra-state variations in pasture season due to the dry climate in certain parts of Texas and California. Different pasture seasons were therefore assigned to parts of the states of California, Texas, Mississippi, Alabama, Georgia, and South and North Carolina. In addition, because there were substantial changes in pasture practices associated with sharp changes in fallout patterns across states close to the test site (Utah, Arizona, and part of California), it was considered that the use of a single pasture practice for the entire state would be too general. Therefore, smaller geographic areas were assigned within these states and the corresponding pasture practices were estimated on the basis of the work of Ward and Whicker (1987). In summary, the contiguous United States were divided into 71 pasture regions:

- 39 pasture regions correspond to the territories of the states that were not subdivided (Arkansas, Colorado, Connecticut, Delaware, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Dakota, Tennessee, Vermont, Virginia, Washington, West Virginia, Wisconsin, and Wyoming);
- 31 pasture regions are in states that were subdivided: Alabama (2), Arizona (2), California (4), Georgia (2), Mississippi (2), North Carolina (2), South Carolina (2), Texas (2), and Utah (13); and
- one pasture region for the District of Columbia, although there were no dairy cows in that area during the 1950s.

The distribution of the pasture regions across the contiguous United States is illustrated in *Figure 4.10*. A more detailed presentation of the geographical territories of the states that were subdivided can be found in **Appendix 3 (Part 3).** General information on the subdivided areas near the NTS is provided in **Appendix 2 (Section A2.3).**

(b) Temporal variations: The experts were initially requested to provide information on the variation of FP throughout the year on a monthly basis. However, in a number of responses, it was indicated that changes occurred "early," "late," or "in the middle of" a given month. It was therefore decided to divide each month into four parts, that would begin on the 1st, 8th, 16th, and 23rd days of each month, and to assign any change in the FP values to one of those days during the month. These four parts of the month are similar to calendar weeks, except that they begin on fixed days and may be 6 to 9 days long. They are denoted as "weeks" in this report.

The beginning and end of the pasture season for each pasture region, obtained on the basis of the experts' advices, as well as the number of days on pasture between the designated start and stop dates, are presented in *Table 4.3*. The average number of days on pasture in DHIA records are presented on this table for comparison. Given the fact that the arithmetic standard deviation for the average number of days on pasture presented from the DHIA varied from approximately 40 to 150 days, there is a good agreement between the values for the length of the pasture season derived from the experts' recommendations and recorded by DHIA.

Given the variability in the dates for the beginning and the end of the pasture season from one county to another in the same pasture region and also from one year to another, the fraction of intake from pasture, FP, has been assumed to increase gradually around those critical dates, as illustrated in *Figure 4.11* for Pennsylvania. The values of FP are assumed to vary linearly for a period of 2 "weeks" centered on the estimated mean date of the beginning of the pasture season. A similar procedure is used to estimate the decrease in pasture intake at the end of the pasture season.

Although subjective, the estimates of FP derived from the experts' recommendations are the best obtainable information on the seasonal variation of pasture practices at that time. *Table 4.3* presents, for each pasture region, the yearly average values of the fraction of diet from pasture, FP, calculated from the experts' estimates for each "week" of the year, as well as the corresponding values derived from the DHIA records. There is, here again, a reasonable (within a factor of about two) agreement between the two sets of values. The values estimated by the experts were used in this analysis.

Figure 4.10. Identification of pasture regions used in the dose assessment.

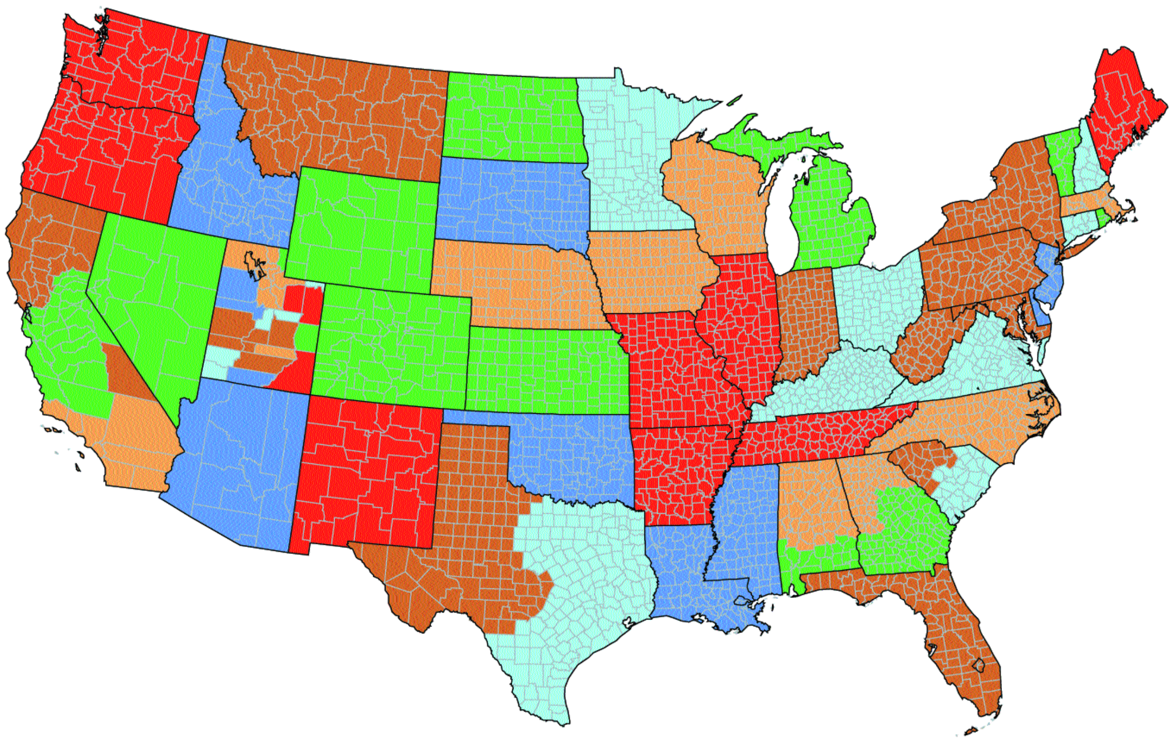


Figure 4.11. Estimated annual variation of the fraction of dry matter intake due to pasture for dairy cows in Pennsylvania during the 1950s.

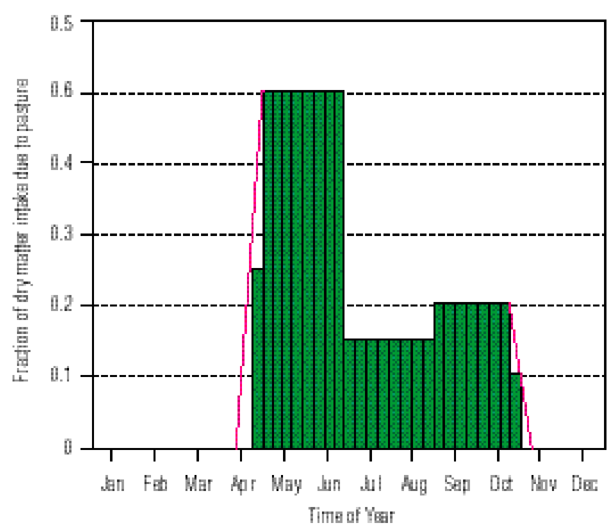


Table 4.3. Summary of pasture season data and of yearly average values of the fraction of diet from pasture for dairy cows in each pasture region, as derived from experts' recommendations. For comparison, average DHIA values for each state are included.

Area	Pasture season				Yearly average of the fraction of diet from pasture	
	beginning (day of year)	end (day of year	duration (days)	duration (days)		
	EXPERTS	EXPERTS	EXPERTS	EXPERTS	EXPERTS	DHIA
ALABAMA-north	60	334	275	260	0.31	0.26
ALABAMA-south	1	365	365	260	0.35	0.26
ARIZONA-remainder	1	365	365	nd[a]	0.05	nd
ARIZONA-northwest	106	288	183	nd	0.17	nd
ARKANSAS	60	304	245	208	0.31	0.25
CALIFORNIA-north	67	304	238	nd	0.24	nd
CALIFORNIA-middle	60	304	245	nd	0.14	nd
CALIFORNIA-south	47	304	258	nd	0.04	nd
CALIFORNIA-Inyo	136	258	123	nd	0.04	nd
COLORADO	136	258	123	48[b]	0.14	0.04[b]
CONNECTICUT	136	296	161	116	0.22	0.11
DELAWARE	106	319	214	174	0.23	0.19
DISTRICT OF COLUMBIA	---	---	---	---	---	---
FLORIDA	1	365	365	249	0.15	0.24
GEORGIA-north	60	334	275	244	0.27	0.24
GEORGIA-south	1	365	365	244	0.36	0.24
IDAHO	136	288	153	104	0.26	0.1
ILLINOIS	121	288	168	107	0.18	0.1
INDIANA	121	288	168	104	0.17	0.11
IOWA	121	288	168	135	0.18	0.14
KANSAS	121	304	184	165	0.26	0.15
KENTUCKY	91	288	198	139	0.19	0.15
LOUISIANA	1	365	365	209	0.46	0.26
MAINE	136	288	153	140	0.26	0.14
MARYLAND	106	319	214	119	0.26	0.12
MASSACHUSETTS	136	288	153	106	0.14	0.1
MICHIGAN	136	280	145	114	0.2	0.1
MINNESOTA	136	280	145	125	0.24	0.12
MISSISSIPPI-north	60	334	275	258	0.18	0.28
MISSISSIPPI-south	1	365	365	258	0.28	0.28
MISSOURI	121	304	184	146	0.27	0.15
MONTANA	136	273	138	101	0.23	0.09
NEBRASKA	121	280	160	108	0.2	0.1
NEVADA	136	273	138	23	0.06	0.03
NEW HAMPSHIRE	136	288	153	133	0.21	0.11
NEW JERSEY	121	296	176	133	0.16	0.12

Area	Pasture season				Yearly average of the fraction of diet from pasture	
	beginning (day of year)	end (day of year)	duration (days)	duration (days)		
	EXPERTS	EXPERTS	EXPERTS	EXPERTS	EXPERTS	DHIA
NEW MEXICO	114	304	191	10	0.08	0.13
NEW YORK	136	288	153	142	0.17	0.14
NORTH CAROLINA-east	75	319	245	177	0.22	0.16
NORTH CAROLINA-west	91	304	214	277	0.19	0.16
NORTH DAKOTA	136	273	138	126	0.18	0.13
OHIO	121	288	168	56	0.27	0.06
OKLAHOMA	60	334	275	178	0.24	0.17
OREGON	106	288	183	23	0.21	0.02
PENNSYLVANIA	121	304	184	147	0.14	0.1
RHODE ISLAND	136	296	161	119	0.25	0.1
SOUTH CAROLINA-east	60	319	260	238	0.27	0.23
SOUTH CAROLINA-west	67	319	253	238	0.26	0.23
SOUTH DAKOTA	136	273	138	105	0.17	0.1
TENNESSEE	75	273	199	214	0.2	0.23
TEXAS-east	67	334	268	142	0.34	0.2
TEXAS-west	1	365	365	142	0.15	0.2
UTAH - region 1	136	258	123	142	0.18	0.14
UTAH - region 2	152	243	92	142	0.2	0.14
UTAH - region 3	136	258	123	142	0.2	0.14
UTAH - region 4	136	258	123	142	0.17	0.14
UTAH - region 5	136	258	123	142	0.2	0.14
UTAH - region 6	152	243	92	142	0.17	0.14
UTAH - region 7	136	258	123	142	0.22	0.14
UTAH - region 8	152	243	92	142	0.19	0.14
UTAH - region 9	144	250	107	142	0.15	0.14
UTAH - region 10	128	266	139	142	0.03	0.14
UTAH - region 11	106	288	183	142	0.22	0.14
UTAH - region 12	121	273	153	142	0.33	0.14
UTAH - region 13	136	258	123	142	0.13	0.14
VERMONT	136	288	153	117	0.22	0.12
VIRGINIA	106	319	214	185	0.26	0.17
WASHINGTON	106	288	183	1[c]	0.21	0.00[c]
WEST VIRGINIA	114	304	191	168	0.23	0.19
WISCONSIN	136	280	145	71[c]	0.21	0.06[c]
WYOMING	136	273	138	24[b]	0.14	0.02[b]

[a] nd = no data available.
[b] DHIA data were either incomplete or a large proportion of herds were not fed fresh pasture.
[c] DHIA data were incomplete.

4.1.3.4. Estimates of daily consumption of pasture by dairy cows

The daily dry matter intake by cows which was obtained from pasture PI(i,j,t) (kg d^{-1}), in a given county, i, at a given time, t, after deposition on day, j, was calculated by:

$$PI\ (i,\ j,\ t) = DM(i) \times FP\ (i,\ j,\ t) \qquad (4.26)$$

where:

DM(i) = total dry matter intake (kg d^{-1}), in the pasture region that includes the county, i, and

FP(i,j,t) = fraction of the diet from pasture at time, t, after deposition on day, j, in the pasture region that includes the county, i.

For each pasture region, an estimate of daily intake from pasture is calculated for each "week" of the year. As an example, the solid curve in *Figure 4.12* shows the estimated variation throughout the year of the daily pasture intake, PI, for dairy cows in the state of Pennsylvania. The complete set of estimates for the 71 pasture regions is provided in **Part 2 of Appendix 3** in tabular form and in **Part 4 of Appendix 3** in the form of histograms. Estimates, for each pasture region, of the yearly average of the daily pasture intake by dairy cows (including zero pasture months) are presented in *Table 4.4.* These estimates range from 0.6 kg (dry) d^{-1} for part of California to 5.9 kg (dry) d^{-1} for Louisiana.

The estimation of the time-integrated concentrations of ^{131}I in milk resulting from deposition of ^{131}I on the ground on day, j, in county, i, as described by *equation 4.1*, involves the calculation of a daily pasture intake equivalent, PI* (i,j), which is the quotient of the activity intake of ^{131}I by the cow from pasture, $AI_p(i,j)$, and of the time-integrated concentration of ^{131}I in the pasture grass consumed by the cow, $IC_p(i,j)$; the daily pasture intake equivalent represents an average of the daily pasture intake PI(i,j,t) over the time period during which ^{131}I is present on pasture, weighted according to the relative amount of ^{131}I present on pasture. From *equations 4.22 and 4.23,* the value of the daily pasture intake equivalent is obtained as:

$$PI^*\ (i,\ j) = \frac{AI_p\ (i,j)}{IC_p\ (i,j)} = \frac{\int_0^\infty PI\ (i,\ j,\ t) \times DG\ (i,j) \times F^*\ (i,\ j) \times e^{-\lambda_e t} \times dt}{DG\ (i,\ j) \times F^*\ (i,\ j)\ /\ \lambda_e} \qquad (4.27)$$

where:

DG(i,j) = the average deposition density of ^{131}I on the ground in a given county, i, on day, j,

F*(i,j) = the average mass interception factor in county, i, on day, j, and

λ_e = the effective rate constant of removal of ^{131}I from pasture.

Since both DG(i,j) and F*(i,j) are independent of the variable t, *equation 4.27* can be simplified as:

$$PI^*\ (i,\ j) = \frac{\int_0^\infty PI\ (i,\ j,\ t) \times e^{-\lambda_e t} \times dt}{\tau_e} \qquad (4.28)$$

The term exp($-\lambda_e$ t) reflects the decrease in the ^{131}I concentration in pasture, expressed as a fraction of the initial concentration on the day of deposition, j, as a function of time, t, after deposition. This term is equal to 0.34 one week after deposition, 0.02 one month after deposition, and 0.0003 two months after deposition. For practical purposes, the upper limit of the variable t in the integral of *equation 4.23* is taken to be equal to 60 days, at which time the concentration of ^{131}I in pasture will have decreased to less than 0.1% of the initial concentration.

The values of the daily pasture intake and of the pasture intake equivalent for dairy cows in the state of Pennsylvania are illustrated in *Figure 4.12.* It is shown on *Figure 4.12* and it also can be inferred from *equation 4.28* that the daily pasture equivalent, PI*(i,j), is equal to the pasture intake on the day of deposition, PI(i,j,0), if the value of PI(i,j,t) during the pasture season remains constant for a period of 2 months following deposition. However, the value of PI*(i,j) is greater than that of PI(i,j,0) if the deposition on the ground occurs before the beginning of the pasture season, and the value of PI*(i,j) is smaller than that of PI(i,j,0) if the deposition on the ground occurs towards the end of the pasture season.

In this report, uncertainties have been assigned to the daily pasture equivalent PI*(i,j). As observed by Breshears et al. (1989) within the framework of the ORERP study, the overall uncertainty of the time-integrated concentration of ^{131}I on milk varies according to the date of the fallout deposition, with the highest values when the cows are placed on, or removed from, pasture. It is assumed in this report that the values of PI*(i,j) are log-normally distributed with GSDs varying as a function of the time difference between the day of deposition, j, and the beginning of the pasture season, bp, as presented in *Table 4.5.* The largest GSDs, reflecting the largest uncertainty in PI*, are estimated for fallout depositions that occur within about 10 days of the start or finish of the pasture season.

Table 4.4. Estimates for each pasture region of the yearly averages including zero pasture months of the daily pasture intakes by dairy cows in kg (dry) /d.

Area	Yearly average pasture intake (kg(dry)/d)	Area	Yearly average pasture intake (kg(dry)/d)
ALABAMA-north	3.73	NEW JERSEY	2.42
ALABAMA-south	4.24	NEW MEXICO	1.29
ARIZONA-remainder	0.72	NEW YORK	2.36
ARIZONA-northwest	2.52	NORTH CAROLINA-east	2.86
ARKANSAS	4.03	NORTH CAROLINA-west	2.46
CALIFORNIA-north	4.08	NORTH DAKOTA	2.49
CALIFORNIA-middle	2.35	OHIO	4.22
CALIFORNIA-south	0.6	OKLAHOMA	3.51
CALIFORNIA-Inyo	0.73	OREGON	3.52
COLORADO	2.24	PENNSYLVANIA	2.19
CONNECTICUT	3.14	RHODE ISLAND	3.65
DELAWARE	3.22	SOUTH CAROLINA-east	3.55
DISTRICT OF COLUMBIA	----	SOUTH CAROLINA-west	3.4
FLORIDA	1.78	SOUTH DAKOTA	2.48
GEORGIA-north	3.79	TENNESSEE	2.36
GEORGIA-south	5.07	TEXAS-east	4.69
IDAHO	3.8	TEXAS-west	2.1
ILLINOIS	2.87	UTAH - region 1	2.47
INDIANA	2.68	UTAH - region 2	2.7
IOWA	2.52	UTAH - region 3	2.7
KANSAS	3.66	UTAH - region 4	2.25
KENTUCKY	2.67	UTAH - region 5	2.7
LOUISIANA	5.86	UTAH - region 6	2.27
MAINE	3.28	UTAH - region 7	3.01
MARYLAND	3.92	UTAH - region 8	2.54
MASSACHUSETTS	2.13	UTAH - region 9	1.97
MICHIGAN	3.1	UTAH - region 10	0.35
MINNESOTA	3.26	UTAH - region 11	3.04
MISSISSIPPI-north	2.25	UTAH - region 12	4.5
MISSISSIPPI-south	3.43	UTAH - region 13	1.8
MISSOURI	3.74	VERMONT	3.06
MONTANA	3.38	VIRGINIA	3.43
NEBRASKA	3.03	WASHINGTON	3.65
NEVADA	0.97	WEST VIRGINIA	2.86
NEW HAMPSHIRE	3.15	WISCONSIN	2.97
		WYOMING	2.13

Figure 4.12. Comparison of the daily pasture intake and of the daily pasture intake equivalent by dairy cows in the state of Pennsylvania during the 1950s.

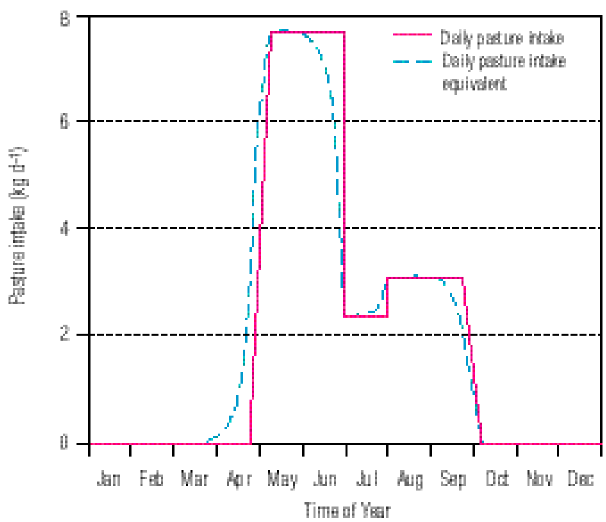


Table 4.5. Estimates of geometric standard deviations, GSD, associated with the daily pasture intakes of dairy cows.

Diff[a] (days)		GSD
From	To	
-60	-46	1.3
-45	-31	1.4
-30	-26	1.5
-25	-23	1.6
-22	-17	1.7
-16	-10	1.9
-9	+9	2.0
+10	+20	1.9
+21	+29	1.8

[a] Diff represents the algebraic difference in the number of days separating the day of fallout deposition, j, from the beginning of the pasture season, bp : Diff = j - bp

4.1.3.5. Estimation of "backyard" cow diet

It is assumed in this report that "backyard" cows were kept to provide the milk requirements of only an individual family. In these cases, the cows would be more likely to be placed on pasture for a larger portion of their diet than would herds of dairy cows, resulting in lower maintenance costs to the family. This feeding regime would also result in lower than average milk production rates; however, less than optimal milk production would be of little consequence to a non-commercial operation.

On the basis of discussions with an experienced dairy farmer (Till 1990), the following parameters were chosen for the average U.S. "backyard" cow:

- weight: 500 kg,
- milk production rate: 10 kg d^{-1} of 3.5% butterfat milk,
- diet during the pasture season: on the basis of the assumed values for the cows' body weight, and for the milk and fat yield, the total dry matter intake of the average U.S. backyard cow is estimated to be approximately 11 kg d^{-1} from *equations 4.24* and *4.25*. It is further assumed that 3 kg d^{-1} of concentrates (eg., grains roughage) are provided to the backyard cow and that the remainder of the diet is comprised totally of pasture. The estimated pasture intake is therefore 8 kg d^{-1} (dry mass): this value is assumed to represent the geometric mean of a log-normal distribution within each county with a geometric standard deviation of 1.3,
- length of the pasture season: it is assumed that the farmers put the backyard cows out to pasture as soon as possible in the spring and allowed them to graze as long as grass was available. The start and stop dates of the pasture season for backyard cows are taken to be one month before and one month after the start and stop dates, respectively, estimated for commercial herds that are presented in *Table 4.3* for all pasture regions.

4.1.4. Secretion of ^{131}I Into Milk

Iodine present in the diet in soluble form is rapidly and probably completely absorbed from the gastrointestinal tract into the blood. Some organs and tissues, notably the thyroid gland, but also the salivary glands, the gastric mucosa, and in some species, the ovaries, mammary glands and placenta, possess the capacity to concentrate iodine from the blood (Garner and Russell 1966; Honour et al. 1952). Iodine is eliminated from the body mainly in the urine with smaller amounts being excreted in the feces. Substantial amounts also are found in the milk of lactating animals and for this reason the transfer of radioactive iodine from the diet of animals to their milk has received particular attention.

Characteristics of all species is a rapid movement of iodine from the digestive tract to the blood and then to milk. Blood iodine is contained almost exclusively in the plasma and is either bound to proteins in the form of thyroxine and tri-iodothyronine or exists as inorganic iodide. Plasma iodide is the chief source of milk iodine as the mammary epithelial membranes are impermeable to protein-bound iodine in the cow and almost impermeable in other animals like the rat and the rabbit (Lengemann et al. 1974). Iodine in milk exists both as protein-bound iodine and as inorganic iodide. According to Lengemann et al. (1974), the milk/plasma iodide ratios are usually greater than one (average values are about 2 in cows, 7 in goats, 20 in dogs and humans, and 40 in sheep). These values indicate that mammary tissue possesses a mechanism (called "iodide pump") that is capable of concentrating iodide in the formation of milk and that this mechanism functions to different extents in different species. In addition, passive diffusion can supply blood iodide into the mammary gland, especially in cases in which the iodide pump is blocked or overwhelmed by a high concentration of plasma iodide (Van Middlesworth 1963).

This section is mainly devoted to the secretion of ^{131}I into cows' milk but the secretion into goats' milk and into human milk are also discussed as the contamination by ^{131}I of these foodstuffs is included in the estimation of the radiation exposures (see **Chapter 7**).

4.1.4.1. Cows' milk

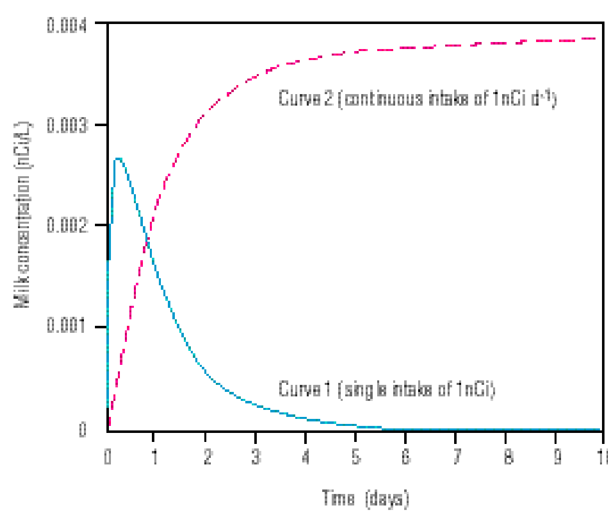
After the oral administration of a single dose of ^{131}I, the radionuclide appears in the milk within 30 minutes and reaches its maximum concentration within 12 hours. The concentration subsequently declines, at first with an effective half-life of about 16 hours, and then more slowly; it is approximately 1 percent of the maximum value 7 days after the intake (Garner and Sansom 1959). Curve 1 in *Figure 4.13* illustrates the variation with time of the ^{131}I concentration in cows' milk, in nCi L^{-1}, following a single intake of 1 nCi (Garner 1967). Curve 2 in *Figure 4.13* depicts the increase of ^{131}I concentration in milk (nCi L^{-1}) when ^{131}I is ingested at a constant rate of 1 nCi d^{-1}. For practical purposes, the equilibrium value is reached after 1 week of intake.

The cumulative fraction of the administered dose of ^{131}I that is secreted in cows' milk is about 5% (Comar 1966), with a range from 1 to 20% (Sasser and Hawley 1966). Considered as a machine for the transfer of ^{131}I from its diet to its milk, the dairy cow seems to be the most inefficient of the ruminants (Garner and Sansom 1959). Large variations in the fraction of the administered dose that is secreted in cows' milk have been observed, not only between individual animals, but also in the same animal at different times. Milk yield has been shown to be one factor, as the greater iodine secretion into milk appears to be related primarily to the greater volume of milk (Miller and Swanson 1963).

Describing the transfer in terms of the concentration in milk reduces the observed variations (Garner 1971). The intake-to-milk transfer coefficient for ^{131}I and for cows, f_m (d L^{-1}), is defined as the time-integrated concentration of ^{131}I in milk (nCi d L^{-1}) per unit of ^{131}I activity consumed by the cow (nCi) or, alternatively, the concentration of ^{131}I in milk (nCi L^{-1}) obtained at equilibrium for a constant rate of activity intake of ^{131}I (nCi d^{-1}). The latter ratio is expressed in nCi L^{-1} per nCi d^{-1} and is numerically equal to the time integral of the ^{131}I concentrations in milk, in nCi d L^{-1}, following a single intake of 1 nCi, represented by the area under curve 1 in *Figure 4.13.*

The transfer coefficient, f_m, has been determined experimentally in a large number of studies, including tracer experiments with stable or radioactive iodine and field studies in which pasture was contaminated by ^{131}I resulting from releases from nuclear facilities or from fallout from nuclear weapons tests. Reported values range from 2×10^{-3} to 4×10^{-2} d L^{-1} (Hoffman 1979; Ng et al. 1977; Voillequé 1989). The intake-to-milk transfer coefficient does not seem to depend on the chemical form of ^{131}I: Bretthauer et al. (1972) administered radioiodine-labelled elemental iodine, methyl iodide, sodium iodide, or sodium iodate to cows and found no significant differences in milk transfer among the compounds tested. There are, however, indications that the physical form of ^{131}I may influence the transfer coefficient. In their literature review, Ng et al. (1977) derived average values for f_m of 8.1×10^{-3} d L^{-1} for tracer experiments, of 4.3×10^{-3} d L^{-1} for ^{131}I in fission-product clouds, and of 2.4×10^{-3} d L^{-1} for ^{131}I in underground test debris.

Figure 4.13. Variation with time of the average concentration of ^{131}I in milk fresh from cow (nCi L^{-1}) in case of a single intake of 1nCi by the cow (curve 1) and of a continuous intake of 1nCi d^{-1} (curve 2).



Other factors that might have an influence on the secretion of ^{131}I in cows' milk have been investigated in a number of studies and reviewed by Tamplin (1965), Garner and Russell (1966), and Lengemann et al. (1974), among others:

- Breed: Tamplin (1965) analyzed the available data on the basis of breed and found the following means and ranges for the values of f_m (d L^{-1}):

Breed	Mean	Range	Number
Ayrshire	0.73	0.50-1.10	4
Holstein	0.90	0.17-2.06	20
Jersey	1.04	0.68-1.40	2
Guernsey	1.20	0.76-1.80	6

The number of animals in each group is too small to allow any substantial conclusions to be drawn from the data.

- The transfer coefficient f_m was found to be higher in the later stage of lactation: the effect of the stage of lactation on the transfer of stable iodine to milk was studied by Hanford et al. (1934) by comparing cows in different stages of lactation during the same season.The transfer coefficient f_m was found to be higher in the later stage of lactation than in the earlier stage, with an average ratio of 1.6 and a range of 1.3 to 5.3 (Hanford et al. 1934). In a typical dairy herd, cows will be at all stages of lactation during any season of the year. Therefore, the effect of stage of lactation will not be evident in the mixed milk of a dairy herd (Tamplin 1965).

- Iodine intake: the normal range of dietary intake of iodine is from 5 to 50 mg d^{-1}; within that range, the iodine content of the cows' diet has little effect on the transfer coefficient f_m (Alderman and Stranks 1967). A daily iodine intake of as much as 4 g causes only a 50% reduction in the f_m value (Lengemann and Swanson 1957). Therefore, the effect of the iodine intake does not appear to be significant under normal agricultural practices (Tamplin 1965). However, it has been suggested that the variations in the f_m values obtained in different countries or using different methods may be due to variations in stable iodine intake (Lengemann and Comar 1964; Voigt et al. 1989).

- Feed type: since iodine is present in milk in higher concentration than is found in blood, experiments were conducted to ascertain whether the iodine pump of the mammaries is inhibited by compounds such as thiocyanate, perchlorate, and nitrate that act on the thyroid gland (Bobek and Pelczarska 1963; Brown-Grant 1961; Garner et al. 1960; Lengemann and Thompson 1963; Miller et al. 1969; Piironen and Virtanen 1963). The results indicate that relatively large amounts of goitrogenic compounds are required to reduce the iodine concentration in milk by one-half (for example, in excess of 2 g of thiocyanate). Nevertheless, it is possible for cows to obtain these quantities in their food. Generally, the higher intakes of goitrogenic compounds would be expected during winter feeding when the cows are given silage, such as turnip or rutabaga (Tamplin 1965). However, differences in the transfer to milk also were observed according to type of pasture: cows fed ^{131}I-contaminated sudangrass were found to secrete half as much of the iodine in their milk as do cows fed similarly contaminated alfalfa (Black et al. 1975) or bromegrass (Moss et al. 1972). The chemical compound in the sudangrass that may affect the cows' mammary glands has not been positively identified (Moss et al. 1972).

- Season: Lengemann et al. (1957) found that seasonal changes in the amount of ^{131}I that reaches milk are so pronounced that they obscure the possible effects of other factors like the stage of lactation or the milk yield. The highest levels were recorded in the spring and summer months. The initial increase in iodine transfer coincided roughly with the onset of spring and was ascribed to the reduced iodine requirement of the thyroid gland. Later, during the spring to summer period, a high ^{131}I concentration in milk was maintained by active concentration in the blood (Lengemann et al. 1957). It is also to be noted that extremes of environmental temperature were found, in goats, to have a substantial effect on the amount of radioiodine transferred to milk; at 33 ºC, the amount transferred to milk was determined to be 6.5 times higher than at 5 ºC (Lengemann and Wentworth 1979). However, Hanford et al. (1934) found the stable iodine content of milk to be lowest from April to September and to exhibit a peak value from October to March. Further, Garner et al. (1960) found no evidence of a clear-cut seasonal effect on transfer of ^{131}I in milk in animals housed throughout the year and receiving a constant diet of hay and dairy nuts.

It is clear from the above that many factors are involved in the variability of the value of the transfer coefficient, f_m. The mechanism by which iodine moves into milk is not well understood; the overall situation is probably very complex involving interrelationships of feed type, breed, stage of lactation, and milk yield, among other factors. The available observations represent the integrated response to particular sets of interacting conditions.

Literature values related to the determination of feed-to-milk transfer coefficients for cows and ^{131}I are presented in *Table 4.6.* The values are classified into three categories according to the type of experiment or measurement that was carried out, as well as to the nature or origin of the iodine measured:

- the f_m values in category 1 result from controlled experiments using ^{131}I from weapons fallout; in these experiments, the activity intake of ^{131}I by a number of cows and the secretion of ^{131}I into milk of those same cows were measured;

- the f_m values in category 2 also result from controlled experiments using ^{131}I (and in some cases ^{125}I). However, the ^{131}I used did not originate in the detonation of nuclear weapons, and thus may have different physical and chemical properties;

- the f_m values in category 3 are derived from field measurements of ^{131}I in pasture grass and in cows' milk following unplanned environmental releases. Those measurements may have been carried out after atmospheric nuclear tests or when radioactive materials were inadvertently released after underground nuclear tests or in an accident such as Chernobyl. Also included are field measurements of ^{129}I around nuclear fuel reprocessing plants and field measurements of stable iodine. In this category, the activity intake of ^{131}I by the cow was not measured, but assessed from cows' consumption estimates.

The 17 average values of f_m listed in category 1 correspond most closely to the conditions considered in this report, i.e., the ingestion by cows of fallout ^{131}I resulting from nuclear tests at the NTS. The geometric mean of those 17 values is 2.1 x 10^{-3} d L^{-1} and the geometric standard deviation of their distribution is 1.9. However, most of the 17 values are related to tests that were conducted at the NTS in the 1960s, i.e. cratering tests and underground tests that inadvertently released radioactive materials into the atmosphere. The ^{131}I released by those tests, which amounts to only 2% of the total ^{131}I released by all NTS tests, may have been in different physical and chemical forms than the ^{131}I produced in the atmospheric tests of the 1950s. Unfortunately, experiments aiming at the determination of f_m values for ^{131}I from the NTS tests were not conducted in the 1950s because the radiological importance of the deposition-pasture-cow-milk exposure route had not been fully recognized in the United States. The only two controlled experiments that investigated the ingestion of ^{131}I from bomb fallout from the 1950s that were reported in the literature were conducted in England and were related to the Buffalo series of 1956 (Squire, Middleton, et al. 1961) and to the Grapple series of 1958 (Squire, Sansom, et al. 1961). These two controlled experiments resulted in an average f_m value of 4 x 10^{-3} d L^{-1}.

As indicated by Ng et al. (1977), the f_m values derived from tracer data (category 2) are usually higher than those derived from fallout ^{131}I (category 1). The geometric mean of the 45 average values of f_m listed under category 2 in *Table 4.6* is 5.9 x 10^{-3} d L^{-1} and the geometric standard deviation of their distribution is 1.9.

The f_m values inferred from field measurements (category 3) are less reliable than those obtained from controlled experiments (categories 1 and 2) because they require estimates of the consumption rates of pasture grass by cows. The geometric mean of the 16 average values of f_m listed under category 3 in Table 4.6 is 2.5 x 10^{-3} d L^{-1} and the geometric standard deviation of their distribution is 2.3.

The log-transformed values of the feed-to-milk transfer coefficient for cows presented in *Table 4.6* are plotted on probability scale in *Figure 4.14*; the overall distribution of the f_m values is relatively well approximated by a log-normal law with a geometric mean of 4.4 x 10^{-3} d L^{-1} and a geometric standard deviation of 2.1.

In this report, the geometric mean value of f_m for ^{131}I in NTS fallout and for cows is taken to be 4 x 10^{-3} d L^{-1} for any county of the contiguous United States and for any time of the year. This value corresponds to the results of controlled experiments on fallout ^{131}I from the 1950s carried out by Squire, Sansom, et al. (1961) and is in agreement with the geometric mean of all average f_m values that could be found in the literature. It is recognized that the value of f_m may be influenced by many factors such as the physical and chemical characteristics of the ^{131}I ingested, the breed of the cow, the stage of lactation, the milk yield, feed type, and time of year. However, the data needed to quantify the influence of these factors on the value of f_m are not available. The distribution of the f_m values is assumed to be lognormal for any county of the contiguous United States and for any time of the year, with a GSD of 2.1. This value is equal to that derived from the experiments, carried out under a large variety of conditions, which are reported in *Table 4.6*.

Figure 4.14. Distribution of the feed-to-milk transfer coefficients for ^{131}I and for cows.

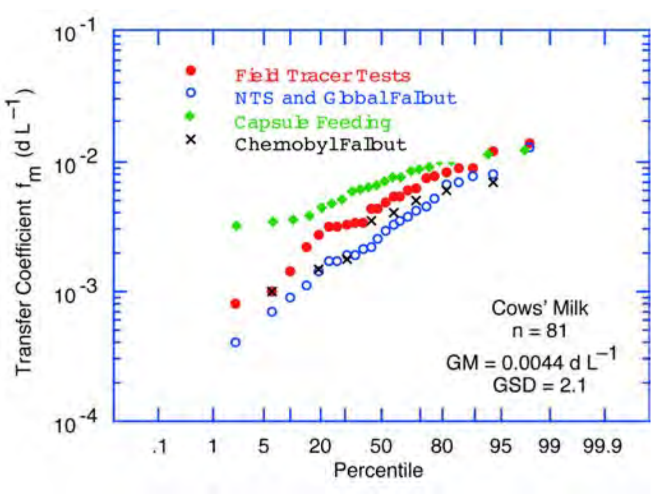


Table 4.6. Available data on the transfer of ^{131}I from feed to cows' milk.

Transfer coefficients f_m (d/L) Mean	Minimum	Maximum	Type of experiment	Type of feed	Physical or chemical form	No. of cows	Stable Iodine intake (mg/d)	Time of year	Breed	Milk yield (L/d)	References
1. CONTROLLED EXPERIMENTS WITH ^{131}I FROM WEAPONS FALLOUT.											
0.0069			Planned release of ^{131}I on spread hay (shot Palanquin)	Alfalfa		6	250	April	Holstein	13.9	Black et al. 1971a
0.0078			Planned release of ^{131}I on spread hay (shot Palanquin)	Alfalfa		3	250	April	Holstein	16.3	Black et al. 1971a
0.0035			Planned release of ^{131}I on spread green chop (shot Palanquin)	Alfalfa		6	250	April	Holstein	16.0	Black et al. 1971a
0.0011			Planned release of ^{131}I on baled hay (shot Cabriolet)	Alfalfa		4	250	January	Holstein	20.1	Black et al. 1971b
0.0007			Planned release of ^{131}I on spread hay (shot Buggy)	Alfalfa	0.6 μm median dia.	4	250	March	Holstein	17.8	Black et al. 1971b
0.0014			Planned release of ^{131}I on spread hay (shot Buggy)	Alfalfa	0.6 μm median dia.	4	250	March	Holstein	19.2	Black et al. 1971b
0.0009			Planned release of ^{131}I on spread hay (shot Buggy)	Alfalfa	0.6 μm median dia.	4	250	March	Holstein	15.1	Black et al. 1971b
0.0021			Planned release of ^{131}I on spread hay (shot Schooner)	Alfalfa	0.6 μm-0.9 μm median diameter	4	250	December	Holstein	19.1	Black et al. 1972
0.0017			Planned release of ^{131}I on spread hay (shot Schooner)	Alfalfa	0.6 μm-0.9 μm median diameter	4	250	December	Holstein	16.7	Black et al. 1972
0.0019			Planned release of ^{131}I on spread hay (shot Schooner)	Alfalfa	0.6 μm-0.9 μm median diameter	4	250	December	Holstein	13.7	Black et al. 1972
0.0037	0.0014	0.0082	Single dose of filters from fallout cloud collected 3-4 days after detonation	Alfalfa	Weapons fallout (Buffalo)	5		Sep-Oct	Ayrshire	7.7	Squire, Middleton et al. 1961
0.0017			Feeding of fallout debris (Schooner)		Weapons fallout	1		December			Porter et al. 1969
0.0041			Single dose of filters from fallout cloud collected 33 hours after detonation (3-d recovery only)		Weapons fallout (Grapple)	1				10.3	Squire, Sansom et al 1961
0.0019			Fallout from accidental underground venting								Porter, unp. (quoted in Ng et al. 1977)
0.0033			Fallout from Plowshare cratering event I								Porter, unp. (quoted in Ng et al. 1977)
0.0025			Fallout from Plowshare cratering event II								Porter, unp. (quoted in Ng et al. 1977)
0.0022			Fallout from accidental underground venting								Porter, unp. (quoted in Ng et al. 1977)
2. CONTROLLED EXPERIMENTS WITH RADIOIODINE TRACERS.											
0.0063			Single dose of carrier free ^{131}I	Brome		6			Holstein	16	Moss et al. 1972
0.0034			Single dose of carrier free ^{131}I	Sudan		6			Holstein	16	Moss et al. 1972
0.0037			Single dose of NaI with ^{131}I		Iodide	8	250	August	Holstein	23.1	Shimoda et al. 1970
0.0032			Controlled release of ^{131}I on spread hay	Alfalfa	Diatomaceous earth dry aerosol 23 μm median dia.	4	250	October	Holstein	20	Barth and Seal 1966

Transfer coefficients f_m (d/L)			Type of experiment	Type of feed	Physical or chemical form	No. of cows	Stable Iodine intake (mg/d)	Time of year	Breed	Milk yield (L/d)	References
Mean	Minimum	Maximum									
0.0008			Controlled release of ^{131}I on green chop	Sudan	Diatomaceous earth dry aerosol 23 μm median dia.	4	250	October	Holstein	24.5	Barth and Seal 1966
0.001			Controlled release of ^{131}I on green chop	Sudan	Diatomaceous earth dry aerosol 23 μm median dia.	4	250	October	Holstein	21	Barth and Seal 1966
0.0031			Controlled release of ^{131}I on spread hay	Alfalfa	Diatomaceous earth dry aerosol 2 μm median dia.	4	250	June	Holstein	21.3	Stanley et al. 1969
0.0053			Controlled release of ^{131}I on spread green chop	Alfalfa	Diatomaceous earth dry aerosol 2 μm median dia.	4	250	June	Holstein	28.1	Stanley et al. 1969
0.0053			Controlled release of ^{131}I on green chop	Alfalfa	Diatomaceous earth dry aerosol 2 μm median dia.	6	250	June	Holstein	23.6	Stanley et al. 1969
0.0022			Controlled release of ^{131}I on spread hay	Alfalfa	$Na^{131}I$ 169 μm droplets	6	250	September	Holstein	20.4	Douglas et al. 1971
0.0034			Controlled release of ^{131}I on green chop	Alfalfa	$Na^{131}I$ 169 μm droplets	6	250	September	Holstein	17.8	Douglas et al. 1971
0.0034			Controlled release of ^{131}I on green chop	Alfalfa	Diatomaceous earth ^{131}I dry aerosol, 0.13 μm	6	250	June	Holstein	22.5	Mason et al. 1971
0.0060			Controlled release of ^{131}I on pasture	Alfalfa	Gaseous ^{131}I	6	250	September	Holstein	19.2	Black and Barth 1976
0.0044			Controlled release of ^{131}I on pasture	Alfalfa	Gaseous ^{131}I	6	250	September	Holstein	19.4	Black and Barth 1976
0.0014			Controlled release of ^{131}I on pasture	Sudan	Diatomaceous earth ^{131}I dry aerosol, 0.6 μm median diameter	3	250	September	Holstein	25.1	Black et al. 1975
0.0031			Controlled release of ^{131}I on pasture	Alfalfa	Diatomaceous earth ^{131}I dry aerosol, 0.6 μm median diameter	3	250	September	Holstein	23.4	Black et al. 1975
0.0048			Planned release of ^{131}I on spread hay (destruction of a rocket reactor)	Alfalfa		5	250	January	Holstein	15.5	Black et al. 1969
0.0136			Planned release of ^{131}I on spread hay (destruction of a rocket reactor)	Alfalfa		5	250	January	Holstein	16.6	Black et al. 1969
0.0075	0.003	0.024	Controlled release of ^{131}I over pasture	Mixed	Iodide gas	6			Holstein	12.6	Sasser & Hawley 1966
0.0044	0.0025	0.0066	Controlled release of ^{131}I over pasture	Mixed	Iodine gas	6		July	Holstein	13.4	Zimbrick & Voilleque 1969; Voilleque 1989
0.0031	0.0021	0.0045	Daily feeding of capsules spiked with Na ^{131}I	Mixed	Iodide	3		August	Holstein	15.0	Zimbrick & Voilleque 1969; Voilleque 1989
0.0089	0.0061	0.011	Controlled release of ^{131}I over open-range grass	Crested wheat grass	Iodide	6		May	Holstein	14.0	Bunch 1968;Bunch 1966
0.0061	0.0025	0.010	Controlled release of ^{131}I over open-range pasture	Mixed	Iodide	6		September	Holstein	12.6	Bunch 1968
0.0070	0.0055	0.0081	Chernobyl: dried grass pellets	Chernobyl fallout		3	6	May	Deutsches Flekvieh	13.6	Voigt et al. 1989

Transfer coefficients f_m (d/L)			Type of experiment	Type of feed	Physical or chemical form	No. of cows	Stable Iodine intake (mg/d)	Time of year	Breed	Milk yield (L/d)	References
Mean	Minimum	Maximum									
0.0090			Single doses of ^{131}I		Iodide	1			Deutsches Flekvieh		Voigt et al. 1988
0.0070	0.005	0.0112	Single dose of carrier free ^{131}I in gelatine capsules		NaI	4	> 4	May-Aug	Ayrshire		Garner, Sansom, and Jones 1960
0.0078	0.0047	0.0174	Single dose of ^{131}I deposited upon grass		Elemental ^{131}I	4	> 4	May-Aug	Ayrshire		Garner, Sansom, and Jones 1960
0.0050	0.0027	0.0171	Single dose of carrier-free ^{131}I								Squire, Middleton et al. 1961
0.0046			Single dose of 50g KI labelled with ^{131}I		Iodide	1			Shorthorn	7.6	Glascock 1954
0.0064			Single intravenous dose of Na I labelled with ^{131}I		Iodide	8				10.7	Miller and Swanson 1963
0.0073			Single intravenous dose of Na I labelled with ^{131}I		Iodide	8				4.9	Miller and Swanson 1963
0.0043			Twice daily feeding of a mixture of ^{131}I & ^{125}I		Iodide & iodate	3			2 Jersey & 1 Ayrshire	7.5	14 Lengemann 1969
0.0035			Single dose of ^{131}I		Salt solution	1			Red Poll	7.7	Steenberg 1959
0.0085	0.0071	0.010	Single dose and daily doses of ^{131}I		Sodium iodide	1			Jersey	6.6	Lengemann & Swanson 1959
0.011	0.005	0.022	Daily doses of carrier-free ^{131}I		Potassium iodide	9		Jan-Oct	Guernsey & Holstein	12.4	Lengemann & Comar 1964
0.0075			Single dose of ^{131}I			3			Jersey		Lengemann 1963
0.0058			Single dose of ^{131}I			3			Jersey		Lengemann 1963
0.0099	0.0038	0.034	Single dose of ^{131}I			5			Jersey		Lengemann, Swanson et al. 1957
0.0059			Administration of carrier-free ^{131}I		NaI	6				6.8	Miller et al. 1963
0.012			Twice daily doses of ^{131}I		NaI	2					Comar, Wentworth et al. 1970
0.0084			Sodium iodide								Porter, unp. (quoted in Ng et al. 1977)
0.012			Controlled release of ^{131}I over open-range grass		Elemental I	6		May-June	Holstein	7.6	Hawley et al. 1964 Hawley 1966
0.0082			Controlled release of ^{131}I over irrigated grass		Elemental I	6		September	Holstein	11.8	Hawley 1966
0.011	0.0084	0.013	Single dose and daily dose of ^{131}I		Sodium iodide	1			Jersey	7.1	Lengemann & Swanson 1957
0.010	0.007	0.017	Twice daily doses of ^{125}I								Miller et al. 1965

Transfer coefficients f_m (d/L)			Type of experiment	Type of feed	Physical or chemical form	No. of cows	Stable Iodine intake (mg/d)	Time of year	Breed	Milk yield (L/d)	References
Mean	Minimum	Maximum									
3. FIELD MEASUREMENTS OF STABLE IODINE, OR OF RADIOIODINE RESULTING FROM UNPLANNED RELEASES.											
0.0052			Accidental release of ^{131}I (shot Pinstripe)	Alfalfa		4	250	April	Holstein	20.1	Barth et al. 1969
0.0029			Accidental release of ^{131}I (shot Pinstripe)	Alfalfa		6	250	April	Holstein	16.7	Barth et al. 1969
0.0004			Measurements in pasture and milk following weapons tests		Fallout ^{131}I	5		Dec.		5.6	Straub & Fooks, 1963 Kahn et al. 1962
0.0015			Measurements in pasture and milk following the Chernobyl accident		Chernobyl ^{131}I	50	Small?	May	Deutsches Flekvieh		Voigt et al. 1989
0.0035			Measurements in pasture and milk following the Chernobyl accident		Chernobyl ^{131}I	1	Small?	May	Deutsches Flekvieh		Voigt et al. 1989
0.0040	0.0028	0.0051	Measurements in pasture and milk following the Chernobyl accident		Chernobyl ^{131}I	30	Small?	May	Deutsches Flekvieh Flekvieh		Voigt et al. 1989
0.0018	0.0004	0.0073	Measurements in pasture and milk following the Chernobyl accident		Chernobyl ^{131}I			May			BIOMOVS 1991
0.0045			Measurements following a Chinese test. Assumes a grass intake of 45 kg/d.	Pasture	Weapons fallout	1		January	Hereford-Angus	11.4	Porter et al. 1967
0.006			Measurements of ^{131}I in grass and milk following the Chernobyl accident	Pasture	Chernobyl ^{131}I	40		May	Holstein		Tracy et al. 1989
0.005			Measurements of ^{131}I in grass and milk following the Chernobyl accident	Pasture	Chernobyl ^{131}I			May			Assimakopoulos et al. 1988
0.001			Measurements of ^{131}I in grass and milk following the Chernobyl accident	Pasture	Chernobyl ^{131}I			May			Dreicer and Klusek 1988
0.0027	0.0017	0.0068	Measurements of stable iodine in feed and in milk			18 herds					Alderman and Stranks 1967
0.009	0.018	0.0048	Measurements of stable iodine in feed and in milk								Kirchgessner 1959
0.0026			Measurements of ^{129}I in grass and milk								Hauschild and Aumann 1989
0.0024			Measurements of ^{129}I released on pasture								Handl et al. 1990
0.0027			Measurements of ^{129}I in grass and milk								Wilkins 1989
0.0127	0.0061	0.0192	Measurements in pasture and milk around the Monticello reactor site following a weapon test	Pasture	Fallout ^{131}I	4		July	Holstein		Weiss et al. 1975
0.0067	0.0034	0.016	Measurements in pasture and milk around the Dresden reactor site following a weapon test	Pasture	Fallout ^{131}I	4		July	Holstein		Weiss et al. 1975
0.0081	0.0041	0.014	Measurements in pasture and milk around the Quad Cities reactor site following a weapon test	Pasture	Fallout ^{131}I	2		July-Oct.			Voilleque et al. 1981

4.1.4.2. Goats' milk

Because of the overwhelming economic importance of dairy cows, relative to dairy goats, much less attention has been given to the transfer of ^{131}I from diet to milk for dairy goats. Literature values are presented in *Table 4.7*, which is primarily based on a review by Hoffman (1978). The fraction of the ^{131}I activity administered or ingested that is transferred to milk is about 5 times higher for goats than for cows as the mammary gland of the goat is a very efficient iodine trap. Because the rate of milk production is about 10 times smaller for goats than for cows, the feed-to-milk transfer coefficient for goats, $f_{m,gt}$, is about 50 times greater than that for cows. The $f_{m,gt}$ values presented in *Table 4.7* range from 0.03 to 0.65 d L^{-1} with an arithmetic mean of 0.27 d L^{-1}. The feed-to-milk transfer coefficients for goats presented in *Table 4.7* are plotted on a log probability chart in *Figure 4.15*. The distribution of the $f_{m,gt}$ values is relatively well approximated by a log-normal distribution with a geometric mean of 0.22 d L^{-1} and a geometric standard deviation of 2.5. The predicted mean of the log-normal distribution (0.33 d L^{-1}) exceeds the computed mean given above. It is assumed in this report that the $f_{m,gt}$ values are log-normally distributed with an average (geometric mean) of 0.2 d L^{-1} and a geometric standard deviation of 2.5 for any county of the contiguous United States and at any time of the year.

4.1.4.3. Human milk

The few experimental data available on the transfer of ^{131}I into human maternal, mt, milk, $f_{m,mt}$, are related to the concern that the administration of radiopharmaceuticals containing ^{131}I to lactating women would result in unacceptable thyroid doses to the nursing infants (Karjaleinen, et al. 1971; Miller and Weetch 1955; Nurnberger and Lipscomb 1952; Weaver, et al. 1960; Wyburn 1973). These experiments showed: (a) that most of the ^{131}I secreted in milk occurs within 24 hours, (b) that most of the activity secreted in the milk is in the form of free or inorganic iodine, irrespective of the chemical form under which iodine is administered, and (c) that the percentage of the administered ^{131}I that is secreted in milk seems to increase with the rate of milk production, resulting in ^{131}I concentrations in milk roughly independent of the rate of milk production.

Table 4.8 summarizes the characteristics of the experiments and the values of the transfer coefficient $f_{m,mt}$ that can be derived from those experiments. The log-transformed values of $f_{m,mt}$ also are plotted on a probability scale in *Figure 4.16*. The values of $f_{m,mt}$ are resonably well represented by a log-normal distribution with a geometric mean of 0.1 d L-1 and a GSD of 2.9. The predicted mean of the log-normal distribution (0.21 d L^{-1}) exceeds the computed mean of 0.14 d L^{-1}. Most of the available data are related to women with health problems; it is assumed that the same distribution of $f_{m,mt}$ applies to healthy women for any county of the contiguous United States.

An indirect confirmation of the representativity of the average value for $f_{m,mt}$ given above can be inferred from the measurements of ^{131}I in cows' and human milk carried out in Europe after the Chernobyl accident (Campos Venuti et al. 1990; Gorlich et al. 1988; Haschke et al. 1987; Lindemann and Christensen 1987). In Vienna, Austria, Haschke et al. (1987) found that the ^{131}I concentration in pooled breast milk was about one-tenth of that in cows' milk on sale in the area. In Rome, Italy, the ^{131}I concentration in human milk was about one per cent of that in cows' milk from the Central Dairy (Campos Venuti et al. 1990), while in the canton Aargau in Switzerland the time-integrated concentration of ^{131}I in human milk was 7% of that in cows' milk (Gorlich et al. 1988). The ratio of the ^{131}I concentrations in human milk and in cows' milk seems therefore to be between 0.01 and 0.1. Assuming that the consumption of cows' milk by lactating women is high (0.8 L d^{-1}, see **Chapter 6**) and that the consumption of cows' milk contaminated by ^{131}I represented the bulk of the activity intake of ^{131}I by women after the Chernobyl accident, the value of the transfer coefficient $f_{m,mt}$ is estimated from those measurements to be in the range from 0.01 to 0.1 d L^{-1}, This range is lower than the range of values presented in *Table 4.8*. A lower assumed milk consumption would increase the post-Chernobyl estimates of $f_{m,mt}$.

Figure 4.15. Distribution of the feed-to-milk transfer coefficient for ^{131}I and for goats.

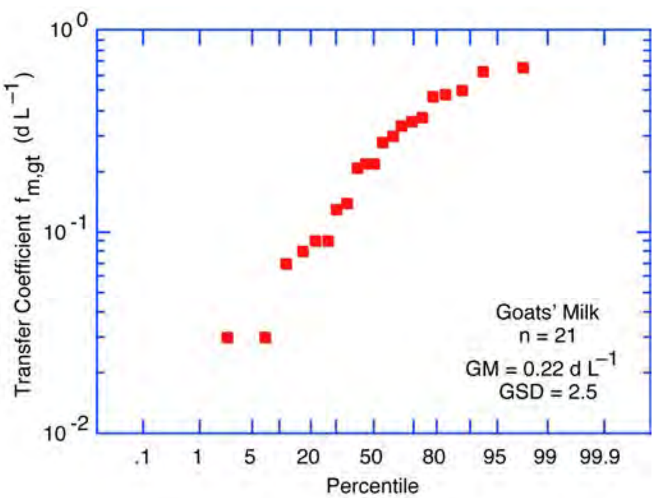


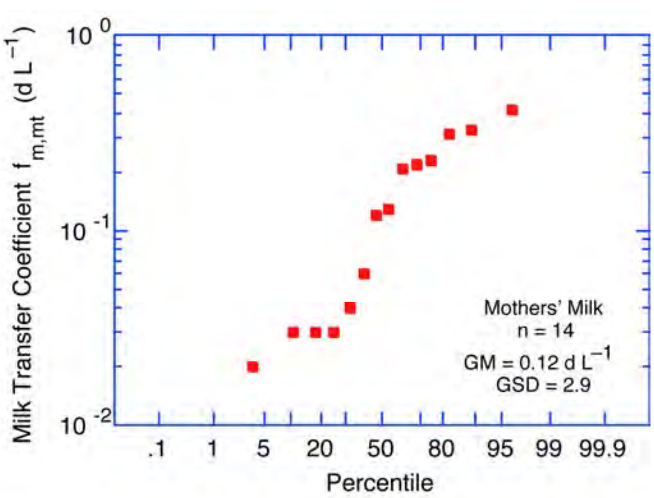
Table 4.7. Available data on the transfer of ^{131}I from diet to goats' milk.

Transfer coefficient $f_{m,gt}$ (d/L)	Fraction of intake transfered to milk	Milk production rate (L/d)	Number of goats	Comments	References
0.21	0.31		1	Value of $f_{m,gt}$ derived from an assumed milk production rate of 1.5 L/d.	Wright et al. 1955
0.30	0.45		1	Value of $f_{m,gt}$ derived from an assumed milk production rate of 1.5 L/d.	Wright et al. 1955
0.34	0.51		1	Value of $f_{m,gt}$ derived from an assumed milk production rate of 1.5 L/d.	Wright et al. 1955
0.35	0.53		1	Value of $f_{m,gt}$ derived from an assumed milk production rate of 1.5 L/d.	Wright et al. 1955
0.09	0.20	2.2	1	Single dose of ^{125}I.	Binnerts et al. 1962
0.03	0.06	2.2	1	Single dose of ^{125}I.	Binnerts et al. 1962
0.65				Average value for ^{131}I steady state; taken from unpublished data.	Comar 1963
0.28	0.45	1.6	14	Gelatine capsules containing ^{131}I fed twice daily for up to 25 days.	Lengemann and Wentworth 1966
0.09	0.14		4	Value of fm,gt derived from an assumed milk production rate of 1.5 L/d.	Cline et al. 1969
0.47	0.56	1.2	2	Twice daily doses of a ^{131}I iodine and ^{131}I iodate mixture given for 14 days.	Lengemann 1969
0.5			9	Daily oral administration of ^{131}I for 25 days.	Lengemann 1970
0.48	0.30	0.6	6	Daily doses of ^{131}I	Lengemann 1970
0.62	0.33	0.5	6	Daily doses of ^{131}I, in addition to 4 mg of stable iodine	Lengemann 1970
0.37			16	Daily doses of ^{131}I for 21 days	Lengemann 1970
0.03	0.08	2.3	1	Feeding for 8 days of alfalfa contaminated by ^{131}I released in gaseous form.	Black et al. 1976
0.07	0.16	2.4	1	Feeding for 8 days of alfalfa contaminated by ^{131}I released in gaseous form.	Black et al. 1976
0.13	0.19	1.5	1	Feeding for 8 days of alfalfa contaminated by ^{131}I released in gaseous form.	Black et al. 1976
0.22	0.29	1.3	1	Feeding for 8 days of alfalfa contaminated by ^{131}I released in gaseous form.	Black et al. 1976
0.08			12	Measurements in pasture and in milk in May (fresh pasture intake of 2.5 kg/d).	Bondietti and Garten 1984
0.22			12	Measurements in pasture and in milk in July (fresh pasture intake of 2.5 kg/d).	Bondietti and Garten 1984
0.14		0.25-1.4	12	Measurements in pasture and in milk in September (fresh pasture intake of 2.5 kg/d).	Bondietti and Garten 1984

Table 4.8. Available data on the transfer of ^{131}I into the milk of lactating women.

Number of lactating women	Chemical form of administered ^{131}I	Rate of milk production (L d^{-1})	Transfer coefficient $f_{m,mt}$ (d L^{-1})	Comments	References
6	Not indicated			Euthyroid patients	Weaver et al. 1960
(Case 1)		0.63	0.42		
(Case 2)		0.11	0.13		
(Case 3)		0.12	0.33		
(Case 4)		0.006	0.23		
(Case 5)		0.009	0.03		
(Case 6)		0.20	0.31		
7	Macroaggregated human serum albumin (MAA)		0.03	Patients subjected to lung scanning. Thyroid blocked with KI.	Karjalainen et al. 1971
25	Ortho-iodohippuric acid	0.27	0.03	Patients subjected to lung scanning. Thyroid blocked with KI.	Karjalainen et al. 1971
2					
(Case 1)	Macroaggregated human serum albumin (MAA)		0.12	Patient with pulmonary embolism.	Wyburn 1973
(Case 2)			0.02	Patient with suspected pulmonary embolus.	
1	Not indicated	0.22	0.21	Suspected case of thyroxicosis.	Miller and Weetch 1955
2	Carrier-free				Nurnberger and Lipscomb 1952
(Case 1)			0.06		
(Case 2)			0.04	Suspected case of thyrotoxicosis.	
(Case 2)			0.22	Same woman, 2 months later.	

Figure 4.16. Distribution of the diet-to-milk transfer coefficient for ^{131}I and for lactating women



4.1.5. Discussion

As indicated at the beginning of this Chapter, the time-integrated concentration of ^{131}I in fresh cows' milk, IMC_p, resulting from the consumption of ^{131}I-contaminated pasture in county, i, following deposition of ^{131}I on the ground on day, j, can be expressed as:

$$IMC_p\,(i, j) = \int_0^\infty C_p\,(i, j, t) \times PI\,(i, j, t) \times f_m \times dt \qquad (4.1)$$

Since the value of the intake-to-milk transfer coefficient for ^{131}I in cows, f_m, is assumed to be independent of the time of the year and of the location of the county in which the deposition took place, *equation 4.1* can be written:

$$IMC_p\,(i,j) = f_m \times \int_0^\infty C_p\,(i, j, t) \times PI\,(i, j, t) \times dt \qquad (4.29)$$

The integral represents the activity intake of ^{131}I by the cow, AI_p(i,j), (see *equation 4.23*), so that *equation 4.29* becomes:

$$IMC_p\,(i, j) = AI_p\,(i, j) \times f_m \qquad (4.30)$$

According to *equation 4.27*, $AI_p(i,j)$ can be expressed as the product of the daily pasture intake equivalent, PI*(i,j), and of the time-integrated concentration of ^{131}I in pasture, $IC_p(i,j)$. *Equation 4.30* can therefore be written:

$$IMC_p\ (i,\ j) = IC_p\ (i,j) \times PI^*\ (i,\ j) \times f_m \qquad (4.31)$$

The time-integrated concentration of ^{131}I in pasture, $IC_p(i,j)$, is, in turn, the product of: (a) the deposition density of ^{131}I, DG(i,j), (b) the mass interception factor, F*(i,j), and (c) the effective mean time of residence of ^{131}I on pasture grass, τ_e (see *equation 4.18*). Replacing $IC_p(i,j)$ by its value in *equation 4.31* yields:

$$IMC_p\ (i,\ j) = DG\ (i,\ j) \times F^*\ (i,\ j) \times \tau_e \times PI^*\ (i,\ j) \times f_m \qquad (4.32)$$

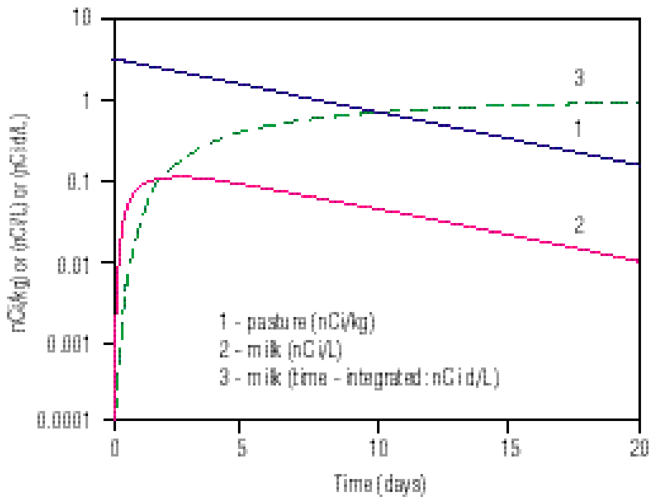
This equation was used to estimate the average time-integrated concentrations (until complete decay of ^{131}I) of ^{131}I in fresh cows' milk, $IMC_p(i,j)$, resulting from deposition, DG(i,j), of ^{131}I in county, i, on day, j. It is recalled that:

- DG(i,j) is expressed in nCi m^{-2} and is estimated, as indicated in **Chapter 3**, for each nuclear test under consideration for each county, i, of the contiguous United States and for a number of days, j, following the explosion,
- F*(i,j) is expressed in m^2 kg^{-1} (dry mass) and depends on the rainfall amount in county, i, on day, j, as well as on the distance of the county centroid from the NTS,
- τ_e is assumed to have an average value (geometric mean) of 6.4 days and to be log-normally distributed with a GSD of 1.3,
- PI*(i,j) is expressed in kg (dry mass) d^{-1} and is estimated as indicated in **Section 4.1.3** for each day of the year and for each county of the contiguous United States,
- f_m is assumed to have an average value (geometric mean) of 0.004 d L^{-1} and to be log-normally distributed with a GSD of 2.1,
- $IMC_p(i,j)$ is expressed in nCi d L^{-1}.

For a deposition density of 1 nCi m^{-2} during the pasture season, the average value of IMC_p varies from 0.003 to 1 nCi d L^{-1} according to the county and the day considered, using a range from 0.7 to 12 kg d^{-1} (**Appendix 3**) for the daily pasture intake equivalent and from 0.13 to 3.1 m^2 kg^{-1} (*Figure 4.7*) for the mass interception coefficient.

The variation with time of the concentration and of the time-integrated concentration of ^{131}I in milk corresponding to the maximum values given in the preceding paragraph are shown in *Figure 4.17*; for comparison purposes, the variation with time of the concentration of ^{131}I in pasture also is shown.

Figure 4.17. Variation with time of the average concentration (nCi/L) and of the time-intergrated concentration (nCi d/L) of ^{131}I in milk fresh from cows due to ingestion of contaminated pasture following a unit deposition of ^{131}I on the ground (1 nCi m^{-2}) for a daily pasture intake equivalent of 12 kg d^{-1} and a mass interception factor of 3.1 m^2 kg^{-1}. The variation with time of the ^{131}I concentration in pasture also is shown.



4.2. ESTIMATION OF THE ^{131}I CONCENTRATIONS IN FRESH COWS' MILK RESULTING FROM TRANSFER PROCESSES OTHER THAN THE CONSUMPTION OF ^{131}I CONTAMINATED PASTURE

Although the largest contribution to the ^{131}I concentrations in cows' milk is usually due to the pasture-cow-milk exposure route, there are other exposure routes by means of which cows can be exposed to ^{131}I, with consequent milk contamination (*Figure 4.18*):

- ingestion of ^{131}I contaminated soil,
- ingestion of vegetation contaminated with ^{131}I resuspended from soil,
- inhalation of ^{131}I in the air,
- ingestion of ^{131}I contaminated water, and
- ingestion of ^{131}I contaminated stored hay.

The respective contributions of these sources of ^{131}I contamination to the total ^{131}I concentration in milk will be compared to that of the ingestion of pasture for the conditions described below. With the exception of inhalation of ^{131}I in the air, these exposure routes are poorly known and difficult to quantify. Very crude assumptions have been made, which are likely to have resulted in overestimates, rather than underestimates, of the ^{131}I concentrations in milk.

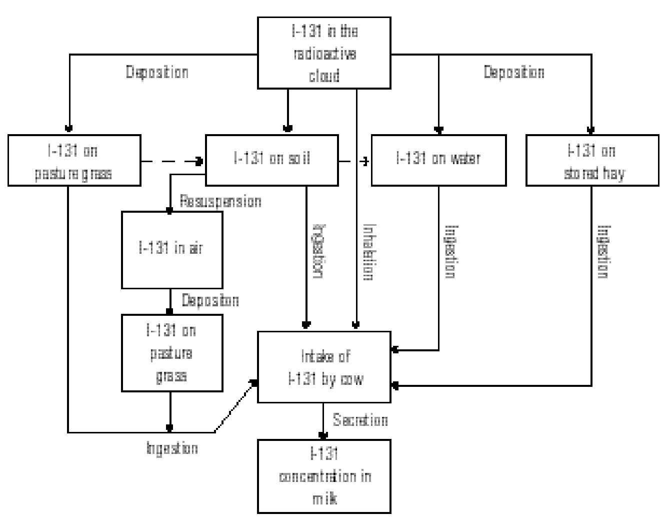
4.2.1. *Scenario Descriptions and General Assumptions*

For illustration purposes, eight scenarios have been considered, representing a range of conditions at two hypothetical sites: (a) one situated far away from the NTS (3000 km), and (b) one close to the NTS (100 km), in an arid region. The factors considered are the amount of rain during deposition, and the presence or absence of cows on pasture during deposition. The characteristics of the eight scenarios are as follows:

Scenario number	Daily rainfall amount (L m^{-2})	Distance from the NTS (km)	Presence of cows on pasture
1	0 (no rain)	3000	yes
2	0 (no rain)	3000	no
3	1 (light rain)	3000	yes
4	1 (light rain)	3000	no
5	100 (heavy rain)	3000	yes
6	100 (heavy rain)	3000	no
7	0 (no rain)	100	yes
8	0 (no rain)	100	no

In each of the eight scenarios, it is assumed that a deposition, DG, of ^{131}I of 1 nCi m^{-2} per unit area of ground has occurred at time t = 0.

Figure 4.18. Exposure routes resulting in the contamination of cows' milk.



The values used for parameters common to several exposure routes, all of which were discussed earlier in this chapter, include:

- Y (standing crop biomass of pasture) = 0.3 kg (dry mass) m^{-2} (**Section 4.1.1.1.1**).
- PI* (daily pasture intake equivalent): PI* = 8 kg d^{-1} (dry mass) for deposition during the pasture season (scenarios 1, 3, 5, and 7), and PI* = 0.1 kg d^{-1} (dry mass) for deposition during the off-pasture season (scenarios 2, 4, 6, and 8). In all cases, the daily pasture intake is assumed to remain constant until the ^{131}I initially deposited on pasture decays to negligible levels (about 60 days), so that the daily pasture intake equivalent is numerically equal to the daily pasture intake during that period (**Section 4.1.3.5**).
- T_r (radioactive half-life of ^{131}I) = 8.04 d, corresponding to a radioactive decay constant λ_r = 0.086 d^{-1}.
- T_w (environmental half-life of stable iodine on pasture) = 10 d, corresponding to a rate constant λw = 0.069 d^{-1} (**Section 4.1.2**).
- T_e (effective half time of residence of ^{131}I on pasture) = 4.5 d, corresponding to an effective mean time of residence τ_e of 6.4 d and to a rate constant λ_e of 0.156 d^{-1} (**Section 4.1.2**).
- f_m (feed-to-milk transfer coefficient for cows) = 4 x 10^{-3} d L^{-1} (**Section 4.1.4**).

4.2.2. *Milk Concentration Due to Ingestion of Pasture (reference conditions)*

Figure 4.19 illustrates the processes involved, which were discussed in detail in **Section 4.1**. The time-integrated concentrations due to the ingestion of pasture, IMC_p, for each of the eight scenarios, sc, are calculated using a modified version of *equation 4.32* (see *Section 4.1.5*):

$$IMC_p\,(sc) = DG \times F^*\,(sc) \times \tau_e \times PI^*\,(sc) \times f_m \tag{4.33}$$

All parameter values have been determined in the preceding **Section 4.2.1**, with the exception of the mass interception factor, F*. The values of F* are estimated as indicated in **Sections 4.1.1.1.2** and **4.1.1.2**:

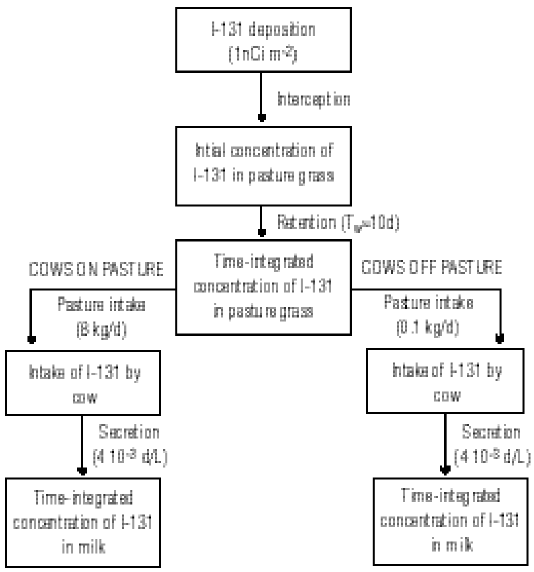
- in the absence of precipitation and for a distance from the NTS, X, equal to 3000 km (scenarios 1 and 2):

$$F^*_{dry} = \frac{(1-e^{-\alpha(X)Y})}{Y} \tag{4.34}$$

with:

$$\alpha(X) = (7.0 \times 10^{-4}) \times (X^{1.13}) \tag{4.35}$$

Figure 4.19. Deposition-pasture grass-cows' milk exposure route (reference conditions).



For distances from the NTS greater than 1,540 km, the value of α is constant and equal to 2.8 m² kg⁻¹ (**Section 4.1.1.1.2**). For scenarios 1 through 6, with X=3,000 km, F^*_{dry} (sc) = 1.9 m² kg⁻¹.

- in the presence of light precipitation (R = 1 mm d⁻¹) and for a distance from the NTS, X, equal to 3,000 km (scenarios 3 and 4), we find from *equation 4.13* that:

$$F^*_{wet} = F^*_{dry}(3) + [3.1 - F_{dry}(3)] \times \frac{R}{2.5} \quad (4.36)$$

Since F^*_{dry} (3) = F^*_{dry} (4) = 1.9 m² kg⁻¹ and R = 1 mm d⁻¹, F^*_{wet} (3) = F^*_{wet} (4) = 2.4 m² kg⁻¹.

- in the presence of heavy precipitation (R = 100 mm d⁻¹) and for a distance from the NTS, X, equal to 3,000 km (scenarios 5 and 6), F^*_{wet} is computed using *equation 4.11*:

$$F^*_{wet} = 0.9 + \frac{11}{R} \quad (4.37)$$

Since R = 100 mm d⁻¹, $F^*_{wet}(5)$ = $F^*_{wet}(6)$ = 1.0 m² kg⁻¹.

- in the absence of precipitation and for a distance from the NTS, X, equal to 100 km (scenarios 7 and 8), *equation 4.9* is used to compute F^*_{dry} :

$$F^*_{dry} = \frac{1 - e^{-\alpha(X)\,Y}}{Y} \quad (4.38)$$

together with *equation 4.8*:

$$\alpha(X) = (7.0 \times 10^{-4}) \times (X^{1.13}) \quad (4.39)$$

For X = 100 km, α = 0.13 m² kg⁻¹, and $F^*_{dry}(7)$ = $F^*_{dry}(8)$ = 0.13 m² kg⁻¹.

The values of F* (i.e., F^*_{dry} for scenarios 1,2,7, and 8, and F^*_{wet} for scenarios 3,4,5, and 6) are summarized below along with the values of the time-integrated concentrations of ^{131}I in pasture grass, IC_p(sc), and the values of the time-integrated concentrations of ^{131}I in milk, IMC_p(sc), obtained from *equation 4.33*, for each scenario, sc:

Scenario number, sc	F* (sc) (m² kg⁻¹)	IC_p (sc) (nCi d kg⁻¹)	IMC_p (sc) (nCi d L⁻¹)
1	1.9	12	0.40
2	1.9	12	0.005
3	2.4	16	0.50
4	2.4	16	0.006
5	1.0	6.5	0.21
6	1.0	6.5	0.003
7	0.13	0.85	0.03
8	0.13	0.85	0.0003

In the table above, the time-integrated concentrations of ^{131}I in pasture grass, IC_p(sc), are derived from *equation 4.22* and estimated as:

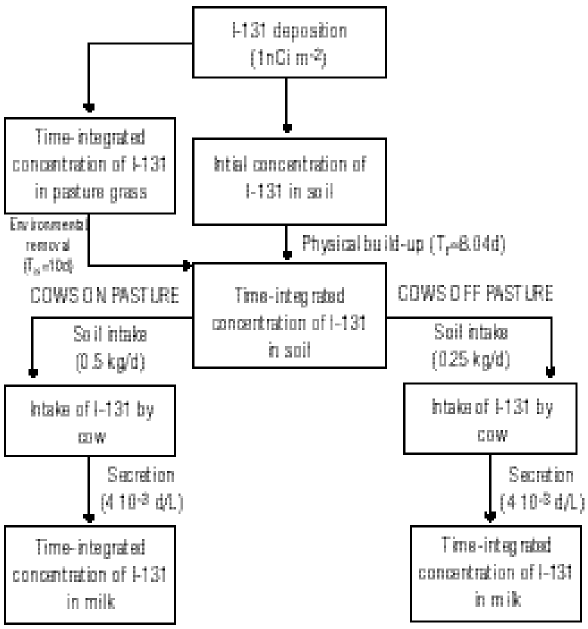
$$IC_p(sc) = DG \times F^*(sc) \times \tau_e \quad (4.40)$$

4.2.3. *Milk Concentration Due to Ingestion of Soil*

Cows on pasture ingest a certain amount of soil that can be contaminated with ^{131}I. Some of the ^{131}I taken in by the cow via this route is then secreted into milk. *Figure 4.20* illustrates the processes involved in this exposure route.

The daily consumption rate of soil, sl, consumed daily by dairy cows, $CR_{sl,c}$, depends on feeding practices as well as on the extent of vegetation cover. Only a few estimates of average values of $CR_{sl,c}$ have been reported (Gilbert et al. 1988a, 1988b; Mayland and Florence 1975; McKone and Ryan 1989; Simmonds and Linsley 1981; Small 1984; Whicker and Kirchner 1987). The estimates range from 0.1 to 0.72 kg d⁻¹. Results from a study conducted in Idaho indicated that the rate of soil consumption by cattle varied from about 0.1 to 0.72 kg d⁻¹ with a median of 0.50 kg d⁻¹ (Mayland and Florence 1975). It is assumed in this report that the average value of $CR_{s,c}$ is 0.5 kg d⁻¹ during the pasture season and is half that value, or 0.25 kg d⁻¹, when cows are not on pasture.

Figure 4.20. Contamination of fresh cows' milk by ^{131}I resulting from the ingestion of soil.



The ways in which soil can be contaminated with ^{131}I are schematically presented in *Figure 4.2*, reproduced here for the reader's convenience. The activity of ^{131}I deposited per unit area of ground, DG, is distributed between the activity intercepted by vegetation, A_p, and the activity that is deposited on the soil, A_{sl}. At time of deposition (t=0), that sum is:

$$DG = A_p\,(sc,\,0) + A_{sl}\,(sc,\,0) \qquad (4.41)$$

As illustrated in *Figure 4.2*,

$$A_p\,(sc,\,0) = DG \times F(sc) \qquad (4.42)$$

where

F(sc) is the fraction of the activity deposited per unit area of ground that is intercepted by vegetation in scenario, sc. Combining the two equations, one finds:

$$A_{sl}\,(sc,\,0) = DG - A_p\,(sc,\,0) = DG \times (1 - F\,(sc)) \qquad (4.43)$$

The value of F(sc) for a particular scenario is the product of the mass interception factor, F*(sc), tabulated above, and of the standing crop biomass, Y=0.3 kg m^{-2} (**Section 4.2.1**). The values of F(sc) and of A_{sl}(sc,0), from *equation 4.43*, are as follows:

Scenario number, sc	Daily rainfall	Distance from NTS (km)	Cows on pasture	F (sc) (dimension - less)	A_{sl}(sc,0) (nCi m^{-2})
1	none	3000	yes	0.57	0.43
2	none	3000	no	0.57	0.43
3	light	3000	yes	0.72	0.28
4	light	3000	no	0.72	0.28
5	heavy	3000	yes	0.30	0.70
6	heavy	3000	no	0.30	0.70
7	none	100	yes	0.04	0.96
8	none	100	no	0.04	0.96

The variation of A_{sl} with time, t, after deposition is obtained by solving the following differential equations, which represent the processes shown in *Figure 4.2:*

$$\frac{dA_{sl}\,(sc,\,t)}{dt} = +\,\lambda_w A_p\,(sc,\,t) - \lambda_r A_{sl}\,(sc,\,t) \qquad (4.44)$$

with:

$$\frac{dA_p\,(sc,\,t)}{dt} = -\,(\lambda_r + \lambda_w)\,A_p\,(sc,t) = -\,\lambda_e A_p\,(sc,\,t) \qquad (4.45)$$

Equation 4.44 reflects the fact that the activity on soil is increased by the activity removed from pasture by environmental processes but is depleted at the same time by the radioactive decay of ^{131}I. The activity on pasture (*equation 4.45*) decreases monotonically with time because of removal by environmental processes and by radioactive decay. It is to be noted that this approach ignores the amount of ^{131}I that is resuspended from soil into the atmosphere as a result of wind action, rainsplash, or re-volatilization, and any redeposition on pasture grass. The influence of resuspension on the ^{131}I concentration in milk is discussed in **Section 4.2.4**. The solution of *equation 4.44* is:

$$A_{sl}\,(sc,\,t) = A_{sl}\,(sc,\,0)e^{-\lambda_r t} + A_p(sc,\,0)\,(e^{-\lambda_r t} - e^{-\lambda_e t}) \qquad (4.46)$$

The time-integrated activity on soil per unit area of ground, IA_{sl}, is obtained by integrating the function in *equation 4.46*. For scenario, sc, the result is:

$$IA_{sl}\,(sc) = \int_0^\infty A_{sl}\,(sc,\,t)\,dt = \frac{1}{\lambda_r}\left(\frac{\lambda_w}{\lambda_e}\,A_p\,(sc,\,o) + A_{sl}\,(sc,\,0)\right) \qquad (4.47)$$

Replacing A_p(sc,0) and A_{sl}(sc,0) by their values as a function of DG and F(sc) (*equations 4.42* and *4.43*) in *equation 4.47* yields:

$$IA_{sl}\,(sc) = \frac{DG}{\lambda_r}\left(1 - F\,(sc)\,\frac{\lambda_r}{\lambda_e}\right) \qquad (4.48)$$

In order to estimate the time-integrated concentrations of ^{131}I in soil, IC_{sl}, for each scenario, it is assumed that the activity deposited is uniformly distributed over a certain depth of soil, H_{sl}. Taking the soil density, U_{sl}, to be 1.5 x 10^3 kg (dry mass) m^{-3}, IC_{sl} (sc) is calculated using:

$$IC_{sl}\,(sc) = \frac{IA_{sl}\,(sc)}{H_{sl}\,(sc) \times U_{sl}} \qquad (4.49)$$

The depth of soil, H_{sl}, over which the activity is assumed to be uniformly distributed, depends on the weather conditions at the time of deposition. On the basis of measurements made after the Chernobyl accident (UNSCEAR 1988), the activity deposited with heavy rain (R > 5 mm d^{-1}) is taken to migrate down to 10 mm. Therefore, for scenarios 5 and 6, $H_{sl}(5) = H_{sl}(6) = 10^{-2}$ m. The activity deposited in the absence of precipitation, or with only traces of precipitation, is considered to remain in the upper millimeter of soil. This condition applies in scenarios 1, 2, 7 and 8 ($H_{sl}(1) = H_{sl}(2) = H_{sl}(7) = H_{sl}(8) = 10^{-3}$ m). For light rain (R < 5 mm d^{-1}), an intermediate value of 5 mm has been assumed and $H_{sl}(3) = H_{sl}(4) = 5 \times 10^{-3}$ m.

The time-integrated activities of ^{131}I in soil per unit area of ground, IA_{sl}, and the time-integrated concentrations in soil, IC_{sl}, obtained for each scenario from *equations 4.48* and *4.49*, respectively, are as follows:

Scenario number, sc	Daily rainfall	Distance from NTS (km)	Cows on pasture	IA_{sl}(sc) (nCi m^{-2})	IC_{sl}(sc) (nCi m^{-2})
1	none	3000	yes	7.8	5.2
2	none	3000	no	7.8	5.2
3	light	3000	yes	6.8	0.91
4	light	3000	no	6.8	0.91
5	heavy	3000	yes	9.6	0.64
6	heavy	3000	no	9.6	0.64
7	none	100	yes	11.4	7.6
8	none	100	no	11.4	7.6

Assuming that all the soil eaten by the cow is contaminated, the activity intake of the cow, AI_{sl}, is the product of the time-integrated concentration of ^{131}I in soil, IC_{sl}, and of the soil consumption rate, $CR_{sl,c}$. For a given scenario:

$$AI\,(sc) = IC_{sl}\,(sc) \times CR_{sl,\,c}\,(sc) \qquad (4.50)$$

As indicated at the beginning of this **Section (4.2.3.)**, it is assumed that the rates of soil consumption, $CR_{sl,c,}$ are 0.5 kg d^{-1} during the pasture season, and 0.25 kg d^{-1} during the off-pasture season.

The time-integrated concentration in milk due to soil consumption, IMC_{sl}, is the product of the activity intake of the cows, AI_{sl}, and of the intake-to-milk transfer coefficient for ^{131}I and for cows, f_m:

$$IMC_{sl}\,(sc) = AI_{sl}(sc) \times f_m \qquad (4.51)$$

The values of AI_{sl} and of IMC_{sl}, calculated from *equations 4.50* and *4.51*, are given below:

Scenario number, sc	Daily rainfall	Distance from NTS (km)	Cows on pasture	IA_{sl}(sc) (nCi)	IC_{sl}(sc) (nCi m^{-2})
1	none	3000	yes	2.6	0.01
2	none	3000	no	0.00	0.005
3	light	3000	yes	0.46	0.002
4	light	3000	no	0.00	0.0009
5	heavy	3000	yes	0.32	0.001
6	heavy	3000	no	0.00	0.0006
7	none	100	yes	3.80	0.02
8	none	100	no	0.00	0.008

The relationship between IMC_{sl}(sc) and DG, derived from *equations 4.48* to *4.51*, is:

$$IMC_{sl}\,(sc) = DG \times \frac{1}{\lambda_r \times H_{sl}\,(sc) \times U_s} \times \left(1 - F\,(sc) \times \frac{\lambda_r}{\lambda_e}\right) \times CR_{sl,c} \times f_m \qquad (4.52)$$

4.2.4. ^{131}I Concentration in Milk Due to Resuspension of Particles From Soil

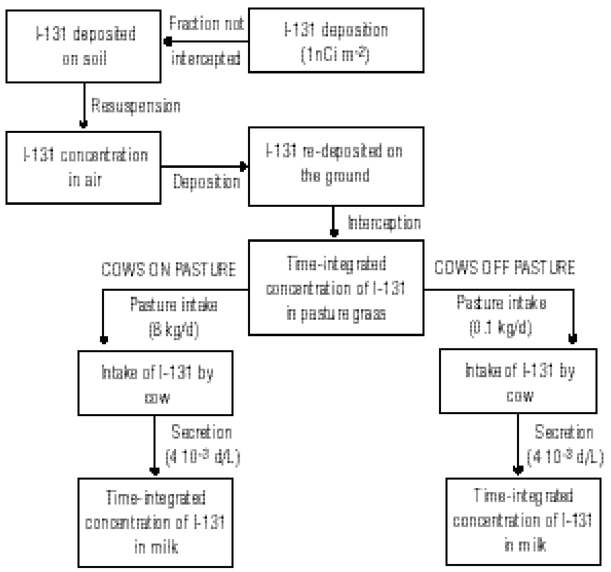
Pasture grass is contaminated to some extent by ^{131}I resuspended from soil into the atmosphere as a result of wind action, rain-splash, or re-volatilization (Amiro and Johnston 1989; Dreicer et al. 1984; Healy 1980). *Figure 4.21* illustrates the processes involved that lead to the contamination of cows' milk. Although this exposure route is conceptually different from the deposition-pasture grass-cows' milk route illustrated in *Figure 4.19*, in practice the ^{131}I concentrations measured in pasture grass reflect the combined effect of the two exposure routes because the value of the half-time of retention of ^{131}I on pasture grass, which was determined experimentally, incorporates the effect of resuspension from soil.

For illustrative purposes, the contribution from resuspension to the ^{131}I concentration in fresh cows' milk is assessed separately in this section and is shown to be quite small under most conditions. Resuspension from soil, however, is later ignored in the estimation of the time-integrated concentrations of ^{131}I in fresh cows' milk resulting from nuclear weapons testing at the NTS.

The evaluation of the resuspension from soil, carried out in this section for illustrative purposes, includes two parts:

- determination of the ^{131}I activity re-deposited per unit area of ground; and
- transfer of the redeposited activity to fresh cows' milk.

Figure 4.21. Contamination of fresh cows' milk by ^{131}I resulting from resuspension from soil.



4.2.4.1. Determination of the ^{131}I activity re-deposited per unit area of ground

The activity that is re-deposited per unit area of ground after resuspension from soil is derived from the time-integrated activity in soil per unit area of ground, IA_{sl}, by calculating first the time-integrated concentration in air due to resuspension, $IC_{air,rs}$, and then the activity re-deposited on the ground, DG_{rs}. It is assumed that wind action accounts for the resuspension from soil into the atmosphere and that the re-deposition occurs under dry conditions. The mechanisms that result in movement of particles deposited onto surfaces as an effect of wind action are: (a) surface creep (essentially, particles rolling across the surface; (b) saltation (akin to bouncing of particles whereby they become airborne for distances of the order of 10 m); and (c) true suspension (in which particles that were once deposited on the ground may become completely airborne and travel up to thousands of meters (Peterson 1983; Travis 1976)).

The time-integrated concentration in air due to resuspension, $IC_{air,rs}$, is obtained for a particular scenario using:

$$IC_{air,rs}(sc) = IA_{sl}(sc) \times RC \qquad (4.53)$$

where:

IA_{sl} = time-integrated fallout activity on soil per unit area of ground, in nCi d m^{-2} (*equation 4.48*)

RC = resuspension coefficient, in m^{-1}

The resuspension coefficient is an empirical quantity that relates the activity deposited on soil per unit area of ground and the concentration in ground-level air. The resuspension coefficient varies according to age of deposit, nature of the surface onto which the activity is deposited, and meteorological conditions (Anspaugh et al. 1974; Healy 1980; Phelps and Anspaugh 1974). Values for the resuspension coefficient are poorly established; they range from 10^{-13} to 10^{-2} m^{-1} and are in the higher part of the range for fresh deposits (Gilbert et al. 1988b; Hawley 1966; Mishima 1964; Peterson 1983; Shinn et al. 1985; Shinn et al. 1986; Stewart 1964). In experiments conducted at the Nevada Test Site, concentrations in air of particles moving in suspension were observed to decrease with half-times of 35-80 d following the nuclear cratering test Schooner and the venting of the underground test Baneberry (Anspaugh et al. 1973). This decrease is believed to be due to weathering and migration of surface deposits deeper into the soil, which reduces the fraction of the activity deposited that is subject to resuspension.

Recommended values for the resuspension coefficient for fresh deposits are 10^{-4} m^{-1} for desert environments (Anspaugh et al. 1974) and 10^{-6} m^{-1} for well-vegetated soils (Linsley 1979).

The ^{131}I activities that are re-deposited per unit area of ground after resuspension, DG_{rs}, are estimated as:

$$DG_{rs}(sc) = IC_{air,rs}(sc) \times v_{g,rs} \qquad (4.54)$$

where

$v_{g,rs}$ = deposition velocity for particles associated with ^{131}I after resuspension, in m d^{-1}.

The deposition velocity is an empirical quantity that relates the time-integrated concentration in ground-level air and the activity deposited per unit area of ground. The deposition velocity depends upon the physical and chemical nature of ^{131}I in ground-level air, on the type of surface, and on environmental conditions. The manner in which the deposition velocity of ^{131}I in the radioactive cloud formed after a test is estimated to vary according to distance from the NTS is presented in **Section A7.4.1** of **Appendix 7**. For ^{131}I attached to particles, the deposition velocity increases with particle size.

The size of the particles associated with resuspended ^{131}I is assumed to be the same for all scenarios and to be independent of the size of the particles that were deposited initially. The value of $v_{g,rs}$ is thus assumed to be the same for all scenarios. A representative size of the particles re-suspended from soil is considered to be intermediate between the size of particles associated with ^{131}I in the radioactive cloud near the NTS (100 km) and far away from the NTS (3000 km). The numerical value of vg,rs is taken to be the geometric mean of the values selected in **Section A7.4.1.4** of **Appendix 7** for those two distances:

$$v_{g,rs} = (4000 \times 1200)^{0.5} = 2000 \text{ m d}^{-1}$$

The values of $DG_{rs}(sc)$, for each scenario, are computed using *equations 4.53* and *4.54* and the values of $IA_{sl}(sc)$ that were tabulated in **Section 4.2.3**. The values are shown below:

Scenario number, sc	Daily rainfall	Distance from NTS (km)	Cows on pasture	DG_{re} (sc) (nCi m^{-2})
1	none	3000	yes	0.16
2	none	3000	no	0.16
3	light	3000	yes	0.14
4	light	3000	no	0.14
5	heavy	3000	yes	0.19
6	heavy	3000	no	0.19
7	none	100	yes	0.23
8	none	100	no	0.23

The estimated activities re-deposited per unit area of ground after resuspension from soil are substantially less than the activities initially deposited (1 nCi m^{-2}).

4.2.4.2. Transfer of the re-deposited activity to fresh cows' milk

Only the most important exposure route (the deposition-pasture grass-cow-milk exposure route) is considered in the transfer of redeposited ^{131}l to fresh cows' milk. The resulting time-integrated concentration of ^{131}I in fresh cows' milk is estimated using the approach discussed in **Section 4.2.2.** For this pathway, *equation 4.33* is revised to consider the redeposited activity, $Dg_{rs}(sc)$:

$$IMC_{rs}(sc) = DG_{rs}(sc) \times F^*_{rs} \times \tau_e \times PI^*(sc) \times f_m \qquad (4.55)$$

Here F^*_{rs} represents the mass interception factor in the absence of precipitation for resuspended particles. The value of F^*_{rs} is determined in the same way as that of $v_{g,rs}$, namely, by taking it to be the geometric mean of the values selected in **Section A7.4.3.1** of **Appendix 7** for the deposition of ^{131}I in particulate form in the radioactive cloud close-in (100 km) and far away (3,000 km) from the NTS. The values selected in **Section A7.4.3.1** are 0.13 and 1.9 m^2 kg^{-1}(dry); the geometric mean is 0.05 m^2 kg^{-1}(dry).

The values of $IMC_{rs}(sc)$, are calculated for each scenario using *equation 4.55*, the tabled values of $DG_{rs}(sc)$ above, and values of the other parameters found in the list of general assumptions for the analysis (**Section 4.2.1**).

Scenario number, sc	$IMC_{rs}(sc)$ (nCi d L^{-1})
1	0.02
2	0.0002
3	0.01
4	0.0002
5	0.02
6	0.0002
7	0.02
8	0.0003

The relationship between $IMC_{rs}(sc)$ and DG, derived from *equations 4.48* and *4.53* to *4.55*, is:

$$IMC_{rs}(sc) = DG \times \frac{1}{\lambda_r} \times \left(1 - F(sc) \times \frac{\lambda_r}{\lambda_e}\right) \times RC \times V_{g,rs} \times F^*_{rs} \times \tau_e \times PI^* \times f_m \qquad (4.56)$$

For scenarios 7 and 8, the estimated milk concentrations are comparable to those in the reference calculations (**Section 4.2.2**). However, as indicated in the first paragraph of **Section 4.2.4**, the values of $IMC_{rs}(sc)$ are not used in the estimation of the ^{131}I concentrations in fresh cows' milk, because the effect of resuspension from soil is implicitly taken into account in the determination of the half-time of retention of ^{131}I on pasture grass.

4.2.5. ^{131}I Concentration in Milk Due to Inhalation of ^{131}I

During the passage of the radioactive cloud that results in the deposition of ^{131}I on the ground, cows are subject to inhalation of ^{131}I. *Figure 4.22* shows the processes involved in that exposure route.

The time-integrated concentration of ^{131}I in ground-level air, IC_{air}, that corresponds to a deposition on the ground of 1 nCi m^{-2} depends, among other factors, upon the physical and chemical form of ^{131}I, and upon environmental conditions (in particular, upon the presence or absence of precipitation). It is assumed in this report that the ^{131}I present in the radioactive cloud is associated with particles, and it is shown in **Appendix 7** that this assumption does not affect substantially the dose estimates. The equations used to relate the time-integrated concentrations of ^{131}I in ground-level air and the depositions per unit area of ground are also presented in **Appendix 7**, along with the selection of the parameter values.

The time-integrated concentration of ^{131}I in ground-level air, IC_{air}, corresponding to deposition via dry processes, is estimated using:

$$IC_{air}(sc) = \frac{DG_{dry}}{v_g(sc)} \qquad (4.57)$$

where:

DG_{dry} is the activity of ^{131}I per unit area of ground deposited via dry processes, in nCi m d-2, and

$v_g(sc)$ in m d^{-1}, is the dry deposition velocity for ^{131}I in particulate form appropriate for the scenario, sc.

The variation of v_g as a function of the distance, X, in km, from the NTS is estimated (**Appendix 7**) using:

$$v_g(x) = 20150 \times X^{-0.35} \qquad (4.58)$$

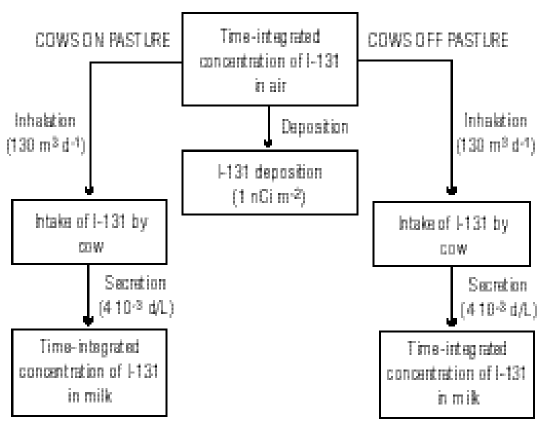
For X = 3,000 km (scenarios 1 to 6), v_g = 1,200 m d^{-1}, while for X = 100 km (scenarios 7 and 8), v_g = 4,000 m d^{-1}.

When precipitation occurs, scavenging of the airborne particles by rainfall adds to the activity deposited by dry processes. The ^{131}I activity deposited via wet processes, DG_{wet}, is proportional to the ^{131}I time-integrated concentrations in rain,

IC_{rain} in nCi d kg^{-1}, and to the daily rainfall. A rainfall amount of 1 mm d^{-1} onto 1 m^2 of ground results in the transfer of 1 kg of water to that area. Here the rainfall rate is expressed in those units (kg m^{-2} d^{-1}):

$$DG_{wet} = IC_{rain} \times R \tag{4.59}$$

Figure 4.22. Contamination of fresh cows' milk by ^{131}I resulting from inhalation.



The time-integrated concentrations of ^{131}I in rain and in air at ground level are related by:

$$IC_{rain} = \frac{IC_{air}}{AD} \times WR\ (X, R) \tag{4.60}$$

where:

AD is the average density of air at ground level (1.2 kg m^{-3}), so that IC_{air}/AD represents the time-integrated concentration of ^{131}I in ground-level air expressed in nCi d kg^{-1}, and

WR is the washout ratio, which is the ratio of the time-integrated concentrations of ^{131}I in rain and in ground-level air.

The washout ratio, WR, depends not only on the daily rainfall, but also, more generally, on the characteristics of the rainfall cloud and of the radioactive cloud as well as on the extent to which the two clouds interact, according to processes that are not well quantified. The values of WR are therefore extremely uncertain. In **Appendix 7**, they are calculated as a function of the daily rainfall, R, and of the distance from the NTS, X, using:

$$WR\ (X, R) = 13000 \times R^{-0.7} \times \left(\frac{X}{100}\right)^{-0.43} \tag{4.61}$$

It is worth noting that the washout ratio is dimensionless but it has a different value according to whether the time-integrated concentrations are expressed per unit mass or per unit volume. The values calculated using *equation 4.61* correspond to time-integrated concentrations expressed in terms of unit mass (nCi d kg^{-1}). It is for that reason that IC_{air} is divided by the air density in *equation 4.60*.

Combining *equations 4.59* and *4.60* yields:

$$DG_{wet}\ (sc) = \frac{IC_{air}\ (sc) \times R\ (sc) \times WR\ (sc)}{AD} \tag{4.62}$$

From *equations 4.57* and *4.59*, the relationship for the total deposition (DG_{dry} + DG_{wet}) can be written:

$$DG\ (sc) = IC_{air}\ (sc) \times v_g\ (sc) + \frac{IC_{air}\ (sc) \times R\ (sc) \times WR\ (sc)}{AD} \tag{4.63}$$

For the unit deposition of DG = 1 nCi m^{-2} considered in each scenario, the time-integrated concentrations in air, IC_{air}(sc), can be obtained by rearranging *equation 4.63* to yield:

$$IC_{air}\ (sc) = \frac{DG}{v_g\ (sc) + \frac{R\ (sc) \times WR\ (sc)}{AD}} \tag{4.64}$$

It is assumed that the time-integrated concentrations of ^{131}I in air are the same outdoors and indoors. This implies that the stables in which the cows are kept when they were not on pasture were drafty enough that they did not provide substantial filtration of incoming air.

The values of v_g, WR, and R used to compute IC_{air}(sc) for each scenario are given below, together with the results:

Scenario number, sc	V_g (sc) (m d^{-1})	R (sc) (kg m^2 d^{-1})	WR (sc) (kg kg^{-1})	IC_{air} (sc) (nCi d m^{-3})
1	1200	0	0.0	.0004
2	1200	0	0.0	.0004
3	1200	1	3000	.0001
4	1200	1	3000	.0001
5	1200	100	120	.00005
6	1200	100	120	.00005
7	4000	0	0.0	.0001
8	4000	0	0.0	.0001

The time-integrated concentrations of ^{131}I in milk due to inhalation of ^{131}I by the cow, IMC_{inh}, are obtained from the relationship:

$$IMC_{inh}\,(sc) = IC_{air}\,(sc) \times BR_c \times f_m \qquad (4.65)$$

where:

BR is the average breathing rate of the cow, taken to be 90 L min^{-1}, or 130 m^3 d^{-1} (Comar 1966)

f_m is the average intake-to-milk transfer coefficient for ^{131}I in cows, (4 x 10^{-3} d L^{-1}) assumed to be the same for inhalation and for ingestion

The numerical values of the time-integrated concentrations of ^{131}I in milk due to inhalation by the cow are obtained from the values of IC_{air}(sc) tabulated above and the stated values of BR_c and f_m using *equation 4.65*.

Scenario number, sc	Daily rainfall	Distance from NTS (km)	Cows on pasture	IMC_{inh} (sc) (nCi d L^{-1})
1	none	3000	yes	0.0004
2	none	3000	no	0.0004
3	light	3000	yes	0.0001
4	light	3000	no	0.0001
5	heavy	3000	yes	0.00005
6	heavy	3000	no	0.00005
7	none	100	yes	0.0001
8	none	100	no	0.0001

The relationship between IMC_{inh} and DG, derived from *equations 4.64* and *4.65*, is:

$$IMC_{inh}\,(sc) = \frac{DG}{v_g\,(sc) + \dfrac{R\,(sc) \times WR\,(sc)}{AD}} \times BR_c \times f_m \qquad (4.66)$$

4.2.6. ^{131}I Concentration in Milk Due to Ingestion of Water

Water drunk by cows can be contaminated with ^{131}I as a result of deposition on the water surface, of run-off of the activity deposited on soil, or of transfer from other materials. *Figure 4.23* illustrates the exposure route leading to the contamination of milk. The time-integrated milk concentration of ^{131}I due to ingestion of ^{131}I-contaminated water, IMC_w, (nCi d L^{-1}) is very much site specific as the time-integrated concentration of ^{131}I in water, IC_w, (nCi d L^{-1}) depends critically on the size of the body of water and on its watershed, among other factors. The values of IMC_w are estimated as:

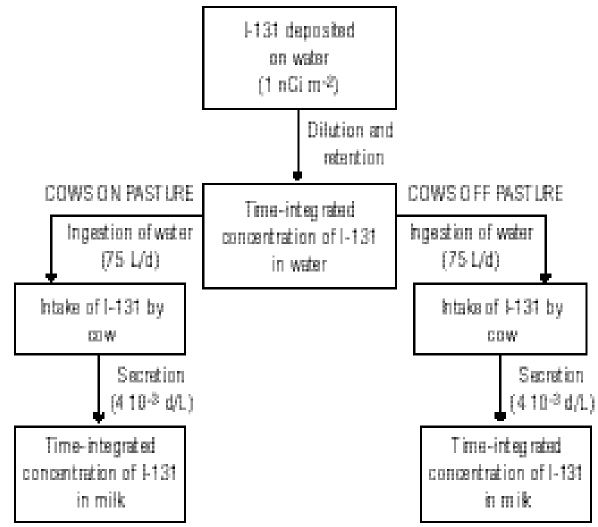
$$IMC_w = IC_w \times CR_{w,c} \times f_m \qquad (4.67)$$

where

$CR_{w,c}$ is the daily rate of water consumption by the cow, in L d^{-1}.

A rough and conservative estimate of IC_w is made in the case of a shallow pond, assumed to be contaminated by direct deposition (no run-off). If the average depth of the pond, H_w, is assumed to be 0.5 m, the ^{131}I concentration in the water, C_w, can be calculated as:

Figure 4.23. Contamination of fresh cows' milk by ^{131}I resulting from ingestion of water.



$$C_w = k_1 \times \frac{DG}{H_w} = 0.002 \text{ nCi } L^{-1} \qquad (4.68)$$

where

$k_1 = 10^{-3}$ m^3 L^{-1} is a unit conversion factor.

Assuming that the ^{131}I concentration in the pond decreases only by radioactive decay, the time-integrated concentration of ^{131}I in water, IC_w, is:

$$IC_w = \frac{C_w}{\lambda_r} = 0.023 \text{ nCi d } L^{-1} \qquad (4.69)$$

The time-integrated concentration of ^{131}I in water, IC_w, is thus estimated to be about 0.2% to 3% of the time-integrated concentration in pasture grass, IC_p, depending on the scenario considered (see **Section 4.2.2**). The only known experiment in which time-integrated concentrations of ^{131}I in both water and pasture grass could be derived from long-term measurements of fallout is that of Barth et al. (1969). Following the Pin Stripe event, Barth et al. (1969) monitored the ^{131}I concentrations in grain, water, hay, green chop, and field forage on two farms in Nevada. The ratios of the time-integrated concentration of ^{131}I in water and in green chop were found to be 0.6 - 0.7%, in good agreement with the ratios obtained in the eight scenarios. It should be noted that Barth et al. (1969) attributed the ^{131}I concentration in water to resuspension or to contamination by ^{131}I contained in the cow's saliva or food.

The rate of water consumption by the cow, $CR_{w,c}$, is 50-100 L d^{-1} (Comar 1966). An average figure of 75 L d^{-1} is used here. Assuming that the same source of water is used whether the cows are on or off pasture, the time-integrated concentrations of ^{131}I in milk due to ingestion of water, IMC_w, are estimated to be the same for all eight scenarios. Using the central value of $CR_{w,c}$, the result from *equation 4.69*, and, as before, the value of f_m =4 x10^{-3} d L^{-1}, *equation 4.67* predicts IMC_w =0.007 nCi d L^{-1} for all scenarios.

The relationship between IMC_w and DG, derived from *equations 4.67* to *4.69*, is:

$$IMC_w = DG \times \frac{k_1}{H_w \lambda_r} \times CR_{w,c} \times f_m \qquad (4.70)$$

4.2.7. ^{131}I Concentration in Milk Due to the Ingestion of ^{131}I Contaminated Stored Hay

Stored hay may be contaminated by direct or indirect deposition of ^{131}I and its consumption by cows off pasture will lead to the contamination of milk (*Figure 4.24*) by the same process described previously. The time-integrated concentration of ^{131}I in milk is the product of the intake of activity and the milk transfer coefficient. The time-integrated concentration of ^{131}I in milk, IMC_{hay}(sc) (nCi d L^{-1}) due to consumption of contaminated stored hay is obtained using:

$$IMC_{hay}\,(sc) = IC_{hay}\,(sc) \times CR_{hay,c}\,(sc) \times f_m \qquad (4.71)$$

where:

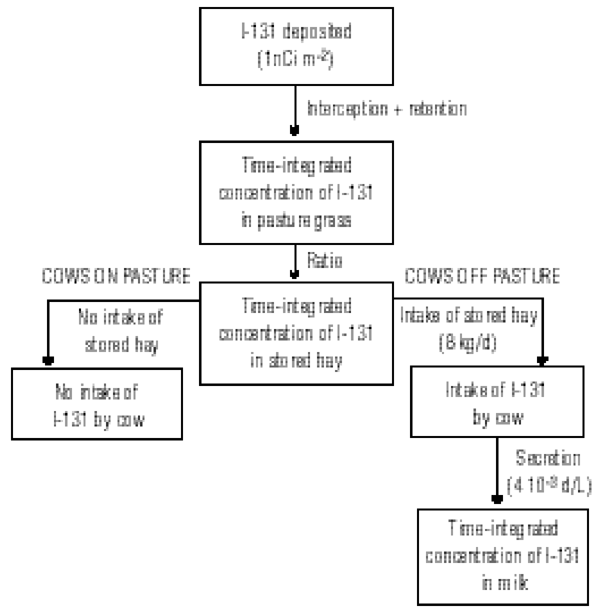
IC_{hay} is the time-integrated concentration of ^{131}I in stored hay, in nCi d kg^{-1}, and

$CR_{hay,c}$ is the daily rate of intake of stored hay by the cow, in kg d^{-1}.

It is very difficult to estimate with accuracy the contamination of milk resulting from this exposure route because the concentration of ^{131}I in hay is very sensitive to the conditions of storage.

Information on the contamination of stored hay may be derived from an experiment conducted in December 1961 in Oregon in which ten lactating cows were divided into two herds: one sheltered and one placed on pasture (Kahn et al. 1962). The sheltered cows, eating stored feed, gave milk containing no detectable ^{131}I (at or below the detection limit of 20 pCi L^{-1}) while levels in milk from cows on pasture were as high as 270 pCi L^{-1}. Assuming that: (a) the actual concentration in milk from sheltered cows was half the detection limit, that is 10 pCi L^{-1}, (b) the daily intake of hay by sheltered cows was equal to that of pasture grass for the cows on pasture in terms of dry weight, (c) the mean time of retention of ^{131}I in stored hay the same as that on pasture grass, and (d) there was no other source of contamination in the feed other than stored hay for the sheltered cows and pasture grass for the cows on pasture, the ratio,

Figure 4.24. Contamination of fresh cows' milk by ^{131}I resulting from ingestion of stored hay.



PR_{hay}, of the time-integrated concentrations of ^{131}I in stored hay (IC_{hay}, nCi d kg^{-1}) and in pasture grass (IC_p, nCi d kg^{-1}) is:

$$PR_{hay} = \frac{IC_{hay}}{IC_p} = \frac{10}{270} = 0.04 \qquad (4.72)$$

The measurements conducted by Barth et al. (1969) in 2 farms in Nevada following the Pin Stripe event resulted in time-integrated concentrations of ^{131}I in hay of about 9% of those in green chop. However, the hay samples were collected in the feed manger and some of the ^{131}I activity in hay was probably due to resuspension or cross-contamination because of some of the ^{131}I contamination of the feed manger by green chop. The ratio of 0.09 for PR_{hay} obtained from the measurements of Barth et al. (1969) is thus an overestimate.

Using the ratio PR_{hay} = 0.04 derived from the experiment of Kahn et al. (1962) and the time-integrated concentrations in pasture, IC_p (sc), obtained for the reference conditions (**Section 4.2.2**), the following values are obtained for the time-integrated concentrations of ^{131}I in stored hay, IC_{hay}(sc) (*equation 4.72*):

Scenario number, sc	Daily rainfall	Distance from NTS (km)	Cows on pasture	IC_{hay} (sc) (nCi d L^{-1})
1	none	3000	yes	0.5
2	none	3000	no	0.5
3	light	3000	yes	0.6
4	light	3000	no	0.6
5	heavy	3000	yes	0.3
6	heavy	3000	no	0.3
7	none	100	yes	0.03
8	none	100	no	0.03

The rate of consumption of stored hay, $CR_{hay,c}$(sc), is assumed to be equal to 8 kg (dry) d^{-1} when the cows are off pasture and to be equal to 0.1 kg d^{-1} when the cows are on pasture. Using *equation 4.71*, the time-integrated milk concentrations due to the ingestion of stored hay are:

Scenario number, sc	IMC_{hay}(sc) (nCi d L^{-1})
1	0.0002
2	0.02
3	0.0002
4	0.02
5	0.0001
6	0.008
7	0.00001
8	0.001

The relationship between IMC_{hay}(sc) and DG, derived from *equations 4.71, 4.72,* and *4.40* is:

$$IMC_{hay}\,(sc) = DG \times F^*\,(sc) \times \tau_e \times PR_{hay} \times CR_{hay,c} \times f_m \qquad (4.73)$$

4.2.8. Discussion

The estimated time-integrated concentrations of ^{131}I in milk resulting from the various exposure routes considered are summarized in *Table 4.9*. Exposure routes other than pasture consumption represent only about 2 to 4% of the total time-integrated concentration in milk when cows are on pasture far away from the NTS. Close to the NTS, however, exposure routes other than pasture consumption are estimated to be about as important as pasture consumption. When cows are off pasture, routes other than pasture consumption are the only contributions to the milk contamination, and the ^{131}I intakes are estimated to be about 10 times less than when cows are on pasture.

The time-integrated concentrations in milk obtained in the eight example scenarios are highly uncertain, but they show that, under the assumptions made, exposure routes other than pasture consumption should not be neglected. Milk contamination by ^{131}I for the routes other than pasture consumption has been evaluated in this report for each county, i, of the contiguous United States and for each day, j, for which deposition of ^{131}I on the ground was estimated following each test using equations presented in **Sections 4.2.3**, **4.2.5**, **4.2.6**, and **4.2.7.** Those equations were modified only to change the variable indices (i and j replacing sc in most cases) and to include the explicit form of the mass interception factor. Those equations, as revised, are summarized below. Definitions of individual variables are given in the sections referenced.

- for the contamination by ^{131}I resulting from the ingestion of soil, *equation 4.52* from **Section 4.2.3** becomes:

$$IMC_{sl}\,(i,j) = DG\,(i,j) \times \frac{1}{\lambda_r \times H_{sl}\,(i,j) \times U_{sl}} \times \left(1 - \frac{F^*\,(i,j) \times Y \times \lambda_r}{\lambda_e}\right) \times CR_{sl,c} \times f_m \qquad (4.74)$$

- for the contamination by ^{131}I resulting from inhalation, *equation 4.66* from **Section 4.2.5** becomes:

$$IMC_{inh}\,(i,j) = DG\,(i,j) \times \frac{1}{v_g\,(i) + \dfrac{R\,(i,j) \times WR\,(i,j)}{AD}} \times BR_c \times f_m \qquad (4.75)$$

- for the contamination by ^{131}I resulting from the ingestion of water, *equation 4.70* from **Section 4.2.6** becomes:

$$IMC_w\,(i,j) = DG\,(i,j) \times \frac{k_1}{H_w \times \lambda_r} \times CR_{w,c} \times f_m \qquad (4.76)$$

- for the contamination by ^{131}I resulting from the ingestion of stored hay, *equation 4.73* from **Section 4.2.7** becomes:

$$IMC_{hay}\,(i,j) = DG\,(i,J) \times F^*\,(i,j) \times \tau_e \times PR_{hay} \times CR_{hay,c} \times f_m \qquad (4.77)$$

The time-integrated concentration in milk resulting from these other exposure, oe, routes, besides pasture consumption, $IMC_{oe,}$ was estimated by adding the separate contributions:

$$IMC_{oe}\,(i,j) = IMC_{sl}\,(i,j) + IMC_{inh}\,(i,j) + IMC_w\,(i,j) + IMC_{hay}\,(i,j) = DG\,(i,j) \times f_m \times TF_{oe}\,(i,j) \qquad (4.78)$$

with:

$$TF_{oe}\,(i,j) = \left(\frac{CR_{sl,c}}{\lambda_r \times H_{sl}\,(i,j) \times U_{sl}} \times \left(1 - \frac{F^*\,(i,j) \times Y \times \lambda_r}{}\right)\right) + \left(\frac{BR_c}{v_g + \dfrac{R\,(i,j) \times WR\,(i,j)}{AD}}\right) + \left(\frac{k_1}{H_w \times \lambda_r} \times CR_{w,c}\right) + (F^*\,(i,j) \times \tau_e \times PR_{hay} \times CR_{hay,c}) \qquad (4.79)$$

The parameter TF_{oe}(i,j) represents the transfer of ^{131}I from the deposition on the ground on day, j, and county, i, to the activity intake by the cow. It is expressed in nCi per nCi m^{-2}.

The uncertainty attached to the values of TF_{oe}(i,j) is admittedly large and extremely difficult to quantify as some of

Table 4.9. Median time-integrated ^{131}I concentration in fresh cows' milk resulting from various exposure routes for a unit deposition density of ^{131}I (nCi d L^{-1} per nCi m^{-2}).

	Distance from the NTS : 3000km						Distance for the NTS: 100km	
	Dry Conditions		Light rain		Heavy rain		Dry conditions	
	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Pasture consumption	0.40	0.005	0.50	0.006	0.21	0.003	0.03	0.0003
Other exposure routes:								
• ingestion of soil	0.01	0.005	0.002	0.0009	0.001	0.0006	0.02	0.008
• ingestion of water	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
• ingestion of stored hay	0.0002	0.02	0.0002	0.02	0.0001	0.008	0.00001	0.001
• inhalation	0.0004	0.0004	0.0001	0.0001	0.00005	0.00005	0.0001	0.0001

the parameter values vary over a wide range and are site specific. In addition some of the mechanisms underlying the environmental transfers are poorly understood. The values of $TF_{oe}(i,j)$ derived from *equation 4.79* were assumed to represent the geometric means of log-normal distributions with GSDs of 4.

4.3. OVERALL CALCULATIONAL PROCEDURES

The average time-integrated ^{131}I concentrations in fresh cows' milk due to all routes of exposure, <IMC(i,j)>, have been estimated for each county, i, of the contiguous United States and for each day, j, of deposition following atmospheric nuclear tests at the NTS as the geometric means of the distributions resulting from the additions of the distributions of the time-integrated ^{131}I in fresh cows' milk from pasture consumption, $IMC_p(i,j)$, and from other exposure routes, $IMC_{oe}(i,j)$. Similar calculations have been made for the average time-integrated ^{131}I concentrations in fresh cows' milk in county, i, resulting from a given test, te, from a given test series, ts, and from all tests.

4.3.1. Time-Integrated ^{131}I Concentrations in Fresh Cows' Milk Resulting From ^{131}I Deposition on a Given Day

The time-integrated ^{131}I concentration in fresh cows' milk in county, i, due to all routes of exposure and resulting from ^{131}I deposition on a day, j, following an atmospheric nuclear test at the NTS is denoted as IMC(i,j) and can be expressed as:

$$IMC(i, j) = IMC_p(i, j) + IMC_{oe}(i, j) \quad (4.80)$$

From *equation 4.32*, $IMC_p(i,j)$ is calculated as:

$$IMC_p(i, j) = DG(i, j) \times f_m \times F^*(i, j) \times \tau_e \times PI^*(i, j) = DG(i, j) \times f_m \times TF_{p,c}(i, j) \quad (4.81)$$

where:

$TF_{p,c}(i,j)$ is the transfer coefficient from deposition of ^{131}I on the ground to the activity intake by the cow resulting from pasture consumption:

$$TF_{p,c}(i, j) = F^*(i, j) \times \tau_e \times PI^*(i, j) \quad (4.82)$$

From *equation 4.78*, $IMC_{oe}(i,j)$ is calculated as:

$$IMC_{oe}(i, j) = DG(i, j) \times f_m \times TF_{oe,c}(i, j) \quad (4.83)$$

From *equations 4.80, 4.82,* and *4.83,* the time-integrated ^{131}I concentrations in fresh cows' milk due to all routes of exposure, IMC(i,j), can be expressed as:

$$IMC(i, j) = DG(i, j) \times f_m \times [TF_{p,c}(i,j) + TF_{oe,c}(i, j)] = DG(i, j) \times f_m \times TF_c(i, j) \quad (4.84)$$

where

$TF_c(i,j)$ is the transfer coefficient from deposition of ^{131}I on the ground on day, j, and county, i, to the activity intake by the cow resulting from all exposure routes. The distribution of $TF_c(i,j)$ is assumed to be log-normal for any values of j and i.

The median time-integrated ^{131}I concentrations in fresh cows' milk due to all routes of exposure, <IMC(i,j)>, are the products of the median depositions of ^{131}I per unit area of ground, <DG(i,j)>, of the median feed-to-milk transfer coefficient, $<f_m>$, and of the median transfer coefficients from deposition to activity intake by the cow, $<TF_c(i,j)>$:

$$< \text{IMC (i, j)} > \; = \; < DG\,(i, j) > \times < f_m > \times < TF_c\,(i, j) > \quad (4.85)$$

The values of <DG(i,j)> are estimated as indicated in **Chapter 3**, while the value of $<f_m>$ is taken to be 4 x 10^{-3} d L^{-1}. Since $TF_{p,c}(i,j)$, $TF_{oe,c}(i,j)$, and $TF_c(i,j)$ are assumed to be log-normally distributed, the values of $<TF_c(i,j)>$ can be derived from the arithmetic means and the standard deviations associated with the distributions of $TF_c(i,j)$, which are in turn inferred from the characteristics of the distributions of $TF_{p,c}(i,j)$ and of $TF_{oe,c}(i,j)$. The arithmetic means of $TF_c(i,j)$, denoted as $m(TF_c(i,j))$, are calculated as:

$$m(TF_c\,(i, j)) = e^{\mu(TF_{p,c}\,(i,j)) \,+\, 0.5\,\sigma^2\,(TF_{p,c}\,(i,j))} + e^{\mu(TF_{oe,c}\,(i,j)) \,+\, 0.5\,\sigma^2\,(TF_{oe,c}\,(i,j))} \quad (4.86)$$

where:

$$\mu(TF_{p,c}\,(i, j)) = \ln\,(< TF_{p,c}\,(i, j) >) \quad (4.87)$$

$$\mu(TF_{oe,c}\,(i, j)) = \ln\,(< TF_{oe,c}\,(i, j) >) \quad (4.88)$$

$$\sigma(TF_{p,c}\,(i, j)) = \ln\,(\text{GSD}\,(< TF_{p,c}\,(i, j) >)) \quad (4.89)$$

$$\sigma(TF_{oe,c}\,(i, j)) = \ln\,(\text{GSD}\,(< TF_{oe,c}\,(i, j) >)) \quad (4.90)$$

while the variances of $TF_c(i,j)$, denoted as $s^2(TF_c(i,j))$, are:

$$s^2(TF_c\,(i, j)) = [e^{2\,\times\,\mu(TF_{p,c}\,(i,j)) \,+\, \sigma^2\,(TF_{p,c}\,(i,j))} \times (e^{\sigma^2\,(TF_{p,c}\,(i,j))} - 1)] + [e^{2\,\times\,\mu(TF_{oe,c}\,(i,j)) \,+\, \sigma^2\,(TF_{oe,c}\,(i,j))} \times (e^{\sigma^2(TF_{oe,c}\,(i,j))} - 1)] \quad (4.91)$$

It follows from the properties of log-normal distributions that the geometric means of $TF_c(i,j)$, denoted as $<TF_c(i,j)>$, are:

$$< TF_c\,(\text{i, j}) > \; = \; \frac{m(TF_c\,(i, j))}{\left(1 + \left(\dfrac{s\,(TF_c\,(i, j))}{m\,(TF_c\,(i, j))}\right)^2\right)^{0.5}} \quad (4.92)$$

while the GSDs of $TF_c(i,j)$ are obtained as:

$$GSD\,(TFc\,(i, j)) = e^{\sigma\,(TFc\,(i,j))} \quad (4.93)$$

with:

$$\sigma TF_c\,(i, j) = \left| log_e\left(1 + \left(\frac{s\,(TF_c\,(i, j))}{m\,(TF_c\,(i, j))}\right)^2\right)\right|^{0.05} \quad (4.94)$$

The average time-integrated ^{131}I concentration in fresh cows' milk due to all routes of exposure, <IMC(i,j)>, can then be calculated from *equation 4.85* while the GSD associated with IMC(i,j) is obtained as:

$$GSD\,(IMC\,(i, j)) \; = \; e^{[\sigma^2(DG\,(i,\,j)) \,+\, \sigma^2\,(fm) \,+\, \sigma^2(Tc\,(i,\,j))]^{0.5}} \quad (4.95)$$

Since the distribution of IMC(i,j) is log-normal, its arithmetic mean, m(IMC(i,j)), can be calculated as:

$$m(IMC\,(i, j)) = < \text{IMC (i, j)} > \times\, e^{(0.5\,x\,\sigma^2\,(IMC\,(i,\,j))} \quad (4.96)$$

and its variance, s^2(IMC(i,j)), as:

$$s^2\,(IMC\,(i, j) = < \text{IMC (i, j)} >^{\,2} \times e^{(\sigma^2(\text{IMC(i, j)})} \times (e^{(\sigma^2(\text{IMC (i, j)}))} - 1) \quad (4.97)$$

4.3.2. Time-integrated ^{131}I concentrations in fresh cows' milk resulting from ^{131}I deposition from a given test

The deposition of ^{131}I on the ground often occurred for several days following a given nuclear test. The time-integrated concentration of ^{131}I in fresh cows' milk in county, i, resulting from a given test, te, is obtained by adding the contributions from each day of deposition, j:

$$IMC\,(i, te) = \sum_{j=1}^{jj} IMC\,(i, j) \quad (4.98)$$

where:

jj is the number of days of ^{131}I deposition in county, i, after test, te.

The median time-integrated concentration, <IMC(i,te)>, is the geometric mean of the distribution resulting from the addition of the distributions of IMC(i,j). In most cases, the value of IMC(i,te) is dominated by the contributions from the ^{131}I depositions on 1 or 2 days. The distribution of IMC(i,te) can be assumed to be log-normal and its geometric mean can be calculated as:

$$<IMC\,(i,te)> = \frac{\sum_{j=1}^{jj} m(IMC(i,j))}{\sqrt{\left(1 + \dfrac{\sum_{j=1}^{jj} s^2(IMC(i,j))}{\left(\sum_{j=1}^{jj} m(IMC(i,j))\right)^2}\right)}} \quad (4.99)$$

where

m(IMC(i,j)) and s^2(IMC(i,j)) are the arithmetic mean and the variance of IMC(i,j) and are determined in *equations 4.97* and *4.98*, respectively.

Other parameters of the distribution of IMC(i,te) are:

- its geometric standard deviation, GSD(IMC(i,te)):

$$GSD\ (IMC\ (i,\ te)) = e^{\sigma (IMC\ (i,\ te))} \qquad (4.100)$$

with:

$$\sigma^2\ (IMC\ (i,\ te)) = \log_e \left(1 + \frac{\sum_{j=1}^{jj} s^2\ (IMC\ (i,\ j))}{(\sum_{j=1}^{jj} m\ (IMC(i,\ j))^2)} \right) \qquad (4.101)$$

- its arithmetic mean, m(IMC(i,te)) :

$$m(IMC\ (i,\ te)) = \ < IMC\ (i,\ te) > \ \times\ e^{0.5 \times \sigma^2\ (IMC\ (i,\ te))} \qquad (4.102)$$

- its variance, s^2(IMC(i,te)):

$$s^2\ (IMC\ (i,\ te)) = \ < IMC\ (i,\ te) >^2 \times\ e^{\sigma^2 (IMC\ (i,\ te))} \times (e^{\sigma^2\ (IMC\ (i,\ te))} - 1) \qquad (4.103)$$

4.3.3. Time-integrated ^{131}I concentrations in fresh cows' milk resulting from ^{131}I deposition from a given test series.

The time-integrated concentration of ^{131}I in fresh cows' milk in county, i, resulting from a given test series, ts, is obtained by adding the contributions from each test, te, in the series:

$$IMC\ (i,\ ts) = \sum_{te=1}^{nte} IMC\ (i,\ te) \qquad (4.104)$$

where nte is the number of tests in the series, ts.

The parameters of the distribution of IMC(i,ts) are obtained in the similar way as those of IMC(i,te), which were determined in **Section 4.3.2**:

$$< IMC\ (i,\ ts) > = \frac{\sum_{te=1}^{nte} m(IMC(i,\ te))}{\sqrt{\left(1 + \frac{\sum_{te=1}^{nte} s^2(IMC(i,\ te))}{(\sum_{te=1}^{nte} m(IMC(i,\ te))^2)} \right)}} \qquad (4.105)$$

where

m(IMC(i,te)) and s^2(IMC(i,te)) are the arithmetic mean and the standard deviation of IMC(i,te) and are determined in *equations 4.102* and *4.103,* respectively.

- geometric standard deviation, GSD(IMC(i,ts)):

$$GSD(IMC\ (i,\ te)) = e^{(\sigma(IMC(i,\ ts)))} \qquad (4.106)$$

with:

$$\sigma^2\ (IMC\ (i,\ ts)) = \log_e \left(1 + \frac{\sum_{te=1}^{nte} s^2\ (IMC\ (i,\ te))}{(\sum_{te=1}^{nte} m\ \ (IMC(i,te))^2)} \right) \qquad (4.107)$$

- arithmetic mean, m(IMC(i,ts)):

$$m(IMC(i,\ ts)) = \ < IMC\ (i,\ ts) > \ \times\ e^{0.5 \times \sigma^2\ (IMC\ (i,\ ts))} \qquad (4.108)$$

- variance, s^2(IMC(i,ts)):

$$s^2\ (IMC\ (i,\ ts)) = \ < IMC\ (i,\ ts) >^2 \times\ e^{\sigma^2 (IMC\ (i,\ ts))} \times (e^{\sigma^2 (IMC\ (i,\ ts))} - 1) \qquad (4.109)$$

4.3.4. Time-integrated ^{131}I concentrations in fresh cows' milk resulting from ^{131}I deposition from all tests

The time-integrated concentration of ^{131}I in fresh cows' milk in county, i, resulting from all tests, is obtained by adding the contributions from each of the eight test series (Ranger, Buster-Jangle, Tumbler-Snapper, Upshot-Knothole, Teapot, Plumbbob, Hardtack, and Underground Era):

$$IMC\ (i) = \sum_{ts=1}^{8} IMC\ (i,\ ts) \qquad (4.110)$$

The parameters of the distribution of IMC(i) are obtained in the similar way as those of IMC(i,te), which were determined in **Section 4.3.2**:

- geometric mean, <IMC(i)>:

$$< IMC\ (i) > = \frac{\sum_{ts=1}^{8} m(IMC(i,\ ts))}{\sqrt{\left(1 + \frac{\sum_{ts=1}^{8} s^2(IMC(i,\ ts))}{(\sum_{ts=1}^{8} m(IMC(i,\ ts))^2)} \right)}} \qquad (4.111)$$

where

m(IMC(i,ts)) and s^2(IMC(i,ts)) are the arithmetic mean and the standard deviation of IMC(i,ts) and are determined in *equations 4.108* and *4.109,* respectively.

- geometric standard deviation, GSD(IMC(i)):

$$GSD\ (IMC\ (i)) = e^{\sigma (IMC\ (i))} \qquad (4.112)$$

with:

$$\sigma 2(IMC\ (i)) = \log_e \left(1 + \frac{\sum_{ts=1}^{8} s^2\ (IMC\ (i,\ ts))}{(\sum_{ts=1}^{8} m\ (IMC(i,\ ts))^2)} \right) \qquad (4.113)$$

- arithmetic mean, m(IMC(i)):

$$m(IMC\,(i)) = \langle IMC\,(i) \rangle \times e^{0.5 \times \sigma^2\,(IMC(i))} \qquad (4.114)$$

- variance, s²(IMC(i)):

$$s^2\,(IMC\,(i)) = \langle IMC\,(i) \rangle^2 \times e^{\sigma^2 (IMC\,(i))} \times (e^{\sigma^2 (IMC\,(i))} - 1) \qquad (4.115)$$

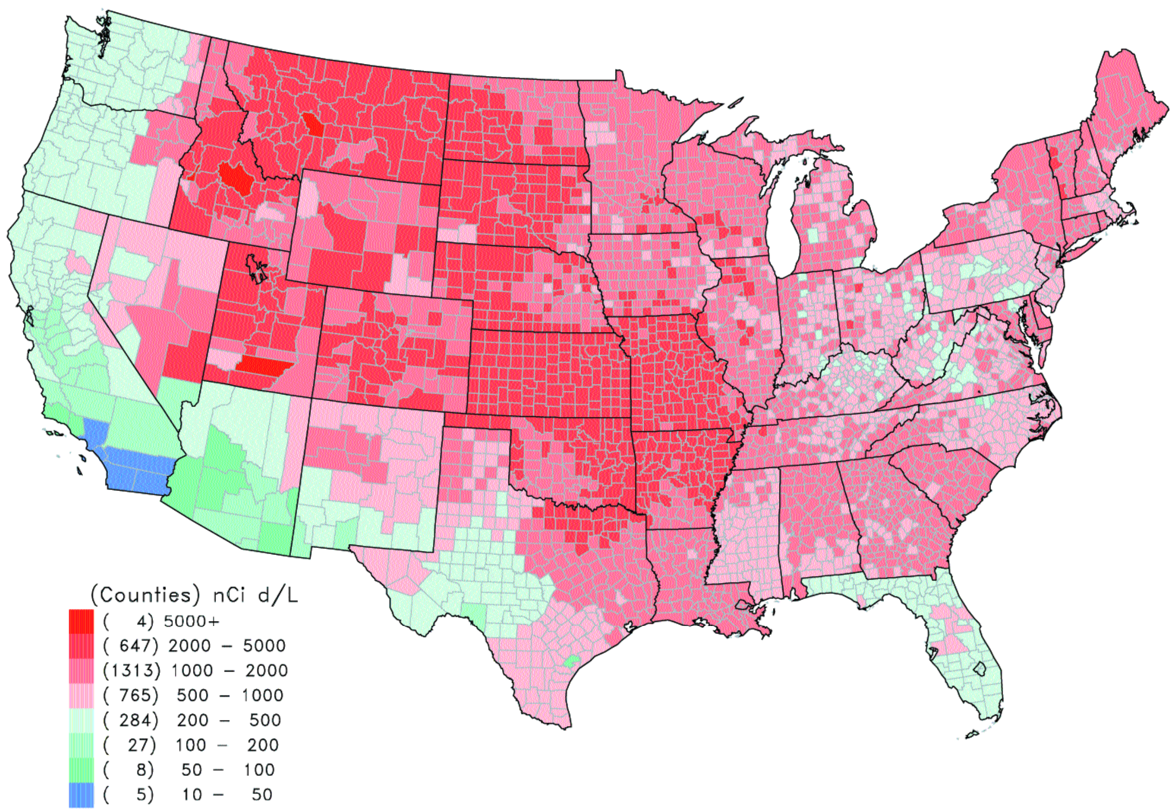
4.4. RESULTS

Figure 4.25 illustrates the spatial distribution over the contiguous United States of the county median estimates for each county of the time-integrated ^{131}I concentrations in fresh cows' milk from all tests, <IMC(i)>. Milk was contaminated with ^{131}I to some extent, at one time or another, in all counties of the contiguous U.S. as a result of the nuclear weapons tests conducted at the NTS. The averages of the total time-integrated concentrations of ^{131}I in fresh cows' milk are estimated to have been as low as 10-20 nCi d L^{-1} in a few counties in California and as high as about 5000 nCi d L^{-1} in several counties in Idaho. The pattern of the ^{131}I time-integrated concentrations in fresh cows' milk reflects by and large the pattern of ^{131}I depositions presented in **Chapter 3**.

The county averages of the time-integrated ^{131}I concentrations in fresh cows' milk, for each test (<IMC(i,te)>) and for each test series (<IMC(i,ts)>), are available in the Annexes (in tables denoted as ts/te/M, where ts is the abbreviation for the test series and te is the test number in the test series) along with the GSDs associated with their distributions. The GSDs vary according to the location of the county and to the time of the year, but are usually rather large, with typical values of 3 to 4.

The county averages of the time-integrated ^{131}I concentrations in fresh cows' milk, for each day of ^{131}I deposition following a given test (<IMC(i,te)>) are intermediate results that are not provided in this report because they are not directly used in the estimation of the thyroid doses.

Figure 4.25. Estimated time-integrated concentrations of ^{131}I in fresh cows' milk in all counties of the contiguous U.S. resulting from all tests conducted at the Nevada Test Site.



4.5. SUMMARY

- The transfer of ^{131}I from deposition on the ground to fresh cows' milk resulted from several environmental pathways, the most important of which was the pasture-cow-milk route.
- The major parameters involved in the pasture-cow-milk exposure route are the mass interception factor of ^{131}I by vegetation, the mean-time of retention of ^{131}I on vegetation, the amount of ^{131}I-contaminated pasture ingested by cows, and the transfer coefficient of ^{131}I from feed to milk for cows.
- The mass interception factor of ^{131}I by vegetation varies, in the absence of precipitation, as a function of the distance from the NTS because large particles, which are less abundant as one moves further away from the NTS, are not intercepted as efficiently by vegetation as are small particles. In the presence of precipitation, results of field experiments that were conducted specifically for this study show that vegetation intercepts water-soluble ^{131}I much less readily than it intercepts ^{131}I attached on particles.
- The mean time of retention of ^{131}I by vegetation is about 1 week. Results of experiments conducted specifically for this study confirmed the values published in the literature.
- The daily amount of pasture consumed by cows in the 1950s was estimated according to the region of the country and the time of the year. The country was divided into 71 separate pasture regions and daily pasture intakes were assigned on each pasture region for each week of the year.
- The transfer coefficient of ^{131}I from feed to milk for cows is found in the literature to range from 1 x 10^{-3} d L^{-1} to 4 x 10^{-2} d L^{-1}. Values pertaining to ^{131}I in fallout seem to be in the lower part of the range. An average value of 4 x 10^{-3} d L^{-1} has been used in the report.
- Milk from cows can be contaminated by pathways other than the deposition of ^{131}I fallout on pasture and subsequent ingestion of pasture by the cow. Milk from cows also can be contaminated by ingestion of ^{131}I-contaminated soil, of ^{131}I-contaminated water, of ^{131}I-contaminated stored hay, of vegetation contaminated with ^{131}I resuspended from soil, and by inhalation of ^{131}I in air. Altogether, these pathways are estimated to be about 10 times less important than is the pasture-cow-milk exposure route.
- Time-integrated ^{131}I concentrations in fresh cows' milk have been estimated for each test and for each county of the contiguous U.S. The pattern of ^{131}I concentrations in milk generally reflects the pattern of ^{131}I depositions. The uncertainties attached to the best estimates, expressed as geometric standard deviations, vary from county to county and from test to test, but are usually rather large, with typical values of about 3 to 4. The time-integrated ^{131}I concentrations in fresh cows' milk in the contiguous U.S., summed for all tests, are estimated to have been as low as 10-20 nCi d L^{-1} in California and as high as about 5000 nCi d L^{-1} in parts of Idaho.

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Chapter 5

Cows' Milk Production, Utilization, Distribution and Consumption

Contents: The assessment of the radiation exposures resulting from the ingestion of ^{131}I contaminated cows' milk necessitates the estimation of the amounts and origins of the fresh fluid milk consumed by people. The production, utilization, and distribution of cows' milk in each county of the contiguous U.S. in the 1950s is derived from agricultural census data combined with the use of simple models. The consumption of milk is determined according to sex, age group, and region of the country from dietary surveys and population census data.

During the 1950s, about 50% of the cows' milk produced in the United States was consumed by the populace as fresh fluid milk (Judkins and Keener 1960), about 3% was used on farms to feed livestock, and the remainder was used in the manufacture of dairy products or other foods. Because of the half-life of ^{131}I and the time interval between milk production and the consumption of manufactured foods containing milk, these products are not considered to be a significant exposure route for ^{131}I. The most important dairy product of concern in the transport of ^{131}I to people via the food chain is fresh fluid milk. This is due to the relatively short time from its production to human consumption. In the remainder of the report, the terms "fluid cows' milk" and "cows' milk" mean fresh fluid milk that is obtained from cows and consumed by people.

Most of the cows' milk produced for consumption as fresh fluid milk is commercially distributed but some of it is consumed on farms. Knowledge of the movement of milk between the areas of production and consumption is necessary because milk originating in different locations will have varying ^{131}I concentrations as a result of the heterogeneous distribution of fallout deposition across the U.S. after each test. In addition, the greater the distribution distance of the milk, the greater the elapsed time between the production and the consumption of the fresh fluid milk, and, in turn, the greater the amount of decay of ^{131}I prior to human consumption.

Individual consumption rates of cows' milk vary according to a number of factors such as age, sex, race, year, geographical area, and degree of urbanization. These factors also need to be taken into consideration in the assessment of individual exposures to ^{131}I.

The methodology for relating the production, distribution and consumption of milk throughout the country is dependent upon a separate analysis of each component:

- the estimation of milk production on a county by county basis;
- the extent to which it was used for human consumption also called fluid use;
- the distribution of milk for fluid use between the site of production and the location at which it was consumed;
- the consumption rates of fresh fluid milk by various subgroups in the population.

Statistical data on amounts of milk produced or distributed are usually reported in the U.S. in units of pounds (or multiple of pounds) per year. They have been systematically converted in this report to liters per year, using a conversion factor

of 2.205 pounds per liter of milk. Survey data on milk consumption are usually reported in fluid ounces; they have been converted to milliliters, using a conversion factor of 30 milliliters per fluid ounce.

5.1. COWS' MILK PRODUCTION

The production of milk in a given county can be estimated from county data published by the U.S. Department of Commerce in the Censuses of Agriculture (for example, USDC 1954) combined with state statistics published by the U.S. Department of Agriculture (USDA 1962a).[1] Censuses of Agriculture were conducted in 1950, 1954 and 1959. Since the most important NTS tests with regard to fallout were carried out in 1952, 1953, 1955, and 1957, and because changes in the dairy milk industry are relatively slow, data from the 1954 Census of Agriculture have been taken to be representative of the situation during the entire period of nuclear weapons testing in the atmosphere at NTS.

Assuming that the average milk production per cow reported for a state does not vary significantly from the average milk production rate in a given county in the same state, the total annual production of milk in a given county is estimated from the number of cows in that county (USDC 1954) and from the average annual milk production per cow in the state (USDA 1962a):

$$MP(i) = C(i) \times CP(s) \tag{5.1}$$

where:

MP(i) = rate of milk production in thousands of liters per year ($kL\ y^{-1}$) in a county

C(i) = number of cows in a county

CP(s) = average milk production ($kL\ y^{-1}$) per cow in the state.

The index i for all variables in this equation, as well as in the following ones, denotes the value for a given county while the index s, in this equation as well as in the following ones, denotes the value for a given state.

5.2. COWS' MILK UTILIZATION

The amount of milk produced in each county of the contiguous United States that is available for fluid use is estimated using:

$$TMFU(i) = MP(i) - MUF(i) - MM(i) \tag{5.2}$$

where:

TMFU(i) = rate of production of milk for fluid use ($kL\ y^{-1}$) in a county

MP(i) = rate of milk production ($kL\ y^{-1}$) in a county

MUF(i) = rate at which milk is used on the farm for purposes other than human consumption ($kL\ y^{-1}$) in a county

MM(i) = rate at which milk produced in a county is used for manufacture of food products ($kL\ y^{-1}$).

Milk that is used on farms for feeding calves and for butter production (referred to as "milk used on farms" in this report) in a given county is estimated by assuming that the number of cows on the farm was an important factor in the amount of milk used on that farm. To apportion the state value for the rate of milk use on farms, MUF(s) ($kL\ y^{-1}$), as reported by USDA (1962a), among the counties, the ratio of the number of cows in each county to the total number in the state was used:

$$MUF(i) = MUF(s) \times \frac{C(i)}{C(s)} \tag{5.3}$$

where:

MUF(i) = rate of milk use on the farms ($kL\ y^{-1}$) in a county

C(i) = number of cows in a county

C(s) = number of cows in a state.

The rates of milk usage in the states for the manufacture of dairy products, MM(s) were reported by the USDA (1962a), but data on the fraction of the milk produced in each county that was used for this purpose in the 1950s and 1960s are not available. Because milk for fluid use would have brought a higher price than would other dairy products (Beal and Baaken 1956), it can be assumed that only the surplus, after the consumption needs of the population of that county had been met, would have been sold, at a lower price, to manufacturing plants.

To estimate the rate of milk use for manufacture of dairy products in each county, it is assumed that in counties where more milk was produced than was needed for fluid use in that county, a portion of the milk produced was purchased by a local

[1] Personal communication (1986) with Robert Miller, Agricultural Marketing Service–USDA, Dairy Divison, Washington, D.C. 20250

or regional manufacturing plant. In each county with a milk surplus, the rate at which milk was used for the manufacture of dairy products, MM(i) (kL y^{-1}), is estimated from:

$$MM(i) = MM(s) \times \frac{MP(i)}{TMP(s)} \qquad (5.4)$$

where:

MM(s) = rate of milk usage for manufacture of food products (kL y^{-1}) in a state

MP(i) = rate of milk production (kL y^{-1}) in the county

TMP(s) = sum of milk production rates (kL y^{-1}) in all the counties with a milk surplus (as defined by DIF(i), shown below) in the state.

To determine the counties that had a surplus of milk production after farm use was taken into account, the following assessment was carried out:

$$DIF(i) = (MP(i) - MUF(i)) - EC(i) \qquad (5.5)$$

where:

DIF(i) = test value (kL y^{-1}) that provides indication of surplus or deficit of milk in a county

MP(i) = rate of milk production (kL y^{-1}) in the county

MUF(i) = rate of milk usage on the farms (kL y^{-1}) in the county

EC(i) = expected rate of milk consumption (kL y^{-1}) in the county (as defined below)

If the value of DIF(i) was positive, there was a surplus of milk in the county. If DIF(i) was negative, the county did not produce enough milk to meet the human consumption needs of its population and is considered to have a milk deficit. The expected consumption rate of fresh fluid milk for the population in the county is estimated using the per capita milk consumption for the state. Those rates and other milk production and usage data for each state are listed in *Table 5.1.*

The expected milk consumption rate for county i, EC(i), (kLy^{-1}), is:

$$EC(i) = POP(i) \times CR_{pc}(s) \times \frac{365}{10^6} \qquad (5.6)$$

where:

POP(i) = population of a county, i, in a state, s

$CR_{pc}(s)$ = per capita milk consumption rate (mL d^{-1}) in a state, s

365 = the number of days in a year

10^6 = the number of mL in a kL

The derivation of the per capita milk consumption rates for each state is discussed in **Section 5.4.**

The rate at which milk was used to make cheese and other products in each county with a surplus is estimated using *equation 5.4.* TMP(s) is determined by adding the amount of milk produced, MP(i), in each of the surplus counties where DIF(i), computed using *equation 5.5,* was greater than zero.

In some cases, due to the methodology, the estimated rate of milk use for manufacture in the county, MM(i), is greater than the rate of milk production in the county, MP(i), minus the rate of milk usage on the farms in the county, MUF(i). In the 55 counties where this occurs, MM(i) is limited to be equal to MP(i) minus MUF(i) minus the volume of milk consumed on the farms in the county, MCF(i) (discussed in **Section 5.3**).

It is difficult to verify these estimates because milk destined for use in the manufacture of dairy products was shipped across county and state boundaries (Meenen 1952) to operating plants and reported in terms of processing rates for specified types of plants. Comparisons of the locations of manufacturing plants (Meenen 1952; Feder and Williams 1954) to the estimated rates of milk for fluid use in the same county did not take into account the milk shipped from counties with no manufacturing plants.

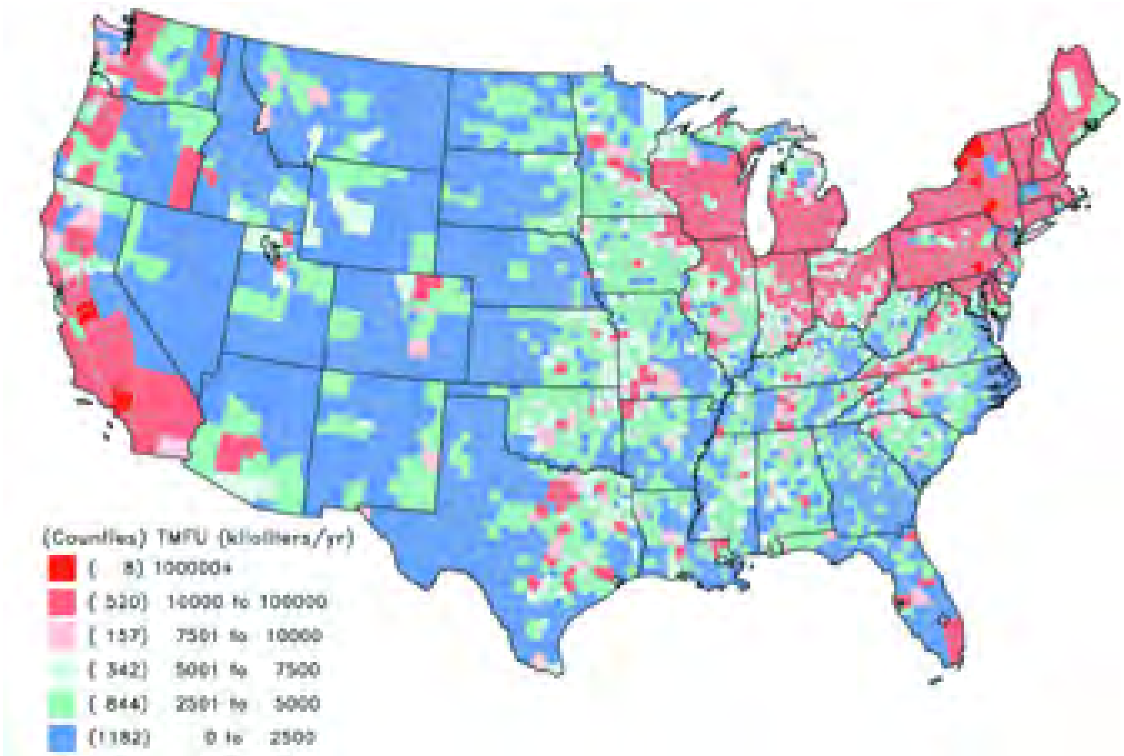
The estimates, calculated using *equation 5.2,* of the rate of production of milk for fluid use, TMFU, are given for each state in the contiguous U.S. in *Table 5.1.* The data for each county are presented in **Appendix 4** and the estimated values of TMFU(i) for each county in 1954 are illustrated in *Figure 5.1.*

Table 5.1. Summary of rates of production and usage of cows' milk in each state estimated for 1954. The units are in thousands of liters per year (kL y^{-1}) except for the consumption rates, $CR_{pc}(s)$, which are in milliliters per day (mL d^{-1}).

State	MP(s)[a]	MM(s)[b]	MUF(s)[c]	POP(s)[d]	$CR_{pc}(s)$[e]	EC(s)[f]	TMFU(s)[g]	MB(s)[h]
Alabama	473213	43705	160440	3140321	250	294365	257066	-37317
Arizona	130395	20465	5442	944100	300	107800	105066	-2732
Arkansas	469067	152971	90703	1857223	330	223701	245414	21713
California	3012305	1161390	60720	12700932	380	1760075	1763564	503
Colorado	393347	244062	27211	1527067	300	167243	122054	-45194
Connecticut	312003	57551	6617	2231603	445	362462	245641	-116040
Delaware	79700	6627	2721	372578	300	40957	68017	13060
Washington DC	0	0	0	763342	365	104707	0	-104707
Florida	331444	54043	10664	3097970	210	234064	205311	-26753
Georgia	466300	46663	121395	3656530	240	319774	319411	-362
Idaho	653514	533016	23025	622046	425	96496	97473	976
Illinois	2163712	1316665	72103	9294032	430	1456676	772916	-683761
Indiana	694656	714331	50794	4243739	430	666055	929733	263076
Iowa	2626051	2045624	100060	2679093	430	420476	481717	61263
Kansas	1027033	607537	73016	2021540	350	258253	340066	67634
Kentucky	1034745	436261	101134	2944011	350	396257	437331	43073
Louisiana	312332	51662	26116	2927346	250	273352	232332	-41020
Maine	269631	32103	24943	937355	445	152251	232779	80526
Maryland	530464	101709	16141	2665026	360	350166	416575	66367
Massachusetts	332716	90703	40616	4665201	445	758465	201136	-532269
Michigan	2239693	1006662	106576	6966071	430	1096657	1160061	63364
Minnesota	3767361	3221361	106122	3165636	450	519967	439679	-80106
Mississippi	631675	205665	123356	2178664	330	262416	302514	40096
Missouri	1661735	1101069	104762	4109047	330	495027	455665	-39142
Montana	234530	95236	22676	626021	500	114356	116077	2313
Nebraska	1012271	603756	66634	1362054	400	198660	133541	-65319
Nevada	39636	11973	2266	213263	302	23472	16395	-7076
New Hampshire	164346	13379	5696	594562	445	91700	145072	53372
New Jersey	465742	127120	3977	5356636	360	704140	348644	-355496
New Mexico	69514	16776	7256	795660	300	87150	63463	-23667
New York	4076437	1271746	127436	15053666	445	2945576	2077253	133075
N. Carolina	716716	130264	160061	4272066	275	428815	426421	-2393
North Dakota	639621	512653	64653	625036	500	114079	115116	1036
Ohio	2363693	1316617	93424	8694533	403	1290362	953356	-343025
Oklahoma	702660	321567	66461	2273712	330	273866	312592	36726
Oregon	539603	293290	31746	1626477	365	216667	214466	-2226
Pennsylvania	2569166	723537	93424	10647129	380	1504466	1772266	267727
Rhode Island	55016	13456	1361	820624	445	133291	34201	-99090
S. Carolina	254961	30703	53515	2223329	275	223632	170743	-53069
South Dakota	555216	357370	42177	664570	500	121263	155669	34396
Tennessee	1034512	437166	136506	3406615	330	410566	400815	-9773
Texas	1171576	200272	122903	8508456	290	900305	848404	-51902
Utah	269726	167691	12696	774016	300	84621	89136	4517
Vermont	731317	97544	13046	382315	445	62135	614356	552166
Virginia	855166	179501	121066	3593703	314	412163	554536	142413
Washington	786539	357007	43391	2505540	400	376759	379541	2782
W. Virginia	353977	73266	63039	1943923	275	195124	217651	22527
Wisconsin	7160037	5513312	263342	3654404	430	573551	1327363	753462
Wyoming	93396	35556	6617	304330	425	47209	49624	2415
TOTALS	51844384	26616288	3165080	162516736	372	22063284	22063028	-259

[a] MP(s) = Total milk produced
[b] MM(s) = Milk used for manufacturing
[c] MUF(s) = Milk used on farms (not consumed by people)
[d] POP(s) = Population
[e] $CR_{pc}(s)$ = Per capita consumption rate (mL/d)
[f] EC(s) = Expected consumption
[g] TMFU(s) = Total fluid milk consumed
[h] MB(s) = Surplus or deficit of milk (=TMFU(s) - EC(s))

Figure 5.1. Volumes of milk available for fluid use.



5.3. COWS' MILK DISTRIBUTION

In the distribution model, milk available for fluid use is either consumed on the farm, distributed for consumption to the local county population, or distributed to areas outside the county where the amount of available milk does not meet the consumption needs of the population. The distribution of milk to other counties usually results in the mixing of milk from a number of sources that may have varying ^{131}I concentrations as a result of differences in fallout deposition.

The way in which milk was collected and distributed in the United States during the 1950s was in a transitional period. More farmers employed bulk tanks to collect the milk, which increased the time between production and processing. During the 1950s the frequency of milk collection at the farm decreased from daily pick-up to every 3 days as the use of bulk tanks for collection and transportation of milk gradually replaced the use of individual milk cans (Beal and Bakken 1956; Henderson 1971; Roadhouse and Henderson 1950; Spencer 1957; USDA 1968a).

Milk, in general, was produced close to the population centers that required the milk supply (Lee 1950; Mighell and Black 1951), but the increasing use of refrigerated tank cars and the reduced cost of transportation also made it possible to ship milk greater distances. For example, although many of the experts surveyed during this study were of the opinion that milk was not routinely distributed more than 300 km away from the farm during the 1950s, there are reports that milk did flow greater distances (e.g., from the Midwest to New England and the East Coast) to satisfy major urban areas and to fulfill emergency shortages (Beal and Bakken 1956; Henderson 1971; Spencer 1957; USDA 1965). This also increased the amount of time between the processing and ultimate consumption of the milk by the population.

The factors that influence where bulk milk is purchased are: availability of surplus milk, price, transportation and handling charges, sanitary regulations, marketing regulations, and purchasing policies of the buyer (Carley 1964). The marketing of milk that was distributed long distances was loosely coordinated. Milk was purchased from farther distances when there was a need to fulfill a deficit. Emergency deficits of milk occurred on both a spot emergency (shortage of local supplies) and a seasonal basis (in most places September through February were lower milk production months). According to interviews conducted by Carley (1964), five out of 19 buyers bought milk from outside sources on a regular basis. They purchased milk from as many as 30 different sellers within a 4-year period starting in 1957. Routine contracts for long distance purchases did not allow for the flexibility needed by the purchasers, so they were not common.

Another factor that increased the time interval between production and consumption of the milk by the consumer was the decline of the total amount of milk delivered directly to the home during the 1950s. The frequency of the milk deliveries to homes also decreased (Henderson 1971).

Information on volumes and directions of milk distribution and on the delay times between production and consumption is, in general, more qualitative than quantitative. Although relevant data have been published for federally administered Milk Marketing Orders (USDA 1958) and for parts of the west (Ward and Whicker 1987), they do not provide all of the information required in this study and cannot be used to derive values for the entire country. It was therefore decided to resort to a simple model based on the nationwide statistics on milk production and utilization reported by the U.S. Department of Commerce (USDC 1954) and the U.S. Department of Agriculture (USDA 1962a), and to validate as much as possible the structure of the model and the assumptions used by means of published information and recollections of experts. Because of the complexity of the system and the associated uncertainties, it was decided to develop only one model of milk distribution for the 1950s and to use the 1954 data for that purpose.

In this model, the total milk for fluid use in a county, TMFU(i), is divided into four categories corresponding to the following population groups:

category 1: those living on the farms in the county where the milk is produced;

category 2: those living in the county where the milk was produced but not on farms;

category 3: those living in a group of neighboring counties within a designated "milk region", or group of neighboring counties in a state, and

category 4: those living at greater distances, that is, in other "milk regions" in the same or another state.

The model assumes that the milk produced in a county is used initially to satisfy the consumption needs within the county and, if there is a surplus, to fulfill the needs that have not been satisfied elsewhere. The volumes of milk that are assigned to each of the four categories are determined as follows:

Category 1. In order to estimate the portion of milk production in the county that was consumed on farms in that county, it is assumed that the consumption of milk on farms in a given county is proportional to the number of farms in that county. The total rate of milk consumption on farms in 1954 in the states, (USDA 1962b) is apportioned to the number of farms reported to be in each county in 1954, as follows:

$$MCF(i) = MCF(s) \times \frac{FA(i)}{FA(s)} \qquad (5.7)$$

where:

MCF(i) = the rate of milk consumption (kL y^{-1}) on farms in a county, i

MCF(s) = rate of milk consumption (kL y^{-1}) on farms in the state, s

FA(i) = number of farms in a county, i

FA(s) = number of farms in a state, s

It is assumed that fresh fluid milk consumed on the farms would be consumed with a 1 day delay time between milk production and consumption.

In some cases, as a result of the methodology, the calculated amount of milk consumed on farms exceeded the calculated total expected milk consumption in the county. In these 37 counties, the amount of milk consumed on the farm was limited to the expected milk consumption in the county (i.e., it was assumed that all the milk consumed by the local population was consumed on farms).

Category 2. The source of milk consumed in a county but not on farms, is dependent on the amount of milk available in the county. The expected milk consumption rate for the county, calculated using *equation 5.6,* is subtracted from the total rate of milk production for fluid use available in the county. The result indicates whether the balance of milk in the county was surplus or deficit:

$$MB(i) = TMFU(i) - EC(i) \qquad (5.8)$$

where:

MB(i) = milk balance (kL y^{-1}) in a county, i

TMFU(i) = rate of production of milk for fluid use (kL y^{-1}) in a county

EC(i) = expected rate of milk consumption (kL y^{-1}).

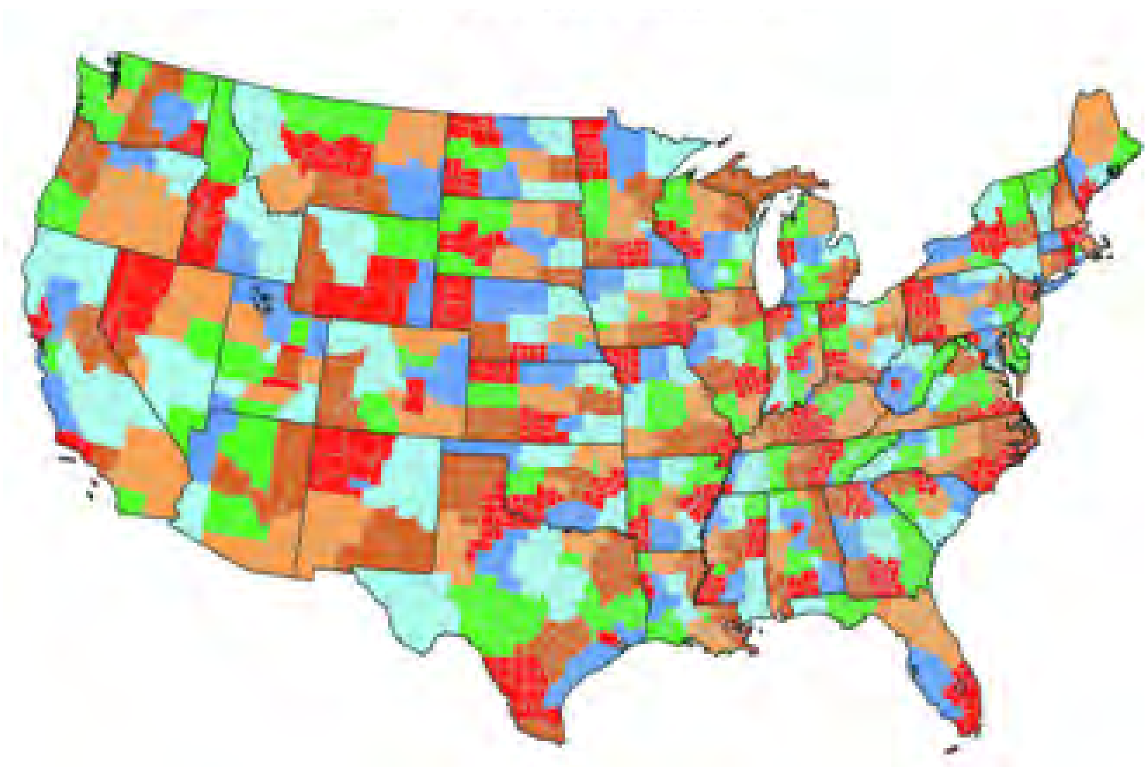
If MB(i) is positive, indicating a surplus of milk, the rate of category 2 milk use is equal to the rate of milk consumption on farms subtracted from the expected human milk consumption rate in the county, EC(i) - MCF(i). Any surplus milk remaining, MB(i), is exported to other counties. If MB(i) is negative, indicating a deficit, the rate of category 2 milk use is equal to the rate of milk consumption on farms subtracted from the rate of production of milk available for fluid use in the county, TMFU(i) - MCF(i). The remainder of milk needed to supply the population in this county is imported from other counties. Category 2 milk is in all cases assigned a delay time of 2 d between production and consumption.

Category 3. To simulate flow of milk over short distances, neighboring counties have been grouped into 429 "milk regions" that have been defined throughout the contiguous United States. The geographic extent of the regions are based on the Crop Reporting Regions and milkshed areas outlined by each state's Department of Agriculture (e.g., Pennsylvania Crop Reporting Service 1980). Additional regions were drawn to isolate the population concentrated around cities in each state. For the states close to the NTS (Nevada, Arizona, Utah, and part of California), available information on milk distribution and pasture practices (Ward and Whicker 1987) were used to designate boundaries of the milk regions. *Figure 5.2* illustrates the grouping of northeastern counties into milk regions. The milk regions for each state in the contiguous U.S. can be found in **Appendix 5.** Each milk region has been assigned an individual number.

The first step to balance the surplus (or deficit) of milk in an individual county is by flow of milk between counties in the same "milk region". The milk pooled from the counties with a surplus of milk is distributed to the counties of the region with a deficit of milk, proportionate to their needs. This rate of milk transfer to deficit counties within the region, constitutes the milk of category 3, to which a delay time of 3 d is assigned. Methods for calculating these transfer rates are given in **Chapter 6.**

Category 4. If the county surpluses of milk in the region does not meet the deficits in other counties, additional milk must be provided by another milk region. Milk of category 4 is that which is imported into a deficit region from another surplus region or, conversely, that which is exported from a surplus region into a deficit region. Milk in this category is assumed to have a delay time of 4 d between production and consumption because it has travelled the greatest distance from producer to consumer. Movements of milk in category 4 between surplus regions and deficit regions were designed to achieve balance between production and consumption at the national level. These transfer patterns are discussed in more

Figure 5.2. Identification of the "milk regions" used in the dose assessment.



[2] Personal communication (1987) with Geoffry Benson at North Carolina State University, Dairy Managing and Marketing, Raleigh, North Carolina.

Figure 5.3. The "milk regions" that provide their surplus milk to satisfy the milk deficit in the metropolitan New York area.

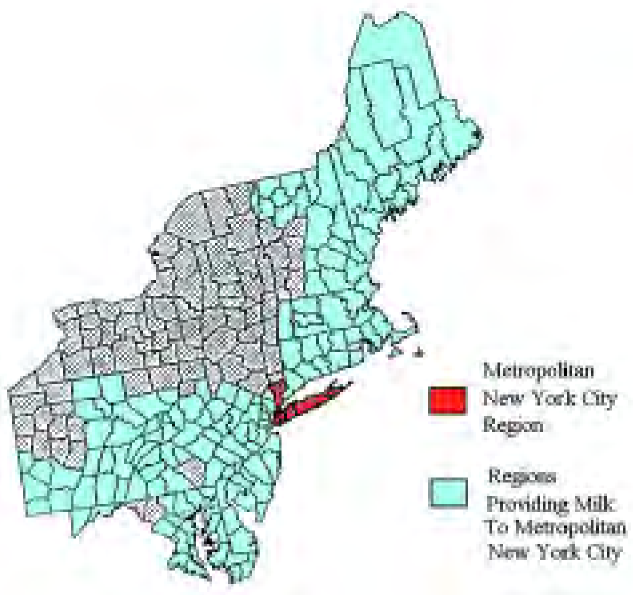
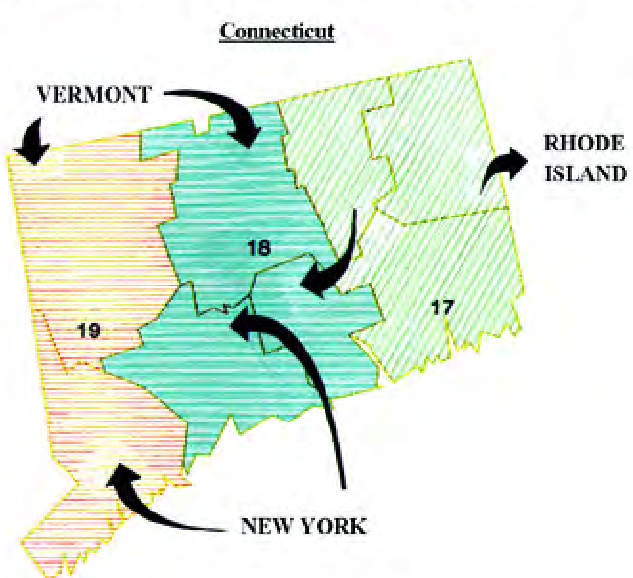


Figure 5.4. Transfer of milk to and from the milk regions of Connecticut in the 1950s, based on data from USDA (1958).



detail in **Chapter 6**.

The assumptions regarding the direction and distance that milk was distributed during the 1950s are based upon Agricultural Research Stations reports as well as information made available from State Agricultural Department Milk Boards, Federal Milk Marketing Administrators Offices, and Agricultural Economists with the Extension Service. Major patterns of milk flow in the U.S. were and are driven by the overall surplus and deficits calculated for each region of the country as a result of the needs of major population areas. The fact that most of the surplus milk in the U.S. is produced in the northern parts of the country and shipped south also had an important influence.[2]

In this study the direction of the distribution of milk was determined largely by using the data supplied by the USDA on the sources of milk for the Milk Marketing Orders operating in the U.S. in 1958 (USDA 1958). In some cases, individual reports from the marketing orders were available for the time in question. Unfortunately, there was very little consistency in the reporting of the sales and distribution of milk in the different orders, thereby making it almost impossible to use the volumes of milk reported. The volumes of milk that were distributed between regions in this model were determined by the surplus and deficits calculated, and the direction of the flow was heavily influenced by the data reported by the USDA (1958).

As an example of the use of these data, the milk regions supplying milk to the metropolitan New York City region are outlined in *Figure 5.3*. For the sake of clarity, other deficit regions in the Northeast such as those including Boston, Washington D.C., Philadelphia and Pittsburgh, are not illustrated in *Figure 5.3*. Regions producing surplus milk may supply milk to more than one deficit region and regional representation such as in *Figure 5.3* would become very complex if milk movements to all deficit areas were included. A simple example of milk flow between regions is illustrated in *Figure 5.4* for the state of Connecticut.

The rates of milk transfer between all regions in the contiguous United States are listed in **Appendix 5.** For each transfer of milk between two regions, there is an indication of the source of the distribution information and an indication of the degree of confidence in the data. If there were data available that showed that one or more counties in a given region were a source of milk for a Milk Marketing Order, the transfer data was considered to be the most reliable (level 1). There are many parts of the U.S. where milk sales were not administered using Milk Marketing Orders. In these cases, distribution between nearby regions also was judged to be fairly reliable (due to the assumption that milk was used close to the source first) (level 2). If the surplus region was not included in the sources of milk for the Milk Marketing Order but a transfer was made in this study, it was considered to be less certain that milk moved in that direction (level 3). This level of uncertainty is also considered appropriate for distribution patterns between non-adjacent counties that seem logical but for which there is no information available.

5.4. COWS' MILK CONSUMPTION

Individual consumption rates of fluid cows' milk vary widely according to age, sex, race, urbanization and area of the country, among other factors. Per capita milk consumption rates for large population groups, as reported by different sources, also vary significantly, primarily because the data were collected to satisfy various objectives, resulting in differences in populations surveyed, definitions of fluid milk for consumption, methods of data collection, and the year of the survey.

The per capita consumption rate of fluid cows' milk for the entire population of the United States can be inferred from USDA statistics on the total amount of milk sold for fluid use in the country (USDA 1962b). From the 1950s to date, the per capita milk consumption in the U.S. has decreased substantially, but most of this change has occurred since 1965. Between 1950 and 1965, the per capita milk consumption rate varied within a relatively narrow range, from the highest rate of 383 mL d^{-1} in 1956 to the lowest rate of 334 mL d^{-1} in 1965 (USDA 1968b).

Variations from the consumption rate for the whole population are seen as a function of age, sex, region of the country, race, season, and degree of urbanization (city vs country lifestyles). In this assessment, the factors of age, sex and region of the country were taken into account in determining the per capita consumption rates for each state *(Table 5.1)*. The other factors are discussed briefly. The statistical data used are, as much as possible, for the year 1954, taken as representative of the time period during which atmospheric weapons tests were carried out at the NTS.

5.4.1. Variation as a Function of Sex and Age

Variation of milk consumption rates as a function of sex and age have been reported by many authors (Durbin et al. 1970; PHS 1963a; PHS 1963b; Rupp 1980; Thompson 1966; Yang and Nelson 1986). The variation as a function of age is particularly important for infants.

Infants (0 to 1 year). The source and amount of milk consumed by infants changes significantly during their first 6 months (Durbin et al. 1970). Infants may consume mothers' milk, fluid cows' milk, evaporated milk, or ready-to-use formula. The fractions of the population of infants consuming mothers' milk and fluid cows' milk (types of milk contaminated with fallout ^{131}I) are presented in *Table 5.2*. The number of infants consuming mothers' milk decreases continuously as a function

Table 5.2. Variation with age of the fraction of infants drinking fluid cows' milk or mothers' milk for the years 1953 to 1962. Remainder of the infants consumed evaporated milk or ready-to-use formula (Durbin et al. 1970).

Year	Month										
	0.33	1	2	3	4	5	6	7	8	9	10
	(a) fraction of infants drinking fluid cows' milk										
1953	0.04	0.09	0.18	0.25	0.41	0.54	0.69	0.83	0.90	0.96	1.0
1954	0.04	0.08	0.17	0.25	0.41	0.55	0.69	0.83	0.90	0.96	1.0
1955	0.04	0.08	0.17	0.25	0.41	0.55	0.69	0.83	0.90	0.96	1.0
1956	0.04	0.08	0.17	0.25	0.41	0.56	0.69	0.83	0.90	0.96	1.0
1957	0.04	0.07	0.16	0.25	0.41	0.57	0.70	0.83	0.90	0.96	1.0
1958	0.04	0.06	0.15	0.24	0.42	0.56	0.69	0.83	0.90	0.96	1.0
1959	0.03	0.06	0.10	0.23	0.42	0.57	0.71	0.84	0.91	0.97	1.0
1960	0.03	0.06	0.10	0.25	0.44	0.58	0.72	0.87	0.97	0.98	1.0
1961	0.03	0.06	0.11	0.22	0.39	0.54	0.70	0.87	0.98	1.0	1.0
1962	0.02	0.06	0.11	0.20	0.38	0.56	0.72	0.88	0.98	1.0	1.0
	(b) fraction of infants that are breastfed										
1953	0.30	0.23	0.15	0.12	0.08	0.06	0.04	0.02	0.01	0	0
1954	0.30	0.23	0.15	0.12	0.08	0.06	0.04	0.02	0.01	0	0
1955	0.29	0.23	0.15	0.12	0.08	0.06	0.04	0.02	0.01	0	0
1956	0.29	0.22	0.15	0.12	0.08	0.06	0.04	0.02	0.01	0	0
1957	0.29	0.22	0.15	0.12	0.08	0.06	0.04	0.02	0.01	0	0
1958	0.29	0.22	0.15	0.12	0.08	0.06	0.04	0.02	0.01	0	0
1959	0.27	0.20	0.14	0.11	0.08	0.06	0.04	0.02	0.01	0	0
1960	0.27	0.20	0.14	0.11	0.08	0.06	0.04	0.02	0.01	0	0
1961	0.27	0.20	0.14	0.11	0.08	0.06	0.04	0.02	0.01	0	0
1962	0.27	0.20	0.13	0.13	0.08	0.06	0.04	0.02	0.01	0	0

Table 5.3. Variation of the per capita consumption of milk of all types and of fluid cows' milk according to age during the first year of age.			
Age (month)	Per capita consumption of milk of all types[a] (mL d^{-1})	Average fraction consuming fluid cows' milk[b]	Per capita consumption of fluid cows' milk[c] (mL d^{-1})
1st	671	0.08	54
2nd	742	0.17	126
3rd	726	0.25	182
4th	742	0.41	304
5th	769	0.55	423
6th	790	0.69	545
7th	718	0.83	596
8th	718	0.90	646
9th	718	0.96	689
10th to 12th	689	1.0	689

[a] Derived from Durbin et al. (1970), Table 1. [b] Data from Table 5.2 for 1954. [c] Product of columns two and three of this table.

of age while, on the contrary, the number of infants consuming fluid cows' milk increases continuously. Fifty percent of infants drink cows' milk by the time they are 5 months old. The data for 1954 in *Table 5.2* were combined with infant consumption rates obtained in household consumption surveys to derive the infant per capita consumption rates of fresh cows' milk during the first year of age (*Table 5.3*). Total milk consumption rates for infants 4 months and older presented in *Table 5.3* were taken from Beal (1954) as published in Durbin et al. (1970). Beal's values for infants under 4 months appear to be at the lower end of the range reported; therefore, for the first 3 months the average of the consumption rates reported for infants consuming milk and some solid food (Beal 1954; Durbin et al. 1970; Filer 1968; Filer and Martinez 1963, 1964; Kahn et al. 1969) are reported in *Table 5.3*. Averaged over the entire population, the total milk consumption reaches a maximum at 6 months of age (790 mL d^{-1}). Consumption of cows' milk is highest during the ninth month (689 mL d^{-1}). Milk consumption during the first year is assumed to be the same for males and for females.

Children (> 1 y) and adults. The fraction of each age group consuming various amounts of milk on an average day was estimated in a household food consumption survey (PHS 1963a) conducted in July of 1962. About 28,000 persons throughout the contiguous United States were interviewed. Two experimental techniques were used: in one subsample, a 3-day recall interview was used; in the other subsample, a 1-day recall interview was conducted and the respondent was asked to maintain a diary for a 3-day period. The results are presented in *Table 5.4*.

The data presented in *Table 5.4* were used by Thompson and Lengemann (1965) to derive the per capita milk consumption rates for the age and sex classes reported in *Table 5.5*. *Table 5.5* presents the consumption rates for ages 1-y and older taken from Thompson and Lengemann (1965), along with data for infants, taken from *Table 5.3*. The data for both age groups obtained from the survey include only consumption of fresh fluid cows' milk. *Table 5.5* includes an increase in milk consumption of 237 mL d^{-1} for school age children, 5 to 19 years, participating in the school milk program (Downen 1955; Thompson and Lengemann 1965). The average per capita fresh cows' milk consumption rates, presented in *Table 5.5,* show a maximum for teenage boys and lower values during adulthood, with a minimum for middle-aged women. Beyond the first year of age, males on average consume more milk than females.

Per capita milk consumption rate for the U.S. population. The per capita fresh cows' milk consumption rate for the U.S. population is obtained by weighting the milk consumption values of *Table 5.5* with the corresponding population fractions in 1954. The population fractions were calculated using a database, provided by the U.S. Environmental Protection Agency (USEPA 1985), in which the populations of each county are listed according to race (white and non-white), sex, and 5-y age group, for each year between 1951 and 1980. *Table 5.6* presents the U.S. population fractions for 1954 according to sex and 5-y age group. Using the milk consumption data of *Table 5.5* and the population data of *Table 5.6,* and assuming that the population fraction for children less than 5 years old applies to both the 0-1 and 1-4 age groups, the per capita fluid cows' milk consumption rates for the U.S. male and female populations and for the entire U.S. population have been calculated. The results are presented in *Table 5.5.* The per capita fluid cows' milk consumption rate

Table 5.4. Percentage distribution of "at home" consumption of whole milk by age and sex - July 1962 (PHS 1963a).

Age	Milk Consumption Rate (mL d^{-1})											
(years)	None	30-119	120-239	240-359	360-479	480-599	600-719	720-839	840-959	960-1079	1080-1200	>1200
MALES												
All ages	32.1	5.7	7.8	11.6	5.9	10.0	4.2	7.6	2.7	6.8	1.3	4.2
under 1	38.0	0.1	1.9	1.4	2.7	4.1	4.2	10.7	5.3	20.4	1.3	9.9
1-4	15.9	1.6	5.1	8.9	10.4	14.2	7.6	14.5	4.7	11.0	1.9	4.3
5-9	20.5	1.3	5.3	10.2	8.3	12.9	7.1	15.1	4.7	8.6	1.8	4.2
10-14	25.0	1.4	4.6	8.6	6.8	10.3	6.7	11.3	5.2	10.2	1.7	8.1
15-19	28.9	2.6	4.9	8.8	5.7	9.3	4.1	9.1	3.0	10.0	3.0	10.5
20-24	35.1	4.1	6.7	14.7	4.4	10.8	3.4	4.6	2.3	6.9	1.5	5.3
25-29	39.1	7.5	7.6	11.0	5.8	10.5	1.7	6.2	2.2	4.5	0.6	3.2
30-34	37.5	9.8	9.1	14.4	5.7	8.0	3.2	4.6	1.1	4.5	0.4	1.7
35-44	39.1	10.4	9.4	13.4	4.6	8.5	2.8	4.0	1.2	4.0	0.8	1.7
45-54	42.0	9.5	11.0	13.7	4.4	7.1	1.9	2.8	1.1	3.4	0.5	2.5
55-64	40.9	8.4	11.2	13.2	4.1	9.5	2.5	2.8	1.1	3.1	0.8	2.4
65+	35.4	8.2	12.8	15.8	4.5	10.1	2.5	3.5	1.2	4.0	0.6	1.5
FEMALES												
All ages	37.9	6.8	9.9	13.1	6.3	9.0	3.4	5.6	1.6	4.1	0.6	1.6
under 1	41.2	0.5	1.1	3.2	2.3	4.5	3.4	9.6	5.7	20.5	1.5	6.5
1-4	17.3	1.1	7.2	10.2	11.1	12.0	7.9	12.6	4.1	10.9	1.7	3.9
5-9	23.6	1.6	6.9	11.5	9.9	13.9	7.2	11.5	2.9	6.8	1.2	3.0
10-14	32.3	2.1	5.6	12.3	7.1	11.2	6.3	10.3	3.1	5.4	1.4	2.8
15-19	39.4	4.0	6.4	13.0	6.3	10.1	4.1	7.2	1.7	5.1	0.6	2.1
20-24	42.8	6.6	7.9	17.2	6.5	7.8	2.3	4.6	1.1	2.1	0.3	0.9
25-29	43.1	10.2	9.9	14.6	5.0	8.2	1.5	2.6	1.3	2.1	0.6	0.8
30-34	43.9	12.3	11.7	14.7	4.3	7.0	1.2	2.3	0.9	1.0	0.2	0.5
35-44	45.3	11.8	12.5	12.2	5.0	6.7	1.6	2.5	0.5	1.5	0.1	0.4
45-54	46.2	9.9	12.3	15.6	4.3	6.0	1.8	1.6	0.2	1.5	0.2	0.3
55-64	45.1	9.3	14.0	13.1	4.9	7.2	1.0	2.2	0.5	1.7	0.2	0.7
65+	39.6	8.2	15.2	15.1	5.2	9.5	1.5	2.4	0.0	2.4	0.2	0.6

Table 5.5. Per capita consumption rates of fluid cows' milk by the U.S. population by age and sex[a].

Age		Consumption rate (mL d^{-1})		
year	month	male		female
	1st		51	
	2nd		126	
	3rd		182	
	4th		304	
	5th		423	
	6th		545	
	7th		596	
	8th		646	
	9th		639	
	10th to 12th		639	
1-4		530		503
5-9[b]		716		684
10-14[b]		747		619
15-19[b]		747		530
20-24		352		213
25-29		293		192
30-34		263		166
35-44		243		160
45-54		228		154
55-64		240		169
65+		246		192
All ages[c]		410		318
Per capita			364	

[a]Sources: Table 5.4 for (0 - 1)-y old infants; Thompson and Lengemann (1964) for all other age groups.

[b] For school age children an additional 23.7 mL per day of milk has been added to account for the School Milk Program (Thompson and Lengemann 1965).

[c]Calculated from the age and sex distribution of the U.S. population in 1954 (Table 5.6).

Table 5.6. Distribution of the U.S. population in 1954 (USEPA 1985).

Age (years)	Population		Population fraction	
	Male	Female	Male	Female
0-4	9,125,929	8,804,507	0.056	0.054
5-9	7,900,225	7,633,600	0.049	0.047
10-14	6,877,552	6,644,760	0.042	0.041
15-19	5,873,326	5,849,395	0.036	0.036
20-24	5,464,362	5,728,013	0.034	0.035
25-29	5,700,503	5,958,170	0.035	0.037
30-34	5,718,862	5,981,822	0.035	0.037
35-39	5,756,379	6,014,770	0.035	0.037
40-44	5,327,654	5,469,732	0.033	0.034
45-49	4,879,777	4,959,519	0.030	0.030
50-54	4,386,275	4,452,765	0.027	0.027
55-59	3,841,355	3,901,531	0.024	0.024
60-64	3,195,719	3,324,021	0.020	0.020
65+	6,522,077	7,570,729	0.040	0.046
TOTAL	80,569,992	82,293,328	0.495	0.505

for the U.S. population, CR_{pc}(US), is found to be 364 mL d^{-1}.

This figure, in agreement with that obtained from USDA statistics on the total amount of milk sold for fluid use in the country (372 mL d^{-1} in *Table 5.1*), is used in this assessment as the representative value of the per capita milk consumption rate for the U.S. population over the period of nuclear weapons testing in the atmosphere.

5.4.2. Variation as a Function of the Region of the Country

Per capita milk consumption rates, for the human population in different areas of the country, were reported in the USDA Household Food Consumption Survey conducted in 1955 as 477 mL d^{-1} in the northeast, 389 mL d^{-1} in the south, 520 mL d^{-1} in the northcentral and 488 mL d^{-1} in the western states (USDA 1955). This survey collected information on food consumption for 1 week during April or May from approximately 6000 households in the U.S. These values are thought to be overestimates because if the consumption rate were maintained throughout the year, the total amount of milk for fluid use reported for 1955 could not satisfy these consumption rates. This difference could be due to the inherent drawbacks of assuming that data collected for 1 week is representative of the whole year (Thompson and Lengemann 1965). The variations in milk consumption in different areas of the country are influenced by urbanization, race, climate and the percentage of the population not drinking any milk. This last point is shown in *Table 5.7,* which shows the percentage distribution of the at home daily consumption of milk by region. On an average day, about 30% of the people surveyed throughout the country did not drink any milk at all. *Table 5.7* also shows that the milk consumption rate in the South was substantially lower than in the North East, the North Central, or the West.

Estimates of per capita milk consumption rates assigned for the population of each state are presented on *Table 5.1.* These values, which are based on the regional milk consumption rates reported in various reports (USDA 1955; Thompson and Lengemann 1965) were adjusted according to the available amount of milk in each state and the milk distribution data.

Table 5.7. Percentage distribution of "at home" consumption of whole milk by sex and area[a] of U.S., July 1962 (PHS 1963[b])

Area	Milk Consumption Rate (mL d^{-1})[b]												
	None	30-119	120-239	240-359	360-479	480-599	600-719	720-839	840-959	660-1079	1080-1200	>1200	mean[c]
MALE													
Northeast	21.7	8.3	8.6	12.7	5.7	10.4	4.0	9.4	3.3	9.0	1.5	5.4	446
North Central	27.8	6.0	9.0	10.5	7.4	10.0	5.0	7.6	4.0	6.1	1.6	5.0	412
South	42.4	5.0	6.7	12.3	5.1	9.0	3.3	6.2	1.6	5.2	0.7	2.4	295
West	34.8	2.2	6.7	10.5	5.7	11.2	4.8	7.8	1.9	8.1	1.5	4.8	400
FEMALE													
Northeast	26.0	10.3	11.6	13.1	7.3	9.9	3.6	7.4	2.0	6.1	0.9	1.8	335
North Central	34.9	7.0	11.3	12.9	7.1	8.8	4.4	5.2	2.0	3.5	0.8	2.1	291
South	48.0	5.4	8.1	13.7	4.8	7.9	2.3	4.3	1.1	3.0	0.3	0.9	214
West	42.1	3.7	8.3	12.2	6.2	10.1	3.3	6.4	1.0	4.2	0.6	1.8	276

[a] Areas of the country that were surveyed included 42 states:
Northeast included: the states of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.
North Central included: the states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.
South included:the states of Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.
West included: the states of Arizona, Oregon, Utah, Washington, and Wyoming.

[b] The original values are reported in ounces per day. They have been converted to mL per day using a conversion factor of 30 mL per ounce of milk.

[c] Volume-weighted mean.

5.4.3. Other Factors

The dose assessment takes into account the variation of the milk consumption rate as a function of age, sex, and region of residence. Other factors which are known to influence the milk consumption rate to some extent not considered are:

- the season of the year,
- the degree of urbanization, defined very loosely in most surveys as living in cities versus rural living, and
- race.

The influence of the season on milk consumption is reported to have only a slight effect, on average, over a large population (Jeffrey 1957). *Figure 5.5* illustrates that the milk production in the northeastern U.S., in 1954, varied significantly during the year, but the human consumption rates did not.

The effect of urbanization on milk consumption rate is shown in *Table 5.8*. On average, people on farms consumed 30% more milk than people living in urban areas. It also is worth noting that the milk consumed on farms was predominately of local origin. Only 10% was purchased at a store as compared to the U.S. average person purchasing 81% at the store. In this assessment, the volume of milk consumed on farms in each state in 1954 is taken from USDA statistics (USDA 1962a).

Differences between the consumption rates of Black and White populations are illustrated in a report on milk consumption in urban North Carolina (Cotton 1950), where the per capita milk consumption for Whites was about 2.8 times greater than for Blacks (273 mL d^{-1} vs. 99 mL d^{-1}) during the late 1940s. One reason cited for these differences was thought to be due to the disparity in the income between the races. In general, in the 1950s, the Black population in the U.S. lived in certain regions of the country, and therefore the difference in milk consumption rates between Blacks and Whites is at least partly reflected in regional variations. These show, for example, a much lower per capita consumption of milk in the South Atlantic States than in New England.

Figure 5.5. Monthly use of market milk in the Northeast, 1954.

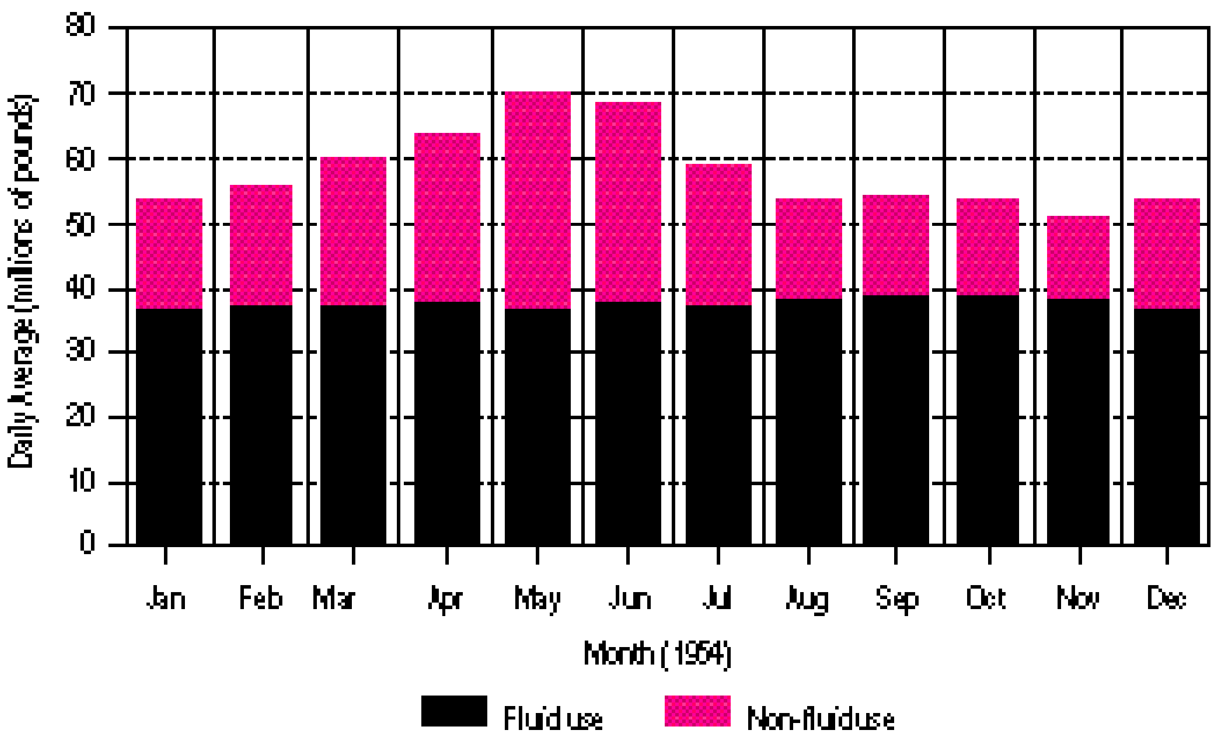


Table 5.8. Household consumption of fresh fluid milk in 1955 (mL d^{-1}).

Urbanization	Per Capita Consumption Rates[a]			
	United States		Northeast[c]	
	mL per day	Percent purchased at the store	mL per day	Percent purchased at the store
All	461	81	467	93
Urban	450	100[b]	478	100[b]
Rural Non-Farm	400	88	449	94
Rural Farm	585	16	599	2

[a] Sources: USDA (1955)

[b] It is assumed that all the milk in urban areas is purchased.

[c] Northeastern states included in the survey: Maine, New Hampshire, Vermont, Massachussetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania.

Table 5.9. Per capita milk consumption rates for the population of the contiguous U.S., according to age and sex, $CR_{pc}(US,k)$. Derived from Tables 5.1 and 5.5 for 1954.

Age group index, k	Age		Population fraction, FPOP(k)	Per capita consumption rate, $CR_{pc}(k)$, in mL d^{-1}
	Year	Month		
5		0-2	0.0055	120
6		3-5	0.0055	420
7		6-8	0.0055	640
8		9-11	0.0055	640
9	1-4		0.088	520
10	5-9		0.095	700
11	10-14		0.083	680
12	15-19		0.072	640
13	Adult male		0.31	260
14	Adult female		0.33	170

More detailed information on factors discussed above that influence the milk consumption rates can be found in USDA (1955), PHS (1963a, 1963b), Spencer and Parker (1961), Thompson (1966), and Yang and Nelson (1986).

5.4.4. Per Capita Milk Consumption Rates Adopted in this Report for the Purpose of the Dose Assessment

For the purpose of the dose assessment, some of the milk consumption rates presented in *Table 5.5* have been averaged in the following manner:

- for the first year of life, four age groups are considered: infants aged 0-2 months, 3-5 months, 6-8 months, and 9-11 months;

- between 1 and 20 years, the age grouping remains the same as in *Table 5.5,* but the data were averaged over the male and female populations;

- age groups over 19 years were combined to form two adult categories (male and female).

The resulting per capita milk consumption rates for the populations in each age class in the contiguous U.S. are presented in *Table 5.9,* along with the population breakdown in each age group.

As shown in *Table 5.1,* the per capita milk consumption rates, $CR_{pc}(s)$, varied from state to state. It is assumed in this report that the milk consumption of (0-1)-y old infants was constant throughout the country, but that the milk consumption of all other age groups was related to the per capita milk consumption in the state:

$$CR_{pc}(s) = \sum_{k=5}^{k=8} (CR_{pc}(US,k) \times FPOP(k)) + \sum_{k=9}^{k=14} (CR_{pc}(s,k) \times FPOP(k)) \qquad (5.9)$$

where:

k is the age and sex class index, and

FPOP(k) is the fraction of population in group k.

It is assumed that all age groups, with the exception of (0-1)-y old infants, drank milk in amounts proportional to the per capita milk consumption for the corresponding U.S. population:

$$CR_{pc}(s,k) = CK(s) \times CR_{pc}(US,k) \quad \text{for } k = 9 \text{ to } 14 \qquad (5.10)$$

where

CK(s) is the coefficient of proportionality for state, s, which is assumed to depend only on the per capita milk consumption rate of the population in the state, so that *equation 5.9* can be written:

$$CR_{pc}(s) = \sum_{k=5}^{k=8} (CR_{pc}(US,k) \times FPOP(k)) + CK(s) \times \sum_{k=9}^{k=14} (CR_{pc}(US,k) \times FPOP(k)) \qquad (5.11)$$

The coefficient of proportionality for each state, CK(s), is derived from *equation 5.11,* using the values of $CR_{pc}(s)$ given in *Table 5.1* and the values of $CR_{pc}(US,k)$ and of FPOP(k) given in *Table 5.9.* The per capita milk consumption in each age group (with the exception of (0-1)-y old infants) for each state, $CR_{pc}(s,k)$, are in turn derived from *equation 5.10*. The results are presented in *Table 5.10*.

Doses to the fetus are calculated assuming that the milk consumption rate of the mother is 800 mL d^{-1} for any area of the country. This consumption rate, which is high, the 95th percentile of the distribution, for an adult female, takes into account the increase of milk consumption by the expectant mother during the last stage of pregnancy. The same milk consumption rate is assumed to apply to the lactating mother.

Table 5.10. Per capita milk consumption rates for the year 1954 and the distribution of the population in each state, according to age and sex, $CR_{pc}(s,k)$, in mL d^{-1}. The per capita milk consumption rates for the (0-1)-y old infants are given in Table 5.9.

State	Age (years)				Adult Male	Adult Female
	1–4	5–9	10–14	15–19		
Alabama	359	486	475	443	180	121
Arizona	423	573	560	523	212	143
Arkansas	467	633	618	577	234	157
California	540	732	714	667	271	182
Colorado	423	573	560	523	212	143
Connecticut	635	860	840	784	319	214
Delaware	511	692	676	631	257	172
Washington D.C.	518	702	685	640	260	175
Florida	303	411	401	375	152	102
Georgia	335	455	444	414	168	113
Idaho	605	821	801	748	304	204
Illinois	613	831	811	757	308	207
Indiana	613	831	811	757	308	207
Iowa	613	831	811	757	308	207
Kansas	496	672	656	613	249	167
Kentucky	505	684	668	624	254	170
Louisiana	359	486	475	443	180	121
Maine	635	860	840	784	319	214
Maryland	511	692	676	631	257	172
Massachusetts	635	860	840	784	319	214
Michigan	613	831	811	757	308	207
Minnesota	642	870	850	793	323	217
Mississippi	467	633	618	577	234	157
Missouri	467	633	618	577	234	157
Montana	715	969	946	883	359	241
Nebraska	569	771	753	703	286	192
Nevada	426	577	564	526	214	144
New Hampshire	635	860	840	784	319	214
New Jersey	511	692	676	631	257	172
New Mexico	423	573	560	523	212	143
New York	635	860	840	784	319	214
North Carolina	386	524	511	478	194	130
North Dakota	715	969	946	883	359	241
Ohio	582	789	770	719	292	196
Oklahoma	467	633	618	577	234	157
Oregon	518	702	685	640	260	175
Pennsylvania	540	732	714	667	271	182
Rhode Island	635	860	840	784	319	214
South Carolina	386	524	511	478	194	130
South Dakota	715	969	946	883	359	241
Tennessee	467	633	618	577	234	157
Texas	408	553	540	505	205	138
Utah	423	573	560	523	212	143
Vermont	635	860	840	784	319	214
Virginia	443	601	587	548	223	149
Washington	569	771	753	703	286	192
West Virginia	386	524	511	478	194	130
Wisconsin	613	831	811	757	308	207
Wyoming	608	825	805	752	306	205

5.5. SUMMARY

- The production and utilization of cows' milk have been estimated for each county of the contiguous U.S. and for the year 1954 from Census data combined with the use of simple models.

- Milk for fluid use has been divided into four categories corresponding to the following population groups:

  category 1: those living on the farms in the county where the milk is produced,

  category 2: those living in the county where the milk is produced but not on farms;

  category 3: those living in a group of neighboring counties within a designated "milk region";

  category 4: those living at greater distances, that is in other "milk regions" in the same or another state.

- About 430 "milk regions" within the contiguous United States have been defined for this study. The flow of milk within the "milk regions", and from one "milk region" to another has been estimated on the basis of data from the U.S. Department of Agriculture.

- Delay times between production and consumption of milk of 1, 2, 3, and 4 days have been estimated for milk in categories 1, 2, 3, and 4, respectively.

- Per capita rates of milk consumption in the U.S. in the 1950s have been estimated as a function of age for eight classes of people under 20 years of age, and as a function of sex for adults. Per capita rates of milk consumption for each of the age groups in each of the 48 contiguous states also have been estimated.

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Chapter 6

Methods and Input Data for Calculating Thyroid Doses to People Resulting from the Ingestion of Cows' Milk

Contents: Estimates of average individual thyroid doses for the population of a county from the ingestion of fresh cows' milk contaminated with ^{131}I deposited after a test are derived from: (1) the estimated time-integrated concentrations of ^{131}I in fresh cows' milk produced in that county after that test, (2) the estimated origin of the cows' milk consumed, (3) the estimated average cows' milk consumption rate by the population group considered, and (4) the estimated thyroid dose factor for ingestion of ^{131}I appropriate for that population group. The data and methodology used to calculate average individual thyroid doses resulting from the ingestion of cows' milk for each age group, as well as average per capita and collective doses in each county, are discussed.

The thyroid dose, D_{mc}(te), in mrad, received by a given individual as a result of the consumption of milk from cows, mc, that ingested ^{131}I from a given test, te, can be estimated by calculating the product:

$$D_{mc}(te) = IMC(te) \times CR \times DCF \qquad (6.1)$$

in which:

IMC(te) = the time-integrated ^{131}I concentration in cows' milk, resulting from the test, te, and consumed by the individual considered. In calculating the value of IMC(te), both decay of ^{131}I due to the time elapsed between production by the cows and consumption by humans, and, as appropriate, the mixing of milk from various locales are considered. The values of IMC(te) are expressed in units of nanocuries per liter of milk x days (nCi d L^{-1});

CR= the individual's consumption rate (L d^{-1}) of cows' milk for a period of 60 days following the test considered;

DCF= the thyroid dose resulting from a unit activity intake of ^{131}I, also called thyroid dose conversion factor, in mrad nCi^{-1}, appropriate for the individual considered.

The purpose of this chapter is to describe the manner in which these variables have been selected and used to calculate the thyroid doses.

Individual doses vary widely from person to person because of variability in such factors as environmental parameters, patterns of milk production and distribution, dietary habits, and biological characteristics. Therefore, realistic estimates of individual doses can be made only if specific information (age, sex, place of residence, source of milk, milk consumption rate, delay time between production and consumption of milk) is available for the individual considered. It will be indicated in **Chapter 9** how an individual can calculate his or her own dose using the personal data mentioned above in conjunction with the information presented in this report.

In the absence of personal data, only average doses over large or homogeneous groups of people can be calculated with reasonable accuracy. For this reason, the doses calculated and presented in this report for each county and for each nuclear test are expressed as geometric means over specified population groups deemed to be representative of a large spectrum of individuals. To accomplish this, the population of each county has

been divided into 13 age groups, with adults subdivided by gender. These 14 groups, which include four pre-natal ages in addition to the 10 groups previously defined in **Chapter 5 (Section 5.4.4)** for the consumption of milk, are shown in *Table 6.1.* Doses have been calculated for each post-natal age and sex group for:

(a) the population of persons drinking cows' milk,

(b) a specified "high-exposure" group, with a high consumption rate of milk containing higher-than-average concentrations of ^{131}I,

(c) a specified "low-exposure" group, with no consumption of fresh cows' milk, and

(d) a group drinking milk from backyard cows.

Collective doses to the population of each county have been obtained by summing, over all post-natal age and sex groups, the products of the arithmetic means of the thyroid doses estimated to have been received by the population of each group by the size of that population group. Per capita doses were computed by dividing the collective doses by the population sizes.

6.1. TIME-INTEGRATED CONCENTRATIONS OF ^{131}I IN COWS' MILK

Time-integrated concentrations of ^{131}I in cows' milk, IMC, are calculated in each county, i, and for each test that is considered, te, for each of four categories of milk defined in **Chapter 5.** The index for the milk categories is q:

- milk produced and consumed on the farm (q=1),
- milk produced and sold in the county (q=2),
- milk originating from another county of the region (q=3),
- milk originating from another region (q=4).

When calculating the thyroid doses received by the "high-exposure" group in a particular county, it is assumed that the group consumes cows' milk having the highest time-integrated concentration of ^{131}I found for any of the four categories of milk in the county. In some circumstances, milk that originates in another county or another region may contain more ^{131}I than milk produced in the county.

In the calculation of the thyroid doses received by the population of cows' milk drinkers in each county for each of the 10 post-natal age and sex groups, the ^{131}I time-integrated concentrations estimated for the total volume of cows' milk pooled from the four categories, called volume-weighted milk concentrations, are used.

Table 6.1. Age and sex groups for which thyroid doses are estimated.

Age group index, k	Pre-natal age, weeks	Post-natal age	
		months	years
1	0-10 (embryo)		
2	11-20 (fetus)		
3	21-30 (fetus)		
4	31-40 (fetus)		
5		0-2 (infant)	
6		3-5 (infant)	
7		6-8 (infant)	
8		9-11 (infant)	
9			1-4 (child)
10			5-9 (child)
11			10-14 (child/teenager)
12			15-19 (teenager)
13			> 19 (adult male)
14			> 19 (adult female)

Finally, the ^{131}I time-integrated concentrations in milk from backyard cows are used in the estimation of the thyroid doses received by the groups drinking milk from backyard cows. Milk from backyard cows is not included in the volume-weighted average that is computed for milk from dairy cows.

6.1.1. Calculation of the Time-Integrated Concentrations of ^{131}I in Each Milk Category From a Given Test

In order to estimate the time-integrated concentrations of ^{131}I in the milk of the four categories, q, the commercial milk distribution results from **Chapter 5** have been combined with the appropriate delay times between production and consumption, and with the time-integrated concentrations of ^{131}I in fresh cows' milk after a test, estimated with the methodology presented in **Chapter 4**:

- the ^{131}I activity in the milk in category 1, that which is consumed on the farm, is assumed to have decayed for 1 d between production and consumption, is never mixed with other milk, and is always consumed in the county in which it was produced;
- the activity in the milk in category 2, consumed in the county but not included in category 1, is assumed to have a 2-d delay time;
- if there is a deficit of milk in the county, milk is brought in first from the surplus counties in the region (category 3), with an assumed delay time of 3 days;
- if, after addition of category 3 milk, there is still a deficit of milk in the county, milk is brought in from specified surplus regions (category 4), with an assumed delay time of 4 days.

It is assumed that all the milk in a county in categories 1-4 is available for fluid use by the population living in that county.

Several indices and symbols are repeatedly used in the calculation of the time-integrated concentrations of ^{131}I in each milk category:

- i denotes the county for which the ^{131}I time-integrated concentrations in milk are calculated;
- ii denotes the counties other than i in the milk region, rr;
- nn denotes the number of counties in the milk region, rr;
- q denotes the milk category;
- rr denotes the milk region that contains the county, i;
- EC(i) is the expected annual milk consumption (kL y^{-1}) in county, i, as determined in **Chapter 5;**
- IMC(i,te) is the time-integrated concentration of ^{131}I (nCi d L^{-1}) in fresh cows' milk resulting from fallout in county, i, following a test, te. The methods for calculating IMC(i,te) and the associated uncertainties are presented in **Chapter 4;**
- IMC_q(i,te) is the time-integrated concentration of ^{131}I in milk (nCi d L^{-1}) of category, q, resulting from fallout in county, i, following a test, te;
- IMC_{vw}(i,te) is the volume-weighted time-integrated concentration of ^{131}I in milk (nCi d L^{-1}) resulting from fallout in county, i, following a test, te;
- IMC_{bc}(i,te) is the time-integrated concentration of ^{131}I in milk (nCi d L^{-1}) from backyard cows, resulting from fallout in county, i, following a test, te;
- λ_r is the radioactive decay constant of ^{131}I, equal to 0.086 d^{-1};
- TD_q is the time delay between production and consumption for milk of category, q, in days;
- TMFU(i) is the production rate (kL y^{-1}) of milk available for fluid use in county, i, as determined in **Chapter 5;**
- TN(rr) is the deficit of milk in region, rr, defined in **Section 6.1.1.3;**
- TP(rr) is the surplus of milk in region, rr, defined in **Section 6.1.1.3;**
- VOL_q(i) is the rate at which milk of category, q, is made available (kL y^{-1}) in county, i;
- VOL(i,ii) is the rate at which milk is imported (kL y^{-1}) from county, ii, to county, i;
- VOL(i,rr) is the rate at which milk is imported (kL y^{-1}) from milk region, rr, to county, i.

All other indices and symbols appear only once and are defined in the text.

6.1.1.1. Category 1

Milk of category 1 is fresh cows' milk that is produced in the county of interest and has decayed during a time, TD_1, prior to consumption on the farms where it was produced. The time-integrated concentration of ^{131}I in milk of category 1, in nCi d L^{-1}, resulting from fallout in county, i, following a test, te, is derived from the time-integrated concentration of ^{131}I in fresh cows' milk, IMC(i,te), by allowing for decay of ^{131}I during time, TD_1. It is estimated as:

$$IMC_1(i, te) = IMC(i,te) \times e^{(-\lambda_r \times TD_1)} \quad (6.2)$$

As indicated in **Chapter 4,** the uncertainties attached to IMC(i,te) are usually rather large, as the GSDs of the log-normal distributions of IMC(i,te) are typically about 3 to 4. In comparison, the uncertainties related to the decay term, $\exp(-\lambda_r \times TD_1)$, are small. The physical constant λ_r is very well known (±0.2%). Variation of TD_1 from 0 to 2 days would result in a variation in the decay term in the narrow range of 0.84 to 1. As a first approximation, the decay term is considered to be exact, so that the distributions of IMC_1(i,te) are assumed to be log-normal and to have the same GSDs as those assigned to IMC(i,te).

The notation that is used here for the median and geometric standard deviation of a log-normal distribution was developed in **Section 3.3.** The relationships between those quantities and the arithmetic mean and standard deviation were also described there. The same symbolic designations are used below and in later sections of this chapter.

The median values of IMC_1(i,te), denoted as $<IMC_1(i,te)>$, are therefore calculated, using:

$$<IMC_1(i, te)> = <IMC(i,te)> \times e^{(-\lambda_r \times TD_1)} \quad (6.3)$$

The arithmetic means of the IMC_1(i,te), denoted as $m(IMC_1(i,te))$, are computed, using:

$$m(IMC_1(i, te)) = <IMC_1(i,te)> \times e^{(0.5 \times \sigma^2 (IMC_1(i,te)))} \quad (6.4)$$

where:

$$\sigma (IMC_1(i, te)) = \ln (GSD (IMC(i,te))) \quad (6.5)$$

The rate of consumption (kL y^{-1}) of milk in category 1, VOL_1(i), is calculated, as indicated in **Chapter 5,** from the annual volume of milk consumed on farms in the state, MCF(s), apportioned according to the ratio of the number of farms in the county, FA(i), to the number of farms in the state, FA(s).

$$VOL_1(i) = MCF(s) \times \frac{FA(i)}{FA(s)} \quad (6.6)$$

The reference year for the calculations is 1954.

6.1.1.2. Category 2

Milk of category 2 is fresh cows' milk that is produced in the county of interest and has decayed during a time TD_2 prior to being consumed in the county, but not on farms. There was milk of category 2 in county, i, if the annual volume of milk available for fluid use in the county, TMFU(i), was greater than the annual milk consumption on farms in the county, VOL_1(i). Otherwise, there was no category 2 milk available for consumption away from farms.

The time-integrated concentration of ^{131}I in milk of category 2, in nCi d L^{-1}, resulting from fallout in county, i, following a test, te, is estimated to be:

$$IMC_2(i, te) = IMC(i,te) \times e^{(-\lambda_r \times TD_2)} \quad (6.7)$$

In the same way as for the milk in category 1, the distributions of IMC_2(i,te) are assumed to be log-normal and the uncertainties attached to IMC_2(i,te) are taken to be equal to those related to IMC(i,te). The median values of the IMC_2(i,te), denoted as $<IMC_2(i,te)>$, are therefore calculated, using:

$$<IMC_2(i, te)> = <IMC(i,te)> \times e^{(-\lambda_r \times TD_2)} \quad (6.8)$$

The arithmetic means of IMC_2(i,te), denoted as $m(IMC_2(i,te))$, are computed, using:

$$m(IMC_2(i, te)) = <IMC_2(i,te)> \times e^{(0.5 \times \sigma^2 (IMC_2(i,te)))} \quad (6.9)$$

in which:

$$\sigma (IMC_2(i, te)) = \ln (GSD (IMC(i,te))) \quad (6.10)$$

The rate of consumption (kL y^{-1}) of milk in category 2, VOL_2(i), depends whether TMFU(i) was greater or smaller than the expected milk consumption in the county, EC(i). Again, 1954 is the reference year for these calculations:

- if TMFU(i) > EC(i), the remaining demand was filled by milk of category 2 and

$$VOL_2(i) = EC(i) - VOL_1(i) \quad (6.11)$$

- if TMFU(i) < EC(i), part of the demand was filled by milk of category 2 and

$$VOL_2(i) = TMFU(i) - VOL_1(i) \quad (6.12)$$

Under the second condition, milk must be imported from other counties in the same milk region or from other regions, as discussed below.

6.1.1.3. Category 3

Milk of category 3 is milk that was imported from other counties of the same milk region. It is assumed to have been pooled within the region before shipment to county, i. There was milk in category 3 in county, i, if two conditions were realized: (1) there was an unfilled demand in county, i, and (2) there was milk available within the region. These conditions can be written:

- TMFU(i) < EC(i), and
- TMFU(ii) > EC(ii) in any other county, ii, in the milk region that includes county, i.

Under those conditions, the time-integrated concentration of ^{131}I in milk of category 3, in nCi d L^{-1}, resulting from fallout in county, i, following a test, te, denoted IMC_3(i,te), is the time-integrated concentration in milk pooled from the number, nn, of counties in the same region that have excess milk. Allowing for decay of ^{131}I during a time, TD_3:

$$IMC_3(i,te) = \frac{\sum_{ii}^{nn} (IMC(ii,te) \times VOL(i,ii))}{\sum_{ii}^{nn} VOL(i,ii)} \times e^{(-\lambda_r \times TD_3)} \qquad (6.13)$$

where

VOL(i,ii) is the rate of milk transfer (kL y-1) from county ii to county i and the ratio of the sums in *equation 6.13* is the concentration of the pooled milk.

Here again, the distributions of IMC_3(i,te) are assumed to be log-normal and to have the same GSDs as those of IMC(i,te). Ignoring the uncertainties in the milk transfer rates, VOL(i,ii), and in the time delay between production and consumption of milk, TD_3, the median values of IMC_3(i,te), denoted as <IMC3(i,te)>, are calculated as follows:

$$<IMC_3(i,te)> = \frac{\sum_{ii}^{nn} (<IMC(ii,te)> \times VOL(i,ii))}{\sum_{ii}^{nn} VOL(i,ii)} \times e^{(-\lambda_r \times TD_3)} \qquad (6.14)$$

The arithmetic means of IMC_3(i,te), denoted as m(IMC_3(i,te)), are obtained from:

$$m(IMC_3(i, te)) = <IMC_3(i,te)> \times e^{(0.5 \times \sigma^2 (IMC_3(i,te)))} \qquad (6.15)$$

with:

$$\sigma (IMC_3(i, te)) = ln (GSD (IMC(i,te))) \qquad (6.16)$$

The values of VOL(i,ii) in *equations 6.13 and 6.14* are based on the surplus and deficit amounts of milk in counties in the milk region, rr, in which county, i, is located. For counties in the region with surpluses, the total positive component of the milk balance for the region, TP(rr), in kL y^{-1}, is:

$$TP(rr) = \Sigma \, (TMFU(ii) - EC(ii)) \qquad (6.17)$$

Similarly, for counties in the region with deficits, the total negative component of the milk balance for the region, TN(rr), in kL y^{-1}, is:

$$TN(rr) = \Sigma \, (EC(ii) - TMFU(ii)) \qquad (6.18)$$

If TP(rr) was greater than TN(rr), the region had a milk surplus. Counties in the region with a surplus were able to provide enough milk for all the deficit counties. The contributions of the counties with surplus milk are computed using:

$$VOL(i,ii) = (EC(i) - TMFU(i)) \times \frac{TMFU(ii) - EC(ii)}{TP(rr)} \qquad (6.19)$$

The contribution of county, ii, which has a surplus, to deficit county, i, is proportional to the size of the deficit in county, i, and to the fraction of the total surplus that is available in county, ii. It is assumed that no milk is transferred out of a county with a deficit of milk.

If TP(rr) is smaller than TN(rr), the region had a milk deficit, but those counties with a surplus could meet part of the needs of deficit counties. The contributions were computed using:

$$VOL(i,ii) = \frac{(EC(i) - TMFU(i))}{TN(rr)} \times (TMFU(ii) - EC(ii)) \qquad (6.20)$$

In this case, the contribution to deficit county, i, from surplus county, ii, is proportional to the deficit in county, i, and to the size of the surplus in county, ii. Again, it is assumed that no milk is transferred out of a county that has a milk deficit.

The rate of transfer (kL y^{-1}) of milk of category 3 to county, i, (VOL_3(i)), is the sum of the volumes of milk imported from other counties in the milk region.

- if TP(rr) > TN(rr), the region has an overall surplus of milk. The deficit in county, i, is completely satisfied using milk produced in the same region, and

$$VOL_3(i) = EC(i) - TMFU(i) \qquad (6.21)$$

- if TP(rr) < TN(rr), the region has an overall deficit of milk. The deficit in county, i, is partially filled using surplus milk from other counties in the region. The rate of transfer of milk to county, i, is proportional to the contribution to the deficits within the region and to the total availability of surplus milk in counties within the region:

$$VOL_3(i) = \frac{(EC(i) - TMFU(i))}{TN(rr)} \times TP(rr) \qquad (6.22)$$

6.1.1.4. Category 4

Milk of category 4 is milk that is imported from other milk regions; it is assumed to be pooled before shipment to county, i. There is milk in category 4 in county, i, only if the county has a deficit and the region of which it is part also has a deficit. The conditions are:

- TMFU(i) < EC(i), and
- TP(rr) < TN(rr).

Under those conditions, the time-integrated concentration of ^{131}I in milk of category 4, in nCi d L^{-1}, resulting from fallout in county, i, following a test, te, denoted IMC_4(i,te), is the time-integrated concentration in milk pooled from other regions with excess milk. Allowing for the decay of ^{131}I during time TD_4:

$$IMC_4(i,te) = \frac{\sum_{rg} (IMC(rg,te) \times VOL(rr,rg))}{\sum_{rg} VOL(rr,rg)} \times e^{(-\lambda_r \times TD_4)} \qquad (6.23)$$

where:

rg	denotes a region that exports milk to region, rr,
VOL(rr,rg)	is the annual volume of milk that is transferred from region, rg, to region, rr, (given in **Appendix 5**), and
IMC(rg,te)	is the time-integrated concentration of 131I in milk pooled from counties in region, rg, that have surplus milk. The index for these counties is: ig. The volume-weighted concentration of the pooled milk is:

$$IMC(rg,te) = \frac{\sum_{ig} (IMC(ig,te) \times (TMFU(ig) - EC(ig)))}{\sum_{ig} (TMFU(ig) - EC(ig))} \qquad (6.24)$$

The uncertainties attached to the values of IMC_4(i,te) are very difficult to determine as they depend on poorly documented volumes and origins of milk that are assumed to have been transferred to region, rr. As a first approximation, it is assumed that the distributions of IMC_4(i,te) are log-normal with GSDs equal to those of IMC(i,te). The median values of IMC_4(i,te), denoted as <IMC_4(i,te)>, are calculated, using:

$$<IMC_4(i,te)> = \frac{\sum_{rg} (<IMC(rg,te)> \times VOL(rr,rg))}{\sum_{rg} VOL(rr,rg)} \times e^{(-\lambda_r \times TD_4)} \qquad (6.25)$$

The arithmetic means of IMC_1(i,te), denoted as m(IMC_1(i,te)), are obtained from:

$$m(IMC_4(i, te)) = <IMC_4(i,te)> \times e^{(0.5 \times \sigma^2 (IMC_4(i,te)))} \qquad (6.26)$$

with:

$$\sigma(IMC_4(i, te)) = \ln(GSD(IMC(i,te))) \qquad (6.27)$$

The rate of transfer (kL y^{-1}) of milk in category 4 to county, i, (VOL_4(i)) is the sum of the transfer rates of milk imported from other regions to satisfy the milk deficit that remains after importation of category 3 milk from within the region.

$$VOL_4(i,ii) = \frac{EC(i) - TMFU(i)}{TN(rr)} \times (TN(rr) - TP(rr)) \qquad (6.28)$$

6.1.1.5. Volume-weighted average

The volume-weighted average of the time-integrated concentration of ^{131}I in milk, IMC_{vw}(i,te), resulting from fallout in county, i, following a test, te, reflects the contributions of each of the four milk categories to the milk supply in the county. The time-integrated concentrations (IMC_q(i,te)) and transfer rates (VOL_q(i)) discussed in the four preceding subsections are used to compute IMC_{vw}(i,te).

$$IMC_{vw}(i,te) = \frac{\sum_{q=1}^{q=4} (IMC_q(i,te) \times VOL_q(i))}{\sum_{q=1}^{q=4} VOL_q(i)} \qquad (6.29)$$

For the purpose of estimating the uncertainties, the median value of IMC_{vw}(i,te), denoted as <IMC_{vw}(i,te)>, is expressed as a function of the median value of the time-integrated concentration of ^{131}I in milk consumed on farms, <IMC_1(i,te)>. The factor of proportionality between those two quantities is called the milk distribution factor. Its median value is denoted by <MF(i,te)>. The relationship between these quantities is:

$$<IMC_{vw}(i,te)> = <IMC_1(i,te)> \times <MF(i,te)> \qquad (6.30)$$

The milk distribution factor for a particular county reflects the transfers of milk from other counties in the region and from other regions, as appropriate, and the differences in concentration between the milk transferred and that produced locally. It is estimated by taking the ratio of the volume-weighted concentration *(equation 6.29)* to the concentration of milk consumed on farms in the county.

If the county's needs for fresh milk were satisfied by milk consumed on farms, then $\langle MF(i,te)\rangle$ is 1. If the county was self-sufficient in milk, the median milk distribution factor is between 0.92 and 1. If all the milk in the county was of category 2, the value of $\langle MF(i,te)\rangle$ would be $\exp(-\lambda_r \times (TD_2 - TD_1)) = 0.92$. If the county imported milk from other counties or regions having different values of the time-integrated concentrations of ^{131}I in fresh cows' milk, then $\langle MF(i,te)\rangle$ may be large or small depending upon the ^{131}I concentrations in and the quantities of imported milk.

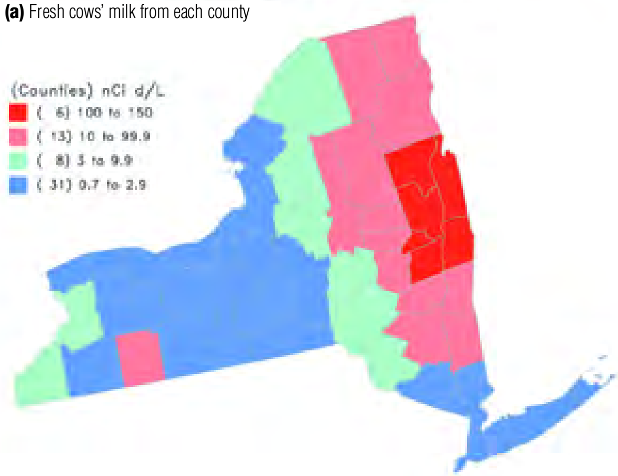
The variability in the values of $\langle IMC_1(i,te)\rangle$, $\langle IMC_{vw}(i,te)\rangle$, and $\langle MF(i,te)\rangle$ is illustrated in *Figure 6.1,* which shows the estimates for those three quantities for the counties of New York state after the shot Simon, detonated 25 April 1953. The figure has three parts:

- The average time-integrated ^{131}I concentrations in milk consumed on farms, $\langle IMC_1(i,te)\rangle$, were high in the region of Albany, where relatively high depositions occurred as a result of heavy thunderstorms coincidental with the passage of the radioactive cloud, and low in the remainder of New York state *(Figure 6.1(a))*. There is a factor of about 200 between the maximum and the minimum values of $\langle IMC_1(i,te)\rangle$ in the figure.

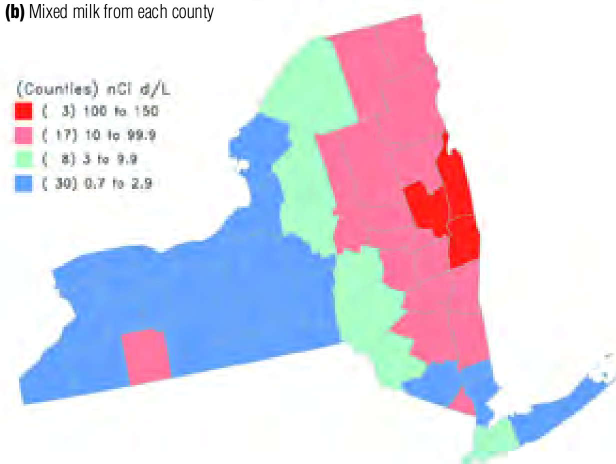
- The average time-integrated ^{131}I concentrations in volume-weighted milk, $\langle IMC_{vw}(i,te)\rangle$, were similar to the values of $\langle IMC_1(i,te)\rangle$ for the majority of the counties, because those counties had an excess production of milk in the 1950s *(Figure 6.1(b))*. However, the populated counties of the Greater New York City area needed to import milk from other regions of the state, where the ^{131}I depositions were higher, and this influx of milk with higher concentrations is the reason why the values of $\langle IMC_{vw}(i,te)\rangle$ are greater than those of $\langle IMC_1(i,te)\rangle$ in the counties of the Greater New York City area. On the other hand, the ^{131}I concentration in volume-weighted milk is lower than that in milk consumed on farms in two western counties, where some milk was imported from counties with lower ^{131}I depositions. There is a factor of about 200 between the maximum and the minimum values of $\langle IMC_{vw}(i,te)\rangle$ in the figure.

Figures 6.1.(a) (b) (c) Time-integrated concentrations of I-131 in milk in New York State counties resulting from the test Simon detonated 25 April 1953

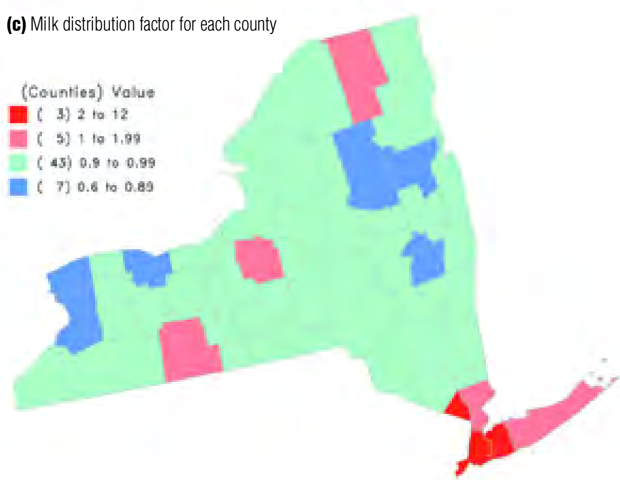
(a) Fresh cows' milk from each county



(b) Mixed milk from each county



(c) Milk distribution factor for each county



- The values of the milk distribution factor, <MF(i,te)>, vary from county to county between 0.65 and 11.5 *(Figure 6.1(c))*. The highest values of <MF(i,te)> are found in counties of the Greater New York City area, which imported milk with higher concentrations. The lowest values are observed in counties around Albany and Buffalo, which imported milk with lower concentrations. Most of the milk distribution factors are close to one because most counties in New York state were self-sufficient in milk.

It is subjectively reasonable to assume that the uncertainty attached to <MF(i,te)> is small when the county is self-sufficient in milk, and becomes larger as the value of <MF(i,te)> deviates from one (that is, when counties import milk from areas with substantially higher or lower milk concentrations than those in the local milk). However, the uncertainties related to MF(i,te) would be extremely difficult to quantify, as they depend on the volumes of milk imported (which are poorly documented), on the origins of the milk imported (which are also poorly documented), and on the ^{131}I time-integrated concentrations in the imported milk (which are, to some extent, correlated with the ^{131}I time-integrated concentrations in the milk of local origin). For the uncertainty analysis, it is assumed that the distributions of MF(i,te) are log-normal with GSDs that vary in the following way:

- GSD(MF(i,te)) = 2 if <MF(i,te)> is greater than 2,
- GSD(MF(i,te)) = 1.5 if <MF(i,te)> is between 1.1 and 2,
- GSD(MF(i,te)) = 1.1 if <MF(i,te)> is between 0.9 and 1.1,
- GSD(MF(i,te)) = 1.5 if <MF(i,te)> is between 0.5 and 0.9,
- GSD(MF(i,te)) = 2 if <MF(i,te)> is less than 0.5.

According to *equation 6.30,* the median value of IMC_{vw}(i,te) is calculated using:

$$<IMC_{vw}(i,te)> = <IMC_1(i,te)> \times <MF(i,te)> \qquad (6.30)$$

The geometric standard deviation of the distribution is calculated using:

$$GSD(IMC_{vw}(i,te)) = e^{(\sigma (IMC_{vw}(i,te)))} \qquad (6.31)$$

in which:

$$\sigma (IMC_{vw}(i,te)) = ((ln(GSD(IMC_1(i,te))))^2 + (ln(GSD(MF(i,te))))^2)^{0.5} \qquad (6.32)$$

The arithmetic mean of IMCvw(i,te) is obtained from:

$$m(IMC_{vw}(i,te)) = <IMC_{vw}(i,te)> \times e^{(0.5 \times \sigma^2(IMC_{vw}(i,te)))} \qquad (6.33)$$

6.1.1.6. Milk consumed by the "high-exposure" groups

In the calculation of the thyroid doses received by the "high-exposure" groups, the value of the median time-integrated concentration of ^{131}I that is used is the highest obtained for any of the four categories.

$$<IMC_{high}(i,te)> = Max(<IMC_q(i,te)>) \text{ with } q= 1 \text{ to } 4 \qquad (6.34)$$

The geometric standard deviation, GSD(IMC_{high}(i,te)), and the arithmetic mean, m(IMC_{high}(i,te)), of the distribution of IMC_{high}(i,te) are those corresponding to the category of milk having the highest concentration.

6.1.1.7. Milk from backyard cows

The time-integrated concentrations of ^{131}I in milk fresh from backyard cows, IMB(i,te) resulting from fallout in county, i, following a test, te, are calculated using the same methodology as for the dairy, or commercial, cows, which is described in **Chapter 4.** The only difference between dairy and backyard cows is in their diet, as it is assumed that backyard cows eat less than dairy cows and are placed on pasture for a larger portion of their diet. As indicated in **Section 4.1.3.5** of **Chapter 4,** the start and stop dates of the pasture seasons for backyard cows are taken to be one month before and one month after the start and stop dates, respectively, estimated for the dairy cows. The pasture intakes of backyard cows are taken to be the same in all parts of the country: 8 kg d^{-1} (dry mass) during the pasture season and 0.1 kg d^{-1} (dry mass) when cows are not on pasture.

Milk from backyard cows is assumed to be consumed rapidly by the families that own the cows. It is assumed that the average delay between production and consumption, TD_{bc}, is equal to 0.5 day. The time-integrated concentration of ^{131}I in milk from backyard cows at the time of consumption, IMC_{bc}(i,te) in nCi d L^{-1}, resulting from fallout in county, i, following a test, te, therefore is derived from the time-integrated concentration of ^{131}I in milk fresh from backyard cows, IMB(i,te), allowing for a decay of ^{131}I during time, TD_{bc}. It is estimated as:

$$IMC_{bc}(i,te) = IMB(i,te) \times e^{(-\lambda_r \times TD_{bc})} \qquad (6.35)$$

As a first approximation, the decay term is considered to be exact, and the distributions of IMC_{bc}(i,te) are assumed to be log-normal and to have the same GSDs as those assigned to IMB(i,te). The median values of IMC_{bc}(i,te), denoted as <IMC_{bc}(i,te)>, are therefore calculated, using:

$$<IMC_{bc}(i,te)> = <IMB(i,te)> \times e^{-\lambda_r \times TD_{bc}} \qquad (6.36)$$

The arithmetic means of $IMC_{bc}(i,te)$, denoted as $m(IMC_{bc}(i,te))$, are obtained from:

$$m(IMC_{bc}(i,te)) = \langle IMC_{bc}(i,te)\rangle \times e^{(0.5 \times \sigma^2(IMC_{bc}(i,te)))} \quad (6.37)$$

with:

$$\sigma(IMC_{bc}(i,te)) = \ln(GSD(IMB(i,te))) \quad (6.38)$$

6.1.2. *Calculation of the Time-Integrated Concentrations of ^{131}I in Each Milk Category From a Given Test Series*

The time-integrated concentration of ^{131}I in cows' milk of category, q, in county, i, resulting from a given test series, ts, is obtained by adding the contributions from each test, te, in the series:

$$IMC_q(i,ts) = \sum_{te+1}^{nte} IMC_q(i,te) \quad (6.39)$$

where

nte is the number of tests in the series, ts. The median time-integrated concentration, $\langle IMC_q(i,ts)\rangle$, is obtained from the addition of the distributions of $IMC_q(i,te)$. In most cases, the value of $IMC_q(i,ts)$ is dominated by the contributions from one or two tests.

The distribution of $IMC_q(i,ts)$ can be assumed to be log-normal. As in **Section 4.3**, the geometric mean is calculated, using

$$\langle IMC_q(i,ts)\rangle = \frac{\sum_{te=1}^{nte} m(IMC_q(i,te))}{\sqrt{\left(1 + \frac{\sum_{te=1}^{nte} s^2(IMC_q(i,te))}{\sum_{te=1}^{nte} m(IMC_q(i,te))^2}\right)}} \quad (6.40)$$

where

$m(IMC_q(i,te))$ and $s^2(IMC_q(i,te))$ are the arithmetic mean and the variance of $IMC_q(i,te)$ and are calculated, using:

$$m(IMC_q(i,te)) = \langle IMC_q(i,te)\rangle \times e^{(0.5 \times \sigma^2(IMC_q(i,te)))} \quad (6.41)$$

and:

$$s^2(IMC_q(i,te)) = \langle IMC_q(i,te)\rangle^2 \times e^{(\sigma^2(IMC_q(i,te))} \times (e^{(\sigma^2(IMC_q(i,te)))} - 1) \quad (6.42)$$

Other parameters of the distribution of $IMC_q(i,ts)$ are:

- its geometric standard deviation, $GSD(IMC_q(i,ts))$:

$$GSD(IMC_q(i,ts)) = e^{(\sigma(IMC_q(i,ts)))} \quad (6.43)$$

computed using $\sigma(IMC_q(i,ts))$ derived from:

$$\sigma^2(IMC_q(i,ts)) = \ln\left(1 + \frac{\sum_{te=1}^{nte} s^2(IMC_q(i,te))}{\sum_{te=1}^{nte} m(IMC_q(i,te))^2}\right) \quad (6.44)$$

- its arithmetic mean, $m(IMC_q(i,ts))$:

$$m(IMC_q(i,ts)) = \langle IMC_q(i,ts)\rangle \times e^{0.5 \times \sigma^2(IMC_q(i,ts))} \quad (6.45)$$

- its variance, $s^2(IMC_q(i,ts))$:

$$s^2(IMC_q(i,ts)) = \langle IMC_q(i,ts)\rangle^2 \times e^{(\sigma^2(IMC_q(i,ts))} \times (e^{(\sigma^2(IMC_q(i,ts)))} - 1) \quad (6.46)$$

The parameters for the distributions of $IMC_{vw}(i,ts)$, $IMC_{high}(i,ts)$, and $IMC_{bc}(i,ts)$ are obtained using similar equations.

6.1.3. *Calculation of the Time-Integrated Concentrations of ^{131}I in Each Milk Category From All Tests*

The time-integrated concentration of ^{131}I in cows' milk of category, q, in county, i, resulting from all tests, is obtained by adding the contributions from each of the eight test series, ts (Ranger, Buster-Jangle, Tumbler-Snapper, Upshot-Knothole, Teapot, Plumbbob, Hardtack, and Underground Era):

$$IMC_q(i) = \sum_{ts=1}^{8} IMC_q(i,ts) \quad (6.47)$$

The parameters of the distribution of $IMC_q(i)$ are obtained using equations similar to those for $IMC_q(i,ts)$, which were described in **Section 6.1.2:**

- geometric mean, $\langle IMC_q(i)\rangle$:

$$\langle IMC_q(i)\rangle = \frac{\sum_{ts=1}^{8} m(IMC_q(i,ts))}{\sqrt{\left(1 + \frac{\sum_{ts=1}^{8} s^2(IMC_q(i,ts))}{\sum_{ts=1}^{8} m(IMC_q(i,ts))^2}\right)}} \quad (6.48)$$

where $m(IMC_q(i,ts))$ and $s^2(IMC_q(i,ts))$ are the arithmetic mean and the variance of $IMC_q(i,ts)$ and are determined in *equations 6.45 and 6.46,* respectively.

- geometric standard deviation, $GSD(IMC_q(i))$:

$$GSD(IMC_q(i)) = e^{\sigma(IMC_q(i))} \qquad (6.49)$$

computed using $\sigma(IMC_q(i))$ derived from:

$$\sigma^2(IMC_q(i)) = \ln\left(1 + \frac{\sum_{ts=1}^{S} s^2(IMC_q(i,ts))}{\sum_{ts=1}^{S} m(IMC_q(i,ts))^2}\right) \qquad (6.50)$$

- arithmetic mean, $m(IMC_q(i))$:

$$m(IMC_q(i)) = \langle IMC_q(i)\rangle \times e^{0.5 \times \sigma^2(IMC_q(i))} \qquad (6.51)$$

- variance, $s^2(IMC_q(i))$:

$$s^2(IMC_q(i)) = \langle IMC_q(i)\rangle^2 \times e^{\sigma^2(IMC_q(i))} \times (e^{(\sigma^2(IMC_q(i)))} - 1) \qquad (6.52)$$

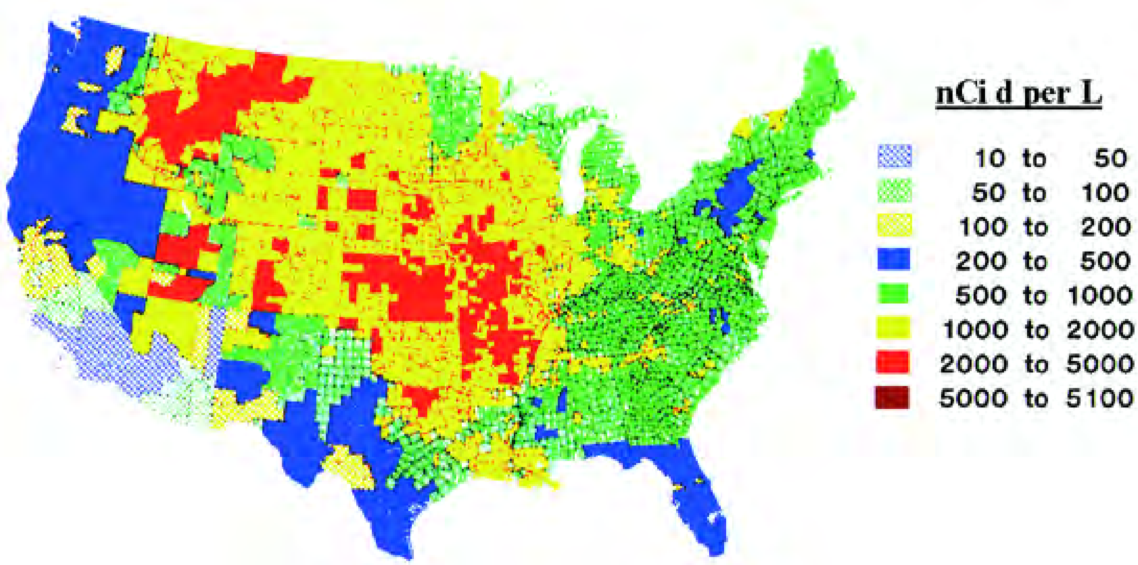
The parameters for the distributions of $IMC_{vw}(i)$, $IMC_{high}(i)$, and $IMC_{bc}(i)$ are obtained using analogous equations.

6.1.4. Results

The estimates of the average time-integrated concentrations of ^{131}I for all categories of milk resulting from the deposition of ^{131}I in each county of the contiguous United States are tabulated in the Annexes for each test and each test series. For example, **Table UK/7/M** (where UK stands for Upshot-Knothole, 7 represents the seventh test in the series (Simon), and M stands for milk), which is found in Annex UK/7, presents the time-integrated concentrations of ^{131}I in fresh cows' milk, milk consumed on farms, milk produced and sold in the county, milk originating from another county of the region, milk originating from another region, milk consumed by the specified "high-exposure" groups, volume-weighted mixed milk, and milk from backyard cows resulting from the shot Simon in all counties of the contiguous United States, along with uncertainty estimates. These uncertainties are characterized by GSDs that are generally in the range from 3 to 5.

Figure 6.2 presents the estimates of average time-integrated concentrations of ^{131}I in volume-weighted mixed milk that are obtained, for each county of the contiguous United States, as a result of all atmospheric tests conducted at the NTS. This figure shows the same general pattern as *Figure 4.25,* related to the time-integrated concentration of ^{131}I in fresh cows' milk. Milk was contaminated with ^{131}I in all counties of the contiguous U.S. The lowest levels of contamination are estimated to have occurred in southern California, while the highest levels are found not only in locations relatively close to the NTS, like Utah and southern Idaho, but also in places that are farther away, e.g., Kansas, Oklahoma, Missouri, Arkansas, and northern Montana.

Figure 6.2. Estimated-integrated concentrations of I-131 in volume weighted milk: All tests.



6.2. COWS' MILK CONSUMPTION RATES

The rates of consumption of cows' milk used in this report for the 10 post-natal age and sex groups are derived from the information provided in **Chapter 5.** The age and sex distribution of the population in the US in 1954 *(Table 5.6),* and the distribution and per capita values of the milk consumption rates as a function of age, sex, and area of the country *(Tables 5.4, 5.9, and 5.10)* were used in the analysis.

6.2.1. Cows' Milk Consumption Rates of Milk Drinkers

The median rates of consumption for drinkers of cows' milk in a given age group, k, from a given state, s, (<CR(s,k)>) are obtained using *equation 6.53:*

$$<CR(s,k)> = CR_{pc}(s,k) \times \frac{1}{FMD(k)} \times RM(k) \qquad (6.53)$$

in which:

Cr_{pc} (s,k) is the per capita consumption rate by group, k, in state, s

MD(k) is the fraction of the members of group, k, who drank cows' milk

RM(k) is the ratio of the median to mean consumption rates for age group, k

Information for infants and older categories is presented in the following subsections.

6.2.1.1. Infants (< 1 y)

For infants aged 0-2, 3-5, 6-8, and 9-11 months, for which the values of k are 5, 6, 7, and 8, respectively:

- the per capita milk consumption rates are taken from *Table 5.9*; they are assumed to be constant throughout the country;
- the fractions of each of these populations that drank cows' milk are obtained from *Table 5.3*;
- the ratios of the median to mean cows' milk consumption rates are calculated from the data in *Table 5.4*; the distribution for 0 to 1 y infants has been assumed to apply to each of the four groups considered (infants aged 0-2, 3-5, 6-8, and 9-11 months).

The fractions of cows' milk drinkers and the median rates of consumption of cows' milk for these four age groups (k = 5 to 8) are presented in *Table 6.2*. The GSDs associated with the median consumption rates are also listed there.

6.2.1.2. Children (>1 y) and adults

For children (1-4, 5-9, 10-14 and 15-19 years) (k = 9 to 12), and adults of each sex (k = 13 and 14):

- the per capita milk consumption rates for the entire US are taken from *Table 5.9* and the values for each state are extracted from *Table 5.10*;
- the fractions that drank cows' milk are derived from *Table 5.4*; the aggregated values corresponding to the age and sex groups considered were weighted using the population distribution data presented in *Table 5.6;*
- the ratios of the median to mean cows' milk consumption rates are calculated from the data in *Table 5.4*; here, also, the aggregated values corresponding to the age and sex groups considered were weighted using the population distribution data presented in *Table 5.6*.

The fractions of milk drinkers that drank cows' milk for the groups (k = 9 to 14) and the median consumption rates for the entire U.S. are presented in *Table 6.2*. The values for each state are provided in *Table 6.3*. The geometric standard deviations of the distributions of the consumption rates, also presented in *Table 6.2,* were derived from the distributions shown in *Table 5.4*. These geometric standard deviations also are assumed to apply to the milk consumption rates for each state that is presented in *Table 6.3*.

6.2.2. Consumption Rates of Cows' Milk for the "High-Exposure" Groups and for the Groups Drinking Milk From a Backyard Cow

The milk consumption rates used in this report for the "high-exposure" groups, CR_{high}, and for the groups drinking milk from a backyard cow, CR_{bc}, correspond to the 95th percentile[1] of the distributions presented in *Table 5.4* of **Chapter 5.** Those values range from 0.8 to 1.4 L d^{-1} and are given for each group in *Table 6.4*. The milk consumption rate for the "high-exposure" groups are assumed to be the same throughout the contiguous U.S.; this assumption is supported by the results of a USDA survey, in which the "high" consumption rates of fresh fluid milk (ninth deciles of per person consumption rates in households) were found to vary over a narrow range (from 0.80 L d^{-1} in the northeast to 0.87 L d^{-1} in the south) (USDA 1960).

6.2.3. Consumption Rates of Cows' Milk by Pregnant Women

Thyroid fetal doses result, in part, from the consumption of ^{131}I-contaminated milk by the expectant mothers. The milk consumption rate of pregnant women is taken to be 0.8 L d^{-1}, corresponding to the 95th percentile of the distribution of milk consumption rates among adult females (shown in *Table 6.4;* derived from data in *Table 5.4*).

[1] This means that 95% of the individuals in the population group considered are expected to have a milk consumption rate lower than CR_{high} and that only 5% of the individuals in that group are expected to have a milk consumption rate greater than CR_{high}.

Table 6.3. Median milk consumption rates of milk drinkers in each state for the year 1954, according to age and sex, <CR(s,k)>, in L d^{-1}. Values for the 0-1 y infants are given in Table 6.2.

State	Age (years)				Adult male	Adult female
	1-4	5-9	10-14	15-19		
Alabama	0.41	0.59	0.63	0.61	0.22	0.18
Arizona	0.48	0.69	0.74	0.71	0.26	0.21
Arkansas	0.53	0.76	0.82	0.79	0.29	0.23
California	0.61	0.88	0.94	0.91	0.34	0.27
Colorado	0.48	0.69	0.74	0.71	0.26	0.21
Connecticut	0.72	1.04	1.11	1.07	0.4	0.32
Delaware	0.58	0.83	0.89	0.86	0.32	0.25
District of Columbia	0.59	0.85	0.9	0.87	0.32	0.26
Florida	0.34	0.5	0.53	0.51	0.19	0.15
Georgia	0.38	0.55	0.59	0.57	0.21	0.17
Idaho	0.69	0.99	1.06	1.02	0.38	0.3
Illinois	0.7	1.0	1.07	1.03	0.38	0.31
Indiana	0.7	1.0	1.07	1.03	0.38	0.31
Iowa	0.7	1.0	1.07	1.03	0.38	0.31
Kansas	0.56	0.81	0.87	0.84	0.31	0.25
Kentucky	0.57	0.82	0.88	0.85	0.32	0.25
Louisiana	0.41	0.59	0.63	0.61	0.22	0.18
Maine	0.72	1.04	1.11	1.07	0.4	0.32
Maryland	0.58	0.83	0.89	0.86	0.32	0.25
Massachusetts	0.72	1.04	1.11	1.07	0.4	0.32
Michigan	0.7	1.0	1.07	1.03	0.38	0.31
Minnesota	0.73	1.05	1.12	1.08	0.4	0.32
Mississippi	0.53	0.76	0.82	0.79	0.29	0.23
Missouri	0.53	0.76	0.82	0.79	0.29	0.23

Table 6.3. cont'd

State	Age (years)				Adult male	Adult female
	1-4	5-9	10-14	15-19		
Montana	0.81	1.17	1.25	1.21	0.45	0.36
Nebraska	0.65	0.93	0.99	0.96	0.36	0.28
Nevada	0.48	0.7	0.74	0.72	0.27	0.21
New Hampshire	0.72	1.04	1.11	1.07	0.4	0.32
New Jersey	0.58	0.83	0.89	0.86	0.32	0.25
New Mexico	0.48	0.69	0.74	0.71	0.26	0.21
New York	0.72	1.04	1.11	1.07	0.4	0.32
North Carolina	0.44	0.63	0.67	0.65	0.24	0.19
North Dakota	0.81	1.17	1.25	1.21	0.45	0.36
Ohio	0.66	0.95	1.02	0.98	0.36	0.29
Oklahoma	0.53	0.76	0.82	0.79	0.29	0.23
Oregon	0.59	0.85	0.9	0.87	0.32	0.26
Pennsylvania	0.61	0.88	0.94	0.91	0.34	0.27
Rhode Island	0.72	1.04	1.11	1.07	0.4	0.32
South Carolina	0.44	0.63	0.67	0.65	0.24	0.19
South Dakota	0.81	1.17	1.25	1.21	0.45	0.36
Tennessee	0.53	0.76	0.82	0.79	0.29	0.23
Texas	0.46	0.67	0.71	0.69	0.26	0.2
Utah	0.48	0.69	0.74	0.71	0.26	0.21
Vermont	0.72	1.04	1.11	1.07	0.4	0.32
Virginia	0.5	0.72	0.78	0.75	0.28	0.22
Washington	0.65	0.93	0.99	0.96	0.36	0.28
West Virginia	0.44	0.63	0.67	0.65	0.24	0.19
Wisconsin	0.7	1.0	1.07	1.03	0.38	0.31
Wyoming	0.69	0.99	1.06	1.03	0.38	0.3

Table 6.2. Median milk consumption rates of milk drinkers in the population of the contiguous U.S. for the year 1954, according to age and sex, <CR(US,k)>.

Age group index, k	Age		Fraction of milk drinkers, FMD(k)	Median consumption rate, <CR(US,k)>, L d^{-1}	GSD
	years	months			
5		0-2	0.17	0.77	1.4
6		3-5	0.55	0.83	1.4
7		6-8	0.90	0.78	1.4
8		9-11	1.00	0.70	1.4
9	1-4		0.83	0.59	1.8
10	5-9		0.78	0.84	1.8
11	10-14		0.71	0.90	1.9
12	15-19		0.66	0.87	2.0
13	Adult male		0.61	0.32	2.5
14	Adult female		0.56	0.25	2.3

Table 6.4. Estimates of average daily milk consumption by "high-exposure" groups according to age and sex, derived from the data in Table 5.4.

Age		Consumption rate (L d^{-1})
months	years	
0-2		1.3
3-5		1.4
6-8		1.3
9-11		1.2
	1-4	1.2
	5-9	1.2
	10-14	1.4
	15-19	1.3
	> 19 (male)	1.0
	> 19 (female)	0.8

6.2.4. Consumption Rates of Cows' Milk for the "Low-Exposure" Groups

It is assumed that the "low-exposure" group does not consume any fresh cows' milk, i.e. $CR_{low} = 0$. As shown in **Chapter 5,** this is true for about 30% of the population in any age class on an average day.

6.3. DOSE CONVERSION FACTORS

The dose conversion factor, DCF, gives the absorbed dose to the thyroid resulting from a unit activity intake of ^{131}I via ingestion. The values of the dose conversion factors for the 10 post-natal age groups are derived from a report prepared by a task group of the Advisory Committee, and is reproduced in **Appendix 6.** The values of the dose conversion factors for the four pre-natal age groups are based on calculations by Zanzonico and Becker (1991). The basis for the dose conversion factors is discussed below.

6.3.1. Post-Natal Age Groups

Iodine-131, when ingested in a water-soluble form, usually iodide, is readily absorbed into the blood from the gastrointestinal tract. Circulating iodide is removed rapidly by both the thyroid and the kidneys. Iodine, an essential trace element, is a component of hormones produced and stored within the thyroid gland. The thyroid hormones, thyroxine (tetraiodothyronine) and triiodothyronine, are required for normal growth, development, and metabolism.

The doses resulting from the intake of ^{131}I via ingestion are at least 1000 times greater in the thyroid gland than in any other radiosensitive organ or tissue in the body (ICRP 1989) because: (a) ^{131}I concentration in the thyroid is much greater than in any other organ, and (b) a substantial fraction of the energy released during the decay of ^{131}I *(Figure 6.3 and Table 6.5)* is absorbed locally. Only thyroid doses are calculated in this report.

The calculation of thyroid doses from ^{131}I requires the assignment of numeric values to various biologic parameters that influence the ^{131}I concentration within the thyroid. Those parameters include the fractional uptake by the thyroid of iodine from the bloodstream, the mass of the thyroid gland, and the retention of ^{131}I by the thyroid. Estimated values of those parameters are provided for various ages in **Appendix 6,** along with the methodology used in this report to calculate the dose conversion factors.

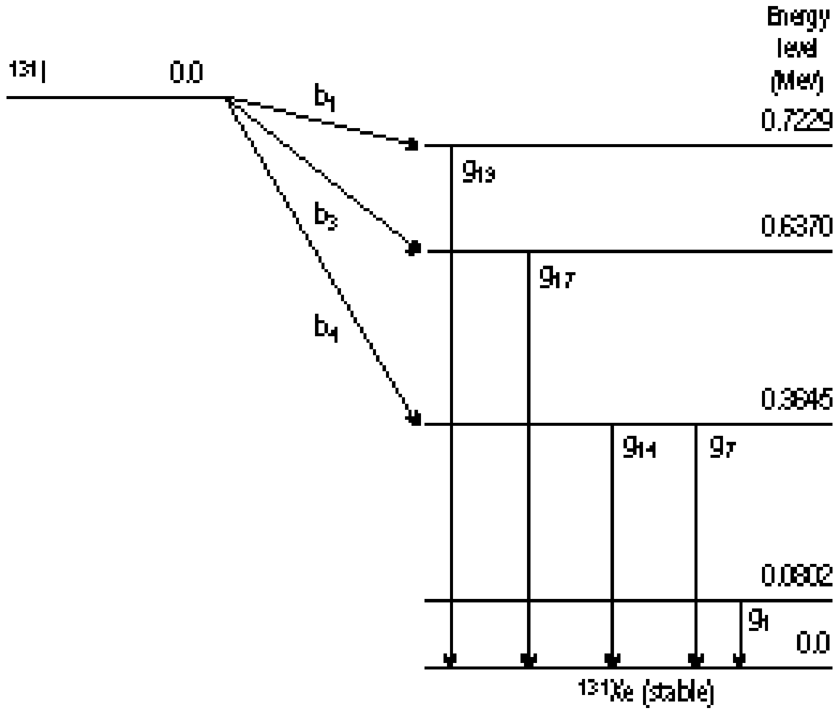
Following a single intake of A (nCi) of ^{131}I by ingestion by an individual in age group, k, a fraction, f(k), of the activity is transferred to the thyroid where it is distributed in the mass of the thyroid, $m_{th}(k)$. Assuming that the transfer to the thyroid is

Table 6.5. Energies and intensities of the main transitions involved in the decay of ^{131}I (ICRP 1983). The corresponding decay scheme of ^{131}I is shown in Figure 6.3.

Radiation	Intensity $(Bq\ s)^{-1}$	Energy (Mev)
β^-_1	0.0213	0.06935[a]
β^-_3	0.0736	0.0960[a]
β^-_4	0.894	0.1915[a]
γ_1	0.0262	0.0802[a]
γ_7	0.0606	0.2843
γ_{14}	0.812	0.3645
γ_{17}	0.0727	0.6370
γ_{19}	0.0180	0.7229

[a] Average beta particle energy.

Figure 6.3. Simplified decay scheme of ^{131}I (ICRP 1983). The energy and intensity of each transition are given in Table 6.5.



instantaneous, the maximum concentration of ^{131}I in the thyroid, $C_{th}(k)$, in nCi g^{-1}, is:

$$C_{th}(k) = A \times \frac{f(k)}{m_{th}(k)} \qquad (6.54)$$

where:

- A = activity intake of ^{131}I (nCi),
- $f(k)$= fractional uptake of ^{131}I by the thyroid from the blood of an individual in age group k, and
- $m_{th}(k)$= mass of the thyroid (g) of an individual in group, k.

As indicated in **Appendix 6**, the standard radiobiological equation for calculating the dose from an internally deposited radionuclide is:

$$D(k) = C_{th}(k) \times T_{eff}(k) \times (73.8 \times E_{\beta} + 0.0346\,\Gamma \times g) \qquad (6.55)$$

where:

- $D(k)$= the total dose from beta and gamma irradiation (mrad)
- $C_{th}(k)$= the maximum concentration of ^{131}I in the thyroid (nCi g^{-1})
- $T_{eff}(k)$= the effective half-life of ^{131}I in the thyroid, d, calculated using $(T_b(k) \times T_r)/(T_b(k) + T_r)$, where $T_b(k)$ and T_r are the biological half-life for group k and the physical half-life of ^{131}I, respectively
- E_{β}= the average energy (0.18 Mev per disintegration) of beta rays resulting from the decay of ^{131}I,
- Γ = the specific gamma-ray constant for ^{131}I (2.2 R h^{-1} per mCi at 1 cm), and
- g= the average geometrical factor for the thyroid, equal to 3r for spheres with radii, r, less than 10 cm.

Substitution of $C_{th}(k)$ from *equation 6.54* and other defined quantities into *equation 6.55* yields:

$$D(k) = A \times \frac{f(k)}{m_{th}(k)} \times \frac{T_b(k) \times T_r}{T_b(k) + T_r} \times (13.3 + 0.717 \times r) \qquad (6.56)$$

The dose conversion factor for an age group, DCF(k), (rad μCi^{-1}) is the thyroid dose per unit activity intake and is obtained from *equation 6.56:*

$$DCF(k) = \frac{D(k)}{A} = \frac{f(k)}{m_{th}(k)} \times \frac{T_b(k) \times T_r}{T_b(k) + T_r} \times (13.3 + 0.717 \times r) \qquad (6.57)$$

The parameter values needed to calculate DCF with this equation were interpolated to the mid-point of each age range considered from data contained in **Appendix 6.** All parameter values were linearly interpolated with the exception of the fractional uptake (f) between 0 and 3 months, for which a linear decrease was assumed from age 0 (value: 0.6) to age 2 weeks (value: 0.25), followed by a constant value between 2 weeks and 3 months. The parameter values obtained for each post-natal age group (k = 5 to 14) are presented in *Table 6.6*. The resulting thyroid doses per unit activity intake via ingestion are given in *Table 6.7*. These dose conversion factors are in reasonably good agreement with the dose conversion values for similar age ranges recommended by the ICRP (ICRP 1989).

The thyroid doses per unit activity intake via inhalation are taken to be equal to those via ingestion. This is likely to be a conservative assumption, especially for ^{131}I attached to particles (ICRP 1995). However, this assumption has a relatively small impact on the thyroid doses, as the intakes via inhalation are usually much smaller than those resulting from ingestion.

6.3.2. Pre-Natal Age Groups

Thyroid doses to the fetus are more difficult to estimate than those to infants and older persons mainly because of: (a) the exchange of iodine between the maternal and fetal circulations, and (b) the rapid changes with gestational age of the fetal thyroid mass and uptake.

The critical event in the fetal thyroid exposure to ^{131}I is the onset of its ability to accumulate iodine; before it is capable of such accumulation, the fetal thyroid dose is approximately equivalent to the fetal whole-body dose, which is very small (a few millirad per microcurie) and is neglected in this report (USNRC 1992; Zanzonico and Becker 1991). The onset of iodine accumulation by the fetal thyroid occurs between the 12th and 15th week of gestation (Book and Goldman 1975; Chapman et al. 1948; Evans et al. 1967; Hodges et al. 1955). Expressed as percentage of total ^{131}I intake by the mother, fetal thyroid uptake remains very low (from 0.003 to 0.4%) through the 18th to the 22nd week, and appears to increase to a maxi-

Table 6.6. Metabolic and anatomic parameters used in calculations of radiation doses to the thyroid gland for post-natal age groups. Uptake and mass data are estimated for pre-1960 values.[a]

Age and sex	Parameter				
	Thyroid uptake fraction, f	Thyroid mass, m_{th} (g)	Quotient f/m_{th} (g^{-1})	Thyroid radius, r (cm)	Biological half-life T_b(d)
Infant 0-2 mo	0.279	1.56	0.179	0.57	24
Infant 3-5 mo	0.25	1.69	0.148	0.58	31
Infant 6-8 mo	0.25	1.81	0.138	0.60	39
Infant 9-11 mo	0.25	1.94	0.129	0.61	46
Child 1-4 [a]	0.25	3.00	0.083	0.70	65
Child 5-9 [a]	0.25	6.25	0.040	0.89	80
Child 10-14 [a]	0.25	9.75	0.026	1.05	85
Child 15-19 [a]	0.25	14.00	0.018	1.18	90
Adult male	0.23	18.00	0.013	1.29	90
Adult female	0.27	16.00	0.017	1.24	90

[a] Derived from **Appendix 6.**

Table 6.7. Calculated thyroid doses per unit activity intake (DCF, mrad nCi^{-1}) for the age and sex groups considered in the assessment.

Age group index, k	Age and Sex		Thyroid dose per unit intake (DCF, mrad nCi^{-1})
1	Fetus:	0-10 wk	0.a
2		11-20 wk	2.7[a]
3		21-30 wk	3.8[a]
4		31-40 wk	1.7[a]
5	Infant:	0-2 mo	15[b]
6		3-5 mo	13[b]
7		6-8 mo	13[b]
8		9-11 mo	12[b]
9	Child:	1-4 y	8.2[b]
10		5-9 y	4.1[b]
11		10-14 y	2.6[b]
12		15-19 y	1.9[b]
13	Adult male		1.3[b]
14	Adult female		1.8[b]

[a] Based on Zanzonico and Becker (1991); values are referenced to the mother's intake.
[b] Computed using *equation 6.57* and parameters in *Table 6.6*.

mum at term of no more than 2 to 3% (Dyer and Brill 1972; Evans et al. 1967; Morreale de Escobar and Escobar del Rey 1988).

Many measurements of fetal thyroid mass at different gestational ages have been reported (Evans et al. 1967; Mochizuki et al. 1963). The thyroid gland, which weighs only 0.001 to 0.002 g by the 9th week, grows rapidly and weighs approximately 0.005 g at 12 weeks, 0.05 g at 13 weeks, 0.1 to 0.3 g at 20 weeks, 0.2 to 0.6 g at 24 weeks, and 1 to 1.5 g at term.

The fetal thyroid dose is, as a first approximation, directly proportional to the quotient of the fetal uptake and of the fetal thyroid mass. This quotient, expressed as percent of ^{131}I intake per gram of fetal thyroid tissue, seems to be about 0.2% per g at 12 to 16 weeks of gestational age, to reach a maximum of about 1% per g at 20 to 28 weeks, and to decrease thereafter to about 0.2% per g at term because the mass of the thyroid gland increases more rapidly than the uptake (Zanzonico and Becker 1991).

The fetal thyroid dose estimates used in this report are based on the calculations of Zanzonico and Becker (1991), who adapted a whole-body compartmental model of iodine in a pregnant woman initially developed by Johnson (1982) (*Figure 6.4*). Zanzonico and Becker (1991) assumed that all of the ^{131}I intake is initially in the maternal and fetal inorganic iodine compartment and varied the exchange rates corresponding to input into and output from the maternal thyroid in order to yield a 24-hour maternal thyroid uptake of 25% and a biologic half-time of residence of iodine in the maternal thyroid of 100 days (assumed average values for a euthyroid mother). A slow transplacental exchange between the fetal and maternal organic iodine (protein-bound iodine (PBI)) compartments was introduced and the corresponding exchange rates adjusted to yield a protein-bound ^{131}I plasma concentration in the fetus equal to 5% of that in the mother prior to the onset of fetal thyroid function (Morreale de Escobar and Escobar del Rey 1988). Using the formulas of Johnson (1982), the variation in fetal uptake with age was modeled by gestational age-dependent exchange rates corresponding to input into and output from the fetal thyroid. All other exchange rates used by Zanzonico and Becker are from Johnson (1982).

The fetal thyroid doses were calculated by Zanzonico and Becker (1991) for several pre-natal ages on the basis of the ^{131}I activities in the fetal thyroid obtained with the model. The variation with gestational age of the fetal thyroid mass and of the fraction of ^{131}I energy absorbed by the fetal thyroid were taken into account. In the dose calculations, the compartmental exchange rates and the mass of the fetal thyroid were fixed at their respective values at the time of the ^{131}I administration; this

means that both gestational age-dependent changes in fetal thyroid function and fetal growth subsequent to the ^{131}I administration were ignored.

Estimates of fetal thyroid doses as a function of gestational age are plotted in *Figure 6.5*. For the purposes of this report, fetal thyroid doses have been averaged over time periods of 10 weeks; the results are presented in *Table 6.7*.

6.3.3. Uncertainties

The DCF values presented in *Table 6.7* are those used in the dose assessment for all population groups in a given age and sex class. It should be noted that they are representative of the 1950s and that current values would be expected to be lower, mainly because of an increase in the dietary intake of stable iodine during the last 30 years. Geographical variations across the United States were not considered in **Appendix 6,** because goitrogenic regions, which would have led to larger than "normal" thyroid glands, were eliminated from the United States before 1940.

When evaluating uncertainties, care must be taken in utilizing the tabled dosimetric estimates, since they reflect the biological estimates used in their development. There is considerable variation in the anatomic and physiologic characteristics of the human thyroid gland, making an accurate description of any single thyroid difficult, particularly in retrospect. It must be recalled, however, that the three biologic parameters influencing the dose (fractional uptake, effective half-time of ^{131}I in the thyroid, and thyroid mass) are interrelated. Conditions resulting in an increased iodine uptake for example, may result in an increased thyroid size and a decreased effective half-time. The resulting interplay would offset the impact of each component of the dose equation on the results and would tend to return the estimate toward the central value **(Appendix 6).** Dunning and Schwarz (1981) estimated that the dose conversion factors for ingestion ^{131}I are log-normally distributed with a GSD of 1.8. It is assumed in this report that the dose conversion factors are log-normally distributed with a GSD of 1.8 for all age groups.

For a given intake of ^{131}I by ingestion, it is shown in *Table 6.7* that the highest thyroid absorbed doses are received by infants less than 2 months old. The lowest DCF is for group

Figure 6.4. Whole-body compartment model of iodine in a pregnant woman (Zanzonico and Becker 1991).

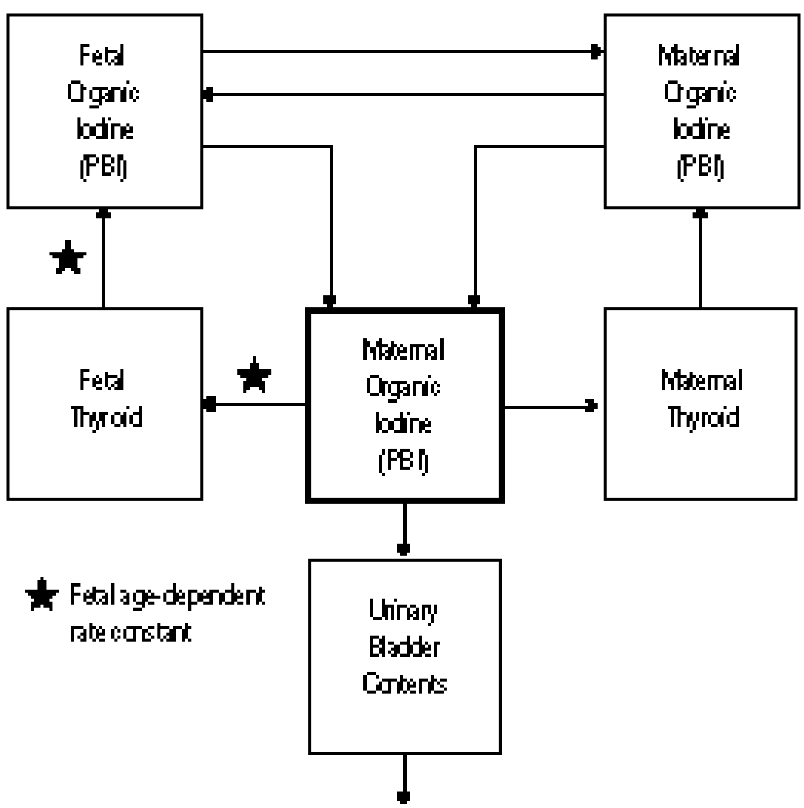
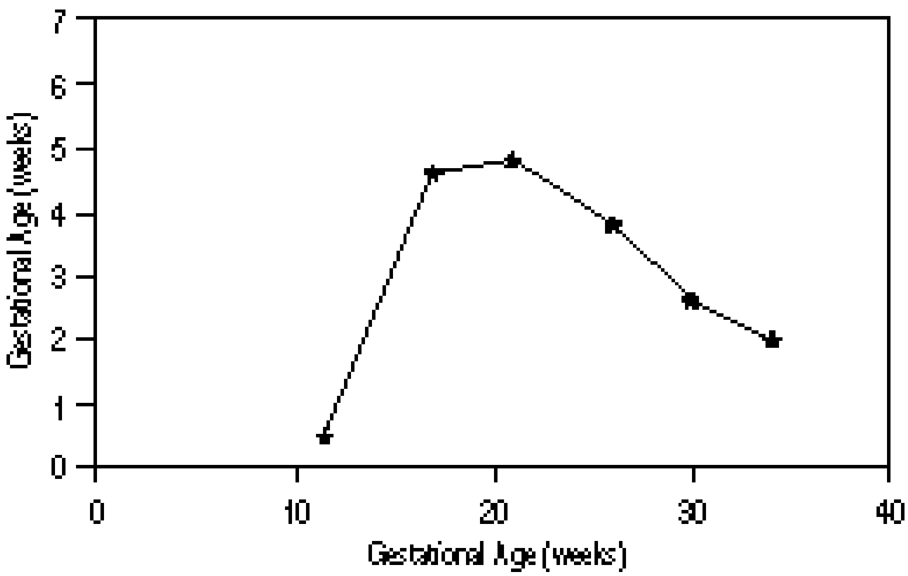


Figure 6.5. Fetal thyroid dose conversion factor for gestational ages, from exposure to ^{131}I ingested by a euthyroid mother (Zanzonico and Becker 1991).



13, the adult male. Doses to the fetus (four age groups) per unit intake by the mother have also been calculated and found to be smaller than those to infants.

6.4. ESTIMATED THYROID DOSES FROM INGESTION OF COWS' MILK

The methodology used in the report to estimate thyroid doses to population groups and collective thyroid doses from ingestion of cows' milk is briefly summarized below. It should be noted that the thyroid doses resulting from ingestion of cows' milk are only one component, but usually the most important component, of the total thyroid doses. Other components (discussed in **Chapter** 7) are the inhalation of ^{131}I-contaminated air and the ingestion of other foodstuffs contaminated with ^{131}I. Only the total thyroid dose estimates are tabulated for each test and each county in the Annexes and Sub-annexes of this report. However, an exception is made for the collective and per capita thyroid doses from ingestion of cows' milk, averaged over all age groups and both sexes for each county and each test, which are presented in the Sub-annexes. (Note that the units of dose in those tables are rad; 1 rad = 1000 mrad.) For the sake of brevity, none of the other detailed estimates of thyroid doses resulting from the ingestion of ^{131}I-contaminated cows' milk are provided in the report; however, they can be readily calculated using the equations given below in this section. **Chapter 8** provides a discussion of the methodology and exposure scenarios used to calculate the total thyroid doses, and examples of the results.

6.4.1. Thyroid Doses From a Given Test

6.4.1.1. Doses to milk drinkers of differing age, sex, and location

The median doses resulting from ingestion of cows' milk, $\langle D_{mc}(i, k, te)\rangle$, due to fallout from a given test, te, received by milk drinkers of a given age and sex group, k, living in a county, i, are estimated as:

$$\langle D_{mc}(i,k,te)\rangle = \langle IMC_{vw}(i,te)\rangle \times CR(i,k)\rangle \times DCF(k)\rangle \quad (6.58)$$

where:

$\langle IMC_{vw}(i,te)\rangle$	is the geometric mean of the volume-weighted time-integrated ^{131}I concentration in milk consumed in county, i, after test, te,
$\langle CR(i,k)\rangle$	is the median consumption rate of cows' milk by milk drinkers of a given age and sex group, k, living in county, i, and
$\langle DCF(k)\rangle$	is the median dose conversion factor for the given age and sex group, k.

Table 6.8. Variation with age and sex of the median milk consumption rate for milk drinkers, of the fraction of milk drinkers, of the median dose conversion factor, and of the median dose over the population of the contiguous U.S. in 1954 for a unit time-integrated concentration of ^{131}I in milk consumed.

Group index, k	Age and sex	Milk consumption rate of milk drinkers, <CR(US,k)> ($L\ d^{-1}$)[a]	Fraction of milk drinkers FMD (k)[a]	Dose conversion factor, DCF ($mrad\ nCi^{-1}$)[b]	Dose per unit contamination of milk ($mrad$ per $nCi\ d\ L^{-1}$)
FETUS					
1	0-10 wk	0.8[c]	0.56[d]	0[e]	0
2	11-20 wk	0.8[c]	0.56[d]	2.7[e]	1.2
3	21-30 wk	0.8[c]	0.56[d]	3.8[e]	1.7
4	31-40 wk	0.8[c]	0.56[d]	1.7[e]	0.8
INFANT					
5	0-2 mo	0.77	0.17	15	2.0
6	3-5 mo	0.83	0.55	13	5.9
7	6-8 mo	0.78	0.90	13	8.4
8	9-11 mo	0.70	1.0	12	8.4
CHILD					
9	1-4 y	0.59	0.83	8.2	4.0
10	5-9 y	0.84	0.78	4.1	2.7
11	10-14 y	0.90	0.71	2.6	1.7
12	15-19 y	0.87	0.66	1.9	1.1
ADULT					
13	Male	0.32	0.61	1.3	0.3
14	Female	0.25	0.56	1.8	0.3

[a] From *Table 6.2.*
[b] From *Table 6.7.*
[c] Milk consumption rate of the mother.
[d] Fraction of milk drinkers in the group of expectant mothers (average value for adult females; k = 14).
[e] Dose to fetal thyroid per unit activity ingestion by mother.

The values of $\langle IMC_{vw}(i,te)\rangle$ are derived from the time-integrated concentrations for each category of milk $\langle IMC_{q}(i,te)\rangle$, as shown in *equation 6.29*. The milk consumption rates <CR(i,k)> are taken from *Tables 6.2 and 6.3*. It should be kept in mind that milk consumption rates vary considerably from one individual to another and that only central values of the intakes of ^{131}I from ingestion are considered here. The values of the dose conversion factors <DCF(k)> are presented in *Table 6.7*.

Table 6.8 presents, for each age and sex group, estimates of the product of: (a) the median milk consumption rate, <CR(k)>, for milk drinkers in the U.S. population (*Table 6.2*); (b) the fraction of milk drinkers, FMD(k) (Table 6.2); and (c) the median dose conversion factor, <DCF(k)> (*Table 6.7*). If a constant time-integrated concentration of ^{131}I in milk consumed by all age and sex groups in a county is assumed, this product is proportional to the average dose received by the age and sex groups. The 6-11 month-old infants are estimated to receive, on average, the highest doses (8.4 mrad per nCi d L^{-1}), whereas the lowest estimated doses (0.3 mrad per nCi d L^{-1}) are received by adults and are 4% of the highest doses. The per capita thyroid dose per unit time-integrated concentration of ^{131}I in cows' milk is 3.4 mrad per nCi d L^{-1}.

6.4.1.2. Doses to the "high-exposure" groups

The median thyroid doses to the "high-exposure" groups, $\langle D_{mc,high}(i,k,te)\rangle$, are estimated using the median dose conversion factors defined above and the milk concentrations and consumption rates appropriate for these groups.

$$\langle D_{mc,high}(i,k,te)\rangle = \langle IMC_{high}(i,te)\rangle \times CR_{high}(i,k) \times \langle DCF(k)\rangle \qquad (6.59)$$

where:

- the value of $\langle IMC_{high}(i,te)\rangle$ is the highest time-integrated concentration of ^{131}I calculated in the four milk categories, q, in county, i, and test, te. The estimates obtained for each county of the contiguous United States are presented in the Annexes for each test and each test series,

Table 6.9. Variation with age and sex of the median dose to the "high-exposure" groups for a unit time-integrated concentration of ^{131}I in milk consumed by each group.

Group index, k	Age and sex	Dose per unit contamination of milk (mrad per nCi d L^{-1})[a]
	FETUS	
1	0-10 wk	0[b]
2	11-20 wk	2.2[b]
3	21-30 wk	3.0[b]
4	31-40 wk	1.4[b]
	INFANT	
5	0-2 mo	20
6	3-5 mo	18
7	6-8 mo	17
8	9-11 mo	14
	CHILD	
9	1-4 y	9.8
10	5-9 y	3.2
11	10-14 y	3.6
12	15-19 y	2.5
	ADULT	
13	Male	1.3
14	Female	1.4

[a] Computed using milk consumption rates in *Table 6.4* and dose conversion factors in *Table 6.8.*
[b] Based upon milk consumption rate of the mother.

- the values of CR_{high}(i,k), which correspond to the 95th percentiles of the distributions presented in *Table 5.4* of **Chapter 5,** range from 0.8 to 1.4 L d^{-1} and are shown in *Table 6.4.*

For a specific time-integrated concentration of ^{131}I in milk, <IMC_{high} (i,te)> the products of the milk consumption rates, <CR_{high} (i.k)>, (*Table 6.4*) and the dose conversion factors, <DCF(te)>, (*Table 6.7*) for all age groups are given in *Table 6.9.* Review of the results shows that the most exposed group consists in this case of 0-2 month old infants. It is emphasized that these results represent approximations to the doses to the most exposed groups. Individual doses may not be the same because of differences in milk consumption rates or dose conversion factors.

6.4.1.3. Doses to the "low-exposure" groups

It is assumed that the "low-exposure" groups do not consume any fresh cows' milk, i.e. CR_{low}(i,k) = 0. The estimates of the doses due to contamination of cows' milk are therefore equal to zero, irrespective of the time-integrated ^{131}I concentrations in fresh cows' milk.

6.4.1.4. Doses to the groups drinking milk from backyard cows

Assumptions about the feeding, pasturage, and milk transfer coefficients for backyard cows are given in Chapter 4. Backyard cows are assumed to consume 8 kg (dry matter) of pasture and 3 kg (dry matter) of concentrates during the pasture season. The duration of the pasture season for the backyard cows is assumed to be longer by 2 months than that for dairy cows. The median time-integrated concentrations of ^{131}I in milk from backyard cows, <IMC_{bc}(i,te)>, estimated for each county, i, are presented in the Annexes for each test, te.

It is assumed that the people drinking milk from backyard cows have "high" consumption rates of milk. These rates are described above and listed in *Table 6.4*. The median doses to the age and sex group, k, located in county, i, following test, te, and drinking milk from backyard cows, <$D_{mc,bc}$ (i,k,te)>, are estimated using the median dose conversion factors discussed above and the following equation:

$$<D_{mc,bc}(i,k,te)> = <IMC_{bc}(i,te)> \times CR_{high}(i,k) \times <DCF(k)> \qquad (6.60)$$

6.4.1.5. Collective and per capita doses

The collective dose, CD_{mc}(i,te), received by the population of county, i, from ^{131}I deposition after a test, te, is the sum of the doses received by all individuals in that population. The collective dose received by the population of a county is estimated by computing the sum of the collective doses received by each of the 10 post-natal age groups (k = 5 to 14), estimated in turn as the products of the arithmetic mean doses received by milk drinkers, m(D_{mc}(i,k,te)), the average fraction of milk drinkers in the groups, FMD(k), and the population sizes of the age groups in the county, POP(i,k). The equation is:

$$CD_{mc}(i,te) = \sum_{k=5}^{k=14} m(D_{mc}(i,k,te)) \times FMD(k) \times POP(i,k) \qquad (6.61)$$

The mean doses, m(D_{mc}(i,k,te)) are derived from the median thyroid dose for milk drinkers, <D_{mc}(i,k,te)>, and from the geometric standard deviation of the thyroid dose distribution using:

$$m(D_{mc}(i,k,te)) = <D_{mc}(i,k,te)> \times e^{0.5 \times \sigma^2(D_{mc}(i,k,te))} \qquad (6.62)$$

The variance, with σ^2(D_{mc}(i,k,te)), is completed using:

$$\sigma^2(D_{mc}(i,k,te)) = (\sigma^2(IMC_{vw}(i,te)) + \sigma^2(CR(i,k)) + \sigma^2(DCF(k)))^{0.5} \qquad (6.63)$$

The collective dose, CD_{mc}(US,te), received by the population of the entire U.S. from ^{131}I deposition in a test, te, can be calculated in turn as the sum of collective doses received by the population of each of the 3,094 counties and subcounties. The summation over the counties is:

$$CD_{mc}(US,te) = \sum_i CD_{mc}(i,te) \qquad (6.64)$$

The contribution of each age and sex group to the collective dose can be estimated by computing the product of the population fraction, the fraction of milk drinkers, the dose conversion factor, and the milk consumption rate for each group. The product of the last three terms was already presented in *Table 6.8. Table 6.10* includes those results, the population fractions from *Table 5.9,* and the products of all four terms for infants, children, and adults. The last column of *Table 6.10* shows the relative contributions of each age and sex group. The largest contribution to the collective dose (about 30%) is from children aged 1-4 years. The adults, which represent more than 60% of the population, contribute less than 20% to the collective dose.

Table 6.10. Relative variation with age and sex of the collective thyroid dose for the population of the contiguous U.S. in 1954 for a unit time-integrated concentration of ^{131}I in consumed milk.

Group index, k	Age and sex	Dose per unit contamination of milk (mrad per nCi d L^{-1})[a]	Population fraction, FPOP(k)[b]	Contribution to collective dose to thyroids[c]	Relative contribution to the collective thyroid dose (%)
INFANT					
5	0-2 mo	2.0	0.0055	0.011	1
6	3-5 mo	5.9	0.0055	0.033	3
7	6-8 mo	8.4	0.0055	0.046	4
8	9-11 mo	8.4	0.0055	0.046	4
CHILD					
9	1-4 y	4.0	0.088	0.352	30
10	5-9 y	2.7	0.095	0.257	22
11	10-14 y	1.7	0.083	0.141	12
12	15-19 y	1.1	0.072	0.079	7
ADULT					
13	Male	0.3	0.31	0.093	8
14	Female	0.3	0.33	0.099	9
		Totals	1.0	1.157	100

[a] From *Table 6.8.*
[b] From *Table 5.9* in **Chapter 5.**
[c] Product of columns three and four; units are mrad per nCi d L^{-1}.

The per capita dose, $D_{mc,pc}(i,te)$, in county, i, resulting from a test, te, is calculated as the quotient of the collective dose, $CD_{mc}(i,te)$, and of the population of the county:

$$D_{mc,pc}(i,te) = \frac{CD_{mc}(i,te)}{\sum_{k=5}^{k=14} POP(i,k)} \qquad (6.65)$$

The per capita dose to the entire U.S. population for a particular test, te, is the ratio of the collective dose CD_{mc} (US, te), given in *equation 6.63,* to the total population of the country. Estimates of collective and per capita thyroid doses due to the ingestion of ^{131}I-contaminated cows' milk are presented in the Sub-annexes for each test, for the population of each county, and for the entire population of the contiguous United States. (Note that the units of dose in those tables are rad; 1 rad = 1000 mrad.)

6.4.2. *Thyroid Doses From A Given Test Series*

The median thyroid doses in a population group due to the consumption of cows' milk contaminated by ^{131}I as a result of a given test series can be estimated by computing the products of: (a) the median time-integrated ^{131}I concentrations for the test series in the cows' milk consumed by the population group considered, $<IMC_{vw}(i,ts)>$, (b) the median milk consumption rate for the population group, $<CR(i,k)>$, and (c) the median dose conversion factor, $<DCF(k)>$, for the population group considered. For example, the median thyroid dose due to the consumption of cows' milk contaminated as the result of ^{131}I fallout during the test series, ts, in county, i, among the population of milk drinkers in age group, k, is calculated as:

$$<D_{mc}(i,k,ts)> = <IMC_{vw}(i,ts)> \times < CR(i,k) > \times < DCF(k) > \qquad (6.66)$$

However, this estimate is valid only if it is assumed that:

- the population remained stable during the test series (no births, deaths, or population movement in and out of the county, which is probably unrealistic), and
- the individuals remained in the same age group during the test series (this is not the case for the infants for most of the test series).

For individuals who changed residence or age group between tests of a test series, the thyroid dose from the test series is calculated by combining the thyroid doses from each test in the series and using the appropriate age-dependent parameter values for each test. A detailed presentation of such calculations is provided in **Chapter 9.**

6.4.3. *Thyroid doses from all tests*

The average thyroid doses in a given age group due to the consumption of milk contaminated by ^{131}I as a result of all tests cannot be obtained by adding the contributions from each of the eight test series (Ranger, Buster-Jangle, Tumbler-Snapper, Upshot-Knothole, Teapot, Plumbbob, Hardtack, and Underground Era). Such an approach presupposes that:

- the population in that age group remained stable during the entire testing era (no population transfer in and out of the county), and
- the individuals remained in the same age group during the entire testing era (this is not the case for most age groups).

In this report, only per capita and collective doses from all tests are calculated for the population of each county.

The calculation of individual thyroid doses from all tests can be carried out by combining the thyroid doses from each test series and using the appropriate parameter values for each test series. A detailed example of such calculations is provided in **Chapter 9.**

6.5. SUMMARY

- Median thyroid doses resulting from the ingestion of cows' milk contaminated with ^{131}I are estimated as the products of the time-integrated concentrations of ^{131}I in milk, of the milk consumption rates, and of the dose conversion factors for ingestion of ^{131}I in milk appropriate for the population group considered.
- The population in each county has been divided into 14 age and sex groups (four stages during fetal development, four groups for infants less than one year old, four age groups for children and teenagers, one group for adult males, and one group for adult females). Median thyroid doses have been calculated for each age and sex groups for: (a) the population that drink cows' milk, (b) specified "high-exposure" groups, with a high consumption rates of cows' milk containing a higher-than-average ^{131}I concentration, (c) specified "low-exposure" groups (non-milk drinkers), and (d) the group that drank milk from backyard cows.
- For a given intake of ^{131}I, the highest average thyroid dose is delivered to the 0-2 month infant, while the lowest average thyroid dose is received by the adult male.
- The methodology used to estimate collective and per capita doses received by the population of each county and by the population of the entire U.S. as a result of the deposition of ^{131}I on the ground following each test also has been presented.

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Methods and Data for Calculating Doses to People Resulting from Exposure Routes to Man Other Than the Ingestion of Cows' Milk

CONTENTS: Exposure routes to man other than the ingestion of cows' milk also contribute to the thyroid dose resulting from ^{131}I released into the atmosphere by nuclear weapons tests. The exposure routes considered in this report are the inhalation of ^{131}I-contaminated air and the ingestion of ^{131}I-contaminated goats' milk, cottage cheese, eggs, and leafy vegetables. The methods and data used to estimate thyroid doses to people resulting from these exposure routes are presented.

The ingestion of cows' milk is usually the most important human exposure route for ^{131}I in fallout from nuclear weapons testing. However, other exposure routes also need to be considered, particularly for those individuals who do not drink cows' milk. The purpose of this chapter is to indicate how the thyroid doses due to exposure routes other than the ingestion of fresh cows' milk have been estimated.

The exposure routes considered in this chapter include the inhalation of ^{131}I-contaminated air and the ingestion of ^{131}I-contaminated goats' milk, cottage cheese, eggs and leafy vegetables. The consumption of mothers' milk also is considered for infants under one year of age. The selection of these exposure routes is based on the experience acquired from measurements of ^{131}I carried out during the period of heavy fallout from nuclear weapons testing in the Pacific and in the USSR in 1961 and 1962, and also after reactor accidents, such as those that occurred at Windscale in 1957 and at Chernobyl in 1986.

In the first part of this chapter, the methodology used for calculating doses to people resulting from exposure routes to man other than the ingestion of cows' milk is described. It is applied to the same example scenarios as those used in **Chapter 4** to show the relative importance of the various environmental pathways leading to the contamination of cows' milk. On the basis of these example scenarios, it is shown that in most cases the ingestion of cows' milk results in thyroid doses that are much greater than those due to any other exposure route to man.

In the second part of this chapter, the calculation procedures used to apply the methodology for calculating doses to people resulting from exposure routes to man other than the ingestion of cows' milk for the populations of each county of the contiguous U.S. following each test are presented. Thyroid dose calculations have been carried out for each of the selected exposure routes following each test and for the populations of each county of the contiguous U.S., subdivided into the same 14 age and sex groups considered in the estimation of the thyroid doses due to consumption of cows' milk. However, in view of the relatively minor importance of these exposure routes, only total doses from these exposure routes have been estimated, and many simplifying assumptions have been made in the assessment of the doses from these sources.

7.1. METHODOLOGY AND EXAMPLE CALCULATIONS

For illustration purposes, the thyroid doses received via inhalation of ^{131}I-contaminated air, ingestion of ^{131}I-contaminated goats' milk, cottage cheese, eggs and leafy vegetables, and, for infants under 1 year of age, consumption of mothers' milk are compared with doses received via ingestion of cows' milk. Comparisons are made both when the cows are on pasture and when cows are off pasture, using the same scenarios and general assumptions as in **Section 4.2** of **Chapter 4**. For convenience, the description of those scenarios is provided again here.

Eight scenarios, denoted as sc, have been considered, representing a range of conditions at two hypothetical sites: (a) one situated far away from the NTS (3000 km), and (b) one close to the NTS (100 km). The factors considered are the presence or absence of rain during deposition, and the presence or absence of cows on pasture during deposition. The characteristics of the eight scenarios are as follows:

Scenario number, sc	Daily rainfall amount R (L m^{-2})	Distance from the NTS, X (km)	Presence of cowsonpasture
1	0 (no rain)	3000	yes
2	0 (no rain)	3000	no
3	1 (light rain)	3000	yes
4	1 (light rain)	3000	no
5	100 (heavy rain)	3000	yes
6	100 (heavy rain)	3000	no
7	0 (no rain)	100	yes
8	0 (no rain)	100	no

In each of the eight scenarios, it is assumed that a deposition, DG, of ^{131}I of 1 nCi m^{-2} has occurred at time t = 0.

The values selected for parameters used in the calculations include:

- T_r (radioactive half-life of ^{131}I) = 8.04 d, corresponding to a radioactive decay constant λ_r = 0.086 d^{-1}.
- T_w (environmental half-life of stable iodine on pasture) = 10 d, corresponding to a rate constant λ_w = 0.069 d^{-1}; the GSD assumed for the distribution of T_w is 1.8 (**Section 4.1.2**).
- T_e (effective half time of residence of ^{131}I on pasture) = 4.5 d, corresponding to an effective mean time of residence τ_e of 6.5 d and to a rate constant λ_e of 0.15 d^{-1}; the GSD assumed for the distributions of T_e and τ_e is 1.3 (**Section 4.1.2**).
- Y (standing crop biomass of pasture) = 0.3 kg (dry mass) m^{-2}, the GSD assumed for the distribution of Y is 1.8 (**Section 4.1.1.1.1**).
- AD (air density) = 1.2 kg m^{-3}.
- U_{sl} (soil density) = 1.5 x 10^3 kg (dry mass) m^{-3}.
- H_w (depth of farm pond) = 0.5 m.
- PR_{hay} (ratio of time-integrated concentration of ^{131}I in stored hay to that in pasture grass) = 0.04 (**Section 4.2.7**).
- F(sc) (fraction of deposited activity intercepted by pasture grass): ranges from 0.04 for dry deposition close to the NTS (100 km) to 0.72 for light rain far away from the NTS (3000 km). Values for each scenario from **Section 4.2.3** are given in the table below.
- F*(sc) (mass interception factor): ranges from 0.13 m^2 kg^{-1} for dry deposition close to the NTS (100 km) to 2.4 m^2 kg^{-1} for light rain far away from the NTS (3000 km). Values for each scenario from **Section 4.2.2** are given in the table below.
- H_{sl}(sc) (depth of soil over which the deposited activity is uniformly distributed): assumed to be equal to 0.001 m for dry deposition, 0.005 m for light rain, and 0.01 m for heavy rain. Values for each scenario from **Section 4.2.3** are given in the table below.
- v_g(sc) (deposition velocity): varies with distance from the NTS and is taken to be equal to 4000 m d^{-1} at 100 km from the NTS and to 1200 m d^{-1} at 3000 km from the NTS (see **Appendix 7**). Values for each scenario from **Section 4.2.5** are given in the table below.
- WR(sc) (washout ratio): varies with distance from the NTS and with daily rainfall amount. Values for WR at 3000 km from the NTS are 120 kg/kg for heavy rain and 3000 kg/kg for light rain (see **Appendix 7**). Values for each scenario from **Section 4.2.5** are given in the table on the next page.

sc	Desctiption of scenario sc			F(sc)[a]	F* (sc) ($m^2 kg^{-1}$)[b]	H_{sl} (sc) (m)[a]	v_g (sc) ($m\ d^{-1}$)[c]	WR (sc) ($kg\ kg^{-1}$)[c]
	Rain	Distance	Cows					
1	none	3000 km	on pasture	0.57	1.9	0.001	1200	0
2	none	3000 km	off pasture	0.57	1.9	0.001	1200	0
3	light	3000 km	on pasture	0.72	2.4	0.005	1200	3000
4	light	3000 km	off pasture	0.72	2.4	0.005	1200	3000
5	heavy	3000 km	on pasture	0.30	1.0	0.01	1200	120
6	heavy	3000 km	off pasture	0.30	1.0	0.01	1200	120
7	none	100 km	on pasture	0.04	0.13	0.001	4000	0
8	none	100 km	off pasture	0.04	0.13	0.001	4000	0

[a]From **Section 4.2.3.**
[b]From **Section 4.2.2.**
[c]From **Section 4.2.5.**

The thyroid doses are the products of: (a) the average time-integrated concentrations of ^{131}I in air or in the foodstuff considered, (b) the corresponding inhalation or consumption rates, and (c) the dose conversion factors. The three quantities are discussed in turn.

7.1.1. Time-integrated Concentrations of ^{131}I in Foodstuffs and Air

In view of the relatively minor importance of the exposure routes other than the ingestion of cows' milk, several important simplifying assumptions are made:

(a) All the foodstuffs were considered to be of local origin. It is recognized that, in most cases, these foodstuffs may have been produced far away from the county where they were subsequently consumed, resulting in time-integrated concentrations of ^{131}I that may have been higher than the time-integrated concentrations in local foodstuffs for some tests and lower for other tests. Because (a) there is no readily available information on the commercial distribution of these foodstuffs across the country during the 1950s and (b) the contribution to the total dose represented by the ingestion of these foodstuffs is in general of minor importance, it seems reasonable to make the simplifying assumption that the foodstuffs other than cows' milk that are consumed in a given county originate within the same county. When estimating the ^{131}I concentrations in mothers' milk, it is assumed that the mother consumes the volume-weighted mixed milk (**Section 6.1.1.5**) for the county of residence.

(b) The time of the year when goats and chickens are kept outdoors is assumed to correspond to the time of year when "backyard" cows are on pasture. Similarly, the time of the year when goats and chickens are under shelter and consume less ^{131}I-contaminated food than when they are kept outdoors is assumed to correspond to the time of year when "backyard" cows are off pasture. These times vary from state to state (see **Section 4.1.3.5**).

(c) Because the foodstuffs are assumed to be of local origin, it is also assumed that the delay times between production and consumption were short. The appropriate delay times are estimated to be at the lower ends of the ranges of published values (Quinault 1989): 0.5 day for goats' milk, 1 day for leafy vegetables, 2 days for cottage cheese, and 3 days for eggs.

7.1.1.1. Cows' milk (reference conditions)

The contamination of cows' milk by ^{131}I for the eight scenarios considered was estimated in **Chapter 4 (Section 4.2)** for five pathways: (a) ingestion by cows of ^{131}I-contaminated pasture; (b) ingestion by cows of ^{131}I-contaminated soil; (c) inhalation by cows of ^{131}I-contaminated air; (d) ingestion by cows of ^{131}I-contaminated water; and, (e) ingestion by cows of ^{131}I-contaminated hay. The results, already presented in **Chapter 4** *(Table 4.9)*, are presented again in *Table 7.1* and are discussed briefly on the following page.

Table 7.1. Median time-integrated ^{131}I concentrations in fresh cows' milk, in nCi dL^{-1}, resulting from various exposure routes for a unit deposition of ^{131}I of 1 nCi m^{-2} (from Section 4.2).

Route of intake by cow	Distance from the NTS: 3000 km						Distance from the NTS: 100 km	
	Dry conditions		Light rain		Heavy rain		Dry conditions	
	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Pasture consumption	0.40	0.005	0.50	0.006	0.21	0.003	0.03	0.0003
Ingestion of soil	0.01	0.005	0.002	0.0009	0.001	0.0006	0.02	0.008
Ingestion of water	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Ingestion of stored hay	0.0002	0.02	0.0002	0.02	0.0001	0.008	0.00001	0.001
Inhalation	0.0004	0.0004	0.0001	0.0001	0.00005	0.00005	0.0001	0.0001
All routes	0.42	0.035	0.52	0.036	0.22	0.021	0.057	0.019

When cows are on pasture, the most important pathway leading to the contamination of cows' milk with ^{131}I is pasture consumption. At 3000 km from the NTS, all pathways other than pasture consumption contribute only a few percent of the total time-integrated ^{131}I concentration in cows' milk. At 100 km from the NTS, the mass interception factor is much lower than at 3000 km from the NTS, and, consequently, pasture is much less contaminated at 100 km than at 3000 km from the NTS, for the same ^{131}I deposition on the ground. At 100 km from the NTS, all pathways other than pasture consumption contribute about as much as pasture consumption to the total contamination of cows' milk with ^{131}I.

For a given ^{131}I deposition on the ground, the time-integrated concentrations in cows' milk are much smaller when cows are off pasture than when they are on pasture. When cows are off pasture, ingestion of stored hay is estimated to be the most important pathway at 3000 km from the NTS. However, at 100 km from the NTS, incidental ingestion of soil leads to a greater contamination of cows' milk than the ingestion of stored hay. The relative importance of the ingestion of soil and of stored hay is linked to the variation of the mass interception factor with distance from the NTS. At short distances from the NTS (e.g., 100 km), the mass interception factor is small, so that soil is more contaminated than vegetation per unit area of ground. At large distances from the NTS (e.g., 3000 km), the mass interseption factor is high, so that vegetation (pasture or stored hay) is more heavily contaminated than soil per unit area of ground.

Whether cows are on pasture or off pasture, the inhalation of ^{131}I-contaminated air contributes very little to the time-integrated ^{131}I concentration in cows' milk.

7.1.1.2. Goats' milk

The contamination of goats' milk by ^{131}I results from the same pathways that cause the contamination of cows' milk. The equations used to estimate the ^{131}I concentration in fresh goats' milk are therefore similar to those used to calculate the ^{131}I concentration in fresh cows' milk presented in **Chapter 4 (Section 4.2)**. The only modifications made in those equations consisted in denoting the time-integrated concentrations of ^{131}I in fresh goats' milk as IMG (instead of IMC for fresh cows' milk), in adding the subscript gt (for goats) to parameter symbols where appropriate, and in adding a term accounting for the activity loss due to delay between production and consumption. Five pathways from ^{131}I deposition to milk contamination are considered: (a) ingestion by goats of ^{131}I-contaminated pasture; (b) ingestion by goats of ^{131}I-contaminated soil; (c) inhalation by goats of ^{131}I-contaminated air; (d) ingestion by goats of ^{131}I-contaminated water; and (e) ingestion by goats of ^{131}I-contaminated hay.

As noted in **Section 7.1**, a unit deposition, DG, of 1 nCi m^{-2} is assumed for all scenarios. The reference values of parameters common to many scenarios are listed in **Section 7.1**. Parameters used or derived in **Chapter 4 (Section 4.2)** for specific scenarios are also listed for convenience in **Section 7.1.**

7.1.1.2.1. ^{131}I concentrations in goats' milk due to the ingestion of pasture

The time-integrated concentration of ^{131}I in goats' milk due to pasture consumption, for a scenario, sc, $IMG_p(sc)$, in nCi d L^{-1}, is estimated in the same way as for cows' milk. The relevant *equation (4.33)* is modified to read:

$$IMG_p\,(sc) = DG \times F^*\,(sc) \times \tau_e \times PI^{*gt}\,(sc) \times f_{m,gt} \times e^{-\lambda_r \times TD_{gt}} \qquad (7.1)$$

Table 7.2. Median time-integrated ^{131}I concentrations in fresh goats' milk, in nCi dL^{-1}, resulting from various exposure routes for a unit deposition of ^{131}I of 1 nCi m^{-2} (from Section 4.2).

Route of intake by cow	Distance from the NTS: 3000 km						Distance from the NTS: 100 km	
	Dry conditions		Light rain		Heavy rain		Dry conditions	
	Goat on pasture	Goat off pasture	Goat on pasture	Goat off pasture	Goat on pasture	Goat off pasture	Goat on pasture	Goat off pasture
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Pasture consumption	3.6	0	4.6	0	1.9	0	0.26	0
Ingestion of soil	0.23	0	0.039	0	0.029	0	0.30	0
Ingestion of water	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Ingestion of stored hay	0	0.13	0	0.16	0	0.073	0	0.0093
Inhalation	0.001	0.001	0.0005	0.0005	0.0004	0.0002	0.0004	0.0004
All routes	3.8	0.15	4.7	0.18	2.0	0.095	0.57	0.027

where:

$PI^*_{gt}(sc)$ is the rate of pasture intake equivalent for goats, which is numerically equal to the rate of pasture consumption for goats. Whicker and Kirchner (1987) estimated as 1.5 kg d^{-1} the rate of pasture consumption for sheep; the same value is used in this report for the median pasture consumption by goats on pasture throughout the country, i.e., for scenarios 1, 3, 5, and 7. The GSD of the distribution of PI^*_{gt} is taken to be 1.4, corresponding to 95% of the values being in the range from 0.8 to 3 kg d^{-1}. During the off-pasture season, PI^*_{gt} is assumed to be negligible.

$f_{m,gt}$ is the intake-to-milk transfer coefficient for goats taken to have a median value of 0.2 d L^{-1} and a GSD of 2.5 (**Section 4.1.4.2**).

TD_{gt} is the time delay between milking and consumption of goats' milk, assumed to be 0.5 day.

Other common and scenario specific parameters were given in **Section 7.1.** Estimates of the time-integrated concentrations of ^{131}I in goats' milk due to the ingestion of pasture were computed using *equation 7.1.* The results are presented in the first row of *Table 7.2.*

7.1.1.2.2. ^{131}I concentrations in goats' milk due to the ingestion of soil

The time-integrated concentration of ^{131}I in goats' milk due to soil consumption for scenario sc, IMG_{sl} (sc), in nCi d L-1, is estimated in the same way as for cows. The relevant *equation (4.52)* is modified to read:

$$IMG_{sl}(sc) = DG \times \frac{e^{-\lambda_r \times TD_{gt}}}{\lambda_r \times H_{sl}(sc) \times U_{sl}} \times \left(1 - F(sc) \times \frac{\lambda_r}{\lambda_e}\right) \times CR_{sl,gt}(sc) \times f_{m,gt} \quad (7.2)$$

where:

$CR_{sl,gt}$ is the ingestion rate of soil by goats. The soil intake by sheep can make up to 14% of the dry matter intake (Healy 1967; Zach and Mayoh 1984). It is assumed in this report that this figure also applies to goats on pasture. It is estimated in this report that the average soil intake is 14% of the dry matter intake, or 0.2 kg d-1, when goats are on pasture, and to be negligible when goats are under shelter.

All other parameters in *equation 7.2* have previously been defined in this chapter. Estimates of the time-integrated concentrations of ^{131}I in goats' milk due to the ingestion of soil were computed using *equation 7.2*. The results are presented in the second row of *Table 7.2.*

7.1.1.2.3. ^{131}I concentrations in goats' milk due to inhalation of air

The time-integrated concentration of ^{131}I in goats' milk due to inhalation of air for scenario sc, IMG_{inh} (sc), in nCi d L^{-1}, is estimated in the same way as for cows. The relevant *equation (4.66)* is modified to read:

$$IMG_{inh}(sc) = \frac{DG \times e^{-\lambda_r \times TD_{gt}}}{v_g(sc) + \frac{R(sc) \times WR(sc)}{AD}} \times BR_{gt} \times f_{m,gt} \quad (7.3)$$

where:

BR_{gt} is the breathing rate (m^3 d^{-1}) of goats. Comar (1966) estimated the breathing rate for sheep to be 9 m3 d^{-1}; the same value is used in this report for goats. All other parameters in *equation 7.3* have previously been defined in this chapter. Estimates of the time-integrated concentrations of ^{131}I in goats' milk due to the inhalation of air were computed using *equation 7.3.* The results are presented in the last row of *Table 7.2.*

7.1.1.2.4. ^{131}I concentrations in goats' milk due to the ingestion of water

The time-integrated concentration of ^{131}I in goats' milk due to the ingestion of water for scenario sc, IMG_w(sc), in nCi d L^{-1} is estimated in the same way as for cows. The relevant *equation (4.70)* is modified to read:

$$IMG_w\ (sc) = DG \times \frac{k_1}{H_w \times \lambda_r} \times CR_{w,gt} \times f_{m,gt} \times e^{-\lambda_r \times TD_{gt}} \quad (7.4)$$

where:

$k_1 = 10^{-3}$ m^3 L^{-1} is a unit conversion factor and $CR_{w,gt}$ is the rate of water consumption (L d^{-1}) by goats. Comar (1966) estimated the rate of water consumption by sheep to be 3.5 L d^{-1}. Although goats are among the most efficient animals in the use of water (Perry 1984), the value reported for sheep has also been used for goats in this report. All other parameters in *equation 7.4* have previously been defined in this chapter. Estimates of the time-integrated concentrations of ^{131}I in goats' milk due to the ingestion of water were calculated using *equation 7.4.* The results are presented in the third row of *Table 7.2.*

7.1.1.2.5. ^{131}I concentrations in goats' milk due to the ingestion of stored hay

The time-integrated concentration of ^{131}I in goats' milk due to consumption of stored hay for scenario sc, IMG_{hay} (sc), in nCi dL^{-1}, is estimated in the same way as for cows. The relevant *equation (4.73)* is modified to read:

$$IMG_{hay}\ (sc) = DG \times F^*\ (sc) \times \tau_e \times PR_{hay,\ gt} \times CR_{hay,\ gt} \times f_{m,\ gt} \times e^{-\lambda_r \times TD_{gt}} \quad (7.5)$$

where:

$CR_{hay,gt}$ is the rate of hay consumption by goats, estimated to be 1.5 kg d^{-1} when goats are under shelter, and to be negligible when goats are on pasture. All other parameters in *equation 7.5* have previously been defined in this chapter. Estimates of the time-integrated concentrations of ^{131}I in goats' milk due to the ingestion of stored hay were calculated using *equation 7.5.* The results are presented in the fourth row of *Table 7.2.*

7.1.1.2.6. Time-integrated concentrations of ^{131}I in goats' milk: Summary

Table 7.2 summarizes the time-integrated concentrations of ^{131}I that are due to each of the exposure routes considered. At long distances from the NTS, the exposure routes that result in the highest time-integrated concentrations of ^{131}I in goats' milk are the consumption of pasture when goats are on pasture and the ingestion of stored hay when goats are under shelter. Other exposure routes are much less important.

At short distances from the NTS, the fraction of fallout ^{131}I that is intercepted by vegetation is much less than at large distances. Consequently, the time-integrated concentrations of ^{131}I in pasture and in stored hay are much lower. The most important exposure routes of exposure at short distances from the NTS are the intake of soil when goats are on pasture and the consumption of water when goats are under shelter.

The contamination of goats' milk by ^{131}I by all mechanisms discussed above has been evaluated in this report for each county, i, of the contiguous United States and for each day, j, for which deposition of ^{131}I on the ground was estimated following each test. *Equations 7.1* to *7.5* were modified only to change the variable indices (i and j replacing sc in most cases) and to replace F with its equivalent (F* x Y) *in equation 7.2.*

For contamination of goats' milk by ^{131}I due to pasture consumption, *equation 7.1* becomes:

$$IMG_p\ (i, j) = DG\ (i, j) \times F^*\ (i, j) \times \tau_e \times PI^*_{gt} \times f_{m,\ gt} \times e^{-\lambda_r \times TD_{gt}} \quad (7.6)$$

For contamination of goats' milk by ^{131}I resulting from the ingestion of soil, *equation 7.2* becomes:

$$IMG_{sl}\ (i, j) = DG\ (i, j) \times \frac{e^{-\lambda_r \times TD_{gt}}}{\lambda_r \times H_{sl}\ (i, j) \times U_{sl}} \times \left(1 - \frac{F^*\ (i, j) \times Y \times \lambda_r}{\lambda_e}\right) \times CR_{sl,\ gt} \times f_{m,\ gt} \quad (7.7)$$

For the contamination of goats' milk by ^{131}I resulting from inhalation, *equation 7.3* becomes:

$$IMG_{inh}\ (i, j) = \frac{DG\ (i, j)\ e^{-\lambda_r \times TD_{gt}}}{v_g\ (i) + \dfrac{R\ (i, j) \times WR\ (i, j)}{AD}} \times BR_{gt} \times f_{m,\ gt} \quad (7.8)$$

For the contamination of goats' milk by ^{131}I resulting from the ingestion of water, *equation 7.4* becomes:

$$IMG_w\ (i, j) = DG\ (i, j) \times \frac{1}{H_w \times \lambda_r} \times CR_{w,\ gt} \times f_{m,gt} \times e^{-\lambda_r \times TD_{gt}} \quad (7.9)$$

For the contamination of goats' milk by ^{131}I resulting from the ingestion of stored hay, *equation 7.5* becomes:

$$IMG_{hay}\ (i, j) = DG\ (i, j) \times F^*\ (i, j) \times \tau_e \times PR_{hay} \times CR_{hay,\ gt} \times f_{m,\ gt} \times e^{-\lambda_r \times TD_{gt}} \quad (7.10)$$

The time-integrated concentration in goats' milk resulting from all exposure routes was estimated by adding the separate contributions:

$$MG\ (i, j) = IMG\ (i, j) + IMG_{sl}\ (i, j) + IMG_{inh}\ (i, j) + IMG_w\ (i, j) + IMG_{hay}\ (i, j) = DG\ (i, j) \times f_{m,\ gt} \times TF_{gt}\ (i, j) \times e^{-\lambda_r \times TD_{gt}} \quad (7.11)$$

with

$$TF_{gt}(i,j) = F^*(i,j) \times \tau_e \times PI^*_{gt} + \left(\frac{CR_{sl,gt}}{\lambda_r \times H_{sl}(i,j) \times U_{sl}} \times \left(1 - \frac{F^*(i,j) \times Y \times \lambda_r}{\lambda_e} \right) \right) + \left(\frac{BR_{gt}}{v_g(i) + \frac{R(i,j) \times WR(i,j)}{AD}} \right) + \left(\frac{k_1}{H_w \times \lambda_r} \times CR_{w,gt} \right) + \left(F^*(i,j) \times \tau_e \times PR_{hay} \times CR_{hay,gt} \right) \quad (7.12)$$

The parameter $TF_{gt}(i,j)$ represents the transfer of ^{131}I from the deposition on the ground on day, j, and county, i, to the activity intake by the goat. It is expressed in nCi per nCi m^{-2}.

The uncertainty attached to the values of $TF_{gt}(i,j)$ is admittedly large and extremely difficult to quantify as some of the parameter values vary over a wide range and are site specific. In addition some of the mechanisms underlying the environmental transfers are poorly understood. The values of $TF_{gt}(i,j)$ derived from *equation 7.12* were assumed to represent the geometric means of log-normal distributions with GSDs of 4.

7.1.1.3. Cottage cheese

Since it is assumed that both fresh cows' milk and cottage cheese are of local origin, the time-integrated concentrations of ^{131}I in cottage cheese for scenario sc, ICC(sc), in nCi d kg^{-1}, are proportional to the time-integrated concentrations of ^{131}I in fresh cows' milk, in nCi d kg-1, from all routes of intake, IMC(sc), according to:

$$ICC(sc) = IMC(sc) \times FCC \times e^{-\lambda_r \times TD_{cc}} \quad (7.13)$$

where:

FCC is the quotient of the ^{131}I concentrations in cottage cheese and in cows' milk at the time of cottage cheese production, expressed in nCi kg^{-1} per nCi L^{-1}. Information on values of FFC derived from measurements is very scarce: Kirchmann et al. (1966) obtained an average value of 2.3. From data published by Reavey et al. (1966) on ^{131}I concentrations in milk and dairy products of the same origin contaminated by global fallout, an average value of 0.33 can be inferred. In this report, the median value of FCC is taken to be 0.9, which is the geometric mean of 2.3 and 0.33. Because the data are sparse and the spread of values is large, the distribution of FCC is assumed to be log-normal with a geometric standard deviation of two.

TD_{cc} is the time delay between production and consumption of cottage cheese; Quinault (1989) reported a range from 2 to 7 days for TD_{cc}. A value of 2 days has been assumed in this report because production is assumed to occur locally in all cases.

The estimates of time-integrated concentrations of ^{131}I in cottage cheese were calculated using *equation 7.13* and the cows' milk concentrations in *Table 7.1* (which are also shown in *Table 7.3*). The results are presented in *Table 7.3*.

7.1.1.4. Eggs

The ^{131}I concentrations in eggs resulting from ^{131}I deposition are very sensitive to the feeding practices for the chickens that produce them. Within the same area, chickens kept confined indoors and fed commercial grain mixes that have undergone considerable storage since harvesting would lay eggs containing much less ^{131}I than those produced by chickens allowed to range freely. The practice of keeping chickens in feed lots was already widespread in the 1950s (Okonski et al. 1961).

Very few measurements of ^{131}I in eggs resulting from ground contamination are available. However, low concentrations of ^{131}I in eggs were found after the nuclear reactor accident at Windscale (Russell 1966), which occurred in 1957. Measurements after that accident indicated that the ^{131}I activity in one whole egg was up to 5% that in one liter of milk. Since one egg weighs about 50 g (Pond and Kilpatrick 1956), this implies that the ^{131}I concentration in eggs, expressed in nCi kg^{-1}, is at most the same as the ^{131}I concentration in cows' milk, expressed in nCi L^{-1}. Barth et al. (1969), following the shot Pin Stripe conducted at the NTS in 1966, measured ^{131}I concentrations in eggs laid by chickens that were observed eating contaminated forage near a dairy farm. The time-integrated concentrations of ^{131}I in eggs derived from those measurements are about twice the time-integrated ^{131}I concentrations in fresh cows' milk produced at the same farm. However, Eisenbud and Wrenn (1963) found that the ^{131}I concentrations in eggs in the New York City area were much lower than those in cows' milk after the nuclear tests conducted by the Soviet Union in 1961.

In this report, the time-integrated ^{131}I concentrations in eggs, expressed in nCi d kg^{-1} and the time-integrated ^{131}I concentrations in cows' milk, expressed in nCi d L^{-1}, are assumed to be equal at the time of production. A delay of 3 days is assumed between production and consumption. For scenario sc, the time-integrated concentrations of ^{131}I in eggs at the time of consumption, IGG(sc), in nCi d kg^{-1}, are calculated using:

$$IGG(sc) = IMC(sc) \times FGG \times e^{-\lambda_r \times TD_{gg}} \quad (7.14)$$

where:

FGG is the quotient of the ^{131}I time-integrated concentrations in eggs and in cows' milk at the time of production, expressed in µCi d kg^{-1} per µCi d L^{-1}. The distribution of FGG is assumed to be log-normal with a median of 1 and a geometric standard deviation of 1.4;

TD_{gg} is the time delay between production and consumption of eggs. Quinault (1989) reported a range from three to 18 days for TD_{gg}. A value of 3 days has been used in this report because all eggs are assumed to be produced in the county where they are consumed.

The estimates of time-integrated concentrations of ^{131}I in eggs were calculated using *equation 7.14* and the cows' milk concentrations in *Table 7.1* (also shown in *Table 7.3*). The results are presented in *Table 7.3*.

Table 7.3. Median time-integrated ^{131}I concentrations in various foodstuffs and in air following a unit deposition density of 1 nCi m^{-2}.

	Distance from the NTS: 3000 km						Distance from the NTS: 100 km	
	Dry conditions		Light rain		Heavy rain		Dry conditions	
	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture	Cows on pasture	Cows off pasture
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Foodstuffs (nCi d L^{-1} per nCi m^{-2}) or (nCi d kg^{-1} per nCi m^{-2})								
cows' milk	0.42	0.035	0.52	0.036	0.22	0.021	0.057	0.019
goats' milk	3.8	0.15	4.7	0.18	2.0	0.095	0.57	0.027
cottage cheese	0.32	0.028	0.39	0.026	0.17	0.014	0.043	0.012
eggs	0.32	0.028	0.39	0.026	0.17	0.015	0.044	0.012
leafy vegetables	0.23	0.0	0.29	0.0	0.12	0.0	0.015	0.0
mothers' milk	0.034	0.0030	0.041	0.0027	0.018	0.0015	0.0046	0.00013
Air (nCi d m^{-3} per nCi m^{-2}):								
	0.00037	0.00037	0.00010	0.00010	0.000033	0.000033	0.00011	0.00011

7.1.1.5. Leafy vegetables

The growing season of leafy vegetables varies according to climatological conditions and is generally limited to a few months during the year. In this report, the growing and harvesting season of leafy vegetables is assumed to coincide with the pasture season of backyard cows. The leafy vegetables that are most frequently consumed include broccoli, cabbage, cauliflower, celery, lettuce, and spinach. To estimate the time-integrated concentrations of ^{131}I in leafy vegetables for scenario sc, ILV(sc), it is further assumed that:

- the ^{131}I deposition is intercepted and retained by the leafy vegetables in the same way as was estimated for pasture grass (**Sections 4.1.1** and **4.1.2**);
- the yield of leafy vegetables is 3 kg (fresh weight) per m^2, or 0.3 kg (dry weight) per m^2— the corresponding dry to fresh weight ratio, DFW, is 0.1;
- there is a delay, TD_{lv}, of 1 day between production and consumption of leafy vegetables;
- culinary practices (washing, removal of outer leaves, etc.) removes 80% of the activity (F_{wr} = 0.2). This average figure is based on the results of Thompson and Howe (1973) who found that 75 to 90% (and, in one case, 34%) of the ^{131}I activity deposited on lettuce was removed by removing the outer leaves and by washing. In more recent experiments, Wilkins et al. (1987) found that 59 to 93% of the ^{131}I activity deposited on lettuce was removed during culinary practices. The distribution of F_{wr} is assumed to be lognormal with a geometric standard deviation of 1.5.

The time-integrated concentrations (fresh weight) of ^{131}I in leafy vegetables for scenario sc, ILV(sc), in nCi d kg^{-1}, are calculated as:

$$ILV(sc) = DG \times F^*(sc) \times \tau_e \times F_{wr} \times e^{-\lambda_r \times TD_{lv}} \times DFW \qquad (7.15)$$

The parameters F_{wr} and DFW are discussed above. Other common and scenario-specific parameters were given in **Section 7.1.** During the non-growing season, the contamination of leafy vegetables is taken to be equal to zero.

The estimates of time-integrated concentrations of ^{131}I in leafy vegetables were calculated using *equation 7.15*. The results are presented in *Table 7.3*.

7.1.1.6. Inhalation

The time-integrated concentration of ^{131}I in ground-level air, IC_{air}(sc), that corresponds to a deposition of 1 µCi m^{-2} depends, among other factors, upon the physical and chemical form of ^{131}I, and upon environmental conditions (in particular, upon the presence or absence of precipitation). It is assumed in this report that the ^{131}I present in the radioactive cloud is associated with particles, and it is shown in **Appendix 7** that this assumption does not substantially affect the dose estimates. The equations used to relate the time-integrated concentrations of ^{131}I in outdoor ground-level air and the depositions per unit area of ground also are presented in **Appendix 7**, along with the selection of the parameter values.

For scenario sc, the time-integrated concentration of ^{131}I in outdoor ground-level air, IC_{air}(sc), corresponding to deposition via dry and wet processes, is estimated using *equation 4.64*, repeated here:

$$IC_{air}(sc) = \frac{DG}{\left[V_g(sc) + \frac{R(sc) \times WR(sc)}{AD}\right]} \quad (7.16)$$

Values for the common and scenario specific parameters in the equation are given in **Section 7.1**.

In general, people spend most of their time indoors, where the ^{131}I concentrations are lower than those outdoors. The average (indoor and outdoor) time-integrated concentrations of ^{131}I in air, in nCi d m^{-3}, ICR(sc), to which people are exposed are calculated using:

$$ICR(sc) = IC_{air}(sc) \times OF_{out} + IC_{air}(sc) \times RIO \times OF_{in} \quad (7.17)$$

where:

OF_{out} is the average fraction of time spent outdoors, taken to be 0.2 (Roy and Courtay 1991; UNSCEAR 1988),

OF_{in} (= 1 - OF_{out} = 0.8) is the average fraction of time spent indoors,

RIO is the average ratio of the indoor and outdoor time-integrated concentrations of ^{131}I, assumed to be 0.3 (Alzona et al. 1979; Cohen and Cohen 1980; Megaw 1962; Yocom et al. 1976).

Replacing IC_{air}(sc) by its value in *equation 7.17* yields:

$$ICR(sc) = DG \times \frac{OF_{out} + RIO \times OF_{in}}{V_g(sc) + \frac{R(sc) \times WR(sc)}{AD}} \quad (7.18)$$

The estimates of time-integrated concentrations of ^{131}I in air, ICR(sc), computed using *equation 7.18* are presented in *Table 7.3*.

7.1.1.7. Mothers' milk

For scenario sc, the time-integrated concentrations of ^{131}I in mothers' milk, IMM(sc), in nCi d L^{-1}, are the products of the daily ^{131}I activity intakes (in nCi) by lactating mothers, AI_{mt}(sc), and of the diet-to-milk transfer coefficient for ^{131}I in lactating women, $f_{m,mt}$, in d L^{-1}. The data on the maternal milk transfer coefficients are discussed in **Chapter 4**. The relationship is shown in *equation 7.12*.

$$IMM(sc) = AI_{mt}(sc) \times f_{m,mt} \quad (7.19)$$

The median value of $f_{m,mt}$ is estimated in **Section 4.1.4.3** to be 0.1 d L^{-1} and the distribution of $f_{m,mt}$ is assumed to be lognormal with a geometric standard deviation of 2.9. The value of $f_{m,mt}$ is higher than the corresponding estimate for cows (f_m = 4 x 10^{-3} d L^{-1}) and only two times lower than the value for goats ($f_{m,gt}$ = 0.2 d L^{-1}). However, for a given deposition of ^{131}I on the ground, the daily activity intake of ^{131}I by lactating women is much lower than those of grazing animals. Consequently, human milk is usually much less contaminated than cows' or goats' milk.

For the scenarios discussed in this section, the values of AI_{mt}(sc) are approximated as the products of the time-integrated concentrations of ^{131}I in fresh cows' milk, IMC(sc), presented in *Table 7.1*, and the daily intake of fresh cows' milk by lactating women, taken to be 0.8 L d^{-1} (see **Section 6.2.2**). However, for the estimation of the thyroid doses due to each test conducted at the Nevada Test Site, the daily intakes of ^{131}I by lactating mothers, AI_{mt}, are calculated more exactly taking into account the ^{131}I time-integrated concentrations in each component of the diet.

The estimates of time-integrated concentrations of ^{131}I in mothers' milk, IMM(sc), computed using *equation 7.19* are presented in *Table 7.3*.

7.1.1.8. Time-integrated concentrations of ^{131}I in air and in foodstuffs: Summary

The time-integrated concentrations of ^{131}I in air or in the foodstuffs of interest corresponding to a unit deposition of 1 nCi m^{-2}, obtained in these example calculations, are summarized in *Table 7.3*. The values of the time-integrated concentrations for cows' milk, cottage cheese, eggs, and leafy vegetables are fairly similar. The time-integrated concentrations of ^{131}I in goats' milk are about 10 times greater than those for cows' milk when goats are on pasture and about five times greater when goats are under shelter. The time-integrated concentrations of ^{131}I in mothers' milk are about 10 times less than those in cows' milk.

Estimates of median time-integrated concentrations of ^{131}I in ground-level air and in the foodstuffs of interest were calculated for each test and each county of the contiguous United States; they are presented in the Annexes.

7.1.2. Consumption Rates of the Foodstuffs of Interest and Breathing Rates

With the exception of cows' milk, information on the variation with age and sex of the consumption rates of the foodstuffs of interest and on the fractions of the population that actually consume those foodstuffs is relatively scarce. The estimates used in this report have been obtained as follows.

7.1.2.1. Cows' milk (reference conditions)

Estimates of median consumption rates of cows' milk for milk drinkers in the contiguous U.S. and the associated GSDs were presented for the 10 post-natal age groups considered in *Table 6.2* of **Chapter 6**.The fractions of the persons in each of the groups that drank milk were also given in *Table 6.2*. The product of the two quantities yields the estimates of consumption rates given in *Table 7.4*.

Table 7.4. Median consumption rates of selected foodstuffs (Ld^{-1} or kg d^{-1}) and average breathing rates (m^3 d^{-1}) as a function of age and sex.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Consumption rates (L d^{-1} or kg d^{-1})											
Cows' milk	0.13	0.46	0.70	0.70	0.49	0.66	0.64	0.57	0.20	0.14	0.37
Goats' milk	0.00003	0.0001	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	0.00007	0.00005	0.0001
Cottage cheese	0.00003	0.0005	0.003	0.003	0.004	0.005	0.005	0.005	0.005	0.005	0.005
Eggs	0	0.005	0.01	0.02	0.04	0.04	0.04	0.06	0.07	0.04	0.06
Leafy vegetables	0	0.002	0.004	0.006	0.009	0.02	0.03	0.03	0.05	0.05	0.04
Mothers' milk	0.16	0.07	0.02	----	----	----	----	----	----	----	----
Breathing rates (m^3 d^{-1})											
Air	2	3	4	5	7	12	17	19	23	18	15

7.1.2.2. Goats' milk

Goats' milk may be consumed as a substitute for cows' milk by people who are allergic to cows' milk. The per capita consumption of goats' milk over the population of the U.S. has been estimated from information on the number of milk goats and an assumed average production rate of milk by goats. Data compiled from the 1974 Census of Agriculture (Shor et al. 1982) show that there were 11,009 milk goats in the country in 1974 (to be compared with about 11 million milk cows). Assuming that the number of milk goats in the 1950s was the same as in 1974 and that the daily production of milk by goats is 1.5 L (*Table 4.7* in **Chapter 4**), the production rate of goats' milk in the U.S. in the 1950s was 16.5 kL d^{-1}. Dividing by the 1954 U.S. population of 163 million (*Table 5.6* in **Chapter 5**) yields a per capita consumption rate of goats' milk by the U.S. population of about 0.0001 L d^{-1} (to be compared with a per capita consumption rate of cows' milk of about 0.4 L d^{-1}).

In a survey of dietary information for Nevada and Utah children in the 1950s (Stevens et al. 1992), it was found that 2.9% of the subjects drank goats' milk at least part of the time from birth through 14 years of age, that the consumption of cows' milk and goats' milk was not mutually exclusive, and that the average consumption rate of milk by goats' milk drinkers and by cows' milk drinkers was very similar (about 0.8 L d^{-1}).

The per capita consumption rates of goats' milk for the populations of the 10 post-natal age groups considered in this report were estimated from the figure of 0.0001 L d^{-1}, using the same relative distribution as a function of age as that of cows' milk (*Table 7.4*). Since only a small fraction of people consumed goats' milk at any age, the median consumption rates of goats' milk for the 10 post-natal age groups considered should be equal to zero. In this report, however, nominal values, equal to the per capita consumption rates of goats' milk, have been adopted (*Table 7.4*). The use of those nominal values does not change the estimates of total thyroid doses, as other components of the dose, in particular the ingestion of cows' milk, are much greater than the ingestion of goats' milk. It should be kept in mind, however, that the individuals with consumption of goats' milk similar to those of cows' milk drinkers are likely to have received greater doses than the cows' milk drinkers because the ^{131}I contamination of goats' milk per unit deposition of ^{131}I generally was about five to 10 times higher than that of cows' milk (*Table 7.3*).

7.1.2.3. Cottage cheese

The per capita consumption rates of cottage cheese for the entire U.S. population have been reported by the USDA (1960) to be 4.6 pounds per year, or 0.006 kg d^{-1}, in 1955 and by Judkins and Keener (1960) to be 4.5 pounds per year, or 0.006 kg d^{-1}, in 1956. Production rates of cottage cheese yield a similar value: there were 1654 manufacturing plants in the U.S. in 1957, each producing on average 420 thousand pounds of cottage cheese per year, leading to a per capita value of 0.005 kg d^{-1}. A per capita consumption rate of 0.005 kg d^{-1} has been adopted in this report.

No information has been found in the literature on the fraction of the population that consumes cottage cheese at any age or on the variation of the consumption rate with age. The small per capita consumption rate for the entire U.S. population seems to indicate that less than 50% of the population consumed cottage cheese, and, consequently, that the median consumption rate was probably zero.

In this report, as was done for goats' milk, nominal values, equal to the per capita consumption rates in each age group, have been used for the median consumption rates of cottage cheese. The variation of the consumption rate as a function of age was estimated from the per capita value of 0.005 kg d^{-1} for the entire U.S. population using the relative variation of the consumption rate of butter and cheese reported by Schwarz and Kersting (1984) for German children under 10 years of age, and

the relative variation of the consumption rate of dairy products other than fresh cows' milk reported by Yang and Nelson (1984) for children over 10 years old and for adults. The resulting estimates are presented in *Table 7.4*.

7.1.2.4. Eggs
The per capita civilian consumption of eggs in the U.S. in 1955 was 46.9 pounds per year, or 0.06 kg d^{-1} (Taylor 1987). This represents about one egg per day. The relative variation of the mean consumption rates with age, taken from Yang and Nelson (1984), was used to make estimates for each age group. It is assumed that the medians of the distributions of the consumption rates of eggs for the various age groups have the same values as the estimated means. The results are presented in *Table 7.4*.

7.1.2.5. Leafy vegetables
The values of the per capita consumption rates of leafy vegetables for the 10 post-natal age groups considered are taken from Yang and Nelson (1984). Their values are presented in *Table 7.4*. For a given age group, it is assumed that the median and per capita values are the same.

7.1.2.6. Mothers' milk
As shown in *Table 5.2* in **Chapter 5**, mothers' milk is consumed primarily by infants under 9 months of age. The fraction of infants consuming mothers' milk is less than 50% in each age group, so that the median consumption rates should be taken equal to zero. In this report, however, as was the case for the consumption rates of goats' milk and of cottage cheese, the median consumption rates of mothers' milk are assumed to be equal to the means. Estimates of mean consumption rates were obtained from the monthly data of the fractions of infants consuming mothers' milk (*Table 5.2*) and of the per capita consumption rates of milk from all types (*Table 5.3*). The results are presented in *Table 7.4*.

7.1.2.7. Breathing rates
The mean breathing rates as a function of age and sex were derived from Roy and Courtay (1991), who compiled the information on: (1) ventilation rates of children of several ages (newborn, 1-, 5-, 10-, and 15-year old) and of adults of both sexes for various types of activity (sleep, school, recreation, work, etc.), and (2) the time budgeted for those activities. The mean breathing rates corresponding to the 10 post-natal ages considered have been interpolated from the results of Roy and Courtay (1991). The medians are assumed to be equal to the means. The results are presented in *Table 7.4*.

7.1.2.8. Uncertainties
For the purposes of the uncertainty analysis, the distributions of the consumption rates of the foodstuffs of interest are assumed to be log-normal with geometric standard deviations equal to those estimated for the consumption rates of cows' milk, which are presented in *Table 6.2*. This assumption is reasonable for the consumption of eggs and leafy vegetables, which are, like cows' milk, consumed regularly by most people. On the other hand, it is recognized that this assumption is clearly not valid for the consumption rates of goats' milk, mothers' milk, and cottage cheese, which are consumed by less than 50% of the population of the age groups considered. However, the average doses resulting from the consumption of those foodstuffs are small when compared to those due to the consumption of cows' milk, so that the estimates of median and per capita thyroid doses are not substantially distorted.

With respect to inhalation, the ratio of the maximum and minimum values of the breathing rates varies by a factor of 2 to 4, depending on the age group considered (Roy and Courtay 1991). Assuming that the minimum and maximum values represent the 5th and 95th percentiles of the distribution, respectively, the corresponding geometric standard deviations are between 1.2 and 1.4. A GSD of 1.3 is assumed in this report for all age groups.

7.1.3. Dose Conversion Factors
The dose conversion factors for ingestion were previously presented in **Section 6.3** of **Chapter 6**. The dose conversion factors for inhalation are taken to be the same as those for ingestion (**Appendix 6**).

7.1.4. Thyroid Doses Corresponding to the Eight Scenarios
Combining the time-integrated concentrations presented in *Table 7.3*, the average consumption rates according to age and sex presented in *Table 7.4*, and the dose conversion factors for the age and sex groups presented in *Table 6.7* yields estimates of dose to the 10 post- natal groups for the eight scenarios considered. *Tables 7.5* to *7.12* provide the results obtained for each of the scenarios.

The variation with age of the thyroid doses for the eight scenarios presented in *Tables 7.5* to *7.12* shows that cows' milk is much more important for infants than for adults. Foodstuffs other than cows' milk are, on average, not significant, except in the absence of milk consumption. This may not be the case for specific individuals, however, because of the wide variability of consumption rates of foodstuffs such as goats' milk or cottage cheese.

The per capita doses corresponding to the eight scenarios are calculated by weighting the thyroid dose estimates from each age and sex category by the population size of each category (*Table 5.6*). Per capita thyroid dose estimates are also presented in *Tables 7.5* to *7.12* and are highest for the cows' milk consumption exposure route. Other pathways make only small contributions to the per capita doses. As a result, the per capita thyroid doses are about three times higher during the pasture season than during the off-season near the NTS (*Tables 7.11* and *7.12*). At the distant location, the differences in per capita doses for pasture and non-pasture seasons are larger.

Table 7.5. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 1. In scenario 1, dry deposition is assumed to occur at 3000 km from the NTS at a time when cows are on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.82	2.5	3.5	3.5	1.7	1.1	0.73	0.45	0.11	0.11	0.43
Goats' milk	0.0017	0.0049	0.0091	0.0091	0.0031	0.0031	0.0021	0.0014	0.00035	0.00034	0.0010
Cottage cheese	0.00014	0.0021	0.012	0.012	0.010	0.0066	0.0043	0.0030	0.0021	0.0029	0.0044
Eggs	0	0.021	0.038	0.077	0.10	0.052	0.035	0.036	0.029	0.023	0.053
Leafy vegetables	0	0.0060	0.011	0.017	0.017	0.019	0.019	0.013	0.015	0.021	0.025
Mothers' milk	0.082	0.031	0.0082	0	0	0	0	0	0	0	0.00066
Inhalation											
Air	0.011	0.014	0.018	0.022	0.021	0.018	0.017	0.013	0.011	0.012	0.015

Table 7.6. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 2. In scenario 2, dry deposition is assumed to occur at 3000 km from the NTS at a time when cows are not on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.068	0.21	0.29	0.29	0.14	0.095	0.060	0.038	0.0091	0.0088	0.036
Goats' milk	0.000068	0.00020	0.00036	0.00036	0.00012	0.00012	0.000081	0.000057	0.000014	0.000014	0.000041
Cottage cheese	0.000013	0.00018	0.0010	0.0010	0.00092	0.00057	0.00038	0.00027	0.00018	0.00025	0.00039
Eggs	0	0.0018	0.0034	0.0067	0.0092	0.0046	0.0030	0.0032	0.0025	0.0020	0.0046
Leafy vegetables	0	0	0	0	0	0	0	0	0	0	0
Mothers' milk	0.0072	0.0027	0.00072	0	0	0	0	0	0	0	0.000059
Inhalation											
Air	0.011	0.014	0.018	0.022	0.021	0.018	0.017	0.013	0.011	0.012	0.015

Table 7.7. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 3. In scenario 3, deposition with light rain is assumed to occur at 3000 km from the NTS at a time when cows are on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	1.0	3.1	4.4	4.4	2.1	1.4	0.90	0.56	0.14	0.13	0.53
Goats' milk	0.0021	0.00061	0.011	0.011	0.0039	0.0039	0.0025	0.0018	0.00043	0.00042	0.0013
Cottage cheese	0.00018	0.0025	0.014	0.014	0.013	0.0080	0.0053	0.0037	0.0025	0.0035	0.0054
Eggs	0	0.025	0.047	0.094	0.13	0.064	0.042	0.044	0.035	0.028	0.064
Leafy vegetables	0	0.0075	0.014	0.021	0.021	0.024	0.023	0.017	0.019	0.026	0.032
Mothers' milk	0.098	0.037	0.0098	0	0	0	0	0	0	0	0.0008
Inhalation											
Air	0.0030	0.0039	0.0048	0.0060	0.0057	0.0049	0.0046	0.0036	0.0030	0.0032	0.0041

Table 7.8. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 4. In scenario 4, deposition with light rain is assumed to occur at 3000 km from the NTS at a time when cows are not on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.070	0.22	0.30	0.30	0.14	0.097	0.062	0.039	0.0094	0.0091	0.037
Goats' milk	0.000081	0.00023	0.00043	0.00043	0.00015	0.00015	0.000097	0.000068	0.000016	0.000016	0.000050
Cottage cheese	0.000012	0.00017	0.00094	0.00094	0.00085	0.00053	0.00035	0.00025	0.00017	0.00023	0.00036
Eggs	0	0.0017	0.0031	0.0062	0.0085	0.0043	0.0028	0.0030	0.0024	0.0019	0.0043
Leafy vegetables	0	0	0	0	0	0	0	0	0	0	0
Mothers' milk	0.0065	0.0025	0.00065	0	0	0	0	0	0	0	0.000053
Inhalation											
Air	0.0030	0.0039	0.0048	0.0060	0.0057	0.0049	0.0046	0.0036	0.0030	0.0032	0.0041

Table 7.9. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 5. In scenario 5, deposition with heavy rain is assumed to occur at 3000 km from the NTS at a time when cows are on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.43	1.3	1.8	1.8	0.88	0.60	0.38	0.24	0.057	0.055	0.22
Goats' milk	0.00090	0.0026	0.0048	0.0048	0.0016	0.0016	0.0011	0.000076	0.00018	0.00018	0.00055
Cottage cheese	0.000077	0.0011	0.0061	0.0061	0.0056	0.0035	0.0023	0.0016	0.0011	0.0015	0.0023
Eggs	0	0.011	0.020	0.041	0.056	0.028	0.018	0.019	0.015	0.012	0.028
Leafy vegetables	0	0.0031	0.0058	0.0086	0.0089	0.0098	0.0097	0.0068	0.0078	0.011	0.013
Mothers' milk	0.043	0.016	0.0043	0	0	0	0	0	0	0	0.00035
Inhalation											
Air	0.00099	0.0013	0.0016	0.0020	0.0019	0.0016	0.0015	0.0012	0.00099	0.0011	0.0014

Table 7.10. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 6. In scenario 6, deposition with heavy rain is assumed to occur at 3000 km from the NTS at a time when cows are not on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.041	0.13	0.18	0.18	0.084	0.057	0.036	0.023	0.0055	0.0053	0.021
Goats' milk	0.000043	0.00012	0.00023	0.00023	0.000078	0.000078	0.000051	0.000036	0.0000086	0.0000086	0.000026
Cottage cheese	0.0000063	0.000091	0.00050	0.00050	0.00046	0.00029	0.00019	0.00013	0.000091	0.00013	0.00023
Eggs	0	0.00098	0.0018	0.0036	0.0049	0.0025	0.0016	0.0017	0.0014	0.0011	0.0025
Leafy vegetables	0	0	0	0	0	0	0	0	0	0	0
Mothers' milk	0.0036	0.0014	0.00036	0	0	0	0	0	0	0	0.000029
Inhalation											
Air	0.00099	0.0013	0.0016	0.0020	0.0019	0.0016	0.0015	0.0012	0.00099	0.0011	0.0014

Table 7.11. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 7. In scenario 7, dry deposition is assumed to occur at 100 km from the NTS at a time when cows are on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.11	0.34	0.48	0.48	0.23	0.15	0.098	0.062	0.015	0.014	0.058
Goats' milk	0.00026	0.00074	0.0014	0.0014	0.00047	0.00047	0.00031	0.00022	0.000052	0.000051	0.00016
Cottage cheese	0.000019	0.00028	0.0015	0.0015	0.0014	0.00088	0.00058	0.00041	0.00028	0.00039	0.00059
Eggs	0	0.0029	0.0053	0.011	0.014	0.0072	0.0048	0.0050	0.0040	0.0032	0.0073
Leafy vegetables	0	0.00039	0.00072	0.0011	0.0011	0.0012	0.0012	0.00086	0.00098	0.0014	0.0017
Mothers' milk	0.011	0.0042	0.0011	0	0	0	0	0	0	0	0.00009
Inhalation											
Air	0.0033	0.0043	0.0053	0.0066	0.0063	0.0054	0.0050	0.0040	0.0033	0.0036	0.0045

Table 7.12. Estimated thyroid doses per unit deposition density (mrad per nCi m^{-2}) as a function of age for scenario 8. In scenario 8, dry deposition is assumed to occur at 100 km from the NTS at a time when cows are not on pasture.

	Age								Adult male	Adult female	Per capita
	0-2 mo	3-5 mo	6-8 mo	9-11 mo	1-4 y	5-9 y	10-14 y	15-19 y			
Ingestion											
Cows' milk	0.037	0.11	0.16	0.16	0.076	0.051	0.033	0.021	0.0049	0.0048	0.019
Goats' milk	0.000012	0.000035	0.000065	0.000065	0.000022	0.000022	0.000015	0.000010	0.0000025	0.0000024	0.0000074
Cottage cheese	0.0000054	0.000078	0.00043	0.00043	0.00039	0.00025	0.00016	0.00011	0.000078	0.00011	0.00017
Eggs	0	0.00078	0.0014	0.0029	0.0039	0.0020	0.0013	0.0014	0.0011	0.00086	0.0020
Leafy vegetables	0	0	0	0	0	0	0	0	0	0	0
Mothers' milk	0.00031	0.00012	0.000031	0	0	0	0	0	0	0	0.0000025
Inhalation											
Air	0.0033	0.0043	0.0053	0.0066	0.0063	0.0054	0.0050	0.0040	0.0033	0.0036	0.0045

7.2. OVERALL CALCULATION PROCEDURES FOR THESE PATHWAYS

The overall calculation procedures used to estimate, for each test and each county of the contiguous United States, the thyroid doses resulting from the exposure routes to man other than the ingestion of cows' milk are similar to those described in **Chapter 4** for the estimation of thyroid doses due to the ingestion of cows' milk. The resulting time-integrated concentrations of ^{131}I in ground-level air and in the relevant foodstuffs, are presented in the Annexes for each of the tests considered in this report. The corresponding thyroid doses for each age and sex group are provided in the Sub-annexes for the tests considered.

7.2.1. Time-integrated Concentrations of ^{131}I

The time-integrated concentrations of ^{131}I in ground-level air, goats' milk, cottage cheese, eggs, leafy vegetables, and mothers' milk have been estimated for each county of the contiguous United States and for each day of ^{131}I deposition on the ground following a nuclear test at the NTS. The results are presented in the Annexes to this report for each test considered in the analysis.

7.2.2. Thyroid Doses

Thyroid doses from the pathways considered in this chapter have been estimated for 14 age and sex groups in each county of the contiguous United States. The results are available for each test, as totals for all exposure routes other than the ingestion of cows' milk in the Sub- annexes. Results for each test series are given in the Annexes. The per capita thyroid doses for the entire population of each county are presented by dose category in a map in the Annex for each test.

7.3. SUMMARY

- The methods and data used for calculating median thyroid doses resulting from exposure routes to man other than ingestion of cows' milk have been presented. The exposure routes considered are inhalation and the ingestion of goats' milk, cottage cheese, eggs, and leafy vegetables. The consumption of mothers' milk is also considered for infants under one year of age. Estimates of median time-integrated concentrations of ^{131}I in ground-level air and in the foodstuffs considered are presented in the Annexes for each test and each county of the contiguous United States. Estimates of median and per capita thyroid doses also are presented for each test and each county, but only as totals for all exposure routes other than the ingestion of cows' milk. These dose estimates for each of the tests considered are in the Sub-annexes.

- Example calculations of thyroid doses have been made for eight scenarios representing a range of precipitation intensities and of distances from the NTS. The results of these example calculations show that, when cows are on pasture, doses from ingestion of fresh cows' milk are, for all age groups, much more important than any of the other exposure routes considered. When cows are off pasture, ingestion of cows' milk is still the predominant pathway but inhalation is also important especially for adults when fallout was deposited by dry deposition.

- In the examples chosen, the per capita ^{131}I thyroid doses per unit deposition, all exposure routes to man included, vary in the range from 0.1 to 0.6 mrad per nCi m^{-2} when cows are on pasture and from 0.02 to 0.05 mrad per nCi m^{-2} when cows are off pasture.

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Estimated Thyroid Doses Resulting from Atmospheric Bomb Tests Conducted at the Nevada Test Site

CONTENTS: Examples of the estimates of thyroid doses due to exposure of the American people to ^{131}I from Nevada atmospheric bomb tests are presented, compared to average thyroid doses resulting from other sources of radiation exposure.

The dose calculation methods presented in **Chapters 6** and **7** were used to estimate thyroid doses resulting from the deposition of ^{131}I in fallout from the bomb tests considered in this analysis. As was described in **Chapter 3**, many atmospheric detonations, some cratering tests, and some tests during the underground testing era have been analyzed. Thyroid doses were calculated for the population of each county divided into 13 age groups, with adults subdivided by gender (i.e., including four fetal periods, four age intervals during the first year of life, four age intervals between ages 1 and 20, plus adults). The doses to one particular fetal age group (the fetus not yet 10 weeks old) have not been reported as they are very low in comparison to those of the other age groups because the thyroid of the fetus is not formed until about the 12th week of gestation. Doses to the other 12 age groups were estimated for a variety of dietary habits pertaining to assumed milk sources and consumption patterns.

All of the ^{131}I fallout data used to make the dose estimates is contained in the Annexes and Sub-annexes to the report. There is an Annex for each test, which begins with a description of the test and contains the fallout deposition data that was obtained near the NTS and across the country in the form of maps. Detailed tabulations of the fallout data, day by day and county by county, are given in the corresponding Sub-annex. Estimates of time-integrated concentrations of ^{131}I in milk (see **Chapter 4**) due to fallout from that test are tabulated in the Annex for each of the counties and subcounties in the contiguous United States. The detailed milk concentration data were used to calculate thyroid doses from milk consumption as described in **Chapter 6**, using the consumption rates given in **Chapter 5**.

Included in the Annex also are the estimates of the time-integrated concentrations of ^{131}I in other foodstuffs (i.e., goats' milk, cottage cheese, eggs, leafy vegetables, air, and mothers' milk) that are discussed in **Chapter 7.** These estimates reflect the fallout ^{131}I distribution for the particular test and are tabulated for each county or sub-county. Estimated consumption rates for these other exposure routes also are given in **Chapter 7**, together with the dose calculation methods.

The estimated thyroid doses resulting from the fallout from a particular test are presented in the Sub-annex for that test. (Note that the dose units are rad; 1 rad = 1000 mrad.) Per capita doses due to milk consumption and for all exposure routes are listed for each county and sub-county. The values of the geometric mean, GM, and the geometric standard deviation, GSD, are provided for doses due to consumption of milk and for doses due to intakes of milk and other foodstuffs, and for airborne contamination. A summary map of the per capita dose from all pathways is included in the Annex for the test. Included in the same table are the estimated collective doses (the sum of the doses to all age and sex groups) for each county and sub-county. The geometric mean collective dose estimates are for milk consumption alone and for all exposure pathways combined. The geometric mean collective doses for the entire country are provided at the end of the tabulation.

Each Sub-annex continues with detailed dose estimates, listed by county, for each age (and sex) group, for which dose conversion factors were developed in **Chapter 6.** There are 13 such tables. Each contains geometric mean dose estimates and the associated measures of uncertainty (the GSDs) for four dietary regimes: average milk consumption, high milk consumption, consumption of milk from a backyard cow, and no milk consumption. These regimes are discussed in **Chapter 6** and below in **Section 8.1**. The first three provide a range of possible doses from milk consumption; the fourth is an estimate of the dose from intakes of other foods and inhalation of airborne contamination. (These doses are also expressed in rad.)

The dose estimates in the Sub-annexes have been computed using the methods appropriate for a multiplicative model of parameters that are log-normally distributed. The mathematical formulas and necessary assumptions for this approach have been presented in **Chapters 3, 4, 6**, and **7**. In the discussion that follows, a simpler calculational procedure is described that illustrates the main components of the methodology. Each component incorporates the detailed analyses performed in the earlier chapters, to which the reader is referred for details.

8.1. ESTIMATED THYROID DOSES

The magnitude of the thyroid dose received by a person from fallout after a bomb test at the NTS depends upon the person's age, location and dietary habits. As discussed in **Chapters 6** and **7**, the thyroid dose, D, resulting from an intake of ^{131}I in fallout from a particular exposure route following a given test can be estimated as the product of:

- The time-integrated ^{131}I concentration, IC, in milk (nCi d L^{-1}) or other foodstuff (nCi d kg^{-1}) ingested or in ground-level air (nCi d m^{-3}) inhaled.
- The consumption rate, CR, of milk (L d^{-1}) or other foodstuff (kg d^{-1}) or the breathing rate, BR (m^3 d^{-1}), during the weeks following the test considered.
- The thyroid dose conversion factor, DCF, appropriate for the age or sex (mrad per nCi).

For ingestion of milk or a particular foodstuff, the equation can be written:

$$D_{food} = IC_{food} \times CR_{food} \times DCF \qquad (8.1)$$

and for inhalation:

$$D_{inh} = IC_{air} \times BR \times DCF \qquad (8.2)$$

The total dose resulting from a given test is obtained by adding the estimated mean dose from inhalation and the estimated mean doses from ingestion of the foodstuffs considered (cows' milk, goats' milk, mothers' milk (for infants), cottage cheese, eggs, and leafy vegetables).

In the absence of person-specific data, only doses to representative groups of people can be estimated with reasonable accuracy. For this reason, the doses systematically estimated in this report are for specified age groups (and for adults, both sexes) and to other population groups deemed to have received relatively high or low doses, for each county and for each test. However, the manner in which doses to specific individuals can be estimated if information pertaining to the individual is available will be illustrated using examples in **Chapter 9**.

The data necessary to estimate doses are provided as follows:

- The estimated time-integrated ^{131}I concentrations, IC, in the four categories of milk identified in **Chapter 5** (milk consumed on the farm, produced and sold in the county, originating from another county of the same milk region, originating from another milk region), plus the maximum and the volume-weighted time-integrated concentrations in those four categories of milk, as well as the ^{131}I concentrations in milk from backyard cows, are found in the Annexes for each of the test series and for each of the tests and for each of the 3,094 counties and sub-counties of the contiguous United States.
- The estimated time-integrated average ^{131}I concentrations, IC, both in the other foodstuffs of interest and in ground-level air for each of the 3,094 counties and sub-counties of the contiguous United States also are given in the Annexes for each of the tests and for each of the test series.
- The estimated average consumption rates, CR, of milk appropriate for each of the 13 age and both of the adult sex groups by state are given in *Table 5.8* of **Chapter 5**. Estimates of daily milk consumption by "high-exposure" groups in each age and sex group are given in *Table 6.4* of **Chapter 6**. The average consumption rates for the other foodstuffs of interest and for breathing rates, BR, are given in *Table 7.4* of **Chapter 7.**
- The estimated average thyroid dose conversion factors, DCF, for the 14 age and sex groups are given in *Table 6.7* of **Chapter 6**.

Central estimates of thyroid doses (median doses) are presented in the Sub-annexes of this report for each nuclear test and for each of the 14 age and sex groups with the following consumption parameters:

- For the assessment of the estimated average dose to the population of milk drinkers of a given age and sex group in a given county:

(a) Cows' milk: average consumption rate of milk drinkers with volume-weighted average time-integrated concentration of ^{131}I.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average dose to the "high-exposure" group in the population of a given age and sex group in a given county:

(a) Cows' milk: "high" consumption rate (95th percentile, (*Table 6.4*)) drinking milk in the category having the highest time-integrated concentration of ^{131}I.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated dose to the group in the population of a given age and sex group in a given county drinking milk from backyard cows:

(a) Cows' milk: "high" consumption rate (95th percentile, (*Table 6.4*)) with the time-integrated concentration of ^{131}I in milk estimated for the backyard cow.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average dose to the "low-exposure" group in the population of a given age and sex group in a given county:

(a) Cows' milk: no consumption.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average doses to the infants in the population of age 0-3 months, 3-6 months, and 6-9 months in a given county drinking mothers' milk:

(a) Cows' milk: no consumption.

(b) Mothers' milk: average consumption rate by the mother of milk having the volume-weighted average time-integrated concentration of ^{131}I.

(c) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(d) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

A series of maps that illustrate the effects of location, age, and diet on the estimated thyroid doses (in rad) are provided for the convenience of the reader. These maps cover the contiguous United States, but the level of detail differs slightly from that in the Sub-annexes. The sub-counties in Nevada, Utah, California and Arizona are not shown separately in the maps; results for a population-weighted composite are shown. The five boroughs of the city of New York have also been combined, as have several small counties in Virginia. The resolution of the printed maps and ordinary visual acuity limit the level of detail that can be presented in the map format.

The maps illustrate the estimated thyroid doses (in rad) to persons who resided in the same county throughout the period (January 1951 through December 1970) when the tests considered in this analysis were conducted. The total doses were computed using the methods described in **Chapters 6** and **7**, as appropriate. The results shown reflect changes in the person's age during this time period, including associated changes in consumption rates and in the dose conversion factor.

Table 8.1 is a guide to the set of maps that is intended to help readers identify the maps of greatest interest to them, depending upon their dates of birth. The first four maps, *Figures 8.1* through *8.4*, show the estimated doses to males who were adults when testing began in 1951. There are clear differences as a function of the four milk consumption scenarios presented above.

For persons in this age group who drank milk, differences between the doses to men, shown in *Figures 8.1* through *8.3*, and those to women (not shown) are small. The doses to women are about 10% higher. For persons who did not drink milk, the doses shown in *Figure 8.4* for men also are about 10% lower than corresponding doses to women. Considering the uncertainties in the dose estimates and the width of the dose categories in this figure, differences of 10% are not significant and *Figures 8.1* through *8.4* may also be applied to women.

Other groups of maps show similar information about dose as a function of residence and milk consumption for persons of various ages during the period of interest.

Table 8.1. Index to maps of estimated thyroid doses (from all bomb test considered) to persons according to year of birth.

Birthdate	Age (y) when tests began [a]	Age (y) when tests ended [b]	Maps of thyroid doses
January 1, l930	21	40	Figures 8.1-8.4
January 1, l935	16	35	Figures 8.5-8.8
January 1, l940	11	30	Figures 8.9-8.12
January 1, l945	6	25	Figures 8.13-8.16
January 1, l950	1	20	Figures 8.17-8.20
January 1, l951	Newborn	19	Figures 8.21-8.24
January 1, l952		18	Figures 8.25-8.28
April 1, 1952		18	Figures 8.29-8.32
January 1, l953		17	Figures 8.33-8.36
January 1, l954		16	Figures 8.37-8.40
January 1, l955		15	Figures 8.41-8.44
January 1, l956		14	Figures 8.45-8.48
January 1, l957		13	Figures 8.49-8.52
January 1, l958		12	Figures 8.53-8.56
January 1, l959		11	Figures 8.57-8.60
January 1, l960		10	Figures 8.61-8.64
January 1, l962		8	Figures 8.65-8.68

[a] First test considered in this analysis was conducted in January 1951.
[b] Last test considered in this analysis was conducted in December 1970.

Figure 8.1. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; average milk consumption)

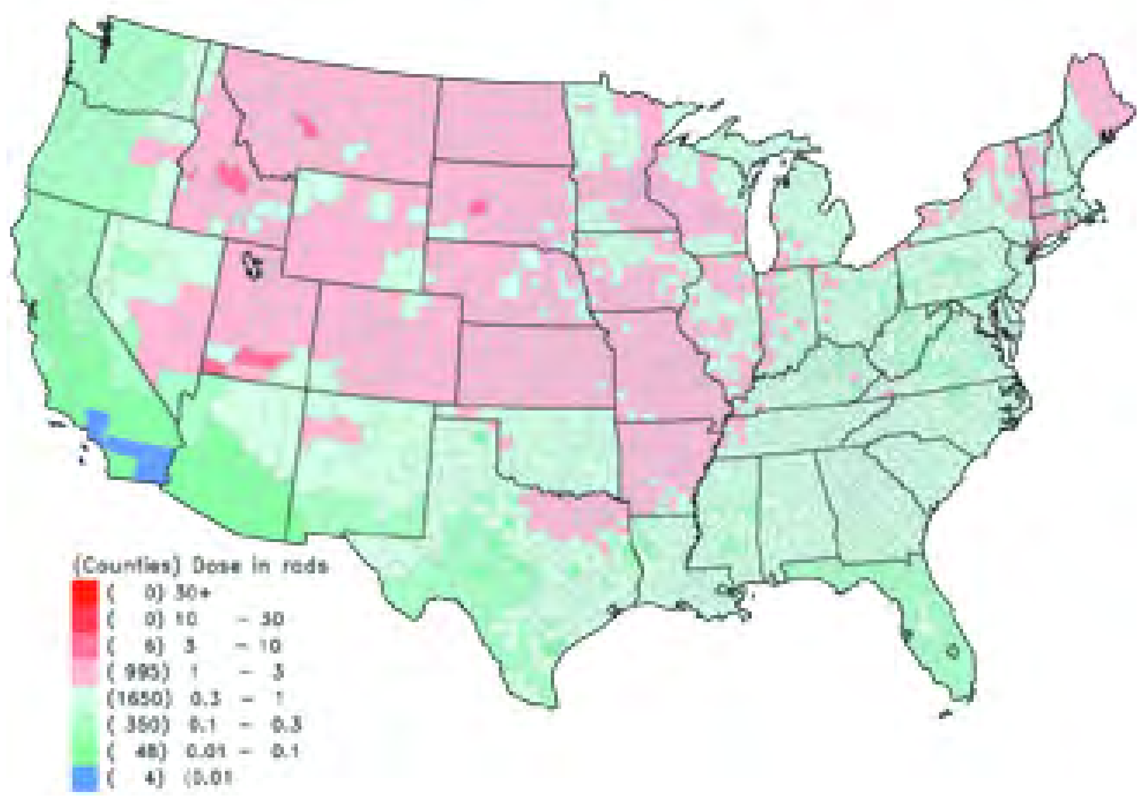


Figure 8.2. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; high milk consumption)

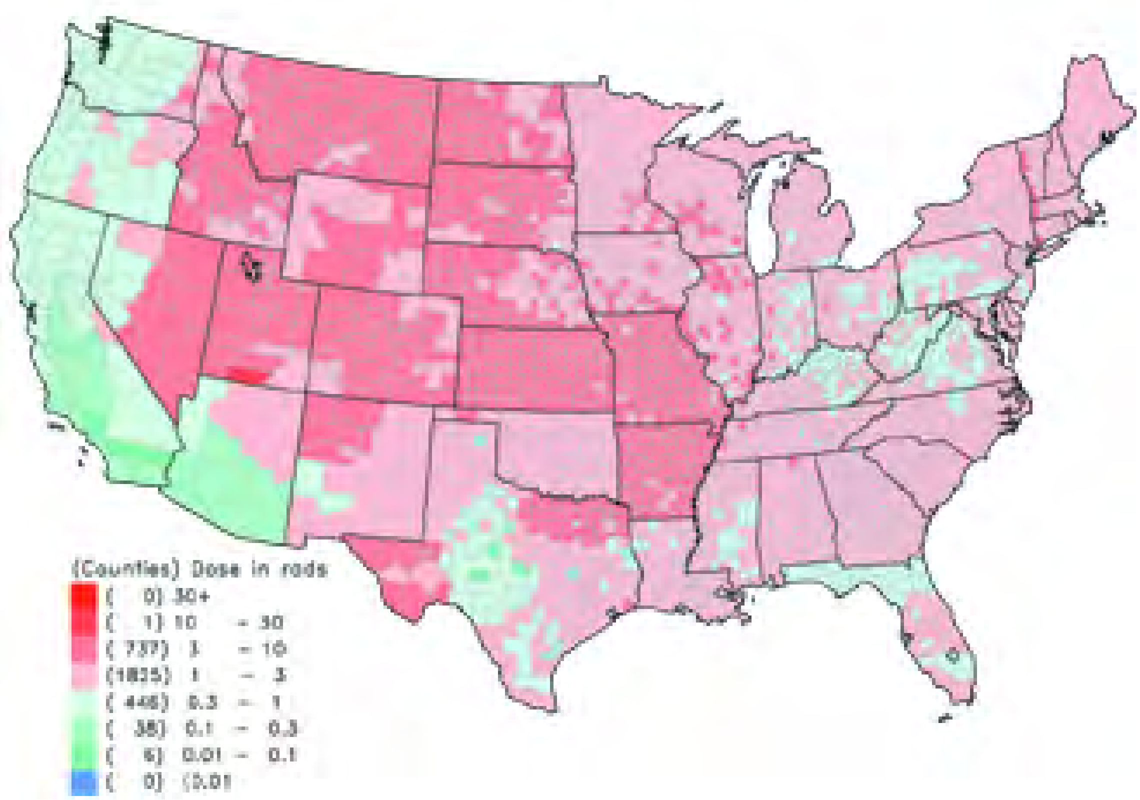


Figure 8.3. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; milk from "backyard cow")

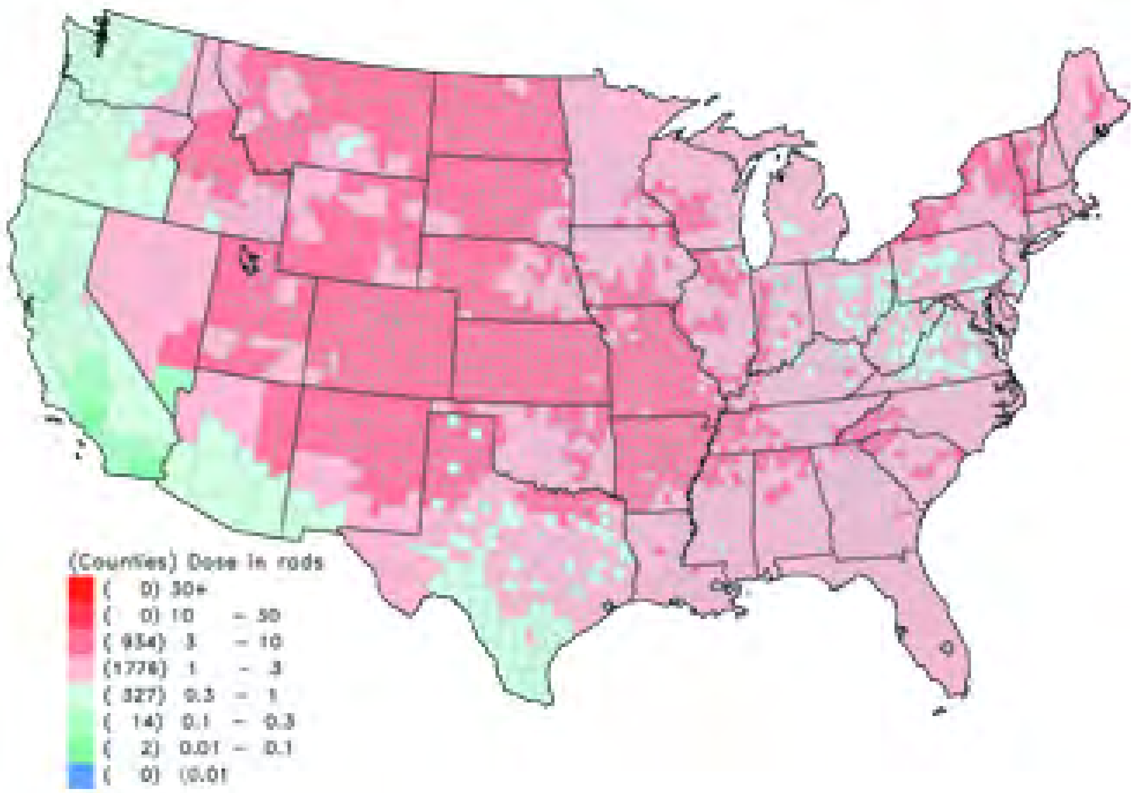


Figure 8.4. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; no milk consumption)

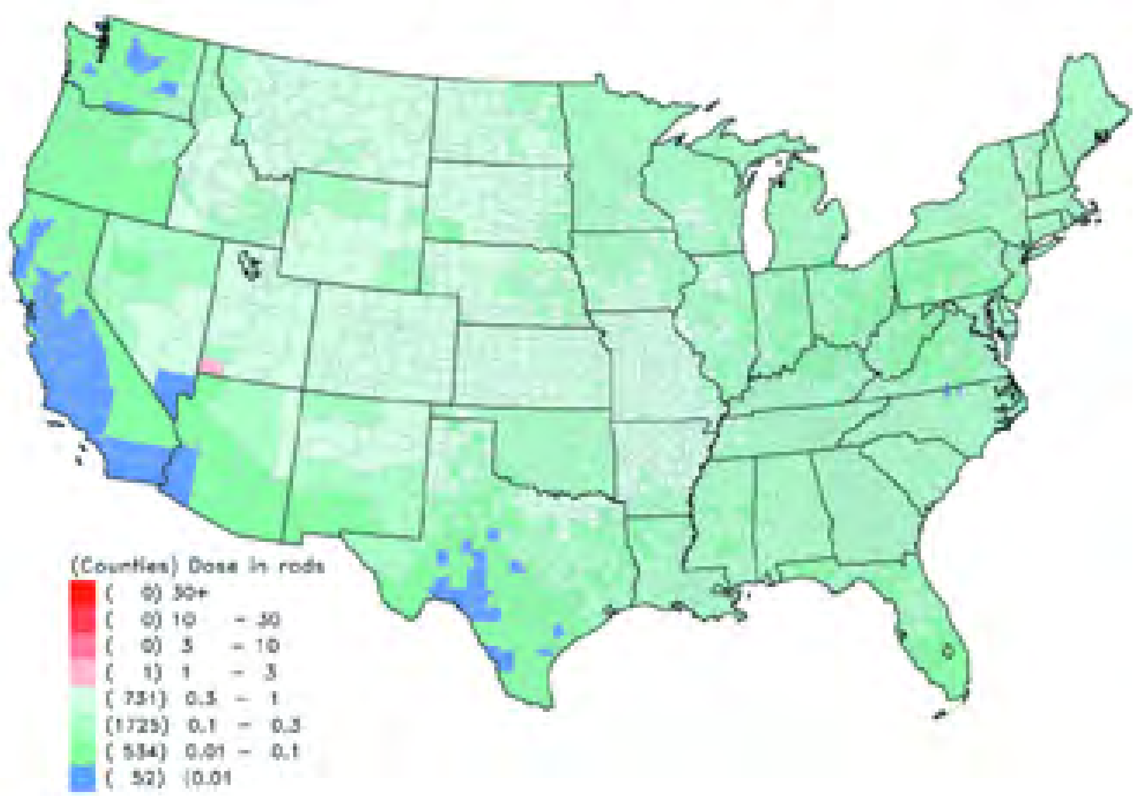


Figure 8.5. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet; average milk consumption)

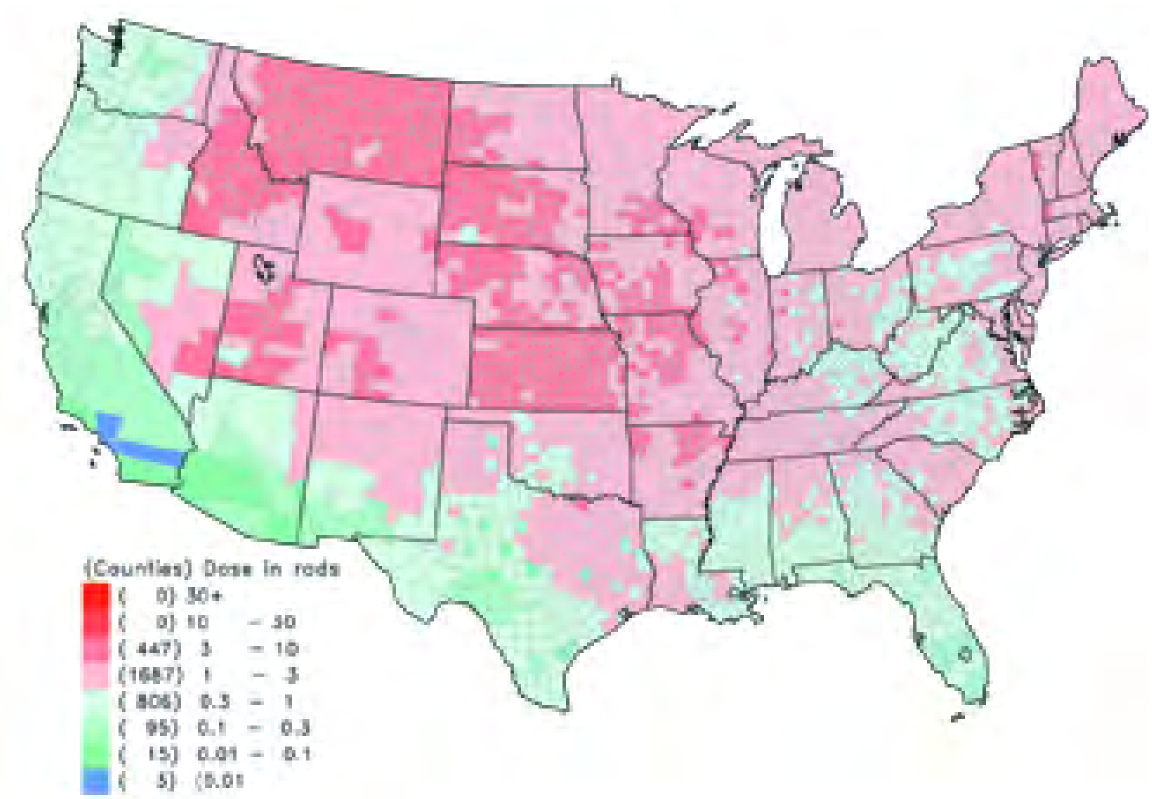


Figure 8.6. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet, high milk consumption)

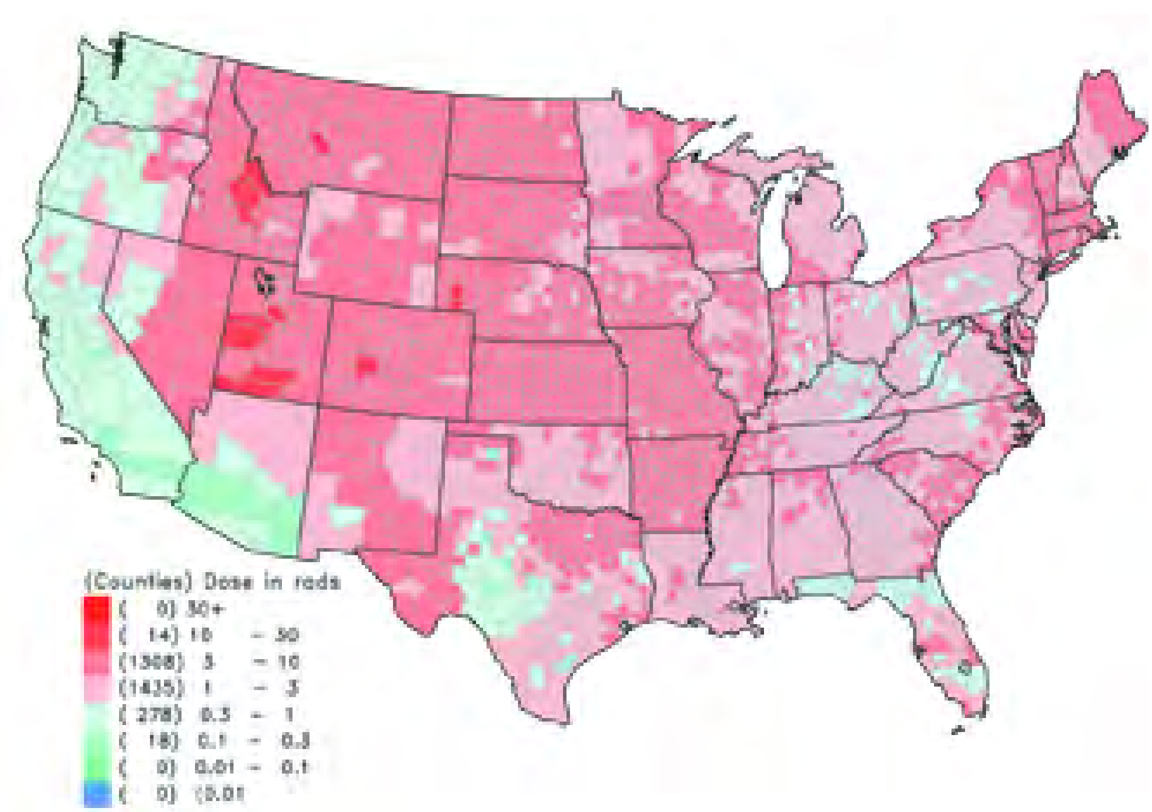


Figure 8.7. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet; milk from "backyard cow")

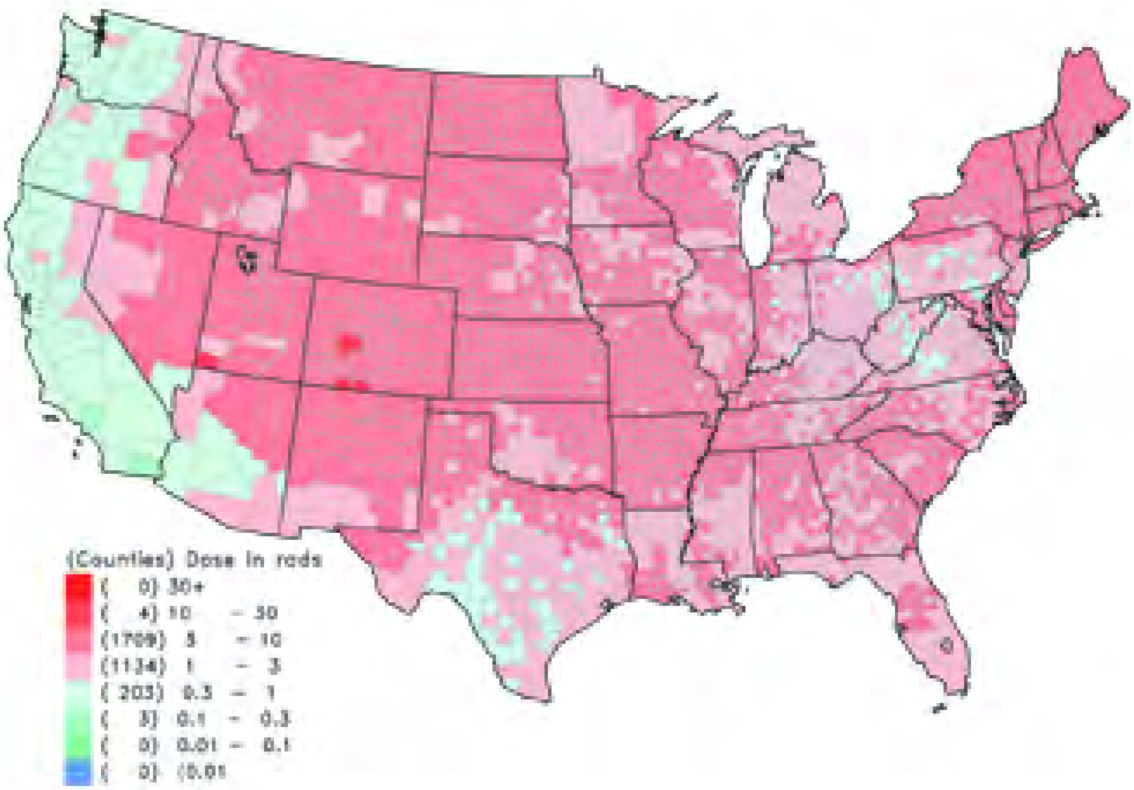


Figure 8.8. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet; no milk consumption)

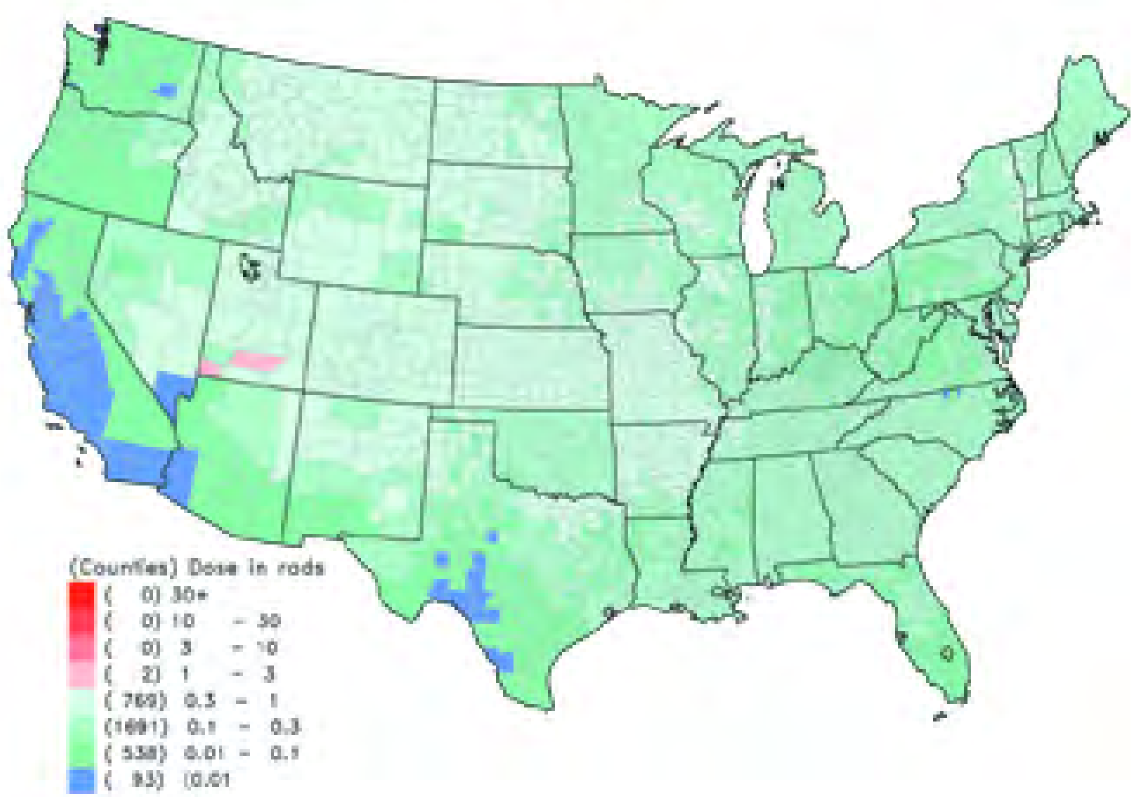


Figure 8.9. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; average milk consumption)

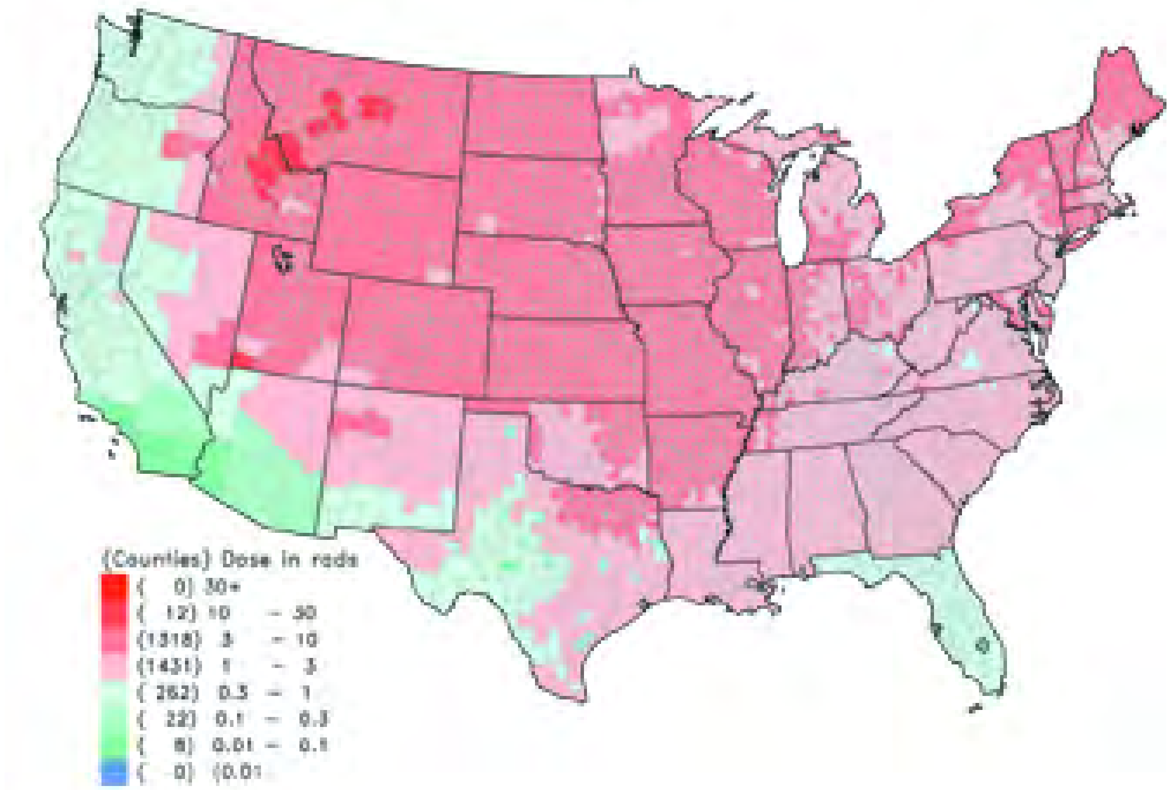


Figure 8.10. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; high milk consumption)

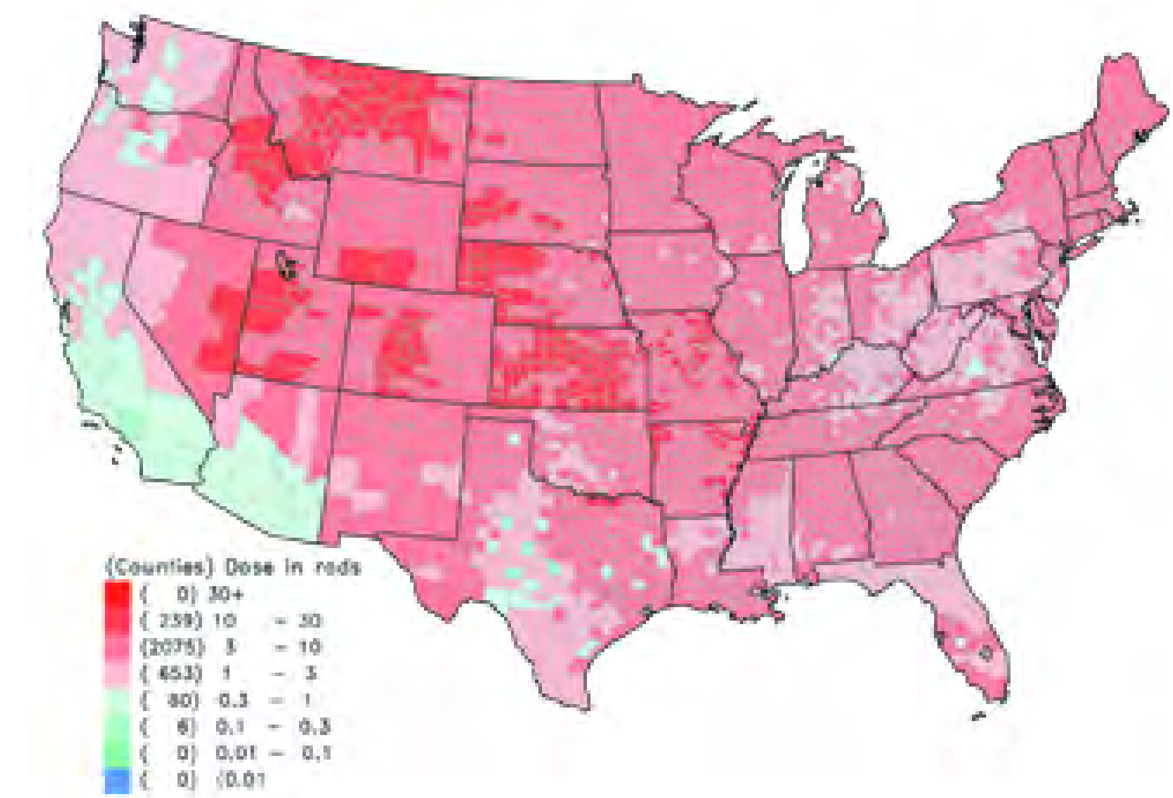


Figure 8.11. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; milk from "backyard cow")

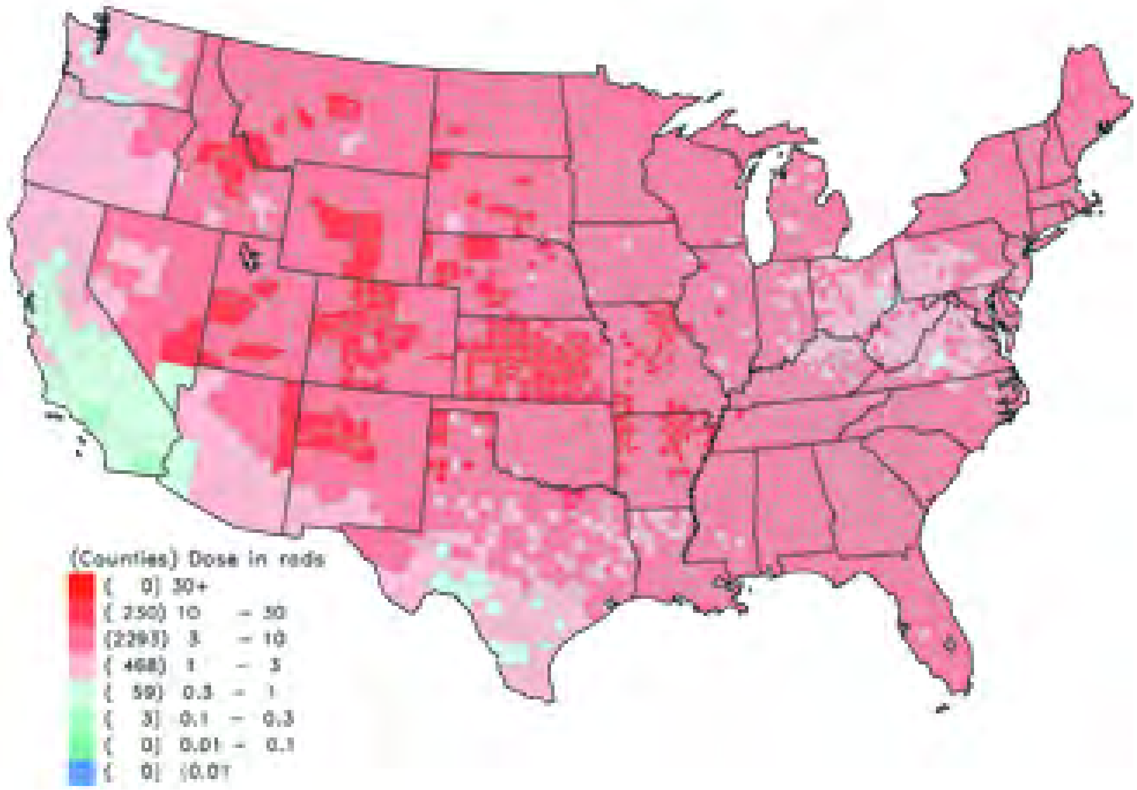


Figure 8.12. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; no milk consumption)

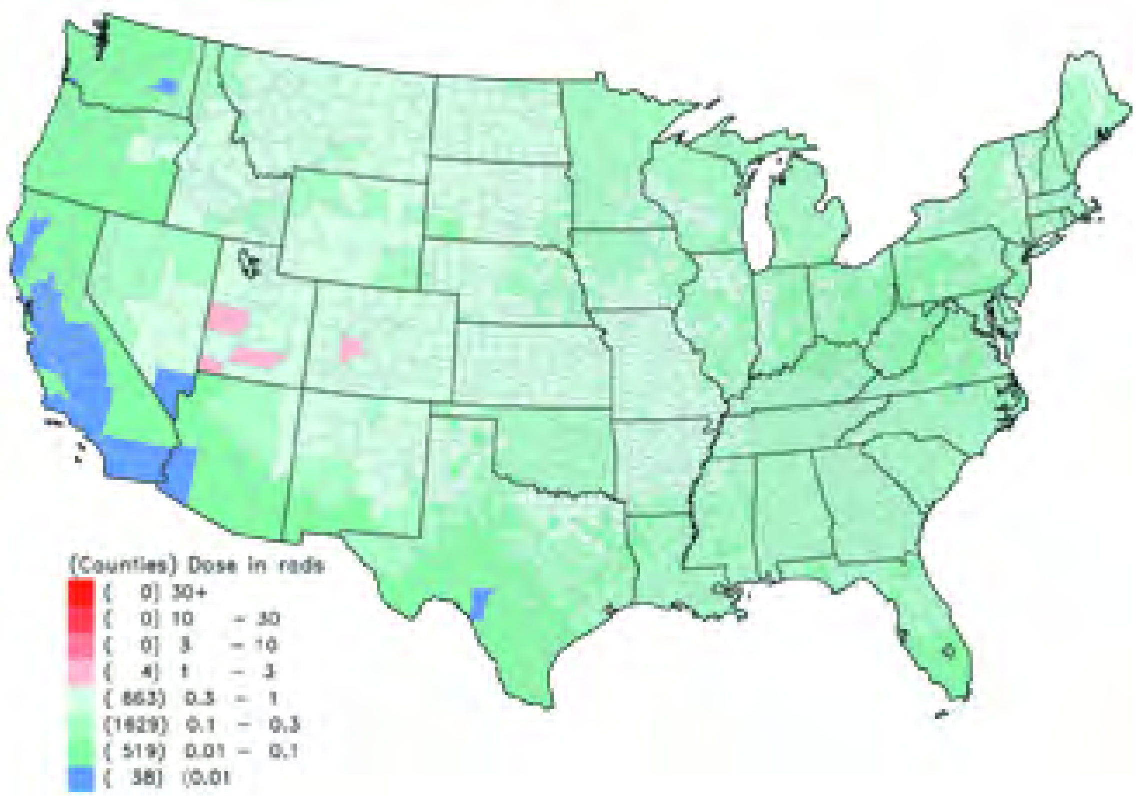


Figure 8.13. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; average milk consumption)

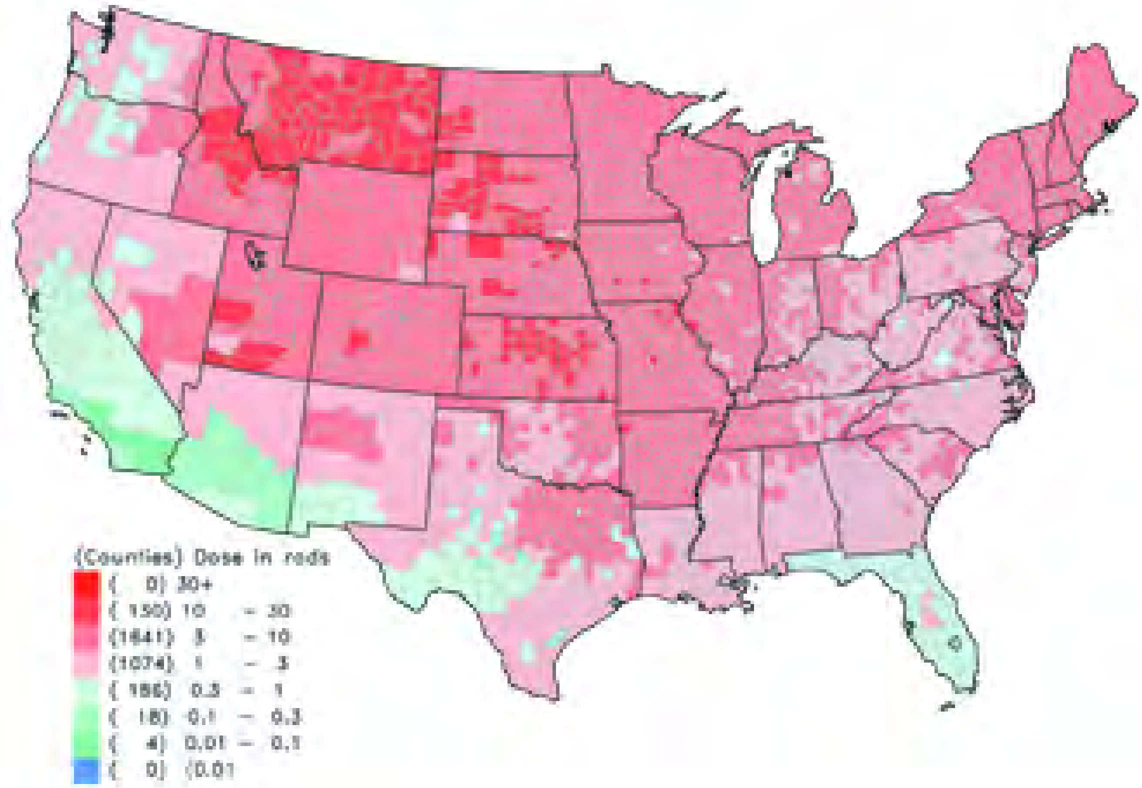


Figure 8.14. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; high milk consumption)

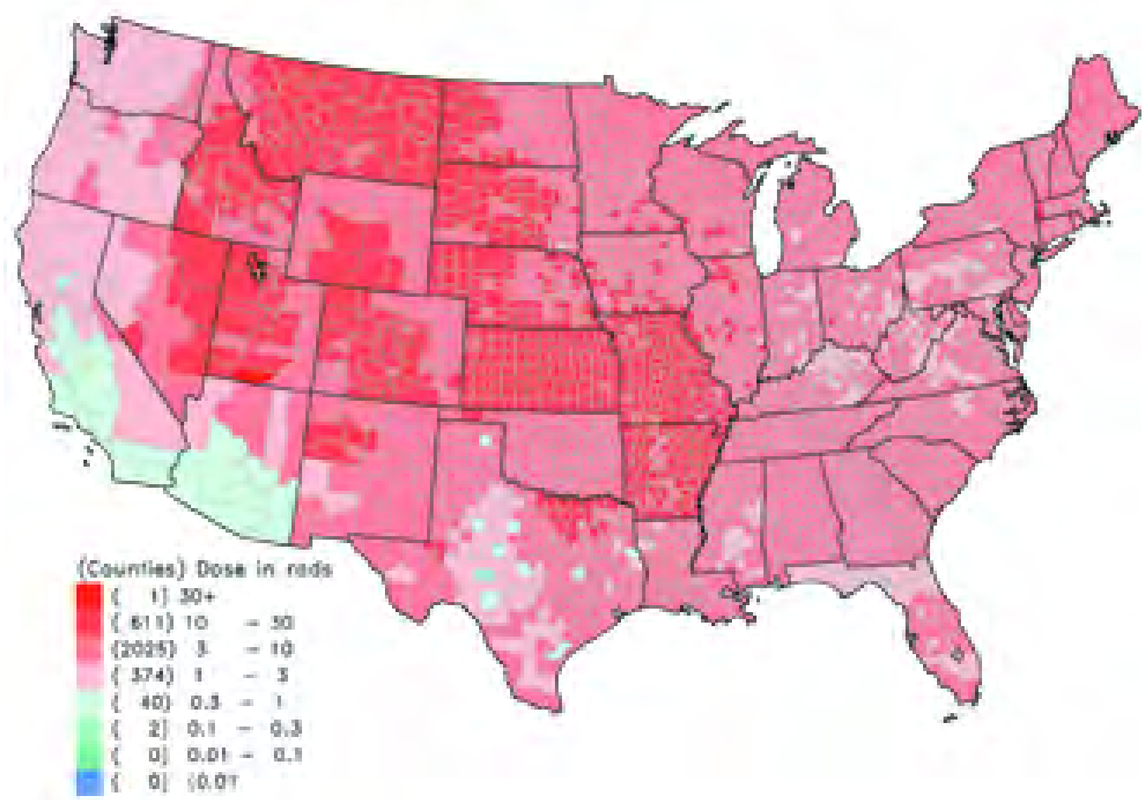


Figure 8.15. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; milk from "backyard cow")

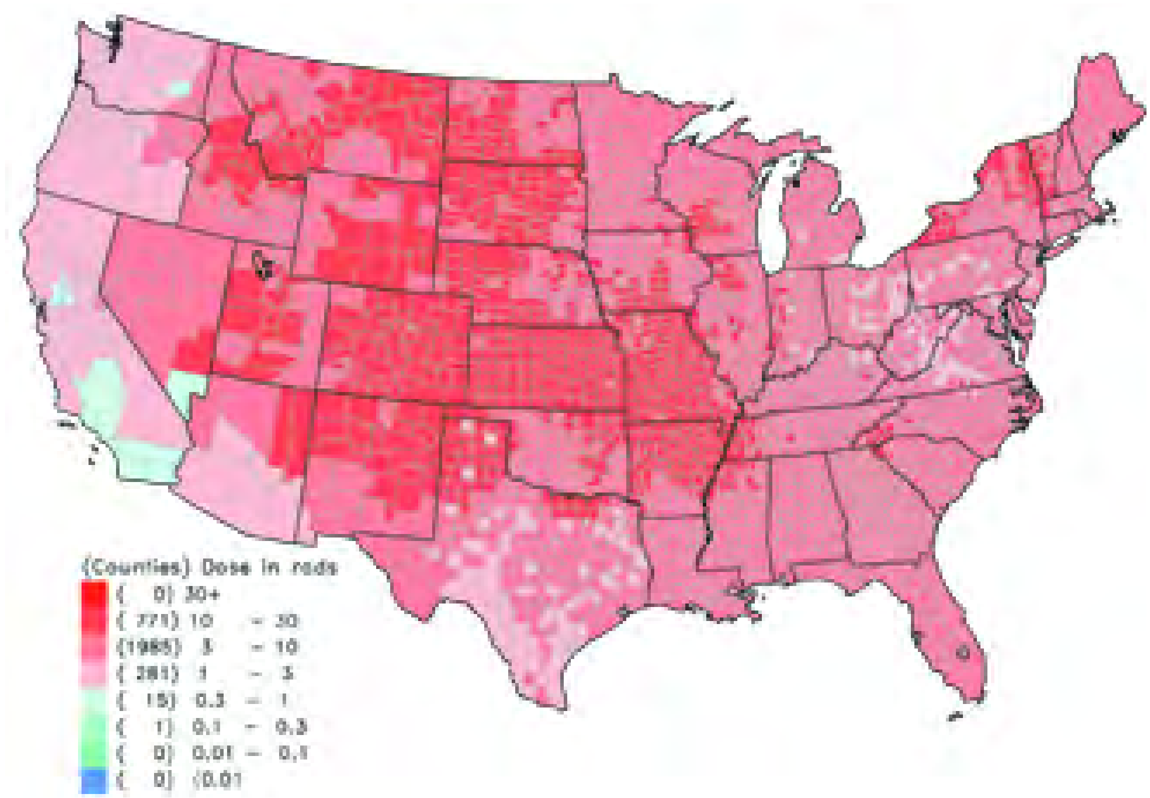


Figure 8.16. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; no milk consumption)

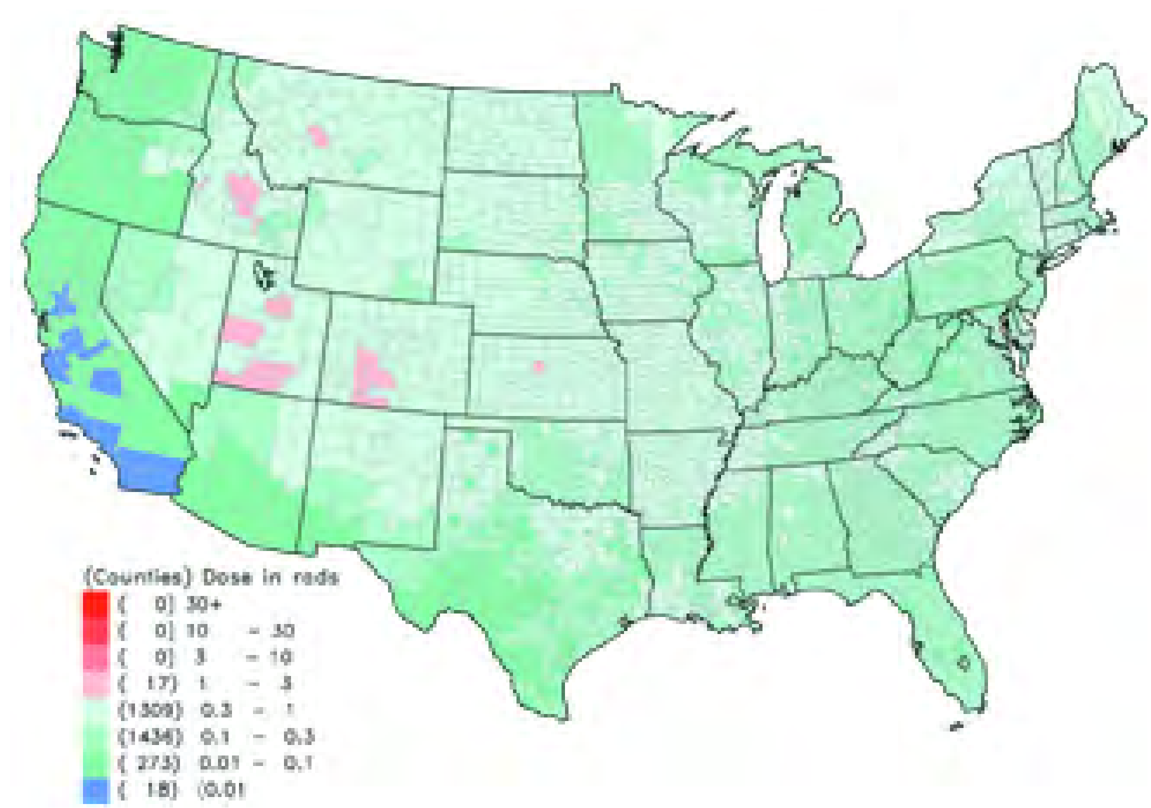


Figure 8.17. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; average milk consumption)

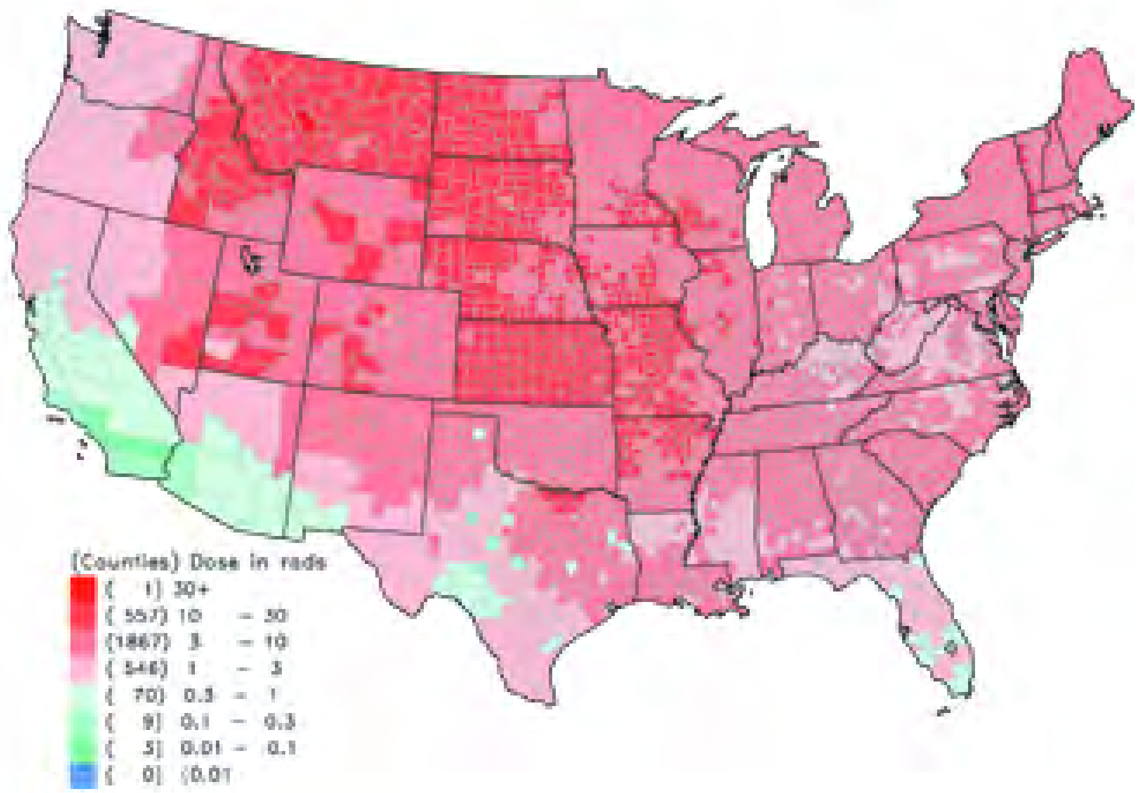


Figure 8.18. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; high milk consumption)

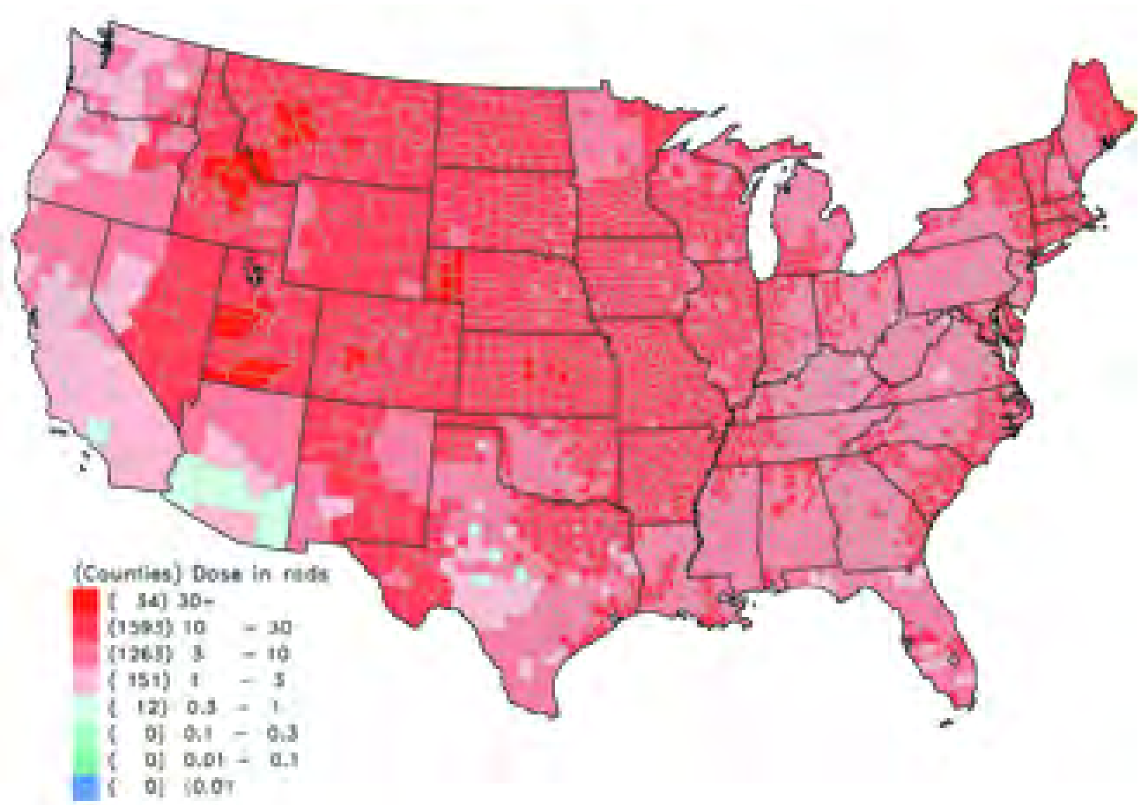


Figure 8.19. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; milk from "backyard cow")

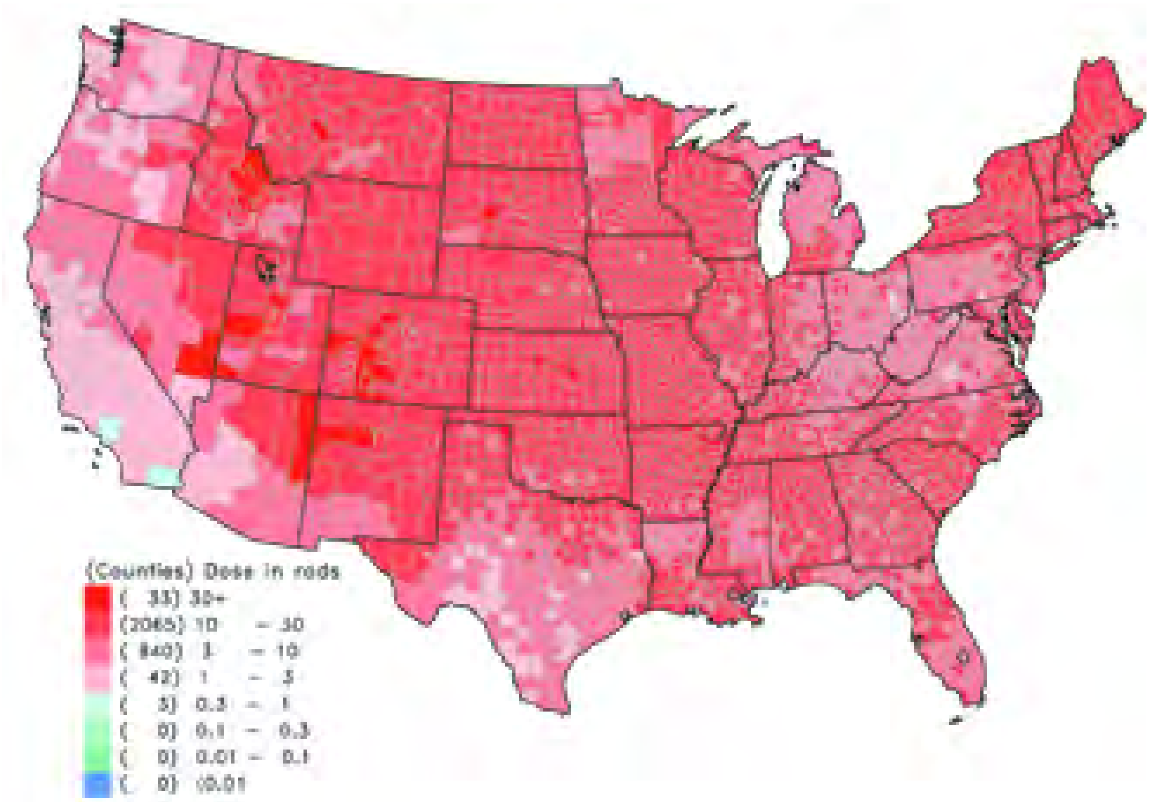


Figure 8.20. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; no milk consumption)

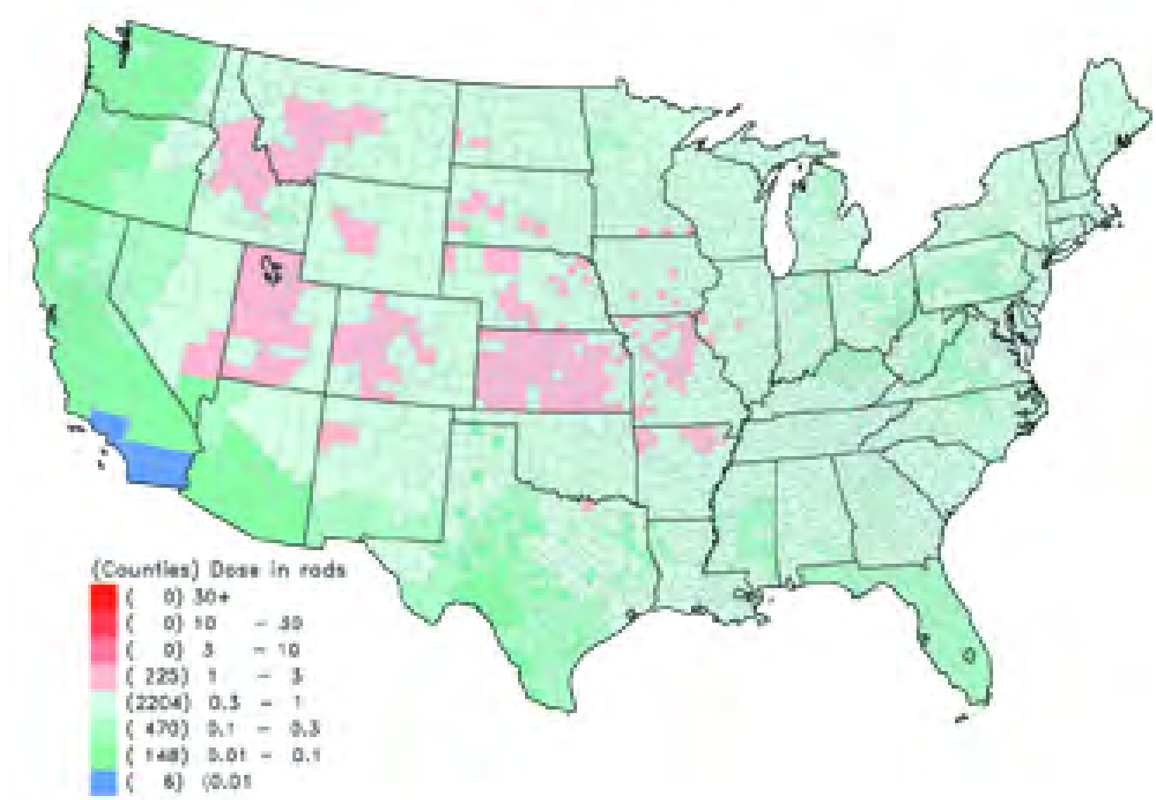


Figure 8.21. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; average milk consumption)

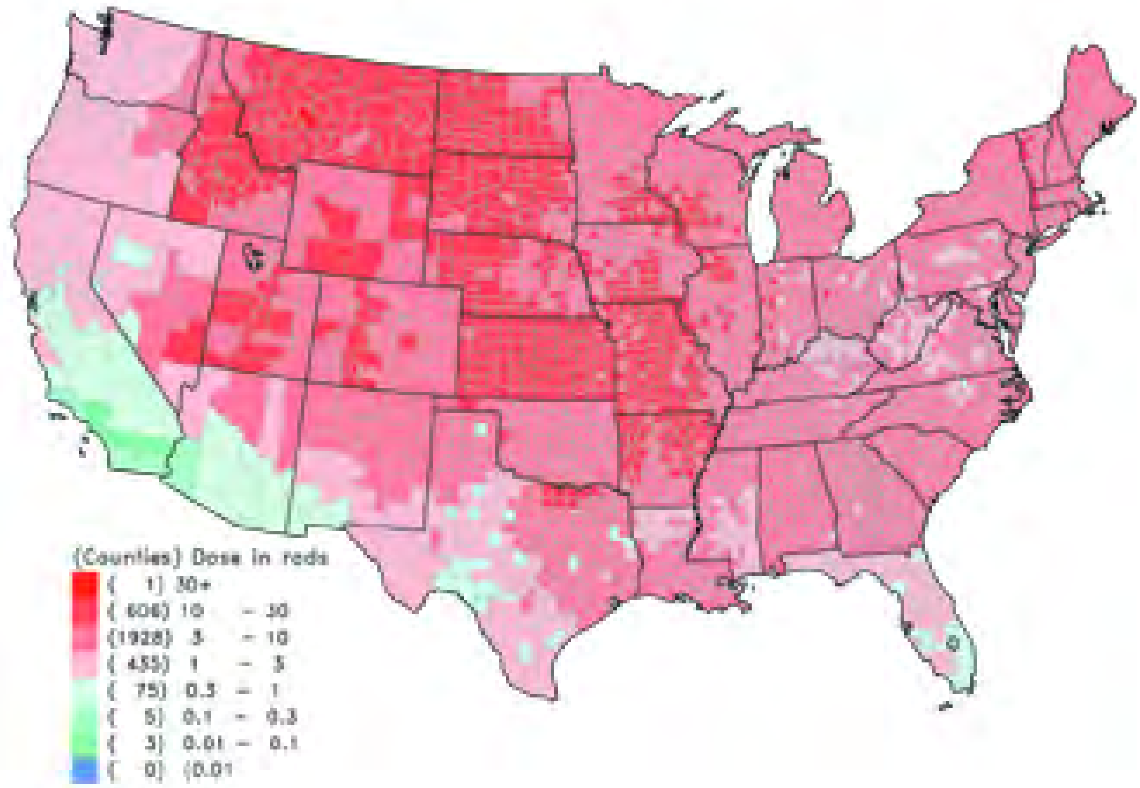


Figure 8.22. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; high milk consumption)

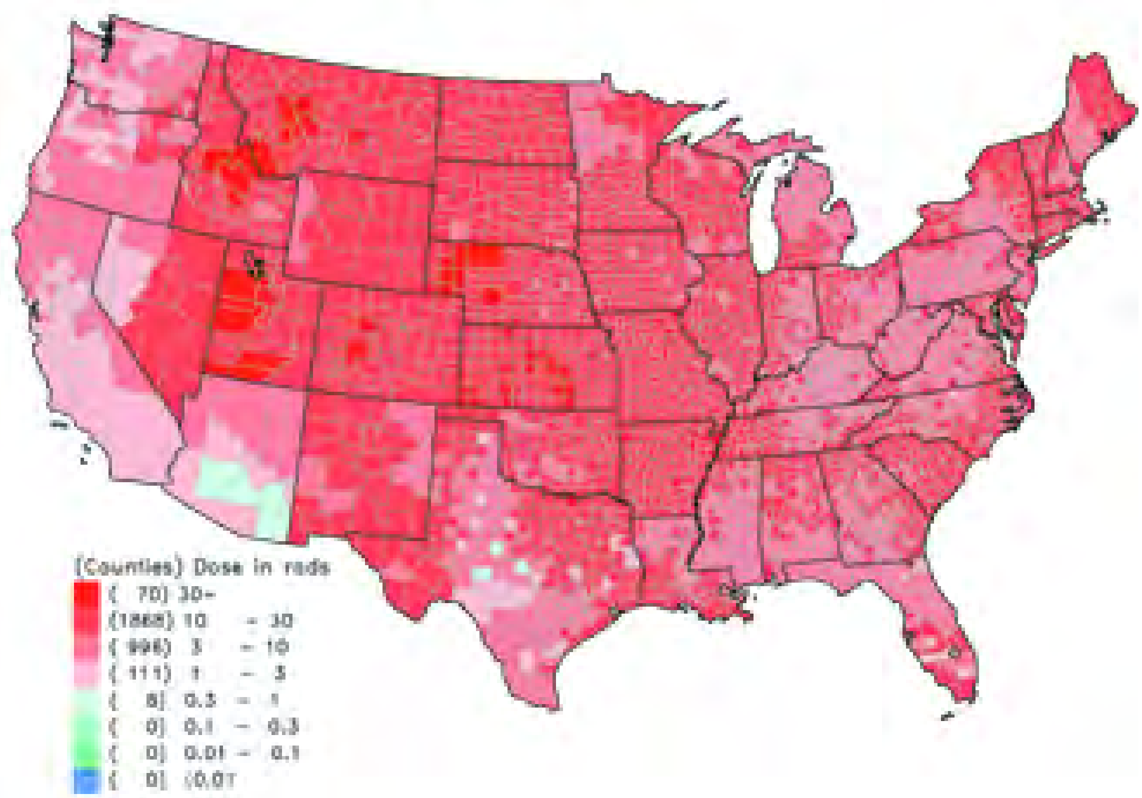


Figure 8.23. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; milk from "backyard cow")

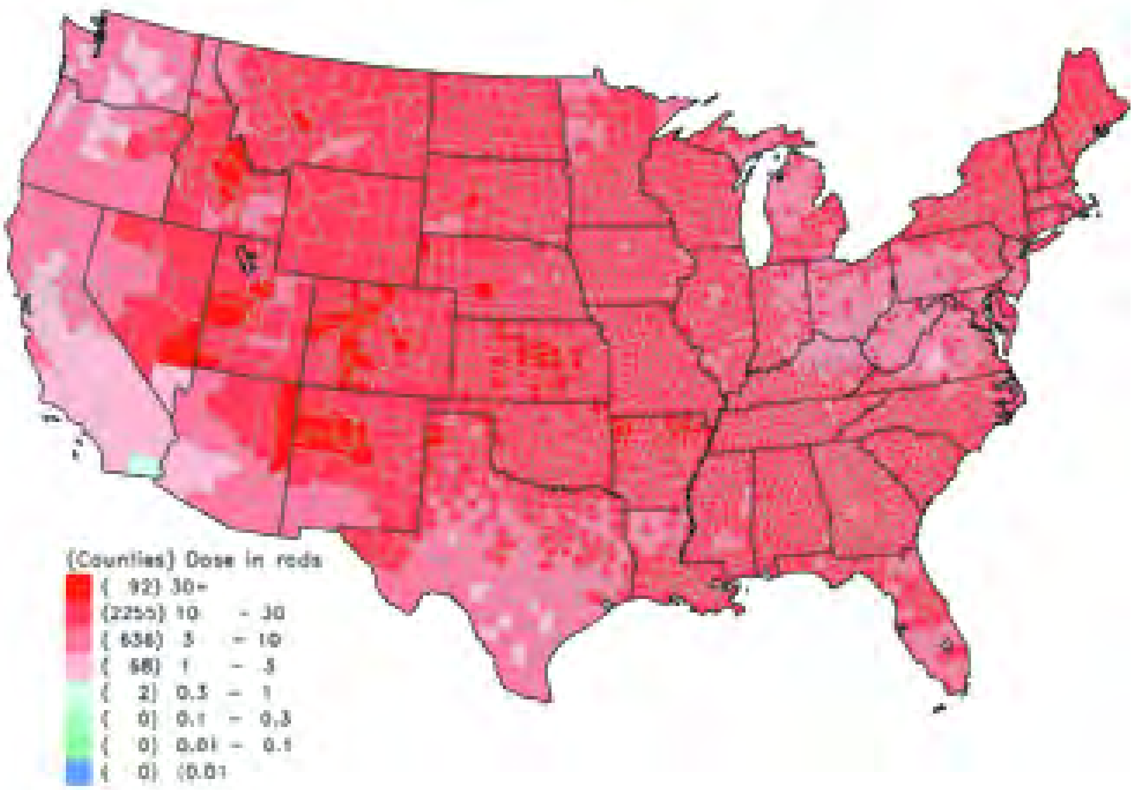


Figure 8.24. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; no milk consumption)

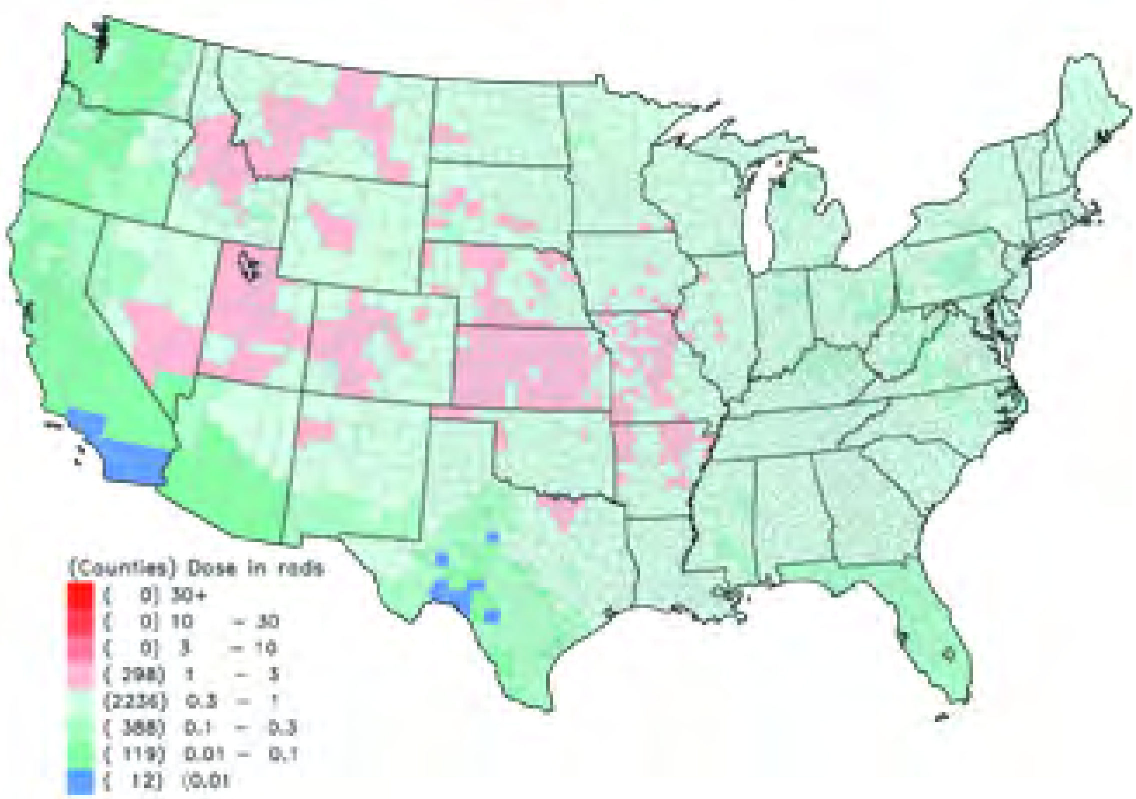


Figure 8.25. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; average milk consumption)

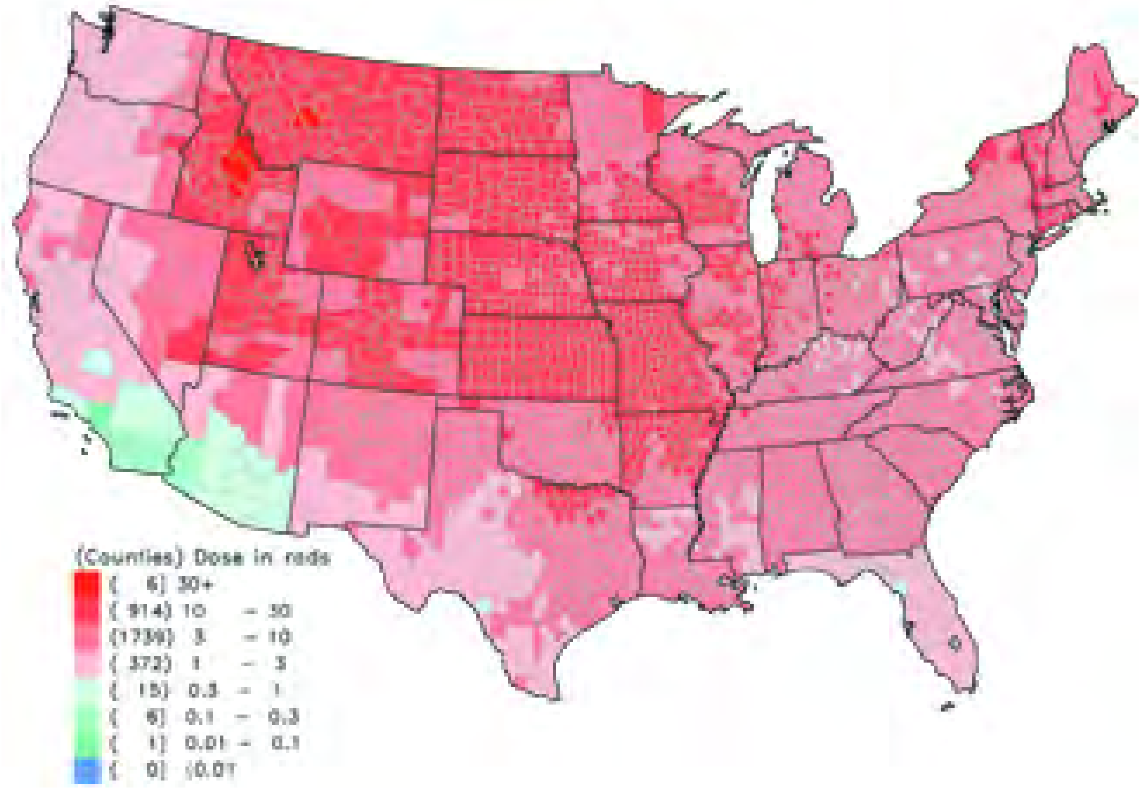


Figure 8.26. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; high milk consumption)

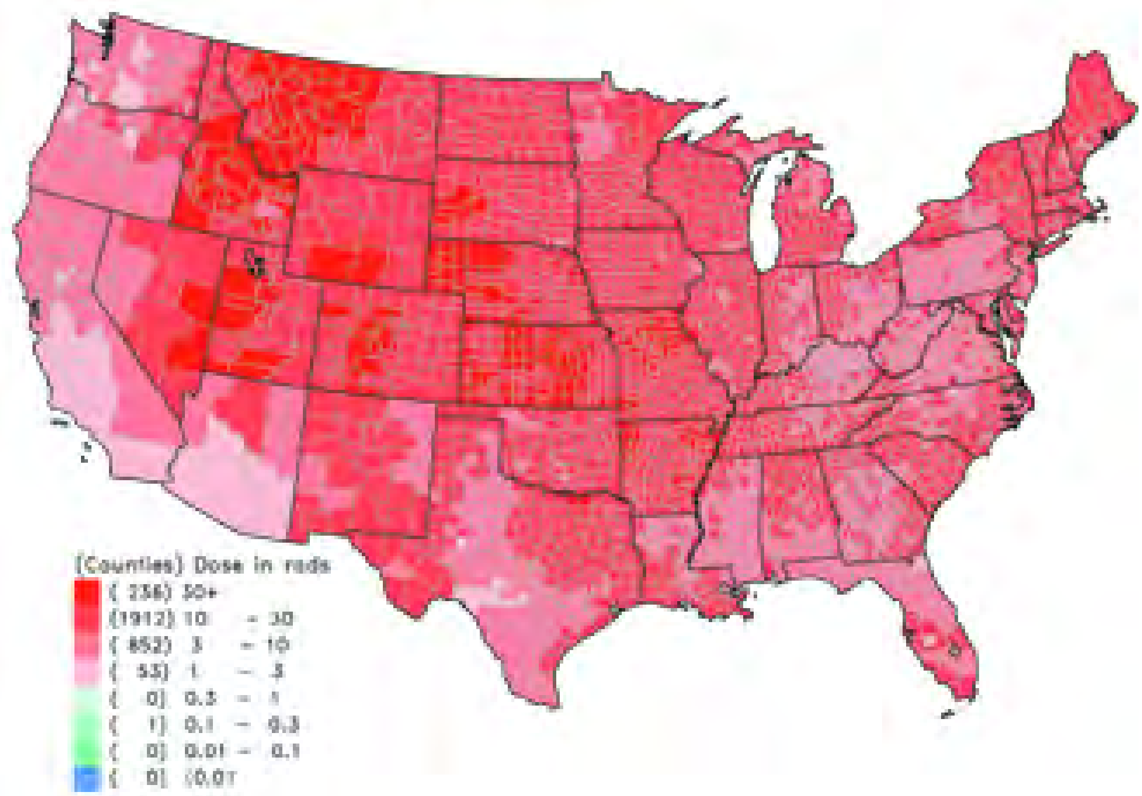


Figure 8.27. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; milk from "backyard cow")

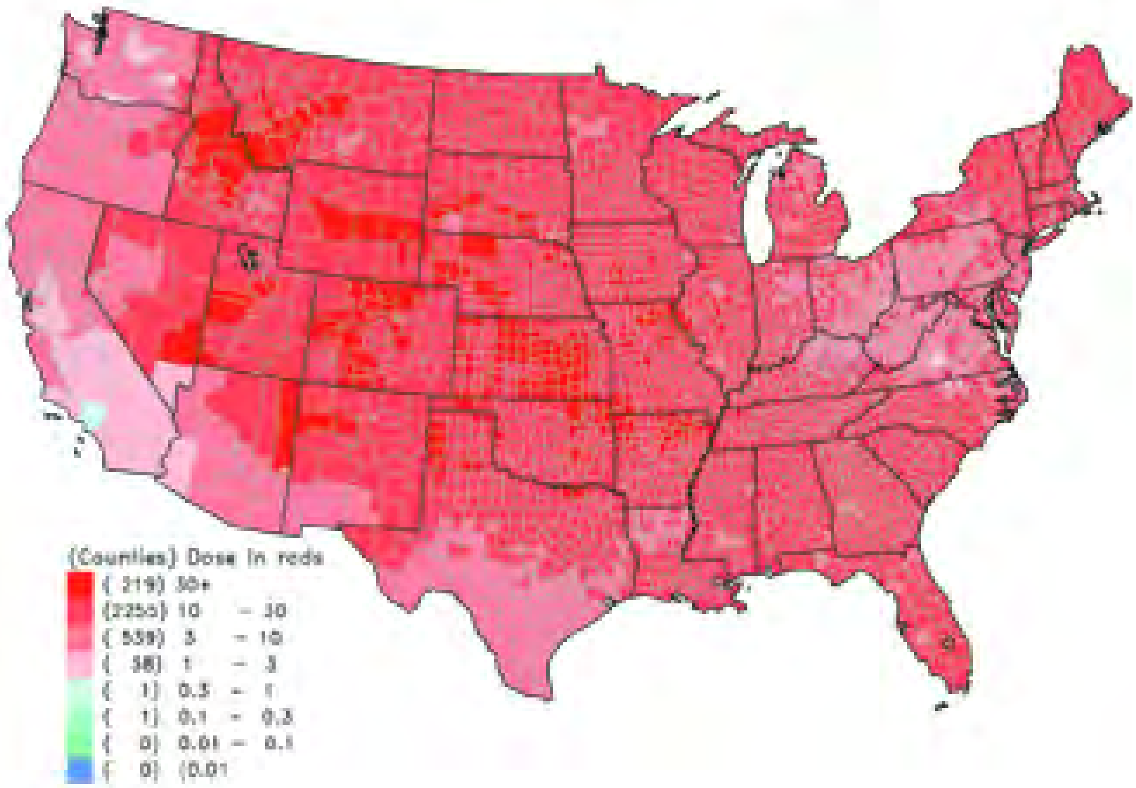


Figure 8.28. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; no milk consumption)

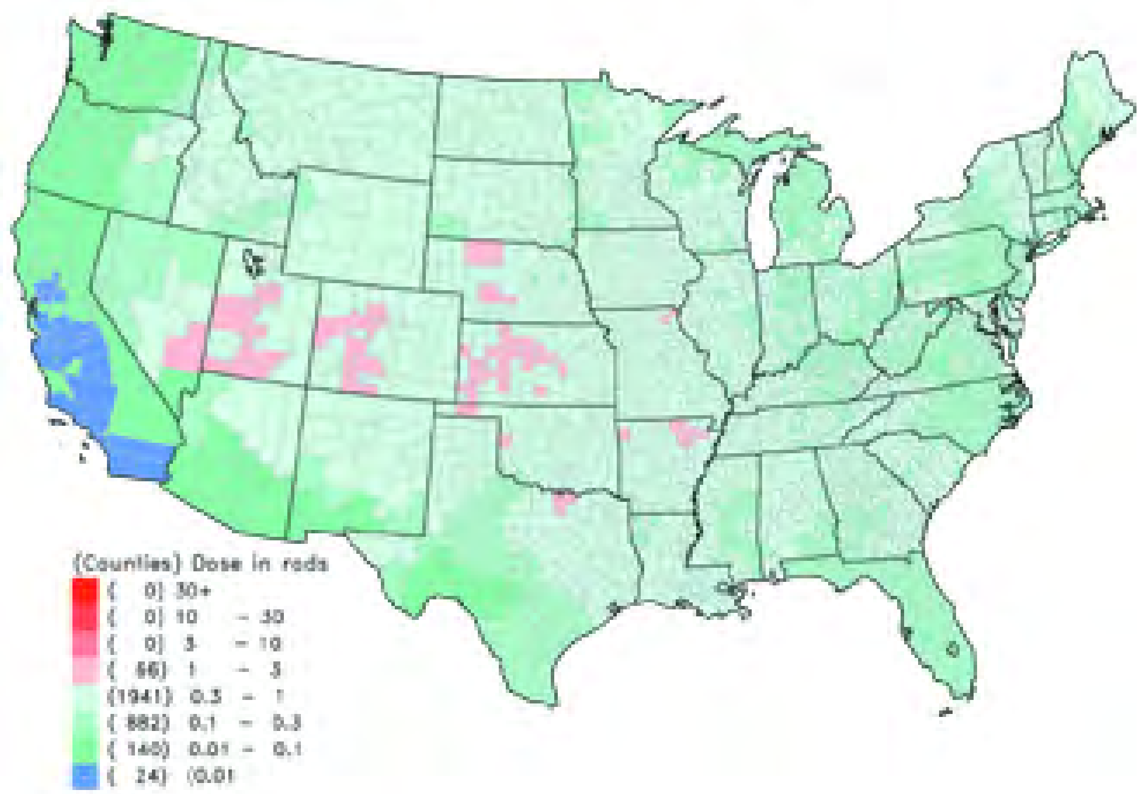


Figure 8.29. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; average milk consumption)

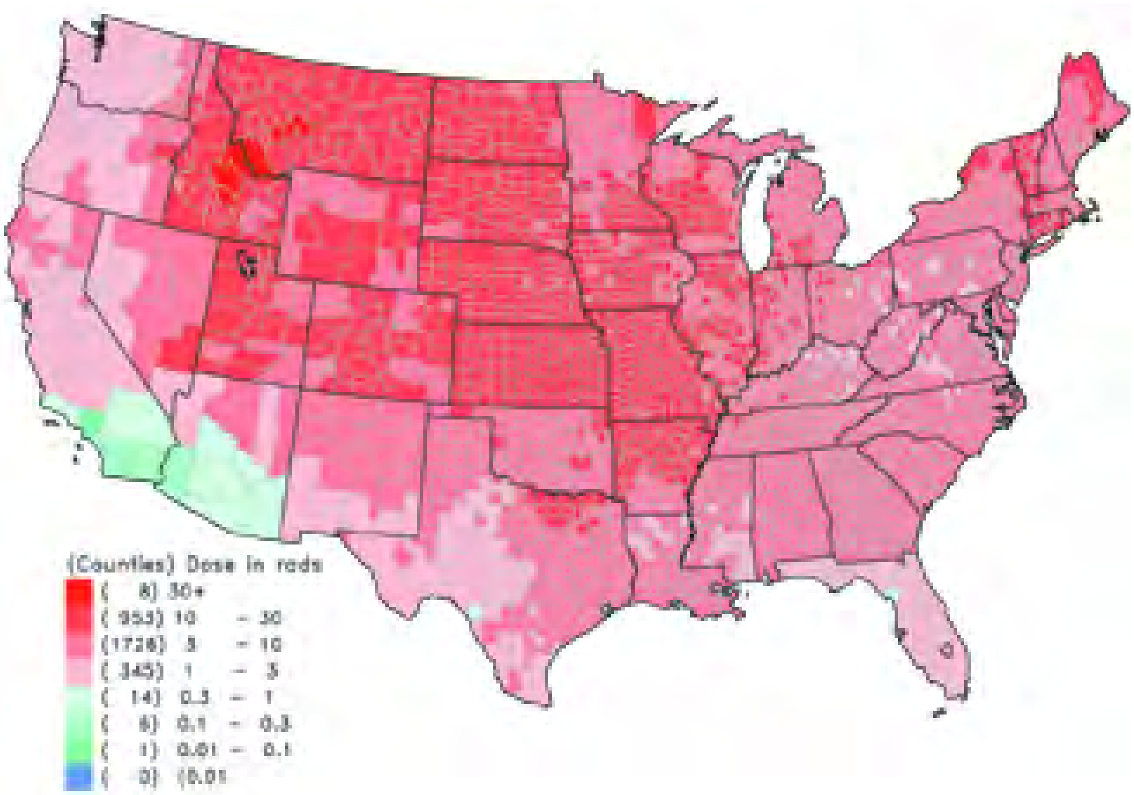


Figure 8.30. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; high milk consumption)

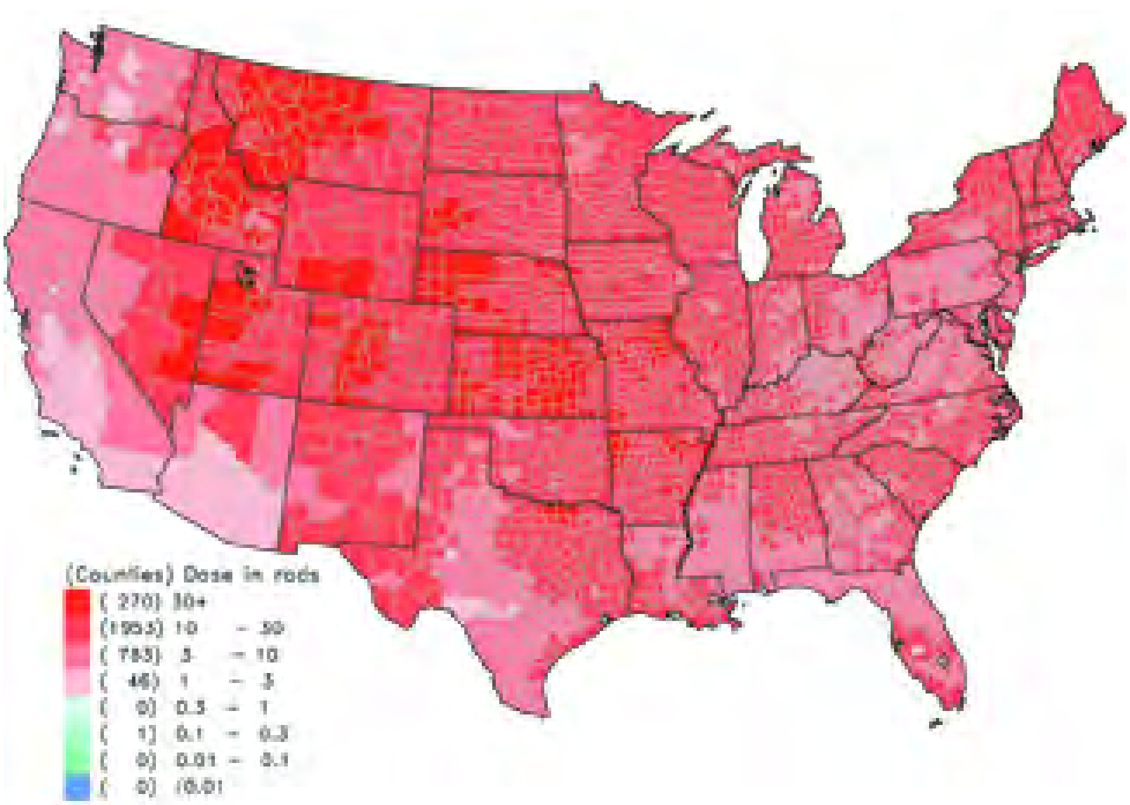


Figure 8.31. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; milk from "backyard cow")

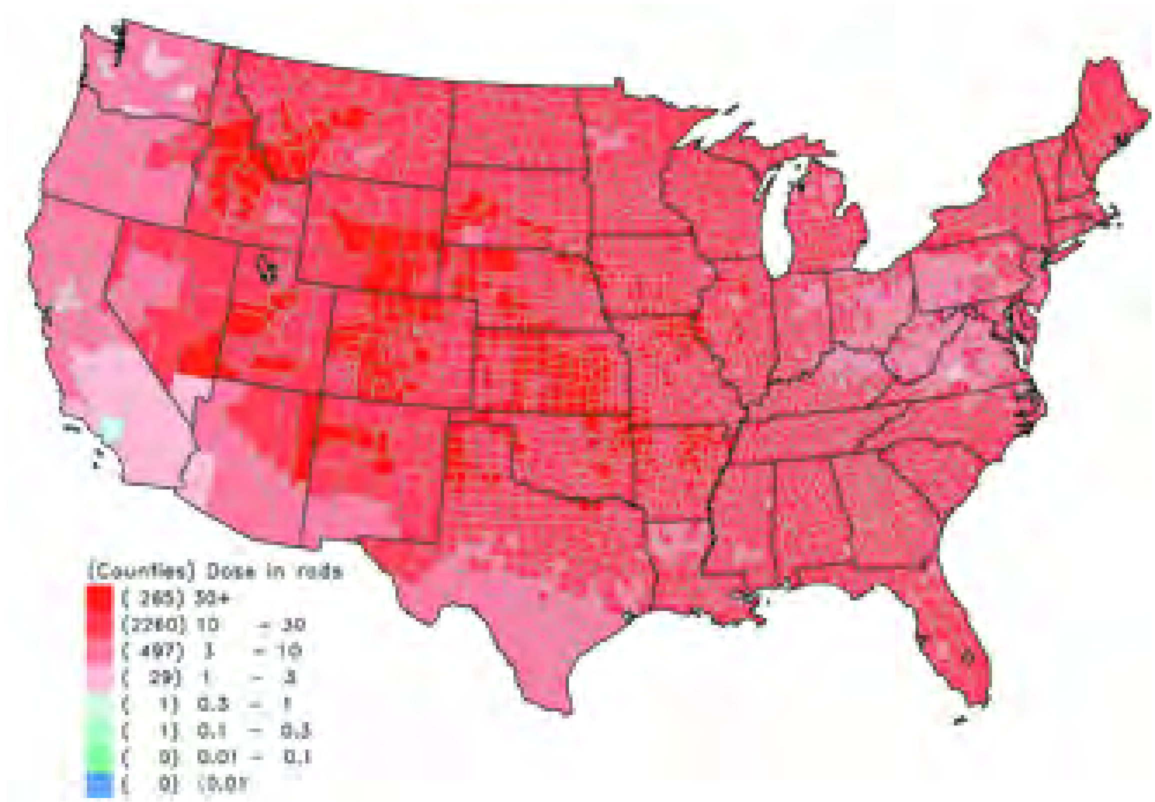


Figure 8.32. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; no milk consumption)

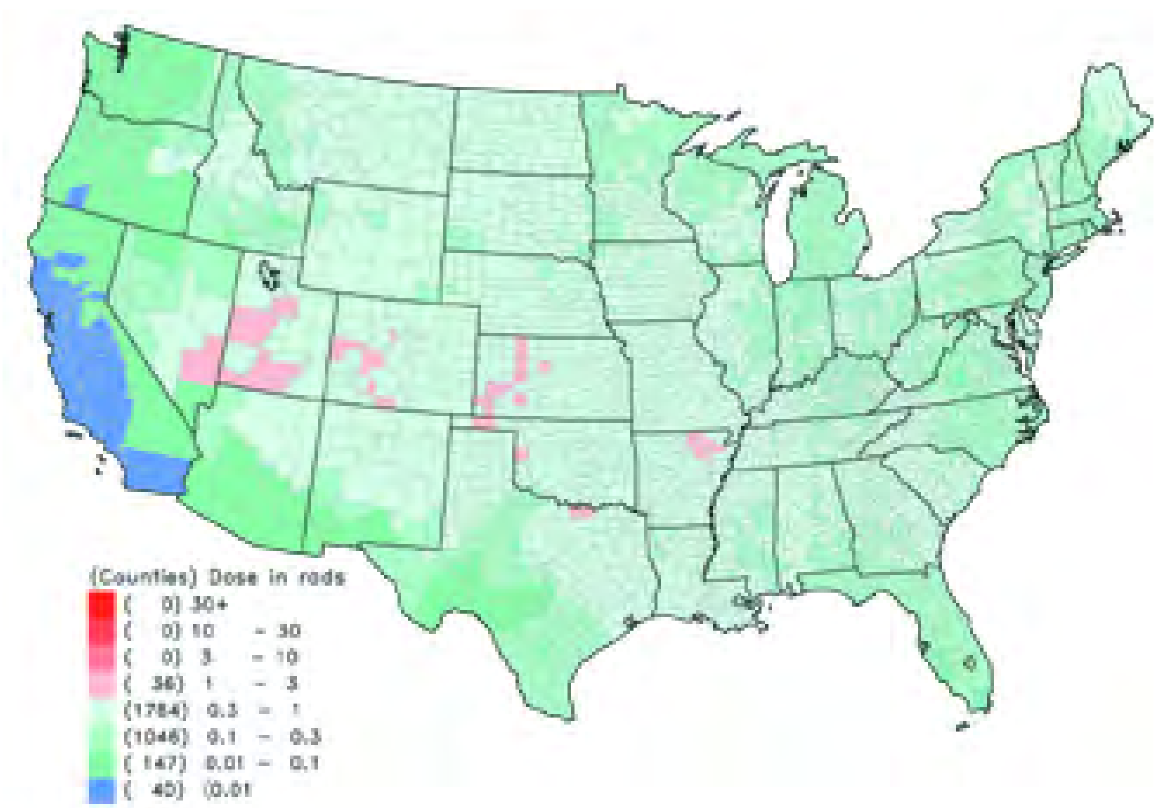


Figure 8.33. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; average milk consumption)

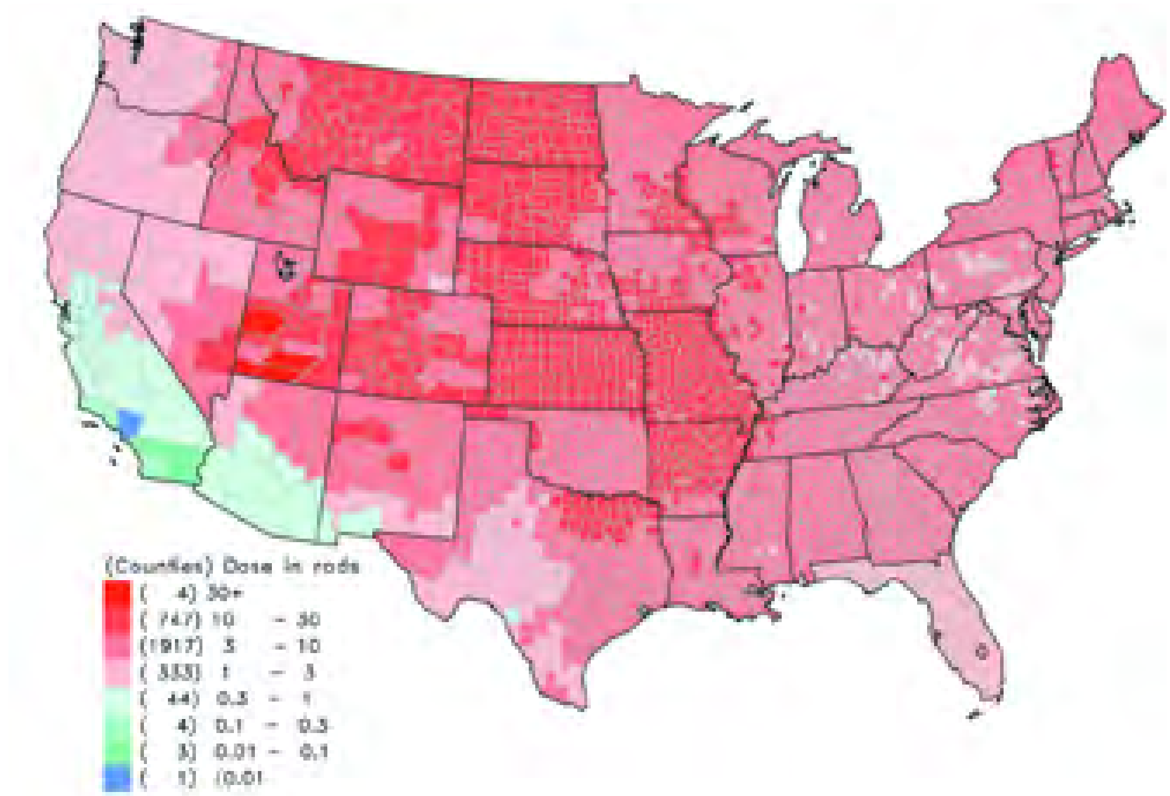


Figure 8.34. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; high milk consumption)

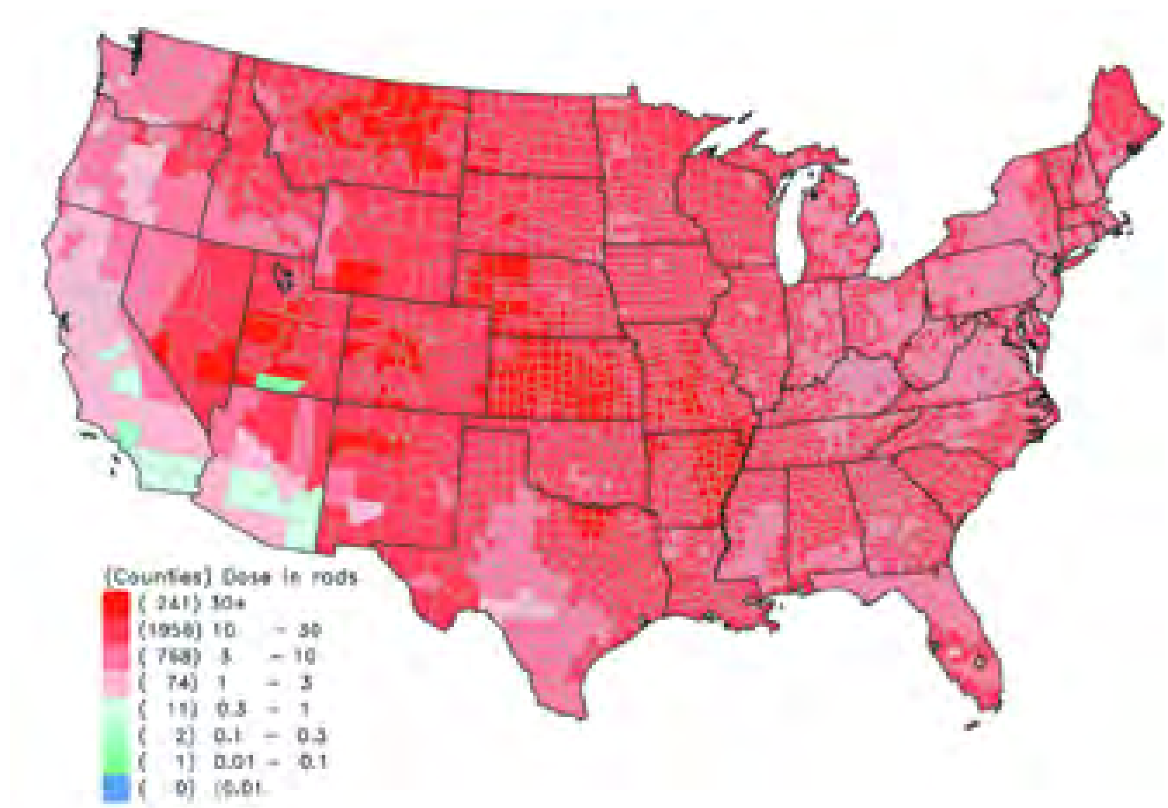


Figure 8.35. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; milk from "backyard cow")

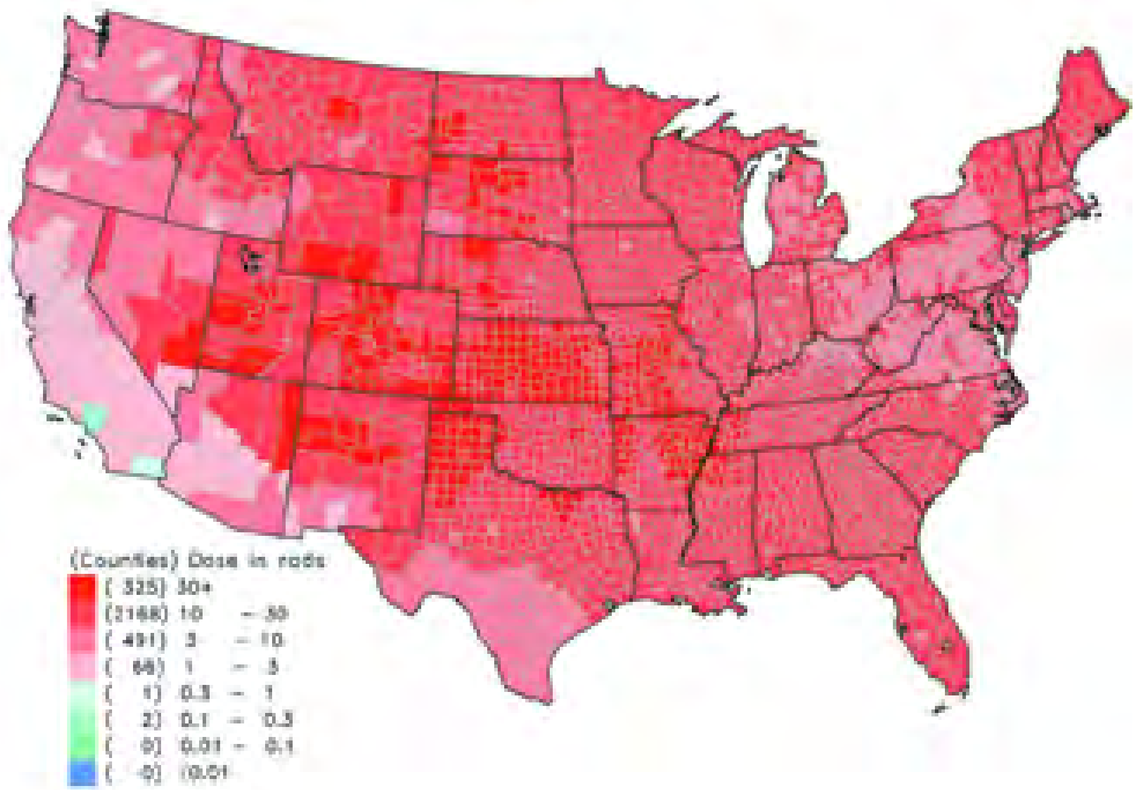


Figure 8.36. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; no milk consumption)

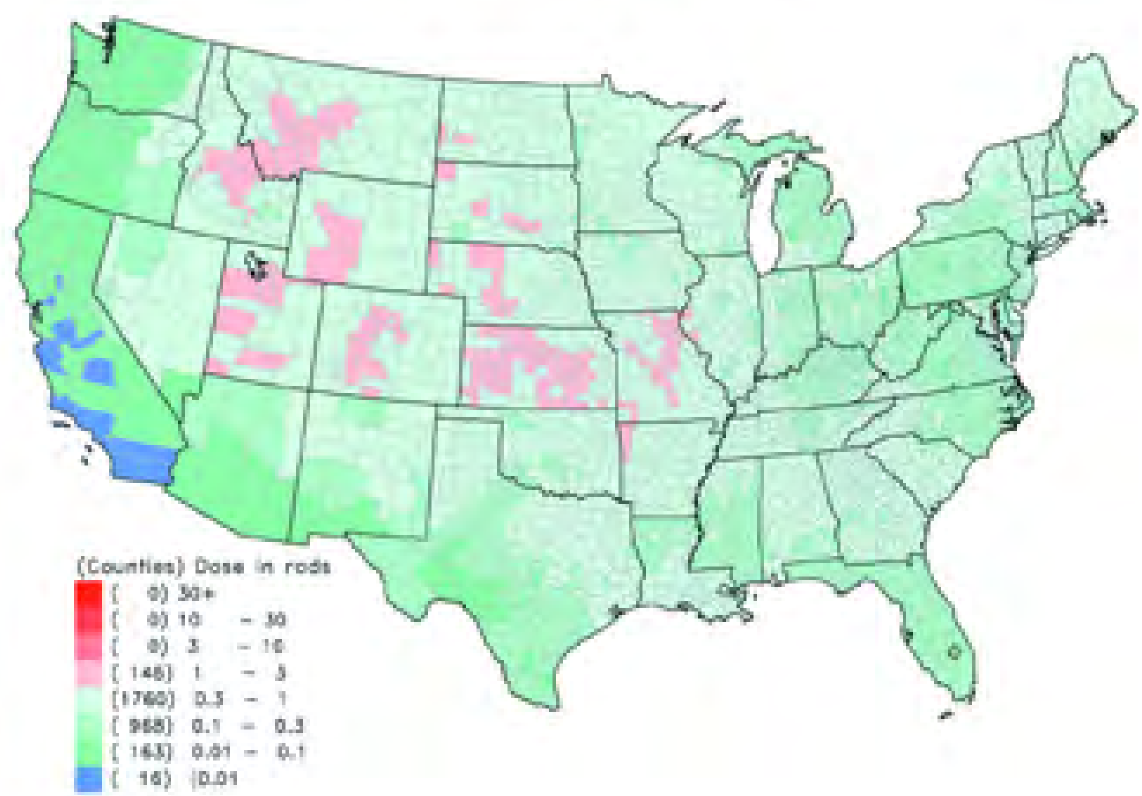


Figure 8.37. Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; average milk consumption)

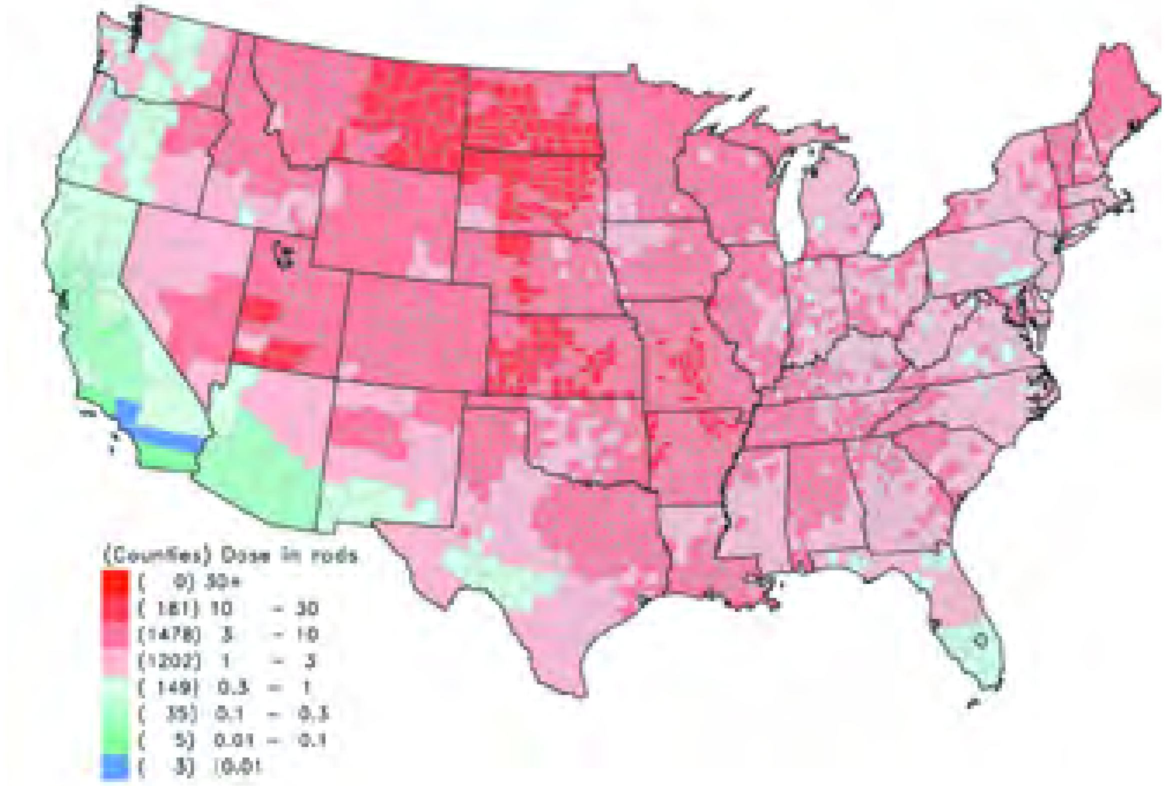


Figure 8.38. Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; high milk consumption)

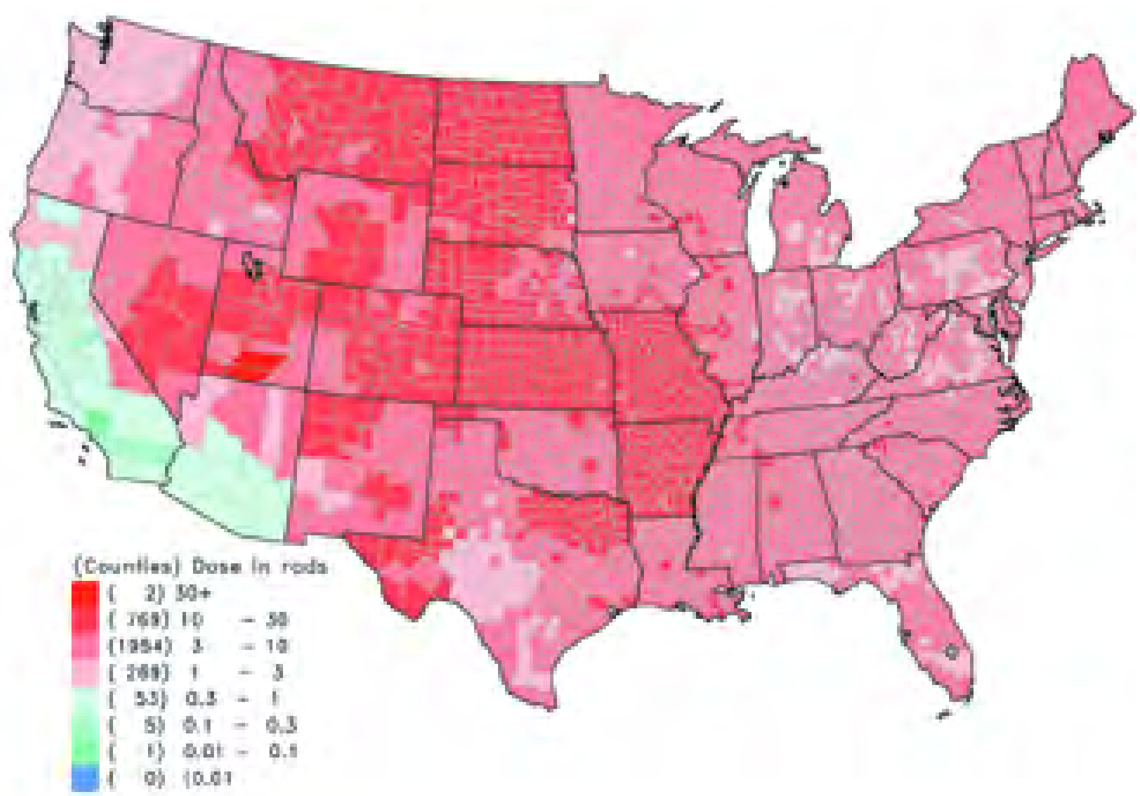


Figure 8.39. Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; milk from "backyard cow")

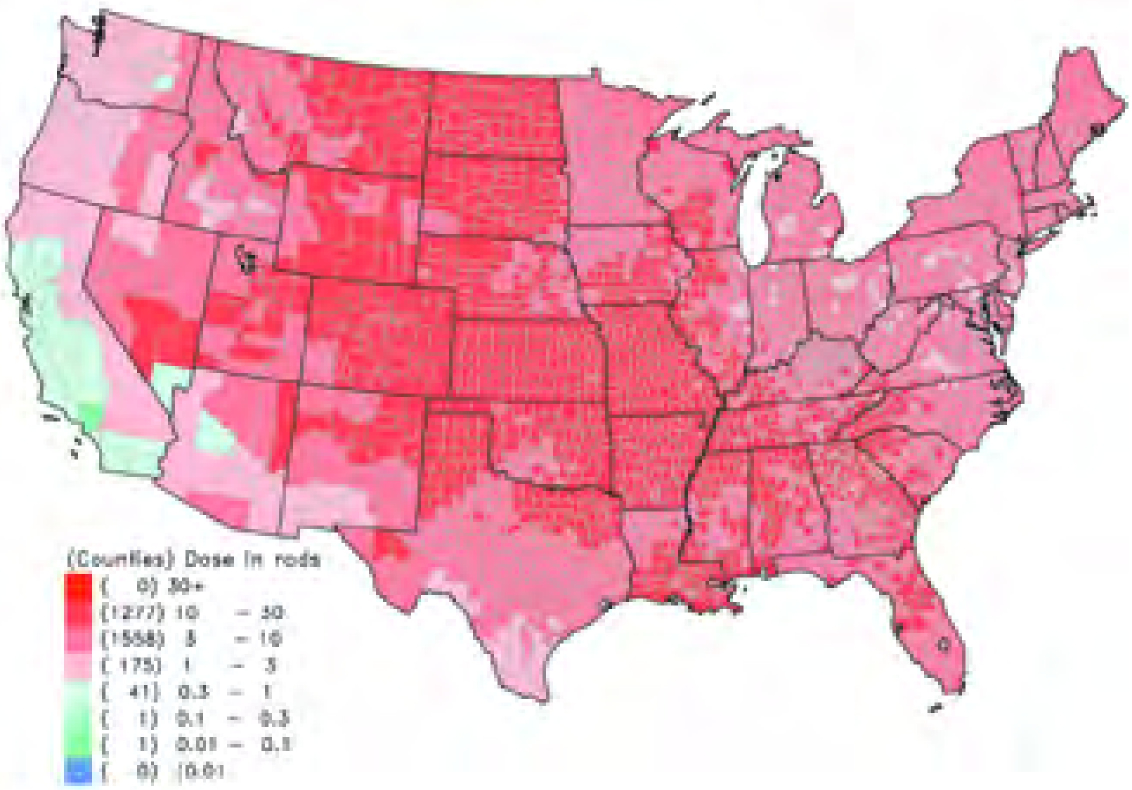


Figure 8.40. Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; no milk consumption)

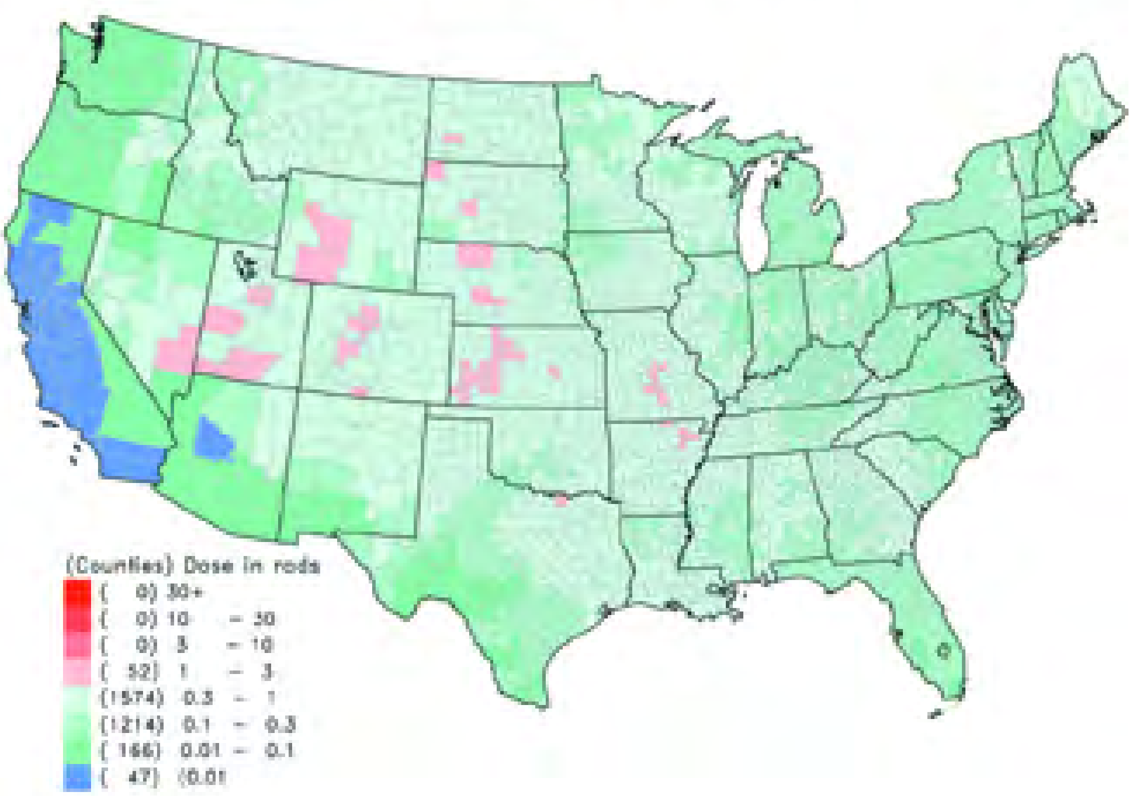


Figure 8.41. Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; average milk consumption)

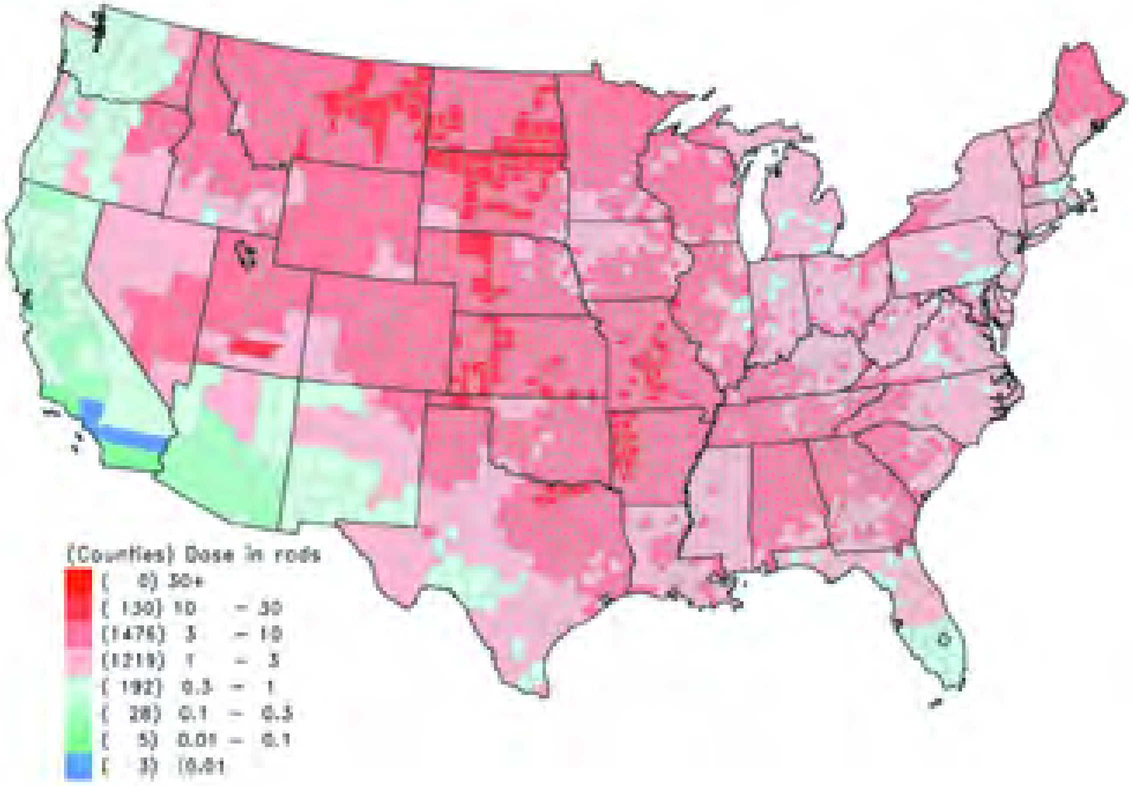


Figure 8.42. Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; high milk consumption)

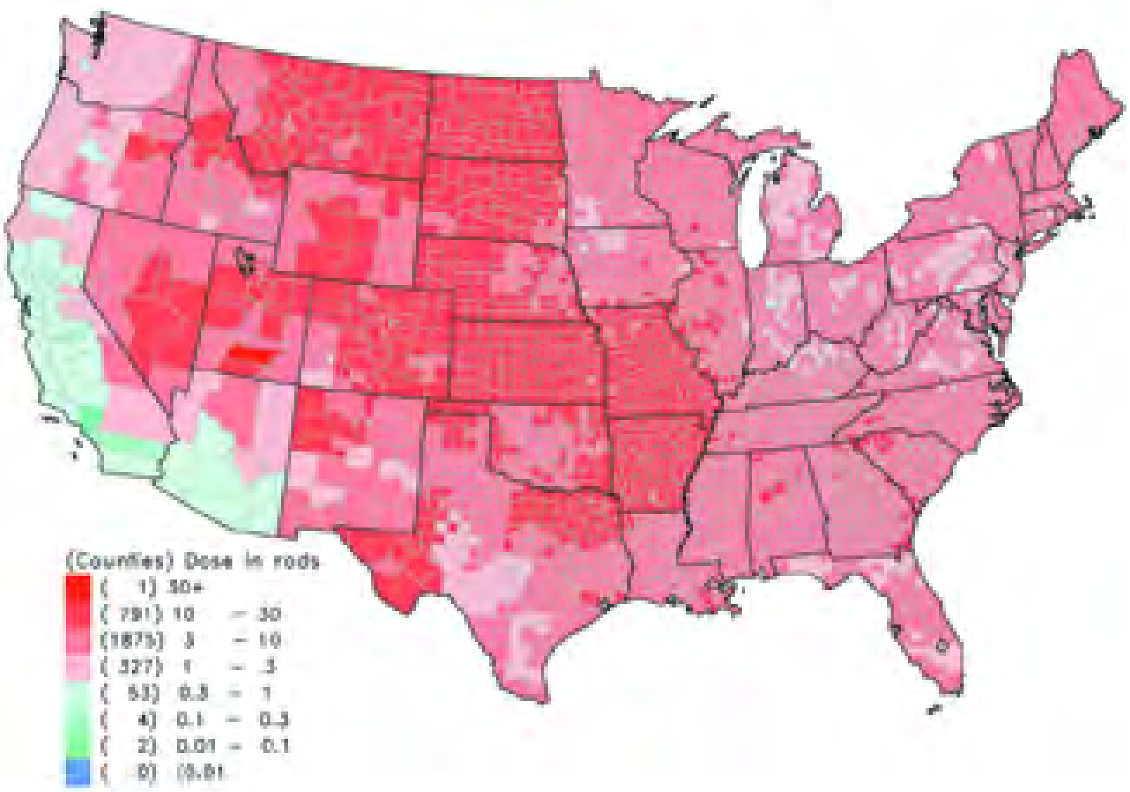


Figure 8.43. Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; milk from "backyard cow")

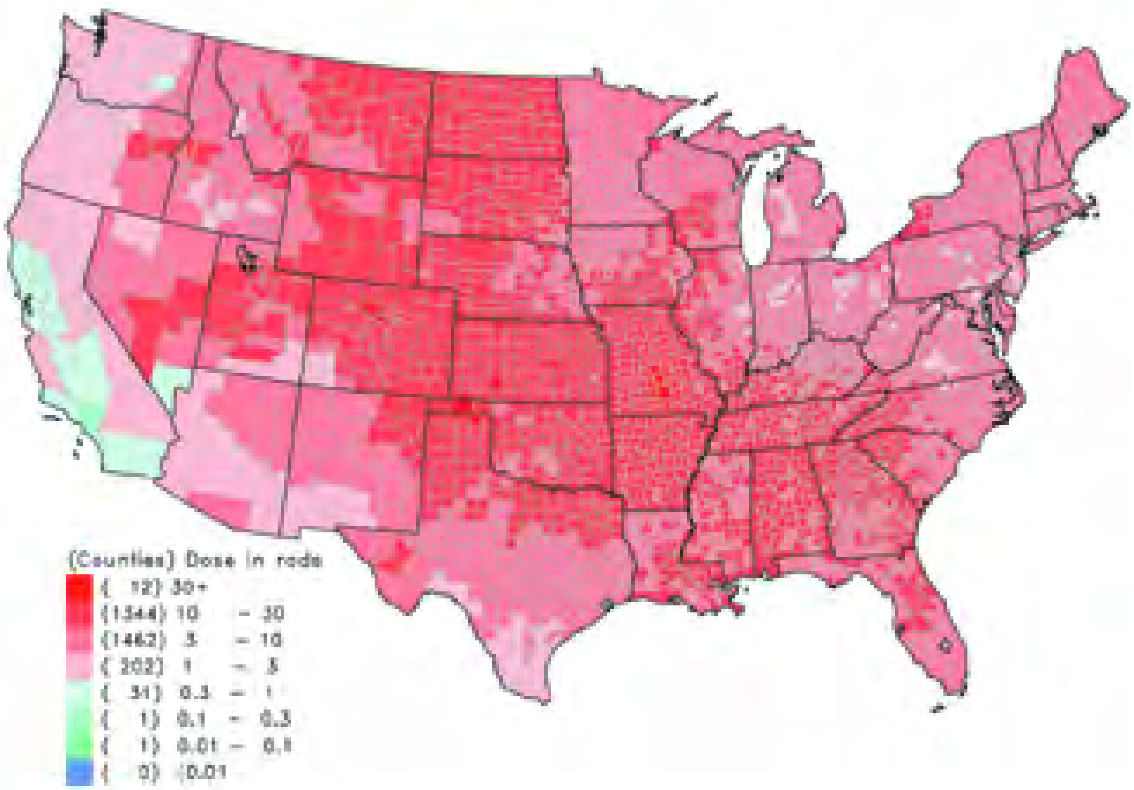


Figure 8.44. Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; no milk consumption)

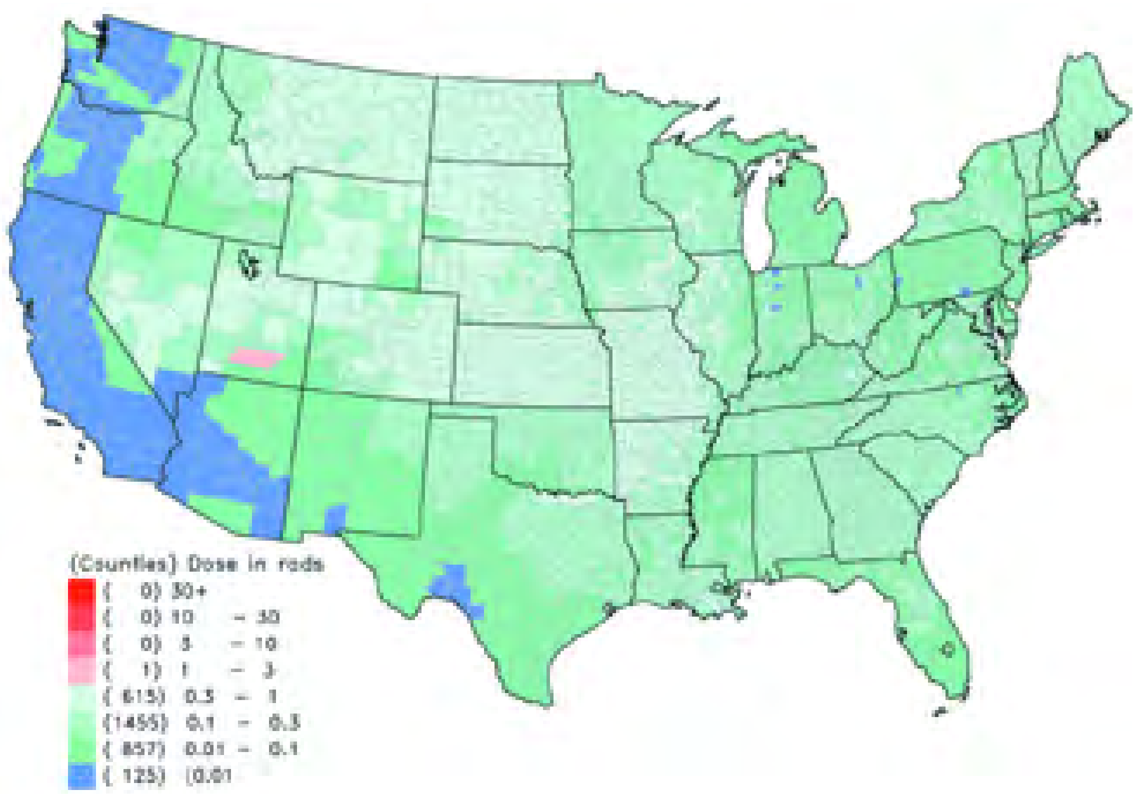


Figure 8.45. Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; average milk consumption)

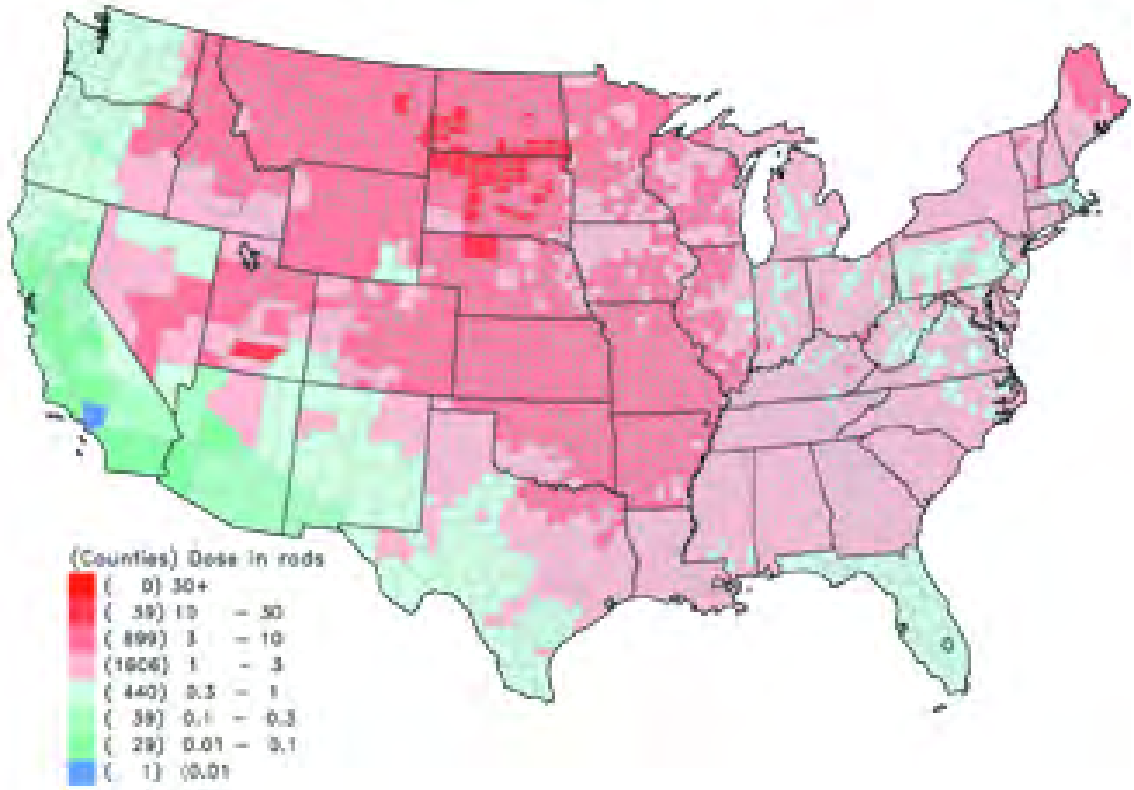


Figure 8.46. Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; high milk consumption)

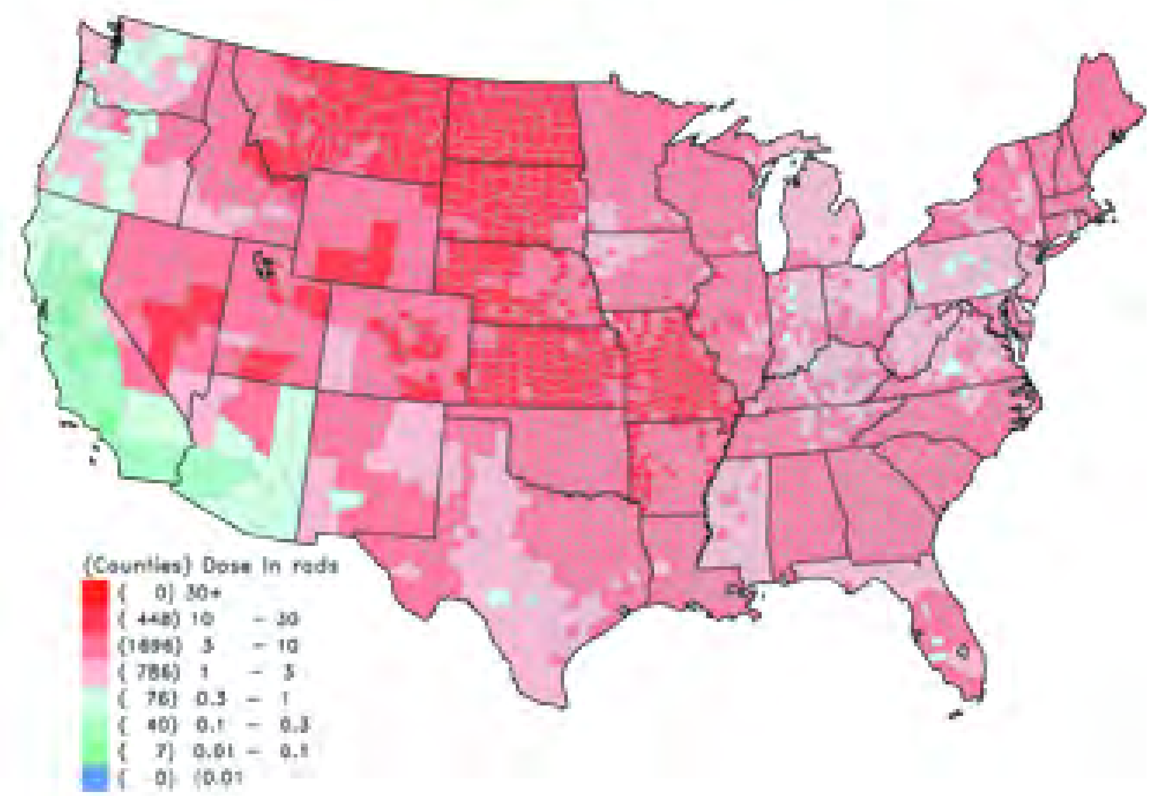


Figure 8.47. Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; milk from "backyard cow")

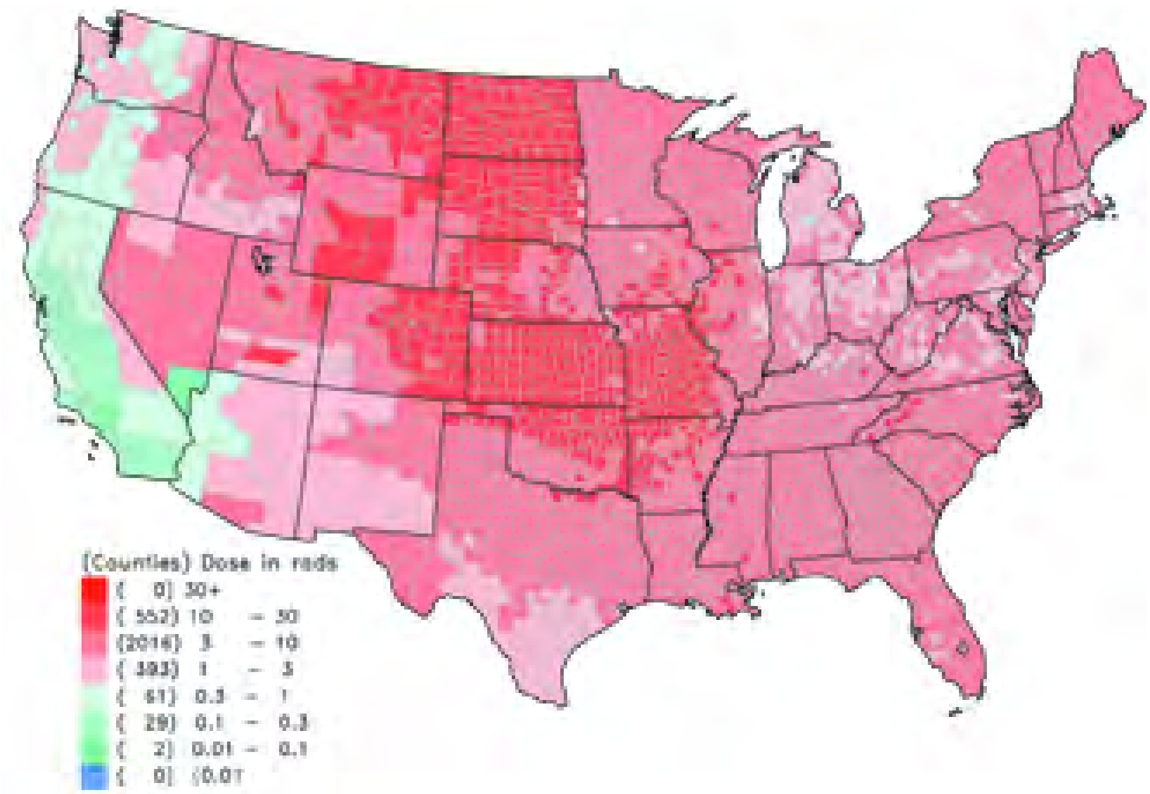


Figure 8.48. Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; no milk consumption)

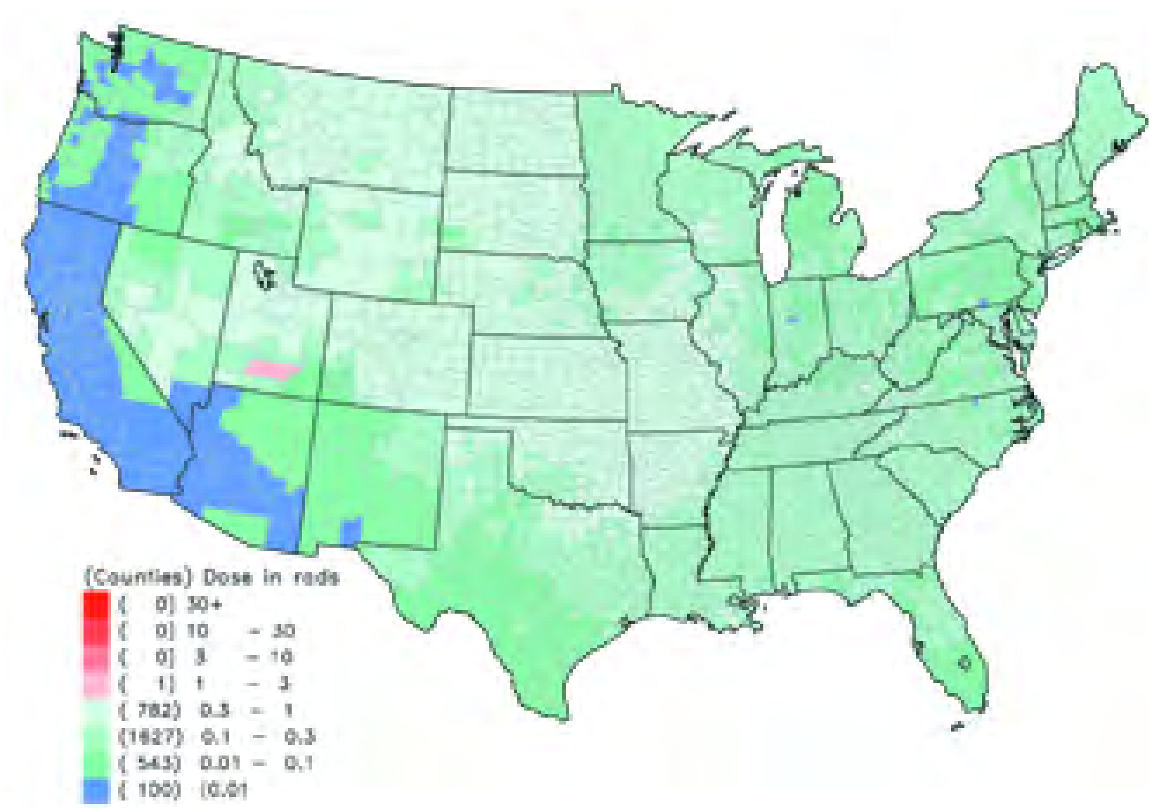


Figure 8.49. Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; average milk consumption)

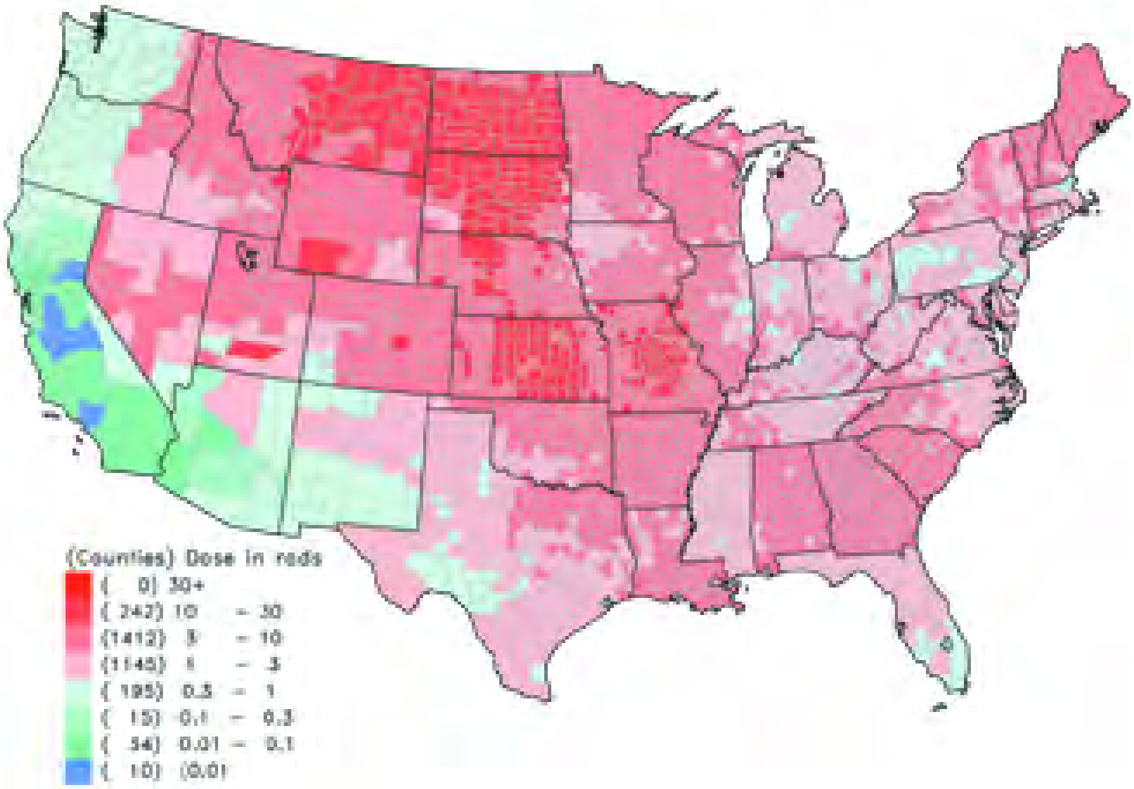


Figure 8.50. Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; high milk consumption)

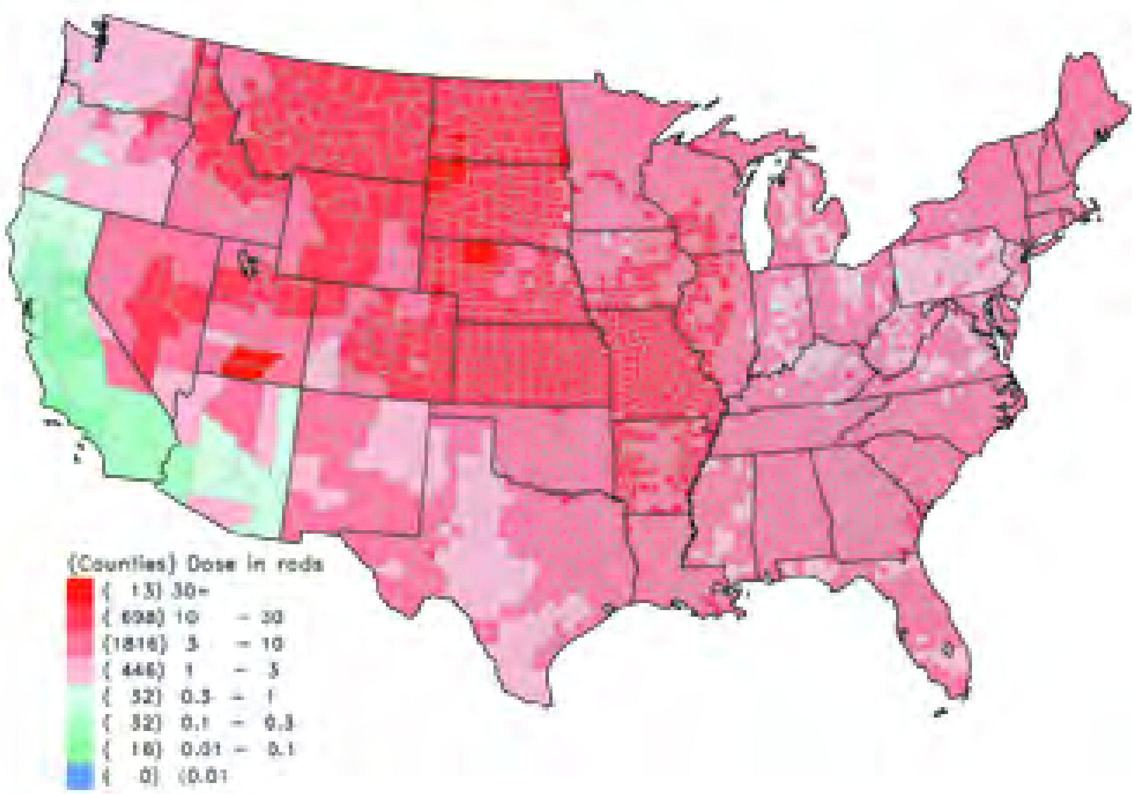


Figure 8.51. Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; milk from "backyard cow")

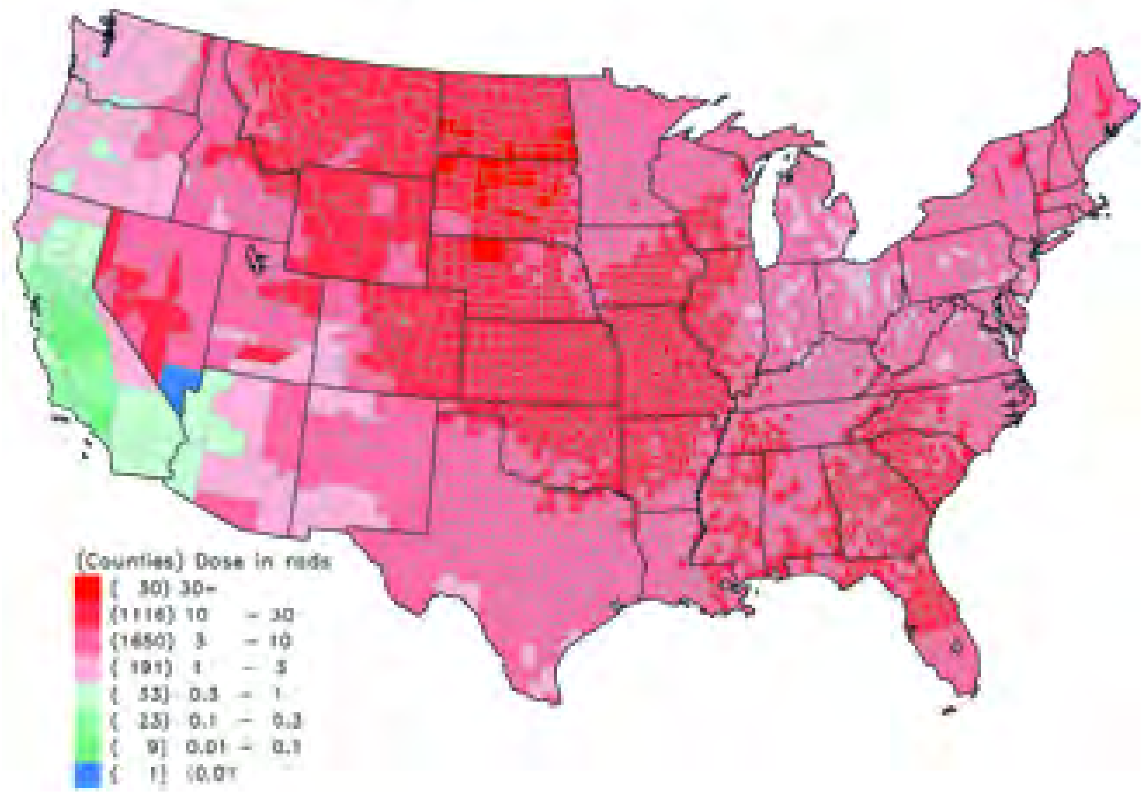


Figure 8.52. Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; no milk consumption)

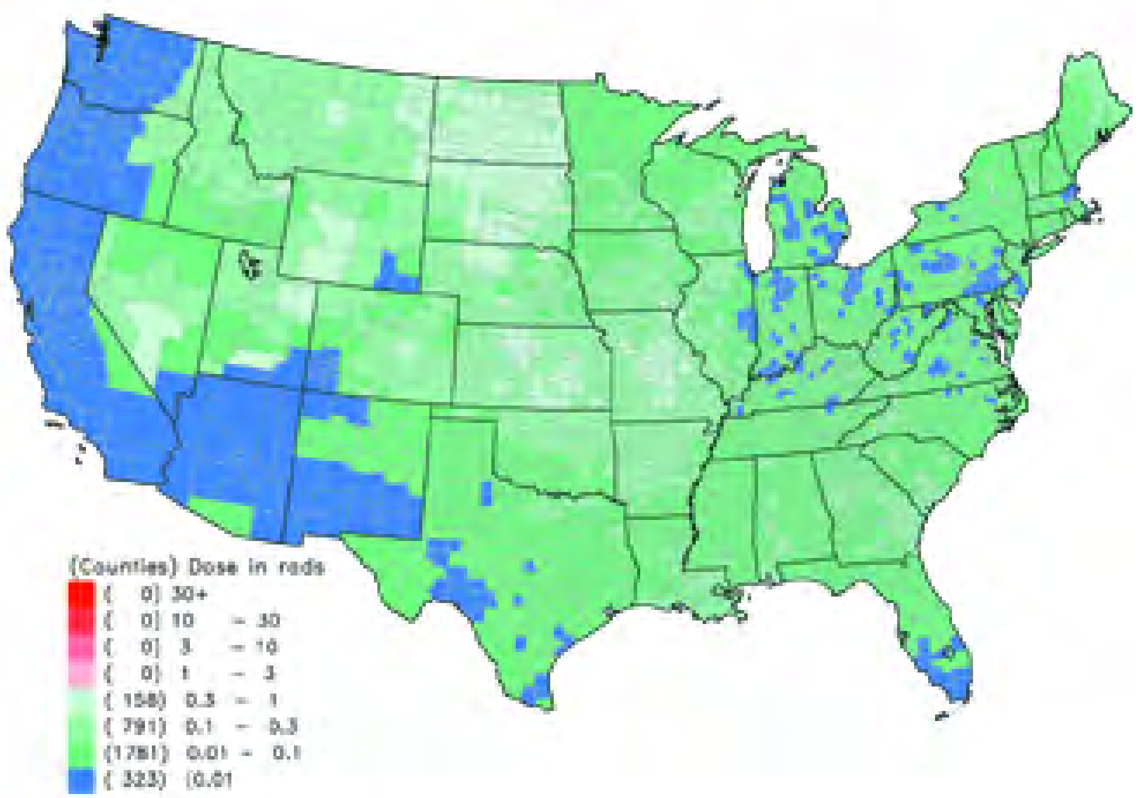


Figure 8.53. Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; average milk consumption)

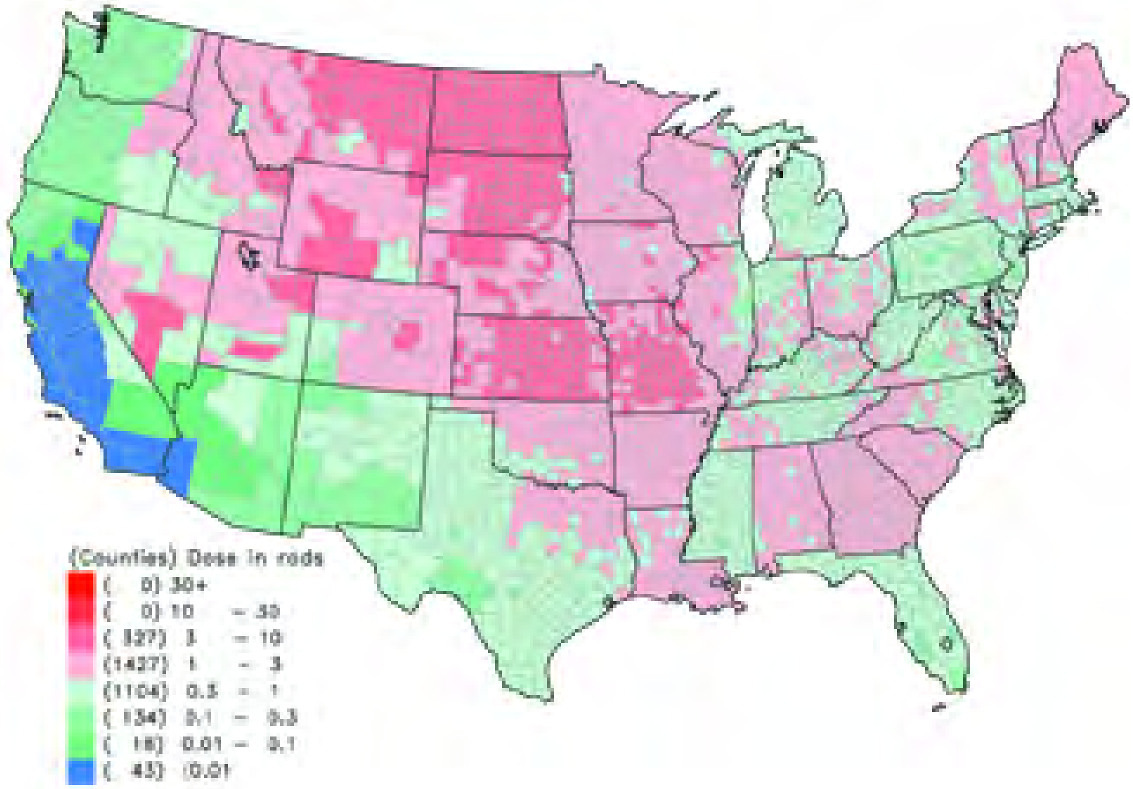


Figure 8.54. Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; high milk consumption)

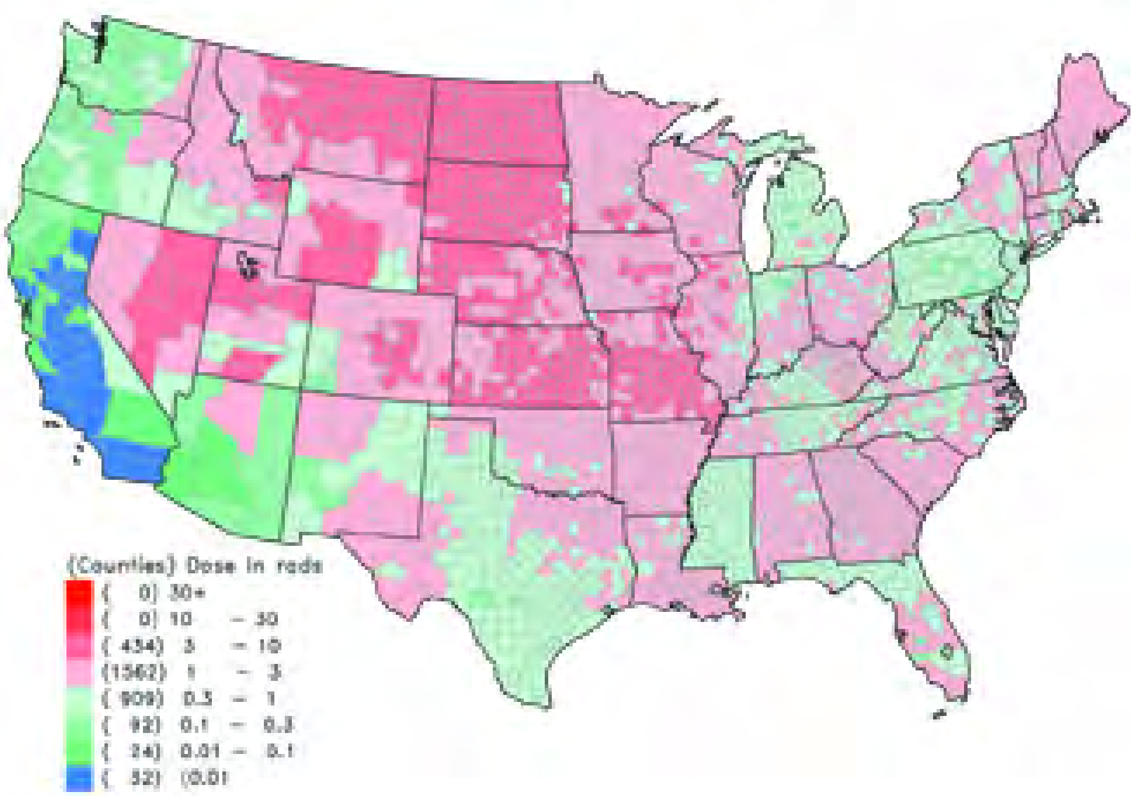


Figure 8.55. Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; milk from "backyard cow")

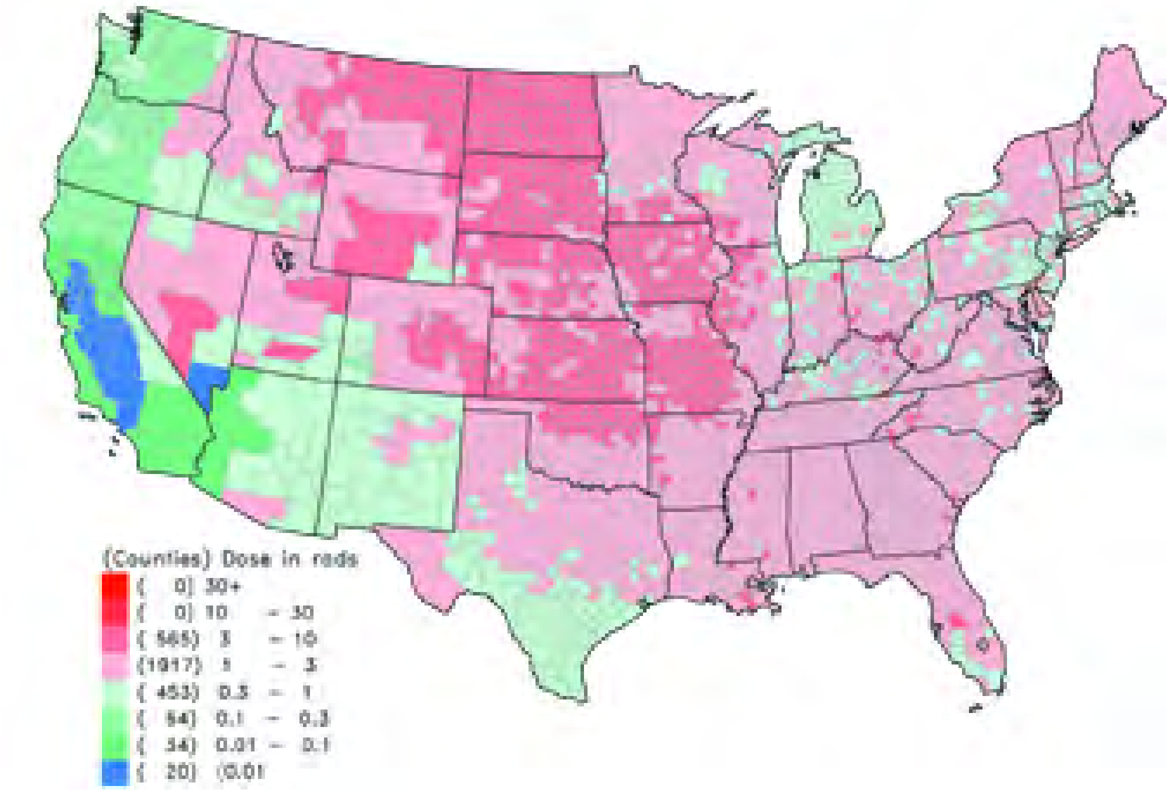


Figure 8.56. Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; no milk consumption)

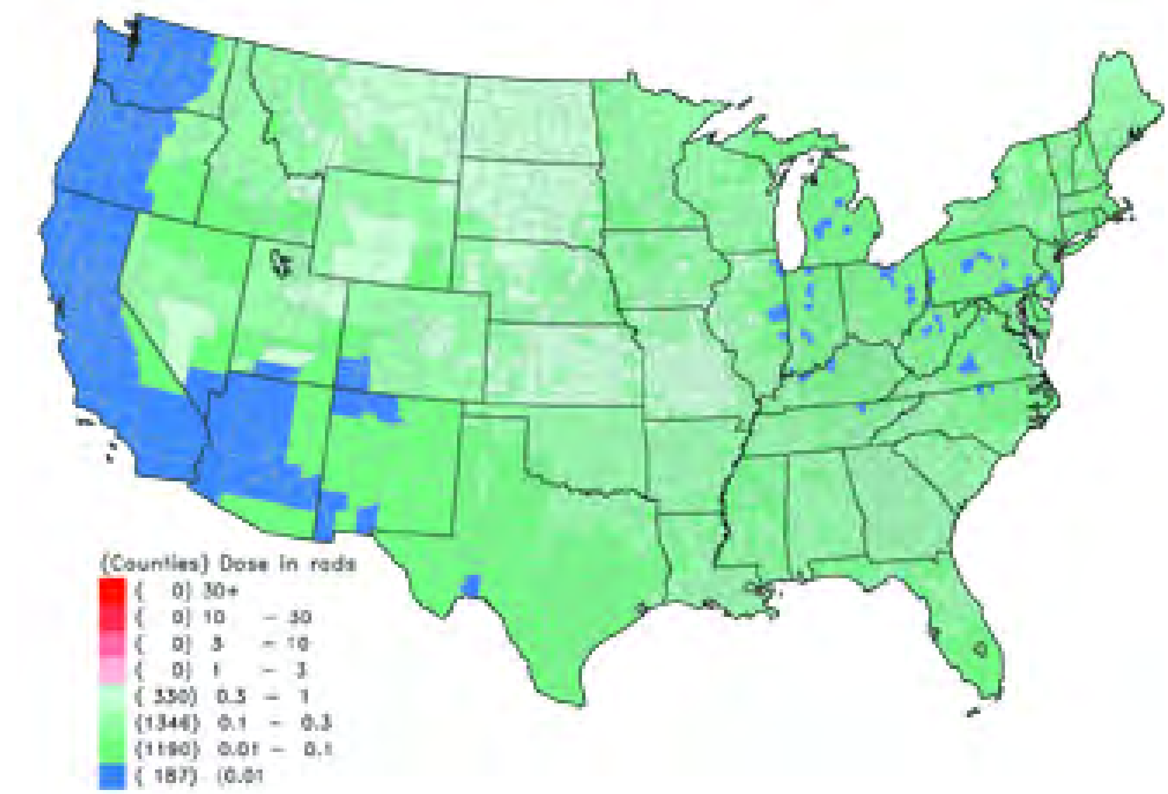


Figure 8.57. Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; average milk consumption)

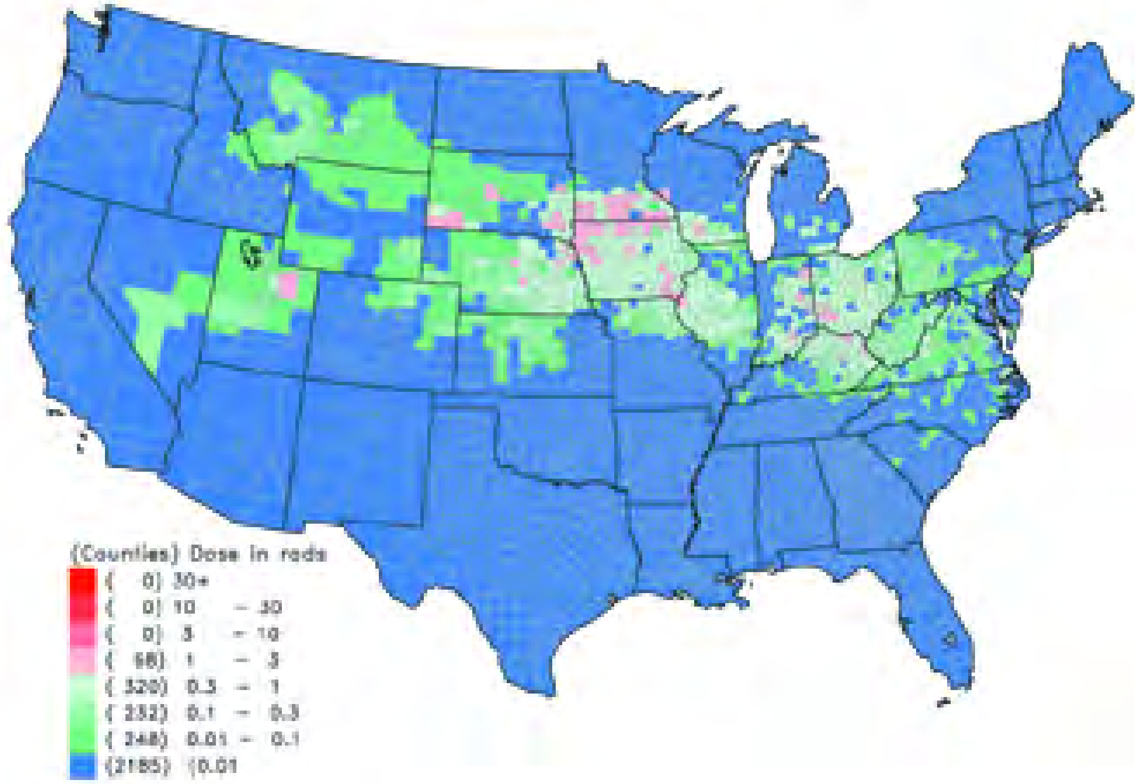


Figure 8.58. Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; high milk consumption)

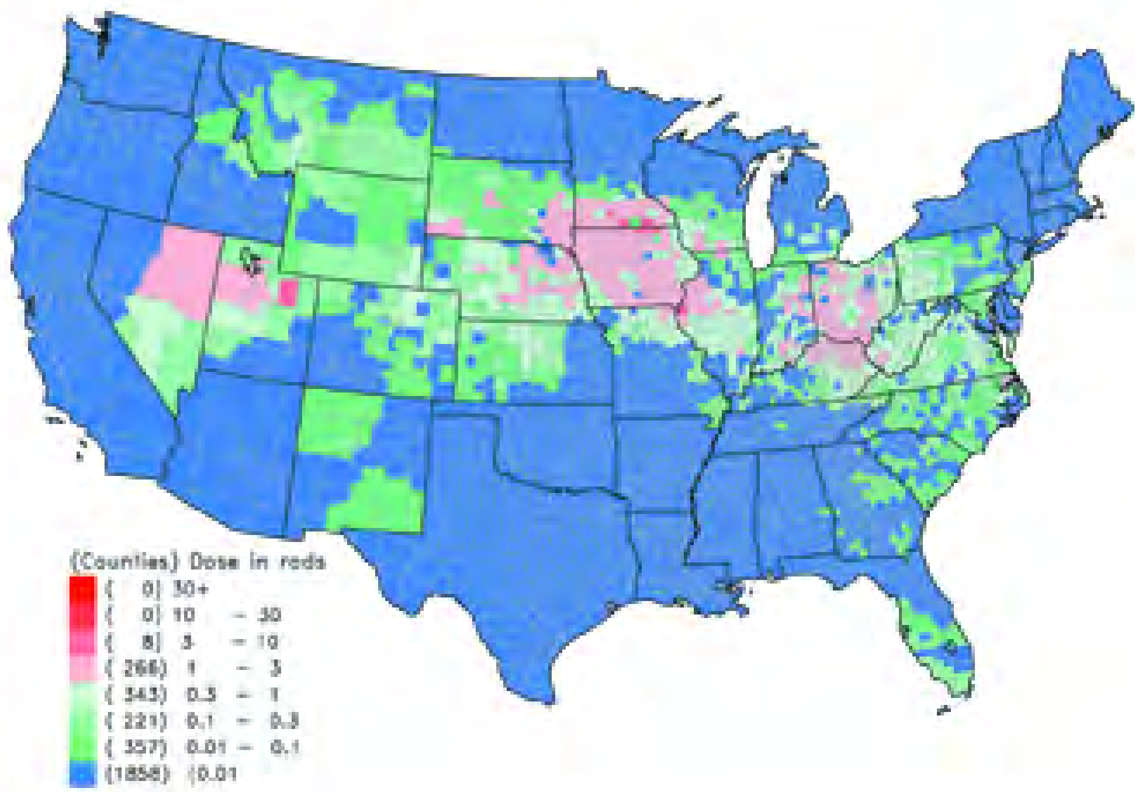


Figure 8.59. Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; milk from "backyard cow")

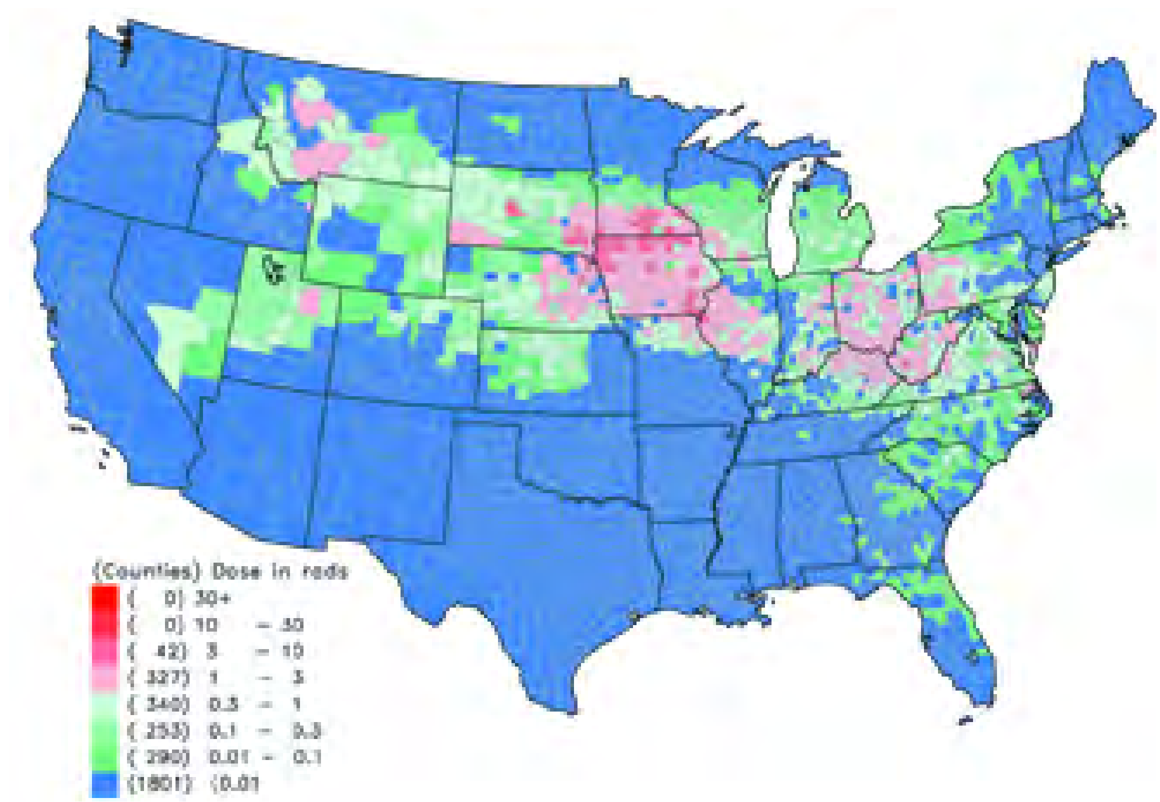


Figure 8.60. Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; no milk consumption)

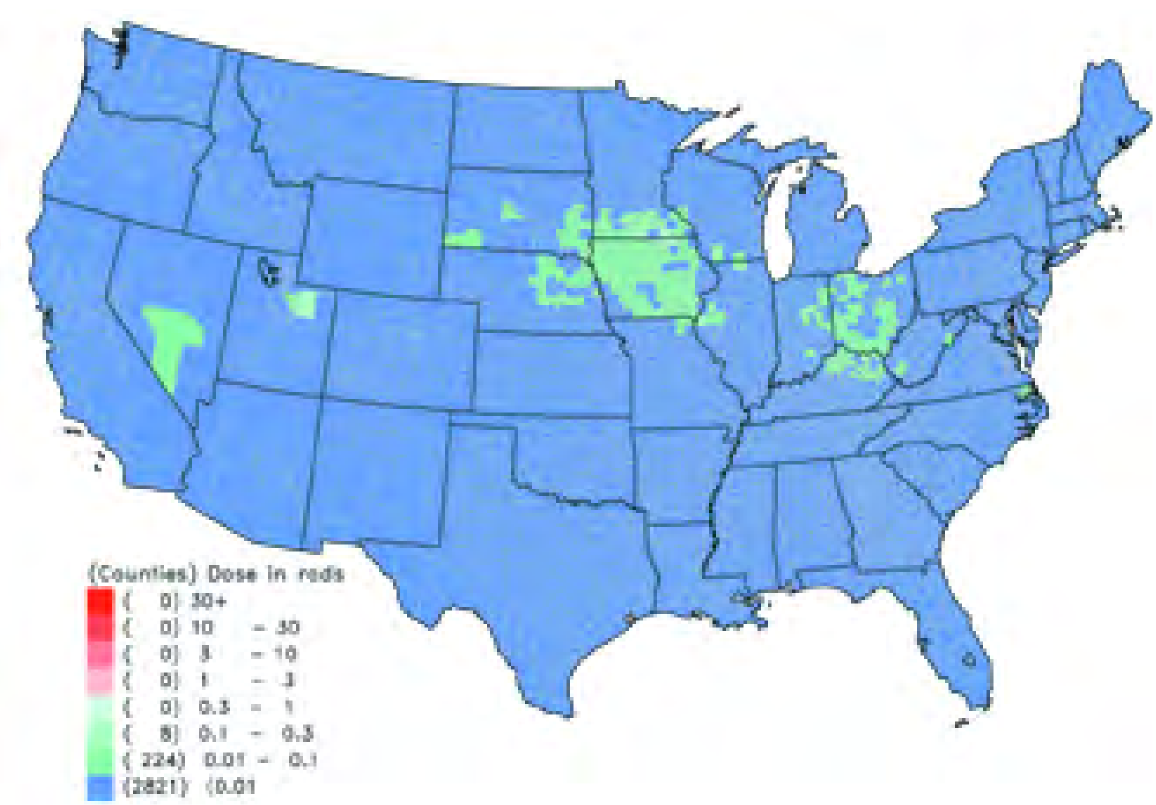


Figure 8.61. Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; average milk consumption)

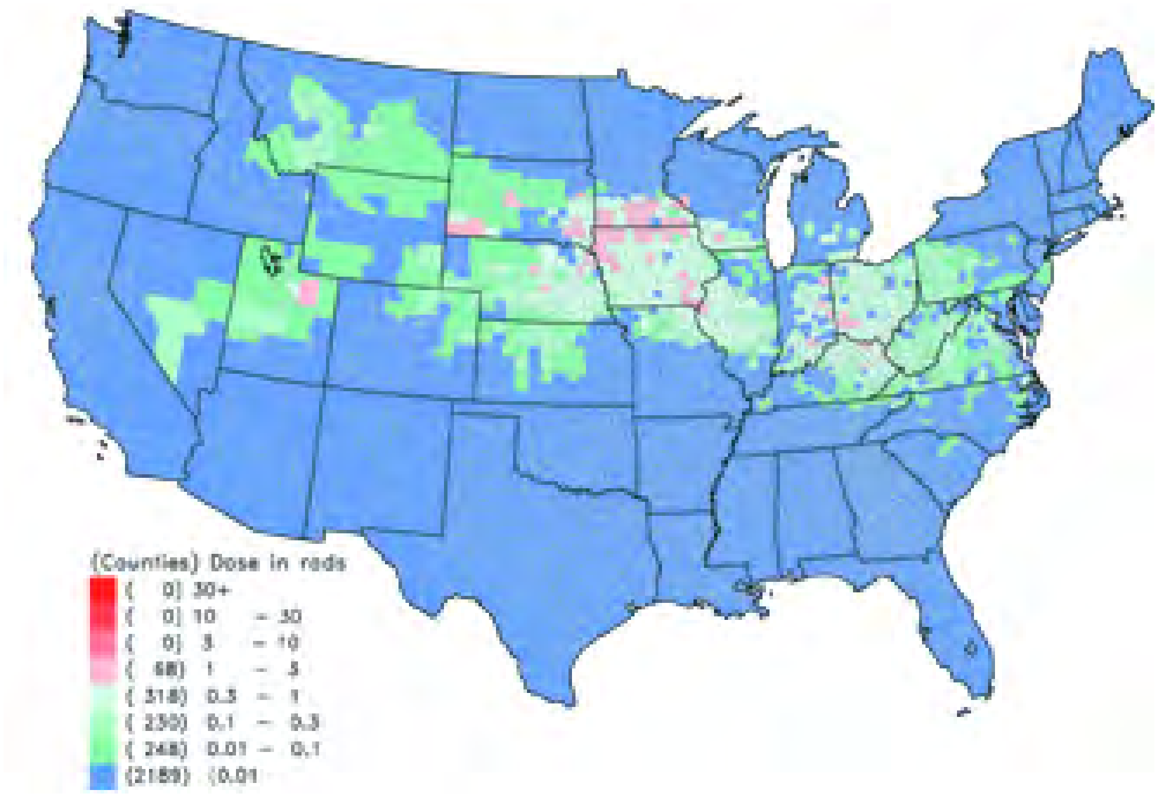


Figure 8.62. Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; high milk consumption)

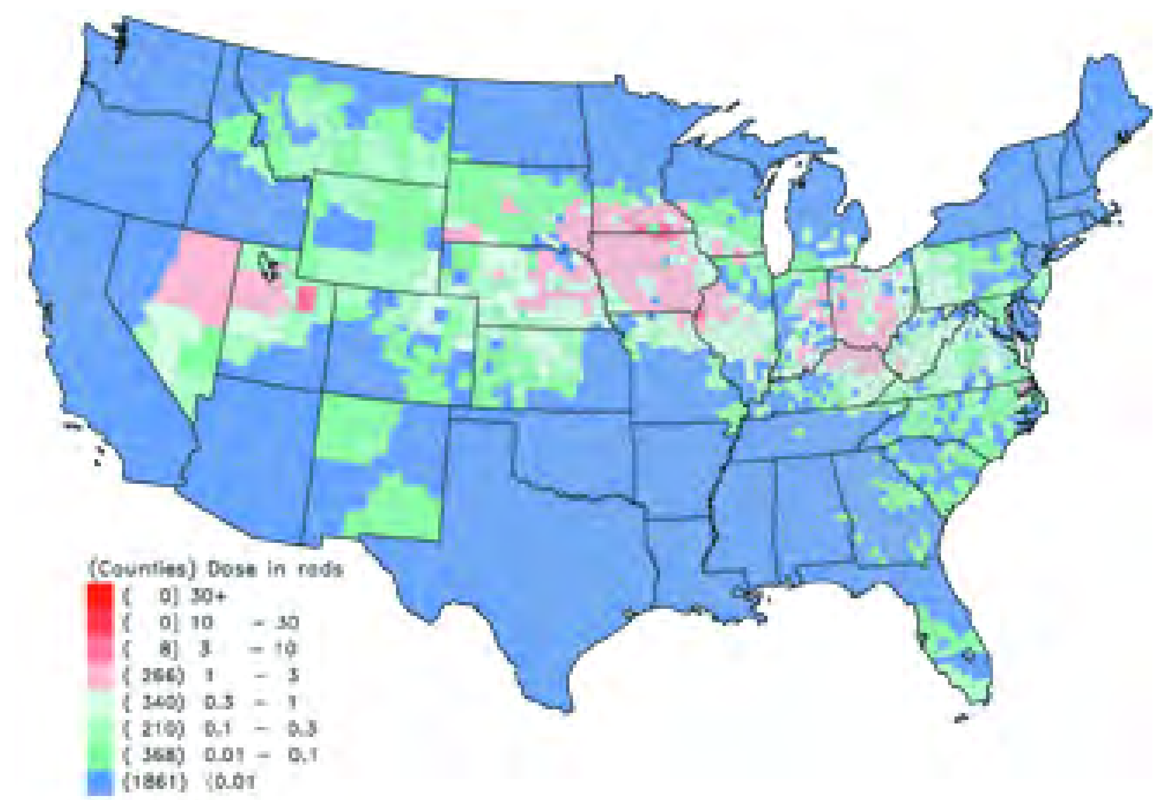


Figure 8.63. Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; milk from "backyard cow")

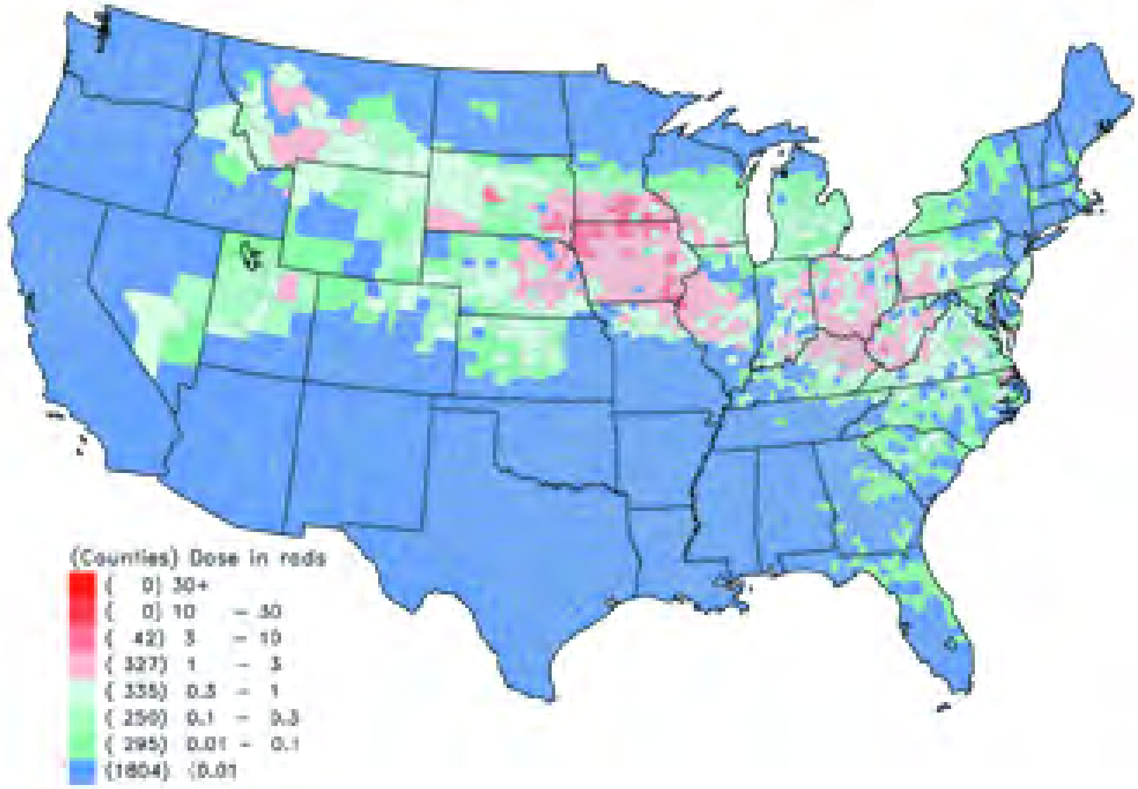


Figure 8.64. Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; no milk consumption)

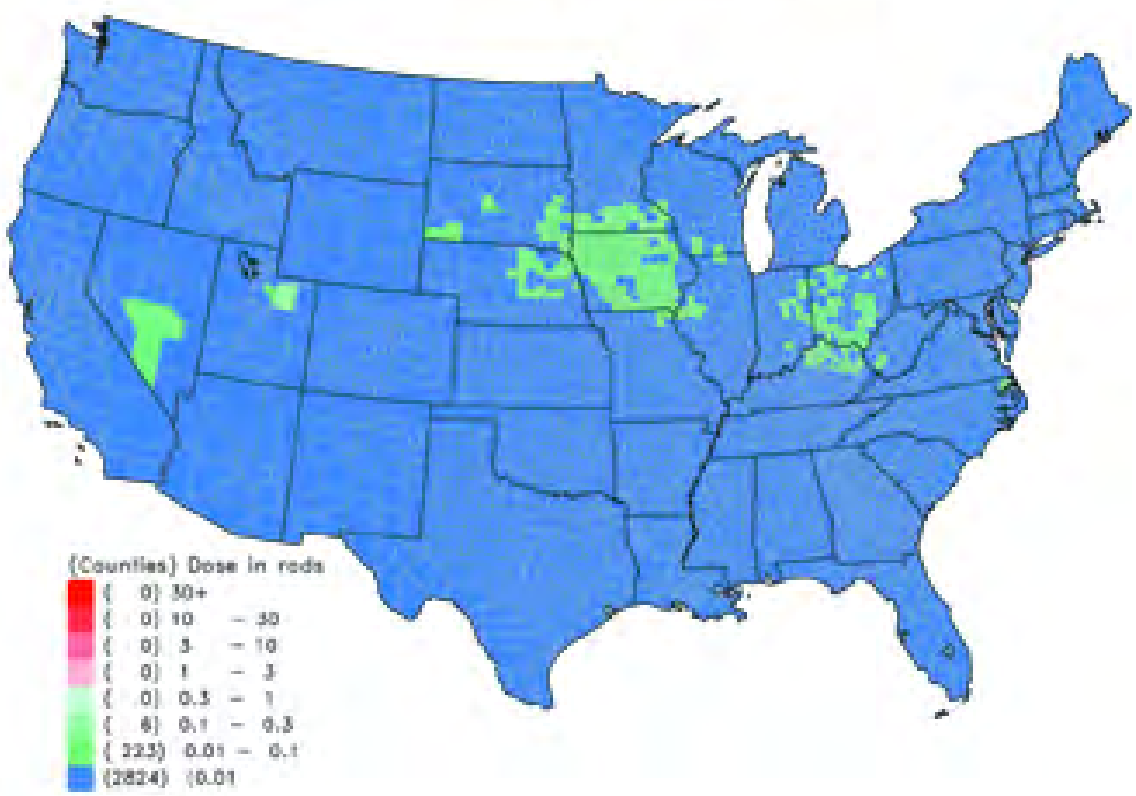


Figure 8.65. Estimates of I-131 thyroid doses for persons born on January 1, 1962 (Average diet; average milk consumption)

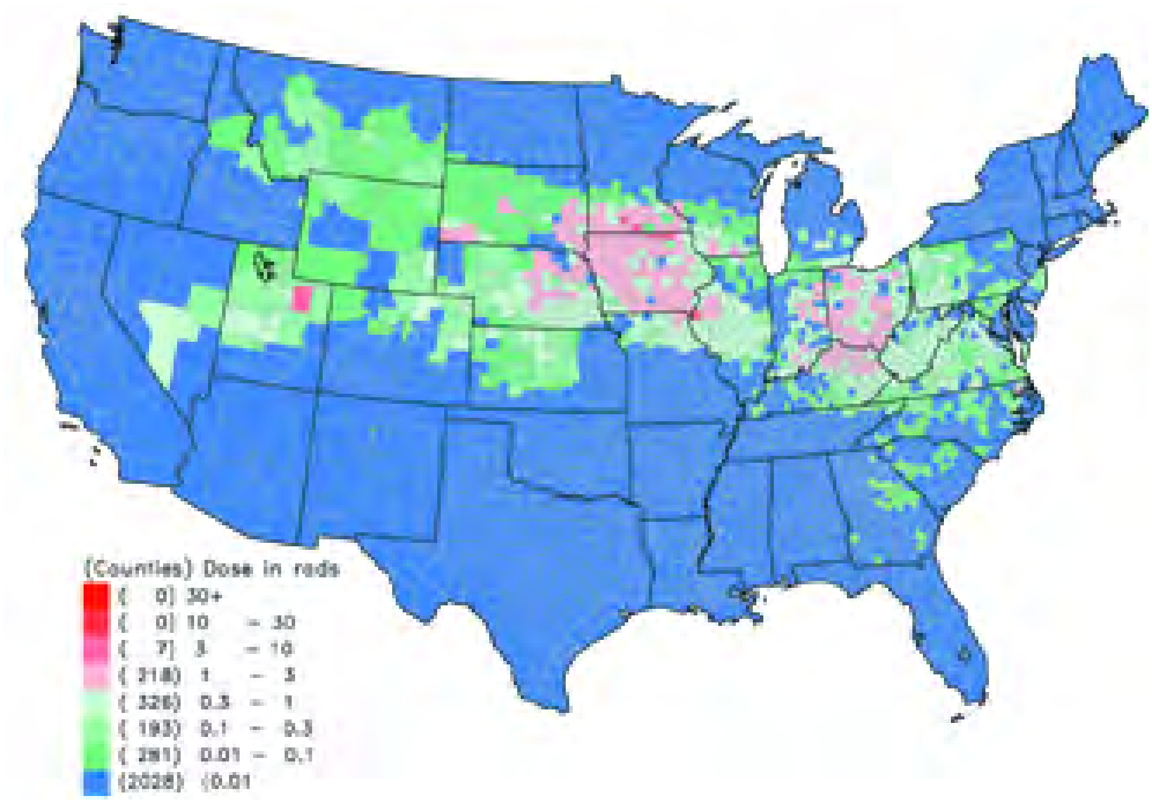


Figure 8.66. Estimates of I-131 thyroid doses for persons born on January 1, 1962 (Average diet; high milk consumption)

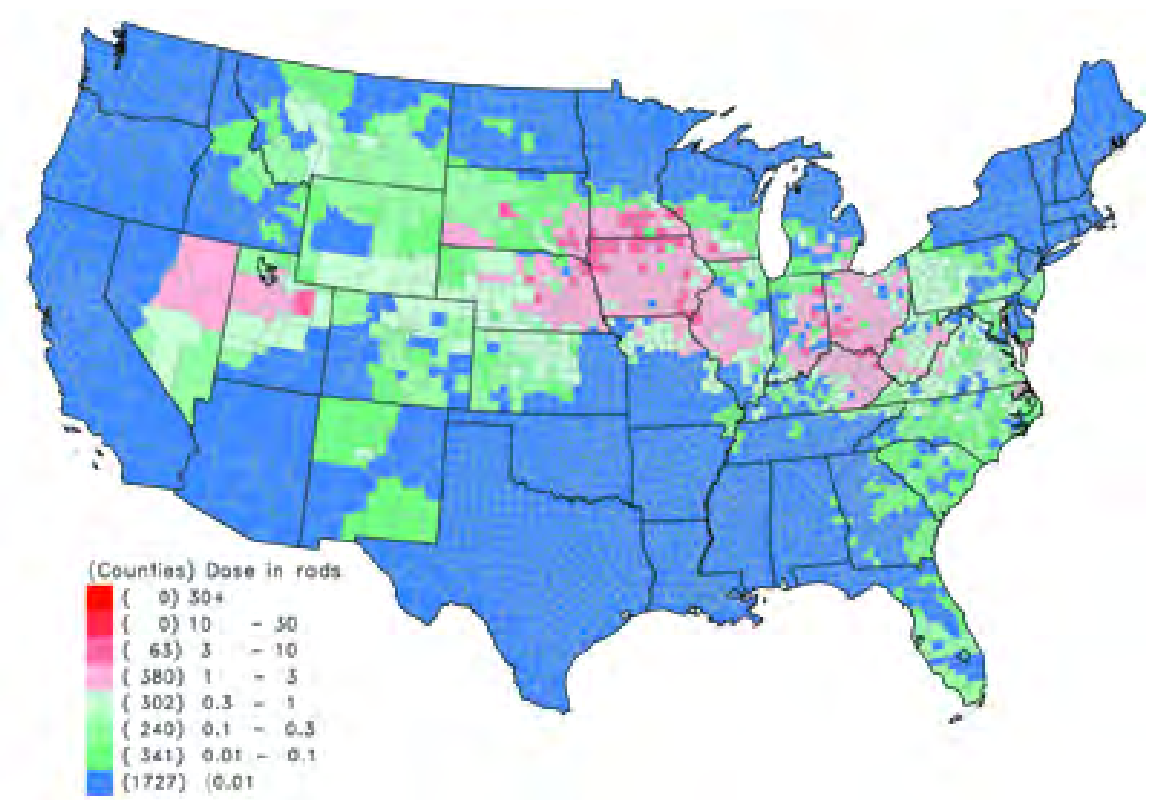


Figure 8.67. Estimates of I-131 thyroid doses for persons born on January 1, 1962 (Average diet; milk from "backyard cow")

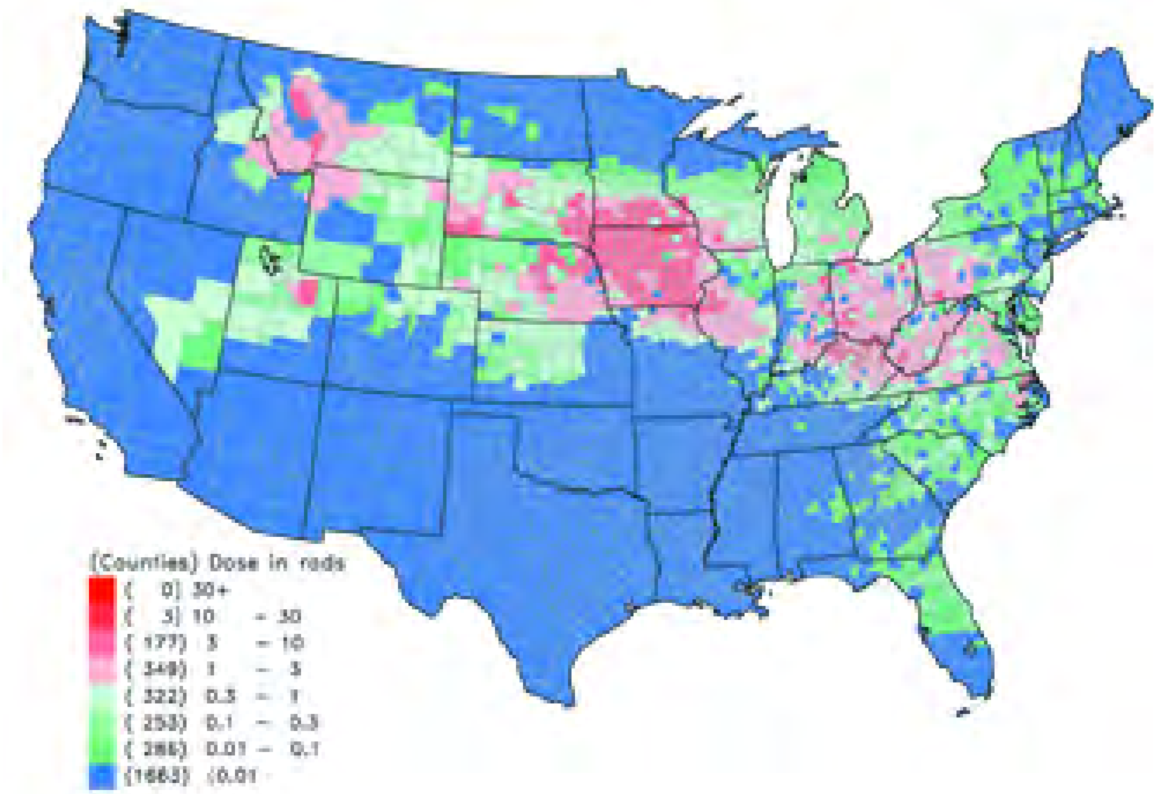
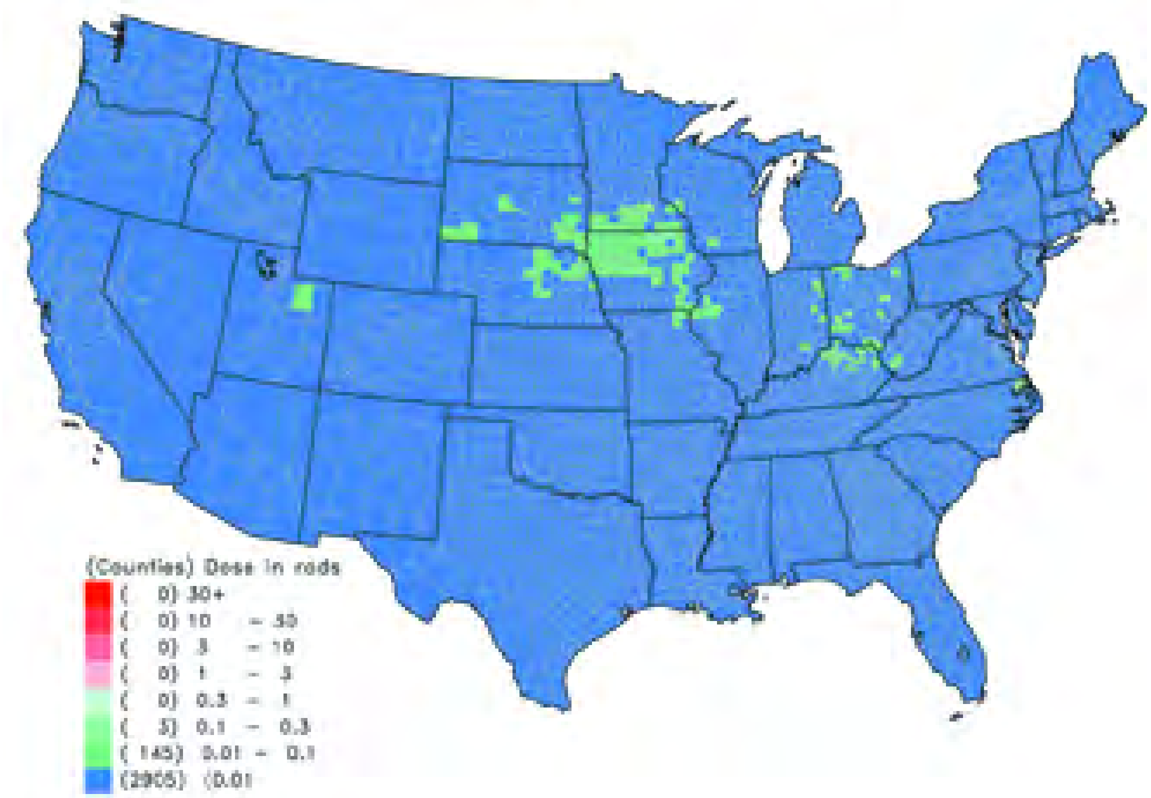


Figure 8.68. Estimates of I-131 thyroid doses for persons born on January 1, 1962 (Average diet; no milk consumption)



CONTENTS: Examples of the estimates of thyroid doses due to exposure of the American people to ^{131}I from Nevada atmospheric bomb tests are presented, compared to average thyroid doses resulting from other sources of radiation exposure.

The dose calculation methods presented in **Chapters 6** and **7** were used to estimate thyroid doses resulting from the deposition of ^{131}I in fallout from the bomb tests considered in this analysis. As was described in **Chapter 3**, many atmospheric detonations, some cratering tests, and some tests during the underground testing era have been analyzed. Thyroid doses were calculated for the population of each county divided into 13 age groups, with adults subdivided by gender (i.e., including four fetal periods, four age intervals during the first year of life, four age intervals between ages 1 and 20, plus adults). The doses to one particular fetal age group (the fetus not yet 10 weeks old) have not been reported as they are very low in comparison to those of the other age groups because the thyroid of the fetus is not formed until about the 12th week of gestation. Doses to the other 12 age groups were estimated for a variety of dietary habits pertaining to assumed milk sources and consumption patterns.

All of the ^{131}I fallout data used to make the dose estimates is contained in the Annexes and Sub-annexes to the report. There is an Annex for each test, which begins with a description of the test and contains the fallout deposition data that was obtained near the NTS and across the country in the form of maps. Detailed tabulations of the fallout data, day by day and county by county, are given in the corresponding Sub-annex. Estimates of time-integrated concentrations of ^{131}I in milk (see **Chapter 4**) due to fallout from that test are tabulated in the Annex for each of the counties and subcounties in the contiguous United States. The detailed milk concentration data were used to calculate thyroid doses from milk consumption as described in **Chapter 6**, using the consumption rates given in **Chapter 5**.

Included in the Annex also are the estimates of the time-integrated concentrations of ^{131}I in other foodstuffs (i.e., goats' milk, cottage cheese, eggs, leafy vegetables, air, and mothers' milk) that are discussed in **Chapter 7.** These estimates reflect the fallout ^{131}I distribution for the particular test and are tabulated for each county or sub-county. Estimated consumption rates for these other exposure routes also are given in **Chapter 7**, together with the dose calculation methods.

Table 8.2. Estimated collective thyroid doses to the U.S. population for each test series

Series	Dates	Collective thyroid dose (Person rad)	Percent of total
Ranger	Jan.-Feb. 1951	1.6×10^5	0.04
Buster-Jangle	Oct.-Nov. 1951	7.4×10^6	2
Tumbler-Snapper	April-June 1952	1.1×10^8	29
Upshot-Knothole	March-June 1953	8.9×10^7	24
Teapot	Feb.-May 1955	4.1×10^7	11
Plumbbob	May-Oct. 1957	1.2×10^8	32
Hardtack II	Sept.-Oct. 1958	1.6×10^2	< 0.0
"Underground era"	1961-1970	9.1×10^6	2
Total		3.8×10^8	100

Figure 8.69. Estimates of I-131 thyroid doses resulting from the test series Ranger (January - February 1951)

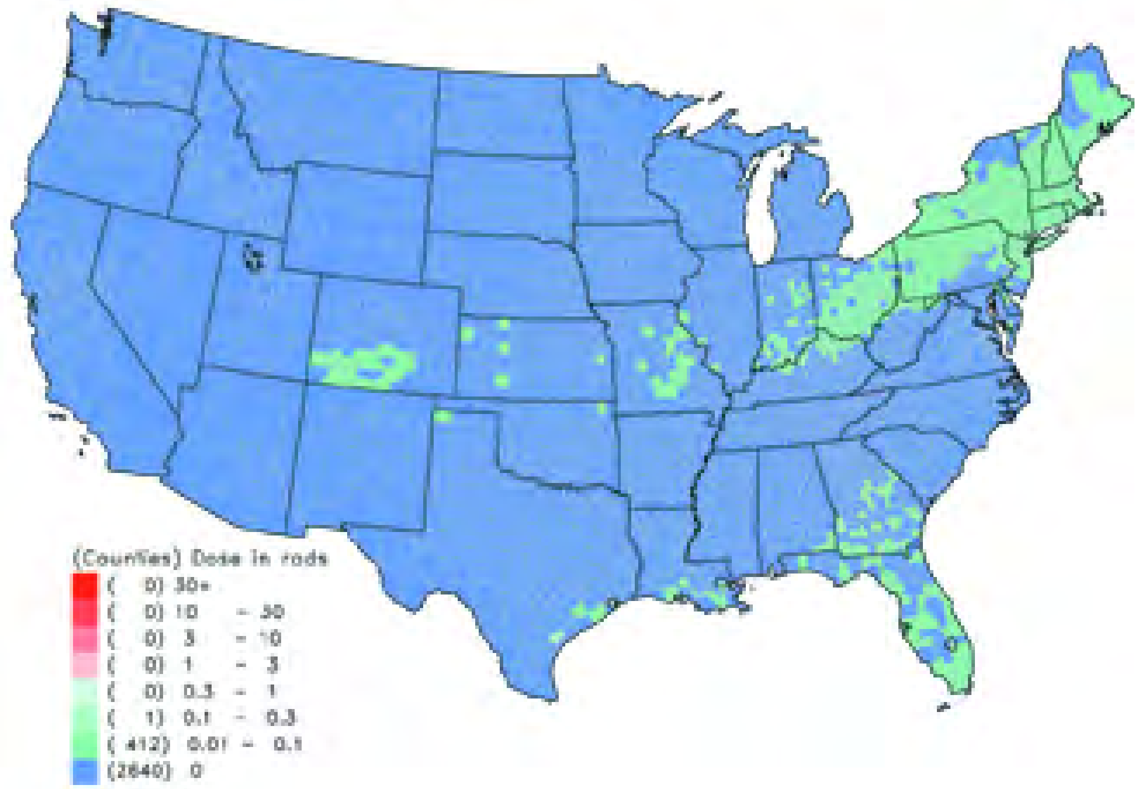


Figure 8.70. Estimates of I-131 thyroid doses resulting from the test series Buster-Jangle (October - November 1951)

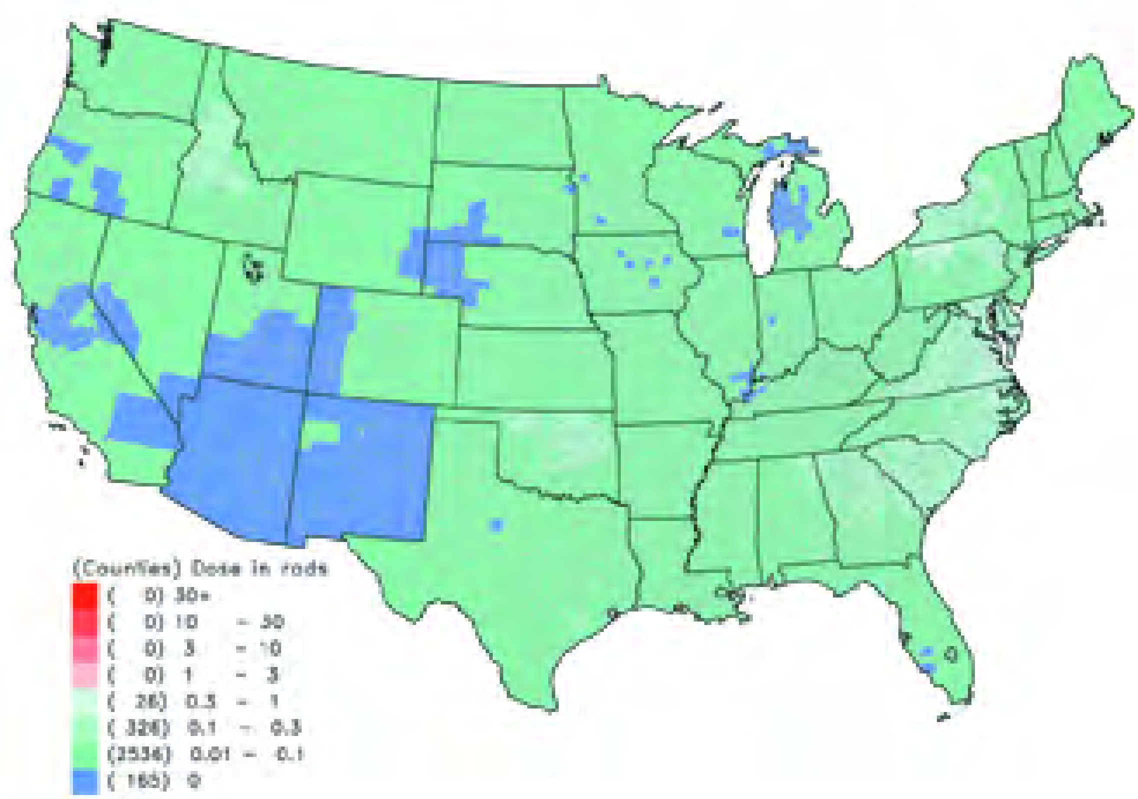


Figure 8.71. Estimates of I-131 thyroid doses resulting from the test series Tumbler - Snapper (April - June 1952)

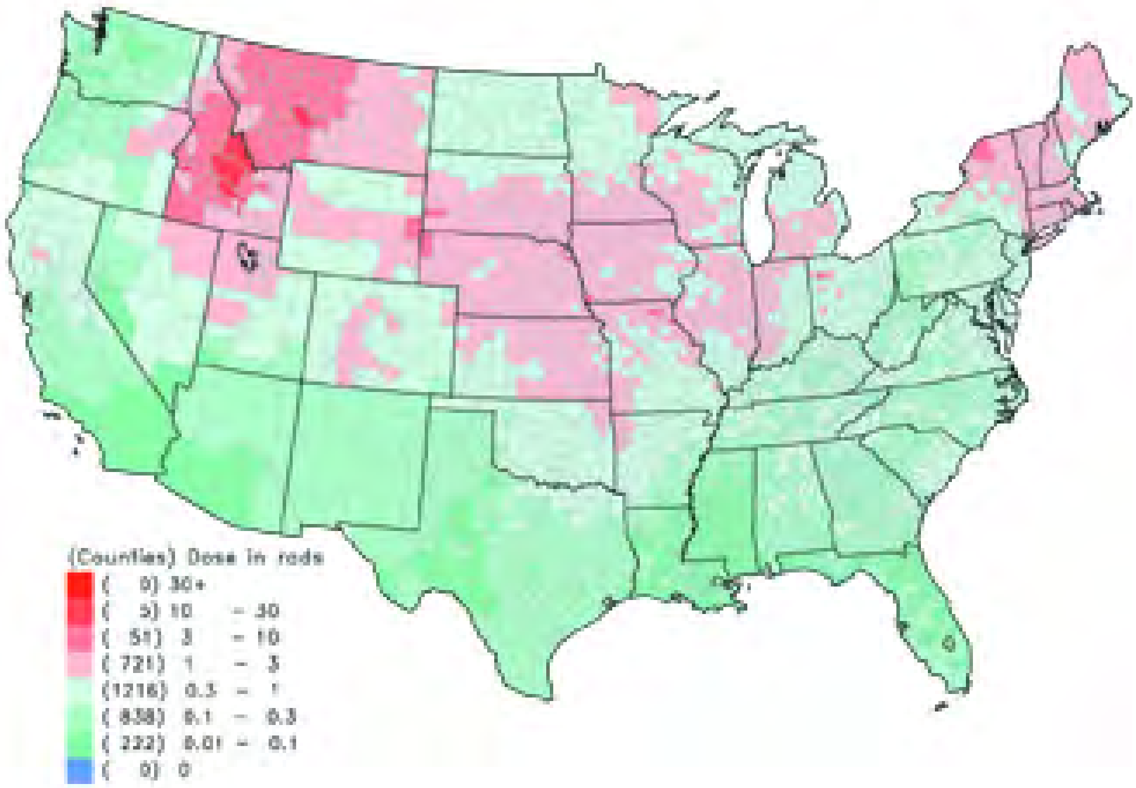


Figure 8.72. Estimates of I-131 thyroid doses resulting from the test series Upshot - Knothole (March - June 1953)

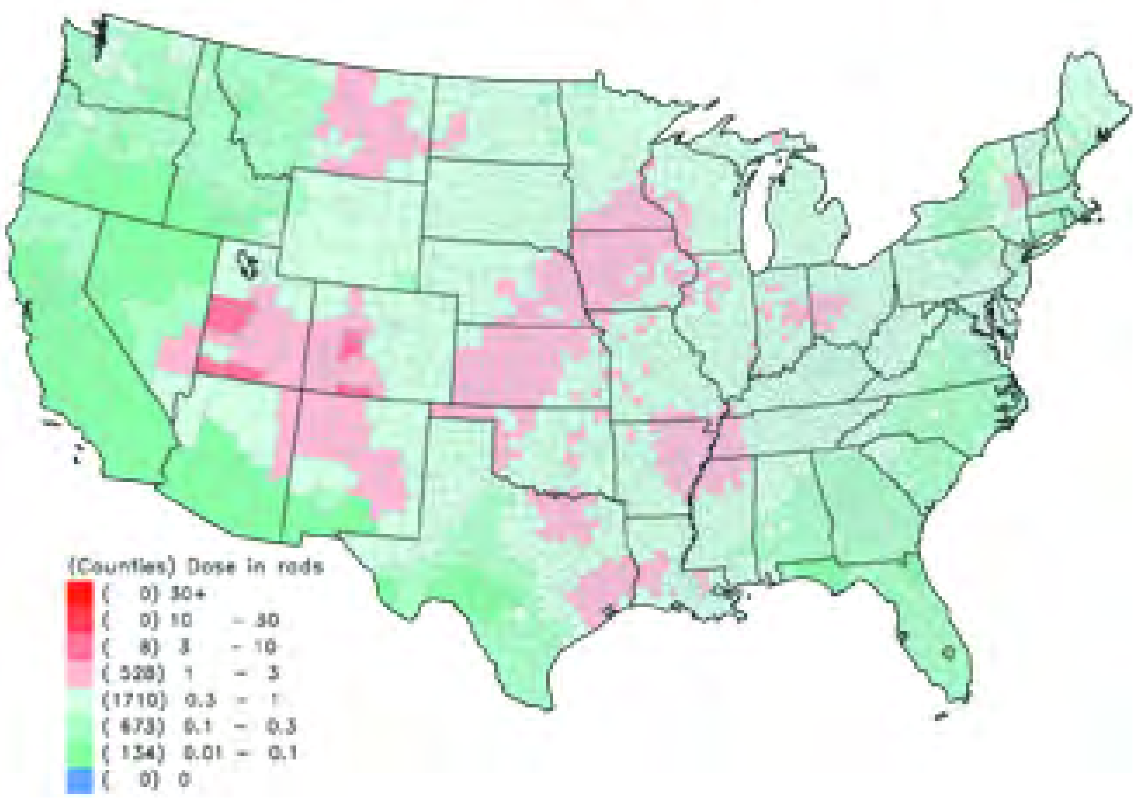


Figure 8.73. Estimates of I-131 thyroid doses resulting from the test series Teapot (February - May 1955)

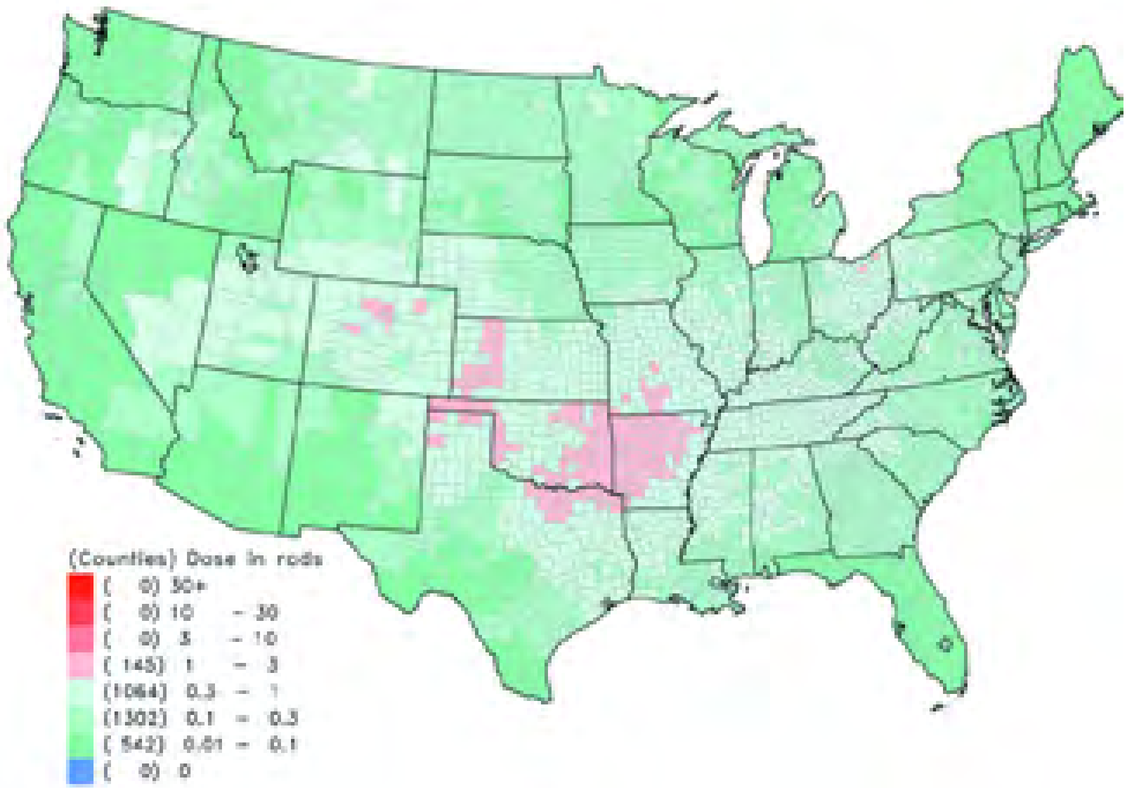


Figure 8.74. Estimates of I-131 thyroid doses resulting from the test series Plumbbob (May - October 1957)

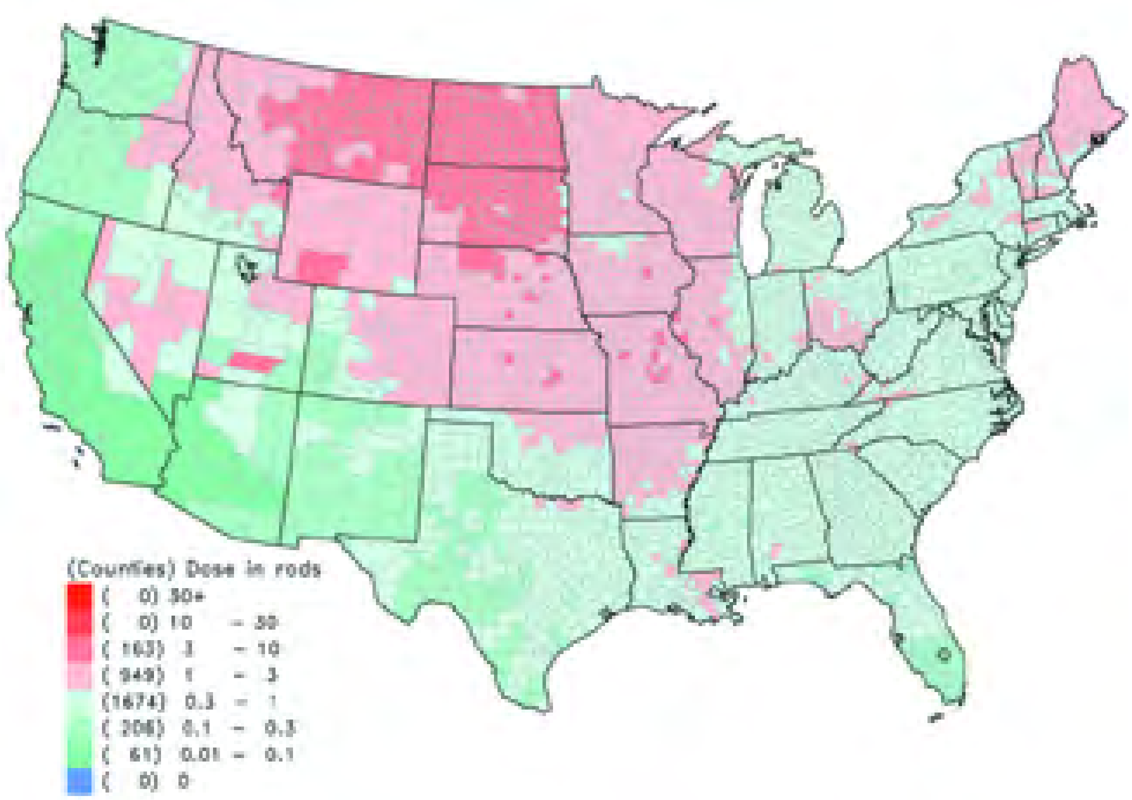


Figure 8.75. Estimates of I-131 thyroid doses resulting from the test series Hardtack - Phase II (September - October 1958)

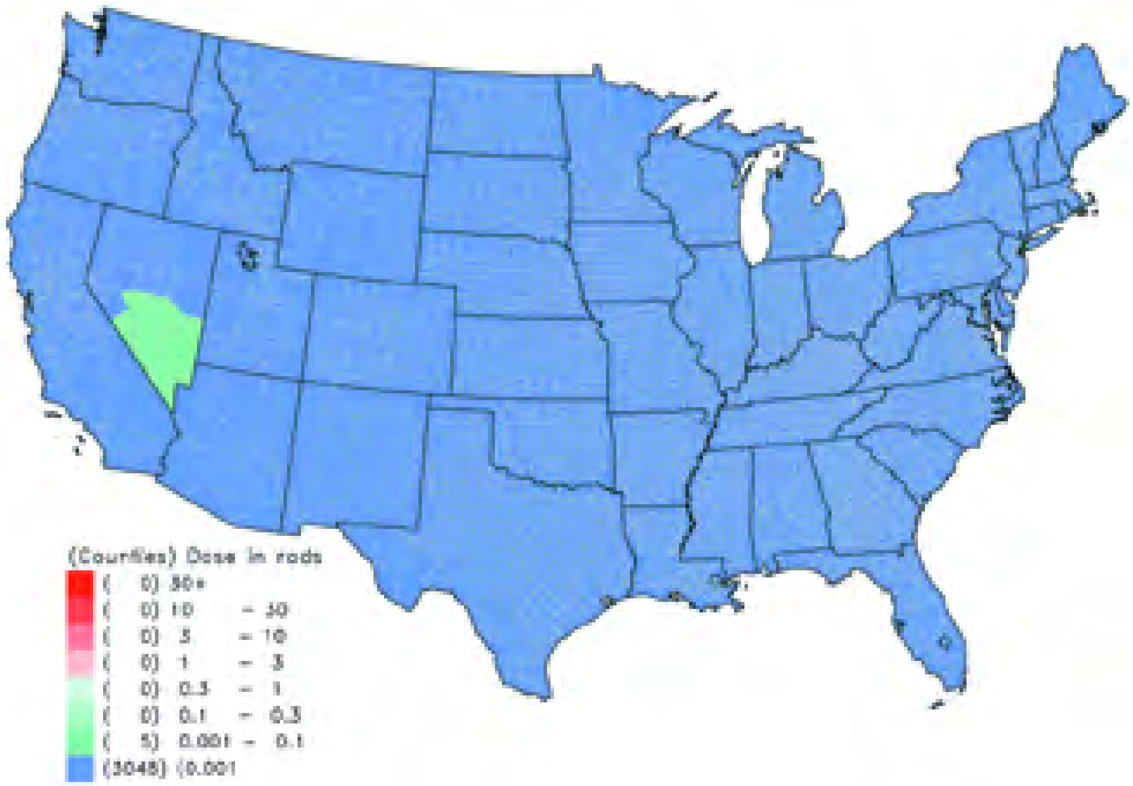
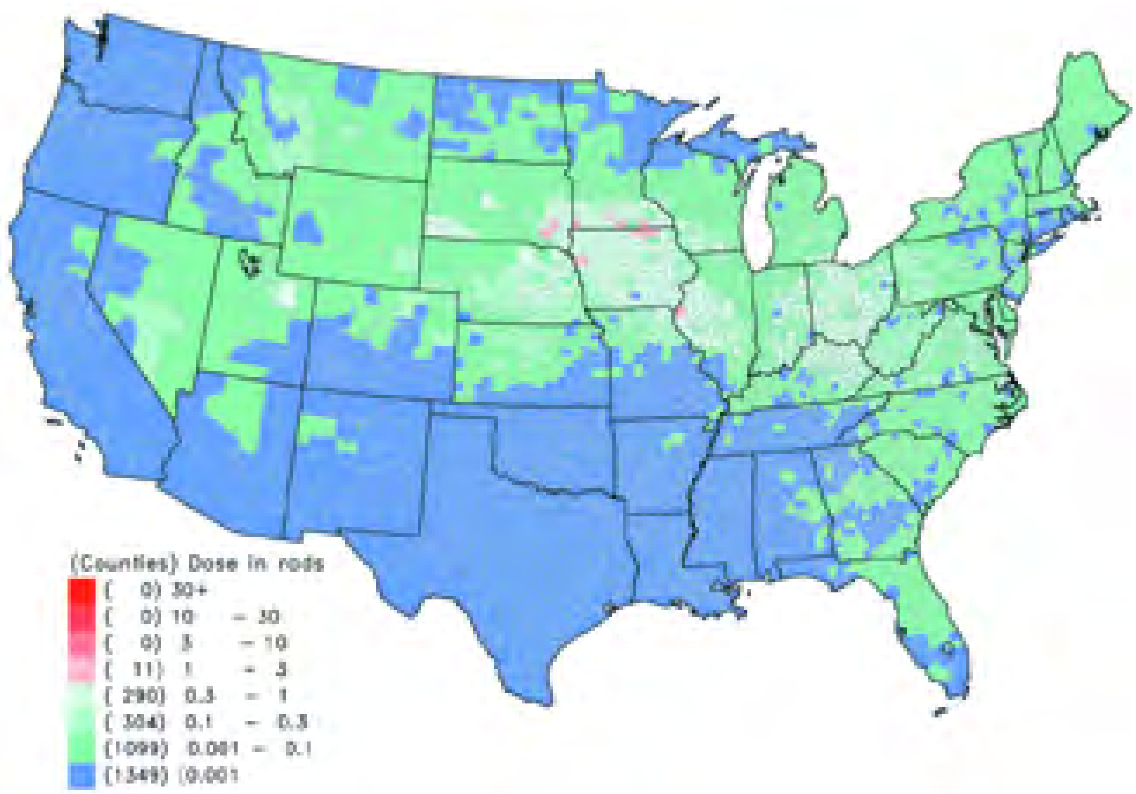


Figure 8.76. Estimates of I-131 thyroid doses resulting from the test series Underground Era (1961 - 1970)



The estimated thyroid doses resulting from the fallout from a particular test are presented in the Sub-annex for that test. (Note that the dose units are rad; 1 rad = 1000 mrad.) Per capita doses due to milk consumption and for all exposure routes are listed for each county and sub-county. The values of the geometric mean, GM, and the geometric standard deviation, GSD, are provided for doses due to consumption of milk and for doses due to intakes of milk and other foodstuffs, and for airborne contamination. A summary map of the per capita dose from all pathways is included in the Annex for the test. Included in the same table are the estimated collective doses (the sum of the doses to all age and sex groups) for each county and sub-county. The geometric mean collective dose estimates are for milk consumption alone and for all exposure pathways combined. The geometric mean collective doses for the entire country are provided at the end of the tabulation.

Each Sub-annex continues with detailed dose estimates, listed by county, for each age (and sex) group, for which dose conversion factors were developed in **Chapter 6.** There are 13 such tables. Each contains geometric mean dose estimates and the associated measures of uncertainty (the GSDs) for four dietary regimes: average milk consumption, high milk consumption, consumption of milk from a backyard cow, and no milk consumption. These regimes are discussed in **Chapter 6** and below in **Section 8.1**. The first three provide a range of possible doses from milk consumption; the fourth is an estimate of the dose from intakes of other foods and inhalation of airborne contamination. (These doses are also expressed in rad.)

The dose estimates in the Sub-annexes have been computed using the methods appropriate for a multiplicative model of parameters that are log-normally distributed. The mathematical formulas and necessary assumptions for this approach have been presented in **Chapters 3**, **4**, **6**, and **7**. In the discussion that follows, a simpler calculational procedure is described that illustrates the main components of the methodology. Each component incorporates the detailed analyses performed in the earlier chapters, to which the reader is referred for details.

8.1. ESTIMATED THYROID DOSES

The magnitude of the thyroid dose received by a person from fallout after a bomb test at the NTS depends upon the person's age, location and dietary habits. As discussed in **Chapters 6** and **7**, the thyroid dose, D, resulting from an intake of ^{131}I in fallout from a particular exposure route following a given test can be estimated as the product of:

- The time-integrated ^{131}I concentration, IC, in milk (nCi d L^{-1}) or other foodstuff (nCi d kg^{-1}) ingested or in ground-level air (nCi d m^{-3}) inhaled.
- The consumption rate, CR, of milk (L d^{-1}) or other foodstuff (kg d^{-1}) or the breathing rate, BR (m^3 d^{-1}), during the weeks following the test considered.
- The thyroid dose conversion factor, DCF, appropriate for the age or sex (mrad per nCi).

For ingestion of milk or a particular foodstuff, the equation can be written:

$$D_{food} = IC_{food} \times CR_{food} \times DCF \qquad (8.1)$$

and for inhalation:

$$D_{inh} = IC_{air} \times BR \times DCF \qquad (8.2)$$

The total dose resulting from a given test is obtained by adding the estimated mean dose from inhalation and the estimated mean doses from ingestion of the foodstuffs considered (cows' milk, goats' milk, mothers' milk (for infants), cottage cheese, eggs, and leafy vegetables).

In the absence of person-specific data, only doses to representative groups of people can be estimated with reasonable accuracy. For this reason, the doses systematically estimated in this report are for specified age groups (and for adults, both sexes) and to other population groups deemed to have received relatively high or low doses, for each county and for each test. However, the manner in which doses to specific individuals can be estimated if information pertaining to the individual is available will be illustrated using examples in **Chapter 9**.

The data necessary to estimate doses are provided as follows:

- The estimated time-integrated ^{131}I concentrations, IC, in the four categories of milk identified in **Chapter 5** (milk consumed on the farm, produced and sold in the county, originating from another county of the same milk region, originating from another milk region), plus the maximum and the volume-weighted time-integrated concentrations in those four categories of milk, as well as the ^{131}I concentrations in milk from backyard cows, are found in the Annexes for each of the test series and for each of the tests and for each of the 3,094 counties and sub-counties of the contiguous United States.
- The estimated time-integrated average ^{131}I concentrations, IC, both in the other foodstuffs of interest and in ground-level air for each of the 3,094 counties and sub-counties of the contiguous United States also are given in the Annexes for each of the tests and for each of the test series.
- The estimated average consumption rates, CR, of milk appropriate for each of the 13 age and both of the adult sex groups by state are given in *Table 5.8* of **Chapter 5**. Estimates of daily milk consumption by "high-exposure" groups in each age and sex group are given in *Table 6.4* of **Chapter 6**. The average consumption rates for the other foodstuffs of interest and for breathing rates, BR, are given in *Table 7.4* of **Chapter 7.**
- The estimated average thyroid dose conversion factors, DCF, for the 14 age and sex groups are given in *Table*

6.7 of **Chapter 6**.

Central estimates of thyroid doses (median doses) are presented in the Sub-annexes of this report for each nuclear test and for each of the 14 age and sex groups with the following consumption parameters:

- For the assessment of the estimated average dose to the population of milk drinkers of a given age and sex group in a given county:

(a) Cows' milk: average consumption rate of milk drinkers with volume-weighted average time-integrated concentration of ^{131}I.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average dose to the "high-exposure" group in the population of a given age and sex group in a given county:

(a) Cows' milk: "high" consumption rate (95th percentile, (*Table 6.4*)) drinking milk in the category having the highest time-integrated concentration of ^{131}I.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated dose to the group in the population of a given age and sex group in a given county drinking milk from backyard cows:

(a) Cows' milk: "high" consumption rate (95th percentile, (*Table 6.4*)) with the time-integrated concentration of ^{131}I in milk estimated for the backyard cow.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average dose to the "low-exposure" group in the population of a given age and sex group in a given county:

(a) Cows' milk: no consumption.

(b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average doses to the infants in the population of age 0-3 months, 3-6 months, and 6-9 months in a given county drinking mothers' milk:

(a) Cows' milk: no consumption.

(b) Mothers' milk: average consumption rate by the mother of milk having the volume-weighted average time-integrated concentration of ^{131}I.

(c) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

(d) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

A series of maps that illustrate the effects of location, age, and diet on the estimated thyroid doses (in rad) are provided for the convenience of the reader. These maps cover the contiguous United States, but the level of detail differs slightly from that in the Sub-annexes. The sub-counties in Nevada, Utah, California and Arizona are not shown separately in the maps; results for a population-weighted composite are shown. The five boroughs of the city of New York have also been combined, as have several small counties in Virginia. The resolution of the printed maps and ordinary visual acuity limit the level of detail that can be presented in the map format.

The maps illustrate the estimated thyroid doses (in rad) to persons who resided in the same county throughout the period (January 1951 through December 1970) when the tests considered in this analysis were conducted. The total doses were computed using the methods described in **Chapters 6** and **7**, as appropriate. The results shown reflect changes in the person's age during this time period, including associated changes in consumption rates and in the dose conversion factor.

Table 8.1 is a guide to the set of maps that is intended to help readers identify the maps of greatest interest to them, depending upon their dates of birth. The first four maps, *Figures 8.1* through *8.4*, show the estimated doses to males who were adults when testing began in 1951. There are clear differences as a function of the four milk consumption scenarios presented above.

For persons in this age group who drank milk, differences between the doses to men, shown in *Figures 8.1* through *8.3*, and those to women (not shown) are small. The doses to women are about 10% higher. For persons who did not drink milk, the doses shown in *Figure 8.4* for men also are about 10% lower than corresponding doses to women. Considering the uncertainties in the dose estimates and the width of the dose categories in this figure, differences of 10% are not significant and *Figures 8.1* through *8.4* may also be applied to women.

Other groups of maps show similar information about dose as a function of residence and milk consumption for persons of various ages during the period of interest.

The next set of maps *Figures 8.5* through *8.8* is for persons who were 16 years old when testing began at the NTS in 1951 and who were teenagers or young adults during the period of highest fallout. *Figures 8.9* through *8.16* provide dose estimates for those persons who were ages 11 and 6, respectively, at the start of the testing program in 1951. Persons born in 1950-1957 or later years were young children throughout the highest fallout years (1952-1957) and received generally higher doses. Those born in 1958 and in later years were, generally speaking, exposed to lower amounts of ^{131}I and received lower doses than those born earlier in the decade. Of course, this generality must be tempered by consideration of the county of residence because the general pattern does not apply universally.

8.2. ESTIMATED COLLECTIVE THYROID DOSES

The estimated collective thyroid dose received by the population of the entire U.S., CD(US), from ^{131}I deposition after a given test can be calculated as the sum of average doses, D, over the population, POP, in each age and sex group, k, and each county, i:

$$CD\,(US) = \sum_{i,k} D\,(i,k) \times POP\,(i,k) \qquad (8.3)$$

As an example collective dose for Simon for all exposure routes is estimated to be about 2 x 10^7 person rad.

The total collective dose to the population of the United States from all atmospheric bomb tests detonated at the Nevada Test Site is estimated to be about 4 x 10^8 person rad (*Table 8.2*). The estimated per capita thyroid dose is about 2 rad. The greatest contribution to the total collective thyroid dose is estimated to have been due to the tests of the Plumbbob series (32%), followed by the tests of the Tumbler-Snapper series (29%) and the tests of the Upshot-Knothole series (23%). The collective doses for each test, total and by county, are tabulated in the Sub-annex for that test.

The per capita doses estimated to have been received by the populations of each county as a result of the test series Ranger, Buster-Jangle, Tumbler-Snapper, Upshot-Knothole, Teapot, and Plumbbob are shown in *Figures 8.69* through *8.76*. The data are presented in tabular form in the Sub-annexes, along with the collective doses. Per capita doses for the population of each county of the contiguous U.S. are presented, for each test, in the form of a map in the Annex for that test.

8.3. OTHER SOURCES OF THYROID DOSES

The internal thyroid doses from ^{131}I in NTS fallout that are calculated in this report are the main component of the total thyroid doses that the American people received from fallout from testing at the NTS. Other exposure routes such as external irradiation contributed somewhat to the thyroid dose from ^{131}I resulting from NTS fallout. Using information from UNSCEAR (1977) the per capita thyroid dose is estimated to be about 0.05 rad for the population of the U.S.

Other radioactive isotopes of iodine (e.g., ^{133}I and ^{132}I) also were present in NTS fallout and irradiated the thyroid, but their physical half-lives are such that the resulting doses were much lower, by a factor of 10 or more, than those delivered by ^{131}I. The per capita thyroid dose due to exposure to these iodine isotopes is estimated, using information from UNSCEAR (1997), to be at most 0.2 rad to the population of the U.S. A large number of radionuclides other than the radioactive isotopes of iodine, such as ^{137}Cs and ^{90}Sr, contributed to the thyroid dose from NTS fallout. However, because they do not concentrate in the thyroid, the thyroid doses from these radionuclides is not large. The per capita thyroid dose from these other radionuclides is estimated, using information from UNSCEAR (1977), to be about 0.02 rad to the population of the U.S.

Nuclear weapons tests were also conducted at sites other than NTS. Some were conducted by the United States; other countries also conducted tests that caused fallout in the United States. The per capita thyroid dose from those tests is estimated to be about 1 rad to the population of the U.S. (WHO 1983).

Natural background radiation (external and internal exposure) contributes about 0.1 rad per year to the thyroid dose (NCRP 1987), or about 0.8 rad from 1951 to 1958.

Some populations may have been exposed to multiple sources of radioiodine. Iodine-131 was used in the 1950s for diagnosis and treatment of thyroid disease, and numerous patients received thyroid doses from these medical procedures. The ^{131}I fallout doses from the NTS to the most highly exposed groups could have been a non-trivial addition to the medical dose from diagnostic procedures. Therapeutic doses are much higher and the fallout contribution would be a small addition to the thyroid doses of persons who received such ^{131}I treatments.

Other populations around weapons production facilities were exposed to both fallout ^{131}I and facility releases. At Hanford, Washington, the largest releases occurred in 1945 although there were also elevated releases in December 1949 and the summer of 1951 (TSP 1994). Persons exposed as infants to those releases would have still been children (7-12 years of age) during the years of highest NTS fallout. Summary doses for the Hanford releases are given in a report of the Technical Steering Panel (TSP 1994). The capability for individual dose assessment for persons exposed to those releases is being developed. Estimates of thyroid doses to persons exposed to both sources of ^{131}I would depend upon the date of birth habits, and residence history of the individual.

Radioiodine releases also occurred at the Oak Ridge Site (Tennessee), and the Savannah River Site (South Carolina). Among these, the releases at Oak Ridge were larger. The estimation of doses received by the local populations from releases at these facilities is currently underway.

8.4. SUMMARY

- Estimates of average thyroid doses resulting from the deposition of ^{131}I on the ground after an atmospheric bomb test are calculated for the population of each county, subdivided into 14 age and sex categories and according to dietary habits.The population groups in each age and sex group and in each county of the contiguous U.S. for which average thyroid doses are estimated in this report for each nuclear weapons test of interest are:

  (a) those drinking milk with average diets,

  (b) those with a high consumption of fresh cows' milk,

  (c) those drinking milk from backyard cows,

  (d) those drinking no cows' milk, and

  (e) infants drinking mothers' milk.

In addition, average per capita and collective doses estimated to have been received by the entire population of each county of the contiguous U.S. are provided for each test.

- Example results illustrate the fact that, for people with the same average diet, estimated thyroid doses from ^{131}I in NTS fallout are more important for people born near the beginning of the tests because estimated average doses to persons who were infants or children at that time are up to about 10 times higher than are the estimated doses to adults.

- Average thyroid doses are also sensitive to the type of diet that is assumed.

- The total collective dose to the population of the United States from all atmospheric bomb tests detonated at the Nevada Test Site is estimated to be about 4 x 10^8 person rad. The estimated per capita thyroid dose is about 2 rad. The greatest contribution to the total collective thyroid dose is estimated to have been due to the tests of the Plumbbob series (32%), followed by the tests of the Tumbler-Snapper series (29%) and the tests of the Upshot-Knothole series (23%).

- The estimated thyroid doses from ^{131}I reported here are the most important component of the thyroid doses due to fallout from the Nevada bomb tests. Other radionuclides in the fallout may also have contributed about 10% to the per capita dose.

- Some groups of people received thyroid doses from other sources (in addition to the 0.1 rad y^{-1} from natural background radiation). This category includes persons who lived near nuclear facilities that released large amounts of ^{131}I (e.g., the Hanford plant) and persons who were given ^{131}I in the course of medical diagnosis or treatment of disease.

REFERENCES

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Chapter 9

Estimation of Doses to Specified Individuals

Contents: The manner in which any individual, without any scientific background, can calculate her or his own thyroid dose from ^{131}I in NTS fallout, using the information available in the report, is demonstrated using examples.

This chapter illustrates how the data provided in the preceding Chapters as well as in the Annexes can be used to calculate doses to any specified individual.

Individual doses present considerable variability according to environmental parameters, pattern of production and distribution of milk and of other foodstuffs, dietary habits, and biological characteristics. Realistic estimates of doses to specific individuals can, therefore, only be made if information is available on the individuals considered (e.g., age, sex, place of residence, source of milk, and milk consumption rate). The manner in which doses to specified individuals can be calculated if person-specific information is available will be illustrated using examples.

As indicated in **Chapter 8**, the thyroid dose, D, resulting from fallout received by an individual from a particular exposure route from a given test can be estimated as the product of:

- The time-integrated ^{131}I concentration, IC, in the foodstuff considered (for ingestion) resulting from that test and consumed by that individual (nCi d L^{-1} for milk and nCi d kg^{-1} for other foodstuffs) or in ground-level air (for inhalation) (nCi d m^{-3}).
- The foodstuff consumption rate, CR, (L d^{-1} for milk or kg d^{-1} for other foodstuffs) or the breathing rate, BR, (m^3 d^{-1}) of that individual for a period of a few weeks following the test considered.
- The thyroid dose conversion factor, DCF, appropriate for that individual (mrad per nCi).

For ingestion of milk or other foodstuff, the equation can be written as:

$$D_{food} = IC_{food} \times CR_{food} \times DCF \qquad (9.1)$$

For inhalation, the equation is:

$$D_{inh} = IC_{air} \times BR \times DCF \qquad (9.1)$$

The total individual thyroid dose resulting from the deposition of ^{131}I on the ground after a given test is obtained by adding the dose from inhalation and the doses from the ingestion of the foodstuffs considered (cows' milk, goats' milk, mothers' milk (for infants), cottage cheese, eggs, and leafy vegetables). The total individual thyroid dose from all tests is obtained by adding the total individual thyroid doses calculated for each test.

The estimation of the thyroid dose to a specified individual from a given test requires the knowledge of:

- The time-integrated concentrations, IC, of ^{131}I in cows' milk, goats' milk, cottage cheese, eggs, leafy vegetables, mothers' milk (only for infants), and ground-level air in the county of residence of the individual considered at the time of the test. These time-integrated concentrations are found in tables provided in the Annexes, where they are expressed in nCi d L^{-1} for milk, in nCi d kg^{-1} for other foodstuffs, and in nCi d m^{-3} for ground-level air. There are separate entries for each county of the contiguous United States and an individual needs only to look up the results corresponding to her or his county of residence at the time of the test.

- The consumption rates of cows' milk, goats' milk, and mothers' milk (only for infants), expressed in L d^{-1}, of cottage cheese, eggs, and leafy vegetables, expressed in kg d^{-1}, as well as the breathing rate, expressed in m^3 d^{-1}, of the individual at the time of the test. This information is to be provided by the individual or by another knowledgeable person (e.g., relative or friend) who could supply estimates of those quantities. Average values for the 10 post-natal age and sex groups are given in *Table 7.4.*[1]

- The appropriate thyroid dose conversion factor, DCF, expressed in mrad per nCi. It may be available for those individuals who underwent thyroid irradiation for medical reasons. In most cases, however, the value of the thyroid dose conversion factor appropriate for the individual is not available and use of the estimated average thyroid dose conversion factors, DCF, presented in *Table 6.7* (and also in *Table 6.8*) of **Chapter 6** for the 14 age and sex groups is recommended.

It should be noted that the scientific notation was used in most of the tables that need to be consulted. This was done in order to minimize the number of pages in the Annexes as the scientific notation allows results that differ by factors of billions or more to be written with the same format. For example, a value of "5.6E + 2" may be found in a table. This means that "5.6", which is the number before "E + ", should be *multiplied* "2" times (i.e., twice) by 10; in other words:

$$5.6E + 2 = 5.6 \times 10 \times 10 = 560.$$

However, if the value found in the table were "5.6E − 2", then "5.6", which is the number before "E − ", should be *divided* "2" times by 10 (i.e., twice); in other words:

$$5.6E-2 = 5.6 / 10 / 10 = 0.056.$$

Finally, if the number after "E + " or "E − " is 0, as in "5.6E + 0", then the number before "E + " or "E − " remains unchanged; in other words:

$$5.6E+0 = 5.6 \text{ and } 5.6E-0 = 5.6.$$

The following sequence of numbers illustrates the range of values that can be found in the Tables and shows why the scientific notation is used to save space:

5.6E−9 = 0.0000000056
5.6E−8 = 0.000000056
5.6E−7 = 0.00000056
5.6E−6 = 0.0000056
5.6E−5 = 0.000056
5.6E−4 = 0.00056
5.6E−3 = 0.0056
5.6E−2 = 0.056
5.6E−1 = 0.56
5.6E−0 = 5.6
5.6E+0 = 5.6
5.6E+1 = 56
5.6E+2 = 560
5.6E+3 = 5600
5.6E+4 = 56000
5.6E+5 = 560000
5.6E+6 = 5600000
5.6E+7 = 56000000
5.6E+8 = 560000000
5.6E+9 = 5600000000

[1] In order to assist the reader in the estimation of the consumption rates, for the purpose of this report it can be assumed that a typical glass of milk contains about 0.2 L and that a typical egg weighs about 0.05 kg.

9.1. EXAMPLES OF EXPOSURE SCENARIOS FOR HYPOTHETICAL PERSONS

To illustrate the manner in which individual exposures can be estimated, the following examples are provided in which results presented in tables in the Annexes are used in conjunction with "hypothetical personal data". Data should be supplied by the individual or a person having knowledge of the relevant information. It is assumed, in these example calculations, that the values used for all quantities are known with certainty. In fact, the uncertainties attached to some of the values may be very large, but a proper uncertainty analysis of thyroid dose estimates for specific individuals would be beyond the scope of this chapter and is not discussed in this report. It is the subjective opinion of the authors that the estimated total thyroid doses, D, obtained for specific individuals with this method have uncertainties within a factor of about 5. In other words, if the dose estimate obtained using this procedure is equal to D, the real value of the dose received by the individual is estimated to range between D / 5 and D x 5.

9.1.1. Example 1 of Individual Thyroid Dose Calculation

The following evaluation is for a hypothetical female conceived on July 20, 1952 and born on April 20, 1953. This evaluation is divided into segments that are related to the times of: her birth, changes of age group, and changes of residence. Each step requires retrieval of information from one or more Annexes containing results of this analysis. The Annexes are listed near the end of the Table of Contents. Each is designated by a two-letter code, for the test series, and a number. For example, BJ.5 refers to the fifth of the Annexes for the Buster-Jangle test series. That test was named Sugar. The contents of the tables in the Annex are indicated by codes: M, for milk, and C, for concentrations of ^{131}I in other foodstuffs and air. The concentrations of ^{131}I in cows' milk following test Sugar are found in *Table BJ/5/M.* The steps in the analysis are described below:

From July 20, 1952 to March 17, 1953, while the subject was a fetus, no tests were conducted at the NTS and, therefore, there was no exposure of the subject.

Between March 17, 1953 and April 20, 1953, the date of birth, the mother resided in Cleburne County, Alabama, and drank milk obtained from a local grocery store (hypothetical personal data). During that period, six tests of the Upshot-Knothole series were detonated. Because the mother consumed milk obtained from a store, the volume-weighted average concentration of ^{131}I is considered the best estimate for her source of milk. Cows' milk concentrations for those tests are in the Annexes for the Upshot-Knothole (UK) series. The volume-weighted average time-integrated milk concentrations are in the sixth column of the milk, M, tables. The following volume-weighted time-integrated milk concentrations of ^{131}I in cows' milk in Cleburne County, Alabama, are found on page 1 of the relevant tables. The results are shown below:

13 nCi d L^{-1} from test Annie on 3-17-53 from *Table UK/6/C*

5.8 nCi d L^{-1} from test Nancy on 3-24-53 from *Table UK/2/M*

0.36 nCi d L^{-1} from test Ruth on 3-31-53 from *Table UK/3/M*

0.28 nCi d L^{-1} from test Dixie on 4-6-53 from *Table UK/4/M*

1.6 nCi d L^{-1} from test Ray on 4-11-53 from *Table UK/5/M*

3.0 nCi d L^{-1} from test Badger on 4-18-53 from *Table UK/6/M*

These yield a total time-integrated concentration of about 24 nCi d L^{-1} in milk consumed by the mother during pregnancy. The mother reported a milk consumption rate of 0.9 L d^{-1} during the last three months of her pregnancy (hypothetical personal data). The thyroid dose conversion factor for the 30-39 week old fetus is 1.7 mrad per nCi of ^{131}I ingested by the mother (from *Table 6.7*). The resulting dose to the fetal thyroid from the tests identified above is estimated to be:

$$D_{milk} = IC_{milk} \times CR_{milk} \times DCF = 24 \text{ nCi d L}^{-1} \times 0.9 \text{ L d}^{-1} \times 1.7 \text{ mrad nCi}^{-1} = 37 \text{ mrad}$$

The mother did not consume other contaminated foodstuffs during this period. However, the tests were sources of airborne ^{131}I contamination in the county where she lived. From the corresponding tables of ^{131}I in other foodstuffs and air, the following time-integrated concentrations in air were found:

0.0051 nCi d m^{-3} from test Annie on 3-17-53 from *Table UK/1/C*

0.0076 nCi d m^{-3} from test Nancy on 3-24-53 from *Table UK/2/C*

0.0001 nCi d m^{-3} from test Ruth on 3-31-53 from *Table UK/3/C*

0.00035 nCi d m^{-3} from test Dixie on 4-6-53 from *Table UK/4/C*

0.00090 nCi d m^{-3} from test Ray on 4-11-53 from *Table UK/5/C*

0.0019 nCi d m^{-3} from test Badger on 4-18-53 from *Table UK/6/C*

By adding the concentrations listed above, the total time-integrated air concentration during this period, IC_{inh}, was estimated to be about 0.016 nCi d m^{-3}. Individuals typically do not know their average breathing rates. The value of 18 m3 d^{-1} from *Table 7.4* was used as the breathing rate, BR, for the mother in this example. The dose to the fetal thyroid from inhalation of contaminated air by the mother is estimated to be:

$$D_{inh} = IC_{inh} \times BR \times DCF$$
$$= 0.016 \text{ nCi d m}^{-3} \times 18 \text{ m}^3 \text{ d}^{-1} \times 1.7 \text{ mrad nCi}^{-1}$$
$$= 0.49 \text{ mrad}$$

At the time the girl was born, her family was moving to a farm in the same county. Between April 20, 1953 and July 20, 1953, while she was less than 3 months old, the (hypothetical) girl lived on the farm in Cleburne County, Alabama, and drank 0.1 L d^{-1} of milk produced on the farm (milk of category 1). That milk was contaminated as the result of five tests in the Upshot-Knothole series. The median estimates of time-integrated concentrations of ^{131}I in milk from those tests are given in the second column of the milk (M) tables for those tests. The following estimates were found:

17 nCi d L^{-1} from test Simon on 4-25-53 from *Table UK/7/M*

0.0 nCi d L^{-1} from test Encore on 4-25-53 from *Table UK/8/M*

54 nCi d L^{-1} from test Harry on 4-25-53 from *Table UK/9/M*

2.4 nCi d L^{-1} from test Grable on 4-25-53 from *Table UK/10/M*

0.84 nCi d L^{-1} from test Climax on 4-25-53 from *Table UK/11/M*

The total time-integrated concentration of ^{131}I in milk of category 1 during this period was about 74 nCi d L^{-1}.

The girl did not drink any other type of contaminated milk nor did she eat any eggs, cottage cheese, or leafy vegetables during her first months of life. However, the air that she breathed was also contaminated. The estimated time-integrated concentration levels are given in the tables of concentrations, C, of other foodstuffs and air in the Annexes for these tests.

0.019 nCi d m^{-3} from test Simon on 4-25-53 from *Table UK/7/M*

0.0 nCi d m^{-3} from test Encore on 4-25-53 from *Table UK/8/M*

0.068 nCi d m^{-3} from test Harry on 4-25-53 from *Table UK/9/M*

0.0038 nCi d m^{-3} from test Grable on 4-25-53 from *Table UK/10/M*

0.00016 nCi d m^{-3} from test Climax on 4-25-53 from *Table UK/11/M*

The total time-integrated concentration of ^{131}I in air in Cleburne County during this time is about 0.09 nCi d m^{-3}. For an infant that age (< 3 mo), a breathing rate of 2 m^3 d-1 (*Table 7.4*) is a good estimate. The thyroid dose conversion factor for that age is 15 mrad per nCi (*Table 6.7*). The estimated dose to the child's thyroid during this period is:

$$D = D_{milk} + D_{inh} = (IC_{milk} \times CR_{milk} + IC_{inh} \times BR) \times DCF$$
$$= (74 \text{ nCi d L}^{-1} \times 0.1 \text{ L d}^{-1} + 0.09 \text{ nCi d m}^{-3} \times 2 \text{ m}^3 \text{ d}^{-1})$$
$$\times 15 \text{ mrad nCi}^{-1}$$
$$= (7.4 + 0.18) \times 15 = \sim 110 \text{ mrad}$$

No further testing occurred during the remainder of the time the girl lived in Cleburne County. In November 1953, the family moved to Orangeburg County, South Carolina. She resided there until January 1981, which is after the end of the tests considered in this analysis. During the periods when the girl was 6-8 months old and 9-11 months old, there were no tests at the NTS and she was not exposed to ^{131}I from that source.

Between the ages of 1 and 4 (April 20, 1954 to April 20, 1958) she was exposed to fallout ^{131}I from 11 tests in the Teapot series, conducted in 1955, and from 18 tests of the Plumbbob series, conducted in 1957. During this period, she drank cows' milk purchased at a local store that obtained milk produced in the same county (milk of category 2). Because the girl was exposed in the same location to all tests in these two series, the summary, S, tables for those test series can be used to obtain the total concentrations for all the tests. The total estimated time-integrated concentrations of ^{131}I in milk of category 2 in Orangeburg County, South Carolina, for the Teapot series and the Plumbbob series are given in *Table TP/S/M* and *Table PB/S/M,* respectively. From those tables:

87 nCi d L^{-1} due to tests of the Teapot series

430 nCi d L^{-1} due to tests of the Plumbbob series

The sum of these estimates gives the total time-integrated milk concentration of 517 nCi d L^{-1} for the period that the girl was aged 1 to 4 years. Her total intake from milk consumption is estimated to be 517 nCi d L^{-1} x 0.5 L d^{-1} = 258 nCi.

During this period the girl did not consume milk from other sources but she did eat cottage cheese, eggs, and leafy vegetables. Her (hypothetical) parents estimated that she consumed, on average, 20 g per day (0.02 kg d^{-1}) of cottage cheese, 10 g per day (0.01 kg d^{-1}) of egg, and 30 g per day (0.03 kg d^{-1}) of leafy vegetables. To find the estimated time-integrated concentrations of ^{131}I in these foods, the Teapot and Plumbbob Summary *Tables TP/S/C* and *PB/S/C*. The same tables provide the time-integrated concentrations of ^{131}I in air in the county. *Table 9.1* contains the information obtained from the tables. The consumption rates estimated by the parents and the breathing rate from *Table 7.4* are also given in *Table 9.1*. Estimated intakes of ^{131}I from these foods and air are shown at the bottom of the columns. The total intake from these pathways is 32 nCi.

Table 9.1. Summary of intakes of other foods and air for example 1

Test series	Table number	Estimated time-integrated concentrations			
		Cottage cheese ($nCi\ d\ kg^{-1}$)	Eggs ($nCi\ d\ kg^{-1}$)	Leafy vegetables ($nCi\ d\ kg^{-1}$)	Air ($nCi\ d\ m^{-3}$)
Teapot	TP/S/C	84	82	55	0.040
Plumbbob	PB/S/C	423	402	430	0.23
	Totals	507	484	485	0.27
	Consumption rates	0.02[a]	0.01[a]	0.03[a]	7[b]
	Estimated intakes (nCi)	10	4.8	15	1.9

[a] In $kg\ d^{-1}$, as estimated by the (hypothetical) parents.
[b] Average value ($m^3\ d^{-1}$) from *Table 7.4.*

Using the thyroid dose conversion factor of 8.2 mrad nCi^{-1} from *Table 6.7,* the thyroid dose for ages 1-4 was estimated to be:

$$D = D_{milk} + D_{other} = (258\ nCi + 32\ nCi) \times 8.2\ mrad\ nCi^{-1}$$
$$= 2378\ mrad \sim 2.4\ rad$$

The total radiation exposure of the hypothetical girl is summarized in the following *Table 9.2.* The estimated thyroid dose obtained using this procedure is about 2.5 rad. The actual dose is believed to be between:

2.5 rad / 5 = 0.5 rad and
2.5 rad × 5 = 12 rad.

9.1.2. Example 2 of Individual Thyroid Dose Calculation

The hypothetical individual for the second example is a male, conceived on February 1, 1956 and born on November 1, 1956. This example is used to illustrate a tabular approach to data collection and calculations of doses during various periods of the individuals life. This example begins with a residential history.

The child's parents lived within a city in Kings County, New York. The child was born there and lived there until he was 9 months old. At that time, August 1, 1957, the family moved to Nassau County, New York, where he resided until 1981. This information has been compiled in *Table 9.3*, together with the birth date and approximate date of conception. Other dates are also listed; these correspond to the age ranges upon which the dose conversion factors (*Table 6.7*) are based. Because the dose conversion factors are averaged over certain ages, the residence history must correspond to these periods.

Examination of the times of the tests, shown in the list near the end of the Table of Contents, can save some effort in the compilation of data on milk and food consumption rates. For this example, it can be seen that no tests are listed between February 1, 1956 (approximate date of conception) and May 1, 1957, when the baby was just 6 months old.

Between May 1, 1957 and August 1, 1957, the boy drank cows' milk, purchased at a market in the city, at the rate of 0.8 L d^{-1} but he did not drink other types of milk or eat other contaminated foods. After moving to Nassau County on August 1, 1957 (at age 9 months), the boy drank milk from a backyard cow (0.5 L d^{-1}) and a glass of goats' milk each day (~0.2 L d^{-1}). His parents recalled that he consumed very little cottage cheese, eggs, or leafy vegetables as an infant or young child. These (hypothetical) consumption data have also been entered into *Table 9.3.* Review of the estimated concentrations for Nassau County, New York, revealed that, although there were numerous tests conducted later at the NTS, there were not appreciable levels of NTS fallout in Nassau County after November 1, 1957. For that reason, additional (hypothetical) details of the individual's life are not presented.

Table 9.2. Dose summary table for example 1.

Age	County	Estimated thyroid dose
In utero	Cleburne, AL	37 mrad
< 3 months	Cleburne, AL	110 mrad
3-5 months	Cleburne, AL	0
6-8 months	Orangeburg, SC	0
9-11 months	Orangeburg, SC	0
1-4 years	Orangeburg, SC	2378 mrad
5-27 years	Orangeburg, SC	
	Total:	2525 mrad or ~ 2.5 rad
	Uncertainty range:	0.6 to 12 rad

Review of the residential history (*Table 9.3*) shows that tests during two time periods must be considered in the assessment of the exposure of this child. They are May 1,1957 to August 1, 1957 and August 1, 1957 to November 1, 1957. Data for these age periods (7 and 8) are recorded in exposure history tables for those age periods (*Tables 9.4* and *9.5*, respectively). The consumption rates also are given in these tables, as is the computed total intakes for each period.

The thyroid dose calculation for this child is summarized in *Table 9.6*. The total dose is estimated to be 2980 mrad, or about 3 rad. The estimated uncertainty range is a factor of 5 in either direction, or 0.6 rad to 15 rad.

Table 9.3. Residential history.

Age range	Age group	County of residence	Starting date	Milk consumption rates (L/d)					
As a fetus			**Conception: Approx. Feb. 1, 1956**	**Cows' milk**	**Goats' milk**		**Cottage cheese**	**Eggs**	**Leafy vegetables**
10 - 19 wk	2[a]	Kings County, NY		NT[b]	NT		NT	NT	NT
20 - 29 wk	3[a]	Kings County, NY		NT	NT		NT	NT	NT
30 - 39 wk	4[a]	Kings County, NY		NT	NT		NT	NT	NT
As an infant			**Birth: Nov. 1, 1956**	**Cows' Milk**	**Goats' Milk**	**Mother's Milk**	**Cottage Cheese**	**Eggs**	**Leafy Vegetables**
<3 months	5	Kings County, NY	Nov. 1, 1956	NT	NT	NT	NT	NT	NT
3 - 5 months	6	Kings County, NY	Feb. 1, 1957	NT	NT	NT	NT	NT	NT
6 - 8 months	7	Kings County, NY	May 1, 1957	0.8 (VW)	0	0	0	0	0
9 - 11 months	8	Nassau County, NY	Aug. 1, 1957	0.5 (BYC)	0.2	0	0	0	0
As a child				**Cows' Milk**	**Goats' Milk**		**Cottage Cheese**	**Eggs**	**Leafy Vegetables**
1 - 4 years	9	Nassau County, NY	Nov. 1, 1957	NTAL[c]	NTAL		NTAL	NTAL	NTAL
5 - 9 years	10	Nassau County, NY	Nov. 1, 1961	NTAL	NTAL		NTAL	NTAL	NTAL
10 - 14 years	11	Nassau County, NY	Nov. 1, 1966	NTAL	NTAL		NTAL	NTAL	NTAL
15 - 19 years	12	Nassau County, NY	Nov. 1, 1971	NTAL	NTAL		NTAL	NTAL	NTAL
As an adult	13	Nassau County, NY	Nov. 1, 1976	NTAL	NTAL		NTAL	NTAL	NTAL

[a] Residence and food consumption rates of the mother.

[b] Data not needed; no tests during this period.

[c] No test that affected this location.

Table 9.4. Exposure history - age period 7.

	County of residence	Age period 7 (6–8 months)		Estimates of consumption of cows' milk					Data from annex table	Estimates of consumption of other milk types and other foodstuffs						Data from annex table
		Start	End	Test date	Annex number	Name of test	Sources	Concen-tration (nCi d/L)		Goats' milk (nCi d/L)	Mother's milk (nCi d/L)	Cottage cheese (nCi d/kg)	Eggs (nCi d/kg)	Leafy vegetables (nCi d/kg)	Air (nCi d/m3)	
7.1	Kings County, NY	May 1, 1957	Aug 1, 1957	May 28, 1957	PB.1	Boltzman++	VW[a]	2.5	PB/1/M	NC[b]	NC	NC	NC	NC	0	PB/1/C
				June 18, 1957	PB.2	Wilson	VW	15	PB/2/M	NC	NC	NC	NC	NC	0.0058	PB/2/C
				June 24, 1957	PB.3	Priscilla	VW	4.1	PB/3/M	NC	NC	NC	NC	NC	0.0011	PB/3/C
				July 5, 1957	PB.4	Hood	VW	5.2	PB/4/M	NC	NC	NC	NC	NC	0.0054	PB/4/C
				July 15, 1957	PB.5	Diablo	VW	45	PB/5/M	NC	NC	NC	NC	NC	0.028	PB/5/C
				July 24, 1957	PB.6	Kepler+	VW	15	PB/6/M	NC	NC	NC	NC	NC	0.014	PB/6/C
7.2	No other residence for age period 7															
Total time-integrated concentrations, age period 7:								*(nCi d/L)* 86.8		*(nCi d/L)* 0	*(nCi d/L)* 0	*(nCi d/kg)* 0	*(nCi d/kg)* 0	*(nCi d/kg)* 0	*(nCi d/m³)* 0.054	
Consumption rates for age period 7:								*(L/d)* 0.8		*(L/d)* 0	*(L/d)* 0	*(kg/d)* 0	*(kg/d)* 0	*(kg/d)* 0	*(m³/d)* [c] 4	Total of intakes
^{131}I intakes for age period 7:								*(nCi)* 69.4		*(nCi)* 0	*(nCi)* 0	*(nCi)* 0	*(nCi)* 0	*(nCi)* 0	*(nCi)* 0.22	*(nCi)* 69.6

\+ Combined with other tests *(Table 3.9).*

[a] Sources of cows' milk: CF, consumed on farm where produced (category 1); RF, retailed from farm where produced (category 2); VW, volume-weighted average for county (e.g., purchased at market); BYC, milk from a backyard cow (not a dairy cow).

[b] NC means no consumption

[c] Inhalation rate from *Table 7.4*

Table 9.5. Exposure history - age period 8.

	County of residence	Age period 8 (9-11 months)		Estimates of consumption of cows' milk					Data from annex table	Estimates of consumption of other milk types and other foodstuffs						Data from annex table
		Start	End	Test date	Annex number	Name of test	Sources	Concen-tration (nCi d/L)		Goats' milk (nCi d/L)	Mother's milk (nCi d/L)	Cottage cheese (nCi d/kg)	Eggs (nCi d/kg)	Leafy vegetables (nCi d/kg)	Air (nCi d/m3)	
8.1	Nassau County, NY	Aug. 1, 1957	Nov. 1, 1957	Aug 7, 1957	PB.7	Stokes	BYC[a]	0.0	PB/7/M	0.0	NC[b]	NC	NC	NC	0.0	PB/7/C
				Aug 7, 1957	PB.8	Shasta	BYC	0.0	PB/8/M	0.0	NC	NC	NC	NC	0.0	PB/8/C
				Aug 18, 1957	PB.9	Doppler	BYC	0.85	PB/9/M	8.3	NC	NC	NC	NC	0.0030	PB/9/C
				Aug. 23, 1957	PB.10	Franklin Prime	BYC	0.0	PB/10/M	0.0	NC	NC	NC	NC	0.0	PB/10/C
				Aug 30, 1957	PB.11	Smoky	BYC	15	PB/11/M	150	NC	NC	NC	NC	0.0038	PB/11/C
				Aug 31, 1957	PB.12	Galileo	BYC	28	PB/12/M	270	NC	NC	NC	NC	0.0080	PB/12/C
				Sep 6, 1957	PB.13	Wheeler++	BYC	4.9	PB/13/M	47	NC	NC	NC	NC	0.0073	PB/13/C
				Sep 14, 1957	PB.14	Fizeau	BYC	0.0	PB/14/M	0.0	NC	NC	NC	NC	0.0	PB/14/C
				Sep 16, 1957	PB.15	Newton	BYC	6.9	PB/15/M	72	NC	NC	NC	NC	0.0047	PB/15/C
				Sep 23, 1957	PB.16	Whitney	BYC	1.4	PB/16/M	15	NC	NC	NC	NC	0.0045	PB/16/C
				Sep 28, 1957	PB.17	Charleston	BYC	14	PB/17/M	150	NC	NC	NC	NC	0.0047	PB/17/C
				Oct 7, 1957	PB.18	Morgan	BYC	0.0	PB/18/M	0.0	NC	NC	NC	NC	0.0	PB/18/C
7.2	No other residence for age period 8															
Total time-integrated concentrations, age period 8:								*(nCi d/L)* 72.1		*(nCi d/L)* 712	*(nCi d/L)* 0	*(nCi d/kg)* 0	*(nCi d/kg)* 0	*(nCi d/kg)* 0	*(nCi d/m^3)* 0.024	
Consumption rates for age period 8:								*(L/d)* 0.5		*(L/d)* 0.2	*(L/d)* 0	*(kg/d)* 0	*(kg/d)* 0	*(kg/d)* 0	*(m^3/d)* [c] 6	Total of intakes
^{131}I intakes for age period 8:								*(nCi)* 36.0		*(nCi)* 142	*(nCi)* 0	*(nCi)* 0	*(nCi)* 0	*(nCi)* 0	*(nCi)* 0.14	*(nCi)* 178

\+ Combined with other tests *(Table 3.9).*

[a] Sources of cows' milk: CF, consumed on farm where produced (category 1); RF, retailed from farm where produced (category 2); VW, volume-weighted average for county (e.g., purchased at market); BYC, milk from a backyard cow (not a dairy cow).

[b] NC means no consumption

[c] Inhalation rate from *Table 7.4*

Table 9.6. Dose summary table for example 2.

Age period	DCF (mrad nCi-1)	County of residence	^{131}I intake (nCi)	Thyroid dose (mrad)
In utero		Kings, NY		
10-19 weeks	1.6	Kings, NY	0	0
20-29 weeks	5.0	Kings, NY	0	0
30-39 weeks	6.6	Kings, NY	0	0
As an infant		Kings, NY		
< 3 months	15	Kings, NY	0	0
3-5 months	13	Kings, NY	0	0
6-8 months	12	Kings, NY	70	840
9-11 months	12	Nassau, NY	178	2140
As a child				
1-4 years	8.2	Nassau, NY	0	0
5-9 years	4.1	Nassau, NY	0	0
10-14 years	2.7	Nassau, NY	0	0
15-19 years	1.9	Nassau, NY	0	0
As an adult male				
	1.3	Nassau, NY	0	0
			Total:	2980

Chapter 10

Model Validation and Uncertainty Analysis

CONTENTS: The results obtained from the models used in this study were compared with limited direct and indirect ^{131}I data available from the time of the tests in order to compare the findings and to provide an estimate of the uncertainty attached to the doses that have been calculated. A simplified uncertainty analysis is also carried out on the basis of the assumed uncertainties attached to the parameter values.

Given the large number of data that are required to estimate thyroid doses in this study, as well as the very large number of results which are presented in the Annexes and Subannexes, it is important to evaluate the reliability of the thyroid doses that are estimated as well as the uncertainties that are associated with these estimates. This chapter addresses these issues and is divided into three parts: (a) model verification, showing the extent to which results calculated with the computer programs agree with results hand-calculated using the equations and the parameter values; (b) model validation, in which the limited available measured ^{131}I concentrations in man, in animals, and in the environment are compared with the results obtained with the models; and (c) uncertainty analysis, in which the uncertainties associated with the dose estimates are evaluated from the assumed uncertainties attached to the parameter values.

10.1. MODEL VERIFICATION

Model verification was carried out at various levels:

- Using hand-calculators, the computer programmers verified the exposure and dose estimates obtained for several counties and carefully examined the estimates for all counties that were plotted on maps in order to detect obvious errors.
- Numerous drafts of the report were discussed and reviewed in whole or in part during meetings of the Task Group on Exposures, at which time experts were able to evaluate the database, methodologies, analyses and exposure estimates.
- Various drafts of the report were presented and discussed at meetings of the Advisory Committee, one member of which reviewed the computer files and prepared independent computer programs in order to verify the results obtained for a large number of counties. Reviewers also carefully verified some of the estimates.

10.2. MODEL VALIDATION

Few measurements of ^{131}I in the environment and in man were made in the 1950s; however, those that are available in the literature were compared with the results obtained in this assessment. Because the thyroid dose received by man is of particular interest, greater importance is given to the measurements in man than to the measurements in the environment.

10.2.1. Measurements in Man

10.2.1.1. Urine

During the weapons test series Teapot in 1955, human urine specimens from 17 United States military posts were analyzed for ^{131}I activity by the Walter Reed Army Institute of Research. These facilities were located across the U.S. in Arizona, California, Colorado, the District of Columbia, Florida, Illinois, Massachusetts, Michigan, Nevada, Ohio, Oklahoma, South Carolina, Texas, Utah, and Washington. Twenty-four-hour urine collections were obtained at weekly intervals from the end of January to the end of May of 1955 from 10 healthy adult males selected at each of these military facilities (Hartgering et al. 1955; Schrodt et al. 1956).

Several assumptions have been used to relate the measured urine concentrations to the predicted time-integrated concentrations in milk:

- The ^{131}I urine concentrations measured in the 24-hour urine samples were taken to represent averages over the weekly collection intervals. This is a very crude assumption since urinary values fluctuate widely, as they reflect exposures within the same 24-hour period and are very sensitive to both the amount of milk consumed and the ^{131}I concentration in that milk. Because of these fluctuations, it seemed reasonable to compare only the observed and predicted time-integrated concentrations of ^{131}I in urine for the entire Teapot series.

- The milk consumed on military posts had the same average concentration as the rest of the milk consumed in the county in which the station was located.

- The milk consumption rate is 0.26 L d^{-1} (average value for adult males given in *Table 5.9* of **Chapter 5**).

- The fraction of ^{131}I intake that finds its way into urine is 0.8 (see **Appendix 6, Section A6.1.1**).

Detailed information on the measurements of ^{131}I in urine is provided by Hartgering et al. (1955) for 15 of the 17 United States military posts. The comparison of the observed and the measured activities in urine for those 15 United States military posts is presented in *Table 10.1*. With one exception, the predicted activities, P, are greater than the observed activities, O. The P/O ratios range from 0.9 to 60, with a geometric mean of about 10; this is considered to be a reasonably good agreement, especially in view of the fact that no information is available on the type, amount, or origin of milk consumed by the service personnel at those military facilities.

Table 10.1. Comparison of predicted and observed activities of ^{131}I in urine from the Teapot series.

Site	Activity in urine (nCi)		Predicted/Observed (P/O) ratio
	observed	predicted	
Ogden, UT	5.9	31	5.3
Camp Mercury, NV	4.3	34	7.9
Belleville, IL	3.3	29	8.8
Denver, CO	3.0	46	15
Oklahoma City, OK	2.3	74	32
Phoenix, AZ	1.5	1.3	0.9
Mount Clemens, MI	1.1	9.1	8.3
Greenville, SC	0.88	53	60
Washington, D.C.	0.88	23	26
Columbus, OH	0.84	36	43
San Antonio, TX	0.71	22	31
Riverside, CA	0.62	0.98	1.6
Spokane, WA	0.57	9.6	17
Chicopee Falls, MA	0.53	5.0	9.4
San Francisco, CA	0.49	4.8	9.8

10.2.1.2. *Thyroid*

Several series of measurements of ^{131}I in human thyroids were made in 1955 and 1957:

- Van Middlesworth (1956) measured the ^{131}I content of human thyroids collected in hospitals of Memphis, Tennessee, during the spring of 1955. The highest concentration (0.1 nCi g^{-1}) observed was after the Zucchini test of May 1955. If a mean residence time of 10 days is assumed for ^{131}I in the thyroid, a time-integrated concentration of 1 nCi d g^{-1} is derived from the observed concentration. The predicted time-integrated concentration of ^{131}I in milk in Memphis was 29 nCi d L^{-1}. If it is assumed that there is: (1) a milk consumption rate of 0.3 L d^{-1}; (2) a fractional uptake by the thyroid of 0.24; (3) a mean time of residence in the thyroid of 10 days; and (4) a thyroid mass of 18 g, the predicted time-integrated concentration in the thyroid is 1.2 nCi d g^{-1}. The predicted-to-observed ratio is 1.2.

- Also in 1955, Comar et al. (1957) analyzed the ^{131}I content of human thyroids from autopsies from various locations in the United States. Unfortunately, results are reported for large areas, so that it is not possible to estimate the corresponding time-integrated concentration of ^{131}I in milk with reasonable accuracy.

- In 1957, human thyroids from autopsies from the San Francisco area were measured for their ^{131}I concentrations by White and Jones (1956). The average concentration during the period from May 20 to July 31 was 1.4 pCi g^{-1}, resulting in a time-integrated concentration of 0.10 nCi d g^{-1} in the thyroid. The predicted time-integrated concentration in milk in the San Francisco area resulting from the six tests conducted at the NTS from May 20 to July 31 was 3.3 nCi d L^{-1}, corresponding to 0.13 nCi d g^{-1} in the thyroid. The predicted-to-observed ratio is equal to 1.3.

10.2.2. *Measurements in Cattle Thyroids*

Measurements in cattle thyroids were made by the same investigators who analyzed human thyroids:

- Van Middlesworth (1956) collected cattle thyroids from slaughterhouses within 200 miles of Memphis, Tennessee. For the test Zucchini of May 1955, an exposure of 4-6 rep was derived from the measurements. Using a relationship of 0.0123 rep per nCi d g^{-1}, as recommended by Dunning (1956), the "observed" time-integrated concentration in the cattle thyroids is 300-500 nCi d g^{-1}.

  The predicted average time-integrated concentration of ^{131}I in milk following Zucchini over a 200-mile circle centered in Memphis, Tennessee, is about 30 nCi d L^{-1}. Using a ratio between cattle thyroids and milk concentration of 3 nCi g^{-1}/nCi L^{-1}, as recommended by Soldat (1963), the predicted time-integrated concentration in cattle thyroids is 90 nCi d g^{-1}. The predicted-to-observed ratio is in the 0.2 to 0.3 range.

- The ^{131}I concentrations measured in cattle thyroids in 1955 by Comar et al. (1957) have not been compared to predicted concentrations because of the imprecise origin of the samples.

- Thyroids from cattle slaughtered in the San Francisco Bay area from February until September, 1955, were collected by White and Dobson (1956). Measured concentrations of ^{131}I in the thyroids corresponded to a maximum time-integrated concentration of 95 nCi d g^{-1} in the cattle thyroids. The predicted time-integrated concentration of ^{131}I in milk in the San Francisco Bay area is 20 nCi d L^{-1} for the Teapot series. This corresponds to a time-integrated concentration in cattle thyroids of 60 nCi d g^{-1}. The predicted-to-observed ratio is 0.6.

- The average thyroid concentration of ^{131}I in range-fed cattle in the San Francisco area over the period from May 20 to July 31, 1957, was 0.63 nCi g^{-1} (White and Jones, 1956). The observed time-integrated concentration in the thyroid is therefore 45 nCi d g^{-1}. The predicted time-integrated concentration in milk is 3.3 nCi d L^{-1}, or 9.9 nCi d g^{-1} in the thyroid. The predicted-to-observed ratio is 0.2.

10.2.3. *Measurements in Milk*

Measurements of the ^{131}I concentration in milk were carried out in five milksheds by the Public Health Service in 1957 (Campbell et al. 1959). One-gallon samples were collected once a month. Unfortunately, the date of collection was not reported, rendering the measured concentrations of little use. More complete information is available beginning in 1962 but global tests contributed much more to the ^{131}I concentrations in milk at that time than did the tests at NTS.

10.2.4. *Discussion*

The infrequent measurements of ^{131}I in the environment and in man that were carried out in the 1950s and reported in the literature point to a relatively good agreeement with the concentrations predicted with the model. The comparison of the predicted concentrations in urine and of the measured values in 15 U.S. military posts in 1955 seems to indicate that the concentra-

tions in urine are overpredicted by a factor of about 10. A better agreement is obtained with the measurements of ^{131}I in human or in cattle thyroids. It should be pointed out, however, that the comparison between measured and predicted values necessitated the use of several assumptions, and that there is no guarantee that the samples measured were representative of county averages. As already indicated, large variabilities are attached to individual doses, mainly as a result of individual dietary habits and metabolisms of iodine. However, to the extent that comparisons can be made, it would seem that the most relevant one would be to compare the predicted values of ^{131}I in the thyroid with those very few human thyroids in which ^{131}I actually was measured. This comparison shows unexpectedly good agreement, however limited the usefulness of the comparison in a more general sense.

10.3. UNCERTAINTY ANALYSIS

10.3.1. Introduction

Uncertainties are associated with the average dose estimates obtained for each test and each county (see **Chapters 6** and **7**); these uncertainties were estimated for the:

(a) per capita thyroid doses over the entire population,

(b) average thyroid doses over the population of milk drinkers in each age and sex group,

(c) average thyroid doses for the high-exposure group in each age and sex group,

(d) average thyroid doses for the low-exposure group in each age and sex group,

(e) average thyroid doses for the group consuming milk from backyard cows in each age and sex group,

(f) average thyroid doses for the infants consuming mother's milk, and

(g) for the collective doses over the entire population of each county and of the entire U.S. for each test.

The parameters and assumptions used in the dose assessment have been discussed in detail in **Chapters 3** through **7**. In carrying out the uncertainty analysis, two guiding principles have been observed:

- That all major sources of uncertainty are taken into account (either implicitly or explicitly).
- That the analysis is no more complex than is deemed to be necessary.

The method selected for the uncertainty analysis is the multiplicative log-normal approach, which is a simple analytical method that does not require many computer resources and the results of which can be verified with a hand-held calculator with power, exponential, and logarithmic functions. This method, however, relies on two critical assumptions:

- All the parameter values must be assumed to be log-normally distributed, regardless of what data or expert opinion may suggest.
- The distribution of the sum of log-normally distributed parameters must be assumed to be log-normal.

Further discussion of the multiplicative log-normal approach can be found in **Chapter 3**.

10.3.2. Results

A very large number of parameters are involved in the dose calculations. For the purposes of the uncertainty analysis, some of those parameters have been combined in order to simplify the equations.The uncertainties attached to all the parameters have been assigned as realistically as possible, given the constraint that all distributions need to be assumed to be log-normal.

Detailed results are tabulated in the Annexes and Subannexes for each test and each county of the contiguous United States. The best estimates of each of the quantities presented in the tables (e.g., deposition of ^{131}I on the ground, time-integrated concentrations of ^{131}I in a certain category of milk, or average thyroid dose to a particular population group) are meant to represent the geometric means, GM, or medians, of the distributions (which means that 50% of the values are expected to be higher than the best estimate found in the table for a given quantity, and that 50% of the values are expected to be lower than the best estimate).

The uncertainties are expressed in terms of geometric standard deviations, GSD, implying that 67% of the values in the distribution associated with a best estimate, GM, are expected to lie between GM / GSD and GM x GSD, while 97% are expected to range from $GM/(GSD)^2$ and GM x $(GSD)^2$. For example, if an average thyroid dose to a particular population group from a given test is listed with a best estimate, GM, of 0.4 rad and with an associated uncertainty, GSD, of 2.5, this means:

(a) That there is a 50% probability that the true value of the average thyroid dose is greater than 0.4 rad, and, conversely, that there is a 50% probability that the average thyroid dose is lower than 0.4 rad;

and,

(b) that the distribution of the expected values is such that there is a 67% probability that the true value of the average thyroid dose lies between:

$$GM / GSD = 0.4 / 2.5 = 0.16 \text{ rad, and}$$

$$GM \times GSD = 0.4 \times 2.5 = 1 \text{ rad,}$$

and that there is a 97% probability that the true value of the average thyroid dose lies between:

$$GM / (GSD)^2 = 0.4 / 6.25 = 0.06 \text{ rad, and}$$

$$GM \times (GSD)^2 = 0.4 \times 6.25 = 2.5 \text{ rad.}$$

The estimates provided in the Annexes and in the Sub-annexes for the average doses to the various population groups show that the associated GSDs range, in general, between 2 and 10, the lowest GSDs being usually related to populations living in the vicinity in the NTS in areas for which County Data Base or Town Data Base data were available. The highest GSDs are associated with the dose estimates for which the depositions of ^{131}I were assessed with the meteorological approach.

10.4. SUMMARY

- Model verification was carried out by the researchers involved in the preparation and discussion of the report using spot check calculations; a set of separate computer programs also was prepared in order to verify the models on a more extensive scale.

- Model validation was effected by comparing the infrequent measured results of ^{131}I in the environment and in man that were carried out in the 1950s and reported in the literature with the results calculated with the models. Although concentrations in man are usually overpredicted, a relatively good agreeement was obtained between measured and calculated results.

- The uncertainties associated with the estimates provided for the average doses to the various population groups are expressed in terms of geometric standard deviations, GSD, which are assessed to range, in general, between 2 and 10, the lowest GSDs being usually related to populations living in the vicinity in the NTS in areas for which County Data Base or Town Data Base data were available. The highest GSDs are associated with the dose estimates for which the depositions of ^{131}I were assessed with the meteorological approach.

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Glossary

LIST OF ACRONYMS

AIPC =	Area of Influence, Precipitation-Corrected
CDB =	County Data Base
DCF =	Dose Conversion Factor
DHIA =	Dairy Herd Improvement Association
DOE =	Department of Energy
EML =	Environmental Measurements Laboratory
EPA =	Environmental Protection Agency
GMT =	Greenwich Mean Time
GSD =	Geometric Standard Deviation
HASL =	Health and Safety Laboratory
ICRP =	International Commission on Radiological Protection
MSL =	Mean Sea Level
NCI =	National Cancer Institute
NCRP =	National Council on Radiation Protection and Measurements
NOAA =	National Oceanic and Atmospheric Administration
NRC =	National Research Council
NRL =	Naval Research Laboratory
NTS =	Nevada Test Site
ORERP =	Offsite Radiation Exposure Review Project
PHS =	Public Health Service
TDB =	Town Data Base
TOA =	Time of Arrival
UNSCEAR =	United Nations Scientific Committee on the Effects of Atomic Radiation
USDA =	United States Department of Agriculture
USNRC =	United States Nuclear Regulatory Commission

DEFINITION OF INDICES

bc =	backyard cow
c =	cow
cl =	calibrated
dry =	dry weather conditions (no precipitation)
gt =	goat
i or ii =	county within the contiguous United States
j =	day of ^{131}I deposition on the ground
k =	age and sex group
mc =	milk from a cow
md =	cows' milk drinker
mm =	mother's milk
mo =	month
mt =	mother
oe =	other exposure routes
p =	pasture grass or vegetation
pr =	pasture region
q =	category of milk
rg or rr =	milk region
rs =	resuspension
s =	state
sc =	scenario or sub-county
sl =	soil
t =	time
te =	test
th =	thyroid
ts =	test series
vw =	volume weighted
w =	water
wet =	wet atmospheric conditions (rain or snow)

DEFINITION OF SYMBOLS

A =	activity, Ci
A_p =	activity that is intercepted by vegetation
A_{rs} =	activity in vegetation due to resuspension of soil, Ci
A_{sl} =	activity deposited on the soil
AD =	average density of air, 1.2 kg m^{-3}
BR =	breathing rate, m3 d^{-1}
BWT =	cow's body weight, kg
C =	number of cows
Ci =	Curie
C_p =	average concentration of ^{131}I in pasture grass
C_w =	average concentration of ^{131}I in water
CK =	coefficient of proportionality
CP =	average milk production per cow, L d^{-1}
CR =	consumption rate, kg d^{-1}
C_{th} =	maximum concentration of ^{131}I in the thyroid, mCi kg^{-1}
d =	day
D =	thyroid dose from beta and gamma irradiation, rad
DCF =	thyroid dose per unit intake of ^{131}I, also called dose conversion factor, rad nCi^{-1} or mrad nCi^{-1}
DG =	deposition density per unit area of ground, nCi m^{-2}
DIF =	test value for indication of surplus of milk
DM =	daily dry matter intake, kg d^{-1}, by cows
E_b =	the average energy, 0.18 MeV per disintegration of beta rays resulting from the decay of ^{131}I
EC =	expected annual consumption of milk, L y-1
EF =	in-storm evaporation fraction per unit areal density of vegetation, m2 kg^{-1}(dry mass)
f =	fractional uptake by the thyroid of the ^{131}I activity that reaches the bloodstream following inhalation or ingestion
f_m =	intake-to-milk transfer coefficient for cows, d L^{-1}
F =	interception factor
FA =	number of farms
F* =	mass interception factor, m^2 kg^{-1}, dry mass

FAT =	fat yield, kg d-1
FCC =	quotient of the ^{131}I concentrations in cottage cheese and in cows' milk at the time of production, nCi kg^{-1} per nCi L^{-1}
FCM =	4% fat-corrected milk production, kg
FMD =	fraction of milk drinkers
FP =	fraction of the cows' diet derived from pasture
F_{sl} =	fallout activity on soil, nCi m^{-2}
g =	average geometrical factor for the thyroid, equal to 3π r for spheres with radii, r less than 10 cm
G =	specific gamma-ray constant for ^{131}I (2.2 R h^{-1} per mCi at 1 cm)
H+12 =	12 hours after detonation; standard time to report exposure rates
ILV =	time-integrated concentration of ^{131}I in leafy vegetables, nCi d kg^{-1}
IC =	time-integrated concentration of ^{131}I, nCi d L^{-1}, nCi d kg^{-1} or nCi d m^{-3}
IMC =	time-integrated concentration of ^{131}I in milk fresh from cow (also called fresh cows' milk, nCi d L^{-1})
IMC_{bc} =	time-integrated concentration of ^{131}I in milk from backyard cows, nCi d L^{-1}
IMC_{inh} =	time-integrated concentration of ^{131}I in fresh cows' milk resulting from inhalation of ^{131}I-contaminated air
IMC_p =	time-integrated concentration of ^{131}I in fresh cows' milk resulting from the consumption of ^{131}I-contaminated pasture
IMC_q =	time-integrated concentration of ^{131}I in the category, q, of commercial milk, nCi d L^{-1}
IMC_{sl} =	time-integrated concentration of ^{131}I in fresh cows' milk resulting from the ingestion of ^{131}I-contaminated soil
IMC_{vw} =	time-integrated concentration of ^{131}I in volume-weighted commercial milk, nCi d L^{-1}
IMM =	time-integrated concentration of ^{131}I in mothers' milk, nCi d L^{-1}
L =	liter
m_{th} =	mass of the thyroid, g
MB =	milk balance in a year, L y^{-1}
MCF =	milk consumed on farms in a year, L y^{-1}
MM =	milk used in manufacture of food products in a year, L y^{-1}
MP =	milk produced in a year, L y^{-1}
MUF =	milk used on the farm in a year, L y^{-1}
MY =	milk yield in a day, kg d^{-1}
OF =	occupancy factor; fraction of time spent either indoors or outdoors

PBWT =	percentage of cow's body weight to be fed to the cow per day
P_i =	precipitation index
PI =	daily pasture intake, kg, dry mass d^{-1}
POP =	population
R =	daily amount of rain, L m^{-2}
RC =	resuspension coefficient, m^{-1}
RIO =	ratio of time-integrated concentrations of ^{131}I indoors and outdoors
Rs_{cl} =	rainfall storage capacity per unit areal density of vegetation
S =	rate of soil consumption, kg d^{-1}
T_b =	radiological half-time of retention of stable iodine in the thyroid, d
T_e =	effective half-time of retention of ^{131}I on vegetation, d
T_{eff} =	effective half-time of retention of ^{131}I in the thyroid, d
T_r =	radioactive half-life of ^{131}I, d
T_w =	environmental half-time, d
TD =	time delay between production and consumption of foodstuffs, d
TF =	transfer of ^{131}I from deposition on the ground to activity intake by cow
TIC =	time-integrated concentration
TMFU =	total volume of milk available for fluid use in a year, L y^{-1}
TMP =	sum of milk production in all the counties in a state with a milk surplus
TN =	deficit of milk in a milk region
TP =	volume of milk available from the counties in a milk region with a surplus of milk
U_{sl} =	soil density, kg m^{-3}
v_g =	deposition velocity, m d^{-1}
VOL_q =	annual volume of milk in category q, L y^{-1}
WR =	wash-out ratio, nCi kg^{-1} (rain) per nCi kg^{-1} (air)
X =	distance from NTS, km
Y =	standing crop biomass, kg (dry mass) m^{-2}
α =	foliar interception constant, m^2 kg^{-1} (dry)
Γ =	specific gamma-ray constant of ^{131}I, 2.2 R/h per mCi at 1 cm
λ_r =	radioactive decay constant, d^{-1}
λ_w =	rate constant for decreased activity due to environmental removal processed, d^{-1}
λ_e =	effective rate constant, d^{-1}

DEFINITION OF TERMS

Absorbed dose: see Dose.

Activity: The amount of a radioactive nuclide in a particular energy state at a given time. It is the quotient of dN by dt, where dN is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval dt. Names for the unit of activity are becquerel, Bq and curie, Ci.

Activity median aerodynamic diameter, AMAD: The diameter of a unit density sphere with the same terminal settling velocity in air as that of the aerosol particle whose activity is the median for the entire aerosol.

Area-of-influence precipitation-corrected, AIPC method: Method devised in this report to estimate the ^{131}I deposition densities in counties where measurements were not available.

Atom: The smallest particle of an element that is capable of entering into a chemical reaction.

Atomic mass: The mass of an atom relative to other atoms. The present-day basis of the scale of atomic masses is carbon; the most common isotope of this element has arbitrarily been assigned an atomic mass of 12. The unit of the scale is 1/12 the mass of the carbon-12 atom, or roughly the mass of one proton or one neutron. The atomic mass of any element is approximately equal to the total number of protons and neutrons in its nucleus.

Backyard cow: Cow kept to provide the milk requirements of only an individual family.

Becquerel: The specific name for the unit of activity in the SI system of units: 1 Bq = 1 s^{-1}.

Beta ray, or beta particle: A charged particle emitted from the nucleus of an atom and having a mass and charge equal in magnitude to those of the electron.

Biological half-life: The time required for a biological system, such as a person, to eliminate by natural processes, other than radioactive decay, one-half of the amount of a substance, such as a radionuclide, that has entered it.

Coefficient of variation: The standard deviation divided by the value of the parameter considered.

Curie: The unit of activity used in this report. It is the quantity of a radioactive nuclide disintegrating at the rate of 3.7 10^{10} disintegrations per second,, abbreviated: Ci. Several multiples and fractions of the curie are in common usage and also are used in this report:

> **Megacurie:** One million curies, 3.7 10^{16} disintegrations per second, abbreviated MCi.
>
> **Kilocurie:** One thousand curies, 3.7 10^{13} disintegrations per second, abbreviated kCi.
>
> **Millicurie:** One thousandth of a curie, 3.7 10^{7} disintegrations per second, abbreviated mCi.
>
> **Microcurie:** One millionth of a curie, 3.7 10^{4} disintegrations per second, abbreviated μCi.
>
> **Nanocurie:** One billionth of a curie, 37 disintegration per second, abbreviated nCi.
>
> **Picocurie:** One millionth of a microcurie, 0.037 disintegration per second, abbreviated pCi.
>
> **Femtocurie:** One billionth of a microcurie, 3.7 10^{-5} disintegration per second, abbreviated fCi.

Decay constant: The fraction of a number of atoms of a radioactive nuclide that decays in unit time.

Decay product: A nuclide resulting from the radioactive disintegration of a radionuclide, being formed either directly or as a result of successive transformations in a radioactive series. A decay product may be either radioactive or stable.

Deposition density: The activity, of a radionuclide deposited per unit area of ground.

Dose: A general term denoting the quantity of radiation or energy absorbed per unit of mass. For special purposes, it must be appropriately qualified. If unqualified, it refers to absorbed dose. The unit of absorbed dose used in this report is the rad, 1 rad = 100 erg g^{-1}. In the SI system of units, the unit of absorbed dose is the gray, Gy. One Gy = 100 rad = 1 J kg^{-1}.

Effective half-life: The time required for the amount of a radionuclide deposited in a living organism to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

Electron: An elementary particle with a unit negative electrical charge and a mass 1/1837 that of the proton. Electrons surround the positively charged nucleus and determine the chemical properties of the atom.

Electron-volt: A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of one volt, abbreviated: eV; 1 eV = 1.6 x 10-12 erg. Multiple units of the electron volt are used in this report, namely: “keV” for thousand electron volts and “MeV” for million electron volts.

Euthyroid: A thyroid that functions normally.

Exposure:

1. A term generally used to mean subjected to or being in the presence of radioactivity or radiation.
2. A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges of all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The unit of exposure used in this report is the roentgen, R. In the SI system of units, the unit of exposure is the coulomb per kilogram, $C\ kg^{-1}$; $1\ R = 2.58 \times 10^{-4}\ C\ kg^{-1}$.

Exposure route: A pathway by which a radionuclide or other toxic material can enter the body. The main exposure routes are inhalation, ingestion, absorption through the skin, and entry through a cut or wound in the skin.

Fallout: The radioactive debris, once having been airborne, following a nuclear detonation, that has been deposited on the earth. Special forms of fallout include “local”, “intermediate”, and “global”.

Fission: A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

Fission yield (or yield): The percentage of fissions leading to a particular nuclide by direct formation and by decay of precursors.

Kriging procedure: Interpolation technique used in this report to estimate the ^{131}I deposition densities in counties where measurements were not available.

Nuclide: A species of atom characterized by the constitution of its nucleus. The nuclear composition is specified by the number of protons Z, the number of neutrons N, and energy content; or alternatively, by the atomic number Z, the mass number = N + Z, and the atomic mass. To be regarded as a distinct nuclide, the atom must also be capable of existing for a measurable time; thus nuclear isomers are separate nuclides, whereas promptly decaying excited nuclear states and unstable intermediates in nuclear reactions are not so considered.

Plowshare: Name of nuclear tests carried out in the U.S. for civilian purposes, e.g., excavation.

Rad: A unit of absorbed dose. One rad is 100 ergs absorbed per gram of any material. It is replaced by the Gray, Gy in the SI system of units. One rad equals one one-hundredth of a Gray.

Radioactive decay: Spontaneous disintegration of the nucleus of a radionuclide.

Radioactive equilibrium: Establishment of a radionuclide parent-daughter relationship whereby the activity of the daughter radionuclide is approximately the same as that of the parent radionuclide.

Radioactivity: The process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha or beta particles and gamma photons.

Radionuclide: A radioactive, unstable nuclide.

Uncertainty: The range of values within which the true value is estimated to lie. It is a best estimate of possible inaccuracy due to both random and systematic error.

Yield (or energy yield): The total effective energy released in a nuclear explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The accepted figure for the energy equivalent of one kiloton of TNT is 10^{12} calories. This corresponds to the complete fission of 0.057 kg of fissionable material or to the fission of 1.45×10^{23} nuclei.

CONVERSION FACTORS

In the metric system of weights and measures, designations of multiples and subdivisions of any unit may be arrived at by combining with the name of the unit the following prefixes:

E, exa, meaning 10^{18}

P, peta, meaning 10^{15}

M, mega, meaning 10^{6}

k, kilo, meaning 10^{3}

m, milli, meaning 10^{-3}

μ, micro, meaning 10^{-6}

n, nano, meaning 10^{-9}

p, pico, meaning 10^{-12}

f, femto, meaning 10^{-15}

a, atto, meaning 10^{-18}

Description of the Meteorological Model Used to Estimate ^{131}I Depositions Per Unit Area of Ground in the Absence of Environmental Radiation Data

Contents

In the absence of environmental radiation monitoring data, a meteorological model was used to estimate the ^{131}I depositions per unit area of ground. The meteorological model consists of three parts:

- Determination of the source term: ^{131}I activity released into the atmosphere and initial distribution of ^{131}I within the stem and the mushroom of the radioactive cloud.
- Modeling of the transport and dispersion across the United States of the ^{131}I present in the radioactive cloud.
- Determination of the fraction of the airborne ^{131}I activity that is scavenged to the ground with precipitation (the model does not calculate dry deposition).

Thus, the amount and vertical distribution of radioactivity is first estimated. This radioactivity is then carried across the country with the winds. Finally, when the spreading cloud encounters precipitation, a fraction of the radioactivity in the overhead column is deposited with the rain or snow.

The transport and dispersion model contains many simplifications. While intuitively more realistic and sophisticated models simulate the atmospheric processes better, they also demand more input information which is often unavailable and have the potential to introduce grossly erroneous as well as better predictions. It should be noted that the meteorological model has been used to reconstruct fallout for only nine of the 90 tests that were analyzed, and that these nine tests represent only 8,100 kCi out of the 150,000 kCi of ^{131}I released to the atmosphere in the NTS. Further, attempts were made to include a few more realistic features in other transport and dispersion models. The calculations of deposition from these "better" models were compared with the measured deposition from several tests and were found not to be significantly better than the simpler model described below.

A1.1. ATMOSPHERIC RELEASE AND INITIAL DISTRIBUTION OF ^{131}I IN THE RADIOACTIVE CLOUD

A1.1.1. Atmospheric Release of ^{131}I

The radioactive cloud that was formed after an atmospheric detonation near the ground surface usually was in the shape of a mushroom with a stem extending from the mushroom cloud base to the ground. The radioactive cloud could penetrate to the highest layers of the troposphere, and occasionally reached into the stratosphere.

The ^{131}I activity released into the atmosphere, Q in Ci, for a given nuclear test detonated at time, H, can be derived for most tests from data in Hicks (1981a) and calculated, in an indirect fashion, as:

$$Q(H) = \frac{DEP(H)}{BF} \qquad (A1.1)$$

where:

BF is the bomb fraction per square meter, as given in Hicks (1981a), and

DEP(H) is the local deposition of ^{131}I per square meter at the time of detonation, H, expressed in Ci m^{-2}, corresponding to an exposure rate of 1 mR h^{-1} at H + 12 hours.

Data in Hicks (1981a) also allow the calculation of the activity of ^{131}I present in the environment at time, T, after detonation, Q(H+T), according to:

$$Q(H+T) = \frac{DEP(H+T)}{BF} \qquad (A1.2)$$

As shown in *Table 2.3* and in *Figure 2.3* of **Chapter 2**, the activity of ^{131}I that is found in the radioactive cloud or on the ground after a nuclear test results not only from the production of ^{131}I itself but also from the decay of its precursors (^{131m}Te, ^{131}Te, and, to a lesser extent, ^{131}Sb). The activity of ^{131}I released into the environment at the time of the nuclear test does not, therefore, represent the "total" activity of ^{131}I that will be found 1 or 2 days later, which is the quantity of interest in this study. In order to take into account the contribution that these precursors eventually will make to the activity of ^{131}I, the activity of ^{131}I at the time of detonation was calculated as if all precursors had already decayed into ^{131}I. The activity obtained is called "total" activity of ^{131}I released into the environment and is denoted as Q* in this report.

The value of Q* for a given test was obtained as follows. First, the activity of ^{131}I present in the environment, Q(H+T), was calculated for a time, T, after detonation large enough that all the precursors of ^{131}I had decayed to negligible levels. Second, that activity was extrapolated back to the time H of detonation using the law of radioactive decay.

The value of Q(H+T) was calculated for T = 10 days from *equation A1.2* and the value of Q* was calculated as:

$$Q^* = Q(H+T) \times e^{\lambda_r \times T} \qquad (A1.3)$$

where:

λ_r is the radioactive decay constant of ^{131}I, expressed in d^{-1}.

The value of DEP(H+T), with T = 10 days, was reported by Hicks (1981a) for all shots that resulted in off-site detection of radioactive materials. However, the value of BF was reported for all above-ground tests and for two cratering shots only (Danny Boy and Sulky). For the cratering shots for which BF was not provided by Hicks (1981a), use was made of the total activity releases, TR, that were provided in Hague (1979) for all cratering shots. As it was observed that the product BF x TR is similar for Danny Boy and Sulky, the mean value of BF x TR for those two cratering shots was divided by the relevant value of TR to estimate the value of BF for all other cratering shots. As will be discussed in **Section A1.3**, the uncertainty in the value of BF is not deemed to contribute substantially to the overall uncertainty.

Table A1.1. Apportionment of the ^{131}I activity produced according to the type of test.

	Fraction of ^{131}I in each category		
Type of test[a]	Cloud top	Cloud stem	Local deposition[b]
Surface or Tower	0.8	0.1	0.1
Balloon or Airdrop	0.9	0.1	0.0

[a] For crater or underground tests the cloud did not have a mushroom shape. It was assumed that 100% of the ^{131}I activity released into the atmosphere was available for transport and dispersion by the wind, usually at 3.1 km altitude.

[b] Local deposition refers to that deposition of radioactivity which occurs within the first few hundred km of the point of detonation and which usually results from the settling of larger particles of the radioactive cloud.

The activity released into the atmosphere by underground shots that vented also has been reported by Hicks (1981b).

The activity released into the atmosphere is equivalent to the total activity produced in a test conducted above ground but may be substantially less in a cratering or in an underground test. The activity of "total" ^{131}I released into the atmosphere, normalized per unit of fission yield, was on average, about 0.14 MCi kt^{-1} for the above-ground shots. The values of Q* for all tests for which data are available are presented in *Tables 2.1* and *2.2* in **Chapter 2**.

A1.1.2. Initial Distribution of ^{131}I in the Radioactive Cloud

The apportionment of the amount of ^{131}I between the mushroom cloud and the stem was estimated by Ferber (1986)[1] according to the type of nuclear test as given in *Table A1.1.*

The initial partitioning of ^{131}I for one test (Simon) is shown in *Figure A1.1* where 10% of the ^{131}I has been subtracted for local fallout. The initial distribution, as illustrated in *Figure A1.1,* was not measured in any NTS test.

After the radioactive cloud stabilizes following the detonation, the larger particles fall and are carried horizontally by the winds. Those particles which fall rapidly enough to reach the ground as local deposition have been measured by their gamma radiation from the ground by exposure meters. Each of these rapidly falling particles reaching the ground has a trajectory which depends upon its height of origin in the cloud, size (or fall speed), and the horizontal wind in the layer through which the particle falls. Because the wind speed and direction (measured at or near the time of detonation at the NTS) varies with altitude, virtually every particle possesses a unique trajectory ending up on the ground occupied only by particles of about the same size and altitude of origin. Alternatively, if one measures the radioactivity of the ground in a given spot, the radioactivity must have come from only one altitude in the stabilized cloud. Further, the size of the particle need not be measured because there was only one fall speed that could have traced the particle's path from a specific point on the ground back to its origin in the cloud. However, particles of several sizes may originate from the same altitude layer but they will deposit in different ground locations.

The distribution of radioactive particles in a stabilized radioactive cloud and the amount of all large particles in a given layer may thus be reconstructed from NTS winds and local fallout measurements from exposure readings. It is assumed, in the absence of better information, that the vertical distribution of ^{131}I in the cloud given in *Table A1.1.* is the same as the radioactivity of the larger particles which are measured in the local deposition. The uncertainties in this reconstruction and its variability from test to test does not justify the breakdown of the ^{131}I into segments beyond the three given in the table.

A1.2. TRANSPORT AND DISPERSION

The transport and dispersion of the radioactive cloud has been calculated for each important atmospheric and vented nuclear test using routine upper air weather charts which depict airflow along surfaces of constant air pressure which are approximately horizontal surfaces. These standard charts, provided twice a day by weather services for their routine weather predictions, were used to construct horizontal trajectories, or paths, of air parcels (List 1953, 1954, 1956; Machta et al. 1957; NY0 1952, 1954) that originated at the Nevada Test Site at the time of each detonation and that moved across the United States between altitudes of about 3 and 12 km above mean sea level (MSL). Air parcels were carried along isopleths of airflow (streamlines) appearing on each 12 hourly weather map (00 and 12 GMT) at speeds which are given by the weather maps. The initial trajectory starts at the NTS at detonation time and is carried along the streamlines of the map closest in time until the next 06 or 18 GMT time. Thereafter, the segments start where the previous segment left off and carried for additional 12-hourly intervals. The 6-hourly positions are found by interpolation. Trajectories for all tests in this report except Sedan, Little Feller I, Des Moines, Bandicoot, Pin Stripe, Schooner, Johnie Boy, Small Boy, and Baneberry were prepared during the period of the tests; trajectories for these tests were calculated for this report at standard altitudes to which the radioactive cloud rose.

[1] Ferber, G. NOAA/Air Resources Laboratory, Silver Spring, MD 20892. Personal communication (1986). The method used by Ferber is explained later in *Section A1.1* from the measurements of local fallout and the NTS winds.

Figure A1.1. Schematic depiction of the mushroom cloud and stem resulting from the test Simon, detonated April 25, 1953.

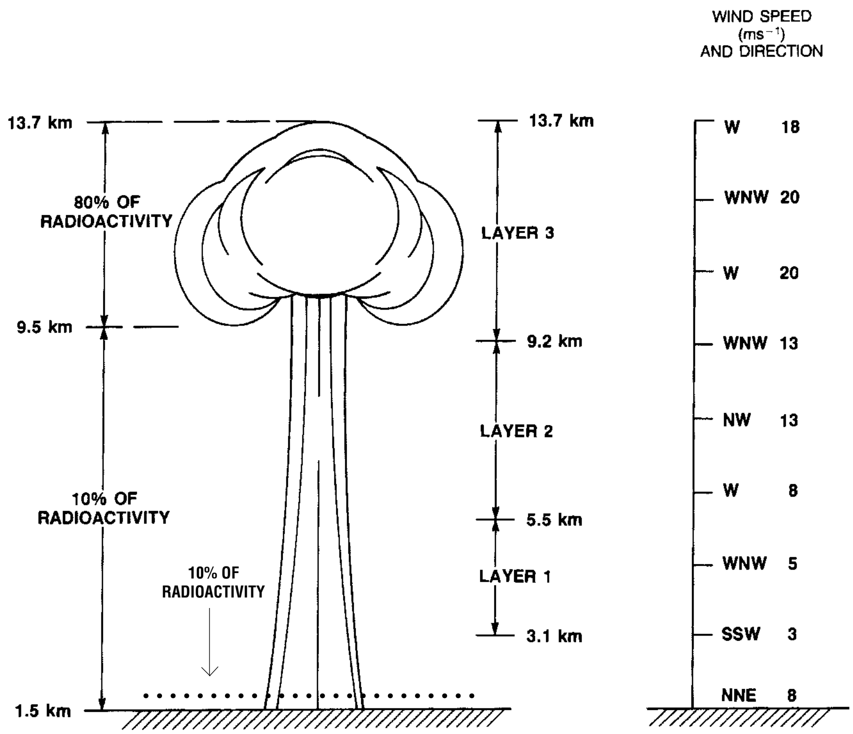


Figure A1.2 is an example of such trajectories at four of the standard levels (usually 3.1, 5.5, 9.2 and 12.2 km above mean sea level) where the successive positions of air parcels at each altitude are indicated every 6 hours. In general, the trajectories at various elevations diverged in both direction and forward distance after leaving the test site. For example, the calculated position of the radioactive cloud after about 36 hours after detonation or at 00 GMT, 27 April 1953 for test Simon appears on *Figure A1.3* based on the trajectories seen on *Figure A1.2*. The center of the cloud at 3.1 km altitude was located over western Wyoming while the cloud center at 5.5 km was over northern New Mexico. However, there was radioactivity at all altitudes between 3.1 and 5.5 km. At the mid-altitude of 4.3 km, the cloud center was assumed to lie midway along the line joining the connected points on the two trajectories labelled "27" (for 00 GMT, 27 April), or over west central Colorado. At every other altitude between 3.1 and 5.5 km, the position of the cloud center can be similarly interpolated along the line.

In addition the cloud has grown by atmospheric turbulent diffusion at an assumed rate of 7.4 km h^{-1} based on the spread of smoke puffs and other tracer clouds (Heffter 1965). At each level in the atmosphere, after 36 h the cloud is assumed to be a circular disc with a radius of 266 km (7.4 km h^{-1} x 36 h). The size of the initial cloud at the time of stabilization is considered to be negligibly smaller compared to the size of the cloud after many hours of transport and atmospheric diffusion. The elongated shaded area presents the projection of all the discs to the ground; it shows where the model calculates the cloud to be overhead.

The layer between 3.1 and 5.5 km lies within the stem of the cloud from test Simon. The total release of ^{131}I from test Simon was reported as 6,250 kCi and 10% or 625 kCi were assigned to the stem of the cloud. The base of the stem is the ground at 1.5 km msl and, from local observations, the top of the stem or the base of the mushroom head was 9.5 km msl. The 625 kCi were uniformly distributed over the 8 km (9.5 km-1.5 km) yielding about 78 kCi for each km of altitude in the stem. Since the lowest trajectory started at 3.1 km rather than 1.5 km, this small amount of ^{131}I in the layer 1.5 to 3.1 km was also assigned to local or close-in fallout. Note that many nearby mountains reach well above 1.5 km downwind of the NTS. Thus, in the layer between 3.1 and 5.5 km or a layer 2.4 km thick, there were about 190 kCi (78 kCi km^{-1} x 2.4 km). This much ^{131}I lies in the shaded area between New Mexico and Wyoming at 00 GMT 27 April 1953 according to the model calculations.

If it rained or snowed anywhere in the shaded area, the model deposits a small fraction of the activity directly overhead as described later. Rainfall information is available only for 24-h periods. It is not known during which of the four periods of a day the rain or snow may have scavenged the radioactivity from the nuclear cloud. (The position of the cloud given by the shaded area is calculated each 6 hours). It is assumed that the rain or snow occurs continuously during the 24-h period. Finally, one must note that the concentration of ^{131}I is the same everywhere in the shaded area between New Mexico and Wyoming. The uniformity applies individually to all segments between the altitudes at which the trajectories are computed.

Figure A1.2. Paths of the trajectories followed by portions of the radioactive cloud at the altitudes of 3.1, 5.5, 9.2, and 12.2 km above mean sea level (MSL) resulting from the test Simon detonated 25 April 1953. The closed dots represent the locations of the trajectories at 00:00 GMT, while the numbers near the closed dots are the day of the month. The open dots represent the locations of the trajectories at 06:00, 12:00 and 18:00 GMT.

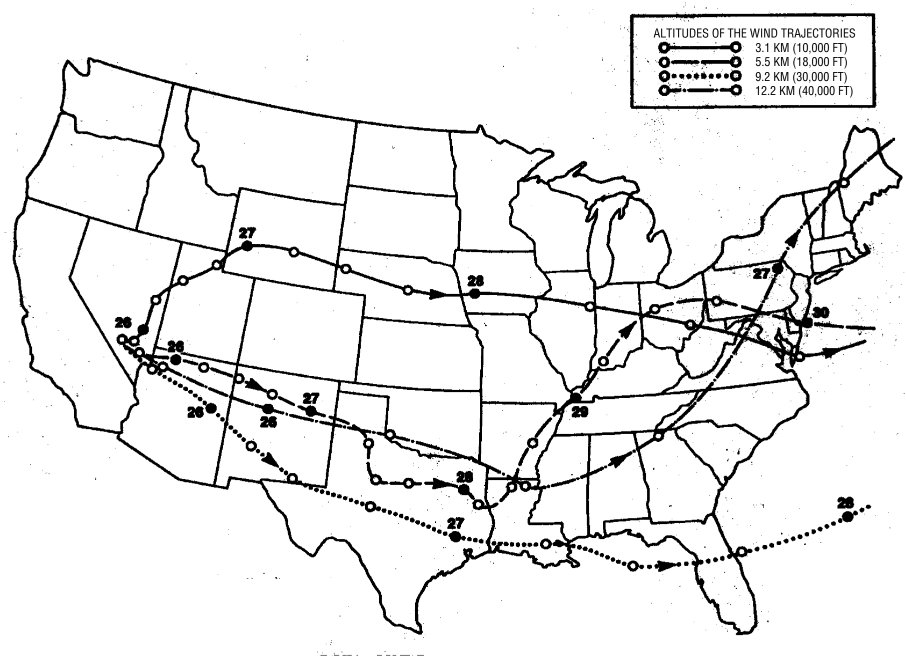
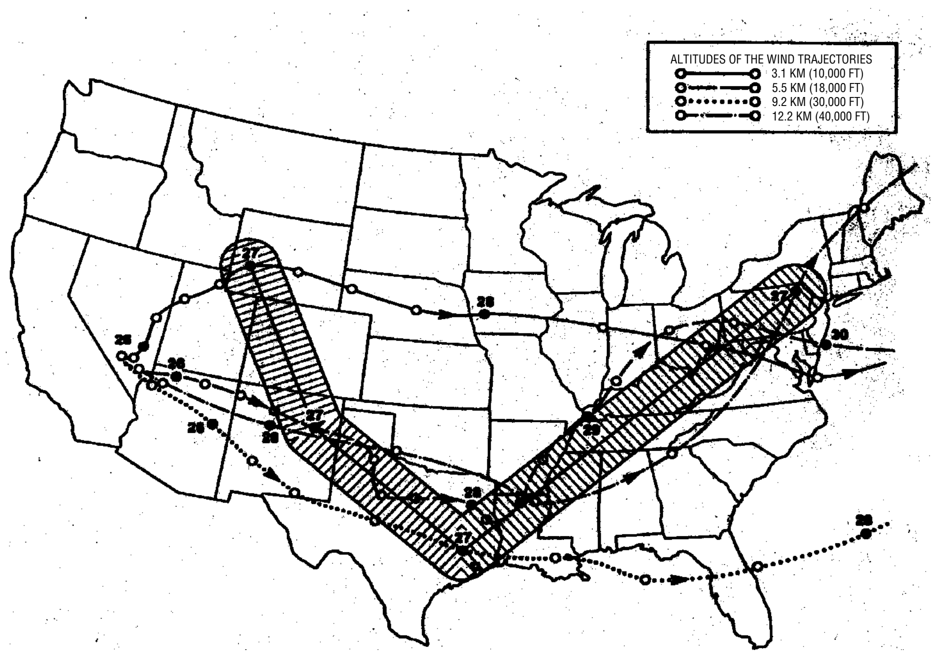


Figure A1.3. Outline of the meteorological reconstruction of the entire Simon nuclear cloud 36 hours after detonation.



The Simon cloud rose initially to heights above 5.5 km. The centerline of the segment of the cloud between 5.5 and 9.2 km lies between northeastern New Mexico and southeastern Texas, again joining the points labeled "27." The line from southeastern Texas and northeastern Pennsylvania shows the centerline position between 9.2 and 12.2 km heights of the topmost trajectory altitude, even though it was observed to rise to 13.8 km, which is in the stratosphere. At an altitude of 10.7 km, the mid-point between 9.2 and 12.2 km, the center of the cloud would be over northern Tennessee in the shape of a disc with a radius of 266 km as in the lower levels. The concentration in each disc at each altitude is assumed to be uniform.

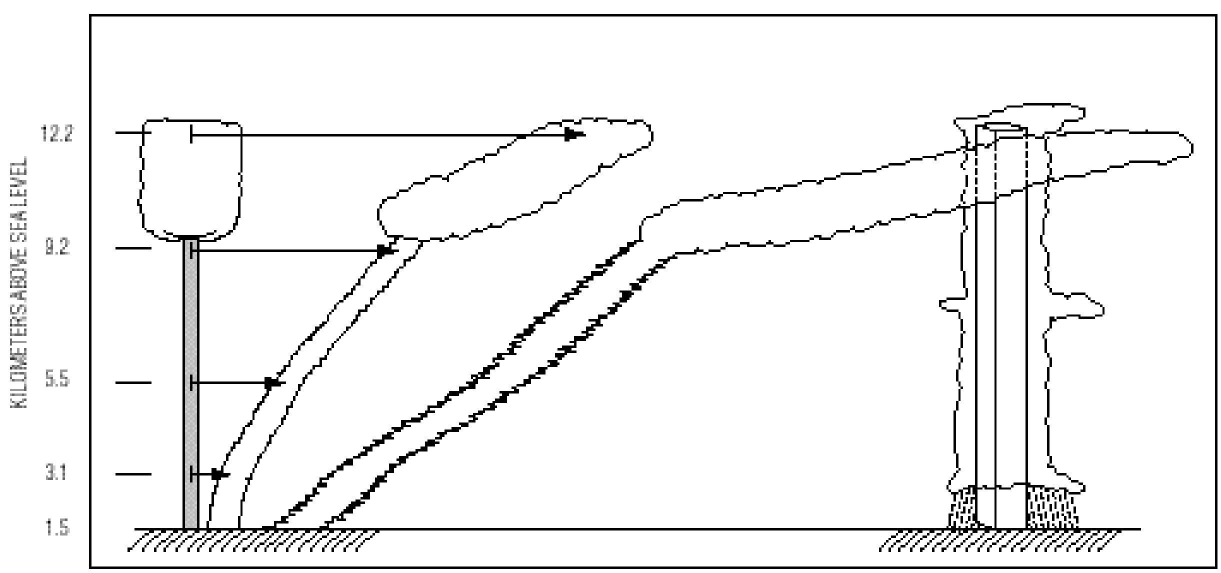
Note that the cloud between 9.2 and 12.2 km is especially strongly sheared by the winds, that is, the end points are far apart. This means that the radioactivity in that segment is spread over a much larger area than is the case at lower altitudes. The amount of radioactivity in a vertical overhead column, the quantity used in precipitation scavenging is reduced by the strong shear. The stretching of an initially vertical column of a nuclear cloud by winds is illustrated schematically in *Figure A1.4* at two successive times. This picture reflects only the change with height of the wind speed, the more common mode of wind shear, but shear due to winds blowing in different directions at successive altitudes also occurs. A weather cloud is shown intersecting the nuclear cloud at the second position.

The total amount of ^{131}I initially released into the atmosphere remains nearly constant during the few days before the cloud moved beyond the borders of the U.S., as only a small fraction of the ^{131}I has time to decay and as the depletion due to deposition processes is relatively small. The empirically derived wet scavenging coefficients remove only a few percent of the overhead cloud radioactivity each day with normal rainfall, as seen later in *Table A1.2*.

The above described method for treating the radioactive cloud following detonation is called the "transport and dispersion model."

As the radioactive cloud was carried over the U.S. by the upper winds, fallout could be expected beneath it, especially if precipitation were involved. During some of the period of nuclear testing, gummed-film samplers were distributed over the U.S. and exposed for 24-h periods and could be compared with predictions of the cloud transport and dispersion model. The fraction of the calculated cloud content deposited on the ground varied greatly. Further, sometimes depositions occurred where no cloud was predicted to be overhead especially for cases after the radioactive cloud was predicted to have moved away from the area. This residual contamination has also been found for other trace substances in the air; after a puff-type "pollutant" has been carried away by stronger upper-level winds, measurable deposition frequently occurs for a few days (Draxler 1987, 1988; Segal et al. 1988). Some discrepancies were resolved by calculating additional trajectories below 3.0 km. When the meteorological model was applied to tests for which there were deposition measurements, the errors were large.

Figure A1.4. Schematic representation of stretching of the nuclear cloud caused by increasing wind speed with height. The cloud shown at time of detonation, at the left, and at two time intervals later. The time-dependent widening of the cloud is also indicated. A schematic unit column used for calculating the cloud's radioactive content is shown intercepting a portion of the highest layer of the cloud.



It must be recognized that estimates of the overhead ^{131}I column content by the above method depend both on the accuracy with which the model initially distributes ^{131}I in the radioactive cloud and on the meteorological transport and dispersion assumptions and calculations. These include also the uncertainties that exist because actual air parcel trajectories are not constrained to the constant pressure surfaces which are quasi-horizontal.

A1.3. DEPOSITION OF ^{131}I

A distinction is usually made between two physical processes producing deposition of radioactive materials to the ground: wet deposition (with falling precipitation) and dry deposition (without precipitation). In the western U.S., most of the deposition of ^{131}I was dry because the area is typically drier than the eastern part of the country and because special efforts were made to avoid detonations when precipitation was present in the region. Experience indicated that rain greatly enhanced the amount of radioactive materials that was deposited from the nuclear tests; hence in the eastern U.S. (generally east of the Rocky Mountains), where rain is more frequent, the largest depositions occurred with rain (Beck et al. 1990). For any one test, the amount of ^{131}I deposited generally increased with the amount of rainfall. Dry deposition, on the other hand, depends upon the concentration of ^{131}I in the air at ground level, low altitude atmospheric turbulence, the nature of the surface upon which the dry deposition occurs, and the chemical and physical form of the ^{131}I.

A1.3.1. Wet Deposition

The amount of ^{131}I that was deposited per unit area of ground with falling precipitation in a given day, DG_{wet} was obtained as:

$$DG_{wet} = A_{cl} \times SC \qquad (A1.4)$$

where:

A_{cl} is the activity of ^{131}I present in the radioactive cloud in a vertical column of unit area during the day considered, and

SC is the scavenging coefficient, which represents the fraction of the activity present in the cloud which is removed with falling precipitation during that day.

The value of the scavenging coefficient depends, among other factors, upon the amount and intensity of rain, on the respective altitudes of the rainfall and radioactive clouds, and on the physical and chemical forms of ^{131}I in the radioactive cloud. Most of the information that would be necessary to estimate the value of the scavenging coefficient for a given day and a given area is usually not available. It is possible, however, to obtain the distribution of the average scavenging coefficients as a function of the precipitation index value (see *Table 3.2,* **Chapter 3**) for tests for which estimates of ^{131}I deposition were derived from gummed-film data. For that purpose, the cloud transport model was used to calculate the values of A_{cl} corresponding to 14 tests which were found in the analysis of gummed-film data to have resulted in relatively important depositions of ^{131}I with falling precipitation in the country. In *equation A1.4,* DG_{wet} was obtained from the gummed-film data, A_{cl} was taken from the cloud transport model, and SC, as the only unknown, could be calculated. *Table A1.2* shows the distribution of the SC values obtained for the 14 tests as a function of precipitation indices greater than 2. Although the table exhibits very wide variability of the scavenging coefficient for each precipitation index, with GSDs ranging from 5 to 10, a general increase in the mean scavenging coefficient with higher index numbers is demonstrated.

Table A1.2. Estimates of wet scavenging coefficients obtained for 14 nuclear tests as a function of the precipitation index.

Precipitation index	Scavenging coefficients[a]		
	Geometric mean	GSD	Number of cases
2	0.013	8.5	93
3	0.013	10.0	69
4	0.020	7.6	79
5	0.020	7.4	74
6	0.058	6.9	84
7-9	0.17	5.2	34

[a] The fraction of the overhead radioactivity deposited per day

Stratification of the scavenging coefficients for available factors other than the precipitation index value, such as the height of the layer of the atmosphere containing the radioactive debris, failed to reduce the variability. Some intuitively important factors, such as the height above the ground at which natural clouds might scavenge the radioactive cloud, were not available. The very large variability of the scavenging coefficient reflects all of the uncertainties in both the radioactive cloud and in the gummed-film measurements as well as other factors such as the uncertainty in the amount of ^{131}I released into the atmosphere, the imperfect coincidence between time of the predicted cloud passage, time and location of the precipitation event, and defects in the gummed-film samples and analyses.

The scavenging coefficients of *Table A1.2* were used to estimate wet deposition for those tests where gummed film was not deployed. It was assumed that, for a given precipitation index, the appropriate coefficient used to predict the wet deposition would have the same GSD and associated uncertainty as it had in the 14 nuclear tests. The uncertainty of the scavenging coefficient would be considered to also be the estimated deposition uncertainty for the model calculations.

A1.3.2. Dry Deposition

Dry deposition of ^{131}I is usually assumed to be related to the concentration of ^{131}I in ground-level air. The transport and dispersion model that is used in this report for nine tests does not allow for the prediction of concentrations of ^{131}I in ground-level air. Consequently, it is not possible to predict the dry deposition of ^{131}I with this method and it is unaccounted for in the analysis of the nine tests by the transport and dispersion model. It should be pointed out, however, that dry deposition is considered in the analysis of the other 81 tests.

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Appendix 2

Structural Characteristics of the Dose Assessment Methodology and Origin and Content of the Databases

Contents

A2.1. INTRODUCTION

The purpose of the study is to estimate collective doses for the entire population of the contiguous United States, as well as representative doses to individuals in each county, resulting from atmospheric bomb testing at the Nevada Test Site. The study is limited to the assessment of thyroid doses from ^{131}I.

The most important exposure route to man from ^{131}I in fallout is from the ingestion of fresh cows' milk contaminated by the deposition of ^{131}I onto pasture grass. The doses from this exposure route have been investigated in as much detail as possible. Other, generally less important, exposure routes also have been considered:

- inhalation,
- ingestion of goats' milk,
- ingestion of eggs,
- ingestion of leafy vegetables, and
- ingestion of cottage cheese.

In the course of the dose assessment, it was necessary to set up several databases containing information on input parameters which varied in space and/or time. The origin, organization, and content of these databases are herein described.

A2.2. DESCRIPTION OF THE DATABASES

Some of the databases are used in a specific part of the study while others have more general application. The latter are discussed first.

A2.2.1. Databases with General Application

(1) Geographical subdivisions

When available in the literature, the statistical data of interest in this study are provided at the county or at the state level. There are about 3000 counties in the 48 contiguous United States. Although the counties differ widely in area and population across the U.S., it was considered appropriate to use the county as the geographical unit and to carry out the dose assignments for each county. From 1950 to 1980, the definition of the counties remained the same with a few exceptions. For reasons of convenience, the definition used here is that of 1974, which was provided as a computer tape by the ORNL (Olson, Emerson and Nungesser 1980).

In that year, there were 3071 counties in the contiguous United States. Each of the counties is characterized by a Federal Information Processing System (FIPS) code designated by the U.S. government. The first two digits denote the state and the last three identify the county. For example, Nye county in Nevada is identified as 32009. The FIPS codes are used in this assessment for all but 14 counties.

The 14 counties which received a special treatment are all situated in the vicinity of the NTS. Environmental monitoring showed that, in that part of the country, there were substantial variations in the deposition of ^{131}I resulting from some of the tests. Consequently, each of those 14 counties was subdivided into two to four parts deemed to be relatively homogeneous with respect to deposition as well as to other factors (pasture practices and milk distribution). The 14 counties of interest were subdivided into a total of 37 sub-counties and assigned new identification codes. The counties subdivided are shown on *Figures A2.1* to *A2.5*. When there is no ambiguity as to what is meant, both the 3057 undivided counties and the 37 sub-counties are referred to as "counties" in this report. A detailed presentation of the data related to the 37 sub-counties is given in **Section A2.3**.

Section A2.4 (Attachment to Appendix 2)contains the area of each county, as well as the longitude and latitude of each county centroid. These data were provided in the ORNL database for the 3057 undivided counties; they were estimated for the 37 subcounties.

The distance from each county centroid to the NTS, the location of which is taken to be 37.00ºN and 116.00ºW, is also included in **Section A2.4**. This distance was calculated assuming the entire territory of the contiguous U.S. to be a flat surface.

(2) Population

The total population in each county is used to estimate the expected milk consumption and, in some cases, the average milk consumption rate. The distribution of the population with age and sex is necessary to compute the collective dose to the entire population of the contiguous United States.

The population data were obtained from EPA (Riggan 1985) in the form of a computer tape. This database includes, for each county and each year from 1950 to 1979, the population in each of the following categories:

Age (years): 0-4; 5-9; 10-14; 15-19; 20-24; 25-29; 30-34; 35-39; 40-44; 45-49; 50-54; 55-59; 60-64; >65

Sex and race: white male, white female, non-white male, non-white female.

The most important tests considered in the dose assessment occurred between 1951 and 1957. For the purpose of this study, it was considered adequate to use the 1954 population data for each test.

The population data for the 37 sub-counties were derived from the Population Censuses of 1950 and 1960. A preliminary estimate of the 1954 population in each sub-county was obtained by linear interpolation of the 1950 and 1960 data given in the Population Censuses. The total of the preliminary estimates for a given county was then adjusted to the value found in the EPA database using a correction factor. That correction factor was then applied to the preliminary estimates of the population in each sub-county in order to obtain the final estimates.

Figure A2.1. Identification of the counties in the vicinity of the NTS. The counties left blank have been subdivided according to the dashed lines.

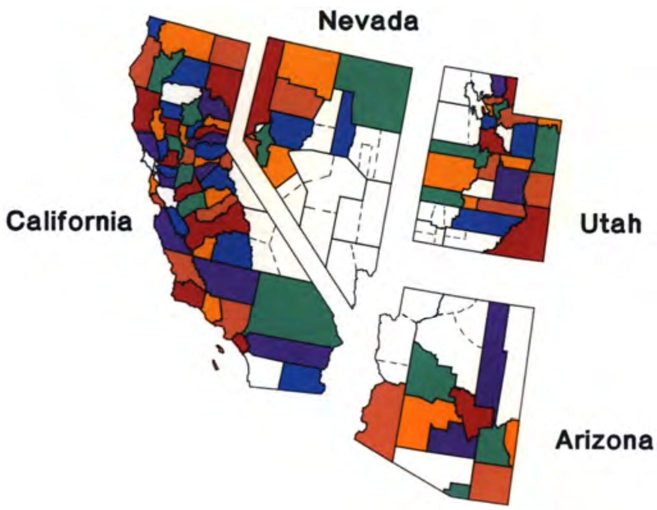


Figure A2.2. Geographical subdivisions for the state of Arizona. The solid lines represent the county boundaries. The counties left blank have been subdivided according to the dashed lines. The numbers identify the sub-counties (see Table A2.1 for further information).

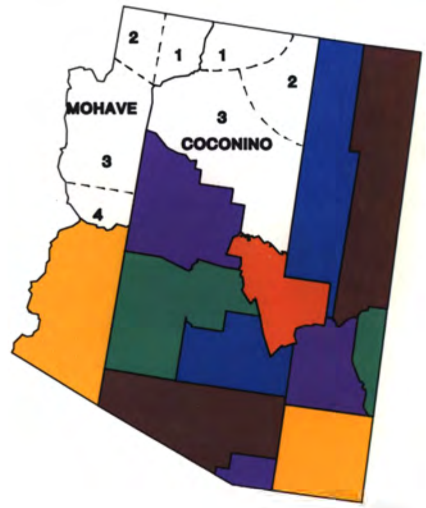


Figure A2.3. Geographical subdivisions for the state of California. The solid lines represent the county boundaries. The counties left blank have been subdivided according to the dashed lines. The numbers identify the sub-counties (see Table A2.1 for further information).

Figure A2.4. Geographical subdivisions for the state of Nevada. The solid lines represent the county boundaries. The counties left blank have been subdivided according to the dashed lines. The numbers identify the sub-counties (see Table A2.1 for further information).

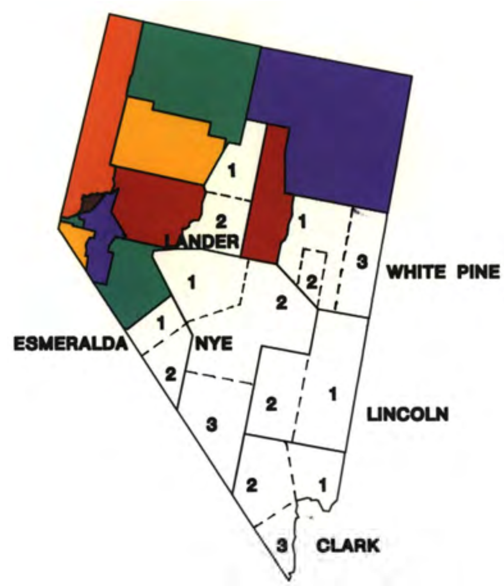
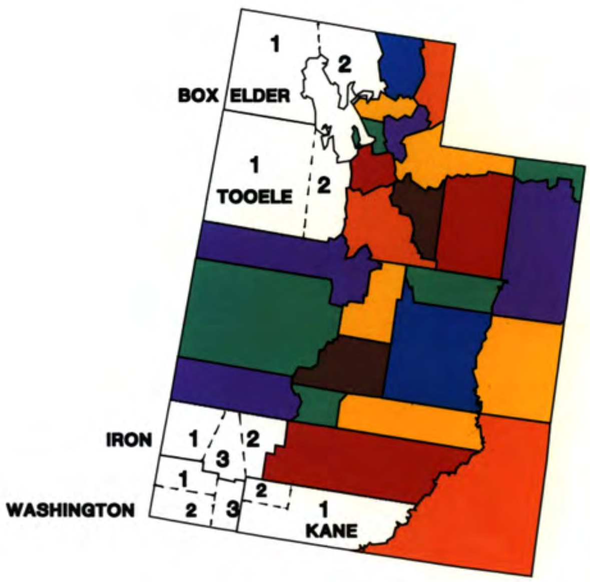


Figure A 2.5. Geographical subdivisions for the state of Utah. The solid lines represent the county boundaries. The counties left blank have been subdivided according to the dashed lines. The numbers identify the sub-counties (see Table A2.1 for further information).



(3) Precipitation

The precipitation data are used to calculate the ^{131}I ground deposition as well as the fraction of the ^{131}I ground deposition that is intercepted by vegetation. The precipitation data were compiled by NOAA using as a basis the very dense national network of precipitation monitoring stations operated for that governmental organization by cooperative observers. This network, with rare exceptions, provides at least one measurement location in each of the counties of the contiguous United States.

The rainfall amounts represent 24-h accumulations ending usually at 9:00 a.m. local time or an hour or two displaced from that time. For the purposes of this report, a single precipitation value for each day, being the arithmetic average of all readings in the county, was assigned to a county and assumed to be located at the county's geographical centroid. Counties without data were rare, but were assigned amounts of rainfall based on measurements from locations in adjacent counties. The amounts of rain were categorized on a logarithmic scale by index value as shown below.

Relationship between the 24-h precipitation amount and the precipitation index:

	24-h precipitation amount	
Precipitation index number	(Inches)	(Millimeters)
1	none	none
2	trace	trace
3	0.01-0.03	0.25-0.76
4	0.03-0.10	0.76-2.5
5	0.10-0.30	2.5-7.6
6	0.30-1	7.6-25
7	1-3	25-76
8	3-5	76-127
9	5 or over	127 or over

The precipitation data are available for each day between 1951 and 1962 in which substantial ^{131}I depositions from nuclear weapons testing at the NTS are found, or are predicted, to have occurred.

A2.2.2. Specific Databases Related to Deposition

Monitoring of long-range fallout deposition in the U.S. in the 1950s was carried out primarily by the Health and Safety Laboratory (HASL) of the Atomic Energy Commission in cooperation with the U.S. Weather Bureau (Beck 1984; Harley et al. 1960). The HASL deposition network evolved gradually, beginning in the fall of 1951 with the Buster-Jangle test series. The original monitoring technique consisted of collectors which were trays of water; these were soon replaced by gummed paper for the 1952 Tumbler-Snapper test series. The gummed paper was replaced by an acetate-backed rubber-base cement gummed film in 1953, and this medium was used until the program ended in 1960.

A 1 square foot (0.093 m^2) exposed area of gummed film was positioned horizontally on a stand 3 feet (0.9 meter) above the ground. Usually two replicate films were exposed during a 24-h period beginning at 1230 Greenwich Mean Time (GMT) for the Upshot-Knothole, Teapot, Plumbbob and Hardtack Phase-II series and at 1830 GMT for the Buster-Jangle and Tumbler-Snapper series. Daily high volume air samples also were collected at many of the gummed-film sites, as well as at additional sites where there was no gummed-film collector.

The number and types of monitoring sites in operation in the U.S. changed from one test series to another. Although only about 40 sites operated continuously throughout the atmospheric testing era, the number generally was increased during the testing periods and reached a maximum of 95 in 1953 (Upshot-Knothole series).

Estimates of daily deposition of ^{131}I were derived from those gummed-film data for the tests carried out between November 1951 and November 1958. The complete results are provided in the **Annexes**.

A2.2.3. Specific Databases Related to Pasture Intake

The pasture feeding practices of dairy cows between 1951 and 1962 were not directly measured. The estimates of pasture intake and length and timing of the pasture season that were reported are averaged for each state over a 10 year period of time. Information collected from expert opinions were for the same time period over an entire state. It is clear that these practices varied from farmer to farmer and county to county in all states: however, in certain cases a definite dividing line between areas of the state were clear. These states, as well as the states close to the Nevada Test Site, were divided into more than one pasture region. The 71 pasture regions are shown in *Figure A2.6*.

A2.2.4. Specific Databases Related to Cows' Milk

Data for milk production, utilization, distribution and consumption are available on a state average or regional basis. The following data are available for each state:

- average milk production for state in 1954,
- milk consumed on farms in 1954,
- milk used for non-fluid use on farms in 1954, and
- milk used for manufacture of dairy products in 1954.

On a regional basis the following data are available:

- milk consumption rates used to determine milk use.

This information is used to derive estimates of annual volumes of milk produced, utilized, and distributed on a county basis. Modeling milk distribution across the country is extremely difficult to do for the 1950s. In general, information exists on the directions of the flow of milk but not much on the volume of milk shipped. It is likely that local distribution was controlled by demand and price, which fluctuated rapidly. It is assumed that milk flowed freely between adjacent counties, therefore by grouping counties into "regions," this flow would be easily simulated. The 3094 counties were grouped into 429 milk regions using established crop reporting districts, metropolitan areas, and proximity to the Nevada Test Site boundaries as guidelines. The boundaries of the 429 are shown in *Figure A2.7*. The federally administered Milk Market Order system published a list of the counties that provided milk to each particular Milk Market Order in the late 1950s and early 1960s. This information was used to estimate the transfer of milk between regions. For each county, demographic information on the age and sex distribution is available. Milk consumption rates and dose conversion factors are assigned to each of these categories.

A2.3. DATA RELATED TO THE CLOSE-IN COUNTIES

The counties close to the Nevada Test Site are treated in greater detail due to the larger degree of complexity of fallout deposition patterns and the increased number of measurements made at the time of the tests. The area that will be discussed in detail in this section includes the complete states of Utah and Nevada and parts of Arizona and California; these areas are illustrated in *Figures A2.1* to *A2.5*. Fourteen counties in these states have been subdivided. The boundaries of the subdivisions were assigned on the basis of the fallout deposition and exposure measurements taken in these counties during the 1950s and 1960s (Beck and Anspaugh 1991; Thompson and Hutchinson 1990). The measurement locations were chosen to monitor the most populated areas of the county. The general characteristics of these subdivisions (description, code numbers, etc.) can be found in *Table A2.1*.

A2.3.1. Populations and Areas

The population of all the counties in the U.S. were obtained from EPA (Riggan 1985). The population by township that are reported in the U.S. Census every 10 years (USDC 1950; USDC 1960) were interpolated to estimate the population in the sub-county divisions in 1954. These estimates are listed in *Table A2.2*.

The areas of the sub-counties were estimated and also can be found on *Table A2.2*.

A2.3.2. Deposition

For counties near the NTS, the primary data are exposure-rate measurements using portable survey instruments. An extensive program of exposure-rate measurements was carried out in a few counties near the NTS for several days following each test. These exposure rate measurements, together with other, less extensive, monitoring data, were evaluated and archived by the Offsite Radiation Exposure Review Project (ORERP) of the Department of Energy. From these data, a Town Data Base (Thompson and Hutchinson 1990) and a County Data Base (Beck and Anspaugh l991) were derived:

1. the Town Data Base (TDB) lists the time of arrival of the radioactive cloud produced by each test and the exposure rate normalized at 12 hours after detonation (H + 12) at 173 stations, representing inhabited locations, in 4 counties of Nevada (Clark, Esmeralda, Lincoln, and Nye) and in Washington County, Utah. The use of H + 12 as the standard time to report exposure rates is an agreed-upon convenience; fallout may have been deposited on the ground before or after H + 12;

Figure A2.6. Identification of the pasture regions used in the dose assessment.

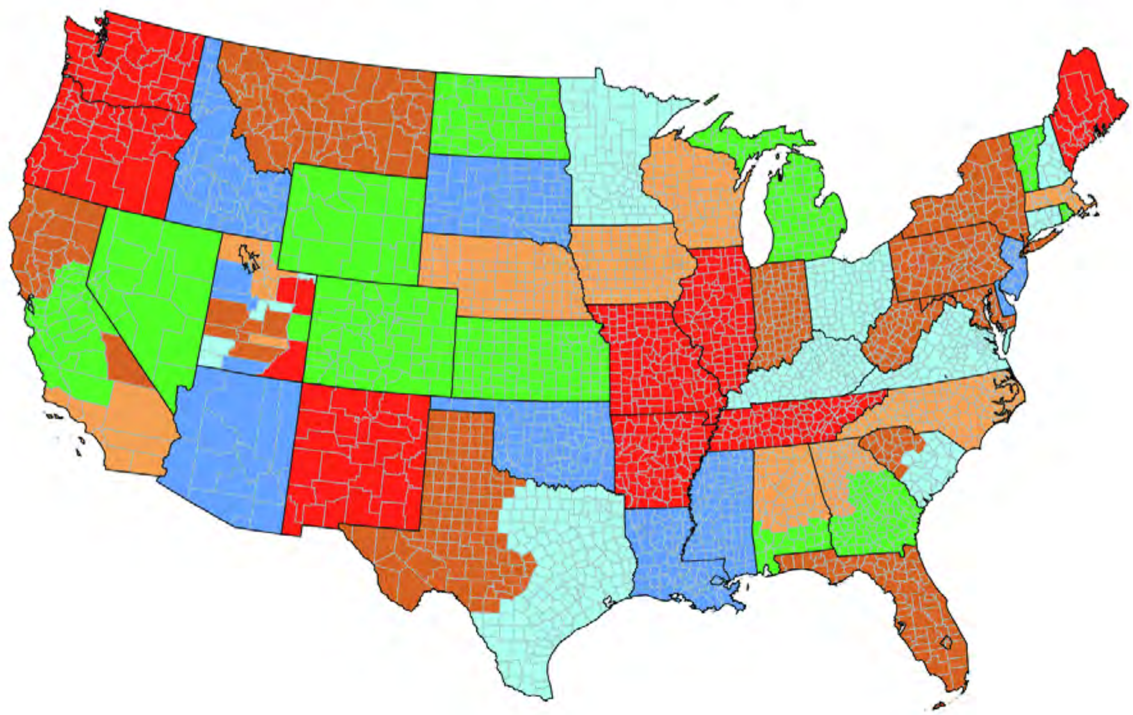
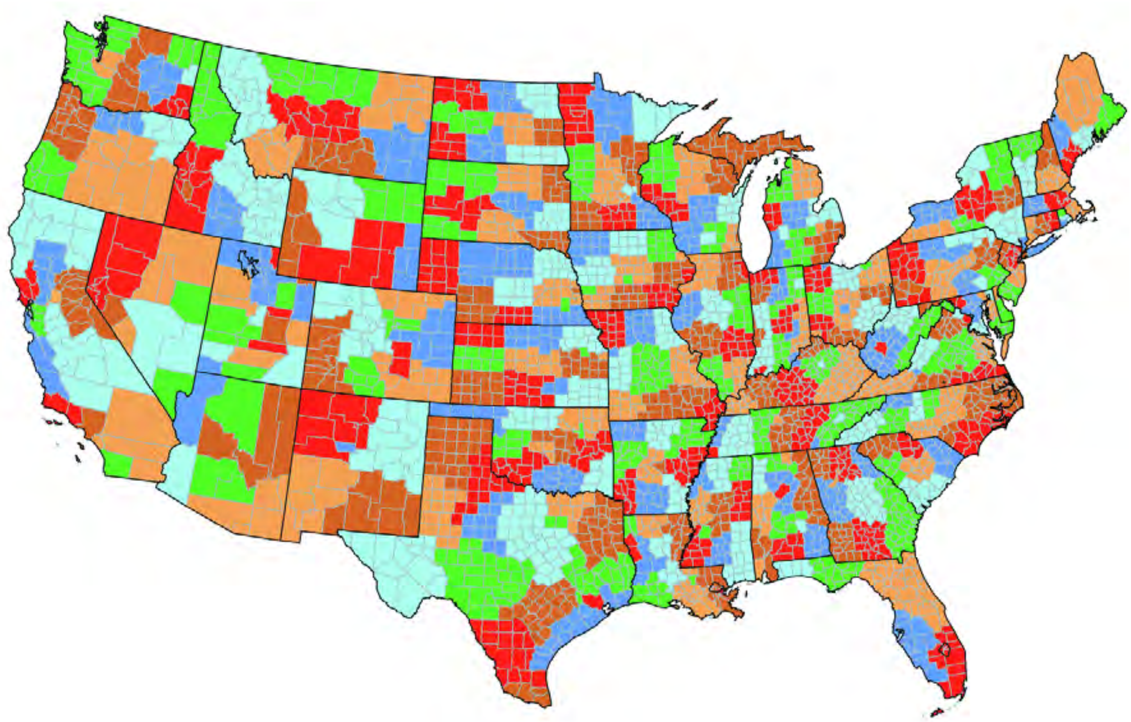


Figure A2.7. Identification of the "milk regions" used in the dose assessment.



2. the County Data Base (CDB) lists the estimated times of initial arrival of the radioactive cloud and the estimated exposure rates normalized at H + 12 in 24 subdivided areas of nine counties in Arizona, California, Nevada, and Utah, along with similar information for 120 additional counties (i.e., not subdivided) in Arizona, California, Colorado, Idaho, New Mexico, Nevada, Oregon, Utah, and Wyoming.

Estimates of deposition of ^{131}I per unit area of ground were derived from the exposure rates normalized at 12 hours after detonation, together with the corresponding times of arrival of the radioactive cloud. The complete results are presented in the form of Tables as well as of Figures in the Annexes.

A2.3.3. Number of Cows and Farms

During the early 1960s, the Public Health Service compiled a directory of farms and cows on the farms "to be used by the Off-Site Surveillance Program in selecting and locating desirable milk sampling points that would be of interest in support of particular events conducted at the Nevada Test Site" (PHS 1964). The PHS data available for each sub-county considered in this report are presented in *Table A2.2*. However, the total number of cows and farms in each county, reported in the Census of Agriculture (USDC 1954), usually does not match the data published by PHS (1964). In this report, the numbers reported in the 1954 Census of Agriculture (USDC 1954) were used but the general trend displayed by the PHS data was followed. A comparison of the two sets of data is presented in *Table A2.2* along with the values adopted in this report for the number of cows and farms in each sub-county.

A2.3.4. Pasture Intake

Estimates of the amount of pasture consumed by cows and the length of the pasture season for these counties are reported in detail in Ward and Whicker (1987). Estimates for the close-in counties and subdivisions are presented in *Table A2.3*.

A2.3.5. Milk Production and Utilization

The volumes of milk annually produced and utilized for various purposes have been estimated for each sub-county and the year 1954 on the basis of the number of cows and farms presented in *Table A2.2* and using the methodology described in **Chapter 5** of this report. Results are presented in *Table A2.4*.

A2.3.6. Milk Distribution

The milk distribution in the close-in counties was estimated using the data provided in Ward and Whicker (1987). The report provides data for the source of the milk supply to a given town or rural area in a county and the proportions of the milk supply that came from the other locations. These data were followed as much as possible, due to the different approaches of the two studies. Details of the milk distribution are presented on *Table A2.5*.

Table A2.1. Characteristics of county subdivisions near the NTS

State, county and FIPS code	No. of subdivisions	"fake" FIPS code	Definition	Deposition	Pasture region number	Milk region number
AZ Coconino 04005	3	04501	Kalbab division	Fredonia (CDB)	AZ-north	403
		04502	Reservation division	RimTuba (CDB)	AZ-north	404
		04503	Coconino and Williams divisions	Flagstaff-Williams (CDB)	AZ-north	405
AZ Mohave 04015	4	04151	Mohave No. div. (West)	Moccasin (CD8)	AZ-north	399
		04152	Mohave No. div. (East)	Littlefield (CDB)	AZ-north	400
		04153	KIngman North division	Kingman (CDB)	AZ-north	401
		04154	Kingman South division	Kingman (CDB)	AZ-north	402
CA Inyo 06027	3	06271	Bishop&Independence div.	Bishop (CDB)	CA-Inyo	406
		06272	Lone Pine div.	Bishop (CDB)	CA-Inyo	407
		06273	Death Valley div.	Furnace creek (CD8)	CA-Inyo	408
NV Clark 32003	3	32301	Bunkerville, Logandale, Mesquite, Moapa, and Overton townships	average deposition In the 5 twp. (TDB)	Nevada	373
		32302	Goodsprinqs, Henderson, and Las Vegas twp.	average deposition In the 3 twp. (TDB)	Nevada	416
		32303	Davis Dam, Nelson, and Searchlight twp.	average deposition in the 3 twp. (TDB)	Nevada	417
NV Esmeralda 32009	2	32901	Fishlake, Millers, and Silverpeak twp.	Average deposition In the 3 twp. (TDB)	Nevada	415
		32902	Goldfield, Goldpoint, and Lida twp.	Average deposition In the 3 twp. (TDB)	Nevada	415
NV Lander 32015	2	32551	Argenta township	Battle Moun. (CDB)	Nevada	409
		32552	Austin township	Austin (CDB)	Nevada	409
NV Lincoln 32017	2	32171	Callente, Panaca, and Ploche twp.	Average deposition In the 3 twp. (TDB)	Nevada	411
		32172	Alamo township	Alamo (TDB)	Nevada	411
NV Nye 32023	3	32231	Gabbs, Manhattan, and Round Mountain twp.	Average deposition In the 3 twp.	Nevada	370
		32232	Tonopah township	Tonopah (TD8)	Nevada	413
		32233	Beatty township	Beatty (TDB)	Nevada	414
NV White Pine 32033	3	32331	Cherry Creek, Ely, Hamilton, and Newark townships	Ely (CDB)	Nevada	410
		32332	Lund and Preston twp.	Lund/Pre (CDB)	Nevada	417
		32333	Osceola&Muncy townships	Baker (CDB)	Nevada	410
UT Box Elder 49003	2	49931	West Box Elder div.	Rosette (CDB)	UT-1	418
		49932	Bear River, Benchland,	Tremonton (CDB) Brigham City, and Howell-Snowville div.	UT-1	418
UT Iron 49021	3	49211	Beryl-Newcastle div.	Modena (CDB)	UT-10	423
		49212	Parowan division	Parowan (CDB)	UT-10	423
		49213	Cedar City division	Cedar City (CDB)	UT-10	423
UT Kane 49025	2	49251	Kanab division	Kanab (CDB)	UT-10	428
		49252	Orderville division	Orderville (CDB)	UT-12	428
UT Tooele 49045	2	49451	Dugway-Wendover div.	West (CDB)	UT-4	421
		49452	Onaqui and Tooele-Grantsville divisions	East (CDB)	UT-4	421
UT Washington 49053	3	49531	Enterprise division	Enterprise (CDB)	UT-11	424
		49532	St George division (without Washington)	St Georgs (CDB)	UT-11	424
		49533	Hurricane division (+ Washington)	Hurricane (CDB)	UT-11	424

Table A2.2. Number of cows and farms in each of the subcounties considered.

		Data from the 1954 Census of Agriculture		Data from the 1964 PHS Directory		Adopted values in this report	
County or Sub-county	FIPS code	Cows	Farms	Cows	Farms and Dairies	Cows	Farms
AZ, Coconino	04005	383	96	30	17	383	96
Sub-county 1	04501			0	0	20	6
Sub-county 2	04502			0	0	1	1
Sub-county 3	04503			30	17	362	89
AZ, Mohave	04015	336	67			336	67
Sub-county 1	04151			0	0	1	1
Sub-county 2	04152			0	0	8	8
Sub-county 3	04153			135	36	324	54
Sub-county 4	04154			2	2	4	4
CA, Inyo	06027	527	34	365	23	527	34
Sub-county 1	06271			254	15	370	22
Sub-county 2	06272			111	8	156	11
Sub-county 3	06273			0	0	1	1
NV, Clark	32003	1565	108	3442	23	1565	108
Sub-county 1	32301			3315	21	1364	87
Sub-county 2	32302			127	2	200	20
Sub-county 3	32303			0	0	1	1
NV, Esmeralda	32009	22	10	17	11	22	10
Sub-county 1	32901			15	9	18	8
Sub-county 2	32902			2	2	4	2
NV, Lander	32015	69	22	37	22	69	22
Sub-county 1	32551			13	9	33	10
Sub-county 2	32552			24	13	36	12
NV, Lincoln	32017	444	78	548	26	444	78
Sub-county 1	32171			30	18	70	60
Sub-county 2	32172			518	8	374	18
NV, Nye	32023	340	76	61	42	340	76
Sub-county 1	32231			41	34	270	60
Sub-county 2	32232			11	5	50	10
Sub-county 3	32233			9	3	20	6
NV, White Pine	32033	642	86	413	31	642	86
Sub-county 1	32331			18	6	50	15
Sub-county 2	32332			373	20	536	54
Sub-county 3	32333			22	5	56	17
UT, Box Elder	49009	8076	1027	245	4	8076	1027
Sub-county 1	49931					160	20
Sub-county 2	49932			245	4	7916	1007
UT, Iron	49021	980	259	309	7	980	259
Sub-county 1	49211			79	2	197	52
Sub-county 2	49212			40	1	58	16
Sub-county 3	49213			190	4	725	191
UT, Kane	49025	287	107			287	107
Sub-county 1	49251					189	71
Sub-county 2	49252					98	36
UT, Tooele	49045	979	225			979	225
Sub-county 1	49451					200	47
Sub-county 2	49452					779	178
UT, Washington	49053	2127	469			2127	469
Sub-county 1	49531					188	42
Sub-county 2	49532			139	3	1211	267
Sub-county 3	49533					728	160

Table A2.3. Summary of parameter values related to pasture practices for the subdivided close-in counties.

State	Code	Total dry matter intake (kg d^{-1})	Fraction of diet from pasture	Daily pasture intake (kg d^{-1})	Pasture Season		
					Start	Stop	Duration (d)
Arizona	04501	14.4	0.35	5.0	106	278	183
	04502	14.4	0.35	5.0	106	278	183
	04503	14.4	0.35	5.0	106	278	183
	04151	14.4	0.35	5.0	106	278	183
	04152	14.4	0.35	5.0	106	278	183
	04153	14.4	0.35	5.0	106	278	183
	04154	14.4	0.35	5.0	106	278	183
California	06271	17.0	0.13	2.2	136	258	123
	06272	17.0	0.13	2.2	136	258	123
	06273	17.0	0.13	2.2	136	258	123
Nevada	32301	17.4	0.15	2.6	136	273	138
	32302	17.4	0.15	2.6	136	273	138
	32303	17.4	0.15	2.6	136	273	138
	32901	17.4	0.15	2.6	136	273	138
	32902	17.4	0.15	2.6	136	273	138
	32551	17.4	0.15	2.6	136	273	138
	32552	17.4	0.15	2.6	136	273	138
	32171	17.4	0.15	2.6	136	273	138
	32172	17.4	0.15	2.6	136	273	138
	32231	17.4	0.15	2.6	136	273	138
	32232	17.4	0.15	2.6	136	273	138
	32233	17.4	0.15	2.6	136	273	138
	32331	17.4	0.15	2.6	136	273	138
	32332	17.4	0.15	2.6	136	273	138
	32333	17.4	0.15	2.6	136	273	138
Utah	49931	13.5	0.55	7.4	136	258	123
	49932	13.5	0.55	7.4	136	258	123
	49211	13.5	0.07	0.9	128	266	139
	49212	13.5	0.07	0.9	128	266	139
	49213	13.5	0.07	0.9	128	266	139
	49251	13.5	0.80	10.8	121	273	153
	49252	13.5	0.80	10.8	121	273	153
	49451	13.5	0.50	6.8	136	258	123
	49452	13.5	0.50	6.8	136	258	123
	49531	13.5	0.45	6.1	144	250	107
	49532	13.5	0.45	6.1	144	250	107
	49533	13.5	0.45	6.1	144	250	107

Table A2.4. Summary of milk production and utilization data for each of the sub-counties considered.

State	Code	Area	Pop	Farms	MCF	MUF	Cows	MP	MM	CR	E	TMFU	MB
Arizona	04501	7203	611	6	29	6	20	148	0	300	148	142	-5
	04502	16807	10346	1	5	0	1	7	0	300	2498	7	-2491
	04503	24009	20586	89	431	106	362	2679	0	300	4970	2572	-23
	04151	5135	227	1	5	0	1	7	0	300	55	7	-48
	04152	6846	227	8	39	2	8	59	13	300	55	43	-11
	04153	15404	6291	54	261	95	324	2390	543	300	1519	1752	233
	04154	6846	1441	4	19	1	4	30	0	300	348	28	-320
California	06271	10495	8297	22	39	61	370	2268	0	380	2535	2207	-328
	06272	5247	2464	11	53	56	156	2075	1023	380	753	996	243
	06273	10495	910	1	28	2	1	84	0	380	278	82	-196
Nevada	32301	5098	2593	87	225	538	1364	7270	3577	380	629	3155	2526
	32302	11217	74220	20	52	79	200	1066	0	380	18009	98	-17022
	32303	4079	4933	1	3	0	1	5	0	380	1197	5	-1192
	32901	5548	267	8	21	7	18	96	47	380	65	42	-23
	32902	3698	347	2	5	2	4	21	0	380	84	20	-64
	32551	7279	406	10	26	13	33	176	87	380	99	76	-22
	32552	7279	1325	12	31	14	36	192	0	380	322	178	-144
	32171	13790	2887	60	155	28	70	373	0	380	701	345	-355
	32172	13790	355	18	47	148	374	1993	981	380	86	865	779
	32231	16375	816	60	155	107	270	1439	708	380	198	625	427
	32232	16375	2065	10	2B	20	50	267	0	380	501	247	-254
	32233	4913	760	6	16	8	20	107	0	380	184	99	-86
	32331	13560	8936	15	78	39	50	533	0	380	2168	494	-1675
	32332	2260	296	54	72	211	536	2857	1406	380	72	1308	123B
	32333	6780	358	17	5	2	56	32	0	380	87	30	-57
Utah	49931	10158	438	20	52	48	160	1106	768	300	106	289	183
	49932	4354	21561	1007	2631	2397	7916	54700	37996	300	5206	14306	9101
	49211	4273	605	52	42	18	197	401	278	300	146	105	-41
	49212	2564	2034	16	136	60	58	1361	946	300	491	356	-135
	49213	1709	7496	191	499	220	725	5010	3480	300	1810	1310	-500
	49251	8594	1516	71	186	57	189	1306	907	300	366	342	-24
	49252	1517	941	36	94	30	98	677	470	300	227	177	-50
	49451	13447	3278	47	123	61	200	1382	960	300	791	361	-430
	49452	4482	12733	178	465	236	779	5383	3739	300	3074	1408	-1667
	49531	1571	887	42	110	57	188	1299	902	300	214	340	126
	49532	2200	5702	267	698	367	1211	836	5813	300	1377	2189	812
	49533	2514	3430	160	418	220	728	5030	3494	300	828	1316	488

Pop = Population in county

Farms = Number of farms in county

MCF = Milk consumed on farms in county (klbs)

MUF = Milk used on farms for non-fluid consumption in county (klbs)

Cows = Number of cows in the county

MP = Total milk produced in county (klbs)

MM = Milk used for manufacturing in county (klbs)

CR = Average consumption rate in state (mL d^{-1})

E = Expected consumption of population in county (klbs)

TMFU = Total fluid milk available for consumption in county (klbs)

MB = Milk balance (surplus or deficit of milk in county) (klbs)

Table A2.5. Volumes of milk (thousands of pounds) distributed between surplus and deficit regions in the southwestern United States during the 1950s. The counties close to the Nevada Test Site are included in this area. The table includes an indication of the sources of information and the level of certainty in the estimate. The region numbers are shown on the maps in Part 3 of Appendix 5. The degree of certainty of the data is as follows: 1 = highest certainty using available data; 2 = less certainty, educated estimate; 3 = least certainty.

Milk distributed from surplus region		Milk received by deficit regions				
Region number	State	Region number	State	Volume transferred (x1000 lb)	Source of information	Level of certainty
213	IOWA	352	NEW MEXICO	7000.	transfer to balance	3
213	IOWA	344	COLORADO	26591.	transfer to balance	3
280	NEBRASKA	344	COLORADO	1000.	shipped to Denver (Feder & Williams 1954)	1
292	KANSAS	353	NEW MEXICO	2677.	shipped to Albuquerque (Ward & Whicker 87)	1
292	KANSAS	354	NEW MEXICO	1330.	shipped to Albuquerque (Ward & Whicker 87)	1
293	KANSAS	344	COLORADO	10000.	mmo data - SW Kansas 1963 report	1
293	KANSAS	353	NEW MEXICO	3720.	mmo data - SW Kansas 1963 report	1
293	KANSAS	354	NEW MEXICO	3720.	mmo data - SW Kansas 1963 report	1
293	KANSAS	352	NEW MEXICO	3804.	mmo data - SW Kansas 1963 report	1
295	KANSAS	344	COLORADO	10000.	mmo data - SW Kansas 1963 report	1
295	KANSAS	353	NEW MEXICO	2676.	mmo data - SW Kansas 1963 report	1
296	KANSAS	349	COLORADO	3795.	mmo data - SW Kansas 1963 report	1
296	KANSAS	344	COLORADO	2000.	mmo data - SW Kansas 1963 report	1
296	KANSAS	353	NEW MEXICO	1163.	mmo data - SW Kansas 1963 report	1
296	KANSAS	354	NEW MEXICO	1163.	mmo data - SW Kansas 1963 report	1
296	KANSAS	352	NEW MEXICO	3000.	mmo data - SW Kansas 1963 report	1
301	OKLAHOMA	366	ARIZONA	341.	Central Arizona mmo	1
315	TEXAS	353	NEW MEXICO	10000.	Central West Texas mmo (AAES1978)	1
315	TEXAS	354	NEW MEXICO	8000.	Central West Texas mmo (AAES1978)	1
315	TEXAS	355	NEW MEXICO	1737.	Central West Texas mmo (AAES1978)	1
339	WYOMING	418	UTAH	500.	Ward & Whicker 1987	1
342	WYOMING	345	COLORADO	1222.	deficit neighbor	2
342	WYOMING	344	COLORADO	1045.	deficit neighbor	1
343	COLORADO	344	COLORADO	34583.	Eastern Colorado mmo	1
346	COLORADO	344	COLORADO	10000.	Eastern Colorado mmo	1
346	COLORADO	347	COLORADO	14815.	Colorado Springs mmo	1
346	COLORADO	349	COLORADO	1013.	Colorado Springs mmo	1
346	COLORADO	350	COLORADO	1205.	deficit neighbor	2
348	COLORADO	353	NEW MEXICO	500.	Rio Grande mmo	1
348	COLORADO	352	NEW MEXICO	500.	Rio Grande mmo	1
348	COLORADO	347	COLORADO	3710.	Colorado Springs mmo	1
348	COLORADO	361	UTAH	387.	guess to balance	3
348	COLORADO	350	COLORADO	2000.	deficit neighbors	1
351	NEW MEXICO	352	NEW MEXICO	20000.	Rio Grands mmo	1
351	NEW MEXICO	354	NEW MEXICO	3324.	Rio Grande mmo	1
351	NEW MEXICO	355	NEW MEXICO	1000.	Rio Grande mmo	1
351	NEW MEXICO	353	NEW MEXICO	4000.	Rio Grande mmo	1
351	NEW MEXICO	318	TEXAS	1000.	Texas Panhandle mmo and AAES197a	1
357	IDAHO	362	UTAH	294.	transfer to balance	1
358	IDAHO	418	UTAH	179.	Ward & Whicker 1987	1
359	IDAHO	418	UTAH	8094.	transfer to balance	3
422	UTAH	423	UTAH	12719.	derived from Ward & Whicker 1987	1
363	UTAH	416	NEVADA	1551.	transfer to balance	3
424	UTAH	423	UTAH	1426.	Ward & Whicker 1987	1
423	UTAH	411	NEVADA	355.	derived from Ward & Whicker 1987	1
423	UTAH	417	NEVADA	1192.	Ward & Whicker 1987	1
423	UTAH	415	NEVADA	87.	Ward & Whicker 1987	1
423	UTAH	416	NEVADA	15044.	Ward & Whicker 1987	1
423	UTAH	402	ARIZONA	96.	derived from Ward & Whicker 1987	1
362	UTAH	418	UTAH	9047.	derived from Ward & Whicker 1987	1
420	UTAH	418	UTAH	69.	derived from Ward & Whicker 1987	1
419	UTAH	418	UTAH	1422.	derived from Ward & Whicker 1987	1
363	UTAH	418	UTAH	4138.	derived from Ward & Whicker 1987	1
364	UTAH	418	UTAH	2042.	derived from Ward & Whicker 1987	1
418	UTAH	409	NEVADA	1221.	Ward & Whicker 1987	1
418	UTAH	410	NEVADA	564.	Ward & Whicker 1987	1
418	UTAH	421	UTAH	2345.	Ward & Whicker 1987	1
364	UTAH	425	UTAH	1056.	deficit neighbor	2
426	UTAH	425	UTAH	1048.	deficit neighbor	2

Table A2.5 continued

Milk distributed from surplus region		Milk received by deficit regions				
Region number	State	Region number	State	Volume transferred (1,000 km)	Source of information	Level of certainty
427	UTAH	428	UTAH	74.	Ward & Whicker 1987	1
427	UTAH	399	ARIZONA	48.	transfer to balance	3
427	UTAH	400	ARIZONA	11.	transfer to balance	3
427	UTAH	403	ARIZONA	5.	transfer to balance	3
365	UTAH	429	UTAH	939.	deficit neighbor	2
365	UTAH	404	ARIZONA	430.	transfer to balance	3
427	UTAH	404	ARIZONA	810.	transfer to balance	3
426	UTAH	404	ARIZONA	571.	transfer to balance	3
368	ARIZONA	366	ARIZONA	6779.	Ward & Whicker 1987	1
368	ARIZONA	367	ARIZONA	31280.	Central Arizona mmo	1
368	ARIZONA	369	ARIZONA	3055.	Central Arizona mmo	1
368	ARIZONA	354	NEW MEXICO	500.	deficit neighbor	2
368	ARIZONA	404	ARIZONA	447.	Ward & Whicker 1987	1
368	ARIZONA	405	ARIZONA	2398.	Ward & Whicker 1987	1
368	ARIZONA	402	ARIZONA	224.	Ward & Whicker 1987	1
401	ARIZONA	404	ARIZONA	233.	Ward & Whicker 1987	1
370	NEVADA	416	NEVADA	427.	derived from Ward & Whicker 1987	1
371	NEVADA	408	CALIFORNIA	911.	Ward & Whicker 1987	1
371	NEVADA	408	CALIFORNIA	197.	Ward & Whicker 1987	1
371	NEVADA	372	NEVADA	1314.	Ward & Whicker 1987	1
371	NEVADA	413	NEVADA	254.	Ward & Whicker 1987	1
371	NEVADA	414	NEVADA	86.	Ward & Whicker 1987	1
373	NEVADA	423	UTAH	2526.	Ward & Whicker 1987	1
412	NEVADA	423	UTAH	779.	Ward & Whicker 1987	1
387	CALIFORNIA	391	CALIFORNIA	10000.	transfer to balance	3
387	CALIFORNIA	392	CALIFORNIA	75470.	transfer to balance	3
388	CALIFORNIA	391	CALIFORNIA	10000.	transfer to balance	3
388	CALIFORNIA	392	CALIFORNIA	110457.	transfer to balance	3
389	CALIFORNIA	392	CALIFORNIA	203701.	deficit neighbor	2
390	CALIFORNIA	391	CALIFORNIA	4572.	deficit neighbor	2
393	CALIFORNIA	366	ARIZONA	2203.	transfer to balance	3
393	CALIFORNIA	392	CALIFORNIA	122521.	deficit neighbor	1
393	CALIFORNIA	391	CALIFORNIA	10203.	deficit neighbor	1
393	CALIFORNIA	394	CALIFORNIA	77299.	deficit neighbor	1
393	CALIFORNIA	395	CALIFORNIA	16537.	deficit neighbor	1
393	CALIFORNIA	397	CALIFORNIA	61674.	deficit neighbor	1
393	CALIFORNIA	396	CALIFORNIA	655892.	deficit neighbor	1
393	CALIFORNIA	398	CALIFORNIA	79795.	transfer to balance	3
393	CALIFORNIA	408	CALIFORNIA	290.	Ward & Whicker 1987	1
407	CALIFORNIA	408	CALIFORNIA	85.	Ward & Whicker 1987	1

Attachment to Appendix 2. Area and population in 1954 of each county of the contiguous United States, and geographical location and distance from the Nevada Test Site of each county centroid.

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
AL AUTAUGA	18421	1551	32.54	86.64	2652
AL BALDWIN	44435	4087	30.74	87.73	2604
AL BARBOUR	27114	2308	31.88	85.40	2775
AL BIBB	16446	1618	33.00	87.13	2600
AL BLOUNT	27474	1655	33.99	86.56	2633
AL BULLOCK	14950	1593	32.11	85.72	2741
AL BUTLER	27248	2001	31.76	86.69	2666
AL CALHOUN	86484	1582	33.78	85.83	2701
AL CHAMBERS	38803	1545	32.92	85.39	2753
AL CHEROKEE	17072	1439	34.19	85.61	2715
AL CHILTON	26401	1810	32.85	86.72	2639
AL CHOCTAW	18607	2358	32.02	88.26	2523
AL CLARKE	26204	3190	31.67	87.82	2569
AL CLAY	13283	1562	33.27	85.86	2707
AL CLEBURNE	11483	1486	33.68	85.53	2729
AL COFFEE	30663	1752	31.40	85.99	2734
AL COLBERT	42512	1544	34.70	87.81	2515
AL CONECUH	20074	2201	31.44	86.99	2647
AL COOSA	11326	1683	32.94	86.25	2679
AL COVINGTON	38359	2548	31.26	86.46	2698
AL CRENSHAW	17250	1582	31.74	86.32	2698
AL CULLMAN	47565	1890	34.14	86.86	2605
AL DALE	25179	1448	31.43	85.62	2766
AL DALLAS	56437	2527	32.33	87.10	2617
AL DE KALB	43506	2015	34.46	85.81	2694
AL ELMORE	31170	1615	32.60	86.15	2693
AL ESCAMBIA	32327	2491	31.13	87.16	2641
AL ETOWAH	95207	1437	34.05	86.03	2679
AL FAYETTE	18011	1624	33.72	87.74	2534
AL FRANKLIN	24126	1667	34.44	87.85	2514
AL GENEVA	24379	1493	31.10	85.85	2755
AL GREENE	15258	1624	32.87	87.95	2531
AL HALE	20285	1714	32.77	87.62	2562
AL HENRY	17232	1434	31.51	85.25	2796
AL HOUSTON	48307	1489	31.15	85.32	2799
AL JACKSON	38015	2795	34.78	86.00	2674
AL JEFFERSON	591199	2888	33.56	86.89	2611
AL LAMAR	15521	1566	33.78	88.10	2502
AL LAUDERDALE	57343	1714	34.90	87.65	2526
AL LAWRENCE	26015	1773	34.53	87.31	2561

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
AL LEE	47070	1584	32.61	85.36	2763
AL LIMESTONE	36089	1414	34.81	86.97	2587
AL LOWNDES	16916	1852	32.16	86.65	2659
AL MACON	28928	1594	32.39	85.69	2737
AL MADISON	91789	2080	34.77	86.54	2626
AL MARENGO	28478	2533	32.25	87.78	2559
AL MARION	24962	1924	34.14	87.88	2515
AL MARSHALL	46335	1479	34.37	86.31	2651
AL MOBILE	266464	3211	30.81	88.21	2560
AL MONROE	24304	2672	31.57	87.36	2612
AL MONTGOMERY	151816	2046	32.23	86.21	2696
AL MORGAN	56126	1476	34.46	86.85	2602
AL PERRY	19133	1901	32.64	87.29	2594
AL PICKENS	23300	2297	33.28	88.09	2511
AL PIKE	28644	1742	31.81	85.94	2729
AL RANDOLPH	21222	1504	33.29	85.46	2741
AL RUSSELL	42909	1624	32.30	85.19	2783
AL ST CLAIR	26135	1658	33.72	86.32	2659
AL SHELBY	31110	2066	33.27	86.67	2636
AL SUMTER	22090	2370	32.59	88.19	2516
AL TALLADEGA	64427	1942	33.39	86.17	2678
AL TALLAPOOSA	35047	1822	32.87	85.80	2719
AL TUSCALOOSA	100446	3451	33.30	87.52	2561
AL WALKER	59709	2084	33.81	87.29	2572
AL WASHINGTON	15511	2760	31.41	88.21	2543
AL WILCOX	21461	2327	31.99	87.30	2607
AL WINSTON	16809	1593	34.15	87.37	2560
AZ APACHE	28902	28932	35.39	109.49	605
AZ COCHISE	41498	16202	31.89	109.76	793
AZ COCONINO1	611	7202	36.91	112.53	308
AZ COCONINO2	10346	16806	36.91	111.48	401
AZ COCONINO3	20586	24009	35.19	111.65	435
AZ GILA	24837	12296	33.80	110.81	582
AZ GRAHAM	13438	11960	32.94	109.90	705
AZ GREENLEE	12256	4866	33.21	109.25	732
AZ MARICOPA	472764	23710	33.35	112.49	511
AZ MOHAVE1	227	5134	36.90	112.76	288
AZ MOHAVE2	227	6846	36.88	113.92	185
AZ MOHAVE3	6291	15404	35.19	114.06	265
AZ MOHAVE4	1441	6846	35.02	114.39	262
AZ NAVAJO	33084	25666	35.38	110.32	535
AZ PIMA	194103	23931	32.11	111.80	659
AZ PINAL	51473	13892	32.91	111.35	614

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
AZ SANTA CRUZ	9968	3227	31.54	110.86	759
AZ YAVAPAI	26658	20955	34.60	112.55	406
AZ YUMA	35756	25855	33.22	113.94	458
AR ARKANSAS	23534	2629	34.30	91.37	2206
AR ASHLEY	25051	2403	33.19	91.77	2191
AR BAXTER	10946	1390	36.29	92.34	2101
AR BENTON	37309	2204	36.34	94.26	1930
AR BOONE	16196	1517	36.31	93.09	2035
AR BRADLEY	15155	1686	33.47	92.17	2151
AR CALHOUN	6651	1628	33.55	92.51	2119
AR CARROLL	12413	1621	36.34	93.54	1994
AR CHICOT	20894	1665	33.26	91.30	2231
AR CLARK	22129	2274	34.06	93.18	2052
AR CLAY	24373	1655	36.37	90.42	2271
AR CLEBURNE	10458	1434	35.53	92.04	2132
AR CLEVELAND	8102	1556	33.90	92.18	2141
AR COLUMBIA	27762	1988	33.22	93.23	2064
AR CONWAY	16985	1452	35.25	92.70	2077
AR CRAIGHEAD	49207	1853	35.83	90.64	2254
AR CRAWFORD	22126	1544	35.58	94.25	1936
AR CRITTENDEN	47349	1575	35.20	90.30	2289
AR CROSS	22549	1618	35.29	90.78	2246
AR DALLAS	11616	1739	33.97	92.65	2099
AR DESHA	23295	1905	33.83	91.27	2222
AR DREW	16793	2154	33.59	91.72	2187
AR FAULKNER	24875	1659	35.14	92.33	2110
AR FRANKLIN	11445	1587	35.51	93.90	1968
AR FULTON	8110	1575	36.38	91.82	2146
AR GARLAND	46929	1704	34.58	93.15	2046
AR GRANT	8716	1634	34.30	92.43	2113
AR GREENE	27476	1500	36.12	90.56	2259
AR HEMPSTEAD	22781	1880	33.74	93.67	2015
AR HOT SPRING	22060	1607	34.32	92.94	2068
AR HOWARD	12297	1473	34.10	94.00	1979
AR INDEPENDENCE	22030	1947	35.74	91.58	2172
AR IZARD	8601	1486	36.09	91.92	2139
AR JACKSON	24608	1628	35.59	91.22	2204
AR JEFFERSON	78330	2260	34.28	91.93	2157
AR JOHNSON	14554	1742	35.56	93.47	2006
AR LAFAYETTE	12281	1355	33.24	93.61	2030
AR LAWRENCE	19586	1528	36.04	91.12	2211
AR LEE	22912	1575	34.78	90.78	2252
AR LINCOLN	15961	1458	33.96	91.73	2180

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
AR LITTLE RIVER	10639	1258	33.71	94.24	1965
AR LOGAN	18432	1859	35.21	93.72	1987
AR LONOKE	26119	2061	34.76	91.89	2154
AR MADISON	10602	2154	36.01	93.73	1979
AR MARION	7519	1513	36.26	92.68	2071
AR MILLER	32222	1614	33.32	93.90	2004
AR MISSISSIPPI	77192	2340	35.76	90.06	2306
AR MONROE	18596	1572	34.68	91.21	2215
AR MONTGOMERY	6122	2007	34.55	93.66	2001
AR NEVADA	13045	1594	33.66	93.31	2048
AR NEWTON	7530	2128	35.91	93.22	2025
AR OUACHITA	32453	1905	33.60	92.89	2085
AR PERRY	5531	1427	34.94	92.94	2059
AR PHILLIPS	45298	1776	34.44	90.85	2250
AR PIKE	9110	1553	34.17	93.66	2007
AR POINSETT	35709	1967	35.57	90.67	2254
AR POLK	13244	2225	34.50	94.24	1951
AR POPE	22394	2102	35.44	93.04	2045
AR PRAIRIE	12388	1711	34.83	91.55	2183
AR PULASKI	216366	1980	34.77	92.31	2116
AR RANDOLPH	14513	1676	36.35	91.04	2216
AR ST FRANCIS	35339	1645	35.02	90.76	2251
AR SALINE	25999	1874	34.65	92.67	2086
AR SCOTT	8882	2325	34.87	94.08	1960
AR SEARCY	9448	1719	35.90	92.70	2071
AR SEBASTIAN	65257	1365	35.21	94.28	1937
AR SEVIER	11383	1351	34.00	94.25	1958
AR SHARP	7865	1504	36.15	91.49	2177
AR STONE	7081	1575	35.85	92.16	2119
AR UNION	49621	2719	33.17	92.60	2119
AR VAN BUREN	8639	1810	35.57	92.53	2089
AR WASHINGTON	52455	2481	35.98	94.22	1936
AR WHITE	35792	2695	35.25	91.75	2161
AR WOODRUFF	16833	1531	35.18	91.25	2206
AR YELL	13160	2405	35.01	93.41	2016
CA ALAMEDA	811673	1897	37.65	121.85	524
CA ALPINE	306	1883	38.60	119.82	382
CA AMADOR	9508	1510	38.45	120.64	442
CA BUTTE	72198	4260	39.67	121.60	579
CA CALAVERAS	10067	2651	38.21	120.56	426
CA COLUSA	11834	2983	39.18	122.24	605
CA CONTRA COSTA	345753	1904	37.92	121.92	535
CA DEL NORTE	12200	2608	41.76	123.90	879

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
CA EL DORADO	21809	4441	38.78	120.53	448
CA FRESNO	314523	15451	36.75	119.65	325
CA GLENN	16213	3403	39.60	122.39	637
CA HUMBOLDT	84392	9287	40.71	123.88	811
CA IMPERIAL	66856	10983	33.05	115.37	443
CA INYO1	8297	10494	37.36	118.39	216
CA INYO2	2464	5247	36.60	118.10	192
CA INYO3	910	10494	36.44	116.86	98
CA KERN	255370	21113	35.34	118.73	304
CA KINGS	48121	3615	36.07	119.81	353
CA LAKE	12462	3265	39.11	122.76	644
CA LASSEN	16400	11812	40.69	120.60	579
CA LOS ANGELES	4953697	10538	34.37	118.21	352
CA MADERA	38458	5555	37.21	119.76	335
CA MARIN	111629	1347	38.07	122.69	606
CA MARIPOSA	5115	3762	37.58	119.90	352
CA MENDOCINO	45195	9092	39.46	123.39	710
CA MERCED	78570	5070	37.19	120.72	420
CA MODOC	9094	10610	41.61	120.74	663
CA MONO	2160	7839	37.94	118.89	276
CA MONTEREY	159337	8608	36.21	121.21	471
CA NAPA	54797	2038	38.51	122.34	587
CA NEVADA	20322	2519	39.31	120.77	495
CA ORANGE	423494	2025	33.72	117.75	396
CA PLACER	48175	3705	39.07	120.72	478
CA PLUMAS	12713	6645	40.02	120.85	545
CA RIVERSIDE	227908	18585	33.75	116.01	361
CA SACRAMENTO	373035	2525	38.45	121.34	500
CA SAN BENITO	14806	3615	36.60	121.07	452
CA SAN BERNADIN	375968	52102	34.85	116.17	240
CA SAN DIEGO	759190	11035	33.04	116.72	444
CA SAN FRANCISC	760465	116	37.76	122.41	575
CA SAN JOAQUIN	221677	3656	37.94	121.27	479
CA SAN LUIS OBI	64006	8243	35.38	120.37	428
CA SAN MATEO	324371	1158	37.44	122.30	561
CA SANTA BARBAR	128286	7088	34.73	120.01	436
CA SANTA CLARA	440051	3366	37.23	121.69	506
CA SANTA CRUZ	74049	1140	37.07	121.99	532
CA SHASTA	46213	9810	40.78	122.06	682
CA SIERRA	2342	2481	39.58	120.51	493
CA SISKIYOU	31647	16218	41.61	122.56	775
CA SOLANO	117487	2132	38.28	121.92	544
CA SONOMA	122095	4153	38.53	122.88	633

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CA STANISLAUS	140011	3912	37.56	121.00	448
CA SUTTER	29274	1562	39.03	121.69	553
CA TEHAMA	21840	7722	40.14	122.25	655
CA TRINITY	7049	8217	40.67	123.13	753
CA TULARE	157398	12462	36.22	118.79	263
CA TUOLUMNE	13357	5832	38.03	119.96	369
CA VENTURA	150555	4824	34.49	119.07	390
CA YOLO	51306	2662	38.69	121.91	557
CA YUBA	28434	1655	39.26	121.35	538
CO ADAMS	74260	3203	39.88	104.37	1081
CO ALAMOSA	10305	1862	37.56	105.80	907
CO ARAPAHOE	89616	2063	39.66	104.36	1074
CO ARCHULETA	2861	3532	37.19	107.04	796
CO BACA	7258	6637	37.32	102.56	1193
CO BENT	8200	3933	37.94	103.08	1151
CO BOULDER	59327	1936	40.09	105.35	1006
CO CHAFFEE	7649	2688	38.75	106.20	891
CO CHEYENNE	3176	4588	38.83	102.61	1205
CO CLEAR CREEK	3079	1020	39.69	105.65	966
CO CONEJOS	9428	3283	37.19	106.19	871
CO COSTILLA	5278	3141	37.28	105.44	938
CO CROWLEY	4696	2077	38.32	103.78	1094
CO CUSTER	1460	1908	38.10	105.37	951
CO DELTA	16617	2988	38.85	107.88	750
CO DENVER	457536	246	39.73	104.97	1024
CO DOLORES	2066	2657	37.76	108.50	671
CO DOUGLAS	4063	2183	39.33	104.93	1016
CO EAGLE	4567	4353	39.62	106.70	875
CO ELBERT	4150	4827	39.29	104.13	1083
CO EL PASO	103940	5586	38.83	104.52	1039
CO FREMONT	19145	4042	38.47	105.44	951
CO GARFIELD	11791	7759	39.60	107.91	774
CO GILPIN	781	382	39.86	105.53	982
CO GRAND	3789	4801	40.10	106.12	942
CO GUNNISON	5613	8339	38.66	107.04	816
CO HINSDALE	238	2729	37.83	107.30	777
CO HUERFANO	9411	4076	37.69	104.96	983
CO JACKSON	1884	4200	40.67	106.35	948
CO JEFFERSON	86219	2028	39.59	105.25	997
CO KIOWA	2757	4576	38.43	102.75	1187
CO KIT CARSON	7907	5622	39.31	102.61	1216
CO LAKE	6551	982	39.19	106.35	890
CO LA PLATA	16728	4358	37.28	107.84	725

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CO LARIMER	47718	6761	40.67	105.47	1020
CO LAS ANIMAS	23392	12415	37.31	104.05	1061
CO LINCOLN	5654	6715	38.99	103.52	1130
CO LOGAN	18512	4718	40.73	103.11	1217
CO MESA	43967	8549	39.02	108.47	705
CO MINERAL	580	2384	37.66	106.93	808
CO MOFFAT	6418	12283	40.62	108.21	800
CO MONTEZUMA	11705	5422	37.34	108.61	657
CO MONTROSE	16525	5795	38.40	108.28	703
CO MORGAN	19396	3310	40.27	103.81	1142
CO OTERO	24787	3247	37.90	103.72	1094
CO OURAY	1891	1399	38.15	107.77	741
CO PARK	1847	5599	39.12	105.72	942
CO PHILLIPS	4718	1760	40.60	102.37	1274
CO PITKIN	1954	2519	39.21	106.92	843
CO PROWERS	14182	4197	37.95	102.40	1212
CO PUEBLO	102311	6228	38.17	104.51	1028
CO RIO BLANCO	4903	8450	39.98	108.21	766
CO RIO GRANDE	12121	2370	37.57	106.39	855
CO ROUTT	7650	6034	40.49	106.99	888
CO SAGUACHE	5157	8142	38.07	106.28	871
CO SAN JUAN	1211	1013	37.76	107.68	743
CO SAN MIGUEL	2800	3322	38.00	108.41	682
CO SEDGWICK	4728	1408	40.88	102.36	1285
CO SUMMIT	1535	1563	39.63	106.12	924
CO TELLER	2644	1431	38.88	105.16	985
CO WASHINGTON	7139	6541	39.97	103.20	1183
CO WELD	69565	10364	40.56	104.39	1103
CO YUMA	10011	6161	40.01	102.42	1250
CT FAIRFIELD	567774	1621	41.28	73.39	3811
CT HARTFORD	603367	1914	41.81	72.73	3876
CT LITCHFIELD	107794	2395	41.80	73.25	3831
CT MIDDLESEX	76485	962	41.47	72.53	3889
CT NEW HAVEN	594458	1563	41.41	72.93	3853
CT NEW LONDON	162215	1728	41.49	72.10	3927
CT TOLLAND	54921	1076	41.86	72.34	3912
CT WINDHAM	64655	1331	41.83	71.99	3942
DE KENT	49679	1538	39.09	75.57	3595
DE NEW CASTLE	256525	1134	39.58	75.65	3592
DE SUSSEX	66374	2460	38.67	75.41	3607
DC WASHINGTON	785942	157	38.90	77.04	3464
FL ALACHUA	64273	2371	29.67	82.36	3095
FL BAKER	6760	1514	30.32	82.28	3083

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FL BAY	53079	1935	30.30	85.63	2796
FL BRADFORD	11878	761	29.94	82.17	3103
FL BREVARD	60960	2617	28.18	80.76	3277
FL BROWARD	190191	3156	26.14	80.50	3373
FL CALHOUN	7712	1452	30.42	85.21	2828
FL CHARLOTTE	7817	1821	26.90	81.89	3228
FL CITRUS	7453	1449	28.85	82.46	3111
FL CLAY	16537	1535	29.98	81.85	3130
FL COLLIER	10424	5195	26.11	81.36	3304
FL COLUMBIA	19008	2031	30.22	82.62	3056
FL DADE	682067	5288	25.61	80.59	3388
FL DE SOTO	10281	1677	27.18	81.85	3221
FL DIXIE	4160	1791	29.61	83.16	3028
FL DUVAL	368369	1983	30.32	81.67	3136
FL ESCAMBIA	138684	1721	30.72	87.40	2632
FL FLAGLER	3878	1261	29.46	81.32	3190
FL FRANKLIN	6140	1387	29.91	84.80	2878
FL GADSDEN	38805	1325	30.58	84.62	2874
FL GILCHRIST	3234	896	29.72	82.80	3055
FL GLADES	2519	1949	26.95	81.21	3283
FL GULF	8515	1462	29.96	85.25	2839
FL HAMILTON	8436	1331	30.49	82.94	3022
FL HARDEE	11049	1628	27.49	81.81	3213
FL HENDRY	6928	3073	26.54	81.17	3302
FL HERNANDO	8614	1254	28.56	82.43	3123
FL HIGHLANDS	16911	2581	27.34	81.34	3258
FL HILLSBOROUGH	312748	2688	27.93	82.31	3155
FL HOLMES	12655	1248	30.89	85.83	2762
FL INDIAN RIVER	17585	1310	27.68	80.62	3306
FL JACKSON	35312	2422	30.80	85.23	2816
FL JEFFERSON	10045	1566	30.44	83.89	2941
FL LAFAYETTE	3205	1421	29.99	83.18	3015
FL LAKE	45284	2488	28.75	81.70	3179
FL LEE	36636	2032	26.58	81.80	3248
FL LEON	61208	1735	30.46	84.27	2908
FL LEVY	10519	2805	29.33	82.73	3073
FL LIBERTY	3162	2173	30.25	84.90	2860
FL MADISON	14178	1821	30.44	83.46	2978
FL MANATEE	49350	1914	27.47	82.30	3172
FL MARION	43898	4143	29.20	82.06	3134
FL MARTIN	11687	1439	27.08	80.39	3347
FL MONROE	37590	2678	25.53	81.07	3351
FL NASSAU	14676	1683	30.60	81.82	3115

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FL OKALOOSA	41833	2444	30.70	86.57	2704
FL OKEECHOBEE	4715	2011	27.43	80.90	3291
FL ORANGE	178105	2356	28.50	81.31	3220
FL OSCEOLA	14647	3400	28.06	81.15	3248
FL PALM BEACH	162889	5239	26.69	80.51	3351
FL PASCO	27444	1921	28.31	82.40	3134
FL PINELLAS	250803	685	27.95	82.73	3119
FL POLK	154234	4812	27.94	81.70	3206
FL PUTNAM	27266	2018	29.60	81.74	3149
FL ST JOHNS	27141	1566	29.89	81.43	3168
FL ST LUCIE	28303	1513	27.37	80.48	3328
FL SANTA ROSA	23227	2672	30.75	87.03	2663
FL SARASOTA	49261	1520	27.18	82.35	3179
FL SEMINOLE	38815	789	28.70	81.22	3221
FL SUMTER	11562	1437	28.69	82.08	3148
FL SUWANNEE	16126	1776	30.19	82.99	3026
FL TAYLOR	11589	2722	30.05	83.60	2977
FL UNION	7688	623	30.04	82.37	3083
FL VOLUSIA	95942	2750	29.05	81.19	3213
FL WAKULLA	5255	1556	30.18	84.41	2904
FL WALTON	15089	2726	30.67	86.17	2739
FL WASHINGTON	11622	1514	30.63	85.68	2782
GA APPLING	13688	1328	31.74	82.31	3046
GA ATKINSON	6864	823	31.28	82.90	3005
GA BACON	8693	758	31.54	82.48	3036
GA BAKER	5353	919	31.31	84.47	2869
GA BALDWIN	31556	660	33.07	83.25	2938
GA BANKS	6750	598	34.35	83.50	2899
GA BARROW	13701	443	33.99	83.72	2884
GA BARTOW	27750	1193	34.23	84.86	2781
GA BEN HILL	14344	660	31.76	83.26	2963
GA BERRIEN	13147	1211	31.27	83.24	2976
GA BIBB	125628	657	32.81	83.72	2902
GA BLECKLEY	9399	567	32.44	83.36	2941
GA BRANTLEY	6174	1158	31.19	82.00	3085
GA BROOKS	16949	1272	30.84	83.60	2955
GA BRYAN	6071	1147	32.02	81.45	3115
GA BULLOCH	24533	1773	32.40	81.75	3082
GA BURKE	22240	2152	33.06	82.01	3048
GA BUTTS	9034	478	33.28	83.96	2873
GA CALHOUN	8052	748	31.52	84.64	2849
GA CAMDEN	8451	1690	30.94	81.69	3118
GA CANDLER	7475	647	32.40	82.09	3052

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GA CARROLL	35112	1282	33.58	85.09	2769
GA CATOOSA	17678	433	34.89	85.14	2748
GA CHARLTON	5029	2061	30.79	82.16	3081
GA CHATHAM	167129	1152	32.01	81.14	3143
GA CHATTAHOOCHE	12563	654	32.34	84.78	2818
GA CHATTOOGA	20674	820	34.46	85.35	2734
GA CHEROKEE	21706	1075	34.24	84.49	2813
GA CLARKE	40297	299	33.95	83.37	2915
GA CLAY	5297	518	31.62	84.99	2816
GA CLAYTON	32859	385	33.54	84.37	2833
GA CLINCH	6236	2063	30.91	82.73	3029
GA COBB	84077	888	33.94	84.59	2808
GA COFFEE	23107	1584	31.54	82.89	3000
GA COLQUITT	34025	1458	31.17	83.79	2931
GA COLUMBIA	11182	751	33.55	82.27	3017
GA COOK	12040	602	31.15	83.45	2961
GA COWETA	28258	1144	33.34	84.78	2800
GA CRAWFORD	5971	816	32.72	83.99	2880
GA CRISP	17709	755	31.92	83.81	2912
GA DADE	7918	435	34.84	85.50	2717
GA DAWSON	3659	546	34.43	84.58	2802
GA DECATUR	24297	1489	30.88	84.18	2905
GA DE KALB	187559	696	33.77	84.24	2842
GA DODGE	17280	1289	32.17	83.20	2960
GA DOOLY	13019	1023	32.15	83.83	2905
GA DOUGHERTY	57245	838	31.52	84.24	2884
GA DOUGLAS	14116	523	33.69	84.77	2795
GA EARLY	15601	1356	31.32	84.92	2829
GA ECHOLS	2234	1100	30.70	82.90	3019
GA EFFINGHAM	9565	1242	32.37	81.34	3118
GA ELBERT	18266	927	34.11	82.84	2960
GA EMANUEL	18949	1776	32.60	82.32	3028
GA EVANS	6776	481	32.16	81.89	3074
GA FANNIN	14526	1020	34.86	84.34	2820
GA FAYETTE	8070	515	33.40	84.51	2823
GA FLOYD	65551	1331	34.25	85.22	2748
GA FORSYTH	11506	567	34.22	84.14	2844
GA FRANKLIN	13948	681	34.38	83.23	2922
GA FULTON	508744	1372	33.79	84.47	2820
GA GILMER	9521	1137	34.68	84.46	2810
GA GLASCOCK	3192	370	33.22	82.63	2991
GA GLYNN	34530	1066	31.24	81.59	3119
GA GORDON	19051	927	34.49	84.89	2774

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GA GRADY	18543	1206	30.87	84.24	2899
GA GREENE	12141	1044	33.58	83.17	2938
GA GWINNETT	37086	1131	33.95	84.04	2857
GA HABERSHAM	17218	730	34.63	83.54	2893
GA HALL	44205	979	34.31	83.83	2870
GA HANCOCK	10597	1238	33.27	83.01	2957
GA HARALSON	14609	737	33.79	85.22	2755
GA HARRIS	11225	1203	32.73	84.91	2799
GA HART	14811	598	34.35	82.97	2946
GA HEARD	6279	768	33.29	85.14	2769
GA HENRY	16606	857	33.45	84.16	2853
GA HOUSTON	28697	983	32.46	83.69	2911
GA IRWIN	10801	962	31.60	83.31	2962
GA JACKSON	18783	896	34.13	83.56	2896
GA JASPER	6900	965	33.31	83.69	2896
GA JEFF DAVIS	9136	857	31.80	82.65	3015
GA JEFFERSON	18267	1372	33.06	82.43	3011
GA JENKINS	9795	909	32.80	81.97	3055
GA JOHNSON	9107	810	32.71	82.68	2995
GA JONES	7933	1041	33.03	83.57	2912
GA LAMAR	10245	468	33.07	84.16	2859
GA LANIER	5133	457	31.02	83.06	2998
GA LAURENS	32779	2097	32.47	82.94	2976
GA LEE	6475	919	31.77	84.17	2883
GA LIBERTY	11017	1331	31.83	81.50	3115
GA LINCOLN	6226	499	33.79	82.46	2998
GA LONG	3717	1041	31.76	81.76	3094
GA LOWNDES	41185	1316	30.83	83.28	2983
GA LUMPKIN	6857	755	34.56	84.01	2851
GA MCDUFFIE	11950	654	33.48	82.49	2999
GA MCINTOSH	6158	1103	31.52	81.43	3128
GA MACON	13770	1044	32.35	84.06	2881
GA MADISON	11815	727	34.13	83.21	2927
GA MARION	6078	944	32.35	84.54	2840
GA MERIWETHER	20507	1292	33.03	84.70	2812
GA MILLER	8123	743	31.15	84.74	2849
GA MITCHELL	21308	1320	31.21	84.21	2893
GA MONROE	10514	1030	33.02	83.93	2880
GA MONTGOMERY	7214	613	32.17	82.54	3017
GA MORGAN	11210	922	33.59	83.50	2909
GA MURRAY	10580	885	34.78	84.76	2783
GA NEWTON	20536	702	33.56	83.86	2878
GA OCONEE	6711	481	33.83	83.44	2910

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GA OGLETHORPE	9101	1127	33.88	83.09	2941
GA PAULDING	12326	823	33.91	84.88	2783
GA PEACH	12613	391	32.58	83.83	2896
GA PICKENS	8877	582	34.46	84.48	2811
GA PIERCE	10503	885	31.35	82.24	3061
GA PIKE	7900	595	33.08	84.40	2837
GA POLK	29721	808	34.00	85.19	2754
GA PULASKI	8552	654	32.23	83.52	2931
GA PUTNAM	7763	878	33.32	83.38	2923
GA QUITMAN	2765	404	31.85	85.03	2807
GA RABUN	7439	952	34.88	83.42	2901
GA RANDOLPH	12647	1128	31.75	84.76	2833
GA RICHMOND	120231	837	33.36	82.08	3037
GA ROCKDALE	9363	332	33.65	84.04	2861
GA SCHLEY	3703	419	32.26	84.34	2858
GA SCREVEN	16693	1686	32.76	81.62	3087
GA SEMINOLE	7436	637	30.93	84.88	2843
GA SPALDING	32895	520	33.25	84.30	2844
GA STEPHENS	17389	447	34.56	83.30	2915
GA STEWART	8420	1171	32.07	84.85	2818
GA SUMTER	24395	1264	32.04	84.23	2873
GA TALBOT	7450	1010	32.70	84.54	2832
GA TALIAFERRO	4029	505	33.56	82.89	2963
GA TATTNALL	15896	1269	32.05	82.07	3061
GA TAYLOR	8770	1044	32.55	84.25	2861
GA TELFAIR	12583	1140	31.92	82.96	2985
GA TERRELL	13645	851	31.77	84.46	2859
GA THOMAS	34098	1400	30.86	83.94	2926
GA TIFT	23005	688	31.45	83.55	2945
GA TOOMBS	17153	952	32.10	82.35	3035
GA TOWNS	4692	429	34.91	83.75	2871
GA TREUTLEN	6247	502	32.40	82.57	3010
GA TROUP	48719	1075	33.02	85.04	2783
GA TURNER	9613	758	31.72	83.66	2930
GA TWIGGS	8152	943	32.67	83.45	2928
GA UNION	6976	799	34.83	84.00	2849
GA UPSON	24538	865	32.88	84.31	2849
GA WALKER	41196	1152	34.72	85.30	2736
GA WALTON	20339	854	33.78	83.74	2885
GA WARE	31967	2361	31.03	82.46	3050
GA WARREN	8178	736	33.41	82.69	2983
GA WASHINGTON	20117	1745	32.97	82.81	2979
GA WAYNE	15812	1670	31.55	81.93	3083

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
GA WEBSTER	3727	505	32.04	84.57	2843
GA WHEELER	6127	792	32.11	82.75	3000
GA WHITE	6372	629	34.64	83.75	2874
GA WHITFIELD	37693	727	34.80	84.97	2764
GA WILCOX	9206	992	31.97	83.47	2940
GA WILKES	11783	1211	33.78	82.76	2972
GA WILKINSON	9558	1186	32.80	83.20	2948
GA WORTH	18221	1500	31.55	83.88	2914
GA COLUMBUS	135231	570	32.50	84.88	2806
ID ADA	80347	2700	43.45	116.24	717
ID ADAMS	3193	3550	44.89	116.44	878
ID BANNOCK	44973	2905	42.66	112.21	714
ID BEAR LAKE	6971	2548	42.29	111.34	718
ID BENEWAH	6116	2040	47.21	116.64	1135
ID BINGHAM	25376	5397	43.22	112.41	761
ID BLAINE	5050	6855	43.41	113.98	734
ID BOISE	1721	4946	43.99	115.72	777
ID BONNER	15164	4487	48.29	116.60	1256
ID BONNEVILLE	37306	4754	43.39	111.64	809
ID BOUNDARY	5868	3301	48.76	116.45	1307
ID BUTTE	3053	5798	43.72	113.17	788
ID CAMAS	1013	2729	43.46	114.81	725
ID CANYON	55326	1497	43.62	116.71	738
ID CARIBOU	5748	4522	42.78	111.56	753
ID CASSIA	15261	6588	42.29	113.62	625
ID CLARK	921	4534	44.29	112.35	872
ID CLEARWATER	8357	6528	46.66	115.62	1074
ID CUSTER	3182	12765	44.24	114.27	819
ID ELMORE	10950	7893	43.35	115.47	708
ID FRANKLIN	9264	1719	42.18	111.82	685
ID FREMONT	9067	4827	44.23	111.50	897
ID GEM	8899	1437	44.07	116.38	786
ID GOODING	10443	1864	42.97	114.82	672
ID IDAHO	12322	22055	45.83	115.46	982
ID JEFFERSON	10996	2838	43.82	112.31	826
ID JEROME	11925	1541	42.69	114.28	651
ID KOOTENAI	26905	3234	47.66	116.69	1186
ID LATAH	21053	2823	46.81	116.70	1091
ID LEMHI	6082	11861	44.94	113.93	902
ID LEWIS	4298	1233	46.23	116.41	1026
ID LINCOLN	4013	3116	43.00	114.15	687
ID MADISON	9267	1224	43.78	111.66	846
ID MINIDOKA	11743	1942	42.86	113.64	684

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
ID NEZ PERCE	24534	2185	46.32	116.73	1037
ID ONEIDA	4050	3085	42.20	112.55	654
ID OWYHEE	6338	19789	42.59	116.18	621
ID PAYETTE	12108	1041	44.00	116.75	781
ID POWER	4044	3659	42.69	112.84	692
ID SHOSHONE	21990	6756	47.34	115.88	1149
ID TETON	2962	1183	43.76	111.22	862
ID TWIN FALLS	41346	5042	42.37	114.69	608
ID VALLEY	4017	9520	44.76	115.56	863
ID WASHINGTON	8486	3786	44.45	116.78	831
IL ADAMS	66300	2232	39.99	91.19	2227
IL ALEXANDER	18507	592	37.21	89.34	2366
IL BOND	14116	979	38.89	89.45	2366
IL BOONE	18453	733	42.33	88.82	2483
IL BROWN	6742	792	39.96	90.75	2264
IL BUREAU	37659	2242	41.41	89.52	2400
IL CALHOUN	6487	640	39.16	90.68	2260
IL CARROLL	19201	1180	42.08	89.93	2381
IL CASS	14860	961	39.97	90.25	2309
IL CHAMPAIGN	117294	2589	40.13	88.21	2491
IL CHRISTIAN	38133	1835	39.55	89.28	2388
IL CLARK	17018	1307	39.33	87.80	2516
IL CLAY	16751	1202	38.75	88.50	2448
IL CLINTON	23202	1124	38.60	89.43	2365
IL COLES	41404	1310	39.52	88.23	2480
IL COOK	4772685	2470	41.84	87.82	2558
IL CRAWFORD	20972	1147	39.00	87.76	2515
IL CUMBERLAND	10256	899	39.28	88.25	2476
IL DE KALB	45428	1646	41.90	88.76	2477
IL DE WITT	17045	1033	40.17	88.90	2430
IL DOUGLAS	17786	1088	39.77	88.22	2484
IL DU PAGE	222116	857	41.85	88.10	2534
IL EDGAR	23044	1627	39.68	87.75	2524
IL EDWARDS	8579	582	38.41	88.06	2485
IL EFFINGHAM	22285	1245	39.06	88.59	2443
IL FAYETTE	23464	1821	39.00	89.04	2403
IL FORD	16202	1264	40.59	88.22	2497
IL FRANKLIN	44694	1124	37.99	88.93	2405
IL FULTON	42963	2270	40.47	90.21	2321
IL GALLATIN	8897	850	37.76	88.23	2465
IL GREENE	18260	1406	39.36	90.40	2287
IL GRUNDY	20547	1119	41.28	88.42	2493
IL HAMILTON	11306	1127	38.08	88.54	2439

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
IL HANCOCK	25273	2063	40.41	91.16	2236
IL HARDIN	6830	474	37.53	88.27	2462
IL HENDERSON	8343	974	40.81	90.93	2265
IL HENRY	47690	2139	41.35	90.12	2347
IL IROQUOIS	32863	2905	40.75	87.83	2535
IL JACKSON	39834	1566	37.79	89.38	2364
IL JASPER	11878	1282	39.01	88.16	2480
IL JEFFERSON	34377	1483	38.29	88.93	2407
IL JERSEY	16013	974	39.09	90.36	2287
IL JO DAVIESS	21611	1569	42.37	90.21	2365
IL JOHNSON	7964	893	37.47	88.88	2407
IL KANE	174978	1347	41.94	88.43	2507
IL KANKAKEE	81402	1756	41.14	87.86	2539
IL KENDALL	14420	829	41.59	88.43	2499
IL KNOX	57302	1886	40.93	90.22	2329
IL LAKE	227787	1183	42.33	88.01	2554
IL LA SALLE	104940	2978	41.34	88.89	2454
IL LAWRENCE	19689	968	38.72	87.74	2515
IL LEE	37430	1886	41.75	89.30	2427
IL LIVINGSTON	38887	2700	40.88	88.56	2473
IL LOGAN	31939	1610	40.12	89.36	2389
IL MCDONOUGH	28507	1507	40.45	90.68	2279
IL MCHENRY	64912	1579	42.33	88.46	2515
IL MCLEAN	79677	3037	40.49	88.85	2440
IL MACON	107100	1497	39.86	88.96	2420
IL MACOUPIN	43909	2257	39.26	89.93	2327
IL MADISON	200321	1897	38.83	89.91	2324
IL MARION	40698	1500	38.65	88.92	2410
IL MARSHALL	13152	1013	41.03	89.34	2408
IL MASON	15270	1400	40.24	89.92	2342
IL MASSAC	13912	634	37.23	88.72	2421
IL MENARD	9478	808	40.03	89.80	2349
IL MERCER	17280	1439	41.20	90.74	2290
IL MONROE	14227	989	38.28	90.19	2295
IL MONTGOMERY	31941	1825	39.23	89.48	2366
IL MORGAN	35995	1452	39.71	90.20	2309
IL MOULTRIE	13372	844	39.64	88.63	2447
IL OGLE	35416	1963	42.05	89.32	2433
IL PEORIA	180596	1614	40.79	89.76	2366
IL PERRY	20620	1137	38.09	89.37	2366
IL PIATT	14394	1131	40.01	88.60	2455
IL PIKE	21469	2145	39.62	90.89	2247
IL POPE	5052	986	37.42	88.56	2435

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
IL PULASKI	12302	527	37.24	89.13	2384
IL PUTNAM	4672	413	41.21	89.29	2416
IL RANDOLPH	30958	1538	38.05	89.82	2326
IL RICHLAND	16636	943	38.71	88.09	2484
IL ROCK ISLAND	140967	1097	41.47	90.57	2311
IL ST CLAIR	230011	1742	38.46	89.93	2319
IL SALINE	30366	992	37.76	88.54	2438
IL SANGAMON	137884	2277	39.76	89.66	2357
IL SCHUYLER	9248	1124	40.15	90.61	2280
IL SCOTT	6878	650	39.64	90.48	2283
IL SHELBY	24001	1947	39.39	88.81	2427
IL STARK	8477	754	41.10	89.80	2369
IL STEPHENSON	43559	1470	42.35	89.66	2412
IL TAZEWELL	86209	1689	40.51	89.51	2382
IL UNION	19287	1076	37.48	89.26	2374
IL VERMILION	90942	2327	40.18	87.73	2533
IL WABASH	14398	574	38.45	87.85	2503
IL WARREN	21812	1400	40.85	90.62	2292
IL WASHINGTON	14083	1461	38.35	89.41	2364
IL WAYNE	20117	1852	38.42	88.43	2451
IL WHITE	20269	1300	38.09	88.18	2471
IL WHITESIDE	53821	1779	41.76	89.92	2374
IL WILL	158684	2194	41.44	87.98	2535
IL WILLIAMSON	47557	1110	37.73	88.93	2403
IL WINNEBAGO	176778	1344	42.34	89.16	2455
IL WOODFORD	22712	1368	40.79	89.21	2414
IN ADAMS	23350	893	40.75	84.95	2786
IN ALLEN	204321	1738	41.10	85.07	2782
IN BARTHOLOMEW	41249	1041	39.21	85.89	2683
IN BENTON	11654	1058	40.60	87.31	2577
IN BLACKFORD	14352	433	40.47	85.34	2748
IN BOONE	25504	1106	40.05	86.46	2643
IN BROWN	6560	826	39.20	86.22	2654
IN CARROLL	16403	968	40.58	86.55	2643
IN CASS	39704	1075	40.76	86.35	2664
IN CLARK	54483	995	38.48	85.71	2693
IN CLAY	24042	943	39.39	87.12	2577
IN CLINTON	30175	1054	40.30	86.47	2646
IN CRAWFORD	8905	808	38.30	86.45	2626
IN DAVIESS	26706	1113	38.71	87.07	2574
IN DEARBORN	26645	792	39.15	84.98	2763
IN DECATUR	18983	958	39.31	85.51	2718
IN DE KALB	26974	947	41.41	85.00	2794

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
IN DELAWARE	99043	1026	40.22	85.41	2738
IN DUBOIS	25350	1120	38.36	86.88	2588
IN ELKHART	93978	1211	41.60	85.86	2723
IN FAYETTE	23845	557	39.63	85.18	2750
IN FLOYD	47123	385	38.32	85.90	2675
IN FOUNTAIN	18208	1027	40.13	87.24	2576
IN FRANKLIN	16453	1020	39.41	85.07	2758
IN FULTON	16726	952	41.05	86.27	2677
IN GIBSON	30396	1289	38.32	87.58	2526
IN GRANT	67932	1089	40.51	85.66	2720
IN GREENE	27222	1421	39.04	86.96	2587
IN HAMILTON	33435	1038	40.07	86.05	2679
IN HANCOCK	23020	789	39.81	85.78	2700
IN HARRISON	18430	1241	38.20	86.11	2656
IN HENDRICKS	31524	1079	39.77	86.50	2636
IN HENRY	46946	1036	39.93	85.41	2734
IN HOWARD	60879	758	40.48	86.12	2680
IN HUNTINGTON	32426	955	40.83	85.50	2740
IN JACKSON	29224	1347	38.91	86.03	2668
IN JASPER	17798	1455	41.02	87.11	2602
IN JAY	22909	999	40.44	85.02	2776
IN JEFFERSON	22652	947	38.79	85.44	2719
IN JENNINGS	16111	975	39.00	85.63	2704
IN JOHNSON	33631	816	39.48	86.10	2668
IN KNOX	42628	1335	38.70	87.42	2543
IN KOSCIUSKO	36134	1399	41.24	85.87	2715
IN LAGRANGE	16210	986	41.66	85.44	2761
IN LAKE	429826	1328	41.42	87.38	2587
IN LA PORTE	84588	1572	41.55	86.73	2646
IN LAWRENCE	35290	1189	38.84	86.47	2628
IN MADISON	113224	1172	40.15	85.73	2709
IN MARION	613741	1014	39.78	86.13	2668
IN MARSHALL	30733	1147	41.33	86.26	2682
IN MARTIN	10648	893	38.71	86.80	2598
IN MIAMI	32369	975	40.77	86.05	2691
IN MONROE	53968	999	39.16	86.51	2628
IN MONTGOMERY	30383	1313	40.04	86.88	2606
IN MORGAN	28039	1051	39.48	86.43	2638
IN NEWTON	11215	1069	40.95	87.40	2576
IN NOBLE	26388	1066	41.41	85.43	2756
IN OHIO	4201	225	38.95	84.98	2761
IN ORANGE	16883	1048	38.54	86.49	2624
IN OWEN	11616	1010	39.32	86.83	2602

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IN PARKE	15306	1152	39.77	87.20	2574
IN PERRY	17310	995	38.09	86.64	2608
IN PIKE	14062	868	38.40	87.24	2557
IN PORTER	48666	1100	41.47	87.07	2615
IN POSEY	19556	1066	38.03	87.87	2499
IN PULASKI	12637	1120	41.04	86.69	2639
IN PUTNAM	23790	1269	39.67	86.84	2605
IN RANDOLPH	27693	1183	40.16	85.02	2771
IN RIPLEY	19556	1144	39.10	85.28	2736
IN RUSH	20050	1058	39.62	85.47	2725
IN ST JOSEPH	219323	1206	41.62	86.29	2686
IN SCOTT	12844	499	38.69	85.74	2691
IN SHELBY	30608	1058	39.52	85.79	2695
IN SPENCER	16127	1026	38.02	87.01	2575
IN STARKE	16398	802	41.28	86.64	2648
IN STEUBEN	17126	799	41.66	85.00	2799
IN SULLIVAN	22839	1183	39.10	87.42	2547
IN SWITZERLAND	7386	571	38.83	85.04	2755
IN TIPPECANOE	80705	1294	40.39	86.89	2611
IN TIPTON	15689	675	40.31	86.05	2683
IN UNION	6433	435	39.63	84.93	2772
IN VANDERBURGH	162709	623	38.03	87.59	2524
IN VERMILLION	18858	681	39.85	87.46	2552
IN VIGO	106559	1075	39.43	87.39	2553
IN WABASH	30557	1030	40.84	85.80	2714
IN WARREN	8540	952	40.35	87.36	2569
IN WARRICK	22399	1013	38.09	87.28	2551
IN WASHINGTON	17069	1335	38.60	86.10	2659
IN WAYNE	70893	1048	39.87	85.02	2768
IN WELLS	20272	952	40.73	85.24	2761
IN WHITE	18754	1286	40.74	86.86	2619
IN WHITLEY	19730	872	41.15	85.52	2744
IA ADAIR	11698	1473	41.33	94.48	1969
IA ADAMS	8207	1103	41.03	94.71	1942
IA ALLAMAKEE	16193	1646	43.29	91.37	2295
IA APPANOOSE	18123	1355	40.75	92.87	2095
IA AUDUBON	11296	1159	41.68	94.92	1942
IA BENTON	22980	1859	42.09	92.05	2199
IA BLACK HAWK	109811	1470	42.47	92.30	2189
IA BOONE	28096	1483	42.04	93.93	2036
IA BREMER	19829	1137	42.78	92.32	2198
IA BUCHANAN	22083	1470	42.48	91.83	2229
IA BUENA VISTA	21147	1480	42.74	95.16	1956

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IA BUTLER	17426	1507	42.74	92.79	2156
IA CALHOUN	16497	1479	42.38	94.65	1987
IA CARROLL	23219	1486	42.04	94.87	1957
IA CASS	18276	1448	41.33	94.94	1930
IA CEDAR	17285	1514	41.78	91.11	2271
IA CERRO GORDO	47686	1489	43.09	93.26	2128
IA CHEROKEE	18856	1483	42.74	95.63	1917
IA CHICKASAW	15143	1307	43.07	92.32	2207
IA CLARKE	8882	1110	41.03	93.79	2021
IA CLAY	18277	1476	43.09	95.16	1969
IA CLAYTON	22281	2018	42.85	91.33	2284
IA CLINTON	51956	1794	41.91	90.52	2326
IA CRAWFORD	19244	1853	42.03	95.39	1913
IA DALLAS	23863	1545	41.69	94.05	2016
IA DAVIS	9639	1317	40.76	92.40	2135
IA DECATUR	11730	1372	40.75	93.79	2014
IA DELAWARE	18056	1480	42.47	91.36	2270
IA DES MOINES	43137	1057	40.94	91.17	2246
IA DICKINSON	12677	983	43.38	95.16	1981
IA DUBUQUE	75041	1584	42.47	90.87	2311
IA EMMET	14431	1020	43.38	94.69	2020
IA FAYETTE	28416	1886	42.87	91.84	2241
IA FLOYD	21338	1303	43.07	92.79	2167
IA FRANKLIN	15928	1517	42.74	93.26	2116
IA FREMONT	11456	1356	40.76	95.61	1857
IA GREENE	15048	1473	42.04	94.40	1997
IA GRUNDY	13898	1297	42.41	92.79	2146
IA GUTHRIE	14517	1544	41.69	94.51	1977
IA HAMILTON	19815	1493	42.38	93.71	2067
IA HANCOCK	14877	1476	43.09	93.74	2088
IA HARDIN	22355	1486	42.39	93.24	2106
IA HARRISON	18726	1803	41.68	95.82	1865
IA HENRY	18488	1140	41.00	91.53	2216
IA HOWARD	12945	1220	43.36	92.32	2217
IA HUMBOLDT	13137	1127	42.78	94.21	2038
IA IDA	10514	1116	42.38	95.52	1913
IA IOWA	16075	1513	41.70	92.05	2188
IA JACKSON	19527	1667	42.17	90.56	2330
IA JASPER	33572	1893	41.69	93.05	2102
IA JEFFERSON	15748	1128	41.04	91.93	2182
IA JOHNSON	49113	1603	41.68	91.57	2229
IA JONES	19951	1514	42.13	91.11	2281
IA KEOKUK	16242	1500	41.35	92.17	2169

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IA KOSSUTH	25845	2536	43.21	94.21	2053
IA LEE	43571	1365	40.66	91.47	2215
IA LINN	118144	1856	42.09	91.59	2239
IA LOUISA	10759	1044	41.23	91.25	2246
IA LUCAS	11583	1124	41.03	93.33	2061
IA LYON	14597	1522	43.38	96.21	1894
IA MADISON	12774	1461	41.34	94.03	2009
IA MAHASKA	24215	1480	41.34	92.63	2129
IA MARION	25916	1289	41.34	93.10	2089
IA MARSHALL	36616	1486	42.04	93.00	2117
IA MILLS	13634	1158	41.03	95.62	1863
IA MITCHELL	13986	1210	43.37	92.79	2178
IA MONONA	15288	1810	42.05	95.96	1865
IA MONROE	11239	1127	41.03	92.87	2101
IA MONTGOMERY	15167	1092	41.03	95.16	1903
IA MUSCATINE	32868	1147	41.49	91.10	2265
IA O BRIEN	18916	1489	43.09	95.63	1930
IA OSCEOLA	10131	1030	43.38	95.63	1942
IA PAGE	22689	1386	40.75	95.15	1896
IA PALO ALTO	15400	1452	43.09	94.68	2009
IA PLYMOUTH	23534	2235	42.73	96.21	1868
IA POCAHONTAS	14961	1504	42.74	94.68	1996
IA POLK	243139	1497	41.69	93.58	2056
IA POTTAWATTAMI	75386	2494	41.33	95.54	1878
IA POWESHIEK	19328	1525	41.70	92.52	2148
IA RINGGOLD	8839	1393	40.75	94.25	1974
IA SAC	17303	1497	42.38	95.12	1947
IA SCOTT	108502	1175	41.65	90.61	2311
IA SHELBY	15895	1520	41.68	95.32	1908
IA SIOUX	26377	1983	43.08	96.17	1885
IA STORY	46439	1470	42.03	93.47	2076
IA TAMA	21565	1864	42.09	92.52	2159
IA TAYLOR	11512	1368	40.75	94.70	1935
IA UNION	14823	1100	41.03	94.25	1981
IA VAN BUREN	10484	1261	40.76	91.94	2176
IA WAPELLO	46855	1131	41.04	92.40	2142
IA WARREN	19064	1445	41.34	93.57	2048
IA WASHINGTON	19495	1470	41.34	91.70	2210
IA WAYNE	10920	1377	40.75	93.33	2054
IA WEBSTER	45758	1859	42.43	94.18	2028
IA WINNEBAGO	13302	1038	43.39	93.74	2099
IA WINNESHIEK	21647	1781	43.30	91.84	2255
IA WOODBURY	105589	2256	42.38	96.04	1869

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
IA WORTH	10724	1036	43.38	93.26	2139
IA WRIGHT	19563	1493	42.74	93.74	2076
KS ALLEN	17415	1307	37.88	95.32	1838
KS ANDERSON	9743	1493	38.21	95.31	1841
KS ATCHISON	21236	1106	39.53	95.32	1857
KS BARBER	8605	2968	37.22	98.69	1536
KS BARTON	30956	2315	38.47	98.75	1539
KS BOURBON	17850	1655	37.86	94.86	1878
KS BROWN	14045	1493	39.83	95.57	1840
KS BUTLER	34144	3734	37.76	96.85	1701
KS CHASE	4446	2004	38.29	96.60	1727
KS CHAUTAUQUA	6777	1676	37.15	96.25	1752
KS CHEROKEE	23926	1517	37.18	94.86	1876
KS CHEYENNE	5262	2660	39.79	101.73	1303
KS CLARK	3710	2546	37.23	99.82	1436
KS CLAY	11261	1645	39.33	97.17	1691
KS CLOUD	15385	1841	39.47	97.65	1651
KS COFFEY	9558	1597	38.23	95.74	1803
KS COMANCHE	3627	2071	37.18	99.29	1483
KS COWLEY	37311	2941	37.23	96.85	1699
KS CRAWFORD	38869	1548	37.51	94.86	1876
KS DECATUR	6012	2327	39.79	100.46	1414
KS DICKINSON	21352	2213	38.85	97.15	1685
KS DONIPHAN	10108	1005	39.80	95.16	1875
KS DOUGLAS	38184	1220	38.89	95.31	1848
KS EDWARDS	5587	1597	37.88	99.31	1484
KS ELK	5985	1676	37.44	96.25	1753
KS ELLIS	19988	2330	38.91	99.32	1496
KS ELLSWORTH	8130	1856	38.69	98.20	1590
KS FINNEY	15518	3369	38.04	100.74	1359
KS FORD	20211	2826	37.69	99.89	1432
KS FRANKLIN	19763	1493	38.57	95.30	1845
KS GEARY	24691	968	38.99	96.75	1722
KS GOVE	4302	2771	38.92	100.48	1394
KS GRAHAM	5259	2308	39.36	99.88	1454
KS GRANT	4907	1479	37.56	101.31	1306
KS GRAY	4681	2257	37.74	100.43	1384
KS GREELEY	2038	2028	38.48	101.81	1270
KS GREENWOOD	12591	2933	37.86	96.24	1756
KS HAMILTON	3464	2568	38.00	101.79	1266
KS HARPER	9961	2074	37.19	98.08	1590
KS HARVEY	23473	1399	38.03	97.43	1651
KS HASKELL	2773	1501	37.56	100.86	1345

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
KS HODGEMAN	3224	2226	38.09	99.90	1434
KS JACKSON	10763	1698	39.41	95.80	1813
KS JEFFERSON	11155	1320	39.24	95.39	1846
KS JEWELL	8646	2356	39.78	98.22	1608
KS JOHNSON	97215	1233	38.89	94.83	1890
KS KEARNY	3327	2213	38.00	101.32	1307
KS KINGMAN	10169	2237	37.55	98.14	1586
KS KIOWA	4693	1864	37.55	99.29	1484
KS LABETTE	28230	1693	37.20	95.31	1836
KS LANE	2918	1864	38.48	100.46	1389
KS LEAVENWORTH	44980	1206	39.21	95.05	1875
KS LINCOLN	6183	1877	39.04	98.21	1595
KS LINN	9301	1569	38.22	94.85	1881
KS LOGAN	4138	2778	38.92	101.14	1336
KS LYON	26723	2177	38.44	96.16	1768
KS MCPHERSON	23932	2320	38.38	97.65	1635
KS MARION	15809	2447	38.35	97.10	1683
KS MARSHALL	16942	2287	39.78	96.53	1756
KS MEADE	5622	2536	37.24	100.36	1388
KS MIAMI	19776	1532	38.57	94.85	1885
KS MITCHELL	9701	1849	39.39	98.21	1601
KS MONTGOMERY	45860	1627	37.20	95.75	1797
KS MORRIS	8022	1804	38.68	96.65	1727
KS MORTON	2927	1886	37.19	101.80	1260
KS NEMAHA	13728	1833	39.78	96.01	1800
KS NEOSHO	19973	1520	37.56	95.32	1836
KS NESS	5962	2799	38.48	99.91	1437
KS NORTON	8479	2257	39.79	99.90	1462
KS OSAGE	12847	1831	38.65	95.74	1807
KS OSBORNE	8114	2294	39.35	98.76	1552
KS OTTAWA	7063	1873	39.12	97.65	1645
KS PAWNEE	10705	1955	38.18	99.24	1493
KS PHILLIPS	9036	2322	39.78	99.35	1510
KS POTTAWATOMIE	12176	2123	39.37	96.34	1764
KS PRATT	12139	1887	37.64	98.74	1533
KS RAWLINS	5537	2792	39.79	101.07	1361
KS RENO	56184	3262	37.94	98.08	1593
KS REPUBLIC	10751	1859	39.82	97.66	1658
KS RICE	14901	1877	38.34	98.20	1587
KS RILEY	37022	1545	39.29	96.74	1728
KS ROOKS	9339	2294	39.35	99.32	1503
KS RUSH	6774	1874	38.52	99.31	1491
KS RUSSELL	12533	2246	38.91	98.76	1544

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
KS SALINE	42468	1864	38.77	97.65	1640
KS SCOTT	5058	1874	38.48	100.90	1350
KS SEDGWICK	273691	2608	37.67	97.47	1646
KS SEWARD	12504	1673	37.19	100.85	1345
KS SHAWNEE	120661	1418	39.04	95.76	1810
KS SHERIDAN	4464	2312	39.36	100.44	1406
KS SHERMAN	7077	2731	39.36	101.72	1294
KS SMITH	8393	2312	39.78	98.79	1559
KS STAFFORD	8235	2059	38.02	98.71	1538
KS STANTON	2194	1750	37.56	101.78	1263
KS STEVENS	4469	1893	37.20	101.31	1304
KS SUMNER	24359	3071	37.23	97.49	1643
KS THOMAS	7481	2771	39.36	101.05	1353
KS TREGO	5704	2333	38.92	99.88	1447
KS WABAUNSEE	6974	2050	38.94	96.21	1770
KS WALLACE	2319	2358	38.92	101.76	1281
KS WASHINGTON	12027	2308	39.78	97.09	1706
KS WICHITA	2695	1874	38.48	101.35	1311
KS WILSON	14082	1486	37.56	95.75	1798
KS WOODSON	6171	1286	37.88	95.75	1800
KS WYANDOTTE	173891	394	39.13	94.77	1899
KY ADAIR	16367	958	37.09	85.30	2725
KY ALLEN	13138	909	36.76	86.18	2646
KY ANDERSON	8826	533	38.00	84.99	2754
KY BALLARD	8441	671	37.07	89.00	2396
KY BARREN	28396	1211	36.97	85.93	2668
KY BATH	9859	743	38.15	83.74	2866
KY BELL	42391	958	36.73	83.68	2869
KY BOONE	16811	644	38.96	84.73	2783
KY BOURBON	17930	777	38.21	84.21	2824
KY BOYD	50892	412	38.36	82.68	2961
KY BOYLE	20840	474	37.62	84.87	2763
KY BRACKEN	8001	527	38.70	84.09	2838
KY BREATHITT	18065	1279	37.53	83.32	2901
KY BRECKINRIDGE	15188	1434	37.78	86.43	2625
KY BULLITT	13212	777	37.97	85.70	2691
KY BUTLER	10578	1147	37.21	86.68	2602
KY CALDWELL	13146	924	37.14	87.86	2497
KY CALLOWAY	20497	995	36.63	88.27	2461
KY CAMPBELL	80709	385	38.95	84.38	2815
KY CARLISLE	5953	505	36.86	88.96	2400
KY CARROLL	8287	336	38.66	85.13	2746
KY CARTER	21825	1027	38.32	83.03	2929

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KY CASEY	16122	1127	37.30	84.94	2756
KY CHRISTIAN	48538	1877	36.89	87.49	2530
KY CLARK	19824	671	37.97	84.14	2829
KY CLAY	22111	1227	37.17	83.71	2865
KY CLINTON	9876	492	36.73	85.14	2739
KY CRITTENDEN	9896	944	37.35	88.10	2476
KY CUMBERLAND	8686	802	36.79	85.40	2716
KY DAVIESS	62916	1196	37.73	87.09	2567
KY EDMONSON	8830	771	37.21	86.24	2641
KY ELLIOTT	6763	622	38.12	83.10	2922
KY ESTILL	13741	672	37.69	83.96	2844
KY FAYETTE	113993	724	38.04	84.46	2802
KY FLEMING	11511	906	38.38	83.68	2872
KY FLOYD	48464	1033	37.56	82.74	2952
KY FRANKLIN	27415	546	38.23	84.88	2765
KY FULTON	12647	526	36.58	89.12	2385
KY GALLATIN	3925	259	38.75	84.86	2771
KY GARRARD	10484	610	37.64	84.54	2793
KY GRANT	9673	644	38.64	84.61	2791
KY GRAVES	30789	1449	36.73	88.65	2427
KY GRAYSON	16546	1285	37.47	86.34	2632
KY GREEN	11254	730	37.27	85.57	2701
KY GREENUP	26732	909	38.55	82.91	2941
KY HANCOCK	5722	484	37.85	86.78	2594
KY HARDIN	57739	1594	37.71	85.97	2666
KY HARLAN	62978	1214	36.86	83.21	2910
KY HARRISON	13725	798	38.44	84.33	2815
KY HART	14810	1088	37.30	85.89	2672
KY HENDERSON	31906	1120	37.79	87.57	2524
KY HENRY	11220	748	38.44	85.12	2745
KY HICKMAN	7341	637	36.68	88.93	2402
KY HOPKINS	38664	1431	37.31	87.54	2526
KY JACKSON	12071	872	37.42	84.00	2840
KY JEFFERSON	538310	971	38.18	85.67	2695
KY JESSAMINE	12956	457	37.87	84.58	2790
KY JOHNSON	22105	684	37.85	82.83	2945
KY KENTON	111246	426	38.93	84.53	2801
KY KNOTT	19064	922	37.36	82.95	2933
KY KNOX	28222	965	36.90	83.85	2853
KY LARUE	10120	672	37.55	85.71	2689
KY LAUREL	25418	1155	37.11	84.11	2830
KY LAWRENCE	13452	1100	38.07	82.73	2955
KY LEE	8180	543	37.60	83.70	2867

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KY LESLIE	13585	1058	37.10	83.37	2895
KY LETCHER	35516	878	37.13	82.85	2942
KY LEWIS	13352	1258	38.54	83.37	2901
KY LINCOLN	17750	881	37.46	84.66	2781
KY LIVINGSTON	7122	805	37.21	88.36	2453
KY LOGAN	21721	1458	36.86	86.88	2584
KY LYON	6456	558	37.01	88.08	2478
KY MCCRACKEN	52610	647	37.06	88.71	2422
KY MCCREARY	14875	1082	36.74	84.48	2797
KY MCLEAN	9740	665	37.53	87.27	2550
KY MADISON	32158	1155	37.72	84.28	2816
KY MAGOFFIN	12702	785	37.71	83.06	2924
KY MARION	17074	888	37.56	85.28	2727
KY MARSHALL	14810	785	36.88	88.33	2456
KY MARTIN	11051	598	37.80	82.51	2973
KY MASON	18474	616	38.60	83.81	2862
KY MEADE	13465	789	37.99	86.22	2645
KY MENIFEE	4577	543	37.95	83.60	2877
KY MERCER	14624	663	37.81	84.88	2763
KY METCALFE	9223	767	36.99	85.64	2694
KY MONROE	12934	865	36.71	85.72	2687
KY MONTGOMERY	13210	527	38.03	83.91	2850
KY MORGAN	12535	955	37.92	83.25	2908
KY MUHLENBERG	30501	1245	37.21	87.14	2561
KY NELSON	20649	1131	37.81	85.49	2709
KY NICHOLAS	7171	527	38.34	84.00	2843
KY OHIO	19518	1544	37.48	86.85	2587
KY OLDHAM	12031	477	38.39	85.46	2715
KY OWEN	9109	909	38.51	84.82	2772
KY OWSLEY	6500	509	37.42	83.68	2869
KY PENDLETON	9766	723	38.69	84.35	2815
KY PERRY	41638	882	37.25	83.21	2910
KY PIKE	75673	2025	37.47	82.39	2983
KY POWELL	6754	447	37.83	83.82	2857
KY PULASKI	36731	1690	37.11	84.56	2790
KY ROBERTSON	2698	261	38.52	84.04	2841
KY ROCKCASTLE	13253	805	37.37	84.31	2812
KY ROWAN	12754	751	38.20	83.40	2895
KY RUSSELL	12594	616	36.98	85.07	2745
KY SCOTT	15243	736	38.29	84.58	2792
KY SHELBY	18159	992	38.21	85.20	2737
KY SIMPSON	11625	619	36.74	86.58	2611
KY SPENCER	5956	499	38.03	85.32	2725

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KY TAYLOR	15202	716	37.36	85.34	2721
KY TODD	12240	974	36.84	87.18	2558
KY TRIGG	9338	1057	36.80	87.87	2496
KY TRIMBLE	5131	378	38.60	85.35	2726
KY UNION	14741	881	37.66	87.95	2491
KY WARREN	43920	1414	37.00	86.42	2625
KY WASHINGTON	12088	795	37.76	85.18	2736
KY WAYNE	15717	1140	36.81	84.83	2766
KY WEBSTER	15000	878	37.52	87.68	2514
KY WHITLEY	29337	1189	36.76	84.15	2827
KY WOLFE	7158	588	37.74	83.49	2886
KY WOODFORD	11515	499	38.04	84.74	2776
LA ACADIA	48277	1717	30.30	92.41	2222
LA ALLEN	19272	2004	30.65	92.82	2174
LA ASCENSION	24743	779	30.20	90.91	2351
LA ASSUMPTION	17586	922	29.90	91.07	2349
LA AVOYELLES	37853	2154	31.08	92.01	2228
LA BEAUREGARD	18376	3058	30.66	93.35	2130
LA BIENVILLE	18093	2154	32.35	93.05	2101
LA BOSSIER	47567	2198	32.68	93.61	2044
LA CADDO	196653	2327	32.59	93.89	2022
LA CALCASIEU	113367	2861	30.24	93.35	2146
LA CALDWELL	9748	1427	32.09	92.12	2188
LA CAMERON	6528	3731	29.89	93.19	2173
LA CATAHOULA	11660	1921	31.67	91.85	2223
LA CLAIBORNE	22661	1976	32.83	93.00	2093
LA CONCORDIA	16978	1859	31.45	91.64	2248
LA DE SOTO	24334	2315	32.07	93.74	2050
LA EAST BATON R	188763	1189	30.54	91.10	2323
LA EAST CARROLL	15511	1128	32.73	91.24	2247
LA EAST FELICIA	19586	1175	30.85	91.05	2317
LA EVANGELINE	31636	1732	30.73	92.40	2206
LA FRANKLIN	27980	1677	32.14	91.68	2225
LA GRANT	13868	1735	31.60	92.56	2165
LA IBERIA	44992	1525	29.97	91.70	2294
LA IBERVILLE	28105	1624	30.26	91.36	2311
LA JACKSON	15606	1507	32.31	92.56	2145
LA JEFFERSON	148455	955	29.72	90.12	2435
LA JEFFERSON DA	27796	1704	30.27	92.81	2190
LA LAFAYETTE	69180	733	30.21	92.06	2254
LA LAFOURCHE	47809	2954	29.58	90.43	2414
LA LA SALLE	12842	1665	31.68	92.16	2196
LA LINCOLN	26952	1214	32.61	92.66	2128

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LA LIVINGSTON	22995	1693	30.44	90.72	2359
LA MADISON	17027	1711	32.37	91.25	2256
LA MOREHOUSE	32749	2081	32.83	91.81	2196
LA NATCHITOCHES	37086	3345	31.73	93.09	2116
LA ORLEANS	594710	509	30.04	89.93	2439
LA OUACHITA	86168	1652	32.48	92.16	2174
LA PLAQUEMINES	17769	2667	29.45	89.62	2486
LA POINTE COUPE	22116	1458	30.72	91.61	2274
LA RAPIDES	99443	3413	31.20	92.53	2180
LA RED RIVER	11208	1051	32.10	93.34	2083
LA RICHLAND	25465	1491	32.42	91.77	2209
LA SABINE	19895	2260	31.57	93.56	2081
LA ST BERNARD	20053	1331	29.90	89.54	2477
LA ST CHARLES	16705	761	29.90	90.36	2408
LA ST HELENA	9076	1088	30.82	90.71	2347
LA ST JAMES	16624	654	30.03	90.79	2367
LA ST JOHN THE	16382	588	30.10	90.55	2385
LA ST LANDRY	79765	2413	30.60	92.01	2245
LA ST MARTIN	27508	1905	29.88	91.27	2333
LA ST MARY	41367	1615	29.72	91.44	2325
LA ST TAMMANY	31946	2297	30.47	89.94	2423
LA TANGIPAHOA	55857	2092	30.65	90.41	2377
LA TENSAS	12612	1621	32.01	91.33	2258
LA TERREBONNE	50746	3542	29.43	90.84	2386
LA UNION	18496	2291	32.84	92.38	2146
LA VERMILION	37750	3120	29.86	92.32	2246
LA VERNON	18689	3498	31.11	93.18	2128
LA WASHINGTON	40769	1721	30.86	90.03	2403
LA WEBSTER	37407	1593	32.72	93.34	2067
LA WEST BATON R	13039	526	30.46	91.33	2307
LA WEST CARROLL	15947	922	32.79	91.46	2227
LA WEST FELICIA	11119	1048	30.88	91.42	2284
LA WINN	16083	2460	31.95	92.64	2148
ME ANDROSCOGGIN	84755	1227	44.17	70.20	4141
ME AROOSTOOK	100296	17665	46.66	68.60	4341
ME CUMBERLAND	174958	2277	43.87	70.43	4115
ME FRANKLIN	20422	4425	44.98	70.44	4139
ME HANCOCK	32185	3977	44.71	68.36	4313
ME KENNEBEC	86118	2257	44.42	69.77	4185
ME KNOX	28312	955	44.18	69.24	4225
ME LINCOLN	18214	1175	44.09	69.54	4197
ME OXFORD	44271	5386	44.52	70.76	4100
ME PENOBSCOT	115906	8779	45.40	68.66	4304

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ME PISCATAQUIS	18094	10079	45.84	69.29	4260
ME SAGADAHOC	21711	665	43.99	69.87	4167
ME SOMERSET	39771	10084	45.52	69.96	4194
ME WALDO	22089	1908	44.52	69.16	4239
ME WASHINGTON	34218	6614	45.05	67.65	4383
ME YORK	96035	2592	43.49	70.71	4083
MD ALLEGANY	87266	1109	39.62	78.70	3323
MD ANNE ARUNDEL	155319	1096	39.01	76.63	3501
MD BALTIMORE	1309861	1750	39.47	76.65	3503
MD CALVERT	13683	561	38.55	76.59	3502
MD CAROLINE	18755	830	38.87	75.84	3570
MD CARROLL	48256	1180	39.56	77.03	3470
MD CECIL	39749	937	39.58	75.95	3566
MD CHARLES	27309	1189	38.50	77.04	3461
MD DORCHESTER	28601	1538	38.49	76.01	3553
MD FREDERICK	66383	1721	39.48	77.41	3436
MD GARRETT	20903	1707	39.54	79.27	3271
MD HARFORD	62382	1172	39.56	76.33	3532
MD HOWARD	28659	650	39.25	76.94	3475
MD KENT	14444	727	39.26	76.04	3555
MD MONTGOMERY	239426	1282	39.14	77.22	3449
MD PRINCE GEORG	263546	1255	38.83	76.86	3479
MD QUEEN ANNES	15426	971	39.08	75.99	3558
MD ST MARYS	33278	965	38.30	76.63	3496
MD SOMERSET	20273	878	38.12	75.74	3575
MD TALBOT	20342	675	38.77	76.09	3547
MD WASHINGTON	84128	1189	39.61	77.82	3400
MD WICOMICO	43636	986	38.37	75.63	3586
MD WORCESTER	23401	1241	38.22	75.35	3610
MA BARNSTABLE	56782	1017	41.74	70.28	4091
MA BERKSHIRE	136865	2436	42.37	73.21	3844
MA BRISTOL	388757	1434	41.81	71.11	4019
MA DUKES	5715	268	41.38	70.64	4055
MA ESSEX	542126	1279	42.67	70.96	4046
MA FRANKLIN	53645	1833	42.58	72.59	3902
MA HAMPDEN	394061	1603	42.14	72.63	3891
MA HAMPSHIRE	94239	1369	42.34	72.66	3891
MA MIDDLESEX	1138593	2136	42.49	71.39	4005
MA NANTUCKET	3516	119	41.29	70.05	4105
MA NORFOLK	442438	1020	42.16	71.22	4014
MA PLYMOUTH	214538	1693	41.96	70.82	4047
MA SUFFOLK	851870	145	42.31	71.11	4027
MA WORCESTER	562056	3907	42.35	71.91	3958

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
MI ALCONA	6065	1756	44.69	83.60	3000
MI ALGER	9686	2343	46.41	86.62	2809
MI ALLEGAN	51850	2139	42.59	85.89	2744
MI ALPENA	24895	1462	45.04	83.63	3008
MI ANTRIM	10573	1233	45.00	85.14	2880
MI ARENAC	9736	951	44.07	83.89	2955
MI BARAGA	7659	2333	46.66	88.38	2676
MI BARRY	28542	1434	42.60	85.31	2793
MI BAY	96359	1158	43.70	83.99	2937
MI BENZIE	8105	817	44.64	86.01	2794
MI BERRIEN	130222	1501	41.96	86.42	2682
MI BRANCH	32201	1310	41.93	85.07	2799
MI CALHOUN	128481	1835	42.25	85.00	2812
MI CASS	31903	1272	41.92	86.00	2718
MI CHARLEVOIX	13454	1072	45.23	85.04	2896
MI CHEBOYGAN	14078	1866	45.45	84.50	2948
MI CHIPPEWA	30675	4118	46.33	84.72	2963
MI CLARE	10843	1479	43.99	84.84	2872
MI CLINTON	34071	1480	42.95	84.60	2864
MI CRAWFORD	4502	1452	44.69	84.60	2914
MI DELTA	33501	3047	45.93	86.94	2763
MI DICKINSON	24447	1960	46.01	87.88	2688
MI EATON	44129	1479	42.60	84.84	2834
MI EMMET	16264	1193	45.51	84.89	2918
MI GENESEE	314887	1662	43.03	83.71	2943
MI GLADWIN	10011	1307	43.99	84.38	2911
MI GOGEBIC	25916	2867	46.40	89.68	2558
MI GRAND TRAVER	30679	1196	44.67	85.56	2833
MI GRATIOT	34951	1465	43.30	84.61	2872
MI HILLSDALE	33118	1553	41.90	84.60	2839
MI HOUGHTON	38019	2633	46.90	88.69	2662
MI HURON	33515	2121	43.84	83.01	3024
MI INGHAM	189239	1448	42.60	84.37	2875
MI IONIA	40274	1489	42.95	85.07	2823
MI IOSCO	13291	1408	44.36	83.64	2986
MI IRON	17475	3033	46.21	88.54	2643
MI ISABELLA	31682	1480	43.64	84.85	2861
MI JACKSON	118158	1807	42.25	84.42	2863
MI KALAMAZOO	144984	1455	42.25	85.53	2766
MI KALKASKA	4503	1465	44.69	85.08	2873
MI KENT	320129	2219	43.03	85.55	2784
MI KEWEENAW	2703	1393	47.36	88.12	2729
MI LAKE	5289	1479	43.99	85.81	2790

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
MI LAPEER	38401	1704	43.10	83.22	2986
MI LEELANAU	8935	893	44.92	85.77	2823
MI LENAWEE	70223	1949	41.91	84.07	2886
MI LIVINGSTON	31617	1480	42.61	83.91	2915
MI LUCE	8014	2346	46.47	85.55	2900
MI MACKINAC	9954	2626	46.10	85.13	2920
MI MACOMB	278821	1242	42.70	82.93	3002
MI MANISTEE	18748	1431	44.34	86.05	2780
MI MARQUETTE	51267	4734	46.43	87.65	2726
MI MASON	21092	1269	43.99	86.25	2752
MI MECOSTA	19853	1449	43.64	85.33	2820
MI MENOMINEE	25033	2688	45.57	87.57	2697
MI MIDLAND	42370	1347	43.65	84.39	2901
MI MISSAUKEE	7176	1462	44.34	85.08	2862
MI MONROE	86486	1442	41.94	83.54	2933
MI MONTCALM	33042	1843	43.31	85.16	2825
MI MONTMORENCY	4253	1437	45.03	84.12	2966
MI MUSKEGON	133617	1297	43.29	86.14	2741
MI NEWAYGO	22667	2198	43.55	85.81	2777
MI OAKLAND	521061	2246	42.67	83.38	2962
MI OCEANA	16298	1387	43.64	86.25	2741
MI OGEMAW	9488	1479	44.34	84.12	2944
MI ONTONAGON	10409	3407	46.67	89.32	2600
MI OSCEOLA	13711	1504	43.99	85.32	2831
MI OSCODA	3268	1458	44.68	84.12	2955
MI OTSEGO	6905	1365	45.02	84.59	2926
MI OTTAWA	84363	1458	42.96	85.99	2744
MI PRESQUE ISLE	12471	1677	45.35	83.91	2994
MI ROSCOMMON	6461	1348	44.34	84.60	2903
MI SAGINAW	169341	2108	43.34	84.05	2921
MI ST CLAIR	98232	1901	42.96	82.70	3028
MI ST JOSEPH	38159	1310	41.93	85.53	2759
MI SANILAC	31463	2488	43.43	82.82	3030
MI SCHOOLCRAFT	9067	3058	46.20	86.21	2834
MI SHIAWASSEE	49143	1399	42.96	84.14	2904
MI TUSCOLA	40410	2111	43.47	83.42	2979
MI VAN BUREN	43098	1562	42.25	86.02	2724
MI WASHTENAW	150689	1841	42.26	83.83	2913
MI WAYNE	2533436	1566	42.30	83.29	2962
MI WEXFORD	18565	1448	44.34	85.57	2821
MN AITKIN	13412	4734	46.61	93.41	2271
MN ANOKA	56974	1097	45.28	93.25	2219
MN BECKER	24468	3358	46.93	95.66	2116

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MN BELTRAMI	24307	6492	47.97	94.91	2233
MN BENTON	16496	1041	45.71	94.01	2179
MN BIG STONE	9328	1269	45.43	96.39	1976
MN BLUE EARTH	40901	1908	44.05	94.07	2097
MN BROWN	26650	1579	44.26	94.73	2053
MN CARLTON	26001	2232	46.59	92.67	2328
MN CARVER	19514	930	44.83	93.80	2153
MN CASS	18302	5174	46.96	94.32	2220
MN CHIPPEWA	16561	1507	45.03	95.56	2021
MN CHISAGO	12985	1085	45.51	92.92	2256
MN CLAY	34069	2706	46.89	96.47	2052
MN CLEARWATER	9634	2589	47.58	95.37	2176
MN COOK	3104	3486	47.90	90.51	2566
MN COTTONWOOD	15937	1646	44.02	95.19	2005
MN CROW WING	31410	2577	46.48	94.07	2213
MN DAKOTA	61465	1491	44.69	93.07	2207
MN DODGE	12890	1127	44.03	92.86	2197
MN DOUGLAS	21308	1676	45.94	95.45	2076
MN FARIBAULT	23793	1841	43.68	93.96	2092
MN FILLMORE	24170	2225	43.69	92.09	2248
MN FREEBORN	35950	1815	43.69	93.35	2143
MN GOODHUE	32511	1949	44.42	92.73	2224
MN GRANT	9258	1414	45.94	96.01	2033
MN HENNEPIN	747246	1469	45.02	93.48	2188
MN HOUSTON	15349	1462	43.68	91.49	2298
MN HUBBARD	10610	2413	47.10	94.91	2183
MN ISANTI	12720	1134	45.57	93.30	2229
MN ITASCA	35316	6818	47.50	93.61	2304
MN JACKSON	15962	1803	43.68	95.17	1992
MN KANABEC	9113	1356	45.96	93.29	2247
MN KANDIYOHI	29216	2028	45.16	95.00	2072
MN KITTSON	9092	2909	48.78	96.76	2151
MN KOOCHICHING	17453	8098	48.24	93.76	2336
MN LAC QUI PARL	14030	1988	45.00	96.17	1972
MN LAKE	10294	5340	47.64	91.43	2480
MN LAKE OF THE	4675	3394	48.78	94.89	2285
MN LE SUEUR	19436	1140	44.39	93.73	2140
MN LINCOLN	9940	1375	44.42	96.25	1937
MN LYON	22426	1835	44.43	95.83	1971
MN MCLEOD	23133	1264	44.83	94.27	2115
MN MAHNOMEN	6756	1458	47.33	95.80	2128
MN MARSHALL	15335	4633	48.36	96.37	2151
MN MARTIN	26220	1821	43.68	94.56	2042

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MN MEEKER	18932	1603	45.13	94.52	2109
MN MILLE LACS	14905	1479	45.95	93.63	2220
MN MORRISON	26171	2919	46.02	94.27	2173
MN MOWER	44920	1821	43.68	92.76	2192
MN MURRAY	14778	1821	44.04	95.76	1959
MN NICOLLET	21891	1119	44.37	94.25	2097
MN NOBLES	22832	1843	43.68	95.76	1943
MN NORMAN	12202	2291	47.33	96.44	2081
MN OLMSTED	55581	1698	44.01	92.40	2234
MN OTTER TAIL	50316	5081	46.41	95.69	2083
MN PENNINGTON	12751	1610	48.07	96.01	2159
MN PINE	17701	3662	46.13	92.74	2300
MN PIPESTONE	13835	1202	44.03	96.24	1920
MN POLK	36020	5213	47.78	96.39	2112
MN POPE	12462	1732	45.59	95.44	2059
MN RAMSEY	383891	401	45.03	93.10	2220
MN RED LAKE	6394	1119	47.87	96.08	2141
MN REDWOOD	21956	2263	44.42	95.25	2017
MN RENVILLE	23653	2536	44.74	94.94	2057
MN RICE	37402	1285	44.37	93.30	2174
MN ROCK	11528	1255	43.68	96.24	1904
MN ROSEAU	13502	4340	48.78	95.79	2220
MN ST LOUIS	216914	15777	47.60	92.46	2398
MN SCOTT	18789	913	44.66	93.53	2168
MN SHERBURNE	11597	1116	45.46	93.78	2184
MN SIBLEY	15997	1510	44.59	94.23	2108
MN STEARNS	74793	3475	45.56	94.61	2123
MN STEELE	22803	1100	44.03	93.23	2166
MN STEVENS	11172	1445	45.59	96.00	2016
MN SWIFT	15455	1914	45.29	95.68	2025
MN TODD	24441	2439	46.08	94.89	2127
MN TRAVERSE	7820	1470	45.78	96.46	1989
MN WABASHA	16936	1351	44.29	92.22	2260
MN WADENA	12548	1387	46.59	94.96	2150
MN WASECA	15421	1075	44.03	93.60	2136
MN WASHINGTON	42149	999	45.04	92.89	2237
MN WATONWAN	14130	1120	43.99	94.62	2050
MN WILKIN	10600	1947	46.36	96.46	2022
MN WINONA	40310	1605	44.00	91.78	2286
MN WRIGHT	28656	1745	45.18	93.96	2156
MN YELLOW MEDIC	15962	1949	44.73	95.86	1983
MS ADAMS	34585	1162	31.49	91.35	2271
MS ALCORN	26359	1048	34.88	88.58	2444

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MS AMITE	17694	1887	31.18	90.81	2327
MS ATTALA	24391	1874	33.09	89.58	2384
MS BENTON	8340	1066	34.82	89.19	2391
MS BOLIVAR	59372	2391	33.80	90.89	2257
MS CALHOUN	17334	1489	33.94	89.33	2390
MS CARROLL	13662	1649	33.45	89.92	2347
MS CHICKASAW	18080	1310	33.92	88.94	2425
MS CHOCTAW	9915	1079	33.35	89.25	2408
MS CLAIBORNE	11479	1266	31.98	90.92	2295
MS CLARKE	18147	1804	32.04	88.69	2485
MS CLAY	18259	1072	33.66	88.78	2444
MS COAHOMA	48023	1473	34.24	90.61	2274
MS COPIAH	29029	2019	31.87	90.46	2337
MS COVINGTON	15018	1076	31.64	89.56	2421
MS DE SOTO	24299	1233	34.88	89.99	2320
MS FORREST	48316	1211	31.19	89.26	2459
MS FRANKLIN	10231	1470	31.48	90.90	2310
MS GEORGE	10474	1245	30.86	88.64	2521
MS GREENE	8280	1886	31.21	88.64	2512
MS GRENADA	18651	1116	33.77	89.80	2352
MS HANCOCK	12806	1248	30.43	89.49	2463
MS HARRISON	99127	1514	30.53	89.12	2491
MS HINDS	161236	2268	32.27	90.45	2327
MS HOLMES	30665	1991	33.13	90.10	2339
MS HUMPHREYS	21407	1089	33.13	90.53	2300
MS ISSAQUENA	4374	1072	32.74	90.99	2269
MS ITAWAMBA	16315	1400	34.28	88.36	2471
MS JACKSON	41653	1905	30.56	88.64	2531
MS JASPER	18060	1769	32.03	89.12	2449
MS JEFFERSON	10811	1348	31.74	91.04	2291
MS JEFFERSON DA	14668	1072	31.58	89.83	2399
MS JONES	58217	1818	31.63	89.17	2455
MS KEMPER	14356	1960	32.76	88.64	2473
MS LAFAYETTE	22187	1729	34.36	89.49	2371
MS LAMAR	13419	1294	31.22	89.51	2436
MS LAUDERDALE	65426	1833	32.40	88.66	2479
MS LAWRENCE	11612	1120	31.56	90.12	2375
MS LEAKE	20357	1517	32.76	89.53	2396
MS LEE	39235	1178	34.29	88.68	2443
MS LEFLORE	49829	1532	33.55	90.31	2312
MS LINCOLN	27418	1517	31.54	90.46	2346
MS LOWNDES	41589	1316	33.47	88.44	2476
MS MADISON	33450	1883	32.64	90.05	2354

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MS MARION	23684	1424	31.24	89.83	2409
MS MARSHALL	24850	1838	34.76	89.50	2364
MS MONROE	35444	1991	33.89	88.48	2467
MS MONTGOMERY	13985	1044	33.49	89.61	2374
MS NESHOBA	23690	1470	32.76	89.12	2432
MS NEWTON	21340	1501	32.40	89.11	2440
MS NOXUBEE	18669	1800	33.11	88.57	2473
MS OKTIBBEHA	25252	1175	33.42	88.88	2440
MS PANOLA	30216	1794	34.37	89.95	2330
MS PEARL RIVER	21393	2145	30.78	89.58	2444
MS PERRY	8952	1690	31.18	88.99	2482
MS PIKE	35101	1058	31.18	90.42	2361
MS PONTOTOC	18821	1297	34.23	89.04	2412
MS PRENTISS	19023	1082	34.62	88.52	2453
MS QUITMAN	23820	1066	34.26	90.29	2302
MS RANKIN	31194	2007	32.27	89.95	2370
MS SCOTT	21470	1593	32.41	89.54	2403
MS SHARKEY	11984	1128	32.88	90.82	2281
MS SIMPSON	21238	1520	31.92	89.93	2382
MS SMITH	15702	1662	32.03	89.51	2415
MS STONE	6579	1159	30.79	89.12	2483
MS SUNFLOWER	51657	1797	33.61	90.59	2286
MS TALLAHATCHIE	27767	1667	33.96	90.18	2316
MS TATE	18067	1048	34.65	89.95	2326
MS TIPPAH	16492	1202	34.77	88.91	2417
MS TISHOMINGO	14844	1147	34.74	88.24	2476
MS TUNICA	19613	1186	34.65	90.37	2289
MS UNION	19686	1092	34.49	89.01	2412
MS WALTHALL	14691	1044	31.15	90.11	2387
MS WARREN	40716	1504	32.37	90.85	2291
MS WASHINGTON	73964	1901	33.28	90.95	2261
MS WAYNE	16693	2142	31.65	88.69	2495
MS WEBSTER	11174	1076	33.61	89.28	2400
MS WILKINSON	13740	1745	31.16	91.32	2284
MS WINSTON	20966	1569	33.09	89.03	2433
MS YALOBUSHA	14045	1264	34.03	89.71	2356
MS YAZOO	33987	2429	32.79	90.40	2319
MO ADAIR	19863	1480	40.20	92.59	2108
MO ANDREW	11442	1128	40.00	94.80	1911
MO ATCHISON	10311	1421	40.45	95.43	1865
MO AUDRAIN	24790	1791	39.21	91.83	2159
MO BARRY	20550	2028	36.72	93.84	1966
MO BARTON	12014	1538	37.51	94.36	1922

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MO BATES	16842	2177	38.26	94.34	1927
MO BENTON	8934	1904	38.30	93.29	2020
MO BOLLINGER	10236	1607	37.32	90.03	2305
MO BOONE	51310	1773	38.99	92.30	2115
MO BUCHANAN	94171	1045	39.67	94.81	1904
MO BUTLER	36411	1852	36.72	90.41	2271
MO CALDWELL	9465	1113	39.67	93.98	1976
MO CALLAWAY	23548	2163	38.84	91.92	2147
MO CAMDEN	8391	1658	38.03	92.76	2065
MO CAPE GIRARDE	39938	1486	37.38	89.68	2336
MO CARROLL	14852	1804	39.44	93.51	2014
MO CARTER	4435	1310	36.93	90.98	2220
MO CASS	23733	1807	38.65	94.36	1929
MO CEDAR	10035	1285	37.72	93.86	1966
MO CHARITON	14004	1952	39.52	92.95	2064
MO CHRISTIAN	12392	1469	36.97	93.20	2023
MO CLARK	8886	1310	40.42	91.72	2188
MO CLAY	63182	1066	39.32	94.42	1932
MO CLINTON	11672	1088	39.61	94.40	1938
MO COLE	37715	995	38.50	92.27	2112
MO COOPER	16119	1465	38.84	92.80	2069
MO CRAWFORD	12052	1967	37.97	91.31	2194
MO DADE	8582	1304	37.44	93.85	1966
MO DALLAS	9935	1390	37.68	93.03	2040
MO DAVIESS	10469	1458	39.97	93.98	1981
MO DE KALB	7702	1096	39.90	94.40	1944
MO DENT	10729	1957	37.60	91.51	2174
MO DOUGLAS	11368	2094	36.94	92.50	2085
MO DUNKLIN	42699	1406	36.28	90.09	2300
MO FRANKLIN	39666	2419	38.41	91.07	2217
MO GASCONADE	12281	1344	38.44	91.51	2179
MO GENTRY	10080	1264	40.22	94.41	1949
MO GREENE	113942	1752	37.26	93.35	2010
MO GRUNDY	12799	1127	40.12	93.56	2021
MO HARRISON	13044	1864	40.37	93.99	1989
MO HENRY	19693	1901	38.39	93.79	1976
MO HICKORY	5018	975	37.95	93.32	2015
MO HOLT	9008	1186	40.11	95.21	1877
MO HOWARD	11436	1221	39.14	92.68	2083
MO HOWELL	22431	2382	36.77	91.89	2139
MO IRON	8856	1434	37.55	90.78	2239
MO JACKSON	575755	1562	39.01	94.35	1934
MO JASPER	79002	1662	37.22	94.35	1921

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MO JEFFERSON	50062	1729	38.26	90.54	2263
MO JOHNSON	24229	2139	38.74	93.81	1979
MO KNOX	7171	1325	40.13	92.13	2146
MO LACLEDE	19003	1994	37.66	92.59	2079
MO LAFAYETTE	25276	1636	39.07	93.79	1984
MO LAWRENCE	23354	1603	37.12	93.84	1966
MO LEWIS	10838	1316	40.10	91.71	2183
MO LINCOLN	14037	1618	39.05	90.97	2233
MO LINN	17999	1610	39.87	93.10	2057
MO LIVINGSTON	16206	1372	39.79	93.55	2016
MO MCDONALD	13145	1399	36.64	94.36	1921
MO MACON	17540	2066	39.83	92.55	2105
MO MADISON	9948	1285	37.47	90.35	2277
MO MARIES	7363	1359	38.16	91.92	2141
MO MARION	29663	1134	39.80	91.61	2186
MO MERCER	6605	1178	40.44	93.57	2027
MO MILLER	13763	1553	38.21	92.42	2097
MO MISSISSIPPI	21765	1075	36.83	89.27	2372
MO MONITEAU	10697	1085	38.63	92.58	2086
MO MONROE	11046	1732	39.49	91.98	2149
MO MONTGOMERY	11365	1383	38.93	91.46	2188
MO MORGAN	9895	1532	38.42	92.88	2057
MO NEW MADRID	36006	1759	36.60	89.64	2339
MO NEWTON	29033	1628	36.92	94.35	1921
MO NODAWAY	23265	2270	40.38	94.89	1911
MO OREGON	11075	2031	36.69	91.42	2182
MO OSAGE	11120	1575	38.46	91.86	2149
MO OZARK	7959	1895	36.65	92.44	2091
MO PEMISCOT	42425	1276	36.21	89.79	2327
MO PERRY	14791	1220	37.70	89.83	2323
MO PETTIS	33081	1759	38.73	93.28	2025
MO PHELPS	23162	1752	37.88	91.79	2150
MO PIKE	16786	1763	39.34	91.17	2219
MO PLATTE	18533	1106	39.39	94.77	1902
MO POLK	15083	1649	37.62	93.41	2006
MO PULASKI	25766	1427	37.82	92.20	2114
MO PUTNAM	8249	1341	40.49	93.01	2077
MO RALLS	8429	1238	39.52	91.51	2191
MO RANDOLPH	22538	1224	39.44	92.48	2105
MO RAY	15993	1483	39.36	93.99	1970
MO REYNOLDS	6169	2115	37.35	90.98	2221
MO RIPLEY	10428	1655	36.65	90.87	2230
MO ST CHARLES	39668	1427	38.77	90.71	2252

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
MO ST CLAIR	9611	1804	38.78	90.67	2256
MO ST FRANCOIS	35800	1183	37.81	90.47	2267
MO ST LOUIS	1343947	1449	38.64	90.45	2274
MO STE GENEVIEV	11614	1292	37.89	90.19	2292
MO SALINE	26040	1960	39.14	93.20	2037
MO SCHUYLER	5459	792	40.48	92.51	2120
MO SCOTLAND	6972	1141	40.46	92.13	2152
MO SCOTT	32801	1089	37.05	89.57	2346
MO SHANNON	7829	2586	37.15	91.41	2182
MO SHELBY	9448	1297	39.79	92.06	2147
MO STODDARD	31776	2132	36.86	89.95	2312
MO STONE	9081	1162	36.75	93.47	1999
MO SULLIVAN	10232	1693	40.21	93.10	2063
MO TANEY	10024	1593	36.66	93.05	2037
MO TEXAS	18468	3064	37.31	91.97	2133
MO VERNON	21779	2170	37.85	94.35	1923
MO WARREN	8127	1103	38.76	91.15	2214
MO WASHINGTON	14543	1967	37.96	90.88	2232
MO WAYNE	9717	1983	37.11	90.47	2265
MO WEBSTER	14514	1528	37.28	92.88	2052
MO WORTH	4616	692	40.50	94.43	1954
MO WRIGHT	15132	1772	37.28	92.27	2106
MT BEAVERHEAD	6891	14376	45.13	112.89	945
MT BIG HORN	9904	13009	45.42	107.49	1203
MT BLAINE	8334	11071	48.43	108.96	1415
MT BROADWATER	2875	3089	46.33	111.49	1111
MT CARBON	9421	5350	45.22	109.04	1103
MT CARTER	2671	8580	45.52	104.53	1390
MT CASCADE	61695	6891	47.30	111.34	1217
MT CHOUTEAU	7135	10170	47.88	110.43	1306
MT CUSTER	12899	9727	46.26	105.55	1385
MT DANIELS	3862	3736	48.78	105.54	1605
MT DAWSON	10460	6137	47.27	104.89	1508
MT DEER LODGE	17438	1917	46.05	113.06	1039
MT FALLON	3803	4228	46.34	104.41	1461
MT FERGUS	14018	10986	47.26	109.22	1289
MT FLATHEAD	32123	13304	48.28	114.04	1266
MT GALLATIN	23661	6518	45.56	111.18	1043
MT GARFIELD	2091	11537	47.28	106.99	1395
MT GLACIER	10462	7676	48.69	112.99	1327
MT GOLDEN VALLE	1282	3045	46.38	109.18	1205
MT GRANITE	2877	4487	46.39	113.43	1068
MT HILL	16144	7580	48.62	110.11	1393

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
MT JEFFERSON	4133	4278	46.15	112.09	1074
MT JUDITH BASIN	3148	4868	47.03	110.26	1226
MT LAKE	13525	3869	47.64	114.07	1195
MT LEWIS AND CL	26013	9002	47.11	112.38	1169
MT LIBERTY	2373	3726	48.55	111.03	1357
MT LINCOLN	10327	9618	48.53	115.39	1283
MT MCCONE	3282	6751	47.65	105.79	1491
MT MADISON	5666	9137	45.30	111.92	991
MT MEAGHER	2300	6096	46.59	110.89	1159
MT MINERAL	2486	3164	47.14	115.00	1130
MT MISSOULA	39388	6764	47.03	113.92	1129
MT MUSSELSHELL	5188	4886	46.49	108.39	1252
MT PARK	12550	7497	45.51	110.52	1064
MT PETROLEUM	970	4285	47.12	108.25	1318
MT PHILLIPS	6200	13501	48.26	107.92	1442
MT PONDERA	6930	4260	48.22	112.22	1291
MT POWDER RIVER	2598	8515	45.40	105.61	1312
MT POWELL	6597	6049	46.85	112.93	1128
MT PRAIRIE	2347	4480	46.86	105.36	1447
MT RAVALLI	12779	6168	46.08	114.12	1023
MT RICHLAND	10426	5384	47.79	104.56	1571
MT ROOSEVELT	10497	6176	48.30	105.00	1590
MT ROSEBUD	6404	13045	46.23	106.71	1316
MT SANDERS	6942	7194	47.67	115.13	1188
MT SHERIDAN	6585	4386	48.72	104.50	1655
MT SILVER BOW	47589	1852	45.89	112.65	1032
MT STILLWATER	5466	4645	45.67	109.40	1127
MT SWEET GRASS	3478	4765	45.81	109.94	1117
MT TETON	7260	5940	47.83	112.22	1249
MT TOOLE	7310	5049	48.65	111.69	1350
MT TREASURE	1379	2550	46.21	107.26	1284
MT VALLEY	13790	12882	48.37	106.66	1511
MT WHEATLAND	3119	3677	46.46	109.85	1184
MT WIBAUX	1820	2305	46.96	104.24	1521
MT YELLOWSTONE	65710	6842	45.94	108.27	1207
NE ADAMS	28895	1455	40.52	98.51	1600
NE ANTELOPE	11012	2208	42.16	98.07	1691
NE ARTHUR	751	1822	41.57	101.69	1367
NE BANNER	1304	1911	41.55	103.71	1202
NE BLAINE	1123	1838	41.92	99.98	1523
NE BOONE	10045	1769	41.70	98.07	1674
NE BOX BUTTE	12026	2757	42.22	103.08	1285
NE BOYD	4739	1393	42.90	98.76	1664

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
NE BROWN	4855	3148	42.43	99.93	1548
NE BUFFALO	25600	2457	40.85	99.08	1561
NE BURT	10964	1251	41.84	96.33	1826
NE BUTLER	10958	1507	41.22	97.13	1739
NE CASS	16983	1437	40.90	96.14	1815
NE CEDAR	13641	1921	42.59	97.25	1776
NE CHASE	4812	2305	40.52	101.70	1328
NE CHERRY	8320	15451	42.54	101.12	1457
NE CHEYENNE	13248	3071	41.22	102.99	1246
NE CLAY	8706	1476	40.52	98.07	1639
NE COLFAX	9832	1051	41.57	97.09	1753
NE CUMING	12757	1479	41.90	96.79	1790
NE CUSTER	18048	6624	41.39	99.74	1524
NE DAKOTA	11152	660	42.38	96.56	1826
NE DAWES	9636	3589	42.72	103.13	1307
NE DAWSON	19402	2525	40.87	99.82	1498
NE DEUEL	3246	1128	41.11	102.33	1296
NE DIXON	8695	1230	42.48	96.86	1804
NE DODGE	28907	1368	41.57	96.65	1791
NE DOUGLAS	307573	868	41.28	96.14	1825
NE DUNDY	4021	2384	40.18	101.69	1318
NE FILLMORE	9532	1493	40.52	97.61	1678
NE FRANKLIN	6400	1497	40.17	98.95	1553
NE FRONTIER	4871	2491	40.53	100.39	1439
NE FURNAS	8673	1869	40.18	99.91	1471
NE GAGE	27529	2222	40.26	96.69	1752
NE GARDEN	3840	4346	41.62	102.33	1317
NE GARFIELD	2826	1473	41.91	98.99	1605
NE GOSPER	2631	1202	40.51	99.84	1487
NE GRANT	1037	1978	41.91	101.74	1378
NE GREELEY	5163	1476	41.56	98.53	1631
NE HALL	33708	1390	40.87	98.51	1610
NE HAMILTON	8749	1390	40.87	98.03	1651
NE HARLAN	6294	1439	40.17	99.40	1514
NE HAYES	2195	1841	40.53	101.06	1383
NE HITCHCOCK	5423	1843	40.18	101.04	1374
NE HOLT	14374	6228	42.45	98.79	1643
NE HOOKER	1090	1869	41.92	101.13	1428
NE HOWARD	6936	1461	41.22	98.53	1620
NE JEFFERSON	12774	1493	40.17	97.14	1710
NE JOHNSON	6836	975	40.38	96.28	1790
NE KEARNEY	6483	1325	40.50	98.96	1562
NE KEITH	7670	2672	41.20	101.67	1355

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NE KEYA PAHA	1952	1988	42.88	99.72	1586
NE KIMBALL	5848	2467	41.20	103.71	1186
NE KNOX	14172	2867	42.63	97.89	1724
NE LANCASTER	134839	2188	40.77	96.69	1764
NE LINCOLN	27852	6531	41.05	100.75	1426
NE LOGAN	1253	1476	41.57	100.48	1468
NE LOUP	1242	1486	41.91	99.46	1566
NE MCPHERSON	790	2216	41.57	101.06	1420
NE MADISON	24681	1480	41.90	97.60	1721
NE MERRICK	8622	1242	41.16	98.05	1658
NE MORRILL	7751	3631	41.72	103.00	1267
NE NANCE	6141	1137	41.39	97.99	1671
NE NEMAHA	10178	1036	40.39	95.85	1827
NE NUCKOLLS	9023	1500	40.17	98.06	1631
NE OTOE	16823	1603	40.64	96.14	1809
NE PAWNEE	6154	1120	40.13	96.24	1787
NE PERKINS	4547	2291	40.85	101.66	1343
NE PHELPS	9367	1408	40.51	99.42	1522
NE PIERCE	9117	1483	42.25	97.60	1734
NE PLATTE	21643	1728	41.56	97.53	1716
NE POLK	7693	1119	41.18	97.57	1700
NE RED WILLOW	12962	1776	40.18	100.47	1422
NE RICHARDSON	15620	1424	40.13	95.72	1833
NE ROCK	2824	2612	42.42	99.45	1587
NE SALINE	13405	1489	40.51	97.14	1718
NE SARPY	22318	619	41.10	96.11	1823
NE SAUNDERS	17070	1966	41.22	96.63	1781
NE SCOTTS BLUFF	33886	1880	41.85	103.70	1217
NE SEWARD	13339	1479	40.86	97.14	1728
NE SHERIDAN	9327	6376	42.51	102.40	1353
NE SHERMAN	5981	1469	41.22	98.98	1581
NE SIOUX	2888	5342	42.49	103.76	1245
NE STANTON	6133	1116	41.90	97.19	1755
NE THAYER	9951	1493	40.17	97.60	1671
NE THOMAS	1155	1853	41.92	100.55	1476
NE THURSTON	8017	1005	42.15	96.54	1819
NE VALLEY	6973	1473	41.56	98.99	1593
NE WASHINGTON	11762	999	41.52	96.22	1826
NE WAYNE	10059	1147	42.19	97.11	1772
NE WEBSTER	6899	1489	40.17	98.51	1592
NE WHEELER	1428	1491	41.91	98.53	1644
NE YORK	14084	1493	40.87	97.61	1688
NV CHURCHILL	7135	12646	39.58	118.35	355

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NV CLARK1	2593	4079	36.59	114.49	142
NV CLARK2	74220	12236	36.16	115.17	119
NV CLARK3	4933	4079	35.46	114.92	196
NV DOUGLAS	2647	1821	38.90	119.61	384
NV ELKO	11811	44449	41.16	115.36	465
NV ESMERALDA1	267	5548	38.01	117.88	201
NV ESMERALDA2	347	3698	37.70	117.23	134
NV EUREKA	840	10830	39.96	116.24	329
NV HUMBOLDT	5209	25127	41.42	118.11	525
NV LANDER1	406	7278	40.60	116.85	407
NV LANDER2	1325	7278	39.49	117.08	293
NV LINCOLN1	2887	16550	37.60	114.52	147
NV LINCOLN2	355	11030	37.35	115.17	83
NV LYON	4728	5257	39.02	119.19	361
NV MINERAL	5885	9750	38.53	118.44	275
NV NYE1	816	14036	38.70	117.07	211
NV NYE2	2065	18714	38.05	117.23	160
NV NYE3	760	14036	36.20	115.99	89
NV PERSHING	3141	15542	40.46	118.41	440
NV STOREY	626	678	39.44	119.53	415
NV WASHOE	64879	16487	40.66	119.67	521
NV WHITE PINE1	8936	13559	39.24	114.90	267
NV WHITE PINE2	296	2259	38.85	115.01	224
NV WHITE PINE3	358	6779	39.01	114.13	278
NV CARSON CITY	5824	388	39.15	119.74	409
NH BELKNAP	27605	1036	43.52	71.42	4021
NH CARROLL	15849	2429	43.88	71.20	4048
NH CHESHIRE	40739	1852	42.92	72.25	3937
NH COOS	36442	4713	44.71	71.31	4057
NH GRAFTON	48321	4485	43.94	71.82	3996
NH HILLSBOROUGH	165985	2297	42.92	71.71	3984
NH MERRIMACK	65046	2408	43.30	71.68	3995
NH ROCKINGHAM	82375	1790	42.99	71.12	4037
NH STRAFFORD	55068	974	43.30	71.03	4051
NH SULLIVAN	27132	1396	43.36	72.22	3948
NJ ATLANTIC	144503	1473	39.48	74.68	3677
NJ BERGEN	641614	606	40.96	74.07	3746
NJ BURLINGTON	173558	2121	39.88	74.66	3682
NJ CAMDEN	339544	571	39.80	74.95	3656
NJ CAPE MAY	41983	692	39.15	74.81	3663
NJ CUMBERLAND	96357	1294	39.37	75.11	3638
NJ ESSEX	913427	336	40.79	74.25	3729
NJ GLOUCESTER	110048	851	39.72	75.14	3638

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NJ HUDSON	631840	122	40.74	74.09	3742
NJ HUNTERDON	47570	1096	40.57	74.91	3667
NJ MERCER	245338	591	40.29	74.70	3683
NJ MIDDLESEX	336692	808	40.45	74.42	3710
NJ MONMOUTH	271681	1233	40.26	74.21	3726
NJ MORRIS	205703	1211	40.86	74.56	3702
NJ OCEAN	78560	1662	39.92	74.28	3716
NJ PASSAIC	366643	496	41.04	74.30	3727
NJ SALEM	53419	944	39.59	75.34	3619
NJ SOMERSET	118117	795	40.57	74.62	3693
NJ SUSSEX	40724	1365	41.14	74.70	3694
NJ UNION	443241	267	40.67	74.32	3721
NJ WARREN	58136	937	40.86	75.00	3663
NM BERNALILLO	195195	3027	35.05	106.68	855
NM CATRON	3212	17862	33.91	108.41	756
NM CHAVES	47845	15757	33.36	104.47	1101
NM COLFAX	15503	9748	36.60	104.65	1008
NM CURRY	27320	3634	34.58	103.35	1154
NM DE BACA	3264	6101	34.34	104.42	1070
NM DONA ANA	48225	9851	32.35	106.84	963
NM EDDY	44953	10792	32.47	104.30	1154
NM GRANT	20394	10281	32.74	108.39	825
NM GUADALUPE	6277	7764	34.86	104.79	1023
NM HARDING	2531	5526	35.85	103.81	1089
NM HIDALGO	5038	8927	31.93	108.73	857
NM LEA	40370	11377	32.78	103.41	1211
NM LINCOLN	7552	12581	33.75	105.49	1000
NM LOS ALAMOS	11565	280	35.85	106.32	868
NM LUNA	9212	7658	32.18	107.76	906
NM MCKINLEY	31598	14125	35.58	108.27	704
NM MORA	7579	5024	36.00	104.95	987
NM OTERO	24288	17191	32.60	105.75	1033
NM QUAY	13251	7445	35.10	103.54	1125
NM RIO ARRIBA	24658	15132	36.50	106.71	826
NM ROOSEVELT	16319	6355	34.02	103.48	1159
NM SANDOVAL	13190	9618	35.68	106.87	823
NM SAN JUAN	33173	14244	36.51	108.33	683
NM SAN MIGUEL	25222	12278	35.47	104.81	1007
NM SANTA FE	41052	4926	35.50	105.98	905
NM SIERRA	6854	10789	33.13	107.20	891
NM SOCORRO	9884	17101	34.01	106.93	871
NM TAOS	16634	5842	36.57	105.64	920
NM TORRANCE	7367	8665	34.63	105.85	939

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NM UNION	6819	9882	36.48	103.47	1113
NM VALENCIA	29536	14648	34.87	107.78	767
NY ALBANY	253645	1362	42.60	73.97	3781
NY ALLEGANY	43864	2712	42.26	78.03	3419
NY BRONX	1440030	105	40.87	73.86	3764
NY BROOME	196583	1849	42.16	75.82	3612
NY CATTARAUGUS	78878	3413	42.25	78.68	3362
NY CAYUGA	71753	1807	42.92	76.55	3562
NY CHAUTAUQUA	139521	2799	42.23	79.37	3302
NY CHEMUNG	91873	1075	42.14	76.76	3528
NY CHENANGO	40882	2339	42.50	75.61	3636
NY CLINTON	61742	2743	44.75	73.69	3852
NY COLUMBIA	44941	1670	42.25	73.64	3804
NY CORTLAND	38839	1300	42.60	76.07	3598
NY DELAWARE	44048	3736	42.20	74.97	3686
NY DUTCHESS	153453	2105	41.77	73.75	3786
NY ERIE	969556	2740	42.76	78.74	3368
NY ESSEX	35172	4721	44.12	73.78	3829
NY FRANKLIN	44792	4335	44.59	74.31	3795
NY FULTON	51140	1289	43.11	74.43	3751
NY GENESEE	50312	1297	43.00	78.20	3420
NY GREENE	29865	1690	42.28	74.13	3761
NY HAMILTON	4172	4493	43.66	74.50	3756
NY HERKIMER	63523	3717	43.41	74.97	3710
NY JEFFERSON	86505	3351	44.03	75.92	3642
NY KINGS	2691063	181	40.64	73.96	3753
NY LEWIS	22830	3344	43.78	75.45	3676
NY LIVINGSTON	41872	1652	42.72	77.78	3450
NY MADISON	49795	1711	42.92	75.67	3638
NY MONROE	529604	1748	43.14	77.70	3466
NY MONTGOMERY	58598	1057	42.90	74.46	3744
NY NASSAU	939411	748	40.75	73.58	3787
NY NEW YORK	1848830	60	40.77	73.97	3753
NY NIAGARA	212214	1377	43.20	78.74	3378
NY ONEIDA	240513	3168	43.24	75.45	3665
NY ONONDAGA	376277	2056	43.01	76.19	3595
NY ONTARIO	63531	1686	42.85	77.30	3495
NY ORANGE	165637	2156	41.40	74.31	3732
NY ORLEANS	31671	1026	43.25	78.24	3422
NY OSWEGO	80974	2496	43.43	76.15	3608
NY OTSEGO	51263	2623	42.63	75.04	3688
NY PUTNAM	25163	598	41.43	73.75	3781
NY QUEENS	1660811	280	40.69	73.81	3766

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NY RENSSELAER	136849	1721	42.71	73.51	3823
NY RICHMOND	204492	150	40.58	74.17	3733
NY ROCKLAND	109476	456	41.15	74.03	3753
NY ST LAWRENCE	104146	7168	44.50	75.07	3726
NY SARATOGA	80914	2118	43.11	73.87	3800
NY SCHENECTADY	146919	536	42.83	74.07	3777
NY SCHOHARIE	22663	1615	42.59	74.44	3740
NY SCHUYLER	14546	854	42.40	76.88	3523
NY SENECA	30411	854	42.77	76.83	3534
NY STEUBEN	94099	3651	42.27	77.39	3476
NY SUFFOLK	442158	2405	40.87	72.85	3853
NY SULLIVAN	42658	2537	41.72	74.78	3695
NY TIOGA	33413	1356	42.17	76.31	3569
NY TOMPKINS	62119	1248	42.46	76.47	3560
NY ULSTER	103752	2954	41.89	74.26	3743
NY WARREN	41242	2297	43.56	73.86	3810
NY WASHINGTON	47709	2164	43.32	73.44	3841
NY WAYNE	61856	1569	43.16	77.04	3525
NY WESTCHESTER	703626	1147	41.17	73.76	3777
NY WYOMING	33657	1548	42.70	78.23	3411
NY YATES	18037	888	42.63	77.12	3506
NC ALAMANCE	77369	1109	36.04	79.40	3249
NC ALEXANDER	15010	671	35.94	81.18	3092
NC ALLEGHANY	7979	582	36.50	81.14	3094
NC ANSON	26010	1379	34.98	80.10	3193
NC ASHE	20977	1103	36.44	81.51	3061
NC AVERY	12783	634	36.09	81.93	3025
NC BEAUFORT	36657	2139	35.50	76.87	3476
NC BERTIE	25557	1807	36.07	76.99	3464
NC BLADEN	29349	2287	34.62	78.55	3334
NC BRUNSWICK	19684	2216	34.08	78.24	3366
NC BUNCOMBE	126811	1701	35.62	82.54	2973
NC BURKE	48576	1323	35.76	81.71	3045
NC CABARRUS	65635	940	35.39	80.56	3150
NC CALDWELL	45992	1214	35.96	81.56	3059
NC CAMDEN	5384	619	36.40	76.22	3530
NC CARTERET	26404	1387	34.84	76.68	3497
NC CASWELL	20460	1109	36.39	79.32	3255
NC CATAWBA	66636	1020	35.67	81.21	3091
NC CHATHAM	25982	1835	35.70	79.24	3265
NC CHEROKEE	17461	1171	35.13	84.07	2841
NC CHOWAN	12197	447	36.15	76.60	3498
NC CLAY	5802	540	35.06	83.75	2870

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
NC CLEVELAND	65075	1211	35.34	81.56	3062
NC COLUMBUS	49922	2447	34.27	78.64	3329
NC CRAVEN	53051	1810	35.13	77.10	3458
NC CUMBERLAND	118286	1693	35.05	78.83	3305
NC CURRITUCK	6367	637	36.32	75.94	3556
NC DARE	5631	1013	35.76	75.85	3565
NC DAVIDSON	69576	1421	35.79	80.21	3179
NC DAVIE	15977	685	35.93	80.54	3149
NC DUPLIN	40732	2111	34.94	77.93	3386
NC DURHAM	106041	764	36.03	78.88	3295
NC EDGECOMBE	52739	1320	35.91	77.60	3410
NC FORSYTH	164530	1085	36.13	80.26	3173
NC FRANKLIN	30242	1272	36.08	78.28	3349
NC GASTON	117736	922	35.31	81.18	3096
NC GATES	9423	872	36.44	76.70	3488
NC GRAHAM	6695	755	35.35	83.84	2860
NC GRANVILLE	32355	1390	36.30	78.65	3315
NC GREENE	17475	692	35.48	77.68	3404
NC GUILFORD	214630	1696	36.07	79.79	3215
NC HALIFAX	58623	1901	36.25	77.64	3405
NC HARNETT	47871	1562	35.37	78.87	3300
NC HAYWOOD	38518	1427	35.56	82.99	2934
NC HENDERSON	33149	979	35.34	82.49	2979
NC HERTFORD	21988	913	36.36	76.99	3462
NC HOKE	16015	1007	34.99	79.24	3270
NC HYDE	6180	1587	35.54	76.24	3532
NC IREDELL	58947	1480	35.81	80.87	3120
NC JACKSON	18637	1272	35.28	83.14	2922
NC JOHNSTON	64643	2063	35.52	78.37	3343
NC JONES	11008	1210	35.03	77.38	3434
NC LEE	24819	663	35.47	79.18	3272
NC LENOIR	49915	1036	35.26	77.65	3409
NC LINCOLN	28039	768	35.50	81.25	3088
NC MCDOWELL	26156	1128	35.68	82.06	3015
NC MACON	15646	1328	35.15	83.42	2898
NC MADISON	19116	1165	35.86	82.71	2957
NC MARTIN	27599	1178	35.84	77.10	3454
NC MECKLENBURG	228952	1372	35.25	80.84	3126
NC MITCHELL	14615	557	36.01	82.17	3004
NC MONTGOMERY	17749	1264	35.34	79.90	3209
NC MOORE	34663	1822	35.30	79.45	3249
NC NASH	60382	1408	35.96	77.98	3376
NC NEW HANOVER	66873	478	34.24	77.89	3396

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
NC NORTHAMPTON	27743	1387	36.42	77.40	3426
NC ONSLOW	59332	1980	34.74	77.43	3431
NC ORANGE	38060	1036	36.06	79.13	3274
NC PAMLICO	9933	875	35.15	76.73	3491
NC PASQUOTANK	24894	591	36.30	76.29	3525
NC PENDER	18460	2256	34.53	77.91	3391
NC PERQUIMANS	9420	637	36.21	76.44	3512
NC PERSON	25231	1038	36.38	78.97	3287
NC PITT	66405	1696	35.60	77.38	3431
NC POLK	11531	619	35.29	82.18	3007
NC RANDOLPH	55349	2066	35.71	79.80	3216
NC RICHMOND	39428	1230	35.00	79.74	3226
NC ROBESON	88337	2457	34.63	79.08	3286
NC ROCKINGHAM	66867	1473	36.40	79.77	3216
NC ROWAN	78560	1355	35.64	80.53	3151
NC RUTHERFORD	45816	1458	35.41	81.93	3029
NC SAMPSON	49029	2447	34.99	78.37	3347
NC SCOTLAND	25848	826	34.83	79.46	3251
NC STANLY	38717	1030	35.31	80.26	3177
NC STOKES	21861	1183	36.40	80.24	3174
NC SURRY	46705	1387	36.42	80.69	3134
NC SWAIN	9266	1356	35.49	83.50	2889
NC TRANSYLVANIA	15698	989	35.20	82.80	2952
NC TYRRELL	4826	1010	35.81	76.21	3533
NC UNION	43158	1655	34.99	80.54	3155
NC VANCE	32060	644	36.36	78.40	3337
NC WAKE	150322	2222	35.79	78.65	3317
NC WARREN	21890	1097	36.39	78.10	3364
NC WASHINGTON	13311	888	35.82	76.58	3501
NC WATAUGA	17998	820	36.23	81.70	3045
NC WAYNE	71829	1442	35.37	78.01	3376
NC WILKES	45256	1960	36.22	81.18	3091
NC WILSON	55872	971	35.70	77.92	3382
NC YADKIN	22423	869	36.16	80.66	3137
NC YANCEY	15330	808	35.90	82.31	2992
ND ADAMS	4715	2561	46.10	102.52	1566
ND BARNES	16810	3831	46.93	98.07	1937
ND BENSON	10148	3634	48.07	99.37	1921
ND BILLINGS	1663	2950	47.03	103.37	1580
ND BOTTINEAU	11792	4342	48.79	100.83	1879
ND BOWMAN	4064	3030	46.11	103.51	1501
ND BURKE	6309	2897	48.79	102.51	1775
ND BURLEIGH	29218	4208	46.98	100.46	1769

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
ND CASS	62309	4529	46.93	97.24	1997
ND CAVALIER	11087	3915	48.77	98.45	2034
ND DICKEY	8707	2959	46.11	98.50	1854
ND DIVIDE	5793	3366	48.82	103.49	1720
ND DUNN	6849	5158	47.35	102.61	1654
ND EDDY	5188	1645	47.72	98.90	1929
ND EMMONS	9184	3892	46.28	100.23	1739
ND FOSTER	5351	1670	47.46	98.88	1912
ND GOLDEN VALLE	3333	2626	46.94	103.85	1544
ND GRAND FORKS	43368	3724	47.92	97.45	2045
ND GRANT	6744	4314	46.36	101.64	1645
ND GRIGGS	5275	1838	47.46	98.23	1959
ND HETTINGER	6767	2937	46.43	102.45	1595
ND KIDDER	5838	3517	46.98	99.78	1817
ND LA MOURE	9160	2941	46.46	98.53	1873
ND LOGAN	5936	2592	46.46	99.47	1804
ND MCHENRY	11933	4866	48.24	100.63	1849
ND MCINTOSH	7212	2568	46.11	99.43	1785
ND MCKENZIE	7038	7083	47.74	103.39	1636
ND MCLEAN	16785	5347	47.61	101.31	1757
ND MERCER	7891	2698	47.31	101.83	1701
ND MORTON	20016	4972	46.72	101.28	1695
ND MOUNTRAIL	9699	4710	48.20	102.35	1737
ND NELSON	7643	2577	47.92	98.19	1993
ND OLIVER	2889	1866	47.12	101.33	1720
ND PEMBINA	13547	2910	48.77	97.54	2096
ND PIERCE	7932	2688	48.25	99.97	1894
ND RAMSEY	13978	3231	48.27	98.72	1979
ND RANSOM	8539	2229	46.45	97.65	1938
ND RENVILLE	5106	2294	48.72	101.66	1821
ND RICHLAND	19423	3752	46.27	96.94	1980
ND ROLETTE	10906	2364	48.78	99.84	1941
ND SARGENT	7296	2208	46.11	97.62	1919
ND SHERIDAN	4867	2561	47.58	100.34	1820
ND SIOUX	3683	2857	46.11	101.03	1670
ND SLOPE	2137	3172	46.45	103.45	1530
ND STARK	17122	3407	46.81	102.65	1609
ND STEELE	4963	1838	47.45	97.71	1995
ND STUTSMAN	24575	5863	46.98	98.96	1875
ND TOWNER	6045	2700	48.69	99.25	1974
ND TRAILL	11027	2229	47.45	97.15	2036
ND WALSH	18493	3330	48.37	97.72	2056
ND WARD	40005	5293	48.22	101.54	1789

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
ND WELLS	9915	3363	47.59	99.66	1867
ND WILLIAMS	18823	5345	48.34	103.48	1680
OH ADAMS	20282	1520	38.86	83.46	2895
OH ALLEN	94777	1061	40.78	84.11	2861
OH ASHLAND	35474	1097	40.86	82.27	3024
OH ASHTABULA	84806	1812	41.71	80.76	3171
OH ATHENS	46332	1304	39.35	82.04	3025
OH AUGLAIZE	32976	1036	40.56	84.22	2847
OH BELMONT	86091	1383	40.03	80.99	3125
OH BROWN	23479	1269	38.94	83.87	2860
OH BUTLER	169255	1220	39.45	84.58	2802
OH CARROLL	19815	1010	40.60	81.08	3124
OH CHAMPAIGN	28032	1119	40.15	83.77	2881
OH CLARK	120066	1041	39.92	83.79	2877
OH CLERMONT	58480	1186	39.06	84.15	2835
OH CLINTON	27455	1061	39.42	83.81	2869
OH COLUMBIANA	102354	1383	40.78	80.77	3154
OH COSHOCTON	31602	1455	40.32	81.92	3047
OH CRAWFORD	42155	1045	40.86	82.92	2967
OH CUYAHOGA	1499339	1180	41.44	81.65	3087
OH DARKE	43422	1566	40.14	84.63	2806
OH DEFIANCE	28295	1066	41.33	84.50	2837
OH DELAWARE	32753	1165	40.29	82.99	2952
OH ERIE	59130	684	41.38	82.63	3001
OH FAIRFIELD	57137	1307	39.76	82.62	2978
OH FAYETTE	23501	1045	39.56	83.45	2902
OH FRANKLIN	579723	1393	39.98	83.00	2947
OH FULTON	27165	1054	41.61	84.13	2874
OH GALLIA	25425	1220	38.84	82.32	2996
OH GEAUGA	35540	1054	41.52	81.18	3130
OH GREENE	74085	1075	39.70	83.89	2865
OH GUERNSEY	38506	1368	40.07	81.49	3081
OH HAMILTON	783525	1072	39.20	84.55	2802
OH HANCOCK	48279	1377	41.01	83.67	2903
OH HARDIN	29081	1210	40.67	83.66	2899
OH HARRISON	18608	1038	40.31	81.08	3120
OH HENRY	23680	1076	41.34	84.07	2874
OH HIGHLAND	28838	1421	39.19	83.61	2885
OH HOCKING	19794	1089	39.51	82.47	2988
OH HOLMES	19961	1097	40.58	81.93	3050
OH HURON	42742	1286	41.16	82.60	3000
OH JACKSON	28448	1085	39.03	82.61	2971
OH JEFFERSON	97645	1064	40.40	80.76	3150

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
OH KNOX	36786	1375	40.42	82.42	3004
OH LAKE	106890	598	41.71	81.24	3129
OH LAWRENCE	51799	1180	38.62	82.54	2975
OH LICKING	78976	1776	40.10	82.48	2994
OH LOGAN	32804	1190	40.40	83.76	2885
OH LORAIN	177629	1282	41.30	82.15	3041
OH LUCAS	421637	888	41.63	83.66	2916
OH MADISON	24067	1199	39.90	83.40	2911
OH MAHONING	275841	1075	41.03	80.77	3158
OH MARION	54320	1048	40.60	83.16	2941
OH MEDINA	51004	1100	41.13	81.89	3061
OH MEIGS	22771	1128	39.10	82.03	3024
OH MERCER	30118	1150	40.54	84.64	2811
OH MIAMI	66236	1054	40.06	84.23	2840
OH MONROE	15324	1180	39.74	81.08	3114
OH MONTGOMERY	453116	1189	39.76	84.30	2830
OH MORGAN	12799	1088	39.63	81.85	3044
OH MORROW	18121	1044	40.54	82.79	2973
OH MUSKINGUM	76503	1686	39.98	81.95	3040
OH NOBLE	11426	1030	39.78	81.45	3081
OH OTTAWA	31960	675	41.55	83.14	2959
OH PAULDING	15790	1079	41.12	84.58	2825
OH PERRY	28518	1061	39.75	82.24	3012
OH PICKAWAY	32120	1304	39.65	83.02	2942
OH PIKE	16635	1147	39.09	83.06	2932
OH PORTAGE	75790	1282	41.18	81.20	3123
OH PREBLE	29384	1106	39.75	84.65	2798
OH PUTNAM	26557	1258	41.03	84.14	2863
OH RICHLAND	102551	1285	40.79	82.54	2999
OH ROSS	57312	1779	39.35	83.05	2936
OH SANDUSKY	50523	1058	41.37	83.15	2955
OH SCIOTO	83468	1575	38.82	82.98	2937
OH SENECA	55674	1427	41.13	83.13	2953
OH SHELBY	30655	1057	40.34	84.21	2846
OH STARK	307483	1491	40.83	81.36	3103
OH SUMMIT	454038	1057	41.14	81.53	3093
OH TRUMBULL	180002	1575	41.32	80.76	3164
OH TUSCARAWAS	73068	1473	40.46	81.47	3088
OH UNION	21611	1124	40.31	83.37	2919
OH VAN WERT	27766	1058	40.86	84.59	2820
OH VINTON	10553	1064	39.26	82.48	2985
OH WARREN	50068	1057	39.43	84.17	2838
OH WASHINGTON	47500	1659	39.47	81.49	3075

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OH WAYNE	65848	1452	40.85	81.89	3057
OH WILLIAMS	27800	1089	41.57	84.58	2834
OH WOOD	65127	1603	41.37	83.63	2913
OH WYANDOT	20578	1051	40.85	83.30	2933
OK ADAIR	14152	1476	35.91	94.66	1897
OK ALFALFA	9744	2247	36.73	98.32	1569
OK ATOKA	12599	2567	34.38	96.04	1795
OK BEAVER	7223	4636	36.74	100.47	1378
OK BECKHAM	19988	2349	35.27	99.69	1460
OK BLAINE	13790	2374	35.87	98.43	1565
OK BRYAN	26978	2302	33.97	96.25	1784
OK CADDO	32240	3293	35.18	98.37	1577
OK CANADIAN	25257	2322	35.54	97.97	1608
OK CARTER	37559	2149	34.25	97.27	1690
OK CHEROKEE	18470	1957	35.94	95.01	1866
OK CHOCTAW	18382	2015	34.05	95.55	1844
OK CIMARRON	4555	4772	36.74	102.51	1197
OK CLEVELAND	44057	1365	35.20	97.33	1669
OK COAL	6993	1362	34.60	96.29	1770
OK COMANCHE	70308	2807	34.67	98.47	1577
OK COTTON	9267	1686	34.29	98.37	1593
OK CRAIG	17433	1978	36.78	95.22	1844
OK CREEK	42019	2423	35.90	96.36	1747
OK CUSTER	21068	2537	35.64	99.00	1517
OK DELAWARE	14079	1831	36.43	94.81	1881
OK DEWEY	7626	2636	35.99	99.00	1512
OK ELLIS	6531	3216	36.21	99.75	1444
OK GARFIELD	52888	2729	36.37	97.78	1618
OK GARVIN	28984	2108	34.71	97.30	1679
OK GRADY	32628	2838	35.02	97.88	1623
OK GRANT	9479	2608	36.79	97.79	1617
OK GREER	10530	1638	34.94	99.56	1477
OK HARMON	7132	1411	34.75	99.85	1455
OK HARPER	5963	2695	36.78	99.67	1449
OK HASKELL	11531	1559	35.26	95.12	1863
OK HUGHES	18320	2090	35.05	96.24	1767
OK JACKSON	24186	2097	34.59	99.42	1496
OK JEFFERSON	9878	2019	34.11	97.82	1645
OK JOHNSTON	9716	1652	34.32	96.65	1743
OK KAY	49807	2460	36.82	97.15	1673
OK KINGFISHER	11916	2340	35.94	97.94	1607
OK KIOWA	17183	2660	34.92	98.97	1529
OK LATIMER	8860	1908	34.91	95.26	1855

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OK LE FLORE	32652	4039	34.93	94.71	1903
OK LINCOLN	20692	2519	35.69	96.88	1703
OK LOGAN	20677	1945	35.91	97.44	1652
OK LOVE	6929	1328	33.95	97.23	1699
OK MCCLAIN	13859	1483	35.00	97.43	1663
OK MCCURTAIN	29153	4661	34.15	94.78	1909
OK MCINTOSH	15512	1575	35.40	95.66	1813
OK MAJOR	9225	2494	36.31	98.53	1552
OK MARSHALL	7791	947	34.03	96.75	1739
OK MAYES	19884	1677	36.33	95.24	1844
OK MURRAY	10710	1096	34.49	97.06	1704
OK MUSKOGEE	63999	2118	35.64	95.39	1836
OK NOBLE	11401	1924	36.39	97.23	1667
OK NOWATA	11928	1390	36.82	95.63	1808
OK OKFUSKEE	14721	1649	35.47	96.31	1756
OK OKLAHOMA	373868	1812	35.54	97.40	1658
OK OKMULGEE	41326	1812	35.66	95.96	1784
OK OSAGE	32805	5883	36.63	96.40	1739
OK OTTAWA	30552	1202	36.85	94.82	1880
OK PAWNEE	12451	1452	36.32	96.70	1714
OK PAYNE	45496	1797	36.07	96.97	1691
OK PITTSBURG	38196	3213	34.95	95.75	1812
OK PONTOTOC	29692	1849	34.73	96.68	1733
OK POTTAWATOMIE	42651	2056	35.20	96.94	1703
OK PUSHMATAHA	10760	3677	34.45	95.39	1851
OK ROGER MILLS	6417	2952	35.68	99.70	1454
OK ROGERS	19991	1773	36.40	95.61	1810
OK SEMINOLE	35314	1631	35.17	96.60	1733
OK SEQUOYAH	19024	1803	35.52	94.76	1892
OK STEPHENS	35737	2308	34.49	97.85	1635
OK TEXAS	14203	5340	36.74	101.48	1289
OK TILLMAN	16343	2333	34.38	98.92	1543
OK TULSA	291784	1483	36.13	95.94	1782
OK WAGONER	16289	1458	35.99	95.54	1819
OK WASHINGTON	36905	1097	36.73	95.91	1783
OK WASHITA	17852	2612	35.29	98.99	1521
OK WOODS	13424	3361	36.77	98.87	1520
OK WOODWARD	14180	3239	36.42	99.26	1487
OR BAKER	16646	7945	44.72	117.67	870
OR BENTON	34797	1729	44.49	123.42	1061
OR CLACKAMAS	97903	4879	45.18	122.21	1063
OR CLATSOP	29336	2084	45.98	123.64	1206
OR COLUMBIA	22721	1655	45.93	123.09	1175

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
OR COOS	47660	4153	43.16	124.04	989
OR CROOK	9178	7704	44.14	120.35	882
OR CURRY	9419	4213	42.46	124.14	943
OR DESCHUTES	22361	7849	43.91	121.22	897
OR DOUGLAS	60460	13112	43.27	123.16	943
OR GILLIAM	2921	3128	45.38	120.22	1003
OR GRANT	8072	11732	44.49	119.00	874
OR HARNEY	6385	26329	43.06	118.97	723
OR HOOD RIVER	13017	1355	45.51	121.64	1070
OR JACKSON	65079	7282	42.43	122.73	849
OR JEFFERSON	6211	4643	44.63	121.17	964
OR JOSEPHINE	27978	4208	42.37	123.56	898
OR KLAMATH	44411	15461	42.69	121.65	807
OR LAKE	6865	21317	42.80	120.38	752
OR LANE	141552	11789	43.93	122.84	981
OR LINCOLN	22725	2553	44.49	122.53	1014
OR LINN	56255	5912	44.63	123.84	1097
OR MALHEUR	23030	25534	43.19	117.63	703
OR MARION	109683	3019	44.90	122.58	1054
OR MORROW	4824	5334	45.42	119.58	988
OR MULTNOMAH	493327	1096	45.53	122.39	1105
OR POLK	26406	1905	44.90	123.40	1096
OR SHERMAN	2345	2149	45.39	120.69	1021
OR TILLAMOOK	18754	2888	45.45	123.68	1160
OR UMATILLA	42830	8357	45.59	118.74	985
OR UNION	18053	5262	45.32	118.00	941
OR WALLOWA	7196	8230	45.59	117.17	960
OR WASCO	17530	6166	45.15	121.16	1015
OR WASHINGTON	74432	1853	45.55	123.08	1139
OR WHEELER	3061	4420	44.72	120.02	929
OR YAMHILL	33054	1841	45.22	123.29	1120
PA ADAMS	47470	1362	39.88	77.22	3456
PA ALLEGHENY	1563413	1886	40.47	79.98	3219
PA ARMSTRONG	80283	1689	40.82	79.46	3270
PA BEAVER	188693	1140	40.68	80.35	3190
PA BEDFORD	41483	2636	40.01	78.49	3345
PA BERKS	264102	2232	40.42	75.93	3576
PA BLAIR	138554	1372	40.48	78.35	3363
PA BRADFORD	53083	2972	41.79	76.53	3543
PA BUCKS	214294	1590	40.35	75.11	3648
PA BUTLER	104684	2056	40.91	79.92	3231
PA CAMBRIA	206887	1791	40.50	78.71	3332
PA CAMERON	7260	1038	41.43	78.21	3390

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
PA CARBON	55573	1045	40.92	75.71	3602
PA CENTRE	71301	2888	40.92	77.83	3415
PA CHESTER	181018	1970	39.98	75.74	3588
PA CLARION	37950	1545	41.19	79.42	3279
PA CLEARFIELD	84077	2950	41.00	78.48	3359
PA CLINTON	36991	2327	41.23	77.64	3436
PA COLUMBIA	53470	1254	41.04	76.40	3542
PA CRAWFORD	78524	2620	41.68	80.11	3227
PA CUMBERLAND	107359	1437	40.17	77.27	3455
PA DAUPHIN	207334	1341	40.41	76.78	3501
PA DELAWARE	473280	477	39.92	75.40	3617
PA ELK	35702	2090	41.42	78.65	3351
PA ERIE	232690	2105	41.99	80.03	3239
PA FAYETTE	181164	2077	39.92	79.65	3242
PA FOREST	4752	1085	41.50	79.23	3301
PA FRANKLIN	81130	1952	39.93	77.72	3412
PA FULTON	10476	1127	39.93	78.11	3378
PA GREENE	42859	1497	39.85	80.22	3191
PA HUNTINGDON	40273	2318	40.42	77.97	3396
PA INDIANA	76368	2136	40.65	79.08	3301
PA JEFFERSON	48147	1689	41.13	79.00	3315
PA JUNIATA	15512	999	40.52	77.41	3447
PA LACKAWANNA	247685	1175	41.44	75.62	3617
PA LANCASTER	253269	2450	40.05	76.25	3544
PA LAWRENCE	108455	951	40.99	80.33	3196
PA LEBANON	85580	940	40.37	76.46	3528
PA LEHIGH	210674	900	40.62	75.59	3608
PA LUZERNE	373001	2294	41.18	75.99	3581
PA LYCOMING	104701	3148	41.33	77.07	3488
PA MCKEAN	55721	2568	41.81	78.57	3364
PA MERCER	118571	1735	41.30	80.26	3207
PA MIFFLIN	43970	1116	40.61	77.61	3430
PA MONROE	36232	1582	41.06	75.34	3636
PA MONTGOMERY	422606	1285	40.22	75.36	3624
PA MONTOUR	16309	336	41.02	76.66	3519
PA NORTHAMPTON	192122	974	40.76	75.31	3635
PA NORTHUMBERLA	111600	1172	40.84	76.71	3513
PA PERRY	25549	1427	40.40	77.25	3459
PA PHILADELPHIA	2042244	333	39.99	75.12	3643
PA PIKE	8738	1403	41.33	75.05	3666
PA POTTER	16672	2827	41.74	77.90	3422
PA SCHUYLKILL	188868	2031	40.71	76.21	3554
PA SNYDER	24189	847	40.77	77.07	3480

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
PA SOMERSET	79966	2792	39.98	79.03	3298
PA SULLIVAN	6531	1238	41.44	76.53	3537
PA SUSQUEHANNA	32467	2156	41.82	75.81	3607
PA TIOGA	35958	2968	41.76	77.26	3478
PA UNION	24209	823	40.96	77.07	3483
PA VENANGO	65314	1756	41.39	79.76	3253
PA WARREN	43924	2343	41.81	79.28	3302
PA WASHINGTON	212879	2219	40.19	80.25	3192
PA WAYNE	28375	1918	41.65	75.31	3647
PA WESTMORELAND	329946	2651	40.31	79.46	3263
PA WYOMING	16783	1030	41.52	76.03	3582
PA YORK	217865	2353	39.93	76.73	3500
RI BRISTOL	32505	64	41.71	71.26	4005
RI KENT	92579	447	41.68	71.58	3976
RI NEWPORT	70188	298	41.57	71.23	4005
RI PROVIDENCE	572343	1076	41.88	71.58	3979
RI WASHINGTON	53009	830	41.49	71.63	3969
SC ABBEVILLE	22016	1310	34.23	82.46	2992
SC AIKEN	64999	2814	33.55	81.65	3072
SC ALLENDALE	11598	1082	32.99	81.36	3106
SC ANDERSON	93983	1939	34.52	82.65	2973
SC BAMBERG	16997	1023	33.22	81.05	3130
SC BARNWELL	17433	1431	33.27	81.44	3095
SC BEAUFORT	34305	1500	32.37	80.78	3167
SC BERKELEY	33627	2874	33.20	79.95	3227
SC CALHOUN	13694	975	33.69	80.78	3147
SC CHARLESTON	186752	2432	32.84	79.97	3230
SC CHEROKEE	35082	1020	35.06	81.63	3058
SC CHESTER	31875	1513	34.69	81.16	3102
SC CHESTERFIELD	35164	2046	34.64	80.14	3193
SC CLARENDON	31061	1551	33.67	80.20	3198
SC COLLETON	28062	2716	32.87	80.67	3168
SC DARLINGTON	51252	1406	34.33	79.95	3213
SC DILLON	30786	1054	34.39	79.37	3264
SC DORCHESTER	23362	1473	33.08	80.40	3189
SC EDGEFIELD	16225	1248	33.78	81.98	3040
SC FAIRFIELD	21330	1803	34.40	81.12	3109
SC FLORENCE	81719	2084	34.03	79.69	3239
SC GEORGETOWN	33050	2102	33.44	79.33	3278
SC GREENVILLE	185842	2050	34.90	82.37	2993
SC GREENWOOD	42784	1155	34.16	82.12	3023
SC HAMPTON	17772	1455	32.78	81.14	3128
SC HORRY	63408	2988	33.92	78.99	3302

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
SC JASPER	11524	1689	32.47	81.04	3143
SC KERSHAW	32838	2022	34.36	80.58	3156
SC LANCASTER	38039	1300	34.71	80.71	3142
SC LAURENS	47246	1841	34.49	82.01	3029
SC LEE	22606	1058	34.17	80.25	3188
SC LEXINGTON	51270	1856	33.91	81.28	3100
SC MCCORMICK	9175	931	33.91	82.32	3008
SC MARION	32642	1261	34.09	79.35	3268
SC MARLBORO	30393	1251	34.60	79.67	3235
SC NEWBERRY	30773	1645	34.29	81.60	3067
SC OCONEE	39539	1693	34.75	83.08	2932
SC ORANGEBURG	68654	2864	33.45	80.80	3148
SC PICKENS	42601	1273	34.90	82.74	2961
SC RICHLAND	167017	1936	34.03	80.90	3132
SC SALUDA	15343	1186	34.01	81.73	3059
SC SPARTANBURG	153108	2152	34.94	81.99	3026
SC SUMTER	64986	1739	33.91	80.38	3180
SC UNION	30775	1331	34.69	81.62	3062
SC WILLIAMSBURG	42582	2422	33.63	79.72	3241
SC YORK	74640	1772	34.98	81.19	3097
SD AURORA	4906	1835	43.72	98.56	1718
SD BEADLE	21341	3261	44.41	98.27	1776
SD BENNETT	3249	3058	43.19	101.67	1446
SD BON HOMME	9349	1449	42.98	97.88	1740
SD BROOKINGS	18784	2071	44.37	96.78	1892
SD BROWN	33249	4335	45.59	98.35	1834
SD BRULE	6181	2118	43.71	99.09	1676
SD BUFFALO	1588	1248	44.07	99.21	1684
SD BUTTE	8347	5826	44.90	103.51	1414
SD CAMPBELL	3828	1895	45.77	100.05	1719
SD CHARLES MIX	13952	2840	43.20	98.59	1692
SD CLARK	7843	2496	44.85	97.73	1841
SD CLAY	10913	1048	42.90	96.98	1811
SD CODINGTON	19488	1779	44.98	97.19	1890
SD CORSON	6013	6396	45.70	101.19	1631
SD CUSTER	5256	4032	43.67	103.45	1338
SD DAVISON	16589	1119	43.67	98.13	1751
SD DAY	11537	2667	45.37	97.61	1878
SD DEUEL	7302	1655	44.76	96.66	1921
SD DEWEY	5093	6088	45.15	100.87	1620
SD DOUGLAS	5417	1127	43.38	98.37	1718
SD EDMUNDS	6765	2988	45.41	99.21	1759
SD FALL RIVER	10548	4513	43.24	103.54	1305

State county	Population	Area (km2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
SD FAULK	4599	2579	45.06	99.14	1744
SD GRANT	10097	1763	45.17	96.75	1934
SD GREGORY	8061	2581	43.19	99.20	1642
SD HAAKON	3224	4702	44.29	101.54	1517
SD HAMLIN	6738	1323	44.67	97.18	1875
SD HAND	6964	3708	44.54	99.00	1725
SD HANSON	4766	1113	43.67	97.77	1780
SD HARDING	2320	6945	45.58	103.49	1463
SD HUGHES	10078	1936	44.38	100.00	1640
SD HUTCHINSON	11280	2111	43.33	97.75	1766
SD HYDE	2724	2235	44.54	99.49	1688
SD JACKSON	1596	2092	43.86	101.60	1488
SD JERAULD	4293	1365	44.06	98.63	1730
SD JONES	2194	2519	43.95	100.69	1563
SD KINGSBURY	9653	2118	44.37	97.48	1836
SD LAKE	11782	1469	44.03	97.11	1849
SD LAWRENCE	16828	2071	44.35	103.78	1358
SD LINCOLN	12599	1491	43.27	96.71	1848
SD LYMA	4514	4358	43.89	99.85	1625
SD MCCOOK	8587	1489	43.67	97.35	1813
SD MCPHERSON	6541	2971	45.76	99.22	1779
SD MARSHALL	7338	2195	45.76	97.60	1901
SD MEADE	11737	8973	44.56	102.71	1448
SD MELLETTE	2881	3382	43.58	100.76	1537
SD MINER	5900	1476	44.03	97.60	1810
SD MINNEHAHA	77568	2105	43.67	96.77	1861
SD MOODY	9066	1355	44.03	96.65	1887
SD PENNINGTON	44316	7197	44.00	102.83	1404
SD PERKINS	6432	7406	45.48	102.47	1526
SD POTTER	4787	2250	45.06	99.96	1682
SD ROBERTS	14188	2869	45.63	96.93	1944
SD SANBORN	4931	1476	44.02	98.09	1771
SD SHANNON	5812	5438	43.33	102.56	1385
SD SPINK	11994	3897	44.94	98.34	1798
SD STANLEY	2921	3662	44.40	100.74	1585
SD SULLY	2669	2599	44.71	100.14	1648
SD TODD	4720	3594	43.19	100.72	1520
SD TRIPP	8979	4195	43.34	99.89	1594
SD TURNER	11698	1584	43.31	97.14	1814
SD UNION	10539	1171	42.83	96.65	1835
SD WALWORTH	7841	1859	45.42	100.03	1698
SD WASHABAUGH	1599	2747	43.56	101.66	1466
SD YANKTON	17123	1344	43.00	97.39	1781

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
SD ZIEBACH	2555	5130	44.97	101.67	1550
TN ANDERSON	59673	868	36.12	84.19	2825
TN BEDFORD	23423	1248	35.53	86.46	2627
TN BENTON	11139	1014	36.08	88.07	2480
TN BLEDSOE	8245	1045	35.60	85.21	2737
TN BLOUNT	55897	1489	35.69	83.92	2850
TN BRADLEY	34878	865	35.15	84.86	2771
TN CAMPBELL	31635	1168	36.40	84.14	2828
TN CANNON	8899	702	35.81	86.05	2661
TN CARROLL	25249	1544	35.97	88.45	2447
TN CARTER	42073	900	36.29	82.13	3007
TN CHEATHAM	9281	789	36.26	87.09	2566
TN CHESTER	10482	737	35.42	88.62	2436
TN CLAIBORNE	22357	1150	36.48	83.67	2869
TN CLAY	8102	602	36.55	85.53	2704
TN COCKE	23160	1097	35.93	83.11	2921
TN COFFEE	25413	1124	35.49	86.06	2662
TN CROCKETT	15763	696	35.82	89.14	2387
TN CUMBERLAND	18985	1756	35.95	85.01	2753
TN DAVIDSON	354905	1316	36.17	86.78	2595
TN DECATUR	8968	872	35.62	88.11	2479
TN DE KALB	11295	720	35.99	85.84	2679
TN DICKSON	18818	1255	36.15	87.36	2543
TN DYER	31799	1369	36.05	89.41	2362
TN FAYETTE	26281	1822	35.20	89.42	2367
TN FENTRESS	14225	1289	36.38	84.93	2758
TN FRANKLIN	25469	1431	35.15	86.08	2663
TN GIBSON	46671	1572	35.99	88.93	2404
TN GILES	25027	1603	35.21	87.03	2579
TN GRAINGER	12844	730	36.28	83.50	2885
TN GREENE	41520	1587	36.18	82.85	2943
TN GRUNDY	12115	927	35.38	85.72	2693
TN HAMBLEN	27851	401	36.22	83.24	2908
TN HAMILTON	220852	1424	35.18	85.17	2743
TN HANCOCK	8542	595	36.52	83.21	2910
TN HARDEMAN	22550	1698	35.21	89.00	2405
TN HARDIN	17121	1520	35.20	88.19	2476
TN HAWKINS	30485	1242	36.44	82.93	2935
TN HAYWOOD	25014	1344	35.59	89.27	2377
TN HENDERSON	16724	1334	35.65	88.39	2455
TN HENRY	23167	1469	36.33	88.31	2459
TN HICKMAN	12720	1579	35.81	87.48	2534
TN HOUSTON	5095	520	36.28	87.74	2509

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
TN HUMPHREYS	11231	1372	36.03	87.78	2506
TN JACKSON	11025	837	36.37	85.67	2692
TN JEFFERSON	20446	709	36.06	83.43	2892
TN JOHNSON	11639	758	36.46	81.85	3031
TN KNOX	234700	1316	35.99	83.94	2847
TN LAKE	10773	433	36.36	89.50	2353
TN LAUDERDALE	23685	1234	35.76	89.62	2345
TN LAWRENCE	28490	1642	35.22	87.39	2546
TN LEWIS	6159	737	35.53	87.49	2535
TN LINCOLN	24861	1501	35.15	86.58	2619
TN LOUDON	23426	613	35.74	84.31	2815
TN MCMINN	32721	1119	35.43	84.61	2791
TN MCNAIRY	19415	1473	35.18	88.57	2442
TN MACON	13006	786	36.53	86.03	2660
TN MADISON	60352	1449	35.61	88.83	2416
TN MARION	20742	1310	35.13	85.62	2704
TN MARSHALL	17382	975	35.48	86.76	2600
TN MAURY	40934	1590	35.63	87.08	2571
TN MEIGS	5686	495	35.52	84.81	2773
TN MONROE	24008	1708	35.45	84.25	2822
TN MONTGOMERY	49060	1396	36.50	87.39	2540
TN MOORE	3741	321	35.29	86.36	2637
TN MORGAN	15119	1396	36.13	84.65	2784
TN OBION	28168	1439	36.35	89.16	2383
TN OVERTON	16332	1141	36.34	85.29	2727
TN PERRY	5956	1064	35.64	87.86	2501
TN PICKETT	4814	409	36.56	85.07	2745
TN POLK	13260	1124	35.12	84.53	2800
TN PUTNAM	29602	1048	36.15	85.50	2708
TN RHEA	15964	808	35.61	84.93	2762
TN ROANE	34836	906	35.85	84.51	2797
TN ROBERTSON	27154	1233	36.53	86.87	2585
TN RUTHERFORD	45658	1584	35.85	86.40	2629
TN SCOTT	16535	1408	36.43	84.50	2796
TN SEQUATCHIE	5787	706	35.38	85.42	2720
TN SEVIER	23750	1545	35.79	83.52	2885
TN SHELBY	543860	1955	35.19	89.88	2326
TN SMITH	13231	837	36.26	85.96	2667
TN STEWART	8613	1217	36.50	87.84	2500
TN SULLIVAN	103171	1069	36.51	82.30	2991
TN SUMNER	34674	1383	36.47	86.45	2622
TN TIPTON	29263	1189	35.50	89.74	2336
TN TROUSDALE	5261	295	36.39	86.15	2650

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
TN UNICOI	15546	478	36.10	82.44	2979
TN UNION	8597	549	36.28	83.83	2856
TN VAN BUREN	3852	657	35.70	85.45	2715
TN WARREN	22621	1137	35.68	85.77	2687
TN WASHINGTON	62035	837	36.30	82.50	2974
TN WAYNE	13037	1914	35.25	87.79	2511
TN WEAKLEY	26379	1491	36.30	88.72	2422
TN WHITE	15936	989	35.93	85.46	2712
TN WILLIAMSON	24714	1535	35.90	86.89	2586
TN WILSON	26896	1469	36.16	86.29	2638
TX ANDERSON	30296	2775	31.83	95.66	1894
TX ANDREWS	8594	3894	32.30	102.64	1296
TX ANGELINA	37636	1911	31.28	94.62	2001
TX ARANSAS	5423	712	28.24	96.95	1951
TX ARCHER	6514	2364	33.61	98.68	1582
TX ARMSTRONG	2107	2349	34.97	101.35	1319
TX ATASCOSA	19531	3123	28.90	98.53	1793
TX AUSTIN	14285	1717	29.89	96.28	1920
TX BAILEY	8233	2163	34.06	102.83	1213
TX BANDERA	4189	1976	29.74	99.25	1692
TX BASTROP	18475	2305	30.10	97.32	1826
TX BAYLOR	6461	2188	33.61	99.21	1537
TX BEE	20548	2180	28.42	97.74	1880
TX BELL	82438	2712	31.04	97.48	1772
TX BEXAR	579801	3227	29.45	98.53	1763
TX BLANCO	3726	1862	30.27	98.39	1732
TX BORDEN	1098	2349	32.74	101.44	1376
TX BOSQUE	11400	2564	31.91	97.64	1725
TX BOWIE	61121	2308	33.47	94.43	1954
TX BRAZORIA	59156	3686	29.22	95.47	2017
TX BRAZOS	41150	1517	30.66	96.31	1884
TX BREWSTER	6940	16067	29.80	103.25	1385
TX BRISCOE	3549	2263	34.53	101.22	1340
TX BROOKS	8951	2340	27.04	98.22	1927
TX BROWN	26959	2429	31.78	99.00	1616
TX BURLESON	12227	1735	30.49	96.62	1865
TX BURNET	9895	2579	30.78	98.18	1725
TX CALDWELL	18445	1408	29.84	97.63	1814
TX CALHOUN	12360	1365	28.52	96.69	1955
TX CALLAHAN	8596	2216	32.30	99.37	1565
TX CAMERON	136190	2320	26.15	97.55	2033
TX CAMP	8362	496	33.00	94.99	1917
TX CARSON	7245	2330	35.40	101.35	1312

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
TX CASS	25361	2436	33.10	94.35	1970
TX CASTRO	6909	2278	34.53	102.28	1248
TX CHAMBERS	8942	1594	29.75	94.61	2062
TX CHEROKEE	36327	2716	31.85	95.17	1935
TX CHILDRESS	10553	1810	34.53	100.20	1428
TX CLAY	9240	2854	33.78	98.21	1619
TX COCHRAN	6132	2028	33.60	102.83	1228
TX COKE	3851	2358	31.89	100.53	1486
TX COLEMAN	14207	3314	31.78	99.46	1578
TX COLLIN	41500	2164	33.19	96.57	1775
TX COLLINGSWORT	7925	2315	34.96	100.27	1414
TX COLORADO	17951	2457	29.62	96.54	1912
TX COMAL	17843	1469	29.82	98.28	1764
TX COMANCHE	13963	2444	31.95	98.55	1647
TX CONCHO	4483	2599	31.33	99.88	1563
TX COOKE	22319	2343	33.64	97.21	1709
TX CORYELL	19549	2700	31.40	97.81	1730
TX COTTLE	5297	2330	34.08	100.27	1433
TX CRANE	4276	2059	31.43	102.52	1347
TX CROCKETT	4081	7235	30.70	101.41	1471
TX CROSBY	9905	2358	33.61	101.29	1359
TX CULBERSON	2239	9973	31.44	104.52	1192
TX DALLAM	7069	3869	36.27	102.61	1191
TX DALLAS	757907	2225	32.77	96.78	1769
TX DAWSON	19141	2336	32.74	101.96	1333
TX DEAF SMITH	10843	3910	34.96	102.61	1210
TX DELTA	7642	715	33.42	95.68	1847
TX DENTON	43943	2358	33.20	97.12	1728
TX DE WITT	22002	2356	29.07	97.36	1874
TX DICKENS	6235	2411	33.61	100.76	1403
TX DIMMIT	10416	3480	28.42	99.76	1728
TX DONLEY	5465	2343	34.97	100.81	1366
TX DUVAL	14689	4698	27.68	98.51	1865
TX EASTLAND	22065	2465	32.33	98.83	1610
TX ECTOR	62884	2349	31.86	102.55	1323
TX EDWARDS	2656	5376	29.96	100.31	1597
TX ELLIS	44691	2434	32.35	96.80	1781
TX EL PASO	245587	2737	31.76	106.24	1044
TX ERATH	17499	2809	32.24	98.21	1665
TX FALLS	24405	1978	31.25	96.93	1808
TX FANNIN	28123	2343	33.60	96.11	1805
TX FAYETTE	22566	2419	29.88	96.92	1869
TX FISHER	9683	2340	32.74	100.40	1463

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
TX FLOYD	11314	2571	34.07	101.29	1345
TX FOARD	3753	1750	33.98	99.77	1479
TX FORT BEND	35082	2250	29.54	95.78	1976
TX FRANKLIN	5767	758	33.20	95.22	1891
TX FREESTONE	14349	2239	31.72	96.15	1856
TX FRIO	10251	2889	28.86	99.11	1750
TX GAINES	10337	3856	32.73	102.64	1277
TX GALVESTON	124670	1033	29.38	94.94	2052
TX GARZA	6423	2367	33.17	101.28	1373
TX GILLESPIE	10320	2731	30.30	98.94	1687
TX GLASSCOCK	1102	2235	31.86	101.51	1406
TX GOLIAD	5882	2256	28.66	97.43	1891
TX GONZALES	19754	2734	29.45	97.50	1843
TX GRAY	27622	2419	35.40	100.81	1360
TX GRAYSON	71565	2434	33.63	96.68	1755
TX GREGG	64732	730	32.51	94.82	1944
TX GRIMES	14104	2074	30.54	96.00	1915
TX GUADALUPE	26931	1849	29.59	97.96	1801
TX HALE	31861	2536	34.07	101.81	1301
TX HALL	9397	2291	34.53	100.68	1387
TX HAMILTON	9741	2185	31.70	98.12	1692
TX HANSFORD	5054	2349	36.27	101.35	1303
TX HARDEMAN	9388	1779	34.30	99.74	1474
TX HARDIN	21701	2322	30.35	94.40	2054
TX HARRIS	992194	4462	29.87	95.40	1992
TX HARRISON	46832	2315	32.58	94.38	1980
TX HARTLEY	2026	3853	35.83	102.60	1196
TX HASKELL	12650	2270	33.17	99.73	1505
TX HAYS	18729	1683	30.05	98.03	1772
TX HEMPHILL	3724	2340	35.83	100.27	1402
TX HENDERSON	22715	2441	32.23	95.87	1864
TX HIDALGO	169142	3995	26.40	98.19	1971
TX HILL	28040	2615	31.99	97.13	1765
TX HOCKLEY	21231	2351	33.61	102.33	1270
TX HOOD	5352	1103	32.43	97.83	1690
TX HOPKINS	21414	2053	33.17	95.57	1862
TX HOUSTON	21362	3203	31.34	95.43	1931
TX HOWARD	32424	2358	32.30	101.44	1393
TX HUDSPETH	3897	11794	31.44	105.38	1126
TX HUNT	41315	2139	33.13	96.08	1819
TX HUTCHINSON	32790	2266	35.83	101.35	1306
TX IRION	1419	2778	31.30	100.99	1475
TX JACK	7612	2447	33.23	98.18	1636

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TX JACKSON	13400	2201	28.93	96.58	1943
TX JASPER	20916	2349	30.76	94.03	2070
TX JEFF DAVIS	1884	5850	30.71	104.14	1263
TX JEFFERSON	216578	2463	29.91	94.17	2091
TX JIM HOGG	5235	2959	27.05	98.71	1891
TX JIM WELLS	30779	2188	27.73	98.10	1893
TX JOHNSON	32804	1917	32.38	97.37	1731
TX JONES	20936	2475	32.74	99.89	1506
TX KARNES	16224	1963	28.90	97.86	1844
TX KAUFMAN	30647	2111	32.61	96.29	1815
TX KENDALL	5627	1735	29.93	98.71	1724
TX KENEDY	739	3610	26.93	97.75	1968
TX KENT	2028	2278	33.17	100.76	1417
TX KERR	15207	2851	30.04	99.36	1667
TX KIMBLE	4329	3299	30.46	99.75	1615
TX KING	774	2444	33.61	100.25	1448
TX KINNEY	2577	3607	29.34	100.43	1623
TX KLEBERG	25418	2204	27.44	97.77	1935
TX KNOX	9138	2204	33.60	99.74	1492
TX LAMAR	39298	2315	33.69	95.57	1849
TX LAMB	20812	2646	34.07	102.34	1256
TX LAMPASAS	9708	1880	31.19	98.25	1702
TX LA SALLE	6845	3884	28.35	99.11	1781
TX LAVACA	21321	2525	29.38	96.94	1892
TX LEE	9636	1649	30.31	96.98	1844
TX LEON	11141	2854	31.31	96.01	1883
TX LIBERTY	28795	3055	30.16	94.81	2028
TX LIMESTONE	23194	2411	31.55	96.58	1827
TX LIPSCOMB	3549	2419	36.27	100.27	1398
TX LIVE OAK	8540	2731	28.35	98.13	1854
TX LLANO	5320	2436	30.70	98.69	1688
TX LOVING	228	1677	31.85	103.59	1241
TX LUBBOCK	124517	2312	33.61	101.80	1315
TX LYNN	10981	2370	33.17	101.80	1330
TX MCCULLOCH	10471	2760	31.20	99.37	1611
TX MCLENNAN	138653	2589	31.56	97.20	1774
TX MCMULLEN	1159	3002	28.35	98.58	1820
TX MADISON	7463	1242	30.97	95.94	1902
TX MARION	9270	983	32.83	94.37	1975
TX MARTIN	5343	2358	32.30	101.95	1351
TX MASON	4450	2422	30.71	99.24	1643
TX MATAGORDA	23340	2996	28.88	96.00	1991
TX MAVERICK	13236	3338	28.74	100.32	1667

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TX MEDINA	17820	3501	29.35	99.12	1722
TX MENARD	3661	2367	30.88	99.83	1587
TX MIDLAND	43606	2432	31.86	102.02	1365
TX MILAM	23018	2662	30.78	96.98	1823
TX MILLS	5348	1901	31.50	98.61	1660
TX MITCHELL	13036	2382	32.30	100.92	1437
TX MONTAGUE	16146	2413	33.67	97.72	1663
TX MONTGOMERY	25496	2823	30.32	95.51	1964
TX MOORE	13958	2353	35.83	101.89	1258
TX MORRIS	10771	672	33.14	94.73	1935
TX MOTLEY	3496	2537	34.08	100.77	1390
TX NACOGDOCHES	29363	2336	31.64	94.63	1988
TX NAVARRO	37581	2771	32.05	96.47	1818
TX NEWTON	10636	2457	30.81	93.75	2091
TX NOLAN	19452	2387	32.30	100.40	1480
TX NUECES	189312	2177	27.73	97.67	1925
TX OCHILTREE	7447	2349	36.27	100.81	1350
TX OLDHAM	1779	3828	35.40	102.60	1202
TX ORANGE	48977	930	30.14	93.89	2105
TX PALO PINTO	18589	2454	32.75	98.32	1639
TX PANOLA	18239	2250	32.19	94.32	1997
TX PARKER	22107	2339	32.77	97.81	1681
TX PARMER	7401	2225	34.52	102.79	1204
TX PECOS	10799	12276	30.78	102.73	1366
TX POLK	15210	2848	30.81	94.84	2000
TX POTTER	91308	2325	35.40	101.89	1264
TX PRESIDIO	6553	10079	29.99	104.24	1302
TX RAINS	3728	543	32.88	95.79	1850
TX RANDALL	22332	2367	34.97	101.89	1272
TX REAGAN	3403	2931	31.36	101.52	1430
TX REAL	2310	1610	29.82	99.83	1642
TX RED RIVER	19231	2674	33.65	95.06	1895
TX REEVES	14253	6754	31.32	103.69	1262
TX REFUGIO	10477	2004	28.34	97.17	1929
TX ROBERTS	1047	2327	35.83	100.81	1354
TX ROBERTSON	18313	2270	31.02	96.52	1852
TX ROCKWALL	6042	381	32.90	96.41	1797
TX RUNNELS	16022	2740	31.83	99.98	1533
TX RUSK	39828	2432	32.13	94.77	1960
TX SABINE	8031	1180	31.36	93.87	2062
TX SAN AUGUSTIN	8365	1224	31.42	94.18	2033
TX SAN JACINTO	6736	1615	30.60	95.18	1979
TX SAN PATRICIO	39740	1773	28.02	97.52	1919

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TX SAN SABA	7700	2900	31.16	98.82	1657
TX SCHLEICHER	2827	3446	30.89	100.54	1530
TX SCURRY	21752	2340	32.74	100.92	1420
TX SHACKELFORD	4571	2297	32.74	99.36	1551
TX SHELBY	22203	2015	31.81	94.15	2023
TX SHERMAN	2511	2371	36.27	101.89	1254
TX SMITH	79650	2419	32.40	95.28	1909
TX SOMERVELL	2558	509	32.23	97.77	1702
TX STARR	15302	3135	26.57	98.74	1920
TX STEPHENS	9870	2327	32.74	98.83	1595
TX STERLING	1240	2367	31.83	101.05	1446
TX STONEWALL	3401	2398	33.17	100.25	1461
TX SUTTON	3741	3866	30.48	100.54	1551
TX SWISHER	9251	2320	34.53	101.76	1293
TX TARRANT	436582	2229	32.77	97.29	1725
TX TAYLOR	79398	2361	32.30	99.89	1522
TX TERRELL	2943	6192	30.22	102.07	1447
TX TERRY	14455	2327	33.17	102.33	1285
TX THROCKMORTON	3251	2382	33.17	99.21	1549
TX TITUS	17081	1082	33.24	94.97	1912
TX TOM GREEN	61352	3884	31.40	100.47	1512
TX TRAVIS	182724	2620	30.33	97.78	1779
TX TRINITY	8979	1831	31.10	95.14	1963
TX TYLER	11023	2380	30.79	94.39	2038
TX UPSHUR	20384	1513	32.76	94.95	1927
TX UPTON	5704	3397	31.36	102.03	1389
TX UVALDE	16360	4112	29.35	99.76	1673
TX VAL VERDE	19964	8393	29.88	101.15	1537
TX VAN ZANDT	21104	2188	32.58	95.85	1854
TX VICTORIA	37712	2309	28.79	96.98	1919
TX WALKER	20721	2046	30.75	95.59	1939
TX WALLER	12005	1317	30.01	95.99	1938
TX WARD	14013	2142	31.51	103.11	1296
TX WASHINGTON	19949	1538	30.22	96.40	1895
TX WEBB	59822	8562	27.76	99.35	1799
TX WHARTON	36964	2786	29.28	96.24	1952
TX WHEELER	9312	2367	35.40	100.27	1407
TX WICHITA	109133	1582	33.99	98.70	1571
TX WILBARGER	19364	2465	34.08	99.24	1522
TX WILLACY	20564	1531	26.48	97.70	2001
TX WILLIAMSON	37235	2858	30.65	97.61	1778
TX WILSON	14067	2077	29.18	98.08	1812
TX WINKLER	11587	2297	31.85	103.07	1282

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TX WISE	16514	2387	33.21	97.66	1681
TX WOOD	19755	1866	32.81	95.38	1888
TX YOAKUM	5906	2149	33.17	102.83	1244
TX YOUNG	17001	2299	33.18	98.68	1594
TX ZAPATA	4401	2478	27.01	99.18	1860
TX ZAVALA	11840	3344	28.86	99.76	1701
UT BEAVER	4633	6692	38.37	113.23	289
UT BOX ELDER1	438	10158	41.85	113.50	583
UT BOX ELDER2	21561	4353	41.71	112.17	624
UT CACHE	34494	3040	41.73	111.75	646
UT CARBON	23300	3822	39.65	110.59	563
UT DAGGETT	703	1766	40.88	109.51	719
UT DAVIS	45270	768	41.00	112.12	562
UT DUCHESNE	7725	8429	40.30	110.43	615
UT EMERY	5980	11496	39.00	110.70	520
UT GARFIELD	3904	13358	37.86	111.43	416
UT GRAND	3791	9535	38.99	109.57	611
UT IRON1	605	4273	37.79	113.92	204
UT IRON2	2034	2564	37.84	112.84	296
UT IRON3	7496	1709	37.67	113.07	270
UT JUAB	5391	8836	39.70	112.78	414
UT KANE1	1516	8594	37.04	112.53	308
UT KANE2	941	1516	37.27	111.64	388
UT MILLARD	8739	17593	39.08	113.10	346
UT MORGAN	2654	1562	41.09	111.59	600
UT PIUTE	1711	1952	38.34	112.12	375
UT RICH	1678	2650	41.63	111.25	665
UT SALT LAKE	320858	1978	40.68	111.93	546
UT SAN JUAN	6897	19960	37.63	109.80	555
UT SANPETE	12688	4135	39.38	111.58	473
UT SEVIER	11433	4995	38.75	111.81	420
UT SUMMIT	6288	4788	40.87	110.96	621
UT TOOELE1	3278	13446	40.73	114.05	449
UT TOOELE2	12733	4482	40.52	112.30	511
UT UINTAH	10845	11620	40.12	109.53	671
UT UTAH	92569	5215	40.13	111.67	518
UT WASATCH	5462	3085	40.33	111.18	566
UT WASHINGTON1	887	1571	37.57	113.72	212
UT WASHINGTON2	5702	2200	37.11	113.58	215
UT WASHINGTON3	3430	2514	37.17	113.29	241
UT WAYNE	2001	6438	38.33	110.90	476
UT WEBER	94981	1504	41.27	111.94	596
VT ADDISON	19712	2031	44.03	73.15	3882

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VT BENNINGTON	24526	1739	43.04	73.10	3866
VT CALEDONIA	23516	1584	44.46	72.10	3983
VT CHITTENDEN	67607	1379	44.46	73.10	3896
VT ESSEX	6183	1717	44.72	71.74	4020
VT FRANKLIN	29716	1708	44.86	72.92	3921
VT GRAND ISLE	3204	215	44.80	73.30	3887
VT LAMOILLE	11236	1227	44.60	72.64	3939
VT ORANGE	16598	1787	44.01	72.38	3948
VT ORLEANS	20747	1852	44.84	72.24	3980
VT RUTLAND	46251	2401	43.58	73.04	3881
VT WASHINGTON	42865	1831	44.28	72.61	3934
VT WINDHAM	29186	2031	42.99	72.72	3898
VT WINDSOR	41568	2491	43.58	72.59	3921
VA ACCOMACK	32478	1233	37.77	75.63	3583
VA ALBEMARLE	55929	1942	38.02	78.56	3325
VA ALLEGHANY	28736	1171	37.78	80.01	3195
VA AMELIA	7873	947	37.33	77.98	3374
VA AMHERST	21448	1217	37.60	79.15	3271
VA APPOMATTOX	8928	893	37.37	78.81	3300
VA ARLINGTON	155994	105	38.88	77.10	3458
VA AUGUSTA	70203	2595	38.16	79.13	3274
VA BATH	5892	1399	38.06	79.74	3219
VA BEDFORD	30123	1901	37.32	79.52	3237
VA BLAN	6244	955	37.13	81.13	3094
VA BOTETOURT	16171	1418	37.55	79.81	3212
VA BRUNSWICK	19133	1500	36.77	77.86	3385
VA BUCHANAN	36165	1316	37.26	82.04	3014
VA BUCKINGHAM	11692	1507	37.57	78.53	3325
VA CAMPBELL	81444	1434	37.22	79.10	3274
VA CAROLINE	12577	1411	38.03	77.35	3432
VA CARROLL	26431	1297	36.73	80.73	3130
VA CHARLES CITY	5027	468	37.36	77.08	3454
VA CHARLOTTE	13767	1217	37.01	78.67	3313
VA CHESTERFIELD	286971	1144	37.39	77.58	3410
VA CLARKE	7444	450	39.12	78.01	3380
VA CRAIG	3412	869	37.47	80.21	3176
VA CULPEPER	14027	1007	38.49	77.96	3380
VA CUMBERLAND	6871	754	37.51	78.25	3350
VA DICKENSON	22047	860	37.12	82.36	2986
VA DINWIDDIE	89445	1355	37.08	77.63	3405
VA ESSEX	6598	647	37.94	76.96	3466
VA FAIRFAX	247759	1054	38.84	77.28	3442
VA FAUQUIER	22449	1708	38.74	77.81	3394

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VA FLOYD	10971	992	36.93	80.37	3162
VA FLUVANNA	7166	746	37.83	78.28	3348
VA FRANKLIN	25138	1853	36.99	79.89	3204
VA FREDERICK	33787	1057	39.21	78.28	3356
VA GILES	18216	940	37.31	80.71	3132
VA GLOUCESTER	11015	591	37.42	76.55	3501
VA GOOCHLAND	9052	748	37.72	77.92	3380
VA GRAYSON	20684	1171	36.65	81.21	3088
VA GREENE	4734	395	38.30	78.47	3334
VA GREENSVILLE	16248	779	36.68	77.56	3411
VA HALIFAX	40669	2074	36.76	78.93	3290
VA HANOVER	24350	1203	37.76	77.49	3418
VA HENRICO	82841	748	37.54	77.42	3424
VA HENRY	53009	1014	36.68	79.89	3204
VA HIGHLAND	3711	1076	38.37	79.58	3236
VA ISLE OF WIGH	15869	820	36.89	76.73	3485
VA JAMES CITY	15180	406	37.31	76.78	3481
VA KING AND QUE	6126	823	37.72	76.90	3470
VA KING GEORGE	6936	456	38.27	77.17	3449
VA KING WILLIAM	7575	720	37.71	77.09	3454
VA LANCASTER	8865	354	37.74	76.47	3509
VA LEE	31732	1134	36.71	83.12	2918
VA LOUDOUN	22590	1338	39.09	77.65	3411
VA LOUISA	12883	1338	37.98	77.96	3377
VA LUNENBURG	13438	1144	36.95	78.24	3351
VA MADISON	8237	847	38.42	78.28	3351
VA MATHEWS	7136	230	37.43	76.35	3519
VA MECKLENBURG	32615	1584	36.68	78.35	3341
VA MIDDLESEX	6542	336	37.63	76.57	3499
VA MONTGOMERY	40287	1033	37.17	80.39	3160
VA NELSON	13497	1220	37.79	78.89	3294
VA NEW KENT	4199	543	37.50	77.00	3461
VA NORTHAMPTON	17160	570	37.37	75.91	3558
VA NORTHUMBERLA	10088	492	37.89	76.42	3513
VA NOTTOWAY	15332	798	37.14	78.05	3367
VA ORANGE	12817	919	38.25	78.01	3374
VA PAGE	15329	817	38.62	78.49	3334
VA PATRICK	15493	1202	36.69	80.30	3168
VA PITTSYLVANIA	102742	2636	36.82	79.40	3248
VA POWHATAN	6063	696	37.55	77.91	3380
VA PRINCE EDWAR	14854	924	37.22	78.44	3333
VA PRINCE GEORG	19915	737	37.19	77.24	3439
VA PRINCE WILLI	34323	899	38.71	77.48	3423

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
VA PULASKI	27547	850	37.06	80.71	3132
VA RAPPAHANNOCK	5797	692	38.69	78.16	3363
VA RICHMOND	6268	492	37.94	76.73	3486
VA ROANOKE	144202	785	37.26	80.06	3190
VA ROCKBRIDGE	29326	1572	37.81	79.45	3245
VA ROCKINGHAM	48661	2256	38.52	78.89	3298
VA RUSSELL	26594	1251	36.93	82.09	3009
VA SCOTT	26860	1396	36.71	82.61	2963
VA SHENANDOAH	21447	1313	38.87	78.57	3327
VA SMYTH	30563	1127	36.83	81.53	3059
VA SOUTHAMPTON	26813	1569	36.72	77.10	3452
VA SPOTSYLVANIA	25519	1075	38.19	77.65	3406
VA STAFFORD	14019	699	38.42	77.46	3424
VA SURRY	6219	716	37.10	76.90	3469
VA SUSSEX	12625	1279	36.92	77.26	3438
VA TAZEWELL	46354	1351	37.12	81.56	3056
VA WARREN	14738	567	38.92	78.21	3360
VA WASHINGTON	54224	1497	36.72	81.96	3020
VA WESTMORELAND	10526	592	38.11	76.83	3478
VA WISE	53037	1076	36.97	82.62	2962
VA WYTHE	22752	1190	36.91	81.07	3100
VA YORK	15689	333	37.22	76.54	3502
VA NORFOLK/CHES	424997	1096	36.70	76.31	3522
VA HAMPTON	72300	142	37.04	76.35	3519
VA NEWPORT NEWS	94805	178	36.97	76.42	3512
VA SUFFOLK/NANS	40137	1057	36.69	76.64	3493
VA VIRGINIA BEA	59052	671	36.74	76.22	3530
WA ADAMS	8005	4904	46.98	118.56	1132
WA ASOTIN	11741	1638	46.20	117.20	1028
WA BENTON	55924	4459	46.24	119.52	1072
WA CHELAN	39914	7557	47.87	120.62	1275
WA CLALLAM	27936	4539	48.06	123.92	1416
WA CLARK	88920	1624	45.77	122.49	1132
WA COLUMBIA	4736	2208	46.30	117.92	1048
WA COWLITZ	55253	2962	46.19	122.68	1181
WA DOUGLAS	12549	4741	47.73	119.70	1236
WA FERRY	4008	5702	48.47	118.52	1294
WA FRANKLIN	17721	3244	46.54	118.90	1091
WA GARFIELD	3106	1835	46.43	117.55	1057
WA GRANT	33751	6927	47.20	119.46	1174
WA GRAYS HARBOR	53994	4946	47.16	123.74	1321
WA ISLAND	14716	549	48.15	122.53	1367
WA JEFFERSON	10777	4674	47.76	123.55	1371
WA KING	818856	5511	47.48	121.78	1272

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
WA KITSAP	79318	1017	47.60	122.65	1317
WA KITTITAS	21482	6000	47.12	120.68	1198
WA KLICKITAT	12646	4941	45.87	120.79	1074
WA LEWIS	42953	6275	46.57	122.40	1206
WA LINCOLN	10946	5972	47.57	118.42	1194
WA MASON	15544	2491	47.35	123.20	1315
WA OKANOGAN	27598	13729	48.55	119.74	1325
WA PACIFIC	15753	2351	46.56	123.68	1261
WA PEND OREILLE	7201	3631	48.53	117.27	1286
WA PIERCE	295305	4340	48.01	122.18	1341
WA SAN JUAN	3086	464	48.45	122.99	1415
WA SKAGIT	46704	4493	48.47	121.71	1372
WA SKAMANIA	4966	4329	46.02	121.92	1131
WA SNOHOMISH	137345	5433	48.04	121.67	1326
WA SPOKANE	245691	4553	47.62	117.40	1187
WA STEVENS	18287	6425	48.40	117.86	1277
WA THURSTON	49204	1849	46.91	122.83	1257
WA WAHKIAKUM	3659	675	46.29	123.41	1224
WA WALLA WALLA	41010	3268	46.23	118.49	1049
WA WHATCOM	68259	5505	48.82	121.69	1407
WA WHITMAN	31956	5575	46.90	117.51	1108
WA YAKIMA	139720	11053	46.45	120.74	1131
WV BARBOUR	17934	882	39.13	80.00	3203
WV BERKELEY	31816	817	39.47	78.03	3381
WV BOONE	31301	1297	38.02	81.71	3045
WV BRAXTON	16837	1323	38.70	80.72	3136
WV BROOKE	27774	228	40.28	80.58	3164
WV CABELL	108110	723	38.43	82.24	3000
WV CALHOUN	9279	727	38.85	81.12	3102
WV CLAY	13679	888	38.46	81.07	3104
WV DODDRIDGE	8151	826	39.27	80.71	3142
WV FAYETTE	73639	1717	38.03	81.07	3101
WV GILMER	9028	878	38.92	80.86	3125
WV GRANT	8561	1238	39.11	79.20	3274
WV GREENBRIER	37235	2657	37.95	80.45	3156
WV HAMPSHIRE	12208	1655	39.32	78.62	3327
WV HANCOCK	36608	215	40.53	80.58	3167
WV HARDY	9726	1514	39.01	78.87	3303
WV HARRISON	82137	1082	39.29	80.39	3171
WV JACKSON	16678	1193	38.85	81.67	3053
WV JEFFERSON	17813	546	39.31	77.86	3394
WV KANAWHA	245281	2349	38.34	81.52	3064
WV LEWIS	20497	1014	39.00	80.50	3158
WV LINCOLN	21531	1134	38.17	82.06	3015

State county	Population	Area (km²)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
WV LOGAN	70671	1180	37.83	81.94	3024
WV MCDOWELL	87191	1379	37.38	81.66	3048
WV MARION	68206	805	39.51	80.24	3186
WV MARSHALL	37380	786	39.87	80.67	3152
WV MASON	23930	1120	38.77	82.03	3021
WV MERCER	72119	1079	37.40	81.11	3096
WV MINERAL	22341	854	39.41	78.95	3299
WV MINGO	44148	1096	37.72	82.14	3006
WV MONONGALIA	58597	944	39.63	80.04	3205
WV MONROE	12470	1224	37.56	80.55	3147
WV MORGAN	8320	602	39.56	78.27	3360
WV NICHOLAS	26730	1662	38.29	80.80	3127
WV OHIO	70300	274	40.10	80.63	3158
WV PENDLETON	8794	1800	38.68	79.36	3257
WV PLEASANTS	6691	333	39.37	81.17	3102
WV POCAHONTAS	11485	2441	38.33	80.01	3197
WV PRESTON	29633	1670	39.47	79.67	3235
WV PUTNAM	22100	900	38.51	81.90	3030
WV RALEIGH	88436	1566	37.77	81.25	3085
WV RANDOLPH	28770	2682	38.78	79.88	3211
WV RITCHIE	11830	1171	39.18	81.06	3110
WV ROANE	17262	1258	38.72	81.34	3081
WV SUMMERS	17678	906	37.65	80.86	3119
WV TAYLOR	16975	450	39.34	80.05	3201
WV TUCKER	9393	1089	39.11	79.56	3242
WV TYLER	10317	663	39.47	80.89	3128
WV UPSHUR	18838	912	38.90	80.24	3181
WV WAYNE	38816	1328	38.15	82.42	2983
WV WEBSTER	16114	1427	38.50	80.42	3162
WV WETZEL	19811	940	39.61	80.64	3152
WV WIRT	4813	609	39.03	81.38	3081
WV WOOD	71550	952	39.22	81.52	3070
WV WYOMING	36391	1304	37.61	81.54	3058
WI ADAMS	7761	1673	43.97	89.76	2454
WI ASHLAND	18575	2688	46.27	90.67	2472
WI BARRON	34517	2237	45.43	91.85	2339
WI BAYFIELD	12978	3780	46.51	91.19	2442
WI BROWN	109694	1356	44.45	88.00	2619
WI BUFFALO	14499	1841	44.39	91.75	2303
WI BURNETT	9802	2175	45.86	92.38	2315
WI CALUMET	20298	833	44.08	88.22	2588
WI CHIPPEWA	43798	2636	45.08	91.28	2370
WI CLARK	32062	3161	44.74	90.61	2412
WI COLUMBIA	35165	2009	43.47	89.33	2473

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
WI CRAWFORD	17101	1470	43.24	90.92	2331
WI DANE	191774	3102	43.07	89.42	2453
WI DODGE	59975	2302	43.42	88.71	2525
WI DOOR	20792	1273	44.91	87.35	2690
WI DOUGLAS	45989	3379	46.43	91.92	2380
WI DUNN	26839	2208	44.95	91.90	2314
WI EAU CLAIRE	55937	1676	44.73	91.29	2355
WI FLORENCE	3621	1261	45.85	88.41	2638
WI FOND DU LAC	70916	1877	43.75	88.50	2553
WI FOREST	8633	2608	45.66	88.77	2601
WI GRANT	42717	2971	42.87	90.70	2338
WI GREEN	24884	1514	42.68	89.61	2426
WI GREEN LAKE	15033	916	43.80	89.04	2509
WI IOWA	19617	1973	43.00	90.14	2390
WI IRON	8338	1935	46.26	90.24	2507
WI JACKSON	15683	2586	44.32	90.81	2379
WI JEFFERSON	46055	1461	43.02	88.78	2507
WI JUNEAU	18317	2004	43.92	90.11	2423
WI KENOSHA	86022	703	42.58	88.05	2557
WI KEWAUNEE	17754	854	44.51	87.61	2653
WI LA CROSSE	69664	1168	43.91	91.12	2338
WI LAFAYETTE	18141	1665	42.66	90.13	2380
WI LANGLADE	21099	2216	45.26	89.07	2560
WI LINCOLN	22278	2309	45.34	89.73	2509
WI MANITOWOC	70580	1528	44.12	87.81	2623
WI MARATHON	83966	4107	44.90	89.75	2489
WI MARINETTE	35284	3569	45.38	88.04	2650
WI MARQUETTE	8700	1178	43.82	89.39	2480
WI MENOMINEE	3031	931	45.00	88.75	2576
WI MILWAUKEE	941174	613	43.01	87.96	2576
WI MONROE	31322	2370	43.94	90.61	2381
WI OCONTO	24478	2592	45.02	88.29	2615
WI ONEIDA	21264	2879	45.70	89.52	2541
WI OUTAGAMIE	90257	1642	44.42	88.46	2579
WI OZAUKEE	29766	610	43.38	87.94	2589
WI PEPIN	7406	609	44.59	92.00	2290
WI PIERCE	21893	1528	44.73	92.43	2261
WI POLK	24954	2411	45.46	92.46	2291
WI PORTAGE	35752	2087	44.47	89.49	2494
WI PRICE	15505	3262	45.68	90.36	2472
WI RACINE	123273	872	42.75	88.06	2561
WI RICHLAND	18583	1510	43.38	90.43	2377
WI ROCK	101761	1866	42.67	89.08	2471
WI RUSK	15939	2346	45.48	91.13	2400

State county	Population	Area (km^2)	Latitude (degrees)	Longitude (degrees)	Distance from NTS (km)
WI ST CROIX	27286	1901	45.04	92.47	2271
WI SAUK	37294	2177	43.43	89.95	2420
WI SAWYER	9965	3261	45.88	91.14	2417
WI SHAWANO	33119	2380	44.84	88.76	2569
WI SHEBOYGAN	83122	1307	43.72	87.94	2599
WI TAYLOR	18193	2525	45.22	90.50	2440
WI TREMPEALEAU	23578	1904	44.31	91.36	2332
WI VERNON	26954	2077	43.60	90.83	2350
WI VILAS	9349	2246	46.05	89.51	2557
WI WALWORTH	46167	1442	42.67	88.55	2516
WI WASHBURN	11086	2115	45.90	91.79	2365
WI WASHINGTON	39097	1110	43.37	88.23	2564
WI WAUKESHA	116651	1434	43.02	88.31	2547
WI WAUPACA	35176	1945	44.47	88.96	2539
WI WAUSHARA	13737	1624	44.11	89.24	2503
WI WINNEBAGO	98257	1159	44.07	88.64	2552
WI WOOD	54157	2090	44.46	90.04	2448
WY ALBANY	20007	11001	41.65	105.72	1048
WY BIG HORN	12636	8176	44.53	107.99	1098
WY CAMPBELL	5268	12317	44.25	105.54	1229
WY CARBON	15403	20473	41.70	106.93	960
WY CONVERSE	6117	11087	42.97	105.50	1144
WY CROOK	4720	7463	44.59	104.57	1320
WY FREMONT	22378	23817	43.04	108.62	937
WY GOSHEN	12344	5770	42.09	104.36	1178
WY HOT SPRINGS	5722	5236	43.72	108.43	1004
WY JOHNSON	5032	10812	44.03	106.57	1145
WY LARAMIE	52970	7000	41.31	104.69	1112
WY LINCOLN	9022	10579	42.25	110.65	752
WY NATRONA	39168	13835	42.97	106.79	1052
WY NIOBRARA	4293	6769	43.06	104.48	1224
WY PARK	13084	18023	44.44	109.31	1018
WY PLATTE	7619	5402	42.13	104.96	1133
WY SHERIDAN	19676	6557	44.79	106.88	1185
WY SUBLETTE	3033	12563	42.77	109.91	838
WY SWEETWATER	20278	27010	41.66	108.88	817
WY TETON	2775	10359	43.71	110.57	888
WY UINTA	7392	5402	41.29	110.55	679
WY WASHAKIE	7947	5858	43.91	107.68	1065
WY WESTON	7446	6233	43.84	104.56	1269
TOTAL	162516697	7674784			

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Information on Pasture Practices

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OF THE YEAR, PIW, IN KG (DRY) D-1

:timated pasture intakes, averaged over the pasture season (PIA),
ıd for the first “week” of January (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	0.0	NEW JERSEY	5.06	0.0
ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.0	OKLAHOMA	4.67	0.0
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	0.0	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.9	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	0.0	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the second “week” of January (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	0.0
.ABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.0
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
.ORIDA	1.78	1.8
EORGIA-north	5.06	0.0
EORGIA-south	5.07	4.9
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	0.0
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0
Area	**PIA (kg/d)**	**PIW (kg/d)**
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	0.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	0.0
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	0.0
SOUTH CAROLINA-west	4.96	0.0
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	0.0
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the third “week” of January (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	0.0
ABAMA-south	4.24	3.6
IZONA-remainder	0.72	0.7
IZONA-northwest	5.04	0.0
KANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.0
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
ORIDA	1.78	1.8
EORGIA-north	5.06	0.0
EORGIA-south	5.07	4.9
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	0.0
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	0.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	0.0
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	0.0
SOUTH CAROLINA-west	4.96	0.0
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	0.0
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the last "week" of January (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	0.0	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.0	OKLAHOMA	4.67	0.0
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	0.0	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.9	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	0.0	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the first “week” of February (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	0.0	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.0	OKLAHOMA	4.67	0.0
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	0.0	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.9	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	0.0	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the second “week” of February (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
_ABAMA-north	4.97	0.0
_ABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.2
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
_ORIDA	1.78	1.8
EORGIA-north	5.06	0.0
EORGIA-south	5.07	4.9
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	0.0
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	0.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	0.0
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	0.0
SOUTH CAROLINA-west	4.96	0.0
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	0.0
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the third "week" of February (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	0.0	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.6	OKLAHOMA	4.67	0.0
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	0.0	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.9	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	0.0	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the last “week” of February (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	1.2	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	1.3	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.6	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	1.8
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	1.7
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	1.2	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.9	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the first “week” of March (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	3.6	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	3.8	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	1.3	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	1.9	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	5.5
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	5.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	1.7
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	3.7	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.9	TEXAS-east	6.44	2.4
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	3.7	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the second “week” of March (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	4.8	NEW JERSEY	5.06	0.0
ABAMA-south	4.24	4.8	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	1.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	3.8	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	7.3
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	5.0
ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	4.9	TENNESSEE	4.36	0.6
EORGIA-south	5.07	4.9	TEXAS-east	6.44	7.3
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	4.9	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the third “week” of March (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8
LABAMA-south	4.24	4.8
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	5.1
ALIFORNIA-north	6.31	5.1
ALIFORNIA-middle	3.51	2.6
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
LORIDA	1.78	1.8
EORGIA-north	5.06	4.9
EORGIA-south	5.07	4.9
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	4.9
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	4.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	7.3
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	6.7
SOUTH CAROLINA-west	4.96	6.7
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	1.8
TEXAS-east	6.44	9.8
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the last “week” of March (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8
LABAMA-south	4.24	4.8
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	5.1
ALIFORNIA-north	6.31	5.1
ALIFORNIA-middle	3.51	2.6
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
LORIDA	1.78	1.8
EORGIA-north	5.06	4.9
EORGIA-south	5.07	4.9
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	1.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	4.9
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	5.3
NORTH CAROLINA-west	4.23	1.3
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	7.3
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	6.7
SOUTH CAROLINA-west	4.96	6.7
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	2.4
TEXAS-east	6.44	9.8
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the first “week” of April (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	5.4	NEW JERSEY	5.06	0.0
LABAMA-south	4.24	4.8	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	5.3
RKANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	5.1	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	7.3
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	6.7
LORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	5.6	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	9.8
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	3.1	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	4.9	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the second "week" of April (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	5.4	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	1.2	NORTH CAROLINA-east	4.28	5.3
RKANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	5.3
ALIFORNIA-north	6.31	5.1	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	7.3
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	1.9
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	2.1	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	2.3	SOUTH CAROLINA-west	4.96	6.7
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	5.6	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	9.8
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
IDIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	4.2	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	2.3	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	1.5
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	4.9	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	2.3
ONTANA	9.02	0.0	WASHINGTON	7.31	1.9
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the third "week" of April (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	5.4	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	0.6
IZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
IZONA-northwest	5.04	3.7	NORTH CAROLINA-east	4.28	5.3
KANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	5.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	7.3
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	5.6
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	6.2	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	6.8	SOUTH CAROLINA-west	4.96	6.7
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	5.6	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	9.8
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	4.2	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	6.8	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	4.6
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	4.9	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	6.9
ONTANA	9.02	0.0	WASHINGTON	7.31	5.8
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	2.2
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the last "week" of April (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
_ABAMA-north	4.97	5.4	NEW JERSEY	5.06	1.9
_ABAMA-south	4.24	4.8	NEW MEXICO	2.49	1.9
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	5.3
RKANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	5.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	2.8
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	7.3
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	7.5
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	1.9
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	8.3	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	9.1	SOUTH CAROLINA-west	4.96	6.7
_ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	5.6	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	9.8
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	1.9	UTAH - region 1	7.43	0.0
DIANA	5.84	1.5	UTAH - region 2	10.80	0.0
WA	5.51	1.8	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	2.1	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	4.2	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	9.1	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	6.1
INNESOTA	8.23	0.0	UTAH - region 12	10.80	2.7
ISSISSIPPI-north	3.01	4.9	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	0.0
ISSOURI	7.47	2.4	VIRGINIA	5.89	9.2
ONTANA	9.02	0.0	WASHINGTON	7.31	7.7
EBRASKA	6.93	1.9	WEST VIRGINIA	5.51	6.5
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the first “week” of May (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	5.4	NEW JERSEY	5.06	5.7
ABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	5.3
RKANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	5.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	8.3
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	5.8
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	7.5
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	5.8
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	8.3	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	9.1	SOUTH CAROLINA-west	4.96	6.7
ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	5.6	TENNESSEE	4.36	5.9
EORGIA-south	5.07	5.6	TEXAS-east	6.44	9.8
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	5.8	UTAH - region 1	7.43	0.0
DIANA	5.84	4.6	UTAH - region 2	10.80	0.0
WA	5.51	5.3	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	6.4	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	6.9	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	9.1	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.2
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	6.1
INNESOTA	8.23	0.0	UTAH - region 12	10.80	8.1
ISSISSIPPI-north	3.01	2.5	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	0.0
ISSOURI	7.47	7.3	VIRGINIA	5.89	9.2
ONTANA	9.02	0.0	WASHINGTON	7.31	7.7
EBRASKA	6.93	5.6	WEST VIRGINIA	5.51	8.7
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the second “week” of May (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	5.4
ABAMA-south	4.24	4.8
IZONA-remainder	0.72	0.7
IZONA-northwest	5.04	5.0
KANSAS	6.04	7.0
LIFORNIA-north	6.31	8.5
LIFORNIA-middle	3.51	5.1
LIFORNIA-south	0.85	0.9
LIFORNIA-Inyo	2.21	0.5
LORADO	6.72	1.2
NNECTICUT	7.16	2.2
LAWARE	5.52	8.3
ASHINGTON DC	6.73	9.1
ORIDA	1.78	1.8
ORGIA-north	5.06	5.6
ORGIA-south	5.07	5.6
AHO	9.14	1.4
LINOIS	6.28	7.8
DIANA	5.84	6.1
WA	5.51	7.1
NSAS	7.34	8.5
NTUCKY	4.92	6.9
UISIANA	5.87	6.4
AINE	7.87	2.4
ARYLAND	6.73	9.1
ASSACHUSETTS	5.09	2.3
ICHIGAN	7.83	2.3
INNESOTA	8.23	2.5
ISSISSIPPI-north	3.01	2.5
ISSISSIPPI-south	3.43	3.7
ISSOURI	7.47	9.8
ONTANA	9.02	1.7
BRASKA	6.93	7.5
VADA	2.61	0.6
W HAMPSHIRE	7.57	2.4

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	7.6
NEW MEXICO	2.49	2.5
NEW YORK	5.67	2.0
NORTH CAROLINA-east	4.28	5.3
NORTH CAROLINA-west	4.23	5.3
NORTH DAKOTA	6.65	2.0
OHIO	9.19	11.1
OKLAHOMA	4.67	5.8
OREGON	7.05	7.5
PENNSYLVANIA	4.36	7.7
RHODE ISLAND	8.34	2.4
SOUTH CAROLINA-east	5.01	6.7
SOUTH CAROLINA-west	4.96	6.7
SOUTH DAKOTA	6.61	1.8
TENNESSEE	4.36	5.9
TEXAS-east	6.44	9.8
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	1.8
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	2.0
UTAH - region 4	6.75	1.7
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	2.2
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.7
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	1.3
VERMONT	7.33	2.5
VIRGINIA	5.89	9.2
WASHINGTON	7.31	7.7
WEST VIRGINIA	5.51	8.7
WISCONSIN	7.53	2.1
WYOMING	5.67	0.7

the third “week” of May (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	5.4
ABAMA-south	4.24	4.8
IZONA-remainder	0.72	0.7
IZONA-northwest	5.04	5.0
KANSAS	6.04	7.0
LIFORNIA-north	6.31	8.5
LIFORNIA-middle	3.51	5.1
LIFORNIA-south	0.85	0.9
LIFORNIA-Inyo	2.21	1.6
LORADO	6.72	3.5
NNECTICUT	7.16	6.6
LAWARE	5.52	8.3
ASHINGTON DC	6.73	9.1
ORIDA	1.78	1.8
ORGIA-north	5.06	5.6
ORGIA-south	5.07	5.6
AHO	9.14	4.3
LINOIS	6.28	7.8
DIANA	5.84	6.1
WA	5.51	7.1
NSAS	7.34	8.5
NTUCKY	4.92	6.9
UISIANA	5.87	6.4
AINE	7.87	7.2
ARYLAND	6.73	9.1
ASSACHUSETTS	5.09	6.8
ICHIGAN	7.83	7.0
INNESOTA	8.23	7.6
ISSISSIPPI-north	3.01	2.5
ISSISSIPPI-south	3.43	2.5
ISSOURI	7.47	9.8
ONTANA	9.02	5.0
BRASKA	6.93	7.5
VADA	2.61	1.9
W HAMPSHIRE	7.57	7.3
Area	**PIA (kg/d)**	**PIW (kg/d)**
NEW JERSEY	5.06	7.6
NEW MEXICO	2.49	2.5
NEW YORK	5.67	6.1
NORTH CAROLINA-east	4.28	5.3
NORTH CAROLINA-west	4.23	5.3
NORTH DAKOTA	6.65	6.1
OHIO	9.19	11.1
OKLAHOMA	4.67	5.8
OREGON	7.05	7.5
PENNSYLVANIA	4.36	7.7
RHODE ISLAND	8.34	7.3
SOUTH CAROLINA-east	5.01	6.7
SOUTH CAROLINA-west	4.96	6.7
SOUTH DAKOTA	6.61	5.5
TENNESSEE	4.36	5.9
TEXAS-east	6.44	9.8
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	5.5
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	6.1
UTAH - region 4	6.75	5.1
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	6.7
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	1.7
UTAH - region 10	0.94	0.9
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	4.0
VERMONT	7.33	7.4
VIRGINIA	5.89	9.2
WASHINGTON	7.31	7.7
WEST VIRGINIA	5.51	8.7
WISCONSIN	7.53	6.4
WYOMING	5.67	2.2

the last “week” of May (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	5.4	NEW JERSEY	5.06	7.6
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	8.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	5.3
RKANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	5.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	8.2
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	11.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	5.8
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	7.5
OLORADO	6.72	4.7	PENNSYLVANIA	4.36	7.7
ONNECTICUT	7.16	8.8	RHODE ISLAND	8.34	9.7
ELAWARE	5.52	8.3	SOUTH CAROLINA-east	5.01	6.7
ASHINGTON DC	6.73	9.1	SOUTH CAROLINA-west	4.96	6.7
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	7.3
EORGIA-north	5.06	5.6	TENNESSEE	4.36	5.9
EORGIA-south	5.07	5.6	TEXAS-east	6.44	9.8
AHO	9.14	5.8	TEXAS-west	2.10	2.1
LINOIS	6.28	7.8	UTAH - region 1	7.43	7.4
DIANA	5.84	6.1	UTAH - region 2	10.80	2.7
WA	5.51	7.1	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	8.5	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	6.9	UTAH - region 6	9.05	2.2
OUISIANA	5.87	6.4	UTAH - region 7	9.05	9.0
AINE	7.87	9.6	UTAH - region 8	10.13	2.5
ARYLAND	6.73	9.1	UTAH - region 9	6.75	5.1
ASSACHUSETTS	5.09	9.1	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	9.3	UTAH - region 11	6.07	6.1
INNESOTA	8.23	10.2	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	2.5	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	2.5	VERMONT	7.33	9.9
ISSOURI	7.47	9.8	VIRGINIA	5.89	9.2
ONTANA	9.02	6.7	WASHINGTON	7.31	7.7
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	8.7
EVADA	2.61	2.6	WISCONSIN	7.53	8.6
EW HAMPSHIRE	7.57	9.8	WYOMING	5.67	3.0

the first "week" of June (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	5.4	NEW JERSEY	5.06	7.6
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	8.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	5.3
RKANSAS	6.04	7.0	NORTH CAROLINA-west	4.23	5.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	8.2
ALIFORNIA-middle	3.51	5.1	OHIO	9.19	11.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	4.4
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	7.9	PENNSYLVANIA	4.36	7.7
ONNECTICUT	7.16	8.8	RHODE ISLAND	8.34	9.7
ELAWARE	5.52	8.3	SOUTH CAROLINA-east	5.01	4.0
ASHINGTON DC	6.73	9.1	SOUTH CAROLINA-west	4.96	4.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	7.3
EORGIA-north	5.06	5.6	TENNESSEE	4.36	5.9
EORGIA-south	5.07	5.6	TEXAS-east	6.44	4.2
AHO	9.14	11.6	TEXAS-west	2.10	2.1
LINOIS	6.28	7.8	UTAH - region 1	7.43	7.4
DIANA	5.84	9.2	UTAH - region 2	10.80	8.1
WA	5.51	7.1	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	8.5	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	6.9	UTAH - region 6	9.05	6.7
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	9.6	UTAH - region 8	10.13	7.6
ARYLAND	6.73	9.1	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	9.1	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	9.3	UTAH - region 11	6.07	6.1
INNESOTA	8.23	10.2	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	2.5	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	2.5	VERMONT	7.33	9.9
ISSOURI	7.47	9.8	VIRGINIA	5.89	6.6
ONTANA	9.02	11.9	WASHINGTON	7.31	6.9
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	6.2
EVADA	2.61	2.6	WISCONSIN	7.53	8.6
EW HAMPSHIRE	7.57	9.8	WYOMING	5.67	7.5

the second “week” of June (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	5.4
LABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	5.0
RKANSAS	6.04	7.0
ALIFORNIA-north	6.31	8.5
ALIFORNIA-middle	3.51	5.1
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	2.2
OLORADO	6.72	7.9
ONNECTICUT	7.16	8.8
ELAWARE	5.52	8.3
ASHINGTON DC	6.73	9.1
LORIDA	1.78	1.8
EORGIA-north	5.06	5.6
EORGIA-south	5.07	5.6
AHO	9.14	11.6
LINOIS	6.28	7.8
DIANA	5.84	9.2
WA	5.51	7.1
ANSAS	7.34	8.5
ENTUCKY	4.92	6.9
OUISIANA	5.87	5.1
AINE	7.87	9.6
ARYLAND	6.73	9.1
ASSACHUSETTS	5.09	9.1
ICHIGAN	7.83	9.3
INNESOTA	8.23	10.2
ISSISSIPPI-north	3.01	2.5
ISSISSIPPI-south	3.43	2.5
ISSOURI	7.47	9.8
ONTANA	9.02	11.9
EBRASKA	6.93	7.5
EVADA	2.61	2.6
EW HAMPSHIRE	7.57	9.8

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	7.6
NEW MEXICO	2.49	2.5
NEW YORK	5.67	8.1
NORTH CAROLINA-east	4.28	5.3
NORTH CAROLINA-west	4.23	5.3
NORTH DAKOTA	6.65	8.2
OHIO	9.19	11.1
OKLAHOMA	4.67	4.4
OREGON	7.05	6.6
PENNSYLVANIA	4.36	7.7
RHODE ISLAND	8.34	9.7
SOUTH CAROLINA-east	5.01	4.0
SOUTH CAROLINA-west	4.96	4.0
SOUTH DAKOTA	6.61	7.3
TENNESSEE	4.36	5.9
TEXAS-east	6.44	4.2
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	7.4
UTAH - region 2	10.80	10.8
UTAH - region 3, 5	8.10	8.1
UTAH - region 4	6.75	6.8
UTAH - region 6	9.05	9.0
UTAH - region 7	9.05	9.0
UTAH - region 8	10.13	10.1
UTAH - region 9	6.75	6.8
UTAH - region 10	0.94	0.9
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	5.4
VERMONT	7.33	9.9
VIRGINIA	5.89	6.6
WASHINGTON	7.31	6.9
WEST VIRGINIA	5.51	6.2
WISCONSIN	7.53	8.6
WYOMING	5.67	7.5

the third “week” of June (PIW), in kg(dry)/d.

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.ABAMA-south	4.24	3.6
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RIZONA-northwest	5.04	5.0
RKANSAS	6.04	5.1
ALIFORNIA-north	6.31	8.5
ALIFORNIA-middle	3.51	5.1
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	2.2
OLORADO	6.72	7.9
ONNECTICUT	7.16	8.8
ELAWARE	5.52	8.3
ASHINGTON DC	6.73	9.1
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EORGIA-north	5.06	5.6
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AHO	9.14	11.6
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ISSISSIPPI-south	3.43	2.5
ISSOURI	7.47	9.8
ONTANA	9.02	11.9
EBRASKA	6.93	7.5
EVADA	2.61	2.6
EW HAMPSHIRE	7.57	9.8

Area	PIA (kg/d)	PIW (kg/d)
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NEW MEXICO	2.49	2.5
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NORTH CAROLINA-east	4.28	3.3
NORTH CAROLINA-west	4.23	3.3
NORTH DAKOTA	6.65	8.2
OHIO	9.19	11.1
OKLAHOMA	4.67	4.4
OREGON	7.05	6.6
PENNSYLVANIA	4.36	7.7
RHODE ISLAND	8.34	9.7
SOUTH CAROLINA-east	5.01	4.0
SOUTH CAROLINA-west	4.96	4.0
SOUTH DAKOTA	6.61	7.3
TENNESSEE	4.36	5.9
TEXAS-east	6.44	4.2
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	7.4
UTAH - region 2	10.80	10.8
UTAH - region 3, 5	8.10	8.1
UTAH - region 4	6.75	6.8
UTAH - region 6	9.05	9.0
UTAH - region 7	9.05	9.0
UTAH - region 8	10.13	10.1
UTAH - region 9	6.75	6.8
UTAH - region 10	0.94	0.9
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	5.4
VERMONT	7.33	9.9
VIRGINIA	5.89	6.6
WASHINGTON	7.31	6.9
WEST VIRGINIA	5.51	6.2
WISCONSIN	7.53	8.6
WYOMING	5.67	7.5

the last “week” of June (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	5.4	NEW JERSEY	5.06	7.6
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	8.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	3.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	3.3
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ALIFORNIA-middle	3.51	5.1	OHIO	9.19	11.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	4.4
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	7.9	PENNSYLVANIA	4.36	7.7
ONNECTICUT	7.16	8.8	RHODE ISLAND	8.34	9.7
ELAWARE	5.52	8.3	SOUTH CAROLINA-east	5.01	4.0
ASHINGTON DC	6.73	9.1	SOUTH CAROLINA-west	4.96	4.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	7.3
EORGIA-north	5.06	5.6	TENNESSEE	4.36	5.9
EORGIA-south	5.07	5.6	TEXAS-east	6.44	4.2
AHO	9.14	11.6	TEXAS-west	2.10	2.1
LINOIS	6.28	7.8	UTAH - region 1	7.43	7.4
DIANA	5.84	9.2	UTAH - region 2	10.80	10.8
WA	5.51	7.1	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	8.5	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	6.9	UTAH - region 6	9.05	9.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	9.6	UTAH - region 8	10.13	10.1
ARYLAND	6.73	9.1	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	9.1	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	9.3	UTAH - region 11	6.07	6.1
INNESOTA	8.23	10.2	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	2.5	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	2.5	VERMONT	7.33	9.9
ISSOURI	7.47	9.8	VIRGINIA	5.89	6.6
ONTANA	9.02	11.9	WASHINGTON	7.31	6.9
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	6.2
EVADA	2.61	2.6	WISCONSIN	7.53	8.6
EW HAMPSHIRE	7.57	9.8	WYOMING	5.67	7.5

the first “week” of July (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	5.4	NEW JERSEY	5.06	2.3
ABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	4.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	3.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	3.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	5.4
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	7.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	7.9	PENNSYLVANIA	4.36	2.3
ONNECTICUT	7.16	5.8	RHODE ISLAND	8.34	9.7
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	2.7
ASHINGTON DC	6.73	4.6	SOUTH CAROLINA-west	4.96	2.7
ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	5.8
EORGIA-north	5.06	4.2	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	4.2
AHO	9.14	10.1	TEXAS-west	2.10	2.1
LINOIS	6.28	6.3	UTAH - region 1	7.43	7.4
DIANA	5.84	7.7	UTAH - region 2	10.80	10.8
WA	5.51	4.2	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	5.6	UTAH - region 6	9.05	9.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	7.7	UTAH - region 8	10.13	10.1
ARYLAND	6.73	4.6	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	3.0	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	7.8	UTAH - region 11	6.07	6.1
INNESOTA	8.23	6.8	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	5.6
ISSOURI	7.47	5.6	VIRGINIA	5.89	3.9
ONTANA	9.02	11.9	WASHINGTON	7.31	6.9
EBRASKA	6.93	6.0	WEST VIRGINIA	5.51	3.7
EVADA	2.61	2.6	WISCONSIN	7.53	8.6
EW HAMPSHIRE	7.57	6.0	WYOMING	5.67	7.5

the second “week” of July (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	5.4	NEW JERSEY	5.06	2.3
LABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	4.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	3.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	3.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	5.4
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	7.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	7.9	PENNSYLVANIA	4.36	2.3
ONNECTICUT	7.16	5.8	RHODE ISLAND	8.34	9.7
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	2.7
ASHINGTON DC	6.73	4.6	SOUTH CAROLINA-west	4.96	2.7
LORIDA	1.78	1.8	SOUTH DAKOTA	6.61	5.8
EORGIA-north	5.06	4.2	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	4.2
AHO	9.14	10.1	TEXAS-west	2.10	2.1
LINOIS	6.28	6.3	UTAH - region 1	7.43	7.4
DIANA	5.84	7.7	UTAH - region 2	10.80	10.8
WA	5.51	4.2	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	5.6	UTAH - region 6	9.05	9.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	7.7	UTAH - region 8	10.13	10.1
ARYLAND	6.73	4.6	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	3.0	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	7.8	UTAH - region 11	6.07	6.1
INNESOTA	8.23	6.8	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	5.6
ISSOURI	7.47	5.6	VIRGINIA	5.89	3.9
ONTANA	9.02	11.9	WASHINGTON	7.31	6.9
EBRASKA	6.93	6.0	WEST VIRGINIA	5.51	3.7
EVADA	2.61	2.6	WISCONSIN	7.53	8.6
EW HAMPSHIRE	7.57	6.0	WYOMING	5.67	7.5

the third “week” of July (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	5.4	NEW JERSEY	5.06	2.3
ABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	4.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	3.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	3.3
ALIFORNIA-north	6.31	8.5	NORTH DAKOTA	6.65	5.4
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	7.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	7.9	PENNSYLVANIA	4.36	2.3
ONNECTICUT	7.16	5.8	RHODE ISLAND	8.34	6.7
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	2.7
ASHINGTON DC	6.73	4.6	SOUTH CAROLINA-west	4.96	2.7
LORIDA	1.78	1.8	SOUTH DAKOTA	6.61	5.8
EORGIA-north	5.06	4.2	TENNESSEE	4.36	4.7
EORGIA-south	5.07	5.6	TEXAS-east	6.44	4.2
AHO	9.14	10.1	TEXAS-west	2.10	2.1
LINOIS	6.28	6.3	UTAH - region 1	7.43	7.4
DIANA	5.84	7.7	UTAH - region 2	10.80	10.8
WA	5.51	4.2	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	5.6	UTAH - region 6	9.05	9.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	7.7	UTAH - region 8	10.13	10.1
ARYLAND	6.73	4.6	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	3.0	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	7.8	UTAH - region 11	6.07	6.1
INNESOTA	8.23	6.8	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	5.6
ISSOURI	7.47	5.6	VIRGINIA	5.89	3.9
ONTANA	9.02	11.9	WASHINGTON	7.31	6.9
EBRASKA	6.93	6.0	WEST VIRGINIA	5.51	3.7
EVADA	2.61	2.6	WISCONSIN	7.53	8.6
EW HAMPSHIRE	7.57	6.0	WYOMING	5.67	7.5

the last "week" of July (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	5.4
LABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	5.0
RKANSAS	6.04	5.1
ALIFORNIA-north	6.31	8.5
ALIFORNIA-middle	3.51	2.6
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	2.2
OLORADO	6.72	7.9
ONNECTICUT	7.16	5.8
ELAWARE	5.52	2.8
ASHINGTON DC	6.73	4.6
LORIDA	1.78	1.8
EORGIA-north	5.06	4.2
EORGIA-south	5.07	5.6
AHO	9.14	10.1
LINOIS	6.28	6.3
DIANA	5.84	7.7
WA	5.51	4.2
ANSAS	7.34	5.7
ENTUCKY	4.92	5.6
OUISIANA	5.87	5.1
AINE	7.87	7.7
ARYLAND	6.73	4.6
ASSACHUSETTS	5.09	3.0
ICHIGAN	7.83	7.8
INNESOTA	8.23	6.8
ISSISSIPPI-north	3.01	1.2
ISSISSIPPI-south	3.43	1.2
ISSOURI	7.47	5.6
ONTANA	9.02	11.9
EBRASKA	6.93	6.0
EVADA	2.61	2.6
EW HAMPSHIRE	7.57	6.0
Area	**PIA (kg/d)**	**PIW (kg/d)**
NEW JERSEY	5.06	2.3
NEW MEXICO	2.49	2.5
NEW YORK	5.67	4.1
NORTH CAROLINA-east	4.28	3.3
NORTH CAROLINA-west	4.23	3.3
NORTH DAKOTA	6.65	5.4
OHIO	9.19	7.1
OKLAHOMA	4.67	2.9
OREGON	7.05	6.6
PENNSYLVANIA	4.36	2.3
RHODE ISLAND	8.34	6.7
SOUTH CAROLINA-east	5.01	2.7
SOUTH CAROLINA-west	4.96	2.7
SOUTH DAKOTA	6.61	5.8
TENNESSEE	4.36	4.7
TEXAS-east	6.44	4.2
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	7.4
UTAH - region 2	10.80	10.8
UTAH - region 3, 5	8.10	8.1
UTAH - region 4	6.75	6.8
UTAH - region 6	9.05	9.0
UTAH - region 7	9.05	9.0
UTAH - region 8	10.13	10.1
UTAH - region 9	6.75	6.8
UTAH - region 10	0.94	0.9
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	5.4
VERMONT	7.33	5.6
VIRGINIA	5.89	3.9
WASHINGTON	7.31	6.9
WEST VIRGINIA	5.51	3.7
WISCONSIN	7.53	8.6
WYOMING	5.67	7.5

the first "week" of August (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	4.2	NEW JERSEY	5.06	2.3
ABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	4.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	3.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	3.3
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ALIFORNIA-middle	3.51	2.6	OHIO	9.19	7.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	6.3	PENNSYLVANIA	4.36	2.3
ONNECTICUT	7.16	5.8	RHODE ISLAND	8.34	6.7
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	2.7
ASHINGTON DC	6.73	4.6	SOUTH CAROLINA-west	4.96	2.7
ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	5.8
EORGIA-north	5.06	4.2	TENNESSEE	4.36	3.5
EORGIA-south	5.07	4.2	TEXAS-east	6.44	4.2
AHO	9.14	10.1	TEXAS-west	2.10	2.1
LINOIS	6.28	6.3	UTAH - region 1	7.43	7.4
DIANA	5.84	4.6	UTAH - region 2	10.80	10.8
WA	5.51	4.2	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	4.2	UTAH - region 6	9.05	9.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	7.7	UTAH - region 8	10.13	10.1
ARYLAND	6.73	4.6	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	3.0	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	7.8	UTAH - region 11	6.07	6.1
INNESOTA	8.23	6.8	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	5.6
ISSOURI	7.47	5.6	VIRGINIA	5.89	3.9
ONTANA	9.02	6.7	WASHINGTON	7.31	6.9
EBRASKA	6.93	6.0	WEST VIRGINIA	5.51	3.7
EVADA	2.61	2.6	WISCONSIN	7.53	7.2
EW HAMPSHIRE	7.57	6.0	WYOMING	5.67	4.5

the second "week" of August (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	4.2	NEW JERSEY	5.06	2.3
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	4.1
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	3.3
RKANSAS	6.04	5.1	NORTH CAROLINA-west	4.23	3.3
ALIFORNIA-north	6.31	5.1	NORTH DAKOTA	6.65	5.4
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	7.1
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	6.6
OLORADO	6.72	6.3	PENNSYLVANIA	4.36	2.3
ONNECTICUT	7.16	5.8	RHODE ISLAND	8.34	6.7
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	2.7
ASHINGTON DC	6.73	4.6	SOUTH CAROLINA-west	4.96	2.7
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	5.8
EORGIA-north	5.06	4.2	TENNESSEE	4.36	3.5
EORGIA-south	5.07	4.2	TEXAS-east	6.44	4.2
AHO	9.14	10.1	TEXAS-west	2.10	2.1
LINOIS	6.28	6.3	UTAH - region 1	7.43	7.4
IDIANA	5.84	4.6	UTAH - region 2	10.80	10.8
WA	5.51	4.2	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	4.2	UTAH - region 6	9.05	9.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	7.7	UTAH - region 8	10.13	10.1
ARYLAND	6.73	4.6	UTAH - region 9	6.75	6.8
ASSACHUSETTS	5.09	3.0	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	7.8	UTAH - region 11	6.07	6.1
INNESOTA	8.23	6.8	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	5.6
ISSOURI	7.47	5.6	VIRGINIA	5.89	3.9
ONTANA	9.02	6.7	WASHINGTON	7.31	6.9
EBRASKA	6.93	6.0	WEST VIRGINIA	5.51	3.7
EVADA	2.61	2.6	WISCONSIN	7.53	7.2
EW HAMPSHIRE	7.57	6.0	WYOMING	5.67	4.5

the third "week" of August (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	4.2
.ABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	5.0
RKANSAS	6.04	5.1
ALIFORNIA-north	6.31	5.1
ALIFORNIA-middle	3.51	2.6
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	2.2
OLORADO	6.72	6.3
ONNECTICUT	7.16	5.8
ELAWARE	5.52	2.8
ASHINGTON DC	6.73	4.6
.ORIDA	1.78	1.8
EORGIA-north	5.06	4.2
EORGIA-south	5.07	4.2
AHO	9.14	10.1
LINOIS	6.28	6.3
DIANA	5.84	4.6
WA	5.51	4.2
ANSAS	7.34	5.7
ENTUCKY	4.92	4.2
OUISIANA	5.87	5.1
AINE	7.87	7.7
ARYLAND	6.73	4.6
ASSACHUSETTS	5.09	3.0
ICHIGAN	7.83	7.8
INNESOTA	8.23	6.8
ISSISSIPPI-north	3.01	1.2
ISSISSIPPI-south	3.43	1.2
ISSOURI	7.47	5.6
ONTANA	9.02	6.7
EBRASKA	6.93	6.0
EVADA	2.61	2.6
EW HAMPSHIRE	7.57	6.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	2.3
NEW MEXICO	2.49	2.5
NEW YORK	5.67	4.1
NORTH CAROLINA-east	4.28	3.3
NORTH CAROLINA-west	4.23	3.3
NORTH DAKOTA	6.65	5.4
OHIO	9.19	7.1
OKLAHOMA	4.67	2.9
OREGON	7.05	6.6
PENNSYLVANIA	4.36	2.3
RHODE ISLAND	8.34	6.7
SOUTH CAROLINA-east	5.01	2.7
SOUTH CAROLINA-west	4.96	2.7
SOUTH DAKOTA	6.61	5.8
TENNESSEE	4.36	3.5
TEXAS-east	6.44	4.2
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	7.4
UTAH - region 2	10.80	10.8
UTAH - region 3, 5	8.10	8.1
UTAH - region 4	6.75	6.8
UTAH - region 6	9.05	9.0
UTAH - region 7	9.05	9.0
UTAH - region 8	10.13	10.1
UTAH - region 9	6.75	6.8
UTAH - region 10	0.94	0.9
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	5.4
VERMONT	7.33	5.6
VIRGINIA	5.89	3.9
WASHINGTON	7.31	6.9
WEST VIRGINIA	5.51	3.7
WISCONSIN	7.53	7.2
WYOMING	5.67	4.5

the last “week” of August (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	4.2
ABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	5.0
RKANSAS	6.04	5.1
ALIFORNIA-north	6.31	5.1
ALIFORNIA-middle	3.51	2.6
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	2.2
OLORADO	6.72	6.3
ONNECTICUT	7.16	5.8
ELAWARE	5.52	2.8
ASHINGTON DC	6.73	4.6
ORIDA	1.78	1.8
EORGIA-north	5.06	4.2
EORGIA-south	5.07	4.2
AHO	9.14	10.1
LINOIS	6.28	6.3
DIANA	5.84	4.6
WA	5.51	4.2
ANSAS	7.34	5.7
ENTUCKY	4.92	4.2
OUISIANA	5.87	5.1
AINE	7.87	7.7
ARYLAND	6.73	4.6
ASSACHUSETTS	5.09	3.0
ICHIGAN	7.83	7.8
INNESOTA	8.23	6.8
ISSISSIPPI-north	3.01	1.2
ISSISSIPPI-south	3.43	1.2
ISSOURI	7.47	5.6
ONTANA	9.02	6.7
EBRASKA	6.93	6.0
EVADA	2.61	2.6
EW HAMPSHIRE	7.57	6.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	2.3
NEW MEXICO	2.49	2.5
NEW YORK	5.67	4.1
NORTH CAROLINA-east	4.28	3.3
NORTH CAROLINA-west	4.23	3.3
NORTH DAKOTA	6.65	5.4
OHIO	9.19	7.1
OKLAHOMA	4.67	2.9
OREGON	7.05	6.6
PENNSYLVANIA	4.36	2.3
RHODE ISLAND	8.34	6.7
SOUTH CAROLINA-east	5.01	2.7
SOUTH CAROLINA-west	4.96	2.7
SOUTH DAKOTA	6.61	5.8
TENNESSEE	4.36	3.5
TEXAS-east	6.44	4.2
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	7.4
UTAH - region 2	10.80	8.1
UTAH - region 3, 5	8.10	8.1
UTAH - region 4	6.75	6.8
UTAH - region 6	9.05	6.7
UTAH - region 7	9.05	9.0
UTAH - region 8	10.13	7.6
UTAH - region 9	6.75	6.8
UTAH - region 10	0.94	0.9
UTAH - region 11	6.07	6.1
UTAH - region 12	10.80	10.8
UTAH - region 13	5.40	5.4
VERMONT	7.33	5.6
VIRGINIA	5.89	3.9
WASHINGTON	7.31	6.9
WEST VIRGINIA	5.51	3.7
WISCONSIN	7.53	7.2
WYOMING	5.67	4.5

the first “week” of September (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.2	NEW JERSEY	5.06	5.3
LABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	5.4
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	4.0
RKANSAS	6.04	6.4	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	5.1	NORTH DAKOTA	6.65	6.8
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	9.5
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	2.2	OREGON	7.05	7.5
OLORADO	6.72	4.7	PENNSYLVANIA	4.36	3.1
ONNECTICUT	7.16	7.3	RHODE ISLAND	8.34	8.2
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	5.3
ASHINGTON DC	6.73	6.1	SOUTH CAROLINA-west	4.96	5.3
LORIDA	1.78	1.8	SOUTH DAKOTA	6.61	7.3
EORGIA-north	5.06	4.2	TENNESSEE	4.36	2.4
EORGIA-south	5.07	4.2	TEXAS-east	6.44	5.6
AHO	9.14	7.3	TEXAS-west	2.10	2.1
LINOIS	6.28	4.7	UTAH - region 1	7.43	7.4
DIANA	5.84	3.1	UTAH - region 2	10.80	2.7
WA	5.51	5.6	UTAH - region 3, 5	8.10	8.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	6.8
ENTUCKY	4.92	2.8	UTAH - region 6	9.05	2.2
OUISIANA	5.87	5.1	UTAH - region 7	9.05	9.0
AINE	7.87	6.4	UTAH - region 8	10.13	2.5
ARYLAND	6.73	6.1	UTAH - region 9	6.75	5.1
ASSACHUSETTS	5.09	3.8	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	6.2	UTAH - region 11	6.07	6.1
INNESOTA	8.23	8.2	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	5.4
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	7.1
ISSOURI	7.47	7.0	VIRGINIA	5.89	5.2
ONTANA	9.02	6.7	WASHINGTON	7.31	7.7
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	5.0
EVADA	2.61	2.6	WISCONSIN	7.53	5.7
EW HAMPSHIRE	7.57	7.5	WYOMING	5.67	4.5

the second “week” of September (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	4.2	NEW JERSEY	5.06	5.3
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	5.4
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	4.0
RKANSAS	6.04	6.4	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	5.1	NORTH DAKOTA	6.65	6.8
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	9.5
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	1.6	OREGON	7.05	7.5
OLORADO	6.72	3.5	PENNSYLVANIA	4.36	3.1
ONNECTICUT	7.16	7.3	RHODE ISLAND	8.34	8.2
ELAWARE	5.52	2.8	SOUTH CAROLINA-east	5.01	5.3
ASHINGTON DC	6.73	6.1	SOUTH CAROLINA-west	4.96	5.3
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	7.3
EORGIA-north	5.06	4.2	TENNESSEE	4.36	2.4
EORGIA-south	5.07	4.2	TEXAS-east	6.44	5.6
AHO	9.14	7.3	TEXAS-west	2.10	2.1
LINOIS	6.28	4.7	UTAH - region 1	7.43	5.5
IDIANA	5.84	3.1	UTAH - region 2	10.80	0.0
WA	5.51	5.6	UTAH - region 3, 5	8.10	6.1
ANSAS	7.34	5.7	UTAH - region 4	6.75	5.1
ENTUCKY	4.92	2.8	UTAH - region 6	9.05	0.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	6.7
AINE	7.87	6.4	UTAH - region 8	10.13	0.0
ARYLAND	6.73	6.1	UTAH - region 9	6.75	1.7
ASSACHUSETTS	5.09	3.8	UTAH - region 10	0.94	0.9
ICHIGAN	7.83	6.2	UTAH - region 11	6.07	6.1
INNESOTA	8.23	8.2	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	4.0
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	7.1
ISSOURI	7.47	7.0	VIRGINIA	5.89	5.2
ONTANA	9.02	6.7	WASHINGTON	7.31	7.7
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	5.0
EVADA	2.61	2.6	WISCONSIN	7.53	5.7
EW HAMPSHIRE	7.57	7.5	WYOMING	5.67	4.5

the third "week" of September (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	4.2	NEW JERSEY	5.06	5.3
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	5.4
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	4.0
RKANSAS	6.04	6.4	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	3.4	NORTH DAKOTA	6.65	6.8
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	9.5
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	0.5	OREGON	7.05	7.5
OLORADO	6.72	1.2	PENNSYLVANIA	4.36	3.1
ONNECTICUT	7.16	7.3	RHODE ISLAND	8.34	8.2
ELAWARE	5.52	5.5	SOUTH CAROLINA-east	5.01	5.3
ASHINGTON DC	6.73	6.1	SOUTH CAROLINA-west	4.96	5.3
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	7.3
EORGIA-north	5.06	4.2	TENNESSEE	4.36	2.4
EORGIA-south	5.07	4.2	TEXAS-east	6.44	5.6
AHO	9.14	7.3	TEXAS-west	2.10	2.1
LINOIS	6.28	4.7	UTAH - region 1	7.43	1.8
DIANA	5.84	3.1	UTAH - region 2	10.80	0.0
WA	5.51	5.6	UTAH - region 3, 5	8.10	2.0
ANSAS	7.34	8.5	UTAH - region 4	6.75	1.7
ENTUCKY	4.92	2.8	UTAH - region 6	9.05	0.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	2.2
AINE	7.87	6.4	UTAH - region 8	10.13	0.0
ARYLAND	6.73	6.1	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	3.8	UTAH - region 10	0.94	0.7
ICHIGAN	7.83	6.2	UTAH - region 11	6.07	6.1
INNESOTA	8.23	8.2	UTAH - region 12	10.80	10.8
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	1.3
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	7.1
ISSOURI	7.47	7.0	VIRGINIA	5.89	5.2
ONTANA	9.02	6.7	WASHINGTON	7.31	7.7
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	5.0
EVADA	2.61	2.6	WISCONSIN	7.53	5.7
EW HAMPSHIRE	7.57	7.5	WYOMING	5.67	4.5

the last “week” of September (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	4.2	NEW JERSEY	5.06	5.3
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	5.4
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	4.0
RKANSAS	6.04	6.4	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	3.4	NORTH DAKOTA	6.65	5.1
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	9.5
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	2.9
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	7.5
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	3.1
ONNECTICUT	7.16	7.3	RHODE ISLAND	8.34	8.2
ELAWARE	5.52	5.5	SOUTH CAROLINA-east	5.01	5.3
ASHINGTON DC	6.73	6.1	SOUTH CAROLINA-west	4.96	5.3
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	5.5
EORGIA-north	5.06	4.2	TENNESSEE	4.36	1.8
EORGIA-south	5.07	4.2	TEXAS-east	6.44	5.6
AHO	9.14	7.3	TEXAS-west	2.10	2.1
LINOIS	6.28	4.7	UTAH - region 1	7.43	0.0
DIANA	5.84	3.1	UTAH - region 2	10.80	0.0
WA	5.51	5.6	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	8.5	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	2.8	UTAH - region 6	9.05	0.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	0.0
AINE	7.87	6.4	UTAH - region 8	10.13	0.0
ARYLAND	6.73	6.1	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	3.8	UTAH - region 10	0.94	0.2
ICHIGAN	7.83	6.2	UTAH - region 11	6.07	6.1
INNESOTA	8.23	8.2	UTAH - region 12	10.80	8.1
ISSISSIPPI-north	3.01	1.2	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	1.2	VERMONT	7.33	7.1
ISSOURI	7.47	7.0	VIRGINIA	5.89	5.2
ONTANA	9.02	5.0	WASHINGTON	7.31	7.7
EBRASKA	6.93	7.5	WEST VIRGINIA	5.51	5.0
EVADA	2.61	1.9	WISCONSIN	7.53	5.7
EW HAMPSHIRE	7.57	7.5	WYOMING	5.67	3.4

the first "week" of October (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	4.8	NEW JERSEY	5.06	5.3
ABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	5.4
RIZONA-northwest	5.04	5.0	NORTH CAROLINA-east	4.28	4.0
RKANSAS	6.04	6.4	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	3.4	NORTH DAKOTA	6.65	1.7
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	9.5
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	4.4
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	7.5
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	3.1
ONNECTICUT	7.16	7.3	RHODE ISLAND	8.34	8.2
ELAWARE	5.52	5.5	SOUTH CAROLINA-east	5.01	5.3
ASHINGTON DC	6.73	6.1	SOUTH CAROLINA-west	4.96	5.3
ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	1.8
EORGIA-north	5.06	5.6	TENNESSEE	4.36	0.6
EORGIA-south	5.07	4.2	TEXAS-east	6.44	5.6
AHO	9.14	7.3	TEXAS-west	2.10	2.1
LINOIS	6.28	3.1	UTAH - region 1	7.43	0.0
DIANA	5.84	3.1	UTAH - region 2	10.80	0.0
WA	5.51	4.2	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	8.5	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	2.8	UTAH - region 6	9.05	0.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	0.0
AINE	7.87	6.4	UTAH - region 8	10.13	0.0
ARYLAND	6.73	6.1	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	3.8	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	4.6	UTAH - region 11	6.07	6.1
INNESOTA	8.23	6.1	UTAH - region 12	10.80	2.7
ISSISSIPPI-north	3.01	3.7	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	7.1
ISSOURI	7.47	7.0	VIRGINIA	5.89	5.2
ONTANA	9.02	1.7	WASHINGTON	7.31	7.7
EBRASKA	6.93	5.6	WEST VIRGINIA	5.51	5.0
EVADA	2.61	0.6	WISCONSIN	7.53	4.3
EW HAMPSHIRE	7.57	7.5	WYOMING	5.67	1.1

the second "week" of October (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8
LABAMA-south	4.24	4.8
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	3.7
RKANSAS	6.04	6.4
ALIFORNIA-north	6.31	3.4
ALIFORNIA-middle	3.51	2.6
ALIFORNIA-south	0.85	0.9
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	7.3
ELAWARE	5.52	5.5
ASHINGTON DC	6.73	6.1
ORIDA	1.78	1.8
EORGIA-north	5.06	5.6
EORGIA-south	5.07	4.2
AHO	9.14	5.5
LINOIS	6.28	2.3
DIANA	5.84	2.3
WA	5.51	3.1
ANSAS	7.34	8.5
ENTUCKY	4.92	2.1
OUISIANA	5.87	5.1
AINE	7.87	4.8
ARYLAND	6.73	6.1
ASSACHUSETTS	5.09	2.8
ICHIGAN	7.83	1.5
INNESOTA	8.23	2.0
ISSISSIPPI-north	3.01	3.7
ISSISSIPPI-south	3.43	3.7
ISSOURI	7.47	7.0
ONTANA	9.02	0.0
EBRASKA	6.93	1.9
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	5.6

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	5.3
NEW MEXICO	2.49	2.5
NEW YORK	5.67	4.0
NORTH CAROLINA-east	4.28	4.0
NORTH CAROLINA-west	4.23	4.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	7.1
OKLAHOMA	4.67	4.4
OREGON	7.05	5.6
PENNSYLVANIA	4.36	3.1
RHODE ISLAND	8.34	8.2
SOUTH CAROLINA-east	5.01	5.3
SOUTH CAROLINA-west	4.96	5.3
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	5.6
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	4.6
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	5.3
VIRGINIA	5.89	5.2
WASHINGTON	7.31	5.8
WEST VIRGINIA	5.51	5.0
WISCONSIN	7.53	1.4
WYOMING	5.67	0.0

the third "week" of October (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8	NEW JERSEY	5.06	4.0
LABAMA-south	4.24	4.8	NEW MEXICO	2.49	2.5
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	1.3
RIZONA-northwest	5.04	1.2	NORTH CAROLINA-east	4.28	4.0
RKANSAS	6.04	6.4	NORTH CAROLINA-west	4.23	4.0
ALIFORNIA-north	6.31	3.4	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	2.6	OHIO	9.19	2.4
ALIFORNIA-south	0.85	0.9	OKLAHOMA	4.67	4.4
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	1.9
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	3.1
ONNECTICUT	7.16	5.5	RHODE ISLAND	8.34	6.1
ELAWARE	5.52	5.5	SOUTH CAROLINA-east	5.01	5.3
ASHINGTON DC	6.73	6.1	SOUTH CAROLINA-west	4.96	5.3
LORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	5.6	TENNESSEE	4.36	0.0
EORGIA-south	5.07	4.2	TEXAS-east	6.44	5.6
AHO	9.14	1.8	TEXAS-west	2.10	2.1
LINOIS	6.28	0.8	UTAH - region 1	7.43	0.0
DIANA	5.84	0.8	UTAH - region 2	10.80	0.0
WA	5.51	1.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	8.5	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.7	UTAH - region 6	9.05	0.0
OUISIANA	5.87	5.1	UTAH - region 7	9.05	0.0
AINE	7.87	1.6	UTAH - region 8	10.13	0.0
ARYLAND	6.73	6.1	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.9	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	1.5
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	3.7	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	3.7	VERMONT	7.33	1.8
ISSOURI	7.47	7.0	VIRGINIA	5.89	5.2
ONTANA	9.02	0.0	WASHINGTON	7.31	1.9
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	5.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	1.9	WYOMING	5.67	0.0

the last "week" of October (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8
LABAMA-south	4.24	4.8
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	4.8
ALIFORNIA-north	6.31	2.5
ALIFORNIA-middle	3.51	1.9
ALIFORNIA-south	0.85	0.6
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	1.8
ELAWARE	5.52	5.5
ASHINGTON DC	6.73	6.1
LORIDA	1.78	1.8
EORGIA-north	5.06	5.6
EORGIA-south	5.07	4.2
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	6.4
ENTUCKY	4.92	0.0
OUISIANA	5.87	5.1
AINE	7.87	0.0
ARYLAND	6.73	6.1
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	3.7
ISSISSIPPI-south	3.43	3.7
ISSOURI	7.47	5.2
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	1.3
NEW MEXICO	2.49	1.9
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	4.0
NORTH CAROLINA-west	4.23	3.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	4.4
OREGON	7.05	0.0
PENNSYLVANIA	4.36	2.3
RHODE ISLAND	8.34	2.0
SOUTH CAROLINA-east	5.01	5.3
SOUTH CAROLINA-west	4.96	5.3
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	5.6
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	5.2
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	3.7
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the first “week” of November (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
ABAMA-north	4.97	4.8
ABAMA-south	4.24	4.8
IZONA-remainder	0.72	0.7
IZONA-northwest	5.04	0.0
KANSAS	6.04	1.6
LIFORNIA-north	6.31	0.8
LIFORNIA-middle	3.51	0.6
LIFORNIA-south	0.85	0.2
LIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	5.5
ASHINGTON DC	6.73	6.1
ORIDA	1.78	1.8
EORGIA-north	5.06	5.6
EORGIA-south	5.07	5.6
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	2.1
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	6.1
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	4.9
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	1.7
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.6
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	4.0
NORTH CAROLINA-west	4.23	1.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	4.4
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.8
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	5.3
SOUTH CAROLINA-west	4.96	5.3
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	5.6
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	5.2
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	1.2
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the second “week” of November (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8
LABAMA-south	4.24	4.8
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.0
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	4.1
ASHINGTON DC	6.73	4.6
LORIDA	1.78	1.8
EORGIA-north	5.06	5.6
EORGIA-south	5.07	5.6
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	4.6
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	4.9
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	3.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	4.4
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	4.0
SOUTH CAROLINA-west	4.96	4.0
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	5.6
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	3.9
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the third “week” of November (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	4.8
LABAMA-south	4.24	4.8
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.0
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	1.4
ASHINGTON DC	6.73	1.5
LORIDA	1.78	1.8
EORGIA-north	5.06	5.6
EORGIA-south	5.07	5.6
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	1.5
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	4.9
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	1.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	4.4
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	1.3
SOUTH CAROLINA-west	4.96	1.3
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	5.6
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	1.3
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the last “week” of November (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	3.6	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	4.8	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.0	OKLAHOMA	4.67	3.3
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	4.2	TENNESSEE	4.36	0.0
EORGIA-south	5.07	5.6	TEXAS-east	6.44	4.2
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	3.7	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

the first “week” of December (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
LABAMA-north	4.97	1.2
LABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.0
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
LORIDA	1.78	1.8
EORGIA-north	5.06	1.4
EORGIA-south	5.07	5.6
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	1.2
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	0.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	1.1
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	0.0
SOUTH CAROLINA-west	4.96	0.0
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	1.4
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3, 5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the second “week” of December (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	0.0	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.0	OKLAHOMA	4.67	0.0
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	0.0	TENNESSEE	4.36	0.0
EORGIA-south	5.07	5.6	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	0.0	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

r the third “week” of December (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)
‿ABAMA-north	4.97	0.0
‿ABAMA-south	4.24	3.6
RIZONA-remainder	0.72	0.7
RIZONA-northwest	5.04	0.0
RKANSAS	6.04	0.0
ALIFORNIA-north	6.31	0.0
ALIFORNIA-middle	3.51	0.0
ALIFORNIA-south	0.85	0.0
ALIFORNIA-Inyo	2.21	0.0
OLORADO	6.72	0.0
ONNECTICUT	7.16	0.0
ELAWARE	5.52	0.0
ASHINGTON DC	6.73	0.0
ORIDA	1.78	1.8
EORGIA-north	5.06	0.0
EORGIA-south	5.07	5.6
AHO	9.14	0.0
LINOIS	6.28	0.0
DIANA	5.84	0.0
WA	5.51	0.0
ANSAS	7.34	0.0
ENTUCKY	4.92	0.0
OUISIANA	5.87	6.4
AINE	7.87	0.0
ARYLAND	6.73	0.0
ASSACHUSETTS	5.09	0.0
ICHIGAN	7.83	0.0
INNESOTA	8.23	0.0
ISSISSIPPI-north	3.01	0.0
ISSISSIPPI-south	3.43	4.9
ISSOURI	7.47	0.0
ONTANA	9.02	0.0
EBRASKA	6.93	0.0
EVADA	2.61	0.0
EW HAMPSHIRE	7.57	0.0

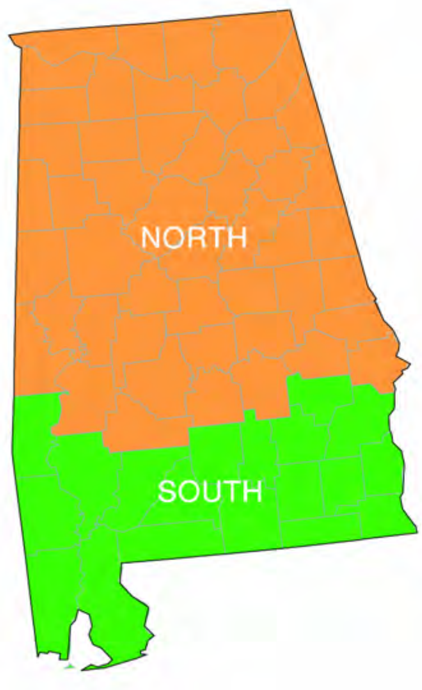
Area	PIA (kg/d)	PIW (kg/d)
NEW JERSEY	5.06	0.0
NEW MEXICO	2.49	0.0
NEW YORK	5.67	0.0
NORTH CAROLINA-east	4.28	0.0
NORTH CAROLINA-west	4.23	0.0
NORTH DAKOTA	6.65	0.0
OHIO	9.19	0.0
OKLAHOMA	4.67	0.0
OREGON	7.05	0.0
PENNSYLVANIA	4.36	0.0
RHODE ISLAND	8.34	0.0
SOUTH CAROLINA-east	5.01	0.0
SOUTH CAROLINA-west	4.96	0.0
SOUTH DAKOTA	6.61	0.0
TENNESSEE	4.36	0.0
TEXAS-east	6.44	0.0
TEXAS-west	2.10	2.1
UTAH - region 1	7.43	0.0
UTAH - region 2	10.80	0.0
UTAH - region 3,5	8.10	0.0
UTAH - region 4	6.75	0.0
UTAH - region 6	9.05	0.0
UTAH - region 7	9.05	0.0
UTAH - region 8	10.13	0.0
UTAH - region 9	6.75	0.0
UTAH - region 10	0.94	0.0
UTAH - region 11	6.07	0.0
UTAH - region 12	10.80	0.0
UTAH - region 13	5.40	0.0
VERMONT	7.33	0.0
VIRGINIA	5.89	0.0
WASHINGTON	7.31	0.0
WEST VIRGINIA	5.51	0.0
WISCONSIN	7.53	0.0
WYOMING	5.67	0.0

the last “week” of December (PIW), in kg(dry)/d.

rea	PIA (kg/d)	PIW (kg/d)	Area	PIA (kg/d)	PIW (kg/d)
.ABAMA-north	4.97	0.0	NEW JERSEY	5.06	0.0
.ABAMA-south	4.24	3.6	NEW MEXICO	2.49	0.0
RIZONA-remainder	0.72	0.7	NEW YORK	5.67	0.0
RIZONA-northwest	5.04	0.0	NORTH CAROLINA-east	4.28	0.0
RKANSAS	6.04	0.0	NORTH CAROLINA-west	4.23	0.0
ALIFORNIA-north	6.31	0.0	NORTH DAKOTA	6.65	0.0
ALIFORNIA-middle	3.51	0.0	OHIO	9.19	0.0
ALIFORNIA-south	0.85	0.0	OKLAHOMA	4.67	0.0
ALIFORNIA-Inyo	2.21	0.0	OREGON	7.05	0.0
OLORADO	6.72	0.0	PENNSYLVANIA	4.36	0.0
ONNECTICUT	7.16	0.0	RHODE ISLAND	8.34	0.0
ELAWARE	5.52	0.0	SOUTH CAROLINA-east	5.01	0.0
ASHINGTON DC	6.73	0.0	SOUTH CAROLINA-west	4.96	0.0
.ORIDA	1.78	1.8	SOUTH DAKOTA	6.61	0.0
EORGIA-north	5.06	0.0	TENNESSEE	4.36	0.0
EORGIA-south	5.07	5.6	TEXAS-east	6.44	0.0
AHO	9.14	0.0	TEXAS-west	2.10	2.1
LINOIS	6.28	0.0	UTAH - region 1	7.43	0.0
DIANA	5.84	0.0	UTAH - region 2	10.80	0.0
WA	5.51	0.0	UTAH - region 3, 5	8.10	0.0
ANSAS	7.34	0.0	UTAH - region 4	6.75	0.0
ENTUCKY	4.92	0.0	UTAH - region 6	9.05	0.0
OUISIANA	5.87	6.4	UTAH - region 7	9.05	0.0
AINE	7.87	0.0	UTAH - region 8	10.13	0.0
ARYLAND	6.73	0.0	UTAH - region 9	6.75	0.0
ASSACHUSETTS	5.09	0.0	UTAH - region 10	0.94	0.0
ICHIGAN	7.83	0.0	UTAH - region 11	6.07	0.0
INNESOTA	8.23	0.0	UTAH - region 12	10.80	0.0
ISSISSIPPI-north	3.01	0.0	UTAH - region 13	5.40	0.0
ISSISSIPPI-south	3.43	4.9	VERMONT	7.33	0.0
ISSOURI	7.47	0.0	VIRGINIA	5.89	0.0
ONTANA	9.02	0.0	WASHINGTON	7.31	0.0
EBRASKA	6.93	0.0	WEST VIRGINIA	5.51	0.0
EVADA	2.61	0.0	WISCONSIN	7.53	0.0
EW HAMPSHIRE	7.57	0.0	WYOMING	5.67	0.0

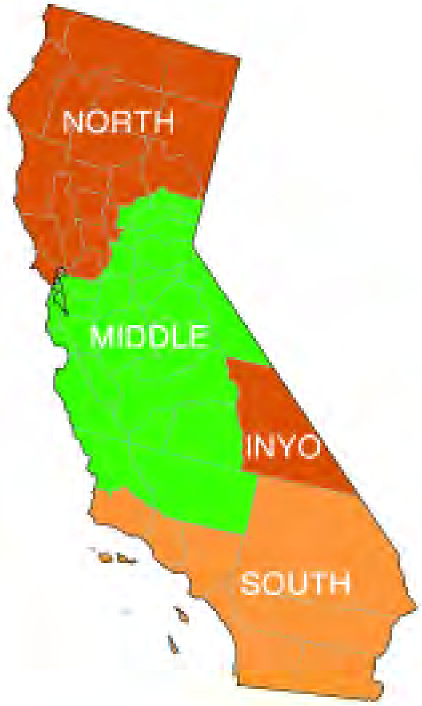
IN THE STATES THAT HAVE BEEN SUBDIVIDED

Alabama pasture regions

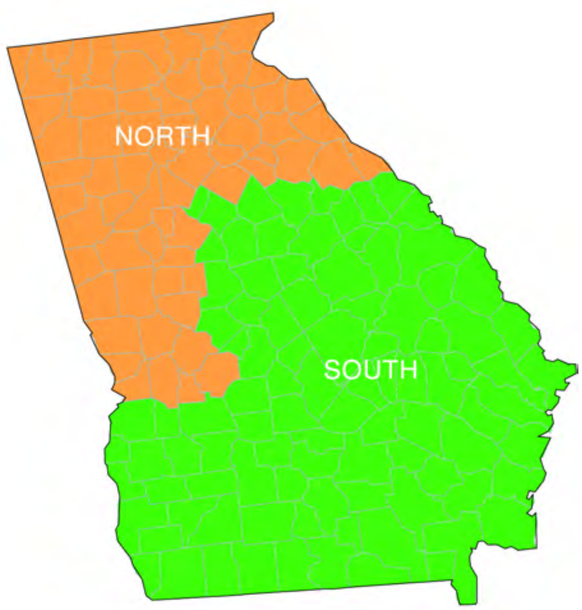


Arizona pasture regions

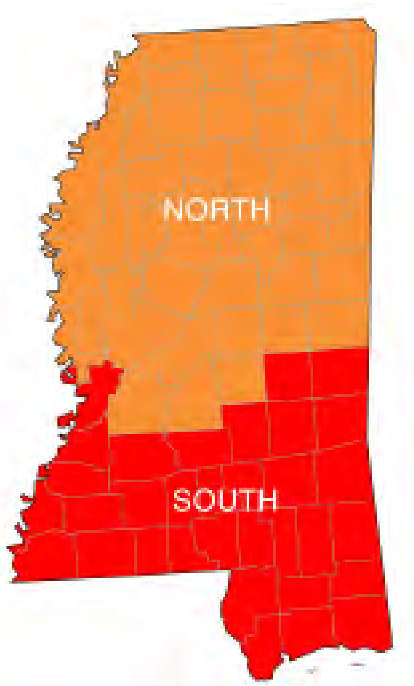
California pasture regions



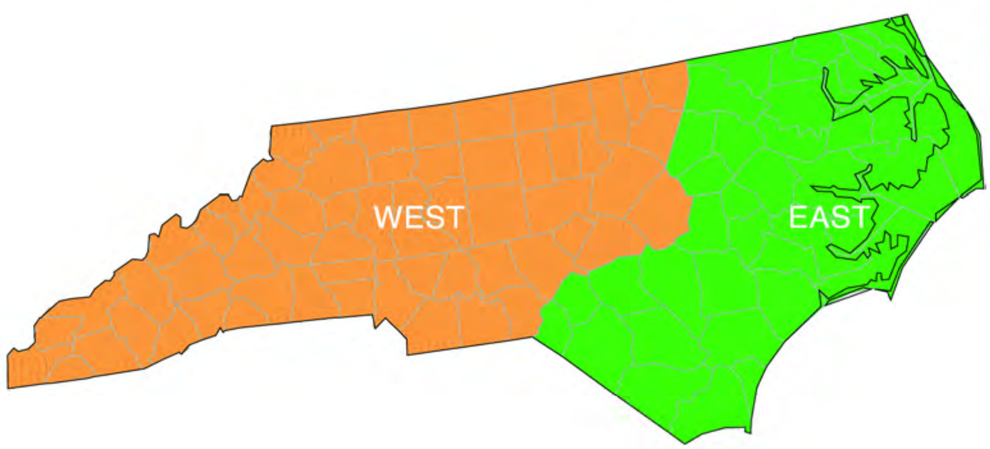
Georgia pasture regions



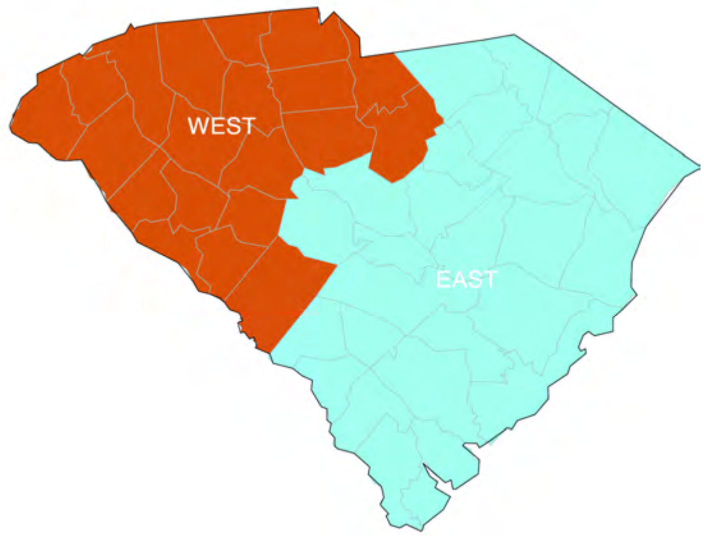
Mississippi pasture regions



North Carolina pasture regions

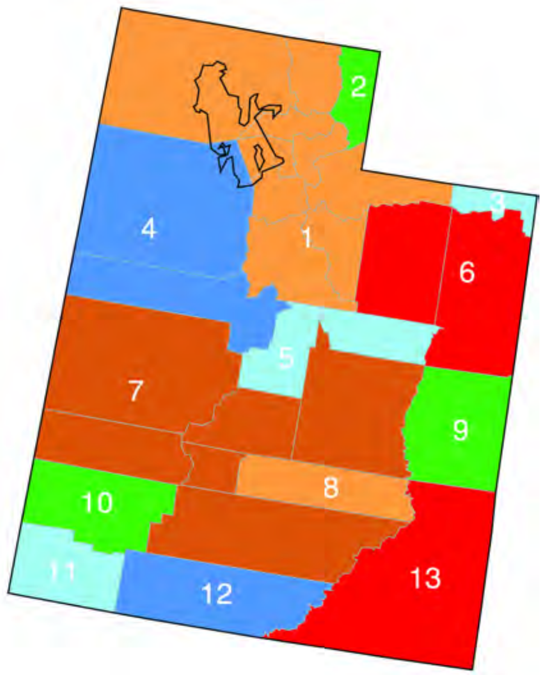


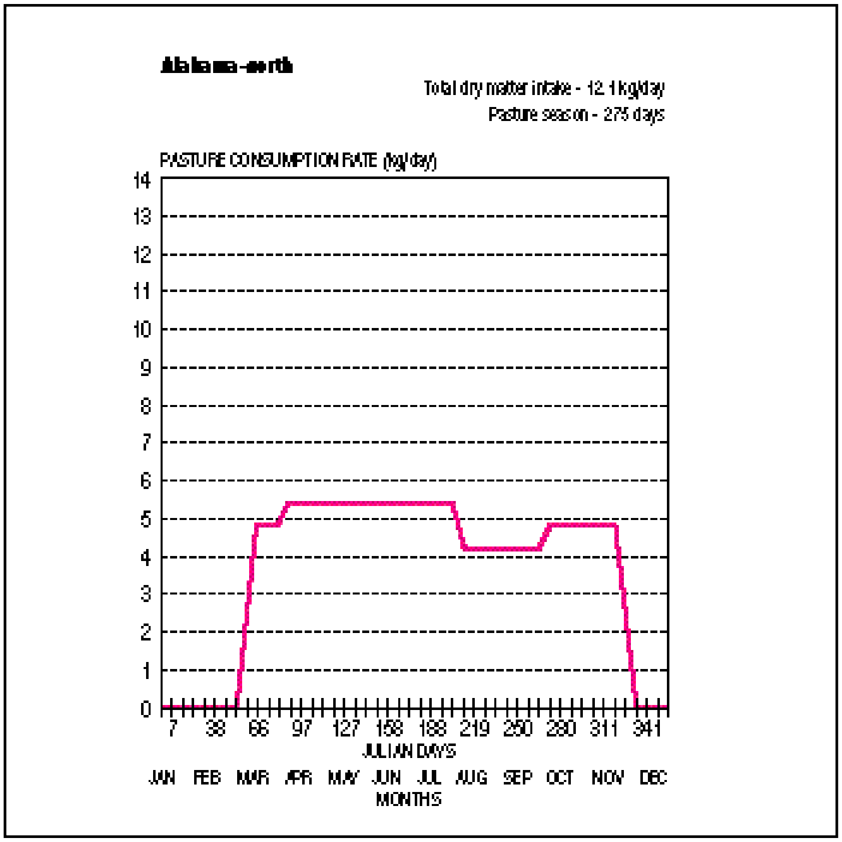
South Carolina pasture regions

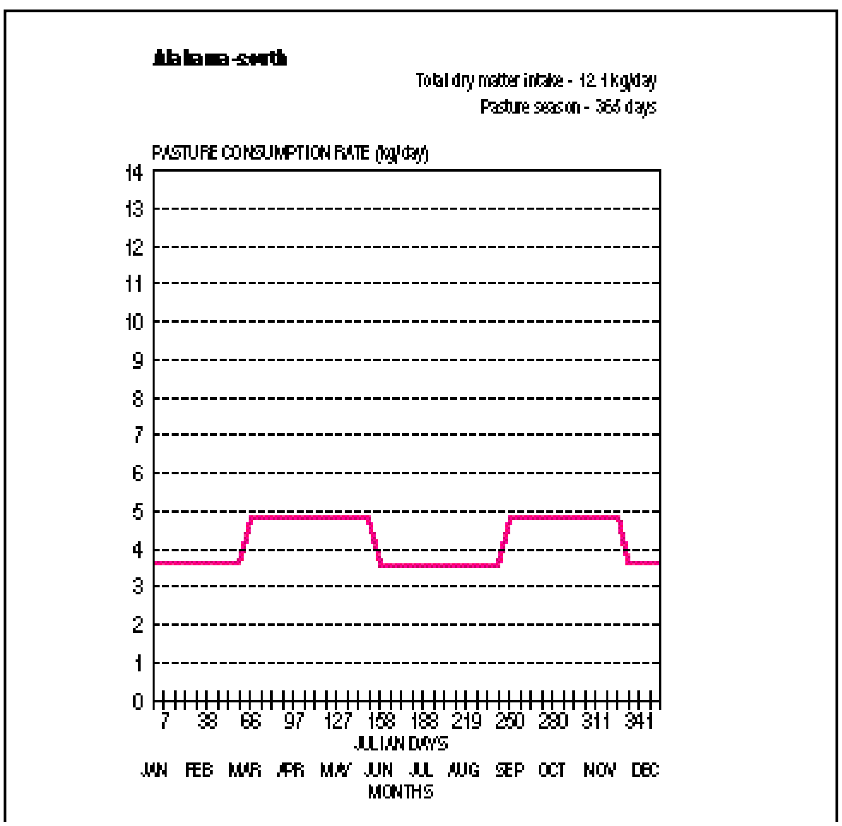


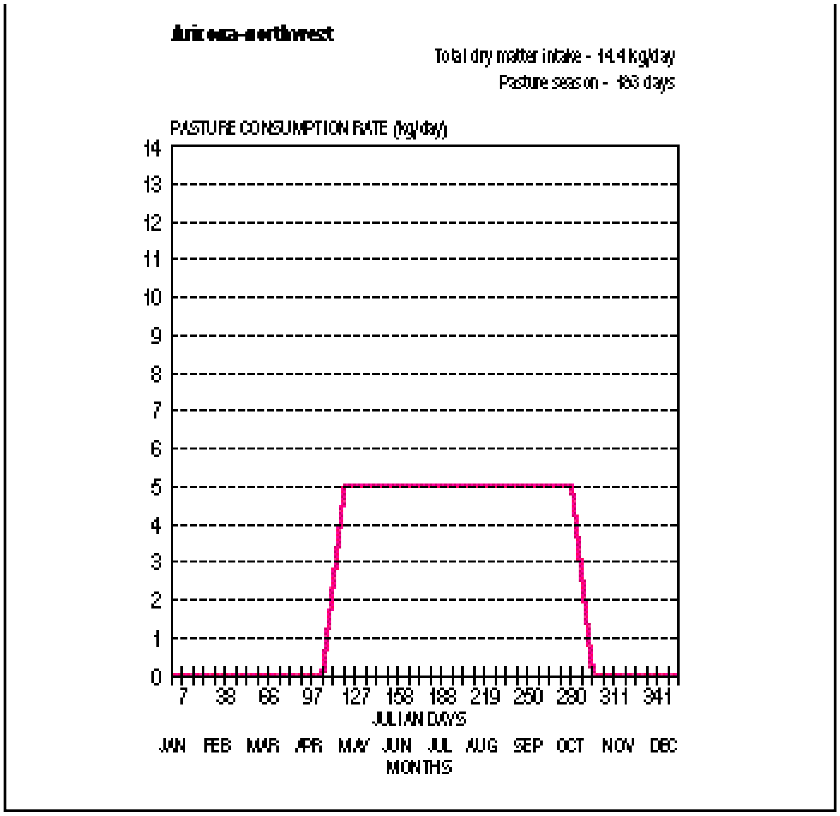
Texas pasture regions

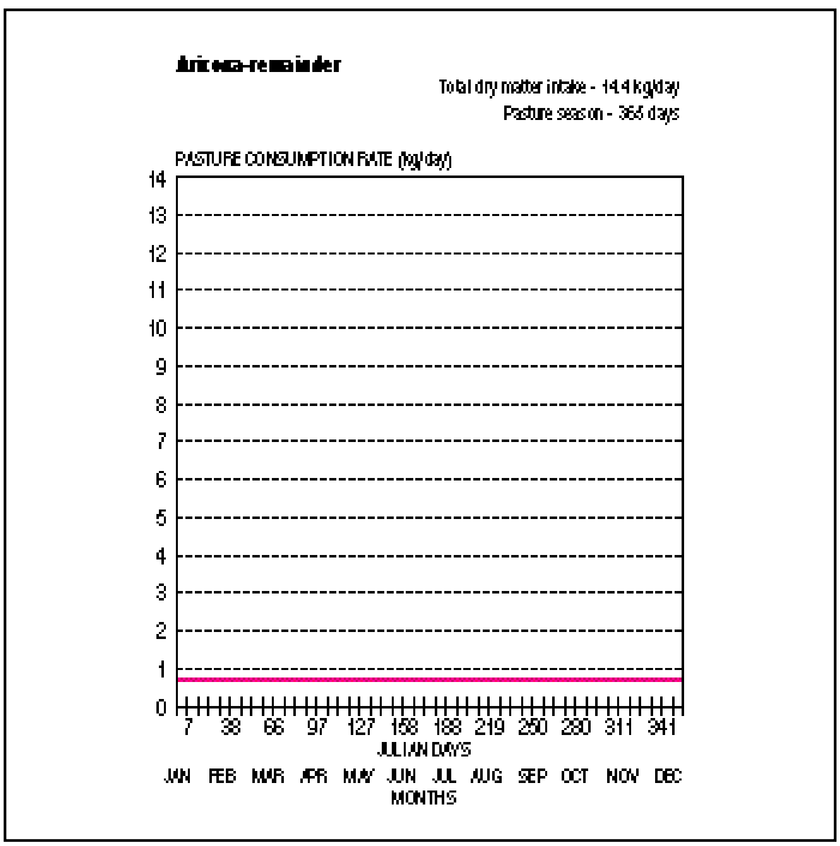
Utah pasture regions




Alabama-north
Total dry matter intake - 12.1 kg/day
Pasture season - 275 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

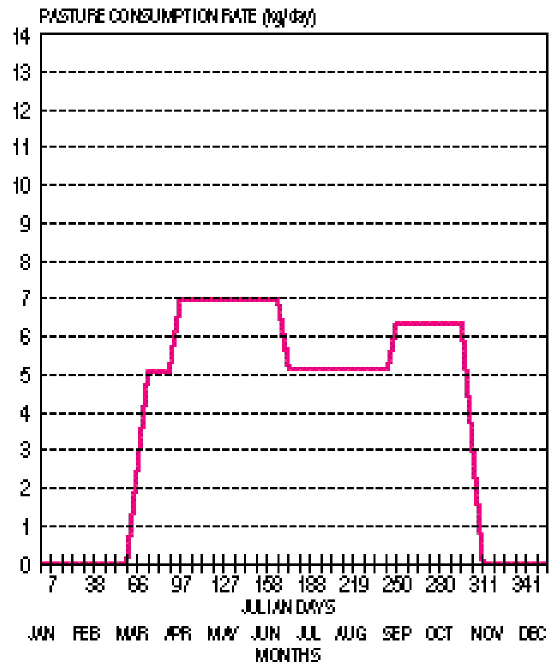

Alabama-south
Total dry matter intake - 12.1 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Arizona-northwest
Total dry matter intake - 14.4 kg/day
Pasture season - 183 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Arizona-remainder
Total dry matter intake - 14.4 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

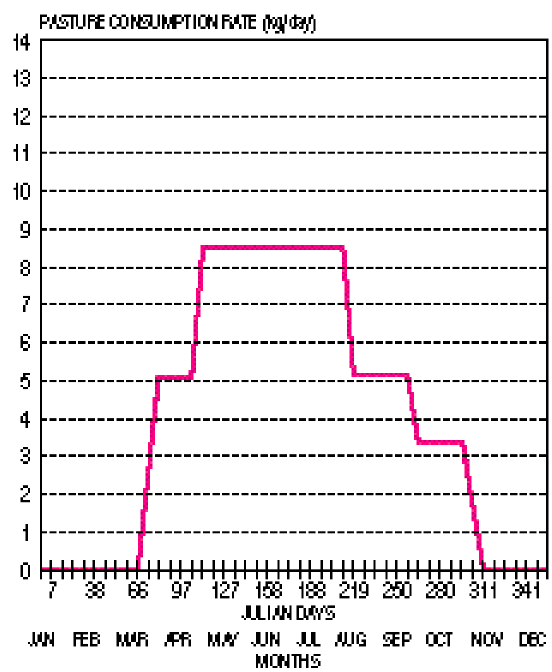
Arkansas

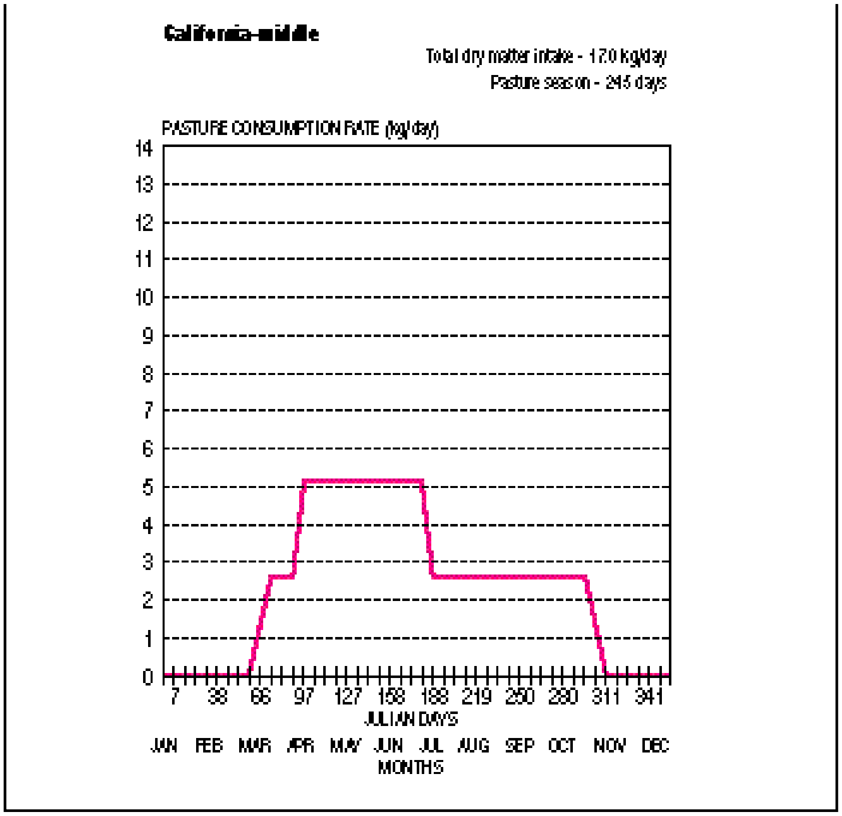
Total dry matter intake - 12.8 kg/day
Pasture season - 245 days

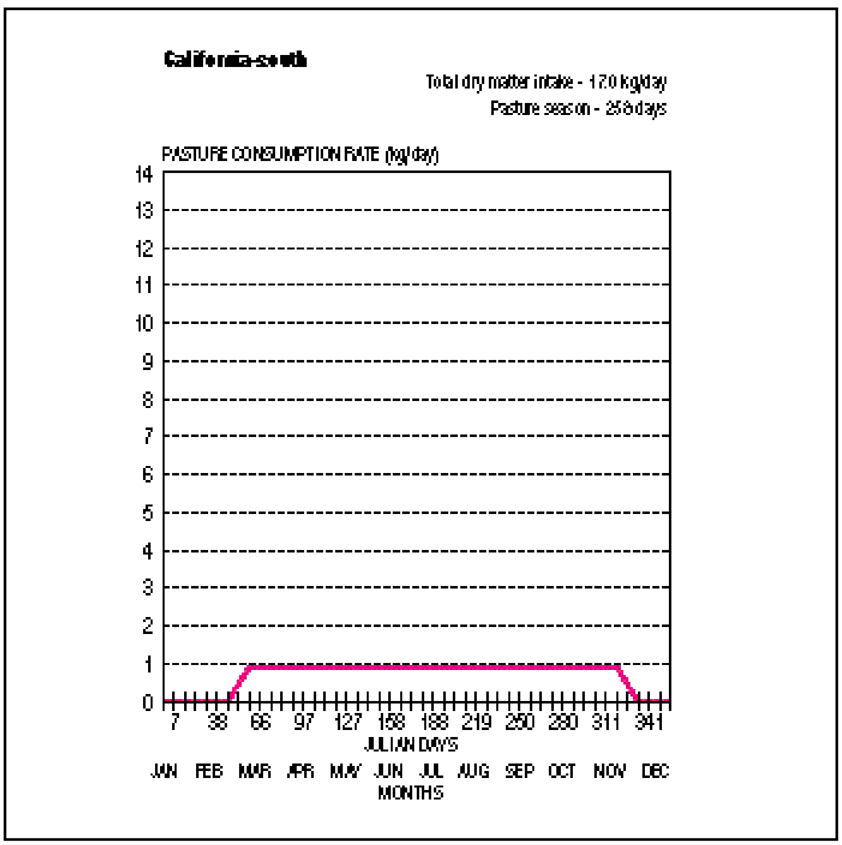


California-north

Total dry matter intake - 17.0 kg/day
Pasture season - 238 days




California-middle
Total dry matter intake - 17.0 kg/day
Pasture season - 245 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


California-south
Total dry matter intake - 17.0 kg/day
Pasture season - 258 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
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4
3
2
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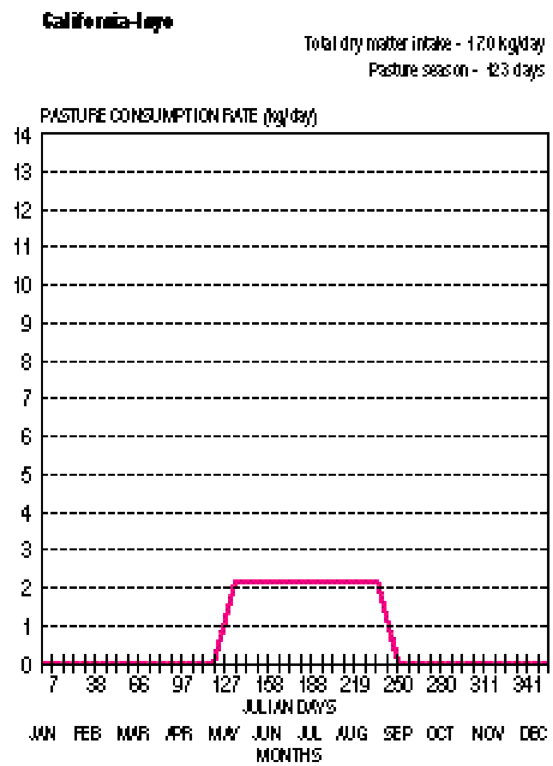
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


California-Inyo
Total dry matter intake - 17.0 kg/day
Pasture season - 123 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
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4
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2
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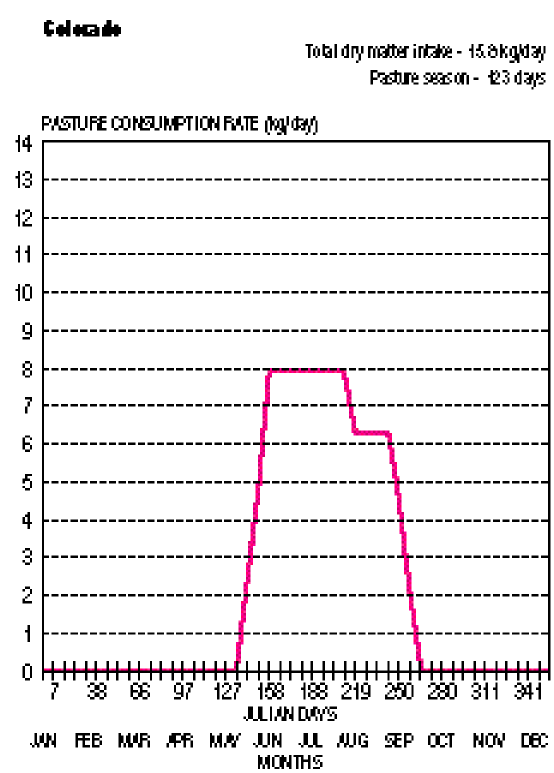
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Colorado
Total dry matter intake - 15.8 kg/day
Pasture season - 123 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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9
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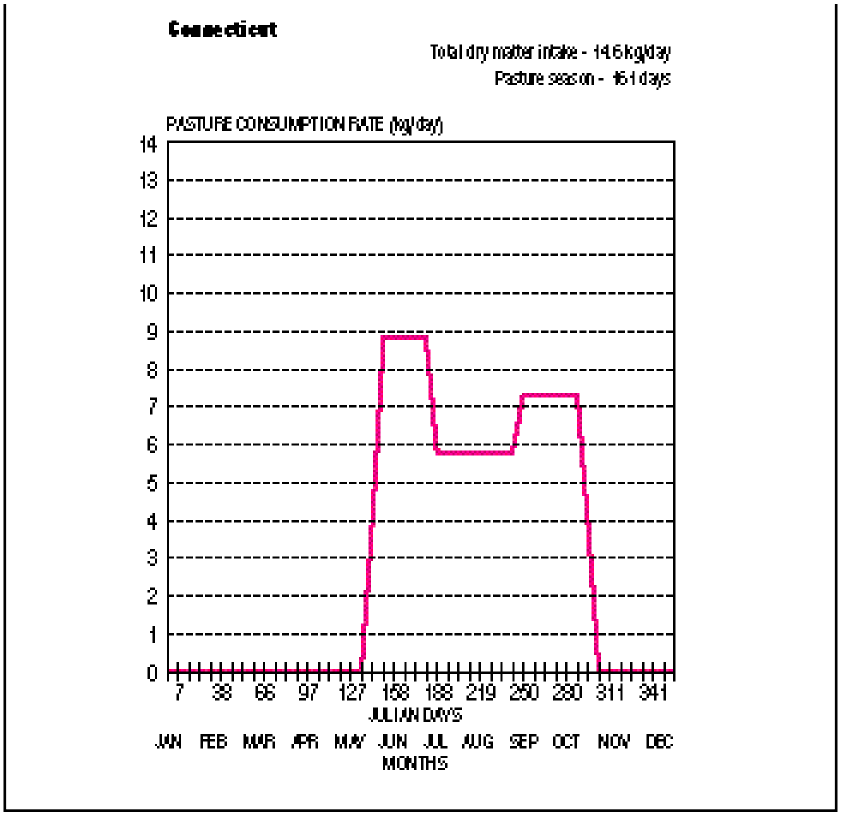
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Connecticut
Total dry matter intake - 14.6 kg/day
Pasture season - 161 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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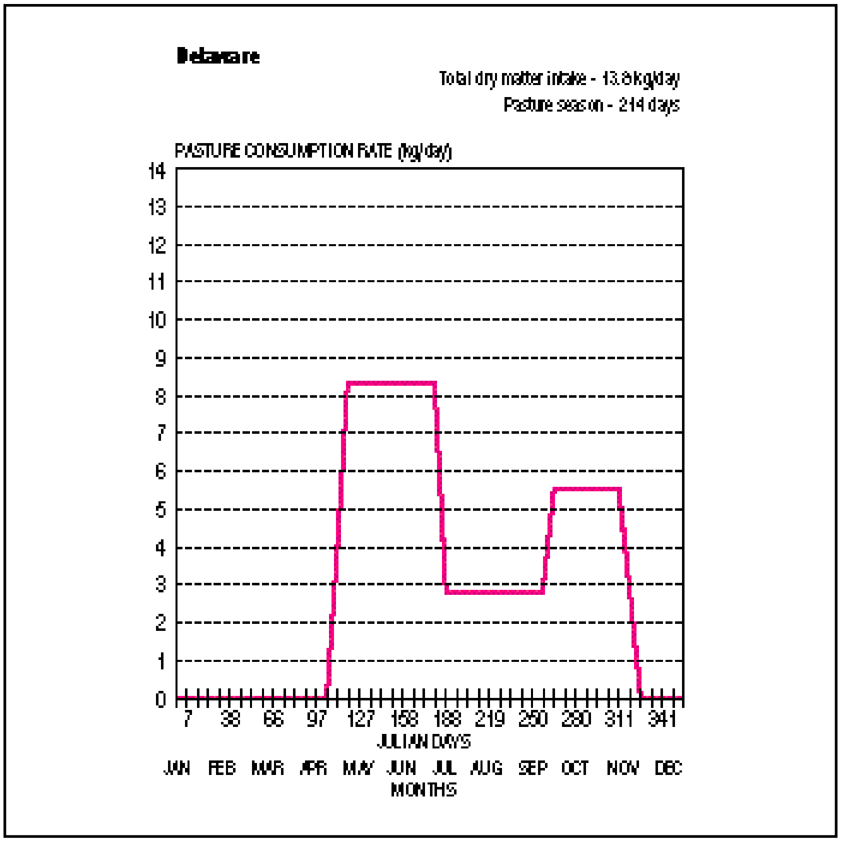
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Delaware
Total dry matter intake - 13.8 kg/day
Pasture season - 214 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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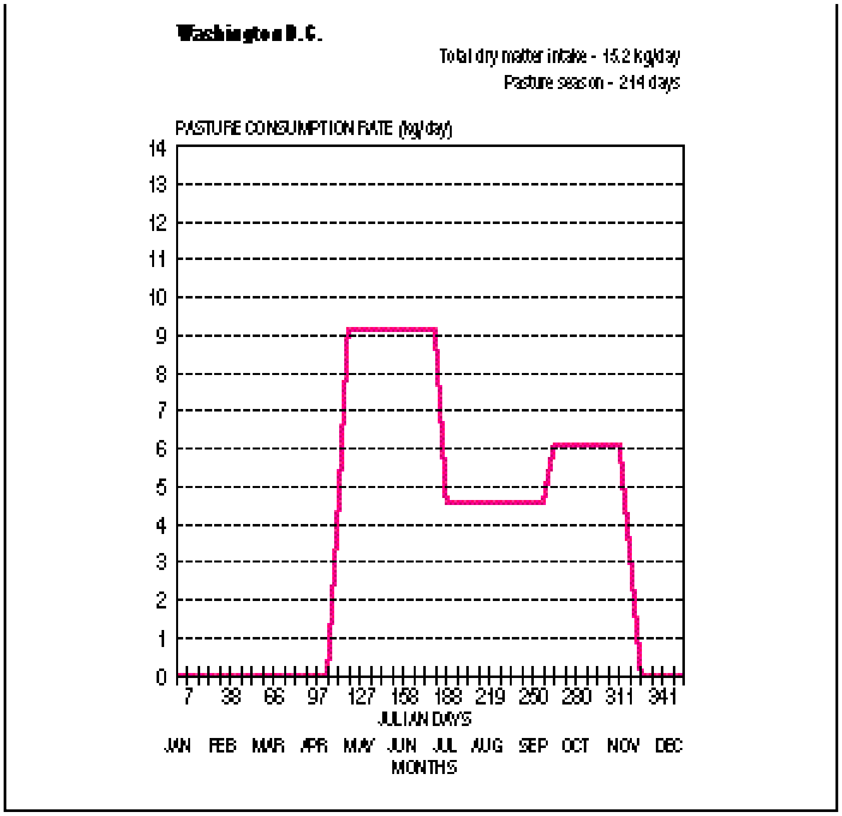
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Washington D.C.
Total dry matter intake - 15.2 kg/day
Pasture season - 214 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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2
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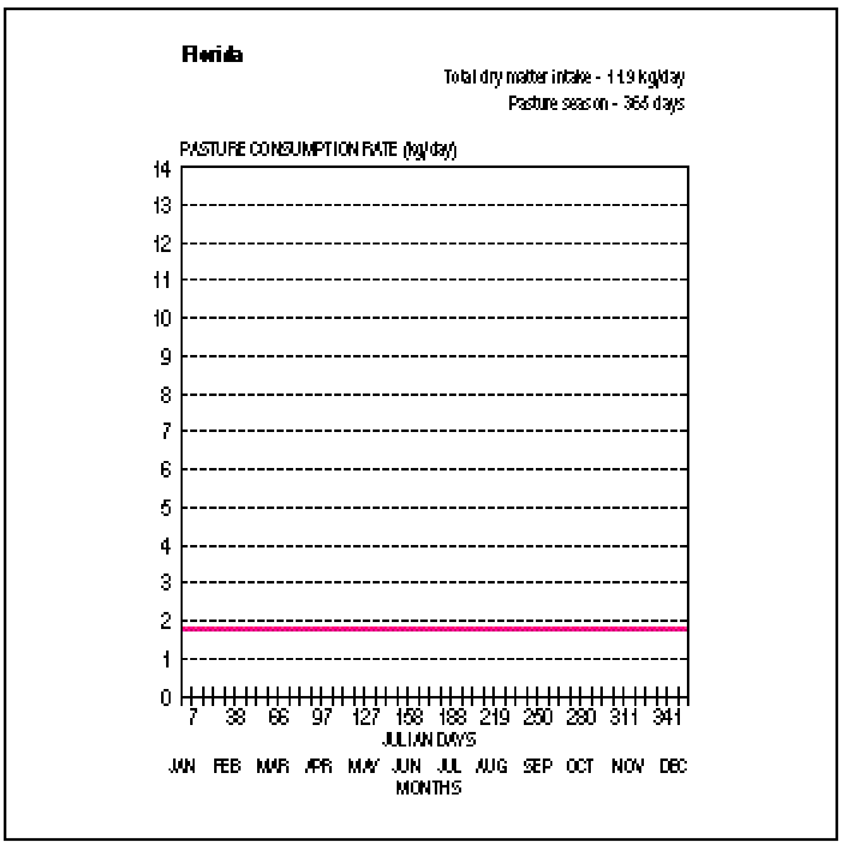
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Florida
Total dry matter intake - 11.9 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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9
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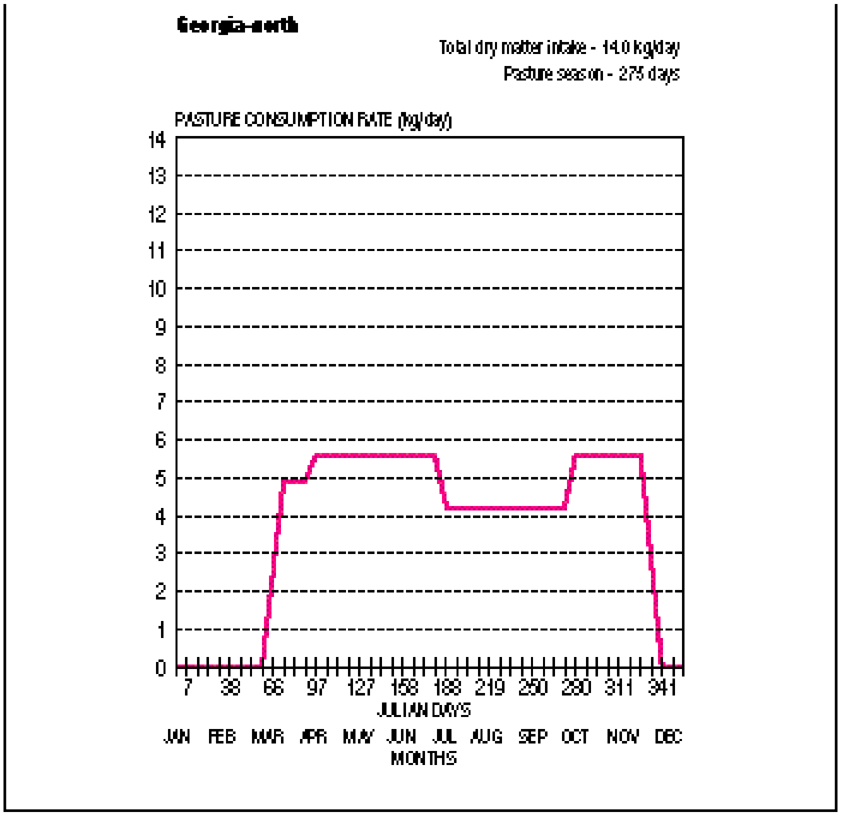
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Georgia-north
Total dry matter intake - 14.0 kg/day
Pasture season - 275 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
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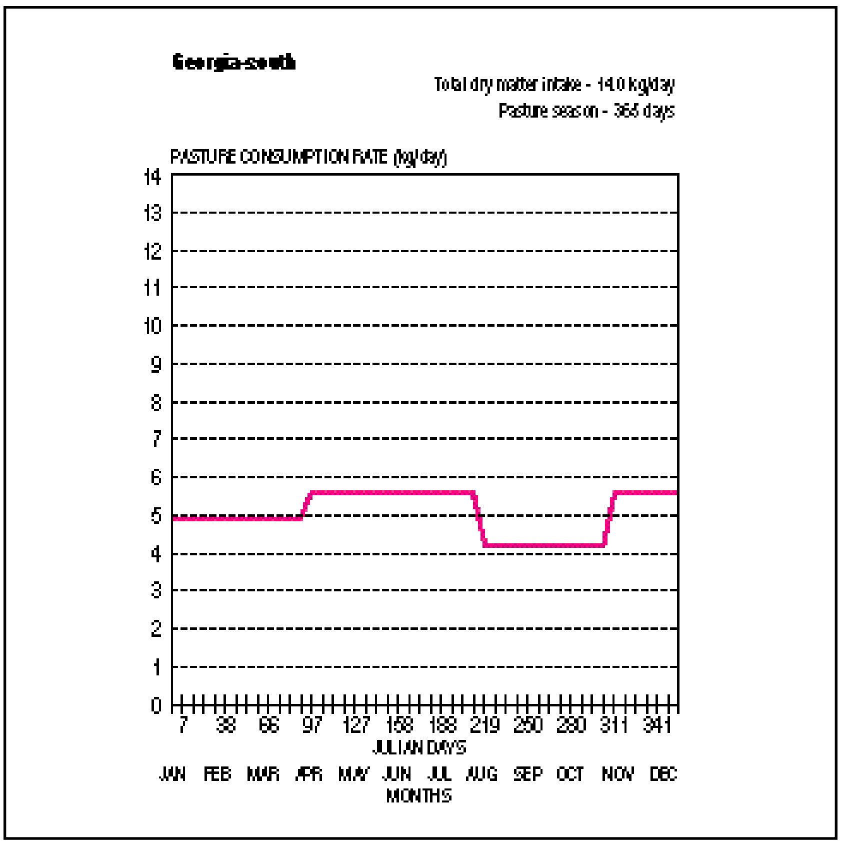
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Georgia-south
Total dry matter intake - 14.0 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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8
7
6
5
4
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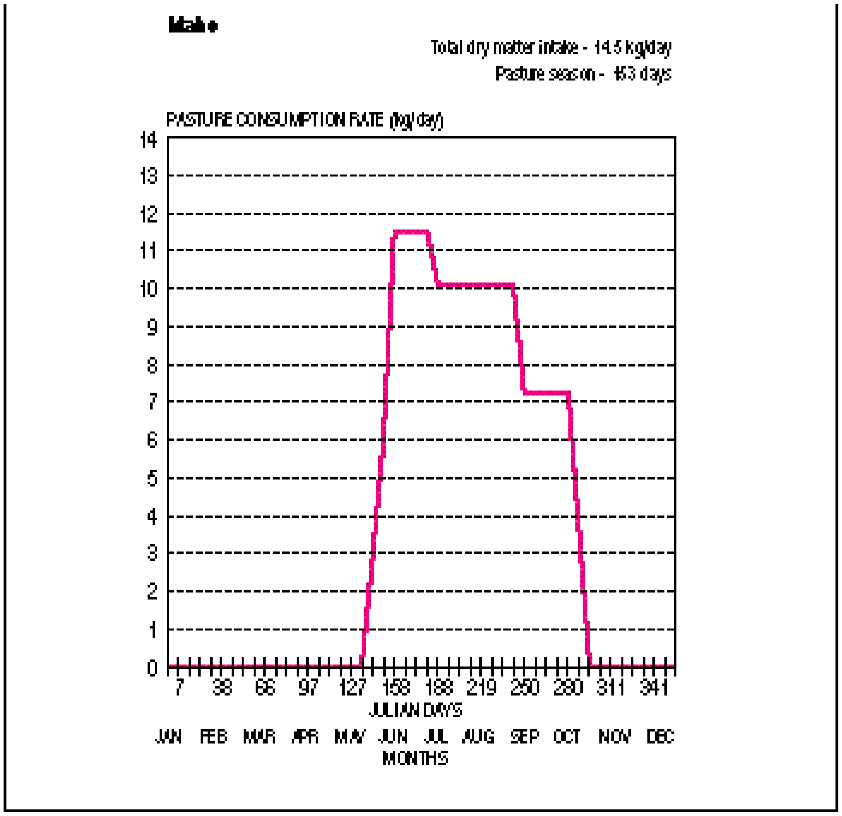
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Idaho
Total dry matter intake - 14.5 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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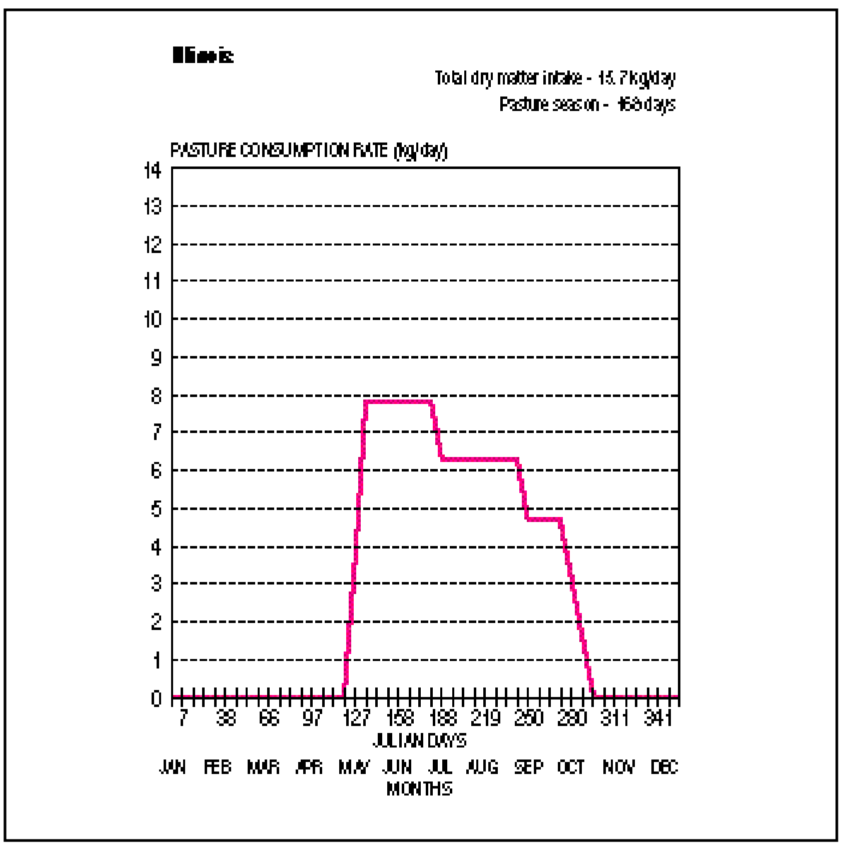
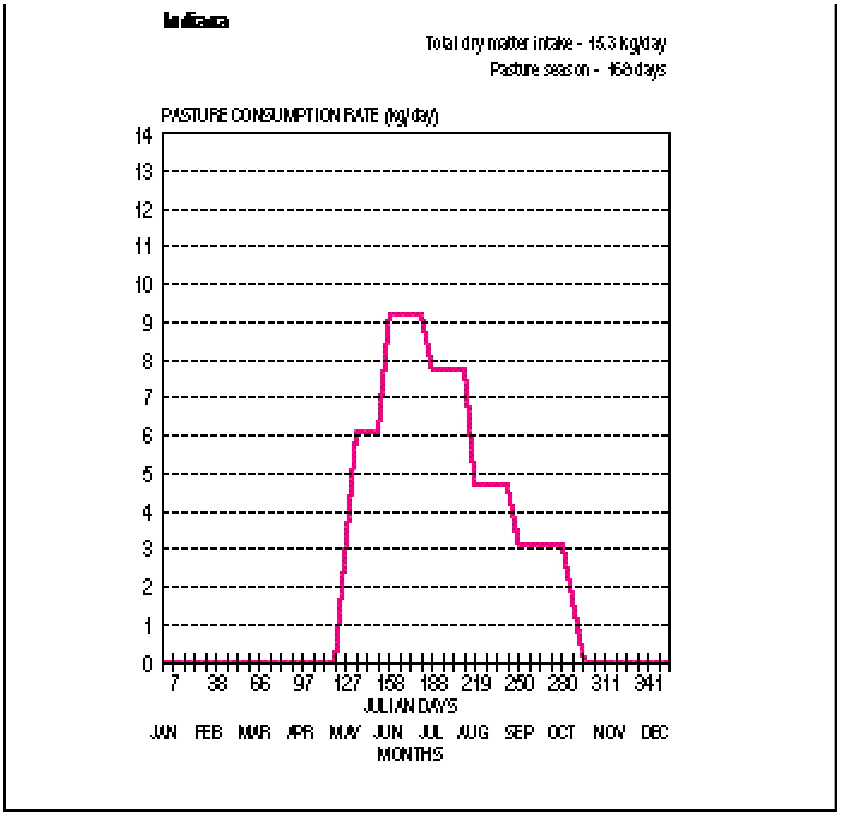
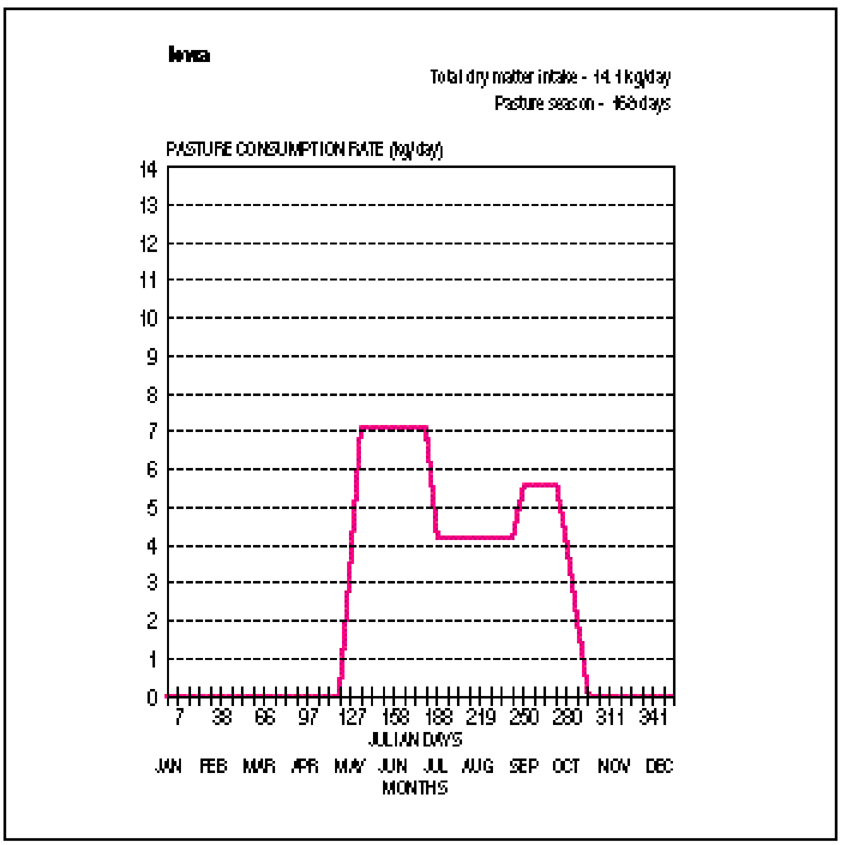
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Illinois
Total dry matter intake - 15.7 kg/day
Pasture season - 168 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

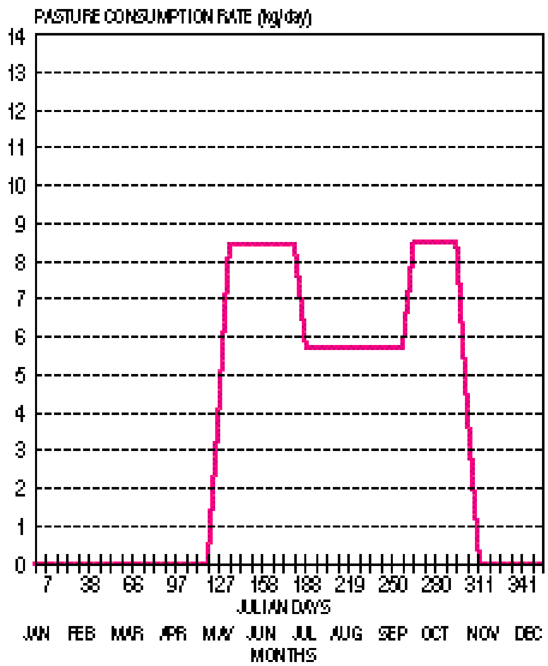

Indiana
Total dry matter intake - 15.3 kg/day
Pasture season - 168 days
PASTURE CONSUMPTION RATE (kg/day)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Iowa
Total dry matter intake - 14.1 kg/day
Pasture season - 168 days
PASTURE CONSUMPTION RATE (kg/day)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

Kansas

Total dry matter intake - 14.2 kg/day

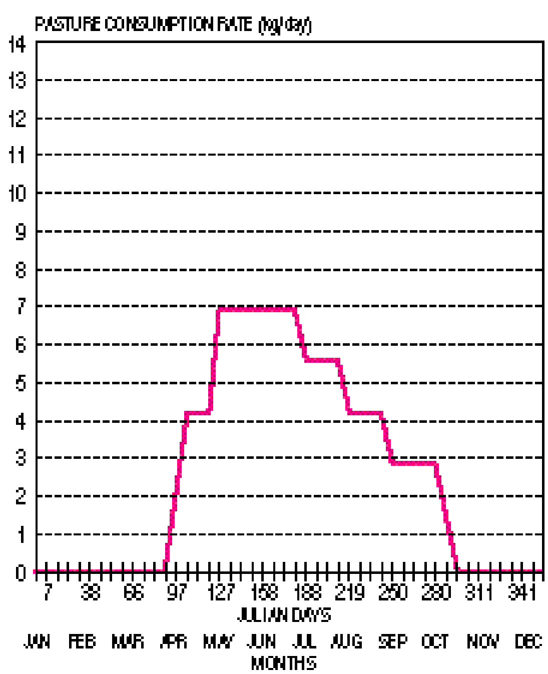
Pasture season - 184 days

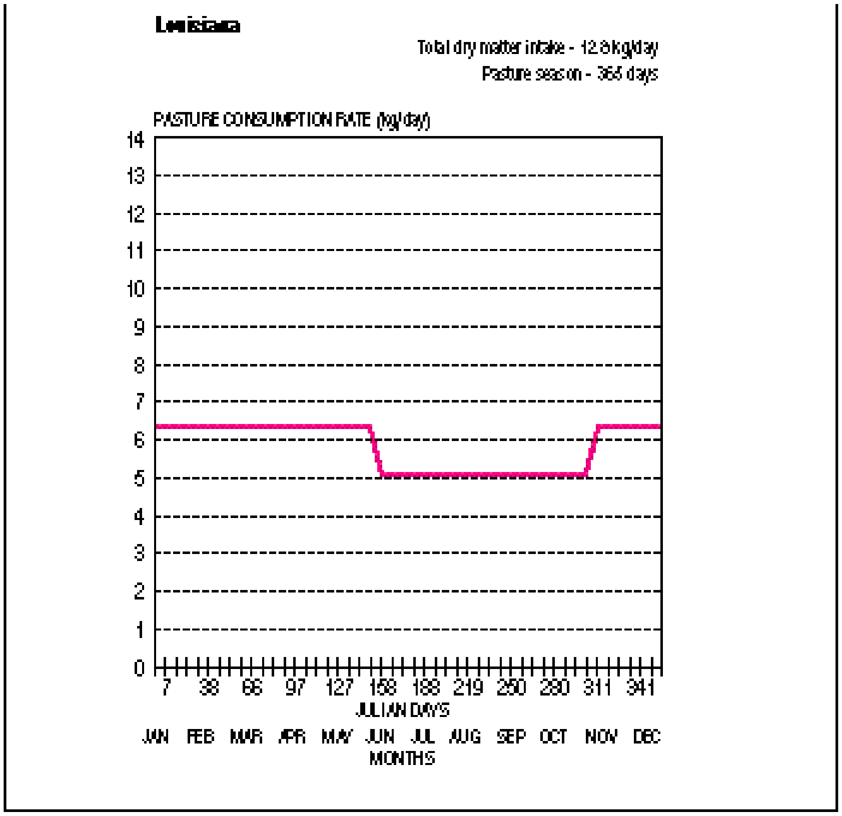


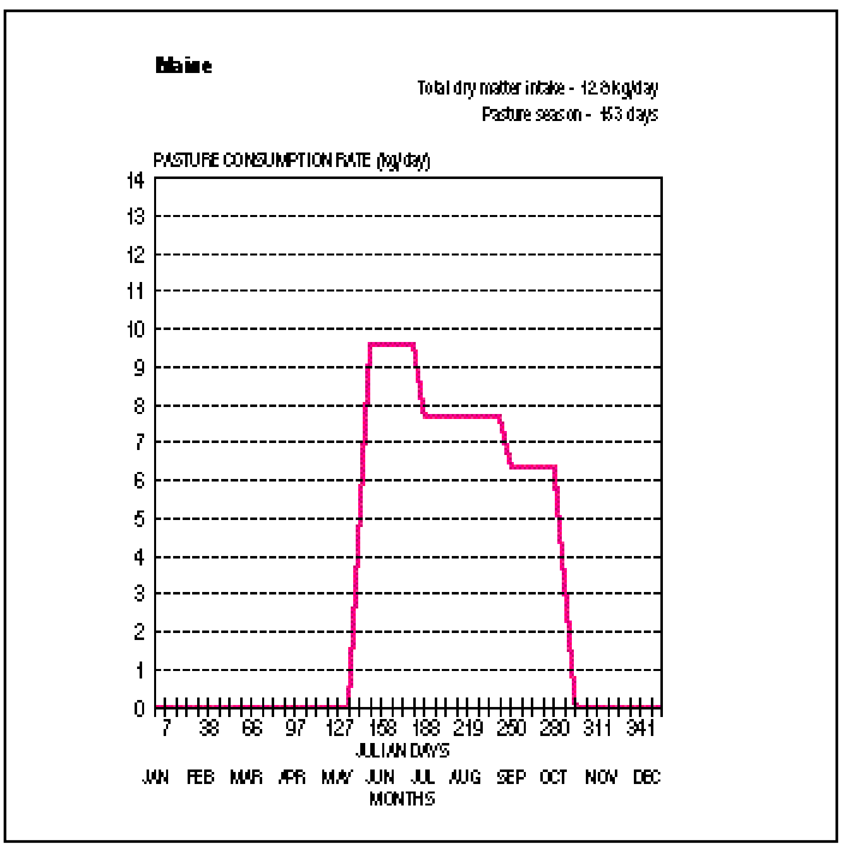
Kentucky

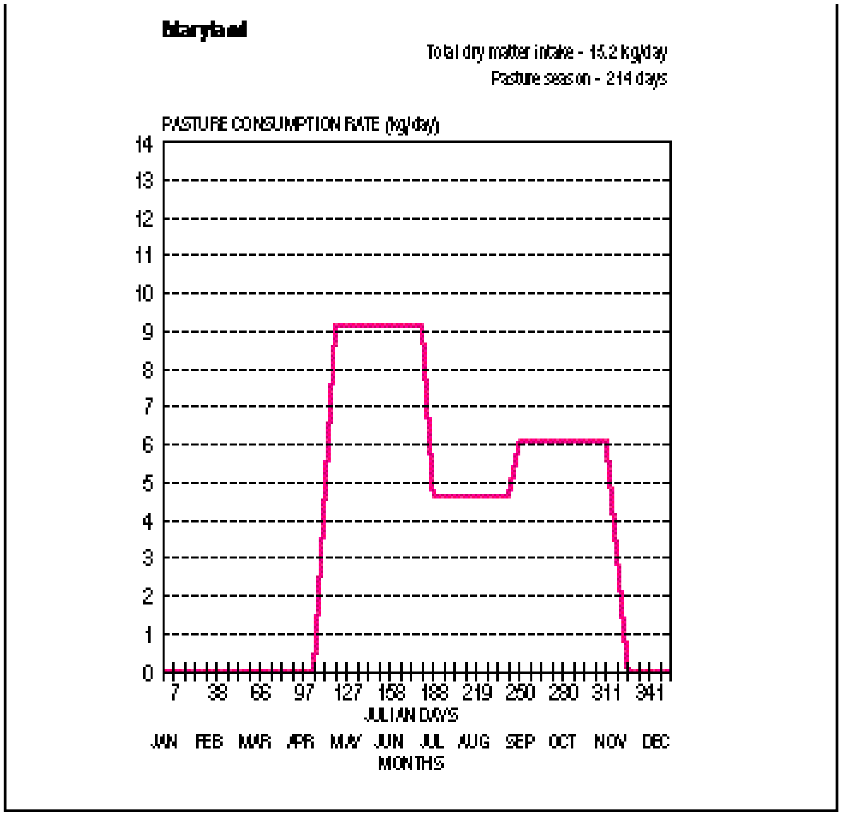
Total dry matter intake - 13.9 kg/day

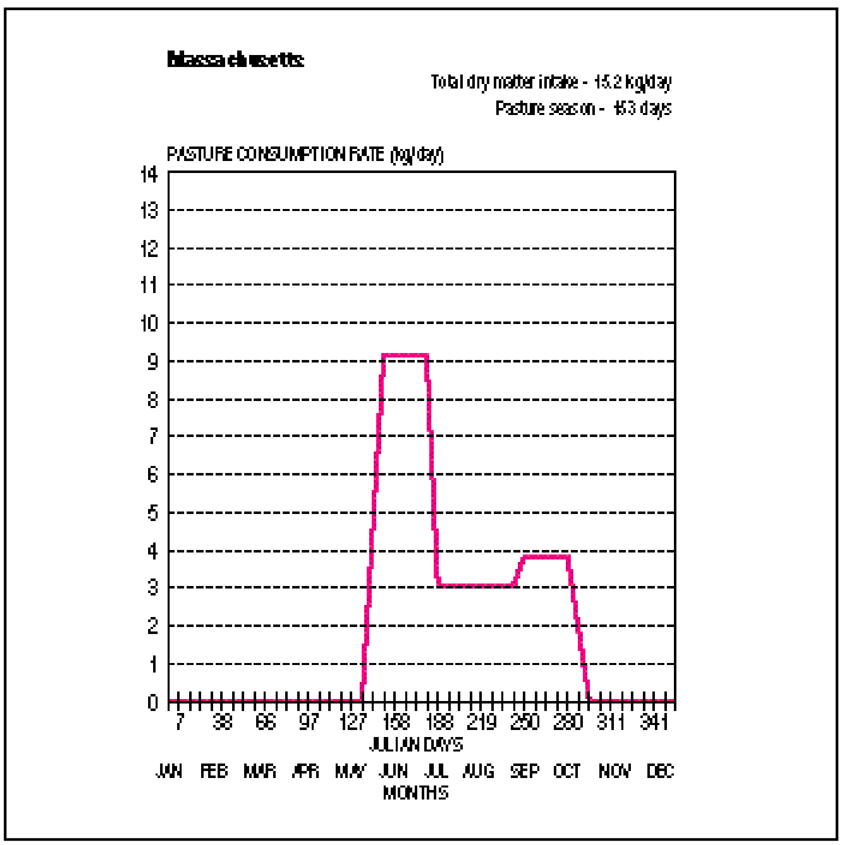
Pasture season - 196 days

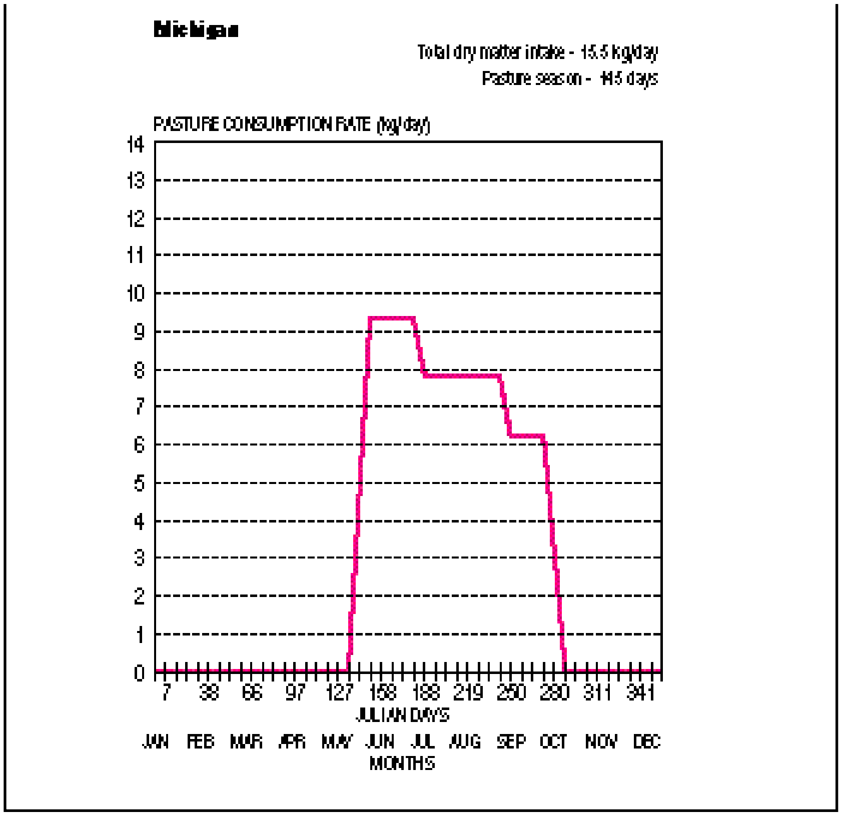


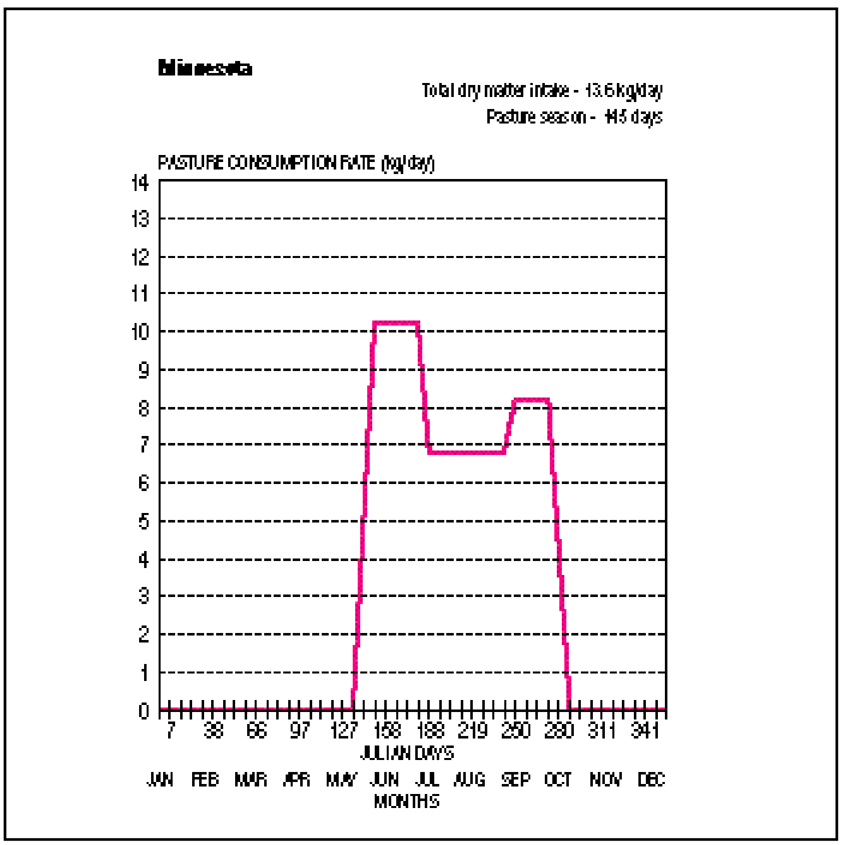

Louisiana
Total dry matter intake - 12.8 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Maine
Total dry matter intake - 12.8 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Maryland
Total dry matter intake - 15.2 kg/day
Pasture season - 214 days
PASTURE CONSUMPTION RATE (kg/day)
JULIAN DAYS
MONTHS


Massachusetts
Total dry matter intake - 15.2 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
JULIAN DAYS
MONTHS


Michigan
Total dry matter intake - 15.5 kg/day
Pasture season - 145 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Minnesota
Total dry matter intake - 13.6 kg/day
Pasture season - 145 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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9
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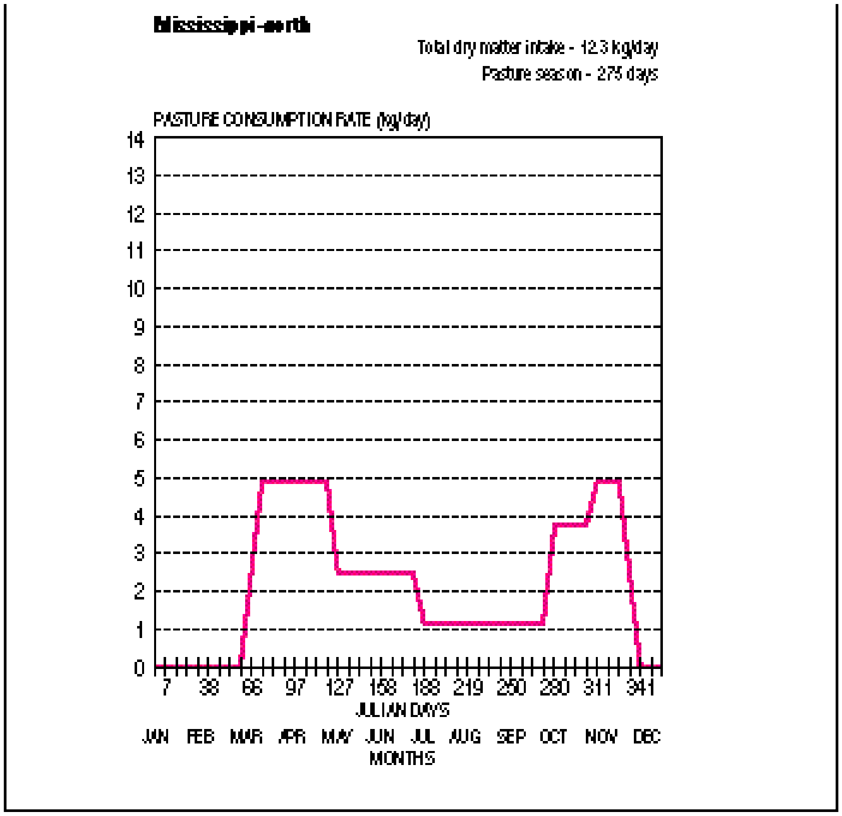
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Mississippi-north
Total dry matter intake - 12.3 kg/day
Pasture season - 275 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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9
8
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6
5
4
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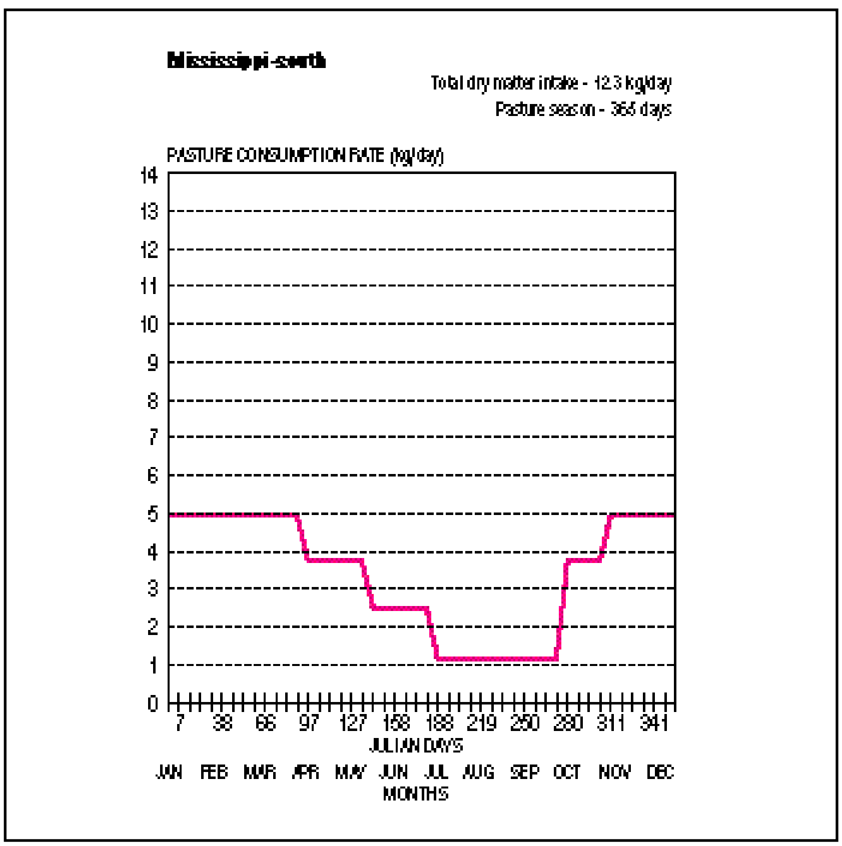
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Mississippi-south
Total dry matter intake - 12.3 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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10
9
8
7
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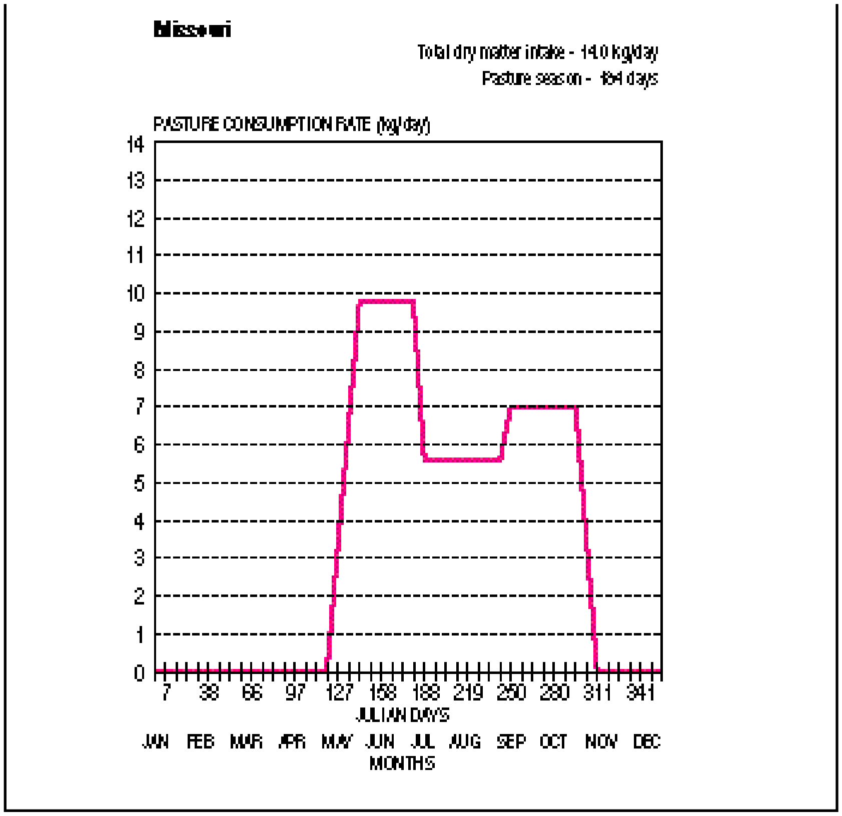
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Missouri
Total dry matter intake - 14.0 kg/day
Pasture season - 184 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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9
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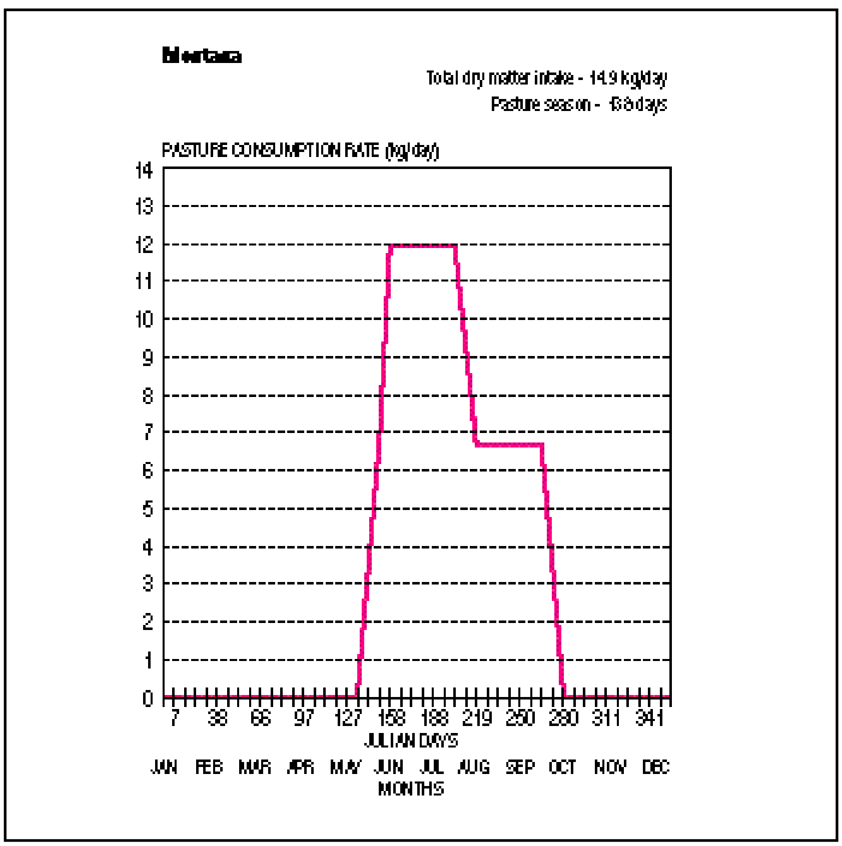
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Montana
Total dry matter intake - 14.9 kg/day
Pasture season - 158 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
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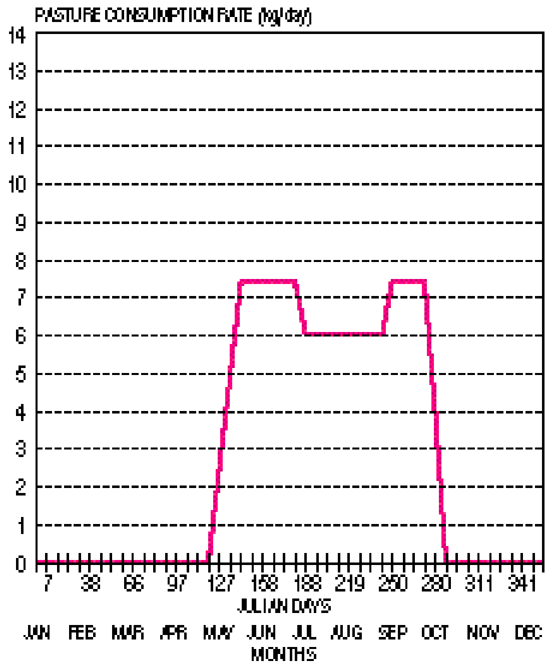
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

Nebraska

Total dry matter intake - 15.0 kg/day

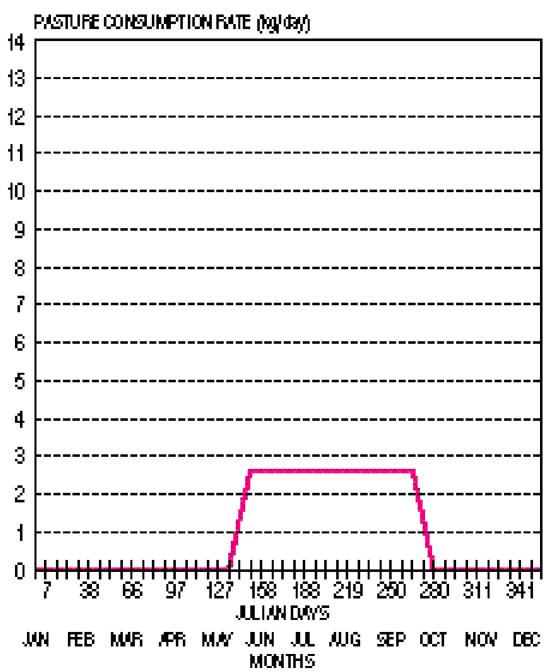
Pasture season - 160 days

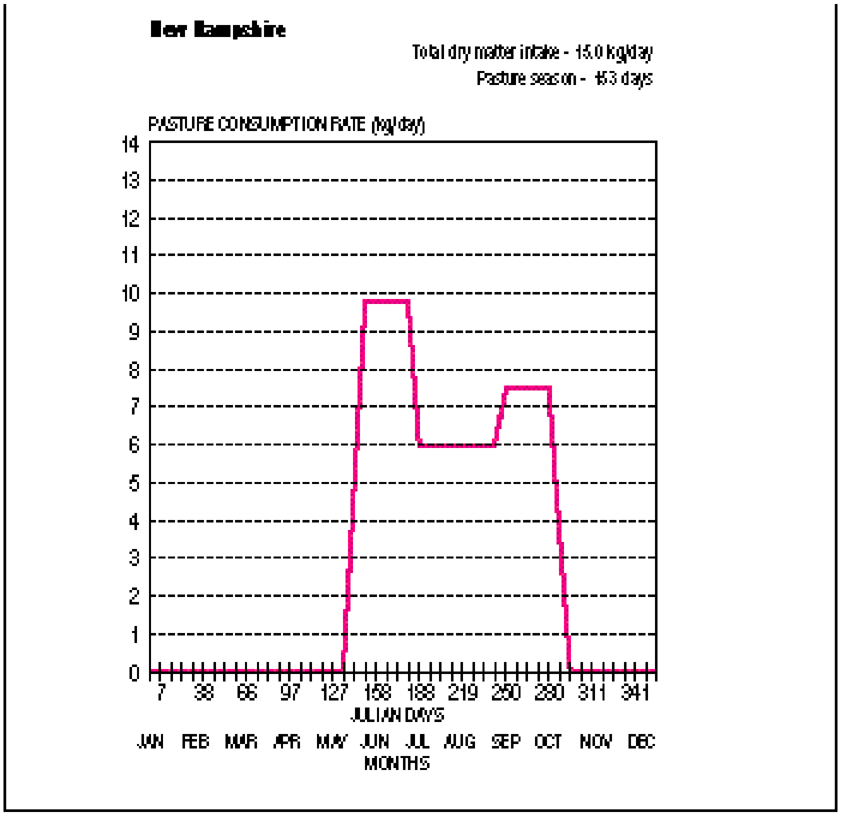


Nevada

Total dry matter intake - 17.4 kg/day

Pasture season - 138 days




New Hampshire
Total dry matter intake - 15.0 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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9
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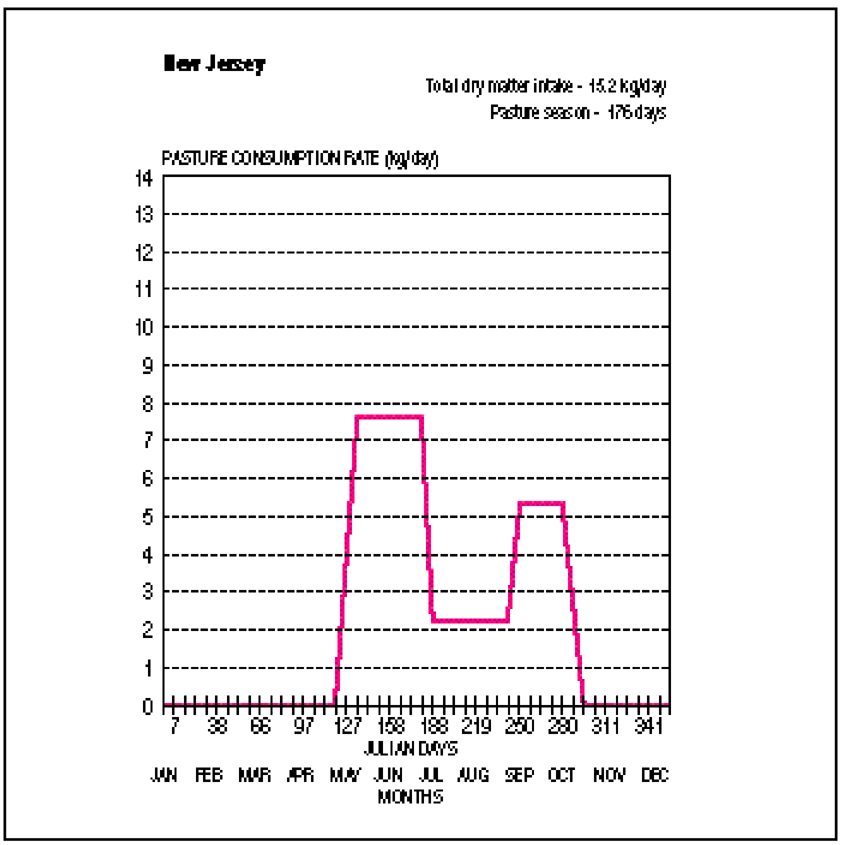
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


New Jersey
Total dry matter intake - 15.2 kg/day
Pasture season - 176 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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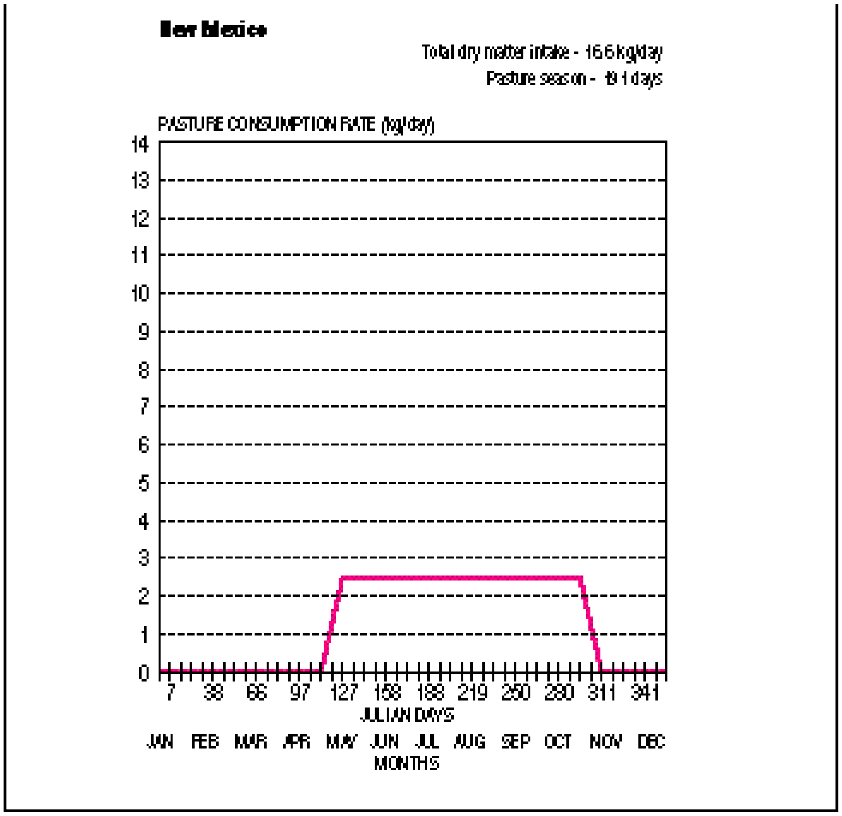
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


New Mexico
Total dry matter intake - 16.6 kg/day
Pasture season - 191 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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6
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4
3
2
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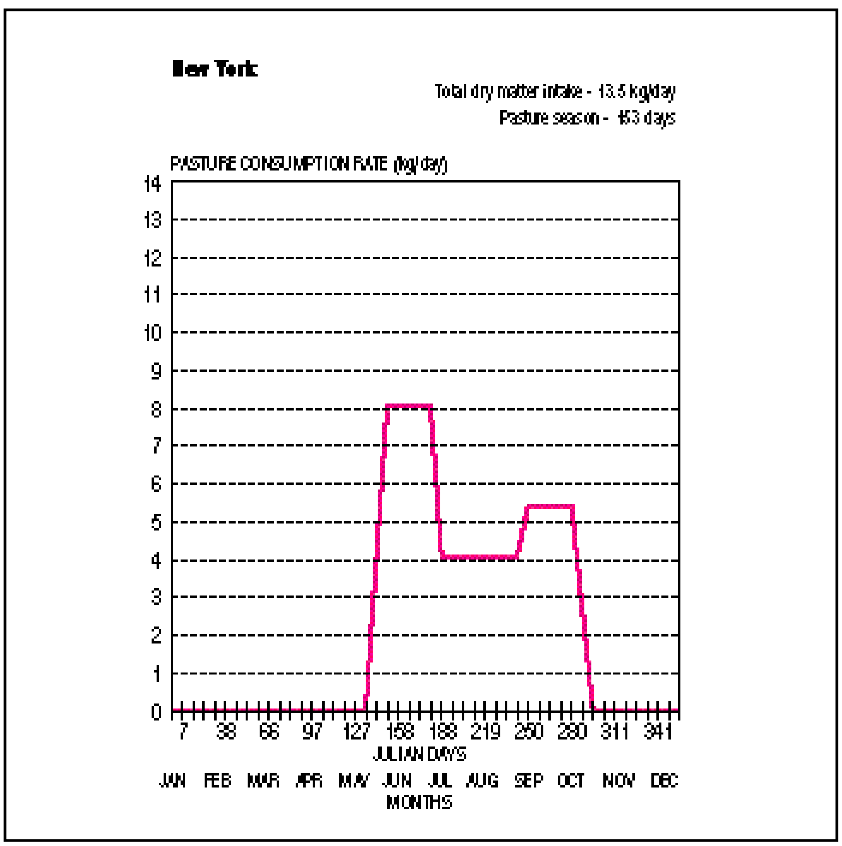
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


New York
Total dry matter intake - 13.5 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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4
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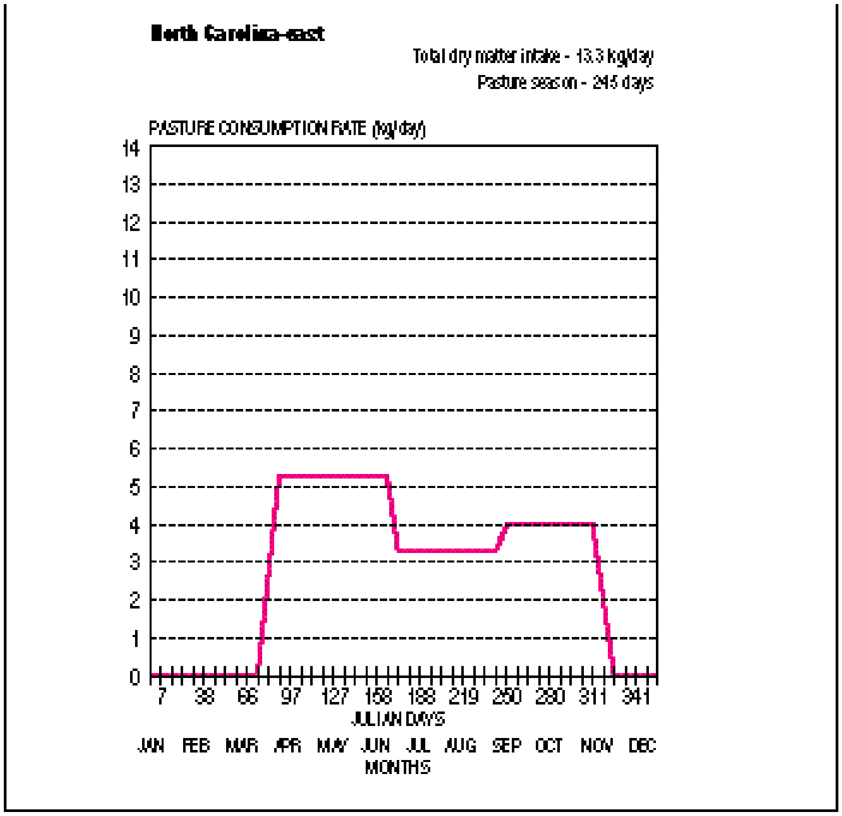
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS



North Carolina-east
Total dry matter intake - 13.3 kg/day
Pasture season - 245 days
PASTURE CONSUMPTION RATE (kg/day)
14
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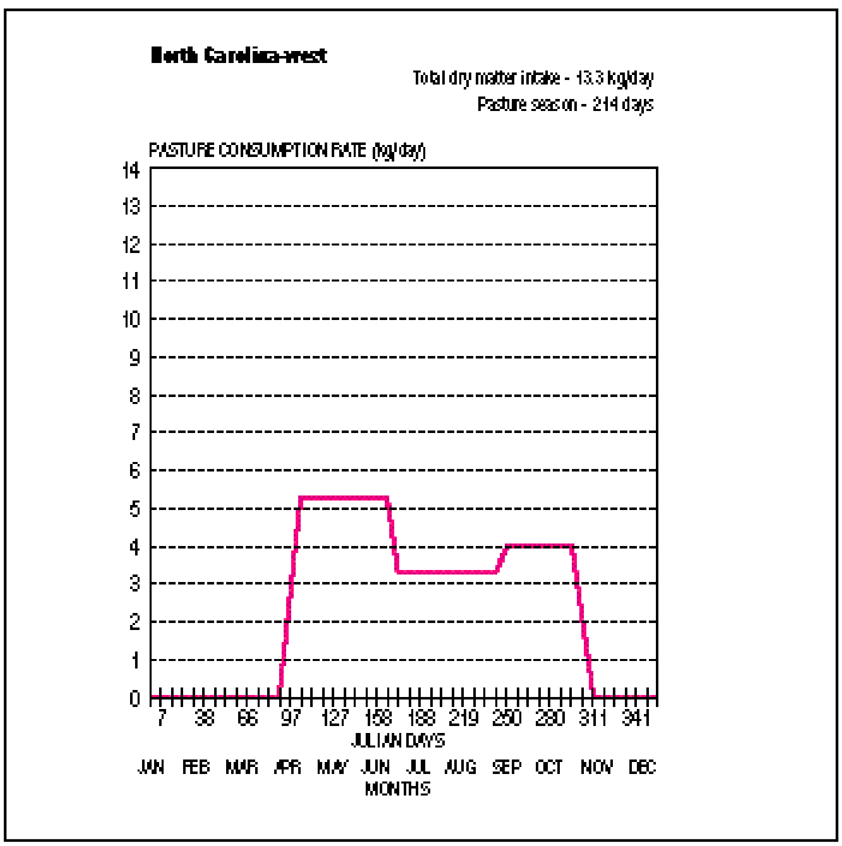
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS



North Carolina-west
Total dry matter intake - 13.3 kg/day
Pasture season - 214 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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7
6
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4
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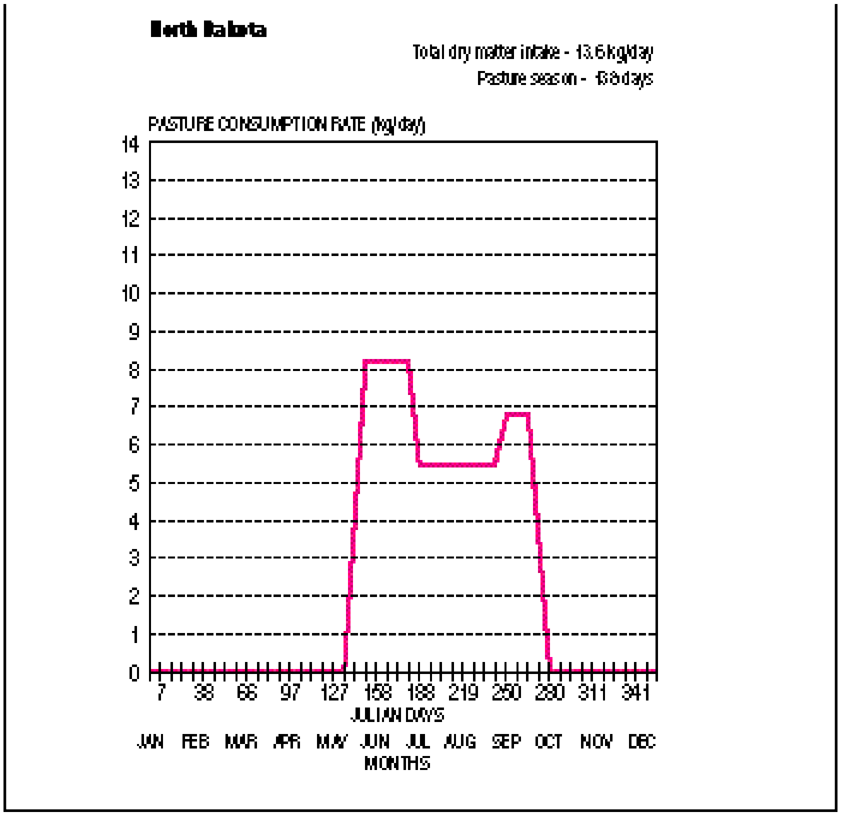
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS



Total dry matter intake - 13.6 kg/day
Pasture season -
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
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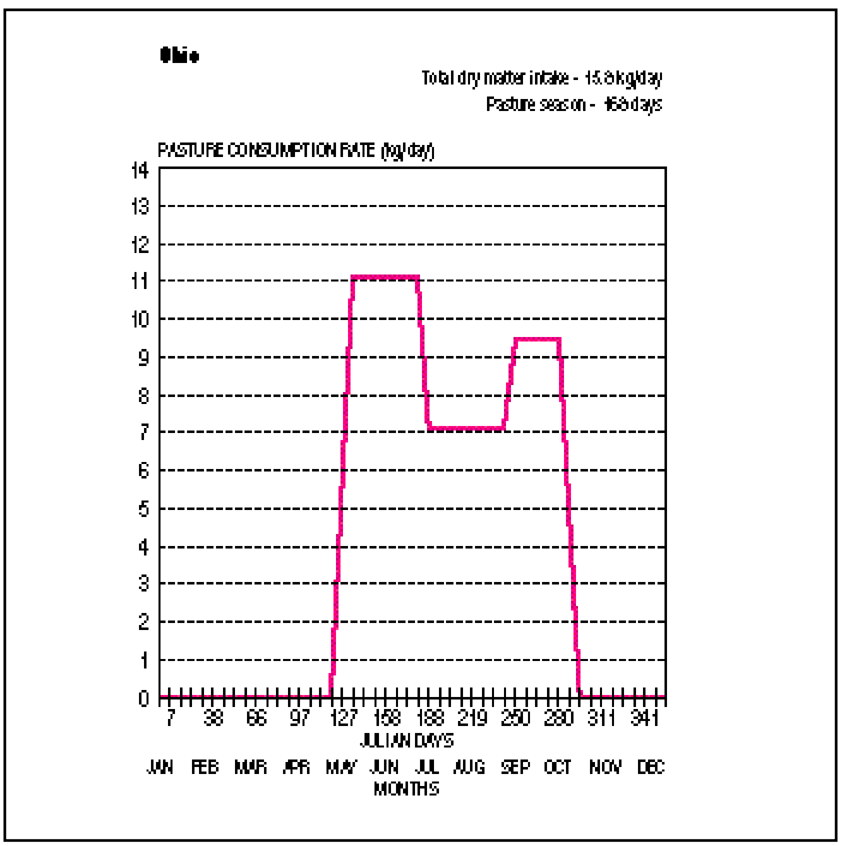
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS



Total dry matter intake - 15.8 kg/day
Pasture season -
PASTURE CONSUMPTION RATE (kg/day)
14
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7
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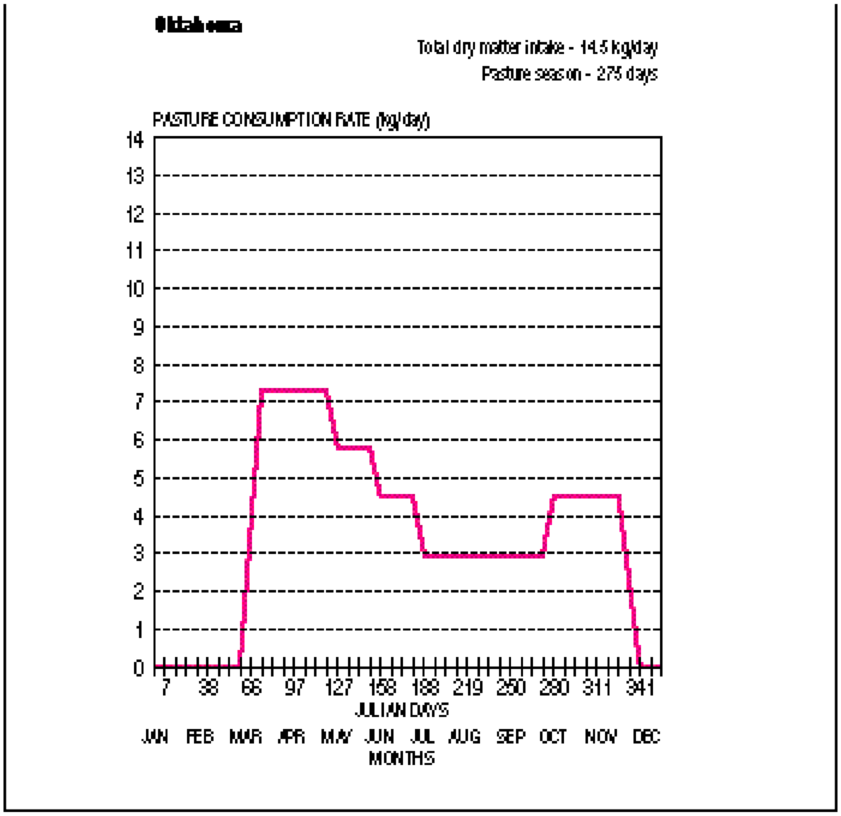
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Oklahoma
Total dry matter intake - 14.5 kg/day
Pasture season - 275 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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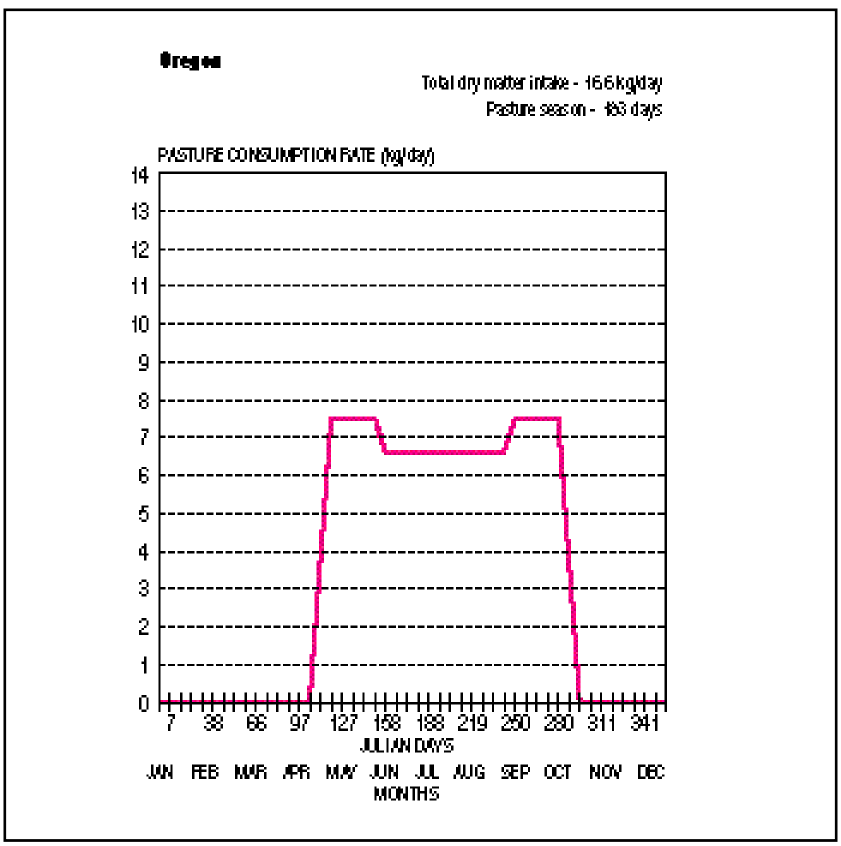
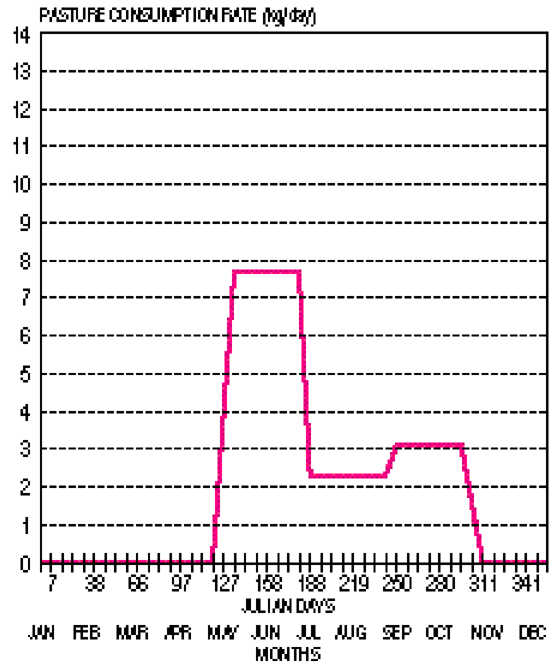
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Oregon
Total dry matter intake - 16.6 kg/day
Pasture season - 183 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

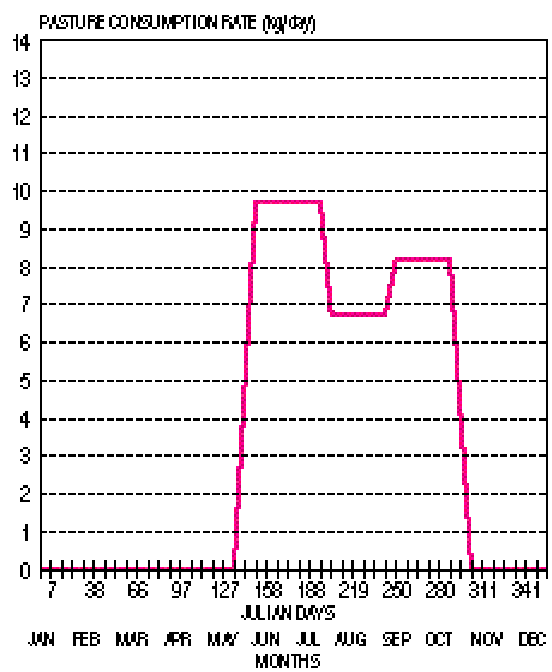
Pennsylvania

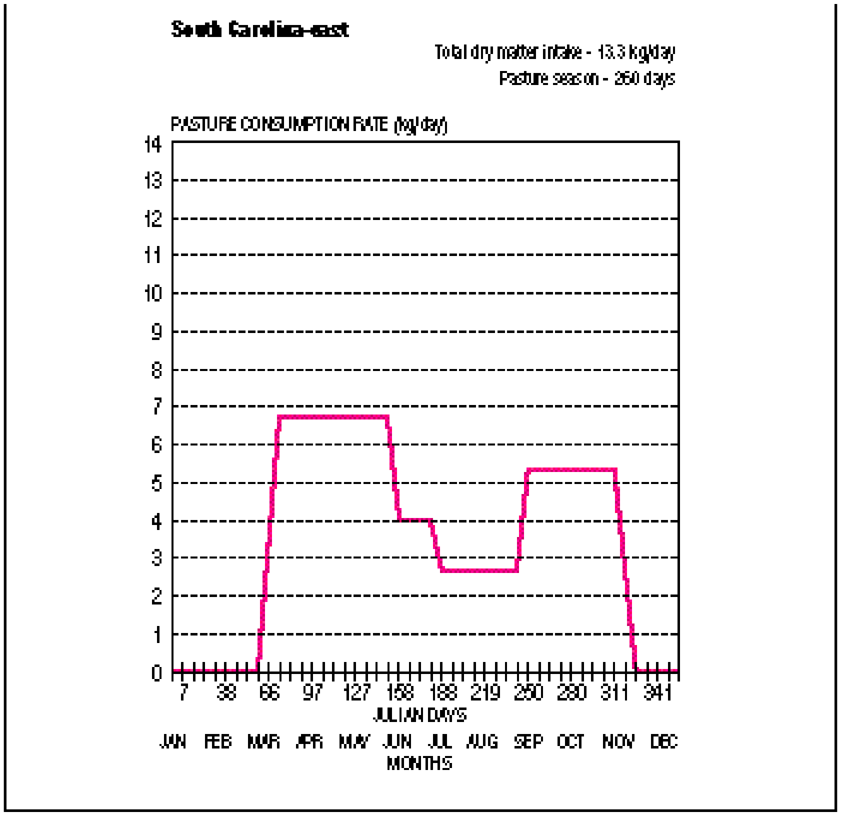
Total dry matter intake - 15.4 kg/day
Pasture season - 184 days



Rhode Island

Total dry matter intake - 14.9 kg/day
Pasture season - 161 days




South Carolina-east
Total dry matter intake - 13.3 kg/day
Pasture season - 260 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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10
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8
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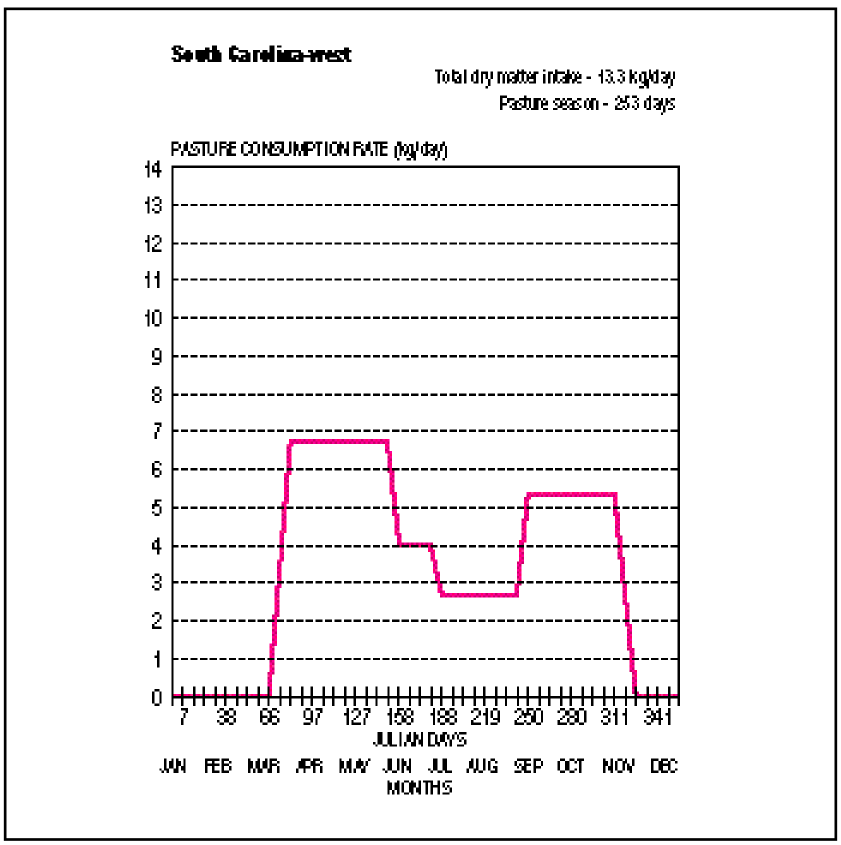
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


South Carolina-west
Total dry matter intake - 13.3 kg/day
Pasture season - 253 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
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6
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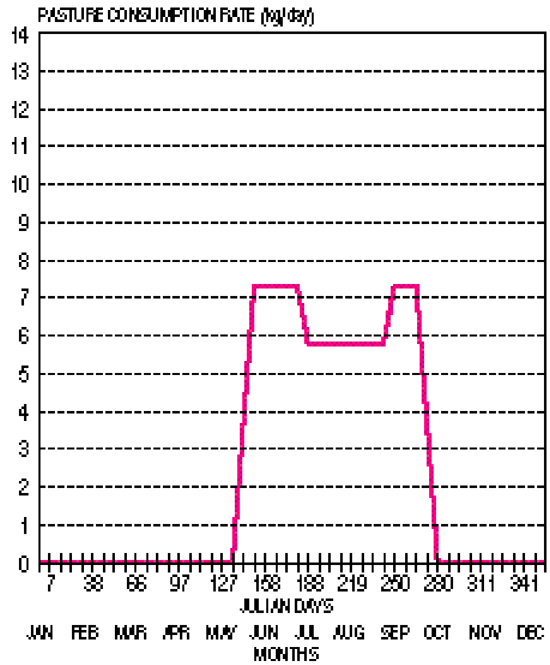
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

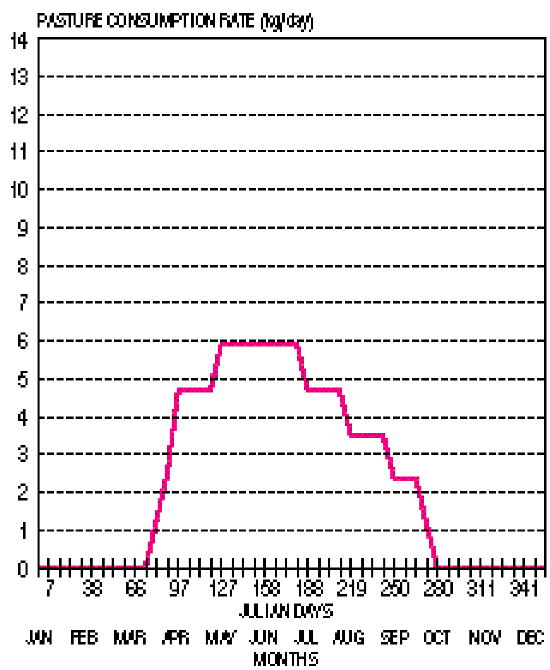
South Dakota

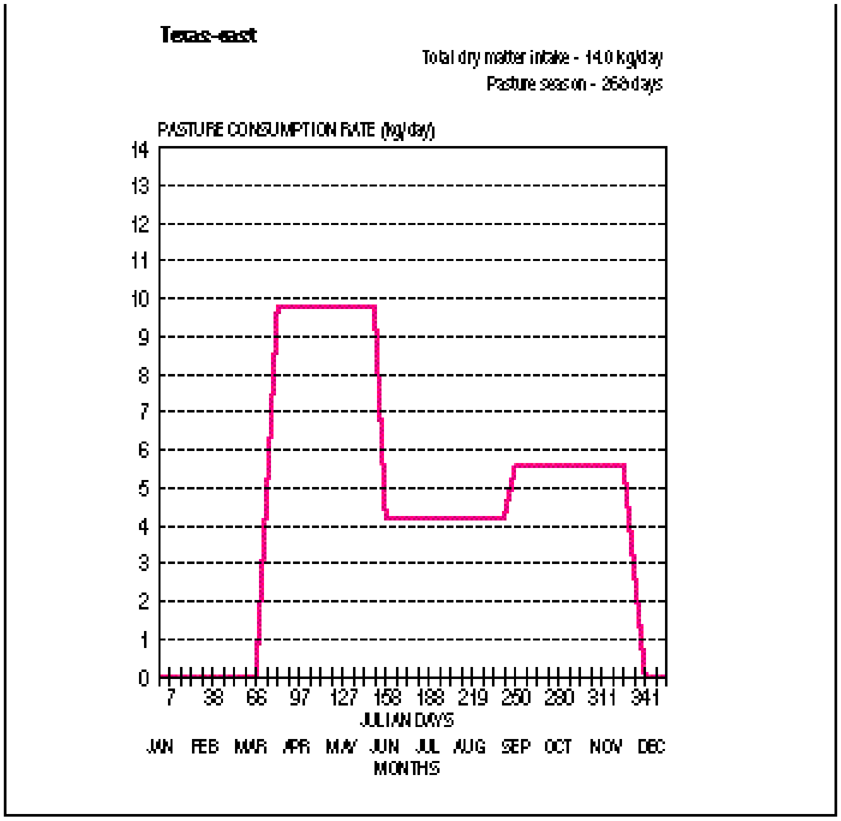
Total dry matter intake - 14.5 kg/day
Pasture season - 136 days



Tennessee

Total dry matter intake - 11.6 kg/day
Pasture season - 199 days




Texas-east
Total dry matter intake - 14.0 kg/day
Pasture season - 268 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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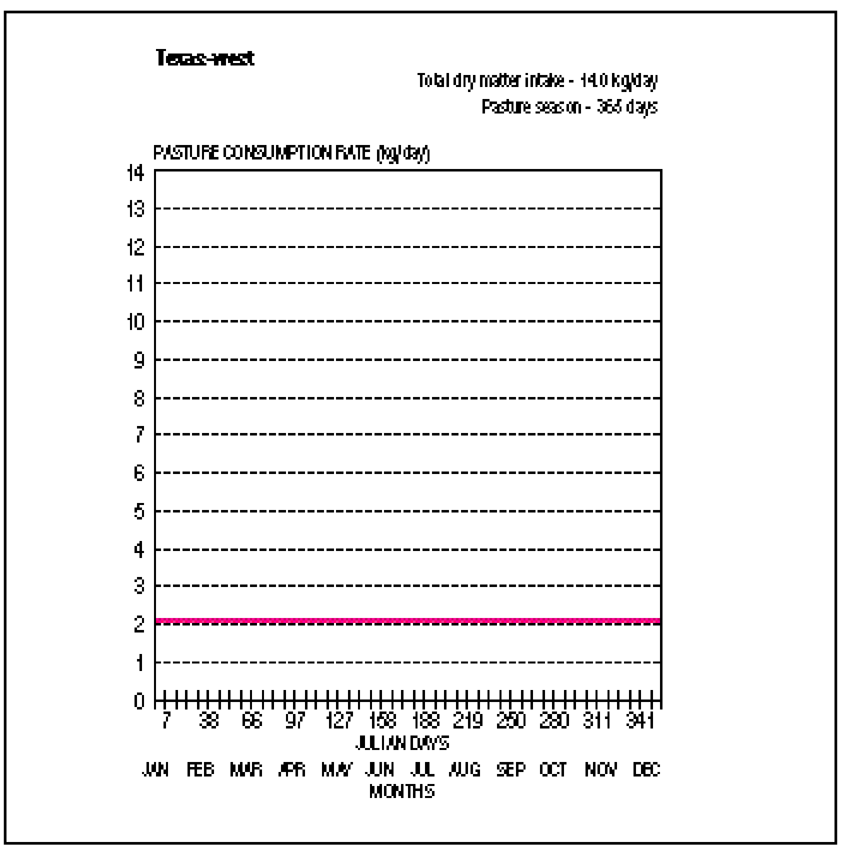
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Texas-west
Total dry matter intake - 14.0 kg/day
Pasture season - 365 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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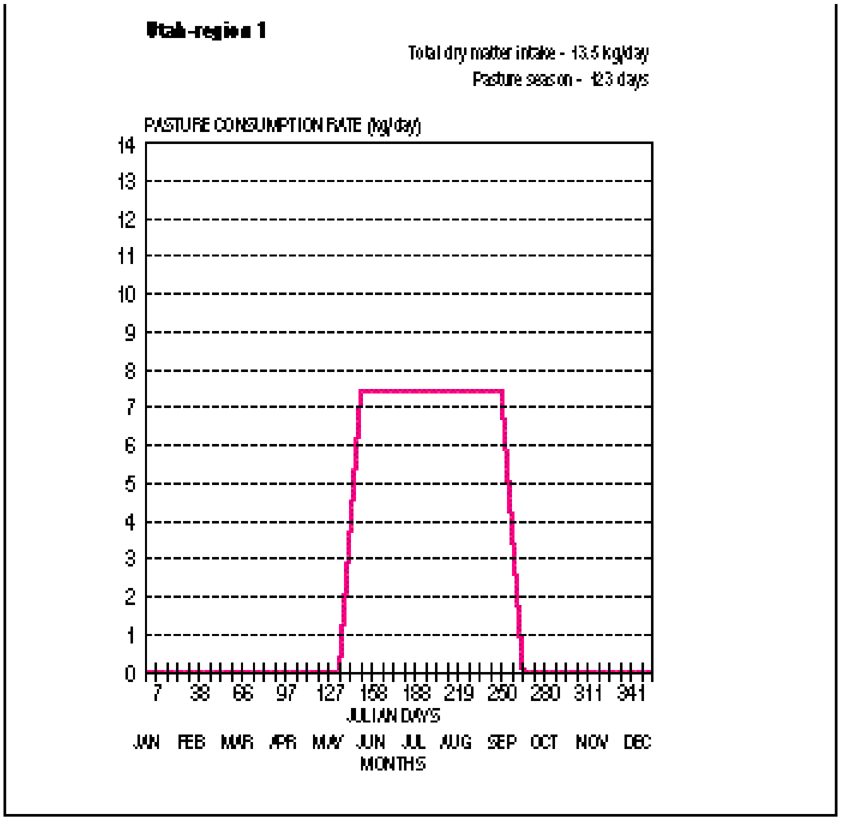
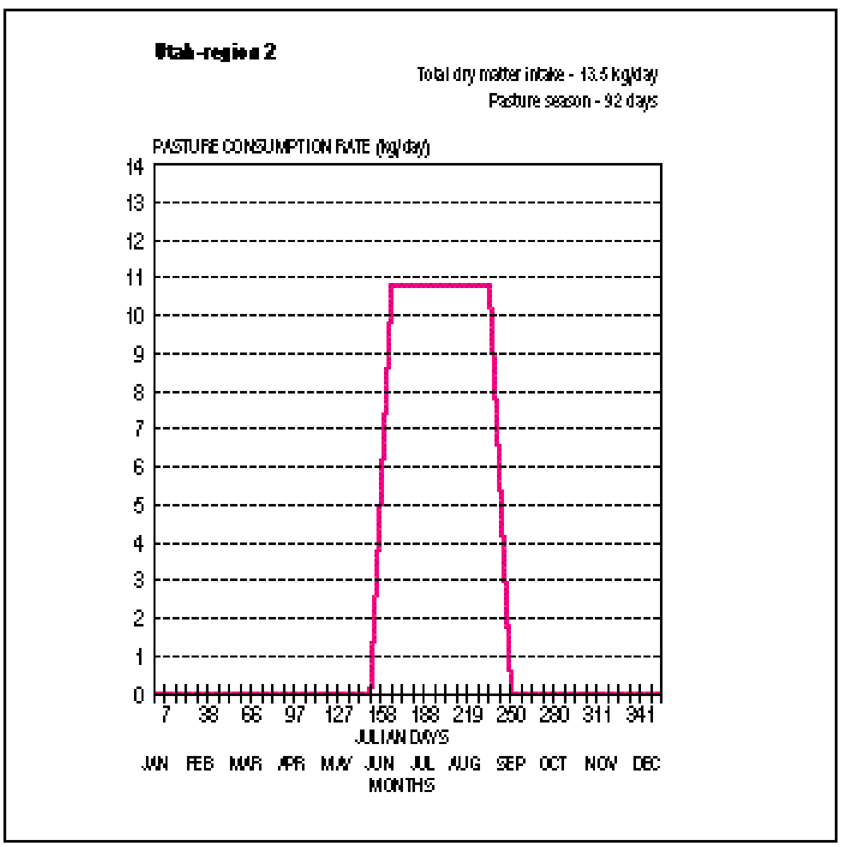
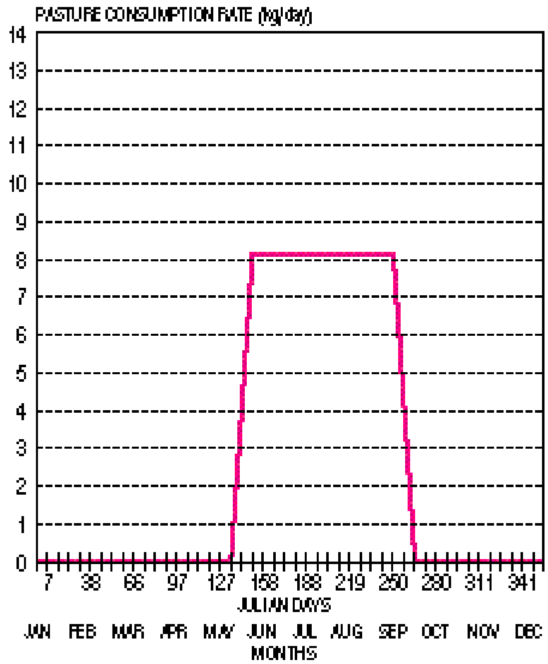
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Utah-region 1
Total dry matter intake - 13.5 kg/day
Pasture season - 123 days
PASTURE CONSUMPTION RATE (kg/day)
JULIAN DAYS
MONTHS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
7 38 66 97 127 158 188 219 250 280 311 341


Utah-region 2
Total dry matter intake - 13.5 kg/day
Pasture season - 92 days
PASTURE CONSUMPTION RATE (kg/day)
JULIAN DAYS
MONTHS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
7 38 66 97 127 158 188 219 250 280 311 341

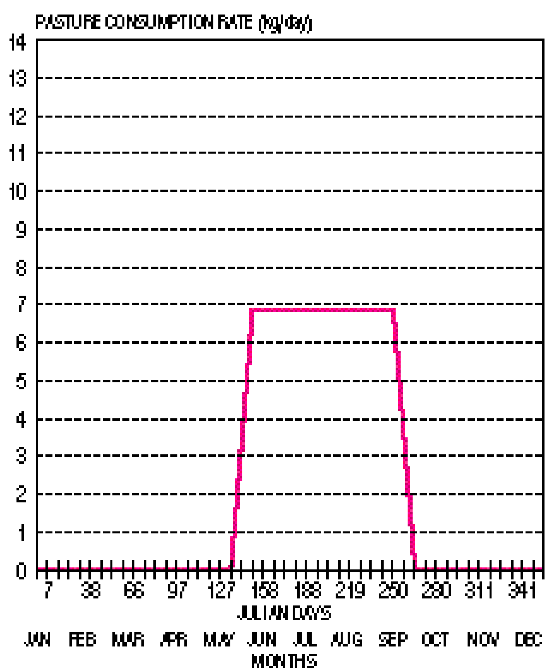
Utah-region 3,5

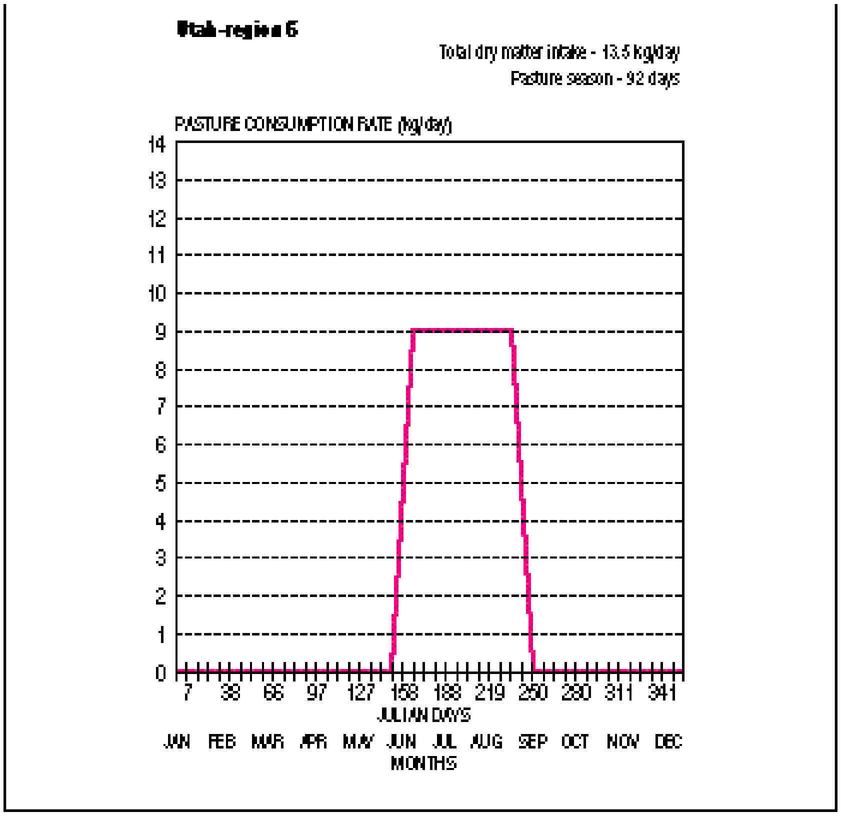
Total dry matter intake - 13.5 kg/day
Pasture season - 123 days



Utah-region 4

Total dry matter intake - 13.5 kg/day
Pasture season - 123 days




Utah-region 6
Total dry matter intake - 13.5 kg/day
Pasture season - 92 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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6
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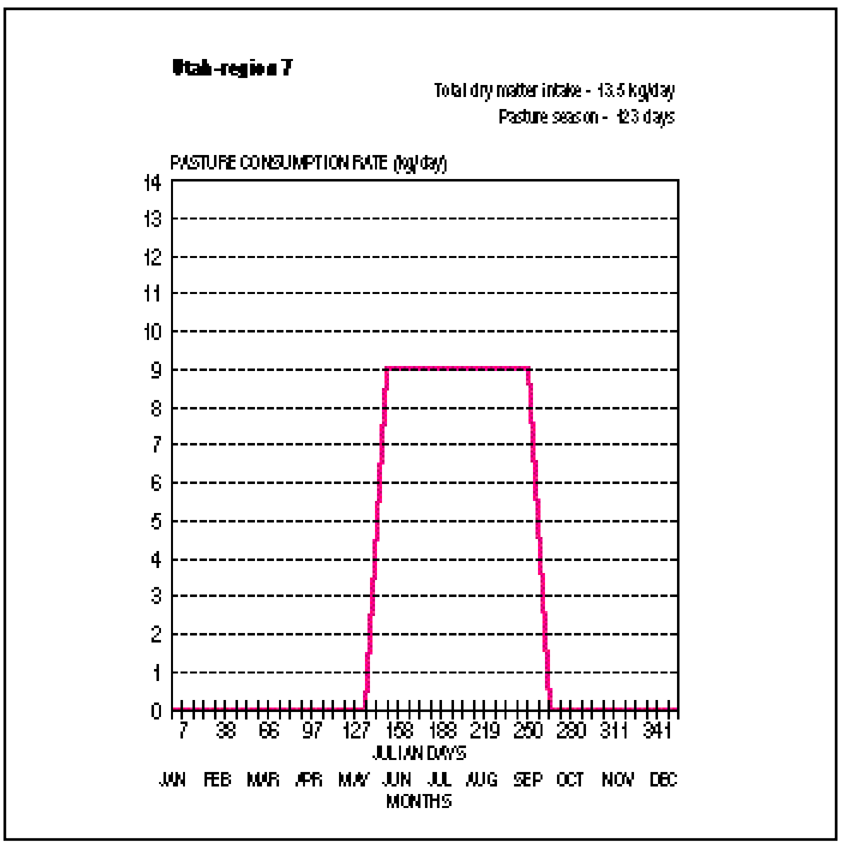
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Utah-region 7
Total dry matter intake - 13.5 kg/day
Pasture season - 123 days
PASTURE CONSUMPTION RATE (kg/day)
14
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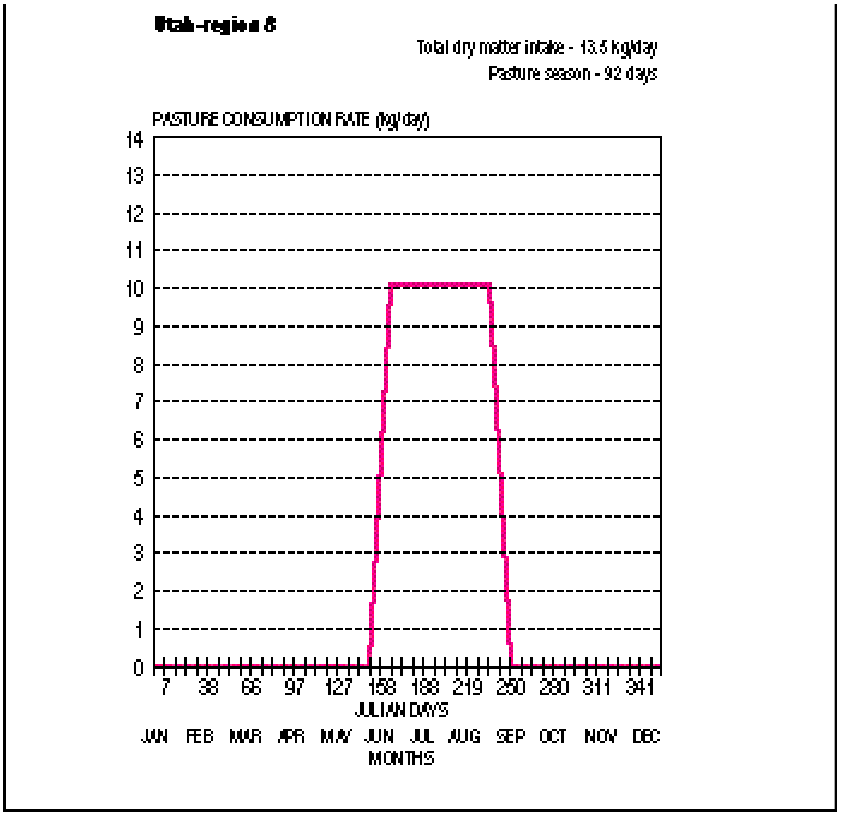
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Utah-region 8
Total dry matter intake - 13.5 kg/day
Pasture season - 92 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
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4
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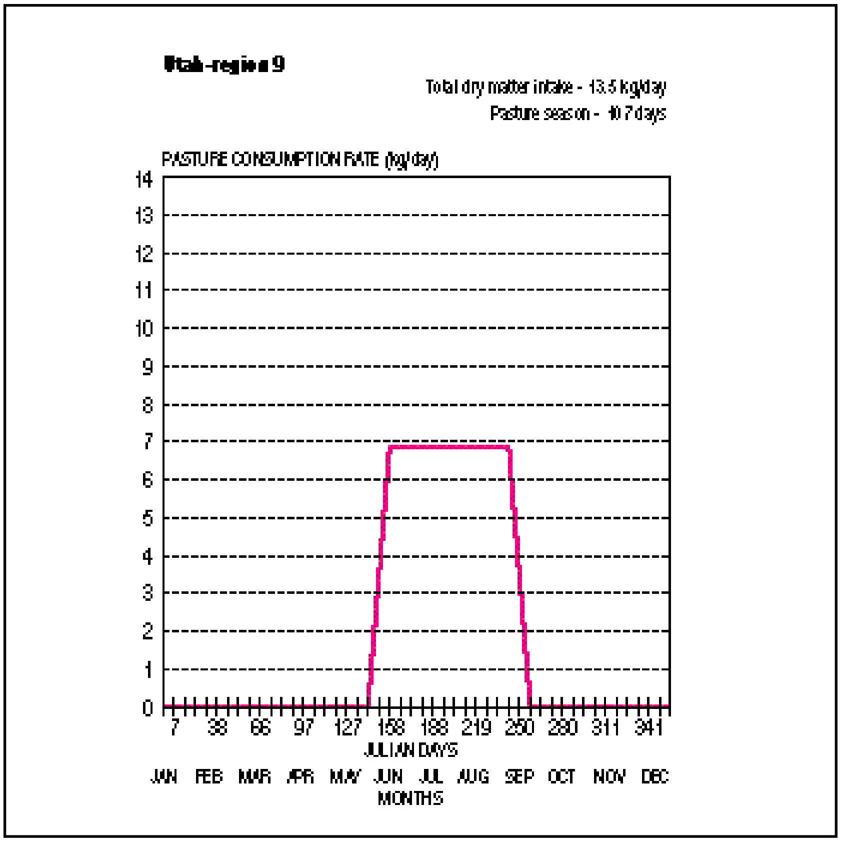
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Utah-region 9
Total dry matter intake - 13.5 kg/day
Pasture season - 107 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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8
7
6
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3
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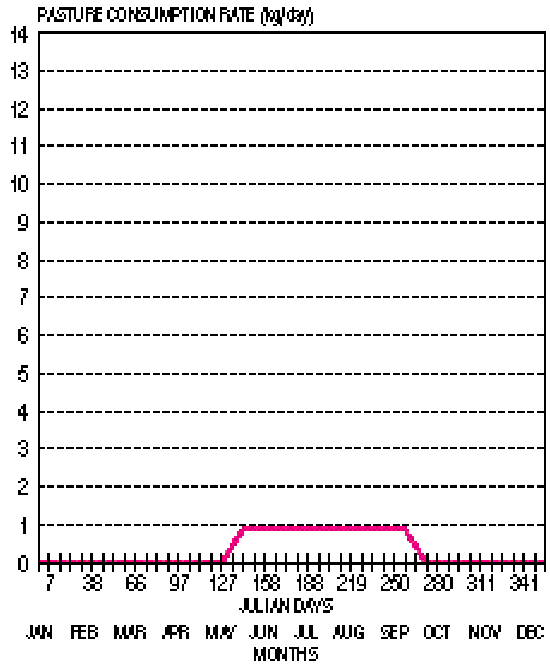
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

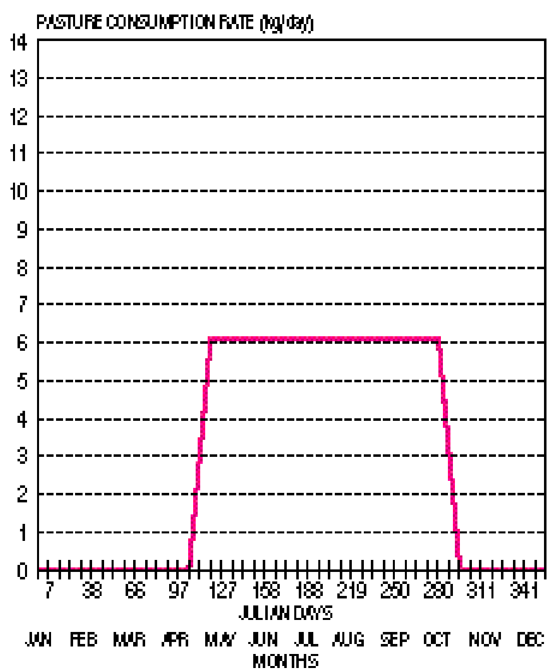
Utah-region 10

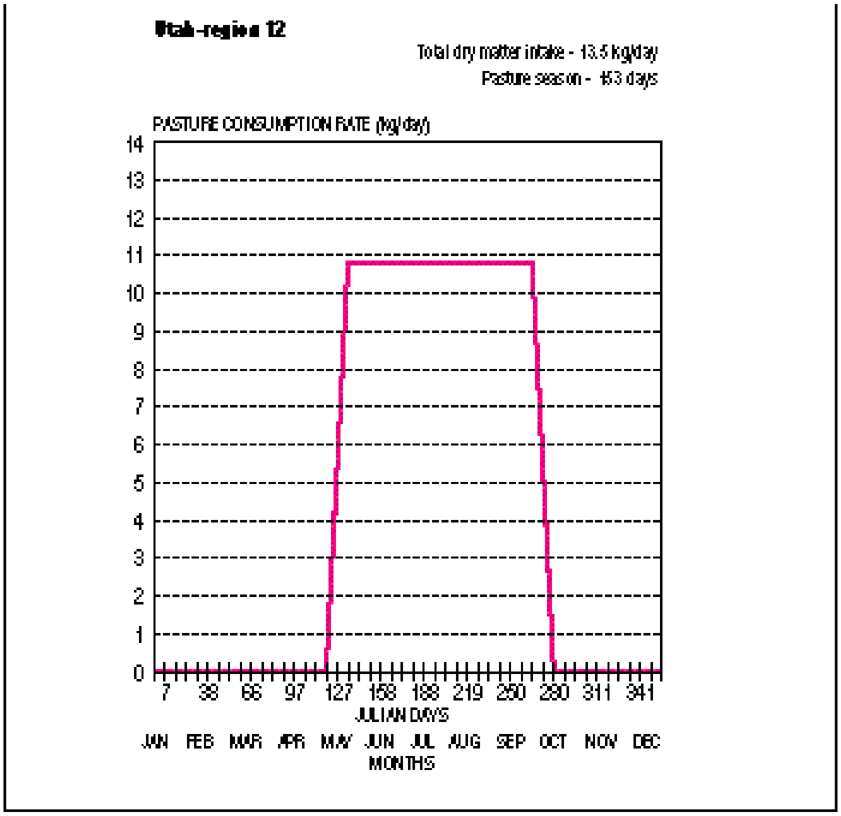
Total dry matter intake - 13.5 kg/day
Pasture season - 139 days



Utah-region 11

Total dry matter intake - 13.5 kg/day
Pasture season - 183 days




Utah-region 12
Total dry matter intake - 13.5 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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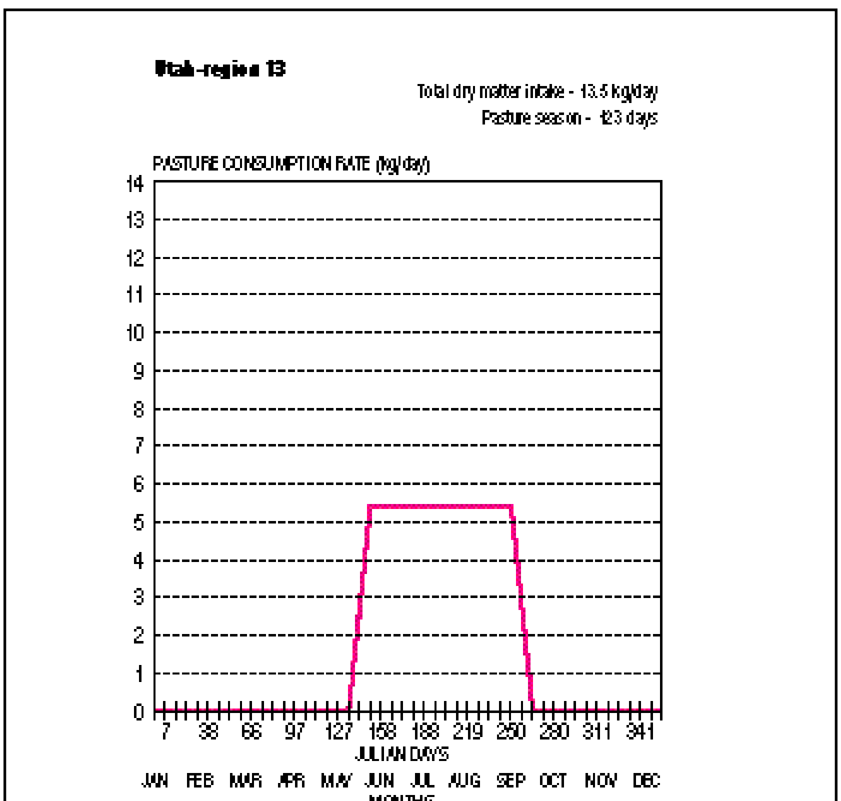
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Utah-region 13
Total dry matter intake - 13.5 kg/day
Pasture season - 123 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
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6
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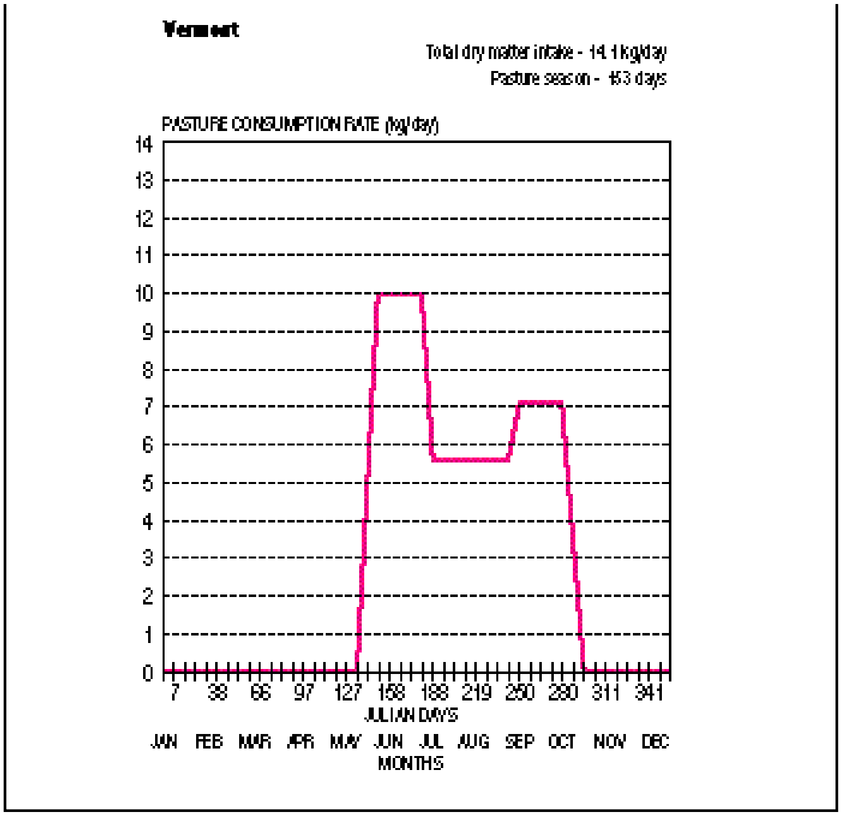
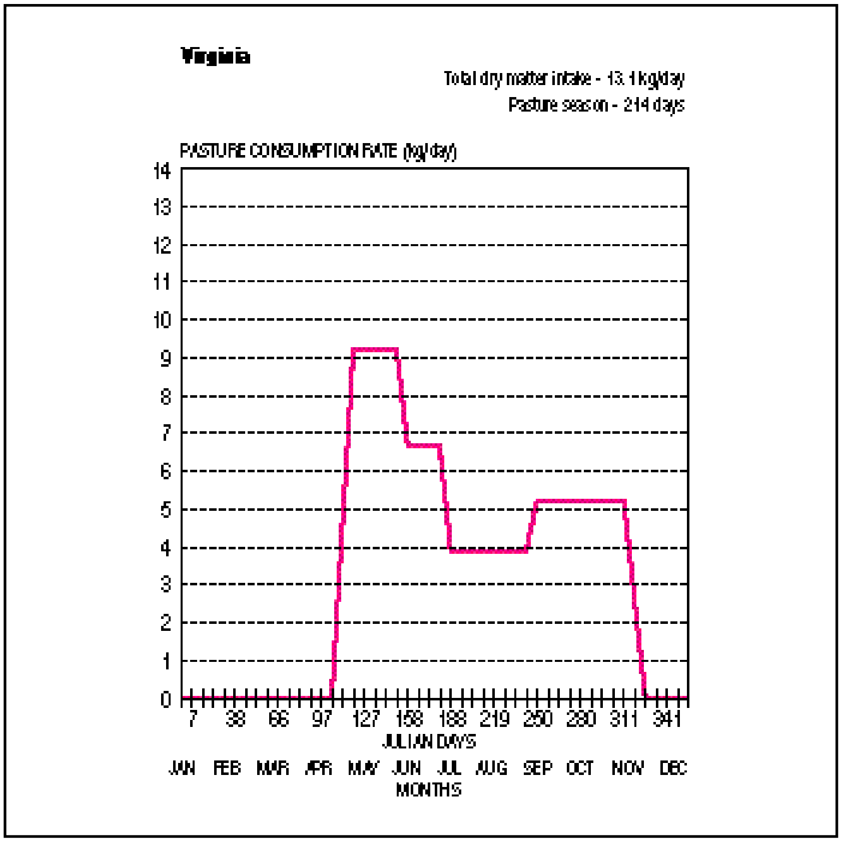
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Vermont
Total dry matter intake - 14.1 kg/day
Pasture season - 153 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Virginia
Total dry matter intake - 13.1 kg/day
Pasture season - 214 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
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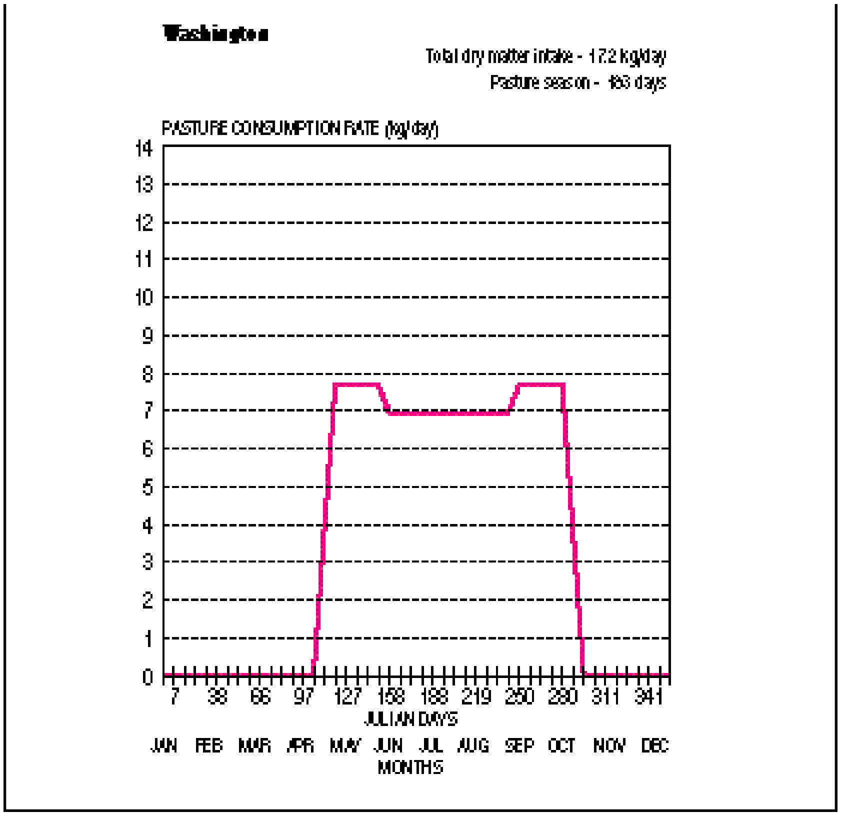
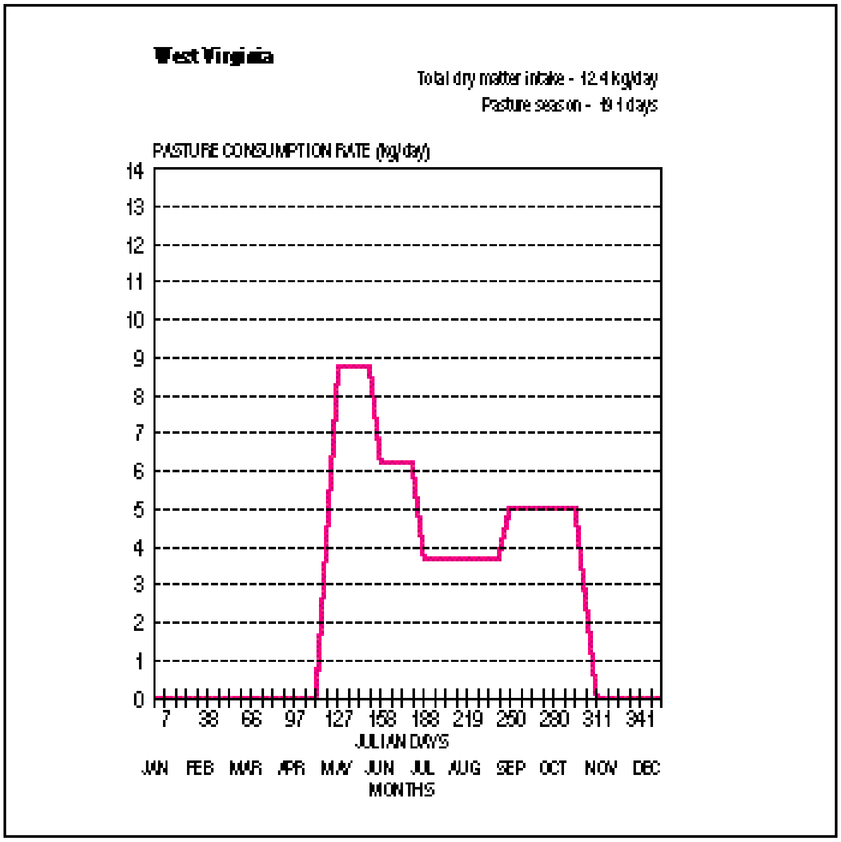
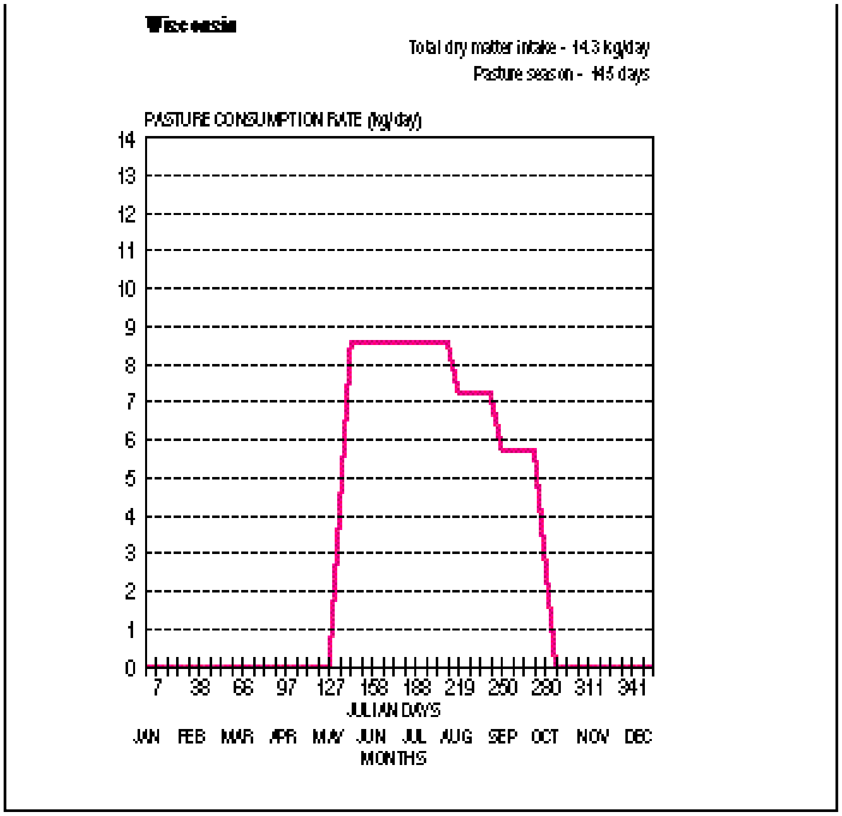
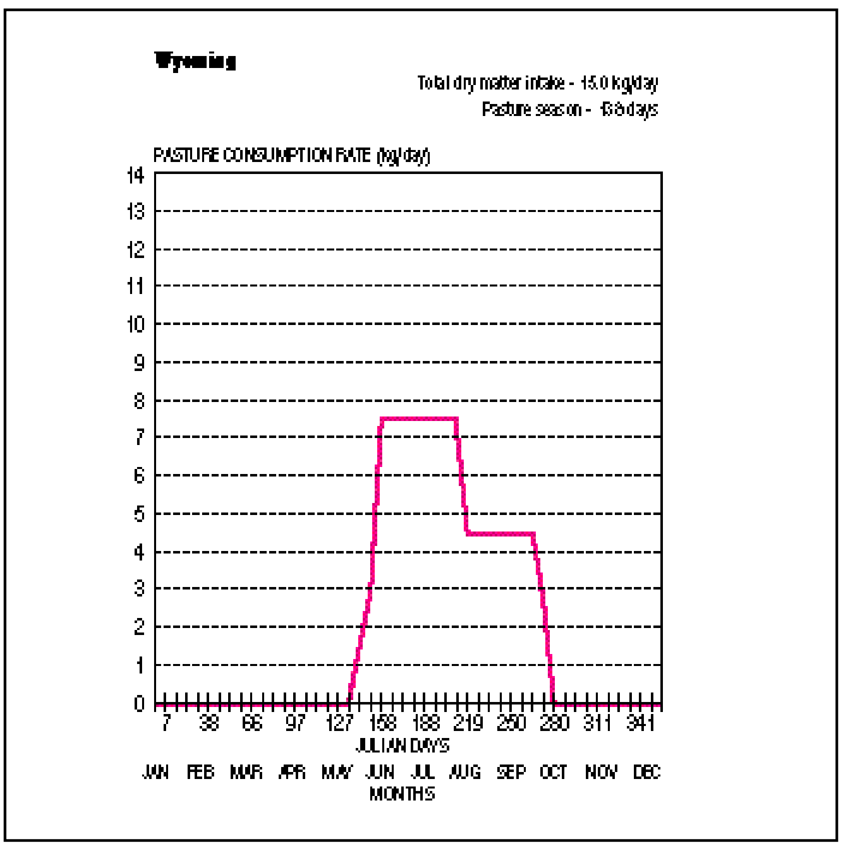
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Washington
Total dry matter intake - 17.2 kg/day
Pasture season - 183 days
PASTURE CONSUMPTION RATE (kg/day)
JULIAN DAYS
MONTHS


West Virginia
Total dry matter intake - 12.4 kg/day
Pasture season - 191 days
PASTURE CONSUMPTION RATE (kg/day)
JULIAN DAYS
MONTHS


Wisconsin
Total dry matter intake - 14.3 kg/day
Pasture season - 145 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS


Wyoming
Total dry matter intake - 15.0 kg/day
Pasture season - 138 days
PASTURE CONSUMPTION RATE (kg/day)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7 38 66 97 127 158 188 219 250 280 311 341
JULIAN DAYS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS

Estimates of the Volumes of Milk (10^3 L) Produced, Available for Fluid Use, and Consumed in Each County of the Contiguous United States in 1954

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
AL AUTAUGA	3471	1766	1721	44
AL BALDWIN	9517	4843	4154	689
AL BARBOUR	5335	2716	2534	180
AL BIBB	1986	1287	1537	-249
AL BLOUNT	7810	4408	2568	1840
AL BULLOCK	3117	1587	1397	189
AL BUTLER	5487	2793	2547	246
AL CALHOUN	5989	3882	8085	-4202
AL CHAMBERS	7056	3591	3627	-35
AL CHEROKEE	4638	2618	1595	1022
AL CHILTON	7003	3564	2468	1096
AL CHOCTAW	4209	2142	1739	403
AL CLARKE	4434	2256	2449	-192
AL CLAY	5159	2970	1241	1729
AL CLEBURNE	2674	1533	1073	459
AL COFFEE	6719	3420	2866	553
AL COLBERT	4835	3135	3974	-839
AL CONECUH	4976	2532	1876	656
AL COOSA	3527	1798	1058	740
AL COVINGTON	8193	4170	3585	584
AL CRENSHAW	4282	2180	1612	567
AL CULLMAN	13249	7780	4446	3333
AL DALE	4077	2075	2353	-278
AL DALLAS	12228	6224	5276	948
AL DE KALB	12931	8233	4067	4165
AL ELMORE	8903	4531	2913	1617
AL ESCAMBIA	4605	2985	3022	-36
AL ETOWAH	6350	4116	8900	-4784
AL FAYETTE	4160	2117	1683	434
AL FRANKLIN	6048	3078	2255	823
AL GENEVA	5136	2614	2278	335
AL GREENE	4559	2320	1426	894
AL HALE	18459	9396	1896	7499
AL HENRY	3008	1531	1610	-79
AL HOUSTON	6638	4303	4516	-212
AL JACKSON	9682	4928	3553	1374
AL JEFFERSON	7680	4979	55269	-50290
AL LAMAR	4839	2785	1450	1334
AL LAUDERDALE	10309	5247	5360	-113
AL LAWRENCE	10194	5452	2432	3020

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
AL LEE	6102	3956	4400	-443
AL LIMESTONE	14357	7307	3373	3934
AL LOWNDES	6261	3186	1581	1605
AL MACON	3441	2231	2704	-473
AL MADISON	11762	7625	8580	-955
AL MARENGO	12031	6124	2662	3461
AL MARION	6253	3193	2333	859
AL MARSHALL	9302	4735	4331	403
AL MOBILE	10853	7035	24911	-17875
AL MONROE	5338	2717	2272	445
AL MONTGOMERY	18733	12144	14192	-2048
AL MORGAN	9434	4801	5247	-445
AL PERRY	12302	6261	1788	4473
AL PICKENS	7887	4014	2178	1836
AL PIKE	5229	2661	2678	-16
AL RANDOLPH	6582	3603	1984	1619
AL RUSSELL	5860	3799	4011	-212
AL ST CLAIR	4899	2493	2443	50
AL SHELBY	8399	4275	2908	1366
AL SUMTER	4532	2307	2065	242
AL TALLADEGA	7951	5154	6023	-868
AL TALLAPOOSA	6692	3406	3276	130
AL TUSCALOOSA	8434	5468	9390	-3922
AL WALKER	5097	3304	5581	-2277
AL WASHINGTON	3452	1757	1449	307
AL WILCOX	4725	2404	2006	398
AL WINSTON	3799	1934	1571	362
AZ APACHE	1238	1189	3164	-1975
AZ COCHISE	5285	3873	4544	-669
AZ COCONINO1	67	64	67	-2
AZ COCONINO2	3	3	1132	-1129
AZ COCONINO3	1214	1166	2253	-1087
AZ GILA	973	934	2719	-1785
AZ GRAHAM	5913	4334	1471	2862
AZ GREENLEE	1328	1276	1341	-65
AZ MARICOPA	100411	73595	51768	21827
AZ MOHAVE1	3	3	24	-21
AZ MOHAVE2	26	19	24	-4
AZ MOHAVE3	1083	794	688	105

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
AZ MOHAVE4	13	12	157	-145
AZ NAVAJO	2497	2397	3622	-1224
AZ PIMA	5366	5153	21254	-16101
AZ PINAL	4238	4070	5636	-1565
AZ SANTA CRUZ	916	879	1091	-211
AZ YAVAPAI	3778	2769	2919	-149
AZ YUMA	2634	2529	3915	-1385
AR ARKANSAS	1986	1618	2834	-1216
AR ASHLEY	4320	1954	3017	-1063
AR BAXTER	4158	1880	1318	562
AR BENTON	35190	16102	4493	11609
AR BOONE	13512	6111	1950	4160
AR BRADLEY	3223	1457	1825	-367
AR CALHOUN	2213	1000	800	199
AR CARROLL	17354	8255	1495	6760
AR CHICOT	2908	2369	2516	-147
AR CLARK	5170	2338	2665	-326
AR CLAY	7059	3192	2935	257
AR CLEBURNE	5767	2878	1259	1619
AR CLEVELAND	3263	1521	975	546
AR COLUMBIA	5680	2569	3343	-774
AR CONWAY	9319	4214	2045	2169
AR CRAIGHEAD	5639	4593	5926	-1333
AR CRAWFORD	5972	2701	2664	36
AR CRITTENDEN	2014	1640	5702	-4062
AR CROSS	2304	1877	2716	-838
AR DALLAS	2468	1116	1399	-282
AR DESHA	3386	2758	2805	-47
AR DREW	3560	1610	2022	-412
AR FAULKNER	13851	6264	2996	3268
AR FRANKLIN	10102	4666	1378	3287
AR FULTON	10212	5130	976	4153
AR GARLAND	4927	4013	5652	-1639
AR GRANT	2758	1247	1049	197
AR GREENE	8016	3625	3309	316
AR HEMPSTEAD	5891	2664	2743	-79
AR HOT SPRING	6880	3112	2657	454
AR HOWARD	3256	1473	1481	-8
AR INDEPENDENCE	8650	3912	2653	1258
AR IZARD	9186	4737	1035	3701

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
AR JACKSON	2981	2429	2964	-535
AR JEFFERSON	4415	3596	9434	-5838
AR JOHNSON	6166	2789	1752	1035
AR LAFAYETTE	2949	1334	1479	-145
AR LAWRENCE	4988	2256	2359	-102
AR LEE	3999	1809	2759	-951
AR LINCOLN	3836	1735	1922	-187
AR LITTLE RIVER	2676	1210	1281	-71
AR LOGAN	15072	6816	2219	4596
AR LONOKE	12119	5481	3146	2335
AR MADISON	11165	5750	1277	4473
AR MARION	7158	3392	905	2486
AR MILLER	4867	2201	3881	-1679
AR MISSISSIPPI	2361	1923	9297	-7374
AR MONROE	2420	1971	2239	-268
AR MONTGOMERY	3058	1521	737	784
AR NEVADA	4858	2197	1571	626
AR NEWTON	5384	2884	907	1977
AR OUACHITA	3087	2514	3908	-1394
AR PERRY	2482	1135	666	469
AR PHILLIPS	4443	3619	5456	-1837
AR PIKE	1921	868	1097	-228
AR POINSETT	2821	2297	4301	-2003
AR POLK	4569	2066	1595	471
AR POPE	8006	3621	2697	923
AR PRAIRIE	4103	1855	1492	363
AR PULASKI	10895	8874	26061	-17185
AR RANDOLPH	5485	2480	1748	732
AR ST FRANCIS	2751	2240	4256	-2015
AR SALINE	5410	2446	3131	-684
AR SCOTT	5662	2566	1069	1497
AR SEARCY	5468	2710	1137	1572
AR SEBASTIAN	11673	5279	7860	-2580
AR SEVIER	2775	1255	1370	-115
AR SHARP	5537	2741	947	1793
AR STONE	3185	1676	853	823
AR UNION	5737	4673	5976	-1303
AR VAN BUREN	6483	3338	1040	2297
AR WASHINGTON	29555	13366	6318	7048
AR WHITE	15737	7117	4311	2806

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
AR WOODRUFF	1771	1442	2027	-584
AR YELL	8829	3993	1585	2408
CA ALAMEDA	24506	23849	112471	-88621
CA ALPINE	22	22	42	-19
CA AMADOR	2917	1400	1317	82
CA BUTTE	31063	14908	10004	4904
CA CALAVERAS	1165	1134	1395	-260
CA COLUSA	8841	4243	1639	2604
CA CONTRA COSTA	10742	10454	47909	-37454
CA DEL NORTE	12815	6150	1690	4460
CA EL DORADO	2361	2298	3022	-723
CA FRESNO	158007	75836	43582	32253
CA GLENN	68883	33061	2246	30814
CA HUMBOLDT	82102	39405	11693	27711
CA IMPERIAL	19082	9158	9263	-105
CA INYO1	1028	1000	1149	-148
CA INYO2	941	451	341	110
CA INYO3	38	37	126	-88
CA KERN	34693	33763	35385	-1622
CA KINGS	98320	47189	6668	40521
CA LAKE	5626	2700	1726	973
CA LASSEN	3809	1828	2272	-443
CA LOS ANGELES	399672	388961	686418	-297456
CA MADERA	63352	30406	5328	25077
CA MARIN	100720	48341	15468	32873
CA MARIPOSA	1192	572	708	-136
CA MENDOCINO	16384	7863	6262	1601
CA MERCED	256567	123140	10887	112253
CA MODOC	5405	2594	1260	1334
CA MONO	110	107	299	-191
CA MONTEREY	34373	16497	22078	-5581
CA NAPA	19961	9580	7593	1987
CA NEVADA	5950	2855	2815	39
CA ORANGE	107912	51793	58682	-6889
CA PLACER	15615	7494	6675	819
CA PLUMAS	1668	1624	1761	-137
CA RIVERSIDE	37668	18079	31580	-13501
CA SACRAMENTO	74803	35902	51690	-15787
CA SAN BENITO	7558	3627	2051	1575
CA SAN BERNADIN	92853	44565	52096	-7531

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
CA SAN DIEGO	70910	69009	105198	-36188
CA SAN FRANCISC	0	0	105375	-105375
CA SAN JOAQUIN	197527	94804	30717	64087
CA SAN LUIS OBI	39222	18825	8868	9956
CA SAN MATEO	6243	6076	44946	-38870
CA SANTA BARBAR	27748	13317	17776	-4458
CA SANTA CLARA	61817	60160	60976	-815
CA SANTA CRUZ	8361	8137	10260	-2122
CA SHASTA	17721	8505	6403	2102
CA SIERRA	658	316	324	-8
CA SISKIYOU	14506	6962	4385	2577
CA SOLANO	14845	14448	16279	-1831
CA SONOMA	152936	73402	16918	56484
CA STANISLAUS	324308	155653	19400	136252
CA SUTTER	19546	9381	4056	5325
CA TEHAMA	35131	16861	3026	13835
CA TRINITY	1039	499	976	-477
CA TULARE	162929	78198	21809	56388
CA TUOLUMNE	2015	967	1850	-883
CA VENTURA	18304	17814	20862	-3047
CA YOLO	12601	6048	7109	-1060
CA YUBA	15180	7286	3940	3346
CO ADAMS	16439	4584	8131	-3547
CO ALAMOSA	3397	947	1128	-180
CO ARAPAHOE	8496	7908	9813	-1904
CO ARCHULETA	1512	421	313	108
CO BACA	4839	1349	794	555
CO BENT	3351	934	897	36
CO BOULDER	18246	5087	6496	-1408
CO CHAFFEE	2151	600	837	-237
CO CHEYENNE	2860	797	347	449
CO CLEAR CREEK	143	133	336	-203
CO CONEJOS	2944	820	1032	-211
CO COSTILLA	636	190	577	-388
CO CROWLEY	3011	839	514	325
CO CUSTER	3184	890	160	730
CO DELTA	11001	3068	1819	1248
CO DENVER	68	63	50100	-50037
CO DOLORES	492	137	226	-88
CO DOUGLAS	6015	1677	444	1232

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
CO EAGLE	1637	456	500	-43
CO ELBERT	12384	3700	454	3245
CO EL PASO	17531	4888	11381	-6492
CO FREMONT	4115	1147	2096	-948
CO GARFIELD	5948	1658	1291	367
CO GILPIN	54	50	85	-34
CO GRAND	1512	421	414	6
CO GUNNISON	1588	442	614	-171
CO HINSDALE	112	31	25	4
CO HUERFANO	3202	892	1030	-137
CO JACKSON	1048	292	206	86
CO JEFFERSON	11638	3245	9441	-6195
CO KIOWA	1564	436	302	134
CO KIT CARSON	8574	2390	865	1525
CO LAKE	203	189	717	-527
CO LA PLATA	8853	2468	1831	637
CO LARIMER	22502	6274	5225	1049
CO LAS ANIMAS	4227	1178	2561	-1382
CO LINCOLN	5061	1411	619	792
CO LOGAN	13635	3802	2027	1775
CO MESA	15836	4416	4814	-398
CO MINERAL	156	43	63	-19
CO MOFFAT	1572	438	702	-264
CO MONTEZUMA	6639	1851	1281	569
CO MONTROSE	9557	2665	1809	855
CO MORGAN	12472	3478	2123	1354
CO OTERO	5611	1565	2714	-1149
CO OURAY	769	214	207	7
CO PARK	610	170	202	-32
CO PHILLIPS	4414	1231	516	714
CO PITKIN	732	204	214	-9
CO PROWERS	4821	1344	1552	-208
CO PUEBLO	9985	9294	11203	-1908
CO RIO BLANCO	1342	374	536	-162
CO RIO GRANDE	2673	745	1327	-581
CO ROUTT	5643	1573	837	736
CO SAGUACHE	1812	505	564	-59
CO SAN JUAN	0	0	132	-132
CO SAN MIGUEL	602	167	306	-138
CO SEDGWICK	2602	725	517	208

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
CO SUMMIT	305	85	168	-82
CO TELLER	636	177	289	-112
CO WASHINGTON	8751	2627	781	1845
CO WELD	67813	18910	7617	11292
CO YUMA	13797	4009	1096	2913
CT FAIRFIELD	22717	22089	92221	-70131
CT HARTFORD	52215	50773	98002	-47229
CT LITCHFIELD	75168	51721	17508	34212
CT MIDDLESEX	16215	11157	12423	-1265
CT NEW HAVEN	34656	33698	96555	-62856
CT NEW LONDON	49282	33909	26347	7561
CT TOLLAND	25236	17364	8920	8443
CT WINDHAM	36517	25126	10501	14624
DE KENT	33681	27110	6527	20582
DE NEW CASTLE	28761	27768	33707	-5939
DE SUSSEX	16322	13138	8721	4416
DC WASHINGTON	0	0	104706	-104706
FL ALACHUA	5734	3916	5121	-1204
FL BAKER	865	591	538	52
FL BAY	1410	1363	4229	-2865
FL BRADFORD	899	869	946	-76
FL BREVARD	1155	1117	4857	-3739
FL BROWARD	42670	29142	15155	13987
FL CALHOUN	2505	1711	614	1096
FL CHARLOTTE	1255	857	622	234
FL CITRUS	669	457	593	-136
FL CLAY	6373	4352	1317	3034
FL COLLIER	27	26	830	-804
FL COLUMBIA	2250	1537	1514	22
FL DADE	32815	31737	54348	-22610
FL DE SOTO	863	590	819	-229
FL DIXIE	271	262	331	-69
FL DUVAL	30341	29344	29352	-7
FL ESCAMBIA	8914	8621	11050	-2429
FL FLAGLER	648	443	308	134
FL FRANKLIN	54	52	489	-436
FL GADSDEN	3473	2372	3092	-719
FL GILCHRIST	842	575	257	317
FL GLADES	1326	906	200	705
FL GULF	444	429	678	-248

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
FL HAMILTON	1612	1101	672	429
FL HARDEE	1537	1049	880	169
FL HENDRY	1028	702	551	150
FL HERNANDO	525	508	686	-177
FL HIGHLANDS	586	566	1347	-780
FL HILLSBOROUGH	31549	21546	24920	-3373
FL HOLMES	5144	3513	1008	2505
FL INDIAN RIVER	1606	1097	1401	-304
FL JACKSON	14046	9592	2813	6779
FL JEFFERSON	2211	1510	800	709
FL LAFAYETTE	2933	2003	255	1747
FL LAKE	2225	2152	3608	-1455
FL LEE	1099	1063	2919	-1855
FL LEON	4141	4004	4877	-872
FL LEVY	759	734	838	-103
FL LIBERTY	319	218	252	-34
FL MADISON	4074	2782	1129	1653
FL MANATEE	4785	3268	3932	-663
FL MARION	4677	3194	3497	-303
FL MARTIN	1165	796	931	-134
FL MONROE	0	0	2995	-2995
FL NASSAU	1003	970	1169	-199
FL OKALOOSA	3027	2927	3333	-405
FL OKEECHOBEE	427	292	375	-83
FL ORANGE	11814	11425	14191	-2765
FL OSCEOLA	1608	1098	1166	-68
FL PALM BEACH	23020	15722	12979	2742
FL PASCO	2131	2062	2186	-124
FL PINELLAS	12053	11658	19984	-8326
FL POLK	9468	9158	12289	-3131
FL PUTNAM	1560	1509	2172	-663
FL ST JOHNS	2121	2052	2162	-110
FL ST LUCIE	586	566	2255	-1688
FL SANTA ROSA	6010	4104	1850	2253
FL SARASOTA	1429	1382	3925	-2543
FL SEMINOLE	3027	2927	3092	-165
FL SUMTER	1600	1092	921	171
FL SUWANNEE	3953	2699	1284	1414
FL TAYLOR	761	736	923	-186
FL UNION	1395	953	612	340

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
FL VOLUSIA	4186	4049	7644	-3595
FL WAKULLA	312	302	418	-116
FL WALTON	4249	2902	1202	1699
FL WASHINGTON	3848	2628	926	1702
GA APPLING	2867	1832	1196	635
GA ATKINSON	850	543	600	-56
GA BACON	1092	697	760	-62
GA BAKER	973	621	468	153
GA BALDWIN	3414	2560	2759	-198
GA BANKS	2285	1739	590	1149
GA BARROW	3853	2462	1198	1264
GA BARTOW	4762	3043	2426	617
GA BEN HILL	2026	1294	1254	40
GA BERRIEN	2556	1634	1149	484
GA BIBB	5758	4319	10986	-6666
GA BLECKLEY	2282	1458	821	636
GA BRANTLEY	935	597	540	58
GA BROOKS	3660	2339	1482	857
GA BRYAN	762	487	531	-43
GA BULLOCH	5495	3512	2145	1366
GA BURKE	4380	2799	1945	854
GA BUTTS	2024	1293	790	503
GA CALHOUN	1590	1016	704	312
GA CAMDEN	171	128	739	-610
GA CANDLER	1826	1167	653	513
GA CARROLL	6843	4374	3070	1303
GA CATOOSA	5301	3388	1546	1842
GA CHARLTON	163	122	439	-317
GA CHATHAM	3799	2849	14615	-11765
GA CHATTAHOOCHE	124	92	1098	-1005
GA CHATTOOGA	2863	1830	1808	22
GA CHEROKEE	3528	2254	1898	356
GA CLARKE	1947	1461	3523	-2063
GA CLAY	1141	729	463	266
GA CLAYTON	2383	1788	2873	-1085
GA CLINCH	158	118	545	-426
GA COBB	4873	3655	7352	-3696
GA COFFEE	3956	2528	2020	507
GA COLQUITT	6968	4453	2975	1478
GA COLUMBIA	4447	2842	977	1864

State County	Production	Amount available for fluid use	Consumption	Excess or deficit
GA COOK	2287	1462	1053	409
GA COWETA	4390	2805	2471	334
GA CRAWFORD	1774	1134	521	612
GA CRISP	2071	1324	1548	-224
GA DADE	1327	848	692	156
GA DAWSON	1247	1025	320	705
GA DECATUR	3420	2185	2124	61
GA DE KALB	4692	3519	16402	-12882
GA DODGE	3732	2385	1511	874
GA DOOLY	2496	1595	1138	457
GA DOUGHERTY	1219	914	5006	-4091
GA DOUGLAS	2158	1379	1234	145
GA EARLY	2919	1865	1364	501
GA ECHOLS	321	205	195	9
GA EFFINGHAM	1572	1004	836	168
GA ELBERT	4256	2720	1597	1122
GA EMANUEL	3322	2123	1657	466
GA EVANS	1128	721	592	128
GA FANNIN	3120	1994	1270	723
GA FAYETTE	1461	933	705	228
GA FLOYD	6734	5052	5732	-680
GA FORSYTH	4011	3017	1006	2010
GA FRANKLIN	6254	4248	1219	3028
GA FULTON	5632	4225	44490	-40264
GA GILMER	2654	1741	832	909
GA GLASCOCK	595	380	279	101
GA GLYNN	997	748	3019	-2271
GA GORDON	4506	2879	1666	1214
GA GRADY	3983	2546	1621	924
GA GREENE	6827	4363	1061	3302
GA GWINNETT	6067	3877	3243	634
GA HABERSHAM	2920	1866	1505	360
GA HALL	6702	4283	3865	417
GA HANCOCK	3874	2476	926	1549
GA HARALSON	2614	1670	1277	393
GA HARRIS	3536	2260	981	1278
GA HART	5469	3523	1295	2228
GA HEARD	2862	1982	549	1433
GA HENRY	4700	3004	1452	1551
GA HOUSTON	2277	1708	2509	-800

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
GA IRWIN	2865	1831	944	886
GA JACKSON	4540	2902	1642	1259
GA JASPER	5103	3262	603	2658
GA JEFF DAVIS	2094	1338	799	539
GA JEFFERSON	2533	1619	1597	22
GA JENKINS	6042	3862	856	3005
GA JOHNSON	2143	1370	796	573
GA JONES	4303	2750	693	2056
GA LAMAR	2403	1536	896	639
GA LANIER	543	407	448	-41
GA LAURENS	6990	4468	2866	1601
GA LEE	1085	693	566	127
GA LIBERTY	535	401	963	-561
GA LINCOLN	2026	1294	544	750
GA LONG	241	181	325	-143
GA LOWNDES	4150	3113	3601	-488
GA LUMPKIN	1581	1120	599	521
GA MCDUFFIE	2675	1710	1044	665
GA MCINTOSH	117	87	538	-450
GA MACON	2271	1451	1204	247
GA MADISON	3325	2231	1033	1198
GA MARION	1843	1178	531	646
GA MERIWETHER	5973	3818	1793	2024
GA MILLER	2251	1439	710	728
GA MITCHELL	3750	2396	1863	533
GA MONROE	9913	6336	919	5416
GA MONTGOMERY	1423	909	630	278
GA MORGAN	12737	8141	980	7160
GA MURRAY	2197	1404	925	479
GA NEWTON	5218	3335	1795	1539
GA OCONEE	2747	1756	586	1169
GA OGLETHORPE	3271	2091	795	1295
GA PAULDING	3123	1996	1078	918
GA PEACH	1090	818	1102	-284
GA PICKENS	1505	961	776	185
GA PIERCE	2009	1284	918	365
GA PIKE	1921	1228	690	537
GA POLK	4342	2775	2599	176
GA PULASKI	1188	759	747	11
GA PUTNAM	11316	7232	678	6553

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
GA QUITMAN	548	350	241	108
GA RABUN	1843	1178	650	527
GA RANDOLPH	1800	1151	1106	44
GA RICHMOND	1727	1295	10514	-9218
GA ROCKDALE	1196	765	818	-53
GA SCHLEY	1203	769	323	445
GA SCREVEN	4574	2923	1459	1463
GA SEMINOLE	1314	839	650	189
GA SPALDING	2380	1785	2876	-1091
GA STEPHENS	2499	1597	1520	77
GA STEWART	2168	1385	736	649
GA SUMTER	4341	2774	2133	641
GA TALBOT	1804	1152	651	501
GA TALIAFERRO	3369	2153	352	1801
GA TATTNALL	2737	1750	1390	359
GA TAYLOR	1897	1212	766	445
GA TELFAIR	2251	1439	1100	338
GA TERRELL	2150	1374	1193	180
GA THOMAS	4001	2557	2981	-424
GA TIFT	3639	2326	2011	314
GA TOOMBS	3156	2017	1500	517
GA TOWNS	2145	1597	410	1186
GA TREUTLEN	1456	930	546	384
GA TROUP	5461	4096	4260	-163
GA TURNER	2568	1641	840	800
GA TWIGGS	1075	687	712	-25
GA UNION	2475	1894	609	1284
GA UPSON	2592	1945	2146	-200
GA WALKER	5956	3806	3602	204
GA WALTON	5717	3654	1778	1875
GA WARE	1033	775	2795	-2020
GA WARREN	2021	1292	715	576
GA WASHINGTON	3932	2513	1759	754
GA WAYNE	2029	1297	1382	-85
GA WEBSTER	1193	762	326	436
GA WHEELER	1513	967	535	431
GA WHITE	2084	1534	557	977
GA WHITFIELD	4979	3182	3296	-113
GA WILCOX	3716	2375	804	1570
GA WILKES	7697	4920	1030	3889

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
GA WILKINSON	1183	756	835	-79
GA WORTH	5539	3540	1593	1946
GA COLUMBUS	1706	1279	11826	-10546
ID ADA	69386	10173	12463	-2289
ID ADAMS	3540	519	495	23
ID BANNOCK	11404	1672	6976	-5304
ID BEAR LAKE	12664	1857	1081	775
ID BENEWAH	3455	506	948	-442
ID BINGHAM	34907	5118	3936	1181
ID BLAINE	5159	756	783	-26
ID BOISE	1086	159	267	-107
ID BONNER	12592	1846	2352	-506
ID BONNEVILLE	22268	3264	5787	-2521
ID BOUNDARY	6412	940	910	29
ID BUTTE	2686	394	473	-79
ID CAMAS	866	126	156	-29
ID CANYON	102196	14984	8582	6402
ID CARIBOU	9496	1392	891	500
ID CASSIA	20860	3058	2367	691
ID CLARK	1010	148	142	5
ID CLEARWATER	1889	283	1296	-1012
ID CUSTER	3322	487	493	-6
ID ELMORE	3688	540	1698	-1157
ID FRANKLIN	24350	3570	1437	2133
ID FREMONT	10699	1568	1406	162
ID GEM	22476	3295	1380	1915
ID GOODING	25757	3776	1619	2156
ID IDAHO	9956	1459	1911	-451
ID JEFFERSON	21118	3096	1705	1390
ID JEROME	20331	2980	1849	1131
ID KOOTENAI	13086	1918	4173	-2254
ID LATAH	9826	1440	3265	-1824
ID LEMHI	6878	1008	943	65
ID LEWIS	1587	271	666	-395
ID LINCOLN	11531	1690	622	1068
ID MADISON	14122	2070	1437	633
ID MINIDOKA	15064	2209	1821	387
ID NEZ PERCE	5688	834	3805	-2971
ID ONEIDA	4500	659	628	31
ID OWYHEE	13524	1983	983	1000

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
ID PAYETTE	25004	3666	1878	1788
ID POWER	4239	621	627	-5
ID SHOSHONE	897	858	3411	-2552
ID TETON	9048	1326	459	867
ID TWIN FALLS	45207	6628	6413	214
ID VALLEY	1946	285	623	-337
ID WASHINGTON	13770	2019	1316	702
IL ADAMS	39591	12033	10405	1628
IL ALEXANDER	2463	2380	2904	-523
IL BOND	20554	6247	2215	4031
IL BOONE	53843	16365	2896	13469
IL BROWN	7697	2339	1058	1281
IL BUREAU	34348	10440	5910	4529
IL CALHOUN	5385	1637	1018	619
IL CARROLL	42511	12921	3013	9907
IL CASS	5425	1648	2332	-682
IL CHAMPAIGN	21754	6612	18409	-11796
IL CHRISTIAN	13791	4191	5985	-1793
IL CLARK	12808	3892	2670	1222
IL CLAY	11419	3471	2629	842
IL CLINTON	37445	11381	3641	7740
IL COLES	10211	3103	6498	-3394
IL COOK	28211	27271	749062	-721791
IL CRAWFORD	9322	2833	3291	-458
IL CUMBERLAND	11822	3593	1609	1983
IL DE KALB	30205	9180	7129	2051
IL DE WITT	8717	2649	2675	-25
IL DOUGLAS	8622	2620	2791	-170
IL DU PAGE	19514	18863	34860	-15996
IL EDGAR	13411	4076	3616	459
IL EDWARDS	6028	1832	1346	485
IL EFFINGHAM	26697	8114	3497	4616
IL FAYETTE	25457	7737	3682	4054
IL FORD	12488	3795	2542	1253
IL FRANKLIN	7511	2282	7014	-4731
IL FULTON	20565	6250	6742	-492
IL GALLATIN	3048	926	1396	-469
IL GREENE	12322	3745	2865	879
IL GRUNDY	12665	3849	3224	624
IL HAMILTON	9205	2798	1774	1023

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IL HANCOCK	28825	8761	3966	4795
IL HARDIN	2548	774	1072	-297
IL HENDERSON	9619	2923	1309	1614
IL HENRY	30900	9391	7484	1907
IL IROQUOIS	30008	9121	5157	3963
IL JACKSON	17405	5290	6251	-961
IL JASPER	14639	4449	1864	2585
IL JEFFERSON	17180	5221	5395	-173
IL JERSEY	10357	3147	2513	634
IL JO DAVIESS	67019	20370	3391	16978
IL JOHNSON	5445	1655	1249	405
IL KANE	67957	20655	27462	-6806
IL KANKAKEE	23122	7028	12775	-5747
IL KENDALL	11545	3509	2263	1246
IL KNOX	19365	5886	8993	-3107
IL LAKE	31317	30273	35750	-5477
IL LA SALLE	36962	11234	16470	-5235
IL LAWRENCE	5162	1569	3090	-1521
IL LEE	35697	10849	5874	4975
IL LIVINGSTON	33551	10197	6103	4094
IL LOGAN	14791	4495	5012	-517
IL MCDONOUGH	17600	5349	4473	875
IL MCHENRY	113439	34479	10187	24292
IL MCLEAN	40702	12371	12505	-133
IL MACON	9471	9155	16809	-7653
IL MACOUPIN	28805	8755	6891	1863
IL MADISON	39740	12078	31439	-19360
IL MARION	16043	4876	6387	-1511
IL MARSHALL	12265	3728	2064	1663
IL MASON	8688	2640	2396	244
IL MASSAC	3954	1201	2183	-981
IL MENARD	5165	1570	1487	82
IL MERCER	15134	4600	2712	1887
IL MONROE	9522	2894	2233	661
IL MONTGOMERY	28534	8673	5013	3659
IL MORGAN	8465	2573	5649	-3076
IL MOULTRIE	9934	3019	2098	920
IL OGLE	60817	18485	5558	12926
IL PEORIA	20311	19634	28344	-8709
IL PERRY	12980	3945	3236	708

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IL PIATT	8891	2702	2258	443
IL PIKE	16708	5078	3369	1708
IL POPE	3314	1007	792	214
IL PULASKI	4951	1504	1930	-425
IL PUTNAM	5648	1717	733	983
IL RANDOLPH	25277	7682	4858	2824
IL RICHLAND	11922	3624	2610	1013
IL ROCK ISLAND	19508	18858	22124	-3266
IL ST CLAIR	20962	20264	36099	-15835
IL SALINE	7205	2190	4765	-2575
IL SANGAMON	14788	14295	21640	-7344
IL SCHUYLER	12165	3697	1451	2246
IL SCOTT	3471	1055	1079	-24
IL SHELBY	29497	8965	3766	5198
IL STARK	8336	2534	1330	1203
IL STEPHENSON	107791	32762	6836	25926
IL TAZEWELL	24274	7378	13530	-6152
IL UNION	10754	3268	3027	241
IL VERMILION	17585	5345	14273	-8927
IL WABASH	3985	1211	2259	-1048
IL WARREN	13688	4160	3423	737
IL WASHINGTON	31182	9478	2210	7267
IL WAYNE	16471	5006	3157	1848
IL WHITE	5357	1628	3180	-1552
IL WHITESIDE	57900	17598	8447	9151
IL WILL	39668	12057	24905	-12848
IL WILLIAMSON	7374	7128	7463	-335
IL WINNEBAGO	54848	16671	27745	-11073
IL WOODFORD	20102	6110	3564	2545
IN ADAMS	31269	16428	3664	12764
IN ALLEN	36981	19429	32067	-12637
IN BARTHOLOMEW	15618	8205	6473	1731
IN BENTON	6829	3588	1829	1759
IN BLACKFORD	10775	5661	2252	3408
IN BOONE	23264	12223	4002	8220
IN BROWN	3609	1896	1029	867
IN CARROLL	15242	8008	2574	5434
IN CASS	21847	11478	6231	5247
IN CLARK	20788	10922	8551	2371
IN CLAY	13446	7064	3773	3291

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IN CLINTON	15437	8111	4736	3375
IN CRAWFORD	8710	4576	1397	3178
IN DAVIESS	17537	9214	4191	5022
IN DEARBORN	21383	11234	4181	7053
IN DECATUR	19310	10145	2979	7166
IN DE KALB	30549	16050	4233	11816
IN DELAWARE	23950	12583	15544	-2961
IN DUBOIS	16989	8926	3978	4947
IN ELKHART	45202	23749	14749	8999
IN FAYETTE	8459	4444	3742	702
IN FLOYD	8695	4568	7395	-2827
IN FOUNTAIN	12463	6548	2857	3690
IN FRANKLIN	22553	11849	2582	9267
IN FULTON	28440	14942	2624	12317
IN GIBSON	11282	5927	4770	1156
IN GRANT	25871	13592	10661	2931
IN GREENE	14046	7380	4272	3107
IN HAMILTON	22757	11956	5247	6708
IN HANCOCK	14300	7513	3613	3900
IN HARRISON	25408	13349	2892	10456
IN HENDRICKS	25329	13307	4947	8360
IN HENRY	24850	13056	7368	5688
IN HOWARD	13810	7256	9554	-2298
IN HUNTINGTON	30811	16188	5089	11098
IN JACKSON	18199	9561	4586	4975
IN JASPER	13017	6839	2793	4045
IN JAY	27562	14481	3595	10885
IN JEFFERSON	18788	9871	3555	6316
IN JENNINGS	13440	7061	2528	4532
IN JOHNSON	18998	9981	5278	4703
IN KNOX	13726	7211	6690	521
IN KOSCIUSKO	36086	18959	5671	13288
IN LAGRANGE	37159	19523	2544	16979
IN LAKE	19980	19382	67460	-48078
IN LA PORTE	27519	14458	13275	1182
IN LAWRENCE	13175	6921	5538	1383
IN MADISON	19770	10387	17770	-7382
IN MARION	14568	14132	96325	-82193
IN MARSHALL	38790	20380	4823	15556
IN MARTIN	5027	2641	1671	970

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IN MIAMI	24250	12741	5080	7660
IN MONROE	11626	6108	8470	-2361
IN MONTGOMERY	20963	11014	4768	6245
IN MORGAN	12620	6630	4400	2230
IN NEWTON	7205	3785	1760	2025
IN NOBLE	36567	19212	4141	15071
IN OHIO	8340	4381	659	3722
IN ORANGE	15738	8268	2649	5619
IN OWEN	8532	4482	1823	2659
IN PARKE	13154	6911	2402	4508
IN PERRY	8579	4507	2716	1790
IN PIKE	5695	2992	2206	785
IN PORTER	22037	11578	7638	3940
IN POSEY	7074	3717	3069	647
IN PULASKI	17438	9161	1983	7178
IN PUTNAM	14192	7456	3733	3722
IN RANDOLPH	29709	15609	4346	11262
IN RIPLEY	23629	12414	3069	9345
IN RUSH	18397	9666	3146	6519
IN ST JOSEPH	24982	24233	34422	-10188
IN SCOTT	7068	3713	2015	1697
IN SHELBY	28528	14988	4804	10184
IN SPENCER	13988	7349	2531	4818
IN STARKE	8477	4453	2573	1880
IN STEUBEN	25824	13568	2687	10880
IN SULLIVAN	13728	7213	3584	3628
IN SWITZERLAND	21296	11199	1159	10039
IN TIPPECANOE	11224	10887	12666	-1778
IN TIPTON	9445	4962	2462	2500
IN UNION	8319	4370	1009	3361
IN VANDERBURGH	7103	6890	25536	-18646
IN VERMILLION	5485	2882	2959	-78
IN VIGO	10448	10135	16724	-6589
IN WABASH	28114	14770	4795	9975
IN WARREN	6692	3516	1340	2175
IN WARRICK	8194	4305	3515	789
IN WASHINGTON	28714	15086	2678	12407
IN WAYNE	27886	14651	11126	3525
IN WELLS	30855	16211	3181	13029
IN WHITE	14224	7473	2943	4530

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IN WHITLEY	24862	13062	3096	9965
IA ADAIR	20087	3609	1835	1774
IA ADAMS	14461	2666	1287	1378
IA ALLAMAKEE	57043	10042	2541	7501
IA APPANOOSE	19512	3435	2844	590
IA AUDUBON	18722	3296	1772	1523
IA BENTON	27484	4838	3606	1232
IA BLACK HAWK	43243	7613	17234	-9621
IA BOONE	19767	3480	4409	-929
IA BREMER	57401	10106	3112	6993
IA BUCHANAN	42246	7437	3465	3971
IA BUENA VISTA	14057	2474	3318	-843
IA BUTLER	46552	8195	2735	5460
IA CALHOUN	15711	2765	2589	176
IA CARROLL	23324	4106	3643	462
IA CASS	19530	3438	2868	570
IA CEDAR	27910	4913	2712	2200
IA CERRO GORDO	24556	4323	7484	-3160
IA CHEROKEE	17058	3003	2959	43
IA CHICKASAW	41721	7345	2376	4968
IA CLARKE	14133	2488	1394	1094
IA CLAY	17313	3048	2868	179
IA CLAYTON	83517	14703	3497	11206
IA CLINTON	31538	5552	8154	-2601
IA CRAWFORD	34670	6103	3020	3083
IA DALLAS	20322	3577	3745	-167
IA DAVIS	19979	3688	1512	2175
IA DECATUR	18656	3284	1840	1443
IA DELAWARE	65411	11516	2834	8682
IA DES MOINES	14097	2482	6770	-4288
IA DICKINSON	15604	2747	1989	757
IA DUBUQUE	69788	12286	11777	509
IA EMMET	13815	2432	2264	167
IA FAYETTE	73521	12943	4459	8483
IA FLOYD	25028	4406	3348	1057
IA FRANKLIN	32704	5757	2499	3258
IA FREMONT	9094	1601	1798	-196
IA GREENE	16145	2842	2361	480
IA GRUNDY	29112	5125	2181	2944
IA GUTHRIE	23225	4088	2278	1810

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IA HAMILTON	17172	3023	3109	-86
IA HANCOCK	25416	4474	2334	2139
IA HARDIN	23985	4222	3508	714
IA HARRISON	22536	3967	2939	1028
IA HENRY	18434	3245	2901	343
IA HOWARD	39825	7011	2031	4979
IA HUMBOLDT	14123	2486	2061	424
IA IDA	13434	2365	1650	715
IA IOWA	24833	4372	2522	1848
IA JACKSON	40984	7215	3064	4150
IA JASPER	31815	5601	5268	332
IA JEFFERSON	16786	2955	2471	483
IA JOHNSON	23165	4078	7708	-3629
IA JONES	41337	7277	3131	4146
IA KEOKUK	22117	3893	2549	1344
IA KOSSUTH	35236	6203	4056	2147
IA LEE	19651	3459	6838	-3378
IA LINN	47299	8327	18542	-10214
IA LOUISA	10531	1853	1688	165
IA LUCAS	13974	2460	1818	642
IA LYON	31694	5580	2291	3288
IA MADISON	17773	3129	2004	1124
IA MAHASKA	27519	4844	3800	1044
IA MARION	24518	4316	4067	248
IA MARSHALL	22486	3958	5746	-1787
IA MILLS	12570	2213	2139	73
IA MITCHELL	25684	4521	2195	2326
IA MONONA	17679	3112	2399	713
IA MONROE	13522	2380	1763	616
IA MONTGOMERY	15746	2772	2380	391
IA MUSCATINE	21524	3789	5158	-1369
IA O BRIEN	26138	4601	2968	1633
IA OSCEOLA	18222	3208	1590	1618
IA PAGE	16687	2937	3560	-623
IA PALO ALTO	19661	3461	2416	1044
IA PLYMOUTH	29326	5163	3693	1469
IA POCAHONTAS	17735	3122	2348	774
IA POLK	24263	23333	38160	-14826
IA POTTAWATTAMI	32070	5646	11831	-6185
IA POWESHIEK	22034	3879	3033	845

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
IA RINGGOLD	16109	3097	1387	1710
IA SAC	20751	3653	2715	937
IA SCOTT	35882	6317	17029	-10712
IA SHELBY	22723	4000	2494	1506
IA SIOUX	49758	8760	4139	4620
IA STORY	19346	3405	7288	-3882
IA TAMA	26383	4644	3384	1260
IA TAYLOR	19106	3473	1806	1667
IA UNION	14312	2519	2326	193
IA VAN BUREN	16304	2870	1645	1224
IA WAPELLO	18348	3230	7353	-4123
IA WARREN	27731	4882	2991	1890
IA WASHINGTON	19663	3462	3059	402
IA WAYNE	21827	3889	1713	2175
IA WEBSTER	22746	4004	7181	-3176
IA WINNEBAGO	22536	3967	2087	1879
IA WINNESHIEK	72671	12794	3397	9396
IA WOODBURY	25174	4432	16571	-12139
IA WORTH	21362	3760	1682	2078
IA WRIGHT	17710	3117	3070	47
KS ALLEN	20358	6213	2224	3989
KS ANDERSON	12258	3741	1244	2497
KS ATCHISON	15455	4717	2712	2004
KS BARBER	3870	1181	1099	82
KS BARTON	11306	3450	3954	-503
KS BOURBON	22551	6882	2280	4602
KS BROWN	19863	6063	1794	4268
KS BUTLER	14709	4489	4361	127
KS CHASE	3235	987	567	419
KS CHAUTAUQUA	5274	1609	865	744
KS CHEROKEE	16773	5119	3056	2063
KS CHEYENNE	7351	2245	672	1573
KS CLARK	1396	426	473	-47
KS CLAY	10412	3178	1438	1739
KS CLOUD	10360	3162	1965	1196
KS COFFEY	13766	4390	1220	3170
KS COMANCHE	2814	858	463	395
KS COWLEY	13634	4161	4766	-604
KS CRAWFORD	18891	5765	4965	800
KS DECATUR	6868	2096	768	1328

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
KS DICKINSON	14104	4304	2727	1577
KS DONIPHAN	9315	2843	1291	1551
KS DOUGLAS	18038	5505	4878	627
KS EDWARDS	3342	1019	713	306
KS ELK	8546	2632	764	1868
KS ELLIS	13020	3974	2553	1420
KS ELLSWORTH	5950	1816	1038	777
KS FINNEY	3580	1092	1982	-889
KS FORD	6643	2028	2581	-554
KS FRANKLIN	21739	6635	2524	4110
KS GEARY	4963	1515	3154	-1639
KS GOVE	5977	1859	549	1310
KS GRAHAM	6226	1900	671	1228
KS GRANT	902	275	626	-351
KS GRAY	4097	1250	598	652
KS GREELEY	839	256	260	-4
KS GREENWOOD	6637	2025	1608	417
KS HAMILTON	1358	414	442	-28
KS HARPER	8607	2627	1272	1354
KS HARVEY	13580	4145	2998	1146
KS HASKELL	1510	460	354	106
KS HODGEMAN	4555	1396	411	984
KS JACKSON	18390	5886	1375	4511
KS JEFFERSON	17809	5485	1424	4060
KS JEWELL	12399	4142	1104	3038
KS JOHNSON	13253	12311	12419	-107
KS KEARNY	1793	547	424	122
KS KINGMAN	11580	3534	1299	2235
KS KIOWA	2551	778	599	179
KS LABETTE	22374	6829	3606	3222
KS LANE	1761	537	372	165
KS LEAVENWORTH	21478	6555	5746	809
KS LINCOLN	7492	2404	790	1614
KS LINN	13308	4230	1188	3042
KS LOGAN	2580	787	528	258
KS LYON	14024	4280	3414	866
KS MCPHERSON	20630	6297	3057	3239
KS MARION	22104	6746	2019	4726
KS MARSHALL	20616	6292	2164	4128
KS MEADE	3972	1212	718	494

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
KS MIAMI	18208	5557	2526	3031
KS MITCHELL	6893	2103	1239	864
KS MONTGOMERY	16040	4896	5858	-962
KS MORRIS	10482	3199	1024	2174
KS MORTON	680	207	374	-166
KS NEMAHA	22979	7148	1753	5395
KS NEOSHO	19317	5896	2551	3344
KS NESS	6761	2063	761	1302
KS NORTON	9097	2776	1082	1693
KS OSAGE	12990	3965	1641	2323
KS OSBORNE	7403	2259	1036	1223
KS OTTAWA	8058	2459	902	1557
KS PAWNEE	5362	1636	1367	269
KS PHILLIPS	9868	3012	1154	1857
KS POTTAWATOMIE	11734	3581	1555	2026
KS PRATT	5156	1573	1550	23
KS RAWLINS	6179	1887	707	1179
KS RENO	21464	6551	7177	-625
KS REPUBLIC	11537	3600	1373	2226
KS RICE	7596	2318	1903	414
KS RILEY	8861	2704	4729	-2024
KS ROOKS	7011	2140	1193	946
KS RUSH	6485	1979	865	1114
KS RUSSELL	7183	2192	1600	591
KS SALINE	9077	2770	5425	-2654
KS SCOTT	1836	560	646	-85
KS SEDGWICK	20990	19498	34964	-15465
KS SEWARD	1358	1261	1597	-335
KS SHAWNEE	12916	11997	15414	-3416
KS SHERIDAN	7519	2377	570	1807
KS SHERMAN	5410	1651	904	747
KS SMITH	11768	3839	1072	2767
KS STAFFORD	4666	1424	1052	372
KS STANTON	859	262	280	-18
KS STEVENS	902	275	570	-295
KS SUMNER	12503	3816	3112	704
KS THOMAS	4106	1253	955	297
KS TREGO	7784	2375	728	1647
KS WABAUNSEE	9761	3131	891	2239
KS WALLACE	2156	658	296	361

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
KS WASHINGTON	19916	6585	1536	5048
KS WICHITA	1975	602	344	258
KS WILSON	10442	3187	1799	1388
KS WOODSON	7145	2180	788	1392
KS WYANDOTTE	3768	3500	22214	-18713
KY ADAIR	17738	7569	2129	5439
KY ALLEN	13579	5703	1709	3995
KY ANDERSON	13372	5181	1148	4033
KY BALLARD	7906	3051	1097	1952
KY BARREN	33041	12751	3693	9057
KY BATH	7858	3033	1282	1751
KY BELL	2177	1964	5514	-3550
KY BOONE	11212	4326	2186	2140
KY BOURBON	5838	2253	2332	-79
KY BOYD	3975	3586	6620	-3033
KY BOYLE	5970	2304	2711	-406
KY BRACKEN	10806	4322	1040	3282
KY BREATHITT	4650	2179	2350	-170
KY BRECKINRIDGE	10463	4037	1975	2062
KY BULLITT	7469	2882	1718	1163
KY BUTLER	6957	2685	1375	1309
KY CALDWELL	8335	3216	1710	1506
KY CALLOWAY	9754	3764	2666	1097
KY CAMPBELL	7831	7066	10499	-3432
KY CARLISLE	5989	2311	774	1536
KY CARROLL	5946	2294	1078	1216
KY CARTER	7783	3003	2839	164
KY CASEY	14345	6136	2097	4039
KY CHRISTIAN	12513	4829	6314	-1484
KY CLARK	6152	2374	2578	-204
KY CLAY	6238	2434	2876	-441
KY CLINTON	6210	2412	1284	1127
KY CRITTENDEN	6095	2352	1287	1064
KY CUMBERLAND	7309	3053	1129	1923
KY DAVIESS	9916	3826	8184	-4357
KY EDMONSON	7960	3204	1148	2055
KY ELLIOTT	3575	1692	879	812
KY ESTILL	3887	1500	1787	-287
KY FAYETTE	5566	5023	14829	-9805
KY FLEMING	14183	5867	1497	4370

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
KY FLOYD	5338	4816	6304	-1487
KY FRANKLIN	5975	2306	3566	-1259
KY FULTON	3402	1312	1645	-331
KY GALLATIN	4590	1771	510	1261
KY GARRARD	9003	3696	1363	2332
KY GRANT	11736	4697	1258	3439
KY GRAVES	18627	7188	4005	3183
KY GRAYSON	12579	4972	2152	2820
KY GREEN	14070	5992	1463	4527
KY GREENUP	4581	1768	3477	-1709
KY HANCOCK	2253	869	744	125
KY HARDIN	15728	6069	7511	-1441
KY HARLAN	1483	1338	8192	-6853
KY HARRISON	9122	3520	1785	1735
KY HART	17275	7060	1926	5134
KY HENDERSON	3581	3231	4150	-919
KY HENRY	14685	5667	1459	4207
KY HICKMAN	7073	2729	955	1774
KY HOPKINS	7128	2751	5029	-2278
KY JACKSON	6254	2638	1570	1067
KY JEFFERSON	13668	12332	70026	-57693
KY JESSAMINE	5314	2050	1685	365
KY JOHNSON	3432	1430	2875	-1445
KY KENTON	7500	6767	14471	-7703
KY KNOTT	2907	1746	2479	-733
KY KNOX	6749	2604	3671	-1066
KY LARUE	10533	4064	1316	2748
KY LAUREL	11459	4422	3306	1115
KY LAWRENCE	6849	2643	1750	893
KY LEE	1930	852	1063	-212
KY LESLIE	1835	1655	1767	-111
KY LETCHER	2474	2233	4619	-2387
KY LEWIS	10786	4162	1736	2425
KY LINCOLN	14339	5533	2308	3224
KY LIVINGSTON	2699	1041	926	115
KY LOGAN	18071	6974	2825	4148
KY LYON	3943	1521	839	682
KY MCCRACKEN	3992	3601	6843	-3241
KY MCCREARY	1956	1765	1935	-170
KY MCLEAN	3177	1226	1267	-40

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
KY MADISON	11907	4595	4183	411
KY MAGOFFIN	4790	2173	1652	521
KY MARION	10297	3973	2221	1752
KY MARSHALL	5310	2049	1926	122
KY MARTIN	1673	910	1437	-526
KY MASON	12351	4766	2403	2363
KY MEADE	5016	1936	1751	184
KY MENIFEE	2618	1171	595	575
KY MERCER	14008	5406	1902	3503
KY METCALFE	13099	5718	1200	4518
KY MONROE	13387	5544	1682	3862
KY MONTGOMERY	7595	2931	1718	1212
KY MORGAN	6452	2858	1630	1228
KY MUHLENBERG	5667	2187	3967	-1780
KY NELSON	14302	5519	2686	2833
KY NICHOLAS	6491	2752	932	1819
KY OHIO	7467	2881	2539	342
KY OLDHAM	10488	4047	1565	2482
KY OWEN	11452	4772	1185	3588
KY OWSLEY	2552	1184	845	338
KY PENDLETON	14983	5887	1270	4616
KY PERRY	2408	2172	5416	-3243
KY PIKE	6712	6056	9843	-3787
KY POWELL	2651	1023	878	144
KY PULASKI	23508	9072	4778	4293
KY ROBERTSON	4085	1745	351	1394
KY ROCKCASTLE	7381	2848	1723	1124
KY ROWAN	3283	1267	1658	-391
KY RUSSELL	9429	3847	1638	2208
KY SCOTT	5463	2108	1982	125
KY SHELBY	31680	12225	2362	9863
KY SIMPSON	14181	5473	1512	3960
KY SPENCER	15881	6295	774	5520
KY TAYLOR	15265	5891	1977	3913
KY TODD	9973	3848	1592	2256
KY TRIGG	4211	1625	1214	410
KY TRIMBLE	6636	2695	667	2028
KY UNION	2434	939	1917	-978
KY WARREN	28696	11074	5713	5360
KY WASHINGTON	15091	5988	1572	4415

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
KY WAYNE	7820	3018	2044	973
KY WEBSTER	4029	1555	1951	-396
KY WHITLEY	5566	2148	3816	-1668
KY WOLFE	3259	1369	931	438
KY WOODFORD	2443	942	1497	-555
LA ACADIA	7710	5437	4507	929
LA ALLEN	2156	1520	1799	-278
LA ASCENSION	2412	2195	2310	-115
LA ASSUMPTION	711	647	1642	-995
LA AVOYELLES	9693	6989	3534	3454
LA BEAUREGARD	2656	1873	1716	157
LA BIENVILLE	4924	3472	1689	1782
LA BOSSIER	3883	3534	4441	-907
LA CADDO	7008	6377	18363	-11985
LA CALCASIEU	2804	2552	10585	-8033
LA CALDWELL	1715	1209	910	299
LA CAMERON	978	690	609	80
LA CATAHOULA	2165	1527	1088	438
LA CLAIBORNE	6512	4592	2116	2476
LA CONCORDIA	1297	1180	1585	-404
LA DE SOTO	11663	8225	2272	5953
LA EAST BATON R	5034	4581	17626	-13044
LA EAST CARROLL	2243	1582	1448	133
LA EAST FELICIA	5530	3899	1829	2070
LA EVANGELINE	5491	3872	2954	918
LA FRANKLIN	9549	6854	2612	4242
LA GRANT	2594	1829	1294	534
LA IBERIA	6329	4463	4201	262
LA IBERVILLE	1080	982	2624	-1641
LA JACKSON	2717	1916	1457	459
LA JEFFERSON	3132	2850	13862	-11011
LA JEFFERSON DA	2550	2321	2595	-274
LA LAFAYETTE	11964	8437	6459	1977
LA LAFOURCHE	1320	1201	4464	-3262
LA LA SALLE	1241	1129	1199	-69
LA LINCOLN	3515	2478	2516	-38
LA LIVINGSTON	4801	3385	2147	1238
LA MADISON	2400	1692	1590	102
LA MOREHOUSE	2939	2674	3058	-383
LA NATCHITOCHES	4748	3348	3463	-114

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
LA ORLEANS	752	684	55533	-54848
LA OUACHITA	3625	3299	8046	-4746
LA PLAQUEMINES	123	112	1659	-1546
LA POINTE COUPE	2900	2045	2065	-19
LA RAPIDES	9651	8782	9285	-503
LA RED RIVER	1964	1385	1046	338
LA RICHLAND	5685	4009	2377	1631
LA SABINE	4024	2838	1857	980
LA ST BERNARD	316	287	1872	-1585
LA ST CHARLES	919	836	1560	-722
LA ST HELENA	12848	9447	847	8600
LA ST JAMES	686	624	1552	-927
LA ST JOHN THE	200	182	1529	-1347
LA ST LANDRY	16034	11307	7448	3859
LA ST MARTIN	5691	4013	2568	1444
LA ST MARY	774	704	3862	-3157
LA ST TAMMANY	4558	3214	2983	231
LA TANGIPAHOA	38557	27190	5215	21974
LA TENSAS	1799	1268	1177	91
LA TERREBONNE	1815	1652	4738	-3086
LA UNION	4353	3069	1726	1342
LA VERMILION	8845	6238	3525	2712
LA VERNON	3675	2591	1745	846
LA WASHINGTON	22309	15732	3806	11925
LA WEBSTER	3708	3374	3492	-118
LA WEST BATON R	988	899	1217	-318
LA WEST CARROLL	4262	3266	1488	1777
LA WEST FELICIA	1546	1090	1038	51
LA WINN	2226	1570	1501	68
ME ANDROSCOGGIN	18661	14807	13766	1041
ME AROOSTOOK	39107	31031	16290	14741
ME CUMBERLAND	17885	16346	28417	-12071
ME FRANKLIN	13066	10368	3317	7051
ME HANCOCK	5346	4886	5227	-341
ME KENNEBEC	32375	25689	13987	11702
ME KNOX	5912	4692	4598	93
ME LINCOLN	6552	5199	2958	2240
ME OXFORD	17790	14116	7190	6926
ME PENOBSCOT	39907	31666	18826	12840
ME PISCATAQUIS	9205	7304	2938	4365

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
ME SAGADAHOC	4759	3776	3526	249
ME SOMERSET	33504	26585	6459	20126
ME WALDO	20519	16282	3587	12694
ME WASHINGTON	6127	4862	5557	-695
ME YORK	19107	15161	15598	-436
MD ALLEGANY	7251	7031	11466	-4435
MD ANNE ARUNDEL	5594	5424	20409	-14984
MD BALTIMORE	32342	31359	172117	-140758
MD CALVERT	2506	1680	1798	-117
MD CAROLINE	19861	13317	2464	10853
MD CARROLL	56331	37772	6341	31431
MD CECIL	35221	23617	5223	18394
MD CHARLES	5439	3647	3588	58
MD DORCHESTER	7434	4984	3758	1226
MD FREDERICK	120500	80799	8722	72076
MD GARRETT	24854	16665	2746	13918
MD HARFORD	55945	37513	8197	29316
MD HOWARD	19406	13012	3765	9247
MD KENT	27129	18190	1897	16292
MD MONTGOMERY	41980	28149	31460	-3311
MD PRINCE GEORG	6476	6279	34630	-28351
MD QUEEN ANNES	37137	24902	2027	22874
MD ST MARYS	6682	4481	4372	108
MD SOMERSET	4808	3224	2663	560
MD TALBOT	16832	11286	2673	8614
MD WASHINGTON	49706	33329	11054	22274
MD WICOMICO	3885	3767	5733	-1966
MD WORCESTER	9153	6137	3074	3063
MA BARNSTABLE	1093	959	9222	-8263
MA BERKSHIRE	38588	1080	22230	-21150
MA BRISTOL	37052	32507	63144	-30637
MA DUKES	938	823	928	-104
MA ESSEX	23807	20886	88055	-67168
MA FRANKLIN	38647	1632	8713	-7080
MA HAMPDEN	19554	17155	64005	-46850
MA HAMPSHIRE	30733	1308	15307	-13998
MA MIDDLESEX	29001	25443	184937	-159493
MA NANTUCKET	15	13	570	-557
MA NORFOLK	14217	12473	71863	-59390
MA PLYMOUTH	18994	16663	34846	-18182

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MA SUFFOLK	111	97	138365	-138268
MA WORCESTER	79959	70150	91292	-21142
MI ALCONA	12199	5922	951	4970
MI ALGER	7995	3881	1520	2361
MI ALLEGAN	59829	29047	8137	20909
MI ALPENA	17256	8378	3907	4470
MI ANTRIM	13654	6629	1659	4970
MI ARENAC	18638	9048	1527	7521
MI BARAGA	8777	4261	1202	3059
MI BARRY	35679	17322	4479	12842
MI BAY	28888	14025	15123	-1097
MI BENZIE	3347	1625	1272	353
MI BERRIEN	23816	11563	20438	-8874
MI BRANCH	43278	21011	5053	15957
MI CALHOUN	46361	22508	20164	2343
MI CASS	24413	11852	5007	6845
MI CHARLEVOIX	12151	5899	2111	3788
MI CHEBOYGAN	10743	5215	2209	3006
MI CHIPPEWA	18529	8995	4814	4181
MI CLARE	14977	7271	1701	5569
MI CLINTON	51282	24897	5347	19550
MI CRAWFORD	800	388	706	-317
MI DELTA	24029	11666	5258	6408
MI DICKINSON	9760	4738	3836	902
MI EATON	48180	23391	6926	16465
MI EMMET	12553	6094	2552	3541
MI GENESEE	38466	36680	49420	-12739
MI GLADWIN	19970	9695	1571	8124
MI GOGEBIC	6288	3053	4067	-1014
MI GRAND TRAVER	12550	6093	4814	1278
MI GRATIOT	40040	19439	5485	13954
MI HILLSDALE	53007	25734	5197	20536
MI HOUGHTON	20639	10020	5966	4053
MI HURON	73505	35686	5260	30426
MI INGHAM	46452	22552	29700	-7147
MI IONIA	46644	22645	6321	16325
MI IOSCO	11092	5385	2086	3299
MI IRON	8089	3927	2742	1184
MI ISABELLA	45853	22261	4972	17289
MI JACKSON	41861	20323	18544	1779

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MI KALAMAZOO	26955	13086	22755	-9668
MI KALKASKA	6769	3286	706	2580
MI KENT	64949	31532	50243	-18710
MI KEWEENAW	310	295	424	-128
MI LAKE	6096	2960	829	2129
MI LAPEER	69041	33519	6026	27492
MI LEELANAU	9359	4543	1402	3141
MI LENAWEE	47444	23034	11021	12013
MI LIVINGSTON	36597	17768	4962	12805
MI LUCE	1626	789	1257	-468
MI MACKINAC	6893	3346	1562	1784
MI MACOMB	37855	36097	43760	-7662
MI MANISTEE	9725	4721	2942	1779
MI MARQUETTE	6474	6174	8046	-1872
MI MASON	25343	12304	3310	8993
MI MECOSTA	31785	15431	3116	12315
MI MENOMINEE	44291	21503	3928	17574
MI MIDLAND	17026	8266	6649	1616
MI MISSAUKEE	21702	10536	1126	9410
MI MONROE	22470	10909	13573	-2664
MI MONTCALM	53281	25868	5185	20682
MI MONTMORENCY	5208	2528	667	1860
MI MUSKEGON	16716	15940	20970	-5030
MI NEWAYGO	34770	16880	3557	13323
MI OAKLAND	30985	29546	81779	-52232
MI OCEANA	21700	10535	2557	7977
MI OGEMAW	19748	9587	1489	8098
MI ONTONAGON	15243	7400	1633	5766
MI OSCEOLA	28174	13678	2151	11526
MI OSCODA	5036	2445	512	1932
MI OTSEGO	7560	3670	1083	2587
MI OTTAWA	54282	26354	13240	13113
MI PRESQUE ISLE	16093	7813	1957	5856
MI ROSCOMMON	1316	639	1014	-374
MI SAGINAW	57550	27940	26577	1363
MI ST CLAIR	63703	30927	15417	15510
MI ST JOSEPH	29801	14468	5989	8479
MI SANILAC	113734	55218	4937	50279
MI SCHOOLCRAFT	4094	1988	1423	565
MI SHIAWASSEE	49523	24043	7712	16330

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MI TUSCOLA	57683	28005	6342	21663
MI VAN BUREN	31144	15120	6764	8356
MI WASHTENAW	51531	25018	23650	1367
MI WAYNE	10203	9729	397617	-387887
MI WEXFORD	12479	6058	2913	3145
MN AITKIN	36098	3699	2202	1496
MN ANOKA	21233	2175	9357	-7181
MN BECKER	58094	5953	4019	1934
MN BELTRAMI	30661	3142	3992	-849
MN BENTON	46062	4720	2709	2011
MN BIG STONE	14907	1527	1531	-4
MN BLUE EARTH	32329	3313	6717	-3404
MN BROWN	39285	4026	4377	-351
MN CARLTON	37343	3827	4270	-443
MN CARVER	82601	8465	3204	5260
MN CASS	30555	3131	3005	125
MN CHIPPEWA	21945	2248	2720	-471
MN CHISAGO	47284	4845	2132	2712
MN CLAY	28172	2887	5595	-2708
MN CLEARWATER	26373	2702	1582	1120
MN COOK	476	463	509	-46
MN COTTONWOOD	26934	2760	2617	142
MN CROW WING	24134	2473	5159	-2685
MN DAKOTA	57890	5932	10095	-4162
MN DODGE	54420	5577	2117	3459
MN DOUGLAS	64341	6594	3499	3094
MN FARIBAULT	31981	3277	3907	-630
MN FILLMORE	82627	8468	3970	4497
MN FREEBORN	66365	6801	5904	896
MN GOODHUE	96660	9906	5340	4565
MN GRANT	22236	2278	1520	758
MN HENNEPIN	56623	55028	122734	-67706
MN HOUSTON	51828	5311	2521	2790
MN HUBBARD	20524	2103	1742	360
MN ISANTI	34888	3575	2089	1486
MN ITASCA	21182	2170	5800	-3629
MN JACKSON	26623	2728	2621	106
MN KANABEC	38599	3955	1496	2458
MN KANDIYOHI	54187	5553	4798	754
MN KITTSON	16438	1684	1493	191

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MN KOOCHICHING	10983	1125	2866	-1741
MN LAC QUI PARL	26723	2738	2304	434
MN LAKE	961	934	1690	-756
MN LAKE OF THE	8918	913	767	146
MN LE SUEUR	40000	4099	3192	907
MN LINCOLN	25089	2571	1632	938
MN LYON	26841	2751	3683	-932
MN MCLEOD	83008	8507	3799	4707
MN MAHNOMEN	18243	1869	1109	760
MN MARSHALL	35062	3593	2518	1074
MN MARTIN	40087	4108	4306	-198
MN MEEKER	70676	7243	3109	4133
MN MILLE LACS	45600	4673	2448	2224
MN MORRISON	87725	8990	4298	4691
MN MOWER	53164	5448	7378	-1929
MN MURRAY	38016	3896	2427	1468
MN NICOLLET	37172	3809	3595	214
MN NOBLES	38668	3962	3750	212
MN NORMAN	29537	3027	2004	1023
MN OLMSTED	72234	7402	9129	-1726
MN OTTER TAIL	154326	15815	8264	7551
MN PENNINGTON	21847	2239	2094	144
MN PINE	69434	7115	2907	4208
MN PIPESTONE	27264	2794	2272	521
MN POLK	55308	5668	5916	-248
MN POPE	42744	4380	2046	2333
MN RAMSEY	3811	3704	63053	-59349
MN RED LAKE	19380	1986	1050	936
MN REDWOOD	31886	3268	3606	-338
MN RENVILLE	43245	4431	3884	546
MN RICE	74835	7669	6143	1526
MN ROCK	26564	2722	1893	829
MN ROSEAU	33915	3475	2217	1258
MN ST LOUIS	49496	5072	35628	-30555
MN SCOTT	56275	5767	3086	2681
MN SHERBURNE	23668	2425	1904	521
MN SIBLEY	59737	6121	2627	3494
MN STEARNS	160365	16434	12284	4150
MN STEELE	56755	5816	3745	2071
MN STEVENS	20897	2141	1834	306

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MN SWIFT	27901	2859	2538	321
MN TODD	97346	9976	4014	5961
MN TRAVERSE	13553	1389	1284	104
MN WABASHA	53161	5448	2781	2666
MN WADENA	33660	3449	2061	1388
MN WASECA	34793	3565	2532	1032
MN WASHINGTON	42251	4330	6922	-2592
MN WATONWAN	21393	2192	2320	-128
MN WILKIN	18629	1909	1741	168
MN WINONA	72164	7395	6620	774
MN WRIGHT	105189	10780	4706	6073
MN YELLOW MEDIC	24921	2554	2621	-67
MS ADAMS	1633	1314	4165	-2851
MS ALCORN	7276	3256	3175	81
MS AMITE	16732	7487	2131	5356
MS ATTALA	11668	5221	2937	2283
MS BENTON	3685	1688	1004	684
MS BOLIVAR	4608	3708	7151	-3443
MS CALHOUN	7873	3523	2087	1435
MS CARROLL	5317	2379	1645	733
MS CHICKASAW	11771	5267	2177	3089
MS CHOCTAW	6928	3277	1194	2082
MS CLAIBORNE	2304	1031	1382	-351
MS CLARKE	4507	2017	2185	-168
MS CLAY	12007	5373	2199	3174
MS COAHOMA	2392	1925	5784	-3858
MS COPIAH	8232	3683	3496	187
MS COVINGTON	6180	2765	1809	956
MS DE SOTO	21413	9582	2926	6655
MS FORREST	4820	3878	5819	-1940
MS FRANKLIN	3843	1720	1232	487
MS GEORGE	3452	1545	1261	283
MS GREENE	1882	842	997	-155
MS GRENADA	3000	1342	2246	-903
MS HANCOCK	3770	1687	1542	144
MS HARRISON	3247	2612	11939	-9326
MS HINDS	8078	6501	19420	-12919
MS HOLMES	7396	3310	3693	-383
MS HUMPHREYS	2568	2067	2578	-511
MS ISSAQUENA	1160	519	526	-7

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MS ITAWAMBA	8201	3806	1965	1841
MS JACKSON	2093	1685	5017	-3331
MS JASPER	6589	2948	2175	773
MS JEFFERSON	2674	1196	1302	-105
MS JEFFERSON DA	6617	3013	1766	1246
MS JONES	12585	5632	7012	-1380
MS KEMPER	7679	3456	1729	1726
MS LAFAYETTE	5779	2585	2672	-86
MS LAMAR	5964	2668	1616	1052
MS LAUDERDALE	6295	5066	7880	-2814
MS LAWRENCE	5865	2624	1398	1226
MS LEAKE	11320	5491	2452	3039
MS LEE	17277	7731	4725	3005
MS LEFLORE	3229	2598	6001	-3403
MS LINCOLN	14523	6499	3302	3196
MS LOWNDES	13018	5825	5009	816
MS MADISON	8646	3869	4029	-159
MS MARION	8840	3956	2852	1103
MS MARSHALL	10055	4500	2993	1507
MS MONROE	11187	5006	4269	736
MS MONTGOMERY	6718	3006	1684	1321
MS NESHOBA	15226	6862	2853	4008
MS NEWTON	16271	7281	2570	4711
MS NOXUBEE	15330	6860	2248	4611
MS OKTIBBEHA	24965	11171	3041	8130
MS PANOLA	7384	3304	3639	-335
MS PEARL RIVER	9648	4317	2576	1741
MS PERRY	2095	937	1078	-140
MS PIKE	14229	6367	4227	2140
MS PONTOTOC	14803	7112	2267	4846
MS PRENTISS	11240	5070	2291	2779
MS QUITMAN	2433	1957	2868	-911
MS RANKIN	9785	4379	3757	621
MS SCOTT	6638	2970	2585	384
MS SHARKEY	1190	958	1443	-484
MS SIMPSON	8252	3692	2558	1135
MS SMITH	6941	3228	1891	1337
MS STONE	2720	1217	792	424
MS SUNFLOWER	5650	4547	6222	-1674
MS TALLAHATCHIE	5386	2410	3344	-933

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MS TATE	11583	5183	2175	3007
MS TIPPAH	10426	4986	1986	3000
MS TISHOMINGO	4358	1950	1787	162
MS TUNICA	2024	1629	2362	-733
MS UNION	12629	5827	2370	3455
MS WALTHALL	15834	7150	1769	5380
MS WARREN	2220	1787	4904	-3117
MS WASHINGTON	3048	2453	8908	-6455
MS WAYNE	3898	1744	2010	-266
MS WEBSTER	7682	3607	1346	2262
MS WILKINSON	2115	946	1654	-708
MS WINSTON	11729	5248	2525	2723
MS YALOBUSHA	5438	2434	1691	741
MS YAZOO	5569	2492	4093	-1601
MO ADAIR	17043	4402	2392	2010
MO ANDREW	17081	4722	1378	3344
MO ATCHISON	6725	1737	1241	495
MO AUDRAIN	6884	1778	2985	-1207
MO BARRY	38310	10372	2475	7897
MO BARTON	15120	4033	1447	2585
MO BATES	27322	7175	2028	5146
MO BENTON	17751	5105	1076	4029
MO BOLLINGER	8413	2497	1233	1264
MO BOONE	10339	2670	6180	-3509
MO BUCHANAN	13361	3451	11342	-7891
MO BUTLER	9329	2409	4385	-1975
MO CALDWELL	9358	2590	1140	1450
MO CALLAWAY	8409	2172	2836	-663
MO CAMDEN	8209	2120	1010	1109
MO CAPE GIRARDE	22557	5827	4810	1016
MO CARROLL	13274	3443	1789	1654
MO CARTER	1531	400	534	-133
MO CASS	26154	6756	2858	3897
MO CEDAR	20561	5727	1208	4519
MO CHARITON	15784	4344	1686	2658
MO CHRISTIAN	34017	9394	1492	7902
MO CLARK	10336	2760	1070	1690
MO CLAY	6481	6073	7610	-1536
MO CLINTON	6999	1808	1405	402
MO COLE	17290	4466	4542	-76

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MO COOPER	9143	2361	1941	420
MO CRAWFORD	7687	1985	1451	534
MO DADE	21662	6274	1033	5241
MO DALLAS	28361	8029	1196	6832
MO DAVIESS	13868	4131	1260	2870
MO DE KALB	11000	3235	927	2307
MO DENT	8367	2161	1292	869
MO DOUGLAS	34000	9620	1369	8251
MO DUNKLIN	4328	4055	5142	-1087
MO FRANKLIN	25576	6606	4777	1829
MO GASCONADE	9216	2380	1479	901
MO GENTRY	11351	3137	1214	1923
MO GREENE	53328	13775	13724	51
MO GRUNDY	14407	3721	1541	2180
MO HARRISON	21541	6335	1570	4764
MO HENRY	16357	4225	2371	1853
MO HICKORY	13856	4026	604	3422
MO HOLT	6271	1619	1084	535
MO HOWARD	5853	1512	1377	134
MO HOWELL	29596	7645	2701	4943
MO IRON	2636	681	1066	-385
MO JACKSON	15986	14978	69349	-54370
MO JASPER	26473	6838	9515	-2677
MO JEFFERSON	10896	2814	6029	-3215
MO JOHNSON	19536	5046	2918	2128
MO KNOX	7804	2313	863	1449
MO LACLEDE	28040	7243	2288	4954
MO LAFAYETTE	21867	5648	3044	2604
MO LAWRENCE	39603	10230	2813	7417
MO LEWIS	10370	2678	1305	1373
MO LINCOLN	7351	1899	1690	208
MO LINN	14811	3826	2167	1658
MO LIVINGSTON	11136	2876	1951	924
MO MCDONALD	20901	5657	1583	4073
MO MACON	17903	4805	2112	2692
MO MADISON	2516	675	1198	-522
MO MARIES	9512	2766	887	1879
MO MARION	16094	4157	3572	584
MO MERCER	10783	3242	795	2446
MO MILLER	15771	4146	1657	2489

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MO MISSISSIPPI	2248	2107	2621	-514
MO MONITEAU	11033	2895	1288	1606
MO MONROE	10268	2987	1330	1656
MO MONTGOMERY	6151	1589	1368	220
MO MORGAN	14628	3929	1191	2737
MO NEW MADRID	3329	3119	4336	-1217
MO NEWTON	35373	9137	3497	5640
MO NODAWAY	23805	6197	2802	3395
MO OREGON	14360	3919	1333	2585
MO OSAGE	14150	3770	1339	2431
MO OZARK	16839	4917	958	3958
MO PEMISCOT	1887	1769	5110	-3341
MO PERRY	13797	3564	1781	1782
MO PETTIS	20402	5270	3984	1285
MO PHELPS	9308	2404	2790	-385
MO PIKE	7503	1938	2021	-83
MO PLATTE	5632	1454	2232	-777
MO POLK	38341	10638	1816	8821
MO PULASKI	7566	1954	3103	-1148
MO PUTNAM	10965	3291	993	2297
MO RALLS	11663	3160	1015	2144
MO RANDOLPH	8559	2211	2714	-503
MO RAY	11323	2925	1926	998
MO REYNOLDS	3460	895	742	152
MO RIPLEY	6204	1602	1256	346
MO ST CHARLES	12535	3238	4777	-1539
MO ST CLAIR	16240	4643	1157	3485
MO ST FRANCOIS	7151	1847	4312	-2464
MO ST LOUIS	4706	4409	161877	-157467
MO STE GENEVIEV	3863	998	1399	-400
MO SALINE	12660	3270	3136	134
MO SCHUYLER	9683	2808	657	2151
MO SCOTLAND	9331	2719	839	1879
MO SCOTT	6314	1631	3951	-2319
MO SHANNON	5991	1627	942	684
MO SHELBY	7497	2131	1137	993
MO STODDARD	10781	2785	3827	-1042
MO STONE	21406	5932	1093	4838
MO SULLIVAN	16188	4841	1232	3609
MO TANEY	9074	2344	1207	1136

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MO TEXAS	35410	9808	2224	7584
MO VERNON	24873	6425	2623	3802
MO WARREN	5782	1493	978	514
MO WASHINGTON	3379	873	1751	-878
MO WAYNE	2684	838	1170	-332
MO WEBSTER	41504		11251	17489503
MO WORTH	5991	1714	556	1158
MO WRIGHT	35443	9810	1822	7988
MT BEAVERHEAD	2091	940	1257	-317
MT BIG HORN	4907	2205	1807	398
MT BLAINE	4831	2171	1521	650
MT BROADWATER	1613	725	524	200
MT CARBON	9572	4303	1719	2584
MT CARTER	2331	1048	487	560
MT CASCADE	8557	7730	11259	-3528
MT CHOUTEAU	2297	1033	1302	-268
MT CUSTER	2870	1290	2354	-1063
MT DANIELS	1810	814	704	109
MT DAWSON	5109	2297	1908	387
MT DEER LODGE	613	553	3182	-2628
MT FALLON	2913	1309	693	615
MT FERGUS	7471	3358	2558	800
MT FLATHEAD	10080	4531	5862	-1330
MT GALLATIN	13795	6201	4317	1883
MT GARFIELD	1233	554	381	172
MT GLACIER	910	822	1909	-1087
MT GOLDEN VALLE	1024	460	234	226
MT GRANITE	1088	489	525	-35
MT HILL	2556	2309	2946	-636
MT JEFFERSON	3272	1471	754	717
MT JUDITH BASIN	2794	1256	574	681
MT LAKE	19194	8629	2468	6160
MT LEWIS AND CL	3319	2999	4747	-1748
MT LIBERTY	613	275	433	-157
MT LINCOLN	1725	1558	1884	-326
MT MCCONE	2385	1072	599	473
MT MADISON	4367	1963	1034	929
MT MEAGHER	910	409	419	-10
MT MINERAL	418	377	453	-75
MT MISSOULA	4215	3808	7188	-3380

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
MT MUSSELSHELL	1639	736	946	-209
MT PARK	4952	2226	2290	-63
MT PETROLEUM	541	243	176	66
MT PHILLIPS	2742	1232	1131	101
MT PONDERA	2640	1186	1264	-78
MT POWDER RIVER	1953	878	473	404
MT POWELL	2390	1074	1204	-129
MT PRAIRIE	1694	761	428	333
MT RAVALLI	21853	9824	2331	7492
MT RICHLAND	5389	2423	1902	520
MT ROOSEVELT	3341	1502	1915	-413
MT ROSEBUD	3018	1356	1168	188
MT SANDERS	4263	1916	1267	649
MT SHERIDAN	4253	1912	1201	710
MT SILVER BOW	1378	1244	8684	-7439
MT STILLWATER	5770	2594	997	1596
MT SWEET GRASS	3937	1770	634	1135
MT TETON	7014	3153	1324	1828
MT TOOLE	1019	921	1334	-413
MT TREASURE	1261	567	251	315
MT VALLEY	4691	2108	2516	-407
MT WHEATLAND	1161	522	569	-46
MT WIBAUX	1922	864	331	531
MT YELLOWSTONE	14859	6680	11991	-5311
NE ADAMS	11005	1318	4218	-2899
NE ANTELOPE	18110	2170	1607	562
NE ARTHUR	919	110	109	0
NE BANNER	1202	174	190	-15
NE BLAINE	1922	230	164	66
NE BOONE	20547	2462	1466	995
NE BOX BUTTE	4946	592	1756	-1162
NE BOYD	6920	829	692	137
NE BROWN	5421	649	708	-59
NE BUFFALO	16548	1983	3737	-1754
NE BURT	13155	1576	1600	-24
NE BUTLER	15217	1823	1600	223
NE CASS	12937	1550	2479	-929
NE CEDAR	27190	3258	1991	1266
NE CHASE	4743	568	702	-134
NE CHERRY	7274	871	1214	-342

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NE CHEYENNE	4351	523	1934	-1410
NE CLAY	7990	957	1271	-313
NE COLFAX	10639	1274	1435	-160
NE CUMING	20391	2443	1862	580
NE CUSTER	28988	3473	2634	838
NE DAKOTA	6259	750	1628	-878
NE DAWES	4341	520	1406	-886
NE DAWSON	10679	1279	2832	-1552
NE DEUEL	1578	224	473	-248
NE DIXON	15435	1849	1269	580
NE DODGE	15131	1813	4220	-2407
NE DOUGLAS	15085	14058	44905	-30847
NE DUNDY	4662	558	586	-28
NE FILLMORE	10571	1266	1391	-124
NE FRANKLIN	8773	1051	934	117
NE FRONTIER	7399	893	711	182
NE FURNAS	8704	1043	1266	-223
NE GAGE	32453	3888	4019	-130
NE GARDEN	3434	411	560	-149
NE GARFIELD	5370	643	412	230
NE GOSPER	4643	623	384	239
NE GRANT	787	94	151	-57
NE GREELEY	8857	1061	753	307
NE HALL	14182	1699	4921	-3221
NE HAMILTON	14096	1689	1277	411
NE HARLAN	6805	815	918	-103
NE HAYES	3500	457	320	136
NE HITCHCOCK	5517	661	791	-130
NE HOLT	23863	2859	2098	760
NE HOOKER	646	77	159	-81
NE HOWARD	18004	2192	1012	1180
NE JEFFERSON	17269	2069	1864	204
NE JOHNSON	10504	1258	998	260
NE KEARNEY	6419	769	946	-177
NE KEITH	3642	436	1119	-683
NE KEYA PAHA	4475	604	284	318
NE KIMBALL	2126	254	853	-599
NE KNOX	23248	2785	2068	717
NE LANCASTER	27925	3346	19686	-16340
NE LINCOLN	14688	1760	4066	-2306

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NE LOGAN	2272	272	182	89
NE LOUP	2961	382	181	201
NE MCPHERSON	1405	196	115	81
NE MADISON	20236	2424	3603	-1178
NE MERRICK	15117	1811	1258	552
NE MORRILL	6496	778	1131	-353
NE NANCE	11091	1329	896	432
NE NEMAHA	8883	1064	1486	-421
NE NUCKOLLS	10291	1233	1317	-83
NE OTOE	15729	1884	2456	-571
NE PAWNEE	9757	1169	898	270
NE PERKINS	4540	544	663	-119
NE PHELPS	6587	789	1367	-578
NE PIERCE	19975	2409	1331	1078
NE PLATTE	26673	3196	3160	36
NE POLK	11702	1402	1123	278
NE RED WILLOW	6470	775	1892	-1117
NE RICHARDSON	14451	1731	2280	-548
NE ROCK	4482	536	412	124
NE SALINE	13785	1651	1956	-305
NE SARPY	8402	1006	3258	-2251
NE SAUNDERS	20016	2398	2492	-93
NE SCOTTS BLUFF	9250	1090	4947	-3857
NE SEWARD	20394	2443	1947	496
NE SHERIDAN	8589	1029	1361	-332
NE SHERMAN	16785	2098	873	1225
NE SIOUX	4200	529	421	107
NE STANTON	12051	1532	895	637
NE THAYER	13421	1608	1453	155
NE THOMAS	972	112	168	-56
NE THURSTON	9578	1147	1170	-22
NE VALLEY	12133	1453	1018	435
NE WASHINGTON	14276	1710	1717	-6
NE WAYNE	18873	2261	1468	793
NE WEBSTER	8957	1073	1007	66
NE WHEELER	4149	543	208	335
NE YORK	15792	1892	2056	-163
NV CHURCHILL	8498	3688	785	2902
NV CLARK1	3297	1430	285	1145
NV CLARK2	483	447	8167	-7719

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NV CLARK3	2	2	542	-540
NV DOUGLAS	2470	1072	291	780
NV ELKO	1912	829	1299	-469
NV ESMERALDA1	43	19	29	-10
NV ESMERALDA2	9	9	38	-29
NV EUREKA	193	83	92	-8
NV HUMBOLDT	674	292	573	-280
NV LANDER1	79	34	44	-9
NV LANDER2	87	80	146	-65
NV LINCOLN1	169	156	317	-160
NV LINCOLN2	903	392	39	353
NV LYON	4143	1798	520	1277
NV MINERAL	55	51	647	-595
NV NYE1	652	283	89	193
NV NYE2	121	112	227	-115
NV NYE3	48	44	83	-39
NV PERSHING	367	340	345	-5
NV STOREY	169	73	68	4
NV WASHOE	4498	4165	7139	-2974
NV WHITE PINE1	241	224	983	-759
NV WHITE PINE2	1295	593	32	560
NV WHITE PINE3	14	13	39	-25
NV CARSON CITY	203	188	640	-453
NH BELKNAP	8101	6999	4483	2516
NH CARROLL	4343	3752	2574	1178
NH CHESHIRE	14615	12627	6617	6010
NH COOS	22068	19066	5919	13147
NH GRAFTON	32723	28272	7848	20423
NH HILLSBOROUGH	21834	21051	26960	-5908
NH MERRIMACK	18318	15826	10565	5261
NH ROCKINGHAM	19631	16960	13380	3580
NH STRAFFORD	8923	8603	8944	-341
NH SULLIVAN	13785	11910	4406	7503
NJ ATLANTIC	532	521	18987	-18465
NJ BERGEN	1797	1760	84308	-82548
NJ BURLINGTON	60771	39036	22805	16230
NJ CAMDEN	3235	3169	44616	-41447
NJ CAPE MAY	940	921	5516	-4595
NJ CUMBERLAND	13687	8792	12661	-3868
NJ ESSEX	982	961	120025	-119063

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NJ GLOUCESTER	12859	12595	14460	-1865
NJ HUDSON	87	85	83024	-82939
NJ HUNTERDON	73358	47121	6250	40870
NJ MERCER	17686	17323	32237	-14914
NJ MIDDLESEX	20880	20451	44241	-23790
NJ MONMOUTH	20511	20090	35699	-15609
NJ MORRIS	24224	23726	27029	-3302
NJ OCEAN	2769	2712	10322	-7610
NJ PASSAIC	1570	1538	48177	-46639
NJ SALEM	42140	27068	7019	20049
NJ SOMERSET	26373	16940	15520	1419
NJ SUSSEX	89725	57634	5351	52283
NJ UNION	581	569	58242	-57672
NJ WARREN	71025	45622	7639	37983
NM BERNALILLO	6082	5590	21374	-15784
NM CATRON	745	443	351	91
NM CHAVES	2748	2525	5239	-2713
NM COLFAX	3192	1897	1697	200
NM CURRY	6400	3805	2991	814
NM DE BACA	957	569	357	211
NM DONA ANA	3101	2849	5280	-2430
NM EDDY	4205	3864	4922	-1058
NM GRANT	1279	1175	2233	-1057
NM GUADALUPE	852	506	687	-180
NM HARDING	1060	630	277	353
NM HIDALGO	728	433	551	-118
NM LEA	3643	3348	4420	-1071
NM LINCOLN	1258	748	826	-78
NM LOS ALAMOS	0	0	1266	-1266
NM LUNA	825	758	1008	-250
NM MCKINLEY	134	123	3459	3336
NM MORA	1297	771	829	-58
NM OTERO	1403	1289	2659	-1370
NM QUAY	5243	3117	1450	1666
NM RIO ARRIBA	1886	1733	2700	-966
NM ROOSEVELT	16134	9592	1786	7805
NM SANDOVAL	612	563	1444	-881
NM SAN JUAN	3594	3303	3632	-329
NM SAN MIGUEL	3210	1908	2761	-853
NM SANTA FE	1017	934	4495	-3560

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NM SIERRA	1537	913	750	163
NM SOCORRO	1102	1012	1082	-69
NM TAOS	2028	1205	1821	-615
NM TORRANCE	3258	1936	806	1130
NM UNION	4970	2955	746	2208
NM VALENCIA	5000	2972	3234	-261
NY ALBANY	34913	33822	41198	-7375
NY ALLEGANY	78320	50014	7124	42889
NY BRONX	0	0	233898	-233898
NY BROOME	74067	47299	31930	15368
NY CATTARAUGUS	141909	90622	12811	77810
NY CAYUGA	72474	46281	11654	34627
NY CHAUTAUQUA	132443	84577	22661	61915
NY CHEMUNG	27204	17372	14922	2449
NY CHENANGO	134938	86170	6640	79530
NY CLINTON	97412	62207	10028	52178
NY COLUMBIA	62882	40156	7299	32856
NY CORTLAND	84995	54277	6308	47969
NY DELAWARE	201784	128858	7154	121703
NY DUTCHESS	73954	47226	24924	22302
NY ERIE	95272	92294	157481	-65187
NY ESSEX	22235	14199	5712	8486
NY FRANKLIN	85356	54508	7275	47233
NY FULTON	23153	14785	8306	6479
NY GENESEE	60094	38375	8171	30204
NY GREENE	39244	25061	4850	20210
NY HAMILTON	226	219	677	-458
NY HERKIMER	114054	72834	10317	62516
NY JEFFERSON	181173	115696	14050	101645
NY KINGS	710	687	437099	-436411
NY LEWIS	106250	67850	3708	64142
NY LIVINGSTON	69117	44138	6800	37336
NY MADISON	119519	76324	8087	68236
NY MONROE	56055	54303	86021	-31717
NY MONTGOMERY	77339	49388	9517	39870
NY NASSAU	2910	2819	152585	-149765
NY NEW YORK	0	0	300298	-300298
NY NIAGARA	37739	24100	34468	-10369
NY ONEIDA	174897	111687	39065	72622
NY ONONDAGA	87050	55590	61117	-5526

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NY ONTARIO	60182	38432	10319	28112
NY ORANGE	120525	76966	26903	50063
NY ORLEANS	28628	18281	5144	13137
NY OSWEGO	75604	48280	13152	35128
NY OTSEGO	156300	99812	8326	91486
NY PUTNAM	10085	6440	4087	2353
NY QUEENS	628	609	269759	-269150
NY RENSSELAER	54871	35040	22227	12812
NY RICHMOND	207	200	33214	-33014
NY ROCKLAND	2014	1951	17781	-15830
NY ST LAWRENCE	244092	155876	16916	138960
NY SARATOGA	43167	27566	13142	14423
NY SCHENECTADY	12273	11889	23863	-11974
NY SCHOHARIE	77707	49623	3681	45942
NY SCHUYLER	16634	10623	2362	8260
NY SENECA	21824	13936	4939	8997
NY STEUBEN	102346	65358	15284	50073
NY SUFFOLK	8124	7870	71818	-63947
NY SULLIVAN	42098	26883	6928	19955
NY TIOGA	57231	36547	5427	31120
NY TOMPKINS	44024	28114	10089	18024
NY ULSTER	36608	23377	16852	6525
NY WARREN	4632	4487	6698	-2210
NY WASHINGTON	105751	67531	7749	59782
NY WAYNE	45276	28912	10047	18865
NY WESTCHESTER	6380	6180	114287	-108107
NY WYOMING	104198	66540	5466	61073
NY YATES	25312	16164	2929	13234
NC ALAMANCE	13804	7387	7765	-378
NC ALEXANDER	7352	3975	1506	2469
NC ALLEGHANY	14872	8918	800	8117
NC ANSON	6393	3421	2610	810
NC ASHE	23100	14513	2105	12408
NC AVERY	5450	3376	1282	2093
NC BEAUFORT	3138	2437	3679	-1242
NC BERTIE	1518	1179	2565	-1385
NC BLADEN	5454	2919	2946	-26
NC BRUNSWICK	2013	1563	1975	-412
NC BUNCOMBE	19484	10427	12728	-2301
NC BURKE	5336	4144	4875	-731

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
NC CABARRUS	11417	6110	6588	-477
NC CALDWELL	7570	4051	4616	-565
NC CAMDEN	590	458	540	-82
NC CARTERET	1391	1081	2650	1569
NC CASWELL	8162	4917	2053	2863
NC CATAWBA	15187	8127	6688	1439
NC CHATHAM	13646	7302	2608	4695
NC CHEROKEE	5932	3175	1752	1422
NC CHOWAN	598	464	1224	-759
NC CLAY	4587	2854	582	2272
NC CLEVELAND	16950	9071	6531	2539
NC COLUMBUS	5608	4355	5010	-655
NC CRAVEN	3453	2682	5325	-2642
NC CUMBERLAND	5421	4210	11873	-7662
NC CURRITUCK	360	280	639	-358
NC DARE	24	19	565	-546
NC DAVIDSON	13424	7184	6983	200
NC DAVIE	11567	6190	1603	4586
NC DUPLIN	4927	3827	4088	-261
NC DURHAM	4181	3247	10643	-7396
NC EDGECOMBE	3851	2991	5293	-2302
NC FORSYTH	9575	7436	16514	-9078
NC FRANKLIN	5723	3063	3035	27
NC GASTON	10821	8404	11818	-3413
NC GATES	1108	861	946	-84
NC GRAHAM	1734	949	672	278
NC GRANVILLE	10034	5370	3247	2122
NC GREENE	1213	942	1754	-811
NC GUILFORD	16874	13105	21543	-8438
NC HALIFAX	5502	4273	5884	-1611
NC HARNETT	5118	3975	4804	-829
NC HAYWOOD	12497	6688	3866	2822
NC HENDERSON	9720	5202	3327	1874
NC HERTFORD	980	760	2207	1446
NC HOKE	1596	1240	1607	-367
NC HYDE	1492	798	620	178
NC IREDELL	27152	14531	5917	8614
NC JACKSON	7617	4235	1870	2364
NC JOHNSTON	7697	5977	6488	-510
NC JONES	1328	1031	1104	-73

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
NC LEE	2707	2102	2491	-388
NC LENOIR	3835	2978	5010	-2031
NC LINCOLN	13217	7073	2814	4259
NC MCDOWELL	3513	1880	2625	-745
NC MACON	7765	4706	1570	3136
NC MADISON	13642	8964	1918	7045
NC MARTIN	2039	1584	2770	-1186
NC MECKLENBURG	16165	12554	22981	-10426
NC MITCHELL	5952	3582	1467	2116
NC MONTGOMERY	2381	1274	1781	-507
NC MOORE	4528	2423	3479	-1055
NC NASH	4056	3150	6060	-2910
NC NEW HANOVER	799	620	6712	-6091
NC NORTHAMPTON	3320	2579	2784	-205
NC ONSLOW	2201	1709	5955	-4245
NC ORANGE	9937	5318	3820	1497
NC PAMLICO	1010	785	996	-212
NC PASQUOTANK	1961	1523	2498	-975
NC PENDER	3585	1918	1853	65
NC PERQUIMANS	1221	653	945	-291
NC PERSON	7537	4206	2532	1673
NC PITT	3130	2430	6665	-4234
NC POLK	3697	1979	1157	821
NC RANDOLPH	17549	9391	5555	3836
NC RICHMOND	2408	1870	3957	-2087
NC ROBESON	7812	6067	8867	-2800
NC ROCKINGHAM	9950	5325	6712	-1386
NC ROWAN	18319	9804	7885	1918
NC RUTHERFORD	9566	5119	4598	521
NC SAMPSON	7498	4013	4921	-908
NC SCOTLAND	1838	1428	2594	1166
NC STANLY	8767	4692	3886	805
NC STOKES	8586	5974	2194	3780
NC SURRY	13014	6965	4687	2277
NC SWAIN	1793	960	930	29
NC TRANSYLVANIA	3536	1892	1575	316
NC TYRRELL	752	402	484	-81
NC UNION	21337	11475	4331	7143
NC VANCE	5061	2708	3218	-509
NC WAKE	11208	8705	15088	6383

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
NC WARREN	9152	4966	2197	2769
NC WASHINGTON	1041	808	1336	-527
NC WATAUGA	11538	7252	1806	5445
NC WAYNE	5912	4591	7209	-2618
NC WILKES	14673	7852	4542	3310
NC WILSON	1789	1390	5608	-4218
NC YADKIN	12317	7257	2250	5006
NC YANCEY	8511	5470	1538	3931
ND ADAMS	5002	831	860	-29
ND BARNES	18394	3056	3068	-11
ND BENSON	16282	2705	1852	853
ND BILLINGS	2316	434	303	131
ND BOTTINEAU	14572	2421	2151	269
ND BOWMAN	3414	567	741	-174
ND BURKE	6268	1041	1151	-109
ND BURLEIGH	13146	2184	5332	-3147
ND CASS	19013	3159	11371	-8212
ND CAVALIER	16869	2802	2023	779
ND DICKEY	14233	2364	1589	775
ND DIVIDE	5347	888	1057	-168
ND DUNN	10800	1794	1249	544
ND EDDY	9102	1512	946	565
ND EMMONS	24612	4089	1676	2413
ND FOSTER	6647	1104	976	127
ND GOLDEN VALLE	2321	385	608	-222
ND GRAND FORKS	15671	2603	7914	-5310
ND GRANT	15926	2646	1230	1415
ND GRIGGS	9521	1581	962	619
ND HETTINGER	10766	1788	1234	553
ND KIDDER	13773	2288	1065	1223
ND LA MOURE	18434	3063	1671	1390
ND LOGAN	22819	3791	1083	2707
ND MCHENRY	21496	3571	2177	1393
ND MCINTOSH	21623	3592	1316	2276
ND MCKENZIE	5531	957	1284	-326
ND MCLEAN	20263	3366	3063	303
ND MERCER	13082	2173	1439	733
ND MORTON	24990	4151	3653	499
ND MOUNTRAIL	9892	1643	1770	-126
ND NELSON	13965	2320	1395	925

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
ND OLIVER	9015	1588	527	1060
ND PEMBINA	7859	1305	2472	-1166
ND PIERCE	15439	2565	1447	1117
ND RAMSEY	13798	2292	2551	-258
ND RANSOM	13464	2237	1558	678
ND RENVILLE	6446	1071	931	139
ND RICHLAND	21000	3488	3544	-55
ND ROLETTE	11165	1854	1990	-135
ND SARGENT	12835	2132	1331	800
ND SHERIDAN	15694	2652	888	1764
ND SIOUX	3602	598	672	-73
ND SLOPE	3052	514	390	124
ND STARK	15912	2643	3124	-480
ND STEELE	8239	1369	905	463
ND STUTSMAN	29222	4855	4484	370
ND TOWNER	7905	1313	1103	210
ND TRAILL	10812	1796	2012	-215
ND WALSH	14601	2425	3375	-948
ND WARD	20925	3476	7300	-3824
ND WELLS	18192	3022	1809	1213
ND WILLIAMS	7326	1217	3435	-2217
OH ADAMS	28750	10721	3024	7697
OH ALLEN	25202	9398	14131	4733
OH ASHLAND	33984	12672	5289	7383
OH ASHTABULA	64420	24022	12644	11377
OH ATHENS	24200	9024	6908	2116
OH AUGLAIZE	33443	12471	4917	7554
OH BELMONT	39212	14622	12836	1785
OH BROWN	32773	12221	3500	8720
OH BUTLER	30707	11450	25236	-13785
OH CARROLL	25370	9460	2954	6506
OH CHAMPAIGN	43446	16201	4179	12021
OH CLARK	26854	10014	17902	7887
OH CLERMONT	21911	8170	8719	-548
OH CLINTON	19763	7369	4093	3276
OH COLUMBIANA	39068	14568	15261	-692
OH COSHOCTON	26622	9927	4712	5215
OH CRAWFORD	25267	9422	6285	3136
OH CUYAHOGA	2865	2751	223554	-220802
OH DARKE	55034	20522	6474	14048

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
OH DEFIANCE	19765	7370	4219	3151
OH DELAWARE	36937	13774	4883	8890
OH ERIE	12031	4486	8816	-4329
OH FAIRFIELD	35365	13187	8519	4668
OH FAYETTE	12342	4602	3503	1098
OH FRANKLIN	25223	24226	86438	-62211
OH FULTON	28126	10488	4050	6438
OH GALLIA	25255	9418	3790	5627
OH GEAUGA	29076	10842	5298	5543
OH GREENE	22229	8289	11046	-2756
OH GUERNSEY	26269	9795	5741	4054
OH HAMILTON	10996	10562	116825	-106263
OH HANCOCK	28532	10639	7198	3441
OH HARDIN	23292	8685	4336	4349
OH HARRISON	15275	5696	2774	2921
OH HENRY	18673	6963	3530	3432
OH HIGHLAND	37210	13875	4299	9575
OH HOCKING	8028	2994	2951	42
OH HOLMES	47667	17775	2976	14798
OH HURON	25458	9493	6372	3120
OH JACKSON	12542	4677	4241	435
OH JEFFERSON	14523	13949	14559	-609
OH KNOX	37813	14100	5484	8615
OH LAKE	4390	4216	15937	-11720
OH LAWRENCE	13882	5176	7723	-2546
OH LICKING	50682	18899	11775	7123
OH LOGAN	37683	14052	4891	9160
OH LORAIN	38474	14346	26484	-12137
OH LUCAS	5222	5015	62867	-57851
OH MADISON	19360	7219	3588	3631
OH MAHONING	26969	25903	41128	-15225
OH MARION	15889	5925	8099	-2173
OH MEDINA	46015	17159	7604	9554
OH MEIGS	21500	8017	3395	4622
OH MERCER	46955	17509	4490	13019
OH MIAMI	23992	8946	9875	-929
OH MONROE	27803	10368	2284	8082
OH MONTGOMERY	21361	20517	67560	-47043
OH MORGAN	19043	7101	1908	5192
OH MORROW	28794	10737	2702	8035

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
OH MUSKINGUM	27356	10201	11406	-1205
OH NOBLE	19751	7365	1703	5661
OH OTTAWA	9289	3463	4765	-1301
OH PAULDING	10265	3827	2354	1473
OH PERRY	14605	5446	4252	1194
OH PICKAWAY	18478	6890	4789	2101
OH PIKE	9812	3658	2480	1178
OH PORTAGE	35094	13087	11300	1786
OH PREBLE	25802	9621	4381	5240
OH PUTNAM	30839	11500	3959	7540
OH RICHLAND	29899	11149	15290	-4141
OH ROSS	19801	7384	8545	-1161
OH SANDUSKY	24944	9301	7532	1768
OH SCIOTO	14723	5490	12445	-6955
OH SENECA	35215	13131	8301	4830
OH SHELBY	37469	13972	4570	9401
OH STARK	50458	18816	45846	-27030
OH SUMMIT	10870	10440	67697	-57257
OH TRUMBULL	41927	15634	26838	-11204
OH TUSCARAWAS	36238	13513	10894	2618
OH UNION	32317	12051	3222	8829
OH VAN WERT	16924	6311	4140	2170
OH VINTON	7270	2711	1573	1137
OH WARREN	25073	9350	7465	1884
OH WASHINGTON	31436	11722	7082	4640
OH WAYNE	79520	29653	9818	19834
OH WILLIAMS	28394	10588	4145	6443
OH WOOD	18955	7068	9710	-2642
OH WYANDOT	21400	7980	3068	4912
OK ADAIR	10681	4522	1704	2818
OK ALFALFA	7370	3120	1173	1946
OK ATOKA	5746	2500	1517	982
OK BEAVER	8108	3592	869	2722
OK BECKHAM	7236	3063	2407	656
OK BLAINE	10531	4458	1660	2798
OK BRYAN	10754	4553	3249	1303
OK CADDO	19032	8058	3883	4175
OK CANADIAN	14756	6248	3042	3205
OK CARTER	6228	2637	4523	-1886
OK CHEROKEE	10491	4442	2224	2217

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
OK CHOCTAW	5768	2442	2214	228
OK CIMARRON	1778	753	548	204
OK CLEVELAND	8137	3445	5306	-1861
OK COAL	3497	1481	842	638
OK COMANCHE	11839	5013	8468	-3455
OK COTTON	2611	1105	1116	-10
OK CRAIG	17069	7227	2099	5127
OK CREEK	6971	2951	5061	-2109
OK CUSTER	12880	5453	2537	2915
OK DELAWARE	13410	6102	1695	4406
OK DEWEY	10765	4882	918	3963
OK ELLIS	10290	4573	786	3786
OK GARFIELD	10071	4264	6370	-2106
OK GARVIN	9272	3925	3491	434
OK GRADY	20572	8710	3930	4780
OK GRANT	6890	2990	1141	1849
OK GREER	4055	1717	1268	448
OK HARMON	2575	1090	858	231
OK HARPER	4746	2009	718	1291
OK HASKELL	4420	1871	1389	482
OK HUGHES	5522	2338	2206	131
OK JACKSON	4766	2018	2913	-895
OK JEFFERSON	3528	1493	1189	304
OK JOHNSTON	5958	2522	1170	1352
OK KAY	10710	4534	5999	-1464
OK KINGFISHER	13158	5634	1435	4198
OK KIOWA	5453	2309	2069	239
OK LATIMER	2878	1219	1067	151
OK LE FLORE	8577	3631	3932	-301
OK LINCOLN	19734	8355	2492	5863
OK LOGAN	9322	3947	2490	1456
OK LOVE	3322	1456	834	621
OK MCCLAIN	10970	4645	1669	2975
OK MCCURTAIN	5549	2349	3511	-1161
OK MCINTOSH	9936	4206	1868	2338
OK MAJOR	11390	5132	1111	4021
OK MARSHALL	2663	1127	938	189
OK MAYES	17749	7515	2395	5120
OK MURRAY	7990	3383	1289	2093
OK MUSKOGEE	15865	6717	7708	-990

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
OK NOBLE	7678	3250	1373	1877
OK NOWATA	8743	3702	1436	2265
OK OKFUSKEE	6585	2788	1773	1014
OK OKLAHOMA	13946	12586	45032	-32445
OK OKMULGEE	6780	2870	4977	-2107
OK OSAGE	11365	4812	3951	860
OK OTTAWA	11980	5072	3679	1392
OK PAWNEE	8770	3713	1499	2214
OK PAYNE	15583	6598	5479	1118
OK PITTSBURG	7674	3249	4600	-1351
OK PONTOTOC	10294	4358	3576	782
OK POTTAWATOMIE	15400	6520	5137	1383
OK PUSHMATAHA	3414	1445	1296	149
OK ROGER MILLS	10457	4879	772	4106
OK ROGERS	15209	6439	2407	4031
OK SEMINOLE	7031	2977	4253	-1276
OK SEQUOYAH	5853	2478	2291	187
OK STEPHENS	7308	3094	4304	-1209
OK TEXAS	4615	1954	1710	243
OK TILLMAN	3262	1381	1968	-587
OK TULSA	17537	15828	35145	-19316
OK WAGONER	11571	4899	1961	2937
OK WASHINGTON	5636	2386	4445	-2058
OK WASHITA	14258	6037	2150	3887
OK WOODS	7039	2980	1616	1363
OK WOODWARD	11041	4675	1707	2966
OR BAKER	12455	4777	2217	2560
OR BENTON	11797	4525	4635	-110
OR CLACKAMAS	33303	12775	13043	-267
OR CLATSOP	9061	3476	3908	-432
OR COLUMBIA	15882	6092	3027	3065
OR COOS	35738	13709	6349	7360
OR CROOK	3544	1359	1222	136
OR CURRY	4955	1900	1254	646
OR DESCHUTES	9266	3554	2979	575
OR DOUGLAS	12901	4949	8054	-3105
OR GILLIAM	1016	390	389	0
OR GRANT	3029	1162	1075	86
OR HARNEY	2525	968	850	118
OR HOOD RIVER	4341	1665	1734	-68

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
OR JACKSON	26523	10175	8670	1504
OR JEFFERSON	3322	1274	827	447
OR JOSEPHINE	16953	6503	3727	2775
OR KLAMATH	9272	3556	5916	-2359
OR LAKE	2974	1141	914	226
OR LANE	26891	10315	18858	-8542
OR LINCOLN	7379	2830	3027	-196
OR LINN	30092	11544	7494	4049
OR MALHEUR	48010	18417	3068	15349
OR MARION	37113	14237	14612	-375
OR MORROW	3352	1286	642	643
OR MULTNOMAH	14153	13319	65723	-52404
OR POLK	15309	5873	3517	2355
OR SHERMAN	922	354	312	41
OR TILLAMOOK	47838	18351	2498	15852
OR UMATILLA	12816	4916	5706	-789
OR UNION	7606	2917	2404	512
OR WALLOWA	9444	3623	958	2664
OR WASCO	3895	1494	2335	-841
OR WASHINGTON	32769	12570	9916	2654
OR WHEELER	1408	540	407	132
OR YAMHILL	20629	7913	4403	3510
PA ADAMS	33865	22424	6584	15839
PA ALLEGHENY	15035	14493	216843	-202349
PA ARMSTRONG	27499	18208	11135	7073
PA BEAVER	17516	16884	26171	-9286
PA BEDFORD	54436	36044	5753	30291
PA BERKS	88810	58805	36630	22175
PA BLAIR	27472	18190	19217	-1026
PA BRADFORD	133082	88119	7362	80756
PA BUCKS	51952	34400	29722	4678
PA BUTLER	41861	27717	14519	13198
PA CAMBRIA	17424	16796	28694	-11898
PA CAMERON	671	647	1006	-360
PA CARBON	4213	4061	7707	-3646
PA CENTRE	41400	27412	9889	17523
PA CHESTER	110171	72949	25107	47842
PA CLARION	26121	17296	5263	12032
PA CLEARFIELD	19095	12643	11661	982
PA CLINTON	10230	6774	5130	1643

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
PA COLUMBIA	25293	16747	7416	9331
PA CRAWFORD	88878	58850	10891	47959
PA CUMBERLAND	56509	37417	14890	22526
PA DAUPHIN	29858	19770	28756	-8985
PA DELAWARE	5434	5238	65643	-60404
PA ELK	5993	3968	4951	-983
PA ERIE	67042	44391	32273	12117
PA FAYETTE	27120	17957	25126	-7169
PA FOREST	2377	1574	658	915
PA FRANKLIN	79741	52800	11252	41548
PA FULTON	19113	12655	1453	11202
PA GREENE	25692	17012	5944	11067
PA HUNTINGDON	29794	19727	5585	14141
PA INDIANA	40639	26909	10592	16317
PA JEFFERSON	24034	15913	6678	9235
PA JUNIATA	20385	13497	2151	11346
PA LACKAWANNA	31384	30252	34353	-4101
PA LANCASTER	172290	114081	35127	78953
PA LAWRENCE	32413	21462	15042	6419
PA LEBANON	44306	29337	11869	17467
PA LEHIGH	15908	15334	29219	-13886
PA LUZERNE	24944	24044	51734	-27690
PA LYCOMING	37292	24692	14521	10171
PA MCKEAN	13983	9258	7728	1530
PA MERCER	64040	42404	16445	25958
PA MIFFLIN	26845	17775	6098	11677
PA MONROE	7191	4761	5025	-263
PA MONTGOMERY	39832	38395	58614	-20219
PA MONTOUR	9849	6521	2262	4259
PA NORTHAMPTON	36721	24315	26647	-2331
PA NORTHUMBERLA	22295	14762	15478	-716
PA PERRY	23211	15369	3543	11825
PA PHILADELPHIA	715	689	283255	-282566
PA PIKE	3308	2190	1211	979
PA POTTER	26136	17306	2312	14993
PA SCHUYLKILL	18459	17794	26195	-8401
PA SNYDER	21221	14051	3355	10697
PA SOMERSET	68872	45603	11091	34512
PA SULLIVAN	11395	7545	905	6639
PA SUSQUEHANNA	100925	66827	4502	62324

State / County	Production	Amount available for fluid use	Consumption	Excess or deficit
PA TIOGA	75658	50097	4987	45109
PA UNION	18699	12381	3357	9024
PA VENANGO	17868	11831	9058	2772
PA WARREN	31473	20839	6092	14747
PA WASHINGTON	68310	45231	29526	15705
PA WAYNE	85194	56411	3935	52475
PA WESTMORELAND	63118	41793	45762	-3969
PA WYOMING	37156	24603	2327	22275
PA YORK	69363	45928	30217	15711
RI BRISTOL	4892	4770	5279	-508
RI KENT	4992	4868	15037	-10168
RI NEWPORT	16878	3706	11400	-7693
RI PROVIDENCE	19386	18907	92963	-74056
RI WASHINGTON	8867	1947	8609	-6662
SC ABBEVILLE	3853	2248	2209	39
SC AIKEN	4946	3907	6524	-2616
SC ALLENDALE	1004	794	1164	-370
SC ANDERSON	17428	10173	9433	740
SC BAMBERG	5082	2967	1706	1261
SC BARNWELL	1642	1297	1749	-452
SC BEAUFORT	2707	2139	3443	-1303
SC BERKELEY	3459	2733	3375	-641
SC CALHOUN	2108	1230	1374	-143
SC CHARLESTON	1960	1549	18745	-17195
SC CHEROKEE	5481	3200	3521	-321
SC CHESTER	10935	6383	3199	3184
SC CHESTERFIELD	4192	3312	3529	-217
SC CLARENDON	4838	2824	3117	-292
SC COLLETON	3776	2204	2816	-612
SC DARLINGTON	3359	2653	5144	-2490
SC DILLON	2459	1943	3090	-1146
SC DORCHESTER	4880	2848	2345	503
SC EDGEFIELD	4989	2912	1628	1283
SC FAIRFIELD	5697	3326	2141	1185
SC FLORENCE	7492	5920	8202	-2282
SC GEORGETOWN	1865	1474	3317	-1843
SC GREENVILLE	11302	8930	18653	-9724
SC GREENWOOD	4907	3878	4294	-416
SC HAMPTON	1806	1427	1783	-356
SC HORRY	4162	3289	6364	-3075

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
SC JASPER	1527	892	1156	-264
SC KERSHAW	3745	2959	3296	-336
SC LANCASTER	4525	3575	3818	-243
SC LAURENS	7964	4648	4742	-93
SC LEE	2454	1939	2268	-329
SC LEXINGTON	4662	3683	5146	-1463
SC MCCORMICK	1863	1087	921	167
SC MARION	2205	1742	3276	-1533
SC MARLBORO	2603	2057	3050	-993
SC NEWBERRY	10957	6396	3088	3307
SC OCONEE	8774	5122	3968	1153
SC ORANGEBURG	15784	9214	6891	2322
SC PICKENS	6540	3817	4276	-458
SC RICHLAND	5959	4708	16764	-12055
SC SALUDA	8189	4780	1540	3240
SC SPARTANBURG	12546	9912	15368	-5455
SC SUMTER	6458	5102	6522	-1419
SC UNION	3735	2951	3088	-137
SC WILLIAMSBURG	7497	4376	4274	102
SC YORK	10621	6200	7492	-1291
SD AURORA	6170	1662	895	767
SD BEADLE	11483	3094	3894	-800
SD BENNETT	2385	642	592	49
SD BON HOMME	12250	3301	1706	1594
SD BROOKINGS	18028	4857	3428	1429
SD BROWN	14551	3921	6068	-2146
SD BRULE	2962	798	1127	-329
SD BUFFALO	1024	275	289	-14
SD BUTTE	4797	1292	1523	-230
SD CAMPBELL	8920	2403	698	1704
SD CHARLES MIX	9414	2536	2546	-9
SD CLARK	11201	3018	1431	1586
SD CLAY	6375	1717	1991	-273
SD CODINGTON	13345	3595	3556	39
SD CORSON	6791	1829	1097	732
SD CUSTER	1934	521	959	-438
SD DAVISON	6918	1863	3027	-1163
SD DAY	20815	5609	2105	3503
SD DEUEL	15142	4080	1332	2747
SD DEWEY	2830	762	929	-166

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
SD DOUGLAS	11257	3033	988	2044
SD EDMUNDS	15272	4115	1234	2880
SD FALL RIVER	2273	612	1925	-1312
SD FAULK	5019	1352	839	513
SD GRANT	17487	4712	1842	2869
SD GREGORY	9527	2567	1471	1096
SD HAAKON	2356	634	588	46
SD HAMLIN	9884	2663	1229	1433
SD HAND	7922	2134	1270	863
SD HANSON	8131	2191	869	1321
SD HARDING	2028	546	423	123
SD HUGHES	2020	544	1839	-1294
SD HUTCHINSON	21999	5927	2058	3868
SD HYDE	2918	786	497	289
SD JACKSON	1217	327	291	36
SD JERAULD	4832	1302	783	518
SD JONES	1522	410	400	9
SD KINGSBURY	8674	2337	1761	575
SD LAKE	11447	3084	2150	934
SD LAWRENCE	3142	2903	3071	-166
SD LINCOLN	14429	3887	2299	1588
SD LYMAN	2651	714	823	-109
SD MCCOOK	12083	3255	1566	1688
SD MCPHERSON	22653	6103	1193	4910
SD MARSHALL	11829	3187	1339	1848
SD MEADE	7267	1958	2141	-183
SD MELLETTE	2383	642	525	116
SD MINER	6595	1777	1076	700
SD MINNEHAHA	26903	7249	14156	6906
SD MOODY	10584	2852	1654	1197
SD PENNINGTON	5407	4996	8087	-3091
SD PERKINS	3988	1074	1173	-99
SD POTTER	3800	1024	873	150
SD ROBERTS	22867	6161	2589	3572
SD SANBORN	3750	1010	899	110
SD SHANNON	717	662	1060	-398
SD SPINK	8310	2239	2189	50
SD STANLEY	741	200	532	-333
SD SULLY	2042	550	487	63
SD TODD	3531	951	861	90

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
SD TRIPP	8822	2377	1638	738
SD TURNER	18234	4913	2134	2778
SD UNION	9984	2690	1923	766
SD WALWORTH	6043	1628	1430	197
SD WASHABAUGH	1016	273	291	-18
SD YANKTON	10622	2862	3124	-262
SD ZIEBACH	1670	449	466	-16
TN ANDERSON	4542	3942	7187	-3244
TN BEDFORD	27438	9603	2821	6781
TN BENTON	2748	967	1341	-374
TN BLEDSOE	3988	1395	993	402
TN BLOUNT	13253	4638	6732	-2094
TN BRADLEY	11767	4118	4200	-82
TN CAMPBELL	4173	3622	3810	-187
TN CANNON	11044	4412	1071	3340
TN CARROLL	9883	3458	3041	417
TN CARTER	6206	2476	5067	-2591
TN CHEATHAM	3109	1088	1117	-29
TN CHESTER	4015	1473	1262	211
TN CLAIBORNE	10923	4005	2692	1312
TN CLAY	4052	1596	975	620
TN COCKE	12217	4275	2789	1486
TN COFFEE	13762	4816	3060	1756
TN CROCKETT	5515	1930	1898	31
TN CUMBERLAND	5097	1784	2286	-502
TN DAVIDSON	17269	14991	42747	-27756
TN DECATUR	3005	1063	1080	-16
TN DE KALB	10796	4043	1360	2682
TN DICKSON	6190	2166	2266	-100
TN DYER	5282	1848	3829	-1981
TN FAYETTE	11893	4162	3165	997
TN FENTRESS	5463	1912	1713	198
TN FRANKLIN	14131	4946	3067	1878
TN GIBSON	14365	5027	5621	-593
TN GILES	34152	12476	3014	9462
TN GRAINGER	10329	4317	1546	2770
TN GREENE	46321	17238	5000	12237
TN GRUNDY	1622	1408	1459	-50
TN HAMBLEN	11734	4106	3354	752
TN HAMILTON	8346	7244	26601	-19356

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TN HANCOCK	6287	2945	1029	1916
TN HARDEMAN	8692	3042	2716	326
TN HARDIN	4539	1759	2062	-302
TN HAWKINS	17167	6008	3672	2336
TN HAYWOOD	7935	2777	3012	-235
TN HENDERSON	6775	2521	2014	507
TN HENRY	10698	3744	2790	954
TN HICKMAN	4782	1673	1531	141
TN HOUSTON	1483	519	613	-94
TN HUMPHREYS	3470	1214	1352	-138
TN JACKSON	8871	3896	1327	2568
TN JEFFERSON	17165	6007	2462	3545
TN JOHNSON	7398	3185	1401	1783
TN KNOX	19574	16990	28269	-11278
TN LAKE	444	385	1297	-911
TN LAUDERDALE	4147	1588	2852	-1264
TN LAWRENCE	13506	4761	3431	1329
TN LEWIS	1904	666	741	-75
TN LINCOLN	38696	13977	2994	10983
TN LOUDON	10066	3522	2821	701
TN MCMINN	21411	7493	3941	3552
TN MCNAIRY	6331	2734	2338	395
TN MACON	11460	4843	1566	3276
TN MADISON	8809	3082	7269	-4185
TN MARION	3012	1053	2498	-1443
TN MARSHALL	25693	8992	2093	6898
TN MAURY	27957	9784	4930	4853
TN MEIGS	4789	1685	684	1000
TN MONROE	17088	5980	2891	3088
TN MONTGOMERY	6999	2449	5909	-3459
TN MOORE	6198	2492	450	2041
TN MORGAN	2892	1012	1820	-808
TN OBION	11153	3903	3392	510
TN OVERTON	8336	3370	1967	1402
TN PERRY	1917	651	717	-66
TN PICKETT	3164	1346	580	767
TN POLK	3379	1182	1597	-414
TN PUTNAM	11197	3918	3565	353
TN RHEA	4466	1563	1922	-359
TN ROANE	5562	1946	4195	-2248

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TN ROBERTSON	14140	4948	3270	1678
TN RUTHERFORD	38845	13595	5499	8095
TN SCOTT	2136	1854	1991	-137
TN SEQUATCHIE	2912	1019	697	322
TN SEVIER	11307	3957	2860	1097
TN SHELBY	12905	11202	65507	-54304
TN SMITH	17464	7031	1593	5438
TN STEWART	2517	895	1037	-141
TN SULLIVAN	16727	5854	12426	-6572
TN SUMNER	22590	7906	4176	3730
TN TIPTON	6750	2362	3524	-1161
TN TROUSDALE	5359	1989	633	1355
TN UNICOI	1973	1712	1872	-159
TN UNION	4978	2106	1035	1071
TN VAN BUREN	2713	959	463	495
TN WARREN	14121	4942	2724	2217
TN WASHINGTON	21799	7629	7472	157
TN WAYNE	5312	1893	1570	322
TN WEAKLEY	20725	7253	3177	4076
TN WHITE	12460	4360	1919	2441
TN WILLIAMSON	28299	9904	2976	6927
TN WILSON	28388	9935	3239	6695
TX ANDERSON	8517	5817	3206	2610
TX ANDREWS	187	167	909	-742
TX ANGELINA	5455	3726	3983	-257
TX ARANSAS	299	268	574	-306
TX ARCHER	3534	2414	689	1724
TX ARMSTRONG	1025	740	223	517
TX ATASCOSA	7346	5018	2067	2951
TX AUSTIN	8753	6253	1512	4741
TX BAILEY	2224	1519	871	648
TX BANDERA	1409	963	443	520
TX BASTROP	4119	2813	1955	858
TX BAYLOR	1530	1045	683	361
TX BEE	2867	1958	2175	-216
TX BELL	9435	8445	8726	-280
TX BEXAR	22700	20319	61372	-41052
TX BLANCO	1986	1439	394	1044
TX BORDEN	629	471	116	355
TX BOSQUE	5875	4043	1206	2836

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TX BOWIE	10530	7193	6469	723
TX BRAZORIA	7092	4843	6261	-1417
TX BRAZOS	9027	6165	4355	1810
TX BREWSTER	248	222	734	-512
TX BRISCOE	1482	1013	375	637
TX BROOKS	1773	1211	947	263
TX BROWN	6011	4106	2853	1253
TX BURLESON	5178	3537	1294	2243
TX BURNET	2656	1814	1047	767
TX CALDWELL	2787	1903	1952	-48
TX CALHOUN	448	401	1308	-906
TX CALLAHAN	4445	3036	909	2126
TX CAMERON	6682	5980	14415	-8434
TX CAMP	4163	2843	885	1958
TX CARSON	717	642	766	-124
TX CASS	5831	3983	2684	1298
TX CASTRO	3782	2583	731	1852
TX CHAMBERS	521	467	946	-479
TX CHEROKEE	10139	6926	3845	3080
TX CHILDRESS	1972	1347	1117	230
TX CLAY	4605	3145	978	2167
TX COCHRAN	1105	755	648	106
TX COKE	1086	742	407	334
TX COLEMAN	4428	3024	1503	1521
TX COLLIN	11938	8155	4392	3762
TX COLLINGSWORT	2493	1702	839	863
TX COLORADO	6445	4402	1900	2502
TX COMAL	3044	2079	1888	190
TX COMANCHE	10704	7718	1478	6240
TX CONCHO	1622	1108	474	633
TX COOKE	13643	9318	2362	6956
TX CORYELL	4448	3039	2069	969
TX COTTLE	1113	760	560	200
TX CRANE	10	9	452	-443
TX CROCKETT	544	371	432	-60
TX CROSBY	2139	1461	1048	413
TX CULBERSON	180	161	237	-75
TX DALLAM	976	666	748	-81
TX DALLAS	11813	10573	80224	-69650
TX DAWSON	2068	1851	2026	-175

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TX DEAF SMITH	2360	1612	1147	464
TX DELTA	3668	2505	809	1696
TX DENTON	17418	11897	4651	7246
TX DE WITT	10351	7071	2328	4741
TX DICKENS	2107	1439	659	779
TX DIMMIT	598	536	1102	-566
TX DONLEY	2823	1928	578	1350
TX DUVAL	6304	4306	1554	2751
TX EASTLAND	5688	3885	2335	1550
TX ECTOR	117	105	6656	-6551
TX EDWARDS	760	519	281	238
TX ELLIS	7209	4924	4730	193
TX EL PASO	10171	9104	25995	-16890
TX ERATH	16282	11121	1852	9269
TX FALLS	6530	4460	2583	1877
TX FANNIN	10083	6887	2976	3910
TX FAYETTE	26239	19062	2388	16673
TX FISHER	4034	2755	1024	1730
TX FLOYD	2904	1984	1197	786
TX FOARD	630	430	397	33
TX FORT BEND	6051	4133	3713	419
TX FRANKLIN	4938	3475	610	2864
TX FREESTONE	3317	2266	1518	747
TX FRIO	1207	1080	1085	-4
TX GAINES	1430	976	1094	-117
TX GALVESTON	7170	6417	13196	-6778
TX GARZA	1113	760	679	81
TX GILLESPIE	4746	3392	1092	2300
TX GLASSCOCK	615	420	116	303
TX GOLIAD	1575	1075	622	453
TX GONZALES	5394	3684	2091	1593
TX GRAY	1585	1418	2923	-1505
TX GRAYSON	12090	8258	7575	682
TX GREGG	2212	1980	6851	-4871
TX GRIMES	8406	5741	1492	4249
TX GUADALUPE	8083	5521	2850	2670
TX HALE	5569	3804	3372	432
TX HALL	1732	1183	994	189
TX HAMILTON	4620	3438	1031	2407
TX HANSFORD	471	421	535	-113

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TX HARDEMAN	2374	1621	993	628
TX HARDIN	1960	1755	2297	-541
TX HARRIS	39146	35039	105024	-69984
TX HARRISON	9403	6422	4957	1465
TX HARTLEY	554	378	214	164
TX HASKELL	2653	1812	1339	473
TX HAYS	4367	2983	1982	1000
TX HEMPHILL	1614	1102	394	708
TX HENDERSON	4692	3204	2404	800
TX HIDALGO	10753	9625	17903	-8278
TX HILL	8068	5511	2968	2542
TX HOCKLEY	3171	2166	2247	-80
TX HOOD	2739	2015	566	1449
TX HOPKINS	30513	20842	2266	18575
TX HOUSTON	6126	4184	2261	1923
TX HOWARD	1784	1596	3432	-1835
TX HUDSPETH	244	219	412	-193
TX HUNT	7841	5356	4373	983
TX HUTCHINSON	643	575	3470	-2895
TX IRION	518	354	150	204
TX JACK	1755	1198	805	393
TX JACKSON	2758	1884	1418	465
TX JASPER	9199	6283	2214	4069
TX JEFF DAVIS	398	271	199	72
TX JEFFERSON	2860	2560	22924	-20364
TX JIM HOGG	1039	709	554	155
TX JIM WELLS	10442	7132	3258	3874
TX JOHNSON	21294	14545	3472	11073
TX JONES	3362	2296	2215	80
TX KARNES	7309	4992	1717	3275
TX KAUFMAN	4750	3244	3243	0
TX KENDALL	2460	1680	595	1085
TX KENEDY	188	128	78	50
TX KENT	902	658	214	443
TX KERR	2622	1791	1609	181
TX KIMBLE	923	630	458	172
TX KING	217	148	82	66
TX KINNEY	302	270	272	-1
TX KLEBERG	2282	2043	2690	-647
TX KNOX	1442	985	967	17

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TX LAMAR	8583	5863	4159	1703
TX LAMB	3692	2521	2203	318
TX LAMPASAS	2996	2046	1027	1019
TX LA SALLE	867	592	724	-131
TX LAVACA	17658	13027	2256	10770
TX LEE	7847	5723	1019	4703
TX LEON	3093	2112	1179	933
TX LIBERTY	2741	2453	3048	-594
TX LIMESTONE	5163	3526	2454	1071
TX LIPSCOMB	1797	1227	375	852
TX LIVE OAK	2263	1546	903	642
TX LLANO	991	677	563	114
TX LOVING	11	10	24	-13
TX LUBBOCK	4498	4026	13180	-9153
TX LYNN	2304	1574	1162	411
TX MCCULLOCH	2921	1995	1108	887
TX MCLENNAN	21289	14541	14676	-134
TX MCMULLEN	306	209	122	86
TX MADISON	4280	2923	790	2133
TX MARION	896	802	981	-179
TX MARTIN	1161	793	565	227
TX MASON	1913	1391	471	920
TX MATAGORDA	2051	1835	2470	-634
TX MAVERICK	591	529	1400	-871
TX MEDINA	4069	2780	1886	893
TX MENARD	780	533	387	145
TX MIDLAND	847	758	4615	-3857
TX MILAM	6129	4186	2436	1750
TX MILLS	2738	2135	565	1569
TX MITCHELL	2348	1604	1380	224
TX MONTAGUE	4348	2970	1708	1261
TX MONTGOMERY	6658	4547	2698	1848
TX MOORE	439	392	1477	-1084
TX MORRIS	1323	903	1140	-236
TX MOTLEY	1093	746	370	376
TX NACOGDOCHES	20392	13929	3107	10821
TX NAVARRO	4523	3090	3977	-887
TX NEWTON	3265	2230	1125	1104
TX NOLAN	2646	1807	2058	-251
TX NUECES	2581	2310	20038	-17727

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TX OCHILTREE	1040	711	788	-77
TX OLDHAM	351	240	188	52
TX ORANGE	2228	1994	5184	-3190
TX PALO PINTO	2289	1563	1967	-404
TX PANOLA	7309	4992	1930	3062
TX PARKER	20372	13915	2340	11575
TX PARMER	2528	1727	783	944
TX PECOS	409	366	1142	-776
TX POLK	3455	2360	1609	750
TX POTTER	868	777	9664	-8887
TX PRESIDIO	380	341	693	-352
TX RAINS	2459	1841	394	1447
TX RANDALL	5500	3756	2363	1393
TX REAGAN	212	190	360	-170
TX REAL	609	415	244	171
TX RED RIVER	5986	4088	2035	2053
TX REEVES	336	301	1508	-1207
TX REFUGIO	496	444	1108	-664
TX ROBERTS	358	244	110	134
TX ROBERTSON	3690	2520	1938	582
TX ROCKWALL	389	348	639	-291
TX RUNNELS	6147	4199	1696	2503
TX RUSK	8448	5770	4215	1555
TX SABINE	2426	1657	849	807
TX SAN AUGUSTIN	2559	1748	885	863
TX SAN JACINTO	2637	1801	712	1088
TX SAN PATRICIO	1627	1456	4206	-2749
TX SAN SABA	2379	1625	814	809
TX SCHLEICHER	702	479	299	180
TX SCURRY	3066	2094	2302	-208
TX SHACKELFORD	887	606	483	122
TX SHELBY	10394	7100	2350	4750
TX SHERMAN	289	258	265	-6
TX SMITH	10404	7107	8430	-1323
TX SOMERVELL	799	568	270	297
TX STARR	1200	1074	1619	-545
TX STEPHENS	1664	1137	1044	92
TX STERLING	294	200	131	69
TX STONEWALL	1076	737	360	377
TX SUTTON	481	328	395	-67

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
TX SWISHER	3358	2294	979	1315
TX TARRANT	26913	24089	46212	-22122
TX TAYLOR	4236	3791	8404	-4612
TX TERRELL	183	164	311	-146
TX TERRY	2187	1493	1530	-36
TX THROCKMORTON	904	618	344	273
TX TITUS	6899	4712	1808	2904
TX TOM GREEN	5414	4846	6494	-1647
TX TRAVIS	14183	12695	19341	-6645
TX TRINITY	1714	1170	950	220
TX TYLER	2267	1548	1166	381
TX UPSHUR	7224	4934	2157	2777
TX UPTON	88	79	603	-524
TX UVALDE	2018	1378	1731	-352
TX VAL VERDE	1153	1032	2113	-1081
TX VAN ZANDT	8872	6063	2234	3829
TX VICTORIA	3986	3568	3991	-423
TX WALKER	4670	3190	2193	996
TX WALLER	3935	2687	1270	1417
TX WARD	396	354	1483	-1128
TX WASHINGTON	14076	9666	2111	7555
TX WEBB	2542	2275	6331	-4056
TX WHARTON	7258	4957	3912	1045
TX WHEELER	3437	2347	985	1361
TX WICHITA	4004	3585	11551	-7966
TX WILBARGER	2727	1863	2049	-186
TX WILLACY	1437	1286	2176	-890
TX WILLIAMSON	12717	8687	3941	4745
TX WILSON	10711	7316	1488	5827
TX WINKLER	127	114	1226	-1112
TX WISE	20721	14153	1747	12405
TX WOOD	11024	7530	2091	5439
TX YOAKUM	795	543	624	-81
TX YOUNG	2537	1733	1799	-66
TX ZAPATA	459	410	465	-54
TX ZAVALA	1413	965	1253	-287
UT BEAVER	8915	2331	507	1824
UT BOX ELDER1	501	131	48	82
UT BOX ELDER2	24807	6487	2360	4127
UT CACHE	45267	11839	3777	8062

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
UT CARBON	1670	1597	2551	-954
UT DAGGETT	413	108	77	31
UT DAVIS	12127	3171	4956	-1785
UT DUCHESNE	18921	4948	845	4102
UT EMERY	5311	1389	654	734
UT GARFIELD	3278	857	427	429
UT GRAND	250	239	414	-175
UT IRON1	181	47	66	-18
UT IRON2	617	161	222	-61
UT IRON3	2272	594	820	-226
UT JUAB	1827	478	590	-112
UT KANE1	592	155	165	-10
UT KANE2	307	80	102	-22
UT MILLARD	9767	2554	956	1597
UT MORGAN	4719	1234	290	943
UT PIUTE	3923	1026	187	839
UT RICH	3168	846	183	662
UT SALT LAKE	17314	16555	35134	-18579
UT SAN JUAN	1259	329	755	-425
UT SANPETE	15176	3969	1389	2580
UT SEVIER	10548	2758	1251	1507
UT SUMMIT	14832	3879	688	3190
UT TOOELE1	626	163	358	-195
UT TOOELE2	2441	638	1394	-756
UT UINTAH	9912	2592	1187	1404
UT UTAH	28555	7468	10136	-2668
UT WASATCH	8859	2317	598	1718
UT WASHINGTON1	589	154	97	57
UT WASHINGTON2	3795	992	624	368
UT WASHINGTON3	2281	596	375	221
UT WAYNE	3212	907	219	688
UT WEBER	21482	5618	10400	-4781
VT ADDISON	87665	73644	3201	70443
VT BENNINGTON	19651	16508	3983	12525
VT CALEDONIA	54293	45610	3819	41790
VT CHITTENDEN	73036	61355	10980	50374
VT ESSEX	11069	9298	1004	8294
VT FRANKLIN	113115	95024	4826	90198
VT GRAND ISLE	15028	12624	520	12104
VT LAMOILLE	35499	29821	1824	27996

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
VT ORANGE	51444	43217	2696	40521
VT ORLEANS	88617	74444	3370	71074
VT RUTLAND	62138	52200	7512	44688
VT WASHINGTON	47695	40067	6962	33104
VT WINDHAM	23556	19789	4740	15048
VT WINDSOR	48503	40746	6751	33994
VA ACCOMACK	1844	1583	3725	-2141
VA ALBEMARLE	11611	7312	6414	898
VA ALLEGHANY	2893	2483	3295	-811
VA AMELIA	10283	6518	902	5615
VA AMHERST	6273	3951	2459	1491
VA APPOMATTOX	6770	4264	1024	3240
VA ARLINGTON	73	63	17891	-17828
VA AUGUSTA	25155	15843	8051	7791
VA BATH	2037	1283	675	607
VA BEDFORD	32648	20562	3454	17107
VA BLAND	7438	4844	716	4128
VA BOTETOURT	10763	6779	1854	4924
VA BRUNSWICK	8878	5591	2194	3397
VA BUCHANAN	6334	3989	4147	-158
VA BUCKINGHAM	5682	3579	1341	2238
VA CAMPBELL	12410	7816	9341	-1524
VA CAROLINE	4218	2657	1442	1214
VA CARROLL	30786	20902	3031	17871
VA CHARLES CITY	805	507	576	-68
VA CHARLOTTE	9593	6165	1579	4586
VA CHESTERFIELD	3171	2722	32913	-30191
VA CLARKE	4551	2866	853	2012
VA CRAIG	3045	2009	391	1618
VA CULPEPER	20517	12922	1608	11313
VA CUMBERLAND	5880	3740	788	2952
VA DICKENSON	4522	2848	2528	319
VA DINWIDDIE	6299	5407	10258	-4851
VA ESSEX	2155	1357	756	600
VA FAIRFAX	12219	10489	28416	-17927
VA FAUQUIER	23591	14858	2574	12283
VA FLOYD	23046	15920	1258	14662
VA FLUVANNA	3918	2468	821	1646
VA FRANKLIN	21992	14250	2882	11367
VA FREDERICK	7855	4947	3875	1072

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
VA GILES	4783	3012	2089	923
VA GLOUCESTER	1216	1044	1263	-219
VA GOOCHLAND	4950	3117	1038	2079
VA GRAYSON	23863	15837	2372	13464
VA GREENE	4316	2894	542	2351
VA GREENSVILLE	2282	1438	1863	-425
VA HALIFAX	14092	8875	4664	4210
VA HANOVER	7038	4433	2792	1640
VA HENRICO	6375	5473	9501	-4028
VA HENRY	4390	3768	6079	-2311
VA HIGHLAND	3390	2401	425	1975
VA ISLE OF WIGH	3319	2090	1819	270
VA JAMES CITY	1996	1713	1741	-27
VA KING AND QUE	3054	1923	702	1220
VA KING GEORGE	1800	1134	795	338
VA KING WILLIAM	3973	2502	868	1633
VA LANCASTER	907	779	1016	-237
VA LEE	12110	7627	3639	3988
VA LOUDOUN	34957	22017	2590	19426
VA LOUISA	7207	4539	1477	3062
VA LUNENBURG	6230	3923	1541	2382
VA MADISON	10868	7160	944	6215
VA MATHEWS	703	604	818	-214
VA MECKLENBURG	11887	7486	3740	3746
VA MIDDLESEX	2035	1282	750	531
VA MONTGOMERY	14787	9313	4620	4692
VA NELSON	5617	3538	1547	1990
VA NEW KENT	936	589	481	107
VA NORTHAMPTON	756	648	1968	-1319
VA NORTHUMBERLA	1826	1150	1156	-6
VA NOTTOWAY	7859	4950	1758	3191
VA ORANGE	8107	5106	1469	3636
VA PAGE	6354	4001	1758	2243
VA PATRICK	10568	7428	1776	5651
VA PITTSYLVANIA	17422	10972	11783	-810
VA POWHATAN	5997	3777	695	3082
VA PRINCE EDWAR	8337	5251	1703	3547
VA PRINCE GEORG	2778	1750	2284	-534
VA PRINCE WILLI	11810	7439	3936	3502
VA PULASKI	8343	5255	3159	2095

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
VA RAPPAHANNOCK	4596	2895	664	2230
VA RICHMOND	2691	1695	718	976
VA ROANOKE	7314	6278	16539	-10260
VA ROCKBRIDGE	12280	7734	3363	4370
VA ROCKINGHAM	30028	18912	5580	13331
VA RUSSELL	17824	11226	3050	8175
VA SCOTT	15727	10333	3080	7253
VA SHENANDOAH	13885	8745	2459	6285
VA SMYTH	14452	9102	3505	5597
VA SOUTHAMPTON	5059	3186	3075	111
VA SPOTSYLVANIA	9093	5727	2926	2800
VA STAFFORD	3173	1999	1607	390
VA SURRY	1416	892	713	178
VA SUSSEX	2198	1384	1448	-63
VA TAZEWELL	10835	6824	5316	1507
VA WARREN	3108	1957	1690	267
VA WASHINGTON	32002	20156	6219	13936
VA WESTMORELAND	2713	1708	1207	501
VA WISE	4594	3943	6082	-2139
VA WYTHE	18525	11668	2609	9058
VA YORK	1255	1078	1799	-721
VA NORFOLK/CHES	5087	4367	48744	-44377
VA HAMPTON	0	0	8292	-8292
VA NEWPORT NEWS	0	0	10873	-10873
VA SUFFOLK/NANS	3123	2681	4603	-1921
VA VIRGINIA BEA	5665	4863	6772	-1909
WA ADAMS	1394	565	1168	-603
WA ASOTIN	2355	955	1714	-758
WA BENTON	11474	4657	8165	-3507
WA CHELAN	3461	3266	5827	-2561
WA CLALLAM	22784	9247	4078	5168
WA CLARK	47446	19256	12982	6274
WA COLUMBIA	1574	639	691	-52
WA COWLITZ	17218	6988	8067	-1078
WA DOUGLAS	1928	1819	1832	-12
WA FERRY	2750	1116	585	531
WA FRANKLIN	1719	1622	2587	-964
WA GARFIELD	2241	909	453	456
WA GRANT	6164	2501	4927	-2425
WA GRAYS HARBOR	23009	9338	7882	1455

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
WA ISLAND	7526	3054	2148	906
WA JEFFERSON	5746	2332	1573	758
WA KING	70193	66237	119552	-53316
WA KITSAP	7074	6675	11580	-4904
WA KITTITAS	19383	7866	3136	4730
WA KLICKITAT	6878	2791	1846	945
WA LEWIS	35845		14548	62718277
WA LINCOLN	5478	2223	1598	624
WA MASON	4438	1801	2269	-468
WA OKANOGAN	10225	4150	4029	121
WA PACIFIC	7153	2903	2299	603
WA PEND OREILLE	5367	2178	1051	1126
WA PIERCE	32314	30493	43114	-12620
WA SAN JUAN	2898	1176	450	726
WA SKAGIT	53635	21768	6818	14949
WA SKAMANIA	1621	658	725	-67
WA SNOHOMISH	72731	29518	20052	9466
WA SPOKANE	38339	15560	35870	-20310
WA STEVENS	30411	12342	2669	9673
WA THURSTON	21700	8807	7183	1623
WA WAHKIAKUM	12719	5162	534	4628
WA WALLA WALLA	8910	3616	5987	-2370
WA WHATCOM	109702	44523	9965	34557
WA WHITMAN	11357	4609	4665	-56
WA YAKIMA	53364	21658	20399	1258
WV BARBOUR	8363	5063	1800	3263
WV BERKELEY	12520	7278	3193	4084
WV BOONE	910	748	3141	-2393
WV BRAXTON	8704	5785	1690	4094
WV BROOKE	1792	1473	2787	-1314
WV CABELL	4887	4017	10851	-6834
WV CALHOUN	5274	3690	931	2758
WV CLAY	2695	1566	1373	193
WV DODDRIDGE	5024	3243	818	2424
WV FAYETTE	4479	3682	7391	-3709
WV GILMER	5068	3420	906	2514
WV GRANT	3539	2117	859	1258
WV GREENBRIER	14144	8222	3737	4485
WV HAMPSHIRE	5060	3030	1225	1805
WV HANCOCK	1083	890	3674	-2783

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
WV HARDY	5158	3216	976	2240
WV HARRISON	11121	6465	8244	-1779
WV JACKSON	13468	8356	1673	6682
WV JEFFERSON	14346	8340	1788	6551
WV KANAWHA	5598	4601	24620	-20019
WV LEWIS	8691	5052	2057	2995
WV LINCOLN	3546	2061	2160	-99
WV LOGAN	1230	1011	7093	-6082
WV MCDOWELL	1733	1424	8751	-7327
WV MARION	5449	4478	6846	-2367
WV MARSHALL	13822	8035	3751	4283
WV MASON	15801	9185	2401	6784
WV MERCER	9098	5289	7239	-1949
WV MINERAL	3878	2254	2242	11
WV MINGO	1580	1299	4431	-3131
WV MONONGALIA	6973	5731	5881	-150
WV MONROE	11954	8034	1251	6782
WV MORGAN	1946	1131	834	296
WV NICHOLAS	6093	3542	2682	858
WV OHIO	5984	4918	7056	-2137
WV PENDLETON	7079	4891	882	4008
WV PLEASANTS	1879	1092	671	421
WV POCAHONTAS	5803	3609	1152	2456
WV PRESTON	13780	8011	2974	5036
WV PUTNAM	6729	3912	2218	1693
WV RALEIGH	5179	4256	8877	-4619
WV RANDOLPH	7908	4597	2887	1709
WV RITCHIE	6278	4009	1187	2822
WV ROANE	6834	4573	1732	2840
WV SUMMERS	6780	3959	1774	2185
WV TAYLOR	4117	2394	1703	690
WV TUCKER	3489	2028	942	1085
WV TYLER	5087	2957	1035	1921
WV UPSHUR	8457	5154	1890	3263
WV WAYNE	6302	3663	3896	-232
WV WEBSTER	2855	1659	1617	42
WV WETZEL	6497	3776	1988	1788
WV WIRT	4196	2758	482	2275
WV WOOD	11219	6521	7181	-659
WV WYOMING	2468	2029	3652	-1624

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
WI ADAMS	20224	3723	1218	2505
WI ASHLAND	24275	4468	2915	1553
WI BARRON	177554	32686	5417	27269
WI BAYFIELD	35838	6597	2036	4560
WI BROWN	142927	26312	17216	9095
WI BUFFALO	84172	15495	2275	13219
WI BURNETT	34408	6334	1538	4795
WI CALUMET	94289	17358	3185	14172
WI CHIPPEWA	165995	30558	6873	23684
WI CLARK	231933	43256	5032	38224
WI COLUMBIA	95445	17570	5519	12051
WI CRAWFORD	80399	14800	2683	12117
WI DANE	283249	52144	30098	22045
WI DODGE	235063	43273	9413	33860
WI DOOR	61066	11241	3263	7978
WI DOUGLAS	28419	5231	7217	-1985
WI DUNN	143835	26478	4212	22266
WI EAU CLAIRE	77005	14175	8779	5396
WI FLORENCE	8388	1544	568	975
WI FOND DU LAC 1	95663	36020	11130	24890
WI FOREST	12995	2392	1355	1037
WI GRANT	176376	32469	6704	25765
WI GREEN	170036	31302	3905	27396
WI GREEN LAKE	56648	10428	2359	8069
WI IOWA	142370	26209	3078	23130
WI IRON	6243	1149	1308	-159
WI JACKSON	73572	13544	2461	11082
WI JEFFERSON	137858	25378	7228	18150
WI JUNEAU	57904	10659	2874	7785
WI KENOSHA	48843	8991	13501	-4509
WI KEWAUNEE	87840	16170	2786	13384
WI LA CROSSE	78779	14502	10933	3569
WI LAFAYETTE	133940	24657	2847	21810
WI LANGLADE	56210	10347	3311	7036
WI LINCOLN	60708	11175	3496	7679
WI MANITOWOC	157729	29036	11077	17959
WI MARATHON	287545	52935	13178	39756
WI MARINETTE	68163	12548	5537	7010
WI MARQUETTE	30660	5644	1365	4278
WI MENOMINEE	0	0	475	-475

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
WI MILWAUKEE	11955	11472	147715	-136242
WI MONROE	138715	25536	4916	20620
WI OCONTO	116111	21375	3841	17533
WI ONEIDA	6668	1227	3337	-2109
WI OUTAGAMIE	176546	32501	14165	18335
WI OZAUKEE	50279	9256	4671	4584
WI PEPIN	31008	5708	1162	4546
WI PIERCE	98762	18181	3436	14745
WI POLK	138944	25642	3916	21726
WI PORTAGE	78508	14453	5611	8841
WI PRICE	49700	9149	2433	6716
WI RACINE	54958	10117	19347	-9229
WI RICHLAND	120696	22219	2916	19302
WI ROCK	146791	27023	15970	11052
WI RUSK	80421	14804	2501	12303
WI ST CROIX	136529	25134	4282	20851
WI SAUK	138145	25431	5853	19578
WI SAWYER	21912	4034	1564	2469
WI SHAWANO	166008	30560	5197	25362
WI SHEBOYGAN	134053	24678	13045	11632
WI TAYLOR	112128	21016	2855	18161
WI TREMPEALEAU	116890	21518	3700	17818
WI VERNON	177432	32876	4230	28645
WI VILAS	2205	405	1467	-1061
WI WALWORTH	137295	25275	7245	18029
WI WASHBURN	33654	6195	1740	4455
WI WASHINGTON	103383	19032	6136	12895
WI WAUKESHA	115093	21188	18307	2879
WI WAUPACA	137170	25252	5520	19731
WI WAUSHARA	56536	10407	2156	8251
WI WINNEBAGO	102655	18897	15421	3477
WI WOOD	104287	19198	8499	10698
WY ALBANY	2291	2081	3103	-1022
WY BIG HORN	6802	3342	1960	1382
WY CAMPBELL	2772	1362	817	545
WY CARBON	3113	1530	2389	-859
WY CONVERSE	2595	1275	948	326
WY CROOK	3792	1863	731	1131
WY FREMONT	10394	5108	3471	1636
WY GOSHEN	8092	3977	1914	2062
WY HOT SPRINGS	1346	661	887	-225

State | County	Production	Amount available for fluid use	Consumption	Excess or deficit
WY JOHNSON	2064	1014	780	234
WY LARAMIE	4401	3998	8216	-4218
WY LINCOLN	12910	6345	1399	4945
WY NATRONA	708	643	6075	-5432
WY NIOBRARA	2378	1169	665	502
WY PARK	7531	3701	2029	1672
WY PLATTE	5151	2531	1181	1349
WY SHERIDAN	7440	3656	3052	604
WY SUBLETTE	1312	644	470	174
WY SWEETWATER	1302	1183	3145	-1962
WY TETON	887	435	430	5
WY UINTA	3483	1712	1146	565
WY WASHAKIE	1844	906	1232	-326
WY WESTON	1377	677	1155	-478
Totals	**51842865**	**22149303**	**22061720**	**87134**

Information on Milk Distribution

Contents

TION ON LOCAL MILK DISTRIBUTION

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kL Y^{-1}, BETWEEN SURPLUS AND DEFICIT REGIONS IN THE
TATES DURING THE 1950s. THE MILK MARKETING ORDERS,
NSTITUTED THE MAIN SOURCE OF INFORMATION. MILK
ARE SHOWN IN THE MAPS IN PART 3 OF THIS APPENDIX.

1. Estimated transfer rates of milk, kL y^{-1}, between surplus and deficit regions in the United States during the 1950s. The milk marketing orders (mmo) constituted the main source of information. Milk regions are shown in the maps in Part 3 of this appendix. The degree of reliability, DR, of the data is as follows: 1 = highest degree of reliability (available data); 2 = intermediate degree of reliability (best estimate); 3 = low degree of reliability.

plus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
ME	2	ME	1096	deficit neighbors
ME	12	MA	16686	Boston milk marketing order (mmo)
ME	13	MA	16686	Boston mmo
ME	5	ME	3957	deficit neighbors
ME	11	MA	16686	Boston mmo
ME	12	MA	12167	Boston mmo
ME	13	MA	12167	Boston mmo
ME	5	ME	3957	deficit neighbor
ME	5	ME	3957	deficit neighbor
ME	12	MA	5418	Boston mmo
ME	13	MA	5418	Boston mmo
NH	12	MA	9600	Boston mmo
NH	11	MA	27178	Boston mmo
NH	12	MA	9600	Boston mmo
NH	13	MA	9312	Fall River & Boston mmo
NH	11	MA	797	Boston mmo
VT	10	MA	88624	Springfield mmo
VT	11	MA	108379	Woster & Boston mmo
VT	12	MA	33600	Boston mmo
VT	13	MA	88624	Fall River mmo
VT	18	CT	17635	deficit neighbor
VT	19	CT	17635	deficit neighbor
VT	10	MA	5656	Springfield mmo
VT	11	MA	101002	Woster mmo
VT	12	MA	24000	Boston mmo
VT	28	NY	39247	New York-New Jersey mmo
VT	18	CT	14400	deficit neighbor
VT	14	RI	14400	South east-
VT	15	RI	7200	New England (SENE) mmo
VT	16	RI	4800	SENE mmo
VT	29	NJ	19200	NY-NJ mmo
CT	14	RI	10806	SENE mmo
CT	18	CT	21612	within-state
NY	12	MA	11270	Boston mmo
NY	28	NY	48000	NY-NJ mmo
NY	14	RI	16800	SENE mmo
NY	29	NJ	35303	NY-NJ mmo
NY	28	NY	255345	NY-NJ mmo
NY	29	NJ	67200	NY-NJ mmo

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
NY	28	NY	85744	NY-NJ mmo
NY	29	NJ	24000	NY-NJ mmo
NY	28	NY	467005	NY-NJ mmo
NY	29	NJ	48000	NY-NJ mmo
NY	28	NY	67354	NY-NJ mmo
NY	29	NJ	24000	NY-NJ mmo
NY	14	RI	16800	SENE mmo
NY	15	RI	5043	SENE mmo
NY	18	CT	32103	CT mmo
NY	12	MA	24000	Boston mmo
NY	28	NY	174278	NY-NJ mmo
NY	29	NJ	72000	NY-NJ mmo
NY	28	NY	50817	NY-NJ mmo
NY	29	NJ	28800	NY-NJ mmo
NY	18	CT	32102	CT mmo
NY	19	CT	20381	CT mmo
NY	28	NY	121820	NY-NJ mmo
NY	29	NJ	72000	NY-NJ mmo
NY	14	RI	19574	SENE mmo
NY	15	RI	7200	SENE mmo
NY	16	RI	2251	SENE mmo
NJ	29	NJ	48000	NY-NJ mmo
NJ	31	NJ	23183	deficit neighbor
NJ	28	NY	31613	NY-NJ mmo
NJ	38	PA	36000	Philadelphia mmo
PA	28	NY	144000	NY-NJ mmo
PA	32	NJ	24312	S NJ deficit neighbor
PA	42	PA	48000	Pittsburgh deficit neighbor
PA	38	PA	61985	Philadelphia mmo
PA	38	PA	11600	Philadelphia mmo
PA	28	NY	24000	NY-NJ mmo
PA	42	PA	72000	Pittsburgh deficit neighbor
PA	110	OH	4800	Cleveland mmo
PA	32	NJ	4800	S NJ deficit neighbor
PA	38	PA	48212	Philadelphia mmo
PA	28	NY	38400	NY-NJ mmo
PA	109	OH	10150	Youngstown-Warren mmo
PA	29	NJ	241	NY-NJ mmo
PA	28	NY	80089	NY-NJ mmo
PA	38	PA	14400	Philadelphia mmo
PA	52	MD	4800	Washington DC mmo
PA	42	PA	28800	Pittsburgh deficit neighbor
PA	36	PA	39545	deficit neighbor
PA	28	NY	24000	NY-NJ mmo
PA	38	PA	19200	Philadelphia mmo
PA	32	NJ	4800	S NJ-deficit neighbor
PA	52	DC	2328	Washington DC mmo
PA	42	PA	29174	Pittsburgh deficit neighbor
PA	36	PA	4061	deficit neighbor
PA	28	NY	36000	NY-NJ mmo
PA	36	PA	19200	deficit neighbor

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
PA	46	MD	489	Upper Chesapeake mmo
PA	32	NJ	13440	S NJ- deficit neighbor
PA	42	PA	9600	Pittsburgh-deficit neighbor
PA	42	PA	24000	Pittsburgh-deficit neighbor
PA	32	NJ	4800	S New Jersey-deficit neighbor
PA	38	PA	11854	Philadelphia mmo
DE	43	DE	6286	deficit neighbor
DE	38	PA	14400	Philadelphia mmo
DE	32	NJ	972	S NJ deficit neighbor
DE	46	MD	4800	Upper Chesapeake mmo
MD	46	MD	9868	Upper Chesapeake mmo
MD	38	PA	9600	Philadelphia mmo
MD	46	MD	53624	Upper Chesapeake mmo
MD	38	PA	31837	Philadelphia mmo
MD	52	DC	14400	Washington DC mmo
MD	52	DC	4800	Washington DC mmo
MD	46	MD	5237	deficit neighbor
MD	52	DC	7200	Washington DC mmo
MD	38	PA	43200	Philadelphia mmo
MD	46	MD	42687	Upper Chesapeake mmo
MD	38	PA	3051	Philadelphia mmo
MD	52	DC	52	Washington DC mmo
VA	46	MD	38588	deficit neighbor DC neighbor
VA	52	DC	36317	Washington DC mmo
VA	53	VA	10042	deficit neighbor DC neighbor
VA	59	VA	1011	deficit neighbor
VA	59	VA	11633	deficit neighbor
VA	53	VA	9600	deficit neighbor DC neighbor
VA	52	DC	4800	Washington DC mmo
VA	58	VA	3659	Roanoke deficit neighbor
VA	52	DC	12000	Washington DC mmo
VA	53	VA	5635	deficit neighbor- DC neighbor
VA	67	NC	696	contribution to Blue Ridge mmo
VA	66	NC	480	deficit neighbor
VA	59	VA	27373	deficit neighbor
VA	58	VA	7200	deficit neighbor
VA	53	VA	12565	transfer to balance
VA	59	VA	29354	transfer to balance
VA	72	NC	3096	transfer to balance
VA	71	NC	8427	transfer to balance
VA	66	NC	21246	transfer to balance
VA	81	SC	14013	transfer to balance
VA	76	SC	9000	transfer to balance
VA	67	NC	2048	transfer to balance
WV	64	WV	4374	deficit neighbor
WV	65	WV	10114	deficit neighbor
WV	52	DC	24123	Washington DC mmo
WV	64	WV	4374	deficit neighbor
WV	65	WV	10114	deficit neighbor
WV	110	OH	3078	deficit neighbor
NC	73	NC	30	Charlotte mmo

us Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
NC	73	NC	12	Charlotte mmo
NC	68	NC	4289	Winston-Salem-Greensboro mmo
NC	67	NC	2048	deficit neighbor
NC	71	NC	9600	deficit neighbor
NC	72	NC	9600	deficit neighbor
NC	66	NC	9743	deficit neighbor
NC	76	SC	4787	transfer to balance
NC	78	SC	1772	transfer to balance
NC	79	SC	708	transfer to balance
NC	73	SC	4787	Charlotte mmo
NC	81	SC	4787	transfer to balance
NC	78	SC	10825	transfer to balance
NC	79	SC	10825	transfer to balance
SC	73	NC	243	deficit neighbor
SC	78	SC	768	Spartanburg-Greenville-Anderson(SGA)mmo
SC	79	SC	864	Columbia mmo
SC	76	SC	480	Florence mmo
SC	85	GA	288	deficit neighbor
SC	81	SC	1765	Charleston mmo
SC	78	SC	1765	SGA mmo
SC	79	SC	1765	Columbia mmo
GA	86	GA	2400	deficit neighbor
GA	85	GA	13439	Atlanta mmo
GA	85	GA	4158	Atlanta mmo
GA	83	GA	960	Carley 1964
GA	85	GA	21206	Atlanta mmo
GA	88	GA	782	Columbus mmo
GA	86	GA	6428	Savannah mmo
GA	83	GA	3812	Atlanta mmo
GA	325	FL	144	transfer to balance
GA	85	GA	3524	Atlanta mmo
GA	86	GA	6429	deficit neighbor
GA	88	GA	1424	deficit neighbor
FL	325	FL	7016	Orlando mmo
FL	325	FL	3969	deficit neighbor
FL	94	FL	3969	deficit neighbor
FL	325	FL	495	deficit neighbor
FL	161	AL	192	Carley & Purcell 1965
FL	94	FL	495	transfer to balance
MI	186	WI	46949	contributes to NE WI
MI	107	MI	37456	Detroit mmo
MI	107	MI	35973	Detroit mmo
MI	103	MI	6741	Detroit mmo
MI	107	MI	138647	Detroit mmo
MI	105	MI	9600	deficit neighbor
MI	107	MI	80055	Detroit mmo
MI	103	MI	6742	deficit neighbor
MI	105	MI	10203	deficit neighbor
MI	107	MI	18790	Detroit mmo
MI	107	MI	3508	Detroit mmo
MI	110	OH	1514	Cleveland mmo

Surplus Region		Deficit Region		Estimated Transfer Rate	Source of Information
o.	St.	No.	St.		
02	MI	112	OH	1994	Toledo mmo
04	MI	107	MI	83148	Detroit mmo
04	MI	108	MI	7565	deficit neighbor
04	MI	110	OH	15761	Cleveland mmo
04	MI	111	OH	240	between Cleveland and Toledo
04	MI	112	OH	16001	Toledo mmo
04	MI	109	OH	15761	Cleveland mmo
06	MI	107	MI	10560	Detroit mmo
06	MI	123	IN	960	deficit neighbor
06	MI	110	OH	7836	Cleveland mmo
06	MI	109	OH	7836	Cleveland mmo
06	MI	192	IL	480	Chicago mmo
06	MI	125	IN	4800	South Bend mmo
11	OH	109	OH	1715	Cleveland mmo
11	OH	110	OH	1716	Cleveland mmo
13	OH	112	OH	6465	Toledo mmo
13	OH	107	MI	2400	Detroit mmo
13	OH	110	OH	14611	Cleveland mmo
13	OH	109	OH	4800	Cleveland mmo
14	OH	110	OH	25110	Cleveland mmo
14	OH	109	OH	10068	Akron mmo
15	OH	110	OH	34741	Cleveland mmo
15	OH	118	OH	15897	Columbus mmo
15	OH	139	KY	960	Tri-state mmo KY-OH-WV
15	OH	65	WV	960	deficit neighbor
16	OH	118	OH	15897	Columbus mmo
16	OH	119	OH	632	deficit neighbor
16	OH	110	OH	40556	Cleveland mmo
17	OH	119	OH	2187	deficit neighbor
17	OH	64	WV	960	deficit neighbor
17	OH	139	KY	960	Tri-state mmo
17	OH	118	OH	15898	deficit neighbor
17	OH	121	OH	17610	deficit neighbor
20	OH	119	OH	623	Cincinnati mmo
20	OH	139	KY	960	Tri-state mmo
20	OH	121	OH	1575	Cincinnati mmo
20	OH	64	WV	960	transfer to balance
22	IN	110	OH	45364	Cleveland mmo
22	IN	112	OH	36767	Toledo mmo
22	IN	123	IN	6207	Fort Wayne mmo
22	IN	125	IN	4800	Chicago mmo
22	IN	109	OH	14400	Cleveland mmo
24	IN	110	OH	14680	Cleveland mmo
24	IN	125	IN	12000	Chicago mmo
24	IN	131	IN	9908	transfer to balance
24	IN	109	OH	14680	Chicago mmo
24	IN	123	IN	3327	Fort Wayne mmo
24	IN	191	IL	12000	Chicago mmo
26	IN	191	IL	9120	Chicago mmo
26	IN	125	IN	6280	Chicago mmo
26	IN	192	IL	480	Chicago mmo

Surplus Region		Deficit Region		Estimated Transfer Rate	Source of Information
o.	St.	No.	St.		
26	IN	194	IL	4800	Chicago mmo
27	IN	195	IL	1645	deficit neighbor
27	IN	123	IN	2880	deficit neighbor
27	IN	137	IN	5	deficit neighbor
27	IN	118	OH	15751	Columbus OH - transfer to balance
27	IN	121	OH	7875	Cincinnati mmo
27	IN	119	OH	7875	Cincinnati mmo
28	IN	131	IN	15588	Indianapolis - deficit neighbor
29	IN	131	IN	20064	Indianapolis - deficit neighbor
29	IN	191	IL	960	Chicago mmo
29	IN	125	IN	1440	Chicago mmo
30	IN	131	IN	13917	Indianapolis - deficit neighbor
30	IN	118	OH	2400	Columbus OH - transfer to balance
32	IN	131	IN	267	deficit neighbor
33	IN	121	OH	36960	Cincinnati mmo
33	IN	119	OH	17796	Cincinnati mmo
33	IN	136	IN	242	Louisville mmo
34	IN	136	IN	240	Louisville mmo
34	IN	142	KY	4800	Louisville mmo
34	IN	121	OH	22119	Cincinnati - deficit neighbor
34	IN	119	OH	13394	Cincinnati - Suburbs-deficit neigh.
35	IN	121	OH	3401	Cincinnati - transfer to balance
35	IN	119	OH	3360	Cincinn. - Suburbs-transfer
35	IN	137	IN	16499	deficit neighbor
38	KY	142	KY	6814	Louisville mmo
38	KY	121	OH	8125	Cincinnati mmo
38	KY	141	KY	2400	deficit neighbor
40	KY	139	KY	14400	deficit neighbor
40	KY	141	KY	7978	deficit neighbor
40	KY	121	OH	4800	Cincinatti mmo
40	KY	142	KY	20371	Louisville mmo
43	KY	142	KY	29077	Louisville mmo
43	KY	155	TN	14596	Memphis TN -transfer to balance
43	KY	151	TN	18681	Nashville mmo
43	KY	139	KY	4015	deficit neighbor
43	KY	154	TN	1736	deficit neighbor
43	KY	137	IN	2394	deficit neighbor
44	KY	151	TN	1433	Nashville mmo
45	KY	155	TN	2725	Memphis mmo
45	KY	154	TN	2725	Memphis mmo
45	KY	233	MO	2400	deficit neighbor
46	TN	147	TN	9600	Knoxville mmo
46	TN	148	TN	4800	Chattanooga
46	TN	156	AL	3095	Chattanooga mmo sends to AL
46	TN	83	GA	240	Chattanooga mmo sends to GA
46	TN	64	WV	480	Appalachian mmo
49	TN	148	TN	4800	Chattanooga mmo
49	TN	147	TN	2337	Knoxville mmo
49	TN	151	TN	2063	Nashville mmo
50	TN	151	TN	7200	Nashville mmo
50	TN	152	TN	669	Nashville mmo

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
TN	155	TN	57476	Memphis -transfer to balance
TN	156	AL	7244	Chattanooga mmo send to AL
TN	148	TN	10646	Chattanooga mmo
TN	161	AL	2669	Birmingham AL -transfer to balance
TN	155	TN	743	Memphis mmo
TN	154	TN	744	Memphis mmo
AL	148	TN	240	deficit neighbor
AL	157	AL	1011	deficit neighbor
AL	161	AL	5665	Tuscaloosa-Birmingham (Carley 1964)
AL	161	AL	2412	Tuscaloosa-Birmingham (Carley 1964)
AL	161	AL	4291	Tuscaloosa-Birmingham (Carley 1964)
AL	156	AL	480	Gadsden-Anniston (Carley 1964)
AL	161	AL	236	Tuscaloosa-Birmingham (Carley 1964)
AL	165	AL	960	Montgomery (Carley 1964)
AL	169	AL	2685	Mobile (Carley 1964)
AL	161	AL	7911	Tuscaloosa-Birmingham (Carley 1964)
AL	165	AL	736	Montgomery (Carley 1964)
AL	161	AL	6197	Tuscaloosa-Birmingham (Carley 1964)
AL	169	AL	2685	Mobile (Carley 1964)
AL	161	AL	240	Tuscaloosa-Birmingham (Carley 1964)
AL	165	AL	471	Montgomery (Carley 1964)
AL	169	AL	2606	Mobile (Carley 1964)
AL	169	AL	1277	Mobile (Carley 1964)
MS	169	AL	9664	deficit neighbor
MS	160	AL	1431	deficit neighbor
MS	172	MS	2400	deficit neighbor
MS	175	MS	2400	deficit neighbor
MS	176	MS	2400	deficit neighbor
MS	161	AL	2198	Birmingham deficit neighbor (Carley)
MS	172	MS	4800	deficit neighbor
MS	175	MS	4800	deficit neighbor
MS	160	AL	463	Birmingham neighbor (Carley 1964)
MS	161	AL	3326	Birmingham neighbor (Carley 1964)
MS	177	MS	12114	Central Mississippi mmo
MS	176	MS	5232	Central Mississippi mmo
MS	172	MS	3257	Mississippi Delta mmo
MS	175	MS	1723	Mississippi Delta mmo
MS	159	AL	634	deficit neighbor (Carley 1964)
MS	160	AL	1920	deficit neighbor (Carley 1964)
MS	161	AL	8314	deficit neighbor (Carley 1964)
MS	175	MS	6040	Mississippi Delta mmo
MS	176	MS	6041	Central Mississippi mmo
MS	258	LA	4437	New Orleans mmo
MS	257	LA	11799	New Orleans mmo
MS	258	LA	4356	New Orleans mmo
MS	257	LA	870	New Orleans mmo
MS	259	LA	476	New Orleans mmo
WS	191	IL	61416	Chicago mmo
WI	192	IL	480	Chicago mmo
WI	191	IL	113644	Chicago mmo
WI	192	IL	480	Chicago mmo

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
WI	191	IL	48299	Chicago mmo
WI	201	MN	32710	Deluth mmo
WI	207	MN	24000	Minneapolis-St.Paul mmo
WI	228	MO	424	St. Louis-Long distance shipment
WI	110	OH	8015	Cleveland-Long distance shipment
WI	95	FL	5414	Long distance emergency shipment
WI	94	FL	8978	Long distance emergency shipment
WI	325	FL	619	Long distance emergency shipment
WI	186	WI	35580	Milwaukee mmo
WI	191	IL	64711	Chicago mmo
WI	192	IL	480	Chicago mmo
WI	125	IN	4236	Chicago mmo
WI	192	IL	480	Chicago mmo
WI	191	IL	71148	Chicago mmo
WI	110	OH	2631	Cleveland transfer to balance
WI	207	MN	27967	Minneapolis-St. Paul mmo
WI	191	IL	113982	Chicago mmo
WI	192	IL	480	Chicago mmo
WI	186	WI	26089	Milwaukee mmo
WI	186	WI	35579	Milwaukee mmo
WI	191	IL	42082	Chicago mmo
WI	125	IN	4236	South Bend mmo, Chicago mmo
WI	192	IL	480	Chicago mmo
WI	110	OH	10646	Cleveland transfer to balance
WI	95	FL	5414	Long distance emergency shipment
WI	94	FL	9425	Long distance emergency shipment
WI	325	FL	628	Long distance emergency shipment
WI	110	OH	2631	Cleveland to balance
WI	191	IL	20547	Chicago mmo
WI	192	IL	154	Chicago mmo
WI	191	IL	158031	Chicago mmo
WI	192	IL	480	Chicago mmo
WI	228	MO	394	St. Louis transfer to balance
IL	191	IL	48000	Chicago mmo
IL	192	IL	480	Chicago mmo
IL	194	IL	12588	Chicago mmo
IL	195	IL	8332	Chicago mmo
IL	198	IL	9804	to balance
IL	195	IL	7953	deficit neighbor
IL	198	IL	2184	deficit neighbor
IL	228	MO	4800	St. Louis mmo
IL	198	IL	3352	St. Louis mmo
IL	199	IL	8309	deficit neighbor
IL	198	IL	960	St. Louis mmo
IL	199	IL	430	deficit neighbor
IL	228	MO	480	St.Louis mmo
MI	202	MN	5806	deficit neighbor
MN	201	MN	480	Duluth-Superior mmo
MN	207	MN	1302	Minneapolis-St. Paul mmo
MN	207	MN	49084	Minneapolis-St. Paul mmo
MN	207	MN	15377	deficit neighbor

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
MN	207	MN	11575	Minneapolis-St. Paul mmo
MN	207	MN	2047	Minneapolis-St. Paul mmo
MN	207	MN	3121	deficit neighbor
IA	195	IL	539	deficit neighbor
IA	198	IL	3685	transfer to balance
IA	215	IA	14091	Quad cities mmo
IA	216	IA	1729	Cedar Rapids mmo
IA	221	IA	5054	both part of Cedar Rapids mmo
IA	218	IA	13125	deficit neighbor
IA	217	IA	4163	both part of Dubuque mmo
IA	284	NE	4804	transfer to balance
IA	220	IA	7437	deficit in state
IA	228	MO	4129	transfer to balance
IA	218	IA	2567	deficit neighbor
IA	352	NM	3360	transfer to balanc
IA	344	CO	12763	transfer to balance
IA	220	IA	4615	Sioux City mmo
IA	282	NE	10995	deficit neighbor
IA	282	NE	11573	Omaha-Lincoln-Council Bluffs mmo
IA	220	IL	795	transfer to balance
IA	224	IL	795	transfer to balance
IA	228	MO	4328	transfer to balance
IA	224	IA	2447	deficit neighbor
IA	233	MO	1440	transfer to balance
IA	284	NE	3874	deficit neighbor
IA	224	IA	3303	Omaha-Lincoln-Council Bluffs mm
IA	286	NE	1704	Omaha-Lincoln-Council Bluffs mmo
MO	229	MO	864	St. Louis mmo
MO	228	MO	8787	St. Louis mmo
MO	228	MO	10705	St. Louis mmo
MO	232	MO	12000	Kansas City mmo
MO	232	MO	11474	Kansas City mmo
MO	228	MO	27281	St. Louis mmo
MO	229	MO	912	St. Louis mmo
MO	232	MO	7200	Kansas City mmo
MO	232	MO	3840	Kansas City mmo
MO	228	MO	24180	St. Louis mmo
MO	228	MO	38332	St. Louis mmo
MO	229	MO	864	St. Louis mmo
MO	233	MO	7247	deficit neighbor
MO	228	MO	42817	St. Louis mmo
AR	236	AR	6327	deficit neighbor
AR	239	AR	7200	Central Arkansas mmo
AR	240	AR	3804	Central Arkansas mmo
AR	240	AR	7554	Central Arkansas mmo
AR	239	AR	2404	Memphis mmo
AR	243	AR	5745	Central Arkansas mmo
AR	248	LA	10271	transfer to balance
AR	254	LA	2577	transfer to balance
AR	259	LA	2577	transfer to balance
AR	257	LA	2577	transfer to balance

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
AR	258	LA	2577	transfer to balance
AR	240	AR	4469	Central Arkansas mmo
AR	243	AR	2400	both part of Cental Arkansas mmo
AR	244	AR	3306	deficit neighbor
AR	240	AR	2361	Central Arkansas mmo
AR	245	AR	1780	deficit neighbors
LA	254	LA	2648	transfer to balance
LA	260	LA	2042	transfer to balance
LA	250	LA	96	Northern Louisiana mmo
LA	254	LA	2708	transfer to balance
LA	257	LA	1136	transfer to balance
LA	248	LA	51	Northern Louisiana mmo
LA	259	LA	266	transfer to balance
LA	254	LA	785	transfer to balance
LA	250	LA	96	Northern Louisiana mmo
LA	250	LA	103	Northern Louisiana mmo
LA	260	LA	2042	transfer to balance
LA	254	LA	2708	transfer to balance
LA	257	LA	1137	transfer to balance
LA	259	LA	1345	transfer to balance
LA	257	LA	35314	New Orleans mmo
LA	258	LA	5646	New Orleans mmo
LA	259	LA	5167	New Orleans mmo
LA	254	LA	2246	deficit neighbor
LA	257	LA	5215	deficit neighbor
LA	254	LA	132	deficit neighbor
LA	259	LA	2637	deficit neighbor
LA	258	LA	2637	deficit neighbor
LA	260	LA	1062	deficit neighbor
ND	263	ND	3360	deficit neighbor
ND	261	ND	348	deficit neighbor
ND	263	ND	513	deficit neighbor
ND	264	ND	2508	deficit neighbor
ND	261	ND	2508	deficit neighbor
ND	263	ND	1784	deficit neighbor
ND	5	MN	533	transfer to balance
ND	264	ND	5275	deficit neighbor
ND	261	ND	3245	deficit neighbor
ND	202	MN	108	transfer to balance
ND	262	ND	160	deficit neighbor
ND	263	ND	1014	deficit neighbor
SD	273	SD	118	deficit neighbor
SD	281	NE	6545	transfer to balance
SD	282	NE	2688	transfer to balance
SD	284	NE	2244	transfer to balance
SD	285	NE	926	transfer to balance
SD	287	NE	3223	transfer to balance
SD	288	NE	2730	transfer to balance
SD	323	TX	150	emergencies transfer(Feder & Williams 1954)
SD	275	SD	2824	deficit neighbor
SD	278	SD	1520	deficit neighbor

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
SD	285	NE	184	transfer to balance
SD	281	NE	2964	transfer to balance
SD	288	NE	1249	transfer to balance
SD	275	SD	362	deficit neighbor
SD	288	NE	33	transfer to balance
SD	285	NE	33	transfer to balance
SD	282	NE	6912	transfer to balance
SD	284	NE	5891	transfer to balance
SD	278	SD	480	deficit neighbor
SD	288	NE	480	transfer to balance
SD	275	SD	480	deficit neighbor
SD	287	NE	615	transfer to balance
NE	282	NE	541	Omaha-Lincoln-Council Bluffs mmo
NE	283	NE	3791	Omaha-Lincoln-Council Bluffs mmo
NE	285	NE	480	deficit neighbor
NE	284	NE	480	Omaha-Lincoln-Council Bluffs mmo
NE	285	NE	1196	deficit neighbor
NE	344	CO	480	shipped to Denver (Feder & Williams 1954)
KS	327	TX	1705	(Feder & Williams 1954) & mmo data
KS	289	KS	48	KS City mmo
KS	290	KS	960	KS City mmo
KS	232	MO	5287	KS City mmo
KS	344	CO	19083	To Denver- some mmo data on export
KS	323	TX	1512	shipped to Texas in emergencies
KS	353	NM	1284	shipped to Albuquerque (Ward & Whicker 87)
KS	354	NM	638	shipped to Albuquerque (Ward & Whicker 87)
KS	290	KS	480	KS City mmo
KS	344	CO	4800	mmo data - SW KS 1963 report
KS	353	NM	1785	mmo data - SW KS 1963 report
KS	354	NM	1785	mmo data - SW KS 1963 report
KS	300	KS	144	Southwest KS mmo
KS	352	NM	1825	mmo data - SW KS 1963 report
KS	289	KS	65	KS City mmo
KS	290	KS	1696	KS City mmo
KS	298	KS	1440	Wichita mmo
KS	232	MO	10859	KS City mmo
KS	327	TX	9600	mmo data - SW KS 1963 report
KS	298	KS	4800	Wichita mmo
KS	300	KS	31	Southwest KS mmo
KS	344	CO	4800	mmo data - SW KS 1963 report
KS	323	TX	1997	mmo data - SW KS 1963 report
KS	353	NM	1284	mmo data - SW KS 1963 report
KS	290	KS	480	KS City mmo
KS	349	CO	1821	mmo data - SW KS 1963 report
KS	344	CO	960	mmo data - SW KS 1963 report
KS	300	KS	144	Southwest KS mmo
KS	353	NM	558	mmo data - SW KS 1963 report
KS	354	NM	558	mmo data - SW KS 1963 report
KS	352	NM	1440	mmo data - SW KS 1963 report
KS	298	KS	2313	Wichita mmo
KS	323	TX	9542	mmo data - SW KS 1963 report

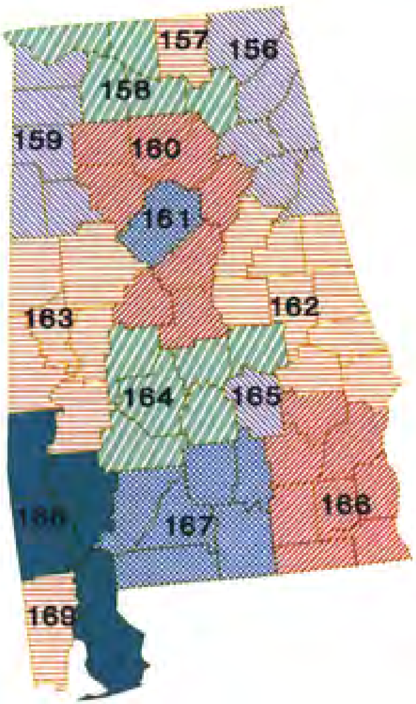
lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
KS	327	TX	4800	mmo data - SW KS 1963 report
KS	232	MO	6884	KS City mmo
KS	300	KS	31	Southwest KS mmo
KS	298	KS	4800	Wichita mmo
KS	344	CO	1988	mmo data - SW KS 1963 report
OK	302	OK	6556	Metropolitan Oklahoma mmo
OK	248	LA	922	transfer to balance
OK	298	KS	2400	Wichita mmo
OK	307	OK	17341	Metropolitan Oklahoma mmo
OK	366	AZ	168	Central Arizona mmo
OK	327	MO	2627	guess to balance
OK	302	OK	1440	Metropolitan Oklahoma mmo
OK	307	OK	2400	Metropolitan Oklahoma mmo
OK	318	TX	960	TX Panhandle mmo
OK	319	TX	2752	TX Panhandle mmo
OK	298	KS	480	Wichita mmo
OK	318	TX	988	TX Panhandle mmo
OK	319	TX	3840	TX Panhandle mmo
OK	327	TX	3504	transfer to balance
OK	309	OK	987	Fort Smith mmo
OK	302	OK	2956	Metropolitan Oklahoma mmo
OK	307	OK	6132	deficit neighbor
OK	302	OK	6132	Metropolitan Oklahoma mmo
OK	307	OK	2400	Metropolitan Oklahoma mmo
OK	319	TX	6408	TX Panhandle mmo
OK	302	OK	1440	Metropolitan Oklahoma mmo
OK	318	TX	1920	TX Panhandle mmo
OK	327	TX	6408	transfer to balance
OK	302	OK	480	Metropolitan Oklahoma mmo
OK	307	OK	2243	Metropolitan Oklahoma mmo
OK	314	TX	3087	North TX mmo
OK	314	TX	4467	transfer to balance
OK	317	TX	55	TX Panhandle mmo
OK	302	OK	1440	Metropolitan Oklahoma mmo
OK	307	OK	2400	Metropolitan Oklahoma mmo
TX	248	LA	2400	Northern Louisiana mmo
TX	314	TX	33600	North TX mmo
TX	323	TX	32973	deficit neighbor
TX	328	TX	2008	deficit neighbor
TX	314	TX	28208	North TX mmo
TX	314	TX	23040	North TX mmo
TX	323	TX	17254	transfer to balance
TX	328	TX	4800	transfer to balance
TX	353	NM	4800	Central West TX mmo (AAES1978)
TX	354	NM	3840	Central West TX mmo (AAES1978)
TX	355	NM	833	Central West TX mmo (AAES1978)
TX	317	TX	960	deficit neighbor
TX	319	TX	625	both part of Central West TX mmo
TX	318	TX	480	deficit neighbor
TX	317	TX	334	deficit neighbor
TX	314	TX	905	deficit neighbor

lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
TX	322	TX	16800	deficit neighbor
TX	323	TX	7763	deficit neighbor
TX	328	TX	4800	Corpus Christi mmo
TX	314	TX	3823	North TX mmo
TX	322	TX	17976	deficit neighbor
TX	323	TX	2880	deficit neighbor
TX	330	TX	14408	part of same mmo
TX	328	TX	6694	Corpus Christi mmo
TX	327	TX	2400	deficit neighbor
TX	330	TX	2400	part of same mmo
TX	328	TX	2400	deficit neighbor
TX	319	TX	820	Central West TX mmo
TX	330	TX	2400	deficit neighbor
TX	328	TX	2683	Corpus Christi mmo
MT	332	MT	63	deficit neighbor
MT	335	MT	1580	deficit neighbor
MT	356	ID	9552	Inland Empire mmo
MT	335	MT	1662	deficit neighbor
MT	337	ID	692	transfer to balance
WY	275	SD	240	Black Hills mmo
WY	278	SD	240	Black Hills mmo
WY	340	WY	321	deficit neighbor
WY	341	WY	1355	deficit neighbor
WY	341	WY	3901	deficit neighbor
WY	418	UT	240	Ward & Whicker 1987
WY	338	WY	321	deficit neighbor
WY	345	CO	586	deficit neighbor
WY	344	CO	501	deficit neighbor
WY	341	WY	3974	deficit neighbor
CO	344	CO	16599	Eastern Colorado mmo
CO	344	CO	4800	Eastern Colorado mmo
CO	347	CO	7111	Colorado Springs mmo
CO	349	CO	486	Colorado Springs mmo
CO	350	CO	578	deficit neighbor
CO	353	NM	240	Rio Grande mmo
CO	352	NM	240	Rio Grande mmo
CO	347	CO	1780	Colorado Springs mmo
CO	361	UT	185	guess to balance
CO	350	CO	960	deficit neighbors
NM	352	NM	9600	Rio Grande mmo
NM	354	NM	1595	Rio Grande mmo
NM	355	NM	480	Rio Grande mmo
NM	353	NM	1920	Rio Grande mmo
NM	318	TX	480	TX Panhandle mmo & AAES 1978
ID	362	UT	141	transfer to balance
ID	418	UT	85	Ward & Whicker 1987
ID	337	ID	5843	deficit neighbor
ID	375	WA	924	deficit neighbor
ID	377	WA	2504	deficit neighbor
ID	360	ID	2290	deficit neighbor
ID	357	ID	166	deficit neighbor

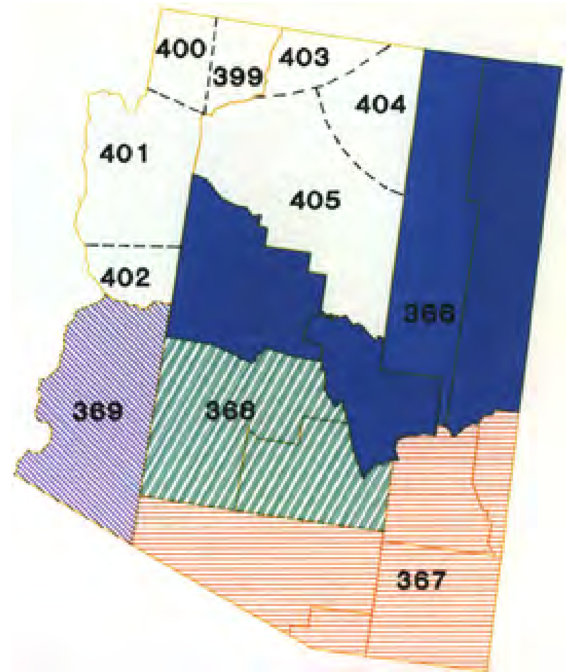
…lus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
ID	356	ID	348	deficit neighbor
ID	418	UT	3885	transfer to balance
ID	337	MT	720	deficit neighbor
UT	423	UT	6105	derived from Ward & Whicker 1987
UT	416	NV	744	transfer to balance
UT	423	UT	684	Ward & Whicker 1987
UT	411	NV	170	derived from Ward & Whicker 1987
UT	417	NV	572	Ward & Whicker 1987
UT	415	NV	41	Ward & Whicker 1987
UT	416	NV	7221	Ward & Whicker 1987
UT	402	AZ	46	derived from Ward & Whicker 1987
UT	418	UT	4342	derived from Ward & Whicker 1987
UT	418	UT	33	derived from Ward & Whicker 1987
UT	418	UT	682	derived from Ward & Whicker 1987
UT	418	UT	1986	derived from Ward & Whicker 1987
UT	418	UT	980	derived from Ward & Whicker 1987
UT	409	NV	586	Ward & Whicker 1987
UT	410	NV	270	Ward & Whicker 1987
UT	421	UT	1125	Ward & Whicker 1987
UT	425	UT	506	deficit neighbor
UT	425	UT	503	deficit neighbor
UT	428	UT	35	Ward & Whicker 1987
UT	399	AZ	23	transfer to balance
UT	400	AZ	5	transfer to balance
UT	403	AZ	2	transfer to balance
UT	429	UT	450	deficit neighbor
UT	404	AZ	206	transfer to balance
UT	404	AZ	388	transfer to balance
UT	404	AZ	274	transfer to balance
AZ	366	AZ	3253	Ward & Whicker 1987
AZ	367	AZ	15014	Central AZ mmo
AZ	369	AZ	1466	Central AZ mmo
AZ	354	NM	240	deficit neighbor
AZ	404	AZ	214	Ward & Whicker 1987
AZ	405	AZ	1151	Ward & Whicker 198
AZ	402	AZ	107	Ward & Whicker 1987
AZ	404	AZ	111	Ward & Whicker 1987
NV	416	NV	204	derived from Ward & Whicker 1987
NV	406	CA	437	Ward & Whicker 1987
NV	408	CA	94	Ward & Whicker 1987
NV	372	NV	630	Ward & Whicker 1987
NV	413	NV	121	Ward & Whicker 1987
NV	414	NV	41	Ward & Whicker 1987
NV	423	UT	1212	Ward & Whicker 1987
NV	423	UT	373	Ward & Whicker 1987
WA	375	WA	8745	Inland Empire mmo
WA	356	ID	3247	Inland Empire mmo
WA	376	WA	564	deficit neighbor
WA	377	WA	240	deficit neighbor
WA	375	WA	240	deficit neighbor
WA	379	WA	69787	Tacoma-Puget Sound mmo

plus Region	Deficit Region		Estimated Transfer Rate	Source of Information
St.	No.	St.		
WA	383	OR	7479	deficit neighbor
WA	375	WA	7267	HEDR Project data Beck 1988, pers.comm.
WA	376	WA	2534	HEDR Project data Beck 1988, pers. comm.
OR	382	OR	237	deficit neighbor
OR	375	WA	4320	transfer to balance
OR	376	WA	480	HEDR Project data Beck 1988, pers. comm.
OR	377	WA	200	deficit neighbor
OR	383	OR	22823	deficit neighbor
OR	383	OR	15444	deficit neighbor
OR	360	ID	128	Kent Hoddick, pers.comm. 1987
OR	383	OR	9718	transfer to balance
CA	391	CA	4800	transfer to balance
CA	392	CA	36225	transfer to balance
CA	391	CA	4800	transfer to balance
CA	392	CA	53019	transfer to balance
CA	392	CA	97776	deficit neighbor
CA	391	CA	2194	deficit neighbor
CA	366	AZ	1057	transfer to balance
CA	392	CA	58810	deficit neighbor
CA	391	CA	4897	deficit neighbor
CA	394	CA	37103	deficit neighbor
CA	395	CA	7937	deficit neighbor
CA	397	CA	29603	deficit neighbor
CA	396	CA	314828	deficit neighbor
CA	398	CA	38301	transfer to balance
CA	408	CA	139	Ward & Whicker 1987
CA	408	CA	40	Ward & Whicker 1987

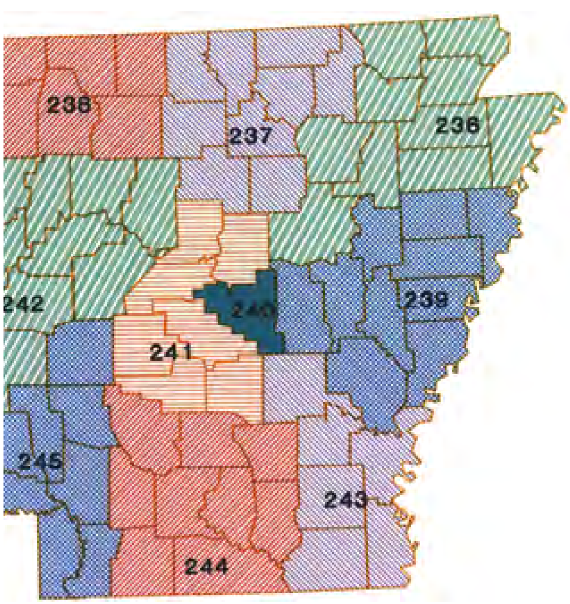
tribution regions: Alabama



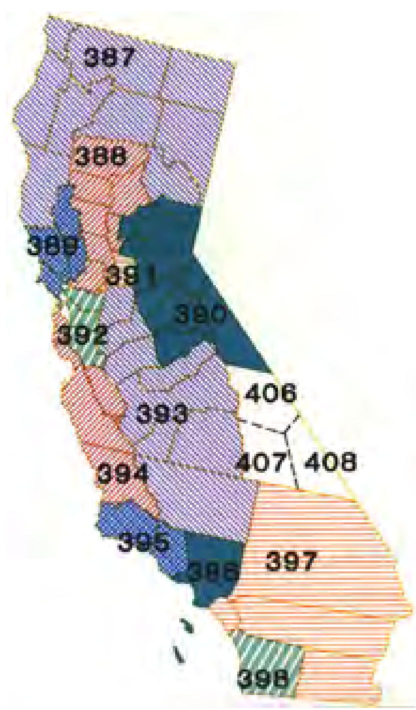
Milk distribution regions: Arizona



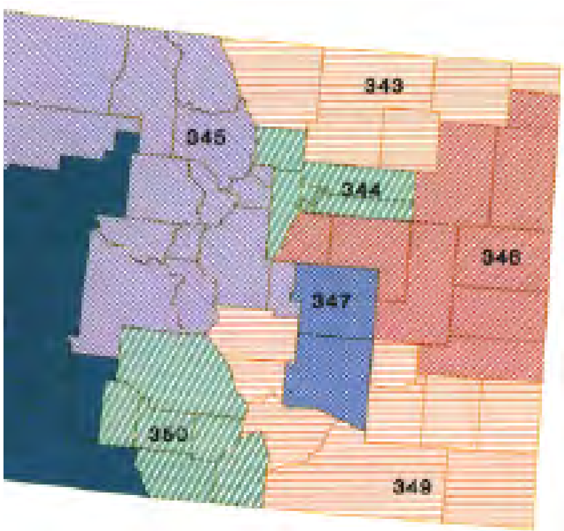
tribution regions: Arkansas



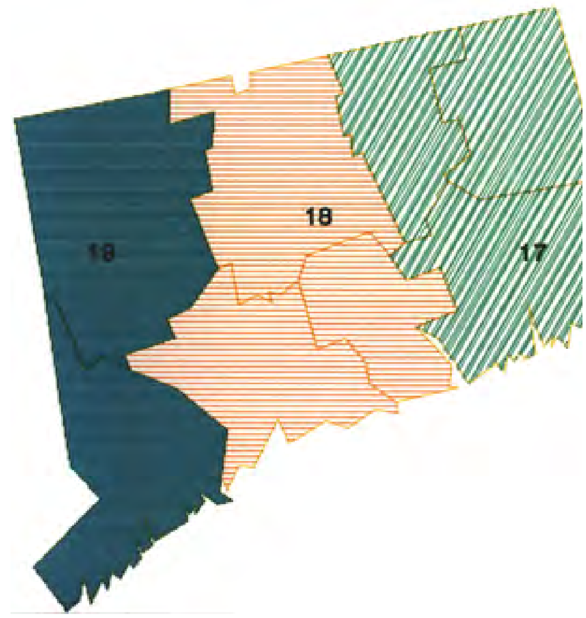
Milk distribution regions: California



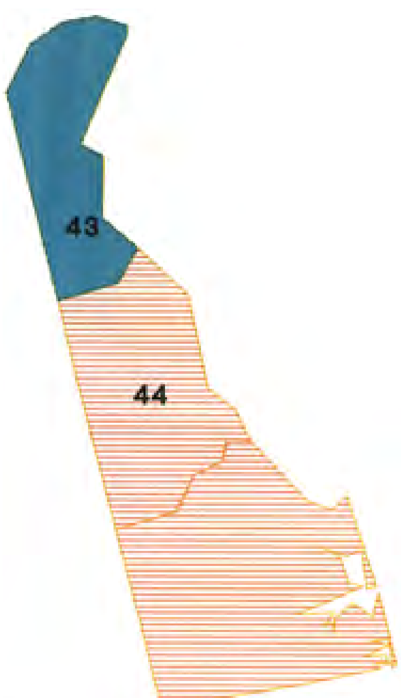
tribution regions: Colorado



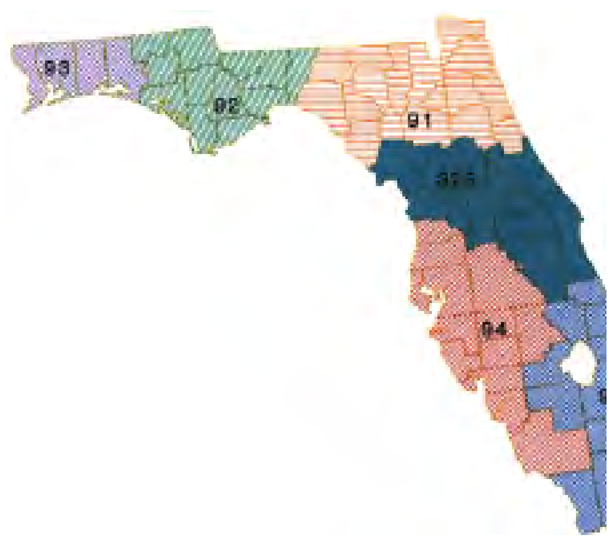
Milk distribution regions: Connecticut



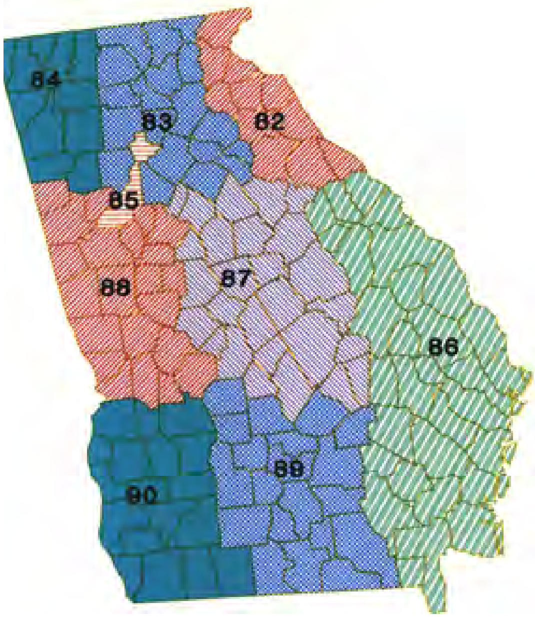
tribution regions: Delaware



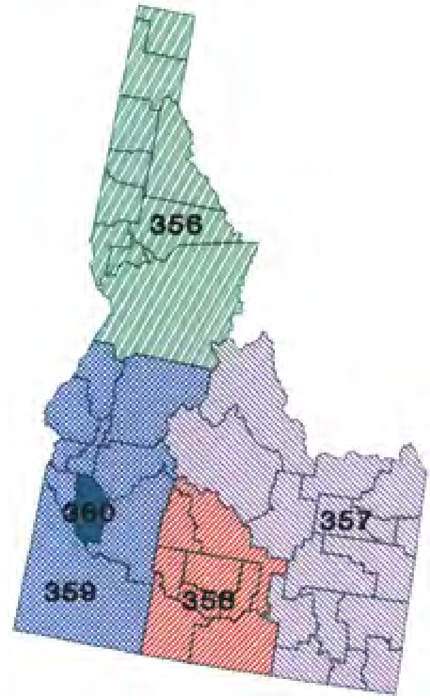
Milk distribution regions: Florida



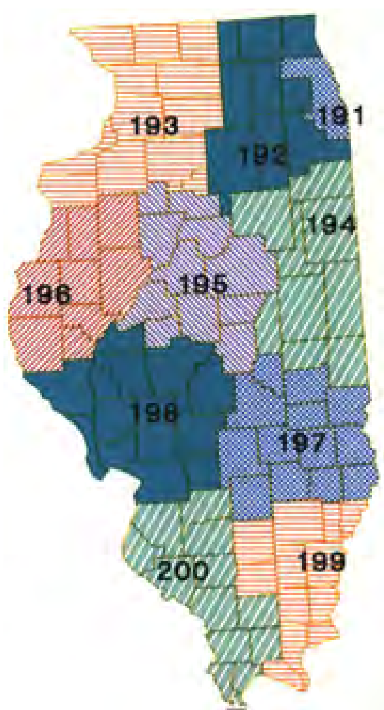
tribution regions: Georgia



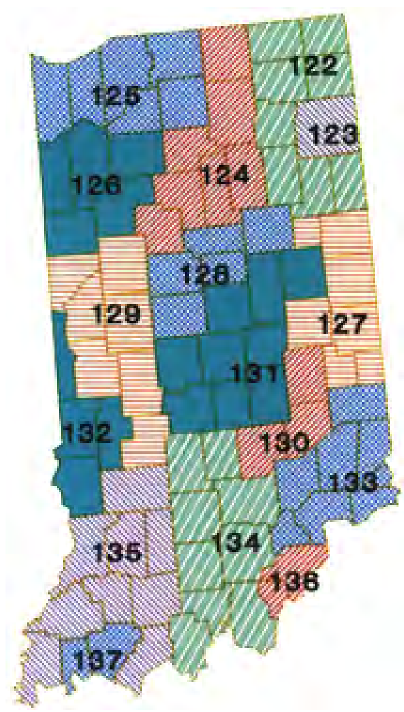
Milk distribution regions: Idaho



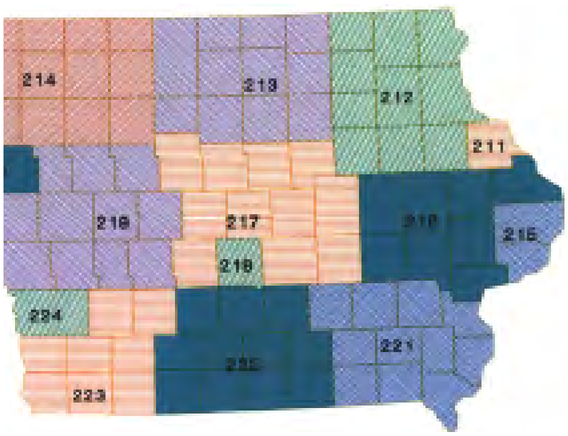
tribution regions: Illinois



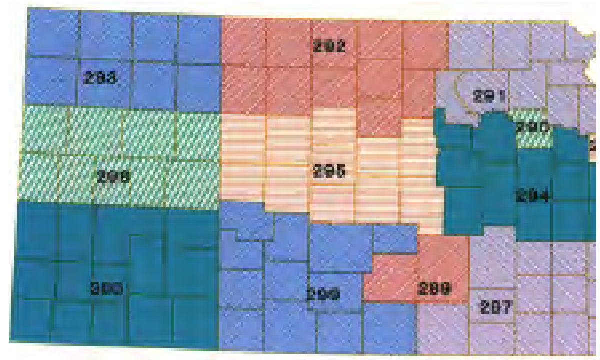
Milk distribution regions: Indiana



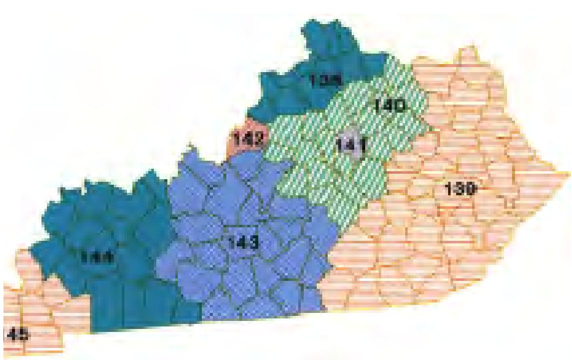
tribution regions: Iowa



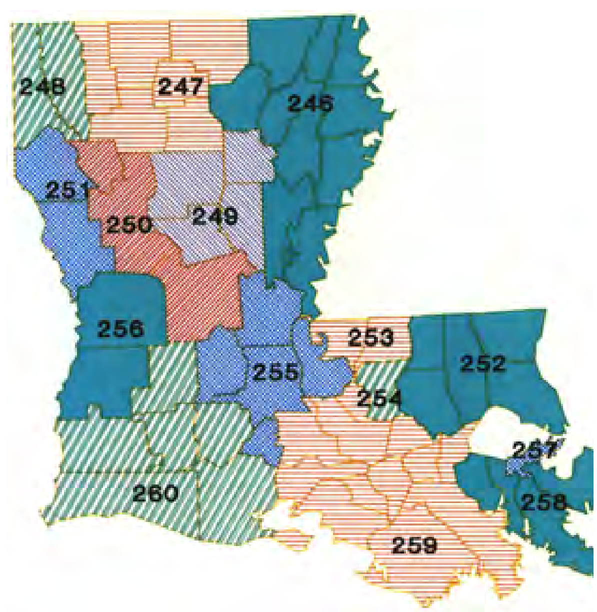
Milk distribution regions: Kansas



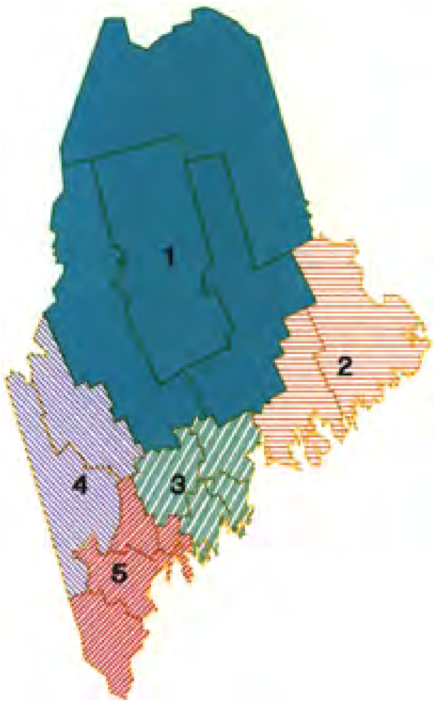
tribution regions: Kentucky



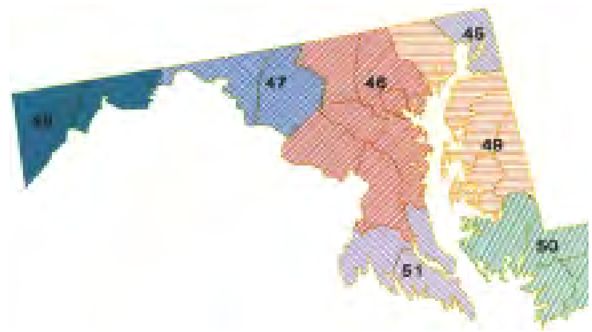
Milk distribution regions: Louisiana



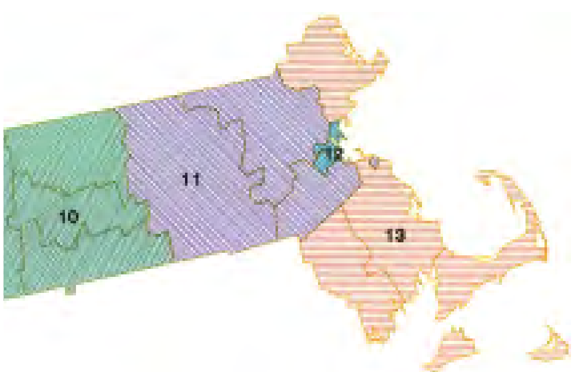
tribution regions: Maine



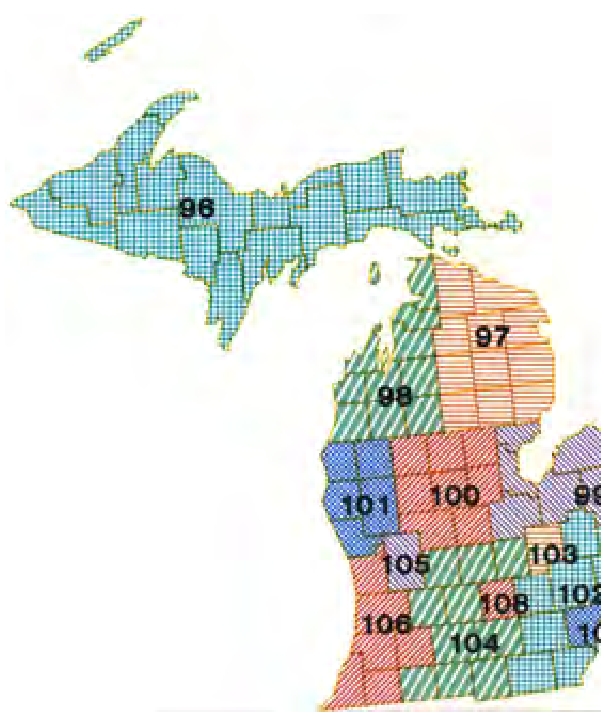
Milk distribution regions: Maryland



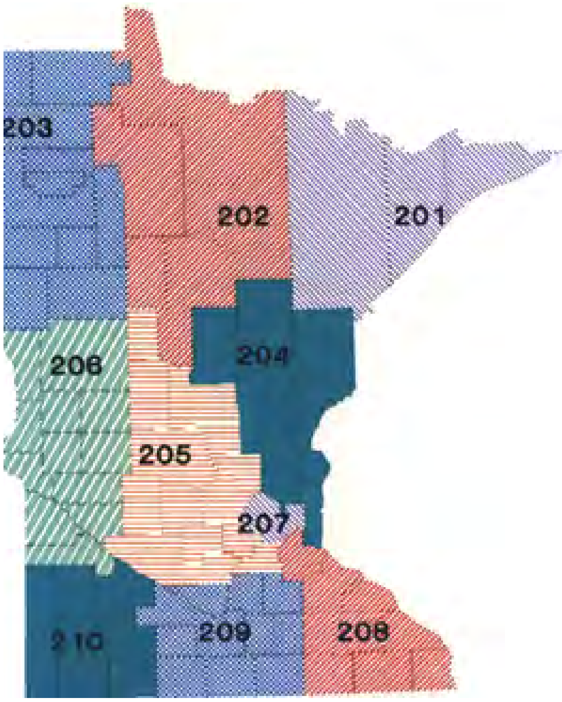
tribution regions: Massachusetts



Milk distribution regions: Michigan



tribution regions: Minnesota



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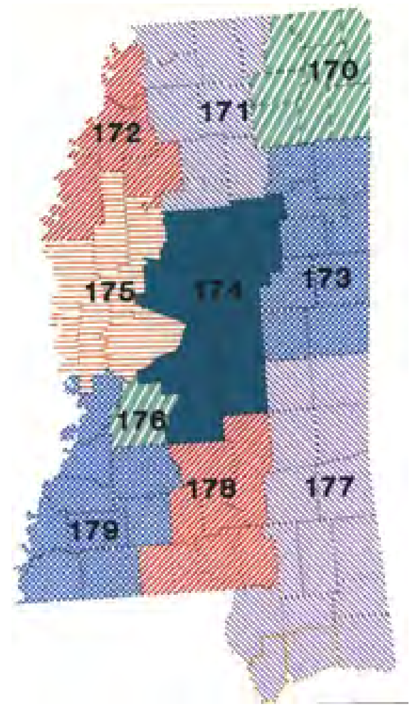
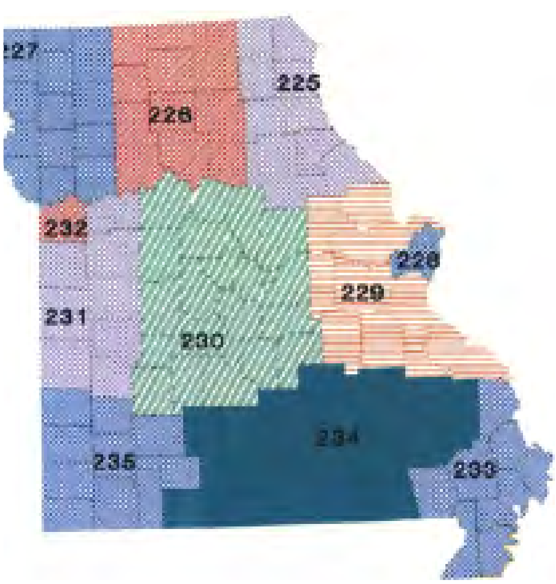


tribution regions: Missouri



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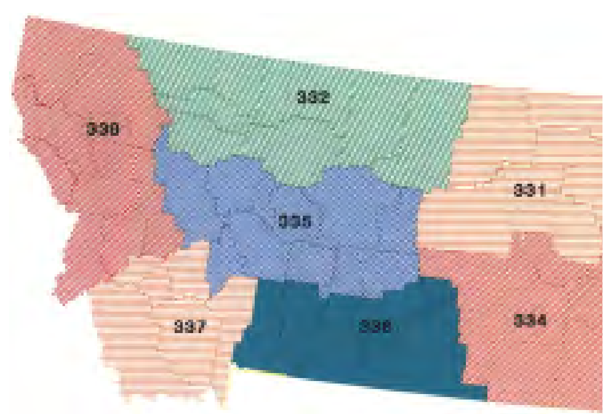
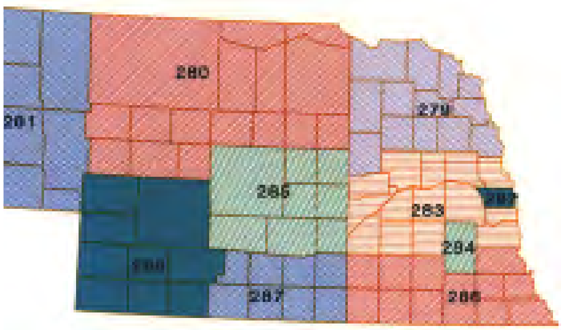


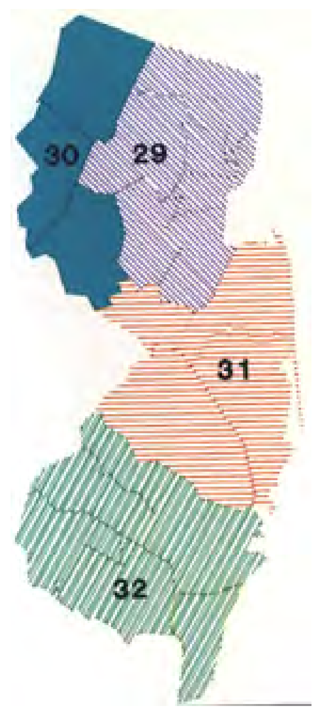
tribution regions: Nebraska



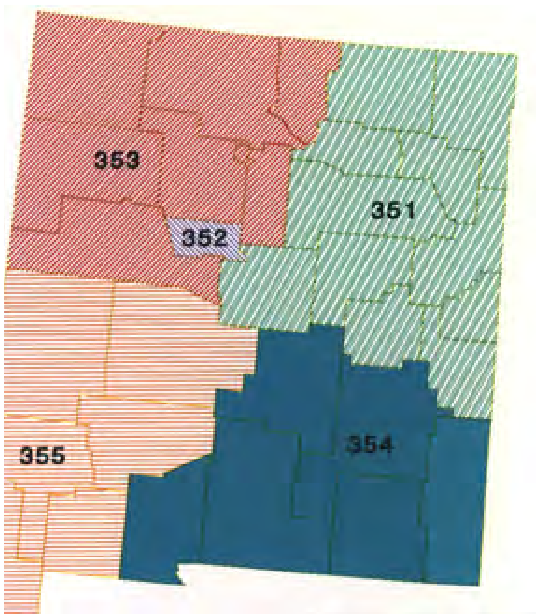
Milk distribution regions: Nevada

tribution regions: New Hampshire

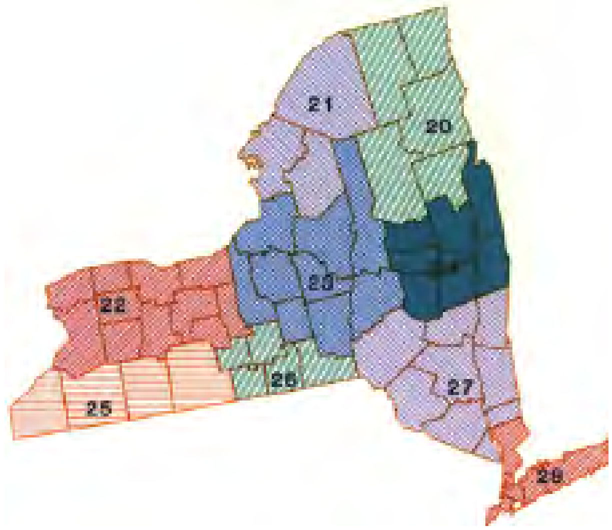
Milk distribution regions: New Jersey



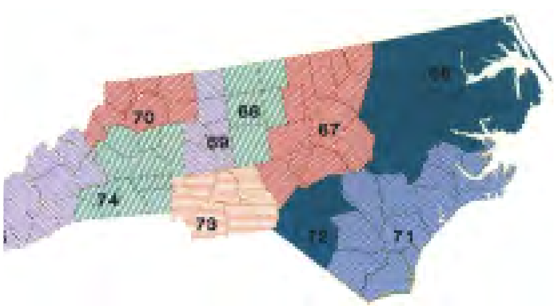
tribution regions: New Mexico



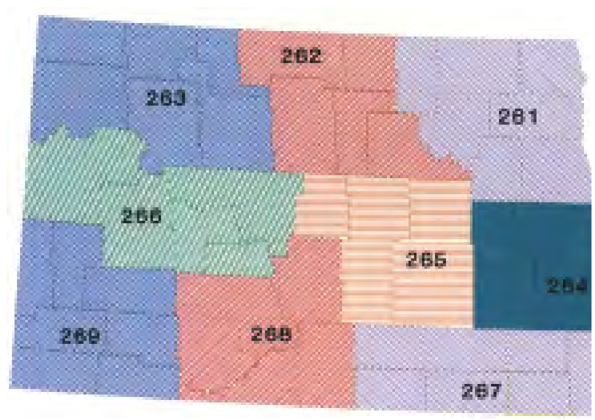
Milk distribution regions: New York



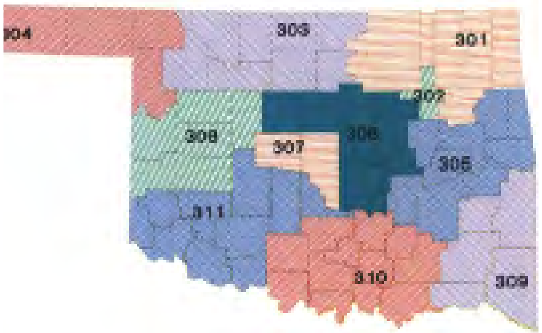
tribution regions: North Carolina



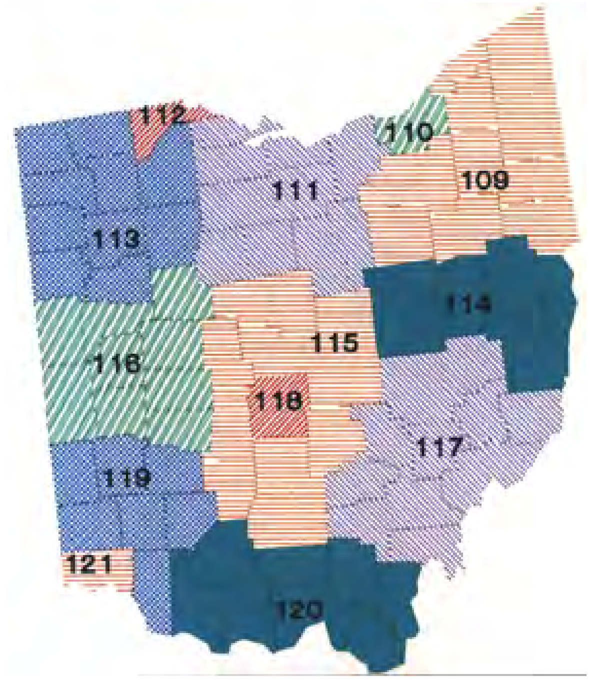
Milk distribution regions: North Dakota



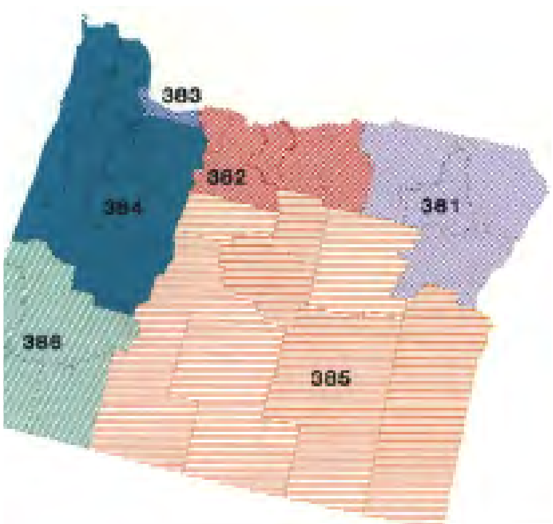
tribution regions: Oklahoma



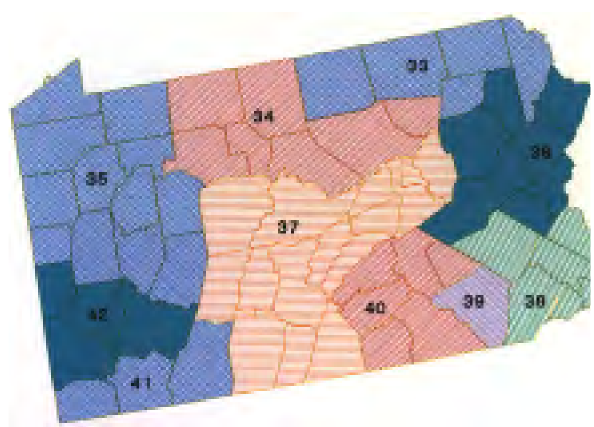
Milk distribution regions: Ohio



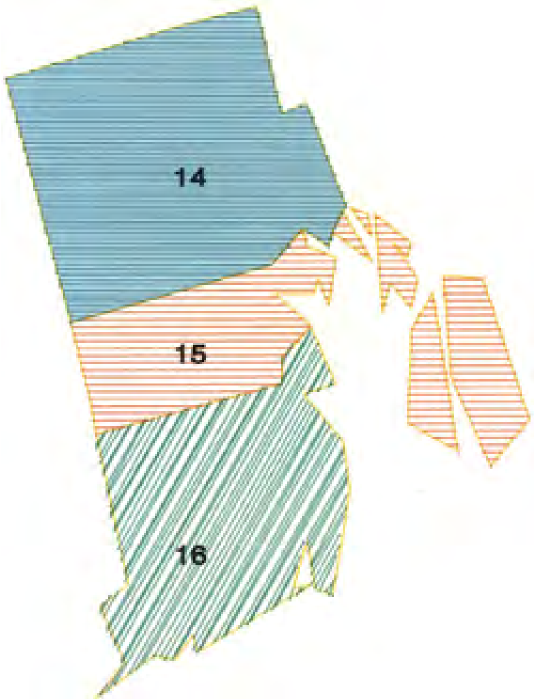
tribution regions: Oregon



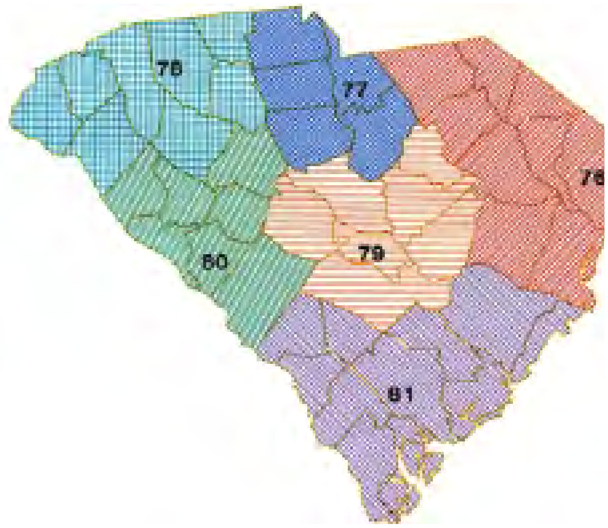
Milk distribution regions: Pennsylvania



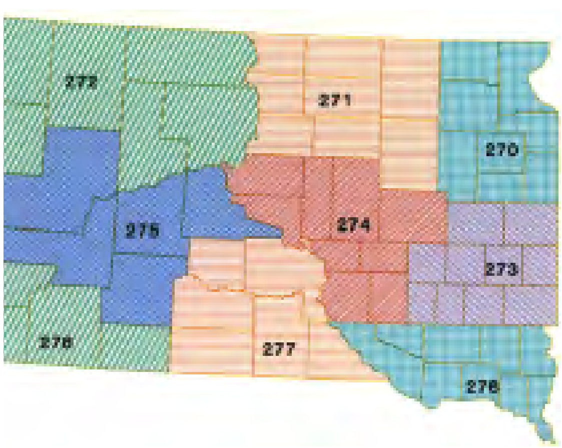
tribution regions: Rhode Island



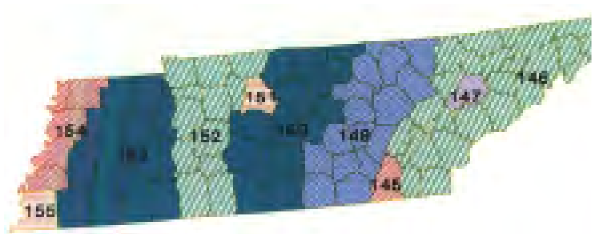
Milk distribution regions: South Carolina



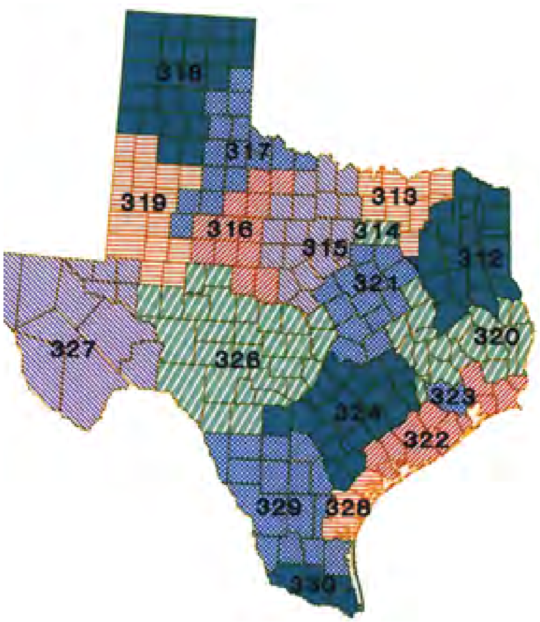
tribution regions: South Dakota



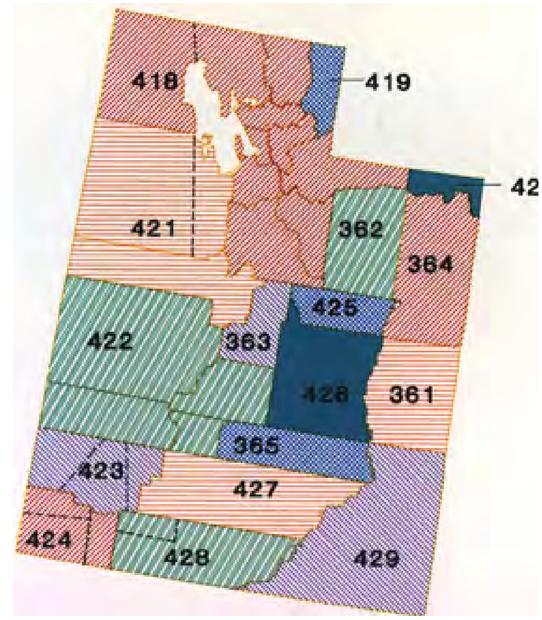
Milk distribution regions: Tennessee



tribution regions: Texas

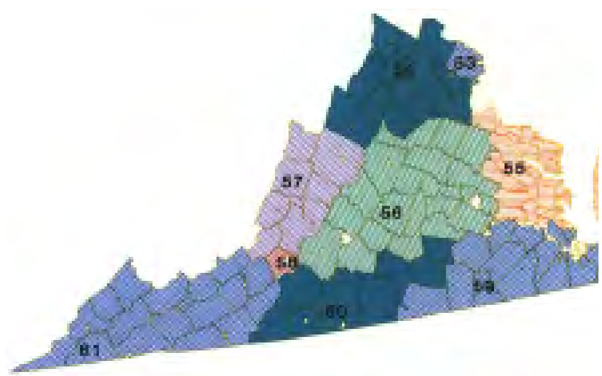


Milk distribution regions: Utah

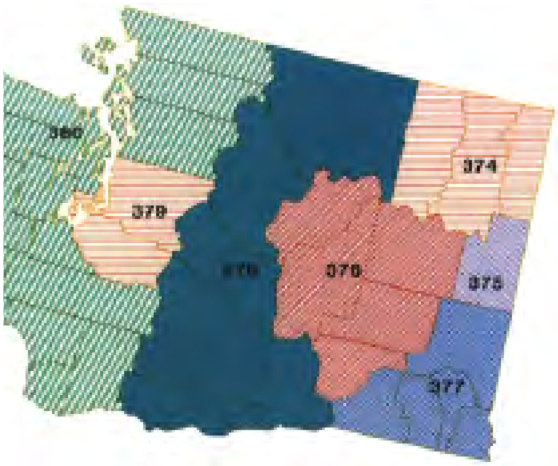


tribution regions: Vermont

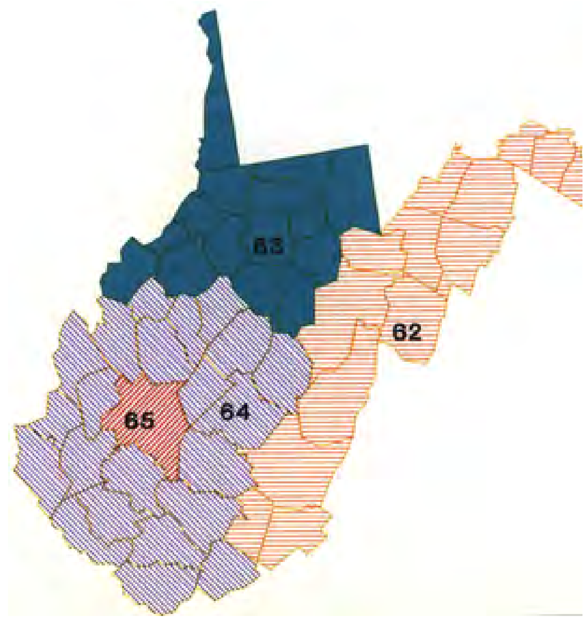
Milk distribution regions: Virginia



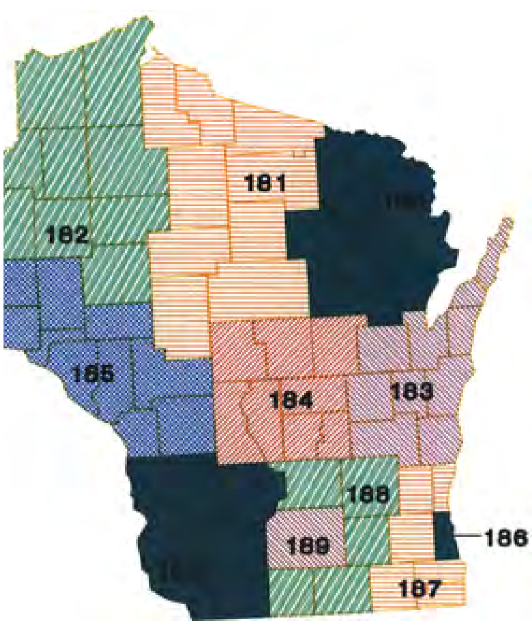
tribution regions: Washington



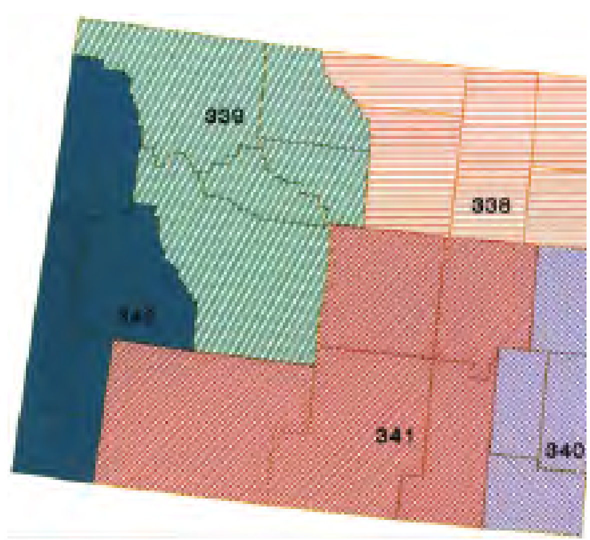
Milk distribution regions: West Virginia



tribution regions: Wisconsin



Milk distribution regions: Wyoming



Metabolism and Dosimetry of ^{131}I

Contents

A6.1. INTRODUCTION

The calculation of radiation dose to the thyroid gland from ^{131}I requires the assignment of numeric values to various biologic parameters that influence the concentration of the radionuclide within the thyroid. These parameters include the fractional uptake of iodine from the blood stream, the mass of the thyroid gland, and the retention of the radioiodine by the thyroid.

This report discusses the factors that alter the radioiodine concentration in the normal thyroid gland. Among the most important of these are: (1) the age of the exposed individual and the level of stable iodine in the diet, since they can considerably affect the size of the thyroid gland during growth and its function at all ages; (2) the dosimetric aspects of ^{131}I in the thyroid gland for normal human populations; and (3) estimates for thyroidal doses for various age groups per unit of assimilated radioiodine.

A6.1.1. The Iodine Cycle

Iodine-131, when incorporated into the body, follows the same pathway as the stable isotope of iodine, ^{127}I. Iodine, a required trace element, is a component of hormones produced by, stored within, and released into the blood from the thyroid gland. The thyroid hormones, thyroxine (tetraiodothyronine) and triiodothyronine, are required for normal growth, development, and metabolism.

Iodine in a water-soluble form, usually iodide, is readily absorbed into the blood from the gastrointestinal tract, lungs, and skin. Following oral administration, most, if not all, of the iodide is rapidly absorbed from the gut into the blood stream.

Circulating iodide is removed rapidly by both the thyroid and kidneys. Usually less than one-fourth of the plasma iodide is cleared by the thyroid gland, with about three-fourths cleared by the kidneys and excreted in the urine. One or two percent of the iodide is removed by the lactating female mammary glands. A small percentage of the iodide also is removed and recirculated by the salivary glands and gastric mucosa.

Iodide enters the thyroid's follicular cells from the blood mainly by active transport and is also available as a result of the de-iodination of organic iodine-containing compounds within the thyroid gland. The iodine concentrated by the thyroid gland is subsequently incorporated into iodotyrosines and iodothyronines (the thyroid hormones), which may be stored in the colloid of the thyroid follicles until required by the body.

Iodine uptake and thyroid hormone synthesis are regulated by a hormone of the anterior pituitary, thyroid stimulating hormone (TSH), the release of which is prompted by insufficient levels of circulating thyroid hormones and by thyrotropic releasing factor (TRF), secreted by the hypothalamus. When demands for thyroid hormone cannot be met by increasing the rate of hormone synthesis and secretion, an increase in the number and size of follicular cells and the size of the thyroid gland will result from TSH stimulation until the body's demands for thyroid hormones can be met.

A number of factors influence thyroid hormone production and utilization, such as age, sex and environmental temperature. Other factors, such as the quantity of stable iodine in the diet, also influence the gland's function, and can markedly alter the uptake and retention of iodine by the thyroid, as well as the size of the thyroid. While these changes result from the homeostatic nature of the thyroid/pituitary/hypothalamic axis to maintain thyroid hormone production at an optimal level, these same changes can have an important influence on the radiation dose that results from the incorporation of ^{131}I into the thyroid gland.

A6.2. ANATOMY

The size of the normal human thyroid gland is dependent upon the age - and to a lesser extent, sex - of a person, and on the functional status of his or her thyroid, as determined by a number of dietary and physiological influences. Hence, the weight of the thyroid gland is highly variable.

The following section focuses on the "normal" thyroid size. In addressing the normal gland, however, a large fraction - perhaps the majority - of the data may be based upon thyroids that are not typical. Most of the available data originated as observations of mostly older hospitalized individuals, with, presumably, more abnormalities than a younger population.

A6.2.1. Influence of Age and Sex on Thyroid Size

A6.2.1.1. Adult thyroid weight

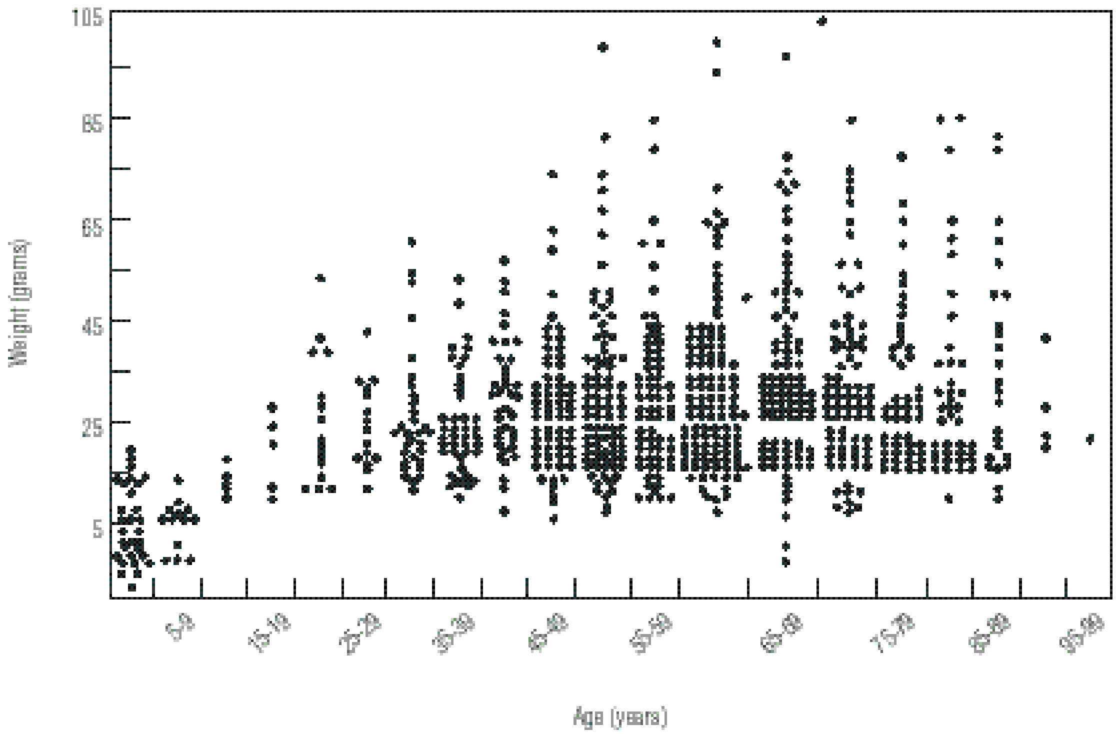
Among the largest studies of clinically normal thyroid glands is a series of 821 thyroids obtained at routine consecutive autopsies of patients without clinical thyroid abnormalities at the Mayo Clinic from 1951 to 1953 (Mortensen et al. 1955). That study showed a wide scatter of individual weights at all ages (*Figure A6.1*), with some tendency for adult weights to increase with age (*Figure A6.2a*). The arithmetic mean of thyroid weights for people between 20 and 70 years of age graphically derived for the present report was about 29 g for men and 25 g for women. Mortensen et al. (1955) found no significant difference in thyroid weights of individuals residing in a goitrogenic versus a non-goitrogenic geographic area (*Figure A6.2b*).[1]

One of the most detailed reports of the weight of the human thyroid is that of Mochizuki et al. (1963), who studied 762 normal thyroid glands, including and extending observations reported earlier (Eisenbud et al. 1962). Thyroid glands were obtained at autopsy from individuals who died suddenly and had no known history of thyroid disease. Dissections were performed within 24 hours after death, and thyroids were placed in preweighed plastic bags to prevent evaporation prior to weighing. The mean (± S.D.) weight of adult thyroids (over age 18) was 16.7 ± 6.9 g. In females, the thyroids weighed 14.9 ± 6.7 g, and in males, 17.5 ± 6.8 g. There was no apparent correlation between thyroid weight and body weight, height, or surface area.

Another study is that of Wellman (1969). The original report included 936 thyroid glands obtained at the University of Cincinnati Medical Center from 1961 to 1964. The glands were

[1] See Attachment (**Section A6.5**)

Figure A6.1. Scattergram showing relationship of age of patients to weight of thyroid gland. Redrawn from Mortensen et al. (1955).



collected at autopsy and immediately weighed and frozen and kept in a frozen state until time of dissection. At that time, the thyroids were reweighed and a correction was made for any amount of dehydration secondary to freezing. The thyroids were then "meticulously dissected" and only those thyroids that were grossly normal were included. All such thyroids were then compared with the results found previously at autopsy. After review of the microscopic sections and the prosectors' descriptions, only 210 of the thyroids were thought to be normal and were included in the study. They found the mean (± S.D.) male thyroid weight to be 16 ± 5 g and the mean adult female thyroid weight to be 14 ± 5 g.

These data, with values from the literature compiled by Wellman et al. (1970), are given in *Figure A6.3.* The data from Mortensen et al. (1955), also shown in *Figure A6.3,* were derived by Wellman et al. by plotting the Mortensen et al. (1955) data as a population distribution taking the median value and applying a correction factor (80%) for nonthyroid tissue contributing to the measured weight (Attachment, **Section A6.5**). This resulted in a corrected median figure from the Mortensen et al. data of approximately 20 g for the adult thyroid weight.

Dunning and Schwarz (1981) reviewed the literature on thyroid weight measurements, including the series by Mochizuki et al. (1963), and by Wellman et al (1970). On the basis of "255 single observations of adult thyroid mass from the literature combining both single observations and sample averages," they estimated the adult (above age 18) thyroid weight to have a mean of 18.3 g (median of 16.5 g) and a range from 2 to 62 g.

The data summarized here are derived only from studies within the U. S., and obtained before 1965. Studies from other countries appear to provide somewhat higher weights (Agerbaek 1974; Hegedus et al. 1983; Rasmussen and Hjorth 1974). A study in Copenhagen (Hegedus et al. 1983) reported on the analysis of thyroid volume by ultrasound and validated the method by comparison to the volumes of the glands when surgically removed.[2] This study showed a mean thyroid volume of 18.6 ± 4.5 ml (male, 19.6 ± 4.7 and female, 14.7 ± 4.2 ml). The influence of body weight on the thyroid volume was 3 times greater than was that of age and explained the difference between the thyroid gland volumes of males and females solely by the difference in body weight. The values obtained in Copenhagen were lower than those measured by Agerbaek (1974) of presumably healthy accident victims in Jutland, Denmark, where a mean thyroid weight of 24.8 g (25.5 g for males and 22.9 g for females) was found. Here, no correlation

[2] The existence of more recent studies, especially those pertaining to anatomic data obtained from ultrasound examinations, is recognized. These data have been published subsequent to the preparation of the initial drafts of this appendix and are consistent with the analysis, results and conclusions presented herein.

Figure A6.2. Relationship of age and (a) sex and (b) geographic residence to weight of thyroid gland. Redrawn from Mortensen et al. (1955).

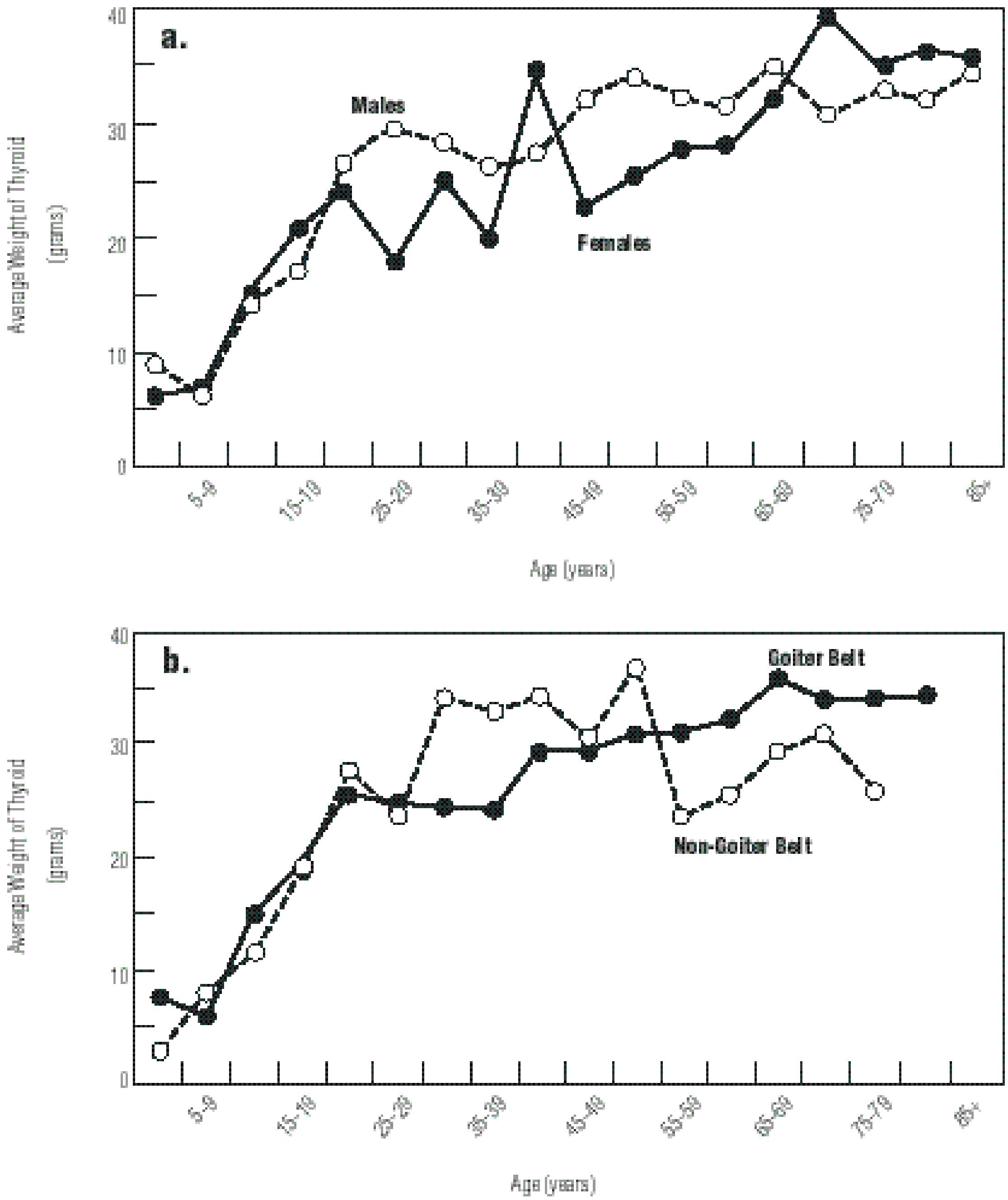
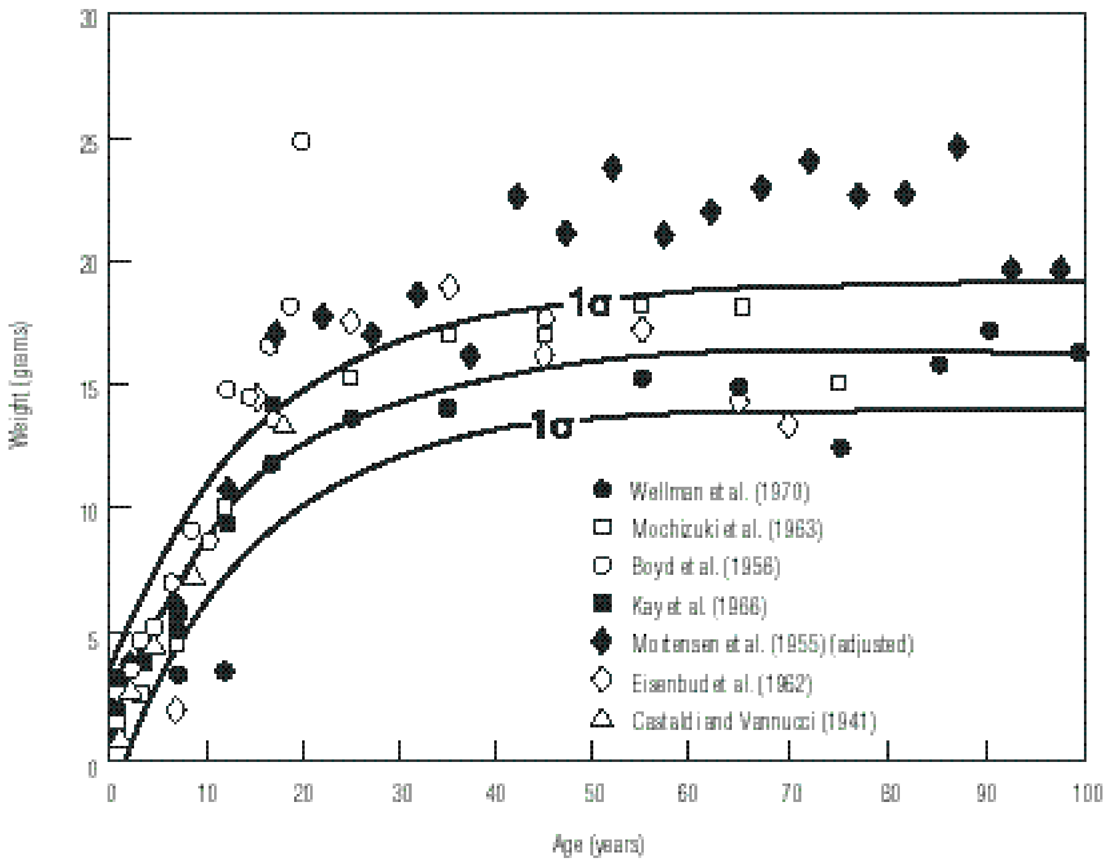


Figure A6.3. Thyroid gland weight as a function of age. Modified from Wellman et al. (1970).



with age was found, but a significant correlation with body weight was apparent in males. The median thyroid weight for the 156 males was 22.8 g, and for the 61 females, 19.3 g.

The ICRP (1975) in its Report of the Task Group on Reference Man suggests a reference adult male thyroid weight of 20 g and for adult female of 17 g. The 20 g weight was also given earlier as the standard adult thyroid weight (Spector 1956).

A6.2.1.2. Geographic variation

Because of the increased prevalence of goiter in the north and central U.S. early in this century, thyroids from individuals living in that region are generally believed to weigh somewhat more than those in the coastal areas. Kay et al. (1966) found thyroid weights of children in Rochester, Minnesota and Detroit, Michigan were significantly greater than those in eastern cities. However, the data of Mortensen et al. (1955), primarily from older people, do not suggest a consistent geographical difference. In addition, thyroid weights from New York (Mochizuki et al. 1963) and Cincinnati (Wellman et al. 1970) are almost identical.

A6.2.1.3. Summary

The most striking characteristic of the measured thyroid weights appears to be the large variability in individual measurements (*Figure A6.1*). There is a general tendency for the gland weight in men to be slightly greater than in women (*Table A6.1*). Since in any individual the error of any weight estimate will be large, it appears reasonable to use a mean adult weight estimate of 17 g, with a value of 18 g for men and 16 g for women.

In some studies (Mochizuki et al. 1963; Mortensen et al. 1955), adult thyroid weights increased with age. In others, (Hegedus, 1983; Wellman et al. 1970), they did not.

A6.2.2. Thyroid Weight in Children

The most detailed study of thyroid weight in children is that of Kay et al. (1966), who studied 537 histologically normal glands of children through the age of 19. These glands were obtained from six hospitals across the U.S. The authors' analysis of the data did not indicate significant weight differences between male and female thyroids. The weights of glands from midwesterners were about 20% higher than easterners. They fitted their data by the method of least squares and derived the following expression for estimating thyroid weight for people up to age 19:

$$T = 1.48 + 0.054 \times A \qquad (A6.1)$$

where:

T is thyroid weight in grams

A is age in months

Their formula also fits the data of Wellman, quoted by Kereiakes et al. (1972). The findings of Mochizuki et al. (1963) are also in general agreement (*Figure A6.4 and Table A6.2*).

A6.2.2.1. Fetal thyroid gland weight

The human thyroid gland begins its anatomic development near the end of the first trimester of gestation. Its functional development begins at the same time, as discussed below in **Section A6.3.6.**

An early study of human prenatal growth in the U.S. (Jackson, 1909) contained data on the fetal weights of 26 thyroid glands and the weights at term of 37 others. Their average weights ranged from 0.07 g in the fourth month to 3.4 g at birth.

The sizes of the thyroids in these studies were considerably larger than those reported later in the scientific literature, particularly in the later stages of gestation. The larger size probably reflects temporal and geographical differences in the iodine content of the diet.

Fetal thyroid weights were reported more recently by Eisenbud et al. (1963). These data were part of a larger body of

Table A6.1. Adult thyroid weight (U.S.), in grams

Reference	Male	Female	Mean
Mortensen et al. (1955)* 1951 - 1953 (Midwest)	29	25	28
Mochizuki et al. (1963) (±S.D.) (New York)	17.5 (±6.8)	14.9 (±6.7)	16.7 (±6.9)
Wellman (1969) (±S.D.) (Ohio)	16 (±5)	14 (±5)	
Wellman et al. (1970)			16
Dunning and Schwarz (1981) (recalculation of other published data)			18.3
Spector (1956) (review)			20
ICRP (1975) (review)	20	17	

* See attachment (**Section A6.5**)

Figure A6.4. Thyroid gland weight as a function of age for children.

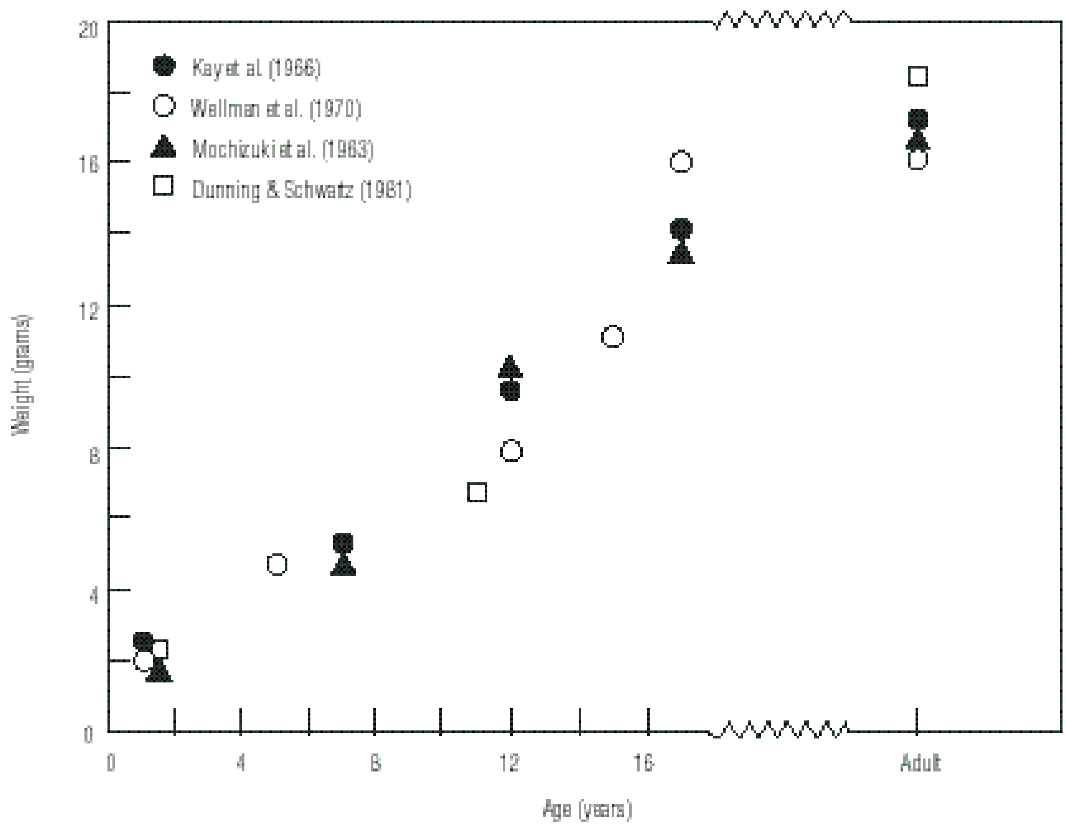
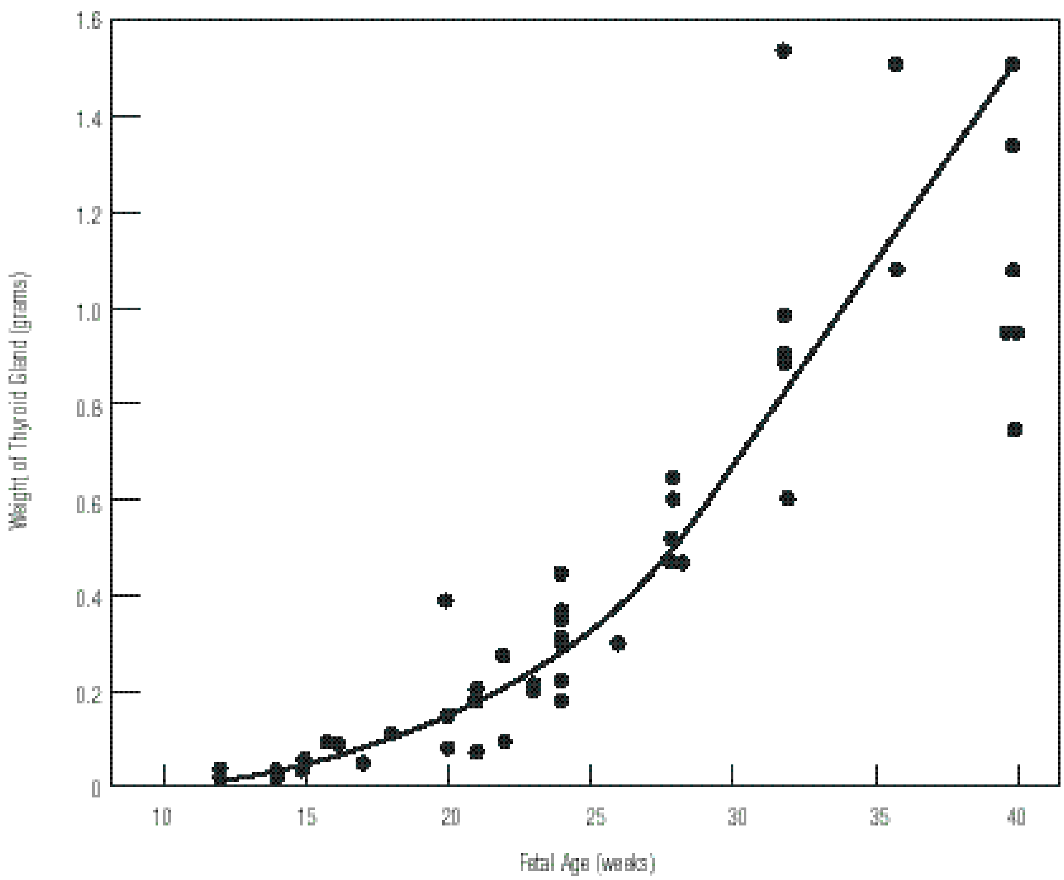


Table A6.2. Children's thyroid weights (grams) as a function of age

Reference	Age in Years								
	Newborn	1	0.5 to 2.0	5	4 to 10	10 to 14	15	6 to 16	15 to 19
Kay et al. (1966)(±SD)	1.5±0.7		2.6±1.4		5.3±2.1	9.6±5.1			14.2±5.2
Kereiakes et al. (1972)	1.5	2.2		4.7		8.0	11.2		16
Mochizuki et al. (1963) (±S.D.)	1.0±0.1	1.8±0.5	1.9±0.5		4.7±1.4	10.2±2.5			13.6±3.5
Dunning and Schwarz (1981)	1.4		2.3					6.7	

Figure A6.5. Thyroid gland weight as a function of fetal age. Data from Eisenbud et al. (1963) and Evans et al. (1967).



data on thyroid weights obtained at autopsy in New York City (Mochizuki et al. 1963). The values, obtained from 31 fetuses, ranged from 0.02 g at about 3 months to 1.5 g at full term.

Costa et al. (1965) reported the weights of 34 fetal thyroid glands obtained for an Italian study on maternal and fetal thyroid and pituitary function. Their weights ranged from 0.02 g at 12 weeks of gestation to 1.9-3.2 g at term.

Aboul-Khair et al. (1966) also reported the thyroid weights from 29 fetuses in Scotland. They found thyroid weights that ranged from 0.02-0.03 g at 13-14 weeks to up to 0.2 g at 20 weeks. The most mature thyroid (23 weeks) in their study weighed 0.17 g.

Evans et al. (1967) reported weights on 18 fetal thyroid glands in the U.S. Their thyroid weights ranged from 0.05 g at about 12 weeks to 0.7-1.5 g at term.

The combined American data (*Figure A6.5*) suggest a curve that departs from zero at 12 weeks of age. Midway through development, the fetal thyroid gland weighs about 0.12 g, increasing to about 0.6 grams by 30 weeks. At parturition, the thyroid gland weighs about 1.5 g.

A6.2.3. Influence of Thyroid Function on Thyroid Size

When thyroid hormone output from the thyroid gland is lower than required, the pituitary gland responds by releasing more thyrotropin (thyroid stimulating hormone, TSH). If the thyroid cells respond normally, a persistent increase in TSH causes them to hypertrophy and to increase in number, and thyroid gland enlargement results. Dietary iodine deficiency produces endemic goiter by this mechanism. A small goiter (about 2 or 3 times normal size) can occur when iodine intake is chronically below 20 μg per day (Stanbury et al. 1954; Wayne et al. 1964).

A6.2.3.1. Goitrogenic regions

In the past, iodine deficiency goiter was found across the northern U.S. and as far south as Nevada, Utah, and Colorado in the west, and Tennessee, Kentucky, and Virginia in the east (*Figure A6.6*). It disappeared from the U.S. before 1940, as evidenced by the low rate of goiter found in World War II recruits (0.06%) (Kelly and Snedden 1960). People who resided in these areas before 1940 might be expected to have larger than "normal" thyroid glands because of the prior iodine deficiency, although

normal function would be expected (**Section A6.3.2.1**).

Antithyroid substances in the diet, chemicals that interfere with hormone synthesis, are thought to exacerbate iodine deficiency goiter in some regions of the world, but firm evidence in support of this belief is lacking. Such substances may be responsible for small pockets of endemic goiter in the U.S. where iodine intake is adequate (e.g., in eastern Kentucky (London et al. 1965), and northern Virginia (Vought et al. 1967)). These goiters are small (enlarged by a factor of < 3), and the etiologic agent or agents have not been identified.

Iodine excess can cause goiter in susceptible individuals (Wolff 1969), and is known to cause endemic goiter in northern Japan (Nagataki et al. 1967). In the U.S., iodide goiter occurs sporadically and infrequently, and most often from medicinal treatment. It occurs when the plasma iodine level is above 20 $\mu g\ d^{-1}$, a level much higher than is achieved even at the highest dietary intake encountered in the U.S.

A6.3. PHYSIOLOGY

A6.3.1. Incorporation of Radioiodine

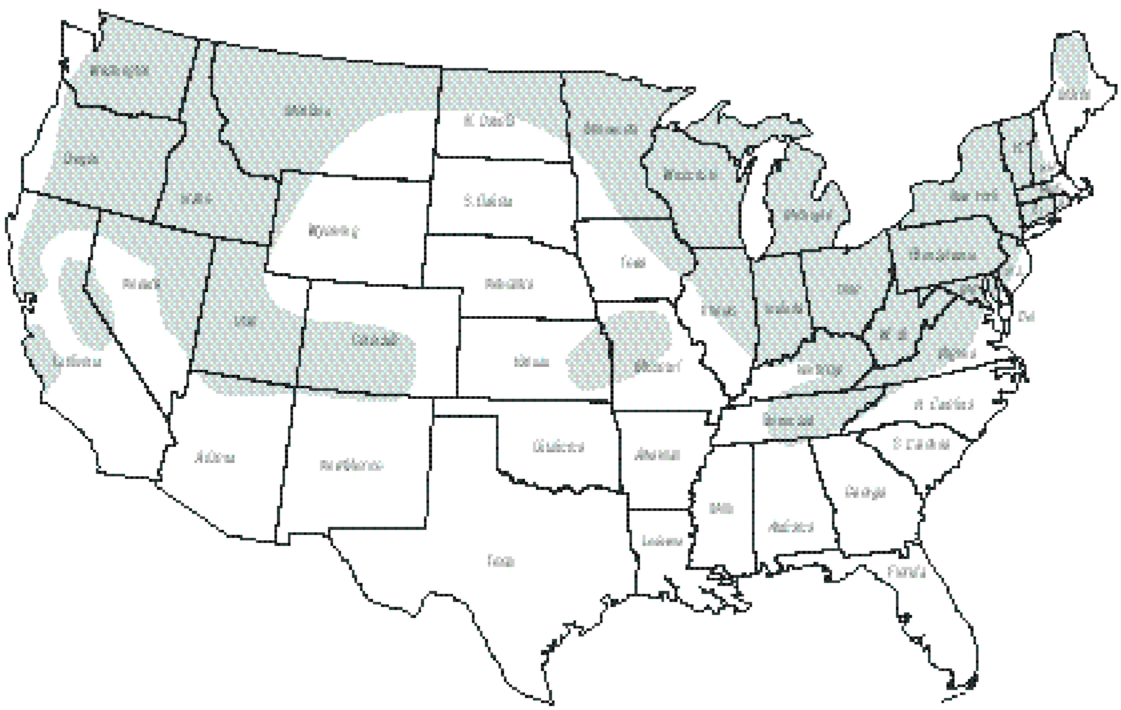
Iodine-131 has three principal routes of entry into the body: ingestion, inhalation, and absorption through the skin. Ingestion is the most important means of entry of ^{131}I present in the normal environment; inhalation and topical absorption are generally considered to be less important.

Generally one-fourth or less of the ingested ^{131}I is taken up by the thyroid gland. Peak uptake of ^{131}I in the thyroid usually occurs 1 to 2 days after ingestion. Under normal conditions, ^{131}I is lost from the thyroid gland with an effective half-life of about 1 week, where the effective half-life expresses the removal of ^{131}I resulting from physical decay and biological turnover.

Following inhalation of ^{131}I, the same partitioning of the radionuclide occurs, with less than one-fourth of the inhaled activity depositing in the thyroid gland. Some models for the metabolism of inhaled radioactivity suggest a slightly lower uptake for inhaled radioiodines than for ingested radioiodines. Because of the high solubility of iodine, however, it is reasonable to assume similar uptakes from both ingested and inhaled ^{131}I.

When ^{131}I is applied to the skin, it appears in the blood soon after application and is taken up by the thyroid gland, as with other modes of exposure. With topical exposures, however, the peak uptake is lower and later than occurs following oral administration of ^{131}I (as demonstrated in sheep (Wood et al. 1964)).

Figure A6.6. Geographic distribution of iodine-deficiency (shaded area) in the U.S. before 1940. Modified from Kelly and Snedden (1960) and Oddie et al. (1970).



Regardless of the mode of exposure, the actual uptake and retention of ^{131}I by the thyroid gland is determined by a number of intrinsic and extrinsic conditions, including the subject's thyroid hormone requirement, age and sex, and the iodine content of the diet. These have considerable influence on the behavior of the radionuclide within the body and on the subsequent radiation dose to the thyroid.

A6.3.2. Radioiodine Uptake and Retention

A6.3.2.1. Influence of dietary iodine

Considerable data exist concerning the intake of iodine in the U.S. and its influence on the fractional uptake of iodine by the thyroid gland. The dietary allowance of iodine recommended by the National Research Council (NRC 1989) is 150 μg d^{-1} for adults and adolescents, and 40 to 120 μg d^{-1} for younger children. This daily intake of iodine is associated with the absence of iodine deficiency goiter in a population.

In the steady state, iodine intake can be equated with urinary iodine excretion since only 10 to 15 μg d^{-1} are excreted in the feces and much less is eliminated by other routes (Robbins et al. 1980). For the following discussion, iodine intake was evaluated from 24-h urinary iodine content, from the urinary iodine/creatinine ratio in random samples, from fractional uptake by the thyroid gland, and from food analysis.

Over the past several decades, dietary iodine intake has increased. Between 1940 and 1950, intake was about 150 μg d^{-1}, and between 1950 and 1960, it ranged from 150 to 250 μg d^{-1} (Oddie et al. 1968a; Pittman et al. 1969). These data were obtained mainly in the northeastern states and to a lesser extent in the southeast and the Pacific Coast (California). From data obtained between 1963 and 1966, Oddie et al. (1970 and personal communication) estimated the geographic distribution of iodine intake in the country. The highest levels (392 to 738 μg d^{-1}) were in the southwest and the lowest (238 to 391 μg d^{-1}) were in the northwest and northeast. The area including northern and central Nevada and Utah had iodine intakes in the middle to lower ranges (*Figure A6.7*). In southern Nevada and Utah in 1963 to 1966, iodine intake was relatively high (392 to 499 μg d^{-1}), and urine iodine measurements conducted in 1966-1967 gave a mean excretion of about 300 μg d^{-1} (Rallison et al. 1974). In 1968 to 1970, a representative 10-state survey by the U. S. Public Health Service (Trowbridge et al. 1975a) showed the median urinary iodine/creatinine ratio to be 250 μg/g, with the highest levels above 800 μg/g; there was no iodine deficiency in any region. The calculated median iodine intake for a 60-kg adult, based on urinary creatinine of 0.025 g/kg body weight, is 375 μg d^{-1}. A four-state survey of children found the mean iodine excretion to be 443 μg d^{-1} (Trowbridge et al. 1975b). Between 1974 and 1980, dietary iodine analysis by the Food and Drug Administration gave an estimated intake from food of 400 to 600 μg d^{-1}, and food analysis in 1963 indicated an average intake in both adults and children of about 400 μg d^{-1} (Allegrini et al. 1983). To these values, "discretionary" intake from iodized salt (300 to 500 μg d^{-1}) should be added.

Based on these reports, iodine intake in the U.S. as a whole may be summarized as shown in *Table A6.3*. The estimate of 800 μg d^{-1} for the median intake after 1970 based on food analysis may, however, be an overestimate, because fractional iodine uptake by the thyroid is usually higher than would be expected for such an intake level.

A6.3.2.2. Iodine uptake

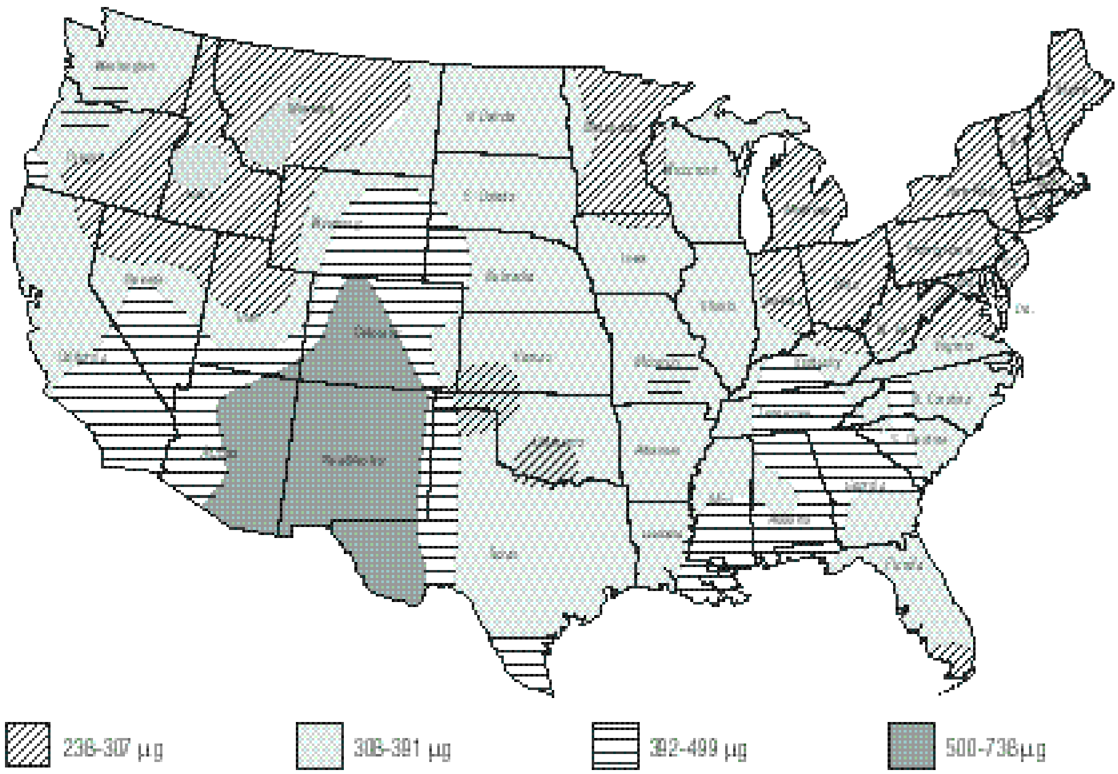
Since the evaluation of iodine intake has revealed wide deviations from the median for individual euthyroid persons, it is important to examine the effect of iodine intake on normal thyroidal iodine uptake. An acute short-term increase in iodine

Table A6.3. Dietary iodine intake in the U.S. in the past three decades.*

Years	Iodine Intake	
	Median (μg d^{-1})	Range (% of the median)
1950-1960	200	− 20% to + 25%
1960-1970	375	− 35% to + 100%
1970-1980	~ 800	− 50% to + 38%

*See **Section A6.3.2.1.** for references

Figure A6.7. Geographical distribution of daily dietary iodine intake in the U.S. between 1963 and 1966, as derived from radioiodine uptakes and renal clearance rates. Modified from Oddie et al. (1970).



intake up to 2 mg d^{-1}, well within the dietary range, has no effect on the fractional uptake (Feinberg et al. 1959; Nagataki 1974; Oddie et al. 1967; Wagner et al. 1961; Wolff 1976). If the increased intake persists for more than several days, radioiodine uptake decreases (Saxena et al. 1962; Wagner et al. 1961) (*Figure A6.8*). Adjustment to a new steady level requires a period of 2 to 4 weeks (Wayne et al. 1964). An extensive study of North Americans and others on their usual diet has shown that the mean iodine intake derived from the fractional thyroidal uptake agrees reasonably well with that derived from urinary ^{127}I excretion (Fisher et al. 1965; Oddie et al. 1970). This indicates that, on the average, North Americans are in iodine balance, although individuals may be in positive or negative balance at any point in time.

Therefore, it is reasonable to expect that the pool of ^{127}I will remain constant in the thyroids of subjects whose long-term average iodine intake is steady (although it may fluctuate from day to day), and that the fractional iodine uptake by the thyroid will not vary with randomly fluctuating iodine intake. In such circumstances, when the average iodine intake is known, the fractional iodine uptake can be estimated from a model such as that described by Stather et al. (1983). Thus,

$$U = \frac{I}{D + R} \qquad (A6.2)$$

where:

U = fractional thyroid iodine uptake

I = thyroid ^{127}I uptake rate = 60 to 70 $\mu g\ d^{-1}$

D = dietary ^{127}I intake per day

R = iodine recycled from the thyroid = 0.8 to 0.9 I.

Figure A6.8. **(a)** Measurements of accumulation of ^{131}I and ^{127}I by the thyroid and circulating Iodide during the first 10 days of increased iodine intake in a euthyroid subject. Redrawn from Wagner et al. (1961).

(b) Each dot represents the uptake of radioactive iodine by one child at the end of 2 weeks' administration of a given stable iodide level Redrawn from Saxena et al. (1962).

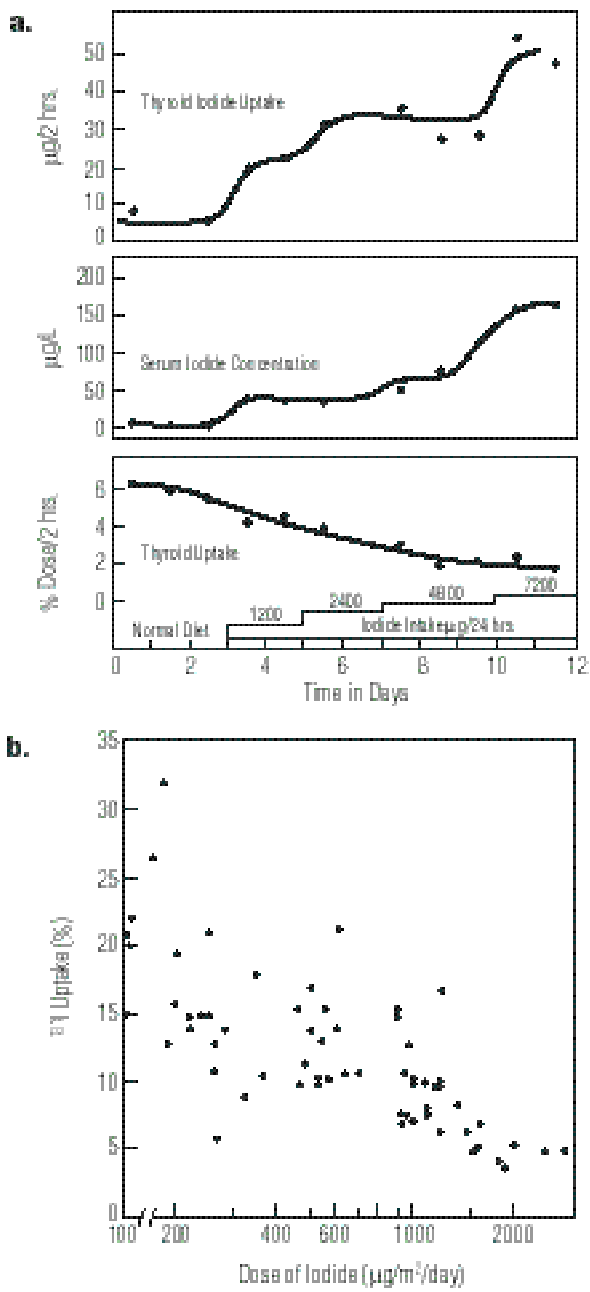


Table A6.4. Fractional iodine uptake by the adult thyroid, calculated from data in Table A6.3, and from equation A6.2*

Years	Fractional thyroid uptake	
	Median	Range
1950-1960	0.24	0.20 to 0.28
1960-1970	0.14	0.075 to 0.25
1970-1980	~ 0.071	0.052 to 0.13

*I = 60 μg d^{-1}, R = 0.8 I

From the intake data in *Table A6.3,* the thyroid uptake can be calculated (*Table A6.4*).

The estimated iodine uptake for 1970-1980 in *Table A6.4* is unrealistically low, whereas that for 1960-1970 (14%) is in reasonable accord with that now existing in North America (**Section A6.3.3.1**), and that for 1950-1960 also agrees well with reported data.

A further consideration concerns the relation of dietary iodine intake to the retention of iodine by the thyroid gland. Studies in Japan, where a chronically high iodine intake exists (Nagataki et al. 1967), in Northern American children given up to 2 mg d^{-1} (Saxena et al. 1962), and in North American adults given up to 100 mg d^{-1} (Sternthal et al. 1980) have shown that the rate of secretion of thyroidal iodine is not inhibited at intake levels up to 10 mg d^{-1} and is only slightly affected from 10 mg d^{-1} to 100 mg d^{-1}. This conclusion is based on measurement of the rate of thyroxine degradation, the serum protein-bound iodine (PBI) level, and the serum TSH level in the three respective studies. In a normal individual, the amount of ^{127}I released from the thyroid is a constant 60-70 μg d^{-1} (Robbins et al. 1980). The proportion of secreted ^{127}I that is recycled into the thyroid, however, varies with the fractional thyroid iodine uptake, and, hence, with the dietary intake (Stather and Greenhalgh 1983).

A6.3.3. Influence of Age and Sex on Radioiodine Uptake

Quimby et al. (1950) reported 24-h ^{131}I uptakes based on over 1000 procedures from 1948-1950. They found mean uptakes to be 23.5% for males and 25.8% for females.

Before 1960, radioiodine uptake measurements varied considerably due to lack of adequate and appropriate technical standardization. By about 1960, standardized procedures developed at the Oak Ridge Institute of Nuclear Studies (Brucer 1957) gained wide usage, and resulted in more consistent and more reliable thyroid uptake data. In 1960, the International Atomic Energy Agency further clarified the radioiodine uptake technique and defined the standard neck phantom (IAEA 1962).

Despite these major improvements, individual differences were still found, with a wide normal range and considerable overlap in the range of observed values among different age groups. Measurements in Europe in general were about 50% higher than those in North America. The analysis in this appendix refers to uptake measurements made in the U.S., however.

Because of the dependence of iodine uptake upon iodine intake, considerable geographic variation in uptake exists even within the U.S., as discussed in **Section A6.3.2.1**. The considerable decrease in radioiodine uptake in the U.S. beginning in the 1960s has been attributed to a widespread increase in dietary iodine content (Pittman et al. 1969).

Pittman et al. (1969) studied 24-h uptakes in 63 euthyroid subjects in 1959 and reported a mean uptake of 28.6% ± 6.57% and a normal range of 16% to 42%. Measurements with the same method in 1967-1968 showed that uptake had decreased to 15.4% ± 6.8%. Blum and Chandra (1971) reported a normal thyroid uptake range of 20 to 45% in the 1960s. The study of Oddie and Fisher (1967) of many medical centers across the U.S. reported a mean normal uptake of 25.6% ± 8.3%. Dunning and Schwartz (1981) recalculated data from a number of studies done prior to about 1975, and found a mean of 19% and a median of 17%, with an observed range of 8% to 46%. The median and the lower limit are in accord with the calculated values in *Table A6.4* for 1960 to 1970.

Several studies have reported normal values for 24-h uptakes in the 1950s and 1960s to lie between 15% and 45%, with an overall range between 9% and 55% (*Table A6.5*). More recent studies (after 1970) have a normal mean uptake in the range of 15% to 20%.

Geographic variations in thyroidal iodine uptake are suggested by urinary iodine excretion data of Oddie et al. (1970). From their data, a mean uptake value of 14% can be calculated for the southwest, 16% for the Gulf states, 26% for the northeast corridor and 20% for the rest of the U.S.

A6.3.3.1. Sex differences

Most investigators have not found significant sex differences in the radioiodine uptake. Those that have been reported appear to be relatively small. Quimby et al. (1950) found slightly higher uptakes in females than males (25.8% compared to 23.5%). Oddie et al. (1968b, 1970) suggested that the iodine intake is about 35% higher in males than females, which would correlate with a lower uptake in males. This was also found by Ghahremani et al. (1971) reporting a 17.8% mean uptake in males and 21% in females, and by Robertson et al. (1975), who reported uptakes of 16.9% in males and 19.6% in females with an overall average of 18.2%.

A6.3.3.2. Influence of age

There is general agreement that radioiodine uptake decreases with age. Quimby et al. (1950) showed significant (but probably not clinically important) decreases in thyroidal uptake of ^{131}I with age.

The average values declined from 27% uptake at < 20

Table A6.5. 24-h thyroid radioiodine uptake in the U.S. as a function of age (before 1970). (Percent of orally administered dose, mean ±SD, and range.)

Reference	Adults	Children (age in years)				
		Newborn	0.5 to 2	3	5 to 10	6 to 16
Van Middlesworth (1954)		69.7*				
Oliner et al. (1957)	32.7 ± 7				28.2	31.7
Pittman et al. (1969)	28.6 ± 6.5 15.4 ± 6.8					
Ogborn et al. (1960)		20.3 ± 8.5 (3-7 days)				
Fisher et al. (1962)		62 (37-82)** 72 (34-93)***				
Kearns and Philipsborn (1962)	41 (23-69)	75 (30-100)		30 (10-42)	34 (6-78)	31 (14-50)
Morrison et al. (1963)		70 (65-75)* 50 (35-60)****				
Van Dilla and Bulwyler (1964)	23.1		20			23
Cuddihy (1966)	22.5					
Oddie and Fisher (1967)	25.6±8.3					
Kereiakes et al. (1972)	27		27			
Dunning and Schwarz (1981)	19	47	39			47

* Intramuscular
** Intravenous
*** Premature infants
**** Oral

years of age to 22-23% uptake for persons over 60 years of age. In some series, values remained constant until age 40 (McGavack and Seegers, 1959) or 60 (Rosenberg, 1958), with uptake decreasing thereafter. Studies of an older population (Gaffney et al. 1962) showed that the 24-h uptake did not change significantly between 50 and 89 years of age. Wellman et al. (1970) in their review of the literature suggested that the uptake decreased with age, as did others (Oddie et al. 1960). However, they suggested that the primary effect was seen in the male, whereas in the female the uptake was constant until the menopause, when it decreased.

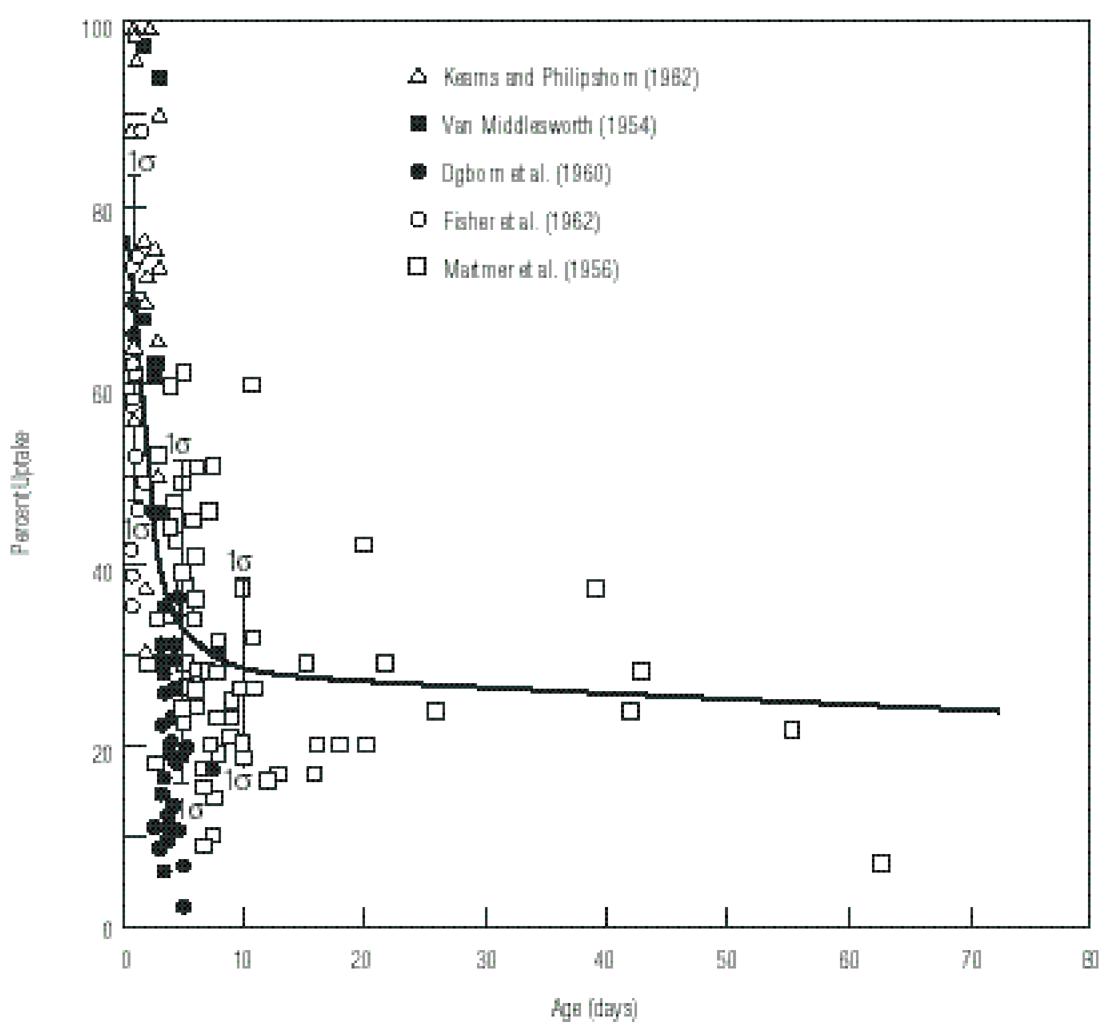
A6.3.3.3. Children

The thyroid gland is intimately involved with the processes of growth, development, and metabolism. Since those processes change with age, the function of the thyroid also changes. Its function, in terms of iodine uptake by the gland and levels of circulating thyroid hormones, appears to be greatest immediately after birth.

Thyroidal uptake of ^{131}I in the newborn is markedly elevated. Uptakes of ^{131}I in seven 2- to 3-day-old infants 24 hrs after intramuscular injection ranged from 46% to 97% of the injected dose, with an average of 70% (Van Middlesworth 1954). Among 25 infants 0.5 to 2 days of age, thyroidal uptakes 24 hrs after intravenous injection ranged from 35% to 88% of the administered dose, with an average of 61%; by comparison, seven premature infants, 0.4 to 3 days of age, had average thyroidal uptakes of 73% of the injected dose, ranging from 46 to 100% (Fisher et al. 1962).

Similar results in 25 infants less than 1.5 days of age were

Figure A6.9. Thyroid uptake of ^{131}I as a function of age in the newborn.



obtained by Morrison et al. (1963). They found that the 24-h uptake by the thyroid was high, averaging 70 percent (17 infants) after intramuscular injection of ^{131}I. Uptake was lower when ^{131}I was administered orally, averaging 50 percent for eight infants.

The elevated ^{131}I uptake of the neonate is relatively short-lived, however. It decreases to “adult” values (*Figure A6.9*) by about 2 weeks of age (Wellman et al. 1970).

A6.3.3.4. Summary

Because of the wide range of individual iodine uptake values, any combined value can only be taken as a general population guide, and therefore estimates are of little value in any individual situation. While uptakes are relatively high in the first weeks of post-partum life, they decline soon to adult-like values. Most of the combined adult values are in the range of 20% to 30% (*Table A6.5*); this seems to be a reasonable estimate of the 24-h adult uptake prior to 1960. Since 1960, in the U.S., iodine uptake values have decreased with the concomitant increase in iodine intake, reaching the current mean uptake value of about 15%.

A6.3.4. Biologic Half-Life

For iodine, the biologic half-life characterizes the thyroid’s turnover of iodine and its net release of hormone, reflecting loss from the gland and recirculation of released iodine back to the gland. A shorter half-life reflects a more rapid turnover.

The ICRP considered the biologic half-life for the adult thyroid to be 130 days (ICRP 1959) and later, 100 days (ICRP 1968). Stather and Greenhalgh (1983) in their proposed dose models selected 79 days for the adult, while Dunning and Schwartz (1981) in their combined value derived a mean of 85 days (median 72 days; range 21 to 372 days). Wellman et al. (1970), combining data from several studies, found a mean value of 68.1 days with a standard deviation of 30 days. Although Wellman et al. (1970) did not find a change in biological half-life with age, Cuddihy (1966) reported a somewhat faster turnover in children under 10 years.

There is general agreement that thyroids of children under 1 year have a considerably more rapid iodine turnover. Morrison et al. (1963) reported a rapid turnover (biologic half-life = 15 to 25 days) when tracer doses were given to newborn infants under 35 hours old. Dunning and Schwartz (1981) reported for newborn infants a mean biologic half-life of 16 days (median 13) and for children 6 months to 2 years, a mean of 13 days (median of 10). Adolescents approached the adult value with a mean of 50 days (median of 44), while the adult mean was 85 days (median 72 days). The ranges of observed values showed considerable overlap among the different age groups and there was no significant difference between the newborn and the 6 month to 2 year population. All other populations were significantly different to the 1% level.

A6.3.4.1. Summary

A thyroidal biologic half-life of 90 days is a conservative estimate for adults. Insufficient data are available to accurately characterize children, but figures of 15 to 20 days for newborns, about 20 days for children 1 to 2 years of age and 50 to 80 days for children under 10 years of age appear to be reasonable estimates (*Table A6.6*).

A6.3.5. Thyroidal Parameters in the Pregnant Woman

Thyroidal uptake of ^{131}I is increased in the pregnant woman from about the 12th week of gestation until a few weeks after parturition (Aboul-Khair et al. 1964; Halnan 1958; and Pochin 1952). Four hours after ^{131}I administration, thyroid uptakes (as indicated by the neck- thigh ratio of ^{131}I activity) were 3 to 4 times higher in pregnant than in nonpregnant women (Pochin 1952). Two hours after ^{132}I administration, neck-thigh ratios averaging 2 to 3 times the nonpregnant value were observed (Halnan 1958). Uptakes of ^{132}I 2.5 hours after administration averaged 30 to 35 percent throughout pregnancy, about 1.5 times the control (nonpregnant) value of 21 percent. Uptakes of ^{131}I 24 hours after administration were higher in pregnant women than in nonpregnant women by about 1.3, 1.6, and 2.0 times in the first, second, and third trimester, respectively (Ferraris and Scorta 1955).

The size of the thyroid gland apparently increases in pregnancy as well. Crooks et al. (1964) examined pregnant and nonpregnant women for visible and palpable goiters. They found that 71 percent of the pregnant women demonstrated mild, observable thyroid gland enlargement, while about 38 percent of the nonpregnant women did, for a ratio of about 2:1.

Few data exist on the release of ^{131}I from thyroid glands of pregnant women, It seems likely that the release of ^{131}I from the thyroid gland would be accelerated, since the processes acting to increase uptake and thyroid gland size will also influence retention values.

It should be noted that practically all these data are from Great Britain, where the dietary iodine intake generally has been lower than in the U.S. With higher dietary iodine levels, the increase in thyroid activity in pregnancy may be modulated or prevented.

A6.3.6. Thyroid Function in the Fetus

A convenient index for the expression of thyroidal radioiodine concentration by the fetus is the ratio of fetal thyroidal uptake to maternal thyroidal uptake. For determining the fetal/maternal (F/M) ratio of ^{131}I concentration, the uptake of each is given in terms of activity per unit of thyroid gland weight.

Some human data exist on the relative concentration of ^{131}I in maternal and fetal thyroid glands, indicating that the F/M ratio is very low during the first trimester of gestation and increases thereafter, exceeding unity in late gestation. For fall-out-derived ^{131}I, Eisenbud et al. (1963) found F/M ratios of 1.6 to 1.8 in three maternal-fetal pairs of thyroids, and 8.2 in a

Table A6.6. Biologic half-life of thyroid iodine (in days) as a function of age . (Mean ± SD)

Reference	Adults	Children (age in years)				
		Newborn	1	0.5 - 2.0	10	6 to 16
ICRP (1975)	80					
Van Dilla and Bulwyler (1964)	108					
Rosenberg (1958) <50 y	92 ± 17					
>50 y	63 ± 4					
Stather and Greenhalgh (1983)	79		17		72	
Morrison et al. (1963)		15-25*				
Dunning and Schwarz (1981)	85	16		13		50
Saxena et al. (1962)			20		83	
Wellman et al. (1970)	68.1 ± 30					

* Range

fourth. Beierwaltes et al. (1963) reported an F/M ratio of 1.3 for a single pair of thyroids. Other studies using ^{131}I administered in a clinical setting (Aboul-Khair et al. 1966; Costa et al. 1965; Evans et al. 1967), wherein F/M ratios were obtained 1-2 days after maternal administrations of ^{131}I, reported ratios averaging about 1.2 at the end of the first trimester of pregnancy, 1.8 during the second trimester, and 7.5 for one thyroid pair in the third trimester, as estimated by Book and Goldman (1975).

Based on these data, and on a review of appropriate large animal data, Book and Goldman (1975) estimated F/M ratios over the entire gestation period. Ratios were lower for chronic exposures, about 1 and 2 for the second and third trimesters, respectively, ranging up to 3 in the latter, than for acute (single injection) exposures. For acute exposures, F/M ratios of about 3 (ranging from less than 1 to 7) and 5 (1 to 9) were midrange estimates for the second and third trimesters, respectively. The lower ratio for chronic exposures probably reflects a more complete labeling of the maternal gland and, hence, a larger denominator.

Although little information exists about the retention of ^{131}I by the fetal thyroid, that which is available clearly shows a more rapid release of the radionuclide from the fetal gland than from the maternal gland. From human fetal thyroids, Aboul-Khair et al. (1966) estimated biological half-times of 0.7 to 1 day for iodine from data obtained between the 13th and 19th weeks of gestation. Data for late gestation are not available, but studies on guinea pigs, who, like people, have thyroids that begin to function early in gestation (Stara et al. 1966) indicate a more rapid ^{131}I turnover early in development than later (Book and McNeill 1975). Fetal guinea pigs in late gestation have a thyroidal iodine turnover approximately 4 times faster than their dams (Book 1977). Based on the human data for early gestation, and scaling from guinea pigs to people for later gestation, biologic half-times of 1, 10, and 20 days for human fetuses in early, middle, and late gestation, respectively, can be assumed.

A6.4. DOSIMETRY

A6.4.1. Uniformity of Dose

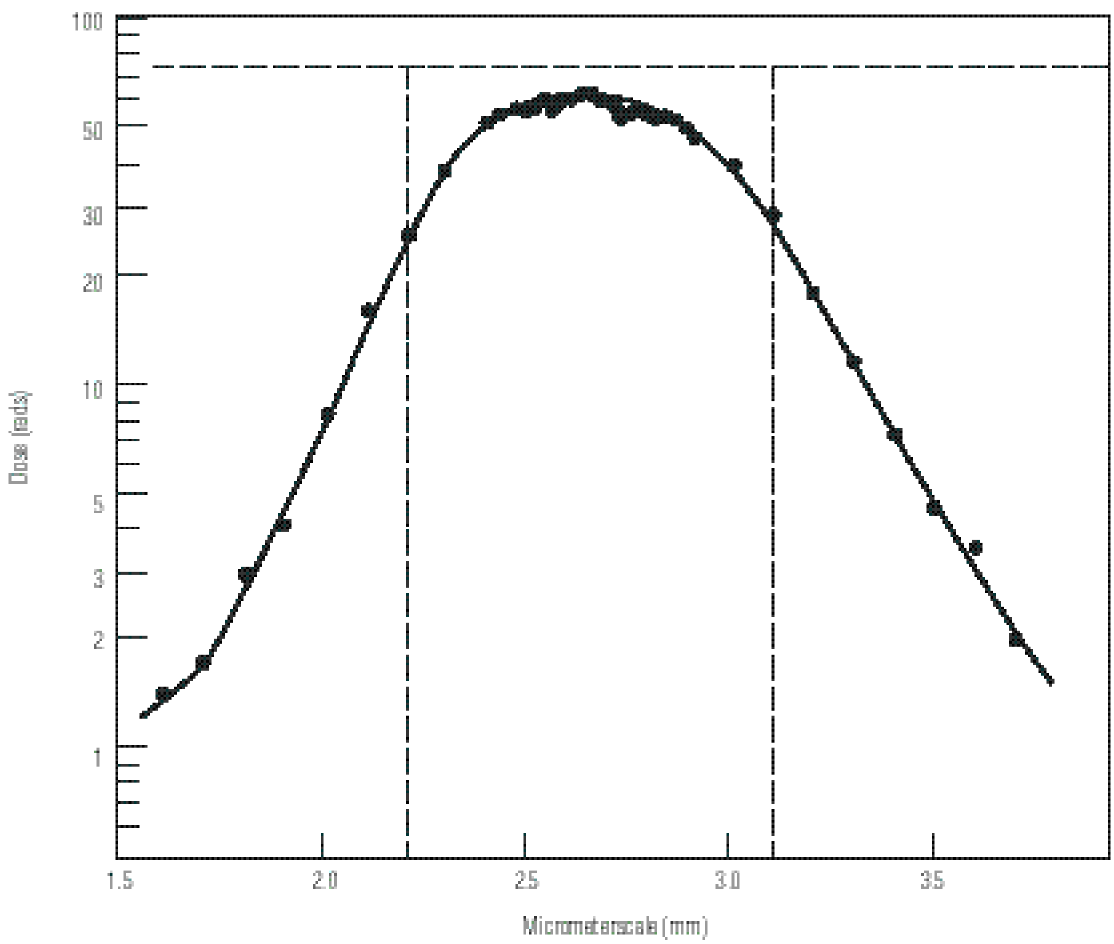
Radioiodine, when incorporated into the thyroid gland, is not distributed homogeneously throughout the follicles (Clayton 1953; Sinclair et al. 1956; Walinder 1972). Hence, radiation doses also can be inhomogeneously distributed, depending upon the energy of the emitted particle. Microdosimetric calculations pertaining to ^{125}I have suggested that the radiation dose to the follicular cell/colloid interface (where iodination occurs) is higher than the dose to cell nucleus (Gillespie et al. 1970; Greig et al. 1970; Vickery and Williams 1971), resulting from the low energy of its emissions that are consequently absorbed in close proximity to their origin. Van Best (1981, 1982) calculated

doses to thyroid follicular cells from several iodine isotopes, including ^{123}I and ^{125}I, which are of medical importance, and ^{131}I. His calculations showed the ratios between dose to the apical region of the cell and average thyroidal dose to be close to unity for ^{131}I, but relatively larger for ^{123}I and ^{125}I. From these and other published observations, it is evident that the intrafollicular dose variation, although important for iodine isotopes such as ^{123}I and ^{125}I, which have relatively weak emissions, is of little significance for ^{131}I.

The irradiation from beta particles from ^{131}I, can be considered to be fairly evenly distributed throughout the thyroid (*Figure A6.10*). Johnson and Myers (1983) indicated that in dose calculations the assumption of a homogeneous distribution of a beta-emitting radionuclide is valid, provided that the range of the particles is much longer than the distance between the follicular lumina. Such is the situation for ^{131}I in the thyroid gland, where the range of the betas is almost 2000 micrometers (Quimby et al. 1970) and follicles in the adult have a diameter of 300 micrometers, including an epithelial cell lining of about 15 micrometers (ICRP 1975). The dose from ^{131}I to the nucleus of a follicular cell is the result not only of beta particles emanating from within its own follicular lumen, but also from the lumina of other follicles (*Figure A6.10*).

Based on the above, the calculations that follow assume that: (1) there is a uniform distribution of ^{131}I in the thyroid gland; and (2) that all of the energy is retained within the gland.

Figure A6.10. The beta dose in the median plane of a mouse thyroid lobe, showing the fall-off of the dose from the center of the lobe. The broken horizontal line denotes the doses in an infinite ^{131}I source with the same concentration of activity as that in the lobe, and the two vertical lines denote the edge of the mouse lobe (data from Walinder, 1971). Since the human thyroid lobe is many times larger than the mouse's, the fall-off at the edge represents a relatively much smaller pat of the total dose.



For fetal thyroids, the calculated dose has been reduced to compensate for the loss of beta particles from the small glands (Quimby et al. 1970).

A6.4.2. Dose Calculations

For the calculation of the radiation dose to the thyroid gland from ^{131}I, equations utilize appropriate values for the energies of emitted particles and photons, the concentration of the radionuclide per gram of thyroid tissue, an expression for the retention of the radioactivity in the thyroid, and constants to relate the various dimensions.

As described by Quimby et al (1970), the standard radiobiological equation for calculating the dose from an internally deposited radionuclide, neglecting the dose accumulated during the period of uptake (~ 5% of the total dose), is:

$$D_{\beta+} = C \times T_{eff} \times (73.8\,\overline{E}_{\beta} + 0.0346\,\tau\overline{g}) \qquad (A6.3)$$

where:

- $D_{\beta+}$= the total dose from beta and gamma irradiation (rad),
- C= the maximum concentration of the radionuclide in tissue ($\mu Ci\ g^{-1}$),
- T_{eff} = its effective half-life (days),
- $\overline{E}_{\beta}$ = its average beta energy (MeV per disintegration),
- τ= its specific gamma ray constant (R per mCi h^{-1} at 1 cm), and
- $\overline{g}$ = the average geometrical factor for the tissue or organ, equal to $3\pi r$ for spheres with radii (R) $\leq$ 10 cm.

The effective half-life, T_{eff}, is calculated from the equation:

$$T_{eff} = \frac{T_{physical} \times T_{biological}}{T_{physical} + T_{biological}} \qquad (A6.4)$$

where $T_{physical}$ and $T_{biological}$ are the physical and biological half-lives, respectively.

In *equation A6.3,* the concentration of radioiodine has been assumed to be exponentially related to time, and all radiation is assumed to have been absorbed within the thyroid except in the case of the small thyroids of the fetus. As shown by Lee et al. (1979), these assumptions lead to overestimates of thyroid gland dose in the rat, with its relatively small gland.

For ^{131}I, the average beta energy, $\overline{E}_{\beta}$, is 0.18 MeV per disintegration and the specific gamma-ray constant, is 2.2 R per mCi per hr at 1 cm from a point source (Quimby et al. 1970). Whereas the physical parameters for *Equation A6.3* are well defined, the biological components of the equation are not, and must be identified for each individual under consideration. These are listed in *Table A6.7*, which summarizes information for different age groups presented in previous discussions.

A6.4.3. Dose Estimates

Doses to thyroid glands of various age groups are presented in *Table A6.8.* The highest dose per microcurie ingested is 33 rad per µCi for the newborn. The dose decreases with age until adulthood, when it is 1.6 rad per µCi ingested. For the elderly, the dose may be slightly lower. Fetal doses ranged from 0.1 rad per µCi administered to the mother in the 12th week of gestation to 6.9 rad per µCi near term.

The gamma-ray contribution to the total dose is small, amounting to only 3% of the dose in infants, rising to 6% in adults. In fetuses, the contribution of gamma-rays to the total dose is less than 2%. In most instances, given the uncertainties in the biological parameters used for dose calculations, the small gamma-ray component could be ignored.

Table A6.8 also includes values for the radiation dose in rad per microcurie present in the thyroid gland.

A6.4.3.1. Uncertainty evaluation

As has been demonstrated above, there is considerable variation in the anatomic and physiologic characteristics of the human thyroid gland. Therefore, an accurate description of any single thyroid is difficult, particularly in retrospect.

Even though the estimates of dose following ^{131}I ingestion (*Table A6.8*) represent best estimates for highly uncertain values, they are quite reasonable and realistic, based on available scientific data. Furthermore, the range of high and low estimates about these best estimates are relatively narrow, for the following reason: one may assume limits equal to 100 percent more or 50 percent less than the various biologic components of the dose equation (*Table A6.7*) to consider the influence of these parameters on the calculated dose. Hence, if the adult uptake were 12.5 or 50 percent of the administered dose, then the calculated dose would be 0.8 or 3.2 rad/µCi, respectively, compared to the best estimate of 1.6 rad/µCi. The same 0.8-3.2-rad/µCi range would result from doubling or halving the thyroid gland size. Changing the biological half-life to 45 or 180 days, resulting in effective half-lives of 6.8 or 7.7 days, leads to doses of 1.5 or 1.7 rad/µCi, showing the insensitivity of this term to large changes.

The largest underestimation of dose from the use of the 1.6-rad/µCi adult value would occur when an individual's uptake and biological half-life are twice and thyroid size is half the assumed typical values, leading to a value of 6 rad/µCi ingested. When these same biologic parameters are altered in the other extreme, a much smaller dose, 0.33 rad/µCi, results. It must be recalled, however, that the three biologic parameters under consideration are interrelated. Conditions resulting in an increased iodine uptake, for example, may also result in an increased thyroid size and a decreased biological half-life; the

resulting interplay would offset the impact of each component of the dose equation on the calculation's outcome, and would tend to return the estimate toward the 1.6-rad/µCi best estimate. For children, the range of uncertainty about the best estimates would be similar in magnitude to that presented for adults.

A6.5. ATTACHMENT

In a letter to Henry Wellman, dated April 1, 1966, J. D. Mortensen reported that in his study

... we did not meticulously dissect off all bits of thyroid tissue before we weighed them. Furthermore, the weight may be somewhat erroneous since the glands were weighed after storage in a formalin solution. They were not weighed accurately at the time of removal from the body.

Since Mortensen's main purpose was in evaluating thyroid nodules, he mentioned that they

...weighed most of the glands and did trim off most of the extra thyroid tissue that happened to remain with the glands but...did not make an accurate dissection of all bits of non-thyroid tissue and did not weigh with great accuracy. Our data as far as weight is concerned should not be considered very accurate scientifically.

Wellman, however, in his study of almost 1,000 thyroids dissected the glands "very meticulously to get accurate weights." By measuring before and after such dissection, Wellman felt that weighing the glands as Mortensen did "can overestimate the weight of the actual thyroid gland by about 20%." For a review article (Wellman et al. 1970), Wellman corrected Mortensen's data by applying a flat 20% factor (i.e., reducing weights by

Table A6.7. Metabolic and anatomic parameters for the calculation of radiation dose to the thyroid gland. Uptake and weight data are estimates for pre-1960 values. (See text for sources).

Age group	Parameter					
	Thyroid uptake (fraction)	Thyroid weight (grams)	Uptake/ gram	Thyroid radius* (cm)	$T_{biological}$ (days)	T_{eff} (days)
Adult	.25	17	0.015	1.27	90	7.3
Male	.23	18	0.013	1.29	90	7.3
Female	.27	16	0.017	1.24	90	7.3
Child						
15 y	.25	11	0.023	1.10	90	7.3
10 y	.25	8.5	0.029	1.00	80	7.1
5 y	.25	4	0.063	0.78	80	7.1
Infant (1 y)	.25	2	0.125	0.62	50	6.9
Newborn	.6	1.5	0.400	0.56	20	5.5
Fetus						
32 wk		0.8	0.085**	0.46	20	5.5
20 wk		0.15	0.051	0.26	8	4.0
12 wk		0.01	0.0085	0.11	1	1.0

* Radius for one sphere, with the assumption that the thyroid consists of two identical spheres of unit density.
** Uptake/gram for fetal thyroids are estimated from Book and Goldman (1975).

Table A6.8. Thyroid gland doses from 1 microcurie of I-131 ingested and from 1 microcurie of I-131 present in the thyroid. Data are based upon parameters presented in Table A6.7 for pre-1960 values.

Age group	Thyroid dose	
	Rad/μCi ingested	Rad/μCi retained in gland
Adult	1.6	6.4
Male	1.4	6.1
Female	1.8	6.8
Child		
15 y	2.5	9.9
10 y	3.1	13
5 y	6.6	26
Infant (1 y)	12	50
Newborn	33	55
Fetus*		
(32 wk)	6.9	100
(20 wk)	2.9	380
(12 wk)	0.1	1000

*See **Section 6.3.2.**

20%). The data presented by Wellman, and discussed in the text, represent "a non-parametric regression analysis" of all of the data in his tables and, therefore, the curve represents the mean of all the data Wellman presents.

It must also be noted that 50% of Mortensen's thyroids were nodular. Their modularity is another factor that should be taken into consideration when interpreting his results. In Wellman's series, all glands that were grossly and microscopically abnormal were eliminated, reducing the original 936 to 210.

Wellman (1969) "corrected" Mortenson's data as a population distribution and pointed out that the weights were skewed to the high side. The log-normal distribution of thyroid gland weight has more recently been discussed by Dunning and Schwarz (1981). Wellman concluded that Mortenson's data, even with a 20% correction, still were above the other data suggesting that they were probably influenced by the abnormal thyroids in their population (50%) and insufficient weight correction for non-thyroid tissue.

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Evaluation of the Influence of the Physico-Chemical Form of ^{131}I on the Thyroid Dose Estimates

Contents

ɔid dose estimates that are calculated in the report are the assumption that ^{131}I in the radioactive cloud is only ı particulate form. This appendix addresses the question ference in the estimated doses that may have resulted : simplifying assumption. The alternative approach ıve been to make more complex calculations that he behavior of various forms explicitly.

:KGROUND AND ASSUMPTIONS

sico-chemical forms of airborne ^{131}I can be classified

iodine associated with particles
molecular (I_2)
organic (such as CH_3I).

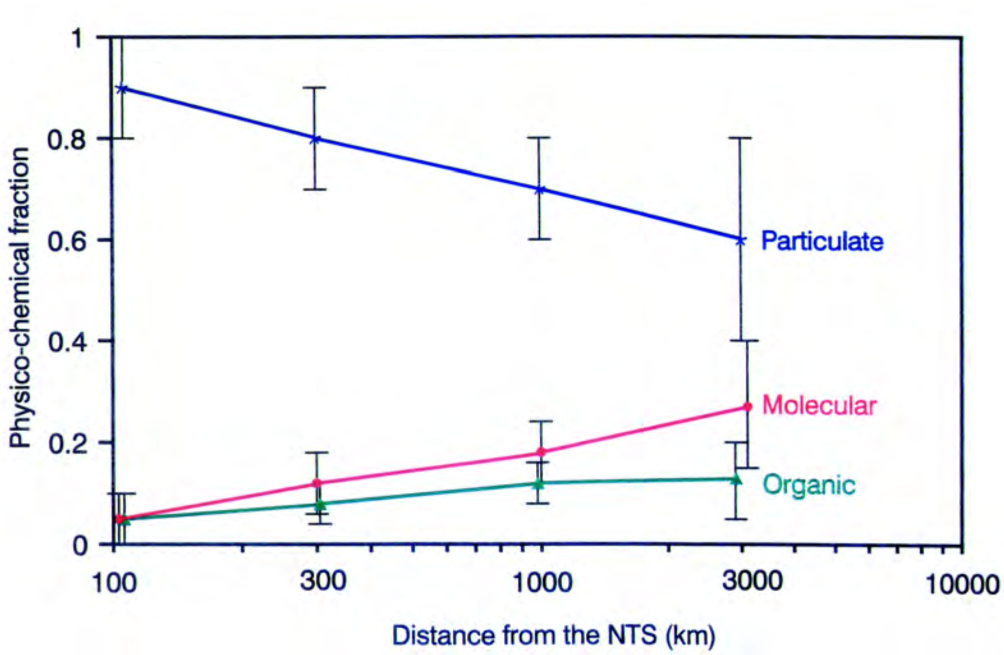
is thought that:

Most of the ^{131}I was in particulate form close to the NTS. There was a broad range of particle sizes soon after detonation. As the radioactive cloud moved away from the NTS, the inventory of large particles was progressively depleted due to deposition. The median particle size in the cloud decreased with increasing travel time and distance from the NTS. Simultaneously, chemical reactions produced organic and molecular forms.

- The fractions of elemental iodine and organic form were small in the initial radioactive cloud but beca larger with increasing time since detonation (or at greater distances from the NTS).

On the basis of observations of fallout from Chinese weapons tests in recent years for long distances from the N (Voilleque 1979) and on measurements following the Banel event of December 1970 for short distances from the NTS (1972; Pendleton et al. 1971), the relative distribution of the physico-chemical forms (PCF) considered is assumed to vaı function of distance X from the NTS as shown in *Figure A7.* in *Table A7.1*.

7.1. Relative distribution of the physico-chemical forms of ^{131}I according to distance from the NTS. (The vertical bars represent the assumed ranges of uncertainty)



.1. Best estimates and ranges of the fractions of ^{131}I associated with particles, in molecular form, and inorganic form, according to distance, X, from the NTS.

chemical form	X = 100 km		X = 300 km		X = 1000 km		X = 3000 km	
	Estimated values		Estimated values		Estimated values		Estimated values	
	Best	Range	Best	Range	Best	Range	Best	Range
:e	0.9	0.8-1.0	0.8	0.7-0.9	0.7	0.6-0.8	0.6	0.4-0.8
r	0.05	0-0.1	0.12	0.06-0.18	0.18	0.12- 0.24	0.27	0.15-0.4
	0.05	0-0.1	0.08	0.04-0.12	0.12	0.08-0.16	0.1	0.05-0.2

or the purposes of the uncertainty analysis, the statistical ons of the molecular and organic form fractions are to be uniform within the specified ranges. In the calcu- ocedure, the fraction of ^{131}I associated with particles is by subtraction of the sum of the values for the molecu- rganic forms; its statistical distribution is observed to be nately triangular.

THOD

oid doses arise from inhalation of ^{131}I-contaminated air gestion of ^{131}I-contaminated foodstuffs. A comparison of oses obtained when ^{131}I is only in particulate form and I is distributed among various physico-chemical forms is o determine whether the dose estimates calculated under ssumptions are greatly different. Because most of the ose is proportional to the deposition density of ^{131}I on n (also called "^{131}I vegetation deposition density" in this :), and since the relationship between the thyroid dose ^{31}I vegetation deposition density is independent of the chemical form of ^{131}I, the comparison of the dose esti- o a large extent equivalent to the comparison of the n densities of ^{131}I on vegetation.

ne comparison of the ^{131}I vegetation deposition densities when ^{131}I is only in particulate form and when ^{131}I is ed among various physico-chemical forms was carried unit time-integrated concentration of ^{131}I in ground- (IC$_{air}$) of 1 nCi d m^{-3} (equivalent to an average concen- ^{131}I in ground-level air of 1 nCi m^{-3} over 1 day).

ne parameters influenced by the physico-chemical form e:

the dry deposition velocity, v_g,

the washout ratio, WR,

the mass interception factor, F*

The calculations of the vegetation deposition densiti were performed for the following conditions:

- 4 distances X from the NTS: 100 km, 300 km, 1000 km, 3000 km

- dry deposition and wet deposition for eight values daily rainfall, R, that are representative values for precipitation index (*Table A7.2*).

- 3 physico-chemical forms (particles (P), molecular and organic (ORG)), the relative distributions of w are assumed to vary as a function of distance from NTS as described above (see *Figure A7.1*).

The vegetation deposition density, A_p in nCi m^{-2}, is t product of the deposition density on the ground, DG in nC and of the interception fraction, F:

$$A_p = DG \times F$$

The deposition density on the ground is:

- under dry conditions, obtained as the product of t time-integrated concentration in ground-level air, I and of the dry deposition velocity, v_g:

$$DG_{dry} = IC_{air} \times v_g$$

where:

IC_{air} = 1 nCi d m^{-3}

v_g is expressed in m d^{-1}

amount of daily rainfall, R, and the density of the air at
evel, AD:

$$DG_{wet} = IC_{air} \times R \times \frac{WR}{AD} \qquad (A7.3)$$

R is the ratio of the time-integrated concentrations of ^{131}I in rain and in air, expressed in (nCi d kg^{-1})(nCi d kg^{-1})$^{-1}$

is the density of air at ground level = 1.2 kg m^{-3}

e total deposition density on the ground, DG_{tot} is the
e depositions due to dry and wet processes:

$$G_{tot} = DG_{dry} + DG_{wet} = IC_{air} \times \left(V_g + \frac{(R \times WR)}{AD}\right) \qquad (A7.4)$$

e interception fraction is the product of the mass inter-
actor, F*, and of the biomass, Y:

under dry conditions:

$$F_{dry} = F^*_{dry} \times Y \qquad (A7.5)$$

for deposition with rain:

$$F_{wet} = F^*_{wet} \times Y \qquad (A7.6)$$

F^*_{dry} and F^*_{wet} are the mass interception factors for dry and wet respectively, expressed in m^2 kg^{-1} (dry weight of vegetation).

The estimates of the vegetation deposition densities given physico-chemical forms, daily rainfalls, and distanc the NTS, are derived from *equations A7.1* to *A7.6*:

- under dry conditions:

$$A_{p,\,dry}\,(X, R, PCF) = IC_{air} \times v_g\,(X, PCF) \times F^*_{dry}\,(X, PCF) \times Y$$

- deposition with rain:

$$A_{p,\,wet}\,(X, R, PCF) = IC_{air} \times R \times WR\,(X, R, PCF) \times F^*_{wet}\,(X, PCF) \times$$

- for the total deposition:

$$A_{p,\,tot}\,(X, R, PCF) = A_{p,\,dry}\,(X, PCF) + A_{p,\,wet}\,(X, R, PCF)$$

.2. Daily rainfalls associated with each precipitation index.

eather conditions	Precipitation, indices and amounts		Representative daily rainfall (mm, L/m^2 or Kg/m^2)
	Index	Daily rainfall range (mm, L/m^2 or Kg/m^2)	
Dry	1	0	0
Wet	2	> 0 - 0.25	0.15
Wet	3	> 0.25 -0.76	0.5
Wet	4	> 0.76 - 2.5	1.5
Wet	5	> 2.5 - 7.6	5
Wet	6	> 7.6 - 25	15
Wet	7	> 25 -76	50
Wet	8	> 76 - 127	100
Wet	9	> 127	150

ne-integrated concentration in air of ^{131}I with the mix of physico-chemical forms, $A_{p,tot}(X,R,MIX)$, is by weighting the results calculated for each physico- form according to the fraction FR(PCF) of ^{131}I in each :hemical form:

$$MIX) = A_{p,\,tot}\,(X,R,P) + A_{p,\,tot}\,(X,R,M) + A_{p,\,tot}\,(X,R,ORG)$$

$$= IC_{air} \times Y \times \Big[\Big((FR(P) \times v_g\,(X,P) \times F^*_{dry}\,(X,P)\Big)$$

$$+ \Big(FR\,(M) \times v_g\,(X,M) \times F^*_{dry}\,(X,M)\Big)$$

$$+ \Big(FR\,(ORG) \times v_g\,(X,ORG) \times F^*_{dry}\,(X,ORG)\Big)$$

$$+ \left(\frac{R}{AD}\right) \times \Big(FR\,(P) \times WR\,(X,R,P) \times F^*_{wet}\,(X,P)\Big)$$

$$+ \Big(FR\,(M) \times WR\,(X,R,M) \times F^*_{wet}\,(X,M)\Big)$$

$$+ \Big(FR\,(ORG) \times WR\,(X,R,ORG) \times F^*_{wet}\,(X,ORG)\Big)\Big] \qquad (A7.10)$$

IMATES OF THE PARAMETER VALUES

Dry Deposition Velocity

leposition velocity can be experimentally defined as the of the activity deposited per unit area of ground and of integrated concentration in ground-level air in the of precipitation.

. Fraction associated with particles

leposition velocity for particles depends on the particle ;e particles (greater than 20 μm in diameter) are from the air mainly by sedimentation; smaller particles nged from the air by impaction and turbulent diffusion. formation on particle sizes in ground-level air near the owing atmospheric tests is available mostly for the Knothole series (Cederwall et al. 1990). Activity median mic diameters (AMADs) and geometric standard devia- Ds) for particle-size distributions observed in St. JT, situated approximately 200 km from the NTS are *Table A7.3* for the tests Annie and Harry. The results are much more typical of the tests sampled in the Knothole series than those for Harry (Cederwall et al. article size distributions for both tests are characterized arge GSD values and AMAD values that tended to with time.

ssuming that the upper and lower values of the ranges e sizes are adequately represented by the values by multiplying and dividing the median estimates by e of the GSDs, the particle-size spectrum is from 0.15 3,000 μm at 200 km from the NTS.

turn reflected in the estimates of dry deposition velocity ne NTS. Cederwall et al. (1990) identified several locations w 320 km of the NTS where paired values of the time-integra concentration in air and the deposition density are availabl a number of tests. The resulting estimates of v_g from 168 p values varied over several orders of magnitude with a geon mean of 3700 m d^{-1} and a GSD of 15. This extremely large value may be partly due to the fact that the data were not s fied according to downwind distance from the NTS or to lo tion relative to the fallout-pattern centerline. In addition, t deposition density and the time-integrated concentration in may have been measured in the same general area but not ly at the same site.

Beyond 320 km of the NTS, the average particle siz expected to be smaller, resulting in turn in smaller deposit velocities. A geometric mean of 2500 m d^{-1} with a GSD of was obtained from 52 pairs of air samples and deposition related to the Tumbler-Snapper series (List 1953).

Dry deposition velocities at greater distances from t NTS have been derived from air concentrations and depos measurements by Pelletier and Voilleque (1971) of fallout from tests conducted in the Pacific and in territories of the mer Soviet Union. The measurements took place in Michig from 1962 to 1964. A distinction was made between fresh out (defined by the presence of measurable quantities of ^{14} air) and old fallout (absence of ^{140}Ba in air). According to t criterion, measurements in the contiguous U.S. following nuclear testing at the NTS would have been defined as fre fallout. The average values of v_g were computed from meas ments to be 1000 m d^{-1} during periods of fresh fallout and m d^{-1} during periods of old fallout (Pelletier and Voilleque 1971), showing presumably the effect of smaller particle si for old fallout. The GSDs associated with the results were r reported but the values of v_g during periods of fresh fallou indicated to be quite variable from week to week.

On the basis of the experimental values that have be reported, the variation with distance from the NTS of the a age values of $v_g(X,P)$ for ^{131}I associated with particles is fou be relatively well modeled with a power function. The emp function that has been adopted is:

$$v_g\,(X,P) = 20150 \times X^{-0.35}$$

where

$v_g(X,P)$ is in m d^{-1}, and X is in km.

The distribution of $v_g(X,P)$ is assumed to be log-tria for the four distances considered with the spread of values decreasing with distance as shown in *Table A7.4*. For the d tance closest to the NTS, X = 100 km, the distribution of v is assumed to have a mode equal to the best estimate and a range from 400 to 200,000 m d^{-1}. This distribution corresp approximately to the central portion (20th to 80th percent of a log-normal distribution with a GSD of 7. Deposition v ties of 400 m d^{-1} or less are associated with very small fallo

sition velocities at other distances as well. The indicated ı the modal and maximum deposition velocities with is intended to reflect the depletion of large particles cloud. The assumed variation of the modes and ranges of the dry deposition velocity for ^{131}I associated with as a function of the distance from the NTS, is illustrated A7.2.

. Molecular fraction

deposition velocities for the molecular fraction of iodine ally been derived from field experiments in which mea- s have been made of the time-integrated concentration l of the activity deposited on vegetation cut at between m above ground. The dry deposition velocities obtained ay are smaller than those derived from measurements of activity deposited on the ground since the additional n on the remaining vegetation, detritus, root mat, and ot been included. Vegetation deposition velocities for r iodine vary as a function of meteorological parameters eed, air temperature, and humidity) and of the biomass; and Sauve (1981) suggested that the vegetation deposi- ity is proportional to the biomass and to the wind speed ases by a factor of 2 for a temperature increase of 10ºC rease in the relative humidity of 25%.

order to avoid confusion between the two quantities on deposition velocity and total deposition velocity) and e the influence of the biomass, Hoffman (1977) recom- that the vegetation deposition velocity should be nor- or biomass (dry weight per square metre of ground). nalized vegetation deposition velocity v_D is expressed in rt in $m^3\ kg^{-1}\ d^{-1}$ and is related to the dry deposition ccording to:

$$v_D = v_g \times F^* \qquad (A7.12)$$

Zimbrick 1970; Vogt et al. 1976), Hoffman (1977) estimate a value for v_D of 0.1 $m^3\ kg^{-1}\ s^{-1}$ is suitable for a generic asse ment calculation; the same value, which corresponds to 90 $kg^{-1}\ d^{-1}$, is adopted in this report. The distribution of $v_D(M)$ assumed to be log-normal with a GSD of 2.0, at all downw distances.

A7.4.1.3. Organic fraction

The major organic form of iodine that is found in the atmo after a nuclear test is methyl iodide (CH_3I). Methyl iodide i that deposits on vegetation to a much smaller degree than c molecular iodine. The ratio of the vegetation deposition vel (or of the normalized vegetation deposition densities) of mo lar and organic iodine has been reported to be approximate 100 (Nakamura and Ohmomo 1980a; Nakamura and Ohm 1980b) and 200 (Heinemann and Vogt 1980). In this repor average ratio of 150 has been used, corresponding to a norı ized vegetation deposition velocity for organic iodine, v_D(O of 9000/150 = 60 $m^3\ kg^{-1}\ d^{-1}$. This value is assumed to be in pendent of distance from the NTS. The distribution of v_D(C is also assumed to be log-normal with a GSD of 2.0.

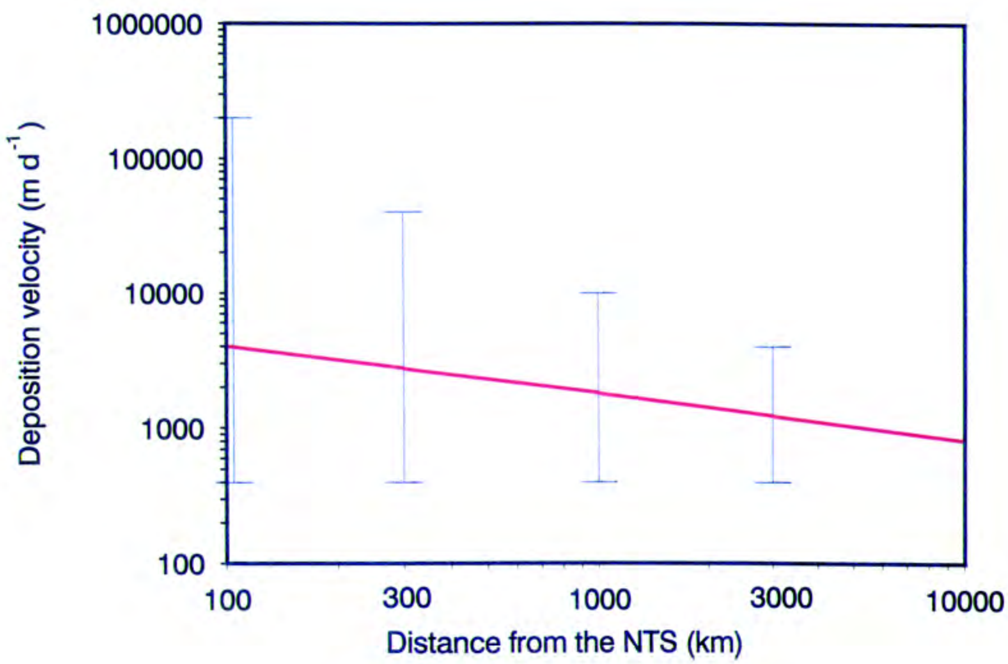
A7.4.2. Washout Ratio

The washout ratio, WR, is the ratio of the concentration of rain to that in air at ground level. The washout ratio is dim sionless but it has a different value according to whether th centrations are expressed per unit mass or per unit volume. this report, the concentrations are expressed per unit mass kg^{-1}).

.3. Variation of particle size with time at St. George, UT, for the tests Annie and Harry of the Upshot-Knothole series (Cederwall et al. 1990).

Test Annie, 1320 GMT, 17 March 1953			Test Harry, 1205 GMT, 19 May 1953		
times,GMT	AMAD (µm)	GSD	Sample times, GMT	AMAD (µm)	GSD
20	76	9	1310-1830	380	10
10	24	8	1840-2145	160	8
00	7.3	7	2150-0600	320	9
			0605-1335	12	6

7.2. Assumed variation of the dry deposition velocity (m d-1) according to distance from the NTS, for ^{131}I associated with particles. (The vertical bars rep sent the assumed ranges of uncertainty)



.4. Variation of the dry deposition velocity of ^{131}I associated with particles according to distance, X, from the NTS.

km)	Type of distribution	v_g (X,P) (m d-1)		
		Minimum	Mode	Maximum
00	Log-triangular	400	4000	200,000
;00	Log-triangular	400	2700	40,000
000	Log-triangular	400	1800	10,000
000	Log-triangular	400	1200	4,000

ıout ratio for particles has been found to increase with ize (Gatz 1977). Increasing the rainfall rate at a particu- vill lead to an increase in washout at that moment ·78). However, washout ratios for ^{90}Sr measured for ıl storms decreased when the total amount of rain for ı increased (Krey and Toonkel 1977). A similar trend d when the washout ratio was plotted against the precipitation (Krey and Toonkel 1977). Gatz (1977) d a negative correlation with storm rainfall for washout most of the elements measured, but the trends were not gnificant when analyzed statistically.

ır the present analysis, washout ratios that are consis- the previous analysis of scavenging factors and relative of wet and dry deposition for U.S. locations have been (**Chapters 3** and **7** and **Appendix 1**). Two reference ere selected: (a) 13000 for a daily rainfall amount of 1 for large particles (X = 100 km); and (b) 3000 for a ıfall amount of 1 mm and for small particles (X = 3000 ıes for other situations were derived from the reference

for a given distance, X, as a function of daily rainfall, R:

$$WR\,(X, R, P) = WR\,(X, 1\text{ mm d}^{-1}, P) \times R^{-0.7} \qquad (A7.13)$$

for a given daily rainfall, R, as a function of distance X:

$$WR\,(X, R, P) = WR\,(100\text{ km}, R, P) \times \left(\frac{X}{100}\right)^{-0.43} \qquad (A7.14)$$

ıe washout ratios obtained in this way are shown in .3 for ^{131}I associated with particles and in *Figure A7.4* ı molecular and organic forms, for a distance from the 00 km and for the range of daily rainfall considered in rt. The higher washout ratios near the NTS reflect the of larger particles in the radioactive cloud. The ratios more sharply with daily rainfall than the results report- ey and Toonkel (1977) for monthly averages or by Gatz

. Molecular fraction

es of WR(R,M) for ^{131}I in molecular form are indepen- ıe distance, X, from NTS. However, they are also to decrease with rainfall amount (Coleman and Postma reference value of 6000 was selected for a daily rainfall of 1 mm, based on the partition coefficient estimate of 1970) and typical airborne iodine concentrations. r other rainfall amounts were derived from the refer- ıe using the same decrease with daily rainfall as for the

The values of WR(R,ORG) for ^{131}I in organic form also are independent of the distance, X, from NTS. Based on the di ence in partition coefficients (Postma 1970), the reference for a daily rainfall of 1 mm is taken to be 10. The variation function of daily rainfall has been assumed to be the same that described above for particles and for elemental iodine.

A7.4.2.4. Summary

Table A7.5 summarizes the best estimates of the washout r expressed in (nCi kg^{-1})(nCi kg^{-1})$^{-1}$, for the three species of and the four distances considered in this report. *Table A7.5* includes the range of washout ratio values that is expected each case. At a given distance from the NTS, for a given ph co-chemical form and rainfall category, the lowest value (m mum) of the washout ratio is assumed to be equal to the b estimate in the next category of higher rainfall, while the h value (maximum) is assumed to be equal to the best estima the adjacent category of lower rainfall. In rainfall category (O<R<0.25 mm), the maximum value was taken to be twic mode. In rainfall category 9 (R>127 mm), the minimum va was taken to be the mode divided by 1.5. The distribution the wash-out ratios in each category is assumed to be trian the mode being equal to the best estimate.

A7.4.3. Mass Interception Factor, F*

The mass interception factor represents the quotient of the radionuclide concentration in vegetation (dry weight) and ground deposition density, immediately after deposition. It ues are expressed in m^2 kg^{-1}(dry). The mass interception fa is denoted as F^*_{dry} and as F^*_{wet} for deposition under dry a wet conditions, respectively.

A7.4.3.1. Fraction associated with particles

Values of F^*_{dry} and F^*_{wet} for particles are calculated using t following equations, which are discussed in **Chapter 4:**

- Dry deposition (F dry):

$$F^*_{dry}\,(X, P) = \frac{1 - e^{\alpha(x)Y}}{Y}$$

with

$$\alpha(X) = 7.01 \times 10^{-4}\, x^{1.13}$$

and

$$Y = 0.3\text{ kg m}^{-2}\text{, dry weight.}$$

: 2.8 m^2 kg^{-1}, which is met for any distance X greater
40 km.

Wet deposition ($R \geq 5$ mm d^{-1}) (F^*_{wet}):

$$F^*_{wet}(R, P) = 0.9 + \left(\frac{11}{R}\right) \quad (A7.17)$$

espective of the distance X from the NTS (i.e., no
nce on the particle size is considered).

Wet deposition (2.5 mm d^{-1} < R < 5 mm d^{-1}):

$$F_{wet}(R, P) = F^*_{wet}(5\ mm\ d^{-1}) = 3.1\ m^2\ kg^{-1} \quad (A7.18)$$

espective of the distance X from the NTS (i.e., no
nce on the particle size is considered).

Wet deposition (R < 2.5 mm d^{-1}):

$$(, R, P) = F^*_{dry}(X, P) + (F^*_{wet}(R_1, P) - F^*_{dry}(X, P))\left(\frac{R}{R_1}\right) \quad (A7.19)$$

= 2.5 mm d^{-1}.

. Molecular fraction

F^*_{dry} for the molecular fraction are not needed as the
on of the vegetation deposition density for that physico-
form make use of the normalized vegetation deposition
which is the product v_g x F^*_{dry}. In case of precipitation,
s of F^*_{wet} for ^{131}I in molecular form are assumed to be
smaller than the values obtained for particles far away
NTS (Hoffman et al. 1989).

. Organic fraction

F^*_{dry} for the organic fraction are not needed for the
son as for the molecular fraction. Values of F^*_{wet} for ^{131}I
c form are assumed to be equal to the values used for
olecular form.

. Summary

6 summarizes the estimated values of the mass inter-
actor. Hoffman and Baes (1979) found that the values
ass interception factor for dry conditions are log-nor-
tributed with a geometric standard deviation of 1.5. In
rt, the distribution of the values of the mass intercep-
or is assumed to be log-normal with a geometric stan-
iation of 1.5, for all physico-chemical forms, daily rain-
distances from the NTS.

ciated with particles is illustrated:

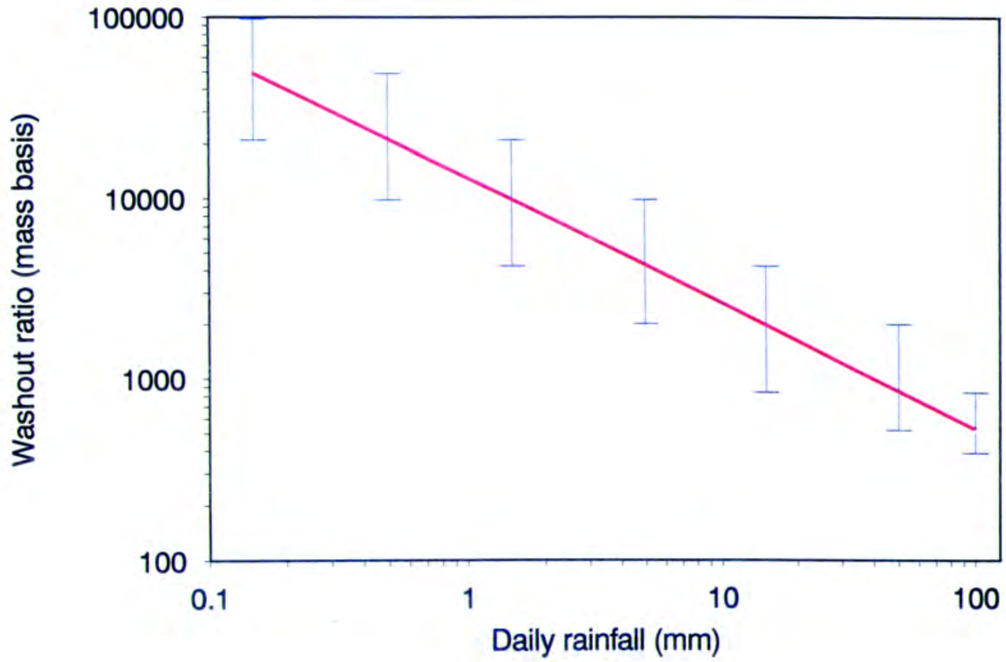
- as a function of distance from the NTS (in the abs
  of rain) in *Figure A7.5,*
- as a function of daily rainfall in *Figure A7.6.*

A7.5. RESULTS

Vegetation deposition densities have been calculated using
tions A7.1 to *A7.4*. The calculations have been made in a st
tic manner, using the distributions indicated previously for
parameter. All parameters have been assumed to be indepe
dent, with the exception of the dry deposition velocity, v_g(
and the mass interception factor, F^*_{dry}, for iodine associate
with particles at the closest distance from the NTS (X = 10
km). The distributions of the vegetation deposition densiti
have been calculated for two sets of physico-chemical form
^{131}I : (a) uniquely associated with particles, and (b) distribu
among particulate, elemental, and organic forms as shown
Table A7.1. Table A7.7 presents the estimated median values
well as the 5 and 95 percentiles, of the vegetation depositio
density, A_p in nCi m^{-2}, corresponding to a unit time-integra
concentration in air of 1 nCi d m^{-3}. The values estimated f
attached to particles and for the assumed mixture of physic
chemical forms, are shown in *Figures A7.7* and *A7.8* for dis
of 100 and 3000 km downwind from the NTS, respectivel

The medians of the ratios of the vegetation depositio
densities obtained when ^{131}I is distributed among the three
physico- chemical forms and when ^{131}I is attached to partic
$\langle A_p(mix) / A_p(P) \rangle$, are presented in *Table A7.7* along with t
and 95 percentiles of the distributions. The ratios obtained
distances of 100 and 3000 km downwind from the NTS ar
illustrated in *Figure A7.9*.

7.3. Variation of the washout ratio as a function of daily rainfall for ^{131}I associated with particles, for a distance of 100 km from the NTS. (The vertical bars represent the assumed ranges of uncertainty)



7.4. Variation of the washout ratio as a function of daily rainfall for ^{131}I in molecular and organic form .
(The vertical bars represent the assumec ranges of uncertainty)

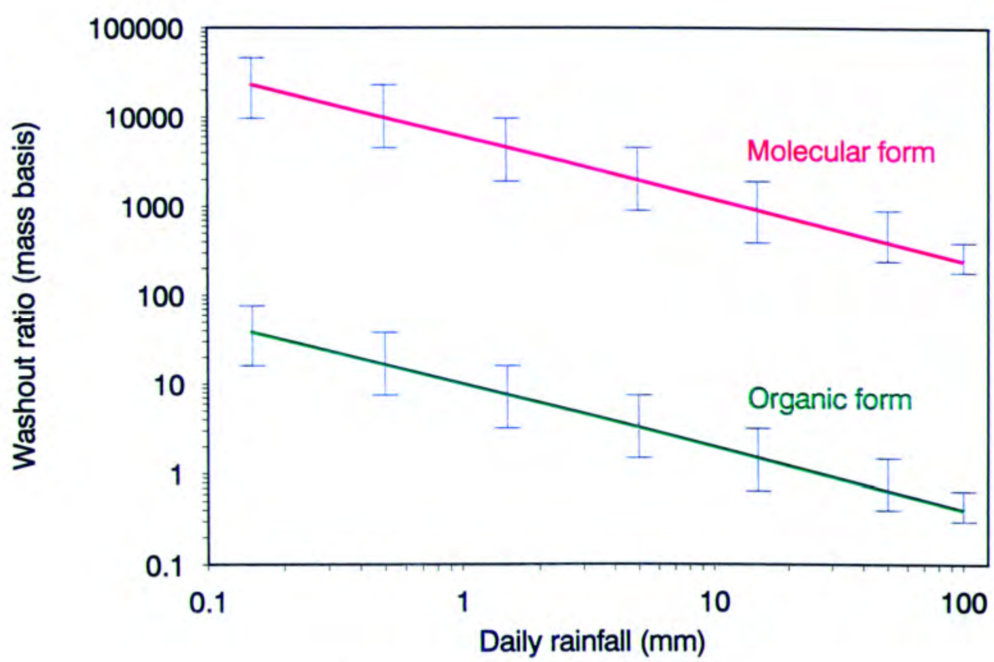


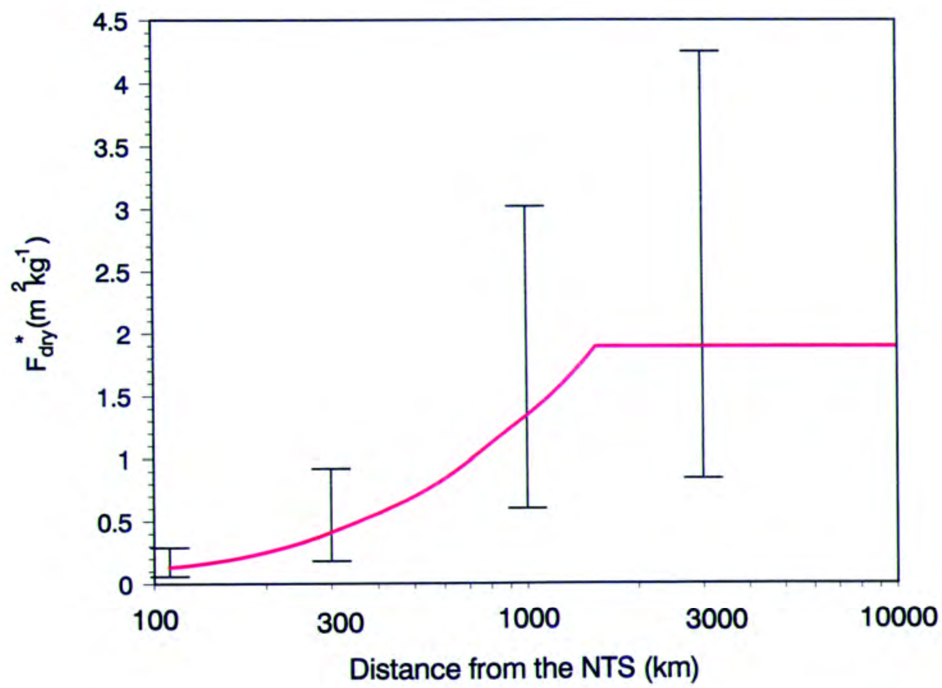
Table A7.5. Best estimates and ranges of wash-out ratios. WR {(nCi kg^{-1}) (nCi $(kg^{-1}))^{-1}$} for ^{131}I in the 3 physico-chemical forms and the 4 distances from the NTS, X (km), considered.

Prec. index	Daily rain	Particulate			Molecular			Organic		
	mm	Min.	Mode	Max.	Min.	Mode	Max.	Min.	Mode	Max
X = 100 km										
2	0.15	21000	49000	98000	9700	23000	46000	16	38	76
3	0.5	9800	21000	49000	4500	9700	23000	7.5	16	38
4	1.5	4200	9800	21000	1900	4500	9700	3.2	7.5	16
5	5	2000	4200	9800	900	1900	4500	1.5	3.2	7.5
6	15	840	2000	4200	390	900	1900	0.65	1.5	3.2
7	50	520	840	2000	240	390	900	0.40	0.65	1.5
8	100	390	520	840	180	240	390	0.30	0.40	0.65
9	150	260	390	520	120	180	240	0.20	0.30	0.40
X = 300 km										
2	0.15	13000	31000	62000	9700	23000	46000	16	38	76
3	0.5	6100	13000	31000	4500	9700	23000	7.5	16	38
4	1.5	2300	6100	13000	1900	4500	9700	3.2	7.5	16
5	5	1200	2600	6100	900	1900	4500	1.5	3.2	7.5
6	15	520	1200	2600	390	900	1900	.065	1.5	3.2
7	50	320	520	1200	240	390	900	0.40	0.65	1.5
8	100	240	320	520	180	240	390	0.30	0.40	0.65
9	150	160	240	320	120	180	240	0.20	0.30	0.40
X = 1000 km										
2	0.15	7800	18000	36000	9700	23000	46000	16	38	76
3	0.5	3600	7800	18000	4500	9700	23000	7.5	16	38
4	1.5	1600	3600	7800	1900	4500	9700	3.2	7.5	16
5	5	720	1600	3600	900	1900	4500	1.5	3.2	7.5
6	15	310	720	1600	390	900	1900	0.65	1.5	3.2
7	50	190	310	720	240	390	900	0.40	0.65	1.5
8	100	140	190	310	180	240	390	0.30	0.40	0.65
9	150	90	140	190	120	180	240	0.20	0.30	0.40
X = 3000 km										
2	0.15	4900	11000	22000	9700	23000	46000	16	38	76
3	0.5	2300	4900	11000	4500	9700	23000	7.5	16	38
4	1.5	980	2300	4900	1900	4500	9700	3.2	7.5	16
5	5	450	980	2300	900	1900	4500	1.5	3.2	7.5
6	15	190	450	980	390	900	1900	0.65	1.5	3.2
7	50	120	190	450	240	390	900	0.40	0.65	1.5
8	100	90	120	190	180	240	390	0.30	0.40	0.65
9	150	60	90	120	120	180	240	0.20	0.30	0.40

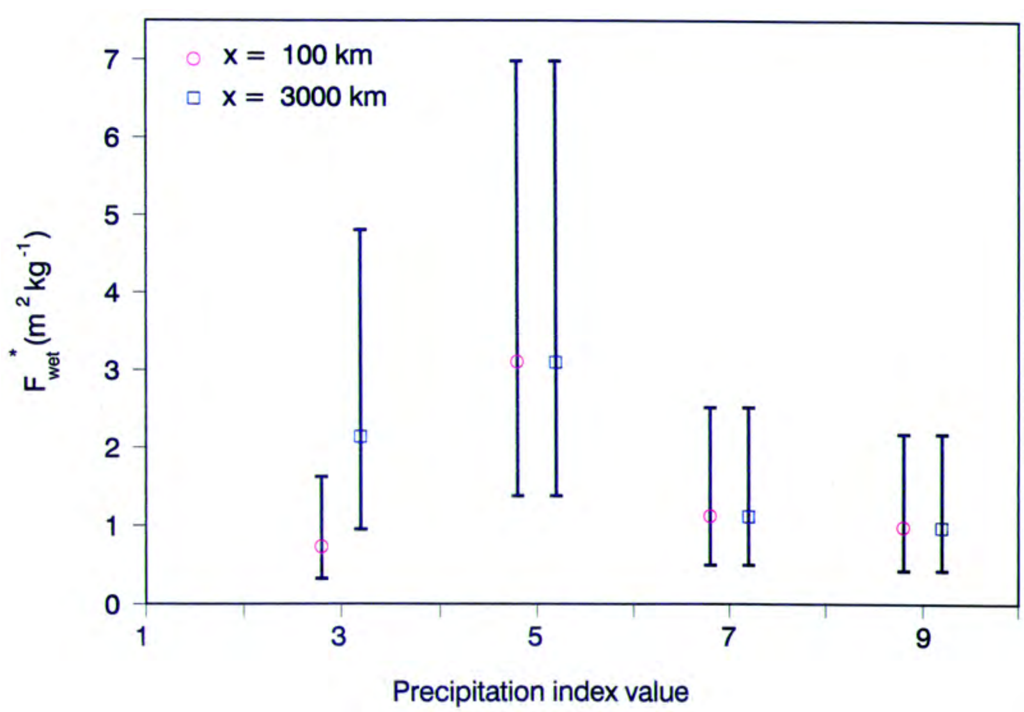
.6. Best estimates of the mass interception factors, F^*_{dry} and F^*_{wet}, in $m^2\ kg^{-1}$ (dry).

o- chemical form	Precip. Index value	Distance from the NTS (km)			
		100	300	1000	3000
		$F^*_{dry}(m^2\ kg^{-1})$			
Particles	1	0.13	0.41	1.34	1.89
Molecular	1				
Organic	1				
		$F^*_{wet}\ (m^2\ kg^{-1})$			
Particles	2	0.30	0.57	1.45	1.97
	3	0.72	0.95	1.70	2.14
	4	1.91	2.03	2.40	2.62
	5	3.10	3.10	3.10	3.10
	6	1.63	1.63	1.63	1.63
	7	1.12	1.12	1.12	1.12
	8	1.01	1.01	1.01	1.01
	9	0.97	0.97	0.97	0.97
cular or Organic	2	0.20	0.20	0.20	0.20
	3	0.21	0.21	0.21	0.21
	4	0.26	0.26	0.26	0.26
	5	0.31	0.31	0.31	0.31
	6	0.16	0.16	0.16	0.16
	7	0.11	0.11	0.11	0.11
	8	0.10	0.10	0.10	0.10
	9	0.10	0.10	0.10	0.10

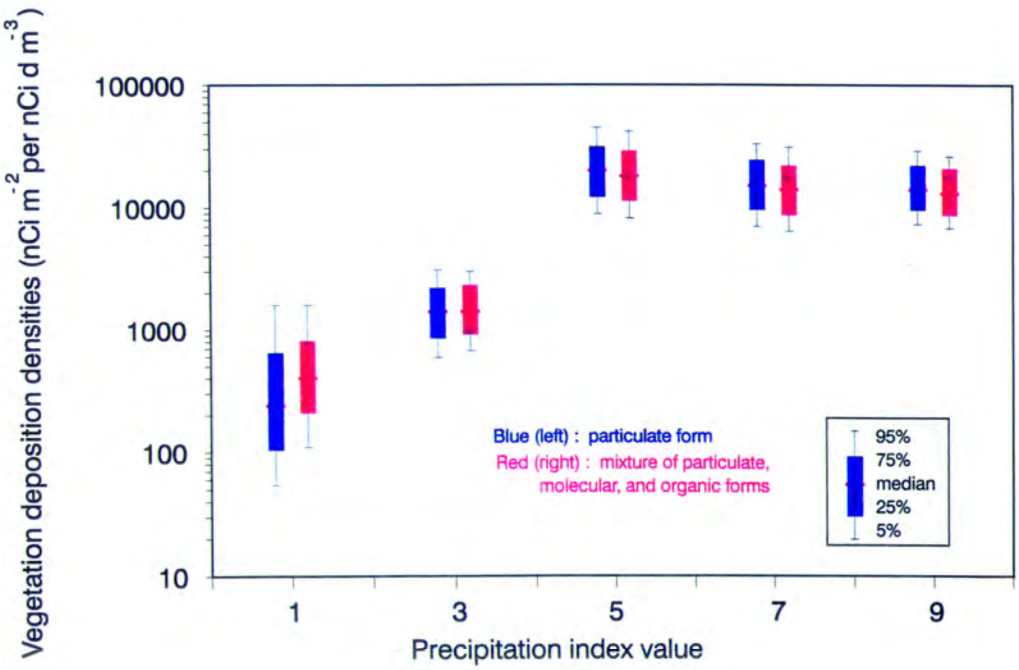
7.5. Variation of the mass interception factor (dry conditions), in $m^2\ kg^{-1}$, as a function of distance from the NTS for ^{131}I associated with particles (the ver cal bars represent 95% confidence intervals).



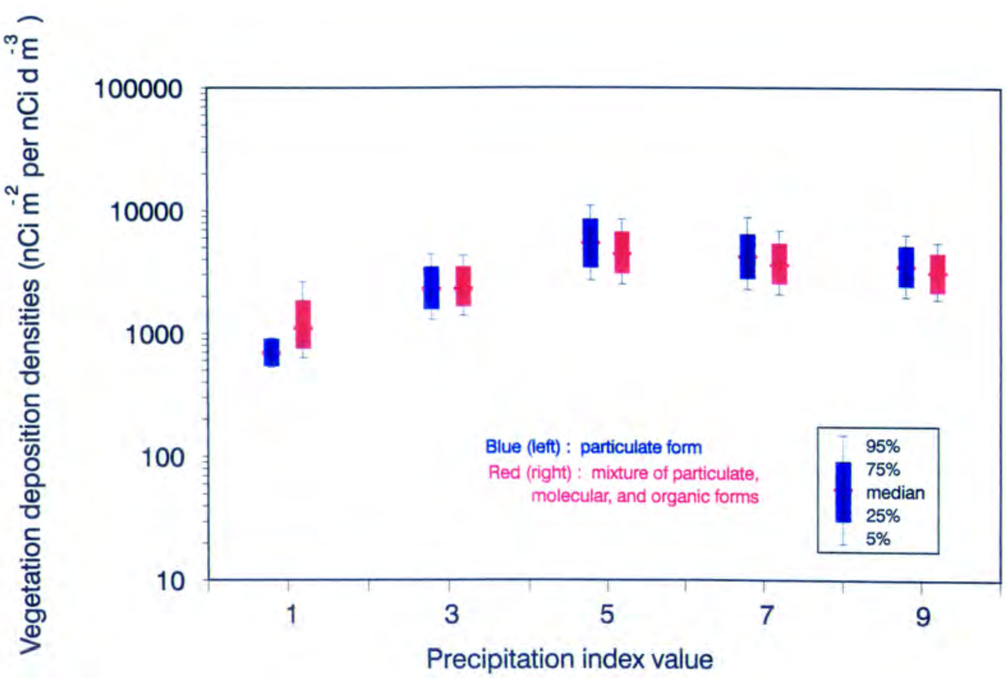
7.6. Variation of the mass interception factor according to the precipitation index value for ^{131}I attached to particles and 2 distances from the NTS. (Media and 95% confidence intervals are shown on the vertical bars)



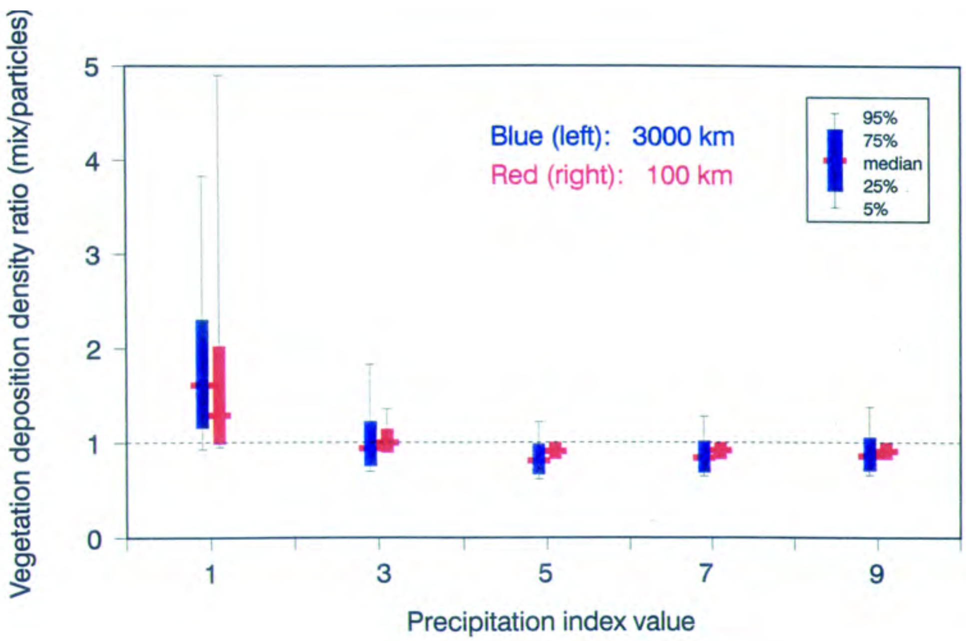
7.7. Variation of the vegetation deposition density as a function of the precipitation index value at the distance of 100 km from the NTS for [131]I attached to particles and distributed among 3 physico-chemical forms. Medians, as well as 50% and 95% confidence intervals, are shown on the vertical bars.



7.8. Variation of the vegetation deposition density as a function of the precipitation index value at the distance of 3000 km from the NTS for [131]I attached to particles and distributed among 3 physico-chemical forms. Medians, as well as 50% and 95% confidence intervals, are shown on the vertical bars.



7.9. Ratios of normalized vegetation deposition densities (mix/particles) as a function of the precipitation index value for downwind distances from the N of 100 and 3000 km. Medians, as well as 50% and 95% confidence intervals, are shown on the vertical bars.



CUSSION

lts of calculations taking into account the distribution of rding to several physico-chemical forms show that these ons do not produce vegetation deposition densities, efore, dose estimates that are substantially different from culated using the assumption that all ^{131}I was in particu-. The median values of the ratios of the ^{131}I vegetation n densities obtained when ^{131}I is distributed among var-sico-chemical forms and when ^{131}I is only in particulate within the range of 1.3 to 1.6 for dry deposition and e range of 0.8 to 1.0 in the presence of precipitation for of distances from the NTS. The assumption that is used port that ^{131}I is only associated with particles leads , on average, to an underestimation of the thyroid doses deposition of ^{131}I occurs in the absence of rain and to a erestimation of the thyroid doses when the deposition of rs in the presence of rain. However, the uncertainty due sumption that ^{131}I is only associated with particles is s than the uncertainties related to the estimation of the n of ^{131}I per unit area of ground.

ne results shown in *Table A7.7* were used to assess the he assumption that all of the ^{131}I was associated with e material on dose estimates for locations relatively near and at greater distances. Distributions of daily rainfalls eriod 1951-1960 were extracted from the climatic or Las Vegas NV, Boise ID, Denver CO, Memphis TN, ille FL, and Albany NY[1]. The median ratios of /A_p(P)] in *Table A7.7.* were used with the distributions of daily rainfall to estimate weighted biases for these particula tions. Some linear interpolations and extrapolations of the r in *Table A7.7.* were used to make the estimates because, exc for Denver, the distance from the NTS of the location consi differed from the distances for which [A_p(mix)/A_p(P)] had b estimated.

Table A7.8. Median estimates of bias derived from precipitation frequencies during 1951-1960

Location	Distance from NTS (km)	Estimate of Bia
Las Vegas, NV	150	1.3
Boise, ID	720	1.3
Denver, CO	1020	1.1
Memphis, TN	2330	1.3
Jacksonville, Fl	3136	1.3
Albany, NY	3780	1.3

Table A7.7. Best estimates (medians) and ranges (5 and 95 percentiles) of vegetation deposition densities, A_p [(nCi m^{-2}) (nCi d m^{-3})$^{-1}$], for ^{131}I associated with particles, A_p (P), and for ^{131}I distributed according to the assumed mixture of physico-chemical forms, A_p (mix), for a range of daily rainfalls and distances from the NTS. The ratios, A_p (mix)/A_p (P), also are presented.

Reference daily rainfall	A_p(P)			A_p(mix)			A_p(mix)/A_p(P)		
	5%	Median	95%	5%	Median	95%	5%	Median	95%
X= 100 km									
0	54	240	1600	110	40	1600	0.95	1.29	4.90
0.15	250	560	1700	320	670	1800	0.94	1.10	2.02
0.5	590	1400	3100	670	1400	3000	0.91	1.00	1.36
1.5	3700	8400	19000	3500	7700	17000	0.86	0.93	0.99
5	8900	20000	45000	8200	18000	42000	0.85	0.91	0.97
15	6300	14000	22000	5800	13000	29000	0.85	0.92	0.98
50	7000	15000	33000	6400	14000	31000	0.85	0.92	0.98
100	7500	15000	31000	7000	13000	28000	0.85	0.91	0.98
150	7300	14000	29000	6800	13000	26000	0.85	0.91	0.98
X = 300 km									
0	170	410	1200	330	700	1700	0.95	1.51	4.22
0.15	630	200	2400	780	1400	2500	0.88	1.06	1.77
0.5	1200	2400	5000	1300	2400	4400	0.83	0.95	1.34
1.5	2700	5800	12000	2500	5100	10000	0.79	0.88	1.04
5	5600	13000	30000	4900	11000	24000	0.77	0.84	0.92
15	4200	9100	20000	3800	7700	17000	0.78	0.86	0.97
50	4400	9500	21000	4000	8200	17000	0.78	0.85	0.95
100	4900	9600	19000	4400	8200	15000	0.78	0.85	0.94
150	4800	9300	18000	4300	7900	15000	0.78	0.85	0.95
X = 1000 km									
0	460	760	1300	590	1000	2000	0.87	1.30	2.64
0.15	1200	1900	3300	1200	1900	3300	0.78	0.96	1.57
0.5	1600	2800	5500	1500	2600	4600	0.75	0.89	1.33
1.5	2300	4600	9500	2200	3900	7400	0.72	0.83	1.10
5	3800	8100	18000	3300	6400	13000	0.70	0.79	0.96
15	2900	6000	13000	2600	5000	9600	0.70	0.81	1.04
50	3300	6400	13000	2900	5200	10000	0.71	0.80	0.99
100	3500	6500	13000	3100	5300	9600	0.71	0.80	0.98
150	3400	5800	11000	2900	4800	8300	0.72	0.81	1.01
X = 3000 km									
0	530	690	9100	630	1100	2600	0.93	1.61	3.83
0.15	1000	1600	2700	1100	1800	3500	0.75	1.06	2.15
0.5	1300	2300	4400	1400	2300	4300	0.70	0.94	1.83
1.5	1800	3300	6400	1800	3000	5500	0.66	0.87	1.47
5	2700	5400	11000	2300	4400	8500	0.62	0.81	1.22
15	2100	3900	7900	2000	3400	6400	0.63	0.84	1.37
50	2300	4200	8900	2100	3600	6900	0.65	0.84	1.28
100	2400	4000	7400	2200	3500	6100	0.65	0.84	1.30
150	2000	3500	6400	1900	3100	5500	0.66	0.86	1.38

/as associated with particulate material may have bias of 10-30% in the dose calculations. Bias estimates of the six locations are shown in *Table A7.8;* the loca- listed in order of increasing distance from the NTS. estimates are generally uniform and do not show a nce on the distance from the NTS.

ne estimates in the table reflect average precipitation fre- during the 10-year period, not necessarily the condi- ler which fallout deposition actually occurred. Detailed n results for the important test series, tabulated in the to the report, were used to estimate the mean bias dur- ds when fallout occurred at four locations. These loca- e chosen in part because of the relative completeness of ds of gummed film deposition results. The estimates of to the assumption that all the radioiodine was associat- particles for the four locations are shown in *Table A7.9.*

.9. Mean estimates of bias derived from records of precipitation during actual fallout depositions from tests at the NTS.

Location	Estimated Mean Bias
Denver	1.3 ± 0.5
Memphis	1.1 ± 0.2
Detroit	1.3 ± 0.4
New York City	1.1 ± 0.2

ne mean estimate and an approximate standard devia- given in the table. These more definitive results, based ls of known fallout deposition, indicate that the likely les of the bias are small. The uncertainties in the esti- sufficiently large that one cannot conclude that there s at these locations due to the assumption that all ne was in particulate form.

duction was kindly performed for the project by Milton Smith (NOAA/Air Laboratory).

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Initial Retention by Vegetation of ^{131}I in Wet Deposition of Fallout

Contents

A8.1. INTRODUCTION

The purpose of this effort is to review the available literature on the initial retention by pasture vegetation of ^{131}I in wet deposition of fallout from the Nevada Test Site (NTS). Debris transported over distances in excess of 200 miles and deposited in rain during the months when cows consume pasture vegetation may have been responsible for the greater portion of the human intake of ^{131}I in the United States. The retrospective assessment of thyroid doses to the population requires knowledge of the interception and retention of fallout ^{131}I in wet deposition.

Some of the rainfall events were no doubt associated with thunderstorms and correspondingly high rainfall rates. At other times, wet deposition at low and moderate rainfall rates occurred. It would be useful to the dose assessment process to know the dependence of the retention factor on the rainfall rate and vegetation characteristics. Fallout near the NTS was generally due to dry deposition of relatively large particles and is not of interest in this review.

In **Section A8.2,** the context in which the initial retention factor is used is considered and its importance is illustrated. Models of transport of fallout to vegetation and of subsequent retention are presented to provide a basis for analysis of the available data. In **Section A8.3,** collected data on the nature of fallout ^{131}I in rainwater and of airborne fallout ^{131}I are reviewed. In **Section A8.4**, measurements of the retention of ^{131}I in wet deposition are summarized and evaluated. A tentative model relating the initial retention to vegetation density and total storm rainfall is presented. Data on retention of other fallout radionuclides in rain are reviewed, as are experiments with artificial sprays of radionuclides. Some available data on the retention of ^{7}Be are also reviewed. Conclusions drawn as a result of the review are presented in **Sections A8.5** and **A8.6.**

A8.2. IMPORTANCE OF INITIAL RETENTION FACTOR TO THE DOSE ASSESSMENT PROCESS

The transport of fallout ^{131}I from explosions at the NTS to members of the population can be modeled in a sequence of steps. For the principal exposure pathway these are:

- atmospheric transport and dispersion as the cloud segments move across the U.S.,
- wet and dry deposition of ^{131}I onto vegetation in the path of the cloud segments,
- consumption of contaminated pasture vegetation by cows,
- transfer of ^{131}I from the cows' feed to milk, and
- consumption by humans of cows' milk containing ^{131}I.

The first three steps define a similar sequence for the transport of ^{131}I to humans consuming fresh vegetables. In both pathways, the fraction of the ^{131}I in rain that is retained by vegetation enters directly into the calculation of the amount of ^{131}I consumed by humans.

The initial retention factor, a_v, is defined as the ratio of the ^{131}I concentration, pCi m^{-2}, on vegetation following a wet deposition event to the total ^{131}I deposited (also in pCi m^{-2}) during the event. This dimensionless parameter may be a function of rainfall rate, vegetation type, vegetation density, and the nature of the ^{131}I. The latter aspect, which includes both physical and chemical properties, is discussed in **Section A8.3.**

The transport of airborne ^{131}I to vegetation can be described mathematically using the following differential equation:

$$\frac{dC_v}{dt} = V_d \chi + a_v D_w - (\lambda_w + \lambda)\, C_v \qquad (A8.1)$$

where:

C_v	is the concentration, pCi m^{-2}, in vegetation
V_d	is the deposition velocity, m s^{-1}, to vegetation
χ	is the air concentration, pCi m^{-3}, normally at 1 m above ground level
a_v	is the dimensionless initial retention factor for wet deposition on vegetation
D_w	is the total wet deposition rate, pCi m^{-2} s^{-1},
λ_w	is the rate constant, s^{-1}, that describes removal by weathering processes
λ	is the radiological decay rate constant, s^{-1}

A similar equation can be written for the concentration of ^{131}I per unit mass of vegetation by dividing both terms of *equation A8.1* by the vegetation density or yield (Y, kg m^{-2}, dry weight).

The dry deposition velocity for elemental iodine (I_2) was found to be proportional to the vegetation density and a normalized deposition velocity, $V_D = V_d/Y$ was defined which reflected this dependence (Zimbrick and Voillequé 1969). In these measurements, the dry deposition onto the vegetation covering a specific area, not the total dry deposition (to vegetation and ground), was measured. This convention is also used in the definition of V_d in *equation A8.1.* The normalized deposition velocity has been recommended as a more useful parameter in dose assessment calculations (Hoffman 1977).

When the deposition velocity reflects the total rate of transfer (to both vegetation and ground) then a retention factor for dry deposition is also required. Chamberlain and Chadwick (1966) measured separately the activity of ^{131}I on both herbage and the underlying mat and soil due to deposition of I_2 released in field experiments. Chamberlain (1970) proposed a relationship of the type:

$$k = 1 - e^{-\mu Y} \qquad (A8.2)$$

where:

k	is the fraction of the radioactivity intercepted by the vegetation
μ	is a proportionality constant, $m^2\ kg^{-1}$, based upon experimental measurements
Y	is the yield or vegetation density, kg m^{-2} dry weight, as defined above.

For small values of Y (Y < 0.3 kg m^{-2}), the interception fraction is approximately directly proportional to the vegetation density. Chamberlain found a value of of $2.78 \pm 0.14\ m^2\ kg^{-1}$ provided a good fit to the measurements of elemental iodine deposition. The measurements at Harwell include values of Y of ~ 0.7 kg m^{-2}; vegetation densities in the Idaho measurements were lower, ~ 0.2 kg m^{-2}, so the linear approximation was adequate.

Chamberlain also found that a variety of other experimental measurements gave similar values of μ when analyzed using the filtration model defined by *equation A8.2.* Releases of ^{89}Sr in a fine spray over grassland were performed by Milbourn and Taylor (1965). Analysis of the measured values of k yielded $\mu = 3.33 \pm 0.56\ m^2\ kg^{-1}$. Because the ^{89}Sr in the solution was carrier free, the particles remaining after evaporation of the liquid were probably quite small. For similar releases of sprays and labeled particles 1 m in diameter (Chamberlain 1970), the best fit was provided by $\mu = 2.30 \pm 0.08\ m^2\ kg^{-1}$. For labeled 30-$\mu$m diameter spores (Chamberlain 1967), a best-fit value of $3.08 \pm 0.15\ m^2\ kg^{-1}$ was obtained. The similarity of values of μ for these physically different tracers (and for both dry deposition and spray application) suggested that reasonable estimates of retention could be made even if the radionuclide form was uncertain. For example, using the mean of the four estimates of μ with Y = 0.25 kg m^{-2} yields k = 0.51, while the extreme values of μ would predict 0.44 and 0.57 for the same vegetation density.

Miller (1979) confirmed that *equation A8.2* was representative of the initial retention of particles of various diameters used to simulate dry fallout. Those dry particles were spread over field vegetation plots and individual plants in small laboratory exposure chambers (Peters and Witherspoon 1972; Witherspoon and Taylor 1970, 1971). Particle sizes ranged from 1 to 44 μm (Witherspoon and Taylor 1970), 44 to 88 μm and 88 to 175 μm (Witherspoon and Taylor 1971), and 44 to 88 μm (Peters and Witherspoon, 1972). Several grasses as well as sorghum, squash, soybeans, and peanut plants were used in the studies. In a related paper, Miller (1980) analyzed the distribution of values of the retention factor and of the ratio of the retention factor to the vegetation density. The ratio (k/Y) was recommended for use for forage grasses in dose assessment calculations because of the lower variability. A median of 1.8 $m^2\ kg^{-1}$ and a geometric standard deviation of 1.6 were found. Seven of the ten experiments evaluated were for dry deposition of particles. The other three were the I_2 and spray results, cited above, that were used by Chamberlain.

Chamberlain's approach has been applied in the PATHWAY model being used to assess radiation doses from fallout near the NTS. Evaluation of field measurements of dry deposition of fallout particles between 80 and 260 miles downwind of the NTS led to the selection of $\mu = 0.39\ m^2\ kg^{-1}$ for fallout dose assessments (Kirchner and Whicker 1983).

Lassey (1982, 1983, 1984) has also used Chamberlain's filtration model to describe the initial retention of radioactivity by vegetation. He has proposed an alternative to the commonly used exponential loss term for weathering processes (λ_w in *equation A8.1*) that is based on an extension of the filtration model.

It is reasonable to expect that the initial retention factor for wet deposition of ^{131}I will also be dependent upon the vegetation yield. Qualitative consideration of the wet deposition process suggests that other factors may also be important. The most prominent of these are the rainfall rate, the duration of the rainfall, and the rainfall sequence. High rainfall rates may result in lower net deposition on vegetation. The rain that falls at the end of a storm is less contaminated and may remove some ^{131}I that was deposited at the outset. Similarly, uncontaminated rain that falls after a wet deposition event may partially cleanse the vegetation. Thus, the fractional retention (a_v) in the wet deposition term of *equation A8.1* may actually be a complex function of many variables.

Different approaches have been used to address the effect of rainfall. In the model described by *equation A8.1* rainfall is just one of several possible mechanisms that contribute to the removal rate constant, λ_w. Peirson and Keane (1962) treated washoff by rain as the primary removal mechanism and assumed that the initial retention fraction was lowered when the rainfall rate increased. Their results are discussed in **Section A8.4.**

Horton (1919) considered the initial retention of rainwater by vegetation and developed the following expression:

$$a_v = \left(\frac{A}{P_s} + B \right) h \qquad (A8.3)$$

where:

a_v	is the fraction of the rainfall retained by the vegetation
A	is a constant equal to the rainfall storage capacity per unit height of vegetation (cm of rain per cm of vegetation)
P_s	is the amount of rain which falls during the storm (cm)
B	is the fraction of the rain that evaporates from the vegetation during the storm per unit of height of vegetation (cm^{-1})
h	is the height of vegetation (cm).

Horton estimated A and B using data collected at Seneca, New York, and some approximations about the rainfall pattern. For pasture grass and alfalfa, he estimated values of A of 4.2 x 10^{-4} and 8.3 x 10^{-4} (cm of rain per cm of vegetation) and values of B of 2.6 x 10^{-3} and 3.3 x 10^{-3} cm^{-1}, respectively.

The wet deposition rate, D_w, is itself complex because it reflects both in-cloud scavenging and washout of ^{131}I in the air nearer to ground level. Several symposia have been devoted to discussion of the relevant processes and field measurements to determine transport parameters (Engelmann and Slinn 1970; Semonin and Beadle 1977; Pruppacher et al. 1982; Georgii and Pankreth 1982).

For gaseous iodine species, the activity distribution between the ^{131}I in a raindrop and in the air around it is dynamic. Radioiodine entering the drop at one elevation may be lost from the drop at a lower elevation where the air concentration is lower. In some cases, wet deposition of ^{131}I will occur when there is no ^{131}I in the air at ground level. However, analysts of environmental measurements of wet deposition have been forced to correlate the wet deposition concentrations with ground level air concentrations because the concentrations at cloud level were not measured. The dimensionless washout ratio, W, is the ratio of the radionuclide concentration in rain, pCi kg^{-1}, to that in air pCi kg^{-1}, near ground level. This parameter can be used to define a wet deposition velocity, analogous to V_d. the washout ratios and wet deposition velocities that have been determined for fallout represent integrations of processes over times ranging from the duration of a single storm (perhaps 2 hours) to 1 week, a typical air sampler operating period. The field measurements frequently do not permit study of processes in the detail required to identify explicit dependencies upon rainfall rate or storm duration. Ground level measurements of washout ratios or wet deposition rates yield only relatively gross parameters that do not address the intricate details of the operative physical processes.

This is not to say that simple models are not useful. The natural integration of many variables that is inherent in a deposition velocity or washout ratio may be quite beneficial. Complex dependencies are smoothed and may counterbalance one another. For example, estimates of the wet deposition, D_w, using washout ratios include a dependence on the rainfall rate, p. If the retention factor, a_v, is inversely proportional to rainfall rate, it may be that the overall wet deposition term, a_v D_w, is approximately independent of p.

Direct correlation of deposition on vegetation with other field measurements of fallout may be an alternative to complex predictive modeling. Measurements of deposition of fallout were made using gummed-film collectors during the 1950s (Beck 1984). The samples were collected during a 24-h period and reflect both wet and dry deposition, removal, and decay. An equation similar to *equation A8.1* can be written for the activity on gummed film and evaluated on a daily basis. To use the gummed film results to estimate deposition on vegetation, it is necessary to know (a) the ratio of the dry deposition velocity for gummed-film to that for vegetation and (b) the ratio of the retention factors for wet deposition onto gummed film and vegetation.

Preliminary measurements (Beck 1986) suggest that the retention factor for both ^{7}Be, a dissolved species (Olsen et al. 1985) and ^{131}I in fallout from Chernobyl, partly particulate, decreases with increasing amounts of rainfall. Horton's conceptual approach, described above, appears quite appropriate for analysis of the retention of wet deposition by gummed-film. Approximate values for the storage capacity and evaporation fraction can be determined experimentally.

A8.3. PHYSICAL AND CHEMICAL FORM OF ^{131}I IN FALLOUT

Early measurements of radionuclides in fallout were frequently accomplished by gross beta counting the samples. Although gamma spectrometry measurements were performed earlier, routine determination of ^{131}I in samples did not begin until after the Windscale accident (Chamberlain and Dunster 1958). Early sample preparation procedures were not designed with ^{131}I in mind and in many cases, led to the loss of ^{131}I before the sample was counted. The gradual change in focus of studies of fallout in the United States is charted in a recently published review (Black and Potter 1986). Most information on ^{131}I in fallout has been obtained since above-ground testing at the NTS was completed. However, this fact should not greatly diminish the usefulness of those results for analysis of the behavior of ^{131}I in fallout generated at the NTS.

Three types of measurements of fallout characteristics are of particular interest. They are: (1) measurements of ^{131}I in wet deposition, (2) measurements of the solubility of ^{131}I in fallout particles, and (3) measurements of the partitioning of airborne fallout ^{131}I between particles and gaseous species. The first measurements are most closely related to retention of ^{131}I in wet deposition, but the other data provide supporting information

for inferences that must be made. Fortunately there are some data in all three categories and these are discussed below.

A8.3.1. ^{131}I in Wet Deposition

Four samples of rain and one of snow containing fallout ^{131}I were collected near Pittsburgh during November and December of 1962 and analyzed to determine the chemical and physical form of the radioiodine (Keisch and Koch 1963). Just prior to the start of these measurements, there was a large (>1000 kt) air drop test at Johnston Island. During the period there were five atmospheric tests (20 to 1000 kt) in the Soviet Union, four underground tests at the NTS, and two missile tests (<20 kt and <1000 kt) at altitudes of tens of kilometers in the Pacific (Reiter 1978). An average of 51 ± 17% of the ^{131}I activity was in the liquid phase, which was operationally defined by passage through a filter with a pore size of 1.2 μm. (Unless otherwise indicated, the mean, M, and the sample standard deviation, s, of measurement results are given in the form M ± s.) The range of the liquid phase fraction for the five samples was 23% to 65%. The solids were described as "fine suspended particles" or "settled particles"; most of the particulate activity (an average of 76 ± 14%) was in the latter category. All of these particles must have exceeded 1.2 μm in diameter.

After the particles were separated from the rainwater, they were exposed to deionized water and gently agitated to determine the further availability of the ^{131}I in the fallout particles. An average of about 8.6 ± 5.6% of the ^{131}I activity was leached from the particles by deionized water in 1 hour; values for six samples (four of fines and two of settled particles) ranged from 3 to 15%.

Measurements of the chemical state of the ^{131}I in the liquid phase of five precipitation samples were also made. An average of 52 ± 15% was determined to be present as iodide or iodine, 37 ± 15% was identified as iodate, and 11 ± 9% was found to be periodate. Similar measurements were made to determine the chemical state of ^{131}1 that was subsequently leached from four samples of the particulate fraction. The distribution of chemical forms of ^{131}I leached from particles deposited in rainwater was similar to that found in the liquid phase of the rainwater. The results for the iodide/iodine, iodate, and periodate fractions were 65 ± 21%, 23 ± 16%, and 10 ± 12%, respectively.

The development of analytical methods for these measurements is described in an earlier report by the same authors. Their original measurements were made on particles collected within about 2 miles from ground zero following the Sedan Test (Koch and Keisch 1962). They found that results of leaching with deionized water and an acid solution determined to resemble gastric juice were similar. Additional measurements of the long-lived isotope ^{129}I in fallout were planned by the same investigators, but a report of that work has not been found.

Indirect evidence of the nature of ^{131}I in wet deposition is provided by the measurements of washout ratios. Measurements of tropospheric fallout from Russian nuclear tests in 1961 yielded washout ratios of 420 for ^{131}I, 480 for ^{140}Ba-La, and 500 for ^{95}Zr-Nb (Peirson and Keane 1962). These results were comparable to those from measurements of long-lived fallout originating in the stratosphere during the previous year. Washout factors of 560 and 520 for ^{137}Cs and ^{144}Ce-Pr, respectively, were reported. The similarity of the ^{131}I washout ratio and those for the particulate radionuclides suggests a common origin, namely fallout particles. Washout factors for a much wider range of conditions are given in the review by Engelmann (1970). Only one value is given for ^{131}I; washout ratios of 100 to 2700 were measured for snow containing ^{131}I from the Cabriolet venting at the NTS. Engelmann (1970) also quotes work by Bradley who analyzed beta activity washout ratios in Illinois from 1962 to 1965 and found a nominal value of 490 with a slight dependence upon total monthly precipitation (P, cm): $W_{beta} = 490\ p^{-0.026}$.

The atmospheric cleansing effect is shown more dramatically in measurements of ^{90}Sr washout (Krey and Toonkel 1977). The ^{90}Sr washout ratio at Seattle was between 1964 and 1967 and was proportional to $P^{-0.3}$. The combined data for three cities (Seattle, Fayetteville, and New York) showed a proportionality to $p^{-0.17}$. For the three sites, the value of W for ^{90}Sr for P = 1 cm was 969, about double that found for gross beta activity in Illinois. During the 1964-1967 period, most of the ^{90}Sr would have come from the large stratospheric inventory built up prior to January 1963. Above ground nuclear testing by the United States and the Soviet Union was stopped by treaty in 1963, but tropospheric explosions occurred in the northern hemisphere throughout 1962. There were, however, six Chinese nuclear explosions during the period when the measurements were made (Reiter 1978).

A8.3.2. Leachability of ^{131}I in Fallout Particles

Airborne particulate material in the Pittsburgh area was collected on glass fiber air filters (Gelman) and used to measure the leachability of ^{131}I into deionized water (Keisch and Koch 1963). The filters were highly efficient for particles as small as 0.05 μm. Weekly samples were collected between November 21, 1962 and January 2, l963. After leaching, the liquid phase was operationally defined by filtration using a filter with a 1.2-μm pore size. An average of 29±5% of the total ^{131}I activity was found in the liquid phase after 4 hours of gentle agitation in deionized water. Most of the ^{131}I activity entered the liquid soon after contact. After the first hour of leaching, an average of 23±4% of the ^{131}I activity was found in the liquid phase.

The chemical form of the leached activity in five samples was identified as 61±18% iodide/iodine and 32± 17% iodate. The average periodate fraction can be estimated by difference to be about 7%, but three of the five analytical results for periodate were below the detection limits. There is a definite similarity between these species distributions to those in the liquid phase of rainwater and to those found after leaching particles brought down by rainwater (**Section A8.3.1**). The results suggest that ^{131}I in the liquid phase of the precipitation samples may have been

due to leaching of ^{131}I from particles during droplet formation and while the precipitation fell.

Other measurements of the solubility of ^{131}I in fallout particles were less oriented toward leaching in raindrops. In two samples, Perkins (1963) found that 42% and 44% of the ^{131}I was leached from particles by a basic solution (pH 12) in a blender in 2 minutes. The filter had a pore size of 2 μm so some of the liquid fraction may have been small particles. Destruction of large particles no doubt occurred in the blender, which further complicates interpretation of this result. The two iodide/iodine fractions were about 57 and 66% and iodate accounted for about 38 and 29% of the leached ^{131}I in these samples, respectively. The periodate fraction was less than 5% in both samples (Perkins, 1963).

A8.3.3. Forms of Fallout ^{131}I in Air

In a series of measurements made during the intensive periods of bomb testing in 1961 and 1962, Perkins and his associates made regular measurements of airborne ^{131}I. The fraction of the ^{131}I that was in particulate form ranged from about 1%, in a single case, to more than 90% and nearly always exceeded 10% (Perkins et al. 1965). The mean particulate fraction can only be estimated from points on a greatly reduced figure that shows the measured particulate fractions (Perkins et al. 1965); it appears to be $\sim$ 0.5. The fraction of the gaseous fallout ^{131}I present as I_2 or HI was estimated to be less than 10%; however, the number of fallout measurements when the gaseous species were separated was not given. The remainder of the gaseous fraction was presumed to be in organic form (Perkins 1963, Perkins et al. 1965).

In a series of measurements at Brookhaven National Laboratory (BNL) during the last 5 months of 1962, Hull (1963) found an average of 65% of the ^{131}I was associated with particles. The particulate fraction ranged from 21% to 82% during the measurement period (Hull 1963). Eggleton et al. (1963) reported an average particulate fraction of 75% during the fall of 1961. The distribution of the gaseous species cannot be determined from the abstract and the entire paper was not published (Eggleton et al. 1963).

Measurements of fallout ^{131}I from Chinese weapons testing in 1976 showed distributions of airborne activity that were similar to the earlier measurements. The samples were collected in the vicinity of a nuclear power plant in New Jersey. Following the test, fallout ^{131}I concentrations in air greatly exceeded those due to facility releases of ^{131}I (Voillequé 1979). Fallout ^{131}I was measured at five sites during a 2-month period; eight weekly samples were collected at each location. About 50 to 60% of the total airborne ^{131}I activity was present as particles during the first 5 weeks following arrival of the fallout. During the last 3 weeks, the particulate fraction decreased to about 30% of the total. The fraction of the gaseous ^{131}I in organic form averaged 35% during the first week and about 40% during the second and third weeks. The gaseous iodine was predominantly in organic form during subsequent weeks with mean values for all sites ranging from 44% to 100%. The amount of ^{131}I in the I_2 or HOI) fraction was often below the detection limit so the total gaseous ^{131}I activity and the fraction that was in organic form were both indeterminate. However, the observed trends indicate that the organic fraction gradually increased with time after detonation.

Measurements made in Germany (Riedel et al. 1977) following the same test showed an initial particulate fraction of 0.72. The fraction associated with particles declined, although not monotonically, to 0.54 after 5 weeks. The gaseous fraction was collected using charcoal; no attempt was made to determine the distribution of the gaseous iodine forms.

Fallout ^{131}I from a Chinese test in September 1977 was observed in the midwestern United States within 5 days of the detonation. Two measurements of the particulate fraction at each of two locations yielded values between 0.54 and 0.59 during the first 3 weeks after the explosion. Subsequent airborne ^{131}I concentrations were too small to permit evaluation of changes in chemical form of the fallout and measurements were discontinued (Keller et al. 1982).

Examination of the plot of the particulate fraction of airborne ^{131}I in 1961 and 1962 (Perkins et al. 1965) shows several distinct declines in that quantity following peaks that presumably indicate arrival in Richland of fresh fallout from a recent test. However, testing was so frequent in those years that mixtures of fallout ^{131}I from a variety of tests would tend to obscure any trends related to the age of the fallout.

The measurements of ^{131}I in particles in precipitation (Keisch and Koch 1963) showed that half of the ^{131}I activity in wet deposition was associated with particles larger than 1.2μm in diameter. Although diameters of the settled particles were not measured, the description suggests that these particles were visible to the unaided eye. Peirson and Keane (1962) reported upper limit diameters in the range of 1 to 4 μm based upon microscopy and autoradiography. Approximately 50 to 80% of fallout particle beta activity was found to be associated with particles with diameters greater than 1 μm (Lockhart et al. 1965). The observed gradual reduction in the particulate fraction probably reflects removal of larger particles by gravitational settling (G1asstone 1964) and perhaps by precipitation scavenging (Gatz 1977; S1inn 1977). Fallout particles with diameters greater than 25 m have predicted residence times of less than 1 day, even when injected at an elevation of 50,000 feet (G1asstone 1964).

Studies of beta activity of fallout particles from a high altitude burst, which had diameters between 2 and 20 μm, showed that the activity was approximately distributed uniformly throughout the particle volume (Benson et al. 1965a). No measurements of the distribution of ^{131}I were reported. Individual particles exhibited widely varying activity concentrations and such differences might be even greater for near surface explosions. The same authors performed radiochemical studies (Benson et al. 1965b) but did not detect ^{131}I (or ^{103}Ru or ^{137}Cs) in particles that they studied. The ^{95}Zr-Nb and ^{140}Ba-La peaks interfered with analyses of these nuclides (a NaI(Tl) detector was

used). The activity distributions and fractionation data were not available for those nuclides. Other studies of fallout particles (Krey and Fried 1965; Crocker et al. 1965; Friedlander and Pasceri 1965) provide precious little information about ^{131}I and its incorporation into fallout particles. One may speculate, using the general scheme provided in Friedlander and Pasceri (1965) and a few bits of information on ^{132}Te and ^{131}I, that more than half the ^{131}I would be associated with particle diameters less than about 20 μm and be found principally in fallout that becomes widely distributed. As a volatile element, iodine might be expected to condense on surfaces rather than be distributed throughout the particle volume, but this has not been demonstrated.

A8.4. MEASUREMENTS OF RETENTION BY VEGETATION OF WET DEPOSITS OF FALLOUT ^{131}I AND OTHER RADIONUCLIDES

Field measurements of total wet deposition and of the activity present on vegetation after rainfall have permitted estimates of the wet deposition retention parameter a_v for ^{131}I and other fallout radionuclides. Artificial applications of radionuclides to vegetated areas have also yielded estimates of a_v. Measurement programs that specifically studied ^{131}I are of course of greatest interest, but results for other radionuclides that define the initial retention of fresh fallout particles are also of great interest. Results from experiments when radionuclides are dispersed at ground level are inherently less valuable for assessing the retention of particulate ^{131}I, although, as indicated in **Section A8.2**, Chamberlain found the filtration model was consistent with results for various physical forms and modes of application.

A8.4.1. Retention by Vegetation of Fallout ^{131}I

Using daily values of the concentrations of ^{131}I in air, rain, and vegetation for the British Isles during the fall of 1961, Chamberlain and Chadwick (1966) evaluated the dry deposition velocity and the wet deposition retention factor. Because there were alternating periods when wet and dry processes were predominant, good estimates could be obtained for both parameters. The frequently observed 5-day effective half-life for ^{131}I on vegetation was used in the calculations. The means and standard errors obtained by least squares fitting procedure were V_d = 0.054 ± 0.009 m/s and a_v = 0.51 ± 0.10. The three largest daily rainfalls occurred in late October and were in the range of 0.8 to 1.4 cm.

At Chilton (UK) measurements were made of fallout ^{131}I from Russian tests conducted in 1961 (Peirson and Keane 1962). Weekly average data obtained during 2.5 months were used to estimate parameters for wet and dry deposition and removal by rainfall. The dry deposition velocity was estimated to be about half that found by Chamberlain and Chadwick. In the analysis, it was assumed that the retention factor was decreased by increased weekly rainfall (P_w) according to:

$$a_v = (1 - m\,P_w) \qquad (A8.4)$$

where

m was a constant to be determined.

Washoff of activity by subsequent rains, also assumed to be proportional to the weekly rainfall, was considered to be the principal removal mechanism. The value of m determined for ^{131}I was 0.015±0.013 (week per mm of rain). The best estimate of the ^{131}I washoff factor was even more uncertain, 0.020±0.028 per mm of rain. Using the value of m stated above, the values of a_v for 9 weekly periods were found to range from 0.48 to 0.99. Measured rainfalls varied from 0.1 to 2.9 cm and 1 week passed without any precipitation. The mean of the computed values of a_v was 0.78 ± 0.18.

One would not expect that these results, which substantially overlap in time, would be so different from the results presented by Chamberlain and Chadwick (1966). Part of the difference lies in the assumptions that were made by Peirson and Keane. The effect of dry deposition on the precipitation collector was not evaluated. Removal mechanisms other than washoff were not considered, so removal was somewhat underestimated. It may also be that the use of weekly average values, rather than day by day results, skewed the results. There are of course relatively large uncertainties in the estimates of V_d (0.26 ± 0.18), m, and the washoff factor. Those uncertainties may be partly due to the approach taken in data evaluation.

It is recognized that other processes may influence the results of such field experiments. Rainsplash of previous deposits onto vegetation and uptake of ^{131}I from the soil are possible confounding factors. In the fall of 1961, the estimated ^{131}I wet deposition rate was about 300 pCi m^{-2} d^{-1}. In about a month, an equilibrium deposit of about 3500 pCi m^{-2} would be achieved. If all the activity were in the top cm of soil, only about 1 pCi m^{-2} would be expected due to soil uptake by vegetation in equilibrium with the soil (NRC 1977). This is substantially lower than the deposition rate. A rainsplash transfer fraction of 1% of the soil activity would not greatly influence the estimates for vegetation. If significant rainsplash occurred, its effect would have been to raise the apparent initial retention factor.

Hull (1963) reported measurements of ^{131}I concentrations in air, precipitation collectors, vegetation, and milk at BNL during the period August to December 1962. Chamberlain and Chadwick's values of V_d = 0.05 m s^{-1} and a_v = 0.5 were used with the BNL measured weekly average concentrations of ^{131}I in air and deposition collectors to predict concentrations of

^{131}I on grass. The fit of predicted values to measured concentrations of ^{131}I on grass was apparently considered satisfactory, and no attempt was made to determine best-fit values of V_d and a_v using the BNL data. The rainfall times and rates were not given. The deposition totals may not have been corrected for the effect of dry deposition, so a best-fit value for av might be slightly greater than 0.5.

During this same period, measurements of ^{131}I in environmental samples at the Studsvik research center in Sweden were also underway. Data on ^{131}I in air, rain, and milk were reported by Bergström (1967) and Bergström and Gyllander (1969). Specific measurement results were not presented for vegetation and ^{131}I retention, but values of a_v of 0.3 for light rains and 0.1 to 0.2 for heavy rains were stated to be "in agreement with the measurements of fallout iodine in Sweden" (Bergström 1967). About half of the rainfall rates during the measurement period were in the range 0.5 to 2.0 cm d^{-1}; the remainder were lower.

Fallout from more recent atmospheric weapons testing has complicated attempts to monitor the behavior of ^{131}I released from nuclear power stations. The environmental concentrations of ^{131}I from fallout episodes are much greater than those due to station effluents. These occurrences have led to collection of data on fallout ^{131}I. In the midwestern United States during June and July 1973, several values of a_v were determined. Grass and precipitation samples were collected following rainfall events. Concentrations of ^{131}I in grass prior to the wet deposition were frequently at the detection limit, so corrections for removal of previous deposits were generally not required. When necessary, extrapolation of vegetation concentrations was used to estimate the concentration prior to the rain. An effective removal half-life of about 5 days was generally observed. Daily rainfall totals ranged from 1.0 to 2.9 cm and the estimated retention factors ranged from <0.09 to 0.52. Two of the lower values of a_v (both < 0.09) were associated with rainfalls of 2.2 and 2.9 cm. The highest value (0.52) was observed for a rainfall of 1.8 cm. Detailed data on rainfall rates during storms were not reported (Weiss et al. 1974).

Radioiodine measurements in the environs of a reactor the following year were again interrupted by Chinese fallout. Four measurements of the initial retention of ^{131}I in wet deposition ranged from 0.11 to 0.27. In this case, the two lowest values (0.11 and 0.18) were associated with the smallest rainfalls (trace to 0.5 cm), and the highest initial retention fractions (0.25 and 0.27) were for a total rainfall of 1.3 cm.

At the reactor site in New Jersey in 1976, no reliable data on wet deposition were available after arrival of the fallout. The published analysis (Riedel et al. 1977) of measurements made in Germany following the same test assumed a_v = 0.2 based on Regulatory Guide 1.109 (NRC 1977). Two effective retention half-lives were examined: 3.9 and 5 days. Dry deposition rates were derived using these assumptions and the assumption that the aerosol deposition velocity was one-tenth that for gaseous iodine. This approach to the data was clearly arbitrary. It may be that the authors felt the number of vegetation samples (one a week) was too small to permit a detailed evaluation of wet deposition. The approach may also have been influenced by the low rainfall. It averaged 0.86 cm/week and in 6 of 9 weeks the total rainfall was less than 1 cm.

Measurements made during the summer of 1977 at a site on the Mississippi River also showed the presence of Chinese fallout (Voillequé et al. 1981). Measurements permitted ten estimates of the initial retention parameter a_v. The range of the estimates was large, 0.1 to 0.9; the mean retention factor was 0.35+0.28. The total rainfalls that carried wet deposition to the ground ranged from 1.0 to 5.8 cm, but these accumulations occurred over varying periods. Descriptions of the rainfall patterns were somewhat more detailed than in other publications, but variations within individual storm periods which lasted from several hours to several days, were not reported.

The need for detailed rainfall data seems clear from the point of view of wet deposition process modeling. Rainfall rates during storms can vary by more than an order of magnitude and scavenging processes are expected to be affected by those changes (S1inn 1977). The retention factor may be lower for higher rainfall rates. More washoff may occur (although it must be said that the importance of washoff as a removal process has not been unequivocally demonstrated). On the other hand, a retrospective study of fallout deposition will be limited in sophistication by the data collected at that time. It is unlikely that precipitation rates during storms will be available; it is probable that storm or daily total rainfalls will be used. So it may be that average retention factors for whole storms, or for 24-h periods in which a specific quantity of rain fell, are the most relevant for the problem at hand.

It is encouraging that Huff (1965) found that the best correlations of beta activity deposition were with rainfall volume, not with duration or rate. Analysis of 15 storms also showed that a single station could be used to predict the deposition of gross beta radioactivity within 10 to 12 square miles within an average error of 22%, however, the average error was as large as 35% in one-third of the storms.

It has long been known that rainfall concentrations decrease during the course of a storm (Weiss 1953). Recent automated measurements of metals in sequential rainfall samples show that the concentrations in rain decrease substantially at first, but are relatively constant after 2 to 3 mm of rain have fallen (Kins 1982). Hence, the largest concentrations are deposited when retention may be most likely, before saturation of the plant surfaces. Horton's estimates indicate that the storage capacity of tall (30-cm high) grass would be reached in less than a minute during a well organized storm with an average rainfall rate of 1.5 cm/hr. However, Burgy and Pomeroy (1958) indicate that the storage capacity is satisfied in increments during a storm (Bu58). More information about binding mechanisms and rates is needed to evaluate this aspect.

In the following discussion, a synthesis of the existing data on initial retention of ^{131}I in fallout is attempted and a ten-

tative model is developed. *Figure A8.1* contains the results of measurements of the initial retention of ^{131}I in Chinese fallout by pasture vegetation in the midwestern United States. Some of the values for a_v for nearly the same densities vary by more than a factor of 4. Also shown for comparison is the predicted line from Chamberlain's best fit to the 30-μm *Lycopodium* spore data. Average values of a_v for three ranges, each of which includes five to seven results for similar vegetation densities, are shown as bars in the figure. These means are not in good agreement with that model and the sample standard deviations, indicated by the vertical bars, are quite large. The single measurement for Y > 0.2 kg m^{-2} is a factor of two below the curve for 30-μm spores. The results of the two analyses of tropospheric fallout in the UK are not shown because vegetation densities were not reported.

Figure A8.2 shows the initial retention factor as a function of total storm rainfall (P_s, cm). As in *Figure A8.1*, the circles are the data from the midwest. The hatched area at the left encompasses the range of storm rainfall totals estimated from Chamberlain and Chadwick (1966); the reported average retention factor of 0.5±0.1 was based on daily grass samples. During some weeks, rain fell for several consecutive days; the maximum value of P_s is estimated to be <2 cm. Grass cut after the first part of an extended rainfall would have experienced a lower value of P_s, but not lower than 0.2 cm. The uncertainty associated with the mean retention factor is not reflected by the hatched area. The uncertainties appropriate for the U.S. data are generally larger (~ 40%). Only the best estimates are shown in the figures to improve legibility. The estimates made by Peirson and Keane are even more uncertain (as they are based on m = 0.015±0.013). The number of storms at Chilton was estimated using data (Chamberlain and Chadwick 1966) and mean values of P_s for the Chilton data were estimated. The average retention factors in Peirson and Keane (1962) are plotted as open squares in *Figure A8.2* using those estimates.

Incorporating the estimates (in an admittedly approximate way) does clarify the overall pattern. While the range of values of a_v for P_s < 2 cm is large, part of the variation is undoubedtly due to differences in vegetation density. Two patterns can be seen. One is a gradual linear decrease of a_v with P_s, as assumed in Peirson and Keane (1962); the other is the sharp decrease for P_s <2 cm, followed by a much slower decrease in a_v for P_s >2 cm. This latter pattern is that predicted by Horton (1919) and a plot of that type of model with assumed values of A and B included in *Figure A8.2*. However, neither type of model satisfactorily predicts all of the experimental results.

For modeling purposes, a combination of the filtration model and Horton's approach could be used. First, we define a normalized retention factor (a^*_v, m^2/kg)

$$a^*_v = \frac{a_v}{Y} \qquad (A8.5)$$

This approach has been suggested by Miller (1980), although it is clear from *Figure A8.l* that this normalization will not greatly reduce the variability in the available data for ^{131}I. Based on data in Chamberlain and Chadwick (1966) and a range of wet to dry weights of 1/4 to 1/3, dry vegetation densities in the late fall in the UK seem likely to have been in the range 0.08 to 0.15 kg m^{-2}. The distribution of values of a_v is expected to be similar to that for a^*_v in *Figure A8.2.* This suggests that a^*_v will depend upon the total rainfall from a storm in a manner similar to that proposed in Horton's model. That dependence could take an alternative form:

$$a^*_v = \frac{S}{P_s} + E \qquad (A8.6)$$

where:

S is the rainfall storage capacity per unit areal density of vegetation

E is the in-storm evaporation fraction per unit areal density of vegetation

To determine the fractional initial retention by pasture vegetation of ^{131}I in fallout from a particular storm, substitute the storm rainfall total, P_s, and vegetation density, Y, into *equation A8.6*.

$$a_v = \left(\frac{S}{P_s} + E \right) Y \qquad (A8.7)$$

Values of S and E are estimated from the data and assumptions discussed above to be 1.6 and 1.3 m^2 kg^{-1}, respectively. Although E in *equation A8.6*, and B in Horton's original formulation shown in *equation A8.3*, are assumed to be constants, the evaporation fraction certainly depends upon the air temperature and relative humidity and thus on the time and duration of the storm.

A8.4.2. Retention by Vegetation of Other Radionuclides in Fallout

To the extent that ^{131}I in fallout is associated with particulate material, the behavior of other radionuclides incorporated in fallout particles should be similar. In fresh fallout, 60 to 90% of the ^{131}I has been found in the particulate fraction and the gaseous ^{131}I is mainly in inorganic form. If the particulate fraction were 75%, for example, about 20% of the total would be expected to be I_2, HI, or HOI, and only about 5% would be expected to be in organic form. The behavior of particulate radionuclides should be reasonably representative of ^{131}I transport soon after detonation.

As the time after detonation increases, the larger particles are removed from the atmosphere and less airborne ^{131}I is associated with particles. At the same time, the less reactive organic iodides become an increasingly larger fraction of the gaseous fraction. Two months after a detonation, the airborne iodine species distribution would be quite different from that cited above. Only about 30% of the ^{131}I would be associated with particles and the organic iodides would comprise about 50 to 60% of the total with the remaining 10 to 20% as inorganic gases. At

Figure A8.1. Initial retention of ^{131}I in Chinese fallout in the Midwest. Data from Voillequé et al. (1981) and Weiss et al. (1974).

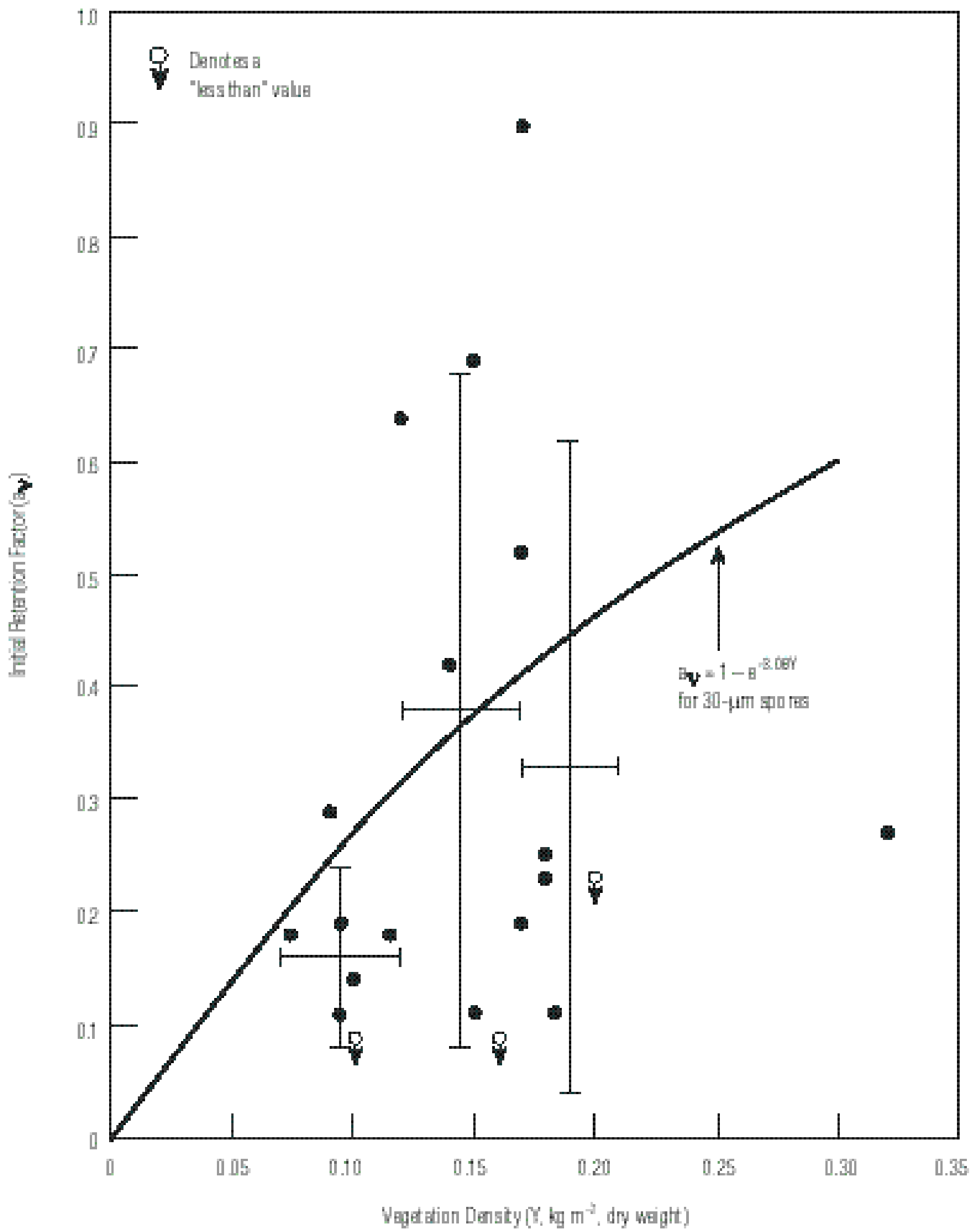
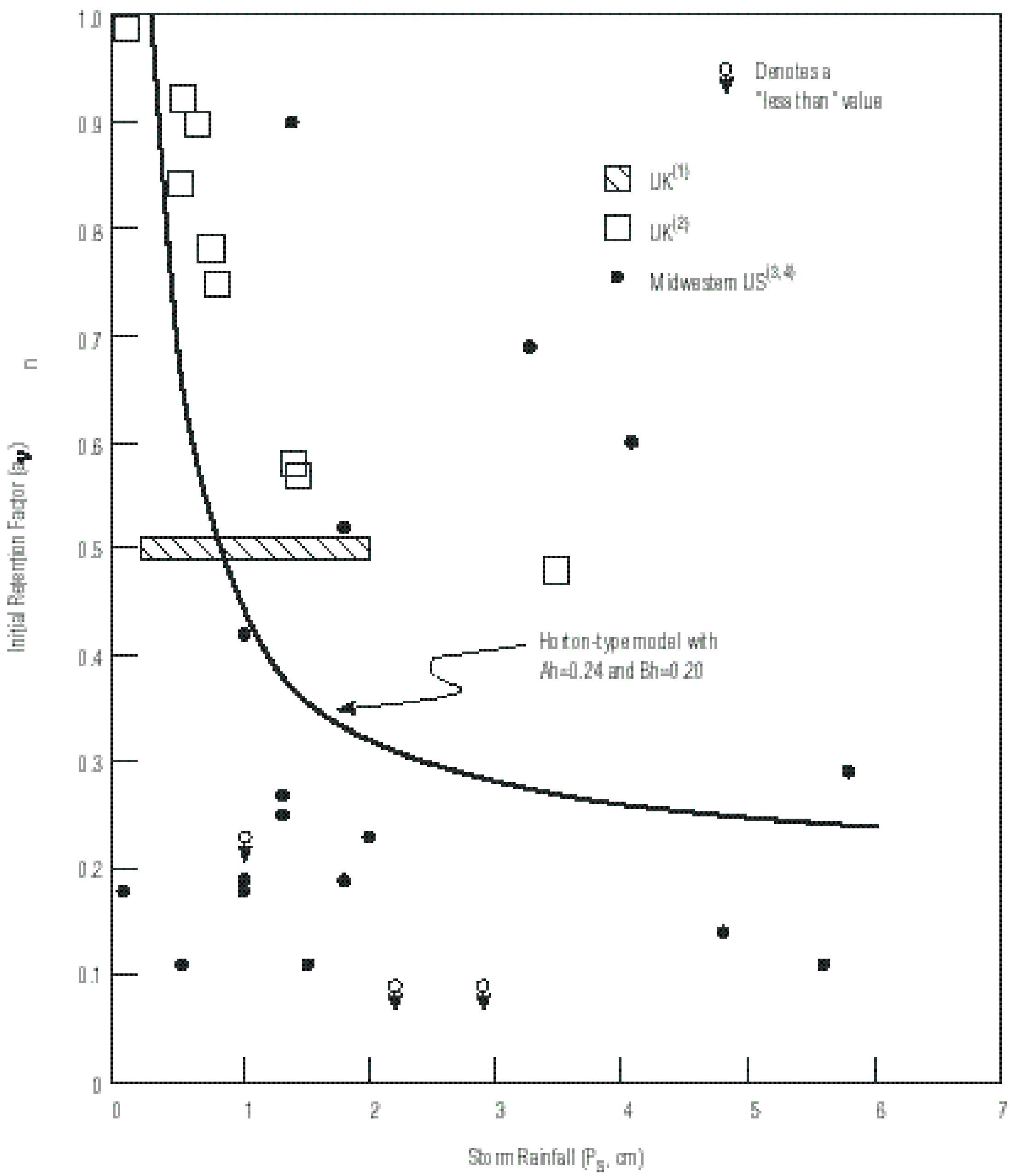


Figure A8.2. Dependence of initial retention of fallout 131I on storm rainfall. Data from (1) Chamberlain and Chadwick (1966), (2) Peirson and Keane (1962), (3) Voillequé et al. (1981) and (4) Weiss et al. (1974).



that and later times, the behavior of residual particulate fallout radionuclides would be representative of less than 1/3 of the total ^{131}I. The principal concern for the NTS fallout is the distribution during the first 10 days following a detonation.

Another distinction is important: many of the measurements of fallout particles (mainly ^{90}Sr and ^{137}Cs) were made after the cessation of atmospheric nuclear testing in the northern hemisphere. The fallout at the later times was derived from the substantial stratospheric inventory established earlier. Only periodic testing by the Chinese has provided recent opportunities for measuring fallout from low level air bursts. It is also noteworthy that the stratospheric particles were found to be quite small, <0.3 μm in diameter (Drevinsky and Pecci 1965; Loysen 1965), although measurements of fallout in the troposphere indicated attachment of fallout particles to naturally occurring aerosol particles or agglomeration to form particles with diameters of about 0.3 to 2 μm (Friedlander and Pasceri 1965; Lockhart et al. 1965). However, even the composite particles are smaller than would be expected within a few days after an explostion at the NTS.

Too little is known of the interactions on the plant surface that result in attachment of radionuclides to predict what the effect of the particle size difference would be. However, caution is advised, both because of that difference and because of the presence of other airborne iodine species.

During the period of tropospheric fallout in the fall of 1961, Peirson and Keane found that the particulate radionuclide ^{140}Ba-La behaved in a manner quite similar to ^{131}I. Estimated mean dry deposition velocities and washout ratios were nearly identical for the two nuclides. The average initial retention fraction for ^{140}Ba-La was estimated to be 1.0±0.3 compared with 0.80±0.17 for ^{131}I using the approach described above.

As indicated above, most studies of ^{90}Sr and ^{137}Cs were of older fallout. Ward et al. (1965) measured the wet deposition of ^{137}Cs and activity on pasture vegetation and cut alfalfa. Deposition on alfalfa from six storms in May and June of 1964 was measured. Five of the evaluations yielded initial retention factors between 0.26 and 0.83, the mean was 0.60±0.21. The sixth result was about 1.8, indicating experimental difficulty or that the predicted removal of previous deposits was less than had actually occurred prior to the storm. During the spring and summer of both 1963 and 1964, the cumulative ^{137}Cs in cut alfalfa hay was measured, as was the wet deposition of ^{137}Cs during the 5- to 7-week growth period. The concentration of ^{137}Cs in air was not reported and neither dry deposition nor weathering was considered. Inclusion of weathering changes the published estimates of av for alfalfa by more than a factor of 2, and 2 of the revised values exceed 1. However, in a thesis (Wilson 1968) cited by Anspaugh (1987), it is stated that their original deposition measurements were found to contain only about half as much ^{137}Cs as was found by an alternative measurement technique, so this would lower computed values of a_v. During 4 of 6 growing periods, the weekly precipitation averaged less than 0.3 cm, so dry deposition was no doubt responsible for most of the activity found in the alfalfa.

Later measurements of retention of wet deposition by alfalfa indicated that washoff of ^{137}Cs occurred during 3 of 7 periods (Wilson et al. 1967). However, the sampling and analysis did not distinguish between washoff and other removal processes. There is also uncertainty about the amount of dry deposition. Dry deposition was shown to be an important process by comparing covered and uncovered vegetation areas, but its effect on the data for exposed alfalfa was not analyzed. Reference is also made to procedural difficulties in the wet deposition measurements. An improved procedure was developed that involved scrubbing of the collector surface to assure collection of all of the deposit in the cation-exchange bed into which precipitation was funneled. This change presumably corrected the problem cited above.

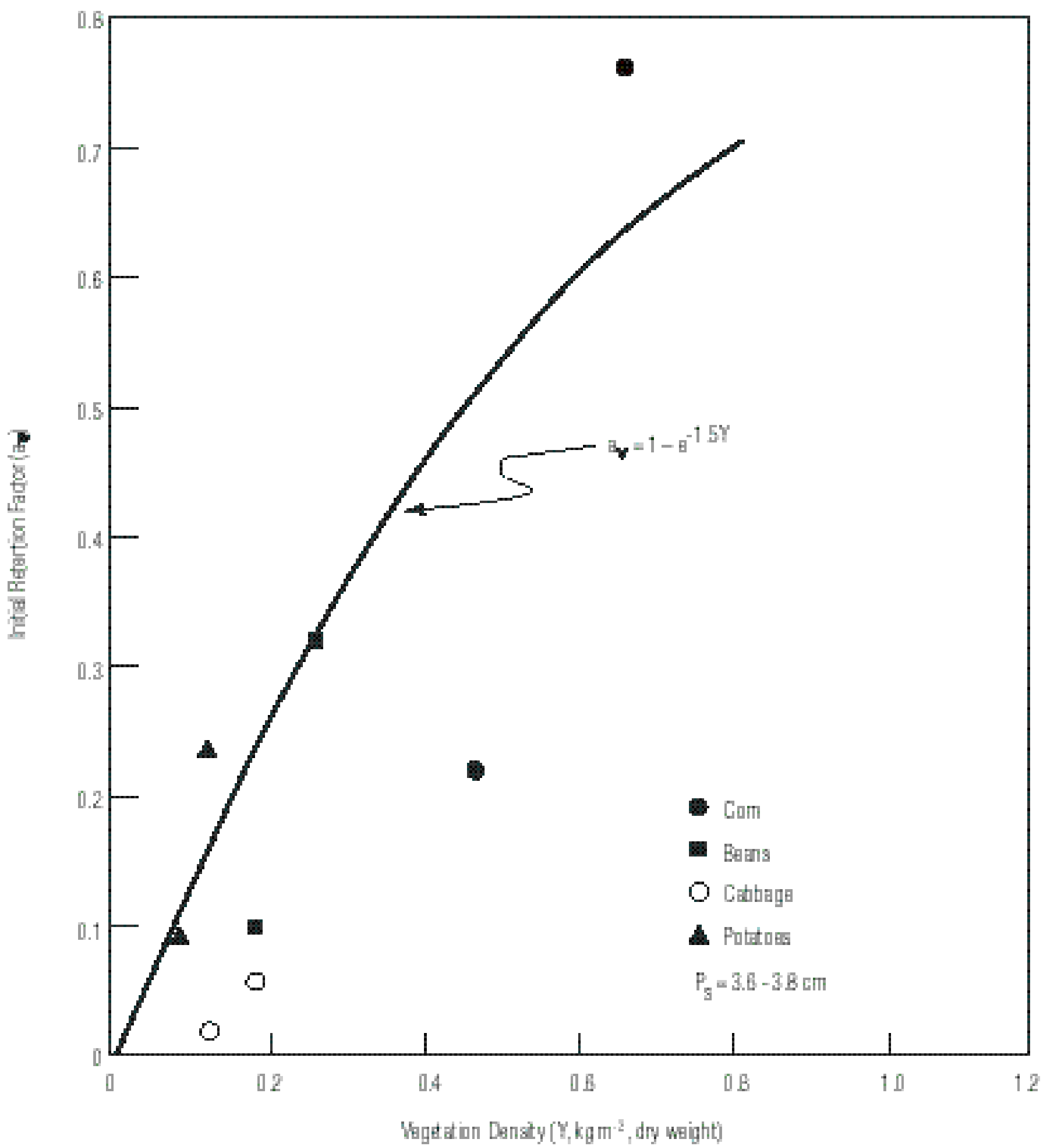
A detailed study of retention by wet deposition was conducted in Florida in the spring of 1962 (Menzel et al. 1963). Retention of ^{90}Sr on low density young plants was less than 10%. As the vegetation grew, the initial retention increased. Vegetation samples were collected before and after each rain, but yields were not stated at the times of the rainfalls. The initial retentions for four crops during two rainfalls of nearly the same amount (3.8 and 3.6 cm) were determined. The initial retention factor estimates are plotted in *Figure A8.3* against vegetation densities obtained by linear interpolation. While there is some uncertainty in the assignment of values of Y, the general dependence of a_v on Y would probably be unchanged if the measured values of Y were to become known. The predicted values for the filtration model with $\mu = 1.5$ m^2 kg^{-1} are shown as a solid line.

Two studies that determined average retention factors for ^{137}Cs and ^{90}Sr in fallout at widely separated locations were published in Health Physics in 1971 (van der Stricht et al. 1971). In the European study, monthly cuttings of herbage fed to cows were measured during a 6-month period in each year between 1961 and 1968. The total deposition during the growing season was measured and allowance was made for soil uptake. The best-fit values of the average retention fractions for ^{90}Sr and ^{137}Cs were 0.13 and 0.084, respectively (van der Stricht et al. 1971). The latter is quite similar to a value of 0.059 for ^{137}Cs found for a farm in Michigan in 1965 by fitting weekly measurements of deposition, rainfall, air concentration, and vegetation concentration to a deposition and retention model. A 14-day weathering half-life was assumed. The fitting process minimized the average fractional deviation between the predictions and measurements over a 6-month period (Pelletier and Voillequé 1971).

Mean values for retention of ^{137}Cs by alfalfa hay were reported by Ward et al. (1966). The estimates for the first cutting ranged from 0.21 to 0.37 and the mean of the long-term average values (0.27±0.07) was less than half the mean of values of a_v measured for individual storms during the early part of the growing season.

Estimates of retention of ^{90}Sr and ^{137}Cs by growing Kentucky bluegrass were reported for spring and summer of

Figure A8.3. Initial retention of ^{90}Sr in wet deposition as a function of vegetation density. Data from Menzel et al. (1963).



1965 (Krey and Fried 1966). The time between samples ranged from 2 to 6 weeks. Neither weathering nor dry deposition was considered, the latter in spite of the fact that covered plots were found to have more than half as much activity as those shielded from rain for three of seven measurement periods. Mean values of the retention factors for uncovered vegetation during the growing season were 0.13±0.10 and 0.072±0.086 for ^{90}Sr and ^{137}Cs, respectively. These values are quite similar to the other long-term values from van der Stricht et al. (1971) and Pelletier and Voillequé (1971).

Studies like these, which average over relatively long time periods, have resulted in lower estimates of the retention of wet deposition by vegetation. The initial retention factor, a_v, is not measured in these studies. A time-averaged retention is computed based on data on wet and dry deposition rates (or only the total) and vegetation concentration. The computed value inevitably reflects a variety of processes (including weathering) and their variations in time. The "retention factor" calculated in this way is not considered to be representative of a_v for ^{131}I in fallout particles.

Figure A8.4 shows the normalized retention factors for ^{90}Sr in fallout on four types of vegetables. The retention data for alfalfa during individual rainstorms at Fort Collins are also shown in the figure. For the alfalfa, it was necessary to estimate yields to obtain a_v; as for the vegetables (*Figure A8.3*), a linear growth rate was assumed. The solid line in the figure is the predicted normalized retention factor from *equation A8.6*. The comparison of the curve with the estimates of a_v is reasonable and provides encouragement that *equation A8.6* may represent a viable approach for estimating retention of fallout ^{131}I. However, *Figures A8.1, A8.2,* and *A8.4* all indicate that there is substantial variability among the measured values and that large uncertainties must be attached to estimates of a_v that are based on existing data.

A8.4.3. Retention by Vegetation of Sprays Containing Radionuclides

The principal alternative to measurements of the retention of wet deposition during rainstorms has been the use of man-made sprays of solutions of radiotracers or suspensions of labeled particles. Some of these studies were discussed in **Section A8.2** in connection with the development of the filtration model by Chamberlain. Two questions arise when the results are considered in connection with wet deposition of fallout, and fallout ^{131}I from the NTS in particular:

- Was the chemical form of the radionuclide similar to that expected in fallout from the NTS?
- Were the drop size distribution, fall velocity, and rainfall rate representative of those found in rainstorms?

When the answers to both questions are negative, the usefulness, for the present problem, of the estimates obtained is highly questionable. In general, the amount of "rainfall" applied in the form of a radioactive spray was quite low, less than 0.2 cm total. Drop size distribution and fall velocity were generally unspecified, but neither was likely to be representative of natural rain.

One of the several tests to measure ^{131}I transport in the milk-food chain performed by the Environmental Protection Agency at the NTS involved spraying a solution of ^{131}I as NaI (Douglas et al. 1971).

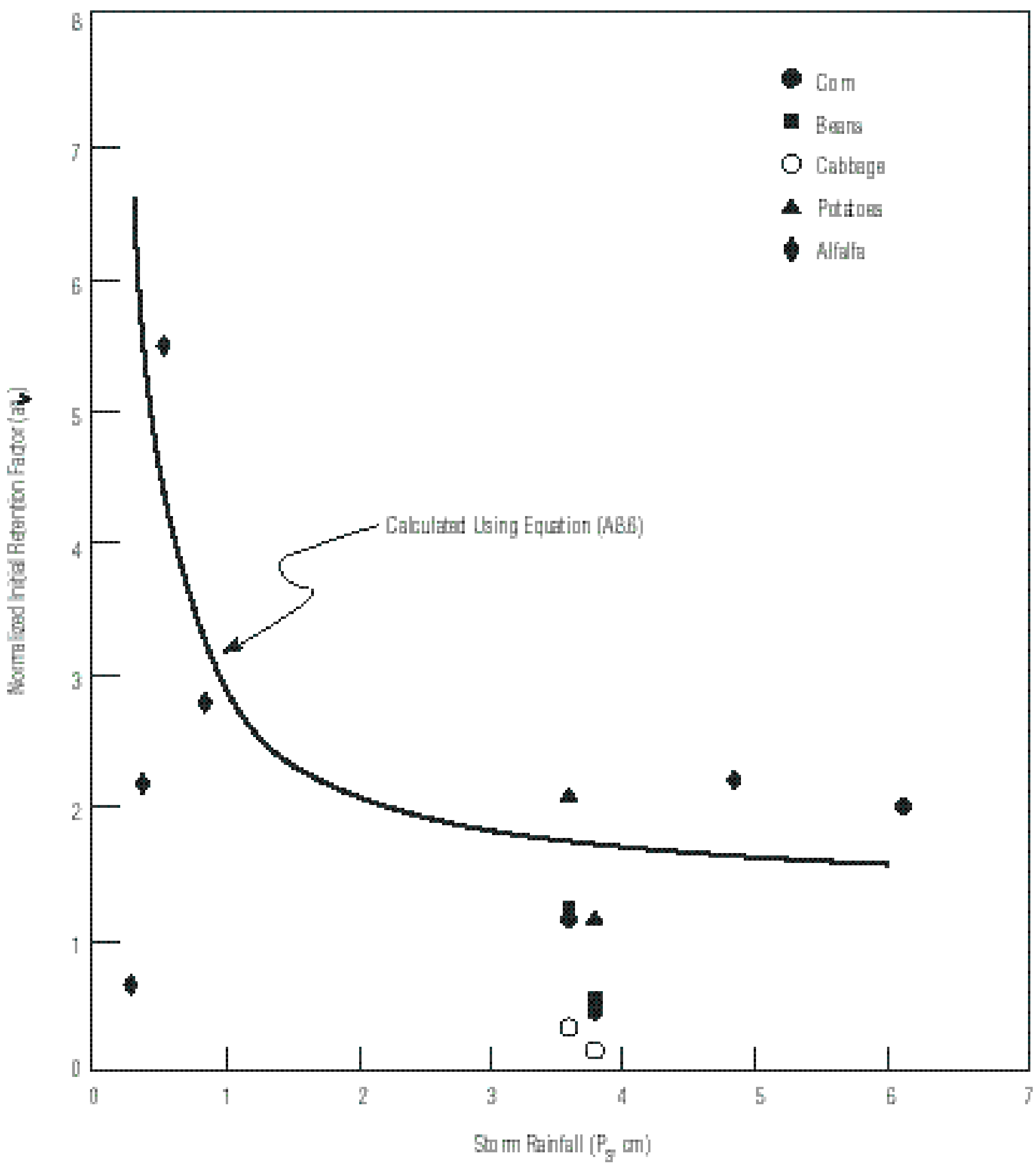
The ^{131}I would be present as iodide (I^-) in the solution. The total spray volume corresponded to a uniform rainfall of about 0.02 cm. The iodide was apparently tightly bound to the alfalfa; no washoff was detected, even for an (artificial) rainfall rate of more than l cm per hour. Neither the vegetation density nor an estimate of the initial retention was given in the report. However, Anspaugh (1987) has obtained an estimate of Y from one of the authors and has extrapolated the retention curve to obtain an estimate of 0.7 for the initial retention factor.

Anspaugh (1987) also cites a Swedish report describing a study by Edvarson and co-workers in which $Na^{131}I$ was sprayed onto a pasture. The equivalent rainfall was 0.008 cm. By assuming uniform ^{131}I metabolism among six cows, and that half the vegetation would be rendered unavailable due to trampling, an estimate of the initial retention of 0.2 was obtained.

Studies that involved spraying radiostrontium on several different pastures were conducted by Milbourn and his associates in the United Kingdom (Milbourn and Taylor 1965; Ellis et al. 1968). Although the pastures were diverse in history and use, similar retention results were obtained. The mean initial retention factor for seven measurements following imitation rainfalls of about 0.02 cm was 0.23±.05. Vegetation densities were low, ranging from 0.05 to 0.13 kg m^{-2}. The mean value of a^*_v is estimated to be 3.2 m^2 kg^{-1}. These data were used by Chamberlain in his development of the filtration model of initial retention. The effect of weathering was also measured and a best value of about 13 days was estimated, with a l-sigma range of 10 to 18 days.

As noted previously, Chamberlain found that fits to these data and some of his own results for labeled particles and solutions of radionuclides gave fairly consistent values for the parameter (m^2 kg^{-1}) in the filtration model. However, the data for fallout ^{90}Sr retention on vegetables are best approximated by a substantially smaller (factor of 2) value of μ (*Figure A8.3*).

Figure A8.4. Dependence of a_v^* for fallout ^{90}Sr and ^{137}Cs on storm rainfall. Data from Menzel et al. (1963) and Ward et al. (1966).



Aarkrog (1969) studied the retention of a solution containing ^{85}Sr, ^{134}Cs, ^{54}Mn, and ^{144}Ce sprayed onto (artifically) high density plantings of grains (barley, oats, rye, and wheat). Similar results were found for all four radionuclides. The retention factors, measured 2 days after very light sprays of contaminated and then clean water, were nearly all above 0.4 and averaged 0.59 ± 0.14, 0.59 ± 0.13, 0.60 ± 0.12, and 0.55±0.15 for ^{54}Mn, ^{85}Sr, ^{134}Cs, and ^{141}Ce, respectively. The spray volume was small, giving $P_s \approx 0.008$ cm, and the clean water spray volume was the same. Vegetation densities ranged from 0.4 to 2.6 kg m^{-2}. Although no single species was tested at the full range of yields, the retention by rye, barley, and oats appears to peak between 1.0 and 1.5 kg m^{-2} and then declines, presumably because the plant mass is so thick that some stalks are protected from contamination. An awnless variety of wheat exhibited the lowest retention, but removal of awns from rye and other wheat varieties appeared to have little effect. Wheat plant densities were grouped at 0.3 to 0.4 and 0.8 to 1.0 kg m^{-2}, the overall mean retention was 0.52 ± 0.11, and no self-shielding could be discerned.

Retention by wheat was also studied by Middleton (1958, 1959), who found retention factors for carrier-free solutions of ^{89}Sr and ^{137}Cs which averaged 0.38 ± 0.11 and 0.39 ± 0.15, respectively. The spray volume for these results was even lower than that of Aarkrog, $P_s \approx 0.0001$ cm; no uncontaminated spray was used.

The complete retention density for rye grass was found to be about 0.6 kg m^{-2} by Kirchmann et al. (1966) using sprays of solutions containing ^{85}Sr and ^{134}Cs. Initial retentions of ^{85}Sr and ^{137}Cs were independent of tracer concentration and averaged 0.08 ± 0.01 and 0.05 ± 0.02, respectively for Y = 0.13 kg m^{-2}. The highest spray volume used decreased retention by about a factor of 2 for both ^{85}Sr and ^{137}Cs, but unfortunately, there is not enough information to determine the rainfall equivalents for the experiments.

Laboratory measurements to identify important variables affecting the initial retention by vegetation of ^{131}I in wet deposition have been performed at the Idaho National Engineering Laboratory (Maeck et al. 1984). Three series of tests were conducted using different chemical forms of ^{131}I added to a rain simulant. Preparation of the rain simulant was based on measurements of the contents of rain in remote, relatively unpolluted areas (Galloway et al. 1982). The three forms were CsI (I^- expected in the rain simulant), I_2 (I_2 and HOI expected in the rain simulant), and CH_3I (CH_3I expected in the simulant). The first of these forms is potentially the most relevant to wet deposition of fallout ^{131}I. The drops used had nominal diameters of 2.8 mm. The quantities applied were relatively low, equivalent to P_s <0.5 cm, and the drops did not fall at terminal velocity. That is, these measurements suffer from the same lack of realism as other experiments described in this section.

Initial retention by lettuce of ^{131}I applied as CsI varied from 0.16 to 0.56 of the total wet deposition in six experiments. Lower retention factors were measured for grass ($0.06 < a_v < 0.1$, 3 tests) and alfalfa ($a_v = 0.02$, 1 test). Vegetation densities ranged from 0.06 to 0.5 kg/m^2 in the 10 experiments. Although the values of a_v generally increased with Y, the correlation was not strong ($r^2 = 0.12$). It was found that results with an acidified rain simulant were comparable to the normal simulant. Retention of contaminated drops was lower when the contamination event was preceded by exposure to uncontaminated drops. This agrees qualitatively with the idea proposed by Horton (1919).

As indicated previously, the relevance of all the results in this section to the problem of predicting the initial retention of ^{131}I in wet deposition of fresh fallout, while uncertain, is believed to be small. In the absence of new information, reliance should be placed on the results of experiments described in **Sections A8.4.1** and **A8.4.2.**

A8.4.4. Retention by Vegetation of ^7Be

Some results of measurements of the behavior of ^7Be in wet deposition were reviewed. Olsen et al. (1985) measured the deposition of ^7Be and the resulting inventories of ^7Be in soil and vegetation at coastal sites and at Oak Ridge. Monthly total deposit on fluxes were measured. The ^7Be was found to all be in the liquid phase, operationally defined by passage through a filter with a pore size of 0.45 µm. Laboratory experiments, theoretical analyses, and the results of other workers all supported the belief that the isotope was present in rain water as $^7Be^{++}$. A comparison of the total ^7Be deposition and the ^7Be wet deposition at Norfolk, Virginia indicated that dry deposition contributed less than 10% of the total. Statistical evaluation of data on total ^7Be deposition and the associated monthly rainfalls led to the conclusion that dry deposition accounted for 30 ± 16% and 19 ± 16% of the total deposition at Norfolk and Oak Ridge, respectively. These estimates were believed to be biased on the high side because of the decrease in the concentration in rain as precipitation increases. Measurements of ^{90}Sr showing such a decrease were reported by Krey and Toonkel (1977) (**Section A8.3.1**). Calculation of the dry deposition rate using a mean deposition velocity of 0.23 cm s^{-1} to grasses (Bondietti et al. 1984) and the average ^7Be concentration in air at Oak Ridge, 0.09 pCi m^{-3} yields 0.054 pCi cm^{-2} $month^{-1}$, about 15% of the total.

The data on ^{7}Be in soil and vegetation at Oak Ridge and several marshes given by Olsen et al. (1985) were analyzed in terms of a simple model. Uptake of deposited ^{7}Be from the soil was expected to be small. The value of the dimensionless uptake ratio, B_v, for Be is estimated to be 4.2×10^{-4} (NRC 1977). Because of the low value of B_v, soil uptake was not considered. The equations used were:

$$\frac{dC_v}{dt} = aD - \lambda_e C_v \qquad \text{(A8.8)}$$

$$\frac{dC_s}{dt} = (1 - a)\, D + \lambda_w C_v - \lambda C_s \qquad \text{(A8.9)}$$

where:

a is the average retention by grass

D is the total (wet and dry) deposition rate (pCi cm^{-2} s^{-1})

λ_e is the effective removal rate constant (s^{-1}), equal to $(\lambda + \lambda_w)$

C_s is the concentration (pCi m^{-2}) of ^{7}Be in soil

The symbols C_v, λ, and λ_w were defined following *equation A8.1.*

The results of measurements of ^{7}Be at the Oak Ridge and three marsh sampling locations are shown in *Table A8.1*. When the grass and soil inventories are compared, it seems clear that either the retention (a) is high or removal of ^{7}Be by weathering is a slow process. Bounding estimates for the average initial retention and weathering half-life can be made from these data if it is assumed that the samples were representative of an equilibrium situation.

When equilibrium is reached, the concentrations in vegetation and soil would be:

$$C_{ve} = \frac{aD}{\lambda_e} \qquad \text{(A8.10)}$$

$$C_{se} = \frac{D}{\lambda} - \frac{aD}{\lambda_e} \qquad \text{(A8.11)}$$

respectively, and the ratio of the two activities would be:

$$\frac{C_{se}}{C_{ve}} = \frac{\lambda_e - a\lambda}{a\lambda} \qquad \text{(A8.12)}$$

Table A8.1. Estimates of minimum average initial retention and weathering half-life for ^{7}Be from inventory measurements.

Location and Date	Measured ^{7}Be Inventories (pCi cm^{-2})		Estimates based on *equation A8.12*	
	Grass	Soil	(If $\lambda_w = 0$) a	(If a = 1) T_w (days)
Oak Ridge, ORNL Soil W-3 (7-3-84)	1.48 ± .030	34 ± .05 (0.64)[a]	0.81 (0.70)	230 (120)
James River Marsh (8-12-82)	1.15 ± .12	0.65 ± .11	0.64	120
Delaware Marsh (7-2-82)	0.33 ± .04	0.23 ± .06	0.60	76
Wallops Island Marsh (1-3-85)	0.77 ± .07	1.05 ± .11 (0.39)[a]	0.42 (0.66)	39 (110)

[a] Computed by taking the difference between the vegetation concentration and the estimated total inventory based on deposition measurements. At ORNL, the estimated inventory was 2.12 pCi cm^{-2}, and at Wallops Island it was 1.16 pCi cm^{-2}.

The last columns of *Table A8.1* show the minimum values of a (assuming no removal by weathering) and of the removal half-life (assuming the maximum initial retention, a = 1). The estimates suggest that the behavior of ^{7}Be differs greatly from the behavior of fallout particles. Long-term average values of retention of fallout ^{137}Cs and ^{90}Sr were typically about 0.1 (**Section A8.4.2**). These results suggest that there must be another source of ^{7}Be in vegetation. Uptake from the soil or rainsplash of soil particles onto vegetation with avid retention seem to be the only alternatives. As noted above, soil uptake was expected to be small.

Measurements by Mahoney (1984) of the initial retention by clover of ^{7}Be during a rainstorm at Oak Ridge in early May 1983 yielded a value of 0.18, substantially lower than the minimum values derived in *Table A8.1*. The clover density was 0.077 kg m^{-2}; therefore, a^*_v was 2.3 m^2 kg^{-1} for P_s = 1.3 cm. Three later measurements for fescue and clover integrated over three storms (the rainfall for the principal ^{7}Be deposition was P_s = 3.6 cm) were reported to yield initial retention estimates of 0.16 to 0.18. However, data tabulated in the report suggest possible mathematical errors and that the values of initial retention factor may have been 0.02 for fescue and 0.02 and 0.06 for clover. Until the inconsistencies can be clarified, it is not possible to say which values are the correct ones.

Two experiments (Mahoney 1984) to measure the weathering half-life of ^{7}Be that was sprayed onto fescue plots at Oak Ridge National Laboratory yielded average values of 36.5 days (during an 80-day period in winter) and 38.5 days (during a 70-day period in spring). During the winter measurements, most of the decrease in concentration was observed during the first 2 weeks. The weathering half-life for that period, estimated from data in the report, was about 6 days.

Mahoney (1984) did find rapid adsorption of soluble ^{7}Be by plant leaves. Freshly harvested fescue and bean leaves were exposed to solutions containing Be^{++}, $^{137}Cs^{+}$, and $^{131}I^{-}$. The leaves were then rinsed prior to analysis. The two positive ions were adsorbed in a similar manner with observed $^{137}Cs/^{7}Be$ ratios in exposed vegetation ranging from 0.8 to 2.4. The ratios of $^{7}Be^{++}$ to $^{131}I^{-}$ ranged from l0 to 40 in one experiment and from 50 to 150 in another. The $^{137}Cs^{+}$ to $^{131}I^{-}$ ratios ranged from 50 to 250 (Mahoney 1984). These results are qualitatively similar to those of Angeletti and Levi (1975) who found substantially greater retention by vegetation of Sr^{++} than of I^{-} when solutions were sprayed on the plants. Mahoney (1984) found that about 1/3 of the total adsorption of both ^{7}Be and ^{131}I occurred within 3 minutes in one experiment ($^{7}Be^{++}/^{131}I^{-}$ ranged from 10 to 40). In the other experiments, the first measurements were not made until 30 minutes after the start of exposure). These results suggest that $^{7}Be^{++}$ in rainwater would be promptly bound to plant leaves and could lead to high initial retentions. They also suggest that $^{7}Be^{++}$ is not a good analog for studying the retention by vegetation of ^{131}I present in rainwater as I^{-}.

One measurement of uptake of ^{7}Be injected into soil in which fescue was growing was reported by Mahoney (1984). It was found that only 0.13 ± 0.04% of the injected activity was present in the vegetation after a 2-month growth period. Although a direct comparison with the reported value of B_v (NRC 1977) is not possible, this result indicates that soil uptake is not adequate to account for the discrepancies implied by analysis of the field data (*Table A8.1*).

When the average values of the retention fraction and weathering half-life measured for fescue at Oak Ridge are substituted into *equation A8.12*, the predicted ratio of the ^{7}Be inventory in soil to that in vegetation is found to be about 13. This ratio is about ten times larger than the largest of the ratios computed from the measured inventories shown in *Table A8.1*. If the estimated weathering half-life is correct, equilibrium will be achieved fairly rapidly. At Oak Ridge (Olsen et al. 1985), the estimated total inventories for the 4 months of April to July 1984 were 1.85, 2.38, 2.12, and 2.17 pCi m^{-2}, respectively. Thus, the assumption of equilibrium in deriving *equation A8.12* does not appear to be invalid for that location. Estimates of the ^{7}Be inventory for the months preceding the measurements at the coastal locations were not given.

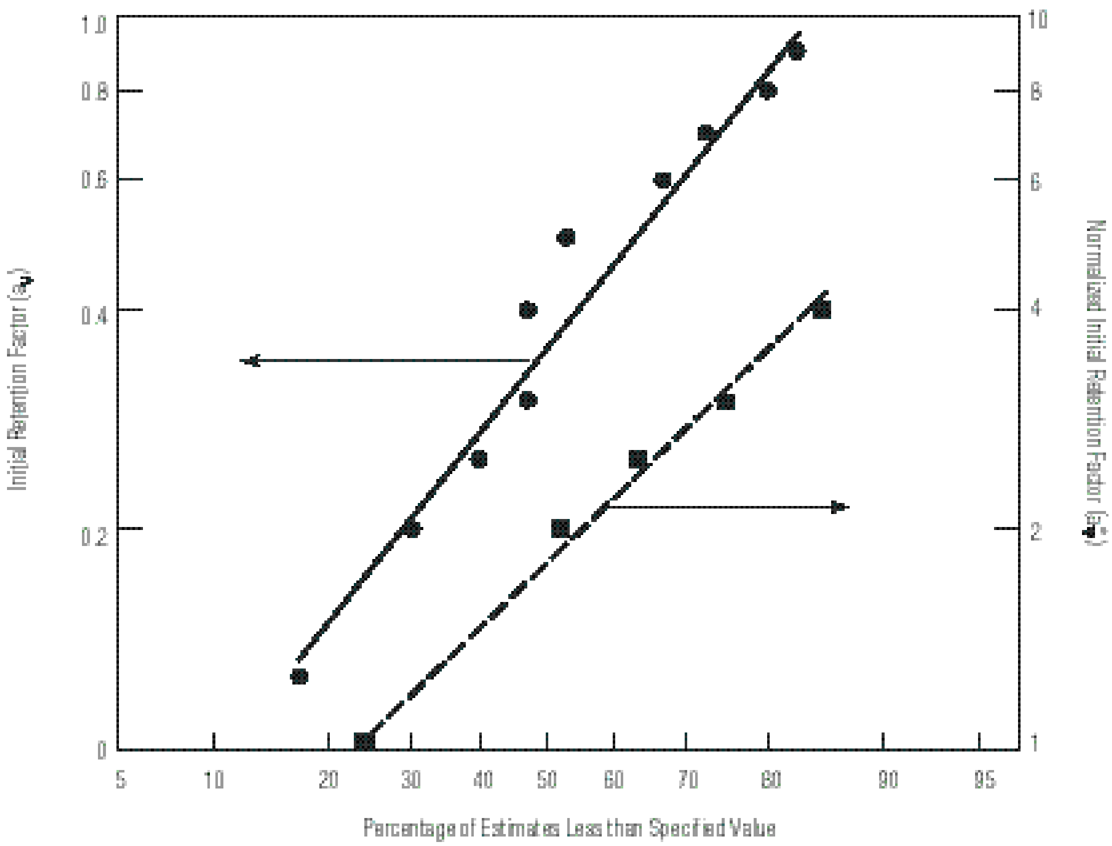
In a study of deposition of Chinese fallout particles onto tree canopies, Russell and Choquette (1976) found wet deposition to be the predominant transport mechanism from atmosphere to leaves. A long retention period was observed with estimated half-lives of 50 to 200 days, depending upon the leaf type. The transport of ^{7}Be was also measured. Relative to ^{141}Ce, only 20% of the ^{7}Be in rainfall was fixed on tree leaves. The reason for this observation is not known but may be related to differences in particle size, solubility, or binding to the leaf surface.

A8.5. SUMMARY OF RELEVANT DATA

The information considered most relevant to the task of assessing the initial retention by vegetation of ^{131}I in wet deposition of fallout from the NTS is that discussed in **Sections A8.4.1** and **A8.4.2.** The available data and conceptual evaluations both suggest that the initial retention factor is dependent upon both the density of the vegetation (Y, kg m^{-2}) and upon the amount of rainfall. Other related parameters (total leaf area, leaf surface characteristics, rainfall rate, rainfall sequence, and so on) clearly enter into the observed interception and initial retention processes, but examination of the processes at that level of detail is beyond the scope and needs of the current dose evaluation effort.

Estimates of the initial retention factor, a_v, based upon field measurements of wet deposition onto pasture grass range from < 0.09 (Chinese fallout in the midwestern U.S.) to 1.0 (Russian fallout in the United Kingdom). Thirty estimates are available from Peirson and Keane (1962), Weiss et al. (1974), and Voillequé et al. (1981). The mean of these values (with sample standard deviation)is 0.45 ± 0.32. Chamberlain and Chadwick (1966) found an average of 0.5 ± 0.10 for a

Figure A8.5. Distributions of a_v and a^*_v for wet deposition of ^{131}I in fallout.



comparable number of measurements. Five measurements for fallout ^{137}Cs in wet deposition onto alfalfa ranged from 0.26 to 0.83 with a mean of 0.60 ± 0.21 (Ward et al. 1965).

A normalized initial retention factor can be used to incorporate the approximately linear dependence upon vegetation density of the filtration model developed by Chamberlain (1970). Twenty values of $a^*_v = a_v/Y$ obtained from measurements of Chinese fallout ^{131}I in the midwestern United States range from 0.56 to 5.5 $m^2\ kg^{-1}$ with a mean of 2.0 ± 1.6 $m^2\ kg^{-1}$. Inclusion of the five results for fallout ^{137}Cs deposited on alfalfa yields a mean of 2.1 + 1.6 $m^2\ kg^{-1}$.

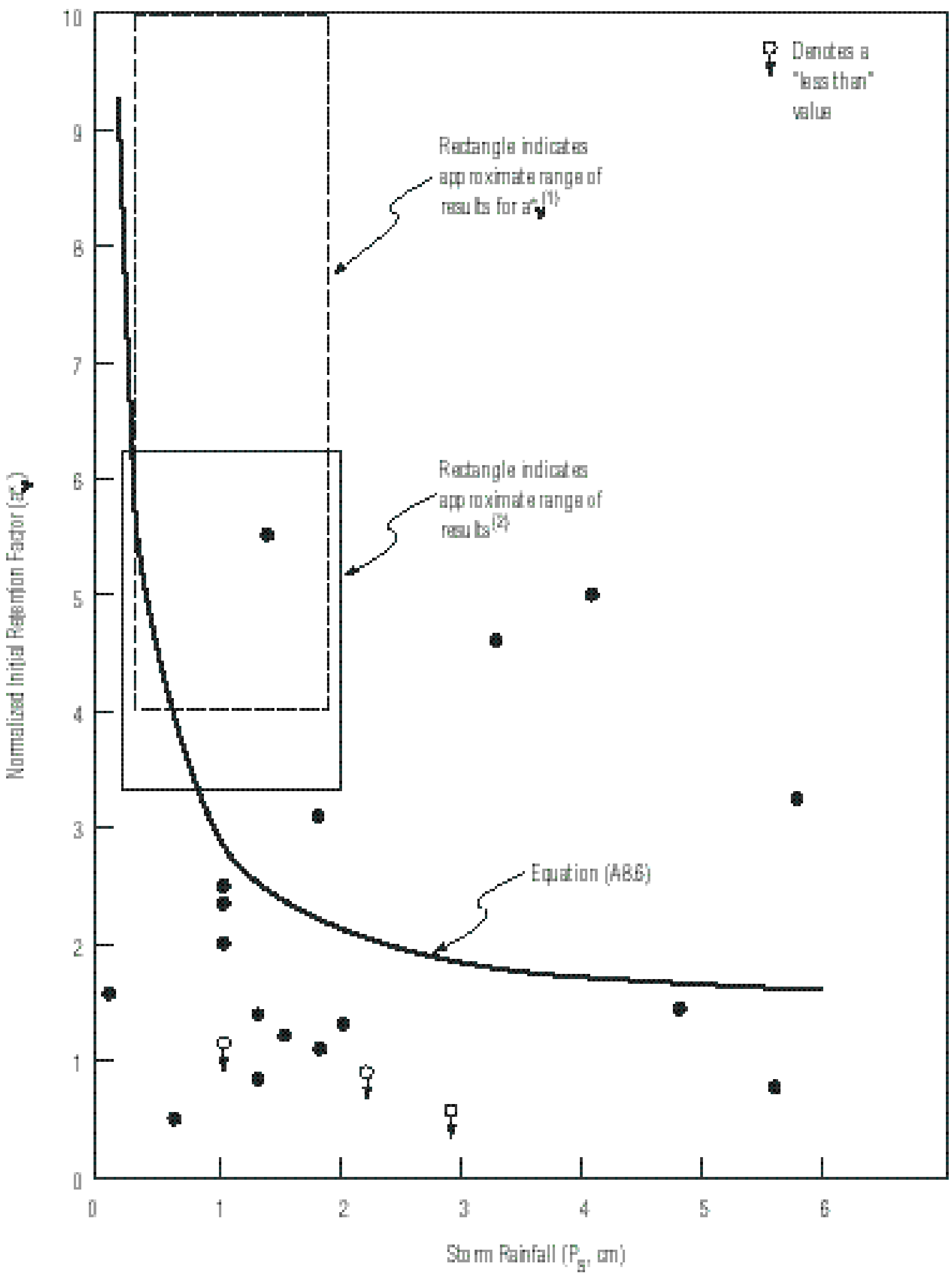
Figure A8.5 shows the distributions of the 30 values of a_v and 20 values of a^*_v. Use of the normalized initial retention factor does reduce the variability somewhat. The median value of a_v is estimated to be 0.35 with a geometric standard deviation of 2.9. The estimated median a^*_v is 1.8 $m^2\ kg^{-1}$, with a geometric standard deviation of 2.3.

The available data on the initial retention of fallout ^{131}I and of particulate fallout nuclides in wet deposition suggest that a model similar to that proposed by Horton (1919) may be used to estimate the effect of differences in rainfall amount. *Figure A8.6* shows the suggested relationship (*equation A8.6*) together with values of a^*_v from the midwestern United States and ranges of a^*_v for the United Kingdom. These ranges are based upon the estimated ranges of storm rainfall (0.2 to 2 cm) and of autumn vegetation densities (0.08 to 0.15 kg m^{-2}). While the comparison between *equation A8.6* and the estimates of a^*_v are not particularly satisfying, other approximations that might be used are likely to have comparable deficiencies when attempting to account for the variety of measurement results.

A8.6. CONCLUSIONS

The initial retention by pasture vegetation of ^{131}I in wet deposition at locations in the United States is an important factor in the assessment of the thyroid doses received from NTS fallout. The projected doses from wet deposition are proportional to the initial retention factor, a_v. Wet deposition will be the most significant transport process for many parts of the country and perhaps for the collective thyroid dose.

Figure A8.6. Estimated values of a_Ψ^* as a function of storm rainfall. Data from (1) Peirson and Keane (1962) and (2) Chamberlain and Chadwick (1966).



Data collected during 1961 and 1962 and more recently suggest that ^{131}I in fresh fallout is primarily associated with particulate debris. During the few days when radioactivity would have been transported from the NTS to other locations in the United States, a minimum of 60%, and as much as 90%, of the ^{131}I activity was in particulate form. Inorganic forms would dominate the gaseous fraction with at most one-third of that component present as organic iodides soon after detonation. At least half of the ^{131}I reaching the ground in rainwater would be contained in scavenged particles having diameters between 1 and 20 μm. Part of the remainder could be composed of submicron particles.

Field measurements of wet deposition of ^{131}I and other radionuclides in fallout and tests involving various types of fallout simulants indicate the initial retention factor depends upon both the vegetation density (Y, kg m^{-2}) and the total amount of rainfall during a storm (P_s, cm). Use of the normalized initial retention factor ($a^*_v = a_v/Y$) reduces the variability of the field measurement results. The median value of 30 estimates of a^*_v was 0.35, with a geometric standard deviation of 2.9. The median of 20 estimates of a^*_v was 1.8 m^2 kg^{-1}, with a geometric standard deviation of 2.3.

Detailed evaluation of variations due to changes in precipitation rate during a storm is beyond the needs and the resources of the fallout dose reassessment effort. However, it is desirable to know the dependence of the initial retention factor on the total storm rainfall. The approach suggested by Horton was used. Existing data for fallout were used to develop a predictive equation for the normalized initial retention factor: $a^*_v = (S/P_S) + E$, where S and E are constants related to rainfall storage capacity and evaporation during a storm (**Section A8.4.1**). In the absence of other information, this equation appears to provide a reasonable estimate of the dependence upon rainfall. The alternative (again in the absence of new measurement results) would be to use the median value of a^*_v.

Most wet deposition simulation experiments have been conducted under extremely light spray conditions. These tests are not considered reliable indicators of fallout ^{131}I behavior for that reason and because the tracer forms were not reflective of fresh fallout containing ^{131}I.

The use of ^{7}Be as an analog for ^{131}I in fresh fallout is not considered to be a reliable alternative. At most, half of the ^{131}I would be expected to be in solution, compared with all of the ^{7}Be. Further, the adsorption by leaves of $^{7}Be^{++}$ from solution appears to be much greater than the adsorption of $^{131}I^{-}$ by the same leaves. The observed behavior of ^{7}Be in wet deposition onto grass and soil differs greatly from that deduced for radionuclides in fallout particles. The fact that both ^{7}Be and ^{131}I are both poorly retained by gummed film as the rainfall amount increases is considered to reflect water saturation of the film surface and runoff rather than an inherent similarity in retention of the two nuclides.

Field experiments performed to determine the dependence of a_v on vegetation density and rainfall parameters should employ ^{131}I as iodide and iodate in solution and particles with diameters of up to about 20 μm with tightly bound radionuclide labels. The spray system used should generate a realistic simulant of natural rain. The raindrop size spectrum as a function of rainfall intensity needs to be well characterized.

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Information on the Main Computer Codes Used in the Dose Assessment

Contents

A9.1. INTRODUCTION

The estimation of the thyroid doses received by the American people from ^{131}I in fallout from Nevada bomb tests is carried out in three steps:

1. Assessment of the extent to which ^{131}I was deposited per unit area of ground. (Step 1)

2. Estimation of the concentrations of ^{131}I in several categories of cows' milk (i.e., fresh cows' milk, milk consumed on the farm, milk sold retail in the same county, milk that originated in another county within the same milk marketing region, volume-weighted mixed milk, and milk obtained from a backyard cow) and in goats' milk, cottage cheese, eggs, leafy vegetables, and ground-level air. (Step 2)

3. Assessment of average thyroid doses for various population groups (i.e., those persons who consumed average diets, the "high-exposure" groups, the "low-exposure" groups, persons who drank milk from backyard cows, and infants who were fed mother's milk) and of the per capita doses. (Step 3)

Those three steps are illustrated in *Figure A9.1*.

A9.2. STEP 1. ESTIMATION OF ^{131}I RADIOACTIVITY DEPOSITED PER UNIT AREA OF GROUND

A schematic representation of the procedure used to derive the daily depositions of ^{131}I in the 3,094 counties and sub-counties of the contiguous United States is provided in *Figure A9.2*.

When gummed-film data were available from DOE/EML, which is the situation for most of the tests, the daily depositions of ^{131}I were estimated for the 3,071 counties of the U.S. together with the use of either the kriging or the AIPC method, and the precipitation data supplied by NOAA/ARL. The computer programs used with the kriging method were developed by EML staff[1]. The computer program implementing the AIPC method is called DEPINTER.FOR (**Attachment A9.1**).

When gummed-film data were not available (nine tests, **Section 3.3.2**), a meteorological model was applied to obtain estimates of daily depositions in 3,071 counties. The computer programs associated with the meteorological model were developed by NOAA staff[1].

Monitoring data from locations in counties and states near the NTS were supplied by DOE/NVO in the County Data Base (CDB) and in the Town Data Base (TDB). These data, which are available for almost all of the tests, are expressed in terms of exposure rates at H + 12 associated with estimated initial times of arrival, and were converted to depositions of ^{131}I per unit area of ground in those locales by the computer programs TDB1089.FOR (**Attachment A9.2**) and CDB290.FOR (**Attachment A9.3**).

[1] Programs developed by agencies other than NCI remain in the possession of those agencies.

Only the most complete and valid database and/or analytical method available for a geographical area was used as a basis for ^{131}I deposition estimates:

Town Data Base:	five counties in Nevada and Utah (**Section 3.2.1**).
County Data Base:	134 counties in Arizona, California, Colorado, Idaho, New Mexico, Nevada, Oregon, Utah, and Wyoming (**Section 3.2.1**).
Gummed-film Data:	the remaining 2,937 counties in the U.S. at the time.
Meteorological Model:	the remaining 2,937 counties in the U.S. at that time when gummed-film data were not available (nine tests, **Section 3.3.2**)

The daily deposition estimates of ^{131}I from the (a) Town Data Base, (b) County Data Base, (c) gummed-film data, to which either the kriging or AIPC method was applied, and (d) the meteorological model were combined using the program DEP(test name).FOR (**Attachment A9.4**). This program will provide the estimated daily depositions of ^{131}I per unit area of ground for any of the nuclear tests included in this analysis, using the most complete and valid of the several sources of deposition estimates. In this Appendix, the test Simon is used as an example,so that the program DEPSIMON.FOR is provided as **Attachment A9.4.**

A9.3. STEP 2. ESTIMATION OF THE CONCENTRATION OF ^{131}I IN FOODSTUFFS AND IN AIR

A schematic representation of the procedure used to derive the concentration of ^{131}I in foodstuffs and in air for the 3,094 counties and sub-counties of the contiguous United States from the daily depositions of ^{131}I per unit area of ground is provided as *Figure A9.3.* A computer program called CONCUST9.FOR (**Attachment A9.5**) calculates those concentrations for each day of fallout resulting from a particular nuclear test, and sums those concentrations for each day of fallout on the basis of:

(a) the calculated distance of each county centroid from the NTS,

(b) the precipitation for each day and for each county,

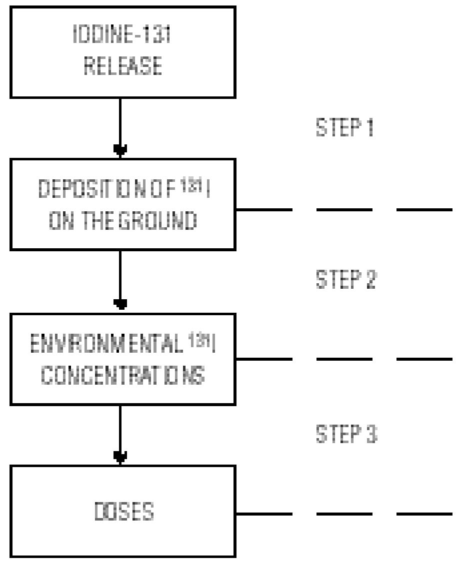
(c) the pasture intake by cows for each day and for each county, and

(d) the volumes of milk available for fluid use in each county and milk transferred into or out of the county.

The computer program CONCUST9.FOR includes:

- the distance from the NTS calculated by DISTANCE.FOR (**Attachment A9.6**),
- the precipitation data provided by NOAA/ARL,
- the pasture data calculated by NUPAST.FOR (**Attachment A9.7**) and NEWPASTREG.FOR (**Attachment A9.8**),
- the milk production, utilization, and distribution data calculated using MILLER.FOR (**Attachment A9.9**), NEWMILLERUS2.FOR (**Attachment A9.10**), and MILKDIST.FOR (**Attachment A9.11**).

Figure A9.1. Schematic representation of the steps used to estimate thyroid doses.



A9.4. STEP 3. ESTIMATION OF AVERAGE THYROID DOSES

A schematic representation of the procedure used to derive estimates of average thyroid doses for various population groups in the 3,094 counties and sub-counties of the contiguous United States from the time-integrated concentrations of ^{131}I in cows' milk, other foodstuffs, and ground-level air is provided in *Figure A9.4.* The computer program GRPDOSE1.FOR (**Attachment A9.12**) estimates the average doses to various population groups using a consumption data file prepared by hand, while the program PERCAP1.FOR (**Attachment A9.13**) estimates the per capita and collective doses for the 3,094 counties and sub-counties of the contiguous U.S. using population data provided by the Environmental Protection Agency.

Figure A9.2. Schematic representation of the procedure used to estimate daily depositions of ^{131}I in each of the 3,094 counties and sub-counties of the contiguous U.S.

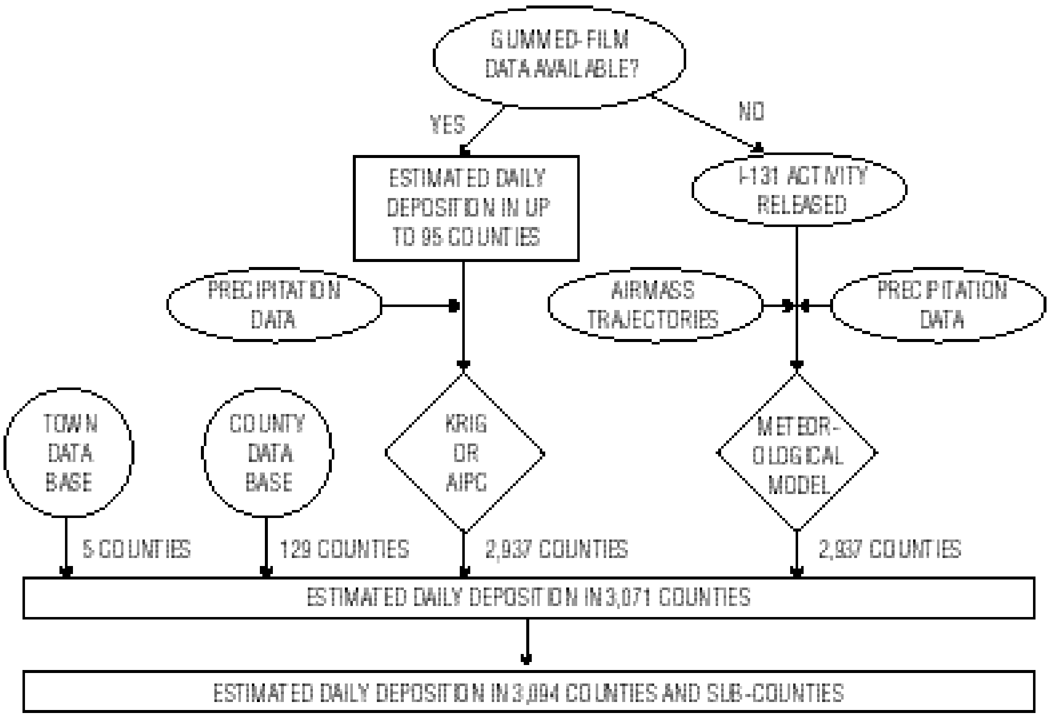


Figure A9.3. Schematic representation of the procedure used to estimate time-integrated concentrations of ^{131}I in the 3,094 counties and sub-counties of the contiguous U.S.

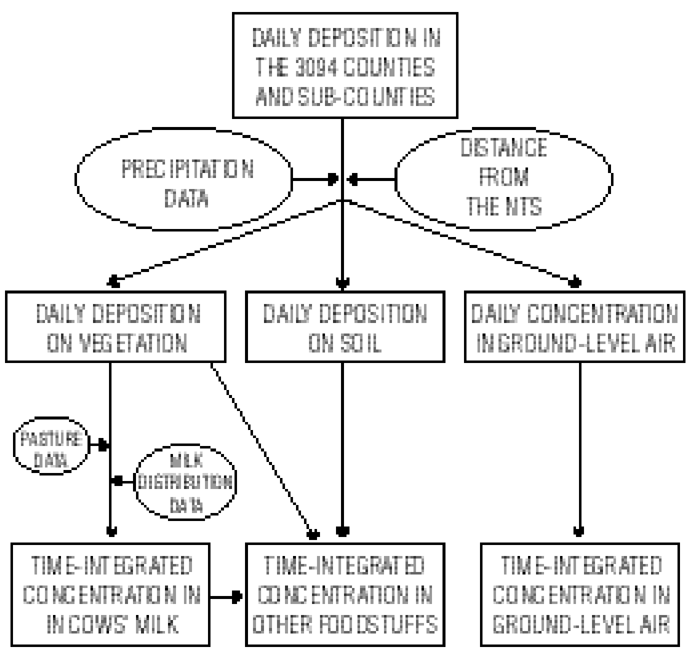
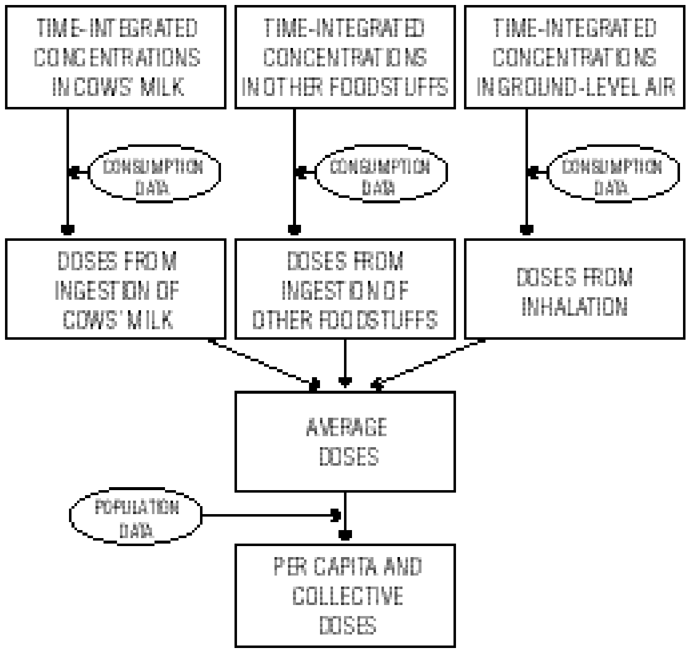


Figure A9.4. Schematic representation of the procedure used to calculate average ^{131}I thyroid doses for population groups in the 3,094 counties and sub-counties of the contiguous U.S.



ATTACHMENT A9.1: PROGRAM DEPINTER.FOR

```
          program depinter
c
c
c         interpolation by "hand": incorporates precip data, uncertainties,
c         and estimated depositions into a GF file.
c         Files: . (test)(date).HAND is the daily GF input file
c                   copied from disk$bouville:[andre.maps](test)(date).HAND
c         . [dreicer.milk]B02.DAT is the FIPS file with county
c           coordinates
c         . PRE(date)F.DAT is the daily precip file copied from
c              disk$bouville:[andre.precip.daily]
c         ***    . GFST.DAT is the GF station file
c         . (test)H(date).FIN is the daily "interpolated" output file
c
c
          dimension fps(130),prec(130),dp(130),cf(10),cgf(130),ef(10)
          dimension gflat(130),gflon(130)
          character*12 GFNAME,bjname
          character*8 TNAME
          integer fps,prec,dp,fips,dep
c
          open (unit = 1, file = 'gfx.dat', status = 'old')
          open (unit = 2, file = '[dreicer.milk]b01.tape', status = 'old')
          open (unit = 3, file = 'day.dat', status = 'old')
          open (unit = 4, file = 'gfst.dat', status = 'old')
          open (unit = 10, file = 'gfx.fin', status = 'new')
          open (unit = 11, file = 'check.dat', status = 'new')
c
          cf(1) = 1.
          cf(2) = 1.5
          cf(3) = 2.
          cf(4) = 2.
          cf(5) = 4.
          cf(6) = 6.
          cf(7) = 10.
          cf(8) = 10.
          cf(9) = 10.
c
          ef(1) = 20. / 20.
          ef(2) = 20. / 20.
          ef(3) = 20. / 30.
          ef(4) = 20. / 25.
          ef(5) = 20. / 15.
          ef(6) = 20. / 10.
          ef(7) = 20. / 7.
          ef(8) = 20. / 7.
          ef(9) = 20. / 7.
c
          read (1,100) tname,im,it,iy,im,id
          read (4,400)
          do 12 k = 1,130
          read (4,401,end=13) bjname,fps(k),gflat(k),gflon(k)
          read (1,101,end=13) gfname,dp(k),prec(k)
          np = prec(k)
c         dp(k) = dp(k) * ef(np)
```

```
          cgf(k) = cf(np)
          if (bjname.ne.gfname) write (11,110) k,bjname,gfname
12        continue
13        kmax = k - 1
c
          write (10,510) tname,im,it,iy
          n = 0
          iyes = 0
          ino = 0
1         CONTINUE
          read (2,200,end=20) nfips,ulat,ulon
          n = n + 1
          dref = 300.
          dep = 0
          kk = 130
          do 2 k = 1,kmax
          if (dp(k).lt.0) go to 2
          x = abs(gflat(k) - ulat)
          y = abs(gflon(k) - ulon)
          if (x.gt.10.) go to 2
          if (y.gt.10.) go to 2
          d = x*x + y*y
          if (d.ge.dref) go to 2
          dref = d
          kk = k
2         continue
c
c         write (11,512) kmax,n,kk,dp(kk),d
c
          mm = 1
          dpp = dp(kk)
          if (dref.eq.300.) go to 5
          mm = 2
          dpp = dp(kk)
          if (dp(kk).eq.0) go to 5
          udep = log(3.)
          if (nfips.eq.fps(kk)) udep = log(1.5)
3         read (3,300,end=4) im,id,iyear,fips,iprecip
          if (fips.ne.nfips) go to 3
          if (nfips.eq.fps(kk)) iprecip = prec(kk)
          dpp = dp(kk) * cf(iprecip) / cgf(kk)
          dep = dpp
          mm = 3
          if (dep.eq.0) go to 5
          iyes = iyes + 1
          write (10,511) nfips,tname,id,dep,udep,iprecip
          go to 1
4         iprecip = 1
          if (nfips.eq.fps(kk)) iprecip = prec(kk)
          dpp = dp(kk) * cf(iprecip) / cgf(kk)
          dep = dpp
          mm = 4
          if (dep.eq.0) go to 5
          iyes = iyes + 1
          write (10,511) nfips,tname,id,dep,udep,iprecip
          rewind 3
          go to 1
```

```
5         continue
          ino = ino + 1
          write (11,512) mm,n,nfips,kk,dpp,dref,iprecip
          go to 1
20        continue
          itot = iyes + ino
          write (11,513) iyes,ino,itot
513       format (3i5)
100       format (1x,a,i2,1x,i2,1x,i2,13x,i3,1x,i2)
101       format (1x,a,4x,i5,i7)
110       format (i5,a,2x,a)
200       format (i5,34x,2f8.3)
300       format (5x,i2,1x,i2,1x,i4,i8,i5)
400       format (//)
401       format (a,7x,i5,f7.2,f8.2)
510       format (/2x,'HAND :',a,'(',i2,'/',i2,'/',i2,')',1x,'I'/
     1'FIPS',7X,'SHOT',7X,'DAY',2X,'131',4X,'ERR',2X,'PRECIP'/)
511       format (i5,1x,a,i10,i8,f6.2,i5)
512       format (4i6,2f8.3,i5)
          stop
          end
```

ATTACHMENT A9.2 : PROGRAM TDB1089.FOR

```
         PROGRAM TDB1089
C
C       CALCULATES THE I-131 DEPOSITION DENSITIES NEAR NTS FROM THE
C       EXPOSURE RATES AND TOA GIVEN IN THE TOWN DATA BASE
C       ONE PROGRAM FOR EACH TEST : CHANGE THE NAME OF THE TEST
C       revised april 1989 : GSD on deposition assumed to be ge 1.4
c       REVISED 30 january 1990
C       OUTPUT FILE TDB(test).RES : results for the 173 TDB stations
C       OUTPUT FILE TDB(test).FIN : results for the 13 sub-counties
C       OUTPUT FILE TDB(test).CTY : results for the 5 counties (for map
c       purposes)
C
         DIMENSION IPS(60),IPSC(5),NUMC(5),AREAC(5),DEPC(5)
         DIMENSION NUM(60),RNAME(4),RI(4),AREA(60),DEPSC(20)
         DIMENSION IPS1(2020),DEP(2020),H12E(2020),DEPCE(5)
         DIMENSION DEPSCE(20),npb(4),x(2020),s(2020),xsc(20),CTYSC(13)
        dimension s2xsc(20),xc(5),s2xc(5),STC(5),CTYC(5),STSC(13)
        REAL LON,LAT,mu,muxsc,muxc
        CHARACTER*10 TNAME,TN,RNAME
        CHARACTER*16 TT
        CHARACTER*2 STC,STSC,SERIES
        CHARACTER*10 CTYC,CTYSC
         OPEN (UNIT=1,FILE='TDBTEST.DAT', STATUS='OLD')
         OPEN (UNIT=2,FILE='TDBNUM1089.CTY', STATUS='OLD')
         OPEN (UNIT=3,FILE='EXTEST.DAT',STATUS='OLD')
         OPEN (UNIT=4,FILE='TDBW.DAT',STATUS='OLD')
         OPEN (UNIT=14,FILE='TDBTEST.RES',STATUS='NEW')
         OPEN (UNIT=15,FILE='TDBTEST.FIN',STATUS='NEW')
         OPEN (UNIT=16,FILE='TDBTEST.CTY',STATUS='NEW')
         OPEN (UNIT=17,FILE='check.dat',STATUS='NEW')
        DO 1 J=1,13
```

```
1       READ (2,100) I,STSC(I),CTYSC(I),IPS(I),NUM(I),AREA(I)
100     FORMAT (I4,2X,A2,2X,A10,5X,I5,I7,F10.0)
        DO 2 J = 1,5
        READ (2,100) I,STC(I),CTYC(I),IPSC(I),NUMC(I),AREAC(I)
2       CONTINUE
        DO 10 I=1,2020
        DEP(I) = 0.
        H12E(I) = 1.
10      CONTINUE
c
c       read depositions (mmCi/m2 at H+12) corresponding to a total
c       exposure rate of 1 mR/h at H+12 for Sb-131,Te-131m, Te-131,
c        and I-131 and for this particular test
c
        READ (3,130) TNAME,ny,nm,nd,q,SERIES,NCODE
        ITEST = ny * 10000 + nm * 100 + nd
130     FORMAT (A,3I2,e10.2,4X,A2,1X,I2)
        DO 6 J=1,4
        READ (3,140) RNAME(J),RI(J)
6       CONTINUE
140     FORMAT (A,E10.3)
c
c       calculation of the "total" I-131 deposition density per
c       unit exposure rate at H + 12
c
        ri1 = ri(1)*23.3/(60.*8.04*24.)
        ri2 = ri(2)*30.0/(8.04*24.)
        ri3 = ri(3)*25.0/(60.*8.04*24.)
        RTI= RI1 + RI2 + RI3 + RI(4)
c
c       read Town Data Base data and calculate the median I-131 deposition
c       densities for all TDB stations
c
        DO 11 I = 1,300
        READ(1,110,END=3) ID,IPS1(ID),H12,H12E(ID),TOA
        RINT = RTI*EXP(-0.69315*(TOA-12.)/(8.04*24.))
        DEP(ID) = 1000.*H12*RINT
        if (h12e(id).lt.1.4) h12e(id) = 1.4
        mu = log (dep(id))
        sig = log (h12e(id))
        x(id) = exp (mu + (sig*sig/2.))
        s(id) = x(id) * sqrt(exp(sig*sig) - 1.)
11      CONTINUE
3       CONTINUE
c
c       prepare the first output file (depositions for all stations)
c
        write (14,219) SERIES,NCODE,tname,nm,nd,ny
219     format(1x,'Table ',A2,'/',I2,'/TDB. Estimates of median I-131',
     4' depositions ',
     1'per unit area of ground',/,12x,
     2' at the Town Data Base sites following the shot ',a,/,13x,
     3'detonated',1x,i2,'/',i2,'/19',i2,'.',/)
        write (14,218)
218     format (2x,'Test',6x,'Test',4x,'Site',1x,'State',2x,'County',
     14x,'Sub-',5x,'I-131',6x,'GSD',2x,'Deposition'/
     22x,'name',6x,'date',4x,'code',17x,'county',3x,
```

```
     3'deposition',9x,'weight'/
     411x,'(y/mo/d)',31x,'(nCi/m2)'/)
       write (15,228)
228    format (3x,'Test',7x,'Test',4x,'State',2x,'County',7x,'FIPS',
     17x,'I-131',4x,'GSD'/3x,'name',7x,'date',24x,'code',
     24x,'deposition'/
     312x,'(y/mo/d)',31x,'(nCi/m2)'/)
       Tl = 1
       npb(1) = 843
       npb(2) = 850
       npb(3) = 841
       gwr = 1.5
       sigwr = log(gwr)
       ND = 0
       DO 12 I = 1,13
       J = NUM(I)
       xsc(i) = 0.
       s2xsc(i) = 0.
       depsc(i) = 0.
       depsce(i) = 1.
       DO 13 K = 1,J
       READ (4,204) IPS2,ID,TT,WR
       ND = ND + 1
       n10 = ips2 / 10
       nsc = ips2 - 10 * n10
       WRITE (14,220) TNAME,ITEST,ND,STSC(I),CTYSC(I),nsc,DEP(ID),
     1H12E(ID),WR
       if (dep(id).eq.0.) go to 16
       xw = x(id) * wr
       xsc(i) = xsc(i) + xw
       sigx = sqrt(log(1. + ((s(id)/x(id))**2)))
       gxw = exp(sqrt(sigx*sigx + sigwr*sigwr))
       sigxw = log(gxw)
       sxw = xw * sqrt(exp(sigxw*sigxw) - 1.)
       s2xsc(i) = s2xsc(i) + (sxw*sxw)
16     continue
       if (id.ne.npb(l)) go to 13
       l = l + 1
       write (14,217) SERIES,NCODE
       write (14,218)
13     CONTINUE
c
c      print the second output file (depositions for all sub-counties)
c
       if (xsc(i).eq.0.) go to 17
       muxsc = log(xsc(i)/sqrt(1. + (s2xsc(i)/(xsc(i)**2))))
       DEPSC(I) = exp(muxsc)
       sigsc = sqrt(log(1. + (s2xsc(i)/(xsc(i)**2))))
       DEPSCE(I) = exp(sigsc)
17     continue
       WRITE (15,250) TNAME,ITEST,stsc(i),ctysc(i),IPS(I),DEPSC(I),
     1DEPSCE(I)
12     CONTINUE
c
c      prepare the third output file (depositions for all counties)
c
       write (16,228)
```

```
      N = 0
      xtot = 0.
      DO 14 I = 1,5
      J = NUMC(I)
      DEPC(I) = 0.
      DEPCE(I) = 1.
      xc(i) = 0.
      s2xc(i) = 0.
      muxc = 0.
      sigxc = 0.
      DO 15 K = 1,J
      N = N + 1
      XC(I) = XC(I) + (XSC(N)*AREA(N))
      xtot = xtot + (0.001 * XSC(N)*AREA(N))
      s2xc(i) = s2xc(i) + (s2xsc(n) * area(n) * area(n))
15    CONTINUE
      XC(I) = XC(I)/AREAC(I)
      s2xc(i) = s2xc(i) / (areac(i)**2)
      if (xc(i).eq.0.) go to 18
      muxc = log(xc(i)/sqrt(1. + (s2xc(i)/(xc(i)**2))))
      DEPC(I) = exp(muxc)
      sigxc = sqrt(log(1. + (s2xc(i)/(xc(i)**2))))
      DEPCE(I) = exp(sigxc)
18    continue
c     write (16,251) xc(i),s2xc(i),muxc,sigxc
c251  format (4e12.3)
      WRITE (16,250) TNAME,ITEST,stc(i),ctyc(i),IPSC(I),DEPC(I),
     1DEPCE(I)
14    CONTINUE
      xpc = 100. * xtot / q
      write (16,261) q,xtot,xpc
261   format (/'Activity released (Curies) :',f10.0,/,
     1'Total activity deposited in the TDB area (Curies) :',f12.3,/,
     2'% of activity released deposited in the TDB area  :',f12.3)
110   FORMAT (I5,38X,I5,19X,E10.4,2E11.4)
204   FORMAT (I6,30X,I4,1X,A16,15X,F7.4)
217   format (/,2x,'Table ',A2,'/',I2,'/TDB  (continued)',/)
220   FORMAT (1X,A,I7,I5,4X,A,3X,A,I2,4x,F10.1,F7.1,F9.4)
230   FORMAT (1X,A,2I7,F10.1,f4.1,f6.1)
250   FORMAT (3X,A,I7,3x,a,3x,a,I8,f12.1,f7.1)
      STOP
      END
```

ATTACHMENT A9.3 : PROGRAM CDB290.FOR

```
      PROGRAM cdb290
C
C     CALCULATES THE I-131 DEPOSITION DENSITIES NEAR NTS FROM THE
C     EXPOSURE RATES AND TOA GIVEN IN THE County DATA BASE
C     ONE PROGRAM FOR EACH TEST : CHANGE THE NAME OF THE TEST
c     prepared in mar 1990 on the basis of tdb1089.for
C     OUTPUT FILE CDB(TEST).FIN : results for the 144 sub-counties
C     OUTPUT FILE CDB(TEST).CTY : results for the 129 counties (for map
c     purposes)
C
       DIMENSION IPSC(130),NUMC(130),AREAC(130),DEPC(130)
       DIMENSION RNAME(4),RI(4),AREA(150),DEPSC(150)
```

```
       DIMENSION H12E(150),DEPCE(130),STC(130),CTYC(130)
       DIMENSION DEPSCE(150),xsc(150),npb(4)
      dimension s2xsc(150),xc(150),s2xc(150)
      REAL LON,LAT,mu,muxsc,muxc
      CHARACTER*10 TNAME,TN,RNAME
       CHARACTER*16 TT
      CHARACTER*2 ST,STC,SERIES
      CHARACTER*10 CTY,CTYC
       OPEN (UNIT=1,FILE='CDBtest.DAT', STATUS='OLD')
       OPEN (UNIT=2,FILE='cdbnum290.cty', STATUS='OLD')
       OPEN (UNIT=3,FILE='EXtest.DAT',STATUS='OLD')
       OPEN (UNIT=4,FILE='cdbloc290.crd', STATUS='OLD')
       OPEN (UNIT=15,FILE='CDBtest.FIN',STATUS='NEW')
       OPEN (UNIT=25,FILE='CDBtest.rep',STATUS='NEW')
       OPEN (UNIT=16,FILE='CDBtest.CTY',STATUS='NEW')
       OPEN (UNIT=17,FILE='check.dat',STATUS='NEW')
100   FORMAT (I4,2X,A2,1X,A10,2X,I6,I5,F10.0)
      DO 2 J = 1,129
      READ (2,100) I,STC(I),CTYC(I),IPSC(I),NUMC(I),AREAC(I)
2     CONTINUE
      DO 10 I= 1,144
      xsc(i) = 0.
      s2xsc(i) = 0.
      DEPSC(I) = 0.
      H12E(I) = 1.
10    CONTINUE
c
c     read depositions (mmCi/m2 at H+12) corresponding to a total
c     exposure rate of 1 mR/h at H+12 for Sb-131, Te-131m, Te-131,
c     and I-131 and for this particular TEST
c
      READ (3,130) TNAME,ny,nm,nd,q,SERIES,NCODE
      ITEST = ny * 10000 + nm * 100 + nd
130   FORMAT (A,3I2,e10.2,4X,A2,1X,I2)
      DO 6 J=1,4
      READ (3,140) RNAME(J),RI(J)
6     CONTINUE
140   FORMAT (A,E10.3)
c
c     calculation of the "total" I-131 deposition density per
c     unit exposure rate at H + 12
c
      ri1 = ri(1)*23.3/(60.*8.04*24.)
      ri2 = ri(2)*30.0/(8.04*24.)
      ri3 = ri(3)*25.0/(60.*8.04*24.)
      RTI= RI1 + RI2 + RI3 + RI(4)
c
c     read County Data Base data and calculate the median I-131 deposition
c     densities for all CDB areas
c
      DO 11 I = 1,144
      READ(1,110,END=3) ID,H12,H12E(ID),TOA
      RINT = RTI * EXP(-0.69315*(TOA-12.)/(8.04*24.))
      DEPSC(ID) = 1000. * H12 * RINT
      if (h12e(id).lt.1.4) h12e(id) = 1.4
      DEPSCE(ID) = H12E(ID)
      mu = log (depsc(id))
```

```
        sig = log (h12e(id))
        xsc(id) = exp (mu + (sig*sig/2.))
        s2xsc(id) = (xsc(id)**2) * (exp(sig*sig) - 1.)
11      CONTINUE
3       CONTINUE
c
c       prepare the first output file (I-131 depositions for all
c       sub-counties)
c
        write (15,219) series,ncode,tname,nm,nd,ny
        write (25,219) series,ncode,tname,nm,nd,ny
219   format(1x,'Table ',A2,'/',I2,'/CDB. ',
     4' Estimates of median I-131 depositions',
     1' per unit area of ground',/,12x,
     2' in the County Data Base area following the shot ',a,/,13x,
     3'detonated',1x,i2,'/',i2,'/19',i2,'.',/)
        write (15,228)
        write (25,228)
228     format (3x,'TEST',7x,'TEST',4x,'State',2x,'County',7x,'FIPS',
     17x,'I-131',4x,'GSD'/3x,'name',7x,'date',24x,'code',
     24x,'deposition'/
     312x,'(y/mo/d)',31x,'(nCi/m2)'/)
        l = 1
        npb(1) = 16031
        npb(2) = 35035
        npb(3) = 49252
        DO 12 I = 1,144
        READ (4,204) ID,ST,CTY,IPS1,AREA(ID)
c
c       conversion of area from ha to km2
c
        area(id) = area(id) / 100.
c
c       print the first output file (depositions for all sub-counties)
c
        WRITE (15,250) TNAME,ITEST,st,cty,IPS1,DEPSC(ID),DEPSCE(ID)
        WRITE (25,250) TNAME,ITEST,st,cty,IPS1,DEPSC(ID),DEPSCE(ID)
        if (ips1.ne.npb(l)) go to 12
        l = l + 1
        write (25,217) SERIES,NCODE
        write (25,228)
12      CONTINUE
c
c       prepare the second output file (depositions for all counties)
c
        write (16,228)
        N = 0
        xtot = 0.
        DO 14 I = 1,129
        J = NUMC(I)
        DEPC(I) = 0.
        DEPCE(I) = 1.
        xc(i) = 0.
        s2xc(i) = 0.
        muxc = 0.
        sigxc = 0.
        DO 15 K = 1,J
```

```
        N = N + 1
        XC(I) = XC(I) + (XSC(N)*AREA(N))
        xtot = xtot + (0.001 * XSC(N)*AREA(N))
        s2xc(i) = s2xc(i) + (s2xsc(n) * area(n) * area(n))
15      CONTINUE
        XC(I) = XC(I)/AREAC(I)
        s2xc(i) = s2xc(i) / (areac(i)**2)
        if (xc(i).eq.0.) go to 18
        muxc = log(xc(i)/sqrt(1. + (s2xc(i)/(xc(i)**2))))
        DEPC(I) = exp(muxc)
        sigxc = sqrt(log(1. + (s2xc(i)/(xc(i)**2))))
        DEPCE(I) = exp(sigxc)
18      continue
c       write (16,251) xtot,xc(i),s2xc(i),muxc,sigxc
c251    format (5e12.3)
        WRITE(16,250)TNAME,ITEST,stc(i),ctyc(i),IPSC(I),DEPC(I),DEPCE(I)
14      CONTINUE
        xpc = 100. * xtot / q
        write (16,261) q,xtot,xpc
261     format (/'Activity released (Curies) :',f10.0,/,
     1'Total activity deposited in the CDB area (Curies) :',f12.3,/,
     2'% of activity released deposited in the CDB area  :',f12.3)
110     FORMAT (20X,I3,17X,E8.2,2X,E9.3,3X,E8.2)
204     FORMAT (I4,2X,A2,1X,a10,2x,i6,f11.0,f7.3,f8.3)
217     format (/,2x,'Table ',A2,'/',I2,'/CDB (continued)',/)
220     FORMAT (1X,A,I7,I5,2X,A,I6,F10.1,F5.1,F8.4)
230     FORMAT (1X,A,2I7,F10.1,f4.1,f6.1)
250     FORMAT (3X,A,I7,3X,A,3X,A,I8,f12.1,f7.1)
        STOP
        END
```

ATTACHMENT A9.4. PROGRAM DEPSIMON.FOR

```
          PROGRAM DEPsimon
c
c         prepared July 1989
c         generates a single deposition file (including errors) for a given test
c
          dimension gsd(56100,13)
          DIMENSION FIPS(3100),DEP(56100,15),PRECIP(56100,15),KM(15)
          CHARACTER*12 NAMCTY
          CHARACTER*2 NAMST
          CHARACTER*8 SHOT
          INTEGER FIPS,DEP,PRECIP,GFDATE
c
c         change the names of the files + LATER CHANGES
c
       OPEN(UNIT=1,FILE = 'disk$nci:[mona.fallout]newsimonB425.FIN',
     9STATUS = 'OLD')
       OPEN(UNIT=2,FILE = 'disk$nci:[mona.fallout]newsimonK426.FIN',
     1STATUS = 'OLD')
          OPEN(UNIT=3,FILE = 'disk$nci:[mona.fallout]newsimonK427.FIN',
     2STATUS = 'OLD')
          OPEN(UNIT=4,FILE = 'disk$nci:[mona.fallout]newsimonK428.FIN',
     3STATUS = 'OLD')
          OPEN(UNIT=5,FILE = 'disk$nci:[mona.fallout]newsimonK429.FIN',
     4STATUS = 'OLD')
```

```
      OPEN(UNIT=6,FILE = 'disk$nci:[mona.fallout]newsimonK430.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=7,FILE = 'disk$nci:[mona.fallout]newsimonK501.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=8,FILE='disk$nci:[mona.fallout]newsimonH502.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=9,FILE='disk$nci:[mona.fallout]newsimonH503.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=10,FILE='disk$nci:[mona.fallout]newsimonH504.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=11,FILE='disk$nci:[mona.fallout]newsimonH505.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=12,FILE='disk$nci:[mona.fallout]newsimonH506.FIN',
     4STATUS = 'OLD')
      OPEN(UNIT=13,FILE='disk$nci:[mona.fallout]newsimonH507.FIN',
     4STATUS = 'OLD')
      OPEN (UNIT = 20, FILE = 'newsimonDEP.DAT', STATUS = 'NEW')
      OPEN (UNIT = 22, FILE = 'newsimonDEP1.DAT', STATUS = 'NEW')
      OPEN (UNIT = 21, FILE = 'newB02.DAT', STATUS = 'OLD')
      DO 1 I = 1,3094
1     READ (21,100) L,NAMST,NAMCTY,FIPS(I),DIST
100   FORMAT (I6,1X,A2,1X,A12,I6,F10.0)
C
C     JD  = NUMBER OF DAYS
C     ID = DAY (FIRST RESULT)
C     IM = MONTH (FIRST RESULT)
C     IY = YEAR
C
C
      ID = 25
      IM = 4
      IY = 53
      JD = 13
      idate = (id*10000) + (im*100) + iy
C
C
C     NO MORE CHANGES
C
C
      GFDATE = (ID*10000) + (IM*100) + IY
      DO 3 J = 1,15
      DO 3 IPS = 1,56100
      DEP(IPS,J) = 0
      PRECIP(IPS,J) = 0
3     CONTINUE
      DO 98 J = 1,JD
      READ (J,102)
      KMAX = KM(J)
      DO 4 K = 1,3094
c     DO 4 K = 1,KMAX
c     IF (J.EQ.1)READ (J,101) IPS,SHOT,IDAY,IDEP,ERR,IPRECIP
c     IF (J.GT.1)READ (J,111) IPS,SHOT,IDAY,IDEP,ERR,IPRECIP
      READ (J,111,end=99) IPS,SHOT,IDAY,IDEP,ERR,IPRECIP
      DEP(IPS,J) = IDEP
      gsd(ips,j) = exp(err)
      PRECIP(IPS,J) = IPRECIP
4     CONTINUE
```

```
99         continue
98         continue
           DO 5 I = 1,3094
           IPS = FIPS(I)
          WRITE(20,103)SHOT,idate,i,IPS,(DEP(IPS,J),gsd(ips,j),
     1PRECIP(IPS,J),J=1,6)
          WRITE(22,103)SHOT,idate,i,IPS,(DEP(IPS,J),gsd(ips,j),
     1PRECIP(IPS,J),J=7,jd)
5          CONTINUE
c101       FORMAT(I5,1X,A8,3X,I7,I8,F6.2,I4)
111        FORMAT(1X,I5,1X,A8,3X,I7,I8,F6.2,I5)
102        FORMAT (///)
c
c          jd = ??
c
103        FORMAT (1X,A,i7,i5,I6,8(I5,f5.1,I2))
           STOP
           END
```

ATTACHMENT A9.5 : CONCUST9.FOR

```
           program concustest9
c
c          prepared in nov 1991 using CONCUStest8.FOR and pasturecalc.for
c          as a basis
c          CALCULATES MILK CONCENTRATIONS AND ACTIVITY IN EACH COUNTY
c          as well as concentrations in other foodstuffs and in air
C          + average values of lumped parameters (mass interception
c          coefficient, pasture intake,..) to be used in the uncertainty
c          analysis
c
           dimension nrp(3100),picdh(100,365),picby(100,365),uncdh(100,365)
           dimension max(430),mm(430,40),reg(430),ips(56100)
           dimension ip(3100,22),ngf(3100,22),surmr(430),crsg(2)
           dimension pc(3100),vfuc(3100),ec(3100),crhc(2),crsc(2),hs(10)
           dimension surpc(3100),surpr(430),cnf(3100,6),crhg(2)
          dimension surm(3100),pi(430,50),tdiet(430),goat(3100)
           dimension ecr(430),ugf(3100,22),g(500,50),vl(500,50)
           dimension ps(9),cg1(3100,22),ntgf(3100),tcg1(3100)
           dimension cc(3100),pastday(60),nrg(3100),tmfu(3100)
           dimension cc1(3100),cc12(3100),cc2(3100),SMR(430)
           dimension tn(430),tp(430),ccr(430),cn(430),ugoat(3100)
           DIMENSION V1(430),C1(430),SRM(3100),C2(3100),cmax(3100)
           DIMENSION AC(6,3100),AR(6,430),CR(6,430),VC(6,3100),C(6,3100)
           DIMENSION VR(6,430),CT(6),VT(6),AT(6),smc(3100)
           dimension vtr(430,430),vin(430),vout(430),ain(430)
           dimension fips(3100),dist(3100),cci(3100,22),pigt(2)
           DIMENSION GFMONTH(12),NAMCTY(3100),NAMST(3100)
           dimension psw(3100),pav(3100),fav(3100),piav(3100),mfav(3100)
           dimension cmot(3100),cbc(3100),uvg(3100,22),pi2av(3100)
           dimension utgf(3100),uf(3100),umf(3100),upi(3100,22),pi2(500,50)
           dimension upi2(3100),vg(3100),bdate(430),sdate(430),uncbeg(400)
           dimension pic(3100,22),piby(3100,22),fst(3100,22),cair(3100,22)
           dimension cow(3100),cowby(3100),pcg1(3100),ucnf(3100,6)
           dimension ucow(3100),ucowby(3100),utcg(3100),ucmot(3100)
           dimension ucc(3100),ucm(3100),ucbc(3100),uc(6,3100),ucmax(3100)
c
```

```
      real mfav
      character*76 t1,t2,t3,t4,t5
      character*12 reg,namcty
      character*19 REGP
      character*2 NAMST,series
      character*15 MONTH
      CHARACTER*8 SHOw
      CHARACTER*10 SHOT
      integer fips,GFDATE,bdate,sdate
C
C         CHANGE test NAME
c
C
      open (unit=1, file = 'ps.dat', status='old')
      open (unit=5, file = '$1$dua2:[soviet.milk]newregUS.dat',
     1 status='old')
      open (unit=3, file = 'testform.dat', status='old')
      open (unit=6, file = 'testdep.dat', status='old')
      open (unit=7, file = 'newmilkdistc.dat', status='old')
      open (unit=8, file = 'pastbyc.res', status='old')
      open (unit=11, file = 'new2milktreg.dat', status='old')
      open (unit=12, file = 'newmilkdistr.dat', status='old')
      open (unit=14, file = 'newb02.dat', status='OLD')
      open (unit=15, file = '$1$dua2:[soviet.pasture]newpastURE2.
     1 res',status='OLD')
      open (unit=16, file = '$1$dua2:[soviet.pasture]uncpi.dat',
     1 status='old')
      open (unit=17, file = 'region.def', status='old')
      open (unit=18, file = 'pastcoef.dhia', status='old')
      open (unit=19, file = 'pastcoef.byc', status='old')
      open (unit=20, file = 'pastunc.dhia', status='old')
c     open (unit=2,  file = 'testparav.dat', status='new')
      open (unit=41, file = 'testapp5.dat', status='new')
      open (unit=33, file = 'testCONC.RES', status='new')
      open (unit=13, file = 'testMILK.RES', status='new')
      open (unit=4, file = 'checkdata.dat',status='new')
c
c         END OF CHANGES
c
C
C         FIXED PARAMETER VALUES
C
c     NC = 500
      NC = 3094
      NN = 429
      UNC = 2.5
      AMBDA = 0.69315/4.5
      teff = 1. / ambda
      AMB = 0.69315/8.04
      tr = 1. / amb
      uteff = 1.3
      uteff2 = uteff*uteff
      DF1 = EXP(-0.69315*1./8.04)
      DFLV = EXP(-0.69315*0.5/8.04)
      DFGT = EXP(-0.69315*0.5/8.04)
      DFCC = EXP(-0.69315*7./8.04)
      DFGG = EXP(-0.69315*1./8.04)
```

```
      fwr = 0.5
      dfw = 0.1
      AD = 1.2
      FCC = 2.3
      pf = -0.35
      pp1 = - 0.7
      pp2 = - 0.043
      pigt(2) = 1.5
      pigt(1) = 0.00001
      crsg(2) = 0.2
      crsg(1) = 0.00001
      crwc = 75.
      crwg = 3.5
      brc = 130.
      brgt = 9.
      hw = 0.5
      prh = 0.04
      y = 0.3
      us = 1500.
      rc = 0.
      frs = 0.5
      crhc(1) = 0.1
      crhc(2) = 8.
      crhg(1) = 0.00001
      crhg(2) = 1.5
      crsc(1) = 0.3
      crsc(2) = 0.5
      hs(1) = 0.001
      hs(2) = 0.001
      hs(3) = 0.005
      hs(4) = 0.005
      hs(5) = 0.005
      hs(6) = 0.01
      hs(7) = 0.01
      hs(8) = 0.01
      hs(9) = 0.01
      utfoe = 4.
      ufc = 1.4
      ufc2 = ufc*ufc
      FGG = 1.
      ufe = 1.4
      ufe2 = ufe*ufe
      FM = 0.004
      ufmc = 2.1
      ufmc2 = ufmc*ufmc
      fmgt = 0.2
      ufmg = 2.5
      ufmg2 = ufmg*ufmg
      crmt = 0.8
      fmmt = 0.1
      TMM = crmt * fmmt
      utmm = 2.0
      utmm2 = utmm*utmm
      uflv = 2.0
      uflv2 = uflv*uflv
C
c
```

```
C         CONVERSION COEFFTS FROM klb TO kg (SIF1), FROM Mlb TO kg (SIF2)
C         AND FROM days TO years (UCF)
c
          SIF1 =  1000./2.205
          SIF2 =  1.e6/2.205
          UCF  =  1./365.
C
C         PRECIPITATION AMOUNTS CORRESPONDING TO PRECIPITATION INDICES (DRY +
C         8 CLASSES OF DAILY RAINFALL)
C         CONVERSION OF CALENDAR DATES TO JULIAN DATES FOR DEPOSITION AND PASTURE
C         INTAKE
C
          READ (1,191) T1
          READ (1,194) (PS(K),K=1,9)
          READ (1,191) T1
          READ (1,251) (GFMONTH(K),K=1,12)
          READ (1,191) T1
          READ (1,252) (PASTDAY(K), K = 1,48)
C
C         DISTANCE(KM) BETWEEN NTS AND EACH COUNTY CENTROID
C         FILE newB02.DAT PREPARED WITH DISTANCE.FOR
C
          DO 402 I = 1,NC
          READ (14,250) L,NAMST(I),NAMCTY(I),LIPS,DIST(I),pc(i)
          IPS(LIPS) = L
          FIPS(L) = LIPS
402       CONTINUE
C
C         DEFINITION AND ORGANIZATION OF REGIONS
C         NN = NUMBER OF REGIONS
C
          do 1 n = 1,NN
          MAX(N) = 0
          read (5,10) L,reg(n),Mmax
          READ (5,20) (mm(n,m),m=1,MMAX)
          MAX(N) = MMAX
1         continue
          read (17,703)
703       format (//)
          do 701 j = 1,nc
          read (17,702) i,nrg(i),nrp(i)
          if (j.le.5) write (4,702) i,nrg(i),nrp(i)
701       continue
702       format (20x,i6,12x,i4,5x,i3)
C
C         PASTURE INTAKE VALUES FOR ALL STATES AND ALL SEASONS
C
          do 710 k = 1,70
          read (18,704) nure,bdate(nure),sdate(nure)
          read (19,705) nure
          read (20,706) nure
          na = 1
          do 707 nm = 1,48
          nb = pastday(nm)
          nx = nb - na + 1
          read (18,708) ny,(picdh(nure,nw),nw=na,nb)
          if (k.eq.1) write (4,711) nure,nm,(picdh(nure,nw),nw=na,nb)
```

```
        read (19,708) ny,(picby(nure,nw),nw=na,nb)
        read (20,709) ny,(uncdh(nure,nw),nw=na,nb)
707     na = nb + 1
710     continue
704     format (/,72x,i3,/10x,i4,10x,i4)
705     format (/,76x,i3/)
706     format (/,73x,i3/)
708     format (i5,8(1PE9.2))
709     format (i5,8f5.1)
715     format (i5,7(1PE9.2))
716     format (i5,7f5.1)
711     format (2i3,8(1PE9.2))
C
        VLMT = 0.
        ECT = 0.
        SURPT = 0.
        SURMT = 0.
        V2T = 0.
        VCFT = 0.
        VRFT = 0.
        SRMT = 0.
        VTT = 0.
        SMT = 0.
        IM = 0
C
C       READ FIPS CODES,PRECIP INDICES, AND DAILY DEPOSITION
C       RESULTS FOR EACH DAY OF THE test CONSIDERED.
C       FILE(s) CREATED BY [mona.usa]newdeptest.for
c       JD IS THE total NUMBER OF DAYS WITH DEPOSITION RESULTS
c       JD1 IS THE NUMBER OF DAYS WITH results in testdep.dat
c       JD2 IS THE NUMBER OF DAYS WITH RESULTS in testdep1.dat (if necessary)
c       JD3 IS THE NUMBER OF DAYS WITH RESULTS in testdep2.dat (if necessary)
C
        read (3,881) series,ns
881     format (8x,a2,9x,i2)
        read (3,882) shot,kd,km,iy
882     format (6x,a10,6x,3i3)
        read (3,604) jd1,jd2,jd3,jd
604     format (25x,4(5x,i2))
       IF(SERIES.eq.'RA') read (6,605)
605     format (///////////)
        do 7 i = 1,NC
       IF(SERIES.NE.'RA') GO TO 698
       read(6,60)SHOt,ID,MH,IY,M,LIPS,
     1(NGF(i,j),ugf(i,j),IP(i,j),J=1,JD1)
c
c       modif for ranger shots (shot instead of show)
c
        GO TO 7
698       read(6,60)SHOw,ID,MH,IY,M,LIPS,(NGF(i,j),ugf(i,j),IP(i,j),
     1J=1,JD1)
7       CONTINUE
        if (jd.gt.8) go to 731
        go to 739
731     continue
        open (unit=61, file = 'testdep1.dat', status='old')
        jd21 = jd1 + 1
```

```
          jd22 = jd1 + jd2
          do 732 i = 1,NC
         read(61,60)SHOw,ID,MH,IY,M,LIPS,(NGF(i,j),ugf(i,j),IP(i,j),
     1J=jd21,JD22)
732       CONTINUE
          if (jd.gt.16) go to 733
          go to 739
733       continue
          open (unit=62, file = 'testdep2.dat', status='old')
          jd31 = jd22 + 1
          do 734 i = 1,NC
         read(62,60)SHOw,ID,MH,IY,M,LIPS,(NGF(i,j),ugf(i,j),IP(i,j),
     1J=jd31,JD)
734       CONTINUE
739       continue
C
C         CG1 = CONCENTRATION IN GRASS IN A PARTICULAR DAY AND COUNTY
C         CCI = TIME-INT. CONCENTRATION IN UNDILUTED MILK (DAY,COUNTY)
C         CC =  TIME-INT. CONCENTRATION IN UNDILUTED MILK FOR THE WHOLE test
C                IN A PARTICULAR COUNTY
C
          do 12 i=1,NC
          PSW(I) = 0.
          CBC(I) = 0.
          CNF(I,6) = 0.
          UCNF(I,6) = 0.
          CC(I) = 0.
          NTGF(I) = 0
          TCG1(I) = 0.
          utgf(i) = 0.
          uf(i) = 0.
          umf(i) = 0.
          upi2(i) = 1.3
          cow(i) = 0.
          cowby(i) = 0.
          pcg1(i) = 0.
          dst = dist(i)
          VG(I) = 20150. * (DST**pf)
c
c         calculation of the median total deposition
c
          xn = 0.
          s2n = 0.
          xw= 0.
          s2w = 0.
          xgw = 0.
          sg2w = 0.
          xy = 0.
          s2y = 0.
          xp = 0.
          s2p = 0.
          xi = 0.
          s2i = 0.
c
c         kpast = 1 (off pasture); kpast = 2 (on pasture)
c
          kpast = 1
```

```
      do 412 j =1,JD
      gfdate = ID + GFMONTH(MH) + J - 1
      nure = nrp(i)
      npdb = bdate(nure)
      npde = sdate(nure)
      if ((gfdate.ge.npdb).and.(gfdate.le.npde)) kpast = 2
      pic(i,j) = picdh(nure,gfdate)
      piby(i,j) = picby(nure,gfdate)
      CAIR(i,j) = 0.
      upi(i,j) = uncdh(nure,gfdate)
      if (i.eq.1) write (4,712) i,nure,gfdate,picdh(nure,gfdate)
712   format (3i5,f6.2)
      fst(i,j) = 0.
      IF (NGF(i,j).EQ.0.) GO TO 412
      dp = ngf(i,j)
      umn = log(dp)
      usn = log(ugf(i,j))
      usn2 = usn*usn
      umsn2 = umn + (usn2/2.)
      xn = exp(umsn2) + xn
      s2n = exp(2.*umn+usn2)*(exp(usn2)-1.)+s2n
      IW = ID + J - 1
      ix = ip(i,j)
      IF (IX.LT.1) IX=1
      IF (IX.GE.5) GO TO 401
      ALPHAD = 2.8
      IF (DIST(I).LE.1540.) ALPHAD = (7.0E-04)*(DIST(I)**1.13)
      fdry = (1.-exp(-alphad*0.3))/0.3
      fstar = fdry + (3.1 - fdry)*(PS(IX)/2.5)
      GO TO 482
401   fstar = 0.9 + (11./PS(IX))
482   CONTINUE
      cg1(i,j) = ngf(i,j) * fstar
      PSW(I) = PSW(I) + NGf(i,j) * PS(IX)
      wr = 0.
      if (ps(ix).gt.0.) wr=13000.*(ps(ix)**pp1)*((dist(i)/100.)**pp2)
      CAIR(i,j) = 0.44 / (VG(I) + (WR * PS(IX) / AD))
c
c     uncertainties on CAIR - reciprocal of apparent deposition velocity
c
      if (dist(i).lt.1540.) go to 511
      uvg(i,j) = 1.5
      if (ps(ix).eq.0.) uvg(i,j) = 1.3
      go to 512
511   uvg(i,j) = 3.
      if (ps(ix).eq.0.) uvg(i,j)=2.0
512   continue
c
      fst(i,j) = fstar
c
c     uncertainties of FAV - mass interception coefficient
c
      if (dist(i).lt.1540.) go to 513
      uf(i) = 1.6
      if (ps(ix).eq.0.) uf(i)=1.3
      go to 514
513   uf(i) = 1.4
```

```
          if (ps(ix).eq.0.) uf(i) = 1.2
514       continue
c
          usf = log (uf(i))
          usf2 = usf*usf
          uspi = log (upi(i,j))
          uspii = uspi*uspi
          uspi2 = log (upi2(i))
          uspii2 = uspi2*uspi2
c
c         transfer to milk fresh from cow
c
          p11 = fst(i,j) * teff * y * amb
          p1 = crsc(kpast) * (1. - p11) / (amb * hs(ix) * us)
          p2 = tr * (1. - p11) * rc * vg(i) * frs * teff * pic(i,j)
          p3 = brc * cair(i,j) / 0.44
          p4 = 0.001 * crwc / hw
          p5 = fst(i,j) * teff * prh * crhc(kpast)
          tfp = fst(i,j) * teff * pic(i,j)
          tfoe = p1 + p2 + p3 + p4 + p5
c
c         transfer to milk fresh from goat
c
          pg1 = crsg(kpast) * (1. - p11) / (amb * hs(ix) * us)
          pg2 = tr * (1. - p11) * rc * vg(i) * frs * teff * pigt(kpast)
          pg3 = brgt * cair(i,j) / 0.44
          pg4 = 0.001 * crwg / hw
          pg5 = fst(i,j) * teff * prh * crhg(kpast)
          tfgp = fst(i,j) * teff * pigt(kpast)
          tfgoe = pg1 + pg2 + pg3 + pg4 + pg5
c
          ust = log(uteff)
          ust2 = ust * ust
          ustfp = sqrt(usf2 + ust2 + uspii)
          ustfp2 = ustfp * ustfp
          utfp = exp(ustfp)
          uxp = log(tfp)
          uxoe = log(tfoe)
          vxp = log(tfgp)
          vxoe = log(tfgoe)
          ustfoe = log(utfoe)
          ustfoe2 = ustfoe * ustfoe
          xc = exp(uxp + 0.5*ustfp2)
          xe = exp(uxoe + 0.5*ustfoe2)
          xtfc = xc + xe
          s2tfc = xc*xc* (exp(ustfp2) - 1.) + xe*xe * (exp(ustfoe2) - 1.)
          x2c = xtfc * xtfc
          xxc = 1. + (s2tfc/x2c)
          tfc = xtfc / sqrt(xxc)
          ustfc = sqrt(log(xxc))
          ustfc2 = ustfc * ustfc
          utfc = log(xxc)
          xgp = exp(vxp + 0.5*ustfp2)
          xge = exp(vxoe + 0.5*ustfoe2)
          xtfg = xgp + xge
          s2tfg = xgp*xgp*(exp(ustfp2)-1.) + xge*xge * (exp(ustfoe2)-1.)
          x2g = xtfg * xtfg
```

```
            xxg = 1. + (s2tfg/x2g)
            tfg = xtfg / sqrt(xxg)
            ustfg = sqrt(log(xxg))
            ustfg2 = ustfg * ustfg
            utfg = log(xxg)
c
c           cowm = ngf(i,j)*fst(i,j)*pic(i,j)
            cowm = ngf(i,j) * tfc
            goatm = ngf(i,j) * tfg
            coym = ngf(i,j)*fst(i,j)*piby(i,j)
            pcgm = ngf(i,j)*fst(i,j)
            carm = ngf(i,j) * cair(i,j)
c
            l=1
       if(goatm.le.0.)write(4,4444)l,i,j,ngf(i,j),fst(i,j),pigt(kpast),
      1goatm,xgw,sg2w
            l=2
       if(coym.le.0.)write(4,4444)l,i,j,ngf(i,j),fst(i,j),piby(i,j),coym,
      1xw,s2w
            l=3
       if(pcgm.le.0.)write(4,4444)l,i,j,ngf(i,j),fst(i,j),cair(i,j),pcgm,
      1xw,s2w
            l=4
       if(carm.le.0.)write(4,4444)l,i,j,ngf(i,j),fst(i,j),cair(i,j),carm,
      1xw,s2w
            l=5
       if(uvg(i,j).le.0.)write(4,4444)l,i,j,ngf(i,j),fst(i,j),cair(i,j),
      1uvg(i,j),xw,s2w
4444        format (i2,i6,i3,i10,5e11.3)
c
c           dp = ngf(i,j)
c           umn = log(dp)
c           usn = log(ugf(i,j))
c           xn = exp(umn + (usn*usn/2.)) + xn
c           s2n = exp(2.*umn+usn*usn)*(exp(usn*usn)-1.)+s2n
            umi = log(carm)
            usi = log(uvg(i,j))
            usi2 = usi*usi + usn*usn
            xi = exp(umi + (usi2/2.)) + xi
            s2i = exp(2.*umi+usi2)*(exp(usi2)-1.)+s2i
            ucwm = log(cowm)
            ugtm = log(goatm)
            ucym = log(coym)
            ucgm = log(pcgm)
c           ucws = sqrt (usn2 + usf2 + uspii)
            ucws = sqrt (usn2 + ustfc2)
            ucws2 = ucws*ucws
                   ugts = sqrt (usn2 + ustfg2)
                   ugts2 = ugts*ugts
            ucys = sqrt (usn2 + usf2 + uspii2)
            ucys2 = ucys*ucys
            ucgs = sqrt (usn2 + usf2)
            ucgs2 = ucgs*ucgs
            xw = exp(ucwm + (ucws2/2.)) + xw
                   xgw = exp(ugtm + (ugts2/2.)) + xgw
            xy = exp(ucym + (ucys2/2.)) + xy
            xp = exp(ucgm + (ucgs2/2.)) + xp
```

```
          s2w = exp(2.*ucwm+ucws2)*(exp(ucws2)-1.)+s2w
                sg2w = exp(2.*ugtm+ugts2)*(exp(ugts2)-1.)+sg2w
          s2y = exp(2.*ucym+ucys2)*(exp(ucys2)-1.)+s2y
          s2p = exp(2.*ucgm+ucgs2)*(exp(ucgs2)-1.)+s2p
412       CONTINUE
          if (xn.eq.0.) go to 492
          x2n = xn*xn
          xx = 1. + (s2n/x2n)
c
c         modif june 1990  (nint + if test below)
c
          ntgf(i) = nint(xn/sqrt(xx))
          if (ntgf(i).eq.0.) go to 492
          usxx = sqrt(log(xx))
          utgf(i) = exp(usxx)
          x2i = xi*xi
          xxi = 1. + (s2i/x2i)
          cnf(i,6) = xi/sqrt(xxi)
          usxxi = sqrt(log(xxi))
          ucnf(i,6) = exp(usxxi)
          x2w = xw * xw
          xg2w = xgw * xgw
          x2y = xy*xy
          x2p = xp*xp
          xxw = 1. + (s2w/x2w)
          ggw = 1. + (sg2w/xg2w)
          xxy = 1. + (s2y/x2y)
          xxp = 1. + (s2p/x2p)
          cow(i) = xw / sqrt(xxw)
                goat(i) = xgw / sqrt(ggw)
          cowby(i) = xy / sqrt(xxy)
          pcg1(i) = xp / sqrt(xxp)
          usxxw = sqrt(log(xxw))
                usggw = sqrt(log(ggw))
          usxxy = sqrt(log(xxy))
          usxxp = sqrt(log(xxp))
          ucow(i) = exp(usxxw)
                ugoat(i) = exp(usggw)
          ucowby(i) = exp(usxxy)
          upcg = exp(usxxp)
          upcg2 = upcg*upcg
          tcg1(i) = teff * pcg1(i)
          utcg(i) = sqrt (uteff2 + upcg2)
c         tcgm = log (tcg1(i) * 1.5)
c         tgf = ntgf(i)
c         tgfm = log (tgf * 5.8)
c         tcgu = log (utcg(i))
c         tcgu2 = tcgu*tcgu
c         tgfu = log (utgf(i))
c         tgfu2 = tgfu*tgfu
c         xa = exp (tcgm + (0.5*tcgu2))
c         xb = exp (tgfm + (0.5*tgfu2))
c         xc = xa + xb
c         sa = xa * sqrt(exp(tcgu2) - 1.)
c         sb = xb * sqrt(exp(tgfu2) - 1.)
c         xc2 = xc * xc
c         sa2 = sa * sa
```

```
c         sb2 = sb * sb
c         sc2 = sa2 + sb2
c         xxc = 1. + (sc2/xc2)
c         goam = xc/sqrt(xxc)
c         usxxc = sqrt(log(xxc))
c         goau = exp(usxxc)
c         goau2 = goau*goau
492       continue
          CNF(I,2) = fmgt * goat(i) * dfgt
          ugot2 = ugoat(i) * ugoat(i)
          ucnf(i,2)= sqrt(ufmg2 + ugot2)
          if (cnf(i,2).le.0.) ucnf(i,2) = 0.
c         cc(i) = fm * teff * cow(i)
          cc(i) = fm * cow(i)
          ucow2 = ucow(i)*ucow(i)
          ucowby2 = ucowby(i)*ucowby(i)
c         ucc(i) = sqrt (uteff2 + ufmc2 + ucow2)
          ucc(i) = sqrt (ufmc2 + ucow2)
          ucm(i) = ucc(i)
          if (cow(i).le.0.) ucm(i) = 0.
          cbc(i) = fm * teff * cowby(i) * dfgt
          ucbc(i) = sqrt (uteff2 + ufmc2 + ucowby2)
          if (cowby(i).le.0.) ucbc(i) = 0.
          cc1(i) = cc(i) * df1
          uc(1,i) = ucm(i)
          cc12(i) = cc(i) * df1 * df1
          uc(3,i) = ucm(i)
          cc2(i) = cc(i) * df1 * df1 * df1
c
c         if (i.eq.110) write (4,4445) i,fm,teff,cow(i),ucow(i),cc(i),
c      1ucm(i)
c4445     format (i6,6e12.3)
c
12        continue
C
C         MILK PRODUCTION AND DISTRIBUTION
C
C
C         REGIONAL TRANSFER IN MATRIX FORM
C         read MILKTREG.DAT (output of MILKDIStest.FOR)
c
          do 211 nd = 1,nn
          do 211 mr = 1,nn
          vtr(mr,nd) = 0.
211       continue
378       continue
          read (11,3770,end=379) nd,reg(nd),mr,reg(mr),vtr(mr,nd)
          go to 378
379       continue
          do 219 n = 1,nn
          do 219 m = 1,nn
219       vtr(n,m) = SIF1*vtr(n,m)
C
C
C         II. MILK TRANSFER BETWEEN COUNTIES OF THE SAME REGION
C
          DO 1202 I = 1,NN
```

```
      read (12,3000) n,reg(n),mmax,tp(n),tn(n),surpr(n),surmr(n)
1202  continue
      do 1201 n = 1,NC
      read (7,120) i,fips(i),nrg(i),vc(1,i),vc(2,i),vc(3,i),vc(4,i),
     1srm(i),surpc(i),surm(i),ec(i),xx,yy
1201  continue
      do 3 n = 1,NN
      cn(n) = 0.
      ccr(n) = 0.
3     continue
      do 4 n = 1,NN
      mmax = max(n)
      do 14 m = 1,mmax
      nA = mm(n,m)
      NI = IPS(NA)
      IF (SURPC(NI).GT.0.) CN(N) = CN(N) + (SURPC(NI)*CC2(NI))
14    CONTINUE
      IF (TP(N).EQ.0.) GO TO 4
      CCR(N) = CN(N)/TP(N)
4     CONTINUE
16    CONTINUE
      do 5 n = 1,NN
      mmax = max(n)
      do 6 m = 1,mmax
      nA = mm(n,m)
      NI = IPS(NA)
      C2(NI) = CCR(N)
6     CONTINUE
5     CONTINUE
C
C     III. MILK TRANSFER BETWEEN REGIONS
C
      DO 31 N = 1,NN
      V1(N) = 0.
      C1(N) = ccr(n)*df1
      vout(n) = 0.
      vin(n) = 0.
      ain(n) = 0.
31    CONTINUE
c
      do 2151 n = 1,nn
      vin(418) = vin(418) + vtr(418,N)
      vout(418) = vout(418) + vtr(n,418)
      ain(418) = ain(418) + vtr(418,N)*c1(n)
      vin(423) = vin(423) + vtr(423,N)
      vout(423) = vout(423) + vtr(n,423)
      ain(423) = ain(423) + vtr(423,N)*c1(n)
2151  continue
      v1(418) = vin(418) - vout(418)
      c1(418) = ain(418)/vin(418)
      v1(423) = vin(423) - vout(423)
      c1(423) = ain(423)/vin(423)
c
      do 214 m=1,417
      if (surpr(m).gt.0.) go to 214
      do 215 n=1,nn
      vin(m) = vin(m) + vtr(M,N)
```

```
          vout(m) = vout(m) + vtr(n,m)
          ain(m) = ain(m) + vtr(M,N)*c1(n)
215       continue
          v1(m) = vin(m) - vout(m)
          if (v1(m).eq.0.) go to 214
          if (vin(m).eq.0.) go to 214
          c1(m) = ain(m)/vin(m)
214       continue
          do 4120 m=419,422
          if (surpr(m).gt.0.) go to 4120
          do 5120 n=1,nn
          vin(m) = vin(m) + vtr(M,N)
          vout(m) = vout(m) + vtr(n,m)
          ain(m) = ain(m) + vtr(M,N)*c1(n)
5120      continue
          v1(m) = vin(m) - vout(m)
          if (v1(m).eq.0.) go to 4120
          if (vin(m).eq.0.) go to 4120
          c1(m) = ain(m)/vin(m)
4120      continue
          do 4121 m=424,nn
          if (surpr(m).gt.0.) go to 4121
          do 5121 n=1,nn
          vin(m) = vin(m) + vtr(M,N)
          vout(m) = vout(m) + vtr(n,m)
          ain(m) = ain(m) + vtr(M,N)*c1(n)
5121      continue
          v1(m) = vin(m) - vout(m)
          if (v1(m).eq.0.) go to 4121
          if (vin(m).eq.0.) go to 4121
          c1(m) = ain(m)/vin(m)
4121      continue
C
C         IV. PREPARATION OF OUTPUT DATA BY COUNTY AND REGION AS WELL
C             AS FOR THE ENTIRE AREA
C
          DO 32 N = 1,NN
          MMAX = MAX(N)
          DO 33 M = 1,MMAX
          nA = mm(n,m)
          NI = IPS(NA)
          SRM(NI) = V1(N)*SURM(NI)/SURMR(N)
c         VC(1,NI) = VCFC(NI)
c         VC(2,NI) = VRFC(NI)
c         VC(3,NI) = VLM(NI)
c         VC(4,NI) = V2(NI)
          VC(5,NI) = SRM(NI)
          VC(6,NI) = 0.
          AC(6,NI) = 0.
          C(1,NI) = CC1(NI)
          C(2,NI) = CC1(NI)
          C(3,NI) = CC12(NI)
          C(4,NI) = 0.
          C(5,NI) = 0.
          if (vc(4,ni).gt.0.) C(4,NI) = C2(NI)
          if (vc(5,ni).gt.0.) C(5,NI) = C1(N)
          DO 310 IN = 1,6
```

```
          AR(IN,N) = 0.
310       VR(IN,N) = 0.
          DO 301 IN = 1,5
          AC(IN,NI) = VC(IN,NI)*C(IN,NI)*ucf
          AC(6,NI) = AC(6,NI) + AC(IN,NI)
          VC(6,NI) = VC(6,NI) + VC(IN,NI)
301       CONTINUE
          AC(6,NI) = AC(6,NI) - AC(2,NI)
          VC(6,NI) = VC(6,NI) - VC(2,NI)
          IF (VC(6,NI).NE.0.) GO TO 654
          VC(6,NI) = 1.
654       C(6,NI) = AC(6,NI)/(VC(6,NI)*UCF)
          SMC(NI) = - EC(NI) + VC(6,NI)
          cmax(ni) = c(1,ni)
          if (c(4,ni).gt.c(1,ni)) cmax(ni) = c(4,ni)
          if (c(5,ni).gt.cmax(ni)) cmax(ni) = c(5,ni)
          IF (C(1,NI).EQ.0.) GO TO 867
          mfav(ni) = c(6,ni) / c(1,ni)
          GO TO 866
867       MFAV(NI) = 0.
866       CONTINUE
c
c         uncertainties of mfav - modifying factor for milk
c
          umf(ni)=2.
          if (mfav(ni).lt.2.) umf(ni) = 1.5
          if (mfav(ni).lt.1.1) umf(ni) = 1.1
          if (mfav(ni).lt.0.9) umf(ni) = 1.5
          if (mfav(ni).lt.0.5) umf(ni) = 2.0
          uc(4,ni) = ucc(ni)
          if (c(4,ni).le.0.) uc(4,ni) = 0.
          uc(5,ni) = ucc(ni)
          if (c(5,ni).le.0.) uc(5,ni) = 0.
          ucc2 = ucc(ni)*ucc(ni)
          umff = umf(ni)*umf(ni)
          uc(6,ni) = sqrt (ucc2 + umff)
          if (c(6,ni).le.0.) uc(6,ni) = 0.
          ucmax(ni) = uc(6,ni)
          if (cmax(ni).le.0.) ucmax(ni) = 0.
33        CONTINUE
32        CONTINUE
C
C         CALCULATION OF I-131 CONCENTRATIONS FOR THE OTHER PATHWAYS
C
          WRITE (33,331) series,ns,shot,mh,kd,iy
c
c
          i1 = 1
          i2 = 40
          NP = 0
          do 614 ij = 1,100
          NP = NP + 1
          if (i1.ge.nc) go to 615
          if (i2.ge.nc) i2 = nc
          if (ij.ne.1) WRITE (33,1331) series,ns
          WRITE (33,332)
          WRITE (33,333)
```

```
          DO 603 I = i1,i2
c
          CNF(I,1) = C(6,I)
c         IF (TCG1(I).LE.0.) GO TO 601
c         RAT = CC(I)/TCG1(I)
c         GO TO 602
c601      RAT = 0.
c602      CNF(I,2) = 0.45*(TCG1(I)*1.5 + NTGF(I)*5.8)
c         IF (RAT.LT.0.01) CNF(I,2) = CNF(I,2)/20.
          CNF(I,3) = CC(I) * fcc * dfcc
          CNF(I,4) = CC(I) * fgg * dfgg
          CNF(I,5) = tcg1(i) * fwr * dflv * dfw
c         CNF(I,5) = NTGF(I) * 1.2 * vl2
          cmot(i) = c(6,i) * tmm
          if (cmot(i).le.1.e-9) cmot(i) = 0.
          ulv2 = utcg(i) * utcg(i)
          uccc = ucm(i)*ucm(i)
          uc66 = uc(6,i)*uc(6,i)
          ucnf(i,3)=sqrt(uccc+ufc2)
          if (ucm(i).le.0.) ucnf(i,3) = 0.
          ucnf(i,4)=sqrt(uccc+ufe2)
          if (ucm(i).le.0.) ucnf(i,4) = 0.
          ucnf(i,5)=sqrt(ulv2+uflv2)
          if (utcg(i).le.0.) ucnf(i,5) = 0.
          ucmot(i)=sqrt(uc66+utmm2)
          if (cmot(i).le.0.) ucmot(i) = 0.
          write (33,330) namst(i),namcty(i),CMot(I),ucmot(i),
     1(cnf(i,k),ucnf(i,k),k=2,6)
603       CONTINUE
          i1 = i2 + 1
          i2 = i2 + 42
          WRITE (33,1332) SERIES,NS,NP
614       continue
615       continue
c
          WRITE (41,772)
          ACS=0.
c         DO 770 I = 68,120
          DO 770 I = 1,NC
          ACS = ACS + AC(6,I)
          WRITE(41,771) SHOT,IY,I,NAMST(I),NAMCTY(I),FIPS(I),NRG(I),PC(I),
c     1DIST(I),NTGF(I),TCG1(I),CC(I),C(6,I),cmax(I),AC(6,I)
     1DIST(I),NTGF(I),utgf(i),TCG1(I),utcg(i),cow(i),ucow(i),cowby(i),
     2ucowby(i)
770       CONTINUE
          WRITE (41,775) ACS
c
c
          WRITE (13,831) series,ns,shot,mh,kd,iy
          i1 = 1
          i2 = 40
          NPM = 0
          do 616 ij = 1,100
          NPM = NPM + 1
          if (i1.ge.nc) go to 617
          if (i2.ge.nc) i2 = nc
          if (ij.ne.1) WRITE (13,1831) series,ns
```

```
          WRITE (13,832)
          WRITE (13,833)
          DO 760 I = i1,i2
c
          CAV = NTGF(I) * FAV(I) * TEFF * PIAV(I) * FM * DF1 * MFAV(I)
          DIF = C(6,I) - CAV
C
          write (13,830) namst(i),namcty(i),cc(i),ucm(i),c(1,i),uc(1,i),
     1c(3,i),uc(3,i),c(4,i),uc(4,i),c(5,i),uc(5,i),c(6,i),uc(6,i),
     2cmax(i),ucmax(i),cbc(i),ucbc(i)
c         WRITE (2,782) FIPS(I),DIST(I),NTGF(I),utgf(i),FAV(I),Uf(i),
c     3PAV(I),PIAV(I),Upi(i),PI2AV(I),Upi2(i),MFAV(I),Umf(i),VGAV(I),
c     4Uvg(i)
760       continue
          i1 = i2 + 1
          i2 = i2 + 42
          WRITE (13,1832) SERIES,NS,NPM
616       continue
617       continue
c
c         do 555 i = 1,100
c         write (4,883) fips(i),(vc(k,i),k=1,6)
c         write (4,883) fips(i),(c(k,i),k=1,6)
c         write (4,883) fips(i),(ac(k,i),k=1,6)
c555      continue
c883      format (i10,6f10.0)
c
10        format (i4,1x,A12,I3)
20        format (20I6)
60        format (1x,a,1x,3i2,i5,i6,8(i5,f5.1,i2))
120       format (i5,i6,i4,4f10.0,f14.0,3f12.0,f14.0,f10.3)
191       FORMAT (1x,a76)
194       FORMAT (9F7.2)
250       FORMAT (I6,1X,A2,1X,A12,I6,F10.0,f12.0)
251       FORMAT (12F5.0)
252       FORMAT (4F5.0)
253       FORMAT (/I5,i2,A,2I3,F6.2,F5.0,F6.2,5X,F6.3,5X,F6.3,f8.2,2x,2i4)
255       FORMAT (/I5,i2,A,2I3)
254       FORMAT (2X,A,4F6.1)
771       FORMAT (1X,A10,2I5,1X,A2,1X,A12,I6,I5,F11.0,F6.0,I6,f5.1,
     13(f11.3,f5.1))
772       FORMAT(/,1X,'test',6X,'YEAR',3X,'I',' ST',' COUNTY',8X,'FIPS',
     13X,'NRG',5X,'POP.',2x,' DIST',3X,' DEP.',2X,'UNC  ',2X,
     2'GRASS    UNC',4X,'COW',4X,'UNC',4X,'COWBY   UNC'/59X,'(km)'
     3,' (nCi/m2)',6x,'(nCi.d/kg)',07X,'(nCi/d)',14X,'(nCi/d)'/)
775       FORMAT (113X,E11.3)
780       format(5x,'Best estimates and uncertainties of lumped parameter'
     1,' values for each county',
     2/,16x,' of the contiguous United States and for the shot ',A,
     3'detonated ',i2,'/',i2,'/','19',i2,'.',//)
781       FORMAT(4x,'fips,dist',3X,'ntgf,unc',5X,'fav,unc',5X,'pav',6X,
     1'piav,unc',5X,'pi2av,unc',7X,'mfav,unc',5X,'vgav,unc'/)
782       format(3x,i5,f6.0,i6,f5.1,f8.2,f6.1,f8.2,f8.1,f6.2,f8.1,f4.1,
     52(F9.1,f5.1))
830       format (3x,a,1x,a,8(1pe7.1e1,0pf5.1,2x))
1832   format(/,60X,'- A.',A,'/',I2,'/M.',I2,' -',//,1H1)
1831   format(
```

```
     11x,'TABLE ',a,'/',i2,'/M (continued)',/,1x,127('-'))
831   format(1x,'TABLE ',a,'/',i2,'/M. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 (nCi d/L) a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in all categories of cows milk considered',/,18x,'for
     4each county of the contiguous United States and for the shot ',
     5A,/,18x,'detonated ',i2,'/',i2,'/','19',i2,':',/,01x,127('-'))
832       FORMAT(61x,'Originating',3x,'Originating',/,22x,'Fresh',6x,
     1'Consumed on',4x,'Retailed',5x,'from the',6x,'from another',
     24x,'Volume-',/,
     322x,'from cow',3x,'the farm',7x,'from farm',4x,'same region',3x,
     4'region',10x,'weighted',21x,'Backyard')
833       format (1x,'State County',20x,'(category 1)',2x,'(category 2)',
     12x,'(category 3)',2x,'(category 4)',4x,'average',08x,'Maximum',
     209x,'cow',/,16x,8(5x,9('-')),/,16x,8(5x,'GM    GSD'),/,
     31x,127('-'))
330       format (3x,a,1x,a,6(1pe9.2e1,0pf5.1,4x))
1332   format(/,60X,'- A.',A,'/',I2,'/C.',I2,' -',//,1H1)
1331   format(
     11x,'TABLE ',a,'/',i2,'/C (continued)',/,01x,122('-'))
331   format(1x,'TABLE ',a,'/',i2,'/C. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in air and foodstuffs other than cows milk',/,18x,'used
     4 to calculate doses in each county',
     5' of the contiguous United States and for the shot ',A,
     6/,18x,'detonated ',i2,'/',i2,'/','19',i2,':',/,01x,122('-'))
332       FORMAT (22X,'Mothers',11x,'Goats ',
     111x,'Cottage',28x,'Leafy',13x,'Ground-level',/,22x,
     2'milk',14x,'milk',13x,'cheese',12x,'Eggs',13x,'vegetables',8x,
     3'air',/,1x,'State',1x,'County',09x,'(nCi d/L)',
     49x,'(nCi d/L)',8x,'(nCi d/kg)',8x,'(nCi d/kg)',7x,'(nCi d/kg)',
     58x,'(nCi d/m3)')
333       format (14x,6(6x,12('-')),/,14x,6(6x,'   GM    GSD'),/,
     101x,122('-'))
3000      format (1x,i3,2x,a12,i3,2x,4f14.0)
3770      format (1x,i3,2x,a12,i3,2x,a12,f10.2)
          stop
          end
```

ATTACHMENT A9.6 : DISTANCE.FOR

```
          PROGRAM DISTANCE
C
C         CALCULATES THE DISTANCE BETWEEN NTS AND EACH COUNTY CENTROID
C         PREPARED 8 JANUARY 1988 and revised 14 july 1989
C
          INTEGER FIPS
          CHARACTER*2 NAMST
          CHARACTER*12 NAMCTY
          REAL LAT,LON,LATX,LONX
          integer area,arekm
          OPEN (UNIT = 1, FILE = 'newB01.TAPE', STATUS = 'OLD')
          OPEN (UNIT = 2, FILE = 'newB01.DAT', STATUS = 'NEW')
          LAT = 37.0
          LON = 116.0
          CTE = 40000./360.
```

```
      DO 1 I = 1,3100
      READ (1,10,END=30) FIPS,NAMST,NAME,NAMCTY,area,LATX,LONX
      dat = 3.1416 * lat / 180.
      cat = cos(dat)
      DIST = CTE*SQRT((LATX-LAT)**2 + (((LONX-LON)*CAT)**2))
      arekm = area / 100
      WRITE(2,20) I,NAMST,NAMCTY,FIPS,arekm,DIST
1     CONTINUE
30    CONTINUE
10    FORMAT (I5,A2,A4,A12,6x,i10,2F8.3)
20    FORMAT (I6,1X,A2,1X,A12,I6,i8,F10.0)
      STOP
      END
```

ATTACHMENT A9.7 :NUPAST.FOR

```
      PROGRAM NUPAST
c     REVISION TO CHANGE DAILY TOTAL DRY MATTER INTAKE TO 305 DAYS
C     OF MILK (ANDRE'S CALCULATION), [AND used to CORRECT NON-NCDRPL
C     STATES TO 30% INCREASE IN PASTURE INTAKE]
C     revised 31 March 1988 After G.Wards visit.
C     PERCENT OF DIET FROM PASTURE
C
c     renamed on 4 April 1988
C     REVISED ON 9 MARCH 1989 TO NEWPASTURE.FOR
C
      DIMENSION STATE(99),IPS(99),MONTH(12),PASTPC(99,90),PASTW(99,90)
      DIMENSION TW(99),PASTAV(99),PASTDAYS(99),TPAST(99),DIET(99)
      DIMENSION seasondiet(99),DHIAPAST(99),ratio(99),spastav(99)
      dimension bdate(99),sdate(99),sdhiapast(99),sdays(99),tdate(99)
      dimension ratioday(99)
      integer bdate,sdate,pastdays,sdays,tdate
      CHARACTER*19 STATE
      Character*15 MONTH
      CHARACTER*80 T1
      OPEN (UNIT=1, FILE = 'NEWPASTure.DAT', STATUS ='OLD')
      OPEN (UNIT=2, FILE = 'NEWpasture.RES', STATUS ='NEW')
C
C     PROGRAM PREPARED BY AB JUNE 1987
C     REVISED BY MD NOVEMBER 11,1987,20 NOV 1987,18 JAN 1988,26Feb88
C     CALCULATES THE INTAKES OF PASTURE BY COW (kg/d) WEEK BY WEEK
C     AND STATE BY STATE
C     I OR M = STATE, J = MONTH, K = WEEK
C
C     USING THE YEARLY AVERAGE OF THE TOTAL DIET
C     COMPARE THE DIET(M) VALUE TO THE CALCULATED
C     DHIA %NE PASTURE (DHIAPAST(M))
C
C
      DO 70 I = 1,99
      TPAST(I) = 0.
70    CONTINUE
C
C
      READ (1,200) T1
      DO 10 I = 1,70
C     N = I
```

```
          READ (1,100) IPS(I)
          M = IPS(I)
          READ (1,120) STATE(M),PASTAV(M),spastav(m),PASTDAYS(M),
     1   sdays(m),DHIAPAST(M),sdhiapast(m),bdate(m),sdate(m)
          JA = -3
          DO 10 J = 1,12
          JA = JA + 4
          JB = JA + 3
          READ (1,110) MONTH(J),(PASTPC(M,JJ),JJ=JA,JB)
10        CONTINUE
          DO 60 I =1,70
          M = IPS(I)
          tw(m) = 0.
          IF (PASTAV(M).EQ.0.) GO TO 60
          DO 20 K = 1,48
          IF (PASTPC(M,K).GT.0.) TW(M) = TW(M) + 1.
          TPAST(M) = TPAST(M) + PASTPC(M,K)
20        CONTINUE
c to calculate the average of the pasture season
          if(tw(m).lt.1.) go to 61
          tdiet(m) = tpast(m)/48.
          seasondiet(m) = (TPAST(M)/TW(M)) * pastav(m)
          tdate(m) = sdate(m) - bdate(m)
          R1 = PASTDAYS(M)
          R2 = TDATE(M)
          ratioday(m) = R1/R2
          go to 60
61        DIET(M) = 0.
60        CONTINUE
          DO 30 I = 1,70
          M = IPS(I)
          IF (PASTAV(M).EQ.0.) GO TO 30
          DO 30 K = 1,48
          PASTW(M,K) = PASTAV(M) * PASTPC(M,K)
          IF (DIET(M).GT.0) ratio(m) = dhiapast(m)/tdiet(m)
30        CONTINUE
          DO 40 I = 1,70
          M = IPS(I)
          IF (PASTAV(M).EQ.0.) GO TO 40
        WRITE(2,130)M,STATE(M),PASTAV(M),spastav(m),DIET(M),
     1 DHIAPAST(M),sdhiapast(m),ratio(m),seasondiet(m),
     2 PASTDAYS(M),sdays(m),bdate(m),sdate(m),tdate(m),ratioday(M)
          JA = -3
          DO 50 J = 1,12
          JA = JA + 4
          JB = JA + 3
          WRITE (2,140) MONTH(J),(PASTW(M,JJ),JJ=JA,JB)
50        CONTINUE
40        CONTINUE
100       FORMAT (I5)
120       FORMAT (A,2F5.1,2I4,2F6.3,2I4)
110       FORMAT (2X,A,4F5.2)
130       FORMAT (/I3,A,2F5.1,F6.3,2F6.2,F6.3,2x,f6.3,/20x,5I4,2x,f5.2)
140       FORMAT (2X,A,4F6.1)
200       FORMAT (A)
          STOP
          END
```

ATTACHMENT A9.8 : NEWPASTREG.FOR

```
        PROGRAM NEWPASTREG
C
C       PREPARED 20 APRIL 1988
C       GENERATES ONE SET OF PASTURE INTAKES PER REGION
C       revised 10 march 1989
c       revised 06 April 1989
c       revised 23 July 1989
c
         DIMENSION REGION(100),NREG(100,11,20),MONTH(12),PI(100,50)
         DIMENSION PASTAV(100),PASTDAYS(100),DIET(100),DHIAPAST(100)
         DIMENSION RATIO(100),bdate(100),sdate(100),pastseason(100)
        dimension spastav(100),sdhiapast(100),seasondiet(100)
        dimension sdays(100),tdate(100),ratioday(100),mm(100)
        integer bdate,sdate,sdays,tdate,pastdays
        character*19 region
        CHARACTER*15 MONTH,REGNAME
        CHARACTER*80 T1,T2
C        OPEN (UNIT=1,FILE='NEWPASTREG.DEF',STATUS='OLD')
         OPEN (UNIT=1,FILE='BYCOWREG.DEF',STATUS='OLD')
         OPEN (UNIT=2,FILE='NEWPASTURE.RES',STATUS='OLD')
         OPEN (UNIT=3,FILE='NEWPASTURE2.RES',STATUS='NEW')
         OPEN (UNIT=4,FILE='NEWCHECK.RES',STATUS='NEW')
        NP=70
        NR=429
        DO 10 M=1,100
        DO 10 N=1,11
        DO 10 L=1,20
10      NREG(M,N,L)=0
        NS=0
        READ (1,400)T1
        READ (1,400) T2
400     FORMAT(A)
        DO 1 I=1,NP
        READ (1,100) M,N,MM(m),REGNAME,NMAX
        NS=NS+NMAX
        READ (1,200) (NREG(M,N,L),L=1,NMAX)
1       CONTINUE
        WRITE (4,500) NS
500     FORMAT (I10)
        DO 2 I=1,NP
        READ (2,253)M,REGION(M),PASTAV(M),spastav(m),
      1 tdiet(m),dhiapast(m),sdhiapast(m),ratio(m),seasondiet(m),
      1 PASTDAYS(M),sdays(m),bdate(m),sdate(m),tdate(m),ratioday(m)
        JA=-3
        DO 405 L=1,12
        JA = JA + 4
        JB = JA + 3
        READ (2,254) MONTH(L),(PI(M,JJ),JJ=JA,JB)
405     CONTINUE
2       CONTINUE
        DO 3 I=1,NR
        DO 4 M=1,100
        DO 4 N=1,11
        DO 4 l=1,20
        IF(NREG(M,N,L).NE.I) GO TO 4
```

```
       WRITE(3,300)NREG(M,N,L),mm(m),REGION(M),L,M,PASTAV(M),PASTDAYS(M),
      2DIET(M),DHIAPAST(M),RATIO(m),seasondiet(m),bdate(m),sdate(m)
        JA=-3
        DO 406 K=1,12
        JA = JA + 4
        JB = JA + 3
        WRITE (3,254) MONTH(K),(PI(M,JJ),JJ=JA,JB)
406     CONTINUE
        GO TO 3
4       CONTINUE
3       CONTINUE
100     FORMAT (1X,I2,I3,I2,2X,A,I3)
200     FORMAT (20I4)
253     FORMAT (/I3,A,2F5.1,F6.3,2f6.2,F6.3,2X,F6.3,/20X,5i4,2x,f5.2)
254     FORMAT (2X,A,4F6.1)
300     FORMAT (/I5,i2,A,2I3,F6.2,i5,f6.2,5X,F6.3,5X,F6.3,2x,f6.2,2x,2i4)
        STOP
        END
```

ATTACHMENT A9.9 : MILLER.FOR

```
        PROGRAM MILLER
C
C
C       SUPERSEDES OLDMILLER
C  Revised 06 JANUARY 1988 by AB - TO PROCESS SEVERAL STATES AT THE SAME
C        TIME
c
c       **10 Feb 1989 - added state 02 for subcounties in NV**
c       14 = UT; 03 = AZ; 07=CA
c        **** so some unit numbers are repeated!!!***
C       Modification in June 1989: MCFC Is always smaller than EC
c
         DIMENSION MPC(1000),RATIO1(1000),RATIO2(1000),MCFC(1000)
         DIMENSION MMC(1000),MFUC(1000),EC(1000),SC(1000),CC(1000)
         DIMENSION FC(1000),PC(1000),EXC(1000),TMFU(1000)
         DIMENSION NCM(40),NC(40,40),RPC(40),RMCFC(40),RMUFC(40)
         DIMENSION RMMC(40),RMFUC(40),REC(40),REXC(40),RTMFU(40)
         DIMENSION RSC(40),IPS(1000),RMPC(40),RATIO3(1000)
         DIMENSION MUFC(1000),IREG(60),ICYX(60)
        REAL MPC, MCFC,  MMC, MFUC, MPAVG, MCFS, MRFS, MMS,
      2  MUFS,MUFC,MPTEST
        INTEGER YEAR
C
C
C       SELECT THE STATES (BY FIPS CODE) AND THE YEAR
C       FILE UNIT NUMBERS = 1 TO 20 FOR CENSUS
C                           21 TO 40 FOR REGION
C                           41 TO 60 FOR POP
C                           61 TO 80 FOR MILLER
C                                             81 (FIXED) FOR newNUMBERS.DAT
c
c        OPEN (UNIT = 1, FILE ='CENSUS01.1954',STATUS = 'OLD')
c        OPEN (UNIT = 1, FILE ='CENSUS02.1954',STATUS = 'OLD')
cc       OPEN (UNIT = 2, FILE ='CENSUS03.1954',STATUS = 'OLD')
```

```
cc       OPEN (UNIT = 2, FILE ='CENSUS04.1954',STATUS = 'OLD')
c        OPEN (UNIT = 3, FILE ='CENSUS05.1954',STATUS = 'OLD')
cc       OPEN (UNIT = 4, FILE ='CENSUS06.1954',STATUS = 'OLD')
cc       OPEN (UNIT = 4, FILE ='CENSUS07.1954',STATUS = 'OLD')
c        OPEN (UNIT = 5, FILE ='CENSUS08.1954',STATUS = 'OLD')
c        OPEN (UNIT = 6, FILE ='CENSUS09.1954',STATUS = 'OLD')
c        OPEN (UNIT = 7, FILE ='CENSUS10.1954',STATUS = 'OLD')
c        OPEN (UNIT = 8, FILE ='CENSUS11.1954',STATUS = 'OLD')
c        OPEN (UNIT = 9, FILE ='CENSUS12.1954',STATUS = 'OLD')
c        OPEN (UNIT = 10, FILE ='CENSUS13.1954',STATUS = 'OLD')
c        OPEN (UNIT = 10, FILE ='CENSUS14.1954',STATUS = 'OLD')
c        OPEN (UNIT = 11, FILE ='CENSUS16.1954',STATUS = 'OLD')
c        OPEN (UNIT = 12, FILE ='CENSUS17.1954',STATUS = 'OLD')
c        OPEN (UNIT = 13, FILE ='CENSUS18.1954',STATUS = 'OLD')
c        OPEN (UNIT = 14, FILE ='CENSUS19.1954',STATUS = 'OLD')
c        OPEN (UNIT = 15, FILE ='CENSUS20.1954',STATUS = 'OLD')
c        OPEN (UNIT = 16, FILE ='CENSUS21.1954',STATUS = 'OLD')
c        OPEN (UNIT = 17, FILE ='CENSUS22.1954',STATUS = 'OLD')
c        OPEN (UNIT = 18, FILE ='CENSUS23.1954',STATUS = 'OLD')
c        OPEN (UNIT = 1, FILE ='CENSUS24.1954',STATUS = 'OLD')
c        OPEN (UNIT = 2, FILE ='CENSUS25.1954',STATUS = 'OLD')
c        OPEN (UNIT = 3, FILE ='CENSUS26.1954',STATUS = 'OLD')
c        OPEN (UNIT = 4, FILE ='CENSUS27.1954',STATUS = 'OLD')
c        OPEN (UNIT = 5, FILE ='CENSUS28.1954',STATUS = 'OLD')
c        OPEN (UNIT = 6, FILE ='CENSUS29.1954',STATUS = 'OLD')
c        OPEN (UNIT = 7, FILE ='CENSUS30.1954',STATUS = 'OLD')
c        OPEN (UNIT = 8, FILE ='CENSUS31.1954',STATUS = 'OLD')
cC       OPEN (UNIT = 9, FILE ='CENSUS32.1954',STATUS = 'OLD')
c        OPEN (UNIT = 10, FILE ='CENSUS33.1954',STATUS = 'OLD')
c        OPEN (UNIT = 11, FILE ='CENSUS34.1954',STATUS = 'OLD')
c        OPEN (UNIT = 12, FILE ='CENSUS35.1954',STATUS = 'OLD')
c        OPEN (UNIT = 13, FILE ='CENSUS36.1954',STATUS = 'OLD')
c        OPEN (UNIT = 14, FILE ='CENSUS37.1954',STATUS = 'OLD')
c        OPEN (UNIT = 15, FILE ='CENSUS38.1954',STATUS = 'OLD')
c        OPEN (UNIT = 16, FILE ='CENSUS39.1954',STATUS = 'OLD')
c        OPEN (UNIT = 17, FILE ='CENSUS40.1954',STATUS = 'OLD')
c        OPEN (UNIT = 18, FILE ='CENSUS41.1954',STATUS = 'OLD')
c        OPEN (UNIT = 1, FILE ='CENSUS42.1954',STATUS = 'OLD')
c        OPEN (UNIT = 2, FILE ='CENSUS44.1954',STATUS = 'OLD')
c        OPEN (UNIT = 3, FILE ='CENSUS45.1954',STATUS = 'OLD')
c        OPEN (UNIT = 4, FILE ='CENSUS46.1954',STATUS = 'OLD')
c        OPEN (UNIT = 5, FILE ='CENSUS47.1954',STATUS = 'OLD')
c        OPEN (UNIT = 6, FILE ='CENSUS48.1954',STATUS = 'OLD')
cCc      OPEN (UNIT = 7, FILE ='CENSUS49.1954',STATUS = 'OLD')
c        OPEN (UNIT = 8, FILE ='CENSUS50.1954',STATUS = 'OLD')
c        OPEN (UNIT = 9, FILE ='CENSUS51.1954',STATUS = 'OLD')
         OPEN (UNIT = 10, FILE ='CENSUS53.1954',STATUS = 'OLD')
         OPEN (UNIT = 11, FILE ='CENSUS54.1954',STATUS = 'OLD')
         OPEN (UNIT = 12, FILE ='CENSUS55.1954',STATUS = 'OLD')
         OPEN (UNIT = 13, FILE ='CENSUS56.1954',STATUS = 'OLD')
c        OPEN (UNIT =21, FILE ='REGION01.DAT',STATUS = 'OLD')
cc       OPEN (UNIT =21, FILE ='REGION02.DAT',STATUS = 'OLD')
cc       OPEN (UNIT =22, FILE ='REGION03.DAT',STATUS = 'OLD')
cc       OPEN (UNIT =22, FILE ='REGION04.DAT',STATUS = 'OLD')
c        OPEN (UNIT =23, FILE ='REGION05.dat',STATUS = 'OLD')
cc       OPEN (UNIT =24, FILE ='REGION06.DAT',STATUS = 'OLD')
cc       OPEN (UNIT =24, FILE ='REGION07.DAT',STATUS = 'OLD')
```

```
c       OPEN (UNIT =25, FILE ='REGION08.DAT',STATUS = 'OLD')
c       OPEN (UNIT =26, FILE ='REGION09.DAT',STATUS = 'OLD')
c       OPEN (UNIT =27, FILE ='REGION10.DAT',STATUS = 'OLD')
c       OPEN (UNIT =28, FILE ='REGION11.DAT',STATUS = 'OLD')
c       OPEN (UNIT =29, FILE ='REGION12.DAT',STATUS = 'OLD')
c       OPEN (UNIT =30, FILE ='REGION13.DAT',STATUS = 'OLD')
c       OPEN (UNIT =30, FILE ='REGION14.DAT',STATUS = 'OLD')
c       OPEN (UNIT =31, FILE ='REGION16.DAT',STATUS = 'OLD')
c       OPEN (UNIT =32, FILE ='REGION17.DAT',STATUS = 'OLD')
c       OPEN (UNIT =33, FILE ='REGION18.DAT',STATUS = 'OLD')
c       OPEN (UNIT =34, FILE ='REGION19.DAT',STATUS = 'OLD')
c       OPEN (UNIT =35, FILE ='REGION20.DAT',STATUS = 'OLD')
c       OPEN (UNIT =36, FILE ='REGION21.DAT',STATUS = 'OLD')
c       OPEN (UNIT =37, FILE ='REGION22.dat',STATUS = 'OLD')
c       OPEN (UNIT =38, FILE ='REGION23.DAT',STATUS = 'OLD')
c       OPEN (UNIT =21, FILE ='REGION24.DAT',STATUS = 'OLD')
c       OPEN (UNIT =22, FILE ='REGION25.DAT',STATUS = 'OLD')
c       OPEN (UNIT =23, FILE ='REGION26.DAT',STATUS = 'OLD')
c       OPEN (UNIT =24, FILE ='REGION27.DAT',STATUS = 'OLD')
c       OPEN (UNIT =25, FILE ='REGION28.DAT',STATUS = 'OLD')
c       OPEN (UNIT =26, FILE ='REGION29.DAT',STATUS = 'OLD')
c       OPEN (UNIT =27, FILE ='REGION30.DAT',STATUS = 'OLD')
c       OPEN (UNIT =28, FILE ='REGION31.DAT',STATUS = 'OLD')
cC      OPEN (UNIT =29, FILE ='REGION32.DAT',STATUS = 'OLD')
c       OPEN (UNIT =30, FILE ='REGION33.DAT',STATUS = 'OLD')
c       OPEN (UNIT =31, FILE ='REGION34.DAT',STATUS = 'OLD')
c       OPEN (UNIT =32, FILE ='REGION35.DAT',STATUS = 'OLD')
c       OPEN (UNIT =33, fILE ='REGION36.DAT',STATUS = 'OLD')
c       OPEN (UNIT =34, FiLE ='REGION37.DAT',STATUS = 'OLD')
c       OPEN (UNIT =35, FIlE ='REGION38.DAT',STATUS = 'OLD')
c       OPEN (UNIT =36, FILe ='REGION39.DAT',STATUS = 'OLD')
c       OPEN (UNIT =37, FILE ='REGION40.DAT',STATUS = 'OLD')
c       OPEN (UNIT =38, FILE ='REGION41.DAT',STATUS = 'OLD')
c       OPEN (UNIT =21, FILE ='REGION42.DAT',STATUS = 'OLD')
c       OPEN (UNIT =22, FILE ='REGION44.DAT',STATUS = 'OLD')
c       OPEN (UNIT =23, FILE ='REGION45.DAT',STATUS = 'OLD')
c       OPEN (UNIT =24, FILE ='REGION46.DAT',STATUS = 'OLD')
c       OPEN (UNIT =25, FILE ='REGION47.DAT',STATUS = 'OLD')
c       OPEN (UNIT =26, FILE ='REGION48.DAT',STATUS = 'OLD')
ccC     OPEN (UNIT =27, FILE ='REGION49.DAT',STATUS = 'OLD')
c       OPEN (UNIT =28, FILE ='REGION50.DAT',STATUS = 'OLD')
c       OPEN (UNIT =29, FILE ='REGION51.DAT',STATUS = 'OLD')
        OPEN (UNIT =30, FILE ='REGION53.DAT',STATUS = 'OLD')
        OPEN (UNIT =31, FILE ='REGION54.DAT',STATUS = 'OLD')
        OPEN (UNIT =32, FILE ='REGION55.DAT',STATUS = 'OLD')
        OPEN (UNIT =33, FILE ='REGION56.DAT',STATUS = 'OLD')
c       OPEN (UNIT =41, FILE ='POP01T.1954',STATUS = 'OLD')
cc      OPEN (UNIT =41, FILE ='POP02T.1954',STATUS = 'OLD')
cc      OPEN (UNIT =42, FILE ='POP03T.1954',STATUS = 'OLD')
cc      OPEN (UNIT =42, FILE ='POP04T.1954',STATUS = 'OLD')
c       OPEN (UNIT =43, FILE ='POP05T.1954',STATUS = 'OLD')
cC      OPEN (UNIT =44, FILE ='POP06T.1954',STATUS = 'OLD')
cc      OPEN (UNIT =44, FILE ='POP07T.1954',STATUS = 'OLD')
c       OPEN (UNIT =45, FILE ='POP08T.1954',STATUS = 'OLD')
c       OPEN (UNIT =46, FILE ='POP09T.1954',STATUS = 'OLD')
c       OPEN (UNIT =47, FILE ='POP10T.1954',STATUS = 'OLD')
c       OPEN (UNIT =48, FILE ='POP11T.1954',STATUS = 'OLD')
```

```
c        OPEN (UNIT =49, FILE ='POP12T.1954',STATUS = 'OLD')
c        OPEN (UNIT =50, FILE ='POP13T.1954',STATUS = 'OLD')
c        OPEN (UNIT =50, FILE ='POP14T.1954',STATUS = 'OLD')
c        OPEN (UNIT =51, FILE ='POP16T.1954',STATUS = 'OLD')
c        OPEN (UNIT =52, FILE ='POP17T.1954',STATUS = 'OLD')
c        OPEN (UNIT =53, FILE ='POP18T.1954',STATUS = 'OLD')
c        OPEN (UNIT =54, FILE ='POP19T.1954',STATUS = 'OLD')
c        OPEN (UNIT =55, FILE ='POP20T.1954',STATUS = 'OLD')
c        OPEN (UNIT =56, FILE ='POP21T.1954',STATUS = 'OLD')
c        OPEN (UNIT =57, FILE ='POP22T.1954',STATUS = 'OLD')
c        OPEN (UNIT =58, FILE ='POP23T.1954',STATUS = 'OLD')
c        OPEN (UNIT =41, FILE ='POP24T.1954',STATUS = 'OLD')
c        OPEN (UNIT =42, FILE ='POP25T.1954',STATUS = 'OLD')
c        OPEN (UNIT =43, FILE ='POP26T.1954',STATUS = 'OLD')
c        OPEN (UNIT =44, FILE ='POP27T.1954',STATUS = 'OLD')
c        OPEN (UNIT =45, FILE ='POP28T.1954',STATUS = 'OLD')
c        OPEN (UNIT =46, FILE ='POP29T.1954',STATUS = 'OLD')
c        OPEN (UNIT =47, FILE ='POP30T.1954',STATUS = 'OLD')
c        OPEN (UNIT =48, FILE ='POP31T.1954',STATUS = 'OLD')
cC       OPEN (UNIT =49, FILE ='POP32T.1954',STATUS = 'OLD')
c        OPEN (UNIT =50, FILE ='POP33T.1954',STATUS = 'OLD')
c        OPEN (UNIT =51, FILE ='POP34T.1954',STATUS = 'OLD')
c        OPEN (UNIT =52, FILE ='POP35T.1954',STATUS = 'OLD')
c        OPEN (UNIT =53, FILE ='POP36T.1954',STATUS = 'OLD')
c        OPEN (UNIT =54, FILE ='POP37T.1954',STATUS = 'OLD')
c        OPEN (UNIT =55, FILE ='POP38T.1954',STATUS = 'OLD')
c        OPEN (UNIT =56, FILE ='POP39T.1954',STATUS = 'OLD')
c        OPEN (UNIT =57, FILE ='POP40T.1954',STATUS = 'OLD')
c        OPEN (UNIT =58, FILE ='POP41T.1954',STATUS = 'OLD')
c        OPEN (UNIT =41, FILE ='POP42T.1954',STATUS = 'OLD')
c        OPEN (UNIT =42, FILE ='POP44T.1954',STATUS = 'OLD')
c        OPEN (UNIT =43, FILE ='POP45T.1954',STATUS = 'OLD')
c        OPEN (UNIT =44, FILE ='POP46T.1954',STATUS = 'OLD')
c        OPEN (UNIT =45, FILE ='POP47T.1954',STATUS = 'OLD')
c        OPEN (UNIT =46, FILE ='POP48T.1954',STATUS = 'OLD')
cC       OPEN (UNIT =47, FILE ='POP49T.1954',STATUS = 'OLD')
c        OPEN (UNIT =48, FILE ='POP50T.1954',STATUS = 'OLD')
c        OPEN (UNIT =49, FILE ='POP51T.1954',STATUS = 'OLD')
         OPEN (UNIT =50, FILE ='POP53T.1954',STATUS = 'OLD')
         OPEN (UNIT =51, FILE ='POP54T.1954',STATUS = 'OLD')
         OPEN (UNIT =52, FILE ='POP55T.1954',STATUS = 'OLD')
         OPEN (UNIT =53, FILE ='POP56T.1954',STATUS = 'OLD')
c        OPEN (UNIT =61, FILE ='[.dist]newmiller01.1954',STATUS = 'NEW')
cc        OPEN (UNIT =61, FILE ='[.dist]newMILLER02.1954',STATUS = 'NEW')
cc        OPEN (UNIT =62, FILE ='[.dist]newMILLER03.1954',STATUS = 'NEW')
cc        OPEN (UNIT =62, FILE ='[.dist]newmiller04.1954',STATUS = 'NEW')
c         OPEN (UNIT =63, FILE ='[.dist]newmiller05.1954',STATUS = 'NEW')
c        OPEN (UNIT =64, FILE ='[.dist]newmiller06.1954',STATUS = 'NEW')
cc        OPEN (UNIT =64, FILE ='[.dist]newMILLER07.1954',STATUS = 'NEW')
c         OPEN (UNIT =65, FILE ='[.dist]newmiller08.1954',STATUS = 'NEW')
c         OPEN (UNIT =66, FILE ='[.dist]newmiller09.1954',STATUS = 'NEW')
c        OPEN (UNIT =67, FILE ='[.dist]newmiller10.1954',STATUS = 'NEW')
c        OPEN (UNIT =68, FILE ='[.dist]newmiller11.1954',STATUS = 'NEW')
c         OPEN (UNIT =69, FILE ='[.dist]newmiller12.1954',STATUS = 'NEW')
c         OPEN (UNIT =70, FILE ='[.dist]newmiller13.1954',STATUS = 'NEW')
c          OPEN (UNIT =70, FILE ='[.dist]newMILLER14.1954',STATUS = 'NEW')
c         OPEN (UNIT =71, FILE ='[.dist]newmiller16.1954',STATUS = 'NEW')
```

```
c         OPEN (UNIT =72, FILE ='[.dist]newmiller17.1954',STATUS = 'NEW')
c         OPEN (UNIT =73, FILE ='[.dist]newmiller18.1954',STATUS = 'NEW')
c         OPEN (UNIT =74, FILE ='[.dist]newmiller19.1954',STATUS = 'NEW')
c         OPEN (UNIT =75, FILE ='[.dist]newmiller20.1954',STATUS = 'NEW')
c         OPEN (UNIT =76, FILE ='[.dist]newmiller21.1954',STATUS = 'NEW')
c         OPEN (UNIT =77, FILE ='[.dist]newmiller22.1954',STATUS = 'NEW')
c         OPEN (UNIT =78, FILE ='[.dist]newmiller23.1954',STATUS = 'NEW')
c         OPEN (UNIT =61, FILE ='[.dist]newmiller24.1954',STATUS = 'NEW')
c         OPEN (UNIT =62, FILE ='[.dist]newmiller25.1954',STATUS = 'NEW')
c         OPEN (UNIT =63, FILE ='[.dist]newmiller26.1954',STATUS = 'NEW')
c          OPEN (UNIT =64, FILE ='[.dist]newmiller27.1954',STATUS = 'NEW')
c          OPEN (UNIT =65, FILE ='[.dist]newmiller28.1954',STATUS = 'NEW')
c          OPEN (UNIT =66, FILE ='[.dist]newmiller29.1954',STATUS = 'NEW')
c         OPEN (UNIT =67, FILE ='[.dist]newmiller30.1954',STATUS = 'NEW')
c         OPEN (UNIT =68, FILE ='[.dist]newmiller31.1954',STATUS = 'NEW')
cC         OPEN (UNIT =69, FILE ='[.dist]newmiller32.1954',STATUS = 'NEW')
c         OPEN (UNIT =70, FILE ='[.dist]newmiller33.1954',STATUS = 'NEW')
c         OPEN (UNIT =71, FILE ='[.dist]newmiller34.1954',STATUS = 'NEW')
c         OPEN (UNIT =72, FILE ='[.dist]newmiller35.1954',STATUS = 'NEW')
c         OPEN (UNIT =73, FILE ='[.dist]newmiller36.1954',STATUS = 'NEW')
c         OPEN (UNIT =74, FILE ='[.dist]newmiller37.1954',STATUS = 'NEW')
c         OPEN (UNIT =75, FILE ='[.dist]newmiller38.1954',STATUS = 'NEW')
c         OPEN (UNIT =76, FILE ='[.dist]newmiller39.1954',STATUS = 'NEW')
c         OPEN (UNIT =77, FILE ='[.dist]newmiller40.1954',STATUS = 'NEW')
c         OPEN (UNIT =78, FILE ='[.dist]newmiller41.1954',STATUS = 'NEW')
c         OPEN (UNIT =61, FILE ='[.dist]newmiller42.1954',STATUS = 'NEW')
c         OPEN (UNIT =62, FILE ='[.dist]newmiller44.1954',STATUS = 'NEW')
c         OPEN (UNIT =63, FILE ='[.dist]newmiller45.1954',STATUS = 'NEW')
c         OPEN (UNIT =64, FILE ='[.dist]newmiller46.1954',STATUS = 'NEW')
c         OPEN (UNIT =65, FILE ='[.dist]newmiller47.1954',STATUS = 'NEW')
c          OPEN (UNIT =66, FILE ='[.dist]newmiller48.1954',STATUS = 'NEW')
ccC         OPEN (UNIT =67, FILE ='[.dist]newmiller49.1954',STATUS = 'NEW')
c         OPEN (UNIT =68, FILE ='[.dist]newmiller50.1954',STATUS = 'NEW')
c          OPEN (UNIT =69, FILE ='[.dist]newmiller51.1954',STATUS = 'NEW')
        OPEN (UNIT =70, FILE ='[.dist]newmiller53.1954',STATUS = 'NEW')
        OPEN (UNIT =71, FILE ='[.dist]newmiller54.1954',STATUS = 'NEW')
         OPEN (UNIT =72, FILE ='[.dist]newmiller55.1954',STATUS = 'NEW')
        OPEN (UNIT =73, FILE ='[.dist]newmiller56.1954',STATUS = 'NEW')
        OPEN (UNIT = 81, FILE ='newNUMBERS.DAT',STATUS = 'OLD')
c         OPEN (UNIT = 81, FILE ='NUMBERS.DAT',STATUS = 'OLD')
        OPEN (UNIT = 82, FILE ='CHECKS.DAT',STATUS = 'NEW')
C
C
C
C       INDICATE THE NUMBER OF STATES YOU WANT TO RUN (UP TO TWENTY)
C       ACCORDING TO THE FILE UNIT NUMBERS FOR CENSUS
C       NS1 = FIRST STATE, NS2 = LAST STATE
C
C
        NS1 =10
        NS2 =13
c
C        NO MORE CHANGES
C
C
        DO 600 J = 1,49
        READ  (81,601) JST,JREG,JCYX
```

```
      IREG(JST) = JREG
      ICYX(JST) = JCYX
600   CONTINUE
601   FORMAT (3I3)
      DO 602 IJK = NS1,NS2
      IR = IJK + 20
      IP = IJK + 40
      IM = IJK + 60
      READ (IJK,200) ITATE,YEAR,MPAVG,FS,PS,MCFS,MRFS,MMS,CONS,MUFS
      WRITE (82,200) ITATE,YEAR,MPAVG,FS,PS,MCFS,MRFS,MMS,CONS,MUFS
      NUMREG = IREG(ITATE)
      NCMAX = ICYX(ITATE)
      WRITE (82,197) ITATE,NUMREG,NCMAX
      PSS = 0.
      CSS = 0.
      fss = 0.
      CSM = 0.
      L=0
      mcfs = mcfs * 1000.
      mufs = mufs * 1000.
      mrfs = mrfs * 1000.
      mms = mms * 1000.
      READ (IP,402)
C     WRITE(82,402)
 10    L = L+1
       READ (IJK,400,END=301) IPS(L),CCL,FCL
       WRITE (82,400) IPS(L),CCL,FCL
      READ (IP,401,END=301) IYR,IST,ICT,NPCL
      write (82,401) iyr,ist,ict,npcl
      PCL = NPCL
      I = IPS(L)
      CC(I) = CCL
      FC(I) = FCL
      PC(I) = PCL
      PSS = PSS + PC(I)
      fss = fss + fc(i)
      CSS = CSS + CC(I)
       GO TO 10
301    CONTINUE
      N = L-1
      WRITE (82,999) N
      DO 40 L = 1,N
      I = IPS(L)
      RATIO1(I) = 0.
      RATIO3(I) = 0.
      MPC(I) = (CC(I) * MPAVG)/1000
      EC(I) =  (CONS * PC(I))/1000
      IF (FSS.GT.0.) RATIO1(I) = FC(I)/FSS
      IF (CSS.GT.0.) RATIO3(I) = CC(I)/CSS
      RATIO2(I) = PC(I)/PSS
      MCFC(I) = MCFS * RATIO1(I)
      MUFC(I) = MUFS * RATIO3(I)
      EXC(I) = MPC(I) - MUFC(I) - EC(I)
       MPTEST = (MPAVG * CSS)/1000
      IF (EXC(I).GT.0.) CSM = CSM + CC(I)
 40   CONTINUE
      DO 30 L = 1,N
```

```
      I = IPS(L)
      MMC(I) = 0.
      IF (EXC(I).GT.0.) MMC(I) = MMS * CC(I) / CSM
c
c     in case MCFC is greater than EC
c
      if (mcfc(i).gt.ec(i)) go to 3001
      MFUC(I) = MPC(I) - MUFC(I) - MCFC(I) - MMC(I)
      TMFU(I) = MPC(I) - MMC(I) - MUFC(I)
      go to 3002
3001  mfuc(i) = (mpc(i)-mufc(i)-mcfc(i)-mmc(i)) + (mcfc(i)-ec(i))
      TMFU(I) = MPC(I) - MMC(I) - MUFC(I)  + (mcfc(i)-ec(i))

      mcfc(i) = ec(i)
3002  SC(I) = TMFU(I) - EC(I)
   30 CONTINUE
      iyr = iyr + 1900
      WRITE (IM,100) ITATE, YEAR,iyr
      WRITE (IM,101)MPAVG,FS,fss,css,PS,PSS,MPTEST,MCFS,MUFS,MRFS,MMS,CONS
      WRITE (IM,501)
      WRITE (IM,102)
      TPC = 0.
      TMCFC = 0.
      TMUFC = 0.
      TMPC = 0.
      TMMC = 0.
      TMFUC = 0.
      TEC = 0.
      TEXC = 0.
      TTMFU = 0.
      TSC = 0.
      DO 15 L=1,N
      II = (Itate * 1000) + IPS(L)
      I = IPS(L)
      WRITE (IM,103) II , PC(I), MCFC(I), MUFC(I),
     2  MPC(I),MMC(I), MFUC(I), EC(I), EXC(I), TMFU(I), SC(I)
      TPC = TPC + PC(I)
      TMCFC = TMCFC + MCFC(I)
       TTMUFC = TMUFC + MUFC(I)
      TMPC = TMPC + MPC(I)
      TMMC = TMMC + MMC(I)
      TMFUC = TMFUC + MFUC(I)
      TEC = TEC + EC(I)
      TEXC = TEXC + EXC(I)
      TTMFU = TTMFU + TMFU(I)
      TSC = TSC + SC(I)
   15  CONTINUE
      WRITE (IM,104) TPC,TMCFC,TMUFC,TMPC,TMMC,TMFUC,TEC,TEXC,TTMFU,
     1TSC
      WRITE(82,195)NUMREG,NCMAX
      READ(IR,105) (NCM(J),J=1,NUMREG)
C
      DO 20 J=1,NUMREG
      RPC(J)= 0.
      RMCFC(J)=0.
      RMUFC(J)=0.
      RMPC(J)=0.
```

```
      RMMC(J)=0.
      RMFUC(J) = 0.
      REC(J) = 0.
      REXC(J) = 0.
      RTMFU(J) = 0.
      RSC(J) = 0.
      NCMAX = NCM(J)
      READ(IR,106)(NC(J,K),K=1,NCMAX)
      WRITE(82,196)NCMAX,(NC(J,K),K=1,NCMAX)
20    CONTINUE
C
       DO 21 J=1,NUMREG
      NM=NCM(J)
C
      DO 21 K=1,NM
      L=NC(J,K)
      RPC(J)=RPC(J) + PC(L)
      RMCFC(J)=RMCFC(J) + MCFC(L)
      RMUFC(J)=RMUFC(J) + MUFC(L)
      RMPC(J)=RMPC(J) + MPC(L)
      RMMC(J)=RMMC(J) + MMC(L)
      RMFUC(J) = RMFUC(J) + MFUC(L)
      REC(J) = REC(J) + EC(L)
      REXC(J) = REXC(J) + EXC(L)
      RTMFU(J) = RTMFU(J) + TMFU(L)
      RSC(J) = RSC(J) + SC(L)
   21  CONTINUE
C
      DO 22 J = 1,NUMREG
      WRITE (IM,107)
      NM = NCM(J)
C
      DO 23 K=1,NM
      L=NC(J,K)
      LL = (ITATE * 1000) + L
   23 WRITE(IM,109)LL,PC(L),MCFC(L),MUFC(L),MPC(L),MMC(L),MFUC(L),EC(L)
     3,EXC(L),TMFU(L),SC(L)
      WRITE (IM,108)
   22  WRITE (IM,109) NM,RPC(J),RMCFC(J),RMUFC(J),RMPC(J),RMMC(J),
     1RMFUC(J),REC(J),REXC(J),RTMFU(J), RSC(J)
602   CONTINUE
402   FORMAT(//)
400   FORMAT (I4,2F10.0)
401   FORMAT (3I3,I12)
  200  FORMAT (I4,I5,F6.0,F8.0,F10.0,F8.0,F7.0,F10.1,F7.2,F8.0)
  201  FORMAT (I4,4F10.0)
  300  FORMAT (3A4,I4)
  100  FORMAT (10X,'**MILLER METHOD - MILK DISTRIBUTION**',2x,
     1'check that the TEST values are the same as the estimates'//10X,
     2  'STATE',I3,30X,'YEAR',I5,2x,'TEST =',i5/)
  101  FORMAT (10X,'AVERAGE MILK PER COW (LBS/YR) = ',F10.0/,
     2  10X,'TOTAL DAIRY FARMS = ',F10.0,'      TEST = ',F10.0/,
     9  10x,'TOTAL DAIRY COWS = ',f10.0/,
     3  10X,'TOTAL POPULATION = ',F10.0,'       TEST = ',F10.0/,
     8  10X,'TOTAL MILK PROD (Klb)- check mpc total = ',F10.0/,
     4  10X,'FARM CONSUMPTION (Klb) = ',F10.0/,
     1  10X,'USED ON FARM (Klb) = ',F10.0/,
```

```
     5  10X,'FARM RETAIL (Klb) = ',F10.0/,
     6  10X,'MANUFACTURED (Klb) = ',F10.0/,
     7  10X,'CONSUMPTION RATE (lbs per capita per year) = ',F10.2)
 501    FORMAT (///30X,'PC = POPULATION '/,
     2  30X,'MCFC = MILK CONSUMED ON FARMS'/,
     3  30X,'MUFC = MILK USED ON FARMS (non-consumption by people)'/,
     4  30X,'MPC  = TOTAL MILK PRODUCED (calculated)'/,
     5  30X,'MMC  = MILK USED FOR MANUFACTURING'/,
     6  30X,'MFUC = MILK TO SELL(does not include farm consumption)-urban
     1 fluid use'/,
     7  30x,'EC   = EXPECTED CONSUMPTION (calculated)'/,
     8  30X,'EXC  = TEST TO SITE MANUFACTURING PLANTS'/,
     9  30X,'TMFU = TOTAL FLUID MILK CONSUMED'/,
     10 30X,'SURP = SURPLUS'//)
 102    FORMAT (//3X,'CNTY',6X,'PC',8X,'MCFC',8X,'MUFC',8X,'MPC',8X,
     2  'MMC',10X,'MFUC',10X,'EC',9X,'EXC',8X,'TMFU',8X,'SURP'/)
 103    FORMAT (I6,10F12.0)
 104   FORMAT (/,6X,10F12.0)
 105    FORMAT(25I3)
 106    FORMAT (15I4)
 195    FORMAT(2I20)
 196    FORMAT (I8,15I4)
 197    FORMAT (6I10)
 107    FORMAT (/,3X,'CNTY',6X,'PC',8X,'MCFC',8X,'MUFC',8X,'MPC',8X,
     2  'MMC',10X,'MFUC',10X,'EC',9X,'EXC',8X,'TMFU',8X,'SURP'/)
 108    FORMAT(/)
 109    FORMAT (I6,10F12.0)
999    FORMAT (' N =',I3)
        STOP
        END
```

ATTACHMENT A9.10 : NEWMILLERUS2.FOR

```
       PROGRAM NEWMILLERUS2
C
C      ADD THE RESULTS OBTAINED FOR THE 49 STATES
C      PREPARED 13 JANUARY 1988 (MILLERUS)
C      REVISED 18 NOVEMBER 1988 (MILLERUS2)
C      REVISED  2 MARCH 1989 (NEWMILLERUS2)
C
        DIMENSION MPC(3100),MCFC(3100),KIPS(3100),TOT(20),TOTS(10)
        DIMENSION MMC(3100),MFUC(3100),EC(3100),SC(3100),CC(3100)
        DIMENSION FC(600),PC(3100),EXC(3100),TMFU(3100),MUFC(3100)
        DIMENSION NCM(430),RPC(430),RMCFC(430),RMUFC(430),totc(10)
        DIMENSION RMMC(430),RMFUC(430),REC(430),REXC(430),RTMFU(430)
        DIMENSION RSC(430),RMPC(430),NCTY(600),region(60)
        DIMENSION REG(430),MAX(600),IST(430),NREG(430,60)
        DIMENSION NST(60,40),IPS(430,60),MM(430,60),NRT(430)
c
       dimension it(60),totr(60,6),tott(6)
c
       CHARACTER*12 REG,REGIN,region
       REAL MPC, MCFC,  MMC, MFUC, MPAVG, MCFS, MRFS, MMS,MSC,
     2  MUFS,MUFC,MPTEST,MCFCL,MUFCL,MPCL,MMCL,MFUCL
        INTEGER YEAR
c
```

```
c       MILKCTY3, MILKREG3, MILKST3 FOR THE TOTAL OVER ALL STATES
c
         OPEN (UNIT=91,FILE='NEWREGIONUS.DAT',STATUS = 'OLD')
         OPEN (UNIT=92,FILE='NEWMILKCTY3.DAT',STATUS = 'NEW')
         OPEN (UNIT=93,FILE='NEWMILKST3.DAT',STATUS = 'NEW')
         OPEN (UNIT=94,FILE='NEWMILKREG3.DAT',STATUS = 'NEW')
C        OPEN (UNIT = 81, FILE ='NEWNUMBERS.DAT',STATUS = 'OLD')
         OPEN (UNIT = 82, FILE ='CHECKS.DAT',STATUS = 'NEW')
C
C       NST(N,J) = NS = REGION CODE (REGION J IN STATE N)
C       NRT(N) = NR = NUMBER OF REGIONS IN STATE N
C       NREG(N,J) = NM = NUMBER OF COUNTIES IN REGION J OF STATE N
C       NCTOT = TOTAL NUMBER OF COUNTIES = 3094
C       NRTOT = TOTAL NUMBER OF REGIONS = 429
C
        DO 6021 K = 1,10
        TOT(K) = 0.
        TOTS(K) = 0.
        TOTC(K) = 0.
6021   CONTINUE
C
c
        do 6121 im=1,60
        do 6121 k=1,6
        totr(im,k)=0.
        tott(k)=0.
6121   continue
c
        write (94,5010)
        write (94,501)
        write (94,5011)
        write (94,1020)
        write (93,931)
        write (93,932)
        write (93,933)
        write (93,934)
c
        DO 1 N = 1,49
        NCTY(N) = 0
        READ (91,199) KST,NR,NMAX,REGIN
        READ (91,110)(NST(N,J),J=1,NR)
        READ (91,140)(NREG(N,J),J=1,NR)
        NRT(N) = NR
        region(kst) = regin
        DO 3 I = 1,NR
        NS = NST(N,I)
        REG(NS) = REGIN
        IST(NS) = KST
        JJ = NREG(N,I)
        NCTY(N) = NCTY(N) + JJ
        MAX(NS) = JJ
        READ (91,120) (IPS(NS,J),J = 1,JJ)
        DO 3 J = 1,JJ
        MM(NS,J) = (IST(NS)*1000) + IPS(NS,J)
3       CONTINUE
1       CONTINUE
199     FORMAT (3I3,1X,A12)
```

```
120     FORMAT (15I4)
110     FORMAT (18I4)
140     FORMAT (18I3)
C
C       RUN FILES IN TWO PARTS (TOP AND BOTTOM HALF OF THE STATES)
C

        OPEN (UNIT =1, FILE ='[.dist]newMILLER01.1954',STATUS = 'OLD')
C       OPEN (UNIT =2, FILE ='[.dist]newMILLER04.1954',STATUS = 'OLD')
        OPEN (UNIT =2, FILE ='[.dist]newMILLER03.1954',STATUS = 'OLD')
        OPEN (UNIT =3, FILE ='[.dist]newMILLER05.1954',STATUS = 'OLD')
C       OPEN (UNIT =4, FILE ='[.dist]newMILLER06.1954',STATUS = 'OLD')
        OPEN (UNIT =4, FILE ='[.dist]newMILLER07.1954',STATUS = 'OLD')
cc      OPEN (UNIT =5, FILE ='[.dist]newMILLER08.1954',STATUS = 'OLD')
        OPEN (UNIT =5, FILE ='[.dist]MILLER78908.1954',STATUS = 'OLD')
         OPEN (UNIT =6, FILE ='[.dist]newMILLER09.1954',STATUS = 'OLD')
        OPEN (UNIT =7, FILE ='[.dist]newMILLER10.1954',STATUS = 'OLD')
        OPEN (UNIT =8, FILE ='[.dist]newMILLER11.1954',STATUS = 'OLD')
        OPEN (UNIT =9, FILE ='[.dist]newMILLER12.1954',STATUS = 'OLD')
         OPEN (UNIT =10, FILE ='[.dist]newMILLER13.1954',STATUS = 'OLD')
cc       OPEN (UNIT =11, FILE ='[.dist]newMILLER16.1954',STATUS = 'OLD')
         OPEN (UNIT =11, FILE ='[.dist]MILLER78916.1954',STATUS = 'OLD')
         OPEN (UNIT =12, FILE ='[.dist]newMILLER17.1954',STATUS = 'OLD')
         OPEN (UNIT =13, FILE ='[.dist]newMILLER18.1954',STATUS = 'OLD')
         OPEN (UNIT =14, FILE ='[.dist]newMILLER19.1954',STATUS = 'OLD')
         OPEN (UNIT =15, FILE ='[.dist]newMILLER20.1954',STATUS = 'OLD')
cc       OPEN (UNIT =16, FILE ='[.dist]newMILLER21.1954',STATUS = 'OLD')
         OPEN (UNIT =16, FILE ='[.dist]MILLER78921.1954',STATUS = 'OLD')
         OPEN (UNIT =17, FILE ='[.dist]newMILLER22.1954',STATUS = 'OLD')
         OPEN (UNIT =18, FILE ='[.dist]newMILLER23.1954',STATUS = 'OLD')
         OPEN (UNIT =19, FILE ='[.dist]newMILLER24.1954',STATUS = 'OLD')
cc       OPEN (UNIT =20, FILE ='[.dist]newMILLER25.1954',STATUS = 'OLD')
         OPEN (UNIT =20, FILE ='[.dist]MILLER78925.1954',STATUS = 'OLD')
         OPEN (UNIT =21, FILE ='[.dist]newMILLER26.1954',STATUS = 'OLD')
         OPEN (UNIT =22, FILE ='[.dist]newMILLER27.1954',STATUS = 'OLD')
         OPEN (UNIT =23, FILE ='[.dist]newMILLER28.1954',STATUS = 'OLD')
cc       OPEN (UNIT =24, FILE ='[.dist]newMILLER29.1954',STATUS = 'OLD')
         OPEN (UNIT =24, FILE ='[.dist]MILLER78929.1954',STATUS = 'OLD')
         OPEN (UNIT =25, FILE ='[.dist]newMILLER30.1954',STATUS = 'OLD')
C
C       ENTER UNIT FILE NAMES FOR FIRST AND LAST STATE TO CONSIDER
C       1 TO 25 FOR TOP HALF
C
        DO 502 IM = 1,25
        READ (IM,100) ITATE, YEAR
        READ (IM,101)MPAVG,FS,fss,css,PS,PSS,MPTEST,MCFS,MUFS,MRFS,MMS,CONS
        READ (IM,501)
        READ (IM,102)
        IJ = 0
        it(im) = itate
        NII = NCTY(IM)
        DO 503 II = 1,NII
        I = II + IJ
        READ (IM,103,ERR=504) KIPS(I) , PC(I), MCFC(I), MUFC(I),
      2  MPC(I),MMC(I), MFUC(I), EC(I), EXC(I), TMFU(I), SC(I)
        WRITE (92,103) KIPS(I) , PC(I), MCFC(I), MUFC(I),
      2  MPC(I),MMC(I), MFUC(I), EC(I), EXC(I), TMFU(I), SC(I)
```

```
        totc(1) = totc(1) + pc(i)
        totc(2) = totc(2) + mcfc(i)
        totc(3) = totc(3) + mufc(i)
        totc(4) = totc(4) + mpc(i)
        totc(5) = totc(5) + mmc(i)
        totc(6) = totc(6) + mfuc(i)
        totc(7) = totc(7) + ec(i)
        totc(8) = totc(8) + exc(i)
        totc(9) = totc(9) + tmfu(i)
        totc(10) = totc(10) + sc(i)
c
        totr(im,3) = totr(im,3) + sc(i)
c
503     CONTINUE
504     IJ = I-1
        READ (IM,104) TPC,TMCFC,TMUFC,TMPC,TMMC,TMFUC,TEC,TEXC,TTMFU,
     1TSC
        TOTS(1) = TOTS(1) + TPC
        TOTS(2) = TOTS(2) + TMCFC
        TOTS(3) = TOTS(3) + TMUFC
        TOTS(4) = TOTS(4) + TMPC
        TOTS(5) = TOTS(5) + TMMC
        TOTS(6) = TOTS(6) + TMFUC
        TOTS(7) = TOTS(7) + TEC
        TOTS(8) = TOTS(8) + TEXC
        TOTS(9) = TOTS(9) + TTMFU
        TOTS(10) = TOTS(10) + TSC
c
        totr(im,1) = tsc
c
        ACONS = TEC*(1.E6)/(2.205*365.*TPC)
        WRITE (93,114) region(itate),ITATE,TPC,TMCFC,TMUFC,TMPC,TMMC,
     1TMFUC,TEC,TEXC,TTMFU,TSC,ACONS
C
        NR = NRT(IM)
        DO 522 J = 1,NR
        READ (IM,107)
        NM = NREG(IM,J)
C
        DO 523 K=1,NM
         READ(IM,109)LL,PCL,MCFCL,MUFCL,MPCL,MMCL,MFUCL,ECL
     3,EXCL,TMFUL,SCL
C        WRITE(94,109)NM,PCL,MCFCL,MUFCL,MPCL,MMCL,MFUCL,ECL
C      3,EXCL,TMFUL,SCL
523     CONTINUE
        READ (IM,108)
         READ (IM,109)NPQ,RPCJ,RMCFCJ,RMUFCJ,RMPCJ,RMMCJ,
     1RMFUCJ,RECJ,REXCJ,RTMFUJ, RSCJ
        L = NST(im,J)
C       WRITE  (94,998) L
        RPC(L) = RPCJ
        RMCFC(L) = RMCFCJ
        RMUFC(L) = RMUFCJ
        RMPC(L) = RMPCJ
        RMMC(L) = RMMCJ
        RMFUC(L) = RMFUCJ
        REC(L) = RECJ
```

```
      REXC(L) = REXCJ
      RTMFU(L) = RTMFUJ
      RSC(L) = RSCJ

c
      totr(im,2) = totr(im,2) + rsc(l)
c
       WRITE (94,1090) reg(l),itate,L,RPC(L),RMCFC(L),RMUFC(L),RMPC(L),
     1RMMC(L),RMFUC(L),REC(L),REXC(L),RTMFU(L), RSC(L)
522   CONTINUE
      close (im)
502   CONTINUE
C
cc     OPEN (UNIT =26, FILE ='[.dist]newMILLER31.1954',STATUS = 'OLD')
       OPEN (UNIT =26, FILE ='[.dist]MILLER78931.1954',STATUS = 'OLD')
C      OPEN (UNIT =27, FILE ='[.dist]newMILLER32.1954',STATUS = 'OLD')
       OPEN (UNIT =27, FILE ='[.dist]newMILLER02.1954',STATUS = 'OLD')
       OPEN (UNIT =28, FILE ='[.dist]newMILLER33.1954',STATUS = 'OLD')
       OPEN (UNIT =29, FILE ='[.dist]newMILLER34.1954',STATUS = 'OLD')
       OPEN (UNIT =30, FILE ='[.dist]newMILLER35.1954',STATUS = 'OLD')
       OPEN (UNIT =31, FILE ='[.dist]newMILLER36.1954',STATUS = 'OLD')
       OPEN (UNIT =32, FILE ='[.dist]newMILLER37.1954',STATUS = 'OLD')
cc     OPEN (UNIT =33, FILE ='[.dist]newMILLER38.1954',STATUS = 'OLD')
       OPEN (UNIT =33, FILE ='[.dist]MILLER78938.1954',STATUS = 'OLD')
       OPEN (UNIT =34, FILE ='[.dist]newMILLER39.1954',STATUS = 'OLD')
       OPEN (UNIT =35, FILE ='[.dist]newMILLER40.1954',STATUS = 'OLD')
       OPEN (UNIT =36, FILE ='[.dist]newMILLER41.1954',STATUS = 'OLD')
       OPEN (UNIT =37, FILE ='[.dist]newMILLER42.1954',STATUS = 'OLD')
       OPEN (UNIT =38, FILE ='[.dist]newMILLER44.1954',STATUS = 'OLD')
       OPEN (UNIT =39, FILE ='[.dist]newMILLER45.1954',STATUS = 'OLD')
       OPEN (UNIT =40, FILE ='[.dist]newMILLER46.1954',STATUS = 'OLD')
cc     OPEN (UNIT =41, FILE ='[.dist]newMILLER47.1954',STATUS = 'OLD')
       OPEN (UNIT =41, FILE ='[.dist]MILLER78947.1954',STATUS = 'OLD')
       OPEN (UNIT= 42, FILE ='[.dist]newMILLER48.1954',STATUS = 'OLD')
C      OPEN (UNIT =43, FILE ='[.dist]newMILLER49.1954',STATUS = 'OLD')
       OPEN (UNIT =43, FILE ='[.dist]newMILLER14.1954',STATUS = 'OLD')
       OPEN (UNIT =44, FILE ='[.dist]newMILLER50.1954',STATUS = 'OLD')
       OPEN (UNIT =45, FILE ='[.dist]newMILLER51.1954',STATUS = 'OLD')
       OPEN (UNIT =46, FILE ='[.dist]newMILLER53.1954',STATUS = 'OLD')
       OPEN (UNIT =47, FILE ='[.dist]newMILLER54.1954',STATUS = 'OLD')
       OPEN (UNIT =48, FILE ='[.dist]newMILLER55.1954',STATUS = 'OLD')
       OPEN (UNIT =49, FILE ='[.dist]newMILLER56.1954',STATUS = 'OLD')
C
C     ENTER UNIT FILE NAMES FOR FIRST AND LAST STATE TO CONSIDER
C     1 TO 25 FOR TOP HALF; 26 TO 49 FOR BOTTOM HALF
C
      DO 602 IM = 26,49
      READ (IM,100) ITATE, YEAR
      READ (IM,101)MPAVG,FS,fss,css,PS,PSS,MPTEST,MCFS,MUFS,MRFS,MMS,CONS
      READ (IM,501)
      READ (IM,102)
      IJ = 0
      it(im) = itate
      NII = NCTY(IM)
      DO 603 II = 1,NII
      I = II + IJ
      READ (IM,103,ERR=604) KIPS(I) , PC(I), MCFC(I), MUFC(I),
```

```
     2  MPC(I),MMC(I), MFUC(I), EC(I), EXC(I), TMFU(I), SC(I)
         WRITE (92,103) KIPS(I) , PC(I), MCFC(I), MUFC(I),
     2  MPC(I),MMC(I), MFUC(I), EC(I), EXC(I), TMFU(I), SC(I)
        totc(1) = totc(1) + pc(i)
        totc(2) = totc(2) + mcfc(i)
        totc(3) = totc(3) + mufc(i)
        totc(4) = totc(4) + mpc(i)
        totc(5) = totc(5) + mmc(i)
        totc(6) = totc(6) + mfuc(i)
        totc(7) = totc(7) + ec(i)
        totc(8) = totc(8) + exc(i)
        totc(9) = totc(9) + tmfu(i)
        totc(10) = totc(10) + sc(i)
c
        totr(im,3) = totr(im,3) + sc(i)
c
603    CONTINUE
604    IJ = I-1
        READ (IM,104) TPC,TMCFC,TMUFC,TMPC,TMMC,TMFUC,TEC,TEXC,TTMFU,
     1TSC
        TOTS(1) = TOTS(1) + TPC
        TOTS(2) = TOTS(2) + TMCFC
        TOTS(3) = TOTS(3) + TMUFC
        TOTS(4) = TOTS(4) + TMPC
        TOTS(5) = TOTS(5) + TMMC
        TOTS(6) = TOTS(6) + TMFUC
        TOTS(7) = TOTS(7) + TEC
        TOTS(8) = TOTS(8) + TEXC
        TOTS(9) = TOTS(9) + TTMFU
        TOTS(10) = TOTS(10) + TSC
c
        totr(im,1) = tsc
c
        ACONS = TEC*(1.E6)/(2.205*365.*TPC)
        WRITE (93,114) region(itate),ITATE,TPC,TMCFC,TMUFC,TMPC,TMMC,
     1TMFUC,TEC,TEXC,TTMFU,TSC,ACONS
C
        NR = NRT(IM)
        DO 22 J = 1,NR
        READ (IM,107)
        NM = NREG(IM,J)
C
        DO 23 K=1,NM
         READ(IM,109)LL,PCL,MCFCL,MUFCL,MPCL,MMCL,MFUCL,ECL
     3,EXCL,TMFUL,SCL
C        WRITE(94,109)NM,PCL,MCFCL,MUFCL,MPCL,MMCL,MFUCL,ECL
C      3,EXCL,TMFUL,SCL
23     CONTINUE
        READ (IM,108)
         READ (IM,109)NPQ,RPCJ,RMCFCJ,RMUFCJ,RMPCJ,RMMCJ,
     1RMFUCJ,RECJ,REXCJ,RTMFUJ, RSCJ
        L = NST(im,J)
C       WRITE  (94,998) L
        RPC(L) = RPCJ
        RMCFC(L) = RMCFCJ
        RMUFC(L) = RMUFCJ
        RMPC(L) = RMPCJ
```

```
      RMMC(L) = RMMCJ
      RMFUC(L) = RMFUCJ
      REC(L) = RECJ
      REXC(L) = REXCJ
      RTMFU(L) = RTMFUJ
      RSC(L) = RSCJ

c
      totr(im,2) = totr(im,2) + rsc(l)
c
       WRITE (94,1090) reg(l),itate,L,RPC(L),RMCFC(L),RMUFC(L),RMPC(L),
     1RMMC(L),RMFUC(L),REC(L),REXC(L),RTMFU(L), RSC(L)
22    CONTINUE
      close (im)
602   CONTINUE
      DO 6020 L = 1,429
      TOT(1) = TOT(1) + RPC(L)
      TOT(2) = TOT(2) + RMCFC(L)
      TOT(3) = TOT(3) + RMUFC(L)
      TOT(4) = TOT(4) + RMPC(L)
      TOT(5) = TOT(5) + RMMC(L)
      TOT(6) = TOT(6) + RMFUC(L)
      TOT(7) = TOT(7) + REC(L)
      TOT(8) = TOT(8) + REXC(L)
      TOT(9) = TOT(9) + RTMFU(L)
      TOT(10) = TOT(10) + RSC(L)
6020  CONTINUE
      ACONSS =TOTS(7)*(1.E6)/(2.205*365.*TOTS(1))
      WRITE (93,6023) (TOTS(K),K=1,10),ACONSS
6023  FORMAT (/1X,'TOTALS',9x,08F11.0,2f10.0,F6.1)
      WRITE (94,6024) (TOT(K),K=1,10)
6022  FORMAT (/1X,'TOTALS',1X,10F12.0)
6024  FORMAT (/4X,'TOTALS',12X,10F11.0)
      WRITE (92,6022) (TOTC(K),K=1,10)
c
      do 6100 im=1,49
      totr(im,4) = totr(im,2) - totr(im,1)
      totr(im,5) = totr(im,3) - totr(im,1)
      totr(im,6) = totr(im,3) - totr(im,2)
      write (82,6101) it(im),(totr(im,k),k=1,6)
6100  continue
6101  format (i5,6f12.0)
      do 6103 im=1,49
      do 6102 k = 1,6
      tott(k) = tott(k) + totr(im,k)
6102  continue
6103  continue
      write (82,6104) (tott(k),k=1,6)
6104  format (/5x,6f12.0)
c
C     WRITE(92,102)
C     DO 605 I = 1,3071
C     WRITE (92,103)  KIPS(I) , PC(I), MCFC(I), MUFC(I),
C    2  MPC(I),MMC(I), MFUC(I), EC(I), EXC(I), TMFU(I), SC(I)
C605  CONTINUE
402   FORMAT(//)
400   FORMAT (I4,2F10.0)
```

```
401     FORMAT (3I3,I12)
  200    FORMAT (I4,I5,F6.0,F8.0,F10.0,F8.0,F7.0,F10.1,F6.1,F8.0)
  201    FORMAT (I4,4F10.0)
  300    FORMAT (3A4,I4)
c  100    FORMAT (25X,'**MILLER METHOD - MILK DISTRIBUTION**'//10X,
c      2  'STATE',I3,30X,'YEAR',I5/)
  100    FORMAT (120x,//10X,
     2  'STATE',I3,30X,'YEAR',I5/)
  101    FORMAT (10X,'AVERAGE MILK PER COW (LBS/YR) = ',F10.0/,
     2  10X,'TOTAL DAIRY FARMS = ',F10.0,'       TEST = ',F10.0/,
     9  10x,'TOTAL DAIRY COWS = ',f10.0/,
     3  10X,'TOTAL POPULATION = ',F10.0,'        TEST = ',F10.0/,
     8  10X,'TOTAL MILK PROD (Klb)- check mpc total = ',F10.0/,
     4  10X,'FARM CONSUMPTION (Klb) = ',F10.0/,
     1  10X,'USED ON FARM (Klb) = ',F10.0/,
     5  10X,'FARM RETAIL (Klb) = ',F10.0/,
     6  10X,'MANUFACTURED (Klb) = ',F10.0/,
     7  10X,'CONSUMPTION RATE (lbs per capita per year) = ',F10.2)
  501    FORMAT (///30X,'PC = POPULATION '/,
     2  30X,'MCFC = MILK CONSUMED ON FARMS'/,
     3  30X,'MUFC = MILK USED ON FARMS (non-consumption by people)'/,
     4  30X,'MPC  = TOTAL MILK PRODUCED (calculated)'/,
     5  30X,'MMC  = MILK USED FOR MANUFACTURING'/,
     6  30X,'MFUC = MILK TO SELL(does not include farm consumption)'/,
     7  30x,'EC   = EXPECTED CONSUMPTION (calculated)'/,
     8  30X,'EXC  = TEST TO SITE MANUFACTURING PLANTS'/,
     9  30X,'TMFU = TOTAL FLUID MILK CONSUMED'/,
     1  30X,'SURP = SURPLUS'//)
932     FORMAT (///30X,'PC = POPULATION '/,
     2  30X,'MCFC = MILK CONSUMED ON FARMS'/,
     3  30X,'MUFC = MILK USED ON FARMS (non-consumption by people)'/,
     4  30X,'MPC  = TOTAL MILK PRODUCED (calculated)'/,
     5  30X,'MMC  = MILK USED FOR MANUFACTURING'/,
     6  30X,'MFUC = MILK TO SELL(does not include farm consumption)'/,
     7  30x,'EC   = EXPECTED CONSUMPTION (calculated)'/,
     8  30X,'EXC  = TEST TO SITE MANUFACTURING PLANTS'/,
     9  30X,'TMFU = TOTAL FLUID MILK CONSUMED'/,30X,'SURP = SURPLUS'/,
     1  30X,'CONS = PER CAPITA CONSUMPTION RATE (g/d)'//)
  102    FORMAT (//3X,'CNTY',6X,'PC',8X,'MCFC',8X,'MUFC',8X,'MPC',8X,
     2  'MMC',10X,'MFUC',10X,'EC',9X,'EXC',8X,'TMFU',8X,'SURP'/)
1020     FORMAT(//2x,'STATE',10X,'REGION',5X,'PC',9X,'MCFC',7X,'MUFC',7X,
     2'MPC',7X,'MMC',9X,'MFUC',9X,'EC',8X,'EXC',7X,'TMFU',7X,'SURP'/)
934     FORMAT(//2x,'STATE',15X,'PC',9X,'MCFC',7X,'MUFC',7X,'MPC',7x,
     2'MMC',9X,'MFUC',8X,'EC',7X,'EXC',6X,'TMFU',6X,'SURP',4x,'CONS'/)
  103    FORMAT (I6,10F12.0)
  104   FORMAT (/,6X,10F12.0)
  114   FORMAT (1X,a,I3,8F11.0,2F10.0,F7.2)
  105    FORMAT(25I3)
  106    FORMAT (15I4)
  195    FORMAT(2I20)
  196    FORMAT (I8,15I4)
  197    FORMAT (6I10)
  107    FORMAT (/,3X,'CNTY',6X,'PC',8X,'MCFC',8X,'MUFC',8X,'MPC',8X,
     2  'MMC',10X,'MFUC',10X,'EC',9X,'EXC',8X,'TMFU',8X,'SURP'/)
  108    FORMAT(/)
  109    FORMAT (I6,10F12.0)
 1090    FORMAT (1x,a12,i3,I6,10f11.0)
```

```
  998  FORMAT (I7)
5011    FORMAT (20X,'THE VOLUME RATES OF MILK ARE IN THOUSANDS ',
     1  'OF POUNDS PER YEAR'/)
5010  format(/,20x,'[file : [.cows]milkreg3.dat] prepared 3 mar 1989',
     1  ' with newmillerus2.for',
     2  /,20x,'MILK UTILIZATION BY REGION (MILLER METHOD): YEAR 1954'/)
933    FORMAT (20X,'THE VOLUME RATES OF MILK ARE IN THOUSANDS ',
     1  'OF POUNDS PER YEAR'/,20x,'except for CONS (grams per day)')
931    format(/,20x,'[file : [.cows]milkst3.dat] prepared 3 mar 1989',
     1  ' with newmillerus2.for',
     2  /,20x,'MILK UTILIZATION BY STATE (MILLER METHOD): YEAR 1954'/)
        STOP
        END
```

ATTACHMENT A9.11 : MILKDIST.FOR

```
         program milkdist
c
c        prepared in NOVEMBER 88
c        essentially extracted from MILKUSANNIE.FOR
c        CALCULATES VOLUMES OF MILK IN EACH CATEGORY AND EACH COUNTY
c        AS WELL AS ORIGIN (OR DESTINATION) OF MILK TRANSFERRED
C
         dimension max(400),mm(400,40),reg(400),ips(56100)
         dimension surmr(400),VTOUT(400),VTIN(400),ECX(400),RATP(400)
         dimension pc(3100),vcfc(3100),vrfc(3100),vfuc(3100),ec(3100)
         dimension surpc(3100),vlm(3100),surpr(400),surp(400,35)
        dimension surm(3100),RATN(400)
         dimension pr(400),vfur(400),vlmr(400)
         dimension LJ(40)
         dimension nrg(3100),tmfu(3100)
         dimension SMR(400)
         dimension tn(400),tp(400),v2(3100),v2r(3100)
         DIMENSION V1(400),SRM(3100)
         DIMENSION smc(3100)
         dimension vtr(400,400),vin(400),vout(400)
         dimension fips(3100),dist(3100)
         DIMENSION GFMONTH(12),NAMCTY(3100),NAMST(3100)
         character*76 t1,t3,t4,t5
         character*12 reg,namcty,REGP
         character*2 NAMST
         character*15 MONTH
         CHARACTER*8 SHOT
         integer fips,GFDATE
C
c        REGUS.DAT = definition of regions
C        MILKCTY3.DAT = production and utilization of milk in each county
c                         (output of [COWS]MILLERUS)
C        BO2.DAT = county characteristics (name, FIPS code, distance from
C                  NTS, population)
C        MILKTREG.DAT = volumes of milk transferred between regions (non-zero)
C        MILKDISTR.DAT = output: volumes of milk by region
C        MILKDISTC.DAT = output: volumes of milk by county (check that the
c                          value of RER (the last one on the right) is
c                  equal or close to 0).
C
```

```
          open (unit=5, file = 'regUS.dat', status='old')
          open (unit=7, file = 'milkcty3.dat', status='old')
          open (unit=14, file = 'b02.dat', status='OLD')
          open (unit=21, file = 'MILKtreg2.dat', status='old')
          open (unit=2, file = 'MILKDISTR.dat', status='new')
          open (unit=20, file = 'MILKDISTC.dat', status='new')
          open (unit=22, file = 'MILKPCR.dat', status='new')
c
C         CONVERSION COEFFTS FROM klb TO kg (SIF1), FROM Mlb TO kg (SIF2)
C         AND FROM days TO years (UCF)
C
          SIF1 =  1000./2.205
          SIF2 =  1.e6/2.205
          UCF  =  1./365.
C
C         READ FIPS CODES AND NAMES OF COUNTIES AND STATES
C
          DO 402 I = 1,3071
          READ (14,250) L,NAMST(I),NAMCTY(I),LIPS,DIST(I),pc(i)
          IPS(LIPS) = L
          FIPS(L) = LIPS
402       CONTINUE
C
C         DEFINITION AND ORGANIZATION OF REGIONS
C         NN = NUMBER OF REGIONS
C
          NN = 398
          do 1 n = 1,NN
          MAX(N) = 0
          ECX(N) = 0.
          VTOUT(N) = 0.
          VTIN(N) = 0.
          read (5,10) L,reg(n),Mmax
          READ (5,20) (mm(n,m),m=1,MMAX)
          MAX(N) = MMAX
          IMM = IMM + MAX(N)
          DO 1 M = 1,MMAX
          NA = MM(N,M)
          NI = IPS(NA)
          NRG(NI) = N
1         continue
C
          VLMT = 0.
          VFURT = 0.
          ECT = 0.
          SURPT = 0.
          SURMT = 0.
          V2T = 0.
          VCFT = 0.
          VRFT = 0.
          SRMT = 0.
          VTT = 0.
          SMT = 0.
          IM = 0
          nmax = 0
          ttp = 0.
          ttn = 0.
```

```
      turpr = 0.
      turmr = 0.
      tcfc = 0.
      trfc = 0.
      tlm = 0.
      t2 = 0.
      trm = 0.
      turpc = 0.
      turm = 0.
      tec = 0.
      tmc = 0.
C
C
C     MILK PRODUCTION AND DISTRIBUTION
C
C
C     REGIONAL TRANSFER IN MATRIX FORM
c     read condensed version of milk transfer between regions
c
      do 377 nd = 1,398
      do 377 mr = 1,398
      vtr(mr,nd) = 0.
377   continue
378   continue
      read (21,3770,end=379) nd,reg(nd),mr,reg(mr),vtr(mr,nd)
      go to 378
379   continue
C
      DO 3700 N = 1,398
      DO 3700 M = 1,398
      VTOUT(N) = VTOUT(N) + VTR(M,N)
      VTIN(N) = VTIN(N) - VTR(N,M)
3700  CONTINUE
      do 219 n = 1,nn
      do 219 m = 1,nn
C     CHANGE
219   vtr(n,m) = SIF1*vtr(n,m)
C     END OF CHANGE
C219  vtr(n,m) = SIF2*vtr(n,m)
C
C
C     I. ENTER DATA FROM MILLER PROGRAM
C
      IM = 3071
      do 8 i = 1,IM
    read(7,70)l,pc(i),vcfc(i),vrfc(i),r1,r2,vfuc(i),ec(i),r3,tmfu(i),
   1surpc(i)
      vlm(i) = vfuc(i)
      if(surpc(i).gt.0.) vlm(i) = ec(i)-vcfc(i)
      if (vlm(i).lt.0.) vlm(i) = 0.
8     continue
      DO 720 N=1,NN
      surpr(n) = 0.
      mmax = max(n)
      do 720 m = 1,mmax
      NA = mm(n,m)
      NI = IPS(NA)
```

```
          NRG(NI) = N
C
          ECX(N) = ECX(N) + (EC(NI)/1000.)
C
          surpr(n) = surpr(n) + surpc(ni)
720       CONTINUE
          DO 721 N = 1,NN
          SURPR(N) = SURPR(N) * SIF1
721       CONTINUE
C
          DO 3701 N = 1,398
          VTOUT(N) = VTOUT(N)/1000.
          VTIN(N) = VTIN(N)/1000.
          RATP(N) = 100.*VTOUT(N)/ECX(N)
          RATN(N) = 100.*VTIN(N)/ECX(N)
3701      CONTINUE
C
C         CONVERSION TO SI UNITS
C
          DO 722  I = 1,IM
          VCFC(I) = VCFC(I) * SIF1
          VRFC(I) = VRFC(I) * SIF1
          VFUC(I) = VFUC(I) * SIF1
          tmFU(I) = tmFU(I) * SIF1
          VLM(I) = VLM(I) * SIF1
          EC(I) = EC(I) * SIF1
          SURPC(I) = SURPC(I) * SIF1
722       CONTINUE
C
C
C         II. MILK TRANSFER BETWEEN COUNTIES OF THE SAME REGION
C
          do 3 n = 1,NN
          pr(n) = 0.
          surmr(n) = 0.
          tn(n) = 0.
          tp(n) = 0.
          SMR(N) = 0.
          mmax = max(n)
          do 2 m = 1,mmax
          nA = mm(n,m)
          NI = IPS(NA)
          surp(n,m) = surpc(ni)
          VFUR(N) = VFUR(N) + VFUC(NI)
          VLMR(N) = VLMR(N) + VLM(NI)
          pr(n) = pr(n) + pc(ni)
          v2(ni) = 0.
2         continue
3         continue
          do 4 n = 1,NN
          mmax = max(n)
          do 14 m = 1,mmax
          nA = mm(n,m)
          NI = IPS(NA)
          IF (SURPC(NI).LT.0.) TN(N) = TN(N) + SURPC(NI)
          IF (SURPC(NI).GT.0.) TP(N) = TP(N) + SURPC(NI)
          surm(ni) = surpc(ni)
```

```
14        CONTINUE
4         CONTINUE
          DO 15 N = 1,NN
          IF (TP(N).EQ.0.) GO TO 15
          IF (TN(N).EQ.0.) GO TO 15
          mmax = max(n)
          IF (SURPR(N).LT.0.) GO TO 18
          do 16 m = 1,mmax
          nA = mm(n,m)
          NI = IPS(NA)
          IF (SURPC(NI).LT.0.) GO TO 17
          SURM(NI) = SURPC(NI)*SURPR(N)/TP(N)
          GO TO 16
17        V2(NI) = -SURPC(NI)
          SURM(NI) = 0.
16        CONTINUE
          GO TO 22
18        DO 19 M = 1,MMAX
          nA = mm(n,m)
          NI = IPS(NA)
          IF (SURPC(NI).LT.0.) GO TO 21
          SURM(NI) = 0.
          GO TO 19
21        V2(NI) =  SURPC(NI)*TP(N)/TN(N)
          SURM(NI) = SURPC(NI)*SURPR(N)/TN(N)
19        CONTINUE
22        CONTINUE
15        CONTINUE
          do 5 n = 1,NN
          mmax = max(n)
          do 6 m = 1,mmax
          nA = mm(n,m)
          NI = IPS(NA)
          V2R(N) = V2R(N) + V2(NI)
          surmr(n) = surmr(n) + surm(ni)
6         CONTINUE
5         CONTINUE
C
C         III. MILK TRANSFER BETWEEN REGIONS
C
          DO 31 N = 1,NN
          V1(N) = 0.
          vout(n) = 0.
          vin(n) = 0.
31        CONTINUE
          do 214 m=1,nn
          if (surpr(m).gt.0.) go to 214
          do 215 n=1,nn
          vin(m) = vin(m) + vtr(M,N)
215       continue
          v1(m) = vin(m)
214       continue
C
C         IV. PREPARATION OF OUTPUT DATA BY COUNTY AND REGION AS WELL
C             AS FOR THE ENTIRE AREA
C
C
```

```
         DO 34 N = 1,NN
         MMAX = MAX(N)
         write (2,30) n,reg(n),mmax,tp(n),tn(n),surpr(n),SURMR(N)
         WRITE (22,3703) N,REG(N),MMAX,ECX(N),VTOUT(N),VTIN(N),
     1RATP(N),RATN(N)
         nmax = nmax + mmax
         ttp = ttp + tp(n)
         ttn = ttn + tn(n)
         turpr = turpr + surpr(n)
         turmr = turmr + surmr(n)
         DO 34 M = 1,MMAX
         nA = mm(n,m)
         NI = IPS(NA)
         IF (SURMR(N).EQ.0.) GO TO 341
         SRM(NI) = V1(N) * SURM(NI) / SURMR(N)
         GO TO 34
341      SRM(NI) = 0.
34       SMC(NI) = -EC(NI) + VCFC(NI)+VLM(NI)+V2(NI)+SRM(NI)
         DO 35 I = 1,3071
         RER = 100. * SMC(I) / EC(I)
         tcfc = tcfc + vcfc(i)
         trfc = trfc + vrfc(i)
         tlm = tlm + vlm(i)
         t2 = t2 + v2(i)
         trm = trm + srm(i)
         turpc = turpc + surpc(i)
         turm = turm + surm(i)
         tec = tec + ec(i)
         tmc = tmc + smc(i)
        write(20,120) i,fips(i),NRG(I),VCFC(I),VRFC(I),VLM(I),V2(I),
     1SRM(I),SURPC(I),SURM(I),EC(I),SMC(I),RER
35       CONTINUE
         trer = 100. * tmc / tec
         write (2,301) nmax,ttp,ttn,turpr,turmr
         write (20,121) tcfc,trfc,tlm,t2,trm,turpc,turm,tec,tmc,trer
C
3703     FORMAT (1X,I3,2X,A12,I3,5F11.3)
C
10       format (i4,1x,A12,I3)
20       format (20I6)
30       format (1x,i3,2X,a12,i3,2x,4F14.0)
70       format (i6,10F12.0)
120      FORMAT (i5,I6,i4,4F10.0,F14.0,3F12.0,F14.0,F10.3)
121      FORMAT (/,15x,4E10.3,E14.5,2F12.0,E12.5,E14.5,F10.3)
190      FORMAT (/,13X,'  CONSUMED      USED    SALES OF ','  COUNTY',
     33X,'  REGION',3X,'  CALC.',4X,'  EXPECTED   DIFF.'/13X,
     4'  ON FARM      ON FARM  LOCAL MILK',' TRANSFER ','  TRANSFER ',
     5'  TOTAL'/)
250      FORMAT (I6,1X,A2,1X,A12,I6,F10.0,f12.0)
301      format (/,6x,'TOTALS',4x,i5,2X,4F14.0)
3770     format (1x,i3,2x,a12,i3,2x,a12,f12.0)
         stop
         end
```

ATTACHMENT A9.12 : GRPDOSE1.FOR

```
          program grpdose1
c
c         revised nov 1992 from groupdose2.for
c         calculates individual doses (rads) for each of the (now) 13 age groups
c         + per capita and collective doses
c         one program per test
c
          dimension d(5,14),ud(5,14),aop(14),uaop(14),cons(9,14),dcf(14)
          dimension cop(9),ucop(9),pb(14),age(14),CM13(60),Cm14(60),MI(60)
          dimension CM9(60),Cm10(60),cm11(60),cm12(60),fmd(14),fmd2(14)
          dimension c(10),uc(10),uas(5,14),as(5,14),vx(5),vs2(5)
          dimension dm(5,14),ds2(5,14),ucons(14),ucn(14),a(5,14),ua(5,14)
          dimension apc(14),uapc(14),amk(14),uamk(14)
          character*2 namst,series
          character*12 namcty
          character*17 namser
          character*20 age
          character*8 shot
          character*80 title
          open (unit=1, file = 'newb02.dat', status = 'old')
          open (unit=2, file = 'conspop2.dat', status = 'old')
          open (unit=3, file = 'age2.dat', status = 'old')
          open (unit=4, file = 'testmilk.res', status = 'old')
          open (unit=5, file = 'testconc.res', status = 'old')
          open (unit=6, file = 'testform.dat', status = 'old')
          open (unit=11, file = 'testd2.res', status = 'new')
          open (unit=12, file = 'testd3.res', status = 'new')
          open (unit=13, file = 'testd4.res', status = 'new')
          open (unit=14, file = 'testd5.res', status = 'new')
          open (unit=15, file = 'testd6.res', status = 'new')
          open (unit=16, file = 'testd7.res', status = 'new')
          open (unit=17, file = 'testd8.res', status = 'new')
          open (unit=18, file = 'testd9.res', status = 'new')
          open (unit=19, file = 'testd10.res', status = 'new')
          open (unit=20, file = 'testd11.res', status = 'new')
          open (unit=21, file = 'testd12.res', status = 'new')
          open (unit=22, file = 'testd13.res', status = 'new')
          open (unit=23, file = 'testd14.res', status = 'new')
          open (unit=30, file = 'testpcd.res', status = 'new')
          open (unit=31, file = 'check.res', status = 'new')
c
          do 20 j=1,6
          read (2,201) title
          read (2,200) (cons(j,k),k=1,8)
          read (2,202) (cons(j,k),k=9,14)
20        continue
          read (2,201) title
          DO 27 I = 1,49
          READ (2,207) L,cm9(L),cm10(L),cm11(L),cm12(L),CM13(L),Cm14(L)
27        CONTINUE
207       FORMAT (I3,3x,f5.0,5F9.0)
          read (6,601) series,ns
          read (6,602) shot,mh,id,iy
          read (2,201) title
          read (2,203) (pb(k),k=1,8)
```

```
          read (2,204) (pb(k),k=9,14)
          read (2,201) title
          read (2,205) (dcf(k),k=1,8)
          read (2,206) (dcf(k),k=9,14)
          read (2,201) title
          read (2,203) (fmd(k),k=1,8)
          read (2,204) (fmd(k),k=9,14)
          read (2,201) title
          read (2,203) (fmd2(k),k=1,8)
          read (2,204) (fmd2(k),k=9,14)
          read (2,201) title
          read (2,203) (ucons(k),k=1,8)
          read (2,204) (ucons(k),k=9,14)
          do 51 k = 1,14
          read (3,310) age(k)
51        dcf(k) = dcf(k) * 0.001
c         uncertainties
          do 91 k = 1,14
          ucn(k) = log (ucons(k))
91        continue
c
          do 21 j = 7,8
          do 22 k = 1,4
22        cons(j,k) = 800.
          cons(j,5) = 1300.
          cons(j,6) = 1400.
          cons(j,7) = 1300.
          cons(j,8) = 1200.
          cons(j,9) = 1200.
          cons(j,10) = 1200.
          cons(j,11) = 1400.
          cons(j,12) = 1300.
          cons(j,13) = 1000.
          cons(j,14) = 800.
21        continue
          do 25 k = 1,8
25        cons(9,k) = cons(1,k)
          do 26 k = 9,14
26        cons(9,k) = 0.
c
          ucdf = log(1.8)
c
          do 71 k = 2,14
          n = k + 9
          nn = k - 1
          write (n,1437) series,ns,k,age(k),shot,mh,id,iy
71        continue
          write (30,445) series,ns,shot,mh,id,iy
c
c         read the concentrations and change the units to nCi.d/g
c
c
c         nc = 100
          nc = 3094
          read (4,831) series,ns,shot,mh,id,iy
c         write (31,831) series,ns,shot,mh,id,iy
          read (5,331) series,ns,shot,mh,id,iy
```

```
c9835     format (/////)
c9335     format (////)
          i1 = 1
          i2 = 40
          npm = 0
          cdmkt = 0.
          cdt = 0.
          do 616 ij = 1,100
          npm = npm + 1
          if (i1.ge.nc) go to 617
          if (i2.ge.nc) i2 = nc
          if (ij.ne.1) read (4,1831) series,ns
c          write (31,1831) series,ns
          if (ij.ne.1) write (30,448) series,ns
          write (30,446)
          read (4,832)
c          write (31,832)
          read (4,833)
c          write (31,833)
          if (ij.ne.1) read (5,1331) series,ns
          read (5,332)
          read (5,333)
          do 710 n = 11,23
          na = n - 9
          if (ij.ne.1) write (n,1435) series,ns,na
          if (n.gt.17) go to 72
          if (n.lt.14) go to 73
c         write (n,433)
          write (n,435)
          write (n,436)
          go to 710
72        continue
c         write (n,433)
          write (n,434)
          write (n,438)
          go to 710
73        write (n,432)
          write (n,434)
          write (n,438)
710       continue
          DO 760 I = i1,i2
          gmdmk = 0.
          gsdmk = 0.
          gmdpc = 0.
          gsdpc = 0.
          cdmk = 0.
          cd = 0.
          READ (1,829) IPS,pop
          L = IPS/1000
          cons(1,9) = cm9(L)
          cons(1,10) = cm10(L)
          cons(1,11) = cm11(L)
          cons(1,12) = cm12(L)
          cons(1,13) = cm13(L)
          cons(1,14) = cm14(L)
          read (4,830) namst,namcty,(c(k),uc(k),k=1,8)
c                write (31,830) namst,namcty,(c(k),uc(k),k=1,8)
```

```
          read (5,330) namst,namcty,(cOP(k),ucOP(k),k=1,6)
          c(6) = c(6) * 0.001
          c(7) = c(7) * 0.001
          c(8) = c(8) * 0.001
          do 52 m = 1,5
52        cop(m) = cop(m) * 0.001
c
c         calculate the intakes of I-131
c
          do 33 k = 2,14
          aop(k) = 0.
          uaop(k) = 0.
          xt = 0.
          s2t = 0.
c         if (c(1).le.0.) go to 531
          do 32 j = 2,6
          CDF = cop(j)*cons(j,k)
c         if(i.eq.1) write (31,9990) j,cdf
c9990     format (2x,'cdf',i2,e10.3)
          IF (CDF.EQ.0.) GO TO 32
          um = log (CDF)
          usig = log (ucop(j))
          usn2 = (usig * usig) + (ucn(k) * ucn(k))
          umsn2 = um + (usn2/2.)
          ux = exp(umsn2)
          us2 = ux * ux * (exp(usn2)-1.)
          xt = xt + ux
          s2t = s2t + us2
32        continue
          if (xt.le.0.) go to 33
          xt2 = xt * xt
          xx = 1. + (s2t/xt2)
          usigt = SQRT(log(xx))
          aop(k) = XT/SQRT(XX)
c         if(i.eq.1) write (31,9991) k,aop(k)
c9991     format (2x,'aop',i2,e10.3)
          uaop(k) = exp(usigt)
33        continue
531       continue
          do 34 k = 2,14
          xt = 0.
          s2t = 0.
          ux = 0.
          us2 = 0.
          do 532 kk = 1,5
          d(kk,k) = 0.
          ud(kk,k) = 0.
          dm(kk,k) = 0.
          ds2(kk,k) = 0.
          uas(kk,k) = 0.
532       continue
          if (aop(k).le.0.) go to 533
          if (uaop(k).le.0.) go to 533
          um = log(aop(k))
          usig = log(uaop(k))
          usn2 = usig * usig
          umsn2 = um + (usn2/2.)
```

```
          ux = exp(umsn2)
c         if(i.eq.1) write (31,9992) k,ux
c9992     format (2x,'ux',i2,e10.3)
          us2 = ux * ux * (exp(usn2)-1.)
533       continue
c
c         calculate the median intakes of milk (5 diets)
c
c         if (c(6).le.0.) go to 534
          as(1,k) = c(6)*cons(1,k)
          as(2,k) = c(7)*cons(7,k)
c         if (c(1).le.0.) go to 534
          as(3,k) = c(8)*cons(8,k)
          as(4,k) = 0.
          as(5,k) = cOP(1)*cons(9,k)
c         if(i.eq.1) write (31,9999) k,(as(mm,k),mm=1,5)
c9999     format (2x,'as(mm,k)',i2,5e10.3)
c        if(as(1,k).gt.0.) uas(1,k)=(log(uc(6))*log(uc(6)))+(ucn(k)*ucn(k))
        if(uc(6).gt.0.) uas(1,k)=(log(uc(6))*log(uc(6)))+(ucn(k)*ucn(k))
        if(uc(7).gt.0.) uas(2,k)=(log(uc(7))*log(uc(7)))+(ucn(k)*ucn(k))
        if(uc(8).gt.0.) uas(3,k)=(log(uc(8))*log(uc(8)))+(ucn(k)*ucn(k))
          uas(4,k) = 0.
          if(ucop(1).gt.0.) uas(5,k) = (log(ucop(1)) * log(ucop(1))) +
     1(ucn(k) * ucn(k))
c
c         calculate the mean intakes of milk (5 diets)
c
          do 535 kk = 1,5
          vx(kk) = 0.
          vs2(kk) = 0.
          if (as(kk,k).le.0.) go to 535
          vm = log(as(kk,k))
          vsn2 = uas(kk,k)
          vmsn2 = vm + (vsn2/2.)
          vx(kk) = exp(vmsn2)
c         if(i.eq.1) write (31,9993) kk,vx(kk)
c9993     format (2x,'vx(kk)',i2,e10.3)
          vs2(kk) = vx(kk) * vx(kk) * (exp(vsn2)-1.)
535       continue
c
c         median intakes of milk + foodstuffs + air (5 diets + per capita)
c
          do 536 kk = 1,5
          xt = vx(kk) + ux
          s2t = vs2(kk) + us2
          if (xt.le.0.) go to 536
          xt2 = xt * xt
          xx = 1. + (s2t/xt2)
          usigt = SQRT(log(xx))
          a(kk,k) = XT/SQRT(XX)
c         if(i.eq.1) write (31,9994) k,a(kk,k)
c9994     format (2x,'a(kk,k)',i2,e10.3)
          ua(kk,k) = exp(usigt)
536       continue
          xpc = (vx(1)*fmd(k)) + (vx(5)*fmd2(k)) + ux
          s2pc = (vs2(1)*fmd(k)*fmd(k)) + (vs2(5)*fmd2(k)*fmd2(k)) + us2
          xmk = (vx(1) * fmd(k)) + (vx(5)*fmd2(k))
```

```
          s2mk = (vs2(1)*fmd(k)*fmd(k)) + (vs2(5)*fmd2(k)*fmd2(k))
          if (xpc.le.0.) go to 534
          if (xmk.le.0.) go to 534
          xpct2 = xpc * xpc
          xxpc = 1. + (s2pc/xpct2)
          apc(k) = xpc/sqrt(xxpc)
c         if(i.eq.1) write (31,9995) k,apc(k)
c9995     format (2x,'apc(k)',i2,e10.3)
          uapc(k) = sqrt(log(xxpc))
          xmkt2 = xmk * xmk
          xxmk = 1. + (s2mk/xmkt2)
          amk(k) = xmk/sqrt(xxmk)
          uamk(k) = sqrt(log(xxmk))
534       continue
c
c         calculation of doses in rads (5 diets)
c
          do 538 kk = 1,5
          if (a(kk,k).le.0.) go to 538
          d(kk,k) = a(kk,k) * dcf(k)
          udk2 = (log(ua(kk,k)) * log(ua(kk,k))) + (udcf * udcf)
          ud(kk,k) = exp(sqrt(udk2))
          vm = log(d(kk,k))
          vsig = log(ud(kk,k))
          vsn2 = vsig * vsig
          vmsn2 = vm + (vsn2/2.)
          dm(kk,k) = exp(vmsn2)
c         if(i.eq.1) write (31,9996) k,dm(kk,k)
c9996     format (2x,'dm(kk,k)',i2,e10.3)
          ds2(kk,k) = dm(kk,k) * dm(kk,k) * (exp(vsn2) - 1.)
538       continue
539       continue
c
c         output doses for the 5 diets
c
          n = k + 9
          do 541 m = 1,5
541       if (d(m,k).le.(1.e-09)) d(m,k) = 0.
          if ((n.gt.17).or.(n.lt.14)) go to 61
          write (n,110) NAMst,NAMcty,(d(m,k),ud(m,k),m=1,5)
          go to 34
61        write (n,111) NAMst,NAMcty,(d(m,k),ud(m,k),m=1,4)
34        continue
c
c         calculation of the per capita doses
c
          xdpc = 0.
          s2dpc = 0.
          xdmk = 0.
          s2dmk = 0.
          do 790 k = 2,14
          dpc = apc(k) * dcf(k) * pb(k)
          dmk = amk(k) * dcf(k) * pb(k)
          if (dpc.le.0.) go to 790
          if (dmk.le.0.) go to 790
          dpcl = log(dpc)
          s2 = (uapc(k)*uapc(k)) + (ucdf*ucdf)
```

```
         sn2 = exp(dpcl+(0.5*s2))
         xdpc = xdpc + sn2
         s2dpc = s2dpc + (sn2 * sn2 * (exp(s2) - 1.))
         dmkl = log(dmk)
         s3 = (uamk(k)*uamk(k)) + (ucdf*ucdf)
         sn3 = exp(dmkl+(0.5*s3))
         xdmk = xdmk + sn3
         s2dmk = s2dmk + (sn3 * sn3 * (exp(s3) - 1.))
790      continue
         if (xdpc.le.0.) go to 31
         if (xdmk.le.0.) go to 31
         x2dpc = xdpc * xdpc
         xxpc = 1. + (s2dpc/x2dpc)
         gmdpc = xdpc/sqrt(xxpc)
         sidpc = sqrt(log(xxpc))
         gsdpc = exp(sidpc)
         cd = gmdpc * pop
         gsdcd = gsdpc
         x2dmk = xdmk * xdmk
         xxmk = 1. + (s2dmk/x2dmk)
         gmdmk = xdmk/sqrt(xxmk)
         sidmk = sqrt(log(xxmk))
         gsdmk = exp(sidmk)
         cdmk = gmdmk * pop
         gcdmk = gsdmk
31       continue
         cdmkt = cdmkt + cdmk
         cdt = cdt + cd
         write (30,555) namst,namcty,gmdmk,gsdmk,gmdpc,gsdpc,cdmk,cd
760      continue
         i1 = i2 + 1
         i2 = i2 + 42
         write (30,447) series,ns,npm
c        modif nov 92
c        i3 = i2 - 42
c        if (i3.ne.nc) read (4,1832) series,ns,npm
c        if (i3.ne.nc) read (5,1332) series,ns,npm
         read (4,1832) series,ns,npm
c        write (31,1832) series,ns,npm
         read (5,1332) series,ns,npm
c        end modif nov 92
         do 616 n = 11,23
         nn = n - 9
         write (n,1334) series,ns,nn,npm
616      continue
617      continue
         write (30,1143) cdmkt,cdt
1143     format (/52x,2f12.0)
442      format (3x,a2,1x,a12,2(f12.3,f7.1),1X,I12,F7.1)
445   format (1x,'TABLE SA/',A,i2,'/CD. Estimates of per capita average'
     1,' (geometric means:GM)',/,15x,'individual doses (rad) and of
     2 collective doses (man.rad),',/,15x,'and associated uncertainties
     3 (geometric standard deviations: GSD)',/,15x,'in each county of
     4 the contiguous United States resulting from',/,15x,'the test ',
     5 a,'detonated ',i2,'/',i2,'/','19',i2,'.'//1x,76('-'))
446     format (2x,'St. County',10x,'Average doses (rad) resulting from'
     1,4x,'Collective doses',/,22x,34('_'),7X,'(man.rad)',/,60x,17('_'),
```

```
     2/,20x,'milk consumption',04x,'all exposure',8x,'milk',7x,'all',/,
     343x,'routes',11x,'cons.',5x,'routes',/,
     424x,'GM',6X,'GSD',6X,'GM',6X,'GSD',9X,'GM',9X,'GM'/1x,76('-')/)
447   format(/,35X,'- ',A,i2,'/CD/',I2,' -',//,1H1)
448      format(1x,'TABLE SA/',a,i2,'/CD (continued)',/,1x,76('-'))
c
555      format (3x,a2,1x,a12,f10.3,f7.1,f10.3,f7.1,2f12.0)
830      format (3x,a,1x,a,8(1pe7.1e1,0pf5.1,2x))
831   format(1x,'TABLE ',a,'/',i2,'/M. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 (nCi d/L) a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in all categories of cows milk considered',/,18x,'for
     4each county of the contiguous United States and for the shot ',
     5A,/,18x,'detonated ',i2,'/',i2,'/','19',i2,':',/,01x,127('-'))
832      FORMAT(61x,'Originating',3x,'Originating',/,22x,'Fresh',6x,
     1'Consumed on',4x,'Retailed',5x,'from the',6x,'from another',
     24x,'Volume-',/,
     322x,'from cow',3x,'the farm',7x,'from farm',4x,'same region',3x,
     4'region',10x,'weighted',21x,'Backyard')
833      format (1x,'State County',20x,'(category 1)',2x,'(category 2)',
     12x,'(category 3)',2x,'(category 4)',4x,'average',08x,'Maximum',
     209x,'cow',/,16x,8(5x,9('-')),/,16x,8(5x,'GM    GSD'),/,
     31x,127('-'))
330      format (3x,a,1x,a,6(1pe9.2e1,0pf5.1,4x))
1334  format(/,40x,'- ',A,i2,'/D',I2,'/',i2,' -',//,1H1)
331   format(1x,'TABLE ',a,'/',i2,'/C. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in air and foodstuffs other than cows milk',/,18x,'used
     4 to calculate doses in each county',
     5' of the contiguous United States and for the shot ',A,
     6/,18x,'detonated ',i2,'/',i2,'/','19',i2,':',/,01x,122('-'))
332      FORMAT (22X,'Mothers',11x,'Goats ',
     111x,'Cottage',28x,'Leafy',13x,'Ground-level',/,22x,
     2'milk',14x,'milk',13x,'cheese',12x,'Eggs',13x,'vegetables',8x,
     3'air',/,1x,'State',1x,'County',09x,'(nCi d/L)',
     49x,'(nCi d/L)',8x,'(nCi d/kg)',8x,'(nCi d/kg)',7x,'(nCi d/kg)',
     58x,'(nCi d/m3)')
333      format (14x,6(6x,12('-')),/,14x,6(6x,'   GM    GSD'),/,
     101x,122('-'))
201      format (a80)
200      format (8f7.2)
202      format (6f7.2)
203      format (8f7.4)
204      format (6f7.4)
205      format (1x,8f5.1)
206      format (1x,6f5.1)
101      format (7x,a2,1x,a12)
310      format (a)
1435     format (1x,'TABLE SA/',A,'/',i2,'/D',i2,' (continued)',/)
1437     format (1x,'TABLE SA/',A,i2,'/D',i2,'. Estimates of average
     1(geometric means: GM) thyroid doses (rad) and associated',/,
     217x,'uncertainties (geometric standard deviations: GSD) to the' ,
     3a,' in each',/,17x,'county of the contiguous United States
     4resulting from the test ',a,'detonated ',i2,'/',i2,'/','19',i2,
     5'.',/)
432      format (50x,'Mothers diet',/,22x,70('-'))
```

```
434       format (22x,'average diet',8x,'high milk',11x,'milk from',11x,
     1'no milk',/,22x,'milk drinker',8x,'consumption',9x,'backyard cow'
     2,8x,'consumption')
435       format (22x,'average diet',8x,'high milk',11x,'milk from',11x,
     1'no milk',13x,'mothers milk',/,22x,'milk drinker',8x,'consumption'
     2,9x,'backyard cow',8x,'consumption')
436       format (22x,12('-'),8x,11('-'),9x,12('-'),08x,12('-'),08x,
     112('-'),/,
     213x,5(9x,'GM',6x,'GSD'),/)
437       format (1x,'Table SA/',A,'/',i1,'/D',i2,'. Estimates of average
     1(geometric means: GM) doses (rad) and associated uncertainties',/,
     220x,'(geometric standard deviations: GSD) to the',a,
     3'in each county of the',/,
     419x,' contiguous United States resulting from the shot ',
     5a,'detonated ',i2,'/',i2,'/','19',i2,'.',/)
438       format (22x,12('-'),8x,11('-'),9x,12('-'),08x,12('-'),/,
     113x,4(9x,'GM',6x,'GSD'),/)
439       format (1x,'Table SA/',A,'/',i2,'/D',i1,'. Estimates of average
     1(geometric means: GM) doses (rad) and associated uncertainties',/,
     220x,'(geometric standard deviations: GSD) to the',a,
     3'in each county of the',/,
     419x,' contiguous United States resulting from the shot ',
     5a,'detonated ',i2,'/',i2,'/','19',i2,'.',/)
440       format (1x,'Table SA/',A,'/',i2,'/D',i2,'. Estimates of average
     1(geometric means: GM) doses (rad) and associated uncertainties',/,
     221x,'(geometric standard deviations: GSD) to the',a,
     3'in each county of the',/,
     420x,' contiguous United States resulting from the shot ',
     5a,'detonated ',i2,'/',i2,'/','19',i2,'.',/)
400       format (a)
401       format (3x,a,1x,a,62x,3(f8.1,f4.1),f8.3,f4.1)
410       format (75x,a,10x,i2,1x,i2,3x,i2)
501       format (3x,a,1x,a,30x,4f15.1,f16.3)
601       format (8x,a,9x,i2)
602       format (6x,a,8x,3i3)
110       format (3x,a,1x,a,5(1pe10.1e1,0pf5.1,5x))
111       format (3x,a,1x,a,4(1pe10.1e1,0pf5.1,5x))
829       FORMAT (23x,i5,10x,f12.0)
835   format(1x,'TABLE ',a,'/S/M. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 (nCi d/L) a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in all categories of cows milk considered',/,18x,'for
     4each county of the contiguous United States and for the test ',
     5'test ',A,/,01x,127('-'))
1331   format(1x,'TABLE ',a,'/',i2,'/C (continued)',/,01x,122('-'))
1332   format(/,60x,'- A.',A,'/',I2,'/C.',I2,' -',//,1H1)
1831   format(1x,'TABLE ',a,'/',i2,'/M (continued)',/,1x,127('-'))
1832   format(/,60x,'- A.',A,'/',I2,'/M.',I2,' -',//,1H1)
335   format(1x,'TABLE ',a,'/S/C. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in air and foodstuffs other than cows milk',/,18x,'used
     4 to calculate doses in each county',
     5' of the contiguous United States and for the test series ',/,
     618x,A,/,01x,122('-'))
          stop
          end
```

ATTACHMENT A9.13 : PERCAP1.FOR

```
          program percap1
c
c         prepared from human5.for
c         calculates per capita doses (rads) for each county
c         one program per test
c
          dimension cons(9,14),dcf(14),pcm(60),pcd(6)
          dimension cop(9),ucop(9),pb(14),age(14),CAMK(60),CAFK(60)
          dimension c(10),uc(10),food(10)
          character*2 namst,series
          character*12 namcty
          character*10 food
          character*20 age
          character*8 shot
          character*80 title
          open (unit=1, file = 'newb02.dat', status = 'old')
          open (unit=2, file = 'dcfunc.res', status = 'old')
          open (unit=4, file = 'TESTmilk.res', status = 'old')
          open (unit=5, file = 'TESTconc.res', status = 'old')
          open (unit=6, file = 'TESTform.dat', status = 'old')
          open (unit=10, file = 'TESTpcd.res', status = 'new')
          open (unit=30, file = 'checks.res', status = 'new')
c
          read(2,810) food(1)
          do 825 mm = 1,49
          read(2,800) i,pcm(i),unc
825       continue
          do 821 i = 2,6
          if (i.ne.6) read(2,801) food(i)
          if (i.eq.6) read(2,802) food(i)
          read(2,800) mm,pcd(mm),unc
821       continue
800       FORMAT (i4,f10.6,f5.1)
810       format (1x,'** per capita dose per conc. (mrad/(nCi.d/L))',
     1' for each state for ',a,' **')
801       format (1x,'** per capita dose per unit concentration',
     1' (mrad/(nCi.d.kg) for ',a,' **')
802       format (2x,'** per capita dose per unit concentration',
     1' (rad/(nCi.d.m3) for ',a,' **')
c
          read (6,601) series,ns
          read (6,602) SHOT,MH,ID,IY
c
c
c         do 51 k = 1,14
c51       dcf(k) = dcf(k) * 0.001
c
c
          write (10,441) series,ns,shot,mh,id,iy
c
c
          nc = 3094
C         nc = 100
          read (4,831) series,ns,shot,mh,id,iy
```

```
      read (5,331) series,ns,shot,mh,id,iy
      i1 = 1
      i2 = 40
      npm = 0
      do 616 ij = 1,100
      npm = npm + 1
      if (i1.ge.nc) go to 617
      if (i2.ge.nc) i2 = nc
      if (ij.ne.1) read (4,1831) series,ns
      read (4,832)
      read (4,833)
      if (ij.ne.1) read (5,1331) series,ns
      read (5,332)
      read (5,333)
      DO 760 I = i1,i2
      READ (1,1829) IPS,pop
      l = IPS/1000
      read (4,830) namst,namcty,(c(k),uc(k),k=1,8)
      read (5,330) namst,namcty,(cOP(k),ucOP(k),k=1,6)
      if (i.eq.68) write(30,830) namst,namcty,(c(k),uc(k),k=1,8)
      if (i.eq.68) write(30,330) namst,namcty,(cOP(k),ucOP(k),k=1,6)
      c(6) = c(6) * 0.001
      c(7) = c(7) * 0.001
      c(8) = c(8) * 0.001
      do 52 m = 1,5
52    cop(m) = cop(m) * 0.001
c
c     calculate the doses in rads
c
c     do 33 k = 2,14
      dop = 0.
      udop = 0.
      xt = 0.
      s2t = 0.
      if (c(1).le.0.) go to 531
      do 32 j = 2,6
      CDF = cop(j)*pcd(j)
      IF (CDF.EQ.0.) GO TO 32
      um = log (CDF)
      usig = log (ucop(j))
      usn2 = usig * usig
      umsn2 = um + (usn2/2.)
      ux = exp(umsn2)
      us2 = ux * ux * (exp(usn2)-1.)
      xt = xt + ux
      s2t = s2t + us2
      if (i.eq.68) write(30,603) ips,l,k,j,ux,us2
603   format (4i6,2e10.3)
32    continue
      xt2 = xt * xt
      xx = 1. + (s2t/xt2)
      usigt = SQRT(log(xx))
      dop = XT/SQRT(XX)
      udop = exp(usigt)
      if (i.eq.68) write(30,604) k,j,dop,udop
604   format (2i6,2e10.3)
c33   continue
```

```
531       continue
c         do 34 k = 2,14
           xt = 0.
           s2t = 0.
           ux = 0.
           us2 = 0.
          dpcm = 0.
          dpc = 0.
          udpcm = 0.
          udpc = 0.
          if (c(1).le.0.) go to 533
           um = log(dop)
           usig = log(udop)
           usn2 = usig * usig
           umsn2 = um + (usn2/2.)
           ux = exp(umsn2)
           us2 = ux * ux * (exp(usn2)-1.)
533       continue
          dpcm = c(6) * pcm(1)
          udpcm = uc(6)
          vx = 0.
          vs2 = 0.
          if (dpcm.le.0.) go to 535
           vm = log(dpcm)
           vsig = log(udpcm)
           vsn2 = vsig * vsig
           vmsn2 = vm + (vsn2/2.)
           vx = exp(vmsn2)
           vs2 = vx * vx * (exp(vsn2)-1.)
          if (i.eq.68) write(30,605) k,kk,vx,vs2
605       format (10x,2i6,2e10.3)
535       continue
           xt = vx + ux
           s2t = vs2 + us2
          if (xt.le.0.) go to 536
           xt2 = xt * xt
           xx = 1. + (s2t/xt2)
           usigt = SQRT(log(xx))
           dpc = XT/SQRT(XX)
           udpc = exp(usigt)
536       continue
           cd = dpc * pop
           ucd = udpc
          write (10,442) ips,dpcm,udpcm,dpc,udpc,cd,ucd
534       continue
c34       continue
31        continue
760       continue
          i1 = i2 + 1
          i2 = i2 + 42
          read (4,1832) series,ns,npm
          read (5,1332) series,ns,npm
616       continue
617       continue
c
442       format (6x,i6,4x,3(f12.3,f7.3))
830       format (3x,a,1x,a,8(1pe7.1e1,0pf5.1,2x))
```

```
1832   format(/,60x,'- A.',A,'/',I2,'/M.',I2,' -',//,1H1)
1831   format(1x,'TABLE ',a,'/',i2,'/M (continued)',/,1x,127('-'))
831   format(1x,'TABLE ',a,'/',i2,'/M. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 (nCi d/L) a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in all categories of cows milk considered',/,18x,'for
     4each county of the contiguous United States and for the shot ',
     5A,/,18x,'detonated ',i2,'/',i2,'/','19',i2,':',/,01x,127('-'))
832       FORMAT(61x,'Originating',3x,'Originating',/,22x,'Fresh',6x,
     1'Consumed on',4x,'Retailed',5x,'from the',6x,'from another',
     24x,'Volume-',/,
     322x,'from cow',3x,'the farm',7x,'from farm',4x,'same region',3x,
     4'region',10x,'weighted',21x,'Backyard')
833       format (1x,'State County',20x,'(category 1)',2x,'(category 2)',
     12x,'(category 3)',2x,'(category 4)',4x,'average',08x,'Maximum',
     209x,'cow',/,16x,8(5x,9('-')),/,16x,8(5x,'GM    GSD'),/,
     31x,127('-'))
330       format (3x,a,1x,a,6(1pe9.2e1,0pf5.1,4x))
1331   format(1x,'TABLE ',a,'/',i2,'/C (continued)',/,01x,122('-'))
1332   format(/,60x,'- A.',A,'/',I2,'/C.',I2,' -',//,1H1)
1333   format(/,40x,'- SA.',A,'/',I2,'/D',I2,'/',i2,' -',//,1H1)
331   format(1x,'TABLE ',a,'/',i2,'/C. Estimates of average (geometr
     1ic means: GM) time-integrated concentrations of I-131 a
     2nd associated',/,18x,'uncertainties (geometric standard deviati
     3ons: GSD) in air and foodstuffs other than cows milk',/,18x,'used
     4 to calculate doses in each county',
     5' of the contiguous United States and for the shot ',A,
     6/,18x,'detonated ',i2,'/',i2,'/','19',i2,':',/,01x,122('-'))
332       FORMAT (22X,'Mothers',11x,'Goats ',
     111x,'Cottage',28x,'Leafy',13x,'Ground-level',/,22x,
     2'milk',14x,'milk',13x,'cheese',12x,'Eggs',13x,'vegetables',8x,
     3'air',/,1x,'State',1x,'County',09x,'(nCi d/L)',
     49x,'(nCi d/L)',8x,'(nCi d/kg)',8x,'(nCi d/kg)',7x,'(nCi d/kg)',
     58x,'(nCi d/m3)')
333       format (14x,6(6x,12('-')),/,14x,6(6x,'   GM    GSD'),/,
     101x,122('-'))
201       format (a80)
200       format (8f7.2)
202       format (6f7.2)
203       format (8f7.4)
204       format (6f7.4)
205       format (1x,8f5.1)
206       format (1x,6f5.1)
101       format (7x,a2,1x,a12)
310       format (a)
431       format (1x,'Table SA/',A,'/',i1,'/D',i1,'. Estimates of average
     1(geometric means: GM) doses (rad) and associated uncertainties',/,
     219x,'(geometric standard deviations: GSD) to the',a,
     3'in each county of the',/,
     419x,'contiguous United States resulting from the shot ',
     5a,'detonated ',i2,'/',i2,'/','19',i2,'.',/)
432       format (50x,'Mothers diet',/,22x,70('-'))
434       format (22x,'average diet',8x,'high milk',11x,'milk from',11x,
     1'no milk',/,42x,'consumption',9x,'backyard cow',8x,'consumption')
435       format (22x,'average diet',8x,'high milk',11x,'milk from',11x,
     1'no milk',13x,'mothers milk',/,42x,'consumption',9x,'backyard ',
     2' cow',8x,'consumption')
```

```
436      format (22x,12('-'),8x,11('-'),9x,12('-'),08x,12('-'),08x,
     112('-'),/,
     213x,5(9x,'GM',6x,'GSD'),/)
437      format (1x,'Table SA/',A,'/',i1,'/D',i2,'. Estimates of average
     1(geometric means: GM) doses (rad) and associated uncertainties',/,
     220x,'(geometric standard deviations: GSD) to the',a,
     3'in each county of the',/,
     419x,' contiguous United States resulting from the shot ',
     5a,'detonated ',i2,'/',i2,'/','19',i2,'.',/)
438      format (22x,12('-'),8x,11('-'),9x,12('-'),08x,12('-'),/,
     113x,4(9x,'GM',6x,'GSD'),/)
439      format (1x,'Table SA/',A,'/',i2,'/D',i1,'. Estimates of average
     1(geometric means: GM) doses (rad) and associated uncertainties',/,
     220x,'(geometric standard deviations: GSD) to the',a,
     3'in each county of the',/,
     419x,' contiguous United States resulting from the shot ',
     5a,'detonated ',i2,'/',i2,'/','19',i2,'.',/)
441   format (1x,'Table SA/',A,'/',i2,'. Estimates of per capita average
     1 (geometric means:GM) doses (rad) and associated uncertainties',/,
     221x,'(geometric standard deviations: GSD) in each county of the',
     3/,20x,' contiguous United States resulting from the shot ',
     4a,'detonated ',i2,'/',i2,'/','19',i2,'.',//,8x,'fips',8x,'milk',
     52x,'unc',9x,'all',5x,'unc',5x,'man.rads'/)
400      format (a)
401      format (3x,a,1x,a,62x,3(f8.1,f4.1),f8.3,f4.1)
410      format (75x,a,10x,i2,1x,i2,3x,i2)
501      format (3x,a,1x,a,30x,4f15.1,f16.3)
601      format (8x,a,9x,i2)
602      format (6x,a,8x,3i3)
110      format (3x,a,1x,a,5(1pe10.1e1,0pf5.1,5x))
111      format (3x,a,1x,a,4(1pe10.1e1,0pf5.1,5x))
1829     FORMAT (23x,i5,12x,f10.0)
         stop
         end
```