

IODINE-129 IN THE SNAKE RIVER PLAIN AQUIFER
AT THE IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO

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CONVERSION FACTORS

For readers who prefer to use International System (SI) units rather than units used in this report, the following conversion factors may be used:

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi ²)	2.590	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
curie (Ci)	3.70×10^{10}	becquerel
millicurie per gram (mCi/g)	3.70×10^7	becquerel per gram
picocurie per liter (pCi/L)	0.037	becquerel per liter
millirem	0.01	millisievert

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ABSTRACT

From 1953 to 1983, an estimated 0.01 to 0.136 Ci (curies) per year of iodine-129 were contained in wastewater generated by the ICPP (Idaho Chemical Processing Plant) at the Idaho National Engineering Laboratory. The wastewater was directly discharged to the Snake River Plain aquifer through a deep disposal well until February 9, 1984, when use of the well was discontinued and the well was replaced by an unlined infiltration pond; a second pond was put into use on October 17, 1985. For 1984-86, the annual amount of iodine-129 in wastewater discharged to the ponds ranged from 0.0064 to 0.039 Ci.

In August 1986, iodine-129 concentrations in water from 35 wells near the ICPP ranged from less than the reporting level to $3.6^{+0.4}$ pCi/L (picocuries per liter). By comparison, in April 1977, the water from 20 wells contained a maximum of 27^{+1} pCi/L of iodine-129; in 1981, the maximum concentration in water from 32 wells was 41^{+2} pCi/L. The average concentration of iodine-129 in water from 18 wells that were sampled in 1977, 1981, and 1986 was 4.0, 6.7 and 1.3 pCi/L, respectively. The marked decrease in the iodine-129 concentrations from 1981 to 1986 was the result of three factors: (1) The amount of iodine-129 disposed annually; (2) a change from the routine use of the disposal well to the infiltration ponds; and (3) dilution of the iodine-129 in the aquifer by an increase in recharge from the Big Lost River.

INTRODUCTION

The ICPP (Idaho Chemical Processing Plant) at the Department of Energy's INEL (Idaho National Engineering Laboratory) recovers uranium from spent fuel elements. From 1953 to 1983, an estimated 0.01 to 0.136 Ci/year of iodine-129 were contained in wastewater directly discharged to the Snake River Plain aquifer through a 580-ft deep injection well at the ICPP. Disposal to the aquifer makes iodine-129 a permanent environmental contaminant owing to its half-life of 15.7 million years. Since 1976 when wastewater monitoring for iodine-129 began, three ground-water sampling and analysis programs have been conducted to define the distribution and concentration of the radionuclide in ground water contained in the Snake River Plain aquifer. The programs were conducted by the U.S. Geological Survey in cooperation with the U.S. Department of Energy's Idaho Operations Office. This report describes the distribution and concentration of iodine-129 in ground water in August 1986 and the changes that have taken place since the April 1977 and September to October 1981 sampling programs.

Physical Setting

The ICPP is in the south-central part of the 890-mi² INEL in southeastern Idaho (fig. 1). The INEL was established in 1949 to build, test, and operate different types of nuclear reactors. Of the 52 reactors constructed, 13 are still operable. The INEL also is a leading center for nuclear safety research, defense programs, nuclear waste technology, and development of advanced energy concepts.

The INEL is on the eastern part of the Snake River Plain. Basaltic-lava flows intercalated with sedimentary deposits underlie the plain and make up the Snake River Plain aquifer, the major aquifer in Idaho. The aquifer provides the INEL's entire water supply and is a major source of irrigation, municipal, and industrial supplies on other parts of the plain. The depth to water in the aquifer ranges from about 200 ft in the northern part of the INEL to more than 900 ft in the southern part. At the ICPP the depth to water is about 450 ft below land surface.

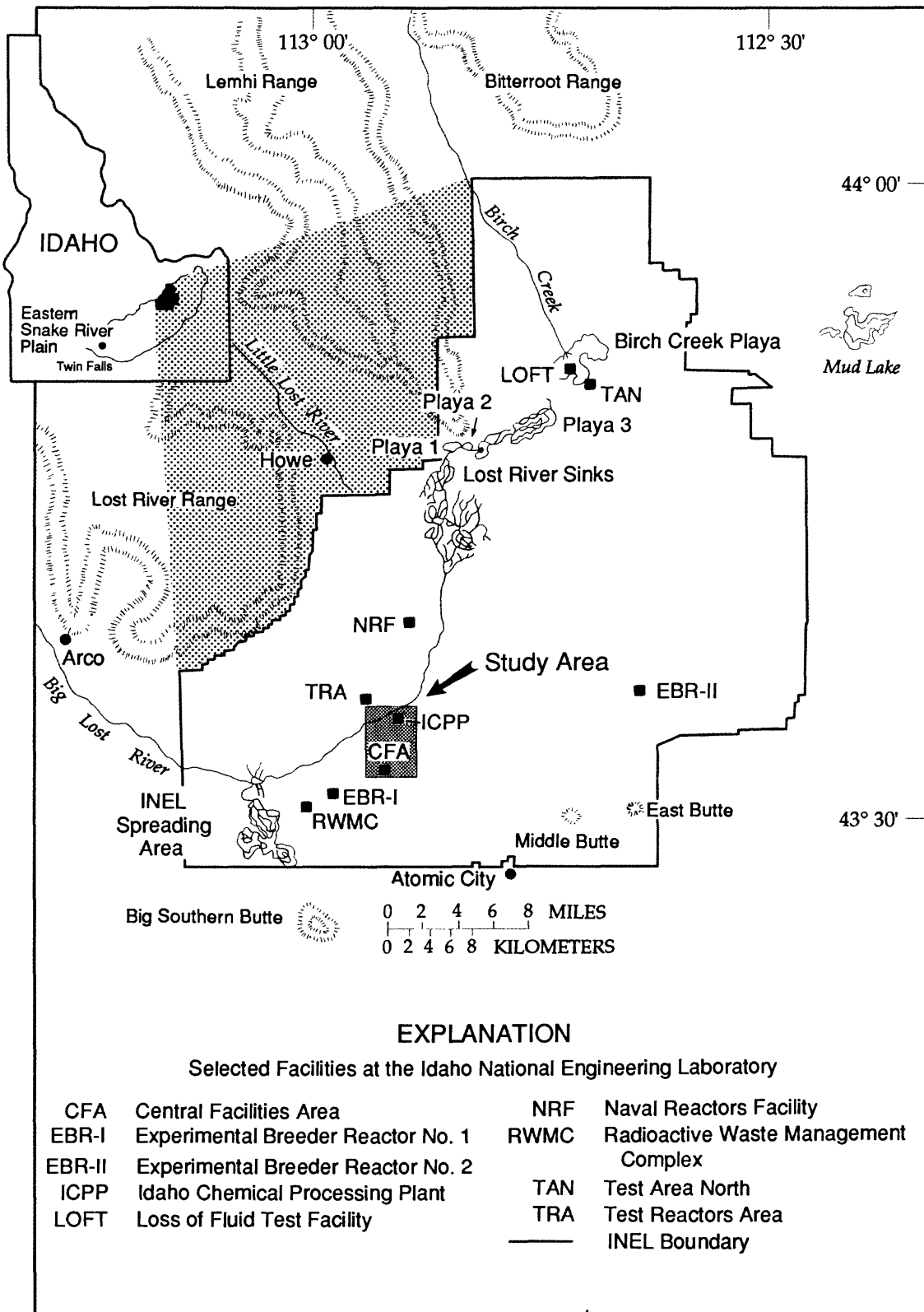


Figure 1.--Location of the Idaho National Engineering Laboratory and selected facilities.

The general direction of ground-water movement at the INEL is to the southwest. Ground-water underflow in the aquifer at the INEL is maintained primarily by recharge in the northeastern part of the plain and from tributary drainages west and north of the INEL. From the recharge areas, the water moves through the INEL and eventually is discharged to springs along the Snake River near Twin Falls (Lewis and Jensen, 1985). Robertson and others (1974, p. 13) estimated the velocity of ground-water movement to be from 5 to 20 ft/day in the southern part of the INEL.

Streams at the INEL flow only in response to rainfall and snowmelt. The Big Lost River is the main drainage at the INEL and is in a topographically closed basin. Flow in the river is regulated by Mackay Dam--about 40 mi upstream from Arco--and the INEL Diversion which is in the southwestern part of the INEL. Water that is not diverted into the INEL Spreading Area (fig. 1) flows to the northeast toward the ICPP and into a series of playas referred to as the Lost River Sinks. A large part of the water that flows onto the INEL infiltrates the permeable sedimentary deposits and basaltic rocks that underlie the river and the sinks recharging the Snake River Plain aquifer.

Previous Investigations

Many investigators have described the geology and hydrology of the Snake River Plain aquifer at the INEL. Robertson and others (1974) described the regional geology and hydrology and the influence of liquid waste disposal on the geochemistry of water for 1952-70. Barraclough and Jensen (1976) reported on conditions from 1971 to 1973. Barraclough and others (1982) provided an update for 1974-78 and Lewis and Jensen (1985) for 1979-81. The latter two reports describe the distribution of iodine-129 in the aquifer near the ICPP for April 1977 and September to October 1981, respectively.

Field Methods

Water samples from the Snake River Plain aquifer were collected at selected wells near and downgradient from the ICPP and were analyzed for iodine-129. Two methods were used to obtain water from the wells: (1) If a well was equipped with a dedicated pump, it was pumped and the samples were collected at the end of the discharge pipe or at a spigot in the discharge pipe; or (2) for ground-water monitoring wells not equipped with dedicated pumps, a remotely operated thief sampler was used to obtain a water sample.

For the 1986 sampling program, wells equipped with dedicated submersible or turbine pumps were pumped until the temperature, pH and specific conductance of the water stabilized using methods described by Wood (1981) and Claassen (1982). When these physical properties of the water stabilized, suggesting probable hydraulic and chemical stability, a water sample was collected provided that an ample volume of water had been pumped from the well. A volume of water equivalent to a minimum of three well-bore volumes was pumped from each well; at most wells, 5 to 10 well-bore volumes were pumped prior to the collection of a sample. The diameter of the well bore was used to calculate the minimum volume rather than the casing diameter because of the potentially large difference between the two.

For wells without dedicated pumps, a thief sampler was lowered inside the well casing to a predetermined level. The thief sampler is constructed in such a manner that water passes through the sampler while it is being lowered to the sampling level. Once at the sampling level, the ends of the sampler are remotely closed, thereby trapping about 1 liter of water. Multiple samples were collected from each well to provide the 4 liters of water needed for laboratory analysis.

On the basis of drillers', geophysical and fluid-conductivity logs, fracture zones in the basaltic rocks opposite perforations in the casing or in uncased intervals have been identified through which water likely moves at a high velocity when compared to the velocity in unfractured zones. Each well was sampled at its predetermined level to obtain a sample that represented water moving through the aquifer rather than water that may have

stagnated in the well bore and casing opposite unfractured zones. The thief sampler was cleaned and rinsed with a pressurized spray of deionized water prior to and after use at each well.

In 1977 and 1981, comparable sample-collection procedures were used, although there were fewer monitoring wells and fewer wells equipped with dedicated pumps. Water obtained from the wells was placed in prerinsed 4-liter polyethylene bottles and hand carried to the Department of Energy's Radiological and Environmental Sciences Laboratory for analysis.

Analytical Methods

In the laboratory, the 4-liter water sample was injected with a stable iodine carrier and an iodine-125 tracer. Hydrochloric acid was used to decrease the pH of the sample to 2, and the acidified sample was filtered through a 0.45-micron pore-size filter. Isotopic exchange between the water, carrier, tracer, and iodine-129 was achieved by oxidizing and then reducing the iodine. The iodine produced during the reducing step was separated from the water by sorption onto a column of anion-exchange resin. Oxidation of the iodine followed by water washes removed the iodide from the resin column. The iodide in the solution was oxidized to elemental iodine, which then was extracted into carbon tetrachloride. After the carbon tetrachloride was washed, the iodine was removed by reduction to iodide. The reducing solution containing the iodide was passed through a small column of anion exchange resin; the iodide was retained in the resin column. The column was washed with deionized water, and gross gamma counted to determine the chemical recovery of iodine.

Resin columns were sealed in small polyethylene capsules for subsequent neutron activation analysis. The capsules and encapsulated neutron-flux monitors containing iodine-129 standards were irradiated by neutrons for 1 hour. The flux monitors were used to accurately determine the neutron flux as seen by the resin containing the sample. After an appropriate period, the samples and flux monitors were analyzed for iodine-130 by gamma

spectroscopy; iodine-130 is the neutron-activation product of iodine-129. Concentrations of iodine-129 were determined from iodine-130 measurements.

Reporting of Data

Concentrations of iodine-129 are reported with an estimated standard deviation, s , that is obtained by propagating sources of analytical uncertainty in measurements. The following guidelines for interpreting analytical results are based on an extension of the method described by Currie (1968).

In the analysis for iodine-129, laboratory measurements are made on a target sample and a prepared blank. Instrument signals for the sample and the blank vary randomly. Therefore, it is essential to distinguish between two key aspects of the problem of detection: (1) The instrument signal for the sample must be greater than the signal observed for the blank to make the decision that iodine-129 was detected; and (2) an estimation must be made of the minimum iodine-129 concentration that will yield a sufficiently large observed signal to make the correct decision for detection or nondetection of iodine-129 most of the time. The first aspect of the problem is a qualitative decision based on an observed signal and a definite criterion for detection. The second aspect of the problem is an intuitive estimation of the detection capabilities of a given measurement process.

In the laboratory, instrument signals must exceed a critical level to make the qualitative decision whether iodine-129 was detected. Iodine-129 concentrations that equal $1.6s$ meet this criterion; at $1.6s$, there is a 95 percent probability that the correct decision--not detected--will be made. Given a large number of samples, up to 5 percent of the samples with measured concentrations greater than or equal to $1.6s$, which were concluded as being detected, might not contain iodine-129. These measurements are referred to as false positives and are errors of the first kind in hypothesis testing.

Once the critical level of $1.6s$ has been defined, the minimum detectable concentration may be established. Iodine-129 concentrations that equal $3s$ represent a measurement at the minimum detectable concentration. For true concentrations of $3s$ or greater, there is a 95 percent or more probability of concluding that iodine-129 was detected in a sample. Given a large number of samples, up to 5 percent of the samples with measured concentrations greater than or equal to $3s$, which were concluded as being non-detected, could contain iodine-129 at the minimum detectable concentration. These measurements are referred to as false negatives and are errors of the second kind in hypothesis testing.

True iodine-129 concentrations between $1.6s$ and $3s$ have larger errors of the second kind. That is, there is a greater than 5 percent probability of false negative results for samples with true concentrations between $1.6s$ and $3s$ and, although iodine-129 might have been detected, such detection may not be considered reliable; at $1.6s$, the probability of a false negative is about 50 percent.

These guidelines are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The use of the critical level and minimum detectable concentration aid in the interpretation of analytical results and do not represent absolute levels of radioactivity which may or may not have been detected.

In this report, if the iodine-129 concentration was less than $3s$ and less than 0.25 pCi/L, the concentration is considered to be below a "reporting level"; the reporting level was established to provide a means of comparing the areal distribution of iodine-129 for the 1977, 1981, and 1986 sampling programs.

OCCURRENCE AND CHARACTERISTICS OF IODINE-129

Iodine-129 is a naturally occurring radioisotope with a half-life of 15.7 million years. It is produced in nature by reaction of cosmic radiation with xenon in the upper atmosphere, by neutron capture reactions

with tellurium, and by the fission of actinides (Markham and others, 1983). The naturally occurring iodine-129 in the environment has been estimated to be about 40 Ci (National Council on Radiation Protection and Measurements, 1983).

Iodine-129 is also produced by the fission of uranium-235 and plutonium-239. Comparatively large amounts have been produced during the atmospheric testing of nuclear weapons and in the production of electricity by nuclear power. The largest source is from spent nuclear fuels, but it only has the potential for release to the environment if the irradiated fuel is reprocessed. The approximate releases of iodine-129 from atmospheric and high-altitude nuclear weapons tests to 1975 totalled about 10 Ci; the estimated inventory in spent fuel through 1982 is about 180 Ci from commercial reactors in the United States (National Council on Radiation Protection and Measurements, 1983), although only a small part of this iodine-129 has been released by reprocessing. Because of its long half-life, iodine-129 released to the environment is essentially a permanent addition to the total inventory of global iodine.

Iodine-129 has been and is being released from some of the Department of Energy facilities including those in Idaho, South Carolina and Washington, and from facilities that reprocess nuclear fuel in other countries. The ICPP reprocesses spent nuclear fuel used in government reactors. Since the ICPP began operations in 1953, it is estimated that about 4.4 Ci of iodine-129 have been released to the atmosphere (Energy Research and Development Administration, 1977; White, 1977 and 1978; and EG&G Idaho, Inc., 1979-87). From 0.56 to 1.18 Ci of iodine-129 have been disposed of in water injected to a disposal well or to waste disposal ponds at the ICPP (O.L. Cordes, Allied Chemical Corp., written commun. 1978; White, 1978; and EG&G Idaho, Inc., 1979-87). Iodine-129 in wastewater at the ICPP accounts for nearly all of the radionuclide released in wastewater at the INEL. For example, from 1977 to 1986, 2.1×10^{-8} Ci of iodine-129 were in wastewater at the Test Reactors Area (see figure 1 for location of the Test Reactors Area); in contrast, 4.02×10^{-1} Ci were in wastewater released at the ICPP (White, 1978, and EG&G Idaho, Inc., 1979-87). Because iodine-129 emits low-energy beta particles with a maximum energy of 150

kiloelectron volts and associated gamma and X-rays below 40 kiloelectron volts in energy, accurate detection and measurement are both difficult and tedious. It is detected most readily in animal and human thyroid glands, because these organs exhibit the highest concentrations of iodine-129 (National Council on Radiation Protection and Measurements, 1983).

Iodine-129 above background levels has been detected near the ICPP in the thyroids of ungulates (Markham and others, 1983) and rabbits (Fraley and others, 1982); the elevated concentrations are attributed to atmospheric releases of iodine-129 from the ICPP. However, the amount of iodine-129 that can be accumulated in the thyroid is limited by the low specific activity of 0.17 mCi/g (National Council on Radiation Protection and Measurements, 1983). Radioiodine uptake and retention by the thyroid gland are altered by a number of factors, including age, amounts of dietary iodine-127 and physiologic state. For the dose to the thyroid to exceed the standards for the protection of the public, the ratio of iodine-129 to iodine-127 in the thyroid must be relatively high--on the order of 0.01 to 0.1. Measured concentration ratios in animal thyroids near fuel reprocessing facilities in the United States have been at least an order of magnitude lower.

Concentration of Iodine-129 in Ground Water

In August 1986, water samples were collected from 35 wells at and near the ICPP to define the concentrations of iodine-129 in ground water obtained from the Snake River Plain aquifer (fig. 2). The samples were collected 2 years and 6 months after the discontinuance of injecting aqueous waste to the aquifer using a 580-ft deep disposal well at the ICPP. On February 9, 1984, the technique for the routine disposal of aqueous waste changed from the ICPP disposal well to an unlined infiltration pond; a second pond was put into use on October 17, 1985.

In April 1977, 13 of 20 samples contained a maximum of 27^{+1} pCi/L of iodine-129. The average concentration in 18 samples was 4.0 pCi/L (table 1); average concentrations were calculated using only those wells at which

iodine-129 samples were collected in 1977, 1981, and 1986. Between 1977 and 1981, the concentrations of iodine-129 in ground water increased markedly. In 1981, iodine-129 was detected in 24 of 32 samples and the maximum concentration was 41^{+2} pCi/L; the average concentration was 6.7 pCi/L (table 1). Six samples from wells not influenced by the ICPP disposal well contained concentrations of iodine-129 that were below the reporting level and are not included on table 1. What constitutes a detectable concentration may vary at a specific well between sampling periods because of differences in analytical uncertainties from analysis to analysis; part of the analyses were more sensitive in 1981 than in 1977. Between 1981 and 1986, the concentrations of iodine-129 in ground water decreased markedly. In August 1986, iodine-129 concentrations ranged from less than the reporting level to $3.6^{+0.4}$ pCi/L. Of the 35 samples collected and analyzed, 20 contained detectable concentrations of iodine-129; the concentration averaged 1.3 pCi/L in water from 18 wells (table 1).

Three factors are mainly responsible for the increase in iodine-129 concentrations in the ground water between 1977 and 1981 and the decrease in concentrations between 1981 and 1986: (1) The amount of iodine-129 disposed annually; (2) a change in disposal techniques from the disposal well to infiltration ponds; and (3) dilution by the infiltration of streamflow. From 1953 to 1977, an estimated 0.16 to 0.78 Ci of iodine-129 were discharged to the ICPP disposal well (O.L. Cordes, Allied Chemical Corp., written commun., 1978). Monitoring for iodine-129 in wastewater generated at the ICPP began in May 1976 and the 1953-77 estimates are based on information collected in 1976 and 1977; the estimated annual amount for 1953-77 was from 0.01 to 0.03 Ci. For 1979-83, the amount of iodine-129 discharged to the disposal well (table 2) generally was of a comparable order of magnitude as that estimated for 1953-77. In 1978, however, 0.136 Ci of iodine-129 were discharged to the disposal well. The 0.136 Ci were at least 4 and, perhaps, 14 times greater than for 1953-77. Additionally, 1979-81 and 1983 discharges were greater than the 1953-77 estimated disposal, although not as markedly different.

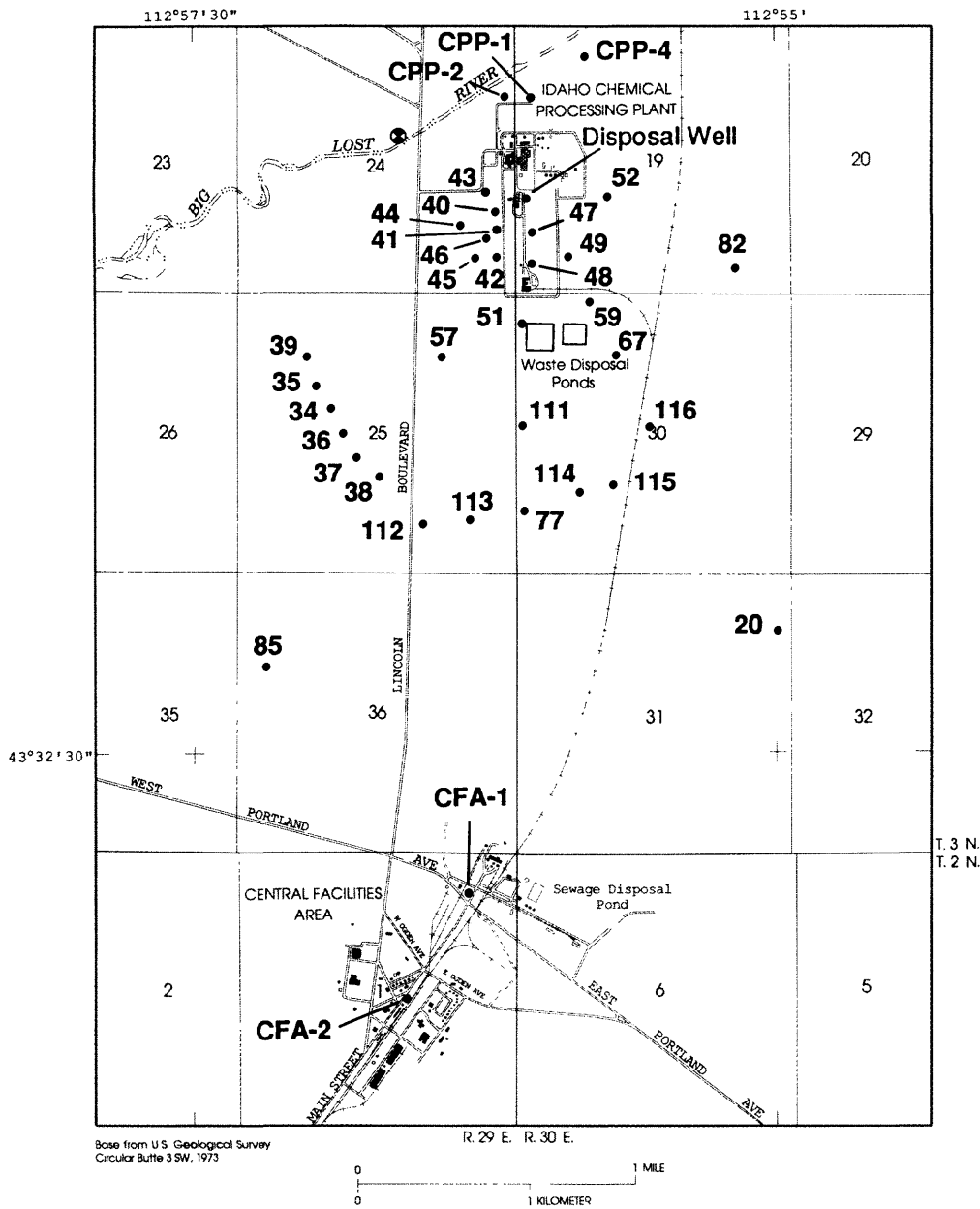
Table 1.--Iodine-129 concentrations in water from selected wells near the ICPP

[Analytical results in picocuries per liter. Refer to figure 2 for location of wells. (RL)--indicates the iodine-129 concentration was less than the reporting level of 0.25 picocuries per liter. (T)--Indicates a thief sampler was used to obtain water sample; other wells were equipped with dedicated pumps. Average concentration calculated using only those wells at which iodine-129 samples were collected in 1977, 1981 and 1986]

Well identifier	April 1977	September to October 1981	August 1986
20	0.8 [±] 0.8 (RL; T)	0.05 [±] 0.05 (RL; T)	0.1 [±] 0.3 (RL; T)
34	--	0.4 [±] 0.1 (T)	0.73 [±] 0.15 (T)
35	0.9 [±] 0.9 (RL; T)	--	1.0 [±] 0.2 (T)
36	--	7.1 [±] 0.7 (T)	2.0 [±] 0.2 (T)
37	2.5 [±] 0.1 (T)	5.1 [±] 0.3 (T)	2.9 [±] 0.3 (T)
38	--	6.2 [±] 0.6 (T)	0.1 [±] 0.1 (RL; T)
39	--	--	0.00 [±] 0.13 (RL; T)
40	27 [±] 1 (T)	0.1 [±] 0.1 (RL; T)	1.4 [±] 0.2
41	--	4.1 [±] 0.2 (T)	0.4 [±] 0.2 (RL; T)
42	1.3 [±] 0.1 (T)	25.1 [±] 0.3 (T)	0.2 [±] 0.2 (RL; T)
43	9.0 [±] 0.5 (T)	7.3 [±] 0.3 (T)	0.17 [±] 0.16 (RL)
44	--	39 [±] 1 (T)	0.4 [±] 0.3 (RL; T)
45	1.0 [±] 1.0 (RL; T)	20 [±] 1 (T)	1.1 [±] 0.2 (T)
46	--	41 [±] 2 (T)	2.3 [±] 0.3 (T)
47	3.7 [±] 0.2	16.3 [±] 0.8 (T)	1.5 [±] 0.2
48	--	3.9 [±] 0.4 (T)	0.5 [±] 0.2 (RL; T)
49	6.1 [±] 0.3 (T)	--	--
51	0.9 [±] 0.4 (RL; T)	0.5 [±] 0.1 (T)	0.57 [±] 0.14 (T)
52	2.8 [±] 0.2 (T)	14.6 [±] 0.7 (T)	0.9 [±] 0.2 (T)
57	6.8 [±] 0.3 (T)	15.3 [±] 0.8 (T)	3.6 [±] 0.4 (T)
59	1.16 [±] 0.06 (T)	2.3 [±] 0.3 (T)	0.3 [±] 0.2 (RL; T)
67	8.2 [±] 0.4 (T)	7.9 [±] 0.4	2.4 [±] 0.3
77	2.2 [±] 0.2 (T)	1.6 [±] 0.1 (T)	2.9 [±] 0.3 (T)
82	0.91 [±] 0.05 (T)	1.5 [±] 0.2 (T)	1.6 [±] 0.3 (T)
85	1.4 [±] 0.6 (T)	1.9 [±] 0.1 (T)	3.3 [±] 0.3 (T)
111	--	--	2.8 [±] 0.3

Table 1.--Iodine-129 concentrations in water from selected wells near the ICPP--Continued

Well identifier	April 1977	September to October 1981	August 1986
112	--	--	3.3 [±] 0.3
113	--	--	2.9 [±] 0.3
114	--	--	0.3 [±] 0.2 (RL)
115	--	--	0.25 [±] 0.16 (RL)
116	--	--	0.65 [±] 0.16
CFA 1	0.7 [±] 0.7 (RL)	0.25 [±] 0.02	0.49 [±] 0.12
CFA 2	0.7 [±] 0.7 (RL)	0.10 [±] 0.02	-0.15 [±] 0.13 (RL)
CPP 1	--	5.8 [±] 0.6	0.5 [±] 0.3 (RL)
CPP 2	0.8 [±] 0.8 (RL)	1.24 [±] 0.06	0.1 [±] 0.2 (RL)
CPP 4	--	--	0.0 [±] 0.2 (RL)
Average concentration	4.0	6.7	1.3



EXPLANATION

- 57** WELL FROM WHICH A WATER SAMPLE FOR IODINE-129 WAS COLLECTED IN 1977, 1981 OR 1986--Number, 57, is the local well identifier
-
- ⊕ GAGING STATION

Figure 2.--Location of wells sampled for iodine-129.

Table 2.--Annual amounts of iodine-129 and volume of water discharged to the ICPP disposal well and ponds [From White, 1977 and 1978, and EG&G Idaho, Inc., 1979-87]

Year	Disposal Well		Ponds	
	Curies of iodine-129	Volume of wastewater (liters)	Curies of iodine-129	Volume of wastewater (liters)
1976	0.009*	1.345x10 ⁹	--	--
1977	.019	1.583x10 ⁹	--	--
1978	.136	1.620x10 ⁹	--	--
1979	.038	1.465x10 ⁹	--	--
1980	.032	1.513x10 ⁹	--	--
1981	.047	2.016x10 ⁹	--	--
1982	.012	2.009x10 ⁹	--	--
1983	.042	2.058x10 ⁹	--	--
1984	.0086	2.958x10 ⁸	0.0064	1.796x10 ⁹
1985	1.06x10 ⁻⁸	5.145x10 ⁵	.022	2.020x10 ⁹
1986	0	3.220x10 ³	.039	2.183x10 ⁹

*May to December 1976

In 1977, the concentration of iodine-129 in the wastewater injected to the ICPP disposal well was about 12 pCi/L. From 1970 to 1976, the estimated annual concentration of iodine-129 in wastewater injected to the ICPP disposal well was from 7 to 29 pCi/L; this estimate is based on 0.01 to 0.03 Ci/year of iodine-129 in 1.05×10^9 to 1.46×10^9 L/year of wastewater (for annual volumes of wastewater, see Lewis and Jensen, 1985). In 1978, the concentration was about 84 pCi/L; from 1979 to 1983, the annual concentration ranged from 6 to 26 pCi/L. The 1970-76 annual concentrations of iodine-129 in wastewater, therefore, were similar to those for 1979-83. However, the concentration in 1978 was 3 to 14 times greater than the annual concentrations for 1970-77 and 1979-83. The 3- to 14-times greater concentration in the wastewater for 1978 supports the premise that the 0.136 Ci of iodine-129 were a controlling factor for the increase in the concentrations of iodine-129 in ground water between 1977 and 1981.

The increase in iodine-129 concentrations in ground water obtained from the Snake River Plain aquifer between 1977 and 1981 is attributed to the marked increase in the disposal rate for 1978 and, to a lesser degree, the disposal rate for 1979-81. The decrease in iodine-129 in ground water between 1981 and 1986, however, is largely the result of the change in disposal techniques. Beginning in February 1984, wastewater containing iodine-129 was discharged to unlined infiltration ponds about 2,000 ft south of the disposal well, although the well was still used as an emergency backup for the ponds. The ponds are about 450 ft above the water table for the Snake River Plain aquifer. For 1984-86, the annual amount of iodine-129 in wastewater discharged to the ponds ranged from 0.0064 to 0.039 Ci (table 2). Water infiltrates the bottom of the pond and percolates downward to the aquifer through a sequence of basaltic lava flows and intercalated sedimentary deposits. Because of the large volume of wastewater discharged to the ponds, one and perhaps more perched-water zones have developed in the unsaturated zone overlying the aquifer. Cores indicate that the sedimentary deposits are largely sand, silt, and clay with lesser amounts of gravel. All or part of the iodine-129 may be sorbed to the silt and clay particles and therefore removed from solution before reaching the aquifer. The iodine-129 that may infiltrate to the aquifer and the iodine-129 that was

injected into the aquifer may also be adsorbing to fine-grained material in sedimentary deposits in the upper part of the aquifer.

Recharge from the infiltration of streamflow in the Big Lost River would further decrease the concentrations of iodine-129 in the aquifer. The annual discharge of the Big Lost River at Lincoln Boulevard for 1975 to 1986 ranged from zero to about 100,100 acre-ft (fig. 3). In 1975-76, the annual flow of the Big Lost River at Lincoln Boulevard was 72,000 and 6,700 acre-ft, respectively. From 1977 to 1979, there was no flow in the river and from 1980 to 1986, the flow ranged from about 1,100 to 100,100 acre-ft/year.

The amount of recharge to the aquifer in the 2-mi reach of the Big Lost River immediately downstream from Lincoln Boulevard can be estimated using the number of days during which flow occurred and the infiltration rate of water from the channel; recharge from this reach would enter the aquifer directly upgradient from the ICPP. From 1977 to 1981, flow occurred at Lincoln Boulevard on 57 days, mainly in 1981. In contrast, flow occurred on 1,380 days from 1982 through 1986 (fig. 3).

Near the ICPP, the rate of infiltration from the river channel is from 1.1 to 3.8 (acre-ft/day)/mi depending on the amount of flow in the channel; these infiltration rates are based on two seepage runs made in May and November 1985. If the average rate of infiltration is assumed to be about 2.5 (acre-ft/day)/mi, an estimated 3,450 acre-ft/mi of water infiltrated the channel from 1982 to 1986. Therefore, nearly 7,000 acre-ft of water were recharged to the aquifer in the 2-mi reach immediately north of the ICPP (fig. 1); in contrast, the recharge for 1977-81 was about 300 acre-ft. For purposes of comparison, the total volume of wastewater discharged to the ICPP disposal well and ponds from 1982 to 1986 was about 8,400 acre-ft (or 1.036×10^{10} L).

The paucity of recharge because of the relatively dry conditions of the Big Lost River from 1977 to 1981, in part, accounts for the increase in the iodine-129 concentrations in the Snake River Plain aquifer from 1977 to 1981. Conversely, the relatively large flows in the river from 1982 to

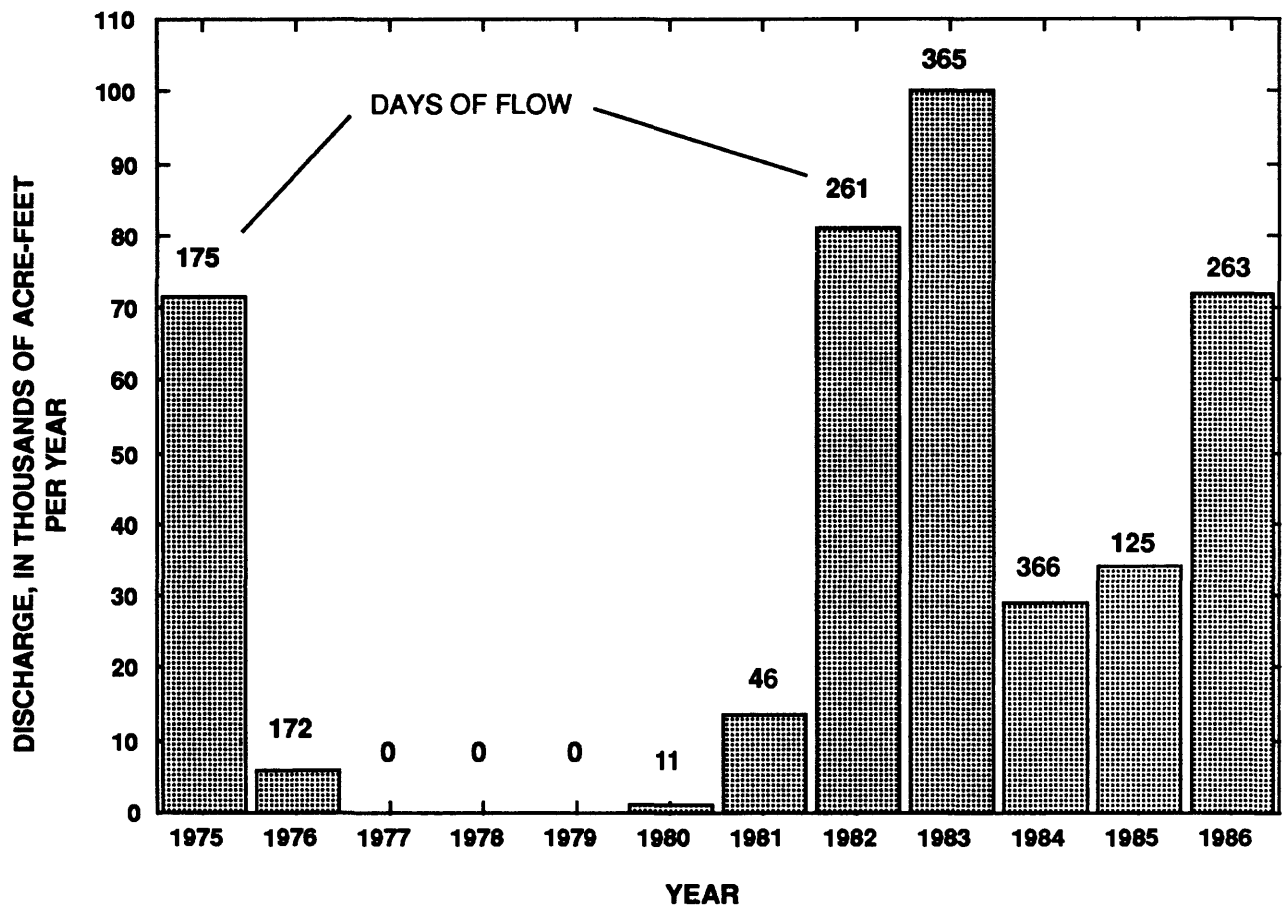


Figure 3.--Annual discharge of the Big Lost River at Lincoln Boulevard.

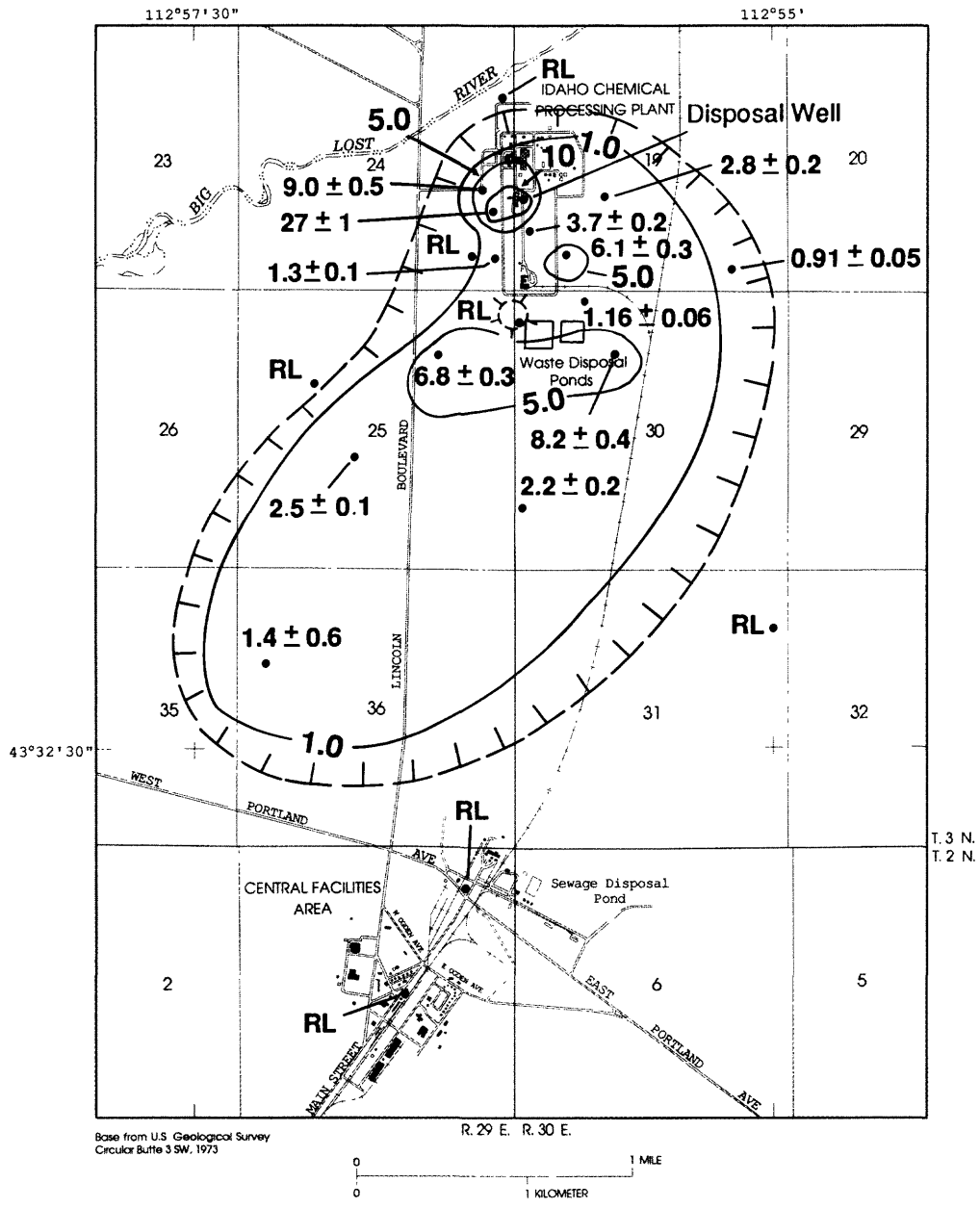
1986, combined with the change in disposal techniques account for much of the marked decrease in iodine-129 concentrations between 1981 and 1986.

Distribution of Iodine-129 in Ground Water

In April 1977, the concentrations of iodine-129 in ground water were above the reporting level in a 3.5 mi² area (fig. 4). The largest concentration was in the general area of the ICPP disposal well and detectable concentrations extended about 2.25 mi south-southwest of the disposal well. Concentrations in the plume shown on figure 4 are unevenly distributed in that there are three areas that contain more than 5 pCi/L of iodine-129. This uneven distribution largely results from month-to-month variations in the releases. For example, in 1977 the amount of iodine-129 discharged to the ICPP disposal well ranged from 0.0002 to 0.0025 Ci per month--a difference of about one order of magnitude.

In September and October 1981, iodine-129 concentrations in ground water were detected in wells about 0.5 mi farther south than in April 1977 (fig. 5). The area containing the largest concentration of iodine-129 was centered about 1,200 ft south-southwest of the disposal well. The area in which the ground-water contained more than 5 pCi/L had increased in size from about 0.3 mi² in April 1977 (fig. 4) to 0.8 mi² in September and October 1981 (fig. 5). The marked increase in area results from a corresponding increase in the amount of iodine-129 discharged to the disposal well and the comparatively small amount of recharge along the Big Lost River.

The size of the area in which the ground water contained iodine-129 at concentrations greater than the reporting level (fig. 6) changed little between 1981 and 1986, but the maximum concentration had decreased by about an order of magnitude. In the area in which the ground water had previously contained more than 5 pCi/L, the iodine-129 was diluted to the extent that the maximum concentration was 3.6[±]0.4 pCi/L. A concentration of more than 3 pCi/L occurred in an area of about 0.4 mi²; an appreciable change when compared to the 1981 concentrations.



Base from U.S. Geological Survey
Circular Butte 3 SW, 1973

R. 29 E. R. 30 E.



EXPLANATION



APPROXIMATE LIMIT OF AREA IN WHICH IODINE-129 CONCENTRATION EXCEEDS 0.25 PICOCURIES PER LITER

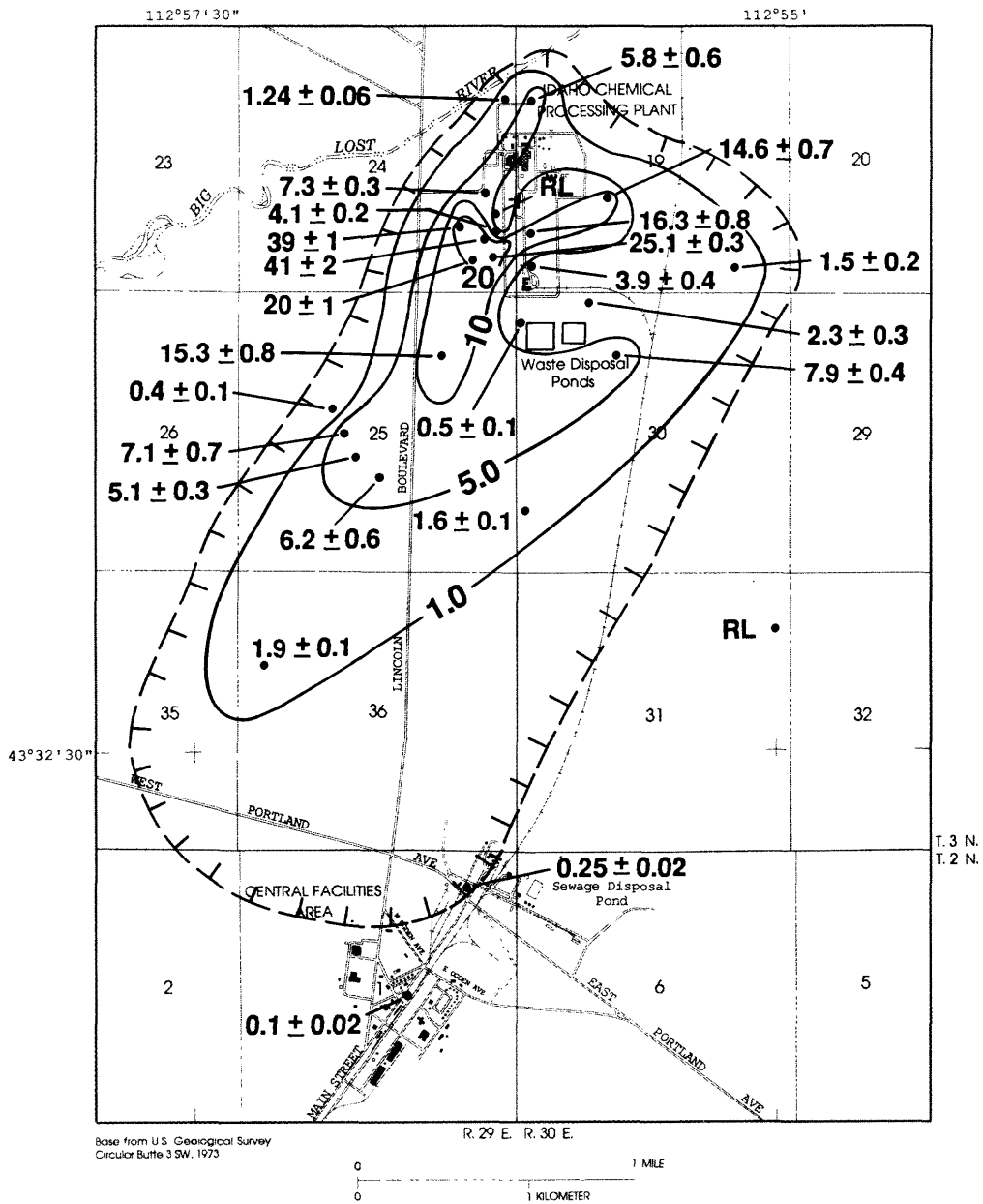
1.4 ± 0.6
•

WELL FROM WHICH A WATER SAMPLE FOR IODINE-129 WAS COLLECTED IN 1977--Number, 1.4, is the iodine-129 concentration in picocuries per liter and ± 0.6 is the analytical uncertainty in picocuries per liter; RL indicates the concentration of iodine-129 was less than the reporting level of about 0.25 picocuries per liter

1.0

LINE OF EQUAL IODINE-129 CONCENTRATION--Interval, in picocuries per liter, is variable

Figure 4.--Distribution of iodine-129 in the Snake River Plain aquifer, April 1977.



EXPLANATION



APPROXIMATE LIMIT OF AREA IN WHICH IODINE-129 CONCENTRATION EXCEEDS 0.25 PICOCURIES PER LITER

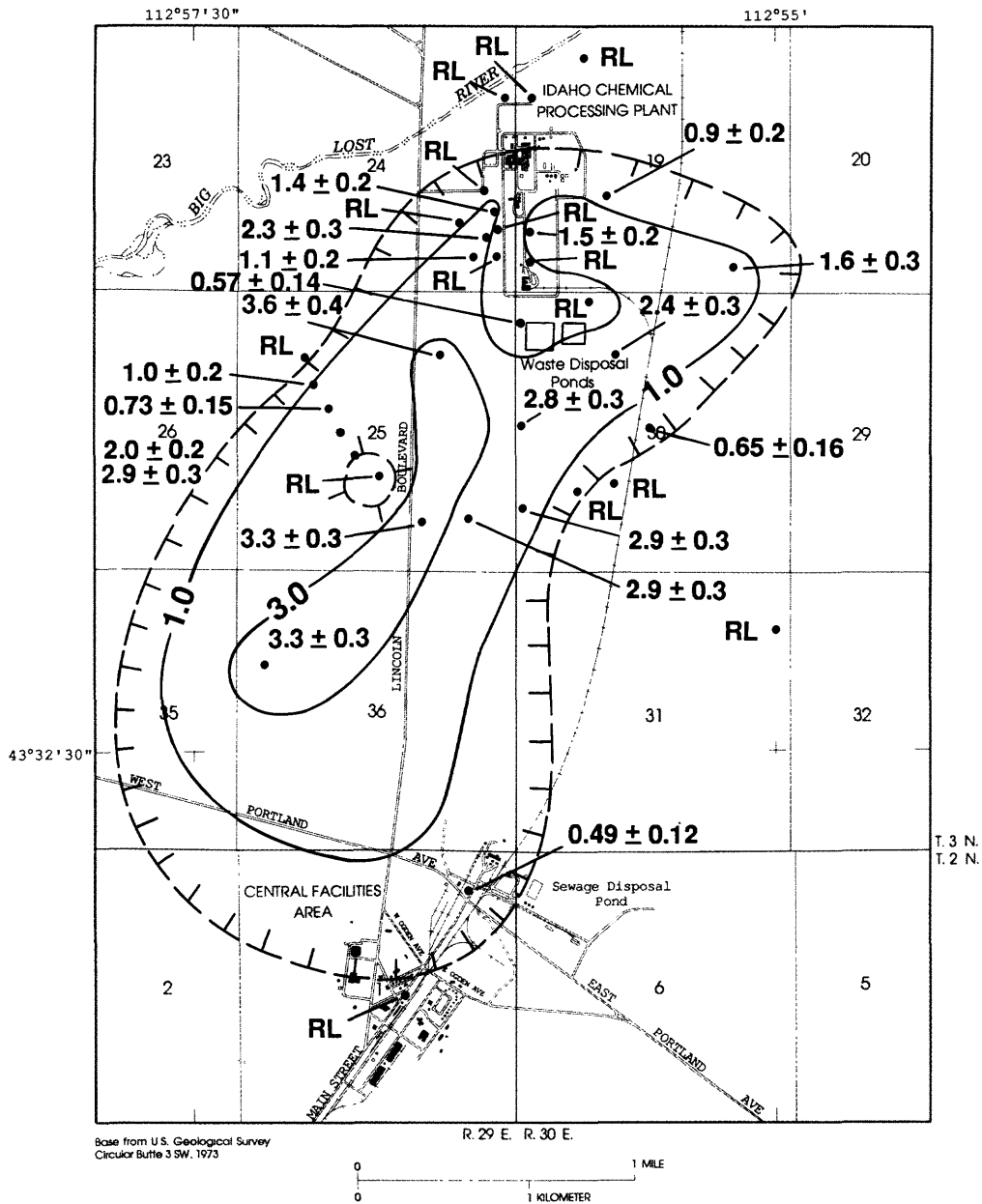
1.9 ± 0.1

WELL FROM WHICH A WATER SAMPLE FOR IODINE-129 WAS COLLECTED IN 1981--Number, 1.9, is the iodine-129 concentration in picocuries per liter and ±0.1 is the analytical uncertainty in picocuries per liter; RL indicates the concentration of iodine-129 was less than the reporting level of about 0.25 picocuries per liter

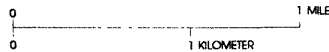
— 1.0 —

LINE OF EQUAL IODINE-129 CONCENTRATION--Interval, in picocuries per liter, is variable

Figure 5.--Distribution of iodine-129 in the Snake River Plain aquifer, September to October 1981.



Base from U.S. Geological Survey
Circular Bulletin 3 SW, 1973



EXPLANATION



APPROXIMATE LIMIT OF AREA IN WHICH IODINE-129 CONCENTRATION EXCEEDS 0.25 PICOCURIES PER LITER

3.3 ± 0.3



WELL FROM WHICH A WATER SAMPLE FOR IODINE-129 WAS COLLECTED IN 1986--Number, 3.3, is the iodine-129 concentration in picocuries per liter and +0.3 is the analytical uncertainty in picocuries per liter; RL indicates the concentration of iodine-129 was less than the reporting level of about 0.25 picocuries per liter

—1.0—

LINE OF EQUAL IODINE-129 CONCENTRATION--Interval, in picocuries per liter, is variable

Figure 6.--Distribution of iodine-129 in the Snake River Plain aquifer, August 1986.

Comparison of Iodine-129 Concentrations to Drinking-Water Standards

The National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1976) set a maximum contaminant level of 4 millirem/year dose equivalent to the total body or any organ for man-made radioactivity. With the assumption of the ingestion of 2 L/day of water for 1 year, the dose conversion factor in NBS Handbook 69 (U.S. Department of Commerce, 1963) can be used to calculate a concentration in drinking water of 1 pCi/L (U.S. Environmental Protection Agency, 1976). The dose conversion factors have been superseded by those of the International Commission on Radiological Protection (1978) which have been adopted by the U.S. Environmental Protection Agency, although there are some differences in the weighting factors for the thyroid and in the period of time over which the dose equivalent is calculated. New concentrations still based on 4 millirem/year for radionuclides have been proposed by the U.S. Environmental Protection Agency (1986). For iodine-129, the proposal assumes that a concentration of 100 pCi/L yields an effective dose equivalent of 4 millirem/year. It should be noted that other radionuclides in the drinking water must also be considered in calculating the dose equivalent as should the amount of water consumed.

The assumptions for both of these calculations for concentrations in drinking water are not applicable to the INEL because there are no permanent residents. However, the Department of Energy has chosen to limit the effective dose equivalent from drinking water to 4 millirem/year. This is a small part of the 5,000 millirem/year effective dose equivalent recommended by the U.S. Environmental Protection Agency as a radiation protection standard for radiation workers and approved on January 27, 1987 (The President, 1987); see also the recommendations of the National Council on Radiation Protection and Measurements (1987).

In August 1986, the concentrations of iodine-129 in water obtained from production wells used for drinking-water supplies at the INEL was less than existing and proposed concentrations assumed to produce a 4 millirem dose equivalent. Two production wells--CFA-1 and CFA-2 (see figures 2 and 6)--are in or immediately downgradient from the area in which ground water from

the Snake River Plain aquifer contained detectable concentrations of iodine-129; other production wells are either upgradient or a large distance from the ICPP and the associated iodine-129 plume. CFA-1 yielded water containing $0.49^{+0.12}$ pCi/L of iodine-129 and the concentration in water from CFA-2 was below the reporting level (table 1).

Wells that yielded water that exceeded the existing derived concentration of 1 pCi/L are not used for drinking-water supplies. They were drilled and constructed for the purpose of monitoring ground-water levels and the quality of ground water. Of the 31 monitoring wells sampled in 1986, 15 wells yielded water in which the iodine-129 concentrations equaled or exceeded the existing derived concentration of 1 pCi/L. However, the concentrations of iodine-129 in water from the monitoring wells were markedly less than the proposed concentration; the greatest concentration was $3.6^{+0.4}$ pCi/L as compared to the proposed derived concentration of 100 pCi/L.

SUMMARY

Since the ICPP began reprocessing spent nuclear fuel in 1953, it is estimated that about 4.4 Ci of iodine-129 have been released to the atmosphere. From 1953 to 1983, an estimated 0.01 to 0.136 Ci/year of iodine-129 were contained in wastewater directly discharged to the Snake River Plain aquifer at the ICPP. A 580-ft deep disposal well was used to dispose of the wastewater until February 9, 1984, when routine use of the well was discontinued and replaced with disposal to an unlined infiltration pond; a second pond was put into use on October 17, 1985. The annual amount of iodine-129 in wastewater disposed to the ponds ranged from 0.0064 Ci in 1984 to 0.039 Ci in 1986.

The concentration of iodine-129 in ground water from the Snake River Plain aquifer increased from 1977 to 1981 and decreased markedly from 1981 to 1986. In 1986, 35 wells yielded water that contained a maximum of $3.6^{+0.4}$ pCi/L of iodine-129. By comparison, in 1977, the maximum

concentration in water from 20 wells was 27^{+1} pCi/L and, in 1981, the maximum was 41^{+2} pCi/L in water from 32 wells.

Water in the Snake River Plain aquifer downgradient from the ICPP contained more than 5 pCi/L in an area of about 0.3 mi² in 1977, and about 0.8 mi² in 1981. However, in 1986, the maximum concentration of iodine-129 was $3.6^{+0.4}$ pCi/L and the area in which the water contained more than 3 pCi/L was about 0.4 mi².

Three factors are mainly responsible for the increase in iodine-129 concentrations between 1977 and 1981 and the decrease in concentrations between 1981 and 1986: (1) The amount of iodine-129 disposed annually; (2) the change from the use of the disposal well to the infiltration ponds; and (3) dilution of the iodine-129 in the aquifer by increased recharge from the Big Lost River owing to relatively large amounts of streamflow for 1982-86 when compared to relatively small amounts of streamflow for 1977-81.

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