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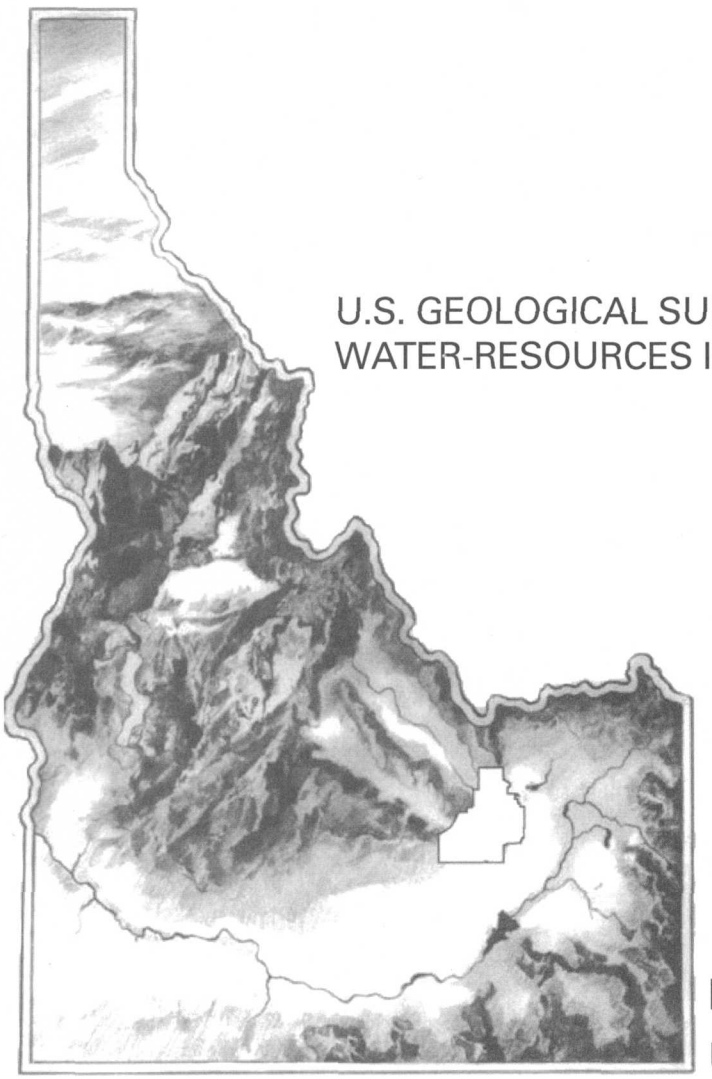
DISTRIBUTION OF SELECTED RADIOCHEMICAL AND CHEMICAL CONSTITUENTS IN PERCHED GROUND WATER, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO, 1996–98



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 00-4222

Prepared in cooperation with the U.S. DEPARTMENT OF ENERGY

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by Roy C. Bartholomay and Betty J. Tucker

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Idaho Falls, Idaho
October 2000

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

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CONVERSION FACTORS AND ABBREVIATED UNITS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	.3048	meter
mile (mi)	1.609	kilometer
square foot (ft^2)	.0929	square meter
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
pound (lb)	.4536	kilogram
curie (Ci)	$3.7x10^{10}$	becquerel
picocurie per milliliter (pCi/mL)	.037	becquerel per milliliter
picocurie per liter (pCi/L)	.037	becquerel per liter

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = (1.8)(°C)+32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated units used in report: µg/L (microgram per liter), and mg/L (milligram per liter).

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By Roy C. Bartholomay and Betty J. Tucker

Abstract

Radiochemical and chemical wastes generated at facilities at the Idaho National Engineering and Environmental Laboratory (INEEL) have been discharged to infiltration ponds at the Test Reactor Area (TRA) and the Idaho Nuclear Technology and Engineering Center (INTEC) and buried at the Radioactive Waste Management Complex (RWMC) since 1952. Disposal of wastewater to ponds and infiltration of surface water at waste burial sites have resulted in formation of perched ground water in basalts and in sedimentary interbeds above the Snake River Plain aquifer. Perched ground water is an integral part of the pathway for waste-constituent migration to the aquifer.

The U.S. Geological Survey, in cooperation with the U.S. Department of Energy, maintains a continuous monitoring network at the INEEL to determine hydrologic trends and to monitor the movement of wastewater discharged from facilities. This report presents an analysis of water-level and water-quality data collected from perched ground water at the INEEL during 1996–98.

During 1996–98, tritium concentrations in water from wells completed in deep perched ground water at the TRA generally decreased or were variable. During 1998, concentrations ranged from less than the reporting level to 116±4 picocuries per milliliter (pCi/mL). Tritium concentrations in water from wells at the TRA were affected by distance of the well from the radioactive-waste ponds, depth of the water below the ponds, the amount of tritium discharged to the radioactive-waste ponds in the past, discontinued use of the radioactive-waste ponds, radioactive decay, and dilution from nonradioactive water.

During 1996–98, strontium-90 concentrations in water from wells completed in deep perched ground water at the TRA were variable. During October 1998, concentrations ranged from less than the reporting level to 59±2 picocuries per liter (pCi/L). Cesium-137 and cobalt-60 were detected in water from a shallow well near the radioactive-waste pond retention basin.

Dissolved chromium concentrations in perched ground water at the TRA during 1998 ranged from less than 14 to 98 micrograms per liter. The largest concentrations were in water from wells north and west of the radioactive-waste ponds. Dissolved sodium concentrations ranged from 6.1 to 1,000 milligrams per liter (mg/L) in 1998. Dissolved sulfate concentrations ranged from 18 to 3,200 mg/L. The largest concentrations of sodium and sulfate were in water from a well near the chemical-waste pond.

During 1996–98, tritium concentrations in water from wells completed in deep perched ground water near the INTEC infiltration ponds generally decreased because of decreased disposal; strontium-90 concentrations were variable. In October 1998, tritium concentrations ranged from less than the reporting level to 9.7±0.5 pCi/mL; strontium-90 concentrations ranged from less than the reporting level to 2.8±0.6 pCi/L.

During 1996–98, concentrations of sodium, chloride, and sulfate in water from wells completed in perched ground water near the INTEC infiltration ponds were similar to the concentrations of the constituents in the wastewater discharged.

During 1996–98, concentrations of selected radiochemical constituents were below the reporting level in all samples from a well completed in perched ground water at the RWMC. Samples contained concentrations greater than the reporting levels of 14 different purgeable organic compounds.

INTRODUCTION

The Idaho National Engineering and Environmental Laboratory (INEEL) encompasses about 890 mi^2 of the eastern Snake River Plain in southeastern Idaho (fig. 1). Facilities at the INEEL are operated by the U.S. Department of Energy (DOE) and are used in the development of peacetime atomic-energy applications, nuclear-safety research, defense programs, advanced energy concepts, and environmental research. Radiochemical and chemical wastes generated at these facilities have been contained in wastewater discharged to infiltration ponds since 1952. Radiochemical and chemical wastes also have been buried at the INEEL. Disposal of wastewater to infiltration ponds and infiltration of surface water at waste-burial sites have resulted in formation of perched ground water in basalts and in sedimentary interbeds that overlie the Snake River Plain aquifer. Perched ground water is an integral part of the pathway for waste-constituent migration to the aquifer.

The DOE requires information about the mobility of dilute radiochemical and chemical-waste constituents in perched ground water at the INEEL to monitor the possible movement of these constituents to the Snake River Plain aquifer. Waste-constituent mobility is, in part, determined by (1) hydraulic properties of saturated and unsaturated basalts and sedimentary interbeds, (2) the location, quantity, and method of waste disposal, (3) waste-constituent chemistry, and (4) the geochemical processes taking place in the perched ground water. This study was done by the U.S. Geological Survey (USGS) in cooperation with the DOE's Idaho Operations Office.

Purpose and Scope

In 1949, the U.S. Atomic Energy Commission, which later became the DOE, requested that the USGS describe the water resources of the area now known as the INEEL. The purpose of the study was to characterize the water resources before development of nuclear-reactor testing facilities. Since 1949, the USGS has maintained a monitoring network at the INEEL to determine hydrologic trends and to delineate the movement of facility-related radiochemical and chemical wastes in perched ground water and in the Snake River Plain aquifer.

The purpose of this report is to present an analysis of water-level and water-quality data collected from selected wells completed in perched ground water at selected INEEL facilities during 1996–98 as part of the continuing hydrogeologic investigation at the INEEL. This report describes the distribution and concentrations of selected radiochemical and chemical constituents in perched ground water and the history of waste disposal at the Test Reactor Area (TRA), Idaho Nuclear Technology and Engineering Center (INTEC), and Radioactive Waste Management Complex (RWMC). Perched ground water also has been detected beneath infiltration ponds and ditches at other facilities at the INEEL but is not discussed in this report because of the relatively small quantity of wastewater and associated radiochemical and chemical constituents discharged. An analysis of data collected from the Snake River Plain aquifer during 1996–98 is found in Bartholomay and others (2000).

Acknowledgments

The DOE Radiological and Environmental Sciences Laboratory (RESL) analyzed water samples for radiochemical constituents. Technical staff at the RESL during 1996–98 were supervised by R. Douglas Carlson, Director. The authors are grateful for technical review of the manuscript by David

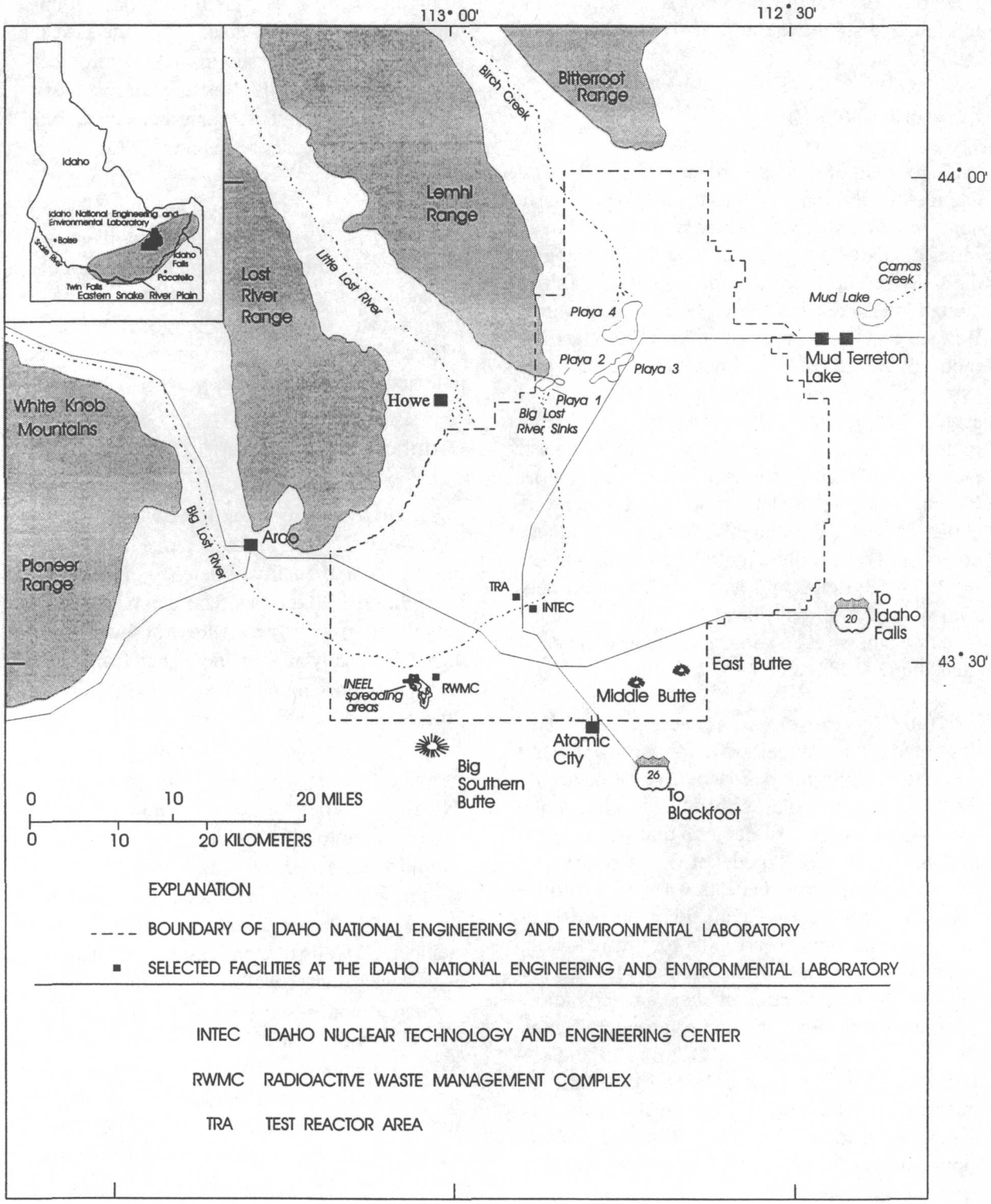

Figure 1. Location of the Idaho National Engineering and Environmental Laboratory and selected facilities.

Frederick, Environmental Scientist, State of Idaho INEEL Oversight Program, and Lonna M. Frans, hydrologist, USGS.

Previous Investigations

The extent of perched ground water at the TRA and the distribution of selected wastewater constituents in perched ground water are discussed in a series of annual reports describing the hydrology of the INEEL. The series includes a report by Barraclough, Teasdale, and Jensen (1967), a report by Barraclough, Teasdale, and others (1967), and a report by Barraclough and Jensen (1976). An analysis of perched ground water at the TRA is presented in a comprehensive discussion of conditions related to the disposal of wastewater to the subsurface at the INEEL (Robertson and others, 1974). Later reports present data on perched ground water at the TRA, INTEC, and RWMC: Barraclough and others (1981) described hydrologic conditions during 1974–78; Lewis and Jensen (1985) described hydrologic conditions during 1979–81; and Pittman and others (1988) described hydrologic conditions during 1982–85.

Hull (1989) developed a conceptual model that described migration pathways for wastewater and constituents from the radioactive-waste ponds at the TRA. Orr (1999) described the development of a transient numerical simulation that was used to evaluate a conceptual model of flow through perched ground-water beneath wastewater infiltration ponds at the TRA. Cecil and others (1991) discussed mechanisms responsible for formation of perched ground water at the TRA and INTEC and described the distribution of chemical and radiochemical constituents in perched ground water at the TRA, INTEC, and RWMC during 1986–88. Tucker and Orr (1998) described the distribution of selected radiochemical and chemical constituents in perched ground water during 1989–91; Bartholomay (1998) described the distribution of the selected constituents during 1992–95.

Anderson and Lewis (1989) and Anderson (1991) correlated cores and geophysical logs to describe a complex sequence of basalt flows and sedimentary interbeds in the unsaturated zone underlying the RWMC, TRA, and INTEC. This stratigraphy is the geologic framework within which perched ground water has formed. Ackerman (1991) analyzed data from 43 aquifer tests conducted for 22 wells to estimate transmissivity of basalts and sedimentary interbeds containing perched ground water beneath the TRA and INTEC.

Robertson (1977) used a three-segment numerical model to simulate flow and transport of chemical and radionuclide constituents through perched ground water at the TRA. The model included effects of convection, hydrodynamic dispersion, radioactive decay, and adsorption.

Ground-Water Monitoring Networks

Ground-water monitoring networks are maintained at the INEEL to characterize the occurrence, movement, and quality of perched ground water beneath INEEL facilities. These networks consist of wells from which water-level and water-quality data periodically are obtained. Data from the monitoring networks are on file at the USGS INEEL Project Office.

Water-Level Monitoring Network.—The INEEL perched-water-level monitoring network was designed to estimate the extent of perched ground water and the volume of perched water in storage. Water levels in 43 wells were monitored during 1996–98 (fig. 2). At the TRA, the network included 22 wells to monitor deep perched ground-water levels and 11 wells to monitor shallow perched ground-water levels. Shallow perched ground water is considered water perched in surficial sediment deposits, and deep perched ground water is water perched at greater depths above sediment interbeds or basalts. At the INTEC, the network included eight wells to monitor perched ground-water levels around the INTEC infiltration ponds and one well to monitor the water-level changes in deep perched ground water beneath the INTEC. Perched ground water at the RWMC was monitored in one well. Well locations and the frequency of water-level measurements as of December 1998 are shown in figure 2.

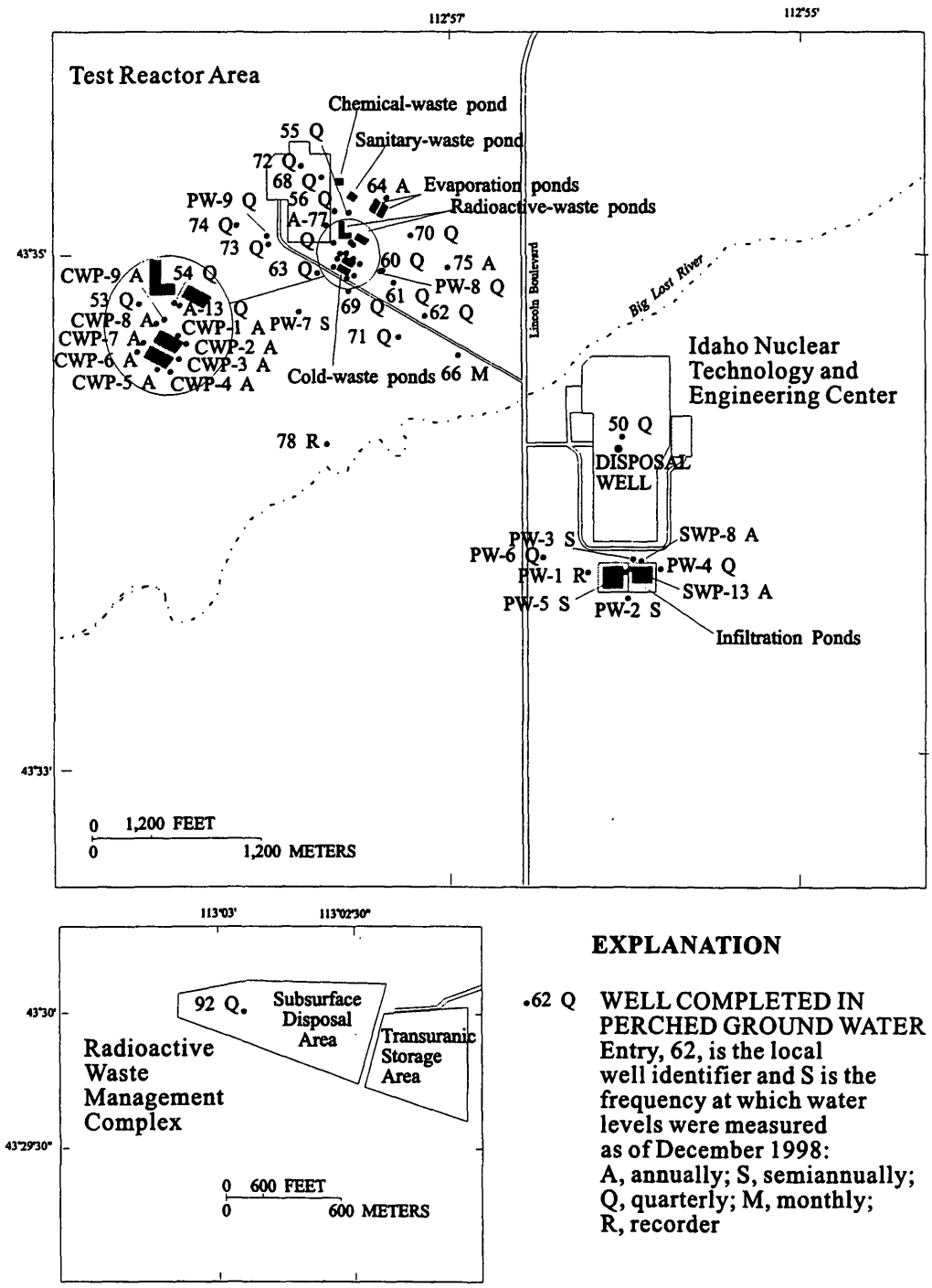

Figure 2. Location of selected wells and frequency of water-level measurements (as of December 1998) in perched ground water, Test Reactor Area, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex.

Water-Quality Monitoring Network.—The radiochemical and chemical character of perched ground water beneath INEEL facilities was determined from analyses of water samples collected as part of the water-quality monitoring network to identify contaminant concentrations and define the pattern of waste migration in perched ground water and in the Snake River Plain aquifer.

The type, frequency, and depth of ground-water sampling generally depended on the information needed in a specific area. Water samples routinely were collected from selected wells and analyzed for concentrations of tritium, strontium-90, cesium-137, cobalt-60, plutonium-238, the sum of plutonium-239 and plutonium-240 (undivided), americium-241, dissolved and hexavalent chromium, sodium, chloride, sulfate, nitrate, and volatile organic compounds. Measurements of specific conductance, pH, and water temperature were made at each well. Water samples were analyzed for concentrations of radiochemical constituents at the RESL and for chemical constituents at the National Water Quality Laboratory (NWQL) in Denver, Colo. The location of wells in the water-quality monitoring network for perched ground water beneath INEEL facilities during 1996–98 and the frequency of sample collection are shown in figure 3 and table 1. The constituents for which each well is sampled for are listed in Mann (1996, attachment 1).

Water-Quality Sampling Methods and Quality Assurance

Methods used to sample for selected constituents generally followed the guidelines established by the USGS (Goerlitz and Brown, 1972; Stevens and others, 1975; Wood, 1981; Claassen, 1982; W.L. Bradford, USGS, written commun., 1985; Wershaw and others, 1987; Fishman and Friedman, 1989; and Wilde and others, 1998).

Water samples were collected according to a quality-assurance plan for quality-of-water activities conducted by personnel at the INEEL Project Office (Mann, 1996). In general, about 10 percent of the samples collected are for quality assurance. Quality-assurance samples collected by the USGS INEEL Project Office include blanks, equipment blanks, splits, duplicates, and replicates. Thirteen quality-assurance replicates were collected for wells sampled for this study; results are included in the tables at the end of the report. Comparative studies to determine agreement between analytical results for individual water-sample pairs by laboratories involved in the INEEL Project Office quality-assurance program are summarized by Wegner (1989), Williams (1996), and Williams (1997). Additional quality-assurance studies by personnel at the INEEL Project Office include an evaluation of field sampling and preservation methods for strontium-90 (Cecil and others, 1989); a study comparing different pump types used for sampling purgeable organic compounds (Knobel and Mann, 1993); an analysis of tritium and strontium-90 concentrations in water from wells after purging different borehole volumes (Bartholomay, 1993); an analysis of the effects of different preservation types on nutrient concentrations (Bartholomay and Williams, 1996); and an analysis of two analytical methods for the determination of gross alpha- and beta-particle activity (Bartholomay and others, 1999).

Guidelines for Interpreting Results of Radiochemical Analyses

Concentrations of radionuclides are reported with an estimated sample 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 a method proposed by Currie (1984).

In the analysis for a particular radionuclide, 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 larger than the signal observed for the blank before the decision can be made that the radionuclide was detected; and (2) an estimation must be made of the minimum radionuclide concentration that will yield a sufficiently large observed signal before the correct decision can be made for detection or non-detection of the radionuclide. The first aspect of the problem is a

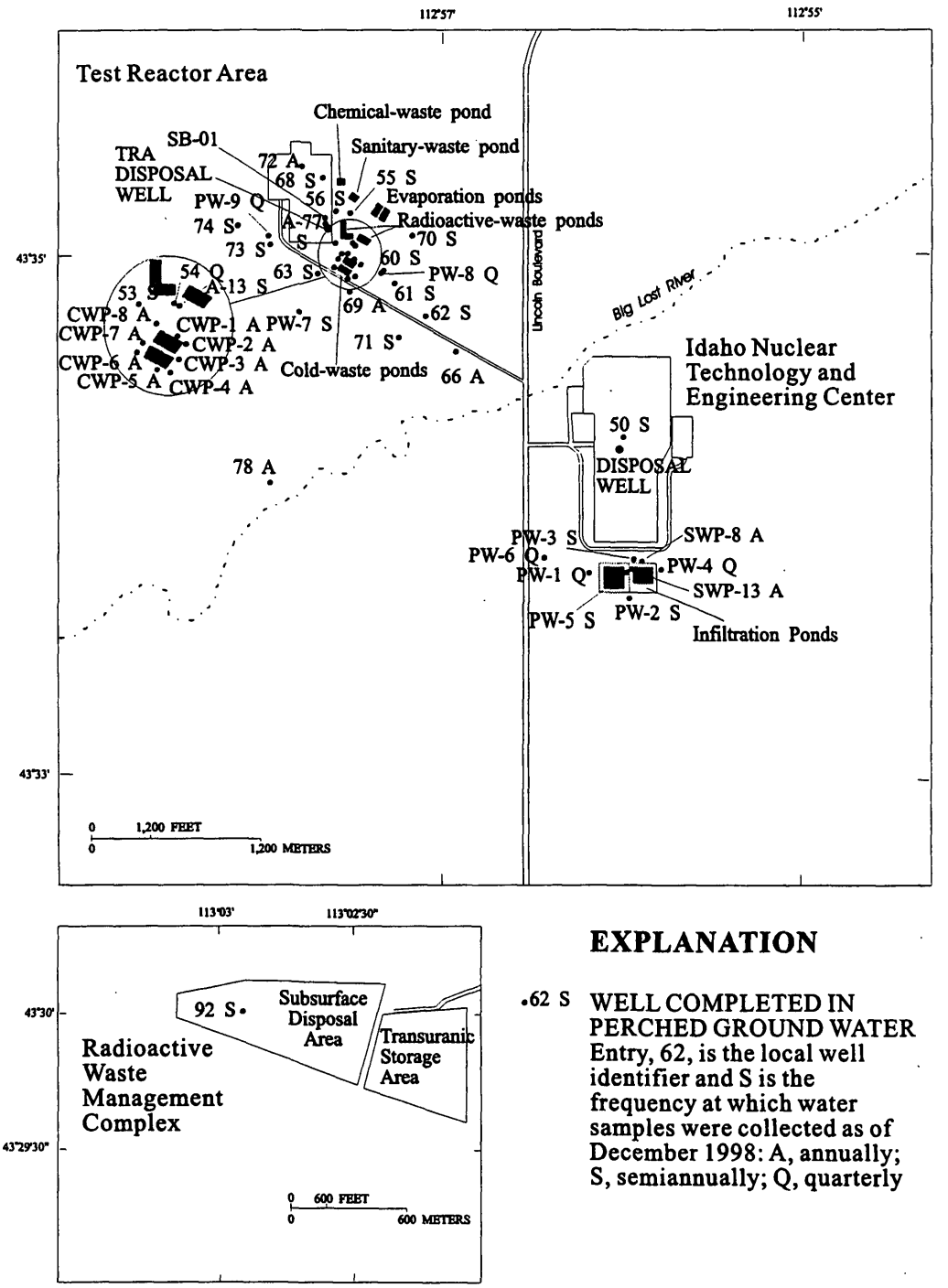

Figure 3. Location of selected wells and frequency of water-quality sample collection (as of December 1998) in perched ground water, Test Reactor Area, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex.

qualitative decision based on an observed signal and a definite criterion for detection. The second aspect of the problem is an estimation of the detection capabilities of a given measurement process.

In the laboratory, instrument signals must exceed a critical level of 1.6s before the qualitative decision can be made as to whether the radionuclide was detected. At 1.6s, there is about a 95-percent probability that the correct conclusion—not detected—will be made. Given a large number of samples, as many as 5 percent of the samples with measured concentrations larger than or equal to 1.6s, which were concluded as being detected, might not contain the radionuclide. 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 determined. Concentrations that equal 3s represent a measurement at the minimum detectable concentration. For true concentrations of 3s or larger, there is a 95-percent or larger probability that the radionuclide was detected in a sample. In a large number of samples, the conclusion—not detected— will be made in 5 percent of the samples that contain true concentrations at the minimum detectable concentration of 3s. These measurements are referred to as false negatives and are errors of the second kind in hypothesis testing.

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

The critical level and minimum detectable concentration are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The values 1.6s and 3s vary slightly with background or blank counts, with the number of gross counts for individual analyses, and for different radionuclides. In this report, radionuclide concentrations less than 3s are considered to be below a "reporting level." The critical level, minimum detectable concentration, and reporting level aid the reader in the interpretation of analytical results and do not represent absolute concentrations of radioactivity which may or may not have been detected.

Many analytical results of environmental radioactivity measurements are at or near zero. If the true concentration for a given radionuclide is zero, a given set of analytical results for that radionuclide should be distributed about zero, with an equal number of negative and positive measurements. Negative analytical results occur if the radioactivity of a water sample is less than the background radioactivity or the radioactivity of the prepared blank sample in the laboratory (American Society for Testing and Materials, 1992, p. 126; Knobel, Orr, and Cecil, 1992, p. 51).

Geohydrologic Setting

The eastern Snake River Plain is a northeast oriented structural basin about 200 mi long and 50 to 70 mi wide. The plain consists of surficial alluvial and eolian sediments and basalt outcrops underlain by a layered sequence of basalt flows and sedimentary interbeds. Individual basalt flows are from 10 to 50 ft thick, although the average thickness is from 20 to 25 ft (Mundorff and others, 1964, p. 143). The surficial sediments and sedimentary interbeds consist of sand, silt, clay, and lesser amounts of gravel. Locally, rhyolitic flows and tuffs are exposed at the land surface or exist at depth.

The top of the Snake River Plain aquifer is about 450 ft below land surface at the TRA and INTEC and about 600 ft below land surface at the RWMC. The unsaturated zone beneath these facilities consists of alluvial and eolian surficial sediments, basalt flows, and sedimentary interbeds and is typical of the stratigraphy at the INEEL. Anderson and Lewis (1989), Anderson (1991), Anderson and Bowers (1995), and Anderson and Liszewski (1997) described the stratigraphic sequence of the unsaturated zone and uppermost part of the Snake River Plain aquifer at selected INEEL facilities and at and near the INEEL. This sequence was formed by extrusion and cooling of basaltic lava followed by periods of volcanic quiescence and sedimentary

deposition (Nace and others, 1975, p. 16; Anderson and others, 1997). Vertical and horizontal fractures developed as lava flows cooled. These fractures and interflow rubble zones are primary conduits through which water is transmitted.

Locally, perched ground water has formed in the basalt and in sedimentary interbeds in response to recharge from wastewater infiltration ponds and localized infiltration of snowmelt and rain. Perched ground water also has formed from infiltration of Big Lost River water (fig. 1). Transmissivity estimates from 22 wells completed in perched ground water ranged from 1.0 to 15,000 ft^2/day (Ackerman, 1991, p. 10). Differences in the vertical hydraulic conductivity of basalt layers and sedimentary interbeds in the unsaturated zone provide mechanisms for the development of perched ground water (Cecil and others, 1991, p. 17). The vertical hydraulic conductivity of a sedimentary interbed is typically smaller than that of an overlying basalt layer. Perched ground water is closely associated with sedimentary interbeds beneath the TRA, INTEC, and RWMC. Several perched water zones exist below each facility and a more detailed description of the perched zones can be found in Cecil and others (1991). Alterations in the baked zones between two basalt layers may contribute to decreased vertical hydraulic conductivity. Dense, unfractured basalt or sediment and chemical filling of fractures near the upper contact of a basalt layer limit the capability of the basalt to transmit water.

DISTRIBUTION OF SELECTED RADIOCHEMICAL AND CHEMICAL CONSTITUENTS IN PERCHED GROUND WATER

Radiochemical and chemical constituents in wastewater migrate to the Snake River Plain aquifer through perched ground water beneath wastewater infiltration ponds at the TRA and INTEC. Perched ground water beneath the RWMC has formed from infiltration of snowmelt and rain, and recharge from the Big Lost River and the INEEL spreading areas, and contains constituents leached from buried radioactive and organic chemical wastes. The extent of this perched ground water is affected by the waste-disposal practices.

Wastewater-disposal sites at INEEL facilities are the principal sources of radiochemical and chemical constituents in the Snake River Plain aquifer. These sites have included infiltration ponds and ditches, evaporation ponds, drain fields, pits, and disposal wells. During 1996–98, wastewater was discharged into infiltration and evaporation ponds and drain fields. Waste materials buried at the RWMC (fig. 1) also are a source of some constituents in ground water.

Radioactive-waste-disposal data presented in this report were obtained from a series of radioactive-waste-management information reports (French and others, 1997b; French and Taylor, 1998; and French and others, 1999b). Chemical-waste-disposal data were obtained from a series of nonradiological-waste-management information reports (French and others, 1997a; French and others, 1998; and French and others, 1999a). The radioactive- and chemical-waste-disposal data were collected by contractors at each facility. A more detailed description of the waste-disposal history at selected facilities is presented by Bartholomay and others, 2000, p. 10–14.

Test Reactor Area

Deep and shallow perched ground water has formed at the TRA in response to wastewater disposal to the radioactive-waste, chemical-waste, cold-waste, and sanitary-waste ponds (fig. 2). During 1996–98, approximately 220 million gal/yr of wastewater was discharged to infiltration and evaporation ponds at the TRA. Selected radiochemical and inorganic chemical constituents in wastewater have been monitored in the shallow and deep perched ground water since the early 1960's.

Water samples from seven wells (A-13, A-77, CWP-1, 3, 4, 7, 8) completed in shallow perched ground water near the TRA routinely were collected and analyzed during 1996–98 (fig. 3) for selected radiochemical and chemical constituents. There was no water in wells CWP 2, 5, and 6. Water samples from 17 wells (54 through 56, 60 through 63, 66, 68 through 73, 78, PW-8, and PW-9) completed in deep perched ground water beneath the TRA also were collected. There was no water in wells 53, 74, and PW-7. The selection of

radiochemical and chemical constituents for analyses was based on waste-disposal history at the TRA. Selected radiochemical constituents were tritium, strontium-90, and gamma analyses; chemical constituents were chromium, sodium, chloride, and sulfate. The distribution of these constituents is summarized in the following sections.

Tritium.—During 1952–93, approximately 10,500 Ci of tritium was in wastewater discharged to the radioactive-waste ponds at the TRA. In August 1993, two lined evaporation ponds, which essentially prevent radioactive wastewater from entering the ground, replaced the radioactive-waste ponds (B.R. Orr, USGS, oral commun., 1996). Before 1980, tritium, which has a half-life of 12.3 years (Walker and others, 1989, p. 20), accounted for less than 20 percent of the total radioactivity discharged to the ponds. After 1980, tritium accounted for more than 90 percent of the total radioactivity. Most other radioactive constituents discharged to the ponds had very short half-lives. During 1996–98, about 96 percent of the total radioactivity was from tritium. About 430 Ci of tritium was discharged to the evaporation ponds during 1996–98. The volume of wastewater and the curies of tritium discharged to the radioactive-waste and evaporation ponds during 1960–98 are shown in figure 4.

Well TRA A-77 (fig. 3) is completed in shallow perched ground water in alluvium near the TRA retention basin (fig. 5), a basin into which radioactive wastewater flowed before discharge to the radioactive waste ponds. Some wastewater reportedly has leaked to the subsurface through cracks in the retention basin (U.S. Department of Energy, 1991, p. 29). To prevent discharge of radioactive wastewater to the retention basin, the retention basin was isolated from an inlet basin in 1993 when discharge to the evaporation ponds began (E. DeWayne King, oral commun., 2000). The largest tritium concentration in water from well TRA A-77 during 1989–91 was 3,790±50 pCi/mL (Tucker and Orr, 1998, p. 15). In 1992, the largest tritium concentration increased slightly to 3,940±60 pCi/mL (Bartholomay, 1998, p. 41). In October 1995, the tritium concentration in water from well TRA A-77 had decreased to 22.4±0.9 pCi/mL (Bartholomay, 1998, p. 41); and by April 1997 had decreased to 1.0±0.15 pCi/mL (table 2). There has been no water in this well since April 1997. Throughout 1986–97, the tritium concentrations were variable. Because of the shallow depth of well TRA A-77 and its proximity to the leaking retention basin, the variability in tritium concentrations in this well may have been the result of variations in tritium disposal rates (Bartholomay, 1998, p. 10). The discontinued use of the retention basin for radioactive wastewater may be the reason for the lack of water in this well. Another shallow well near the retention basin, SB-01, was sampled from March to May 1997 as part of a special request. Tritium concentrations ranged from 248±8 pCi/mL to 365±12 pCi/mL. There has been no water in this well since May 1997.

The largest tritium concentration in water from well TRA A-13, also completed in the shallow perched ground water, was 1.1±0.3 pCi/mL during 1986–88 (Cecil and others, 1991, p. 33); during 1989–98, tritium concentrations were less than the reporting level. The small tritium concentrations in well TRA A-13, located between the radioactive-waste ponds and the cold-waste ponds, likely are affected by the large quantity of nonradioactive water discharged to the cold-waste ponds.

During 1989–98, tritium concentrations were below the reporting level in water from wells CWP-1 through CWP-8, which monitor shallow perched ground water around the cold-waste ponds at the TRA. Before 1988, tritium was below the reporting level in water from wells CWP-1 through CWP-7. During 1986–88, a maximum tritium concentration of 0.8±0.2 pCi/mL in water from well CWP-8 was measured. The maximum tritium concentration in water from well CWP-9 (fig. 2) decreased from 6.3±0.2 pCi/mL during 1982–85 to 1.1±0.2 pCi/mL during 1986–88 (Cecil and others, 1991, p. 35). CWP-9 has not been sampled since 1988. The absence of detectable concentrations of tritium in most of the CWP wells is attributed to the large quantity of nonradioactive wastewater discharged to the cold-waste ponds since 1982, which has diluted any residual radioactive-waste pond water.

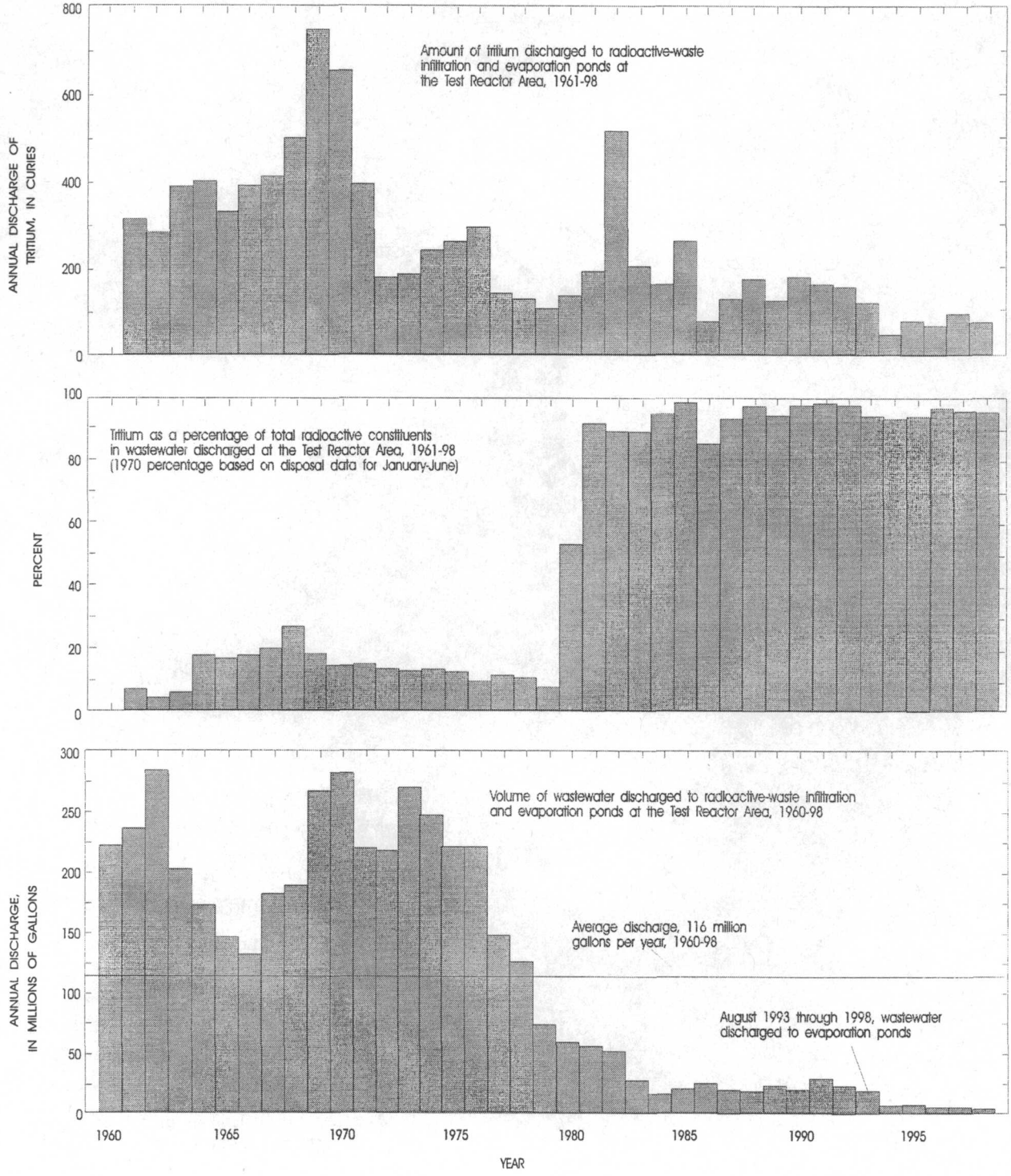

Figure 4. Amount of tritium discharged, tritium as a percentage of total radioactive constituents in wastewater discharged, and volume of wastewater discharged to the radioactive-waste infiltration and evaporation ponds, Test Reactor Area, 1960–98.

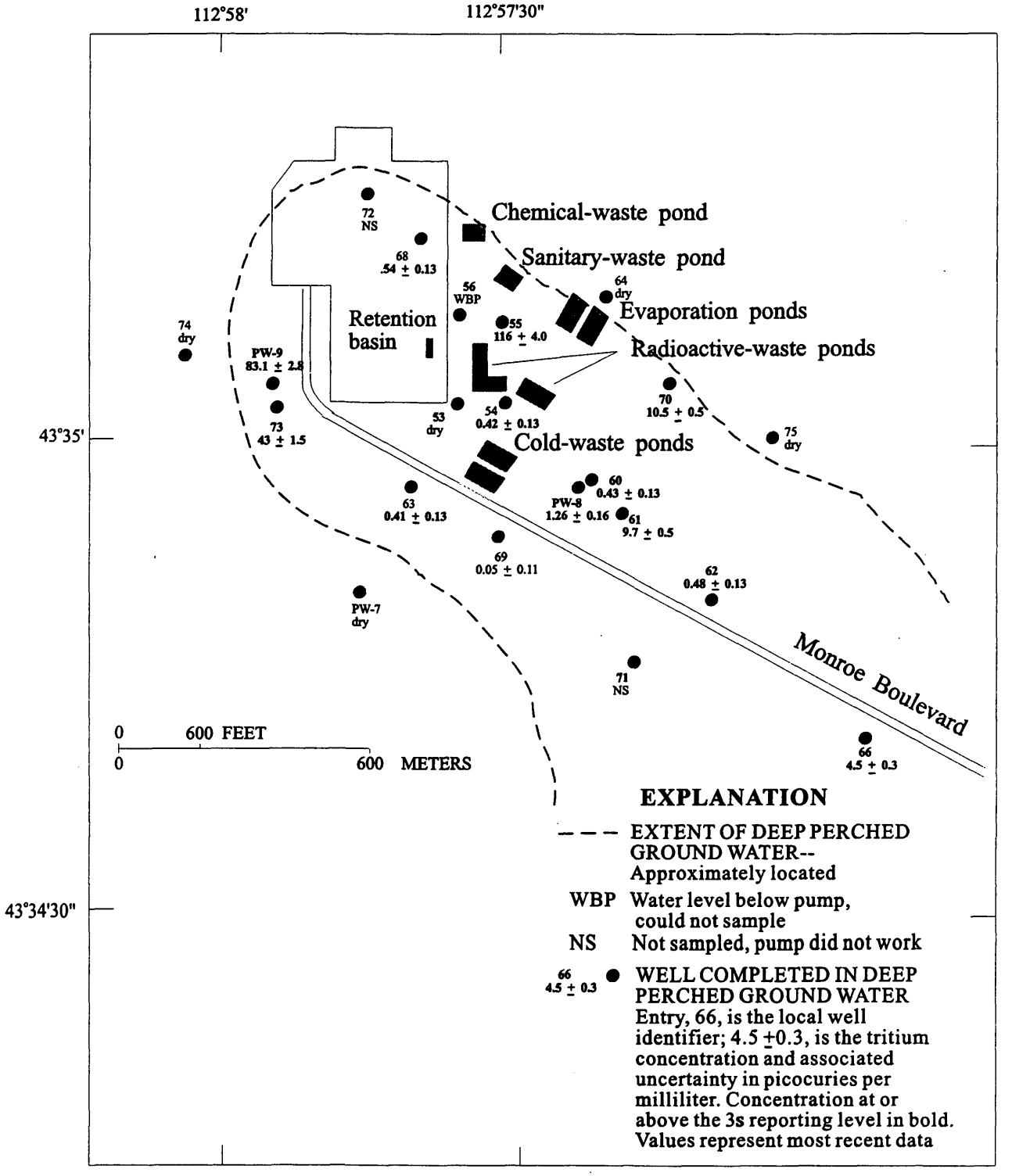

Figure 5. Tritium concentrations in deep perched ground water, Test Reactor Area, July–December, 1998.

In July-December 1998, tritium concentrations were at or above the reporting levels in water from 13 wells completed in deep perched ground water at the TRA. Concentrations are shown in figure 5 and in table 2. Tritium concentrations ranged from 0.41±0.13 pCi/mL in well 63 to 116±4.0 pCi/mL in well 55. Water from three wells contained tritium concentrations from 43±1.5 to 116±4.0 pCi/mL; water from the 10 other wells contained 0.41±0.13 to 10.5±0.5 pCi/mL.

Water samples collected in October 1998 from wells 73 and PW-9 contained 43±1.5 and 83.1±2.8 pCi/mL of tritium, respectively. These concentrations represent steady declines since 1993 when the radioactive waste ponds were taken out of service. Water in well 74 contained 93.1±1.7 pCi/mL in April 1992; there has been no water in this well since 1992. These wells are more than 1,500 ft west of the radioactive-waste ponds. Relatively large tritium concentrations in water from these wells indicate that the chemistry of perched ground water west of the TRA has been affected by water from the radioactive-waste ponds.

Tritium concentrations in water from 12 wells completed in the deep perched ground water were constant or declined during 1996–98. During 1996–98, tritium concentrations remained near reporting levels in water from wells 60, 62, and 63; concentrations in water from wells 68, 69, and 72 were less than reporting levels except for the December 1998 concentration in water from well 68 (table 2). The concentration in the December 1998 replicate sample for well 68 was less than the reporting level. Concentrations in water from wells 61, 66, 71, 73, PW-8, and PW-9 all were above reporting levels and generally have declined since October 1993. There has been no water in well 53 since 1995. The water level in well 56 declined below the pump in 1997 and has not been above the pump since. The concentration declines and lack of water in wells 53 and 56 are attributed to the discontinued use of the radioactive-waste ponds.

In contrast, tritium concentrations in water from wells 54, 55, and 70 varied considerably during 1996–98. For example, the tritium concentration in water from well 55 ranged from 1.4±0.2 to 116±4.0 pCi/mL (table 2). Wells 54 and 55 are directly adjacent to the radioactive-waste ponds and well 70 is about 900 ft east of the radioactive-waste ponds (fig. 3). The water level in well 55 declined to the top of the pump in April 1998, but rose after April. The large tritium concentration in well 55 in October 1998 indicates that the water-level increase is from a radioactive source water. The water level in USGS 54 declined below the pump in January and April 1998 but rose after April. Variations in tritium concentrations in water from these wells may be attributed to fluctuations in disposal rates and to mixing of water from the radioactive- and cold-waste ponds. The reason for the large increase in the tritium concentration in water from well 55 in October 1998 (table 2) is unknown.

Hydrographs of water levels in wells 60 and 73 (fig. 6) indicate that wastewater disposal to the cold-waste ponds since 1982 has hydraulically dominated perched ground-water flow to the west and south. The effect of disposal to the cold-waste ponds was attenuated in well 70 water levels, to the east. Water levels in these wells declined significantly in 1992 (fig. 6), when wastewater discharge to the cold-waste ponds was much less than in other years. Because of the effect of disposal to the cold-waste ponds on water levels and the removal of the radioactive-waste ponds as a water source, tritium concentrations in perched ground water at the TRA are likely to decrease as nonradioactive wastewater from the cold-waste ponds displaces water derived from earlier radioactive-waste pond disposal.

Monthly tritium disposal rates and tritium concentrations in water from selected wells were plotted during 1986–95 in Bartholomay (1998, p. 13) to define the distribution of tritium in perched ground water and to determine the effects of variations in tritium disposal rates. Bartholomay (1998) found that corresponding increases in tritium concentrations in water from wells 53, 56, and 70 indicated that tritium concentrations were related partly to tritium disposal rates. The dependence of wells 53 and 56 on water from the radioactive-waste ponds is demonstrated by the fact that well 53 has dried up and the water level in 56 has declined below the pump intake. Bartholomay (1998) found that increases and

decreases in tritium concentrations in water from well 73 lagged from 3 to 13 months behind increases and decreases in well 56. This time lag suggested that tritium in ground water moved from the radioactive-waste ponds to well 73 within that period. Bartholomay (1998) also found that changes in tritium concentrations in water from well 54 did not correspond directly to monthly changes in tritium disposal. The lack of correspondence indicated that other factors, including hydraulic effects and dilution from the cold-waste ponds, affected tritium concentrations in water from that well.

Several factors have affected the distribution of tritium in perched ground water at the TRA. These factors include proximity of the well to the radioactive-waste ponds, the depth of the water below the ponds, variations in the tritium disposal rate, and radioactive decay. Since 1982, tritium concentrations also have been affected by dilution from the cold-waste ponds. The replacement of the radioactive-waste ponds with the evaporation ponds in 1993 also contributed to declines in tritium concentrations in perched ground water and decreases in the quantity of perched water in some wells. Also, infiltration from the Big Lost River has diluted tritium concentrations in perched ground water southeast of the TRA.

Strontium-90.—During 1952–93, approximately 93 Ci of strontium-90 was in wastewater discharged to the radioactive-waste ponds at the TRA, an average of 2.3 Ci/yr. During 1996–98, about 0.03 Ci was discharged to the evaporation ponds. Strontium-90 has a half-life of 29.1 years (Walker and others, 1989, p. 29).

During 1996–98, strontium-90 concentrations in water from wells TRA A-77 and TRA A-13, completed in shallow perched ground water, were above the reporting levels (table 2). Concentrations in water from well TRA A-77 ranged from 4,710±140 pCi/L in October 1996 to 6,800±200 pCi/L in April 1997 (table 2). Concentrations in water from well TRA A-13 ranged from 23.5±1.2 to 39±2 pCi/L.

In October 1998, concentrations of strontium-90 in water from wells 54, 55, 60, 61, 62, 63, 70, and PW-8, completed in deep perched ground water at the TRA were above reporting levels (table 2 and fig. 7); concentrations ranged from 1.6±0.5 pCi/L in well 61 to 59±2 pCi/L in well 54. The distribution of strontium-90 concentrations in water from these wells during 1996–98 is attributed to chemical equilibrium reactions between strontium-90 sorbed to sediments beneath the radioactive-waste ponds and strontium-90 in solution in water passing through those sediments. Strontium-90 has not been detected in water from the Snake River Plain aquifer beneath the TRA (Bartholomay and others, 1997, p. 30); the absence of detectable concentrations indicates that strontium-90 probably is sorbed to sediments. Study of strontium distribution coefficients for samples of surficial sediment, sedimentary interbeds, and sediment-infill in basalts (Liszewski and others, 1997, 1998; Pace and others, 1999) at the INEEL support this theory.

Water in wells 60, 61, and 63 contained strontium-90 concentrations below reporting levels in some samples collected during 1996–98, but above the reporting levels in other samples (table 2). Fluctuations could not be correlated with disposal of strontium-90 because of the use of the evaporation ponds during 1996–98.

Cesium-137.—About 138 Ci of cesium-137 was in wastewater discharged to the radioactive-waste ponds at the TRA during 1952–93. The average disposal rate decreased from 2.0 Ci/yr during 1979–81 (Lewis and Jensen, 1985) to 0.65 Ci/yr during 1982–85 (Pittman and others, 1988, p. 35). The average disposal rate of cesium-137 during 1986–88 was 0.23 Ci/yr (Cecil and others, 1991, p. 36). The rate decreased during 1989–91 to 0.02 Ci/yr (Tucker and Orr, 1998, p. 17), and averaged 0.7 Ci/yr during 1992–93 (Bartholomay, 1998, p. 16). Cesium-137 has a half-life of 30.17 yrs (Walker and others, 1989, p. 34).

During 1996–98, the only detectable concentrations of cesium-137 were in water from shallow well TRA A-77. Concentrations that exceeded the reporting level ranged from 1,200±110 pCi/L in April 1997 to 42,300±1,800 pCi/L in April 1996.

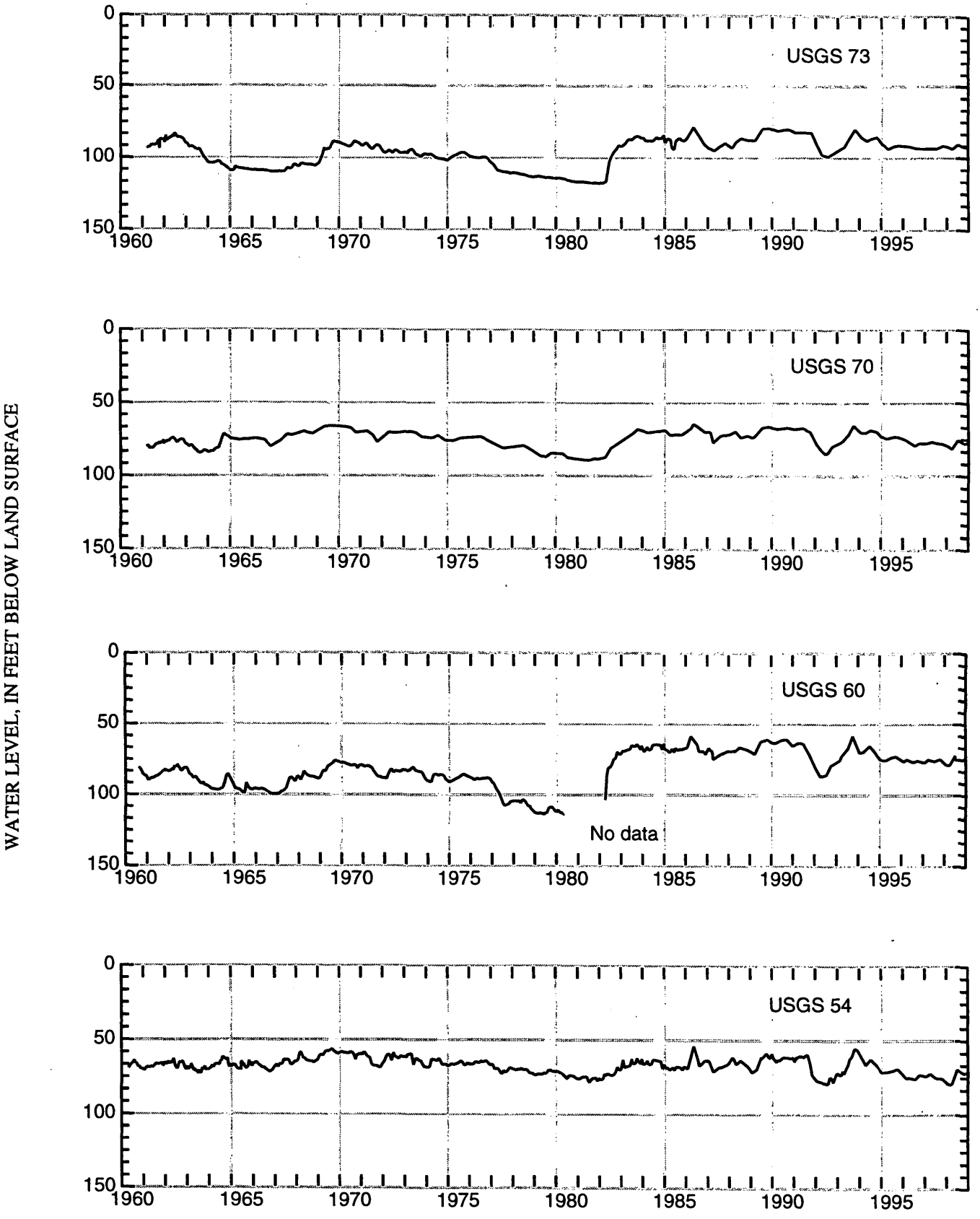

Figure 6. Water-level changes in selected wells, Test Reactor Area, 1960–98.

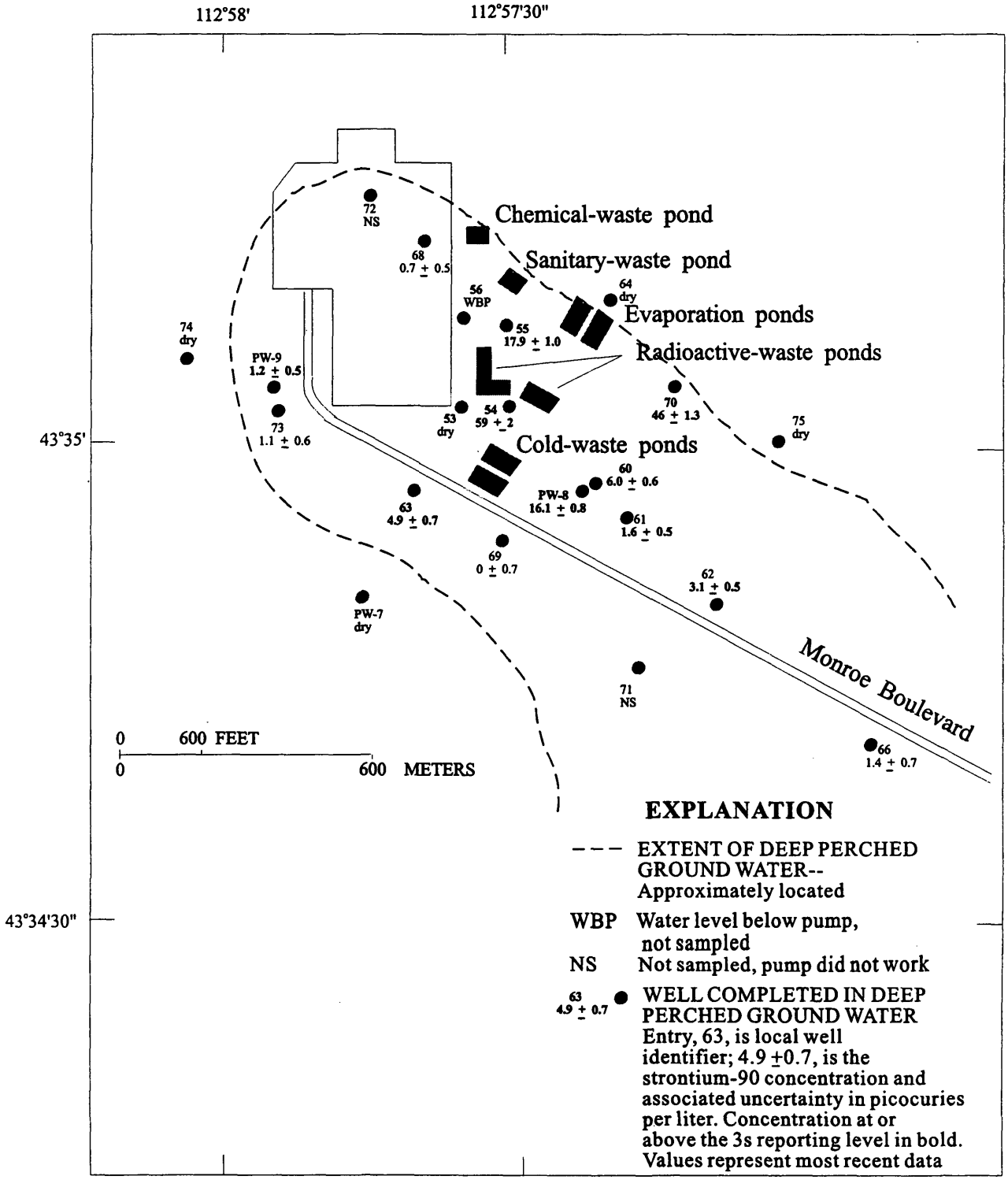

Figure 7. Concentrations of strontium-90 in deep perched ground water, Test Reactor Area, July–December 1998.

The general absence of detectable concentrations of cesium-137 in perched ground water at the TRA probably is due to a decrease in cesium disposal rates and to sorption of cesium-137 to minerals in sediments. The variable presence of cesium-137 in water from well TRA A-77 probably is due to the proximity of the well to a once leaky retention basin and to the amount of suspended sediment in the water samples collected.

Chromium-51.—About 2,390 Ci of chromium-51 was in wastewater discharged to the radioactive-waste and evaporation ponds during 1979–98. The average disposal rate of chromium-51 during 1979–81 was 766 Ci/yr (Pittman and others, 1988, p. 35). A total of 25.7 Ci of chromium-51 was discharged during 1986–88, an average of 8.6 Ci/yr (Cecil and others, 1991, p. 35). During 1989–91 a total of 11.6 Ci was discharged for an average of 3.9 Ci/yr (Tucker and Orr, 1998, p. 17). During 1992–95, a total of 10 Ci was discharged, an average of 2.5 Ci/yr (Bartholomay, 1998, p. 16). During 1996–98, a total of 6.2 Ci was discharged, an average of 2.1 Ci/yr. The half-life of chromium-51 is 27.7 days (Walker and others, 1989, p. 24).

Because of the decrease in the amount of chromium-51 discharged and the relatively short half-life, this radionuclide was not detected in water from wells completed in deep perched ground water during 1986–88 (Cecil and others, 1991, p. 35). Chromium-51 was not detected in shallow perched ground water from wells TRA A-13 and CWP-1 through CWP-9 during 1982–88. During 1989–91, chromium-51 was detected in water from wells TRA A-77, 53, and 56 (Tucker and Orr, 1998, p. 17). During 1992–95, chromium-51 was detected only in shallow well TRA A-77. Concentrations ranged from 2,700±500 to 24,500±1,300 pCi/L (Bartholomay, 1998, p. 16). During 1996–98, chromium-51 was not detected in any wells.

Cobalt-60.—Approximately 442 Ci of cobalt-60 was in wastewater discharged to the radioactive-waste ponds at the TRA during 1952–88. The average disposal rate of cobalt-60 decreased from 2.3 Ci/yr during 1979–81 to 1 Ci/yr during 1982–85 (Pittman and others, 1988). The average disposal rate was 2.2 Ci/yr during 1986–88, 0.15 Ci/yr during 1989–91, 0.8 Ci/yr during 1992–95 (Bartholomay, 1998, p. 16), and about 0.3 Ci/yr during 1996–98. The half-life of cobalt-60 is 5.27 years (Walker and others, 1989, p. 25).

During 1996–98, cobalt-60 concentrations in water from wells TRA A-77 and 56 (table 2) exceeded the reporting level. Concentrations of cobalt-60 in water from well TRA A-77 ranged from 7,700±260 to 44,000±1,400 pCi/L. The presence of cobalt-60 in the wells probably is due to their proximity to the radioactive-waste ponds and to the retention basin.

Chromium.—An estimated 24,000 lb of nonradioactive chromium in wastewater from TRA cooling-tower operations was discharged to the radioactive-waste ponds during 1952–64 (Mann and Knobel, 1988, p. 7–10). During 1964–72, a disposal well at the TRA was used for disposal of chromium directly to the Snake River Plain aquifer. In October 1972, chromium was replaced by a polyphosphate as a corrosion inhibitor in cooling-tower operations. No disposal of chromium to the subsurface was reported after 1972.

During 1996–98, concentrations of dissolved chromium in water from shallow perched ground water ranged from less than 5 µg/L in several wells to 26 µg/L in well TRA A-77. During 1996–98, dissolved chromium was detected in water from 14 wells completed in deep perched ground water at the TRA (table 3). The maximum concentration of dissolved chromium was 200 µg/L in well 56 in April 1996. In July–December 1998, concentrations of dissolved chromium from deep perched ground water ranged from an estimated 9.8 µg/L in well 54 and less than 14 µg/L in wells 66, 69, and 78 to 98 µg/L in well PW-9 (table 3 and fig. 8). The largest concentrations were in water from wells north and west of the radioactive-waste ponds (55, 73, and PW-9). The distribution of chromium indicates that water from these wells contains constituents discharged to the radioactive-waste ponds before 1965.

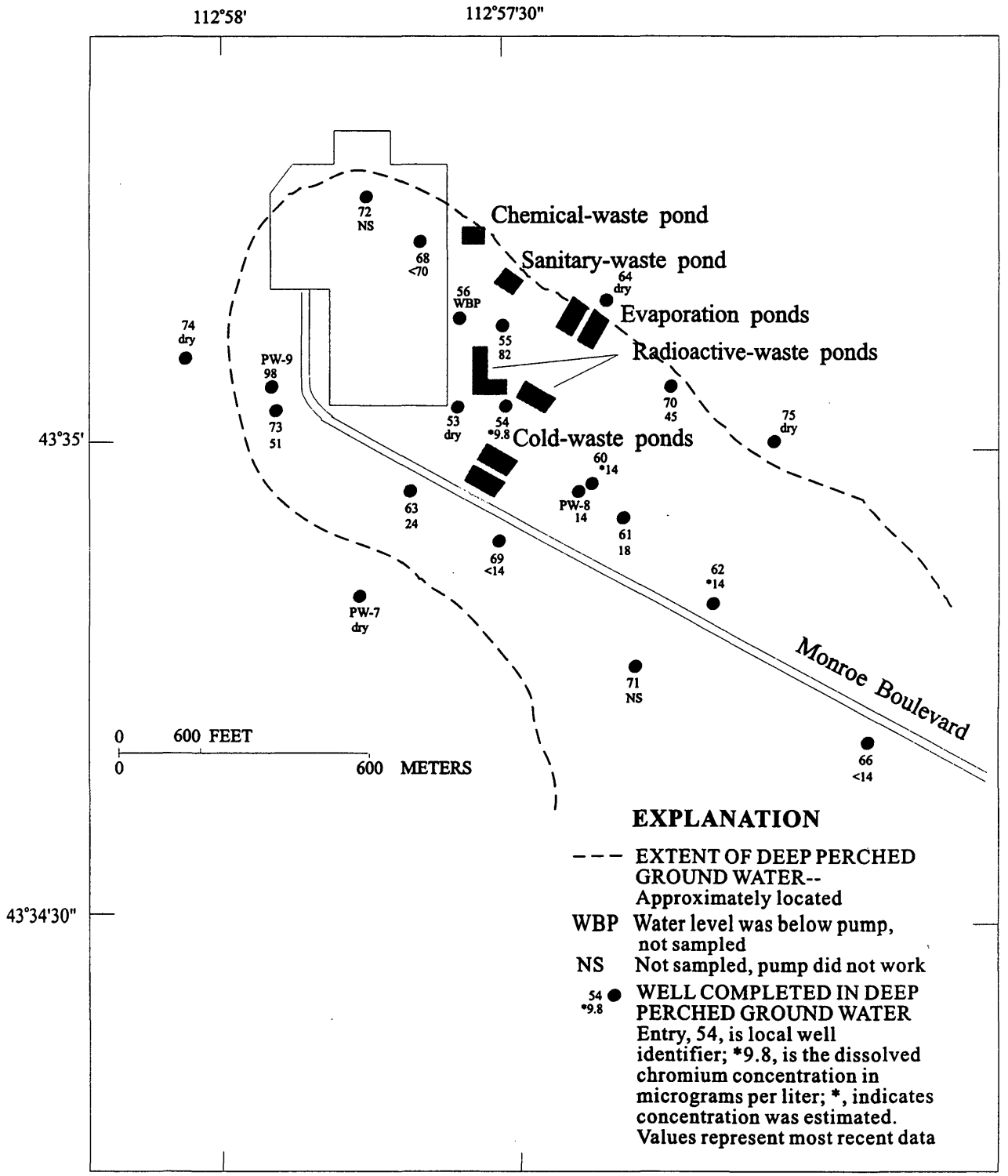

Figure 8. Concentrations of dissolved chromium in deep perched ground water, Test Reactor Area, July–December 1998.

In addition to dissolved chromium, samples were analyzed for hexavalent chromium until January 1997 because of its potential toxic effect on living organisms. Hexavalent chromium analysis was discontinued at the NWQL in January 1997. During 1996, concentrations of dissolved hexavalent chromium in shallow perched ground water ranged from 1 to 5 µg/L and, in deep perched ground water, from less than 1 to 160 µg/L (table 3).

Sodium.—An estimated 173,000 lb of sodium was in wastewater discharged to the chemical-waste pond during 1996–98. The total is the amount of sodium ion estimated from the sodium hydrate solution discharged. The average sodium concentration in wastewater discharged to the chemical-waste pond was about 2,000 mg/L.

During 1996–98, sodium concentrations in shallow perched ground water ranged from 7.6 mg/L in well TRA A-77 to 20 mg/L in well TRA A-13. Sodium concentrations in water from 17 wells completed in deep perched ground water also were determined. In July–December 1998, sodium concentrations ranged from 6.1 mg/L in well 78 to 1,000 mg/L in well 68 (table 3). The large concentration in water from well 68 is attributed to the large concentrations of sodium in wastewater discharged to the chemical-waste pond.

Chloride.—During 1996–98, approximately 3,600 lb of chloride was in wastewater discharged to the cold-waste ponds. Chloride concentrations in shallow perched ground water ranged from 9.3 mg/L in well CWP-4 to 27 mg/L in wells CWP-1 and TRA A-13 and, in deep perched ground water, from 3.1 mg/L in well 78 to 43 mg/L in wells 68 and 73 (table 3).

Sulfate.—During 1996–98, approximately 833,000 lb of sulfate was in wastewater discharged to the chemical-waste and cold-waste ponds at TRA, an average of 278,000 lb/yr. This represents a decline from the 595,500 lb/yr discharged during 1992–95 (Bartholomay, 1998).

Sulfate concentrations in water from wells completed in deep perched ground water ranged from 18 mg/L in well 78 to 3,200 mg/L in well 68 (table 3). The large concentration of sulfate in water from well 68 is due to the large quantity of sulfate discharged to the chemical-waste pond. The average sulfate concentration in wastewater discharged to the chemical-waste pond was about 4,300 mg/L during 1996–98. The maximum concentration in shallow perched ground water was 340 mg/L in well CWP-1. This concentration is attributed to sulfate disposal to nearby cold-waste ponds which, in 1996–98, averaged 272 mg/L. Concentrations in water from wells 54, 60, 63, 69, and PW-8, completed in deep perched ground water near the cold-waste ponds, ranged from 92 to 276 mg/L in July–October 1998 (fig. 9). These large concentrations indicate that water in the wells also was affected by discharge into the cold-waste ponds. Although similar quantities of sulfate were discharged to both the chemical-waste and cold-waste ponds, the larger volume of water discharged to the cold-waste ponds diluted the sulfate concentration in the perched water near the ponds.

Idaho Nuclear Technology and Engineering Center

Two wastewater-infiltration ponds were constructed south of the INTEC in 1984 and 1985 to replace the INTEC deep disposal well (fig. 3). Wastewater infiltrating from these ponds has formed perched ground water in the basalt and in sedimentary interbeds above the eastern Snake River Plain aquifer. The volumes of wastewater discharged to the well and infiltration ponds during 1962–98 are shown in figure 10. Annual discharge to the well and ponds ranged from 260 million gal in 1963 to 665 million gal in 1993 and averaged about 442 million gal. The average annual discharge during 1996–98 was about 570 million gal. Perched ground water also has been identified in other areas beneath the INTEC and may be attributed to other infiltration ponds, leaking wastewater lines, leach fields, ruptured casing in the upper part of the INTEC deep disposal well, and landscape irrigation (Tucker and Orr, 1998).

Many auger holes were drilled in 1983 to obtain geohydrologic and engineering data at the site of the planned INTEC infiltration ponds. Two of these holes (SWP-8 and SWP-13) subsequently were used to monitor shallow perched ground water in surficial sediment at the ponds. Wells PW-1, -2, -3, -4, -5, and -6 were completed in 1986 to

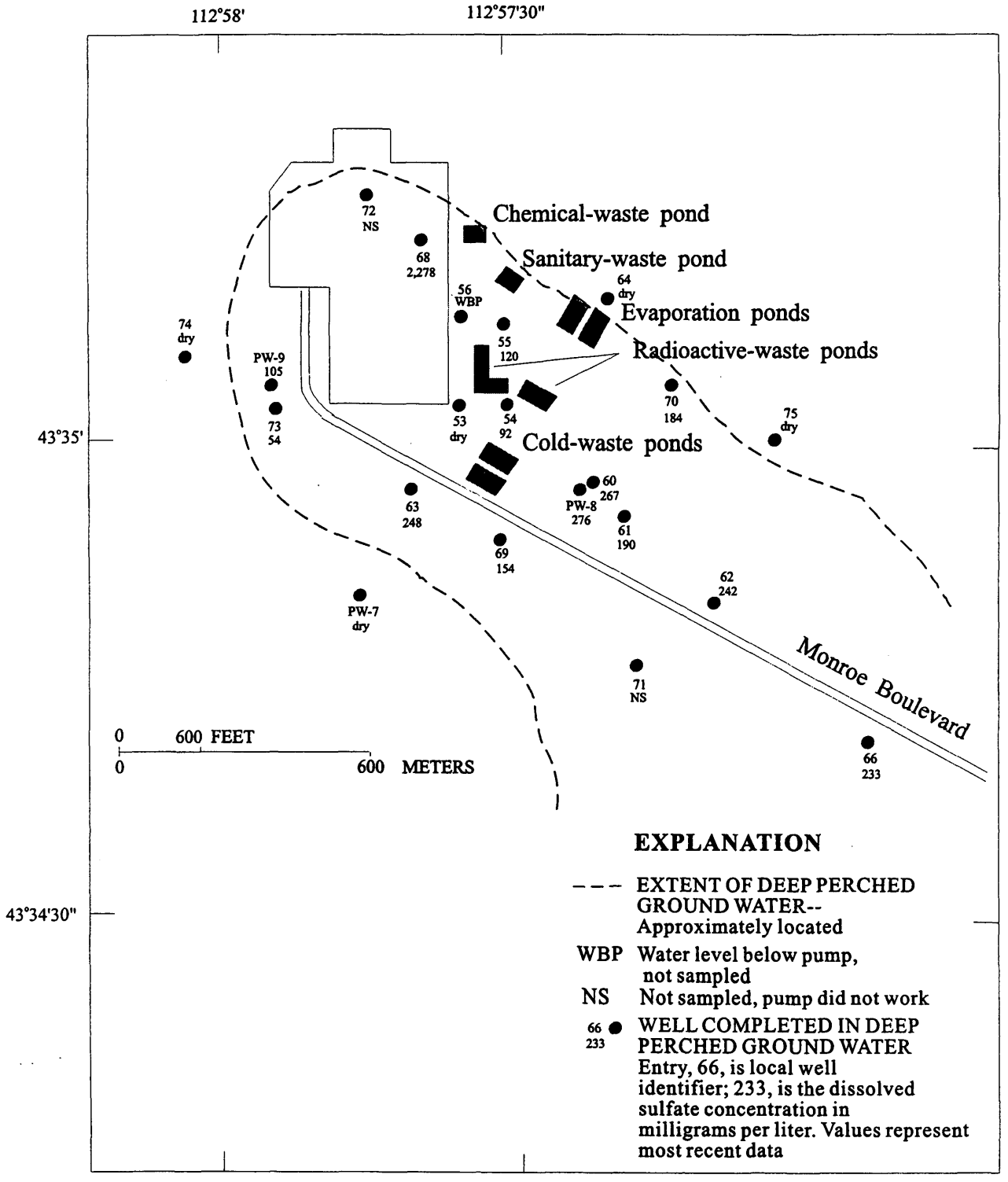

Figure 9. Concentrations of dissolved sulfate in deep perched ground water, Test Reactor Area, July–December 1998.

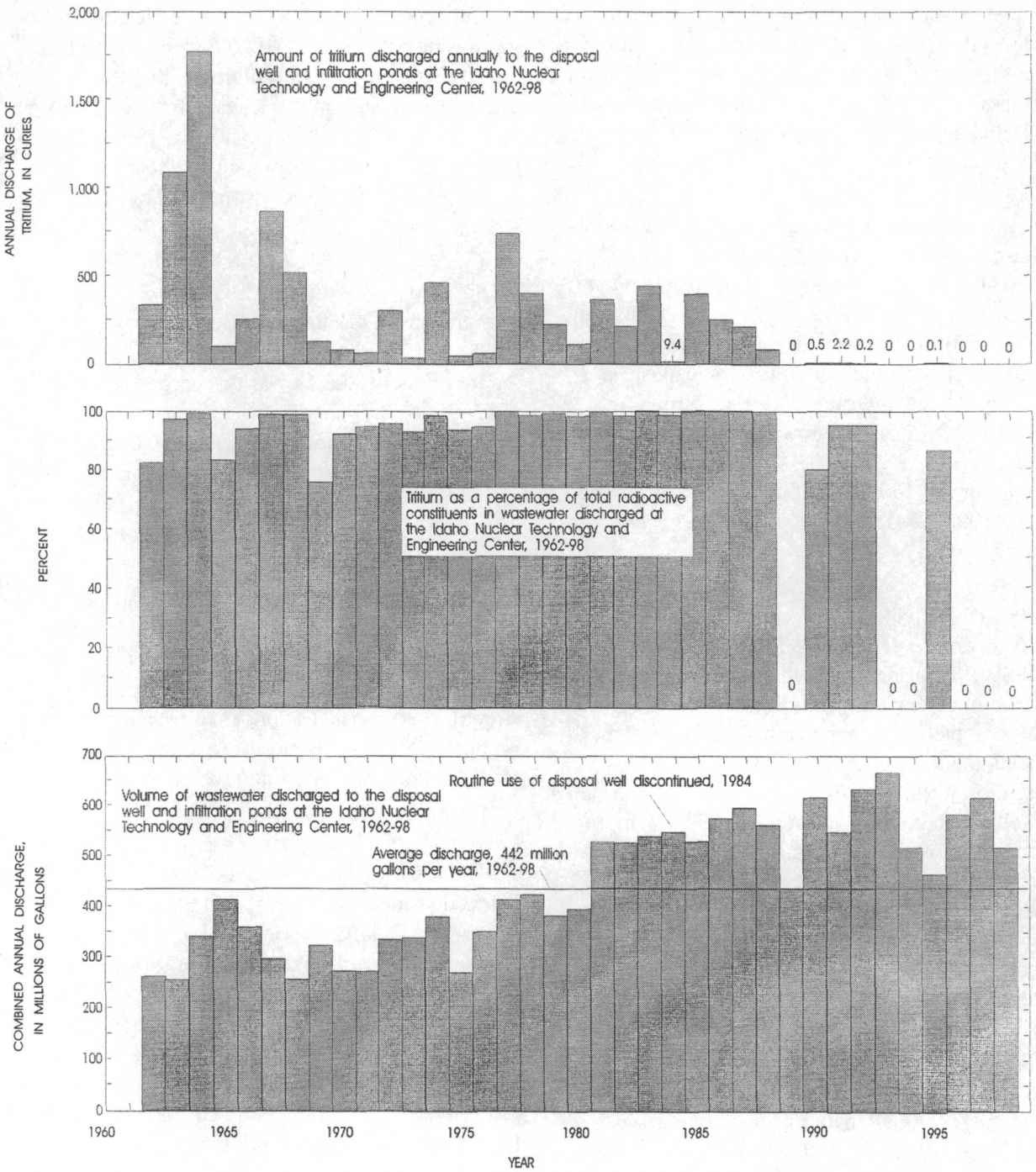

Figure 10. Amount of tritium discharged, tritium as a percentage of total radioactive constituents in wastewater discharged, and volume of wastewater discharged to the disposal well and infiltration ponds, Idaho Nuclear Technology and Engineering Center, 1962–98.

monitor deep perched ground-water levels and water-quality changes under the INTEC disposal ponds (fig. 3). Well 50 was used to monitor deep perched ground water near the INTEC deep disposal well. All these wells were sampled quarterly or semiannually during 1996–98 (table 1). Concentrations of selected constituents in water from these wells and auger holes are summarized in the following sections.

Tritium.—Most of the radioactivity in wastewater discharged to the infiltration ponds at the INTEC has been from tritium. Approximately 960 Ci of tritium in wastewater was discharged to the INTEC infiltration ponds during 1984–88. During 1986–88, the average rate of tritium disposal was 185 Ci/yr (Cecil and others, 1991). During 1989–91, 2.7 Ci of tritium was discharged to the ponds; during 1992–95, 0.3 Ci was discharged (Bartholomay, 1998); and there was no discharge during 1996–98 (fig. 10).

The tritium concentration in well SWP-13, completed in shallow perched water, was less than the reporting level in 1996. There was no water in well SWP-8 during 1996–98. During 1996–98, the maximum tritium concentration in water from wells completed in deep perched ground water beneath the infiltration ponds was 11.3±0.5 pCi/mL in well PW-6 (table 4). There was no water in well PW-6 in 1996 and January 1997. Tritium concentrations in water from wells near the infiltration ponds had declined significantly from concentrations during 1986–88, when disposal of tritium was about 185 Ci/yr. In October 1998, tritium concentrations in deep perched ground water beneath the infiltration ponds ranged from less than the 3s reporting level in PW-1 and PW-5 to 9.7±0.5 pCi/mL in PW-6 (table 4 and fig. 11).

During 1996–98, tritium concentrations in perched ground water in the wells closest to the ponds declined or remained less than 1 pCi/mL (table 4); declines can be attributed to the large decrease in disposal of tritium to the ponds and to radioactive decay. Tritium concentrations in water from well PW-6 were variable during 1996–98 but declined from concentrations reported during 1992–95 (Bartholomay, 1998).

During 1996–98, tritium concentrations in water from well 50 (fig. 11) generally declined from 55.5±2.0 pCi/mL in April 1996 to 37.3±1.4 pCi/mL in October 1998. The large tritium concentrations in water from well 50 may be due to leakage of wastewater from ruptures in the deep disposal well casing or to leakage from wastewater lines at the INTEC (Tucker and Orr, 1998). The tritium decline can be attributed to radioactive decay and dilution of well water from a nonradioactive source.

Strontium-90.—Approximately 0.3 Ci of strontium-90 was in wastewater discharged to the INTEC infiltration ponds during 1984–95. Approximately 0.03 Ci was discharged during 1996–98. Additional sources of strontium-90 in perched ground water at the INTEC include more than 33 Ci of strontium-90 reported to have been discharged to a shallow pit (fig. 12) in 1962–63 (Robertson and others, 1974, p. 119).

During 1996–98, concentrations of strontium-90 were variable in water from all the wells completed in the deep perched ground water beneath the INTEC infiltration ponds. In October 1998, strontium-90 concentrations in deep perched ground water in wells closest to the ponds ranged from less than the reporting level to 2.8±0.6 pCi/L in well PW-1 (fig. 12).

The largest concentrations of strontium-90 in perched ground water at the INTEC were in well 50 near the INTEC disposal well. During 1996–98, strontium-90 concentrations in water from well 50 were variable and ranged from 142±5 pCi/L in April 1997 to 190±20 pCi/L in April 1998 (table 4). Strontium-90 concentrations in water from well 50 may be due to leakage of wastewater from ruptures in the deep disposal well casing or to leakage from wastewater pipelines at the INTEC.

Cesium-137.—Wastewater discharged to the INTEC infiltration ponds during 1984–95 contained about 0.5 Ci of cesium-137. During 1996, wastewater discharged to the ponds contained about 0.0006 Ci of cesium-137; no cesium-137 was discharged during 1997–98.

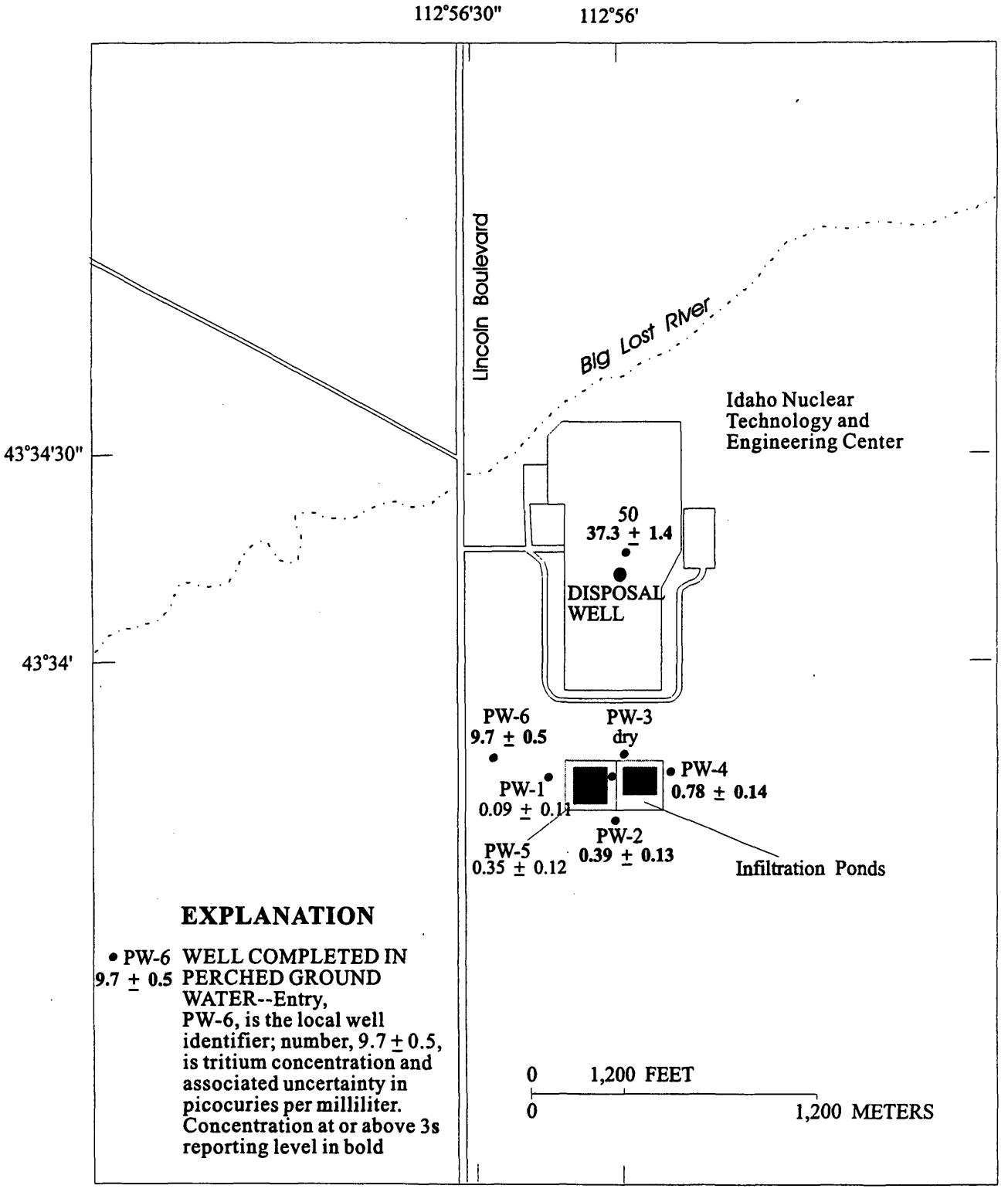

Figure 11. Concentrations of tritium in deep perched ground water, Idaho Nuclear Technology and Engineering Center, October 1998.

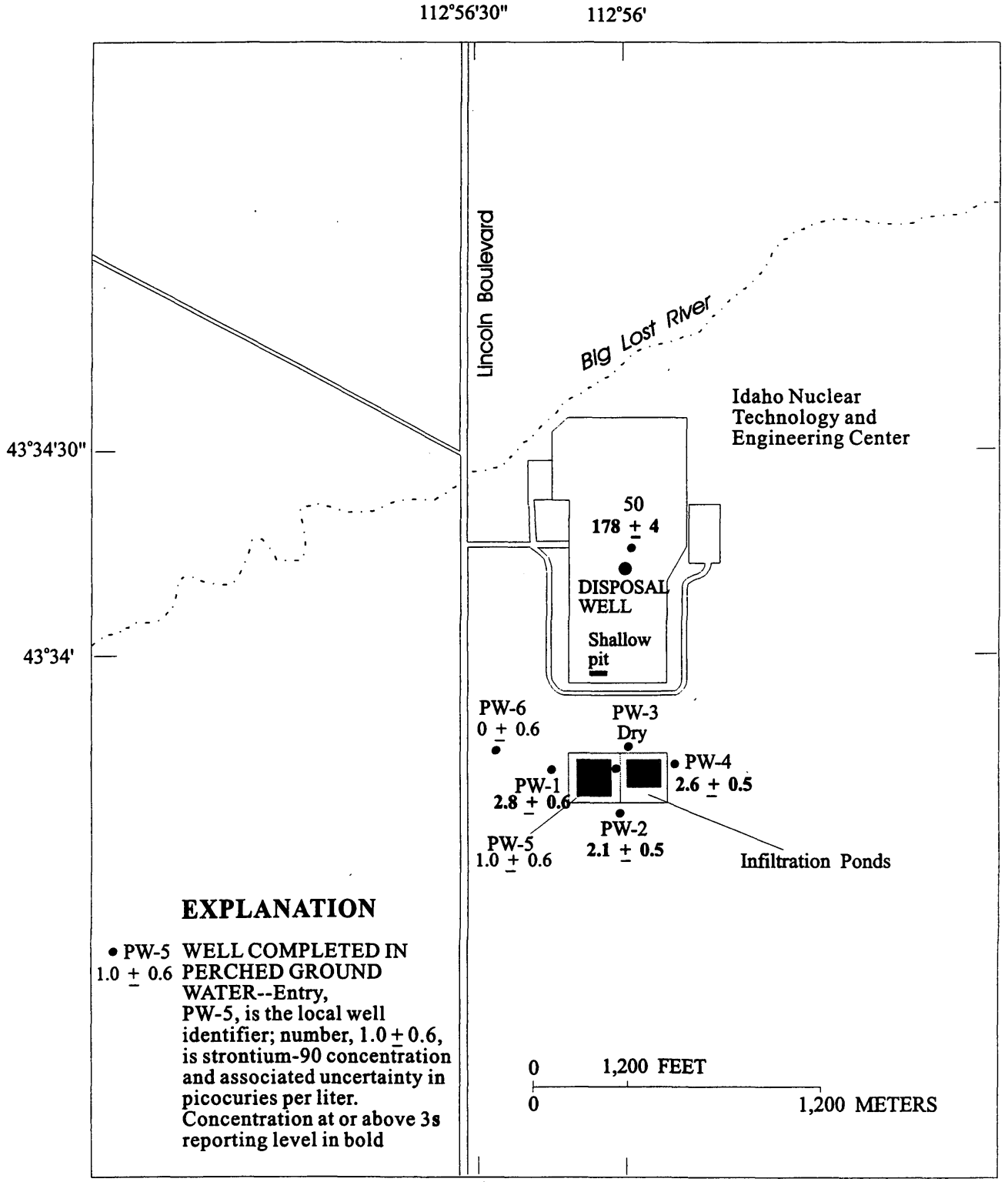

Figure 12. Concentrations of strontium-90 in deep perched ground water, Idaho Nuclear Technology and Engineering Center, October 1998.

During 1996–98, concentrations of cesium-137 did not exceed the reporting level in the perched ground water in wells closest to the infiltration pond or in well 50. The absence of detectable concentrations of cesium-137 in perched ground water at the INTEC is attributed to decreased disposal and to sorption of cesium-137 to minerals in sediments.

Sodium.—Approximately 708,000 lb of sodium was discharged to the INTEC infiltration ponds during 1996–98. The concentration of sodium in wastewater declined from a discharge-weighted average of 163 mg/L in 1996 to 124 mg/L in 1998.

The shallow perched ground water from well SWP-13 contained 170 mg/L of sodium in July 1996. During 1996–98, sodium concentrations in deep perched ground water in wells closest to the infiltration ponds ranged from 105 mg/L in well PW-1 in October 1998 to 197 mg/L in well PW-1 in October 1997 (table 5). In October 1998, sodium concentrations ranged from 105 to 142 mg/L in all wells with water. Sodium concentrations in shallow and deep perched ground water at the INTEC infiltration ponds were similar to the sodium concentrations in the wastewater.

Sodium concentrations in water from well 50 were nearly constant during 1996–98. The concentration in October 1998 was 62 mg/L. These sodium concentrations may be due to leakage of wastewater from ruptures in the deep disposal well casing or to leakage from wastewater pipelines at the INTEC.

Chloride.—Approximately 3.5 million lb of chloride was in wastewater discharged to the INTEC infiltration ponds during 1996–98. The concentration of chloride in wastewater declined from a discharge-weighted average of 281 mg/L in 1996 to 186 mg/L in 1998.

During 1996, the chloride concentration in water from well SWP-13, used for monitoring shallow perched ground water near the ponds, was 270 mg/L. During 1996–98, chloride concentrations in deep perched ground water in wells closest to the infiltration ponds ranged from 135 mg/L in well PW-6 to 386 mg/L in well PW-1 (table 5); in October 1998, concentrations ranged from 143 to 227 mg/L (table 5 and fig. 13). The chloride concentrations in shallow and deep perched ground water at the INTEC infiltration ponds were similar to the chloride concentrations in wastewater.

During 1996–98, chloride concentrations in water from well 50 were from 56 mg/L in October 1998 to 70 mg/L in October 1996 (table 5). The chloride concentrations may be due to leakage of wastewater from ruptures in the deep disposal well casing or to leakage from wastewater pipelines at the INTEC.

Sulfate.—Approximately 440,000 lb of sulfate was in wastewater discharged to the INTEC infiltration ponds during 1996–98. The concentration of sulfate in wastewater was nearly constant; the discharge-weighted average concentration in 1996–98 was 31 mg/L.

Sulfate concentrations in shallow perched ground water from well SWP-13 contained 30 mg/L of sulfate in July 1996, which was similar to the average wastewater concentration. Sulfate concentrations in water from wells completed in the deep perched ground water closest to the INTEC infiltration ponds ranged from 14 to 41 mg/L in 1998 (table 5). These concentrations were consistent with the average concentration in the wastewater.

The concentrations of sulfate in samples from well 50 (table 5) ranged from 39 to 44 mg/L during 1996–98. The sulfate concentrations may be due to leakage of wastewater from ruptures in the casing of the deep disposal well or to leakage from wastewater pipelines at the INTEC.

Nitrate.—Approximately 260,000 lb of nitrate was in wastewater discharged to the INTEC infiltration ponds during 1996–98; about 221,000 lb was discharged in February 1996. The concentration of nitrate (as nitrogen) in wastewater ranged from a discharge-weighted average of 50 mg/L in 1996 to 1.1 mg/L in 1998.

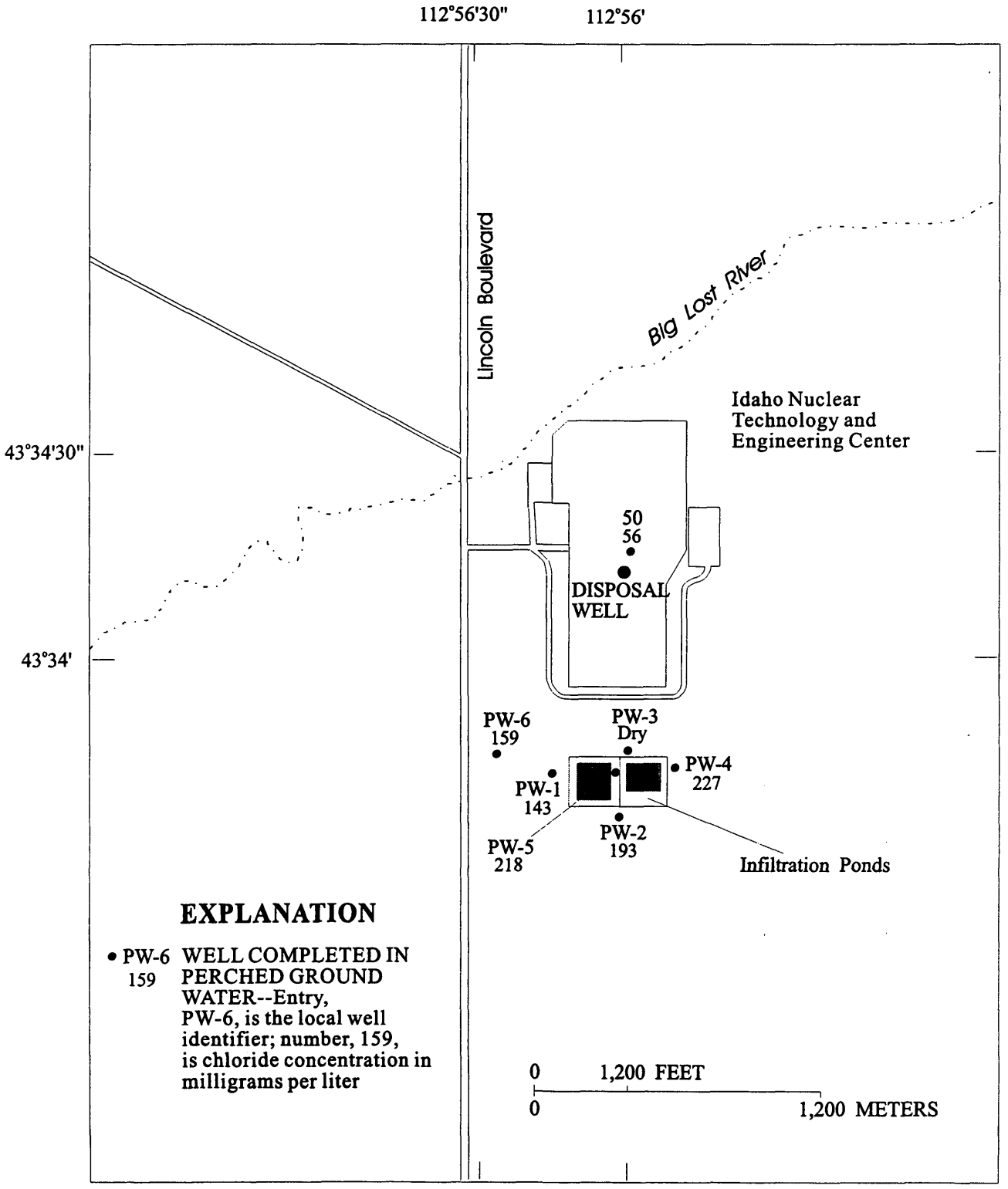

Figure 13. Concentrations of dissolved chloride in deep perched ground water, Idaho Nuclear Technology and Engineering Center, October 1998.

Nitrite plus nitrate (as nitrogen) analyses are done annually on shallow perched ground-water wells at the infiltration ponds and on water from well 50. Nitrite analyses indicate that almost all the nitrite plus nitrate concentration is from nitrate.

The nitrite plus nitrate (as nitrogen) concentration in water from SWP-13 during July 1996 was 1.3 mg/L. This concentration was less than the nitrate concentrations in wastewater.

During 1996–98, nitrite plus nitrate (as nitrogen) concentrations in water from well 50 ranged from 31 mg/L in October 1996 to 59 mg/L in October 1998 (table 5). The nitrate concentration may be due to a combination of leakage of wastewater from the ruptured deep disposal well casing and from leakage from wastewater pipelines at the INTEC.

Radioactive Waste Management Complex

Solid and liquid radioactive and chemical wastes have been buried in trenches and pits excavated in the surficial sediment at the Subsurface Disposal Area (SDA) at the RWMC (fig. 3) since 1952. Before 1970, little or no sediment was retained between the excavation bottoms and the underlying basalt. Since 1970, a layer of sediment has been retained in trenches and pits to inhibit downward migration of waste constituents. These constituents include transuranic wastes (disposed of in trenches until 1970), other radiochemical and inorganic chemical constituents, and organic compounds.

About 9,600 Ci of plutonium-238, 160,000 Ci of plutonium-239, 38,000 Ci of plutonium-240, 960,000 Ci of plutonium-241, and 365,000 Ci of americium-241 were buried at the SDA during 1952–70 (Becker and others, 1998, table 4–1). An estimated 88,400 gal of organic waste was buried before 1970 (Mann and Knobel, 1987, p. 1). These buried wastes included about 24,400 gal of carbon tetrachloride, 39,000 gal of lubricating oil, and about 25,000 gal of other organic compounds, including trichloroethane, trichloroethylene, perchloroethylene, toluene, and benzene.

Perched ground water beneath the RWMC is in sedimentary interbeds in basalts and can be attributed partly to local infiltration of snowmelt and rain and to recharge from the Big Lost River and the INEEL spreading areas.

Well 92 (fig. 3) is in the SDA of the RWMC and is completed in a sedimentary interbed (Anderson and Lewis, 1989, p. 29) 214 ft below land surface. Perched water in this well has moved through overlying sediments and basalt and may contain waste constituents leached from radiochemical and organic chemical wastes buried in the SDA. Small amounts of water in well 92 frequently preclude collection of an adequate sample for analyses. Full samples were collected during October 1996 and in the spring of 1996–98; a partial sample was collected in October 1997; and there was no water in the well in October 1998.

During 1996–98, radiochemical constituents in all water samples from well 92 (table 6) were below the reporting level. The concentration of americium-241 was above the reporting level in October 1992, and the concentration of plutonium-238 was above the reporting level in November 1994 (Bartholomay, 1998).

Chloride concentrations in water from four samples collected from well 92 ranged from 69 to 78 mg/L during 1996–98 (table 6).

In 1987, nine purgeable organic compounds were detected in water from well 92 (Mann and Knobel, 1987, p. 16–17); in January 1990, six purgeable organic compounds were detected; and in April 1992, water contained concentrations of 18 different purgeable organic compounds (Bartholomay, 1998, p. 28; Greene and Tucker, 1998). Table 7 lists the concentrations of 14 different purgeable organic compounds detected in 1996–98.

A water sample was collected from well 92 in June 1989 for analyses of 54 extractable acid and base/neutral organic compounds. None of the 54 compounds were detected at concentrations exceeding their respective reporting levels, but several tentatively identified organic compounds were detected (Knobel, Bartholomay, and others, 1992, p. 37–38).

SUMMARY

Deep and shallow perched ground water is present in basalt and sediments beneath several facilities at the INEEL as a result of low-level radioactive, chemical, and sanitary wastewater discharge to infiltration ponds since 1952. During 1996–98, approximately 220 million gal/yr was discharged to infiltration and evaporation ponds at the TRA, and 570 million gal/yr was discharged to infiltration ponds at the INTEC.

During 1952–93, approximately 10,500 Ci of tritium was in wastewater discharged to the TRA radioactive-waste ponds. About 430 Ci of tritium was discharged to the TRA radioactive-waste evaporation ponds during 1996–98. In 1998, tritium concentrations in water from nine wells completed in shallow perched ground water near the cold-waste pond at TRA were less than the reporting level. In 1998, tritium concentrations in water from wells completed in deep perched ground water ranged from less than the reporting levels to 116±4 pCi/mL.

Several factors have affected the distribution of tritium in perched ground water in wells at the TRA. These factors include proximity of the well to the radioactive-waste ponds, depth of water below the ponds, variations in tritium disposal rates, and radioactive decay. Tritium concentrations also were affected by dilution from the cold-waste ponds. The replacement of the radioactive-waste ponds by evaporation ponds in 1993 contributed to declines in tritium concentrations in perched ground water. Additional dilution of tritium concentrations in perched ground water southeast of the TRA can be attributed to infiltration of Big Lost River water.

During 1952–93, approximately 93 Ci of strontium-90 was in wastewater discharged to the TRA radioactive-waste ponds. Only 0.03 Ci was discharged to the evaporation ponds during 1996–98. In October 1998, concentrations of strontium-90 in deep perched ground water from seven wells were above reporting levels; concentrations were from 1.6±0.5 to 59±2 pCi/L. The distribution of strontium-90 in perched water at the TRA and the small quantity of strontium-90 discharged indicate that concentration variations probably are due to chemical equilibrium reactions between strontium-90 sorbed to sediments beneath the radioactive-waste ponds and strontium-90 in solution in water passing through those sediments.

The general absence of detectable concentrations of cesium-137 in perched ground water at the TRA probably is due to a decrease in disposal rates and to sorption of cesium-137 to minerals in sediments. The presence of cesium-137 and cobalt-60 in one well completed in shallow perched ground water is attributed to the proximity of the well to a once leaky retention basin and to the large amount of suspended sediment in the water samples collected.

Wastewater from TRA cooling-tower operations containing an estimated 24,000 lb of chromium was discharged to the radioactive-waste ponds during 1952–64. In July–October 1998, concentrations of dissolved chromium in deep perched ground water at the TRA ranged from less than 14 to 98 µg/L. The largest concentrations were in water from wells north and west of the radioactive-waste ponds. This distribution of chromium indicates that water from these wells contains constituents that were discharged to the radioactive-waste ponds before 1965.

Approximately 173,000 lb of sodium was discharged to the TRA chemical-waste pond during 1996–98. In July–December 1998, sodium concentrations ranged from 6.1 to 1,000 mg/L. The large sodium concentration in water from a well near the chemical-waste pond was due to the large sodium concentrations in wastewater discharged to the chemical-waste pond.

Wastewater that contained about 833,000 lb of sulfate was discharged to the chemical-waste and cold-waste ponds at TRA during 1996–98. During 1998, the sulfate concentration in water from wells completed in deep perched ground water ranged from 18 to 3,200 mg/L. The large sulfate concentration in water from a well near the chemical-waste pond was due to the large sulfate concentrations in wastewater discharged to the pond.

Two infiltration ponds were constructed south of the INTEC in 1984 and 1985 to replace the INTEC deep disposal well. Wastewater from these ponds has formed perched ground water in the basalt and in sedimentary interbeds above the Snake River Plain aquifer. Perched ground water has been identified in other areas beneath the INTEC and may be attributed to other infiltration ponds, leaking wastewater lines, leach fields, ruptured casing in the upper part of the INTEC deep injection well, and landscape irrigation.

Approximately 960 Ci of tritium was discharged to the INTEC infiltration ponds during 1984–88. During 1986–88, the average rate of tritium disposal was 185 Ci/yr. During 1989–91, 2.7 Ci of tritium was discharged to the ponds; during 1992–95, 0.3 Ci was discharged; there was no discharge during 1996–98. During 1996–98, tritium concentrations in water from wells closest to the infiltration ponds declined significantly from concentrations during 1986–88. In October 1998, tritium concentrations in deep perched ground water beneath the infiltration ponds ranged from less than the reporting level to 9.7±0.5 pCi/mL.

Approximately 0.03 Ci of strontium-90 was in wastewater discharged to the INTEC infiltration ponds during 1996–98. During 1996–98, the maximum strontium-90 concentration was 5.7±1.5 pCi/L in water from well PW-6 in 1997. In October 1998, strontium-90 concentrations in deep perched ground water in wells closest to the ponds ranged from below the reporting level to 2.8±0.6 pCi/L.

Wastewater discharged to the INTEC infiltration ponds during 1984–95 contained about 0.5 Ci of cesium-137. During 1996–98, wastewater discharged to the ponds contained about 0.0006 Ci of cesium-137. Concentrations of cesium-137 did not exceed the reporting level in perched ground water. The absence of detectable concentrations of cesium-137 in perched ground water at the INTEC is attributed to decreased disposal and sorption of cesium-137 to minerals in sediments.

Approximately 708,000 lb of sodium was discharged to the INTEC infiltration ponds during 1996–98. Sodium concentrations in deep perched ground water near the infiltration ponds ranged from 105 to 197 mg/L and were similar to sodium concentrations in the wastewater.

Approximately 3.5 million lb of chloride was discharged to the INTEC infiltration ponds during 1996–98. Chloride concentrations in deep perched ground water near the infiltration ponds ranged from 135 to 386 mg/L and were similar to chloride concentrations in wastewater.

Approximately 440,000 lb of sulfate was discharged to the INTEC infiltration ponds during 1996–98. During 1998, sulfate concentrations in deep perched ground water beneath the INTEC infiltration ponds ranged from 14 to 41 mg/L and were similar to sulfate concentrations in wastewater.

Approximately 260,000 lb of nitrate was discharged to the INTEC infiltration ponds during 1996–98. Nitrite plus nitrate (as nitrogen) concentrations in perched water near the INTEC deep disposal well ranged from 31 to 59 mg/L.

Tritium and other radiochemical and inorganic chemical constituents in perched water from well 50, near the INTEC deep injection well, may be due to leakage of wastewater from ruptures in the deep disposal well casing or from leaky wastewater pipelines.

Perched ground water beneath the RWMC is in sedimentary interbeds in basalts and can be attributed partly to local infiltration of snowmelt and rainfall and to recharge from the Big Lost River and the INEEL spreading areas and, therefore, may contain waste constituents leached from radiochemical and organic chemical wastes buried at the RWMC. During 1996–98, radiochemical constituents in all water samples from well 92 were below the reporting level. Chloride concentrations in four samples from well 92 ranged from 69 to 78 mg/L. During 1996–98, samples contained concentrations greater than the reporting levels of 14 different purgeable organic compounds.

SELECTED REFERENCES

Ackerman, D.J., 1991, Transmissivity of perched aquifers at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 91–4114 (DOE/ID–22099), 27 p.

American Society for Testing and Materials, 1992, ASTM standards on precision and bias for various applications: Philadelphia, Pa., American Society for Testing and Materials Publication code number (PCN) 03–511092–34, 478 p.

Anderson, S.R., 1991, Stratigraphy of the unsaturated zone and uppermost part of the Snake River Plain aquifer at the Idaho Chemical Processing Plant and Test Reactors Area, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 91–4010 (DOE/ID–22095), 71 p.

Anderson, S.R., and Bowers, B., 1995, Stratigraphy of the unsaturated zone and uppermost part of the Snake River Plain aquifer at Test Area North, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 95–4130 (DOE/ID–22122), 47 p.

Anderson, S.R., and Lewis, B.D., 1989, Stratigraphy of the unsaturated zone at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 89–4065 (DOE/ID–22080), 54 p.

Anderson, S.R., and Liszewski, M.J., 1997, Stratigraphy of the unsaturated zone and the Snake River Plain aquifer at and near the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 97–4183 (DOE/ID–22142), 65 p.

Anderson, S.R., Liszewski, M.J., and Cecil, L.D., 1997, Geologic ages and accumulation rates of basalt-flow groups and sedimentary interbeds in selected wells at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 97–4010 (DOE/ID–22134), 39 p.

Barraclough, J.T., and Jensen, R.G., 1976, Hydrologic data for the Idaho National Engineering Laboratory site, Idaho, 1971 to 1973: U.S. Geological Survey Open-File Report 75–318 (DOE/ID–22055), 52 p.

Barraclough, J.T., Lewis, B.D., and Jensen, R.G., 1981, Hydrologic conditions at the Idaho National Engineering Laboratory, Idaho, *emphasis* 1974–1978: U.S. Geological Survey Water-Resources Investigations Open-File Report 81–526 (DOE/ID–22060), 77 p.

Barraclough, J.T., Robertson, J.B., and Janzer, V.J., 1976, Hydrology of the solid waste burial ground, as related to the potential migration of radionuclides, Idaho National Engineering Laboratory, *with a section on* Drilling and sample analyses, by L.G. Saindon: U.S. Geological Survey Open-File Report 76–471 (DOE/ID–22056), 183 p.

Barraclough, J.T., Teasdale, W.E., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1965: U.S. Geological Survey Open-File Report (DOE/ID–22048), 107 p.

Barraclough, J.T., Teasdale, W.E., Robertson, J.B., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1966: U.S. Geological Survey Open-File Report (DOE/ID–22049), 95 p.

Bartholomay, R.C., 1993, Concentrations of tritium and strontium-90 in water from selected wells at the Idaho National Engineering Laboratory after purging one, two, and three borehole volumes: U.S. Geological Survey Water-Resources Investigations Report 93–4201 (DOE/ID–22111), 21 p.

——1998, Distribution of selected radiochemical and chemical constituents in perched ground water, Idaho National Engineering Labora-

tory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 98–4026 (DOE/ID–22145), 59 p.

Bartholomay, R.C., Hill, G.M., and Randolph, R.B., 1999, Statistical comparison of gross alpha- and gross beta-particle activity in water analyzed using two different laboratory methods: 1999 41st Rocky Mountain Conference on Analytical Chemistry, final program and abstracts, p. 132.

Bartholomay, R.C., Orr, B.R., Liszewski, M.J., and Jensen, R.G., 1995, Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, Idaho National Engineering Laboratory, Idaho, 1989 through 1991: U.S. Geological Survey Water-Resources Investigations Report 95–4175 (DOE/ID–22123), 47 p.

Bartholomay, R.C., Tucker, B.J., Ackerman, D.J., and Liszewski, M.J., 1997, Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, Idaho National Engineering Laboratory, Idaho, 1992 through 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4086 (DOE/ID–22137), 57 p.

Bartholomay, R.C., Tucker, B.J., Davis, L.C., and Greene, M.R., 2000, Hydrologic conditions and distribution of selected constituents in water, Idaho National Engineering and Environmental Laboratory, Idaho, 1996 through 1998: U.S. Geological Survey Water-Resources Investigations Report 00-4192, (DOE/ID–22167), 52 p.

Bartholomay, R.C., and Williams, L.M., 1996, Evaluation of preservation methods for selected nutrients in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 96–4260 (DOE/ID–22131), 16 p.

Becker, B.H., Burgess, J.D., Holdren, K.J., Jorgensen, D.K., Magnuson, S.O., and Sondrup, A.J., 1998, Interim risk assessment and contaminant screening for the waste area group 7 remedial investigation: Lockheed Martin Idaho Technologies Co. report, DOE/ID–10569, [variously paged].

Cecil, L.D., Knobel, L.L., Wegner, S.J., and Moore, L.L., 1989, Evaluation of field sampling and preservation methods for strontium-90 in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 89–4146 (DOE/ID–22083), 24 p.

Cecil, L.D., Orr, B.R., Norton, T., and Anderson, S.R., 1991, Formation of perched groundwater zones and concentrations of selected chemical constituents in water, Idaho National Engineering Laboratory, Idaho, 1986–88: U.S. Geological Survey Water-Resources Investigations Report 91–4166 (DOE/ID–22100), 53 p.

Claassen, H.C., 1982, Guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an aquifer: U.S. Geological Survey Open-File Report 82–1024, 49 p.

Currie, L.A., 1984, Lower limit of detection-definition and elaboration of a proposed position for radiological effluent and environmental measurements: U.S. Nuclear Regulatory Commission NUREG/CR–4007, 139 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

French, D.L., Lisee, D.J., and Taylor, K.A., 1997a, Idaho National Engineering and Environmental Laboratory nonradiological waste management information for 1996 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10057 (96), [variously paged].

——1997b, Radioactive waste management information for 1996 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10054 (96), [variously paged].

French, D.L., Tallman, R.E., and Taylor, K.A., 1998, Idaho National Engineering and Environmental Laboratory nonradiological waste management information for 1997 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10057 (97), [variously paged].

——1999a, Idaho National Engineering and Environmental Laboratory nonradiological waste management information for 1998 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations office Publication, DOE/ID–10057 (98), [variously paged].

——1999b, Radioactive waste management information for 1998 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10054 (98), [variously paged].

French, R.L., and Taylor, K.A., 1998, Radioactive waste information for 1997 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10054 (97), [variously paged].

Goerlitz, D.F., and Brown, Eugene, 1972, Methods for analysis of organic substances in water: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 40 p.

Greene, M.J., and Tucker, B.J., 1998, Purgeable organic compounds in water at or near the Idaho National Engineering Laboratory, Idaho, 1992–95: U.S. Geological Survey Open-File Report 98–51 (DOE/ID–22146), 21 p.

Hull, L.C., 1989, Conceptual model and description of the affected environment for the TRA warm waste pond (Waste Management Unit TRA-03); EG&G Idaho Informal Report EGG–ER–8644, 125 p.

Jones, P.H., 1961, Hydrology of waste disposal, National Reactor Testing Station, Idaho, an interim report: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22042–USGS, 152 p.

Knobel, L.L., Bartholomay, R.C., Cecil, L.D., Tucker, B.J., and Wegner, S.J., 1992, Chemical constituents in the dissolved and suspended fractions of ground water from selected sites, Idaho National Engineering Laboratory and vicinity, Idaho, 1989: U.S. Geological Survey Open-File Report 92–51 (DOE/ID–22101), 56 p.

Knobel, L.L., Bartholomay, R.C., and Orr, B.R., 1997, Preliminary delineation of natural geochemical reactions, Snake River Plain aquifer system, Idaho National Engineering Laboratory and vicinity, Idaho: U.S. Geological Survey Water-Resources Investigations Report 97–4093 (DOE/ID–22139), 52 p.

Knobel, L.L., and Mann, L.J., 1993, Sampling for purgeable organic compounds using positive-displacement piston and centrifugal submersible pumps—a comparative study: Ground Water Monitoring Review, Spring 1993, p. 142–148.

Knobel, L.L., Orr, B.R., and Cecil, L.D., 1992, Summary of background concentrations of selected radiochemical and chemical constituents in ground water from the Snake River Plain aquifer, Idaho—estimated from an analysis of previously published data: Journal of the Idaho Academy of Science, v. 28, no. 1, p. 48–61.

Lewis, B.D., and Jensen, R.G., 1985, Hydrologic conditions at the Idaho National Engineering Laboratory, Idaho, 1979–1981 update: U.S. Geological Survey Hydrologic Investigations Atlas HA–674, 2 sheets.

Liszewski, M.J., Rosentreter, J.J., and Miller, K.E, 1997, Strontium distribution coefficients of surficial sediment samples from the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 97–4044 (DOE/ID–22140), 33 p.

Liszewski, M.J., Rosentreter, J.J., Miller, K.E, and Bartholomay, R.C., 1998, Strontium distribution coefficients of surficial and sedimentary interbed samples from the Idaho National Engineering and Environmental Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 98–4073 (DOE/ID–22149), 55 p.

Mann, L.J., 1996, Quality-assurance plan and field methods for quality-of-water activities, U.S. Geological Survey, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 96–615 (DOE/ID–22132), 37 p.

Mann, L.J., and Knobel, L.L., 1987, Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 87–766 (DOE/ID–22074), 23 p.

——1988, Concentrations of nine trace metals in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 88–332 (DOE/ID–22075), 17 p.

Morris, D.A., Barraclough, J.T., Chase, G.H., Teasdale, W.E., and Jensen, R.G., 1965, Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho, annual progress report, 1964: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22047–USGS, 186 p.

Morris, D.A., Barraclough, J.T., Hogenson, G.M., Shuter, Eugene, Teasdale, W.E., Ralston, D.A., and Jensen, R.G., 1964, Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho, annual progress report, 1963: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22046–USGS, 97 p.

Morris, D.A., Hogenson, G.M., Shuter, Eugene, and Teasdale, W.E., 1963, Hydrology of waste disposal, National Reactor Testing Station, Idaho, annual progress report, 1962: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22044–USGS, 99 p.

Mundorff, M.J., Crosthwaite, E.G., and Kilburn, Chabot, 1964, Ground water for irrigation in the Snake River Basin in Idaho: U.S. Geological Survey Water-Supply Paper 1654, 224 p.

Nace, R.L., Voegeli, P.T., Jones, J.R., and Deutsch, Morris, 1975, Generalized geologic framework of the National Reactor Testing Station, Idaho: U.S. Geological Survey Professional Paper 725–B, 49 p.

Olmsted, F.H., 1962, Chemical and physical character of ground water in the National Reactor Testing Station, Idaho: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22043–USGS, 142 p.

Orr, B.R., 1999, A transient numerical simulation of perched ground-water flow at the Test Reactor Area, Idaho National Engineering and Environmental Laboratory, Idaho, 1952–94: U.S. Geological Survey Water-Resources Investigations Report 99–4277 (DOE/ID–22162), 54 p.

Orr, B.R., and Cecil, L.D., 1991, Hydrologic conditions and distribution of selected chemical constituents in water, Snake River Plain aquifer, Idaho National Engineering Laboratory, Idaho, 1986 to 1988: U.S. Geological Survey Water-Resources Investigations Report 91–4047 (DOE/ID–22096), 56 p.

Pace, M.N., Rosentreter, J.J., and Bartholomay, R.C., 1999, Strontium distribution coefficients of basalt and sediment infill samples from the Idaho National Engineering and Environmen-

tal Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 99–4145 (DOE/ID–22158), 56 p.

Pittman, J.R., Jensen, R.G., and Fischer, P.R., 1988, Hydrologic conditions at the Idaho National Engineering Laboratory, 1982 to 1985: U.S. Geological Survey Water-Resources Investigations Report 89–4008 (DOE/ID–22078), 73 p.

Robertson, J.B., 1977, Numerical modeling of subsurface radioactive solute transport from waste-seepage ponds at the Idaho National Engineering Laboratory: U.S. Geological Survey Open-File Report 76–717 (DOE/ID–22057), 68 p.

Robertson, J.B., Schoen, Robert, and Barraclough, J.T., 1974, The influence of liquid waste disposal on the geochemistry of water at the National Reactor Testing Station, Idaho, 1952–1970: U.S. Geological Survey Open-File Report (DOE/ID–22053), 231 p.

Stevens, H.H., Jr., Ficke, J.F., and Smoot, G.F., 1975, Water temperature—influential factors, field measurement, and data presentation: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. D1, 65 p.

Timme, P.J., 1995, National Water Quality Laboratory, 1995 services catalog: U.S. Geological Survey Open-File Report 95–352, 120 p.

Tucker, B.J., and Orr, B.R., 1998, Distribution of selected radiochemical and chemical constituents in perched ground water, Idaho National Engineering Laboratory, Idaho, 1989–91: U.S. Geological Survey Water-Resources Investigations Report 98–4028 (DOE/ID–22144), 62 p.

U.S. Department of Energy, Environmental Sciences Branch, Radiological and Environmental Sciences Laboratory, 1991, INEL site environmental surveillance data for the fourth quarter, 1990: U.S. Department of Energy Environmental Surveillance Quarterly Report, 49 p.

Walker, E.H., 1964, Subsurface geology of the National Reactor Testing Station, Idaho: U.S. Geological Survey Bulletin 1133–E, 22 p.

Walker, F.W., Parrington, J.R., and Feiner, Frank, 1989, Nuclides and isotopes, chart of the nuclides (14th ed.): General Electric Company, Nuclear Energy Operations, 57 p.

Wegner, S.J., 1989, Selected quality assurance data for water samples collected by the U.S. Geological Survey, Idaho National Engineering Laboratory, 1980 to 1988: U.S. Geological Survey Water-Resources Investigations Report 89–4168 (DOE/ID–22085), 91 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 80 p.

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., 1998, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, variously paged.

Williams, L.M., 1996, Evaluation of quality assurance/quality control data collected by the U.S. Geological Survey for water-quality activities at the Idaho National Engineering Laboratory, Idaho, 1989 through 1993: U.S. Geological Survey Water-Resources Investigations Report 96–4148 (DOE/ID–22129), 115 p.

——1997, Evaluation of quality assurance/quality control data collected by the U.S. Geological Survey for water-quality activities at the Idaho National Engineering Laboratory, Idaho, 1994 through 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4058 (DOE/ID–22136), 87 p.

Wood, W.W., 1981, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. D2, 24 p.

Table 1. Location, construction, and sample-collection method and frequency of wells completed in perched ground water at the Idaho National Engineering and Environmental Laboratory

[Well identifier: see figure 3 for location of wells. Sampling method: Pump - sample collected with a pump (pumping rate in gallons per minute); Bail - sample collected with a bailer; depth, where samples were collected, in feet below land surface. Sampling frequency: A, annually; S, semiannually; Q, quarterly. Symbol: <, less than]

Well identifier	Location		Well construction		Water-sample collection	
	Latitude	Longitude	Well diameter (inches)	Well depth (feet)	Method	Frequency
CWP-1	43°34'59"	112°57'26"	10	66.0	Bail (65)	A
CWP-2	43°34'58"	112°57'24"	10	52.5	Bail (52)	A
CWP-3	43°34'55"	112°57'25"	10	60.5	Bail (60)	A
CWP-4	43°34'54"	112°57'26"	10	61.0	Bail (60)	A
CWP-5	43°34'55"	112°57'29"	10	53.5	Bail (53)	A
CWP-6	43°34'56"	112°57'33"	10	52.5	Bail (52)	A
CWP-7	43°34'58"	112°57'32"	10	53.5	Bail (53)	A
CWP-8	43°35'00"	112°57'30"	10	66.0	Bail (65)	A
PW-1	43°33'49"	112°56'08"	10	117	Pump (3)	Q
PW-2	43°33'45"	112°55'57"	10	131	Bail (125)	S
PW-3	43°33'51"	112°55'58"	10	125	Bail (120)	S
PW-4	43°33'49"	112°55'49"	10	136	Pump (6)	Q
PW-5	43°33'49"	112°55'57"	10	124	Pump (8)	S
PW-6	43°33'53"	112°56'22"	10	125	Bail (125)	Q
PW-7	43°34'47"	112°57'47"	10	237	Bail (237)	S
PW-8	43°34'57"	112°57'21"	10	166	Pump (8)	Q
PW-9	43°35'01"	112°57'55"	10	200	Pump (5)	Q
SWP-8	43°33'51"	112°55'54"	8	26	Bail (26)	S
SWP-13	43°33'49"	112°55'57"	8	32	Bail (32)	S
TRA A-13	43°35'02"	112°57'28"	1.5	59	Bail (59)	A
TRA A-77	43°35'07"	112°57'38"	2	33	Bail (33)	A
50	43°34'19"	112°56'02"	6	405	Pump (<1)	S
53	43°35'02"	112°57'35"	6	62	Bail (62)	S
54	43°35'02"	112°57'28"	6	91	Pump (6)	Q
55	43°35'09"	112°57'29"	6	79	Pump (6)	S
56	43°35'09"	112°57'35"	6	80	Pump (1)	S
60	43°34'57"	112°57'20"	6	117	Pump (6)	S
61	43°34'53"	112°57'16"	10	123	Pump (6)	S
62	43°34'46"	112°57'06"	8	165	Pump (5)	S

Table 1. Location, construction, and sample-collection method and frequency of wells completed in perched ground water at the Idaho National Engineering and Environmental Laboratory—Continued

Well identifier	Location		Well construction		Water-sample collection	
	Latitude	Longitude	Well diameter (inches)	Well depth (feet)	Method	Frequency
63	43°34'55"	112°57'40"	10	97	Pump (5)	S
66	43°34'39"	112°56'57"	6	475	Bail (214)	A
68	43°35'15"	112°57'39"	10	128	Pump (1)	S
69	43°34'50"	112°57'29"	10	115	Pump (5)	A
70	43°35'03"	112°57'10"	8	100	Pump (6)	S
71	43°34'40"	112°57'15"	8	184	Pump (<1)	S
72	43°35'19"	112°57'46"	6	177	Pump (1)	A
73	43°35'01"	112°57'54"	6	127	Pump (1.5)	S
74	43°35'05"	112°58'06"	6	192	Bail (192)	S
78	43°34'13"	112°57'36"	7	204	Bail (200)	A
92	43°30'01"	113°02'53"	6	214	Bail (213)	S

Table 2. Concentrations of tritium, strontium-90, cesium-137, and other radionuclides in perched ground water from selected wells, Test Reactor Area, 1996–98

[Analyses were performed by the Radiological and Environmental Sciences Laboratory. Analytical uncertainties are reported as 1s. Concentrations that are equal to or greater than the reporting level of 3 times the 1s value are shown in boldface type. Sample identifier: QA, quality assurance replicate sample. Abbreviations: (m/d/y), month/day/year; pCi/mL, picocurie per milliliter; pCi/L, picocurie per liter; Co-60, cobalt-60; Eu-152, europium-152; Eu-154, europium-154. Symbol: NR, analysis not requested; ND, not detected; NS, not sampled for lack of water; SL, sample lost in analysis]

Sample identifier	Date sampled (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Other radionuclides (pCi/L)
CWP-1	7/23/96	0±0.2	.6±0.7	NR	NR
	7/15/97	.13±0.12	-.2±0.7	NR	NR
QA-3	7/15/97	-.03±0.11	.8±0.7	NR	NR
CWP-1	7/23/98	.05±0.11	.9±0.6	NR	NR
CWP-3	7/23/96	.2±0.2	.3±0.7	NR	NR
	7/15/97	.08±0.11	.5±0.8	NR	NR
	7/23/98	.04±0.11	1.2±0.6	NR	NR
CWP-4	7/23/98	-.04±0.11	.4±0.6	NR	NR
CWP-7	7/15/97	.05±0.11	.8±0.7	NR	NR
CWP-8	7/23/96	.16±0.2	1.2±0.7	NR	NR
	7/15/97	.09±0.12	-.1±0.8	NR	NR
	7/27/98	.05±0.11	.4±0.6	NR	NR
PW-8	1/8/96	**5.1±0.4**	**19.9±1.2**	NR	NR
	4/2/96	**3.3±0.3**	**19.5±1.2**	30±30	ND
	8/1/96	**2.0±0.3**	**21.4±1.3**	NR	NR
	10/2/96	**2.2±0.3**	**18.9±1.2**	NR	NR
	1/8/97	**2.0±0.2**	**16.7±1.2**	NR	NR
	4/2/97	**.97±0.15**	**17.5±1.1**	-10±20	ND
	7/7/97	**1.6±0.2**	**18.0±1.2**	NR	NR
	10/21/97	**.58±0.13**	**18.8±1.0**	NR	NR
QA-6	10/21/97	**.69±0.14**	**19.5±1.3**	NR	NR
PW-8	1/29/98	**1.37±0.17**	**13.8±0.9**	NR	NR
	3/30/98	**1.33±0.17**	**11.0±1.0**	15±14	ND
	7/1/98	**1.05±0.15**	**12.7±1.0**	NR	NR
	10/8/98	**1.26±0.16**	**16.1±0.8**	NR	NR
PW-9	1/8/96	**166±6**	1.5±0.8	NR	NR
	4/3/96	**159±5**	1.2±0.8	30±30	ND
	10/21/96	**137±5**	1.3±0.7	NR	NR

Table 2. Concentrations of tritium, strontium-90, cesium-137, and other radionuclides in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date sampled (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Other radionuclides (pCi/L)
PW-9-cont.	1/8/97	**135±5**	.3±0.7	NR	NR
	4/1/97	**123±4**	-.12±0.68	16±34	ND
	7/7/97	**118±4**	-.4±0.7	NR	NR
	1/29/98	**88.6±3**	-.2±0.6	NR	NR
	4/13/98	**95.2±3.2**	-1.3±4.0	20±40	ND
	7/1/98	**89.5±3.0**	1.4±0.6	NR	NR
	10/26/98	**83.1±2.8**	1.2±0.5	NR	NR
SB-01	3/20/97	**358±12**	NR	NR	NR
	4/9/97	**248±8**	NR	NR	NR
	5/15/97	**365±12**	NR	NR	NR
TRA A-13	10/22/96	-.3±0.2	**39±2**	10±20	ND
	4/10/97	-.08±0.1	**36±2**	40±40	ND
	10/28/98	.23±0.12	NR	NR	NR
	10/29/98	NR	**23.5±1.2**	13±25	ND
TRA A-77	4/1/96	**1.9±0.2**	**6,000±200**	**42,300±1,800**	**Co-60, 13,900±500**
	10/22/96	**.6±0.2**	**4,710±140**	**2,890±140**	**Co-60, 7,700±260; Eu-152, 340±90**
	3/20/97	**.56±0.13**	NS	NS	NS
	4/9/97	**1.0±0.15**	**6,800±200**	**1,200±110**	**Co-60, 44,000±1,400; Eu-152, 1,800±200 Eu-154, 400±120**
54	4/8/96	**12.4±0.6**	**94±3**	-10±40	ND
	7/24/96	**4.7±0.3**	**104±4**	NR	NR
	10/1/96	**1.3±0.3**	**117±4**	NR	NR
	1/23/97	**1.7±0.2**	**111±4**	NR	NR
QA-336	1/23/97	**1.9±0.2**	**119±4**	NR	NR
54	4/1/97	**1.38±0.17**	**101±4**	40±40	NR
	7/7/97	**2.7±0.2**	**93±3**	NR	NR
	10/21/97	**2.1±0.2**	**97±10**	NR	NR
	7/1/98	**.44±0.13**	**80±3**	NR	NR
	10/26/98	**.42±0.13**	**59±2**	30±30	NR
55	4/8/96	**1.4±0.2**	1.3±0.9	-10±20	ND
	10/1/96	**3.4±0.3**	**8±0.9**	NR	NR

Table 2. Concentrations of tritium, strontium-90, cesium-137, and other radionuclides in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date sampled (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Other radionuclides (pCi/L)
55-cont.	4/1/97	**77.4±2.6**	**11.8±1.1**	14±15	ND
	10/21/97	**46.1±1.6**	**12.3±0.8**	NR	NR
	3/30/98	**22.3±0.9**	**8.6±1.1**	0±20	ND
	10/26/98	**116±4.0**	**17.9±1.0**	NR	NR
56	4/8/96	**143±5**	**17.9±1.2**	0±20	ND
	10/1/96	**268±9**	**18.6±1.2**	NR	NR
	4/15/97	**148±5**	**15.5±1.1**	20±30	**Co-60, 220±30**
60	4/2/96	**1.1±0.2**	2.1±1.1	50±40	ND
	10/2/96	.5±0.2	SL	NR	NR
	4/2/97	**.41±0.13**	**6.6±0.9**	-30±20	ND
QA-9	4/2/97	**.55±0.13**	**5.8±0.9**	-30±30	ND
60	10/21/97	.07±0.11	**3±0.6**	NR	NR
	3/30/98	**.54±0.14**	**3.3±0.6**	-13±33	ND
	10/8/98	**.43±0.13**	**6±0.6**	NR	NR
61	4/9/96	**19.7±0.8**	.8±0.8	12±22	ND
	10/1/96	**17.7±0.8**	-.16±0.75	NR	NR
	4/10/97	**14.3±0.6**	.8±0.8	15±22	ND
	10/23/97	**11.2±0.5**	.6±0.6	NR	NR
	4/21/98	**11.3±0.5**	.3±0.7	20±20	ND
	10/20/98	**9.7±0.5**	**1.6±0.5**	NR	NR
62	4/9/96	**.9±0.2**	1.4±0.9	10±20	ND
	10/1/96	.5±0.2	1.1±0.8	NR	NR
	4/3/97	.32±0.12	**2.4±0.8**	30±20	ND
	10/22/97	**.39±0.13**	**2.9±0.7**	NR	NR
	4/16/98	**.46±0.13**	-5±4	0±40	ND
	10/20/98	**.48±0.13**	3.1±0.5	NR	NR
63	4/10/96	.2±0.2	1.7±0.9	14±38	ND
	10/1/96	.2±0.2	**6.6±0.9**	NR	NR
	4/22/97	**.53±0.13**	**4.3±0.8**	-11±24	ND
QA-337	4/22/97	**.62±0.13**	**4.1±0.9**	1±16	ND

Table 2. Concentrations of tritium, strontium-90, cesium-137, and other radionuclides in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date sampled (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Other radionuclides (pCi/L)
63-cont.	10/22/97	.16±0.11	**2.5±0.7**	NR	NR
	4/15/98	.2±0.12	-2±4	20±20	ND
	10/20/98	**.41±0.13**	**4.9±0.7**	NR	NR
66	7/25/96	**5.1±0.4**	.6±0.8	NR	NR
QA-6	7/25/96	**5.4±0.4**	.9±0.8	NR	NR
66	7/17/97	**5.9±0.3**	-.4±0.8	NR	NR
	7/23/98	**4.5±0.3**	1.4±0.7	NR	NR
	4/18/96	0±0.2	1.9±1.3	-16±39	ND
	10/22/96	-.2±0.2	2±2	NR	NR
68	4/9/97	-.03±0.11	-.2±0.9	-50±40	ND
	10/28/97	.1±0.11	-.2±0.6	NR	NR
	4/20/98	-.04±0.11	-6±4	30±20	ND
	12/1/98	**.54±0.13**	.7±0.5	NR	NR
QA-5	12/1/98	.04±0.11	1.1±0.5	NR	NR
69	7/30/96	.1±0.2	0±0.8	NR	NR
	7/17/97	.06±0.11	.5±0.8	NR	NR
	7/1/98	.05±0.11	0±0.7	NR	NR
QA-5	7/1/98	-.12±0.1	-.5±0.6	NR	NR
70	4/15/96	**36.2±1.4**	**65±3**	0±20	ND
	10/1/96	**20.8±0.9**	**62±3**	NR	NR
	4/29/97	**17.1±0.7**	**52±2**	-10±20	ND
	10/21/97	**12.6±0.6**	**56±2**	NR	NR
	3/30/98	**26.1±1.0**	**37±3**	20±20	ND
	10/20/98	**10.5±0.5**	**46±1.3**	NR	NR
71	4/22/96	**5.0±0.4**	.8±0.7	20±20	ND
	10/2/96	**4.5±0.4**	.2±0.8	NR	NR
	4/7/97	**4.2±0.3**	-.3±1.4	20±50	ND
	10/23/97	**3.4±0.2**	1.2±0.5	NR	NR
72	7/30/96	0±0.2	.12±0.75	NR	NR
QA-8	7/30/96	.1±0.2	1.2±0.8	NR	NR
72	7/23/97	-.02±0.11	.3±0.7	NR	NR

Table 2. Concentrations of tritium, strontium-90, cesium-137, and other radionuclides in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date sampled (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Other radionuclides (pCi/L)
73	4/25/96	**95.4±3.3**	.3±0.6	-40±40	ND
	10/23/96	**78.2±2.7**	.3±0.7	NR	NR
QA-4	10/23/96	**77.1±2.7**	.7±0.7	NR	NR
73	4/17/97	**52.6±1.8**	-.3±0.7	-50±30	ND
	10/29/97	**42.7±1.5**	1.2±0.6	NR	NR
	4/13/98	**41.9±1.5**	-5±4	17±21	ND
	10/27/98	**43±1.5**	1.1±0.6	NR	NR
78	7/23/96	.2±0.2	1.2±0.7	NR	NR
	7/22/97	.02±0.11	0±0.7	NR	NR
	7/30/98	-.04±0.11	-.11±0.61	NR	NR

Table 3. Concentrations of selected dissolved ions in perched ground water from selected wells, Test Reactor Area, 1996–98

[Analyses were performed by the National Water Quality Laboratory. Sample identifier: QA-3, quality-assurance replicate. Abbreviations: (m/d/y), month/day/year; µg/L, microgram per liter; mg/L, milligram per liter. Symbols: <, less than; NR, analysis not requested; *, concentration is estimated]

Sample identifier	Date (m/d/y)	Chromium (µg/L)	Hexavalent chromium (µg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
CWP-1	7/23/96	<5	1	NR	27	340
	7/15/97	5	NR	NR	26	323
QA-3	7/15/97	<5	NR	NR	26	322
CWP-1	7/23/98	<14	NR	NR	13	82
CWP-3	7/23/96	<5	1	NR	23	250
	7/15/97	<5	NR	NR	24	303
	7/23/98	<14	NR	NR	14	111
CWP-4	7/23/98	<14	NR	NR	9.3	39
CWP-7	7/15/97	<5	NR	NR	25	307
CWP-8	7/23/96	<5	1	NR	23	240
	7/15/97	<5	NR	NR	9.4	60
	7/27/98	<14	NR	NR	13	80
PW-8	1/8/96	11	2	NR	23	260
	4/2/96	8	5	NR	22	NR
	8/1/96	8	8	NR	24	280
	10/2/96	12	<1	17	23	260
	1/8/97	14	NR	NR	23	270
	4/2/97	12	NR	NR	22	NR
	7/7/97	11	NR	NR	26	298
	10/21/97	12	NR	19	24	283
QA-6	10/21/97	11	NR	18	24	279
PW-8	1/29/98	<14	NR	NR	22	252
	3/30/98	<14	NR	NR	22	NR
	7/1/98	<14	NR	NR	19	193
	10/8/98	14	NR	19	23	276
PW-9	1/8/96	180	130	NR	23	81
	4/3/96	170	150	NR	24	NR
	10/21/96	150	140	19	26	94
	1/8/97	150	NR	NR	25	94
	4/1/97	152	NR	NR	26	NR

Table 3. Concentrations of selected dissolved ions in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date (m/d/y)	Chromium (µg/L)	Hexavalent chromium (µg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
PW-9-cont.	7/7/97	140	NR	NR	26	97
	1/29/98	114	NR	NR	27	101
	4/13/98	110	NR	NR	26	NR
	7/1/98	102	NR	NR	26	103
	10/26/98	98	NR	20	26	105
TRA A-13	10/22/96	<5	2	20	21	220
	10/28/98	<14	NR	17	NR	NR
	10/29/98	NR	NR	NR	27	63
TRA A-77	4/1/96	NR	NR	NR	9.7	NR
	10/22/96	26	5	7.6	9.5	19
	4/9/97	12	NR	NR	9.8	NR
USGS 54	4/8/96	13	11	NR	19	NR
	7/24/96	12	12	NR	21	220
	10/1/96	12	9	18	24	280
	1/23/97	15	NR	NR	27	330
QA-336	1/23/97	16	NR	NR	26	320
54	4/1/97	10	NR	NR	24	NR
	7/7/97	13	NR	NR	23	271
	10/21/97	12	NR	18	23	238
	7/1/98	<14	NR	NR	17	149
	10/26/98	*9.8	NR	15	14	92
55	4/8/96	47	35	NR	17	NR
	10/1/96	58	55	32	18	210
	4/1/97	78	NR	NR	16	NR
	10/21/97	103	NR	26	19	133
	10/26/98	82	NR	22	17	120
56	4/8/96	200	160	NR	34	NR
	10/1/96	98	140	56	16	140
	4/15/97	115	NR	NR	16	NR
60	4/2/96	<5	4	NR	21	NR
	10/2/96	9	7	17	24	260
	4/2/97	9.8	NR	NR	21	NR

Table 3. Concentrations of selected dissolved ions in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date (m/d/y)	Chromium (µg/L)	Hexavalent chromium (µg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
QA-9	4/2/97	10	NR	NR	21	NR
60	10/21/97	10	NR	18	24	283
	3/30/98	<14	NR	NR	22	NR
	10/8/98	*14	NR	18	22	267
61	4/9/96	24	9	NR	16	NR
	10/1/96	21	9	14	18	160
	4/10/97	20	NR	NR	19	NR
	10/23/97	16	NR	14	20	187
	4/21/98	16	NR	NR	18	NR
	10/20/98	18	NR	14	20	190
62	4/9/96	10	2	NR	23	NR
	10/1/96	14	5	16	25	270
	4/3/97	15	NR	NR	25	NR
	10/22/97	12	NR	17	23	259
	4/16/98	<14	NR	NR	21	NR
	10/20/98	*14	NR	17	23	242
63	4/10/96	15	13	NR	22	NR
	10/1/96	30	28	17	23	250
	4/22/97	33	NR	NR	23	NR
QA-337	4/22/97	30	NR	NR	22	NR
63	10/22/97	14	NR	17	23	245
	4/15/98	15	NR	NR	21	NR
	10/20/98	24	NR	17	23	248
66	7/25/96	35	24	15	19	190
	7/17/97	29	NR	16	21	210
	7/23/98	<14	NR	15	22	233
68	4/18/96	22	<1	NR	25	NR
	10/22/96	26	3	1,000	27	3,200
	4/9/97	<15	NR	NR	23	NR
	10/28/97	16	NR	690	35	2,449
	4/20/98	<42	NR	NR	43	NR
	12/1/98	<70	NR	662	27	2,278

Table 3. Concentrations of selected dissolved ions in perched ground water from selected wells, Test Reactor Area, 1996–98—Continued

Sample identifier	Date (m/d/y)	Chromium (µg/L)	Hexavalent chromium (µg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
QA-5	12/1/98	<70	NR	674	26	2,342
69	7/30/96	<5	1	11	19	140
	7/17/97	<5	NR	13	20	164
	7/1/98	<14	NR	12	20	154
QA-5	7/1/98	<14	NR	11	19	152
70	4/15/96	33	15	NR	19	NR
	10/1/96	26	21	17	22	220
	4/29/97	30	NR	NR	22	NR
	10/21/97	23	NR	18	23	239
	3/30/98	45	NR	NR	21	NR
	10/20/98	24	NR	16	20	184
71	4/22/96	55	30	NR	16	NR
	10/2/96	87	<1	12	17	140
	4/7/97	48	NR	NR	18	148
	10/23/97	7.8	NR	13	18	157
72	7/30/96	<5	<1	22	13	30
QA-8	7/30/96	<5	1	21	14	30
72	7/23/97	<5	NR	31	16	35
73	4/25/96	83	50	NR	38	NR
	10/23/96	80	54	13	34	61
QA-4	10/23/96	77	15	14	33	61
73	4/17/97	63	NR	NR	43	NR
	10/29/97	50	NR	13	31	56
	4/13/98	45	NR	NR	37	NR
	10/27/98	51	NR	12	30	54
78	7/23/96	<5	<1	6.6	3.8	20
	7/22/97	<5	NR	6.6	3.1	18
	6/30/98	<14	NR	6.1	3.8	18

Table 4. Concentrations of tritium, strontium-90, and cesium-137 in perched ground water from selected wells, Idaho Nuclear Technology and Engineering Center, 1996–98

[Analyses were performed by the Radiological and Environmental Sciences Laboratory. Analytical uncertainties are reported as 1s. Concentrations that are equal to or greater than the reporting level of 3 times the 1s value are shown in boldface type. Sample identifier: QA-3, quality-assurance replicate. Abbreviations: (m/d/y), month/day/year; pCi/mL, picocurie per milliliter; pCi/L, picocurie per liter. Symbol: NR, analysis not requested]

Sample identifier	Date (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)
PW-1	1/18/96	**1.0±0.2**	1.1±0.8	NR
	4/25/96	.3±0.2	1.1±0.7	-50±20
	7/25/96	**.7±0.2**	.8±0.8	NR
	10/23/96	.2±0.2	1.8±1	NR
	1/23/97	.06±0.11	1.5±0.8	NR
	4/17/97	.1±0.11	.7±0.8	11±22
	7/22/97	.34±0.13	.7±0.7	NR
	10/29/97	.18±0.12	1.7±0.6	NR
	1/26/98	0±0.12	.5±0.6	NR
QA-3	1/26/98	.04±0.12	1.3±0.5	NR
PW-1	4/13/98	.17±0.12	-4±3	-10±40
	6/30/98	.35±0.13	.8±0.7	NR
	10/21/98	.09±0.11	**2.8±0.6**	NR
PW-2	4/16/96	.5±0.2	1.8±0.9	0±20
	10/23/96	.2±0.2	1.5±0.8	NR
	4/22/97	**.62±0.13**	1±1.5	-11±46
	10/29/97	.32±0.12	1.5±0.7	NR
	4/13/98	.32±0.13	**3±0.5**	-11±22
	10/21/98	**.39±0.13**	**2.1±0.5**	NR
PW-3	4/16/96	.5±0.2	**3.1±0.8**	20±20
	10/23/96	.14±0.22	1.4±0.8	NR
QA-5	10/23/96	.2±0.2	1.0±0.8	NR
PW-3	4/22/97	.31±0.12	1.3±0.8	14±22
	10/29/97	.28±0.12	.9±0.6	NR
	4/13/98	.28±0.13	**2±0.5**	-12±23
PW-4	4/4/96	**.8±0.2**	1.5±0.8	0±20
	7/24/96	**.7±0.2**	1.8±0.9	NR
	10/3/96	**.6±0.2**	1.6±0.9	NR
	1/27/97	**.78±0.15**	1.8±0.9	NR
	4/2/97	**.64±0.14**	**4.7±0.8**	10±30
	7/17/97	**.64±0.14**	**3±0.8**	NR

Table 4. Concentrations of tritium, strontium-90, and cesium-137 in perched ground water from selected wells, Idaho Nuclear Technology and Engineering Center, 1996–98—Continued

Sample identifier	Date (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)
PW-4-cont.	10/23/97	**.63±0.14**	**1.8±0.6**	NR
	1/28/98	.29±0.13	**3.9±0.7**	NR
	4/14/98	**.67±0.14**	-5±3	-60±40
	7/1/98	**.61±0.14**	**2.5±0.7**	NR
	10/26/98	**.78±0.14**	**2.6±0.5**	NR
PW-5	4/30/96	.4±0.2	1.5±0.8	10±20
	10/28/96	.5±0.2	1.6±0.8	NR
	4/23/97	.35±0.12	1.7±0.8	0±30
	10/27/97	.22±0.12	1.3±0.6	NR
	4/8/98	.09±0.12	3±2	20±20
	10/22/98	.35±0.12	1±0.6	NR
PW-6	4/3/97	**7.1±0.4**	**5.7±1.5**	0±50
	7/17/97	**11.1±0.5**	-1±0.7	NR
	10/30/97	**10.2±0.5**	.5±0.5	NR
	1/26/98	**9.6±0.5**	.3±0.5	NR
	4/13/98	**11.3±0.5**	.8±0.6	-10±37
	7/9/98	**10.7±0.5**	-1±0.6	NR
	10/27/98	**9.7±0.5**	0±0.6	NR
QA-4	10/27/98	**10.1±0.5**	.5±0.6	NR
SWP-13	7/25/96	.4±0.2	1.7±0.9	0±40
USGS 50	4/17/96	**55.5±2.0**	**168±5**	40±20
	10/21/96	**52.2±1.9**	**177±6**	30±30
	4/7/97	**47.1±1.7**	**142±5**	0±30
	10/14/97	**46.6±1.7**	**150±13**	-40±30
	4/9/98	**42.2±1.5**	**190±20**	20±40
	10/28/98	**37.3±1.4**	**178±4**	17±24

Table 5. Concentrations of selected dissolved ions in perched ground water from selected wells, Idaho Nuclear Technology and Engineering Center, 1996–98

[Analyses were performed by the National Water Quality Laboratory. Analytical results in milligrams per liter. Sample identifier: QA-3, quality-assurance replicate. Abbreviations: (m/d/y), month/day/year. Symbols: <, less than; NR, analysis not requested; SL, sample lost]

Sample identifier	Date (m/d/y)	Sodium	Chloride	Sulfate	Nitrite plus nitrate (as nitrogen)
PW-1	1/18/96	NR	250	NR	NR
	4/25/96	NR	230	NR	NR
	7/25/96	NR	240	NR	NR
	10/23/96	160	240	26	NR
	1/23/97	NR	280	NR	NR
	4/17/97	NR	222	NR	NR
	7/22/97	NR	258	NR	NR
	10/29/97	197	386	27	NR
	1/26/98	NR	225	NR	NR
QA-3	1/26/98	NR	222	NR	NR
PW-1	4/13/98	NR	177	NR	NR
	6/30/98	NR	155	NR	NR
	10/21/98	105	143	41	NR
PW-2	4/16/96	NR	280	NR	NR
	10/23/96	170	280	26	NR
	4/22/97	NR	311	NR	NR
	10/29/97	171	286	26	NR
	4/13/98	NR	225	NR	NR
	10/21/98	129	193	41	NR
PW-3	4/16/96	NR	290	NR	NR
	10/23/96	170	290	27	NR
QA-5	10/23/96	180	300	27	NR
PW-3	4/22/97	NR	337	NR	NR
	10/29/97	184	337	27	NR
	4/13/98	NR	245	NR	NR
PW-4	4/4/96	NR	290	NR	NR
	7/24/96	NR	300	NR	NR
	10/3/96	170	300	27	NR
	1/27/97	NR	300	NR	NR
	4/2/97	NR	325	NR	NR
	7/17/97	NR	317	NR	NR

Table 5. Concentrations of selected dissolved ions in perched ground water from selected wells, Idaho Nuclear Technology and Engineering Center, 1996–98—Continued

Sample identifier	Date (m/d/y)	Sodium	Chloride	Sulfate	Nitrite plus nitrate (as nitrogen)
PW-4-cont.	10/23/97	179	317	27	NR
	1/28/98	NR	309	NR	NR
	4/14/98	NR	258	NR	NR
	7/1/98	NR	232	NR	NR
	10/26/98	142	227	41	NR
PW-5	4/30/96	NR	260	NR	NR
	10/28/96	170	270	28	NR
	4/23/97	NR	330	NR	NR
	10/27/97	177	317	26	NR
	4/8/98	NR	245	NR	NR
	10/22/98	127	218	41	NR
PW-6	4/3/97	NR	135	NR	NR
	7/17/97	NR	175	NR	NR
	10/30/97	117	184	13	NR
	1/26/98	NR	208	NR	NR
	4/13/98	NR	199	NR	NR
	7/9/98	NR	205	NR	NR
	10/27/98	112	159	14	NR
QA-4	10/27/98	112	167	14	NR
SWP-13	7/25/96	170	270	30	1.3
USGS 50	4/17/96	NR	65	NR	NR
	10/21/96	64	70	44	31
	4/7/97	NR	61	NR	NR
	10/14/97	61	61	43	40
	4/9/98	NR	62	NR	NR
	10/28/98	62	56	39	59

Table 6. Concentrations of tritium, strontium-90, cesium-137, selected transuranic elements, and dissolved chloride in perched ground water from well 92 at the Radioactive Waste Management Complex, 1996–98

[Analyses were performed by the Radiological and Environmental Sciences Laboratory and the National Water Quality Laboratory. Analytical uncertainties are reported as 1s. Abbreviations: (m/d/y), month/day/year; pCi/mL, picocuries per milliliter; pCi/L, picocuries per liter; mg/L, milligrams per liter. Symbol: NW, not enough water for analysis]

Well identifier	Date (m/d/y)	Tritium (pCi/mL)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Plutonium-238 (pCi/L)	Plutonium-239, 240 (undivided) (pCi/L)	Americium-241 (pCi/L)	Chloride (mg/L)
USGS 92	2/29/96	0.2±0.1	1.6±1	-11±26	-0.08±0.04	0.05±0.04	0.05±0.03	75
	10/22/96	0±0.2	2.2±1.2	12±36	-.01±0.03	-.017±0.03	.14±0.08	69
	4/8/97	.32±0.12	2.2±0.8	0±40	0±0.02	.01±0.02	.06±0.04	78
	10/28/97	.31±0.12	.4±1	-20±20	-.005±0.015	-.004±0.014	.04±0.02	NW
	3/31/98	.39±0.13	7.2±1	19±20	−.018±0.01	−.001±0.01	.001±0.005	78

Table 7. Concentrations of selected purgeable organic compounds in water from well 92 at the Radioactive Waste Management Complex, 1996–98.

[Analyses were performed by the National Water Quality Laboratory using an analytical method that conforms to U.S. Environmental Protection Agency method 524.2. Analytical results in micrograms per liter; <, the concentration was less than the respective reporting level]

Date (m/d/y)	Carbon tetrachloride	1,2-Dichloroethane	Chloroform	Toluene	Methylene chloride	Tetrachloroethylene	1,1-dichloroethane	1,1-dichloroethylene	1,1,1-trichloroethane	1,1,2-trichloroethane	1,2-dichloropropane	Trichloroethylene	Cis-1,2-dichloroethene	Freon-113
2/29/96	1,800	1.8	920	<0.2	<0.2	180	15	2.2	170	.6	6.7	1,400	.8	3.6
4/8/97	990	1.2	633	.29	.20	110	8.8	1.4	98	.32	4.0	786	.39	2.4
3/31/98	260	.96	540	<.2	5.3	50	7.7	.95	55	<1.7	3.2	360	.32	1.3