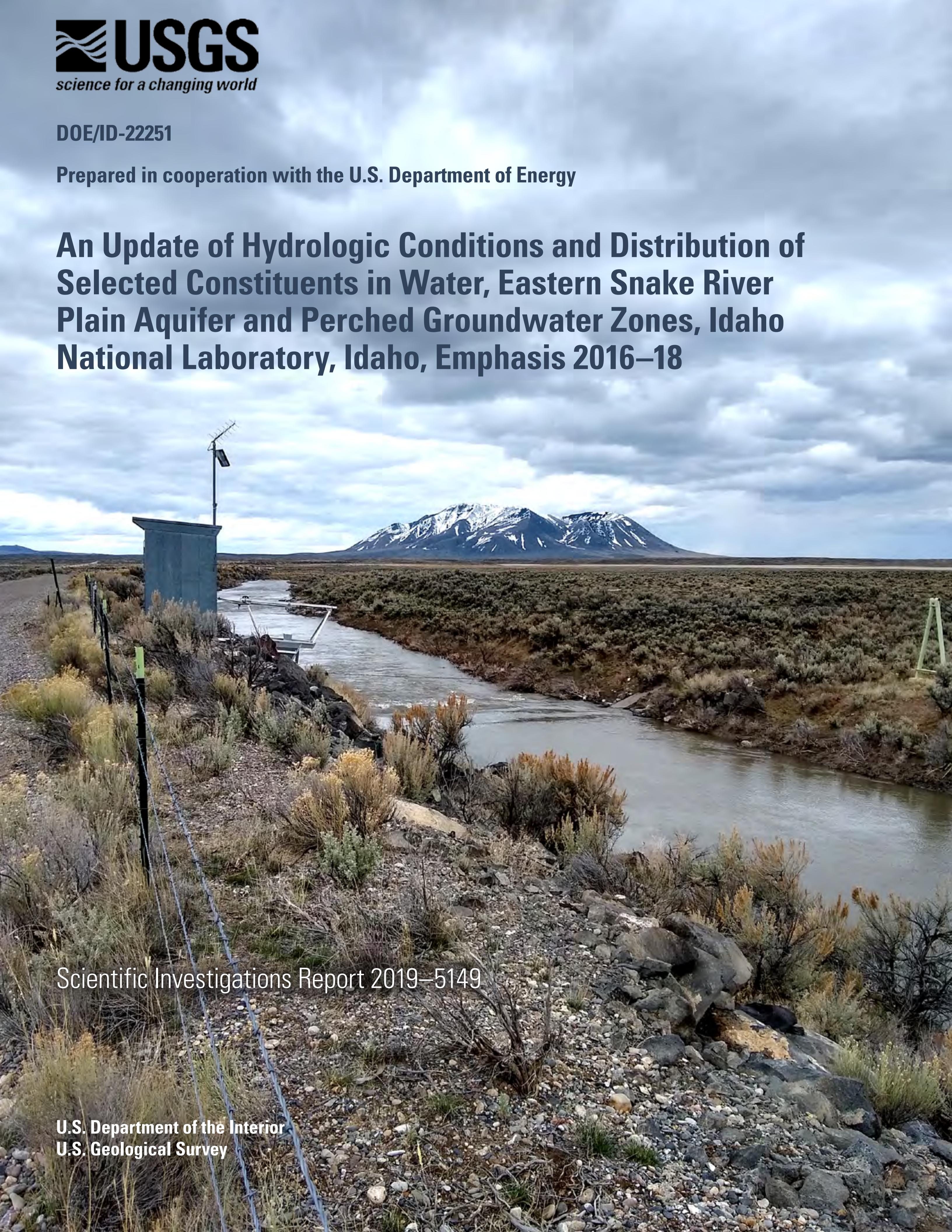

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Prepared in cooperation with the U.S. Department of Energy

An Update of Hydrologic Conditions and Distribution of Selected Constituents in Water, Eastern Snake River Plain Aquifer and Perched Groundwater Zones, Idaho National Laboratory, Idaho, Emphasis 2016–18

Scientific Investigations Report 2019–5149

U.S. Department of the Interior
U.S. Geological Survey

Cover: U.S. Geological Survey (USGS) streamgage 13132513, INL diversion at head near Arco, Idaho, with Big Southern Butte in background. Photograph by Roy Bartholomay, USGS, April 10, 2019.

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DAVID BERNHARDT, Secretary

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Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per mile [(ft^3/s)/mi]	0.01760	Cubic meter per second per kilometer [(m^3/s)/km]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
Curie (Ci)	3.7 x 1010	becquerel (Bq)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NAVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Activities for radioactive constituents in water are given in picocuries per liter (pCi/L).

Abbreviations

ATR Complex	Advanced Test Reactor Complex
CFA	Central Facilities Area
Ci	Curie
DLDQC	detection limits from DQCALC
DOE	U.S. Department of Energy
DQCALC	detection and quantification calculation
ESRP	eastern Snake River Plain
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory (1974–97)
INEEL	Idaho National Engineering and Environmental Laboratory (1997–2005)
INL	Idaho National Laboratory (2005-present)
INTEC	Idaho Nuclear Technology and Engineering Center
LRL	laboratory reporting level
LT-MDL	long-term method detection level
MCL	maximum contaminant level
MRL	minimum reporting level
MLMS	multilevel monitoring system
NAD	normalized absolute difference
NRF	Naval Reactors Facility
NRTS	National Reactor Testing Station (1949–74)
NWIS	National Water Information System
NWQL	National Water Quality Laboratory (USGS)
PBF	Power Burst Facility
QA	quality-assurance
RESL	Radiological and Environmental Sciences Laboratory (DOE)
RSD	relative standard deviation
RWMC	Radioactive Waste Management Complex
RWMC PROD	RWMC Production Well
s	sample standard deviation
SDA	Subsurface Disposal Area
TAN	Test Area North
TCE	trichloroethylene
TRA DISP	Test Reactor Area disposal well
TSF	Technical Support Facility

USGS	U.S. Geological Survey
VOC	volatile organic compound

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By Roy C. Bartholomay, Neil V. Maimer, Gordon W. Rattray, and Jason C. Fisher

Abstract

Since 1952, wastewater discharged to infiltration ponds (also called percolation ponds) and disposal wells at the Idaho National Laboratory (INL) has affected water quality in the eastern Snake River Plain (ESRP) aquifer and perched groundwater zones underlying the INL. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, maintains groundwater-monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the aquifer and in perched groundwater zones. This report presents an analysis of water-level and water-quality data collected from the ESRP aquifer and perched groundwater wells in the USGS groundwater monitoring networks during 2016–18.

From March–May 2015 to March–May 2018, water levels in wells completed in the ESRP aquifer declined in the northern part of the INL and increased in the southwestern part. Water-level decreases ranged from 0.5 to 3.0 feet (ft) in the northern part of the INL and increases ranged from 0.5 to 3.0 ft in the southwestern part.

Detectable concentrations of radiochemical constituents in water samples from wells in the ESRP aquifer at the INL generally decreased or remained constant during 2016–18. Decreases in concentrations were attributed to radioactive decay, changes in waste-disposal methods, and dilution from recharge and underflow.

In 2018, concentrations of tritium in water samples collected from 46 of 111 aquifer wells were greater than the reporting level of three times the sample standard deviation and ranged from 260±50 to 5,100±190 picocuries per liter (pCi/L). Tritium concentrations in water from 10 wells completed in deep perched groundwater above the ESRP aquifer near the Advanced Test Reactor (ATR) Complex generally were greater than or equal to the reporting level during at least one sampling event during 2016–18, and concentrations ranged from 150 ±50 to 12,900 ±200 pCi/L.

Concentrations of strontium-90 in water from 17 of 60 ESRP aquifer wells sampled during April or October 2018 exceeded the reporting level, ranging from 2.2±0.7 to 363±19 pCi/L. Strontium-90 was not detected in the ESRP aquifer beneath the ATR Complex. During at least one sampling event during 2016–18, concentrations of strontium-90 in water from eight wells completed in deep perched groundwater above the ESRP aquifer at the ATR Complex equaled or exceeded the reporting levels, and concentrations ranged from 0.57±0.17 to 34.3±1.2 pCi/L.

During 2016–18, concentrations of cesium-137 were less than the reporting level in all but one ESRP aquifer well, and concentrations of plutonium-238, -239, and -240 (undivided), and americium-241 were less than the reporting level in water samples from all ESRP aquifer wells.

In April 2009, the dissolved chromium concentration in water from one ESRP aquifer well, USGS 65, south of the ATR Complex equaled the maximum contaminant level (MCL) of 100 micrograms per liter (µg/L). In April 2018, the concentration of chromium in water from that well had decreased to 76.0 µg/L, less than the MCL. Concentrations in water samples from 62 other ESRP aquifer wells sampled ranged from less than 0.6 to 21.6 µg/L. During 2016–18, dissolved chromium was detected in water from all wells completed in deep perched groundwater above the ESRP aquifer at the ATR Complex, and concentrations ranged from 4.2 to 98.8 µg/L.

In 2018, concentrations of sodium in water from most ESRP aquifer wells in the southern part of the INL were greater than the western tributary background concentration of 8.3 milligrams per liter (mg/L). After the new percolation ponds were put into service in 2002 southwest of the Idaho Nuclear Technology and Engineering Center (INTEC), concentrations of sodium in water samples from the Rifle Range well increased steadily until 2008, when concentrations generally began decreasing. The increases and decreases were attributed to disposal variability in the new percolation ponds. During 2016–18, dissolved sodium concentrations in water

from 18 wells completed in deep perched groundwater above the ESRP aquifer at the ATR Complex ranged from 6.37 to 143 mg/L.

In 2018, concentrations of chloride in most water samples from ESRP aquifer wells south of the INTEC and at the Central Facilities Area exceeded the background concentrations. Chloride concentrations in water from wells south of the INTEC generally have decreased since 2002 when chloride disposal to the old percolation ponds was discontinued. After the new percolation ponds southwest of the INTEC were put into service in 2002, concentrations of chloride in water samples from one well rose steadily until 2008 then began decreasing. During 2016–18, dissolved chloride concentrations in deep perched groundwater above the ESRP aquifer from 18 wells at the ATR Complex ranged from 3.89 to 176 mg/L.

In 2018, sulfate concentrations in water samples from ESRP aquifer wells in the south-central part of the INL exceeded the background concentration of sulfate and ranged from 22 to 151 mg/L. The greater-than-background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds. In 2018, sulfate concentrations in water samples from wells near the Radioactive Waste Management Complex (RWMC) mostly were greater than background concentrations and could have resulted from well construction techniques and (or) waste disposal at the RWMC or the ATR complex. The maximum dissolved sulfate concentration in shallow perched groundwater above the ESRP aquifer near the ATR Complex was 215 mg/L in well CWP 3 in April 2016. During 2018, dissolved sulfate concentrations in water from wells completed in deep perched groundwater above the ESRP aquifer near the cold-waste ponds at the ATR Complex ranged from 65.8 to 171 mg/L.

In 2018, concentrations of nitrate in water from most ESRP aquifer wells at and near the INTEC exceeded the western tributary background concentration of 0.655 mg/L. Concentrations of nitrate in wells southwest of the INTEC and farther away from the influence of disposal areas and the Big Lost River show a general decrease in nitrate concentration through time. Two wells south of the INTEC show increasing trends that could be the result of wastewater beneath the INTEC tank farm being mobilized to the aquifer.

During 2016–18, water samples from several ESRP aquifer wells were collected and analyzed for volatile organic compounds (VOCs). Sixteen VOCs were detected. At least 1 and as many as 7 VOCs were detected in water samples from 15 wells. The primary VOCs detected include carbon tetrachloride, trichloromethane, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. In 2016–18, concentrations for all VOCs were less than their respective MCLs for drinking water, except carbon tetrachloride in water from two wells and trichloroethene in one well.

During 2016–18, variability and bias were evaluated from 37 replicate and 15 blank quality-assurance samples. Results from replicate analyses were investigated to evaluate sample variability. Constituents with acceptable reproducibility were major ions, trace elements, nutrients, and VOCs. All radiochemical constituents had acceptable reproducibility except for gross alpha- and beta-particle radioactivity. The gross alpha- and beta-particle radioactivity samples that did not meet reproducibility criteria had low concentrations. Bias from sample contamination was evaluated from equipment, field, and source-solution blanks. Cadmium had a concentration slightly greater than its reporting level in a source-solution blank, and chloride and ammonia had concentrations that were slightly greater than their respective reporting levels in field and equipment blanks. Subtracting concentrations of chloride and ammonia in field blanks from the concurrently collected equipment blank indicates that adjusted concentrations for chloride and ammonia in the equipment blanks were less than their respective reporting levels. Therefore, no sample bias was observed for any of the sample periods.

Introduction

The Idaho National Laboratory (INL), operated by the U.S. Department of Energy (DOE), encompasses about 890 mi^2 of the eastern Snake River Plain (ESRP) in southeastern Idaho (fig. 1). The INL was established in 1949 to develop atomic energy, nuclear safety research, defense programs, environmental research, and advanced energy concepts. Wastewater disposal sites at the Test Area North (TAN), the Naval Reactors Facility (NRF), the Advanced Test Reactor Complex (ATR Complex), and the Idaho Nuclear Technology and Engineering Center (INTEC) (fig. 1) have contributed radioactive- and chemical-waste contaminants to the ESRP aquifer since 1952. These sites incorporated various wastewater disposal methods, including lined evaporation ponds, unlined percolation (infiltration) ponds and ditches, drain fields, and injection wells. Waste materials buried in shallow pits and trenches in the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) also have contributed contaminants to groundwater.

Wastewater disposal has resulted in detectable concentrations of several waste constituents in water from the ESRP aquifer underlying the INL. Disposal of wastewater to infiltration ponds and infiltration of surface water at waste-burial sites resulted in the formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer (Cecil and others, 1991). Perched groundwater is an integral part of the pathway for waste-constituent migration to the aquifer.

The DOE requires information about the mobility of radiochemical- and chemical-waste constituents in the ESRP aquifer and in perched groundwater above the aquifer so

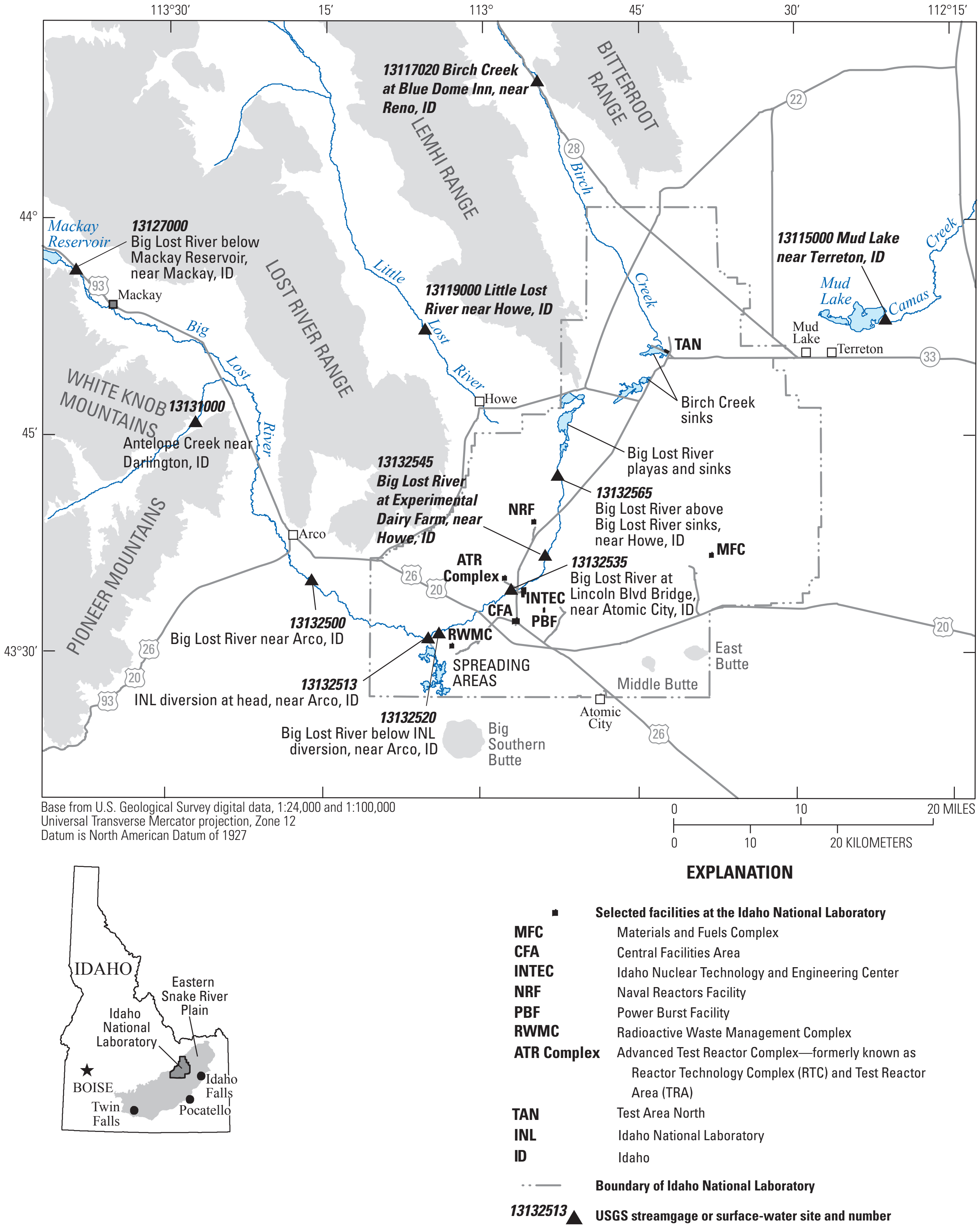


Figure 1. Location of the Idaho National Laboratory, surface-water streamgages, and selected facilities, eastern Snake River Plain, southeastern Idaho.

they can assess the effect of INL facility operations on water quality and to aid in remediation activities. Waste-constituent mobility is determined, in part, by (1) the rate and direction of groundwater flow; (2) the locations, quantities, and methods of waste disposal; (3) waste-constituent chemistry; and (4) the geochemical processes taking place in the aquifer. This study was conducted by the U.S. Geological Survey (USGS) in cooperation with the DOE 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 INL. The purpose of the resulting study was to characterize these resources before the development of nuclear-reactor testing facilities. Since that time, the USGS has maintained water-level and water-quality monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the ESRP aquifer and in perched groundwater.

This report presents an analysis of water-level and water-quality data collected from wells in the USGS groundwater monitoring networks during 2016–18 as part of the continuing hydrogeologic investigations conducted by the USGS at the INL. This report describes the distribution and concentration of selected radiochemical and chemical constituents in groundwater and perched groundwater at the INL, and the changes in the regional water levels from 2015 through 2018. The report also summarizes the history of waste disposal at the ATR Complex (formerly known as the Test Reactor Area [TRA]), INTEC (formerly known as the Idaho Chemical Processing Plant [ICPP]), RWMC, TAN, NRF, and the Central Facilities Area (CFA). A separate report will be written on water-level changes and water-quality data collected from 11 wells that are completed in multiple levels of the aquifer.

Previous Investigations

Hydrologic conditions and the distribution of selected wastewater constituents in groundwater and perched groundwater are discussed in a series of reports describing the INL. Table 1 summarizes selected previous investigations on the geology, hydrology, and water characteristics at and near the INL, and periods included in those investigations. Numerous previous investigations on the hydrology and geology at the INL have been conducted by INL contractors, State agencies, and the USGS. A list of all the reports published by the USGS on project work completed at the INL is available at https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/INL_Bibliography_0120.pdf.

Table 1. Summary of selected previous investigations on geology, hydrology, and characteristics of groundwater and perched groundwater, Idaho National Laboratory, Idaho, 1961–2018.

[**Summary:** ATRC, Advanced Test Reactor Complex; ICPP, Idaho Chemical Processing Plant; INEEL, Idaho National Engineering and Environmental Laboratory; INEL, Idaho National Engineering Laboratory; INL, Idaho National Laboratory; INTEC, Idaho Nuclear Technology and Engineering Center; NRTS, National Reactor Testing Station; RTC, Reactor Testing Complex; RWMC, Radioactive Waste Management Complex]

Reference	Investigation period	Summary
	Groundwater	
Jones (1961)		Hydrology of waste disposal at the NRTS, Idaho.
Olmsted (1962)		Chemical and physical character of groundwater at the NRTS, Idaho.
Morris and others (1963, 1964, 1965)		Hydrology of waste disposal at the NRTS, Idaho.
Barraclough, Teasdale, and Jensen (1967)	1965	Hydrology of the NRTS, Idaho.
Barraclough, Teasdale, Robertson, and Jensen (1967)	1966	Hydrology of the NRTS, Idaho.
Nace and others (1975)		Generalized geologic framework of the NRTS, Idaho.
Robertson and others (1974)		Effects of waste disposal on the geochemistry of groundwater at the NRTS, Idaho.
Barraclough and others (1976)		Hydrology of the solid waste burial ground (now the RWMC).
Barraclough and Jensen (1976)	1971–73	Hydrologic data for the INEL, Idaho.
Barraclough and others (1981)	1974–78	Hydrologic conditions for the INEL, Idaho.
Lewis and Jensen (1985)	1979–81	Hydrologic conditions for the INEL, Idaho.
Pittman and others (1988)	1982–85	Hydrologic conditions for the INEL, Idaho.
Orr and Cecil (1991)	1986–88	Hydrologic conditions and distribution of selected chemical constituents in water at the INEL, Idaho.
Bartholomay and others (1995)	1989–91	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, INEL, Idaho.
Bartholomay and others (1997)	1992–95	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, INEL, Idaho.
Bartholomay and others (2000)	1996–98	Hydrologic conditions and distribution of selected constituents in water, INEEL, Idaho.
Davis (2006a)	1999–2001	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, INL, Idaho.
Ackerman and others (2006)		Conceptual model of groundwater flow in the eastern Snake River Plain aquifer, INL, with implications for contaminant transport.
Davis (2008)	2002–05	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Bartholomay and Twining (2010)	2006–08	Vertical distribution of selected constituents in water from wells equipped with Westbay™ packer sampling systems.
Davis and others (2013)	2009–11	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Bartholomay, Maimer, and others (2017)	2012–15	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Bartholomay and others (2015)	2009–13	Vertical distribution of selected constituents in water from wells equipped with Westbay™ packer sampling systems.
Bartholomay and others (2012)	1949–2009	Water-quality trends for wells believed to be not influenced by wastewater disposal.
Davis and others (2015)	1981–2012	Water-quality trends for wells influenced by wastewater disposal at the INL.
Bartholomay and Twining (2015)	1949–2014	Hydrologic influences on water level changes in groundwater wells at the INL.

Table 1. Summary of selected previous investigations on geology, hydrology, and characteristics of groundwater and perched groundwater, Idaho National Laboratory, Idaho, 1961–2018.—Continued

Reference	Investigation period	Summary
	Perched groundwater	
Barraclough, Teasdale, and Jensen (1967)	1965	Extent of perched groundwater and distribution of selected wastewater constituents in perched groundwater at the ATRC.
Barraclough, Teasdale, Robertson, and Jensen (1967)	1966	Extent of perched groundwater and distribution of selected wastewater constituents in perched groundwater at the ATRC.
Robertson and others (1974)		Analysis of perched groundwater and conditions related to the disposal of wastewater to the subsurface at the INEL.
Barraclough and Jensen (1976)		Extent of perched groundwater and distribution of selected wastewater constituents in perched groundwater at the ATRC.
Robertson (1977)		Numerical model simulating flow and transport of chemical and radionuclide constituents through perched water at the ATRC.
Barraclough and others (1981)	1974–78	Hydrologic conditions for the INEL, Idaho.
Lewis and Jensen (1985)	1979–81	Hydrologic conditions for the INEL, Idaho.
Pittman and others (1988)	1982–85	Hydrologic conditions for the INEL, Idaho.
Hull (1989)		Conceptual model that described migration pathways for wastewater and constituents from the radioactive-waste infiltration ponds at the ATRC.
Anderson and Lewis (1989)		Correlation of drill cores and geophysical logs to describe a sequence of basalt flows and sedimentary interbeds in the unsaturated zones underlying the RWMC.
Anderson (1991)		Correlation of drill cores and geophysical logs to describe a sequence of basalt flows and sedimentary interbeds in the unsaturated zones underlying the RTC and INTEC.
Ackerman (1991)		Analyzed data from 43 aquifer tests conducted in 22 wells to estimate transmissivity of basalts and sedimentary interbeds containing perched groundwater beneath the ATRC and INTEC.
Cecil and others (1991)	1986–88	Mechanisms for formation of perched water at the ATRC, ICPP, and RWMC, INEL, Idaho; distribution of chemical and radiochemical constituents in perched water at the ATRC, ICPP and RWMC.
Tucker and Orr (1998)		Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched groundwater, INEL, Idaho.
Bartholomay (1998)	1992–95	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched groundwater, INEL, Idaho.
Orr (1999)		Transient numerical simulation to evaluate a conceptual model of flow through perched water beneath wastewater infiltration ponds at the ATRC.
Bartholomay and Tucker (2000)	1996–98	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched groundwater, INEEL, Idaho.
Davis (2006b)	1999–2001	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched groundwater, INL, Idaho.
Davis (2008)	2002–05	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Davis (2010)	2006–08	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Davis and others (2013)	2009–11	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Bartholomay, Maimer, and others (2017)	2012–15	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Davis and others (2015)	1981–2012	Water quality trends for wells influenced by wastewater disposal at the INL.

Groundwater Monitoring Networks

The USGS maintains groundwater monitoring networks at the INL to characterize the occurrence, movement, and quality of water, and to delineate waste-constituent plumes in the ESRP aquifer and perched groundwater zones. Periodic water-level and water-quality data are obtained from these networks. Data from these monitoring networks are available through the USGS National Water Information System (NWIS) web page at https://waterdata.usgs.gov/id/nwis/nwis.

Water-Level Monitoring Network

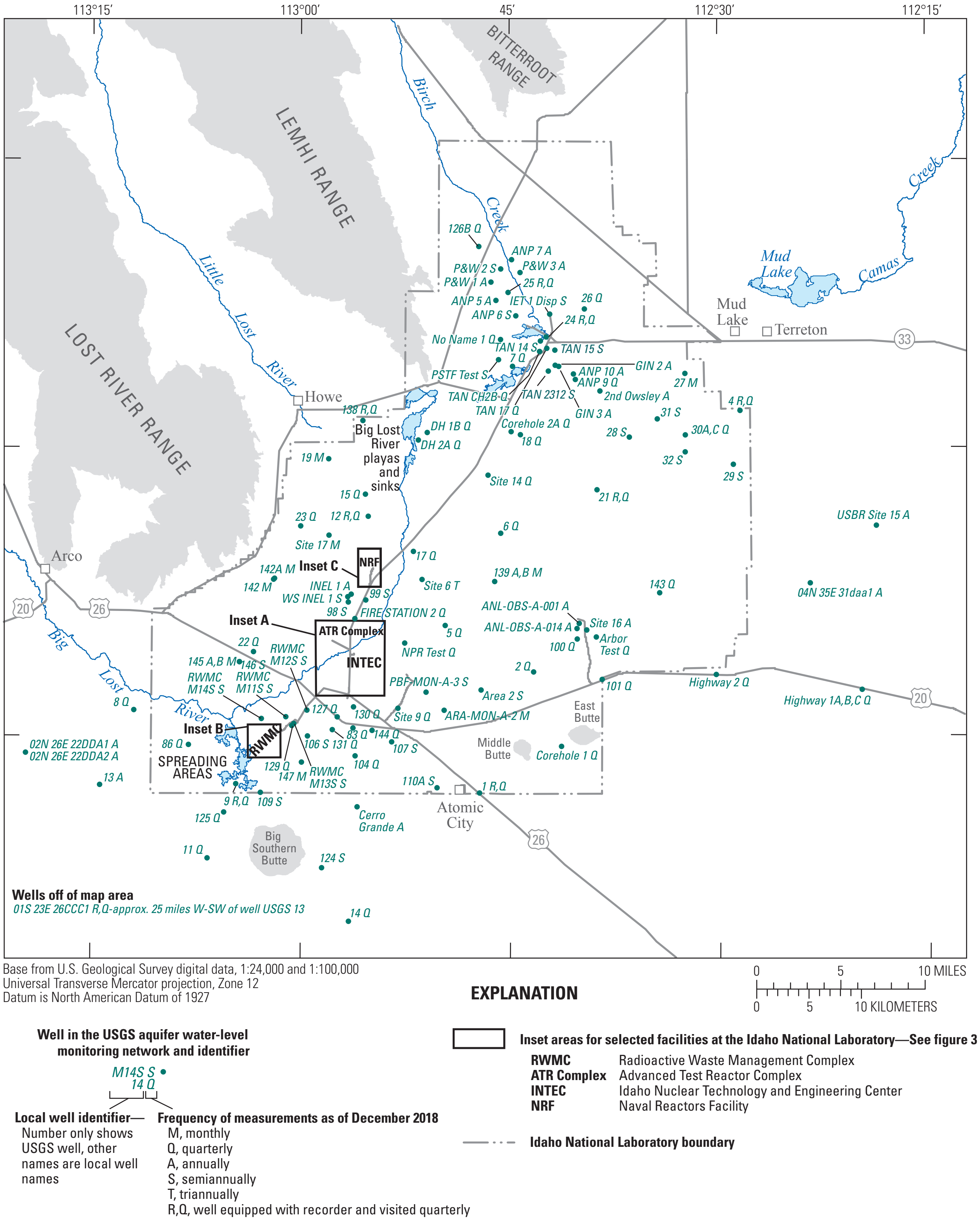
The USGS aquifer water-level monitoring network was designed to determine hydraulic-gradient changes that affect the rate and direction of groundwater and waste-constituent movement in the ESRP aquifer, to identify sources of recharge to the aquifer, and to measure the effects of recharge. A continuous monitoring transducer was installed in USGS 12 in 2018 to provide additional change information for water-level information in the west-central part of the INL. Two dual piezometer wells, USGS 142 (Twining and others, 2017) and USGS 145, were completed in 2016 and 2018, respectively, to provide additional water-level information in the west-central and southwestern part of the INL. New monitoring wells (TAN-2312, USGS 143, 144, 146, and 147) were completed during 2016–18 and were added to the water-level monitoring program in locations needing additional water-level information. As of December 2018, water levels were monitored in 179 aquifer wells. Five of the wells have two or more piezometers in them to measure different levels of the aquifer. Water levels were measured annually in 49 wells, semiannually in 51 wells, triannually in 2 wells, quarterly in 57 wells, and monthly in 12 wells; and were continuously recorded in 8 aquifer wells. The locations of aquifer wells and the frequency of water-level measurements as of December 2018 are shown in figures 2 and 3.

The USGS perched groundwater-level monitoring network was designed so that the extent and volume of perched groundwater in storage could be estimated. Perched groundwater occurs at the INL because unique features of the basalt layers and sedimentary interbeds in the unsaturated zone above the regional aquifer system that lie beneath some of the facilities provide a mechanism for the development of zones that hold water for a long time (Cecil and others, 1991, p. 17). As of December 2018, water levels in 29 wells (fig. 4) were monitored. At the ATR Complex, the network included 9 wells to monitor shallow perched groundwater levels and 18 wells to monitor deep perched groundwater levels. Shallow perched groundwater is considered to be water perched in surficial sediment deposits, and deep perched groundwater is water perched at a greater depth. Perching mechanisms are attributed to contrasting hydraulic properties between sedimentary interbeds and basalts or between low-permeability basalt-flow interiors and overlying fractured basalt. Southwest of the INTEC, the network included one well (ICPP-MON-V-200) to monitor perched groundwater levels around the INTEC percolation ponds. Perched groundwater at the RWMC was measured in well USGS 92. Well locations and frequency of water-level measurements as of December 2018 are shown in figure 4.

Water-Quality Monitoring Network

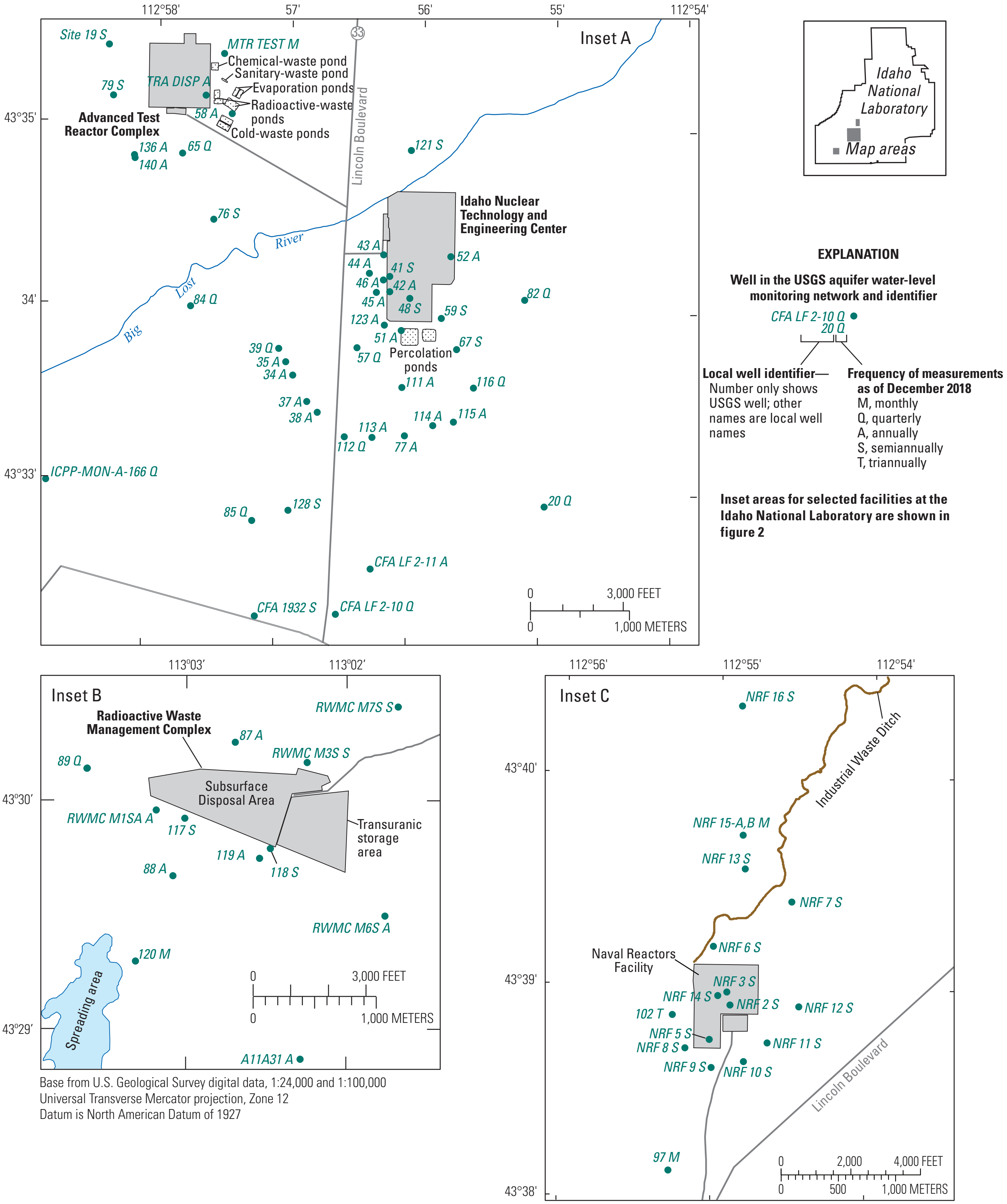
The radiochemical and chemical character of groundwater and perched groundwater in the ESRP aquifer was determined from analyses of water samples collected as part of a comprehensive sampling program to identify contaminant concentrations and to define patterns of waste migration in the aquifer and perched groundwater zones. Water samples were collected annually and analyzed to identify trends in water quality from wells that penetrate the aquifer at various depths and with differing well completions (open hole or screened). Numerous water samples were collected from aquifer and perched groundwater wells near areas of detailed study, such as the ATR Complex, INTEC, RWMC, TAN, and CFA. Water samples from the NRF and multi-level monitoring systems were collected and analyzed as part of separate studies, and the results are available on the USGS NWIS web page at https://waterdata.usgs.gov/id/nwis/nwis.

The type and depth of groundwater sampling generally depend on the information needed in a specific area. Water samples were routinely collected and analyzed for some combination of concentrations of tritium; strontium-90; cesium-137; plutonium-238, -239, and -240 (undivided); americium-241; gross alpha- and beta-particle radioactivity; chromium; sodium; chloride; sulfate; nutrients including nitrite plus nitrate (as nitrogen [N]), nitrite (as N), orthophosphate (as phosphorus), and ammonia (as N); volatile organic compounds (VOCs); and measurements of specific conductance, pH, and temperature. Additionally, as part of the INL groundwater monitoring program adopted in 1994 (Sehlke and Bickford, 1993), water samples from several wells also were analyzed for fluoride and an extensive suite of trace elements. When a new well is drilled by the USGS at the INL, samples are collected and analyzed for all constituents previously listed, together with a full suite of cations and anions and carbon, deuterium, oxygen, and uranium isotopes. A schedule listing the constituents that typically are analyzed is provided in a report by Bartholomay and others (2014, appendix A). The location and construction of wells, and the water sample collection method in the aquifer water-quality monitoring network as of December 2018, are shown in figures 5 and 6, and in table 2. Wells USGS 143, 144, 146, 147 and well TAN 2312 (Twining and others, 2018) were completed during 2016–18 for water-quality monitoring. Well location and construction of wells in the USGS water-quality monitoring network for perched groundwater beneath INL facilities as of December 2018 are shown in figure 7 and table 3. All wells were scheduled to be sampled annually, however; some pump problems or wells being dry did prevent some samples from being collected.



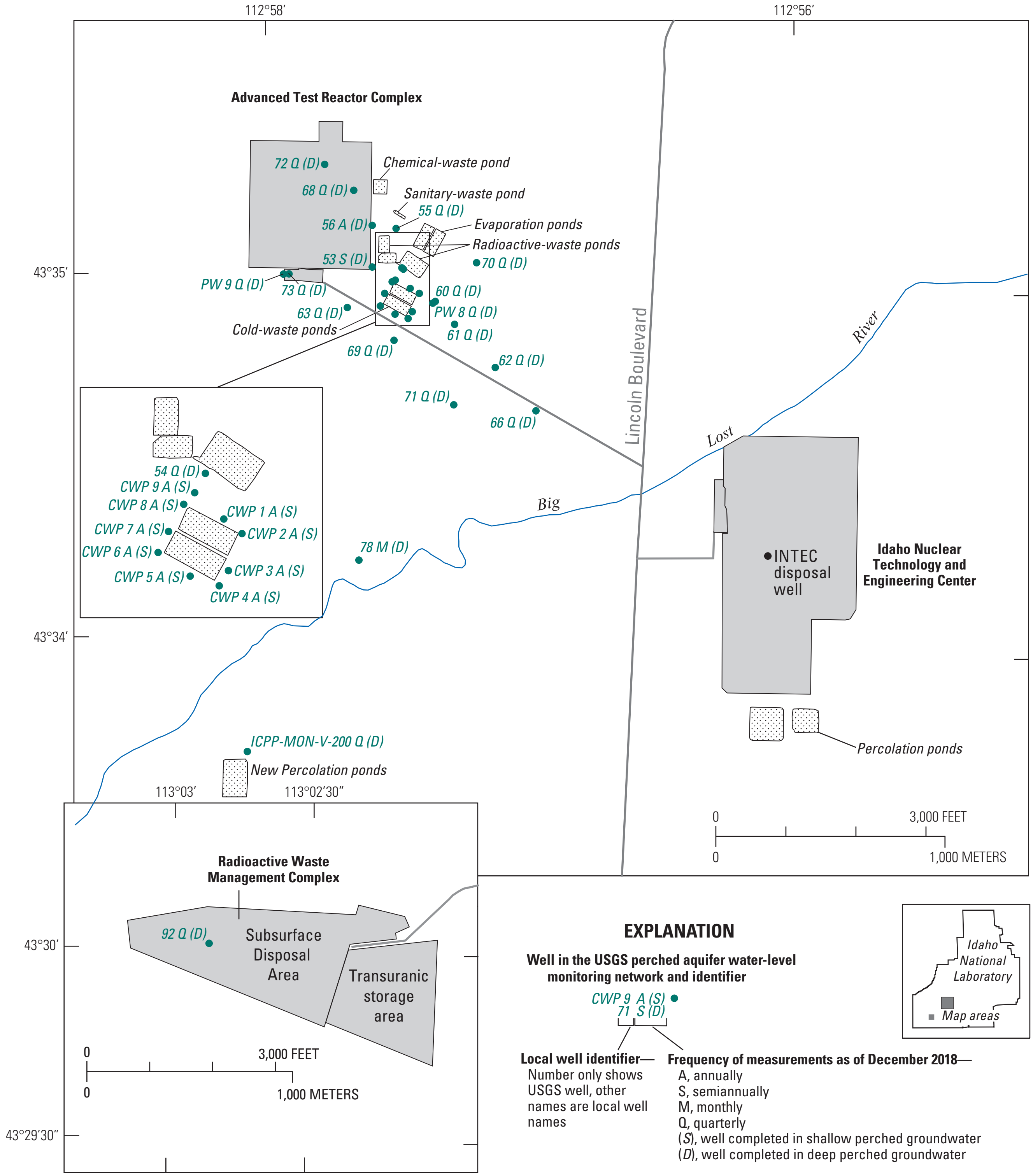
Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 2. Location of wells in the U.S. Geological Survey aquifer water-level monitoring network at and near the Idaho National Laboratory, Idaho, and frequency of water-level measurements, as of December 2018.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 3. Location of wells in the U.S. Geological Survey aquifer water-level monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Radioactive Waste Management Complex, and Naval Reactors Facility, Idaho National Laboratory, Idaho, and frequency of water-level measurements, as of December 2018.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 4. Location of wells in the U.S. Geological Survey perched groundwater-level monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, and frequency of water-level measurements, as of December 2018.

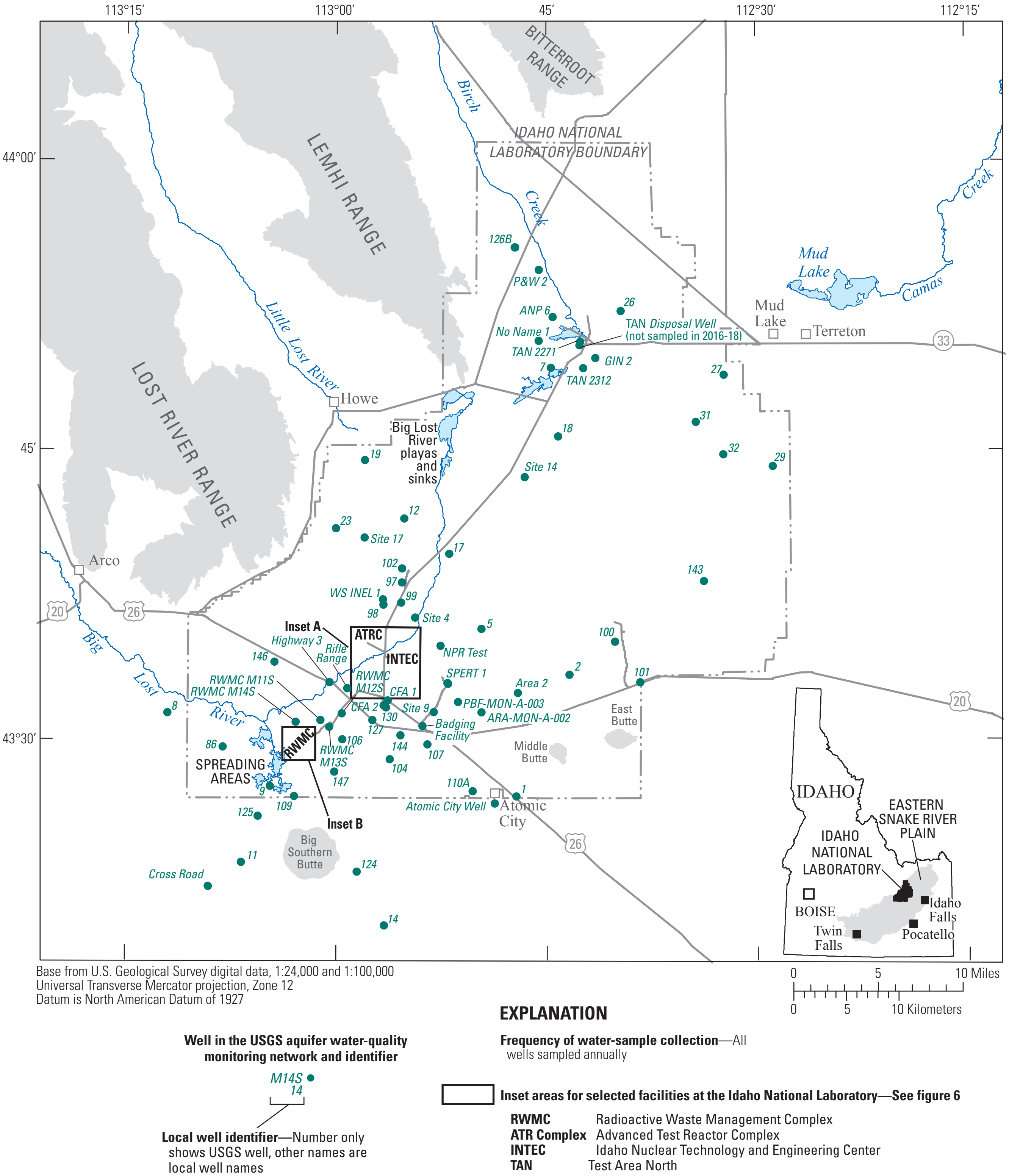
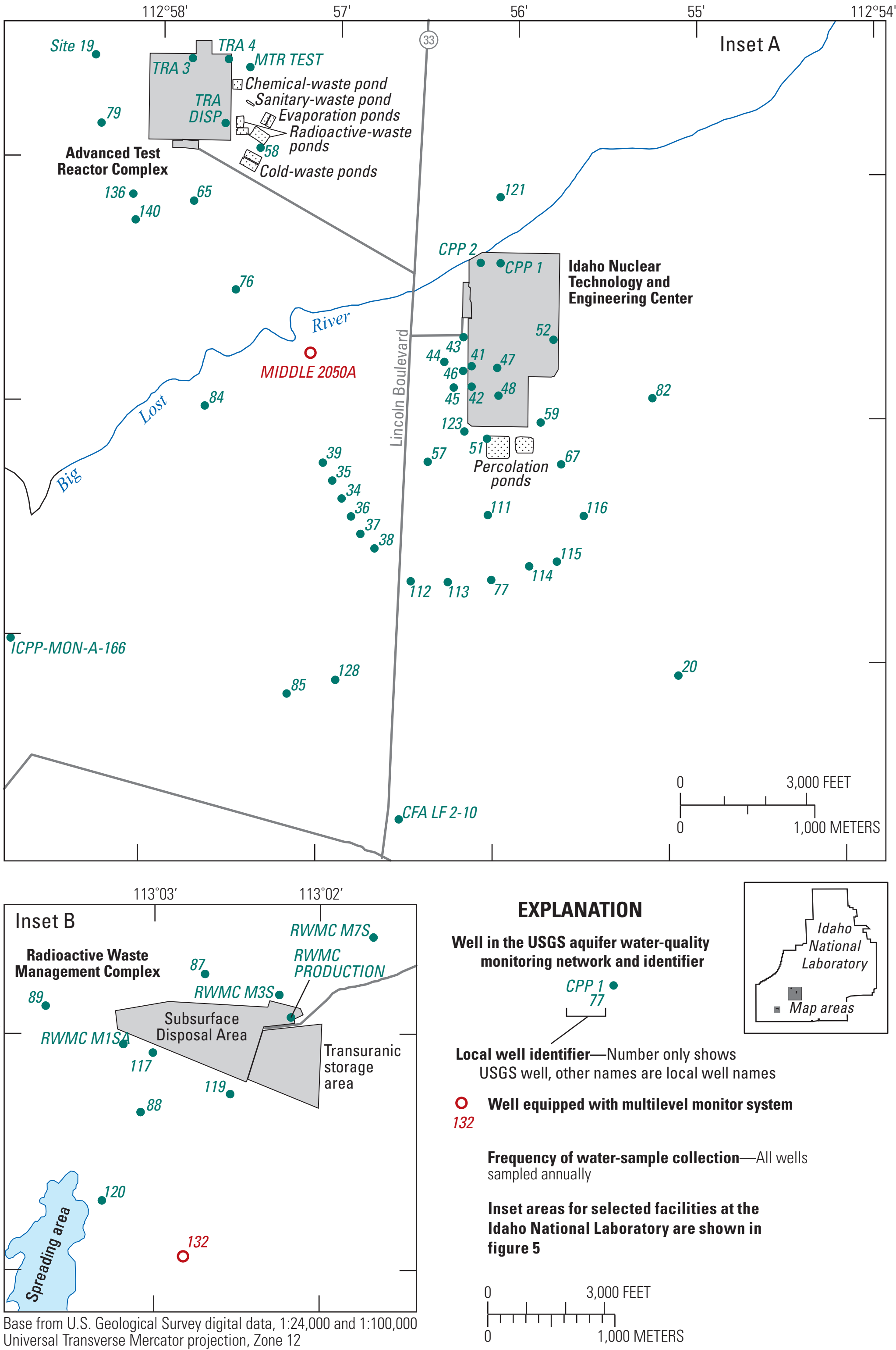


Figure 5. Location of wells in the U.S. Geological Survey aquifer water-quality monitoring network, Idaho National Laboratory and vicinity, Idaho, December 2018.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 6. Location of wells in the U.S. Geological Survey aquifer water-quality monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, December 2018.

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2018.

[All wells are sampled annually. **Well name:** Well locations are shown in figures 5 and 6. **Sample-collection method:** Pump, sampled from pumping well (pumping rate in gallons per minute); Tap, sampled from faucet. **Abbreviations:** No., number; USGS, U.S. Geological Survey]

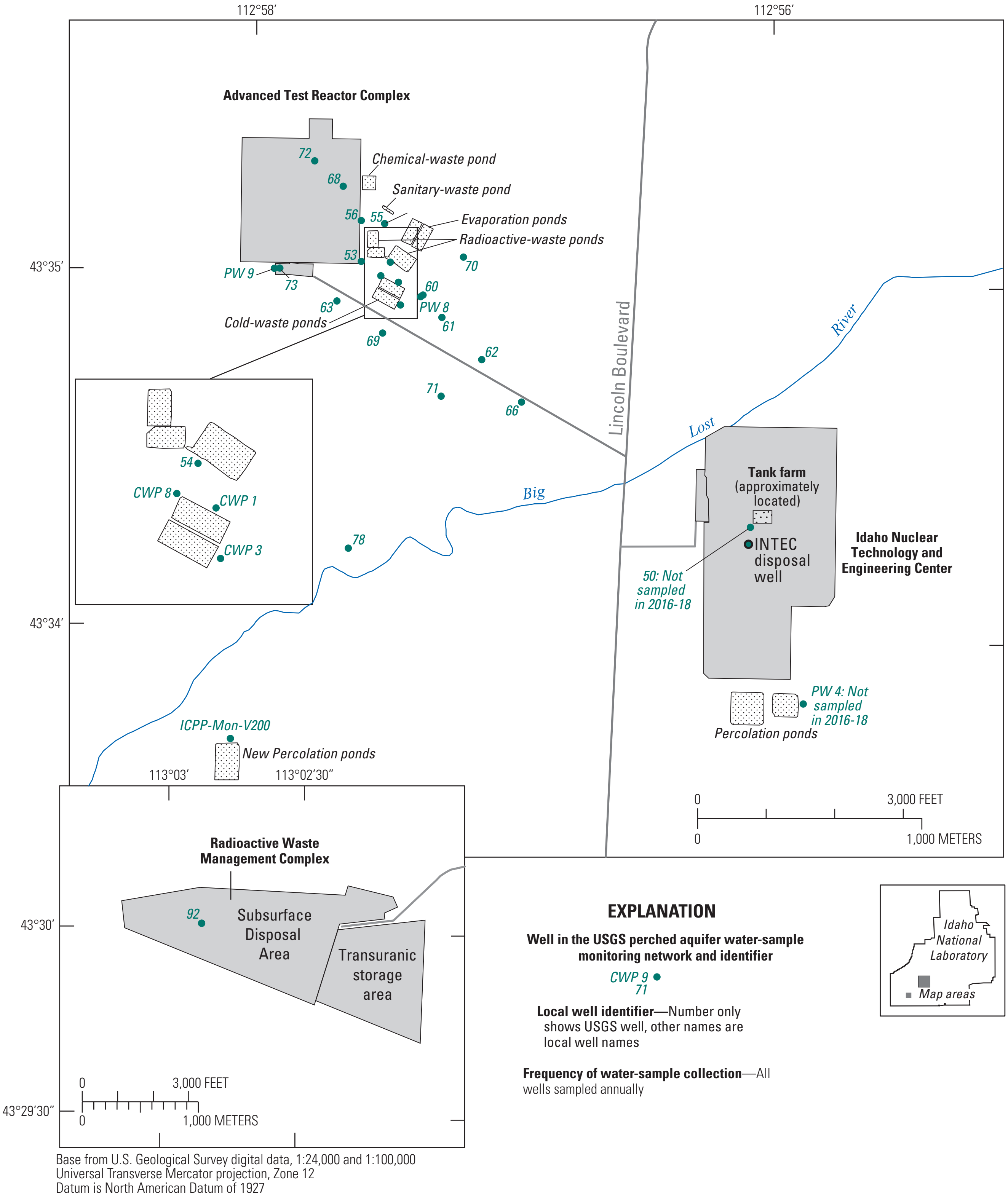
Well name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
ANP 6	435152112443101	10	305	Pump (25)
ARA-MON-A-002	433054112492102	6	620	Pump (15)
AREA 2	433223112470201	16	877	Pump (18)
ATOMIC CITY	432638112484101	8	639	Tap
BADGING FACILITY	433042112535101	8	644	Pump (35)
CFA 1	433204112562001	16	639	Pump (1,000)
CFA 2	433144112563501	16	681	Pump (1,400)
CFA LF 2-10	433216112563301	6	716	Pump (8.3)
CPP 1	433433112560201	16	586	Pump (3,000)
CPP 2	433432112560801	16	605	Pump (3,000)
CROSS ROAD	432128113092701	8	796	Pump (35)
GIN 2	434949112413401	2	381	Pump (2)
HIGHWAY 3	433256113002501	8	750	Pump (18)
ICPP-MON-A-166	433300112583301	6	527	Pump (3)
MTR TEST	433520112572601	8	588	Pump (26)
NO NAME 1	435038112453401	12	550	Pump (42)
NPR TEST	433449112523101	6	600	Pump (28)
PBF-MON-A-003	433203112514201	5	575	Pump (10)
P&W 2	435419112453101	10	386	Pump (35)
RIFLE RANGE	433243112591101	5	620	Pump (25)
RWMC M1SA	432956113030901	6	638	Pump (6)
RWMC M3S	433008113021801	6	633	Pump (6)
RWMC M7S	433023113014801	6	628	Pump (5)
RWMC M11S	433058113010401	6	624	Pump (12)
RWMC M12S	433118112593401	6	572	Pump (6)
RWMC M13S	433037113002701	6	643	Pump (6)
RWMC M14S	433052113025001	6	635	Pump (14)
RWMC PROD	433002113021701	10, 14	685	Pump (200)
SITE 4	433617112542001	8	495	Pump (500)
SITE 9	433123112530101	10	1,057	Pump (30)
SITE 14	434334112463101	8, 12	717	Pump (36)
SITE 17	434027112575701	15	600	Pump (30)
SITE 19	433522112582101	8, 10	860	Pump (15)
SPERT-1	433252112520301	14	653	Pump (400)
TAN 2271	435053112423101	10	282	Pump (4)
TAN 2312	434939112421601	10	522	Pump (2)
TRA 3	433522112573501	20	602	Pump (3,800)
TRA 4	433521112574201	16, 18	965	Pump (2,000)
TRA DISP	433506112572301	6, 8	1,267	Pump (25)
USGS 1	432700112470801	5	630	Pump (22)

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2018.—Continued

Well name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
USGS 2	433320112432301	5	699	Pump (16)
USGS 5	433543112493801	6	494	Pump (5)
USGS 7	434915112443901	4, 6	903	Pump (45)
USGS 8	433121113115801	6	812	Pump (15)
USGS 9	432740113044501	6	654	Pump (15)
USGS 11	432336113064201	6	704	Pump (23)
USGS 12	434126112550701	10	563	Pump (35)
USGS 14	432019112563201	5	752	Pump (16)
USGS 17	433937112515401	5, 6	498	Pump (15)
USGS 18	434540112440901	4	329	Pump (30)
USGS 19	434426112575701	6	399	Pump (17)
USGS 20	433253112545901	6	658	Pump (18)
USGS 23	434055112595901	5, 6	458	Pump (25)
USGS 26	435212112394001	6	266	Pump (20)
USGS 27	434851112321801	6	312	Pump (20)
USGS 29	434407112285101	6	426	Pump (30)
USGS 31	434625112342101	8, 10	428	Pump (40)
USGS 32	434444112322101	5.5, 6	392	Pump (35)
USGS 34	433334112565501	10	700	Pump (30)
USGS 35	433339112565801	7	579	Pump (25)
USGS 36	433330112565201	6	567	Pump (25)
USGS 37	433326112564801	6	572	Pump (25)
USGS 38	433322112564301	4	724	Pump (18)
USGS 39	433343112570001	8	492	Pump (25)
USGS 41	433409112561301	6	666	Pump (25)
USGS 42	433404112561301	6	678	Pump (25)
USGS 43	433415112561501	6	564	Pump (6)
USGS 44	433409112562101	6	650	Pump (25)
USGS 45	433402112561801	6	651	Pump (25)
USGS 46	433407112561501	6	651	Pump (25)
USGS 47	433407112560301	6	651	Pump (8)
USGS 48	433401112560301	6	750	Pump (29)
USGS 51	433350112560601	6	647	Pump (4)
USGS 52	433414112554201	6	602	Pump (30)
USGS 57	433344112562601	6	582	Pump (30)
USGS 58	433500112572502	6	503	Pump (26)
USGS 59	433354112554701	6	587	Pump (18)
USGS 65	433447112574501	4	498	Pump (8)
USGS 67	433344112554101	4, 6	694	Pump (8)
USGS 76	433425112573201	6	718	Pump (29)
USGS 77	433315112560301	6	586	Pump (25)
USGS 79	433505112581901	6	702	Pump (30)

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2018.—Continued

Well name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
USGS 82	433401112551001	6	693	Pump (25)
USGS 84	433356112574201	6	505	Pump (20)
USGS 85	433246112571201	6	614	Pump (23)
USGS 86	432935113080001	8	691	Pump (19)
USGS 87	433013113024201	4	673	Pump (2)
USGS 88	432940113030201	4	663	Pump (8)
USGS 89	433005113032801	6	714	Pump (2)
USGS 97	433807112551501	4	510	Pump (27)
USGS 98	433657112563601	4	508	Pump (25)
USGS 99	433705112552101	4	440	Pump (25)
USGS 100	433503112400701	6	750	Pump (10)
USGS 101	433255112381801	4, 6	842	Pump (12)
USGS 102	433853112551601	6	445	Pump (30)
USGS 104	432856112560801	8	700	Pump (26)
USGS 106	432959112593101	8	760	Pump (24)
USGS 107	432942112532801	8	690	Pump (30)
USGS 109	432701113025601	4	800	Pump (22)
USGS 110A	432717112501502	6	644	Pump (6)
USGS 111	433331112560501	8	560	Pump (12)
USGS 112	433314112563001	8	507	Pump (12)
USGS 113	433314112561801	6	556	Pump (15)
USGS 114	433318112555001	6	560	Pump (10)
USGS 115	433320112554101	6	581	Pump (5)
USGS 116	433331112553201	6	572	Pump (20)
USGS 117	432955113025901	6.5	655	Pump (12)
USGS 119	432945113023401	6.5	705	Pump (15)
USGS 120	432919113031501	6.5	705	Pump (18)
USGS 121	433450112560301	6	480	Pump (10)
USGS 123	433352112561401	6	515	Pump (12)
USGS 124	432307112583101	4	800	Pump (20)
USGS 125	432602113052801	5	774	Pump (18)
USGS 126B	435529112471401	6	472	Pump (10)
USGS 127	433058112572201	6	596	Pump (25)
USGS 128	433250112565601	4.5	615	Pump (23)
USGS 130	433130112562801	4.5	636	Pump (25)
USGS 136	433447112581501	6	551	Pump (21)
USGS 140	433441112581201	6	546	Pump (24)
USGS 143	433736112341301	6	801	Pump (20)
USGS 144	433021112552501	6	620	Pump (20)
USGS 146	433359113042501	6	800	Pump (15)
USGS 147	432851112001401	8	729	Pump (15)
WS INEL1	433716112563601	6	490	Pump (30)



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 7. Location of wells in the U.S. Geological Survey perched groundwater-quality monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, as of December 2018.

Table 3. Construction of wells in the U.S. Geological Survey perched groundwater-quality monitoring network and water sample-collection method at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, as of December 2018.

[All wells were sampled annually. **Well no.:** Well locations are shown in figure 7. **Sample-collection method:** Bail, sample collected with a bailer (sample collection depth in feet below land surface); Pump, sample collected with a pump (pumping rate in gallons per minute). **Abbreviation:** No., number; USGS, U.S. Geological Survey]

Well No.	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
CWP 1	433459112572601	6	58	Bail (55)
CWP 3	433455112572501	6	55	Bail (50)
CWP 8	433500112573001	6	64	Bail (58)
ICPP-Mon-V-200	433321112581501	4	127	Pump (1.5)
PW 8	433456112572001	6	166	Pump (8)
PW 9	433500112575401	6	200	Pump (5)[1]
USGS 53	433503112573401	6	71	Bail
USGS 54	433503112572801	6	82	Pump (4)
USGS 55	433508112573001	6	81	Pump (1)
USGS 56	433509112573501	6	105	Bail (74)
USGS 60	433456112571901	6	117	Pump (6)
USGS 61	433453112571601	4	123	Pump (6)
USGS 62	433446112570701	8	165	Pump (5)
USGS 63	433455112574001	10	109	Pump (5)
USGS 66	433436112564801	4	202	Bail (195)
USGS 68	433516112573901	10	128	Pump (1)
USGS 69	433450112573001	4	115	Pump (5)
USGS 70	433504112571001	8	100	Pump (6)
USGS 71	433439112571501	5	171	Bail (165)
USGS 72	433519112574601	4	174	Bail (148)
USGS 73	433502112575401	6	127	Bail (125)
USGS 78	433413112573501	7	204	Bail (165)
USGS 92	433000113025301	3.5	214	Bail (213)

[1] Well was bailed in 2016 and 2017 and had a pump re-installed for 2018 sample.

Waste-Disposal Sites at the Idaho National Laboratory

Wastewater disposal at INL facilities (fig. 1) has been the principal source of radioactive- and chemical-waste constituents in water from the ESRP aquifer and in perched groundwater zones at and near the INL. In the past, wastewater disposal sites included infiltration ponds (percolation ponds) and ditches, evaporation ponds, drain fields, and disposal wells. Currently (2019), wastewater is being discharged to infiltration ponds, evaporation ponds, and ditches at the INL; and the effluent is sampled and analyzed by the INL contractor for radionuclides and various other constituents prior to discharge. Solid and liquid wastes buried at the RWMC (fig. 1) also are sources of some constituents in groundwater.

Contractors at each INL facility collected and reported concentrations of radioactive- and chemical-waste-disposal data from 1976 to 1998 (French and others, 1999a, 1999b); however, prior to 1976 and since 1999, no formal program has been in place to compile annual amounts of constituents discharged at each facility (Richard Kauffman, U.S. Department of Energy, oral commun., 2005). Highlights of the waste disposal history at INL facilities are summarized here; a more comprehensive summary of waste disposal at the INL from 1952 through 1998 is available in Bartholomay and others (2000).

Advanced Test Reactor Complex

Since 1952, low-level radioactive, chemical, and sanitary wastewater has been discharged to infiltration and lined evaporation ponds located east of the ATR Complex (fig. 3). Nonradioactive cooling-tower wastewater was discharged to radioactive-waste infiltration ponds from 1952 to 1964, to the ESRP aquifer through a 1,267-ft-deep Test Reactor Area disposal well (TRA DISP, fig. 3) from 1964 until March 1982, and into two cold-waste infiltration ponds from 1982 to the present (2019). A more complete summary of potential groundwater contamination sources at the ATR Complex is available in U.S. Department of Energy (2011a, table 4-1).

In 1976, the DOE contractor at the ATR Complex began a three-phase program to reduce radioactivity in wastewater. The first phase was 1976–80, and the second phase was 1981–87. The contractor finished the final phase of the program in 1993. In August 1993, the radioactive-waste infiltration ponds at the ATR Complex were replaced with lined evaporation ponds. The evaporation ponds were designed to prevent radioactive wastewater from entering the aquifer.

During 1961–79, less than 25 percent of radioactivity in wastewater discharged was attributed to tritium; most other radioactivity consisted of radionuclides with half-lives of about several weeks, as well as small amounts of strontium-90, cesium-137, and cobalt-60 (Barraclough and others, 1981). In 1980, about 50 percent of radioactivity was attributed to tritium, and during 1981–93, more than 90 percent was attributed to tritium (Bartholomay and others, 1997, fig. 6). Overall, about 8,920 curies (Ci) of tritium were discharged to the radioactive-waste infiltration ponds from 1952 through 1993.

A chemical-waste infiltration pond was used for disposal of chemical wastewater from an ion-exchange system at the ATR Complex (fig. 3) from 1962 to 1999. The average annual discharge to this pond was about 17.5 million gallons (Mgal) during 1962–98. Sulfate and sodium hydrate were the predominant constituents in the chemical wastewater (Bartholomay and others, 2000). In 1999, the chemical-waste infiltration pond was closed and covered with a protective cap (S.M. Stoller Corporation, 2002a).

From 1964 to March 1982, the TRA disposal well (TRA DISP, fig. 3) was used to inject nonradioactive wastewater from cooling-tower operations at the ATR Complex into the ESRP aquifer and also was used to discharge some radioactive wastewater from reactor operations (U.S. Department of Energy, 2011a). Since March 1982, wastewater from cooling-tower operations has been discharged to two cold-waste infiltration ponds (fig. 3). The TRA disposal well has been used as an observation well since 1982. Prior to 1964, well USGS 53 (fig. 4) also was used intermittently to discharge wastewater into the perched groundwater system (U.S. Department of Energy, 2011b) and has been used as an observation well since 1964.

Large quantities of chromate-contaminated wastewater were injected directly into the ESRP aquifer or infiltrated through the unsaturated zone beneath the radioactive-waste infiltration ponds (fig. 3). From 1952 through 1972, an estimated 17,790 lb of chromium was discharged to the radioactive-waste infiltration ponds and 31,131 lb of chromium was discharged to the TRA disposal well. Other contaminants discharged at the ATR Complex, such as those associated with sanitary sewage in the sanitary-waste pond (fig. 3) included nitrate, phosphate, and chloride (U.S. Department of Energy, 2011a).

Idaho Nuclear Technology and Engineering Center

From 1952 to February 1984, the INTEC discharged most low-level radioactive, chemical, and sanitary wastewater into the ESRP aquifer through a 600-ft-deep disposal well (INTEC disposal well, fig. 4). Two percolation ponds (also called infiltration ponds) were used for wastewater disposal from 1984 through August 25, 2002 (fig. 4). The first pond was completed in February 1984 and the second pond was completed in October 1985. On August 26, 2002, the “old” percolation ponds were taken out of service and wastewater was discharged to the “new” percolation ponds about 2 mi southwest of the INTEC (fig. 4). The new percolation ponds were designed to be a rapid infiltration system, and each pond can accommodate as much as 3 Mgal/d of continuous discharge (S.M. Stoller Corporation, 2004).

Tritium has accounted for most of the radioactivity in wastewater discharged to the disposal well and old percolation ponds at the INTEC (Davis, 2008, fig. 9). During 1953–2000, a total of about 21,135 Ci of tritium was discharged at the INTEC (Mann and Cecil, 1990; Davis, 2008). Other radionuclides discharged at the INTEC included strontium-90, cesium-137, iodine-129, plutonium isotopes, uranium isotopes, neptunium-237, americium-241, and technetium-99 (U.S. Department of Energy, 2011a). In 1972, about 18,100 Ci of strontium-90, 19,100 Ci of cesium-137, and 18,600 gallons of sodium-bearing waste were released to soil at the INTEC tank farm during a failed transfer between two underground storage tanks (fig. 7) (Cahn and others, 2006). This accounts for about 88 percent (about 15,900 Ci) of the source of strontium-90 to groundwater at the INTEC tank farm (fig. 7). Three other locations at the INTEC tank farm are the source of the remaining 12 percent of strontium-90 (Cahn and others, 2006).

Historically, chloride, fluoride, nitrate, sodium, and sulfate were the predominant chemical constituents in wastewater discharged at the INTEC (Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995, 1997, 2000). Mercury also has been listed as a constituent that potentially could affect groundwater quality (U.S. Department of Energy, 2011a).

Naval Reactors Facility

Wastewater at the NRF is discharged to a 1.65-mi-long industrial-waste ditch and sewage ponds (fig. 3). The waste ditch was first used in 1953 to dispose of non-radioactive, non-sewage industrial wastewater. Chloride, sulfate, and sodium have been the predominant chemical constituents in wastewater discharged to the ditch throughout its history of operation (Lewis and Jensen, 1985; Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995, 1997, 2000).

Radioactive Waste Management Complex

Solid and liquid radioactive and chemical wastes have been buried in trenches and pits at the SDA at the RWMC (fig. 3) since 1952. These include transuranic wastes, other radiochemical and inorganic chemical constituents, and organic compounds. The transuranic wastes were buried in trenches until 1970 and stored above ground at the RWMC after 1970. Only low-level mixed waste has been buried at the RWMC since 1970. 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 excavations to inhibit downward migration of waste constituents.

About 17,100 Ci of plutonium-238, 64,900 Ci of plutonium-239, 17,100 Ci of plutonium-240, and 183,000 Ci of americium-241 were buried in the SDA during 1952–99 (Holdren and others, 2002, table 4-1). An estimated 88,400 gal of organic waste were buried before 1970 (Mann and Knobel, 1987, p. 1). These buried organic 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.

Test Area North

From 1953 to 1972, low-level radioactive, chemical, organic, and sanitary wastewater was discharged at TAN (fig. 1) into the ESRP aquifer through a 310-ft-deep disposal well (TAN Disposal Well, fig. 5). In 1972, the disposal well was replaced by a 35-acre infiltration pond. Records are not available to indicate the amount of radioactivity in wastewater discharged at TAN before 1959. During 1959–93, about 61 Ci of radioactivity in wastewater were discharged to the disposal well and infiltration pond. It is estimated that as little as 350 gal to as much as 35,000 gal of trichloroethylene (TCE) were disposed of in the disposal well (U.S. Department of Energy, 2011a). Based on information available through 1998, radioactive wastewater has not been discharged since 1993 (Bartholomay and others, 2000). The principal contaminants at TAN from use of the disposal well include several VOCs (including TCE, tetrachloroethylene, *cis*-dichloroethene, *trans*-1,2-dichloroethene, and vinyl chloride) and several radionuclides (strontium-90, cesium-137, tritium, and uranium-234) (U.S. Department of Energy, 2011a).

Chemical wastewater containing predominantly chloride and sodium was discharged to the infiltration pond at the Technical Support Facility (TSF) near TAN during 1971–2007. Some low-level radioactive waste containing about 0.039 Ci of strontium-90 also was released to the pond during 1972–85 (U.S. Department of Energy, 2011a). A closure plan for the pond was submitted to the Idaho Department of Environmental Quality in November 2007, and wastewater discharge to the pond ceased on November 29, 2007. All activities proposed in the plan were completed by February 2008 (S.M. Stoller Corporation, 2009).

Central Facilities Area

About 65 Ci of radioactivity in about 1,500 Mgal of wastewater were discharged to the sewage-plant tile drain field at the CFA (fig. 1) during 1952–93. Most radioactive wastes discharged to this drain field were from aquifer water pumped from well CFA 1 (fig. 5), which obtains water from within the INTEC contaminant plume in the ESRP aquifer. Most radioactivity in wastewater discharged at the CFA was attributed to tritium.

Chloride and sodium were the predominant chemical constituents in wastewater at the CFA (Lewis and Jensen, 1985; Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995, 1997, 2000). Nitrate in the southern part of the CFA has been attributed to wastewater disposal at the former CFA mercury pond (U.S. Department of Energy, 2011b).

Hydrologic Conditions

The ESRP aquifer is one of the most productive aquifers in the United States (U.S. Geological Survey, 1985, p. 193). The aquifer consists of a thick sequence of basalts and sedimentary interbeds filling a large, arcuate, structural basin in southeastern Idaho (fig. 1). Recharge to the ESRP aquifer is primarily from infiltration of applied irrigation water, infiltration of streamflow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation.

Surface Water

The Big Lost River drains more than 1,400 mi^2 of mountainous area that includes parts of the Lost River Range and the Pioneer and White Knob Mountains west of the INL (fig. 1). Surface water flow along the Big Lost River infiltrates to the ESRP aquifer through the river channel and at sinks and playas at its terminus (fig. 1). When flow in the Big Lost River exceeds about 300 ft^3/s in the river channel, excess streamflow is diverted to spreading areas, where it rapidly infiltrates. This excess streamflow has been diverted since 1965 to spreading areas in the southwestern part of the INL to prevent potential flooding at the INL facilities (Bennett, 1990, p. 15). Other surface drainages that provide recharge to the ESRP aquifer at the INL include Birch Creek, the Little Lost River, and Camas Creek (fig. 1).

The average streamflow recorded at USGS streamgage 13127000, Big Lost River below Mackay Reservoir near Mackay, Idaho (fig. 1) for complete water years (October 1–September 30) 1905–2018 was 218,280 acre-ft/yr (fig. 8). Streamflow at streamgages at and downstream of streamgage 13127000 (fig. 1) for water years 2016–18 are shown in table 4 and figure 8. Most of the flow between Mackay Reservoir and Arco, Idaho, is diverted for irrigation and groundwater recharge; therefore, flow only reaches the INL during wet years or when heavy rainfall or rapid snowmelt warrant brief periods of high discharge out of Mackay Reservoir.

Recharge to the ESRP aquifer downstream of Arco, Idaho (fig. 1), is substantial during wet years because of streamflow infiltration from the Big Lost River channel, diversion areas, sinks, and playas. For example, infiltration losses at various discharges measured during 1951–85 ranged from 1 (ft^3/s)/mi in the river channel to 28 (ft^3/s)/mi in the sinks (Bennett, 1990, p. 24–26). Bennett (1990) considered streamflow losses to evapotranspiration minor as compared to infiltration losses. However, infiltration can be zero in years when there is little or no flow in the Big Lost River channel at or downstream of streamgage 13132500 (fig. 1), as was the case during water years 2002–04 (Davis, 2008, table 4); 2008 (Davis, 2010, table 4); 2013–15 (Bartholomay, Maimer, and others, 2017, table 4); and 2016 (table 4).

Groundwater

Water in the ESRP aquifer primarily moves through interflow and fracture zones in the basalt. A large proportion of groundwater moves through the upper 200–800 ft of basaltic rocks (Mann, 1986, p. 21). Ackerman (1991, p. 30) and Bartholomay and others (1997) reported a range of transmissivity of basalt in the upper part of the aquifer of 1.1–760,000 ft^2/d. Anderson and others (1999) reported a range of hydraulic conductivity at the INL of 0.01–32,000 ft/d. The hydraulic conductivity of rocks underlying the aquifer varies from 0.002 to 0.03 ft/d (Mann, 1986, p. 21). The effective base of the ESRP aquifer was measured in different wells from about 815 to 1,710 ft below land surface in the western half of the INL (Anderson and others, 1996, table 3). Wells in the eastern half of the INL do not penetrate the base of the aquifer, so the effective base of the aquifer has only been estimated from surface-based electrical-resistivity surveys (Ackerman and others, 2010, fig. 6).

Depth to water in wells completed in the ESRP aquifer ranges from about 225 ft in the northern part of the INL to more than 900 ft in the southeastern part. During March–May 2018, the altitude of the water table was about 4,560 ft in the northern part of the INL and about 4,410 ft in the southwestern part (fig. 9). Water flowed south and southwestward beneath the INL (fig. 9) at an average hydraulic gradient of about 4 ft/mi.

Water levels in wells declined about 0.5 to more than 2.5 ft in the northern part of the INL from March–May 2015 (Bartholomay, Maimer, and others, 2017) to March–May 2018 (fig. 10). In the central and eastern parts of the INL, water levels rose slightly in some wells and declined slightly in others during March to May 2015–18 (fig. 10). In the southwestern part of the INL, water levels generally rose by about 0.5 to more than 2.5 ft during March to May 2015–18. Water-level rises in wells near the Big Lost River can be attributed to a large amount of flow in the river during the last 2 years of the study period (table 4).

Water levels monitored in wells USGS 12, 17, and 23 (fig. 2), and 20 (fig. 3) show long-term water-level changes in the ESRP aquifer in the central part of the INL in response to infiltration of streamflow (fig. 11). Long-term water-level fluctuations were about 20 ft in well USGS 20, 30 ft in well USGS 17, 35 ft in well USGS 23, and 40 ft in well USGS 12. Water levels in these wells increased during 2016–18.

Groundwater moves southwestward from the INL and eventually discharges to springs along the Snake River near Twin Falls, Idaho, about 100 mi southwest of the INL. Discharge from the springs estimated by methods given by Kjelstrom (1995, table 6) was about 3.55 million acre-ft/yr for water year 2018, up slightly from the estimate of 3.45 million acre-ft/yr for water year 2015. Historically, the discharge to these springs has ranged from 2.97 million acre-ft/yr in 1904 to 4.94 million acre-ft/yr in 1951 (Daniel J. Ackerman, U.S. Geological Survey, written commun., 2007).

Perched Groundwater

Disposal of wastewater to infiltration ponds and infiltration of surface water at waste-burial sites at the INL has resulted in the formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer (Cecil and others, 1991). Perched groundwater has formed in a complex sequence of basalt flow and sedimentary interbeds beneath the ATR Complex, the INTEC, and the RWMC. Perched groundwater also has been detected beneath infiltration ponds and ditches at other facilities at the INL in the past but is not monitored by the USGS.

Anderson and Lewis (1989) and Anderson (1991) correlated geophysical logs to describe the stratigraphic sequences in which perched groundwater has formed at the ATR Complex, the INTEC, and the RWMC. Although the subsurface stratigraphy, geohydrologic characteristics, and waste disposal practices at each of these areas differs, the

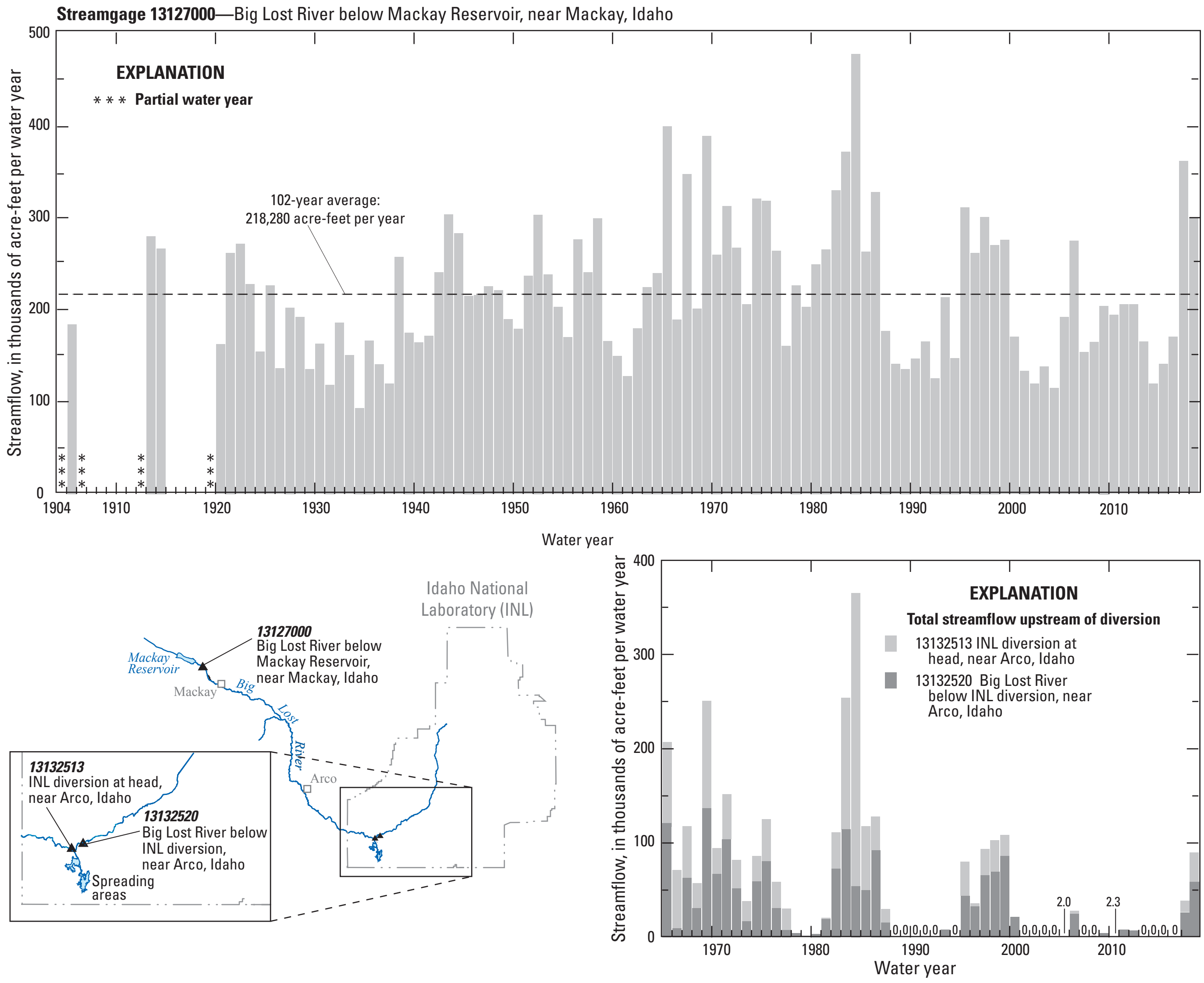
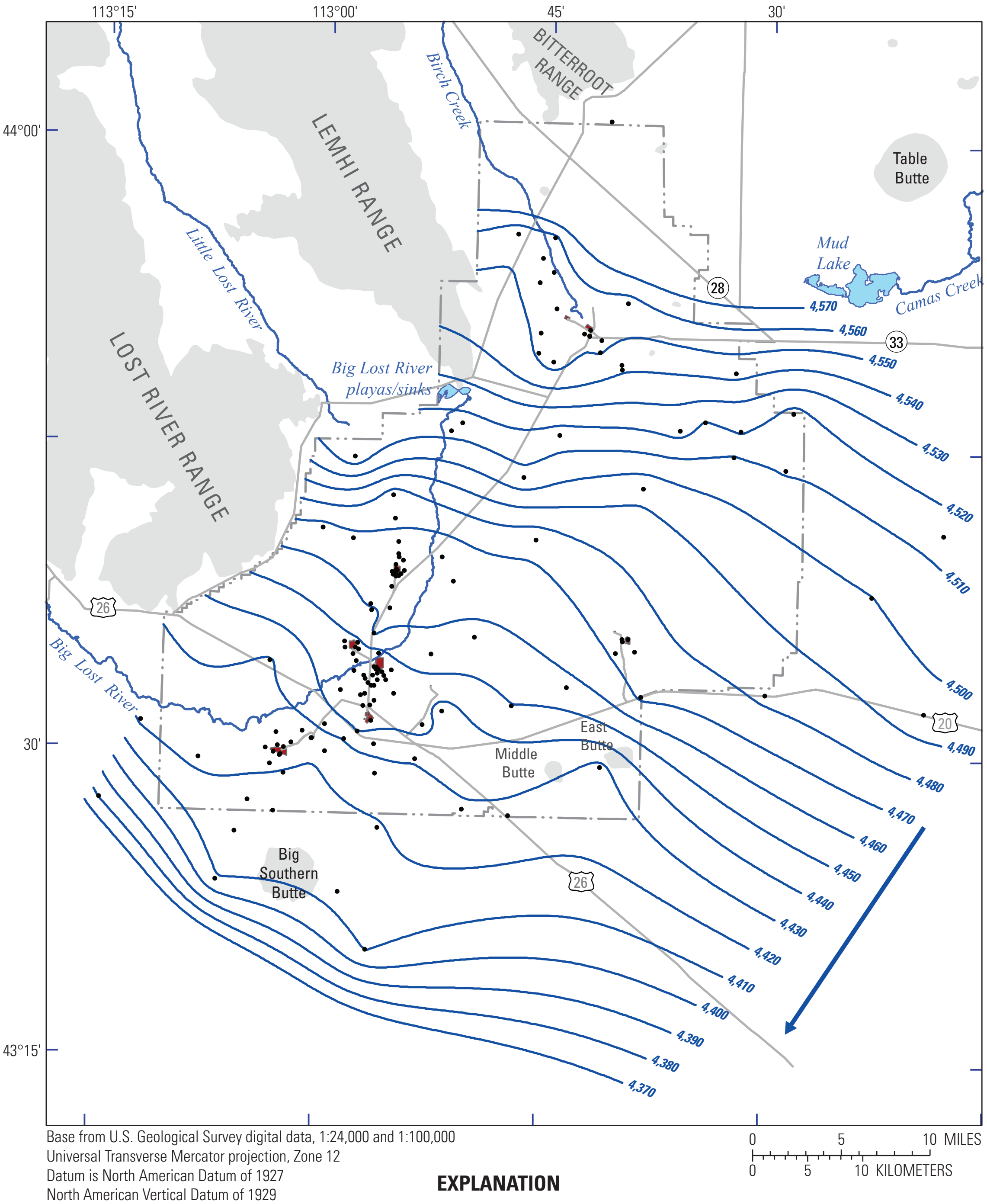


Figure 8. Streamflow at streamgages along the Big Lost River, Idaho.

Table 4. Average annual streamflow at U.S. Geological Survey streamgage stations along the Big Lost River, Idaho, water years 2016–18.

[**USGS streamgage:** Station locations are shown in figure 1. **Streamflow:** Data are from National Water Information System (U.S. Geological Survey, 2019a). **Abbreviations:** INL, Idaho National Laboratory; WY, water year; Blvd., boulevard]

USGS streamgage No. and name	Streamflow (acre-feet)		
	WY 2016	WY 2017	WY 2018
13127000—Big Lost River below Mackay Reservoir, near Mackay, Idaho	171,336	359,111	300,961
13132500—Big Lost River near Arco, Idaho	0	72,778	105,655
13132513—INL diversion at head, near Arco, Idaho	0	13,000	30,922
13132520—Big Lost River below the INL Diversion, near Arco, Idaho	0	47,378	53,370
13132535—Big Lost River at Lincoln Blvd. Bridge, near Atomic City, Idaho	0	45,265	41,350
13132565—Big Lost River above Big Lost River Sinks, near Howe, Idaho	0	34,370	30,053



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927
North American Vertical Datum of 1929

EXPLANATION

🟥 **Selected facilities at the Idaho National Laboratory**

4,400 **Water-table contour**—Shows altitude of the water table, March-May 2018. Contour intervals are 10 feet. Datum is National Geodetic Vertical Datum of 1929. Contours approximately located.

← **General direction of groundwater flow**

— · — **Idaho National Laboratory boundary**

● **Well in the USGS water-level monitoring network at which water level was measured**

Figure 9. Altitude of the water table in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, Idaho, March–May 2018.

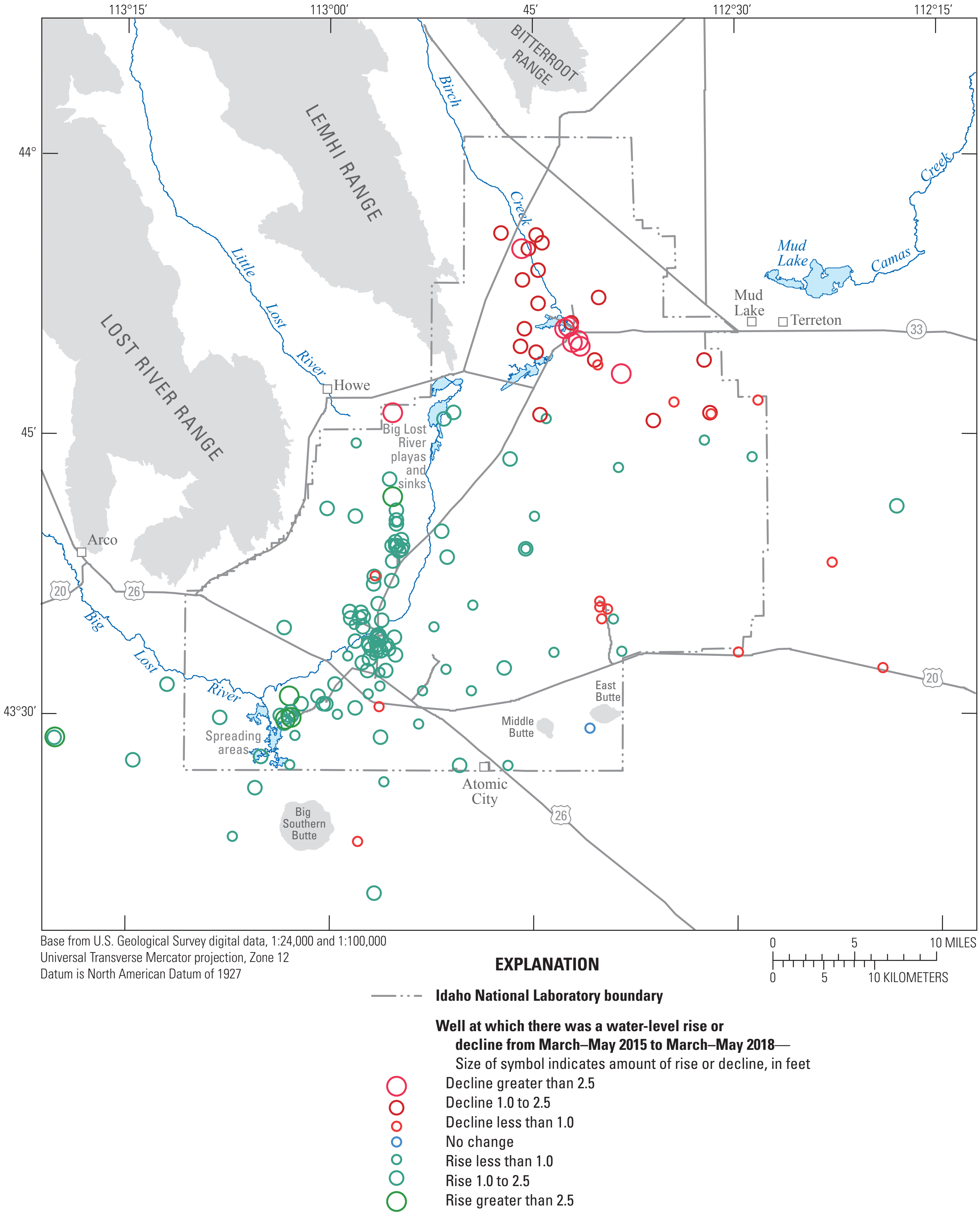


Figure 10. Generalized rise or decline in groundwater levels in the eastern Snake River Plain aquifer at and near Idaho National Laboratory, Idaho, March–May 2015 to March–May 2018.

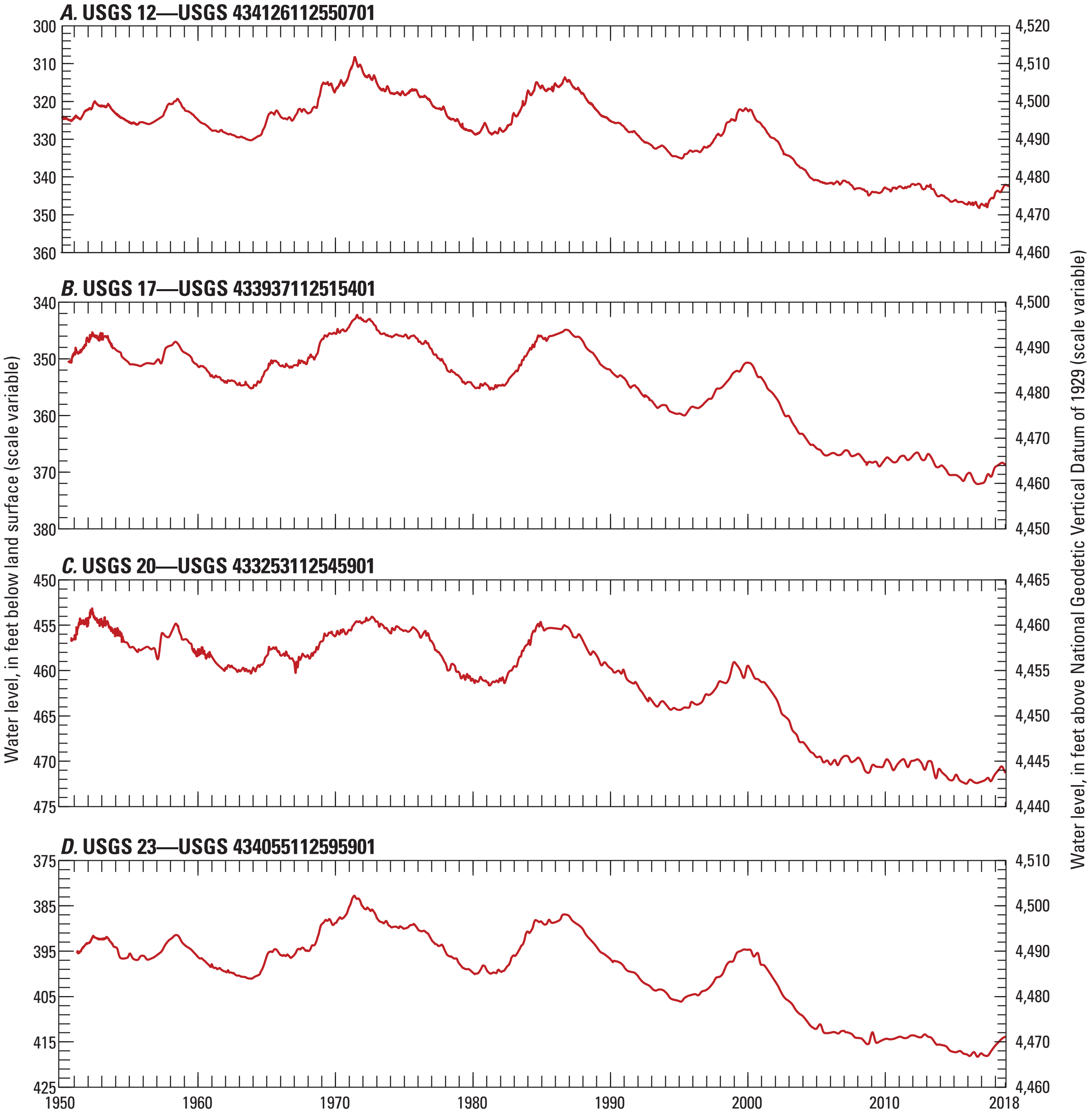
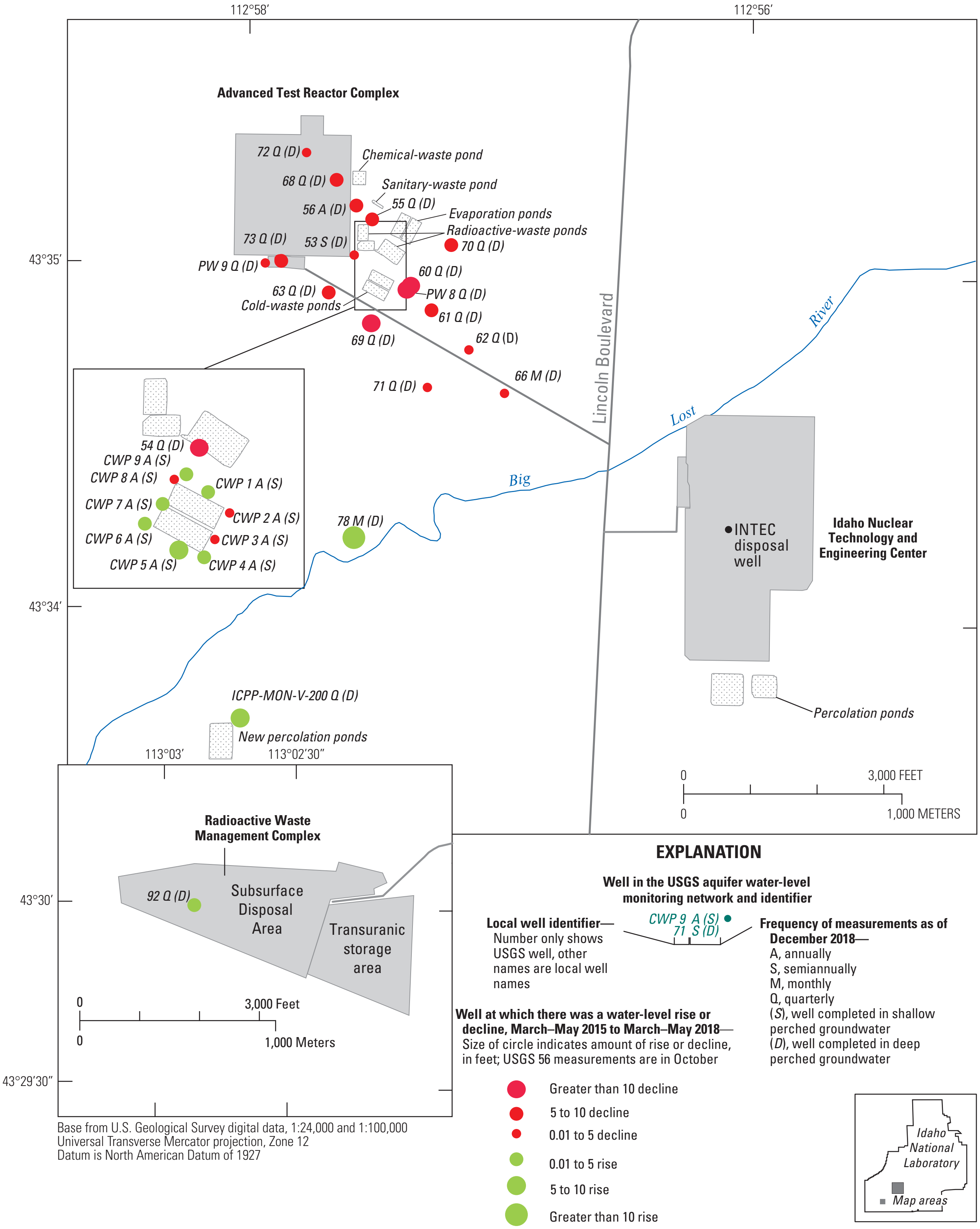


Figure 11. Water levels in U.S. Geological Survey (USGS) wells 12 (*A*), 17 (*B*), 20 (*C*), and 23 (*D*), in the central part of the Idaho National Laboratory, Idaho 1950–2018.

features controlling the formation of perched groundwater at these sites are similar (Cecil and others, 1991). Sedimentary interbeds in the subsurface may have smaller vertical hydraulic conductivities than overlying basalt flows, and alteration between basalt flows may contribute to reduced vertical hydraulic conductivity in the interflow rubble zones (Perkins and Winfield, 2007). Dense, unfractured basalt flows may have a decreased vertical hydraulic conductivity and may inhibit downward flow, and sedimentary or chemical infilling of fractures in basalt may reduce vertical hydraulic conductivity by limiting the interconnectivity of fractures reducing the water-transmitting capability of the basalts (Cecil and others, 1991). Any combination of these factors may disrupt the downward vertical movement of water and contribute to the formation of perched groundwater zones.

At the ATR Complex, deep and shallow perched groundwater zones have formed in response to disposal of wastewater to infiltration ponds (Tucker and Orr, 1998). South of the INTEC, perched groundwater zones formed previously in response to wastewater disposal to the old percolation ponds, but they have dried up since the ponds were taken out of use in 2002 (fig. 4). Perched groundwater also has been detected in other areas at the INTEC and may be attributed to leaking pipelines, leach fields, damaged casing in the upper part of the INTEC disposal well, other infiltration ponds, or landscape irrigation (Tucker and Orr, 1998). Recharge from the Big Lost River also is a potential source of some perched water in the northern part of the INTEC. Perched groundwater also is present beneath the new percolation ponds (fig. 4) that were put in service during 2002. Perched groundwater beneath the RWMC formed from infiltration of snowmelt and rain, and recharge from the Big Lost River and INL spreading areas. This perched groundwater contains constituents leached from buried radioactive and organic-chemical wastes. Perched groundwater beneath wastewater infiltration ponds and buried waste is an integral part of the pathway for waste-constituent migration to the ESRP aquifer. The extent of perched groundwater is affected by the waste-disposal practices.

During March–May 2018, water levels in most deep perched groundwater wells around the ATR Complex declined since the March–May 2015 reporting period. Water-level declines ranged from 0.33 ft in well PW 9 to 12.5 ft in well USGS 54 (fig. 12). Water-level declines may be attributed to variable recharge from ponds still in use or possibly from the repair of water leaks around the ATR Complex. A rise of 31.4 ft occurred in the deep perched zone in well USGS 78. Rises also occurred in the perched zone near the new INTEC infiltration pond (ICPP-MON-V-200) and at the RWMC (well USGS 92) (fig. 12). The rises in all three wells probably are due to flow in the Big Lost River during 2017–2018. During March–May 2018, water levels completed in shallow perched groundwater wells rose and declined near the cold-waste ponds (fig. 12); this probably is due to variability in the amount of wastewater discharged to the ponds.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 12. Generalized rise or decline in perched groundwater levels at the Idaho National Laboratory, Idaho, March–May 2015 to March–May 2018.

Methods and Quality Assurance of Water Sample Analyses

Water samples were analyzed for (1) radiochemical constituents at the DOE Radiological and Environmental Sciences Laboratory (RESL) at the INL, (2) low-level tritium at the USGS Tritium Laboratory in Menlo Park, California, and (3) chemical constituents at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. Until 2008, water samples analyzed by the RESL were entered into the USGS NWIS database with an uncertainty of 2***s***, where ***s*** is the sample standard deviation. Beginning in 2008 because of a USGS policy change, data were entered into the NWIS database with an uncertainty of 1***s***. Analytical uncertainties in this report are reported as 1***s*** for consistency with conventions used in previous USGS reports.

Methods used to sample and analyze for selected constituents generally follow the guidelines established by the USGS (Goerlitz and Brown, 1972; Stevens and others, 1975; Wood, 1976; Claassen, 1982; Wershaw and others, 1987; Fishman and Friedman, 1989; Faires, 1993; Fishman, 1993; U.S. Geological Survey, various dates). Water samples were collected according to a quality-assurance plan for water-quality activities done by personnel at the USGS INL Project Office. The plan was finalized in June 1989 and revised in March 1992, in 1996 (Mann, 1996), in 2003 (Bartholomay and others, 2003), in 2008 (Knobel and others, 2008), and in 2014 (Bartholomay and others, 2014).

Field processing of water samples differed depending on the constituents for which analyses were requested. Water samples analyzed by the NWQL were placed in containers and preserved in accordance with laboratory requirements specified by Timme (1995) and Bartholomay and others (2014, appendix A). Containers and preservatives used for this study were supplied by the NWQL and were processed using a rigorous quality-control procedure (Pritt, 1989, p. 75) to minimize sample contamination. The process for water samples requiring filtration consisted of filtering the water through a disposable 0.45-µm filter cartridge that had been pre-rinsed with at least 1 L of deionized water. Water samples analyzed by the RESL were placed in containers and were preserved in accordance with laboratory requirements specified by Bodnar and Percival (1982) and Bartholomay and others (2014, appendix A). Water samples analyzed by the USGS Tritium Laboratory followed procedures specified in U.S Geological Survey (2019b).

Guidelines for Interpreting Results of Radiochemical Analyses

Concentrations of radionuclides are reported with an estimated sample standard deviation, ***s***, which 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 greater than the signal observed for the blank before a 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 a correct decision can be made for detection or nondetection of the radionuclide. The first aspect of the problem is a qualitative decision based on an observed signal and a definite criterion for detection. The second aspect of the problem is an estimation of the detection capabilities of a given measurement process.

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

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

The critical level and minimum detectable concentrations are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The values 1.6***s*** and 3***s*** 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 3***s*** are considered to be less than a “reporting level.” The critical level, minimum detectable concentration, and reporting level aid the reader to interpret analytical results and do not represent absolute concentrations of radioactivity, which may or may not have been detected. Analytical uncertainties in this report are reported as 1*s* for consistency with conventions used in previous reports.

Guidelines for Interpreting Results of Chemical Analyses

Concentrations of inorganic and organic constituents are reported with reference to reporting limits determined using detection and quantitation calculation (DQCALC) software and are reported as detection limits from DQCALC (DLDQC) for inorganic constituents and minimum reporting levels (MRLs) for organic constituents. The MRL is the smallest measured constituent concentration that can be reliably reported using a specific analytical method (Timme, 1995). The DLDQC is one of four new report level codes adopted by the NWQL to replace the long-term method detection limit (U.S. Geological Survey, 2015). DLDQC is described as the lowest concentration that with 90-percent confidence will be exceeded no more than 1 percent of the time when a blank sample is measured (≤1 percent false positive risk; U.S. Geological Survey, 2015, p. 11). DQCALC is a Microsoft Excel®-based software package used to compute a method detection estimate (Standard Practice D7510-10; American Society for Testing and Materials International, 2010). See U.S. Geological Survey (2015) for a more detailed explanation of the DQCALC procedures. Childress and others (1999) provide details about the approach used by the USGS regarding detection levels and reporting levels. For most of the constituents in this report, reported concentrations generally are greater than the DLDQCs or MRLs, but some are given as less than.

Evaluation of Quality-Assurance Samples

Investigations to determine variability and bias for individual constituents were summarized by Wegner (1989), Williams (1996, 1997), and Rattray (2012, 2014). Additional quality-assurance (QA) studies by USGS INL Project Office personnel include:

- An evaluation of field sampling and preservation methods for strontium-90 (Cecil and others, 1989);
- A study comparing pump types used for sampling VOCs (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 effects of various preservation types on nutrient concentrations (Bartholomay and Williams, 1996);
- An analysis of two analytical methods to determine gross alpha- and beta-particle activity (Bartholomay and others, 1999);
- An evaluation of well-purging effects on water-quality results (Knobel, 2006);
- An evaluation of 2009–11 and 2012-15 QA data for routine sampling (Davis and others, 2013; Bartholomay, Maimer, and others, 2017); and
- An evaluation of the 2006–08 and 2009–13 multilevel monitoring system (MLMS) QA data (Bartholomay and Twining, 2010; Bartholomay and others, 2015).

During 2016–18, variability and bias was evaluated from 37 replicate and 15 blank QA samples (tables 5 and 6). Constituents analyzed from these samples included the constituents identified in section, “Water-Quality Monitoring Network.”

Variability

Results from replicate analyses were investigated to evaluate sample variability. Replicates consisted of two water samples, an environmental sample and a replicate sample, with the replicate sample collected immediately after collection of the environmental sample. Replicates were submitted blind to the analytical laboratories, ensuring that the laboratories did not know the source of the water or that the samples were replicates.

Sample variability was evaluated by calculating the reproducibility and reliability of individual constituents (Rattray, 2012, 2014). Reproducibility (the closeness of agreement between individual measurements) was calculated as normalized absolute difference (NAD) for radiochemical constituents (measurements that include analytical uncertainties) and relative standard deviation (RSD) for inorganic and organic constituents (measurements that do not include analytical uncertainties). Reliability (the error associated with a measurement) was calculated as a pooled RSD for each constituent. Equations for calculating the NAD, RSD, and pooled RSD are presented in Rattray (2012, 2014).

Reproducibility

Reproducibility of constituent measurements was considered acceptable if (Rattray, 2012, p.10):

- The NAD was less than or equal to 1.96;
- The RSD was less than 14 percent (this corresponds to a relative percent difference of less than 20 percent);
- Both measurements were less than the reporting level for that analysis; or

- One measurement was censored or estimated and the other measurement was within one detection limit of the larger of the estimated value or the reporting level, or the measurements were within one detection limit of each other. For results reported using the MRL as the reporting level, the detection limit was approximated as one-half of the MRL. For results reported using the DLDQC as the reporting level, the detection limit is the DLDQC value.

If the percentage of replicates with acceptable reproducibility for a constituent was greater than or equal to 90 percent, then the reproducibility for that constituent was considered acceptable for 2016–18.

Constituents with acceptable reproducibility were major ions (100 percent), nutrients (96–100 percent), trace elements (100 percent), and VOCs (100 percent). All radiochemical constituents had acceptable reproducibility (100 percent) except for gross alpha-particle radioactivity (89 percent) and gross beta-particle radioactivity (89 percent). The gross alpha and beta radioactivity replicates that exceeded a NAD of 1.96 were influenced by small activities, as each of the replicates consisted of analytical results that were near and less than the reporting level of 3s.

Reliability

Reliability and RSDs are generally a function of concentration (or activity), where reliability increases and RSDs decrease with increasing concentration. Because pooled RSDs should be calculated from samples with similar variability, reliability was estimated for discrete concentration ranges, of an order of magnitude or less, that had a similar range of RSDs (Rattray, 2012, p. 11).

Pooled RSDs for discrete concentration ranges for each constituent that had a calculated RSD are shown in table 6. RSDs were calculated for radiochemical constituents, in order to calculate pooled RSDs, if at least one concentration from a replicate sample pair equaled or exceeded the reporting level of 3***s***. Pooled RSDs were less than or equal to 12 percent for all constituents and their concentration ranges except for gross alpha-particle radioactivity (107 percent), gross beta-particle radioactivity (18 percent), ammonia (26 percent), and lead (17 percent). The larger pooled RSDs and lower reliability for these constituents were the result of small concentrations that were near or less than their respective reporting levels. The overall small pooled RSDs for QA samples indicate that the associated environmental samples probably have high reliability. The pooled RSDs in table 6 are similar to pooled

Table 5. Number of replicates and blanks collected for individual constituents, Idaho National Laboratory, Idaho, 2016–18.

[**Constituent:** Ag, silver; Al, aluminum; As, arsenic; Ba, barium; Be, beryllium; Cd, cadmium; Co, cobalt; Cr, chromium; Cu, copper; f, filtered; Hg, mercury; Mn, manganese; Mo, molybdenum; Ni, nickel; Pb, lead; RESL, Radiological and Environmental Sciences Laboratory; Sb, antimony; Se, selenium; Tl, thallium; U, uranium; uf, unfiltered**;** Zn, zinc; VOCs, volatile organic compounds]

Constituent	Number of replicates	Number of source-solution blanks	Number of equipment blanks	Number of field blanks
Tritium (RESL)	35	3	6	5
Tritium (Menlo Park)	2	0	0	0
Strontium-90	21	0	2	2
Gross-alpha particle radioactivity, gross-beta particle radioactivity	9	3	2	2
Cesium-137	11	0	0	0
Americium-241, plutonium-238, plutonium-239	3	0	0	0
Sodium	34	4	5	4
Chloride	37	4	6	5
Sulfate	31	4	5	5
Fluoride	1	2	0	0
Bromium, calcium, magnesium, potassium, silica	0	2	0	0
Ammonia, nitrite, nitrate, orthophosphate	27	4	5	4
Ag, Al, As, Ba, Be, Cd, Co, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Tl, U, Zn (f)	2	2	0	0
Ag, Al, As, Ba, Cd, Cr, Hg, Pb, Se (uf)	1	0	0	0
Chromium (f)	18	4	3	3
Boron, iron, lithium, mercury, strontium, vanadium (f)	0	2	0	0
VOCs	6	0	0	0

Table 6. Ranges of concentrations, number of replicates with calculated relative standard deviations, and pooled relative standard deviations for individual constituents, Idaho National Laboratory, Idaho, 2016–18.

[**Constituent:** f, filtered; N, nitrogen; P, phosphorous; uf, unfiltered. **Abbreviations:** RSD, relative standard deviation; µg/L, microgram per liter; mg/L, milligram per liter; pCi/L, picocurie per liter]

Constituent	Concentration range	Number of replicates with calculated RSDs	Pooled RSD (percent)
Tritium (pCi/L)	[1]5–20	2	3.4
	100–1,000	11	10
	1,000–6,000	5	3.8
Strontium-90 (pCi/L)	1.5–15	2	9.5
Gross-alpha particle radioactivity (pCi/L)	1–10	1	107
Gross-beta particle radioactivity (pCi/L)	2–13	7	18
Sodium (mg/L)	6–30	32	1.1
	50–120	2	5.7
Chloride (mg/L)	1–10	4	0.2
	10–100	33	0.4
Sulfate (mg/L)	10–80	27	0.5
	100–500	4	1.0
Fluoride (mg/L)	0.1–0.2	1	0.4
Ammonia (µg/L as N)	20–50	2	26
Nitrate (mg/L as N)	0.6–5.0	27	2.3
Orthophosphate (µg/L as P)	5–40	27	2.9
Antimony (µg/L)	0.1–0.3	2	5.9
Arsenic (f) (µg/L)	1–3	2	1.9
Arsenic (uf) (µg/L)	1–3	1	0.6
Barium (f) (µg/L)	50–200	2	0.7
Barium (uf) (µg/L)	30–50	1	0.7
Chromium (f) (µg/L)	2–20	18	2.4
Chromium (uf) (µg/L)	100–200	1	1.4
Lead (µg/L)	0.02–0.04	1	17
Manganese (µg/L)	1–2	1	7.3
Molybdenum (µg/L)	3–6	2	1.4
Nickel (µg/L)	0.1–1.0	2	7.4
Selenium (uf) (µg/L)	1–2	1	6.0
Uranium (µg/L)	1–2	2	0.8
Zinc (µg/L)	6–8	1	6.4
1,1-Dichloroethene (µg/L)	0.1–0.2	1	1.8
Tetrachloroethene (µg/L)	0.2–2.0	2	2.0
Tetrachloromethane (µg/L)	4–5	1	1.0
1,1,1-Trichloroethane (µg/L)	0.3–0.4	1	1.2
Trichloroethene (µg/L)	1–10	2	0.7
Trichloromethane (µg/L)	0.1–1.0	2	0.5
1,2,4-Trimethylbenzene (µg/L)	0.2–0.3	1	12

[1] Results from the U.S. Geological Survey Menlo Park Tritium Laboratory.

RSDs determined from replicate samples from 1996 to 2015 (Rattray, 2012, 2014; Davis and others, 2013; Bartholomay, Maimer, and others, 2017), which indicates a consistency in reliability over time.

Bias

Bias from sample contamination was evaluated from equipment, field, and source- solution blanks (table 5). Other sources of bias associated with field samples, such as matrix interference and sample degradation, were not evaluated. However, the NWQL and the RESL evaluate laboratory bias (including sample contamination, matrix interference, and sample degradation) with analysis of blank samples and reference materials. Equipment and field blanks were collected at field sites, and deionized water source-solution blanks were collected at the USGS Idaho Water Science Center, Idaho Falls Field Office. The equipment, field, and source-solution blanks were collected as described by Rattray (2012, p. 7).

Equipment blanks were collected to identify bias of environmental samples due to inadequate cleaning of stainless-steel sampling pipes that are reused at each sample site. Inadequate cleaning of sampling pipes may cause cross-contamination between sample sites.

Equipment blanks include bias from sources other than the sampling pipes, such as field collection and processing, sample storage and shipping, and laboratory processing and analysis. Therefore, field and source-solution blanks were collected to determine whether bias identified in equipment blanks may be from sources other than the sampling pipes. Field blanks were collected to identify all potential sources of bias in the equipment blanks except for bias from the sampling pipes. Source-solution blanks were collected to identify bias in the deionized water source solution collected from the USGS Idaho Water Science Center, Idaho Falls Field Office.

Bias was evaluated from results of 6 equipment blanks, 5 field blanks, and 4 source-solution blanks. Concentrations in blank samples were considered detections if the concentration for a constituent exceeded the reporting level for that constituent.

Numerous radiochemical, inorganic, and organic constituents were analyzed in equipment, field, and source-solution blanks (table 5). All constituents measured in blank samples were less than or equal to three times the reporting level except for detections of (1) cadmium (0.10 µg/L) in a source-solution blank collected in February 2016, (2) chloride in field (0.04 mg/L) and equipment (0.065 mg/L) blanks collected in April 2016, and (3) ammonia in field (0.035 and 0.035 mg/L as N) and equipment (0.033 and 0.034 mg/L as N) blanks collected in October of 2017 and 2018. Trace elements were not measured from field and equipment blanks, so the detection of cadmium in the source solution blank was inconsequential. Detections of chloride and ammonia were measured in both field and equipment blanks. Subtracting the measured concentration of the field blank from the concurrent equipment blank for each constituent results in adjusted concentrations for equipment blanks that are less than the constituent detection level (ammonia) or reporting level (chloride). These blank sample results indicate that there probably was no bias of radiochemicals, major ions, and nutrients in the associated environmental samples.

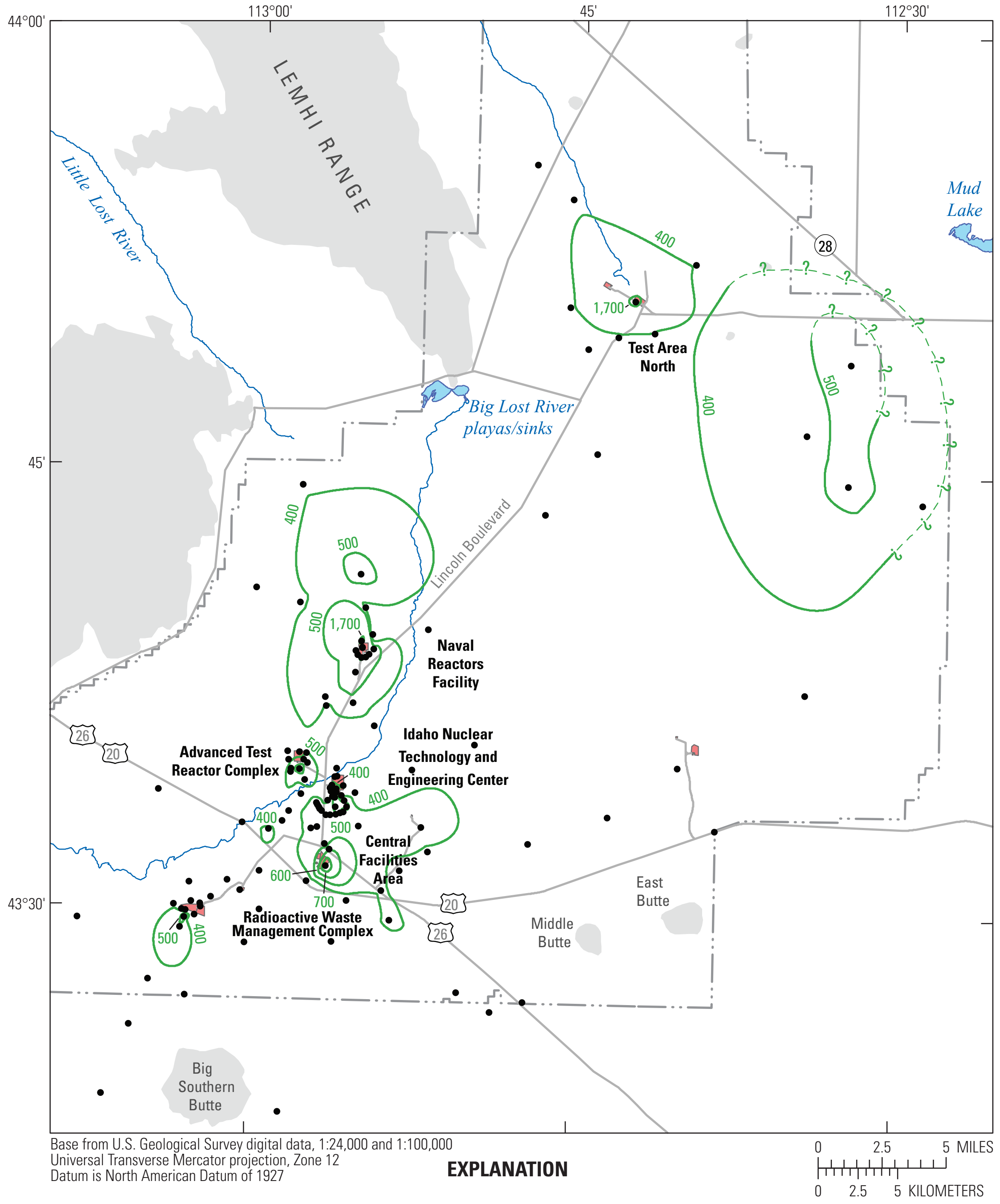
Selected Physical Properties of Water and Radiochemical and Chemical Constituents in the Eastern Snake River Plain Aquifer

Physical properties of water measured during sampling events included specific conductance, temperature, and pH. Contaminant plumes of radiochemical and chemical constituents in the ESRP aquifer at the INL are attributed to waste-disposal practices. Areal distribution of the plumes was interpreted from analyses of water samples collected from a three-dimensional flow system. Concentrations of these constituents represent water samples collected during April or October 2018 from wells completed at various depths in the aquifer and with differing well completions; for example, single and multiple screened intervals and open boreholes. No attempt was made to determine the vertical extent and distribution of these plumes. Radiochemical and chemical constituents analyzed for in groundwater samples collected from wells at the INL during 2016–18 included tritium; strontium-90; cesium-137; plutonium-238, -239, and -240 (undivided); americium-241; gross alpha- and beta-particle radioactivity; chromium and other trace elements; sodium; chloride; sulfate; nitrate (as N); fluoride; and VOCs. Results are reported in USGS NWIS.

Specific Conductance, Temperature, and pH

Specific conductance is a measure of the electrical conductivity of water and is proportional to the quantities of dissolved chemical constituents in the water. Dissolved chemical constituents such as chloride, sodium, and sulfate in wastewater discharged to disposal wells and infiltration ponds at INL facilities generally have increased the specific conductance of groundwater through time.

In 2018, the specific conductance of water from 125 wells that sample the ESRP aquifer ranged from 241 to 1,770 µS/cm; the highest value was in water from well TAN 2271 located near the TAN Disposal Well (fig. 5). Specific conductance also was large in NRF 6 (1,740 µS/cm), which is located near the NRF industrial waste ditch near the NRF (fig. 3). Specific conductance measurements for water from most wells around the NRF area were greater than 500 µS/cm (fig. 13).



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

EXPLANATION

🟥 **Selected facilities at the Idaho National Laboratory**

400 **Line of equal specific conductance measurement**—April, May, or October 2018. Lines of equal specific conductance were interpreted from measurements of water samples collected from a three-dimensional flow system. Mapped measurements represent water samples collected from various depths in boreholes with differing well completions; for example, single- and multiple-screened intervals, and open boreholes. Location is approximate. Interval, in microsiemens per centimeter, is variable.

— · · — **Idaho National Laboratory boundary**

● **Well in the U.S. Geological Survey water-level monitoring network**—Water samples analyzed for specific conductance

Figure 13. Distribution of specific conductance of water from wells at the Idaho National Laboratory, Idaho, April, May, or October 2018.

The background specific conductance of water in the ESRP aquifer was about 300–325 µS/cm in the INTEC area in 1962 (Robertson and others, 1974, p. 159). A plume of increased specific conductance originated from the INTEC disposal well and old percolation ponds (fig. 7) and extended downgradient of the INTEC to the CFA (fig. 13). The specific conductance of water from several wells in this plume increased from about 500 µS/cm in 1985 (Pittman and others, 1988, p. 64) to more than 1,000 µS/cm in 1998 (Bartholomay and others, 2000, p. 37) and has decreased since then to 591 µS/cm in 2018 (fig. 13).

The specific conductance of water from several wells at the ATR Complex exceeded 400 µS/cm in 2018 (fig. 13). The maximum specific conductance measurement was from water from well USGS 65 (fig. 6), downgradient of the infiltration ponds at the ATR Complex. Well USGS 65 had a measurement of 604 µS/cm in April 2018, about the same value as in April 2015.

At the CFA, the specific conductance of water from well CFA 1 decreased slightly from 612 µS/cm in 2015 to 586 µS/cm in April 2018. The largest specific conductance measurement in wells near the CFA was in well USGS 130 at 822 µS/cm, which was about the same as in 2015.

Near the RWMC, the maximum specific conductance measured was in water from well USGS 88, at 619 µS/cm in October 2018, slightly smaller than the measurement of 639 µS/cm in October 2015. Water from most other wells near the RWMC had measurements of about 250–400 µS/cm (fig. 13).

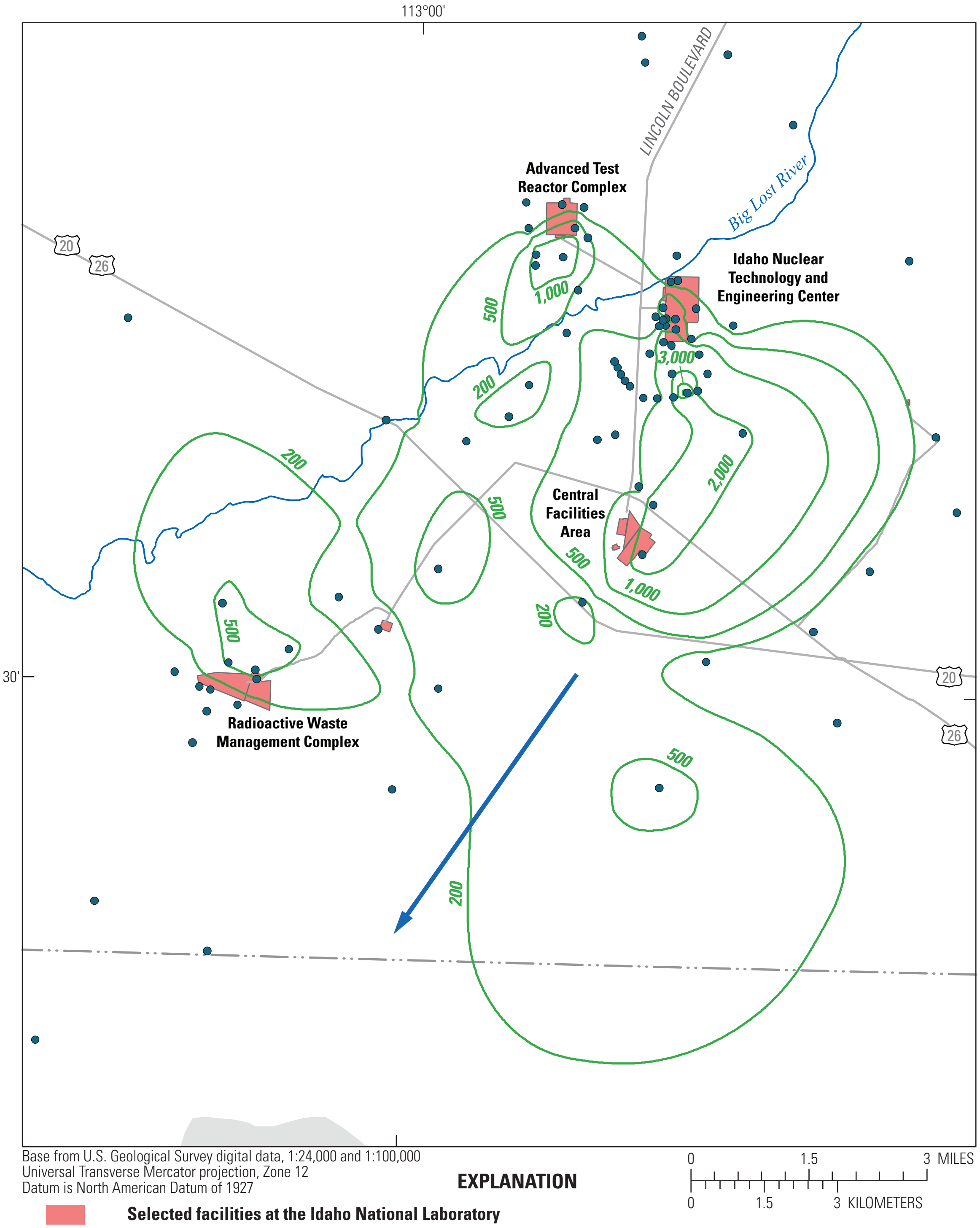
Water temperature of 125 wells measured in 2018 ranged from 9.6 °C in well Cross Road located south of the INL to 21.0 °C in well USGS 146 located in the southwestern part of the INL. The median water temperature was 12.7 °C. In 2018, the pH for the 124 wells measured ranged from 6.9 in well USGS 29 to 9.4 in well USGS 84 with a median of 7.9. Water temperature and pH measurements were similar to what they have been in the past for the ESRP aquifer.

Tritium

A tritium plume has developed in the ESRP aquifer from discharge of wastewater at the INL since the 1950s. Tritium has a half-life of 12.3 years (Walker and others, 1989, p. 20). The MCL for tritium is 20,000 pCi/L (U.S. Environmental Protection Agency, 2015). About 31,810 Ci of tritium (Davis, 2006a) was discharged to wells and ponds at the INL from 1952 through 2000; no records are available since 2000. The primary sources of tritium in the aquifer have been the injection of wastewater through the disposal well at the INTEC and the discharge of wastewater to percolation ponds at the INTEC and ATR Complex (fig. 4). Routine use of the disposal well at the INTEC ended in February 1984; subsequently, radioactive wastewater was discharged to the old percolation ponds until 1993 when discharge of low- and intermediate-level radioactive waste solutions ceased with the installation of the Liquid Effluent Treatment and Disposal Facility (U.S. Department of Energy, 2011a). Radioactive wastewater was discharged to the radioactive-waste ponds at the ATR Complex until 1993; since then, tritium at the ATR Complex has been discharged to lined evaporation ponds, which should prevent migration to the aquifer. Concentrations of tritium in water samples collected in 2018 from 46 of 111 aquifer wells exceeded the RESL laboratory detection level of 200 pCi/L and ranged from 260±50 to 5,100±190 pCi/L. The tritium plume extended south-southwestward in the general direction of groundwater flow (fig. 14). Since 1997, tritium concentrations in water samples collected by the USGS from the ESRP aquifer have not exceeded the MCL.

Long-term radioactive-decay processes and an overall decrease in tritium disposal rates since the 1960s (Davis, 2008) contributed to decreased concentrations of tritium in water from most wells at the INL during 2016–18. Tritium concentrations in water from several wells at and south-southwest of the INTEC decreased during 2016–18 (fig. 15). The greatest decrease in tritium concentrations in wells south of the INTEC disposal well was in well USGS 114, which decreased from 5,760±120 pCi/L in October 2015 to 5,100±190 pCi/L in October 2018 (fig. 15). Concentrations of tritium in well CFA 1 (figs. 5 and 15) at the CFA decreased from 3,380±110 pCi/L in April 2015 to 2,730±90 pCi/L in April 2018. The overall decrease in tritium concentrations in water from wells at and south-southwest of the INTEC likely is the result of discontinued discharge of tritium in wastewater since the early 1990s, along with dilution, dispersion, and radioactive decay.

Tritium concentrations in water from well USGS 59, near the old INTEC percolation ponds (figs. 6 and 15), have decreased since 1980, but were unusually high in October 1983, 1985, 1991, and 1995, and in 2002–03 (fig. 15). The higher concentrations in 1983 and 1985 correlate with higher annual discharge rates of tritium; however, annual discharge of tritium was low in 1991 and 1995 (Davis, 2008, fig. 9). In 1986, perched groundwater was detected outside the casing in well USGS 59. Following modifications to the well to prevent seepage of water into the well, a video log showed that some water from the perched groundwater zone was still seeping into the well. The higher concentrations in 1991, 1995, and 2002–03 probably resulted from seepage from a perched groundwater zone. The high concentrations also correlate with the use of the old east percolation pond and with disposal of tritium to the ponds. The low concentrations in water from well USGS 59 in 1989, 1993, 1994, and 1996–2000 correlate with years in which little or no tritium was discharged to the old percolation ponds (Davis, 2008, fig. 9). The steady decreasing concentrations since 2003 (fig. 15) after the ponds were taken out of service and the perched zone dried up, support the theory that leakage from the percolation ponds attributed to changes in this well's historical concentrations. The relative stability in tritium concentrations in wells USGS 38, 47, 59, 77, and 114 from 2001 to 2004 (fig. 15), could have resulted from disposal of 0.03 Ci of tritium (S.M. Stoller Corporation, 2002b) to the old INTEC percolation ponds and



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

EXPLANATION

🟥 **Selected facilities at the Idaho National Laboratory**

200 **Line of equal tritium concentration**—April or October 2018. Lines of equal concentration were interpreted from analyses of water samples collected from a three-dimensional flow system. Mapped concentrations represent water samples collected from various depths in boreholes with differing well completions; for example, single- and multiple-screened intervals, and open boreholes. Location is approximate. Interval, in picocuries per liter, is variable.

— · — **Idaho National Laboratory boundary**

← **General direction of groundwater flow**

● **Well in the USGS water-level monitoring network**—Water samples analyzed for tritium

Figure 14. Distribution of tritium in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex at the Idaho National Laboratory, Idaho, April or October 2018.

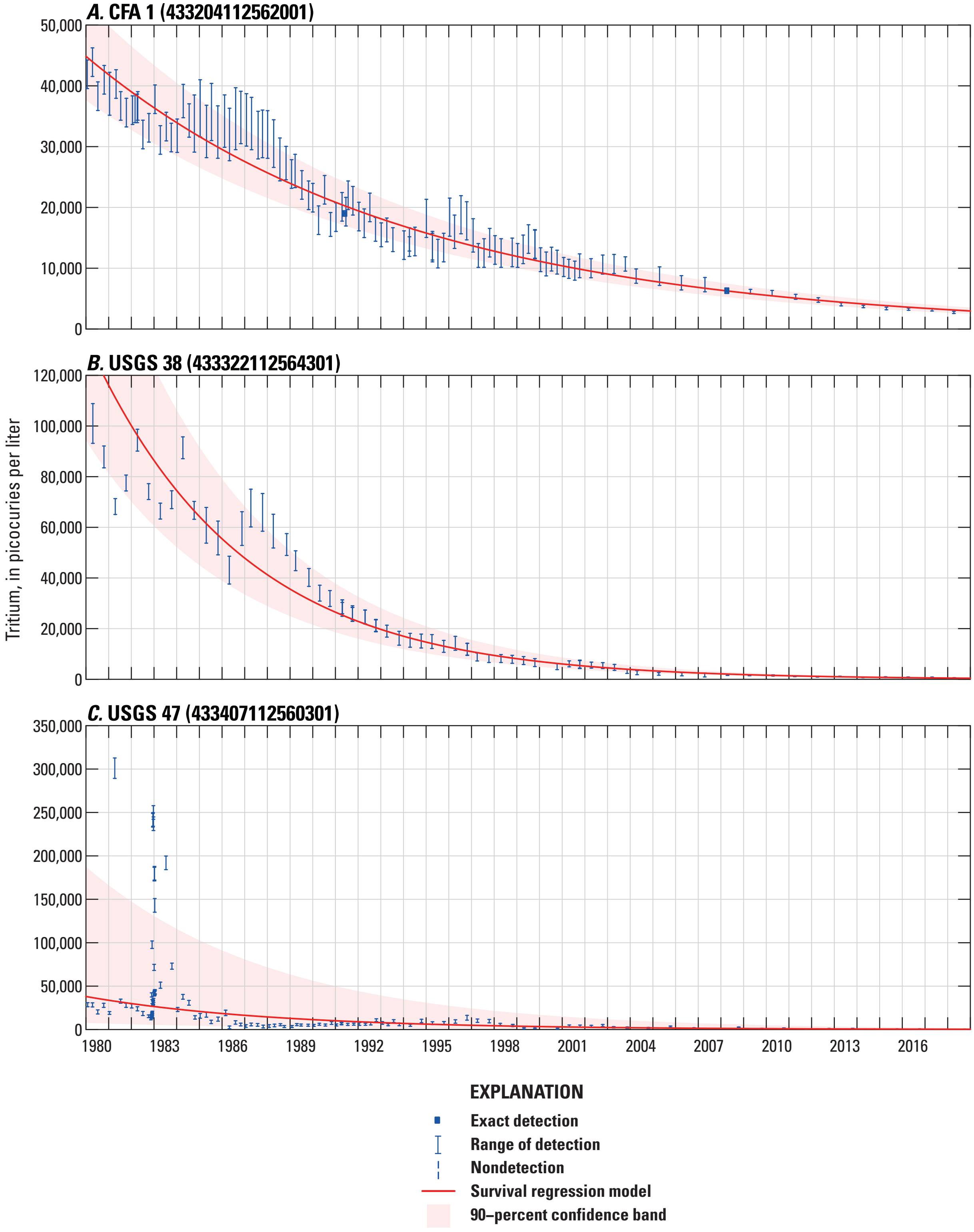
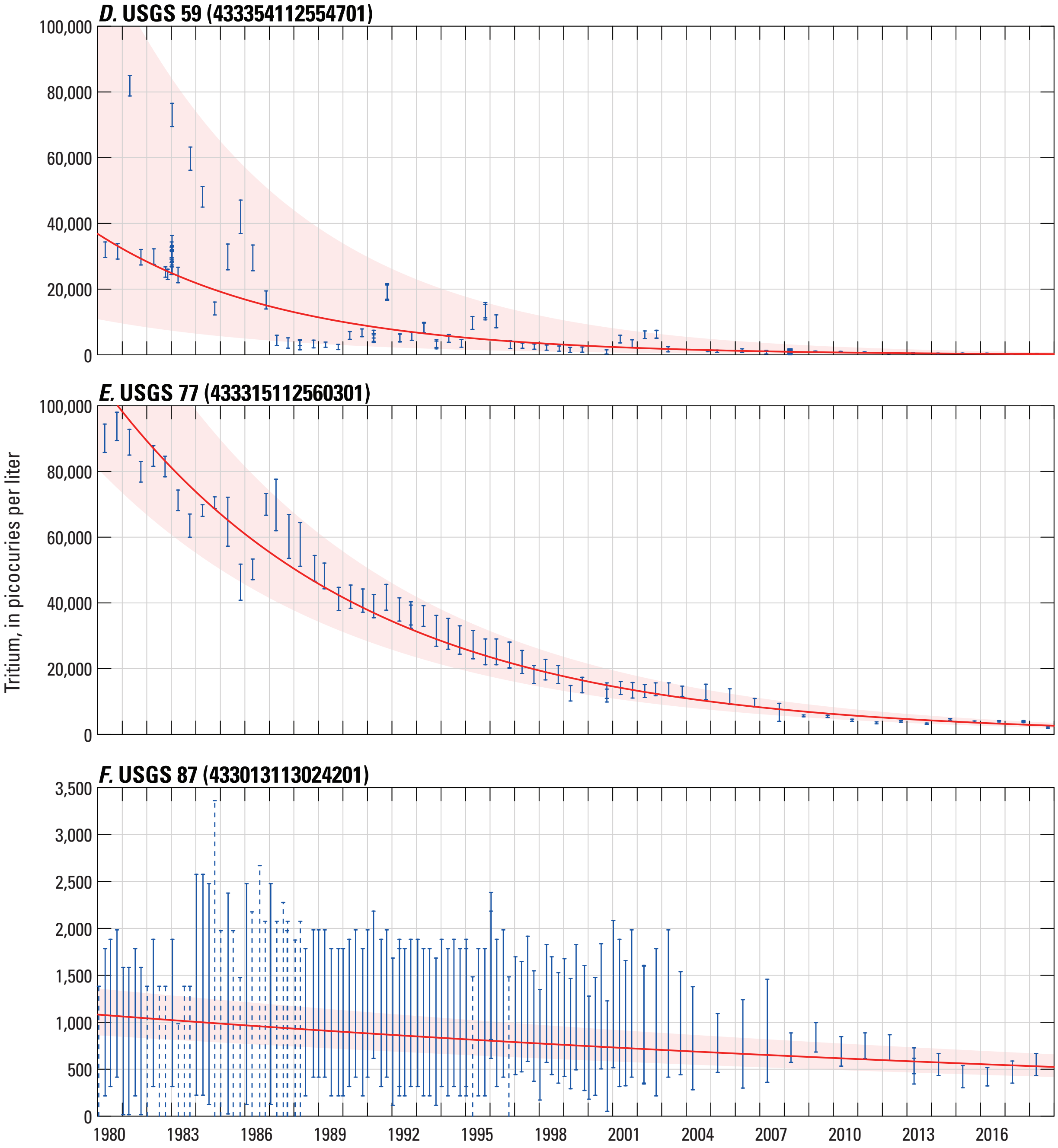


Figure 15. Tritium concentrations in water from eight wells at and near the Central Facilities Areas, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, 1980–2018. Locations of wells are shown in figures 5 and 6.



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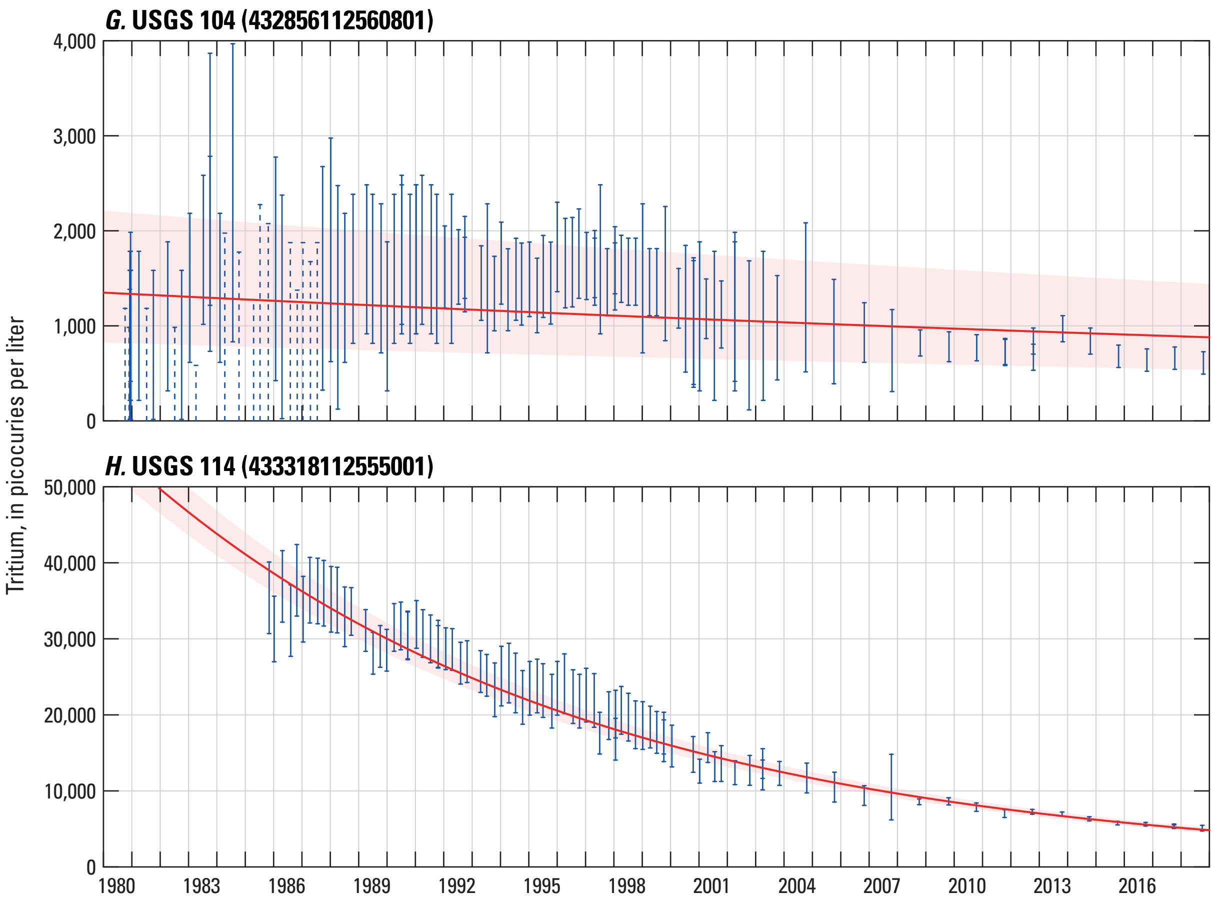


Figure 15.—Continued

from the lack of dilution by groundwater recharge because of no streamflow in the Big Lost River during 2001–4 (Davis, 2008). The general decrease in concentrations from 2004 to 2018 (fig. 15) occurred after the old percolation ponds were taken out of service and replaced with the new percolation ponds about 2 mi southwest of the INTEC.

A water-quality trend report examining data through 2012 (Davis and others, 2015) showed that one well near the RWMC (USGS 87) had an increasing trend, and the trend was attributed to water from upgradient disposal still contributing to the water concentration. The additional data collected through 2018 indicates a statistically significant decreasing trend (fig. 15), which should be an indication that peak tritium values have moved past this well.

Tritium concentrations in water from several wells (figs. 5 and 6) in and near the tritium plume (CPP 1, CPP 2, Highway-3, ICPP-MON-A-166, RWMC M11S, RWMC M13S, TRA 3, USGS 88, 89, 117 and USGS 119) (fig. 14) have been consistently less than the RESL 200 pCi/L detection level through time. These wells were sampled in 2017 and 2018 using a lower analytical detection limit of about 1 pCi/L. Concentrations are given in table 7. Tritium data from CPP 1, ICPP-MON-A-166, Highway-3, and USGS 127 indicate that they have concentrations greater than the upper background concentration of western tributary water of 34 pCi/L (Bartholomay and Hall, 2016), so their water probably is slightly influenced by wastewater disposal (table 7). The other wells have either all or mostly all old water not influenced by wastewater disposal (table 7).

In addition to the wells listed in the previous paragraph, two wells that were discontinued from the sample program in 2012 (well USGS 83, which penetrates about 250 ft of the ESRP aquifer; and well EBR 1, which penetrates about 490 ft of the aquifer) also historically showed tritium concentrations less than the reporting level. Mann and Cecil (1990, p. 18) speculated that tritium was not present in wells USGS 83 and EBR 1 because of dilution from deeper water. Rattray (2018) determined that the water sampled from wells EBR 1; and USGS 83, 89, 117, and 119 were all very old Big Lost River water and (or) Little Lost River Valley water. Rattray (2018) also reported that several of these wells had very low hydraulic conductivities and that the low conductivities probably limit current areas of recharge from influencing the water in the wells. Bartholomay, Hodges, and Champion (2017) analyzed wastewater influence in relation to the basalt flows and similarly noted that the wells not influenced by wastewater had low conductivities, although they all were completed in mostly the same two- or three-flow units.

Table 7. Sites sampled for low-level tritium analyses at and near the Idaho National Laboratory, Idaho, 2017 and 2018.

[Samples were analyzed by USGS Menlo Park Tritium Laboratory. Concentrations greater than three times the sample standard deviation are considered greater than the reporting level and are shown in **bold.** **Abbreviations:** blw, below; ID, identifier; USGS, U.S. Geological Survey; pCi/L, picocuries per liter]

Site name	USGS Site ID	Collection date	Time	Tritium Concentration (pCi/L)	One-sigma error (pCi/L)
USGS 143	433736112341301	11-08-2016	1140	**17.12**	**2.09**
ICPP-MON-A-166	433300112583301	04-24-2017	1014	**55.50**	**1.58**
SITE 17	434027112575701	04-11-2017	1339	**7.66**	**1.68**
USGS 119	432945113023401	04-18-2017	1120	-2.26	1.61
USGS 127	433058112572201	04-19-2017	1449	**156.38**	**1.93**
USGS 144	433021112552501	04-03-2017	1250	2.99	1.56
QA 9	433000113000001	04-27-2017	1305	1.19	1.55
TAN-2312	434939112422001	09-27-2017	1305	2.32	2.11
Highway 3	433256113002501	10-12-2017	0855	**63.49**	**3.62**
USGS 117	432955113025901	10-12-2017	1153	1.78	2.40
RWMC M11S	433058113010401	10-17-2017	1237	2.85	2.09
RWMC M13S	433037113002701	10-18-2017	1455	5.50	2.25
USGS 146	433359113042501	10-25-2017	1015	0.16	2.03
QA 9	433000113000001	10-25-2017	1020	**52.83**	**3.19**
BLR blw INL diversion	13132520	04-03-2018	1327	**24.3**	**1.52**
CPP 1	433433112560201	04-19-2018	0820	**72.1**	**2.65**
Cross Road	432128113092701	04-10-2018	1054	**9.2**	**1.17**
Spert 1	433252112520301	04-11-2018	0855	**8.06**	**1.13**
USGS 76	433425112573201	04-05-2018	0920	**411**	**11**
USGS 79	433505112581901	04-05-2018	1110	**17.6**	**1.35**
USGS 89	433005113032801	05-09-2018	1257	**4.38**	**1.1**
USGS 124	432307112583101	04-09-2018	1143	**51.4**	**2.15**
CPP 2	433432112560801	10-04-2018	0900	**17.6**	**2.17**
Replicate	433432112560801	10-04-2018	0905	**18**	**2.33**
GIN 2	434949112413401	10-18-2018	1011	**8.31**	**1.91**
Replicate	434949112413401	10-18-2018	1016	**7.53**	**2.08**
PBF MON A3	433203112514201	10-15-2018	1226	1.73	1.81
TRA 3	433522112573501	10-16-2018	1259	4.93	1.83
TRA Disp	433506112572301	10-16-2018	1129	**767**	**21.6**
USGS 88	432940113030201	10-22-2018	1325	**9.57**	**2.52**

Prior to 1999, concentrations of tritium in water from wells near the southern boundary of the INL (USGS 1, 103, 105, 108, 109, 110A) varied between exceeding and not exceeding the reporting levels (Pittman and others, 1988; Mann and Cecil, 1990; Bartholomay and others, 1997, 2000). During 1999–2005, concentrations of tritium in water from these wells and all wells sampled south of the INL boundary were less than the reporting level (Davis, 2008). During 2006–15, some of the wells with MLMS showed concentrations in some zones greater than the reporting level (Bartholomay, Maimer, and others, 2017, p. 37), whereas all other wells along the southern boundary and south of the INL had concentrations less than the reporting level. Well USGS 124, located east of Big Southern Butte (fig. 5), was sampled using a lower detection level of about 1 pCi/L in 2018 and its concentration was greater than the background concentration of 34 pCi/L (table 7), which probably indicates that this well was influenced by wastewater disposal.

Strontium-90

A strontium-90 plume developed in the ESRP aquifer from wastewater disposal at the INL. Strontium-90 has a half-life of 29.1 years (Walker and others, 1989, p. 29). The MCL for strontium-90 in drinking water is 8 pCi/L (U.S. Environmental Protection Agency, 2015).

During 1952–98, about 24 Ci of strontium-90 was in wastewater that was injected directly into the aquifer through the disposal well and was discharged to the old percolation ponds at the INTEC (Bartholomay and others, 2000). During 1962–63, more than 33 Ci of strontium-90 in wastewater was discharged into a pit at the INTEC (Robertson and others, 1974, p. 117). In 1972, about 18,100 Ci of strontium-90 was leaked at the INTEC tank farm (fig. 7) (Cahn and others, 2006). During 1952–1998, about 93 Ci of strontium-90 also was discharged to radioactive-waste infiltration and evaporation ponds at the ATR Complex. During 2000, 0.21 Ci of strontium-90/yttrium-90 was discharged at the ATR Complex (S.M. Stoller Corporation, 2002b, table 6-2). Data are not available for strontium-90 discharged at either the INTEC or the ATR Complex during 2001–18, but the amount that could move to the aquifer is thought to be zero.

During April or October 2018, water from 60 aquifer wells was sampled for strontium-90 throughout the INL. Concentrations of strontium-90 in water from 17 aquifer wells exceeded the reporting level. Concentrations of strontium-90 greater than the reporting level ranged from 2.2±0.7 pCi/L in water from well USGS 45 to 363±19 pCi/L in water from well TAN 2271. Well TAN 2271 is located near the TAN Disposal Well (fig. 5) where strontium-90 was disposed, and no other wells near TAN sampled by the USGS have concentrations of strontium-90 greater than the reporting level.

The largest 2018 strontium-90 concentration near the INTEC was in well USGS 47 at 14.6±0.9 pCi/L which is smaller than the 2015 concentration of 17.6±0.9 pCi/L. The area of the strontium-90 plume near the INTEC extended south-southwestward in the general direction of groundwater flow (fig. 16). In 2015, concentrations of strontium-90 in nine wells in the INTEC area exceeded the MCL of 8 pCi/L for drinking water; by 2018, only 4 wells had concentrations that exceeded the MCL. The concentrations of strontium-90 in water from most wells near and southwest of the INTEC have fluctuated and generally have exceeded the reporting level since 1980; however, most wells have shown an overall decrease in strontium-90 concentration (fig. 17). Strontium-90 concentrations in most wells have been decreasing likely because of factors including radioactive decay, diffusion, dispersion, discontinued disposal, and dilution from natural recharge.

Strontium-90 has not been detected in the ESRP aquifer beneath the ATR Complex partly because of the exclusive use of waste-disposal ponds and lined evaporation ponds rather than the disposal well for radioactive-wastewater disposal at that facility. Sorption processes in sediments in the unsaturated zone beneath the radioactive waste-disposal pond have minimized or prevented strontium-90 migration to the aquifer at the ATR Complex. Additionally, the stratigraphy beneath the ATR Complex includes more sedimentary interbeds than the stratigraphy beneath the INTEC (Anderson, 1991, p. 22–28).

Cesium-137

From 1952 to 2000, about 138 Ci of cesium-137 in wastewater was discharged to the ATR Complex radioactive-waste infiltration and lined evaporation ponds, and about 23 Ci was discharged to the INTEC disposal well and percolation ponds. In 1972, an additional 19,100 Ci of cesium-137 leaked at the INTEC tank farm (fig. 7) (Cahn and others, 2006). The half-life of cesium-137 is 30.17 years (Walker and others, 1989, p. 34). Cesium-137 is analyzed by gamma analyses (which may yield detections of cesium-137, cobalt-60, or chromium-51).

During 2016–18, water from 53 aquifer wells was sampled and analyzed for cesium-137. Water from one of these wells (CFA-LF 2-10) had a Cesium-137 concentration that equaled the reporting level at a concentration of 39±13 pCi/L. Given that this concentration is right at the reporting level, it may be a false positive.

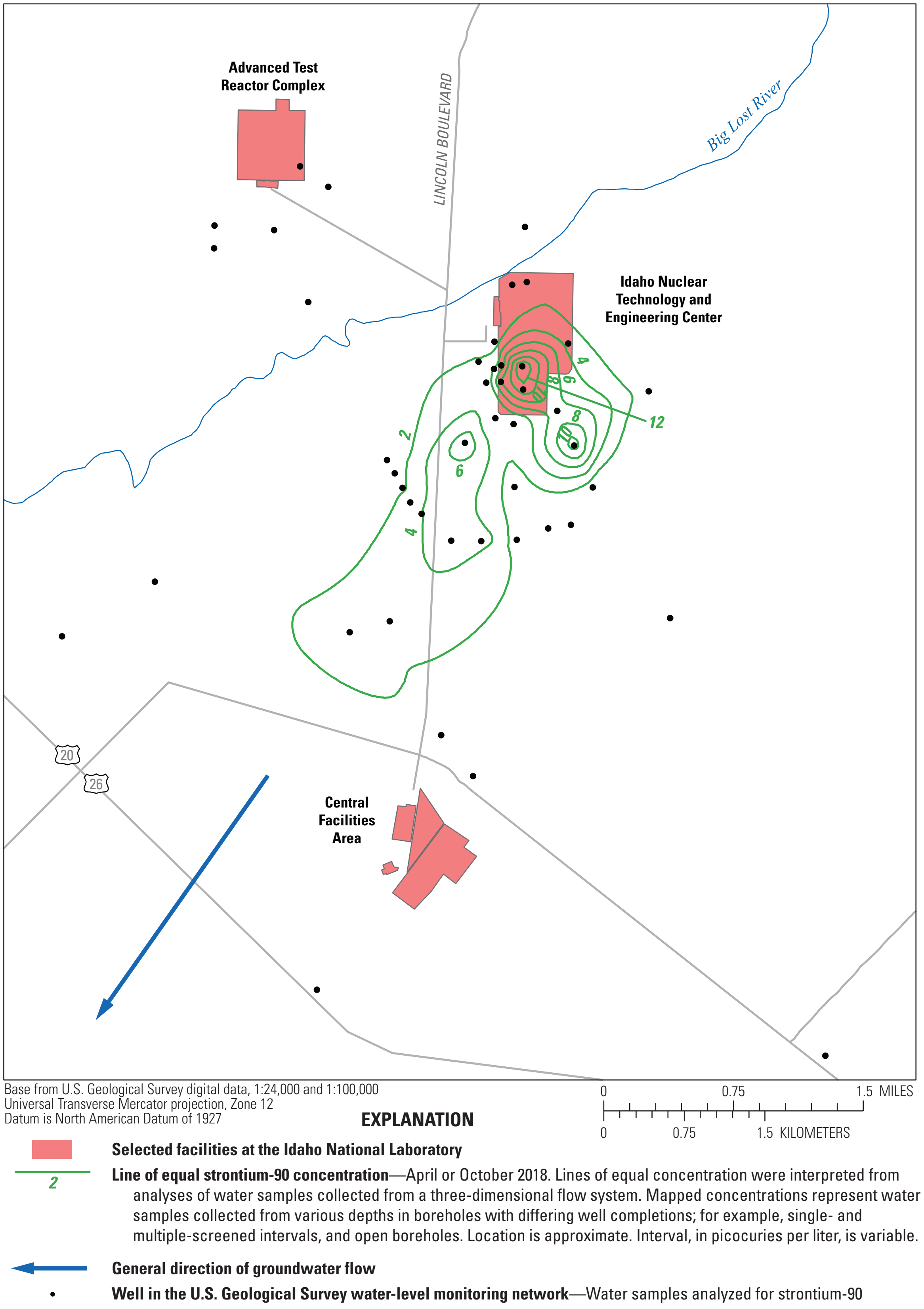
The absence of significant concentrations of cesium-137 probably resulted from discontinuation of wastewater discharge to the INTEC disposal well and ATR Complex radioactive waste infiltration ponds, and sorption processes in the unsaturated and perched groundwater zones.

Plutonium

In 1974, the USGS began monitoring plutonium-238, -239, and -240 (undivided) in wells to track wastewater discharged to the ESRP aquifer through the disposal well (fig. 6) at the INTEC. During 1974–2000, about 0.26 Ci of plutonium in wastewater was discharged to the disposal well and percolation ponds at the INTEC (Davis, 2008). About 17,100 Ci of plutonium-238, 64,900 Ci of plutonium-239, and 17,100 Ci of plutonium-240 were buried in the SDA during 1952–99 (Holdren and others, 2002, table 4-1).

Before 1974, alpha radioactivity from disintegration of plutonium was not separable from the monitored, undifferentiated alpha radioactivity. The half-lives of plutonium-238, -239, and -240 are 87.7, 24,100, and 6,560 years, respectively (Walker and others, 1989, p. 46). Because of radioactive wastewater discharged to the disposal well at the INTEC, concentrations of plutonium isotopes in some water samples from wells USGS 40 and 47 near the INTEC (fig. 6) through January 1987 exceeded the reporting level (Orr and Cecil, 1991, p. 37). Concentrations in water samples collected from these wells since 1987 have been less than the reporting level.

During 2016–18, concentrations of plutonium-238, -239, and -240 (undivided) in water from all 16 aquifer wells sampled were less than the reporting level.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

EXPLANATION

🟥 **Selected facilities at the Idaho National Laboratory**

2 **Line of equal strontium-90 concentration**—April or October 2018. Lines of equal concentration were interpreted from analyses of water samples collected from a three-dimensional flow system. Mapped concentrations represent water samples collected from various depths in boreholes with differing well completions; for example, single- and multiple-screened intervals, and open boreholes. Location is approximate. Interval, in picocuries per liter, is variable.

← **General direction of groundwater flow**

● **Well in the U.S. Geological Survey water-level monitoring network**—Water samples analyzed for strontium-90

Figure 16. Distribution of strontium-90 in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Central Facilities Area, Idaho National Laboratory, Idaho, April or October 2018.

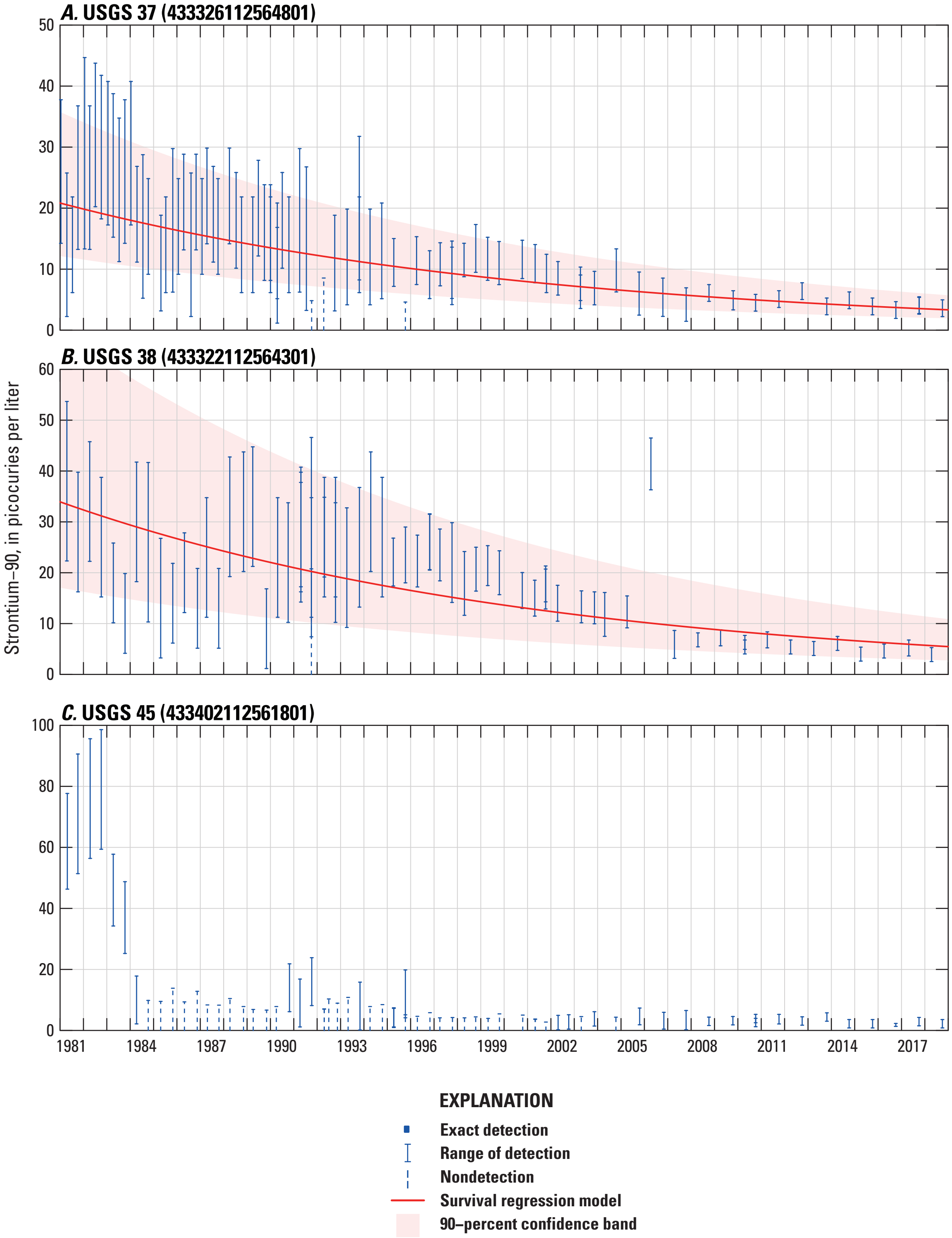


Figure 17. Strontium-90 concentrations in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center, Idaho, 1981–2018. Location of wells is shown in figure 6.

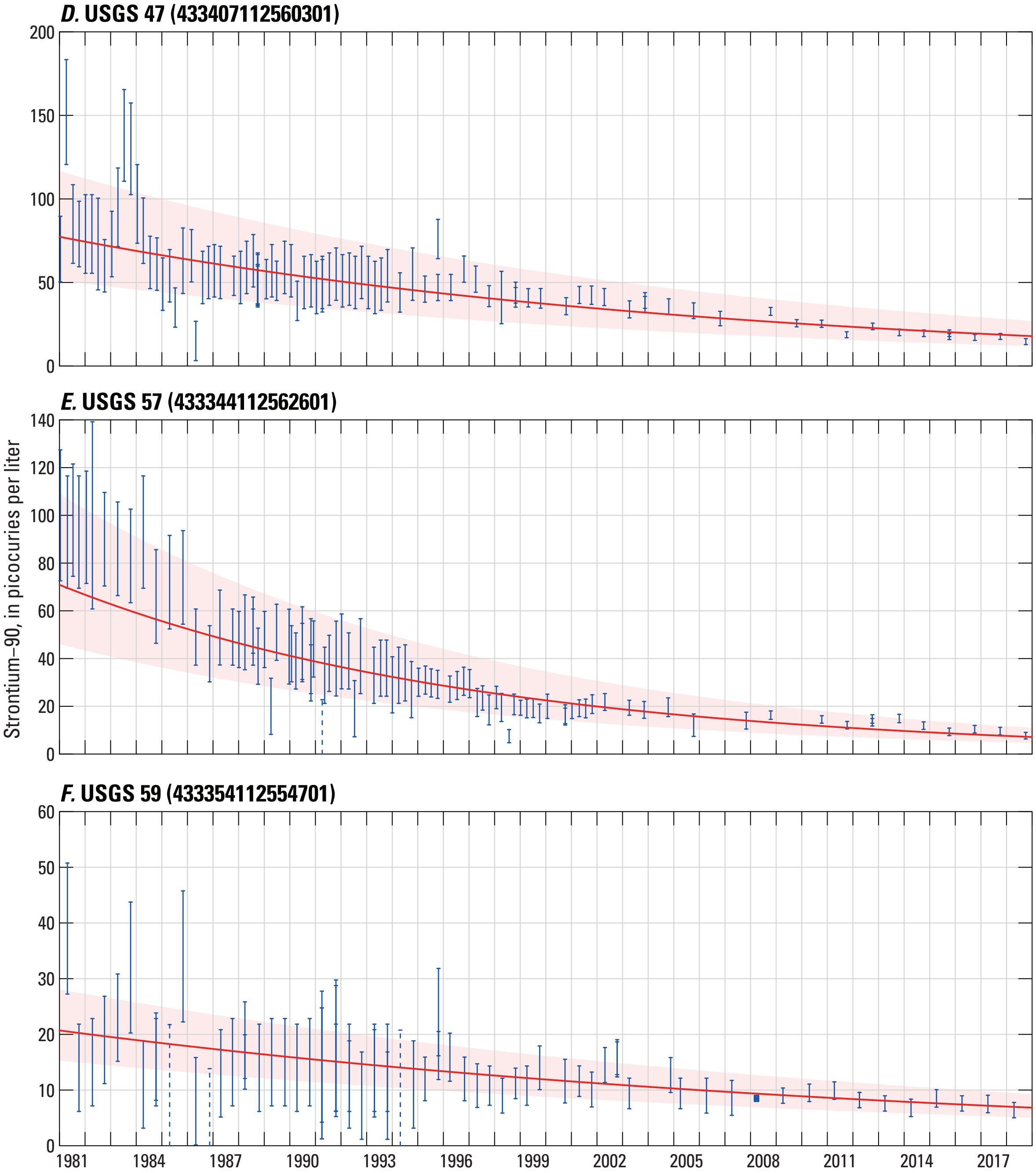


Figure 17.—Continued

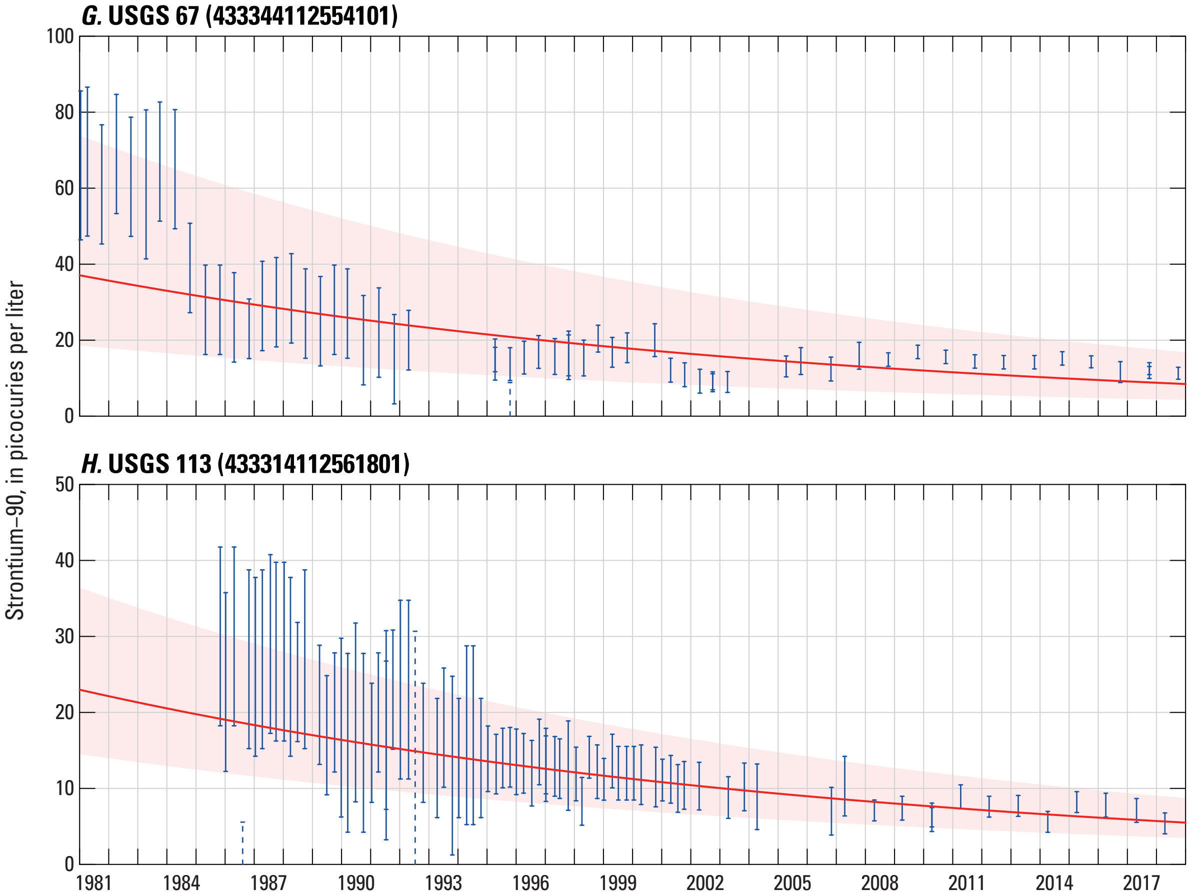


Figure 17.—Continued

Americium-241

Americium-241 is a decay product of plutonium-241. Plutonium isotopes were in wastewater discharged to the ESRP aquifer at the INL and are in wastes buried at the RWMC. The half-life of americium-241 is 432.7 years (Walker and others, 1989, p. 46).

Concentrations of americium-241 in some water samples collected from September 1972 to July 1982 from wells USGS 87, 88, 89, and 90 at the RWMC and in water samples collected through 1988 from the TAN Disposal Well exceeded the reporting level (Orr and Cecil, 1991, p. 38–39). During 1992–95, concentrations of americium-241 in water samples from two wells were equal to the reporting level. On October 2, 1992, the concentration in water from well USGS 37 was 0.09±0.03 pCi/L; on April 20, 1993, the concentration in water from well USGS 120 was 0.06±0.02 pCi/L (Bartholomay and others, 1997). The concentration in one water sample collected on April 12, 2001, from the RWMC Production Well (RWMC PROD) was 0.003±0.001 pCi/L, equal to the reporting level (Davis, 2008). During 2016–18, concentrations in water from all 16 aquifer wells sampled were less than the reporting level.

Gross Alpha- and Beta-Particle Radioactivity

Gross alpha- and beta-particle radioactivity is a measure of the total radioactivity given off as alpha and beta particles during the radioactive decay process. The radioactivity is usually reported as if it occurred as 1 radionuclide. Gross alpha and beta measurements are used to screen for radioactivity in the aquifer as a possible indicator of groundwater contamination. Water samples collected during 2016–18 were analyzed for gross alpha- and gross beta-particle radioactivity by the RESL. Some of the wells sampled in 2016 were analyzed at a USGS contract laboratory, but results are not discussed here because they are not comparable with historical sampling results. In 2008, the RESL increased the sensitivity of the gross alpha- and gross beta- particle radioactivity and changed the radionuclide reported for gross alpha-particle radioactivity from plutonium-239 to thorium-230, and for gross beta-particle radioactivity from cesium-137 to strontium-90/yttrium-90. The minimum detectable activity decreased from about 1.6 to 1.5 pCi/L for gross alpha-particle radioactivity and from about 6.4 to 3.4 pCi/L for gross beta-particle radioactivity, allowing for increased detectable concentrations (Bartholomay and Twining, 2010).

During 2016–18, water from 55 aquifer wells was sampled and analyzed for gross alpha-particle radioactivity. Six wells had concentrations of gross alpha-particle radioactivity that equaled or exceeded the reporting level, and concentrations ranged from 6±2 pCi/L in wells USGS 11 and CPP 1 to 141±29 pCi/L in well TAN-2271. Concentrations of gross alpha-particle radioactivity in water from all other wells sampled and analyzed were less than the reporting level.

During 2016–18, concentrations of gross beta-particle radioactivity in water from about one-half of the wells equaled or exceeded the reporting level in at least one of the sampling periods and ranged from 2.4±0.8 in several wells to 1,390±80 pCi/L in well TAN 2271.

Chromium

From 1952 to 1972, an estimated 17,790 lb of chromium was discharged to the radioactive-waste infiltration ponds, and 31,131 lb of chromium was discharged to the TRA disposal well (U.S. Department of Energy, 2011a). In October 1972, chromium used as a corrosion inhibitor in cooling-tower operations was replaced by a polyphosphate. No disposal of chromium to the subsurface at the ATR Complex was reported after 1972.

During 1971–83, about 265 lb of chromium in wastewater were discharged to the disposal well at the INTEC, and 720 lb of chromate were discharged at the Power Burst Facility (fig. 1) (Cassidy, 1984, p. 3). About 130 lb of chromium were discharged to the old INTEC percolation ponds during 1992–98 (Bartholomay and others, 2000).

Background concentrations of dissolved chromium in the ESRP aquifer in the eastern regional and western tributary water were 3 and 4 µg/L, respectively (Bartholomay and Hall, 2016). In April 2009, the dissolved chromium concentration in water from one well, USGS 65, south of ATR Complex (fig. 6), equaled the MCL of 100 µg/L (U.S. Environmental Protection Agency, 2015) for total chromium in public drinking water supplies. In April 2018, the concentration of chromium in water from that well had decreased to 76.0 µg/L, much less than the MCL. Concentrations in water samples from 63 other wells sampled in 2018 ranged from <0.6 to 21.6 µg/L.

Sodium

During 1989–98, an estimated average annual 1.3 million lb/yr of sodium in wastewater were discharged at the INL (Bartholomay and others, 1995, 1997, 2000). During 1996–98, about 708,000 lb/yr of sodium were discharged to the INTEC percolation ponds, about 58,000 lb/yr were discharged to the ATR Complex chemical-waste infiltration pond, about 524,000 lb/yr were discharged to the NRF industrial-waste ditch, and about 5,000 lb/yr were discharged at the CFA (Bartholomay and others, 2000). The background concentration of sodium in water from the ESRP aquifer is about 8.3 mg/L in the western part of the INL and about 14.8 mg/L in the eastern part (Bartholomay and Hall, 2016). In 2018, concentrations in water from most wells in the southwestern part of the INL were greater than 8.3 mg/L.

Concentrations of dissolved sodium in water from wells near the INTEC generally were variable in the 1980s and 1990s because of variable discharge to the disposal well and infiltration ponds south of the INTEC (figs. 7 and 18). Since 2002, when the infiltration ponds were taken out of service, sodium concentrations mostly have decreased (Davis and others, 2015, appendix D). During 1999–2018, the high concentrations of sodium were in water from wells at or near the INTEC (figs. 6 and 18). During 2018, the highest sodium concentration in water samples from aquifer wells near the INTEC was 29.0 mg/L in a water sample from well USGS 57 (fig. 6), a slight decrease from 2015 (32.9 mg/L). Concentrations of sodium in water from other wells south of the INTEC during 2016–18 generally also were less than or equal to sodium concentrations detected during 2012–15 (fig. 18).

Davis and others (2015, figs. 21 and 22) found increasing trends in several wells downgradient of the INTEC near and south of the CFA. The increasing trends were attributed to the movement of the high-concentration water discharged during the 1970s–1990s at the INTEC, finally reaching these wells resulting in increasing concentration trends.

Installation and use of the new percolation ponds 2 mi southwest of the INTEC have contributed to increased concentrations of sodium in the Rifle Range well (fig. 18). In 1988, the concentration of sodium in this well was about at background concentrations at 9 mg/L. After the new percolation ponds were put into service in 2002, concentrations of sodium increased steadily to a concentration of 16 mg/L until 2008; since then, concentrations of sodium have decreased (fig. 18), probably due to more consistent rates of discharge of sodium to the new percolation ponds.

In October 2018, the sodium concentration in water from well USGS 88 (fig. 6), near the RWMC, was 46.8 mg/L, slightly less than the 52 mg/L concentration in 2015. In April 2018, the sodium concentration in water from well MTR Test at the ATR Complex near the chemical-waste pond (fig. 6) was 9.85 mg/L, significantly less than the high concentration of 42 mg/L in 1998. Concentrations of sodium in this well have remained fairly constant in the 9–13 mg/L range since about 2002 (Davis and others, 2015, appendix D). This concentration decrease from the high in 1998 may be a result of the discontinued use of the chemical-waste pond in 1999.

The largest concentration in wells near TAN was in TAN 2271 at 120 mg/L. This well was drilled very near the TAN Disposal Well which had sodium discharged into it in the past.

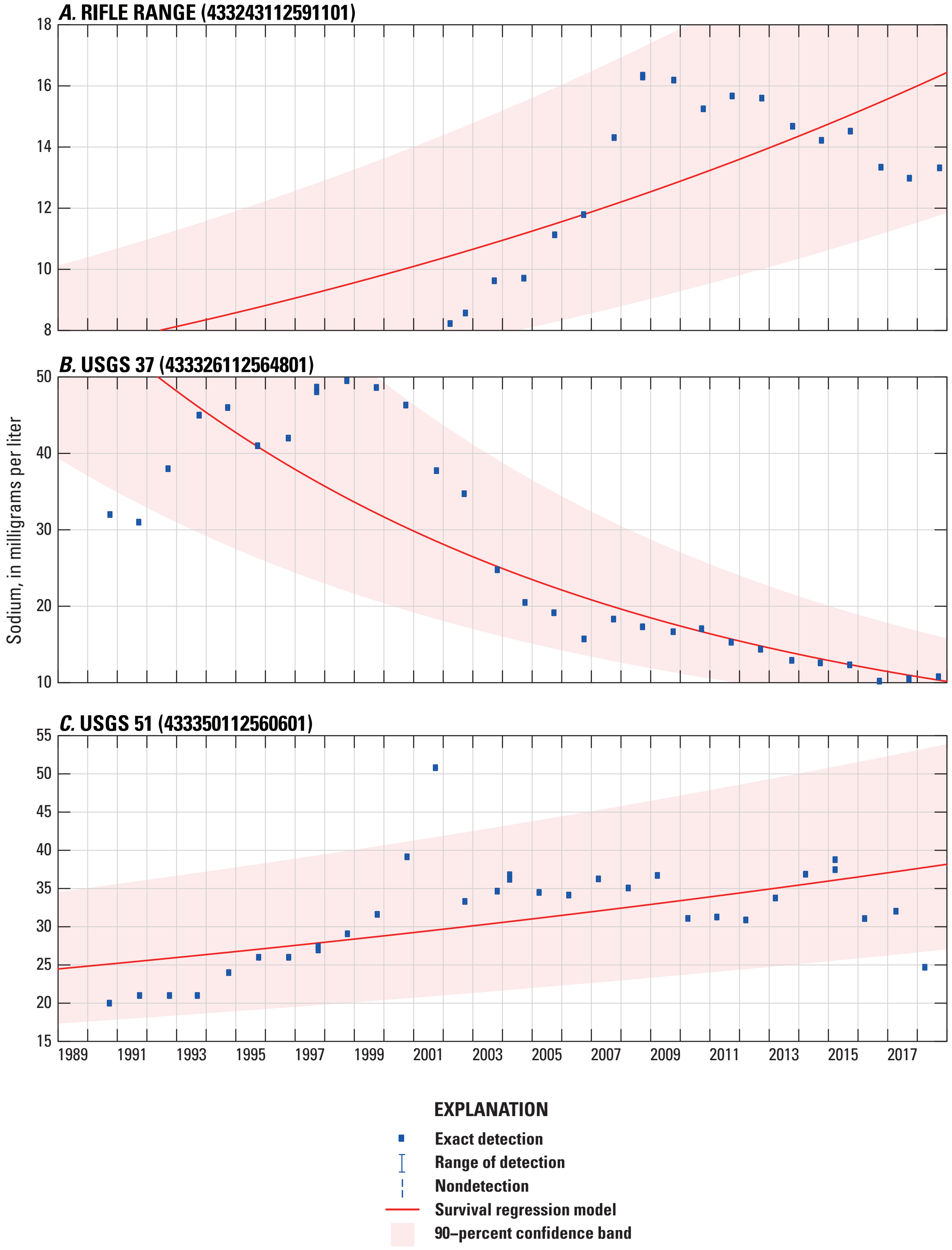
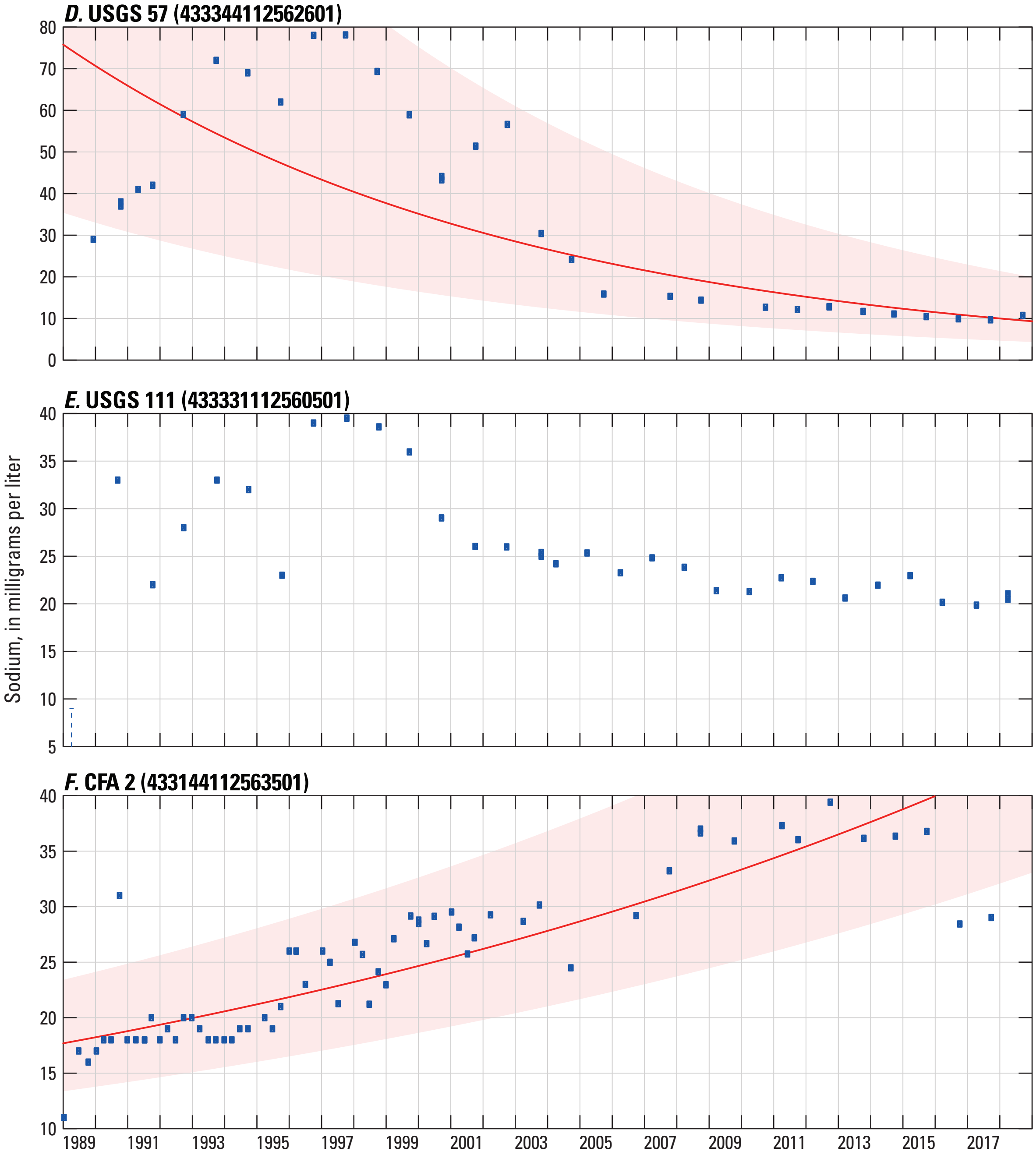


Figure 18. Dissolved sodium concentrations in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center and Central Facility Area, Idaho, 1989–2018. Location of wells is shown in figures 5 and 6.



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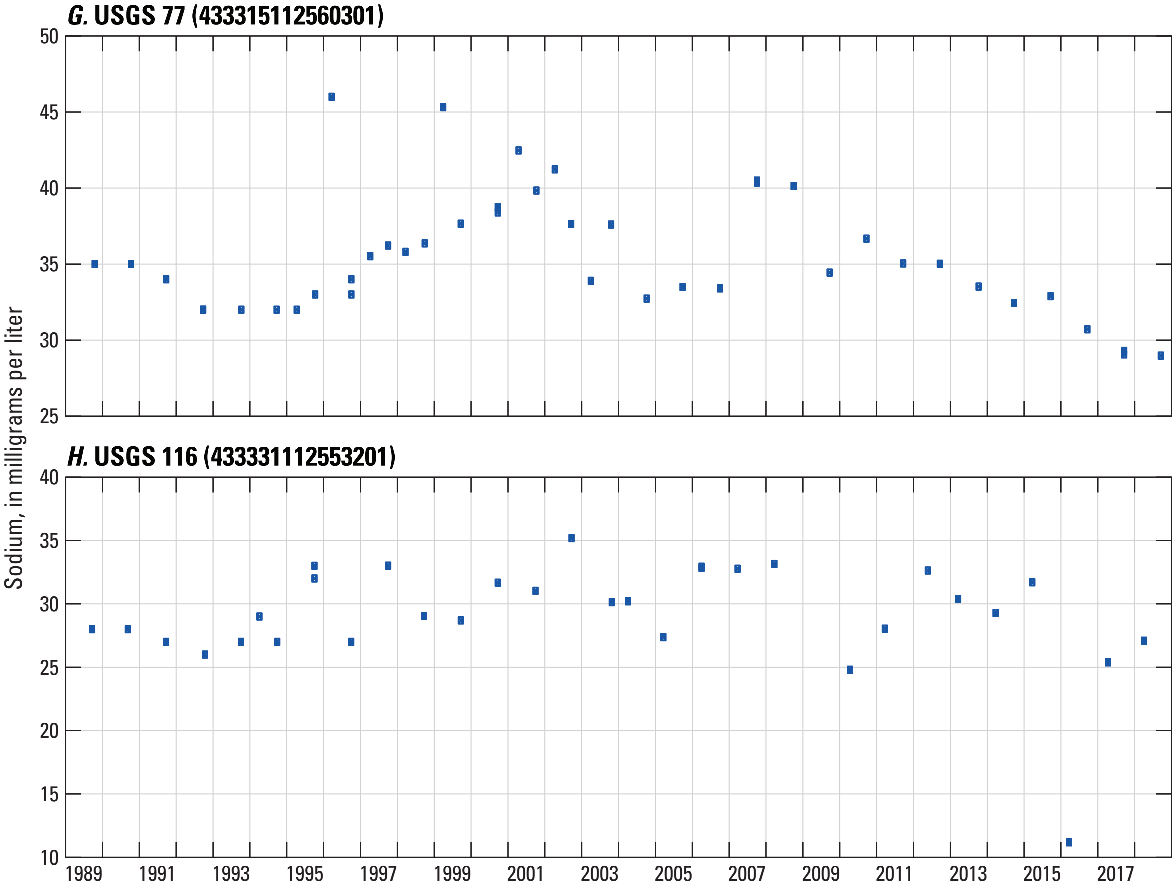


Figure 18.—Continued

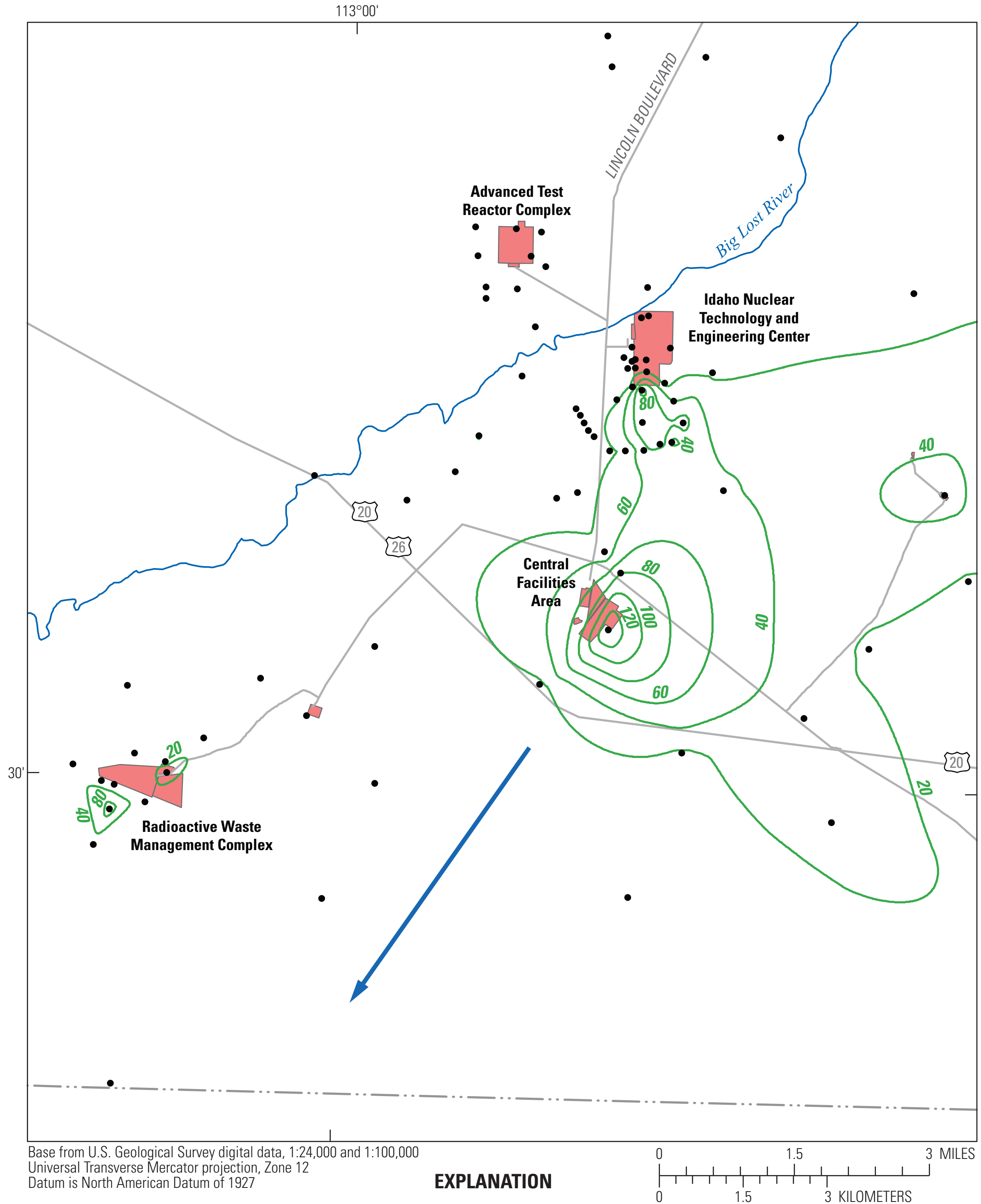
Chloride

Chloride in wastewater has been discharged to infiltration ponds at the INL. The background chloride concentration in water in the western part of the ESRP aquifer at the INL is about 12 mg/L (Bartholomay and Hall, 2016), the background dissolved chloride concentration near the INTEC is about 10 mg/L, and the ambient chloride concentration near the CFA is about 20 mg/L (Robertson and others, 1974, p. 150). The secondary MCL for total chloride in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 2015). In 2018, concentrations of dissolved chloride in most water samples from wells south of the INTEC and at the CFA (figs. 19 and 20) exceeded 20 mg/L but were less than the secondary MCL.

Concentrations of dissolved chloride in water from wells near the INTEC generally were variable in the 1980s and 1990s because of variable discharge to the disposal well and infiltration ponds south of the INTEC (figs. 6 and 20). Since 2002, when the infiltration ponds were taken out of service, chloride concentrations mostly have decreased except for wells southeast of the INTEC (Davis and others, 2015, fig. 18, appendix D). During 2018, the highest chloride concentration in water samples from aquifer wells near the INTEC was 90.7 mg/L in a water sample from well USGS 51 (fig. 6), a decrease from 2015 (170 mg/L). This well is located at the old infiltration ponds and was one of the few that showed an increasing concentration trend near the INTEC since the late 1980s (fig. 20); however, the recent decrease could be an indication that remnant water below the infiltration ponds is infiltrating less to this part of the ESRP aquifer. Concentrations of chloride in water from other wells south and southwest of the INTEC during 2016–18 generally were less than or equal to chloride concentrations detected during 2012–15 and generally show decreasing trends (fig. 20).

Chloride concentrations in the Rifle Range well (figs. 5 and 20) increased from 9 mg/L in October 2002 to 42 mg/L in 2008 and decreased to 22.7 mg/L in October 2018. This well is downgradient of the new INTEC percolation ponds so the changes in concentrations probably are due to variable rates of chloride discharge to the ponds.

The chloride concentration in water from well CFA 2 at the CFA decreased slightly from 134 mg/L in October 2015 to 125 mg/L in October 2017; however, the trend for concentrations from 1989 to 2017 is increasing (fig. 20). Concentrations of other wells in the CFA area ranged from 16 to 144 mg/L in 2018. The concentrations at the CFA are attributed to past disposal at the INTEC and the increasing



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

EXPLANATION

🟥 **Selected facilities at the Idaho National Laboratory**

— 20 **Line of equal dissolved chloride concentration**—April or October 2018. Lines of equal concentration were interpreted from analyses of water samples collected from a three-dimensional flow system. Mapped concentrations represent water samples collected from various depths in boreholes with differing well completions; for example, single- and multiple-screened intervals, and open boreholes. Location is approximate. Interval, in milligrams per liter, is variable.

← **General direction of groundwater flow**

• **Well in the U.S. Geological Survey water-level monitoring network**—Water samples analyzed for chloride

Figure 19. Distribution of chloride in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, April or October 2018.

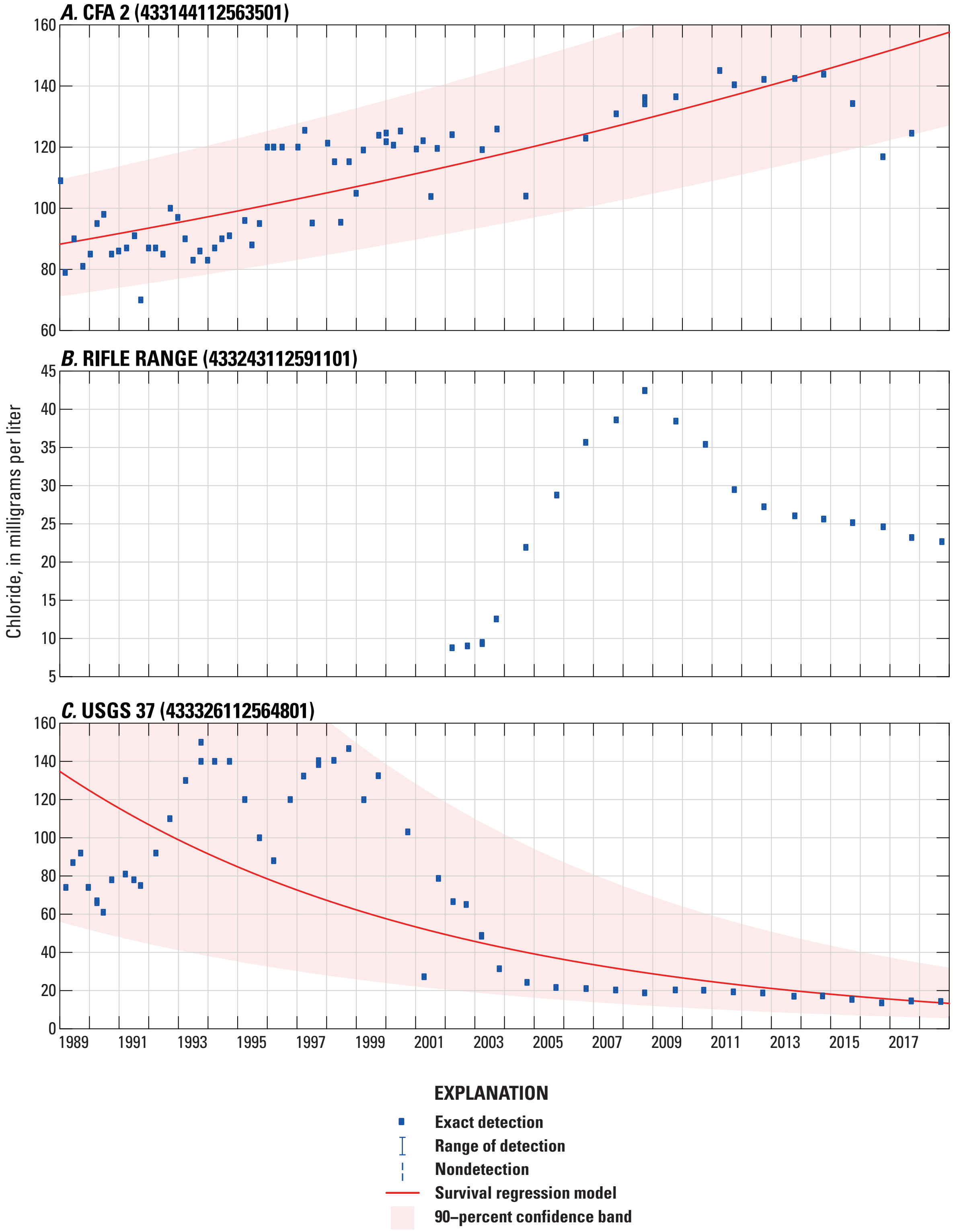
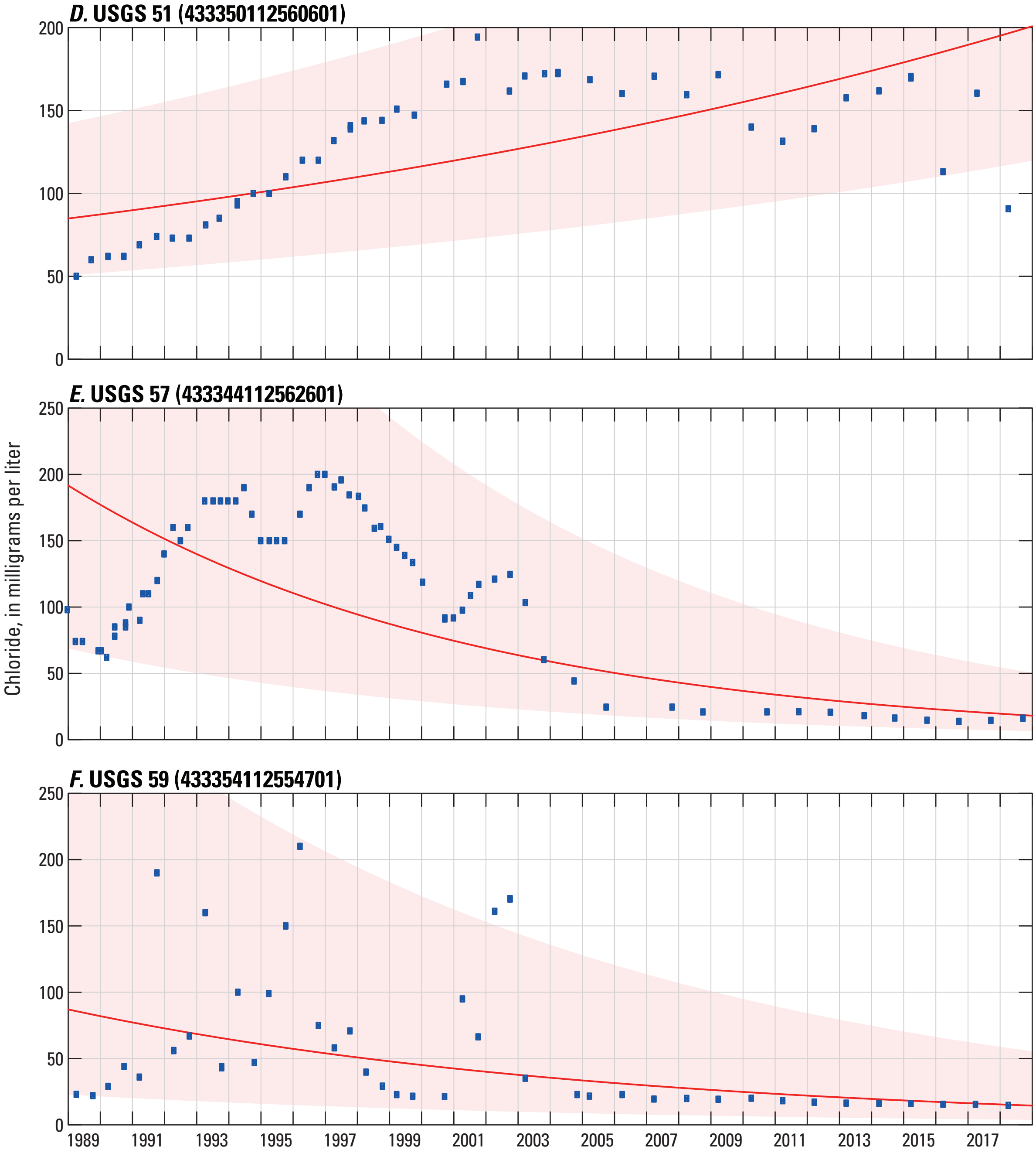


Figure 20. Dissolved chloride concentrations in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center, Idaho National Laboratory, Idaho, 1989–2018. Location of wells is shown in figures 5 and 6.



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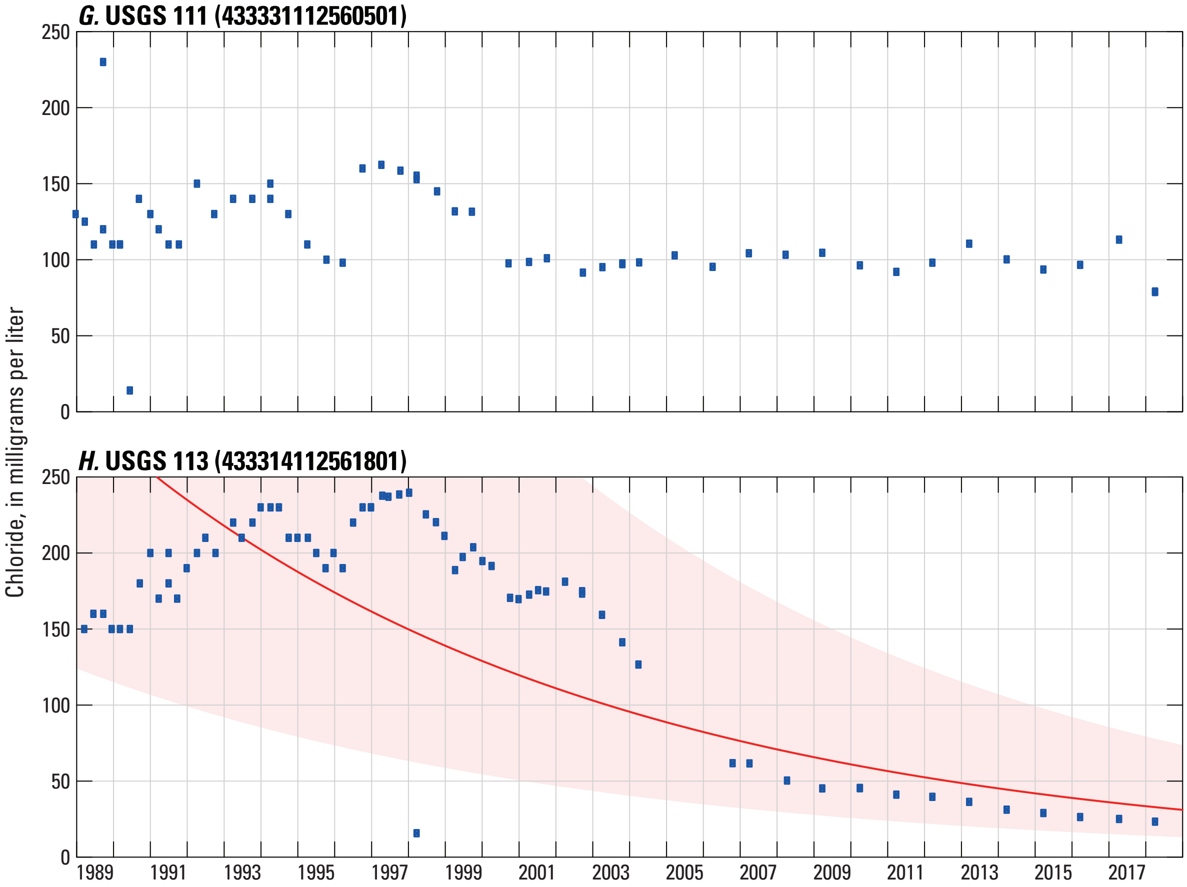


Figure 20.—Continued

trend in CFA 2 probably is representative of a period of increased wastewater disposal at the INTEC during some previous timeframe.

In April 2018, the 18.5-mg/L chloride concentration in water from well USGS 65 south of the ATR Complex (fig. 6) was greater than the background concentration. Chloride concentrations in water from all other wells completed in the ESRP aquifer at or near the ATR Complex were near background concentrations and ranged from 9.72 to 12.3 mg/L during 2018, similar to concentrations during the 2012–15 reporting period (Bartholomay, Maimer, and others, 2017).

During 2018, chloride concentrations in water from wells USGS 88 and 89 at the RWMC were 105 and 40.1 mg/L, respectively, slightly lower than concentrations during the 2012–15 reporting period. Concentrations of chloride in all other wells near the RWMC ranged from 6.05 to 26.7 mg/L.

The largest concentration in wells near TAN was 117 mg/L in well TAN 2271. This well was drilled very near the TAN Disposal Well, which explains its large concentration.

Sulfate

Sulfate in wastewater has been discharged to percolation (infiltration) ponds at the INTEC and ATR Complex, and to the NRF industrial-waste ditch (Bartholomay and others, 2000). Background concentrations of sulfate in the ESRP aquifer in the western part of the INL are about 21 mg/L (Bartholomay and Hall, 2016). The secondary MCL for sulfate in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 2015).

Because of the sulfate disposal history at the various facilities, water-sample collection for dissolved sulfate analyses at several wells was added to the USGS water-quality monitoring network in 1995. In 2018, sulfate concentrations in water samples from several wells in the western part of the INL exceeded the 21 mg/L background concentration of sulfate and ranged from 22 mg/L in well USGS 57 to 151 mg/L in well USGS 65 (fig. 6). During 2018, concentrations were 46.7, 45.6, and 44.6 mg/L in water from wells USGS 34, 35, and 36, respectively, southwest of the INTEC. Davis and others (2015, fig. 25) indicated increasing trends in these and several other wells southwest of the INTEC from 1989 to 2012, but also indicated that sulfate concentrations fluctuated in response to water-level changes. Water levels in this part of the aquifer mostly have increased in the past 2 years but declined from 2001 to 2016, so the increasing concentrations may be due to decreasing dilution. The greater-than-background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds.

In April or October 2018, sulfate concentrations in water samples from most wells around and near the RWMC (fig. 6) were greater than the background concentration of 21 mg/L and were highest in well USGS 120 at 56.6 mg/L, but long-term trend data indicated either decreasing or no trends in the wells. The sulfate concentrations in water from these wells that were greater than the upper background level could have resulted from the well construction techniques (Pittman and others, 1988, p. 57–61) and (or) waste disposal at the RWMC or the ATR Complex.

Nitrate (As Nitrogen)

Wastewater containing nitrate was injected into the ESRP aquifer through the INTEC disposal well from 1952 to February 1984 and was discharged to the INTEC percolation ponds after February 1984 (Orr and Cecil, 1991). Additionally, nitrate was present in waste leaked at the INTEC tank farm during a transfer from one tank to another (Cahn and others, 2006). Concentrations of nitrate (as N) in groundwater not affected by wastewater disposal from INL facilities are less than the background concentrations of about 0.655 mg/L for western tributary water and about 1 mg/L for eastern tributary water (Bartholomay and Hall, 2016).

Concentrations of dissolved nitrate in this report are reported as N. Until the 2006–08 reporting period for publications in this series, nitrate was reported as nitrate. To convert concentrations as N to concentrations as NO_3^-, the nitrate (as N) concentration should be multiplied by 4.4266 (Hem, 1989, table 8) so that concentrations reported here can be compared with those given in previous reporting-period publications. Historical nitrite analyses indicate that almost all nitrite concentrations are less than the laboratory reporting level (LRL) for analyses at the INL, so concentrations of nitrite plus nitrate are referred to as nitrate in this report.

All nitrate concentrations measured in 2018 were less than the 10-mg/L MCL for drinking water (U.S. Environmental Protection Agency, 2015). Nitrate concentrations at the INL near the INTEC mostly have decreased in response to reduced disposal rates and to the transition in 1984 from injection of wastewater to the INTEC disposal well to discharge to the old percolation ponds (Davis and others, 2015, fig. 28). Although concentrations generally have decreased, concentrations in several of the wells have shown variable increases and decreases. The variability may have resulted from periodic dilution by recharge from the Big Lost River and variation in discharge rates to the percolation ponds from 1984 to 2002. The two exceptions to decreasing or no trends near INTEC are wells USGS 20 and 67, which show variable decreases and increases but overall have been increasing (fig. 21).The increases could be due to mobilization of nitrate beneath the INTEC tank farm, as both wells are downgradient of the INTEC tank farm and nitrate was present in the reported 1972 leak (Cahn and others, 2006; U.S. Department of Energy, 2011a). The increases occurred during and after wet periods such as the late 1990s when more recharge to the aquifer was occurring and presumably mobilizing these constituents below the tank farm. Low concentrations occurred in the early to mid-2000s when dryer conditions occurred and presumably less opportunity existed for surface recharge to mobilize constituents (fig. 21).

In April or October 2018, concentrations of nitrate in water from most wells at and near the INTEC exceeded the background concentration of 0.655 mg/L. Concentrations ranged from 0.555 mg/L in well USGS 82 to 7.00 mg/L in well USGS 43. USGS 43 historically has had some of the largest nitrate concentrations because of its location near the INTEC disposal well. It also has periodically had variably high concentrations that are not correlated to influxes from the Big Lost River (for example, in 2001 and 2004, fig.21), and in 2017 had a concentration of 9.41 mg/L when flow occurred in the river, so it is not clear what may cause the occasional rise in concentrations.

Concentrations of nitrate in wells south of the INTEC and farther away from the influence of disposal areas and the Big Lost River (wells CFA 1, USGS 77, 111, 113, 114, and 116 [figs. 5 and 6]) show much less variability and a general decrease in nitrate concentration trends through time (Davis and others, 2015, figs. 27–28, appendix D). In the southern part of the CFA, well CFA-2 shows an increasing trend (fig. 21). Nitrate concentrations of samples collected in 2017 from well CFA-2 and in 2018 from USGS 130 in the southern part of the CFA were 3.69 and 3.48 mg/L, respectively, and these concentrations are higher than for other wells upgradient and downgradient of the CFA. Nitrate contamination south of the CFA has been attributed to contamination from the old CFA mercury pond south of the facility (U.S. Department of Energy, 2011b), and increased nitrate in these wells possibly could be due to movement of nitrate in the unsaturated zone from the old CFA pond.

Historically, nitrate concentrations in water from wells near the RWMC have been near or have slightly exceeded the western tributary background concentration of about 0.655 mg/L (Bartholomay and Hall, 2016) in most wells. In 1998, nitrate concentrations in water samples from wells USGS 88 and 89 near the RWMC (fig. 6) exceeded the background concentration and were 1.6 and 2.0 mg/L, respectively (Bartholomay and others, 2000). Concentrations in wells USGS 88 and 89 show decreasing trends (Davis and others, 2015, fig. 28), and concentrations were 0.996 and 1.68 mg/L, respectively, in 2018.

In 2018, near the ATR Complex, the concentration of nitrate in water from several wells was equal to or greater than the background concentration of 0.655 mg/L, with the largest concentration of 1.42 mg/L in well USGS 65.

Nitrate concentrations in several wells in the eastern part of the INL were greater than the background concentration of about 1 mg/L for eastern regional recharge. The trends for

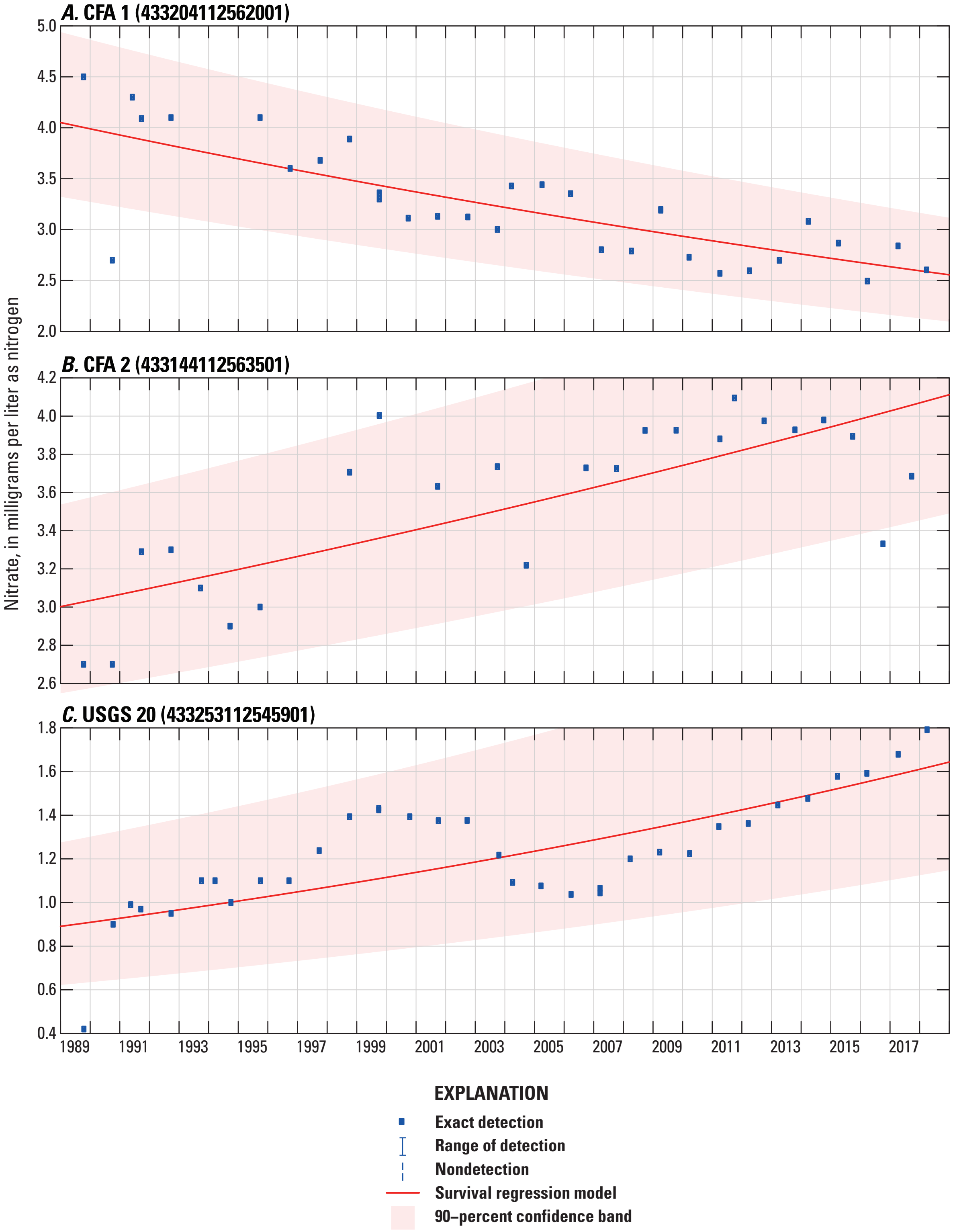
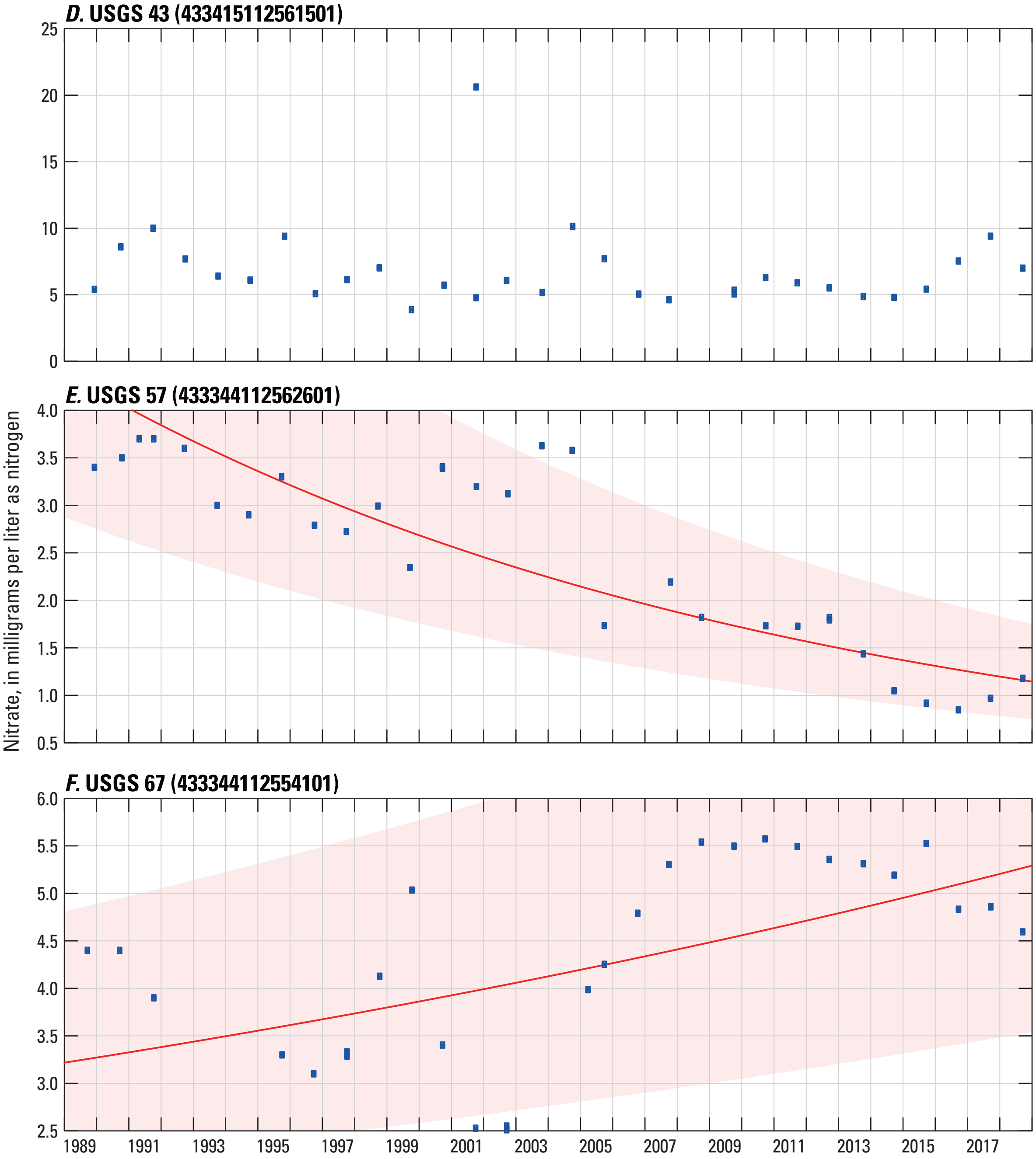


Figure 21. Concentration of nitrate (as N) in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center and Central Facilities Area, Idaho National Laboratory, Idaho, 1989–2018.



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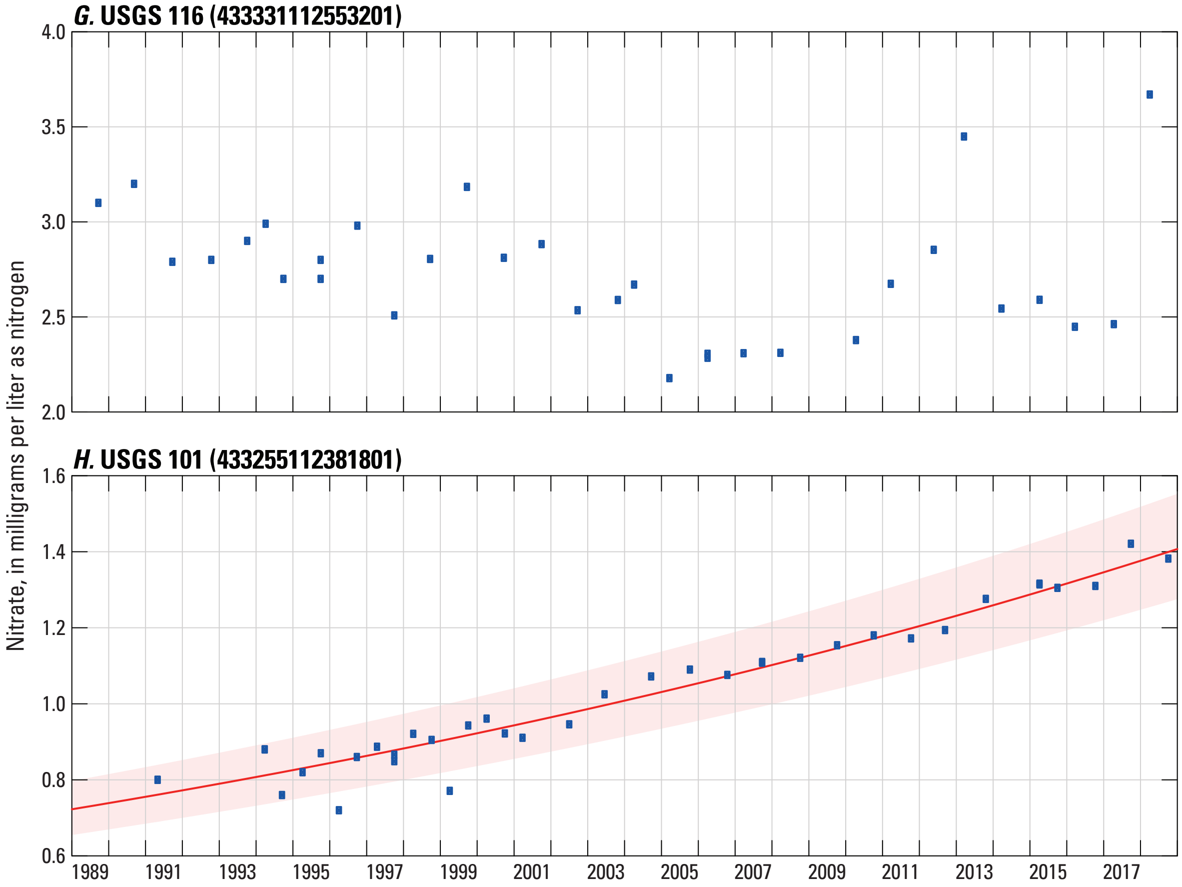


Figure 21.—Continued

many of these wells also were increasing and the increasing trends were attributed to agricultural and other anthropogenic influences upgradient of the INL (Bartholomay and others, 2012, p. 26). An example of the increasing trend is shown in fig. 21 for USGS 101.

Fluoride

The USGS began analyzing water samples collected near the INTEC for fluoride in 1994 because fluoride in wastewater was being discharged to the old percolation ponds. During April or October 2018, water samples from four wells near the INTEC (CPP 1, USGS 34, 38, and 77, fig. 6) were analyzed for dissolved fluoride; detected concentrations ranged from 0.171 to 0.225 mg/L. These concentrations were near the range of background concentrations of dissolved fluoride of the ESRP aquifer for the western part of the INL reported by Bartholomay and Hall (2016), which indicates that wastewater disposal has not had an appreciable effect on fluoride concentrations in the ESRP aquifer near the INTEC. Additionally, fluoride was collected from five new wells (USGS 143, 144, 146, and 147; and TAN 2312) and concentrations ranged from 0.255 to 0.823 mg/L, which were within the range of other concentrations for fluoride at the INL (Bartholomay and Hall, 2016, appendix B)

Trace Elements

As part of the INL groundwater monitoring program adopted in 1994 and several special sampling programs, water samples from 14 wells were collected and analyzed for various trace elements during 2016–18. These trace elements included dissolved concentrations of aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium (stable), thallium, tungsten, uranium, vanadium, and zinc. A summary of background concentrations of selected constituents in ESRP aquifer water samples is presented in Knobel and others (1992, p. 52). Bartholomay and others (2000, p. 32–34) reported estimated disposal amounts of various trace elements in wastewater through 1998. Beginning in 1998, the NWQL began implementing new reporting procedures based on long-term method detection levels (LT-MDLs) for some analytical methods (Childress and others, 1999). This change in LRLs (as opposed to MRLs) for some trace elements accounts for concentrations of some elements detected during 1999–2018, although historically the concentrations were less than the MRL. A summary of past disposal data, disposal periods, and trace-element concentration ranges in water samples analyzed during 2016–18 by the USGS is shown in table 8.

Volatile Organic Compounds

Volatile organic compounds (VOCs) are present in water from the ESRP aquifer because of waste-disposal practices at the INL. From 1987 to 2018, water samples from many wells completed in the ESRP aquifer at and near the INL were analyzed for VOCs for various water-quality studies (Mann and Knobel, 1987; Mann, 1990; Liszewski and Mann, 1992; Greene and Tucker, 1998; Bartholomay and others, 2000; Davis, 2006a, 2008, 2010; Davis and others, 2013; Maimer and Bartholomay, 2016; Bartholomay, Maimer, and others, 2017). Analyses from these studies indicated that from 1 to 19 VOCs in water samples from several wells exceeded their reporting levels during those years. The primary VOCs detected included carbon tetrachloride; 1,1-dichloroethane; 1,1,1-trichloroethane; trichloroethylene; tetrachloroethylene; chloroform; and toluene.

During 2016–18, water samples from 30 wells were collected and analyzed for VOCs. Sixteen different VOCs were detected (table 9). Water samples collected from 15 wells during 2016–18 each contained at least one and as many as seven of the different VOCs detected. Table 9 shows the VOCs and concentrations detected in the 15 different wells.

Table 8. Trace elements disposed during various periods, number of wells sampled, and range of concentrations detected in water, Idaho National Laboratory, Idaho, 2016–18.

[Because the amounts of each constituent in wastewater discharged from INL facilities have not been compiled annually from monitoring data since 1998, no amounts are available for 1999–2018. **Approximate amount disposed**, **disposal period**, and **disposal facility** from Bartholomay and others, 2000; and French and others, 1999a. **Abbreviations:** NR, none recorded; INL, Idaho National Laboratory; INTEC, Idaho Nuclear Technology and Engineering Center; µg/L, microgram per liter. **Symbol**: <, less than]

Constituent	Approximate amount disposed (pound)	Disposal period	Disposal facility	Number of wells sampled at the INL during 2016–18	Range of Concentrations (µg/L)
Aluminum	117	1995–98	INTEC	14	<3–7.45
Antimony	NR	NR	INL	14	<0.06–0.222
Arsenic	11	1971–98	INL	14	0.810–3.31
Barium	4,740	1971–98	INL	14	11.5–894
Beryllium	<1	1971–98	INL	14	<0.01–<0.19
Boron	26,429	1971–98	INL	5	12.6–53.0
Cadmium	22	1971–98	INL	14	<0.03–<0.21
Cobalt	NR	NR	INL	14	<0.03–1.33
Copper	81	1995–98	INTEC	14	<0.2–0.467
Iron	752	1995–98	INTEC	5	<5–<10
Lead	556	1971–98	INL	14	<0.02–<0.14
Lithium	NR	NR	INL	5	2.4–29.6
Manganese	44	1995–98	INTEC	14	<0.4–3,105
Mercury	141	1971–98	INL	14	<0.005
Molybdenum	NR	NR	INL	14	<0.35–6.55
Nickel	NR	NR	INL	14	<0.2–8.67
Selenium	9	1971–98	INL	9	0.285–2.30
Silver	190	1971–98	INL	14	<0.02–<7
Strontium (stable)	NR	NR	INL	5	121–227
Thallium	NR	NR	INL	14	<0.02–<0.14
Tungsten	NR	NR	INL	3	0.238–1.13
Uranium	NR	NR	INL	14	<0.06–2.88
Vanadium	NR	NR	INL	5	4.50–16.8
Zinc	5,240	1971–98	INL	14	<2–54.8

Table 9. Concentrations of volatile organic compounds in aquifer wells at the Idaho National Laboratory, Idaho, 2016–18.

[Table 9 is a Microsoft Excel® file available for download at https://doi.org/10.3133/sir20195149.]

The primary VOCs detected included carbon tetrachloride, trichloromethane, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. Concentrations for all VOCs except carbon tetrachloride in two wells near the RWMC (RWMC M7S and RWMC PROD) and trichloroethene in one well near TAN (GIN 2) were less than the MCL for drinking water (U.S. Environmental Protection Agency, 2015).[Table 9 is a Microsoft Excel® file available for download at https://doi.org/10.3133/sir20195149.]

Historically, concentrations of VOCs in water samples from several wells at and near the RWMC exceeded the reporting levels (Bartholomay, Maimer, and others, 2017). In December 2018, five VOCs were detected in water from well RWMC PROD. The VOCs and concentrations detected in December 2018 were 5.85 µg/L of carbon tetrachloride (tetrachloromethane), 1.89 µg/L of trichloromethane (chloroform), 0.323 µg/L of 1,1,1-trichloroethane, 0.428 µg/L of tetrachloroethene, and 4.05 µg/L of trichloroethene (table 9). The same five VOCs were also present in wells RWMC M7S and USGS 87 (table 9). A graph of carbon tetrachloride concentrations in water from well RWMC PROD (fig. 22) indicates that concentrations have increased with time from about 1 to 11.6 µg/L from 1987 to 2008. The MCL for carbon tetrachloride in drinking water is 5 µg/L. Although carbon tetrachloride concentrations increased from 1987 to 2008 (Davis and others, 2015), more recent data since 2005 show a statistically significant decreasing trend, indicating that concentrations probably have reached their highest level and should decrease in the future (fig. 22). The more recent decreasing VOC concentrations are attributed to engineering practices at the RWMC that are removing the volatile organic gases from the unsaturated zone.

During 2016–18, water from well USGS 87, just north of the RWMC (fig. 6), had concentrations of carbon tetrachloride less than the MCL, but concentrations were greater than the MCL of 5 µg/L in 2011 and in 2014. Concentrations of carbon tetrachloride in this well have increased with time from less than 1 to 5.62 µg/L in April 2014 (fig. 22). During 2016–18, carbon tetrachloride, trichloromethane, and trichloroethylene were detected in wells USGS 88 and 120 near the RWMC (fig. 6). Trend information for well USGS 88 indicated that these constituents were decreasing over time but were increasing in well USGS 120 (Davis and others, 2015, appendix E). Concentrations of VOCs showed marked increases in the late 1990s in USGS 120 when much water was released to the INL spreading areas (fig. 8). Carbon tetrachloride data for 2017 and 2018 show similar increases in concentration (fig. 22), and it is thought that, when water from the spreading areas infiltrates to the aquifer, it moves organics in the unsaturated zone to the aquifer, thereby increasing concentrations.

With changes to the USGS sampling program, sampling began in well GIN 2 near TAN in 2012, in well TAN 2271 in 2015 (Twining and others, 2016), and in well TAN 2312 in 2017 (Twining and others, 2018). Trichloroethene is present at concentrations greater than drinking water standards in several wells in the TAN area, and remediation by the INL cleanup project site contractor is occurring to try to reduce concentration levels (Twining and others, 2016). Trichloroethene concentrations exceeded the MCL in all three samples collected from well GIN 2 during 2016–18, but concentrations in samples collected from well TAN 2271 for the same time period were less than the MCL even though the first sample collected from the well in August 2015 exceeded the MCL (Twining and others, 2016). Lower trichloroethene concentrations measured in samples collected from well TAN 2271 since August 2015 (table 9) may be attributable to sampling at a different well depth and (or) with a smaller-volume pump during subsequent sampling events.

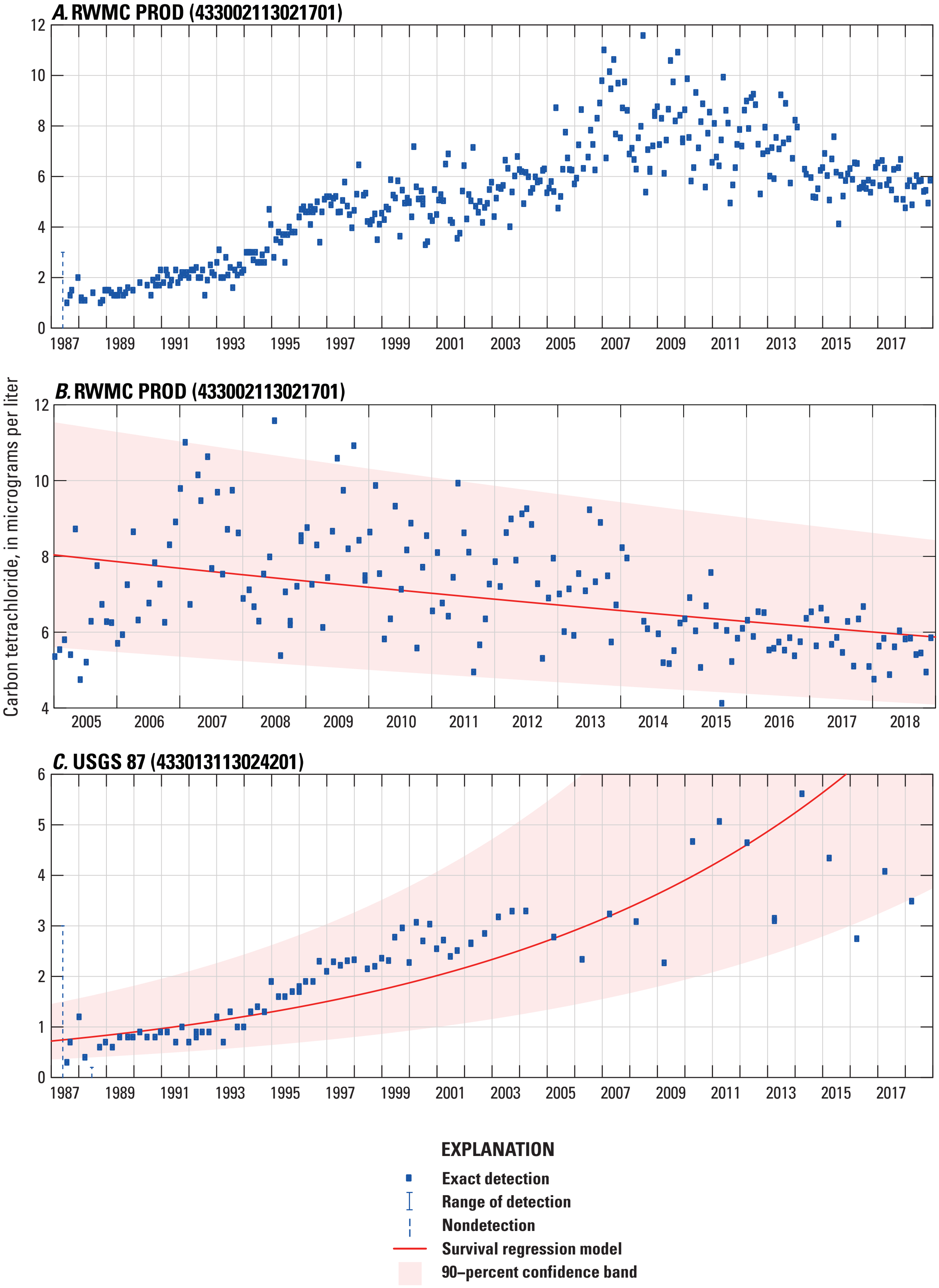


Figure 22. Carbon tetrachloride concentrations in water from the Radioactive Waste Management Complex Production Well (RWMC PROD) and wells USGS 87 and 120, Idaho National Laboratory, Idaho, 1987–2018.

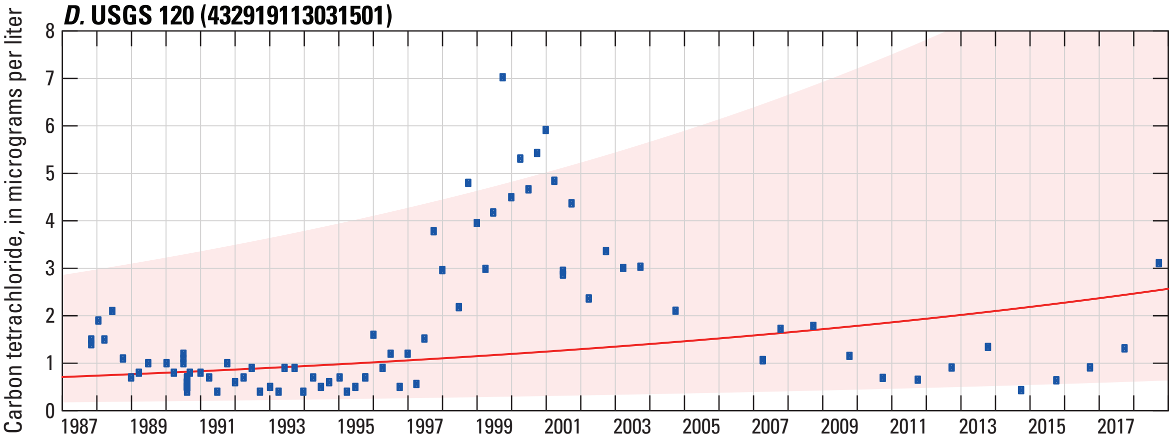


Figure 22.—Continued

Selected Radiochemical and Chemical Constituents in Perched Groundwater at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex

Disposal of wastewater to infiltration ponds and ditches, lined evaporation ponds, and drain fields; and infiltration of surface water at waste-burial pits resulted in formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer (Cecil and others, 1991) beneath the ATR Complex, the INTEC, and the RWMC. Wastewater-disposal sites at these INL facilities are the primary sources of radiochemical and chemical constituents in perched groundwater at the INL. During 2016–18, wastewater was discharged to infiltration and lined-evaporation ponds. Bartholomay and others (2000) provides a comprehensive summary of waste disposal at the INL through 1998, and little disposal information is available since 1998.

Advanced Test Reactor Complex

Bodies of shallow and deep perched groundwater formed at the ATR Complex in response to wastewater disposal into radioactive-, chemical-, cold-, and sanitary-waste ponds (Tucker and Orr, 1998) (fig. 6). Radiochemical and chemical constituents in wastewater migrate to the ESRP aquifer through perched groundwater beneath these wastewater infiltration ponds. The extent of perched groundwater is affected by the waste-disposal practices. Selected radiochemical and inorganic chemical constituents in wastewater have been monitored in the shallow and deep perched groundwater since the early 1960s.

Water samples from three wells (CWP 1, 3, and 8) completed in shallow perched groundwater near the ATR Complex (fig. 7) routinely were collected and analyzed for selected radiochemical and chemical constituents during 2016–18. Water samples were collected from 18 wells (PW 8, PW 9, USGS 53–56, 60–63, 66, 68–73, and 78) that were completed in deep perched groundwater beneath the ATR Complex. Sampling was discontinued at some perched groundwater wells during the 2002–05 reporting period because of lack of water in the wells (Davis, 2008, fig. 21).

Selection of radiochemical and chemical constituents for analyses was based on the waste-disposal history at the ATR Complex. Selected radiochemical constituents were tritium, strontium-90, and gamma analyses (which may yield detections of cesium-137, cobalt-60, or chromium-51); chemical constituents were dissolved chromium, sodium, chloride, and sulfate.

Tritium

Wells CWP 1, 3, and 8 (fig. 4) are used to monitor shallow perched groundwater around the cold-waste ponds at the ATR Complex. During 2016–18, tritium concentrations in water samples collected from wells CWP 1, 3, and 8 were less than the reporting level (table 10).

Concentrations of tritium in deep perched groundwater near the ATR Complex during April or October 2018 are shown in figure 23. Concentrations of tritium in wells near the ATR Complex in 2018 were less than historical measurements. Tritium concentrations continued to decrease during the 2016–18 reporting period in all wells and show long-term decreasing trends in most wells around the ATR Complex (Davis and others, 2015, fig. 13). The decrease in tritium concentrations in water from wells near the ATR Complex likely is a result of changes in wastewater disposal practices dating back to the early 1990s when evaporation ponds began

Table 10. Concentrations of tritium, strontium-90, and cesium-137 in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2016–18.

[Analyses were completed by the Department of Energy Radiological and Environmental Sciences Laboratory. Analytical uncertainties are reported as 1 times the sample standard deviation. Concentrations equal to or greater than three times the sample standard deviation are considered to be greater than the reporting level and are shown in **bold. Well No.:** Locations of wells are shown in figure 7. DP, well completed in deep perched groundwater; SP, well completed in shallow perched groundwater. **Abbreviations:** NR, analysis not requested; NS, not enough water for sample; USGS, U.S. Geological Survey; pCi/L, picocurie per liter. **Symbol:** ±, plus or minus]

Well No.	Date sampled	Tritium (pCi/L)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)
CWP 1 (SP)	04-13-16	40±50	0.149±0.65	NR
	04-20-17	70±50	-0.1±0.7	NR
	04-04-18	30±50	1±0.6	NR
CWP 3 (SP)	04-13-16	10.2±44.8	**2.1±0.7**	NR
	04-20-17	-70±50	1±0.7	NR
	04-04-18	14.7±48.1	0.4±0.6	NR
CWP 8 (SP)	04-13-16	-20±40	1.5±0.8	NR
	04-20-17	-60±50	1.2±0.7	NR
	04-04-18	-60±50	1±0.6	NR
PW 8 (DP)	04-19-16	40±50	**5.3±0.7**	25±9
	04-05-17	50±50	**4.6±0.7**	20±30
	04-02-18	-16.8±47.4	**3.2±0.7**	10±7
PW 9 (DP)	10-19-16	**3,820±100**	1.1±0.7	20±8
	10-17-17	**2,950±90**	0.3±0.6	17±10
	10-17-18	**2,030±100**	0.1±0.6	10±8
USGS 53 (DP)	04-04-16	NS	NS	NS
	04-17-17	NS	NS	NS
	04-17-18	NS	NS	NS
USGS 54 (DP)	10-25-16	**160±50**	**28±1.1**	8±8
	10-24-17	100±40	**22.1±1**	0±120
	10-17-18	30±50	**24.7±1**	12±8
USGS 55 (DP)	04-05-16	NS	NS	NS
	04-05-17	**2,000±80**	**34.3±1.2**	30±20
	04-04-18	**12,900±200**	**23.9±1**	10±9
USGS 56 (DP)	10-26-16	**690±60**	**34.1±1.2**	29±10
	10-12-17	**700±60**	**29.9±1.1**	32±11
	10-17-18	**960±70**	NS	NS
USGS 60 (DP)	10-19-16	40±40	**0.57±0.17**	-0.06±1.41
	10-10-17	40±40	0.6±0.6	6±9
	10-17-18	-50±40	0.4±0.6	4±7
USGS 61 (DP)	04-14-16	**1,210±70**	2.0±0.7	17±7
	04-05-17	**740±60**	-0.1±0.7	-20±20
	04-05-18	**610±60**	-0.1±0.6	26±10
USGS 62 (DP)	04-14-16	40±50	**2.8±0.7**	36±14
	04-05-17	-50±50	1.9±0.7	6±9
	04-05-18	40±50	0.9±0.7	15±10

Table 10. Concentrations of tritium, strontium-90, and cesium-137 in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2016–18.—Continued

Well No.	Date sampled	Tritium (pCi/L)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)
USGS 63 (DP)	10-18-16	80±40	-0.6±0.6	20±10
	10-24-17	90±40	0.6±0.7	22±14
	10-17-18	50±50	1.4±0.6	16±14
USGS 66 (DP)	10-19-16	**160±50**	-0.2±0.7	16±8
	10-17-17	**230 ±50**	0.6±0.6	6±6
	10-10-18	50±50	0.7±0.6	35±74
USGS 68 (DP)	04-19-16	**270 ±50**	**6.3 ±0.8**	22±9
	04-04-17	30±50	1.9±0.8	9±8
	04-11-18	**150±50**	**7.2±0.7**	7±6
USGS 69 (DP)	10-25-16	110±40	0.5±0.7	7±7
	10-24-17	50±40	0.6±0.6	6±5
	10-15-18	-10±40	0±0.6	13±6
USGS 70 (DP)	04-14-16	**1,780±80**	**24.9±1**	1±4
	04-06-17	**460±60**	**18.8±1.1**	-20±20
	04-05-18	**910±60**	**17.5±0.9**	10±7
USGS 71 (DP)	10-26-16	**510±50**	0.7±0.7	39±14
	10-12-17	**340±50**	0.9±0.6	16±12
	10-17-18	**330±50**	0.2±0.7	10±6
USGS 72 (DP)	04-11-16	-10±40	0.1±0.7	16±8
	04-04-17	-80±50	1.2±0.7	50±20
	04-12-18	-20±50	0.3±0.6	6±5
USGS 73 (DP)	10-19-16	**1,070±60**	0±0.7	-10±14
	10-17-17	**950±60**	1.8±0.7	4±6
	10-10-18	**600±60**	1±0.6	8±6
USGS 78 (DP)	10-19-16	10±50	0.119±0.648	8±9
	10-12-17	70±40	1.0±0.6	9±10
	10-22-18	-10±50	0.2±0.6	5±5

to be used in place of infiltration ponds. In some cases, the change in disposal practices also may have led to a decrease in the amount of perched groundwater available to sample.

Tritium concentrations in water from 10 wells completed in deep perched groundwater (PW 9; and USGS 54, 55, 56, 61, 66, 68, 70, 71, and 73) near the ATR Complex generally were greater than or equal to the reporting level during at least one sampling event during 2016–18 (table 10). Tritium concentrations in water from the other wells (PW-8; and USGS 60, 62, 63, 69, 72, and 78) were less than the reporting level during 2016–18 (table 10). USGS 53 was dry during all the sample periods during 2016–18.

Tritium concentrations equal to or greater than the reporting level ranged from 150±50 pCi/L in water from well USGS 68 in 2018 to 12,900±200 pCi/L in water from well USGS 55 in 2018 (table 10). Water samples collected in October 2018 from well USGS 73 had a tritium concentration of 600±60 pCi/L, substantially less than the October 2015 concentration of 1,510±70 pCi/L. Well PW 9 had a concentration of 2,030±100 pCi/L in 2018, also substantially less than the October 2015 concentration of 3,320±100 pCi/L. Concentrations of tritium in these two wells have decreased significantly since October 1993 when concentrations were 296,000±10,000 pCi/L in water from well USGS 73 and 193,000±6,000 pCi/L in water from well PW 9. Historically, high tritium concentrations in water from wells USGS 73 and PW 9 indicate that the chemistry of perched groundwater west of the ATR Complex was affected by radioactive-waste infiltration pond disposal. Discontinuation of wastewater discharge to the radioactive-waste infiltration ponds and the subsequent use of lined evaporation ponds, together with the radioactive decay process, most likely is the cause for the decreased tritium concentrations in this area from 1993 to 2018.

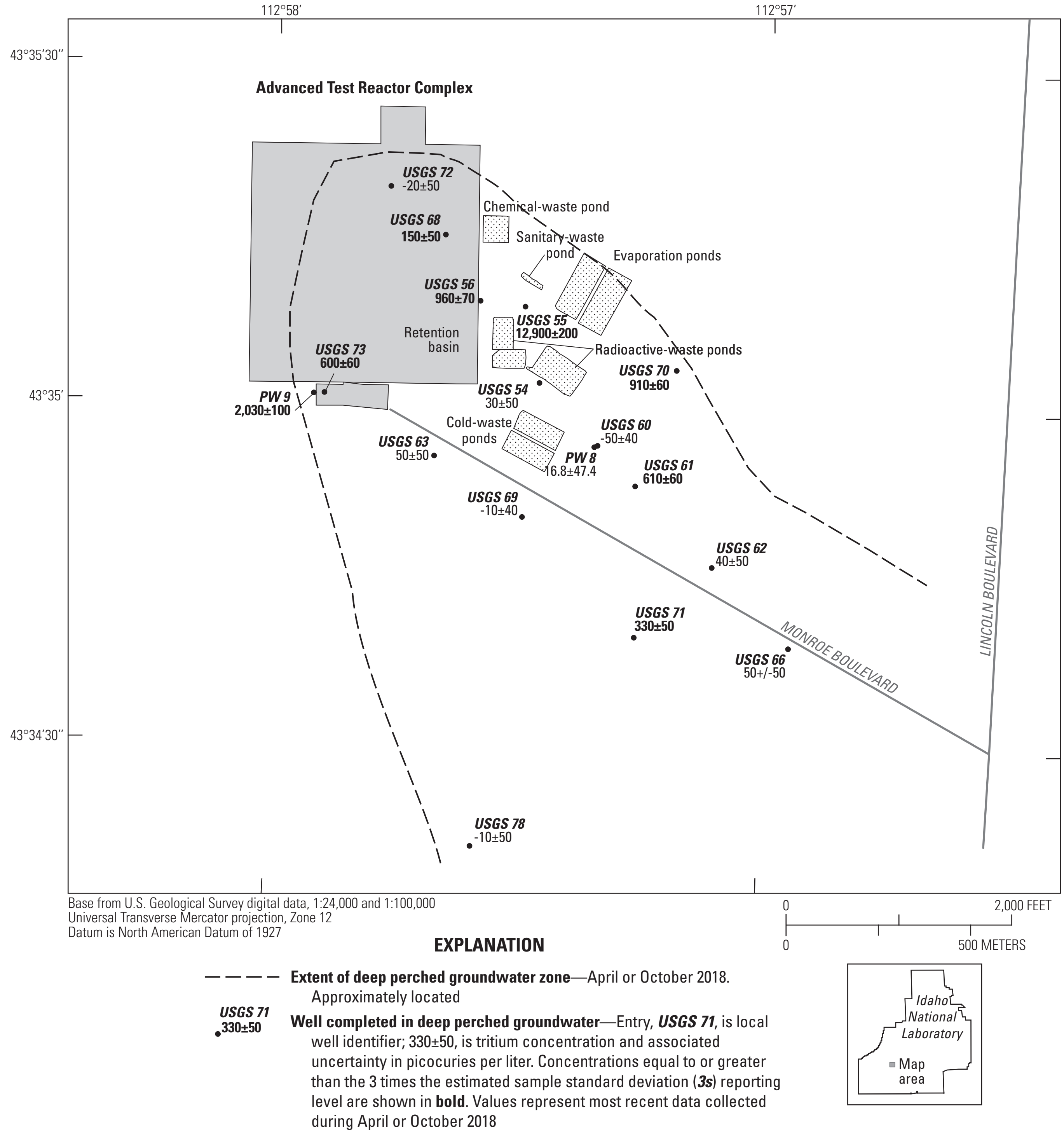


Figure 23. Concentrations of tritium in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2018.

Tritium concentrations have fluctuated substantially in USGS 55 (located between the evaporation ponds and the radioactive-waste ponds [fig. 7]) during recent sampling periods, with a large concentration of 12,900±200 pCi/L in 2018, and a small concentration of 2,000±80 pCi/L in 2017. Similar large and small values were noted in Davis (2008, table 10; 2010, table 7), Davis and others (2013, table 9), and Bartholomay, Maimer, and others (2017, table 9). These variable changes may indicate that remnant radioactive-waste pond wastewater is still present between the land surface and the perched groundwater zone, or there is possible leakage coming from the evaporation ponds or piping to the ponds.

Bartholomay, Maimer, and others (2017, fig. 24) evaluated possible leakage, by plotting tritium concentrations with water levels in this well. The higher concentrations mostly occurred right after a period when water levels were low, so it was concluded that when water levels rise, tritium becomes more diluted with fresh water that reduces the concentration level.

Several factors affected the distribution of tritium in perched groundwater at the ATR Complex, including proximity of wells to the old radioactive-waste infiltration ponds, depth of water below the ponds, variations in tritium disposal rate, and radioactive decay. Since 1982, tritium concentrations also have been affected by dilution from the cold-waste ponds. Replacement of the radioactive-waste infiltration ponds with the lined evaporation ponds in 1993 contributed to decreases in tritium concentrations in perched groundwater and declines in perched groundwater in some wells. Infiltration from the Big Lost River when it has had flow may have contributed to diluted tritium concentrations in perched groundwater southeast of the ATR Complex, although a direct connection has never been documented. Given that water levels in all the wells except well USGS 78 decreased in the past 2 years when there was significant flow in the Big Lost River (table 4), there probably is no connection between the perched groundwater around the ATR Complex and the Big Lost River. The chemistry in well USGS 78 indicates that it probably is influenced completely by flow in the Big Lost River.

Strontium-90

Wells CWP 1, 3, and 8 (fig. 4) completed in shallow perched groundwater at the ATR Complex were sampled for strontium-90 during 2016–18 and concentrations were less than the reporting level from all but one of the collected samples (table 10). The April 2016 sample from CWP-3 was at the reporting level with a concentration of 2.1±0.7 pCi/L.

Concentrations of strontium-90 were greater than or equal to reporting levels during at least one sampling event during 2016–18 in water from wells PW 8, USGS 54–56, 60, 62, 68, and 70 completed in deep perched groundwater at the ATR Complex (table 10). Concentrations equal to or greater than the reporting level ranged from 0.57±0.17 pCi/L in well USGS 60 to 34.3±1.2 pCi/L in well USGS 55. The distribution of strontium-90 concentrations in perched groundwater from these wells during 2016–18 is attributed to exchange reactions between strontium-90 in solution and to sediments beneath the radioactive-waste infiltration ponds. Well USGS 56 showed variable concentrations through time and well USGS 55 showed an increasing trend until about 2006 when concentrations started to decrease (Davis and others, 2015, appendix C). Both these wells are near the chemical-waste ponds that were taken out of service in 1999, and high sodium concentrations in remnant water from the old chemical-waste ponds still may be periodically exchanging with sediments in the unsaturated zone and mobilizing strontium-90.

Although strontium-90 has been detected in water from shallow and deep perched groundwater at the ATR Complex, it has not been detected in the ESRP aquifer beneath the ATR Complex. This may be because of the exclusive use of waste-disposal ponds and lined evaporation ponds rather than injection of waste directly to the aquifer (Bartholomay and others, 1997, p. 30). The absence of detectable concentrations in the aquifer indicates that strontium-90 in solution is removed possibly by sorption and (or) exchange reactions in the unsaturated zone. Studies of strontium distribution coefficients for samples of surficial sediment, sedimentary interbeds, and sediment-filled fractures in basalts at the INL (Liszewski and others, 1997, 1998; Pace and others, 1999) support this theory.

Gamma Spectrometry

Water samples collected are routinely analyzed by gamma spectrometry, and the results may yield concentrations of cesium-137, chromium-51, and cobalt-60. Water samples from wells completed in both shallow and deep perched groundwater at and near the ATR Complex have not yielded concentrations of cesium-137 greater than the reporting level during 1997–2011 (Davis and others, 2013). However, in April 2012, cesium-137 concentrations in wells USGS 68 and 70 were equal to the reporting level (Bartholomay, Maimer, and others, 2017, table 8). Concentrations in all samples collected during 2016–18 were less than the reporting level (table 10). Water from wells at and near the ATR Complex has not had concentrations greater than the reporting level of chromium-51 since 1995 or cobalt-60 since 1998 (Davis, 2010).

Chromium

In October 1972, chromium used as a corrosion inhibitor in cooling-tower operations was replaced by a polyphosphate. No disposal of chromium to the subsurface at the ATR Complex was reported after 1972 (Bartholomay and Tucker, 2000). The presence of dissolved chromium in water from wells completed in perched groundwater represents chromium in cooling-tower blowdown water that was discharged to the radioactive-waste infiltration ponds before 1965 when disposal practices changed to injection of water to the disposal well; concentrations in the perched groundwater zone are expected to continue to decrease in the future.

Historically, dissolved chromium concentrations in shallow perched groundwater at the ATR Complex have been very low (less than or slightly greater than the LRL) because of lack of disposal of chromium to the cold-waste ponds. Over the past decade, several wells completed in shallow perched groundwater were not sampled because they were dry and were removed from the USGS sampling program. During 2016–18, three shallow perched groundwater wells (CWP 1, 3, and 8) were sampled for chromium. Chromium was detected in well CWP 1 in April of each year, and concentrations ranged from 3.10 to 4.30 µg/L (table 11). All other concentrations were less than the reporting levels of 0.6, 1.2, and 2.4 µg/L during 2016–18.

Dissolved chromium was detected in water from all the wells sampled for chromium and completed in deep perched groundwater at the ATR Complex during 2016–18 (table 11). The highest concentrations during 2018 were in water from wells north and west of the radioactive-waste infiltration ponds (PW 9, and USGS 55 and 56) (table 11; fig. 24). During April or October 2018, detectable concentrations of dissolved chromium in wells completed in deep perched groundwater near the ATR Complex ranged from 4.20 µg/L in well USGS 61 to 56.4 µg/L in well USGS 55; well USGS 56 had a concentration of 98.8 in 2017 but did not have enough water for a sample in 2018. The maximum concentration of chromium of 98.8 µg/L in well USGS 56 in October 2017 increased from 28.7 µg/L in October 2015 (Bartholomay, Maimer, and others, 2017, table 10). The long-term trend for this constituent has been variable but is decreasing overall in this well (fig. 25), and most other perched wells around the ATR Complex also show decreasing trends (Davis and others, 2015, appendix D).

Sodium

Dissolved sodium was not sampled for in shallow perched groundwater at the ATR Complex (table 11). During April or October 2018, dissolved sodium concentrations in water from 18 wells completed in deep perched groundwater were determined and ranged from 6.37 to 143 mg/L (table 11). The highest concentration was in water from well USGS 68 (table 11); the sodium concentration in well USGS 68 increased from 33.4 mg/L in April 2015 (Bartholomay, Maimer, and others, 2017, table 10). Sodium concentrations in this well have varied through time, but overall show a decreasing trend (fig. 25; Davis and others, 2015, fig. 23). Concentration variability in well USGS 68 probably is a result of water movement through the unsaturated zone from the chemical-waste pond. Pond closure in 1999 likely is responsible for overall lower concentrations, although concentrations in the past 3 years have increased from the low in 2015 (fig. 25).

Chloride

Concentrations of dissolved chloride in most wells varied during 2016–18 (table 11). During April 2018, dissolved chloride concentrations in shallow perched groundwater ranged from 8.69 mg/L in well CWP 8 to 19.7 mg/L in well CWP 1 (table 11). Dissolved chloride concentrations in deep perched groundwater during April or October 2018 ranged from 3.89 mg/L in well USGS 78 to 176 mg/L in well USGS 73. High concentrations of chloride were in water from deeper perched groundwater wells in the western part of the perched groundwater zone at the ATR Complex, and both USGS 73 (fig. 25) and PW 9 have shown increasing trends with time (Davis and others, 2015, fig. 19). The increasing concentrations may be a result of movement of remnant water through the unsaturated zone from the chemical-waste pond, or variable high pulses of chloride that have moved from the cold-waste ponds.

Sulfate

The maximum dissolved sulfate concentration in shallow perched groundwater at the ATR Complex was 215 mg/L in well CWP 3 in April 2016 (table 11). Concentrations of dissolved sulfate in this well varied greatly and ranged from 69.8 to 215 mg/L during 2016–2018. During 2012–15, the concentrations ranged from 44.4 to 175 mg/L (Bartholomay, Maimer, and others, 2017, table 10). The variable concentrations are the result of changes in the amount of sulfate disposal to the cold-waste ponds.

Concentrations of dissolved sulfate in water from wells completed in deep perched groundwater at the ATR Complex near the cold-waste ponds (USGS 54, 55, 56, 60, 61, 62, 63, 66, 69, 70, and 71; and PW 8) ranged from 65.8 mg/L in well USGS 56 to 171 mg/L in well USGS 54 during 2017–18 (table 11, fig. 26). These high concentrations indicate that water in these wells also was affected by discharge into the cold-waste ponds. During 2009–11, the largest concentration of dissolved sulfate measured in deep perched groundwater was 1,546 mg/L in well USGS 68 (Davis and others, 2013, table 10), located west of the chemical-waste pond (fig. 7). The dissolved sulfate concentration in this well decreased to 89.8 mg/L by April 2015 but increased to 586 mg/L in 2018 (table 11), Overall, this well shows a decreasing trend that can be attributed to discontinued use of the chemical-waste pond in 1999 (fig. 25). The more recent concentration variability may indicate that remnant pockets of perched water still are moving to the deeper perched water zone.

Idaho Nuclear Technology and Engineering Center

Two percolation ponds were constructed south of the INTEC in 1984 and 1985 to replace the INTEC disposal well (fig. 7). Wastewater infiltrating from these ponds formed perched groundwater in the basalt and sedimentary interbeds above the ESRP aquifer in the southern part of the INTEC. The old percolation ponds were taken out of service when new percolation ponds, located about 2 mi southwest of the INTEC (fig. 4), began to be used in August 2002 (U.S. Department of Energy, 2011a). The USGS continued to monitor water from wells in the perched groundwater zone near the old percolation ponds until the last well (PW 4, fig. 7) went dry in 2008. Deeper perched groundwater near the center of the INTEC was monitored from samples collected from well USGS 50 (fig. 7) until the well was abandoned in 2009. Davis (2010)

Table 11. Concentrations of selected dissolved ions in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2016–18.

[Analyses were completed by the U.S. Geological Survey National Water Quality Laboratory. **Well No.:** Locations of wells are shown in figure 7. DP, well completed in deep perched water; SP, well completed in shallow perched water. **Abbreviations:** NR, analysis not requested; NS, not enough water for a sample; USGS, U.S. Geological Survey; µg/L, microgram per liter; mg/L, milligram per liter. **Symbol:** <, less than respective reporting level]

Well No.	Date sampled	Chromium, dissolved (µg/L)	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate dissolved (mg/L)
CWP 1 (SP)	04-13-16	3.10	NR	23.2	211
	04-20-17	4.30	NR	12.5	44.4
	04-04-18	3.10	NR	19.7	191
CWP 3 (SP)	04-13-16	<0.6	NR	23.0	215
	04-20-17	<0.6	NR	14.5	80.6
	04-04-18	<2.4	NR	14.6	69.8
CWP 8 (SP)	04-13-16	<0.6	NR	8.83	30.5
	04-20-17	<0.6	NR	10.6	40.0
	04-04-18	<1.2	NR	8.69	22.0
PW 8 (DP)	04-19-16	6.40	16.6	22.7	211
	04-05-17	6.40	16.0	20.7	178
	04-02-18	6.60	14.7	18.0	133
PW 9 (DP)	10-19-16	<0.6	20.9	60.8	62.5
	10-17-17	19.5	21.4	58.9	59.2
	10-17-18	26.8	21.3	66.8	55.6
USGS 53 (DP)	04-04-16	NS	NS	NS	NS
	04-17-17	NS	NS	NS	NS
	04-17-18	NS	NS	NS	NS
USGS 54 (DP)	10-25-16	8.40	15.0	19.7	159
	10-24-17	8.20	13.3	14.3	71.1
	10-17-18	7.40	14.6	20.0	171
USGS 55 (DP)	04-05-16	NS	NS	NS	NS
	04-05-17	16.8	15.5	16.0	90.7
	04-04-18	56.4	16.2	15.2	80.1
USGS 56 (DP)	10-26-16	51.7	18.7	16.1	35.8
	10-12-17	98.8	36.5	11.8	65.8
	10-17-18	NS	NS	NS	NS
USGS 60 (DP)	10-19-16	5.70	13.5	16.0	92.7
	10-10-17	5.10	11.8	12.8	50.5
	10-17-18	4.50	14.2	17.9	137
USGS 61 (DP)	04-14-16	<0.6	13.1	16.8	109
	04-05-17	5.70	13.1	17.6	116
	04-05-18	4.20	13.2	16.7	104
USGS 62 (DP)	04-14-16	9.70	16.6	19.8	166
	04-05-17	8.60	16.6	22.7	201
	04-05-18	7.10	15.9	18.4	129
USGS 63 (DP)	10-18-16	11.0	13.3	15.8	86.1
	10-24-17	11.8	13.8	16.7	58.7
	10-17-18	18.6	14.8	20.3	142

Table 11. Concentrations of selected dissolved ions in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2016–18.—Continued

Well No.	Date sampled	Chromium, Dissolve (µg/L)	Sodium, Dissolve (mg/L)	Chloride, Dissolve (mg/L)	Sulfate Dissolve (mg/L)
USGS 66 (DP)	10-19-16	11.2	14.4	17.5	129
	10-17-17	10.5	15.4	18.3	141
	10-10-18	7.20	14.6	18.1	127
USGS 68 (DP)	04-19-16	NR	106	23.8	476
	04-04-17	NR	129	52.1	691
	04-11-18	NR	143	66.0	586
USGS 69 (DP)	10-25-16	1.1	11.1	16.2	83.0
	10-24-17	NR	11.3	19.0	63.1
	10-15-18	NR	11.8	19.1	73.9
USGS 70 (DP)	04-14-16	20.6	15.5	16.9	125
	04-06-17	10.8	14.8	16.5	110
	04-05-18	14.4	14.6	16.0	99.4
USGS 71 (DP)	10-26-16	15.3	13.9	18.8	163
	10-12-17	18.2	13.4	19.0	151
	10-17-18	15.5	13.8	18.5	150
USGS 72 (DP)	04-11-16	NR	16.5	18.0	23.8
	04-04-17	NR	21.9	29.9	24.8
	04-12-18	NR	20.4	26.0	23.8
USGS 73 (DP)	10-19-16	18.0	18.2	91.4	51.4
	10-17-17	39.3	21.6	79.8	43.2
	10-10-18	9.6	20.5	176.0	43.5
USGS 78 (DP)	10-19-16	NR	6.67	3.95	18.7
	10-12-17	NR	6.09	2.78	14.2
	10-22-18	NR	6.37	3.89	18.7

provided the final analyses of data collected from the USGS perched groundwater monitoring around the INTEC. Perched groundwater has been detected in other areas at the INTEC as well and may be attributed to leaking wastewater pipelines, leach fields, damaged casing in the upper part of the disposal well, leakage from the Tank Farm pits, other infiltration ponds, flow from the Big Lost River, precipitation recharge, or landscape irrigation (Tucker and Orr, 1998; Mirus and others, 2011). Information on water-quality monitoring of perched groundwater wells in other areas of the INTEC done by INL contractors is documented in annual groundwater-monitoring reports, with 2017 data presented in U.S. Department of Energy (2018).

Starting in April 2010, the USGS began to monitor perched groundwater in well ICPP-MON-V-200 (fig. 4), about 2 mi southwest of the INTEC, for a general indication of water chemistry from the new percolation ponds installed in 2002 to better understand what effects the ponds may have on water quality in the ESRP aquifer. Comparison of water chemistry from wells ICPP-MON-V-200 and CPP 1 (a production well at the INTEC used to represent water quality before wastewater constituents were added; [Knobel and others, 1999]) indicated that wastewater discharged to the new percolation ponds had increased concentrations of dissolved chloride, sodium, and nitrate (Davis and others, 2013). During 2016–18, concentrations of dissolved chloride, sodium, and nitrate ranged from 19.5 to 23.0 mg/L; 15.4 to 16.1 mg/L; and 0.956 to 1.08 mg/L, respectively. The concentration ranges were lower than for previous years of sample collection; nitrate concentrations were similar to those in well CPP 1 during the same time period, and the sodium and chloride concentrations were still elevated compared to water from CPP 1.

Radioactive Waste Management Complex

Perched groundwater beneath the RWMC is in sedimentary interbeds in basalts and can be attributed primarily to local snowmelt and rain infiltration, and to recharge from the Big Lost River and the INL spreading areas.

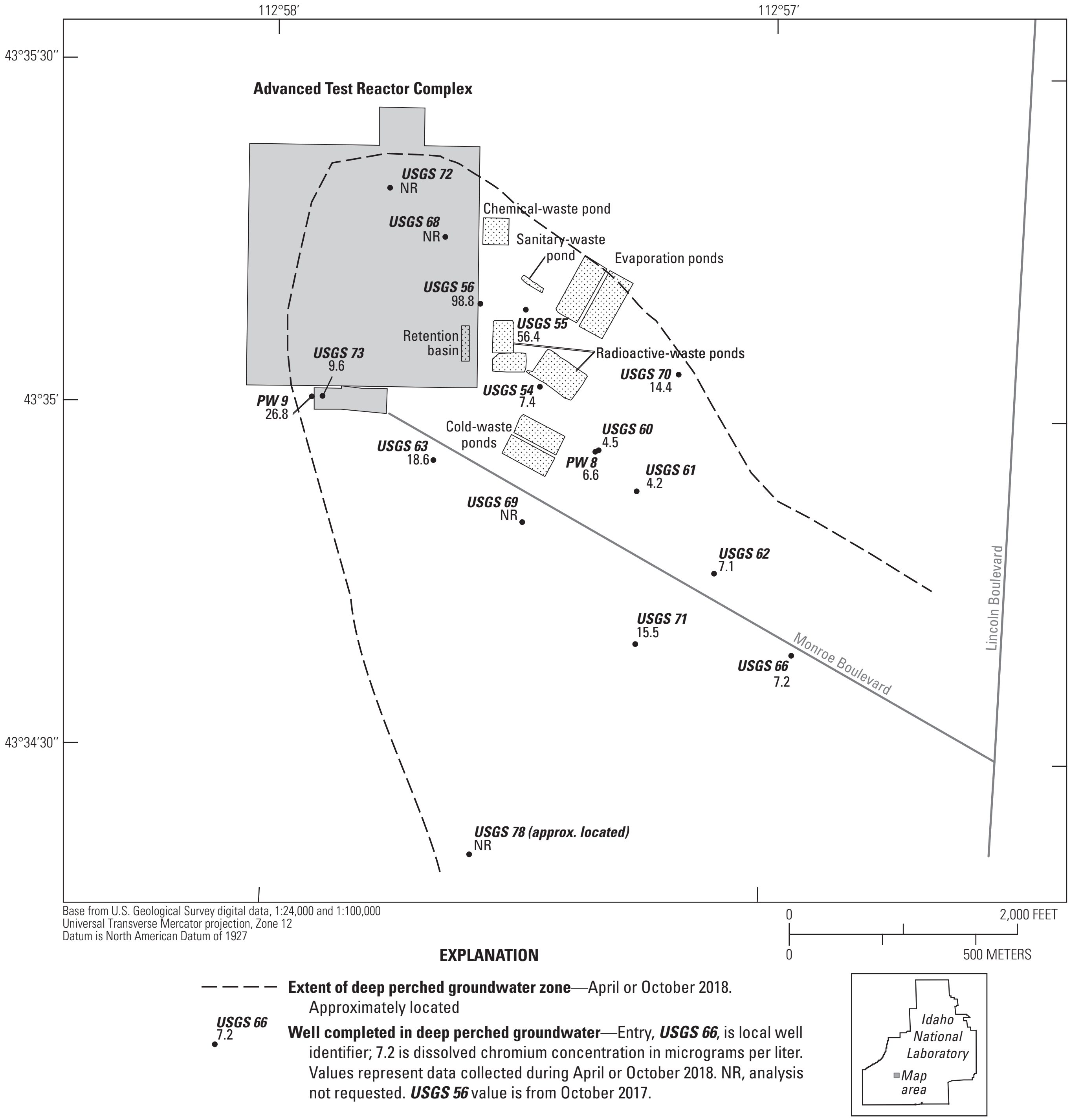


Figure 24. Concentrations of dissolved chromium in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2018.

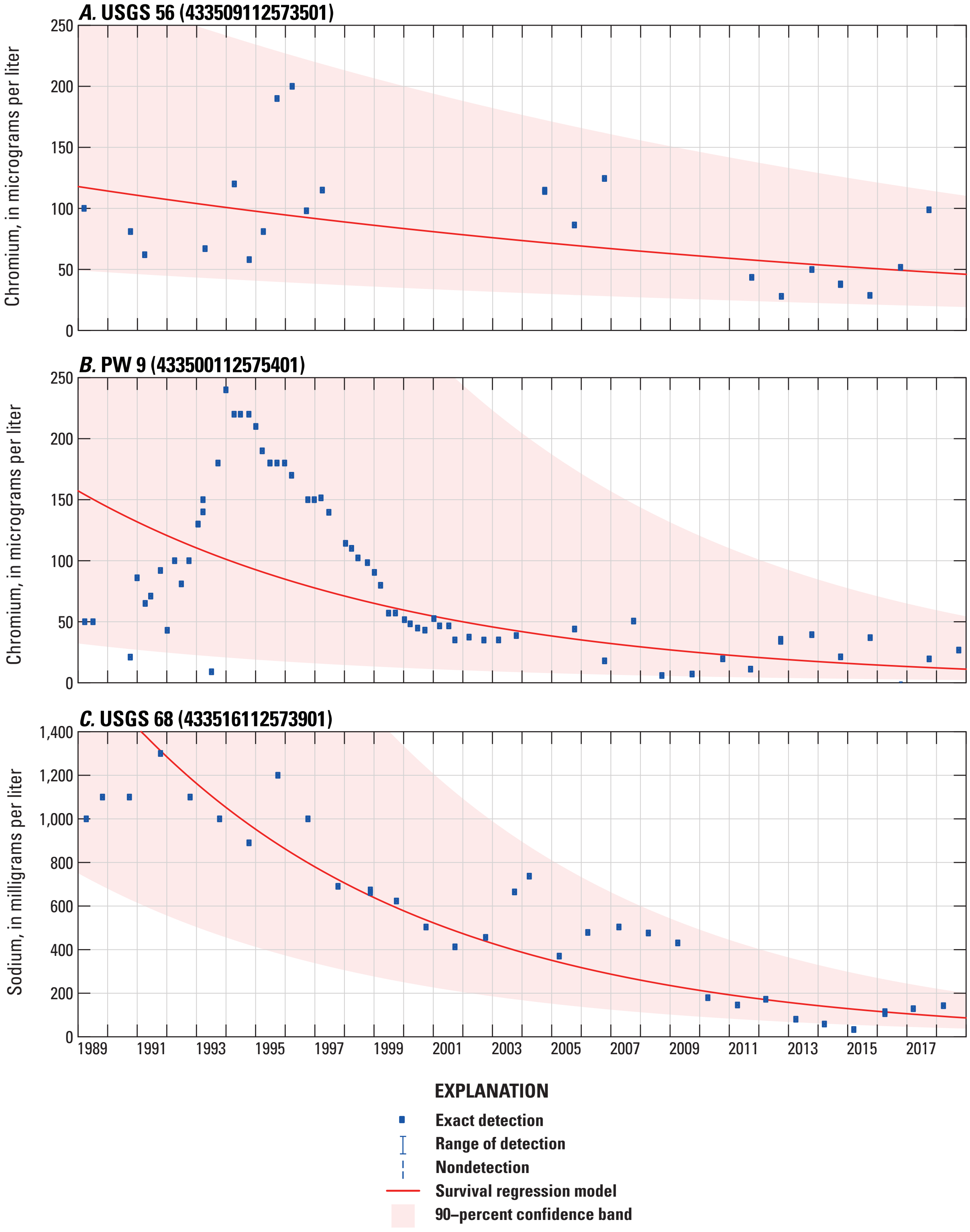
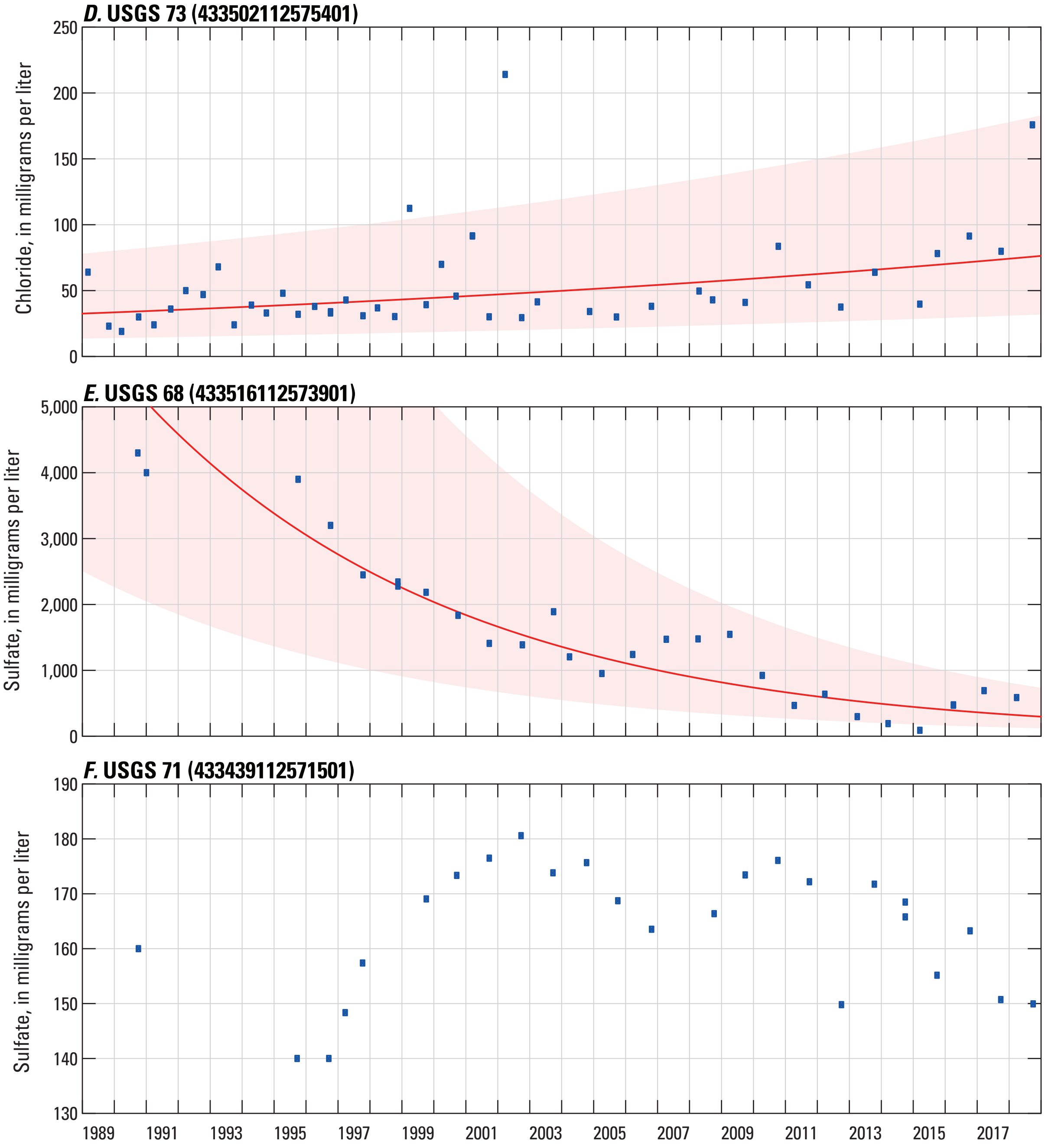


Figure 25. Chromium concentrations in water from wells USGS 56 (*A*) and PW 9 (*B*), sodium concentrations in water from well USGS 68 (*C*), chloride concentrations in water from well USGS 73 (*D*), and sulfate concentrations in water from wells USGS 68 (*E*) and 71 (*F*), Idaho National Laboratory, Idaho, 1989–2018.



***D.* USGS 73 (433502112575401)**

***E.* USGS 68 (433516112573901)**

***F.* USGS 71 (433439112571501)**

Figure 25.—Continued

This perched groundwater contains constituents leached from buried radioactive and organic-chemical wastes. Liquid and solid waste materials buried at the RWMC (fig. 1) also are sources of some constituents in perched groundwater. Perched groundwater beneath buried waste can be an integral part of the pathway for waste-constituent migration to the ESRP aquifer. The extent of this perched groundwater is affected by the waste-disposal practices.

Well USGS 92 (fig. 4) is in the SDA at the RWMC and is completed in a sedimentary interbed (Anderson and Lewis, 1989, p. 29) at 214 ft below land surface. Perched groundwater in this well has moved through overlying sediments and basalt and contains waste constituents leached from radiochemical and organic-chemical wastes buried in the SDA.

During 2016–18, tritium concentrations in water samples from well USGS 92 (table 12) exceeded the reporting level in one sample and ranged from less than the reporting level in April 2017 and 2018 to 200 ±50 pCi/L in April 2016. Tritium concentrations in water from well USGS 92 have varied through time and show no trend (Davis and others, 2015, appendix C).

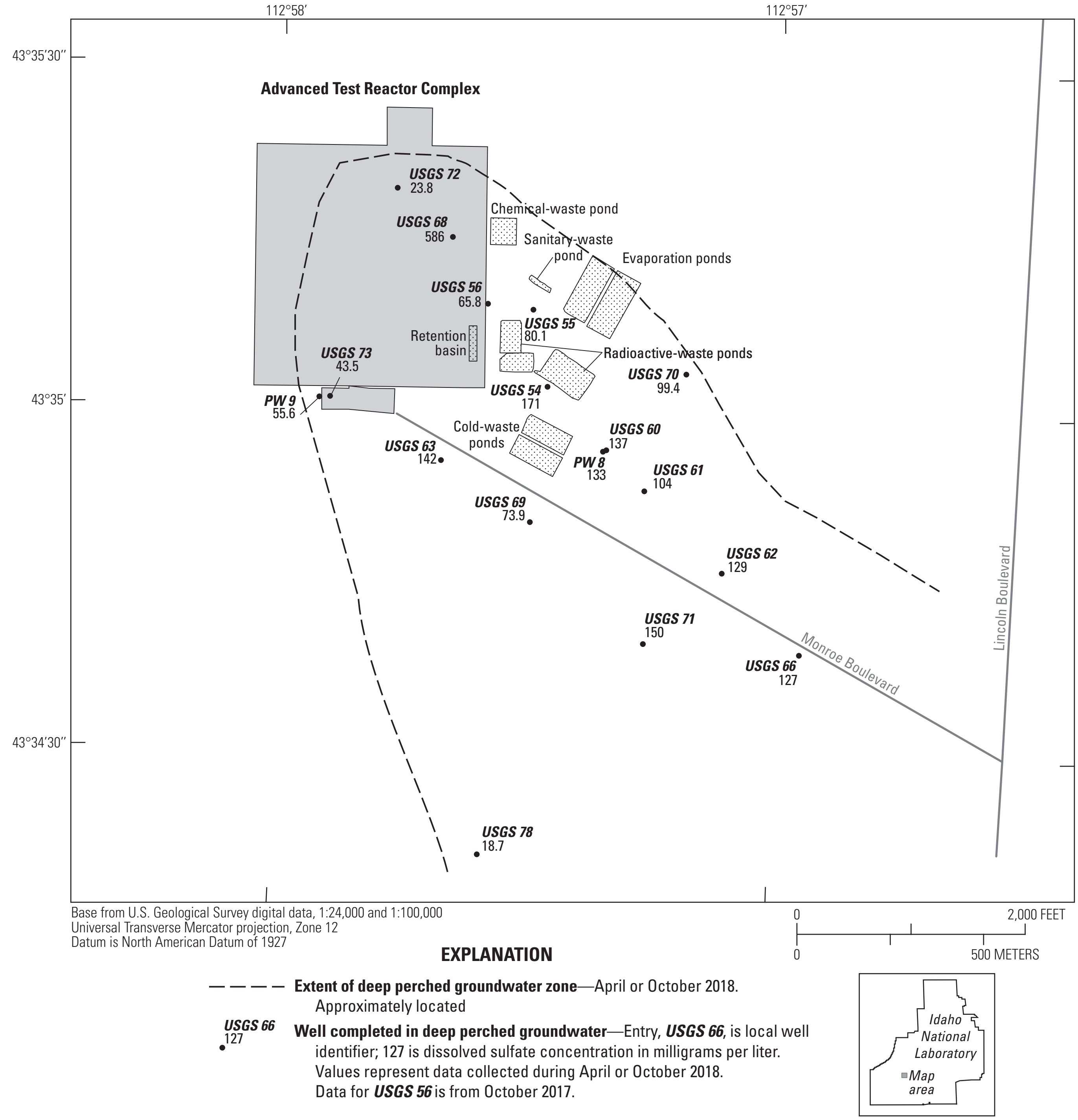


Figure 26. Concentrations of dissolved sulfate in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2018.

Historically, the concentration of americium-241 in water from well USGS 92 was greater than the reporting level in October 1992, and the concentration of plutonium-238 was greater than the reporting level in November 1994 (Bartholomay, 1998). Since the 1990s, concentrations of these constituents—as well as strontium-90, cesium-137, and plutonium-239 and 240 (undivided) —have been less than the reporting levels. An exception to this is that in April 2016, a reportable concentration of americium-241 was detected at a concentration of 0.13 ±0.02 pCi/L; however, a resample collected in November of 2016 indicated a concentration less than the reporting level (table 12).

Table 12. Concentrations of tritium, strontium-90, cesium-137, selected transuranic elements, and dissolved chloride in perched groundwater from well USGS 92, Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, 2016–18.

[Analyses were completed by the U.S. Department of Energy Radiological and Environmental Sciences Laboratory and the USGS National Water Quality Laboratory. Analyses for radionuclides, analytical uncertainties are reported as 1 times the sample standard deviation. Concentrations equal to or greater than three times the sample standard deviation are considered to be greater than the reporting level and are shown in **bold.** **Well No.:** Location of well is shown in figure 7. **Abbreviations:** NS, not sampled; USGS, U.S. Geological Survey; mg/L, milligram per liter; pCi/L, picocurie per liter. **Symbol:** ±, plus or minus]

Well No.	Date sampled	Tritium (pCi/L)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Plutonium-238 (pCi/L)	Plutonium-239 and -240 (undivided) (pCi/L)	Americium-241 (pCi/L)	Chloride (dissolved) (mg/L)
USGS 92	04-18-16	**200±50**	-1.2±0.8	25±11	-0.004±0.004	-0.008±0.008	**0.13±0.02**	102
Resample	11-17-16	NS	NS	NS	-0.004±0.004	0.007±0.009	0.01±0.016	NS
	04-17-17	20±50	1.9±0.7	-11±12	-0.003±0.006	0.003±0.009	-0.01±0.02	91.8
	04-16-18	90±50	1.2±0.6	8±5	0.004±0.004	-0.007±0.007	0.003±0.009	93.4

Concentrations of dissolved chloride measured in water samples collected from well USGS 92 during 2016–18 ranged from 91.8 to 102 mg/L (table 12). Dissolved chloride concentrations have increased over time, but the increase is not statistically significant (Davis and others, 2015, appendix D).

In 1987, nine VOCs were detected in water from well USGS 92 (Mann and Knobel, 1987, p. 16–17). Since then, from 6 to 18 different VOCs have been detected during various sampling periods. Well USGS 92 was sampled for VOCs in April 2016–18. The concentrations of eight VOCs detected are shown in table 13. All VOCs detected in April 2016–18 had been detected previously in this well. Additionally, all VOC concentrations measured in 2016–18 were substantially lower than those measured in 2012–15 (table 13, this report; Bartholomay, Maimer, and others, 2017, table 12). The lower VOC concentrations measured in 2016–18 may be a result of VOC removal from the subsurface at the SDA by vapor vacuum extraction processes used by the INL contractor from 1996 to present (2019). Lower concentrations in 2017–18 also can be attributed to flow in the spreading areas diluting the VOC concentrations because the water level increased in the well when flow occurred in the spreading areas. A tracer study done by Nimmo and others (2002) indicated that movement of water from the spreading areas to USGS 92 does occur.

Table 13. Concentrations of selected volatile organic compounds in perched groundwater from well USGS 92, Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, 2016–18.

[Location of well USGS 92 is shown in figure 7. Analyses were completed by the U.S. Geological Survey National Water Quality Laboratory using an analytical method that conforms to U.S. Environmental Protection Agency Method 524.2. Names in parentheses are alternate compound names. **Abbreviations:** NWIS, National Water Information System; µg/L, microgram per liter. <, less than]

Volatile organic compound name	NWIS parameter code	Date sampled 04-18-16	Date sampled 04-17-17	Date sampled 04-16-18
		Concentration (µg/L)		
Carbon Tetrachloride (Tetrachloromethane)	32102	5.77	7.38	7.38
Chloroform (Trichloromethane)	32106	9.77	10.6	10.6
Tetrachloroethylene (Tetrachloroethene)	34475	0.861	1.85	1.40
1,1-dichloroethane	34496	<0.2	0.16	0.146
1,1-dichloroethylene (1,1,-dichloroethene)	34501	<0.2	0.114	<0.1
1,1,1-trichloroethane	34506	0.411	0.735	0.66
1,2-dichloropropane	34541	<0.2	0.144	0.134
Trichloroethylene (Trichloroethene)	39180	7.12	10.6	9.26

Summary

Radiochemical and chemical wastewater discharged since 1952 to infiltration ponds and disposal wells at the Idaho National Laboratory (INL) has affected water quality in the eastern Snake River Plain (ESRP) aquifer and in perched groundwater zones at the INL. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, maintains ESRP aquifer and perched groundwater monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the ESRP aquifer and in perched groundwater zones.

Water in the ESRP aquifer primarily moves through fractures and interflow zones in basalt, generally flows southwestward, and eventually discharges at springs along the Snake River near Twin Falls, Idaho, about 100 mi southwest of the INL. Estimated discharge from the springs was about 3.55 million acre-feet per year for water year 2018. The aquifer is recharged primarily from infiltration of irrigation water, infiltration of streamflow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation.

During March–May 2018, the altitude of the water table of the ESRP aquifer was about 4,560 feet (ft) in the northern part of the INL and about 4,410 ft in the southwestern part. Water flowed south and southwestward beneath the INL at an average hydraulic gradient of about 4 ft per mile.

Water levels in ESRP aquifer wells declined from about 0.5 to more than 2.5 ft in the northern part of the INL from March–May 2015 to March–May 2018. In the central and eastern parts of the INL, water levels increased slightly in some wells and decreased slightly in others during March to May 2015–18. In the southwestern part of the INL, water levels generally rose by about 0.5 to more than 2.5 ft during March to May 2015–18. The water-level rises in wells near the Big Lost River can be attributed to a large amount of flow in the river during the last 2 years of the study period.

Disposal of wastewater to infiltration ponds and infiltration of surface water at the Advanced Test Reactor Complex (ATR Complex) and Idaho Nuclear Technology and Engineering Center (INTEC) resulted in formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer. Perched groundwater beneath the Radioactive Waste Management Complex (RWMC) formed from infiltration of snowmelt and rain and recharge from the Big Lost River and INL spreading areas. This perched groundwater contains constituents leached from buried radioactive and organic-chemical wastes. Perched groundwater is an integral part of the pathway for waste-constituent migration to the ESRP aquifer.

A tritium plume developed in the ESRP aquifer from discharge of wastewater at the INL since the 1950s. Concentrations of tritium in water samples collected in 2018 from 46 of 111 aquifer wells were greater than the reporting level and ranged from 260±50 to 5,100±190 picocuries per liter (pCi/L). The tritium plume extended south-southwestward in the general direction of groundwater flow. In 2018, concentrations of tritium in water samples generally decreased from 2012 to 2015 and continued to show decreasing trends, and all concentrations were less than the U.S. Environmental Protection Agency maximum contaminant level (MCL) of 20,000 pCi/L.

Tritium concentrations in water from 10 wells completed in deep perched groundwater near the ATR Complex generally were greater than or equal to the reporting level during at least one sampling event during 2016–18, and concentrations ranged from 150 ±50 to 12,900 ±200 pCi/L.

During 2018, concentrations of strontium-90 in ESRP aquifer water from 17 of 60 aquifer wells exceeded the reporting level. Concentrations that exceeded the reporting level in the aquifer wells ranged from 2.2 ±0.7 to 14.6 ±0.9 pCi/L in wells near the INTEC; the largest concentration of 363 ±19 pCi/L was in a well at Test Area North (TAN). The area of the strontium-90 plume near the INTEC extended south-southwestward in the general direction of groundwater flow and all wells were showing decreasing concentrations. Strontium-90 has not been detected in the ESRP aquifer beneath the ATR Complex partly because of the exclusive use of waste-disposal ponds and lined evaporation ponds rather than the disposal well for radioactive-wastewater disposal at that facility. Sorption processes in sediments in the unsaturated zone beneath the radioactive waste-disposal pond could have minimized or prevented strontium-90 migration to the aquifer at the ATR Complex.

During at least one sampling event during 2016–18, concentrations of strontium-90 in water from eight wells completed in deep perched groundwater at the ATR Complex equaled or exceeded the reporting levels, and concentrations ranged from 0.57±0.17 to 34.3 ±1.2 pCi/L.

During 2016–18, water from 53 ESRP aquifer wells was sampled and analyzed for cesium-137. Cesium-137 concentrations in water from one of these wells equaled the reporting level, the rest were less than the reporting level. During 2016–18, concentrations of plutonium-238, -239, and -240 (undivided) in water from all 16 aquifer wells were less than the reporting level. Perched groundwater from the RWMC had a concentration of americium-241 that exceeded the reporting level in one sample in 2016; however, the well was resampled and the concentration was less than the reporting level.

Gross alpha and beta measurements are used to screen for radioactivity in the ESRP aquifer as a possible indicator of groundwater contamination. During 2016–18, water from 55 ESRP aquifer wells was sampled and analyzed for gross alpha- and beta-particle radioactivity. Concentrations of gross alpha-particle radioactivity in six wells equaled or exceeded the reporting level and ranged from 6 ±2 to 141±29 pCi/L. Concentrations of gross alpha-particle radioactivity in water from all other samples in the wells sampled and analyzed were less than the reporting level. During 2016–18, concentrations of gross beta-particle radioactivity in water from about one-half of the ESRP wells equaled or exceeded the reporting level in at least one of the sampling periods and ranged from 2.4 ±0.8 to 1,390±80 pCi/L.

In April 2009, the dissolved chromium concentration in water from one ESRP aquifer well, USGS 65, south of ATR Complex, equaled the MCL of 100 micrograms per liter (µg/L). In April 2018, the concentration of chromium in water from that well had decreased to 76.0 µg/L, much less than the MCL. Concentrations in water samples from 62 other wells sampled ranged from less than 0.6 to 21.6 µg/L. During 2016–18, dissolved chromium was detected in water from all wells completed in deep perched groundwater at the ATR Complex and concentrations ranged from 4.2 to 98.8 µg/L.

In 2018, concentrations of dissolved sodium in water from most ESRP aquifer wells in the southern part of the INL were greater than the background concentration of 8.3 milligrams per liter (mg/L). During 2018, the highest sodium concentration in water samples from aquifer wells near the INTEC was 29.0 mg/L in a water sample from well USGS 57. After the new percolation ponds were put into service in 2002 southwest of the INTEC, concentrations of sodium in water samples from the Rifle Range well increased steadily until 2008, when the concentrations generally began decreasing.

During 2018, dissolved sodium concentrations in water from 18 wells completed in deep perched groundwater ranged from 6.37 to 143 mg/L. The highest concentration was in water from well USGS 68. The concentration increased from 33.4 mg/L in April 2015 to 143 mg/L in 2018, and the increase is attributed to remnant water from the former chemical-waste ponds still being moved to the well.

In 2018, concentrations of dissolved chloride in most water samples from ESRP aquifer wells closest to the INTEC and the Central Facilities Area (CFA) exceeded background concentrations. Trends in chloride concentrations in water from wells downgradient of the old percolation ponds at the INTEC generally decreased because of discontinued disposal. After the new percolation ponds were put into service in 2002 southwest of the INTEC, concentrations of chloride increased steadily in water samples from the Rifle Range well until 2008, when the concentrations began decreasing.

During 2016–18, dissolved chloride concentrations in deep perched groundwater from 18 wells at the ATR Complex ranged from 3.89 to 176 mg/L. Higher concentrations of chloride were in water from deeper perched groundwater wells in the western part of the perched groundwater zone at the ATR Complex. The increasing concentrations may be a result of movement of remnant water through the unsaturated zone from the chemical-waste pond that was closed in 1999 or movement of water from the cold-waste ponds.

In 2018, sulfate concentrations in water samples from ESRP aquifer wells in the south-central part of the INL that exceeded the background concentration of sulfate ranged from 22 to 151 mg/L. The greater-than-background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds. In 2018, sulfate concentrations in water samples from wells near the RWMC mostly were greater than background concentrations and could have resulted from well construction techniques and (or) waste disposal at the RWMC or the ATR Complex.

The maximum dissolved sulfate concentration in shallow perched groundwater near the ATR Complex was 215 mg/L in well CWP 3 in April 2016. During 2018, dissolved sulfate concentrations in water from wells completed in deep perched groundwater near the cold-waste ponds at the ATR Complex ranged from 65.8 to 171 mg/L; the largest concentration of sulfate was in well USGS 68 at 586 mg/L.

In 2018, concentrations of dissolved nitrate in water from most ESRP aquifer wells at and near the INTEC exceeded the background concentration of 0.655 mg/L. Concentrations ranged from 0.555 to 7.00 mg/L. Nitrate concentrations at the INL near the INTEC mostly have decreased in response to reduced disposal rates and to the transition in 1984 from injection of wastewater to the INTEC disposal well to discharge to the old percolation ponds. The two exceptions to decreasing or no trends were wells USGS 20 and 67, which showed variable decreases and increases but overall have been increasing. The cause of the increases could be due to mobilization of nitrate beneath the INTEC tank farm, as both wells are downgradient of the INTEC tank farm.

In the southern part of the CFA, nitrate concentrations in water from ESRP aquifer well CFA-2 indicate an increasing trend. Nitrate concentrations in water samples collected in 2017 from well CFA-2 and in 2018 from well USGS 130 in the southern part of the CFA were 3.69 and 3.48 mg/L, respectively, and these concentrations are higher than most other wells upgradient and downgradient of the CFA. Nitrate contamination south of the CFA has been attributed to contamination from the old CFA mercury pond south of the facility, and the elevated nitrate in these wells possibly could be due to movement of nitrate in the unsaturated zone from the old CFA pond.

Nitrate concentrations in several ESRP aquifer wells in the eastern part of the INL were greater than the background concentration of about 1 mg/L for eastern regional recharge. The concentration trends for many of these wells also were increasing and the increasing trends were attributed to agricultural and other anthropogenic influences upgradient of the INL.

During 2018, water samples from four ESRP aquifer wells near the INTEC were analyzed for fluoride and concentrations ranged from 0.171 to 0.225 mg/L. These concentrations were in the range of background concentrations of fluoride in the ESRP aquifer for the western part of the INL, which indicates that wastewater disposal has not had an appreciable effect on fluoride concentrations in the ESRP aquifer near the INTEC.

During 2016–18, water samples from 30 ESRP aquifer wells were collected and analyzed for volatile organic compounds (VOCs). Sixteen different VOCs were detected. Water samples collected from 15 wells during 2016–18 each contained at least 1 and as many as 7 of the different

VOCs detected. The primary VOCs detected included carbon tetrachloride; trichloromethane; tetrachloroethene; 1,1,1-trichloroethane; and trichloroethene. Concentrations were less than the MCL for drinking water for all VOCs except for carbon tetrachloride in two wells near the RWMC and trichloroethene in one well near TAN.

During 2016–18, eight VOCs were detected in perched aquifer water from well USGS 92 near the RWMC. All VOC concentrations were substantially less than those measured during 2012–15. This decrease in VOC concentration may be a result of removal of VOCs from the subsurface at the SDA by vapor vacuum extraction processes done by the INL contractor from 1996 to the present (2019) and dilution by Big Lost River water during 2017–18.

During 2016–18, variability and bias were evaluated from 37 replicate and 15 blank quality-assurance samples. Results from replicate analyses were investigated to evaluate sample variability. Constituents with acceptable reproducibility were major ions, trace elements, nutrients, and VOCs. All radiochemical constituents had acceptable reproducibility except for gross alpha- and beta-particle radioactivity. The gross alpha- and beta-particle radioactivity samples that did not meet reproducibility criteria had very small concentrations. Bias from sample contamination was evaluated from equipment, field, and source-solution blanks. Cadmium was detected at a concentration slightly more than its reporting level in a source solution blank, and chloride and ammonia were detected at concentrations that were slightly more than their respective reporting levels in field and equipment blanks. Subtracting concentrations of chloride and ammonia in field blanks from the concurrently collected equipment blank indicates that adjusted concentrations for chloride and ammonia in the equipment blanks were less than their respective reporting levels. Therefore, no sample bias was observed for any of the sample periods.

References Cited

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. [Also available at https://doi.org/10.3133/wri914114.]

Ackerman, D.J., Rattray, G.W., Rousseau, J.P., Davis, L.C., and Orr, B.R., 2006, A conceptual model of ground-water flow in the eastern Snake River Plain aquifer at the Idaho National Laboratory and vicinity with implications for contaminant transport: U.S. Geological Survey Scientific Investigations Report 2006–5122 (DOE/ID-22198), 62 p. [Also available at https://doi.org/10.3133/sir20065122.]

Ackerman, D.J., Rousseau, J.P., Rattray, G.W., and Fisher, J.C., 2010, Steady-state and transient models of groundwater flow and advective transport, eastern Snake River Plain aquifer, Idaho National Laboratory and vicinity, Idaho: U.S. Geological Survey Scientific Investigations Report 2010-5123 (DOE/ ID-22209), 220 p., https://pubs.usgs.gov/sir/2010/5123/

American Society for Testing and Materials International, 2010, Standard practice for performing detection and quantitation estimation and data assessment utilizing DQCALC software, based on ASTM practices D6091 and 20 D6512 of Committee D19 on water: American Society for Testing and Materials International, ASTM D7510-10, 2 p. [Also available at https://www.astm.org/Standards/D7510.htm.]

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. [Also available at https://doi.org/10.3133/wri914010.]

Anderson, S.R., Ackerman, D.J., Liszewski, M.J., and Freiburger, R.M., 1996, Stratigraphic data for wells at and near the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 96–248 (DOE/ID-22127), 27 p., 1 diskette. [Also available at https://doi.org/10.3133/ofr96248.]

Anderson, S.R., Kuntz, M.A., and Davis, L.C., 1999, Geologic controls of hydraulic conductivity in the Snake River Plain aquifer at and near the Idaho National Engineering and Environmental Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 99–4033 (DOE/ ID-22155), 38 p. [Also available at https://doi.org/10.3133/wri994033.]

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. [Also available at https://doi.org/10.3133/wri894065.]

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 (IDO-22055), 52 p. [Also available at https://doi.org/10.3133/ofr75318.]

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 (IDO-22060), 116 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 (IDO-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 IDO-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 67–12 (IDO-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. [Also available at https://doi.org/10.3133/wri934201.]

Bartholomay, R.C., 1998, Distribution of selected radiochemical and chemical constituents in water from perched ground-water zones, Idaho National Engineering Laboratory, Idaho, 1992–95: U.S. Geological Survey Water-Resources Investigations Report 98–4026 (DOE/ID-22145), 59 p. [Also available at https://doi.org/10.3133/wri984026.]

Bartholomay, R.C., Davis, L.C., Fisher, J.C., Tucker, B.J., and Raben, F.A., 2012, Water-quality characteristics and trends for selected sites at and near the Idaho National Laboratory, Idaho, 1949–2009: U.S. Geological Survey Scientific Investigations Report 2012–5169 (DOE/ID 22219), 68 p. [Also available at https://pubs.usgs.gov/sir/2012/5169/.]

Bartholomay, R.C., and Hall, L.F., 2016, Evaluation of background concentrations of selected chemical and radiochemical constituents in water from the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, Idaho: U.S. Geological Survey Scientific Investigations Report 2016-5056 (DOE/ID-22237), 19 p., https://doi.org/10.3133/sir20165056.

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

Bartholomay, R.C., Hodges, M.K.V., and Champion, D.E., 2017, Correlation between basalt flows and radiochemical and chemical constituents in selected wells in the southwestern part of the Idaho National Laboratory, Idaho: U.S. Geological Survey Scientific Investigations Report 2017–5148 (DOE/ID-22245), 39 p., https://doi.org/10.3133/sir20175148.

Bartholomay, R.C., Hopkins, C.B., and Maimer, N.V., 2015, Chemical constituents in groundwater from multiple zones in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, 2009–13: U.S. Geological Survey Scientific Investigations Report 2015-5002 (DOE/ID-22232), 110 p. [Also available at https://dx.doi.org/10.3133/sir20155002.]

Bartholomay, R.C., Knobel, L.L., and Rousseau, J.P., 2003, Field methods and quality assurance plan for quality-of-water activities, U.S. Geological Survey, Idaho National Engineering and Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 2003–42 (DOE/ID-22182), 45 p. [Also available at https://doi.org/10.3133/ofr0342.]

Bartholomay, R.C., Maimer, N.V., Rattray, G.W., and Fisher, J.C., 2017, An update of hydrologic conditions and distribution of selected constituents in water, eastern Snake River Plain aquifer and perched groundwater zones, Idaho National Laboratory Idaho, emphasis 2012–15: U.S. Geological Survey Scientific Investigations Report 2017–5021 (DOE/ID-22242), 87 p., https://doi.org/10.3133/sir20175021.

Bartholomay, R.C., Maimer, N.V., and Wehnke, A.J., 2014, Field methods and quality-assurance plan for water-quality activities and water level measurements, U.S. Geological Survey, Idaho National Laboratory, Idaho: U.S. Geological Survey Open-File Report 2014-1146 (DOE/ID-22230), 66 p., https://dx.doi.org/10.3133/ofr20141146.

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, Snake River Plain aquifer, 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., and Tucker, B.J., 2000, 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 2000–4222 (DOE/ID–22168), 51 p. [Also available at https://doi.org/10.3133/wri004222.]

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, Snake River Plain aquifer, Idaho National Engineering Laboratory, Idaho, 1992 through 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4086 (DOE/ID–22137), 57 p. [Also available at https://doi.org/10.3133/wri974086.]

Bartholomay, R.C., Tucker, B.J., Davis, L.C., and Green, M.R., 2000, Hydrologic conditions and distribution of selected constituents in water, Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory, Idaho, 1996 through 1998: U.S. Geological Survey Water-Resources Investigations Report 2000–4192 (DOE/ID-22167), 52 p. [Also available at https://doi.org/10.3133/wri004192.]

Bartholomay, R.C., and Twining, B.V., 2010, Chemical constituents in groundwater from multiple zones in the eastern Snake River Plain aquifer at the Idaho National Laboratory, Idaho, 2005–08: U.S. Geological Survey Scientific Investigations Report 2010–5116 (DOE/ID 22211), 81 p. [Also available at https://doi.org/10.3133/sir20105116.]

Bartholomay, R.C., and Twining, B.V., 2015, Hydrologic influences on water-level changes in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, Idaho, 1949–2014: U.S. Geological Survey Scientific Investigations Report 2015-5085 (DOE/ID-22236), 36 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. [Also available at https://doi.org/10.3133/wri964260.]

Bennett, C.M., 1990, Streamflow losses and ground-water level changes along the Big Lost River at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 90–4067 (DOE/ID-22091), 49 p. [Also available at https://doi.org/10.3133/wri904067.]

Bodnar, L.Z., and Percival, D.R., eds., 1982, Analytical Chemistry Branch procedures manual–Radiological and Environmental Sciences Laboratory: U.S. Department of Energy Report IDO-12096 [variously paged].

Cahn, L.S., Abbott, M.L., Keck, J.F., Martian, P., Schafer, A.L., and Swenson, M.C., 2006, Operable Unit 3-14 tank farm soil and groundwater remedial investigation/baseline risk assessment: U.S. Department of Energy, Idaho Operations Office, DOE/NE-ID-11227 [variously paged].

Cassidy, G.B., 1984, Idaho National Engineering Laboratory industrial waste management information for 1983 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication DOE/ID-10057 (83), 99 p.

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: U.S. Geological Survey Water-Resources Investigations Report 89–4146 (DOE/ID-22083), 24 p. [Also available at https://doi.org/10.3133/wri894146.]

Cecil, L.D., Orr, B.R., Norton, T., and Anderson, S.R., 1991, Formation of perched ground-water 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. [Also available at https://doi.org/10.3133/wri914166.]

Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p. [Also available at https://doi.org/10.3133/ofr99193.]

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. [Also available at https://doi.org/10.3133/ofr821024.].

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.

Davis, L.C., 2006b, An update of the distribution of selected radiochemical and chemical constituents in perched ground water, Idaho National Laboratory, Idaho, emphasis 1999–2001: U.S. Geological Survey Scientific Investigations Report 2006–5236 (DOE/ID-22199), 48 p. [Also available at https://pubs.usgs.gov/sir/2006/5236/index.html.]

Davis, L.C., 2006a, An update of hydrologic conditions and distribution of selected constituents in water, Snake River Plain aquifer, emphasis 1999–2001: U.S. Geological Survey Scientific Investigations Report 2006–5088 (DOE/ID-22197), 48 p. [Also available at https://doi.org/10.3133/sir20065088.]

Davis, L.C., 2008, An update of hydrologic conditions and distribution of selected constituents in water, Snake River Plain aquifer and perched-water zones, emphasis 2002–05: U.S. Geological Survey Scientific Investigations Report 2008–5089 (DOE/ID-22203), 74 p. [Also available at https://doi.org/10.3133/sir20085089.]

Davis, L.C., 2010, An update of hydrologic conditions and distribution of selected constituents in water, Snake River Plain aquifer and perched groundwater zones, Idaho National Laboratory, Idaho, emphasis 2006–08: U.S. Geological Survey Scientific Investigations Report 2010–5197 (DOE/ID-22212), 80 p. [Also available at https://doi.org/10.3133/sir20105197.]

Davis, L.C., Bartholomay, R.C., Fisher, J.C., and Maimer, N.V., 2015, Water-quality characteristics and trends for selected wells possibly influenced by wastewater disposal at the Idaho National Laboratory, Idaho, 1981–2012: U.S. Geological Survey Scientific Investigations Report 2015-5003 (DOE/ID-22233), 106 p.

Davis, L.C., Bartholomay, R.C., and Rattray, G.W., 2013, An update of hydrologic conditions and distribution of selected constituents in water, eastern Snake River Plain aquifer and perched groundwater zones, Idaho National Laboratory, Idaho, emphasis 2009–11: U.S. Geological Survey Scientific Investigations Report 2013-5214 (DOE/ID-22226), 90 p.

Faires, L.M., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determinations of metals in water by inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 92–634, 28 p. [Also available at https://doi.org/10.3133/ofr92634.]

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments, U.S. Geological Survey Open-File Report 93-125, 217 p. [Also available at https://doi.org/10.3133/ofr93125.]

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. [Also available at https://pubs.usgs.gov/twri/twri5-a1/.]

French, D.L., Tallman, R.E., and Taylor, K.A., 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].

French, D.L., Tallman, R.E., and Taylor, K.A., 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].

Goerlitz, D.F., and Brown, E., 1972, Methods for analysis of organic substances in water: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 40 p. [Also available at https://doi.org/10.3133/twri05A3_1972.]

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. [Also available at https://doi.org/10.3133/ofr9851.]

Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254 (3rd ed.), 263 p.

Holdren, K.J., Becker, B.H., Hampton, N.L., Koeppen, L.D., Magnuson, S.O., Meyer, T.J., Olson, G.L., and Sondrup, A.J., 2002, Ancillary basis for risk analysis of the Subsurface Disposal Area: Idaho National Engineering and Environmental Laboratory, U.S. Department of Energy, Idaho Operations Office, INEEL/EXT-02-01125 [variously paged].

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.

Kjelstrom, L.C., 1995, Methods to estimate annual mean spring discharge to the Snake River between Milner Dam and King Hill, Idaho: U.S. Geological Survey Water-Resources Investigations Report 95–4055, 9 p. [Also available at https://doi.org/10.3133/wri954055.]

Knobel, L.L., 2006, Evaluation of well-purging effects on water-quality results for samples collected from the eastern Snake River Plain aquifer underlying the Idaho National Laboratory, Idaho: U.S. Geological Survey Scientific Investigations Report 2006–5232 (DOE/ID-22200), 52 p. [Also available at https://pubs.er.usgs.gov/publication/sir20065232.]

Knobel, L.L., Bartholomay, R.C., Tucker, B.J., Williams, L.M., and Cecil, L.D., 1999, Chemical constituents in ground water from 39 selected sites with an evaluation of quality assurance data, Idaho National Engineering and Environmental Laboratory and vicinity, Idaho: U.S. Geological Survey Open-File Report 99–246 (DOE/ID-22159), 58 p. [Also available at http://pubs.er.usgs.gov/publication/ofr99246.]

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, v. 13, no. 2, p. 142–148, https://doi.org/10.1111/j.1745-6592.1993.tb00446.x.

Knobel, L.L., Orr, B.R., and Cecil, L.D., 1992, Summary of background concentrations of selected radiochemical and chemical constituents in groundwater 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.

Knobel, L.L., Tucker, B.J., and Rousseau, J.P., 2008, Field methods and quality-assurance plan for quality-of-water activities, U.S. Geological Survey, Idaho National Laboratory, Idaho: U.S. Geological Survey Open-File Report 2008–1165 (DOE/ID-22206), 36 p. [Also available at http://pubs.er.usgs.gov/publication/ofr20081165.]

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. [Also available at https://doi.org/10.3133/ha674.]

Liszewski, M.J., and Mann, L.J., 1992, Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho, 1990 and 1991: U.S. Geological Survey Open-File Report 92–174 (DOE/ID-22104), 19 p. [Also available at https://doi.org/10.3133/ofr92174.]

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 Investigative Report 97–4044 (DOE/ID-22140), 33 p. [Also available at https://doi.org/10.3133/wri974044.]

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 Investigative Report 98–4073 (DOE/ID-22149), 55 p. [Also available at https://doi.org/10.3133/wri984073.]

Maimer, N.V., and Bartholomay, R.C., 2016, Purgeable organic compounds at or near the Idaho Nuclear Technology and Engineering Center, Idaho National Laboratory, Idaho, 2015: U.S. Geological Survey Open-File Report 2016–1083 (DOE/ID 22238), 17 p.

Mann, L.J., 1986, Hydraulic properties of rock units and chemical quality of water for INEL-1—A 10,365-foot deep test hole drilled at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 86–4020 (DOE/ID-22070), 23 p. [Also available at https://doi.org/10.3133/wri864020.]

Mann, L.J., 1990, Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho—1988 and 1989: U.S. Geological Survey Open-File Report 90–367 (DOE/ID-22089), 17 p. [Also available at https://doi.org/10.3133/ofr90367.]

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. [Also available at https://doi.org/10.3133/ofr96615.]

Mann, L.J., and Cecil, L.D., 1990, Tritium in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 90–4090 (DOE/ID-22090), 35 p. [Also available at https://doi.org/10.3133/wri904090.]

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. [Also available at https://doi.org/10.3133/ofr87766.]

Mirus, B.B., Perkins, K.S., and Nimmo, J.R., 2011, Assessing controls on perched saturated zones beneath the Idaho Nuclear Technology and Engineering Center, Idaho: U.S. Geological Survey Scientific Investigations Report 2011–5222, (DOE/ID-22216), 20 p. [Also available at https://pubs.usgs.gov/sir/2011/5222/.]

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, E., 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, E., 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.

Nace, R.L., Voegeli, P.T., Jones, J.R., and Deutsch, M., 1975, Generalized geologic framework of the National Reactor Testing Station, Idaho: U.S. Geological Survey Professional Paper 725-B, 48 p. [Also available at https://doi.org/10.3133/pp725B.]

Nimmo, J.R., Perkins, K.S., Rose, P.E., Rousseau, J.P., Orr, B.R., Twining, B.V., and Anderson, S.R., 2002, Kilometerscale rapid transport of naphthalene sulfonate tracer in the unsaturated zone at the Idaho National Engineering and Environmental Laboratory: Vadose Zone Journal, v. 1, no. 1, p. 89–101, https://doi.org/10.2136/vzj2002.8900.

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. [Also available at https://doi.org/10.3133/wri994277.]

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. [Also available at https://doi.org/10.3133/wri914047.]

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 Environmental Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 99–4145 (DOE/ID-22158), 56 p. [Also available at https://doi.org/10.3133/wri994145.]

Perkins, K.S., and Winfield, K.A., 2007, Property-transfer modeling to estimate unsaturated hydraulic conductivity of deep sediments at the Idaho National Laboratory, Idaho: U.S. Geological Survey Scientific Investigations Report 2007–5093 (DOE/ID-22202), 22 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. [Also available at https://doi.org/10.3133/wri894008.]

Pritt, J.W., 1989, Quality assurance of sample containers and preservatives at the U.S. Geological Survey National Water Quality Laboratory, *in* Pederson, G.L., and Smith, M.M., compilers, U.S. Geological Survey second national symposium on water quality—Abstracts of the technical sessions, Orlando, Florida, November 12–17, 1989: U.S. Geological Survey Open-File Report 89–409, p. 75. [Also available at https://doi.org/10.3133/ofr89409.]

Rattray, G.W., 2012, Evaluation of quality-control data collected by the U.S. Geological Survey for routine water-quality activities at the Idaho National Laboratory, Idaho, 1996–2001: U.S. Geological Survey Scientific Investigations Report 2012–5270, (DOE/ID-22222), 74 p. [Also available at https://doi.org/10.3133/sir20125270.]

Rattray, G.W., 2014, Evaluation of quality-control data collected by the U.S. Geological Survey for routine water-quality activities at the Idaho National Laboratory and vicinity, southeastern Idaho, 2002-08: USGS Scientific Investigations Report 2014-5027 (DOE/ID-22228), 66 p., https://doi.org/10.3133/sir20145027.

Rattray, G.W., 2018, Geochemistry of groundwater in the eastern Snake River Plain aquifer, Idaho National Laboratory and vicinity, eastern Idaho: U.S. Geological Survey Professional Paper 1837-A (DOE/ID-22246), 198 p., https://doi.org/10.3133/pp1837A.

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 (IDO-22057), 68 p.

Robertson, J.B., Schoen, R., 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 73–238 (IDO-22053), 231 p.

Sehlke, G., and Bickford, F.E., 1993, Idaho National Engineering Laboratory ground-water monitoring plan: EG&G Idaho, Inc., and Golder Associates, Inc., DOE/ID-10441, v. 1–2 [variously paged].

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 1, chap. D1, 65 p. [Also available at https://doi.org/10.3133/twri01D1.]

S.M. Stoller Corporation, 2002a, Idaho National Engineering and Environmental Laboratory site environmental report, calendar year 1999: U.S. Department of Energy, Idaho Operations Office, DOE/ID-12082 (99) [variously paged].

S.M. Stoller Corporation, 2002b, Idaho National Engineering and Environmental Laboratory site environmental report, calendar year 2000: U.S. Department of Energy, Idaho Operations Office, DOE/ID-12082 (00) [variously paged].

S.M. Stoller Corporation, 2004, Idaho National Engineering and Environmental Laboratory site environmental report, calendar year 2003: U.S. Department of Energy, Idaho Operations Office, DOE/ID-12082 (03) [variously paged].

S.M. Stoller Corporation, 2009, Idaho National Laboratory site environmental report, calendar year 2008: U.S. Department of Energy, Idaho Operations Office, DOE/ID-12082 (08) [variously paged].

Timme, P.J., 1995, National Water Quality Laboratory, 1995 services catalog: U.S. Geological Survey Open-File Report 95–352, 120 p., https://doi.org/10.3133/ofr95352.

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. [Also available at https://doi.org/10.3133/wri984028.]

Twining, B.V., Bartholomay, R.C., and Hodges, M.K.V., 2016, Completion summary for boreholes TAN 2271 and TAN 2272 at Test Area North, Idaho National Laboratory, Idaho: U.S. Geological Survey Scientific Investigations Report 2016–5088 (DOE/ID-22239), 37 p. plus appendixes, https://doi.org/10.3133/sir20165088.

Twining, B.V., Bartholomay, R.C., and Hodges, M.K.V., 2018, Completion summary for boreholes TAN-2312 at Test Area North, Idaho National Laboratory, Idaho: U.S. Geological Survey Scientific Investigations Report 2018–5118 (DOE/ID-22247), 29 p. plus appendixes, https://doi.org/10.3133/sir20185118.

Twining, B.V., Hodges, M.K.V., Schusler, K., and Mudge, C., 2017, Drilling, construction, geophysical log data, and lithologic log for boreholes USGS 142 and USGS 142A, Idaho National Laboratory, Idaho: U.S. Geological Survey Data Series 1058 (DOE/ID-22243), 21 p., plus appendixes, https://doi.org/10.3133/ds1058.

U.S. Department of Energy, 2011b, Five-year review of CERCLA response actions at the Idaho National Laboratory site—Fiscal years 2005–2009, DOE/ID-11429, Rev. 0 [variously paged].

U.S. Department of Energy, 2011a, Idaho National Laboratory groundwater monitoring and contingency plan update: U.S. Department of Energy, DOE/ID-11034, Rev. 2 [variously paged].

U.S. Department of Energy, 2018, Fiscal year 2017 Annual report for operable unit 3-14, tank farm soil and INTEC groundwater: U.S. Department of Energy, DOE/ID-11575, Rev. 0 [variously paged].

U.S. Environmental Protection Agency, 2015, National primary drinking water regulations—Maximum contaminant levels and maximum residual disinfectant levels: Code of Federal Regulations, Title 40, Part 141, Subpart G.

U.S. Geological Survey, 1985, National water summary, 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, 467 p. [Also available at https://doi.org/10.3133/wsp2275.]

U.S. Geological Survey, 2015, Changes to National Water Quality Laboratory (NWQL) procedures used to establish and verify laboratory detection and reporting limits: National Water Quality Laboratory Technical Memorandum 15.02, accessed January 26, 2016, at http://wwwnwql.cr.usgs.gov/rapi-notes/15-14_NWQL_TM_15-02_(DQCALC).pdf.

U.S. Geological Survey, 2019a, National Water Information System—Web interface: U.S. Geological Survey web page, accessed February 12, 2019, at https://dx.doi.org/10.5066/F7P55KJN.

U.S. Geological Survey, 2019b, The Menlo Park tritium laboratory: U.S. Geological Survey web page, accessed May 27, 2019, at https://water.usgs.gov/nrp/menlo-park-tritium-laboratory/.

U.S. Geological Survey [various dates], National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations Report, book 9, chaps. A1–A9 [variously paged]. [Also available at https://water.usgs.gov/owq/FieldManual/.]

Walker, F.W., Parrington, J.R., and Feiner, F., 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 Idaho, 1980 to 1988: U.S. Geological Survey Water-Resources Investigations Report 89–4168 (DOE/ID-22085), 91 p. [Also available at https://doi.org/10.3133/wri894168.]

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. [Also available at https://doi.org/10.3133/twri05A3.]

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), 116 p. [Also available at https://doi.org/10.3133/wri964148.]

Williams, L.M., 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. [Also available at https://doi.org/10.3133/wri974058.]

Wood, W.W., 1976, 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. [Also available at https://doi.org/10.3133/twri01D2.]

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