PART III – SECTION J, ATTACHMENT F-3

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AND THE IDAHO OPERATIONS OFFICE
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U.S. Geological Survey Fiscal Year 2018 Task Plan

Prepared by: USGS INL Project Office for the U.S. Department of Energy Idaho Operations Office

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1. Background and Objectives

The eastern Snake River Plain (ESRP) aquifer of southeastern Idaho, a part of which underlies the Idaho National Laboratory (INL) (fig. 1), is an important resource to both the State of Idaho and the U.S. Department of Energy (DOE). The entire water supply for the INL (including drinking water) is obtained from the aquifer. At the INL, the aquifer is part of an extensive geohydrologic system that also includes a thick, overlying unsaturated zone; perched groundwater zones; and intermittent streams, playas, and water-diversion areas.

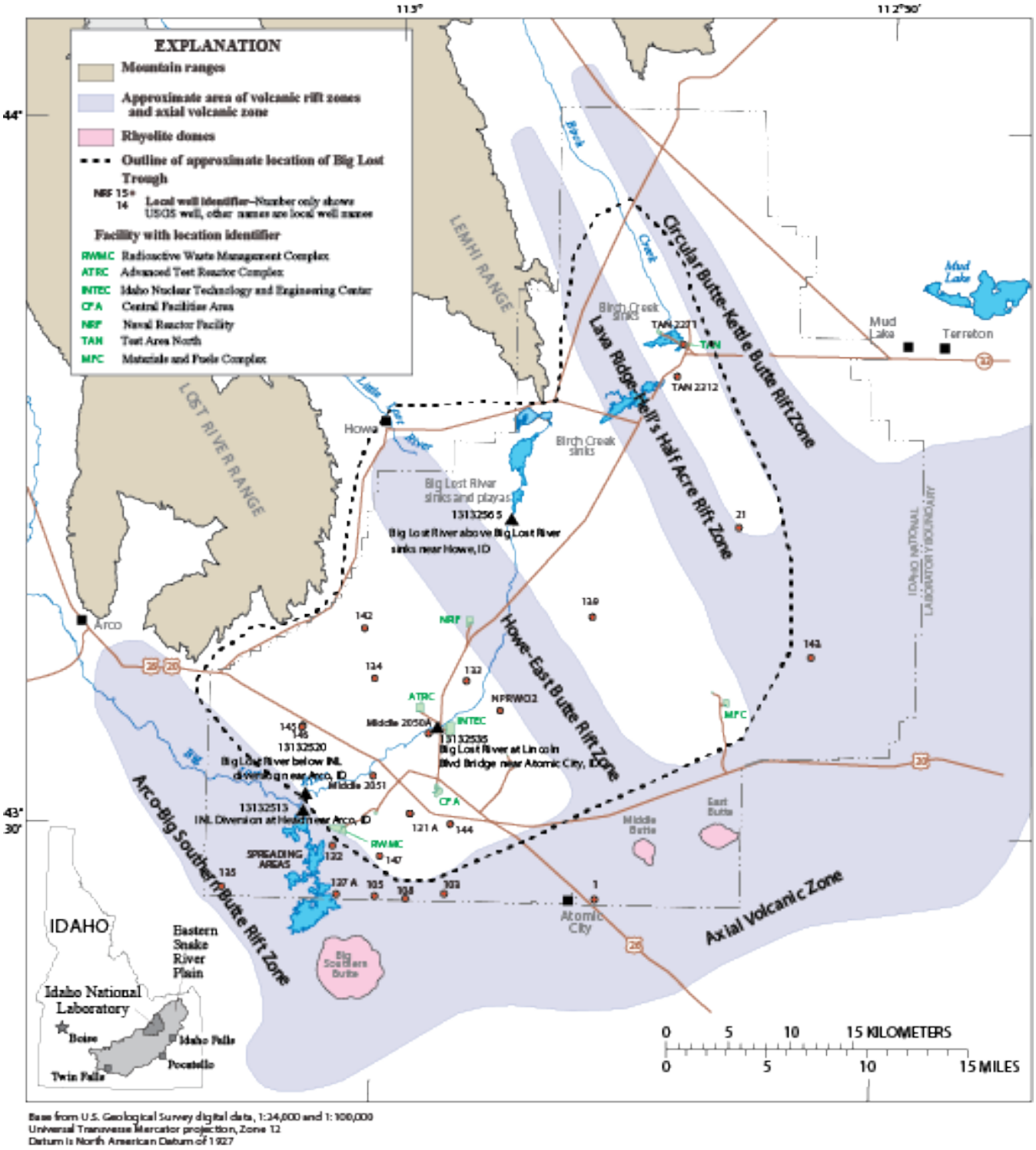

Figure 1. Selected wells and selected sites at the Idaho National Laboratory, Idaho

Some parts of the ESRP aquifer, unsaturated zone, and perched groundwater zones contain low-level radiochemical- and chemical-aqueous wastes generated by activities at the INL. From 1952 to the present, wastewater was either injected directly into the aquifer through disposal wells or was discharged to infiltration ponds. Routine effluent discharge to the last remaining wastewater disposal well located at the Idaho Nuclear Technology and Engineering Center (INTEC) was discontinued in February 1984 following construction of a percolation pond; however, the well was used in emergencies from 1984 to 1986.

Ponded wastewater infiltrates the soil and underlying rock units, and eventually percolates downward to the aquifer. Perched groundwater zones have formed in places where the downward movement of wastewater is impeded by decreased vertical hydraulic conductivity of the subsurface material. When wastewater reaches the aquifer, it moves downgradient toward the southern boundary of the INL.

Both the INL Groundwater Monitoring Plan (U. S. Department of Energy, 2012) and the Idaho Completion Project describe the concern about water pollution and the need for continuing data collection. In response, the U.S. Geological Survey (USGS), in cooperation with the DOE Idaho Operations Office, designed and implemented an extensive geohydrologic, hydraulic, chemical, and radiochemical data collection network. Data collected from the network are used in interpretive studies to describe the temporal and spatial distribution of the radiochemical- and chemical-waste solutes, and to describe the processes that control their concentration and migration rates. These processes include dispersion, adsorption, advection, radioactive decay, and chemical reactions. The interpretive studies form an integral part of a comprehensive assessment of groundwater availability and water-quality conditions at the INL. USGS data and reports are used by the DOE and its contractors, Region 10 of the U.S. Environmental Protection Agency, and the State of Idaho.

The USGS is responsible for the regional component of groundwater monitoring conducted under the INL Site-wide Groundwater Monitoring Plan. The plan uses a subset of wells from the existing regional observation well network maintained and sampled by the USGS, and it includes recommendations for adding new wells to the observation network. The regional wells included in the plan provide a connection among the area-specific monitoring networks, and they offer supplementary monitoring support for area-specific wells. Because many of these USGS wells have a long data-acquisition history, USGS personnel use them to identify and track long-term trends. The wells generally obtain water samples from open aquifer intervals of 50 to 200 feet. These long open intervals offer the possibility of detecting contaminants that might be missed by wells with shorter open intervals.

The monitoring networks and interpretive studies provide detailed descriptions of the effects of waste disposal on the quality of groundwater in the ESRP aquifer, and they provide information about water availability and groundwater movement. Geologic and hydrologic complexities of the aquifer at the INL require a continuing data-collection program to provide a detailed description of the migration of radiochemical and chemical waste solutes in the subsurface. Also, INL operational activities and the disposal of wastes to the environment continually change and therefore require frequent monitoring and interpretation of their effects on the aquifer. The monitoring networks and interpretive studies also provide baseline data to support future geohydrologic research that can resolve problems arising from the migration and disposition of radiochemical and chemical wastes. Interpretive reports are prepared and released to document the findings of the research. New USGS reports are posted on the World Wide Web at *https://water.usgs.gov/pubs/*. Water data, including those collected by the USGS at the INL, are publicly available from the USGS National Water Information System (NWIS) website at *https://waterdata.usgs.gov/nwis/*.

USGS staff at the INL are available to the DOE and its contractors to develop and interpret information, to advise, and to collect additional data on a wide array of geohydrologic problems, including waste disposal, waste migration, site remediation, well rehabilitation, water supply, flood control, streamflow, and pond-water infiltration. The USGS coordinates with DOE contractors to avoid duplication of effort while maximizing the integration of information.

The USGS program at the INL has two major components:

- Geohydrologic Studies and Monitoring
- Site Support Services

Geohydrologic Studies and Monitoring

Horizontal and vertical migration of solutes in the subsurface are controlled by advection and dispersion and are the result of complex physical and chemical processes. Physical and chemical stresses on the geohydrologic system must be evaluated and monitored to describe the variation in these processes. Understanding these processes is necessary to evaluate the sensitivity of waste migration to natural conditions.

Work continues on a comprehensive, long-range study to update the groundwater-flow and contaminant-transport models that were constructed in the early 1970s. A model for groundwater flow and advective transport was published in 2010. An evaluation of the model was published in 2012. Several generalizing assumptions in the previous models are being quantified using data that were collected from the 1950s to the present. The assumptions include the:

- amount and timing of potential recharge to the aquifer from the infiltration of streamflow;
- geologic framework of the ESRP aquifer;
- hydraulic characteristics of the aquifer; and
- geochemical processes.

Improving the definitions of these four assumptions will provide a more accurate representation of the processes taking place in the aquifer and how those processes affect the distribution and migration of radiochemical and chemical wastes in the aquifer.

Hydrologic Monitoring

Data collected from hydrologic monitoring activities are added to the USGS NWIS database. In fiscal year (FY) 2000, the USGS provided public access to NWIS through a Web interface. This system lets users access and retrieve USGS water data, including INL groundwater-level and water-quality data. The website address is *https://water.usgs.gov/nwis/*.

Water-Quality and Water-Level Monitoring

Since the inception of the monitoring program in 1949, water-quality samples and water-level measurements have been collected from a network of more than 200 wells. Samples and measurements have been collected primarily from wells open to the aquifer through their entire depth below the water table. This type of construction is good for maximum water-production rates, for identifying the time of arrival of contaminant plumes, and for delineating the horizontal extent of contaminants. Starting in FY 2010, the USGS began to evaluate long-term trends of the monitoring wells at the INL. An analysis and interpretation of data collected between 1949-2009 for wells believed to be not affected by wastewater

disposal was published in 2012 (Bartholomay and others, 2012; DOE/ID-22219). An analysis and interpretation of data collected between 1949-2012 for wells believed to be affected by wastewater disposal was published in 2015 (Davis and others, 2015; DOE/ID-22233). In FY 2011, the USGS began developing a management tool to evaluate the efficiency of the water-level monitoring network. The information related to the tool's development was published in 2013 (Fisher, 2013; DOE/ID-22224). The management tool helps to determine which wells to exclude from the monitoring network because they add little or no beneficial information and to define areas where more information could be useful. Findings from this report were used to optimize the existing water-level program, reducing both the number of sites and the frequency of measurements.

Vertical Water-Quality and Water-Level Monitoring Network

Starting in 2005, the USGS collaborated with CH2M-WG Idaho, LLC (CWI) to develop a monitoring network that uses multilevel monitoring systems (MLMS) to better characterize and define vertical changes in contaminant concentrations, liquid pressure (hydraulic head), and water temperature in the ESRP aquifer. More information on how MLMS are constructed can be found in Twining and Fisher 2015 (DOE/ID-22235). The network was expanded through FY 2012 to include 11 wells instrumented with MLMS. These hydraulically isolated depth intervals coincide with the vertical location of layers in the USGS groundwater-flow model for the INL. The USGS has developed analysis tools and collection methods that have helped to improve the reliability and consistency of these data. Hydraulic head and temperature measurements will be used to recalibrate various parameters in the existing model; such as hydraulic conductivity, a major parameter affecting the output accuracy of groundwater flow and transport models. Water-quality data, collected from discrete zones, will be used to compare model-derived and independently derived estimates of source areas and travel times.

Streamgaging Stations

From 1984 through 2009, the USGS Idaho Water Science Center's Idaho Falls Field Office operated a hydrologic network in the Big Lost River Basin that consisted of eight streamgages, six crest-stage gages, and one lake-stage gage. During FY 2009, the USGS and the DOE decided to reduce the number of sites in the network to only seven streamgages. Data Collection Platforms with satellite telemetry are installed at all seven of the streamgages to provide real-time hydrologic information. Data have been collected continuously at two of the three most upstream gages since the early 1900s; data collection at the third upstream gage started in the 1940s. The current hydrologic network in the Big Lost River Basin is used to determine annual snowmelt runoff, to calculate seepage losses from the main channel and diversions, to estimate infiltration in ponded areas, and to aid in flood-control studies. In addition, telemetry in the basin lets the INL facilities immediately assess storage and flow conditions in the Big Lost River. Hydrologic data for the network are available on the Web at *https://water.usgs.gov/nwis/*. In 2016, the USGS installed two new streamgages in the Little Lost River Basin to better track flow. USGS INL funds partially supported one of the gages in 2016. In 2017, other funding sources were found for the two upper gages in the Big Lost River basin and the gage in the Little Lost River basin.

Geologic Framework

The solid part of the ESRP aquifer beneath the INL is comprised of olivine tholeiite basalt flows, interlayered with thin wind- and water-borne sediment. Basalts and sediments were deposited in a subsiding basin over the past 10 million years. At the INL, subsidence, episodic emplacement of basalt flows, and sediment deposition resulted in a succession of basalt flows and sediment layers that range in total thickness from about 2,600 to 5,500 ft. Groundwater movement through the sediment is affected

by the amount and type of sediment that is present; fine-grained sediment generally impedes groundwater movement, and coarse-grained sediment may enhance groundwater movement. Groundwater movement through basalt is affected by the size and character of individual lava flows, as a series of thin flows allows water movement more readily than a thick, massive flow. The fractures at the tops, sides, and bases of basalt flows form interconnected networks (interflow zones) where most groundwater movement occurs. Sediment layers and dense, thick basalt flows can significantly impede groundwater movement.

In past years, borehole geophysical data (natural gamma logs) from 333 wells and lithological data from numerous cores were used to create a two-dimensional geologic framework for a variety of facility-scale and INL-scale hydrologic investigations. The stratigraphic information was used in 2006 to develop a conceptual geologic framework for the USGS groundwater-flow and contaminant-transport models. Key elements of the conceptual framework, including the location, extent, depth, and thickness of basalt flow groups that make up hydrogeologic units 1 and 2 (as defined in Ackerman and others 2006; DOE/ID-22198; and used in Ackerman and others, 2010; DOE/ID-22209) are, in places, uncertain.

The basalt-flow groups and sedimentary interbeds that make up hydrogeologic units 1 and 2 significantly affect groundwater flow and contaminant transport. To improve the geologic framework used in the conceptual and numerical models, the USGS recommends additional core drilling, rock core testing, and mapping and sampling of surface flow vents to trace them from the surface to the subsurface. The areas of greatest interest are between the Idaho Nuclear Technology and Engineering Center (INTEC) and the Radioactive Waste Management Complex (RWMC), east and west of the Central Facilities Area (CFA), and near the southern boundary of the INL. Three-dimensional modeling that incorporates paleomagnetic measurements, age dates, and other data from recently-cored wells is being used to better define the stratigraphy and hydrogeologic properties of the aquifer beneath the INL.

Hydrogeologic units were described using hydrogeologic zones in the current numerical flow models and are represented as homogeneous, anisotropic porous media. Small-scale heterogeneity is not represented, and particle plume simulations do not incorporate the effects of small-scale heterogeneities and anisotropies; the dispersion caused by these small-scale heterogeneities and anisotropies cannot be adequately represented. Dispersive effects can be modeled within the larger-scale model by using local grid refinement in areas affected by contamination if sufficient geologic and hydrologic data can be obtained. Improved understanding of the geologic framework, particularly in the areas affected by INTEC and RWMC contamination, will allow local grid refinement in those areas.

Nearly all ESRP olivine tholeiite basalts are so similar that they cannot easily be distinguished from one another without sophisticated quantitative analysis. Differences in paleomagnetic polarity and inclination, petrologic texture, mineral assemblages, and geochemical composition of the basalts are the chief means of differentiating individual basalt flows and basalt-flow groups. Absolute age dates are an additional tool to aid in differentiating basalt flows and basalt-flow groups. These differences are being used to evaluate and refine the geologic framework that was used to develop the USGS conceptual model of groundwater flow and contaminant transport.

Paleomagnetic Characterization of Basalt Stratigraphy

One of the more reliable and cost-effective means of differentiating and correlating basalt flows in the ESRP aquifer is to identify differences in the polarity and inclination of remnant magnetization present in the basaltic volcanic rocks. Although it is possible for basalts of different ages to have the same paleomagnetic signature because the orientation, strength, and polarity of the Earth’s magnetic field varies through time, the long-term sequence of secular variations of the Earth’s magnetic field are

known. Inclinations and polarities obtained from paleomagnetic experiments on basalt cores are used to correlate individual basalt flow units and basalt flows based on the vertical sequencing of magnetic polarity and inclination measurements. To obtain measurements for the ESRP aquifer at the INL, continuously cored boreholes that penetrate a substantial thickness of the subsurface are needed. Cores are usually sampled at intervals averaging 4 feet, depending on the location of flow tops and bottoms. Matches in the vertical sequencing of magnetic polarity and inclination are used to correlate basalt flows.

Since 1980, the paleomagnetic polarities and inclinations of cores from 56 shallow and deep boreholes have been measured, and most of the results were published in Champion and others, 2011 (DOE/ID-22214). The report indicates that the AEC Butte basalt-flow group, which was used to represent the massive hydrogeologic unit 2 and which was previously correlated over the entire model area, extends from AEC Butte (just north of the Advanced Test Reactor Complex (ATR Complex) east to borehole NPR W-02, south to the northern side of the CFA, and north to the Naval Reactors Facility (NRF). Champion and others, 2013 (DOE/ID-22223) found that the AEC Butte basalt flow group does not extend more than about a quarter mile north of the NRF where it abruptly terminates against an older, reverse polarity flow. The AEC Butte flows do not appear to extend to the CFA or into the southern part of the INL as previously indicated, so future model interpretation will need to be refined.

Basalt Radiometric Dating

Absolute ages of rocks can be obtained through Argon-40/Argon-39 ($^{40}Ar/^{39}Ar$) age experiments. The ages are obtained by comparing the ratio of argon derived from the decay of naturally occurring radioactive isotopes of potassium to that of other argon isotopes. In geologically young, low-potassium rocks like the olivine tholeiite basalts that make up most of the ESRP aquifer, it is difficult to obtain accurate age determinations. Previous age experiments have yielded mixed results, and error was often greater than 40 percent.

Recent research from Wright-Rieman Labs at Rutgers University has demonstrated improved techniques to reduce the amount of error in age dates (Turrin and others, 2008). In FY 2011, in an effort to identify individual basalt flows, Rutgers University was contracted to conduct twelve age experiments as part of a multi-year study. Results of that study were published in 2015 (Hodges and others, 2015; DOE/ID-22234). The age dates, along with paleomagnetic information will be used to better understand basalt flow stratigraphy in the southwestern part of the INL. The age and distribution of basalt flow groups in the subsurface could also be used to trace the development of the historic course of the Big Lost River, which could provide additional information on the sediment stratigraphy.

Subsurface Visualization

The USGS is using Rockworks™ software and GIS-linked maps and databases to construct the three-dimensional (3-D) geologic and hydrogeologic models for the INL and vicinity. Rockworks™ is a tool that provides visualization needed for a comprehensive approach to understanding and managing post-remediation issues at the INL. With these models, scientists can analyze georeferenced data, geologic structures, hydrologic properties of the media, groundwater-flow paths, and contaminant distribution in three dimensions. A 3-D model of the hydrogeologic framework, as implemented in the USGS numerical models of groundwater flow and contaminant transport, is complete (Ackerman and others, 2010; DOE-ID 22209). Paleomagnetic data is being added to a 3-D model of the basalt stratigraphy beneath the INL as new data become available.

Hydrochemistry

The hydrochemistry program at the INL has evolved over time to meet the needs of the DOE. The earliest studies were designed to evaluate the quality and availability of water for human consumption and the usability of the water for facility construction, cooling systems, and concentrated waste stream dilution. In response to this need, the USGS published a report (Olmsted, 1962; IDO-22043) describing the chemical and physical character of groundwater at the INL. This report defined different types of groundwater at the INL, the areal and vertical distribution of selected constituents and physical properties, and the temporal variations in water chemistry resulting from waste disposal.

Beginning in 1952, the introduction of waste constituents into the subsurface at the INL led to a need for information about the location and movement of wastewater contaminants in the ESRP aquifer and to the development of an early detection network for wastes moving past the INL boundaries. The result was an expanded water-quality monitoring network and the frequent publication of reports describing the hydrologic conditions at the INL. The most recent hydrologic conditions report was published in 2017 (Bartholomay and others, 2017; DOE/ID-22242).

Geochemical Modeling

The chemical and radiochemical constituents in groundwater at the INL are derived from natural and anthropogenic processes involving reactions between the solid, liquid, and gaseous phases. To define these reactions and their impact on contaminant transport, it is necessary to understand the natural geochemistry of the system. This includes understanding the geochemistry and geochemical evolution of source water to the aquifer at the INL. Source water includes infiltrating surface water and irrigation return flows, groundwater from tributary valleys, groundwater from the ESRP aquifer northeast of the INL, industrial-waste discharges, and geothermal water. The water from each of these sources has a chemistry that is related to the unique water-rock interactions and other processes that have taken place throughout its travel history. When these waters mix, the chemistry of water in the ESRP aquifer at the INL is affected. Several zones of mixing have been identified (Birch Creek Playa area, Little Lost River/Big Lost River Playa area, Big Lost River Channel/Big Lost River spreading area, and the southeastern INL throughflow area). As recharge waters mix with groundwater in these areas, the thermodynamic characteristics of the system change and cause reactions that further change the natural chemistry of the system. As this water moves in the ESRP aquifer at and downgradient of the INL, the water continues to be affected by the natural reactions of groundwater and the solid-phase matrix of the aquifer, by the characteristics of the groundwater flow system, and by the effects of waste disposal. To understand the chemistry of groundwater and the transport of wastewater in the system, the physical (evaporation, mixing) and chemical (chemical reactions) processes controlling the chemistry of groundwater need to be well understood.

The USGS has conducted numerous studies to compile the geologic and chemical information necessary to understand the chemistry of the water sources and the aquifer system. A report in 1974 (Robertson and others, 1974; IDO-22053) described the influence of liquid-waste disposal on the geochemistry of water at the INL, identified areas of recharge to the ESRP aquifer, characterized the chemistry of the recharge, and identified geochemical reactions controlling the chemical composition of the recharge water and water in the ESRP aquifer. Other studies conducted in the mid-1970s investigated the hydrogeochemistry of the unsaturated zone in order to understand the influence that this thick zone has on the movement of wastewater contaminants and the geochemistry of groundwater, including a better conceptualization of weathering reactions and geochemical processes occurring in the unsaturated zone. These studies included determining the (1) particle-size distributions of sediments; (2) mineralogy of

sediments and rocks; (3) isotopic composition of precipitation, soil water, organic material, and selected solid-phase materials; (4) ability of geologic materials to adsorb dissolved constituents; and (5) the chemical composition of infiltrating soil water.

Additional studies beginning in the late 1980s included solid-phase studies describing the mineralogy and chemistry of rocks, sediments, fracture- and vesicle-fill materials, and soil samples from the ESRP aquifer and the Big Lost River, Little Lost River, and Birch Creek drainages. The USGS also began collecting from the aquifer and drainages an expanded suite of water-chemistry data (major ions, dissolved trace elements, stable isotope ratios, radiochemical constituents, chlorofluorocarbons [CFCs], sulfur hexafluoride [SF_6]) and dissolved gas (O_2, Ar, Ne, He, N_2) from atmospheric precipitation, perched water, and groundwater. Results of these studies were used to describe the hydrochemical facies, thermodynamic properties, and plausible chemical reactions taking place in the ESRP aquifer at the INL (Knobel and other, 1997; DOE/ID-22139) and to describe the estimated age and source of the young fraction of groundwater at the INL (Busenberg and others, 2001; DOE/ID-22177).

Studies of the geochemistry of drainage basins providing recharge to the ESRP aquifer at the INL began in 1999. Studies conducted with Idaho State University include geochemical models of the Big Lost River, Little Lost River, Birch Creek, Medicine Lodge Creek, and Camas Creek drainages (Carkeet and others, 2001; DOE/ID-22174; Swanson and others, 2002; DOE/ID-22179; Swanson and others, 2003; DOE/ID-22188; Ginsbach, 2013; and Rattray and Ginsbach, 2014; DOE/ID-22227). In 2015, a study was completed on the geochemistry of the Mud Lake basin (Rattray, 2015).

Vertical Water-Quality Sampling

Water sampling from discrete zones from MLMS has allowed the USGS and contractors to better define the vertical variations in the ESRP aquifer as INL facility wastewater migrates and disperses in the aquifer system. MLMS sampling provides sample concentration variation with depth, resulting in a dataset that eliminates the vertical mixing component often observed under open borehole conditions. Through examination and continued data collection of fluid pressure (hydraulic head), temperature, and water chemistry, an evolving understanding of contaminant movement with changing fluxes from recharge sources can be applied to groundwater-flow models.

The data related to conservative tracers, selected radionuclides, and stable isotopes are useful for identifying the movement of water and wastes through the aquifer and the sources and ages of recharge for the zones isolated in these wells. For example, tritium concentrations in deep zones from several of the MLMS-instrumented wells indicate that groundwater and wastes travel to much greater depths than originally believed in the southwestern corner of the INL (Bartholomay and Twining, 2010). Stable-isotope ratios of strontium-87/strontium-86, sulfur-34/sulfur-32 and nitrogen-15/nitrogen-14, and carbon-13/carbon-12 (in conjunction with carbon-14) may provide information about sources of recharge, sources of contaminants, and ages of groundwater, respectively. Radionuclides such as chlorine-36 and iodine-129 may provide insight on vertical movement of water in the aquifer.

The vertical distribution of dissolved gases and CFC age dates would be useful for identifying travel times from recharge areas to the zones isolated in these wells. Similar data were used in a report (Busenberg and others, 2001; DOE/ID-22177) to estimate the age and source of young water in the aquifer. The results of that study indicated that many wells contained a mixture of younger and older water. A likely explanation for those results is that water from different zones mixed in the well because of open-borehole well construction. Four wells were sampled for dissolved gases and CFCs in 2006, but analytical results indicated that the samples were contaminated by excess modern air in the sample bottles. An alternative sample collection method that purges the air in the sample collection cylinders

with CO_2 was attempted in the summer of FY 2014, but it was unsuccessful. Therefore, age-dating water samples from MLMS will be limited unless new techniques for analyses are discovered.

Hydraulic Properties

Unsaturated Zone

In FY 1998, the USGS began to evaluate the unsaturated zone at the INL by quantifying groundwater flow and contaminant transport. Initial efforts focused on the possibility that sedimentary interbeds may either enhance or retard the spread of contamination. Extensive measurements of unsaturated hydraulic properties and bulk properties have been completed and published in four reports (Perkins and Nimmo, 2000; DOE/ID-22170; Perkins, 2003; DOE/ID-22183; Winfield, 2003; DOE/ID-22187; Perkins, 2008; DOE/ID-22207). Property-transfer models, which can predict the hydraulic properties of INL sediments from more easily measured bulk properties, have subsequently been developed and tested using these data. The results were published in two reports (Winfield, 2005; DOE/ID-22196; Perkins and Winfield, 2007; DOE/ID-22202). The hydraulic property measurements and property-transfer models provide a firm foundation for large-scale simulations of water and contaminant transport at the INL using conventional numerical models based on diffuse flow theory. In recognition of the importance of preferential flow through the fractured basalts at the INL, efforts in FY 2010 shifted toward evaluating correlations among perched-well water levels, weather, and fluctuating inputs at the land surface to assess the sensitivity of water movement to preferential-flow behaviors. Because complex preferential-flow behaviors are not typically considered in conventional flow models, parallel efforts have also focused on establishing means for incorporating preferential flow into conceptual and numerical models of contaminant transport. Preliminary work with a source-responsive model demonstrates that a simple approach can be applied to quantify the effects of preferential flow at the INTEC. Water-level analysis and modeling work demonstrates the potential utility of the approach, which is summarized in two reports (Mirus and others, 2011; DOE/ID-22216; Mirus and Nimmo, 2013).

Saturated Zone

The USGS recognizes that revisions to groundwater-flow and contaminant-transport models require reasonable hydraulic property estimates acquired through aquifer testing and/or geophysical methods. Futhermore, incorporation of hydraulic head and temperature data (MLMS data) in groundwater-flow and contaminant-transport models will provide a valuable dataset to help explain how key geologic features such as sediment layers and layers of dense basalt affect the flow and direction of groundwater within the ESRP aquifer. The current MLMS dataset extends through wet and dry water years, and will be used to examine episodic events, such as surface-water flow in the Big Lost River, to better quantify groundwater recharge from surface-water sources, a potential mechanism for contaminant mobilization in the unsaturated zone.

The USGS continues to collect independently derived hydraulic-property estimates through examination of aquifer test data, MLMS hydraulic head data, and geophysical logging. New techniques are being employed to estimate hydraulic properties of discrete fracture networks using analytical techniques developed by the USGS Branch of Geophysics. The USGS continues to make hydraulic testing and geophysical logging a high priority as new boreholes are drilled at the INL. These hydraulic-property estimates are valuable for model testing and validation.

Groundwater-Flow and Contaminant-Transport Models

The DOE and the State of Idaho need a thorough understanding of the movement and fate of contaminants in the ESRP aquifer is needed by the DOE and the State of Idaho to minimize health and safety risks and to effectively plan for remediation should this become necessary. To achieve these goals, the groundwater-flow and contaminant-transport models are being used to determine the long-term risks associated with contaminants that are present in the aquifer today or that might be present in the future from additional, slow releases of residual contamination. The models will also be used to determine the risk of groundwater contamination associated with site selection and operation of future nuclear research facilities.

Present Groundwater-Flow and Contaminant-Transport Models

The present groundwater-flow and contaminant-transport models are based on a conceptual model that identifies the important features, processes, and events controlling fluid flow and contaminant movement in the aquifer (Ackerman and others, 2006; DOE/ID-22198). The conceptual model represents a qualitative description of how water and contaminants move through the aquifer. It encompasses an area of 1,940 mi^2 and includes most of the INL's 890 mi^2. The subregional scale of the conceptual model is intermediate in size between that of the groundwater-flow model that was developed by the USGS in 1992 as part of its Regional Aquifer System Analysis of the ESRP aquifer (10,800 mi^2) (Garabedian, 1992) and that of the local INL facility-scale models (less than about 10 mi^2). The ESRP aquifer is represented in the conceptual model as an equivalent porous media with non-uniform properties.

Numerical models derived from the conceptual model provide quantitative estimates of hydraulic properties and head, flow paths, travel times, and contaminant-plume migration throughout the modeled aquifer. Two types of 3-D flow models have been developed: (1) a steady-state model that assumes inflows into the aquifer equal outflows and that there are no time-dependent changes in aquifer storage or changes in the direction and velocity of water movement; and (2) a transient model that allows water inflows and outflows to vary in response to short- and long-term changes in climate or water-use patterns resulting in an increase or decrease in aquifer storage and changes in the direction and velocity of water movement. A report describing these flow models (Ackerman and others, 2010; DOE/ID-22209) was published in FY 2010. The steady-state flow model was calibrated to 1980 water-table elevations (or hydraulic heads) that were assumed to approximate steady-state conditions based on water-level observations made between 1949 and 1996. The transient model was calibrated to seasonal changes in water-table elevations accompanying a long wet cycle from 1982 to 1986, followed by a long dry cycle from 1987 to 1994.

Particle-tracking simulations were used to model the growth of tritium plumes that originated from two INL facilities over a 16-year period under steady-state and transient flow conditions (1953-68). The distance downgradient of the facilities where simulated particle plumes were able to reasonably reproduce the 1968 tritium plume extended only to the boundary separating sediment-rich from sediment-poor aquifer layers about 4 miles downgradient of the contaminant source. Particle plumes simulated beyond this boundary were narrow and long, and they did not reasonably reproduce the shape, dimensions, or position of the leading edge of the tritium plume; however, few data were available to characterize its true areal extent and shape. Model-derived groundwater velocities downgradient of the INTEC were generally faster than independently derived estimates.

An evaluation of the numerical models was conducted to determine whether model-derived estimates of groundwater movement are consistent with results from previous studies on water chemistry type and independently derived estimates of the average linear groundwater velocity. Simulated steady-state flow fields were analyzed using backward particle-tracking simulations. The results of the evaluation indicated several shortcomings in the way the model represented flow in the aquifer. Model inconsistencies can be attributed to large contrasts in hydraulic conductivity between hydrogeologic zones and (or) a short-circuiting of underflow from the Little Lost River valley to an area of high hydraulic conductivity. Agreement between velocity estimates was good at wells with travel paths in areas of sediment-rich rock and poor in areas of sediment-poor rock. The model's over-prediction of groundwater velocities in sediment-poor rock may be attributed to large contrasts in hydraulic conductivity and a very large, model-wide estimate of vertical anisotropy. A report describing the evaluation of the numerical models (Fisher and others, 2012; DOE/ID-22218) was published in FY 2012.

Site Support Services

The USGS provides on-call video and geophysical-logging services to DOE contractors and core-sampling and analysis support to contractor personnel and local and national researchers.

Borehole Logging

Geophysical and video logging services provided by the USGS are used to support borehole construction and instrumentation, well-maintenance, unsaturated- and saturated-zone monitoring, and interpretative studies to characterize the geologic and hydrologic controls on water movement in the vadose-zone and the ESRP aquifer beneath the INL. When required, logging services are available on a twenty-four hour, seven-day-per-week basis. To provide this service, the USGS maintains eleven geophysical logging tools, a support van for mobilization, downhole video equipment, logging computer and software (Century™ and WellCAD™), and a logging draworks system. Current borehole geophysical logging tools include neutron, gamma-gamma (density), natural gamma, three-arm caliper, gyroscopic deviation, magnetic deviation, temperature, fluid resistivity (specific conductance), electromagnetic flowmeter, acoustic televiewer, spontaneous potential, and multi-point resistivity. Current video logging capabilities include black-and-white and high-resolution color video with side-view features. Annually, the USGS produces about 25 geophysical and video log files, either at the request of the INL contractors during drilling and well-maintenance, or to support the USGS Geohydrologic Studies and Monitoring Program.

Geophysical logging and analyses continue to be used to evaluate how basalt flows and sediment affect groundwater flow and contaminant transport. The caliper logs provide data about fracture locations in basalt, areas of competent basalt, and cavernous zones. Natural gamma logs provide information about stratigraphy and are used at the INL to identify sediment layers and basalt flows with varying potassium-40 content. Gamma-gamma logs provide information about the density of rock and sediment units. Neutron logs support understanding of stratigraphic change in rock and sediment units and approximate saturated formation porosity. Electromagnetic flow meter data suggest flow direction and can also be used to approximate hydraulic properties. Acoustic televiewer logs determine the preferential orientation and frequency of fractures along a borehole wall; additionally, the acoustic caliper log provides detailed change in borehole diameter, not always captured in 3-arm caliper data. Fluid resistivity is useful for determining the location of groundwater chemical changes and to suggest areas where the aquifer is stratified. Gyroscopic and magnetic well deviation surveys are used to assess

borehole deviation and to determine adjustments to water-level measurements based on survey data. The USGS INL Project Office improves its capacity to perform both video and geophysical logging through training, calibration, equipment upgrades, and collaboration with geophysical logging units within the larger USGS.

Radioactive-source logging (neutron and gamma) conducted by the USGS INL Project Office requires a Radioisotope Utilization Permit. This permit is administered by the USGS radiation safety committee in Denver, CO under a license issued by the Nuclear Regulatory Commission (NRC). Annual audits of the logging program and annual re-certification of logging personnel are required to meet NRC, U.S. Department of Transportation, and DOE regulations to handle radioactive sources. Three USGS INL Project Office employees are certified to conduct radioactive-source logging.

Lithologic Core Storage Library

The INL Lithologic Core Storage Library (Core Library), operated by the USGS, was established by the DOE in FY 1991 as part of the INL Environmental Restoration Program. The Core Library provides a centralized area to store, examine, and sample drill core. Core samples are used for site-wide and site-specific characterization of the subsurface in support of the USGS and INL contractor groundwater-flow and contaminant-transport modeling and the construction of new facilities. By examining and (or) analyzing core samples, a 3-D representation of basalts and sediments in the subsurface can be developed. Modelers use this information to refine model input of the geologic framework, to improve the conceptual model of groundwater flow and contaminant transport, and to improve the numerical model output simulations. Additionally, detailed subsurface information will support future facility-scale 2-D and 3-D groundwater-flow and contaminant-transport modeling. Cores are also used by the scientific community (including university faculty and students, researchers from state agencies, and other national laboratories) to investigate geologic and hydrologic aspects of the evolution of the ESRP.

Approximately 67,000 feet of drill core and 9,000 feet of drill cuttings are stored in the Core Library and Annex. We anticipate that 8,000-15,000 feet of additional core will be collected in the next 5-10 years as part of the subsurface characterization and remediation at the INL. The Core Library includes a laboratory equipped with standard rock and sediment processing equipment for use by USGS, DOE, and contractor personnel.

By FY 1999, the original core storage space capacity was exceeded, and additional space was identified and prepared at the CFA to permit interim core storage expansion (Core Library Annex). Since 1999, the main Core Library and Annex have exceeded their capacity twice. In 2011, additional space in the existing Core Library Annex was identified, pallet racks were installed, and the overflow cores were transported from the main Core Library to this space in early FY 2012; that space has again been filled. The USGS requested more space from DOE in FY 2015 and received and moved into the space in FY 2016. The new space located in Building CF-674 should allow for new cores to be housed for at least the next 5-10 years.

Core information is stored in paper and digital files at the Core Library. Various types of documentation are available for each core, depending on the purpose for which it was drilled. The following information is also documented:

- location and unique identifier for the well or borehole from which the core was obtained;
- altitude of the land surface at the well or borehole;
- interval cored;

- general rock types included in the core;
- parts of a core that have been destructively analyzed;
- radiological surveys (if performed);
- Chain of custody;
- record of the types of analyses that have been performed on selected sections of the core; and
- references to the publication in which analyses are contained when identified.

Starting in late FY 2003, the USGS developed a standardized procedure to digitally catalog core data, to produce lithologic, geophysical, and geochemical logs, and to produce high-resolution core photographs. The procedure is designed to maximize description and to minimize interpretation of core features, because those who have an interest in the cores/data will make their own interpretations for the purpose of their research. The procedure was developed with the intent that USGS summer employees with some geologic experience would be able to follow the guidelines to produce core logs consistent with those previously produced. Funding cuts in 2013 have not allowed this service to continue as part of our task plan; however, several recent cores have been logged with funding from other sources.

The ultimate goal of cataloging core data was to allow researchers access to the logs and data via the Internet in a practical, clear, timely, and scientifically accurate manner. Much of the data presented will guide researchers as to what subsurface features occur at and near the INL. This publicly available information also will reduce the time necessary for Core Library personnel to respond to information requests by researchers. In 2008, the USGS published a data series report of the lithologic and geophysical logs, core descriptions, photos, and associated data for 10 coreholes at the INL (Twining and others, 2008; DOE/ID 22205). A second data series report with similar data for 7 additional coreholes at the INL was published in FY 2012 (Hodges and others, 2012; DOE/ID-22217). From 2012 to 2017, three scientific investigation reports and one Data Series report were published that described the data collected from three coreholes near the ATR Complex; two coreholes near TAN; and one corehole west of NRF. Report results included core logs, geophysical logs, water-quality sampling and the results of single-well aquifer tests (Twining and others, 2012; DOE/ID 22220; Twining and others, 2014; DOE/ID 22229; Twining and others 2016; DOE/ID 22239; Twining and others 2017; DOE/ID 22243).

Databases

The USGS INL Project Office maintains several databases, both locally and nationally, to ensure the integrity and availability of the site schedule, geophysical-log, water-level, and water-quality data it collects.

Site Schedule Database

Since 1949, the USGS has provided and continuously updates well-site data including general site information, construction, and maintenance records that are the foundation to all database activity within NWIS and Log Archiver. The USGS routinely provides well-site data to DOE contractors for inclusion in the Environmental Data Warehouse (EDW), a site-wide INL database. The USGS has opened NWIS to the public through a Web interface. This website provides access to and retrieval of USGS site information from the INL through a menu-driven or a map interface. The address for this site is *https://water.usgs.gov/nwis/*.

Geophysical-Log Database

Since 1957, the USGS has collected video and (or) geophysical logs for over 500 wells. With changes in technology, the USGS has modified how video and geophysical log data are archived. Video files are being converted to digital format and stored on a USGS external hard-drive system. In 2000, a national policy to archive borehole-geophysical logs was established by the USGS Office of Groundwater Technical Memorandum 00.03. Since that time, the Log ASCII Standard has become the accepted format for storage and transmittal of log data in the geophysical and groundwater science community. The USGS INL Project Office, however, continues to preserve the original geophysical log files (LOG format). Additionally, log files collected at the INL are reviewed for content and then converted to Log ASCII Standard file format for archiving on the USGS server space and on USGS GeoLog Locator (https://webapps.usgs.gov/GeoLogLocator/#!/) Video and geophysical logs support borehole and well construction, well maintenance, borehole instrumentation, unsaturated- and saturated-zone monitoring, and special INL studies.

As newer and more advanced logging tools become available, the video and geophysical-log database has grown significantly with the addition of new boreholes and the systematic re-logging of existing boreholes. We project logging activities to continue at about the same manpower level for the next several years. We are distributing new logging data to the database, however, populating older logging files will be limited because of manpower availability. The USGS routinely provides video and geophysical-log updates to DOE contractors for inclusion in the EDW.

Water-Level Database

The USGS has monitored water levels at the INL since 1949, and it currently (2017) measures 213 aquifer or perched wells. Water levels are measured annually, semi-annually, quarterly, monthly, or continuously. All wells are measured annually in either March or April. Monthly water-level measurements and continuous water-level measurements using data recorders at selected sites document water-level changes throughout the year. The USGS maintains eight continuous data recorders in wells at the INL. Two of these, USGS 1 and 21, are instrumented with telemetry and transmit real-time water-level data. These data are used to develop and refine groundwater-flow and contaminant-transport models.

All water-level data, including the real-time data and data collected as part of USGS studies at the INL, can be found in NWIS, a publicly available Web interface. This system permits the public electronic access to and retrieval of USGS water-level data, including water-level data from the INL. The address for NWIS Web is *https://water.usgs.gov/nwis/*. The USGS data is electronically downloaded to DOE contractors for inclusion in the EDW.

Water-Quality Database

The USGS has collected water-quality data at the INL since 1949 using USGS water-quality sampling and analytical procedures. Currently (2017), samples are collected from 145 groundwater sites and 7 surface-water sites. About half of these samples are collected in April and half in October. The USGS INL Project Office maintains all of the original records and performs quality-assurance checks on the data. These data are used to define the areal location of contaminant plumes and to monitor the migration of contaminants in the aquifer. Data from the MLMS are being used to investigate the 3-D distribution of contaminants to better understand contaminant movement in the aquifer. Water-quality data also are used to calibrate numerical contaminant transport models. Federal, State, and local agency

managers as well as contractors and private citizens use the data for resource management, regulatory compliance, scientific investigation, and environmental reporting. USGS personnel use the information to prepare data and interpretive reports on water-quality issues.

Two accredited laboratories routinely analyze water-quality samples collected at the INL. Samples for chemical analyses are sent to the USGS National Water Quality Laboratory (NWQL) in Lakewood, CO, and samples for radionuclide analyses are sent to the DOE Radiological and Environmental Sciences Laboratory (RESL) at the INL. The NWQL results are automatically entered into the NWIS database as the samples are analyzed. USGS INL Project Office personnel enter field data parameters and the analytical results from RESL into the NWIS database after each sampling event. The data become publicly available after they are reviewed by USGS INL Project Office personnel. This database is accessible to the public at *https://water.usgs.gov/nwis/*.

Publications

Part of the annual budget for the USGS INL Project Office supports the preparation of hydrologic-data reports and interpretive reports. Data reports provide documentation of field conditions at the INL and include groundwater-level measurements, water-quality analyses, streamflow measurements, and other site information needed to document hydrologic conditions. Interpretive reports are prepared to describe the geohydrologic conditions at the INL and how those conditions affect, control, or interact with the ESRP aquifer, perched-water bodies, chemical- and radiochemical-contaminant migration, and the geochemical processes in the subsurface. Reports published by the USGS are provided to the DOE and its contractors; other Federal, State, and local agencies; and the general public. The data and interpretive reports provide information that is critical to the long-term management and use of the ESRP aquifer by the INL and the State of Idaho. Reports planned for submittal to DOE in FY 2018 for cooperator review or planned for release are described in table 1. Reports that were published during FY 2017 are shown in table 2. Future report topics for drafts started in 2018 or beyond are given in table 3. Published reports are available on the Internet at *https://pubs.er.usgs.gov/* or can be accessed through the USGS INL Project Office website at *https://id.water.usgs.gov/INL/Pubs/index.html*. Reports also are available in PDF and (or) paper format and are available upon request from the USGS INL Project Office.

Table 1. USGS reports planned for DOE review or release to the public during FY 2018

Topic	Title	Milestone date to DOE	Status
Hydrochemistry	Groundwater geochemistry in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, eastern Idaho: Implications for hydrology and hydrogeology.	09/2017	Response to peer review
Core storage library	Updated procedures for using drill cores and cuttings available for study at the Lithologic Core Storage Library, Idaho National Laboratory, Idaho.	09/2017	Preparation of draft report.
Geologic Framework	Correlation of basalt flows with chemical constituents in selected wells influenced by wastewater disposal in the Southwestern part of the Idaho National Laboratory, Idaho.	10/2017	In peer review.
Hydrologic monitoring	Optimization of water-quality monitoring networks in the eastern Snake River Plain aquifer at the Idaho National Laboratory, Idaho.	12/2017	Preparation of draft report.
Hydrologic monitoring	Completion summary for borehole TAN-2312 at Test Area North, Idaho National Laboratory, Idaho.	07/2018	Preparation of draft report.
Geologic Framework	Geologic map for Butte City 7.5’ topographic quadrangle.	07/2018	Preparation of draft map.
Hydrologic monitoring	Field methods and quality-assurance plan for water-quality activities and water-level measurements, U.S. Geological Survey, Idaho National Laboratory, Idaho	07/2018	Not started.
Hydrologic Monitoring	Transmissivity of the eastern Snake River Plain aquifer at the Idaho National Laboratory, Idaho.	08/2018	Preparation of draft report.
Hydrochemistry	Geochemical evolution of groundwater in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory.	09/2018	Preparation of draft report.

Table 2. USGS, Idaho Water Science Center, INL Project Office reports published in FY 2017

Topic	Title	Publisher	Access
Hydrologic monitoring	Borehole deviation and correction factor data for selected wells in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, Idaho.	USGS	*SIR 2016-5163 (DOE/ID 22241)* https://doi.org/10.3133/sir20165163
Hydrologic monitoring	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.	USGS	*SIR 2017-5021 (DOE/ID 22242)* https://doi.org/10.3133/sir20175021
Hydraulic properties	Preferential flow, diffuse flow, and perching in an interbedded fractured-rock unsaturated zone.	Hydrogeology Journal	https://doi:10.1007/s10040-016-1496-6
Hydrologic monitoring	Drilling, Construction, Geophysical log data, and Lithologic log for Boreholes USGS 142 and USGS 142A, Idaho National Laboratory, Idaho.	USGS	*Data Series 1058 (DOE/ID 22243)* https://doi.org/10.3133/ds1058

Table 3. USGS reports planned for publication in future years

Topic	Working Title	Status
Hydrologic monitoring	Multilevel groundwater monitoring of hydraulic head and temperature in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho 2014-15.	Not begun.
Hydrologic monitoring	Multilevel groundwater monitoring of hydraulic head, temperature, and water chemistry in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho 2016-18.	Not Begun.
Hydologic monitoring	Iodine-129 in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, 2017-18.	Not begun.
Hydrologic monitoring	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.	Not begun.
Hydrochemistry	Geochemistry of multiple levels of the eastern Snake River Plain aquifer in the southwestern part of the Idaho National Laboratory, Idaho.	Not begun.
Hydrochemistry	Reactive-transport model of water from the central and southwestern part of the Idaho National Laboratory, Idaho.	Not Begun.

Hydrochemistry	Sources of water and mixing ratios for the eastern Snake River Plain aquifer at the Idaho National Laboratory using sulfur isotopes.	Not Begun.
Hydrochemistry	Mixing ratios of groundwater influenced by the Big Lost River, Idaho National laboratory, Idaho.	Not begun
Groundwater-flow and Contaminant-transport Models	Comparative analysis of hydraulic conductivity determinations for a fractured basalt and sediment aquifer.	Not begun.
Groundwater-flow and Contaminant-transport Models	Recalibrated models of groundwater flow and advective transport, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho.	Not begun.
Geologic framework	Paleomagnetism of surface vents and flows in the southwestern part of the Idaho National Laboratory correlated to subsurface well information.	Not begun.
Geologic framework	Inferred isopach maps and estimated eruption volumes for selected subsurface basalt flows, southern Idaho National Laboratory, Idaho.	Not begun.
Geologic framework	Paleomagnetic correlation of basalt flows in the central part of the Idaho National Laboratory, Idaho.	Not Begun.
Geologic framework	Paleomagnetic correlation of basalt flows and surface vents near the Test Area North, Idaho National Laboratory, Idaho.	Not Begun.

In FY 2006, the USGS implemented a nationwide program to consolidate and streamline its editorial review and reports publication process through the establishment of regional publishing service centers. The USGS INL Project Office is serviced by the Publishing Service Center in Tacoma, WA. This center provided editing, illustration, manuscript preparation, and electronic publishing support on a fee-for-service basis until FY 2016. Starting in FY 2016, the USGS Idaho Water Science Center was assessed a charge based on the average of its last three years of use, including use by the INL Project Office.

Technical Support and Outreach

As part of the general scope of the Interagency Agreement in support of characterization studies at the INL, USGS INL Project Office staff provide technical support to DOE and its contractors as well as outreach to the scientific community and the general public. A summary of FY 2016 and FY 2017 technical support and outreach activities is shown in table 4 as an example of activities to expect in FY 2018.

Table 4. Examples of technical support and outreach FY 2016/2017

Category	Activity	Topic: *Title*
Symposium	Pacific Northwest National Association of Geoscience Teachers (NAGT) Symposium, Idaho Falls, ID, June 2017.	Presentations: Overview of the hydrologic conditions of the ESRP aquifer at the INL; Subsurface stratigraphic architecture of the ESRP aquifer at INL; Led INL field trip stops at well 131A, Big Lost River, and core library.

Conference	Idaho Water Quality Workshop: Boise, ID, Feb 2017.	Presentations: Evaluating background concentrations of selected chemical and radiochemical constituents from the ESRP aquifer; Geochemistry of the INL.
Conference	R-user group conference, Stanford University, June 2016.	Presentation: Groundwater flow model reproducibility using R.
Conference	Tobacco Root Geological Society Field Conference, Heise, Id, July 2016.	Field Trip: Volcanic geology, hydrogeology, and geothermal potential of the eastern Snake River Plain.
Conference	USGS National Groundwater Workshop, August 2016.	Presentations: Water quality trends at INL; Reproducible model building; INL multilevel chemistry, pressure, and temperature.
Conference	USGS Data Conference, Spokane, WA, August 2017.	Presentations: INL Geophysical logging capabilities; Recent hydrologic conditions of the ESRP aquifer at INL; Updates on Log Archiver.
Community outreach	Idaho Falls Earth Day celebration, April 2016; 2017.	Hosted a booth on USGS science at the INL.
Community outreach	Menan elementary 4th grade presentation, April, 2016.	Water cycle.
Community outreach	Menan elementary 3rd and 5th grade presentation, May 2017.	Water cycle and rocks and minerals.
Community outreach	Idaho Science, Technology, Engineering and Math (I-STEM) Science Fair judging.	USGS employee served as a judge.
Community outreach	Idaho Science, Technology, Engineering and Math (I-STEM) Science Fair judging.	USGS employee served as a judge.
Community outreach	Idaho Science, Technology, Engineering and Math (I-STEM) teachers workshop, June 2016; 2017.	USGS groundwater sampling at INL well.
Community outreach	Idaho Science, Technology, Engineering and Math (I-STEM) teachers workshop, August 2017.	USGS presentation on education materials, careers and work at the USGS.
Training	Brigham Young University geology class, February 2016.	USGS geologist did a presentation and class exercise on core identification.
Training	DOE Facility Representatives training, September 2017.	Presentation on recent hydrologic conditions of the ESRP aquifer at the INL.
Technical Support	DOE Monitoring and Surveillance Committee.	Attendance and participation.

Technical Support	DOE Federal Employee Occupational Safety and Health Council.	Attendance and participation.
Technical Support	INL Land Use Committee.	Attendance and participation.
Technical Support	INL Water Committee.	Attendance and participation.
Technical Support	Distribution of data and information to site contractors, governmental agencies, universities, and the general public as requested.	FY 2016: responded to 78 requests for information and data; during the first 3 quarters of FY 2017 responded to 74 requests for information and data.
Technical Support and review	INL Site Environmental Monitoring Plan Reports, 2015 and 2016.	USGS provides data and technical review of the annual report.
Review	Idaho Water Science Center quarterly project reviews: Boise, ID, 2016, 2017.	INL staff presents ongoing project work to Idaho Water Science Center Leadership.
Review	2015, 2016 INL water use report and comprehensive well inventory 05/2016, 2017.	Reviewed draft contractor reports.
Meeting	Monitoring and Surveillance Committee, January 2016; 2017.	Presentation: USGS INL 2016 and 2017 Program overview.
Meeting	INL Water Committee Meeting; November 2015.	Presentation: USGS INL water quality trends.
Meeting	INL Water Committee Meeting, March 2016.	Presentation: Pressure, temperature, and water chemistry for eleven multilevel monitoring systems at the Idaho National Laboratory.
Meeting	INL Water Committee Meeting, November2016.	Presentation: Background concentrations of selected chemical and radiochemical constituents in water from ESRP aquifer at INL.
Meeting	Idaho American Water Resources Association Meeting, March 2016.	Presentation: Water quality trends at the INL.
Meeting	INL Citizens Advisory Board meeting, April 2016.	Presentation: Hydrologic conditions of the eastern Snake River Plain aquifer, Idaho National Laboratory and Magic Valley, Idaho.
Meeting	INL Citizens Advisory Board meeting, October 2016.	Presentation: Multiport monitoring systems-Looking at the Aquifer in 3-D.

2. FY 2018 Activities and Deliverables

This section outlines activities planned for the FY 2018 and defines specific deliverables to DOE in the form of data collected and entered into USGS databases. The deliverable milestones are summarized in table 5. Milestones for reports that use the data are given in table 1.

Table 5. Milestones and deliverables for FY 2018

Category	Deliverable/Activity	Date
Hydrologic monitoring		
Water Quality	INL water-quality sampling, first quarter, FY 2018 (Multiple analytes from approximately 77 groundwater and surface-water sites). Drawdown measurements for aquifer wells.	11/15/2017
Water Quality	INL water-quality sampling, third quarter, FY 2018 (Multiple analytes from approximately 75 groundwater and surface-water sites).	05/15/2018
Water Quality	INL water-quality sampling, FY 2017 (Multiple analytes from about 20 sample zones in 11 boreholes instrumented with multi-level monitoring systems).	09/30/2018
Water Level	Monthly, quarterly, semi-annual, and annual water-level measurements (more than 725) in approximately 213 wells, with continuous recorders on selected wells.	09/30/2018
Water Level	INL water-level and temperature measurements, annual and quarterly, FY 2018 (measure temperature and pressure profiles at 11 boreholes equipped with multi-level sampling systems).	12/31/2017 03/31/2018 06/30/2018 09/30/2018
Surface water	Operate streamgaging stations on the Big Lost River and Antelope Creek, provision for real-time streamflow data; data presented on USGS National Water Information System website.	09/30/2018
Maintenance	Well maintenance, rehabilitation, and repair; removal and replacement of pumps in about 3 wells in FY 2018; maintenance of physical and environmental security.	09/30/2018 and as required.
Reports	Milestone for reports are given in table 1.	See table 1.
Geologic framework		
Evaluation	Complete USGS 145 and 147 as water monitoring wells.	09/2018

Evaluation	Characterize the paleomagnetic properties of INL cores from USGS 145 and 147 and cores from surface flows to evaluate stratigraphic and structural controls on groundwater flow at the INL.	09/2018
Development	Develop GIS coverages of stratigraphic and hydrogeologic data.	As required.
Evaluation		
Groundwater-flow and contaminant-transport models	Use geochemical modeling to evaluate water reactions in wells from the INL.	In progress.
Development	Recalibrate subregional flow model after improvements to parameterization of hydraulic conductivity.	In progress.

Geohydrologic Studies and Monitoring

Horizontal and vertical migration of solutes in the subsurface and the resultant dispersion, dilution, sorption, and radioactive decay are a result of complex physical and chemical processes that need to be evaluated by continual water-quality monitoring. Similarly, stresses on the geohydrologic system must be evaluated and monitored to describe the temporal variation in processes and to estimate the sensitivity of waste migration to natural conditions.

Work is continuing in FY 2018 on a comprehensive, long-range study to better understand groundwater flow and contaminant transport in the ESRP aquifer. Several generalized assumptions in the previous models are being quantified using data that were collected from the 1950s to the present. The assumptions include the:

- amount and timing of potential recharge to the aquifer from the infiltration of streamflow;
- geologic framework of the ESRP aquifer;
- hydraulic characteristics of the aquifer; and
- geochemical processes.

Further defining these four assumptions will provide a more accurate representation of the processes taking place in the aquifer and how those processes affect the distribution and migration of radiochemical and chemical contaminants in the aquifer from past and future waste-disposal practices.

Hydrologic Monitoring

Hydrologic monitoring includes collecting water samples from monitoring wells, wells instrumented with MLMS, and surface-water sites; water-level measurements from monitoring wells and MLMS installations; and streamflow discharge measurements from the Big Lost River and Antelope Creek. In addition, monitoring includes the work required to install new monitoring wells and to maintain the current USGS monitoring well network. In FY 2018, the USGS will continue monitoring as described in the INL Groundwater Monitoring Plan (U.S. Department of Energy, 2012) and will evaluate data needs for the future water-level and water-quality sample programs. To better determine which wells to

sample, in FY 2016 the USGS started developing a management tool that uses measures of correlation and iterative thinning to optimize the water-quality monitoring network; that is, to determine which wells or constituents to exclude from the monitoring network because they add little or no beneficial information and to determine the sampling frequency at each of the remaining wells. The management tool will be used to revamp the existing water-quality program, potentially reducing both the number of sites and the frequency of sample collection. A report documenting this effort was started during FY 2016 with the goal of publishing it in FY 2018 (table 1). Results from this study will be used to revise our future water sample schedule that we plan to revise and publish in our updated quality assurance plan, which is scheduled for review in late FY 2018 (Table 1).

During the summer of 2016, wells at the INL recorded new record-low water levels based on up to 67 years of record. During 2017, water levels were expected to rise because of above-average precipitation and flow in the the Big Lost River. We will continue to evaluate our water-level monitoring program by applying corrections from newly derived deviation corrections published in the 2016 report (Table 2) and revised tape calibrations performed by our Hydrologic Instrumentation Facility.

We plan to core and drill one new well in FY 2018 and to complete the current well being cored (USGS 145). The new well (USGS 147) will be drilled and completed as a monitoring well to monitor aquifer conditions southwest of the CFA. The well completion at this location will provide the USGS with additional information on the geologic and hydrologic properties in the southwestern part of the INL. The location also ties in with the area of the aquifer where more data are needed to improve the groundwater-flow and contaminant-transport models.

During FY 2018, the USGS will collect data to describe the hydrologic and hydrochemical conditions at the INL, and to evaluate effects of waste disposal and other activities on the geohydrologic system (milestone deliverables are given in table 5). Much of the data will be used to prepare interpretive reports. The following data will be collected in FY 2018:

- About 152 water samples will be collected from 145 deep and shallow wells and 7 surface-water sites. The groundwater samples will be analyzed for selected chemical and radiochemical constituents to aid in defining contaminant plumes and water chemistry. On the INL, surface-water samples from the Big Lost River will be collected and analyzed to determine the effect that surface-water flow has on the chemistry of groundwater beneath the INL. Samples also will be collected from tributaries upstream of the INL to characterize the chemistry of water flowing onto the INL. The water samples will be analyzed by the DOE RESL for radiochemistry and by the USGS NWQL for organic and inorganic constituents.
- During June and July 2018, water samples will be collected from selected zones in 11 MLMS wells (Middle 2050A, Middle 2051, USGS 103, 105, 108, 131A, 132, 133, 134, 135, and 137A). These samples will be analyzed by the RESL and NWQL for selected radiochemical and chemical constituents. Data from these analyses will be used in conjunction with particle-tracking techniques to evaluate the USGS models of groundwater flow and contaminant transport and to identify vertical variations in water chemistry. During FY 2016, the USGS and site contractor, Fluor, founsome unexpected volatile organic compound (VOC) results for the compound tetrachloroethene (PCE) in all 5 zones of the Middle 2051 MLMS. Follow-up sampling of the internal fluid found it to be contaminated. In 2017, the USGS assisted Fluor in sampling some of the wells and will continue to work with Fluor to try to determine the source of the PCE in 2018.

- In FY 2012, the USGS initiated a study to use a kriging-based genetic algorithm methodology to optimize the water-level monitoring network (Fisher, 2013; DOE/ID-22224); that is, to determine which wells to exclude from the monitoring network because they add little or no beneficial information. The management tool was used to revamp the existing water-level program, reducing both the number of sites and the frequency of measurements, highlighting two locations where more information was needed (wells USGS 142 and 143). About 650 depth-to-water measurements in approximately 213 wells will be made during 2018 to denote changes in storage and hydraulic gradient in the ESRP aquifer and perched-water systems. Operation of eight continuous recorders will detect short-term water-level fluctuations and identify recharge events. Quarterly pressure and temperature profiles will be measured in three MLMS wells (Middle 2050A, Middle 2051, and USGS 137A). Eight other MLMS wells (USGS 103, 105, 108, 131A, 132, 133, 134, and 135) will be measured during June/July to further evaluate changes to the aquifer. Results of these measurements will be used to define vertical variations in hydraulic head and temperature and to test and evaluate the USGS groundwater-flow model.
- Water year 2017 resulted in good recharge to the ESRP aqufer at the INL. Past abundant recharge years have shown that some constituents increase, possibly because of movement of past constituents that have remained in the unsaturated zone around site facilities. The USGS has periodically collected samples for iodine-129; given that 2017 was a large recharge year, funding was put into place in 2017 to collect samples in FY 2018. Samples from 30 wells will be collected in FY 2018 and sent to the Purdue Rare Isotope Measurement Laboratory for analyses. Results will be published in a future report (table 3).
- During FY 2018, real-time streamflow information will be collected and processed at five sites along the Big Lost River and one site on Antelope Creek to provide estimates of snowmelt runoff and recharge to the aquifer and to provide data for flood-control studies. Partial funding for the two uppermost sites that were previously covered by DOE were picked up by other cooperators for FY 2017. The uppermost site upgradient from the INL to be funded by DOE (Big Lost River nr Arco, ID) will be run all year. To reduce costs in FY 2012, four of the streamgaging stations at the INL (INL Diversion at head near Arco, Big Lost River below INL Diversion, Big Lost River at Lincoln Boulevard Bridge near Atomic City, and Big Lost River above Big Lost River Sinks near Howe, fig. 1) were reduced to a 6-month data-collection schedule –March 1 through August 31, 2015. The USGS started two streamgages (Little Lost River near Howe, Idaho and Little Lost River above Flood Diversion near Howe, Idaho) in the lower part of the Little Lost River during FY 2015. Data from these two sites will help the USGS better understand the amount of recharge coming out of the Little Lost River basin for future groundwater-flow model efforts. Starting in FY 2016, some funding was used to help run real-time information from one of the streamgages along the Little Lost River (Little Lost River above Flood Diversion near Howe, Idaho, station 13118975). Another funding partner was found to pick up those costs in FY 2017.
- In recent years, concern for well security has increased. These concerns center on the need to protect both the environment and the integrity of the groundwater dataset. The USGS will continue with security modifications of wells as required. Additionally, well rehabilitation activities such as downhole fishing, retrieval projects, and screen purging will take place as required. Pump replacement will be handled in part through the project site-support account in collaboration with the site contractor's ongoing well rehabilitation program. The USGS met with the site contractor in FY 2008 to determine custody for wells at the INL. Based on this discussion, the USGS is responsible for custody of about 140 wells. In FY 2018, maintenance

will be performed on the wells that break down, which averages about 3 per year. During well maintenance, the USGS examines condition of the well (borehole video), updates geophysical log data, and replaces components (pump, pump motor, wire, stainless pipe), as required.

- As shown in table 6, we estimate that staffing salary, lab costs, and supplies of about $441,000 will be required in FY 2018 to maintain water-sampling, water-level monitoring, streamflow measurements, and other activities administered through the hydrologic monitoring program. A more detailed breakdown of some of the costs is given in tables 7 and 8. Data collected from hydrologic monitoring activities will be added to the USGS NWIS database. The website address is *https://water.usgs.gov/nwis/*.

Table 6. Estimated program costs for FY 2018 through FY 2022

[Costs in thousands of dollars]

Investigations by category	FY18	FY19	FY20	FY21	FY22
Geohydrologic studies and monitoring					
Hydrologic Monitoring	387	395	406	414	420
Big Lost River Streamgaging Stations	54	55	56	57	58
Geologic Framework	357	375	365	365	365
Hydrochemistry	194	198	203	208	212
Groundwater Flow and Contaminant Models	312	322	332	341	350
Databases	120	123	125	127	128
Publications	34	35	35	36	36
Site support services					
Borehole Logging	120	124	127	130	132
Lithologic Core Storage Library	54	53	53	54	54
Idaho State University Research Assistant	72		73		74
Total Program Costs	1,704	1,680	1,775	1,732	1,829

Table 7. Expected personnel expenses for FY 2018

Position	Grade/step	Annual hours	Hourly wage & benefits	Annual cost	Primary duties
Supervisory Hydrologist	GS 14/8	1930	84.50	163,085	Manage the program and staff.
Technician	GS 9/5	1930	41.00	79,130	Water levels, water quality, geophysical logging, RSO, database management.
Hydrologist	GS 13/4	2080	75.00	156,000	Groundwater modeler.
Technician	GS 11/8	2030	51.00	103,530	Driller, geophysical logger.
Geologist	GS 11/4	1980	44.00	87,120	Stratigraphy, core library.
Hydrologist	GS 13/7	1480	67.00	99,160	Geochemistry, water quality.
Secretary/Hydrologic Aid	GS 6/4	1980	24.00	47,520	Secretarial/hydrologic aid duties.
Supervisory Hydrologist	GS 12/6	1880	52.50	98,700	Team lead, geophysical logging, and drilling.
Driller Assistant	WG 7/3	2030	26.50	53,795	Drill rig helper.
Hydrologist	GS 9/5	1790	36.00	64,440	Water quality, database management, GIS support.
Technician	GS 11/7	2040	50.50	103,020	Water levels, water quality, database management.
Geologist	GS5/1	240	21.00	5,040	NAGT intern.
			Wage/Benefit Subtotal	1,060,540	
			Overtime	2,500	
			Performance Awards	5,000	
			Travel	7,500	
			Training	2,700	
			Personnel Expense Subtotal	17,700	
			Total Personnel Expense	1,078,240	

Table 8. Expected operating expenses for FY 2018

Item	Cost	Remarks
Subtotal Personnel Expenses	1,078,240	
Laboratory Analyses	30,600	Water-quality samples and supplies.
Telephone and Communication	1,400	Cell phones.
Vehicle Operation	13,800	gas, oil, tires, repairs.
ADP	6,000	intranet fees, licenses, software, hardware replacement.
Equipment Maintenance and Repair	16,200	generators, drill rigs, trailers, pumps, field equipment.
Supplies and Materials	17,100	drilling, office, field supplies and materials.
Freight/Shipping/Misc.	8,000	Fed ex, ups, storage, equipment rental.
Publications Processing	28,000	editorial and reports publication charges.
Working Capital - vehicles and computers	10,200	replacement plan for vehicles and server.
NRC License	2,000	NRC fee for logging sources.
Subtotal Operating Expenses	133,300	
Idaho Falls Field Office Suballocation	54,200	Big Lost and Antelope Creek streamgages.
Menlo Park (GD) Suballocation	15,000	Paleomagnetic analyses and interpretation.
Subtotal Suballocations	69,200	
Laboratory and report overhead	7,032	12% on net 58,600.
Science Center and Headquarters Overhead	277,858	24.1% on net 1,152,940.
Subtotal Overhead Assessments	284,890	
Total Assessable	1,565,630	
Rounded	1,566,000	
INL Site Support Services	66,000	DOE payment to INL contractor for site services.
ISU Research Assistant	72,000	
Total	1,704,000	

Geologic Framework

Paleomagnetic Characterization of Basalt Stratigraphy

In FY 2018, core from wells USGS 145, 147, and TAN 2312 (appendix A) will be sampled and analyzed for paleomagnetic properties. In addition, several surface vent samples collected during the summer of 2017 will be analyzed for paleomagnetic properties and geochemical composition of basalts. Work was started on compiling a geologic map of surface basalt flows and vents that includes interpretations from surface paleomagnetic data and x-ray fluorescence chemical analyses of the flows by a student employee and volunteer. The employee/volunteer resigned before completing the map. Work was picked up by another National Association of Geoscience Teachers intern in the summer of 2017. Publication of the product is planned to be completed in FY 2018 (table 1). Additionally, work will be started in 2018 to compile paleomagnetic information for several wells in the central part of the INL with the goal of publishing a report on the stratigraphic interpretation in FY 2019 (table 3).

Basalt Radiometric Dating

In FY 2012 and 2013, results were obtained from Wright-Rieman Labs at Rutgers University on 12 samples sent for radiometric age dating analyses in FY 2011. Work was published in FY 2015 (Hodges and other, 2015). Some additional samples were sent to the lab in FY 2017 for analyses to help constrain stratigraphic interpretations at the INL with the hope that results will be available in FY 2018.

Subsurface Visualization

The subregional-scale groundwater-flow model developed by the USGS INL Project Office in 2010 was based on a conceptually simple spatial representation of sediment distribution in the subsurface. However, calibration work to date has shown that the model is sensitive to the spatial extent and volumetric proportion of sediment in the ESRP aquifer. The subregional conceptual model recognizes the importance of sediment accumulation in the Big Lost Trough volcanic/sedimentary basin that underlies much of the northern and central parts of the INL, but it does not attempt to portray the extreme geologic and hydraulic heterogeneity of the aquifer or its complexly layered, three-dimensional architecture. Work in 2018 will focus on better understanding the stratigraphy in the southwestern part of the INL through coring and analyzing data from new wells. Additionally newly compiled data from wells USGS 139,142, and 143 will be used to derive statigraphic relations in the central part of the INL.

As shown in table 6, about $357,000 will be required in FY 2018 to maintain and update the stratigraphic information; to refine the geologic, hydrogeologic, and visualization models; and to support ongoing drilling and research to refine the conceptual and numerical groundwater-flow and contaminant-transport models. Recent discussion with DOE indicated to try to fund Idaho State University research assistant positions out of base funds. Another $72,000 of base funds (table 7) are needed in FY 2018 to support funding a new Geology Research Assistant student for two school years; the position would start in August 2018 with a projected thesis in May 2020. It is anticipated that the student research will focus on better understanding basalt stratigraphy at the INL.

Hydrochemistry

Hydrochemical investigative studies for FY 2018 will continue to obtain information needed for understanding the 3-D fate and transport of wastes in the southwestern part of the INL. These studies will include (1) continuing work on a geochemical mass-balance model of groundwater in the ESRP aquifer beneath the INL, and (2) collecting data to characterize the quality of groundwater and three-

dimensional movement of groundwater and chemical constituents at the INL. In addition, if funds are available, sulfur isotopes will be collected to determine sources of water and mixing ratios in groundwater at the INL.

Geochemical Modeling

The USGS is developing geochemical mass-balance models that can be used to (1) evaluate the effects of mixing recharge waters from various sources, (2) identify physical and chemical processes occurring in the aquifer, (3) evaluate fluxes used as boundary conditions in the USGS groundwater-flow and contaminant-transport models, and (4) provide the geochemical understanding of the system necessary to develop a reactive-transport model (combining a geochemical model with a groundwater-flow model) at the INL. Geochemical mass-balance models of groundwater from the Big Lost River, Little Lost River, and Birch Creek drainages, which provide groundwater recharge to the ESRP aquifer north of the INL, were completed in 2001-03. A geochemical mass-balance model of the Medicine Lodge Creek drainage basin was published in an ISU master thesis (Ginsbach, 2013) in 2013, and a geochemical mass-balance model of the Beaver and Camas Creek drainage basins was published in 2014 (Rattray and Ginsbach, 2014). These basins extend onto the ESRP, and each model will extend to the Mud Lake region that is adjacent to the northeast part of the INL. A geochemical mass-balance model of the Mud Lake area was published in 2015 (Rattray, 2015). The results of these studies and the earlier tributary valley geochemical mass-balance models, as well as extensive geochemical data from the late 1980s to the early 2010s, are being used to better understand the hydrology and hydrogeology of the ESRP aquifer at the INL. A report describing this work will be published in early FY2018 as a USGS Professional Paper (table 1). Geochemical modeling of groundwater at the INL will commence in FY 2017 and will be published in late 2018 (table 1).

Sulfur Isotope Study

If funds are available during 2018, water samples will be collected at approximately 10 to 20 surface water and groundwater sites for analysis of sulfur isotopes ($^{34}S/^{32}S$; $\delta^{34}S$). $\delta^{34}S$ values are distinct for different sources of water or sulfur. For example, a measurement of $\delta^{34}S$ from the Big Lost River was 4.4 permil, tributary valley groundwater has values ranging from 6 to 9 permil, regional groundwater has values greater than 9 permil, and groundwater influenced by agriculture has values between 1 and 5 permil. Consequently, $\delta^{34}S$ values are an excellent tool for identifying sources of water to the ESRP aquifer at the INL and for determining mixing ratios, including temporally-variable mixing ratios, for groundwater at the INL. Sample collection sites will be selected to provide information about $\delta^{34}S$ values in recharge from tributary streams, tributary valleys, regional groundwater, and groundwater influenced by agricultural practices. Sample collection at some wells on the INL that are near or south of the Big Lost River will occur over a number of years to determine time-varying $\delta^{34}S$ values in groundwater in response to differing amounts of recharge from the Big Lost River during wet and dry cycles. A report will be written that (1) identifies the sources of water across the INL, (2) calculates the percentage of water from the various sources of water (mixing ratios) at select wells at the INL, and (3) provides temporally-variable mixing ratios for a number of wells at the INL that are near or south of the Big Lost River.

Vertical Water-Quality Sampling

During 2018, selected zones from eleven MLMS wells will continue to be monitored for long-term changes in the aquifer. In FY 2016, some unexpected VOC results were found in well Middle 2051, but investigation seemed to indicate contamination from water inside the casing. Some additional

investigation into the source of the PCE contamination was done in FY 2017. Some monitoring for VOCs in all zones in Middle 2051 and USGS 132 and 137A were completed in FY 2017 to better resolve sample collection issues and to understand why concentrations occurred in Middle 2051.

As shown in table 6, about $194,000 will be required to accomplish tasks for hydrochemical studies in FY 2018. Costs are expected to increase with cost of living increases in 2019-22 while work continues on the primary geochemical models for the aquifer at the INL.

Hydraulic Properties

Unsaturated Zone

In FY 2015, USGS personnel finished the previous analyses of data from available core from sedimentary interbeds to help parameterize a traditional unsaturated-flow model based on Richards' equation. The model will be applied to the complex vadose-zone beneath the Remote-Handled Low-Level Waste Facility south of the ATR Complex. In addition, the USGS tested the methods needed to parameterize the recently developed source-responsive fluxes model of unsaturated-zone preferential flow, and published the results in FY 2017 (Table 2). No more work is planned for future unsaturated zone studies at the INL unless additional funds can be identified. If funding is identified, research would focus on better understanding the unsaturated zone-flow at INTEC as outlined in the 2012 task plan.

Saturated Zone

The USGS recognizes that to have confidence in the predictive capability of the groundwater model, it is important to develop reasonable estimates for hydraulic properties. These estimates are based on the analysis of aquifer tests and (or) geophysical data. The USGS is incorporating aquifer test results with geophysical techniques, such as flow-meter logging, neutron measurements, and eventually acoustic televiewer measurements, to improve estimates of hydraulic properties and to better predict the flow and direction of groundwater in the aquifer. These advanced borehole testing techniques were applied to wells USGS 140 and 141 drilled in FY 2014 and to wells USGS 142, TAN 2271, and TAN 2272 completed in 2016. Data collected from these wells will be used to better understand contaminant transport in the aquifer south of the ATR Complex, west of the NRF, and at TAN. The improved estimation techniques will be applied to other wells in the study area and will be used to calibrate a plume-scale groundwater model in the future.

During FY 2012, the USGS instrumented two additional MLMS boreholes in USGS 131A and USGS 137A. Hydraulic head and temperature measurements collected from these two wells, along with more data from the other nine MLMS from 2011-13, were summarized in a report published in FY 2015 (Twining and Fisher, 2015). During FY 2018, the USGS plans to continue collecting hydraulic head and temperature data from 11 MLMS wells, with measurements collected quarterly at three of the MLMS wells and annually for the rest. A future report is planned to look at 2014-15 data and provide interpretation (Table 3).

With record low water levels in the ESRP aquifer in 2016 came the realization that transmissivity estimates for the aquifer published in 1991 (Ackerman, 1991) were for 10 to 40 feet of aquifer material that is no longer saturated. Additionally, many new monitoring wells have been drilled since the 1991 study. To reassess the transmissivity of the aquifer at the INL, drawdown data was collected in April 2017 from wells sampled for the routine monitoring program. During FY 2018, drawdown in the wells to be sampled in October 2017 will be collected and information will be compiled and interpretated in a report (table 1).

As the USGS continues to core boreholes into the ESRP aquifer, attempts will be made to expand our capacity to collect hydraulic properties by exploring new geophysical methods as they become available. Additional data describing the hydraulic properties of the saturated media will provide increased credibility in our understanding of groundwater flow through the aquifer's complex basalt stratigraphy.

Groundwater-Flow and Contaminant-Transport Models

In FY 2018, model capabilities will be extended to simulate both groundwater movement and heat transport. The simulation of heat transport will improve our understanding of the temperature distribution and heat flux in the aquifer. And the inclusion of groundwater temperature data in the model calibration process will improve estimates of groundwater flow and hydraulic properties. Model development will continue at the subregional scale and focus on reconciling differences between model-derived and independently derived estimates of groundwater movement and temperature using alternative realizations of the hydrogeologic framework and hydraulic and thermal properties of the aquifer. Continued development at the subregional scale will provide a robust foundation for the development of contaminant-transport models in the future.

An unstructured model grid will be used to refine the current grid resolution in areas of interest, such as site facilities, giving us greater detail and accuracy of groundwater flow and direction in these parts of the aquifer. The grid refinements in the flow model could then be used to simulate possible effects on water levels and groundwater discharge caused by changes in well withdrawals and recharge. Particle tracking simulations will also be made to enhance our understanding of the direction and rate of contaminant migration.

Regularized inversion, the combined use of large numbers of parameters with mathematical approaches for stable parameter estimation, will be used to improve the parameterization of hydraulic conductivity in the current model. Intuitive knowledge and geological expertise will be incorporated into the calibration process, together with information of historical water levels and groundwater temperatures, expanding the period of record to include 1953 through 2017 field observations. This broader historical range of field observations should better constrain the optimization problem. Other types of data that will be employed in the parameter estimation process include: (1) water-level changes from an annual baseline; (2) depth-discrete measurements of hydraulic head monitored at 11 MLMS boreholes; (3) independently derived estimates of flow directions and velocities; (4) geochemical data describing a water-type separation between a water type that is primarily composed of tributary valley underflow and streamflow-infiltration recharge to a water type primarily composed of regional aquifer water; and (5) results from an existing geostatistical model of sediment abundance. A report describing this geostatistical model (Welhan and others, 2006; DOE/ID-22201) was published in FY 2006 (*https://pubs.usgs.gov/sir/2006/5316/*).

An estimated $312,000 will be required in FY 2018 to support ongoing modeling and reporting activities, to evaluate the significance of newly acquired data, and to implement any refinements necessary to improve the reliability and defensibility of the conceptual and numerical models. Staffing requirements for this activity are expected to remain stable in the future.

Site Support Services

The USGS provides on-call geophysical-logging services to DOE contractors and core-sampling and analysis support to contractor personnel and local and national researchers.

Borehole Logging

During FY 2018, the USGS will continue to support INL research with borehole logging as needed. We estimate that the borehole logging program will require about $120,000 in FY 2018 to collect and produce well logs, update software, purchase logger supplies, keep staff updated with required training, perform equipment calibrations, repair equipment, and maintain and distribute records.

Lithologic Core Storage Library

During FY 2016, we acquired more core storage space in CFA 674. During 2017, Core Library personnel inventoried existing cores to compile an update of drill cores and cuttings available for study (table 1). A report summarizing these data is planned for publication in late 2017 (table 1). About $54,000 is needed to continue Core Library activities in FY 2018. Core drilling is a very costly procedure; however, archiving the cores multiplies the value of the cores because they become an ongoing, important resource for investigation of the nature of the subsurface geology and hydrology at and near the INL and the evolution of the ESRP. Prior to the establishment of the Core Library, no attempt had been made to consolidate, catalog, or determine the spatial distribution and physical locations of cores and cuttings available for use by researchers. The Lithologic Core Storage Library is a valuable scientific resource that should be maintained for future researchers.

Databases

As new data are collected, the data will be added to the site schedule, geophysical-log, water-level, and water-quality NWIS databases. The data also will be provided to the INL EDW. Through FY 2012, historical water-quality data from the RESL and field data collected before 1990 were still being added to the NWIS database as time permitted. Historical geophysical log data were still being populated to the database and website as time permitted. With the retirement of a USGS hydrologic technician and decreased funding in FY 2013, we do not anticipate that time or resources are available for us to continue populating the historical databases. For FY 2018, it will cost about $120,000 to enter and check new data. Database costs are expected to remain stable other than for cost-of-living increases for staff projected through FY 2022 (table 6).

Publications

Publication of USGS scientific investigations reports remains one of the primary mechanisms available to document USGS hydrologic studies and monitoring at the INL. Table 1 lists the reports planned for submittal to DOE for review and also lists reports that will be released to the public following publication during FY 2018. Cost estimates for reports for editorial reviews, illustration support, and formatting according to USGS standards are estimated to be about $34,000 in FY 2018 (table 6).

Budget

Cost estimates for all work to be performed in FY 2018 are given in tables 6-8. Table 6 gives a breakdown of costs by study, monitoring, and support topic. Table 7 gives a breakdown of planned personnel expenses. Table 8 gives the breakdown of the operating expenses, suballocations, and total costs. With the planned funding, several of the INL staff will only be funded for a portion of their time and will work on other reimbursable work that can be identified at the INL or by the USGS Idaho Water Science Center. Other work the USGS will be involved with in FY 2018 with other funding sources include completing a report on sampling and drilling proposed and started in 2017 at TAN (appendix

A), sampling monitoring wells for the Naval Reactors Facility (NRF), operating one real-time well (USGS 1) for the National Climate Response Network, and possibly starting a geochemical study and column batch study with the NRF to see if potassium acetate can be used as a road melt at the facility.

3. Five-Year Plan

Future tasks done by the USGS at the INL involve continuing hydrologic monitoring and comprehensive long-range studies to better understand groundwater flow, contaminant transport, and water availability in the ESRP aquifer. Potential funding for USGS work at the INL could be much less in the future as the DOE wraps up the Idaho Clean-Up Project and as Congress struggles with budget deficits. However, hydrologic studies and monitoring will still be needed as long as DOE maintains a viable mission at the INL.

Table 6 projects estimated funding that will allow the USGS to move forward with its long-term studies. Actions taken because of the cost reductions from FY 2012 to 2013 included:

- discontinued unsaturated zone studies in FY 2013;
- discontinued funding for research students from Idaho State University starting in late FY 2013 (other DOE funds were found in FY 2016 to support a student in FY 2017 and 2018);
- reduced number of sites sampled and measured following evaluation studies;
- reduced full-time equivalent USGS staff by one;
- discontinued installation of MLMS; and
- some staff are not fully funded for their time (table 7).

In FY 2014, the office secretary and the hydrologist in charge of the core library and GIS support retired. The secretary was replaced with a half-time employee, the hydrologist duties were backfilled by converting a hydrologic technician to a hydrologist position. Our half-time secretary was converted to a full time hydrologic aid/administrative operations assistant to help backfill some of the hydrologic technician duties. Core Library support is being handled as an additional duty of our project geologist. If funding levels are even less than projected in the future, the USGS INL Project Office management will attempt to find additional work outside the INL project. INL Project Office staff may be assigned to other projects at the INL and (or) to details on other USGS projects. This approach would allow the INL Project Office to maintain the technical expertise of the current staff and still cover any salary deficits.

Hydrologic Monitoring

The USGS expects to continue with monitoring as outlined in the 2011 INL Groundwater Monitoring Plan (U.S. Department of Energy, 2012; (DOE/ID-11034) and will continue to publish reports on hydrologic conditions and the distribution of chemical constituents on a three to four year basis. Data evaluated in the coming year for a water-quality optimization report (table 1) will help determine if changes to the sample program can be accomplished without loss of important information. New wells will continue to be sampled for a large suite of chemical and radiochemical constituents as they are drilled to better understand the ESRP aquifer system. Management tools will be used to increase the efficiency of the long-term water-quality and water-level monitoring network at the INL. The current zones from MLMS wells will continue to be monitoried to establish trends and future reports on pressure, temperature, and water chemistry information will be compiled on a 3 to 4 year basis coinciding with the hydrologic conditions reports.

Geologic Framework

The USGS expects to continue building many different types of 3-D visualization models over the next several years. New paleomagnetic and map information, including that from surface vents outside the INL boundary, flows that come onto the INL site, on the surface and into the subsurface, will be entered into the database to develop models that include data from USGS 142, 143, 144, 145, and 147 along with other new cores, as soon as the information is available. Reports will be completed from the data compiled to reinterpret the stratigraphy of the INL (Table 3). Sediment information will also continue to be entered into databases. These models will help manage the substantial amount of geologic, hydrologic, geophysical, thermal, geochemical, and contaminant data that are currently available; will enhance understanding of contaminant movement in the subsurface; will improve capabilities for long-term monitoring in support of Long-Term Stewardship Plan objectives; and will improve the ability to communicate stewardship issues to concerned stakeholders and to management.

Hydrochemistry

Geochemical mass-balance modeling will continue for the next several years and eventually will be incorporated into a reactive-transport model. It is anticipated that geochemical mass-balance modeling will be wrapped up by 2019. The vertical water-quality monitoring network will be expanded as funds allow, and water-quality samples will continue to be collected for the foreseeable future to establish long term trends in zones influenced by wastewater disposal. Collection and interpretation of sulfur isotopes will continue to to occur as funds allow.

Geochemical Modeling

Geochemical mass-balance modeling of the INL (regional groundwater) commenced in FY 2014 with retrieval of chemical data from the USGS NWIS database. Site description information (geology, mineralogy, hydrology, climate, land use) necessary for developing the geochemical model will be evaluated in FY 2015, and a draft of a USGS Professional Paper was started. This report investigates geochemical evidence for the sources and movement of groundwater in the aquifer and should be published in late 2017 (Table 2). Geochemical modeling of groundwater at the INL commenced in FY 2017, and the report will be sent out for review in FY 2018 (table 1). Three-dimensional geochemical mass-balance modeling of deep groundwater at the INL will commence after completion of mass-balance modeling of the shallow aquifer at the INL (table 3). Work on a reactive-transport model of groundwater at the INL is planned after completion of the 3-D mass-balance modeling (table 3). The goal of the reactive-transport model is to describe the fate and transport of wastes disposed at the ATR Complex, INTEC, and RWMC facilities.

Vertical Water-Quality Sampling

In FY 2018, no new wells will be added to the MLMS network because of funding levels. If funding levels change in the future, new installations will be done in the area of greatest need. As wells are installed, they will be sampled for the same chemical constituents that were used at each previous well to establish a water-quality baseline. In subsequent sampling events, modification of the constituent list will allow us to address specific questions without unnecessarily duplicating information already available. Each modification of the constituent list will be executed consistently at each new well to acquire a consistent database of water-quality data at each well. This process minimizes analytical costs while maximizing the amount of data available for analysis. We plan to continue to sample the same

zones we sample at each well currently (2017) to establish a long-term trend. Instructions, datasets, and functions for processing and analyzing the MLMS data sets will be bundled together in an *R package* in a future report (table 3). R is a language and environment for statistical computing and graphics (R Core Team, 2017). In R, the primary mechanism for sharing with others is the package. An MLMS R-package will make it easier to (1) manage the study, (2) collaborate with other scientist working with MLMS wells, and (3) update our analysis as new data is made available.

Sulfur Isotope Study

Collection of sulfur isotopes will continue in FY19 and beyond. An initial report (table 3) will describe the sources of water at the INL and calculate mixing ratios of various sources of water for selected groundwater at the INL. A second report (table 3) will calculate time-varying mixing ratios for groundwater at the INL (near and south of the Big Lost River) due to differing amounts of recharge from the Big Lost River during wet and dry climate cycles.

Groundwater-Flow and Contaminant-Transport Models

A Scientific Investigations Report describing a groundwater-flow and heat-transport model calibrated using a regularized inversion approach will be published in FY 2019. Construction of a contaminant-transport model that simulates the dispersive effects of smaller-scale heterogeneities and anisotropies within the subregional-scale model will begin in FY 2020. This plume-scale model will enhance our understanding of the direction and rate of contaminant migration, as well as the processes and factors that control chemical transformations. A Scientific Investigations Report describing the plume-scale model will be published in FY 2021. Flow model simulations at both the subregional- and plume-scale will be used to identify new boreholes.

In an effort to make our modeling information more accessible, discoverable, and usable by the public, web-based applications will be developed to provide users with interactive maps and data for them to quickly visualize and analyze the models' inputs and outputs. For example, a web-based mapping application will be developed that shows the simulated water table altitude during each model stress period.

Publications

Table 3 lists report titles for future report ideas that will be accomplished beyond FY 2018. The list is included to identify the type of research we intend to focus on. Report costs are estimated for about five medium-sized reports to be published each fiscal year and are based on the current report production costs based on a three-year average.

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Appendix A

Hydrological and Hydrochemical Characterization of the Eastern Snake River Plain Aquifer Near the Test Area North

A proposal prepared by the U.S. Geological Survey Idaho National Laboratory Project Office

April 19, 2017

Background

The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy (DOE), has collected borehole information at the Idaho National Laboratory (INL) since 1949 to provide baseline data for monitoring and studying the migration and disposition of radioactive and chemical wastes in the eastern Snake River Plain (ESRP) aquifer. The USGS is refining numerical models for the movement of water and contaminants in the ESRP aquifer, and more data in the vicinity of Test Area North (TAN) is needed to understand the hydrologic effects on the movement of waste constituents in the northern part of the INL (fig. 1).

The USGS monitors groundwater from four wells upgradient from TAN (USGS 126B, ANP-6, P&W 2, and USGS 26), from three wells downgradient from TAN (NoName 1, USGS 7 and GIN 2), and from one well within the area of the TAN facility (TAN-2271) (figs.1 and 2). The downgradient wells are spaced several miles apart, so another well is needed to fill in data gaps west of GIN 2 (fig. 2). Additional USGS monitoring downgradient from TAN will provide information about hydrologic conditions of the aquifer related to past disposal practices that occurred at TAN.

Select geophysical log information is available for wells within 0.5 mi of the TAN facility (Bartholomay, 1990; Anderson and Bowers, 1995); however, paleomagnetic data and core information are available for only five sites in the vicinity of the TAN facility (Gin 5, Gin 6, TAN Ch1, TAN Ch2, and TAN-2271) (Champion and others, 2011; Twining and others, 2016) (fig. 2). Although, gamma log information was used to define the stratigraphy of the area around TAN (Anderson and Bowers, 1995), paleomagnetic data is being used elsewhere at the INL to refine stratigraphic interpretation useful for the future refinement of the USGS groundwater-flow model (Ackerman and others, 2010). Additional core information will improve understanding of how volcanic eruptions occurring between the Circular Butte-Kettle Butte Rift zones and the Lava Ridge-Hells Half Acre Rift zones (fig. 1) interfinger in the vicinity of TAN. These rift areas surrounding TAN contribute to the direction and magnitude of groundwater and (or) waste constituent movement downgradient from TAN; therefore, additional data from drilling and sample collection will be useful for the ongoing cleanup effort at TAN.

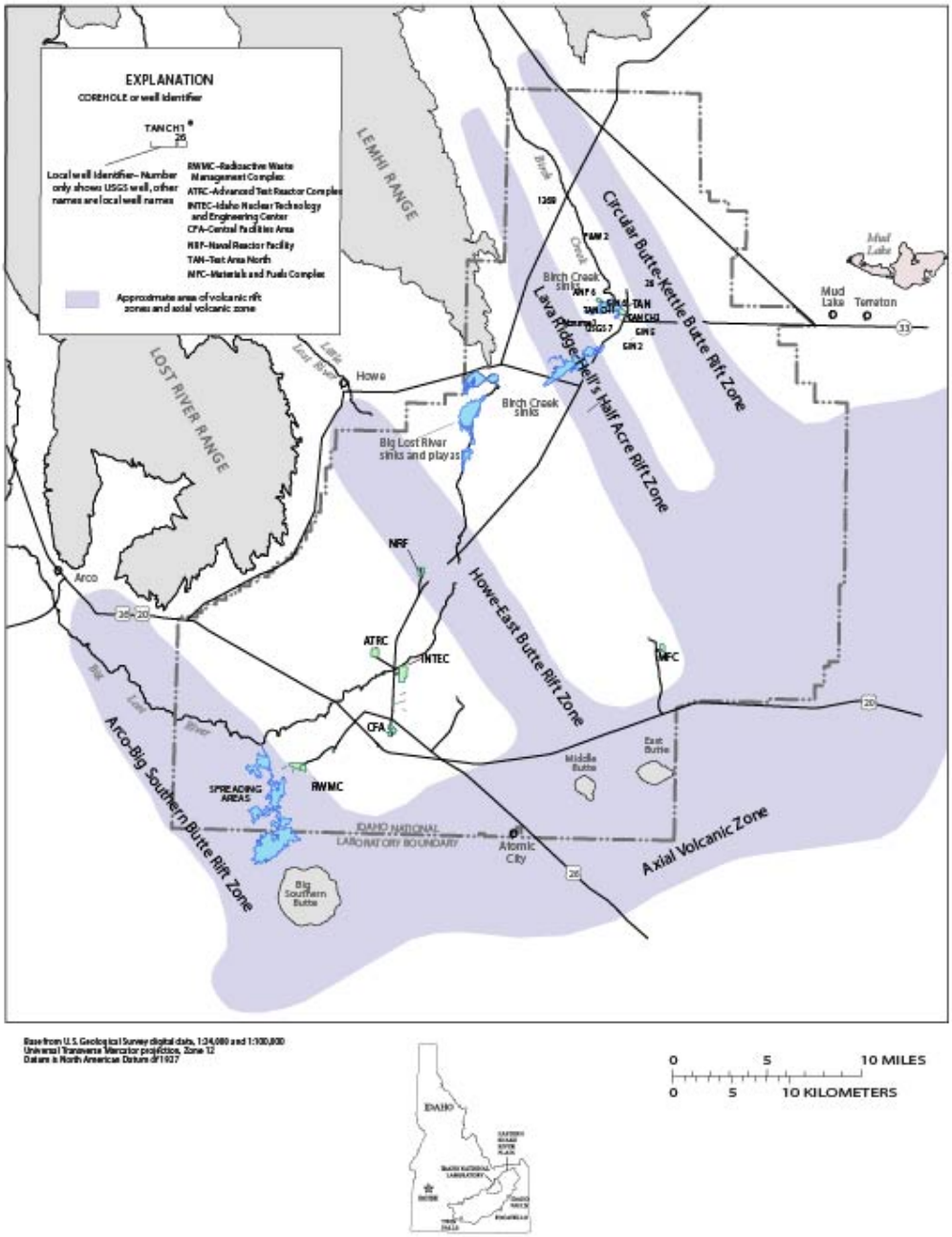

Figure 2. Location of the Study area

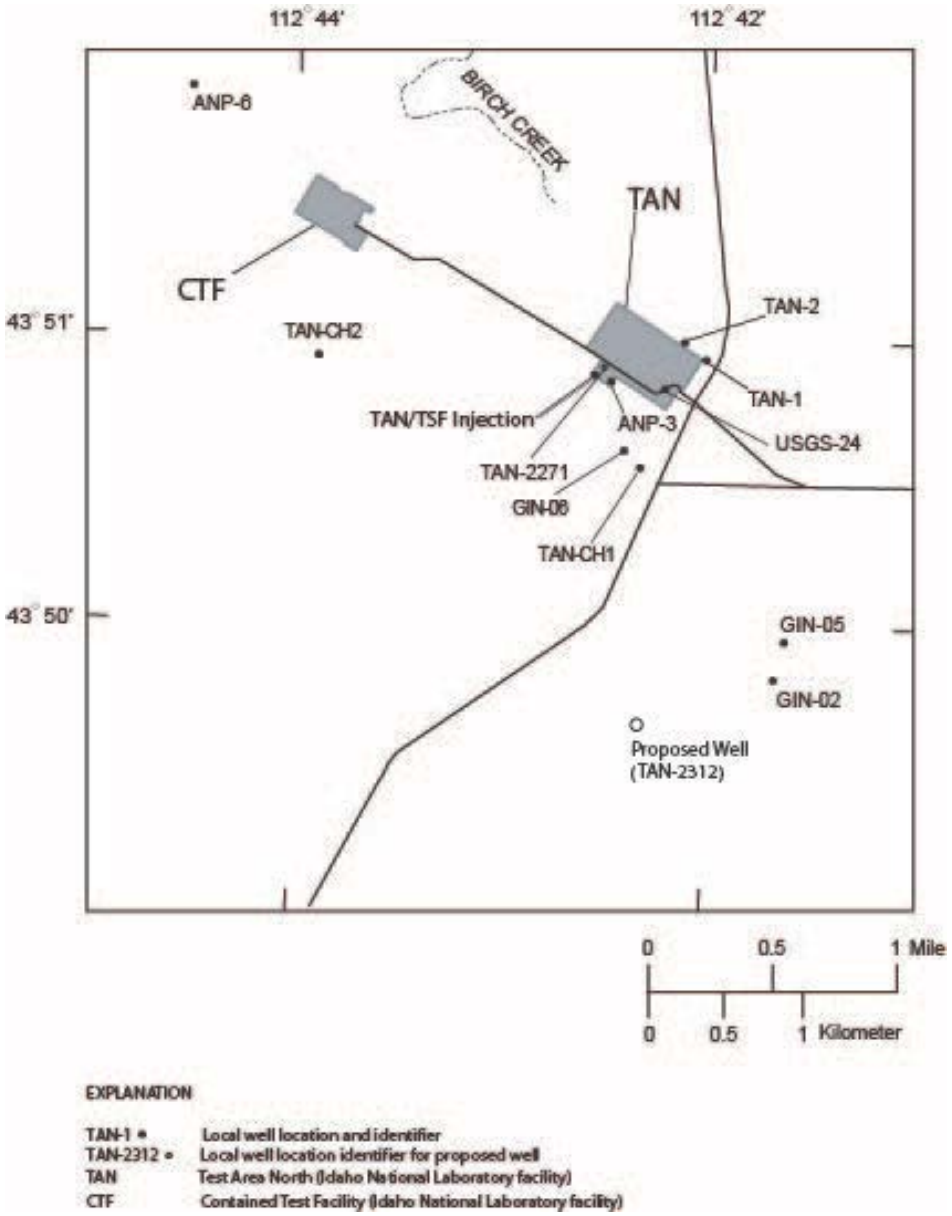

Figure 3. Location of USGS monitoring wells and study wells supplying paleomagnetic and core data in the vicinity of TAN.

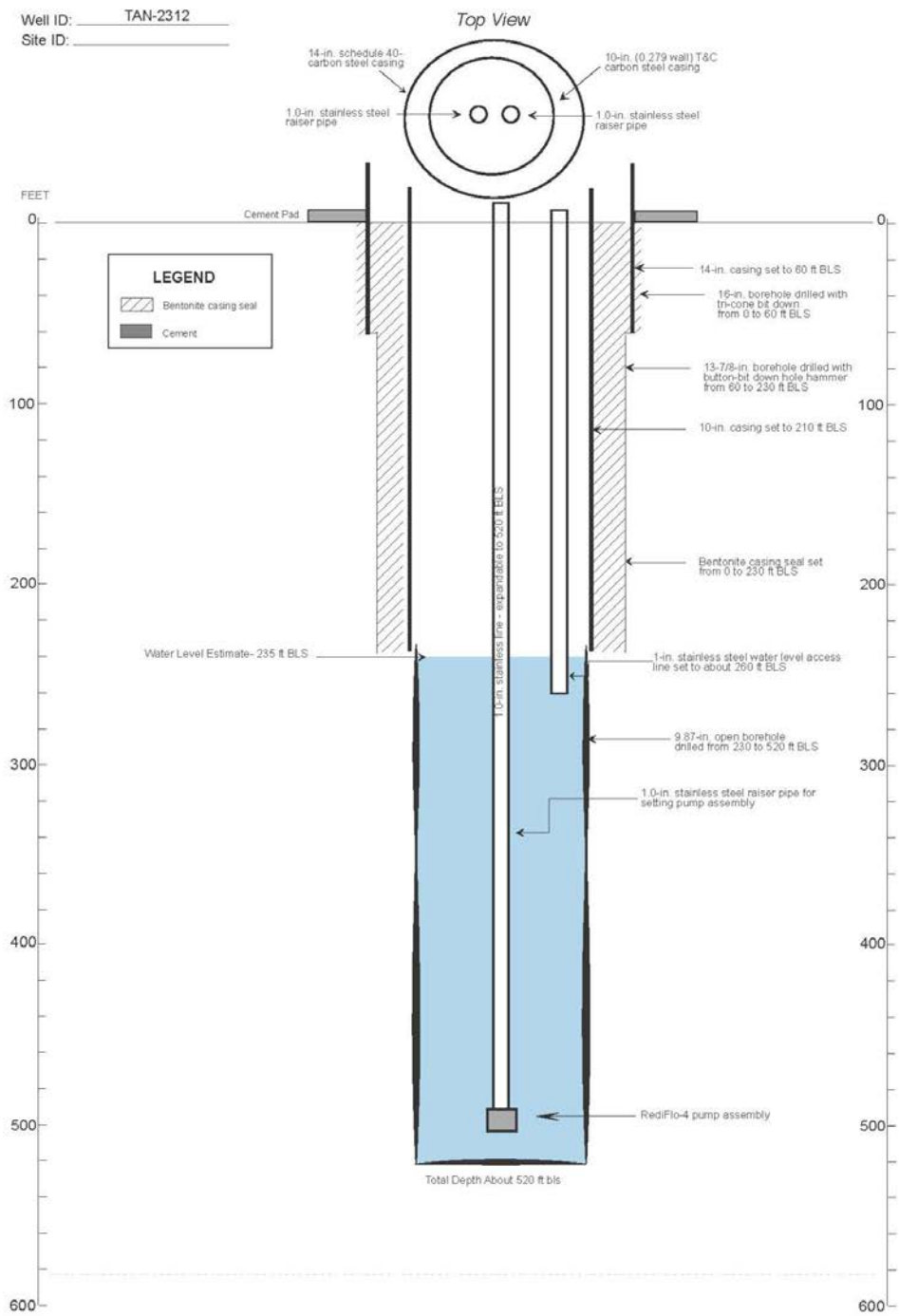

Figure 4. Proposed well design for TAN-2312

Purpose and Scope

The USGS proposes to core, drill, and construct a monitoring well about 1 mile south of TAN to support the scientific need (figs. 2 and 3) to improve the understanding of hydrogeology in the northern part of the INL. The USGS will core the monitoring well from the first basalt contact (believed to be about 60 ft below land surface (BLS)) to about 500 to 520 ft BLS, which is believed to be the depth of the QR sedimentary interbed (Anderson and Bowers, 1995). After core drilling is completed, all material recovered will be photographed, described, and sampled for paleomagnetic interpretation. After drilling and well construction, the USGS and DOE (subcontractor FLUOR) will examine geophysical log data and core material to identify primary fracture/flow zones within the open borehole. The location of the fracture zones will be sampled to determine which if any zone should be sampled long term. Prior to sampling the individual fracture zones, the USGS will set a submersible pump to purge the well for approximately 24 hours. During this purge process, the USGS will conduct an aquifer test and collect water samples at the conclusion of the test. After sampling of selected intervals, an interval will be selected by DOE in consultation with FLUOR, EPA, and DEQ for final well completion with a single pump depth at the zone determined to be most productive.

Coring will begin approximately the end of July 2017, and the monitoring well will be completed by about late September 2017. Results for the coring, geophysical logs, water sampling, and flow meter tests will be summarized in a USGS report at the completion of the study. Results from hydraulic property analyses will also be included in the report.

Relevance and Benefits

This study is consistent with the national USGS mission and goals and to water-resource issues identified in the USGS Science Strategy (U.S. Geological Survey, 2007). The study addresses groundwater availability and sustainability, which are priority issues under the Water Census of the United States (U.S. Geological Survey, 2007). The information derived from coring geologic material will provide the DOE and the State of Idaho with information for analyzing future risks to the ESRP aquifer. The core will be sampled to provide additional data for the interpretation of the geologic evolution of the ESRP and to provide additional stratigraphic information to improve the understanding of groundwater-flow model inputs at the INL. The monitoring well will provide additional water-quality and water-level data to further characterize groundwater at the INL in the TAN area. Geophysical and video data will be collected for the monitoring well during various stages of drilling to support construction, to characterize groundwater-flow conditions (hydraulic properties of fractures), and to supplement bedrock lithology.

Approach

Pre-drilling Activities

Prior to USGS mobilization, the DOE will be responsible for a written Project Interface Agreement between the USGS and the DOE and/or their representatives to define roles and responsibilities and safe work boundaries and protocols.

Site preparation activities will include, but are not limited to, drilling location clearance through subsurface and surface investigations, well surface location survey and issuance of an identification number, and delineation and signage marking the site boundary.

Coring and Drilling

In July 2017, the USGS will mobilize equipment, setup the drill site, and conduct a pre-job safety briefing. Work will be done in accordance with USGS site safety and job hazard analyses plan (Roy Bartholomay, USGS, written communication, December 16, 2016). Prior to setup, the USGS will review and comply with INL Environmental Checklist requirements outlined in the final document. Equipment will be staged inside an established construction zone with a defined perimeter. Access into the USGS construction zone will be limited to USGS personnel during drilling operations; however, visitors to the drilling site will be granted access on request. The construction site will be labeled and contact information will be provided.

The construction perimeter must be large enough to include staging of two drill rigs, semi-truck and pipe trailer, Sullair air-compressor, water truck, water storage tanks, and drill trailer(s). Two drill rigs will be used to core and construct the well. The coring rig will be a Christensen CS-1500; the reaming and construction rig will be a Gefco™ SD-300 drill rig. During the coring process, only clean water and air will be used and misted continuously during the drilling. During the reaming and construction, attempts will be made to use only air and (or) water; however, if necessary an NSF/ANSI Standard 60 biodegradable drilling foam (Baroid QUIK-FOAM®) may be necessary to remove drill cuttings during reaming to accomplish required well diameters (fig. 3). Protective tarps will be placed under drill equipment prior to drilling, and equipment will be routinely inspected and documented. Any fluid leaks that require containment will be given immediate attention and repaired where necessary. Water used for drilling will be transported from the proposed monitoring well, USGS 7 (fig. 1). Recovered drill core will be boxed, labeled, and surveyed (if necessary) and transported to the Lithologic Core Storage Library (CFA-663), located at the Central Facilities Area for further examination and permanent archival (Davis and others, 1997).

Core drilling and construction will be coordinated and supervised by the USGS. In general, the USGS plans to collect HQ-size core (about 2.8-in.), starting at the first basalt contact (near 60 ft BLS) to completion depth (near 520 ft BLS). The completion depth will be determined by the depth of the QR sedimentary interbed (Anderson and Bower, 1995) with the goal to core about 2 ft into the interbed to confirm its presence. After coring, the USGS will collect geophysical data to the final completion depth prior to reaming and final construction (fig. 3). The drilling conditions will factor into the final reaming and construction. For example, if the unsaturated zone becomes unstable during the coring process, the USGS may determine it is better to ream and set 10-in. casing down prior to drilling into the aquifer. However, if the conditions allow continuous coring to completion depth, the USGS will first core the well and then ream and construct the well once coring is done. Progress and weekly updates will be provided to contractor FLUOR and the DOE. The final well design, well and casing diameters, annular seal, and open-hole construction depths will be similar to that provided in fig. 3. Any deviation to

the well design will be communicated to the aforementioned parties. Borehole video, geophysical data, and well driller notes will also be provided as the drilling progresses.

Final construction of the TAN monitoring well will include 14-in. surface casing to about 60 ft, 10-in. well casing to about 235 ft, and 9.87-in. open-hole between about 235 and 520 ft BLS (fig. 3). After construction, the USGS will install a temporary submersible pump to develop the well as described above. USGS personnel will collect additional geophysical logs and borehole video, as required, prior to interval sampling.

A low flow pump will be used to test discrete zones. The pump will be lowered to pre-selected zones and pumped in accordance with contractor FLUOR requirements. Up to seven zones will be tested, taking up to two weeks. The USGS will work with FLUOR to complete required testing. On conclusion of the interval testing, the USGS will install the pump in the monitoring well at a zone identified by Fluor.

Geophysical Logging and Groundwater Sampling

Geophysical and video data will be collected for the monitoring well to support construction, to characterize groundwater-flow conditions (hydraulic properties of fractures), and to supplement bedrock lithology. The geophysical logging methods will include conventional logs, borehole imagery (video), acoustic televiewer, and electromagnetic flowmeter (EMFM). Logs will be compiled on completion of core drilling to assist in selection of zones for low flow sampling.

EMFM logging will be collected after major fractures have been identified and the well has stabilized from drilling. Single-well EMFM analysis will be examined under both ambient and stressed conditions in conjunction with acoustic televiewer data. EMFM station measurements will be collected above and below major fractures to identify vertical flow direction, to establish relative hydraulic gradients, and to identify transmissive fracture zones. Stationary flow measurements may require water to be injected to create a stressed condition to compare against ambient conditions. EMFM measurements interpreted under both ambient and stressed conditions will be used to identify hydraulically active fractures and to approximate open-hole specific capacity and transmissivity.

After total depth is reached, conventional and video logs will be used to support well construction, to supplement gaps in geologic core, to compute borehole deviation, to examine changes in fluid properties, and to identify fracture flow contacts and (or) interbedded sediment contacts. The USGS plans to run the following geophysical logs through drill pipe:

- neutron,
- gyroscopic deviation, and
- gamma-gamma.

After drill rods are removed, the following select open-hole geophysical and borehole video surveys will be coordinated:

- color video,
- natural gamma,

- caliper,
- resistivity,
- fluid conductivity,
- temperature,
- EMFM, and
- Acoustic televiewer

Groundwater samples will be collected after the well is purged and during the initial aquifer test. The water samples will be collected according to procedures outlined in the USGS INL field methods and quality-assurance plan (Bartholomay and others, 2014). Constituents analyzed will include cations; anions; trace elements; nutrients; volatile organic compounds; stable isotopes of oxygen and hydrogen; uranium isotopes; and radiochemical constituents including tritium, strontium-90, plutonium 238, plutonium 239-240 undivided, americium-241, gross alpha and beta, and gamma spectroscopy.

USGS personnel will collect additional geophysical logs and borehole video, as required. After logging, a low-flow pump will be lowered to pre-selected zones and pumped in accordance with contractor FLUOR requirements. Up to seven discrete zones may be tested, and is expected to take up to two weeks to complete. The USGS will work with FLUOR to complete required testing. On conclusion of testing, the USGS will set a pump in the monitoring well at a zone identified by DOE.

Well Completion

Following installation, the USGS will install a well box to protect well components.

Prior to demobilization, the USGS will demonstrate operational functionality of the following well infrastructure:

- Sample pump will be in working order. The sample pump will be started and demonstrated to pump water to the surface. DOE will provide the power, via Grundfos BMI/MP1-115V variable frequency drive, for starting the pump and will subsequently manage purge water as project waste.
- A water level measurement will be taken.

Prior to release of equipment and tools (e.g., rig, drill string, bits, hoses, pumps, and ancillary equipment) that have contacted groundwater, they will be decontaminated (if necessary) to remove constituents and potential radioactive contamination, or disposed of as directed, and subsequently surveyed for release by RadCon if needed. Decontamination waste will be managed by the DOE.

DOE is responsible for installing required surface completions and the locking well head cover.

Safety and Health

The USGS will ensure drilling safety through compliance with requirements specified in the USGS INL Site Safety and Job Hazard Analyses Document (Roy Bartholomay,

USGS, written communication, December 16, 2016). Further detail will be documented in the Project Interface Agreement.

The USGS will be responsible for training personnel assigned to the job. The DOE will be responsible for training of their personnel and/or that of their representatives. Minimum training requirements for conducting CERCLA activities within the OU 1-07B project site include 40 Hour HAZWOPER

Products

After completion of coring, core will be stored at the INL Lithologic Core Storage Library if not radioactive. Construction diagrams, well completion information, the aquifer test results, geophysical logs, water quality analyses, and lithologic descriptions of the borehole will be published in a USGS report. The draft USGS report will be provided to DOE after the completion of the monitoring well and the return of water-quality sample results from the lab. The final USGS report will include a description of the geologic material cored, the geophysical logging results including interpretation of flow characteristics, a monitoring well completion diagram, and water-quality sampling results. The final report will be made available to the public as part of the USGS mission, and all information for the study will be sent to the INL Environmental Data Warehouse (EDW).

Schedule and Funding

The proposed timeframe for the study is approximately July 2017 through July 2018. Field work will be completed during normal INL work hours from about 6:00 am to 6:00 pm Monday through Thursday. With advanced notice, some drilling may take place on Friday, if needed, to meet completion schedules. Drilling/coring will start in late July 2017. Any deviation from the proposed schedule will be communicated to DOE. A draft USGS report summarizing well completion, water analyses, and geophysical logging will be ready for DOE review by the spring of 2018.

Total funding for USGS efforts is proposed as $216,700 to core, drill, and complete the monitoring well (fig. 3); perform laboratory water-quality analyses; perform an aquifer test; and publish a USGS report. Costs excluded from this proposal include; some salary, core storage and analysis (including paleomagnetic properties), geophysical logging, and performing a flow meter test as they are functions that will be done as part of ongoing USGS hydrologic investigations at the INL.

Proposed funding details for USGS efforts related to well installation are shown in Table 1. Costs in Table 1 include overhead. Maintenance, repairs, lab analysis, and equipment costs include such items as: steam cleaner maintenance, wellhead completion materials (e.g., landing plates, Swagelok® fittings), maintenance for core and drill rig, casing and pump, and contingency funds for repairs or loss of equipment. Miscellaneous supplies and fuel costs are based on consumable items and include estimates for such items as casing seal, drill bits, fuel, core barrels, tarps, cement baskets, tremie pipe, drive shoes, tape, gloves, oil, lubricants, pipe dope, welding materials, well caps, and seal materials. These costs are approximated based on drilling other INL boreholes.

Table 1. Proposed funding for USGS efforts related to well installation project.

General item	Total cost
USGS salary and report costs (includes salary and overtime for driller and driller helpers, salary for hydrologist to lead project and prepare final report, report illustration and editorial staff support, and salary for general management support).	71,000
Maintenance, repairs, lab analyses, and equipment.	30,000
Miscellaneous supplies .	8,000
Site support funds for fuel.	13,000
Materials.	94,700
Total	216,700

The material cost breakdown for well construction is provided in Table 2.

Table 2. Proposed costs for USGS supplied materials

General item	Quantity	Total Costs
Casing14 in. and 10 in., schedule 40 carbon steel, welded.	60/240	18,000
Hammer bits, stabilizers, core components, water level line, pump assembly, pump wire, 760 ft 1-in. stainless steel sample and water-level line.	Varies.	76,700
Total		$94,700

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