THE INEEL WATER INTEGRATION PROJECT: COORDINATING SURFACE WATER, VADOSE ZONE, AND GROUNDWATER ACTIVITIES AT THE INEEL

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ABSTRACT

The U. S. Department of Energy, Idaho Operations Office (DOE-ID) places a high priority on the protection of groundwater and the Snake River Plain Aquifer from contaminants generated by operations at the Idaho National Engineering and Environmental Laboratory (INEEL). To this end, DOE-ID is developing a site-wide strategy to assess the impacts of INEEL contaminants on the vadose zone, and the Snake River Plain Aquifer beneath the INEEL and to understand the effects of temporal flow of surface waters on contaminant transport. Over the 50-year history of the INEEL a substantial amount data has been gathered on groundwater contamination, but there are uncertainties and data gaps in the current understanding of the inventory, distribution, and movement of contaminants in the subsurface. Uncertainty reduction is needed to fully evaluate and integrate the impacts of radioactive or otherwise hazardous releases to the Snake River Plain Aquifer and to efficiently mitigate these impacts in a cost effective manner.

The Water Integration Project has been established to develop a single comprehensive technical baseline (i.e., an initial set of critical observations or data used to compare changes in the INEEL subsurface, including interactions between buried wastes, water infiltration and flooding events, and the aquifer.) Inherent to this task, the Project must coordinate and integrate with all INEEL programs and stakeholders to reach a common understanding of the assumptions applied to the technical baseline.

These objectives will be met by completion of the following five project tasks.

A. **Technical Baseline:** Identify steps needed to establish a broad and complete subsurface technical baseline for the INEEL. This effort will include identifying and implementing methods for improving the quality and completeness of INEEL conceptual models, subsurface sampling data, numeric modeling input files and output results, geologic cross sections, well construction data, and other sources of INEEL subsurface information. As research and development advances are made, the technical baseline will be updated after new information has been thoroughly reviewed by appropriate internal and external technical experts.

B. **Focused Science and Technology Research:** Establish a risk-prioritized groundwater research strategy that meets the needs of the Environmental Management Programs. This strategy will focus on identifying, prioritizing, and resolving gaps in the INEEL technical baseline that may prevent successful completion of INEEL EM projects.

C. **Stakeholder Involvement:** Enhance the decision making process through open communications, active stakeholder involvement, and ongoing opportunities for stakeholders to influence DOE water management decisions.

D. **Program Integration:** Establish a single, integrated groundwater/vadose zone management process for the INEEL.

E. **Expert Peer Review:** Establish a strong and effective independent technical review process, to include participation by a panel of experts from applicable fields of science and technology.

INTRODUCTION

Due in part to the volume and productivity of the underlying Snake River Plain Aquifer, the INEEL was located in 1949 in the remote Arco Desert of eastern Idaho to build and test nuclear reactors for electricity generation, materials irradiation, and use by the U.S. Navy for training. Originally called the National Reactor Testing Station, the INEEL built 52 reactors during its history. Three reactors are operating today.

The Snake River Plain Aquifer provided millions of gallons of water each day for reactor cooling and facility operations. Organic and radioactive contaminants, by products of nuclear fuel reprocessing, reactor operations, and other Cold War activities, were discharged into the Snake River Plain Aquifer or to unlined evaporation ponds. These wastewater disposal methods, although industry-accepted practices at the time, have ceased, but have resulted in contaminated plumes in the aquifer that must be addressed.

In 1989, the INEEL was added to the U.S. Environmental Protection Agency's Superfund National Priorities List due to confirmed contaminant releases to the Snake River Plain Aquifer above drinking water standards. In 1991, the DOE, EPA, and state of Idaho signed the *Federal Facility Agreement and Consent Order*, which was a legally binding agreement to remediate contaminated areas of the INEEL and address contaminants in the Snake River Plain Aquifer. For ease of characterization, the 890-square-mile laboratory was divided into 10 waste area groups: nine of which correspond with facilities while the tenth comprises miscellaneous contaminated sites and the entire Snake River Plain Aquifer.

During the past decade, the INEEL has removed thousands of cubic feet of radioactively contaminated soil, capped two reactor burial grounds, removed thousands of post-World War II unexploded ordnance devices, removed and treated mixed waste, and collected and properly disposed of heavy metal- and PCB-contaminated soils. Despite these successes, the INEEL's cleanup mission is far from over. The DOE, EPA, and state of Idaho are applying what they've learned over the last 15 years to tackle the most challenging contaminated areas.

Development of facility-specific conceptual models is recognized as a critically important task for any environmental remediation project. Use of conceptual models is mandated by CERCLA and as a result all of the 10 INEEL Waste Area Groups have developed facility-specific conceptual models and in some cases, multiple conceptual models exist at individual facilities. Because of the geographic, regulatory, and organizational separation of the various WAGs at the INEEL discrepancies have developed in the technical base line for the conceptual models at INEEL facilities.

Background and Purpose

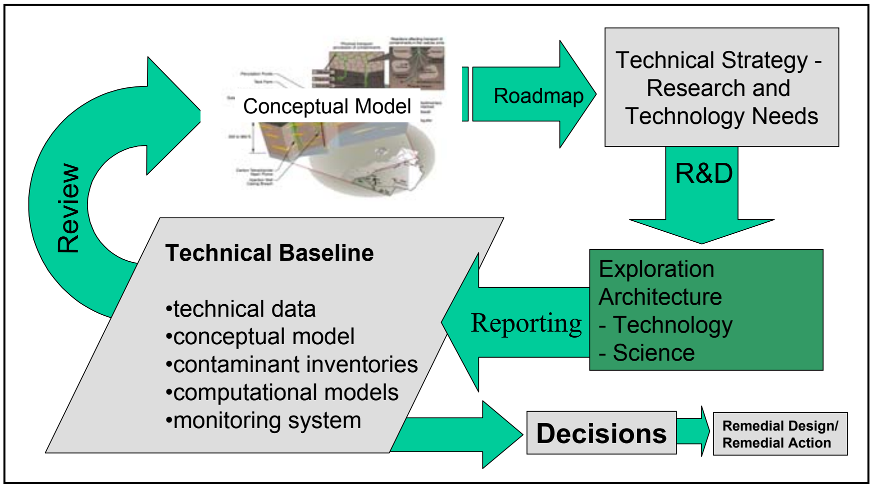
DOE formed the Water Integration Project in 2002 to establish a basis for integrating and coordinating the acquisition of existing and new knowledge about the subsurface characteristics of the Eastern Snake River Plain. The mission of the project is to establish a basis for integrating and coordinating present and future activities that characterize, monitor, and remediate the ground water and vadose zone beneath the INEEL. In early FY 2002, the Water Integration Project established a set of objectives to accomplish its 3-year mission. These objectives were to:

- Produce a comprehensive, conceptual model of the subsurface that can be used to strategically plan future ground water and vadose zone research activities at the INEEL.
- Establish science strategies that align subsurface research and development (R&D) with operations needs, and produce research data that supports credible, sustainable risk-based decisions.
- Establish an internet-based system that encompasses available subsurface data and information that users can access with their desktop computers, comprehensively search, and download to meet their needs.
- Develop a tool to calculate facility-wide cumulative risk and the contribution of individual sources to that risk for Environmental Management Operations use in determining appropriate remedial actions.
- Identify actions necessary to maximize the usefulness of INEEL ground water monitoring data for research and for environmental compliance needs.
- Identify metrics that INEEL water and vadose zone project managers can use to monitor and consistently report project performance sitewide.
- Demonstrate the value of collaborative stakeholder participation in strengthening the technical basis for strategic decisions related to INEEL ground water/vadose zone projects.

A fundamental premise underpinning the design and implementation of the project was that the participation of a wide range of stakeholders would improve the final project results. This premise applies to internal as well as external stakeholders. The project's activities can affect and be affected by many groups and individuals, including but not limited to: livestock and crop producers, industries, community residents, and state and local government officials. Also interested and affected are: Native American tribal members and governments, state and federal regulators, public interest groups, the Department of Energy and its sister federal agencies, and INEEL research and management personnel. Since its inception, the project has involved stakeholders in key project decisions by routinely practicing open, transparent decision-making that provides opportunities for them to develop and weight decision criteria and establish priorities. Key stakeholder involvement activities are inseparable and fundamental to meeting the project's technical objectives.

TECHNICAL BASELINE

As a first step toward integrating the technical baseline for the INEEL as a whole, the project has undertaken the development of five conceptual models for the site. These include the Snake River Plain aquifer, Source Term, the Vadose Zone, Geochemistry and near surface environmental conditions. To guide the construction of the INEEL conceptual models the project adopted the National Research Council definition of a conceptual model: "...an evolving hypothesis identifying the important features, processes, and events controlling fluid flow and contaminant transport of consequence at a specific field site in the context of a recognized problem." The individual conceptual models are discussed below.



INEEL Aquifer Subregional Conceptual Model

Numerous subregional and facility-scale scientific studies have been conducted during the 50-year history of the INEEL to characterize its geologic and hydrologic setting and to evaluate the fate and transport of radioactive, inorganic, and organic chemical wastes in the Snake River Plain Aquifer. Out of this body of work two primary subregional conceptual models have been developed, one by the USGS and the other by WAG 10. The Water Integration Project aquifer conceptual model compiles and compares these two evolving aquifer models and exposed areas of convergence and areas of divergence and identifies significant data gaps

Geochemistry Conceptual Model

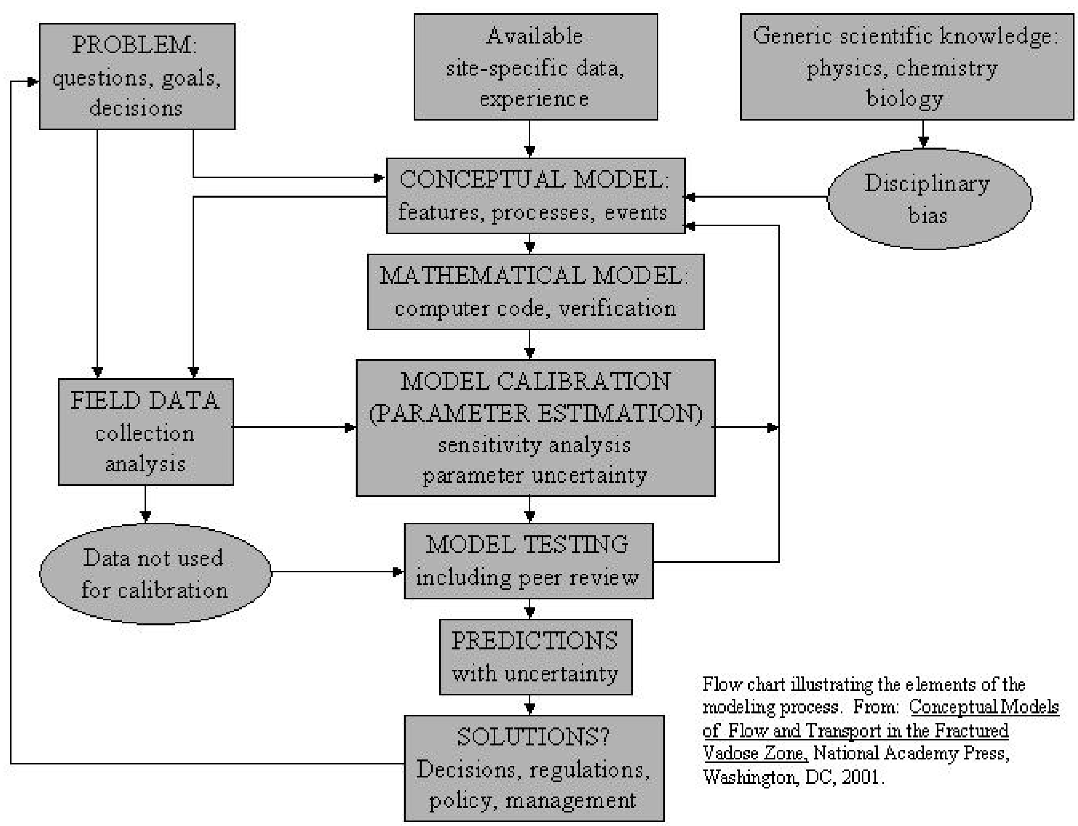
This work will summarize geochemical system conceptual models for the vadose zone and groundwater zone (aquifer) beneath the Idaho National Engineering and Environmental Laboratory (INEEL). The primary focus is on groundwater because contaminants derived from wastes disposed at INEEL are present in groundwater, groundwater provides a pathway for potential migration to receptors, and because geochemical characteristics in and processes in the aquifer can substantially affect the movement, attenuation, and toxicity of contaminants. The secondary emphasis is perched water bodies in the vadose zone and processes that affect solutes during transport from near-surface disposal facilities downward through the vadose zone to the aquifer.

Source Term Conceptual Model

This document summarizes the present understanding of contaminant source terms and identifies source-term data gaps. One chapter of the document focuses on contaminant generation, transport, and fate mechanisms. Another chapter includes a discussion of the various source term categories (e.g., injection wells, buried waste, infiltration ponds and ditches, and contaminated surface soils) and the final chapter is a discussion organized by contaminant (source term inventory and locations, mechanisms and rates of release).

Vadose Zone Conceptual Model

Fluid flow and solute transport within the subsurface including the vadose zone, the unsaturated zone between the land surface and the water table, is the cause of expanded plumes arising from localized contaminant sources, and an understanding of vadose zone processes is an essential prerequisite for cost-effective contaminant remediation efforts. Contamination of the vadose zone can result from many causes, including chemical spills, leaky underground storage tanks, leachate from waste disposal sites and mine tailings, and application of agricultural chemicals. Another major environmental concern is the potential for long-term migration of radionuclides from low- and high-level nuclear waste disposal facilities. Development of flow and transport models for the vadose zone is a key requirement for designing remediation and long-term stewardship strategies. The presence of fractures and other channel-like openings in the vadose zone poses a particularly significant problem, because such features are potential avenues for rapid transport of chemicals from contamination sources to the water table. The underpinning of any vadose zone fluid transport model is the conceptualization of (1) the relevant processes, (2) the structure of the subsurface, and (3) the potential events or scenarios that impact the behavior of the modeled system.



Flow chart illustrating the elements of the modeling process. From: Conceptual Models of Flow and Transport in the Fractured Vadose Zone, National Academy Press, Washington, DC, 2001.

FOCUSED SCIENCE AND TECHNOLOGY RESEARCH

The objective of this task is to insure that the INEEL long-term science and technology strategy is aligned with site programs, that site programs take advantage of research and development progress made to date, and that INEEL research can assist in meeting site operations milestones and budgets. Establishing science strategies facilitates monitoring, characterization, prediction, and assessment activities to reduce the uncertainties in long-term risk predictions, assist in risk management decisions, and ensure that long-term stewardship of contaminated sites at the INEEL is achieved.

Ten Highest Priority Uncertainties

To determine gaps in knowledge, the project engaged scientists and engineers knowledgeable in geosciences, flow and transport modeling, source term issues, and surface and ground-water issues to prepare a listing of uncertainties. These uncertainties represent gaps in knowledge and capabilities for the vadose zone and ground water at the INEEL. Twenty-five uncertainties were identified and validated. In April 2002, 25 people participated in a facilitated value engineering (VE) session to prioritize the uncertainties. This group included representatives of the general public, federal and state regulators, INEEL State Oversight, the United States Geological Survey, DOE Headquarters, DOE-ID, and the INEEL M&O contractor (Bechtel BWXT). They brought diverse backgrounds and expertise to the session, including INEEL Operations, flow and transport modeling, geochemistry, contaminant transport, applied geosciences, agriculture, and project management.

The VE session prioritized all 25 uncertainties. Prioritization scores ranged from 15.85. to 7.29. The following list summarizes the 10 highest priority uncertainties and their scores (in order of priority):

1. Mechanisms and parameters describing adsorption of contaminants onto INEEL materials have not been adequately developed or measured. (score 15.85)
2. Knowledge of stratigraphic and structural controls on flow patterns in the vadose zone and the aquifer is limited. (score 15.49)
3. Available field data are of insufficient quality and quantity for use in predictive simulation. (score 15.25)
4. Conceptual models are often inadequate for prediction because they do not incorporate necessary physical and biogeochemical processes. (score 14.88)
5. Chemistry of the near-field environment (e.g. solubility effects) may significantly affect the release and the rate of migration. (score 14.77)
6. Knowledge of flow direction and temporal behavior in the aquifer is limited. (score 14.43)
7. Conditions leading to facilitated transport are unknown. (score 14.19)
8. Preferred pathways are not detected or monitored, and there is relatively little information available. (score 14.12)
9. Contaminant inventory uncertainties (score 14.02)
10. Various sources of uncertainty and their relative impact on the predictability of transport are unknown and currently unqualified. (score 13.90)

Identification of Specific Operational Needs

As part of this task, project staff interviewed approximately 50 people with INEEL operations expertise and knowledge of the need to meet regulatory milestones and provide for long-term monitoring of the site. The categories of major operational needs are summarized as follows (in no particular priority):

- Plutonium geochemistry/transport
- Carbon-14 research
- Actinide geochemistry research

- K_d value research
- Development of better monitoring methods
- Source-term research
- Flow characterization methods
- Development of models and codes
- Research on caps, barriers, grouting, and remediation methods
- Studies of long term degradation of landfill covers in arid environments.

The prioritized uncertainties and operational needs will be used to develop subsurface science strategies and define the hypotheses (research questions) that need to be tested to implement those strategies. The project will also write test plans for incorporation into calls for research proposals through which the research necessary to implement the strategies will be performed.

CUMULATIVE RISK TOOL

DOE has committed to accelerating environmental cleanup at the INEEL. A method to prioritize the cleanup of contamination sources at each INEEL facility and across the INEEL according to associated risk, risk reduction, and cost.

A cumulative risk assessment model is being developed during this year that will be used to help make facility closure decisions. The model will evaluate all contaminant sources within a facility's boundary and estimate the risk to a downgradient receptor from that contamination. The model will be designed to consider alternate remediation strategies for each source and it will be capable of evaluating uncertainties associated with source inventories and contaminant transport properties. The model output will give decision-makers necessary information about the cumulative risk impacts of all remediation efforts within a facility. A parallel effort will be made to identify or develop a method that will take the results of this assessment and determine cleanup priorities.

Even though the risks posed by most of the contaminant sources at the INEEL have been evaluated, the evaluations are not always consistent and comparable. They have been derived using different conceptual model assumptions and different levels of conservatism for inventory, source release, flow, and transport. The results of these analyses may be sufficient for individual source decision-making but may not be sufficient for evaluating the effect of remediation on cumulative risk from all sources within a facility, or for prioritizing where cleanup funds are expended in order to achieve the greatest risk reduction benefit.

The cumulative risk assessment model will integrate multiple sources of contamination into a comprehensive environmental transport and exposure assessment model that will:

1. Estimate contaminant fluxes to the subsurface unsaturated zone, aquifer, and atmosphere from all sources of contamination at a given facility,
2. Estimate contaminant concentrations in groundwater at any point within a facility model domain from all sources of contamination within the facility,
3. Estimate contaminant concentrations in air at any point within a facility model domain from all sources of contamination within the facility,
4. Calculate exposure from the groundwater and inhalation pathways and the associated risk to a hypothetical individual at a given point in the facility model domain from all sources of contamination within the facility.

The approach will evaluate each contaminant source using a consistent set of assumptions so that the source specific risks can be accumulated into a meaningful cumulative risk. Model development will involve the use of pre-existing codes (that have been used at the INEEL) coupled with additional coding to interface existing code into the computational framework.

STAKEHOLDER INVOLVEMENT

The Water Integration Project has been actively reaching out to stakeholders to enhance their understanding of surface water, groundwater, and contaminant movement at the INEEL. This is being done in advance of three upcoming cleanup decisions involving the Subsurface Disposal Area at the Radioactive Waste Management Complex, Tank Farm soils at the Idaho Nuclear Technology and Engineering Center, and the Groundwater Remedial Investigation/Feasibility Study (Operable Unit 10-08). Input from a representative group of Idaho interests from around with the state was incorporated into a Stakeholder Involvement Plan published in July 2002. The plan lays out public participation objectives and activities to be accomplished over the life of the project.

Field tours, fact sheets, webpage, science workshops, briefings, regular meetings open to the public and available via conference call, and other avenues are being used to reach a diverse group of stakeholders around the region.

Three Hydrogeology Fields tours were conducted in 2002 and five tours were held during June, July, and August of 2003 with a total of over 150 people attending. Each tour was sponsored by an Idaho group interested in groundwater. A full-color tour guide was produced and printed at the INEEL. The tours were designed to give the public an opportunity to interact with INEEL and other scientists regarding the hydrology and geology of the Eastern Snake River Plain, the current understanding of contaminant movement, and ongoing research, remediation, and monitoring efforts. Attendees included Idaho Environmental Board and Department of Environmental Quality representatives, a number of county commissioners, Shoshone-Bannock tribal representatives, Snake River Alliance members, and INEEL employees. Tour stops included a general discussion of the formation of the Eastern Snake River Plain at Hell's Half Acre or Crater's of the Moon National Monument, a history and status of operations and monitoring at the Radioactive Waste Management Complex (RWMC), research at the Vadose Zone Research Park, and bioremediation work at TAN.

Fact Sheets describing the Water Integration Project and the Conceptual Modeling Effort were developed and printed for distribution to internal and external stakeholders. The Project Fact sheet includes general information on the Snake River Plain Aquifer and issues related to activities at the INEEL. The role of the project to integrate science, technology, and cleanup applications and project's primary products are described along with information on how to keep informed and opportunities for the public to be involved are included. The Conceptual Model fact sheet includes information on what a conceptual model is and how it is used is included on a level understandable to less technical audiences.

Regular meetings of project personnel are open to the public and available via conference call. Monthly focused meetings that cover various aspects of the Water Integration Project were instituted in 2003. The monthly meetings were instituted as a forum to better inform stakeholders on project issues and activities outside of the regular weekly meetings, which tend to be more project management oriented. Topics included detailed discussions of the status of the conceptual modeling effort, Groundwater Awareness Project planning (see below), planning of hydrogeology field tours, and detailed work planning for the project. A number of these monthly meetings were attended by 20 or more interested stakeholders, including INEEL personnel, external stakeholders, and representatives of other agencies (e.g., U.S. Geological Survey, Argonne National Laboratory). These meetings are announced via the project webpage and an email notice sent to over 200 stakeholders.

A website with links to project related documents, general information on the project was developed and maintained. Agenda, handouts, and minutes of meetings are posted regularly. Website usage statistics throughout 2003 indicate an average of 35 visits per day.

Four public workshops were held throughout Idaho (Coeur d'Alene, Boise, Twin Falls, and Idaho Falls) in May 2003, to discuss what scientists are learning about contaminants and the subsurface environment at the INEEL. Sixty-five people including elected officials, federal, state, and local agency representatives, tribal representatives, and university scientists attended the workshops. These workshops were intended to introduce the process of developing a conceptual model of flow and contaminant transport for the INEEL subregion, and help build the public's capacity to engage in future clean up decisions at the Subsurface Disposal Area and the Idaho Nuclear Technology and Engineering Center. Speakers included INEEL and USGS scientists who summarized the current state of knowledge with respect to:

- Geological Framework of the Eastern Snake River Plain Aquifer
- Contaminant Source Term Inventory and Release Mechanisms
- Vadose Zone Geometry and Transport Processes
- Aquifer Flow and Transport Processes
- Use of Conceptual Models to Address Uncertainty in Scientific Predictions.

Workbooks intended to serve as accurate references for the participants included presentation slides and profiles of 120 individual subsurface research projects sponsored by DOE or the USGS that convey the comprehensive scope of current investigations. Compact discs of the information in the binders have been produced for broader distribution, so this current reference material can be shared more economically with those unable to attend the original workshops

Groundwater Awareness Project: Building Community Capacity to Engage in the INEEL Water Integration Project

The Water Integration Project teamed with the University of Idaho to develop a comprehensive groundwater outreach and education program designed to help students and the general public better understand how the aquifer works and is managed. Joining in this statewide effort are representatives from state and federal agencies responsible for water quality and quantity, the Idaho Water Policy Group, as well as educators from the Idaho State Department of Education, and Idaho universities and school districts. A team of middle school and high school teachers will be invited to participate in a curriculum review workshop late this fall. The INEEL has provided seed funding for the planning and development stage of the project as well as the technical expertise of INEEL scientists.

SUMMARY

The Water Integration Project will continue to proceed toward developing a site-wide strategy to assess the INEEL's impacts on the vadose zone and Snake River Plain Aquifer in advance of three upcoming remediation projects. By involving stakeholders in the Water Integration Project, they will become better informed as to how the aquifer works and how contaminants move in the vadose zone. This partnership between science and the public will be of benefit to the INEEL's remediation managers and stakeholders alike when DOE, EPA, and the state of Idaho release proposed cleanup plans for public comment.

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