Chapter 10 Highlights

The Idaho National Laboratory Site was designated as a National Environmental Research Park in 1975. The National Environmental Research Park program was established in response to recommendations from citizens, scientists, and members of Congress to set aside land for ecosystem preservation and study. In many cases, these protected lands became the last remaining refuges of what were once extensive natural ecosystems. The National Environmental Research Parks provide rich environments for training researchers and introducing the public to ecological sciences. NERPs have been used to educate grade school and high school students and the general public about ecosystem interactions at U.S. Department of Energy (DOE) sites; train graduate and undergraduate students in research related to site-specific, regional, national, and global issues; and promote collaboration and coordination among local, regional, and national public organizations, schools, universities, and federal and state agencies.

During 2012, six ecological research projects were conducted on the Idaho National Environmental Research Park:

- Long-term Vegetation Transects
- Surveying, Monitoring and Predicting the Occurrence and Spread of Native and Non-Native Plant Species at the Idaho National Laboratory Site
- Studies of Ants and Ant Guests at the Idaho National Laboratory Site
- Post-wildfire Wind Erosion In and Around the Idaho National Laboratory Site
- The Influence of Precipitation, Vegetation and Soil Properties on the Ecohydrology of Sagebrush Steppe Rangelands on the Idaho National Laboratory Site
- Distribution, Movements, and Space Use by Elk on the Idaho National Laboratory Site

The United States Geological Survey (USGS) has been studying the hydrology and geology of the eastern Snake River Plain and eastern Snake River Plain aquifer since 1949. The USGS INL Project Office collects data from research and monitoring wells to create and refine hydrologic and geologic models of the aquifer, to track contaminant plumes in the aquifer and improve understanding of the complex relationships between the rocks, sediments and water that compose the aquifer. Six reports were published in 2012 by the Idaho National Laboratory Project Office:

- Construction diagrams, geophysical logs, and lithologic descriptions for boreholes USGS 103, 105, 108, 131, 135, NRF-15, and NRF-16, Idaho National Laboratory, Idaho
10.2 INL Site Environmental Report

- A comparison of U.S. Geological Survey three-dimensional model estimates of groundwater source areas and velocities to independently derived estimates, Idaho National Laboratory and vicinity, Idaho
- Water-quality characteristics and trends for selected sites at and near the Idaho National Laboratory, Idaho, 1949–2009
- Completion summary for borehole USGS 136 near the Advanced Test Reactor Complex, Idaho National Laboratory, Idaho
- Multilevel groundwater monitoring of hydraulic head and temperature in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, 2009–10
- Evaluation of quality-control data collected by the U.S. Geological Survey for routine water-quality activities at the Idaho National Laboratory, Idaho

10. ENVIRONMENTAL RESEARCH AT THE IDAHO NATIONAL LABORATORY SITE

This chapter summarizes ecological research performed at the Idaho National Environmental Research Park (Section 9.1) and research conducted on the eastern Snake River Plain and eastern Snake River Plain aquifer by the United States Geological Survey (Section 9.2) during 2012.

10.1 Ecological Research at the Idaho National Environmental Research Park

The Idaho National Laboratory (INL) Site was designated as a National Environmental Research Park in 1975. The National Environmental Research Park Program was established in response to recommendations from citizens, scientists, and members of Congress to set aside land for ecosystem preservation and study. This has been one of the few formal efforts to reserve land on a national scale for ecological research and education. In many cases, these protected lands became the last remnants of what were once extensive natural ecosystems.

Five basic objectives guide activities on National Environmental Research Parks:

- Develop methods for assessing and documenting environmental consequences of human actions related to energy development
- Develop methods for predicting environmental consequences of ongoing and proposed energy development
- Explore methods for eliminating or minimizing predicted adverse effects from various energy development activities on the environment
- Train people in ecological and environmental sciences
- Educate the public on environmental and ecological issues.

National Environmental Research Parks provide rich environments for training researchers and introducing the public to the ecological sciences. They have been used to educate grade
school and high school students and the general public about ecosystem interactions at
Department of Energy (DOE) sites; train graduate and undergraduate students in research
related to site-specific, regional, national, and global issues; and promote collaboration and
coordination among local, regional, and national public organizations, schools, universities and
federal and state agencies. Ecological research on National Environmental Research Parks is
leading to better land-use planning, identifying sensitive areas on DOE sites so that restoration
and other activities are compatible with ecosystem protection and management, and increased
contributions to ecological science in general.

Ecological research was conducted at federal laboratories long before National
Environmental Research Parks were established. For example, at the INL Site, ecological
research began in 1950 with the establishment of the long-term vegetation transect study.
This is perhaps DOE’s oldest ecological data set and one of the most intensive data sets for
sagebrush steppe. In addition, in 1989, a long-term reptile monitoring study was initiated, which
is the longest continuous study of its kind in the world. Also, in 1993, a protective cap biobarrier
experiment was initiated, which evaluated the long-term performance of evapotranspiration caps
and biological intrusion barriers. Those long-term plots are now being used to test hypotheses on
the potential effects of climate change.

The Idaho National Environmental Research Park provides coordination of ecological
research and information exchange at the INL Site. It facilitates ecological research on the
INL Site by attracting new researchers to use the area, providing background data for new
research projects, and assisting researchers to obtain access to the INL Site. The Idaho
National Environmental Research Park provides infrastructure support to ecological researchers
through the Experimental Field Station and reference specimen collections. The Idaho National
Environmental Research Park tries to foster cooperation and research integration by encouraging
researchers to collaborate, developing interdisciplinary teams to address more complex
problems, encouraging data sharing, and leveraging funding across projects to provide more
efficient use of resources. It also integrates research results from many projects and disciplines
and provides analysis of ecosystem-level responses. The Idaho National Environmental
Research Park has developed a centralized ecological data repository to provide an archive for
ecological data and to facilitate data retrieval for new research projects and land management
decision making. It also provides interpretation of research results to land and facility managers
to support compliance with natural resource laws including the National Environmental Policy Act,
Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection
Act.

A total of 33 graduate students, post-doctoral students, faculty, and agency and contractor
scientists participated in six research projects on the Idaho National Environmental Research
Park in 2012. Several undergraduate students and technicians also gained valuable experience
through participation in these research activities. The six projects include six graduate student
research projects, with students and faculty from Idaho State University, Boise State University,
the College of Idaho, and Montana State University. Other researchers represented the
Department of Agriculture – Forest Service Rocky Mountain Research Station, and the Idaho
National Laboratory.
Three of the graduate students received at least part of their research funding from the Department of Energy, Idaho Operations Office (DOE-ID) through the Environmental Surveillance, Education, and Research Program. Three of the six projects received funding in whole or part from DOE-ID through the Environmental Surveillance, Education, and Research Program. Other funding sources included the National Science Foundation, Bureau of Land Management, Idaho State University, U.S. Environmental Protection Agency, U.S. Department of Agriculture – Forest Service Rocky Mountain Research Station, U.S. Department of Defense, U.S. Geological Survey – Forest and Rangeland Ecosystem Science Center, U.S. Geological Survey – Northwest Climate Science Center, The Berryman Institute, and The Rocky Mountain Elk Foundation.

Most of the DOE-ID-funded research and much of the research funded by other agencies addresses land management issues applicable to the INL Site. These issues include preparing for potential Endangered Species Act listings, understanding wildland fire effects, minimizing invasive species impacts, and understanding long-term trends in plant community composition, sagebrush health, and potential effects of climate change. The results of these projects will be used to support the preparation of a Conservation Management Plan.

10.1.1 Long-Term Vegetation Transects

Investigators and Affiliations

- Amy D. Forman, Plant Ecologist, Environmental Surveillance, Education, and Research Program, Gonzales-Stoller Surveillance, Idaho Falls, ID.
- Roger D. Blew, Ecologist, Environmental Surveillance, Education, and Research Program, Gonzales-Stoller Surveillance, Idaho Falls, ID.
- Jackie R. Hafla, Natural Resource Specialist, Environmental Surveillance, Education, and Research Program, Gonzales-Stoller Surveillance, Idaho Falls, ID.

Funding Source

- U. S. Department of Energy-Idaho Operations Office

Background

Abiotic and biotic conditions across the entire region have been characterized by rapid change over the past decade. These changes include shifts in land cover, land use, and climate. Several large wildland fires have removed sagebrush from a large portion of the Upper Snake River Plain over the past ten to twenty years. INL Site specifically, nearly 60,000 ha have burned in the past five years alone. Soil disturbance associated with fighting wildland fires and soil disturbance associated with general increases in the use of remote backcountry areas are notable at the INL Site and throughout the Intermountain West. Finally, some of the hottest and driest years during the 60-year weather record occurred during the past decade. All of these factors contribute to increasing stress on native plant communities and potentially set the stage for a period of dramatic change in vegetation composition across the region.

The Long-Term Vegetation (LTV) Transects and associated permanent vegetation plots were
established on what is now the INL Site in 1950. Vegetation abundance data, including density and cover, have been collected periodically once every two to ten years from plots located along two macro-transects, which are perpendicular to one another and intersect near the center of the INL Site (Figure 10-1). In 2011, 89 plots were sampled, which represents the twelfth LTV sample period. Eleven plots were sampled again in 2012 because they burned just a few weeks subsequent to sampling in 2011. Fourteen ancillary plots were also established to better address mechanisms affecting trends in sagebrush cover. Results from those analyses are included with the current LTV effort as well. LTV data are generally used to monitor vegetation condition and change in sagebrush steppe communities across the INL Site, while specific uses range from support for NEPA to conservation management planning. They are also uniquely suited to characterize native vegetation response to climate, land cover, and land use change.

**Objectives**

The current LTV technical report, which integrates data from the most recent sampling effort, is organized into four chapters, each with specific objectives. Chapter 1 provides a brief overview of the LTV project and summarizes changes since the previous LTV sample period. Recent land cover change from wildland fire and changes in the amount and timing of precipitation are discussed, along with the potential for those factors to affect native vegetation. A summary of vegetation monitoring and research outside the scope of the LTV, but which inform our interpretation of the LTV data, were included in Chapter 1 as well.

The second chapter is an update of long-term trend analyses for major vegetation functional groups across the INL Site. It includes information about native shrub, grass, and perennial forb abundance, as well as distribution and abundance patterns of non-native species. The results of analyses presented in this chapter provide an indication of general vegetation condition on the INL Site.

The T-17 fire burned 11 LTV plots just a few weeks after data collection had been completed in 2011, providing a unique opportunity to monitor post-fire recovery on well-characterized sites. We resampled the 11 burned plots in 2012, and Chapter 3 compares vegetation abundance and composition immediately pre- and post-fire. Eventually, these data will be used to develop a better understanding of how pre-fire condition affects post-fire recovery and to help identify indicators of potential post-fire recovery issues in the first few years after a wildland fire.

Chapter 4 includes INL-specific data and discussion about big sagebrush (Artemisia tridentata) population biology and its effects on sagebrush steppe plant communities. In the late 1990s and early 2000s it became evident in the LTV data that big sagebrush was undergoing a dramatic and prolonged period of decline. The nature of big sagebrush decline on the INL Site coupled with increasing conservation pressures for sagebrush-obligate species, made obvious the need for an investigation into big sagebrush ecology. Fourteen plots were established in the center of the INL Site (Figure 10-1) for the purposes of characterizing big sagebrush population dynamics. Results of the big sagebrush population study, as well as the implications of these results on conservation measures and land management strategies at the INL Site are also included in this chapter.
Figure 10-1. Map of the INL Site with plot locations for the LTV permanent plots and the ancillary Sagebrush Demography study plots.
Accomplishments through 2012

During the 2012 growing season, a full suite of abundance and distribution data were collected on the 11 plots that burned in the T-17 Fire in late August of 2011. Those data, along with data from the 2011 project database were integrated into the primary LTV database after undergoing final QA/QC and data verification/validation processes. The final, comprehensive project database was archived on the ESER server. Data analyses were finished and a draft of the LTV technical report, as described above, was completed by the end of 2012. The report was finalized shortly thereafter.

Results

Some of the more important vegetation composition patterns resulting from incorporation of the 2011 LTV data into the long-term trend analyses were related to the abundance and distribution of non-native species. Crested wheatgrass (*Agropyron cristatum*) abundance has continued to increase linearly since about 1990 (Figure 10-2) and is of particular concern because it has invaded the plots were it is found, it continues to increase in the plots it occupies, and where present, it occurs with much greater mean abundance than comparable native, perennial bunchgrass species. Cheatgrass (*Bromus tectorum*) distribution increased between

![Figure 10-2. Trends in total perennial grass cover, native perennial grass cover, and introduced perennial grass (crested wheatgrass) cover from 1950 to 2011 for the core subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.](image-url)
the 2006 and 2011 sample periods, and cheatgrass abundance, which historically fluctuates, increased significantly over the past five years (Figure 10-3). Introduced annual forbs, primarily desert alyssum (*Alyssum desertorum*), continued along a trajectory of exponential increase which began in the mid-1990s. It doesn’t appear as though increases in non-native species were at the expense of the native herbaceous understory, but these trends do mark a departure from ranges of historical herbaceous composition.

The 2011 LTV surveys provided an opportunity to assess the relationship between pre- and post-fire vegetation condition when the T-17 Fire burned 11 of the LTV plots only a few weeks after they were sampled. Despite the extremely dry conditions during the first growing season following the T-17 Fire, recovery of native perennial grasses, was notable and was consistent with results reported from earlier studies at the INL Site (Table 10-1). Results from this limited data set, indicate a striking post-fire decline in introduced annual species such as cheatgrass. These results suggest a different post-fire response of introduced annuals than may be otherwise expected.

Previous reports from the LTV data have demonstrated a decline in big sagebrush cover that is not associated with loss due to fire. Between 1975 and 2006 average big sagebrush cover on the unburned, core LTV plots declined from more than 20 percent to less than 10 percent. In order to better understand the losses of big sagebrush cover and the declines in stand condition at the INL Site, we completed the sagebrush demography study. Big sagebrush was generally

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**Figure 10-3.** Density and frequency trends for *Bromus tectorum* on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site from 1950 to 2011. Data are means ± 1 SE.  
*Frequency data are missing from the 1995 data archives.*
much younger than we had anticipated (Figure 10-4). Based on our results, mechanisms controlling big sagebrush stand replacement appear to be related to a combination of general precipitation patterns and fine-scale microsite conditions. Across the study site, annual recruitment patterns are cyclic and patterns in annual age class size reflect patterns in annual precipitation, but recruitment in some stands appears to be more affected by annual precipitation than in others. Our results suggest that disturbance is not required for stand replacement. In fact, all stands sampled for this project had a mean age of living individuals of less than 25 years and a mean age of individuals at death of less than 50 years, indicating that natural rates of turnover at the INL Site are much higher than expected.

**Plans for Continuation**

The 2011 sample effort, along with the database updates and technical report are complete. The LTV plots are scheduled to be sampled again in their entirety in 2016.

**Publications, Theses, Reports**


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Table 10-1. Mean absolute cover by functional group and one-way repeated measures ANOVA results comparing pre- and post-fire vegetation on 11 Long-Term Vegetation Transect plots at the Idaho National Laboratory Site.

<table>
<thead>
<tr>
<th>Functional Group</th>
<th>2011</th>
<th>2012</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Shrubs</td>
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<td>0.48</td>
<td>Yes</td>
</tr>
<tr>
<td>Native Perennial Graminoids</td>
<td>7.81</td>
<td>5.98</td>
<td>No</td>
</tr>
<tr>
<td>Native Perennial Forbs</td>
<td>1.60</td>
<td>0.74</td>
<td>Yes</td>
</tr>
<tr>
<td>Native Succulents</td>
<td>0.16</td>
<td>0.03</td>
<td>Yes</td>
</tr>
<tr>
<td>Native Annuals and Biennials</td>
<td>0.23</td>
<td>0.09</td>
<td>No</td>
</tr>
<tr>
<td>Introduced Annuals and Biennials</td>
<td>11.96</td>
<td>0.55</td>
<td>Yes</td>
</tr>
</tbody>
</table>

a. ANOVA = Analysis of Variance.
10.1.2 Survey, Monitoring and Predicting the Occurrence and Spread of Native and Non-Native Plant Species at Idaho National Laboratories

Investigators and Affiliations

- Lisa Rew, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana
- Bruce Maxwell, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana
- Matt Lavin, Department of Plant Sciences and Plant Pathology, Montana State University, Bozeman, Montana
- Tyler Brummer, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana
- Kimberley Taylor, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana

Funding Sources

- U.S. Department of Energy, Idaho Operations Office

Figure 10-4. Annual age class distributions for 636 big sagebrush plants sampled on the INL Site. Data are pooled from 14 sample locations.
Background

Management of both non-indigenous plant species (NIS) and rare plant species (RPS) is a high priority in many managed forests, wildlands and rangeland areas. However, rarely do either public or private agencies have sufficient resources to manage all NIS or conserve all RPS. Neither do agencies have sufficient information on the potential impacts of future anthropogenic development. Therefore, a better understanding of the temporal and spatial processes which drive both NIS and RPS population distributions and dynamics is required to improve management effectiveness and efficiency. The difficulty in increasing our knowledge of NIS and RPS population dynamics in the sagebrush-steppe plant community is that they occur with low frequency on the landscape and can be difficult to detect because they are similar in morphology to the co-occurring species. By using knowledge of probable routes of introduction for the NIS, and particular habitat requirements for the RPS, appropriate survey methods can be developed. Repeated sampling can then help to elucidate the spatiotemporal dynamics of select populations. From such data, predictive occurrence maps can be generated for the current landscape, but also for a range of future scenarios including anthropogenic development. Incorporating the information into a decision support management prioritization framework can help resource managers prioritize populations to manage and help evaluate the potential impacts of different disturbance scenarios to minimize the negative (RPS) or positive (NIS) impacts on plant population dynamics.

Objectives

The goal of this study was to determine the current distribution of NIS and RPS on the INL Site and predict the potential spatial and temporal metapopulation dynamics of these species to help inform management and future development decisions.

Accomplishments through 2012

Survey detection error and metapopulation dynamics: A total of 33 ten-meter-wide belt transects that originated on roads or facility margins and traveled two km away from the road or facility were selected for survey in 2012, to evaluate extinction and colonization rates. Transects were repeats from previous years and selected according to stratification on fire chronology and proximity to facilities. Presence and absence of eight targeted NIS were recorded along these transects in two 200 m sections. The 200 m sections were randomly located, one within 0-1000 m and the other 1001-2000 m from the road.

To assess the role of fire on the availability of seed for colonization we collected soil samples at approximately 40 locations along the fire chronology. The soil samples were potted in a glass house and individuals are being counted and identified as they germinate.

Results

Survey detection error and metapopulation dynamics: We now have three seasons of extinction/colonization data (2009-2010, 2010-2011, 2011-2012). Data analysis and model summarization of these rates are being completed for the eight targeted NIS – *Agropyron cristatum*, *Alyssum desertorum*, *Bromus tectorum*, *Carduus nutans*, *Descurainia sophia*, *Halogeton glomeratus*, *Lepidium perfoliatum*, and *Sisymbrium altissimum*. We are aiming to define the relative importance of propagule pressure/isolation, habitat quality, disturbance
(wildfire) and inter-annual climate variability on colonization and extinction dynamics of these species.

Seedlings germinating from the seed bank samples are still being assessed.

**Plans for Continuation**

Data analysis, interpretation and finalization and revision of manuscripts is on-going.

**Publications, Theses, Reports**

*Publications:*


*Presentations:*


10.1.3 Studies of Ants and Ant Guests at the Idaho National Laboratory Site

Investigators and Affiliations


Funding Sources

• Funding is by the principal investigator with some assistance from and collaboration with the Orma J. Smith Museum of Natural History.

Background

Clark and Blom (2007) reported the first comprehensive annotated checklist of ants at the INL Site. This publication gives a starting point for additional research relating to ants, their natural history and ecology, and ant guests at INL Site. Ant guests (myrmecophiles) are organisms that live in close association with ants. These are generally mutualistic associations, but may also be commensal or parasitic.

Objectives

Immediate objectives are to locate living larvae of the ant guest beetle (Gonasida elata) (Coleoptera: Tenebrionidae) within nests of the harvester ant (Pogonomyrmex salinus) (Hymenoptera: Formicidae). These beetles have been documented from the harvester ant nests here in the past by Clark and Blom (unpublished data), but the larvae have not been previously described. Fresh larvae are needed for scanning electron microscopy (SEM) to provide for a proper description of these organisms. The overall objective will be to document the interaction of this beetle with the ants.

Other observations on additional ant guests will be made as they are encountered. Information relating to the ants of INL Site will be documented as possible.

Accomplishments through 2012

During the fall of 2011, 100 nests of the harvester ant (Pogonomyrmex salinus) were selected and marked along Road T-17 near Circular Butte (Figure 10-5). These nests were then surveyed by INL archaeologists for cultural resources and approval was given for excavation of nests as needed. A total of 10 percent of the nests were excavated during late 2011 and no Gonasida elata were found. Additional nests were excavated during the fall of 2012 and again no Gonasida elata were found. Searches will continue, perhaps during other seasons of the year.

Results

Two ant guest taxa; an ant beetle (Coleoptera: Tenebrionidae: Araeoschizus sp.) (Figure 10-6) and a Jerusalem cricket (Orthoptera: Stenopelmatidae, Stenopelmatus) were found at the INL Site. The Stenopelmatus is likely also a species that has not been previously described. Both taxa will require more study during future visits to the INL Site.

Plans for Continuation

Field research will continue into the foreseeable future.
Figure 10-5. Nest of *Pogonomyrmex salinus* (*Hymenoptera: Formicidae*) marked for future study. Nest near Circular Butte, November 2011, W.H. Clark photo. Ant mound is approximately 0.75 m diameter.

Figure 10-6. *Araeoschizus* (*Coleoptera: Tenebrionidae*) found in a *Pogonomyrmex salinus* nest. Nest near Circular Butte, November 2011, W.H. Clark photo. Beetle is approximately 4 mm in length.
Publications, Theses, Reports

The project is still in the field data collection phase and no publications have been prepared.

10.1.4 Post-wildfire Wind Erosion In and Around the Idaho National Laboratory Site

Investigators and Affiliations

• Matthew J. Germino, Ph.D., Research Ecologist, United States Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise Idaho

Collaborators

• Nancy F. Glenn, Ph.D., Professor, Geosciences Department, Idaho State University, Boise, Idaho
• Joel Sankey, Ph.D., Research Scientist, United States Geological Survey, Flagstaff, Arizona
• Amber N. Hoover, Technician, Idaho National Laboratory, Idaho Falls, Idaho
• Mike Griffel, student, Idaho State University, Idaho Falls, ID
• Natalie Wagenbrenner, Engineer, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Moscow, Idaho
• Brian Lamb, Ph.D., Washington State University, Laboratory for Atmospheric Research, Pullman, Washington
• Peter Robichaud, Ph.D., U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Moscow, Idaho

Funding Sources

• U.S. Department of Defense
• Bureau of Land Management
• US Geological Survey
• USDA Forest Service Rocky Mountain Research Station

Background

Wind erosion following large wildfires on and around the INL Site is a recurrent threat to human health and safety, DOE operations and trafficability, and ecological and hydrological condition of the INL Site and down-wind landscapes. Causes and consequences of wind erosion are mainly known from warm deserts (e.g., Southwest U.S.), dunefields, and croplands, and some but not all findings are transferable to the cold desert environments such as where the INL Site lies.
Objectives

This is a large and multifaceted research program with the overall goal being to determine and describe wildland fire effects on wind erosion in rangelands on and around the INL Site. The specific objectives include the following:

• To quantify the role of wind erosion and dust emissions in post-fire environments as well as the associated potential impacts on site fertility, invasibility by exotic grasses, micro-scale geomorphology, and regional air quality.

• To determine if the aerodynamic parameters friction velocity, roughness length, and displacement height change through time following wildland fire, and to identify how these parameters relate to vegetation recovery after fire.

• To determine the effects of repeat burning on levels of wind erosion, for sites that reburn a few years following prior fires.

• To determine how surface-soil moisture variations relate to (i.e., control) erodibility over the months when vegetation has yet to recover on the site.

• To link monitoring of near-soil saltation activity to dust emission and model regional dust plumes culminating from INL Site fires, using a combination of ground-level, air quality, and remotely sensed approaches.

Accomplishments through 2012

In 2012, we continued to evaluate the large and complex array of remotely sensed and ground-based data we collected from 2010 through 2011 on the very high levels of wind erosion on the 2010 Jefferson Fire, and on the 2010 Middle Butte Fire. These analyses will help guide development of standardized protocols for monitoring erosion, which is increasingly a need on the Snake River Plain.

Results

Jefferson Fire, example of preliminary results:

Adding to analyses conducted in prior years, we made evaluations of different time frames and calculation methods for assessing the amount of erosion occurring after the Jefferson wildfire, and the critical threshold windspeed. Our preliminary results suggest different threshold windspeed and duration of soil movement events for PM$_{10}$ dust well above ground (2-5 m) compared to saltation of larger particles near ground (Table 10-2). Threshold windspeeds appear to have increased substantially over time since burning.

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.

Plans for Continuation

In 2013, we do not plan to collect more field data unless new fire and erosion conditions arise. Our efforts will continue to focus on using existing data for modeling, analysis, and publication.
Table 10-2. Comparison of different methods for evaluating threshold windspeeds for erosion (windspeed required to move soil) and erosion events, in the first few months after July wildfire (2010 Jefferson Fire, 108K acres; Aug to mid-Nov 2010), and after the first winter but prior to the first bit of vegetation recovery (Apr through Jun 2011). Erosion was measured as saltation (bouncing soil particles within a few cm of the soil surface) by a “Sensit” instrument along with windspeeds with cup anemometers, and PM$_{10}$ was measured with a Met-One (E-sampler) PM$_{10}$ (particles < 10 micron) detector, and friction velocity (U*) with sonic anemometers and eddy covariance calculations. The Gaussian method relates saltation or PM$_{10}$ activity to a frequency distribution of windspeeds within 5-min periods, whereas the “instantaneous” method is simply finding the windspeed at which saltation or PM$_{10}$ emissions occur. *(Unpublished data of MJ Germino, in preparation for publication.)*

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<th>2011 (m/s)</th>
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<tr>
<td>Sensit Windspeed Threshold Gaussian Method</td>
<td>8.57</td>
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<td>Sensit Windspeed Threshold Instantaneous Method</td>
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<tr>
<td>Sensit U* Threshold</td>
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<td>PM10 Windspeed Threshold</td>
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<td>Sensit Windspeed Threshold Gaussian Method</td>
<td>8.86</td>
<td>11.15</td>
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<td>Sensit Windspeed Threshold Instantaneous Method</td>
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Publications, Theses, Reports

Publications:


Presentations:


Germino, M. 2012. Weather and post-fire wind erosion Climate Forum, Great Basin. Desert Research Institute, Reno NV, October 17


10.1.5 The Influence of Precipitation, Vegetation and Soil Properties on the Ecohydrology of Sagebrush Steppe Rangelands on the INL Site

Investigators and Affiliations

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• Marie-Anne deGraff, Ph.D., Assistant Professor, Boise State University, Boise, Idaho
• David Huber, Ph.D. candidate, Idaho State University, Pocatello, Idaho
• Patrick Sorenson, M.S., Boise State University, Boise, Idaho
• Patricia Xochi Campos, M.S. candidate, Boise State University, Boise Idaho
• Carrier Jilek, B.S. candidate, Boise State University, Boise, Idaho
• Cassandra Gause, B.S./M.S. candidate, Idaho State University, Pocatello, Idaho
• Jennifer Forbey Ph.D., Assistant Professor, Boise State University, Boise, Idaho
• Lisa Lam, B.S. candidate, Boise State University, Boise, Idaho

Funding Sources

• Idaho Experimental Program to Stimulate Competitive Research (EPSCoR), National Science Foundation.
• US Geological Survey, Forest and Rangeland Ecosystem Science Center
• US Geological Survey, Northwest Climate Science Center

In-kind facilities and infrastructure support from DOE-ID, logistics support through Gonzales Stoller Surveillance LLC.

Background

The INL Site and other landscapes having sagebrush steppe vegetation are experiencing a simultaneous change in climate and floristics that result from increases in exotic species. Determining the separate and combined/interactive effects of climate and vegetation change is important for assessing future changes on the landscape and for hydrologic processes.

This research uses the 72 experimental plots established and initially maintained for many years as the “Protective Cap Biobarrier Experiment” by Dr. Jay Anderson and the Stoller ESER program, and the experiment is also now referred to as the “INL Site Ecohydrology Study.” We are evaluating long-term impacts of different plant communities commonly found throughout Idaho subject to different precipitation regimes and to different soil depths. Treatments of amount and timing of precipitation (irrigation), soil depth, and either native/perennial or exotic grass
vegetation allow researchers to investigate how vegetation, precipitation and soil interact to influence soil hydrology and ecosystem biogeochemistry. This information will be used to improve a variety of models, as well as provide data for these models.

**Objectives**

The goal of this study is to assess the interactive and reciprocal effects of hydroclimate shifts and plant community composition on ecohydrological and biogeochemical processes, with the specific objectives to:

- Determine response of vegetation to timing of irrigation and soil depth, and conversely the influence of plant communities and vegetation type on deep soil water infiltration
- Investigate microbial communities and soil microbial enzymatic activity and soil aggregation/porosity, to assess whether fundamental ecosystem changes to treatments are occurring and could feed back on water flow patterns
- Investigate changes in plant and soil nutrient pools and fluxes due to vegetation and precipitation differences.

**Accomplishments through 2012**

In 2012 we inserted an additional set of Time Domain Reflectometry (TDR) water content sensors in an effort to reduce our reliance on manual neutron-probe measurements, an effort that will continue. In 2011 we inserted Decagon Echo probes at 3 depths in shrub interspaces in about 1/3 of the plots, and in 2012 we inserted Campbell 616 probes into all 72 plots, with one sensor spanning 0-30 cm depth in interspace microsites. We installed litter traps to begin a formal evaluation of plant litter inputs, dug soil pits and analyzed the stratigraphy and pedogenesis of the soils, analyzed soil respiration, and made a number of soil biogeochemical measurements. We finished an extensive analysis of point-intercept data on vegetation cover of all plots, comparing the sampling method used from 1993 to 2006 with a revised method that will focus on aerial cover and leaf-area indices. We began a newly funded project on sagebrush demographic responses to the treatments, including detailed sampling of sagebrush responses. As part of this, we tested several approaches for measuring sagebrush growth, including marking stems and measuring stem elongation in the field compared to clipping stems to measure stem lengths along annual growth increments revealed by buds and the number of annual xylem (vascular) rings in the wood.

**Results**

Preliminary results from soil pits reveal a surprisingly large amount of pegogenic activity since 1993 that has caused the soil profiles of experimental plots to resemble soil structure in the surrounding and natural sagebrush steppe. Features including the formation of calcic pedogenic minerals, silt layers that suggest vertical transport of fine soil particles, and these all vary by treatment. In a preliminary round of soil respiration, we did not detect appreciable differences among treatments, but did reveal strong differences between shrub and interspace microsites. Very large differences in sagebrush growth and seedling establishment are evident among the treatments, with winter irrigation continuing to promote greater sagebrush presence than other treatments. Preliminary data suggest large differences in growth estimated by measuring stem
elongation in the field compared to clipping stems to measure stem lengths along annual growth increments revealed by buds and the number of annual xylem (vascular) rings in the wood (Figure 10-7). Sagebrush growth is an important variable to measure for assessing ecosystem change and function (e.g., for carbon storage, grazing impacts, hydrology, etc), and these data show much greater sensitivity of lab-based measurements, but also raise questions about sources of error in the field, assuming the laboratory measurement is more reliable.

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.

**Plans for Continuation**

We will continue making the same types of measurements as in the past year, generating multiple-years of data to substantiate our findings. New additions will continue to include 1) assessments of soil solution biogeochemistry done through installation of lysimeters via cores from the surface, 2) measurements of net primary productivity, 3) assessment of litter inputs and decomposition processes, along with root growth assessed by root-ingrowth tubes, 4) sagebrush demography.

![Figure 10-7. Difference in annual stem growth estimated by marking stems and repeatedly measuring growth along them in the field, compared to clipping stems and measuring annual growth increments in the laboratory. Each datum is a plant, from all plots with native vegetation and 2 m deep soil.](image)
Publications, Theses, Reports


10.1.6 Distribution, Movements, and Space Use by Elk on the Idaho National Laboratory Site

Investigators and Affiliations

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- Jericho C. Whiting, Ph.D., Wildlife Biologist, Environmental Surveillance, Education, and Research Program, Gonzales-Stoller Surveillance, LLC, Idaho Falls, Idaho
- R. Terry Bowyer, Ph.D., Professor, Department of Biological Sciences, Idaho State University, Pocatello, Idaho
- John G. Kie, Ph.D., Research Professor, Department of Biological Sciences, Idaho State University, Pocatello, Idaho

Funding Sources

- U. S. Department of Energy-Idaho Operations Office
- U. S. Environmental Protection Agency
- The Berryman Institute
- The Rocky Mountain Elk Foundation
- Idaho State University

Background

Large mammals play important functional roles in many ecosystems, including sagebrush-steppe. Indeed, large herbivores often act as keystone species, and thus understanding the causes and consequences of their patterns of behavior can provide important insights into a variety of ecosystem processes. In addition, detailed data on movements of large mammals can provide land managers with critical information on ecological interactions between those animals and their environment. Such information is necessary for understanding past effects of anthropogenic disturbance on mammals and for predicting effects of future development, as well as for minimizing the negative effects of development on mammals. Such data may also provide important clues about the potential transport of nutrients and environmental contaminants by large mammals across landscapes. Nevertheless, the detailed data necessary to understand large-scale patterns of movement and resource selection by large mammals on the INL Site have never been obtained.

Previous research on large herbivores at the INL Site has focused primarily on documenting presence-absence or general locations of those animals through aerial surveys, with some notable exceptions. For example, Strohmeyer and Peek (1996), Strohmeyer et al. (1999), and Comer (2000) reported that elk (*Cervus elaphus*) on the INL Site foraged primarily in burned areas and agricultural fields at night, but strongly selected sagebrush habitat on lava located far from foraging areas during the day. Even in those studies, however, locations of individual elk were collected infrequently via very high frequency (VHF) radio-collars, and consequently a large number of important questions remain unanswered. For example: 1) To what extent do elk on the INL Site utilize surrounding agricultural lands, and how does that use vary seasonally?
2) What proportion of the elk population on the INL Site is resident (i.e., remains on the Site all year) versus migratory (i.e., leaves the Site for some portion of the year)?  3) How do elk on the INL Site respond to anthropogenic factors already in place, such as roads and Site facilities?  4) How do general patterns of movement and space use by elk on the INL Site change seasonally?  These and similar questions can be addressed using high-frequency location data, and answers to these questions will allow biologists and land managers to minimize the negative effects of future development on populations of elk and other large herbivores on the INL Site, and will also provide information useful for managers desiring to minimize depredation of crops surrounding the INL Site by large herbivores. In addition, detailed movement data for elk will provide insights into the potential role of this species in distributing environmental contaminants both on and off of the INL Site.

**Objectives**

The overall goal of our project was to document landscape-scale patterns of movement and space use by elk at the INL Site. Results of our study will be integrated into the Conservation Management Plan for the INL Site, and will provide the U. S. Department of Energy with important information for environmental planning purposes. In addition, our results will provide information useful for managers desiring to minimize depredation of crops surrounding the INL Site by large herbivores, and will provide insights into the potential role of large mammals in distributing environmental contaminants both on and off of the study site.

- Capture 20 elk per during 2010-2012 on the INL Site in order to collect data on body condition, morphology, disease, and pregnancy status, and to fit each of those animals with a GPS collar programmed to collect hourly locations between March and December.
- Determine the extent to which critical habitat (e.g., calving grounds) for elk occurs within the Development Zone.
- Determine when, where, and to what extent elk move between the INL Site and surrounding agricultural lands to aid in quantifying potential depredation problems and potential transport of contaminants off of the INL Site by elk.

**Accomplishments through 2012**

- A total of 58 female elk were captured and fit with GPS collars in the winters of 2010, 2011 and 2012 by net-gun from a helicopter or by drive-netting. During the capture, data on body condition, morphology, and blood parameters were collected.
- We plotted all locations obtained from GPS-collared elk in ArcGIS 10 and calculated the proportion of locations occurring in agricultural fields (based on 2011 NAIP imagery) on a seasonal basis.
- We used the “near” tool in ArcGIS to calculate the distance from each elk location on the INL Site to the nearest Site facility, as well as to the nearest primary road. We then calculated the percentage of elk locations that occurred within 1 km of either INL Site facilities or primary roads on the Site.
Results

We captured a total of 58 adult female elk on the INL Site during winters of 2010-2012. After accounting for post capture mortality and equipment failure (primarily during 2010), we obtained usable GPS data from 35 of those animals (Figure 10-8). A total of 55,998 hourly GPS locations were obtained for elk during spring (April-June; Figure 10-9), 39,907 locations were obtained during summer (July-September; Figure 10-10), and 35,671 locations were obtained during autumn (October-November; Figure 10-11). The proportion of elk locations occurring on the INL Site was 27 percent, 23 percent, and 63 percent during spring, summer, and autumn, respectively.

Overall, elk spent very little time in agricultural fields surrounding the INL Site during spring through autumn, or within 1 km of Site facilities or primary roads (Table 10-3). The amount of time spent in close proximity to each of these areas (agricultural fields, facilities, and roads) increased, however, between spring and autumn (Table 10-3). A maximum of 9 percent of elk locations occurred in agricultural fields, 1 percent within 1 km of a Site facility, and 10 percent within 1 km of a primary road on the Site during autumn (Table 10-3). The majority of elk locations occurring within 1 km of a primary road on the INL Site were in the southwestern portion of the Site along U.S. highway 26/20 (Figure 10-12).

Our results indicate that use of the INL Site by many elk during spring-autumn is largely transient. Indeed, only a small proportion of our study animals remained on the INL Site.
Figure 10-9. 55,998 hourly GPS locations obtained from 35 collared female elk (*Cervus elaphus*) on the INL Site during spring (April-June), 2010-2012.

Figure 10-10. 39,907 hourly GPS locations obtained from 35 collared female elk (*Cervus elaphus*) on the INL Site during summer (July-September), 2010-2012.
throughout the entire year. Most elk that were captured and fit with GPS collars during late winter dispersed long distances during early spring, and home ranges of collared animals covered hundreds of square miles of the Big Desert. Nearly all of those animals, however, returned to the INL Site during winter, and many of them returned during autumn. One of the most likely explanations for the substantial increase in the proportion of elk locations occurring within the boundaries of the INL Site during autumn is that the Site provides a refugium from hunters. Most hunting seasons in units surrounding the INL Site occur during autumn and early winter, and it is likely that elk respond rapidly to hunting pressure by shifting their distribution, as well as the timing of various behaviors, such as foraging (Naylor et al. 2009).
Our results do not support the hypothesis that elk have been successful in occupying the Big Desert ecosystem largely as a result of the high quality forage provided by agricultural fields. Although agricultural fields did appear to provide an increasingly important source of forage for elk as quality of native forages presumably declined between spring and autumn, elk still spent only a small amount of time utilizing those fields, and many elk never used agricultural fields at all. Consequently, we conclude that the combination of burned habitat and native sagebrush-steppe in the Big Desert provided forage of sufficient quality and abundance to support a substantial number of elk during spring through autumn, even in the absence of agriculture. This conclusion
is also supported by results of other studies of elk conducted in similar sagebrush-steppe ecosystems (e.g., McCorquodale 1991).

It is not clear from our study how elk in the Big Desert obtain the water necessary for their survival. Although we did document some use of guzzlers by elk, many collared animals never utilized a known water source throughout the duration of our study. This included waste water ponds associated with many INL Site facilities. Collared elk in our study were almost never found within 1 km of a Site facility, and only a small number of GPS locations occurred near waste water ponds. As a result, we conclude that the probability of elk transporting environmental contaminants off of the INL Site as a result of drinking contaminated water is likely very low.

Numerous studies of elk and other large herbivores have documented strong avoidance of primary roads and other forms of human disturbance (e.g., Rowland et al. 2000, Naylor et al. 2009). Our results are consistent with the hypothesis that elk generally try to avoid areas with substantial disturbance (this included both roads and INL Site facilities in our study). Nevertheless, because 10 percent of the GPS locations we obtained from elk that were on the INL Site during autumn were located within 1 km of a primary road, the potential for vehicle collisions with elk does indeed exist. Our results indicate that the highest potential for a vehicle collision with elk exists in the southwestern corner of the INL Site along highway 26/20, and this potential is greatest during October-November. Consequently, we recommend that any efforts made by the Department of Energy to reduce dangerous interactions between humans and elk be focused along that stretch of highway. Such efforts could include the placement of warning signs along the highway to indicate that elk frequently cross in that area. In addition, during the hunting season, it may be useful to place temporary electronic signs along that stretch of highway to draw further attention among motorists to the potential for a collision with elk crossing the highway.

Data collected during the course of this project were useful for quantifying the seasonal distribution of elk on the INL Site, as well as how that distribution was influenced by agriculture, roads, and INL Site facilities. Like many large mammals, however, the distribution of elk is highly fluid, and can vary with seasonal and annual changes in factors such as habitat, anthropogenic disturbance, or risk of predation. For example, during the course of this study several large wildfires on and around the INL Site resulted in a substantial change in the abundance and distribution of sagebrush and grassland habitat. This change affected the distribution of elk on the INL Site almost immediately, and in 2012 many collared elk never left the boundaries of the Jefferson Fire during the entire spring-autumn period. Consequently, we recommend that high frequency (e.g. hourly) location data be collected for at least 30 elk on the INL Site every 3-5 years in order to keep track of changes in the distribution of elk that may influence potential conflicts with humans near roads, agriculture, or INL Site facilities. Such data could also be of great importance if wolves take up residence on the INL Site in the near future. Recent confirmed sightings of wolves on the INL Site highlight the potential for such a shift in distribution of these predators, and if such a shift occurs, it will undoubtedly influence the movement and distribution of elk on the INL Site. Indeed, some researchers have reported that elk select areas that are closer to human disturbance when in the presence of wolves, because it reduces the risk of predation. If this occurred on the INL Site, then conflicts with elk near roads or Site facilities could increase dramatically. In addition, it would be useful to collect similar data for other species
of large mammal on the INL Site (e.g., pronghorn and mule deer) in order to determine how those species interact both with the environment on the INL Site, as well as with each other.

**Plans for Continuation**

The field work for the project has been completed and is in the data analysis and writing phase.

**Publications, Reports, and Theses**

This project is ongoing (i.e., field data are still being collected), and thus no publications have been completed at this time. Several peer-reviewed publications and a Ph.D. dissertation will be forthcoming when the project is completed in 2013.

### 10.2 U.S. Geological Survey 2012 Publication Abstracts

In 1949, the United States Geological Survey (USGS) was asked to characterize water resources prior to the building of nuclear-reactor testing facilities at the INL Site. Since that time, USGS hydrologists and geologists have been studying the hydrology and geology of the eastern Snake River Plain and the eastern Snake River Plain aquifer.

At the INL Site and in the surrounding area, the USGS INL Project Office:

- Monitors and maintains a network of existing wells
- Drills new research and monitoring wells, providing information about subsurface water, rock and sediment
- Performs geophysical and video logging of new and existing wells
- Maintains the Lithologic Core Storage Library (CSL).

Data gathered from these activities is used to create and refine hydrologic and geologic models of the aquifer, to track contaminant plumes in the aquifer and improve understanding of the complex relationships between the rocks, sediments and water that compose the aquifer. The USGS INL Project Office publishes reports about their studies, available through the USGS Publications Warehouse (http://id.water.usgs.gov/projects/INL/pubs.html.)

Six reports were published by the USGS INL Project Office in 2012. The abstracts of these studies and the publication information associated with each study are presented below.

**10.2.1 Construction diagrams, geophysical logs, and lithologic descriptions for boreholes USGS 103, 105, 108, 131, 135, NRF-15, and NRF-16, Idaho National Laboratory, Idaho (Mary K.V. Hodges, Stephanie M. Orr, Katherine E. Potter, and Tynan LaMaitre)**

This report, prepared in cooperation with the DOE-ID, summarizes construction, geophysical, and lithologic data collected from about 4,509 feet of core from seven boreholes deepened or drilled by the U.S. Geological Survey (USGS), Idaho National Laboratory (INL) Project Office, from 2006 to 2009 at the INL. USGS 103, 105, 108, and 131 were deepened and cored from 759 to 1,307 feet, 800 to 1,409 feet, 760 to 1,218 feet, and 808 to 1,239 feet, respectively. Boreholes USGS 135, NRF-15, and NRF-16 were drilled and continuously cored from land surface to
1,198, 759, and 425 feet, respectively. Cores were photographed and digitally logged by using commercially available software. Borehole descriptions summarize location, completion date, and amount and type of core recovered.

**10.2.2 A comparison of U.S. Geological Survey three-dimensional model estimates of groundwater source areas and velocities to independently derived estimates, Idaho National Laboratory and vicinity, Idaho (Jason C. Fisher, Joseph P. Rousseau, Roy C. Bartholomay, and Gordon W. Rattray)**

The USGS, in cooperation with the DOE-ID, evaluated a three-dimensional model of groundwater flow in the fractured basalts and interbedded sediments of the eastern Snake River Plain aquifer at and near the Idaho National Laboratory to determine if model-derived estimates of groundwater movement are consistent with (1) results from previous studies on water chemistry type, (2) the geochemical mixing at an example well, and (3) independently derived estimates of the average linear groundwater velocity. Simulated steady-state flow fields were analyzed using backward particle-tracking simulations that were based on a modified version of the particle tracking program MODPATH. Model results were compared to the 5-microgram-per-liter lithium contour interpreted to represent the transition from 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. This comparison indicates several shortcomings in the way the model represents flow in the aquifer. The eastward movement of tributary valley underflow and streamflow-infiltration recharge is overestimated in the north-central part of the model area and underestimated in the central part of the model area. Model inconsistencies can be attributed to large contrasts in hydraulic conductivity between hydrogeologic zones.

Sources of water at well NPR-W01 were identified using backward particle tracking, and they were compared to the relative percentages of source water chemistry determined using geochemical mass balance and mixing models. The particle tracking results compare reasonably well with the chemistry results for groundwater derived from surface-water sources (–28 percent error), but overpredict the proportion of groundwater derived from regional aquifer water (108 percent error) and underpredict the proportion of groundwater derived from tributary valley underflow from the Little Lost River valley (–74 percent error). These large discrepancies may 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.

Independently derived estimates of the average groundwater velocity at 12 well locations within the upper 100 feet of the aquifer were compared to model-derived estimates. Agreement between velocity estimates was good at wells with travel paths located in areas of sediment-rich rock (root-mean-square error [RMSE] = 5.2 feet per day [ft/d]) and poor in areas of sediment-poor rock (RMSE = 26.2 ft/d); simulated velocities in sediment-poor rock were 2.5 to 4.5 times larger than independently derived estimates at wells USGS 1 (less than 14 ft/d) and USGS 100 (less than 21 ft/d). The models overprediction 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 (14,800).
10.2.3 Water-quality characteristics and trends for selected sites at and near the Idaho National Laboratory, Idaho, 1949–2009 (Roy C. Bartholomay, Linda C. Davis, Jason, C. Fisher, Betty J. Tucker, and Flint A. Raben)

The USGS, in cooperation with the DOE-ID, analyzed water-quality data collected from 67 aquifer wells and 7 surface-water sites at the INL from 1949 through 2009. The data analyzed included major cations, anions, nutrients, trace elements, and total organic carbon. The analyses were performed to examine water-quality trends that might inform future management decisions about the number of wells to sample at the INL and the type of constituents to monitor. Water-quality trends were determined using (1) the nonparametric Kendall’s tau correlation coefficient, p-value, Theil-Sen slope estimator, and summary statistics for uncensored data; and (2) the Kaplan-Meier method for calculating summary statistics, Kendall’s tau correlation coefficient, p-value, and Akritas-Theil-Sen slope estimator for robust linear regression for censored data.

Statistical analyses for chloride concentrations indicate that groundwater influenced by Big Lost River seepage has decreasing chloride trends or, in some cases, has variable chloride concentration changes that correlate with above-average and below-average periods of recharge. Analyses of trends for chloride in water samples from four sites located along the Big Lost River indicate a decreasing trend or no trend for chloride, and chloride concentrations generally are much lower at these four sites than those in the aquifer. Above-average and below-average periods of recharge also affect concentration trends for sodium, sulfate, nitrate, and a few trace elements in several wells. Analyses of trends for constituents in water from several of the wells that is mostly regionally derived groundwater generally indicate increasing trends for chloride, sodium, sulfate, and nitrate concentrations. These increases are attributed to agricultural or other anthropogenic influences on the aquifer upgradient of the INL.

Statistical trends of chemical constituents from several wells near the Naval Reactors Facility may be influenced by wastewater disposal at the facility or by anthropogenic influence from the Little Lost River basin. Groundwater samples from three wells downgradient of the Power Burst Facility area show increasing trends for chloride, nitrate, sodium, and sulfate concentrations. The increases could be caused by wastewater disposal in the Power Burst Facility area.

Some groundwater samples in the southwestern part of the INL and southwest of the INL show concentration trends for chloride and sodium that may be influenced by wastewater disposal. Some of the groundwater samples have decreasing trends that could be attributed to the decreasing concentrations in the wastewater from the late 1970s to 2009. The young fraction of groundwater in many of the wells is more than 20 years old, so samples collected in the early 1990s are more representative of groundwater discharged in the 1960s and 1970s, when concentrations in wastewater were much higher. Groundwater sampled in 2009 would be representative of the lower concentrations of chloride and sodium in wastewater discharged in the late 1980s. Analyses of trends for sodium in several groundwater samples from the central and southern part of the eastern Snake River aquifer show increasing trends. In most cases, however, the sodium concentrations are less than background concentrations measured in the aquifer. Many of the wells are open to larger mixed sections of the aquifer, and the increasing trends may indicate that the long history of wastewater disposal in the central part of the INL is increasing sodium concentrations in the groundwater.
10.2.4 Completion summary for borehole USGS 136 near the Advanced Test Reactor Complex, Idaho National Laboratory, Idaho (Brian V. Twining, Roy C. Bartholomay, and Mary K.V. Hodges)

In 2011, the USGS, in cooperation with the DOE-ID, cored and completed borehole USGS 136 for stratigraphic framework analyses and long-term groundwater monitoring of the eastern Snake River Plain aquifer at the Idaho National Laboratory. The borehole was initially cored to a depth of 1,048 feet (ft) below land surface (BLS) to collect core, open-borehole water samples, and geophysical data. After these data were collected, borehole USGS 136 was cemented and backfilled between 560 and 1,048 ft BLS. The final construction of borehole USGS 136 required that the borehole be reamed to allow for installation of 6-inch (in.) diameter carbon-steel casing and 5-in. diameter stainless-steel screen; the screened monitoring interval was completed between 500 and 551 ft BLS. A dedicated pump and water-level access line were placed to allow for aquifer testing, for collecting periodic water samples, and for measuring water levels.

Geophysical and borehole video logs were collected after coring and after the completion of the monitor well. Geophysical logs were examined in conjunction with the borehole core to describe borehole lithology and to identify primary flow paths for groundwater, which occur in intervals of fractured and vesicular basalt.

A single-well aquifer test was used to define hydraulic characteristics for borehole USGS 136 in the eastern Snake River Plain aquifer. Specific-capacity, transmissivity, and hydraulic conductivity from the aquifer test were at least 975 gallons per minute per foot, $1.4 \times 105$ feet squared per day (ft$^2$/d), and 254 feet per day, respectively. The amount of measurable drawdown during the aquifer test was about 0.02 ft. The transmissivity for borehole USGS 136 was in the range of values determined from previous aquifer tests conducted in other wells near the Advanced Test Reactor Complex: $9.5 \times 103$ to $1.9 \times 105$ ft$^2$/d.

Water samples were analyzed for cations, anions, metals, nutrients, total organic carbon, volatile organic compounds, stable isotopes, and radionuclides. Water samples from borehole USGS 136 indicated that concentrations of tritium, sulfate, and chromium were affected by wastewater disposal practices at the Advanced Test Reactor Complex. Depth-discrete groundwater samples were collected in the open borehole USGS 136 near 965, 710, and 573 ft BLS using a thief sampler; on the basis of selected constituents, deeper groundwater samples showed no influence from wastewater disposal at the Advanced Test Reactor Complex.

10.2.5 Multilevel groundwater monitoring of hydraulic head and temperature in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, 2009–10 (Brian V. Twining and Jason C. Fisher)

During 2009 and 2010, the USGS’s INL Project Office, in cooperation with the DOE-ID, collected quarterly, depth-discrete measurements of fluid pressure and temperature in nine boreholes located in the eastern Snake River Plain aquifer. Each borehole was instrumented with a multilevel monitoring system consisting of a series of valved measurement ports, packer bladders, casing segments, and couplers. Multilevel monitoring at the INL has been ongoing since 2006. This report summarizes data collected from three multilevel monitoring wells installed during 2009 and 2010 and presents updates to six multilevel monitoring wells. Hydraulic heads
(heads) and groundwater temperatures were monitored from 9 multilevel monitoring wells, including 120 hydraulically isolated depth intervals from 448.0 to 1,377.6 feet below land surface.

Quarterly head and temperature profiles reveal unique patterns for vertical examination of the aquifer’s complex basalt and sediment stratigraphy, proximity to aquifer recharge and discharge, and groundwater flow. These features contribute to some of the localized variability even though the general profile shape remained consistent over the period of record. Major inflections in the head profiles almost always coincided with low-permeability sediment layers and occasionally thick sequences of dense basalt. However, the presence of a sediment layer or dense basalt layer was insufficient for identifying the location of a major head change within a borehole without knowing the true areal extent and relative transmissivity of the lithologic unit. Temperature profiles for boreholes completed within the Big Lost Trough indicate linear conductive trends; whereas, temperature profiles for boreholes completed within the axial volcanic high indicate mostly convective heat transfer resulting from the vertical movement of groundwater. Additionally, temperature profiles provide evidence for stratification and mixing of water types along the southern boundary of the Idaho National Laboratory.

Vertical head and temperature change were quantified for each of the nine multilevel monitoring systems. The vertical head gradients were defined for the major inflections in the head profiles and were as high as 2.1 feet per foot. Low vertical head gradients indicated potential vertical connectivity and flow, and large gradient inflections indicated zones of relatively low vertical connectivity. Generally, zones that primarily are composed of fractured basalt displayed relatively small vertical head differences. Large head differences were attributed to poor vertical connectivity between fracture units because of sediment layering and/or dense basalt. Groundwater temperatures in all boreholes ranged from 10.2 to 16.3°C.

Normalized mean hydraulic head values were analyzed for all nine multilevel monitoring wells for the period of record (2007–10). The mean head values suggest a moderately positive correlation among all boreholes, which reflects regional fluctuations in water levels in response to seasonality. However, the temporal trend is slightly different when the location is considered; wells located along the southern boundary, within the axial volcanic high, show a strongly positive correlation.


The USGS, in cooperation with the DOE-ID, collects surface water and groundwater samples at and near the INL Site as part of a routine, site-wide, water-quality monitoring program. Quality-control samples are collected as part of the program to ensure and document the quality of environmental data. From 1996 to 2001, quality-control samples consisting of 204 replicates and 27 blanks were collected at sampling sites. Paired measurements from replicates were used to calculate variability (as reproducibility and reliability) from sample collection and analysis of radiochemical, chemical, and organic constituents. Measurements from field and equipment blanks were used to estimate the potential contamination bias of constituents.

The reproducibility of measurements of constituents was calculated from paired measurements as the normalized absolute difference (NAD) or the relative standard deviation
(RSD). The NADs and RSDs, as well as paired measurements with censored or estimated concentrations for which NADs and RSDs were not calculated, were compared to specified criteria to determine if the paired measurements had acceptable reproducibility. If the percentage of paired measurements with acceptable reproducibility for a constituent was greater than or equal to 90 percent, then the reproducibility for that constituent was considered acceptable. The percentage of paired measurements with acceptable reproducibility was greater than or equal to 90 percent for all constituents except orthophosphate (89 percent), zinc (80 percent), hexavalent chromium (53 percent), and total organic carbon (TOC; 38 percent). The low reproducibility for orthophosphate and zinc was attributed to calculation of RSDs for replicates with low concentrations of these constituents. The low reproducibility for hexavalent chromium and TOC was attributed to the inability to preserve hexavalent chromium in water samples and high variability with the analytical method for TOC.

The reliability of measurements of constituents was estimated from pooled RSDs that were calculated for discrete concentration ranges for each constituent. Pooled RSDs of 15 to 33 percent were calculated for low concentrations of gross-beta radioactivity, strontium-90, ammonia, nitrite, orthophosphate, nickel, selenium, zinc, tetrachloroethene, and toluene. Lower pooled RSDs of 0 to 12 percent were calculated for all other concentration ranges of these constituents, and for all other constituents, except for one concentration range for gross-beta radioactivity, chloride, and nitrate + nitrite; two concentration ranges for hexavalent chromium; and TOC. Pooled RSDs for the 50 to 60 picocuries per liter concentration range of gross-beta radioactivity (reported as cesium-137) and the 10 to 60 milligrams per liter (mg/L) concentration range of nitrate + nitrite (reported as nitrogen [N]) were 17 percent. Chloride had a pooled RSD of 14 percent for the 20 to less than 60 mg/L concentration range. High pooled RSDs of 40 and 51 percent were calculated for two concentration ranges for hexavalent chromium and of 60 percent for TOC.

Measurements from (1) field blanks were used to estimate the potential bias associated with environmental samples from sample collection and analysis, (2) equipment blanks were used to estimate the potential bias from cross contamination of samples collected from wells where portable sampling equipment was used, and (3) a source-solution blank was used to verify that the deionized water source-solution was free of the constituents of interest. If more than one measurement was available, the bias was estimated using order statistics and the binomial probability distribution. The source-solution blank had a detectable concentration of hexavalent chromium of 2 micrograms per liter. If this bias was from a source other than the source solution, then about 84 percent of the 117 hexavalent chromium measurements from environmental samples could have a bias of 10 percent or more. Of the 14 field blanks that were collected, only chloride (0.2 milligrams per liter) and ammonia (0.03 milligrams per liter as nitrogen), in one blank each, had detectable concentrations. With an estimated confidence level of 95 percent, at least 80 percent of the 1,987 chloride concentrations measured from all environmental samples had a potential bias of less than 8 percent. The ammonia bias, which may have occurred at the analytical laboratory, could produce a potential bias of 5–100 percent in eight potentially affected ammonia measurements. Of the 11 equipment blanks that were collected, chloride was detected in 4 of these blanks, sodium in 3 blanks, and sulfate and hexavalent chromium were each detected in 1 blank. The concentration of hexavalent chromium in the equipment blank was the same concentration as in the source-solution blank collected on the same day, which indicates
that the hexavalent chromium in the equipment blank is probably from a source other than the portable sampling equipment, such as the sample bottles or the source-solution water itself. The potential bias for chloride, sodium, and sulfate measurements was estimated for environmental samples that were collected using portable sampling equipment. For chloride, it was estimated with 93 percent confidence that at least 80 percent of the measurements had a bias of less than 18 percent. For sodium and sulfate, it was estimated with 91 percent confidence that at least 70 percent of the measurements had a bias of less than 12 and 5 percent, respectively.
References for Section 10.1


References for Section 10.2


Solarized Early 20th Century Bottle
Exposed after Middle Butte Fire