National Park Service
U.S. Department of the Interior

Great Basin National Park
Nevada

HYDROGEOLOGIC RESEARCH PROJECT

Environmental Assessment

July 2011

Summary
Great Basin National Park is concerned that proposed large-scale, permanent groundwater pumping from the hydrologic basin outside the Park and immediately adjacent to it may deplete the flow of surface-water features and water levels in cave features inside the Park and immediately adjacent to it. This, in turn, would likely adversely affect the water-dependent ecosystems associated with these critical natural resource features. In order to better quantify the potential for depletion, a hydrogeologic research project has been developed by the Water Resources Division of the National Park Service to study the hydrology of certain areas in more detail.

Areas of concern include several park watersheds close to the Park boundary, including Lehman, Baker, and Snake. These areas contain surface-water and cave resources that have been identified as being likely susceptible to groundwater pumping outside of the Park.

This hydrogeologic research project proposes to conduct investigations to better understand these important water resources and connections. Specifically, the project would help to better understand basin-fill deposits, assess quantitatively the interaction of surface water and groundwater along selected creeks, delineate the source of water to two important springs, refine estimates of how water is flowing from Spring Valley west of the Park to Snake Valley east of the Park, and conduct a dye tracing study to improve understanding of cave and surface-water connections.

Four alternatives are presented: 1) the No Action Alternative would not allow the Hydrogeologic Research project to be undertaken; the Park would have to rely on incomplete information to assess effects of other cumulative actions, such as the Southern Nevada Water Authority Groundwater Project; 2) the Proponent Action-All Sites that includes all the proponent proposed actions in original locations; 3) No Lehman Creek Drilling that includes all the proponent actions except for drilling three wells near Lehman Creek within a culturally-sensitive area; and 4) the Preferred Alternative-Lehman Alternate Site that includes all the proponent actions, but with an alternate location for drilling three wells near Lehman Creek in an area that is less culturally sensitive.

The Preferred Alternative is Alternative 4, the Lehman Alternate Site. This alternative would have negligible, minor, or moderate impacts to cultural resources, geologic resources, soundscape, water quality/quantity, and visitor experience. Long-term benefits derived from the information gathered in this research project outweigh short-term adverse impacts. Alternative 4 is also the environmentally preferred alternative.

There will be a 30-day comment period on the EA. Comments may be submitted online at: http://parkplanning.nps.gov/hydrogeologic, or in writing to the following address:

Planning
Great Basin National Park
100 Great Basin National Park
Baker, NV 89311

Abbreviations and Acronyms

ARPA – Archaeological Resources Protection Act
BLM – Bureau of Land Management
CEQ - Council on Environmental Quality
cfs – cubic feet per second
DTS – digital optical temperature sensing
EA – Environmental Assessment
ESA – Endangered Species Act
GMP – General Management Plan
gpm – gallons per minute
GRBA – Great Basin National Park
NEPA – National Environmental Preservation Act
NHPA – National Historic Policy Act
NPS – National Park Service
NRCS – Natural Resources Conservation Service
NRHP – National Register of Historic Places
PVC – polyvinyl chloride
SHPO – State Historic Preservation Office
SNPLMA – Southern Nevada Public Lands Management Act
SNWA – Southern Nevada Water Authority
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United States Geologic Survey
WRD – Water Resources Division

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PURPOSE AND NEED

INTRODUCTION

This Environmental Assessment (EA) has been prepared to satisfy the requirements of the National Environmental Policy Act (NEPA) of 1969, as amended, as well as other laws and regulations pertaining to the management of activities within the National Park Service (NPS), specifically within Great Basin National Park (GRBA, "the Park"). The purpose of this Environmental Assessment is to identify, evaluate, and document the potential effects of the proposed Hydrogeologic Research Project.

PROJECT BACKGROUND

Great Basin National Park is located in the Great Basin Desert, where water is scarce. Water applications outside the Park are closely monitored to determine if they might have effects on park resources. In 1989, the Southern Nevada Water Authority (SNWA) applied to the Nevada State Engineer for groundwater rights in numerous valleys in southeastern Nevada, including Snake and Spring valleys adjacent to GRBA. The number of water applications, locations, and amount of water caused concern among the Park managers. The Water Rights Branch of the Water Resources Division (WRD) of the NPS protested these applications on the grounds that they might impact NPS resources. In 2004 SNWA applied to the Bureau of Land Management (BLM) for a right of way for a pipeline to reach these valleys. SNWA also asked the Nevada State Engineer to hold hearings on Spring Valley and other valleys. In the event of a successful development application, GRBA needed additional information to analyze potential impacts to the Park from the proposed groundwater withdrawals. WRD subsequently developed a proposal to fund a local groundwater study to assess those potential impacts. The proposal was co-sponsored by the BLM, U.S. Forest Service (USFS), and U.S. Fish and Wildlife Service (USFWS). It was funded by the Southern Nevada Public Lands Management Act (SNPLMA), Round 8, Conservation Initiatives Program. Within the Park, the study included the activities described in this EA.

BACKGROUND OF THE PARK

Great Basin National Park consists of 77,082 acres situated on mountains within the southern Snake Range in east-central Nevada (Figure 1). The Park was established in 1986, expanding the boundaries around and incorporating the previous Lehman Caves National Monument. The Park occupies higher portions of two hydrologic basins, Spring Valley to the west and Snake Valley to the east. All but 80 acres of the Park are located in the mountain range, with a small administrative site located in the basin next to the gateway community of Baker, Nevada, five miles from park headquarters. Surrounding the Park are mostly public lands administered by the BLM, along with a few private holdings. The Park is 300 miles north of Las Vegas, Nevada; 230 miles southwest of Salt Lake City, Utah; and 350 miles east of Reno, Nevada. About 65 miles to the west, Ely, Nevada, provides major services and a regional airport. Delta, Utah, is 90 miles to the east and also provides major services.

Purpose and Significance of Great Basin National Park

Great Basin National Park boasts the second highest peak in the state of Nevada, Wheeler Peak, at 13,063 ft. It also is home to highly decorated Lehman Caves, along with 41 other caves.

Several of the caves are home to endemic invertebrate species, including some that are new to science. Several old-growth bristlecone pine groves are nestled at high elevations, with trees dated over 3,000 years old. The Park is home to the only remaining glacier in Nevada; it also contains several rock glaciers and other glacial features. A wide diversity of wildlife and vegetation is found throughout the Park, and the Park is pursuing several restoration projects to enhance native species and habitats.

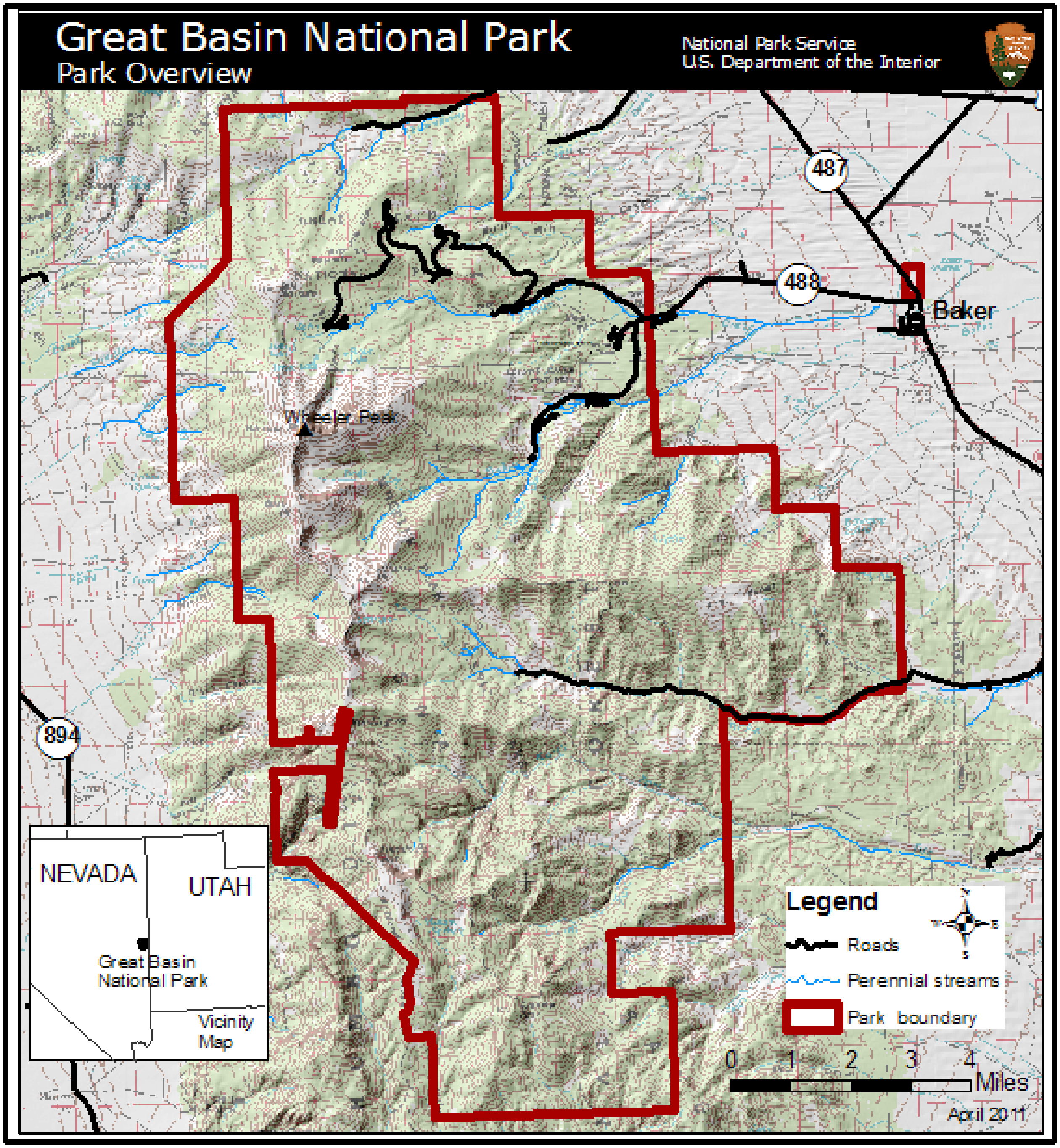

Figure 1. Map of Great Basin National Park.

PURPOSE AND NEED

The purpose of this project is to enable better understanding of hydrogeologic characteristics in critical areas of the Park where cave features and surface-water features have been identified as "likely susceptible" and "potentially susceptible" to adjacent groundwater withdrawals (Elliott et al. 2006). This project focuses on the three main areas that were identified: Baker, Lehman, and Snake watersheds near the Park boundary, as well as the Strawberry Creek watershed in the northern part of the Park.

Findings resulting from this proposed research could be applied as: (1) evidence presented by the NPS in upcoming water-rights hearings on SNWA's applications before the State of Nevada regulatory agency (the Nevada Division of Water Resources) for permits to go forward with the proposed groundwater development (for which WRD has filed legal protests on behalf of GRBA); (2) input to a groundwater flow model, which would be used to make predictive estimates of the timing and magnitude of potential adverse effects to Park water resources resulting from the proposed groundwater development immediately adjacent to the Park (which also likely will be submitted as evidence in the water-rights hearings); and (3) a basis for long-term monitoring of groundwater within the Park.

Ground-water resources from basin-fill and carbonate-rock aquifers in White Pine County, Nevada have been identified as a potential water-supply source for Las Vegas and surrounding areas of southern Nevada. These aquifers provide water to springs, streams, wetlands, limestone caves, and associated water-dependent ecosystems in and adjacent to the Park. SNWA has applied to the Nevada State Engineer's Office for water rights in Spring Valley for about 90,000 acre-feet per year (afy), and up to 50,700 afy in Snake Valley. A hearing on their Spring Valley water-right applications is currently scheduled for fall of 2011. A hearing on Snake Valley water-right applications has been postponed indefinitely. SNWA has proposed to develop the water rights they may be granted by withdrawing groundwater from the aquifers in Spring and Snake valleys adjacent to the Park and exporting produced water via large pipeline to the Las Vegas area about 250 miles to the south (SNWA 2007).

The NPS is concerned that this proposed large-scale, permanent groundwater pumping from the hydrologic basin outside the Park and immediately adjacent to it may deplete the flow of surface-water features and water levels in cave features and immediately adjacent to it. This, in turn, will likely adversely affect the water-dependent ecosystems associated with these critical natural-resource features. Impacts could include reduced habitat for aquatic organisms, changes in wetland and riparian vegetation species, and changed water quality that might limit functions such as spawning and overwintering.

Based on conclusions contained in USGS Scientific Investigations Report 2006-5099 "Characterization of Surface-Water Resources in the Great Basin National Park Area and Their Susceptibility to Ground-Water Withdrawals in Adjacent Valleys, White Pine County, Nevada" (Elliott et al. 2006), NPS hydrologists know that there are two principal local aquifer types – basin-fill and carbonate-rock – and they have identified places in and adjacent to the Park where surface-water resources are connected to these aquifers.. Results of this study are based on streamflow characteristics along selected perennial reaches of several streams in and adjacent to the Park. More detailed information is needed on the aquifer connections to the springs, streams, and limestone caves for the purpose of better quantifying potential effects to Park ecosystems caused by large-scale groundwater pumping immediately adjacent to the Park and to provide long-term monitoring of groundwater within the Park.

PROJECT GOALS

The proposed investigations have been designed to address four principal research objectives:

- Delineation of the composition, geometry, and hydraulic properties of the basin-fill deposits;
- Quantitative assessment of the interaction of surface water and groundwater along selected creeks;
- Delineation of the source of water to Rowland Spring (the largest spring in the Park) and Big Springs (a series of large springs that are important to the understanding of interbasin groundwater flow between Spring and Snake valleys); and
- Refinement of estimates of interbasin flow between southern Spring and southern Snake valleys through the Limestone Hills.

Additional goals of the proposed investigation would include employing a dye-tracing experiment to: 1) improve understanding of the interactions between surface water and groundwater where the Baker Creek cave system captures streamflow from Baker and Pole Canyon creeks, 2) identify and delineate areas that contribute water to springs, seeps, and streams in and near the Park downstream and down gradient from this area, and 3) characterize subsurface flow paths in karst limestone and fractured-rock regions.

PROJECT AREA LOCATION

The project area is located in the Baker, Lehman, Strawberry, and Snake watersheds (Figure 2).

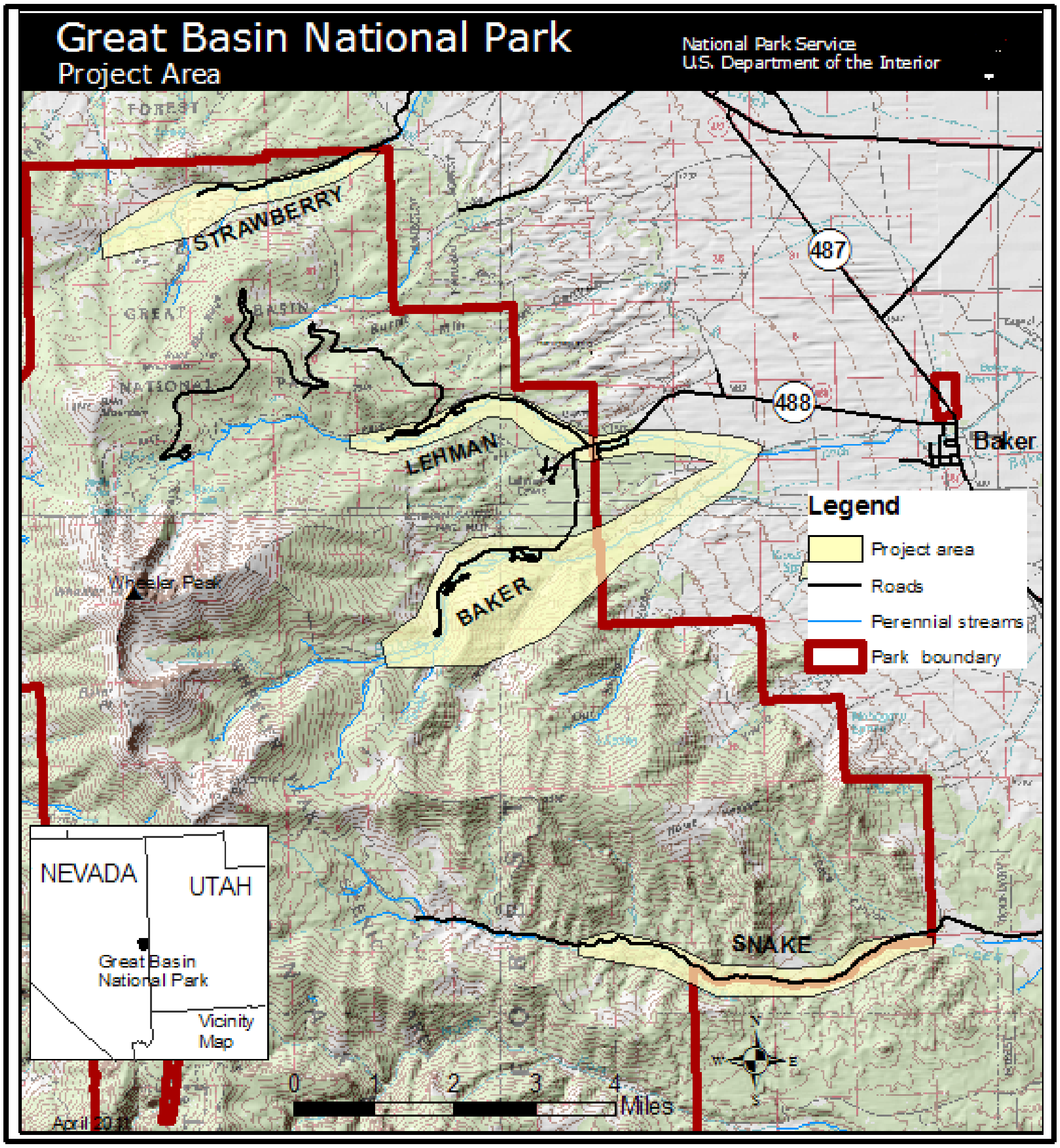

Figure 2. Map of Project Area.

SCOPE OF ENVIRONMENTAL ASSESSMENT

This EA analyzes three Action Alternatives and the No Action Alternative relative to their impacts on the human and natural environment. It fully describes project alternatives, existing conditions in the project area, and analyzes the potential effects of each project alternative on the environment.

This EA was prepared pursuant to the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4341 et seq.), as amended in 1975 by P.L. 94-52 and P.L. 94.83. Additional guidance includes NPS Director's Order 12 (NPS, 2001a) which implements Section 102(2) of NEPA and the regulations established by the Council on Environmental Quality (CEQ) (40 CFR 1500-

1508). The project must comply with requirements of NEPA as well as other legislation that governs land use, natural resource protection, and other policy issues within the Park.

RELATED LAWS, LEGISLATION AND MANAGEMENT GUIDELINES

The following is a summary of several relevant guidance documents and regulations for this EA.

National Park Service Organic Act
The NPS Organic Act directs the NPS to manage units "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner as will leave them unimpaired for the enjoyment of future generations." (16 U.S.C. § 1). Congress reiterated this mandate in the Redwood National Park Expansion Act of 1978 by stating that the NPS must conduct its actions in a manner that will ensure no "derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress." (16 U.S.C. § 1 a-1). The Organic Act prohibits actions that permanently impair park resources unless a law directly and specifically allows for the acts. An action constitutes an impairment when its impacts "harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources and values." (*Management Policies* 1.4.3).

Management Policies 2006
NPS Management Policies (2006) include direction for preserving and protecting cultural resources, natural resources, processes, systems, and values (NPS 2006). Although management policies are not applicable to non-NPS lands, it is the goal of the NPS to avoid or minimize potential impacts to resources to the greatest extent practicable consistent with the management policies.

National Historic Preservation Act of 1966
The National Historic Preservation Act (NHPA) of 1966 (as amended) requires that proposals and alternatives relating to actions that could affect cultural resources both directly and indirectly, and the potential effects of those actions, be provided for review and comment by the State Historic Preservation Officer (SHPO), Tribal Historic Preservation Officer, and the Advisory Council on Historic Preservation. Therefore, the document will be submitted to the appropriate offices for review and comment according to the procedures in 36 CFR Part 800 and delineated in the 1995 Programmatic Agreement signed by the NPS, the National Conference of State Historic Officers, and the Advisory Council on Historic Preservation.

Great Basin National Park Legislation
Lehman Caves National Monument was established in 1922. After decades of proposals to expand the national monument and to redesignate it as a national park, the idea came to fruition when the authorizing legislation for Great Basin National Park was signed on October 27, 1986. Public Law 99-565 established Great Basin National Park "to preserve for the benefit and inspiration of the people a representative segment of the Great Basin of the Western United States possessing outstanding resources and significant geological and scenic values." It further stated that the NPS is to "protect, manage and administer the Park in such a manner as to

conserve and protect scenery, the natural, geologic, historic and archeological resources of the Park, including fish and wildlife and to provide for the public use and enjoyment of the same in such a manner as to perpetuate these qualities for future generations." In addition to establishing the purpose of the Park, Public Law 99-565 also designated the size of the Park; stated that fishing and grazing would be allowed; mining would not be allowed; and that no new water-related rights with respect to land would be established.

General Management Plan for Great Basin National Park
The Record of Decision for the General Management Plan (GMP) for the Park was approved March 2, 1993. The purpose was to guide visitor use, natural and cultural resource management, and general development for the next 15 years.

ISSUES AND IMPACT TOPICS

Scoping

A list of issues and concerns related to the project were identified through park internal scoping and through the public scoping process. Internal scoping involved an interdisciplinary team of NPS staff who determined potential issues and impact topics.

The Park conducted public scoping November 19, 2010 to January 7, 2011. The project was noticed on the NPS Planning, Environment and Public Comment (PEPC) website, and two public meetings were held in Ely and Baker, Nevada to obtain input on the proposed plan. Additional details of the scoping process can be found in the Consultation and Coordination chapter of this EA.

During scoping, the following issues and concerns were expressed about the project:

- Dye tracing impacts
- Wilderness areas
- Impacts to caves due to drilling

ISSUES AND IMPACT TOPICS IDENTIFIED FOR FURTHER ANALYSIS

Based on scoping, the following issues and impact topics were identified and retained for further analysis:

Impact Topic	Reasons for Retaining Impact Topic
Cultural Resources (archeological resources, historic structures)	Cultural sites occur within the proposed research project area, including artifact scatters, potential cultural landscapes, and historic structures. The Park's GMP states that the objective of cultural resource management is to protect and interpret the Park's cultural, historical and ethnographic resources in accordance with NPS policies. The NPS will give consideration to and apply appropriate protection measures to these sites in their development plans consistent with Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended.
Geologic Resources (soils, caves)	The proposed drilling will take place in areas where Pole Canyon limestone is found. This carbonate rock has demonstrated potential to contain caves. In addition, the proposed drilling will disturb soil resources.
Soundscapes	In accordance with 2006 *Management Policies* (NPS 2006) and Director's Order 47 *Sound Preservation and Noise Management*, an important component of the NPS's mission is the preservation of natural soundscapes associated with national park units. Natural soundscapes exist in the absence of human-caused sound. The natural ambient soundscape is the aggregate of all the natural sounds that occur in park units, together with the physical capacity for transmitting natural sounds. The frequencies, magnitudes, and durations of human-caused sound considered acceptable varies among National Park Service units as well as potentially throughout each park unit, being generally greater in developed areas and less in undeveloped areas. The proposed drilling would involve loud noise levels that would last approximately one week at each of the three drill locations.
Water quality/quantity	This project would include introducing dye into creeks and cave water, conducting a pump test, and activities within flowing streams to conduct some of the proposed research actions. These actions have the potential to impact water quality and quantity.
Visitor experience	The visitor experience during the drilling part of the project could be altered slightly due to the presence of a drilling rig or encounters with personnel conducting research in or near the streams.

IMPACT TOPICS CONSIDERED BUT DISMISSED

Rationale for dismissing specific topics from further consideration is given below.

<u>Air quality</u>

Air quality is of critical importance to visitor enjoyment, human health, scenic vistas, and preservation of natural systems. Great Basin National Park is a class II park, meaning that it has less stringent air quality parameters to meet than a class I area. Diesel engines on the drilling rig and support generator, and dust created by drilling could have impacts of short duration and are considered to be negligible. Therefore, the impact topic of air quality has been dismissed.

Streamflow Characteristics
Streams in GRBA fluctuate greatly from baseflow to spring runoff. The pump test on the wells proposed to be drilled near Lehman Creek would return water to the stream. This would be of short duration, relatively low volume, and have a negligible effect, thus the impact topic of streamflow characteristics has been dismissed.

Introduce or promote non-native species
The Park's GMP states that non-native plant species will be eradicated and controlled if they threaten to spread or compete with park resources. NPS *Management Policies* (2006, Section 4.4.4) state that "Exotic species will not be allowed to displace native species if displacement can be prevented." All exotic plant species can decrease the diversity and resilience of native communities, affect site productivity, and affect hydrologic functioning of a watershed. The proposed research actions have the potential to introduce or promote additional non-native plant species, but mitigation measures, including cleaning of drilling equipment and vehicles, would be implemented in the limited areas where work would occur. Therefore, the impact topic of introduce or promote non-native species has been dismissed.

Threatened and Endangered Species and Species of Special Concern
The Endangered Species Act (ESA) of 1973 requires examination of impacts on all federally-listed threatened, endangered, and candidate species. Section 7 of the ESA requires all federal agencies to consult with the U.S. Fish and Wildlife Service (or designated representative) to ensure that any action authorized, funded, or carried out by the agency does not jeopardize the continued existence of listed species or critical habitats. In addition, the 2006 *Management Policies* and NPS 77: *Natural Resources Management Guidelines, Chapter 2* require the National Park Service to examine the impacts on federal candidate species, as well as state-listed threatened, endangered, candidate, rare, declining, and sensitive species (NPS 2006a).

There are currently no federally threatened, endangered, or candidate species inhabiting the action areas or GRBA. The Park maintains a list of wildlife species of management concern and manages them and their habitats to promote their continuity. The park has had an active restoration program for Bonneville cutthroat trout, and a small number inhabit the Strawberry Creek section of the project area. The potential actions are of short duration, low impact to the streams, and would occur in areas not critical for these species of special concern. Therefore, the impact topic of threatened and endangered species and species of special concern has been dismissed.

Wilderness
There are no Designated, Recommended, Proposed, Study, or Potential Wilderness classifications assigned to areas within Great Basin National Park. However, the Park General Management Plan designates the predominant portion of the Park outside of the rural and modern management zones as Suitable for Wilderness. According to NPS policy, such areas are to be managed in the same manner as wilderness. No actions under any of the alternatives considered would take place outside of the rural and modern zones, and the topic of wilderness has been dismissed.

Floodplains
Executive Order 11988 Floodplain Management requires all federal agencies to avoid construction within the 100-year floodplain unless no other practicable alternative exists. The National Park Service under 2006 *Management Policies* and Director's Order 77-2 *Floodplain Management* will strive to preserve floodplain values and minimize hazardous floodplain conditions. According to Director's Order 77-2 *Floodplain Management*, certain construction within a 100-year floodplain requires preparation of a Statement of Findings for floodplains. While some of the proposed activities might occur within floodplains, they would not alter the function of any floodplains, and there would be no construction of temporary or permanent structures. Therefore a Statement of Findings for floodplains will not be prepared, and the topic of floodplains has been dismissed.

Recreation resources
The primary recreation resources in GRBA are touring Lehman Cave, visiting the Wheeler Peak Scenic Drive, and hiking on trails. Secondary recreation activities in the Park include bird watching, fishing, and animal viewing. The proposed research actions would not impact or would have negligible, short-term effects on any of these activities; therefore this impact topic has been dismissed.

Cultural landscapes
A cultural landscape is a reflection of human adaptation and use of natural resources. It is expressed in the way land is used and organized, patterns of settlement, systems of circulation, and the types of structures that are built (NPS 1998b:87). Of the known cultural sites in the area of the proposed research actions, none currently have been determined significant as a cultural landscape resource.

Ethnographic resources
Ethnographic resources are comprised of features of the landscape that are linked by members of a contemporary community to their traditional ways of life. A traditional cultural property is an ethnographic resource that is eligible for listing on the National Register of Historic Places. There are no known ethnographic resources within the areas of the proposed research actions; therefore this impact topic has been dismissed.

Museum collections
Museum collections would only be affected by the proposed research actions if mitigation for cultural resources included collecting. If collecting is required, the expected quantity of items is considered to be negligible, thus this impact topic has been dismissed.

Socioeconomics
The proposed research actions would neither change local and regional land use nor impact local businesses or other agencies. Therefore, socioeconomics was dismissed from further consideration as an impact topic in this document.

Prime and Unique Farmlands
In August 1980, the Council on Environmental Quality (CEQ) directed that federal agencies

must assess the effects of their actions on farmland soils classified by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) as prime or unique. According to NRCS, there are no soils in Great Basin National Park classified as prime and unique farmlands. Therefore, the topic of prime and unique farmlands was dismissed as an impact topic in this document.

Environmental Justice

The actions proposed in this analysis would not have disproportionate health or environmental effects on minorities or low-income populations or communities as required by Executive Order 12898 and defined in the Environmental Protection Agency's Environmental Justice Guidance (1998). Therefore, the impact topic of environmental justice has been dismissed.

Wetlands

For regulatory purposes under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."

Executive Order 11990 *Protection of Wetlands* requires federal agencies to avoid, where possible, adversely impacting wetlands. Further, Section 404 of the Clean Water Act authorizes the U.S. Army Corps of Engineers to prohibit or regulate, through a permitting process, discharge or dredged or fill material or excavation within waters of the United States. National Park Service policies for wetlands as stated in 2006 *Management Policies* and Director's Order 77-1 *Wetlands Protection*, strive to prevent the loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. In accordance with DO 77-1 *Wetlands Protection*, actions that have the potential to adversely impact wetlands must be addressed in a Statement of Findings for wetlands. No proposed research actions would occur within wetlands; therefore a Statement of Findings for wetlands will not be prepared, and the impact topic of wetlands has been dismissed.

Wild and Scenic River

The existing GMP did not recommend or consider any stream system within the boundaries of GRBA for Wild & Scenic River status. The proposed research actions will not result in the possibility of a river or stream being eliminated from consideration as a Wild & Scenic River. Therefore, the impact topic of wild and scenic river has been dismissed.

Park Operations

The proposed research actions do not interfere with park operations; therefore the impact topic of park operations has been dismissed.

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ALTERNATIVES

INTRODUCTION

This EA includes three Action Alternatives and a No Action Alternative.

DESCRIPTION OF ALTERNATIVES

Alternative 1– No Action Alternative

The No Action Alternative would continue park operations as normal and would not allow the hydrogeologic research project to occur. No additional information about hydrogeologic resources in the Park would be collected.

Features Common to Action Alternatives

The Action alternatives (Alternatives 2, 3, and 4) are identical except that Alternative 3 does not include the Lehman Creek site and Alternative 4 has an alternate Lehman Creek site (Table 1).

Table 1. Features common to action alternatives.

Common Features	Alternative 2 All Sites	Alternative 3 No Lehman Ck	Alternative 4 Lehman Alt.
Investigation of the source of water to Rowland Spring	Yes	Yes	Yes
Investigation of stream-aquifer interactions along selected reaches of Lehman, Baker, Snake, and Strawberry Creeks within the Park	Yes	Yes	Yes
Focused investigation of stream-aquifer interactions at a specific site on Lehman Creek	Yes	No	Yes
Dye-tracing study	Yes	Yes	Yes

Alternative 2 – Proponent Action-All Sites

The Proponent Action consists of a multi-component hydrologic research project. This action includes: (A) the drilling and installation of five groundwater monitoring wells inside the Park in the Lehman Creek drainage; (B) the placement of several temporary shallow well points and other temporary monitoring equipment along Lehman, Baker, Snake and Strawberry creeks; (C) hydraulic testing, water-quality sampling, and physical measurements collected from this monitoring network; and (D) a dye-tracing study along Baker and Lehman drainages.

Specific components of the proposed project work within the Park are:

INVESTIGATION OF THE SOURCE OF WATER TO ROWLAND SPRING:
This involves:
--- Drilling and constructing two groundwater monitoring wells, each about 200-to-300 feet deep, within Great Basin National Park – one near Cave Springs and one near the lined sewage ponds by the Baker Creek Road;
--- Performing two 48-hour continuous pumping tests - one test at each of the two monitoring wells;
--- Installing a precipitation collector near the existing weather station in the Park; and
--- Collecting water samples monthly for laboratory analysis from each of the two wells, from the precipitation collector, from Rowland Spring, and from one location each along Lehman and Baker creeks for one year.

INVESTIGATION OF STREAM-AQUIFER INTERACTIONS ALONG SELECTED REACHES OF LEHMAN, BAKER, SNAKE, AND STRAWBERRY CREEKS WITHIN THE PARK:
This involves:
--- Installing up to 10 shallow well points at selected locations in each of Lehman, Snake, and Strawberry creeks, driven by hand to a depth of about three feet beneath the streambed;
--- Installing temporarily a digital optical temperature-sensing cable in selected reaches of Lehman, Snake, and Strawberry creeks, and its subsequent removal after data collection is completed;
--- Slug testing of selected well points along Lehman and Snake creeks;
--- Manually measuring stream flow in Lehman, Baker, Snake, and Strawberry creeks; and
--- Installing up to five stream gauges in the Baker Creek drainage.

FOCUSED INVESTIGATION OF STREAM-AQUIFER INTERACTIONS AT A SPECIFIC SITE ON LEHMAN CREEK:
This involves:
--- Drilling a cluster of three shallow boreholes within the Park, each less than 60 feet deep, located within 50 feet of Lehman Creek, and construction of a total of five monitoring wells within the three boreholes;
--- Performing a 72-to-96-hour continuous pumping test – by pumping the farthest well from Lehman Creek, and monitoring water levels and water temperature in the other four monitoring wells, the shallow well points, and the stream; and
--- Collecting water samples for laboratory analysis from the pumped well during the pumping test.

A DYE TRACING STUDY:
This involves:
--- The introduction of three fluorescent tracer dyes within the Park, one in Baker Creek, one in a cave in the Baker Creek cave system, and one in Pole Canyon creek; and

--- Water sampling at approximately 22 selected locations - to see if dye can be detected in Baker and Lehman creeks, at selected springs (most notably Rowland Spring), and at cave locations downhill to the east and northeast.

A detailed description of each of the components of proposed work within the Park is provided in the following paragraphs.

INVESTIGATION OF THE SOURCE OF WATER TO ROWLAND SPRING:

Purpose
The purpose of the installation of groundwater monitoring wells northwest and southwest of Rowland Spring is to determine aquifer properties, direction of groundwater flow, and groundwater chemistry in the Pole Canyon Limestone upstream of Rowland Spring. Rowland Spring is the largest perennial spring in the vicinity of Lehman Caves. Additionally, chemistry of precipitation and water in Baker and Lehman Creeks will be sampled and used to evaluate the source(s) of water to Rowland Spring. Understanding the direction and rate of groundwater flow in the vicinity of Lehman Caves is important to assessing the potential for diminished water resources caused by potential pumping of groundwater in adjacent Snake Valley.

Monitoring Wells
Location and Depth: Two 6-inch diameter test wells northwest and southwest of Rowland Spring are proposed to be drilled in the Lehman Creek drainage. One proposed location is along the road to Cave Springs, and the other is near the lined sewage ponds along the Baker Creek Road. The locations of the proposed wells are shown in Figure 3. The latitude and longitude location of each proposed well, proposed well depths, and well dimensions are listed in Table 2. Both wells will be drilled to a depth of 100 feet below the initial water level encountered in the well, and are planned to be completed in the Pole Canyon Limestone. Total well depth at each site likely will be between 200 and 250 feet, depending on geologic and hydrologic conditions encountered during drilling, and will not exceed 300 feet.

The first drill site is along the west side of Baker Creek Road and east of the lined sewage lagoons, and is denoted as Site 1 (Figure 3). Access is along Baker Creek Road south of the entrance to the lagoons. The approximate area of disturbance around Site 1 is shown in Figure 4. The drill site will require the removal of up to 30 pinyon trees in a roughly 30-feet-wide path from the road to the drill site (approximately 120 feet long, not to exceed 150 feet) in order to get the drilling rig and equipment into the site. The second drill site is along the water-supply maintenance road to Cave Springs, and is denoted as Site 2 (Figure 3). The approximate area of disturbance around Site 2 is shown in Figure 5. The removal of some branches or the complete removal of up to 10 pinyon trees and one juniper tree may be required at Site 2 to allow access by the drilling rig and associated equipment.

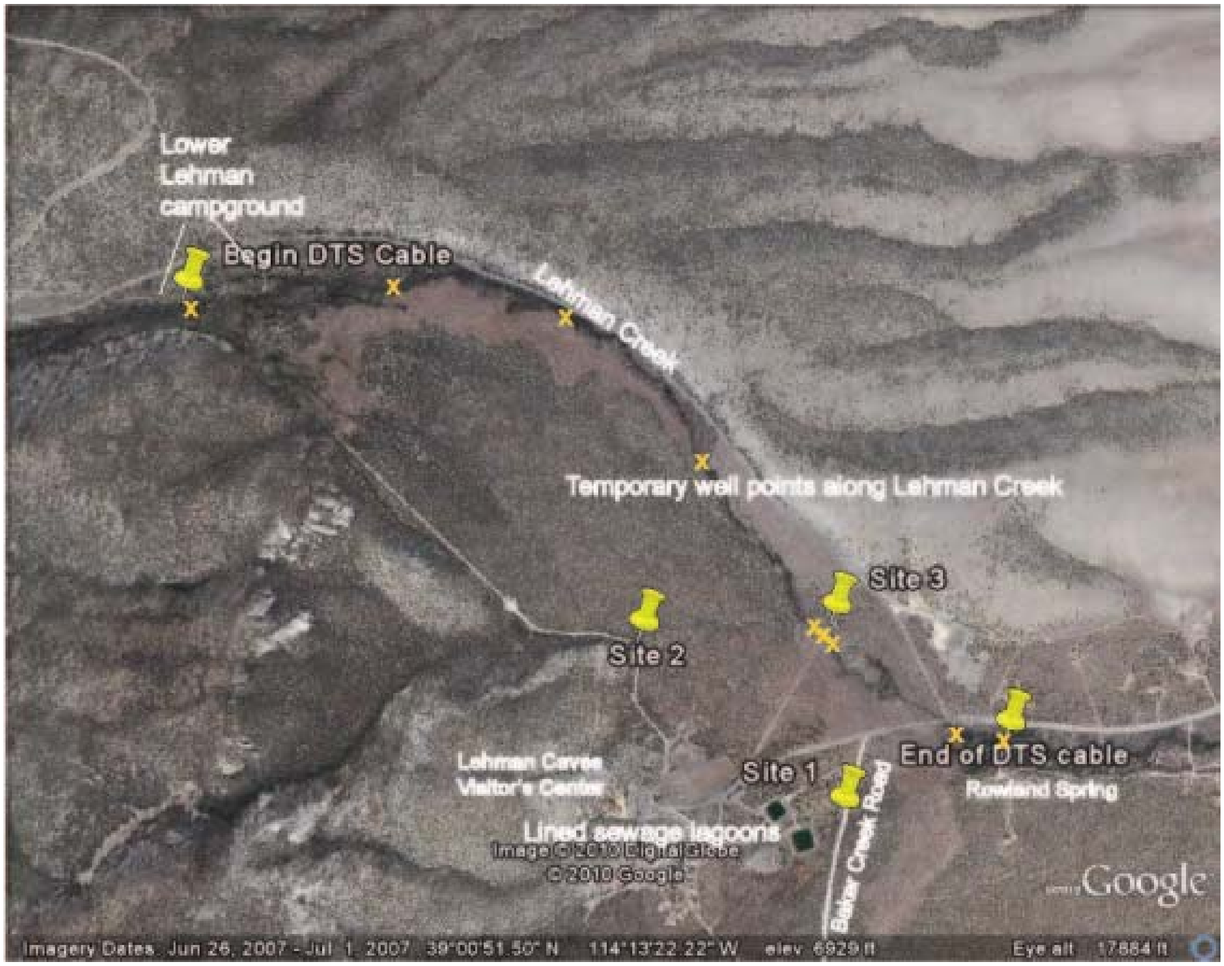

Figure 3. Locations of proposed monitoring wells (sites 1, 2, and 3), extent of digital temperature sensing (DTS) cable in Lehman Creek, and approximate locations of temporary well points along Lehman Creek between Lower Lehman Campground (upstream of contact between quartzite and granite) and Joe's Way just east of park boundary.

Table 2. Locations and expected sizes of proposed wells.

Site number	NAD83 Latitude	NAD 83 Longitude	Elevation in feet above mean sea level	Expected depth of well in feet	Hole diameter, in inches	Casing diameter, in inches	Screened interval or open hole, in feet
1	39° 00.395'	114° 12.727'	7000	<250	10	6	40
2	39° 00.579'	114° 13.223'	7035	<250	10	6	40
3p	39° 00.701'	114° 12.836'	6650	~60	10	6	20
3u*	39° 00.701'	114° 12.836'	6650	40	8	2	10
3d*	39° 00.701'	114° 12.836'	6650	40	8	2	10

*Sites 3u ("upstream") and 3d ("downstream") are near Lehman Creek about 25 feet upstream and downstream of site 3p ("pumping well") and 20 to 40 feet from the creek (see Figure 11).

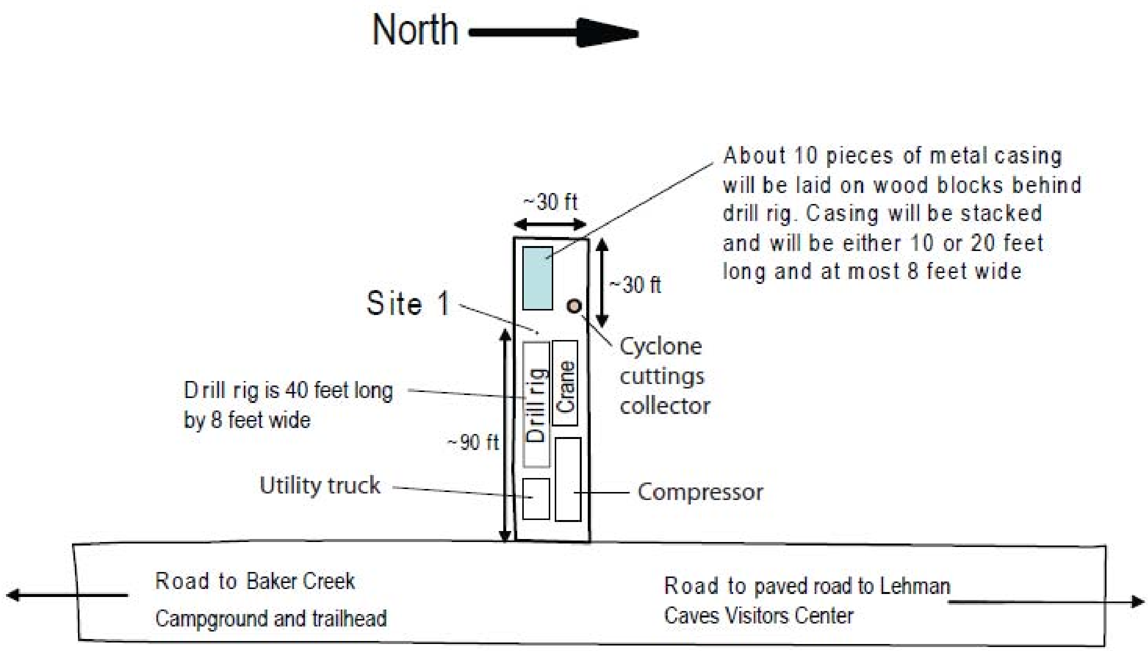

Figure 4. Diagram showing approximate area of disturbance at proposed well site 1.

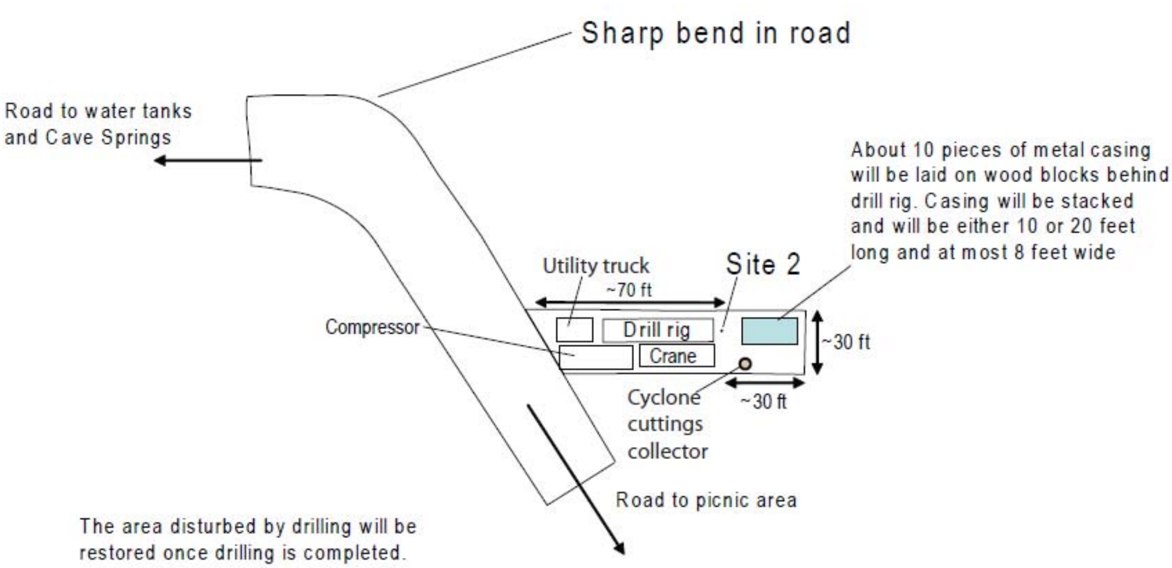

Figure 5. Diagram showing approximate area of disturbance at proposed well site 2.

Well-Drilling Equipment: The wells would be drilled using the USGS Western Research Drilling Unit rig. The drilling rig is approximately 8 feet wide and 40 feet long. A photograph of the drilling rig is shown in Figure 6. The method of drilling uses a 10-inch diameter air-percussion hammer attached to steel well casing while drilling through basin fill deposits. Once the drilled borehole penetrates limestone, a 9-inch percussion hammer is used to advance the hole. Cuttings of soil and rock fragments from the borehole are brought to the surface through the well casing and pumped to a cyclone separator.

Figure 6. Photograph of drilling rig and support equipment.

Well-Drilling Operation: The well drilling would likely occur within the September-to-November time period, starting after the Labor Day weekend. The drilling rig would need to be driven off the access roads to each of the drill sites. Thick plastic sheeting would be placed underneath all drilling rig and any other support vehicles used in the drilling, completion, and aquifer testing of the well to prevent any potential oil and hydraulic fluid spills from contaminating soils. The actual disturbed area would be limited to the tracks from the drilling rig and support vehicles, the area in which the drill operators would be working around the rig, an area approximately 20 feet long by 10 feet wide where the casing is laid on the ground behind or next to the drilling rig, the accumulation of cuttings concentrated beneath the cyclone separator, and the 10-inch diameter hole used to install the well. The USGS would make every effort to minimize the disturbance from the drilling operation.

At each well site, the 10-inch diameter well casing would extend down the borehole from land surface to about 5 feet into the top of the Pole Canyon Limestone. Once in the Pole Canyon Limestone, each well would be drilled without casing unless a large cavity is encountered that would prevent the circulation of cuttings to the surface. If the circulation of cuttings to the surface is lost while drilling in the limestone, then well casing would be advanced into the limestone during drilling. At no time would cement or any drilling fluids other than small amounts of water be used during the drilling process. Plans are for both wells to be completed using 6-inch diameter metal well casing, placed inside the 10-inch casing. Depending on the requirements of the Nevada Division of Environmental Protection, schedule 80 PVC with flush threads may be used in place of metal casing at Site 1. A stainless steel wire-wound screen with 0.030-inch openings would be used for the well at Site 2. For the well at Site 1 (near the sewage ponds), the 6-inch casing would extend above land surface 2.5 feet and the casing would be capped with a lockable sanitary seal to ensure that unwanted surface contamination cannot enter the well. Large boulders could be placed around the well to prevent accidental damage to the casing from future potential vehicle impacts. At Site 2 (along the road to Cave Springs), the top of the 6-inch casing would be a few inches below land surface, and the well top fitted with a 12-inch diameter locking steel cover flush with land surface.

When drilling above the water table, a wetted cloth would be placed over the top of the cyclone where soil and rock cuttings from the borehole are pumped to minimize airborne dust. Some water would be removed from the borehole during drilling once the water table has been reached. Native groundwater removed from the borehole during drilling would be pumped through the hose used for cuttings and allowed to flow through the cyclone and onto the cuttings that have mounded around the cyclone. If water from the hole is sufficient to cause flow away from the immediate area of the cyclone, straw would be placed around the cyclone to minimize erosion and the water directed to the nearest dry channel, where it can infiltrate. The quantity of water that may be brought to the surface during the drilling process cannot be determined prior to drilling. Experience from other drilling in Snake Valley is that there has been a small quantity of water produced (less than 10 gallons per minute) while drilling in shallow unconsolidated sediments and the upper 120 feet of limestone. This water traveled less than 10 feet from the cyclone and none of it caused erosion. However, when we encountered fractured limestone at a depth of 295 feet in a well near Snake Creek on BLM lands adjacent to the Park, the quantity of water produced was about 50 gallons per minute. The drilling continued for another five minutes. The water produced from the well was routed down a naturally dry depression parallel to Snake Creek and all of it seeped into the ground after flowing less than 200 feet. None of the water reached the creek. No erosion occurred because the water spread over a width of 3 to 5 feet and was less than ¼-inch deep. In the event that we encounter a similar condition at the wells inside the Park, the well would be deepened no more than an additional 20 feet and a shorter screened interval (less than the proposed 50 feet) installed in the hole. This would minimize the quantity of water pumped through the cyclone and onto the ground. Periodic water samples would be analyzed for temperature, pH, and specific conductance.

<u>Site Cleanup:</u> Once each well installation is completed, all drill cuttings from the boreholes would be hauled away to disposal sites outside of the Park. Finally, the well sites in the Park would be cleaned, leveled, and raked, in preparation for final restoration.

Aquifer Testing

Aquifer properties of the Pole Canyon Limestone would be determined from a single-well aquifer test at each well. Each well would be pumped at a rate of about 50 gallons per minute (gpm), not to exceed 90 gpm, for a period of 48 hours or less. This equates to a total pumped volume of about 144,000 gallons of water, not to exceed 259,200 gallons. A temporary discharge permit must be obtained from the Nevada Division of Environmental Protection prior to the aquifer testing. At Site 1 (near the sewage ponds), water from the aquifer test would be piped from the well to the culvert that goes under the Baker Creek road. At Site 2 (along the road to Cave Springs), water from the aquifer test would be piped from the well to the nearest ephemeral drainage. Cylindrical straw berms could be placed across the drainage to slow the movement of water down the drainage and thus inhibit erosion. The straw would be removed once pumping has ceased. Water pumped from the well would be monitored for temperature, pH, specific conductance, and the extent of flow along the ephemeral drainage. A water quality sample are collected during the test and analyzed for dissolved minerals and metals as required by the Nevada Division of Environmental Protection.

The water level in the well is monitored before, during, and after the well has been pumped. A pressure transducer is placed in the well for a period of one-to-two weeks before the well is pumped and remains in the well for another two-to-three weeks after the well is pumped. A water quality sample is collected from the well during the test and analyzed for a complete suite of chemical constituents. Water level in the wells would be routinely monitored in addition to the collection of water quality samples.

Water-Quality Sampling

Each well should be pumped for a short time and samples collected for water quality analysis once every two months for a period of one year after the well is drilled. A pickup-truck-mounted pump and apparatus could be used. All equipment is contained on the truck. The truck would not be driven off the road. The pumping rate during this process is usually about 1 gallon per minute and a total of not more than 2000 gallons total would normally be discharged from the well during each sampling. This water will be allowed to infiltrate into the ground several feet from the well.

Long-term Monitoring

Pressure transducers are placed in the wells and provide a continuous record of water level fluctuations over time. These transducers remain in the wells for at least one year. Water levels are measured during each sampling event, and data from the transducers downloaded to a computer at the same time. The transducers could be made available to Park personnel should they decide to continue monitoring water levels in the wells.

INVESTIGATION OF STREAM-AQUIFER INTERACTIONS ALONG SELECTED REACHES OF LEHMAN, BAKER, SNAKE, AND STRAWBERY CREEKS WITHIN THE PARK:

Purpose
The purpose of this component of work is to evaluate the connection of the selected creeks with groundwater in the adjacent alluvium and to determine the aquifer properties of the streambed along selected reaches of each creek that have been identified as being susceptible to groundwater pumping (Elliott et al. 2006). The reason for placing the digital optical temperature cable, installing the shallow wells, installing temporary stream gauges, and making streamflow measurements is to collect data that can be used to determine where groundwater is discharging into the creeks from the alluvium and the aquifer properties of the streambed. Information on how and where groundwater interacts with each creek and the aquifer properties of the streambed are needed for assessing potential impacts within the Park from groundwater pumping outside the Park's boundary.

Shallow Well Points
Temporary shallow well points (aka piezometers) are proposed to be driven into the streambed along selected reaches of Lehman, Snake, and Strawberry creeks in the Park. These temporary well points are normally driven by hand with a large hammer or fence-post driver (Figure 9) to a depth of about three feet beneath the streambed, approximately every 500 to 750 feet along the streams, in places where there is access and in consideration of changes in the geology or slope of the streambed. Well points would be installed along a reach from lower Lehman Creek campground to the Park boundary on Lehman Creek (Figure 3); from near the end of the pipeline on Snake Creek to the Park boundary (Figure 10), and for about 1½ miles upstream of the Park boundary on Strawberry Creek (Figure 11). A maximum of 10 well points are proposed for each creek. An approximately one-inch diameter pilot hole may be necessary in some locations, in which case a large steel rod is driven into the streambed and then withdrawn prior to driving the well point.

Figure 7. Photograph of well point and pipe being driven into streambed of Lehman Creek east of the Park and near Circle M Ranch Road.

The temporary well points are made of nominal 1¼-inch diameter stainless-steel pipe that have a drive point attached at the end. The drive point is made of hardened steel, and the 1¼-inch pipe above the screen is galvanized steel. The diameter is sufficient to install a pressure transducer and three temperature loggers inside the well points. They include a 6-inch long screened interval, which is located just above the drive point. The well points extend about 1-to-2 feet above the water level of the stream and are capped with a lockable cap. The well points would be placed in areas not readily accessible by the public and not easily seen. The well points would be removed once data collection is complete (i.e., after one year or less). Selected well points could be left in the creek if Park personnel desire to use them for long-term water-level monitoring.

Figure 8. Extent of digital temperature sensing (DTS) cable in Snake Creek and approximate locations of temporary well points in the Park.

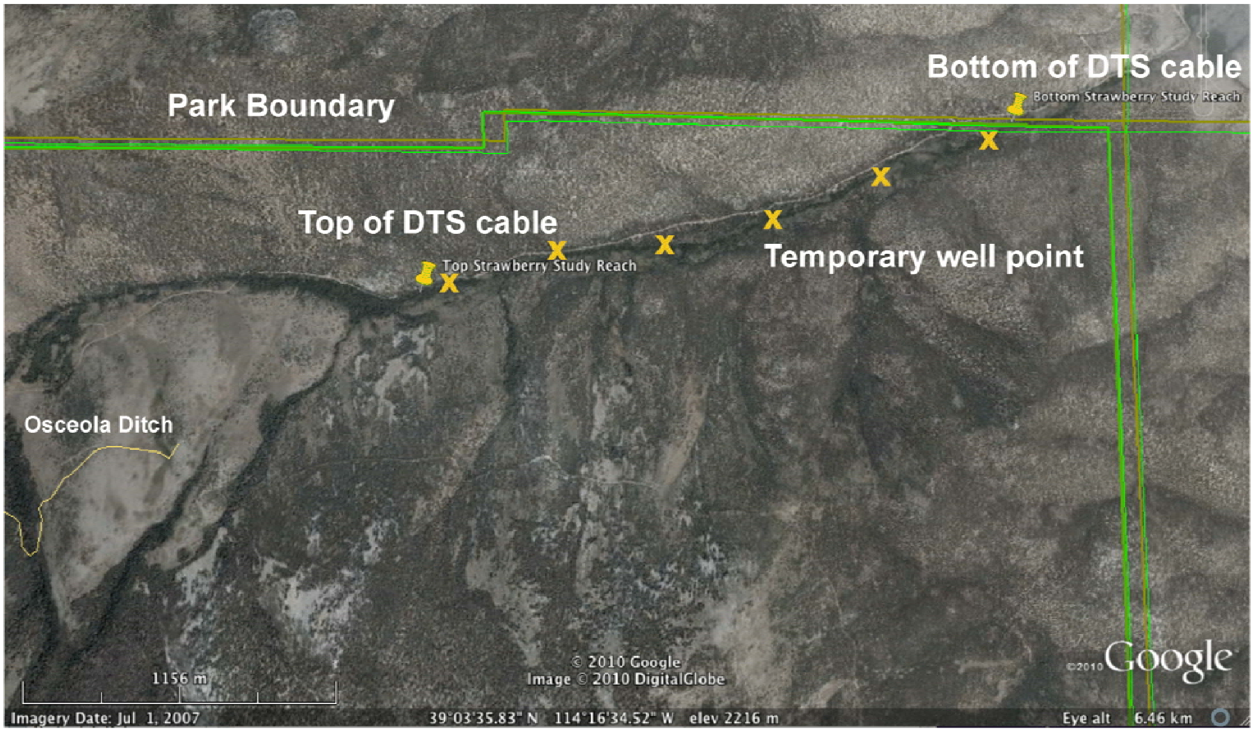

Figure 9. Extent of digital temperature sensing (DTS) cable in Strawberry Creek and approximate locations of temporary well points in the Park.

Stream gauges

A series of temporary stream gauges would be installed and operated to measure discharge along Baker Creek, Pole Canyon Creek, and Model Cave (Figure 12). Five stream-gauge sites are proposed at locations where there are significant changes in the bedrock geology, and Baker Creek is known to gain or lose a substantial fraction of its total streamflow. Stream gauge sites are proposed on Baker Creek just downstream of the B Loop at the Grey Cliffs group site campground, at the Narrows, and at the Park Boundary (presently in operation), as well as on Pole Canyon Creek upstream of where the creek crosses onto Pole Canyon Limestone and at the outflow from Model Cave at the same location as the miscellaneous streamflow measurements reported by USGS (Elliott et al. 2006). Each stream gauge consists of a staff plate and Global Water W16 vented pressure transducer connected to a 2" PVC conduit pipe via buried flexible 1" PVC conduit. The PVC pipe has a 2" galvanized steel cap, and houses the data logger attached to the pressure transducer. Staff plate, conduit, and PVC pipe would be secured with necessary hardware or via burial 6" to 18" deep to withstand high flows. Hand tools would be used to dig a trench for the conduit, which is then be re-buried. Some boulders may be moved in the streambed adjacent to the gauges to provide a tranquil pool for measurements at both low and high flows. One or two survey control pins would be installed within 50 feet of the stream. These consist of a roughly 12"-long piece of rebar encased in concrete, with about ½" of rebar exposed. The concrete would be mixed in a bucket over a tarp to ensure no excess is spilled.

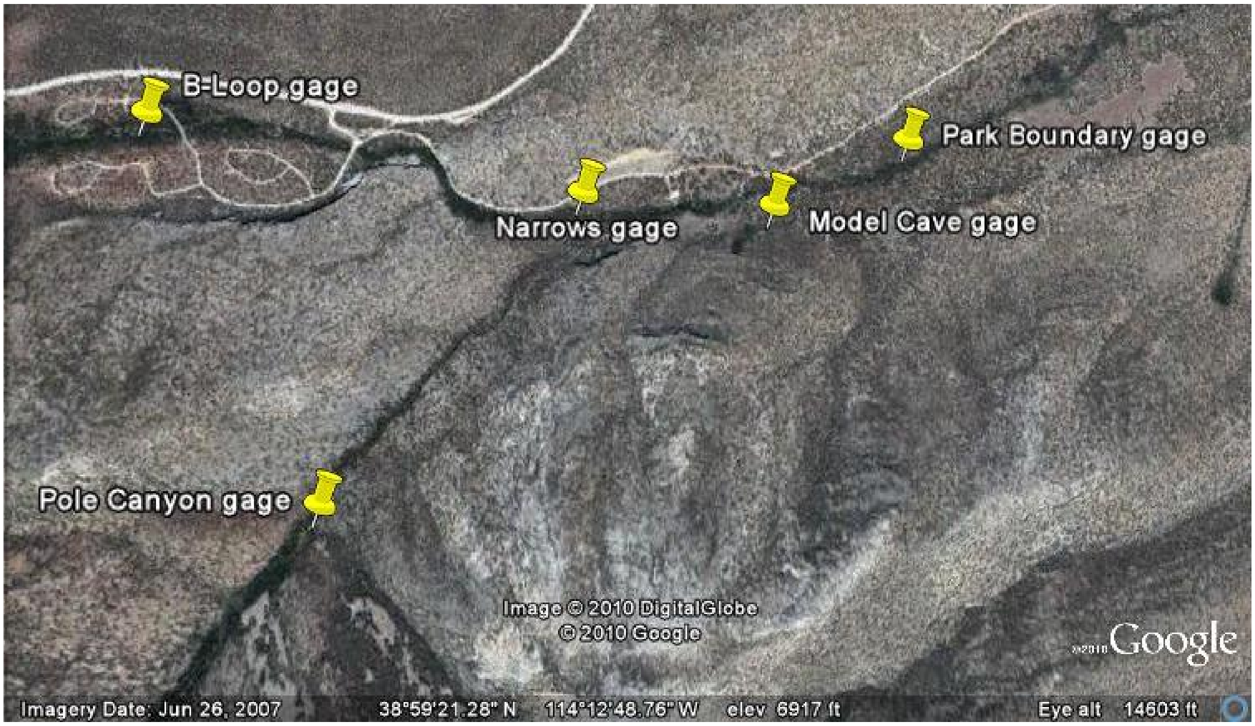

Figure 10. Locations of proposed temporary stream gauges along Baker Creek, Pole Canyon Creek, and outflow from Model Cave. The gauge at the Park boundary is currently in operation.

Optical Temperature-Sensing Cable

A digital optical temperature sensing (DTS) cable would be installed temporarily along selected reaches of Lehman, Snake, and Strawberry creeks within the Park. The cable would be placed by hand on the streambed over an approximately 3000-feet-long reach of stream. The cable is attached to a computer either in a portable box or in a trailer in instances in which access for the trailer is available. If used, the trailer may be parked along the shoulder of existing roadways. A gasoline-powered portable generator is used to power the computer. The generator can be placed along the shoulder of existing roadways in a durable plastic tray whose capacity is 2-to-3 times that of all of the fluids in the generator. This generator would be used for one week at a time approximately four times per year on each stream where DTS cable is installed. It is barely audible from a distance of 50 feet. In areas too inaccessible for the cable, individual temperature loggers may be secured to the temporary wells and placed on the streambed. Temperature loggers used are the ONSET Hobo type, which are the same as those used by Park personnel for monitoring temperature in streams and springs. They are installed by attaching them to the temporary well points using a nylon cord. The cable would remain in the stream at each location from approximately 1 to 6 months. Upon completion of water-temperature data collection, the cable would be removed from the stream by hand.

Slug Tests

Slug tests are used to determine how readily water enters the well from the surrounding materials (in this case the materials are the streambed). These tests are proposed to be completed on each of the shallow well points. For each test, water is poured into a well point and the water-level rise and subsequent decline monitored over time. The duration of each test is approximately a few minutes, and in all cases would last less than four hours.

Monitoring

Pressure transducers and temperature loggers are placed in each of the shallow well points and in the stream adjacent to each well. Data on changes in water levels and temperature is used to determine the direction and rate of groundwater flow beneath the stream at each location. The transducers continuously monitor water levels, which information is recorded on data loggers. The DTS cable monitors stream-water temperature continuously during the selected times the DTS computer is connected to the cables. The best time for evaluating groundwater discharge into the creeks is from December through March when stream temperatures are much colder than the underlying groundwater, therefore much of this work is planned for that time interval.

Streamflow Measurements

Measurements of stream discharge are made periodically over the duration of time that the digital optical cable is collecting temperature data from each stream. Stream-discharge measurements are made by the wading method, in which a small vane meter is attached to a metal rod and inserted into the water at selected stream-width intervals. Stream velocity is calculated on the basis of the number of complete revolutions of the vane cups.

FOCUSED INVESTIGATION OF STREAM-AQUIFER INTERACTIONS AT A SPECIFIC SITE ON LEHMAN CREEK:

Purpose

The purpose of this component of the proposed work is to determine the permeability of the streambed and the alluvial deposits underlying Lehman Creek by pumping one of the wells near the creek and monitoring the response of temperature and groundwater levels beneath and adjacent to the creeks. Information on the permeability of the streambed and aquifer properties of the alluvial materials beneath the streambed may be used to facilitate assessments of the potential impacts of proposed groundwater withdrawals adjacent to the Park.

Monitoring Well Cluster

<u>Location and Depths:</u> Three relatively shallow boreholes would be installed at a single site near the USGS streamflow gauging station on Lehman Creek (Site 3, Figure 3 and Table 2). The deepest well would be drilled to a depth of not more than 60 feet and located at least 70 feet north of Lehman Creek. Two additional boreholes would be drilled closer to the creek to a total depth of about 40 feet. Two well casings, deeper and shallower, would be set in each of the two boreholes nearest the creek. A photograph of the site is shown in Figure 13. A detailed sketch of the disturbed area for each of the proposed boreholes at Site 3 is shown in Figure 14. Site 3p indicates which well would be pumped. For the boreholes to be drilled nearest the stream, site 3u indicates the upstream well site, which will be drilled 20 to 30 feet north of the creek near the existing USGS stream gauge shelter, and site 3d indicates the downstream well site, which will be drilled 30 to 40 feet north of the creek on the old overgrown roadway.

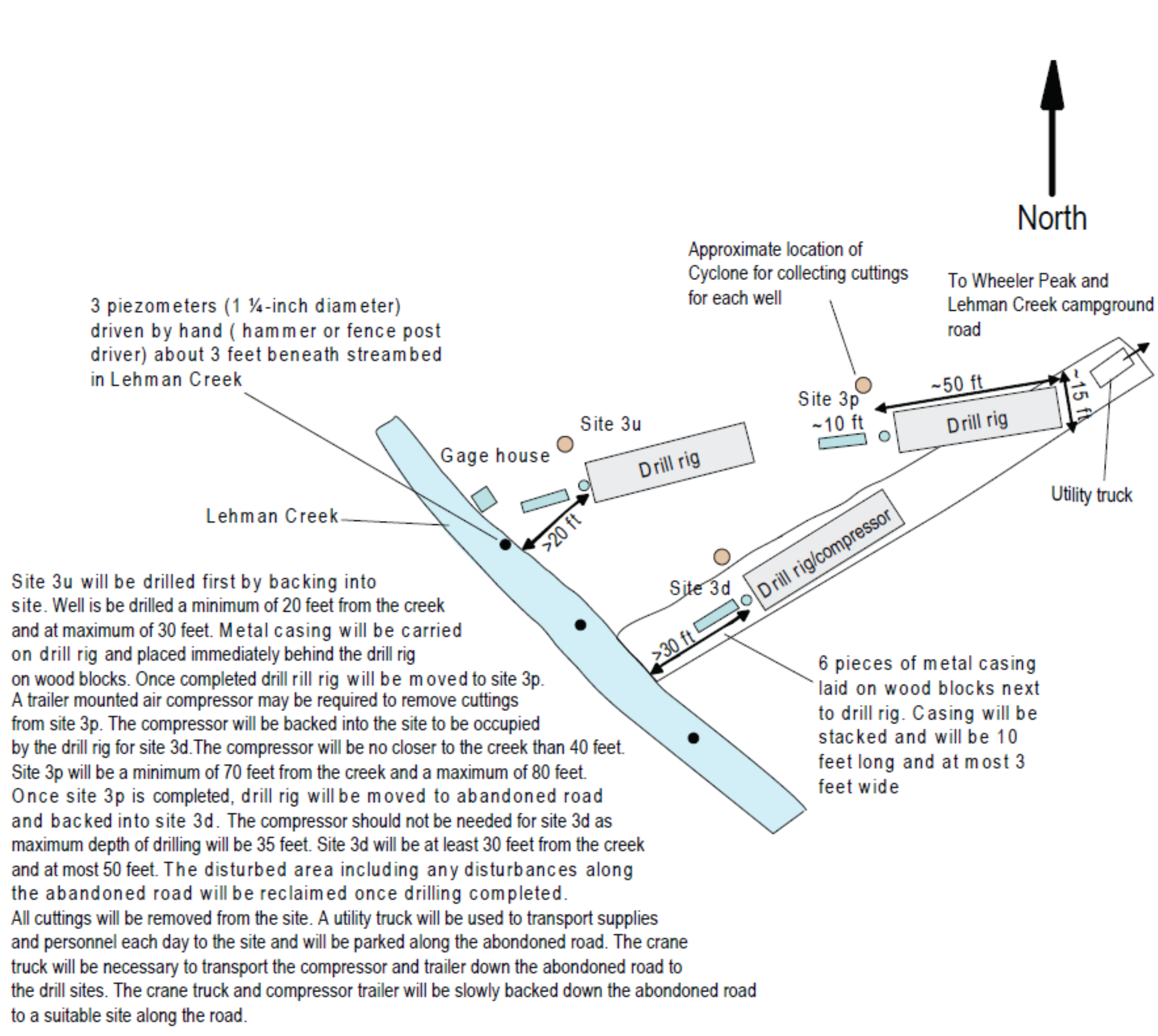

Figure 11. Diagram showing approximate area of disturbance at proposed well site 3.

<u>Well-Drilling Equipment:</u> These wells would be drilled using the same USGS Western Research Drilling Unit rig described previously. The well located about 70 feet from the creek will be drilled with a 10-inch diameter air-percussion hammer attached to steel well casing, such that the casing is advanced down the hole as the hole is deepened. The two boreholes nearest the creek will be drilled using the same method but with an 8-inch diameter air-percussion hammer attached to steel well casing. Cuttings of soil and rock fragments from the borehole will be brought to the surface through the well casing and pumped to a cyclone separator. An extra air compressor may be needed to remove cuttings from the 10-inch diameter hole after the hole has been drilled deeper than 30 feet. A trailer mounted compressor would be moved to the site using a crane truck and left on the old road near the drill rig. A utility truck about 6 feet wide and 15 feet long would be used to carry personnel and supplies to the drill site.

<u>Drilling Operation and Installation of Monitoring Wells:</u> Thick plastic sheeting would be placed underneath the drilling rig and all other support vehicles used for the drilling, well completion, and aquifer testing at this site. PVC well casing and screen would be placed inside the steel

casing at the well sites. Pea gravel and/or course sand would be placed around the screened area, with bentonite chips placed on top. Cement grout would seal the hole. The top of each well casing would be a cut a few inches below land surface, and the well fitted with a 12-inch diameter locking steel cover flush with land surface, in the same manner as used for the pumping and monitoring wells installed next to Baker Creek on BLM land adjacent to the Park.

When drilling above the water table, a wetted cloth is placed over the top of the cyclone where soil and rock cuttings from the borehole are pumped, to minimize airborne dust. Some water will be removed from the well during drilling and after the well has been completed. Water from the drilling could be kept from entering Lehman Creek but allowed to infiltrate into the ground near the cyclone separator and onto the cuttings that have accumulated around the cyclone. If water from the hole is sufficient to cause flow away from the immediate area of the cyclone, straw would be placed around the cyclone to minimize erosion and the water directed to away from Lehman Creek. The quantity of water brought to the surface during the drilling process is impossible to determine ahead of time. However, our experience from other drilling at a site near Baker Creek on BLM lands adjacent to the Park was that less than 5 gallons per minute of water was generated from drilling and this rate was insufficient to generate flow more than a few feet from the cyclone. If fractured limestone should be encountered sufficient to produce quantities of water similar to what was encountered at the Snake Creek well (about 50 gallons per minute), drilling would stop after drilling an additional 10 feet into the limestone (a few minutes of drilling). The total amount of water produced while drilling in the fractured limestone will be less than 1000 gallons, of which none would be allowed to reach Lehman Creek. Periodic water samples are analyzed during the drilling for temperature, pH, and specific conductance.

Site Cleanup: Once each well installation is completed, all drill cuttings from the boreholes will be hauled away to disposal sites outside of the Park (or to the gravel pit if maintenance has a use for them). Finally, the sites will be cleaned, leveled, and raked, in preparation for final restoration.

Stream-Aquifer Testing

Aquifer properties of the alluvium beneath Lehman Creek and the permeability of the streambed would be determined from a 72- to 96-hour aquifer test. A pump rig isused to set a 4-inch diameter pump inside the 6-inch diameter well located at least 70 feet from the creek. The pump rig is similar in size to the drilling rig. The well at least 70 feet from Lehman Creek would be pumped at a rate of about 30 gpm, not to exceed 90 gpm, for a period of approximately 72-96 hours, depending on conditions encountered. Under any circumstances, the continuous pumping would last for less than 5 days. This equates to a total pumped volume of about 172,800 gallons of water (30 gpm x 96 hours), not to exceed 648,000 gallons (90 gpm x 120 hours). A temporary discharge permit must be obtained from the Nevada Division of Environmental Protection prior to the aquifer testing. Pumping the well at the proposed rate is not expected to cause an appreciable change in the flow rate in Lehman Creek during or after the test. (Note: The proposed pumping rate of 30 gpm equals roughly 3% of the typical flow rate of Lehman Creek in autumn). Water from the well would be piped to Lehman Creek approximately 100 feet downstream of the test to eliminate erosion from overland flow. Water pumped from the well is monitored for temperature, pH, and specific conductance. A water sample is collected during the test and analyzed for dissolved minerals and metals as required by the Nevada Division of Environmental Protection.

The water levels in all wells and piezometers would be monitored before, during, and after the pumping of water from the 6-inch well. Pressure transducers and temperature sensors would be placed in all three wells and in Lehman Creek upstream and downstream of the test area for a period of one-to-two weeks before the well is pumped and remain for another two-to-three weeks afterwards.

Stream Monitoring
The water level of the stream is monitored at the location of the USGS stream gauge on Lehman Creek. A second transducer would be placed at the farthest downstream temporary piezometer. Water temperature is monitored along the entire reach by placing a digital optical temperature cable along the channel or by placing Hobo temperature loggers at selected locations. Stream temperature would be monitored for two days before the test and for up to seven days after the test. Stream discharge would be measured at the USGS stream gauge and at the downstream site periodically before, during, and after the test. The digital optical temperature cable would be removed from the channel approximately one month after the test. The temporary piezometers would be removed approximately one year after the test.

Water-Quality Sampling
Water from the 6-inch diameter well near Lehman Creek would be sampled as part of the aquifer test.

DYE TRACING STUDY:

A comprehensive written study plan for the dye tracing experiment, entitled: *"Study Plan for a Dye Tracing Study in the Pole Canyon Limestone, Great Basin National Park, Nevada"*, was prepared by Tom Aley, President, Ozark Underground Laboratory, Inc., dated August 11, 2009, for the National Park Service, Water Resources Division, on behalf of Great Basin National Park (Appendix A). In addition, Mr. Aley provided the National Park Service with a written report that documents sampling and analytical protocols for the dye tracing experiment, entitled: *"Procedures and Criteria, Analysis of Fluoescein, Eosine, Rhodamine WT, Sulfurhodamine B, and Pyranine Dyes in Water and Charcoal Samplers"*, dated December 15, 2008 (Appendix B).

A summary of the dye tracing experiment procedure is provided below.

Purpose
The purpose of the dye-tracing experiment is to improve understanding of groundwater flow paths and quantify interactions between surface water and groundwater in the area of Lehman Creek and Baker Creek drainages in and adjacent to the Park.

Introduction of Tracer Dyes
Three separate dye introductions are proposed as part of the dye-tracing experiment. "Trace 1", five pounds of fluoroscein dye mixture, would be introduced at a location on Baker Creek about 500 feet upstream of the upstream end of the lower Baker Creek campground. "Trace 2", six

pounds of rhodamine WT dye mixture, would be introduced at a location in the Baker Creek Cave System at a point as far upgradient in the system as possible under the conditions existing when the dye is placed. "Trace 3", six pounds of eosine dye mixture, would be introduced into the flow of Pole Canyon stream a short distance upstream of the point where the stream flows onto the Pole Canyon Limestone. The locations of these proposed dye introductions are shown in Figure 12.

Water Sampling
Prior to introduction of dyes waters in the area must be sampled for background levels of fluorescent tracer dyes and compounds that might interfere with the use of the planned dyes. Water samples would be collected at 22 sampling locations during the dye tracing experiment, predominantly northeast of the dye introductions (Figure 12). Activated carbon samplers capable of adsorbing and retaining all of the tracer dyes would be placed at all of the sample sites prior to the beginning of the dye tracing experiment. Then grab samples of water are collected periodically and the carbon samples concurrently collected and replaced at each sample site. Water samples would be collected at least once per day during for the first week after dye introduction. Thereafter, sampling would occur once per week for six weeks, then on weeks 8, 10, and 12 after dye introduction.

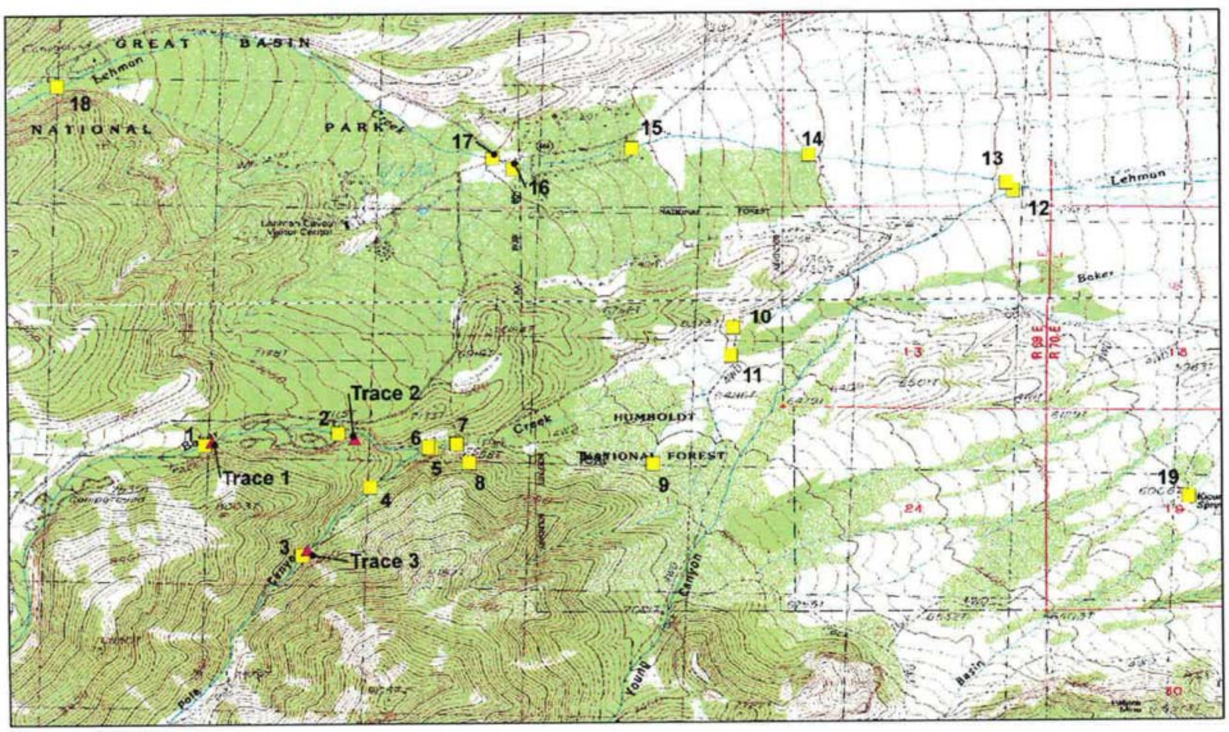

Figure 12. Sampling Stations and Dye Introduction Points. The introduction location for Trace 2 is approximate. The locations of Stations 20 through 22 are in caves and are not shown.

Alternative 3 – All Sites Excluding Lehman Creek Drilling

Alternative 3 would implement the Proponent Action except for the part involving drilling near Lehman Creek. Specifically, this part of the Proponent Action would be excluded:

FOCUSED INVESTIGATION OF STREAM-AQUIFER INTERACTIONS AT A SPECIFIC SITE ON LEHMAN CREEK, as described on pages 25-28.

All other parts of the Proponent Action would be allowed.

Alternative 4 –Alternate Lehman Creek Drilling Sites

Alternative 4 would implement the Proponent Action except that the Lehman Creek drilling sites would be moved farther downstream (Figure 13). Access would be off the Wheeler Peak Scenic Drive. Several pinyon and/or juniper trees would need to be removed to allow access for the drill rig and pipe truck. The wells would be drilled to a similar depth and diameter of those in Alternative 2 (Table 2).

Figure 13. Locations of alternate Lehman Creek drilling sites.

Table 3. Locations and expected sizes of proposed wells at the alternate Lehman Creek site.

Site number	NAD83 Latitude	NAD 83 Longitude	Elevation in feet above mean sea level	Expected depth of well in feet	Hole diameter, in inches	Casing diameter, in inches	Screened interval or open hole, in feet
alt3p	39° 00.616’	114° 12.581’	6610	~60	10	6	20
alt3u*	39° 00.616’	114° 12.581’	6610	40	8	2	10
alt3d*	39° 00.616’	114° 12.581’	6610	40	8	2	10

*Sites 3u (“upstream”) and 3d (“downstream”) are near Lehman Creek about 25 feet upstream and downstream of site 3p (“pumping well”) and 20 to 40 feet from the creek

MITIGATION

Mitigation measures are specific actions designed to reduce, minimize, or eliminate impacts of alternatives and to protect GRBA resources and visitors. Mitigation measures to protect cultural resources, geologic resources, soundscapes, water quality/quantity, and visitor experience, as described in Table 4, would apply to the Action Alternatives (Alternatives 2, 3, & 4).

ALTERNATIVES AND ACTIONS CONSIDERED BUT DISMISSED

Alternatives considered but dismissed included different locations for the Lehman Creek well sites. A site near Lehman Creek by the Park entrance was dismissed as being a potential safety hazard and having a large impact to cultural resources. Building a new road into Lehman Creek to access drilling sites was considered too cost prohibitive and would cause too much damage to restored sagebrush habitat and was thus dismissed.

HOW ALTERNATIVES MEET PROJECT OBJECTIVES

Action alternatives selected for analysis must meet all objectives to a large degree. Action alternatives must also address the stated purpose of taking action and resolve the need for action. Alternatives that did not meet the plan objectives were dismissed from further analysis (see the *Alternatives Considered but Dismissed* section above).

Table 4. Mitigation Measures for Action Alternatives.

Resources Area	Mitigation	Responsible Party
General Considerations	Prior to beginning the project, all equipment and vehicles will be thoroughly pressure washed to remove foreign soil and vegetative matter; this will minimize potential that nonnative plants are introduced to the project area.	Contractor/Weed Program Manager
General Considerations	A resource advisor from NPS will be on site to monitor the transport of equipment into and out of the project area. This will ensure that the equipment follows the designated route to the project site and that there is no undue impact to resources on the ground.	NPS Hydrologist
General Considerations	Equipment will be inspected daily to ensure there are no leaks of petroleum products or other hazardous materials.	Contractor/ NPS Hydrologist
General Considerations	Heavy equipment will be parked in previously disturbed areas designated by NPS; no new staging areas will be created.	Contractor/ Archeologist
General Considerations	Following the completion of the project, all portions of the route used to transport equipment that are not part of a public road system will be sufficiently restored to prevent unauthorized use.	Contractor/ Chief of Natural Resources
Cultural Resources	All necessary steps will be taken to avoid cultural resources. The contractor will provide orange safety fence and cultural resource staff will mark avoidance areas and install in well sites 1 & 2. The Park will provide a cultural resource steward to monitor project activities.	Contractor/ Archeologist
Geologic Resources	If a void is encountered in the Pole Canyon limestone during drilling, casing will be extended further into the hole sufficiently to bypass the void.	Contractor/NPS Hydrologist
Soundscapes	The drill rig will only operate between the hours of 7 a.m. and 8 p.m.	Contractor/NPS Hydrologist
Water quality/quantity	At least 7 days prior, notices providing the dye introduction schedule will be posted at the Park visitor centers, the Baker post office, and on the Snake Valley Connection listserve.	Contractor/ Chief of Interpretation
Visitor Experience	Notices about the project will be posted at the Park visitor centers, the Baker post office, and on the Snake Valley Connection listserve. Interpreters will be provided information sheets so as to advise the public. The contractor will update the Park daily of progress.	Contractor/ Chief of Interpretation

COMPARISON OF ALTERNATIVES

A comparison of the alternatives is shown in Table 4.

Table 5. Comparison of Alternatives for the Hydrogeologic Research Project.

Actions	Alternative 1 No Action	Alternative 2 All Sites	Alternative 3 No Lehman	Alternative 4 Lehman Alt.
Investigation of the source of water to Rowland Spring	No investigation is completed.	Drilling 2 groundwater monitoring wells; conducting two 48-hour continuous pumping tests; installing a precipitation collector; collecting water samples monthly for laboratory analysis	Same as Alternative 2.	Same as Alternative 2
Investigation of stream-aquifer interactions along selected reaches of Lehman, Baker, Snake, and Strawberry Creeks	No investigation is completed.	Installation of up to 10 shallow well points in each of 3 creeks; digital optical temperature-sensing cable installed in 3 creeks; slug testing; stream flow measurements; up to 5 stream gauges installed in Baker Creek drainage.	Same as Alternative 2.	Same as Alternative 2
Focused investigation of stream-aquifer interactions at a specific site on Lehman Creek	No investigation is completed.	Drilling a cluster of three shallow boreholes near Lehman Creek; conducting a 72-to96-hour continuous pumping test; collecting water samples for laboratory analysis; collecting water level data for one year afterward.	No investigation is completed.	Same as Alternative 2, but at a different location along Lehman Creek.
Dye-tracing study	No investigation is completed.	Introducing three fluorescent tracer dyes into water sources in the Baker Creek drainage; water sampling at approximately 22 locations to detect dye.	Same as Alternative 2.	Same as Alternative 2.

IMPACT SUMMARY

A summary of the impacts to each topic are shown for each alternative in Table 5. These impacts are described in more detail in Chapter 3.

Table 6. Summary of Environmental Consequences for Each Alternative.

Impact Topic	Alternative 1 No Action	Alternative 2 All Sites	Alternative 3 No Lehman	Alternative 4 Lehman Alt.
Cultural Resources	Current conditions are unaltered because no action would be taken. No effects to cultural resources would occur.	Drilling would have minor to moderate impact and adverse effect to cultural resources in well site 3. Drill rig equipment would likely damage the historic road and drilling operation vibrations have potential to damage the historic bridge foundation and structure. Non-historic features would be introduced into a historic setting. Artifacts could be crushed and destroyed. These impacts are direct, adverse, local, long-term, and moderate.	Cultural resources would be avoided in well sites 1 & 2. Impacts would be direct, local, short-term, and negligible.	Cultural resources would be avoided in well sites 1, 2 & 3. Impacts would be direct, local, short-term, and negligible.
Geologic Resources	The lack of data informing park management decisions could result in indirect, adverse, regional, long-term, major impacts to geologic resources.	Drilling would disturb small areas of soil, as would equipment moving to and around the drill sites. The wells could potentially intercept subterranean voids, although the probability is very low. Impacts are expected to be direct, adverse, local, long-term, and minor.	Impacts would be the same as Alternative 2 except for 3 fewer drilling holes and no soil disturbance at the Lehman Creek site.	Same as Alternative 2.

Table 6 (continued)

Impact Topic	Alternative 1 No Action	Alternative 2 All Sites	Alternative 3 No Lehman	Alternative 4 Lehman Alt.
Soundscapes	Current conditions are unaltered.	Air hammer drilling and engine noise would be the primary source of human-created noise, although the project areas are in developed areas of the Park and away from high-visitation areas. Drilling would take approximately one week at each site, for a total of three weeks. The impacts are expected to be direct, adverse, local, short-term, and locally moderate.	Impacts would be the same as Alternative 2 except for approximately one week less noise due to no drilling at Lehman Creek.	Same as Alternative 2.
Water quality/quantity	Lack of data informing management actions could result in indirect, adverse, regional, long-term, major impacts on park resources.	Conducting studies in creeks, including a dye-trace study, and performing a pump test with discharge into Lehman Creek are the primary activities that would affect water quality/quantity. Impacts are expected to be direct, adverse, local, short-term, and negligible.	Impacts would be the same as Alternative 2 except that no water from the Lehman Creek wells pump test would be discharged into Lehman Creek	Same as Alternative 2.
Visitor Experience	Current conditions will be unaltered.	Visitor experience could be affected by visitors seeing and/or hearing noise from the drill equipment or meeting personnel who are working in the creeks. Impacts are expected to be direct, adverse, local, short-term, and minor.	Impacts would be the same as Alternative 2 except for approximately one week less of visual obstructions and equipment noise due to no drilling at Lehman Creek.	Same as Alternative 2.

ENVIRONMENTALLY PREFERRED ALTERNATIVE

The CEQ Regulations implementing NEPA and the NPS NEPA guidelines require that "the alternative or alternatives which were considered to be environmentally preferable" be identified (Council on Environmental Quality Regulations, Section 1505.2). Ordinarily, this means the alternative that causes the least damage to the biological and physical environment; it also means the alternative that best protects, preserves, and enhances historic, cultural, and natural resources.

The Council on Environmental Quality defines the environmentally preferred alternative as "…the alternative that will promote the national environmental policy as expressed in the National Environmental Policy Act's §101." Section 101 of the National Environmental Policy Act states that "… it is the continuing responsibility of the Federal Government to … (1) fulfill the responsibilities of each generation as trustee of the environment for succeeding generations; (2) assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings; (3) attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences; (4) preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity, and variety of individual choice; (5) achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and (6) enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources."

The National Park Service has determined that the environmentally preferred alternative for this project is Alternative 4- Lehman Creek Alternate Site. Alternative 4- Lehman Creek Alternate Site meets all the research objectives as well as minimizes the cultural resource concerns found in Alternative 2- Proponent Action-All Sites. Alternative 3- No Lehman would not provide information about the interaction of surface waters with the aquifer, which is important to the Park. Thus Alternative 3 is not environmentally preferred because it could result in a lack of information that could help protect park surface waters. Alternative 1- No Action is not the environmentally preferred alternative, because even though there would not be short-term disturbances, it could set the stage for deleterious regional watershed impacts by not providing sufficient information for NPS response.

AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter provides a description of the Affected Environment for a resource followed by an evaluation of the Environmental Consequences of the alternatives. The resource descriptions provided in this chapter serve as a baseline with which to compare the potential effects of the management actions considered in this EA. The Environmental Consequences portion of each impact topic analyzes both beneficial and adverse impacts that could result from implementing any of the alternatives described in Chapter 2: Alternatives.

The analysis includes a summary of laws and policies relevant to each impact topic, definitions of impact thresholds (negligible, minor, moderate, and major), methods used to analyze impacts, and the analysis methods used for determining cumulative effects. As required by the CEQ, a summary of the environmental consequences of each alternative is provided in Table 5 in Chapter 2: Alternatives.

GENERAL METHODS FOR ANALYZING IMPACTS

The NPS based the impact analyses and conclusions on scientific literature; information and insights provided by NPS experts, other agencies, and the public; and best professional judgment.

For each impact topic, impacts are defined in terms of thresholds of effect, context, intensity, duration, and timing. Impacts and cumulative effects are discussed in each impact topic. Definitions of intensity levels vary by impact topic. Where it is not specifically stated otherwise under each impact topic, the following definitions apply.

Under each impact topic is a brief description of relevant components of existing conditions and information for determining the effects of implementing each alternative. The effects are based on the following factors:

Type: Whether the impact would be beneficial or adverse.

Intensity: Identify the intensity of the effect as negligible, minor, moderate, or major. Intensity is defined individually for each impact topic.

Duration: Duration of impact is analyzed independently for each resource. Depending on the resource, impacts may last for the construction period, a single year, or other time period. For purposes of this analysis, impact duration is described as short- or long-term as defined for each resource.

- *Short-term* impacts are temporary, transitional, or construction-related impacts associated with project activities.
- *Long-term* impacts are typically those effects that would last several years or more or would be permanent.

Context: Context is the setting within which an impact would occur.

- *Local impacts* would generally occur within the immediate vicinity of the proposed project.
- *Regional impacts* would occur on surrounding lands and/or in adjacent communities.

Impact: The following types of impact must be considered and examined for any park proposal and alternatives.

- *Direct Impact:* effects are caused by an action and occur at the same time and place as the action.
- *Indirect Impacts:* effects are caused by the action and occur later or farther away, but are still reasonably foreseeable.
- *Cumulative Impacts:* effects of the alternatives in conjunction with past, present, or reasonably foreseeable future actions.

Impairment

In addition to determining the environmental consequences of the alternatives, NPS *Management Policies* (2006) require the analysis of potential effects to determine if actions would impair park resources. Under the NPS Organic Act and the General Authorities Act, as amended, the NPS may not allow the impairment of park resources and values except as authorized specifically by Congress.

Impairment is an impact that would harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources or values. An impact would be more likely to constitute an impairment to the extent that it: 1) affects a resource or value whose conservation is necessary to fulfill specific purposes identified in the enabling legislation or proclamation of the Park; 2) is key to the cultural or natural integrity of the Park or to opportunities for enjoyment of the Park; 3) or as identified as a goal in the Park's general management plan or other relevant NPS planning document. An impact would be less likely to constitute an impairment to the extent that it is an unavoidable result, which cannot be reasonably further mitigated, of an action necessary to preserve or restore the integrity of park resources or values.

In this EA, potential for impairment is evaluated for cultural resources, geologic resources, soundscapes, and water quality/quantity. The NPS does not make impairment determinations for Visitor Experience.

THRESHOLDS FOR IMPACT ANALYSIS

The intensity and duration of effects vary by resource; therefore, the definitions for each impact topic are described separately before each impact topic. These definitions were formulated through the review of existing laws, policies, and guidelines; and with assistance from park and region NPS staff and other resource specialists.

CUMULATIVE IMPACTS ANALYSIS

The CEQ regulations for implementing NEPA requires the assessment of cumulative impacts in the decision-making process for federal actions. A cumulative impact is described in the Council on Environmental Quality, Regulation 1508.7, as follows:

> *A "cumulative impact" is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.*

Cumulative impacts are considered for both the No Action and Action Alternatives. Cumulative impacts were determined by combining the effects of the alternative with other past, present, and reasonably foreseeable future actions with the effects of the alternatives. The following table lists of actions that could result in cumulative impacts.

Table 7. Other projects that could result in cumulative impacts.

Action	Description	Resources Potentially Affected
Past Projects		
Wells on BLM land	Monitoring wells were drilled on BLM land in 2009 on Baker Creek, Snake Creek, and two near Big Springs to the southeast of the Park. All wells were capped upon completion.	Geologic Resources Cultural Resources
Baker General Improvement District Wells	Two wells were drilled near Lehman Creek just outside the Park in 2003 in an attempt to develop a water system for local residents. Currently the wells are capped and not in production use.	Geologic Resources Cultural Resources
Sewage lagoon and access road	Creation of the sewage lagoon, excavation, creation of access road to sewage lagoon in 1982.	Cultural Resources
Water tanks and access road	Creation of water tanks for park drinking water adjacent to Lehman Aqueduct, creation of access road	Cultural Resources
Reclamation of South Section of Historic Road	The south section of the historic road to Lehman Caves was reclaimed in 2004.	Cultural Resources
Present Projects		
None		
Future Projects		
SNWA Groundwater Development Project	Approximately 75-93 groundwater production wells in Spring Valley and 39-48 groundwater production wells in Snake Valley, along with accompanying infrastructure, are proposed for development. The produced water would be exported to Southern Nevada. This action is currently being analyzed by the BLM in an EIS. Construction is expected to commence in Spring Valley in 2017 and in Snake Valley in 2021.	Geologic Resources Water Quality/ Quantity Visitor Experience Cultural Resources

GEOGRAPHIC ANALYSIS AREA

The geographic area for the analysis of impact related to this project encompasses Great Basin National Park and its immediate surroundings (Figure 1).

CULTURAL RESOURCES

Regulatory Framework

National Historic Preservation Act of 1966, as amended (NHPA) (16 USC 470 et sequential). Congressional policy set forth by the NHPA includes preserving "the historical and cultural foundations of the Nation" and preserving irreplaceable examples important to our national heritage to maintain "cultural, educational, aesthetic, inspirational, economic and energy benefits."

Historic Properties are defined by the NHPA Title III Sec. 301 (5), (*16 U.S.C. 470w (5))*"any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on the National Register;" such terms include artifacts, records, and remains which are related to such district, site, building, structure, or object (16 U.S.C. Section 470(w)(5)). Also included are properties of traditional religious and cultural importance to any Native American tribe if that property meets defined National Register criteria.

Section 106 of the NHPA requires federal agencies assess the effects of their actions on historic properties listed or potentially eligible for listing on the National Register of Historic Places, and consult as appropriate. This is accomplished by applying a "criteria of adverse effect." Defined by (36 CFR 800.5[a][1], "an adverse effect is found when an undertaking may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling or association."

Section 106 further requires federal agencies to propose and evaluate alternatives to undertakings that would adversely affect historic properties or to adequately mitigate adverse effects if avoidance cannot be reasonably achieved. All actions affecting the Park's historic resources must comply with this legislation.

Archeological Resources Protection Act of 1979. This act (PL 96-95, 93 Stat. 712, 16 USC Section 470aa et seq. and 43 CFR 7, subparts A and B, 36 CFR) secures the protection of archeological resources on public or Indian lands and fosters increased cooperation and exchange of information between private, government, and the professional community in order to facilitate the enforcement and education of present and future generations. It regulates excavation and collection on public and Indian lands. It requires notification of Indian tribes who may consider a site of religious or cultural importance prior to issuing a permit.

Management Policies 2006 – 5.3.1 states, "The National Park Service will employ the most effective concepts, techniques, and equipment to protect cultural resources against theft, fire, vandalism, overuse, deterioration, environmental impacts, and other threats without compromising the integrity of the resources."

Affected Environment

Historic Properties

Human history of the Great Basin spans over 13,000 years. Within Great Basin National Park archaeological and historic sites provide a sample of the full span of North American history. The archaeologically defined periods include Paleo Indian beginning 13,500 years ago continuing to 11,000 years ago; the Archaic from 11,000 years ago to 2000 years ago; the Late Archaic from 2000 years ago until Euro-American contact. The period includes the archaeologically defined Formative period, manifest in this area by the Fremont Culture practicing horticulture from 2000 years ago to 600 years ago (A.D. 1400). Native cultures present at the time of Euro-American contact remain in the area today and recognize ethnographically significant resources within the Park. Sites from the more recent Historic period represent the trend of development identified in varying levels of documentary history. Within the Park historic themes identified in the NPS Historic Resource Study by Unrau (1990) are represented by sites, structures, and features. Some of the represented themes include Mormon settlement, ranching, government survey, mining, and government administration (U.S.Forest Service and NPS) of recreation and resources.

There are five historic properties identified in the area of potential effect for the Hydrogeologic Research Project alternatives. These resources include historic sites with contributing features and archaeological sites. Of these, two are historic sites including one listed on the National Register of Historic Places (NRHP) and one eligible for NRHP. Three sites have both historic and prehistoric components. One is currently considered eligible for the National Register of Historic Places, one is not eligible and one should be re-evaluated for eligibility.

Environmental Consequences

Impact Criteria and Thresholds

The area of consideration for this topic is the project area. Defining potential impacts from management actions is based on professional judgment and experience with similar actions. The thresholds of change for the intensity of an impact are defined as follows:

Impact Intensity	Intensity Description

Negligible	Impact is barely perceptible and not measurable. Significant character-defining attributes of historic properties (including the informational potential of archaeological resources) are not appreciably diminished by the undertaking. The determination of effect for Section 106 would be *no historic properties affected.*
Minor	Impact is perceptible and measurable. The effects remain localized and confined to a single element contributing to the significance of a larger national register property/district, or archaeological site(s) with low to moderate data potential. Alteration of a feature(s) would not diminish the overall integrity of the resource and the property may still be eligible for the National Register of Historic Places. The determination of effect for Section 106 would be *no adverse effect.*
Moderate	Impact is sufficient to alter character-defining features of historic properties, generally involving a single or small group of contributing elements, or archaeological site(s) with moderate to high data potential. The overall integrity of the resource would be diminished, the property may not retain its National Register eligibility. The determination of effect for Section 106 would be *adverse effect.*
Major	Impact results in a substantial and highly noticeable change in character-defining features of historic properties, generally involving a large group of contributing elements and/or individually significant property, or archaeological site(s) with high to exceptional data potential seriously diminishing the overall integrity of the resource to the point where it is not eligible for the National Register. The determination of effect for Section 106 would be *adverse effect.*

Area of Potential Effect

In accordance with the Advisory Council on Historic Preservation's regulations implementing Section 106, the "area of potential effects" is determined as the geographic area within which an undertaking may directly or indirectly cause alteration in the character or use of historic properties (36 CFR 800.16(d)). For analysis of effects to cultural resources for the Hydrogeologic Research Project, the area of potential effects is defined as the immediate project area, equipment transport and access, and the area defined as potential historic landscape. Direct impacts include any ground disturbing activity including truck travel and maneuvering that disturbs soil and vegetation cover. Indirect impacts may include alteration of the historic setting, drilling vibration, discharge of water that may cause erosion in the event of rupture or failure of drill casings or hose that transports well water to the stream.

Alternative 1- No Action

Under Alternative 1, the 'No Action' alternative, the proposed Hydrogeologic Research Project would not be implemented. No project-related disturbance would occur and no related impacts identified would occur. The finding of effect for NHPA Section 106 would be "no historic properties affected."

Cumulative Impacts

The 'No Action' alternative would not contribute any additional impact or adverse effect to the character or integrity of historic properties. Properties considered eligible for the National Register of Historic Places would retain their eligibility. There would be no addition to the cumulative impacts as a result of the No Action, Alternative 1.

Conclusion

Under Alternative 1- No Action, there would be no additional impact to historic properties including archaeological and historic sites.

Alternative 2- Proponent Action-All Sites

Alternative 2- Proponent Action-All Sites would involve disturbance through excavation and manipulation of surface and small areas of deep subsurface soils for the installation of wells near the Baker Creek road, the Water Tank road, and near Lehman Creek. Any ground disturbance either shallow surface, or deeper disturbance in drilling, has the potential to damage the context of a historic property. The total area of ground disturbance would be 15,840 sq. ft. Approximately 450 sq. ft. of the disturbance would be surface disturbance associated with the actual well head location where the wells casings would be capped and sealed leaving a non-historic feature in a historic site. The additional 15,390 sq. ft. of disturbance would be caused by heavy drilling equipment and vehicles accessing and maneuvering on the site. Access roads and disturbed areas around the well cap would be revegetated using salvaged vegetation from disturbed sites and seed mixes. To avoid further subsurface soil disturbance by revegetation, deep holes would be filled to prevent future erosion and seed would be broadcast rather than drilled or scarred. Archaeologists would monitor the well drilling operations to ensure there are no subsurface deposits of historic or prehistoric artifacts. This mitigation would reduce the potential impacts to historic resources adjacent to the project locations.

Alternative 2- Proponent Action-All Sites has the potential to have minor to moderate negative impact historic resources. This impact would be local and long term but should also be considered in a park landscape scale. This alternative requires avoidance of known historic properties in the well sites 1 and 2 and also requires archaeological monitoring during operation. This alternative would not compromise the National Register eligibility of sites identified in well sites 1 and 2. Because historic properties cannot be avoided in well site 3 this alternative would compromise the National Register eligibility of sites identified in the Lehman Creek test well locations (identified in this document as well sites 3p, 3u, and 3d) with the introduction of non-historic features in a historic site (sealed well head) and by the potential to damage historic features including the historic Lehman Cave National Monument road segment and the historic Lehman Creek bridge foundation. This alternative would have direct, adverse, local, long-term, moderate impacts on historic properties. In terms of NHPA Section 106 it would have adverse effect on the NRHP eligibility on a historic property.

Cumulative Impacts

Alternative 2- Proponent Action-All Sites, when combined with previous park projects, would result in direct, local, long term, impacts of moderate intensity. For purposes of NHPA the determination of effect for Section 106 purposes would be an ‘adverse effect.’

Previous park actions have impacted historic properties in the project areas. In well site 1, prior to installation of the sewage lagoon, historic sites were tested and artifacts in the immediate location were collected. A small area of the total site was affected. Well site 1 would affect a small area within the larger historic property area. This project would add to the disturbance of the larger site area. The site was previously determined not eligible for the National Register but reevaluation is required due to the length of time since determination. This project would avoid disturbance in sensitive areas but would add to the long term cumulative impacts. It would not affect National Regsiter eligibility of a historic property.

In well site 2 the installation of the water tanks and access road introduced non-historic features adjacent to the historic National Register listed Lehman Aqueduct. This project would not directly disturb the historic resource but it would add another non-historic feature with the sealed well casing. This is not within a visually sensitive area and would not affect the historic integrity of the listed property. This is a localized, long term effect that would add to the cumulative impacts.

Historic properties cannot be avoided in well site 3. There would be minor to moderate impacts. In well site 3 of Alternative 2- Proponent Action-All Sites, project activities would have direct cumulative impacts to a historic property. When considered in addition to the previous Park reclamation of the historic road south of Lehman Creek, the potential physical damage to the remaining road feature and the addition of non-historic features in a historic site, the three sealed well heads in the historic road and site area, the cumulative impact would be local, long term, and moderate. In terms of Section 106 of the NHPA this is an adverse effect.

Conclusion
Alternative 2- Proponent Action-All Sites would result in direct, adverse, local, long-term, moderate impacts to historic properties in the project area. There would also be measurable cumulative impacts resulting from actions in Alternative 2.

<u>Alternative 3- All Sites Excluding Lehman Creek Drilling</u>

Alternative 3- All Sites Excluding Lehman Creek Drilling, would involve ground disturbance through excavation and manipulation of surface and small areas of deep subsurface soils for the installation of wells near the Baker Creek road, the Water Tank road. Any ground disturbance either shallow surface, or deeper disturbance in drilling, has the potential to damage the context of a historic property. The total area of ground disturbance would be 570 sq. ft. Approximately 180 sq. ft. of the disturbance would be surface disturbance associated with installing the wells. The additional 390 sq. ft. of disturbance would be caused by heavy drilling equipment and vehicles accessing and maneuvering on the site. Archaeologists would monitor the well drilling operations to ensure there are no subsurface deposits of historic or prehistoric artifacts. This mitigation would reduce the potential impacts to historic resources adjacent to the project locations.

Alternative 3- <u>All Sites Excluding Lehman Creek Drilling,</u> would result in direct, minor, negative impacts to historic resources. This impact would be local and long term but should also be considered in a park landscape scale. This alternative would not compromise the National Register eligibility of sites identified in well sites 1 and 2. This alternative requires avoidance of known historic properties in the well sites 1 and 2 and also requires archaeological monitoring during operation. This alternative would not compromise the National Register eligibility of sites identified in well sites 1 and 2. In terms of NHPA Section 106 there would be no adverse effect.

Cumulative Impacts

In Alternative 3 - All Sites Excluding Lehman Creek Drilling, the project would have the same cumulative effects for well sites 1 and 2 as described in Alternative 2 above. Previous park actions have impacted historic properties in the project areas. Historic properties and associated artifacts would be avoided in well sites 1 & 2.

In well site 1, prior to installation of the sewage lagoon, historic sites were tested and artifacts in the immediate location were collected. A small area of the total site was affected. Well site 1 is a small area within the larger site area. This project would add to the disturbance of the larger site area. The site was previously determined not eligible for the National Register but reevaluation is required due to the length of time since determination. This project would avoid disturbance in sensitive areas but would add to the long term cumulative impacts. It would not affect National Register eligibility of a historic property.

In well site 2 the installation of the water tanks and access road introduced non-historic features adjacent to the historic National Register listed Lehman Aqueduct. This project would not directly disturb the historic resource but it would add another non-historic feature with the sealed well casing. This is not within a visually sensitive area and would not affect the historic integrity of the listed property. This is a localized, long term effect that would add to the cumulative impacts.

Conclusion

Alternative 3- All Sites Excluding Lehman Creek Drilling would result in direct, adverse, local, long-term, minor impacts to historic properties in the project area well sites 1 and 2. In terms of Section 106 of the NHPA this project would not damage the integrity or NRHP eligibility of any historic properties. There would be no adverse effects to historic resources. There may be additions to the cumulative impacts due to the addition of non-historic features in the area of eligible historic properties. There would be minor measurable cumulative impacts resulting from actions in Alternative 3.

<u>Alternative 4- Lehman Creek Alternate Site</u>

Alternative 4- Lehman Creek Alternate Site, would involve ground disturbance through excavation and manipulation of surface and small areas of deep subsurface soils for the installation of wells near the Baker Creek road, the Water Tank road and the alternate well site on Lehman Creek. Any ground disturbance either shallow surface, or deeper disturbance in drilling, has the potential to damage the context of a historic property. Alternative 4 would have an area of potential impact roughly the same total space as Alternative 2. The total area of soil disturbance would be 15,840 sq. ft. Approximately 450 sq. ft. of the disturbance would be surface disturbance associated with installing the wells. The additional 15,390 sq. ft. of disturbance would be caused by vehicles accessing the site. Archaeologists would monitor the well drilling operations to ensure there are no subsurface deposits of historic or prehistoric artifacts. This mitigation would reduce the potential impacts to historic resources adjacent to the project locations.

With Alternative 4 there were no additional historic properties identified in the alternate well location on Lehman Creek. One archaeological site was identified in the area and determined not eligible for NRHP. There is no additional impact to historic properties and no additional effect under NHPA.

Alternative 4-Lehman Creek Alternate Site would have the same impact on historic properties as Alternative 3. Alternative 4 would have direct, minor, negative impact historic resources. This impact would be local and long term but should also be considered in a park landscape scale. This alternative would not compromise the National Register eligibility of sites identified in well sites 1 and 2. This alternative requires avoidance of known historic properties in the well sites 1 and 2 and also requires archaeological monitoring during operation. This alternative would not compromise the National Register eligibility of sites identified in well sites 1 and 2. In terms of NHPA Section 106 there would be no adverse effect.

Cumulative Impacts
Alternative 4- Lehman Creek Alternate Site, would have the same cumulative impacts as Alternative 2 and Alternative 3 in well sites 1 and 2. Previous park actions have impacted historic properties in the well areas. Historic properties and associated artifacts would be avoided in all well sites.

In well site 1, prior to installation of the sewage lagoon historic sites were tested and artifacts in the immediate location were collected. A small area of the total site was affected. Well site 1 is a small area within the larger site area. This project would add to the disturbance of the larger site area. The site was previously determined not eligible for the National Register but reevaluation is required due to the length of time since determination. This project would avoid disturbance in sensitive areas but would add to the long term cumulative impacts. It would not affect National Register eligibility of a historic property.

In well site 2 the installation of the water tanks and access road introduced non-historic features adjacent to the historic National Register listed Lehman Aqueduct. This project would not directly disturb the historic resource but it would add another non-historic feature with the sealed well casing. This is not within a visually sensitive area and would not affect the historic integrity of the listed property. This is a localized, long term effect that would add to the cumulative impacts.

In this Alternative 4 - Lehman Creek Alternate Site the alternate well location 3 there were no historic properties identified. One archaeological site was identified in the area and determined not eligible for NRHP. There is no additional impact to historic properties and no additional effect under NHPA. There would be no additional cumulative effect in this alternate well location.

Conclusion

This alternative would result in direct, local, long-term, minor impacts to historic resources in the project area well sites 1 and 2. In terms of Section 106 of the NHPA this project would not damage the integrity or NRHP eligibility of any historic properties. There would be no adverse effects to historic properties. There may be additions to the cumulative impacts due to the addition of non-historic features in the vicinity of eligible historic properties. This should be considered minor cumulative impact.

Impairment

None of the affected historic resources is considered key to the cultural integrity of the Park, therefore impacts would not be considered impairment to cultural resources for any of the alternatives.

GEOLOGIC RESOURCES

Regulatory Framework

NPS *Management Policies* (2006) state, "The Park Service will preserve and protect geologic resources as integral components of park natural systems. As used here, the term "geologic resources" includes both geologic features and geologic processes. The Service will (1) assess the impacts of natural processes and human activities on geologic resources; (2) maintain and restore the integrity of existing geologic resources; (3) integrate geologic resource management into Service operations and planning; and (4) interpret geologic resources for park visitors."

Affected Environment

Geologic Resources in the project area consist primarily of alluvial fill underlain by carbonate bedrock. This bedrock is Pole Canyon limestone, the same layer of rock containing Lehman Cave. Pole Canyon limestone also underlies most of the Baker Creek project area. Creeks in the Lehman, Strawberry, and Baker drainages have numerous boulders, cobble, and gravel of metamorphic rock on the stream bed, derived from the Prospect Mountain Quartzite that has washed down from upper reaches. Within the drilling areas, no caves are known. The soils consist of Badena extremely stony sandy loam, 2-8 percent slopes for all three drilling sites. This soil is composed of 20 percent cobbles, 35 percent gravels, 5 percent sands. The parent material is alluvium derived from quartzite. It is considered well-drained with medium run-off properties (USDA 2009). The principal components of geologic resources considered in this EA are soils and caves.

Environmental Consequences

Impact Criteria and Thresholds

The area of consideration for this topic is the project area. Defining potential impacts from management actions is based on professional judgment and experience with similar actions. The thresholds of change for the intensity of an impact are defined as follows:

Impact Intensity	Intensity Description
Negligible	The effects to soils would be below or at the lower levels of detection. Any effects on productivity or erosion potential would be slight. The effects to caves would be below or at the lower levels of detection.
Minor	An action's effects on caves and soils would be detectable. It would change the soil profile in a relatively small area, but it would not appreciably increase the potential for erosion of additional soil. Drilling may enter a subterranean void, but it would have little effect on it. If mitigation were needed to offset adverse effects, it would be relatively simple to implement and would likely be successful.
Moderate	An action would result in breaking into a large cavern; in a change in quantity or alteration of the topsoil, overall biological productivity, or the potential for erosion to remove small quantities of additional soil. Changes to localized ecological processes would be of limited extent. Mitigation measures would probably be necessary to offset adverse effects and would likely be successful.
Major	An action would result in subsidence or sinkholes; and/or a change in the potential for erosion to remove large quantities of additional soil, alterations to topsoil, and overall biological productivity in a relatively large area. Key ecological processes would be altered, and landscape-level changes would be expected. Mitigation measures to offset adverse effects would be necessary, extensive, and their success could not be guaranteed.

Alternative 1- No Action

No action would be taken in this alternative; therefore there would be no impacts to geologic resources, including caves or soils.

Cumulative Impacts

Three projects could contribute to cumulative impacts, although past well drilling is at a sufficient distance to have no cumulative impact on geologic resources of the current wells. Future drilling and groundwater extraction by SNWA could lower the water table substantially, causing subsidence or sinkholes which could potentially affect park resources. Subsidence and sinkholes would be most likely in areas underlain by carbonate rock, which within the susceptible areas (Elliot et al. 2006) include parts of Baker, Lehman, and Snake watersheds.

Conclusion

Although the hydrogeologic study would not occur under Alternative 1-No Action, the lack of data informing park management decisions could result in indirect, adverse, regional, long-term, major impacts to geologic resources in the project area.

Alternative 2- Proponent Action-All Sites

Alternative 2-Proponent Action-All Sites would involve excavation and manipulation of small areas of soil for the installation of wells near the Baker Creek road, the Water Tank road, and near Lehman Creek. The total area of soil disturbance would be 15,840 sq. ft. Approximately 450 sq. ft. of the disturbance would be surface disturbance associated with installing the wells. The additional 15,390 sq. ft. of disturbance would be caused by vehicles accessing the site. There would be little potential for soil erosion associated with the disturbance because the sites are relatively flat, however some soil compaction could occur. Access roads and disturbed areas around the well cap would be revegetated using salvaged vegetation from disturbed sites and seed mixes.

Drilling into bedrock has the potential to penetrate subterranean voids. Alternative 2 states that if large voids are encountered, casing will be extended through the cavity. Drilling would be conducted with an air-percussion hammer drill. No mud or foam or other fluids except for water would be injected into the well. Thus if a cave is encountered, a metal casing would be installed to isolate that part of the cave from other impacts. Although the area is expected to contain many voids due to the karst nature of the carbonate rock, the small-diameter drilling holes have a relatively small chance of intercepting these voids.

Cumulative Impacts

Three projects could contribute to cumulative impacts, although past well drilling is at a sufficient distance to have no cumulative impact on geologic resources of the current wells. Future drilling and groundwater extraction by SNWA could lower the water table substantially, causing subsidence or sinkholes which could potentially affect park resources. However, the information gained from this project could help prevent impacts to the park’s geologic resources that might result from future SNWA actions. Therefore there are no cumulative impacts to geologic resources for this project.

Conclusion
This alternative would result in direct, adverse, local, long-term, minor impacts to geologic resources in the project area.

<u>Alternative 3- All Sites excluding Lehman Creek Drilling</u>
Alternative 3 would involve excavation and manipulation of small areas of soil for the installation of wells near the Baker Creek road and the Water Tank road. The total area of soil disturbance would be 570 sq. ft. Approximately 180 sq. ft. of the disturbance would be surface disturbance associated with installing the wells. The additional 390 sq. ft. of disturbance would be caused by vehicles accessing the site. There would be little potential for soil erosion associated with the disturbance because the sites are relatively flat. Access roads and disturbed areas around the well cap would be revegetated using salvaged vegetation from disturbed sites and seed mixes.

Drilling into bedrock has the potential to penetrate subterranean voids. The Proponent Action-All Sites alternative states that if large voids are encountered, casing would be extended through the cavity.
Drilling would be conducted with an air-percussion hammer drill. No mud or foam or other fluids except for water would be injected into the well. Thus if a cave is encountered, a metal casing would be installed to isolate that part of the cave from other impacts.

Cumulative Impacts
Three projects could contribute to cumulative impacts, although past well drilling is at a sufficient distance to have no cumulative impact on geologic resources of the current wells. Future drilling and groundwater extraction by SNWA could lower the water table substantially, causing subsidence or sinkholes which could potentially affect park resources. However, the information gained from this project could help prevent impacts to the park’s geologic resources that might result from future SNWA actions. Therefore there are no cumulative impacts to geologic resources for this project.

Conclusion
This alternative would result in direct, adverse, local, long-term, minor impacts to geologic resources in the project area.

<u>Alternative 4- Lehman Creek Alternate Site</u>
Alternative 4 would have the same impacts as Alternative 2, as the same number of wells would be drilled, although the three near Lehman Creek would be farther downstream. This alternative drilling location is still in the same soil and geologic layers as the site in Alternative 2.

Cumulative Impacts
Three projects could contribute to cumulative impacts, although past well drilling is at a sufficient distance to have no cumulative impact on geologic resources of the current wells. Future drilling and groundwater extraction by SNWA could lower the water table substantially,

causing subsidence or sinkholes which could potentially affect park resources. However, the information gained from this project could help prevent impacts to the park's geologic resources that might result from future SNWA actions. Therefore there are no cumulative impacts to geologic resources for this project.

Conclusion
This alternative would result in direct, adverse, local, long-term, minor impacts to geologic resources in the project area.

Impairment
Because the impacts to geologic resources are minor, there would be no impairment to geologic resources for any of the alternatives.

SOUNDSCAPE

Regulatory Framework

NPS *Management Policies 2006*, states that "the National Park Service will preserve, to the greatest extent possible, the natural soundscapes of parks." The policy requires the restoration of degraded soundscapes to the natural condition whenever possible, and the protection of natural soundscapes from degradation due to unnatural sounds (noise) (*Management Policies 2006,* sec. 4.9). The NPS is specifically directed to "take action to prevent or minimize all noise that, through frequency, magnitude or duration, adversely affects the natural soundscape or other park resources or values, or that exceeds levels that have been identified as being acceptable to, or appropriate for, visitor uses at the sites being monitored" (*Management Policies 2006*, sec. 4.9). Overriding all of this is the fundamental purpose of the national park system, established in law (e.g., 16 USC 1 et seq.), which is to conserve park resources and values (*Management Policies 2006*. sec. 1.4.3). NPS managers must always seek ways to avoid, or to minimize to the greatest degree practicable, adverse impacts on park resources and values (*Management Policies 2006,* sec 1.4.3).

Affected Environment

The project area is primarily located within the developed areas of Great Basin National Park and contains both natural sounds and human-generated sounds. Natural sounds include those associated with natural phenomena such as wind, rain, creeks, insects, and bird song. Human-generated sounds heard in these areas include traffic noise, commercial overflights, and water filtration and sewage treatment facility noises.

Environmental Consequences

Noise can adversely affect park resources by modifying or intruding upon the natural soundscape, and can also interfere with sounds important for animal communication, navigation, mating, nurturing, predation and foraging functions. Noise can also adversely affect park visitor experiences by intruding upon or disrupting experiences of solitude, serenity, tranquility, contemplation, or a completely natural or historical environment.

Impact Criteria and Thresholds

Context, time and intensity together determine the level of impact for an activity. It is usually necessary to evaluate all three factors together to determine the level of noise impact. In some cases an analysis of one or more factors may indicate one impact level, while an analysis of another factor may indicate a different impact level, according to the criteria below. In such cases, best professional judgment based on a documented rationale must be used to determine which impact level best applies to the situation being evaluated.

The thresholds of change for the intensity of an impact to soundscape are defined as follows:

Impact Intensity	Intensity Description
Negligible	Natural sounds would prevail. Effects to natural sound environment would be at or below the level of detection and such changes would be so slight that they would not be of any measurable or perceptible consequence to the visitor experience or to biological resources.
Minor	Natural sounds would prevail. Effects to natural sound would be localized, short-term and would be small and of little consequence to the visitor experience or to biological resources. Mitigation measures, if needed to offset adverse effects, would be simple and successful.
Moderate	Natural sounds would prevail, but activity noise could occasionally be present at low to moderate levels. Effects to the natural sound environment would be readily detectable, localized, short- or long-term, with consequences at the regional or population level. Natural sounds would be occasionally heard during the day. Mitigation measures, if needed to offset adverse effects, would be extensive and likely successful.
Major	Natural sounds would be impacted by activity noise frequently for extended periods of time. Effects to the natural sound environment would be obvious, long-term, and have substantial consequences to the visitor experience or to biological resources in the region. Extensive mitigation measures would be needed to offset any adverse effects and success would not be guaranteed.

The methodology used to assess noise impacts in this document is consistent with NPS *Management Policies* 2006 and Director's Order #47: Soundscape Preservation and Noise Management.

Alternative 1- No Action

If the project is not implemented, no change to the soundscape of the Park would occur.

Cumulative Impacts

No other projects would contribute to cumulative impacts.

Conclusion

There would be no impact to Soundscape under the No Action alternative.

Alternative 2- Proponent Action-All Sites

Drill rigs would be present at each of the three drill sites for approximately one week. These drills would result in a noise that could be heard approximately 0.25 miles from the work site. The noise from an SD300 drill rig is approximately 66 decibels at 300 feet. A normal conversation is between 60-70 decibels. The USGS Western Research Drilling Unit rig is expected to be slightly louder than the SD300 drill rig. At the work site (within 100 feet of the drill rig), the noise is loud enough to require hearing protection. The drill would be used periodically during daylight hours.

A gasoline-powered portable generator would be used to power the computer that records data from the digital optical temperature sensing cable. This generator would be used for one week approximately four times per year on Strawberry, Lehman, and Snake creeks. From 50 feet away, the generator is barely audible.

The wells installed under the Proponent Action-All Sites alternative would not create unnatural sounds and would have no impact on soundscapes.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
This alternative would result in direct, adverse, local, short-term, and moderate impacts to the soundscape in the project area.

Alternative 3- All Sites excluding Lehman Creek Drilling
Impacts from Alternative 3 would be similar to Alternative 2, but the duration would be about one week less. Overall, the impact to soundscape in the Park would be direct, adverse, local, short-term, and moderate.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
This alternative would result in direct, adverse, local, short-term, and moderate impacts to the soundscape in the project area.

Alternative 4- Lehman Creek Alternate Site
Impacts from Alternative 4 would be nearly identical to Alternative 2. The alternative Lehman Creek drilling site is closer to both the main park road and the Wheeler Peak Scenic Drive, so visitors traveling on those roads could experience slightly louder noises due to the drill rigs.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
This alternative would result in direct, adverse, local, short-term, and moderate impacts to the soundscape in the project area.

Impairment
Because there would be no major, adverse impacts to soundscape whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation and proclamation of Great Basin National Park; (2) key to the natural or cultural integrity of the Park; or (3) identified as a goal in the Park's GMP or other relevant NPS planning documents, there would be no impairment of the Park's resources or values.

WATER QUALITY/QUANTITY

Regulatory Framework

NPS *Management Policies* (2006) state, "The pollution of surface waters and groundwaters by both point and nonpoint sources can impair the natural functioning of aquatic and terrestrial ecosystems and diminish the utility of park waters for visitor use and enjoyment. The Service would determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside the Parks."

Affected Environment

The project area encompasses parts of four of the 10 perennial streams in Great Basin National Park: Baker, Lehman, Strawberry, and Snake. These are all steep, mountain streams, with flows that vary from less than 1 cfs during winter baseflow to more than 300 cfs during summer runoff. Several springs are also included in the project area, including Rowland Spring, the largest spring in the Park, with a mean annual flow of about 3 cfs. Water quality in all the streams and springs is near pristine, although some minor impacts, especially increased turbidity, can occasionally result from rainwater runoff from nearby roads, campgrounds, and other disturbances.

The project involves new well borings that intersect groundwater in the Park. Little is known about this park resource. Water in caves has been sampled periodically, with all parameters falling within normal ranges of variation.

Environmental Consequences

Impact Criteria and Thresholds

The following definitions of impact intensity are used in the analysis of effects on water quality:

Impact Intensity	Intensity Description
Negligible	Impacts would not be measurable. Water quality parameters would be well within all water quality standards. Quality and flows would be within historical normal variability conditions.
Minor	Measurable changes from historical norms would occur, but quality and flows would be within the range of historical variability. All water quality parameters would be within water quality standards. State water quality antidegradation policy would not be violated.
Moderate	Water quality or flows would be outside the range of normal variability. However, while changes to water quality or flows would be readily apparent, water quality parameters would be within water quality standards. Mitigation would probably be necessary to offset adverse effects and would likely be successful. State water quality antidegradation policy would not be violated.
Major	Changes to water quality or flows would be readily apparent and, in the case of adverse effects, some water quality parameters periodically would be equaled or exceeded. Flows would be outside the range of normal variability, and could include a complete loss of water in some areas or unusual flooding. Extensive mitigation would be needed to offset adverse effects, and its success would not be assured. State water quality antidegradation policy may be violated.

<u>Alternative 1- No Action</u>
Under the No Action Alternative, the hydrologic research project would not be conducted.

Cumulative Impacts
If this hydrogeologic research project is not completed, information would not be available to quantify impacts to park resources resulting from external groundwater withdrawals. The Park would thus have a reduced ability to protect park resources. According to groundwater models (BLM 2011, Halford and Plume 2011), the SNWA project would lower water tables more than ten feet in some areas of the Park. Due to the removal of substantial amounts of groundwater from aquifers connected to the Park, the SNWA project would have adverse, direct, long-term, regional, major impacts on park resources.

Conclusion
The No Action Alternative would result in no changes to water quality/quantity, however the cumulative impacts would be adverse, direct, long-term, regional, and major.

<u>Alternative 2- Proponent Action-All Sites</u>
The project involves walking through the creek to install DTS cables in Strawberry, Lehman, and Snake creeks. This would take approximately 3-5 days for both installation and removal on each creek. Moving through the creek may stir up sediments slightly, increasing turbidity for the short-term. Likewise, installing pressure transducers in Baker Creek would take approximately 0.5 -1 days per site, and a small amount of sediments may be stirred up in the water, increasing the turbidity for the short term. No other water quality changes are anticipated from these activities.

The three dyes planned for use at Great Bain National Park are fluorescein (also known as uranine), eosine, and rhodamine WT, all in small quantities (Table 8).

Table 8. Amounts of dye to be used in study.

Dye Introduction Point	Dye Type and Weight of Dye Mixture (pounds)	Actual Amount of Dye in Dye Mixture
Baker Creek 500 ft. upstream of lower campground	Fluorescein. 5 pounds	3.75 pounds
Baker Creek Cave System at upstream end of system	Rhodamine WT. 6 pounds	1.2 pounds
Pole Canyon short distance upstream of contact with Pole Canyon Limestone	Eosine. 6 pounds	4.5 pounds

While the dyes produce colored water at high concentrations, there are four steps that can be taken to reduce the amount of dye needed and minimize the chance of creating colored water in streams and springs and reduce impacts to humans and wildlife.

1. Use no more dye than is needed for credible instrumental detection.

2. Use dyes (fluorescein and eosine) that are rapidly destroyed by sunlight for as many of the traces as possible.
3. Place primary sampling reliance on activated charcoal samplers. A charcoal sampler in place for a week would yield a dye concentration in the laboratory that is about 400 times greater than the mean dye concentration in the water (Table 9).
4. Perform analysis using a spectrofluorophotometer operated under a synchronous scan protocol. This permits dye detections at extremely low concentrations.

Table 9. Dye detection thresholds, parts per billion (Aley 2002).

Column 1 Dye Type	**Column 2 Visual detection threshold for general public**	**Column 3 Instrument detection threshold for instrument analysis of charcoal samplers**	**Detection Ratio Col 2/Col 3**
Eosine	13,500	0.050	270,000
Fluorescein	140	0.025	5,600
Rhodamine WT	2,500	0.170	14,700

The dyes have been shown to be non-toxic, especially at the low concentrations that would be used in this study and would pose no safety threat to humans, fish, aquatic invertebrates, or wildlife (Smart 1984, Field et al. 1995).

The quantity of water that may be brought to the surface during the drilling process cannot be determined prior to drilling. Experience from other drilling in Snake Valley is that there has been a small quantity of water produced (less than 10 gallons per minute) while drilling in shallow unconsolidated sediments and the upper 120 feet of limestone. At another site, the quantity of water produced was about 50 gallons per minute. The proponents state that if similar conditions are encountered in wells in the Park, they would minimize the quantity of water pumped through the cyclone and onto the ground. Water samples would be analyzed periodically during drilling for temperature, pH, and specific conductance.

The pumping tests for the wells at Locations 1 and 2 would be at a rate of about 50 gallons per minute (gpm), not to exceed 90 gpm, for a period of 48 hours or less. This equates to a total pumped volume of about 144,000 gallons of water, not to exceed 259,200 gallons. At Site 1 (near the sewage ponds), water from the aquifer test would be piped from the well to the culvert that goes under the Baker Creek road. At Site 2 (along the road to Cave Springs), water from the aquifer test would be piped from the well to the nearest ephemeral drainage. Cylindrical straw berms could be placed across the drainage to slow the movement of water down the drainage and thus inhibit erosion. The straw would be removed once pumping has ceased. Water pumped from the well would be monitored for temperature, pH, specific conductance, and the extent of flow along the ephemeral drainage.

The pumping test at Lehman Creek would pump for 72-96 hours, producing a volume of about 172,800 gallons of water, not to exceed 648,000 gallons. The pumping rate of 30 gpm is about 3% of the typical flow rate of Lehman Creek in autumn. The water would be discharged into the creek. The water in the aquifer is likely cleaner than the water in the creek, and the small amount is not expected to change water quality or quantity by perceptible levels.

Cumulative Impacts
The SNWA project would have adverse, direct, long-term, regional, major impacts on park resources due to the removal of substantial amounts of groundwater from aquifers connected to the Park. However, if the information that would result from this hydrogeologic project is available, it could inform park management as to strategies that would protect park resources and ideally prevent impacts to those park water resources from the proposed SNWA project.

Conclusion
This alternative is expected to result in direct, adverse, local, short-term, negligible impacts to water quality and quantity.

<u>Alternative 3- All Sites excluding Lehman Creek Drilling</u>
Alternative 3 is identical to Alternative 2 for water quality/quantity analysis except that there would be no pumping test next to Lehman Creek conducted.

Cumulative Impacts
The SNWA project would have adverse, direct, long-term, regional, major impacts on park resources due to the removal of substantial amounts of groundwater from aquifers connected to the Park. However, if the information that would result from this hydrogeologic project is available, it could inform park management as to strategies that would protect park resources and ideally prevent impacts to those park water resources from the proposed SNWA project.

Conclusion
This alternative is expected to result in direct, adverse, local, short-term, negligible impacts to water quality and quantity.

<u>Alternative 4- Lehman Creek Alternate Site</u>
Alternative 4 is identical to Alternative 2 for water quality/quantity analysis.

Cumulative Impacts
The SNWA project would have adverse, direct, long-term, regional, major impacts on park resources due to the removal of substantial amounts of groundwater from aquifers connected to the Park. However, if the information that would result from this hydrogeologic project is available, it could inform park management as to strategies that would protect park resources and ideally prevent impacts to those park water resources from the proposed SNWA project.

Conclusion
This alternative is expected to result in direct, adverse, local, short-term, negligible impacts to water quality and quantity.

Impairment

Because there would be no major, adverse impacts to water quality/quantity whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation and proclamation of Great Basin National Park; (2) key to the natural or cultural integrity of the Park; or (3) identified as a goal in the Park's GMP or other relevant NPS planning documents, there would be no impairment of the Park's resources or values.

VISITOR EXPERIENCE

Regulatory Framework

NPS *Management Policies* (2006) state that the enjoyment of park resources and values by the people of the United States is part of the fundamental purpose of all parks and that the NPS is committed to providing appropriate, high-quality opportunities for visitors to enjoy the Parks. Part of the purpose of Great Basin National Park is to offer opportunities for recreation, education, inspiration and enjoyment. Consequently, one of the Park's management goals is to ensure that visitors safely enjoy and are satisfied with the availability, accessibility, diversity, and quality of park facilities, services and appropriate recreational opportunities.

Affected Environment

Approximately 90,000 visitors come to GRBA each year. The primary attractions are touring Lehman Cave, driving the Wheeler Peak Scenic Drive, and hiking trails. The project area is not located in any of these areas, although a portion of the work would occur adjacent to the Wheeler Peak Scenic Drive. The project area could be visible to park visitors when the drilling rig is in place, for approximately one week at each drilling site. It is also possible that visitors who are fishing or bird watching might encounter personnel who are conducting water quality sampling, streamflow measurements, and/or installing or removing digital temperature sensing cable in the creeks.

Environmental Consequences

Impact Criteria and Thresholds

Public scoping input and observation of visitation patterns combined with assessment of areas and attributes that are available to visitors under current management were used to estimate the effects of the actions in the alternatives in this document. The impact on the ability of the visitor to experience a full range of park resources was analyzed by examining resources and objectives presented in the park significance statements, as derived from its enabling legislation. The potential for change in visitor use and experience proposed by the alternatives was evaluated by identifying projected increases or decreases in access and other visitor uses, and determining whether or how these projected changes would affect the desired visitor experience and to what degree and for how long. The thresholds of change for the intensity of an impact to visitor experiences are defined as follows:

Impact Intensity	Intensity Description
Negligible	Changes in visitor use, experience and recreational resources would be below or at the level of detection. The visitor would not likely be aware of the effects associated with the alternative.
Minor	Changes in visitor use, experience and recreational resources would be detectable, although the changes would be slight. The visitor would be aware of the effects associated with the alternative, but the effects would be slight.
Moderate	Changes in visitor use, experience and recreational resources would be readily apparent. The visitor would be aware of the effects associated with the alternative and would likely be able to express an opinion about the changes.
Major	Changes in visitor use, experience and recreational resources would be readily apparent and severely adverse or exceptionally beneficial. The visitor would be aware of the effects associated with the alternative and would likely express a strong opinion about the changes.

Alternative 1- No Action
Under this alternative, there would be no changes to the Park, thus there would be no impacts to visitor experience.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
There would be no impacts to visitor experience under the No Action Alternative.

Alternative 2- Proponent Action-All Sites
The Proponent Action-All Sites alternative would include using drill rigs that could be seen as visitors are driving within the Park. These drill rigs would be in the Park for approximately one month. Drilling is anticipated to take place after Labor Day, when park visitation decreases substantially. Signage at the visitor centers would explain the project.

Visitors who are near streams might encounter personnel implementing this project. These personnel would be able to explain why the project is being conducted. Visitor experience may be adversely impacted by the visual intrusion of the drilling rig, localized drilling noise, and diesel engine exhaust.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
This alternative would result in direct, beneficial or adverse, local, short-term, and minor impacts to the visitor experience in the project area.

Alternative 3- All Sites excluding Lehman Creek Drilling
Impacts would be similar to Alternative 2, but with one week less of drilling in the Park, which would thereby reduce the duration of adverse effects for visitor experience.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
This alternative would result in direct, beneficial or adverse, local, short-term, and minor impacts to the visitor experience in the project area.

Alternative 4- Lehman Creek Alternate Site
Alternative 4 would have almost identical impacts to Alternative 2. The alternative Lehman Creek drilling site is closer to the main park road and the Wheeler Peak Scenic Drive, therefore visitors would be more likely to notice the drill rig and associated sights, sounds, and smells

upon entering the Park.

Cumulative Impacts
No other projects would contribute to cumulative impacts.

Conclusion
This alternative would result in direct, beneficial or adverse, local, short-term, and minor impacts to the visitor experience in the project area.

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CONSULTATION AND COORDINATION

SCOPING

Internal Scoping

Internal scoping was held from November 16, 2010 to December 15, 2010. It defined the purpose and need, identified potential actions to address the need, determined what the likely issues and impact topics would be, and identified the relationship, if any, of the proposed research actions to other planning efforts at the Park.

Public Involvement

Public scoping was conducted by mailing out letters (Appendix C) to individuals and groups on the Park's NEPA mailing list on November 18, 2010. A press release (Appendix D) was issued on November 18, 2010, and *The Ely Times* published it on November 19, 2010. Public meetings were held in Ely, NV on December 8, 2010 and in Baker, NV on December 9, 2010. Nineteen people attended the Ely meeting and about 50 people attended the Baker meeting. Two letters and emails were received. One author asked that Material Safety Data Sheets for the proposed dyes as part of the dye tracing test be brought to the public meetings, which was done. The second comment asked if the proposed research actions were in wilderness areas and was concerned about the potential of drilling into caves. There are no wilderness areas in the project area and this comment was not followed up on. The potential of drilling into caves is considered in the proposed research actions and is addressed in a mitigation measure.

CONSULTATION

Advisory Council on Historic Preservation and Nevada State Historic Preservation Officer

The undertakings described in this document are subject to Section 106 of the National Historic Preservation Act, as amended in 1992 (16 USC Section 470 et seq.). Consultations with the Nevada State Historic Preservation Office (SHPO) were initiated March 2011.

Tribes

On November 18, 2010, a scoping notice was sent to all consulting Tribes. This includes the Ely Shoshone Tribe, Kanosh Band of Southern Paiute Tribe, Confederated Tribes of the Goshute Reservation, Kaibab Paiute Tribe, and the Southern Paiute Tribe of Utah. The scoping letter informed the tribes of the proposed Hydrogeologic Research Project in GRBA. No responses were received.

U.S. Fish and Wildlife Service

No state or federally listed or candidate species are found in the project area, thus no consultation was needed with the USFWS.

Army Corps of Engineers

No construction was planned in any wetlands or floodplains, thus no consultation was needed with the Army Corps of Engineers.

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LIST OF EA RECIPIENTS

The following is a list of agencies and entities that will receive a notice of availability or a copy of the environmental assessment. In addition, about 20 individuals and organizations will receive a notice of availability. A complete list of names on the NPS mailing list for this project is in the project file and is available from the Park.

Tribes
Ely Shoshone Tribe
Goshute Business Council
Southern Paiute Consortium, Kaibab Paiute Tribe
Southern Paiute Tribe, Indian Peaks Band
Southern Paiute Tribe of Utah

Federal Agencies
Bureau of Land Management, Ely District Office
Natural Resources Conservation Service, Ely Service Center
U.S. Fish and Wildlife Service, Reno Office
U.S. Forest Service, Ely District
U.S. Post Office, Baker
U.S. Post Office, Garrison

Elected Officials
Senator John Ensign
Senator Harry Reid
Representative Dean Heller
Representative Shelley Berkley
Representative Jon Porter

State Agencies
Desert Research Institute
Ely State Museum
Nevada Department of Wildlife
State Historic Preservation Officer

Regional, County, and Municipal Agencies
Baker Citizens Advisory Board
White Pine County Chamber of Commerce
White Pine County Commissioners
White Pine County Economic Diversification Council
White Pine County Sheriff's Office

Organizations
Eastern Nevada Landscape Coalition
Great Basin National Heritage Area
Great Basin National Park Foundation
Great Basin Water Network
National Parks Conservation Association
Nevada Land Conservancy
Toiyabe Chapter of the Sierra Club

Libraries
The following is a list of libraries and public venues where the public can access this EA and review the document onsite.

EskDale Center
Great Basin Visitor Center, Great Basin National Park
Lehman Caves Visitor Center, Great Basin National Park
White Pine County Library

There will be a 30-day comment period on the EA. Comments may be submitted online at: http://parkplanning.nps.gov/hydrogeologic, or in writing to the following address:

Planning
Great Basin National Park
100 Great Basin National Park
Baker, NV 89311

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APPENDICES

Appendix A: Dye Tracing Study

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STUDY PLAN FOR A DYE TRACING STUDY IN THE POLE CANYON LIMESTONE, GREAT BASIN NATIONAL PARK, NEVADA

August 11, 2009

Tom Aley, PHG & PG
President, Ozark Underground Laboratory, Inc

A study plan prepared for the National Park Service under Purchase Order P2380093521, WASO-WRD, Fort Collins, Colorado 80525

Introduction

Groundwater tracing using fluorescent tracer dyes is a well-established methodology for identifying and delineating areas that contribute water to important springs, and for determining and characterizing subsurface flow paths in karst and fractured rock regions. Tracing work is routinely and extensively used in the major karst regions and karst aquifers of the United States. Dye tracing methods are explained in detail in a 24-page chapter in a recently published textbook on hydrogeology field methods (Aley 2008), and substantial information on characteristics of the dyes is found in Aley (2002), which is available on-line. About 90% of all groundwater tracing in the United States uses fluorescent tracer dyes.

Most of America's karst lands are east of the Rocky Mountains and people living further west are often unfamiliar with dye tracing work. As a result, they sometimes ask if the dyes are environmentally safe. Yes they are and they have been studied extensively (Field et al., 1995) and found to be safe when used in professionally directed groundwater studies such as outlined in this study plan. They have been used in a number of studies to trace water to public drinking water supply wells, and at least one state (Alabama) routinely requires that such tracing work be done for new public water supply wells in karst areas.

People also sometimes ask if the use of tracer dyes requires formal environmental assessments. The answer is no, even when federal agencies fund the work. In fact, in karst areas dye tracing of groundwater is a common tool used in basic studies for the preparation of environmental impact statements. The following are some examples of dye tracing work conducted by the Ozark Underground Laboratory (OUL) to develop data for federal environmental impact statements.

1. Tracing to delineate springs that could be impacted by the proposed Northwest Arkansas Regional Airport and connecting highways, Rogers, Arkansas. Some of the springs of concern provide habitat for the Ozark Cavefish (*Amblyopsis rosae*), a federally listed threatened species and the Benton Cave Crayfish (*Cambarus aculabrum*), a federally listed endangered species.
2. Tracing to delineate springs that could be impacted by a major airport expansion and connecting new highways at the Springfield-Branson National Airport, Springfield, Missouri. Again, one of the associated springs provides habitat for the Ozark Cavefish.
3. An extensive tracing program involving 31 separate dye introductions designed to identify all springs that could be impacted by approximately 20 miles of highway corridor for Interstate 69 in and around Bloomington, Indiana. A number of the traces discharged from multiple springs. Aquatic species of state concern occurred at some of the sampling stations.
4. A tracing program to identify springs that might be impacted by construction of about 25 miles of new corridor for U.S. Highway 71 in northwest Arkansas. Most of the work focused on Cave Springs which provides habitat for the largest known population of Ozark Cavefish and for a large summer colony of federally endangered Gray Bats,

(*Myotis grisescens*). The tracing work resulted in re-alignment of part of the highway corridor.

5. Corridor H tracing, West Virginia where multiple dye traces were conducted from a proposed interstate highway corridor. Tracing was focused on a municipal well, a warm spring at a resort, and trout waters. The total corridor length was over 100 miles.
6. Five tracing projects at numerous sites on the Tongass National Forest in southeastern Alaska to assess potential impacts of timber harvest and road construction on springs with major emphasis on identifying potential impacts on salmon streams.

We have also done a substantial amount of groundwater tracing work for the National Park Service. This has included extensive tracing projects on the Ozark National Scenic Riverways, MO; Wilson Creek National Battlefield, MO; George Washington Caver National Monument, MO; Buffalo National River, AR; and Great Smoky Mountains National Park, TN. We have done smaller projects for Timpanogos Cave National Monument, UT and Oregon Caves National Monument, OR. In addition to our work, very extensive groundwater tracing over a number of years has been conducted at Mammoth Cave National Park, KY and some tracing work has been done at Jewel Cave National Monument, SD.

The OUL has also done extensive groundwater tracing work for the U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Navy, U.S. Air Force, and for a number of state agencies. None of this work has ever required conducting an environmental impact assessment prior to doing the tracing work. In fact, much of our tracing work has involved sensitive issues in areas with substantial human populations and often has involved federally listed threatened and endangered aquatic species.

Given the importance of cave and karst resources at Great Basin National Park (GBNP) it is somewhat surprising that a modern groundwater tracing has not been previously conducted at this park. People studying caves in the Baker Creek topographic basin made some simple tracing efforts a few decades ago, but modern analytical methods were not available at that time and the work that was done was narrowly focused.

This study plan:

- Outlines the purposes and objectives of the planned groundwater tracing study.
- Provides a rationale (that includes case histories) demonstrating why the groundwater tracing work is essential.
- Specifies how the work will be conducted.

Purposes, Objectives, and Study Overview

Concerns over water rights applications by the Southern Nevada Water Authority (SNWA) have prompted and necessitated detailed hydrogeologic work in and around GBNP.

This work is designed to better understand and quantify interactions between surface water and groundwater in Snake Valley and adjacent lands including GBNP.

The Baker Creek and Lehman Creek area has the most extensive cave development of any area in Nevada. The caves contain abundant evidence that they are part of a large and old system of caves that was primarily formed by ascending waters derived from deep sources. Such caves are called hypogenic caves. In contrast, caves formed by shallower waters rather recently derived from the surface are called epigenic caves and are typically of more recent origin. The areal extent of hypogenic caves is routinely about five times larger than is the case for epigenic caves, and cavern porosity in hypogenic aquifers is typically about an order of magnitude greater than for epigenic aquifers (Klimchouk 2007). Complex groundwater flow routes undoubtedly exist in the area given the hypogenic nature of the caves and the karst aquifer in the region. Characterizing these flow systems requires a well-designed and conducted groundwater tracing study such as outlined in this study plan.

The dye tracing work is planned for a period when there is no water discharging from the resurgence below Model Cave. Under these conditions, the tracing work as designed will answer the following five questions:

1. Does water that sinks in the channel of **Baker Creek** contribute to the flow Rowland Spring, Rose Thorn Spring, Kious Spring, or any other springs feeding Lehman or Baker Creeks? Which springs, if any, are involved?
2. Does water in the main stream in the **Baker Creek Caves Complex** contribute to the flow Rowland Spring, Rose Thorn Spring, Kious Spring, or any other springs feeding Lehman or Baker Creeks? Which springs, if any, are involved?
3. Does water that sinks in the channel of **Pole Canyon** upstream of Baker Creek contribute to the flow Rowland Spring, Rose Thorn Spring, Kious Spring, or any other springs feeding Lehman or Baker Creeks? Which springs, if any, are involved.
4. Lange (1958) concluded that waters that flow through caves in the Baker Creek basin and waters that sink in Pole Canyon and Baker Creek recharge regional groundwater supplies. This is an appreciable volume of water. The proposed tracing program will yield data to either support or refute this important possibility.
5. To the extent that in-cave sampling can be conducted, the tracing work will determine if Baker Creek, the main Baker Creek Cave stream, or Pole Canyon contribute water to Model Cave.

We considered the possibility of conducting the dye tracing during higher flow conditions when water would be discharging from the resurgence below Model Cave. This flow is known to discharge from Model Cave, and it enters Baker Creek at an elevation higher than the springs to be sampled for tracer dyes. As a result, any dye discharging from the Model Cave resurgence would enter Baker Creek where it could again sink into the groundwater system and possibly discharge from one or more of the springs that are to be sampled. We believe that supporting or refuting Lange's conclusion that a substantial volume of water in the vicinity of the Baker Creek Caves Complex and Model Cave enters the regional groundwater system is of major importance and that the data should be as unambiguous as possible. As a result, we recommend that the tracing work be done when water is not discharging from the resurgence below Model Cave.

Nettle Spring has intermittent flow and discharges from the base of a springhead about 3800 feet east of the entrance to Model Cave. Water flows only during relatively high flow conditions and cannot be effectively sampled except under these conditions. Based upon channel appearance the peak discharge rate of this spring is about 0.5 cfs. If dye introductions are made under conditions where there is no flow from the resurgence below Model Cave it is possible (but not certain) that some residual dye from the tracing work might be detectable on activated carbon samplers in place at this spring during the early portion of the snow-melt runoff period.

Three different tracer dyes will be used and they will be introduced as "slugs" at three separate points. The analytical protocol that will be used for dye sampling can separate and quantify each of the three dyes.

Sampling for tracer dyes will be conducted at a comprehensive network of 22 sampling stations. Several of these are upstream "control" stations on Lehman Creek, Baker Creek, and Pole Canyon. Sampling will place primary reliance on activated carbon samplers and secondary reliance upon grab samples of water. A few stations will be sampled at frequent intervals during the first week of the study and then at lesser frequencies as the study progresses.

OUL staff will introduce the tracer dyes, although NPS assistance with the dye introduction within the Baker Creek Caves Complex may be needed. OUL staff will also be on-site for approximately one week after dye introduction to conduct the intensive sampling for tracer dyes and to train NPS staff in dye sampling methods. The frequency of sampling after the first week will be greatly decreased. After OUL staff leaves the Park activated carbon samplers will need to be periodically collected by NPS staff. NPS personnel will do any in-cave sampling in the Baker Creek Cave System or Model Cave. We anticipate that almost all sampling will end 12 weeks after dye introduction, but the end of sampling will need to be based upon sampling results.

All schedules can be changed slightly to adjust for weather conditions, holidays, and logistical considerations. If snow makes some stations inaccessible changing the samplers can be suspended until more favorable conditions exist as long as samplers are eventually collected from all sampling stations.

Rationale for Groundwater Tracing Work

The current impetus for conducting the proposed groundwater tracing work is water rights applications by SNWA. A National Park Service response to the applications has been to develop basic hydrologic data for GBNA (see for example Elliott et al. 2006). This work is complicated by the karst aquifer, and is especially complicated in areas where surface streams lose part of their flow to the groundwater system and where springs with appreciable flow volumes exist. In calculating water budgets knowing whether or not the losing streams contribute flow to some or all of the springs, and knowing which springs are related to which losing streams, is needed to credibly calculate total water yield. This is especially important in view of Lange's (1958) conclusion that there is a substantial volume of water that is being lost from the Baker Creek basin into the deep karst groundwater system. The groundwater tracing program will provide critical data for developing science-based water budget data.

Large groundwater extractions that lower groundwater levels in karst aquifers are notorious for pirating water out of surface streams, diminishing or causing the ceasing of flow in springs, drastically lowering groundwater elevations in wells, and causing the catastrophic formation of sinkholes. Impacted areas around a groundwater extraction point can encompass a number of square miles and the shape and location of impacted areas is difficult to accurately delineate in advance. Furthermore, the severity and extent of the problems commonly increases with time and with increases (and sometimes fluctuations) in pumping rates. The following quote from the abstract in Newton (1984) states the issue clearly.

"Numerous sinkholes resulting from the declines in the water table due to ground-water withdrawals in carbonate terranes have occurred in the eastern United States and elsewhere. In Alabama alone, it is estimated that more than 4,000 of these sinkholes, areas of subsidence, or related features have formed since 1900. Almost all occur where cavities develop in residual or other unconsolidated deposits overlying openings in carbonate rocks. The downward migration of the deposits into underlying openings in the bedrock and the formation and collapse of resulting cavities are caused or accelerate by a decline in the water table that results in (1) loss of buoyant support, (2) increase in the velocity of movement of water, (3) water-level fluctuations at the base of unconsolidated deposits, and (4) induced recharge."

The following case history is illustrative of the problems that can occur. While the case history is for a quarry, a quarry pumping groundwater can be visualized as a well with very large lateral dimensions.

A limestone quarry was developed at Opelika, Alabama. Mean annual precipitation in the area is about 58 inches per year with groundwater recharge commonly estimated at 20% of precipitation. Groundwater extraction to permit deep quarrying began in the summer of 1999. A large perennial spring called Spring Villa was located 6,800 feet from the quarry in a different topographic basin and supplied water to a swimming pool in an Opelika city park. Prior to quarry activity the mean flow of the spring was 3.74 cfs (2.42 mgd). The spring ceased flowing in late spring 2000 and flow has never returned. By late 2002 Little Uchee Creek, a perennial stream adjacent to Spring Villa, ceased flowing and numerous large sinkholes began forming catastrophically in and around the stream channel. Mean quarry pumping rates increased with time and reached about 8 million gallons per day by 2006. This represents about 9,000 acre feet of water per year.

Groundwater elevations at the quarry declined by about 115 feet from pre-quarry to 2006 condition. At Spring Villa the water table decline during this period was about 60 feet. Prior to quarry operations there were few if any sinkholes in the region, but new sinkholes now continue to form due to the loss of buoyant support for overlying alluvium and residuum. An inventory in January 2006 identified 185 new sinkholes and 344 piping holes in an area of 2.03 square miles around the quarry. One of the larger sinkholes was 50 feet by 20 feet by 12 feet deep. The entire area was not inventoried; the calculated Zone of Influence for the quarry at current pumping rates is 17.4 square miles. Sinkholes have formed catastrophically under a county highway and a bridge, beneath vehicles, beneath one of a pair of poles for an electric transmission line, under a propane transmission line, and beneath ponds.

Geologic mapping conducted for the quarry showed that the limestone at the quarry was separated from the limestone at Spring Villa by quartzite and schist units. However, dye tracing from the point where flow in Little Uchee Creek terminated in a sinkhole showed that this water reappeared in the quarry pumping.

The case history demonstrates that pumping large volumes of water that result in groundwater level declines in karst aquifers can seriously impact springs, surface streams, and various human land uses over large areas. This is the case even in a region with many times the annual precipitation and annual groundwater recharge of GBNP. When karst aquifers are involved groundwater studies, including groundwater tracing, should be conducted prior to major groundwater extraction projects that may be difficult or impossible to terminate if or when they create problems.

Conduct of the Study

This section of the study plan outlines how the study will be conducted. It identifies (1) dye introductions points, (2) background sampling, (3) dye types and quantities, (4) sampling approach, (5) sampling stations, sampling frequency, and study duration, (6) analytical methods, and (7) reports.

Dye Introduction Points.

We plan to make three separate dye introductions. Trace 1 will be on Baker Creek about 500 feet upstream of the upstream end of the lower campground on Baker Creek. The dye introduction point will be close to the trail that connects the two campgrounds, and will be at an elevation of about 7,300 feet. The rationale for this introduction is to determine the points at which water sinking in Baker Creek reappears on the surface. This dye introduction point is designed to be immediately upstream of the point where Baker Creek first flows onto the Pole Canyon Limestone.

Groundwater recharge into karst aquifers is often divided into discrete and diffuse recharge. Discrete recharge is concentrated in localized areas and diffuse recharge is more dispersed. The stream entrance to Ice Cave and the entrance to Dynamite Cave are two examples of discrete recharge zones associated with overflow channels of Baker Creek and more examples undoubtedly exist. The dye from Trace 1 will enter the karst groundwater system through both discrete and diffuse recharge from the channel of Baker Creek.

The dye introduction point for Trace 2 will be in the Baker Creek Cave system at a point as far upgradient in the system as possible under the conditions existing when the dye is placed. If water were flowing into Ice Cave we would introduce the dye where flow from Baker Creek cascades into Ice Cave. If, as we recommend, dye introductions are made under lower flow conditions then a point further downstream in the system where there is flow of at least 5 gallons per minute will be selected. The rationale for this introduction is to determine if (or where) water flowing through this cave stream discharges to the surface.

The dye introduction point for Trace 3 will be into the flow of Pole Canyon a short distance upstream of the point where this stream flows onto the Pole Canyon Limestone. This point is located at an elevation of about 7,200 feet and is about 3,700 feet straight-line distance upstream of the mouth of this stream. This dye introduction will be made at a time when surface flow in Pole Canyon does not reach Baker Creek. A passage in Model Cave passes beneath Pole Canyon near the stream segment where surface flow commonly disappears into the groundwater system. This losing stream segment is downstream of the planned dye introduction point. The rationale for this introduction is to determine if (or where) waters entering the groundwater system from the losing stream segment discharge to the surface.

Background Sampling.

On July 16 and 17, 2009 the OUL conducted background sampling of waters in the area for fluorescent tracer dyes and compounds that might interfere with the use of the planned dyes. The sampling used grab samples of water. The sampling and analytical protocols were in accordance with the OUL's Procedures and Criteria document included as Appendix A to this study plan. No dyes and no fluorescent compounds that might cause interference with the tracer dyes were detected. Sampling locations for the July 2009 background sampling were as follows:

- Baker Creek near planned dye introduction point for Trace 1.
- A spring discharging from quartzite near the planned dye introduction point for Trace 1.
- Baker Creek at the Pole Canyon Trail crossing.
- Discharge waters from Model Cave.
- Pole Canyon along the Pole Canyon Trail and downstream of the planned dye introduction point for Trace 3
- Rowland Spring
- Kious Spring

Prior to the introduction of dyes for the tracing work additional samples will be collected to characterize fluorescence background conditions. Control stations to demonstrate the absence of extraneous fluorescent compounds will be established and maintained during the duration of the tracing study. These control stations will be located:

- On Lehman Creek where the road up Wheeler Peak is near the creek at an elevation of about 7,400 feet (thus higher than any of the dye introduction points).
- On Baker Creek upstream of the dye introduction point for Trace 1.
- On Pole Canyon upstream of the dye introduction point for Trace 3.

Dye Types and Quantities

Five pounds of fluorescein dye mixture will be used for Trace 1, the Baker Creek Trace. Fluorescein is also known as Acid Yellow 73 and its Color Index Number is 45350. This dye is also known as uranine. The powdered dye mixture to be used contains 75% dye equivalent and 25% diluent (corn starch) as a standardizing agent and to aid in dissolving the mixture in water. This dye has a green color and decomposes fairly rapidly in sunlight and, as a result, will not persist long in surface waters in the sunlight.

Six pounds of rhodamine WT dye mixture will be used for Trace 2, the Baker Creek Caves Trace. Rhodamine WT is also known as Acid Red 388; it has no assigned Color Index Number. The letters "WT" in the name stand for Water Tracing since this dye was developed for this purpose. This dye should not be confused with Rhodamine B, a totally different dye inappropriate for groundwater tracing. Rhodamine WT is a liquid dye mixture containing 20% dye equivalent and 80% diluent (water) as a standardizing agent and to aid in dissolving the mixture into receiving waters. This dye has a red color.

Six pounds of eosine dye mixture will be used for Trace 3, the Pole Canyon Trace. Eosine is also known as Acid Red 87 and its Color Index Number is 45380. This dye is also known as D&C Red 22. The powdered dye mixture to be used contains 75% dye equivalent and 25% diluent (corn starch) as a standardizing agent and to aid in dissolving the mixture in water. This dye has a pink or green color depending upon concentration and decomposes fairly rapidly in sunlight and, as a result, will not persist long in surface waters in the sunlight.

Sampling Approach

Sampling for tracer dyes at most stations will place primary reliance on activated carbon samplers and secondary reliance on grab samples of water. The types of samples are explained in the OUL's Procedures and Criteria document in Appendix A, and all sampling will be consistent with this document.

Activated carbon is coconut charcoal that is capable of adsorbing and retaining all of the tracer dyes. The activated carbon is similar to the charcoal filters found in some cigarettes and in home water treatment systems. Activated carbon samplers function as continuous and accumulating samplers for any dyes present during the period that the samplers are in place. Given the clean waters present in the study area the samplers will work effectively for the sampling intervals planned in the study plan even if some intervals need to be lengthened due to adverse weather conditions or logistical considerations.

Grab samples of water are reflective of conditions existing at a sampling station at the time the sample was "grabbed". Each grab sample will contain about 30 ml of water.

As a general rule all activated carbon samplers are collected and replaced each time a sampling station is visited and a grab sample of water is also collected. During the early phases of the study periodic water samples may be collected at more frequent intervals from a few sampling stations without collecting the activated carbon. However, activated carbon samples will be collected at least once per day.

Water samples are routinely analyzed only if dye is detected in the associated activated carbon samplers. Exceptions are made if carbon samplers are lost or if it is believed that the quality of the study will be enhanced by the analysis of additional water samples.

Sampling Stations, Sampling Frequency, and Study Duration

Table 1 identifies 22 sampling stations and the planned sampling frequency. The five categories of sampling frequency identified in the table are explained at the bottom of the table. Figure 1 is a map showing sampling stations and dye introduction points.

Table 1 Sampling stations and anticipated frequency of sampling.

Station Number and Name	Comments	Sampling Frequency
1. Baker Cr. u/s of dye intro. point Trace 1.	Control Station	3)
2. Baker Creek at rd. xing u/s of Ice Cave	To determine duration of dye pulse from Trace 1	1) End 3 weeks after dye intro
3. Pole Canyon u/s of dye intro point Trace 3	Control Station	3)
4. Pole Canyon about 100 ft. d/s of end of surface flow	To verify the end of surface flow during study	3)
5. Pole Canyon about 50 ft. u/s of mouth	To verify no flow during study and no dye from Trace 1.	2)

Table 1 (continued). Sampling stations and anticipated frequency of sampling.

Station Number and Name	Comments	Sampling Frequency
6. Baker Cr. about 50 ft. u/s mouth of Pole Can.	Sample for all traces	2)
7. Baker Creek @ Pole Canyon Trail	Sample for all traces, determine duration of dye pulse from Trace 1.	1)
8. Model Cave discharge	Should not flow if traces conducted under low to moderate flow conditions.	3) and 4)
9. Nettle Spring.	Should not flow if traces conducted under low to moderate flow conditions	3) and 4)
10. Rose Thorn Spring	Critical station for all three traces	1)
11. Baker Creek u/s Thorn Spring Branch		2)
12. Baker Cr. diversion 100 ft. u/s Lehman Creek	Furthest d/s station on Baker Cr.	2)
13. Lehman Cr. 100 ft. u/s Baker Cr. diversion	Furthest d/s station on Lehman Cr.	2)
14. Lehman Cr. @ rd. xing at elev. about 6205 ft.		2)
15. Lehman Cr. @ rd. xing at elev. about 6420 ft.		2)
16. Rowland Spring	Critical station for all three traces	1)
17. Lehman Cr. @ Hwy 488	Sample for all three traces	3)
18. Lehman Cr. @ about elev. 7,400 ft.	Control station	3)
19. Kious Spring	Critical for all traces	1)
20. Lehman Cave Pool at end of tour trail	No dye expected, but a verification station	3)
21. Inside Model Cave	All sampling by NPS	5)
22. Other station(s) in Baker Cr. Cave Sys.	All sampling by NPS	5)

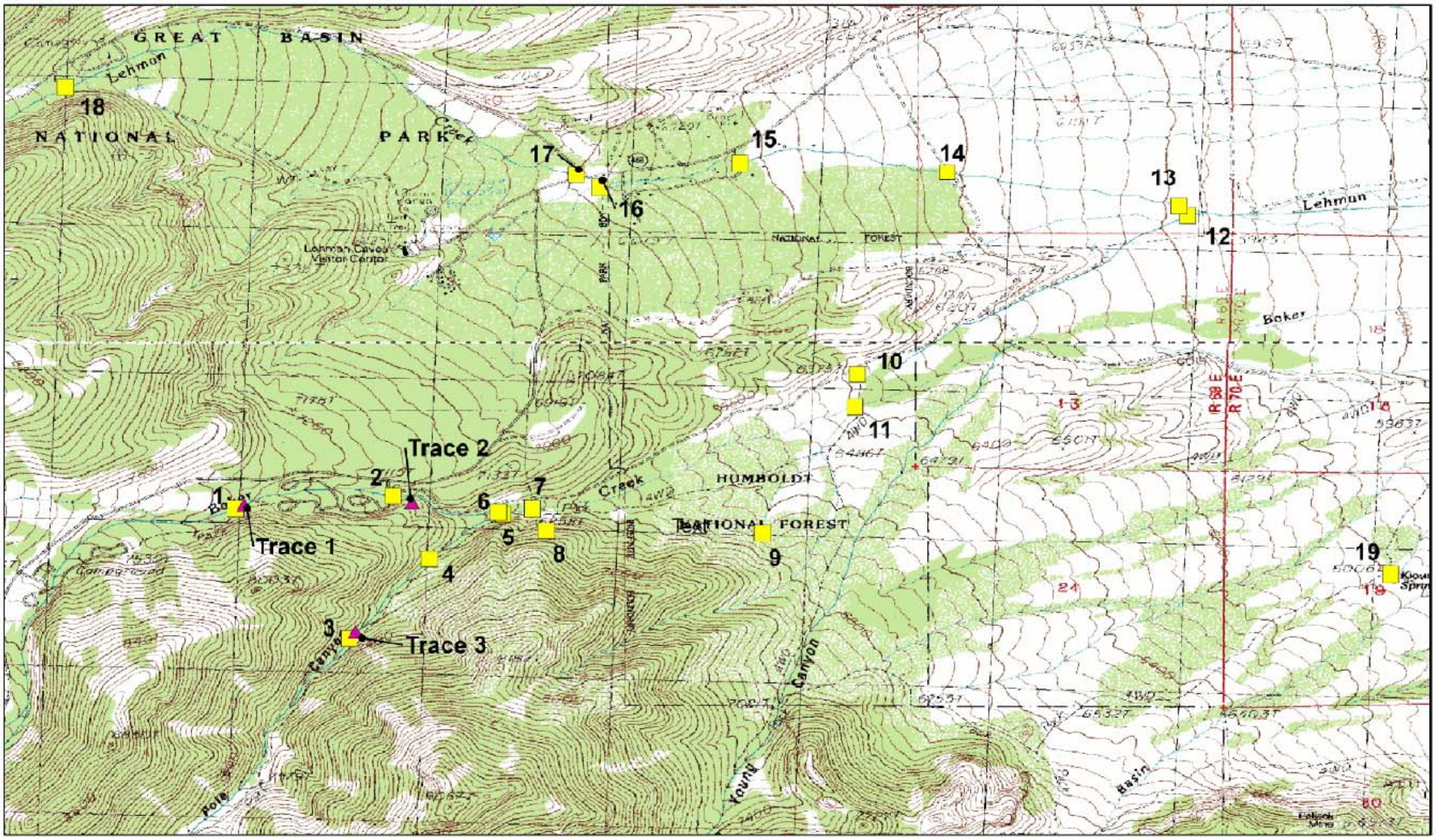
Abbreviations:

u/s = upstream
d/s = downstream
xing = crossing
rd = road
intro= introduction

Sampling Frequencies:

1) Intense Sampling. At least once per day for first week after dye introduction. More frequently if feasible. Sample 10 and 14 days after dye introduction, then weekly for the remainder of the study.*
2) Routine Sampling. Once a week after dye introduction for the first six weeks then on weeks 8, 10, and 12 after dye introduction.
3) Control Sampling. Collect 1, 4, and 8, and 12 weeks after dye introduction.
4) Snow-Melt Sampling. Collect about 1 and 2 weeks after flow starts in the spring.
5) As Feasible. Sampling at these stations would be desirable but is dependent upon logistical considerations and the availability of NPS personnel.

*Snow and ice could limit access to Rose Thorn Spring and especially Kious Spring. To the extent reasonable the schedule will be maintained with these stations being sampled at least once every 2 weeks.



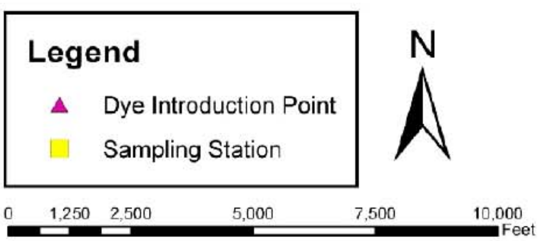


Figure 1. Sampling Stations and Dye Introduction Points

The introduction location for Trace 2 is approximate. The locations of Stations 20 through 22 are in caves and are not shown.

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Intense sampling is planned for 5 sampling stations. At one of these (Station 2, Baker Creek at road crossing upstream of Ice Cave) sampling can be terminated 3 weeks after dye is introduced. The other four stations are designed to detect and quantify dye rapidly reaching springs in the area. If the tracing work can be started in late summer or early fall all of these stations are easy to reach and most or all of them could be sampled twice per day during the first week by OUL staff. The intense sampling stations are:

- Station 2. Baker Creek at road crossing upstream of Ice Cave.
- Station 7. Baker Creek at Pole Canyon Trail. This station may detect dye from Traces 2 and 3.
- Station 10. Rose Thorn Spring. A critical sampling station that could receive dye from all three traces.
- Station 16. Rowland Spring. A critical sampling station that could receive dye from all three traces.
- Station 19. Kious Spring. A possible, but not likely, detection site for dye from one or more of the traces.

Rowland Spring is located east of Lehman Caves and near the GBNP boundary at an elevation of about 6580 feet in the Lehman Creek topographic basin. This perennial spring discharges from alluvium that is underlain by the Pole Canyon Limestone.

One important objective of the planned groundwater tracing study is to determine if any waters from Baker Creek, Pole Canyon, or some of the Baker Creek caves contribute water to Rowland Spring (Station 16). If they do, the time of travel is important. Very rapid groundwater movement toward Rowland Spring is possible and the study is designed to sample this spring frequently during the week after dye introductions are made.

Elliott et al. (2006) includes daily flow rate data for Rowland Spring and Baker Creek at the Narrows for water years 2003 and 2004. Table 2 presents selected data from these two stations. Among other things Table 2 shows that minimum monthly flow rates of both the spring and Baker Creek occurred during February of each of the two years. Maximum monthly flow rates occurred in May and June of the two years on Baker Creek and in July for Rowland Spring. This suggests that a lag time of a month or so may be involved between peak snow-melt runoff entering the karst groundwater system and the time at which it discharges from Rowland Spring. The total annual flow of Rowland Spring in Water Year 2003 was 38% of the flow in Baker Creek at the Narrows, and in Water Year 2004 it was 45%.

Given the data provided in the Elliott et al. (2006) report the planned duration for the tracing study is 12 weeks after dye introduction. Results obtained during the study may result in a somewhat earlier or later termination of the sampling work.

Table 2. Comparison of Flow Rate Data from Rowland Spring and Baker Creek at the Narrows for Water Years 2003 and 2004. Data from Elliott et al. (2006).

Parameter	Rowland Spr. WY 2003	Rowland Spr. WY 2004	Baker Cr. at Narrows WY 2003	Baker Cr. at Narrows WY 2004
Total Annual Flow (A.ft)	1,699	1,606	4,496	3,555
Maximum Daily cfs	3.7	3.5	116	25
Minimum Daily cfs	1.3	0.75	0.94	0.95
Peak Monthly Flow	July	July	June	May
Peak Monthly Flow (A.ft.)	213	202	1850	1,000
Minimum Monthly Flow	Feb.	Feb.	Feb.	Feb.
Min. Monthly Flow (A.ft.)	82	55	56	59

A second objective of the planned study is to determine if Baker Creek, Pole Canyon Creek, or the Baker Creek Caves contribute water to Rose Thorn Spring (Station 10). This spring is located in the Baker Creek Valley at an elevation of about 6500 feet and is along the gravel road on the north side of the valley. The specific conductance of this spring was 142 micromhos/cm on July 16, 2009 at 0957 hours. In contrast, the specific conductance of Rowland Spring on July 17, 2009 at 1325 hours was 113 micromhos/cm. As a generalization, the higher the specific conductance value the longer the water has been in contact with the limestone bedrock. During the same period the specific conductance in Baker Creek at the Pole Canyon trail crossing was 27 micromhos/cm. Given these values, it is reasonable to expect that any dye from the planned dye introductions might not appear at Rose Thorn Spring for as much as two months after dye introduction.

A third objective of the planned study is to determine if any of the tracer dyes discharge at any intermediate points on Baker Creek downstream of the planned dye introduction point or at any points on Lehman Creek downstream of the point where the stream is crossed by Nevada Highway 488. Several sampling stations were established to permit these assessments.

Stations 8 and 9 (Model Cave Discharge and Nettle Spring) only flow during periods of substantial snow-melt runoff. If the tracing work is conducted in the fall as planned these springs will not flow until late spring to early summer. However, the springs can be sampled in the event that some dye from one or more of these traces discharges during the snowmelt runoff period.

There are three control stations designed to show that no dye or fluorescent compounds that could interfere with dye tracing have flowed into the study area during the study period. These are sampling stations 1, 3, and 18. In addition, there are two sampling stations (stations 4 and 5) designed to verify that no dyed water from Trace 3 flows down the channel of Pole Canyon to reach these stations. Station 17 is at an elevation lower than the dye introduction points but is not viewed as a location likely to receive any dye. Station 20 in Lehman Caves might receive dye if the pool in the cave is sometimes the upper surface of the water table and not simply a perched pool. This seems unlikely, but the sampling station will address this possibility with minimal effort. It is worth remembering that vertical water level fluctuations in Model Cave can be in excess of 240 feet.

As indicated earlier in this study plan, schedules for collecting samples and placing new samplers can be modified as necessary to accommodate weather conditions, holidays, and logistical considerations.

Analytical Methods

Dye analysis will be conducted in accordance with the OUL's Procedures and Criteria document included with this study plan as Appendix A.

Reports

We will prepare a final report on the tracing work once the work has been completed. Progress report can be provided if they are requested.

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PROCEDURES AND CRITERIA
ANALYSIS OF FLUORESCEIN, EOSINE, RHODAMINE WT, SULFORHODAMINE B, AND PYRANINE DYES IN WATER AND CHARCOAL SAMPLERS

February 3, 2011

Thomas Aley, PHG 179
President
Ozark Underground Laboratory, Inc.

PROCEDURES

Introduction

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or up-graded. The Ozark Underground Laboratory maintains a summary of changes in standard procedures and criteria.

Dye Nomenclature

Fluorescein is C.I. Acid yellow 73, Color Index Number 45350. Rhodamine WT is Acid Red 388; there is no assigned Color Index Number for this dye. Eosine (sometimes called eosin) is Acid Red 87, Color Index Number 45380. Sulforhodamine B is C.I. Acid Red 52, Color Index Number 45100. Pyranine is Solvent Green 7 (also called D&C Green 8), Color Index Number 59040.

Description of the Samplers

The charcoal samplers are packets of fiberglass screening partially filled with approximately 4.25 grams of activated coconut charcoal. The charcoal used by the Ozark Underground Laboratory is Calgon 207C coconut shell carbon, 6 to 12 mesh.

The most commonly used samplers are about 4 inches long by two inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1 inch diameter wells); this is a special order item and should be specifically requested when it is needed. All of the samplers are closed by heat sealing.

Placement of Samplers

Samplers (also called charcoal packets) are placed so as to be exposed to as much water as possible. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than being flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are placed in sample holders made of PVC pipe fittings. Brass hose fittings are installed at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose. The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consists of 1.5 inch diameter pipe and pipe fitting.

Charcoal packets can also be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Some sort of weight should be added near the charcoal packet to insure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a white or uncolored plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. Do not use colored cord. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with small diameter wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a stainless steel weight may be added to the top of the disposable bailer. We have had good success with two to three ounce segments of stainless steel pipe which have an outside diameter of 1.315 inches and an inside diameter of 1.049 inches; such pipe weighs about 1.7 pounds per linear foot. The weight of the stainless steel is approximately 497 pounds per cubic foot. The pipe segments can be attached over the anchoring cord at the top of the bailer. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

Placement of samplers requires adjustment to field conditions. The above placement comments are intended as guidance, not firm requirements.

Rinsing of Charcoal Packets Prior to Sampling

Charcoal packets routinely contain some fine powder that washes off rapidly when they are placed in water. Since such material could remain in monitoring wells, charcoal packets to be placed in such wells are triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach, approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

Collection and Replacement of Samplers

Samplers are routinely collected and replaced from each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of travel. As an illustration, we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled. This is typically not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak bags are ideal). The bag is labeled on the outside with a permanent type felt marker pen. Use only pens that have black ink; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels must not be inserted inside the sample bags.

For most projects the Ozark Underground Laboratory supplies the Whirl-Pak bags. Prior to use, 1% of the new bags are randomly selected. Each bag is soaked in the standard eluting solution and then analyzed for the presence of any of the tracer dyes being used.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. We prefer (and in some studies require) that samples be placed on "blue ice" or ice upon collection and that they be shipped refrigerated with "blue ice" by overnight express. Do not ship samplers packed in ice since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration, yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

Water samples are often collected. They should be collected in either glass or plastic; the Ozark Underground Laboratory routinely uses 50 ml research grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. We need no more than 30 ml of water. The vials should be placed in the dark and refrigerated immediately after collection. They should be refrigerated until shipment. For most projects the Ozark Underground Laboratory supplies the vials. Prior to use, 1% of the new vials are randomly selected. Each vial is soaked in the standard eluting solution and then analyzed for the presence of any of the tracer dyes being used.

When water or charcoal samplers are collected for shipment to the Ozark Underground Laboratory they should be shipped promptly. We receive good overnight and second day air service from both UPS and Fed Ex; the Postal Service does not provide next day service to us. DHL works adequately for international shipments.

Each shipment of charcoal samplers or water samples must be accompanied by a sample tracking sheet. These sheets (which bear the title "Samples for Fluorescence Analysis") are provided by the Ozark Underground Laboratory and summarize placement and collection data. These sheets can be augmented by a client's chain of custody forms or any other relevant documentation. Figure 1 is one of our blank sample forms.

Figure 1. Sample Collection Data Sheet

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SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

Project:________________________________**Week No:**__________**SamplesCollected By:**__________________________

Samples Shipped By:______________________________**SamplesReceived By:**______________________________

Date Samples Shipped:____/____/____ **Date Samples Received:**____/____/____ **Time Samples Received:**_____:_____ **Return Cooler? Yes**_____**No**______

Bill to:______________________________**Send Results to:** ______________________________

Analyze for: Fluorescein_____**Eosine**_____**Rhodamine WT**_____**Other**______________**Ship cooler to:** ______________________________

OUL use only		*Please indicate stations where dye was visible in the field* *for field technician use - use black ink only*						*OUL use only*
# CHAR REC'D	**LAB NUMBER**	**STATION NUMBER 1-4 Numbers**	**STATION NAME**	**PLACED**		**COLLECTED**		**# WATER REC'D**
				DATE	**TIME**	**DATE**	**TIME**	

COMMENTS:____

____

This sheet filled out by OUL staff? Yes_________________**No**_________________**Charts for samples on this page proofed by OUL:**______________________________

Page ______ of ______

Digital cameras can provide an independent verification of the date and time of sample collection. A digital photo can be taken of each sampling location during each sample collection. The photo file has a date and time created. If the camera's clock is set correctly, the photo provides an independent reference of the date and time the sample was collected. It is critical that the photos be taken in the order of sampling; that is, if one has forgotten to take a photo of the previous station and remembers at the current sampling station, do not go back and take the previous station photo.

When we are using a digital camera for sampling documentation we initially take a high resolution photo of each station that shows its context broadly enough for an observer to distinguish it from other sampling station, but narrow enough not to include another sampling station. Subsequently, we download he high-resolution photos into a reference folder and rename the photos to the station number and name. We also make a copy of the photo to another folder and digitally draw arrows to the exact locations of the samplers. During subsequent sampling events a low-resolution digital photo is taken of each sampling station in the order they are visited. It is best to establish a routine of taking the photo upon arrival at the station. We then download these photos into a folder whose name indicates the dates of the photos. We do not rename these photos.

Some sites do not permit cameras. An alternative is to collect a Global Positioning System (GPS) location during each visit. GPS records the date and time each point (sampling station) is visited. While these files are not as easy to review as photographs, they can be used with a base map to show which locations were visited at which dates and times.

Receipt of Samplers

Samplers shipped to the Ozark Underground Laboratory are refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number. All samples are logged in upon receipt.

It sometimes occurs that there are discrepancies between the chain-of-custody sheets and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. A copy of this form is enclosed as Figure 2. The purpose of the form is to help resolve discrepancies, even when they may be minor.

Cleaning of Samplers

Samplers are cleaned by spraying them with jets of clean water. At the Laboratory we use unchlorinated water for the cleansing to minimize dye deterioration. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

Figure 2. Discrepancy Sheet

OZARK UNDERGROUND LABORATORY, INC.

DISCREPANCIES BETWEEN CHAIN-OF-CUSTODY SHEETS AND ACTUAL SAMPLES RECEIVED **Page ______ of ______**

Company & Project Name: **Date Rec'd by OUL:** **Wk # ______________**

Lab #	Sta #	Station Name	Date Pulled	Problem	Solution

Comments:

Elution of the Charcoal

There are various eluting solutions that can be used for the recovery of tracer dyes. The solutions typically include an alcohol, some water, and a strong basic solution such as aqueous ammonia.

The standard elution solution now used at the Ozark Underground Laboratory is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide flakes to saturate the solution. The isopropyl alcohol solution is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution we use will elute fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in some samplers.

Fifteen ml of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded.

Analysis on the Shimadzu RF-5000U or RF-5301

The Laboratory uses two Shimadzu spectrofluorophotometers. One is a model RF-5000U, and the other is a model RF-5301. Both of these instruments are capable of synchronous scanning. The RF-5301 is the primary instrument used; the RF-5000U is primarily used as a back-up instrument except for tracing studies which were begun using this instrument. The OUL also owns a Shimadzu RF-540 spectrofluorometer which is occasionally used for special purposes.

A sample of the elutant is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 ml of the elutant is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 ml. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The spectral range of the cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5000U or the RF-5301. Both instruments are controlled by a programmable computer. Each instrument is capable of conducting substantial data analysis.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of the instruments and a training session on the use of spectrofluorophotometers was provided by Delta Instrument Company.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes, the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm.

The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "very fast" on the RF-5000U; it is “fast” on the RF-5301. The typical sensitivity setting used on both instruments is "high."

Our typical analysis of an elutant sample where pyranine dye may be present includes a synchronous scanning of excitation and emission spectra with a 35 nm separation between excitation and emission wavelengths. For this dye, the excitation scan is from 360 to 600 nm; the emission scan is from 395 to 635 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "very fast" on the RF-5000U; it is “fast” on the RF-5301. The typical sensitivity setting on both instruments is "high."

Excitation and emission slit width settings vary between the two instruments. The widths vary with the dyes for which we are sampling and for the matrix in which the dyes may be present. Excitation and emission slit width settings are summarized in Table 1.

Table 1. Excitation and emission slit width settings routinely used for dye analysis. Units are nanometers (nm)

Parameter	**RF5000U**	**RF5301**
Excitation slit for Eos, Fl, RWT, and SRB in elutant	5	3
Emission slit for Eos, Fl, RWT, and SRB in elutant	3	1.5
Excitation slit for Eos, Fl, RWT, and SRB in water	5	5
Emission slit for Eos, Fl, RWT, and SRB in water	10	3
Excitation slit for Pyranine in elutant	5	5
Emission slit for Pyranine in elutant	3	3
Excitation slit for Pyranine in pH adjusted water	5	5
Emission slit for Pyranine in pH adjusted water	3	3

Eos = Eosine. Fl = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

The instrument produces a plot of the synchronous scan for each sample; the plot shows emission fluorescence only. The synchronous scans are subjected to computer peak picks; peaks are picked to the nearest 0.1 nm. All samples run on the RF-5000U and RF-5301 are stored on disk and printed on normal typing paper with a laser printer; sample information is printed on the chart.

All samples analyzed are recorded in a bound journal.

Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes. Dye quantities are expressed in microgram per liter (parts per billion; ppb). On the RF-5000U and RF-5301 the dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

Where there are multiple fluorescence peaks it is sometimes necessary to calculate dye concentrations based upon the height of the fluorescence peak rather that the area. The heights of the peaks are also proportional to dye concentrations.

We run dye concentration standards each day the machine is used. Ten separate standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
4) 10 ppb pyranine in well water from the Jefferson City-Cotter Formation. A sample of the standard is placed for at least two hours in a high ammonia atmosphere to adjust the pH to a value of 9.5 or greater.
5) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
6) 10 ppb eosine in elutant.
7) 100 ppb sulforhodamine B in elutant.
8) 10 ppb pyranine in elutant.

Preparation of Standards

Dye standards are prepared as follows:

Step 1. A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to insure that all dye is fully dissolved.

Step 2. One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein, rhodamine WT, eosine, sulforhodamine B, and pyranine. The resulting solutions contain 100 mg/l dye (100 parts per million dye). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 ml. of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 ml at intervals of 0.005 ml. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 ml, 0.90%

At 0.300 ml, 0.28%

At 1.000 ml, 0.30%

The Step 2 solution is called the long term standard. Ozark Underground Laboratory experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

Step 3. A series of intermediate-term dye solutions are made. Approximately 45 ml. of each intermediate-term dye solution is made. All volume measurements of less than 5 ml are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 ml. capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) A solution containing 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.
2) A solution containing 1 ppm eosine.
3) A solution containing 10 ppm sulforhodamine B dye.
4) A solution containing 1 ppm pyranine.

Step 4. A series of eight short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the Ozark Underground Laboratory these standards have a useful shelf life in excess of one week. However, in practice, they are kept under refrigeration and new standards are made weekly.

Dilution of Samples

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilution is 100 fold. One part of the test sample is combined with 99 parts of water (if the test sample is water) or with 99 parts of the standard elutant (if the test sample is elutant). Typically, 0.300 ml of the test solution is combined with 29.700 ml of water (or elutant as appropriate) to yield a new test solution. All volume measurements of less than 5 ml are made with a digital Finnpipette. which is capable of measuring volumes between 0.200 and 1.000 ml at intervals of 0.005 ml. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 ml, 0.90%

At 0.300 ml, 0.28%

At 1.000 ml, 0.30%

All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 ml. capacity pump dispenser which will pump within plus or minus 1% of the set value.

The water used for dilution is from a carbonate aquifer. All dilution water is pH adjusted to greater than pH 9.5 by holding it overnight in open containers in a high ammonia concentration chamber.

Quality Control

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds that might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing typically includes approximately 1% of materials used.

Reports

Reports are provided in accordance with the needs of the client. We typically provide copies of the analysis graphs and a listing of stations and samples where dye was detected. The reports indicate dye concentrations.

Work at the Ozark Underground Laboratory is directed by Mr. Thomas Aley. Mr. Aley has 45 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #179) by the American Institute of Hydrology. Mr. Aley has 40 years of professional experience in groundwater tracing with fluorescent tracing agents.

CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

Normal Emission Ranges and Detection Limits

The OUL has established normal emission fluorescence wavelength ranges for each of the five dyes. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 2 provides normal emission wavelength ranges and detection limits for the five dyes when analyzed on the OUL's RF-5000U spectrofluorophotometer. Table 3 provides similar data for the OUL's RF-5301. As indicated earlier in Table 1, the analytical protocols used on the two instruments are somewhat different, especially in regard to the widths of excitation and emission slit settings.

Table 2. RF-5000U Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes in water and elutant samples. Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Eosine in Elutant	533.0 to 539.6	0.035
Eosine in Water	529.6 to 538.4	0.008
Fluorescein in Elutant	510.7 to 515.0	0.010
Fluorescein in Water	505.6 to 510.5	0.0005
Pyranine in Elutant	500.4 to 504.6	0.055
Pyranine in Water*	495.5 to 501.5	0.030
Rhodamine WT in Elutant	561.7 to 568.9	0.275
Rhodamine WT in Water	569.4 to 574.8	0.050
Sulforhodamine B in Elutant	567.5 to 577.5	0.150
Sulforhodamine B in Water	576.2 to 579.7	0.040

* pH adjusted water with pH of 9.5 or greater.

Note: The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in the table.

Table 3. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes in water and elutant samples. Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Eosine in Elutant	538.1 to 543.9	0.050
Eosine in Water	531.2 to 535.7	0.015
Fluorescein in Elutant	514.0 to 518.1	0.025
Fluorescein in Water	506.2 to 510.0	0.002
Pyranine in Elutant	502.1 to 508.1	0.015
Pyranine in Water*	498.4 to 504.4	0.010
Rhodamine WT in Elutant	565.4 to 572.0	0.170
Rhodamine WT in Water	572.7 to 578.0	0.015
Sulforhodamine B in Elutant	572.8 to 579.6	0.080
Sulforhodamine B in Water	580.1 to 583.7	0.008

* pH adjusted water with pH of 9.5 or greater.

Note: The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in the table.

Criteria for Determining Positive Dye Recoveries

The following sections identify normal criteria used by the OUL for determining positive dye recoveries. Beginning January 1, 2001, the primary analytical instrument in use at the OUL was the RF-5301; the RF-5000U was the principal backup instrument. Studies which were in progress prior to January 1, 2001 continued to have samples analyzed on the RF-5000U.

Except for pyranine dye, the analytical protocol used for the RF-5301 provides for the use of narrower excitation and/or emission slit settings than the RF-5000U protocol. This enhances our ability to discriminate between dyes and other fluorescent compounds. The protocol which is possible with the RF-5301 (as contrasted with the RF-5000U) also provides for a better balance in the sizes of the fluorescence peaks associated with an equal concentration of all of the dyes.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Eosine Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of eosine dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be eosine dye.

Criterion 1. There must be at least one fluorescence peak at the station in question in the range of 538.1 to 543.9 nm for samples analyzed by the RF-5301. The range must be 533.0 to 539.6 nm for samples analyzed by the RF-5000U.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. For the RF-5301, the eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb. For the RF-5000U the eosine detection limit in elutant samples is 0.035 ppb, thus this dye concentration limit equals 0.105 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Eosine Dye Recoveries in Water Samples.

There is generally little or no detectable fluorescence background in the general range of eosine dye encountered in most groundwater tracing studies. The following three criteria are used to identify fluorescence peaks which are deemed to be eosine dye.

Criterion 1. The associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. For samples analyzed on the RF-5301, the fluorescence peak should generally be in the range of 531.2 to 535.7 nm. For samples analyzed on the RF-5000U, the fluorescence peak should generally be in the range of 529.6 to 538.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples analyzed on the RF-5301 is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb. For samples analyzed on the 5000U the detection limit is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Fluorescein Dye Recoveries in Elutants from Charcoal Samplers.

There is often some fluorescence background in the range of fluorescein dye present at some of the stations used in groundwater tracing studies. We routinely conduct background sampling prior to the introduction of any tracer dyes to characterize this background fluorescence and to identify the existence of any tracer dyes which may be present in the area. The fact that a fluorescence peak is identified in our analytical results is not proof that it is fluorescein dye or that it is fluorescein dye from the trace of concern. The following 4 criteria are used to identify fluorescence peaks which are deemed to be fluorescein dye recoveries from our tracing work.

Criterion 1. There must be at least one fluorescence peak at the station in question in the range of 514.0 to 518.1 nm for samples analyzed by the RF-5301. The range must be 510.7 to 515.0 for samples analyzed by the RF-5000U.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. For the RF-5301, the fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb. For the RF-5000U, the fluorescein detection limit in elutant samples is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Fluorescein Dye Recoveries in Water Samples.

There is commonly some fluorescence background in the general range of fluorescein dye at some sampling stations used in groundwater tracing studies. The following criteria are used to identify fluorescence peaks which are deemed to be fluorescein dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. For samples analyzed on the RF-5301, the fluorescence peak should generally be in the range of 506.2 to 510.0 nm. For samples analyzed on the RF-5000U, the fluorescence peak should generally be in the range of 505.6 to 510.5 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples analyzed on the RF-5301 is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb. For the RF-5000U the detection limit is 0.0005 ppb, thus this dye concentration limit equals 0.0015 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Rhodamine WT Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of Rhodamine WT dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be Rhodamine WT.

Criterion 1. For samples analyzed on the RF-5301, there must be at least one fluorescence peak at the station in question in the range of 565.4 to 572.0 nm. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 561.7 to 568.9 nm.

Criterion 2. The dye concentration associated with the Rhodamine WT peak must be at least 3 times the detection limit. For the RF-5301, the detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb. For the RF-5000U, the detection limit in elutant samples is 0.275 ppb, thus this dye concentration limit equals 0.825 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of Rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Rhodamine WT Dye Recoveries in Water Samples.

The following criteria are used to identify fluorescence peaks which are deemed to be Rhodamine WT dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain Rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be Rhodamine WT dye from the tracing work under investigation. For samples analyzed with the

RF-5301, the fluorescence peak should generally be in the range of 572.7 to 578.0 nm. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 569.4 to 574.8 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our Rhodamine WT detection limit in water samples analyzed on the RF-5301 is 0.015 ppb, thus this dye concentration limit is 0.045 ppb. For samples analyzed on the RF-5000U the detection limit is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Sulforhodamine B Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of sulforhodamine B dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be sulforhodamine B.

Criterion 1. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 567.5 to 577.5 nm. The acceptable range for samples analyzed on the RF-5301 is 572.8 to 579.6 nm.

Criterion 2. The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. For the RF-5000U, the detection limit in elutant samples is 0.150 ppb, thus this dye concentration limit equals 0.450 ppb. For the RF-5301, the detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Sulforhodamine B dye Recoveries in Water Samples.

The following criteria are used to identify fluorescence peaks which are deemed to be sulforhodamine B dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 576.2 to 579.7 nm. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 580.1 to 583.7 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. For samples analyzed on the RF-5301 the detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb. For samples analyzed on the RF-5000U the detection limit in water samples is 0.040 ppb, thus this dye concentration limit equals 0.120 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Pyranine Dye Recoveries in Elutants from Charcoal Samplers.

It must be remembered that the analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in this document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

There is often some detectable fluorescence background encountered in the general range of pyranine dye in groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be pyranine.

Criterion 1. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 500.4 to 504.6 nm. The acceptable range for samples analyzed on the RF-5301 is 502.1 to 508.1 nm.

Criterion 2. The dye concentration associated with the pyranine dye peak must be at least 3 times the detection limit. For the RF-5000U, the detection limit in elutant samples is 0.055 ppb, thus this dye concentration limit equals 0.165 ppb. For the RF-5301, the detection limit in elutant samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of pyranine dye. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Pyranine Dye Recoveries in Water Samples.

It must be remembered that the analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in this document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

The fluorescence of pyranine decreases below a pH of about 9.5. Prior to analysis water samples are placed in a high ammonia atmosphere for at least two hours. A pyranine dye in water standard is placed in the same atmosphere as the samples. Prior to analysis samples are tested to insure that their pH is 9.5 or greater. If pyranine dye concentrations in a sample are so great as to require dilution for quantification of the dye concentration the diluting water used is OUL reagent water which has been pH adjusted in a high ammonia atmosphere.

The following criteria are used to identify fluorescence peaks which are deemed to be pyranine dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain pyranine dye in accordance with the criteria listed earlier. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be pyranine dye from the tracing work under investigation. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 495.5 to 501.5 nm. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 498.4 to 504.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. For samples analyzed on the RF-5301 the detection limit in water is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb. For samples analyzed on the RF-5000U the detection limit in water samples is 0.030 ppb, thus this dye concentration limit equals 0.090 ppb.

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United States Department of the Interior

NATIONAL PARK SERVICE
Great Basin National Park
Baker, Nevada 89311-9701

IN REPLY REFER TO:
N16(GRBA)

November 15, 2010

Dear Interested Parties:

Great Basin National Park is currently seeking issues and comments for a proposed Hydrogeologic Research Project. Your issues and comments will assist with developing alternatives to the proposed action presented below and help in conducting an environmental analysis consistent with the National Environmental Policy Act (NEPA).

The proposed action consists of a multi-component hydrologic research project. These components consist of:

1. INVESTIGATION OF THE SOURCE OF WATER TO ROWLAND SPRING

This involves:
--- Drilling and constructing two groundwater monitoring wells, each about 200-to-300 feet deep, within Great Basin National Park – one near Cave Springs and one near the lined sewage ponds by the Baker Creek Road;
--- Doing two 48-hour continuous pumping tests - one test at each of the two monitoring wells;
--- Installing a precipitation collector near the existing weather station in the park; and
--- Collecting water samples for laboratory analysis monthly from each of the two wells, from the precipitation collector, from Rowland Spring, and from one location each along Lehman and Baker creeks for one year.

2. INVESTIGATION OF STREAM-AQUIFER INTERACTIONS ALONG SELECTED REACHES OF LEHMAN, SNAKE, AND STRAWBERY CREEKS WITHIN THE PARK

This involves:
--- Installing up to 10 shallow well points at selected locations in each of Lehman and Snake creeks, driven by hand to a depth of about three feet beneath the streambed;
--- Installing temporarily a digital optical temperature-sensing cable in selected reaches of Lehman, Snake, and Strawberry creeks, and its subsequent removal after data collection is completed; and
--- Manually measuring stream flow in Lehman, Baker, Snake, and Strawberry creeks.

3. FOCUSED INVESTIGATION OF STREAM-AQUIFER INTERACTIONS AT A SPECIFIC SITE ON LEHMAN CREEK

This involves:
--- Drilling a cluster of three shallow boreholes within the Park, each less than 100 feet deep, located within 100 feet of Lehman Creek;
--- Doing a 72-to-96-hour continuous pumping test – by pumping the farthest well from Lehman Creek, and monitoring water levels and water temperature in the other monitoring wells, the shallow well points, and the stream; and
--- Collecting water samples for laboratory analysis from the pumped well during the pumping test.

4. A DYE TRACING STUDY

This involves:
--- The introduction of three fluorescent tracer dyes within the Park, one in Baker Creek, one in a cave in the Baker Creek cave system, and one in Pole Canyon creek; and
--- Water sampling at approximately 22 selected locations - to see if dye can be detected in Baker and Lehman creeks, at selected springs (most notably Rowland Spring), and at cave locations downhill to the east and northeast.

Preliminary issues developed by park staff include the effects to and impacts on: cultural resources, visitor experience, socioeconomics, fisheries, wildlife, soils, and water quality.

Two public meetings will be held to describe the project. The first is in Ely, NV at the Conference Center on December 8, 2010. The second is in Baker, NV at the Great Basin Resource Building classroom on December 9, 2010. Both meetings will be from 6 -8 p.m. Comments on the project will be accepted following the presentation.

Information is also available on the National Park Service Planning, Environment & Public Comment (PEPC) website at: http://parkplanning.nps.gov. This website provides access to current National Park Service plans, environmental impact analyses, and related documents on public review. Comments may be submitted through the PEPC website.

Mailed comments will also be accepted. Please submit comments no later than January 7, 2011, to Attn: Planning, 100 Great Basin National Park, Baker, NV, 89311.

Sincerely,

Tod B. Williams

for Andrew J. Ferguson
Superintendent

Appendix D: Press Release

National Park Service
U.S. Department of the Interior

Great Basin National Park

100 Great Basin National Park
Baker, Nevada 89311

775-234-7331 phone
775-234-7269 fax

Great Basin National Park News Release

Release Date:	Immediate
Contact:	Gretchen Baker, Ecologist
Phone Number:	(775) 234-7331
Date:	November 15, 2010

Comments Requested for Proposed Hydrogeologic Research Project

Great Basin National Park is currently seeking comments for a proposed Hydrogeologic Research Project. Your issues and comments will assist with developing alternatives to the proposed action presented below and help in conducting an environmental analysis consistent with the National Environmental Policy Act (NEPA).

The proposed project entails (A) the drilling and installation of five groundwater monitoring wells inside the Park in the Lehman Creek drainage; (B) the placement of several temporary shallow well points and other temporary monitoring equipment along Lehman, Snake and Strawberry creeks; (C) hydraulic testing, water-quality sampling, and physical measurements collected from this monitoring network and (D) a dye tracing study in the Baker and Lehman drainages.

Two public meetings will be held to describe the project. The first is in Ely, NV at the Bristlecone Convention Center on December 8, 2010. The second is in Baker, NV at the Great Basin Resource Building classroom on December 9, 2010. Both meetings will be from 6 -8 p.m. Comments on the project will be accepted following the presentations.

Information is also available on the National Park Service Planning, Environment & Public Comment (PEPC) website at: http://parkplanning.nps.gov. This website provides access to current National Park Service plans, environmental impact analyses, and related documents on public review. Comments may be submitted through the PEPC website.

Mailed comments will also be accepted. Please submit comments no later than January 7, 2011, to Attn: Planning, 100 Great Basin National Park, Baker, NV, 89311.

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As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historic places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

NPS 611/101091 March 2010

United States Department of the Interior □ National Park Service