

Prepared in cooperation with the National Park Service

The Water-Quality Partnership for National Parks— U.S. Geological Survey and National Park Service, 1998–2016

Background

The U.S. Geological Survey (USGS) and the National Park Service (NPS) work together through the USGS–NPS Water-Quality Partnership to support a broad range of policy and management needs related to high-priority water-quality issues in national parks. The program was initiated in 1998 as part of the Clean Water Action Plan, a Presidential initiative to commemorate the 25th anniversary of the Clean Water Act. Partnership projects are developed jointly by the USGS and the NPS. Studies are conducted by the USGS and findings are used by the NPS to guide policy and management actions aimed at protecting and improving water quality.

The National Park Service manages many of our Nation's most highly valued aquatic systems across the country, including portions of the Great Lakes, ocean and coastal zones, historic canals, reservoirs, large rivers, high-elevation lakes and streams, geysers, springs, and wetlands. So far, the Water-Quality Partnership has undertaken 217 projects in 119 national parks. In each project, USGS studies and assessments (http://water.usgs.gov/nps_partnership/pubs.php) have supported science-based management by the NPS to protect and improve water quality in

parks. Some of the current projects are highlighted in the NPS Call to Action Centennial initiative, Crystal Clear, which celebrates national park water-resource efforts to ensure clean water for the next century of park management (<http://www.nature.nps.gov/water/crystalclear/>).

New projects are proposed each year by USGS scientists working in collaboration with NPS staff in specific parks. Project selection is highly competitive, with an average of only eight new projects funded each year out of approximately 75 proposals that are submitted. Since the beginning of the Partnership in 1998, 189 publications detailing project findings have been completed. The 217 studies have been conducted in 119 NPS-administered lands (fig. 1), extending from Denali National Park and Preserve in Alaska to Everglades National Park in Florida, and from Acadia National Park in the Northeast to park lands in Hawaii and Pacific Island territories in the West. Project goals range from periodic stream monitoring, to determining the occurrence and concentrations of contaminants and the potential for them to exceed human health or aquatic life criteria, to conducting interpretive studies to evaluate the effect(s) on or vulnerability of national park resources to visitor usage and other natural and anthropogenic activities.

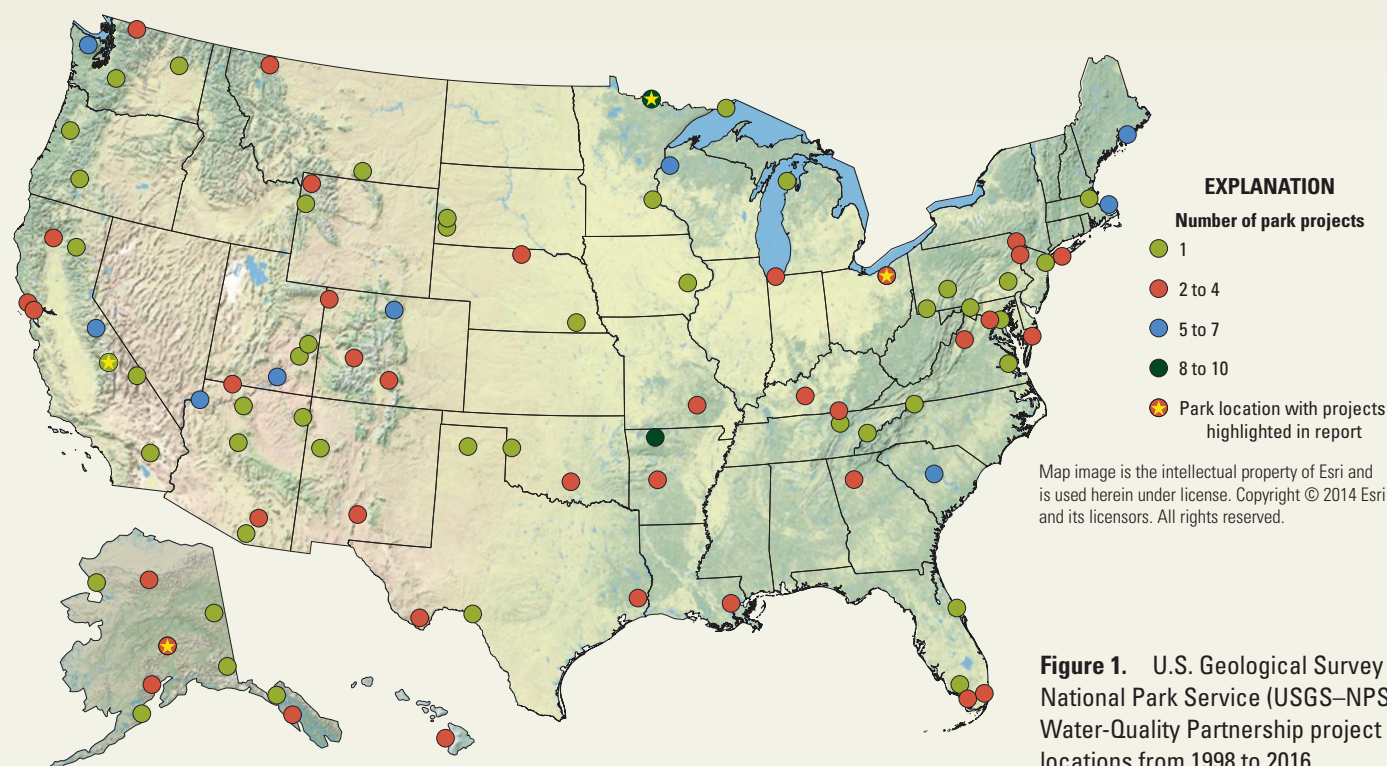


Figure 1. U.S. Geological Survey and National Park Service (USGS–NPS) Water-Quality Partnership project locations from 1998 to 2016.

Examples of Partnership Studies and Science-Based Management

Several examples help illustrate how the USGS and the NPS have developed and applied scientific information resulting from partnership studies to the management of water quality in our national parks. Recent projects in four national parks illustrate how the USGS and the NPS have worked together to: (1) identify and quantify impacts of historical mining operations to help prioritize cleanup efforts, (2) evaluate effects of nutrient loading and water-level management on reservoir eutrophication, (3) evaluate recreational-use effects on water quality, and (4) provide visitors with near real-time estimates of bacterial water-quality conditions for those planning direct water-contact recreation in park waters.

Historic Mining and Reclamation: Denali National Park and Preserve

Many NPS-managed lands have experienced impacts from land use activities, including mining, logging, road construction, urban and suburban growth, and development and water diversion projects. Evaluation of both water-quality impacts from past development and the effectiveness of environmental remediation projects has been an important contribution of the partnership program. In Denali National Park and Preserve (NP&P) alone, there were 35 active mining operations underway when a court-ordered injunction ceased most activity in 1985. A recently completed assessment of mining reclamation at Kantishna Hills in Denali NP&P in Alaska shows how research on the effectiveness of specific management strategies was used to improve water quality (Brabets and Ourso, 2013).

The Kantishna Hills is an area of low-elevation mountains in the northwestern part of Denali NP&P. Streams draining the Kantishna Hills are clear-water streams derived from rain, snowmelt, and subsurface aquifers, and they support nine species of fish, including the arctic grayling and three other species of salmon. Past mining, primarily for gold, silver, lead, antimony, and zinc, which began in 1903 and continued until 1985, caused acid mine drainage and excessive sediment loads that severely degraded water quality and aquatic habitat. Currently, the effects of mining are visible on more than 1,500 acres of land within 12 watersheds in the Kantishna Hills area (fig. 2).

Due to a short growing season and other factors, recovery through natural processes is limited and several reclamation projects have been implemented on multiple streams in the Kantishna Hills region in an effort to improve degraded water quality. Reclamation strategies consisted of (1) removing hazardous materials, such as barrels of diesel fuel and lead acid batteries, contaminated soils, and abandoned mining equipment; (2) reconstructing flood-plain and stream-channel structures to stabilize stream banks from erosion; (3) flattening and moving tailing piles out of the flood plain or rerouting channels away from tailings piles; and (4) revegetating sites. A study by the USGS and the NPS was undertaken during the years 2008–2011, in order to assess the water quality of Kantishna Hills streams and to determine whether reclamation efforts have proven effective and could be applied to other streams (fig. 3).

The macroinvertebrate data from Kantishna Hills were compared with other macroinvertebrate data in Alaska collected by the USGS, mostly representing pristine, undeveloped watersheds and using the same data-collection protocols. Results showed that Caribou Creek, a reclaimed stream, had biological quality, as estimated from macroinvertebrate populations, similar to an undisturbed reference site (Rock Creek). In contrast, Slate Creek and Friday Creek, two streams that were abandoned after extensive mining, with no reclamation efforts, exhibited the



Figure 2. Iron red-stained streambed in Slate Creek, Kantishna Hills area, Alaska, resulting from acid mine drainage caused by the mobilization and transport of iron sulfides from upstream ore deposits. Photograph taken August 21, 2008, by Dan Long, U.S. Geological Survey.

worst biological stream conditions. This study showed the success of site reclamation following intensive mining within this sensitive environment and supports the likely benefits of similar reclamation to restore water quality in other mining-affected streams.

Due to reclamation efforts, the study established that Caribou Creek now meets the U.S. Environmental Protection Agency (EPA) turbidity water-quality standard and, as a result, the Alaska Department of Environmental Conservation removed the creek from the Clean Water Act section 303(d) list. During the study period, with the exception of Slate Creek, measured values of stream acidity (pH) for all sites were within an acceptable range (from 7.5 to 8.5) for cold-water fish growth and survival.



Figure 3. Assessment of the effectiveness of mine reclamation for restoring the water quality of Caribou Creek in Denali National Park and Preserve, Alaska, required extensive monitoring, which included onsite field measurements and collection of water samples for laboratory analyses. Photograph by Dan Long, U.S. Geological Survey.

Measurements of pH at Slate Creek ranged from 6.2 to 7.8. The NPS used these results to proceed with reclamation of Slate Creek, which accomplished a similar result with reduced turbidity. The Denali National Park and Preserve is now proceeding to apply these reclamation practices to other streams to continue reducing the number of impaired stream miles.

Nutrient-Loading Impacts at Voyageurs National Park

Nutrient loading to NPS-managed lakes and streams from land use development outside national park boundaries, as well as park activities, is a common operational challenge. Excessive nutrient enrichment from sources such as septic systems, agricultural production, atmospheric deposition, and municipal wastewater can lead to eutrophication and degraded biological conditions. Nutrient enrichment has led to excessive algal growth in Kabetogama Lake in Voyageurs National Park, Minnesota. The southwest shore of Kabetogama Lake is not part of the park and, therefore, the shore is open for development; numerous homes, cabins, and resorts have been built along the roughly 19 kilometers of shoreline. This southwest lake shore is a potential source of nutrients to Kabetogama Lake. Residential and commercial areas on Ash River, which flows into Kabetogama Lake from the south, also are a potential source of nutrients.

USGS–NPS partnership projects were initiated in 2008 and 2012 to examine nutrient loading to Kabetogama Lake and to evaluate the effectiveness of water-management operations intended to improve water quality (fig. 4).

In 2000, dam operations at Kabetogama Lake were modified with the intent to restore more natural water dynamics and to improve water quality by reducing nutrient levels. In particular, the new operational rules for water storage and discharge were



Figure 4. Water-quality monitoring of Kabetogama Lake in Voyageurs National Park, Minnesota, showed the effectiveness of reservoir water-level management for reducing nuisance algae. Photograph by Victoria Christenson, U.S. Geological Survey.

expected to lower phosphorus loading by lessening the effects of drying and rewetting of sediments from fluctuating water levels, reducing nutrient inputs resulting from littoral vegetation, and reducing nutrient concentrations because of increased volume and dilution.

Nutrient concentrations, algae, and nuisance-bloom conditions were evaluated in relation to changes in water-level management of Kabetogama Lake through extensive water-quality sampling in 2008 and 2009 (Christensen and others, 2011). This study found that algal levels had decreased since the beginning of water-level manipulations, even though there had not been substantial changes in total phosphorus concentrations. Comparisons were made of measurements of water clarity, chlorophyll *a* (Chla), and trophic state indices taken before and after the water-level management changes in 2000—1977–1999 and 2000–2011, respectively (Christensen and Maki, 2015). Average Secchi-depth transparency improved (from 1.9 to 2.1 meters), average open-water season Chla concentration decreased from 9.9 to 6.2 micrograms per liter, and the trophic state index decreased from 57 to 50 in Kabetogama between 1977–1999 and 2000–2011, respectively. Together, these studies indicate that the water-management rules instituted in 2000 had improved water quality in Kabetogama Lake.

As the United States and Canada border splits the system of lakes that include Kabetogama Lake, rules governing operation of the privately owned dams on these lakes are set by the International Joint Commission (IJC). An objective of the IJC's 2000 Rule Curves was to benefit the aquatic ecosystems of these lakes. In prescribing these rules, the IJC requested that resource agencies evaluate whether the intended ecological benefits are occurring in the system. This USGS–NPS study of Kabetogama Lake provided information that has been shared with the IJC for consideration during their ongoing review and will be used to determine whether to maintain or modify the 2000 Rule Curves. Nutrient impacts to water bodies are a growing concern at many other parks and recreation areas. The use of hydrologic controls and other nutrient-management information resulting from this study can play an important role in assisting management decisions in these other areas as well.

Visitor-Use Impacts at Sequoia, Kings Canyon, and Yosemite National Parks

Wilderness areas in the United States are extensively used by day hikers, backpackers, and pack animals, with recreational visitor-use days approaching 17 million per year in 2010, with an expected increase of nearly 20 percent by 2050. The NPS is concerned that visitor activities in high-use areas of wilderness may be degrading water quality. The influence of pack animals and backpackers on water quality in wilderness lakes and streams was evaluated in Sequoia, Kings Canyon (Clow and others, 2013), and Yosemite National Parks, California. The project included synoptic surveys of water quality in park wilderness areas with differing types and amounts of visitor use, classified as (1) minimal use, (2) backpacker only, and (3) mixed backpacker and pack-animal use (fig. 5). The study paired water-quality sampling upstream and downstream of areas with these three use classifications and applied intensive monitoring using instream sensors to examine temporal variations in water quality.

Mean fecal-indicator bacterial (*Escherichia coli* [*E. coli*]) concentrations, measured during the synoptic sampling at minimal-use, backpacker, and mixed-use (backpacker and stock animal use) sites, were 0.3, 1.1, and 2.8 colony-forming units (CFU) per 100 milliliters (mL), respectively. Mean total coliform concentrations at minimal, backpacker, and mixed-use sites were 79, 162, and 214 CFU per 100 mL, respectively (fig. 6). For both *E. coli* and total coliforms, concentrations were lower at minimal-use sites than at mixed-use sites, and concentrations at backpacker use sites were intermediate. The paired sampling component of the project showed that in comparison to upstream values, water downstream of mixed-use areas had higher concentrations of *E. coli* and some nutrients, while water downstream of backpacker use was minimally influenced when compared to upstream values. Visitor use with pack animals appears to have a small, but statistically significant influence on stream-water quality, as indicated by both the synoptic sampling and the paired upstream-downstream sampling approach. Intensive monitoring



Figure 5. Streamflow and water-quality sampling at Sequoia, Kings Canyon, and Yosemite National Parks, California, showed that pack animals can have a small, but statistically significant influence on water quality in wilderness areas. Photograph by Harrison Forrester, National Park Service.

Recreational Use Warnings at Cuyahoga Valley National Park

Many waters within national parks are used recreationally and must be monitored by park management to ensure the waters are safe for human contact. The EPA designates recreational waters as bathing, primary contact, or secondary contact, and each designation has its own water-quality standards. Based on the EPA guidance, the State of Ohio has designated the Cuyahoga River within Cuyahoga Valley National Park (CUVA) as primary contact water. Primary contact waters are suitable for full body-contact recreation, such as swimming, canoeing, and scuba diving, and have an *E. coli* single-sample standard of 298 CFU per 100 mL. Between 2004 and 2011, 50 percent of the samples collected by the USGS exceeded this water-quality standard. The EPA has named sections of the Cuyahoga River, including sections within CUVA, as areas of concern within the Great Lakes region.

The Cuyahoga Valley National Park managers wanted the ability to promote greater recreational use of the river and needed an automated approach to give advance warning to the 2.2 million annual park visitors when bacterial levels are expected to exceed standards. A nowcasting system used to estimate recreational water-quality conditions of the Cuyahoga River was a result of several projects within CUVA that started in 2004. Regression models, based on turbidity levels within the river, were used to estimate *E. coli* concentrations. The estimated recreational water-quality condition (based on the Ohio single-sample standard) was then posted to the Ohio Nowcast Web site (<http://ny.water.usgs.gov/maps/ohnowcast/>) for public notification. Prior to 2012, regression models were dependent on manual daily sample collection and were labor intensive (fig. 7).



Figure 7. Water-quality sampling at the Cuyahoga River's Lock 29 Bridge in the Cuyahoga Valley National Park, Ohio. Photograph by Amie Brady, U.S. Geological Survey.

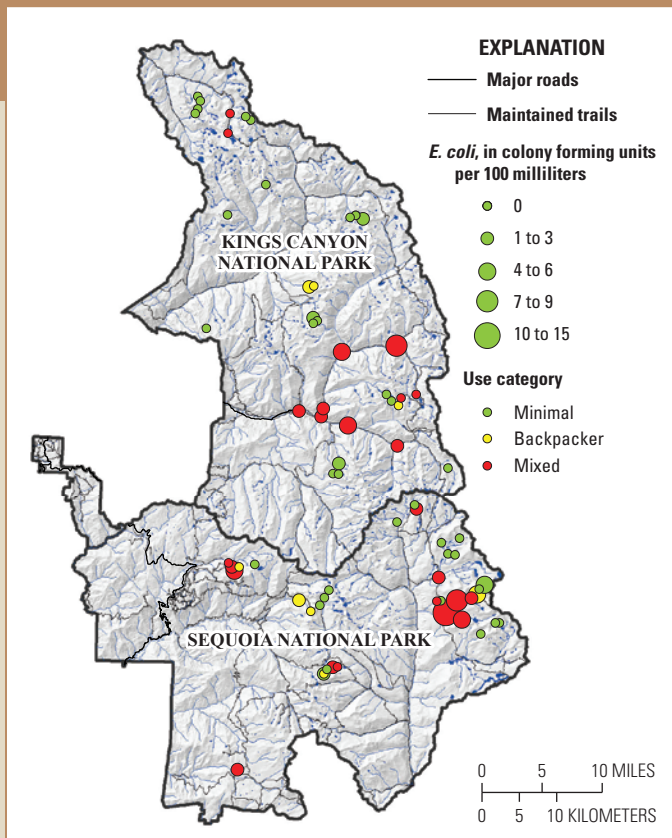


Figure 6. Concentrations of *E. coli* bacteria in streams and lakes of Sequoia and Kings Canyon National Parks, California, during fall 2010, categorized by the level and major type of recreational land use.

at a subset of sites documented that nutrient, *E. coli*, and particulate concentrations were low, except during storms, when they sometimes substantially increased. Additional USGS–NPS partnership studies in other parks are currently underway to better understand the relationships between specific visitor-use activities and water-quality impacts.

Sequoia and Kings Canyon National Parks have used results from the USGS–NPS partnership study to support the parks' Wilderness Stewardship Plan. Prior to the study, the parks had received anecdotal reports of water-quality degradation in heavily used areas, but data were not available to ascertain the veracity of those observations. Although total coliforms are ubiquitous in the environment, previous studies used total coliforms as an indicator of fecal contamination and suggested pack stock as the source. In contrast, the partnership study demonstrated that levels of *E. coli*, a fecal-indicator bacterial species within the total coliform group, were low, except during brief periods at the height of over-land runoff and did not relate to the levels of total coliforms. Multiple potential sources for *E. coli* and other bacteria, such as humans, wildlife, and pack animals, were identified. The new science-based information from the USGS study indicates that visitor use, including pack animals at current and projected levels, has some effects during runoff events; however, they do not occur at levels that represent a major threat to natural resources or human health.

Recreational Use Warnings at Cuyahoga Valley National Park—Continued

In 2012, a new partnership project installed an instream water-quality turbidity sensor and a near real-time data transmitter at Jaite, Ohio, a site centrally located on the Cuyahoga River within the national park (Brady and Plona, 2015). Turbidity and water-temperature data from the sensor are relayed every 15 minutes, providing near real-time values for the Cuyahoga River nowcast.

Project personnel developed new regression models based on the instream sensor values for turbidity and hourly radar rainfall data from the National Weather Service. Manual sample collection was not needed to run the models; therefore, estimated water-quality conditions could be posted to the Nowcast Web site by 9 a.m. each day during the recreational season. New models were tested during the recreational seasons of 2012–2014 and accurately predicted the *E. coli* levels 79 percent of the time. Project personnel determined that the Jaite Nowcasts could predict conditions at another site—Lock 29, 5.3 miles upstream, 77 percent of the time. Therefore, the Jaite Nowcasts can be used to predict *E. coli* concentrations for the Cuyahoga River between Jaite and Lock 29.

The installation of a near real-time sensor on the Cuyahoga River gives CUVA's managers a new tool in providing park visitors timely water-quality results for recreational activities. Because the data are near real time, the likelihood of park managers unnecessarily issuing an alert that limits river activities is greatly reduced. This stretch of the river is a favorite among kayakers and the public, who can now plan their recreational activities by checking online for predicted daily bacteria levels.

Summary

The U.S. Geological Survey and National Park Service (USGS–NPS) Water-Quality Partnership supports USGS-led studies that provide scientific information needed by the NPS to protect and restore water quality in national parks. Identification of research and investigation needs by NPS resource managers, combined with a rigorous proposal and study plan review process, ensures that priority NPS water-quality issues are addressed by USGS scientists.

Since 1998, the Water-Quality Partnership has enabled the NPS to make informed management decisions based on USGS data analyses and interpretations. The partnership promotes the interaction of park staff with USGS scientists and creates long-standing relationships for continued science-based resource management. This program continues to

produce high-quality, cost-effective products that are used to make informed decisions regarding aquatic-resource protection of national park lands for current and future generations to enjoy.

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