

National Park Service
U.S. Department of the Interior



Natural Resource Program Center

Water Resources Stewardship Report

Denali National Park and Preserve

Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2007/051



ON THE COVER

Photograph: Toklat River, Denali National Park and Preserve (Guy Adema, 2007)

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September 2007

U.S. Department of the Interior
National Park Service
Natural Resources Program Center
Fort Collins, Colorado

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Please cite this publication as:

Karle, K.F. 2007. Water Resources Stewardship Report, Denali National Park and Preserve. Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2007/051 National Park Service. Ft. Collins, Colorado.

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EXECUTIVE SUMMARY

The objective of this Water Resources Stewardship Report is to build from the “Water Resources Information and Issues Overview Report” (The Mangi Environmental Group, 2005) and develop an interim set of water resource goals for the fundamental water resources at Denali National Park and Preserve. This report identifies issues preventing the achievement of the water resource goals, and develops strategies that work through those issues and towards the goals. These goals and strategies are intended to be reviewed and updated every five to ten years.

The Denali General Management Plan (GMP) was completed in 1986. Though fundamental resources of the park were not described as such, descriptions of resources in the document enforced the importance of various landscape components as part of a more complete ecosystem. One of the most important components of the ecosystem at Denali is water. Its physical availability and quality are critical determinants of a park’s overall natural resource condition.

The fundamental water resources at Denali include:

- Rivers and Streams
- Glaciers
- Lakes and Ponds
- Groundwater
- Wetlands

A critical component for assuring proper stewardship of Denali’s water resources is to define what the condition or state of those fundamental water resources should be in the future (Water Resource Goals). The Water Resource Goals are a qualitative description of the integrity and character for water resources and values that park management has committed to achieve and maintain. The Water Resource Goals are those ecological and physical attributes that characterize or exemplify the outcomes of appropriate and legislated NPS management.

Identifying both the Water Resource Goals and the existing conditions of those resources is a critical step toward proper management of, and planning for, the water resources of Denali National Park and Preserve. With this understanding, strategies can then be developed that ultimately work towards maintaining water resource conditions that meet the goals and move impacted water resource conditions towards these goals.

Though the issue of water rights is of major concern in many NPS units, especially in the western states, DENA park managers consider water rights issues to be of limited strategic concern for Denali for the next several decades. As such, the acquisition of water rights is not included as a water resource goal for Denali at this time.

Water Resource Goal-Water Quality

Chemical (water quality) integrity of park waters is improved and/or maintained to support a diverse aquatic community and ecosystem function, and to meet or exceed federal and state water quality standards.

Because of its importance to the biota which drink, transpire, or live in the water flowing through the park's lakes, rivers, and wetlands, water quality has long been regarded as an important characteristic in the assessment and description of natural watersheds. Surface water quality, as related to organic and inorganic chemistry, suspended sediments, and bacterial parameters, is essential to maintain both a functioning ecosystem as well as recreational use. Subsurface water quality is essential both for human health reasons, when tapped as a source of drinking water, and when viewed as a key component in the hydrologic cycle of natural waters.

Where no baseline water quality data exists, such data will be acquired for areas threatened by industrial or transportation-related development, prior to such development. However, acquisition of new water quality information must be carefully planned. Needs must be carefully prioritized to insure that the most important data needs are given the tools and funding necessary to accomplish the goal. Partners, especially those with the required expertise and analytical know-how, must be solicited to assist with the data collection and analyses.

Factors preventing or impeding the achievement of this Water Resource Goal include:

- Contaminated Aquifers
- Long-range contaminant transport
- Pathogenic bacteria on glaciers
- Dust palliative application on park road
- Product water from coalbed methane
- New 'North Access' road construction
- Placer-mining effects

NPS management strategies to meet the Water Resource Goal for Water Quality should begin by understanding the current status of the diverse aquatic community and ecosystem function. The recommended strategies include:

- Water quality monitoring
- Groundwater remediation
- Baseline data acquisition (water quality and other appropriate indicators)
- Air quality monitoring.

Water Resource Goal-Functional Morphology

Physical channel and floodplain integrity of park streams and rivers is maintained and/or improved to support natural geomorphic processes of fluvial systems and to support natural aquatic flora and fauna.

The driving forces that form the stream channel/floodplain structure include climate, lithology, and vegetation. These variables, along with water temperature, also play a critical role in the ecological significance of streams and rivers, by determining the form and extent of the structure within which aquatic organisms make their “homes.” The quality and quantity of aquatic habitat is a direct result of the hydrological, geological, morphological, and vegetational setting of the stream. Natural changes in one or more of those settings will result in adjustments to a stream’s shape and habitat features.

Factors preventing or impeding the achievement of this Water Resource Goal include:

- Floodplain incursions from road construction and maintenance
- Past placer mining activities
- Lack of floodplain delineation
- Global climate change

NPS management strategies to meet the Water Resource Goal for Functional Morphology should begin by understanding the current status of natural geomorphic processes of the park’s fluvial systems, and supporting the natural aquatic flora and fauna that use these systems. The recommended strategies include:

- Stream channel and floodplain monitoring
- Floodplain delineation
- Glacier monitoring
- Aquatic biological monitoring

Water Resource Goal-Navigability Determination

All necessary data is acquired to assess navigability issues and support continued Federal ownership on upcoming State of Alaska applications, and protect affected water resources within the park and preserve regardless of determination of title ownership.

The task of protecting the quality and quantity of streams and rivers becomes extremely difficult when the National Park Service does not retain ownership of the submerged lands for those streams and rivers. In 1992, the Secretary of the Interior directed the NPS and other Department of Interior agencies to assume responsibility for navigability research for quiet title (court action to establish ownership) through negotiations and litigation. However, no additional funding has been allocated to accomplish this work. The subsequent lack of research and documentation may lead to an undue loss of submerged lands to State ownership.

The most important strategy that NPS management may follow to address the factors impeding the Water Resource Goal, and ultimately meet the Water Resource Goal for Navigability is one of data collection and navigability determination.

SECTION 1.0 INTRODUCTION

Denali National Park and Preserve serves as a setting for spectacular mountains, glaciers, and snow- and ice-covered high country along the Alaska Range. The water resources of this 6 million-acre park are vast. For example, over twenty major glaciers, some among the longest in the world, flow out of large basins ringed by high, rugged peaks on both the north and south sides of the range. Silt-laden streams flowing from these glaciers converge into wide braided rivers. Upland spruce forests support small clear water streams, which are fed from snow-melt at high alpine tundra valleys. In the northwest corner of the park, a vast, untracked expanse of flat boggy tundra features uncountable lakes, ponds, and wetland areas.

Water is a particularly important and sensitive ecosystem component, and it plays a central role in the social, economic, environmental, and political mosaic of units of the national park system. Its physical availability and quality are critical determinants of a park's overall natural resource condition. Because of the important role of water in maintaining resource condition, it is the policy of the NPS to maintain, rehabilitate, and perpetuate the inherent natural integrity of water resources and water-dependent environments occurring within the national park system (The Mangi Environmental Group, 2005).

Though the vast majority of the water resources of Denali National Park and Preserve maintain their natural integrity through lack of disturbance, localized historical impacts to Denali's water resources have led to serious degradation in some areas. The placer mining activity that occurred in the Kantishna Hills region is the most visible example of intensive localized impacts.

Though mining activities ended twenty years ago, new and substantial threats to the water resources are threatening to disrupt the high quality of the water resources. A proposal to begin coalbed methane production near the park's northeastern boundary threatens both adjacent aquifers and surface water quality. Another proposal by the State of Alaska involves the construction of a ninety mile gravel road along the north boundary of the park; threats from that project include large scale disruptions to wetlands, floodplains, rare springs, and important fisheries.

NPS management actions may also have detrimental impacts to water resources. From gravel mining on large braided floodplains to non-conforming wastewater treatment, management activities required to provide for a large and increasing summer visitor population also threaten to impact critical water resources.

The water resource goals are a qualitative description of the integrity and character for water resources and values that park management has committed to achieve and maintain. The water resource goals are those ecological and physical attributes that characterize or exemplify the outcomes of appropriate and legislated NPS management.

Identifying both the water resource goals and the existing conditions of those resources is a critical step toward proper management of, and planning for, the water resources of Denali National Park and Preserve.

1.1 Scope and Purpose of Report

The objective of this Water Resources Stewardship Report is to develop and describe an interim set of water resource goals for the fundamental water resources at Denali National Park and Preserve. Additionally, the report identifies issues preventing the achievement of the water resource goals, and develops strategies that work through those issues and towards the goals. These goals and strategies are intended to be reviewed and updated every five to ten years. This report follows the development and publication of the report titled 'Water Resources Information and Issues Overview Report-Denali National Park and Preserve,' (The Mangi Environmental Group, 2005) and should be used in conjunction with that report.

The report is divided into eight major parts. The first part, Introduction, includes a general overview of the National Park Service water resource planning overview. The second section describes the scope and purpose of this report and summarizes the new park planning elements, which this report supports. The third section develops the park's fundamental water resources, and the fourth section defines the Water Resource Goals, which provide coverage to the fundamental water resources within DENA's boundary. They describe the integrity and character for those water resources that park management has committed to achieve and maintain.

The fifth section summarizes the existing information on Denali's water resources. In the sixth and seventh sections, the current state of the water resources are assessed in terms of existing conditions, and issues and management actions, from both NPS and outside entities, that either currently impede, or may impede in the future, attainment of the water resource goals.

In the eighth section, long-term comprehensive strategies are developed that will enable Denali to achieve or maintain the water resource goals. Target conditions are developed to help quantitatively assess the state of the water resource goals, and a list of measurable indicators is provided.

Appendix A includes a discussion of the concept of trend analysis to describe long-term changes to those measurable values, with examples.

1.2 New NPS Planning Overview

Since 2004, there have been significant changes in the NPS general planning framework (new 2004 *Park Planning Program Standards*), including resources planning (draft *Director's Order 2.1: Resource Stewardship Planning*), requiring programmatic revision to the existing NPS Water Resources Planning Program to assure that its products support the new NPS planning framework within which planning and decision-making are now

accomplished. Within this new planning framework, six discrete elements of planning are in place; these elements are captured in six planning-related documents (Figure 1).

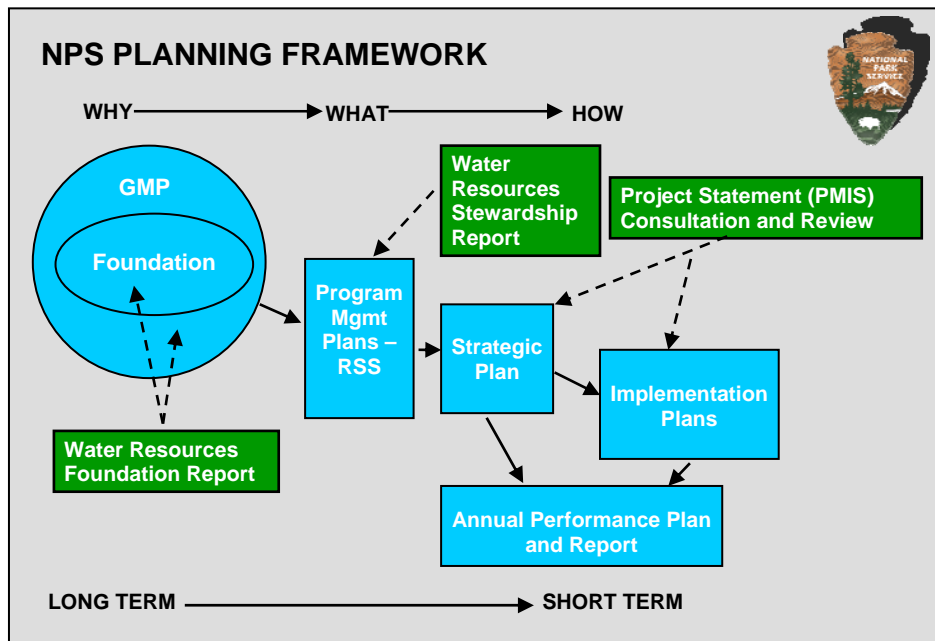


Figure 1. The new NPS framework for planning and decision making (blue boxes). Green boxes represent WRD planning or assistance. RSS = Resource Stewardship Strategy.

The *Foundation for Planning and Management* (Foundation) document defines the legal and policy requirements that mandate the park’s basic management responsibilities, and identifies and analyzes the resources and values that are fundamental to achieving the park’s purpose or otherwise important to park planning and management.

The *General Management Plan* (GMP) uses information from the Foundation document to define broad direction for resource preservation and visitor use in a park, and serves as the basic foundation for park decision-making, including long-term direction for *desired conditions* of park resources and visitor experiences.

The *Program Management Plan* tiers off the GMP identifying and recommending the best strategies for achieving the desired resource conditions and visitor experiences presented in the GMP. Program planning serves as a bridge to translate the qualitative statements of *desired conditions* established in the GMP into measurable or objective indicators that can be monitored to assess the degree to which the *desired conditions* are being achieved. Based on information obtained through this analysis, comprehensive strategies are developed to achieve the *desired conditions*. The Program Management Plan component for natural and cultural resources is the Resource Stewardship Strategy. The *Strategic Plan* tiers off the Program Management Plan identifying the highest-priority strategies, including measurable goals that work toward maintaining and/or restoring the park’s *desired conditions* over the next 3 to 5 years.

Implementation Plans tier off the Strategic Plan describing in detail (including methods, cost estimates, and schedules) the high-priority actions that will be taken over the next several years to help achieve the *desired conditions* for the park.

The *Annual Performance Plan and Report* measures the progress of projects from the Implementation Plan with objectives from the Strategic Plan.

The *Water Resources Foundation Report* and the *Water Resources Stewardship Report* will support this new planning framework. The Water Resources Foundation Report (Figure 1) addresses the needs of either the Foundation Document or phase one of the GMP. The Water Resources Stewardship Report (Figure 1) is designed specifically to address the water resource needs in a park's Resources Stewardship Strategy.

Following the new NPS planning framework, water resource management planning has begun for Denali. The first product, *Water Resources Information and Issues Overview Report-Denali National Park and Preserve*, was completed in 2005. That report provides a wide range of information on the water resources of Denali, including:

1. descriptions of the applicable Federal and State legislation and regulations, NPS management policies and Director's Orders, and park-specific planning documents that provide the mandates and foundation for management decisions related to water resources;
2. a narrative of the park's physical, biological, and socioeconomic resources in relation to water resources;
3. a prioritized listing of water-related issues and management concerns at Denali;
4. a brief discussion of the baseline inventory and monitoring needed to address each of the water-related issues identified (The Mangi Environmental Group, 2005).

The second phase of the planning effort is the publication of this product, *Water Resources Stewardship Report-Denali National Park and Preserve*.

SECTION 2.0

FUNDAMENTAL WATER RESOURCES

2.1 Policies and Legislation

The National Park Service seeks to define and protect the natural and cultural resources in a park unit that serve as an essential or fundamental component of that park. The fundamental resources of a park are those particular features, systems, structures, processes, experiences, stories, scenes, sounds, landscapes, etc. that are key to achieving the park's purpose and maintaining its significance. Fundamental resources will be given primary consideration during park planning and management.

The document *Management Policies* (NPS, 2006) is the basic Service-wide policy document for the agency, and is used to provide information on NPS policy and required actions to management and staff. This document clearly defines the agency's responsibility to preserve the natural resources, processes, systems, and values of units of the national park system in an unimpaired condition.

Specifically included in this umbrella of resource preservation is the protection of water resources as integral components of park aquatic and terrestrial ecosystems. This policy describes in detail the need and requirement to protect surface waters, groundwater, water quality, floodplains, wetlands, and watershed processes. Implicit in this policy is the acknowledgement that in parks such as Denali where the water resources are significant components of larger ecosystems, they are fundamental resources.

In many documents and policies, from the park's enabling legislation through the Alaska National Interest Lands Conservation Act (ANILCA), which enlarged and renamed Mount McKinley National Park as Denali National Park and Preserve, water is readily described as one of the primary resources at the park.

In 1917, Congress established the park "for the preservation of animals, birds, and fish and for the preservation of the natural curiosities and scenic beauties thereof..." (39 Statute 938). Justification for water as a fundamental resource of DENA is also found in Section 101 of ANILCA, which described the broad purposes of the new conservation system units throughout Alaska (including DENA). These included the following:

- Preserve lands and waters for the benefit, use, education, and inspiration of present and future generations;
- Preserve unrivaled scenic and geological values associated with natural landscapes;
- Maintain sound populations of, and habitat for, wildlife species;
- Preserve extensive, unaltered ecosystems in their natural state;
- Protect and preserve historic and archeological sites, rivers and lands;
- Preserve wilderness resource values and related recreational opportunities such as hiking, canoeing, fishing, and sport hunting.

Section 202 states that the new units of the enlarged Denali National Park and Preserve are to be managed for the following additional specific purposes:

- To protect and interpret the entire mountain massif and the additional scenic mountain peaks and formations;
- To protect habitat for, and populations of fish and wildlife including, but not limited to, brown/grizzly bears, moose, caribou, Dall sheep, wolves, swans, and other waterfowl.

The Denali GMP was completed in 1986. Though fundamental resources of the park were not described as such, descriptions of resources in the document enforced the importance of various landscape components as part of a more complete ecosystem. For example, in a section under the *Natural Resources-Shorelands, Tidelands, and Submerged Lands* heading, the Denali GMP states that:

“...The National Park Service will work cooperatively with the state to ensure that existing and future activities occurring on shorelands underlying the waters within and adjacent to the unit boundary are compatible with the purposes for which the unit was created. Any actions, activities, or uses of nonfederal lands that will alter these lands or result in adverse effects on water quality or the natural abundance and diversity of fish and wildlife species will be opposed by the National Park Service. The National Park Service will manage the unit uplands adjacent to shorelands to protect their natural character.”

2.2 Fundamental Water Resources

The fundamental water resources at Denali National Park and Preserve include surface water streams and rivers, small tundra ponds, large lakes, wetlands, subsurface aquifers, and glaciers. This section briefly describes these various water resources; additional discussion of the hydrology and water quality of DENA’s water resources is found in the DENA Water Resources Information and Issues Overview Report (The Mangi Environmental Group, 2005).

Rivers and streams - Silt-laden streams flowing from large glaciers converge into wide braided rivers. Upland spruce forests support small clear water streams, which are fed from snow-melt at high alpine tundra valleys. These free-flowing streams and rivers provide habitat for 22 species of fish, including all five species of Pacific salmon (*Oncorhynchus tshawytscha*). The streams used by the anadromous species receive high levels of protection because of the value of these species for subsistence, commercial, and sport harvest (The Mangi Environmental Group, 2005).

Glaciers- Over twenty major glaciers, some among the longest in the world, flow out of large basins ringed by high, rugged peaks on both the north and south sides of the Alaska range. Glaciers are a dominant feature of the landscape of Denali; they currently cover

17% of the park. Glaciers are a critical component of the hydrologic cycle in watersheds fed in part or wholly by glacial melt. On glacial rivers, glaciers act as naturally regulated reservoirs that reduce the runoff variability by storing water as ice and snow during cool, wet periods, and increasing flow during hot, dry periods as snow and ice melt.

Lakes and Ponds - The lakes and tundra ponds of Denali are important habitat to many species of fish and wildlife. These lakes and ponds provide habitat and food for a wide variety of fauna. The outstanding water quality allows for submerged aquatic vegetation to thrive in shallow areas, providing a constant source of food for moose. Relatively constant water levels have supported sustainable areas of riparian vegetation, used by beaver and other animals for food and shelter. River otters use these waterbodies as do muskrats and water shrews. Many species of waterfowl, including trumpeter swans and loons, nest and feed on the lakes and ponds in Denali.

Wetlands – Wetlands are found extensively throughout the 6-million acre park and preserve. The park’s wetlands serve critical hydrologic and water quality functions, including flow regulation, erosion control, sediment retention, and nutrient uptake. These wetlands help reduce peak flows through detaining water behind hummocks and within depressions, ponds, and lakes, and decrease flow velocity through wetland vegetation. In permafrost areas, wetland vegetation also reduces erosion by preventing the warming and thawing of ice-rich soils. DENA wetlands provide critical breeding, feeding, and resting habitat for waterfowl and shorebirds, mammals such as moose, beaver, and muskrat, and many fish species.

Groundwater – Subsurface aquifers are important for the recharge of surface water systems, including wetlands. Additionally, they provide a safe drinking water source for the developed areas along the park road.

SECTION 3.0

WATER RESOURCE GOALS

A primary element for assuring proper stewardship of the water resources of DENA is to define what the condition or state of those fundamental water resources should be in the future. The Water Resource Goals should describe the ecological and physical attributes that characterize or exemplify the outcomes of NPS management. These Water Resource Goals should provide coverage to the fundamental water resources within the DENA boundary. Those fundamental water resources identified in the previous section include:

- Rivers and streams
- Glaciers
- Lakes and ponds
- Wetlands
- Groundwater

3.1 Guidelines For Water Resource Goals

Within the National Park system, Desired Conditions for various natural resources are often described in a park's General Management Plan (GMP). Members of the public are generally encouraged to participate during the preparation of a GMP and the compilation of Desired Conditions. The Denali GMP was completed in 1986, and did not include a list of Desired Conditions. This document will provide a set of Water Resource Goals for future consideration as Desired Conditions in the GMP. Though the goals describe an endpoint, they are not intended to be reached in a single step, but rather in a series of small steps over decades.

In the GMP, some guidance is given in terms of the expected future condition or state of the park's fundamental water resources. For example, in a section under the *Natural Resources-Shorelands, Tidelands, and Submerged Lands* heading, the Denali GMP states that:

“...The National Park Service will work cooperatively with the state to ensure that existing and future activities occurring on shorelands underlying the waters within and adjacent to the unit boundary are compatible with the purposes for which the unit was created. Any actions, activities, or uses of nonfederal lands that will alter these lands or result in adverse effects on water quality or on the natural abundance and diversity of fish and wildlife species will be opposed by the National Park Service. The National Park Service will manage the unit uplands adjacent to shorelands to protect their natural character.”

Additional guidance for determining a set of Water Resource Goals can be found in the National Park Service Management Policies (NPS, 2006). This volume is the basic Service-wide policy document of the National Park Service.

In this document, the NPS describes the policy goals for water resource management. Short excerpts from sections describing various water resource components are listed below:

Protection of Surface Waters and Groundwaters.The Service will perpetuate surface waters and groundwaters as integral components of park aquatic and terrestrial ecosystems.

Water Quality.The Service will 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 of parks.

Floodplains.In managing floodplains on park lands, the National Park Service will: (1) manage for the preservation of floodplain values; (2) minimize potentially hazardous conditions associated with flooding.....

Wetlands.The Service will: (1) provide leadership and take action to prevent the destruction, loss, or degradation of wetlands; (2) preserve and enhance the natural and beneficial values of wetlands; and (3) avoid direct and indirect support of new construction in wetlands unless there are no practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands.

Watershed and Stream Processes. The Service will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams.

A partner to the water resource goals listing is the ability to measure the value of the condition of the water resource. The condition is determined by establishing and using a measurable parameter or an index of multiple measurable parameters; these are used to track progress toward achieving the goals. Indicators are measures that change in response to human activity or other forces and can be used to assess the quality of resource or experience conditions.

By noting its condition in a current timeframe, managers will be able to set realistic goals as to what improvement in value a water resource should attain in the future. Conversely, it will also be possible to determine how far a resource has degraded, in undesirable conditions or events.

Goals for water resources at Denali National Park and Preserve can be readily condensed into two main categories: water quality and functional morphology. Navigability (ownership of the stream bed) is addressed in a separate water resource goal. Though the issue of water rights is of major concern in many NPS units, especially in the western states, DENA park managers consider water rights issues to be of limited strategic concern for Denali for the next several decades. As such, the acquisition of water rights is not included as a water resource goal for Denali at this time.

3.2 Water Resource Goal-Water Quality

Chemical (water quality) integrity of park waters is improved and/or maintained to support a diverse aquatic community and ecosystem function, and to meet or exceed federal and state water quality standards.

Because of its importance to the biota which drink, transpire, or live in the water flowing through the park's lakes, rivers, and wetlands, water quality has long been regarded as an important characteristic in the assessment and description of natural watersheds. Surface water quality, as related to organic and inorganic chemistry, suspended sediments, and bacterial parameters, is essential to maintain both a functioning ecosystem as well as recreational use. Subsurface water quality is essential both for human health reasons, when tapped as a source of drinking water, and when viewed as a key component in the hydrologic cycle of natural waters.

Contaminants, generated from both point and non-point sources, have long been recognized as direct contributors to both degraded biological integrity and human health in numerous waters throughout the United States. Results from a number of discrete studies and water quality measurements throughout the park have linked most current water quality degradation issues with ongoing park management actions. In addition, results from a preliminary study indicate that water-borne contaminants found in the sediments of Wonder Lake are derived from non-point sources transported into the park from long-range atmospheric transport.

The acquisition of water resources information is extremely expensive. This is due to a number of reasons:

- The study area (Denali National Park and Preserve) is vast, over 6 million acres
- Sampling sites are remote, and generally require air transportation to access
- Water resource-related sampling requires specialized equipment and training.

For example, water chemistry analyses, other than a few basic parameters that can be measured reliably in the field, require a qualified analytical laboratory. Such analysis can be a complex undertaking. In addition to analyzing many water quality variables with several alternative procedures, other operational aspects such as the handling and flow of samples, quality control and quality assurance, and recording of data, all require a substantial level of expertise and expense.

Acquisition of new information must be carefully planned. Needs must be carefully prioritized to insure that the most important data needs are given the tools and funding necessary to accomplish the goal. Partners, especially those with the required expertise and analytical know-how, must be solicited to assist with the data collection and analyses.

3.3 Water Resource Goal-Functional Morphology

Physical channel and floodplain integrity of park streams and rivers is maintained and/or improved to support natural geomorphic processes of fluvial systems and to support natural aquatic flora and fauna.

The driving forces that form the stream channel/floodplain structure include climate, lithology, and vegetation. Viewed on a smaller scale, six independent variables are generally considered to control the dimensions of natural channels. They include discharge, bed load discharge, bed material size, bank material characteristics, valley slope, and bank vegetation (Hey, 1978). These variables, along with water temperature and nutrient concentrations, also play a critical role in the ecological significance of streams and rivers, by determining the form and extent of the structure within which aquatic organisms make their “homes.”

The quality and quantity of aquatic habitat is a direct result of the hydrological, geological, morphological, and vegetational setting of the stream. Natural changes in one or more of those settings will result in adjustments to a stream’s shape and habitat features. The goal of the National Park Service is to insure that fluvial conditions remain, or are returned to a state that is natural and unaffected by management activities. That goal is met by eliminating non-natural changes to those four settings above.

Unregulated rivers with no anthropogenic disturbances generally construct and maintain a channel for a capacity to carry flows of an intermediate size. The effective flow, or that flow which carries the most sediment and does the most ‘work’ over time, is approximated by the bankfull flow, with a recurrence interval of approximately 1.5 years. In proper function, overflow from the channel spills onto the floodplain at flows above bankfull. Floodplain riparian vegetation acts to slow the floodwaters and reduce erosion; sediment drops from the floodwaters as the velocity decreases, providing a moist nutrient-rich soil to enhance continued vegetative growth.

Channel stability does not imply lack of movement or change in the cross-section; stable channel geometry will change around a long-term average, involving erosion some years and deposition in others. Stable channels may also migrate laterally, but will maintain their bankfull width and width/depth ratio. Channel instability is the result of significant and long-term scour or excessive sediment deposition.

3.4 Water Resource Goal-Navigability Determination

All necessary data is acquired to assess navigability issues, support continued Federal ownership on upcoming State of Alaska applications, and protect affected water resources within the park and preserve regardless of determination of title ownership.

The task of protecting the quality and quantity of streams and rivers becomes extremely difficult when the National Park Service does not retain ownership of the submerged lands for those streams and rivers. For example, in 1991 the State of Alaska signed a

finding that Moose Creek was “navigable in fact” downstream of its confluence with Rainy Creek to its confluence with the Bearpaw River. This action was perceived by many at the time as a prelude to the issuance of State placer mining permits for Moose Creek, especially in the road-accessible reach in the historic Kantishna mining district. Though the State determination of navigability was later withdrawn, that action provided a glimpse of the potential threats to water resources from this issue.

A major goal of the state’s navigability program is to identify the proper criteria for determining title navigability in Alaska and to gather sufficient information about the uses and physical characteristics of individual water bodies so that accurate navigability determination can be made. The greatest hurdle to overcome in identifying and managing navigable waters in Alaska has been the differences of opinion between the state and federal government regarding the criteria for determining the title navigability. The criteria for navigability takes into account geography, economy, customary modes of water-based transportation, and the particular physical characteristics of the waterbody.

In 1992, the Secretary of the Interior directed the NPS and other Department of Interior agencies to assume responsibility for navigability research for quiet title through negotiations and litigation. Quiet title is a court action intended to establish or settle the title to a particular property. However, no additional funding has been allocated by the NPS, BLM, or USFWS to accomplish this work. According to the Denali Water Resources Information and Issues Overview Report, the subsequent lack of research and documentation may lead to an undue loss of submerged lands to State ownership. Critical actions, including data collection and database development, are required to enable the Federal government to prepare for future attempts by the State of Alaska to assert navigability on streams and rivers within the Denali Park boundary, including portions of the Muddy, McKinley, Kantishna, Tokositna, Nenana, Teklanika, and others.

SECTION 4.0

SUMMARY OF WATER RESOURCE INFORMATION

Compared to many parks and natural areas in the lower 48 states, Denali National Park and Preserve has a limited database of its water resources. For example, studies of surface water quality in Denali have been sporadic in the past, and generally focused on the Kantishna Hills mining district. Some studies have focused on contaminated aquifers in populated areas, generally in response to oil spills. Essentially, there is no comprehensive database for water quality, stream discharge, lake levels, or visitor use levels. A list of data gaps in water-related baseline inventory and monitoring are described in The Mangi Environmental Group (2005).

As a result, there is a basic lack of understanding of the park water systems. Without a baseline inventory of current conditions, understanding water resource ecosystems, threats to those ecosystems, and whether or not water resource goals are being met becomes an almost impossible task. A baseline inventory of current water resource conditions is the first step towards achieving the park's Water Resource Goals.

The studies that have been conducted in Denali have covered a wide range of topics, and include chemical, physical, and biological water-related issues. In the following discussion, studies to acquire water resource information have been classified according to three main topics:

- General Water Quality Studies,
- Long-Term Ecological Monitoring
- Kantishna Hills Studies

The General Water Quality Studies range in topic from water chemistry baseline studies on both north and south side watersheds, to sediment transport and a discussion on the use of radio-tagged rocks to track sediment movement in large braided rivers. Some water resource studies were specifically conducted as part of, and generally funded directly by, the park's now-defunct Long-Term Ecological Monitoring (LTEM) program.

The Kantishna Hills Studies section includes two separate headings. The first heading lists reports describing the effects of placer mining on various aquatic components of the area. The second heading is a compilation of stream restoration projects that have occurred in the Kantishna Hills since the cessation of mining.

4.1 General Water Quality Studies

One of the first studies to obtain comprehensive baseline surface water quality data for Denali was conducted from 1985 through 1988. Stottlemeyer and McLoone (1990) used small first and second-order watersheds to assess water chemistry throughout the park. Study results showed that the surface waters are highly mineralized and very well buffered. The authors found a strong correlation between watershed bedrock type and

streamwater chemistry. They also noted heavy metals concentrations in Kantishna-area streams. Intensive sampling in Rock Creek was used to highlight the benefits of using a watershed ecosystem design for describing and quantifying the terrestrial and aquatic interactions that account for variability in water quality throughout the park.

Stottlemyer (1992) reported extensively on the Rock Creek sampling. This study looked at changes in upstream-downstream water chemistry and nitrogen mineralization. The objectives of the study were (1) to compare vegetation productivity and nutrient cycling rates as indicated by nitrification and nitrogen mineralization, and (2) see if variations in these processes might be reflected in streamwater. He noted the high riparian contributions of nitrogen from nitrogen-fixing vegetation (alder) into Rock Creek.

Edwards and Tranel (1998) also conducted a parkwide study to characterize water quality baseline conditions. Clear water and glacier-fed streams were sampled, both on the north side and south side of the park. They noted significant differences in mean pH, alkalinity, and conductivity values when comparing north and south side samples (Figure 2). The authors speculated that differences were probably due to differences in geology on either side of the Alaska Range. Additionally, streams in Kantishna were sampled to determine the level of recovery that may have occurred since mining ceased. Turbidity levels recorded on mined streams from 1979 to 1983 were considerably greater than those observed on the same streams during the project sampling. However, the report does not provide the source of the historical data, or provide the names of the streams used for comparison.

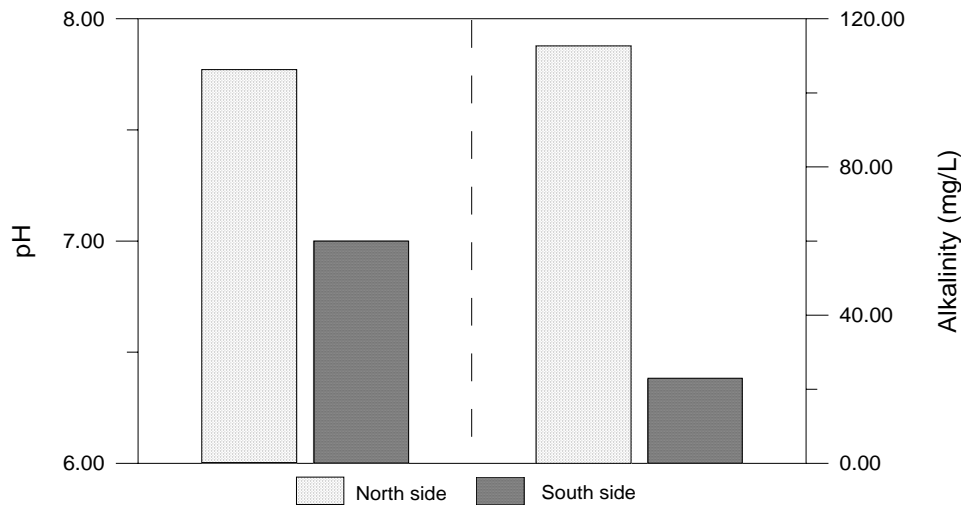


Figure 2. Mean pH and alkalinity values for north side versus south side streams in Denali (after Edwards and Tranel, 1998).

As part of the National Water Quality Assessment Program, the United States Geological Survey (USGS) conducted water quality studies in Denali and reported the results in a number of publications. For example, Frenzel and Dorava (1999) identified and described the physical, chemical, and biological aspects of the two Denali sites included in the Cook Inlet study basin, Costello Creek and Colorado Creek. Physical stream

characteristics included channel geometry surveys and water velocity measurements. Biological characteristics were evaluated by sampling algal, benthic macroinvertebrate, and fish communities.

Frenzel (2000) reported on the program to investigate organochlorines, semi-volatile organic compounds, and trace elements in the study watersheds. He noted that Colorado and Costello Creeks tended to have some of the highest natural trace-element concentrations in the Cook Inlet Basin. For example, streambed sediment samples from Colorado Creek contained the highest concentration of arsenic, chromium, and nickel, and extremely high concentrations of selenium, cadmium, and zinc.

LaPerriere and Casper (1976) conducted one of the few limnological studies to take place within Denali. Their investigation of Wonder Lake included measurements of temperature, pH, depth, conductivity, dissolved oxygen, nutrient chemistry and others, and also included the first complete bathymetric map of the lake. The authors also studied light penetration, algal C-14 productivity, and vascular hydrophyte colonization on Wonder Lake. LaPerriere and Casper evaluated the lake's extreme depth (+80 m), harsh winter environment, morphometric rock setting, and long residence time affecting the lake's primary productivity.

In 1991, sediment cores from Wonder Lake were analyzed as part of a study to investigate the atmospheric deposition of organochlorine compounds in the United States (Gubala et al., 1995). Anthropogenic contaminants, including polycyclic aromatic hydrocarbons (PAHs), dioxins, dibenzofurans, and polychlorinated biphenyls (PCBs), were found in the sediment samples. Two classes of PAHs were found: parental PAHs produced from combustion, and biogenic PAHs derived from natural precursors. Concentrations of PCBs, while low compared to levels found in more industrialized regions, were the highest of any remote arctic or subarctic lake surveyed throughout the circumpolar north.

Due in part to those findings, Wonder Lake, along with two other lakes in Denali (McLeod Lake and Foraker Lake) are included in an ongoing project to assess a number of western U.S. and Alaska national parks for presence of organic compounds and metals from long-range transport. The sediments in these lakes were sampled in 2004, along with other resources such as snow and lichen. The project is being conducted by the Western Airborne Contaminants Assessment Project (WACAP), and project cooperators include the NPS, USGS, EPA, and others. Analysis is currently underway, and final reports are due to be published in 2006 and 2007 (NPS, n.d).

In addition to the WACAP study, the USGS is currently studying the water quality of Wonder Lake. The goal of this study is to try and determine if increased human use at and adjacent to the Wonder Lake campground has degraded water quality. During 2006, Wonder Lake was sampled three times each at three locations on the lake. The surface was sampled for *E. coli* bacteria; other samples were taken at one-meter depth and one-meter above lake bottom for the following parameters: chlorophyll a, dissolved organic carbon, major ions, and nutrients. In addition, this study included the sampling of snow

near the lake in late winter for an analysis of semi-volatile compounds and trace elements. These data will supplement the WACAP study.

At Wonder Lake, the *E. coli* sampling resulted in zero counts for all locations, and nutrient levels were extremely low at all locations (Tim Brabets, USGS, personal communication, 2006). These results indicate that human activities at and near Wonder Lake are likely having little impact to the water quality.

Sampling for the *Giardia lamblia* cyst was conducted by Saltonstall (1988) in an effort to determine if the presence of *Giardia* could be confirmed within Denali National Park. Saltonstall sampled both water from the Jenny Creek watershed, and feces from animals and humans throughout the park. Two of the nineteen water samples, both from a beaver pond, had detectable *Giardia* cysts. Additionally, five of the fecal samples were positive, including three caribou samples and two ground squirrel samples. Saltonstall noted that an association between *Giardia* and beaver was common; however, his study was the first finding of caribou carrying *Giardia* cysts.

Surveys of fishery resources and water quality were conducted in Denali during the summer of 1981 (Miller, 1981). Fish were found to be present in 22 of the 26 stream examined. Arctic grayling (*Thymallus arcticus*) had the widest distribution of all fish species found, which included Dolly Varden, lake trout, king salmon, and slimy sculpins.

Schalk et al. (2001) researched methods to delineate floodplains and assess erosion potential on large braided river systems in Denali. Cross-section data from the Toklat and Teklanika Rivers were used to construct hydraulic computer models to estimate flood depths, degree of inundation and water surface profiles. The authors noted that due to the high rates of hydrologic activity associated with large, braided rivers, and the presence of highly erodible banks that are found on this stream type, accurate bank erosion predictions are difficult to determine.

In response to the need for a replenishable source of gravel, the National Park Service conducted a study to provide a comprehensive analysis of the fluvial processes that occur near and in an alluvial floodplain gravel removal site (Karle, 1989). The report identified the hydraulic characteristics unique to braided rivers, and described the hydrology of the Toklat River basin.

In a companion study, the U.S. Geological Survey monitored the movement of bed material in the Toklat River (Emmett et al., 1996). Bedload sediment was sampled and measured using a handheld bedload sampler; median bedload size was about 8 millimeters, and transport rates ranged from less than 10 to nearly 3000 megagrams per day. As transport rates increased, mean and maximum sizes of bedload tended to increase.

Additionally, the authors used radio transmitters placed inside coarse sediment cobbles to track the rate of downstream movement of bedload in the Toklat River (Emmett et al., 1996). Radio-tagged particles moved distances between about 500 and 2,000 meters

during a 6- to 8-week period of high flow. The authors reported that most particle movement occurred during the first few days of submersion in water; after that, the particles tended to get abandoned on the floodplain or deposited and buried underneath other bedload.

Hydrologic data collection, and specifically stream gaging data, has been deficient in Alaska in general, and in Denali in particular. The only programmatic stream gaging measurements were conducted by the U.S. Geological Survey on the Teklanika River. Ten years of daily discharge measurements are available, from 1965 through 1974. Several years of stream gaging data were also obtained by NPS, as part of the Long-Term Ecological Monitoring Program. A gaging station was located on Rock Creek, and was operated only during the summer months.

Based on extensive fieldwork conducted from 1997 through 2002, a comprehensive effort to describe and map the soils of Denali National Park and Preserve was completed and published in 2003 (Clark and Duffy, 2003). Area soils were mapped at a scale of 1:63,360 and detailed descriptions of map units, soil types, and Landtypes, including potential natural plant communities and major seral communities, are included in the report. Based on an ecological stratification of the area, general maps and descriptions of park and preserve resources were created. Also included are oblique landscape diagrams showing typical soils and vegetation of the various regions of the Park and riverine illustrations displaying soils, parent materials, vegetation and hydrology of several riverine map units.

4.2 Long-Term Ecological Monitoring

Programs Past and Present

In 1992, the National Park Service began to develop prototype long-term ecological monitoring (LTEM) programs in selected parks representing major biogeographic regions within the United States. Denali was selected as one of the first four parks in the prototype program, and was chosen as the testing ground for the Subarctic Biogeographic Association, in which most of the national parks in Alaska are found. The original design of the Denali LTEM program centered on a watershed approach, and much of the monitoring effort was focused in the Rock Creek Watershed, located near park headquarters. Several of the studies described below were funded directly through that program.

In 2002, the LTEM program was dissolved and integrated into the NPS Inventory and Monitoring Program, as part of the Central Alaska Network (CAKN). CAKN is composed of Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. The general focus of the CAKN program is to monitor ecosystems in order to detect change in ecological components and in the relationships among the components. To accomplish this, the network has selected 37 'vital signs' for monitoring; of these 37 signs, nine relate to physical drivers (e.g., air, soil, water disturbance), six relate to vegetation (e.g., exotic species, vegetation structure,

plant phenology), fifteen relate to animals (e.g., freshwater fish, ptarmigan, caribou, macroinvertebrates), and seven relate to ‘near field’ human drivers (e.g., human populations, human presence, and consumptive uses of resources) (NPS, n.d.(c)).

In terms of water resources, the CAKN program has identified the following vital signs to be monitored: 1) the abundance, water quality, and size of shallow lakes and ponds 2) macroinvertebrate communities of shallow lakes and ponds, and 3) trends in flow and flood dynamics of rivers and streams. Protocols are currently being developed for the first two vital signs, and are scheduled to be developed for the third at a later date (MacCluskie and Oakley, 2005).

Program Studies

Thorsteinson and Taylor (1997) described the conceptual model used to design the LTEM watershed approach to long-term ecological monitoring in Denali. The authors noted that, though not all ecosystem attributes are captured within watershed boundaries, those boundaries are easily defined by soil, vegetation, topographic, and hydrologic conditions. Thorsteinson and Taylor noted that Rock Creek was selected as the primary study area because of several reasons, including: (1) existing data from previous studies; (2) representation of Denali’s environmental-elevational gradient for vegetation and successional patterns; (3) existing monitoring infrastructure; and (4) accessibility. The authors presented an example of integrated monitoring, in which the timing of peak spring hydrologic flow is correlated indirectly to key biological events such as first nest fledging.

One of the studies funded through the Denali LTEM program investigated the relationship of stream water quality to the stream productivity in a small second-order watershed. By sampling water chemistry, nutrient status, retention of organic matter, and primary production, Popovics (1999) determined that phosphorus is the limiting nutrient of the Rock Creek system. Popovics also noted that physical factors such as limited organic matter retention, increased stream discharge, and unstable channel morphology characteristics are more significant in acting to limit the productivity of Rock Creek.

Roberts and Milner (1998) reported on the effectiveness of aquatic macroinvertebrates as monitoring tools, as they provide an integrated reflection of the geology, water source, and terrestrial vegetation of the watershed. Using macroinvertebrates, the authors used TWINSPLAN classification of 58 river sites, sampled three times during 1995, to identify 8 groups of distinct rivers. Correlation with physicochemical variables indicated that nutrient chemistry and channel stability were the most significant variables in river classification. Studies in 1996 of longitudinal variations within 11 rivers from 6 of these groups showed that between river variations were greater than within river variation. A multivariate predictive model was developed which will predict the community assemblage of a particular stream in Denali (Conn and Milner, 1999).

Following that study, Milner et al. (2006) examined macroinvertebrate communities for biological monitoring in Denali National Park, Alaska. Macroinvertebrate communities

were studied from 1994 to 2002 (except 1997) in six 'reference' streams in Denali with no known degradation. Among other findings, they noted that abundance of individual taxa varied markedly from year to year. Overall, abundance decreased over the study period, particularly with respect to mayflies. Stonefly taxa showed lower persistence and were sometimes absent from a stream in any particular year. Assemblage persistence between years was higher in more stable streams and was found to be significantly correlated with low total snow cover over the winter. This finding infers that high snow cover in the spring leads to high flood peaks that have a major effect on macroinvertebrate persistence (Milner et al. 2003). The authors note that there exists a wide range of natural variation in benthic macroinvertebrate communities in pristine Denali streams; this large natural variation limits the applicability of composition metrics for the biological monitoring of water quality in these systems.

Karle (1997) compiled protocols for the sampling and analysis of aquatic systems for the park's LTEM program. Included in the report are protocols for assessing stream morphology and hydrology, sampling water quality, and measuring water quantity. Karle and Sousanes (2000) described the use of stream channel reference sites to monitor water quality and geomorphic parameters as part of the park's LTEM program. They noted that Rock Creek is a highly buffered system, with a strong negative correlation for ion concentrations and discharge. The authors also provided channel morphometry data, and described Rock Creek as steep, entrenched, and confined, with low sinuosity and with unconsolidated, heterogeneous, noncohesive channel materials.

This shortened paper was based on a comprehensive report by Karle (1998), which included five years of data and explanations of study sites and methods. Other studies also looked at water quality in the Rock Creek watershed. For example, Hanneman (1993) sampled for heavy metals and noted that high alkalinity concentrations appear to be precipitating heavy metals, thereby decreasing dissolved metal concentration in stream water.

As part of the NPS Inventory and Monitoring Program, a freshwater fish inventory was conducted in the CAKN between 2001 and 2003 (Markis et al., 2004). The purpose of this inventory was to document 90% of the expected yet undocumented species, and to collect baseline data of species abundance and distribution. A secondary objective of the inventory was to provide initial descriptions of the distribution, abundance, and biologic characteristics of the freshwater fish species present in the CAKN. Additionally, a list of expected yet undocumented species was created for each park unit, based on the fish communities of adjacent watersheds. Six previously undocumented species were documented in Denali:

- inconnu (*Stenodus leucichthys*)
- longnose sucker (*Catostomus catostomus*)
- northern pike (*Esox lucius*)
- Alaska blackfish (*Dallia pectoralis*)
- Arctic lamprey (*Lampetra camtschatica*)
- humpback whitefish (*Coregonus pidschian*)

As part of the original Denali LTEM Program, a glacier monitoring effort was initiated in 1991. Monitoring efforts began with single point index site measurements on three glaciers in Denali National Park and Preserve: Traleika, Kahiltna, and Kichatna. This method, adopted from USGS, involved visiting an index site twice per year to measure mass balance, volume change, and rate of ice flow. The program subsequently expanded through the next 10 years, in cooperation with the USGS and the Geophysical Institute at the University of Alaska-Fairbanks, and is now incorporated into the CAKN Vital Signs monitoring program. It currently includes a number a techniques and methods to monitor and map glaciers in Denali, including:

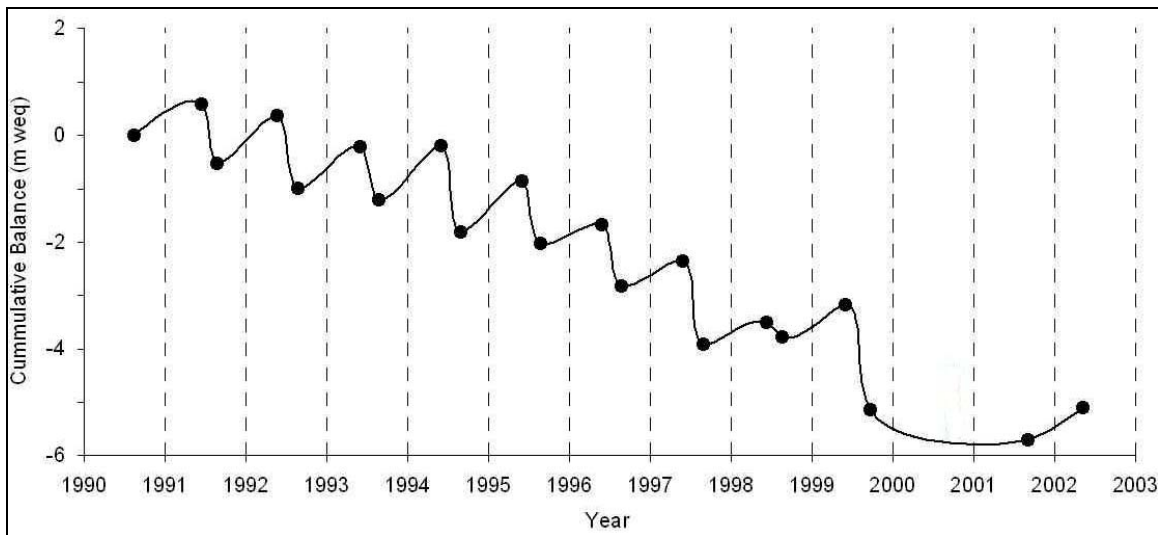
- index site measurements
- GIS-derived glacier inventory
- terminus surveys
- longitudinal surveys
- radar depth measurements
- Muldrow glacier outflow monitoring
- photo-point documentation
- glacier movement surveys
- glacial landform mapping
- surging glacier monitoring

Some preliminary analyses have been conducted, based on these monitoring efforts. For example, two index monitoring sites are still maintained in Denali, on the Kahiltna glacier (south side of the Alaska Range) and on the Muldrow glacier (north side of the Alaska Range). Since monitoring began in 1991, the Kahiltna glacier index site has had a slightly positive mass balance and a variable velocity that ranges from 180 to 250 meters per year. Seasonal balances are on the order of +/- one meter of water equivalency per year. During the same time period, the Traleika glacier has shown a consistently negative mass balance within a slightly narrower range of seasonal balances (Figure 3). Interestingly, the surface altitude of the index site has been increasing steadily despite the period of negative mass balance. Since 1991, the Traleika glacier has flowed at a rate between 20 and 70 meters per year (Adema et al., 2003).

4.3 Kantishna Hills Studies

Water Quality

Resource studies of the Kantishna Hills Mining District were mandated by the ANILCA legislation. NPS, along with many other agencies, conducted these studies over a six-year period, from 1979 to 1985. For water resources alone, twenty technical reports and many trip summaries were generated during that time period. Deschu (1985a) compiled a summary of the water resource reports for the Kantishna Hills. Each report is summarized in 2 or 3 pages; the reports range in topics from the hydraulic characteristics of streams to aquatic insect emergence.



**Figure 3. Cumulative mass balance at the Traleika Glacier index site (Adema et al., 2003).
Data is missing for Year 2000.**

Deschu (1985b) studied arsenic concentrations in water, sediment, and benthic fish in two placer-mined streams (Caribou Creek and Glacier Creek) and two unmined streams (Moonlight and Myrtle Creeks) in Denali over two mining seasons. The data was collected during 1983 and 1984. Findings showed that suspended sediments, introduced by mining and associated with total arsenic by adsorption, were transported up to 35 kilometers downstream from the study reaches.

Deschu noted that arsenic in stream sediments varied greatly among sample sites in the Kantishna Hills; this variance corresponded with variations in the mineralization of the underlying geologic structure more so than sediment loading from mining. However, placer mining did increase the concentration of instream arsenic. Sculpins from mined streams contained a higher mean arsenic burden in their livers than sculpins from unmined streams (Deschu, 1985b).

Several studies also looked at the effects of placer mining on the available concentration of heavy metals in the Kantishna area. West and Deschu (1984) concluded that a major problem on mined streams is the high level of heavy metals in the stream, as a result of adsorption onto settleable solids in the stream from mining. They also noted that arctic grayling in mined streams generally exhibited higher metals concentrations and liver and gill cellular abnormalities than fish from unmined streams.

Deschu and Kavanaugh (1986) noted that certain heavy metals (antimony, arsenic, lead, mercury, and iron), settleable solids, and turbidity significantly impact the water quality and fish habitat of several mined streams, while unmined streams supported fish populations and presented acceptable water quality.

In addition to water quality studies, research was conducted in the Kantishna Hills to document the presence and abundance of fish species (Meyer and Kavanaugh, 1983). Their study indicated that placer mining had extensively altered riparian vegetation and aquatic habitat on at least 15 streams in Kantishna; alterations included the removal of riparian vegetation, processed stream gravels, channelization, straightening, channel diversion, extremely high sedimentation and turbidity, litter, settling ponds, and other barriers to fish movement. Meyer and Kavanaugh noted an inverse proportional relationship of grayling abundance to aquatic habitat alterations from mining. Additionally, they found that steep unmined streams generally did not contain fish, due to insufficient cover and poor feeding habitat.

Oswood et al. (1990) investigated the effects of mining disturbances on macroinvertebrate abundance, taxonomic richness, and trophic structure. That study concluded that, in the Kantishna Hills, decreased algal abundance, moss abundance, and invertebrate abundance were all clearly associated with mining disturbances. However, they also found that biotic systems in mineralized but unmined streams may also be impacted by heavy metals.

Van Maanen and Solin (1988) looked at possible changes to channel morphology and streambed composition from mining activities in the Kantishna Hills area. They noted that no major differences in stream channel configuration characteristics were detected between mined and unmined basins over the 1983 study year. However, they did note that particle count data indicated that the average mean particle size tended to be finer in mined drainage basins (34 mm) compared to unmined basins (65 mm).

Several individual data collection projects also occurred during the 1980s and 1990s; though they did not lead to publications or reports, the datasets are still available. For example, Deschu recruited a research geomorphologist to measure stream channel characteristics at six sites in the Kantishna Hills in 1986 (Emmett and Deschu, 1986). The data collected included discharge, channel geometry, water temperature, suspended sediment, and bedload. Similar data were collected at thirteen sites in 1989 by Emmett and a co-worker (Emmett and Averett, 1989).

Stream Restoration

Techniques for the hydrologic restoration of placer-mined streams and floodplains were developed in Kantishna and described by Karle and Densmore (1994). This study described the design of channel geometry using hydraulic capacity and shear stress equations for a 2-year project on Glen Creek. The authors also described the need to dissipate floodwater energy on newly constructed floodplains by constructing alder bundles adjacent to the channel. A small flood near the end of the project provided data on channel design, stability, and floodplain erosion.

A companion paper described the revegetation techniques used on the project, and the effects of the flood on the streamside vegetation (Densmore and Karle, 1997). Karle et al. (1996) examined the streambed stability and structure, and macroinvertebrate density

and diversity before, during, and after the Glen Creek restoration project, in an effort to describe and quantify temporal changes to those systems due to the restoration activities. They noted an increase in sediment fines during channel disturbances, and low numbers and diversity of macroinvertebrates before and during restoration. Two years after channel construction, streambed stability improved and the percentage of fines in the streambed decreased. The authors concluded that restoration activities resulted in only short-term deleterious conditions, and the rapid improvement in stream conditions suggested that the short-term disturbances attributable to channel restoration were justified.

Based on nine years of cross-section surveys at the Glen Creek project site, Karle and Densmore (2001) reviewed the original hydraulic design process, and described changes to the channel and floodplain geometry over time. They noted that their original estimates for new floodplain revegetation were accurate in areas where remnant topsoil and organic overburden materials were still available for use during construction. However, the use of the alder brush bars proved to be ineffective against large bed and bank shear stresses during high water events, even at the closer spacing of one channel width. The low critical shear stress of a non-cohesive, unvegetated gravel bank requires that substantial and continuous bank stabilization, such as willow brush layering, be used during stream channel reconstruction. Additionally, it is important that hydraulic design calculations be as accurate as possible, and attempt to account for all possible conditions that may be encountered during field construction.

Karle (2000) described the stream restoration program at Denali, and listed the project sites to date. He described the Caribou Creek restoration project, and outlined the watershed based approach for future stream restoration projects at the park.

The use of macroinvertebrate sampling to evaluate the short- and long-term effects of stream restoration methods was reported by Major (1996). In that study, benthic samples were collected on a restored stream in Kantishna, as well as a control stream. Major reported that macroinvertebrate numbers were low throughout the restoration period, but densities and diversity improved after restoration was complete and the stream channel stabilized. However, researchers could not distinguish between restoration activities and natural recovery as the cause for macroinvertebrate recovery.

SECTION 5.0

EXISTING WATER RESOURCE CONDITIONS

Once water resource goals are established, park managers should assess existing conditions, using the values defined for achievement of the water resource goals. Accurate assessments can only be made if adequate information is available. As noted earlier, Denali National Park and Preserve has a limited database of its water resources. As a result, there is a basic lack of a holistic understanding of the park water systems. However, a preliminary discussion of the current water resource conditions can be based on a number of discrete and narrowly focused studies and measurements conducted in the park during the past twenty years or so. Until a comprehensive baseline inventory of current water resource conditions is achieved, understanding water resource ecosystems, and the threats to those ecosystems, will be restricted to simple and apparent issues.

The initial steps to meeting the water resource goals for Denali National Park and Preserve are to:

1. assess the conditions of the fundamental water resources, based on available data,
2. identify and analyze any management issues that are impediments to meeting the water resource goals, and
3. identify data gaps and additional studies necessary for understanding the existing conditions of the fundamental water resources.

A thorough park-wide quantitative assessment of the fundamental water resources is not possible, due to the lack of a comprehensive data base for water quality, stream discharge, lake levels, or visitor use levels. However, the perception is that, for the vast majority of the park, the existing conditions of the water resources are in an undisturbed and pristine condition. This is due to a number of reasons:

- Most DENA streams and rivers originate in the park, and flow either north or south from the Alaska Range. Because the headwaters are protected, upstream sources of contaminants from non-NPS actions, common to other natural areas in the lower 48 states, are virtually non-existent here.
- Park infrastructure and visitation has been focused on the East entrance area, and a single gravel road that runs 90 miles into the park interior. As such, the lack of physical non-natural disturbance on and near most lakes, ponds, wetlands, and stream/floodplain complexes has prevented changes to the functional morphology.
- Climbing activities have focused on just a few of the numerous glaciers in Denali; most glaciers are rarely, if ever, visited by climbers. Water quality and litter impacts are essentially limited to one or two staging areas on the Kahiltna Glacier.

- Without large-scale border industrial activity that requires substantial fresh water or produces large wastewater quantities, the only impacts to the subsurface aquifers in and around the park have been small and localized.
- To date, the State of Alaska has not successfully asserted ownership of any waterbody within Denali National Park and Preserve.

Within the largely undeveloped setting of Denali, areas of development and related impacts to the fundamental resources do exist, primarily due to management action (or inaction). Those impacts, both existing and potential, are described in Section 6.

5.1 Streams and Rivers-Water Quality

Based on a number of stand-alone water quality projects conducted over the past 20 years throughout several distinct areas of the park, a qualified assessment can be made of the existing conditions of the water quality of Denali's waterbodies. The constituents that have been measured include: water temperature, dissolved oxygen, fecal coliform, turbidity, pH, macroinvertebrate and fish communities, water chemistry (including nutrients and metals), total sediment yield including bed load, levels of chemicals in bioassays, change in trophic status. For the vast majority of the park, the existing condition of waterbody water quality meets the water resource goals for water quality.

The most comprehensive attempt to measure and characterize surface water quality throughout the park was conducted during the mid 1990s (Edwards and Tranel, 1998). Water samples were collected from 91 sites on 62 rivers and streams, both clear and glacier-fed. Field measurements and laboratory analyses were performed for pH, electrical conductivity, total dissolved solids, dissolved oxygen, temperature, major ions, nutrients, dissolved organic carbon, alkalinity, turbidity, suspended sediment, and discharge (Figure 4).

The results from the water chemistry analyses and accompanying statistic tests indicate that the water quality of these waterbodies is good. For example, most pH values were in the pH 7.51-8.00 range (Edwards and Tranel, 1998). Sites on the North side of the Alaska range had a mean pH of 7.77; the pH of sites on the South side averaged 7.00.

Differences between north and south side sites were also found in the alkalinity concentrations. South side alkalinity sites averaged 22.8 mg CaCO₃/L; streams on the north side were much more strongly buffered, and averaged 112.7 mg CaCO₃/L. Generally speaking, a well-buffered system will resist quick and dramatic changes to the pH of the water from sources such as atmospheric acidic deposition.

Turbidity is another commonly used indicator of water quality. It quantitatively describes the cloudiness of the water; high turbidity levels are generally related to soil runoff. Turbidity measurements from the Edwards/Tranel study were well within expected ranges throughout the park. For example, north-side glacier fed rivers, such as the East Fork River, had a mean turbidity of 258 NTU; south-side glacier fed rivers had a

mean turbidity of 79 NTU. Turbidity measurements for those rivers reflect the high suspended sediment loads common in glacier fed systems. The turbidity values for the North-side clearwater streams (mean = 21 NTU) and south-side (mean = 15 NTU) were slightly above the typical range for clear water rivers in Alaska, which generally have turbidities of less than 10 NTU (Milner and Oswood, 1997).

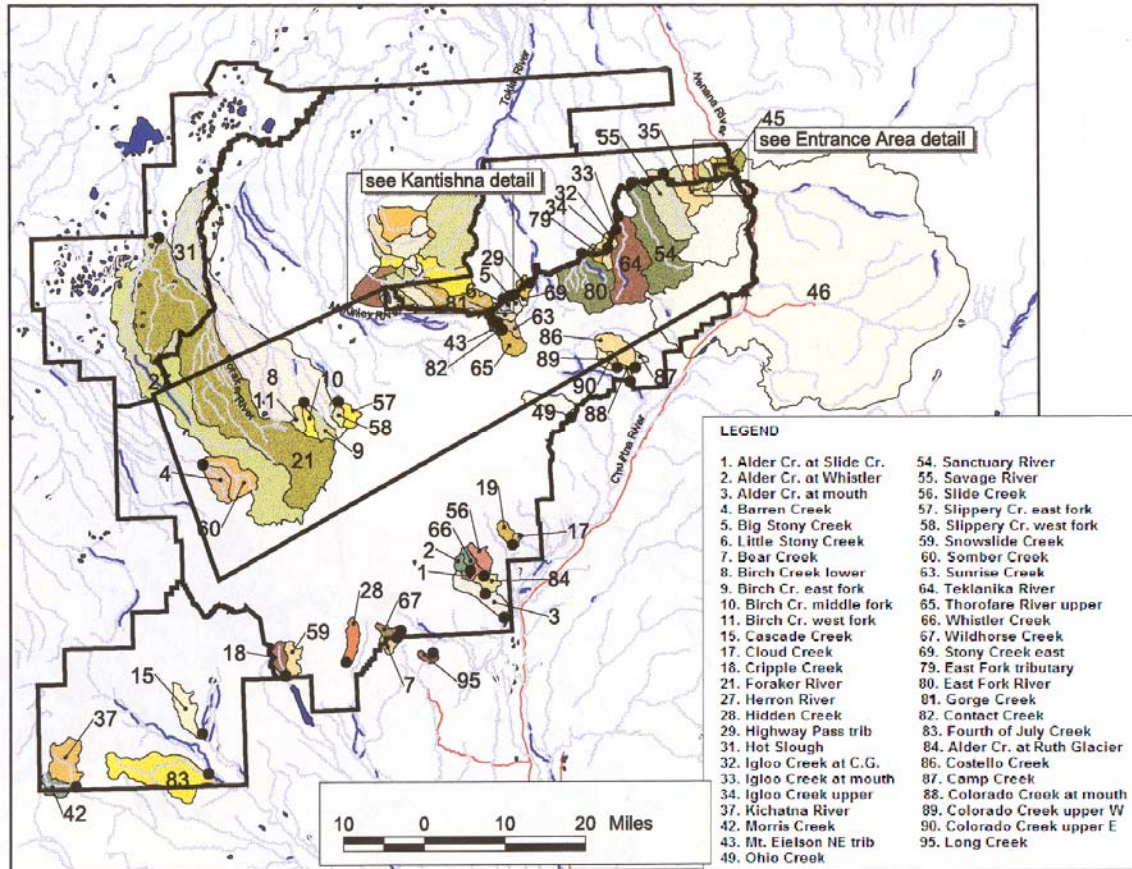


Figure 4. Sampling sites for the Edwards and Tranel water quality study.

Dissolved oxygen is an important water quality variable for aquatic life. There are two main sources of dissolved oxygen in stream water: the atmosphere and photosynthesis. Oxygen readily dissolves into cold water up to a saturation point through the actions of waves and tumbling water. Additionally, oxygen is introduced by aquatic plants and algae as a byproduct of photosynthesis. All dissolved oxygen values measured for the Edwards/Tranel study were at or close to saturation values for fresh water. The measured values of water temperature and dissolved oxygen values are sufficient for fish growth and activity.

In several areas of the park, organic and other pollutants have been noted. For example, the USGS conducted water chemistry sampling on three South Side streams that are near or receive runoff from the Dunkle Mine, an abandoned lignite coal mine that was active primarily from 1940 to 1954. Several semi-volatile organic chemicals (SOC) that are typically associated with coal tar or coal gas were detected in the creeks (Frenzel and Dorava, 1999), along with relatively high concentrations of trace-elements, including

arsenic, chromium, and nickel (Frenzel, 2000). Streambed sediment concentrations of chromium and nickel may be indicative of the area's metamorphic and igneous bedrock geology (Frenzel, 2002). Though high potential toxicity from trace elements is indicated at several South Side streams, no concomitant biological data were collected to verify whether toxicity actually exists (Frenzel, 2002).

The USGS noted that SOCs result from both anthropogenic and natural sources, and trace elements are derived from natural sources. In mineralized areas where mining might occur, background levels of trace elements might be elevated. The USGS concluded through extensive sampling of water, sediment, and biotic concentration chemistry, and through evaluation of the macroinvertebrate populations, that there were no effects from the Dunkle Mine on water quality (Brabets and Whitman, 2004).

5.2 Streams and Rivers-Morphology

A thorough park-wide quantitative assessment of the existing conditions of this resource is not possible, due to the lack of data. However, the perception is that, because of the lack of physical anthropogenic disturbance on and near most floodplains, the existing physical conditions of stream channels and floodplains meet the water resource goal for functional morphometry for the vast majority of the park.

Based on a number of stand-alone channel/floodplain morphometry studies conducted over the past 20 years throughout several distinct areas of the park, a qualified assessment can be made of the existing conditions of the functional morphometry of Denali's streams and rivers. The values that have been measured include: surveyed cross-sections, slope, bed material, bedload material, and habitat descriptions. For the vast majority of the park, the existing condition of the functional morphometry of streams and rivers meets the water resource goal.

As part of the Long-Term Ecological Monitoring Program, stream morphology was monitored at two stream channel reference sites within the Rock Creek watershed near park headquarters. Channel morphometry measurements include measurements of three permanently monumented cross-sections at each sampling station, bed material size analysis, and channel profile measurements. Measurements were made approximately every 2 years. Surveys are plotted with X-Y pairs, showing station (distance from left bank) versus elevation.

At the lower sampling station, cross-section 1 shows patterns of both erosion and deposition. The thalweg has moved slightly toward the right bank (all cross-sections looking downstream) (Figure 5). Cross-section 2 shows similar patterns. These two cross-sections may represent a typically 'stable' channel. Channel stability does not imply lack of movement or change in the cross-section; stable channel geometry will change around a long-term average, involving erosion some years and deposition in others. Cross-section 3 shows significant sediment deposition in both the channel and near channel (Figure 5).

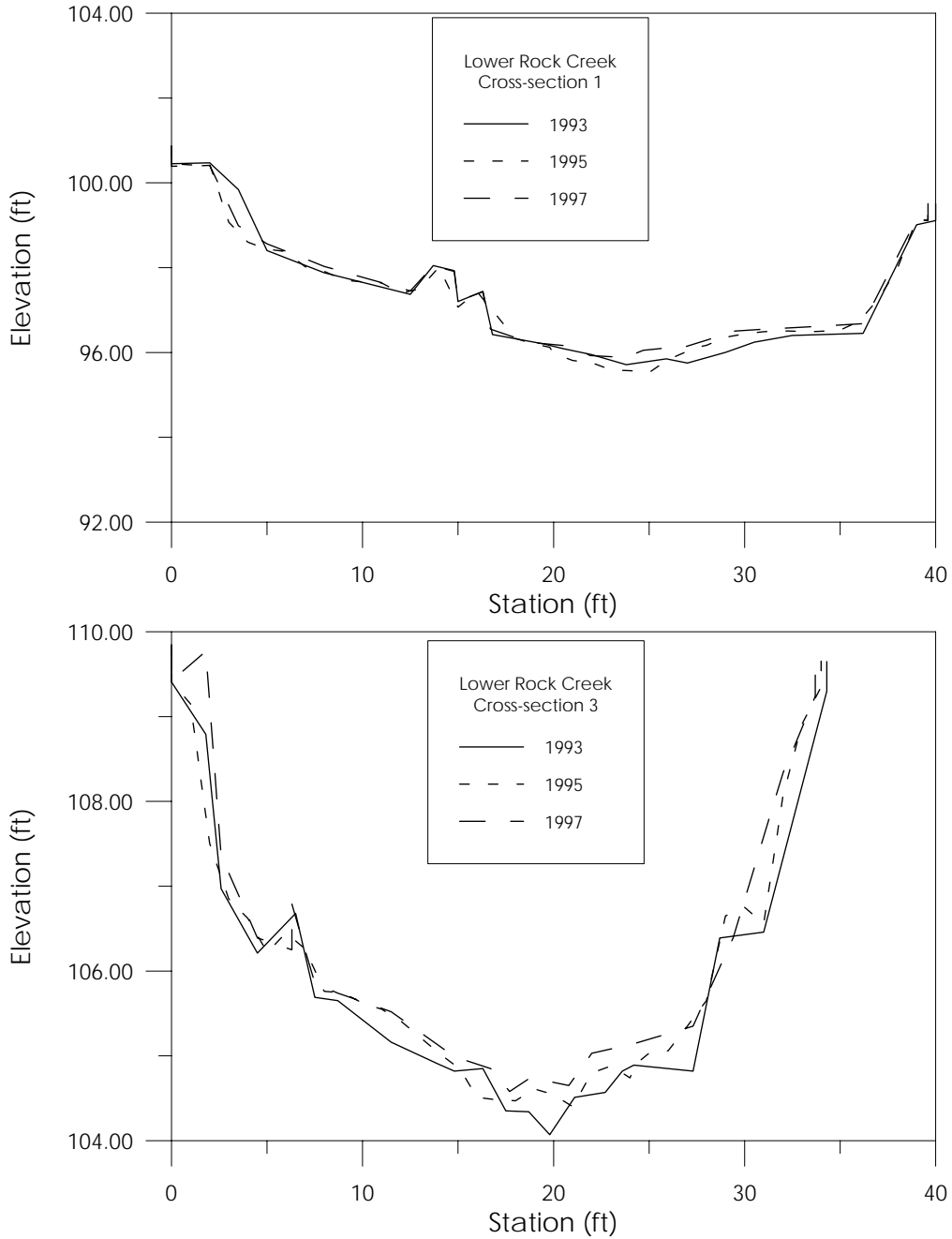


Figure 5. Cross-sections from Rock Creek, DENA Long-Term Monitoring Program (Karle and Sousanes, 2000).

A morphological analysis was conducted on five rivers in the Toklat Basin, as part of a larger study to document the hydrology of the Toklat Basin. Using basic cross-section survey techniques, all major features of the stream channel and floodplain for the East Fork, Toklat, Sushana, and Clearwater Fork Rivers and Wigand Creek at a potential road corridor crossing were measured and mapped. Based on measurements, observations, and numerical modeling, morphological descriptions were developed for the five rivers.

The East Fork and Toklat Rivers are both multiple-channel, or braided systems, and consist of interconnected distributary channels formed in depositional environments. The channel bed materials are predominantly gravels, with a mixture of cobbles, silt, and occasional boulders. Typical braided channel systems such as these two rivers are characterized by high bank erosion rates, excessive deposition occurring as both longitudinal and transverse bars, and annual shifts of the bed locations (Rosgen, 1996).

Bed location shifts have been noted by this author much more frequently upstream on the Toklat and East Fork rivers, often in the space of a month or less. The bed morphologies for both rivers are characterized by a closely spaced series of rapids and scour pools formed by convergence/divergence processes that are very unstable, though more pronounced in the Toklat River.

As mentioned before, the primary causes of braiding are an abundant sediment load, large and sudden discharge variations, erodible banks, and a steep gradient. Previous studies have shown that the presence of glaciers in a watershed, even in small amounts, can significantly modify the hydrograph from precipitation-dominated rivers (Anderson, 1970). The flow of glacier-fed rivers in Denali National Park and Preserve may be expected to steadily increase from early May to the middle of June, as snowmelt occurs. High flashy peaks in the hydrograph are often observed in July and August, and are due to a combination of warmer weather (glacial melt) and precipitation events (Karle, 1989).

Rosgen noted that width to depth ratios for braided rivers are very high, and may range from 40 to 400 or larger (Rosgen, 1996). Large width to depth ratios were noted for all surveyed cross-sections for this study for these two rivers. Emmett et al. (1996) noted very high sediment supply yields for both the East Fork and Toklat Rivers.

The Denali Park Road crosses Igloo Creek and runs parallel to it within the flood-prone zone through a 6.5 mile stretch in Igloo Canyon. Gravel berms were constructed years ago by NPS maintenance actions to reduce the annual flooding of the road; these berms have long been identified by resource managers as impediments to proper floodplain function in this area.

Another area of degraded existing conditions is the Toklat River, where a long gravel causeway connects two short bridges on either side of the wide braided gravel floodplain. The long causeway acts to restrict the natural flow patterns that would normally cross the wide floodplain; most of the flow is forced to the right bank of the river at this location, causing changes to the natural morphology of the wide channel both upstream and downstream of the causeway.

Rivers with disturbed channel/floodplain morphometry have been well-documented. These systems are the result of placer-mining operations or management actions, and are discussed in the next section.

5.3 Lakes and Ponds

A thorough park-wide quantitative assessment of the existing conditions of this resource is not possible, due to the lack of data. As mentioned earlier, there have been no comprehensive studies involving the measurement of typical water quality parameters on lakes or ponds in Denali since the Wonder Lake study in the 1970s (LaPerriere and Casper, 1976). Though that data is valuable for comparison purposes, it cannot be used to describe existing conditions.

Analysis is currently underway to determine the extent and types of long-range airborne contaminants in the bottom sediments of three large lakes. Previous studies have detected the presence of organochlorine compounds in the sediments of Wonder Lake, including polycyclic aromatic hydrocarbons (PAHs), dioxins, dibenzofurans, and polychlorinated biphenyls (PCBs). However, it is still unclear how these contaminants are impacting the biotic communities of the lakes.

Little is also known about the state of small tundra ponds in Denali. However, the CAKN network has noted concern regarding the apparent decline in water level in shallow lake ecosystems in Alaska over the past 20 years, including scientists, native elders and local people who have noticed a drying trend in shallow lake ecosystems throughout the CAKN parks (MacCluskie and Oakley, 2005). The CAKN report cites empirical evidence in Alaska that corroborates this trend and shows a dramatic decrease in lake surface area, which is most likely due to global climate change; the report also presents imagery showing the reduction of shallow lake surface water area in an area of central Alaska over a 50-year period (Larsen and Verbyla, 2004).

5.4 Groundwater Aquifers

A thorough park-wide quantitative assessment of the existing conditions of groundwater aquifers is not possible, due to the lack of data. However, the perception of the existing conditions is that, for the vast majority of the park, the water quality of most groundwater aquifers is good. This is due to the lack of industrial pumping activities, and a lack of threats to groundwater from contamination. Exceptions do exist, and existing conditions at several aquifers near developed areas of the park are poor. These areas are discussed in Section 6.

5.5 Glaciers

A thorough quantitative assessment of the existing conditions of glaciers is not possible, due to the lack of data. However, the perception of the existing conditions is that the vast majority of the park's glaciers are in relatively good condition. During the summer, large diurnal variations in discharge are commonly noted, especially on warm days, on glacially fed rivers such as the Toklat, East Fork, and McKinley Rivers. This indicates that glaciers continue to act as naturally regulated reservoirs of frozen water. The pristine condition of most glaciers is due to the lack of disturbance from human activities, and can

be attributed to their remote locations. Exceptions do exist, and existing conditions at several glaciers near developed areas of the park are poor. See Section 6 for details.

5.6 Wetlands

Some of the measurable parameters that indicate riparian and wetlands areas are in a properly functioning physical condition include: plant composition, age class distribution, and community structure; streambank/shoreline stability, watershed conditions of adjacent uplands, and frequency/duration of soil saturation. Results from an extensive soil survey and associated ecological site information provide a robust baseline to assess the existing condition of wetlands and riparian areas. For the overwhelming majority of the park, the existing condition of these areas meets the water resource goals.

Again, exceptions to the water resource goals are noted in the Kantishna Hills region of the park, where past mining activities have resulted in continued existing degraded conditions on some streams. These exceptions are discussed in Section 6.

SECTION 6.0

MANAGEMENT ACTIONS THAT IMPEDE WATER RESOURCE GOALS

It is important to note the difference between management issues that control or create degraded existing conditions, and non-management issues. For example, the water quality of large lakes in Denali is threatened by the contamination of long-range pollutants that are carried through the atmosphere. Similarly, the size, depth, and even very existence of small tundra ponds in Denali is threatened by global climate change. It is difficult to imagine a scenario where a change to the local, regional, or national NPS water resource management actions will help create the improvement of the existing conditions to water resource goals, at least for those values.

It is also important to note that of the 40 water resource issues listed in the Water Resources Information and Issues Overview Report, only a few may be directly responsible for impairing current and ongoing existing conditions (The Mangi Environmental Group, 2005). The vast majority of the issues do threaten the achievement and maintenance of water resource goals; however, either due to the lack of data or because the action/issue occurs in the future, these issues are not currently affecting or impairing water resource conditions.

6.1 Issues Currently Affecting Fundamental Water Resources

6.1.1 Management of Park Infrastructure

Some NPS infrastructure management activities have led directly to the degradation of Denali's water resources. Such situations are often the result of conflicts that arise when the requirements to provide safe and efficient facilities for a large visitor influx conflict with other requirements to preserve and protect the water resources of the park.

- Floodplain modification has recently occurred along the left bank of the Toklat River downstream from the Denali Park road bridge. To protect the NPS Toklat road camp infrastructure constructed on or near the left bank, the NPS installed steel sheet pile along the left side in the active gravel channel, from the west Toklat bridge to a point downstream of the new gravel processing area. This sheetpile has effectively and artificially prevented the lateral migration of the channel along the left bank, and has unknown effects on the downstream hydraulic stability of the channel.
- Since 1992, the NPS has been mining gravel from the active gravel floodplain of the Toklat River in an area adjacent to the Toklat Road Camp. Based on studies conducted jointly by NPS and the USGS, the NPS set an annual limit of 7,500 cubic yards of gravel, which was estimated to represent about 5 percent of the annual bedload of the Toklat River. Desires by the NPS to increase gravel extraction quantities led to an additional study in 2000, and a subsequent increase

in the upper annual extraction limit of 11,000 cubic yards. Included in the 2003 Gravel Acquisition Plan, which describes and justifies these actions, is an NPS Floodplain Statement of Finding for the floodplain gravel extraction plan. As a condition of the gravel extraction program, the NPS committed to conducting annual cross-section surveys across, above and below the reach of river where the gravel mining occurs, and analyzing the data to determine if the gravel mining is creating degraded conditions by adversely altering the channel's natural morphology. However, as of this writing, cross-sections have not been surveyed and analyzed since 2001. Therefore, the NPS is unable to evaluate the effects of the management decisions on the functional morphology of the Toklat River.

- The park's existing NPS-operated wastewater system, an aerated lagoon system with a percolation basin, is currently not in regulatory compliance with State of Alaska regulations, and is impairing water resource goals for groundwater. Groundwater nitrate concentrations measured in the aquifer exceed state limits, in some monitoring wells by up to 5 times the allowable level. In addition to the summer system, the park's winter wastewater system does not meet ADEC requirements. The park has entered into a bi-lateral agreement with the Alaska Department of Environmental Conservation to implement a plan of action to achieve compliance (The Mangi Environmental Group, 2005).
- A number of heating oil spills, many related to leaking underground storage tanks, have occurred in the developed areas of the park, including the old park hotel, and the headquarters/seasonal housing area. These spills have resulted in the contamination of local aquifers, and have led to some sampling and data collection. Groundwater characteristics have been sampled at a number of sites, both by the USGS and NPS, and existing measurable values (water level and water quality) may be used to assess the existing conditions.
 - a. Groundwater near the old Park Hotel has high levels of diesel range organics contamination (DRO).
 - b. Groundwater at several locations at the C-Camp residential area show exceedance levels of DRO, benzene, solvents, and gasoline range organics.
 - c. Groundwater at Buildings 51/54 in the Park Headquarters area has floating petroleum product.

Based on these data, existing conditions of aquifers at several locations may be described as degraded, though the extent of the contamination beyond the monitoring wells is unclear (The Mangi Environmental Group, 2005).

6.1.2 Other Park Management Issues

- Placer Mine Restoration-Because of the extensive amount of placer mining that occurred in twelve drainages of the Kantishna Hills, many of the streams have suffered severe disturbance to the channel and floodplain. Placer mined streams

are characterized by significant stream adjustments, unstable banks, confined streambeds, and non-functional or non-existent floodplains (Figure 6). On several streams, the vegetative cover on channel banks and adjacent wetland areas is minimal or non-existent, and is inadequate to capture sediment and promote floodplain vegetation development. As a result, the lack of floodplain vegetation results in continued erosion during high flows. Riparian vegetation is also absent for wildlife habitats, stream shading, aesthetic values and other ecosystem functions. Inattention to the restoration needs in Kantishna has resulted in continued degraded conditions for stream channels, floodplains, and water quality in Kantishna.



Figure 6. Typical existing conditions for stream channel and floodplain disturbed by placer mining.

For example, two streams in Kantishna continue to be listed on the State of Alaska's Category 5 Section 303(d) listing (ADEC, 2006a). Sixteen miles of Caribou Creek and two and one-half miles of Slate Creek are listed as impaired waterbodies within Denali National Park and Preserve. The water quality standard causing the listing is turbidity, as a result of placer mining.

Still unresolved is the issue of whether water quality in Kantishna is currently degraded by high heavy metals concentrations. Though studies conducted during mining activities in the early 1980s raised concerns about high levels of trace and heavy metals in water and higher metals concentrations and liver and gill cellular abnormalities in fish (Deschu and Kavanaugh, 1986), essentially no sampling of those metals has occurred in the past twenty years.

With this lack of data, it is impossible to determine if heavy metals still degrade the water quality in Kantishna's previously mined streams. In fact, Edwards and Tranel (1998) noted that high pH values observed during their 1994-1996 Kantishna sampling effort suggest that dissolved trace and heavy metals are not present in high concentrations. Even if sampling reveals high metals

concentrations, additional analysis will be required to determine whether or not such concentrations are the result of past mining or natural background conditions. For example, Oswood et al. (1990) noted that biotic systems in mineralized but unmined streams in the Kantishna Hills may also be impacted by heavy metals.

Stream restoration efforts, including long-term research and individual projects, have been occurring since 1991. However, the funding for such projects has generally come from outside funding sources, such as the NPS-WRD and NPS-GRD project funding programs. Though progress has been made in the past, and an Environmental Assessment to conduct such restoration was completed in 2000, the park still lacks a coherent, well-organized plan for acquiring funding and conducting restoration projects.

- Glaciers-The Kahiltna Glacier is heavily used as a landing strip and camping/staging area for hundreds of climbers hoping to ascend Mt. McKinley each spring. This creates a concentrated amount of human waste in one small area near the base camp at 7,000 feet. In the recent past, pit toilets for outhouses have been dug to a depth of 15 feet or so near the camp for climbers to use. Climbers are required to carry and use small toilet containers (Clean Mountain Cans) above 17,200 feet; below 17,200 feet, climbers are required to use the NPS pit outhouses, or to dispose of human waste in a deep crevasse, using a biodegradable bag.

Observers have noted, however, that human waste is often found in the snow adjacent to camps; such behavior is probably due to the difficulty of carrying waste to a deep crevasse or using the CMCs at high altitude. At lower elevations, glacial meltwater can expose and carry bacterial contamination from the waste. Even at higher elevations, high winds can spread feces onto the top layers of snow, which is source of drinking water for climbers who need to keep hydrated during the average 2 1/2 weeks on the mountain (ADN, n.d.).

Generally, the climbing season ends before the deep pit waste is exposed by melting snow and ice; new snowfall buries the used pit, and the process is repeated annually. In 2005, for the first time, the pit toilet was visible in an August flyover of the glacier. Surface exposure of human waste threatens the water quality in the area downstream of these pits, and may have serious health implications for glacier users.

- Lack of Hydrologist Position-Since April 2002, the park has been without a hydrologist on the resource management staff. From 1989 to 2002, the park maintained a hydraulic engineer on staff to perform many water resource duties. The duties for this position, which was funded as a seasonal subject-to-furlough position, included the following:
 - conducting the stream restoration program

- long-term monitoring of stream channels and water quality
- gravel extraction monitoring at the Toklat River
- bedload studies for rivers considered for use as gravel extraction sites
- coordination with outside water resource investigators such as the USGS
- floodplain delineation
- wetlands issues
- others

This position is critical to the mission of achieving and maintaining the park's water resource goals. A few of the duties listed above have subsequently been assigned to other staff as secondary duties; most have been dropped altogether.

6.2 Management Issues-Potential Impacts To Water Resource Goals

In addition to management actions that are clearly and actively impairing water resource goals, there are many issues, of immediate or future management concern, that will likely pose impediments to achieving the goals of several park water resources.

Effects of transportation infrastructure on stream channel and floodplain function

The Denali Park road crosses numerous streams and rivers, using bridges and culverts. Channel constriction from bridge construction can lead to severe changes to the stream geometry and morphology, by limiting the area available for water to flow during high water flow events. As high water flows through the constricted opening, the velocity increases, which can lead to local scour and downstream deepening of the channel.

Other impacts include increased water velocities, channel scour, upstream channel widening, and loss of wetlands and riparian zones. Constrictions caused by short bridge spans and culverts can block the movement of fishes by creating excessive water velocities during high flows. Bridges and culverts can result in habitat degradation that leads to fragmentation of large habitat areas.

Additionally, roads in the park have the potential to convey hydrocarbons and other toxic materials from accidental spills into the water column of adjacent streams and lakes. In addition to short-term effects such as fish killoff, such toxic chemicals often persist in streambed sediments, producing long-term effects.

Impacts From Lack of Floodplain Delineation

NPS management inaction threatens other floodplain water resource goals. NPS Director's Orders 77-2 require identification of the floodplain areas within the park and an inventory of the existing and proposed structures and facilities. Floodplain delineations have not been conducted for streams and rivers in DENA, except for the Toklat and Teklanika Rivers. As such, existing developments on the Sanctuary and East Fork Rivers, and proposed development actions, such as a bridge over Riley Creek on the

relocated Triple Lakes trail, and gravel acquisition from the Teklanika River, have occurred or will occur without the benefit of a floodplain delineation.

Moose Creek is another area where the lack of a floodplain delineation may threaten future stream channel and floodplain functions. Two lodges and a campground are located along a 2-mile reach of Moose Creek. At least one of the lodges has installed dikes along the channel in an attempt to prevent flooding on the lodge grounds. In addition, the NPS is considering a gravel removal operation on the left bank, and the installation of a bridge to access the gravel operation location. These actions may impair floodplain water resource goals in a number of ways.

Impacts From Calcium Chloride Application For Dust Suppression

An NPS program designed to reduce the generation of fugitive dust by vehicle traffic on the Park Road may endanger the water quality of streams and ponds adjacent to the road. Though calcium chloride is the most effective dust suppressant tested on the road, it has been found to be harmful to vegetation and aquatic biota in numerous studies (D'Itri, 1992; and others). While application rates for dust suppression are much smaller than those of deicing rates, there is a concern that the concentration of salt will build up over time in the roadside soils and water, as application continues year after year.

To date, monitoring efforts of the calcium chloride application program have not been sufficient to determine either the amounts of chlorides that are likely to accumulate with repeated years of calcium chloride application, or the levels of chlorides that can be applied without adverse effects. Without such a study, the NPS may be creating a long-term time bomb that could impair desired water quality conditions years into the future.

Navigability Determinations May Convey Submerged Lands to the State

The State of Alaska has indicated its interest in having thousands of rivers, streams, and lakes declared navigable; on waterbodies within federal land management units such as Denali National Park and Preserve, such actions could transfer ownership of the submerged lands to the State. State ownership of streambeds could lead directly to degradation of water resource goals. For example, the State may issue placer mining permits for state-owned riverbeds within the Kantishna Hills historic mining district. The State has recently filed two Recordable Disclaimer of Interest applications for rivers inside Denali National Park and Preserve: the Muddy River, and the Kantishna River.

In 1992, the Secretary of the Interior directed the NPS to assume responsibility for navigability research for quiet title through negotiation and litigation. However, the NPS has received no additional funding to conduct this work. If the NPS cannot conduct the required research and documentation needed to retain federal ownership of park rivers, undue loss of submerged lands to State ownership may occur (The Mangi Environmental Group, 2005).

6.3 Proposed Actions From Outside Entities

In addition to NPS management actions, there are a number of non-NPS entities that are proposing actions within and near the boundaries of DENA; such actions have the potential to cause serious and long-term degradation to the water resources of the park, and to impede the achievement and maintenance of the water resource goals of stream channels and floodplains, groundwater aquifers, and riparian and wetland areas.

Coal-Bed Methane Drilling

A proposal by a privately-held Healy-based coal mining company to begin exploration drilling for coal-bed methane in the Denali Borough just north and east of the park boundary is currently under consideration by the State of Alaska (Figure 7). The production of methane gas from CBM wells generally requires the pumping, using deep wells, of significant quantities of water from the overlying aquifer so that the gas is released from the coal beds. There are a number of significant potential impacts to the water resources in and adjacent to an area subject to coal-bed methane wells. Because such large quantities of groundwater are pumped out to the surface to bring methane to the surface, aquifers and local wells could be impacted by a loss of water levels and methane pollution.

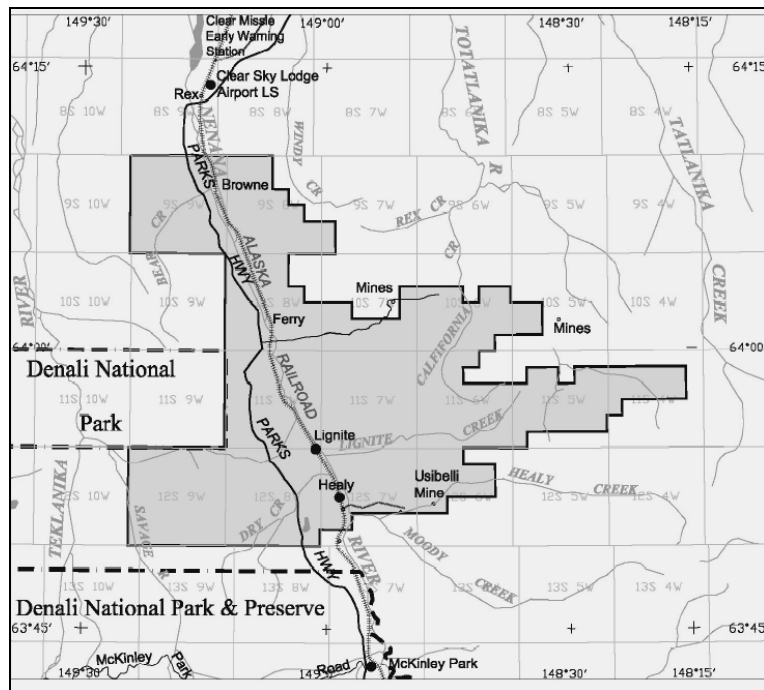


Figure 7. Healy basin proposed exploration license area.

There are basically three options available for the disposal of the water produced in the dewatering process: discharge it into existing drainages; put it in holding ponds and let it evaporate or seep into the ground; or re-inject it into the aquifer. All of these options

have the potential for immediate and pervasive impacts to the water resource goals of several park water resources.

Other water quality parameters may be of concern when considering the disposal of deep groundwater into surface waters or shallow aquifers. Parameters may include the presence (or absence) of heavy metals, nutrients, or other minerals in concentrations significantly different from those of area surface waters. In addition to the alteration and degradation of water chemistry, disposal of CBM product water can have other significant impacts. Such water, when disposed into an existing channel, can create significant changes to the morphology of the receiving stream channel.

The NPS response to this proposed action will be an important component of a concerted effort by adjacent landowners and others interested in eliminating or minimizing impacts to water resource goals. In the event that the coal-bed methane drilling program is conducted, NPS management direction is needed to initiate and maintain a robust monitoring program to detect and track impacts to the water resources of DENA.

Proposed North Access Route

A proposed State of Alaska massive road building project will, if constructed, bisect the Toklat Basin area along one of three proposed routes (Figure 8). The proposed North Access Route and its associated gravel pits will affect hundreds of pristine waterbodies, aquatic habitat, and wetlands. At particular risk are spring-fed gravel-bed streams which act as salmon spawning, rearing, and overwintering areas. A basic and severe lack of knowledge of the water resources along this corridor seriously threatens the NPS's ability to analyze, manage, and protect this area, and subsequently mitigate impacts if this road construction occurs (Karle, 2006).

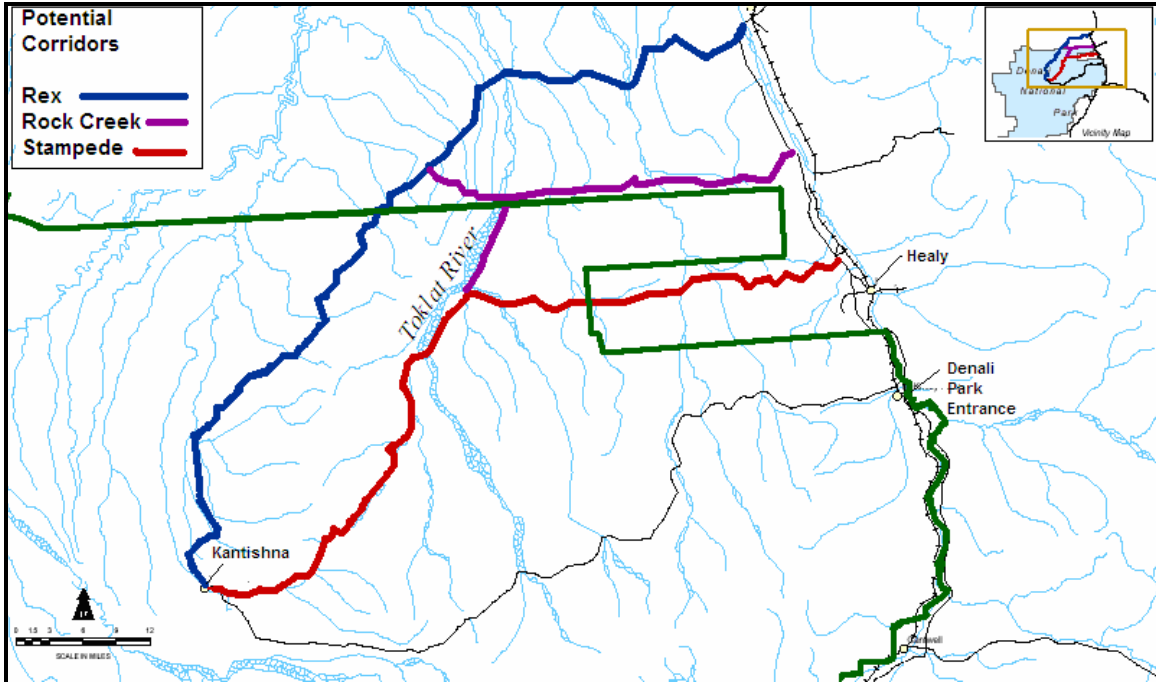


Figure 8. Three potential transportation corridors for the proposed State of Alaska North Access road.

The construction of a travel corridor will require the extraction of extremely large quantities of gravel in and adjacent to these aquatic systems. The construction of a gravel roadbed and associated gravel pits could pose both immediate and long-term threats to the water resources and associated habitat. Impacts could include the degradation of wetlands and aquatic habitat from increased sedimentation, changes to stream morphology, impacts to fisheries from bridge and culvert construction and the reduction of water quality from traffic-related contaminants.

SECTION 7.0 STRATEGIES FOR ACHIEVING WATER RESOURCE GOALS

One of the objectives of this Water Resources Stewardship Report is to develop strategies that will enable Denali to achieve or maintain the water resource goals described in Section 4 and summarized below. In order to quantitatively assess the state of the water resource goals, target conditions for the fundamental water resources must be developed and clearly defined. These water resource goals and their target conditions provide the foundation for the development of peer-reviewed science-based comprehensive strategies designed to achieve and/or maintain the goals. With the target conditions in place, measurable indicators are then used to determine if the goals are being met.

The implementation of many of these strategies will be the direct responsibility of the NPS management team at Denali. However, other programs will share this responsibility. For example, the CAKN program has selected 37 ecosystem ‘vital signs’ to be monitored, several of which are identified here as important indicators of the condition of the fundamental water resources. As part of the CAKN program, monitoring protocols are in various stages of development for these vital signs; once activated, these long-term monitoring components will provide park managers with critical information for assessing the state of the water resource goals. However, it is important to remember that the CAKN program is a network of three parks, and that implementation of some monitoring programs may initiate in the other two parks before being transferred to Denali.

7.1 Water Resource Goals

Goals for water resources at Denali National Park and Preserve can be readily condensed into two main categories: water quality and functional morphology. Navigability (ownership of the stream bed) is addressed in a separate water resource goal. In the following narrative, each goal is followed by a table. The table lists key elements used to provide the direction and scope of the strategy. Those elements are described below:

Factors preventing or impeding the achievement of this Water Resource Goal-The factors and issues that are preventing or impeding the achievement of pristine conditions for several of the park’s water resources are described in Section 6 of this report.

Stressor-Stressors are those agents that directly cause stress or degradation to the water resource. The ability to accurately identify stressors and defend the evidence supporting those findings is a critical step in developing strategies that will improve the quality of water resources and meet the water resource goals. The table describes the important environmental stressors that impair or threaten water quality in Denali.

Indicators-A partner to the water resource goals listing is the ability to measure the value of the condition. The value is determined by establishing and using a measurable

parameter or an index of multiple measurable parameters; these are used to track progress toward achieving a water resource goal. Indicators are measures that change in response to human activity and can be used to assess the quality of resource or experience conditions.

Current Condition-The existing condition of the degraded water resource is described using quantitative values from measurements of the indicator. Indicators that have not been recently measured are listed as Unknown.

Target Value-The target value is typically a quantitative goal for the indicator. Generally, these target values are representative of pristine conditions, though in some circumstances, normal background conditions may result in target values that are either lower or higher than ‘typical’ undisturbed values. Target values not set by water quality statute, policy, or requiring additional analysis are listed as Unknown.

7.2 Water Resource Goal: Water Quality

Chemical (water quality) integrity of park waters is improved and/or maintained to support a diverse aquatic community and ecosystem function, and to meet or exceed federal and state water quality standards.

Table 1. Key elements for Water Resource Goal: Water Quality

Factor Impeding Goal	Stressor	Indicator	Current Condition	Target Value
Contaminated Aquifers	Excessive Nitrate	Nitrate	As high as 25 mg/L	< 5mg/L
Contaminated Aquifers	Hydrocarbons	DRO GRO Benzene	Varies	No visual sheen
Long-range contaminant transport	Organchlorine compound	Organchlorine compound	TBD ²	Unknown
Pathogenic bacteria	Coliform bacteria	<i>E. Coli</i>	Unknown	30-day mean < 20 FC/100 ml
Dust palliative application on park road	Excessive chloride	Calcium chloride	TBD ²	TBD
Product water from coalbed methane production	Salts, heavy metals and other CBM product water	Water chemistry, heavy metals	Unknown	Unknown
New North access road construction	Pollutants from vehicles and construction activities	Water chemistry parameters, turbidity, organic pollutants	Unknown	Unknown
Placer-mining ¹	Suspended sediment	Turbidity	Unknown	≤ 5 NTU above natural conditions
Placer-mining	Heavy metals	Heavy metals	Unknown	Unknown

¹ Monitoring to be conducted as part of the CAKN program

² Monitoring program is in progress, though data analysis is not yet complete

7.2.1 Comprehensive Management Strategy For Water Quality

NPS management strategies to meet the Water Resource Goal for Water Quality should begin by understanding the current status of the diverse aquatic community and ecosystem function. The recommended strategies include:

- Water quality monitoring
- Groundwater remediation
- Baseline data acquisition (water quality and other appropriate indicators)
- Air quality monitoring.

7.2.2 Water Quality Monitoring

Central to measuring the effectiveness of any efforts to achieve and maintain water quality is routine water quality monitoring. The park does not operate a routine integrated Water Quality Monitoring Program, but instead has relied upon individual studies and sampling efforts driven by specific programs or water quality issues.

For the most part, surface waters in Denali National Park originate within the park boundaries; as such, managers have not had to worry about upstream sources polluting park waters. Based on the results from a number of individual water quality studies, and the overall lack of development in the vast majority of the park, it is recommended that for the immediate future, water quality assessments efforts continue to be based on specific issues and known problems, rather than instituting a repetitive parkwide sampling strategy.

Water Quality Monitoring Actions

1. Continue to monitor hydrocarbon contamination in groundwater wells in the headquarters and C-Camp areas. Sampling should occur at least twice a year, and will be tied to groundwater remediation efforts. Additional monitoring wells downgradient from the existing wells should be installed if needed.
2. Continue to monitor nitrate levels in the five groundwater monitoring wells near the park's existing aerated lagoon. Sampling should occur at least once a year, and will be tied to the ongoing bi-lateral compliance agreement with ADEC to implement a plan of action to achieve wastewater discharge compliance.
3. Institute a water quality monitoring program on the Kahiltna Glacier during the annual climbing season. Surface water running in channels on top of the glacier, downstream from the camp, pit toilets and staging areas should be sampled for the presence of *E. coli*, which is a type of total coliform that is closely associated with recent human fecal contamination.

4. Continue to facilitate the development of results from the NPS Western Airborne Contaminants Assessment Project (WACAP), and continue to encourage periodic sampling of lake and pond sediments for the presence of metals (including mercury) and organic compounds.
5. Continue the ongoing monitoring study of the effects of dust suppressants on the roadside environment along the Park Road, with a continued focus on chloride contamination of adjacent soils and waterbodies. Long-term studies are needed to determine if chlorides and other contaminants are accumulating over time with repeated applications of calcium chloride.
6. Initiate a turbidity monitoring program for Slate Creek and Caribou Creek, in the Kantishna Hills, funded and managed under the CAKN program (MacCluskie and Oakley, 2005). Turbidity measurements, along with anecdotal information (such as restoration progress, riparian revegetation, comparisons of aerial photography, etc) can be used to support a determination for removal of these streams from the State of Alaska 303d listing.
7. Conduct a sampling effort on both previously mined and unmined streams in the Kantishna Hills to determine the presence and levels of trace or heavy metals.

Methods-Water Quality Monitoring

The Clean Water Act requires states to establish beneficial use classifications for all water bodies within their boundaries. The beneficial uses of water bodies at DENA include: 1) water supply (groundwater and fresh water), 2) recreation (freshwater), and 3) growth and propagation of fish, shellfish, other aquatic life, and wildlife (freshwater). For waterbodies in Alaska with multiple uses, the most stringent water quality criteria (water supply) will apply (ADEC, 2006b).

To support these designated beneficial uses, the CWA mandates development of water quality criteria. The State of Alaska's water quality criteria are generally numeric descriptions of the physical, chemical, and biological characteristics of waters, and are used to determine whether water bodies are meeting specific beneficial uses. Where appropriate and applicable, they may be used as the target value for achieving DENA's water resource goals.

Monitor hydrocarbon contamination in groundwater-In the State of Alaska, groundwater is protected as the highest beneficial use classification (water supply). The criteria for the water quality standards for petroleum, hydrocarbon, oil, and grease pollutants are:

May not cause a visible sheen upon the surface of the water. May not exceed concentrations that individually or in combination impart odor or taste as determined by organoleptic tests (ADEC, 2006b).

DENA has funded a program to install wells and monitor contaminate levels at the known problem sites, including C-camp and the Headquarters area. Product recovery devices have been installed and are emptied periodically. Additional wells to monitor contaminate levels should be installed at the C-camp UST site. The contamination source for that site is currently scheduled for excavation in 2011. These actions should continue until water quality criteria are met.

Monitor groundwater nitrate levels-The current monitoring action funded by DENA includes routine sampling of four monitoring wells. A plan has been developed to replace the existing treatment lagoon with a new wastewater treatment package that will discharge effluent to surface water. This action, in addition to the planned elimination of the park's portable chemical toilets, should correct the groundwater contamination problem. DENA should continue to pursue this action.

Kahiltna Glacier water quality-Fecal coliform sampling should occur twice a month through the climbing season, on any identifiable open water channels that flow through or near the pit toilets. To meet State of Alaska water quality requirements, the following criteria must be met:

In a 30-day period, the geometric mean may not exceed 20 FC/100 ml, and not more than 10% of the samples may exceed 40 FC/100 ml (ADEC, 2006b).

Fecal coliform bacteria must be determined by the membrane filter technique or most probable number procedure according to *Standard Methods for the Examination of Water and Wastewater*, 18th edition. Park personnel (climbing rangers) should receive training in appropriate sampling techniques, and should conduct such sampling as part of DENA's climbing program.

Monitor dust suppressants-DENA has developed a monitoring plan to monitor the possible effects on soil, water, and vegetation of applying calcium chloride as a dust palliative on the park road. Buried lysimeters adjacent to the park road will allow park staff to monitor the migration of chloride ions away from the roadbed. In this way, the lysimeters will provide an early-warning system for potential negative effects of these chemicals on roadside biota. DENA funding and staff participation should continue.

Turbidity monitoring program-Turbidity measurements, along with coincident discharge measurements, should be made above, in, and below the mined sections of the streams. Measurements should be made at typical low summer flows, and at higher flows following precipitation events. To meet State of Alaska water quality requirements, the following criteria must be met:

May not exceed 5 nephelometric turbidity units (NTU) above natural conditions when the natural turbidity is 50 NTU or less,

and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU (ADEC, 2006b).

This program should be funded by CAKN and conducted by either NPS physical science staff trained in the use of a portable turbidimeter, or by a qualified private consultant.

Kantishna Hills water quality-Sampling for trace and heavy metals should occur in both previously mined and unmined streams. A careful analysis will be required to determine if high metals concentrations, if detected, are due to historic mining activities, or simply reflect natural background conditions. New studies should be designed to provide data directly comparable with data obtained from previous sampling efforts during the early 1980s, including both water and fish tissue samples.

Evaluation of Water Quality Monitoring

At a minimum, water quality monitoring, as described above, will provide park managers enough immediate and ongoing data to be able to determine the extent of water quality contamination for a number of issues, including groundwater contamination from oil spills and dysfunctional wastewater treatment systems, and to be able to detect whether or not remedial actions are succeeding in some cases, or warranted in others.

Water quality monitoring will enable managers to determine if degraded water quality conditions present a health risk to park visitors, such as backpackers or climbers. Additionally, several of the datasets will enhance the datasets for parkwide water quality values, and provide a baseline for long-term data collection and trend analysis.

New turbidity data from Caribou and Slate Creeks will allow the National Park Service to address the long-term inclusion of those two streams on the State of Alaska 303(d) listing. Although a waterbody has been placed on the Section 303(d) list, there are a number of instances under which a waterbody may be removed from the Section 303(d) list. This includes the acquisition of more recent and accurate data that shows the water quality standards are being attained. The State of Alaska (ADEC, 2006a) has described the steps and conditions that will support a determination to remove a waterbody from the Category 5/Section 303(d) list:

- There is a demonstration of “good cause,” i.e., an explanation of why, or on what basis, the water was originally listed and why it is now appropriate to remove the listed water or redefine the listed area.

- An administrative record and documentation supporting the recommended determination (in some instances such as the need for public discussion or notice over a de-listing determination) is needed.
- A public notice of the proposed de-listing is published and public comment is sought. Typically the Integrated Report acts as the vehicle for public noticing and comment. In special instances, a public meeting could be held in the community closest to the waterbody in question.
- When considering a determination to remove a waterbody from the Section 303(d) list, the level of data to support a determination and burden of proof shall be no greater than was used in the initial listing determination. Such a determination is subject to approval by the EPA (from ADEC, 2006a).

In addition to assorted restoration activities on both Caribou and Slate Creeks, substantial riparian revegetation growth has occurred along many of the disturbed reaches for those streams, resulting in increased bank stability and a reduced sediment availability. New turbidity measurements, along with other supporting documentation such as recent photographs and descriptions of the restoration projects, could lead to the removal of these two National Park streams from the Impaired Waterbodies list. At the least, new information will help NPS managers develop a strategy to address the impairment, through a Total Maximum Daily Load (TMDL), or equivalent waterbody recovery plan.

7.2.3 Baseline Data Acquisition

New information is needed to support efforts to reduce or eliminate the impacts from proposed major developments in the park. At the time of this writing, the two major threats to future water quality conditions in the park are the proposed North Access Road, and the proposed Coalbed Methane Drilling project.

Baseline Data Acquisition Actions

1. Prior to the start of a North Access road construction project, baseline data should be collected on all streams crossed by the road project in advance of road construction, in order to evaluate potential source and non-source water quality impacts later. Chemical variables to be sampled include major metals, trace elements, major ions, major nutrients, and dissolved organic contaminants. Additionally, chemical contaminants such as pesticides should be measured in the water column, as well as the streambed sediment and in biological tissues.
2. Contingent on the likely approval of exploratory drilling permits, baseline water quality sampling should begin prior to drilling in areas in and adjacent to the park that are at high risk from CBM drilling. If disposal of CBM product water relies on surface treatment, sampling should include surface waterbodies that may receive or are downstream from product water from related well pumping.

Methods-Baseline Data Acquisition

It is critical that any monitoring program used to collect both baseline and subsequent data be conducted by experienced stream ecologists and hydrologists, using well-established protocols and laboratory methods. For example, scientists with the USGS NAWQA program have been collecting and analyzing data and information in a large number of watersheds, using a set of well-established monitoring and measuring protocols for the evaluation of physical, chemical, and biological characteristics (Crawford and Luoma, 1993; Cuffney et al., 1993; and Fitzpatrick et al., 1998). Other methods and monitoring protocols are available to NPS staff. The methods and protocols selected for use in a DENA water quality monitoring program should be well-suited to allow park managers to determine the following:

- What is the condition of a study watershed?
- How are these conditions changing over time?
- How do natural features and human activities affect these conditions?

Evaluation of Baseline Data Acquisition

These data gaps were identified during the preparation of the Denali Water Resources Information and Issues Overview Report. The existing water quality database for Denali is inadequate to fully analyze or address the issues identified above. For the protection of those fundamental water resources, it is crucial that these data sets are collected before disturbances begin, especially for the areas that will be affected by the North Access road construction and the coal-bed methane drilling. Acquisition of these data will allow managers to determine the potential for degradation from such development, and will provide a foundation for future long-term monitoring programs to track trends in water quality conditions.

7.2.4 Air Quality Monitoring

Denali National Park and Preserve is a Class I area as designated by the Clean Air Act. This designation requires the prevention of significant deterioration of air quality over baseline conditions. Denali is the only national park unit in Alaska with such a designation.

Denali participates in several air quality monitoring programs, including:

1. NPS Ozone Monitoring-measures ozone.
2. National Atmospheric Deposition Program/National Trends Network (NADP/NTN)-measures precipitation chemistry.

3. Alaska State and Local Air Monitoring System and Interagency Monitoring of Protected Visual Environments Program-monitors aerosols and visibility.
4. Clean Air Status and Trends Network (CASTNet)-measures dry particulate concentrations of sulfur and nitrogen compounds.

As a Class 1 airshed, Denali has developed a set of Air Quality Related Values (AQRV). These AQRVs describe resources in Denali that may be adversely affected by a change in air quality. The Denali AQRVs include aquatic resources, fauna/wildlife, night skies, soils, vegetation, and visibility.

Of the four monitoring programs, the most important in terms of the AQRV for aquatic resources are the NADP/NTN and CASTNet programs. Studies have long noted the potential adverse ecological effects from atmospheric deposition of nitrogen and sulfur; such effects include surface water acidification, soil nutrient leach, and others. Denali experiences some of the lowest values of nitrogen and sulfur deposition measured in the national NADP/NTN network. Additionally, many of the streams, especially on the North Side, are well buffered from the effects of atmospheric pollutants like nitrogen and sulfur compounds that can cause acidification. However, other aquatic environments, such as high altitude lakes and ponds, may be sensitive to airborne contaminant inputs. As such, continued long-term monitoring is essential to maintain trend detection capability.

As a Class 1 watershed, Denali is also tasked with the responsibility of assessing proposed new or modified sources of air pollutant emissions within a 300 km radius of the park. These sources are asked to consult with the NPS to determine whether emission impact modeling to the Class I area should be conducted and submitted to the NPS for review. Factors to be considered include distance to the Class I area, magnitude of emissions, current conditions of air sensitive resources in the Class I area, potential for source growth in an area or region, prevailing meteorological conditions, and cumulative effects of multiple sources to air sensitive resources (NPS, n.d.(b)).

For example, a 50 Megawatt Healy Clean Coal Power plant (HCCP) was constructed in 1998 about 4 miles north of the nearest border of the Denali National Park and Preserve and 8 miles north of the entrance to the DNPP. Prior to construction during the NEPA process, the NPS expressed concerns that increased emissions from the combined operation of the HCCP and the existing Healy Unit No. 1 would adversely affect the park. To address these concerns, the Department of Energy facilitated negotiations between the project participants and the Department of the Interior. This resulted in a Memorandum of Agreement that provides specific mitigating measures to ameliorate potential impacts on the park.

Air Quality Monitoring Actions

1. As required by the Clean Air Act, continue to monitor air quality through an assortment of programs and networks. In terms of water quality, continue to

include the monitoring of key compounds and elements associated with wet and dry deposition.

2. Continue to monitor developments as new efforts are made to retrofit the HCCP with more traditional technology (which may produce higher emission levels than the original HCCP facility) and re-start the power plant.
3. Continue to participate in Permit Reviews of other permitted facilities within 300 km of the park.

Methods-Air Quality Monitoring

DENA actively participates in four national air quality monitoring/sampling programs. A dedicated air quality technician conducts the scheduled sampling and maintenance for the instruments, and maintains a dialog with the NPS-WASO Air Quality Division. DENA should continue to support this position and these programs.

Evaluation of Air Quality Monitoring

Like water quality monitoring, there are set standards for air quality parameters. Though many water quality standards are based on State-designated use standards for each waterbody, DENA must conform to national standards set for Class I areas. Air quality as set by the USEPA National Ambient Air Quality Standards include CO, Pb, NO_x, PM₁₀, PM_{2.5}, O₃, and SO_x. The existing DENA Air Quality Monitoring Program is sufficient to determine if most of those standards are met.

7.2.5 Remediate Degraded Groundwater Conditions

Some actions have been taken to remediate some of the degraded aquifers described above. Compliance plans and orders have been developed in conjunction with the Alaska Department of Environmental Conservation and consultants. For example, product recovery devices have been installed in wells located in hydrocarbon-contaminated wells. Long-term monitoring has allowed managers and agency personnel to determine reduction of contaminant concentrations below cleanup levels. Continued action is needed to improve ongoing aquifer contamination issues and meet water resource goals.

Contaminated Groundwater Remediation Actions

1. Replace the existing aerated lagoon and percolation basin with a surface discharge wastewater system. Discontinue the park usage of portable chemical toilets.
2. Continue to develop and test methods to remove hydrocarbons from aquifers in the C-Camp, park hotel, and HQ areas.

3. Identify extent of, and develop remediation plan for recently discovered solvent contamination in the C-camp east side area.

Methods-Groundwater Remediation

DENA staff are collaborating with the ADEC and consulting firms to identify the extent of the groundwater problems, and determine cost-effective solutions, to bring the park back into compliance. Acquiring funding for major wastewater treatment upgrades should continue to be a high-priority task.

Evaluation of Groundwater Remediation Actions

The evaluation of groundwater remediation actions will be based directly on the measurable indicators listed in Table 1, and how those values change to meet the target values. Remediation of aquifer contamination is a long-term action, and generally requires substantial pre-planning and funding preparations. The park has initiated these actions, in coordination with other construction projects planned for the future. Monitoring wells and a commitment to a long-term monitoring program will allow managers to determine if remediation actions are effective.

7.3 Water Resource Goal-Functional Morphology

Physical channel and floodplain integrity of park streams and rivers is maintained and/or improved to support natural geomorphic processes of fluvial systems and to support natural aquatic flora and fauna.

7.3.1 Comprehensive Management Strategy For Functional Morphology

NPS management strategies to meet the Water Resource Goal for Functional Morphology should begin by understanding the current status of natural geomorphic processes of the park's fluvial systems, and supporting the natural aquatic flora and fauna that use these systems. The recommended strategies include:

- Stream channel and floodplain monitoring
- Floodplain delineation
- Glacier monitoring
- Aquatic biological monitoring

The ultimate recipient and beneficiary of functional channel/floodplain morphology are aquatic organisms. They are subject to both chronic and acute contamination and habitat disruption. Several projects conducted in the park have studied the presence and viability of macroinvertebrates as indicators of ecological change (Milner et al. 2003). However, in the past twenty years, only two discrete short-term studies have looked at local fish species distribution in different areas of the park. Further studies are required to be able

to determine the condition of several water resources, and measure the impact of several proposed major projects that threaten to severely impact fisheries and their habitats.

Table 2. Key elements for Water Resource Goal: Functional Morphology

Factor Impeding Goal	Stressor	Indicator	Current Condition	Target Value
Floodplain incursions from road construction and maintenance	Floodplain modifications, artificial berms, constrictions, excavations	Cross-sections, water velocities	Unknown	Functional stream channels and floodplains
Past placer mining activities	Mechanical disturbance of channel/floodplain systems	Cross-sections, slope, suspended sediment	Unstable banks, confined streambeds, and non-functional or non-existent floodplains.	Functional stream channels and floodplains
Past placer mining activities	Mechanical disturbance of wetlands complex	Hydrology, soils, vegetation	Non-functional or non-existent riparian wetlands	Functional riparian wetlands
Lack of Floodplain Delineation	Development within floodplain	100-year, 200-year, and 500-year floodplain delineation	No delineations	Delineations for rivers with proposed development
North Access road construction	Culverts, bridge constrictions	Increased velocities	Unknown	Maintenance of current conditions
Global climate change ¹	Warming climate	Glacier mass	Unknown	Unknown
Global climate change ¹	Decreased water levels	Pond water levels	Unknown	Unknown
Global climate change ¹	Decreased water levels and quality	Macro-invertebrates	Unknown	Unknown
Global climate change ¹	Altered water levels	River discharge	Unknown	Unknown
Sport fishing ¹	Reduced fish populations	Fish populations	Unknown	Unknown

¹ Monitoring to be conducted as part of the CAKN program

The CAKN has developed its Prototype Vital Signs Monitoring Program, and has chosen to develop monitoring protocols for macroinvertebrates as a tool for detecting trends in the abundance, size, distribution, water quality, and biological communities of shallow lake and pond systems in all three of its parks (MacCluskie and Oakley, 2005). Protocols for monitoring macroinvertebrates in lotic systems are further being refined.

The CAKN program has also selected river discharge as one of the vital signs to be monitored (MacCluskie and Oakley, 2005). The goal is to determine long term trends in flood frequency and discharge of selected rivers and streams in the network. Protocols for monitoring stream discharge are in a very early stage of development.

Additionally, the Vital Signs Monitoring Program proposes to monitor the consumptive use of fish in CAKN parks in the near future. Undocumented fishing pressure on grayling at stream-road crossings and on lake trout at Wonder Lake have led to concerns of local extirpation (The Mangi Environmental Group, 2005). Given these immediate threats, baseline studies of fisheries populations, habitat, and sport-fishing studies are needed immediately.

Once these elements of the Vital Signs Monitoring Program have been developed, and a timeline for implementation in Denali is established, they should be added to the comprehensive management strategy for functional morphology.

7.3.2 Stream Channel and Floodplain Monitoring

The park does not operate a routine channel/floodplain Monitoring Program, but instead has relied upon individual studies and surveying efforts driven by specific programs. Routine long-term monitoring of undisturbed channels was part of the original Denali LTEM program; such information, though academically interesting, provides managers with little useful information unless it is developed as a reference site for a specific project. Focused monitoring efforts at both disturbed areas and for areas threatened with development (such as the North Access corridor) will be much more effective in guiding efforts to achieve water resource goals.

Long-term monitoring of cross-sections in Glen Creek has been conducted since 1990, in an effort to assess stream restoration techniques. The project has been highly successful, and has allowed researchers to adjust techniques and methods for other stream restoration projects based on the results from Glen Creek. Similar techniques for monitoring other areas can and should be used.

Stream Channel Monitoring Actions

1. A Toklat River channel monitoring program was originally developed in the late 1980s in response to the park's need for a long-term replenishable source of gravel. Discontinued after the departure of the park staff hydrologist, the program for long-term monitoring and analysis program of the Toklat River floodplain upstream of, through, and downstream of the areas used for annual gravel extraction should be re-instated, as required by the Gravel Acquisition Plan Analysis EA Statement of Findings (2003). Cross-sections that were first established for this purpose in the late 1980s and early 1990s should be re-established and resurveyed, using the same local benchmarks as the original surveys.
2. Develop and implement a restoration assessment plan for Kantishna area streams and riparian wetlands. Resurvey existing long-term cross-sections at the Glen Creek study area. Establish new long-term cross-sections for the most recent channel restoration activities on upper Glen Creek and Caribou Creek.

Methods-Stream Channel Monitoring

1. **Toklat River surveys**-Cross-sections should be resurveyed every one to two years, contingent on the continuation of the gravel floodplain extraction operation at the Toklat River. Methods for establishing permanent cross-sections and conducting long-term repeatable surveys are found in NPS (1997) and Osterkamp et al. (1991). Until an engineering hydrologist or geomorphologist is recruited for the park staff, this project should be contracted to a qualified consultant.
2. **Kantishna surveys**-Long-term revegetation monitoring of restoration efforts on Glen Creek has been conducted by a USGS research ecologists. DENA should continue to foster and help fund this program and ensure that stream channel and wetlands surveys remains included in the long-term program.

Evaluation of Stream Channel Monitoring

Measuring and replicating stream channel cross-sections over a period of years provides a vital record with which to determine impacts and improvements to water resources. Long-term measurements of stream channel/floodplain geometry for the early Glen Creek restoration project provided investigators with important data for improving channel designs and techniques (Karle and Densmore, 2001). As personnel change, new technicians can be trained to make accurate measurements. However, assessments of long-term monitoring data should be conducted by qualified engineering hydrologists or geomorphologists.

7.3.3 Floodplain delineation

The National Park Service is responsible for implementing the Executive Order on Floodplain Management (11988), as well as following its own floodplain guidelines, as outlined in NPS Director's Orders 77-2: Floodplain Management. The DO specifically directs NPS to:

- Protect and preserve the natural resources and functions of floodplains;
- Avoid the long- and short-term environmental effects associated with the occupancy and modification of floodplains; and
- Avoid direct and indirect support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks.

These guidelines require identification of the floodplain areas within the park and an inventory of the existing and proposed structures and facilities (e.g. buildings, campsites, and rest stops). Planning and development in the park should recognize and protect floodplains, and restrict construction and other development in such areas. The management policy should allow natural floods to occur without loss of lives or property.

Floodplain Delineation Actions

Delineate the 100-year and 500-year floodplains for rivers and streams associated with existing or proposed development. Map and assess the risk of hazards in the flood-prone zones.

Methods-Floodplain Delineation

Large braided rivers can experience high rates of lateral bank erosion during both flood events and normal flows. Such erosion can confound attempts to delineate floodplains on braided rivers such as the Toklat and Teklanika. Floodplain delineations should be conducted by competent hydrologists familiar with the issues of erosion and bank stability. Guidance for floodplain mapping on braided rivers in DENA is found at Schalk et al., (2001).

Evaluation of Floodplain Delineation

Successful floodplain delineation will allow DENA to (1) manage for the preservation of floodplain values; (2) minimize potentially hazardous conditions associated with flooding; and (3) comply with the NPS Organic Act and all other federal laws and executive orders related to the management of activities in flood-prone areas.

7.3.4 Glacier Monitoring

Glaciers are one of the most valuable and visually stunning features of the fundamental water resources of Denali National Park and Preserve. Glaciers cover over one million acres of the park, and are an integral component of the hydrologic system and aquatic ecosystem. They also influence soil development, the distribution of vegetation, flooding and are unique indicators of climate change.

To understand climate change, the glacier resource, and the effect of glaciers on other resources at Denali, long-term monitoring of glaciers is needed. A formal glacier monitoring program began in Denali in 1991 as part of the National Park Service's Long-term Ecological Monitoring Program, in cooperation with the US Geological Survey and the Geophysical Institute at the University of Alaska-Fairbanks. The fundamental aspect of the program was an "index" method, or single point mass balance monitoring. The monitoring program is now conducted under the auspices of the CAKN, and the original monitoring methods have been supplemented with more detailed mass balance measurements on smaller glaciers, terminus monitoring on multiple glaciers, selected movement monitoring, depth measurements, and photo documentation.

Glacier Monitoring Actions

1. Continue index site measurements on the Kahiltna and Traleika glaciers
2. Continue Muldrow glacier outflow monitoring

3. Develop and test new techniques for depth measurements
4. Continue Traleika glacier movement surveys
5. Develop GIS-derived glacier inventory

Methods-Glacier Monitoring

DENA has a long-established and well-recognized glacial monitoring program, and has also firmly established relationships with other glacier monitoring scientists from the USGS and University of Alaska. Since 1991, mass balance measurements are conducted on two index glaciers (Traleika, Kahiltna) and a benchmark glacier (East Fork Toklat). Measurements of mass balance and movement are made in late May and early September, at the end of the accumulation and ablation seasons. Benchmark glacier monitoring involves the long-term measurement of 11 stakes, which are assessed for mass balance trends. The CAKN should continue to fund this program; DENA should continue to support qualified staff physical scientists to conduct this monitoring.

Evaluation of Glacier Monitoring

Protocols for glacier monitoring were established at DENA during the DENA LTEM program. Glaciers have been recognized as one of the Vital Signs to be monitored in the CAKN network. The long-standing glacier monitoring program in Denali provides a stable and experienced platform with which to continue this effort. This monitoring program, coupled with a robust trend detection analysis, will not only provide managers with critical information on Denali's fundamental water resources, but will provide scientists world-wide with important data and evidence for use in discussions of global change.

7.3.5 Aquatic Biology

Aquatic habitat for fish and other species is directly dependent on proper morphological function. Both habitat and aquatic species may be measured directly to provide an indication of how well DENA meets the Water Resource Goal for functional morphology and aquatic habitat. The strategies for baseline data collection and long-term monitoring are described below.

Aquatic Biological Monitoring

1. Prior to the construction of a North Access road, a baseline survey of the aquatic biological resources should be initiated along the streams and rivers intersected by the proposed road corridor. The focus of the baseline study is to determine fish species presence and relative abundance. All major streams (crossed by a bridge or culvert larger than 24" diameter) should be surveyed.
2. Before a North Access road construction project begins, aquatic habitat should be described and identified on all streams crossed by the project road that

support fish communities. Aquatic habitat forms the structure within which aquatic organisms make their home. Measurements of such forms in an undisturbed setting are generally more predictable, less variable, and more easily measured than biological and chemical factors.

3. Once baseline conditions of water quality, channel morphology, aquatic organisms, and aquatic habitat are measured and assessed along the North Access route, it will be critical to follow up with additional and periodic monitoring following road construction. Following road construction, fish should be monitored every several years on key waterways. Monitoring of species, length, weight, and age class should specifically occur upstream and downstream of the road crossing, particularly on streams where culverts are suspected of impeding fish passage. Habitat degradation downstream of a newly constructed roadbed is highly probable, and monitoring should be conducted every several years to detect changes to bank stability, riparian vegetation, and other characteristics. Once baseline conditions are established, monitoring may only be required on the downstream side of the roadbed. Additionally, habitat should be monitored in areas where in-stream or near-stream gravel mining is conducted.
4. Continue to develop protocols for long-term monitoring of invertebrates and water levels in small ponds as part of the CAKN Vital Signs Network. The monitoring program should be designed to allow managers to determine the status and track trends in aquatic biological parameters such as macroinvertebrates, which will act as indicators of the condition of the water resource (small ponds). Accurate trend analysis will provide an early warning of abnormal changes in the conditions of these water resources, and allow managers to make better-informed decisions.
5. Evaluate the long-term monitoring of macroinvertebrate communities in long-term study streams within Denali to determine if natural variation provides a stable enough baseline to evaluate influences of climate change including drivers like the Pacific Decadal Oscillation.

Methods-Aquatic Biological Monitoring

1. **North Access Baseline Fish presence-** Fish should be sampled using several methods, including electrofishing and seining. Fish should be identified as to species, length, and weight. Additionally, the presence of any external anomalies that may be related to habitat degradation, including skeletal deformities, eroded fins, lesions, tumors, diseases, and parasites, should be noted.
2. **North Access Baseline Habitat measurements-** Using a USGS method, habitat sampling is based on a tiered design. At the basin level, GIS is used to obtain such characteristics as the hydrology, geology, and soils of a watershed.

At the stream-segment level, stream morphology is described in a reach of the study area bounded by major tributaries. Morphological descriptions include gradient, elevation, sinuosity, and other channel/floodplain features. Finally, stream-reach level sampling is used to describe local characteristics of streamflow, bank stability, and others. The description and quantification of riparian vegetation, including species, density, and species dominance, is critical for establishing the relationship between the stream environment and aquatic organisms.

3. **Macroinvertebrate monitoring**-Protocol development for monitoring small lake levels and sampling macroinvertebrate populations is continuing as part of a larger study to develop a Shallow Lake Limnology Monitoring Protocol for the CAKN Vital Signs Program. The current plan is to sample for macroinvertebrates within the littoral zone of the pond, along a transect situated along a line perpendicular to the shoreline. Remote sensing platforms such as RadarSat II will be utilized to measure changes in pond size. See Larsen and Verbyla (2004) for details. The CAKN should continue to fund this program, and DENA should continue to provide assistance for field operations in the park.

Measurable Results: Aquatic Biological Monitoring

With a robust monitoring design and data collection program, park managers should have an excellent picture of critical aquatic biological conditions at areas facing degradation from either new road construction, global climate change, or sport fishing pressure. In combination with water quality and habitat data, the fisheries monitoring will yield critical information to determine the severity of impacts from new road construction. For example, data can be used to demonstrate the impacts of culvert installation on juvenile fish passage, and if culverts are preventing or limiting access to upstream rearing or spawning habitat. Once impacts are identified and quantified, managers can implement appropriate Best Management Practices to restore and improve aquatic habitat features in affected areas.

7.4 Water Resource Goal-Navigability Determination

All necessary data is acquired to assess navigability issues, support continued Federal ownership on upcoming State of Alaska applications, and protect affected water resources within the park and preserve regardless of determination of title ownership.

7.4.1 Comprehensive Management Strategy For Navigability Determinations

The task of protecting the quality and quantity of streams and rivers becomes extremely difficult when the National Park Service does not retain ownership of the submerged lands for those streams and rivers. For example, in 1991 the State of Alaska signed a finding that Moose Creek was “navigable in fact” downstream of its confluence with

Rainy Creek to its confluence with the Bearpaw River. This action was perceived by many at the time as a prelude to the issuance of State placer mining permits for Moose Creek, especially in the road-accessible reach in the historic Kantishna mining district. Though the State determination of navigability was later withdrawn, that action provided a glimpse of the potential threats to water resources from this issue.

The State of Alaska Department of Natural Resources (ADNR) is currently using the recordable disclaimer of interest (RDI) process to help assert the State's claim to navigability and ownership of waters in Alaska. A "recordable disclaimer of interest" is a document that affirms the United States does not claim an interest in specific lands. It is prepared in such a way that will meet local requirements so that it may be "recorded." The State has recently filed two RDI applications for rivers inside Denali National Park and Preserve: the Muddy River, and the Kantishna River. The Bureau of Land Management (BLM) Alaska is the only bureau office currently applying the RDI process on a systematic basis to navigable waterbodies within the state.

The following strategies describe approaches that NPS management may follow to address the factors impeding the Navigability Determination Goal. The strategies include data collection and database development.

Data Collection

Critical actions, including data collection and database development, are required to enable the Federal government to prepare for current and future attempts by the State of Alaska to assert navigability on streams and rivers within the Denali Park boundary, including portions of the Muddy, McKinley, Kantishna, Tokositna, Nenana, Teklanika, and others. Navigability is a question of fact, not a simple legal formula. Variations in waterbody use that result from different physical characteristics and transportation methods and needs must be taken into account.

For rivers, lakes, and streams throughout the park, the following information is needed to assist both with navigability determinations, and to help protect affected watersheds regardless of the outcome of title determinations:

- local geography
- local economy
- historic and customary modes of water-based transportation
- physical characteristics of the waterbody under consideration.

Methods-Navigability Determinations

Currently, the NPS is organizing a team to investigate, review, and make an assessment of navigability on upcoming State applications for RDI on several rivers in DENA (The Mangi Environmental Group, 2005). This team requires strong leadership and direction, as focus may easily be lost to other, more

visible, needs. The NPS team needs to establish and foster relationships with other federal agencies involved in the navigability process, most notably the BLM and USFWS. Resources must be dedicated to assigning priorities for the data collection needs described above. Cooperation must also be fostered with the ADNR to improve the RDI process.

Evaluation of Navigability Determinations

Both Federal and State agencies benefit by improving the efficiency and effectiveness of navigability determinations. Though court decisions are still needed to provide legal guidance for accurate navigability determinations, the need persists to increase the baseline information for targeted rivers, lakes, and streams. Conducting timely and accurate navigability research will improve management of streambeds, provide more certainty for public users, and help settle issues regarding development within submerged lands that may be incompatible with the purposes of national parks and preserves. An effective program will reduce or eliminate the undue loss of submerged lands to State ownership.

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APPENDIX A

TREND ANALYSIS FOR WATER RESOURCES

Trend Analysis

An integral component of the development of a strategy that works toward achieving or maintaining the interim water resource goals, is the ability to measure how successful that strategy is, and whether or not the water resource goals" are being achieved. Initial characterizations of a water resource, using the values and measurable parameters for that resource, provide a foundation for this strategy. However, the most useful tool for assessing the success of a programmatic strategy is the trend analysis. Trends in observed rates of changes to water resource conditions will provide invaluable information for needs assessment, program planning, program evaluation, and policy development activities. Examining water resource data over time also permits making predictions about future conditions and rates of achieving those conditions.

Null Hypothesis: No Trend

Once an initial characterization of a water resource parameter is made, managers are interested in being able to detect trends in the water resource condition. To be able to identify and measure long-term temporal variations and trends, long-term monitoring of the parameter in question is required. The goal is to determine whether general increases or decreases in observed values of the water resource parameter variables are statistically significant, as opposed to being the coincidental result of random or natural variability. For a natural area such as Denali National Park and Preserve, we propose that the null hypothesis is: there are no long-term trends in the study area in changes to water quality or stream hydrology due to anthropogenic causes.

The objective of monitoring and subsequent trend analysis is to accept the null hypothesis of no trend with specified probability when no real trend exists, and to reject the null hypothesis with high probability when real trends do exist (EPA, 1989). A trend, for the purposes of this study, is one that results from physical or chemical changes, not from natural hydrologic variability. For example, change in water quality or channel morphometry resulting from natural variations in precipitation patterns is not considered a 'real' trend. Climatic events such as catastrophic floods can effect rapid, substantial, and long-term changes to monitoring variables such as channel cross-sections; however, attributing these changes to such long-term changes in global climate requires a clear record of multiple years, perhaps a minimum of 20 to 50 years.

The significance level of a test is the probability of rejecting the null hypothesis of no trend when it is true. In similar studies, a high level of significance of 10% is used (confidence level is 90%) (EPA, 1989). A similar level of significance is recommended for use in any future studies of water resource parameters at Denali National Park and Preserve. The justification of using a high significance level lies in the concern for the magnitude and international importance of the resources at Denali.

Timeframe

The timeframe for detecting temporal variations and trends in water quality is not universally agreed upon; a 20 year record or less has been described as too short a time period for detecting trends of this sort (EPA, 1989). Similarly, timeframes for detecting long-term changes in channel geomorphometry are also difficult to quantify. However, the increasing concern about the extent and rapidity of global climate change could shorten the length of period that scientists deem is required for trend detection.

As of this writing, there are no water resource datasets at DENA with a long enough record to be able to conduct a trend analysis. In fact, with the exception of the now defunct Denali Long-Term Ecological Monitoring Program, there has never been a data collection effort specifically designed with the intention of providing enough temporal data to conduct a trend analysis.

However, some individual data sets, as described above, are now approaching 20 years or more in age. For example, the U.S. Geological Survey initiated stream gaging on the Teklanika River in 1965; the first year of that dataset is 40 years old. A number of water quality datasets from the Kantishna Hills mining studies are approaching 20 years or more in age.

There are several water quality data sets from the Rock Creek watershed. The Stottlemyer dataset is approaching 20 years in age. Similarly, the Rock Creek LTEM dataset is approaching 15 years or more in age.

Several attempts have been made to use assorted datasets for the purposes of estimating change to a water resource over time. However, using unrelated datasets to conduct a trend analysis is often difficult or impossible to do. Studies often have different objectives, methods, or sampling locations. An attempt to conduct a trend analysis of turbidity of mined streams in Kantishna provides an excellent example of why such analyses often fail.

Suspended sediment and turbidity are often used as measurable parameters to assess the level of damage to a placer-mined stream. Increases above background levels often indicate unnatural bank or channel erosion. Suspended solids and turbidity in an undisturbed stream may also change over time as a function of precipitation patterns, snowmelt pulses, and changes in erosive sources. Mine-disturbed streams are also affected by the same natural processes, but sediment inputs on such streams generally overwhelm the subtle natural changes (Deschu, 1985a).

Suspended sediment and turbidity data have been collected in the Kantishna Hills region since 1981. At least five separate datasets with sediment data are still in existence. In the early 1980s, these data were used to document the impacts of placer mining on water quality. Later data were collected in an attempt to determine if water quality had

improved with the cessation of mining and onset of restoration projects. The five datasets span 15 years and would seem ideal for use in a trend analysis.

Table 3. Suspended sediment and turbidity data sets for the Kantishna Hills.

Dataset	Year	Turbidity	Method	Suspended Sediment	Method	Coincident Discharge Measurement
Miller	1981	Yes	Visual/Field measurement	No	-	No
Deschu	1982-1984	Yes	Field measurement	Yes (multiple)	TSS	Yes
Emmett & Deschu	1986	No	-	Yes (single)	SSC	Yes
Emmett & Karle	1989	No	-	Yes (single)	SSC	Yes
Edwards & Tranel	1994-1997	Yes	Laboratory analysis	Yes (multiple)	SSC	Yes

TSS-Total Suspended Solids

SSC-Suspended Sediment Concentration

Several methods were used for collection of the suspended sediment data. The TSS method, which was originally designed for analyses of wastewater samples, has been shown to be fundamentally unreliable for the analysis of natural-water samples. SSC and TSS data collected from natural water are not comparable and should not be used interchangeably (Gray et al., 2000).

The differences in methods and parameters collected essentially allow only two of the five datasets to be used in direct comparison for each parameter. Because of the stochastic nature of water quality, multiple data sets should be used for an accurate trend analysis.

Planning For Trend Analysis

To be meaningful, a trend analysis program for the water resources of DENA needs to be carefully planned and executed. Specific goals and objectives need to be identified and clearly formulated. A critical component of a trend analysis is the selection of the confidence level at which the analysis will be conducted. The pitfalls are obvious: a low confidence level will indicate a trend where there is none, and a high confidence level may prevent the detection of an actual trend.

As a general guideline, we suggest that for any given water resource, a monitoring program designed as part of the data acquisition process for trend analysis should be set up to detect monotonic trends (generally increasing or generally decreasing over time) in annual data series, for selected measurable parameters at the 90% confidence level. A secondary goal of a sophisticated program would have as its goal, the ability to compare

patterns and trends in observed measurable values to forecasts made using empirical or process-oriented procedures.

In order to achieve these goals, such a project will have the following objectives:

- Provide a standard set of repeatable methods for measuring water resource condition parameters.
- Provide an early and ongoing indication of regional trends in water resource conditions and variation, using the most appropriate techniques to detect such trends.
- Quantify, with known certainty, the rate at which changes are occurring, the subpopulation characteristics of the affected streams, and the regional extent of these systems.
- Compare local trends in changes to water resource parameters with regional trends of the same.

By acquiring new data to compare with existing databases, trend analysis may be possible, depending on the water resource being analyzed, and the importance of achieving water resource goals. For example, some of the older datasets do not provide information regarding methods and techniques used to collect the data. Though the lack of supporting information for a historic dataset may be unacceptable for some purposes, it may not be important for some comparisons.

Acquisition of Data for Future Trend Analysis

As mentioned previously, new data acquisition is expensive and often difficult to plan for. The best method for supporting data for trend analysis is to incorporate the data collection into a long-term monitoring program, such as the Central Alaska Network Vital Signs Monitoring Program. The broad goals of the CAKN monitoring program are to: (1) better understand the dynamic nature and condition of park ecosystems; and (2) provide reference points for comparisons with other, altered environments. The focus of the CAKN program will be to monitor ecosystems in order to detect change in ecological components and in the relationships among the components (MacCluskie and Oakley, 2005).

Though water quality monitoring is fully integrated within the CAKN monitoring program, the focus to date has been on lentic systems monitoring. However, the program for lotic systems (moving water) is still under development, and may present an ideal foundation to support long-term trend analysis with the goal of improving or maintaining newly developed water resource water resource goals.

In addition to well-funded and established long-term monitoring programs, smaller studies with short-term goals and objectives may also be used effectively to aid in trend

analysis. Many such studies have occurred in Denali in the past, as investigators from many different sources (universities, agencies, etc.) desire to conduct research in large, natural laboratories such as Denali.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-381, September 2007

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