

Surface Water Dynamics and Distribution

Parks Where Protocol will be Implemented: BELA, CAKR, GAAR, KOVA, NOAT

Justification/Issues Being Addressed:

Seven Wild and Scenic Rivers, tens of thousands of streams and lakes, and 450 km of shoreline with coastal lagoons and estuaries are embedded within a complex mosaic of wetlands throughout the ARCN. The distribution and extent of these waterbodies is largely influenced by the balance between precipitation and evapotranspiration, the presence of frozen ground, and, in the case of lagoons and estuaries, the dynamics of coastal erosion and sea level rise. As climate warming changes the hydrologic balance, thaws permafrost, decreases the extent of sea-ice, and changes rates of coastal erosion, the dynamics and distribution of surface water in the ARCN may change dramatically.

Understanding surface water dynamics of streams and rivers and the distribution of lakes, lagoons and estuaries in the ARCN is important at several scales. Locally, the distribution and dynamics of surface water is important to aquatic organisms, migratory waterfowl and native wildlife and subsistence users who are dependant on these species. Decreases in water quantity and/or connectedness of waterbodies in ARCN may further restrain abundance and distribution of fish populations surviving in an already extreme environment. Decreasing depth will affect the physical environment of shallow water bodies in particular. At depths less than two meters, waterbodies in ARCN tend to freeze solid, limiting the presence of several macroinvertebrate and overwintering fish species. As some salmonid species extend their range northward to the Brooks Range, changes in surface water dynamics and distribution of rivers and headwater streams could affect their potential to establish viable populations in ARCN. Shallow lakes and wetlands also provide important habitat and breeding areas for several migrant waterfowl populations including relatively dense populations of yellow-billed loons which are currently considered a threatened species. People living in park inholdings and native villages are reliant on large rivers as a mode of transportation for subsistence and recreational activities, trading with other subsistence users, access to medical care, attending cultural events and visiting friends and family members. Populations of native villages along the Kobuk and Noatak River are reliant on shipments of barged goods to supplement subsistence resources and in recent years scheduled barges have been cancelled due to low flow. During the summer, several of the rivers and lakes in ARCN are important to recreational users and sport fishermen. Changes in lake depth and the magnitude and timing of peak discharge may impair their experience. Changes in the quantity and distribution of water across the landscape will also affect processing of nutrients and contaminants associated with wet and dry deposition and local point source pollution.

At park, regional and national levels, NPS managers have been tasked with reporting status and trends and managing water quantity and quality when necessary (Organic Act 1964, Clean Water Act 1971, Wild and Scenic Rivers Act 198x, E.O. 1190). Managers are also responsible for protecting subsistence resources (ANILCA, 198X), recreational/wilderness use areas (Wilderness Act 19xx), floodplains (E.O. xxxx), threatened and endangered species (Endangered species Act, 198X) and species of concern (Executive Order #xxxx). National Park Service policy states that parks must ensure that there is no net loss of wetland habitat. This policy also requires parks to

conduct wetland inventories to assuring proper management and protection of the continued integrity and functioning of these resources. Understanding the dynamics and distribution of wetland surface areas will be particularly important to park managers and other agencies when making decisions regarding land-trades, proposed road development and gas and mining claims. Executive Order XXXX indicates parks must maintain the functioning of floodplains.

At the global level, surface water balance in the arctic is an important driver of heat balance of the planet and may play an important role in the quantity and quality of freshwater and nutrients delivered to the Arctic Ocean. Studies conducted in ARCN may provide scientists with useful information to help them understand some of these changes.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Some of the specific monitoring questions that will be addressed by this protocol include:

1. River Discharge Monitoring Questions:
 - Is the timing and magnitude of flooding and base flow in large rivers that originate in the parks changing over time?
2. Coastal Lagoon Monitoring Questions:
 - Are surface areas and abundance of coastal lagoons changing over time?
3. Shallow Lake Questions:
 - Is surface area and abundance of shallow lakes changing over time?
4. Watershed Monitoring Questions:
 - Is hydrologic connectivity within basins changing over time?
 - Is surface area and abundance of glacial-fed lakes and streams changing over time?
5. Potential Linkages to other Vital Signs:
 - Are changes in the timing and magnitude of flooding and base flow correlated with changes in precipitation (see PDS' for Climate and Weather and Snow and Ice)
 - Are changes in lagoon surface area and abundance related to changes in water quality and aquatic organisms in intensively studied Tier-one lagoons (see Lagoon Communities and Ecosystems PDS)
 - Are changes in the surface area and distribution of lakes affecting water quality and aquatic organisms in lakes (see Lake Communities and Ecosystems)
 - Extent and timing of lake ice cover (see Snow and Ice PDS)

Objectives:

1. Estimate current status and long term trends in the timing and magnitude of peak and base flows and perform flood frequency analysis on an annual basis for rivers currently outfitted with USGS gaging stations (GAAR, NOAT, CAKR, KOVA and BELA). With less confidence we will estimate high-duration flow statistics for ungaged streams and rivers located in basins where precipitation and temperature are measured (see Climate and weather PDS and Snow and Ice PDS). Justification: Large rivers integrate landscape scale changes in permafrost, vegetation, precipitation and evapotranspiration. Changes in the

magnitude and timing of peak and base flows may shift to an extent that impairs their value to aquatic organisms and subsistence and recreational users. These data will inform managers of important river conditions that may influence management and policy decisions related to protection or restoration, subsistence issues, and interactions with other land management agencies. Because the USGS has been gaging some of these sites since 1975, long-term trends and current status is readily available. Flood-frequency analysis will provide managers with information about the magnitude and frequency of selected flood discharges that will be important for defining flood-hazard areas and managing floodplains. Data will also be relevant to subsistence users, park residents and recreational users who rely heavily on rivers for subsistence activities, transportation and/or recreation. Globally these data will be important to the general scientific community as they strive estimate the magnitude of freshwater export to the arctic ocean (Holmes et al 200X, Peterson et al. 2006).

2. Lagoons go here --
3. Shallow Lakes go here --
4. Is surface connectivity between waterbodies changing? Objective: Determine if key characteristics (eg., node frequency, sinuosity, distance between nodes, network patterns, bifurcation rates) of stream networks are changing in sentinel watersheds.
5. Linkages to other VS

Basic Approach:

This protocol will provide instructions on collecting, compiling and synthesizing information about surface water dynamics and distribution. This information will be critical to assessing relationships between and potential effects of changes in water quantity on stream, lake and lagoon ecosystem vital signs. It may also provide information that will allow us to assess the potential effects of other vital signs (climate and weather, coastal erosion, snow and ice, and permafrost) on surface water dynamics and distribution. Co-locating several aspects of this protocol with other vital signs will not only help us better understand linkages between surface water and these vital signs but it will also allow us to make additional use of imagery and data already being acquired for other monitoring purposes.

Large river approach: We will analyze long term trends and variability in timing and magnitude of peak and base flows data from USGS gaging stations located on rivers that run through or near the parks. This will include rivers flowing northward to the North Slope of the Brooks Range, southward toward the Yukon River (Koyukuk) and westward toward the Bering Sea (Kobuk, Noatak, Kivalina and Wxxxx). These data will be incorporated into outreach products that will be distributed to local communities, scientists and NPS managers when relevant. Development of this standard operating procedure will begin FY2009.

Lagoons: By nature lagoon monitoring will be co-located with coastal erosion monitoring. This will allow ARC/N to make more efficient use of remote sensing imagery already being acquired for monitoring of coastal erosion. Every five years, imagery will be analyzed to assess the current status and long term trends in distribution and abundance of coastal lagoons. Development of this standard operating procedure will begin FY2009 and will utilize orthorectified coastal imagery obtained in 2003, 1950 and 198x.

Lake surface area and abundance approach: Routine remote sensed images will be collected from select index sites annually to estimate lake surface area and number. These images will be used in combination with historic photographs and satellite images to identify long-term trends in lake surface area and number. An initial retrospective analysis of available imagery will take place in FY09. Specific protocols for this metric will be developed in FY08 via an agreement with Benjamin Jones (U.S. Geological Survey [USGS] Alaska Science Center) and Guido Grosse (University of Alaska Fairbanks). Protocols developed here will be closely linked with the lake monitoring vital sign and will serve as important ground truthing for remote sensed images. When possible, imagery acquired and orthorectified for coastal erosion monitoring will be used.

Watershed stream networks: Every five years, a small subset of watersheds in the ARCN will be monitored for changes in key characteristics including node frequency, sinuosity, distance between nodes, network patterns, bifurcation rates, and erosion rates. These characteristics will be monitored via remote sensed imagery every five years. An initial retrospective analysis using historic images will be completed in FY09. Specific protocols for this metric will be developed and employed in FY09. Protocols developed here will be closely linked with the streams monitoring vital sign which will serve as important ground truthing for remote sensed images. When possible, imagery acquired and orthorectified for glacial mass-balance in GAAR.

Linkages to other vital signs: In the long-term, ARCN may be able to use the long-term trends in surface water dynamics and distribution data to explore linkages between vital signs, in particular co-located vital signs.

Principal Investigators and NPS leads:

- Overall project development -- remote sensing scientist (TBD) and Jim Lawler, ARCN coordinator (907-455-0624)
- Large Lakes and Rivers – Greta Burkart, Aquatic Ecologist, ARCN, NPS (907-455-0622) and Amy Larsen, Aquatic Ecologist, WRD, NPS (907-455-0622)
- Shallow Lakes and wetlands -- Amy Larsen and Greta Burkart
- Coastal Lagoons – Greta Burkart and Amy Larsen will work with Melinda and Terry Reynolds (University of North Carolina) to develop protocols to analyze coastal imagery that has already been acquired and orthorectified by Bill Manley (INSTAAR).
- Andrew Balser (UAF) has conducted extensive analyses of aerial photos and satellite imagery. When these analyses are received by ARCN, they may provide valuable insight into our monitoring program.
- Matt Nolan (UAF) and/or ARCN's Remote Sensing Scientist will acquire GAAR imagery.
- Ben Jones (USGS), and Guido Grosse (University of Alaska Fairbanks) may be contracted to further develop remote sensing techniques for this vital sign.

Development Schedule, Budget, and Expected Interim Products

The Central Alaska Network has developed protocols for monitoring shallow lakes using RADARSAT imagery. The PIs will evaluate this work, consider the possibilities of using imagery acquired for other vital signs and conduct a critical review of the literature to develop a long-term strategy for surface water dynamics. This review will be completed by the end of FY08. Based on this review the PIs will draft a monitoring protocol by December 1, 2009. Beginning in FY09 the PIs will initiate an historical evaluation of past imagery to identify any changes that have occurred

over the past 50 years. The PIs will produce draft protocols ready for external peer review by December 1, 2009. After peer review, revision, and approval, we hope to implement the protocol in June 2009. \$40,000 has been requested for development and assessment of this protocol in FY08.

Additional references to add to the overall list:

Romanovsky, V., M. Burgess, S. Smith, K. Yoshikawa, and J. Brown (2002), Permafrost temperature records: Indicators of climate change, Eos Trans. AGU, 83(50), 589.

CUT FROM PDS, BUT COULD BE USED IN CHAPTERS 1-3??

In the past five years several studies in arctic and subarctic regions have documented declines in lake surface area (Berg 2007, Riordan et al. 2006, Smith et al. 2005, Yoshikawa et al. 2003) and an increase in permafrost melting and degradation that is associated with a rise in temperature in high latitude regions (Romanovsky et al 2002). Extensive permafrost degradation has been documented in western Canada (Bielman et al. 2001), Russia (Pavlov 1994), China (Ding 1998), Mongolia (Shakuruu 1998), and interior Alaska (Osterkamp et al. 2000). The cascading effects of warming conditions on aquatic ecosystems will be magnified in this region where ice plays such an important role in the hydrologic cycle. These data will be closely related to data collected for fish assemblages, stream and lake ecosystems, and permafrost and active layer vital signs.

The fluvial geomorphology of the ARCN is largely dictated by interactions between the cryosphere and the hydrologic cycle, thus climate warming will undoubtedly affect surface water dynamics and distribution in ARCN. Climate warming in the Arctic is expected to accelerate the hydrologic cycle, increase soil water holding capacity and alter the balance between precipitation and evapotranspiration, leading to a warmer, drier Arctic (Chapin et al. 2002). By increasing depth of the active layer, thawing of permafrost will increase hydraulic conductivity, soil water holding capacity, and connections between water flowing from the soil to groundwater. These subsurface changes may decrease connectedness, size, and number of lakes, streams, and rivers across the ARCN. Decreases in quantity of water and connectedness of lakes and streams may place further limitations on the abundance and distribution of fish populations surviving in an already extreme environment.

The balance between precipitation, evapotranspiration, and soil water holding capacity result in an environment that is considerably wetter than would be expected based on the low precipitation measured in this polar desert.

Upper soil horizons underlain by continuous permafrost have a low soil water holding capacity relative to horizons that lack this impenetrable frozen boundary layer (Chapin 2002).

The importance of these waterbodies is a reflection of their importance to aquatic and terrestrial organisms, subsistence communities, recreational users, the general public, the scientific community, park managers and policy makers.

permafrost distribution, aufeis, freezing, thawing, flooding, drying, and drainage, and variation in these factors is dependent on local and global climatic cycles. Our objective is to determine the natural variation and long-term trends of surface water dynamics and distribution in the ARCN.