Protocol Development Summary

Protocol:Permafrost and Active Layer

Parks Where Protocol will be Implemented: Bering Land Bridge, Kobuk Valley, Cape Krusenstern National Monument, Noatak National Preserve, and Gates of the Arctic National Park and Preserve (BELA, KOVA, CAKR, NOAT, GAAR)

Justification/Issues Being Addressed:

Most of ARCN is underlain by continuous or discontinuous permafrost since mean annual air temperatures are typically well below freezing. Above the permafrost is the seasonally unfrozen ground of the active layer, with perhaps an unfrozen talik between them. Various disturbances and changes in surface energy balance can affect permafrost, causing thermokarst, solifluction, and other surface disturbances (Jorgenson and Osterkamp 2005, Jorgenson et al. 2006). This vital sign focuses on monitoring long-term changes in permafrost extent and temperature, active layer depths, and the evolution of permafrost landscapes whether due to climate change or other processes.

Permafrost extent and thickness is largely controlled by air temperature, snow thickness and duration, and vegetative cover – each of these parameters is currently changing and so must be affecting permafrost. This anticipated change in permafrost will have broad impacts on regional hydrology, soils, biogeochemistry, trace gas emissions, and vegetation patterns and therefore on large-scale ecosystem structure and function. Extensive thermokarst will lead to altered soil nutrient dynamics in ARCN parklands as soil organic matter reservoirs formerly icebound become available for redistribution. Thermokarst will likely have significant effects on carbon sequestration in wetter areas, and loss of permafrost may cause drier, more aerobic soil conditions in upland areas.

Specific Monitoring Questions and Monitoring Objectives to be Addresses by the Protocol

The overall intent of the Permafrost monitoring plan is to understand the current thermal state of ARCN ground, to understand how this is changing over time (past 150 years to future), to monitor changes to the land surface, to determine whether these are caused by climate change or not, and to use this knowledge to facilitate monitoring of other vital signs such as terrestrial vegetation and aquatic ecosystem dynamics. The specific monitoring objectives of the Permafrost Vital Sign are to:

1. Determine the current status (extent, thickness) of permafrost in ARCN parks and detect trends and changes to the distribution and abundance of permafrost in ARCN parks. ***Justification:*** *Permafrost is a widespread landscape feature in ARCN parks, and interacts with other features and processes such as the hydrologic regime, fire, vegetation, and regional climate.*
2. Detect broad-scale trends in permafrost condition by measuring temperatures in boreholes at selected sites in ARCN parks. ***Justification:*** *Permafrost is highly regulated by temperature and is sensitive to climate change. Boreholes are used throughout the Arctic to assess permafrost condition and the effects of climate change. The establishment of boreholes in ARCN parks will add to this knowledge network.*
3. Detect trends in surface disturbance (e.g., thermokarst, solifluction) and other permafrost-related features in ARCN parks. ***Justification:*** *Surface disturbances can be indicative of the condition of and changes to the underlying permafrost.*
4. Detect the effects of permafrost melting on nutrient cycling and hydrologic networks at index thermokarst sites in ARCN parks. ***Justification:*** *Thermokarst and other surface*

changes related to changes in the cryosphere are expected to affect nearby nutrient cycling, hydrologic networks and soil condition.

Basic Approach:

This monitoring plan is an optimization process, and focuses on economical metrics which integrate seasonal or annual impacts. There will be three components of the monitoring plan.

1. Monitoring permafrost temperatures will be based on a tiered approach, with one or two deep boreholes (to at least 60 m) surrounded by a series of spatially-distributed inexpensive shallow boreholes (to about 6 m) with continuously logging thermistor strings. The deep boreholes would be associated with primary weather stations and the shallow holes associate with any other weather stations throughout ARCN parks. The deep boreholes can provide information on recent climate changes by modeling the temperature distribution within the hole and will provide an integrative metric to assess the impact of future changes in climate.

2. Spatial extent and anticipated changes in thermokarst and other permafrost terrain features will be assessed through aerial photography and space-borne remote sensing. Imagery will provide baseline information on total extent, morphology, and expansion rates of these features. Aerial photography and the acquisition of other remote sensing imagery will be repeated on a decadal basis over large areas and more frequently at themokarst index areas.

3. Field campaigns to measure physical characteristics and collect soil, vegetation, and water samples at thermokarst index sites will be conducted approximately every three years in conjunction with aerial photography of these areas. Active layer depths and water pH, electrical conductivity, and dissolved oxygen will be measured above, within, and below each thermokarst feature. Additionally water and soil samples will be collected above, within and below each feature for analysis of total nitrogen, total phosphorus, base cations, silicate, metals and DOC. These samples will be analyzed to study the impacts of thermokarst on the surrounding terrestrial and aquatic ecosystems. Ground temperature, surface elevation, and active layer depth measurements will be conducted at additional index sites (e.g., climate stations) as often as every year where there may or may not be thermokarst. In association with other vital sign monitoring, organic thickness accumulation, sediment flux, fire-soil interactions, and other metrics will be monitored as opportunity and need arises.

NPS Leads

The interim NPS contact for protocol development Amy Larsen, Alaska Region NPS, Aquatic Ecologist, 907-455-0622; The Arctic Network Physical Scientist (to be hired in FY 2008) will ultimately be responsible for this vital sign. Collaborators include: Andrew Balser (University of Alaska Fairbanks), Breck Bowden (University of Vermont), Mike Goosef (Pennsylvania State University), Jeremy Jones (University of Alaska Fairbanks), Torre Jorgenson (ABR, Inc.), Matt Nolan (University of Alaska Fairbanks)

Development Schedule, Budget, and Expected Interim Products

An ARCN permafrost/thermokarst scoping meeting will be convened in the spring of 2008 to include collaborators and interested permafrost scientists. A Permafrost Monitoring Protocol with Standard Operating Procedures will be completed by a group designated at the meeting for peer review by March 2009. Implementation and testing of the Protocol may begin in summer 2009 with the installation of boreholes at designated ARCN weather and climate stations.

References

Jorgenson, M.T. and T.E. Osterkamp. 2005. Response of boreal ecosystems to varying modes of permafrost degradation. Canadian Journal of Forest Research. 35:2100-2111.

Jorgenson, M.T, Y.L. Shur, and E.R. Pullman. 2006. Abrupt increase in permafrost degradation in Arctic Alaska. Geophysical Research letters. 33:L02503, doi:10.1029/2005GL024960.