Emerging Issue Summary
HYDROLOGY AND LAKE DRYING

Highlights:

- Given the ongoing industrial development and environmental change, the short- and long-term information from hydrological and meteorological networks in the Arctic is critical to the management of the North Slope. This information need applies to all waters—from rivers and streams to lakes, ponds, and wetlands.

- Remote sensing technologies useful for understanding and monitoring hydrology have yet to mature, but warrant further research and development.

- The current status and trends of hydrological processes on the North Slope are poorly understood. In addition, changes expected to occur due to climate change are difficult to predict and, given the current paucity of information on status and trends, may even be difficult to document.

Ice and water flow over ice road on the North Slope. (Doug Kane, UAF)

Overview and Management Relevance:

The following concerns were raised in regard to the general topic of arctic hydrology:

- What are the needed water resource engineering design data requirements associated with conservation needs and industrial growth on the North Slope?
- Can we make surface water withdrawals while satisfying instream flow needs?
- How can we guarantee instream flow amounts or even establish minimum required flow rates to sustain existing habitat?
- In light of climate variability and change, and increased water use related to development, can we maintain critically important habitat in the drainage network?
- Can we meet future water demands associated with spatial expansion of resource exploration and development?
- Will we be able to ensure habitat protection/maintenance for water-related subsistence resources?
- Is lake drying widespread, and if so, how will it impact water availability, fish and wildlife habitat, and the food chain?

These broad concerns translate into more specific management questions, which are discussed below and followed by STAP recommendations on the highest priority needs to advance management supportive science related to hydrology and lake drying.

1. *What kind of network of long-term stream gauging stations is needed on the North Slope of Alaska?*

   Clearly, our present stream gauging program is not robust enough for the ongoing activities and anticipated future activities on the North Slope. Most stations were installed after development had been initiated and those stations are often impacted by logistical concerns. Because gauges were not installed prior to exploration and development, we do not have a record of adequate length to make reasonable decisions regarding streamflow. This problem persists for both large streams where bridges may be constructed and for small streams that recharge lakes where water withdrawals are made for a variety of uses. These uncertainties from lack of data result in decisions that are unnecessarily costly in terms of time and money. In addition to better distributed and long-term (>25 years) streamflow data, we desperately need other complementary meteorological data (addressed in detail in the "Weather and Climate" issue paper). These meteorological stations need to be distributed from the headwaters to the gauged outlet of the basin. At present, most meteorological stations are at low elevations along the coast.

A workshop involving the important contributors and users should be held to evaluate the present hydrometeorological data collection system and to identify future needs. The final product would be a vision of what the network should be to meet present and future demands, plus a plan to fund this system. At this time, oil and gas exploration and development are the major drivers of environmental data collection, but other resources such as coal, subsistence resources, and wildlife habitat need to be considered when evaluating and designing a data collection program. This would include a discussion of improved measurement methods for better quality hydrometeorological data.

2. *Is the Arctic hydrologic cycle undergoing significant and rapid change in response to climate change and is it well understood how this will affect cycle complexity (floods, drought, etc.)?*

There is no doubt that change is occurring in the Arctic. Spatial and temporal sea ice extent and thickness is decreasing, permafrost is warming, vegetation change is ongoing, glaciers are mass wasting, later freeze-up and earlier break-up are occurring, and mean annual air temperatures are increasing. To date, we have not seen strong trends in hydrometeorological variables, but model predictions indicate increases in precipitation. Although we have not done an adequate job of documenting extreme hydrologic events in the Arctic, these events may become more prevalent. The fact that we do not have long-term, good quality, hydrometeorological data makes it difficult for us to discern trends that may already be occurring. Climate change has the potential to alter the hydrologic response of watersheds; and this change can further cascade down to the Arctic's biological system (wildlife and vegetation). However, right now we do not have a complete understanding of how warming may affect the current processes of lakes and streams.

In Russia, some of the large north-draining rivers have shown an increase in streamflow to the Arctic Ocean. Elsewhere, such as Canada, flows have decreased. The likelihood of mid-winter snowmelt or rain-on-snow events increases as the climate warms. These types of events would be very detrimental to both small and large animals. Will the pattern of floods and droughts continue or will they become more severe and frequent? Drought is probably more damaging because it impacts the entire watershed (or even several watersheds) while floods mainly impact the channel and adjacent floodplain.

It has been observed in some parts of the Arctic that lakes are drying up (e.g., Seward Peninsula with warm permafrost) at the same time lakes are expanding elsewhere (e.g., Northern Russia with cold permafrost). Remote sensing of various modes is the best tool to observe this change; but yet again, the lack of quality, long-term data prevents us from pinpointing the exact cause of these processes. Possible causes could be drainage due to thawing of permafrost below the lakes or a reduction in precipitation minus evapotranspiration. The expansion of lakes could be caused by warming of cold permafrost that triggers thermokarst and eventual lake development. If lake drying (or even lake expansion) is widely distributed and governed by climate change, management actions to control these processes will be futile. We should continue to monitor lake evolution, both drying and expansion. In the case of drying, studies should include lakes, ponds and all forms of vegetated and non-vegetated wetlands to determine if drying is more widespread than currently thought.

3. *Are alternative technologies for better quality data collection being developed? If so, will they lead to alternative regulatory requirements?*

The quality of data presently being collected in the Arctic is average at best. We still struggle in this environment to make simple measurements of solid precipitation, minimal seasonal streamflows, and many other variables. However, we should not stop collecting data because of the less-than-optimal quality. Real data is still the only yardstick that we have to compare and evaluate model output. There are some improvements being made (like various unmanned vehicles) that allow us to collect much more data than was previously logistically possible. Presently we do a very poor job of capturing spatial variability. Although remote sensing is maturing very slowly, it is still our best hope for wide scale hydrologic measurements of snowcover, evapotranspiration, precipitation, and other important attributes. At this time, it is impossible to know how alternative technologies for better data collection will change regulatory requirements, but it seems reasonable that regulatory requirements will change as technology and data collection methods improve.

4. *Hydrologic data for individual small headwater hydrologic systems (streams and lakes) are severely lacking, but might these systems, collectively, be very important?*

These headwater systems are an integral part of the ecosystem. It is in the headwaters where much of the runoff is generated and they are often the most biologically productive systems. What transpires in headwater systems is transported down through the whole system. Because they are small (although quite numerous), headwater systems receive very little attention from a monitoring viewpoint. It is challenging to study these basins on the coastal plain because they are very low-gradient watersheds, making it very difficult to accurately delineate the watershed boundary (a small snowdrift can divert water into the adjacent watersheds). High-quality digital elevation data (DEM) is needed to define these low-gradient watershed boundaries.

On the coastal plain, many of these small watersheds have lakes that are repeatedly pumped winter-after-winter. This brings up two relevant questions: "Are the lakes completely recharged the next spring during snowmelt?" and "Are there any cumulative effects?" If discharge emanates from a lake during snowmelt, it can be reasonably assumed that the lake has fully recharged. However, the occurrence of recharge one year is not a guarantee that it will occur every year. Natural year-to-year variability may result in years when complete recharge does not occur, even though the volume of pumping was similar each year. Climate change adds another unknown to this equation.

5. *Are there significant data gaps in relating annual surface runoff to annual precipitation?*

There are only a few watersheds (approximately 40) in the whole of the circumpolar Arctic where sufficient hydrologic data have been collected so that water balance computations can be completed. These studies were done on small watersheds (less than 400 km^2, most much smaller), of short duration, and using quite different instrumentation. Today, only about one dozen studies are active. The quality of the data collected in these studies is the best that we have, but there are still limitations to the data used in these water balance studies. The major weaknesses of these studies are the poor quantification of the various storage terms (active layer, surface lakes, ponds and wetlands, snowpack, snowfields, glaciers, groundwater, etc.) and the evapotranspiration fluxes at the watershed scale. Measuring the snowpack at winter's end at a watershed scale where redistribution by the wind and sublimation have been ongoing over the winter is also a challenge. Data have been collected for three watersheds on the North Slope at Imnavait Creek (2.2 km^2), Upper Kuparuk River (142 km^2) in the foothills, and Putuligayak River (471 km^2) on the coastal plain, showing considerable variability from year-to-year and between the three studied catchments.

6. *How does snow water equivalent (SWE) vary on a local scale? How accurately can we determine how much water is available in the snowpack at the watershed scale?*

The relatively shallow snowpack in the Arctic undergoes significant redistribution by the wind and is subjected to potential sublimation throughout the winter. It is relatively easy to quantify SWE at a small scale, but we need to know what the distribution is along transects crossing tens of kilometers or more (for tundra travel and ice roads) and over watersheds (for lake recharge where winter pumping has occurred). Sublimation of the snowpack is challenging to measure and estimates range from 0 to 50 percent of the SWE. Because arctic snowpacks are so light, moderate sublimation rates can be significant. Automated snow depth sensors are useful for the local scale, but interference from blowing snow and shrub vegetation makes it difficult to analyze data. Quantifying spatial variation is the main problem. For example, SWE is currently being estimated using various sensors on aircraft and satellites with some success. Remote sensing may have some improved future contributions here.

7. *Spatially and temporally, how does water availability vary on the North Slope? Will energy exploration and development be able to move forward in water challenged environments?*

There is no doubt that water availability on the North Slope depends on location. Securing a reliable water source over the winter months is one of the largest challenges as much of the freshwater is in the ice phase during the winter season. Lakes represent the most reliable source at any time of the year. Unfortunately, lakes are not evenly distributed on the North Slope. Rivers in the winter are not reliable because of the low baseflows (the only flow in some streams during the winter may be subsurface flow in the thawed bed below the channel). Every year, streams have an abundance of water during break-up. Can this water be captured and used later as an over-winter source? Spatially, lakes that provide storage are more abundant on the coastal plain than in the foothills and mountains. Reliable year-round water supplies will require innovations if development proceeds in the foothills and other areas with few or no deep lakes.

Lack of water may force energy developers to consider new alternatives such as using steel platforms typically associated with offshore development on the tundra. In some cases, water may be imported. What transpires in these cases will be dictated by the economics of each operation.

8. *How important are ephemeral streams to fish?*

Fish are pervasive on the North Slope and they move around using various pathways. They over-winter in bodies of water (lakes and deep pools in rivers mainly) that do not completely freeze during the winter and have sufficient oxygen. During the warm season fish disperse widely, probably in search of food and/or spawning habitat. In the fall, they need to return to their over-wintering sites. In the spring, there is plenty of water from snowmelt to aid with dispersal. However, this may not be true for the fall return. Drought, which we have experienced in 2005 and 2007, can make it difficult for fish to return and congregate at over-wintering sites. Will climate change alter past patterns of drought? We have no answer for this question yet. Studies of the patterns of fish movement, habitat use, and stream flow requirements on the North Slope can document the life history needs of native fishes and help model how these species may respond to various climate change scenarios. However, there is very little we can do about controlling drought and its direct impact on stream fishes other than through protection of stream flow needs as they are identified. In sum, ephemeral streams can be very important to fish dispersal during spring and to the return of fish to overwintering sites during autumn, but are of unknown value for example as fish rearing areas.

Recommendations:

1. Schedule a workshop to identify and define hydrological and meteorological data needs, including a detailed planning design of an arctic-wide stream gauging and complementary meteorological station network and that this design reflect the biological considerations for which the data will be used.

2. Support the development of remote sensing technologies that can supplement measurements from gauging stations and other conventional hydrological and meteorological methods. However, high-quality field data is still needed for ground truthing the remotely collected data.

3. Incorporate local knowledge into the planning and assessment of monitoring and modeling efforts.

***