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U.S. Geological Survey**

Grand Portage Reservation Environmental Monitoring Program

By Robert M. Goldstein

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Prepared in cooperation with the Grand Portage Band of the Minnesota Chippewa Tribe

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Conversion Factors and Abbreviations

Multiply	by	To obtain
micron (µm)	0.00003937	inch
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
gram (g)	0.03527	ounce
milliliter (mL)	0.000264	gallon
square kilometers (km ²)	0.38361	square mile

Grand Portage Reservation Environmental Monitoring Program

By Robert M. Goldstein

ABSTRACT

There are seven types of aquatic resources on the Grand Portage Reservation. An ecological monitoring program was proposed for these resources. Some of the resources are pristine, while others have been affected by development. Each type of resource has physical (habitat, sediment, and hydrology),

chemical, and biological (fish, invertebrates, and algae) characteristics that are monitored in a consistent manner so that change may be detected. Not all aspects of the physical, chemical, and biotic components are monitored at each resource type. Monitoring is focused on those aspects most susceptible to change. Replication and comparison with pristine components are a significant part of the program so that actual change can be determined from natural temporal and spatial variability.

INTRODUCTION

The Grand Portage Reservation of the Grand Portage Band of the Minnesota Chippewa Tribe is located at the boundary of Minnesota, USA with Ontario, Canada at Lake Superior (fig. 1). The reservation is 228 square kilometers located entirely within the Northern Lakes and Forests Ecoregion (Omernick, 1987) and contains numerous hills, small valleys, and an assortment of aquatic resources: streams, lakes, and wetlands. Although some areas of the reservation have been recently logged and logging continues, the majority of the forest is second growth forest and undisturbed (the entire area was logged during the late 1800's and early 1900's). Members of the Grand Portage Band are concerned that development and changing land use practices on the reservation may affect these aquatic resources. To conserve and protect these resources, a monitoring program was designed to detect changes in the physical, chemical, and biological components.

BACKGROUND AND PROBLEM

The Grand Portage Band has drafted water-quality standards for reservation waters that include narrative and

chemical criteria, but lack biological criteria because there are no baseline biological data available for comparison. The narrative for biological criteria has been written in the draft of water-quality standards in a very general format. While the Clean Water Act mandates biological criteria, and the state of Minnesota is pursuing biocriteria in the Northern Lakes and Forest Ecoregion, the Index of Biological Integrity (IBI) approach (Karr, 1981; Karr and Chu, 1999) may not be feasible on the reservation. To develop an IBI, a range of environmental conditions must exist for comparison. Conditions must range from excellent (undisturbed or reference) to poor (fully degraded). Biological conditions at monitored resources are compared to those observed across the full range of conditions. The quality of the monitored resource can then be evaluated in the context of the full range of possible conditions. While excellent to good conditions occur on the Reservation, conditions at the low end of the spectrum may not exist.

The alternative to an IBI approach is a long-term monitoring program designed to account for natural temporal and spatial variability and able to detect change in the aquatic resources. A long term monitoring program that addresses multiple resources should consist of several parts, each designed specifically

for each particular resource. Although each of the four types of resources will have a specific design, elements of each program will be similar.

Currently there is minimal biological monitoring on the reservation. A specific program of standardized sampling will satisfy the requirements of the Clean Water Act and provide the information necessary to detect long term changes to aquatic environments. Although specific biological criteria are not yet available, the data collected in this program should be applicable to Indexes of Biotic Integrity developed for streams and wetlands in the future.

PURPOSE AND SCOPE

The purpose of the report is to provide documented guidance in establishing a consistent, integrated monitoring program needed to identify factors affecting aquatic resource quality on the Grand Portage Reservation. The monitoring program is a long term standardized sampling program to define current conditions and determine change. The primary objectives are to define natural variations in physical, chemical and biological components of each of the aquatic resources on the Grand Portage Reservation. Once the range of natural variation is known, change can be detected in future samples by comparison

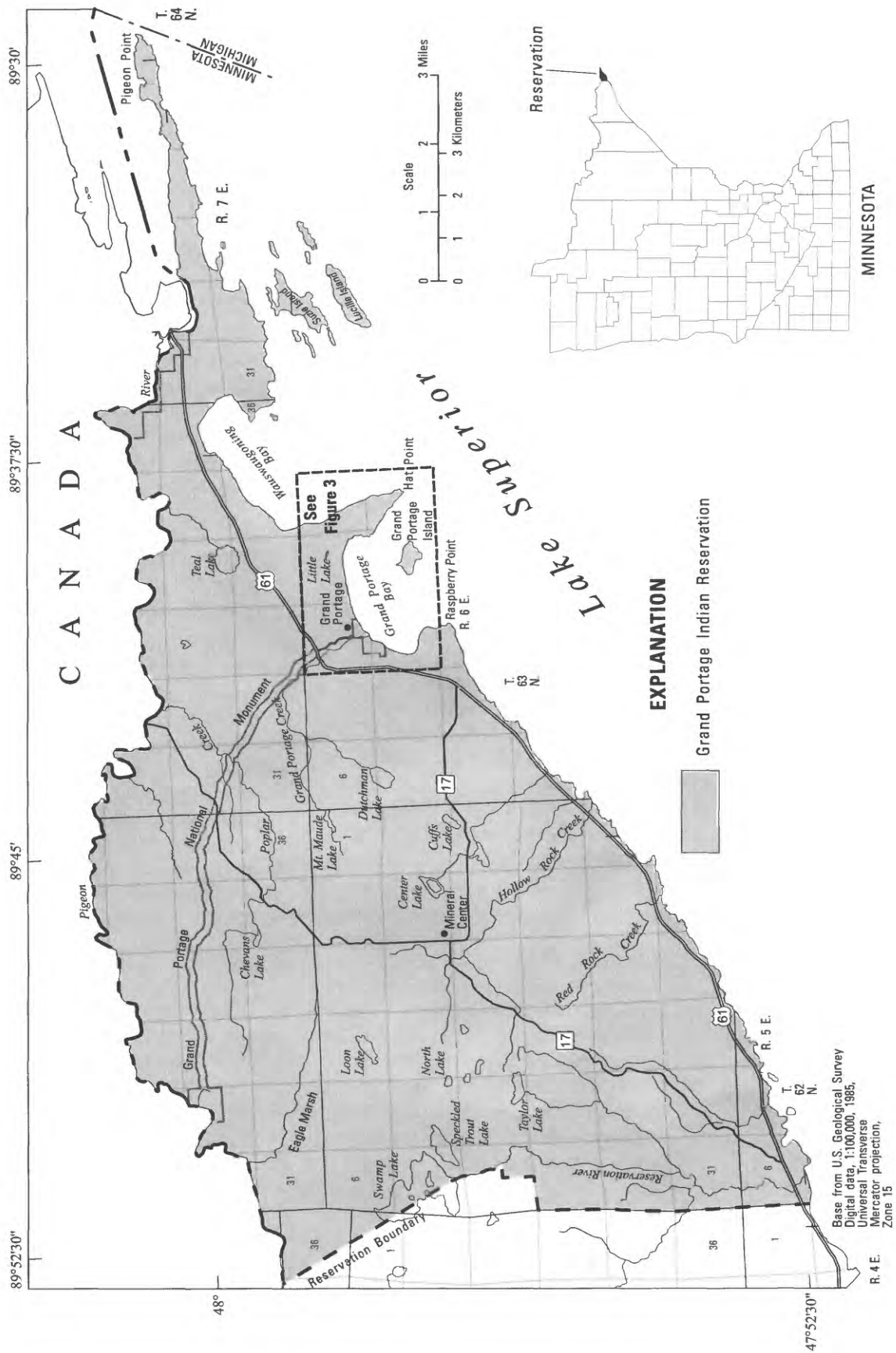


Figure 1. Location of the study area, Grand Portage Indian Reservation, northeastern Minnesota.

to the established baseline conditions. Some of the resources that will be monitored are pristine. Because they are considered close to unaffected, they will be treated as reference conditions to which the other resources can be compared and contrasted. Components in aquatic ecosystems vary through time. Knowledge of the range of values that occur due to natural processes, such as the amount of annual precipitation or the range of temperature, define the ambient background conditions against which change can be detected. The standardization applies to time of sampling, location of sampling, and equipment and techniques used in sampling. Standardization insures that all data collected are comparable.

Data collected will be applied to both short term analyses and long term analyses. In the short term, the data will be used to define baseline and background conditions. These are the starting points from which variability and long term trends can be established. The data collected can be used in various environmental multi-metric evaluation systems (e.g., Index of Biotic Integrity) that are being developed by the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources. Until such time as the biological criteria based multimetric systems are developed, the monitoring system (that will provide data that can be used for these evaluation systems) will follow the status and trends of the aquatic resources on the reservation.

The monitoring program will address each of the several types of aquatic resources on the Resource and Trust Lands. Monitoring will include habitat, water quality, hydrology, and the biotic communities of fish, invertebrates, and plants. The sampling matrix is presented below (table 1).

Resource Type:

1. Natural lakes, pristine (North Lake, Mt. Maude Lake, Chevans Lake, Cuffs Lake, and Little Lake) will be monitored as reference conditions.
2. Natural lakes, stocked or fished (Taylor Lake, Speckled Trout Lake, and Swamp Lake) will be monitored for change in resource quality and to provide additional information about the fishery.
3. Small Streams, not managed (Poplar Creek; upstream of lake barriers on Reservation River and Hollow Rock Creek; and the disturbed Red Rock Creek) will be monitored to detect changes in resource quality.
4. Small streams with lake access and managed for coaster brook trout (Reservation River, Hollow Rock Creek, and Grand Portage Creek) will be monitored for resource quality and to provide additional information to augment the restoration of coaster brook trout.
5. The Pigeon River, the largest river on the reservation, will be monitored to detect changes in the quality of the resource and to provide additional information on the walleye fishery.

6. Natural wetlands (Eagle Marsh and Raspberry Point) may be among the most sensitive aquatic systems on the trust lands and therefore will be monitored.

7. Lake Superior Bays (Grand Portage and Wausaugoning Bays) will be monitored.

Most of the aquatic resources on the reservation are not in danger of perturbation by direct human influence, but may be affected by atmospheric and precipitation inputs.

The monitoring program will consist of several parts for each type of resource (table 1). The specific program for each type of resource will consist of four general types of monitoring:

1. Habitat
2. Hydrology
3. Chemistry
4. Biota—Fish, invertebrates, plants, and algae

LAKES

The two types of lakes on the Grand Portage Reservation will be monitored similarly, although more emphasis will be placed on the fishing lakes. Monitoring the natural lakes will serve two purposes. The first is to determine their natural state. Because these lakes have not been subject to development or direct human contact, they constitute a reference condition. The only source of degradation for these lakes may be from atmospheric deposition of contaminants and acid rain. Data generated by the

Table 1. Sampling matrix for Grand Portage Reservation.
[X indicates the components sampled in each aquatic resource type.]

Resource Type	Sampling Component						
	Habitat	Hydrology	Chemistry	Fish	Invertebrates	Vegetation	Algae
Natural Lakes	X	X	X	X	X	X	
Fishing Lakes	X	X	X	X	X	X	
Coaster Streams	X	X	X		X		X
Small Streams	X	X	X	X	X		X
Pigeon River	X	X	X	X	X		X
Wetlands	X	X				X	
Grand Portage and Wausaugoning Bay			X				X

monitoring program will establish the reference or baseline conditions from which changes may be detected. The second purpose of lake monitoring is for comparison to the fishing lakes. While stocking programs to maintain a successful sport fishery usually have minor effects on the quality of the resource, forage populations may fluctuate due to differential predation leading to a "chain reaction" in other species. Comparison to the natural lakes will provide baseline information on similar biological communities. The information from the fishing lakes will provide the fisheries managers with additional information to assist the management efforts.

Lake Habitat

The purpose of the habitat monitoring program is to define current habitat conditions. Current conditions are the baseline data needed to detect changes in the system from either degradation or improvement.

Habitat for natural lakes, will have an initial mapping survey and bottom substrate identification. This aspect of the habitat program is done once. With either geographic information systems (GIS) coverages or aerial photographs, the lake outline is quantified and scaled. For each lake, depth soundings are used to make a bathymetric map (U.S. Corps of Army Engineers maps of Taylor and Speckled Trout Lake already exist). While the depth sounding is being conducted using a simple fish finder or even a calibrated rope with a weight, substrate types can be identified and mapped using a dredge or pole dragged across the bottom substrate.

Locations for all other sampling should be indicated on the map with the appropriate global positioning system (GPS) coordinates. Therefore, each lake map will contain depths, substrate types, and transect or sampling locations. Baseline maps of each lake with depth contours and bottom type can then be used as the base maps for vegetation mapping, another part of the lake biotic survey.

Lake Hydrology

Water levels will be monitored in several of the lakes. Staff gages will be placed at lakes with relatively easy access so that all gages can be checked within the period of a day or two. Gages will be checked and the water levels recorded every other week or monthly. In conjunction with water level monitoring, precipitation records will also be kept. Based on access, gages will be set up at Speckled Trout Lake, Taylor Lake, Cuffs Lake, and Little Lake.

All staff gages will be surveyed in location and triangulated to on shore benchmarks. This will allow each gage to be removed prior to ice cover and re-installed in exactly the same position and elevation after ice out. The gage does not need to be surveyed into the local datum, i.e., it measures relative changes in lake level, not absolute level.

Lake Chemistry

Water chemistry at each of the lakes will provide the background information necessary to evaluate biotic communities in the context of their chemical environment. At each lake, a depth profile will be made at the deepest area during the late summer. Along with a general depth profile of dissolved oxygen and temperature, other basic measures to include in the profile are pH, alkalinity, conductivity, total dissolved solids, and turbidity. General water chemistry will be taken at five locations throughout the lake. The locations are at the deepest hole in the lake and four sites half-way to the shore on each of the four compass points. All sampling locations will be identified by GPS so that the same sites can be revisited. These will be the standard sampling sites to use whenever lake chemistry is sampled. Additional parameters to include at the sampling locations are nutrients, chlorophyll *a*, coliform bacteria, and some measure of BOD (biological oxygen demand) and DOC (dissolved organic carbon).

Full chemical protocols will be conducted in at least two of the fishing lakes (Speckled Trout and Taylor) and two of the natural lakes (Cuffs and Little). General water chemistry (no

depth profiles, just measurements along transects) will be done at the other lakes.

A single winter sample will be made at the end of winter. This sample will consist of a depth profile of dissolved oxygen and temperature. At the same time, the ice thickness should be measured as well as the amount of snow cover (depth of snow). Even though no winter kills have been reported, the potential for winter kill in the region is high. Although monitoring may not predict the onset of a winter kill, monitoring may provide data that can be used retroactively to indicate winter kill conditions in the future.

Lake Biological Sampling

Biological sampling in lakes will include fish, invertebrates, and plants.

Fish

Fish sampling will be accomplished in both fishing lakes and natural lakes in September. In the natural lakes, fish sampling will be done by setting 4 to 6 baited minnow traps. The minnow traps will remain in place for two complete days prior to collection. The locations of the traps will be standardized and recorded on the lake maps and with GPS. On the fishing lakes, additional sampling will be accomplished by netting. A shoreline sample can be accomplished with three seine hauls with a 3 to 5 m long minnow seine (3.2 mm mesh). Each seine haul is made in a semi-circle and returns to shore. The locations of the seine hauls are recorded on the lake map and GPS. In conjunction with the fisheries program, trap nets or hoop nets (smaller mesh sizes—25 mm to 50 mm bar) should be deployed as well. Trap or hoop nets should be set for one day (24 hours). The nets should be perpendicular to shore with the leads extending from shallow water about 1 m deep to deep water. Again the locations are standardized and recorded on lake maps and with GPS so the same sites can be resampled annually.

Invertebrates

Invertebrates will be collected using a light trap with both white and black light. Three to five traps will be set up

near the lake access point and left out overnight. The light trap will collect adult flying invertebrates. Light trapping will occur twice during the summer. The first sample will be taken during the last week of July and the second sample during the middle of September. The timing of the samples is designed to capture the adult stages of most resident insects; however, light trapping is ineffective during a full moon so sampling times should be adjusted accordingly. If feasible, three samples would be more complete. The first sample should be taken the first week of July, the second sample during the middle of August, and the third sample during the middle of September.

Light trap construction and operations are as follows: Use an Eveready three way flashlight (model number 9450). Replace the tube light with a black light (number F6T5 350 BL-coated tube UV bulb). Power supply is four D-cell batteries. Use heavy duty batteries (not alkaline—they are not as durable). The entire light sits on a 23 x 15 cm plastic tray which contains about 2 cm of ethanol which traps and preserves the invertebrates. The black light bulb is positioned to face the lake and the entire light unit is secured with rubber bands. The unit can be mounted on a stump or board attached to a tree to provide a relatively level surface for the unit to rest on. The rubber bands can be used to secure the entire unit to the level surface. After deployment for a night, the liquid containing the invertebrates is poured into a labeled plastic bag. The bag is sealed and ready for shipment to a laboratory for identification and enumeration of the collected invertebrates.

Vegetation

Each year during the month of August, a map delimiting the emergent aquatic vegetation of each lake will be made. The map will outline the extent of emergent aquatic vegetation and identify the types of vegetation in the lake. The data for the map can be collected by aerial photography, site transects, or a combination of both methods. Where possible, the various emergent aquatic vegetation types will be identified and labeled on the annual baseline map. The

purpose of the mapping is to detect changes in the distribution and abundance of aquatic vegetation. Changes in the extent, distribution, and abundance of vegetation may indicate nutrient enrichment when the vegetation is expanding or deleterious inputs if the vegetation retreats. Because the extent of emergent aquatic vegetation depends on depth and light penetration, the maps (total area covered by vegetation) should be evaluated in conjunction with water levels and chemical data (see Lake Hydrology and Lake Water Chemistry, above). A second reason to monitor aquatic vegetation is to detect if the lakes have been invaded by non-native plant species.

Methods for vegetation mapping:

1. Aerial photography—aerial photographs of the each lake may indicate the extent of emergent vegetation. The information from the photographs can be transferred to the baseline maps using a grid system in which both photo and baseline maps have similar grids (number of grid lines) drawn on them. The outline of the vegetation from the photograph is drawn on the baseline map with the aid of the gridlines. The vegetation identification can be accomplished by visiting the lake and identifying the vegetation in the different areas indicated.

2. Transect sampling—a set of transects are drawn on a baseline map. Each transect has sampling points established every 20 m (two or three canoe lengths—to establish a distance, use a rope with a float. Drop the float at the sampling point and paddle to other end of the 20 m rope to make the observation of vegetation, drop an anchor to prevent drifting and repeat the procedure). At each transect point determine whether there is any vegetation and if so, what type. A grappling hook or similar device can be used to sample the vegetation.

Determination of submerged vegetation and mapping may not be possible due to physical constraints such as depth, or biological constraints such as the lack of flowering and reproductive structures needed for taxonomic keys.

SMALL STREAMS AND COASTER BROOK TROUT STREAMS

Stream habitats are resilient, but subject to change from both natural and anthropogenic sources. Periodic documentation of habitat conditions will provide the background information needed to supply the context for evaluation of biotic communities.

Stream Habitat

Numerous stream habitat evaluation protocols exist. The monitoring program consists of the initial collection of baseline data, and annual monitoring of key components. Habitat monitoring should be done in the early spring prior to leaf out. At that time, the bank and riparian characteristics can more easily be seen. Water-level monitoring can continue throughout the open water season, with the objective of confirming that water continues to flow in the streams. A zero discharge situation can have devastating effects on chemical and biological samples taken at a future time. The exception to the early spring monitoring is the substrate sampling. Substrate sampling will be conducted in late summer or early fall (September or early October). Brook trout spawning occurs during the fall. Substrate conditions can have significant effects on redd construction, survival of eggs, and hyporheic water flow. Therefore, knowledge of the substrate conditions just prior to the spawning period are required. The amount of change, in terms of fine sediment accumulation, embeddedness, or scouring that may occur between spring and fall may be significant.

Reach designation

For the designated coaster brook trout streams, a 200-m length of stream between the lake and the first barrier is the reach for monitoring. For the other small streams, a reach is defined as a minimum of 20 times the average channel width (Meador and others, 1993) to a maximum of 35 times the average width (Lyons 1992). Ideally, the reach

should contain at least two riffles and two pools.

Habitat components

The boundaries of the reach should be permanently marked. This can be accomplished by non-destructive means by using flagging tape and refreshing the tape annually. Alternatively, a small concrete marker with brass marker plate or a piece of steel bar (painted) in the ground would be better and provide a benchmark for future surveying.

Habitat data will be collected for five general groups: hydrologic, geomorphologic, substrate, instream habitat, and riparian land use.

See references for definitions and methods of measurement (Meador and others, 1993; Fitzpatrick and others, 1998).

Hydrologic

Hydrologic data for each stream will include:

1. Drainage area—determined by GIS or planimetry from USGS topographic maps.
2. Water level—determined from a staff gage (see Stream Hydrology below) and recorded with discharge at time of sampling.
3. Storage—the percent water and wetland to the total drainage area.

Geomorphologic

The geomorphologic data will include:

1. Number of riffles in the reach
2. Number of pools in the reach
3. Number of runs in the reach
4. Sinuosity
5. Gradient

(see Fitzpatrick and others, 1998 for definitions of geomorphologic terms)

The first three items can be measured directly during sampling. Sinuosity and gradient can be determined from USGS topographic maps.

Substrate

The reach substrate will be determined at 12 equally spaced transects throughout the reach. Additionally, the

depth of fine substrates (sand, silt, gravel, and clay) will be determined at three equally spaced points along each transect. At each transect the percent of each type of substrate is estimated for the area 1 meter on each side of each transect.

1. Percent boulders
2. Percent cobble
3. Percent sand
4. Percent silt
5. Percent clay
6. Depth of fined (cm)
7. Embeddedness

Instream Habitat

Instream habitat consists of various types of structural components in the stream that can provide shade, shelter, or velocity protection for fish or invertebrates. Using the same transects, the percent of the area in the 1-m band on each side of each transect is estimated and categorized.

1. Percent cover as boulders
2. Percent cover as woody debris
3. Percent cover as root wads
4. Percent cover as undercut banks
5. Percent cover as overhanging vegetation
6. Canopy angle (sun angle) or percent shade
7. Depth at three equally spaced points along each transect

(see Fitzpatrick and others, 1998 for details of measurements)

Riparian land use

The riparian land use within the 100 m buffer on both sides of the stream will be determined by a combination of GIS and direct observation.

1. Percent of forested land use within 100 m of the stream
2. Percent of agricultural land use within 100 m of the stream
3. Percent developed land use within 100 m of the stream

When the data collection is complete, a map/diagram of the reach is drawn. This map/diagram will include the location of geomorphic units, the general details of instream cover types, riparian composition, and anything else of note. These maps will be used to identify and locate sampling sites for some of the fish

sampling and the invertebrate samples. The map is complemented by photographs of the reach. A permanent marker is placed at the photography location. Each year, a photograph is taken from the same site for a continuous record of the reach.

Stream Hydrology

The amount and velocity of water in a stream is a critical factor in evaluating the biological community. The hydrologic history of the stream is important because it determines the volume of aquatic habitat available to the biotic community through time. The hydrologic history also provides data that are useful for the interpretation of biological data, i.e., during low water years, production of coaster brook trout and stream trout may be lower than during high water years. Staff gages should be installed at each of the bridge crossings of the streams at Highway 61. Water levels should be monitored on a weekly basis during the open water period.

Stream water level monitoring is very important for the coaster brook trout streams. Each life history stage of the coaster brook trout requires different habitat conditions that are dependent on the amount of water in the stream.

Stream Chemistry

Chemical monitoring of streams is not a required component of the monitoring program. However, during low discharge periods, chemical monitoring will be initiated at weekly intervals to provide water chemistry data for periods when dissolved oxygen may approach lethal concentrations.

Stream Sediment

It is also advisable to collect and store sediment samples from each stream for future analysis for trace elements and organic contaminants. Those samples should be analyzed as time and funds permit. Sediment samples will be collected from depositional areas. For trace elements the top 2–4 cm of sediment should be removed, transferred to acid rinsed polypropylene containers

and returned to the laboratory and stored in a refrigerator until analysis. Samples for organic contaminants should be collected just prior to analysis.

Stream Biota

Fish will not be sampled in the coaster brook trout streams to preclude brook trout mortality.

Should fish sampling be deemed necessary in the small non-coaster brook trout streams, the following methods may be used.

Fish

The fish stream community will be sampled from the entire reach during the late summer or early fall period. Fish will be collected by electrofishing (backpack shocking unit), a single pass, throughout the reach. Fish can be maintained alive in live cars or buckets prior to data collection (during warm weather, aeration is recommended). Every attempt to sample all the available habitats will be made during sampling. Because electrofishing gear is size selective (success on individuals less than 5 cm is poor), a second sampling method will be used. At two pool locations within the reach, minnow traps will be baited and placed in the stream, the day before electrofishing. The location for the traps should be marked so that the same location can be used year after year.

The minnow traps will be removed just prior to electrofishing. Catch data from each method should be recorded separately. All fish captured will be identified to species. Each fish collected will be measured for total length and examined for any disease, deformities, or other anomalies. The total weight (batch weight) of each species will be determined. After processing, all fish will be returned to the stream.

Invertebrates

Invertebrates will be sampled in the coaster brook trout streams. A rectangular frame, measuring $1/4 \text{ m}^2$ can be constructed from metal bars and used as the areal template. At five locations in riffles, a sample will be taken by holding a 500- μm mesh Surber sampling net or D frame net downstream of the metal

frame. The area inside the metal frame is sampled. Each rock is picked up and while being held under water, it is rubbed by hand to dislodge any invertebrates. A metal rod is used to disturb the substrate down to a depth of 10 cm. The samples are composited, sieved through a 500- μm mesh, and preserved in 10% buffered formalin. (See Cuffney and others, 1993 for details of sample elutriation).

The invertebrate sample will be processed at a certified laboratory. Identifications will be to the family level. More detailed taxonomic identification is not required. Data required are the densities of the organisms identified to family level. Relative abundance can be determined from the densities.

The selection of sampling sites in riffles insures consistent and comparable substrates are sampled in all streams. If any of the streams do not contain riffles, then alternative sampling is indicated. Streams without riffles can be sampled with an artificial substrate such as a Hester-Dendy sampler, or a dredge of some type (Eckman or Ponar).

In either case, the sampling sites are indicated on the reach maps for future reference.

Algae

Artificial substrates consisting of a brick with a hole drilled through it may be placed at five or six locations within the reach. Each brick is tied to a tree on the bank to insure that it remains in the same place and so that recovery is simplified. A measured area is scraped and brushed from each brick to produce the sample. Each sample is fixed and preserved in a solution of 5 percent formaldehyde at the stream side by adding several ml of 37.5 percent (full strength) formaldehyde buffered with 4 g/L of borax to the samples to get the 5 percent mixture. An alternative to using bricks is to collect rocks from the stream and scrape and brush the rocks for the sample. The surface area of each rock is determined by wrapping the rock in just enough aluminum foil to cover the surface. The area of the aluminum foil can then be determined by measurements or tracing on a sheet of grid paper and

counting the number of grids (of known area) inside the outline.

PIGEON RIVER

Monitoring on the Pigeon River is indicated for habitat, hydrology, sediment, and biota. Habitat monitoring is encouraged but not required because the main sources of habitat alteration are natural geomorphologic processes.

Pigeon River Habitat

A partial habitat quantification is required for the Pigeon River. The size of the river precludes any but the most general measurements. The emphasis is on the geomorphology of the river. The gradient of the river in conjunction with the local geology dictates the geomorphology. At two selected pools and riffles, two transects will be established to quantify the width and depth profile of the river. Substrate variables will be determined by direct observation, dredge, or touch (dragging a pole over the bottom). Fish sampling and invertebrate sampling will occur at the same pools and riffles.

At two bends, permanent locations will be established as benchmarks (fig. 2) one on the inside of the bend and one on the outside of the bend. The bench marks should be out of the flood plain. The benchmarks can be any permanent location such as a tree or rock. In any case the benchmark should be an object not subject to change. The distance from the benchmarks to the apex of the inside and outside bend at the edge of water will be measured annually to determine whether any degradation is occurring on the outside of the bends and whether any complementary accretion is occurring on the inside of the bends. The water level on the staff gage should be noted at the time of the measurements.

Pigeon River Hydrology

The hydrology of the Pigeon River will be monitored by an existing gage and hydrologic data collection. The gage water levels will be recorded weekly during the open water season.

Pigeon River Chemistry

Chemical monitoring of streams is not a required component of the monitoring program. However, during low discharge periods, chemical monitoring should be initiated at weekly intervals to provide water chemistry data for periods when dissolved oxygen may approach lethal concentrations. Sampling should occur as early in the morning as possible because the lowest dissolved oxygen concentrations occur just before sunrise.

Pigeon River Sediment

It would also be advisable to collect and store sediment samples from each stream for future analysis for trace elements and organic contaminants. Sediment samples will be collected from depositional areas. For trace elements, the top 2–4 cm of sediment will be removed, transferred to acid rinsed polypropylene containers, returned to the laboratory, and stored in a refrigerator until analysis. Samples for organic contaminants should be collected just prior to analysis.

Pigeon River Biota

Fish

Fish communities can be monitored as part of the general fishery surveys. At the two pools where habitat transects are established, fish sampling can be accomplished by electrofishing in an electrofishing boat, minnow traps, and seining. Electrofishing will cover the perimeter of the pool and two transects across the pool. Minnow traps can be baited and left overnight. If the bottom type and water velocity permit, three seine hauls at the tail of the pool (water hauls—the seine stretched and then lifted out of the water) will produce a representative sample. At the riffle sites, seining and backpack electrofishing can be used to sample fish. A single backpack electrofishing pass up one bank of the river and laterally about 5 m can serve as the sampling area. The boundaries should be marked so the same area can be sampled in future years. Also at the riffle sites, three kick net samples should be taken. A small kick net (a seine about 1 m wide with 3.2 mm mesh) can be held in position by one person (holder). A 3-m length piece of rope tied to the net is pulled taut upstream of the net by the

other person (herder) to establish the upstream limit of the sample. The herder begins at the upstream end of the rope (3 m upstream of the net) and kicks and disturbs the bottom attempting to dislodge benthic species and herd them into the net. As soon as the herder reaches the base of the net, the holder lifts the net to capture any benthic fish that have been driven into the net.

Catch data from each method will be recorded separately. All fish captured will be identified to species. Each fish collected will be measured for total length and examined for any disease, deformities, or other anomalies. The total weight (batch weight) of each species will be determined. After processing, all fish will be returned to the stream.

Invertebrates

Macroinvertebrates will be sampled from riffles. A rectangular frame, measuring $1/4 \text{ m}^2$ can be constructed from metal bars and used as the areal template. At three transects in the riffle at the mouth of Poplar Creek, three equidistant samples will be taken along each transect by holding a 500 μm mesh Surber sampling net or a D frame net downstream of the metal frame. The area

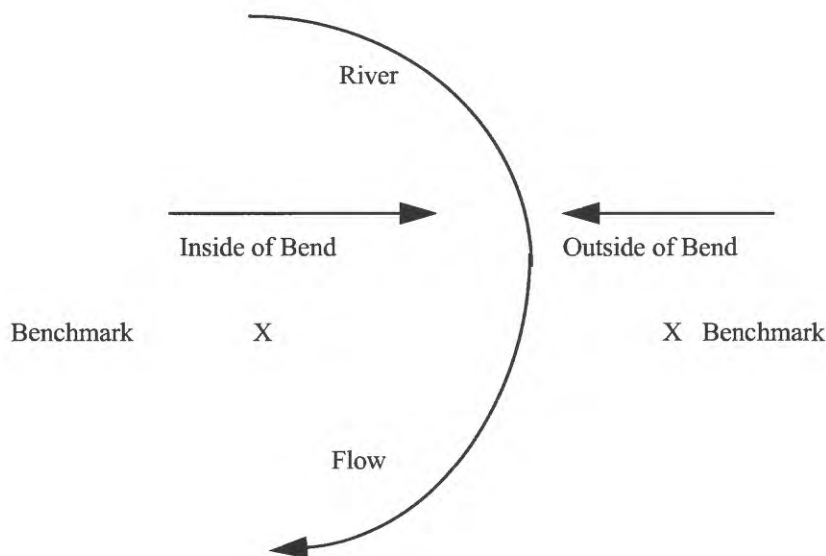


Figure 2. Habitat measurement reference points for a bend of the Pigeon River.

inside the metal frame is sampled. Each rock is picked up and while being held under water, it is rubbed by hand to dislodge any invertebrates. A metal rod is used to disturb the substrate down to a depth of 10 cm. The samples are composited, sieved through a 500 μ m mesh, and preserved in 10% buffered formalin. (See Cuffney and others, 1993 for details of sample elutriation).

The invertebrate sample will be processed at a certified laboratory. Identifications will be to the family level. More detailed taxonomic identification is not required. Data required are the densities of the organisms identified to family level. Relative abundance can be determined from the densities.

Algae

Phytoplankton will be sampled at the lower reaches of the Pigeon River in approximately the same areas as the fish sampling occurs. Three horizontal plankton tows will be made along a fixed transect of measured length. Using the measured diameter of the net, the total amount of water filtered can be calculated.

WETLANDS

There are two types of wetlands on the reservation, a coastal wetland on Raspberry Point adjacent to Lake Superior, and scattered inland wetlands such as Eagle Marsh.

Wetland Hydrology

Two simple monitoring wells will be established in both the Eagle Marsh and Raspberry Point wetlands. These wells will be encased in a pipe or cylinder large enough to hold a staff gage or similar water level monitoring device. During the course of the ice-free seasons, the water level will be monitored monthly and the water elevations recorded.

Wetland Biota

Invertebrates

Invertebrates will be collected using a light trap with both white and black light. Two traps will be set up in each of two vegetation plots and left out over night. The light trap will collect adult

flying invertebrates. Light trapping will occur twice during the summer. The first sample will be taken during the last week of July and the second sample during the middle of September. The timing of the samples is designed to capture the adult stages of most resident insects; however, light trapping is ineffective during a full moon so sampling times will be adjusted accordingly. If feasible, three samples would be more complete. The first sample would be taken the first week of July, the second sample during the middle of August, and the third sample during the middle of September.

Plants

At each of the two wetlands, two permanent vegetation plots will be established and monitored. Each plot will be 10 m by 10 m. Every year, the plants in the plot will be counted and identified to the lowest practical level to obtain a representative community sample. The location of the plots are permanently marked so the same area is sampled every year.

At both wetlands, two permanent transects, 50 m long will be established running from the interior of the wetland to the upland, i.e., from where wetland plants are obvious (black spruce, Labrador tea) to where non-wetland or upland trees (poplar, birch, oak) are obvious. The plants along each transect will be mapped to follow the transition of upland to wetland species and the successional changes that occur through time.

GRAND PORTAGE BAY AND WAUSWAUGONING BAY

Sampling Transects

Establish two transects (fig. 3). The transects will be firmly located by using GPS to establish starting points, midpoints, the intersections, and end points. For example, at Grand Portage Bay, one transect will begin at the dock in Grand Portage and end at the western point of Grand Portage Island. The second transect will intersect the first transect. Flagging or some other type of

marks on shore will indicate the ends of the transects to facilitate navigation. Each transect will have three locations for sampling. One in the center (at the intersection of the two transects) and one half way between the intersection of the transect and the end points. That would yield five total sampling points.

Grand Portage and Wausaugoning Bay Water Chemistry

At each sampling location on the transects, a depth profile should be made each month during the ice free seasons. Sampling should occur at approximately the same time of day. Along with a general depth profile of dissolved oxygen and temperature, other basic measures to include are pH, alkalinity, conductivity, total dissolved solids, and turbidity. Additional measures to include at the sampling locations are nutrients, chlorophyll *a*, coliform bacteria, and some measure of BOD (biochemical oxygen demand).

Grand Portage and Wausaugoning Bay Algae

At each of the transect sampling locations, a vertical plankton net tow will sample for phytoplankton. Collections should be made at approximately the same time of day. The five plankton tows can be composited for analysis. Record the depth of the water (bottom to surface) and the area of the plankton net mouth. Using those measurements, the volume of water sampled (strained the net) can be calculated and the densities of the algae determined. Upon collection and compositing, the sample will be preserved. To estimate the volume of the sample, use the same size jar as is used for the entire composited sample. Add 50 mL of water to the empty jar and mark the side of the jar with a line at the 50 mL water level. Continue to add 50 mL of water and mark the level each time. Continue until the jar is completely calibrated like a graduated cylinder, with lines indicating every 50 mL level. After the plankton tows, when the five samples have been composited in a separate jar,

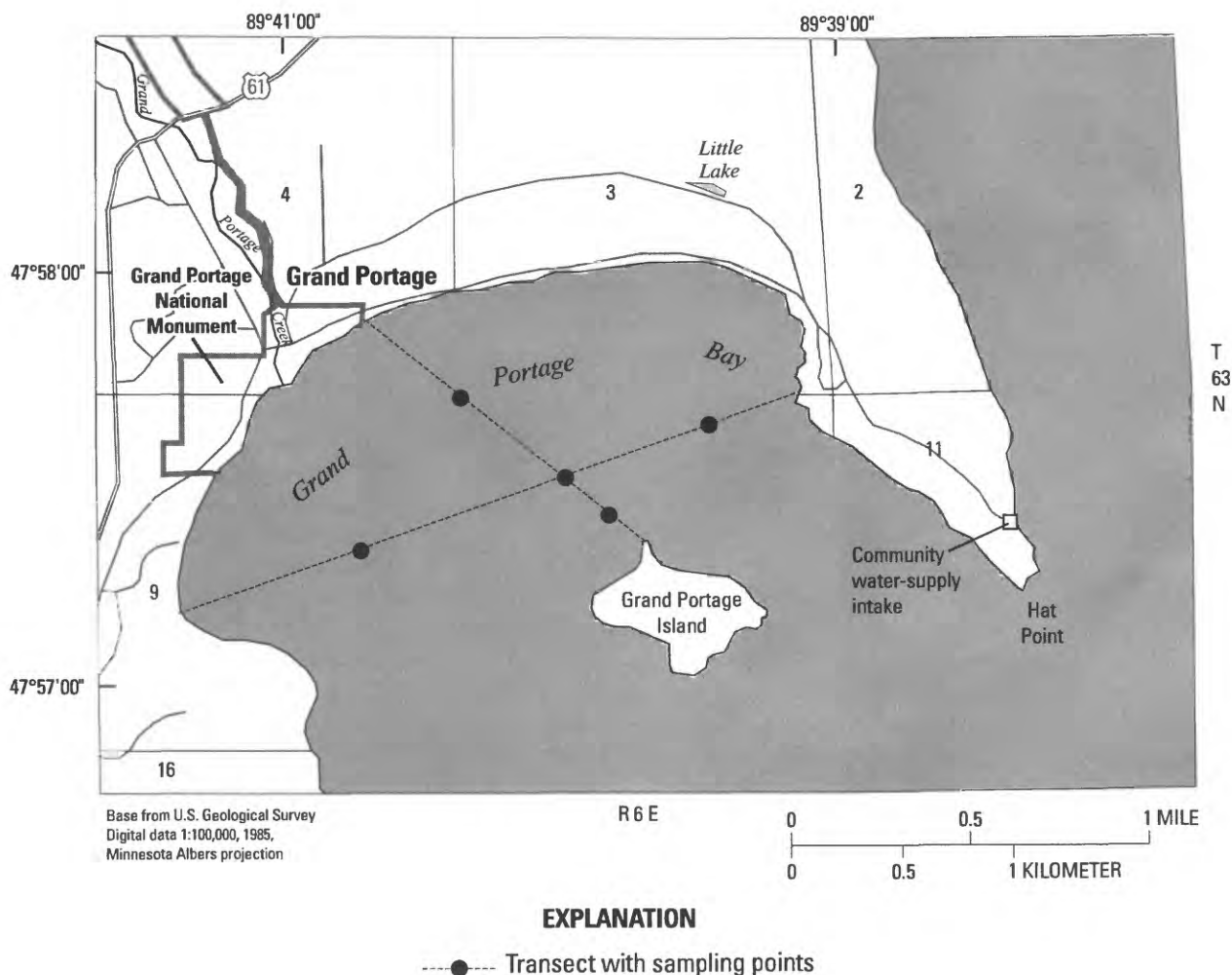


Figure 3. Transects with sampling points indicated for Grand Portage Bay.

use the graduated jar to estimate the total volume of sample by holding the two jars side by side. Each sample is fixed and preserved in a solution of 5 percent formaldehyde by adding several ml of 37.5 percent (full strength) formaldehyde buffered with 4 g/L of borax to the samples to get the 5 percent mixture.

Phytoplankton sampling will be conducted monthly in conjunction with water chemistry. Phytoplankton communities change through time as environmental conditions such as temperature and nutrient concentrations change.

DATA ANALYSIS

Natural Variability

The main purpose of the long term monitoring program is to define the current conditions and determine the amount of natural variance in the physical, chemical, and biological data so that any observations that are outside the range of natural variability can be detected immediately. There are two sources of natural variability that need to be addressed so that the total amount of variance in the collected data can be determined.

Temporal Variability

The nature of the monitoring program provides for annual observations. Each year the data or observations can be plotted against time (year) and the upper and lower bounds defined visually on the graph. The longer the period of record, the more confidence there is in the defined range. The graphic approach is analogous to calculating the statistical mean and confidence limits. Temporal variability is affected by the annual hydrologic regime and climate.

While there is annual variation, there is also seasonal variation. Seasonal variation in biological communities

centers about the life history and population dynamics of the different species within the community. Hence, the reason for sampling at the same time every year is to avoid the complexities of seasonal variation except where the seasonal data are crucial. Within biological communities, the annual variation has a noise or the inherent variation component due also to population dynamics, predation, disease, and behavioral considerations. There is as of yet no means to account or predict the amount of natural variability in the community.

Spatial Variability

A second source of variability is spatial. Because no two sections of a stream or parts of a lake are identical, there will be some variability in the observations of habitat and biota due to location. One approach to determining the variance of the observations is with spatial sampling. The same data are determined for two or more similar locations. The objective is to generate replication of the same types of data from similar locations so that a statistical mean and confidence limits can be determined. Due to minor changes in the physical habitat, annual samples at the same location will have both temporal and spatial components. A long period of data collection at the same site will include both variance components. However, to generate the necessary confidence limits by maximizing the number of samples, the best method of determining variance will require the collection of both spatial and temporal data. Replicate spatial samples will be taken as time permits.

Context

Hydrology

One aspect of the hydrologic monitoring program is to provide the context for the measures of biological variance. This is accomplished with the hydrologic data. The history of water levels in the streams, lakes, and wetlands provides the background for determining changes in the other data. Certainly, aquatic systems require water; the question is how much water and when is the water there. The amount of water determines the extent and vegetation

composition of the wetlands, the volume of habitat or living space available to each life history stage of each aquatic species, and the context for all aquatic studies. In the lakes and wetlands the vegetation (the extent, types, and amount) will fluctuate with water levels and should be graphed with that data. Annual and spatial data on vegetation is designed to detect trends not associated with water levels.

Statistically, the hydrology data are covariates, a known influence on the other data. The other data must be "corrected" for the hydrologic history of high, low, or average water levels. Graphic display of the hydrologic data plotted through time with the other types of data will provide the means for including the influence of hydrologic variability and help to determine truly divergent data points.

Habitat

The habitat monitoring program is designed to detect changes in the physical habitat. Change to physical systems requires time unless the reason for the change is catastrophic (in which case it can be detected immediately). Annual monitoring of the streams and Pigeon River should be sufficient to detect physical habitat changes.

Habitat data should also be graphed in conjunction with water-level data from the hydrologic component of the monitoring program. For example, changes in stream habitat such as the number of riffles may be attributable to different water levels in different years.

Biological Communities

The general data analysis can follow two lines: general community statistics and autecological conditions. The first is the graphic presentation of the data on the number of species, weight per species, number of individuals per species, and other measures of diversity or relative abundance such as areal extent of emergent vegetation. These data should be graphed along with the appropriate hydrologic data on an annual basis. The incorporation of replicate samples in time and space can be plotted as well to provide additional data on variance.

The autecological data are derived from the life history requirements of the individual species. For example, the presence of brook trout indicates that specific conditions associated with the ecological niche of brook trout must be present. These conditions include water temperatures less than 20°C, gravel and cobble substrates with less than 20 percent fines, and dissolved oxygen concentrations greater than 5 mg/L (milligrams per liter). The presence of brook trout also indicates that certain conditions do not occur at the sampling site, i.e., those conditions detrimental to any life history stage.

Some species are considered keystone species, that is, they have a critical role in the community. In some cases, keystone species create spawning sites for other species. For example, creek chubs build mounds of gravel and spawn on the downstream side. Other species such as common shiners, blacknose dace, and other nest-building minnows use the same pile of gravel. Creek chubs could be a keystone species in the streams on the reservation. However, creek chubs are very plastic in their own life history requirements. They possess a wide range of conditions under which they can live. By having such a broad niche, they lose appeal as a keystone species.

Some species are considered indicator species. Their presence and abundance are indicative of certain environmental conditions as evidenced by their life history requirements. The brook trout example above indicates the use of an indicator species. Among invertebrates the proportion of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera, which are the mayflies, stoneflies, and caddisflies, respectively) is an indicator of water quality. A large proportion of EPT taxa in the community indicate good water quality.

The monitoring program contains numerous elements for each of the various aquatic resources (table 2). The data collect from this program can be used to incorporate both a community metric based analysis and an indicator species analysis. The data will be available for both.

Table 2. Site by sample matrix for the Grand Portage Reservation aquatic resource monitoring program

Site	Gage	Invert	Light Traps	Habitat	Fish	Vegetation	Algae
Reservation River	staff (existing)	6 dip nets	none	200 meters	yes	no	6 bricks or rocks
Red Rock Creek	staff (needed)	6 dip nets	none	200 meters	no	no	6 bricks or rocks
Hollow Rock Creek	needs two staffs	6 dip nets	none	200 meters	yes	no	6 bricks or rocks
Grand Portage Creek	staff (existing)	6 dip nets	none	200 meters	yes	no	6 bricks or rocks
Poplar Creek	staff (needed)	6 dip nets	none	200 meters	no	no	6 bricks or rocks
Pigeon River	existing	dip nets on each of 3 transects	none	no (optional)	yes	no	3 horizontal plankton tows
Little Lake	staff (needed)	none	three	bathymetric map from transects	no	vegetation mapping	no
Taylor Lake	staff (needed)	none	three	bathymetric map from transects	yes	vegetation mapping	no
Speckled Trout Lake	staff (needed)	none	five	bathymetric map from transects	no	vegetation mapping	no
Cuffs Lake	staff (needed)	none	three	bathymetric map from transects	no	vegetation mapping	no
North Lake	staff (needed)	none	three	bathymetric map from transects	no	vegetation mapping	no
Raspberry Point	bucket wells (2 needed)	none	four, two on each plant transect	none	no	two transects, two plots	no
Eagle Marsh	bucket wells (2 needed)	none	four, two on each plant transect	none	no	two transects, two plots	no
Grand Portage Bay	none	none	none	none	no	none	five vertical tows on two transects
Wauswaugon-ing Bay	none	none	none	none	no	none	five vertical tows on two transects

SUMMARY

The monitoring program is a long term standardized sampling program to define natural variations in physical, chemical, and biological components of each of the aquatic resources on the Grand Portage Reservation so that change can be detected.

There are seven types of aquatic resources on the reservation. Each type of resource has a specific monitoring program that includes habitat, hydrology, chemistry, and biota, although not each component is included in the plan for each resource. Sampling components that are not included are those not likely to experience measurable changes such as the habitat of a large river. All sampling is standardized in terms of

location, time, and equipment so that the data are comparable from year to year or site to site.

There are two types of lakes on the Grand Portage Reservation, lakes that are pristine and receive very little disturbance and lakes that are managed for recreational fishing. Both types of lakes, fishing lakes and pristine, are sampled for habitat, by bathymetric and vegetation mapping. Hydrology is monitored by a staff gage, and biotic collections are primarily aquatic vegetation and adult invertebrates, which are collected with a light trap.

There are two types of streams on the Grand Portage Reservation, small streams and coaster brook trout streams. From the mouth of a stream at Lake Superior to the first barrier waterfall, the stream is the part accessible by coaster brook trout. The remainder, upstream of the waterfall, is a small stream. In both types (or portions) the resources are monitored by a combination of hydrology, chemistry, habitat, and biotic sampling. Fish are not sampled in the coaster brook trout portions of the streams to protect juvenile coaster brook trout, however, invertebrates and algae are sampled. In the other small streams, fish are sampled as part of the monitoring program.

The major river resource, the Pigeon, is monitored by hydrology, chemistry, and biotic samples of fish, invertebrates,

and phytoplankton. In the upstream areas away from Lake Superior, benthic invertebrates will be sampled at three locations along each of three transects. At the downstream area near the lake, fish and phytoplankton collections will be made as part of the monitoring program.

The two major wetlands on the reservation are a coastal wetland, Raspberry Point; and an inland wetland, Eagle Marsh. Both wetlands will be monitored with water level gages. The biotic component of the wetland monitoring program includes two transects where the vegetation will be identified and quantified. Additionally, adult invertebrates will be collected from each end of the vegetation transects.

Monitoring of Grand Portage and Wausaugoning Bays, will be accomplished by monitoring water chemistry and phytoplankton. A total of five samples will be collected from two transects in each bay.

Data analysis will be accomplished mostly through graphical techniques. Additional samples may be required to define temporal and spatial variability. Due to the influence of abiotic factors, all data will be evaluated within the context of water levels and available habitat.

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