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VOYAGEURS NATIONAL PARK, MINNESOTA

WATER RESOURCES SCOPING REPORT

Don P. Weeks and Roger J. Andrascik

Technical Report NPS/NRWRS/NRTR-98/201

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

United States Department of the Interior • National Park Service

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United States Department of the Interior
National Park Service

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EXECUTIVE SUMMARY

Water Resource Scoping Reports (WRSRs) provide National Park Service (NPS) management with a better understanding of a park's water resources and the current issues it faces. These reports typically summarize existing hydrological information, identify and analyze major water resource issues and management concerns, and determine if a more comprehensive Water Resources Management Plan (WRMP) is warranted. In certain cases, WRSRs meet the current water management needs for park units, where the number and complexity of issues are minimal. In such cases, park Resource Management Plan (RMP) project statements are included in the report to provide park management with the necessary action plan(s) to address the high-priority issues.

For Voyageurs National Park (VOYA), the water-related issues are numerous and complex. Thus, the primary objective of this report is to define the high-priority water-related issues at the park, which will ultimately provide the justification for a more comprehensive assessment of these issues and the resulting project statements that properly address them (i.e., WRMP).

This Water Resources Scoping Report identifies and briefly describes the natural resources at VOYA and the surrounding area, and the significant water-related issues that park management is challenged to address. The report also summarizes the park's existing natural resources program to evaluate current staffing and natural resource management projects and identify some of the park's management needs. Based on the assessment of these natural resource issues, a recommendation and justification to produce a more comprehensive WRMP for VOYA is presented. Contents are limited to information made available to the authors during the time the report was prepared. Issue specific recommendation(s) previously proposed by NPS management via existing VOYA planning documents (i.e., RMP) are included in this report. As a result, descriptions of the natural resources and water resource issues vary in detail, and inclusion of issue-related recommendations is inconsistent.

VOYA, established in 1975, lies in a hydrologically complex and politically sensitive environment where numerous natural resource issues have arisen over the past several decades. Almost all of these issues relate directly or indirectly to water. The factors contributing to this complex management challenge include: 38% of the park covered by water; VOYA sharing a common boundary with Canada; surface water elevations strictly regulated for anthropogenic needs; and intense visitor usage.

Water is critical to the natural ecosystem function and economic vitality of the region. The park's natural aquatic ecology has evolved around several glacial events, which transformed the waters and lands in the region to their present condition. There exists both widespread and local threats, which have the potential to degrade VOYA's water resources. Park water quantity and quality are affected by the water level management regime administered by the International Joint Commission (IJC), which regulates the levels of the four major lakes in VOYA. Studies in the park have shown that the unnatural fluctuating water levels have resulted in profound negative effects on the aquatic ecology. The presence of cabins, resorts, campsites, houseboat mooring sites, and day-use sites along the park's shoreline has led to local instances of erosion, improper garbage disposal, and improper septic treatment. Additionally, widespread use of powerboats and snowmobiles has resulted in the release of petroleum byproducts into the park's environment.

In an effort to identify the most critical water-related issues for VOYA, the NPS Water Resources Division participated in a November 1997 Resource Management Plan Scoping meeting at the park. Participants included representatives from VOYA, U.S. Geological Survey – Biological Resources Division, University of Minnesota – Department of Forest Resources, NPS - Midwest Region, and NPS - Water Resources Division (Appendix A). The following fifteen water-related issues were identified during this meeting:

- Surface Water Quantity and Seasonal Fluctuations
- Surface Water Quality
- Fishery and Aquatic Ecology
- Riparian Zone Management
- Floodplains Management
- Wetlands Management
- Recreational Management
- Wastewater and Regulated Storage Tank Management
- Water Rights
- Baseline Inventory and Monitoring
- Atmospheric Deposition
- Interior Lakes Management
- Minerals
- Exotic Species
- Coordination

These issues have aspects that affect the park's water resources, though they may not be under NPS control; therefore, it is important to recognize the fact that multi-agency communication and coordination are essential to successfully managing VOYA's watershed. The WRMP process recommended for the park encourages other stakeholders to participate with the NPS during and after plan development. This process, if carried through, will produce regional ownership of the WRMP, which is needed to drive the plan's recommended actions.

INTRODUCTION

Voyageurs National Park (VOYA) encompasses 218,055 acres, of which approximately 83,789 acres (38%) are covered by water (U.S. National Park Service, 1994). The National Park Service (NPS) is challenged with proper management of this water-dominated ecosystem to preserve for the inspiration and enjoyment of present and future generations. Concurrent with the park's enabling legislation, this responsibility is supported in two of the mission goals presented in the 1997 Strategic Plan for NPS units:

- "Natural and cultural resources and associated values are protected, restored, and maintained in good condition and managed within their broader ecosystem and cultural context."
- "The NPS contributes to the knowledge about natural and cultural resources and associated values; management decisions about resources and visitors are based on adequate scholarly and scientific information."

This Water Resources Scoping Report examines the existing natural resource conditions and water resource issues facing VOYA. The objective of this report is to provide NPS management with an overview of existing hydrological information and water resource issues, and to begin identifying the "data needs" that will assist NPS management in providing a greater level of water resource protection. An evaluation of this information is presented at the end of the report to determine if a more comprehensive Water Resources Management Plan (WRMP) is warranted for the park.

Location, Legislation, and Management

VOYA is located approximately 300 miles north of Minneapolis, Minnesota along the Minnesota-Ontario border (Figure 1). The northern boundary of this national park is shared with Canada and is part of a relatively undisturbed ecosystem of 2.7 million acres, which includes the 1.2-million-acre Boundary Water Canoe Area Wilderness and the 1.1-million-acre Quetico Provincial Park. Federal lands south and east of the park are controlled by the U.S. Forest Service as either Superior National Forest or the Boundary Waters Canoe Area Wilderness. South of the park, national forest lands are largely checkered with state, Boise Cascade, and private lands. Boise Cascade manages its lands primarily for pulpwood production to supply its paper mill at International Falls, Minnesota. The majority of Boise Cascade lands are concentrated directly south of Black Bay. Private landowners manage their property for either pulpwood production, agriculture (grains and cattle), residential use, or recreational related activities (U.S. National Park Service, 1994). International Falls is located 10 miles west of VOYA's western boundary and has a population (1990) of 8325.

VOYA was authorized in 1971 by Public Law 91-661 and established in 1975 to preserve "...the outstanding scenery, geological conditions, and waterway system...". As a unit of the National Park System, park management is committed to conserving the scenery and natural resources for the enjoyment of future generations (1916 NPS Organic Act).

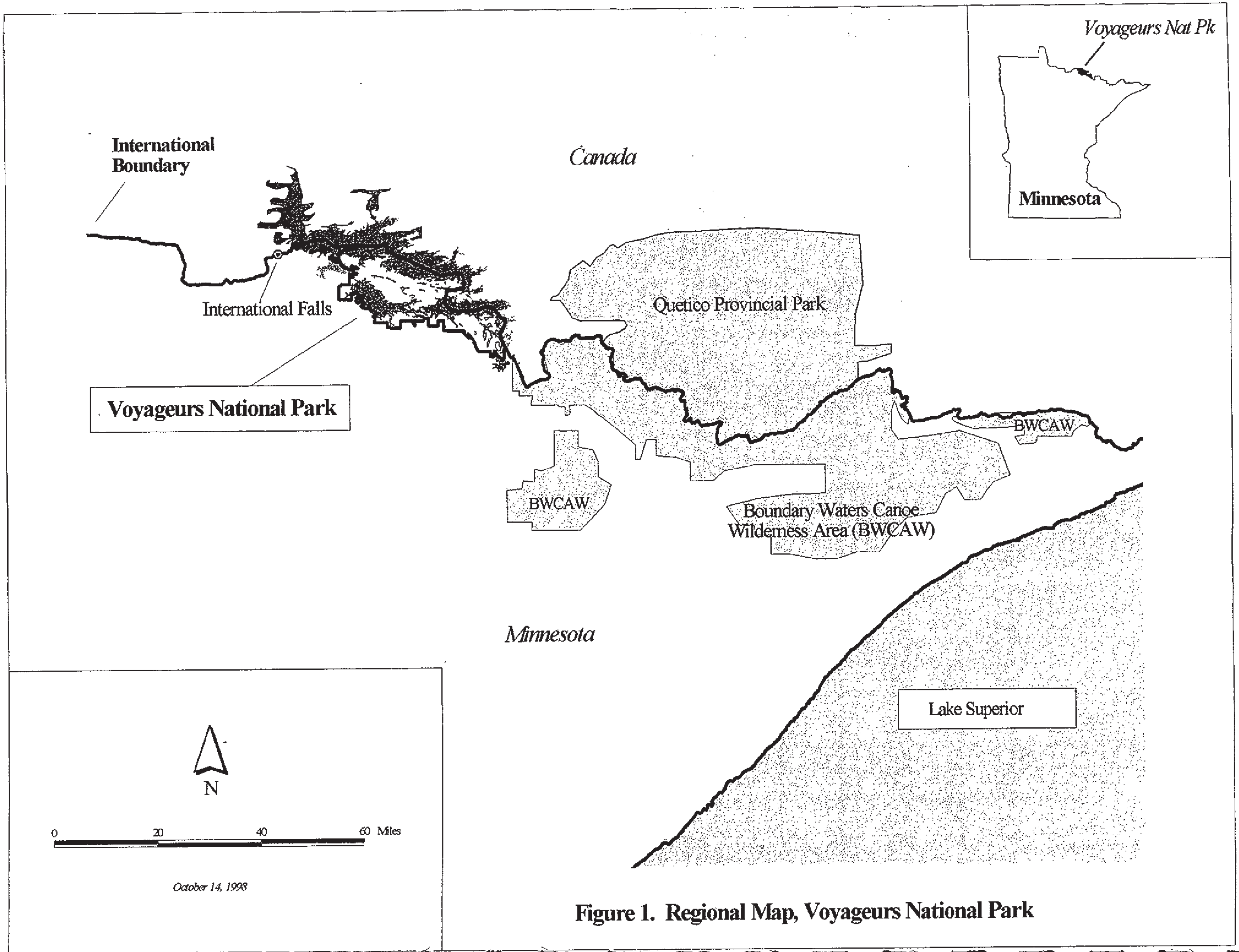

Figure 1. Regional Map, Voyageurs National Park

The 1971 enabling legislation authorized management of the park to include:

- All mining and mineral activities and commercial waterpower development within the park boundaries shall be prohibited.
- Recreational fishing shall be permitted in accordance to all applicable U.S. and Minnesota laws, except in designated areas for reasons of public safety, administration, fish & wildlife management, and/or public use and enjoyment.
- The seining of fish at Shoepack Lake by the State of Minnesota to secure eggs for propagation shall be continued in accordance with plans mutually acceptable with the state and NPS.
- The park shall include appropriate provisions for (1) winter sports, including the use of snowmobiles, (2) use by seaplanes, and (3) recreational use by all types of watercraft (i.e., houseboats, canoes, fishing boats, sailboats).
- Nothing in the enabling legislation shall be construed to affect the provisions of any treaty (including any order or agreement made or entered into pursuant to any such treaty) now or hereafter in force between the United States and Great Britain relating to Canada or between the United States and Canada which would be applicable to the lands and waters which may be acquired by the Secretary, including the Convention Between the United States and Canada on Emergency Regulation of Level of Rainy Lake and of Other Boundary Waters in the Rainy Lake Watershed, signed September 15, 1938, and any order issued pursuant thereto.
- The authorization of such roads within the park to assure access from present and future state roads to public facilities within the park.
- Owners of improved property on the date of NPS acquisition may retain use and occupancy rights for noncommercial residential purposes for a period not to exceed 25 years or life, whichever is later.
- Ability to negotiate and enter into concessions contracts with former owners of commercial, recreational, resort or similar properties within the park to accommodate park visitors.

VOYA is dominated by four major lakes: Rainy, Kabetogama, Namakan, and Sand Point (Figure 2). The park is divided into four land/water management zones to ensure that proposed developments, recreational uses, and resource management practices are mutually compatible to the natural résource and recreational needs. These zones and their respective management strategies are described in VOYA's Natural Resources Management Plan and Environmental Assessment (U.S. National Park Service, 1994) as follows:

- <u>Natural Zone</u>: The Natural Zone comprises 99 percent (215,782 acres) of land and water in VOYA. This zone includes the park's four major lakes, numerous islands, and the Kabetogama Peninsula. The purpose of this zone is to provide for quality resource-related recreation consistent with the protection of the park's natural ecosystem, and with respect to private property rights; to promote

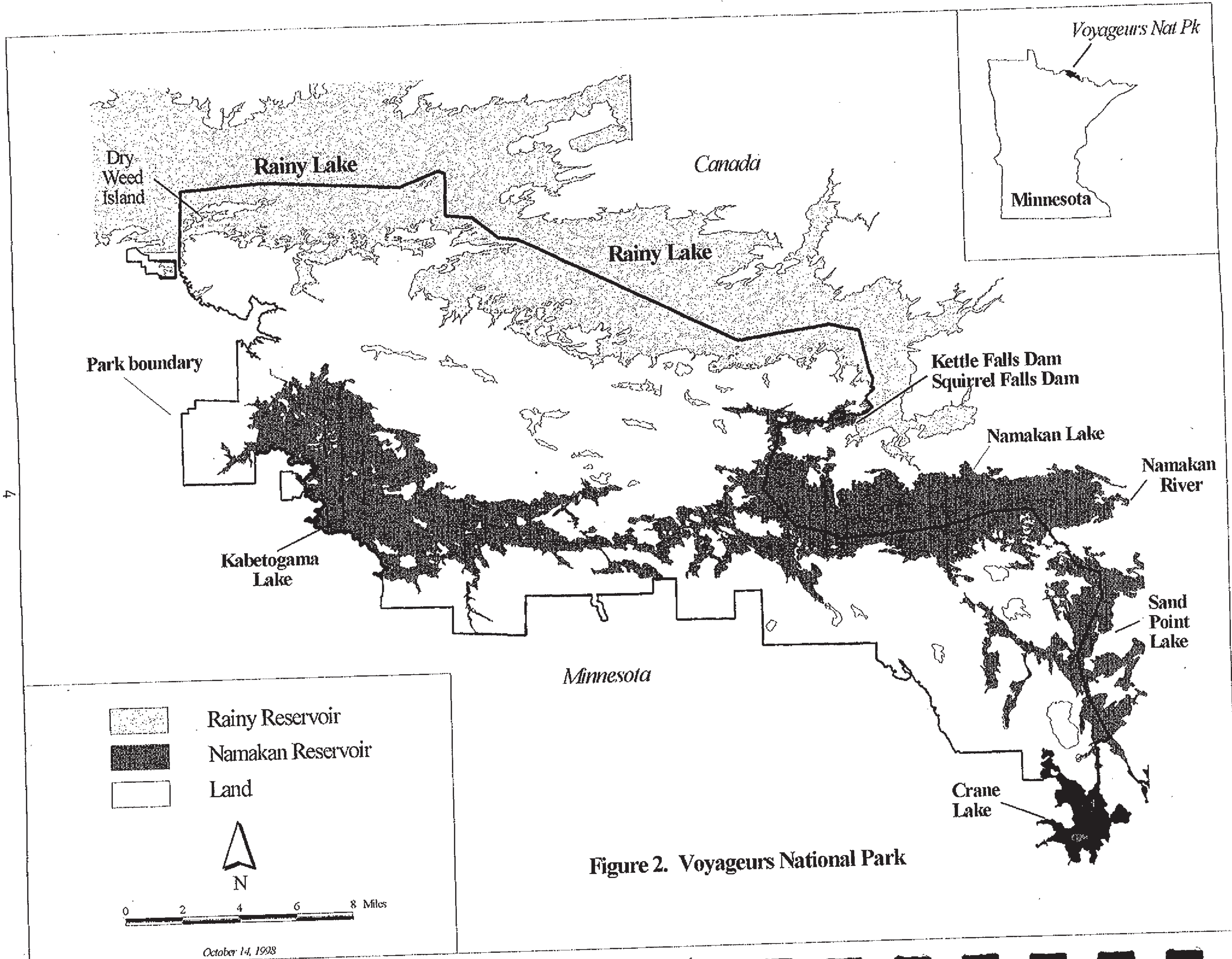

Figure 2. Voyageurs National Park

understanding and appreciation of park values; and, to enhance recovery of park lands and waters to their natural condition.

- Historic Zone: The Historic Zone is associated with significant cultural resources and comprises 0.83 percent (1,822 acres) of land and water. This zone includes Kettle Falls Historic District and the Gold Mine Historic District, as well as the Rainy Lake City site. This zone provides maximum protection for the valuable cultural resources in the park from development and/or visitor use.

- Development Zone: The Development Zone encompasses 0.21 percent (450 acres) of the land and water in VOYA. This zone includes lands and waters utilized intensively for park access, recreational activities, and related NPS and visitor-use developments. The purpose of this zone is to develop facilities in the most effective, efficient, aesthetic manner possible; minimize adverse impacts on natural, historic, scientific, scenic, and recreational values; and, provide optimum benefit to park visitors.

- Special Use Zone: The Special Use Zone is used for intensive spectator related recreational activities and other activities associated with the resort community. This zone boundary is: West – the Koochiching/St. Louis counties line from the southern shore of Kabetogama Lake to a point 0.25 miles offshore; North – 0.25 miles offshore from and parallel to the southern shore of Kabetogama Lake intersecting the western most point of Sphunge Island, to a point 0.25 miles offshore.

In 1983, Congress approved a minor boundary revision to VOYA (P.L. 97-405) in order to facilitate park development and resolve a conflict between hunters and the NPS. As of 1997, there were 1,939 acres of land in 86 tracts within the park's boundary that were not owned by the National Park Service. Of these, nine tracts totaling 174 acres are owned by Counties or the State of Minnesota, nine tracts totaling 137 acres are owned by other federal agencies, and 68 tracts totaling 1,627 acres are in private ownership. Forty one of the private tracts are improved with summer residences; the remaining 27 tracts are undeveloped.

DESCRIPTION OF NATURAL RESOURCES

Climate

The regional climate of north-central Minnesota is severe, characterized by extreme temperature fluctuations on an annual as well as a diurnal basis. Cold, typically dry, continental polar air masses flowing southward from Canada, collide with maritime air masses producing extreme variations in weather. Mean air temperatures for the area range from -10 degrees Fahrenheit (° F) to 12° F during January, typically the coldest month, and from 54° F to 79° F in July, typically the warmest month (Figure 3). Winter temperatures frequently fall well below 0° F, and temperatures in the -30° F to -40° F range are not uncommon (U.S. National Park Service, 1994). The average annual precipitation for International Falls, which is typically drier than Kabetogama and Crane lakes, is 24.3 inches divided between rain and snow (National Oceanic and Atmospheric Administration, 1997). Approximately two-thirds of the precipitation occurs from May to September.

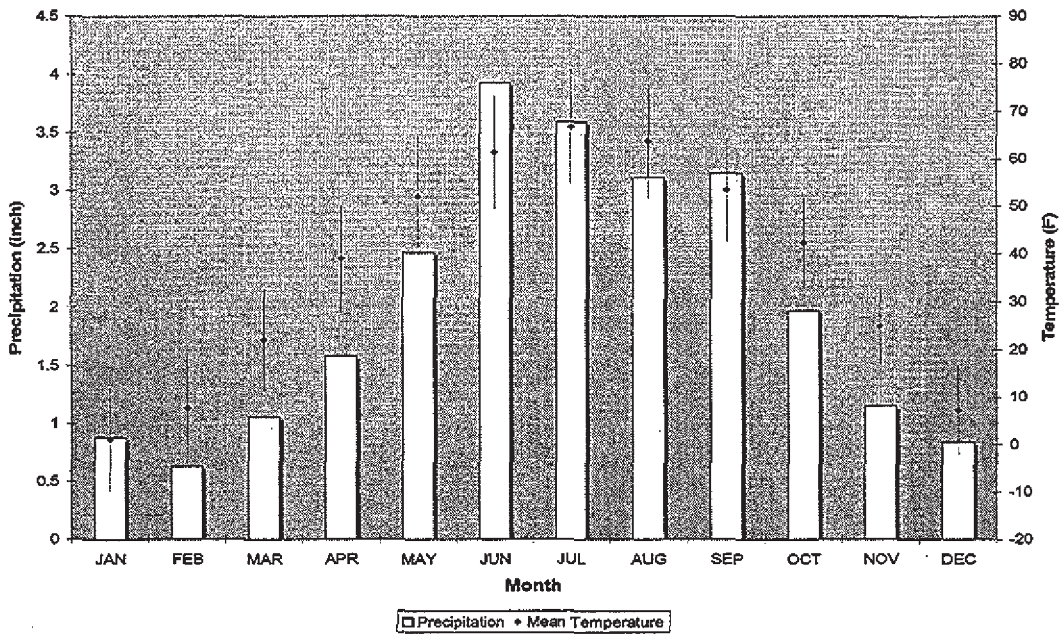

Figure 3. Monthly Mean Precipitation and Air Temperature Range (1961-1990), International Falls, MN (National Oceanic and Atmospheric Administration, 1997).

Physiography

VOYA is located in the southern part of the Superior Province, which is a component of the Canadian Shield physiographic region, a vast area of Precambrian (< 2.5 billion years old) foliated and crystalline rocks that form the nucleus of North America (Minnesota Geologic Survey and University of Minnesota, 1969). The region was extensively covered by continental sheet glaciers throughout the Ice Age, beginning approximately 190,000 years ago (Davis et al., 1994). Pleistocene glaciation was responsible for creating the surface features seen today. The most recent period of glaciation, the Wisconsin period, lasted from 50,000 to 11,000 B.C. and resulted in the exposure of the Precambrian formations and the deposition of unconsolidated morainal materials in the park (U.S. National Park Service, 1994). The topography is predominantly rolling with irregular slopes and outcrops of bedrock. Land elevations in the west and north sections of the park rarely exceed the lake elevations (approx. 1,100 feet above mean sea level (msl)) by more than 100 feet. Elevations in the east section of the Kabetogama Peninsula and along the south shores of Kabetogama, Namakan, and Sand Point lakes are commonly 100 to 200 feet higher (U.S. National Park Service, 1994).

Geology

VOYA and the immediate area were mapped geologically by the Minnesota Geological Survey (MGS) in 1968 to appraise the potential for significant metallic mineral deposits (Minnesota Geological Survey and University of Minnesota, 1969). In 1994, the U.S. Bureau of Mines assessed the hardrock mineral potential and environmental sensitivity of the park, including a 30-mile radius area on the United States side of the International Border (Davis et al., 1994). The results from these two projects are presented in this section.

VOYA straddles the transition from granitic rocks of the Vermilion batholith on the south to metamorphosed sedimentary and volcanic rocks on the north. The most widespread rock type in the park is biotite schist. It forms the bedrock for most of the Kabetogama Peninsula. The schist was more easily eroded by the glaciers than was the granite, creating less rugged exposures. Most schist outcrops are relatively low and flat.

Trending through the middle of Kabetogama and Namakan lakes is a broad belt of mixed gneiss, which lies between biotite schist to the north and massive granite to the south. These rocks consist of layers and irregular masses of biotite schist separated by sheets of granite. Highly contorted folds can been seen in most outcrops.

The terrain south of a line extending roughly from Sphunge Island (southwestern part of Kabetogama Lake) to Sullivan Bay is composed mostly of granitic rocks. These rocks range in composition from a true granite to hornblende quartz diorite. Commonly, the mineral composition and texture vary rapidly over short distances, so that a large exposure may contain rocks of various colors and textures. Granite outcrops are generally rounded and smooth and commonly display glacial striations, chattermarks, and polished surfaces.

The youngest rocks in VOYA are mafic dikes, which are common in the area. These mafic igneous rocks are composed of gabbro or diorite, and cut through older members of the granitic series.

Structural Geology

The Superior Province in north-central Minnesota has undergone a great number of tectonic faulting and folding events (Davis et al., 1994). There is strong evidence to suggest that VOYA is located within major faults having substantial displacement (Day, 1985). The following information supports a major fault (Rainy Lake-Seine River Fault) extending through the channel of Rainy Lake south of Dryweed Island:

- Numerous faults and shear zones identified on Little American Island.
- Meta-arkose on Grindstone and Dryweed island outcrops to the south, whereas biotite schist on the mainland outcrops to the north.
- Canadian geologic maps identify a major fault coming into this vicinity from the northeast.

A prominent set of topographic lineaments in Kabetogama Lake trend to the northwest. These lineaments, found in Mud Bay and Blind Ash Bay, may be controlled in part by oblique faults, but are known to be subparallel to a prominent joint set (Minnesota Geological Survey and University of Minnesota, 1969). The numerous fractures and faults in the region likely provide some structural control for the limited ground water resources.

Minerals

A "greenstone belt" passes through the extreme northwestern corner of VOYA , including Dryweed Island. The belt's composition includes: chloritic schist, massive greenstone, and meta-arkose with lesser quantities of felsic tuffs, pillowed lava flows, and conglomerate. This belt contains one formerly productive gold mine and several prospect pits and adits. Silver and copper have also been identified within this belt (Minnesota Geologic Survey and University of Minnesota, 1969). The greenstone belt is part of a broader mineralized zone, the Rainy Lake District, that crosses into Canada. In Canada, mining from this district has produced more than a million dollars in gold and several copper prospects (Grout, 1937). A gold mine in Ontario (located in the greenstone belt) near Lake Superior is being developed and is projected to produce $300 million worth of gold per year (U.S. National Park Service, 1994).

Although almost 1,000 mineral interests (4 federal, 102 state, 73 private and 795 "non confirmed" private due to improper registration or tax delinquency) exist within the park, they are not subject to mineral entry or exploration. VOYA's enabling legislation (Section 301(c)) specifically prohibits "all mining and mineral activities" within the park (U.S. National Park Service, 1994).

Soils

Soil development has occurred in the region over the last 20,000 years (U.S. National Park Service, 1992). The primary processes affecting soil formation in the region were glaciation and lacustrine sedimentation. There are two basic soil associations that occur in the park: shallow upland forest soils and deep organic soils (Arneman, 1963). The soils at VOYA are classified within the Tower-Ely Glacial Drift and Bedrock Complex. Five of the 12 soil units contained within this geomorphic area are present in the park. Table 1 identifies and describes these five soil units, beginning with the most dominant soil types. The soils are grouped into landscape units based on the following factors (University of Minnesota, 1981):

1. Texture of soil material greater than 5 feet – sandy (S), loamy or silty (L), clayey (C), and bedrock (R).
2. Texture of soil material less than 5 feet – sandy (S), loamy or silty (L), and clayey (C).
3. Drainage – moderately well to excessively drained (W), somewhat poorly to very poorly drained (P).
4. Color of surface soil – dark color (D) and light color (L).

The available water capacity of most soils in the region ranges from very low to moderate (University of Minnesota, 1981).

Table 1. Soils Identification and Description, Voyageurs National Park (modified after University of Minnesota, 1981).

Soil Landscape Units (pH range)	Soil Description typical thickness (feet)	Substratum Description Typical thickness (feet)
RLWL (5.0 – 6.0)	Gravelly sandy loam, cobbly sandy loam, and gravelly loamy sand (0 - 2)	Bedrock, cobbly sandy loam and gravelly sandy loam (2+)
CCWL (5.2 – 6.2)	silty clay (3)	Clay (3 - 20+)
NP (organic soils) (5.5 – 7.0)	peat (1 - 3)	Peat (3+)
CCPL (5.2 – 6.2)	silty clay (3)	Clay (3+)
R (bedrock) (5.0 – 6.0)	gravelly sandy loam, gravelly loamy sand, and bedrock (0 –2)	Bedrock and gravelly sandy loam (2+)

Note: Over 90% of VOYA soils are classified as RLWL.

Hydrology

Surface Water

VOYA lies within the 14,900 mi^2 Rainy Lake basin, which forms part of the headwaters of the Hudson Bay watershed (Figure 4). This basin includes three watersheds that contribute to the park: Rainy Headwaters (USGS # 9030001), Vermilion (USGS # 9030002),

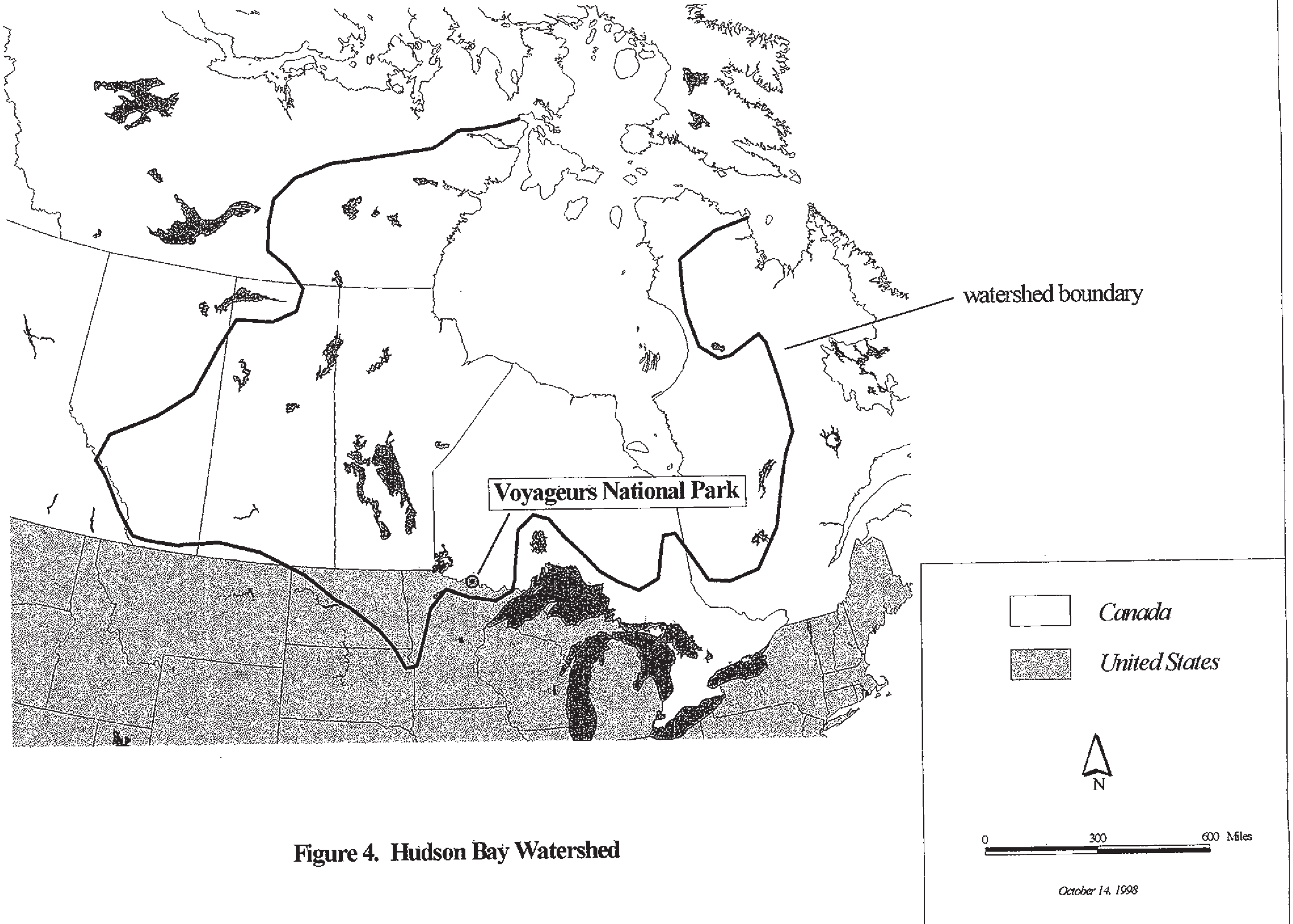

Figure 4. Hudson Bay Watershed

and Rainy Lake (USGS # 9030003). Approximately 70% of the basin is located in Ontario, and the remainder is in Minnesota. Flow through the basin is generally northwesterly. Rainy Lake is the largest lake in the basin (331 mi^2), 75% of which is in Ontario. Namakan Reservoir (Namakan, Kabetogama, Sand Point, Crane, and Little Vermilion lakes) has a surface area of 100 mi^2, 77% of which is in Minnesota (Kallemeyn et al., 1993). The Rainy Lake basin contains a complex network of lakes, ponds, and connecting rivers and streams (U.S. National Park Service, 1994).

The Namakan River is the largest single source of inflow to the park (Payne, 1991). This watershed provides nearly 70% of the total inflow to Lake of the Woods (U.S. National Park Service, 1994). Other significant park inflow sources include the Vermilion River, Ash River, Loon River, and Seine River (Canada). A three-reservoir (Namakan, Rainy, Lake of the Woods) network model for this drainage basin is presented in Figure 5.

The lakes in the region vary in size, depth and area (Table 2), and the productivity of these lakes is directly related to the morphological features of the lake basin (Kepner and Stottlemyer, 1988). For example, Kabetogama Lake, which is relatively shallow, has a higher nutrient content than the other three large lakes (Rainy, Namakan, and Sand Point) (Payne, 1991).

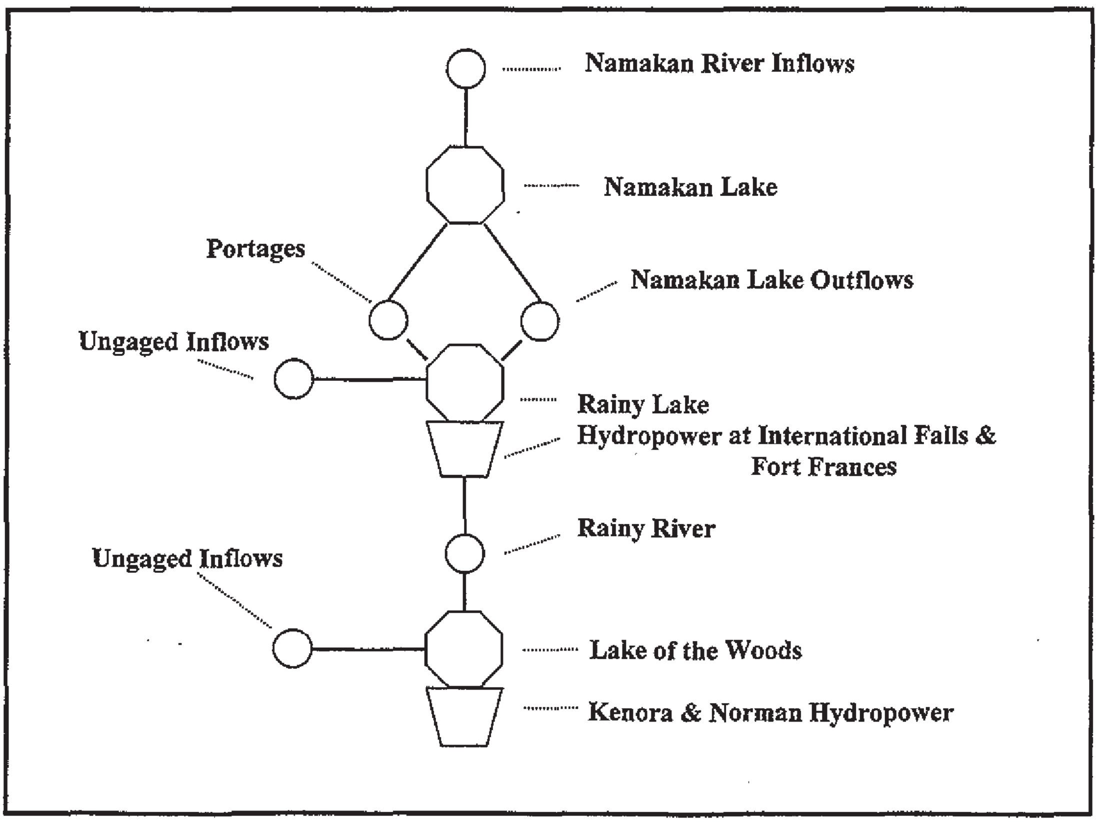

Figure 5. Schematic Network of Surface Water Flow through the Three Lake System (modified after Flug, 1986).

Table 2. Morphometric Parameters for Kabetogama, Namakan, Rainy, and Sand Point Lakes at Full Capacity. (modified after Kepner and Stottlemyer, 1988).

	Kabetogama	Namakan	Rainy	Sand Point
Lake area (acres)	24216	24710	219919	8401
Island area (acres)	697	2943	-----	385
Drainage basin (acres)	155673	4694900	4694900	------
Max. depth (feet)	49.8	120.0	161.0	184.0
Mean depth (feet)	29.8	48.8	32.4	42.9

Kabetogama Lake and the portions of Sand Point and Namakan lakes that lie within VOYA have a combined area of 45,491 acres (21% of VOYA). Water levels in these three lakes were originally controlled by natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake. Two dams constructed at this outlet in 1914, are now used to regulate the water levels in all three lakes (Kallemeyn, 1987a). Hydropower facilities located at International Falls and Fort Frances are independently operated and control water levels in Rainy Lake and discharge to Lake of the Woods. These dams are owned and operated by Boise Cascade and Abitibi Consolidated for the generation of electricity used in plant operations at International Falls.

Lakes are important to the ecology and recreation of this region. VOYA is comprised of more than 26 small interior bodies of water (approximately 3300 acres) located on Kabetogama Peninsula and the mainland. Interior lakes are the primary destination of the park's hiking trails. Snowmobiles are allowed on the frozen waters of Rainy, Kabetogama, Namakan, and Sand Point lakes, Chain of Lakes Trail (Locator, War, Club, Quill, Loiten, Shoepack, Little Trout, and Mukooda lakes) and on several portage trails within the park. Aircraft may be operated on the entire water surface and frozen lake surface of the following lakes: Rainy, Kabetogama, Namakan, Sand Point, Locator, War Club, Quill, Loiten, Shoepack, Little Trout, and Mukooda. The Superintendent has authority to close trails and/or lake surfaces to snowmobiles and/or aircraft to meet park management objectives (i.e., public safety, wildlife management) (36 CFR, Ch 1, §7.33).

Numerous streams also contribute to the water resources of the region. Annual maximum flows usually occur in April or early May as a result of snowmelt. Annual low flows occur in winter when water is stored as snow and ice, and during dry periods in late summer or early fall (University of Minnesota, 1981). Due to minimal groundwater resources in the region, surface water is the primary water source for industrial and domestic needs. The cities of International Falls and Fort Frances (Ontario), and local industry (paper mills) rely on Rainy Lake for their water supplies (University of Minnesota, 1981).

Surface Water Management

Water levels for Rainy Lake and Namakan Reservoir (Kabetogama Lake, Sand Point Lake, Namakan Lake, Crane Lake and Little Vermilion Lake), which impact VOYA, are managed from water control structures at two locations: Kettle Falls/Squirrel Falls and International Falls/Fort Frances. Flug and Kallemeyn (1993) presented the following chronology of water policies and events associated with surface water management for Rainy Lake and Namakan Reservoir:

1905-1909: The United States and Canada allowed construction of the International Falls Hydroelectric Project at Koochiching Falls, the natural outlet of Rainy Lake. The dam spans International Falls, Minnesota and Fort Frances, Ontario with the international boundary crossing the middle of the dam. The dam is privately owned and operated to provide water storage and power for pulp and paper mills.

1909: The Boundary Waters Treaty between the United States and Canada established the International Joint Commission (IJC), to prevent disputes in use of boundary waters, to provide a framework for cooperation, and for regulation of water levels and flows.

1916: High May flood waters and severe street flooding inspire an increase in the design outflow capacity from Rainy Lake.

1938 – 1940: A convention between the United States and Canada, duly ratified in 1940, empowers the IJC to determine emergency conditions in the Rainy Lake watershed and to adopt measures of control or rules of regulation for dams and control works. The primary objective was to secure the most advantageous use of waters for the combined purposes of navigation, sanitation, water supply, power production, recreation, and other beneficial purposes.

1949: The 1940 convention led to the 1949 IJC Order, which set criteria for dam releases, defined emergency conditions, and set monthly water elevations for both Namakan and Rainy lakes. Individuals from the United States and Canada expressed concerns about impacts from regulated lake levels on riparian lands, shore properties, bank erosion, flooding, recreational use, and creation of unsanitary conditions.

1957: In response to floods in 1950 and 1954, and to complaints expressing dissatisfaction with operations under the 1949 IJC Order, a five-year trial period of amendments was implemented. These amendments established a set of maximum elevations on Namakan Lake for the period October 1 to June 1. No changes to Rainy Lake were made. To accommodate resort owners, full elevation on Namakan Lake was targeted for June 1 instead of July 1, and to improve fish spawning activity, a maximum lake level was set from April 1 to 21.
1970: In 1968, the IJC ordered the International Rainy Lake Board of Control to further investigate regulation of Rainy and Namakan lakes. This was in response to heavy rains that resulted in lake levels above full pool and to low-water events that resulted in lake levels to fall below the prescribed minimum elevations. The

that resulted in lake levels to fall below the prescribed minimum elevations. The 1970 Amendments redefined emergency conditions, allowed a 0.15 m flood reserve, modified ranges for water elevations on both lakes, defined minimum elevations on Rainy Lake, and established minimum flow releases for pollution abatement by maintaining downstream dissolved oxygen concentrations that approximated natural flow conditions.

The current water management programs or "rule curves" established in 1970 by the IJC, define the upper and lower water stage elevations within which the dam operators must maintain the water levels at any given time (Figure 6). In several instances, the IJC amended the rules for water management in order to overcome operational difficulties at the hydropower plant or in response to flood or drought conditions that caused the lakes to reach elevations outside the "rule curves". The dams and lake levels are currently managed for the authorized purposes of hydropower production, navigation, domestic water supply, sanitation, recreation, and other public purposes (Kallemeyn et al., 1993).

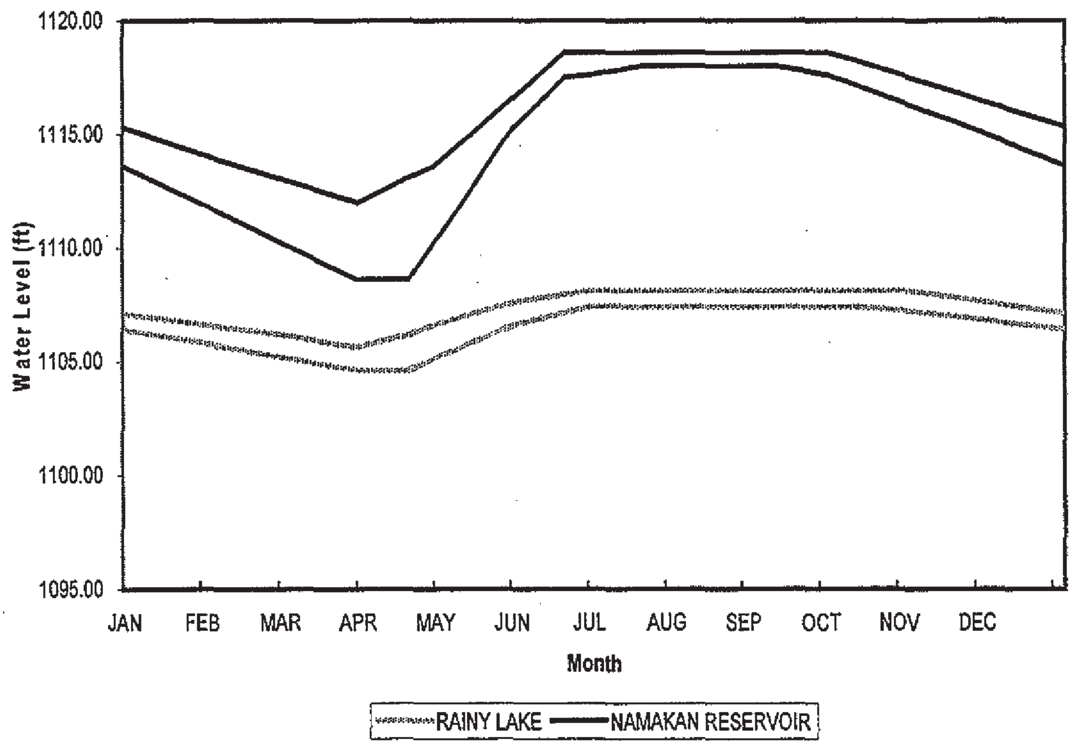

Figure 6. Existing Rule Curves for Rainy Lake and Namakan Reservoir. (Data provided by L.M. Kallemeyn, USGS – BRD.)

The present average annual lake-level fluctuations are 2.7 m (8.9 ft) for Namakan Reservoir and 1.1 m (3.6 ft) for Rainy Lake. Namakan Reservoir's fluctuation is approximately 0.9 m (3.0 ft) greater than the estimated "natural" or pre-dam fluctuation, whereas Rainy Lake's is 0.8 m (2.6 ft) less (Flug, 1986). Regulated lake levels usually peak in late June or early July rather than late May or early June as they did prior to dam construction, and they remain stable throughout the summer rather than gradually declining (Kallemeyn, 1987a).

Article 401 of the International Falls Project license states that water level management shall be operated according to the existing rule curve regulating the level of Rainy Lake as prescribed by the IJC (Robinson, 1995). The International Steering Committee (ISC), a voluntary nine-member group of private citizens, government officials from Canada and United States, and a Boise Cascade representative, was formed in 1991 to analyze the existing water level management system (rule curves) for Rainy Lake and Namakan Reservoir. Numerous studies and reports [Osborn et al. (1981), Flug (1986), Monson (1986), Kallemeyn (1987a), Kallemeyn (1987b), Kallemeyn et al. (1988), Kepner and Stottlemyer (1988), Kraft (1988), Reiser (1988a), Reiser, (1988b), Smith and Peterson (1988), Thurber and Peterson (1988), Flug et al. (1989), Kallemeyn and Cole (1990), Wilcox and Meeker (1991), Cohen and Radomski (1993)] indicate that, while existing "rule curves" provide advantages for power generation and spring flood control, they have detrimental effects on the aquatic habitat and biota. As a result, new "rule curves" have been proposed by the Steering Committee and are currently under review by the IJC's technical advisory committee, the International Rainy Lake Board of Control (International Steering Committee, 1993). The Energy and Water Development Appropriations Act of 1996 was signed into law November 13, 1995 by President Clinton. The Act includes provisions to establish interim lake levels for Rainy Lake and the Namakan Reservoir. The Act requires that, within the existing rule curves, water levels of Rainy Lake and Namakan Reservoir be maintained as close as possible to the rule curves proposed by the Steering Committee (Robinson, 1995).

Ground Water

Ground water resources in the park are very limited due to the thin soil regolith and bedrock conditions. Geologic mapping has determined that the metamorphic and granitic rock underlying the park has an extremely limited potential to host ground water. The Minnesota Department of Natural Resources (MDNR) considers these units as "non-aquifers" (Davis et al., 1994). Hydraulic conductivity for unfractured metamorphic and igneous rocks typically range between $10^{-12} - 10^{-8}$ cm/s, which is less than the typical range for an unweathered clay, $10^{-10} - 10^{-7}$ cm/s (Freeze and Cherry, 1979). Wells in the region commonly yield less than five gallons per minute (University of Minnesota, 1981).

Water Quality

Waters within VOYA, have been designated as "Outstanding Resource Value Waters" (ORVWs) by the State of Minnesota (MPCA Ch. 7050.0180). These regulations state that no person may cause or allow a new or expanded discharge of any sewage, industrial waste, or other waste to these waters. These regulations further assert that new or expanded discharges to waters that ultimately flow into VOYA shall not deteriorate VOYA's current water quality (Jacobson, pers. comm., 1998). The Minnesota Pollution

Control Agency (MPCA) has prepared a decision chart (Table 3) as a guide to determining potential discharge compliance with ORVWs.

Table 3. Nondegradation Key for Outstanding Resource Value Waters (modified after Davis et al., 1994).

1. Is the discharge to an ORVW?	a. yes (see 2)
	b. no (see 4)
2. Is the discharge prohibited or restricted?	a. prohibited (see 3)
	b. restricted (see 6)
3. No discharge will be allowed.	
4. Is the discharge upstream from an ORVW?	a. yes (see 5)
	b. no (see 9)
5. The discharge will be controlled to assure no deterioration in the ORVW.	
6. Is the discharge new or expanded as of 11/04/84 (03/07/88 for new ORVWs)?	a. yes (see 7)
	b. no (see 8)
7. The discharger must identify prudent and feasible alternatives. If alternatives are not available, the MPCA will decide whether to issue a permit and what restrictions would apply.	
8. Nondegradation does not apply.	
9. Is the discharge new or expanded as of 03/07/88?	a. yes (see 10)
	b. no (see 8)
10. Is the discharge significant (200,000 gallons/day or 1% increase in toxic concentration)?	a. yes (see 11)
	b. no (see 8)
11. Using information from the discharger, the MPCA will decide whether additional control measures are reasonable to minimize an impact.	

A water-quality investigation in four interconnected lakes (Namakan, Rainy, Kabetogama, and Sand Point) and two embayments (Black Bay and Sullivan Bay) comprising most of the park's surface water, was conducted from 1977 – 1984. Based on the results from this study, Payne (1991) made the following conclusions:

- The three large lakes, Sand Point, Namakan, and Rainy (near the eastern and northern boundaries of the park), were oligotrophic (deficient in plant nutrients) to mesotrophic (moderate supply of plant nutrients), having low dissolved solids and alkalinity and dimictic circulation (two overturns annually).

- Kabetogama Lake, Black Bay, and Sullivan Bay (near the western and southern boundaries of the park) were eutrophic (high level of plant nutrients), having high dissolved solids and alkalinity, and polymictic circulation (continuous mixing with no persistent thermal stratification).

- Kabetogama Lake had a higher nutrient content than the three large lakes (Sand Point, Namakan, and Rainy), and algal blooms, which reduced transparency, were documented. Kabetogama Lake is much shallower than the other three large lakes.

- The two large embayments, Sullivan Bay in Kabetogama Lake and Black Bay in Rainy Lake, were shallow and had the highest levels of nutrients and algal productivity found in the park lakes.

- Waters in the large lakes and embayments met nearly all EPA water quality criteria for protection of fresh-water aquatic life, drinking water, and recreation. Some drinking water criteria were exceeded at some monitoring sites due to elevated concentrations of oil/grease and phenols. Sulfide concentrations in Black Bay and Sullivan Bay exceeded EPA criteria for protection of aquatic life. Ammonia also exceeded EPA criteria for protection of aquatic life in Sullivan Bay. PCB concentrations exceeded EPA criteria for protection of aquatic life at one site in Kabetogama Lake.

- The Namakan River had moderate levels of dissolved solids, nutrients, and algal productivity.

- The Ash River generally had higher dissolved solids and total phosphorus concentrations than the receiving waters, and transparency was low because of high algal productivity. A temperature gradient, reduced dissolved oxygen concentrations, and the presence of sulfides and ammonia were measured in the three-mile-long pool above the mouth.

- A reconnaissance sampling of 19 small interior lakes found these lakes to have a lower in dissolved solids and alkalinity concentration than the large lakes. All except two interior lakes experienced sharp thermal stratification during the summer.

Water quality research [Anderl (1977); Glass and Loucks (1980); Sorenson et al.(1990); Payne (1979/1991)] has also shown that Namakan Lake, Sand Point Lake, and Rainy Lake are receiving water from the Namakan River, which is a higher quality than that contained in the lakes (Davis et al., 1994).

Biological Resources

<u>Flora</u>

Vegetation in the park is abundant and diverse. VOYA occupies a zone of transition between the boreal forests to the north, the mixed forests to the south and southeast, and the Great Plains forests to the west and southwest. Boreal forest species occupy about 70% of the park's total land area (U.S. National Park Service, 1994). The ecosystem limits have not yet been clearly defined; however, there are certainly no less than three regional biological habitats present in the park (Lincoln et al., 1982). One extensive habitat is that of the mixed conifer and deciduous southern boreal forest. This habitat consists of extensive pine, fir, and spruce species mixed with deciduous species including poplar, birch, and aspen. A second regional habitat is the wetlands and associated bogs and peatlands of the forest and lake margins. The wetlands and peatlands host the greatest biodiversity present in the park (Davis et al., 1994). The third major habitat present in the park comprises the lakes and rivers.

Fire suppression since 1936 and secession of logging in the park, after its establishment in 1971, have changed the dominant plant communities from a fire tolerant species (i.e., pine, aspen forest) to fire intolerant species (i.e., fir-spruce-birch, ash-elm, black ash) in some areas of the park (U.S. National Park Service, 1994). The goals for wildland fire management at VOYA are to: (1) allow fire to achieve its natural role; (2) use fire to accomplish desired resource management objectives; (3) protect life, property, and resources from unwanted fire; and, (4) avoid unacceptable effects of fire and fire suppression. The NPS is returning fire to the park ecosystem under carefully monitored and controlled conditions.

Rare, Threatened, and Endangered Species

There are no known federally listed threatened or endangered plants that occur in VOYA. However, two plant species that occur in the park are under review for federal listing: the New England violet (*Viola novae-angiliae*) and Oregon fern (*Woodsia oregana var. cathcartiana*). VOYA has one endangered and one threatened species listed by the State of Minnesota: the alwort (*Subularia aquatica*) is listed as endangered and the sterile sedge (*Carex sterilis*) is listed as threatened (U.S. National Park Service, 1994). The American shore-plantain (*Littorella americana*) is listed as a state species of special concern (Andrascik, pers. comm., 1998).

<u>Fauna</u>

There have been 48 fish species, 16 reptile and amphibian species, and over 240 species of birds observed in VOYA. The fishery resource in VOYA is an important link in the ecological food chain, providing a significant food source for the osprey, bald eagle, loon, otter, black bear and other birds and mammals in the park. The bald eagle and osprey have a strong presence in VOYA and nest regularly throughout the park. A diverse assemblage of mammal species (44) has also adapted well in the park's boreal forest ecosystem (U.S. National Park Service, 1994). Large ungulates, such as the white-tailed deer and moose, are among the park's greatest wildlife attractions. An estimated seven to nine gray wolf packs (each pack ranges from two to 11 individuals) utilized the park during the 1990-91 winter. Beaver are abundant (estimated population is 3000) in the park and serve as a seasonal prey species for wolves (U.S. National Park Service, 1992). The number of reptile and amphibian species present in VOYA is extremely limited because of the park's relatively high latitude and its associated short summers and long, cold winters (Palmer, 1988).

Rare, Threatened, and Endangered Species

There are two federally and state listed threatened animal species that occur in the park: the gray wolf (*Canis lupus*) and bald eagle (*Haliaeetus leucocephalus*). One animal species that is proposed for federal listing is the lynx (*Felis lynx canadensis*). Two federal species of special concern that occur in the park are the lake sturgeon (*Acipenser fulvescens*) and northern goshawk (*Accipiter gentilis*). The common loon (*Gavia immer*) is a NPS special concern species that is protected by park management. The common tern (*Sterna hirundo*) and white pelican (*Pelecanus erythrorhynchos*) are listed as state threatened species of concern (U.S. National Park Service, 1994) (Andrascik, pers. comm., 1998).

WATER RESOURCE ISSUES

The water resource issues presented in this section were identified during the November 1997 Resource Management Plan Scoping Meeting at VOYA. Participants included representatives from VOYA, U.S. Geological Survey - Biological Resources Division, University of Minnesota - Department of Forest Resources, NPS - Midwest Region, and NPS - Water Resources Division (Appendix A).

Surface Water Quantity and Seasonal Fluctuations

Currently, the most significant water resources issue for VOYA is water level management for Rainy Lake and Namakan Reservoir. Regulation has altered the magnitude and timing of water level fluctuations and has removed much of the hydrologic variability the lakes would experience under natural conditions (Kallemeyn et al., 1993). As previously discussed, lake levels are strictly regulated within a set range of water elevations (rule curves) established by the IJC. In response to the numerous biological impacts created by the current water level management, new rule curves have been proposed by the ISC to reduce these impacts.

The computer model "REGUSE", developed by Environment Canada, has been used to assess a range of operating practices within the existing and proposed rule curves. Historical daily inflows for the 1958-96 period were used for each of the "runs" (a day- by-day simulation of lake regulation for a specific period with set operating rules). Based on these model runs, the key findings presented by the International Rainy Lake Board of Control (1997a) are:

- The maximum flood level in the 1958-96 period is somewhat higher with the proposed rule curves than with the existing rule curves.
- The choice of operating practice has little or no effect on flooding, but does affect the severity and extent of drought events and the number of rule curve violations.
- The minimum drought level on Namakan is 10 to 100 cm (4 - 40 in) lower with the existing rule curves than with the proposed rule curves. On Rainy Lake, the minimum drought level is 7 to 38 cm (2.8 – 15.2 in) higher with the existing curves than the proposed curves.
- Based on the number of rule curve violations, the proposed curves appear to be nominally more viable than the existing curves on Namakan Lake, but less viable on Rainy Lake.
- The average annual hydropower generation is 6.6% to 7.7% less with the proposed curves than with the existing curves.

- Due to the earlier refill required by the proposed rule curves, there is a significant shift in timing of outflow, with less in the winter and more in the summer.

A separate modeling effort was completed that simulates the natural water levels and outflows as if the dams had never been built, so that the assumptions regarding the timing of the spring refill can be checked. This model uses the same 1958-96 inflow data as used by REGUSE. The key findings from this work presented by the International Rainy Lake Board of Control (1997a) are:

- On Namakan Lake, the proposed rule curve appears to better fit the natural timing in a majority of years, despite the wide variation in natural refill timing.

- On Rainy Lake, the timing of the existing rule curve appears to better fit the natural refill timing than the proposed rule curve.

- On both lakes, the existing and proposed rule curves provide a much narrower time slot for refill than occurred naturally.

The ISC suggested that an increased potential for flooding associated with their proposed new rule curves, could be offset by inflow forecasting. According to an International Rainy Lake Board of Control (1997b) report, when the IJC or ISC rule curves are used, a perfect seven-day forecast would reduce the amount of time the upper and lower rule curves are violated by no more than 0.8% and 0.4%, respectively. This was based on a simulation model of the lakes using historical (1958-1996) daily inflow data. As a result, the International Rainy Lake Board of Control concluded that an attempt to develop a forecast is not warranted as part of the Rainy-Namakan rule curve study.

Marshall Flug of the U.S. Geological Survey (pers. comm., 1997) stated that the assumptions used in the inflow study (no violations of the rule curves in responding to the forecast) greatly restrict any meaningful reduction in flood levels. Thus, the best early warning that can be achieved is to hold the lake levels at the lower rule curves. He suggested that there should be allowances for violating the lower rule curves. As a result, the lake levels would still rise according to the pattern of the rule curves with only small violation to the shape of the lower rule curves (probably in June). These lower-end violations in anticipation of high runoff would provide considerably greater storage of water in the lakes, thereby reducing or eliminating the violations of the upper rule curves in July. If violation of the lower rule curves is allowed, an extended (> 28 days) forecast should be evaluated. It is not unrealistic to anticipate a high runoff year 60 days early and adequately prepare the lakes for these inflows (i.e., drawdown the lakes early and start releasing maximum outflows).

Surface Water Quality

Based on surface-water quality data retrieved from five U.S. Environmental Protection Agency (EPA) databases for VOYA, the following seven parameters exceeded the EPA acute or chronic criteria for the protection of freshwater aquatic life at least once: dissolved oxygen, pH, alkalinity, cadmium, copper, lead and zinc. Cadmium, lead, and nickel exceeded their respective EPA drinking water criteria (U.S. National Park Service, 1995).

King and Mace (1974) found coliform bacteria concentrations in waters at canoe campsites with pit toilets significantly higher than at control points in the Boundary Waters Canoe Area. Effluent from these toilets was the probable bacteria source. VOYA plans to continue using the existing pit toilets located at backcountry sites and to convert existing pit toilets located at lakecountry sites to vault systems where a barge can pump and properly remove human wastes (Andrascik, pers. comm., 1998).

In 1982, failure of a septic system threatened the water supply at Kettle Falls. Failure for soil-based wastewater treatment systems in the region is not uncommon due to the thin soil regolith. In northern Minnesota, there has been an increase in lakeshore property use as well as modernization of facilities without improving the sanitary systems. On Crane, Sand Point, and Kabetogama lakes there are numerous small lots created years ago by the Minnesota Department of Natural Resources (MDNR) as leased sites for seasonal cabins. With the installation of electricity in the area, pressurized water systems were installed without proper waste treatment systems. This is a "high priority" issue for the Saint Louis County Environmental Health Division (EHD). The Saint Louis County EHD, along with surrounding counties and the University of Minnesota, has been working to modernize wastewater treatment technologies to help correct the high number of wastewater problems. The goal is to install more effective treatment systems, at similar costs, with less dependence on soil absorption (Kolb, 1998).

Analysis with a total phosphorus mass-balance model indicated peak spring total phosphorous levels in Kabetogama Lake would be reduced from about 34 µg/L to 30 µg/L if the present rule curve was replaced by one approximating natural conditions (Kepner and Stottlemyer, 1988). This was attributed to: (1) a reduction in bottom areas exposed by drawdown and accompanying sediment-water interactions; (2) reduced nutrient inputs resulting from die-off of littoral vegetation; and, (3) reduced nutrient concentrations because of volume changes. Influences from these changes would likely extend throughout the food web (Kallemeyn et al., 1993).

Logging activities within the boundaries of the park have ceased since its authorization in 1971. However, evidence of past logging exists in VOYA, particularly at Hoist Bay on Namakan Lake, which was a terminus in the log transport system. Studies identified a large concentration of undecomposed logs and other organic material submerged in Hoist Bay (U.S. National Park Service, 1994). Studies in other logging areas have shown that the decomposition of logs causes increased biochemical oxygen demand (BOD), hydrogen sulfide and ammonia production, and the release of soluble organic compounds (Sedell and Duval, 1985). This creates an adverse environment for the natural aquatic system. Logging in the Superior National Forest, Kabetogama State Forest, Boise Cascade and other private lands continues immediately adjacent to the park. Effects of logging may contribute to water-quality problems (i.e., sediment loading, BOD increases, etc.). These and future timber practices must be monitored and best management practices (BMPs) should be employed (Andrascik, pers. comm., 1998).

Mining and mineral exploration is still actively pursued within the region. Although these activities are prohibited within the boundaries of the park, the potential for water quality impacts associated with mining and mineral exploration will continue to exist as long as there is an economic interest within VOYA's watershed (see **Minerals,** page 33).

Fishery and Aquatic Ecology

The current water level management programs for Rainy Lake and Namakan Reservoir adversely affect key elements of the aquatic ecosystem: littoral vegetation, benthic organisms, fish, aquatic birds, and furbearers (Kallemeyn et al., 1993). Lake depth is considered to have a significant influence on biologic productivity, based upon the assumption that nutrients are more efficiently used in shallow systems (Kepner and Stottlemyer, 1988). Concern about the impacts of water level regulation on aquatic biota has existed since the dams were constructed. Kepner and Stottlemyer (1988) report that volume changes in lakes can influence nutrient availability through concentration and dilution effects. Elevated nutrients in the lakes will increase the numbers and possibly the species composition of primary producers.

The effects of regulated lake levels on the reproductive success, distribution and abundance of the aquatic and marsh avifauna were studied at the park. Based on a report by Reiser (1988b), the unnatural water level fluctuations on Rainy Lake and Namakan Reservoir exerted a negative influence on the reproductive success of the common loon and red-necked grebe (*Podiceps grisegena*). Using natural lake levels computed for Namakan Reservior (June 1983-85), the percentages of common loon nest losses due to flooding would have declined from 37% to 27%, and red-necked grebes would have experienced an 85% decline in nest losses. It should be noted that natural lake levels computed for Rainy Lake for the same period indicated a 5% increase and 21% increase in nests lost to flooding for the common loon and red-necked grebe, respectively (Reiser, 1988b).

Kraft (1988) studied the effect of increased winter drawdown on benthic macroinvertebrates in Namakan Reservoir. During the three-year study, the reservoir drawdown averaged 2.5 m (8.2 ft), and numerous invertebrates became stranded and died each year. The isopod genus *Asellus*, appeared to have been completely eliminated. According to Kraft, the invertebrate density was significantly higher in the year with the least drawdown.

The effects on regulated lake levels on beavers (*Castor canadensis*) were studied at several park areas that differed in winter drawdown [present, minor, absent] (Smith and Peterson, 1988). The study found that beavers living in a drawdown environment utilized their food cache less and were in poorer condition. Springtime wolf predation due to low water levels was hypothesized to be a contributing factor toward beaver mortality. Recommendations in Smith and Peterson's (1988) report included changing water management to approximate a more natural fluctuation [total yearly fluctuations ≤ 1.5 m (4.9 ft), and winter drawdowns ≤ 0.7 m (2.3 ft)] for Namakan Reservoir.

VOYA has a relatively high density river otter (*Lutra canadensis*) population. The distribution and abundance of otters in relation to regulated lake levels was studied from 1985-87 in VOYA (Route and Peterson, 1988). Management recommendations from this study included: reduction of fluctuations on Namakan Reservoir to more natural conditions to decrease crowding and shifting of winter home ranges; and, increasing fluctuations on Rainy Lake to improve littoral habitat for primary food supply (crayfish).

Before 1960, the commercial fish harvest on Rainy Lake was usually greater than 660,000 lb/year. Since then, harvest has declined to about 220,000 lb/year, where most of the harvest (190,000 lb/year) is taken from Canadian waters (Kallemeyn et al., 1993). A number of fish species are currently being harvested by three commercial fishing operators licensed to work in the park by the MDNR (Kallemeyn, pers. comm., 1998). No additional operators will be allowed to commercial fish within the park.

VOYA waters, including the large and small lakes, have been stocked since the early 1900's with native and exotic species. The more recent stocking was done with species native of the watershed, but earlier stocking may have included transplants from other watersheds, potentially forming genotypically different populations. Lake trout of a non-native genotype continued to be stocked in Little Trout and Mukooda lakes by MDNR. A NPS policy review, which states no artificial stocking of exotic fish species will occur, will be completed as part of an interagency agreement between the park and MDNR in the future.

The future of VOYA's fish populations is uncertain for three reasons:

1) Unnatural lake fluctuations, especially in the Kabetogama-Namakan-Sand Point complex, adversely affect walleye (*Stizostedion vitreum*), yellow perch (*Perca flavescens*) and northern pike (*Esox lucius*) spawning success.

2) Low buffering capacities associated with shallow soils and soft water in the region make some lakes in the park susceptible to acid deposition.

3) Continued fish harvest in the park and Canada after significant declines in fish populations have been documented.

Concerns in the relationship between managed lake levels and the fish community have been expressed in several reports [Sharp (1941), Johnson et al. (1966), Chevalier (1977), Osborn et al. (1981)]. Kallemeyn (1987b) reported that northern pike spawning habitat and reproductive success have been reduced in Namakan Reservoir under the current water management program. In February 1996, contracts were let to retain two fisheries experts, one in Canada and one in the United States, to review existing information regarding the fisheries of Rainy and Namakan lakes. A final report was submitted to the International Rainy Lake Board Control in August 1996. According to the International Rainy Lake Board of Control (1996), the fisheries experts endorse the proposed rule curve changes recommended by the ISC and presented the following five major findings and conclusions in their final report:

1) Further analysis of the existing data sets will not offer significant improvement in understanding the effects of water regulation on fisheries.

2) Overexploitation has played a major role in the decline of fish stocks.

3) Water level regulation has contributed to the decline of fish stocks.

4) Fisheries managers should develop and implement a more aggressive program to evaluate the importance of invasion by the exotic smelt (*Osmerus mordax*).

5) Management actions such as those embodied in new rule curves and more restrictive fishery regulations require follow-up studies.

Riparian Zone Management

Natural riparian areas contain some of the most diverse, dynamic, and complex biophysical habitats. Interfaces between terrestrial and freshwater ecosystems (i.e., littoral lake zones, marginal wetlands, riparian forests) are sensitive to environmental change (Naiman and Décamps, 1997). Unfortunately, the natural riparian biota in the park have been significantly impacted by the management of water levels for Rainy Lake and Namakan Reservoir. Documented impacts to the riparian ecology include decreases in macroinvertebrate density (Kraft, 1988) and littoral vegetation die-offs (Wilcox and Meeker, 1991). These impacts also extend into the higher order food chain (i.e., avifauna, mammals, etc.). The spatial extent of specific riparian zones can be difficult to delineate in the park due to a history of natural versus managed water level fluctuations. Defining and ultimately managing riparian habitat is important to the preservation of VOYA's natural resources.

Floodplains Management

It is NPS policy to recognize and manage for the preservation of floodplain values as defined in Executive Order 11988, *Floodplain Management*. The NPS procedure for implementing floodplain management is presented in Figure 7. As stated in the Special Directive 93-4, "If a proposed action is found to be in the applicable regulatory floodplain and relocating the action to a non-floodplain site is considered not to be a viable alternative, then flood conditions and associated hazards must be quantified as a basis for management decision making, and appropriate prescribed actions must be taken." A formal Statement of Findings must be prepared if the NPS decides to locate an action

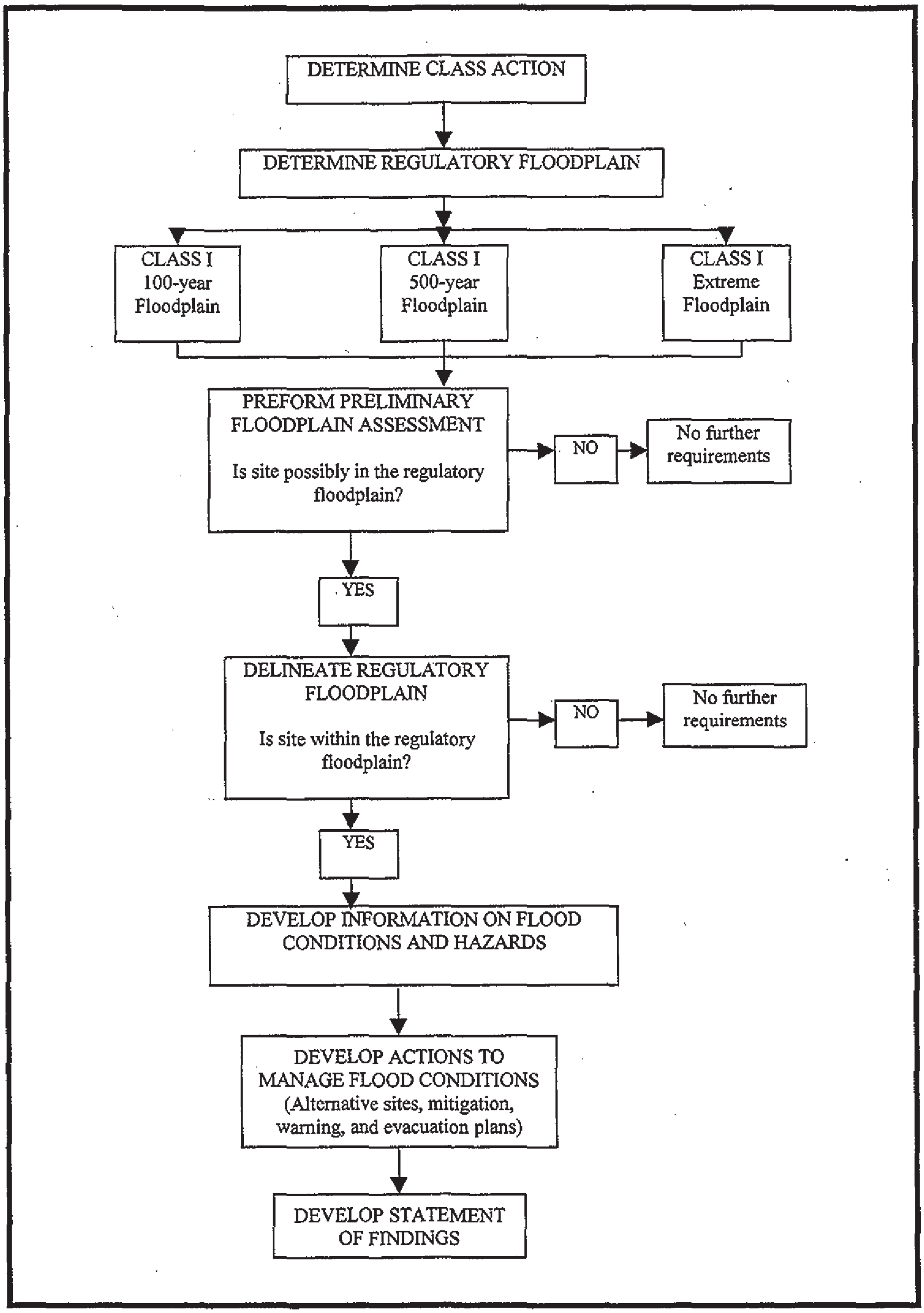

Figure 7. Procedure for Implementing the National Park Service Floodplain Management Guideline (U.S. National Park Service, 1993).

in an applicable regulatory floodplain. Mapping of the 100-year and 500-year floodplains within the park's boundary is needed to compliment this process. Appropriate management of future development and operations within these floodplains is an important aspect in minimizing the hazards associated with flooding.

Wetlands Management

The National Park Service implements a "no net loss of wetlands" policy. Presently, VOYA does not have an adequate inventory of wetlands within its boundaries. According to Davis et al. (1994), the park's wetlands host the greatest biodiversity of the three biotopes identified in VOYA, and their protection is important to ensure ecological balance. A wetland inventory would assist the park with properly implementing Executive Order 11990: "Protection of Wetlands" (42 Fed. Reg. 26961; Appendix 2 of these procedures). This Executive Order directs the NPS to: 1) provide leadership in wetlands preservation, protection, and management; 2) take action to avoid, to the extent possible, the long and short term adverse impacts associated with the destruction or modification of wetlands; and, 3) avoid direct or indirect support of new construction in wetlands unless there are no practicable alternatives to such construction and the proposed action includes all practicable measures to minimize harm to wetlands.

NPS wetland compensation is required as follows:

1. If the adverse impact on wetlands from the entire project totals less than 0.1 acres, then wetland compensation is strongly encouraged, but may be waived if the loss of wetland functions is considered to be minimal.

2. If the adverse impacts on wetlands from the entire project totals 0.1 acres or more, then wetland compensation in the form of restoration of degraded or former wetland habitats is required.

It should be noted that the U.S. Fish & Wildlife Service (USFWS) has developed National Wetlands Inventory (NWI) maps for Minnesota. Information from these NWI maps have been imported into the park's Geographic Information System (GIS) and will benefit VOYA in producing site-specific wetland maps for areas that are susceptible to adverse impacts associated with development or other activities.

Recreational Management

The presence of cabins, resorts, campsites, houseboat mooring sites, visitor centers and concession facilities along various park shorelines has produced erosion and water quality threats to the park's watershed (U.S. National Park Service, 1994). Two-stroke engines in outboard motors and snowmobiles typically discharge 10% to 20% of their fuels (oil and gas), and as much as 40%, into the environment (Hammitt and Cole, 1987). During the ice-free months, motorboats are the principal means of transportation in the park. Along with the potential water-quality impacts, wave generation by intensive watercraft traffic may accelerate erosion within the park's riparian areas, especially in narrow channels. Personal motorized watercraft is also a concern because of their impacts to water quality, emergent vegetation, wildlife, and the recreational experience of the majority of park visitors who use nonmotorized craft. Snowmobiles are the principal means of transportation in the park during the ice months. Potential impacts (hydrocarbon) to the park's water resources from snowmobiles have not been studied. The park estimated 44,848 snowmobile visits during the 1995-96 winter (Andrascik, pers. comm., 1998). Annual estimated park visitation documented by VOYA ranged from 226,104 to 260,226 between 1991 and 1997.

Solid waste discarded by recreational users in the Boundary Waters Canoe Area (immediately southeast of VOYA, see Figure 1) in 1969 totaled an estimated 360,000 pounds, averaging 3 pounds per person (King and Mace, 1974). In the past, developed campsites adjacent to surface waters included pit toilets that may have been inadequate for sewage containment and contributed to bacteria and nutrient loading to local waters. Most of the pit toilets in the park have been converted to a more environment friendly vault-toilet system. Even with the park's attempt to improve water quality, many other water quality problems continue to exist as a result of recreational activities in the park. For example, gray water from houseboats is typically disposed of directly into park waters (U.S. National Park Service, 1994).

Wastewater and Regulated Storage Tank Management

There are four different types of septic systems used in the park: (1) Kettle Falls Hotel and Villa rental units use a spray field system, which consists of a septic tank, lift station, dousing chamber, sand filter, chlorinator, collection tank with lift pumps and spray field lines. (2) Rainy and Kabetogama Visitor centers use a pressure mound system, which pumps the effluent via lift pumps into a crushed rock bed and then into a sand filter mound. (3) There is one holding tank located at the Rainy Lake maintenance building, which consists of a 1000-gallon holding tank and a 500-gallon overflow tank. This system is maintained by park staff. (4) The other septic systems in the park are conventional septic tank and leach field designs. As previously stated, failure of soil-based wastewater treatment systems in the region is common due to inadequate soils in the region. Saint Louis County EHD and the University of Minnesota are working to modernize wastewater treatment technologies to help correct the high number of wastewater problems (Kolb, 1998).

An undetermined number of resorts provide boat and snowmobile fuel for their clients along Kabetogama Lake adjacent to the park. In addition, there are resort marina fueling stations on the other large lakes both in the United States and Canada, including Crane Lake. The potential for petroleum releases from these sites exists, but there are no on-going programs to monitor hydrocarbons at these locations (Andrascik, pers. comm., 1998).

VOYA has six fuel stations located within the park. All systems use above-ground storage tanks. One of these systems uses single-wall tanks set within a concrete containment dike. All others are double-wall tanks. The West Kabetogama fuel station has one 2000-gallon tank and one 1000-gallon concrete vault tank for unleaded and diesel fuel, respectively. The Ash River station uses three 1000-gallon tanks and one 500-gallon double-wall steel tank with above-ground piping to the dispensing units. Two tanks contain unleaded fuel, one contains diesel fuel, and one contains mixed fuel. Rainy Lake uses two 1000-gallon double-wall steel tanks, one for unleaded and one for diesel fuel. Kettle Falls has three separate fuel stations. One located on the Rainy Lake side, which has two 1000-gallon single-wall steel tanks located in a concrete containment dike. The dispensing lines are buried underground to the dispensing units located at the fuel dock. On the Namakan side, there is one 1000-gallon double-wall concrete vault tank with secondary containment for the tank and fuel lines. The maintenance yard at Kettle Falls has one 500-gallon double-wall vault tank with a tank mounted dispensing pump.

Above-ground storage tanks over 110-gallon capacity must be registered with the state. Tanks within 500 feet of surface water must have full secondary containment (110% capacity of largest tank in immediate area). Tanks greater than 500 feet from a surface water must have reasonable safeguards to prevent a release into the environment, such as concrete floor, sorbent material on site, and spill plan on site (Minnesota Pollution Control Agency, 1998). Tanks should be monitored a minimum of once per month for leaks or other problems, and the results must be documented. Additional monitoring requirements apply to tanks 2000-gallons or greater (Minnesota Pollution Control Agency, 1996).

Water Rights

Water rights for VOYA are complicated by the fact that the park is located along an international boundary. As previously stated, approximately 70% of the 14,900 mi^2 Rainy Lake basin is located in Canada. Seventy-five % of Rainy Lake (248 mi^2) and 23% of Namakan Reservoir (23 mi^2) are located in Canada. Canadian management of these large bodies of water can easily impact the park's water resources.

Minnesota administers water rights under the Riparian Doctrine (Waters and Water Rights, 1991a). Riparian rights refer to legal rights the landowner has in regard to uses of that water adjacent to the owned bank of a stream or lake. These include: use of water without transforming it; access to build a warf or pier; ownership of the bed of non-navigable streams and other private waters; and, acquisition of accretions (accretions are the gradual enlargement of land by fluvial processes such as the accumulation of sediment on a floodplain by stream action or the deposition of sand on a beach). In Minnesota, water is considered public water and administered by the state if it is considered navigable.

The basis and limit of water use is governed by the Reasonable Use Doctrine in Minnesota. Under this doctrine, each riparian owner is allowed to use a waterbody regardless of the effect on natural flows as long as each user does not adversely affect the equal right of another riparian owner (Waters and Water Rights, 1991b). Permits are a method used by states to control the amount of water use and to vest the right of a user to continue that use (Sherk, 1990). In Minnesota, a state permit is required for any consumptive use of more that 10,000 gallons per day or 1,000,000 gallons per year for surface or ground water (Waters and Water Rights, 1991a). The surface water permits can be revoked if the diversion is harmful to other riparian water users (Sherk, 1990). Minnesota acknowledges instream flow rights for such uses as fishing, navigation, and swimming.

In addition to riparian rights, the United States may have rights based upon Federal law to the minimum amount of water necessary to achieve the primary purposes for which Voyageurs National Park was created. A significant portion of land comprising the park was never out of Federal ownership, and these lands contain many lakes and streams. The Office of the Solicitor should be consulted to determine if Federal reserved water rights apply to the park.

Baseline Inventory and Monitoring

NPS units are required to assemble baseline inventory data describing the natural resources and to monitor those resources on a scheduled frequency to detect or predict changes. This information is to be analyzed to detect changes that may require intervention by the NPS.

Payne (1991) presented results of a VOYA water-quality investigation using eight years of data (1977-1984). In 1995, the NPS Water Resources Division completed a comprehensive summary of existing surface-water quality data for VOYA, *Baseline Water Quality Inventory and Analysis, Voyageurs National Park*. The information contained in this report represents data retrievals from five EPA national databases: (1) Storage and Retrieval (STORET); (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); and (5) Flow Gages (GAGES). Unfortunately, water-quality monitoring in the park is not continuous and water-quality programs from other county, state, and federal agencies are minimal to nonexistent. There are currently no U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) study basins within the Rainy Lake watershed. Two NAWQA study basins are located immediately to the west and south of VOYA (Red River of the North and Upper Mississippi Basin).

EPA has developed rapid bioassessment protocols for macroinvertebrates and fish that were designed as inexpensive screening tools for determining if aquatic environments were supporting the designated biota (Plafkin et al., 1989). Although these protocols were made for use in fluvial environments, EPA has initiated efforts to develop protocols for lake systems, which would be more applicable for VOYA (Vana-Miller, pers. comm., 1998). This basic information enhances the coverage of broad geographical assessments, such as State and National 305(b) Water Quality Inventories and can be extended to:

- Characterize the existence and severity of use impairment.
- Help identify sources and causes of use impairment.
- Evaluate the effectiveness of control actions.

- Support use-attainability studies.
- Characterize regional biotic components.

Biosurvey techniques, such as the rapid bioassessment protocols, are effective in providing a preliminary evaluation of natural systems health. If impairments to the aquatic environment are suggested through biosurveys, additional chemical and biological (toxicity) testing is the next step toward identifying the causative agent and its source.

The MPCA - Division of Water Quality, has started conducting surveys on fish, macroinvertebrates, and zooplankton communities to develop field techniques and interpretive tools needed to establish water-quality evaluations in fluvial systems. In cooperation with Minnesota's Department of Natural Resources (MDNR), MPCA has completed fish surveys in streams of the Minnesota River basin. This effort was primarily conducted to develop a fish community index for this region. The development of biotic indices for Minnesota represents the first step toward establishing numerical biological criteria (Davis et al., 1996). It will be important for VOYA to monitor the progress and, when possible, participate in the state's biological assessment program.

The park has expressed the need for a comprehensive interior lake survey to establish baseline water/sediment quality and aquatic biota information. Inventories of baseline species data exist for higher-order plants and animals in the park, but do not exist for most lower-order species. Long-term monitoring of some species is ongoing, but the status and trend of many key species remains incomplete or undocumented (U.S. National Park Service, 1994).

Atmospheric Deposition

Although precipitation in the park is generally non-acidic ($pH > 5.6$) to slightly acidic ($pH = 4.81 - 5.59$), highly acidic deposition ($pH < 4.4$) has been recorded (Minnesota Pollution Control Agency, 1986). The MPCA has developed a lake classification system based on the alkalinity or buffering capacity (Payne, 1991). Under this system, Kabetogama Lake is classified as "non-sensitive", while Namakan, Rainy, and Sand Point lakes are classified as "potentially sensitive". Of the smaller interior lakes within the park, two lakes are classified as "non-sensitive", two are "potentially sensitive", thirteen are "moderately sensitive", and two are "extremely sensitive". Acidic deposition has significantly impacted the flora and fauna of similar lakes in Ontario, New York and Scandinavia, which have low buffering capacities. Input from acid deposition can decrease pH, alkalinity, and chlorophyll *a* concentrations while increasing conductivity. This can ultimately suppress natural cycles in biota and nutrients (U.S. National Park Service, 1994).

Locally, mercury concentrations in the lake sediments have increased significantly since the Industrial Revolution [Merger (1986), Swain et al. (1992)]. Since there are no known point source inputs for mercury, atmospheric input is the likely source for the increase (U.S. National Park Service, 1994). Merger (1986) observed significant increases in mercury in the sediments of Kabetogama and Crane lakes during the last 100 years. Atmospheric deposition of mercury is an increasing problem across the United States and Canada. The Florida Atmospheric Mercury Study estimated 40 to 50 kilograms of mercury per year are being deposited by wet deposition from the air into the Everglades.

Over time, elevated concentrations of mercury have entered VOYA's aquatic food chain, and many of the sport fish (walleye, northern pike) contain high mercury concentrations. The effects of elevated mercury levels in fish and fish consumers (bald eagles, ospreys, loons, and river otters) are currently unknown. The MDNR and Ontario Ministry of Natural Resources have issued fish consumption warnings to the public (U.S. National Park Service, 1994).

Lakecountry and Backcountry Management

Prior to the establishment of VOYA in 1975, there were a host of uses on the lands and lakes that would become a national park. Aircraft (float and ski planes), snowmobiling, winter ice roads, fishing, hunting, trapping, logging, cabin and campsite development, and trail/road development were all permitted. Establishing appropriate levels and types of recreational use on the large lakes and the interior lakes have been a challenge for park management. The Master Plan (U.S. National Park Service, 1980) and various management plans combined with NPS Management Policies (U.S. National Park Service, 1988a) and 36 CFR have formed the basis for management actions. Currently, the park does not have a permit system or require reservations for camping. VOYA is presently developing its General Management Plan. This plan will set forth a management concept for the park; establish the park's role within the context of regional trends and plans for conservation, recreation, transportation, economic development, and other regional issues; and, identify strategies for resolving issues and achieving management objectives.

In the park's natural zone, the lakecountry and backcountry environments provide two distinct types of recreational experience. The lakecountry includes the shoreline of the four large lakes (Rainy, Kabetogama, Namakan, and Sand Point) and is primarily accessible by motor powered vessels, aircraft and hand propelled watercraft in the summer, and snowmobiles and aircraft in the winter. It provides visitors with a semi-primitive motorized experience with opportunities for some isolation from the sights and sounds of humans, a high degree of interaction with the natural environment, moderate challenge and risk, and use of outdoor skills and motorized equipment. The park's backcountry includes the majority of the Kabetogama Peninsula and 26 interior lakes, large lake islands and remaining land mass. The backcountry is primarily accessible by trails and portages. However, some motorized access is permitted on Locator, War Club, Quill, Loiten, Shoepack, Little Trout, and Mudooda lakes including snowmobiles, aircraft and hand carried motors for boats. The backcountry provides visitors with a more primitive experience where they have opportunities for greater isolation from the sights and sounds of humans, a high degree of interaction with natural environment, high degree of challenge and risk, and use of outdoor skills with some motorized equipment.

Minerals

The potential for extracting minerals in the region continues to exist. A report prepared by Davis et al., (1994) concluded that the only metallic mineral likely to be discovered in the area is a greenstone-hosted gold deposit with minor accessory silver. Increasing world gold prices to levels of greater than $1000 per troy ounce would likely stimulate additional exploration in northern Minnesota.

If economics favored mineral extraction within VOYA's watershed, activities associated with mine development could produce airborne particulates and runoff-related erosion, as well as the potential for discharge of solids into the adjacent surface waters. Excessive sediment loading could cause an increase in turbidity and sediment deposition, which could adversely affect aquatic life. The geology in the region (shallow or exposed impervious bedrock) would allow contaminants to move very quickly over the surface or along the soil-bedrock interface and make its way into surface waters. Potential contamination of the surface and ground waters during a typical mining operation can occur from three primary effluent sources: (1) excess water pumped out of the underground mine, (2) contaminated water derived from the mill, particularly from the flotation process (this water goes to the tailings pond), and (3) tailings pond effluents, derived either from surface overflow or, more likely, from seepage loss. Mine effluent may be somewhat acidic and contain dissolved salts (i.e., calcium, magnesium, sodium) and traces of heavy metals (i.e., copper, iron, lead, zinc) (Davis et al., 1994).

Even though mining is a highly regulated industry, the NPS's best means of protecting park resources from potentially adverse mining effects is to stay informed and involved. The first step in this process is becoming aware of the proposed changes in state minerals leasing rules, and seeking help to analyze and respond to these proposals (Davis et al., 1994). It should be noted that mineral rights themselves cannot be "taken" legislatively without compensation, thus holders of valid rights within the park that wish to mine would have to be compensated for the fair market value of the right (U.S. National Park Service, 1994).

Exotic Species

The NPS defines exotic species as those that occur in a given place as the result of direct or indirect, deliberate or accidental actions by humans. Exotic species are non-native components of one ecosystem, and as a result, have not evolved in concert with the evolution of species that are native to the area. The main concern with exotic species is to avoid or compensate for disruption of natural ecosystems by exotics. Management of populations of exotic plant and animal species, up to and including eradication, will be undertaken whenever such species threaten park resources or public health and when control is prudent and feasible.

VOYA has a least 36 exotic plant species that have invaded and displaced some of the park's native vegetation. A comprehensive inventory of VOYA's exotic plant and animal species, including distribution and abundance has not been completed.

Approximately 175 acres of purple loosestrife (*Lythrum salicaia*) have currently invaded park wetlands. Purple loosestrife is a wetland plant from Europe and Asia. It invades marshes and lakeshores, replacing cattails and other wetland plants. The plant can form dense, impenetrable stands which are unsuitable as cover, food, or nesting sites for a wide range of native wetland animals. Eradication is difficult because of the enormous number of seeds produced and purple loosestrife's ability to resprout from the roots. A major reason for the expansion is the lack of pests specific to the species. Previous efforts to control the populations in the park have included pulling and cutting of seed heads and use of herbicides. Plant densities have been reduced, but the distribution is increasing. Several insects from Eurasia, specific to purple loosestrife have been used to manage the plant. The park is developing insectaries of (*Galerucella spp.*) biological control agents to reduce plant densities.

There has been a recent invasion of rainbow smelt (*Osmerus mordax*) in Rainy and Namakan lakes. Rainbow smelt, which has colonized numerous areas in the upper Rainy Lake watershed after being introduced by humans (Franzin et al., 1994), first appeared in Rainy and Namakan lakes in 1990. Based on studies conducted elsewhere, the rainbow smelt may have a significant affect on the park's aquatic ecosystem, and in particular, its cool- and cold-water fish species (Evans and Loftus, 1987). Due to their intermediate trophic position – as consumers of zooplankton (including icthyoplankton) and as prey for top predators – rainbow smelt have the potential to introduce a wide array of ecological impacts from both direct and indirect effects (Kerfoot and Sih, 1987; Carpenter, 1988). Another ramification of the establishment of rainbow smelt may be elevated mercury concentrations in piscivores. Mercury concentrations in walleye (*Stizostedion vitreum*) and northern pike (*Esox lucius*) may increase further if they switch from an indigenous forage fish diet to one of rainbow smelt (Mathers and Johansen, 1985).

Species of concern which have the potential to invade park waters include Eurasian watermilfoil (*Myriophyllum spicatum*), zebra mussel (*Dreissena polymorpha*), and rusty crayfish (*Orconectus rusticus*). Eurasian watermilfoil is a species spread by boats and waterbirds. It can form thick underwater stands of tangle stems and vast mats of vegetation at the water's surface. It can interfere with water recreation and crowd out important native water plants. The zebra mussel is from Asia and can severely reduce and eliminate native mussel species. Rusty crayfish can severely reduce lake and stream vegetation, depriving native fish and their prey of cover and food. They also reduce native crayfish populations. Rusty crayfish are already in waters adjacent to the park (Spring Lake and Lake Vermillion). Zebra mussel and rusty crayfish preliminary surveys are planned in 1998.

Coordination

Chapter 84B.10 of the Minnesota Statutes declares that the state and VOYA will "cooperate to maintain in the park the highest standards relating to air, land, and water quality, whether these highest standards be state or federal, consistent with the lawful authority possessed by the State of Minnesota and the Secretary of the Interior in his administration of the National Park System to maintain air, land, and water in the park." A strong justification for coordination at VOYA is seen with fisheries management. In addition to the NPS, the MDNR regulates fisheries in state waters, including those in the park (U.S. National Park Service, 1994). Although the U.S. agencies have many complementary fisheries management objectives, some management policies conflict due to differing legislative mandates.

Approximately 70% of the 14,900 mi^2 Rainy Lake basin is in Ontario. With the park located along the Canadian/United States international boundary, the need for international coordination is warranted to properly manage VOYA's natural resources, which share a common watershed. There has been some effort to establish this international coordination as early as 1909 with the creation of the IJC for cooperative regulation of water levels and flows. Additional coordination between the United States and Canada should extend to the flora and fauna. The Ontario Ministry of Natural Resources (OMNR) regulates fisheries in Ontario waters, some which are contiguous to park waters along the international boundary in Rainy, Namakan and Sand Point lakes.

Development of an Interior Lakes Management Plan consistent with other park plans is proposed in VOYA's Natural Resources Management Plan (U.S. National Park Service, 1994). Cooperation between the NPS and MDNR during this process is recommended. VOYA should also work to establish other multi-agency partnerships. For example, the USGS could provide assistance with monitoring waters within the park. As stated before, there are two USGS NAWQA study basins immediately west and south of VOYA (Red River of the North and Upper Mississippi River basin). USGS-supported programs have made positive contributions to other NPS units by providing continuous water quality and/or water quantity evaluations.

RESOURCES MANAGEMENT STAFFING AND PROGRAMS

VOYA currently has a small, but very knowledgeable Natural Resource Management staff whose organizational structure is presented in Figure 8. This Division consists of seven permanent positions, which includes three permanent Fire Management positions. The Chief of Resource Management reports directly to the Superintendent and is responsible for the park's natural and cultural resource management, fire management, and geographic information system. In 1993, all NPS research scientist positions were eliminated, and most were transferred to the USGS - Biological Resources Division (BRD). In response to this, VOYA developed a research partnership with the USGS – BRD. This effort allowed Larry Kallemeyn (USGS-BRD) to remain stationed at the park. Mr. Kallemeyn's contributions toward numerous biological studies and reports have been very beneficial in understanding the natural systems in the park.

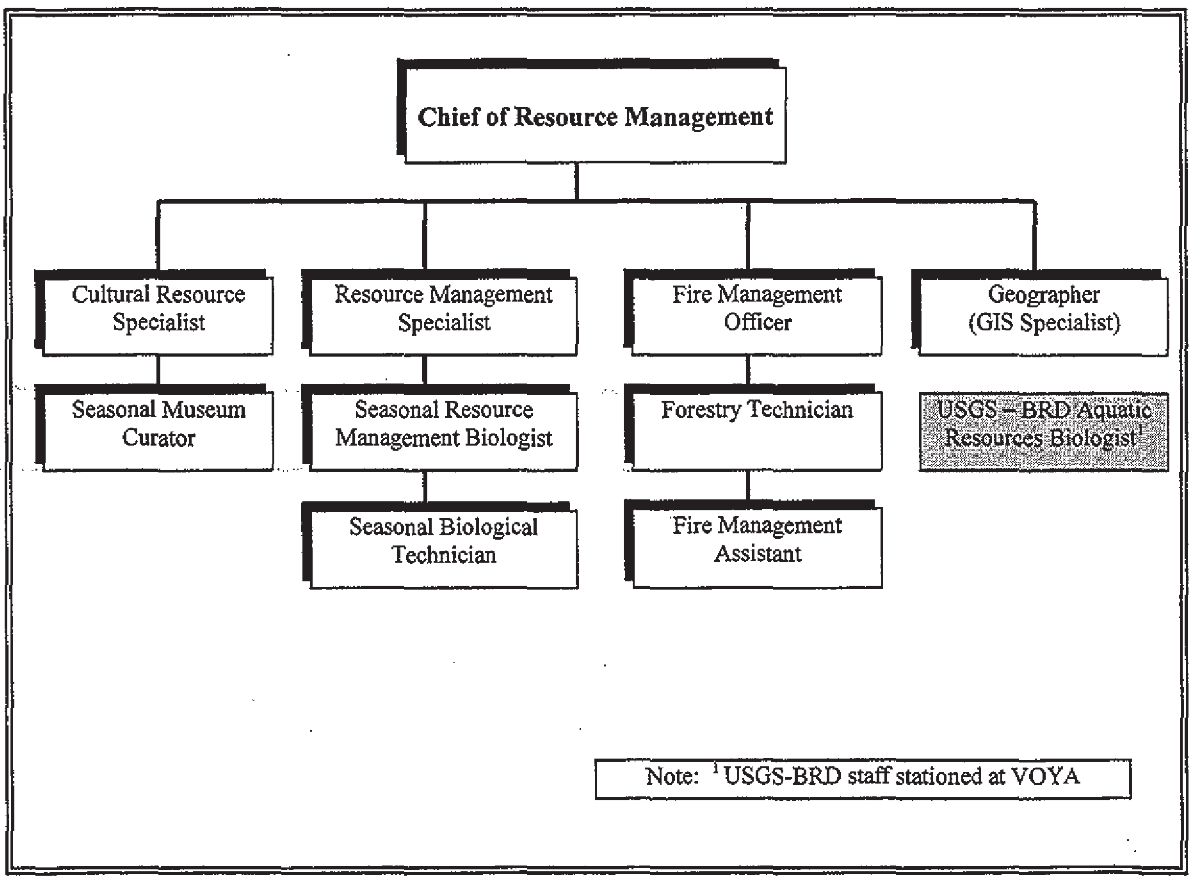

Figure 8. Voyageurs National Park, Natural and Cultural Resources Program: Organization and Structure.

Based upon VOYA's 1997 Investigator's Annual Report and correspondence from Larry Kallemeyn (USGS-BRD), current projects in the park that directly or indirectly relate to water resources are listed on pages 37 - 39. The numerous fisheries projects that focus on management and species population dynamics and habitat have not been included in this listing.

1. Atmospheric Deposition of Mercury and Atmospheric and Non-point Pollution Trends in Minnesota Lakes

Since 1995, the St. Croix Watershed Research Station, MPCA, and University of Minnesota have been involved in a cooperative effort to reconstruct from sediment cores, the history of mercury inputs to 50 Minnesota lakes. The project will be expanded in 1998 to evaluate geographic and historic trends in lake eutrophication and inputs of toxic metals and organic pollutants to 55 Minnesota lakes. Five of these lakes (Locator, Loiten, Shoepack, Tooth, and Little Trout) are located within VOYA. The geochemical analysis of sediment cores has been completed. Data are currently being analyzed, and a final project report is scheduled for a 1998 completion.

2. Control of Productivity and Plant Species Segregation by Nitrogen Fluxes to Wetland Beaver Meadows

The University of Minnesota initiated a five-year research project in 1997 to examine how plant species segregation and productivity are influenced by: (a) the spatial distribution of water and nutrients; (b) light limitations imposed by tall graminoids that would shade shorter grasses and forbs; and, (c) the vertical distribution of leaf area and nitrogen within the plant canopy. The objective is to produce a spatially explicit model of hydrology and nutrient budgets within beaver ponds and meadows, coupled with a model of plant growth, canopy allocation, and the vertical light gradient under different nutrient and water regimes.

3. Loons: Indicators of Mercury in the Environment

Since 1992, Dave Evers (along with Dr. Francie Cuthbert) has conducted a research project to monitor lakes within VOYA for breeding common loons and productivity. Blood and feather samples have been collected from adults and juveniles for mercury analyses.

4. Mercury Deposition and Lake Quality Trends in Minnesota

Since 1995, the University of Minnesota, Duluth, has conducted a benchmark survey of 80 Minnesota lakes (seven within VOYA) to quantify mercury residues in northern pike and walleye and various water-quality parameters. Relationships between mercury in fish will be determined. An assessment of differences between historic (1976-1990) and recent (1995-1996) mercury concentrations will be made. The project is in the final stages of reporting.

5. Effect of Exotic Rainbow Smelt on Nutrient/Trophic Pathways and Mercury Contaminant Uptake in the Aquatic Food Web of Voyageurs National Park

This three-year research project (1996-1998) by the University of Minnesota, Duluth, will evaluate the contaminant effect(s) (i.e., mercury) that a dietary shift to rainbow smelt has on northern pike and walleye. Final data analyses are underway.

6. Holocene Paleoenvironments of Voyageurs National Park

The objectives of this 5.5-year paleolimnology/paleoecology research project initiated in 1993 by the University of Wisconsin are to: (a) understand the dynamics of past, present, and future changes within undisturbed natural ecosystems; (b) reconstruct past ecosystem responses to past climatic changes; (c) document Holocene vegetation and fire history changes; and, (d) understand fresh-water nutrient dynamics. All macroanalytical work has been completed and a final report written. Additional charcoal is being analyzed for regional fire history, and an interpretative summary for NPS personnel is being written.

7. Inspect, Assess and Monitor Inland Lakes of the Great Lakes Cluster Parks

This two-year research project was started in 1997 by the USGS, Lake Michigan Ecological Research Station. The project objective is to characterize biological and limnological conditions of Locator and Mukooda lakes, along with other selected inland lakes. Characterizations include inventory of the biological communities, identifying environmental problems, and installing a water-quality monitoring network for selected lakes within the Great Lakes Cluster parks. The 1997 field sampling and most sample analyses have been completed.

8. Contaminant Exposure of Bald Eagles via Prey at Voyageurs National Park, Minnesota, 1993

This four-year monitoring project by the USFWS has recently been completed and includes a final report. The project assessed the impacts from environmental contaminants on reproductive success of eagles at VOYA. No significant correlation between eaglet tissue and mean productivity for total PCB's, DDE, or total mercury were observed. High mercury concentrations were found in the eagle's prey base (four fish species).

9. Long-Term Monitoring of Rainy, Kabetogama, Namakan and Sand Point Lakes

This 17-year monitoring project includes water-quality collection and analyses for the following parameters: water temperature, dissolved oxygen, pH, alkalinity, and transparency (Secchi disc), at the park's four large lakes. The principal investigator for this project is Larry Kallemeyn (USGS-BRD).

10. Reports or papers that Larry Kallemeyn will be working on in the near future include:

- Analysis of data from VOYA's lakes on phyto- and zooplankton, fish, water chemistry, and lake morphometry. The objective is to develop a classification system for the park's 30 lakes.

- Comparing mercury concentrations in fish from VOYA and Isle Royale to water chemistry and lake morphometry. This will be a cooperative effort with the University of Minnesota, Duluth.

Based upon the issues, current park staff, and natural resource programs presented in this report, a base-funded hydrologist, aquatic biologist, and technical support staff are needed at VOYA. With surface-water management identified as a top resource management issue and water being directly or indirectly associated with almost all the park's natural resource issues, water resource expertise is not a luxury, but a necessity.

RECOMMENDATIONS

This scoping report has presented numerous impacts to VOYA's aquatic habitat and biota, which have been documented through various research and monitoring programs. These impacts included:

- Various impacts to littoral vegetation, beaver, river otter, red-necked grebe, common loon, walleye, yellow perch, northern pike, and macroinvertebrates (possibly eliminating the isopod genus *Asellus*) as a result of regulated lake levels in the park.

- Seven surface-water quality parameters exceeded the EPA acute and chronic criteria for protection of freshwater aquatic life in the park.

- Increasing mercury concentrations in the sediments and fish in the park. Fish consumption warnings have been issued.

- Approximately 175 acres of exotic purple loosestrife have invaded park wetlands.

- Park waters have been invaded by exotic rainbow smelt, which compete with the native species.

- Current wastewater treatment systems are failing within the park's watershed due to inadequate soils.

- Two-stroke engines from snowmobiles and outboard motors typically discharge between 10 to 20 percent of their fuels (oil and gas) into the environment. The park estimated 44,848 snowmobile visits during the 1995-96 winter.

To effectively address these impacts and the potential for future impacts, a complete analysis of the issues presented below is needed, along with issue-specific recommendations to guide park management actions. The park is fortunate to have such a diverse number of biotic studies that begin to expose the numerous water-related issues. It is important to build from this information base through complimentary programs (i.e., water quality monitoring, water quantity monitoring, biological indexing, etc.) to better understand actions necessary to mitigate the water resource threats and to monitor the effectiveness of management decisions.

1. Surface Water Quantity and Seasonal Fluctuations
2. Surface Water Quality
3. Fishery and Aquatic Ecology
4. Riparian Zone Management
5. Floodplains Management
6. Wetlands Management
7. Recreational Management

8. Wastewater and Regulated Storage Tank Management
9. Water Rights
10. Baseline Inventory and Monitoring
11. Atmospheric Deposition
12. Interior Lakes Management
13. Minerals
14. Exotic Species
15. Coordination

The political and environmental complexity of these issues elevates the need for strong *coordination, planning,* and *management* by the NPS and other stakeholders to adequately protect and preserve VOYA's water resources. Essential to developing these three important needs is to expand upon the information contained in this scoping report by producing a more comprehensive Water Resources Management Plan (WRMP) for the park. A WRMP will provide a more detailed description of the hydrologic environment and priority issues, while including an overview of existing state and federal legislation that pertains to the park's water resources. Finally, the plan will include recommended actions (project statements) for the park's Resource Management Plan that address the high-priority issues. These project statements will define the problem(s) and recommended action(s), including a representative budget, that can compete for future NPS calls for funding.

The WRMP process encourages other stakeholders to participate with the NPS during and after plan development. Many of the issues presented in this report extend beyond NPS and international boundaries; thus, it is important to recognize the fact that multi-agency and international communication and coordination are essential to successfully manage VOYA's water resources.

The park is encouraged to place a high priority in seeking funds, both internally and externally, to expand its resource management program and to develop a strong WRMP. It is estimated that a WRMP for the park will take two years to complete and cost approximately $50,000. Until a WRMP is prepared for VOYA, components of this scoping report should be used in the development of time-sensitive management strategies and project statements relating to water resource issues.

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APPENDIX B. Acronyms used in Report.

EHD	Environmental Health Division
EPA	U.S. Environmental Protection Agency
ISC	International Steering Committee
MDNR	Minnesota Department of Natural Resources
MGS	Minnesota Geological Survey
MPCA	Minnesota Pollution Control Agency
NAWQA	National Water Quality Assessment
NPS	U.S. National Park Service
NOAA	National Oceanic and Atmospheric Administration
USGS	U.S. Geological Survey
VOYA	Voyageurs National Park
USFWS	U.S. Fish & Wildlife Service
WRMP	Water Resources Management Plan

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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