Aquatic Vegetation of Sand Chain of Lakes

Itasca County, Minnesota

2012

Sand Lake, ID# 31-0826-00
Little Sand Lake, ID# 31-0853-00
Portage Lake, ID# 31-0824-00
Bird's Eye Lake, ID# 31-0834-00

Southern bay of Portage Lake, 2012.

COPYRIGHT Minnesota Department of Natural Resources (MNDNR) 2012

Report by:
Stephanie Simon, Aquatic Biologist
Donna Perleberg, Aquatic Plant Ecologist

Minnesota Department of Natural Resources
Division of Ecological and Water Resources
Lakes and Rivers Program
1601 Minnesota Drive, Brainerd, MN 56401

Surveyors (Point-Intercept Survey):
Stephanie Simon
Donna Perleberg
Aaron Johnson, student at University of Wisconsin – Stout, 2012 intern with MNDNR
Kyle Walker-O'Beirne, student at Bemidji State University, 2012 intern with MNDNR

Acknowledgements:
We would like to thank David Wright, MNDNR Lakes and Rivers Unit Supervisor (St. Paul) and David Weitzel, MNDNR Assistant Area Fisheries Supervisor (Grand Rapids) for their helpful review of this report.

This report is also available online at:
http://www.dnr.state.mn.us/eco/pubs_aquatics/veg_reports.html

---

This report should be cited as:
S. Simon and D. Perleberg. 2012. Aquatic vegetation of the Sand Chain of Lakes: Sand (31-0826), Little Sand (31-0853), Portage (31-0824) and Bird's Eye (31-0834), Itasca County, Minnesota, 2012. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, Lakes and Rivers Unit, 1601 Minnesota Drive, Brainerd, MN 56401. 41 pages plus PDF maps.

Copyright MNDNR 2012

Survey Context

Vegetation surveys of Sand, Little Sand, Portage and Bird's Eye lakes in Itasca County were conducted as part of the MNDNR's Sensitive Lakeshore Identification project. During 2012, MNDNR biologists conducted field surveys of aquatic vegetation, and near-shore fish and frogs in these lakes. Field data will be used to identify areas along lakeshores that provide unique or critical ecological habitat. Once those areas are identified, local and state resource managers can use the information to help ensure that sensitive habitats are receiving sufficient protection.

More information on the MNDNR's Sensitive Lakeshore Identification, including Sensitive Lakeshore reports for individual lakes or lake chains, can be found online at: http://www.dnr.state.mn.us/eco/sli/index.html

A note to readers:

Text that appears in **green underline** is a hypertext link to the glossary provided at the end of this report.

Text that appears in blue underline is a hypertext link to a web page where additional information is provided. If you are connected to the Internet, you can click on the blue underlined text to link to those web pages.

Throughout the report there will be a tag called "Map" that you can click on to view the PDF maps. For instructions on how to view these interactive maps, please see the end of Appendix 3. Printable versions of these maps are provided in Appendix 3.

Copyright MNDNR 2012

Summary

Aquatic vegetation surveys of four Itasca County lakes: Sand (31-0826-00), Little Sand (31-0853-00), Portage (31-0824-00) and Bird's Eye (31-0834-00), were conducted from late June through August of 2012. Surveys included characterization of shoal substrate types, mapping of emergent and floating-leaf plant beds and lakewide assessments of vegetation and water depths at over 1,300 sample stations throughout the Sand Chain of Lakes. Survey results for each individual lake and the combined Chain of Lakes are included in this report and, because previous aquatic vegetation surveys for the Sand Chain of Lakes are available, major changes that have occurred since 1957 are noted.

Forty-four native aquatic plant species were found including nine emergent, five floating-leaved, four free-floating and 26 submerged species. Ten of these taxa were recorded for the first time during the 2012 survey. Non-native submerged plant species were not found. The non-native emergent wetland plant, purple loosestrife (*Lythrum salicaria*) was found along shorelines of Portage and Sand lakes.

Emergent and floating-leaved plants were restricted to shallow water and within the 0-6 feet depth zone, 55% of the lake, 388 acres were occupied by emergent or floating-leaved plant beds. About 97 acres of wild rice (*Zizania palustris*) or mixed beds of wild rice and other plants were mapped. Approximately 249 acres of bulrush (*Schoenoplectus* sp.) beds were delineated. Floating-leaf plants covered about 15 acres and included white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*) and floating-leaf pondweed (*Potamogeton natans*). The near-shore areas that were historically dominated by bulrush and wild rice historically retain the same type of emergent beds today. The most striking difference between the historical and current plant bed maps is that many of the beds mapped in 2012 have been bisected by navigational channels where the historical map indicates continuous, uninterrupted beds.

Submerged plants occurred to a maximum depth of 20 feet but were most common in depths from 0-5 feet, where 97% of the sites contained at least one submerged species. The most common submerged plant species were coontail (*Ceratophyllum demersum*) (16% occurrence within the shore to 20 feet zone), narrow-leaf pondweeds (*Potamogeton* spp.) (15%), flat-stem pondweed (*Potamogeton zosteriformis*) (12%), northern watermilfoil (*Myriophyllum sibiricum*) (12%), broad-leaf pondweeds (*Potamogeton* spp.) (11%), wild celery (*Vallisneria americana*) (9%) and muskgrass (*Chara* sp.) (9%). Determining whether the historical species composition within these beds has changed is difficult but the general areas that contained submerged plants in 1957 were also dominated by submerged plants in 2012.

The diversity of native plants, including the extensive beds of emergent and floating-leaf plants and mixture of many types of submerged plants, provides critical habitat for fish and wildlife in these lakes.

Copyright MNDNR 2012

Introduction

The Sand Chain of Lakes is located in Itasca County, about six miles east of the town of Squaw Lake. It occurs within the boundaries of the Chippewa National Forest and the Leech Lake Reservation (Map 1). The chain includes four lakes: Sand, Little Sand, Portage and Bird's Eye and is part of the larger Bowstring Chain of Lakes (Map 2) within the Big Fork Watershed. The Bowstring River flows north from Bowstring Lake through Sand and Little Sand to Rice Lake. It then drains to the Big Fork River which continues north to the Rainy River which forms the Minnesota/Canada border. Portage and Bird's Eye lakes are directly connected to Sand Lake. Other lakes in the Bowstring Chain include Wilson, Mushgee, Rush Island, Cedar, and Stone Axe lakes. Canoes or small boats can access these other lakes but they were not included in the 2012 vegetation surveys. Vegetation of Rice Lake was surveyed in June 2010 by MNDNR Wildlife.

Lake Characteristics

Sand Lake is the largest of the four lakes with a surface area of 4,225 acres and 23 miles of shoreline (Table 1). It has an irregular outline with a main oval-shaped basin and branching arms that connect to the other three lakes (Map 3). An elongated channel, known as the "Straights" on the southeast end of Sand Lake leads to Lakewood Bay, Casper Bay, and to Portage Lake. An eastern channel connects Sand Lake to Bird's Eye Lake and a northern channel enters Little Sand Lake. A public boat ramp is on the southeast shore of Sand Lake and boat access to the other four lakes is possible from Sand Lake.

Table 1. Lake morphological characteristics

Lake Name	Total Surface Area (acres)	Littoral Area[1] (acres)	Percent Littoral Area (%)	Shoreline Length (miles)	Max depth (feet)
Sand	4,225	1,897	45	23.0	70
Little Sand	353	231	64	3.6	20
Portage	64	36	52	1.5	60
Bird's Eye	80	45	55	2.0	50
Entire Chain	4,722	2,209	47	30.1	N/A

Most of Sand Lake is shallower than 15 feet in depth but the southeastern "Straights" have steeply sloping shores with depths of 50 to 70 feet. Big Arrowhead Island is a 103 acre mixed upland-wetland island and sits nearly in the center of the north half of Sand Lake. Little Arrowhead Island (7 acres) and Weed Island (2 acres) are smaller islands.

Portage Lake is the smallest of the four lakes with a surface area of 64 acres and 1.5 shoreline miles (Table 1). A shallow channel from Casper Bay of Sand Lake connects to the north end of

[1] Lake area where water depths are 15 feet or less.

Copyright MNDNR 2012

Portage Lake and a stream on the east shore connects to Wilson Lake. Portage Lake has a maximum depth of 60 feet and the shallowest zones are on the western and southern shores. Bird's Eye Lake is another small (80 acre) lake that connects to the east shore of Sand Lake by a 0.2 mile long channel. A small stream flows west from Rush Island Lake to Bird's Eye Lake. Little Sand Lake is a shallow (20 foot maximum depth), 353 acre lake that connects the north end of Sand Lake to Rice Lake. A small stream flows west out of Stone Axe Lake into Little Sand Lake.

The uplands surrounding these lakes are mostly forested and shoreline ownership includes a mix of federal, state, tribal and private. Shoreline development includes residential homes and several resorts.

All four lakes are **hard-water** lakes with alkalinity recorded as 140 ppm during July 2012 surveys. These lakes are characterized as **mesotrophic**, based on phosphorus (nutrients), chlorophyll-a (algae concentration) and Secchi[2] depth (transparency) (Table 2). Portage and Bird's Eye tend to have higher water clarity than Sand and Little Sand and these differences could be due to the fact that the Bowstring River flows directly through Sand and Little Sand carrying nutrients and sediments from upstream in the watershed. Based on Secchi disc measurements alone, aquatic plants have the potential to reach depths about 10-15 feet in these lakes. As a general rule, sunlight can penetrate to a depth of two times the Secchi depth and aquatic plants can grow to a depth of one and a half times the Secchi depth. Other factors that can influence the depth of plant growth include substrate, wind fetch and the types of plants present.

Table 2. Lake water quality characteristics (from MPCA, based on 10 year average of all summer samples)

Lake Name	Secchi depth[3] (feet)	Phosphorus (ppb)	Chlorophyll-a (ppb)	Overall Trophic State index[4]
Sand	6.5	22	7	48
Little Sand	6.0	19	5	47
Portage	11.0	10	4	41
Bird's Eye	10.0	***	***	44

Historic aquatic plant community

Previous lakewide, aquatic plant surveys of the Sand Chain of Lakes were conducted in 1957, 1975, 2001, and 2002 (MNDNR Lake files). These surveys focused on the commonly occurring in-lake plants and recorded a total of 36 aquatic plant **taxa**: 10 emergent, 4 floating-leaf, 3 free-

[2] The Secchi disc transparency measures the depth to which a person can see into the lake and provides a rough estimate of the light penetration into the water column. Water clarity is influenced by the amount of particles in the water column as well as by the water's color and can fluctuate seasonally and annually.
[3] Mean mid-summer (June-September) Secchi disc readings (Source: MPCA, 2012).
[4] Overall Trophic State Index (Source: MPCA, 2012)

Copyright MNDNR 2012

floating, and 19 submerged taxa (Appendix 2). In 1957, surveyors delineated major plant beds on a map; we have used that information to compare general plant communities found in 1957 with current survey results. The 1975 survey reported submerged plants to a depth of 13 feet and found emergent plants scattered along the shoreline. Plants that were reported in the previous surveys included native plants that are commonly found in many Minnesota lakes: a variety of pondweeds (*Potamogeton* spp., *Stuckenia pectinata*), northern watermilfoil (*Myriophyllum sibiricum*), coontail (*Ceratophyllum demersum*), and Canada waterweed (*Elodea canadensis*). Non-native aquatic plants have not been documented in these lakes.

Objectives

The purpose of this vegetation survey was to provide a quantitative description of the 2012 plant population of the Sand Chain of Lakes. Specific objectives included:

1. Describe the general distribution of plants in the lake including the depths at which plants occur.
2. Record the aquatic plant taxa that occur in the lake
3. Estimate the frequency of occurrence of each taxa within the vegetated zone.
4. Develop distribution maps for the commonly occurring taxa

Methods

Mapping floating-leaf and emergent vegetation beds

Mapping focused on plant beds that were at least 0.01 acres, or about 400 square feet, in size (generally larger than the surface area covered by a pontoon boat). Field surveys were conducted September 14, 15, 2011 and August 21, 22, 27, 28, 2012 to map plants like bulrush (*Schoenoplectus* spp.), which are difficult to identify from aerial photos, and to verify photo-interpretation of other plant beds. Surveyors mapped emergent and floating-leaf plant beds in the field by motoring or wading around the perimeter of each bed and recording a track with a handheld Global Positioning System (GPS) unit. Field data were uploaded to a computer and a Geographic Information System (GIS) software program was used to estimate acreage. Plant beds were classified by the dominant species or species-group.

Lakewide vegetation survey

Lakewide vegetation surveys were conducted in June and July 2012 using a point-intercept survey method (Madsen 1999, MNDNR 2012). Survey waypoints were created using a GIS computer program and downloaded into a handheld GPS unit. Survey points were spaced 65 meters (213 feet) apart on the southeast arm of Sand, Portage, and Little Sand lakes. Survey points were placed 125 meters apart on the main basin of Sand Lake. Bird's Eye Lake survey points were placed 40 meters apart. In the field, surveyors sampled all sites where water depth at the survey point was less than 21 feet. Surveyors conducted preliminary sampling within the 21-25 feet depth zone and detected no vegetation; a decision was made to focus sampling within the shore to 20 feet depth zone. A total of 1,334 sites were surveyed in the entire Sand Chain of Lakes and 1,309 sites occurred within the 0-20 feet depth zone (Appendix 1).

Copyright MNDNR 2012

The surveys were conducted by boat and a GPS unit was used to navigate to each sample point. One side of the boat was designated as the sampling area. At each site, water depth was recorded in one-foot increments using a measured stick in water depths less than 7 feet and an electronic depth finder in deeper water.

Substrate sampling

At each sample site where water depths were 7 feet and less, surveyors described the bottom substrate using standard substrate classes (Table 3). Surveyors evaluated substrate by tapping a pole into the lake bottom; soft substrate could usually be brought to the surface on the pole or sampling rake for evaluation. If this method was not feasible, substrate was evaluated by visual observation of the lake bottom. If more than one substrate type was found, surveyors recorded the most common type. Surveyors attempted to record a substrate description around the entire perimeter of the lake. If a sample site occurred near shore but in water depths greater than 7 feet, surveyors collected depth and vegetation data and then motored into shallower water and recorded the substrate type adjacent to the actual survey point; this information was used for mapping purposes.

Table 3. Substrate classes

muck	decomposed organic material
marl	calcareous material
silt	fine material with little grittiness
sand	diameter < 1/8 inch
gravel	diameter 1/8 - 3 inches
rubble	diameter 3 - 10 inches
boulder	diameter > 10 inches

Plant sampling

Surveyors recorded all plant taxa found at each **sample site** (approximately a one square meter sample site at the pre-designated side of the boat). A double-headed, weighted garden rake, attached to a rope was used to survey vegetation not visible from the water surface (Figure 3). Any additional plant taxa found outside of sample sites were recorded as “present” in the lake but these data were not used in frequency calculations. Plant identification followed Crow and Hellquist (2000) and Flora of North America (1993+) and nomenclature followed MNTaxa (2012).

Figure 3. Survey rake.

Frequency of occurrence was calculated for the entire vegetated zone (0-20 feet) and data were also separated into five feet increment depth zones for analysis (Appendix 1). Frequency estimates were also calculated for individual taxa and selected groups of plants.

This method is designed to estimate the frequency of occurrence of commonly occurring taxa. To detect infrequently occurring taxa, thousands of samples would be required. Surveyors did conduct some special searches for infrequent taxa; any additional plant taxa found outside of

Copyright MNDNR 2012

sample sites were recorded as "present" in the lake but these data were not used in frequency of occurrence calculations.

Historical 1957 map interpretation

In 1957, surveyors estimated locations of major plant beds by drawing polygons on the lake map and listing the dominant species they encountered within those beds. We rectified those original polygons into a GIS program and assigned plant community classes to each plant bed based on the plant species present:

Emergent and floating-leaf beds

1. Bulrush (*Schoenoplectus* spp.)
2. Wild rice (*Zizania palustris*)
3. Waterlilies (*Nymphaea odorata* and/or *Nuphar variegata*)
4. Other emergents: giant cane (*Phragmites* sp.), horsetail (*Equisetum* sp.), spikerush (*Eleocharis* sp.), cattail (*Typha* sp.)

Submerged beds

5. Muskgrass-bushy pondweed (primarily monotypic beds of *Chara* sp. and *Najas* sp.)
6. Muskgrass-pondweed mix (heterogeneous beds of *Potamogeton* spp., *Chara* sp. and/or other submerged species)
7. Coontail-watermilfoil (primarily monotypic beds of *Ceratophyllum demersum* and/or *Myriophyllum sibiricum*)
8. Mixed submerged aquatics (heterogeneous beds that may include all of the above species but not *Chara*).

Results and Discussion

Shoal Substrates

As their names imply, sand, or mixtures of sand and gravel, dominated the near-shore zones of Sand and Little Sand lakes (Map 4). A few sites, such as the west shore of Little Arrowhead Island, contained natural boulders along the shoreline (Figure 4). The shoal substrates of Bird's Eye and Portage lakes were primarily softer substrates of silt and muck.

Figure 4. Boulders along shore on Little Arrowhead Island in Sand Lake.

Types of plants recorded

"Richness" is a term used to describe the total number of plant taxa present in a lake and can help describe the general health of the waterbody. In Minnesota, plant taxa richness can range from zero (un-vegetated lakes) to more than 40 taxa in a lake (Radomski and Perleberg 2012). Plant taxa richness is generally higher in high clarity lakes than in turbid lakes and more plant taxa are usually found in moderately fertile lakes than in nutrient poor lakes. Therefore, lakes of north central Minnesota are often among the "richest" in terms of numbers of plant taxa.

Copyright MNDNR 2012

Water quality changes that result in lower clarity may also result in the loss of some plant taxa, or a lower taxa richness. However, caution must be used when comparing historical and present survey data because of differences in how the surveys were conducted. For example, if a current MNDNR plant survey locates more species than found during a historical "one-day" survey, it may be due to the more extensive sampling that occurs during current surveys. If fewer taxa are located during current surveys, it may indicate a true decline in the plant taxa richness of the lake.

A total of 44 aquatic plant taxa (types) were recorded in the Sand Chain of Lakes. Collectively, this chain of lakes is in the top five percent of waterbodies in the Big Fork River watershed in terms of plant richness; only two other lakes in the watershed, Coon-Sandwick and North Star, had a higher number of plants recorded in recent surveys[5]. The number of taxa found in each individual lake of the Sand Chain of Lakes was 41 in Sand Lake, 32 in Portage, 29 in Little Sand and 26 in Bird's Eye Lake.

The plants included nine emergent and five floating-leaved (Table 4), and four free-floating and 26 submerged plants (Table 5). In 2012, eight of these taxa were recorded for the first time (Appendix 2) but were present at low frequencies. These taxa were likely present historically but simply not detected during earlier surveys that were designed to detect commonly occurring taxa. Similarly, two taxa (*Potamogeton strictifolius* and *Stuckenia filiformis*) were reported in historical surveys but were not relocated in 2012. These two taxa are "narrow-leaved pondweeds" that are likely still present in the lakes but at low frequencies; additionally these taxa are difficult to identify if fruits or flowers are not present and if they were sampled in 2012 they may have been recorded under the generic name of "narrow-leaved pondweeds".

No non-native submerged aquatic plants were detected in the chain. The non-native emergent wetland plant, purple loosestrife (*Lythrum salicaria*) was found along shorelines of Portage and Sand lakes.

[5] From a review of MNDNR lake plant surveys conducted between 1993 and 2010 (Radomski and Perleberg 2012)

Table 4: Frequency of floating-leaf and emergent aquatic plant taxa within the 0-6 feet depth zone in the Sand Chain of Lakes, 2012. (N= number of samples)

Floating-leaf and Emergent within 0 to 6 feet depth zone			Entire Chain	Sand	Little Sand	Portage	Bird's Eye
			Frequency (% occurrence)				
	Common name	**Scientific Name** **N→**	373	237	68	45	23
Emergent	River bulrush	*Bolboschoenus fluviatilis*	<1	<1	--	--	--
	Spikerush	*Eleocharis palustris*	4	5	6	P	--
	Horsetail	*Equisetum fluviatile*	P	P	--	P	--
	Arrowhead - Emergent	*Sagittaria* sp.	<1	2	1	4	P
	Bulrush	*Schoenoplectus* sp.[G]	23	27	19	20	P
	Giant burreed	*Sparganium eurycarpum*	[G]1	[G]1	--	[G]P	--
	Narrow-leaved cattail	*Typha angustifolia*	2	2	P	4	--
	Broad-leaved cattail	*Typha latifolia*	<1	<1	--	P	P
	Wild rice	*Zizania palustris*	20	11	21	20	100
		Total number of emergent taxa	9	9	5	8	4
Floating-leaf	White waterlily	*Nymphaea odorata*	6	5	7	9	13
	Yellow waterlily	*Nuphar variegata*	15	10	19	29	30
	Floating-leaf pondweed	*Potamogeton natans*	5	3	7	7	13
	Floating-leaf smartweed	*Persicaria amphibia*	P	P	--	--	--
	Arum-leaved arrowhead	*Sagittaria cuneata*	<1	P	--	--	<1
		Total number of floating-leaf taxa	5	5	3	3	4

[G]Some plants were only identified to the genus level in this lake. It is possible that additional species of the genus were present in the lake, but only one species was positively identified.
P= Present in lake but not found in any survey sites

Copyright MNDNR 2012

Table 5: Frequency of submerged and free-floating aquatic plant taxa within the 0-20 feet depth zone in the Sand Chain of Lakes, 2012. (N= number of samples)

Submerged and Free-floating within 0 to 20 feet depth zone

*Surveyors could not always distinguish *Najas flexilis* from *Najas guadalupensis* and they were grouped together for analysis.

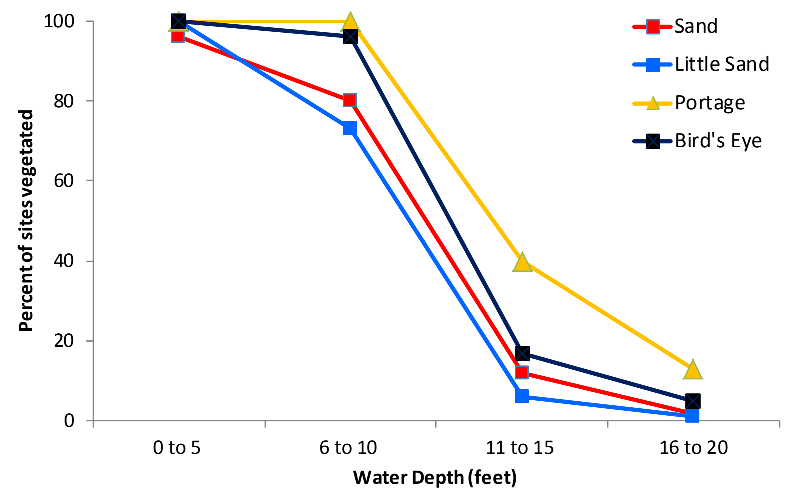
Frequency (% occurrence)

		Common name	Scientific Name N→	Entire Chain	Sand	Little Sand	Portage	Bird's Eye
			N	1309	792	327	81	109
Lg algae + moss		Muskgrass	*Chara* sp.	9	9	5	33	4
Lg algae + moss		Stonewort	*Nitella* sp.	3	5	1	--	--
Lg algae + moss		Watermoss	*Not identified to genus*	1	2	--	5	--
Monocots		Needlegrass	*Eleocharis acicularis*	<1	1	--	--	--
Monocots		Canada waterweed	*Elodea canadensis*	2	1	3	9	1
Monocots		Water stargrass	*Heteranthera dubia*	<1	<1	--	--	1
Monocots		Mare's tail	*Hippuris vulgaris*	<1	<1	--	--	--
Monocots		Bushy pondweed	*Najas flexilis**	6	6	8	7	4
Monocots		Southern naiad	*Najas guadalupensis**					
Monocots	Narrow-leaf pondweed group	Fries' pondweed	*Potamogeton friesii*	15	15	17	2	16
Monocots	Narrow-leaf pondweed group	Small pondweed	*Potamogeton pusillus*					
Monocots	Narrow-leaf pondweed group	Sago pondweed	*Stuckenia pectinata*	2	2	2	4	2
Monocots	Broad-leaf pondweed group	Large-leaf pondweed	*Potamogeton amplifolius*	1	2	P	5	1
Monocots	Broad-leaf pondweed group	Variable pondweed	*Potamogeton gramineus*	3	5	2	--	--
Monocots	Broad-leaf pondweed group	Illinois pondweed	*Potamogeton illinoensis*	<1	<1	--	P	1
Monocots	Broad-leaf pondweed group	White-stem pondweed	*Potamogeton praelongus*	1	1	1	--	--
Monocots	Broad-leaf pondweed group	Clasping-leaf pondweed	*Potamogeton richardsonii*	6	8	3	P	4
Monocots		Flat-stem pondweed	*Potamogeton zosteriformis*	12	14	8	27	3
Monocots		Creeping spearwort	*Ranunculus flammula*	<1	--	<1	1	--
Monocots		Arrowhead - Submerged	*Sagittaria* spp.	1	--	--	--	--
Monocots		Wild celery	*Vallisneria americana*	9	12	6	2	6
Dicots		Water marigold	*Bidens beckii*	1	1	1	--	--
Dicots		Coontail	*Ceratophyllum demersum*	16	13	14	44	23
Dicots		Northern watermilfoil	*Myriophyllum sibiricum*	12	11	16	20	2
Dicots		White water buttercup	*Ranunculus aquatilis*	5	6	6	4	1
Dicots		Greater bladderwort	*Utricularia vulgaris*	1	1	<1	2	6
			Total number of submerged taxa	26	24	20	18	17
Free-floating		Star duckweed	*Lemna trisulca*	3	3	2	1	6
Free-floating		Lesser duckweed	*Lemna* sp.	<1	<1	--	--	--
Free-floating		Greater duckweed	*Spirodela polyhriza*	<1	<1	--	2	--
Free-floating		Water meal	*Wolffia* sp.	<1	--	--	1	--
			Total number of free-floating taxa	4	3	1	3	1
			Total number of all taxa	44	41	29	32	26

Copyright MNDNR 2012

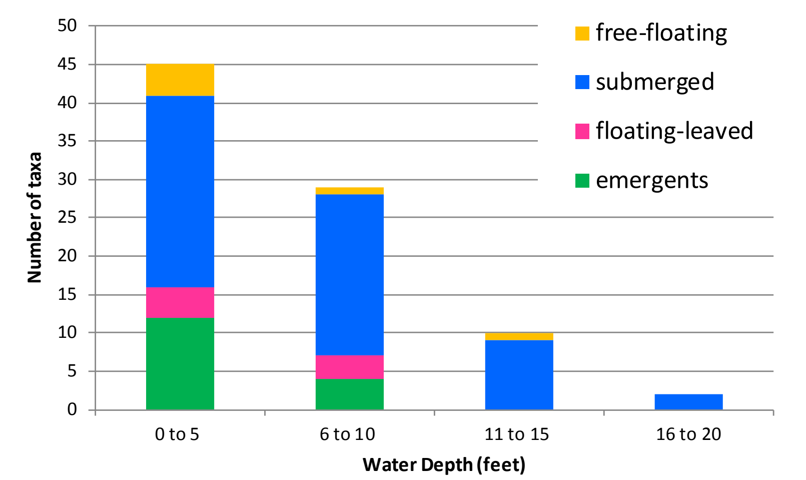
Distribution and richness of aquatic plants

Figure 5. Plant occurrence by water depth.



Plants were found to a maximum depth of 20 feet in Sand Lake and from 17 to 19 feet in other lakes. Within the 0-20 feet depth zone, 47% of all survey sites contained vegetation and Portage Lake contained the highest frequency of vegetated sites (72%) followed by Sand (52%), Bird's Eye (42%) and Little Sand (32%). In all lakes, plants were most common in the 0-5 feet depth zone, where 97% of sites contained plants (Figure 5). In Portage and Bird's Eye lakes, plant occurrence remained high (96-100%) in the 6-10 feet zone but was less frequent (73-80%) in Sand and Little Sand lakes. In all lakes, plant abundance declined with increasing water depth and in depths of 16-20 feet, only 2% of all sites were vegetated.

Figure 6. Number of taxa in each life form observed by water depth.



The highest number of plant taxa was found in the shallow water, in depths less than 11 feet. All 44 taxa found in the chain were present within this shallow zone (Figure 6). Emergent and floating-leaved plants were restricted to the 0-10 feet depth zone and were primarily found in depths less than seven feet. Only 10 taxa were found in depths greater than 10 feet and only two taxa, coontail (*Ceratophyllum demersum*) and stonewort (*Nitella* sp.), occurred in depths greater than 15 feet.

Plants were distributed around the entire shoreline of each lake as well as around the Sand Lake islands. The broadest zones of vegetation occur on the south shore of Sand Lake, around Big Arrowhead Island and in protected bays (Map 5). The number of plant taxa found at each sample site ranged from 0-10 with a mean of 1.4 species per site. Sites where the highest taxa

Copyright MNDNR 2012

richness was observed (six or more taxa per site) often occurred in depths less than 10 feet and included sites of where emergent, floating-leaf, and submerged plants co-occurred.

Emergent and Floating-leaf Plant Beds

In water depths from 0-6 feet, 55% of the sites contained at least one emergent or floating-leaf plant. Emergent and floating-leaf plant beds were found along most shorelines and covered approximately 388 acres (Map 6). The entire shoreline of Bird's Eye Lake contained emergent and floating-leaf plant beds while the other lakes ranged from 48% to 62% of their shorelines having these plant beds (Table 6). Heavily developed shorelines often lacked emergent or floating-leaf plant beds or the beds were fragmented by boat channels and/or docks and there was evidence that lakeshore development had impacted emergent and floating-leaf plant beds on Sand, Little Sand and Portage lakes.

Table 6. Emergent and floating-leaf plant acres in Sand Chain of Lakes.

Lakes	Emergent acres	Floating-Leaf acres	Total acres of emergent and floating-leaf	Acres of Shallow Water (0-6 ft)	% shallow w/emergents and floating-leaf (0-6 ft)
Sand	302	11	313	657	48
Little Sand	40	1	41	83	49
Portage	10	3	13	21	62
Bird's Eye	21	0	21	24	88
Entire Chain	373	15	388	785	49

Most of these plant beds were dominated by bulrush (*Schoenoplectus* spp.) and classified as bulrush (Figure 7) or "mixed bulrush" beds (Figure 8) if intermixed with other taxa. Bulrush was found in 23% of the sites within the 0-6 feet depth zone and often occurred on sandy and rubble substrates (Table 5). The largest bulrush beds occurred in Sand Lake where nearly the entire perimeter of the lake and Big Arrowhead Island were ringed with bulrush or mixed bulrush stands. Bulrush is an emergent, perennial plant that is rooted in the lake bottom with narrow stems that may extend several feet above the water. In addition to providing valuable fish and wildlife habitat, the extensive root network of these plants help to stabilize sandy shorelines. In shallow water, they may spread by underground rhizomes but these plants are particularly susceptible to destruction by direct cutting by human, motorboat activity and excess herbivory. Restoration of bulrush beds can be very difficult, making

Figure 7. Bulrush bed in Sand Lake.

Figure 8. Great blue heron in mixed bed of waterlilies, bulrush and wild rice in Sand Lake.

established beds particularly unique and valuable.

Figure 9. Wild rice bed in Bird's Eye.

Wild rice (*Zizania palustris*) occurred in 20% of the shallow water (0-6 feet) sites and beds were found around the shoreline of Bird's Eye Lake, the west shore of Little Sand Lake, the inlet of the Bowstring River into Sand Lake and in several smaller protected bays. It frequently co-occurred with waterlilies and/or other emergent vegetation. Wild rice is an annual plant that germinates each year from seed that fell to the lake bottom in the previous fall. The plant begins growth underwater and then forms a floating-leaf stage before becoming fully emergent (Figure 9). The plant prefers soft substrates (Lee 1986, Nichols 1999) and generally requires moving water for abundant growth (MNDNR 2008). Wild rice is susceptible to disturbance because it is weakly rooted to the lake bottom. In addition to its ecological value as habitat and food for wildlife, wild rice has important cultural and economic values in Minnesota (MNDNR 2008). This valuable plant is increasingly threatened by factors such as lakeshore development and increased water recreational use (MNDNR 2008).

Figure 10. Dragonfly on yellow waterlily leaf, Sand Lake.

Most of the other plant beds were classified as "waterlily" beds and were dominated by floating-leaf plants such as white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*) and floating-leaf pondweed (*Potamogeton natans*). Waterlily beds often contained scattered emergent plants such as wild rice, burreed, bulrush and submerged plants. The floating leaves of waterlilies provide shade and shelter for fish, frogs and invertebrates (Figure 10). The showy flowers produce seeds that are eaten by waterfowl and the rhizome are a food source for muskrats and deer (Borman et al. 2001).

Other emergent plants included spikerush (*Eleocharis acicularis*), burreed (*Sparganium* sp.), arrowhead (*Sagittaria* sp.), cattail (*Typha* sp.), giant cane (*Phragmites australis*) and river bulrush (*Bolboschoenus fluviatilis*). In addition to providing critical habitat for fish and wildlife, the extensive root network of emergent and floating-leaf plants help to stabilize shorelines and provide a buffer from waves. This is particularly important on large lakes such as Sand Lake where even low winds can create substantial wave action.

Submerged aquatic plants

Submerged plants were found to a depth of 20 feet in the Sand Chain but were common in depths of 10 feet and less. The most frequently occurring species, or species groups, were rooted plants: coontail (*Ceratophyllum demersum*), narrow-leaf pondweeds (*Potamogeton* spp.), flat-stem pondweed (*Potamogeton zosteriformis*), northern watermilfoil (*Myriophyllum sibiricum*), broad-leaf pondweeds (*Potamogeton* spp.), wild celery (*Vallisneria americana*) and

Copyright MNDNR 2012

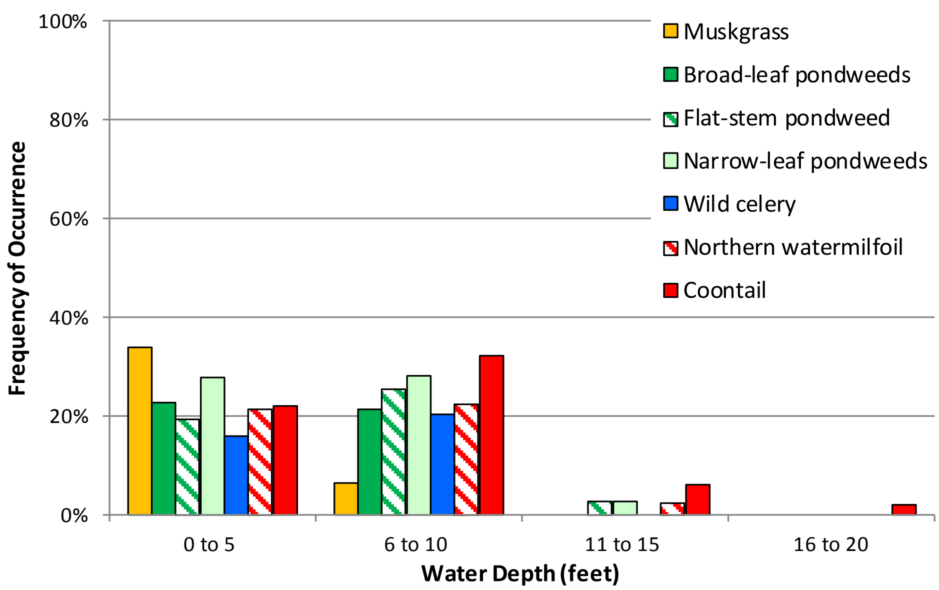
the macroalgae, muskgrass (*Chara* sp.). Within the 0-20 feet depth zone, each of these taxa occurred in at least 9% of the sites (Table 5). (Map 7)

Figure 11. Coontail

Coontail (*Ceratophyllum demersum*; Figure 11) is the most common submerged plant in Minnesota and was also common in the Sand Chain where it occurred with a frequency of 16% (Table 5). It was most abundant in Portage Lake where it was found in 44% of the sites. Coontail was one of only two taxa (in addition to *Nitella* sp.) to occur in the 16-20 feet depth zone (Figure 12).

This plant grows entirely submerged and its roots are only loosely anchored to the lake bottom. It is adapted to a broad range of lake conditions and is tolerant of higher turbidity and can grow in muck substrates (Nichols 1999). Coontail is perennial and can over winter as a green plant under the ice and then begins new growth early in the spring, spreading primarily by stem fragmentation. The finely divided leaves of this plant provide a home for insects valuable as fish food.

Figure 12. Frequency of common submerged aquatic plants in Sand Chain of Lakes, 2012.



Pondweeds (*Potamogeton* spp. and *Stuckenia* spp.) are primarily submerged, perennial plants that are anchored to the lake bottom by underground rhizomes. Depending on water clarity and depth, these plants may reach the water surface and may produce flowers that extend above the water. Pondweed seeds and tubers are an important source of waterfowl food (Fassett 1957) and the foliage of pondweeds is food for a variety of marsh birds, shore birds and wildlife and provides shelter, shade and spawning sites for a range of fish species (Borman et al. 2001).

Narrow-leaf pondweeds occurred in 15% of the survey sites (Table 5). They were found to a depth of 14 feet and within the 0-10 feet depth zone they occurred in about 28% of the sites (Figure 12). They were common in all lakes except Portage Lake. These include taxa that can be difficult to identify if not found in flower or fruit. Fries' pondweed (*Potamogeton friesii*), small pondweed (*P. pusillus*), and sago pondweed (*Stuckenia pectinata*; Figure 13) were positively identified in the lake, but additional narrow-leaf species may have also been present.

Flat-stem pondweed (*Potamogeton zosteriformis*) occurred in 12% of all survey sites and was most frequent in Portage Lake (Table 5). It was most frequent in the 0-10 feet depth zone, where it was found in 23% of the sites (Figure 12). Flat-stem pondweed is named for its flattened, grass-like leaves (Figure 14).

Figure 13. Sago Pondweed

Figure 14. Flat-stem pondweed.

photo: Andrew Hipp, U of WI-Stevens Point Herbarium

Broad-leaf pondweeds include large-leaf pondweed (*Potamogeton amplifolius*), variable pondweed (*P. gramineus*), Illinois pondweed (*P. illinoensis*), white-stem pondweed (*P. praelongus*), and clasping-leaf pondweed (*P. richardsonii*; Figure 15). These plants are often called "cabbage" plants by anglers. Some broad-leaf pondweeds may form floating-leaves in sheltered areas while other taxa have only submerged leaves. Taxa like white-stem and large-leaf pondweed are common in many clear water Minnesota lakes but are often among the first species to decline in degraded water. White-stem and large-leaf pondweeds are not tolerant of turbidity (Nichols 1999) and may be negatively impacted by increased lake development. Broad-leaf pondweeds were found in 11% of the sites (Table 5) and were found to a depth of 10 feet (Figure 12).

Figure 15. Clasping-leaf pondweed

Photo: Vic Ramey, Univ of Florida

Northern watermilfoil (*Myriophyllum sibiricum*) is a native[6], submerged plant. It is a rooted perennial with finely dissected leaves. Particularly in depths less than 10 feet, this plant may reach the water surface and its flower stalk will extend above the water surface (Figure 16). It spreads primarily by stem fragments and over-winters by hardy rootstalks and winter buds. Northern watermilfoil is not tolerant of turbidity (Nichols 1999) and grows best in clear water lakes. Northern watermilfoil was found in 12%

Figure 16. Northern watermilfoil

Photo by: Andrew Hipp (UW Madison-Wisc State Herbarium)

[6] For information on how to distinguish the native northern watermilfoil from the non-native, Eurasian watermilfoil, click here: identification.

Copyright MNDNR 2012

of all sites (Table 5). It occurred to a depth of 14 feet and was most common in the 0-10 feet depth zone (Figure 12).

Figure 17. Wild celery

Wild celery (*Vallisneria americana*; Figure 17) is a rooted, perennial submerged plant that resembles ribbon-leaved pondweeds. Unlike the pondweeds that have branches of leaves, wild celery leaves all arise from the base of the plant. Beds of wild celery provide food and shelter for fish and all parts of the plant are consumed by waterfowl, shorebirds and muskrats (Borman et al. 2001). Wild celery is a particularly important food source for canvasback ducks (Varro 2003). Wild celery occurred in 9% of all sample sites (Table 5) and was found to a depth of 10 feet (Figure 12).

Figure 18. Muskgrass

Muskgrass (*Chara* sp.) is a freshwater macroalgae[7] and is common in many hard water Minnesota lakes. It has a brittle texture and a characteristic "musky" odor. Because muskgrass does not form true stems, it is a low-growing plant, often found entirely beneath the water surface where it may form low "carpets" on the lake bottom (Figure 18). Muskgrass is adapted to variety of substrates and is often the first taxa to colonize open areas of lake bottom where it can act as a sediment stabilizer. Beds of muskgrass can provide important fish spawning and nesting habitat. Muskgrass occurred in 9% of all survey sites (Table 5) and was the most frequent plant in the 0-5 feet depth zone where it occurred in 34% of the sites (Figure 12). It was most abundant in Portage Lake where it occurred in 33% of the sites.

Unique plants

In addition to the commonly occurring native submerged plants in the Sand Chain of Lakes, there were several unique plants located during the survey including mare's tail (*Hippuris vulgaris*) and creeping spearwort (*Ranunculus flammula*). These species are not widespread in Minnesota but are usually associated with undisturbed areas in clear water lakes of northern Minnesota.

Figure 19. Mare's tail

Mare's tail (*Hippuris vulgaris*) is a submerged plant with whorls of leaves that resemble a horse's tail (Figure 19). This plant occurs primarily in northern Minnesota lakes

[7] Algae are primitive forms of plants that do not form true roots, flowers or vascular tissue. They range in size from single cell to giant seaweed. Freshwater algae that live in Minnesota lakes include tiny, free-floating planktonic algae, filamentous algae and macroalgae. Macroalgae often resemble rooted plants and provide similar habitat and water quality benefits and were therefore included in this survey.

Copyright MNDNR 2012

but is relatively uncommon. In the Sand Chain of Lakes, it was found in only one site. It is often associated with cold-water streams or springs (Voss 1985) and its presence in a waterbody may be indicative of relatively good water quality. This submerged plant may form emergent leaves and stems in shallow water.

Creeping spearwort (*Ranunculus flammula*) is mostly found in the northern half of Minnesota (Flora of North America 1993+). It grows on hard substrates like sand and gravel (Borman et al. 2001). In the Sand Chain of Lakes, this plant was found in two sites in shallow water along sandy shoreline. Creeping spearwort often grows as a submerged plant but may grow as a short emergent on mudflats. It has linear leaves that emerge in small clusters from the arched runners or stolons. This plant is in the buttercup family and if stranded on mudflats, it may form characteristic yellow buttercup flowers (Figure 20).

Figure 20. Creeping spearwort

Photo by: Emmit Judziewicz, U of WI-Stevens Point Herbarium

Historical changes in vegetation of the Sand Chain of Lakes.

Monitoring change in the aquatic plant community can be helpful in determining whether changes in the lake water quality are occurring and for estimating the quality of vegetation habitat available for fish and wildlife communities. The 1957 historical vegetation map of the Sand Chain can be used to make some general comparisons with the current 2012 survey results. The 1957 map must be interpreted carefully because surveyors did not have GPS technology to accurately map plant beds. It is also challenging to compare the large polygons delineated during the historical survey with the individual sample points surveyed in 2012. Because of the different methods used to generate these maps, it is most appropriate to compare locations of plant beds and not aerial extent. This comparison is useful for detecting large changes in plant communities.

In general, the aquatic plant communities mapped during the 1957 survey appear similar to the plant communities observed in 2012 (Map 8). The nearshore areas that were historically dominated by bulrush and wild rice historically retain the same type of emergent beds today. The most striking difference between the historical and current plant bed maps is that many of the beds mapped in 2012 have been bisected by navigational channels where the historical map indicates continuous, uninterrupted beds.

As with the emergent plant beds, the general areas that contained submerged plants in 1957 were also dominated by submerged plants in 2012 (Map 9) (Map 10). Determining whether the species composition within these beds has changed is difficult. Muskgrass and bushy pondweed are low growing submerged plants and in 1957 they appear to have dominated large stretches of shorelines. Muskgrass and bushy pondweed remain important components of the plant community in 2012 but were often found intermixed with taller pondweeds (*Potamogeton* spp). In 1957, surveyors recorded beds of watermilfoil and coontail along the southeast shore of the Sand Lake Straights. Both watermilfoil and coontail were commonly found in the 2012 survey but were most often intermixed with other submerged species.

New areas of plant beds were recorded in 2012 (such as the extensive muskgrass-pondweed bed on the south side of Big Arrowhead Island) but these submerged plants may have been present in 1957 but not detectable from the water surface.

Potential future changes in the plant communities of Sand Lake chain

The annual abundance, distribution and composition of aquatic plant communities may change due to environmental factors, predation, the specific phenology of each plant taxa, introductions of non-native plant or animal taxa, and human activities in and around the lake. Multiple factors can influence plant communities at the same time. While it may be possible to detect a change in plant communities, it may not be possible to determine the cause or causes.

Many submerged plants are perennial and regrow in similar locations each year. However, a few species such as wild rice and bushy pondweed are annuals and are dependent on the previous year's seed set for regeneration. These species are both relatively common in areas of the Sand Lake chain and annual changes in these species may also result in changes to other species (for example if bushy pondweed declines another species may invade the vacated area).

Non-native lake plant species such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) have not been documented in the Sand Chain lakes but are present in other lakes in Itasca County. These plants are easily spread to new lakes on trailered boats or even by waterfowl. If they are introduced into any of the Sand Chain lakes, the presence of healthy native plant communities may help mitigate the harmful effects of these exotics.

Humans can impact aquatic plant communities directly by destroying vegetation with herbicide or by mechanical means. Motorboat activity in vegetated areas can be particularly harmful for species such as bulrush and wild rice. Shoreline and watershed development can also indirectly influence aquatic plant growth if it results in changes to the overall water quality and clarity. Limiting these types of activities can help protect native aquatic plant species. Water level management may also impact aquatic vegetation but the effects can be difficult to predict and may vary among different plant species.

Copyright MNDNR 2012

Literature Cited

Borman, S., R. Korth and J. Temte. 2001. Through the looking glass: A field guide to aquatic plants. The Wisconsin Lakes Partnership. Stevens Point, Wisconsin. 248 pp.

Crow, G.E. and C.B. Hellquist. 2000. Aquatic and wetland plants of Northeastern North America. 2 volumes. The University of Wisconsin Press.

Fassett, N.C. 1957. A manual of aquatic plants. The University of Wisconsin Press. 405 pp.

Flora of North America Editorial Committee, eds. 1993+. Flora of North America north of Mexico. 12+ vols. New York and Oxford. www.efloras.org

Lee, P. F. 1986. Ecological relationships of wild rice, *Zizania aquatica*. 4. Environmental regions within a wild rice lake. Canadian Journal Botany 64:2037-2044.

Madsen, J. D. 1999. Point intercept and line intercept methods for aquatic plant management. *APCRP Technical Notes Collection* (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/elpubs/pdf/apcmi-02.pdf

MNDNR Fisheries Lake Files. Minnesota Department of Natural Resources. Division of Fish and Wildlife, Section of Fisheries, Lake Survey Program. 500 Lafayette Rd., St. Paul, MN 55155.

MNDNR. 2008. Natural wild rice in Minnesota. A wild rice study document submitted to the Minnesota Legislature by the Minnesota Department of Natural Resources, February 15, 2008. 117 pp.
http://files.dnr.state.mn.us/aboutdnr/reports/legislative/20080215_wildricestudy.pdf

MNDNR. 2012. Minnesota's Sensitive Lakeshore Identification Manual: a conservation strategy for Minnesota lakeshores (version 3). Division of Ecological and Water Resources, Minnesota Department of Natural Resources.

MNTaxa. 2012. Minnesota State checklist of vascular plants. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, St. Paul. Updated April 2011. Available on Internet: http://www.dnr.state.mn.us/eco/mcbs/plant_lists.html

MPCA. 2012. Minnesota Pollution Control Agency. St. Paul, MN. Lake Water Quality Assessment Program. Lake Water Quality Data Search website:
http://www.pca.state.mn.us/water/lkwqSearch.cfm (accessed October 3)

Nichols, S.A. 1999. Distribution and habitat descriptions of Wisconsin lake plants. Wisconsin Geological and Natural History Survey. Bulletin 96. Madison. 266 pp.

Copyright MNDNR 2012

Radomski, P. and D. Perleberg. 2012. Application of a versatile aquatic macrophyte integrity index for Minnesota lakes. Ecological Indicators. 20:252-268.

Varro, F. 2003. The interactions between *Aythya valisineria* (Canvasback Duck) and *Vallisneria americana* (Wild Celery): Effects on restoration in the Upper Mississippi River. Restoration and Reclamation Review. Student on-line journal. University of Minnesota, St. Paul. 8 pp.

Voss, E.G. 1985. Michigan Flora: a guide to the identification and occurrence of native and naturalized seed-plants of the state. Part II: Dicots (Saururaceae-Cornaceae). Cranbrook Institute of Science Bulletin 59 and University of Michigan Herbarium. 724 pp.

Copyright MNDNR 2012

Glossary

Within this glossary, text that appears in blue underline is a hypertext link to a web page where additional information is provided. If you are connected to the Internet, you can click on the blue underlined text to link to those web pages.

Water quality terms

Alkalinity is a measure of the amount of carbonates, bicarbonates, and hydroxide present in the water. Carbonate and bicarbonate are two alkaline compounds that provide acid buffering to the lake. These compounds are usually found with two hardness ions: calcium and magnesium. Lakes with high quantities of calcium and magnesium in the water are described as "**hard water**" and lakes with low quantities are described as "**soft water**". A lake's hardness and alkalinity are affected by the type of minerals in the soil and watershed bedrock. In Minnesota, there is a general trend of increasing alkalinity from northeast to southwest, with soft-water lakes primarily found in the northeast, hard water lakes in central Minnesota, and very hard-water lakes in the southwest. Regardless of their location in the state, if a lake receives most of its water input from precipitation, hardness and alkalinity may be low.

Level of hardness	total hardness as mg/l of calcium carbonate
Soft	0 - 60
Moderately hard	61 - 120
Hard	121 - 180
Very hard	>180

Hard-water lakes are usually in watersheds with fertile soils that add phosphorus to the lake; they tend to produce more fish and aquatic plants than soft water lakes. Increasing alkalinity is often related to increased algae productivity.

Conductivity measures the water's ability to conduct an electric current and is related to the amount of dissolved minerals in the water. It is related to hardness; soft water lakes typically have lower conductivity than hard water lakes.

Lake trophic status refers to the fertility of the lake and is based on the amount of nutrients (phosphorus and nitrogen) available for organisms. Lakes can be classified based on their fertility:

Oligotrophic lakes have very low nutrients. These lakes are usually found in northern Minnesota, have deep clear water, rock and sandy bottoms and very little algae. Cold water fish like lake trout and whitefish may be found in these lakes. Aquatic plants growth is limited and may be dominated by short, rosette-forming plants.

Copyright MNDNR 2012

Mesotrophic lakes have a medium amount of nutrients and are usually found in central Minnesota. These lakes have clear water and algal blooms may occur in late summer. These lakes often support sportfish populations of walleye, perch, smallmouth bass, muskellunge and/or northern pike. Submerged plant growth may be abundant, particularly in shallow areas.

Eutrophic lakes are very fertile with high levels of nutrients. Algal and fish populations may be high. If sufficient light is available, submerged plant growth may be moderate but is often limited due to competition with algae.

Hypereutrophic lakes have excessive nutrients and are dominated by algal blooms. Rough fish typically dominate the community and few aquatic plants are present due to limited light availability.

	Oligotrophic	Oligotrophic-Mesotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (ppb)	<6	6-12	12-24	24-48	48-200+
Secchi depth (feet)	>26	13-26	6.5-13	1.5-6.5	<1.5
Chlorophyll a (ppb)	<0.95	.95-2.6	2.6-7.3	7.3-56	56-155+

Sources: RMB Environmental Laboratories Inc. and Minnesota Pollution Control Agency

Plant identification terms

Species is a term to define a group of plants that are capable of interbreeding and producing fertile offspring in nature. Botanists assign a scientific name to each species that is a combination of the genus and species. As an example, red oak and bur oak are both species within the "Oak" genus. Red oak is assigned the scientific name of *Quercus rubra* and bur oak is named *Quercus macrocarpon*. If a surveyor cannot distinguish between a red oak and a bur oak tree, they give it the generic name of *Quercus* sp.

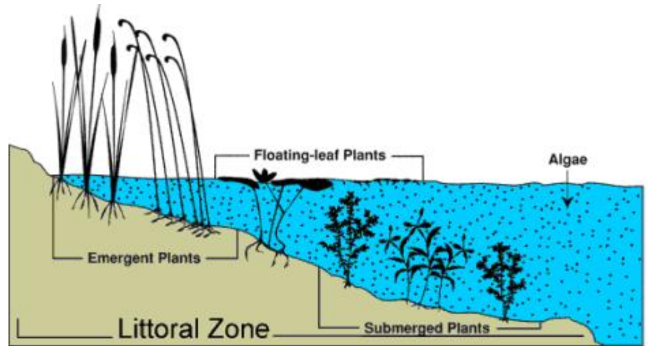
Taxa (singular taxon) is a term that refers to any group of plants, such as species or genus. In this report it is used to identify the number of different types of plants that were identified during a lake survey. In several cases, plants could not be identified to the species level but could be distinguished as unique types of plants. As an example, a surveyor may locate a maple tree and an oak tree during a survey but may not be able to distinguish the exact species of each tree (ex. red maple vs. sugar maple or red oak vs. bur oak). In this case, since the trees were not identified to the species level, it is more accurate to state that two taxa of trees were identified as opposed to two species.

Copyright MNDNR 2012

Plant growth form terms

Aquatic plants can be divided into four groups or "life forms" based on whether the main portion of the plant occurs above, on, or below the water surface. These life forms: emergent, floating-leaved, free-floating and submerged plants (Figure A), often favor certain water depth zones around the lake but overlap occurs with one life form grading into another. Each life form group has unique functions and values.

Figure A. Forms of aquatic plants found in Minnesota lakes.



Emergent plants are rooted in the lake bottom with most of their leaves and stems extending above the water surface. Root systems of these plants form extensive networks that take up nutrients and help consolidate and stabilize bottom substrate. Beds emergent plants help buffer the shoreline from wave action, offer shade and shelter for insects, young fish, and frogs and provide food, cover and nesting material for waterfowl, marsh birds and muskrat.

Floating-leaf plants such as waterlilies, are anchored in the lake bottom with leaves and flowers that float on the water surface. Root systems of these plants form extensive networks that take up nutrients and help consolidate and stabilize bottom substrate. Beds of floating-leaf plants help buffer the shoreline from wave action, offer shade and shelter for insects, young fish, and frogs and provide food, cover and nesting material for waterfowl, marsh birds and muskrat.

Free-floating plants are the smallest of Minnesota's lake plants and include small flowering plants that are commonly known as "duckweeds" as well as microscopic algae. Different survey methods are required to assess microscopic algae and they are not included in this report. Duckweeds are present in many Minnesota lakes and if present in sufficient amounts, they can accumulate into mats and create a shade barrier along protected shorelines. As their name implies, they are also an important food source for waterfowl.

Submerged plants have stems and leaves that primarily grow underwater and many may also form flowers, fruits and/or some leaves that emerge above or float on the water surface. Submerged plants are typically anchored to the lake bottom but some types drift freely with the currents. Growth forms of these plants range from low-growing mats to plants that grow several feet in the water column. Some plants obtain nutrients from the lake substrate and the water column, while others rely exclusively on the water column for nutrients. These plants play a key role in the ecosystem of a lake: they release oxygen into the water column, compete for nutrients with microscopic algae, and provide food and shelter for a variety of invertebrates, fish, amphibians and other wildlife.

Copyright MNDNR 2012

Pondweeds (*Potamogeton* spp. and *Stuckenia* spp.) are the largest group of submerged aquatic plants in Minnesota lakes with about 25 different species considered native to the state. These perennial plants are anchored to the lake bottom by underground rhizomes. Some species of pondweeds may form specialized floating leaves, while others grow entirely submerged below the water surface. Depending on water clarity and depth, any pondweed may produce flowers that extend above the water. Pondweed seeds and tubers are an important source of waterfowl food (Fassett 1957) and the foliage of pondweeds is food for a variety of marsh birds, shore birds and wildlife and provides shelter, shade and spawning sites for a range of fish species (Borman et al. 2001). Pondweeds are often named and described based on their leaf shape and size. Some pondweed species have very specific habitat requirements while others can grow in a wide range of lake conditions. Certain species have the ability to form submerged and floating leaves while others form only submerged leaves. The vegetative portions of pondweeds can be highly variable depending on water levels, water flow and other habitat conditions. If flowers or fruits are not present, pondweeds can be difficult to identify to the species level.

Plant abundance terms

"Abundance" is a general term that does not have any quantitative meaning. For vegetation sampling, there are several ways to quantify abundance.

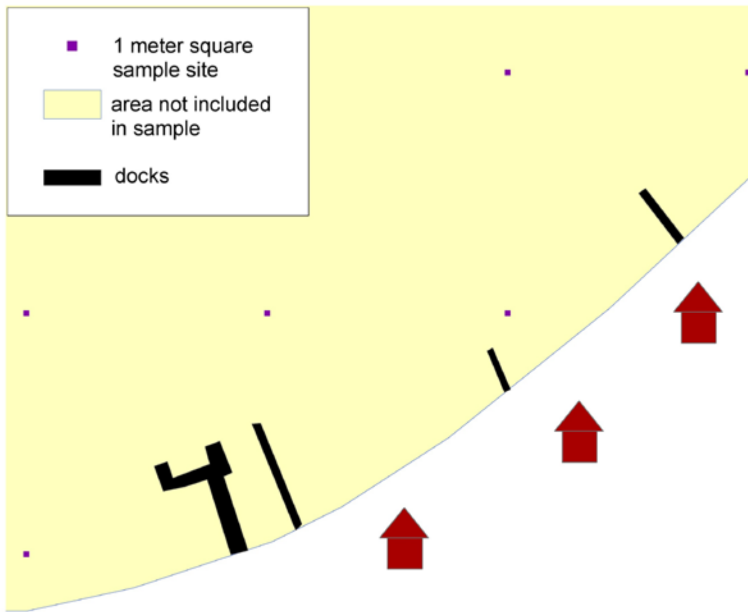
Frequency of occurrence = the percentage of sites where the plant taxon or taxa of interest occurred. This is the simplest way to measure plant abundance in lakes because it does not require underwater sampling with SCUBA gear nor does it require collecting and weighing plant biomass samples. Frequency of occurrence is less likely to change over the growth season than are other measurements such as stem density or biomass.

Example:
In the Sand Chain of Lakes there were 1309 sample sites in the 0-20 feet depth zone.
Coontail occurred in 209 sites.
Frequency of Coontail in 0-20 feet zone = (209/1309)*100 = 16%

Point intercept sample site: For point-intercept surveys, a very small area is actually sampled (see Figure B). Many small sites (represented by purple boxes) are surveyed and used to estimate plant abundance in much larger area of lake (yellow area). This information is useful on a lakewide basis but is not appropriate to describe "site-specific" conditions, such as abundance of plants immediately adjacent to an individual's shoreline home. For that type of information, a specific site visit is required.

Copyright MNDNR 2012

Figure B. Actual area of sample site used in point-intercept survey compared to non-sampled areas of lake.



Other measures of “abundance” include:

Cover = the amount of surface area occupied by a plant. For submerged lake plants, this is very difficult to measure from the boat surface. Additionally, it is difficult to consistently measure cover because it is a visual estimate. For emergent and floating-leaf plants, cover is a useful measurement that can be reliably estimated from aerial photographs and/or by delineating plant beds with GPS.

Density = the number of stems within a sample area. For aquatic plants, this requires SCUBA gear and intensive underwater measurements. It is also complicated because many aquatic plants are highly branching and it is difficult to determine where one stem begins and another on ends.

Biomass = the mass or weight of plants within a sample area. For aquatic plants, this requires SCUBA gear or other specialized equipment and plant samples must be separated, cleaned and dried before measuring. Biomass typically increases throughout the growing season.

Copyright MNDNR 2012

Appendix 1: Sampling effort by lake

Lake	Survey Dates	Total number of sites sampled	Number of sample sites in each water depth zone (feet)						Max depth sampled
			0-5	6-10	11-15	16-20	Total sites sampled 0 to 20 feet	21-25	
Sand	6/27-28; 7/10-12, 18/2012	792	178	277	146	191	792	5	*26
Little Sand	7/18-19/2012	327	42	77	81	127	327	0	20
Portage	6/26/2012	100	41	9	15	16	81	19	25
Bird's Eye	7/11-12/2012	109	15	25	25	44	108	1	*21
Entire Chain		1334	276	388	267	378	1309	25	n/a

*not all sites at this depth were sampled

Appendix 2: Historical and current aquatic plants in the Sand Chain of Lakes, 1957 to 2012

Submerged

	Common name	Scientific name	1957	1975	1984	2001	2002	2012
Lg algae + moss	Muskgrass	*Chara* sp.	X					X
	Stonewort	*Nitella* sp.						X
	Watermoss	*Not identified to genus*	X					X
Monocots	Needlegrass	*Eleocharis acicularis*						X
	Canada waterweed	*Elodea canadensis*	X	X	X		X	X
	Water stargrass	*Heteranthera dubia*						X
	Mare's tail	*Hippuris vulgaris*	X					X
	Bushy pondweed	*Najas flexilis*	X		X	X	X	X
	Southern naiad	*Najas guadalupensis*						X
	Large-leaf pondweed	*Potamogeton amplifolius*			X	X		X
	Variable pondweed	*Potamogeton gramineus*			X	X		X
	Illinois pondweed	*Potamogeton illinoensis*				X		X
	Narrow-leaf pondweed group	*Potamogeton friesii*				X	X	X
		Potamogeton pusillus			[G]X	X		X
		Potamogeton strictifolius		X				
	White-stem pondweed	*Potamogeton praelongus*	X	X	X	X	X	X
	Clasping-leaf pondweed	*Potamogeton richardsonii*	X	X		X	X	X
	Flat-stem pondweed	*Potamogeton zosteriformis*	X	X	X	X	X	X
	Arrowhead – submerged	*Sagittaria* sp.						[G]X
	Filiform pondweed	*Stuckenia filiformis*				X		
	Sago pondweed	*Stuckenia pectinata*	X			X		X
	Wild celery	*Vallisneria americana*	X	X		X	X	X
Dicots	Water marigold	*Bidens beckii*				X		X
	Coontail	*Ceratophyllum demersum*	X	X	X	X	X	X
	Northern watermilfoil	*Myriophyllum sibiricum*	X	X	X	X	X	X
	White water buttercup	*Ranunculus aquatilis*				X	X	X
	Creeping spearwort	*Ranunculus flammula*						X
	Greater bladderwort	*Utricularia vulgaris*	X	X		X	X	X
		Total	13	9	9	17	11	26

Free-floating

Common name	Scientific name	1957	1975	1984	2001	2002	2012
Star duckweed	*Lemna trisulca*		X		X	X	X
Lesser duckweed	*Lemna* sp.	X	X				X
Greater duckweed	*Spirodela polyhriza*					X	X
Watermeal	*Wolffia* sp.						X
	Total	1	2	0	1	2	4

Copyright MNDNR 2012

Appendix 2 (cont'd): Historical and current aquatic plants in the Sand Chain of Lakes, 1957 to 2012

Floating-leaved

Common name	Scientific name	1957	1975	1984	2001	2002	2012
White waterlily	*Nymphaea odorata*	X	X	X	X	X	X
Yellow waterlily	*Nuphar variegata*	X	X	X	X	X	X
Floating-leaf pondweed	*Potamogeton natans*	X	X	X		X	X
Floating-leaf smartweed	*Persicaria amphibia*				X		X
Arrowhead	*Sagittaria cuneata*						X
	Total	3	3	3	3	3	5

Emergents

<table>
<tr><th>Common name</th><th>Scientific name</th><th>1957</th><th>1975</th><th>1984</th><th>2001</th><th>2002</th><th>2012</th></tr>
<tr><td>River bulrush</td><td>Bolboschoenus fluviatilis</td><td></td><td></td><td></td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Spikerush</td><td>Eleocharis palustris</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Horsetail</td><td>Equisetum fluviatile</td><td>X</td><td>X</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Broad-leaf arrowhead</td><td>Sagittaria latifolia</td><td rowspan="2">[G]X</td><td>X</td><td></td><td></td><td></td><td rowspan="2">[G]X</td></tr>
<tr><td>Stiff wapato</td><td>Sagittaria rigida</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td rowspan="2">Bulrush</td><td>Schoenoplectus acutus</td><td rowspan="2">[A]X</td><td rowspan="2">[A]X</td><td rowspan="2">[A]X</td><td rowspan="2">[A]X</td><td rowspan="2">[A]X</td><td rowspan="2">[A]X</td></tr>
<tr><td>Schoenoplectus tabernaemontani</td></tr>
<tr><td>Giant burreed</td><td>Sparganium eurycarpum</td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>[G]X</td></tr>
<tr><td>Narrow-leaved cattail</td><td>Typha angustifolia</td><td rowspan="2">[G]X</td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Broad-leaved cattail</td><td>Typha latifolia</td><td>X</td><td>X</td><td></td><td></td><td>X</td></tr>
<tr><td>Wild rice</td><td>Zizania palustris</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td></td><td>Total</td><td>6</td><td>6</td><td>4</td><td>6</td><td>5</td><td>9</td></tr>
</table>

Wetland emergents

Common name	Scientific name	1957	1975	1984	2001	2002	2012
Sweet flag	*Acorus calamus*	X					
Sedge	*Carex comosa*		X				
Sedge	*Carex* sp.						X
Purple loosestrife (I)	*Lythrum salicaria*						X
Reed Canary grass (I)	*Phalaris arundinaceae*						X
Giant cane	*Phragmites australis*	X	X	X		X	X
	Total	2	2	1	0	1	4

(I) = Introduced to Minnesota

[A]species of bulrush (*Schoenoplectus* sp.) was used to record bulrush plants that were hard-stem bulrush (*Schoenoplectus acutus*), soft-stem bulrush (*S. tabernaemontani*) or the hybrid.

[G]Some plants were only identified to the genus level in this lake. It is possible that additional species of the genus were present in the lake, but only one species was positively identified.

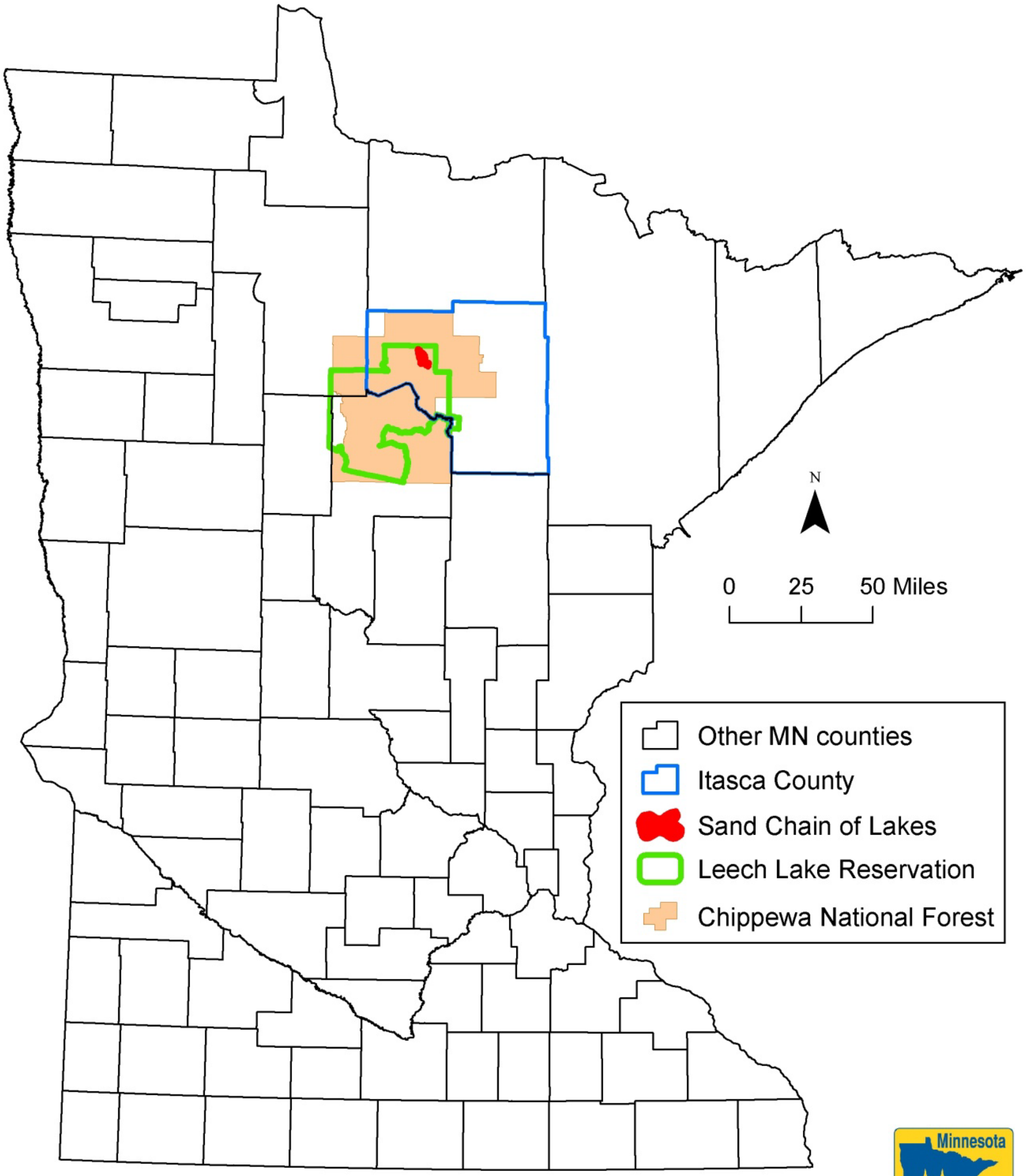
1957 (July 16, August 2, 13) Arthur Peterson, Robert Bredemus, Minnesota Department of Conservation, Bureau of Research and Planning
1975 (June 30, July 3, 7-11) Marc Olson, Lloyd Steen, MNDNR Division of Game and Fish.
1984: MNDNR Division of Game and Fish
2001 (June 28) Karen Myhre, Minnesota Biological Survey of Sand Lake, MNDNR Division of Ecological and Water Resources
2002 (August 1) Karen Myhre, Minnesota Biological Survey of Little Sand Lake, MNDNR Division of Ecological and Water Resources

Copyright MNDNR 2012

2012 (June, July, August) Simon, Perleberg, Johnson, Walker-O'Beirne, Point-Intercept survey, MNDNR Division of Ecological and Water Resources

Appendix 3: Printable versions of Maps 1 through 10

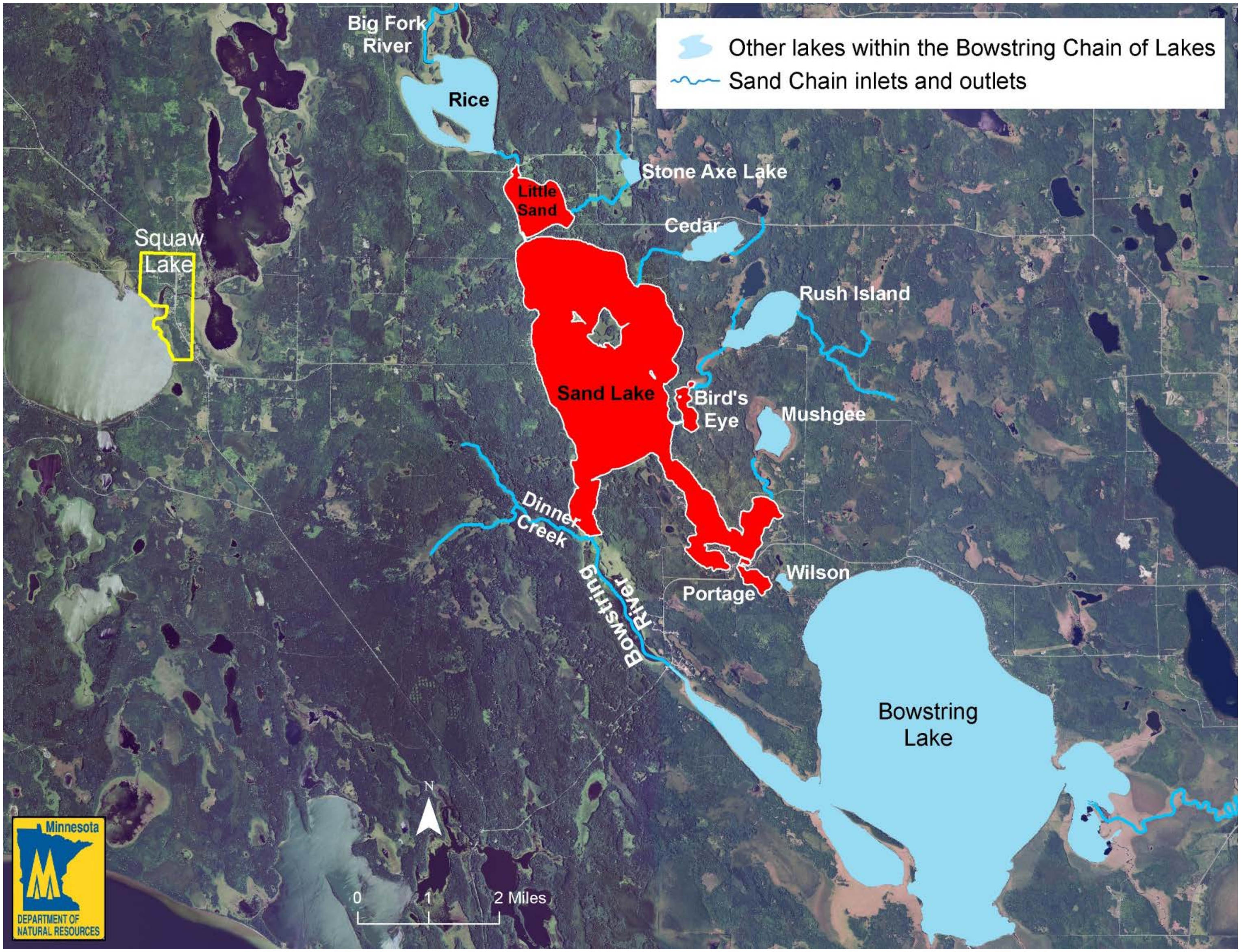
Map 1: Sand Chain of Lakes, Itasca County, Minnesota.



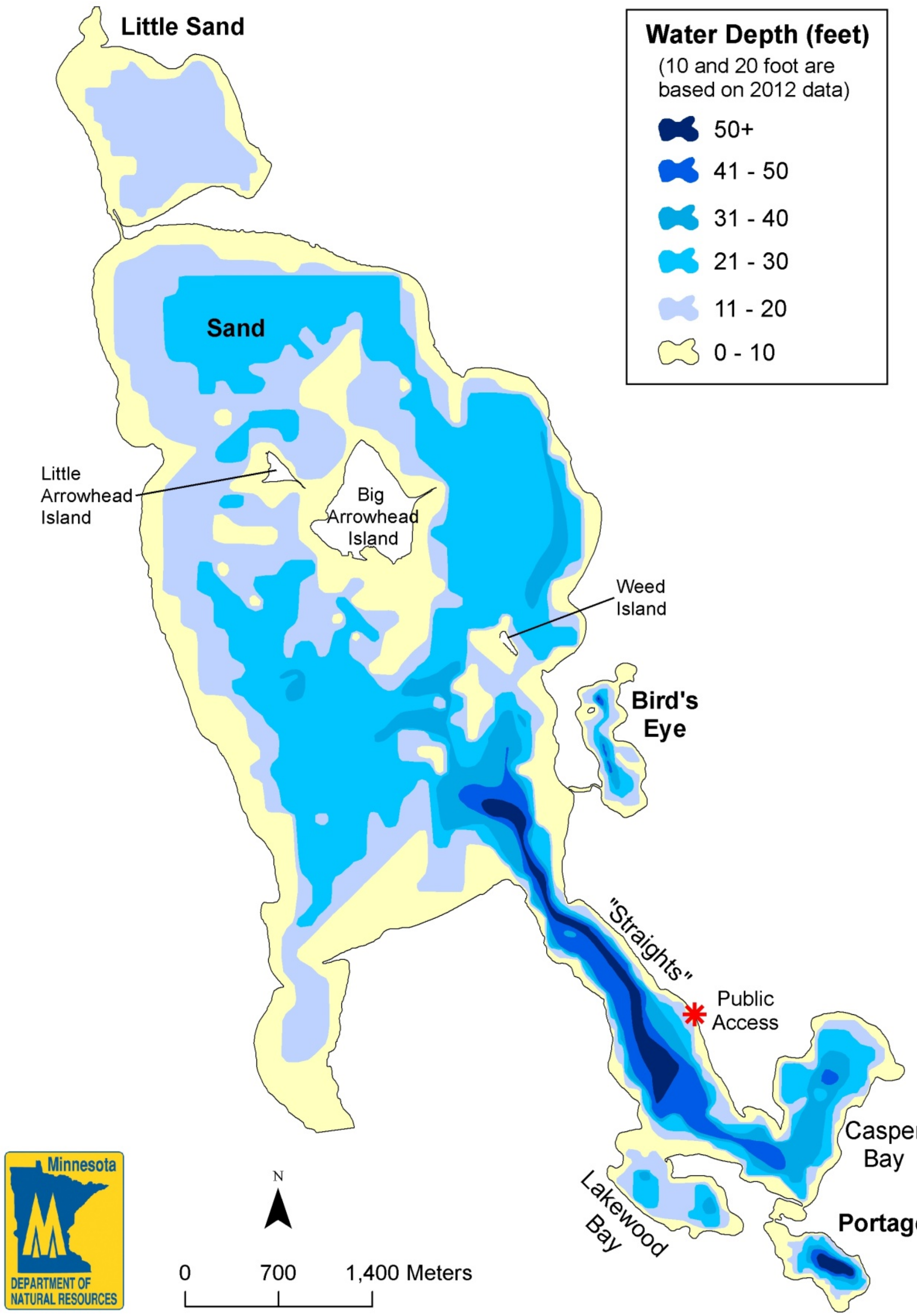
Minnesota DEPARTMENT OF NATURAL RESOURCES

Copyright MNDNR 2012

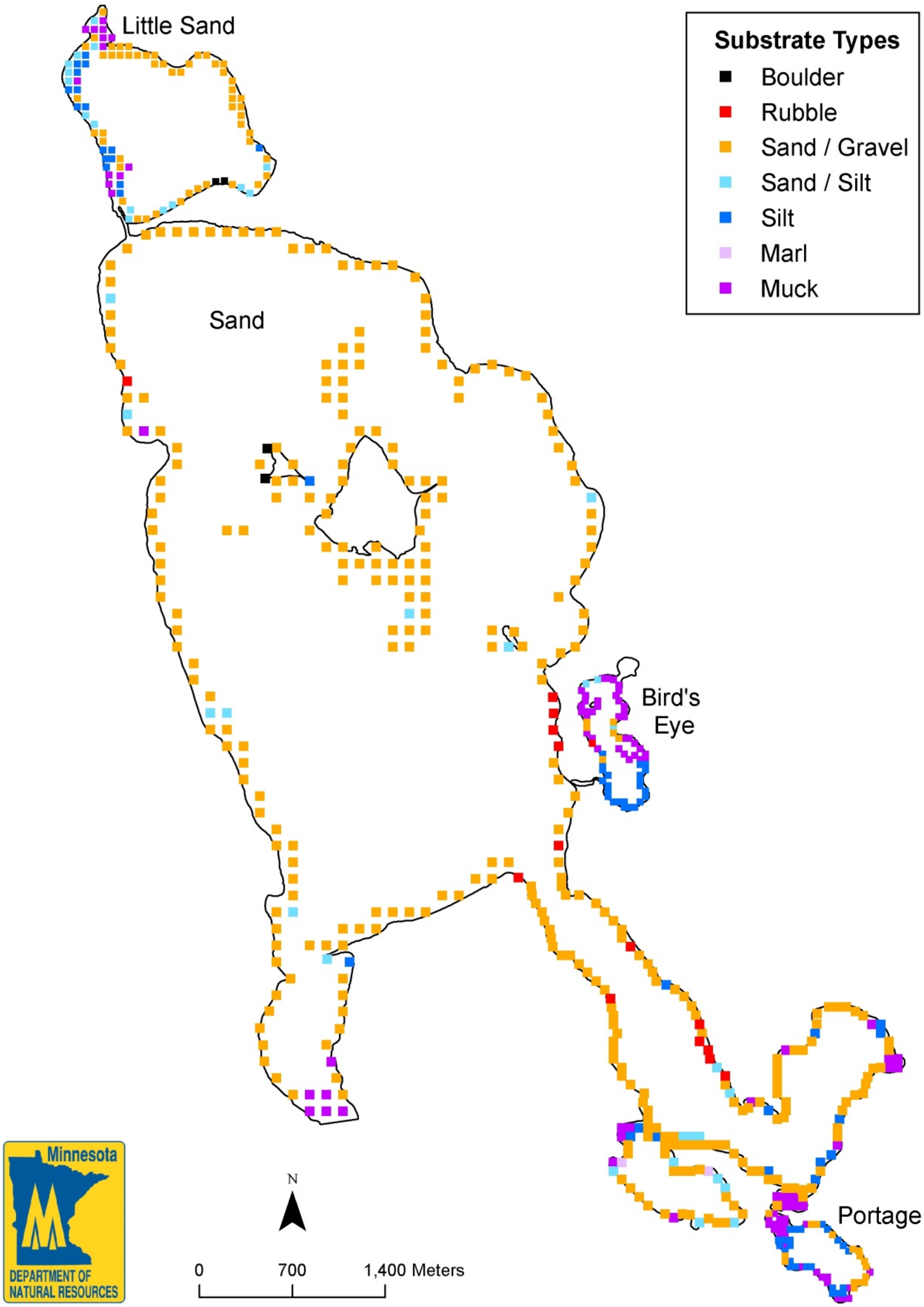
Map 2: Sand Chain of Lakes within the larger Bowstring Chain of Lakes.



Map 3: Depth contours of the Sand Chain of Lakes

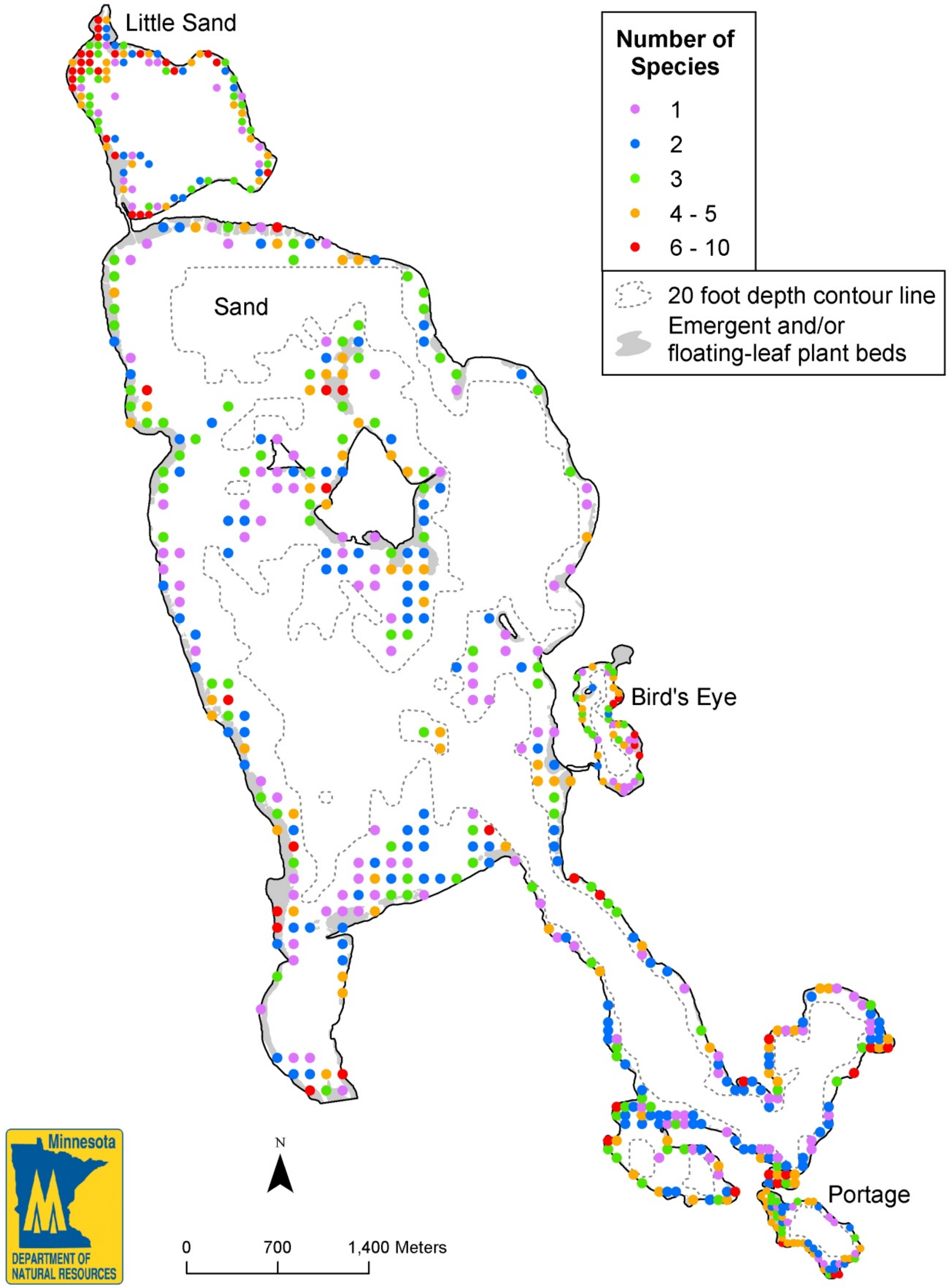


Map 4: Substrate within the Sand Chain of Lakes

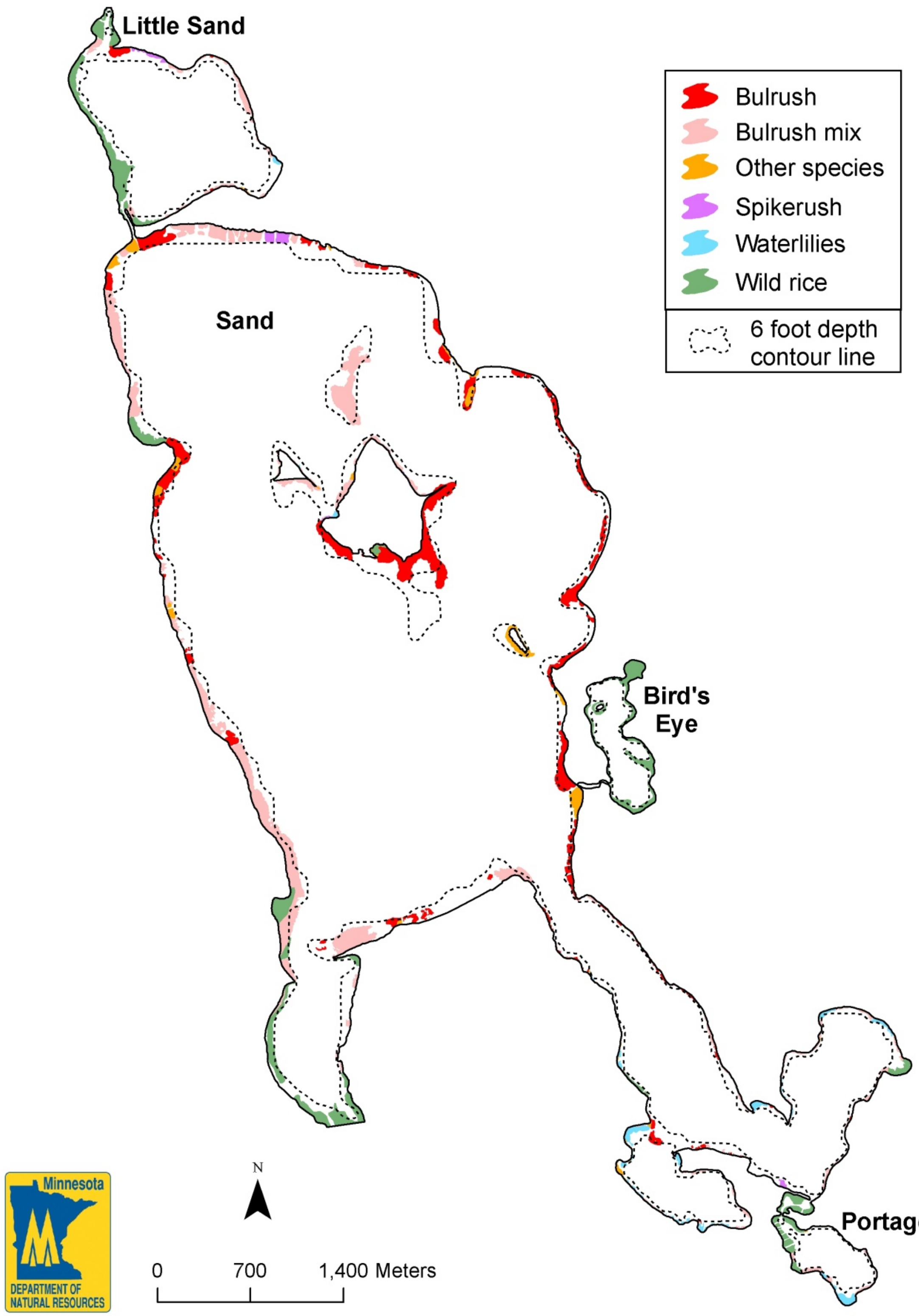


Copyright MNDNR 2012

Map 5: Number of species per sample site, Sand Chain of Lakes, 2012.

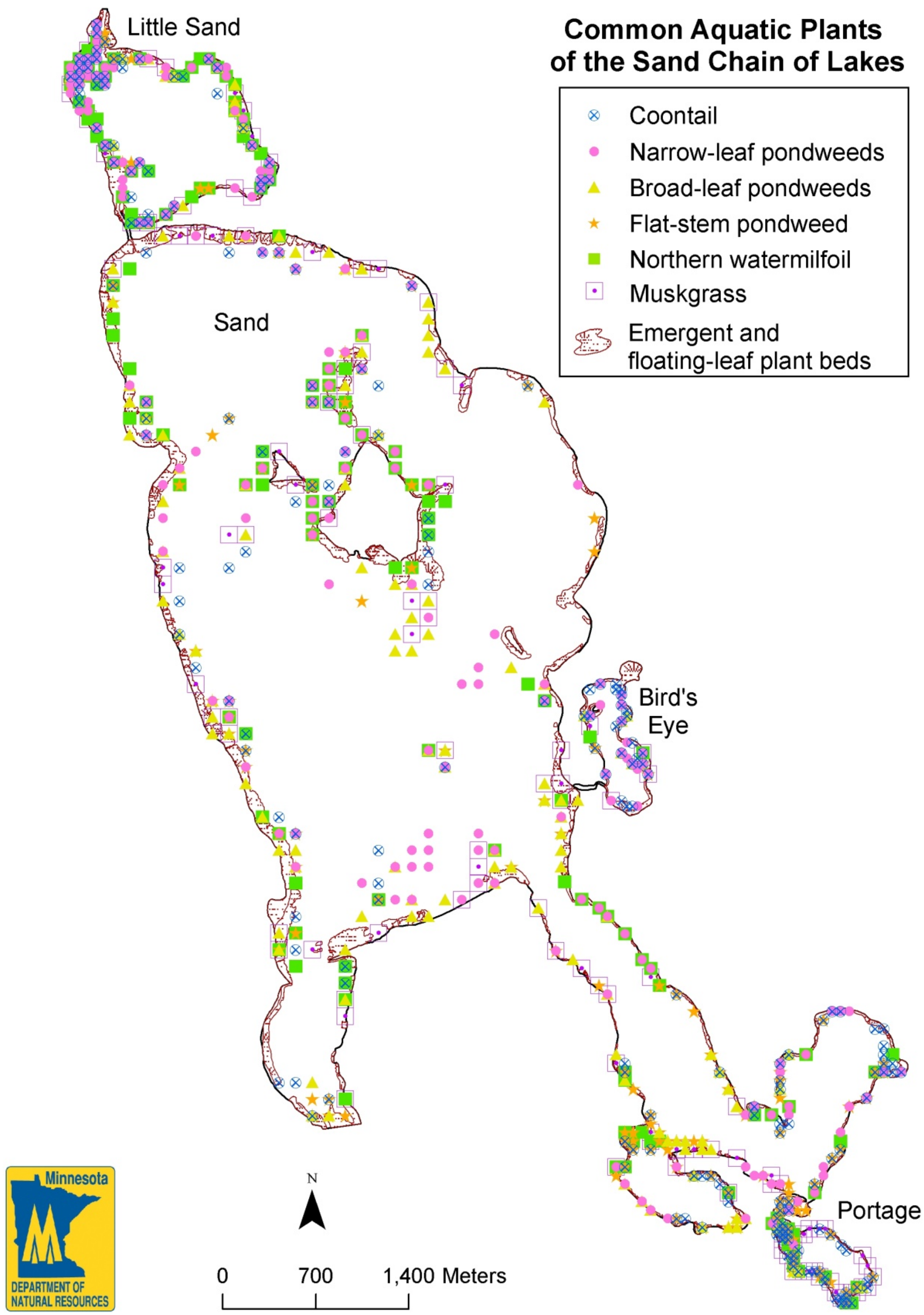


Map 6: Emergent and floating-leaf plant beds, Sand Chain of Lakes, 2012.

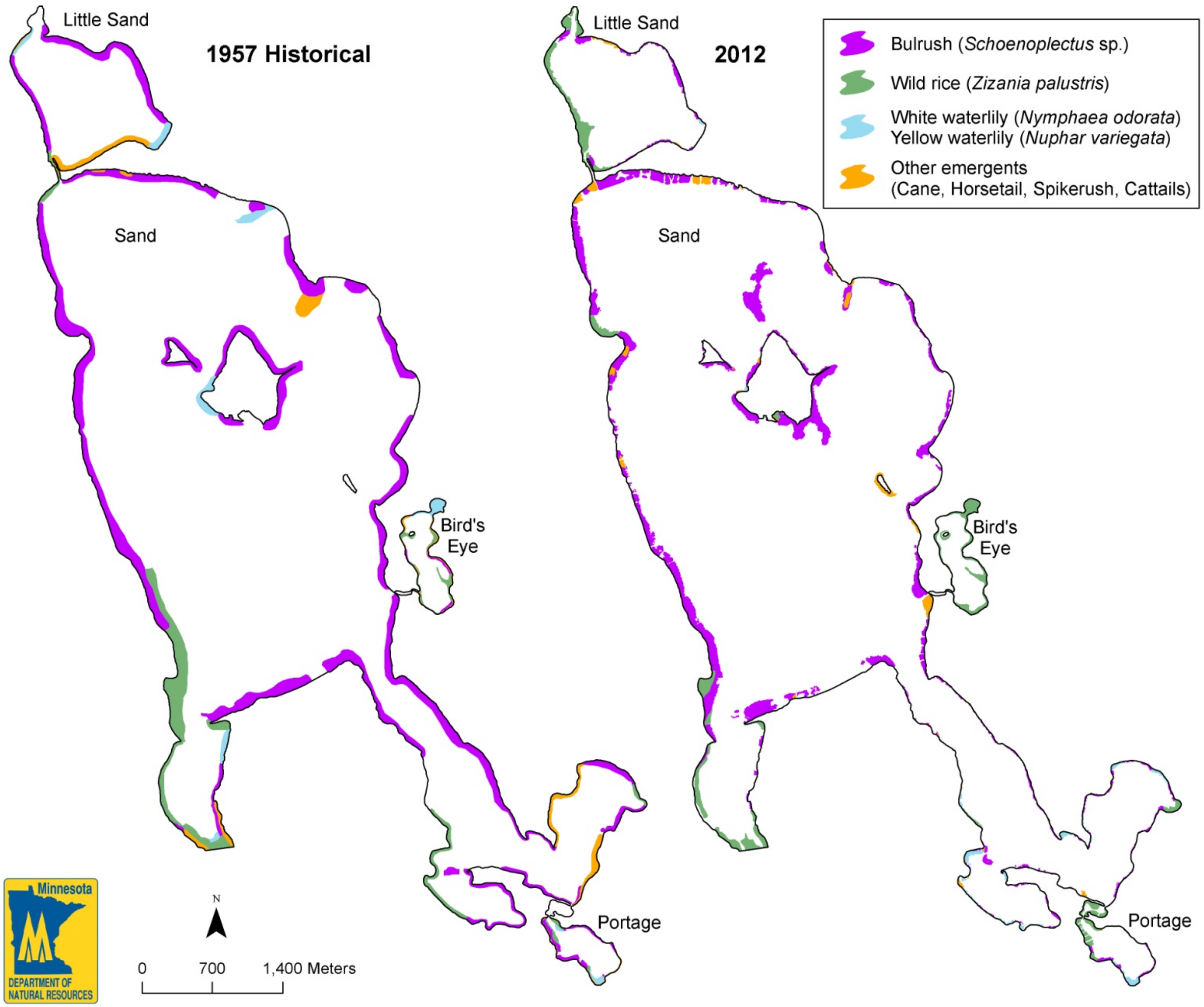


Copyright MNDNR 2012

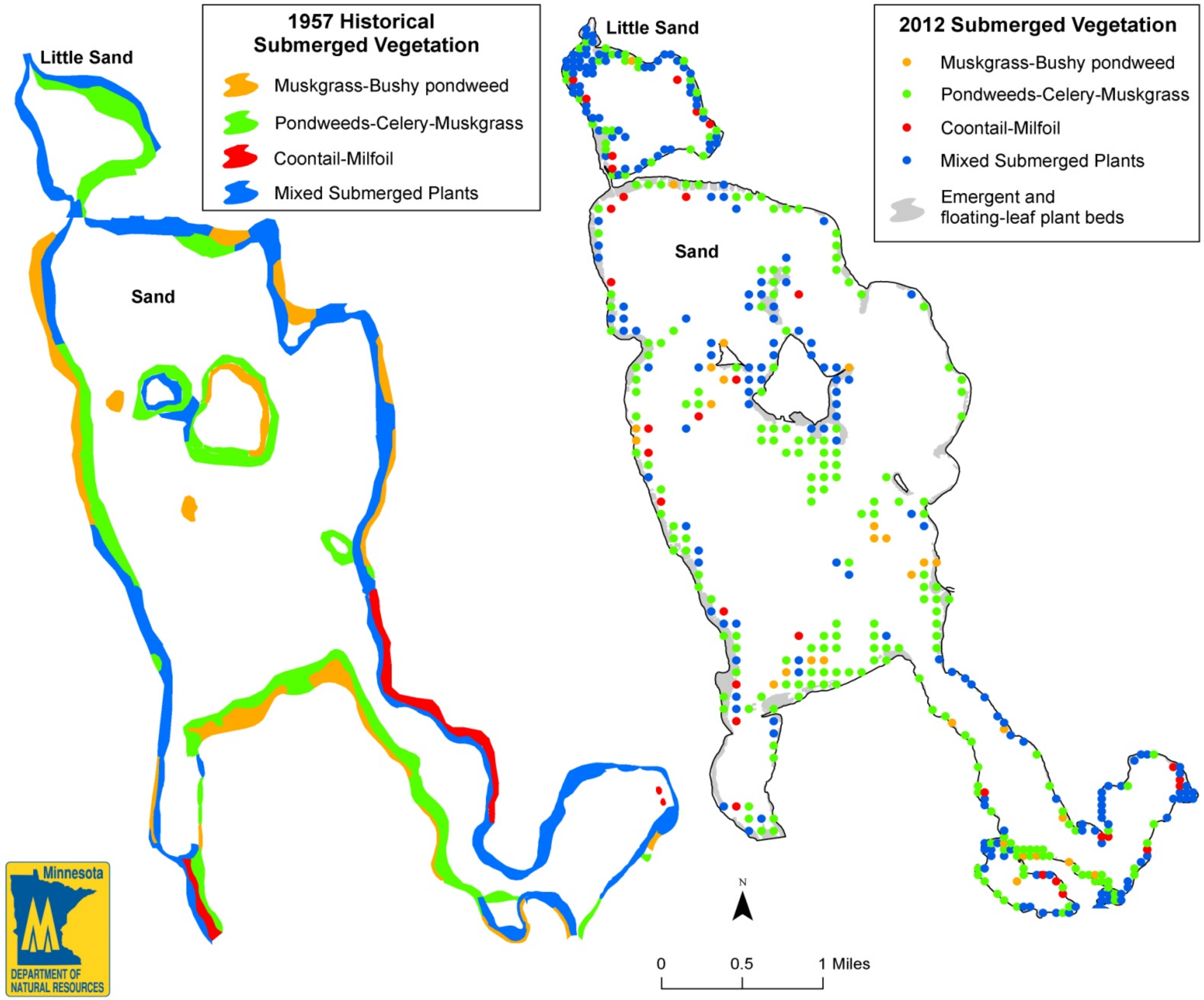
Map 7: Common submerged aquatic plant species, Sand Chain of Lakes, 2012.



Map 8: Historical and current emergent and floating-leaf plant beds.

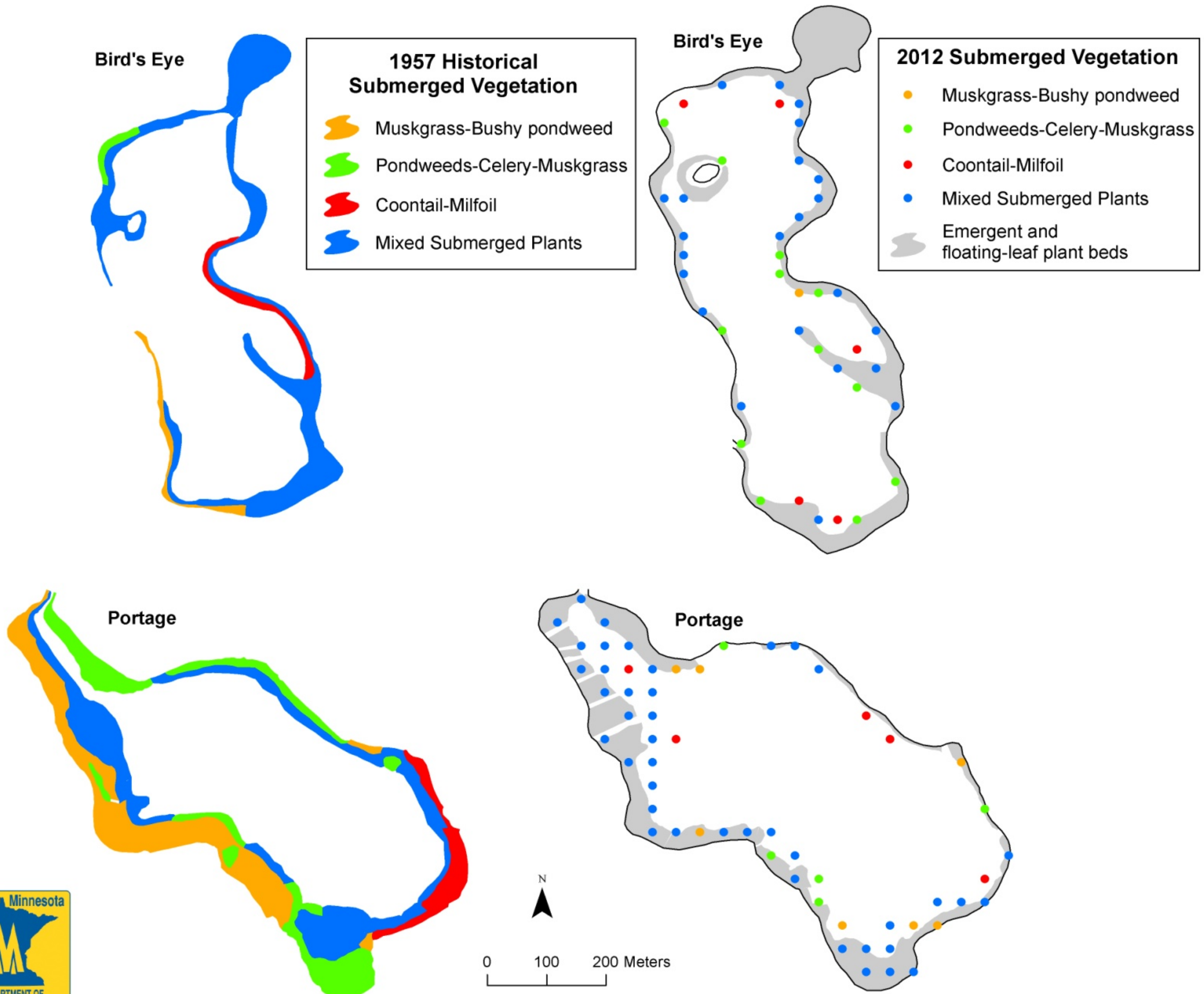


Map 9: Little Sand and Sand lakes submerged historical and current aquatic plants.



Copyright MNDNR 2012

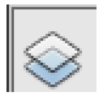
Map 10: Bird's Eye and Portage lakes, submerged historical and current aquatic plants.

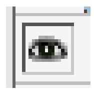


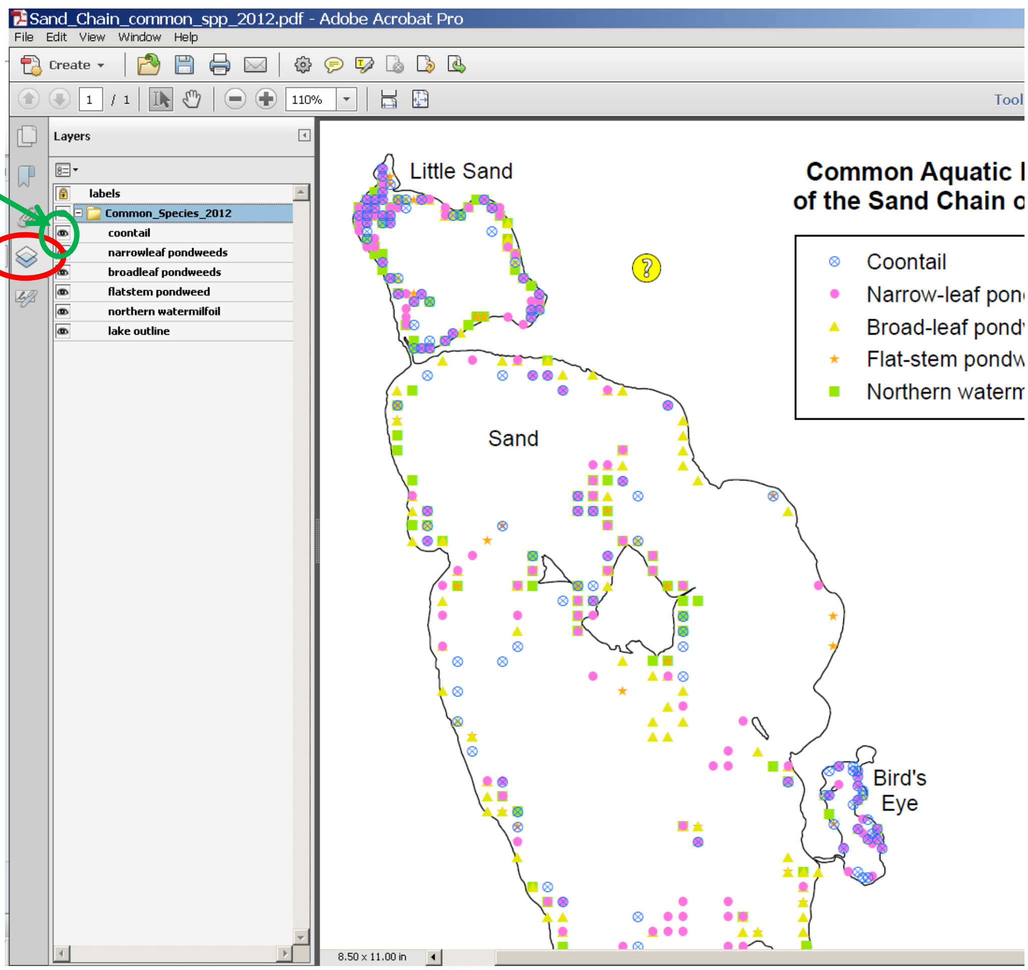
Minnesota DEPARTMENT OF NATURAL RESOURCES

How to view layers in pdf maps.

Each pdf Map is set up with all of the layers visible as the default view. The reader can toggle each layer on or off by following these steps:

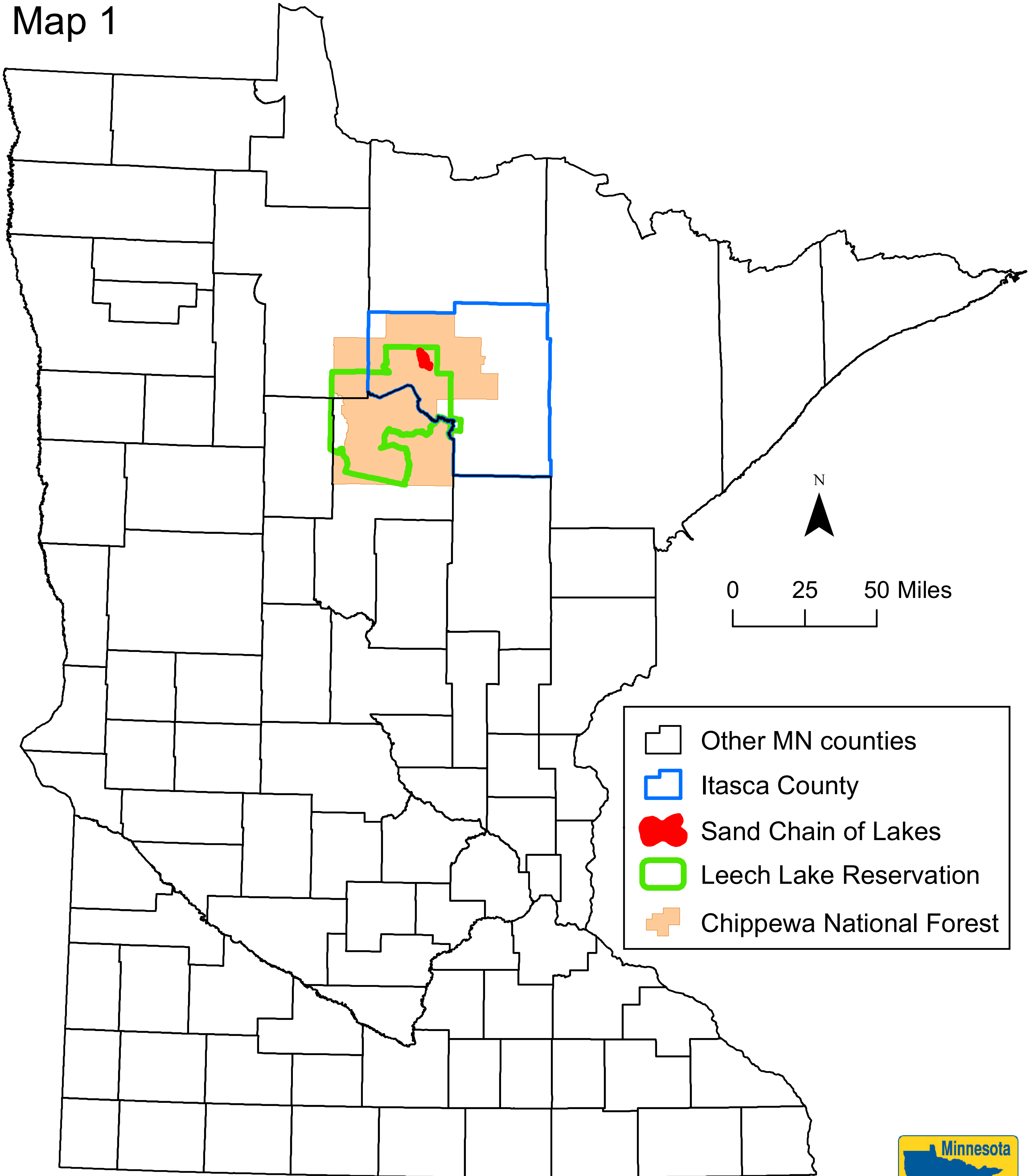
1. Click layer button  to display each individual layer

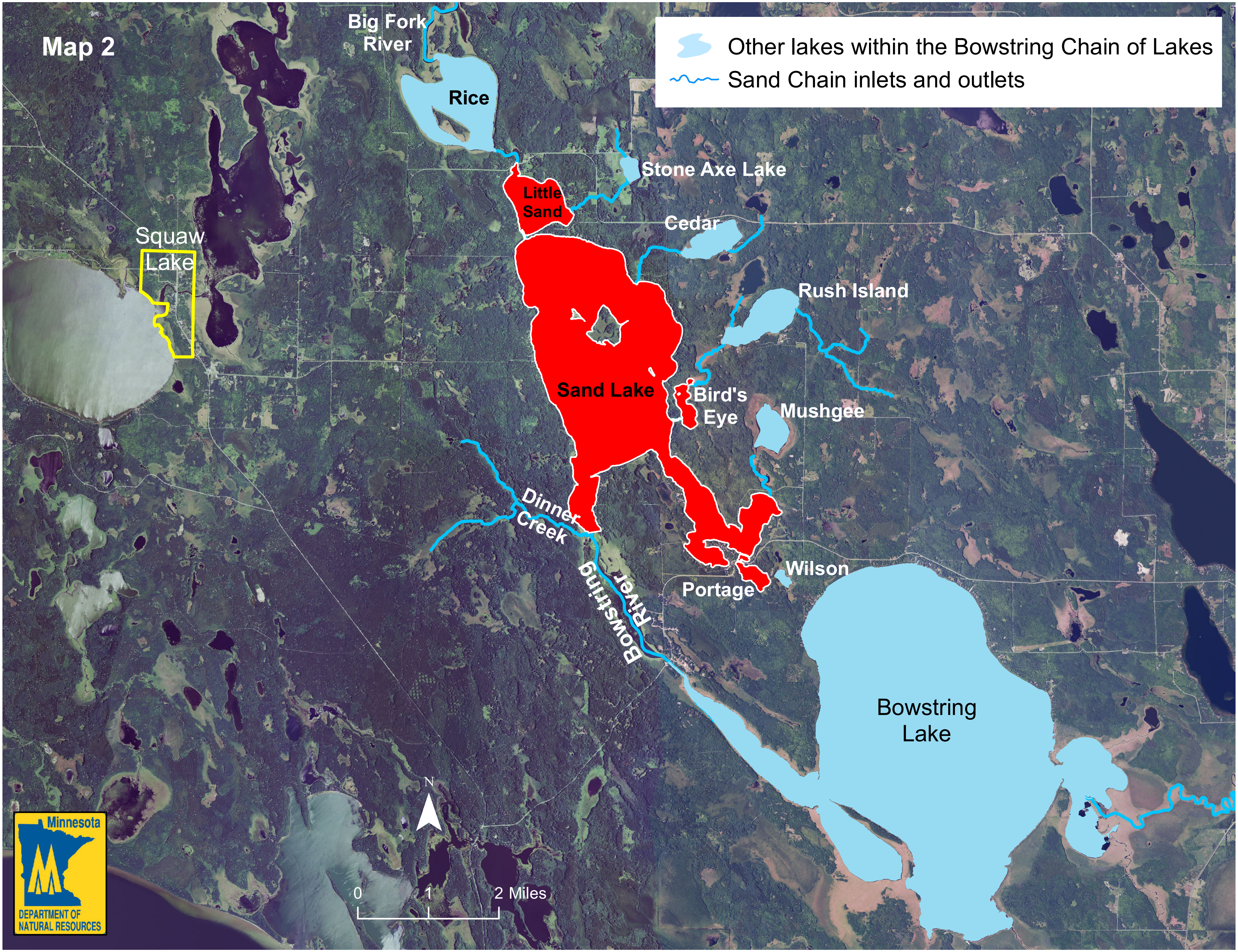
2. Click on eyeball  of any layer to turn layer on or off.

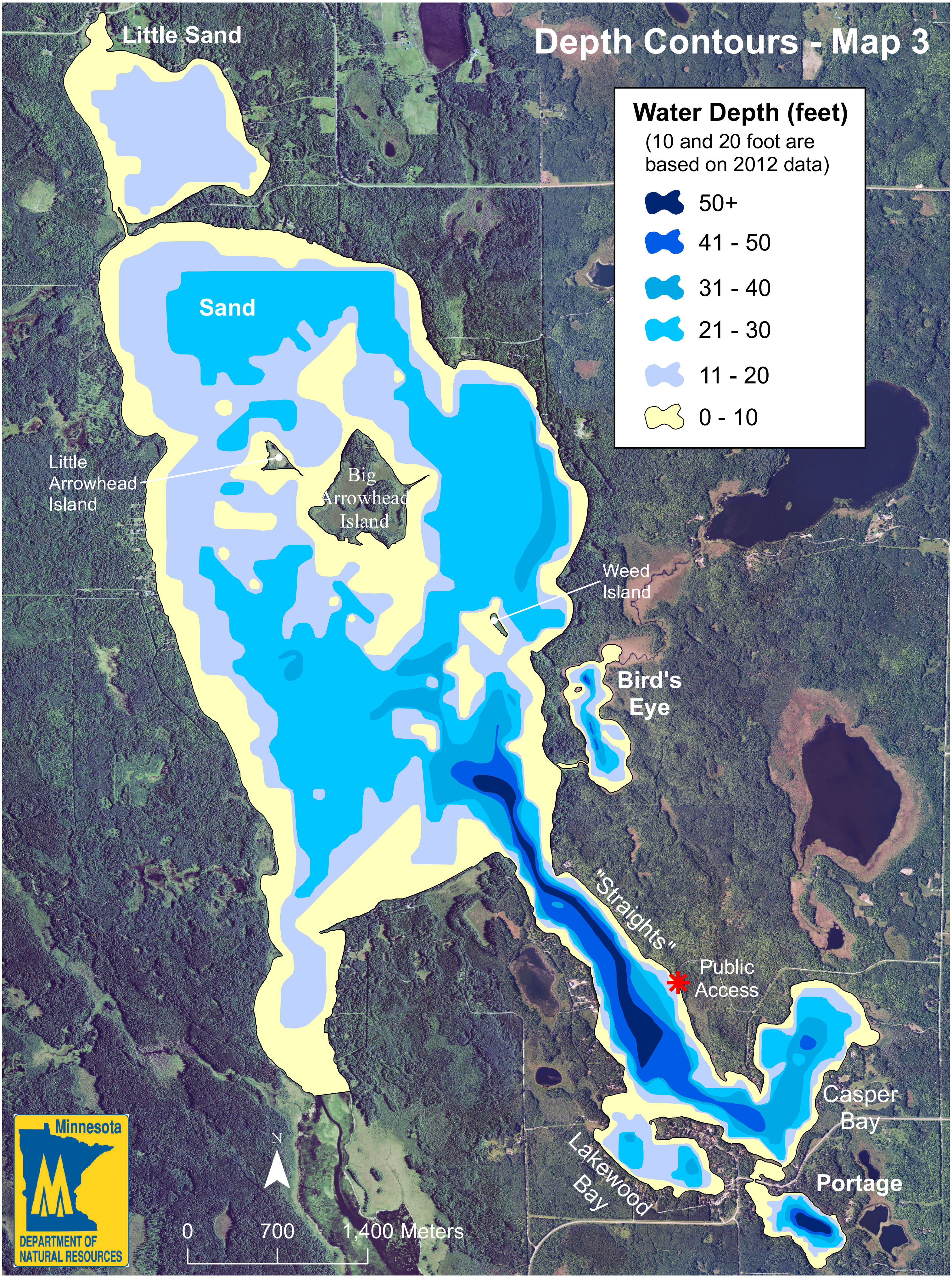


Copyright MNDNR 2012

Map 1

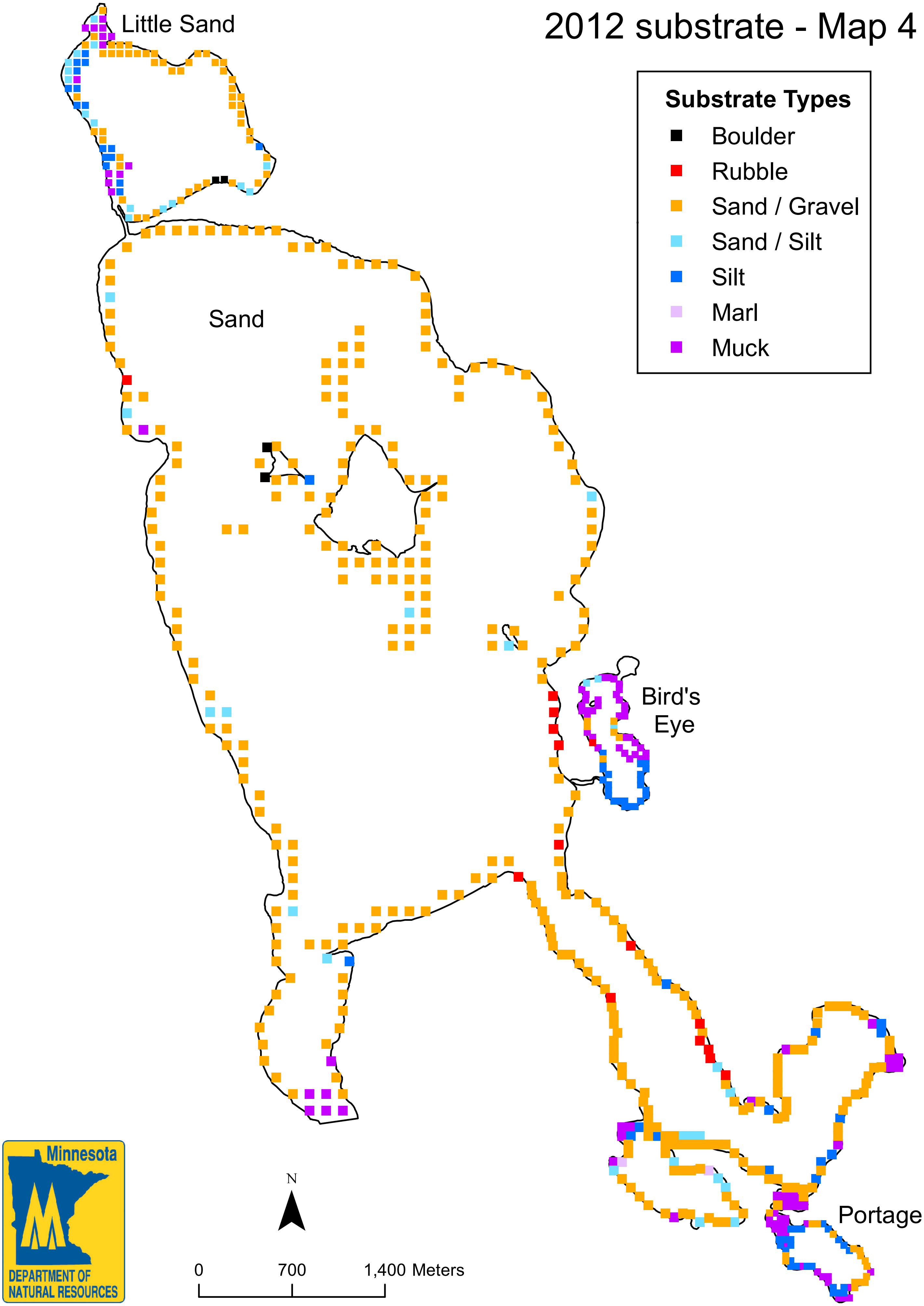

N
0
25
50 Miles
Other MN counties
Itasca County
Sand Chain of Lakes
Leech Lake Reservation
Chippewa National Forest

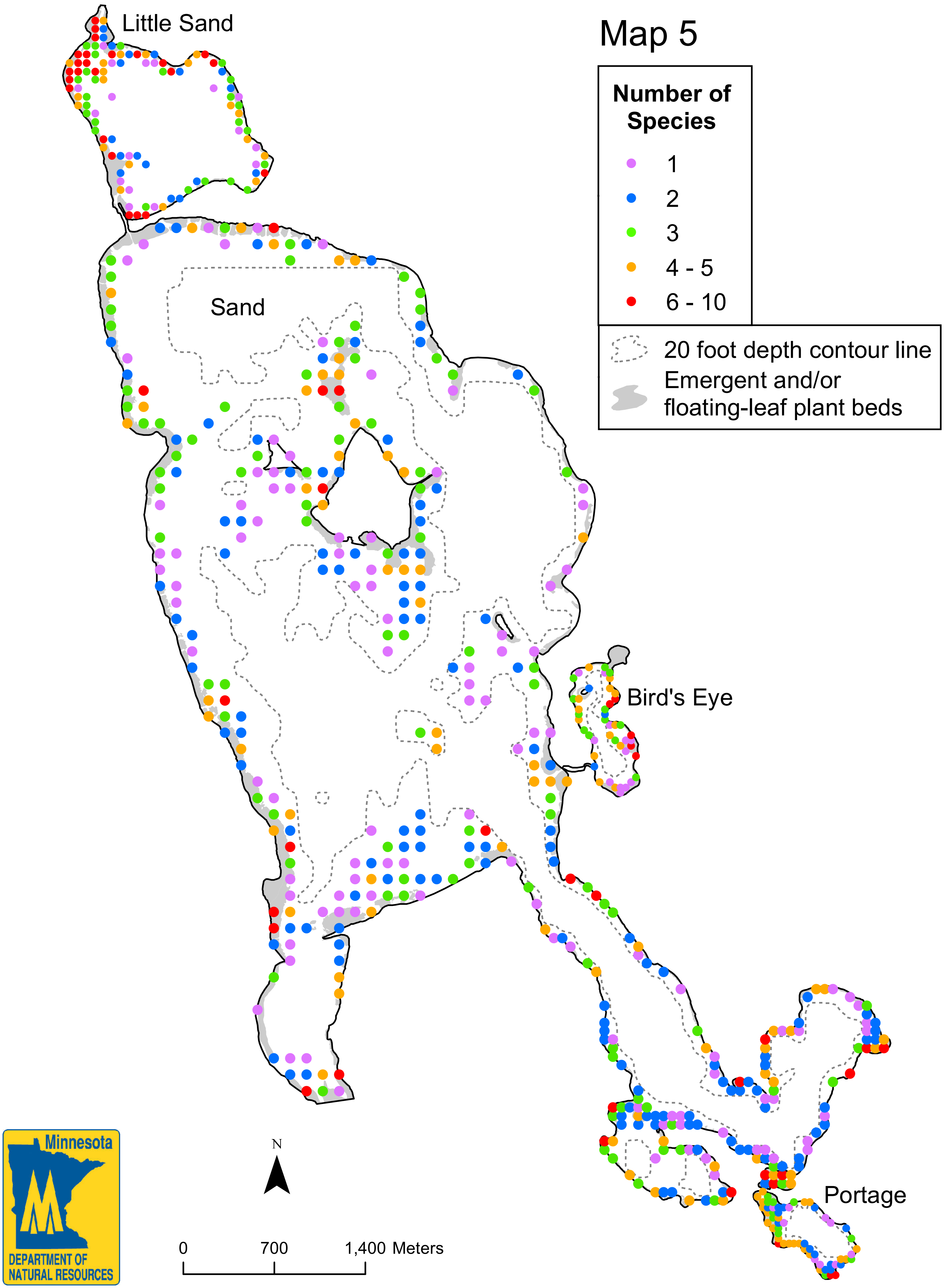

Map 2
Big Fork River
Rice
Other lakes within the Bowstring Chain of Lakes
Sand Chain inlets and outlets
Stone Axe Lake
Little Sand
Cedar
Squaw Lake
Rush Island
Sand Lake
Bird's Eye
Mushgee
Dinner Creek
Bowstring River
Wilson
Portage
Bowstring Lake
N
0
1
2 Miles
Minnesota
DEPARTMENT OF NATURAL RESOURCES

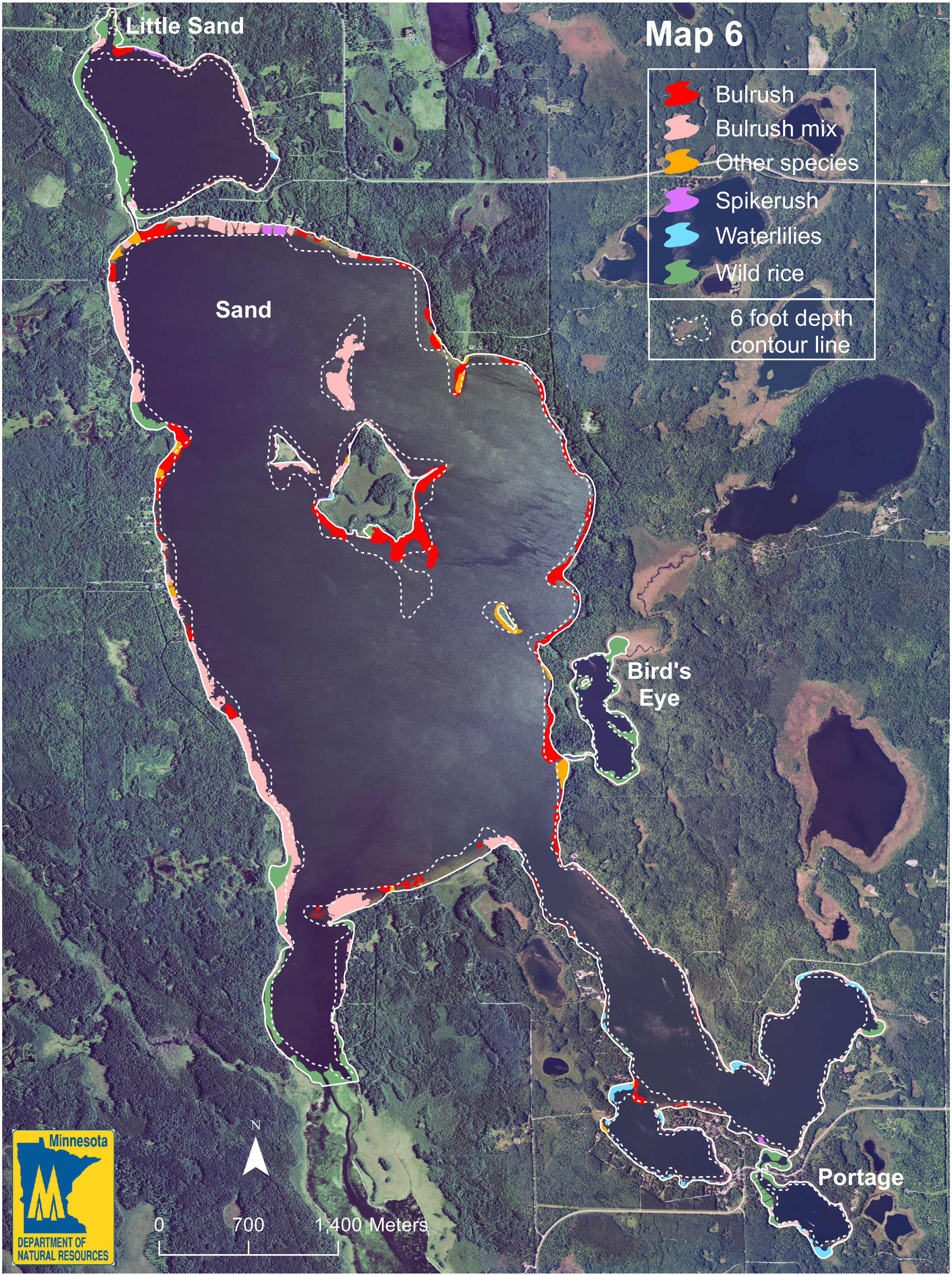


Depth Contours - Map 3
Water Depth (feet)
(10 and 20 foot are based on 2012 data)
50+
41 - 50
31 - 40
21 - 30
11 - 20
0 - 10
Little Sand
Sand
Little Arrowhead Island
Big Arrowhead Island
Weed Island
Bird's Eye
"Straights"
Public Access
Casper Bay
Lakewood Bay
Portage
N
0
700
1,400 Meters
Minnesota
DEPARTMENT OF NATURAL RESOURCES

2012 substrate - Map 4

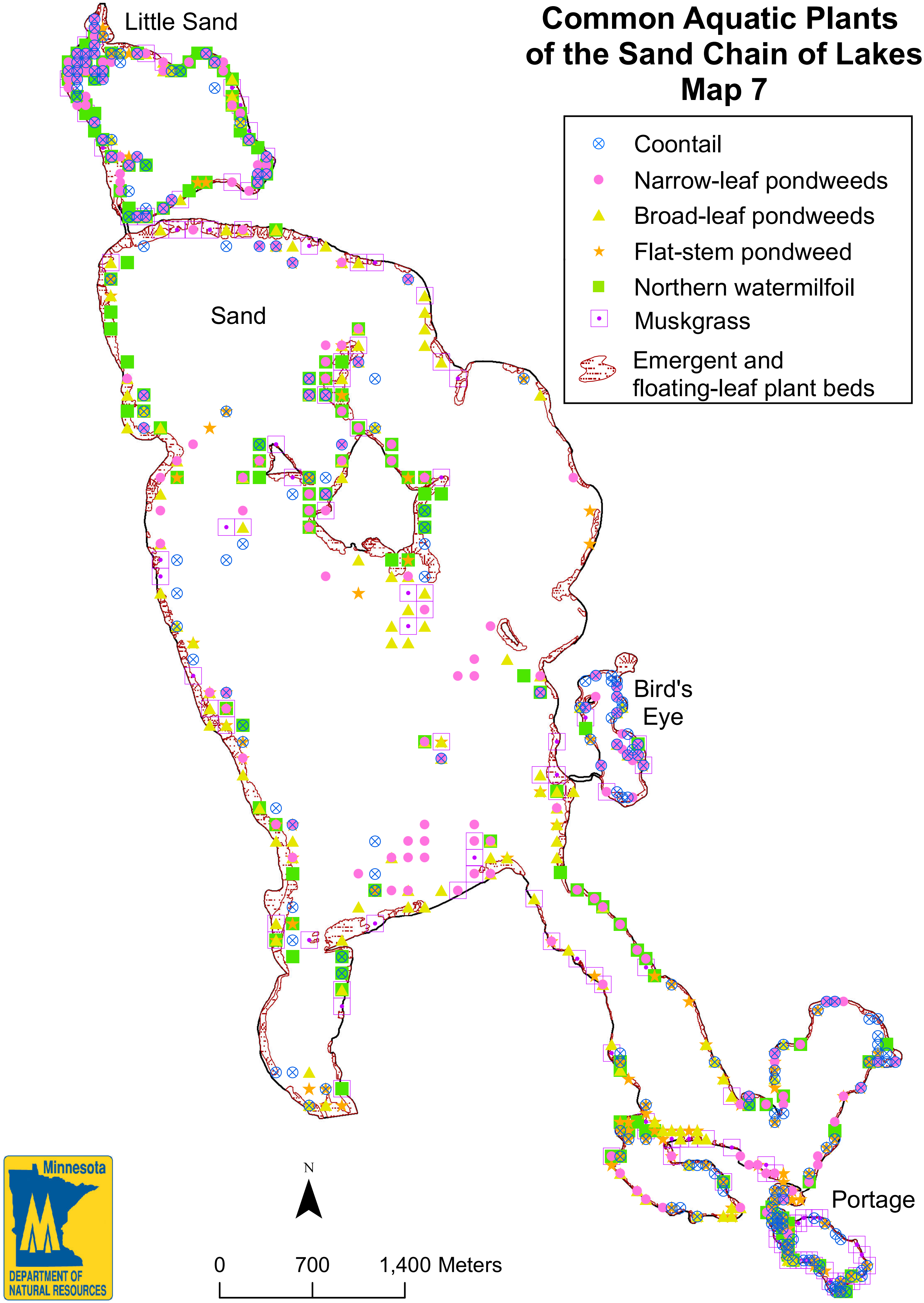


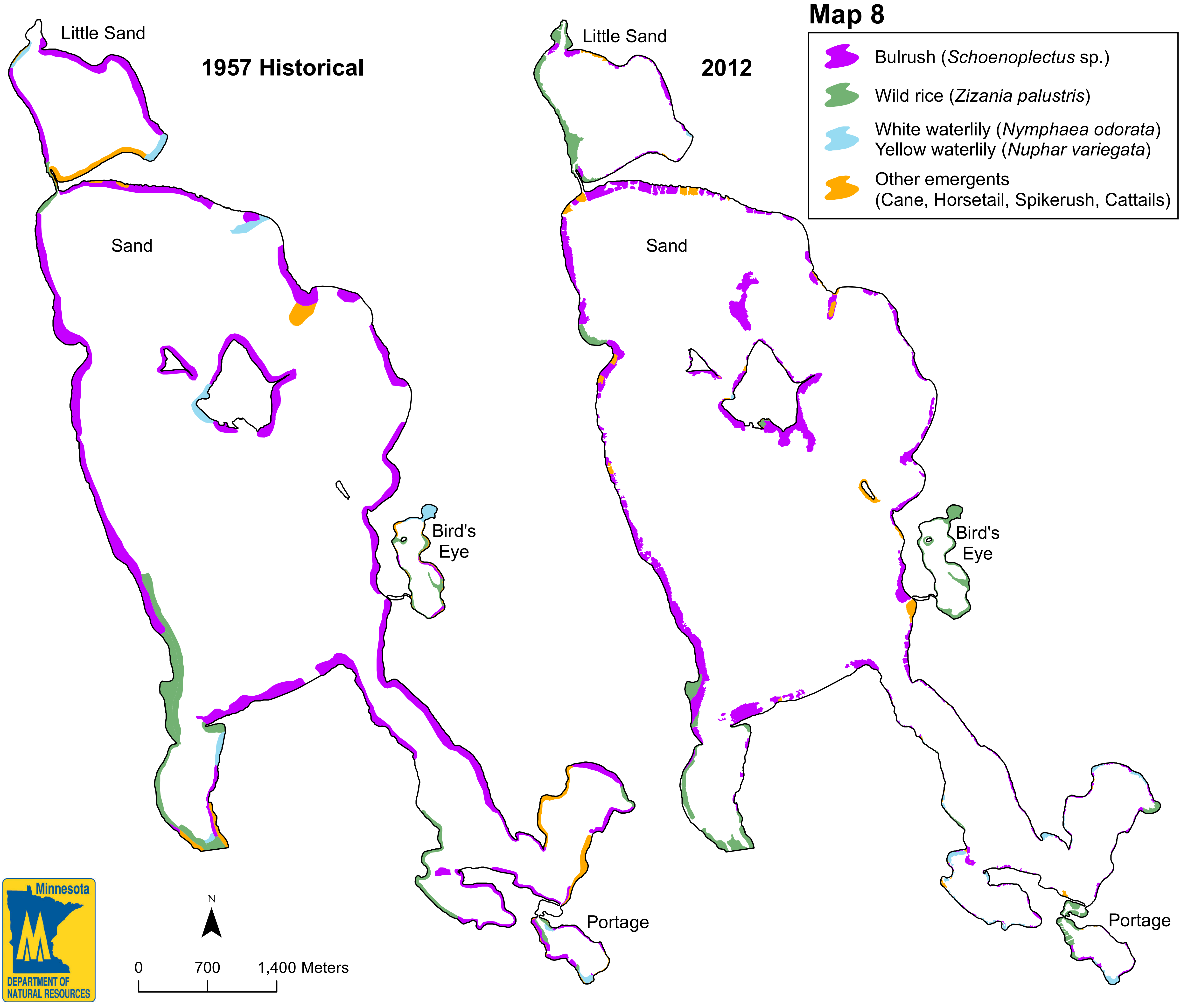

Map 5
Number of Species
1
2
3
4 - 5
6 - 10
20 foot depth contour line
Emergent and/or floating-leaf plant beds
Little Sand
Sand
Bird's Eye
Portage
N
0
700
1,400 Meters
Minnesota
DEPARTMENT OF NATURAL RESOURCES



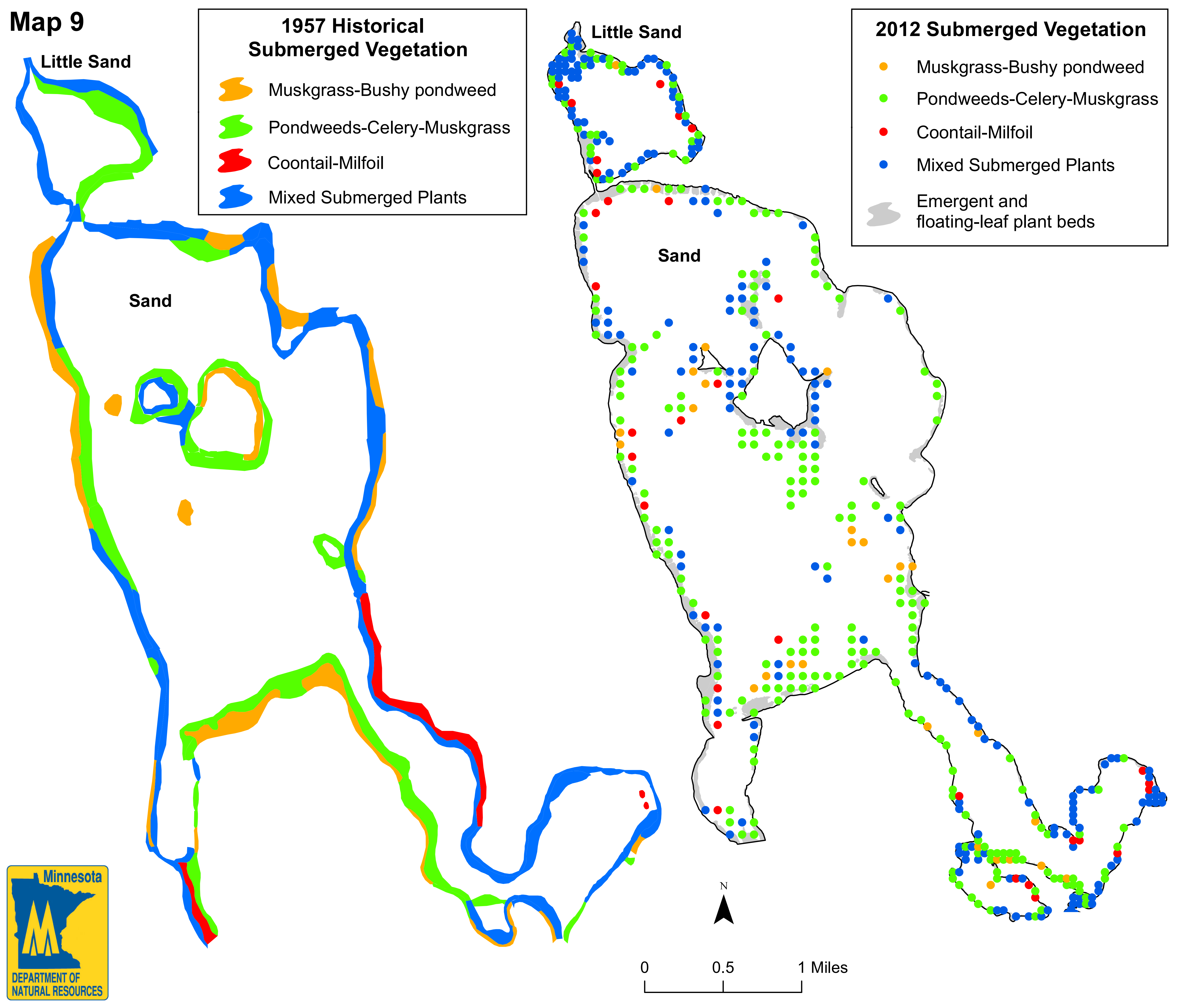
Map 6
Bulrush
Bulrush mix
Other species
Spikerush
Waterlilies
Wild rice
6 foot depth contour line
Little Sand
Sand
Bird's Eye
Portage
N
0
700
1,400 Meters
Minnesota
DEPARTMENT OF NATURAL RESOURCES

Common Aquatic Plants of the Sand Chain of Lakes
Map 7



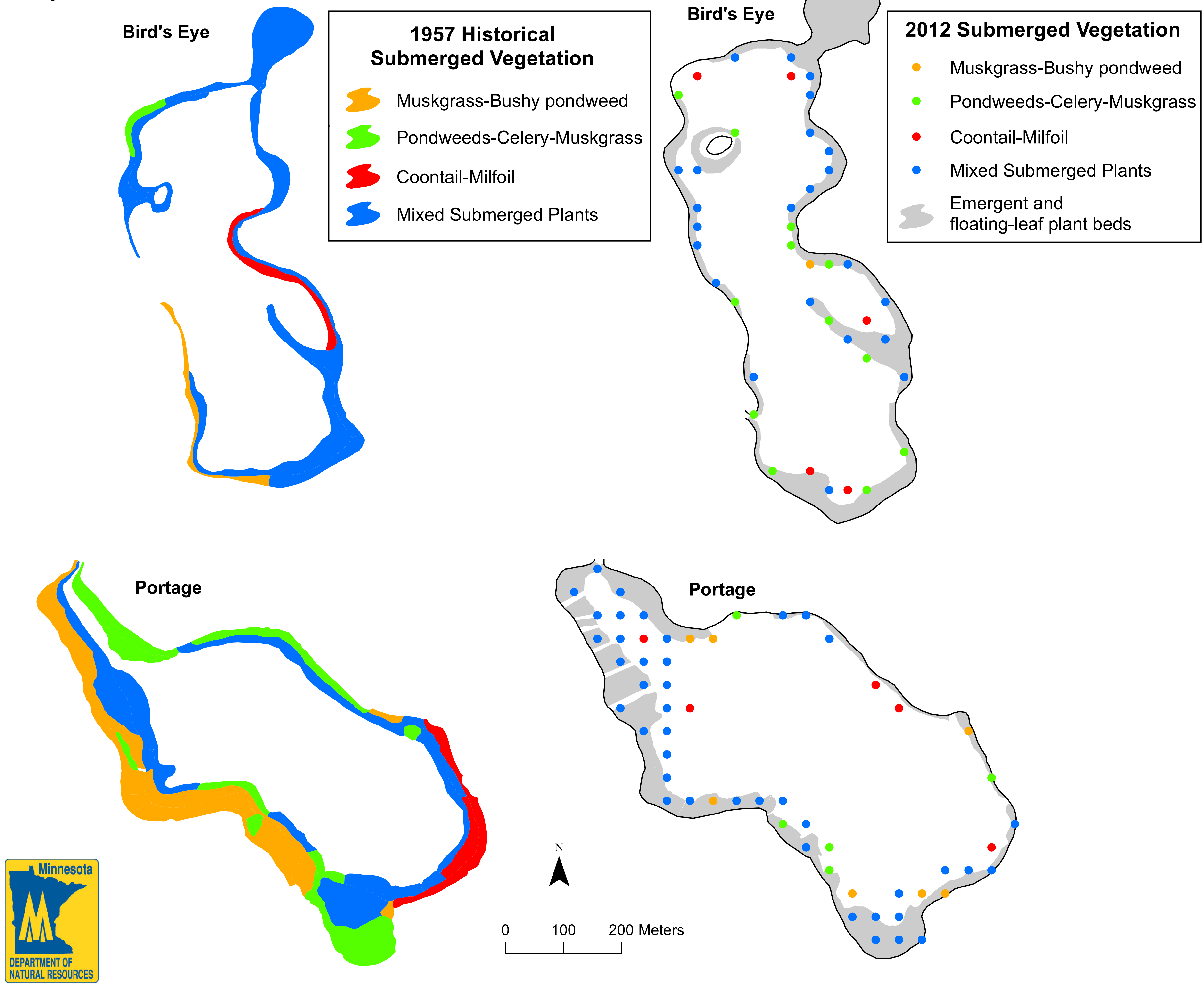


Map 8
1957 Historical
2012
Little Sand
Sand
Bird's Eye
Portage
Little Sand
Sand
Bird's Eye
Portage
Bulrush (*Schoenoplectus* sp.)
Wild rice (*Zizania palustris*)
White waterlily (*Nymphaea odorata*)
Yellow waterlily (*Nuphar variegata*)
Other emergents
(Cane, Horsetail, Spikerush, Cattails)
N
0
700
1,400 Meters
Minnesota
DEPARTMENT OF NATURAL RESOURCES



Map 9
Little Sand
Sand
1957 Historical Submerged Vegetation
Muskgrass-Bushy pondweed
Pondweeds-Celery-Muskgrass
Coontail-Milfoil
Mixed Submerged Plants
Little Sand
Sand
2012 Submerged Vegetation
Muskgrass-Bushy pondweed
Pondweeds-Celery-Muskgrass
Coontail-Milfoil
Mixed Submerged Plants
Emergent and floating-leaf plant beds
N
0
0.5
1 Miles
Minnesota
DEPARTMENT OF NATURAL RESOURCES

Map 10


Bird's Eye
1957 Historical Submerged Vegetation
Muskgrass-Bushy pondweed
Pondweeds-Celery-Muskgrass
Coontail-Milfoil
Mixed Submerged Plants
Bird's Eye
2012 Submerged Vegetation
Muskgrass-Bushy pondweed
Pondweeds-Celery-Muskgrass
Coontail-Milfoil
Mixed Submerged Plants
Emergent and floating-leaf plant beds
Portage
Portage
N
0
100
200 Meters
Minnesota
DEPARTMENT OF NATURAL RESOURCES