Half Moon Lake

2023 Eurasian Watermilfoil Management Results

Prepared for
Half Moon Lake Protection & Rehabilitation District

December 2023

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Abbreviations

AIS	Aquatic Invasive Species
APM	Aquatic Plant Management, LLC
ERS	Endangered Resource Services, LLC
EWM	Eurasian Watermilfoil
DASH	Diver Assisted Suction Harvesting
FQI	Floristic Quality Index
GPS	Global Positioning System
MNDNR	Minnesota Department of Natural Resources
PI	Point Intercept
Sub PI	Sub Point Intercept
WDNR	Wisconsin Department of Natural Resources

1 Executive Summary

Eurasian watermilfoil (EWM), an invasive plant not native to Wisconsin, was first observed at the Half Moon Lake boat landing on October 6th, 2021. A bed mapping survey of the EWM on October 30th, 2021 indicated it covered about 0.59 acres (0.24% of the plant inhabitable area) (ERS, 2021). The Half Moon Lake Protection and Rehabilitation District (District) with assistance from Barr Engineering Co., applied for and was awarded a Wisconsin Department of Natural Resources (WDNR) Rapid Response Grant to help fund EWM management efforts and preparation of an Aquatic Plant Management Plan (APM Plan). The District managed EWM during 2022 and 2023.

EWM rapidly expanded to an extent of 22 acres by June 2022. EWM removal in 2022 was fairly successful, but not all EWM was removed. Within the 22 acres managed for EWM in 2022, EWM was only visually observed at 1 sample location during fall bed-mapping surveys. However, spread of EWM to areas not managed in 2022 resulted in EWM beds with an extent of 1.0 acre and single EWM plants at two locations during fall 2022. EWM removal was not permitted by WDNR until late summer in 2022, hindering efforts to prevent the spread of EWM. No EWM removal occurred in the additional EWM areas resulting from this spread.

EWM removal in 2023 was unsuccessful. WDNR did not permit the use of ProcellaCOR to remove EWM from the lake in 2023. A Diver Assisted Suction Harvesting (DASH) permit was issued on June 21 for removal of the EWM documented by the fall 2022 plant surveys and EWM removal occurred on July 17-21, the earliest available DASH removal dates. Removal of EWM in mid-summer was challenging because the EWM was mixed with densely growing native plants in the southern and eastern areas of the lake where most of the DASH removal occurred. In addition, EWM was growing more densely in 2023 than 2022. EWM removal in 2022 averaged 19 cubic feet per acre compared with 46 cubic feet per acre in 2023. The challenges slowed DASH removal and made it difficult to effectively remove the EWM. Consequently, EWM removal only occurred in 7 of the 15 areas intended for DASH removal during the scheduled one week period. An August 2, 2023 bed-mapping survey found a continued presence of EWM in all 7 of the DASH removal areas. Although DASH removal of some EWM in 2023 resulted in a decline of EWM extent between June and August, rapid spread of EWM caused its extent to more than double between August and October 8. An August 24, 2023 plant survey documented a significant increase in EWM frequency in the lake between June 5 and August 24 despite DASH removal efforts.

Because DASH was ineffective in 2023, the District intends to use herbicide to remove the EWM from the lake in 2024. The District will collaborate with WDNR staff to select a treatment plan. The treatment plan will consist of a map that shows EWM herbicide treatment areas and the type of herbicide and dose applied to each treatment area. When the treated area is large enough to attain a lake-wide impact, the expected "whole lake" concentration will be shown on the treatment map. Potential treatment plans using 2,4-D and fluridone are presented in this report for consideration. The 2,4-D and fluridone treatment plans are consistent with the recommendations for EWM removal detailed in the Half Moon Lake Aquatic Plant Management Plan (Barr 2023).

Pre-treatment and post-treatment sub point intercept plant surveys were completed on June 5 and August 24, 2023 to assess the plant community within EWM managed areas. The data document several favorable changes to the plant community, including increases in the number of plant species, average number of native species per sites shallower than the maximum depth of plant growth, plant diversity as measured by the Simpson Diversity Index, the quality of the plant community as measured by the Floristic Quality Index (FQI), plant frequency, and plant density as measured by mean rake fullness. The increases are likely caused by seasonal changes in the plant community between June and August.

Significant frequency changes of native species before and after EWM removal from the managed areas were documented by a Chi Squared analysis of June 5 and August 24 data. Significant changes include increased frequency of 5 native species and a significant decrease for 1 native species.

A whole lake point intercept plant survey of Half Moon Lake was completed on July 1 to assess the lake's entire plant community. The survey results indicate the Half Moon Lake plant community was healthy and diverse.

Half Moon Lake aquatic plant data collected during July 16 through 17, 2007 by the WDNR and during June 21 through 23, 2018, July 1, 2022, and July 1, 2023 by the Half Moon Lake Protection and Rehabilitation District were compared to assess changes. Favorable changes in the 2023 plant community include increases in plant frequency, number of plant species, average number of native plant species per sample location, and FQI which indicates improved quality of the plant community.

While EWM is the Aquatic Invasive Species (AIS) of primary concern in Half Moon Lake for residents, three additional AIS were observed during 2023, curly-leaf pondweed (CLP), hybrid cattail, and reed canary grass.

CLP was found at two locations in 2022 and 2023 compared with 3 locations in 2007 and 6 locations in 2018. CLP currently seems to be a latent problem, but annually produces turions which are winter buds that act like seeds and can remain viable for several years. CLP may languish at a low level in Half Moon Lake until a favorable environmental circumstance happens that allows it to expand rapidly into a problematic condition. Removal of CLP from Half Moon Lake now will minimize the risk of rapid expansion to problematic conditions in the future. Herbicide treatment to remove the CLP from the lake is recommended.

Hybrid cattail was found at the same location in the northwestern corner of the lake during 2018, 2022, and 2023. Because it is only found at one location and has not spread, it is not considered problematic.

Reed canary grass was observed at one location in 2018 and 2023, but was not observed in 2007 and 2022. Because it has only been intermittently observed at one location, it is not considered problematic.

2 Introduction

Half Moon Lake, located in the Town of Milltown in Central Polk County, Wisconsin, is a 550-acre stratified drainage lake. It reaches a maximum depth of 60 feet in the deep hole on the southeast end of the central basin and has an average depth of 25 feet (WDNR 2022).

Eurasian watermilfoil (EWM) was first observed in Half Moon Lake at its boat landing on October 6th, 2021. A bed mapping survey of the EWM on October 30th, 2021 indicated it covered about 0.59 acres (0.24% of the plant inhabitable area). EWM extent from the October 30th survey is shown in Figure 1. The Half Moon Lake Protection and Rehabilitation District, with assistance from Barr Engineering Co., applied for and was awarded a WDNR Rapid Response Grant to help fund EWM management efforts. The District managed EWM during 2022 and 2023.

A June 8, 2022 sub point intercept (PI) plant survey and EWM bed-mapping survey documented 22.03 acres of EWM in Half Moon Lake (Figure 2 (Barr 2022). The plant surveyor commented, "Floating EWM fragments common throughout – plant appears to be spreading rapidly."

The Half Moon Lake Protection and Rehabilitation District contracted with Aquatic Plant Management, LLC (APM) to obtain WDNR permits and manage the EWM in the lake. After receiving WDNR permits on July 28, 2022, APM completed ProcellaCOR treatment of 13.7 acres of EWM on August 1, 2022 (Figure 3) and DASH removal of 158 cubic feet of EWM from 8.3 acres during August 8-12, 2022 (Figure 4) (Barr 2022).

The effectiveness of the ProcellaCOR and DASH EWM removal was documented by post-treatment plant surveys on September 18 and October 15, 2022. In fall 2022, EWM was visually observed at only 1 sample location within the 2022 EWM managed areas, but was present at 19 other locations within the lake (Figure 5). EWM removal was not permitted by WDNR until late summer in 2022, hindering the efforts to prevent the spread of EWM. No EWM removal occurred in the additional EWM areas resulting from this spread. The spread of EWM to areas not managed in 2022 resulted in EWM beds with an extent of 1.0 acre and single EWM plants at two locations during fall 2022 (Figure 5) (Barr 2022).

This report presents the results of 2023 Half Moon Lake EWM management efforts and plant surveys completed for the project.

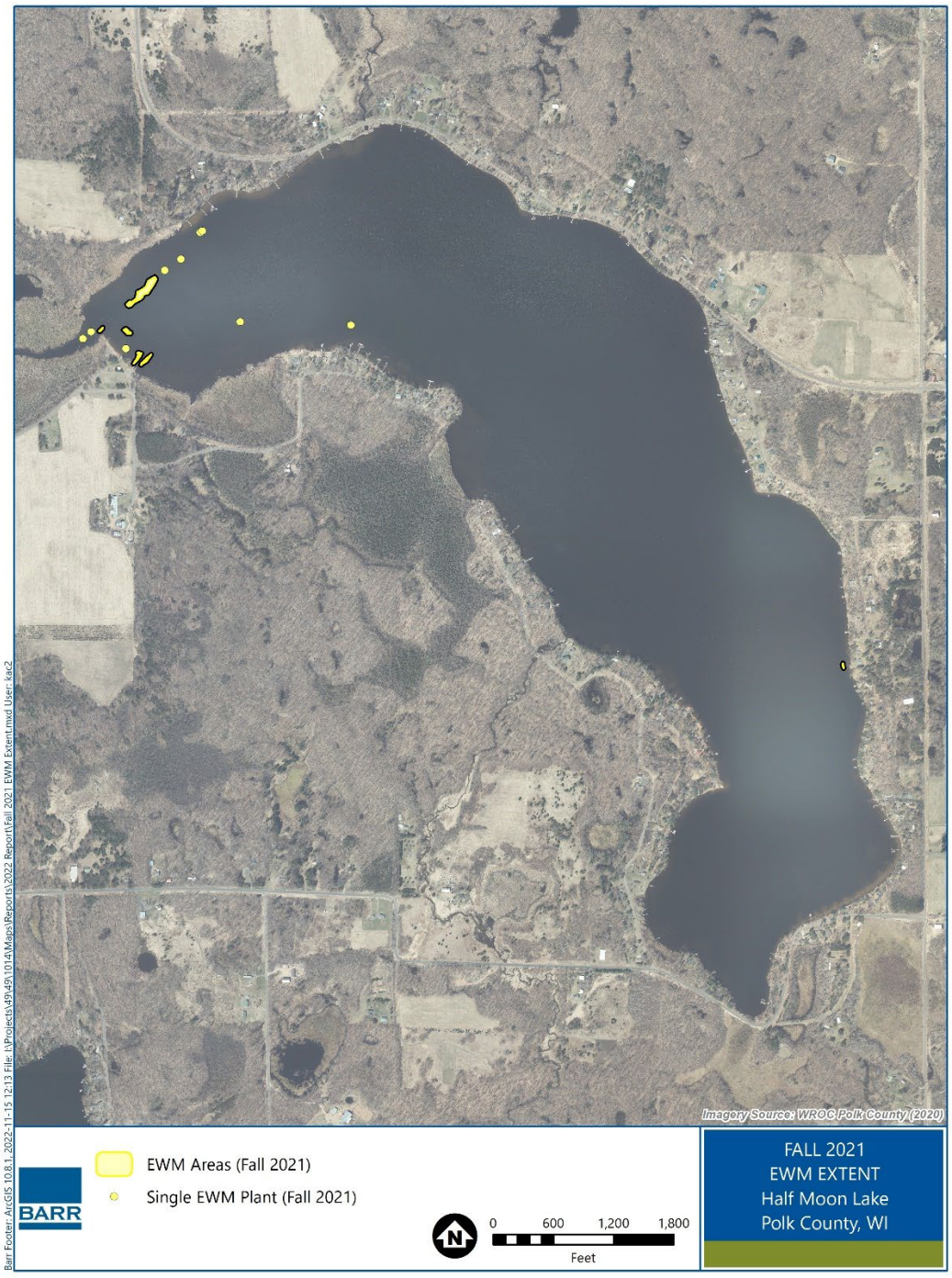

Figure 1 Fall 2021 EWM Extent in Half Moon Lake

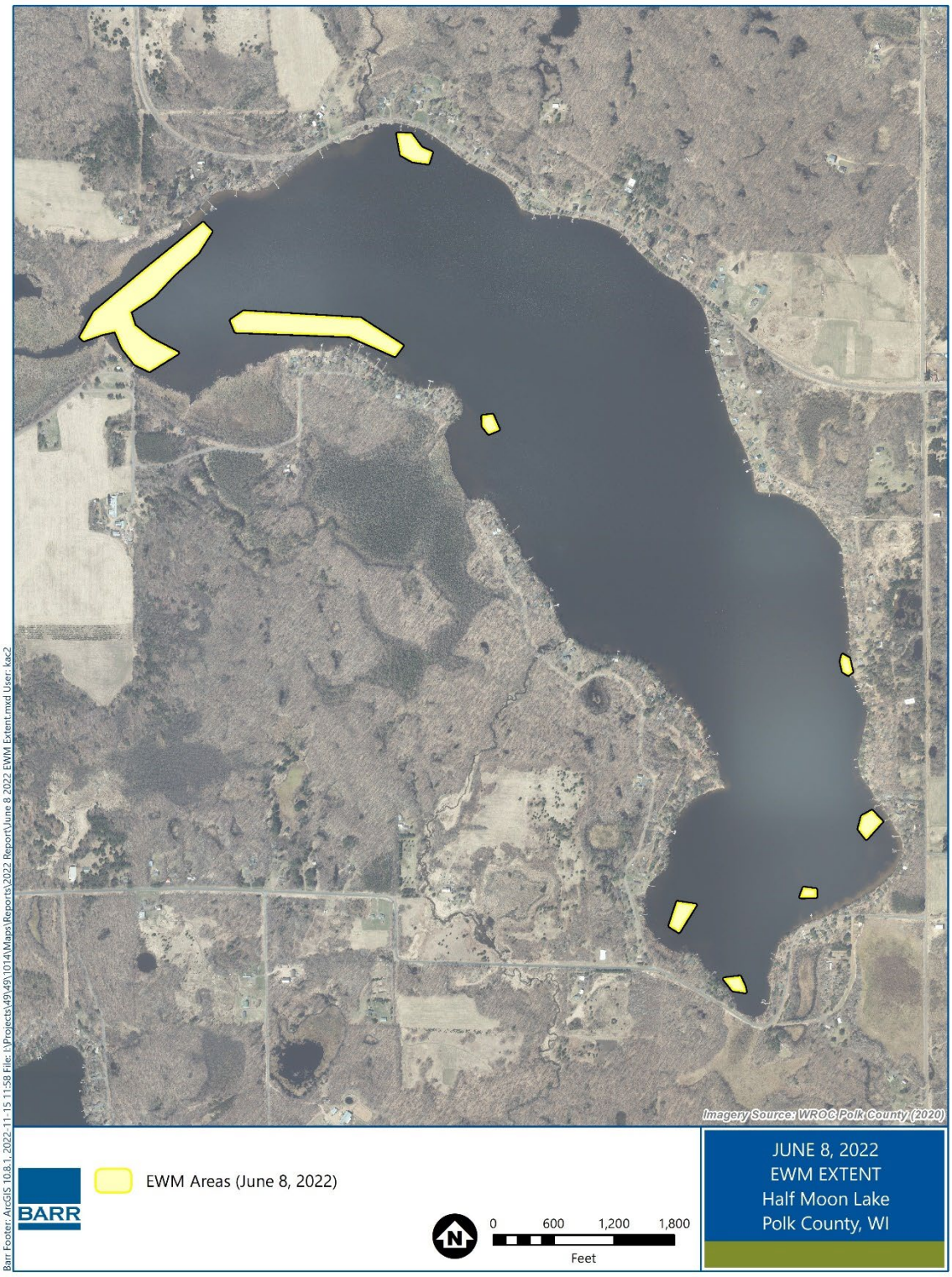

Figure 2 June 8, 2022 EWM Extent

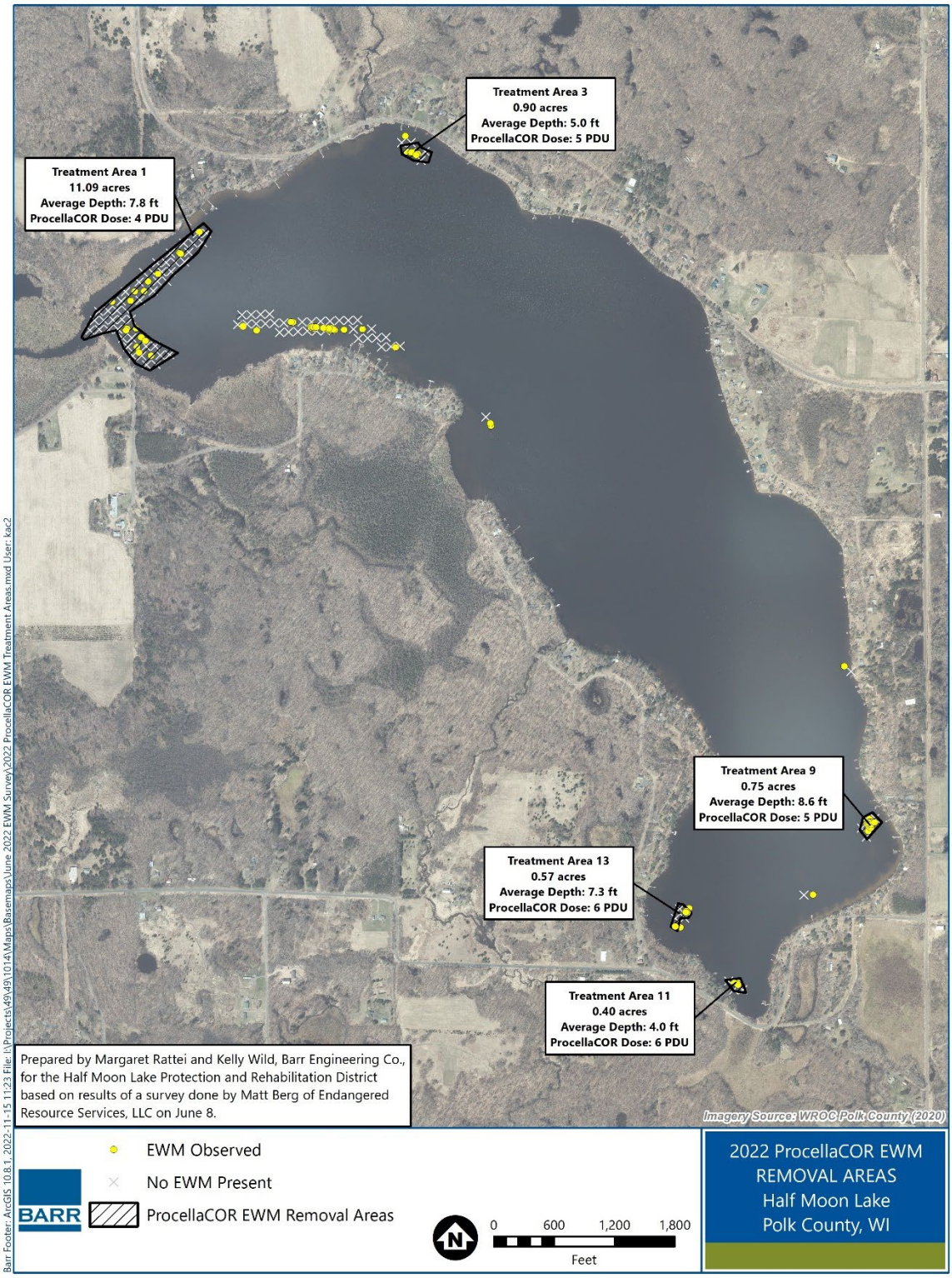

Figure 3 August 1, 2022 ProcellaCOR Treatment Areas in Half Moon Lake

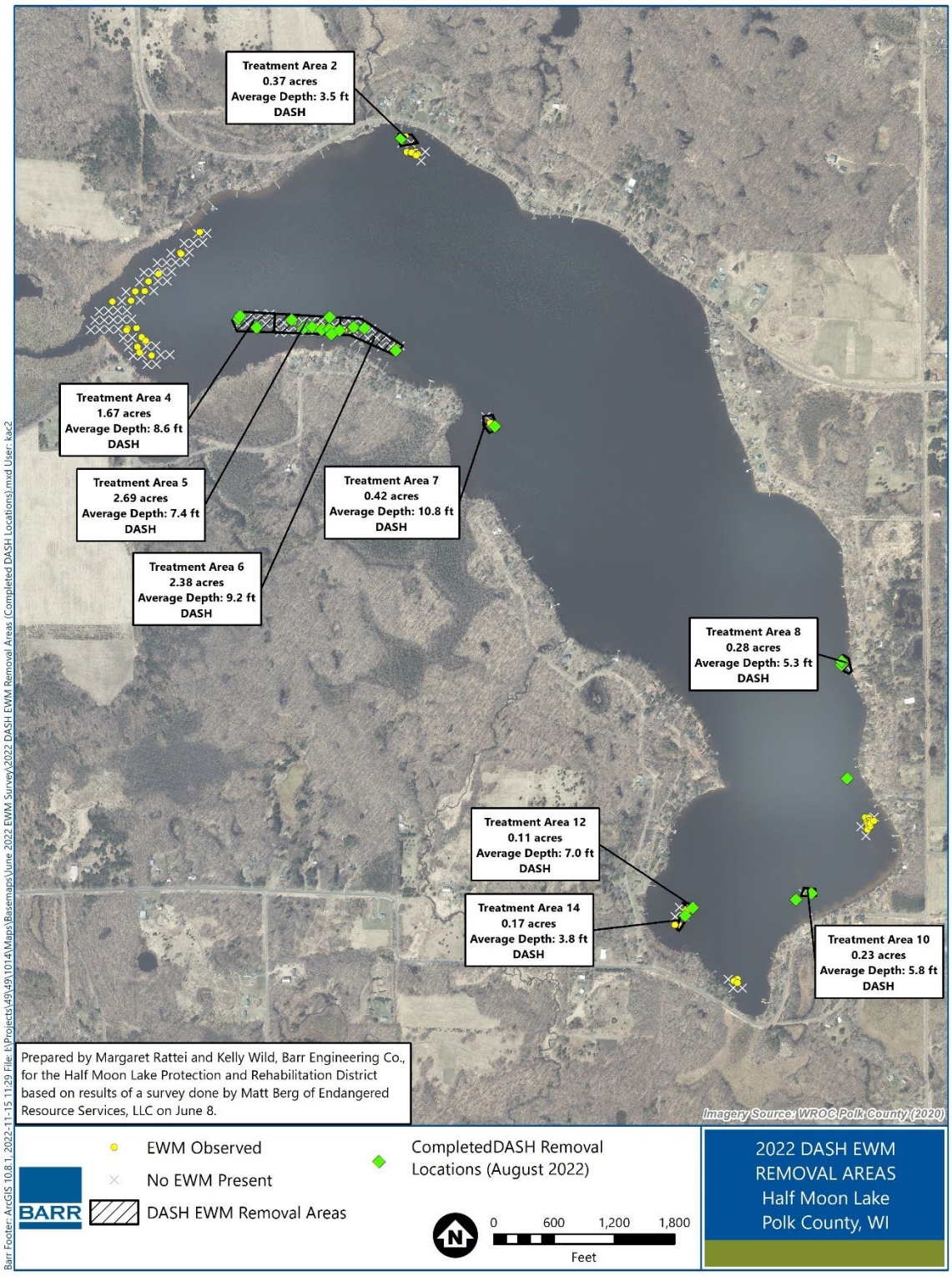

Figure 4 **August 8-12, 2022 DASH EWM Removal Areas in Half Moon Lake**

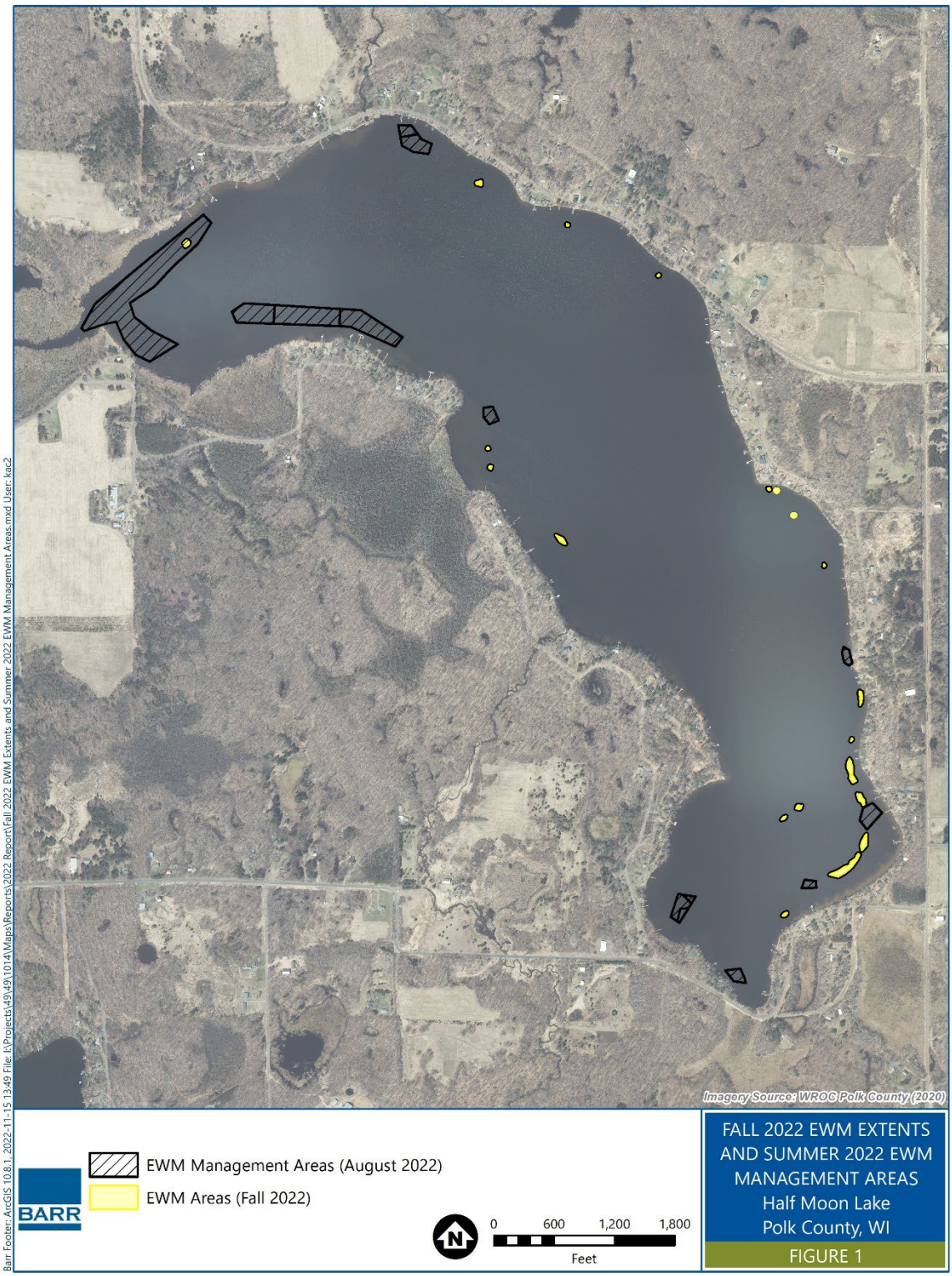

Figure 5 **Comparison of Fall 2022 EWM Extents with Summer 2022 EWM Management Areas**

3 2023 Plant Survey Methods

Multiple plant surveys were completed in 2023 to (1) determine EWM extent, (2) determine locations requiring EWM removal, (3) determine results of EWM removal efforts, (4) assess the plant community before and after EWM removal, (5) and determine locations requiring EWM removal in 2024. Pre-management plant surveys included a sub point intercept (sub PI) plant survey and EWM bed-mapping survey June 5 and a whole lake point intercept plant survey on July 1. The sub PI survey was a detailed survey of the areas in which EWM was documented during the fall of 2022. For the sub PI survey, a pre-determined equally spaced grid of 125 sample points was surveyed to document all plant species within the surveyed areas and their density. Post-management plant surveys include a bed-mapping survey on August 2, a sub PI plant survey and EWM bed-mapping survey on August 24, and a EWM bed-mapping survey on October 8. Plant survey methods are detailed in the following paragraphs.

3.1 2023 Pre-Management Plant Surveys on Half Moon Lake

3.1.1 June Sub Point Intercept (Sub PI) and Bed-Mapping Surveys

Endangered Resource Services (ERS), LLC, a subcontractor to Barr, completed a pre-treatment sub PI plant survey on June 5. For the survey, a total of 125 sample points were surveyed within the EWM beds and high density EWM areas identified in the fall 2022 plant survey (Figure 6). ERS located equally spaced preset points in the field with a global positioning system (GPS) and took measurements at each point. The measurements included the following:

1. Individual species present
2. The overall density of plants, as measured by the rake method
3. The density of individual species, as measured by the rake method
4. Water depth
5. Dominant sediment type

ERS also completed a EWM bed-mapping survey of Half Moon Lake in areas not included in the sub PI survey. ERS used transects to locate EWM, including beds, high density areas, multiple EWM plants that are not considered beds or high-density areas, and single EWM plants.

Following the pre-management plant surveys, ERS summarized the survey data in tabular format and prepared a map showing the EWM areas and locations of single EWM plants which were rake removed during the survey (Figure 7Figure 7).

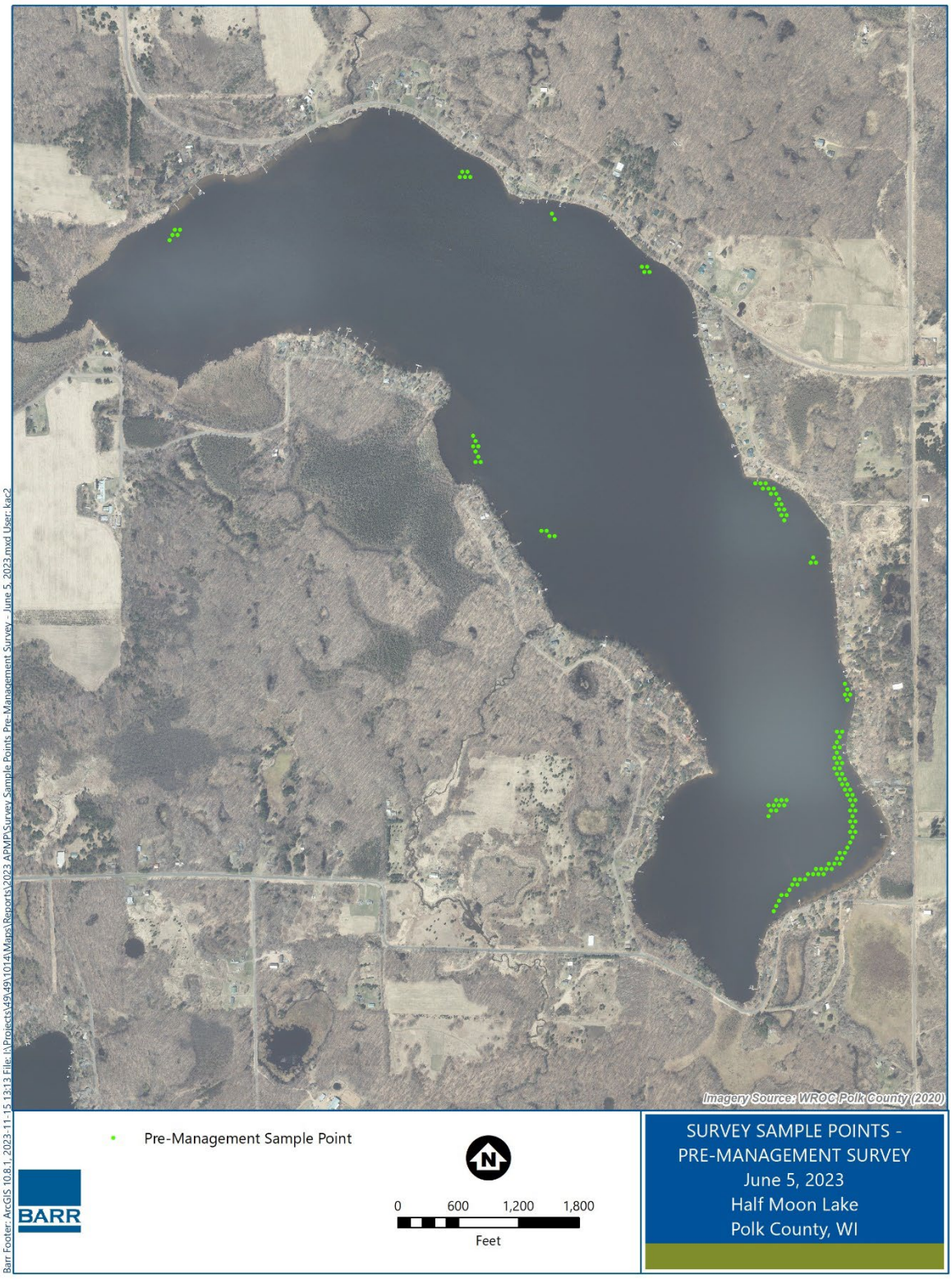

Figure 6 Sample Points for June 5, 2023 Sub PI Plant Survey

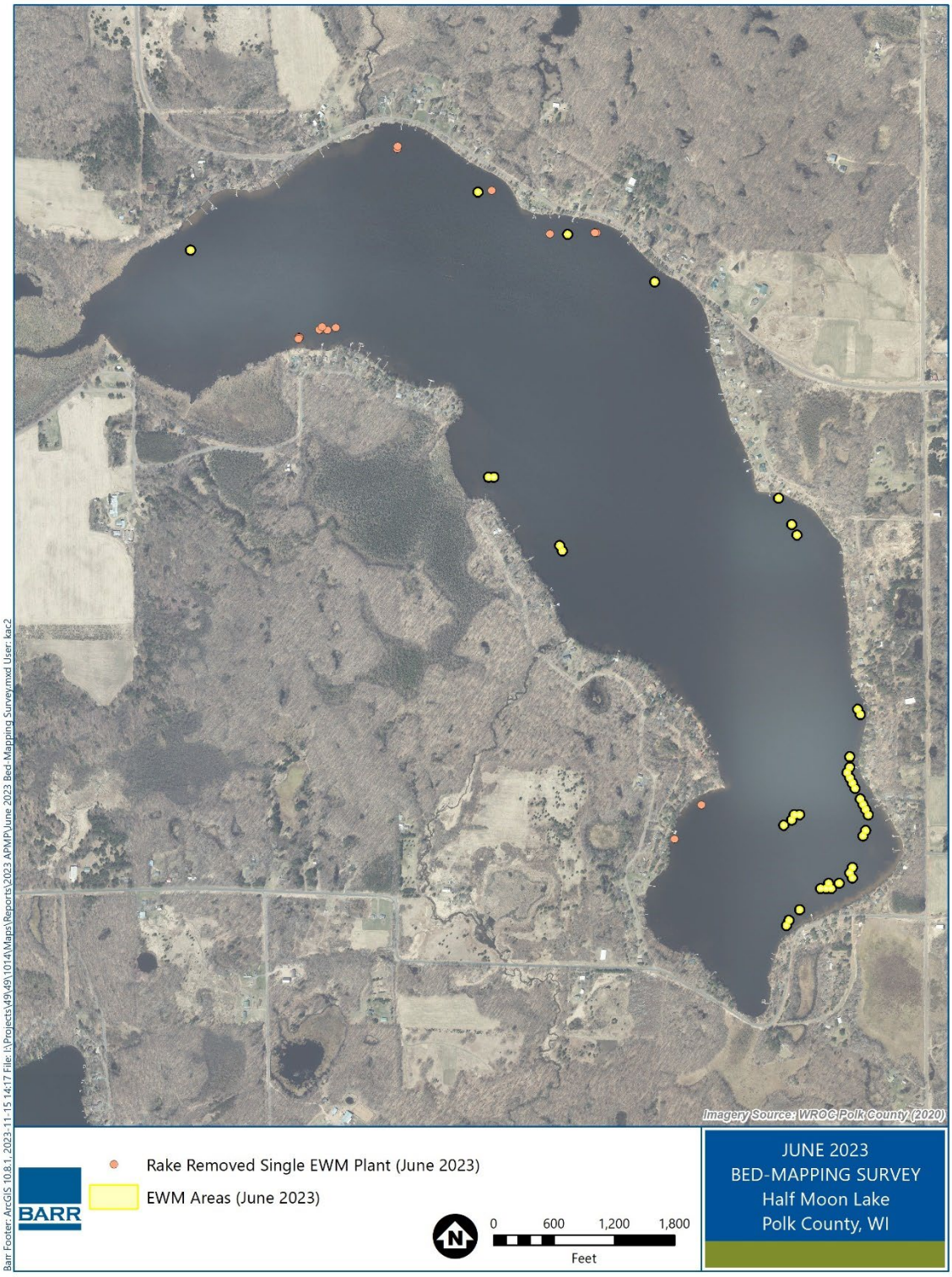

Figure 7 June 5, 2023 Bed-Mapping Survey

3.1.2 July 1 Whole Lake Aquatic Plant Survey

ERS performed a whole lake pre-management plant survey on July 1 to assess the distribution and growth density of all plants in the lake including EWM. ERS conducted the plant survey according to the methodologies used in the 2018 and 2022 Point Intercept (PI) plant surveys of Half Moon Lake and incorporated assessments at the same 734 GPS points surveyed in 2018 and 2022 surveys and shown in Figure 9. ERS located the equally spaced preset points in the field with a Global Positioning System (GPS) and took measurements at each point.

A rake was used to collect plant samples at each sample location and the overall quantity of plants on the rake was determined to evaluate plant density. Next, the individual species collected on the rake were identified. After identification of each species, the quantity of each individual species was determined to evaluate the plant density of each species at each sample location. Rake fullness was used to determine the overall quantity (density) of plants and the quantity (density) of individual species at each sample location. Rake fullness is measured on a scale of 1 to 3 (Figure 8) where:

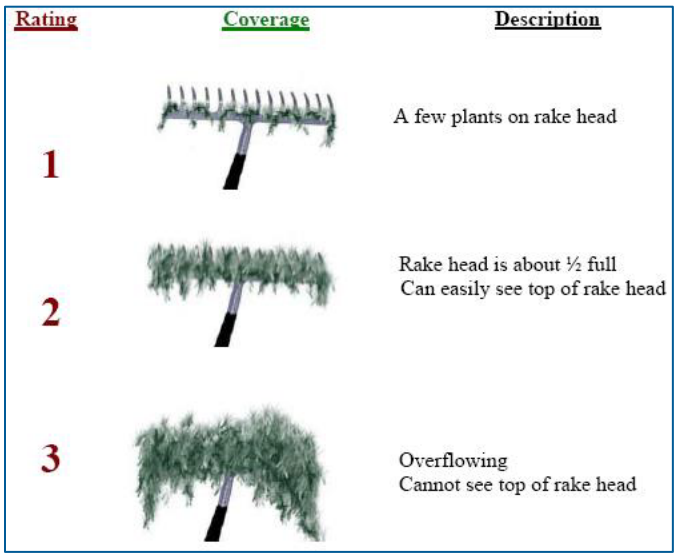

Figure 8 Rake fullness rating, rake coverage, and description of rake fullness rating (Source: Endangered Resource Services, LLC, 2021)

Water depth and dominant sediment type were determined and documented for each sample location.

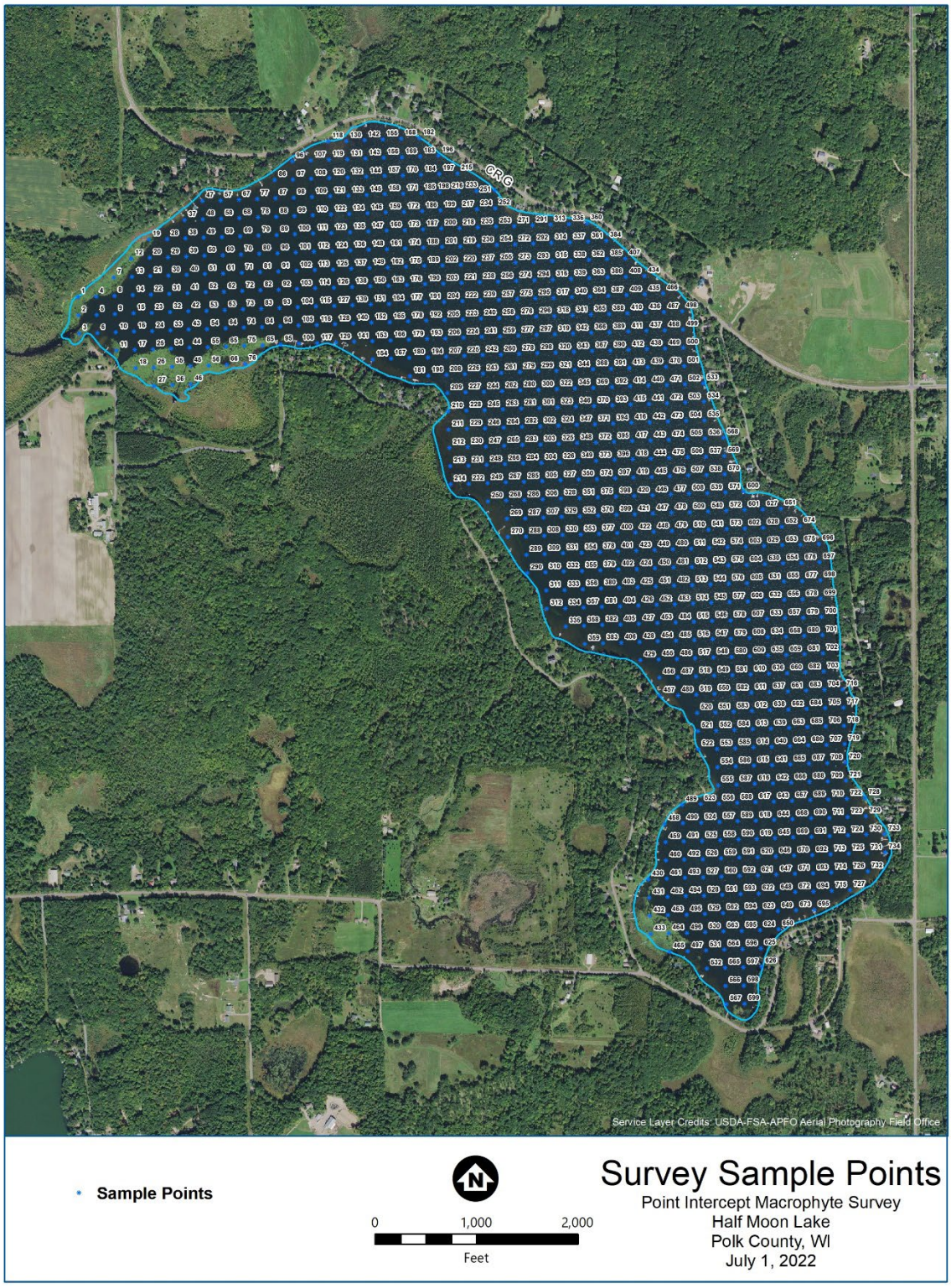

Figure 9 **Sample Points for July 1, 2023 Point Intercept Plant Survey**

3.2 2023 Post-Management Plant Surveys on Half Moon Lake

3.2.1 August Bed-Mapping Survey

ERS completed a EWM bed-mapping survey of Half Moon Lake on August 2. ERS used transects to locate EWM, including beds, high density areas, multiple EWM plants that are not considered beds or high-density areas, and single EWM plants.

ERS prepared a map showing the EWM areas and locations of single EWM plants which were rake removed during the survey (Figure 10).

3.2.2 August Sub Point Intercept (Sub PI) Survey

ERS completed a post-management sub PI plant survey on August 24. For the survey, a total of 125 sample points were surveyed within the EWM beds and high density EWM areas identified in the fall 2022 plant survey (Figure 11). The sample points surveyed for the August sub PI survey were the same points surveyed for the June 5 sub PI survey. ERS located equally spaced preset points in the field with a global positioning system (GPS) and took measurements at each point. The measurements included the following:

1. Individual species present
2. The overall density of plants, as measured by the rake method
3. The density of individual species, as measured by the rake method
4. Water depth
5. Dominant sediment type

Following the post-management sub PI plant survey, ERS summarized the survey data in tabular format.

3.2.3 October Bed-Mapping Survey

ERS completed a EWM bed-mapping survey of Half Moon Lake on October 8, 2023. ERS used transects to locate EWM, including beds, high density areas, multiple EWM plants that are not considered beds or high-density areas, and single EWM plants.

Following the October bed-mapping survey, ERS prepared a map showing the EWM areas and locations of single EWM plants (Figure 12).

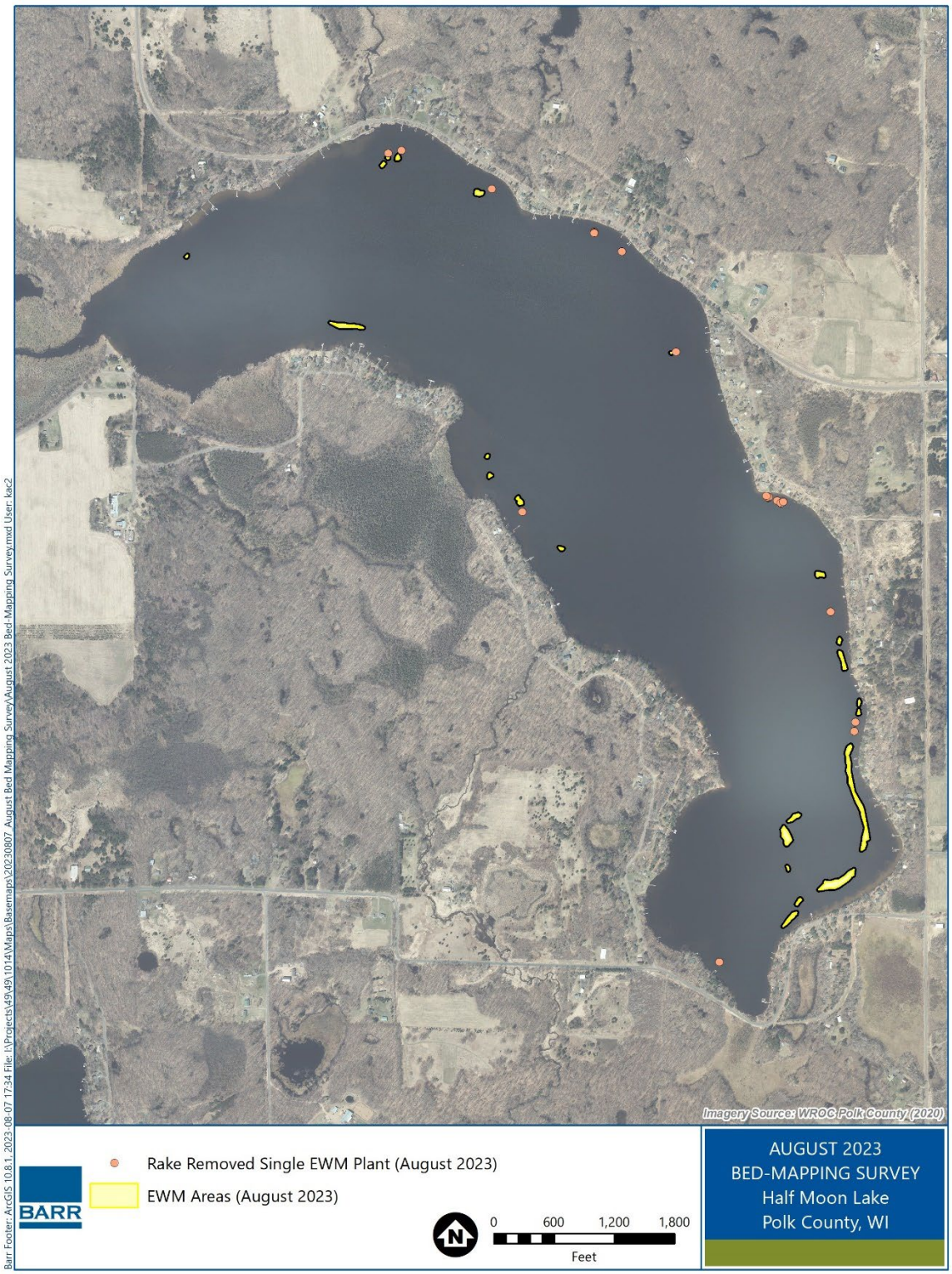

Figure 10 August 2, 2023 Bed-Mapping Survey

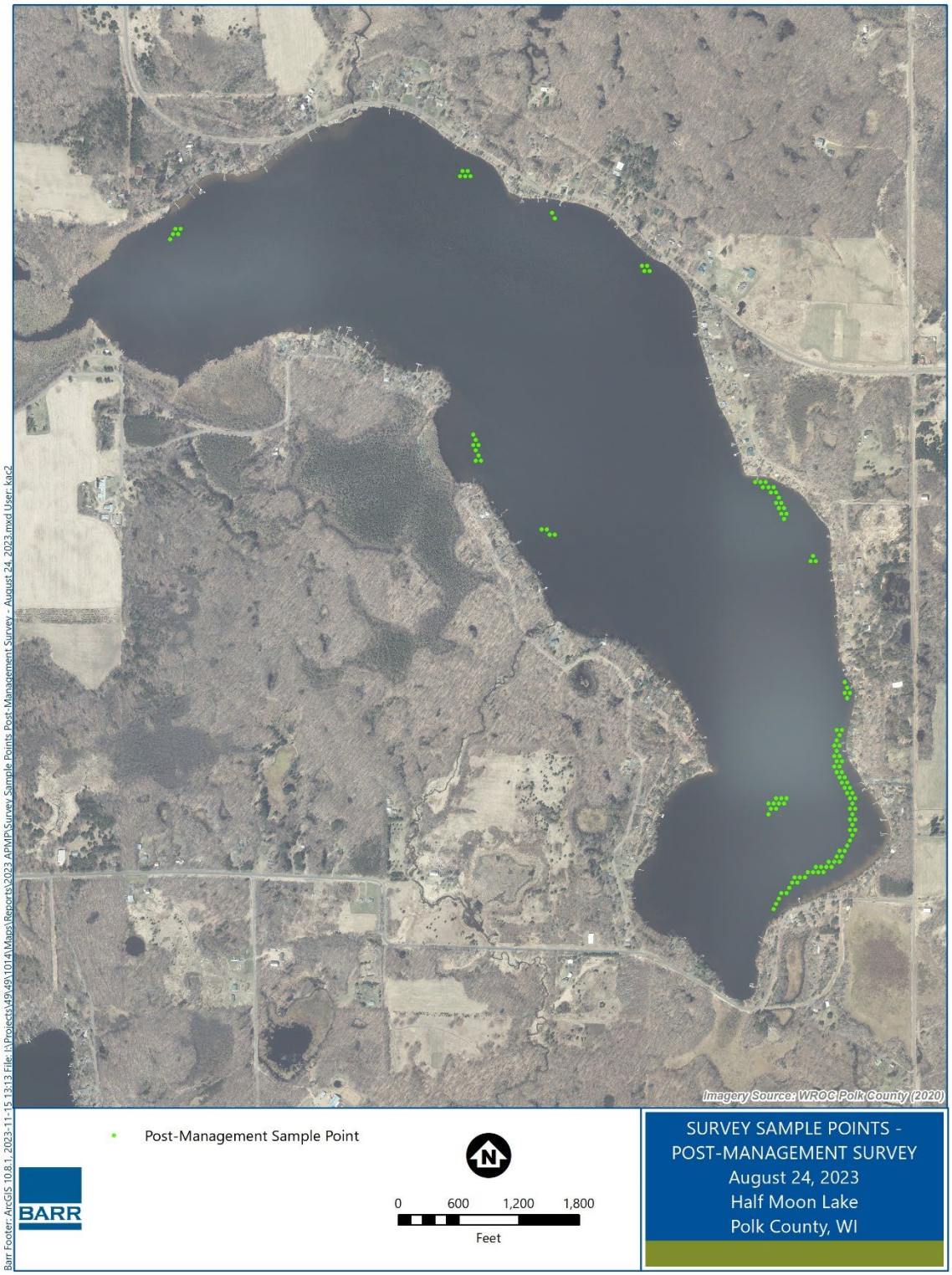

Figure 11 Sample Points for August 24, 2023 Sub PI Plant Survey

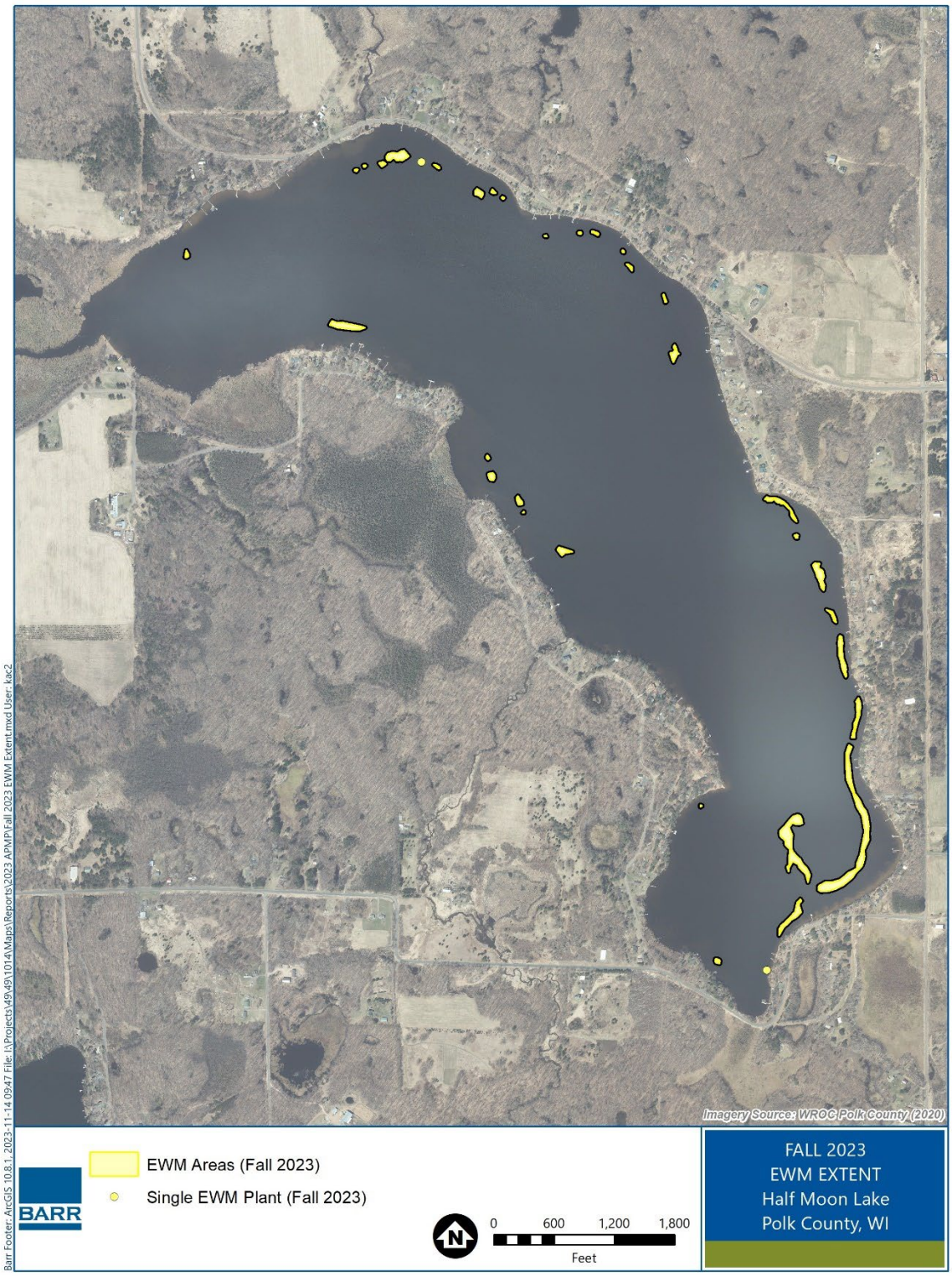

Figure 12 October 8, 2023 Bed-Mapping Survey

4 EWM Extents and EWM Management

4.1 June 5 EWM Extent and 2023 EWM Management

The June 5 sub PI plant survey and EWM bed-mapping survey documented 2.6 acres of EWM in Half Moon Lake (Figure 7). EWM more than doubled between fall 2022 (1.0 acres) and June 5, 2023 (2.6 acres).

The Half Moon Lake Protection and Rehabilitation District contracted with Aquatic Plant Management, LLC (APM) to obtain a WDNR permit to manage the EWM in the lake. The Half Moon Lake Protection and Rehabilitation District preferred a permit to treat the EWM with ProcellaCOR, the herbicide used to treat EWM in Half Moon Lake during 2022. WDNR did not permit the use of ProcellaCOR to remove EWM from the lake in 2023, but issued a permit on June 21 to remove EWM using DASH.

EWM removal occurred on July 17-21, the earliest available DASH removal dates when the permit was issued. Removal of EWM in mid-summer was challenging because the EWM was mixed with densely growing native plants in the southern and eastern areas of the lake where most of the DASH removal occurred. In addition, EWM was growing more densely in 2023 than 2022. EWM removal in 2022 averaged 19 cubic feet per acre compared with 46 cubic feet per acre in 2023. The challenges slowed DASH removal and made it difficult to effectively remove the EWM. Consequently, EWM removal only occurred in 7 of the 15 areas intended for DASH removal during the scheduled one week period (Figure 13).

4.2 August 2 EWM Extent

An August 2, 2023 bed-mapping survey found a continued presence of EWM in all 7 of the DASH removal areas (Areas 1-2 and 11-15 on Figure 13). The EWM extent on August 2, 2023 (1.9 acres) (Figure 10) was less than the EWM extent on June 5, 2023 (2.6 acres) (Figure 7), but nearly double the EWM extent in fall of 2022 (1.0 acre) (Figure 5). Because DASH removal was ineffective, no further DASH removal occurred in 2023.

4.3 October 8 EWM Extent

An October 8, 2023 EWM bed-mapping survey documented an EWM extent of 5.8 acres (Figure 12) which was more than double the August 2, 2023 EWM extent of 1.9 acres (Figure 10) and nearly 6 times greater than the fall 2022 EWM extent of 1 acre (Figure 14).

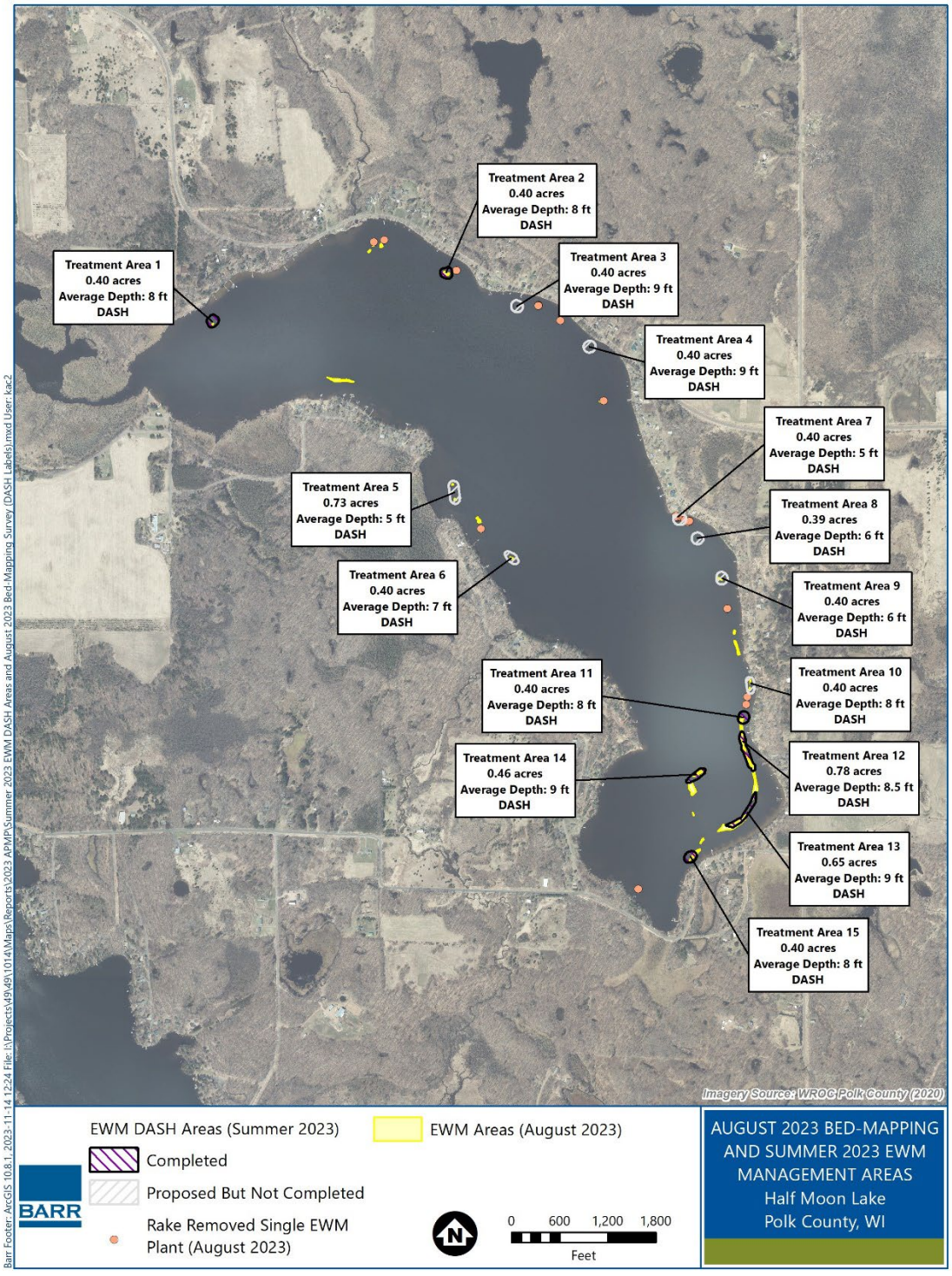

Figure 13 **Comparison of August 2, 2023 EWM Extent with Summer 2023 DASH Removal Areas**

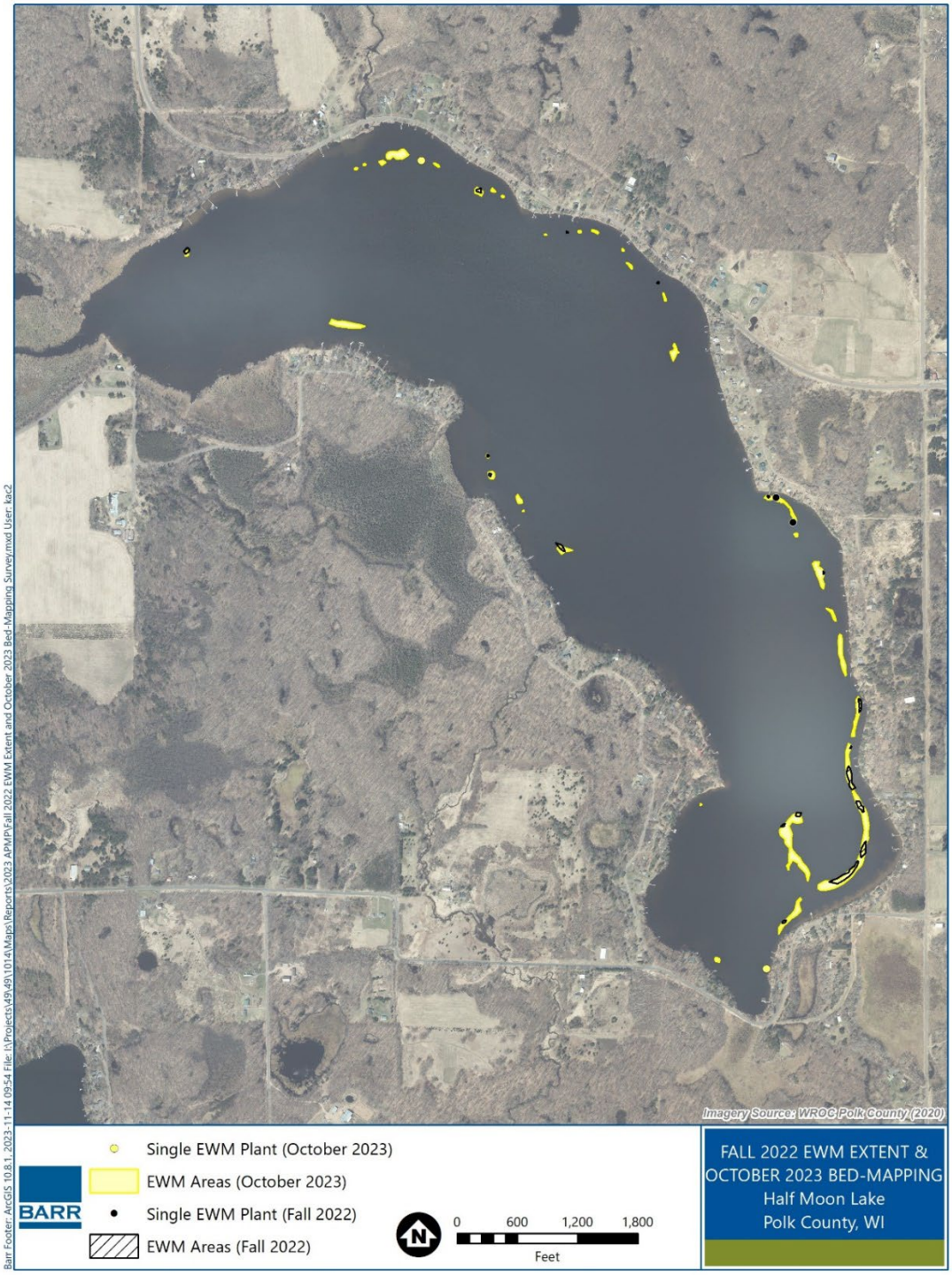

Figure 14 Comparison of October 8, 2023 EWM Extent with Fall 2022 EWM Extent

4.4 Fall EWM Extent and Proposed 2024 EWM Management.

A post-management bed-mapping survey on October 8, 2023 documented 5.8 acres of EWM. Because DASH was ineffective in 2023, the District intends to use herbicide to remove the EWM from the lake in 2024. The District will collaborate with WDNR staff to select a treatment plan. The treatment plan will consist of a map that shows EWM herbicide treatment areas and the type of herbicide and dose applied to each treatment area. When the treated area is large enough to attain a lake-wide impact, the expected "whole lake" concentration will be shown on the treatment map. Two potential treatment plans are presented in Figure 15 and Figure 16 and discussed below. The treatment plans are consistent with the recommendations for EWM removal detailed in the Half Moon Lake Aquatic Plant Management Plan (Barr 2023).

4.4.1 2,4-D Treatment

The herbicide 2,4-D, could be used to remove the EWM from Half Moon Lake. If this treatment option is selected, treatment of 207 acres of the littoral area could occur in spring of 2024 (Figure 15). A herbicide dose of 1.6 ppm is recommended to attain a whole lake concentration of 0.5 ppm. The 2,4-D treatment would be completed in a single day. Herbicide treatment is intended to occur when the average water column temperature is 60 degrees Fahrenheit or less. It is expected that the average water column temperature would be at least 55 degrees Fahrenheit and the thermocline would be 20 feet or less at the time of treatment. To determine the thermocline depth and to guide treatment timing, water temperature measurements in Half Moon Lake could be taken by a lake resident on Mondays, Wednesdays, and Fridays beginning 2 weeks after ice out and continuing up to and including the day of treatment. The lake resident could measure temperatures at 1-meter intervals from the surface to bottom of Half Moon Lake at the location shown in Figure 16.

Herbicide residue monitoring would be required for large scale treatment of Half Moon Lake. If a large-scale 2,4-D treatment is selected for 2024, 2,4-D herbicide residue monitoring would occur in three representative locations in Half Moon Lake (Figure 17) to determine whether the target dose was attained as well as the rate of herbicide decline due to dilution, mixing, and natural degradation. Samples would be collected at mid-depth from all locations during the monitoring period. Specific sample collection times for the treatment areas are shown in Table 1. It should be noted that (1) if the sample collection time for 1 and 4 hours after treatment occurs after dark, the sample would not be collected; and (2) if weather conditions make sample collection unsafe during any of the scheduled sample collection times, samples would not be collected. Samples would be analyzed by the Wisconsin State Laboratory of Hygiene.

Table 1 2024 2,4-D Residue Monitoring Plan for Half Moon Lake

Lake	Sample Site ID	Sample Collection Time (Hours After Treatment)	Sample Collection Time (Days After Treatment)
Half Moon Lake	2	1 and 4	1, 2, 3, 5, 7, 12, 19, and 26
Half Moon Lake	Center	1 and 4	1, 2, 3, 5, 7, 12, 19, and 26
Half Moon Lake	5	1 and 4	1, 2, 3, 5, 7, 12, 19, and 26

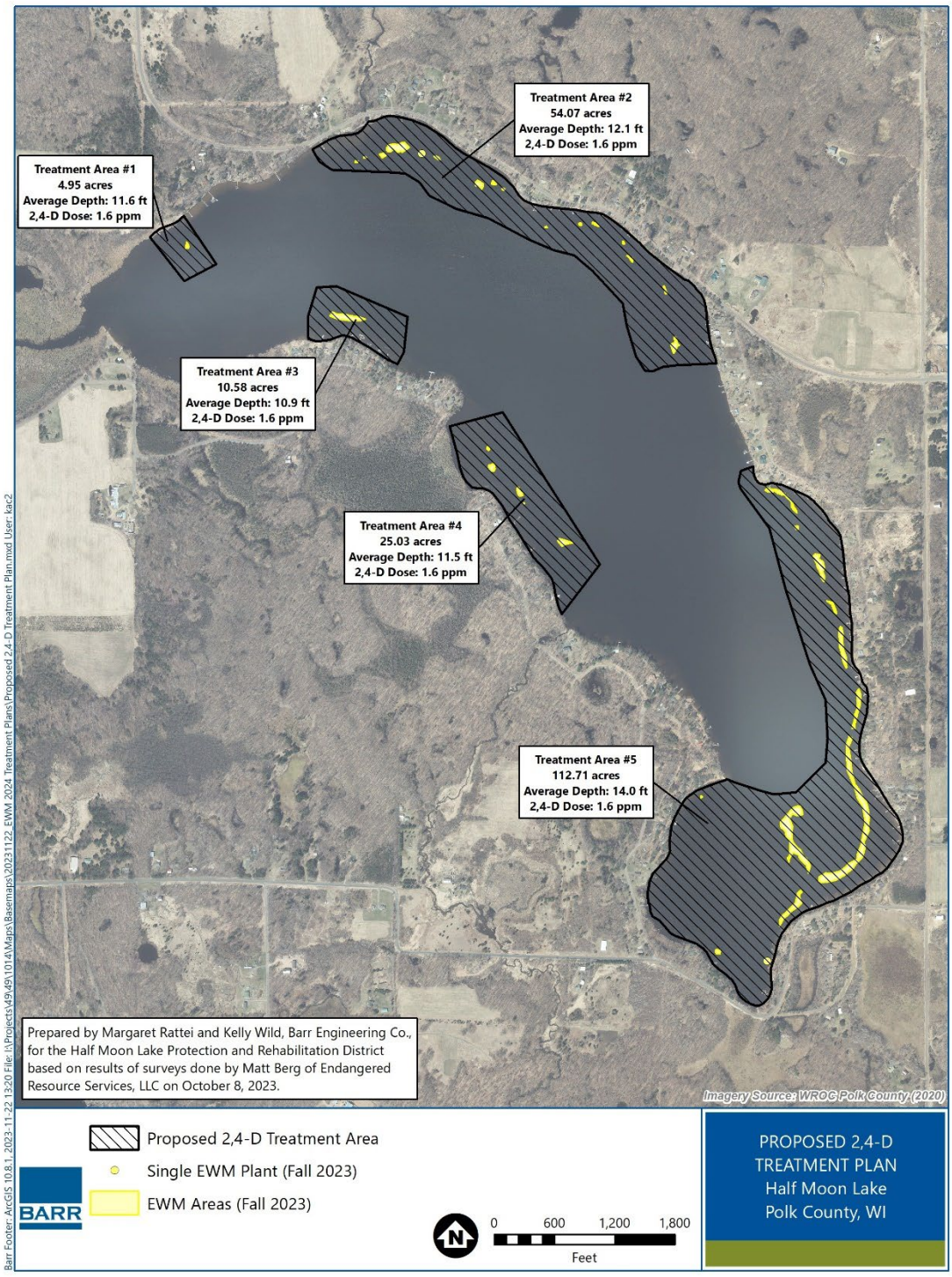

Figure 15 Proposed Half Moon Lake 2,4-D Treatment Plan

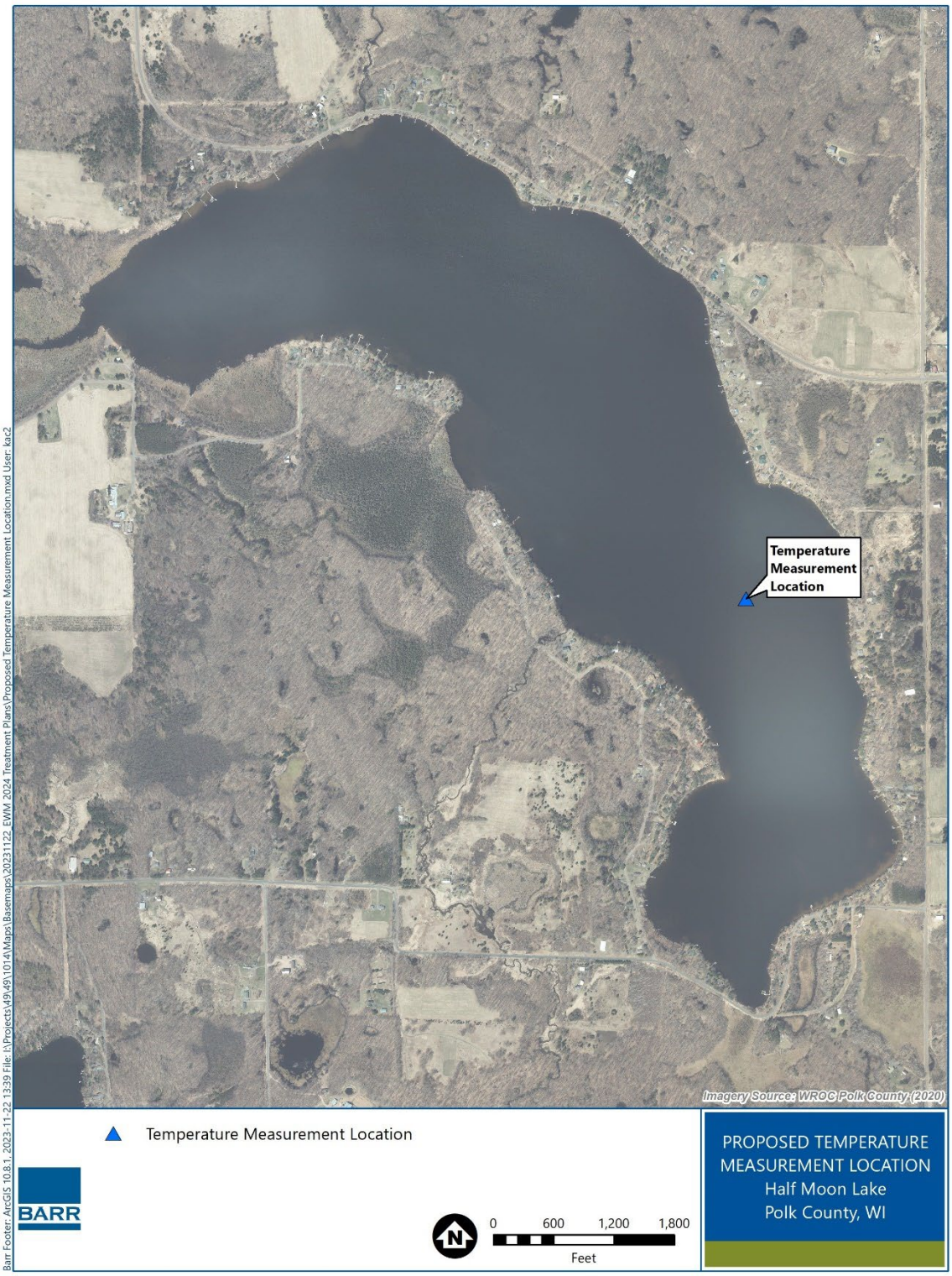

Figure 16 Proposed Half Moon Lake Temperature Measurement Location

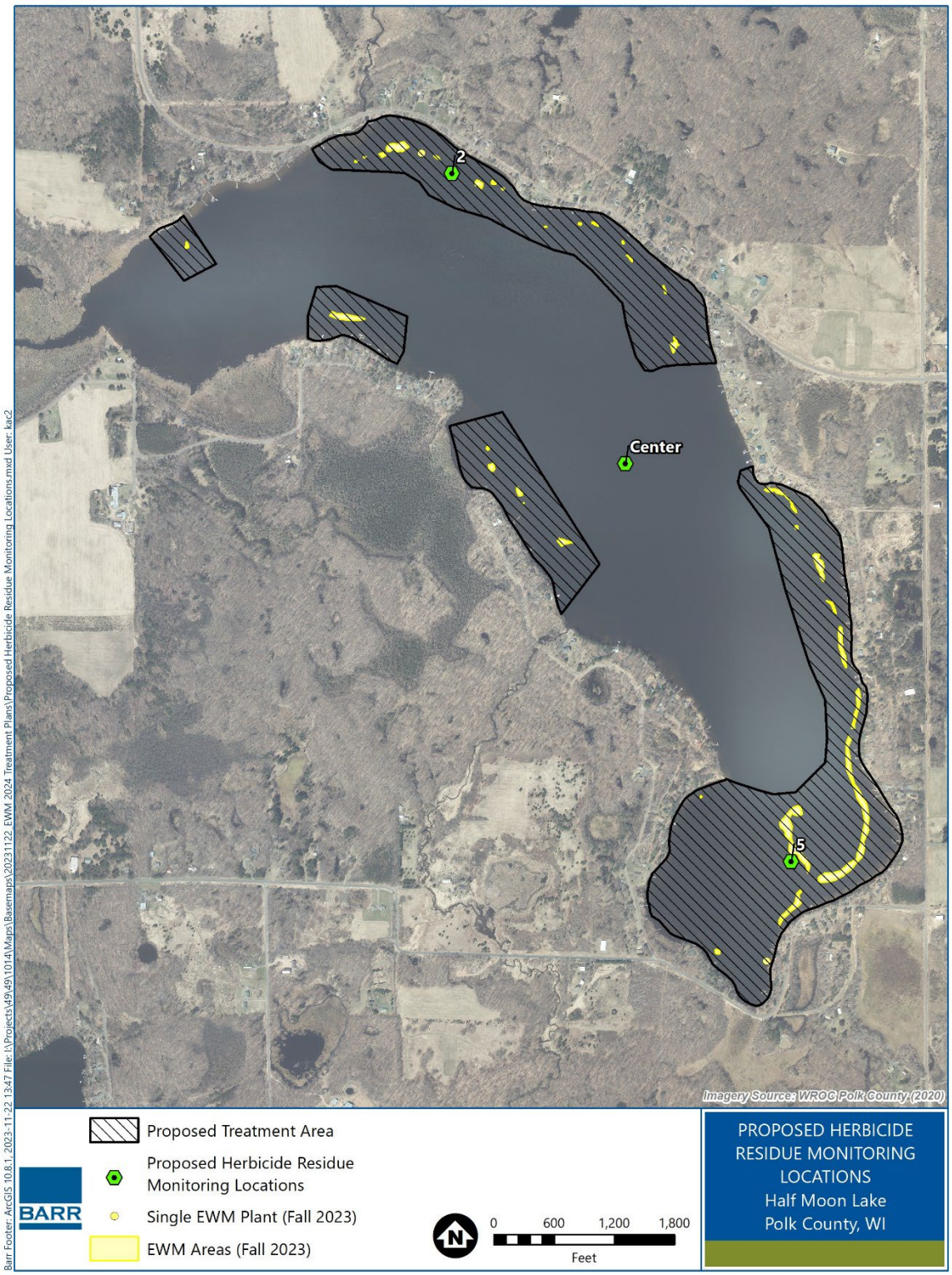

Figure 17 Proposed Half Moon Lake Herbicide Residue Monitoring Locations

4.4.2 Fluridone Treatment

The herbicide fluridone could be used to remove EWM from Half Moon Lake. Fluridone is a slow-acting systemic herbicide used to control EWM and other underwater plants. It may be applied as a pellet or a liquid. Like other systemic herbicides, it moves from submerged foliage to roots. When enough herbicide reaches the roots, the plant's root crown—which enables EWM to grow year after year—is destroyed. Fluridone controls EWM by destroying both the plant and its root crown. A plant's susceptibility to fluridone is associated with its uptake rate and rate of movement to its roots.

Fluridone is absorbed from water by plant shoots and the hydrosoil by the roots of aquatic vascular plants. Once in the plant, it inhibits the formation of carotene, a plant pigment essential for photosynthesis, the process by which plants use sunlight to make food. Plants die of starvation. EWM and curly-leaf pondweed (CLP) are more vulnerable than native plants to fluridone's impacts. A 2 to 4 parts per billion (ppb) dose of fluridone is lethal to EWM and CLP, but does not harm native plants.

Fluridone impacts plant pigments and does not harm humans, fish, and other animals when used according to label instructions. The United States Environmental Protection Agency (USEPA) has placed fluridone in the lowest acute toxicity rating category. The USEPA has not placed restrictions on swimming or fishing in water treated with fluridone or drinking water treated with fluridone.

Aquatic plant control is obtained by maintaining an adequate concentration of the product in the treated area for a sufficient time. Damage in susceptible plants usually appears in 7 to 10 days after treatment. However, the desired level of plant control is usually achieved 30 to 90 days after applying the herbicide. Sunlight breaks down fluridone (photolysis), removing it from the lake.

After the initial treatment, samples are collected at weekly intervals to monitor the fluridone level in the water. Additional fluridone is added when needed, termed "bump" treatments, to sustain a lethal dose of 2 to 4 ppb fluridone for up to 90 days. Fluridone has generally been applied in spring, with a lethal dose sustained for about 90 days.

If fluridone is used to remove EWM from Half Moon Lake, treatment of 207 acres of the littoral area could occur in spring of 2024. An initial fluridone dose of 13 ppb could be applied to the treatment areas shown in Figure 18 to attain a whole lake concentration of 4 ppb. Beginning one week after initial treatment, twelve weekly water samples could be collected from three locations (Figure 17) to monitor fluridone levels. When fluridone concentrations in Half Moon Lake near 2 ppb, additional fluridone could be added to the lake (a 'bump" treatment) to increase the whole lake fluridone concentration to 4 ppb (Figure 19). If the bump treatment occurs when the whole lake concentration is 2 ppb, a fluridone dose of 6.5 ppb could be applied to the treatment areas shown in Figure 19 to attain a whole lake concentration of 4 ppb. Bump treatments could occur as needed to sustain the fluridone concentration in Half Moon Lake at 2 to 4 ppb for 90 days. While it is anticipated that bump treatments would be needed approximately monthly, results from the water sampling would determine the actual timing of bump treatments and the number of bump treatments needed.

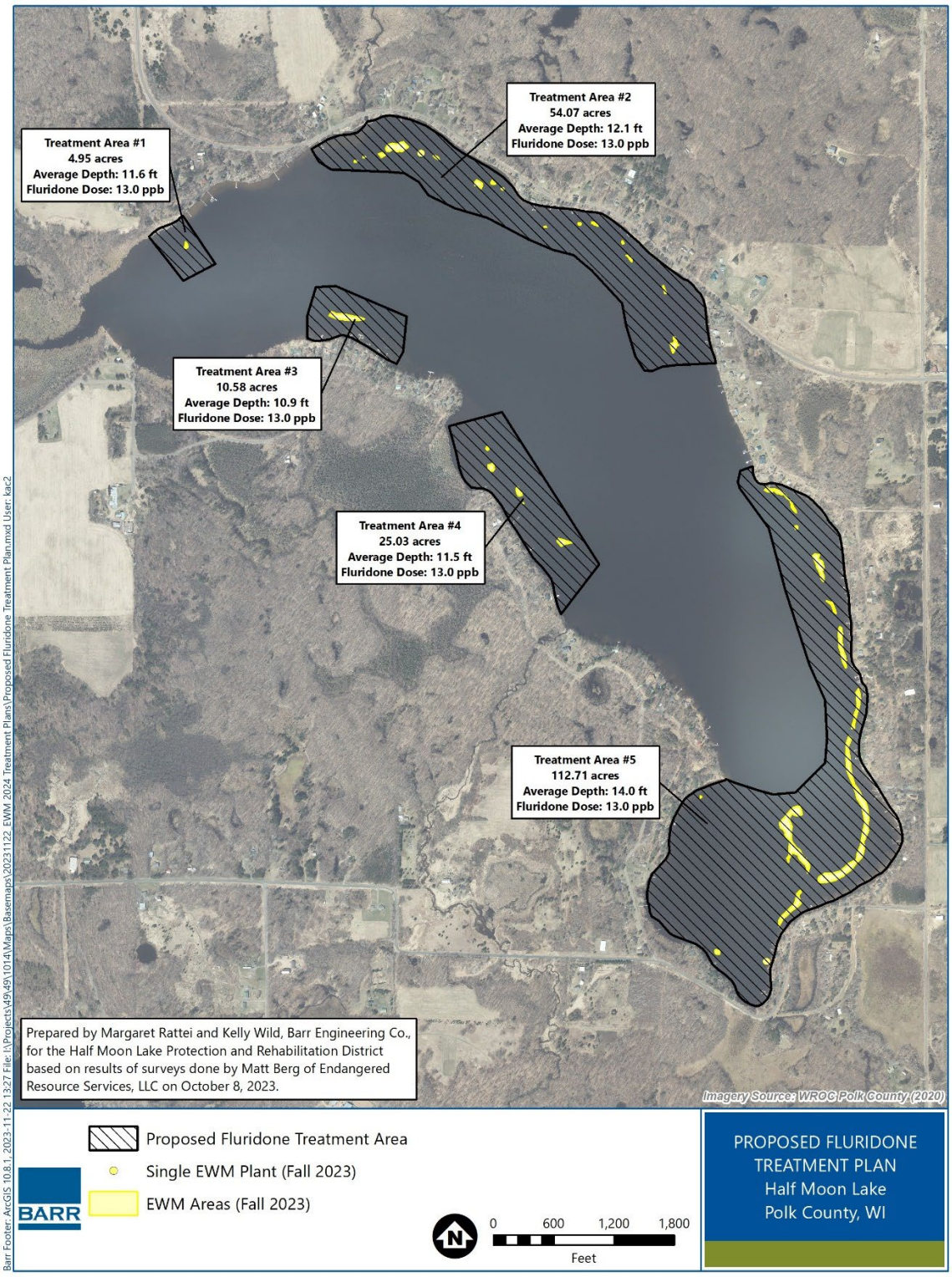

Figure 18 Proposed Half Moon Lake Fluridone Treatment Plan: Initial Treatment Plan

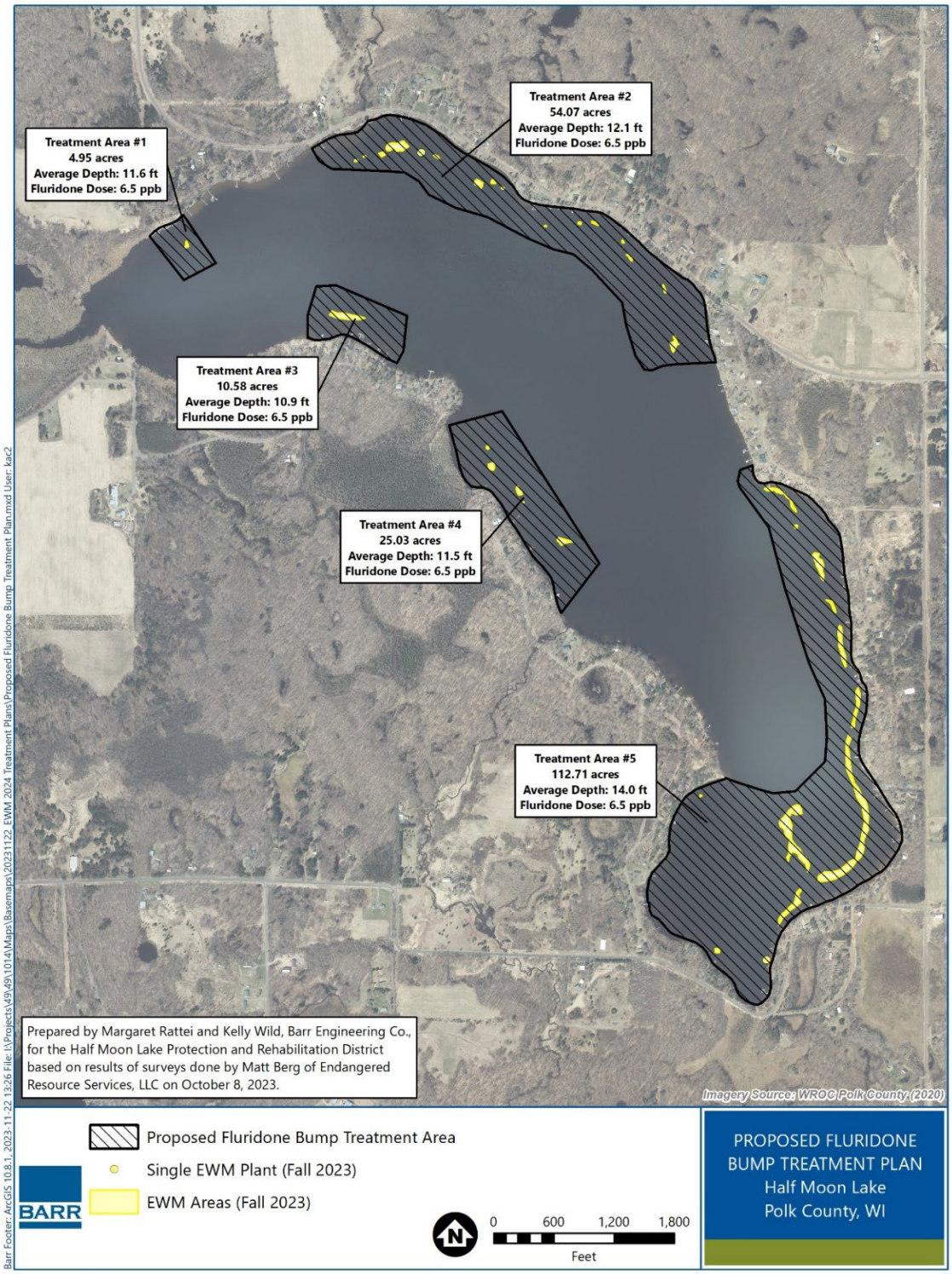

Figure 19 Proposed Half Moon Lake Fluridone Treatment Plan: Bump Treatment Plan

Monitoring results from fluridone treatments of lakes with EWM and hybrid milfoil have documented the effectiveness of fluridone to control both (Figure 20) (Freshwater Scientific Services 2017a, Freshwater Scientific Services 2017b, MNDNR 2021a, MNDNR 2021b, and MNDNR 2021c).

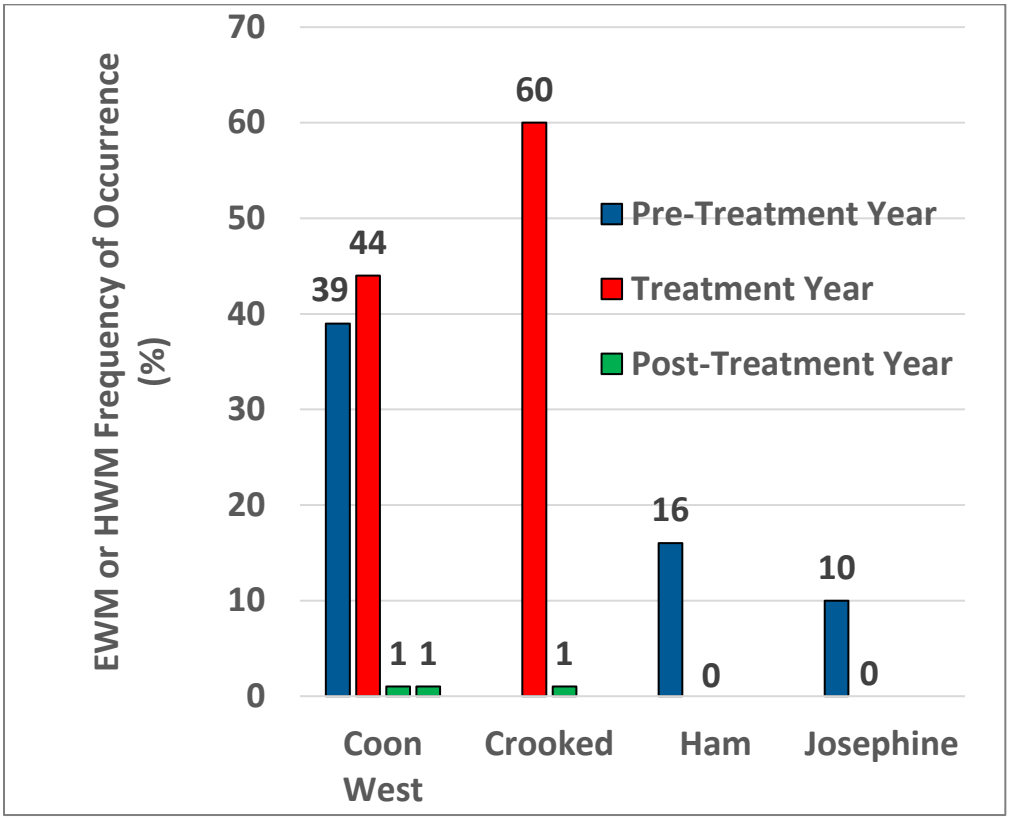

Figure 20 **EWM or HWM Frequency of Occurrence during Pre-Treatment, Treatment, and/or Post-Treatment Years: Coon West Lake, Crooked Lake, Ham Lake, and Lake Josephine**

5 Assessment of Half Moon Lake Plant Community

5.1 Comparison of June 5 and August 24 sub PI Survey Results

Pre-management and post-management sub PI plant surveys were completed on June 5 and August 24 to assess the plant community within EWM managed areas. Sample points are shown in Figure 6 and Figure 11. The survey results are summarized in

Table 2, Table 3, Figure 20, Appendix A and Appendix B.

Post-management data document increases in the number of plant species (from 19 to 21), average number of native species per sites shallower than the maximum depth of plant growth (from 2.5 to 3.7), plant diversity as measured by the Simpson Diversity Index (from 0.90 to 0.91), the quality of the plant community as measured by the Floristic Quality Index (FQI) (from 27 to 28), plant frequency (from 95 percent to 98 percent), and plant density as measured by mean rake fullness (from 1.6 to 2.3) (

Table 2). The increases are favorable changes for the lake's plant community. The increases are likely caused by seasonal changes in the plant community between June and August.

Significant frequency changes of species before and after EWM removal from the managed areas were documented by a Chi Squared analysis of June 5 and August 24 data. A significant post-management frequency increase for EWM documents the ineffectiveness of the EWM removal efforts using DASH (Figure 21 and Table 3). Significant post-management frequency increases occurred for slender naiad (*Najas flexilis*), variable pondweed (*Potamogeton gramineus*), small pondweed (*Potamogeton pusillus*), clasping-leaf pondweed (*Potamogeton richardsonii*), and wild celery (*Vallisneria americana*). Significant post-management frequency decreases occurred for filamentous algae and two native plant species—forked duckweed (*Lemna trisulca*) and Fries' pondweed (*Potamogeton friesii*) (Figure 21and Table 3). The increases are likely caused by seasonal changes in the plant community between June and August. The increased frequency of the native species is a positive change for the lake.

Table 2 Half Moon Lake 2023 Sub PI Summary Statistics

SUMMARY STATS:	6/5/2023	8/24/2023
Total number of points sampled	125	125
Total number of sites with vegetation	117	120
Total number of sites shallower than maximum depth of plants	123	122
Frequency of occurrence of all species at sites shallower than maximum depth of plants	95.1	98.4
Simpson Diversity Index	0.90	0.91
Maximum depth of plants (ft)	15.5	15.0
Average number of all species per site (shallower than max depth)	2.6	3.9
Average number of all species per site (veg. sites only)	2.7	4.0
Average number of native species per site (shallower than max depth)	2.5	3.7
Average number of native species per site (veg. sites only)	2.6	3.8
Species Richness	19	21
Species Richness (including visuals)	19	21
Species Richness (including visuals and boat survey)	19	21
Mean depth of plants (ft)	7.7	8.0
Median depth of plants (ft)	7.5	7.5
Mean rake fullness (veg. sites only)	1.6	2.3
Mean C	6.4	6.5
FQI	27.3	28.8

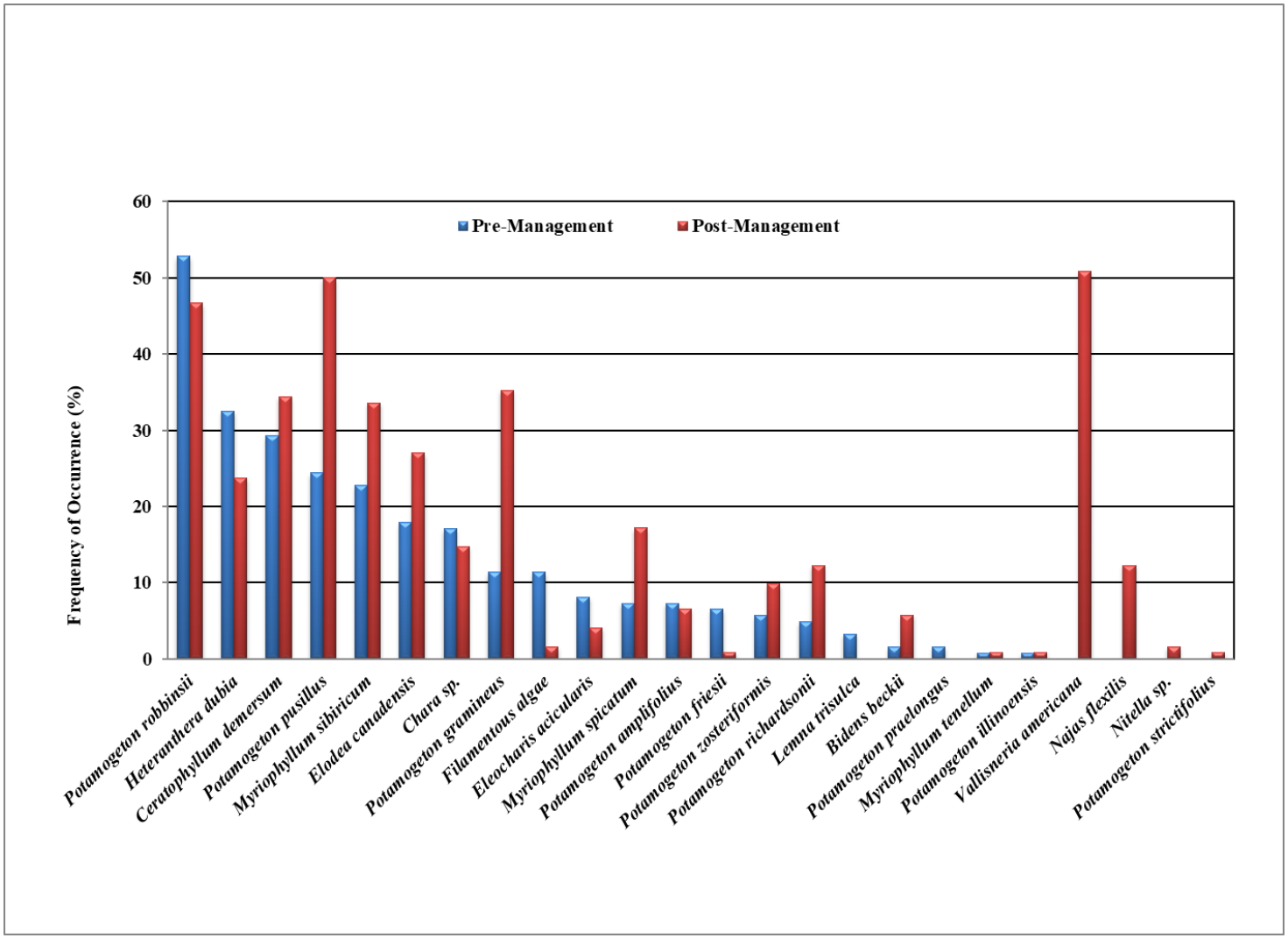

Figure 21 **2023 Comparison of Half Moon Lake Pre-Management (June 5) and Post-Management (August 24) Frequency of Occurrence (% of Sites Shallower than Maximum Depth of Plants)**

Table 3 **Half Moon Lake 2023 Sub PI Survey Results: Frequency of Occurrence at Sites Shallower Than Maximum Depth of Plant and Significant Change Between June 5 and August 24**

Scientific Name	Common Name	Frequency of occurrence at sites shallower than maximum depth of plants		Significant Changes 6/5/2023 to 8/24/2023	Significant Increase/Decrease
		6/5/2023	8/24/2023		
Bidens beckii	Water marigold	1.63	5.74	--	--
Ceratophyllum demersum	Coontail	29.27	34.43	--	--
Chara sp.	Muskgrass	17.07	14.75	--	--
Eleocharis acicularis	Needle spikerush	8.13	4.10	--	--
Elodea canadensis	Common waterweed	17.89	27.05	--	--
Filamentous algae	Filamentous algae	11.38	1.64	**	Decrease
Heteranthera dubia	Water star-grass	32.52	23.77	--	--
Lemna trisulca	Forked duckweed	3.25	0	*	Decrease
Myriophyllum sibiricum	Northern watermilfoil	22.76	33.61	--	--
Myriophyllum spicatum	Eurasian watermilfoil	7.32	17.21	*	Increase
Myriophyllum tenellum	Dwarf watermilfoil	0.81	0.82	--	--
Najas flexilis	Slender naiad	0	12.30	***	Increase
Nitella sp.	Nitella	0	1.64	--	--
Potamogeton amplifolius	Large-leaf pondweed	7.32	6.56	--	--
Potamogeton friesii	Fries' pondweed	6.50	0.82	*	Decrease
Potamogeton gramineus	Variable pondweed	11.38	35.25	***	Increase
Potamogeton illinoensis	Illinois pondweed	0.81	0.82	--	--
Potamogeton praelongus	White-stem pondweed	1.63	0	--	--
Potamogeton pusillus	Small pondweed	24.39	50.00	***	Increase
Potamogeton richardsonii	Clasping-leaf pondweed	4.88	12.30	*	Increase
Potamogeton robbinsii	Fern pondweed	52.85	46.72	--	--
Potamogeton strictifolius	Stiff pondweed	0	0.82	--	--
Potamogeton zosteriformis	Flat-stem pondweed	5.69	9.84	--	--
Vallisneria americana	Wild celery	0	50.82	***	Increase

A p value, or probability value, describes how likely it is that the differences are due to random chance and, hence, are not statistically significant differences.

* means $p \leq 0.05$ and there is less than a 5% probability; ** means $p \leq 0.01$ and indicates there is less than a 1 percent probability; ***means $p \leq 0.001$ and indicates there is less than a 0.1 percent probability.

5.2 Results of July 1 Whole Lake Point Intercept Plant Survey

A whole lake point intercept plant survey of Half Moon Lake was completed on July 1 to assess the lake's entire plant community. The survey results indicate the Half Moon Lake plant community was healthy and diverse. A total of 61 species were observed, 57 native species and 4 non-native species (EWM; curly-leaf pondweed, *Potamogeton crispus*; reed canary grass, *Phalaris arundinacea*; and hybrid cattail, *Typha X glauca*) (

Table 4, Figure 22, and Appendix C). The number of species in Half Moon Lake was more than 4 times greater than the median value for lakes in the same ecoregion (median value of North Central Hardwood Forests is 14) (Nichols 1999). The maximum water depth plants were found growing in was 17.5 feet (

Table 4). The area of the lake up to the 17.5-foot depth is called the littoral area of the lake because this is the area of the lake in which plants were found growing. A total of 228 sample points were found in the littoral area of the lake and 202 sample points had vegetation. Hence, plants were found in 89 percent of the sample sites in the littoral area. Plant species abundance was balanced between many types and 82 percent of the lake's plant species had a frequency of less than 10 percent (i.e., were found at less than 10 percent of the sample locations within the littoral area of the lake). The 11 most prevalent species in Half Moon Lake, ranging in frequency from 11 percent to 43 percent, were muskgrass (*Chara sp.*), variable pondweed (*Potamogeton gramineus*), fern pondweed (*Potamogeton robbinsii*), wild celery (*Vallisneria americana*), small pondweed (*Potamogeton pusillus*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), dwarf watermilfoil (*Myriophyllum tenellum*), flat-stem pondweed (*Potamogeton zosteriformis*), needle spikerush (*Eleocharis acicularis*), and slender naiad (*Najas flexilis*) (Figure 22).

Plant density in Half Moon Lake was measured by rake fullness on a scale of 1 (low) to 3 (high) (Figure 8). In 2023, plant density ranged from low to high (Figure 23). The average rake fullness in the lake's vegetated sample sites was 2.0 indicating, on average, the rake was about half full (

Table 4). The most densely growing plant species in Half Moon Lake during 2023, ranging in average rake fullness from 2.0 to 2.1, were pickerelweed (*Pontederia cordata*), watershield *(Brasenia schreberi*), hardstem bulrush (*Schoenplectus acutus*), water bulrush (*Schoenplectus subterminalis*), sago pondweed (*Stuckenia pectinata*), and broad-leaved cattail (*Typha latifolia*) (Figure 24).

Table 4 Half Moon Lake 2007, 2018, 2022, and 2023 Summary Statistics

SUMMARY STATS:	7/16-7/18/2007	6/21/2018	7/1/2022	7/1/2023
Total number of points sampled	372	734	734	734
Total number of sites with vegetation	197	213	205	202
Total number of sites shallower than maximum depth of plants	285	335	235	228
Frequency of occurrence of all species at sites shallower than maximum depth of plants	69.1	63.6	87.2	88.6
Simpson Diversity Index	0.93	0.95	0.95	0.94
Maximum depth of plants (ft)	25.0	25.0	18.0	17.5
Average number of all species per site (shallower than max depth)	2.8	2.7	3.0	3.4
Average number of all species per site (veg. sites only)	4.0	4.3	3.5	3.8
Average number of native species per site (shallower than max depth)	2.8	2.7	3.0	3.4
Average number of native species per site (veg. sites only)	4.0	4.2	3.5	3.8
Species Richness	32	44	46	49
Species Richness (including visuals)	35	50	48	54
Species Richness (including visuals and boat survey)	37	58	55	61
Mean depth of plants (ft)	7.0	6.1	5.6	5.5
Median depth of plants (ft)	4.5	4.5	4.0	4.0
Mean rake fullness (veg. sites only)	1.8	1.8	2.1	2.0
Mean C	6.0	6.3	6.6	6.5
FQI	32.5	41.5	43.0	45.3

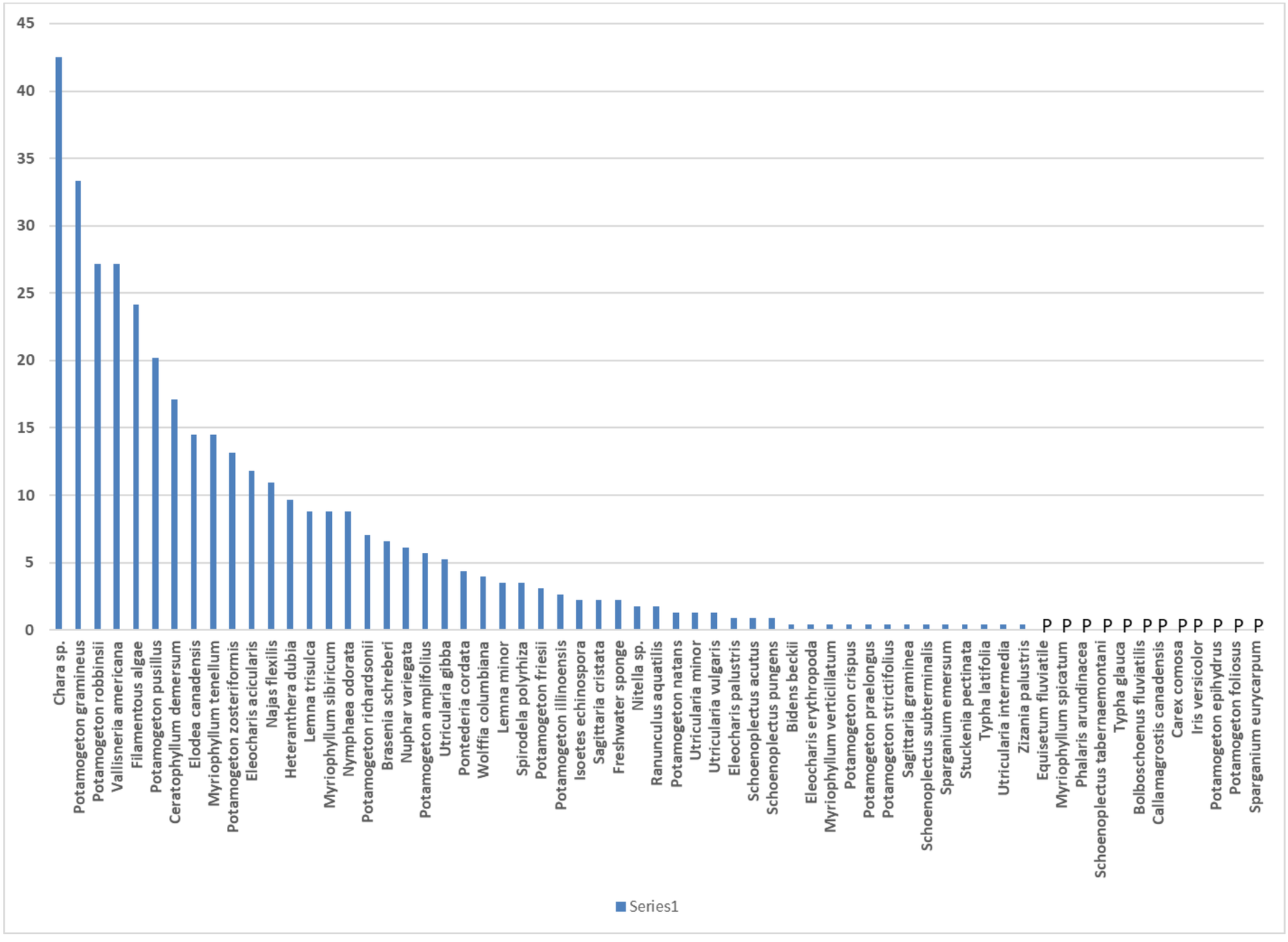

Figure 22 Frequency of Occurrence of Half Moon Lake Plants During July 1, 2023 Plant Survey

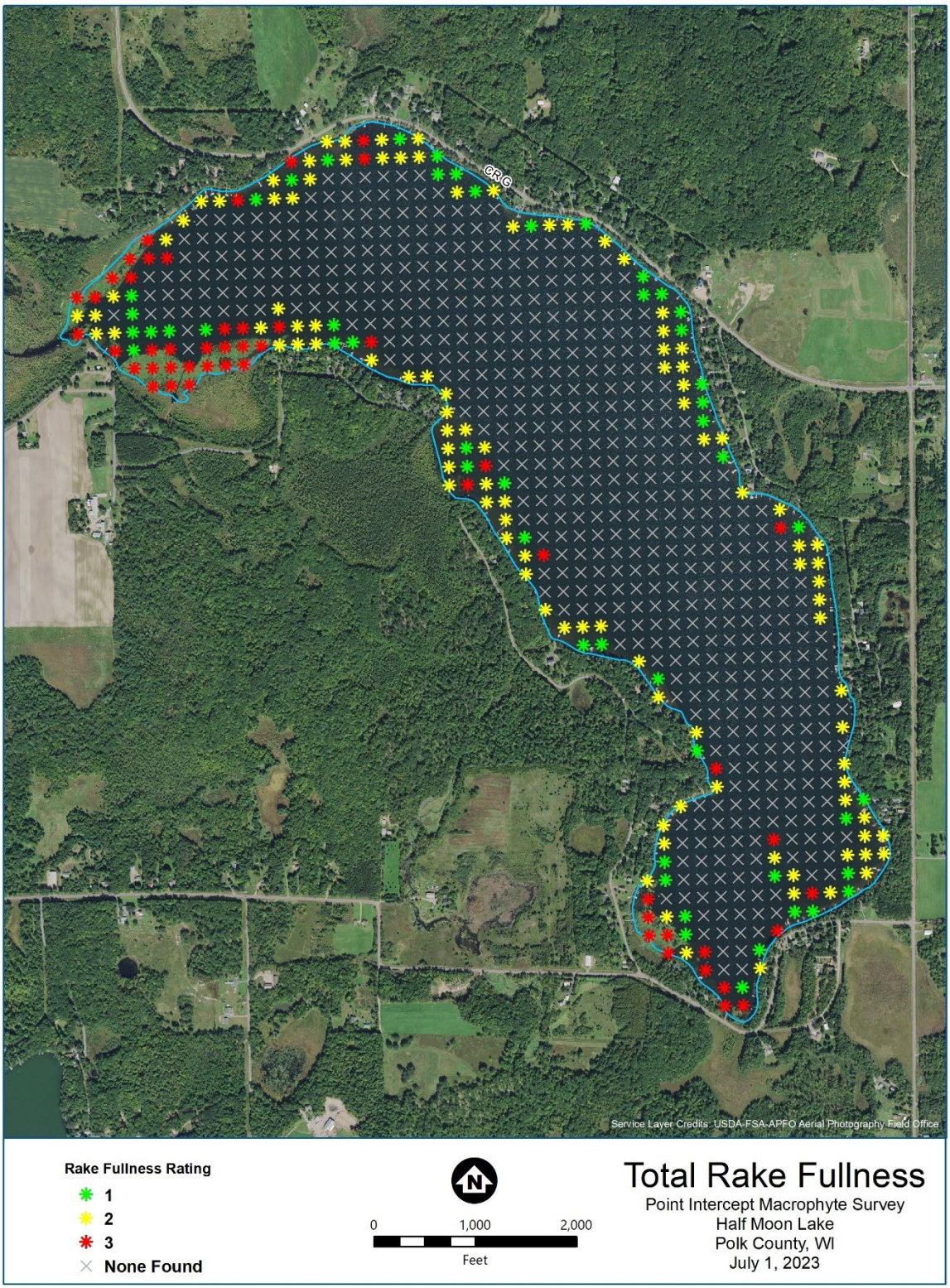

Figure 23 **Total Rake Fullness at Half Moon Lake Vegetated Sites During July 1, 2023 Plant Survey**

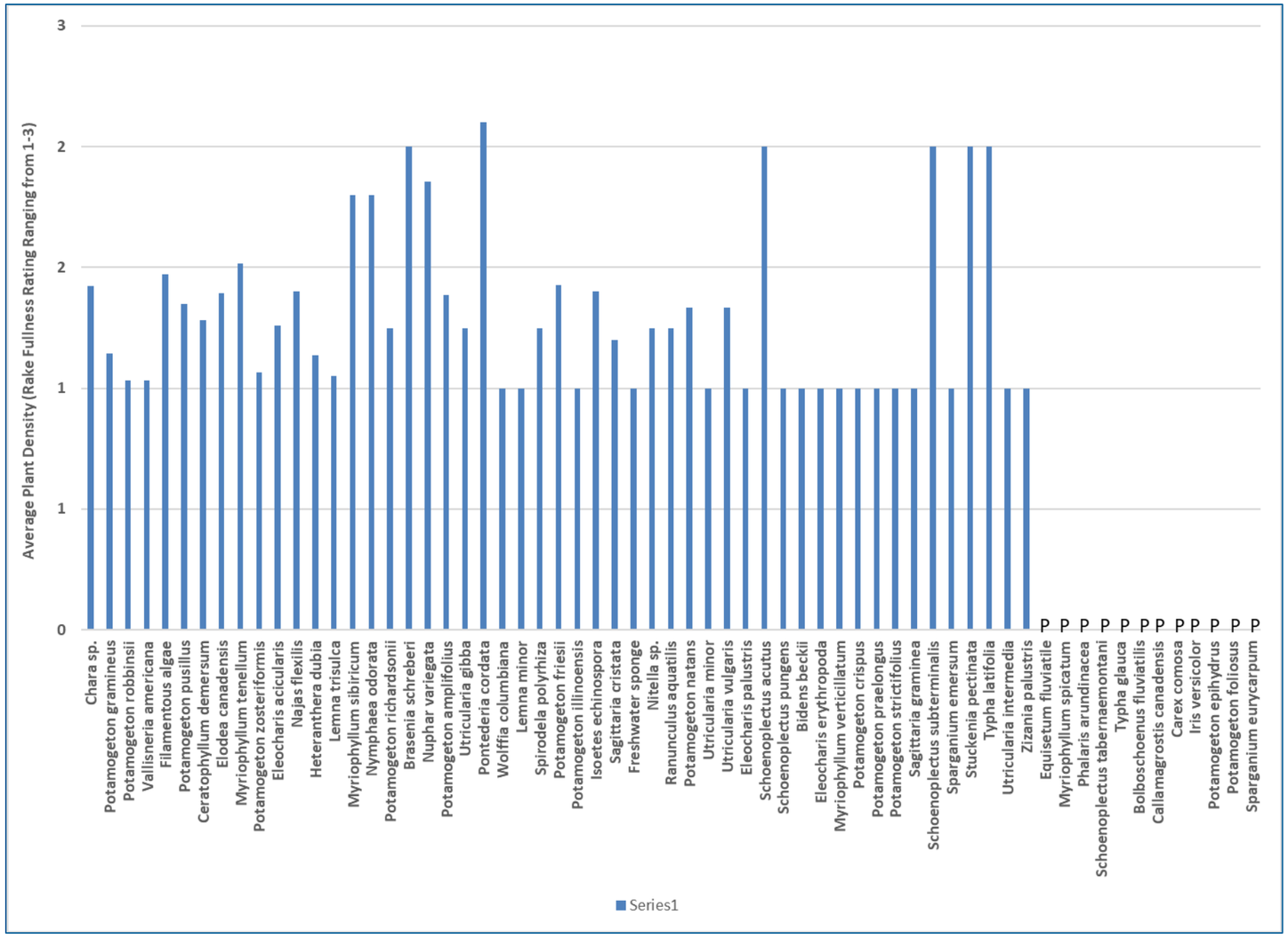

Figure 24 Average Density of Half Moon Lake Plants During July 1, 2023 Plant Survey

The Simpson Diversity Index was used to measure the diversity of the 2023 Half Moon Lake plant community. The index, with scores ranging from 0 to 1, considers both the number of species present and the evenness of species distribution. The scores represent the probability that two individual plants randomly selected from the lake will belong to different species. A high score indicates a more diverse plant community—a higher probability that two randomly selected plants will represent different species. Half Moon Lake had a score of 0.94 which indicates the probability that two randomly selected plants will belong to different species is 94 percent (

Table 4). Hence, plant diversity in Half Moon Lake in 2023 was high.

The diversity in the Half Moon Lake plant community was also indicated by the number of plant species found at each sample site. The average number of individual species collected from vegetated sample sites was 3.8 and the range was 1 to 11 (

Table 4 and Figure 25). The average number of individual native species collected from vegetated sample sites was 3.8. The presence of more than 3 species per sample site on average indicates high plant diversity in Half Moon Lake. The high diversity in Half Moon Lake indicates the plant community is very healthy.

The quality of the Half Moon Lake aquatic plant community was measured by the Floristic Quality Index (FQI). The number of native species collected on the rake during the aquatic plant survey and the average tolerance of the plant community to degraded conditions are used to compute FQI. The average tolerance of the plant community to degraded conditions is measured by a value called the C value. Plant species are assigned C values on a scale of 0 to 10, with increasing values indicating plants are less tolerant of degraded conditions and of better quality. An average of the C values for individual species within a lake's plant community indicates the average tolerance of the community to degraded conditions. The average C value for the Half Moon Lake plant community in 2023 was 6.5 (

Table 4). The FQI value for Half Moon Lake in 2023 was 45. This value is more than double the median FQI value for lakes in the same ecoregion (20.9) (Nichols 1999). The high FQI indicates (1) the plant community is intolerant to development and other human disturbances; (2) the plant community has not been degraded by human impacts; and (3) the lake has high water quality.

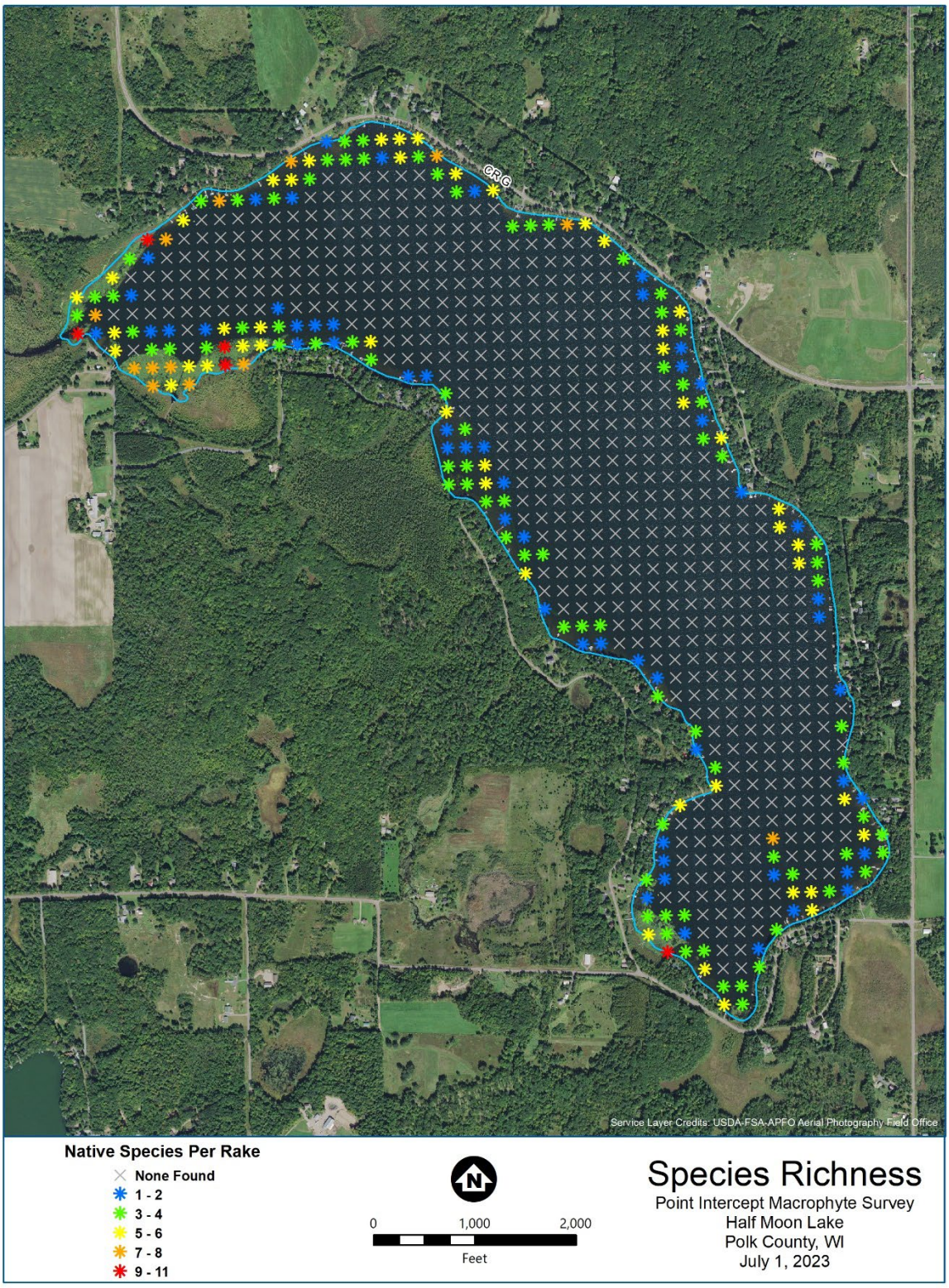

Figure 25 July 1, 2023 Half Moon Lake Native Species Richness

5.3 Comparison of 2007, 2018, 2022, and 2023 Point Intercept Plant Survey Results

Half Moon Lake aquatic plant data collected during July 16 through 17, 2007 by the Wisconsin Department of Natural Resources and during June 21 through 23, 2018, July 1, 2022, and July 1, 2023 by the Half Moon Lake Protection and Rehabilitation District were compared to assess changes.

In 2023, the maximum and mean depths of plant growth were lower than previous years. The maximum depth of plant growth was 25 feet in 2007 and 2018 compared with 18 feet in 2022 and 17.5 feet in 2023 (

Table 4). The mean depth of plant growth was 7.0 feet in 2007, 6.1 feet in 2018, 5.6 feet in 2022, and was 5.5 feet in 2023 (

Table 4). The lower depths in 2023 were likely a result of dry climatic conditions (Wisconsin State Climatology Office 2023)

The 2023 plant survey results indicated the plant community in Half Moon Lake was very healthy and of high quality. The number of species (including visuals and boat surveys) in Half Moon Lake in 2023 was higher than previous years—61 in 2023 compared with 37 in 2007, 58 in 2018, and 55 in 2022 (

Table 4). In 2023, the number of species in Half Moon Lake was more than 4 times greater than the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2023, the quality of the plant community, measured by FQI, was higher than previous years—45.3 in 2023 compared with 32.5 in 2007, 41.5 in 2018, and 43.0 in 2022 (

Table 4). Half Moon Lake FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). In 2023, diversity, measured by Simpson Diversity Index, was within the range of previous years—0.94 in 2023 compared with 0.93 in 2007 and 0.95 in 2018 and 2022 (

Table 4).

In 2023, plant frequency and the average number of native plant species per sample location were higher than previous years. During 2007 and 2018, the plant frequency of occurrence at sites shallower than the maximum depth of plants was 69 percent and 64 percent, respectively, and compared with 87 percent in 2022 and 89 percent in 2023 (

Table 4). The average number of native plant species at each littoral sample location was 2.8 in 2007 and 2.7 in 2018, increasing to 3.0 in 2022 and 3.4 in 2023 (

Table 4).

In 2023, the average density of the plant community was within the range of previous years—an average rake fullness of 2.0 in 2023 compared with 1.8 during 2007 and 2018 and 2.1 in 2022 (

Table 4). The data indicate the plant sample rake, on average, was slightly less than half full during 2007 and 2018, was slightly more than half full in 2022, and about half full in 2023.

A statistical tool, Chi Squared Analysis, was used to identify significant frequency changes of individual species in Half Moon Lake. Significant frequency changes have occurred in nearly half of the native species since 2007 (Figure 26 and Table 5).

- 24 of the 52 native species collected on the sampling rake have significantly changed in frequency on at least one occasion since 2007.
- 5 native species have both significantly declined and significantly increased in frequency since 2007.
- 14 native species have significantly increased in frequency since 2007.
- 5 native species have significantly decreased in frequency since 2007.

Five native species significantly changed in frequency between 2022 and 2023 (Figure 26 and Table 5).

- 4 native species significantly increased in frequency—small pondweed (*Potamogeton pusillus*), clasping-leaf pondweed (*Potamogeton richardsonii*), wild celery (*Vallisneria americana*), and common watermeal (*Wolffia columbiana*).
- 1 native species significantly decreased in frequency—large-leaf pondweed (*Potamogeton amplifolius*).

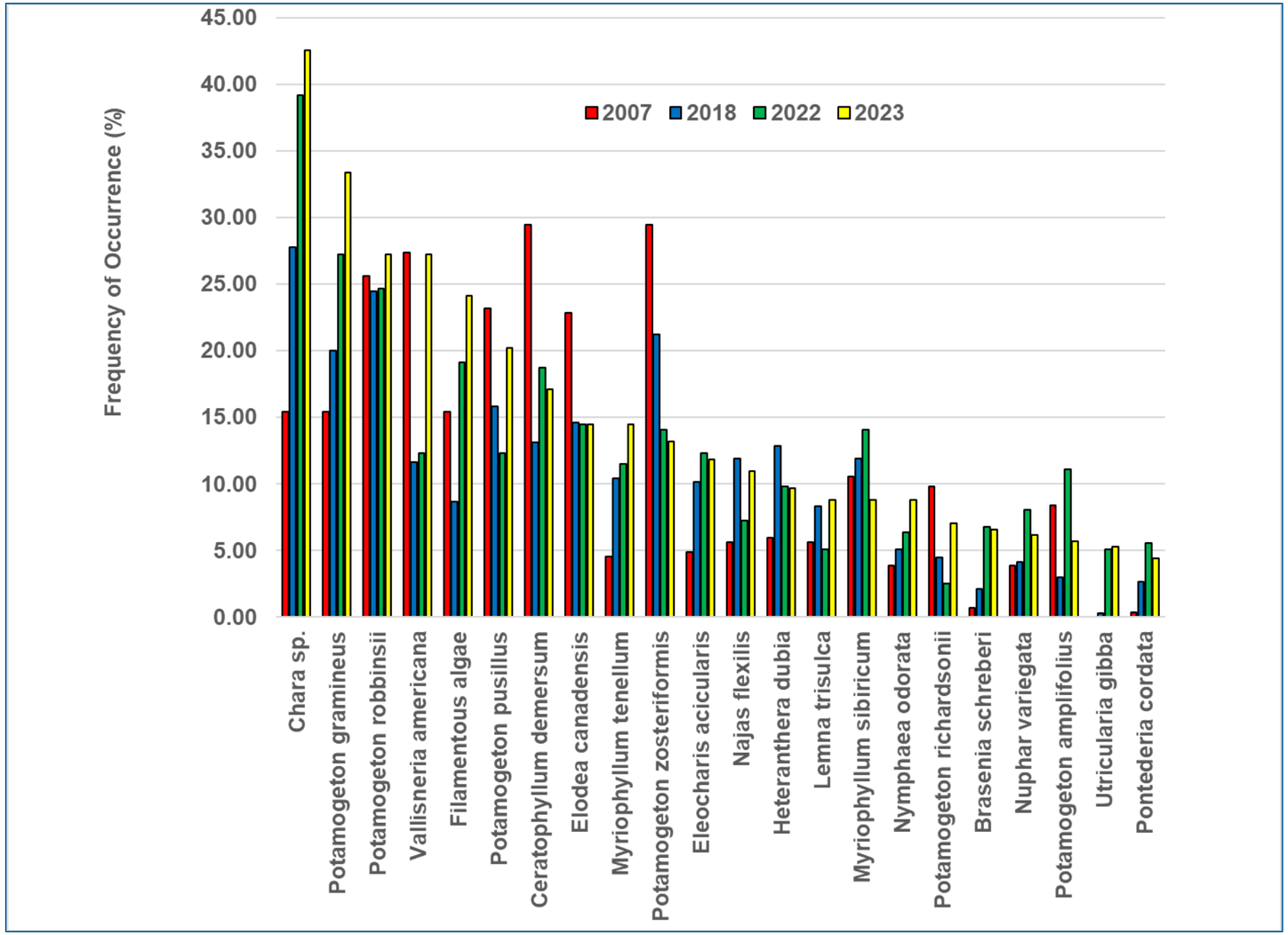

Figure 26 **Frequency of Occurrence of Half Moon Lake Plants During 2007, 2018, 2022, and 2023**

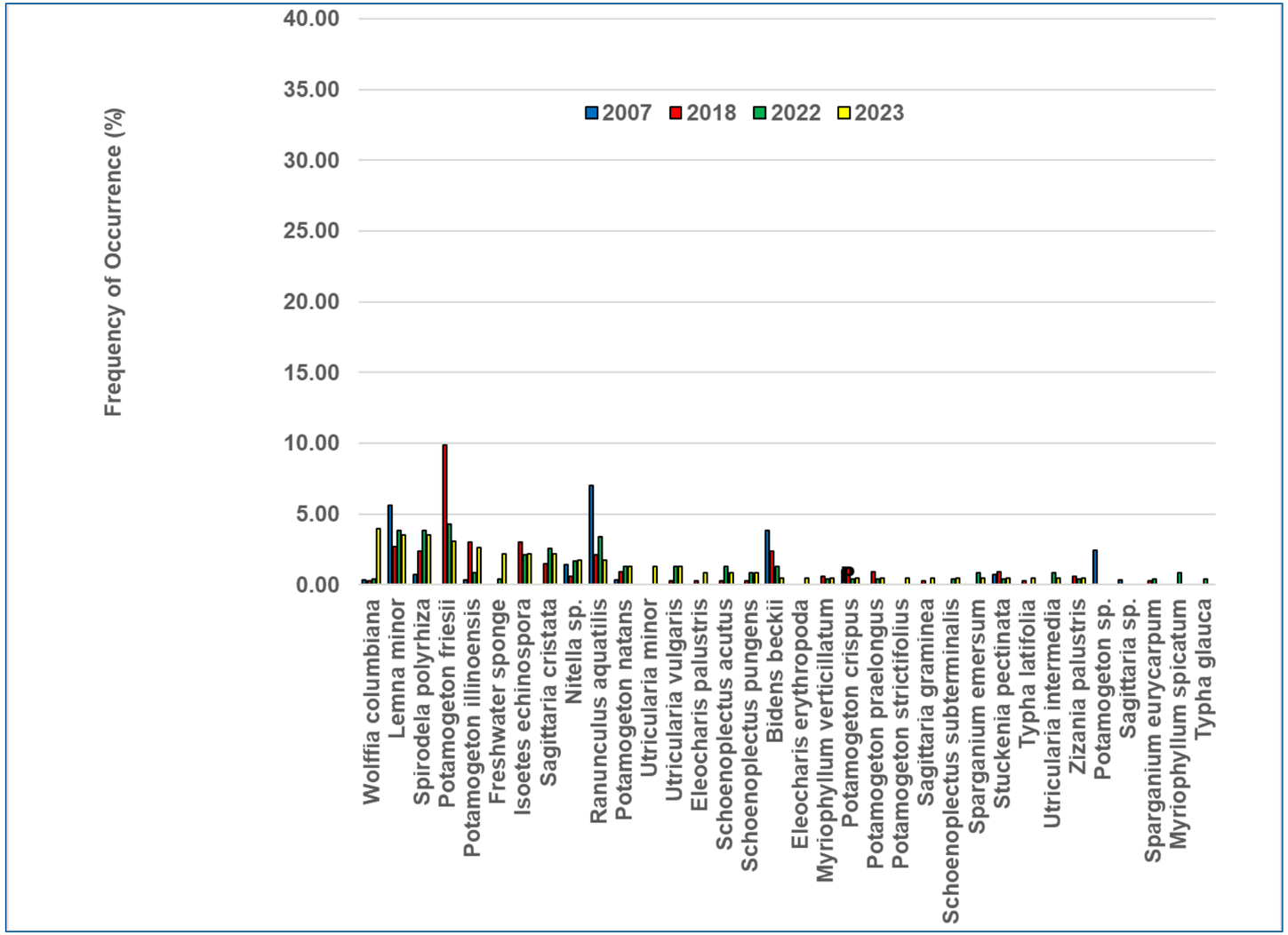

Figure 26 (Continued) Frequency of Occurrence of Half Moon Lake Plants During 2007, 2018, 2022, and 2023

Table 5 **2007-2023 Half Moon Lake Frequency of Occurrence at Sites Shallower Than Maximum Depth of Plants and Significant Change Between Years**

Scientific Name	Common Name	Frequency of occurrence at sites shallower than maximum depth of plants				2007-2023 Significant Changes			Increase/Decrease/Both
		7/16/2007-7/18/2007	06/21/18	7/1/2022	7/1/2023	2007-2018	2018-2022	2022-2023	
Chara sp.	Muskgrass	15.44	27.76	39.15	42.54	***	**		Increase
Potamogeton gramineus	Variable pondweed	15.44	20.00	27.23	33.33	--	*		Increase
Potamogeton robbinsii	Fern pondweed	25.61	24.48	24.68	27.19	--	--		--
Filamentous algae	Filamentous algae	15.44	8.66	19.15	24.12	**	***		Not included with Native Species
Ceratophyllum demersum	Coontail	29.47	13.13	18.72	17.11	***	--		Decrease
Elodea canadensis	Common waterweed	22.81	14.63	14.47	14.47	**	--		Decrease
Myriophyllum sibiricum	Northern watermilfoil	10.53	11.94	14.04	8.77	--	--		--
Potamogeton zosteriformis	Flat-stem pondweed	29.47	21.19	14.04	13.16	*	*		Decrease
Eleocharis acicularis	Needle spikerush	4.91	10.15	12.34	11.84	*	--		Increase
Potamogeton pusillus	Small pondweed	23.16	15.82	12.34	20.18	*	--	*	Both
Vallisneria americana	Wild celery	27.37	11.64	12.34	27.19	***	--	***	Both
Myriophyllum tenellum	Dwarf watermilfoil	4.56	10.45	11.49	14.47	**	--		Increase
Potamogeton amplifolius	Large-leaf pondweed	8.42	2.99	11.06	5.70	**	***	*	Both
Heteranthera dubia	Water star-grass	5.96	12.84	9.79	9.65	**	--		Increase
Nuphar variegata	Spatterdock	3.86	4.18	8.09	6.14	--	*		Increase
Najas flexilis	Slender naiad	5.61	11.94	7.23	10.96	**	--		Increase
Brasenia schreberi	Watershield	0.70	2.09	6.81	6.58	--	**		Increase
Nymphaea odorata	White water lily	3.86	5.07	6.38	8.77	--	--		--
Pontederia cordata	Pickerelweed	0.35	2.69	5.53	4.39	**	--		Increase
Lemna trisulca	Forked duckweed	5.61	8.36	5.11	8.77	--	--		--
Utricularia gibba	Creeping bladderwort	0.00	0.30	5.11	5.26	--	***		Increase
Potamogeton friesii	Fries' pondweed	0.00	9.85	4.26	3.07	***	*		Both
Lemna minor	Small duckweed	5.61	2.69	3.83	3.51	--	--		--
Spirodela polyrhiza	Large duckweed	0.70	2.39	3.83	3.51	--	--		--
Ranunculus aquatilis	White water crowfoot	7.02	2.09	3.40	1.75	**	--		Decrease
Potamogeton richardsonii	Clasping-leaf pondweed	9.82	4.48	2.55	7.02	**	--	*	Both
Sagittaria cristata	Crested arrowhead	0.00	1.49	2.55	2.19	*	--		Increase
Isoetes echinospora	Spiny-spored quillwort	0.00	2.99	2.13	2.19	**	--		Increase
Nitella sp.	Nitella	1.40	0.60	1.70	1.75	--	--		--
Bidens beckii	Water marigold	3.86	2.39	1.28	0.44	--	--		--
Potamogeton natans	Floating-leaf pondweed	0.35	0.90	1.28	1.32	--	--		--
Schoenoplectus acutus	Hardstem bulrush	0.00	0.30	1.28	0.88	--	--		--
Utricularia vulgaris	Common bladderwort	0.00	0.30	1.28	1.32	--	--		--
Myriophyllum spicatum	Eurasian watermilfoil	0.00	0.00	0.85	P	--	--		Non-native invasive species
Potamogeton illinoensis	Illinois pondweed	0.35	2.99	0.85	2.63	*	--		Increase

Scientific Name	Common Name	Frequency of occurrence at sites shallower than maximum depth of plants				2007-2023 Significant Changes			Increase/Decrease/Both
		7/16/2007-7/18/2007	06/21/18	7/1/2022	7/1/2023	2007-2018	2018-2022	2022-2023	
Schoenoplectus pungens	Three-square bulrush	0.00	0.30	0.85	0.88	--	--		--
Sparganium emersum	Short-stemmed bur-reed	0.00	P	0.85	0.44	--	--		--
Utricularia intermedia	Flat-leaf bladderwort	0.00	P	0.85	0.44	--	--		--
Freshwater sponge	Freshwater sponge	0.00	0.00	0.43	2.19	--	--		Not included with native species
Myriophyllum verticillatum	Whorled watermilfoil	0.00	0.60	0.43	0.44	--	--		--
Potamogeton crispus	Curly-leaf pondweed	1.05	1.19	0.43	0.44	--	--		Non-native invasive species
Potamogeton praelongus	White-stem pondweed	0.00	0.90	0.43	0.44	--	--		--
Schoenoplectus subterminalis	Water bulrush	0.00	P	0.43	0.44	--	--		--
Sparganium eurycarpum	Common bur-reed	P	0.30	0.43	P	--	--		--
Stuckenia pectinata	Sago pondweed	0.70	0.90	0.43	0.44	--	--		--
Typha glauca	Hybrid Cattail	0.00	P	0.43	P	--	--		Non-native invasive species
Wolffia columbiana	Common watermeal	0.35	0.30	0.43	3.95	--	--	**	Increase
Zizania palustris	Northern wild rice	0.00	0.60	0.43	0.44	--	--		--
Potamogeton sp.	Narrow-leaved pondweed	2.46	0.00	0.00	0.00	**	--		Decrease
Sagittaria graminea	Grass-leaved arrowhead	0.00	0.30	0.00	0.44	--	--		--
Sagittaria sp.	Arrowhead	0.35	0.00	0.00	0.00	--	--		--
Typha sp.	Cattail	P	0.00	0.00	0.00	--	--		--
Eleocharis palustris	Creeping spikerush	P	0.30	P	0.88	--	--		--
Typha latifolia	Broad-leaved cattail	0.00	0.30	P	0.44	--	--		--
Eleocharis erythropoda	Bald spikerush	0.00	0.00	P	0.44				
Potamogeton strictifolius	Stiff pondweed	0.00	0.00	0.00	0.44				
Utricularia minor	Small bladderwort	0.00	0.00	P	1.32				

A p value, or probability value, describes how likely it is that the differences are due to random chance and, hence, are not statistically significant differences.

* means p≤0.05 and there is less than a 5% probability; ** means p≤0.01 and indicates there is less than a 1 percent probability; ***means p≤0.001 and indicates there is less than a 0.1 percent probability.

6 Aquatic Invasive Species (AIS)

AIS are nonnative species that have the potential to cause serious problems. Because they are not native, they lack predators and can rapidly spread, displacing native species and dominating the community.

One AIS was observed during the 2007 plant survey (curly-leaf pondweed) (Barr, 2018). Five AIS were observed during the 2018 aquatic plant survey (curly-leaf pondweed, yellow iris, common forget-me-not, hybrid cattail, and reed canary grass) (Barr, 2018). Three AIS were observed during the 2022 plant survey (EWM, curly-leaf pondweed, and hybrid cattail). Four AIS were observed during the 2023 plant survey (EWM, curly-leaf pondweed, hybrid cattail, and reed canary grass. The EWM in Half Moon Lake was discussed in Sections 1, 2, and 4 of this report.

In 2007, curly-leaf pondweed (*Potamogeton crispus*) was collected on the rake at three sample locations in the northern end of the lake (Barr, 2018). In 2018, curly-leaf pondweed was collected on the rake at four sample locations and observed near two additional locations in the northern end of the lake (Barr, 2018). In 2022, curly-leaf pondweed was found at fewer locations than 2007 and 2018. It was collected on the rake at one location in the northwestern corner of the lake and visually observed at one location near the east side of the lake. In 2023, curly-leaf pondweed was collected on the rake at one location near the northeast side of the lake and visually observed at one location near the northwest corner of the lake (Figure 27). In 2022 and 2023 the plant surveyor commented that most curly-leaf pondweed plants were observed in 5 to 10 feet of water over organic muck and there was very little of this type of habitat in the lake.

Although CLP has not been problematic to date, problematic conditions could occur in the future. While CLP has been found to grow best in 1 to 3 meters of water, it has been found at depths up to 7 meters (Bolduan 1994) and could expand from the 5 to 10 foot depth to deeper depths in Half Moon Lake. CLP appears to utilize a variety of sediments for growth (Bolduan 1994) and could expand from organic muck to other types of sediment in Half Moon Lake. CLP currently seems to be a latent problem, but annually produces turions which are winter buds that act like seeds. Yeo (1966) found that CLP plants in 5.9 m^2 produced 23,520 turions during a growing season. Kunii (1989) found that CLP plants produced 7,000 to 9,000 turions per square meter during a growing season. Turions can remain viable for several years. CLP may languish at a low level in Half Moon Lake until a favorable environmental circumstance happens that allows it to expand rapidly into a problematic condition.

Removal of CLP from Half Moon Lake now will minimize the risk of rapid expansion to problematic conditions in the future. Herbicide treatment to remove the CLP from the lake is recommended. Treatment may need to occur over multiple years because turions in the sediment could grow and populate the lake with CLP in the years after treatment. Follow up plant surveys after treatment are recommended to determine whether subsequent herbicide treatments are needed. Because the herbicide fluridone controls both EWM and CLP, a fluridone treatment to remove EWM from Half Moon Lake would also remove CLP from the lake. Alternatively, the herbicide diquat could be used to treat the small patches of CLP in the lake.

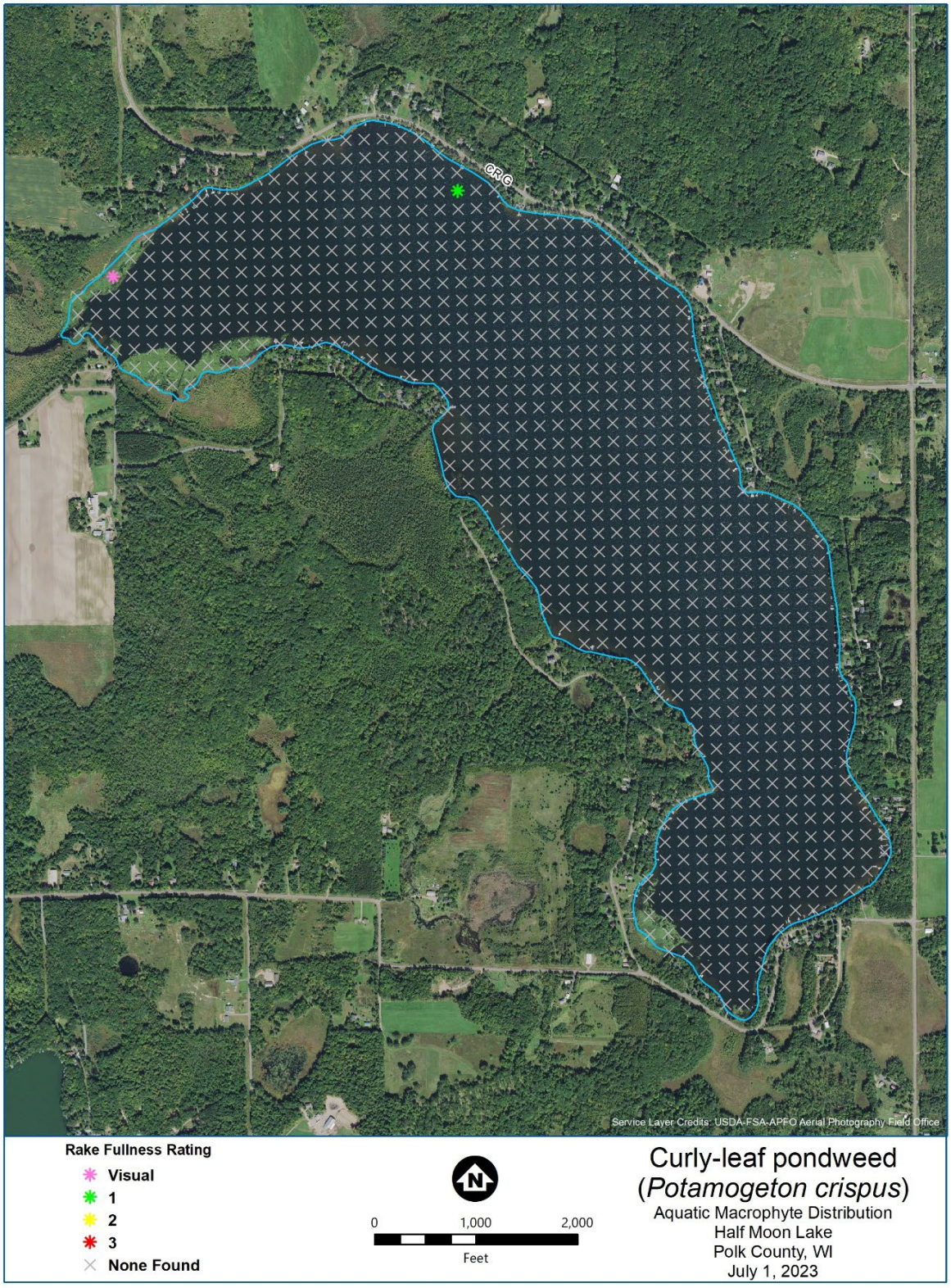

Figure 27 Curly-leaf Pondweed Locations in Half Moon Lake on July 1, 2023

Hybrid cattail has remained stable during 2018 through 2023 and was found at the same location in the northwestern corner of the lake during the 2018 (Barr, 2018), 2022 (Barr 2022), and 2023 (Figure 28) plant surveys. Because it is only found at one location and has not spread, it is not considered problematic.

Reed canary grass (*Phalaris arundinacea*) has been intermittently observed at one location in the lake. It was observed in the northwest corner of the lake near the boat landing in 2018, was not observed in the lake during 2022, and was observed at one location at the southeast corner of the lake in 2023 (Figure 29). Reed canary grass is not considered problematic because it has only been intermittently observed at one location in the lake.

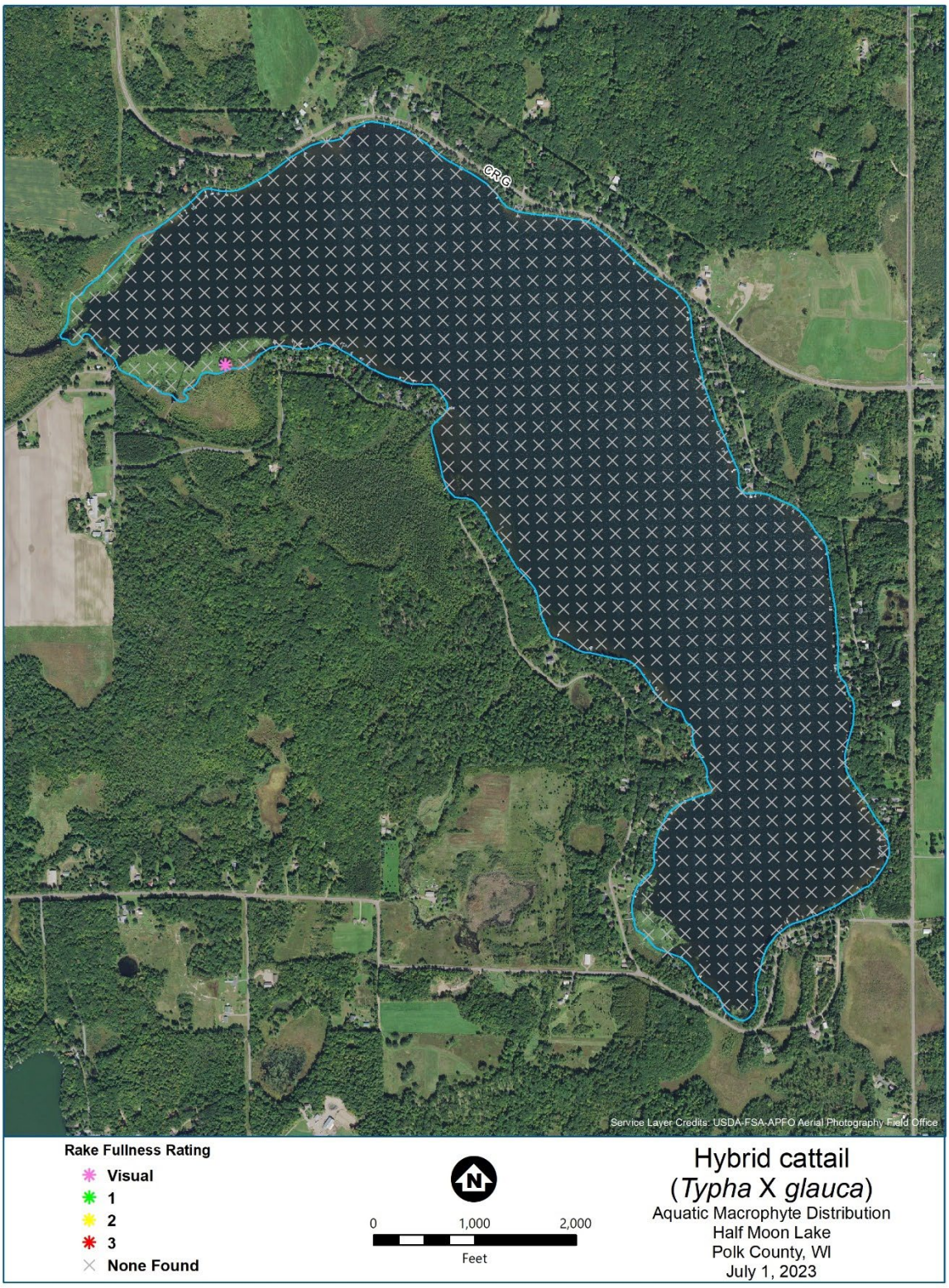

Figure 28 Hybrid Cattail Location in Half Moon Lake on July 1, 2023

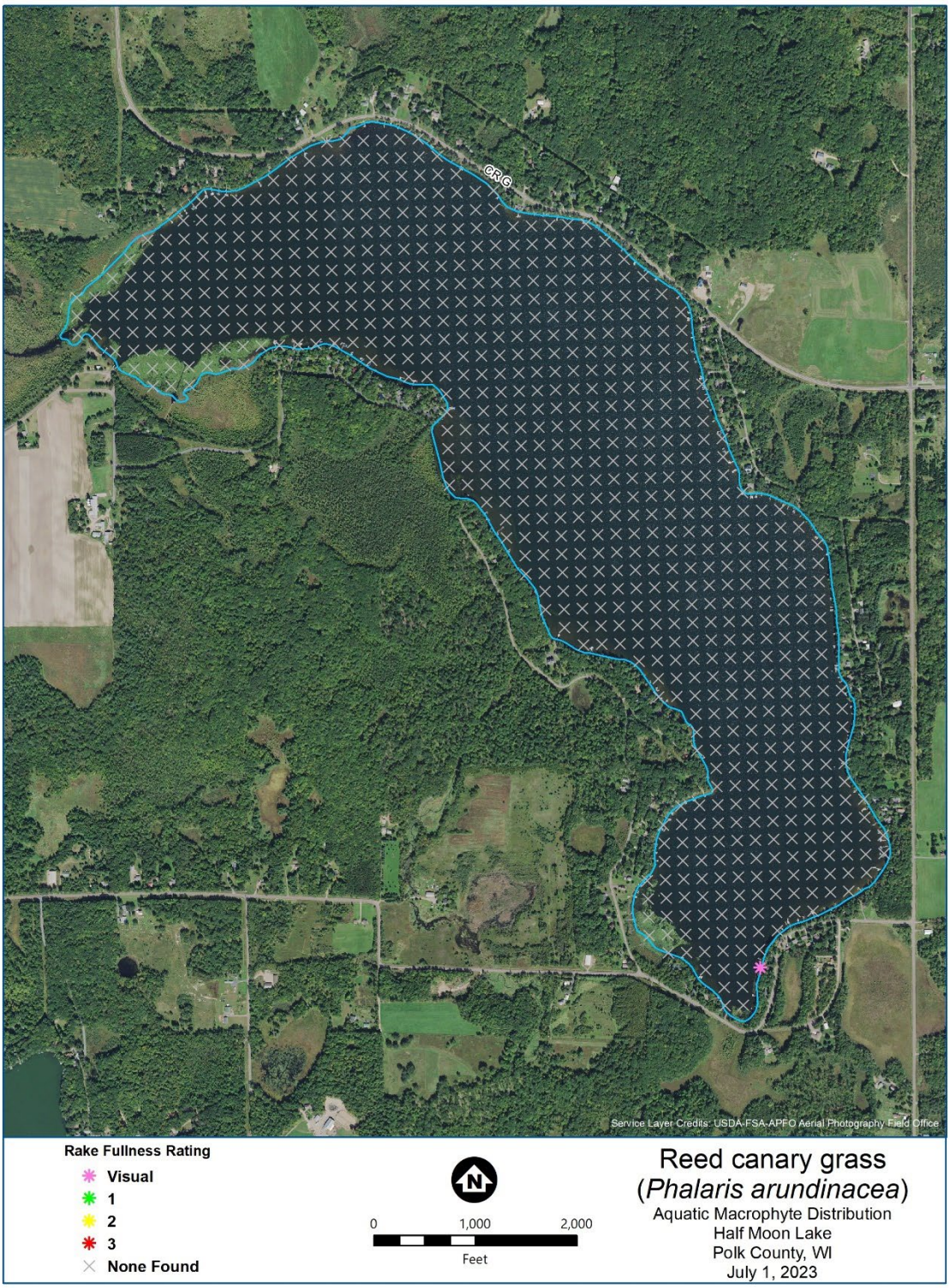

Figure 29 Reed Canary Grass Location in Half Moon Lake on July 1, 2023

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Appendix A

Half Moon Lake Pre-Treatment Plant Survey Data Summary

June 5, 2023

Half Moon Lake Pre-Treatment Data Summary: June 5, 2023

Scientific name	Common name	Number of sites where species found	Relative Frequency (%)	Frequency of occurrence within vegetated areas (%)	Frequency of occurrence at sites shallower than maximum depth of plants	Average rake fullness	#Visual sightings
Potamogeton robbinsii	Fern pondweed	65	20.63	55.56	52.85	1.45	0
Heteranthera dubia	Water star-grass	40	12.70	34.19	32.52	1.30	0
Ceratophyllum demersum	Coontail	36	11.43	30.77	29.27	1.25	0
Potamogeton pusillus	Small pondweed	30	9.52	25.64	24.39	1.07	0
Myriophyllum sibiricum	Northern watermilfoil	28	8.89	23.93	22.76	1.36	0
Elodea canadensis	Common waterweed	22	6.98	18.80	17.89	1.14	0
Chara sp.	Muskgrass	21	6.67	17.95	17.07	1.38	0
Potamogeton gramineus	Variable pondweed	14	4.44	11.97	11.38	1.00	0
--	Filamentous algae	14	*	11.97	11.38	1.07	0
Eleocharis acicularis	Needle spikerush	10	3.17	8.55	8.13	1.20	0
Myriophyllum spicatum	Eurasian watermilfoil	9	2.86	7.69	7.32	1.44	31
Potamogeton amplifolius	Large-leaf pondweed	9	2.86	7.69	7.32	1.22	0
Potamogeton friesii	Fries' pondweed	8	2.54	6.84	6.50	1.00	0
Potamogeton zosteriformis	Flat-stem pondweed	7	2.22	5.98	5.69	1.00	0
Potamogeton richardsonii	Clasping-leaf pondweed	6	1.90	5.13	4.88	1.17	0
Lemna trisulca	Forked duckweed	4	1.27	3.42	3.25	1.00	0
Bidens beckii	Water marigold	2	0.63	1.71	1.63	1.00	0
Potamogeton praelongus	White-stem pondweed	2	0.63	1.71	1.63	1.00	0
Myriophyllum tenellum	Dwarf watermilfoil	1	0.32	0.85	0.81	1.00	0
Potamogeton illinoensis	Illinois pondweed	1	0.32	0.85	0.81	1.00	0

*Excluded from relative frequency analysis

Appendix B

Half Moon Lake Post-Treatment Plant Survey Data Summary

August 24, 2023

Half Moon Lake Post-Treatment Data Summary: August 24, 2023

Scientific name	Common name	Number of sites where species found	Relative Frequency (%)	Frequency of occurrence within vegetated areas (%)	Frequency of occurrence at sites shallower than maximum depth of plants	Average rake fullness	# Visual sightings
Vallisneria americana	Wild celery	62	13.05	51.67	50.82	1.18	0
Potamogeton pusillus	Small pondweed	61	12.84	50.83	50.00	1.89	
Potamogeton robbinsii	Fern pondweed	57	12.00	47.50	46.72	1.33	
Potamogeton gramineus	Variable pondweed	43	9.05	35.83	35.25	1.42	
Ceratophyllum demersum	Coontail	42	8.84	35.00	34.43	1.26	
Myriophyllum sibiricum	Northern watermilfoil	41	8.63	34.17	33.61	1.78	
Elodea canadensis	Common waterweed	33	6.95	27.50	27.05	1.36	
Heteranthera dubia	Water star-grass	29	6.11	24.17	23.77	1.31	
Myriophyllum spicatum	Eurasian watermilfoil	21	4.42	17.50	17.21	1.71	26
Chara sp.	Muskgrass	18	3.79	15.00	14.75	1.33	
Najas flexilis	Slender naiad	15	3.16	12.50	12.30	1.13	
Potamogeton richardsonii	Clasping-leaf pondweed	15	3.16	12.50	12.30	1.33	
Potamogeton zosteriformis	Flat-stem pondweed	12	2.53	10.00	9.84	1.08	
Potamogeton amplifolius	Large-leaf pondweed	8	1.68	6.67	6.56	1.13	
Bidens beckii	Water marigold	7	1.47	5.83	5.74	1.43	
Eleocharis acicularis	Needle spikerush	5	1.05	4.17	4.10	1.00	
Nitella sp.	Nitella	2	0.42	1.67	1.64	1.00	
--	Filamentous algae	2	*	1.67	1.64	1.50	
Myriophyllum tenellum	Dwarf watermilfoil	1	0.21	0.83	0.82	1.00	
Potamogeton friesii	Fries' pondweed	1	0.21	0.83	0.82	1.00	
Potamogeton illinoensis	Illinois pondweed	1	0.21	0.83	0.82	1.00	
Potamogeton strictifolius	Stiff pondweed	1	0.21	0.83	0.82	2.00	

*Excluded from relative frequency analysis

Appendix C

Half Moon Lake Whole Lake Point Intercept Plant Survey Data Summary

July 1, 2023

Half Moon Lake Whole Lake Point Intercept Data Summary: July 1, 2023

Scientific name	Common name	Number of sites where species found	Relative Frequency (%)	Frequency of occurrence within vegetated areas (%)	Frequency of occurrence at sites shallower than maximum depth of plants	Average rake fullness	# Visual sightings
Chara sp.	Muskgrass	97	12.50	48.02	42.54	1.42	2
Potamogeton gramineus	Variable pondweed	76	9.79	37.62	33.33	1.14	13
Potamogeton robbinsii	Fern pondweed	62	7.99	30.69	27.19	1.03	3
Vallisneria americana	Wild celery	62	7.99	30.69	27.19	1.03	3
--	Filamentous algae	55	*	27.23	24.12	1.47	0
Potamogeton pusillus	Small pondweed	46	5.93	22.77	20.18	1.35	1
Ceratophyllum demersum	Coontail	39	5.03	19.31	17.11	1.28	1
Elodea canadensis	Common waterweed	33	4.25	16.34	14.47	1.39	2
Myriophyllum tenellum	Dwarf watermilfoil	33	4.25	16.34	14.47	1.52	1
Potamogeton zosteriformis	Flat-stem pondweed	30	3.87	14.85	13.16	1.07	4
Eleocharis acicularis	Needle spikerush	27	3.48	13.37	11.84	1.26	0
Najas flexilis	Slender naiad	25	3.22	12.38	10.96	1.40	2
Heteranthera dubia	Water star-grass	22	2.84	10.89	9.65	1.14	2
Lemna trisulca	Forked duckweed	20	2.58	9.90	8.77	1.05	0
Myriophyllum sibiricum	Northern watermilfoil	20	2.58	9.90	8.77	1.80	9
Nymphaea odorata	White water lily	20	2.58	9.90	8.77	1.80	3
Potamogeton richardsonii	Clasping-leaf pondweed	16	2.06	7.92	7.02	1.25	5
Brasenia schreberi	Watershield	15	1.93	7.43	6.58	2.00	0
Nuphar variegata	Spatterdock	14	1.80	6.93	6.14	1.86	3
Potamogeton amplifolius	Large-leaf pondweed	13	1.68	6.44	5.70	1.38	10
Utricularia gibba	Creeping bladderwort	12	1.55	5.94	5.26	1.25	0
Pontederia cordata	Pickerelweed	10	1.29	4.95	4.39	2.10	8
Wolffia columbiana	Common watermeal	9	1.16	4.46	3.95	1.00	0

Half Moon Lake Whole Lake Point Intercept Data Summary: July 1, 2023 (Continued)

Scientific name	Common name	Number of sites where species found	Relative Frequency (%)	Frequency of occurrence within vegetated areas (%)	Frequency of occurrence at sites shallower than maximum depth of plants	Average rake fullness	# Visual sightings
Lemna minor	Small duckweed	8	1.03	3.96	3.51	1.00	0
Spirodela polyrhiza	Large duckweed	8	1.03	3.96	3.51	1.25	0
Potamogeton friesii	Fries' pondweed	7	0.90	3.47	3.07	1.43	1
Potamogeton illinoensis	Illinois pondweed	6	0.77	2.97	2.63	1.00	2
Isoetes echinospora	Spiny-spored quillwort	5	0.64	2.48	2.19	1.40	0
Sagittaria cristata	Crested arrowhead	5	0.64	2.48	2.19	1.20	4
--	Freshwater sponge	5	*	2.48	2.19	1.00	0
Nitella sp.	Nitella	4	0.52	1.98	1.75	1.25	0
Ranunculus aquatilis	White water crowfoot	4	0.52	1.98	1.75	1.25	1
Potamogeton natans	Floating-leaf pondweed	3	0.39	1.49	1.32	1.33	0
Utricularia minor	Small bladderwort	3	0.39	1.49	1.32	1.00	1
Utricularia vulgaris	Common bladderwort	3	0.39	1.49	1.32	1.33	1
Eleocharis palustris	Creeping spikerush	2	0.26	0.99	0.88	1.00	0
Schoenoplectus acutus	Hardstem bulrush	2	0.26	0.99	0.88	2.00	1
Schoenoplectus pungens	Three-square bulrush	2	0.26	0.99	0.88	1.00	0
Bidens beckii	Water marigold	1	0.13	0.50	0.44	1.00	0
Eleocharis erythropoda	Bald spikerush	1	0.13	0.50	0.44	1.00	0
Myriophyllum verticillatum	Whorled watermilfoil	1	0.13	0.50	0.44	1.00	0
Potamogeton crispus	Curly-leaf pondweed	1	0.13	0.50	0.44	1.00	1
Potamogeton praelongus	White-stem pondweed	1	0.13	0.50	0.44	1.00	2
Potamogeton strictifolius	Stiff pondweed	1	0.13	0.50	0.44	1.00	0
Sagittaria graminea	Grass-leaved arrowhead	1	0.13	0.50	0.44	1.00	3
Schoenoplectus subterminalis	Water bulrush	1	0.13	0.50	0.44	2.00	1
Sparganium emersum	Short-stemmed bur-reed	1	0.13	0.50	0.44	1.00	0

Half Moon Lake Whole Lake Point Intercept Data Summary: July 1, 2023 (Continued)

Scientific name	Common name	Number of sites where species found	Relative Frequency (%)	Frequency of occurrence within vegetated areas (%)	Frequency of occurrence at sites shallower than maximum depth of plants	Average rake fullness	# Visual sightings
Stuckenia pectinata	Sago pondweed	1	0.13	0.50	0.44	2.00	1
Typha latifolia	Broad-leaved cattail	1	0.13	0.50	0.44	2.00	0
Utricularia intermedia	Flat-leaf bladderwort	1	0.13	0.50	0.44	1.00	0
Zizania palustris	Northern wild rice	1	0.13	0.50	0.44	1.00	0
Equisetum emersum	Water horsetail	**	**	**	**	**	1
Myriophyllum spicatum	Eurasian watermilfoil	**	**	**	**	**	2
Phalaris arundinacea	Reed canary grass	**	**	**	**	**	1
Schoenoplectus tabernaemontani	Softstem bulrush	**	**	**	**	**	1
Typha X glauca	Hybrid cattail	**	**	**	**	**	1
Bulboschoenus fluviatilis	River bulrush	***	***	***	***	***	***
Callamagrostis canadensis	Bluejoint	***	***	***	***	***	***
Carex comosa	Bottlebrush sedge	***	***	***	***	***	***
Iris versicolor	Northern blue flag	***	***	***	***	***	***
Potamogeton epihydrus	Ribbon-leaf pondweed	***	***	***	***	***	***
Potamogeton foliosus	Leafy pondweed	***	***	***	***	***	***
Sparganium eurycarpum	Common bur-reed	***	***	***	***	***	***

*Excluded from relative frequency analysis

**Visual Only

***Boat Survey