Management of Aquatic Plants and Sediments in the Harmony Grove Channels

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Introduction

The Harmony Grove Lake Protection and Rehabilitation District is located in southwest Columbia County. The District is comprised of five boating channels connected to Harmony Grove Bay on the Columbia County side of Lake Wisconsin (**Figures 1 and 2**). Lake Wisconsin is an impoundment lake on the Wisconsin River. The channels of Harmony Grove cover an area of 21 acres and have 3.9 miles of shoreline, a maximum depth of 7 feet, and an average depth of 4 feet. Over 175 homes are located on the Harmony Grove channels. As a result, boating use is high in the channels. Boaters have noted that navigation within in the channels has become increasingly problematic. Excessive weed growth and continued sediment accumulation have been identified as the main causes of this problem. It is not uncommon for a shallow, nutrient–rich system, such as the Harmony Grove channels, to support abundant growth of aquatic plants both native and exotic.

Recent Management

In recent years a considerable amount of money and time has been spent on studies to address the District's main concerns. Studies conducted in 2001 by Foth & Van Dyke (2001a, 2001b) focused on hydrology, water quality, and sediment characteristics. Management recommendations focused primarily on dredging. Results from this study were used to design a hydraulic dredging project, which included bids from two out-of-state environmental firms. However, the priority for dredging was not made clear in the results of these studies. Members of the Lake District voted not to proceed with the dredging project due in large part to the costs involved. Instead the District wished to investigate additional management practices to address the concerns over sediment accumulation as well as excessive aquatic plant growth.

In the late 1990's Lake Wisconsin was added to the list of Wisconsin waterbodies containing Eurasian watermilfoil (*Myriophyllum spicatum*). Curly-leaf pondweed (*Potamogeton crispus*) and purple loosestrife (*Lythrum salicaria*) have also recently been identified in the channels. These three species are exotic plants capable of reaching nuisance levels in and around lakes throughout Wisconsin. Prior to this study, the distribution of exotic species in the Harmony Grove channels had not been determined

Prior to this study, aquatic plant management has been carried out primarily on an individual property basis. Riparian property owners have either manually removed nuisance plants or hired applicators to chemically treat the shoreline. The District has also sponsored limited treatments for the purpose of navigation within the channels. Currently, with the continued nuisance caused by Eurasian watermilfoil, curly-leaf pondweed, and native plant species, the District wishes to take a more proactive approach to aquatic plant management.

Although much work has been accomplished in recent years, there were still some areas of concern which needed to be addressed before embarking on a management program. These concerns include improved sediment sampling methods, identification of the sources of sediment accumulation, and a more extensive review of sediment management alternatives. Also, excessive aquatic plant growth needed to be addressed in relation to the accumulation of sediments. In general, further analysis was needed to build a broader picture of the lake environment over time to prepare a long-term management plan.

Therefore, the primary goals of this management plan are 1) to address excessive weed growth and sediment accumulation through field investigations and a review of management alternatives, 2) to review options and associated costs for the management of aquatic plants and sediments, and 3) to gather additional information needed to develop a long-range management plan. It is the intention of the author to provide a document that both the District as well as individual riparian property owners can use to improve the conditions of the Harmony Grove channels.

Figure 1. Harmony Grove Bay on Lake Wisconsin, Columbia County and the surrounding area.

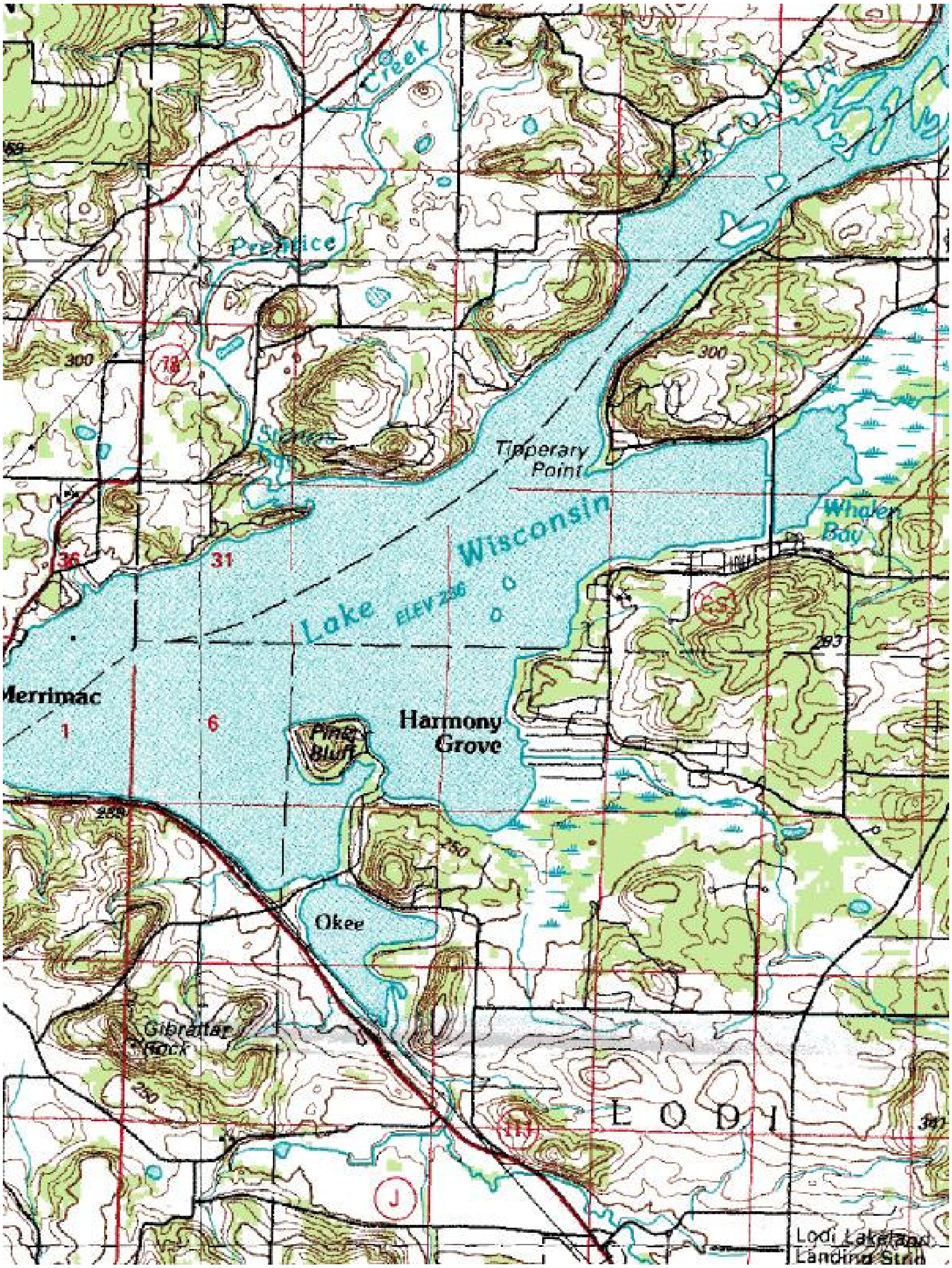
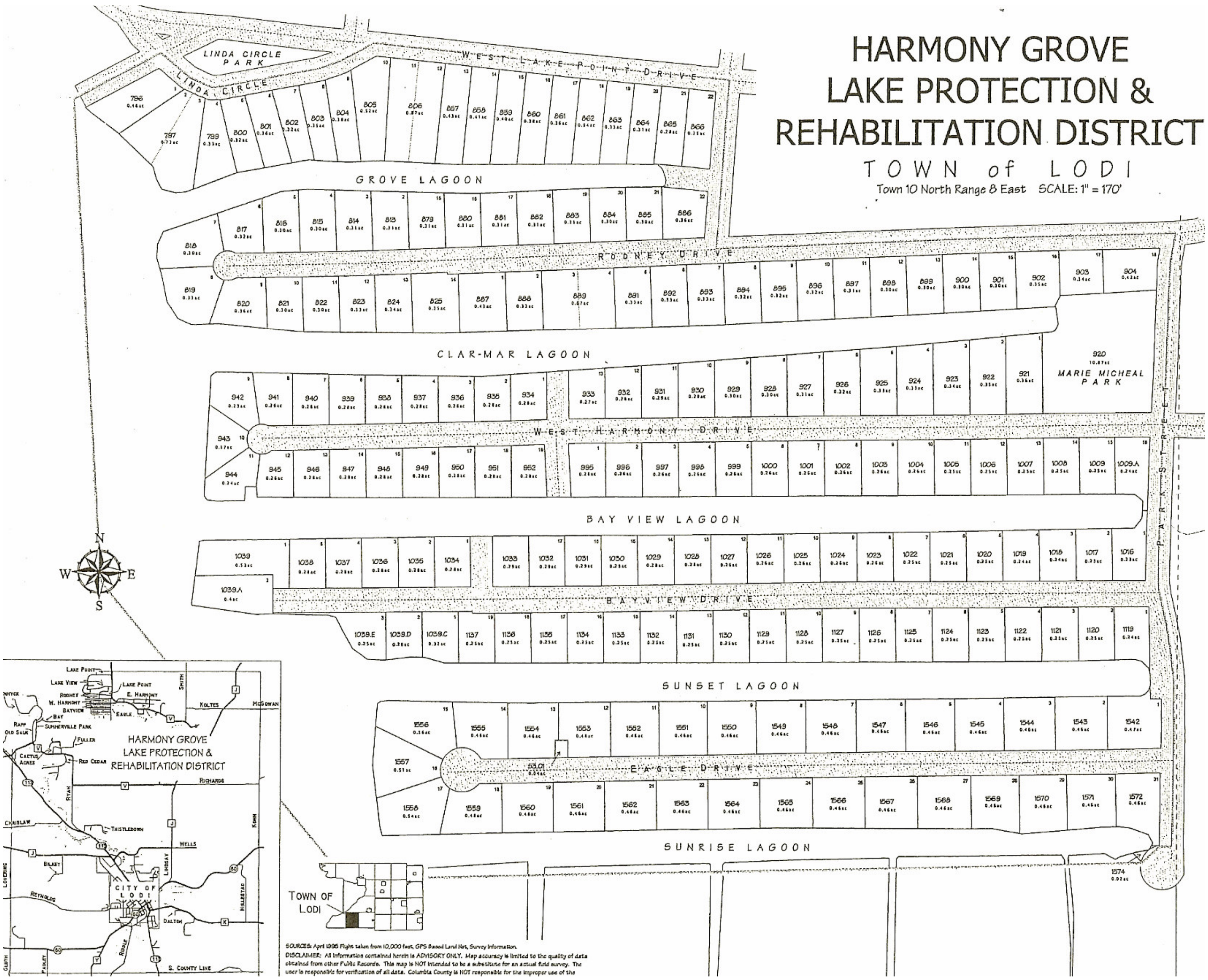


Figure 2. Harmony Grove Lake Protection and Rehabilitation District near the Town of Lodi in Columbia County, Wisconsin.



Methods

Sediment Analysis and Watershed Assessment

In order to obtain a permit to dredge sediments from Wisconsin waters, certain sediment sampling protocols need to be followed. These methods are described in Wis. Adm. Code NR 347.06 (4-6) (http://www.legis.state.wi.us/rsb/code/nr/nr347.pdf).

One important step in this process is the sampling of sediments and the analysis of these sediments for potentially hazardous compounds. On April 8, 2005, sediment core samples were collected using a two-inch diameter piston sediment corer. Following DNR recommendations, samples were collected at the center of each of the five Harmony Grove channels (**Figure 3**). For the purposes of this report, the five channels will be identified as channel A through channel E with channel A being the northern most. Data presented in the Phase 2 Lake Study Report from Foth & Van Dyke (2001b) were used to determine the depth of the core in each channel (**Table 1**). Since dredging would remove the upper soft sediment, it was important to determine the thickness of sediments in the channels.

Table 1*
Sediment Thickness
Harmony Grove Lake District

Sample Point – Lagoon ID	A	B	C	D	E
Average Sediment Thickness – Ft.	1.90	1.96	2.51	2.84	3.05
Range of Sediment Thickness – Ft.	1.4-2.6	1.0-2.3	1.8-4	1.3-4.5	1.5-4.5

* from Foth & Van Dyke, *Harmony Grove Lake District Phase 2 Lake Study Report*, August 2001

The total depth of the cores extended 2 feet deeper than the anticipated dredge cut. The cores were each separated at the dredge cut depth. This created two samples from each location; sediment that would be removed during dredging and sediment left behind. In each case, sediments from the upper and lower sections of the core were well mixed before being sent for analysis. Wis. Adm. Code NR 204 (http://www.legis.state.wi.us/rsb/code/nr/nr204.pdf) provides a list of analyses which are required to obtain a dredging permit. These analyses include heavy metals and organic pollutants.

Metal analyses for core samples included:

Arsenic	Lead
Cadmium	Mercury
Chromium	Nickel
Copper	Zinc

During the 2001 sampling by Foth & Van Dyke, sediment samples were tested for PCBs (Arochlor 1016, 1221, 1232, 1242, 1248, 1254, and 1260). Results from these tests showed no detection of PCBs in any of the samples (detection limits from 29-70 µg/kg ppb). As a result, DNR personnel did not require that additional tests for organic pollutants be run during this study.

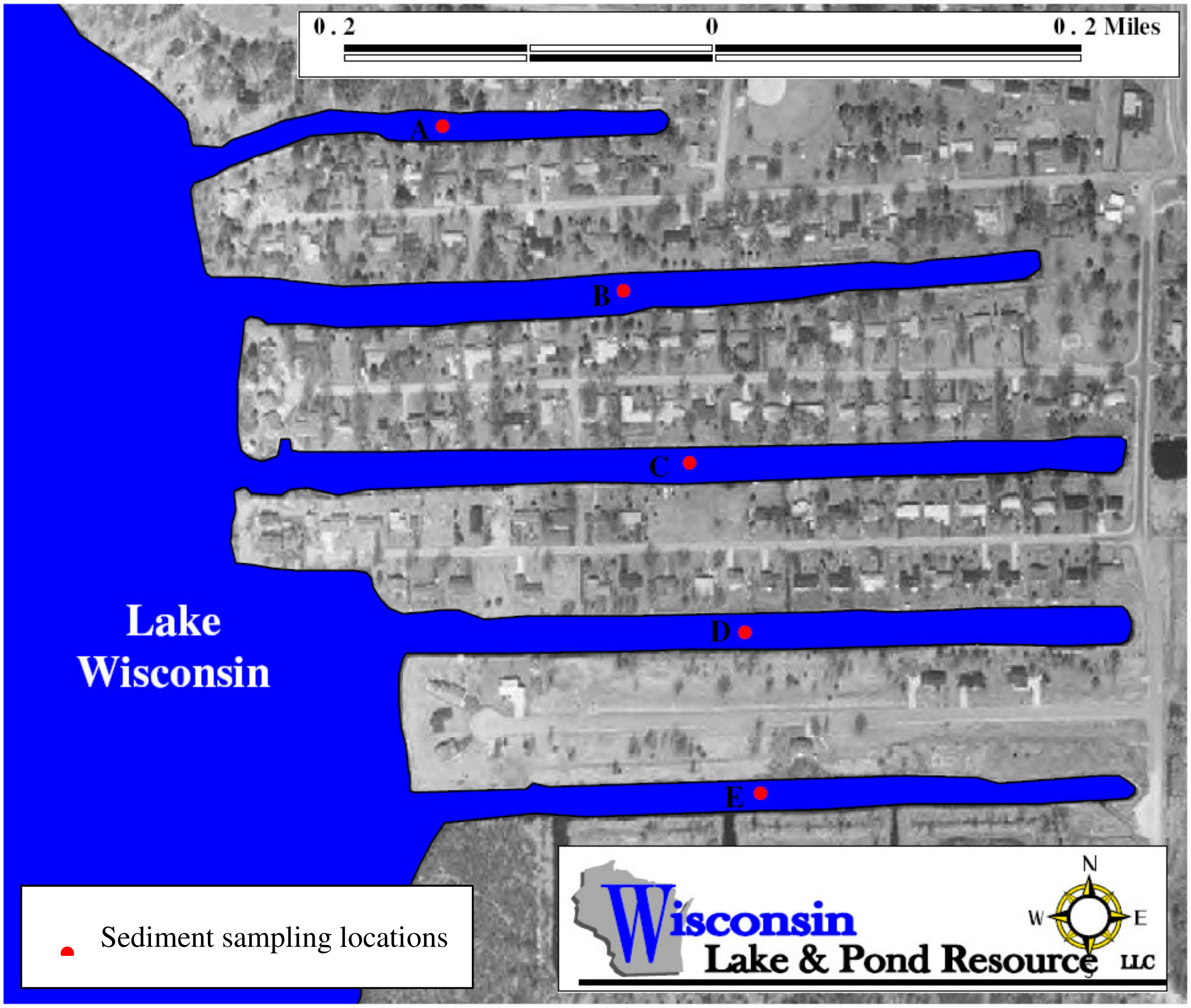
In addition to the heavy metal analyses conducted on the sediment samples, tests were run to determine the percent solids and nutrient concentrations in the sediments. This was done to determine if a correlation existed between sediment nutrient levels and aquatic plant growth.

These additional analyses included:

Ammonia – nitrogen,	Total phosphorus
Nitrate plus nitrite – nitrogen	Total organic carbon
Total Kjeldahl nitrogen	Total solids

Each parameter was analyzed by EPA approved method. All samples collected were sent to the State Lab of Hygiene for analysis. In addition to the analyses listed above, tests for percent volatile solids were requested. However, the State Lab of Hygiene does not perform this analysis. As a result, duplicate samples were sent to Badger Laboratories & Engineering, Inc. in Neenah, WI. In the process of running this additional test, Badger Labs were able to analyze total solids as well.

Figure 3. Location of sediment sampling points in the Harmony Grove channels



Aquatic Plant Survey

The aquatic plant community was not one of the focuses of the 2001 Foth & Van Dyke study. However, a number of concerns regarding the aquatic plant community and the effect it has had on the navigation and aesthetics of the Harmony Grove channels have recently been raised. These concerns have warranted the inclusion of an assessment of the aquatic plant community. An aquatic plant survey was conducted on July 7, 2005. It utilized reproducible methods so future surveys can accurately assess changes to the plant community. Because of the unique shape of the channels, the technique used was modified from current Wisconsin DNR sampling protocols developed to assess aquatic plant communities. A series of sampling transects (69 total) approximately 150 ft. apart from one another were mapped along the length of the channels (**Figure 4**). Samples were collected at three locations evenly spaced along each transect. Plant samples and bottom substrate composition data were collected at each sampling point. In addition, GPS and depth data were collected at the center of each transect. A total of 207 sites were sampled throughout the channels. To collect aquatic plant samples, one rake tow was made at each point. The rake used consisted of two short-toothed garden rake heads welded together and attached to a 15 foot telescoping pole. At each sample point, the rake was dragged along the bottom for approximately 2.5 feet to collect plants. All plant samples collected (including emergent and floating- leaf species) were identified to *genus* and *species* whenever possible, and recorded. An abundance rating was given for each species collected in each rake tow using the criteria described in **Figure 5**. Data collected were used to determine species composition, percent frequency and relative abundance. Voucher specimens for each aquatic plant species found were sent to the Robert W. Freckmann Herbarium at the University of Wisconsin – Stevens Point where the accuracy of all field identifications was verified. These samples were then returned to the Lake District.

Exotic plant species mapping

During the course of this project, a concerted effort was made to determine the extent of exotic aquatic plant species in the channels. Efforts focused primarily on mapping Eurasian watermilfoil, and curly-leaf pondweed growing in the channels and purple loosestrife growing along shore. Mapping took place at the time of the aquatic plant survey. The location and extent of Eurasian watermilfoil and curly-leaf pondweed beds were determined using surface observations and rake tows. The map drawings were superimposed upon an acreage grid to determine the area of the beds. Locations of purple loosestrife plants growing along the shoreline were also identified at the time of the plant survey.

Figure 4. Transects for the aquatic plant survey conducted on July 7, 2005 in the channels of Harmony Grove P & R District.

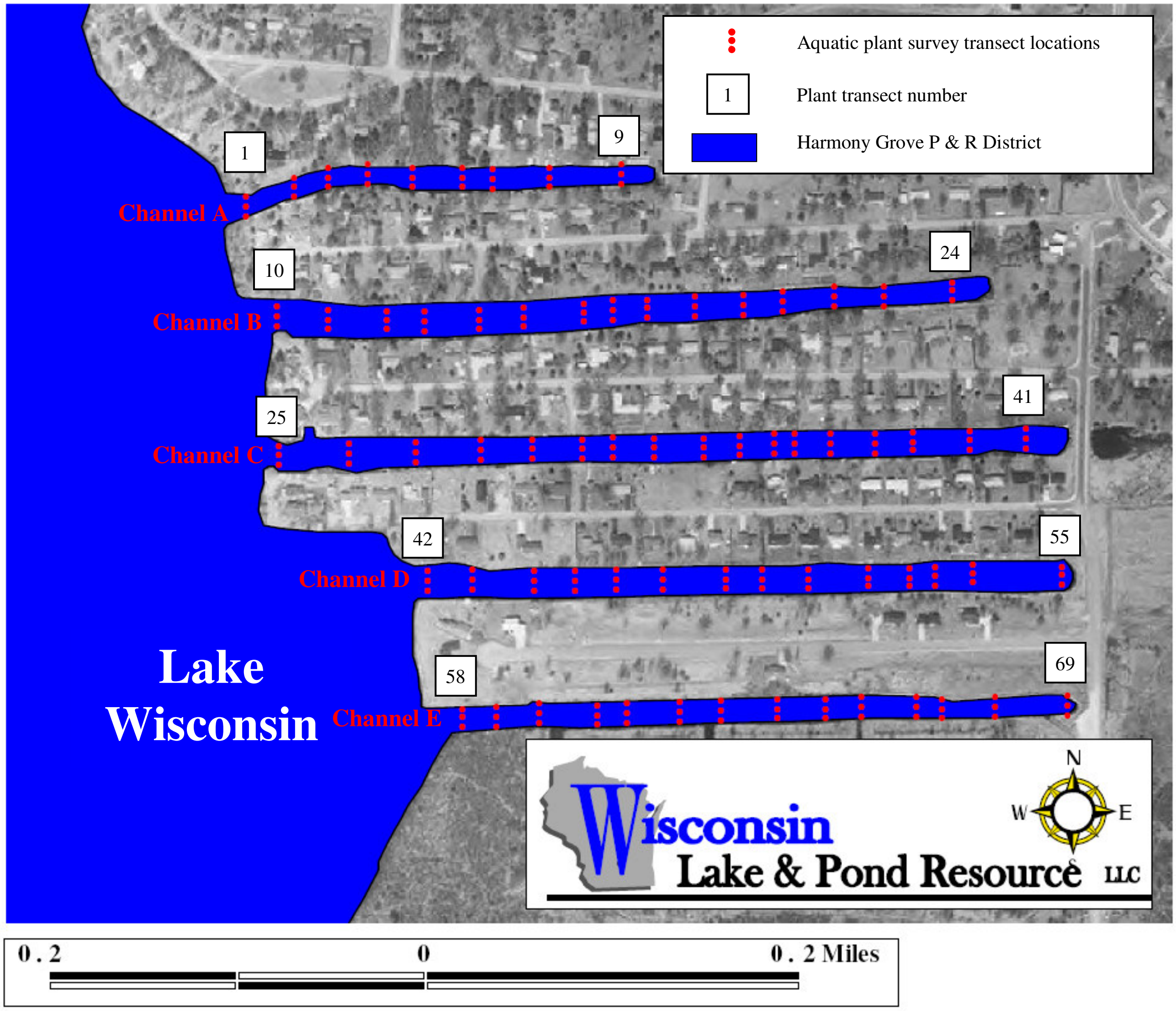
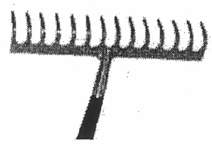
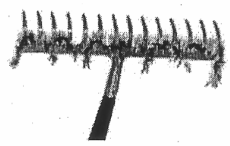
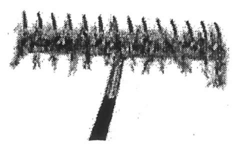
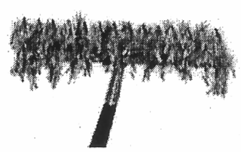
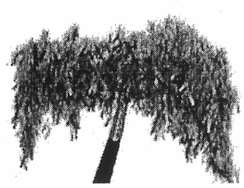


Figure 5. Plant abundance rating criteria used for all species during the aquatic plant survey conducted on the Harmony Grove channels on July 7, 2005.

Rating	Coverage	Description
0		➢ No plants on rake head
1		➢ Obviously less than ½ ➢ Uniform cover toward base
2		➢ Rake head is about ½ full ➢ Can easily see top of rake head
3		➢ Obviously more than ½ full ➢ Not overflowing ➢ Can barely see top of rake head
4		➢ Overflowing ➢ Cannot see top of rake head

Water Quality

An effort was made to assess the general water quality and health of the channels. In June and September 2005, water chemistry and limnology analyses were conducted at the center of each channel. Analyses conducted included dissolved oxygen, temperature, water transparency (Secchi depth), and pH. Profiles of dissolved oxygen and temperature as well as surface pH values were collected with the use of a Hach LDO - HQ20 portable dissolved oxygen/pH meter. .Measurements for dissolved oxygen and temperature were taken at 1-foot intervals from surface to bottom. A Secchi disc, a weighted black and white disc, was used to visually measure the water clarity in the channels.

From May to October 2005, volunteers from the Lake District also monitored the water quality in the Harmony Grove channels. Measurements of water clarity (Secchi depth), surface oxygen and temperature were made. Sample were also collected and sent to the State Lab of Hygiene for analysis of total phosphorus, and chlorophyll *a*. Values obtained for Secchi depth, total phosphorus, and chlorophyll *a* were used to calculate Trophic State Index (TSI) values. This index is a mathematical tool used to quantify the productivity or trophic state of a lake.

Watershed Assessment

A previous watershed delineation and description for the Harmony Grove channels was presented in the Foth & Van Dyke study (2001a). To expand on this work, a visual assessment of potential sediment and nutrient loading sources in the immediate watershed was performed.

Special attention was made to the condition of the Harmony Grove shoreline. Since a significant amount of nutrients and sediments can enter a lake from areas closest to the lake, it was important to focus on the entire shore and identify potential areas of concern. These included areas of disturbance, high erosion, or generally poor riparian health.

Results

Sediment Analysis

Results of metal, nutrient and solid analyses for the sediment samples collected in the Harmony Grove channels can be found in **Tables 2 and 3**.

Metal analysis results
Wis. Adm. Code NR 204 provides limits for heavy metal pollutant concentrations for dredged materials intended for land application. All heavy metal analyses conducted on the Harmony Grove sediments show concentrations well below the acceptable pollutant concentrations. In fact, half of the analyses conducted had metal concentrations below detectable levels. The highest metal concentrations were found in the upper sediment layer of Channels C and E.

Nutrient and solids analysis results
Although Wis. Adm. Code NR 204 does not specifically require analysis of nutrients or solids in sediments, these tests were performed to better understand the characteristics of the sediments in Harmony Grove. These tests also shed some light on the possible relationships between these parameters and metal concentrations and the distribution of aquatic plants.

Both the State Lab of Hygiene and Badger Labs performed analyses of percent solids on all samples collected. In addition, the State Lab of Hygiene performed a percent organic carbon test while Badger Labs conducted a percent volatile solids test. Both tests are designed to estimate the amount of organic material in the sediments. Generally speaking, results from the two labs were in agreement. Percent solids results agreed within eight percentage points with the exception of the upper sediment layer of channel B. During the aquatic plant survey, sediment types were recorded for all sampling locations. As expected, those samples that showed the highest percent solids were those dominated by sand, while those with the lowest solids concentrations had a more organic or muck-like quality. This is also seen in the additional test results. For example, the upper sediment layers of channels C and E had relatively lower percent solids and correspondingly higher concentrations of both total organic carbon and volatile solids.

Sediments with higher volatile solids concentrations also have high levels of naturally occurring levels of humic substance. Humic substances are organic compounds that are degradation-resistant materials most commonly formed during the decomposition of vegetation. These compounds are important players in aquatic chemistry (Manahan, 1994, Caillie et al., 2003). Many of these compounds will naturally bind or *chelate* to metals and nutrients such as phosphorus. It is not surprising then to see that the samples with the highest organic content (Channels C and E) had correspondingly higher concentrations of nutrients and, as previously stated, metal concentrations. Keep in mind that the metal concentrations are high in relation to the other samples collected but still fall well below the acceptable level for dredging.

Table 2. Results of sediment analyses performed in April 2005 from Channels A, B and C of Harmony Grove, Columbia, County, Wisconsin.

Parameter	Units	LOD[1]	Pollutant concentration[2]	Channel A		Channel B		Channel C	
				Upper	Lower	Upper	Lower	Upper	Lower
Arsenic	mg/kg	5	41	ND	ND	ND	ND	ND	ND
Cadmium	mg/kg	0.6	39	ND	ND	ND	ND	ND	ND
Chromium	mg/kg	0.5	n/a	5.9	3.2	5.8	1.9	32.5	4.5
Copper	mg/kg	0.5	1500	2.7	2.0	4	1.4	18.3	2.1
Lead	mg/kg	3	300	ND	ND	4.0	ND	15.0	ND
Mercury	mg/kg	0.015	17	ND	ND	ND	ND	0.1	ND
Nickel	mg/kg	2	420	2.0	ND	3.0	ND	11.0	ND
Zinc	mg/kg	2	2800	6	4	10	3	44	4
Ammonia - nitrogen	mg/kg	0.16	n/a	9.7	3.6	26.6	4.9	81.3	5.7
Nitrate plus nitrite - nitrogen	mg/kg	0.25	n/a	0.3	0.5	0.6	ND	2.0	ND
Total Kjeldahl nitrogen	mg/kg	n/a	n/a	380	<230	1840	<230	5260	727
Total phosphorus	mg/kg	9.9	n/a	111	57.9	343	47.9	484	87.1
Total organic carbon	ug/g	1650	n/a	6760	2510	39000	ND	54800	6100
Percent Solids (SLOH)	%	0	n/a	72.1	75.2	31.5	78.2	31.6	73.8
Percent Solids (Badger Labs)	%	0.1	n/a	65.6	72.5	73	74	24.1	66.1
Volatile Solids	%	0.1	n/a	2.1	0.84	0.75	0.46	13.1	2.7

[1] Limit of Detection
[2] Concentration limit for pollutant for sludge to be considered high quality.

n/a = not applicable

ND = not detected

Table 3. Results of sediment analyses performed in April 2005 from Channels D and E of Harmony Grove, Columbia, County, Wisconsin.

Parameter	Units	LOD[1]	Pollutant concentration[2]	Channel D Upper	Channel D Lower	Channel E Upper	Channel E Lower
Arsenic	mg/kg	5	41	ND	ND	15	ND
Cadmium	mg/kg	0.6	39	ND	ND	ND	ND
Chromium	mg/kg	0.5	n/a	2.2	1.7	27.9	2.4
Copper	mg/kg	0.5	1500	1.7	1.4	10.1	0.8
Lead	mg/kg	3	300	ND	ND	8	ND
Mercury	mg/kg	0.015	17	ND	ND	0.022	ND
Nickel	mg/kg	2	420	ND	ND	10	ND
Zinc	mg/kg	2	2800	3	3.0	21	4.0
Ammonia - nitrogen	mg/kg	0.16	n/a	4.7	1.7	43	2.2
Nitrate plus nitrite - nitrogen	mg/kg	0.25	n/a	ND	ND	n/a	0.4
Total Kjeldahl nitrogen	mg/kg	n/a	n/a	<230	<230	5030	<230
Total phosphorus	mg/kg	9.9	n/a	66.5	54.8	297	54.0
Total organic carbon	ug/g	1650	n/a	3960	ND	52900	ND
Percent Solids (SLOH)	%	0	n/a	73.9	79.4	29.8	79.7
Percent Solids (Badger Labs)	%	0.1	n/a	75.5	74.1	28	73.7
Volatile Solids	%	0.1	n/a	0.35	0.2	17.2	0.3

[1] Limit of Detection
[2] Concentration limit for pollutant for sludge to be considered high quality.

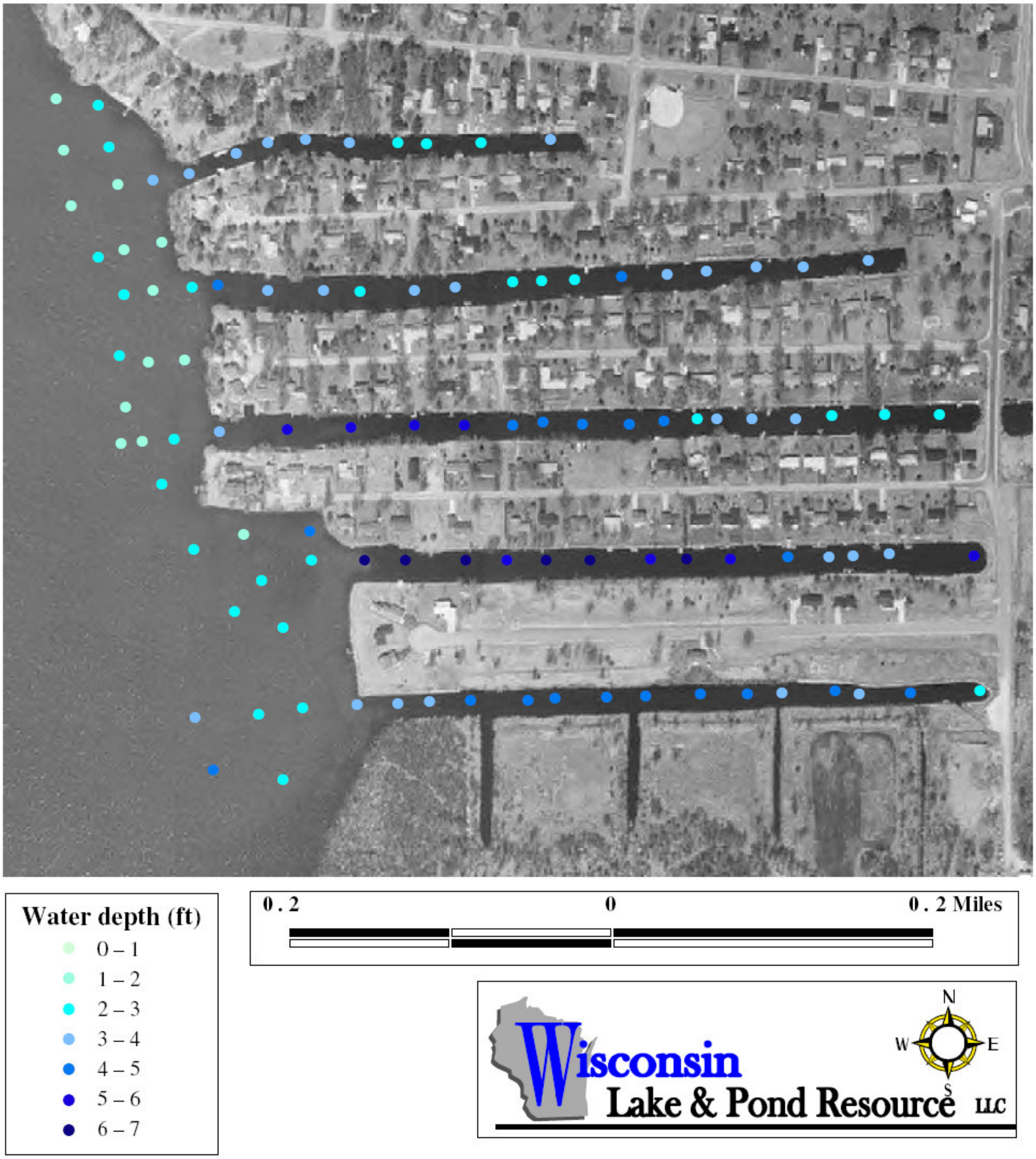
n/a = not applicable

ND = not detected

Depths of Channels

Data collected during the aquatic plant survey were used to map the depths of the channels (**Figure 7**). Additional data points were measured outside the channels as well. Channels A and B are the shallowest of the channels. It is in these channels that navigation is most hindered by sediment. Much of the remaining channels are deeper and currently do not to hinder boating to the same extent. In general the eastern portions of each channel appear to be the areas of greatest sediment accumulation. However, at the time of the survey, it was noted that the areas of Lake Wisconsin just outside the channels are also extremely shallow. These areas likely pose an equal, if not greater, hindrance to boating.

Figure 5. Water depths on July 7, 2005 in the Harmony Grove Lake Protection and Rehabilitation District



Aquatic Plant Community

Data collected during the July 7, 2005 aquatic plant survey found a total of 17 plant species growing in the Harmony Grove channels (**Table 4**). These included 13 species of submergent macrophytes (including Eurasian watermilfoil and curly-leaf pondweed), three species of floating-leaf plant species, and filamentous green algae. These results show a high degree of species richness in the channels, particularly for artificial channels in southern Wisconsin. Of the 207 sites sampled, aquatic plants were found at all but six locations. The most abundant plant species encountered were common waterweed (*Elodea canadensis*) filamentous green algae (*Cladophora*, *Pithophora*, etc.), coontail (*Ceratophyllum demersum*), and white water lily (*Nymphaea odorata*). Each of these species was found in more than two-thirds of the sampling points. Eurasian watermilfoil and curly-leaf pondweed were also found in high numbers, as were the duckweeds (*Lemna minor*, *Wolffia columbiana*). The *Percent Frequency* column in **Table 4** describes the occurrence of a particular species in relation to the total number of sites sampled, while *Percent Composition* describes the occurrence of a species in relation to all other plant species found on site. **Figure 4** presents the relative abundance of aquatic plant species found in The Harmony Grove channels at the time of the survey.

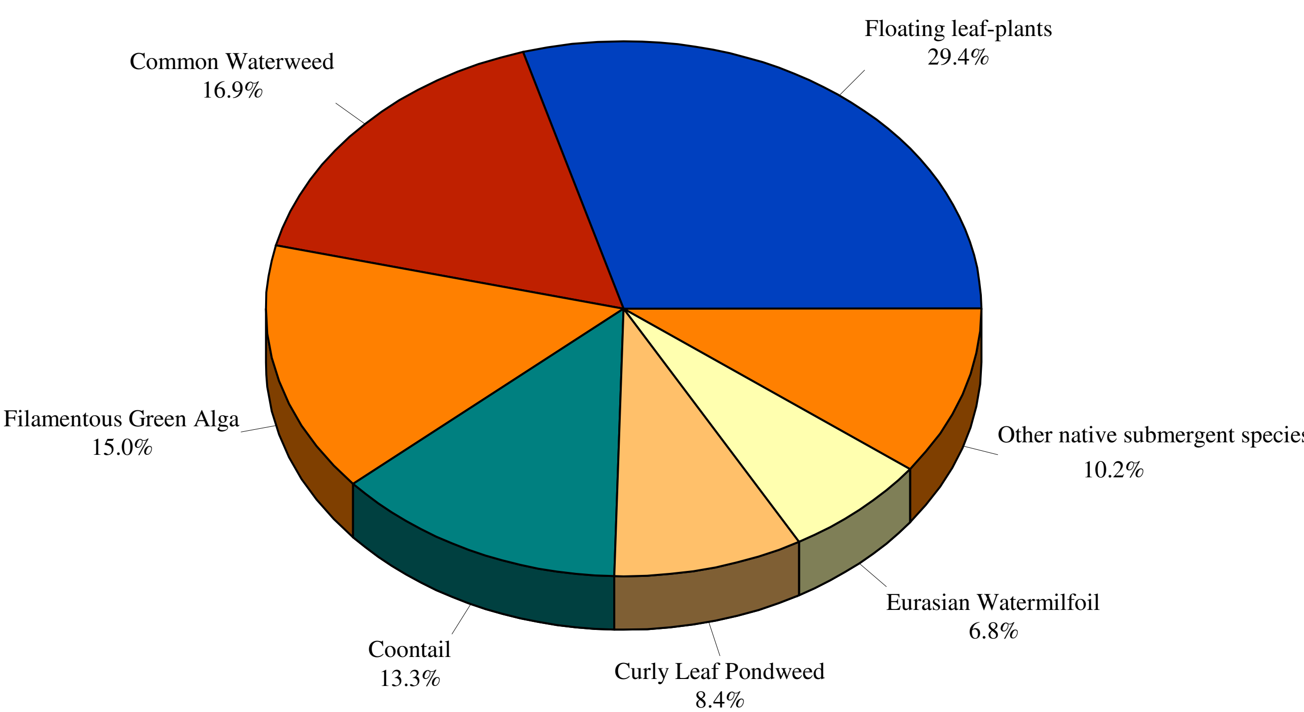
Figures 7 to 12 present the distribution of the six most abundant native plant species according to the transect survey data. The abundance rating given corresponds to the criteria described in the plant survey methods and shown in **Figure 5**. For floating leaf species the abundance ratings given were in relation to the amount of surface area covered by the particular species. **Figures 13 and 14** present the distribution of Eurasian watermilfoil and curly-leaf pondweed. The purpose of these figures is to illustrate the abundance of each of these species in the Harmony Grove Channels. Eurasian watermilfoil and curly-leaf pondweed in particular are a concern because they are both non-native species with the potential to dominate a plant community. However, as is evident from the distribution maps a number of native species in the Harmony Grove Channels, namely common waterweed and coontail have reached nuisance levels and should be taken into account when management decisions are made. Additionally, the wide distribution of species such as duckweeds and filamentous algae *may* indicate that low water quality and areas of possible stagnation could occur within the channels.

The results of comparing sediment nutrient characteristics and plant distribution did not reveal a strong correlation. If a correlation existed, one would expect to find a higher density of rooted aquatic macrophytes in the channels with the highest volatile organic and nutrient content. However, as is evident in **Figures 7 -13**, channels C and E which had the highest concentrations of nutrients and total volatile solids did not have noticeably higher macrophyte densities. While aquatic plant growth can typically be correlated with sediment nutrient levels, it is evident from these findings that sufficient nutrients exist in all of the channels to support diverse macrophyte communities.

Table 4. Results of the aquatic plant survey conducted in Harmony Grove, July 7, 2005.

Plant Species		Total	Percent	Percent
Common name	Scientific name	Frequency	Frequency	Composition
Common waterweed	*Elodea canadensis*	*182*	90.55	16.88
Filamentous green algae	*Cladophora, Pithophora,* etc.	*162*	80.60	15.03
Coontail	*Ceratophyllum demersum*	*143*	71.14	13.27
White Water Lily	*Nymphaea odorata*	*136*	67.66	12.62
Common watermeal	*Wolffia columbiana*	*93*	46.27	8.63
Curly-leaf pondweed	*Potamogeton crispus*	*91*	45.27	8.44
Small duckweed	*Lemna minor*	*88*	43.78	8.16
Eurasian watermilfoil	*Myriophyllum spicatum*	*73*	36.32	6.77
Wild celery	*Vallisneria americana*	*58*	28.86	5.38
Small pondweed	*Potamogeton pusillus*	*12*	5.97	1.11
Flatstem pondweed	*Potamogeton zosteriformis*	*11*	5.47	1.02
Clasping-leaf pondweed	*Potamogeton richardsonii*	*11*	5.47	1.02
Sago pondweed	*Stuckenia pectinata*	*9*	4.48	0.83
Slender naiad	*Najas flexilis*	*3*	1.49	0.28
Long-leaf pondweed	*Potamogeton nodosus*	*3*	1.49	0.28
Water stargrass	*Heteranthera dubia*	*2*	1.00	0.19
Variable pondweed	*Potamogeton gramineus*	*1*	0.50	0.09
		1078		*100*

Figure 6. Plant community composition for Harmony Grove, July 7, 2005.



Assessment of Floristic Quality

The plant data collect for Harmony Grove were used to assess the "floristic quality" of the channels. The method used assigns a value to each native plant species called a Coefficient of Conservatism. Coefficient values range from 0 -10 and reflect a particular species' likelihood of occurring in a relatively undisturbed landscape. Species with low coefficient values, such as coontail, are likely to be found in a variety of habitat types and can tolerate high levels of human disturbance. On the other hand, species with higher coefficient values, such as long-leaf pondweed, are much more likely to be restricted to high quality natural areas. Eurasian watermilfoil and curly-leaf pondweed are exotic species and therefore are not assigned coefficient values. By averaging the coefficient values available for the submergent and emergent species found in Harmony Grove a lake-wide value of 5.36 was calculated (**Table 5**).

By utilizing the Coefficients of Conservatism for the plant species of Harmony Grove, further assessment of floristic quality can be made. By multiplying the average coefficient values for Harmony Grove by the square root of the number of plant species found (not including exotic species) a Floristic Quality Index (FQI) value was calculated at 20.04 (**Table 5**). In general, higher FQI values reflect higher lake quality. The average for Wisconsin lakes is 22.2.

Both Coefficient of Conservatism and the Floristic Quality Index values are just slightly below the State-wide average. This is not a reason for concern considering these are artificially constructed channels in Southern Wisconsin where FQI values are often even lower. A number of species found had relatively high coefficient values (*Potamogetons* in particular). For this reason, it is important that aquatic plant management in the channels include the protection of native species.

Table 5. Harmony Grove Floristic Quality Index (FQI) analysis table.

Common Name	Species	C
Coontail	*Ceratophyllum demersum*	3
Common waterweed	*Elodea canadensis*	3
Small duckweed	*Lemna minor*	5
Bushy pondweed	*Najas flexilis*	6
White water lily	*Nymphaea odorata*	6
Variable pondweed	*Potamogeton gramineus*	7
Long-leaf pondweed	*Potamogeton nodosus*	7
Small pondweed	*Potamogeton pusillus*	7
Clasping-leaf pondweed	*Potamogeton richardsonii*	5
Flat-stem pondweed	*Potamogeton zosteriformis*	6
Sago pondweed	*Stuckenia pectinata*	3
Wild celery	*Vallisneria americana*	6
Common watermeal	*Wolffia columbiana*	5
Water star-grass	*Zosterella dubia*	6
	N	14
	mean C	5.36
	FQI	20.04

Figure 7. **Distribution of common waterweed (*Elodea canadensis*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.**

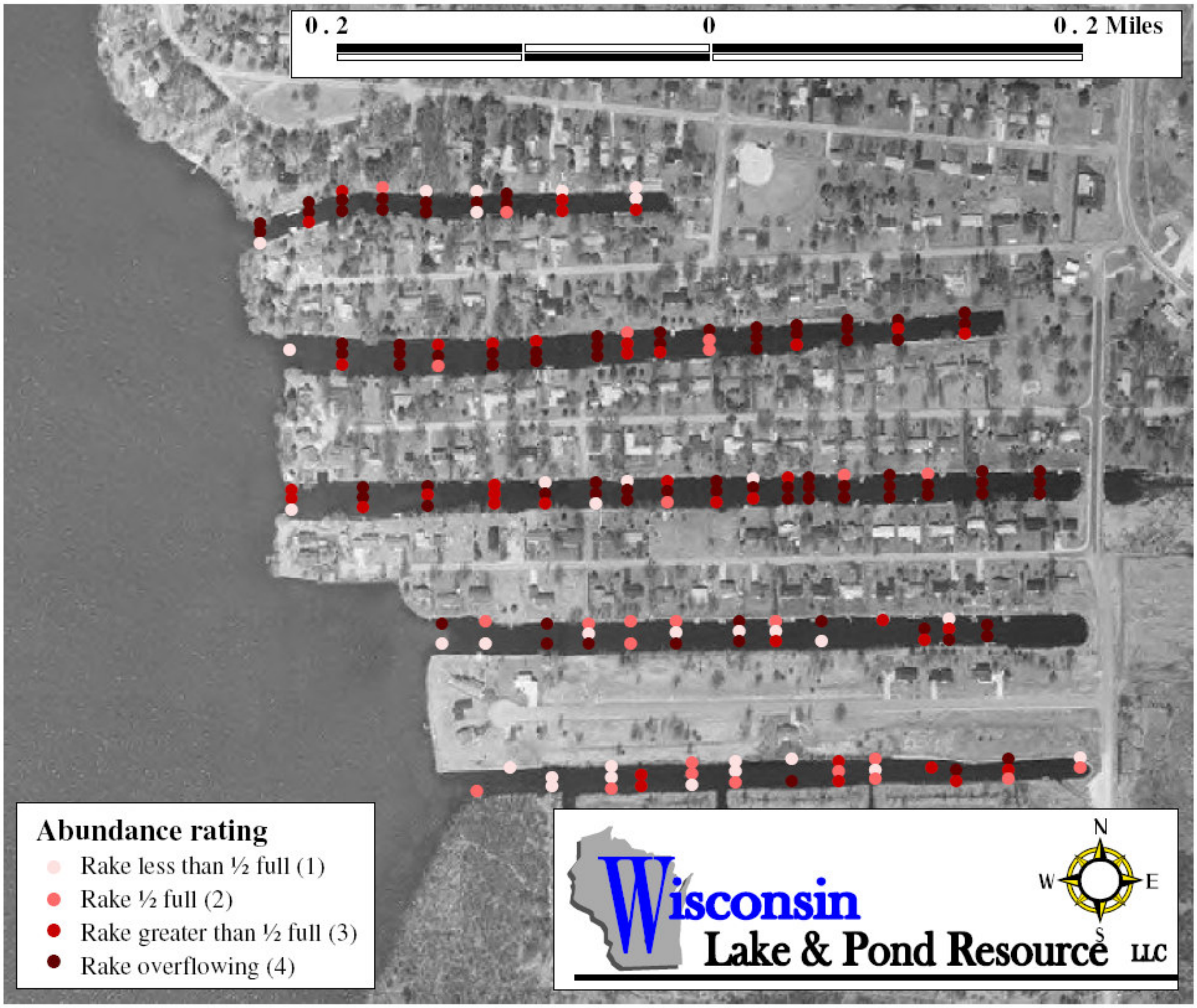


Figure 8. **Distribution of filamentous algae on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.**

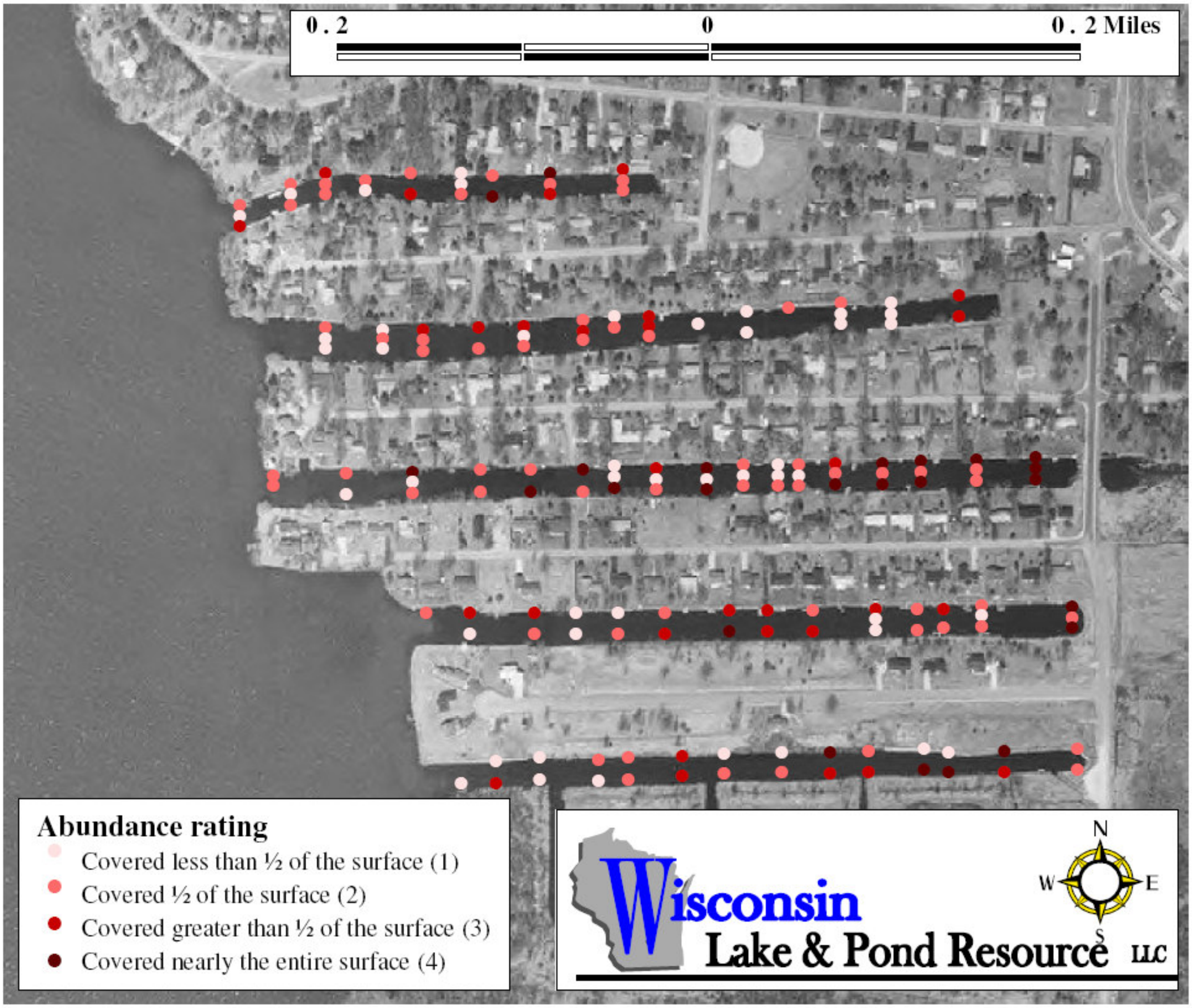


Figure 9. **Distribution of coontail (*Ceratophyllum demersum*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.**

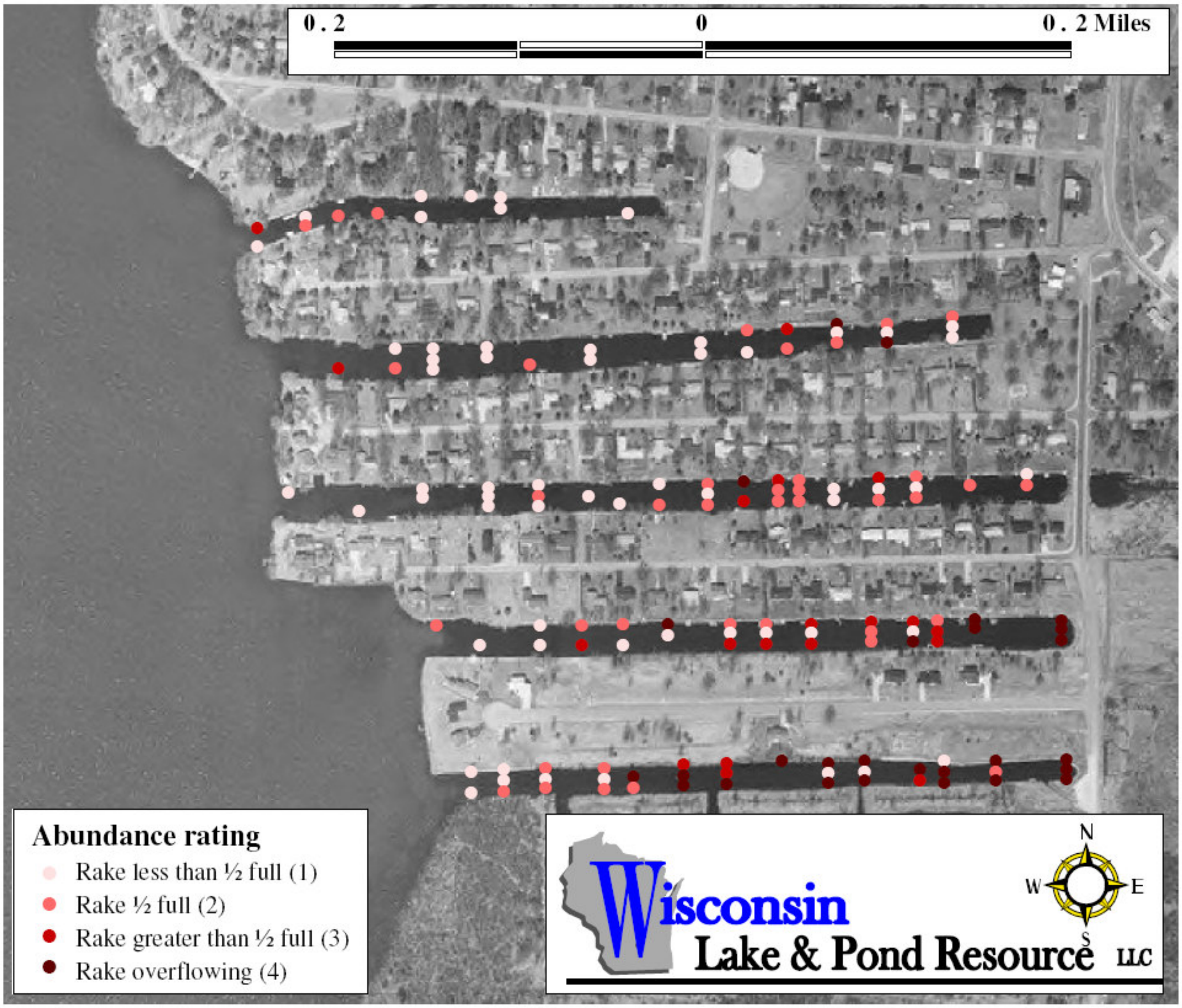


Figure 10. Distribution of white water lily (*Nymphaea odorata*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.

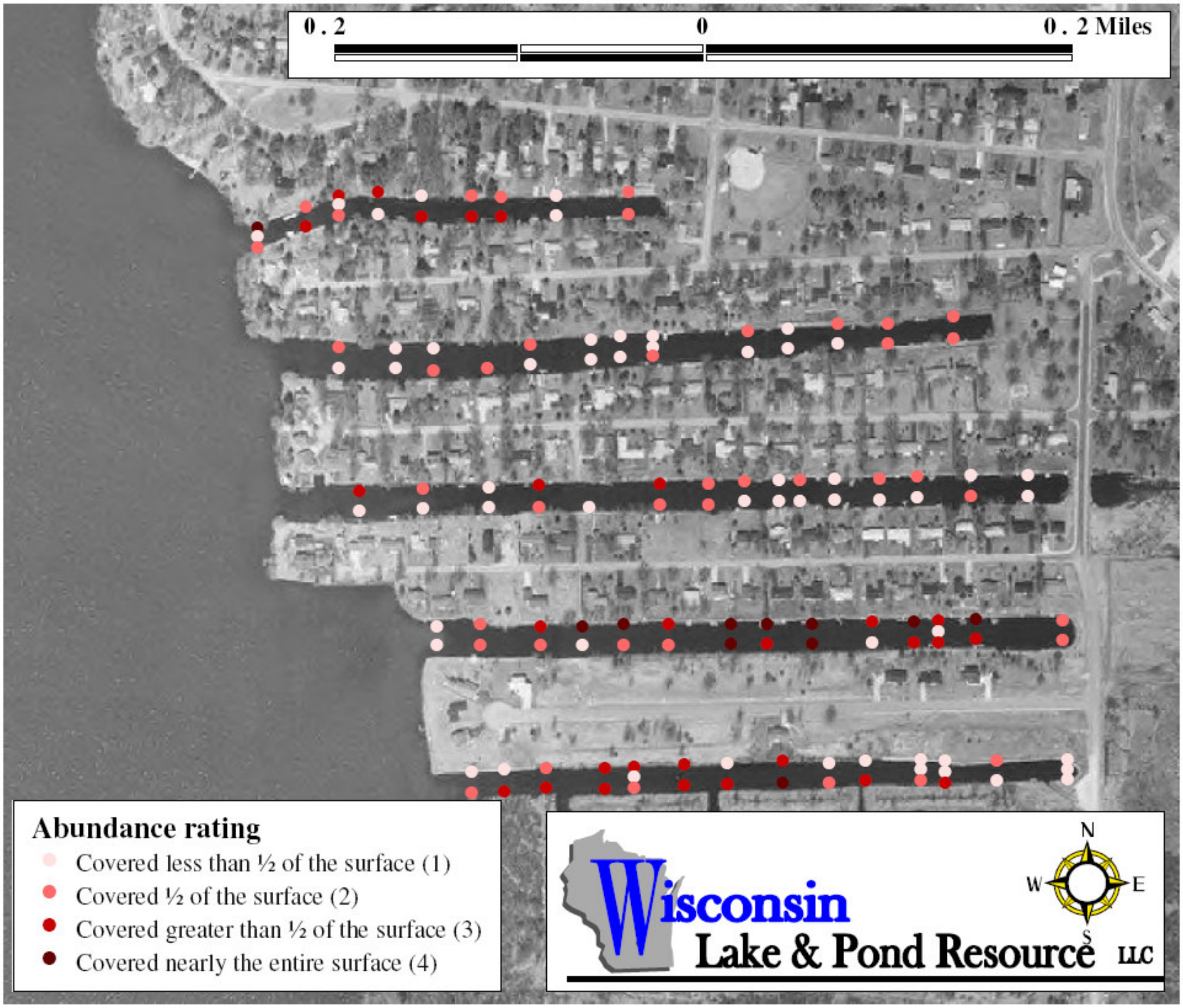


Figure 11. Distribution of duckweeds (*Lemna minor*, *Wolffia columbiana*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.

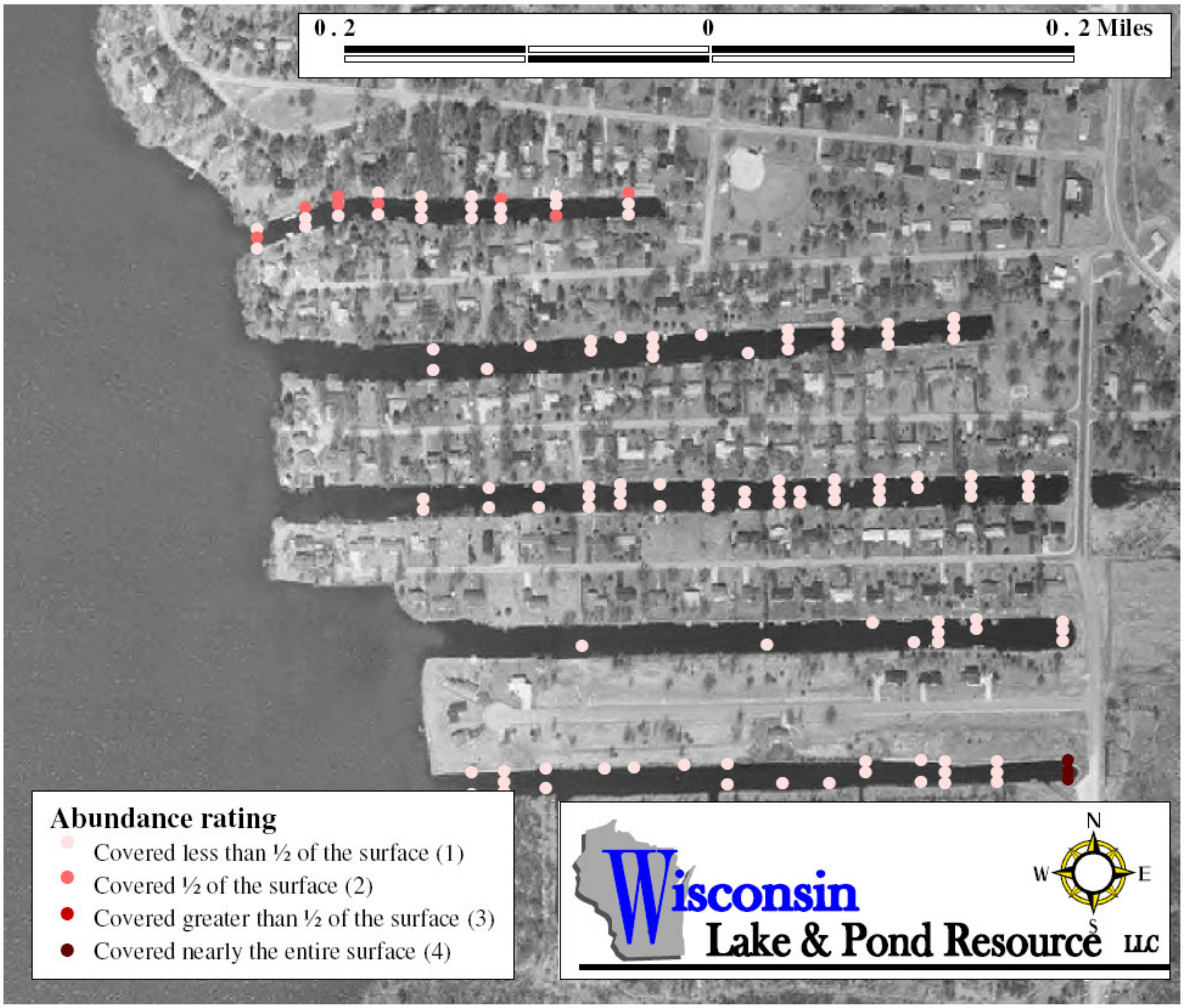


Figure12. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.

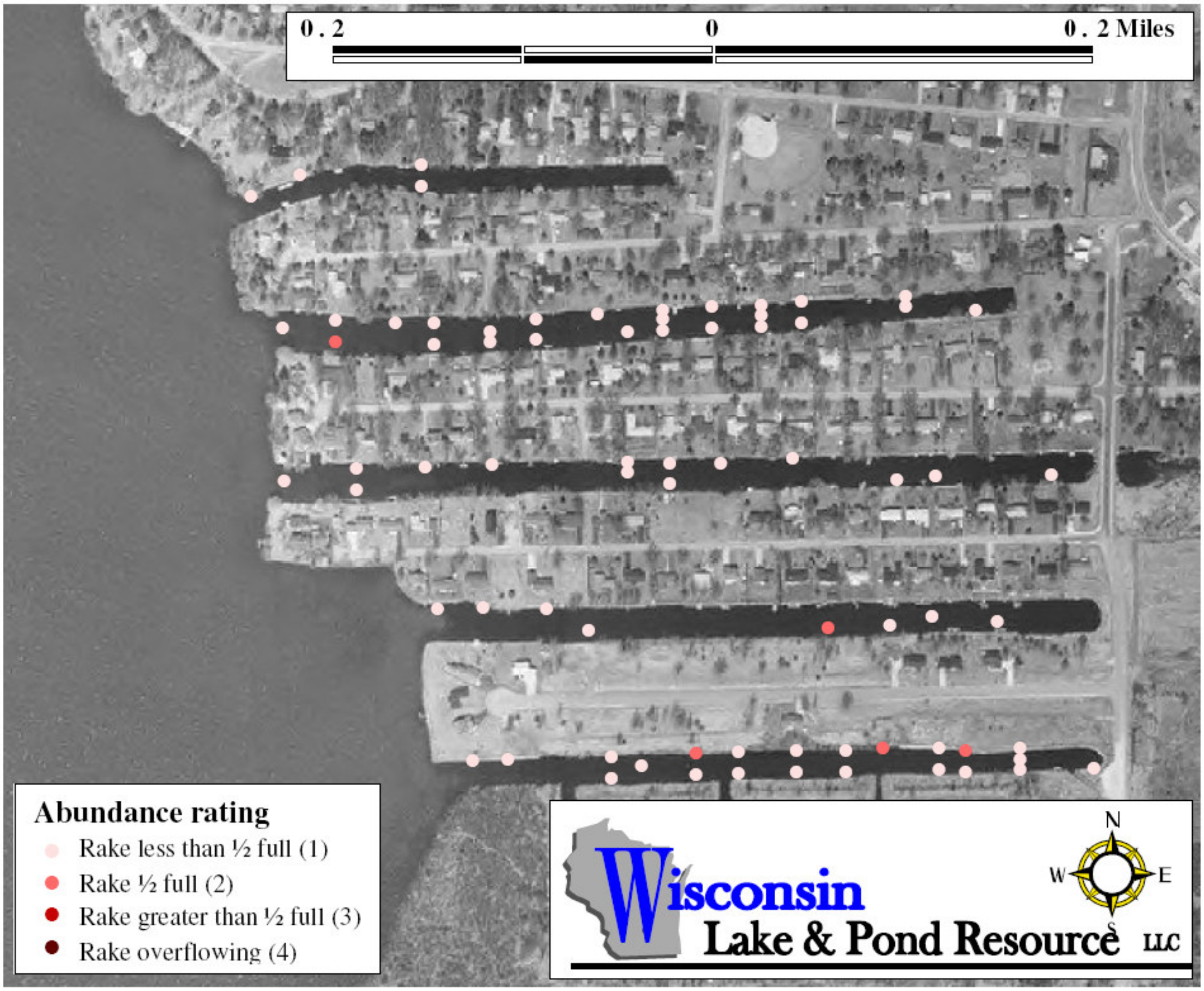
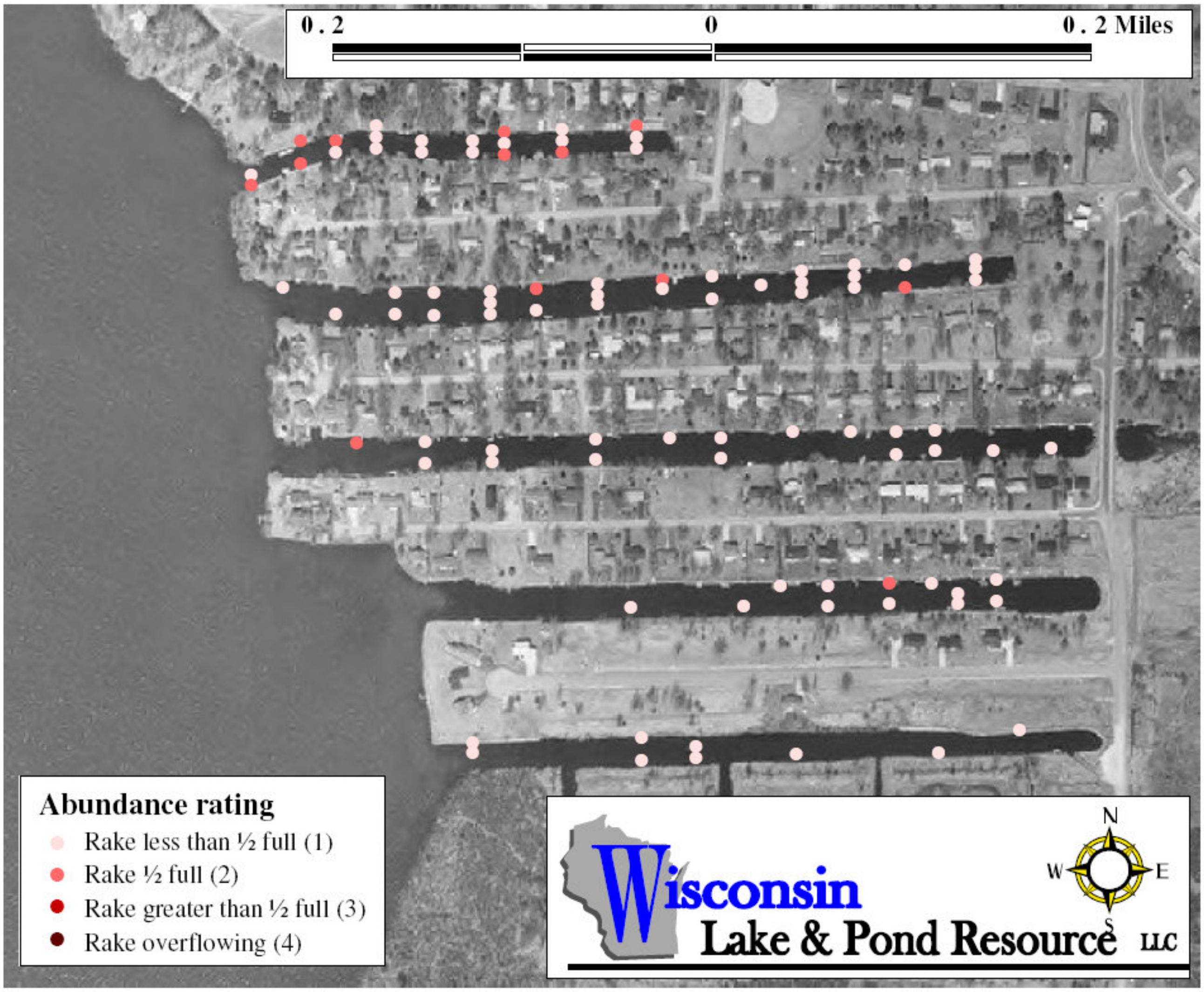


Figure 13. Distribution of curly-leaf pondweed (*Potamogeton crispus*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.



Exotic Species Mapping

The exotic species mapping, which took place in July 2005, found approximately 6.7 acres of Eurasian watermilfoil (**Figure 14**) and 6.8 acres of curly-leaf pondweed (**Figure 15**). It was noted at the time of the plant survey that the distribution of curly-leaf pondweed had been greater in the weeks prior. However, the warm water conditions at that time likely contributed to the beginning stages of curly-leaf die off (senescence). Curly-leaf pondweed is a cold-adapted plant species. It can begin growing under the ice while other plants are dormant. By mid-summer when temperatures reach the upper 70º F range, however, the plant begins to die. There is a good likelihood that this had begun prior to the plant survey. As a result, the data collected for curly-leaf pondweed, likely do not sufficiently reflect the full extent of this species in the Harmony Grove Channels.

A visual survey of the emergent plants growing along the lakeshore found purple loosestrife, an exotic wetland species, growing along several areas of the lake shoreline (**Figure 16**). Although not extensive at this point, if left alone, it too can reach nuisance levels.

Many property owners have noted that the dense vegetation in the channels has limited motor boating activities. The results of the aquatic plant survey show that although Eurasian watermilfoil and curly-leaf pondweed are present, they are at lower levels than a number of native species. At the time of the plant survey, the native plants, namely common waterweed and coontail, were a greater nuisance than either of the two exotic species.

Figure 14. **Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.**

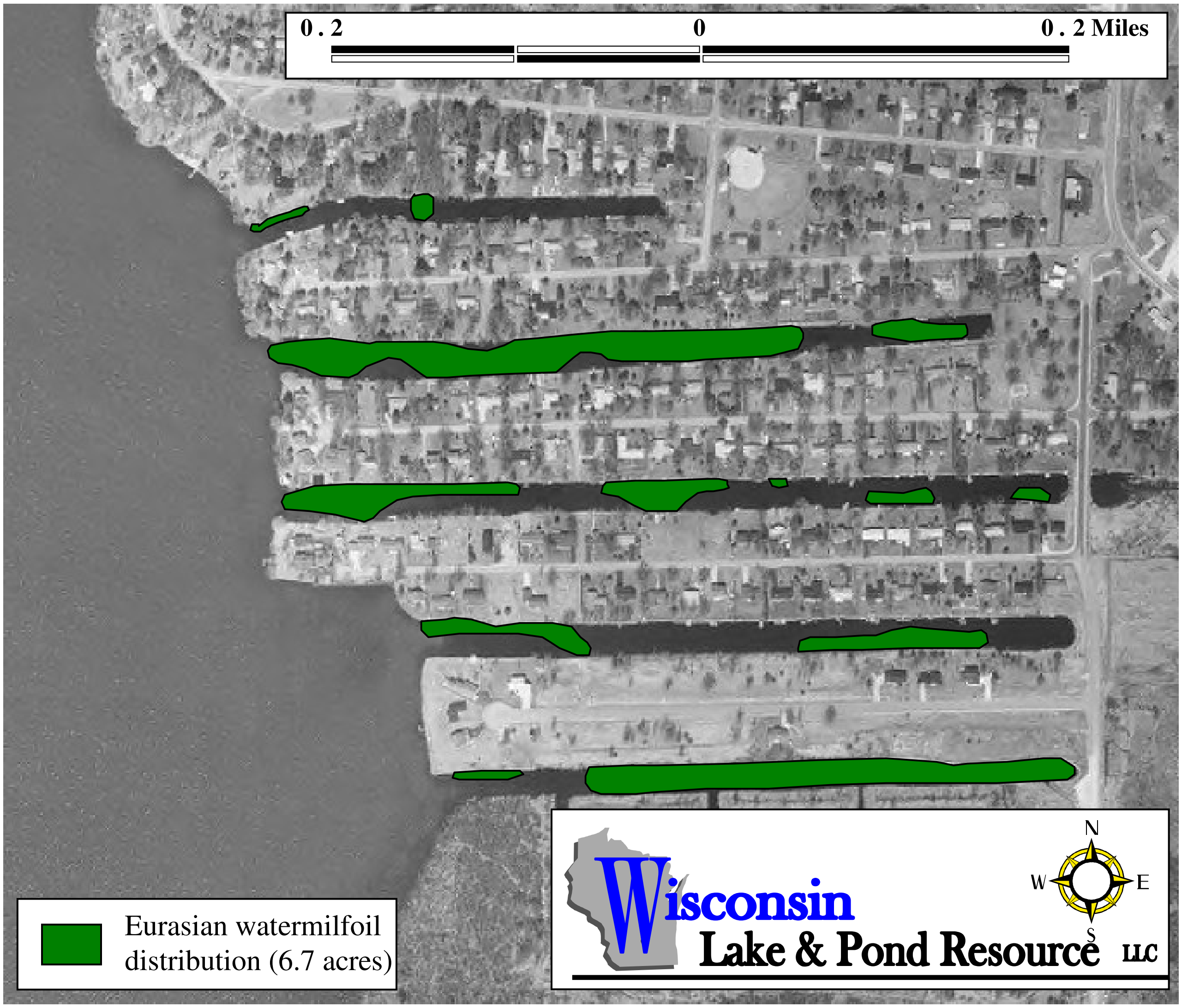


Figure 15. Distribution of curly-leaf pondweed (*Potamogeton crispus*) on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.

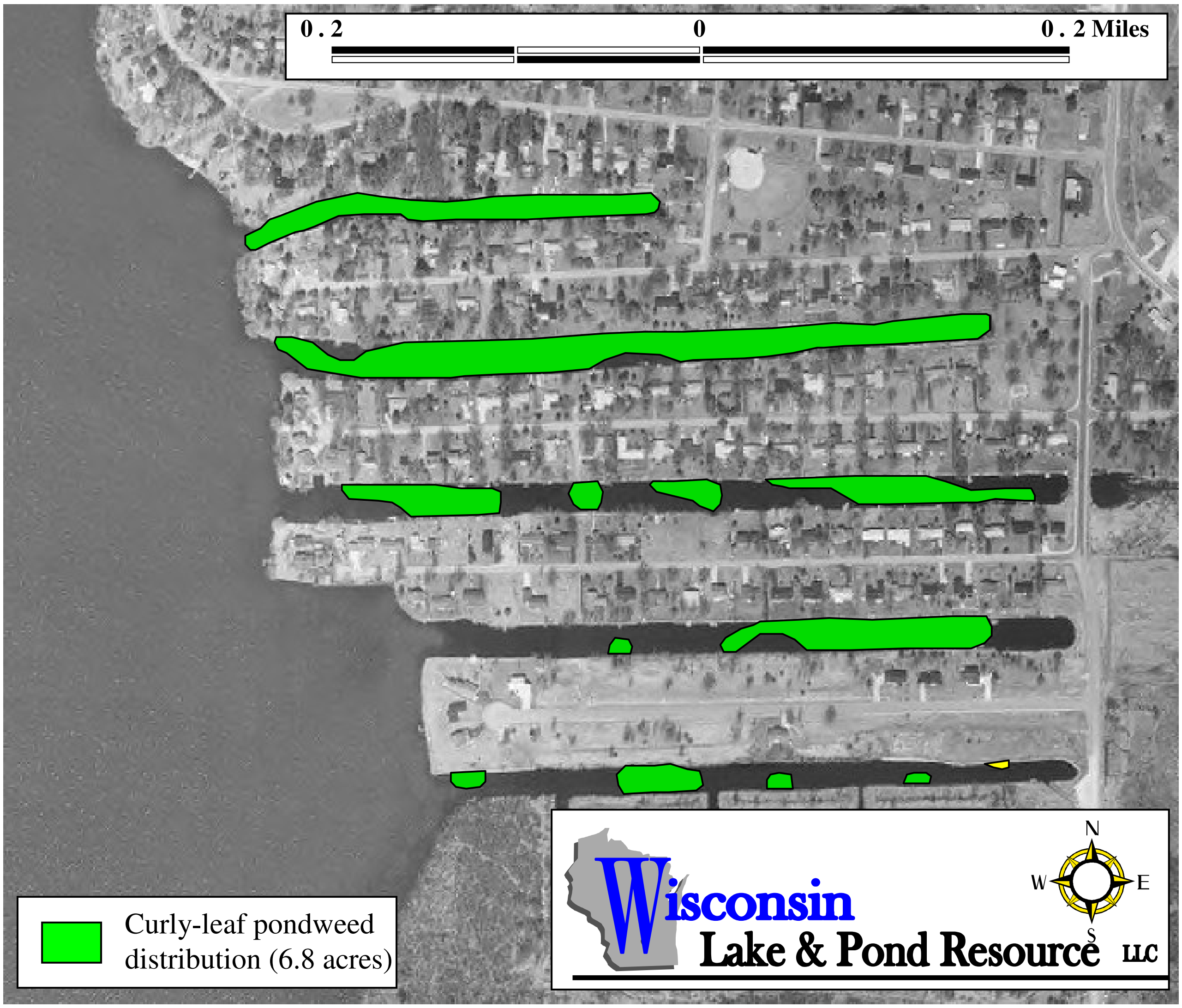
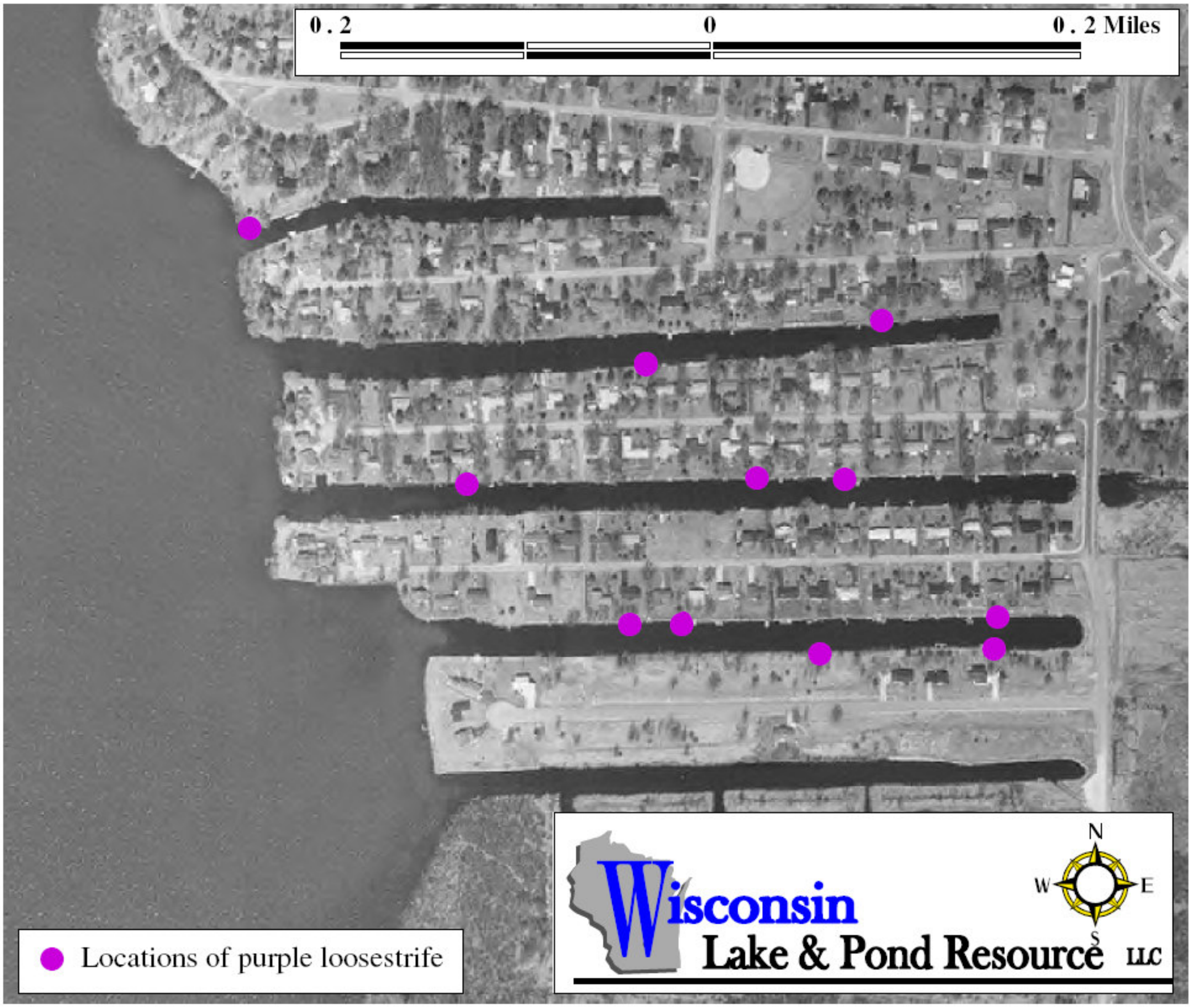


Figure 16. **Locations of purple loosestrife growing on July 7, 2005 along the shore of the Harmony Grove Protection and Rehabilitation District channels.**



Water Quality

Dissolved Oxygen and Temperature
Oxygen concentration is one of the greatest limiting factors in aquatic ecosystems. Because water is capable of holding relatively low levels of oxygen in comparison to air, oxygen is easily depleted by respiration and decomposition. Atmospheric diffusion and photosynthesis are the main sources of dissolved oxygen in lakes. However, photosynthesized oxygen concentrations vary considerably. In fact, very productive lakes may experience large fluctuation in oxygen concentrations.

It is important to understand the relationship between dissolved oxygen and temperature. As a rule, colder water can hold more oxygen than warmer water (Shaw, et al. 1998). The percent saturation column in **Tables 7, 8, and 9** and the data presented in **Table 6** illustrate this point.

Table 6. Oxygen solubility in water at different temperatures (from Shaw, et al. 1998).

Temperature		Oxygen solubility
ºC	ºF	(mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

Percent saturation is a measure of how much oxygen is present in the water in comparison to the solubility of oxygen at a given temperature (Mitchell, et al. 2000). However, some of the dissolved oxygen readings do not appear to follow the solubility rules for oxygen and temperature. Percent saturation values of 80-120% are considered to be excellent and values less than 60% or over 125% are considered to be poor. A condition referred to as supersaturation occurs when saturation levels are above 100%. This can result from wind, wave, and certain biological activities. Very often, as is case with Harmony Grove, daily cycles in the level of dissolved oxygen can occur as a result of elevated levels of algae. During the day, large amounts of oxygen are produced through photosynthesis causing levels to reach over 100% saturation. With nightfall, and the cessation of photosynthesis, levels can drop dramatically.

The lowest oxygen conditions were recorded in late summer. However, generally speaking levels throughout the season were above the water quality standard for oxygen in “warm water” lakes (5 mg/L). These oxygen levels allow most fish species to survive and grow.

Table 7. Dissolved oxygen and temperature data collected in 2005 from Channels A and B of Harmony Grove, Columbia, County, Wisconsin.

		Channel A			*Channel B*		
Date	Depth (ft)	Temp (F.)	D.O. (mg/l)	% Saturation	Temp (F.)	D.O. (mg/l)	% Saturation
5/24/2005	1	67	8	85	67	7	74
6/7/2005	1	80	9	108	78	9	107
6/21/2005	1	79	9	107	77	9	105
6/28/2005	0	80.8	14.00	>150	83.1	15.20	>150
	1	79.9	14.10	>150	82.5	14.90	>150
	2	78.4	13.40	>150	81.8	14.60	>150
	3	77.8	14.20	>150	80.3	11.90	146
	4	76.7	10.40	117			
7/11/2005	1	82	7	85	84	7	88
7/25/2005	1	80	6	72	80	6	72
8/8/2005	1	80	7	84	77	7	82
8/21/2005	1	73	7	79	73	7	78
9/7/2005	1	77	n/a	--	77	n/a	--
9/8/2005	0	75.4	7.97	97.00	74.5	6.10	73.60
	1	74.1	8.31	99.90	74.7	6.45	78.00
	2	73.9	8.24	98.80	74.9	6.46	78.20
	3	73.2	8.33	99.10	74.7	5.90	70.70
	4	79	9.00	107	74.6	3.14	37.90
9/23/2005	1	67	7	74	67	6	63
10/13/2005	1	57	9	86	58	9	86

Table 8. Dissolved oxygen and temperature data collected in 2005 from Channels C and D of Harmony Grove, Columbia, County, Wisconsin.

		Channel C			*Channel D*		
Date	Depth (ft)	Temp (F.)	D.O. (mg/l)	% Saturation	Temp (F.)	D.O. (mg/l)	% Saturation
5/24/2005	1	70	6	65	n/a	n/a	--
6/7/2005	1	82	9	111	83	9	110
6/21/2005	1	80	9	108	82	9	111
6/28/2005	0	80.1	12.90	>150	84.6	8.44	106
	1	80.3	13.20	>150	84.2	8.13	103
	2	78.6	15.30	>150	83.6	7.56	96
	3	78.2	14.30	>150	82.6	6.40	78
	4	78.3	14.70	>150	81.7	2.07	25
7/11/2005	1	82	8	99	81	6	72
7/25/2005	1	79	7	83	82	6	74
8/8/2005	1	76	7	80	80	9	108
8/21/2005	1	73	7	77	73	7	78
9/7/2005	1	75	n/a	--	72	n/a	--
9/8/2005	0	75.6	7.18	87.50	76.0	7.47	91.7
	1	74.5	7.34	88.50	76.3	7.28	89.7
	2	73.9	6.55	78.50	76.3	6.99	86.2
	3	73.5	5.60	66.70	76.1	6.22	72.4
	4	73.2	5.09	60.60	75.3	5.58	68.2
		73.2	4.86	57.90	74.9	3.76	45.6
					74.9	3.61	43.7
9/23/2005	1	67	7	74	68	7	75
10/13/2005	1	57	9	86	57	9	85

Table 9. Dissolved oxygen and temperature data collected in 2005 from Channel E of Harmony Grove, Columbia, County, Wisconsin.

		Channel E		
Date	Depth (ft)	Temp (F.)	D.O. (mg/l)	% Saturation
5/24/2005	1	n/a	n/a	--
6/7/2005	1	83	9	110
6/21/2005	1	83	9	110
6/28/2005	0	83.3	9.40	117
	1	83.0	8.94	111
	2	82.3	8.41	103
	3	79.9	7.22	87
	4	79.6	6.83	83
7/11/2005	1	81	8	98
7/25/2005	1	81	6	72
8/8/2005	1	81	9	110
8/21/2005	1	73	7	78
9/7/2005	1	75	n/a	--
9/8/2005	0	76.1	8.28	101.5
	1	76.3	7.51	92.3
	2	75.6	5.77	70.8
	3	74.5	4.46	53.5
	4	74.4	4.05	48.8
	5	74.3	3.59	43.0
9/23/2005	1	66	7	74
10/13/2005	1	56	9	85

pH

pH is an index of the acidity of a lake. It is the negative log of the hydrogen ion concentration in the water. The pH scale ranges from 0 – 14. A pH value of 7 is considered neutral. Lower numbers indicate more acidic conditions, while higher values indicate alkaline conditions. pH levels between 7 and 9 are common in lakes of central Wisconsin. It is only in the more extreme pH levels that concern arise over the possible impacts to the environment. Many factors influence pH including geology, productivity, pollution, etc. In particular, increased photosynthetic activity can raise the pH in a lake. pH values recorded for the Harmony Grove channels can be found in **Table 10**. With the exception of the pH for June in channel D, pH values for the Harmony Grove channels fell between 7 and 9 and are not cause for concern.

Table 10. pH values measure in 2005 for the channels of Harmony Grove.

	June 28, 2005	September 8, 2005
Channel A	8.47	8.47
Channel B	8.66	7.69
Channel C	7.02	8.11
Channel D	6.87	7.89
Channel E	7.31	8.14

Water Quality and Lake Productivity

Water quality data collected as part of the volunteer Self-Help program can be found in **Table 11**. This includes values for total phosphorus, chlorophyll *a* and Secchi depth.

Phosphorus

Total phosphorus is one of the most important water quality indicators. Phosphorus levels are an important factor in determining the amount of plant and algae growth in a lake. Phosphorus can come from the watershed (fertilizers, erosion) or to a lesser extent, from groundwater and atmospheric deposition. Phosphorus can also come from within the lake. Internal loading can occurs through the decomposition of plant matter and through a number of chemical processes. Under oxygen depleted conditions (anoxia) phosphorus located in the sediments of a lake are released into the water column.

Phosphorus data for Harmony Grove reached levels as high as 126 µg/l in 2005. Channels A and B, the two northern most channels, had average total phosphorus concentrations of approximately 45 µg/l, while the three southern channels each average approximately 76 µg/l. Average levels for natural lakes in Wisconsin are 25 µg/l. Values over 50µg/l are indicative of poor water quality. In July and August concentrations of phosphorus reached their maximum.

Because the dissolved oxygen data collected for the Harmony Grove channels do not indicate that oxygen levels were depleted, it is unlikely that nutrient release from the sediments is of great concern. Since the channels are relatively shallow sufficient mixing likely occurs from wind and wave action. If the channels are experiencing anoxia, it is a localized occurrence and does not have a significant impact to water quality.

Generally speaking, the highest concentrations of phosphorus occurred in July and August. At the time of the plant survey in early July, large amounts of curly-leaf pondweed were beginning to die back. Often in late summer after this occurs, a spike in phosphorus concentrations is seen as a result of the decomposition of these plants under warm conditions. It is expected that the Harmony Grove channels will continue to see increases in internal nutrient cycling until control of curly-leaf pondweed is accomplished.

Chlorophyll *a*

Chlorophyll is the pigment found in all green plants including algae (or phytoplankton) that give them their green color. It is the site in plants where photosynthesis occurs. Although there are a number of forms of chlorophyll, chlorophyll *a* is the form of chlorophyll used primarily in lake research. Chlorophyll data is collected because it can be used to estimate how much algae there is in the lake. This is directly related to nutrient concentrations. Generally speaking, the more nutrients there are in the water and the warmer the water, the higher the production of algae.

The trends seen in the phosphorus data for Harmony Grove are reflected in the chlorophyll data as well. Chlorophyll *a* concentrations gradually rose in 2005 peaking in July. As with phosphorus, chlorophyll *a* levels for Channels A and B were lower than those for the remaining channels.

Secchi Transparency

Water clarity is often used as a quick and easy test for a lake's overall water quality, especially in relation to the amount of algae present. There is an inverse relationship between Secchi depth and the amount of suspended matter, including algae, in the water column. The less suspended matter, the deeper the Secchi disc is visible. As a season progresses, the water clarity in a lake generally decreases. Because the channels in Harmony Grove are shallow, it wasn't always possible to obtain accurate transparency readings. Often the Secchi disk was either obstructed from view by the abundant plant growth or could be seen lying on the lake bottom.

Table 11. Phosphorus, chlorophyll, and Secchi disc data collected in 2005 in the Harmony Grove channels.

Total Phosphorus (mg/L)

	Channel				
Date	A	B	C	D	E
05/24/05	34	66	80	n/a	n/a
06/07/05	52	46	126	60	65
06/21/05	35	32	57	66	80
07/11/05	24	45	50	77	70
07/25/05	56	42	106	112	100
08/08/05	65	52	55	82	99
08/21/05	41	51	67	74	64
09/07/05	53	32	66	60	64
09/23/05	56	40	78	82	66
10/13/05	n/a	n/a	n/a	n/a	n/a
Average	46.22	45.11	76.11	76.63	76.00

Chlorophyll a (µg/L)

	Channel				
Date	A	B	C	D	E
05/24/05	n/a	n/a	n/a	n/a	n/a
06/07/05	n/a	n/a	n/a	n/a	n/a
06/21/05	3.26	2.85	13	13.5	18.6
07/11/05	3.25	2.7	7.89	17.2	17.5
07/25/05	17.9	5.48	30.1	55.3	21.4
08/08/05	19.8	7.77	10.9	29.2	22.9
08/21/05	9.34	11.8	9.08	16.6	10.9
09/07/05	24.6	6.36	29.8	19.2	11.8
09/23/05	26	6.32	19.8	24.4	9.76
10/13/05	17.7	12.2	17.5	16.5	32.7
Average	15.23	6.94	17.26	23.99	18.20

Secchi Depth (ft)

	Channel				
Date	A	B	C	D	E
05/24/05	2.5+	3+	4+	n/a	n/a
06/07/05	3+	2.5	3	2.5	2.75
06/21/05	3+	2.5+	3.5+	3	2.5
07/11/05	3+	3+	3.75+	2.5	2.5
07/25/05	2.75+	2.5+	3.25	1.75	2.5
08/08/05	2.5+	3+	4.5	2.75+	2.75+
08/21/05	3.25+	3.25+	4+	3.0	3.5+
09/07/05	3+	3+	3.25	3.5	3.5
09/23/05	3+	3+	2.5	2.5	3
10/13/05	3+	3+	4+	3.75	3.25
Average	n/a	n/a	n/a	n/a	n/a

+ Secchi disk obstructed from view by vegetation or visible on bottom of lake.

Trophic State

The productivity of a lake reflects the level of nutrients and amount of plant and animal biomass present. A lake's trophic state is a measure of its productivity and thus its ability to support living things. This is often directly linked to the water quality of the lake. The most significant and often detrimental consequence is large amounts of algae – a reflection of high productivity or trophic level in a lake. Lakes are broadly categorized into three trophic levels:

- oligotrophic - low productivity, high water quality
- mesotrophic - medium productivity and water quality
- eutrophic - high productivity, low water quality

Oligotrophic lakes are typically deep and clear with exposed rock bottoms and limited plant growth. Eutrophic lakes are often shallow and marsh-like, typically having heavy layers of organic silt and abundant plant growth. Mesotrophic lakes are typically deeper than eutrophic lakes with significant plant growth, and areas of exposed sand, gravel or cobble bottom substrates.

Lakes can naturally become more eutrophic with time, however the trophic state is more influenced by nutrient inputs than by time. Although lakes can naturally evolve from oligotrophic to eutrophic conditions, this process is often accelerated by human activity (Lund, 1972, Megard, et al. 1980). When humans influence the trophic state of a lake the process is called *cultural eutrophication*. A sudden influx of available nutrients may cause a rapid change in a lake's ecology. Opportunistic species such as algae take advantage of the increased nutrient load. This leads to a number of undesirable conditions including decreased water clarity, fish kills, changes to the aquatic plant community, and reduced recreational opportunities.

Total phosphorus, chlorophyll *a* and Secchi depth are often used as trophic state indicators for lakes. Values measured for these parameters can be used to calculate Trophic State Index (TSI) (Wetzel, 2001, Carlson, 1977) values. The formulas for calculating the TSI values for Secchi disk, chlorophyll *a*, and total phosphorus are as follows:

$$\text{TSI} = 60 - 14.41 \ln \text{Secchi disk (meters)}$$

$$\text{TSI} = 9.81 \ln \text{Chlorophyll } a \ (\mu\text{g/L}) + 30.6$$

$$\text{TSI} = 14.42 \ln \text{Total phosphorus } (\mu\text{g/L}) + 4.15$$

The higher the TSI value calculated for a lake, the more eutrophic it is (**Figure 17**). Phosphorus is the best estimate of late-season peaks in trophic index values because levels of phosphorus are not as dependent upon seasons and weather conditions as chlorophyll or Secchi transparency are. Often earlier in the spring water temperature are lower and day lengths are shorter. As a result the levels of chlorophyll in the form of algae often have not reached seasonal peaks.

There is a strong relationship between phosphorus and chlorophyll *a* concentrations in lakes. As a response to rising levels of phosphorus, chlorophyll *a* levels increase and transparency values decrease.

Trophic State Index values for the Harmony Grove channels (**Table 12**) indicate they fall within the range of eutrophic conditions. Due to the inconclusive nature of the Secchi transparency data, Secchi TSI values were not calculated for the Harmony Grove channels.

Table 12. Trophic State Index values for phosphorus and chlorophyll collected in 2005 in the Harmony Grove channels.

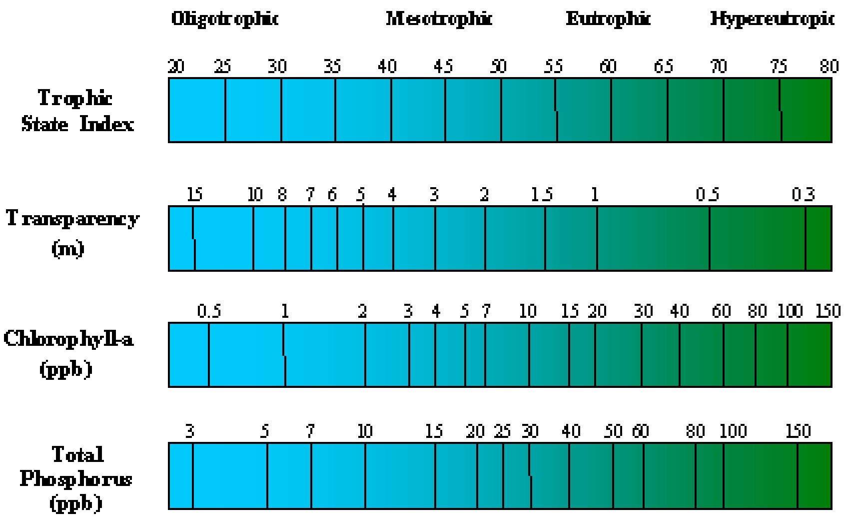
Phosphorus TSI TSI = 14.42 ln [total phosphorus (µg/L)] + 4.15

	Channel				
Date	A	B	C	D	E
05/24/05	55.00	64.56	67.34	n/a	n/a
06/07/05	61.13	59.36	73.89	63.19	64.34
06/21/05	55.42	54.13	62.45	64.56	67.34
07/11/05	49.98	59.04	60.56	66.79	65.41
07/25/05	62.20	58.05	71.40	72.19	70.56
08/08/05	64.34	61.13	61.94	67.69	70.41
08/21/05	57.70	60.85	64.78	66.21	64.12
09/07/05	61.40	54.13	64.56	63.19	64.12
09/23/05	62.20	57.34	66.97	67.69	64.56
10/13/05	n/a	n/a	n/a	n/a	n/a
Average	58.82	58.73	65.99	66.44	66.36

Chlorophyll TSI TSI = 9.81 ln [chlorophyll *a* (µg/L)] + 30.6

	Channel				
Date	A	B	C	D	E
05/24/05	n/a	n/a	n/a	n/a	n/a
06/07/05	n/a	n/a	n/a	n/a	n/a
06/21/05	42.19	40.87	55.76	56.13	59.28
07/11/05	42.16	40.34	50.86	58.51	58.68
07/25/05	58.90	47.29	64.00	69.97	60.65
08/08/05	59.89	50.71	54.03	63.70	61.32
08/21/05	52.52	54.81	52.24	58.16	54.03
09/07/05	62.02	48.75	63.90	59.59	54.81
09/23/05	62.56	48.69	59.89	61.94	52.95
10/13/05	58.79	55.14	58.68	58.10	64.81
Average	54.88	48.33	57.42	60.76	58.32

Figure 17. Relationship between trophic state in lakes and parameters including water transparency and concentrations of chlorophyll *a* and total phosphorus.



Watershed Assessment

During the visual assessment of the Harmony Grove watershed, few features stood out as obvious sources of sedimentation or nutrient loading for the channels. There is a significant amount of agriculture and urbanization surrounding the channels. These types of features are known sources of non-point source pollution. However in terms of more direct point sources, there are a couple of features worth noting. The first is the prevalence of storm drains and culverts leading into the channels. In total there are eight storm drains and two culverts which deposit storm water and water from adjoining wetlands directly into the channels. Storm water in particular contains a number of chemical and debris found on streets and parking lots including oils, pesticides, leaves and grass, and litter. When these materials enter a lake they can be a source of pollution and nutrient loading.

The second area of concern is found along the southern shore of Channel E (**Figure 18**). There are a number of locations along this channel where the bank is collapsing into the channel. This not only contributed to the sedimentation of the channel but can also be a significant source of nutrients.

Figure 18. Shoreline degradation located on the southern most channel within Harmony Grove, Columbia, County, Wisconsin

Because of the large number of homes on the Harmony Grove channels, it is likely that nutrients and other pollutants are entering the channels directly from the area's lawns. Increases in nutrients result in increased plant growth followed by increased sediment deposition. Later in this report a number of options are given for ways individual property owners can improve water quality through such actions as improved lawn care practices and shoreline restoration.

Discussion

Sediment Accumulation

Lake sediment accumulation is a common problem faced by many lakes in Wisconsin. Sediments build up as a result of contributions from both internal and external sources. Erosion from within the watershed transports sediments over land and deposits them in lakes and rivers. Increases in sedimentation rates are often associated with increases in internal and external nutrient cycling contributions and excessive plant and algal growth (Kim, 2002, Garbaciak, 2003). In particular for the Harmony Grove channels, organic sediments are most likely internally generated while the sandier sediments are externally generated.

The first and most obvious source of sediment to the Harmony Grove channels is Lake Wisconsin and the Wisconsin River. Because the channels are located away from the main channel of the river, they can catch sediments that settle out of the lake water as the flow of water slows. In addition, wave action can contribute to the drift of sediments into the channels. In most cases, these sediments appear to be accumulating at a higher rate in the eastern most portions of the channels where the movement of water ceases.

Another likely source of sediments is the inflowing creek on Channel C. As is evident in **Figure 7**, the portion of the channel nearest the creek is quite shallow. While this stream likely contributes to the sedimentation of this channel, its effects are isolated to that channel alone. None of the remaining channels have a steady inflow of water, however, they still have areas of shallow water and sediment accumulation.

Organic sediments can often accumulate from the annual life cycle of aquatic plants. As winter approaches, aquatic plants begin to die back and decompose. Over time this process results in a build up of organic matter. Sediments with higher organic content are more heavily influenced by this process.

Sediment Reduction Options

Increased sedimentation in shallow lakes can lead to obstructions in navigation as has occurred in Harmony Grove. Consequently, effective management of sediments must be carried out in both the lake and the watershed to maximize its effectiveness. This management must include practices which reduce the input of sediments, nutrients, and contaminants from external sources and the internal control of these elements within the lake. If sediment removal alone is chosen, any improvements to the lake will be short-lived and limited by the continued addition of nutrients and organic matter from external sources. To best meet the wishes of all concerned, the symptoms *and* causes of sediment accumulation must be addressed.

Management of Existing Sediments

Sediment management practices can be carried out either by reducing sediments on-site or by physically removing sediments from the lake. A limited number of options are available to reduce accumulated sediments in lakes. Of these, sediment removal (dredging) shows the most potential for the Harmony Grove Lake District. **Table 13** provides a comparison of sediment reduction options for consideration by the Harmony Grove Lake District.

Sediment Removal and Disposal

Dredging
The dredging of sediments is a commonly used method for maintaining navigation in surface waters. Historically dredging was a crude and inefficient method of sediment removal. With the assistance of today's GPS technology, dredge operators are able to achieve much greater efficiency, saving time and money while providing safer navigation. The selection of the dredging technique and equipment should be based on the accuracy and speed of sediment removal and the impact of resuspended matter to the environment. Two types of dredges that should be considered for Harmony Grove are mechanical dredges and hydraulic dredges.

Mechanical Dredges
Mechanical dredges remove lake sediments by physically digging the desired materials from the bottom and disposing of the dredged materials. Mechanical dredges are rugged devices often mounted on barges and secured in place with specialized anchors or pilings called *spuds*. These barge-mounted dredges allow the operators to work in tightly confined areas such as the channels of the Harmony Grove Lake District. Dredged materials are removed by large *dipper* or *clamshell* buckets which then place the materials into a barge, called a *dump scow*. The dump scow is used to transport the dredged materials to a predetermined disposal location. Mechanical dredging operates most efficiently when two or more large barges are used in tandem. Once one barge is filled and is transported to the disposal site, another barge can take its place. This allows for minimal interruptions in the dredging operations. Mechanical dredges are best suited for use with denser, consolidated materials including rocks and large debris. This method of sediment removal is not efficient at removing loose materials such as finer sediments that can easily wash from the dredge bucket.

Hydraulic Dredges
Hydraulic dredges remove lake sediments by sucking a mixture of dredged materials and water from the lakebed. Like mechanical dredges, hydraulic dredges are often mounted on barges. Two types of hydraulic dredges are the *pipeline* and *hopper* dredges.

Pipeline dredges suck dredge materials through a large intake pipe and discharge directly into a barge or other the disposal site. Most pipeline dredges have a *cutterhead*, a mechanical devise with rotating blades or teeth used to break up or loosen the sediment materials. As a result, cutterhead pipeline dredges are able to excavate most materials. Pipeline dredges can be operated continuously and can be, as a result, very cost efficient. Cutterhead pipeline dredges work best where the cutterhead is buried deep in the sediment. The amount of water removed should be controlled during operation for best efficiency. Water that is pumped with the dredge material

Table 13. Comparison of Sediment Management Options for Harmony Grove Lake District

Option	Advantages	Disadvantages
Dredging	Useful in maintaining navigational lanes	Often causes resuspension of sediments and declines in water quality
	Sediments quickly removed from waterbody	Associated with increases in nutrients and pollutants; impacts to wildlife
	Efficient at providing safe navigation	Sediment removal may only be short-term fix
		Must dispose of potentially polluted dredged materials
		Does not address sources of sediment accumulation
Mechanical Dredging	Able to operate in tightly confined areas	Not suited for high traffic areas
	Can operate continuously if in conjunction with multiple barges	Not efficient at removing fine or loose materials
	Rugged; works best for hard, consolidated materials	Produces large quantities of sediment resuspension
	Can be used to remove rocks and debris	
Hydraulic Dredging	Able to remove finer materials more efficiently	Efficiency dependent upon mixture of dredged material and water
	Results in decreased sediment resuspension	
Cutterhead Pipeline Dredging (Hydraulic)	Operate continuously, cost efficient	Pipes can clog if large amounts of debris are present
	Able to break up hard materials	Pipelines may obstruct navigation
Hopper Dredging (Hydraulic)	Mobile; useful in high traffic areas	Dredged materials discharged from ship, not removed from waterbody
		Cannot be used in confined or shallow areas
		Does not operate continuously; stop dredging during transit to disposal site
Aeration Systems	Designed to improve dissolved oxygen profile and breakdown organic sediments	Sediment reduction slow in comparison to removal by dredging
	Increase habitat for fish and other aquatic animals	Do not impact accumulation of inorganic sediments
	Can prevent fish kills	Unable to remove contaminated sediments
	Reduce concentrations of metals and nutrients in the water	
	Reduce hydrogen sulfide, ammonia, methane and carbon dioxide	
Watershed and Lakeshore Erosion Controls	Designed to reduce rates of sedimentation and soil and shoreline erosion	Preventative maintenance; do not address accumulated sediments
	Can lead to improved water quality, filter nutrients and trap sediments	Will not directly affect internal nutrient cycling
	Can improve fish and wildlife habitat, aesthetics	

must be contained on site until a reasonable amount of solids settle out. The water can then be discharged back into the waterbody.

Hopper dredges are self-propelled ships with large hoppers or containment areas. These dredges suck dredge material from the lakebed through intake pipes called *drag arms*. These arms have difficulty dredging denser, consolidated materials. Dredged materials are stored onboard. As a result, hopper dredges are limited to deeper water. Again, water is drained and discharged back to the waterbody from the vessel. Once the containment areas are full, the barge is moved to an in-water disposal site and the dredged materials are discharged through the bottom of the ship. Although hopper dredges can quickly move to disposal sites, because they are self-propelled, dredging operations must stop during transport, affecting operation and cost efficiencies.

Environmental Impacts of Dredging

Removal of sediments from lakes and ponds is an established management technique *intended* to enhance sport fisheries, manage aquatic plants, and improve navigation. However, data available on the effects of dredging on lake ecosystems is limited. By its nature, dredging causes physical changes to the lake ecosystem both in terms of the sediments and the water column. Sediment resuspension and increases in nutrient and other pollution levels are constant concerns associated with dredging operations (Marsh, 2003). Research has suggested that physical sediment removal can be detrimental to certain wildlife species including populations of reptiles and amphibians (Aresco and Gunzburger, 2004). Whenever possible, the best management practices available should be utilized to reduce sediment resuspension during dredging.

One of the most challenging problems associated with dredging is in the disposal of the dredged materials. If the sediments to be removed have relatively low concentrations of compounds such as heavy metals and/or organic pollutants, they can be applied to agricultural soils as a fertilizer or soil conditioner. This is the case with the sediments of Harmony Grove. Ideally, disposal on nutrient poor soils can be of great benefit to the disposal site. In addition, dredged sediments can make ideal substrate for establishing upland prairie areas because they contain little or no upland weed seeds.

Regardless of possible contamination, sediment resuspension and relocation are two of the most significant environmentally damaging results of dredging. Rates of sediment resuspension are higher for mechanical dredging that for hydraulic dredging. This is simply due to the techniques used in these two approaches. Because mechanical dredging is inefficient at removing the finer loose sediments, they become easily resuspended. Ranges for total suspended solids (TSS) concentrations near mechanical *and* hydraulic dredging operations rarely if ever reach levels of acute (short-term) lethal toxicity. However, levels do often exceed chronic (long-term) sublethal toxicity levels. This means that although there often are no immediate lethal effects to the biota of a lake, there are other less than lethal stresses placed on the lake community in the long term. There are a number of control options that can be used to reduce the incidence of both chemical and physical impacts. These include physical controls (silt curtains, silt booms, settling chambers, etc.), operational controls, and specialty dredging equipment. Improper implementation of these practices can affect their performance (Stivers et al., 2004, Rokosch and Berb, 2003).

On-site Sediment Reduction

Artificial Aeration Systems
Lakes naturally get much of their oxygen from the atmosphere through a process called diffusion. Artificial aeration systems can increase a lake's oxygen levels by forcefully exposing much of the lake to the atmosphere. Various aeration systems are available. These systems work by either injecting air or mechanically mixing water. The most effective aeration systems used in lake sediment management are injection (diffusion) systems. The purpose of an aeration system in sediment management is to increase the dissolved oxygen content at the water-sediment interface and encourage the rapid breakdown of organic matter in the sediment. This method does not involve physical removal of sediments, but instead boosts natural biological and chemical processes to reduce organic sediments through decomposition. However, it should be noted that it may take years to see a noticeable reduction in sediments through this method.

This approach has been highly debated in Wisconsin. The Wisconsin DNR does not support aeration as a sediment reduction option for lakes. However, other lake managers in the State have seen successful sediment management through aeration. Little peer-reviewed literature is available to support either side of this debate. Regardless, in a system such as Harmony Grove which receives sediments from Lake Wisconsin through a continuous exchange of water, aeration would not be sufficient to offset the rate of sedimentation.

Preventing Sediment Accumulation

In order to properly develop a long-term sediment control strategy for Harmony Grove Lake District, it is important to not only consider the current sediment accumulation in the channels but to also plan for the mitigation of future sedimentation from external sources. A number of control efforts should be considered for implementation. Many efforts to control sediment accumulation will also result in benefits to water quality and wildlife habitat.

Watershed Sediment Control
Erosion is a natural process. However, human activities often accelerate rates of erosion leading to detrimental effects. In watersheds, the erosion of shorelines, riverbanks, and drainage ditches accounts for large quantities of sediments reaching lakes. This type of erosion is primarily due to the removal of shoreline vegetation for agriculture and urbanization. Consequently, control practices should be carried out for the benefit of the landowners and the health of the lake. The prevention of soil erosion in watersheds is an imperative step in the control of non-point sources of nutrients and sediments. Where possible, erosion control efforts should be used to compensate for the losses that have occurred because of previous mismanagement. Careful planning must be an integral part of landscape management.

Shoreline vegetation
Natural vegetation is one of the most important and effective erosion control options. Shoreline plants can stabilize the bank by holding soil particles together and dampening wave action. Vegetation also acts as a buffer to trap suspended sediment and induce its deposition. To prevent continued bank erosion where vegetative cover has been removed, it is important to restore the slope of the bank and reestablish ground cover vegetation, such as native trees, shrubs, and

aquatic riparian vegetation. The creation of a native vegetative buffer strip would not only be a benefit to sediment management, but also to water quality protection. This buffer also provides excellent fish and wildlife habitat, including nesting sites for birds, and spawning habitat for fish.

Research has shown that the placement of wire-wrapped square straw bales, coconut fiber logs, and pine logs are also effective in controlling wave action and trapping sand (Sistani and Mays 2001). Brush mats, and rock riprap are also options against erosion.

A recommended buffer zone consists of native vegetation that may extent from 25 – 100 feet or more feet from the water's edge onto land, and up to 50 feet into the water depending upon water depth. The buffer should cover at least 50%, and preferably 75% of the shoreline frontage (Henderson, et al., 1998). In most cases this still allows plenty of room for a dock, a swimming area, and lawn. Buffer zones are made up of a mixture of native trees, shrubs, upland plants, and aquatic plants and are quite aesthetically pleasing.

Sedimentation Basins

The use of sediment basins or traps is an additional watershed sediment control option. These basins are man-made depressions designed to collect and store runoff water and to allow suspended solids to settle out. The design and construction of these basins vary depending upon flow rates and site requirements. The basin must be large enough to allow sediments to drop out before the water is discharged into the lake. These basins are created by excavating, or by building earthen embankments across low areas or drainage paths. As a result the creation of sedimentation basins would likely require the acquisition of land for construction and possibly the diversion of storm water to the construction location. Although, sedimentation basins can have long-term benefits to a system such as the Harmony Grove watershed, they are most effective as short-term devices in small watersheds.

To the east of channel C is an area where the inflowing stream widens before flowing under the street. This area is likely acting as a sedimentation basin. Water entering this pool from the stream slows and some suspended materials are able to settle out. By expanding or duplicating this area, the District may be able to keep additional sediments from entering the channels. However, finding an appropriate location for this or any other sedimentation basin may be the biggest challenge given the area nearest the channels is relatively densely populated.

Lawn care practices

Individuals can place a large part in reducing sedimentation from local sources. Mowed grass up to the water's edge is a poor choice for the well being of a lake. Studies show that a mowed lawn can cause 7 times the amount of phosphorus and 18 times the amount of sediment to enter a waterbody (Korth and Dudiak, 2003). Lawn grasses also tend to have shallow root systems that cannot protect the shoreline as well as deeper-rooted native vegetation (Henderson et al., 1998). Property owners within the District should take care to keep leaves and grass clippings out of the streets and away from storm drains and the channels themselves. Storm drains should not be used to dispose of used motor oil, antifreeze, paints, etc. The use of chemicals should be minimized in yards. If chemicals are to be used, paved areas such as sidewalks and driveways should be swept, not washed to avoid flushing chemical into the storm sewer.

Fertilizers that enter the channels will encourage an increase in plant biomass. Fertilizers contain nutrients, including phosphorus and nitrogen that can wash directly into the lake. While elevated levels of phosphorus can cause unsightly algae blooms, nitrogen inputs have been shown to increase weed growth. Increases in plant biomass will lead to further sedimentation Landowners are encouraged to perform a soil test before fertilizing. A soil test will help determine if you need to fertilize, and give you direction on fertilizing. For assistance in having your soil tested, contact your county UW-Extension office. If there is a need to fertilize your lawn, use a fertilizer that does not include phosphorus. Most lawns in Wisconsin don't need additional phosphorus. The numbers on a bag of fertilizer are the percentages of available nitrogen, phosphorus and potassium found in the bag. Phosphorus free fertilizers will have a 0 for the middle number (e.g. 10-0-3).

To further reduce nutrient loading, keep twigs, leaves, and grass clippings out of the lake whenever possible. They contain nitrogen and phosphorus. The best disposal for organic matter, like leaves and grass clippings is to compost them.

Other practices can be adopted by the Township and District to reduce the amount of materials entering the channels from the watershed. These include adopting and enforcing erosion control ordinances for construction sites, requiring storm water controls in all new developments, and increasing the frequency of spring and fall street sweeping.

Obtaining a Permit to Dredge

If dredging is chosen as an option for the Harmony Grove channels, there are a number of steps that need to be taken in order to obtain a permit for dredging.

The first step is to determine if the waterway has a special designation that might affect the permit requirements. No designation exist for the Harmony Grove channels specifically, however, Lake Wisconsin has been designated an Area of Special Natural Resources Interest (ASNRI), a Priority Navigable Water (PNW), and a Natural Heritage Inventory (NHI) water. As part of the permit review process these designations will be taken into account. However, it is unlikely these designations would result in a denied request to dredge.

There are two types of permits issued for dredging; the general and the individual permit. In addition, some dredging projects can qualify for a permit exemption. However, since this is not a small-scale (3,000 cubic yards) project it would not be exempt from requiring a permit. General Permits are available for two types of projects: Utility Crossings and Drainage District Dredging. The proposed dredging in Harmony Grove is neither, therefore the District would need to apply for an Individual (Chapter 30) Permit.

The individual permit is available online (http://dnr.wi.gov/org/water/fhp/waterway/permits/pack09a.pdf) as well as the associated fee sheet (http://dnr.wi.gov/org/water/fhp/waterway/permits/feesheet.pdf). A project of this type would require a fee of approximately $500. Five copies of the permit must be submitted to the Wisconsin DNR.

As part of the Individual Permit requirements an Environmental Assessment (EA) would need to be completed in accordance with NR 150 Wis. Admin. Code. An EA is intended to be used as a means to determine the environmental consequence, or impact of a proposed project or activity (Jain et al., 2002). The EA would need to be completed by a consultant which would cost the District additional consulting fees. The EA is sent to the Wisconsin DNR for their review. It is required that there be 30 day public notice period and possibly a public information meeting. If during the review, the DNR determines the proposed project may cause serious impact to the environment, an Environmental Impact Statement may be required. This happens on rare occasions, but the District should be prepared for the possibility of this requirement.

In addition, a Wisconsin Pollution Discharge and Elimination System (WPDES) permit is required for the disposal of the dredged materials as well as a US Army Corps of Engineers (USACOE) general permit authorizing the project. However one of the five copies of the individual permit application sent to the Wisconsin DNR is in turn sent to the USACOE. Therefore there is not a separate application needed for the Corps' permit.

In general the permit process can take six months or more to complete. A dredging project can be a long, costly, and inconvenient process. It is important that the District be aware of the process and the amount of work required to obtain a permit and to complete a dredging project of this magnitude.

Undertaking an dredging project

Most often, dredging projects are not completed due to a lack of money, a lack of an appropriate disposal site, permit denial or the lack of persistent local coordination. The question often arises regarding how long the effects of dredging will last. Although each situation is unique, the effects of a project of this type may last as long as ten years. A more accurate estimation would require extensive research into the direct causes and rates of sedimentation in the Harmony Grove channels.

A thorough review of the physical steps taken in the dredging of the Harmony Grove channels is found in the Foth & Van Dyke design report (2002). Keep in mind this process will require locating or constructing both a staging area and a disposal site. If a pipeline system is used, it will affect a number of property owners (listed in the report). A decision will need to be made regarding the specifics of the dredging process as well as the disposal options. The dredging contractor hired will assist in making these decisions. The contractor may request that boats and piers be removed from the dredging sites in order to better navigate the relatively narrow channels of Harmony Grove. As a result, general use of the area being dredged will likely be restricted for a number of days.

Cost is also a common concern in any dredging project. A thorough dredging project was outlined in the Foth & Van Dyke design report (2002). A project of this nature would likely cost between \$10 - \$20 per cubic yard of dredged material. This estimate is for sediment removal only. This estimate does not include the costs for the disposal site and staging area preparations, or the cost for the permit and EA process. Four scenarios were presented in the 2001 study. These scenarios differed based on the extent of dredging both within the channels and out into Lake Wisconsin. They included volume estimations for dredged materials ranging from 23,800 to 51,800 cubic yards. This translates between \$238,000 to \$1,036,000 to dredge the Harmony Grove channels (again based on \$10-\$20 per cubic yard). The costs are likely to fall on the higher end of this estimate if all five channels are dredged. However, it may be wise to dredge fewer channels based on the desires of the property owners. Regardless of the number of channels dredged, the permit process will be the same and a large disposal site will still need to be constructed. The District should expect to pay between \$10,000 and \$15,000 for the EA process. The cost for the EA will vary depending upon the contractor hired to complete it, however, completion of the Foth & Van Dyke study and this management plan will certainly help to expedite the process and minimized the cost to the District.

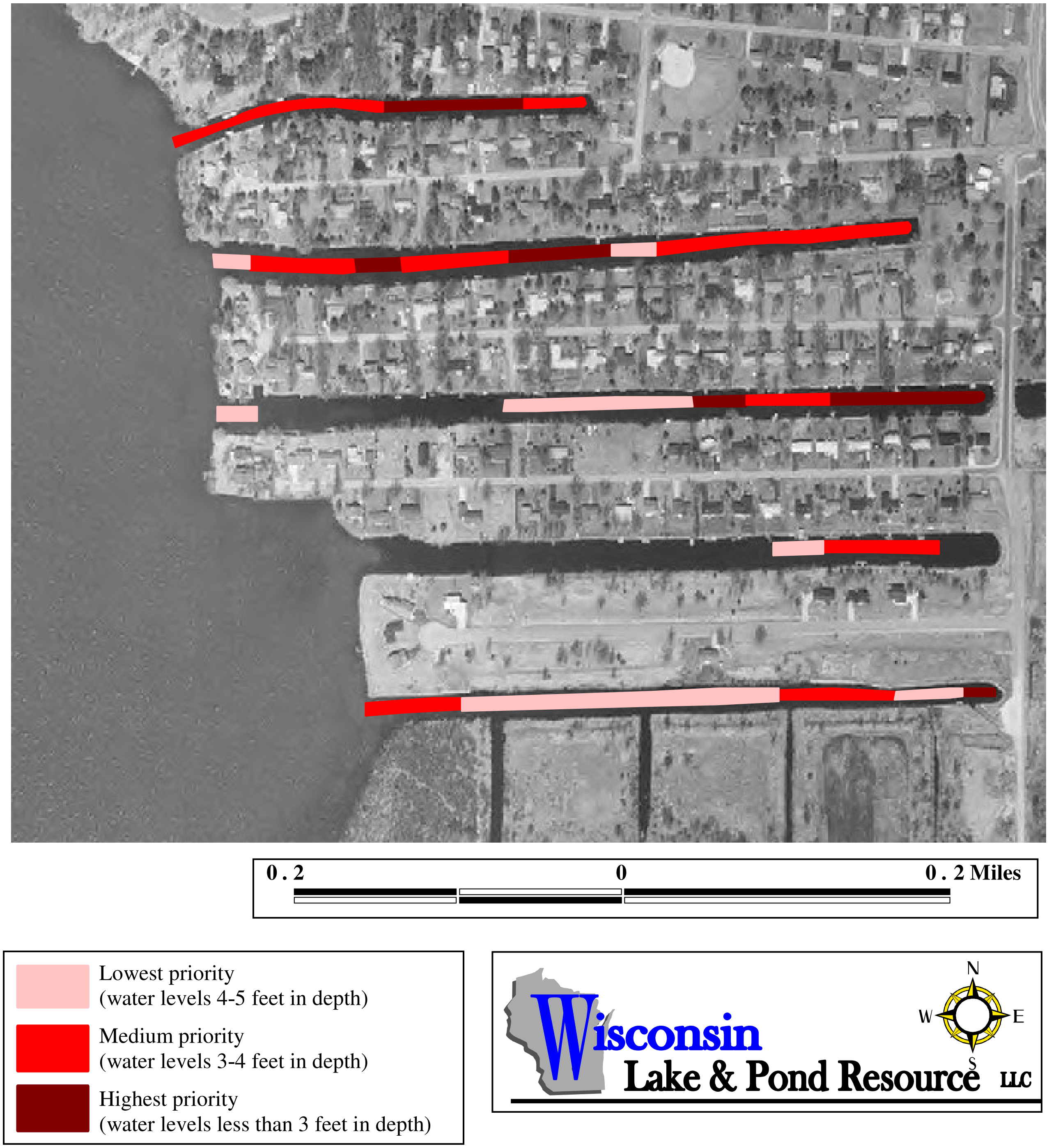
Figure 19 shows a prioritization of dredging based on the depth data collected in 2005. The priority ranking assumes a desired water depth of five feet and the removal of materials from the center of the channel. This is similar to Scenario D in the Foth & Van Dyke study. The areas of highest priority would be those which are three feet or shallower and the lowest priority would be in areas between four and five feet. It was estimated that 18,700 cubic feet of materials would be removed if all highlighted areas were dredged. The breakdown of this by channel is found in **Table 14**. The total estimated cost for this approach would be approximately \$374,000. Again this is an estimate for the cost of removal only at \$20/cubic yard.

Note that all dredging costs presented here and in the Foth & Van Dyke study are estimates. Because the District is a municipal body, formal bids would have to be requested and accepted before a dredging contractor could be hired.

Table 14. Estimated volume and cost of materials to be dredged from the Harmony Grove channels.

Channel	Vol. of dredge materials (yd^3)	Cost ($20 per yd^3)
A	3900	$78,000
B	5900	$118,000
C	4100	$82,000
D	1200	$24,000
E	3600	$72,000
Total	18,700	$374,000

Figure 19. Recommended priority for sediment dredging based on water depth on July 7, 2005 in the Harmony Grove Protection and Rehabilitation District channels.



Wisconsin Lake & Pond Resource LLC

The Importance of Aquatic Plants

Aquatic plants serve an important purpose in the aquatic environment. They play an instrumental role in maintaining ecological balance in ponds, lakes, wetlands, rivers, and streams. Native aquatic plants have many values. They serve as important buffers against nutrient loading and toxic chemicals, they act as filters that capture runoff-borne sediments, they stabilize lakebed sediments, they protect shorelines from erosion, and they provide critical fish and wildlife habitat. Therefore, it is essential that the native aquatic plant community in Harmony Grove channels be protected. The following is a list of common native aquatic plants that were found in Harmony Grove channels. Ecological values and a description are given for each plant. Plant information was gathered from Borman et al. (1997), Eggers and Reed (1997), Fasset (1940), Fink (1994), Nichols and Vennie (1991), and Whitley et al. (1999). Images obtained from Schmidt and Kannenberg, 1998 and Borman et al., 1997.

Submersed Plants - Plants that tend to grow with their leaves under water.

Elodea (*Elodea canadensis*) or **common waterweed** is made up of slender stems with small, lance-shaped leaves that attach directly to the stem. Leaves are found in whorls of two or three and are more crowded toward the stem tip. The branching stems of elodea provide valuable cover for fish and are home for many insects that fish feed upon. Elodea also provides food for waterfowl.

Coontail *(Ceratophyllum demersum)* produces whorls of narrow, toothed leaves on a long trailing stem that often resembles the tail of a raccoon. The leaves tend to be more crowded toward the tip. Coontail blankets the bottom, which helps to stabilize sediments. Tolerant to nutrient rich environments, coontail filters a high amount of phosphorus out of the water column. Coontail provides a home for invertebrates and juvenile fish. Seeds are consumed by waterfowl, but are not of high preference.

Although **native pondweeds** (*Potamogeton spp.*) may vary in appearance, there are a number of key features members of this genus have in common. Pondweed leaves are alternate with a noticeable midvein. The nutlets, leaves, and stipules can often be used to reliably identify a particular species. Pondweeds grow in a wide range of aquatic habitats. They all emerge from rhizomes, which help the plants overwinter. The pondweeds are a valuable food source for waterfowl and a number of mammals. They also provide a home for fish and invertebrates.

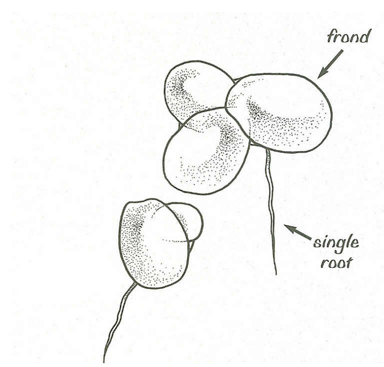
Slender Naiad (*Najas flexilis*) also known as **bushy pondweed** has a finely branched stem that grows from a rootstock. Leaves are short (1-4 cm), pointed and grow in pairs. Slender naiad is an annual and must grow from seed each year. It tends to establish well in disturbed areas. Slender naiad is a one of waterfowl's favorite foods and considered very important. Waterfowl relish seeds, leaves and stems. Slender naiad stabilizes bottom sediment and offers cover for fish.

Water Stargrass (*Heteranthera dubia*) resembles some of the narrow-leaved pondweeds. It is dark green to brown with thread-like leaves scattered on flexible stems. A close examination of the leaves will show that they have several veins but no obvious midvein. It reproduces from plant fragments. Water stargrass usually becomes abundant in late summer. It settles to the bottom in late autumn where it forms a decaying mat in the winter that provides habitat to many small aquatic animals. Water stargrass provides valuable habitat for fish and serves as a source of invertebrates for fish.

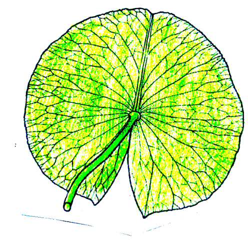
Wild Celery (*Vallisneria americana*) also known as **eelgrass** has long ribbon-like leaves that emerge in clusters. These leaves have a prominent central stripe and leaf tips tend to float at the water's surface. In the fall, a vegetative portion of the rhizome will break free and float to other locations. Wild celery is considered one of the best all natural waterfowl foods. The entire plant is relished by waterfowl, especially canvasbacks. Fish also find wild celery to be a popular hiding spot.

Floating Leaf Plants - Plants that have leaves that float at the water's surface.

Common Duckweed (*Lemna minor*) and **Watermeal** (*Wolffia columbiana*) are among the world's smallest vascular plants. Individual plants are tiny, round, and bright green. In lakes, they are found scattered among emergent plants or massed together in floating mats. Duckweeds are also commonly found in stagnant waters. They provide food for waterfowl and habitat for aquatic invertebrates.



White Water Lily (*Nymphaea odorata*) emerges from a buried rhizome. Durable round stalks grow up from the rhizome. This perennial herb supports large round leaves (4-10 inches wide) that float at the water's surface. Leaves appear waxy green on top and reddish-purple on their undersides. At mid-summer showy white flowers float at the waters surface. Lilies serve as important fish cover, especially for largemouth bass. White water lily seeds are eaten by waterfowl. With large broad leaves, lilies also help prevent shoreline erosion by slowing wave action.



Exotic Species

The invasive exotic plants identified in the Harmony Grove channels are Eurasian watermilfoil, curly-leaf pondweed and purple loosestrife. The following descriptions are given to promote awareness of these plants.

Eurasian watermilfoil

Eurasian Watermilfoil (*Myriophyllum spicatum*) produces long spaghetti-like stems that often grow up to the water's surface. Leaves are feather-like and resemble bones on a fish. 3-5 leaves are arranged in whorls around the stem, and each leaf contains 12-21 pairs of leaflets. At mid-summer small reddish flower spikes may emerge above the water's surface. Perhaps the most distinguishing characteristic though, is the plant's ability to form dense, impenetrable beds that inhibit boating, swimming, fishing, and hunting.

Eurasian watermilfoil is native to Europe, Asia and Northern Africa. Of the eight milfoil (*Myriophyllum*) species found in Wisconsin, Eurasian watermilfoil is the only exotic. The plant was first introduced into U.S. waters in 1940. By 1960, it had reached Wisconsin's lakes. Since then, its expansion has been exponential (Brakken, 2000).

Eurasian watermilfoil begins growing earlier than native plants, giving it a competitive advantage. The dense surface mats formed by the plant block sunlight and have been found to displace nearly all native submergent plants. Over 200 studies link declines in native plants with increases in Eurasian watermilfoil (Madsen, 2001). The resultant loss of plant diversity degrades fishery habitat (Pullman, 1993), and reduces foraging opportunities for waterfowl and aquatic mammals. Eurasian watermilfoil has been found to reduce predatory success of fish such as largemouth bass (Engel, 1985), and spawning success for trout (*Salmonidae spp.*) (Newroth, 1985).

The continued spread of Eurasian watermilfoil can produce significant economic consequences. In the Truckee River Watershed below Lake Tahoe, located in western Nevada and northeastern California, economic damages caused by Eurasian watermilfoil to the recreation industry have been projected at $30 to $45 million annually (Eiswerth et al., 2003). In Tennessee Valley Authority Reservoirs, Eurasian watermilfoil was found to depress real estate values, stop recreational activities, clog municipal and industrial water intakes and increase mosquito breeding (Smith, 1971).

Eurasian watermilfoil has been found to reduce water quality in lakes by several means. Dense mats of Eurasian watermilfoil have been found to alter temperature and oxygen profiles – producing anoxic conditions in bottom water layers (Unmuth et al., 2000). These anoxic conditions can cause localized die-offs of mollusks and other invertebrates. Eurasian watermilfoil has also been found to increase phosphorus concentration in lakes through accelerated internal nutrient cycling (Smith and Adams, 1986). Increased phosphorus concentrations released by dead and dying Eurasian watermilfoil have been linked to algae blooms and reduced water clarity.

Eurasian Watermilfoil Management Options

Historically, management of Eurasian watermilfoil has included mechanical, biological, and chemical means. It is important to consider each of these control measures before continuing with management efforts on the Harmony Grove channels. After weighing the pros and cons of each option, the wisest course of action should be chosen and control efforts continue.

Manual removal
Manual removal of Eurasian watermilfoil is a useful tool when the extent of milfoil occurs at very low frequencies. Manual removal can include pulling individual plants by hand, or using a rake, or a cutter and then removing the cut plants. For this method to be successful care must be taken to remove the entire root mass along with the plant or else it will quickly regenerate. Given the current high occurrence and wide distribution of Eurasian watermilfoil in the Harmony Grove channels, this method is impractical as a lake-wide control option at this time. However, if other management options are successful in reducing Eurasian watermilfoil to a sparse distribution, this option should be reconsidered. This is still a viable option for riparian property owners. Without obtaining a permit, individuals can hand pull aquatic plants in a 30-foot strip along their property extending out as far as necessary. If *exotic* plants are singled out, there are no restrictions on the extent of manual removal. If large amounts of milfoil are present, it will be hard work and time consuming, but if started early in the year and maintained, can be effective and inexpensive. If individuals choose to manually remove Eurasian watermilfoil, care should be taken to properly identify this species and minimize its fragmentation.

Mechanical harvesting
Mechanical control methods include hand cutters and boat-mounted mechanical weed harvesters (Nichols, 1974). While these methods provide temporary nuisance relief, they are rarely recommended as control methods for Eurasian watermilfoil. Eurasian watermilfoil can reproduce effectively through fragmentation (Borman et al. 1997). Free-floating plant matter left from cutting operations can spread quickly and encourage additional infestations within the lake or in neighboring lakes. Although harvesting does remove plant matter, a source of nutrients to the lake, it is unlikely that harvesting will induce a shift back to a native plant-dominated community. Additionally, harvesting is best suited for deeper waters than exist in the Harmony Grove channels. In the shallow, narrow waters of the channels, damage would likely occur to standard harvesting equipment. Small harvesting units may be able to operate in the deeper (>3 feet) channels, however, the very shallow water outside the channels would not allow for movement amongst the channels. Therefore operation would be limited to deeper channels with boat launches. At this time, it is not recommended that Eurasian watermilfoil be controlled in the Harmony Grove channels through mechanical harvesting.

Milfoil weevils
There has been considerable research on biological vectors, such as insects, and their ability to affect a decline in Eurasian watermilfoil populations. Of these, the milfoil weevil (*Euhrychiopsis lecontei*) has received the most attention. Native milfoil weevil populations have

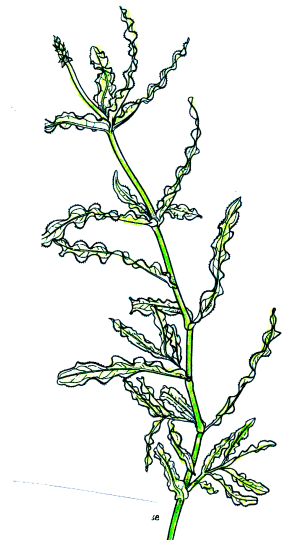
been associated with declines in Eurasian watermilfoil in natural lakes in Vermont (Creed and Sheldon, 1995), New York (Johnson et al., 2000) and Wisconsin (Lillie, 2000). While numerous lakes have attempted stocking milfoil weevils in hopes of controlling milfoil in a more natural manner, this method has not proven successful in Wisconsin. A twelve-lake study called "The Wisconsin Milfoil Weevil Project" (Jester et al. 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the Wisconsin DNR researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, and that Eurasian watermilfoil was unaffected by weevil stocking in any of the study lakes. Until more evidence that suggests weevil stocking is an effective control agent for Eurasian watermilfoil, this method should be discouraged as a control option for the Harmony Grove channels.

Herbicides

Herbicides have been the most widely used and often most successful tools for controlling Eurasian watermilfoil. The two herbicide groups most commonly employed are fluridone (Avast®, Sonar®) and 2,4-D (Aquacide®, Aquakleen®, Navigate®, and Weedar 64®). Whole-lake fluridone treatments have been conducted on several Wisconsin Lakes. While initial results were encouraging (moderate species selectivity, 95-100% initial control), continued monitoring found that desired long-term control was not achieved (Cason, 2002). In addition, for fluridone to be most effective, a relatively long contact time is needed. Since the Harmony Grove channels are open to an exchange of water with Lake Wisconsin, dilution of the fluridone and a resulting loss of efficacy would result. 2,4-D herbicides, on the other hand, have been very effective at controlling Eurasian watermilfoil in hundreds of Wisconsin lakes. 2,4-D is a herbicide which rapidly biodegrades and does not persist in the environment. When applied at labeled rates, 2,4-D has been shown to be an effective tool at selectively controlling Eurasian watermilfoil. Although treatments can occur at various times of the year, early season treatments have the advantage of minimizing the impact to native species and water quality.

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) has oblong leaves that are 2-4 inches long and attach to a slightly flattened stem in an alternate pattern. The most distinguishing characteristics are the curled appearance of the leaves, and the serrated leaf edges. Curly-leaf pondweed also produces a seed-like turion, which resembles a miniature pinecone. Curly-leaf pondweed produces turions in early summer allowing the plant to regenerate annually



This exotic pondweed is a cold-water specialist. Curly-leaf pondweed can begin growing under the ice, giving it a competitive advantage over native plants, which are still lying dormant. By mid-summer when water temperatures reach the upper 70° F, it begins to die off.

Curly-leaf pondweed has been found in the U.S. since at least 1910. A native of Europe, Asia, Africa and Australia, this plant is now found throughout much of U.S. (Baumann et al., 2000).

As with Eurasian watermilfoil, curly-leaf pondweeds aggressive early season growth allows it to out compete native species and grow to nuisance levels. Because the plant dies back during the peak of the growing season for other plants though, it is better able to coexist with native species than Eurasian watermilfoil. Perhaps the most significant problem associated with curly-leaf pondweed involves internal nutrient cycling. The die-off and decomposition of the plant during the warmest time of year leads to a sudden nutrient release in the water. This often leads to nuisance algae blooms and poor water quality.

Curly-leaf Pondweed Management Options

Curly-leaf pondweed has primarily been managed through mechanical and chemical means. Since curly-leaf pondweed is more widely spread in the Harmony Grove channels than Eurasian watermilfoil, the following control options should be considered to determine the best course of action.

Manual removal
As with Eurasian watermilfoil, this method may be appropriate for riparian property owners on the Harmony Grove channels. Manual removal is most effective when curly-leaf pondweed is discovered in its pioneering stage. If it has existed long enough to produce turions, a vegetative reproductive structure, manual removal may become a long-term, labor-intensive process. To be most effective, as with other curly-leaf pondweed control options, early response is recommended. Turion production begins when water temperatures reach into the 60's.

Mechanical harvesting and cutting
Both mechanical harvesting and hand cutting are commonly used to control curly-leaf pondweed. Cutting the plant provides temporary nuisance relief and may increase recreational opportunities on the lake. And although harvesting may not encourage dispersal of the plant, as

it does with Eurasian watermilfoil, it is unlikely to provide any long-term control. Therefore this method is currently not a good choice for Harmony Grove channels.

Herbicides

The herbicide most often used to control curly-leaf pondweed is Aquathol®. Aquathol® is an endothall salt-based herbicide which also rapidly biodegrades. While endothall herbicides are effective on a broad range of aquatic monocots, early season applications made at low rates are highly species-selective for curly-leaf pondweed. While herbicides effectively kill the parent plant, the turions are resistant to herbicides, allowing curly-leaf pondweed to regenerate annually.

Studies conducted by the Army Corps of Engineers have found that conducting treatments of curly-leaf pondweed using Aquathol® early in the spring when water temperatures are in the 50-60° F range will kill plants before turions form, thus providing long-term control. Researchers found that conducting two or more treatments over consecutive seasons for established curly-leaf pondweed populations will target both the standing crop of the pondweed as well as the resulting regrowth from the turions (Skogerboe and Poovey, 2002). These findings make Aquathol® the tool of choice for controlling curly-leaf pondweed in the Harmony Grove channels.

Studies currently being conducted by ACOE are evaluating the efficacy of doing early spring treatments targeting BOTH milfoil and CLP. To date, results are promising. Early spring treatments naturally avoid hurting native species because they aren't growing in the time immediately after ice-out.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) forms bright purple flowers in a spike atop stems that reach 2 to 7 feet in height. Lance-shaped leaves are arranged oppositely along the stem. Purple loosestrife can be found in a wide variety of habitats from shallow water to moist soils. Like Eurasian watermilfoil it is a very aggressive plant that can displace many native wetland plants including cattails (*Typha spp.*). Purple loosestrife plants produce hundreds of thousands of tiny seeds. When purple loosestrife is cut, seeds stick to mowing equipment and are spread to new locations. This invasive plant causes significant economic damage by clogging waterways and irrigation canals. Unlike cattails, purple loosestrife has little food or cover value for wildlife (Borman et. al. 1997). When food and cover disappear, so do the species that depend on it.

Purple Loosestrife Management Options

Small patches of purple loosestrife can be found throughout the Harmony Grove channels. Although these areas have not become a large nuisance, the District and individual property owners should still consider control options to stop the spread of this exotic in the State. There are several methods that are commonly used for purple loosestrife control including manual removal, herbicide treatments and biological controls. The key factor that dictates the best option for control is the density and distribution of the species.

Manual removal
Manual removal is most effective for small infestations. Individual property owners are encouraged to use this method if they are able. This option involves removal and destruction of flowers and seed heads to inhibit plant propagation. Since cut plants tend to re-grow and since seeds present in the soils can sprout new plants, this method may need to be done for a number of years before desired control is achieved.

Herbicides
Herbicide treatments are the least labor intensive of methods. The preferred herbicide is glyphosate (Eagre®, Rodeo®). This compound rapidly biodegrades upon contact with soil or water. As a result, there are no water use restrictions following treatment. Because it is non-selective, each individual plant must be treated, first by cutting each stem followed by “painting” the stem with herbicide, as opposed to broadcast applications. Glyphosate is extremely effective in controlling purple loosestrife at a very low cost of treatment. The biggest disadvantage is that seeds in the soil will sprout new plants, requiring annual treatments for a number of years before desired control is achieved. A DNR permit is required for treatment; however the fee is waived.

Loosestrife beetles
Two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) are currently available from the Wisconsin DNR in an effort to control purple loosestrife by biological means. Research has shown that these insects are almost exclusively dependent upon purple loosestrife

and do not threaten native plants. Although, as with most biological control agents, these insects will not eradicate loosestrife, but may significantly weaken the population and allow native species to reclaim infested areas. According to the WDNR, tests have shown significant declines in loosestrife as a result of biological control. The District should consider using biological control for loosestrife. The purple loosestrife control program established through the DNR provides a parent stock of beetles to individuals who are willing to raise the insects in a controlled environment until they are able to reproduce. Once the young have matured, they are released and are able to begin control of the purple loosestrife. As with other exotic plant control project, annual monitoring should be employed to assess the success of control measures. If significant progress is not made, alternative management options can be considered to control purple loosestrife.   To obtain a starter kits of beetles, contact Brock Woods at the UW-Extension at (608) 221-6349

Lake Wisconsin and Harmony Grove Fishery

During the development of this management plan, information regarding the fishery of lake Wisconsin and more specifically the Harmony Grove channels was requested from the Wisconsin DNR In addition, a fishery biologist had the opportunity to review a draft of the plan.

According to the DNR, fall shocking occurs in Lake Wisconsin annually and all gamefish species are collected. The data are primarily used to evaluation walleye and sauger recruitment as well as sturgeon numbers. Sturgeon monitoring has shown that the population is stable and harvesting is down. Walleye data show fluctuations in numbers over recent years. Other species receive less attention in terms of data analysis and subsequent management. The bass data collected form the Moon Valley sampling station since 1993 suggest numbers are improving in the lake.   For the past 15 years, no specific data has been available for the remainder of the lake including Harmony Grove channels. However, various fish species frequent the channels throughout the year. A number of panfish spawn in the channels. Walleyes frequent the channels from spring to fall. Bass and bluegills are the most common species found ad caught in the channels. Research has shown that the abundance of gamefish is positively correlated to aquatic vegetation. Control of exotic species in favor of native species is an objective in all waters. Limited control or management of native species is recommended by the DNR in terms of fishery health. Water quality is also important for the health of the fish. The DNR noted that the far end of the channels become “downright putrid” in late summer. Addressing water quality will also improve fishery habitat in the channels.

Conclusions and Recommendations

The management recommendations presented in the previous reports by Foth and Van Dyke (2001a, 2001b) focused primarily on sediment reduction through dredging. It was clear during the course of the 2005 study that additional management concerns should be addressed and priorities established. These primarily include exotic and native aquatic plant management and issues relating to water quality. Before any management option is chosen it is recommended that each channel be considered on an individual basis. Aquatic plant management may be a higher priority in one channel versus sediment management in another. District board members should sit down with representatives living on each channel to identify the priorities for each channel. By doing so, the District will best utilize the District's financial resources by directly addressing property owners' concerns.

The channels of Harmony Grove are directly connected to Lake Wisconsin, which is itself a portion of the larger Wisconsin River. As a result, there is a continuous exchange of plants, animals, water and sediments. It is important to keep in mind that management of the channels, whether it is in terms of sediments, aquatic plants, or water quality, will be an on-going process. Management options chosen for implementation will likely need to be carried out on a regular basis to maintain the conditions of the channels desired by the District and riparian property owners.

Sediment Management Objectives

At present the most effective and most immediate option for reducing sediments in the Harmony Grove channels would be hydraulic dredging. Again, keep in mind that dredging is a big commitment not only in economic terms but also the time required to obtain a permit and conduct the dredging. There will also be some inconveniences to lakefront property owners adjacent to the dredging operations. Also the problematic shallow areas outside the channels will continue to impede navigation for the foreseeable future.

The District and individuals should also focus on preventing sediment reaccumulation and the related impacts to water quality. Although there isn't much that can be done to prevent the movement of sand and other sediments from entering from the lake, other external and internal sources can be more easily management. These include improved lawn care and farming practices within the watershed, the restoration of shoreline vegetation, the installation of sedimentation basins, etc. However, depending on the extent of management, these additional options will take time and financial commitments from both the District as well as individual property owners. Again many of the sediment management efforts will also result in improvements to water quality and fisheries habitat

Exotic Species Management Objectives

The Harmony Grove channels are relatively unique in that they continuously receive boat traffic and water movement from Lake Wisconsin. As a result there currently is no feasible approach to monitor or eliminate the flow of exotic species entering the Harmony Grove channels. It would be unrealistic to expect complete eradication of exotic species from Lake Wisconsin, and subsequently the Harmony Grove channels, within the foreseeable future. However, a much more feasible approach can be taken by implementing a management plan designed to suppress and maintain exotic species at sub-nuisance levels. While control efforts can play a large part in this plan, it can also rely heavily on continued volunteer-based education and prevention efforts. Through this plan, members of the Harmony Grove Lake District can hope to restore the aquatic plant community within the channels and set an example of effective exotic species and lake management to other lake organizations.

At present, curly-leaf pondweed and Eurasian watermilfoil can be found in each of the five Harmony Grove channels. These exotics have interfered with recreational activities including swimming, pleasure boating, hunting, and fishing in numerous lakes throughout Wisconsin. Communities of native aquatic plants as well as fish and wildlife have also suffered as a result of these aquatic invaders. In terms of exotic species, it is safe to say curly-leaf pondweed and Eurasian watermilfoil currently pose the greatest threat to the Harmony Grove channels. As a result, one of the primary management objectives for the Harmony Grove Lake District should be long-term control of these exotic species. In order to maintain the beneficial uses of the Harmony Grove channels, it is recommended that the full distribution of curly-leaf pondweed and Eurasian watermilfoil be targeted for control on an annual basis until sufficient control (less than 1 acre in total) is reached. Again, treatments should take place in the early spring to minimize the impact to the native plant community and water quality. If needed, follow-up spot treatments for Eurasian watermilfoil in the summer or fall can be used to further control this species. Once the desired level of control is achieved, the District should revisit additional control measures to determine the best course of action. As exotic species control measures are undertaken, it is important to maintain the diversity of native species in the channels.

Additional management objectives should include: 1) targeted control of purple loosestrife, 2) monitoring the effects of exotic species control on the native aquatic plant community, and 3) the continued involvement of District members and other lake users in preventing the spread of exotic species.

Herbicide Treatment of Navigation Lanes

As was evident from the results of the aquatic plant survey, native aquatic plants play a large part in interfering with navigation in the Harmony Grove channels. And as was previously stated, the shallow nature of the channels would make harvesting of vegetation as a means of native plant control very difficult. In the past, the center of each channel has been treated with a broad spectrum herbicide to open the channel up for navigation. Although targeting exotic species should be an important focus of aquatic plant management, the District will likely need to continue with the treatment of native species for navigational purposes. In fact, as exotic species control proceeds, native plants may take the place of exotics. This may result in further navigation impairments due to native species. Often a mixture of herbicides is used to target all plants and algae. This treatment approach would be most effective if conducted during the summer months when specific locations of impairment can be identified. If particular species are targeted such as the water lilies, a more specific herbicide may be applied in a manner that would target that particular species.

During the treatment of navigation lanes, care should be taken to ensure protection for the native aquatic plant community. Treatment should only occur in areas of the channels where navigation is impeded by plant growth. By taking such measures, the impact to the remaining native community can be minimized.

Management of Shoreline Vegetation

Aquatic vegetation can grow to nuisance levels in the near-shore areas of a lake. Since conventional weed harvesting equipment is unable to operate in the shallow waters along shore, other management options are available to riparian property owners. Typically, there are four management options for control of aquatic vegetation. They are biological, physical, manual/mechanical or chemical. Biological and physical options are used in very specific circumstances. For the homeowners living on the Harmony Grove channels, manual removal and chemical control are the best options for successful control. It is important to note that the removal of native vegetation from a lake regardless of the method being employed can create conditions favorable for colonization by opportunistic plants. This is particularly the case for more aggressive exotics species such a Eurasian watermilfoil.

Manual removal of shoreline vegetation
Individuals can remove aquatic vegetation in front of their homes, however, there are limitations as to where it can occur and how much can be removed. In most instances, control of native aquatic plants is discouraged or should be limited to areas next to piers and docks.

While larger-scale mechanical removal of vegetation requires a permit from the Wisconsin DNR, manually removing plants along shore (i.e. hand-pulling or using rakes) does not. However, when aquatic vegetation is manually removed it is restricted to an area that is 30 feet or less in width along the shore. The non-native invasive plants (Eurasian watermilfoil, curly-leaf pondweed, and purple loosestrife) may be manually removed beyond 30 feet without a permit, as long as native plants are not harmed.

Herbicide treatment of shorelines
Members of the Harmony Grove Lake P & R District must contend with the problems associated with excessive growth of both native and exotic aquatic plants. One option commonly utilized by individual property owners involves near shore chemical treatment of aquatic plants. Individuals can obtain a permit from the Wisconsin DNR to chemically treat aquatic plants in a 30-foot strip along their property extending out to the center of the channel if necessary. The same three chemicals used in treating navigation lanes would be use in this approach as well.

Herbicide treatments

Before an herbicide treatment plan is adopted for a lake, the following concerns should be addressed:

Are these herbicides safe for humans? The Environmental Protection Agency (EPA) lists 2,4-D and endothall as Class D herbicides. This classification means that there are insufficient data to suggest that either compound causes cancer or is harmful to humans. The EPA product label lists no water use restrictions for swimming or fish consumption following treatment with 2,4-D. The product label for endothall however lists a three-day fish consumption waiting period. The University of Michigan School of Public Health recently concluded a review of more than 160 toxicological and epidemiological studies on 2,4-D and concluded that there was not adequate evidence to link 2,4-D exposure to any forms of cancer. Nor does 2,4-D from treated lakes appear to be able to contaminate well water. The Michigan Department of Environmental Quality recently released results of a 4-year study of drinking water wells surrounding twelve lakes heavily treated with 2,4-D. To date, no traces of 2,4-D have been found in any of the test wells (Bondra, 2002). While it is not possible to guarantee that any herbicide is 100% safe, the overwhelming body of evidence suggests that both 2,4-D and endothall pose minimal risks to humans when used as directed.

Are these herbicides safe for the environment? 2,4-D and endothall are both organic herbicides that biodegrade quickly in aquatic environments and do not bioaccumulate. Even if fish consume 2,4-D pellets, the chemical is quickly excreted without entering muscle tissues. For these reasons, there are no label restrictions on fish consumption. Generally, fish species are tolerant of the Aquathol® formulation of endothall at concentrations of approximately 100 ppm or over. Meanwhile, concentrations of only 0.5 to 5.0 ppm are generally required for aquatic weed control. Endothall also has a low toxicity to crustaceans and a medium toxicity to aquatic insects while aquatic invertebrates do not in general seem to be very sensitive to 2,4-D.

Will these herbicides affect desirable plants? Applied correctly at prescribed rates (100-150 lbs/acre), 2,4-D is highly selective to Eurasian watermilfoil. According to the product label, the following plants found in Harmony Grove channels are susceptible or slightly to moderately resistant to 2,4-D at higher rates (150+ lbs/acre): bladderwort, coontail, northern watermilfoil, spatterdock, watershield, water stargrass, and white water lily. At lower rates these and other native plants typically respond positively to treatments and the resulting decreases in Eurasian watermilfoil occurrences.

When applied at low rates (0.5-1.5 ppm), endothall can be used as an effective control option for curly-leaf pondweed. At rates above 1.0 ppm, other native pondweeds as well as coontail, slender naiad, water stargrass and milfoils can also be affected. As a result endothall treatments are timed early in the season to target curly-leaf pondweed while native plant species have not begun to actively grow.

Are they effective? 2,4-D and endothall have been used on thousands of lakes throughout North America. To date 2,4-D treatments have been the single most effective Eurasian watermilfoil control method. In fact, the number of lakes in Michigan having Eurasian watermilfoil problems has actually declined as a result of 2,4-D use (Pullman, 1993). The success of endothall in the control of curly-leaf pondweed depends heavily on timing as well as application rates. As previously stated, early season, low-dose applications have been the most successful control measure for curly-leaf pondweed.

Are they economical? While no control method could be considered cheap, herbicide treatments are among the least costly of methods. This is in part due to the relatively low labor costs in comparison to measures such as hand-pulling, mechanical harvesting, etc. Perhaps the greatest consideration is that these herbicides often produce long-term control of exotics. If treatments are successful, lake management units will not need to spend as much in the long-term as they do for the initial treatments. Once the target species are brought under control, the costs of annual maintenance treatments are often minimal. Because exotics will continuously be introduced to the channels via Lake Wisconsin, it may take longer than expected to reacht he desired level of control.

What are the disadvantages? The greatest disadvantage of herbicide treatments is that they rarely produce 100% control. In most cases, herbicides tend to work only where applied. This is more so the case with granular formulations. Unnoticed and untreated plants may eventually grow to dense beds if left unchecked. Factors such as pH and plant maturity may also reduce treatment efficacy. Several follow-up treatments, whether in-season or in subsequent years, may be needed to reduce exotic species to target levels.

Impacts to water quality can also result from herbicide treatments. When aquatic plant biomass decays following a treatment, it can reduce dissolved oxygen and/or feed planktonic and filamentous algae blooms. This fact can be a major determining factor in any herbicide permit and application.

Herbicide Treatment Costs

There are a number of factor that affect the cost of herbicide treatments. Different plant species whether native or exotic require different herbicides for treatment. The cost of herbicides also vary depend in the type. In general, the District should expect to pay $500 or more per acre for herbicide treatments whether the treatments are designed to target exotic or native species. This cost typically includes chemicals, travel and labor.

Aquatic Plant Surveys

An important component of any plant control effort, whether native or exotic, is the continual monitoring of the plant community. It is recommended that plant surveys be planned for the Harmony Grove channels every three years. If exotic species control efforts result in observed changes in the plant community, it may be wise to conduct the plant survey more frequently. The aquatic plant surveys should utilize previous sampling protocols so that the data collected can be used to accurately assess changes to the plant community. The same transects plotted on the lake for the original survey (Figure 2) should again be used in subsequent surveys. Previous GPS coordinates should again be used to locate each transect.

Protecting Lake Water Quality

Elevated nutrient inputs from human activities around Harmony Grove channels can adversely affect both water clarity and water quality. This may directly affect the fishery, by reducing or eliminating conditions needed for survival of certain fish species. Further, many of the important plant and animal species found in Harmony Grove channels could be adversely affected by decreases in water quality. A large-scale loss of species would negatively affect the lake's ecology. Therefore protecting lake water quality is essential to maintaining and enhancing the fishery of Harmony Grove channels. Many of the options for reducing sediment accumulation previously discussed in this report will also improve water quality.

Emergent plant restoration

Shoreline vegetation can benefit lake ecology tremendously. A properly vegetated shoreline provides habitat for a variety of birds, furbearers, amphibians, and reptiles. Much of the shoreline and emergent vegetation in the Harmony Grove channels appears to have been destroyed by lakefront development. Benefits to lake water quality, fishery and wildlife could be achieved by restoring shoreline plants in the Harmony Grove channels. Lakefront habitat improvement is often done on a property-by-property basis. In recent years many new techniques have been developed for restoring lakefronts. This type of work often incorporates many attractive flowering plants and adds a great deal of aesthetic appeal to lakefronts as well. Studies have also shown that providing complex habitats through shoreline features such as plants and erosion control devices can result in significant increases in fish species richness (Jennings et al., 1999).

Informational resources for property owners

Lakescaping for Wildlife and Water Quality. This 180-page booklet contains numerous color photos and diagrams. Many consider it the bible of shoreline restoration. It is available from the Minnesota Bookstore (651-297-3000) for $19.95.

The Living Shore. This video describes buffer zone construction and gives information on selecting and establishing plants. May be available at local library, or order from the Wisconsin Association of Lakes (800-542-LAKE) for $17.00.

A Fresh Look at Shoreland Restoration. A four-page pamphlet that describes shoreland restorations options. Available from UW Extension (#GWQ027) or WDNR (#DNR-FH-055).

What is a Shoreland Buffer? A pamphlet that discusses both ecological and legal issues pertaining to riparian buffer zones. Available from UW Extension (#GWQ028) or WDNR (#DNR-FH-223).

Life on the Edge…Owning Waterfront Property. A guide to maintaining shorelands for lakefront property owners. Available from UW Extension-Lakes Program, College of Natural Resources, University of Wisconsin, Stevens Point, WI 54481, for $4.50.

The Water's Edge. A guide to improving fish and wildlife habitat on your waterfront property. Available from WDNR (#PUB-FH-428-00).

District Involvement

Improved public awareness is one of the most important aspects of an effective exotic plant species control program. By becoming knowledgeable about the condition of the Harmony Grove channels, the Lake District can learn what practices are necessary to restore the plant community and keep the lake healthy. There are a number of activities that Lake District members can carry out to improve lake users' awareness of the problems facing Harmony Grove channels.

It is important that all access points to the lake be posted with exotic species prevention signs available through the DNR. Because the channels are directly connected to Lake Wisconsin, it is important to control the amount of exotic plant material leaving the channels at the boat landings. It is recommended that signs be posted to encourage boaters leaving the channels to remove any plant material from their watercrafts before entering another waterbody.

Several other prevention and educational awareness activities should be planned. This can include public notices regarding exotic species, distribution of WDNR educational literature to public lake users, and conducting watercraft inspections. These volunteer efforts should focus on preventing the spread of Eurasian watermilfoil and other exotic species. Watercraft inspections can also be used as a tool to document potential watercraft infestations that can be communicated to the WDNR.

Clean Boats, Clean Waters
The Wisconsin DNR in cooperation with the EW-Extension Lakes Program have developed a volunteer watercraft inspection program designed to educate motivated lake organizations in preventing the spread of exotic plant and animal species in Wisconsin lakes. Through the Clean Boats, Clean Waters program volunteers are trained to organize and conduct boater education programs.

For more information contact:
Laura Felda-Marquardt
Clean Boats, Clean Waters Program Coordinator
Wisconsin Invasive Species Program
Ph: 715-365-2659 (Rhinelander)
Ph: 715-346-3366 (Stevens Point)

To download a printable brochure regarding the Clean Boats, Clean Waters program go to http://www.uwsp.edu/cnr/uwexlakes/CBCW/Pubs/CBCW_brochure.pdf.

Plan Development and Approval Process

The Harmony Grove Lake Protection and Rehabilitation District has been actively involved with all aspects of developing this management plan for the Harmony Grove channels. Members of the District helped design the study in order to address the concerns of the property owners living along the channels. District members also assisted with much of the field work conducted during this study.

A number of meetings were held to discuss the progress of this project and to allow District members the opportunity to further express their concerns regarding future management of the channels. Specifically, the Harmony Grove Lake Protection and Rehabilitation District held two special meetings to discuss the 2005 "Management of Aquatic Plants and Sediments in the Harmony Grove Channels" report. The first meeting was held on June 21, 2006 to discuss issues involving the northern two channels. A second special meeting was held on July 13, 2006 to discuss issues involving the southern three channels. Extra effort was made to provide a notice to each resident in addition to the usual public notices prior to each meeting.

The purpose of both meetings was to discuss the results of the 2005 report. A report summary was given to each attendee and full color reports were available for anyone who wanted more detail. The meetings involved a presentation followed by an extensive question and answer session.

At the August 19, 2006 annual meeting the same handouts, presentations and reports were given and provided again. The District unanimously approved an exotic plant and navigation channel treatment program.

The District has begun implementing a number of the recommendations included in the plan. These include a fall 2006 herbicide treatment for Eurasian watermilfoil and plans to remove purple loosestrife from the District in 2007. In addition, the District is currently developing a sediment removal plan. The 2005 plan has been the basis for these activities.

The District is in the process of developing a web site and hopes to make the full report available on that site.

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Appendix A

- Harmony Grove submergent aquatic plant survey data, July 2005.

- Statistical analysis of the Harmony Grove submergent aquatic plant survey data, July 2005.

Channel	Sample point	lat N 43° 22.---'	long w 89° 33.---'	Depth (ft)	Dominant sediment type (M=muck, S=Sand, R=Rock)	Sampled holding rake pole (P) or rake rope (R)?	*Ceratophyllum demersum,Coontail*	*Elodea canadensis,Common waterweed*	*Heteranthera dubia,Water star-grass*	*Lemna minor,Small duckweed*	*Myriophyllum spicatum,Eurasian water milfoil*	*Najas flexilis,Bushy pondweed*	*Najas marina,Spiny naiad*	*Nymphaea odorata,White water lily*
A	1.1				S	P								
A	1.2	398	104	4.5	S	P		1			1			
A	1.3				S	P								
A	2.1				S	P		4			1			2
A	2.2	407	067	3.5	M	P		4						
A	2.3				S	P	3	3			2			1
A	3.1				S	P	1	4			1			1
A	3.2	413	043	3.5	M	P		4						
A	3.3				M	P	2	4						1
A	4.1				S	P	1	3	1	1	1			1
A	4.2	416	014	2.5	M	P	1	4						
A	4.3				S	P	1	2		1	1			2
A	5.1				S	P	1	3						
A	5.2	416	982	3.1	M	P	1	4			1			
A	5.3				S	P		4	1	1	1			2
A	6.1				S	P		3		1	1			2
A	6.2	415	945	3.1	M	P		4						
A	6.3				S	P	2	4			1			1
A	7.1				S	P		4		1	1			1
A	7.2	415	923	2.8	M	P	1	4		1				
A	7.3				S	P	1	4						1
A	8.1				S	P		2						1
A	8.2	414	881	2.5	M	P		3						
A	8.3				S	P		3			1			1
A	9.1				S	P		4		1	1			1
A	9.2	414	829	2.7	M	P		4		1	1			1
A	9.3				S	P		3		1	1			2
B	10.1				S	P		4			1			
B	10.2	335	082	4.8	M	P	1	2						
B	10.3				S	P	1	2			1			
B	11.1				M	P	2	4			1			2
B	11.2	232	043	3.9	M	P		4			1			
B	11.3				S	P	1	4			1			1
B	12.1				S	P	3	4			1			1
B	12.2	334	001	3.8	M	P		4						
B	12.3				M	P	2	3			1			1
B	13.1				S	P	4	4						2
B	13.2	331	974	3.4	M	P	1	4						
B	13.3				S	P	2	4						1
B	14.1				S	P	2	4			1			2

Channel	Sample point	lat N 43° 22.---'	long w 89° 33.---'	Depth (ft)	Dominant sediment type (M=muck, S=Sand, R=Rock)	Sampled holding rake pole (P) or rake rope (R)?	*Ceratophyllum demersum,Coontail*	*Elodea canadensis,Common waterweed*	*Heteranthera dubia,Water star-grass*	*Lemna minor,Small duckweed*	*Myriophyllum spicatum,Eurasian water milfoil*	*Najas flexilis,Bushy pondweed*	*Najas marina,Spiny naiad*	*Nymphaea odorata,White water lily*
B	14.2	335	934	3.5	M	P	1	3			1			
B	14.3				M	P	4	4						2
B	15.1				S	P	2	4						2
B	15.2	334	902	3.5	M	P	1	4						
B	15.3				S	P	1	3			1			2
B	16.1				S	P	3	4			1			4
B	16.2	336	856	3.5	M	P		4						1
B	16.3				S	P	1	1						2
B	17.1				S	P		4						2
B	17.2	336	837	3.3	M	P	1	4			1			
B	17.3				S	P	2	3						3
B	18.1				S	P		3		1				3
B	18.2	330	810	3.6	M	P		4		1				1
B	18.3				M	P	2	4						2
B	19.1				M	P		2		1				3
B	19.2	330	775	3.1	M	P		4						
B	19.3				M	P	2	4						1
B	20.1				S	P	1	1			1			1
B	20.2	342	741	3.1	M	P		4		1				
B	20.3				S	P	1	4		1	1			3
B	21.1				S	P	1	1		1				2
B	21.2	341	712	3.0	M	P		4		1				
B	21.3				S	P		1		1				3
B	22.1				S	P	1	4		1				2
B	22.2	342	674	2.9	S	P	1	4		1				
B	22.3				S	P		2		1				3
B	23.1				S	P		1		1				1
B	23.2	343	637	3.0	M	P		3		1				
B	23.3				S	P		3		1				1
B	24.1				S	P		1		1				2
B	24.2	348	589	3.1	M	P		1		1				
B	24.3				S	P	1	3		1				2
C	25.1				S	P	1	3						
C	25.2	258	080	3.9	S	P		3			1			
C	25.3				S	P		1						
C	26.1				S	P		4			1			3
C	26.2	257	030	5.4	M	P		4						
C	26.3				S	P	1	3			1			1
C	27.1				S	P	1	4			1			2
C	27.2	259	980	5.8	S	P	1	3		1				

Channel	Sample point	lat N 43° 22.---'	long w 89° 33.---'	Depth (ft)	Dominant sediment type (M=muck, S=Sand, R=Rock)	Sampled holding rake pole (P) or rake rope (R)?	*Ceratophyllum demersum,Coontail*	*Elodea canadensis,Common waterweed*	*Heteranthera dubia,Water star-grass*	*Lemna minor,Small duckweed*	*Myriophyllum spicatum,Eurasian water milfoil*	*Najas flexilis,Bushy pondweed*	*Najas marina,Spiny naiad*	*Nymphaea odorata,White water lily*
C	27.3				S	P		4		1				1
C	28.1				S	P	1	3		1	1			1
C	28.2	259	932	5.3	M	P	1	3						
C	28.3				S	P	1	3		1				1
C	29.1				S	P	1	1		1				3
C	29.2	262	895	5.2	M	P	2	4						
C	29.3				S	P	1	3		1				2
C	30.1				S	P		4		1				
C	30.2	260	859	4.7	M	P	1	4		1				
C	30.3				S	P		1		1				1
C	31.1				S	P	1	3		1	1			3
C	31.2	264	837	4.5	M	P		4						
C	31.3				S	P	2	2		1	1			2
C	32.1				S	P		1		1	1			
C	32.2	263	806	4.4	M	P		4		1	1			
C	32.3				S	P	1	4		1				
C	33.1				S	P	2	4		1	1			2
C	33.2	261	770	4.1	M	P	1	4		1				
C	33.3				S	P	2	3		1				2
C	34.1				S	P	4	1						2
C	34.2	262	744	4.2	M	P		4		1				
C	34.3				S	P	3	3		1				1
C	35.1				S	P	3	3		1	1			1
C	35.2	262	717	2.6	M	P	2	4		1				
C	35.3				S	P	2	4		1				1
C	36.1				S	P	2	4						2
C	36.2	263	703	3.5	M	P	2	4		1				
C	36.3				S	P	2	4		1				1
C	37.1				S	P		2		1				1
C	37.2	261	676	3.5	M	P	1	4		1				
C	37.3				S	P	1	4		1				1
C	38.1				S	P	3	4		1				2
C	38.2	262	643	3.4	M	P	1	4		1				
C	38.3				S	P	2	4			1			1
C	39.1				S	P	2	2		1				2
C	39.2	263	617	2.9	M	P	1	4		1				
C	39.3				S	P	2	4			1			1
C	40.1				S	P		4		1				1
C	40.2	262	577	2.7	M	P	2	4		1				
C	40.3				S	P		4		1				2

Channel	Sample point	lat N 43° 22.---'	long w 89° 33.---'	Depth (ft)	Dominant sediment type (M=muck, S=Sand, R=Rock)	Sampled holding rake pole (P) or rake rope (R)?	*Ceratophyllum demersum*,*Coontail*	*Elodea canadensis*,*Common waterweed*	*Heteranthera dubia*,*Water star-grass*	*Lemna minor*,*Small duckweed*	*Myriophyllum spicatum*,*Eurasian water milfoil*	*Najas flexilis*,*Bushy pondweed*	*Najas marina*,*Spiny naiad*	*Nymphaea odorata*,*White water lily*
C	41.1				M	P	1	4		1				1
C	41.2	263	533	2.5	M	P	2	4		1				
C	41.3				M	P		4		1	1			1
D	42.1				S	P	2	4			1			1
D	42.2	187	971	6.5	M	P								
D	42.3				S	P		1						1
D	43.1				S	P		2			1			2
D	43.2	187	941	6.5	M	P								
D	43.3				S	P	1	1						2
D	44.1				S	P	1	4						3
D	44.2	185	894	6.5	M	P					1			
D	44.3				S	P	1	4						2
D	45.1				S	P	2	2						4
D	45.2	186	863	5.8	M	P		1						
D	45.3				S	P	3	4		1	1			1
D	46.1				S	P	2	2						4
D	46.2	187	834	6.5	M	P								
D	46.3				S	P	1	2						2
D	47.1				S	P	4	2						3
D	47.2	186	800	6.4	M	P	1	1						
D	47.3				S	P		4						2
D	48.1				S	P	2	4						4
D	48.2	187	755	5.5	M	P	1	1						
D	48.3				S	P	3	4						4
D	49.1				S	P	2	2						4
D	49.2	189	729	6.1	M	P	1	1						
D	49.3				S	P	3	3		1				3
D	50.1				S	P	3	4						4
D	50.2	188	694	5.3	M	P	1							
D	50.3				S	P	3	1			2			4
D	51.1				S	P	3	3		1				3
D	51.2	188	650	4.4	M	P	2							
D	51.3				S	P	2				1			1
D	52.1				S	P	3							4
D	52.2	189	620	3.5	M	P	1	4			1			
D	52.3				M	P	4	3						3
D	53.1				S	P	2	1						3
D	53.2	189	600	3.4	M	P	3	3						1
D	53.3				S	P	3	4						3
D	54.1				S	P	4			1				4

Channel	Sample point	lat N 43° 22.---'	long w 89° 33.---'	Depth (ft)	Dominant sediment type (M=muck, S=Sand, R=Rock)	Sampled holding rake pole (P) or rake rope (R)?	*Ceratophyllum demersum*,Coontail	*Elodea canadensis*,Common waterweed	*Heteranthera dubia*,Water star-grass	*Lemna minor*,Small duckweed	*Myriophyllum spicatum*,Eurasian water milfoil	*Najas flexilis*,Bushy pondweed	*Najas marina*,Spiny naiad	*Nymphaea odorata*,White water lily
D	54.2	188	574	3.5	M	P	4	4						
D	54.3				S	P		4			1			3
D	55.1				S	P	4							2
D	55.2	190	510	5.1	M	P	4							
D	55.3				M	P	4							2
E	56.1				S	P	1			1	1			1
E	56.2	110	948	3.6	M	P								
E	56.3				M	P	1	2		1			1	2
E	57.1				S	P	1	1		1	1			1
E	57.2	110	923	3.4	M	P	1							
E	57.3				M	P	2			1				3
E	58.1				M	P	2			1				2
E	58.2	111	891	4.4	M	P	1	1						
E	58.3				M	P	2	1		1				3
E	59.1				M	P	2	1		1	1			3
E	59.2	111	849	4.5	M	P	1	1						
E	59.3				M	P	2	2			1		1	3
E	60.1				M	P				1				3
E	60.2	113	828	5.0	M	P	4	3			1			1
E	60.3				M	P	2	3					1	2
E	61.1				S	P	3	2		1	2			3
E	61.2	111	788	4.5	M	P	4	2						
E	61.3				M	P	4	1			1			3
E	62.1				S	P	3	1		1	1			1
E	62.2	114	759	4.1	M	P	3	1						
E	62.3				M	P	4	2		1	1			3
E	63.1				S	P	4	1			1			3
E	63.2	113	718	4.5	M	P								
E	63.3				M	P		4		1	1			4
E	64.1				S	P	4	3			1			1
E	64.2	113	682	4.4	M	P	1	2						
E	64.3				M	P	4	3		1	1			2
E	65.1				S	P	4	2		1	2			1
E	65.2	114	654	3.8	M	P	1	1						
E	65.3				M	P	4	2						3
E	66.1				S	P					1			1
E	66.2	114	616	4.3	M	P	4	3						1
E	66.3				M	P	3			1	1			2
E	67.1				S	P	1			1	2			1
E	67.2	114	597	3.9	M	P	4	4						1

Channel	Sample point	lat N 43º 22.---'	long w 89º 33.---'	Depth (ft)	Dominant sediment type (M=muck, S=Sand, R=Rock)	Sampled holding rake pole (P) or rake rope (R)?	*Ceratophyllum demersum,Coontail*	*Elodea canadensis,Common waterweed*	*Heteranthera dubia,Water star-grass*	*Lemna minor,Small duckweed*	*Myriophyllum spicatum,Eurasian water milfoil*	*Najas flexilis,Bushy pondweed*	*Najas marina,Spiny naiad*	*Nymphaea odorata,White water lily*
E	67.3				M	P	4	3		1	1			3
E	68.1				M	P	4	4		1	1			2
E	68.2	114	558	4.1	M	P	2	3			1			
E	68.3				M	P	4	2		1	1			1
E	69.1				M	P	4	1		1				1
E	69.2	121	504	2.4	M	P	4	2		1				1
E	69.3				M	P	4			1	1			1

Channel	Sample point	*Potamogeton crispus, Curly-leaf pondweed*	*Potamogeton gramineus, Variable pondweed*	*Potamogeton nodosus, Long-leaf pondweed*	Potamogeton pusillus, Small pondweed	*Potamogeton richardsonii, Clasping-leaf pondweed*	*Potamogeton zosteriformis, Flat-stem pondweed*	*Stuckenia pectinata, Sago pondweed*	*Vallisneria americana, Wild celery*	*Wolffia columbiana, Common watermeal*	*Cladophora, Pithophora, etc., Filamentous algae*
A	1.1	1						1			
A	1.2										
A	1.3										
A	2.1								1		2
A	2.2										1
A	2.3	1									1
A	3.1	1									1
A	3.2										2
A	3.3	1									1
A	4.1	1						1			3
A	4.2										2
A	4.3	1						1			2
A	5.1	1									3
A	5.2	1									
A	5.3	1							1		2
A	6.1	2						1			3
A	6.2										1
A	6.3	1									2
A	7.1	1							1		2
A	7.2	1								1	3
A	7.3	1						1			2
A	8.1				1					1	1
A	8.2										2
A	8.3								1		
A	9.1	2								1	3
A	9.2	1								1	3
A	9.3									1	2
B	10.1	1								1	
B	10.2										1
B	10.3	1									
B	11.1										1
B	11.2	1									
B	11.3									1	1
B	12.1	1								1	2
B	12.2	1							1	1	
B	12.3	1								1	
B	13.1	1								1	2
B	13.2	1								1	1
B	13.3	1								1	1
B	14.1	1							1	1	1

Channel	Sample point	*Potamogeton crispus,Curly-leaf pondweed*	*Potamogeton gramineus,Variable pondweed*	*Potamogeton nodosus,Long-leaf pondweed*	Potamogeton pusillus,Small pondweed	*Potamogeton richardsonii,Clasping-leaf pondweed*	*Potamogeton zosteriformis,Flat-stem pondweed*	*Stuckenia pectinata,Sago pondweed*	*Vallisneria americana,Wild celery*	*Wolffia columbiana, Common watermeal*	*Cladophora, Pithophora, etc., Filamentous algae*
B	14.2									1	1
B	14.3	2								1	1
B	15.1	1								1	3
B	15.2	1								1	
B	15.3	1							1	1	3
B	16.1									1	2
B	16.2	1								2	1
B	16.3	2								1	3
B	17.1	2								2	2
B	17.2									1	1
B	17.3	2								1	2
B	18.1									2	3
B	18.2									2	2
B	18.3	2			1					1	2
B	19.1	1								1	
B	19.2	1								2	2
B	19.3	1								1	1
B	20.1									1	2
B	20.2	1								1	
B	20.3	1			1				1	1	3
B	21.1			1						1	1
B	21.2	1								1	1
B	21.3	1			1					1	2
B	22.1	2								2	2
B	22.2	1								1	
B	22.3	2			1					1	4
B	23.1	1								1	4
B	23.2	1								1	2
B	23.3	2							1	2	3
B	24.1	2							1	2	3
B	24.2	1								1	2
B	24.3	1						1		1	2
C	25.1										2
C	25.2								1		2
C	25.3										
C	26.1	2						1	3		2
C	26.2										
C	26.3				1				1		1
C	27.1	1							2		4
C	27.2										1

Channel	Sample point	*Potamogeton crispus,Curly-leaf pondweed*	*Potamogeton gramineus,Variable pondweed*	*Potamogeton nodosus,Long-leaf pondweed*	Potamogeton pusillus,Small pondweed	*Potamogeton richardsonii,Clasping-leaf pondweed*	*Potamogeton zosteriformis,Flat-stem pondweed*	*Stuckenia pectinata,Sago pondweed*	*Vallisneria americana,Wild celery*	*Wolffia columbiana, Common watermeal*	*Cladophora, Pithophora, etc., Filamentous algae*
C	27.3	1						1	2		2
C	28.1								2	1	2
C	28.2	1									
C	28.3	1									2
C	29.1								1	1	2
C	29.2								1		
C	29.3										4
C	30.1	1			1				1		4
C	30.2				1				1		
C	30.3	1			1				1	1	2
C	31.1	1								1	3
C	31.2					1			2		1
C	31.3						1		1		2
C	32.1								1	1	1
C	32.2		1				1			1	1
C	32.3						1		1	1	4
C	33.1	1				1				1	4
C	33.2								2	1	1
C	33.3	1							1		4
C	34.1								1		2
C	34.2								1		1
C	34.3								1	1	2
C	35.1	1				1	1				1
C	35.2								1		1
C	35.3								2	1	2
C	36.1								1		2
C	36.2								1		1
C	36.3						1			1	2
C	37.1	1				1	1				3
C	37.2					1					2
C	37.3									1	4
C	38.1	1				1					4
C	38.2										2
C	38.3	1				1				1	4
C	39.1	1				1					4
C	39.2					1			1		2
C	39.3	1									4
C	40.1										4
C	40.2										2
C	40.3	1				1	1				2

Channel	Sample point	*Potamogeton crispus,Curly-leaf pondweed*	*Potamogeton gramineus,Variable pondweed*	*Potamogeton nodosus,Long-leaf pondweed*	Potamogeton pusillus,Small pondweed	*Potamogeton richardsonii,Clasping-leaf pondweed*	*Potamogeton zosteriformis,Flat-stem pondweed*	*Stuckenia pectinata,Sago pondweed*	*Vallisneria americana,Wild celery*	*Wolffia columbiana, Common watermeal*	*Cladophora, Pithophora, etc., Filamentous algae*
C	41.1										4
C	41.2					1					4
C	41.3	1					1			1	4
D	42.1								2		2
D	42.2										
D	42.3										
D	43.1								3		3
D	43.2										
D	43.3							1			1
D	44.1										3
D	44.2										
D	44.3										2
D	45.1										1
D	45.2										
D	45.3								1		1
D	46.1										1
D	46.2										
D	46.3	1							1		2
D	47.1								1		2
D	47.2										
D	47.3			1							3
D	48.1				1				2		3
D	48.2										
D	48.3	1									4
D	49.1	1									3
D	49.2				1						
D	49.3								1	1	3
D	50.1	1							1		2
D	50.2						1				
D	50.3	1									3
D	51.1	2								1	3
D	51.2						2				1
D	51.3	1			1						1
D	52.1	1									2
D	52.2										
D	52.3									1	2
D	53.1									1	3
D	53.2	1							1	1	
D	53.3	1							3	1	2
D	54.1	1								1	2

Channel	Sample point	*Potamogeton crispus, Curly-leaf pondweed*	*Potamogeton gramineus, Variable pondweed*	*Potamogeton nodosus, Long-leaf pondweed*	Potamogeton pusillus, Small pondweed	*Potamogeton richardsonii, Clasping-leaf pondweed*	*Potamogeton zosteriformis, Flat-stem pondweed*	*Stuckenia pectinata, Sago pondweed*	*Vallisneria americana, Wild celery*	*Wolffia columbiana, Common watermeal*	*Cladophora, Pithophora, etc., Filamentous algae*
D	54.2									1	1
D	54.3	1									2
D	55.1									1	4
D	55.2									1	2
D	55.3									1	4
E	56.1	1									
E	56.2	1							1		
E	56.3										1
E	57.1								2	1	1
E	57.2									1	
E	57.3										3
E	58.1									1	1
E	58.2										
E	58.3										1
E	59.1										2
E	59.2										
E	59.3										1
E	60.1	1								1	2
E	60.2										
E	60.3	1							1		2
E	61.1								1		3
E	61.2	1									
E	61.3	1									3
E	62.1					1				1	1
E	62.2										
E	62.3					2			1		2
E	63.1					2					1
E	63.2										
E	63.3	1							2		2
E	64.1					1			1		4
E	64.2										
E	64.3					2	1		2	1	3
E	65.1					2				1	2
E	65.2					1				1	
E	65.3					2					3
E	66.1			1					1	1	1
E	66.2										
E	66.3	1				1			2	1	4
E	67.1					1			1	1	1
E	67.2									1	

Channel	Sample point	*Potamogeton crispus,Curly-leaf pondweed*	*Potamogeton gramineus,Variable pondweed*	*Potamogeton nodosus,Long-leaf pondweed*	Potamogeton pusillus,Small pondweed	*Potamogeton richardsonii,Clasping-leaf pondweed*	*Potamogeton zosteriformis,Flat-stem pondweed*	*Stuckenia pectinata,Sago pondweed*	*Vallisneria americana,Wild celery*	*Wolffia columbiana, Common watermeal*	*Cladophora, Pithophora, etc., Filamentous algae*
E	67.3									1	4
E	68.1	1				1				1	4
E	68.2					1				1	
E	68.3					1			1	1	3
E	69.1					1				4	2
E	69.2								1	4	
E	69.3									4	2

STATS	Total vegetation	*Ceratophyllum demersum* ,Coontail	*Elodea canadensis* ,Common waterweed	*Heteranthera dubia* ,Water star-grass	*Lemna minor* ,Small duckweed	*Myriophyllum spicatum* ,Eurasian water milfoil	*Najas flexilis* ,Bushy pondweed	*Nymphaea odorata* ,White water lily	*Potamogeton crispus* ,Curly-leaf pondweed	*Potamogeton gramineus* ,Variable pondweed
Total number of points sampled	20									
Total number of sites with vegetation	201									
Total number of sites shallower than maximum depth of plants	207									
Frequency of occurrence within vegetated areas (%)	97.1	71.14	90.55	0.995	43.78	36.32	1.493	67.66	45.27	0.498
Frequency of occurrence at sites shallower than maximum depth of plants	97.1	69.08	87.92	0.966	42.51	35.27	1.449	65.7	43.96	0.483
Relative Frequency (%)	100.0	17.4	22.1	0.2	10.7	8.9	0.4	16.5	11.1	0.1
Relative Frequency (squared)	0.144	0.030	0.049	0.000	0.011	0.008	0.000	0.027	0.012	0.000
Simpson Diversity Index	0.86									
Maximum depth of plants (ft)	7									
Number of sites with Eurasian water-milfoil	73									
Average Rake Fullness Eurasian water-milfoil	1.068									
Number of sites with Curly-leaf pondweed	91									
Average Rake Fullness Curly-leaf pondweed	1.143									
Number of sites where species found		143	182	2	88	73	3	136	91	1
Number of sites where species found using rake on Pole (P)	207									
Number of sites where species found using rake on Rope (R)	0									

STATS

STATS	*Potamogeton nodosus* ,Long-leaf pondweed	Potamogeton pusillus,Small pondweed	Potamogeton *richardsonii* ,Clasping-leaf pondweed	*Potamogeton zosteriformis* ,Flat-stem pondweed	*Stuckenia pectinata* ,Sago pondweed	*Vallisneria americana* ,Wild celery	*Wolffia columbiana* , Common watermeal	*Cladophora, Pithophora* , etc., Filamentous algae
Total number of points sampled								
Total number of sites with vegetation								
Total number of sites shallower than maximum depth of plants								
Frequency of occurrence within vegetated areas (%)	1.493	5.97	5.473	5.473	4.478	28.86	46.27	80.6
Frequency of occurrence at sites shallower than maximum depth of plants	1.449	5.797	5.314	5.314	4.348	28.02	44.93	78.26
Relative Frequency (%)	0.4	1.5	1.3	1.3	1.1	7.0	11.3	19.7
Relative Frequency (squared)	0.000	0.000	0.000	0.000	0.000	0.005	0.013	0.039
Simpson Diversity Index								
Maximum depth of plants (ft)								
Number of sites with Eurasian water-milfoil								
Average Rake Fullness Eurasian water-milfoil								
Number of sites with Curly-leaf pondweed								
Average Rake Fullness Curly-leaf pondweed								
Number of sites where species found	3	12	11	11	9	58	93	162
Number of sites where species found using rake on Pole (P)								
Number of sites where species found using rake on Rope (R)								