

# Diamond Lake Aquatic Management Plan



Prepared for:  
Middle Fork Crow Watershed District



189 County Road 8 NE  
P.O. Box 8  
Spicer, MN 56288



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Prepared by:

**WENCK Associates, Inc.**  
1800 Pioneer Creek Center  
Maple Plain, MN 55359  
Phone: 7963-479-4200  
Fax: 763-479-4242

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# 1.0 Introduction

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## 1.1 PURPOSE

The Middle Fork Crow River Watershed District (MFCRWD) and the Diamond Lake Area Recreational Association (DLARA) desire an aquatic plant management plan for Diamond Lake that addresses effective long-term management of aquatic invasive plant species. MFCRWD and the DLARA have recently managed invasive aquatic plants through the use of harvesters and herbicide application. However, MFCRWD and the DLARA believe a plan that focuses on long-term management will better address improving water quality, lake navigation, and native vegetation health. These goals will be addressed through:

- ▲ Identifying the current status of aquatic plants in Diamond Lake.
- ▲ Specifying quantifiable management goals.
- ▲ Recommending specific management action items to improve lake conditions.
- ▲ Developing an annual budget for program implementation.

The development of an aquatic plant management plan will also provide a number of other benefits to lakeshore property owners and the surrounding area around Diamond Lake. Typical benefits of an aquatic plant management plan include but are not limited to:

- ▲ Improved lake access for lakeshore property owners or other property owners sharing a private lake access.
- ▲ Improve opportunities for recreation on the lake for property owners and surrounding neighbors by creating opportunities for fishing, boating, wildlife habitat, and swimming.
- ▲ Provide a low cost service for management of aquatic plants to help improve navigability of the lake.
- ▲ Reduced internal nutrient loading, which will ultimately reduce the number and severity of algal blooms.

## 1.2 MANAGEMENT GOALS

### 1.2.1 Issues

As part of the plan development, MFCWD hosted a public meeting with the lake association Board (October 4, 2014) to discuss the lake's issues and the goals that should be established. The issues facing Diamond Lake are:

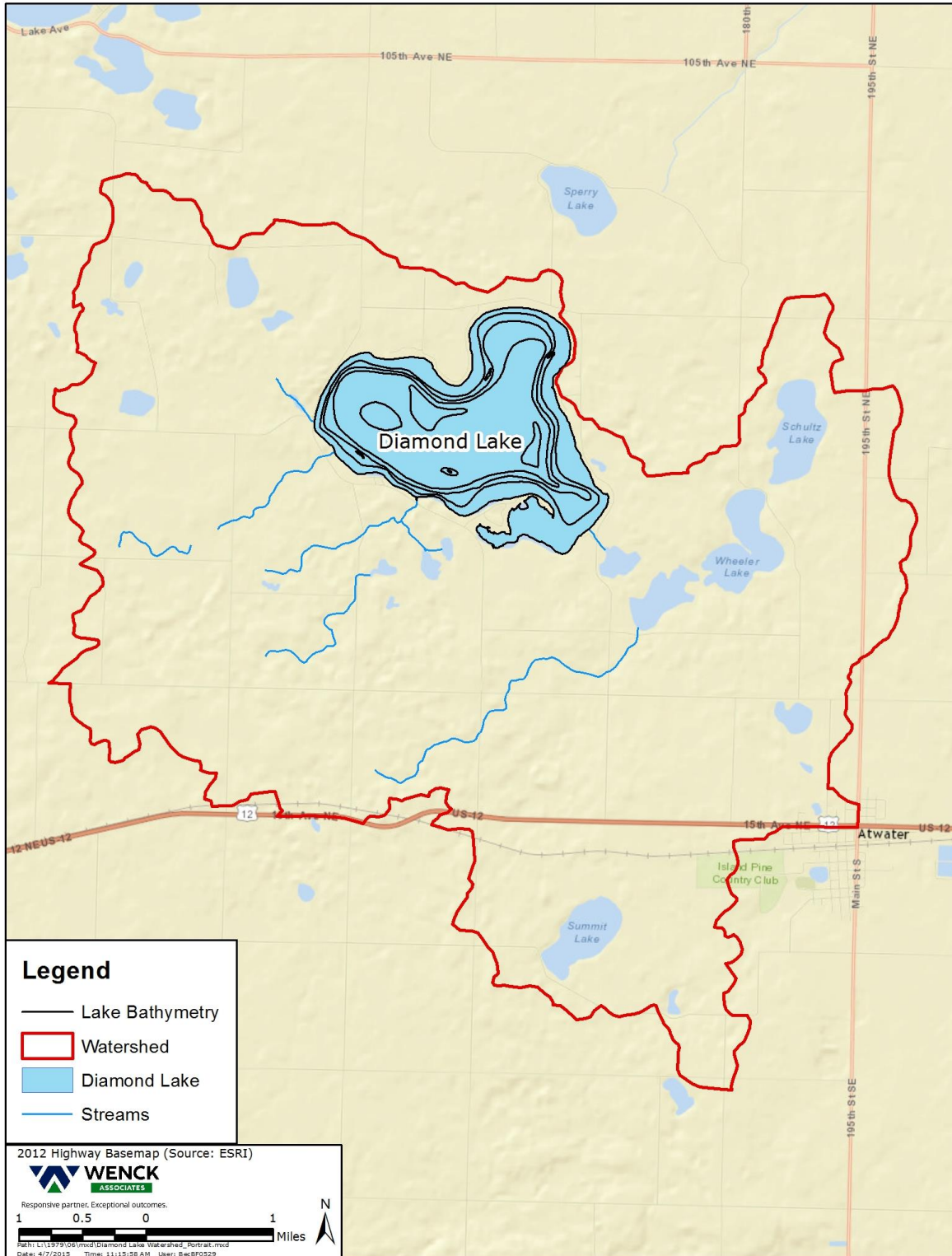
- ▲ An over abundant plant community that reduces the aesthetic value of the lake leading to nuisance levels of dead plant biomass in shallow areas.
- ▲ Excess aquatic invasive species limit plant diversity due to excessive early season growth.
- ▲ Submerged aquatic vegetation is overabundant in the lake leading to limited swimming opportunities.

### 1.2.2 Goals

- ▲ Improve and maintain the ecological conditions of the lake including minimizing nuisance plant abundance, invasive species dominance, filamentous algae mats, foul odors, and nuisance algal blooms.
- ▲ Improve and maintain a healthy and balanced fishery that supports reasonable fishing opportunities and local bird populations.
- ▲ Improve and maintain the wildlife habitat of the lakes including birds and mammals through plant diversity.
- ▲ Protect the lake from invasive species including Curly-leaf pondweed and Eurasian water milfoil.
- ▲ Improve water quality conditions by reducing excessive plant buildup and subsequent nutrient release.
- ▲ Improve and maintain the recreational uses of the lake including boating, fishing, and winter recreation.

### 1.3 CURRENT CONDITIONS

Diamond Lake's watershed resides within multiple municipal boundaries (Green Lake Township, Harrison Township, Kandiyohi Township, Genesee Township, and Atwater City) and is approximately 17,989 acres (Figure 1-1). Diamond Lake is a 1,607 acre lake with a maximum depth of approximately 27 feet. The littoral area of Diamond Lake covers 635 acres or 39.5% of the total lake area.



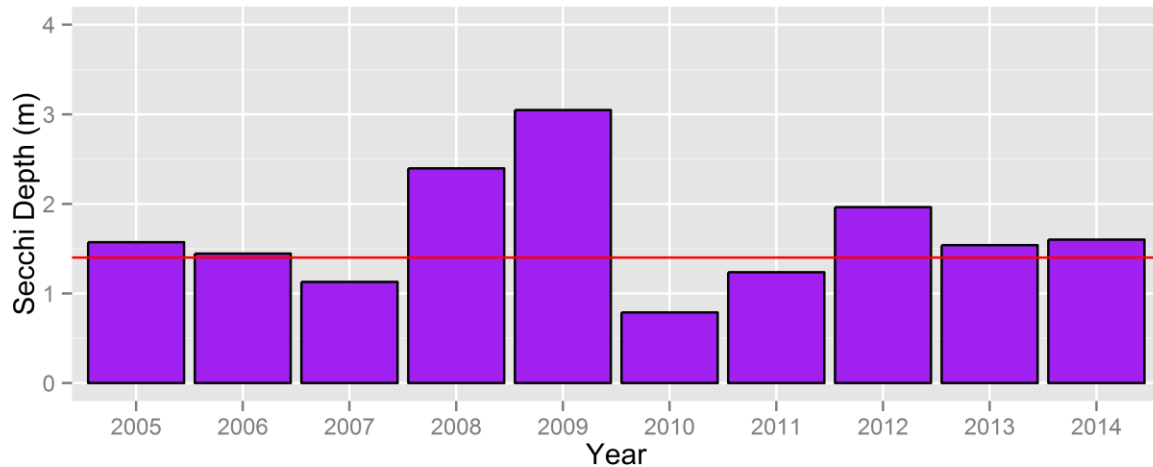
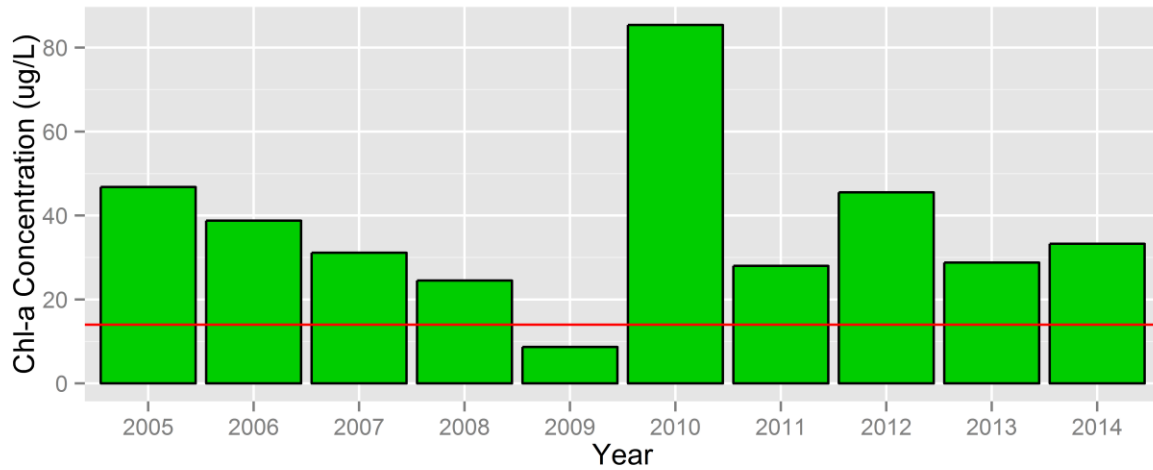
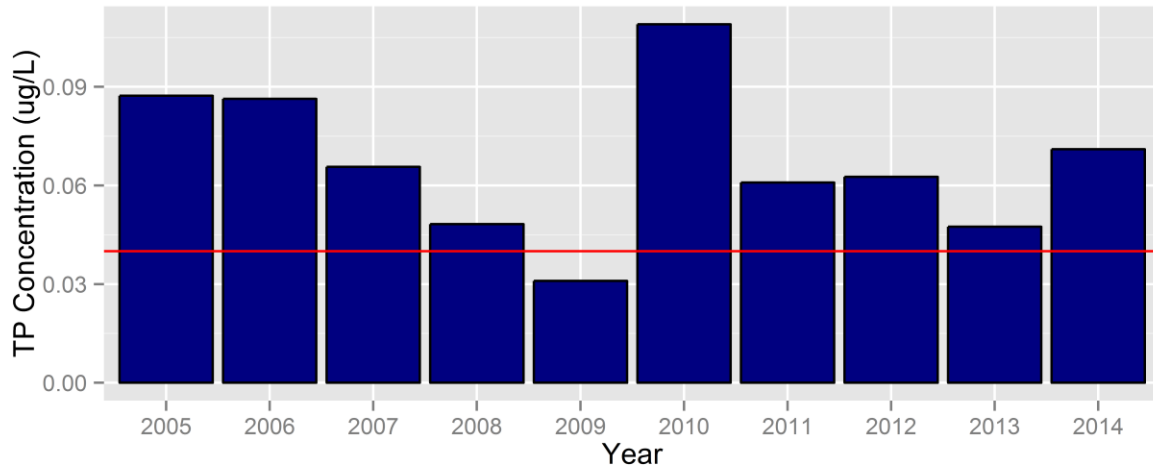
**Figure 1-1: Diamond Lake watershed**

### **1.3.1 Water Quality: Total Phosphorus, Chlorophyll-a, and Water Clarity**

Algal growth (measured as total chlorophyll-a) is typically limited by the amount of phosphorus in the water column in most Minnesota lakes. Therefore, total phosphorus is typically considered the causative factor for algal growth. Summer average total phosphorus concentrations in Diamond Lake range from 31 to 109 µg/L, which exceeds the state deep lake standards for North Central Hardwood Forest Ecoregion Lakes (<40 µg/L) in 9 of the 10 monitored years (Figure 1-2).

Chlorophyll-a is a measure of the biomass in a lake at any given time. The greater the algal biomass and corresponding chlorophyll-a values, the more green and productive a lake appears with worst case scenarios including algal scum and foul odors. These conditions are considered nuisance algal blooms, and are both aesthetically displeasing and create detrimental conditions for fish and other aquatic organisms. Summer average chlorophyll-a concentrations in Diamond Lake range from 8 to 85 µg/L (Figure 1-2), with 9 of the 10 monitored years exceeding the state water quality standard for deep lakes in the North Central Hardwood Forest Ecoregion (<14 µg/L) as a summer average.

Water clarity in lakes is typically measured using a Secchi disk, which is a black and white disk that is lowered into the water column until it can no longer be seen. The depth at which the disk disappears is known as the Secchi depth and is considered the depth where 90% of the light is extinguished. Water clarity in lakes is controlled by several factors including the amount of algae in the water column as well as other suspended particles such as suspended sediment. Summer average water clarity measurements in Diamond Lake range from 0.8 to 3.0 meters (Figure 1-2), with 7 out of 10 years meeting water quality standards.



**Figure 1-2: Diamond Lake total phosphorus (TP), chlorophyll-a, and water clarity summer averages. Red lines on each graph represent the state standard for deep lakes for each respective parameter.**



### 1.3.2 Submerged Aquatic Vegetation

Table 1-1 and Figure 1-3 depict the most recent vegetation surveys on Diamond Lake. Although there is only one vegetation survey on Diamond Lake, it does give a snapshot of the general aquatic vegetation distribution in Diamond Lake (Table 1-1). In general, Diamond Lake has a diverse aquatic vegetation community with many native plants growing such as muskgrass, northern watermilfoil, coontail, flat-stem pondweed, sago pondweed, clasping leaf pondweed, narrowleaf pondweed, Canada waterweed, and wild celery (Table 1-1).

Curly-leaf pondweed (CLP) was observed in 18% of the sites in the 2012 vegetation survey (Figure 1-3). This survey may underestimate the actual abundance of CLP since it was conducted in mid-June, which is after the peak CLP growth period; however, this survey does depict the main areas of CLP. Interestingly, there was no recorded Eurasian watermilfoil even though lakes in the area are heavily infested with the aquatic invasive species.

**Table 1-1: Aquatic Vegetation Species Occurrence and abundance on Diamond Lake.**

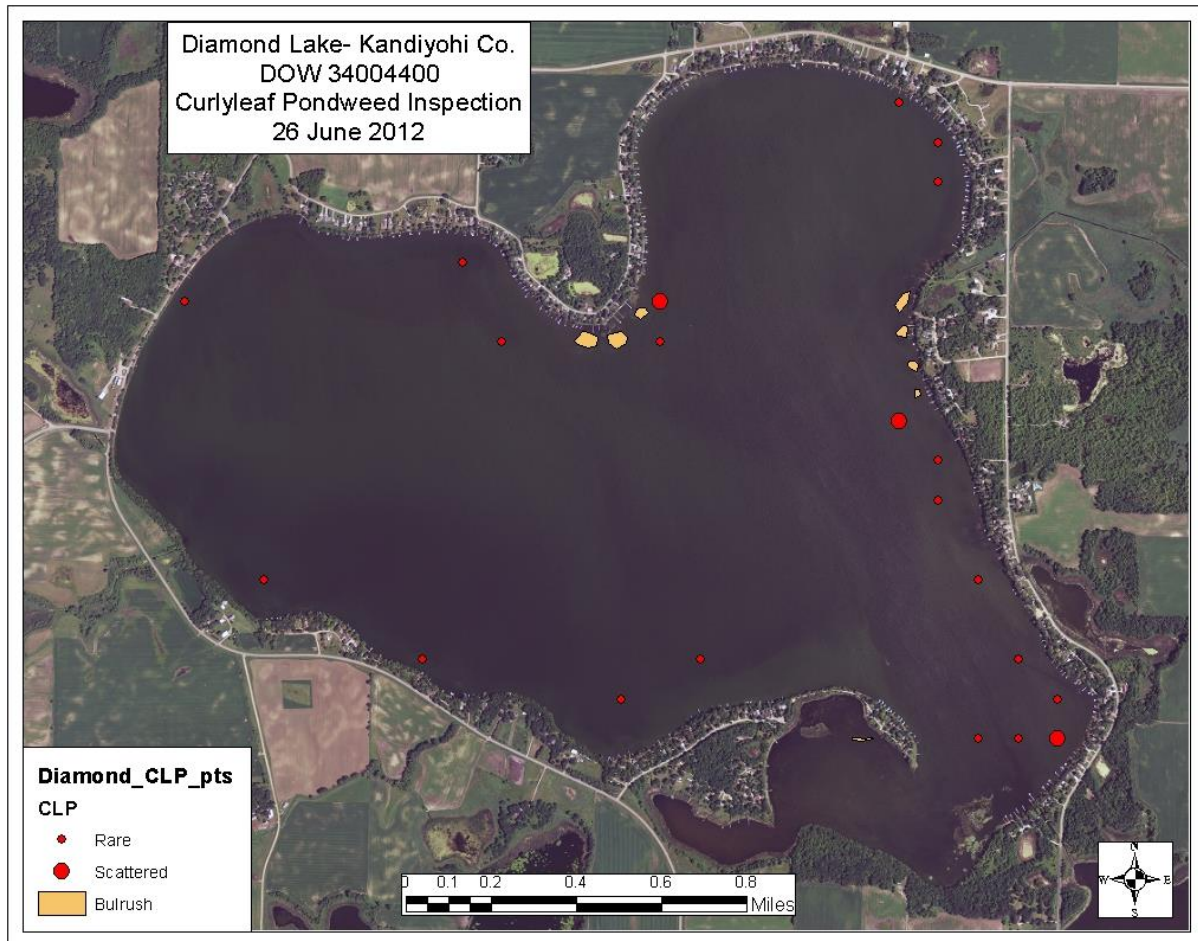
| Species               | Species Frequency |
|-----------------------|-------------------|
| Curly-leaf pondweed   | 18%               |
| Muskgrass (Chara)     | 40%               |
| Northern Watermilfoil | 8%                |
| Coontail              | 13%               |
| Flat-stem Pondweed    | 8%                |
| Sago Pondweed         | 5%                |
| Claspingleaf Pondweed | 3%                |
| Narrowleaf Pondweed   | 34%               |
| Canada Waterweed      | 5%                |
| Wild Celery           | 6%                |

### 1.3.3 Past Management Activities

Past management activities on the lake have included herbicide application and mechanical vegetation removal. These activities were not formalized into a long-term aquatic plant management plan.

**Table 1-2: Past Aquatic Vegetation Management Activities on Diamond Lake**

| Species            | Species Frequency           |
|--------------------|-----------------------------|
| Mechanical Cutting | Early 1990s-2005; 2008-2009 |
| Chemical Treatment | 2013-2014                   |



**Figure 1-3: 2012 Curly-leaf pondweed vegetation map (Source: MnDNR, personal communication).**

## 1.4 AQUATIC PLANT MANAGEMENT PERMIT REQUIREMENTS

### 1.4.1 Introduction

The management of aquatic plants in Minnesota is regulated by Minnesota Statute, Section 103G.615, Chapter 6280 and is enforced by the Minnesota Department of Natural Resources (DNR). Aquatic plant management activities may or may not require an Aquatic Plant Management (APM) permit, based on the nature of the activity.

APM permits may be issued to provide riparian access, enhance recreational use, control invasive aquatic plants, manage water levels, and protect or improve habitat. Separate permits are required for controlling natives for recreational access and controlling aquatic invasive species. A specific list of criteria is considered to determine if a permit should be granted. A permit will not be issued to improve the appearance of undeveloped shoreline or for aesthetic reasons alone. A permit also cannot be issued in areas given special designations, such as Scientific and Natural Areas or in areas posted as protected fish spawning areas. Permits are required for the control of invasive species and recreational access.

There are a number of permit fees associated with the control of vegetation in Minnesota lakes. For recreational access, the fee for offshore (>150 feet from shore) mechanical control of submerged aquatic vegetation is \$35.00 for the first acre, plus \$2.00 for each additional acre up to a maximum fee of \$2,500.00. The fee for offshore mechanical control of rooted vegetation on lakes 20 acres or less in size is \$17.50 for the first acre plus \$1.00 per acres for each additional acre. To control rooted aquatic vegetation with pesticides, the fee is \$35 for each contiguous parcel of shoreline up to a maximum of \$2,500. If multiple methods are used, only the larger of the fees applies. There is typically no fee for a permit to control aquatic invasive species.

#### **1.4.2 Activities Not Requiring a Permit**

Chapter 6280.0250 allows certain activities without an Aquatic Plant Management (APM) permit. Specifically, mechanical control of submersed aquatic plants is allowed by individual property owners in an area not to extend along more than 50 feet or one-half the length of the owner's total shoreline, whichever is less, and not to exceed 2,500 sq. ft. plus the area needed to extend a channel no wider than 15 feet to open water.

These rules also allow for the mechanical control of floating-leaf aquatic plants to obtain a channel extending to open water with the provisions that the channel is no more than 15 feet wide and follows the most direct route to open water, the channel is maintained by cutting or pulling, and the channel remains in the same location from year to year.

The skimming of duckweed or filamentous algae off of the surface of a water body is also allowed without a permit.

#### **1.4.3 Activities Requiring a Permit**

An APM permit is required for all other activities below the Ordinary High Water (OHW) level not mentioned above, including all herbicide control of aquatic plants, relocating or removing bogs, and installing or operating an automated aquatic plant control device (weed harvester).

#### **1.4.4 Types of Aquatic Plant Management Control**

##### **Mechanical Control**

Mechanical control of aquatic vegetation typically involves the cutting, pulling, raking or otherwise removing or altering aquatic plants by physical means. Mechanical control of aquatic plants is limited to an area that does not exceed 50% of the littoral area of a lake. Additionally, vegetation must be immediately removed from water and delivered to disposal or reuse site. Removal can occur as frequently as the applicant desires; however, the frequency must be approved by the DNR.

Advantages to mechanical harvesting include:

- ▲ A specific area can be targeted using mechanical cutting.
- ▲ Harvesting can cover a much larger area (50% of littoral area) without needing a permit variance.
- ▲ Harvesting removes actual plant material from lake, which consequently removes nutrients stored in the plant matter. This may reduce internal loading of phosphorus

Drawbacks to mechanical harvesting include:

- ▲ Plant material harvested during mechanical removal must be disposed of immediately.
- ▲ The process can be time intensive relative to herbicide application.
- ▲ Per acre costs are relatively high (\$482/acre).
- ▲ A dump site must be identified by LGU.
- ▲ Incidental fish mortality is possible if fish are caught in mechanical blades.
- ▲ Plant debris may not be completely removed from the lake during harvesting, which decrease the effectiveness of invasive removal.

Long term benefit:

- ▲ If harvesting continues over a long time period, the continued removal of plant matter, and subsequently nutrients, may positively impact internal phosphorus loading to Diamond Lake.

## Herbicide Control

Herbicide control of aquatic vegetation typically involves the applying herbicides to desired treatment areas, which subsequently kills specific aquatic plants. Herbicide control of aquatic plants is limited to an area that does not exceed 15% of the littoral area of a lake. Only specific pesticides that are labeled for use in aquatic sites can be used, and they must be applied according to the label instructions. Removal can occur as frequently as the applicant desires, however the frequency must be approved by the DNR.

Advantages to herbicide control include:

- ▲ Lower per acre cost relative to mechanical control (\$266/acre).
- ▲ No disturbance to sediments or shoreline property.
- ▲ Can treat small and large areas.
- ▲ Targeted treatment areas should decrease after multiple years of treatment due to invasive area shrinkage.

Drawbacks to herbicide control include:

- ▲ The use of chemicals may upset some landowners.
- ▲ Herbicide treatment may decrease in-lake oxygen concentrations due to plant decomposition; however, oxygen decreases will be temporary.
- ▲ Although endothall is a fast acting herbicide, results from application are not immediate (results may take days).
- ▲ Only 15% of the total littoral area can be treated unless a variance from the Minnesota DNR is obtained.

Long term benefit of herbicide control:

- ▲ Continued annual treatment areas will gradually diminish, which will result in decreasing costs over time.
  - Decreased areas of aquatic invasives will likely improve aquatic diversity and decrease internal loading

#### **1.4.5 Permit Requirements**

A riparian lakeshore owner, lake association, or government agency may apply for an APM permit. Before the permit is issued, it is necessary to obtain the permission and signature of all landowners whose shorelines will be treated.

Applications for permits must be submitted by August 1 of each year. An APM permit is valid for one growing season and expires on December 31 of the year that it is issued.

## 2.0 Vegetation Management Alternatives

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This study finds that an aquatic plant management plan would be beneficial for Diamond Lake due to the presence of invasive species and an abundance of submerged aquatic vegetation in littoral areas. To identify the optimum amount of management, the following assessment was completed.

- ▲ Descriptions of assessments of alternatives for aquatic plant management.
- ▲ Targeted Alternatives (harvesting and herbicide treatment).
  - An assessment of management impacts to fisheries, fish habitat, and water quality due to proposed management alternatives.
- ▲ Identifications of other considerations for management actions.

### 2.1 DESCRIPTION OF ALTERNATIVES

As mentioned previously, herbicide application and mechanical vegetation removal for management of aquatic plants has occurred in the past on Diamond Lake. The focus of these past activities was to facilitate greater recreational and navigational use on the lake and contain activities within permit limits.

Proposed alternatives were developed to be in line with goals identified in Section 1. Two targeted alternatives were assessed that are within state permit guidelines as part of this plan.

#### 2.1.1 Targeted Invasive Species Alternative #1 – Contract Mechanical Removal

The lead LGU would hire a Contractor to harvest targeted areas of aquatic invasive species (e.g. Curly-leaf pondweed) (Figure 2-1). The designated area was assumed to be harvested once in the spring (late May to early June). It is important to note that past surveys have not identified Eurasian watermilfoil in Diamond Lake, however, management of Eurasian watermilfoil may be required in the future and contingencies may be required for the additional treatments although they should be small enough to be included in current activities.

Harvesting would be conducted by a contract harvester one time per year focused on harvesting in areas identified with high invasive abundance (Figure 2-1 and Figure 1-3). The main harvesting area is less than the maximum allowed 324 acres but was selected based on the density of aquatic invasive species (e.g. Curly-leaf pondweed) (Table 2-1). A contractor would be selected by the lead LGU from the Minnesota DNR “Commercial Mechanical Control Companies” list to complete the harvesting. Contractors would be selected early in the year and could be selected for multi-year contracts.

Lakeshore residents could hire the Contractor selected by the LGU to cut access paths to their personal docks if desired. The harvester would not be available later in the summer as plants grow and fill in the cut areas. The cutting area associated with these access paths was not incorporated in this plan, but the addition of these paths cannot exceed the DNR permit limit of 50% of the littoral zone (324 acres). The primary goal of this alternative is to manage invasive species.

The following assumptions have been made for this alternative:

- ▲ A Minnesota licensed mechanical harvesting contractor would be hired to provide the treatment service at a cost of approximately \$482/acre in 2016 dollars.
- ▲ Monitoring would be completed by the Lake Association, Watershed District, or by volunteer residents every year to confirm effectiveness of treatment options.
- ▲ The size of the treatment area to be treated does not change annually.

**Table 2-1: Aquatic Vegetation Species Occurrence and abundance on Diamond Lake.**

| Location                | Treatment Area                                | Acres      |
|-------------------------|---|------------|
| Diamond Lake Harvesting | Harvesting Areas                              | 86         |
|                         | Spot Harvesting Area                          | 48         |
|                         | <b>Total Harvesting Area</b>                  | <b>134</b> |
|                         | Maximum Possible Harvesting Area <sup>1</sup> | 324        |

<sup>1</sup>Maximum harvesting areas are calculated as 15% of the total littoral area for herbicide and 50% of the total littoral area for harvesting

### 2.1.2 Targeted Invasive Species Alternative #2 – Contract Herbicide Application

The lead LGU would contract to have areas with high aquatic invasive species (e.g. Curly-leaf pondweed) treated with herbicides once a year. The treatment would occur annually in early spring targeting the appropriate water temperatures (Figure 2-1).

Herbicide would be used to manage moderate and high density stands of aquatic invasive species (e.g. Curly-leaf pondweed). The LGU would contract to have CLP infested areas treated with a DNR approved herbicide once a year (Figure 2-1). The use of endothall was assumed for developing the cost estimate. Endothall is currently an industry standard for controlling Curly-leaf pondweed. The targeted area to be treated is 86 acres, which does not exceed the maximum annual DNR permitted area that can be treated with herbicide; however, there is 48 acres that may require spot treatment (Table 2-2). Only 11 acres of the 48 acres could be treated to stay within the confines of DNR rules. If more than 97 acres will be treated, a permit variance would be required.

**Table 2-2: Aquatic Vegetation Species Occurrence and abundance on Diamond Lake.**

| Location               | Treatment Area                               | Acres     |
|------------------------|--|-----------|
| Diamond Lake Herbicide | Herbicide Treatment Areas                    | 86        |
|                        | Herbicide Spot Treatment Area                | 11*       |
|                        | <b>Total Herbicide Treatment Area</b>        | <b>97</b> |
|                        | Maximum Possible Herbicide Area <sup>1</sup> | 97        |

\*There is 48 acres that may require spot treatment but only 11 acres of the 48 acres could be treated to stay within the confines of DNR rules. It is assumed the 11 acres would be chosen annually based on plant density.

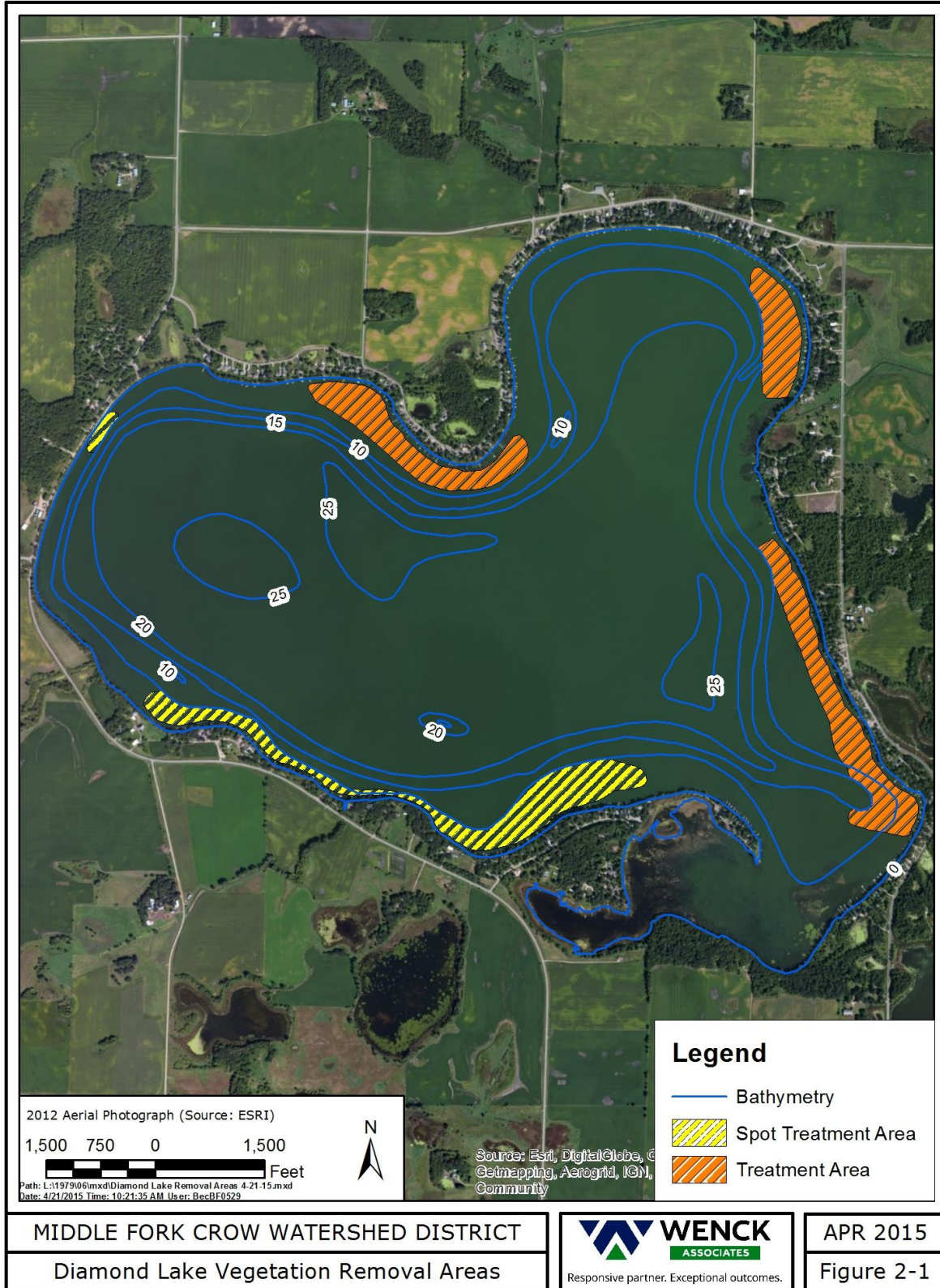
The following assumptions have been made for this alternative:

- ▲ A Minnesota licensed herbicide applicator would be hired to provide the treatment service at a cost of approximately \$266/acre in 2016 dollars.
- ▲ Monitoring would be completed by the Lake Association, Watershed District, or by volunteer residents every year to confirm effectiveness of treatment options.
- ▲ The size of the treatment area to be treated does not change annually.

### **2.1.3 Alternatives Not Assessed**

Another alternative that was not assessed as a part of this study was for the lead LGU to own and operate a harvester. This alternative was not deemed feasible at this time due to the logistics associated with operating a harvesting program and high initial capital costs. This approach requires storage, equipment maintenance, operator training, insurance, and trailering. Since the areas are relatively small for removal and none of the potential lead LGU are currently set up to take this on, this alternative was not assessed. This could potentially be reevaluated in the future.





**Figure 2-1: 2012 Curly-leaf pondweed vegetation map**

## 3.0 Assessment of Alternatives

### 3.1 ALTERNATIVE ASSESSMENT

Each of the alternatives was evaluated for a 15 year life-cycle cost for long term comparison and budgetary planning. Both management alternatives are focused specifically on managing aquatic invasive vegetation. Assumptions made for life-cycle cost estimates include:

- ▲ Each scenario assumes the project begins in 2016.
- ▲ Each Scenario evaluated to determine cost based on a 15-year operations period to give a total present worth cost for each scenario.
- ▲ A 4% discount rate and 3% inflation rate were used in present worth calculations.
- ▲ Harvesting and chemical applications were assumed to occur once annually.
- ▲ Harvesting alternatives assume a minimum cutting width of 7 feet.

#### 3.1.1 Invasive Species Control

The cost of using herbicides is roughly half of the costs harvesting (\$482/acre versus \$266/acre respectively; Table 3.1). Mechanical harvesting of vegetation allows for a larger area to be addressed but herbicide use can affect an equal area with drift and is generally more effective at controlling invasive species. Additionally, mechanical harvesting allows for early spring cutting for recreational access from local docks to open water. Each of these scenarios requires preliminary mapping each year to identify the target areas for mechanical removal and herbicide application which may result in changes to the treatment area.

| Alternative | Description        | Acres       | Total Life Cycle Cost | Average Annual Cost <sup>1</sup> | Cost/Acre/Year | Initial Year Cost (2016) |
|-------------|--------------------|-------------|-----------------------|----------------------------------|----------------|--------------------------|
| 1           | Contract Harvest   | 86<br>(48)* | \$968,410             | \$64,561                         | \$482          | \$69,018                 |
| 2           | Contract Herbicide | 86<br>(11)* | \$386,297             | \$25,753                         | \$266          | \$27,531                 |

<sup>1</sup>Each annual cost adjusted to inflation and summed to obtain a total lifetime cost.  
(\*) Area in parenthesis is the area designated for spot treatments.

### 3.2 OTHER AQUATIC PLANT MANAGEMENT ACTIVITIES

There are a number of other activities that can be completed to improve native vegetation in Diamond Lake and offset any potential negative impacts to the lake. Following is a description of these activities.

#### 3.2.1 Nitrogen Load Reductions

One of the likely contributors to the overabundance of native vegetation in littoral areas in Diamond Lake is the buildup of nitrogen in lake sediments. To offset these impacts, opportunities to reduce nitrogen loading to the lake should be explored. Recent technological advances in nitrogen removal such as woodchip bioreactors recently demonstrated a high potential for nitrogen removal from stormwater runoff. However, an



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analysis of the watershed for suitability and impact would be required. Furthermore, there is no required nitrogen reductions listed in the Diamond Lake TMDL since nitrogen is not typically a limiting nutrient for algal growth in Minnesota lakes.

### **3.2.2 Shoreline Restoration**

Submerged aquatic vegetation is critical for supporting a healthy biological condition in Diamond Lake. Some of these ecosystem services may be disturbed by management activities aimed at improving recreational access to the lake. To offset these impacts, lakeshore owners should maintain as much native shoreline as possible and minimize fragmentation of the plant community as much as possible. Homeowners could work with the LGU for planning and to determine funding availability.

### **3.3 ASSESSMENT OF IMPACTS**

A brief description of impacts of aquatic plant management (both positive and negative) for proposed alternatives were completed to address environment impacts on fisheries, fish habitat, and water quality and is presented below.

#### **3.3.1 Environmental Impacts on Fisheries and Fish Habitat**

Aquatic plants are an important part of lake ecosystems, and the value of maintaining aquatic plants in fostering diverse aquatic ecosystems has been well documented. Aquatic plants are an important component of fish and wildlife habitat. The Aquatic Ecosystem Restoration Foundation (2003) states that aquatic and littoral vegetation provides fish, waterfowl and some mammals with:

- ▲ Oxygen
- ▲ Habitat
- ▲ Food sources
- ▲ Breeding areas
- ▲ Refuge for predators and prey
- ▲ Stabilized bottom sediments and nutrients

These resources are not only important for good sport fisheries, but also for other recreational activities, aesthetic enjoyment of water resources, and maintenance of healthy aquatic and littoral ecosystems. Diamond Lake has significant coverage of aquatic plants. However, much of this coverage contains native non-invasive species.

Management of aquatic plants through the operation of harvesting equipment may impact lake fauna. Physical disturbance of bottom sediments can occur in shallow areas, turbulence caused by the motors can suspend sediments, and harvesting is not selective for specific plant species within the targeted area. In other words, beneficial plants as well as nuisance plants may be harvested. These impacts can affect fish and fish habitat. However, the negative impacts of harvesting could be largely limited by doing the following:

- ▲ Limit harvesting in water depths less than 3-4 feet, where fish spawning typically occurs in shallow areas. This limitation would also limit the potential for resuspension of bottom sediments.
- ▲ Limit harvesting in areas within 150 feet of the shore to cutting pathways for access from docks and boat turnaround areas.

Along with harvesting, herbicide treatment with endothall was investigated for this project. The use of low-dose applications of endothall to control aquatic vegetation is expected to have virtually no negative impact on fisheries and fish habitat. The compound is a selective contact herbicide that disrupts biological processes unique to plants, such as interfering with plant respiration and disrupting plant cell membranes. Finally, endothall compounds do not bioaccumulate in fish or hydrosol.

### **3.3.2 Impacts on Water Quality**

Water quality impacts of aquatic plant control methods may be both positive and negative. For harvesting, the biggest negative impact is related to the potential for suspending sediments. The impacts associated with the harvesting project in Diamond Lake should be minor because of the limited amount of cutting in shallow areas (i.e., areas less than 3-4 feet deep).

Positive water quality impacts of harvesting occur because nutrients in the plant tissue are removed along with the harvested plant materials. Not all of the plant material is removed with harvesting since there are some materials that are not captured. Based on estimates for tissue phosphorus content, there is 0.95-1.2 lbs. of phosphorus /acre for heavy growths. If all the tissue-bound phosphorus were removed in the harvested area, a substantial amount of phosphorus could be potentially removed from the lake system. However, phosphorus removal associated with harvesting and removal is likely a small portion of the overall phosphorus budget. Though long-term management of aquatic plants will not have a significant impact on loading to the lake, it will contribute to meeting long-term water quality goals for the lake.

Controlling the abundance of nutrients can also prevent negative water quality impacts associated with the life cycle of aquatic plants. According to James, et al. (2001), the plants can directly recycle phosphorus from the sediments through root uptake, incorporation into plant tissue, and subsequent senescence (i.e., decomposition). They can also indirectly recycle phosphorus from the sediments by increasing pH in the water column through photosynthetic activities. Phosphorus release from sediments can be enhanced at high pH as a result of ligand exchange on iron oxide contained in the sediment. In addition, senescence/decomposition of the plant material can contribute to low dissolved oxygen conditions at the sediment water interface. Low oxygen conditions contribute to weakening of the iron-phosphate bond leading to phosphorus release from sediments. Phosphorus loads from plant senescence and sediment effects cannot be estimated without detailed study. However, it can be significant especially if the subsequent release of phosphorus from senescence can then be used by algae leading to nuisance algae blooms and decreased water clarity.

Thus, effective control options – whether based on mechanical harvesting or low-dose endothall treatments or a combination of these – should have an overall positive effect on water quality (improved water clarity and lower phosphorus loading) and the native plant and animal community in Diamond Lake.

## 4.0 Summary and Recommendations

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### 4.1 SUMMARY

Diamond Lake supports a robust submerged aquatic vegetation population in littoral areas that often inhibits recreational uses such as swimming, boating and fishing. Currently, the only aquatic invasive species identified that are actively managed in Diamond Lake is Curly-leaf pondweed. Curly-leaf pondweed is found throughout the lake and is often at nuisance densities. Continued management of Curly-leaf pondweed will benefit the lake plant community.

The native submerged aquatic vegetation population is dominated by multiple species, which grow to nuisance levels, matting at the surface and inhibiting recreational use of the lake. The thick mats often inhibit safe boating and swimming due to their density. Fishing can also be difficult due to the density of the plants. Therefore, some management of the native vegetation population would support recreational uses of the lake.

### 4.2 LONG TERM CHANGES IN PLANT MANAGEMENT

One of the primary assumptions in this study is that the same area is treated every year for both invasive control. However, the long term goal is to minimize and ultimately control the invasive aquatic plant population. The void left by the invasives will likely be filled by more aggressive native plants such as coontail that will still require control for early season recreational access. Therefore, while the invasive species might be controlled to some minimum population density and therefore costs to control invasives go down, some early season control would be necessary if recreational access is a goal. So, maintaining the costs constant from year to year allows for flexibility in implementing plant control in the lakes.

### 4.3 PREFERRED ALTERNATIVE

#### 4.3.1 Preferred Alternative

Based on cost and project benefits, the best alternative for improving vegetation conditions in the lake appears to be alternative 2, herbicide control. Since the effectiveness and benefits of herbicide and harvesting management options are equivalent, it would be difficult to recommend harvesting due to its high price. This plan will require the Lead LGU to contract with a commercial herbicide applicator listed on the Minnesota DNR "Commercial Herbicide Control Companies" list. Herbicide application will occur once annually in the early spring.

### 4.4 PROJECT FACILITATION

A lead LGU must be selected to facilitate and lead the project. This lead LGU will serve as the lead agency for implementation and monitoring of the project, but will work closely with lakeshore residents and the DNR regarding implementation. It should be noted that that two LGU's could take the lead for different aspects of the project such as invasive species control versus recreational access. However, coordination between these two efforts would be needed.

The lead LGU must work with the DNR to confirm harvesting and herbicide areas annually. Coordination among the groups will ensure the application and harvesting are effective in meeting the goals of this plan.

## 5.0 References

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- Aquatic Ecosystem Restoration Foundation. 2003. Draft Best Management Practices Handbook for Aquatic Plant Management in Support of Fish and Wildlife Habitat ([www.aquatics.org](http://www.aquatics.org))
- James, William., J.W., Banks, and H.L., Eazin. 2001. Direct or Indirect Impacts of Submersed Aquatic Vegetation on the Nutrient Budget of an Oxbow Lake. ERDC TN-APCRP-EA-02.
- MFCWD. 2011. Diamond Lake Total Maximum Daily Load. wq-iw8-28e.

## Appendix A: Detailed Cost Breakdown

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**Table A1. Total and annual cost estimate by alternative. Cost estimates assume a 3% annual inflation rate and 4% discount rate.**

| Year         | Invasive Removal<br>Harvesting | Invasive Removal<br>Herbicide |
|--------------|--------------------------------|-------------------------------|
| 1            | \$69,018                       | \$27,531                      |
| 2            | \$68,354                       | \$27,266                      |
| 3            | \$67,697                       | \$27,004                      |
| 4            | \$67,046                       | \$26,744                      |
| 5            | \$66,402                       | \$26,487                      |
| 6            | \$65,763                       | \$26,233                      |
| 7            | \$65,131                       | \$25,980                      |
| 8            | \$64,504                       | \$25,731                      |
| 9            | \$63,884                       | \$25,483                      |
| 10           | \$63,270                       | \$25,238                      |
| 11           | \$62,662                       | \$24,995                      |
| 12           | \$62,059                       | \$24,755                      |
| 13           | \$61,462                       | \$24,517                      |
| 14           | \$60,871                       | \$24,281                      |
| 15           | \$60,286                       | \$24,048                      |
| <b>Total</b> | <b>\$968,410</b>               | <b>\$386,295</b>              |









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