Kohlman Lake Dredging Feasibility Study

Prepared for
Ramsey-Washington Metro Watershed District

January 2007

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Executive Summary

The feasibility of using dredging as a tool to reduce internal phosphorus loading in Kohlman Lake was investigated in this study using the results from analysis of sediment cores collected in 2005 and 2007. An average internal phosphorus loading rate after dredging was also estimated from the mass of mobile phosphorus in the sediment cores.

Dredging sediment from the shallower area of the lake to a sediment depth of approximately 35 cm is expected to remove the pool of mobile phosphorus in the surficial sediment and decrease internal phosphorus loading from that area. However, mobile phosphorus remains elevated in the deep sediment (i.e. > 50 cm sediment depth) from the deeper area of the lake, and dredging of that area is not recommended. Although core data indicate dredging the deeper area will remove a substantial amount of phosphorus, the sediment mobile phosphorus concentration would remain high and thus, little to no improvement of internal phosphorus loading would result from dredging the deeper area.

Options for dredging and disposal of sediment from the shallow area were investigated as part of this study. Approximately 100,000 cubic yards of sediment would be removed from the shallow areas of Kohlman Lake to limit internal loading with either land application or landfill disposal being viable options. The total estimated costs below are all inclusive but are contingent upon material meeting pollutant requirements for landfill cover or land application. If contaminants in the dredged sediment are detected at unacceptable levels, landfill cost will increase beyond the range shown and land application will not be an option. Other considerations that may substantially affect cost are discussed in the report, but are not included in the cost estimate because they are speculative and depend upon specific analytic outcomes not known at this time.

Disposal Option	Cost Range	
Land Application	$7,840,000	$8,820,000
Sanitary Landfill	$7,460,800	$7,945,600

Dredging the shallow area will reduce internal phosphorus loading by approximately 70 percent. Controlling watershed loading of phosphorus will extend the life of treatment; however, buildup of phosphorus from external loading will require future maintenance. Summer total phosphorus concentrations during wet, average and dry years are estimated to be 63, 74, and 85 µg/L after dredging, compared to 66, 102 and 94 µg/L for existing conditions, respectively. Total dredging cost per pound of phosphorus removed, including maintenance, is estimated to be $2,318.

1 Introduction

The *Strategic Lake Management Plan for the Phalen Chain of Lakes* (draft, Barr 2004) indicates that reducing the internal load of phosphorus in Kohlman Lake is an important step in achieving water quality goals listed for the lake in the District's Water Management Plan (draft – 2007). Previous studies have considered the use of herbicide treatment to manage macrophytes coupled with alum treatment to inactivate phosphorus in the lake sediment. The purpose of this study was to evaluate in detail the feasibility of dredging as a possible method to reduce internal phosphorus loading in Kohlman Lake.

The main component of this study was to determine the amount and depth of sediment containing excess phosphorus that contributes to internal loading in the lake. From these results, a total amount of sediment that would have to be dredged to reduce internal phosphorus loading, and the associated total cost to complete the dredging, were estimated.

The cost estimates in this report are considered preliminary. This is due to the many unknowns associated with the work, particularly the unknowns related to permitting this type of activity. However, this report does provide a range of costs given likely implementation scenarios. Similar project examples are provided to help understand the many issues and costs associated with a dredging project of this magnitude.

2 Methods

2.1 Sediment Coring

Sediment coring and testing were performed to characterize the existing material to be dredged. Results are intended to identify depth of dredge cut necessary to limit internal phosphorus loading in Kohlman Lake.

Guidance for sediment coring was provided in Chapter 4 of the *Guidance Document* (MPCA, April 2006). The location of the sediment cores was determined based on review of the *Guidance Document*, discussions with Kohlman Lake Association members, and review of previous sediment coring results (Internal Phosphorus Loading Study: Kohlman and Keller Lakes 2005, Barr). To reach a sufficient sediment depth, a piston coring device was used. Two sediment cores (Core 1 and Core 2, Figure 1) ranging from core sediment depths of 1.5 and 1.28 meters were collected on January 12th, 2007. Core 1 was sliced at 2 cm intervals throughout and Core 2 was sliced at 2-cm intervals down to 60 cm and 4-cm intervals thereafter. Samples were stored in plastic sample containers at 4 ºC until analysis within one week of sampling. Water column depth was measured by lowering an 8-inch diameter Secchi disc until it rested upon the sediment surface.

2.2 Sediment Analysis

Sediment samples were analyzed for water content by freeze-drying after cooling at -70 °C for 24 hours, and loss on ignition (LOI) of the dried sediment was measured after combustion at 550 °C for 2 hours (Håkansson and Jansson 1983). Reductant soluble (mainly iron bound phosphorus) and loosely sorbed phosphorus (the sum of these two fractions is termed ‘mobile phosphorus’) and total phosphorus fractions were determined according to a modified version of the phosphorus fractionation technique developed by Psenner et al. (1988). Aliquots from the sediment phosphorus fractionation procedure were analyzed as soluble reactive phosphorus using the ascorbic acid, molybdate blue method (Murphy and Riley 1962). Lead^{210} dating of the sediment is ongoing and will be used to determine sedimentation rate.

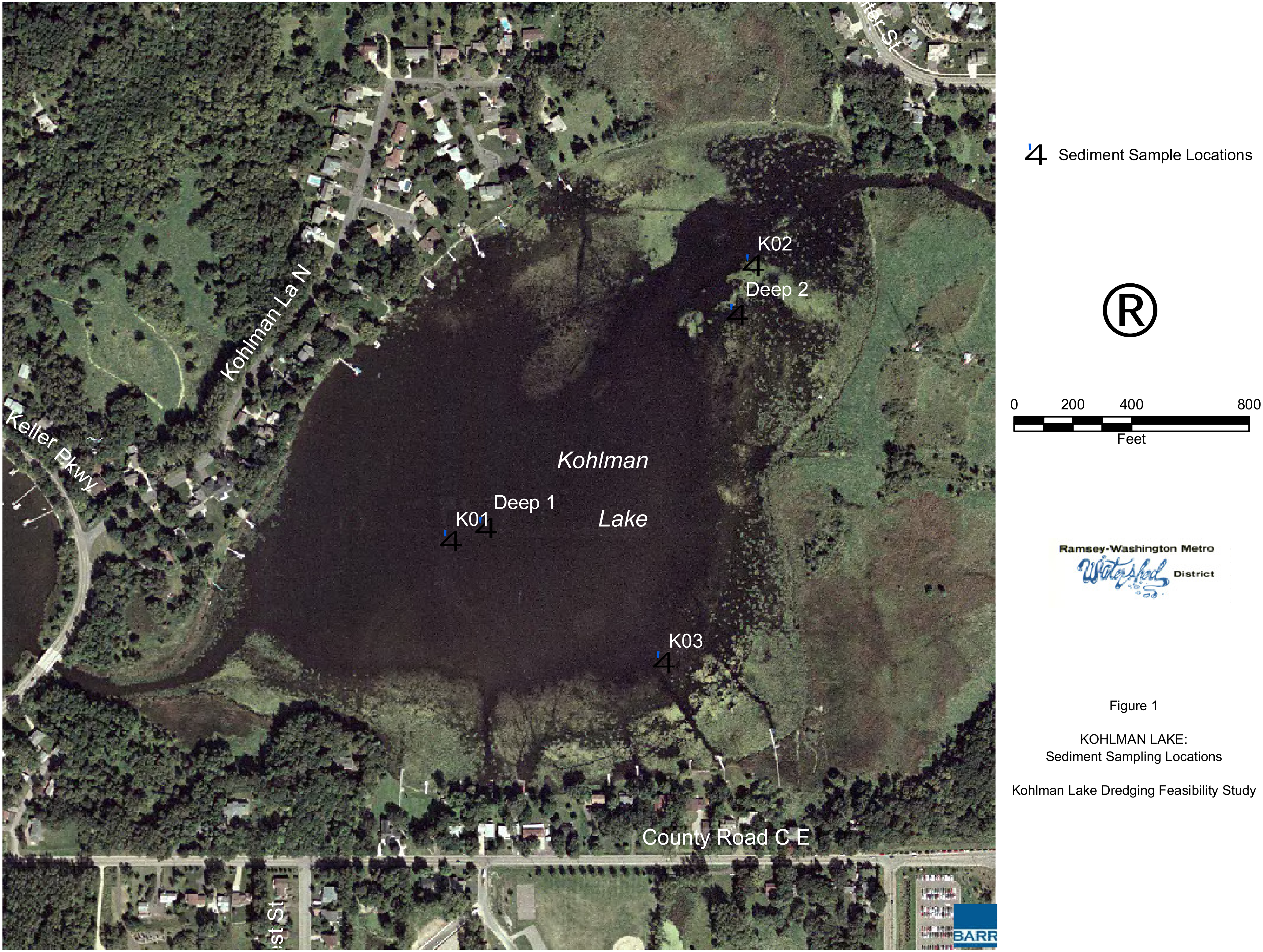

Figure 1

KOHLMAN LAKE:
Sediment Sampling Locations

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3 Results and Discussion

3.1 Sediment Study Results and Discussion

Three short sediment cores (22 cm in length) and two long cores (1.28 to 1.5 m in lenth) were collected from Kohlman Lake in the spring of 2005 and winter of 2007, respectively (Figure 1). An initial dredging cost estimate was made using the short cores with the qualifier that longer cores would need to be analyzed to make a more precise estimate. The sediment cores collected in 2005 were used for surficial sediment mobile phosphorus and internal phosphorus loading determination (see Internal Phosphorus Load Study: Kohlman and Keller Lakes, Barr 2005) and did not contain the amount, or length, of sediment required to make an accurate dredging cost estimate based on phosphorus content. However, information from all sediment cores collected from Kohlman Lake in 2005 and 2007 is included in this report.

For the purposes of this study, ***sediment phosphorus content was analyzed to determine the amount of sediment that would need to be removed to reduce internal phosphorus loading to the lake.*** The pool of phosphorus in the sediment that can be released to the water column and contributes directly to internal loading is called mobile phosphorus. Mobile phosphorus includes iron bound phosphorus, loosely sorbed and pore water phosphorus, and easily degradable organic bound phosphorus. By determining the amount of mobile phosphorus in the sediment, it is possible to calculate the expected internal phosphorus loading rate within the lake (Pilgrim et al. 2007).

3.1.1 2007 Sediment Core Results

Two long sediment cores were collected and analyzed to determine the depth of excess phosphorus in the sediment (Figure 2). The first core was collected at a water column depth of 2.68 meters and the core length was 1.5 meters. The second core, collected near the inlet to Kohlman Lake at approximately 1 meter water column depth, was 1.28 meters in length. Core 1 contained the maximum amount of sediment that could be collected with the coring unit while Core 2 collection depth was limited due to refusal by deeper, hard packed sediment below 1.3 meters.

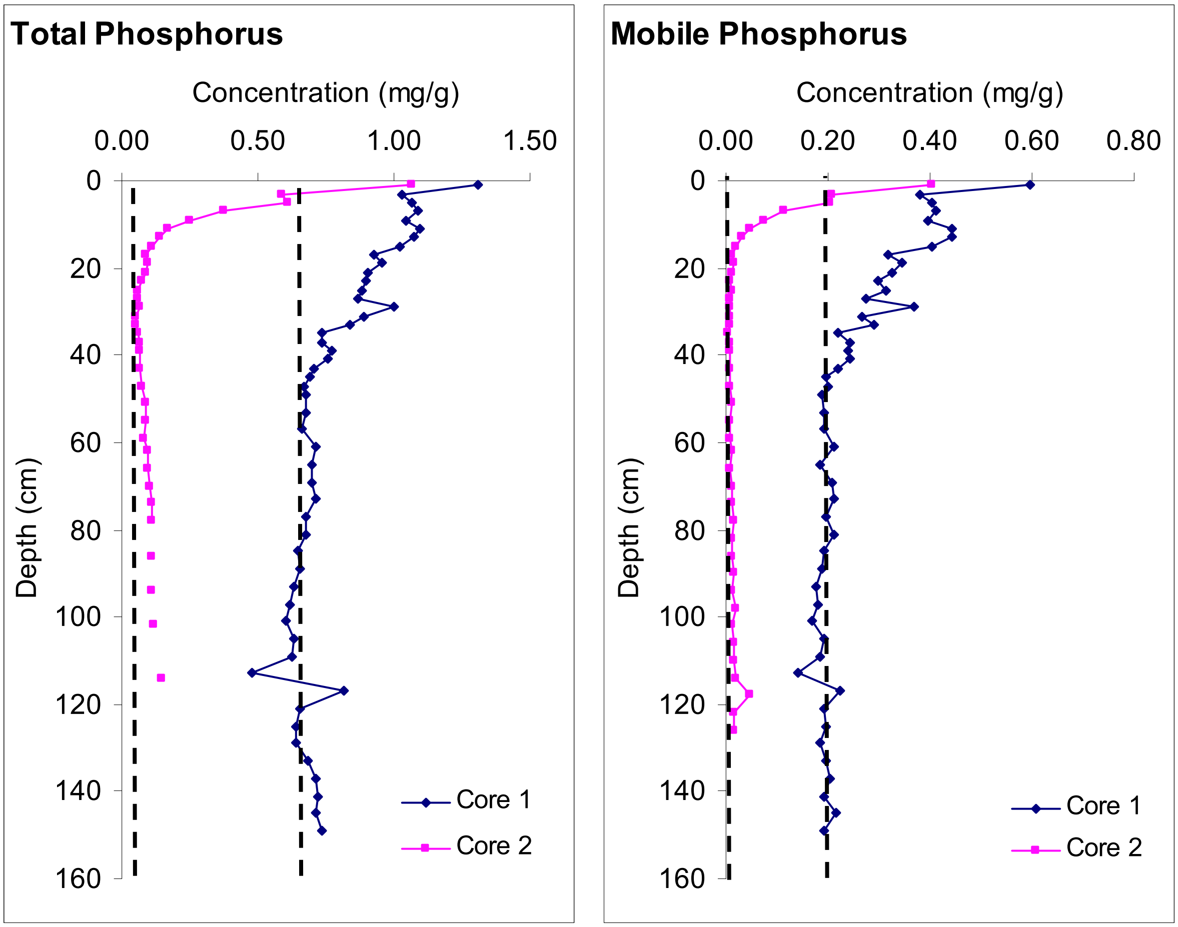


Figure 2 Concentrations of total and mobile phosphorus fractions (dry weight) in two deep sediment cores collected from Kohlman Lake, 2007.

Core 1 contained both elevated total and mobile sediment phosphorus concentrations in the upper 50 cm of sediment. Core 2 had elevated concentrations of total and mobile phosphorus in the upper 25 cm of sediment. At first glance, this would seem to indicate that removal to these depths (50 cm and 25 cm) would alleviate the sediment with excess phosphorus and return internal phosphorus loading to previous conditions. Although this is partially true, dredging to these depths may still result in elevated, but not excessive, internal loading for Kohlman Lake. As shown in Figure 3, the estimated internal phosphorus release rate (based on mobile sediment phosphorus content) would be reduced to 0.2 mg/m^2/day in Core 2 (Shallow core) taken near the inlet of the lake. However, even though dredging will remove a substantial pool of excess phosphorus detected in the upper 50 cm of Core 1, that was collected from the deeper area of Kohlman Lake, the average internal loading rate throughout the remainder of the core is estimated to be 8.4 $mg/m^2/day$ if this previously inactive sediment is uncovered. This is similar to the estimated average internal phosphorus loading rate that currently exists for this area of the lake. Because of the age of these sediments, however, accurate estimates of expected internal loading are difficult. Many unknowns exist including, but not limited to, sediment phosphorus binding capacity and the physical effects (i.e. expansion) on the sediment after exposure.

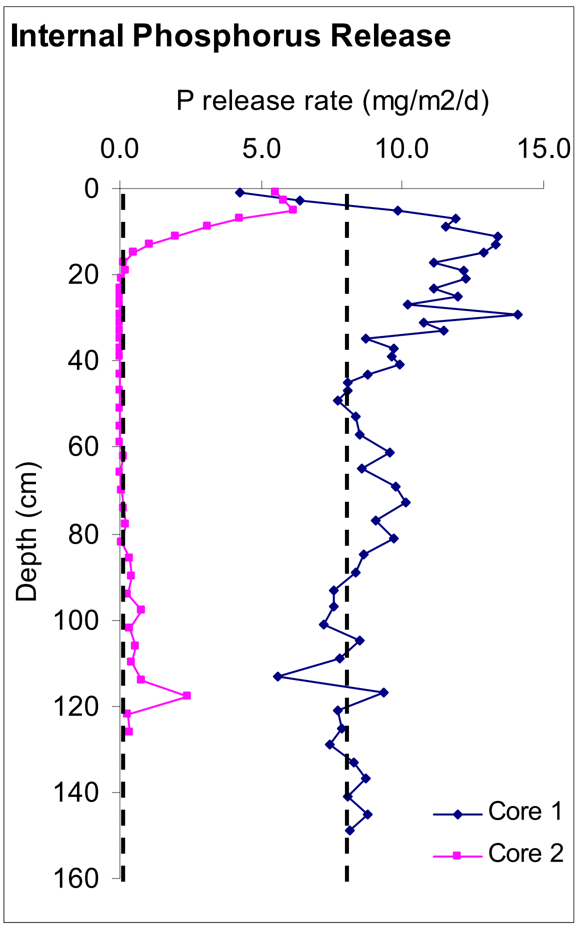


Figure 3 Internal phosphorus release rate estimated from two deep sediment cores collected from Kohlman Lake, 2007.

It is likely that Kohlman Lake has always been productive, and that wastewater effluent to the lake caused excess phosphorus input seen in both Figures 1 and 2 as elevated concentrations and mass of phosphorus in the sediment. The elimination of wasterwater effluent around 1960 reduced phosphorus input to the lake and lake sediment and has resulted in an improvement in water quality. However, excess phosphorus in the sediment remains high in the upper layers due to recycling of phosphorus deposited from earlier years (Figure 2). Looking specifically at the results from Core 1, internal phosphorus loading estimates based on average mobile phosphorus in the upper, active layer of sediment (0 to 10 cm sediment depth) range from 8.0 mg/m^2/day (2005 study) to 8.8 mg/m^2/day (2007 study). These estimates (summarized in Table 1) fit within the range of internal phosphorus loading calculated in the deeper part of the core (50-150 cm sediment depth) of 5.6 to 10.1 mg/m^2/day (average of 8.4 mg/m^2/day).

Table 1 Sediment phosphorus parameters in the two deep cores collected in Kohlman Lake, 2007.

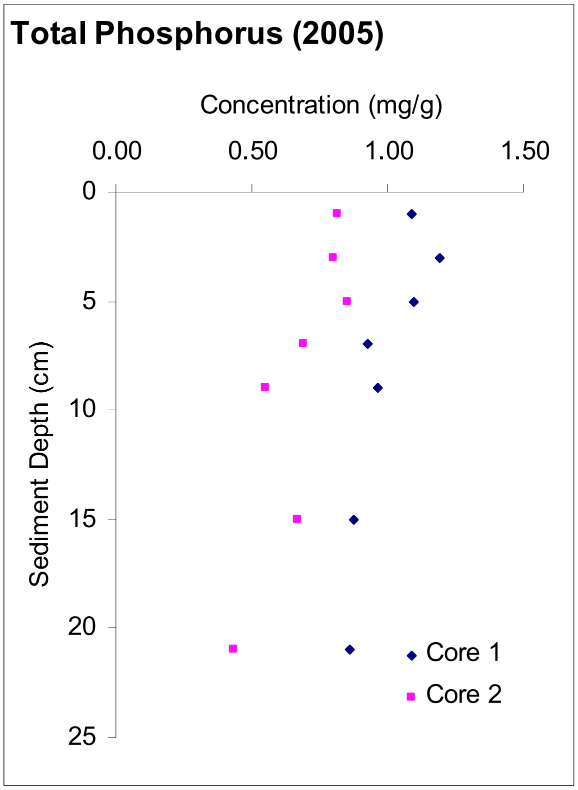
	Water Depth	Core Length	Depth of Excess P	Ave. Internal P Loading Rate Surface	Ave. Internal P Loading Rate Below Cut
	(meters)	(meters)	(meters)	(mg/m2/day)	(mg/m2/day)
Core 1 (Deep)	2.68	1.5	0.5	8.8	8.4
Core 2 (Shallow)	0.95	1.28	0.25	5	0.2

It may seem counterintuitive that the highest concentration of phosphorus is at the surface of the sediment while internal loading would be higher from layers between 20 and 50 cm in sediment depth. The concentration of sediment phosphorus is normalized as dry weight. This means water content is not taken into account in the concentration calculation when reported as dry weight. Because the sediment surface in lakes contains more water than deeper sediment (due to compaction), there is less overall sediment and therefore a lower *mass* of phosphorus. Looking at concentration helps determine where excess phosphorus in the sediment exists while internal loading estimates are based on the total *mass* of mobile phosphorus that can be released into the water column. Therefore, even though internal phosphorus release is estimated to be relatively high in the deeper sediment layers from Core 1, phosphorus concentration shows that there is not an excess of phosphorus at these levels and this would be considered background, or natural phosphorus loading throughout the range of sediment collected. The water content in Core 2 is generally more consistent (except for the first 6 cm) and therefore the trends between phosphorus concentration and internal loading rate are similar.

The results of the current study indicate that dredging the shallower area of the lake (approximately 2/3 of the total sediment surface area) will reduce sediment phosphorus levels and decrease internal phosphorus loading from the sediment to Kohlman Lake. Dredging the deeper area of the lake (approximately 1/3 of the sediment surface area) may not yield much, if any improvement with regard to internal phosphorus loading from the sediment in that area. While a large pool of excess phosphorus attributable to previous excess external inputs will be removed, dredging will uncover previously inactive sediment that contains phosphorus levels that may contribute to internal phosphorus loading similar to that detected in more current studies. It should be noted that before a dredging plan is finalized, additional coring will be required and the exact area to be dredged may change according to the additional sediment data collected.

3.1.2 2005 Sediment Core Results

The three sediment cores collected in 2005 generally contained similar amounts of sediment phosphorus when compared to the results from the 2007 core study. The results from the 2005 study are shown in Figure 4.



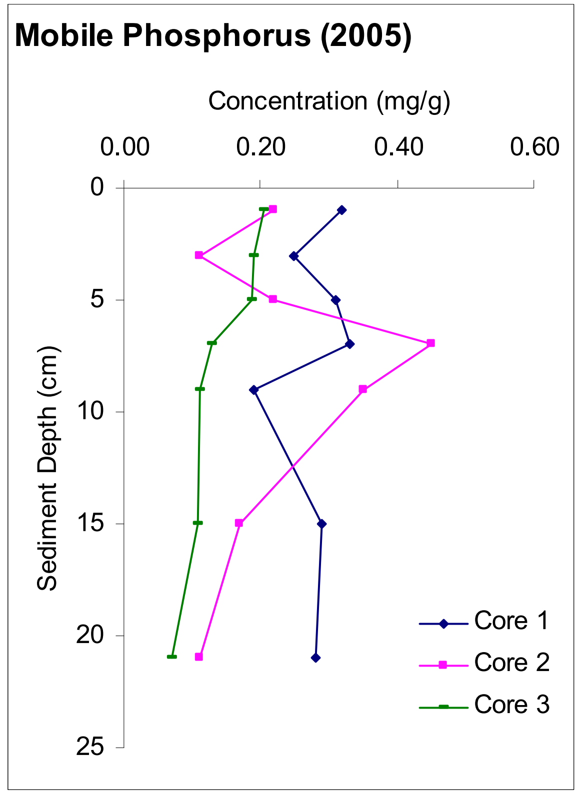


Figure 4 Total and mobile sediment phosphorus concentrations in Kohlman Lake (2005).

Table 2 compares the results of both studies in terms of sediment phosphorus and expected internal phosphorus loading rates.

Table 2 General parameters for all sediment cores collected from Kohlman Lake in 2005 and 2007.

	2007		2005		
	Core 1	Core 2	Core 1	Core 2	Core 3
General Location	Deep, Center	Shallow, Inlet	Deep, Center	Shallow, inlet	Shallow, SSE
Water column Depth (feet)	8.8	3.1	8.5	2.9	4.3
Surficial Mobile P (g/m2/cm)	0.63	0.38	0.58	1.17	0.33
Internal P Loading rate (mg/m2/day)	8.8	5.0	8.0	17	4.2

It appears there is greater variability in sediment phosphorus near the inlet from Kohlman Basin to Kohlman Lake. This is not unexpected because of the high flows entering the lake from this area and the associated historical and current loadings. It should also be noted that mobile phosphorus content and expected internal phosphorus release in the shallow area of the lake do not decrease as rapidly when comparing 2005 cores to those collected in 2007 (Figure 5). Concentrations remained elevated even at 22 cm sediment depth and appeared to potentially extend down to 30 to 35 cm. Thus, it is recommended that the dredge cut be extended to approximately 35 cm sediment depth to assure complete removal of excess phosphorus in shallower areas of the lake.

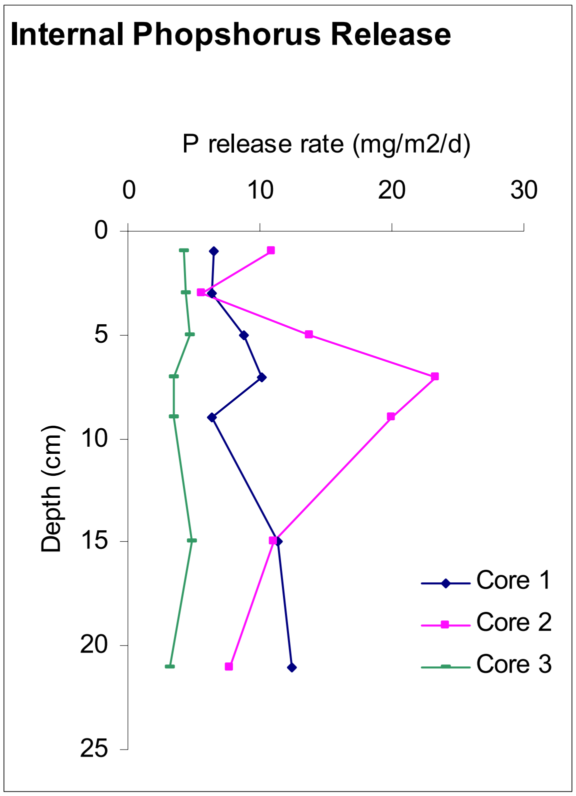


Figure 5 Internal phosphorus release rates estimated using mobile phosphorus content from sediment cores collected from Kohlman Lake (2005).

4 Dredge Volume Estimates

Elevated phosphorus exists in Kohlman Lake sediment down to approximately 35 to 50 cm in sediment depth. To estimate total sediment volume that needs to be removed to limit internal phosphorus loading, two areas (Figure 6), designated shallow (52 acres) and deep (25 acres), were sectioned from the total surface area in Kohlman Lake. The areas were estimated based on sediment data collected in both 2005 and 2007 along with bathymetry data for the lake. The approximate sediment volumes to be removed are shown in Table 3.

Table 3 Volume of dredge material based on sediment phosphorus depth in Kohlman Lake.

	Area	Dredge Depth	Dredge Depth	Total Volume
	(acres)	(meters)	(feet)	(yards^3)
Shallow Area	52	0.35	1.1	100000
Deep Area	25	0.50	1.6	70000
Total	76			170000

Depth of dredge cut was estimated by locating approximate background concentrations of phosphorus in Kohlman Lake sediment. Using these dredge cut depths and the area of sediment bottom in Kohlman Lake, an approximate total of 170,000 cubic yards of phosphorus rich sediment could be dredged from Kohlman Lake. Again, however, dredging the Deep area, shown in Figure 6, is not likely to yield much, if any water quality benefit and thus, only the Shallow area should be targeted if dredging is decided upon to reduce internal phosphorus loading. As stated in the previous section, before a dredging plan is finalized, additional coring should be conducted to assure that internal phosphorus loading is properly controlled through dredging. Final dredge area and volume may change from the stated figures herein due to any additional sediment data collected.

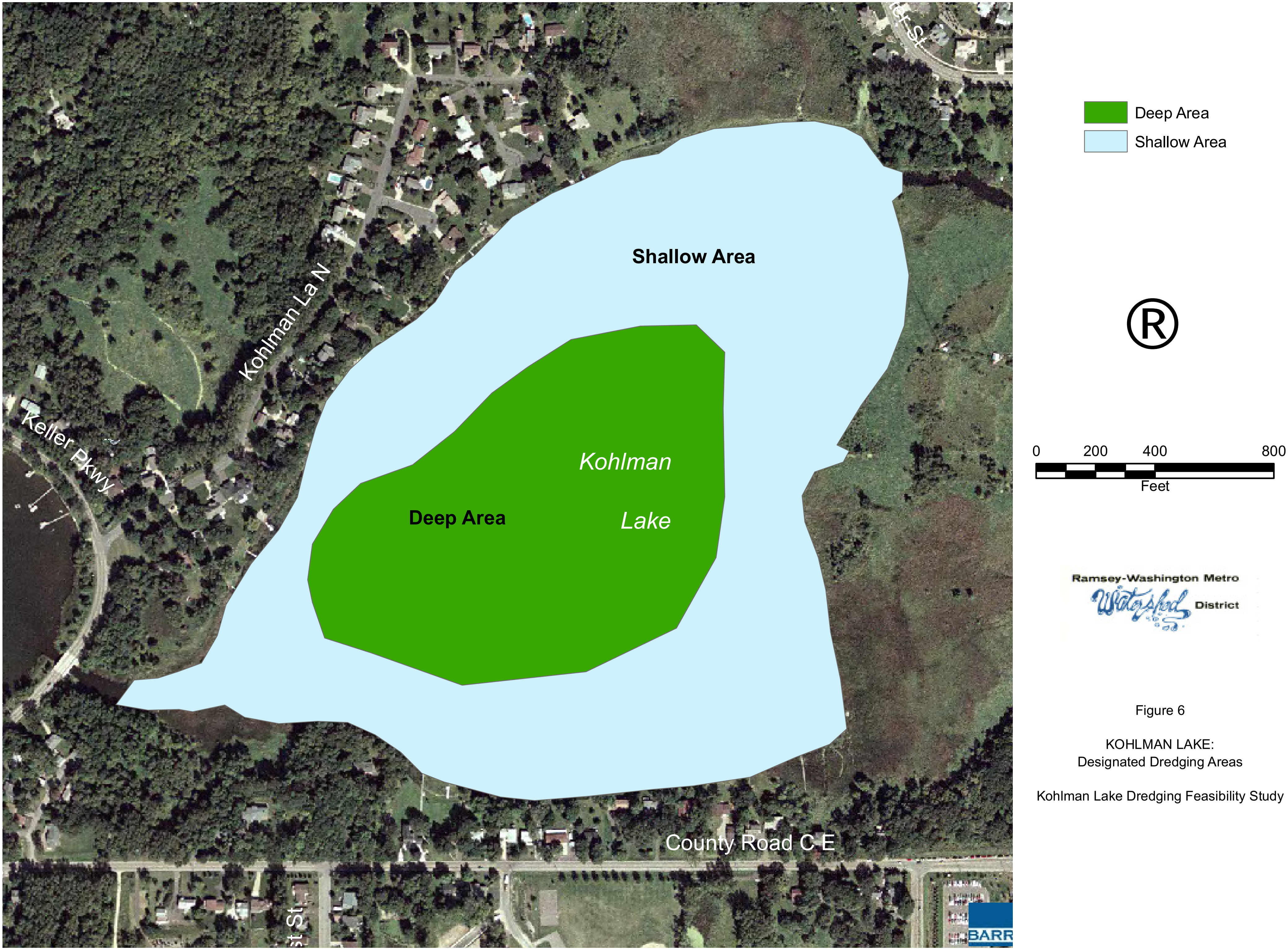


Figure 6

KOHLMAN LAKE:
Designated Dredging Areas

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5 Dredging Process

5.1 General

Managing the internal phosphorus load in Kohlman Lake by removal of the sediment involves a number of steps. Those steps include:

- Planning and permitting
- Selection of a qualified contractor
- Verification of dredging depths/locations
- Actual removal of the sediments from the lake bottom
- Dewatering of the dredged material and
- Disposal of the dredged material

Each of these steps is described in more detail below. Before work can begin, permits must be received. However, method of dredging, dewatering location, and the chosen disposal site must all be identified and approved as part of the permitting process. Therefore, options for these elements of the work are discussed below prior to the actual permitting process.

5.2 Dredging Methods

As a part of this study, discussions with contractors were conducted and dredging methods were identified. From those discussions, mechanical and hydraulic dredging methods were determined to be the most likely approaches that would be considered for the work. A brief description of each method follows:

1. **Mechanical Dredging:** Mechanical dredging consists of removing material by excavating or scooping sediment from the channel or lake bottom and placing the material on a barge, truck or disposal area. Mechanical dredging equipment includes clamshells, draglines, backhoes or other mechanical equipment for excavating bottom sediments. Typically, mechanical dredging equipment is mounted on a large barge and towed to the dredge site and secured with vertical anchor piling called spuds. Excavated material would then be placed and transported by shuttle barges or off-road trucks to the disposal area. Dredge spoils could be

placed directly in off-road trucks and hauled to the identified disposal areas. Because Kohlman Lake has limited access and the dredge area is large, dredging would most likely require the use of barges to transport dredge spoils to off-road trucks prior to hauling to disposal areas. Mechanical dredges work best in consolidated material and can be used to remove rocks, timbers, stumps and other debris that may exist at the identified sites. Mechanical dredges have difficulty retaining loose fine material which can wash out of the bucket as it is raised. Typical removal rates of sediment are on the order of 60-120 cubic yards (CY) per hour.

2. **Hydraulic Dredging:** Hydraulic dredging includes the use of pumps and piping for removing (pumping) a mixture of dredged material and water from the channel or lake bottom. A typical pipeline hydraulic dredge sucks the mixture (slurry) of sediment and water through one end and pumps the material through the discharge pipeline directly to the final disposal or dewatering area. A mechanical cutting head, consisting of rotating blades, is often included at the intake pipe to agitate and loosen bottom sediments so they can be pumped through the system. Hydraulic dredging equipment is also typically mounted on a large barge and towed to the dredge site and secured with spuds during dredging operations. Hydraulic dredging generally requires greater spoils disposal area than mechanical dredging due to the high volume of water that must be handled to minimize environmental impacts from return water. The dredge spoils may contain between < 5% to 20% solids depending on characteristics of the sediment and whether polymers or additives have been introduced to increase the solids content of the slurry. Hydraulic pipeline dredges can be relatively cost efficient since they can operate continuously and pump directly to the disposal site, if one is located nearby. However, if there is a lot of debris in the dredging site, the pumps can clog and impair efficiency. Typical removal rates of sediment are on the order of 120-240 CY per hour.

In selecting potential dredging methods for this work, several site parameters were considered. Following is a list of some of these issues:

- Sediment characterization for potential environmental concerns (e.g. heavy metals, PCBs, etc.)
- Depth of water and sediment to be dredged
- Permit conditions including allowable return water turbidity
- Location, access, and distance to disposal area

- Proposed dewatering system; containment dikes, ponds, polypropylene tubes
- Time constraints, dredge spoils consisting of silt and fine material may take well over a year to dry without additives
- Potential beneficial reuse of material
- Available land for disposal, containment, water quality and drying/dewatering

Although hydraulic dredging is likely the most efficient and effective method for removing sediment from the lake, of all the methods considered, it does require the largest land area for equipment staging near the lake, which substantially affects cost. Hydraulic dredging will initially increase the amount of spoils due to the additional water incorporated with the sediment during removal. The large land area is needed to stage and dewater the material, and is discussed in more detail in Section 6.3. However, both dredging methods (hydraulic and mechanical) were considered in developing the cost estimates in this report.

5.3 Sediment Dewatering

The degree of sediment dewatering is dependent upon the disposal location selected. And, as mentioned previously, depending on the dredging method selected, the water content of the sediment will range from approximately 70 to 95% (most likely 90-95% using hydraulic dredging). Methods to effectively remove the required water volume from the dredged material considered in this study are listed below.

- On-site or near on-site staging and settling ponds *without* using chemical additives to decrease settling time.

- On-site or near on-site staging and settling ponds using chemical additives to decrease settling time. (The maximum horizontal and vertical distances that dredge spoils may be piped are approximately 1 mile and 200 feet, respectively.)

- Off-site staging and settling ponds. (Dredged material could be hauled by tanker semi tractor-trailer trucks to a location for dewatering.)

- Mechanical dewatering on-site or near on-site. These methods include the addition of chemical additives to make dewatering more effective.

A cursory analysis of the dewatering option associated with trucking the material to an off-site location for dewatering revealed substantially higher costs than other methods listed here and therefore, this course was not considered a viable option.

Because of the silty nature of the surficial sediment in Kohlman Lake, it is likely that adequate dewatering could take up to a year and greater than 5 acres of land to achieve required dewatering for disposal without chemical additives and, therefore, this option was not considered.

For all other dewatering methods listed above, a substantial area for either geotextile fabric tubing (See Appendix A for pictures) and/or excavation/berming is a necessary part of the dewatering process. A staging area is also required to treat and manage the return water removed from the sediment. Less area would be needed for mechanical dewatering; however, costs will be higher due to the combination of equipment and chemical additive needed for the process.

Through the addition of chemical additives (coagulant polymers) and use of geotextile tubes or mechanical dewatering, the necessary dewatering site area could be reduced to approximately 2 to 4 acres and dewatering time could be shortened to approximately 4-6 months.

It appears there are essentially three options available for the on-site or near on-site dewatering operations of expected dredged sediments and those are listed below.

- Kohlman Park south of the Kohlman Lake. Because of nearby wetland areas, this option may or may not be feasible.

- Condemnation of properties and removal of structures, including homes, directly adjacent to Kohlman Lake to accommodate the selected dewatering method. No particular home sites were identified at this time, since it is unlikely this option would be exercised.

- Former Country View Golf Course site, northeast of Beam Avenue and Highway 61. However, since development plans are already prepared for this site, availability is likely limited to the very near future, if at all.

The most likely of the three sites listed above is the parkland southeast of County Road C and the cost estimates, as such, were based on the assumption that it or a similar site could be utilized. However, the City of Maplewood has not been approached and extensive research into this site as a viable option was beyond the scope of this study.

5.4 Disposal Options and Sites

5.4.1 Disposal Options

A number of options exist for the disposal of dredged materials based on the nutrient, grain size and pollutant content of the sediment. Three Tiers have been designated by the MPCA to categorize sediment and disposal options.

- **Tier 1** Dredged Material is suitable for use or reuse on properties with a residential or agricultural use category. It is the most restrictive category and assumes human exposure to contaminants is long term (chronic).

- **Tier 2** Dredged Material is suitable for use or reuse on properties with an industrial or recreational use category. This category is less restrictive and is based on the human exposure scenario that fits the intended use. Examples can be road fill, beach sand, fill on parkland, etc.

  Tier 3 Dredged Material is characterized as having significant contamination, as demonstrated by one or more monitored parameter concentrations being greater than Tier 2 requirements. Tier 3 Dredged Material is considered to be significantly contaminated and must be managed specifically for the contaminants present.

Because of the expected high nitrogen content generally found in productive lake sediments, restrictions will likely prohibit the use of Kohlman Lake sediment for use as either beach material or fill in areas such as parks or industrial areas. Requirements are in place to limit the amount of nitrate and ammonium contamination of both surface and groundwater resources. TKN (Total Kjehldahl Nitrogen) can range from 0.3 to 24.1 mg/g nitrogen in typical lake sediment (Barko and Smart 1986) More productive lakes typically have TKN concentrations at the higher end of the scale. In additions, none of the lakes in this study received waste water effluent in the past.

The silty nature of the sediment, determined by the sediment cores that have been collected from the lake, indicates that road or other construction fill will not be suitable. This, for the most part, leaves direct land application, landfill cover or direct landfill disposal. Due to the previous input of wastewater to Kohlman Lake, the sediment may contain elevated pollutants requiring additional permitting and landfill disposal. This can not be determined, however, until an exhaustive sediment characterization, according to MPCA protocols, has been made. For the purposes of this study, costs are included for the three likely disposal scenarios including: land application, landfill cover, and direct landfill disposal.

5.4.2 Disposal Sites

Facilities for disposal of dredged materials must be designed by a professional engineer registered in the state of Minnesota. A detailed list of design, management, and closure requirements are provided in the *Guidance Document* beginning on page 41.

Based on the *Guidance Document* and previous projects conducted by Barr Engineering, two landfills (Table 4) were identified near Kohlman Lake that will accept dredge spoils. Land application was assumed to occur within 40 miles of Kohlman Lake but a specific site was not determined.

Table 4 Landfill facilities located near Kohlman Lake.

Facility	Locations	Miles from Kohlman Lake
SKB	Rosemount, MN 55068	22.5
Pine Bend	Inver Grove Heights, MN 55077	21.2

5.5 Planning and Permitting

At a minimum, permits to perform the dredging activity itself would likely be needed from:

- City of Maplewood
- Minnesota Department of Natural Resources (MN/DNR)
- Army Corp of Engineers (ACOE)
- Minnesota Pollution Control Agency (MPCA)
- Ramsey Washington Metro Watershed District (RWMWD)

As a result of the dredging activity in Kohlman Lake, wetland impacts may result because much of the shallow area of the lake is technically a wetland or adjacent to wetland areas. While WCA

(Wetland Conservation Act) requirements do not necessarily apply in this situation, due to the lake being a “Protected Water” under MN/DNR jurisdiction, mitigation may still be required depending on how the MN/DNR and the ACOE view the impacts to wildlife habitat and fisheries.

Permits to dispose of the material are dependent upon the disposal option selected but would primarily include regulation by the MPCA after testing of both the sediment and the resulting runoff from dewatering activities.

Also, since the dredging activity will likely be perceived as having the potential for large-scale environmental impacts, an EAW (Environmental Assessment Worksheet) would be required. The EAW may show the need for an EIS (Environmental Impact Statement), a costly effort in almost all cases. For the purposes of this study, both scenarios were considered (with EIS and without an EIS).

A decision making flow diagram is provided in Figure 1 of the MPCA *Guidance Document*. This diagram shows that for dredged materials disposed of or stored for more than 1 year, an individual NPDES/SDS permit (National Pollutant Discharge Elimination System/State Disposal System) would be needed if water discharge exists from the dredged material (e.g. ongoing dewatering). The silty nature of the sediment indicates that a water discharge would exist. Reuse options would reduce these permitting requirements.

5.6 Selection of a Qualified Contractor

Selection of a contractor will be completed after the development of plans and performance specifications. During the bidding process, evaluation of qualifications and references, project experience, financial stability, etc. will be reviewed and used for selection. Due to the uniqueness and magnitude of this project and potential environmental ramifications associated with a poor-performing contractor, it was assumed that this effort would require a higher than normal amount of effort.

5.7 Verification of Dredging/Quality Control

Verification of dredging will be conducted by collection and analysis of sediment cores from the dredged areas. The results will be compared to previous data (herein) to assure that the target areas of sediment have been removed. It is recommended that a thorough study of lake depth (using soundings) in the target areas be completed before the dredge work begins. Using the results from this study, and depth soundings made after dredging has been completed, will assure that the contractor has fulfilled the required obligations.

Monitoring of water within and flowing through Kohlman Lake may be required during the procedure to assure that water quality degradation is kept within standard requirements. This may involve standard nutrient analysis or more intensive, and costly, pollutant testing if the sediment in Kohlman Lake is found to be contaminated.

5.8 Follow-up Maintenance and Macrophyte Management

As with any internal phosphorus loading control measure employed in Kohlman Lake, future maintenance is expected. Because Kohlman Lake is situated in a well developed, urbanized setting, external loading will be a continued source of sediment and phosphorus to the lake. The expected longevity of the dredging project, in terms of internal phosphorus load reduction, is conservatively estimated at 10 to 15 years. After that time, additional measures may be necessary to control internal phosphorus loading in the lake. A more precise estimate of expected longevity will be made with the sediment dating results, however, analysis was ongoing at the time this report was completed.

Because dredging will reduce phosphorus loading to the lake, water quality is expected to increase. The current macrophyte community in Kohlman Lake is dominated by two invasive species, *Myriophyllum spicatum* (Eurasian watermilfoil) and *Potamogeton crispus* (Curlyleaf pondweed). Dredging will remove some, but not all of the plant material in the areas to be dredged. A substantial portion of plant matter fragments and seed bank will remain available for colonization within the lake. Macrophyte management may be necessary to ensure that invasive species do not proliferate due to increased water clarity following treatment. Lake wide treatment will be required for at least the first two years with follow-up treatment recommended for the following 2 or more years.

6 Estimated Cost

Because a number of options exist for disposal and dredging techniques, a range of costs were developed for the dredging of Kohlman Lake. Cost estimates were broken down into the following categories:

- Dredge cost
- Dewatering
- Disposal
- Bidding and contract activities
- Quality control and monitoring
- Maintenance and macrophyte management

If dredging of the lake is chosen as an appropriate internal phosphorus loading management technique, as mentioned previously, it is recommended that only the sediment in the Shallow area in Kohlman Lake be dredged. Dredging the Deep area is not expected to produce much, if any improvement to internal phosphorus loading in the lake. Therefore the following cost estimate assumes only the Shallow area will be dredged.

6.1 Dredging

Based on discussions with contractors, hydraulic dredging of Kohlman Lake sediment is estimated to cost approximately \$4 to \$7 per cubic yard. This unit is somewhat higher than "normal" due to the limited access to the lake from pubic right-of-way. Contractors also provided unit price estimates for mechanical dredging. Unit costs associated with mechanical dredging are expected to range between \$5 and \$11 per cubic yard. Cost estimates for both dredging options are shown in Table 5.

Table 5 Estimated costs for dredging Kohlman Lake sediment.

Area	Dredging cost Low	Dredging cost High
	(\$4/CY)	(\$11/CY)
Shallow Area	**\$400,000**	**\$1,100,000**

6.2 Dewatering

For the purposes of estimating the costs associated with the dewatering portion of this study, two scenarios were considered. They include:

- Dewatering near Kohlman Lake using chemical additives to shorten the dewatering time.
- Mechanical dewatering near Kohlman Lake (including the use of chemical additives).

In both methods listed above, dredged sediment would need to pumped and piped to a location near Kohlman Lake. As mentioned earlier, it was assumed for the purposes of this study that homes would not be purchased to acquire nearby land for dewatering. However, this remains a potential option that should be considered further, if dredging of Kohlman Lake is pursued. For the purposes of this study, Kohlman Park appears to be the most likely candidate for the dewatering site. Construction easements on private property on the lake would still be necessary for access, pumps, piping, etc. In addition, installing a pipeline either through or over County Road C would be necessary to transport the dredged material from the lakeshore to the dewatering site. The estimated capital cost of setting up a system to convey the dredged material, as well as the operation and maintenance costs associated with this system for the duration of the project is estimated to be $75,000 to $125,000 for setup (capital cost) and then $1/CY - $2/CY for operation and maintenance.

Dewatering of dredged sediment without the addition of chemical additives would likely require more than five acres of land. Due to the high silt content of the surficial material, up to one to two years may be needed to dewater to acceptable moisture content for trucking and disposal. Because this extended timeframe is likely to be unacceptable to the City and other regulators, and additional NPDES/SDS permitting would be required, the addition of chemical additives (coagulant polymers) is a likely option.

To reduce the dewatering time and space necessary for both settling and mechanical dewatering of Kohlman Lake sediment, the addition of a polymer is recommended. The cost of the polymer addition will result in an additional cost for the dewatering process. Using chemical additives, dewatering is estimated to cost between $25 and $35 per CY. Chemical (polymer) additives alone can cost up to $18 per gallon with approximately 1 gallon required per CY (~200 gallons of dredged spoils).

As a part of the dewatering process preparation, removal of trees, fences, structures, etc. from the dewatering site will be necessary. For the “settling” method, approximately two to four acres will be needed for staging and the use of geotextile bags and/or ponding, if a polymer is used. For mechanical dredging, approximately two acres is needed. Additional power requirements may be needed at the site as well. Restoration of these areas is also a portion of the dewatering cost. For these elements of the dewatering process, approximately $20,000/acre to $35,000/acre restoration cost of the dewatering area was assumed. Total costs for dewatering of sediment from Kohlman Lake are presented in Table 6.

It should also be noted that hydraulic dredging may increase the total volume of material removed from the lake due to the incorporation of water during the process. Volume may increase by 20% or more over the initial estimates presented herein.

Table 6 Estimated costs for dewatering of the dredged sediment.

Area	Operation Setup	Dewatering	Operation and Maint.	Land Restoration	Total Cost
	$	($25/CY)	($1.50/CY)	($25,000/acre)	($)
Shallow Area	**$100,000**	**$2,500,000**	**$150,000**	**$50,000**	**$2,700,000**

6.3 Disposal

6.3.1 Sanitary Landfill

If the dredged material does not meet Tier 1 requirements by the MPCA or other options are deemed unsuitable, disposal in a sanitary landfill is a likely option. After sufficient dewatering that dries the sediment enough to meet the Paint Test (a test used to ensure sufficient water has been removed for landfill disposal of wet sediment), dredge spoils from Kohlman Lake can be disposed of in a landfill. Depending on the quality of the spoils, they can either be used as cover for the landfill or they must be disposed of as waste. There is a 50% cost difference between the two options, ranging from approximately $10 per ton for cover use to $15 for disposal within the landfill. Additional cost includes transportation ($10/ton) to the landfill. Below are the estimated costs for landfill disposal. Volume is based on a 40% reduction from dewatering activities.

Table 7 Estimated costs for landfill transportation and disposal.

Landfill Disposal	Dewaterd Volume	Transportation	Landfill (as cover)	Total 1	Landfill (non cover)	Total 2
	(CY)	($10/ton)	($10/ton)	($)	($15/ton)	($)
Shallow Area	**60000**	**$606,349**	**$606,349**	**$1,212,699**	**$909,524**	**$1,515,873**

Factors that increase dredging cost include:

- Limited site access for barge and dredging equipment
- Distance to potential disposal locations

If an on-site or near on-site dewatering area is not found, transportation costs will increase by up to twice as much as the listed figure here, mainly due to the increased volume of the high water content sediment.

6.3.1 Land Application

If the dredge spoils meet Tier 1 specifications for pollutants, they may be disposed at a landfill (as stated above) or land applied. Land application and distribution of the material will be dependent upon the nitrogen content of the sediment. If mineralization tests show that if minimum amounts organic nitrogen are released during testing (5%-10%), approximately 1000 acres would be required for application of the dredge spoils. This is based on an expected uptake rate for nitrogen of 100 lbs per acre and the minimum value for mineralization. A 100 lbs per acre uptake rate was chosen so that flexibility would be allowed for different types of crop land application. Some crops, such as corn, will have a somewhat higher uptake rate than that used in this study, but, assuming both the highest possible nitrogen uptake with the lowest possible nitrogen mineralization rates is not a likely scenario.

Including hauling (estimated at 40 miles) and spreading, land application would cost approximately $5,200,000. Distance from Kohlman Lake was estimated based upon the amount and type of land needed and conversations with dredge spoil brokers. Spreading includes all handling, application and equipment costs associated with the activity. Land rental fees are based on the assumption of expected land cost 40 miles from Kohlman Lake. A selected bio-solids broker will determine marketability of the dredge spoils and potential rental sites and/or use as crop fertilizer.

If distance to the selected application site or sites is shorter, cost will decrease. If mineralization of nitrogen in the sediment is greater, cost will increase due to additional acreage needed for application and additional spreading time. This cost does not include the act of dredging the lake.

Table 8 Estimated costs for land application of dredge spoils.

Land Application	Sediment Volume	Transportation	Spreading	Land Rental	Total Cost
	(CY)	($30/CY)	($20/CY)	($200/acre)	
Shallow Area	**100000**	**$3,000,000**	**$2,000,000**	**$200,000**	**$5,200,000**

Overall cost is relatively high for land application due to transportation and spreading costs. Land application is usually best utilized when sediment can be directly applied from the lake to available land. The generally high nitrogen content of productive lake sediment requires that a large amount of land be used to protect both surface and ground water from contamination. It is estimated that Kohlman Lake sediment will need to spread over 1000 acres of land, requiring substantial time. Land rental fees may be avoided if there is a need for sediment of this type at the time of dredging. Because this cost is comparatively small however, it will not substantially impact the overall cost of land application. A change in distance will impact overall cost greatly. On site dewatering will lower transportation and spreading costs but the savings will be offset by the cost of dewatering.

In addition, **hydraulic dredging will likely increase the amount of dredge spoils** due to the incorporation of water during dredging. **An increase of 20% in volume** or more may occur during the process. Any increase in volume will increase cost by either dewatering and treating the excess volume or transporting and spreading the entire volume extracted.

6.4 Bidding and Contract Activities

As mentioned earlier, due to the uniqueness and magnitude of this project and potential environmental ramifications associated with a poor-performing contractor, it was assumed that bidding and contract activities would require higher than normal amount of effort. A normal effort on a job of this magnitude would be approximately 5% to 10% of the total cost. But, to address the unique and complex contracting and quality control issues associated with this dredging effort, a cost range of 10% to 15% of the total cost is more likely.

6.5 Quality Control and Monitoring

Depth sounding surveys should be completed before and after dredging activities have been completed. Additional sediment core testing should also be conducted to assure the required sediment (and phosphorus) has been removed. Quality control is expected to cost $60,000 (Table 9).

Monitoring during the excavation may also be required to ensure water quality limits are not severely impacted both in Kohlman Lake and downstream Lake Gervais. Costs associated from quality control and monitoring are included below. If heavy metals are found in the lake sediment, monitoring costs could increase due to additional laboratory analyses needed.

Table 9 Estimated costs for quality control and monitoring.

	Depth Surveys (2)	Sediment Coring	Water quality monitoring	Total
Cost ($)	$30,000	$20,000	$10,000	$60,000

6.6 Maintenance and Macrophyte Management

Because Kohlman Lake is in an urban setting, external flows of phosphorus to the lake will eventually overcome internal phosphorus loading control measures. Therefore, future treatment of the lake will be required, based on the extent of external flows. Estimated longevity of dredging is based on the control of phosphorus loading to the lake, and not the amount of sediment removed. Thus, the estimated longevity is similar to other in-lake proposals for control of internal phosphorus loading. Maintenance cost is estimated at $160,000 and is based on 10 to 15 year assumed treatment longevity.

A macrophyte management plan is recommended to prevent the proliferation of invasive species after treatment and the resulting increase in water clarity. This involves intensive treatment of the whole lake for the first 2 years followed by spot treatment the following 2 years (Table 10). Additional spot treatment, if desired, is included as well. Costs associated with macrophyte management are estimated at $96,000 and are considered as part of the maintenance cost for this project.

Table 10 Estimated costs for macrophyte management.

Intensive Treatment	Year		Cost
	1		$45,000
	2		$30,000
	3		$14,000
	4		$7,000
Total (1-4)			$96,000
Maintenance Treatment			Cost
	Per year		$7,000

6.7 Cost of Similar Projects

The following information is provided as further support of the cost estimates derived in this study. Costs (2006 adjusted) of similar dredging projects are listed in Table 11 and were considered in addition to other reference data. It should be noted that access to the sites listed below was readily available in all situations, lowering overall cost for each of the projects.

Table 11 Costs from previous dredging projects or feasibility studies, not including engineering or contingency (2006 adjusted).

Location	Area or amount	Action	$/CY or Total
Dalecarlia Reservoir	250,000 CY	Dredge, dewater and dispose	$36.3/CY
Kohlman	**100,000 CY**	**Dredge, dewater and dispose**	**$43-56/CY**
Tanners*	2500 CY	Dredge, dewater and dispose	$75-$131/CY
Contaminated spoils**	130,000 CY	Dredge, dewater and dispose	$154/CY
Boom Island (MPRB)*	3000 CY	Dredge and disposal	$26-$33/CY
Stoneman Lake	30 Acres	Dredge only	$790,000
Mississippi	>250,000 CY	Dredge only	$7/CY
Zumbro River	1,200,000 CY	Dredge only	$4-$8/CY

*Bids submitted

**Feasibility study with disposal at SKB, Rosemount, MN (includes engineering and contingency)

7.1 Timeline

A general timeline including steps prior to actual dredging activity is included below.

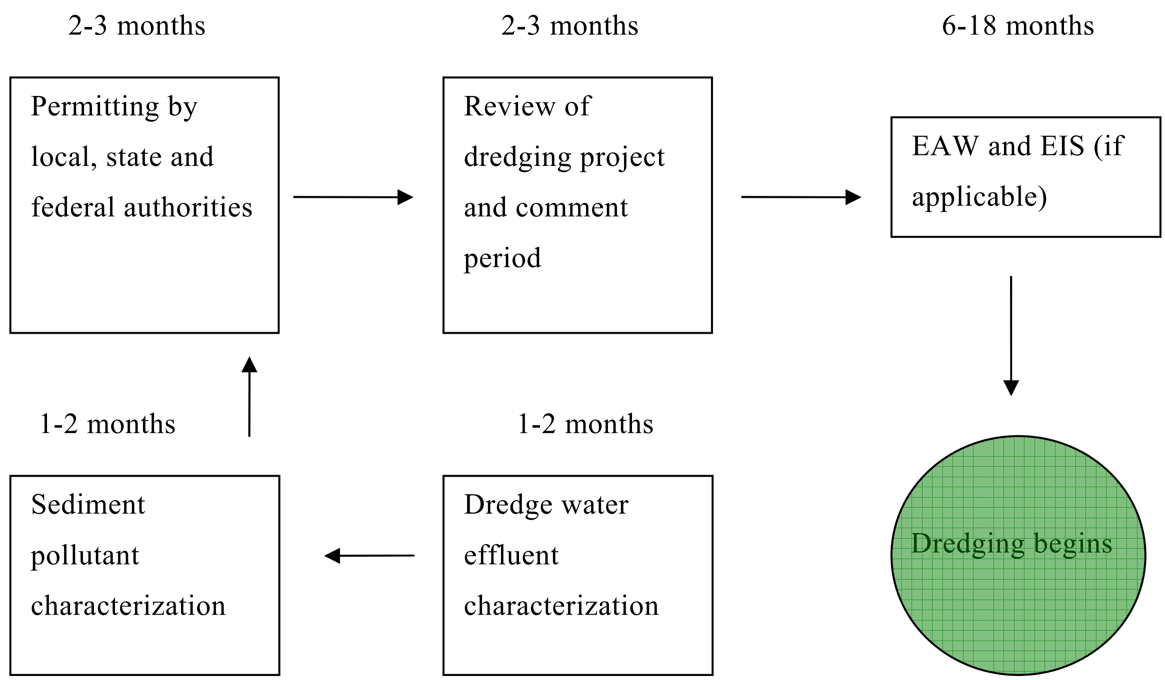


Figure 7 Timeline of steps leading up to dredging Kohlman Lake.

It is estimated to take from 1 to 2.5 years from submission of the dredging plan to the appropriate governing units to project initiation. The estimated cost of the permitting portion of this dredging project could range from $50,000 to $100,000+, with no guarantee of permit for the actual activity. The dredging process will take approximately 2 to 6 months (assuming multiple dredges or cutter heads) and on-site dewatering may take 2 to 6 months if chemical additives and/or mechanical dewatering options are utilized. Dredge time may also be affected by land availability, if land application is a feasible option for disposal and dredge spoil storage availability is limited.

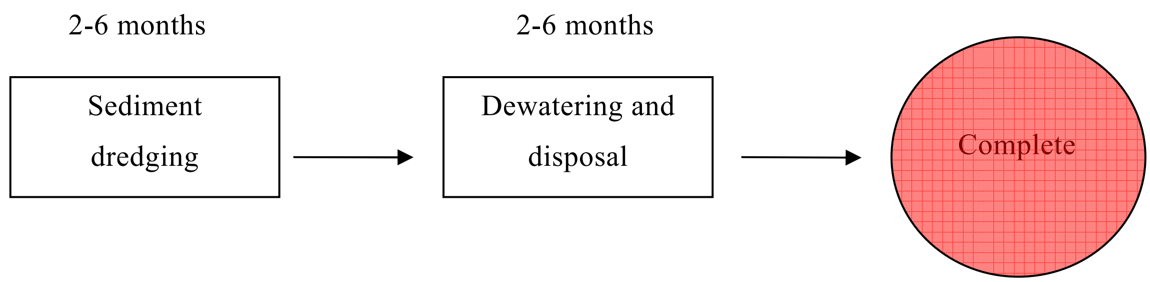


Figure 8 **Timeline for dredging Kohlman Lake. The 2 to 6 month time frame will mostly overlap between dredging and dewatering/disposal.**

7.2 Potential Obstacles and Concerns

During the process of review, there exist a number of potential roadblocks that may delay, or even prevent dredging in Kohlman Lake. Some of these include, but are not limited to:

- EAW or EIS concerns, for example:
  - Damage to fish spawning habitat
  - Re-suspension of contaminants potentially present in the sediment may require the design and implementation of extensive measures (i.e. curtains) to control sediment suspended by the dredging process.
  - Removal of aquatic plants (both invasive and native) may create an environment after dredging that is highly susceptible to being taken over by aggressive invasive species.
- The need for a staging area (minimum of 0.5 acres, depending on equipment used) on the lake meaning one or two parcels of property may need to be purchased on the lake in addition to the approximately four acres that will be needed for dewatering of the dredge spoils.
- The overall cost of the project coupled with the fact that Kohlman Lake does not have direct public access may lead to a condition of the permits that requires the acquisition of land on the lake to allow greater public use of the lake, if public monies are used. Condemnation of properties on the lake for park or viewing area development may be required.

- The greatest cost overruns in dredging projects come with the act of dredging. Hydraulic dredging will likely increase the overall volume of spoils removed, substantially increasing cost by 20% or more. In addition, debris within the lake will slow down the process, potentially extending the project through the next season, also substantially increasing cost and increasing the need for additional permitting requirements (NPDES/SDS permitting potential).

- One possible negative outcome is that without a stable plant community present after dredging, the lake may change into a permanently turbid state. Without the protection of the plant community, sediment resuspension may increase causing reduced water clarity and plant growth. Reduced refuges for zooplankton may decrease algal grazing, potentially decreasing water clarity. Additional or accelerated transport of phosphorus from the lake bottom to the surface may make algal growth significantly worse under turbid state conditions.

- Unknown pockets of sediment phosphorus (or other pollutants) deeper in the sediment may exist and be exposed after dredging.

- Sloughing of phosphorus rich, surficial sediment from non-dredged areas into dredged areas may cause a portion of the targeted sediment phosphorus to remain in the lake. Easily dissolved and pore-water phosphorus may also be difficult to remove. EPA case studies have shown that a "fluff" layer of up to 1-2 feet in thickness can remain after dredging. This layer contains fine sediment that can be high in nutrient concentration and is difficult to detect, let alone remove because it can be displaced by objects such as a cutter head or sampling gear.

- Water depth may limit access of the dredge barge in areas of the lake. In this case, dredging from shoreline areas may be required, slowing the operation leading to increased costs.

While these potential obstacles are a realistic possibility, their cost/project impacts are highly speculative at this point in the process and can not be quantified until the permitting and EAW/EIS work begins. Therefore, costs for these and other obstacles have not been included in the range of costs, listed above, for the dredging effort.

8 Recommendations and Expected Outcome

If dredging is decided upon as the best alternative to reduce internal phosphorus loading in Kohlman Lake, it is recommended that only the Shallow area designated in this report be dredged. It appears that Kohlman Lake has always been productive and uncovering buried sediment in the deeper area of the lake is not expected to reduce internal loading in that area. The costs associated with dredging the Shallow area designated in this report are listed below and include engineering and contingency.

Table 12 Estimated costs for dredging, transportation, disposal, and engineering and contingency for the Kohlman Lake dredging project.

Cost Summary	If used as cover in landfill		Direct Landfill	
	Low	High	Low	High
Shallow Area	$6,900,800	$8,020,800	$7,385,600	$8,505,600
Shallow Area Average	$7,460,800		$7,945,600	

Cost Summary	Land Application	
	Low	High
Shallow Area	$7,840,000	$8,820,000
Shallow Area Average	$8,330,000	

The approximate cost for dredging Kohlman Lake according to the recommendations in this study is estimated to be between $7,460,800 and $7,945,600 for landfill disposal and between $7,840,000 and $8,820,000 for land application. Due to the cost difference between landfill and land application (using current assumptions), landfill disposal is recommended. Using the low end figure results in a cost of $2,318 per pound of phosphorus removed from Kohlman Lake, including maintenance over a 20 year period (Table 9). Maintenance includes cost for macrophyte management and additional maintenance to control additional phosphorus accumulation over the 20 year project period.

It should be noted that if dredged sediment meets Tier 1 qualifications, and an appropriate site for land application is found closer than 40 miles to Kohlman Lake, land application should be considered as it will likely be the least costly option under this scenario.

With the reduction of existing internal phosphorus loading from the shallower areas, average, lake-wide internal loading is estimated to be 2.8 $mg/m^2/day$, including elevated phosphorus loading from deeper areas that are not dredged (see Table 1). It should be noted that this estimate assumes that there will be no sloughing/slumping of sediment from non-dredged areas to dredged areas during the dredging process, a potentially unlikely scenario with high water content, silty type sediment. Because it is difficult to predict any sloughing that may occur, however, the best case scenario is used in this report.

With dredging based on the above assumption, expected in-lake total phosphorus concentrations for wet, average, and dry years are estimated to average 63, 74, and 85 µg/L during the summer months. Existing conditions for, wet, average, and dry year averages are 66, 103, and 94 µg/L, respectively. These values, along with estimated Secchi depth changes, are included in Table 13. Secchi depth was estimated using the relationship developed with historical total phosphorus and Secchi depth measurements shown in Figure 9.

Table 13 Estimated costs for dredging, transportation, disposal, and engineering and contingency for the Kohlman Lake dredging project.

Climactic Condition	Total Phosphorus (ug/L)			Secchi depth (feet)		
	Pre	Post	Change	Pre	Post	Change
Wet	66	63	-3	3.0	3.1	0.08
Ave	103	74	-29	2.3	2.8	0.48
Dry	94	85	-9	2.4	2.6	0.15

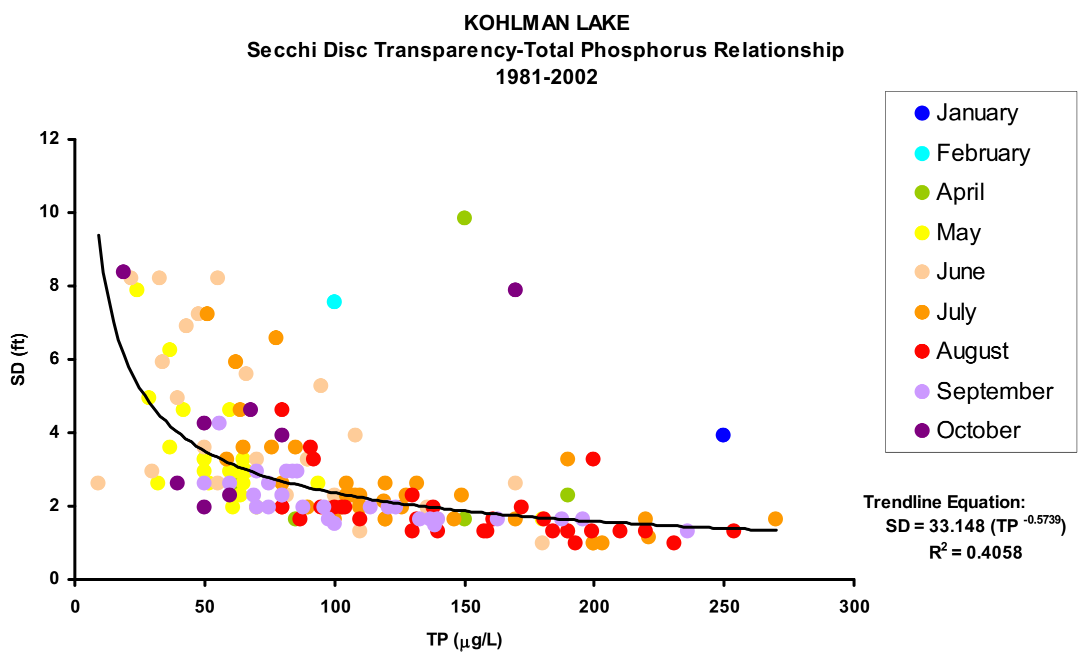


Figure 9 Secchi depth versus total phosphorus (TP) in Kohlman Lake.

Table 14 Proposed project costs including engineering, contingency, and maintenance for dredging Kohlman Lake.

Proposed Project	Capital Cost (2005 \$)[1,2]	Permitting	Assumed Life Span (years)	Annual Maintenance (2005 \$)[3]	Annualized Capital Cost (A/P I = 6%, n = 20, Factor = 0.0872)	Total Annual Costs (2005 \$)	Annual P Removed (lbs P removed)[4]	Annualized Cost per Annual Pound P Removed
Dredging (Shallow area only)	\$7,459,200	\$60,000	10-15	\$12,800	\$655,700	\$668,500	288	\$2,321

General Notes:

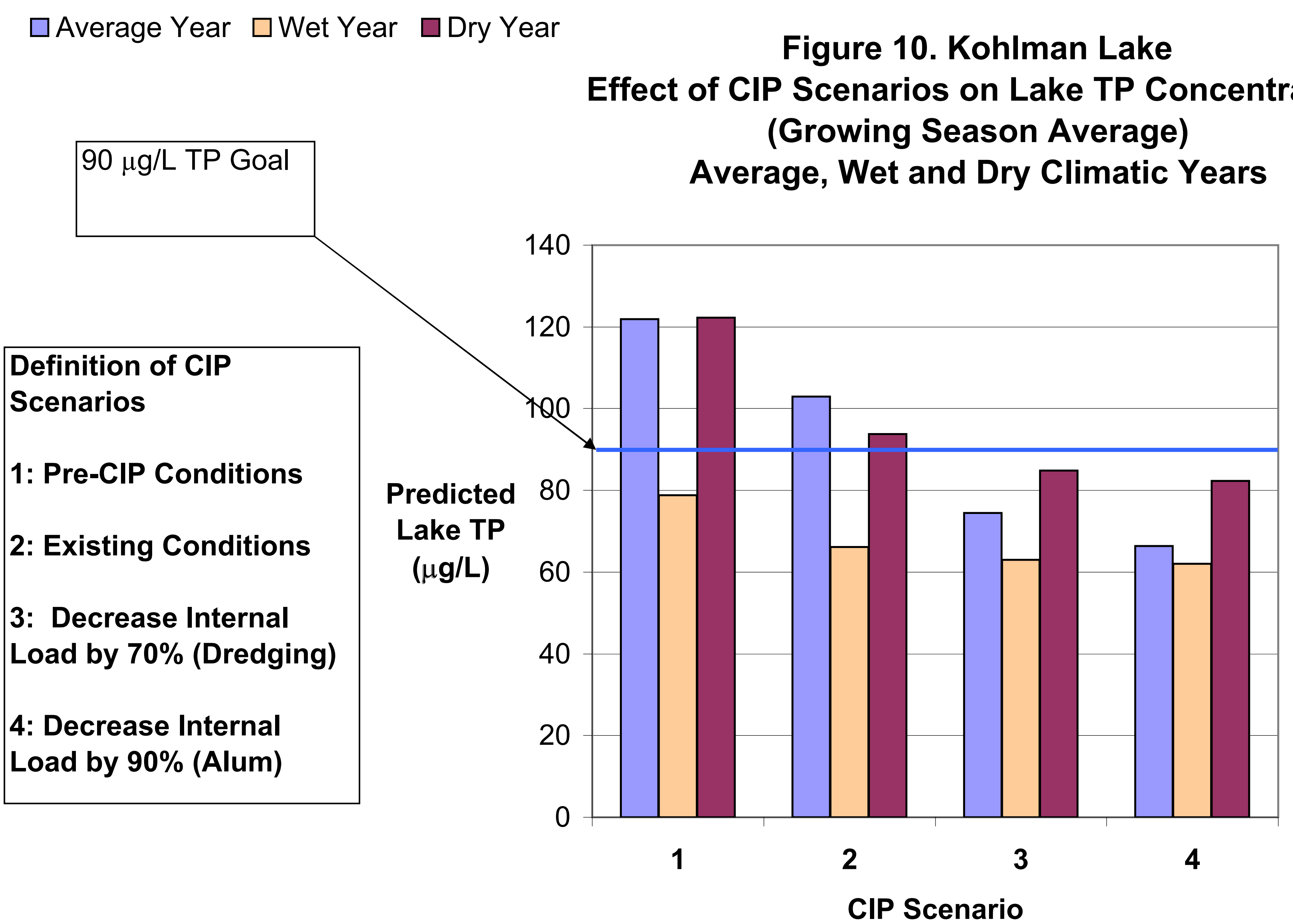
[1]Costs are in 2005 dollars and include a 30% engineering cost and a 30% contingency

[2]Dredging cost estimate does not include monies for an EIS, if required

[3]Includes macrophyte management and management of phosphorus accumulated after initial removal over 20 years

[4]Based on expected mobile sediment phosphorus removal

Figure 10. Kohlman Lake
Effect of CIP Scenarios on Lake TP Concentration (Growing Season Average)
Average, Wet and Dry Climatic Years



9 Other Considerations

Any option chosen to manage internal phosphorus loading will eventually be overcome, over the long term, in an urban setting. The success of proposed in-lake treatments to reduce phosphorus loading will be directly affected by the amount of external phosphorus loading to the lake. There is no permanent solution for continued reduction of phosphorus levels in Kohlman Lake with a one time treatment, regardless of method. Eventually, external inputs of phosphorus will accumulate in the sediment, increasing internal loading of phosphorus. This can be seen in other urban lakes that have been managed to reduce internal phosphorus loading from the sediment. Therefore, the life expectancy of dredging the lake sediment is similar to other options to control internal loading and is based on external loading of phosphorus.

It is likely that the act of dredging will increase phosphorus levels in the lake leading to a temporary degradation of water quality. This is due to the physical transfer of phosphorus from the pore water of the sediment to the photic zone where algae are able to use it. Another concern is that a portion of the phosphorus present in the sediment will remain in the lake even though the sediment is removed. Any phosphorus present in the pore water or loosely sorbed phosphorus may be released to the water column during the dredging process. This phosphorus will remain in the lake water, potentially affecting water quality in Gervais Lake as well.

Other factors suggested to affect internal loading in shallow lakes, such as benthiverous fish and wave action, could have similar physical effects on the sediment after dredging. Because these factors do not create internal phosphorus loading in and of themselves, but rather promote the transfer of phosphorus released by the sediment to the water column, any reduction of mobile phosphorus in the sediment will reduce such impacts.

A macrophyte management plan should be in place before dredging is finished. The increase in water clarity following the removal of phosphorus rich sediment may promote the proliferation of invasive species *Myriophyllum spicatum* (Eurasian watermilfoil) and *Potamgeton crispus* (Curlyleaf pondweed) in Kohlman Lake. Eurasian watermilfoil can grow from fragments less than an inch long and Curlyleaf pond weed turions have been shown to regenerate from 30 cm in sediment depth after exposure to light.

10 References

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Geotextile Tubing and Treatment Facility Components

Pumps moving water to the treatment facility