Little Green Lake Phosphorous Management w/ Destratification

LPL-636

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BACKGROUND

Little Green Lake is located in Township 15 North, Range 13 East, Sections 29-32, Green Lake County, Wisconsin. The lake is characterized as a seepage lake with two intermittent inlets and one intermittent outlet. It is a small, shallow system that is highly productive as a result of nutrient-enrichment. The shoreline is moderately developed with approximately 167 residences bordering the lake. Little Green Lake is used primarily for recreational purposes such as fishing, boating, swimming, wildlife viewing and relaxation.

A lake management plan was completed in December 1997 in response to concerns raised by many of the more than 240 lake residents regarding the deterioration of Little Green Lake's water quality. According to the Little Green Lake Protection and Rehabilitation District (Lake District), present lake conditions (namely excessive aquatic plant and algae growth) were interfering with desired lake uses and jeopardizing the long-term health of the lake.

Concerns raised by many of the lake residents regarding these conditions prompted the Lake District to develop a comprehensive lake management plan. The purpose of the lake management plan was to (1) compile and analyze existing lake and watershed data, (2) identify and prioritize desired lake uses and problems, and (3) determine the appropriate management options that are best designed to address the key issues. The lake management plan included recommendations to conduct a limited phosphorous budget and obtain additional outflow data, to fill in data gaps and provide pertinent information necessary to determine the major phosphorous loading factors. The plan also included recommendations to conduct aquatic plant management, such as mechanical weed harvesting as an integral part of lake quality improvement.

The limited phosphorous budget was completed in May of 1999. The limited phosphorous budget concluded that the majority (70%) of the present day phosphorus loading is from internal loading or "internal recycling" of phosphorus. Internal loading/recycling refers to the introduction of phosphorous into the lake from phosphorous sources within the lake itself. In the case of Little Green Lake it is believed that the excessive internal loading is predominantly caused by Little Green Lake's polymictic condition. Polymictic indicates a lake, which goes through stages of thermal stratification and destratification. During periods of thermal stratification, the deeper, cooler water becomes oxygen deficient or anoxic. This causes a release of phosphorous from the nutrient rich deeper sediment into the water column. These nutrients are subsequently mixed throughout the lake during periods of destratification. This process causes a dramatic increase in phosphorous levels over the course of the summer (10 fold). Several strategies for reducing internal loading were outlined in the report including alum treatments, hypolimnion withdrawal, and artificial circulation.

A meeting between the parties involved (USGS, WDNR, Little Green Lake District, and Ramaker & Associates, Inc.) was held to discuss the findings of the lake management plan and the limited phosphorus budget. The discussions included alternatives for reducing internal phosphorus loading. After reviewing the phosphorus budget along with inflow/outflow data, it was agreed that the best alternative for Little Green Lake would be artificial circulation.

A preliminary project design has been completed. This design consists of five aeration lines supplied by two air compressors. This design has been reviewed by both the USGS and the WDNR research team. Recently, alternative equipment vendors have been interviewed regarding designs.

At this time, the Little Green Lake Protection & Rehabilitation District is applying for a Lake Protection Grant for the artificial circulation system and the associated systems monitoring. A Lake Planning Grant has already been obtained for the initial year of sampling. This sampling will be completed by WDNR staff. This report is intended to provide the project scope and description, engineering and design plans, and estimated lake improvement costs, for the lake protection grant application.

PROJECT SCOPE AND DESCRIPTION

PROJECT DESCRIPTION

The proposed lake protection project involves the installation of an artificial circulation system that will affect the areas of deeper water in Little Green Lake (15 to 25 feet depths). The purpose of circulation system is to remove the anoxic hypolimnion by mixing the lake and keeping it destratified with respect to dissolved oxygen. This in turn should prevent internal phosphorous loading by preventing the exchange of phosphorous from bottom sediments to the anoxic hypolimnion. For further discussion of the internal phosphorous loading refer to Ramaker & Associates, Inc.'s *Little Green Lake Limited Phosphorus Budget*, May 20, 1999.

Project Need

Little Green Lake has experienced significant water quality deterioration over the years. This deterioration has resulted in a severely impaired waterbody. Excessive plant and algae growth are impacting desired lake uses. Significant measures have been undertaken to reduce nutrient, sediment, and pollutant loads to the waterbody. These efforts have included the implementation of Best Management practices throughout much of the watershed and in key areas. In addition, a major detention basin has been designed and construction is planned this spring. However, these efforts have resulted in little improvement in water quality. A recent phosphorous budget has indicated that nearly 70% of the phosphorous loading is due to internal recycling.

It is believed that the excessive internal loading is predominantly caused by Little Green Lake's polymictic condition. Polymictic indicates a lake, which goes through stages of thermal stratification and destratification. During periods of thermal stratification, the deeper, cooler water becomes oxygen deficient or anoxic. This causes a release of phosphorous from the nutrient rich deeper sediment into the water column. These nutrients are subsequently mixed throughout the lake during periods of destratification. This process causes a dramatic increase in phosphorous levels over the course of the summer (10 fold).

Similar observations were made on a northern Wisconsin lake (Cedar Lake). The Wisconsin Department of Natural Resources installed and operated an artificial circulation system on this lake. The system was used on an experimental basis, and several configurations were tried. Operation of the system resulted in a 70% decrease in phosphorous concentrations and reduction in the duration and intensity of nuisance algae blooms.

In discussions with USGS and WDNR research staff, it appears that in many respects conditions on Little Green Lake are even more favorable to such a system. Little Green Lake has a smaller, rounder (spatially compact) anoxic zone, as opposed to an irregular shaped or discontinuous anoxic zone. The proposed system is expected to provide for more complete mixing.

It has been generally agreed that this project provides for the greatest chance of water quality improvement on Little Green Lake, a major natural resource for local residents and the general public.

PREVIOUS STUDIES

Little Green Lake Management Plan Recommendations

The Little Green Lake Management plan included the following recommendations.

1. Rectify the identified information gaps. The U.S. Geological Survey is currently obtaining discharge measurements at the outlet. Annual mean discharge is a critical input variable used in a number of lake-modeling applications. This information is also needed to develop a phosphorus budget for Little Green Lake, which is another identified information gap.

Therefore, the Lake District is now encouraged to develop a "limited" phosphorus budget that will show whether the majority of the nutrient loading to the lake is occurring from external (watershed) sources or internal (in-lake) sources. This information is needed to help focus management efforts appropriately. If it is confirmed that internal, rather than external nutrient loading is the problem, the Lake District will have to decide whether to pursue the funds to precisely identify and remedy the internal nutrient recycling problem.

2. Re-evaluate management options that were recommended on a tentative basis as a result of information gaps that previously prevented sufficient analysis. For instance, if the limited phosphorus budget suggests that the level of external nutrient loading is unacceptable, management options should be implemented that are designed to address the external loading problem (i.e., landowner activities and watershed planning/runoff control). This scenario should also warrant further analysis to determine actual phosphorus contributions from individual septic systems, and the feasibility of sewering the lake as a cost-effective management alternative. Conversely, if the limited phosphorus budget suggests that the in-lake recycling of nutrients is the main problem, management options should be implemented that are designed to address the internal nutrient-loading problem (i.e., phosphorus precipitation/inactivation and hypolimnetic withdrawal).

3. Select and implement viable management options that satisfy the Lake District's budgetary constraints, address the identified problem areas, support desired lake-use activities, etc. The Lake District should pay close attention to the potential benefits, potential negative impacts, estimated costs, and longevity of effectiveness associated with each management technique. Viable management options based on current information include the following:

Control of external nutrient loading

- Individual landowner activities and watershed planning/runoff control measures (currently being addressed).

Control of internal nutrient loading

- Phosphorus precipitation/inactivation (also known as an alum treatment) and hypolimnetic withdrawal; note that mechanical harvesting and removal of aquatic plant biomass has been shown to remove nutrients from lakes.

Control of biological consequences of nutrient loading

- Mechanical plant harvesting (also shown to remove nutrients) and sediment covers to specifically control nuisance aquatic plant growth.
- Biomanipulation (e.g., through fish stocking programs) to specifically control nuisance algae growth.

Notes:

A majority of the desired lake uses and values will be supported if a reduction in algae growth is achieved in conjunction with a thriving, but controlled plant community. Therefore, mechanical plant harvesting is recommended as a management technique to be used along with nutrient loading reduction strategies. If mechanical harvesting is selected as a management technique, the preparation of an Aquatic Plant Harvesting Plan is recommended to meet eligibility requirements for financial assistance programs administered by the Wisconsin Department of Natural Resources. These programs offer grants that can be used to purchase mechanical harvesters.

Little Green Lake Limited Phosphorous Budget Recommendations

As recommended in the Little Green Lake Management Plan, a limited phosphorous budget was conducted for the entire lake watershed. The purpose of the phosphorus budget was to evaluate the impacts of internal and external loading. This information is necessary to determine high nutrient-loading areas, and to select the management techniques that are most cost-effective and best designed to address these problem areas.

The conclusion of the report was that, the majority of Little Green Lake's total phosphorus is coming from internal loading. The budget shows that internal recycling contributes the majority of the phosphorus to the lake. The best-fit lake model estimated that 69% of the load is coming from internal recycling whereas 25% of the load is coming from land use, 5% from precipitation and 1% from septic tanks. The majority of the internal loading is believed to occur in the deep section of the lake. In the deep areas of the lake (15 to 25 foot depths) dissolved oxygen stratifies into layers, with the lower layer (hypolimnion) containing the lowest dissolved oxygen. In this case the hypolimnion is considered anoxic. The anoxic hypolimnion allows for the release of phosphorous from the lake bottom sediments. When the lake mixes and is de-stratified, the phosphorous is subsequently mixed into the entire lake and produces algae blooms.

Internal loading is a significant problem because the lake is polymictic (mixes several times per year). There are several alternatives to reduce the internal loading including the following: artificial circulation (de-stratification achieved by artificial circulation), hypolimnetic withdrawal and alum treatments (phosphorous precipitation).

The current condition of the lake is hyper eutrophic. If internal loading were eliminated, the lake would still be lowering eutrophic since the lake has a low outflow rate and a high hydraulic retention time. Lakes with high retention times are more susceptible to external loads. Therefore, if the lake residents would like Little Green Lake to be as close to mesotrophic as possible, the external loading should be reduced. Using additional best management practices in the watershed can reduce external loads. Best management practices may include swale buffers, sedimentation ponds and low fertilizer applications around the lake.

Final Recommendations

The findings of the Little Green Lake Management Plan and the Little Green Lake Limited Phosphorous Budget were discussed in meetings with the interested parties. The following people were in attendance; Ms. Jill Geisthardt; Mr. William Rose, Hydrologist with the U.S. Geological Survey; Mr. Mark Sesing, Water Resources Manager for the Wisconsin Department of Natural Resources; Mr. James Hebbe, County Conservationist for the Green Lake County Conservation Department; Mr. Dale Robertson, Limnologist for the U.S. Geological Survey; and Mr. Paul Garrison, Water Resources Manager for the Wisconsin Department of Natural Resources.

The main purpose of the meetings was to discuss options for reducing internal phosphorous loading. As noted, previously the options included alum treatments, hypolimnetic withdrawal and artificial circulation. The final consensus on the options was as followed:

Alum Treatment: Alum treatments are expensive and have had mixed results on similar lakes. The WDNR indicated that on some lakes the alum treatment was affected by currents, a uniform application was not achieved, and was not successful at reducing algae blooms. On other lakes the alum treatments only had a short-term effect on the algae blooms and had to be re-applied on a 2 to 5 years after the initial application. If not dosed properly, alum treatments could also have a potentially toxic effect on the lake.

Hypolimnetic Withdrawal: For hypolimnetic withdrawal to be considered a viable phosphorous loading reduction alternative, a phosphorus budget should suggest that external nutrient loading is acceptable and internal nutrient recycling is a significant problem (it should also be confirmed whether the majority of phosphorus is released from sediment in the hypolimnion during periods of anoxia). Second, discharge measurements should indicate that the lake has sufficient recharge capacity to support a summer withdrawal. This technique is an effective strategy to remove anoxic, nutrient-rich water as it develops in the hypolimnion during the summer months.

Low summer inflow and outflow from Little Green Lake indicate that the lake cannot support hypolimnetic withdrawal during the summer months. If significant volumes of water are withdrawn from the hypolimnion, lake levels will experience significant fluctuations. Therefore this option was not recommended for Little Green Lake.

Artificial circulation: Artificial circulation was not recommended in the Little Green Lake Management Plan because it was thought that artificial circulation was not suited to relatively shallow lakes. However, after discussions with the WDNR, this option was re-evaluated. The WDNR has conducted a pilot project at a similar lake with some success (Cedar Lake). It is believed that the majority of the internal phosphorous loading at Little Green Lake occurs in the center of the lake where depths reach 25 feet. On Cedar Lake, a 70% reduction in internal phosphorous loading was achieved. This resulted in a reduction in algae blooms and a general improvement in water quality. Little Green has several advantages over Cedar Lake: smaller size, smaller anoxic zone, and shorter distance for line run. These advantages should result in more complete mixing. The goal of the proposed system is greater than 70% reduction in internal phosphorous loading. Other positive aspects of artificial circulation include the flexibility of the proposed system. The system will have two air compressors and five separate aeration lines. The system can be adjusted to optimize its performance. The five-aeration line system proposed by General Environmental Systems is a more aggressive artificial circulation system than the one used in the WDNR pilot project, which had only one aeration line. If it is determined that not all 5 aeration lines are needed to achieve desired results, one or more of the lines, and possibly one compressor can be shut off to conserve on electricity costs.

In conclusion, it was agreed that artificial circulation should have the effect of reducing the hyper eutrophic conditions of the lake. However, it is not know if the artificial circulation system will bring the lake to a mesotrophic state.

As with any system, which is designed to deal with a complex biological and ecosystem problem, there are no guarantees of ultimate success. However, after careful consultation with experts at the USGS, WDNR, consulting industry, and considering all data/analysis performed so far, there is a general consensus that this plan of action is the best opportunity to improve water quality on Little Green Lake.

Artificial Circulation System

The artificial circulation system that is being proposed is an air supply system that provides aeration at the bottom of the lake in the areas of the lake with 15 to 25 foot total depths. Air compressors stationed in one location on the shoreline will provide air through submerged piping to aeration lines anchored to the lake bottom.

Ramaker & Associates, Inc. has been primarily working with one contractor who has provided a proposal to furnish and supervise installation of the system. The General Environmental Systems (GES) proposal includes a conceptual plan for the aeration system and specifications/quantities for air compressors and aeration lines that GES would furnish. The GES proposal does not include specifications for aeration lines, which it claims, is proprietary information. The GES plan is to install five aeration lines that will be supplied by two 40 hp power air compressors. The total length of airline in the proposal is 14,300 feet. The system also includes an anchoring system, and can be floated by filling a buoyancy line with air. The GES proposal does not include costs for the equipment building, electrical hook-ups, some plumbing, and trenching that will be necessary during the system installation. A local contractor will be hired to provide these services during installation. A copy of the GES proposal has been included with the Grant application.
This proposal is somewhat conceptual in nature. The exact design and cost will be finalized once an equipment location has been determined.

The system proposed by GES is over-designed. The system is over-designed because of risks associated with an under-designed system not capable of maintaining lake de-stratification. If the system does not maintain de-stratification it will routinely mix nutrient-rich water throughout the system, rather than preventing phosphorous release in the first place.

Additional proposals for the artificial circulation system are being sought at this time. A meeting has been held with another equipment vendor to review alternative designs and potential cost saving measures.

A specific shoreline site for the equipment building has not been finalized at this time. A suitable location has been found. The site is an abandoned road right-of way. However, the right to use this location will need to be obtained. The site is on the south end of the lake where access to 3-phase power is available from utility lines along Highway 44. Once a site and equipment supplier has been selected, a more detailed engineering and design plans, for the aeration system, will be available.

The pipes can be installed above ground using galvanized piping. However, since the artificial circulation system is planned as a long term or permanent structure, it is recommended that the lines be buried.

The artificial circulation system will require a 12 ft. x 16 ft. building. The construction of the building will be completed by a local contractor.

Systems Monitoring

The proposed artificial circulation plan includes a water-sampling plan to document water quality conditions before and after implementation of the system. The proposed water quality sampling has two purposes; to define conditions that lead to stratification, for system operation optimization, and to document trophic conditions before and after system implementation to gauge the performance of the system as it relates to the overall goal of reducing the trophic status of the lake.

The reason for using artificial circulation at the lake is to reduce the trophic status of the lake by reducing the amount of internal phosphorous loading caused by the anoxic hypolimnion. To optimize the system performance it is necessary to gather data to demonstrate when the lake becomes stratified in terms of dissolved oxygen. The lake sampling will therefore include dissolved oxygen vertical profiling in approximately five locations on the lake. To gauge the effectiveness of the artificial circulation approach, the sampling plan will also include some analyses for total phosphorous. The phosphorous samples will be collected to compare concentrations during periods of dissolved oxygen stratification, to phosphorous concentrations during artificial circulation.

The WDNR has offered to hire an intern to conduct the systems monitoring. The plan will require twice weekly sample collection. The process will also require tracking and interpretation of data for selecting which samples will be chosen for phosphorous analysis. To reduce sampling costs, phosphorous samples will be submitted from select sampling events, and will be limited to only those necessary to establish trends and optimize the system performance. For these reasons, it was decided that an intern under the direction of the WDNR would be appropriate for the sampling. The first year of the intern costs have been included in an extension to the existing lake planning grant. The Little Green Lake Protection & Rehabilitation District will be responsible for funding the intern for the second year. The cost of the intern, including laboratory sample analysis charges, is estimated to be $6,000 per year.

After the two-year sampling program has been completed, the sampling plan should be reviewed and a new plan may be implemented. The long-term plan may include sampling conducted by the USGS along with sampling provided by lake volunteers.

Public Education and Participation

Public informational meetings will be held to discuss the artificial circulation system. The first informational meeting will be held during the Little Green Lake annual meeting, prior to the system installation. The discussion during this meeting will include the artificial circulation system project goals, estimated project cost, potential benefits and potential risks associated with the artificial circulation.

The second informational meeting will be held after one year of system operation. At this second informational meeting the project results and long-term implications will be discussed.

In addition to the informational meetings, project fact sheets will be prepared and provided to all of the Little Green Lake Protection and Rehabilitation District members, as well as other interested parties. Project fact sheets will include an outline of the current lake conditions, a description of the artificial circulation system, descriptions of the project goals, projected benefits and an outline of possible ecological effects.

WORK TASKS/TIME SCHEDULE

Lake Sampling – May - September 2000 The detailed water quality sampling is already scheduled to begin this year. The sampling will occur in May - September of 2000.

Building Location – Summer 2000 The Little Green Lake Protection & Rehabilitation District needs to finalize the building location. To reduce the length of airline required, the building should be on the shoreline nearest the deep area of the lake where the artificial circulation will take place. These areas are located on the northwest and southeast shorelines of Little Green Lake. The system also requires 3-Phase power. The nearest existing 3-phase power location is along Highway 44 south of the lake. Therefore the system should be located on the south end of Little Green Lake.

System Installation – Late Fall 2000 After a site is chosen, the building and circulation system will be installed. It is estimated that the system will be installed in fall of 2000. ** All necessary water regulatory permits will be obtained prior to the installation of the system.

System Operation - 2001 The system will begin operating in 2001. It is expected that system optimization work will be necessary in the first few months of operation.

Lake Sampling – June – August 2001 Lake sampling will be conducted in the summer of 2001 while the system is being implemented.

ENGINEERING AND DESIGN PLANS

Artificial circulation was proposed for Little Green Lake after discussions with the WDNR who had had previous success with a pilot project artificial circulation on another lake.

After it was decided to implement artificial circulation Ramaker & Associates, Inc. requested a proposal from GES to provide a custom system to Little Green Lake. The GES proposal has been attached with this grant. The GES proposal includes a conceptual model of the system and specifications for the compressors.

ESTIMATED LAKE IMPROVEMENT COSTS

Ramaker & Associates, Inc. has received a proposal for an artificial circulation system from General Environmental Systems, Inc. (GES), of Kernersville, North Carolina. Alternative layouts and equipment proposals are being obtained.

Cost Breakdown

G.E.S. Artificial Circulation System

Aeration Lines and Compressors $97,980

* The GES proposal is based on optimal siting of the system, therefore a 15% factor of safety has been included to account for changes that may occur after final site determination. This is done to ensure that the grant application is adequate to cover some contingencies.

Establish 3-Phase Electrical Utilities	$5,000
Building, Electrical, Plumbing and Trenching	$20,000
U.S.G.S., Data Compilation, Analysis and Report Writing	$12,000
Post Installation Evaluation Sampling	$6,000

Consulting Costs

Project Coordination	$4,000
Contract Administration, Permitting	$1,000
Installation Oversight	$2,400
System Optimization	$3,600
Reporting	$4,000

Estimated Project Total **$155,980**

Cost Sharing Breakdown Assuming the Lake District applies for and receives a lake protection grant, the costs outlined above will be shared between the lake protection grant and the Little Green Lake District. The lake protection grant will cover 75% of the costs, while the Lake District will provide the remaining 25%. Applying this formula to the costs noted above yields the cost breakdown that follows:

Lake Protection Grant Request	$116,985
Little Green Lake District Match	$38,995

It is understood that volunteer time that is donated during the implementation of this plan can be counted towards the Little Green Lake District 25% match. Non-professional volunteer time applies to the matching portion at a rate of $6/hour volunteered. It is estimated that 6 volunteers will be needed for a period of 6 days during the installation. This amount of time would account for $1,728 of the local match services. Actual in-kind contributions may vary. It is likely that Lake District members will be asked to contribute additional time and equipment to complete the project.

6-1-99

LPL 656

RAMAKER
& ASSOCIATES, INC.
Consulting Engineers

PHOSPHORUS BUDGET STATISTICS
LITTLE GREEN LAKE

Program Inputs

Mean depth:	3.15 m (10.34 ft)
Max depth:	8.2 m (27 ft)
Lake surface:	466 acres
Anoxic zone:	> 4.6 m (> 15 ft) 119 acres, 503 acre-ft
Watershed:	2,111 acres
Volume:	4,817 acre ft
Runoff:	2.1 inches (Rose USGS)

Hydraulic residence time: 12.8 yrs (Rose USGS)

Total Phosphorus Concentrations:

- ♦ Spring: 46 micrograms
- ♦ Summer: 183 micrograms
- ♦ Total phosphorus mass increase from spring to August: 814 kg

Total Phosphorus Loading

External Load

- ♦ External Load: 340 kg (750 lbs), Seepage Lake Response Model, 30% of total load
- ♦ External Load from Land Use: 285 kg (629 lbs), Watershed Inventory
- ♦ High External Loading Areas: Area 6, Area 9 and Area 4

Internal Loads

- ♦ Internal Load: 750 kg (1,653 lbs), Seepage Lake Response Model, 69% of total load
- ♦ Internal Load: 814 kg (1,794 lbs), Total Phosphorus mass increase spring to August

Total Load: ~1,100 kg (2,425 lb)
Total phosphorus outflow: ~ 23 kg (51.7 lbs) (Rose) ****High total phosphorus retention

Total Phosphorus apparent settling velocity: 2 m/yr. After alum: 6-7 m/yr. Estimated 6.2 m/yr.

Notes:

- ♦ Apparent settling velocity analysis and Wisconsin Internal Load Estimator Spreadsheet (Panuska's models) indicate lake is polymictic (mixes several times a year).
- ♦ Dam rebuilt in 1998 can handle stage fluctuations
- ♦ Lake has dense macrophyte growth during summer
- ♦ Good muskey fishery

Figure 1.

LITTLE GREEN LAKE

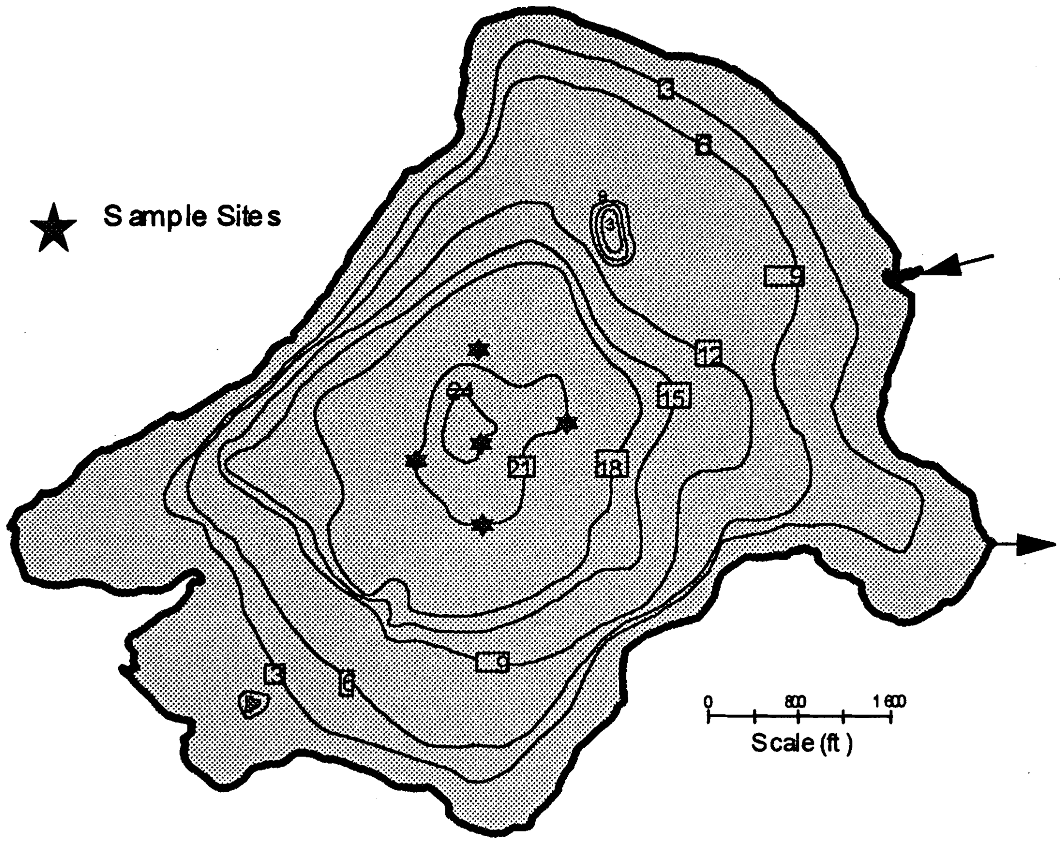

Figure 2. LGL Area & Volume of Anoxic Water, Summer 2000

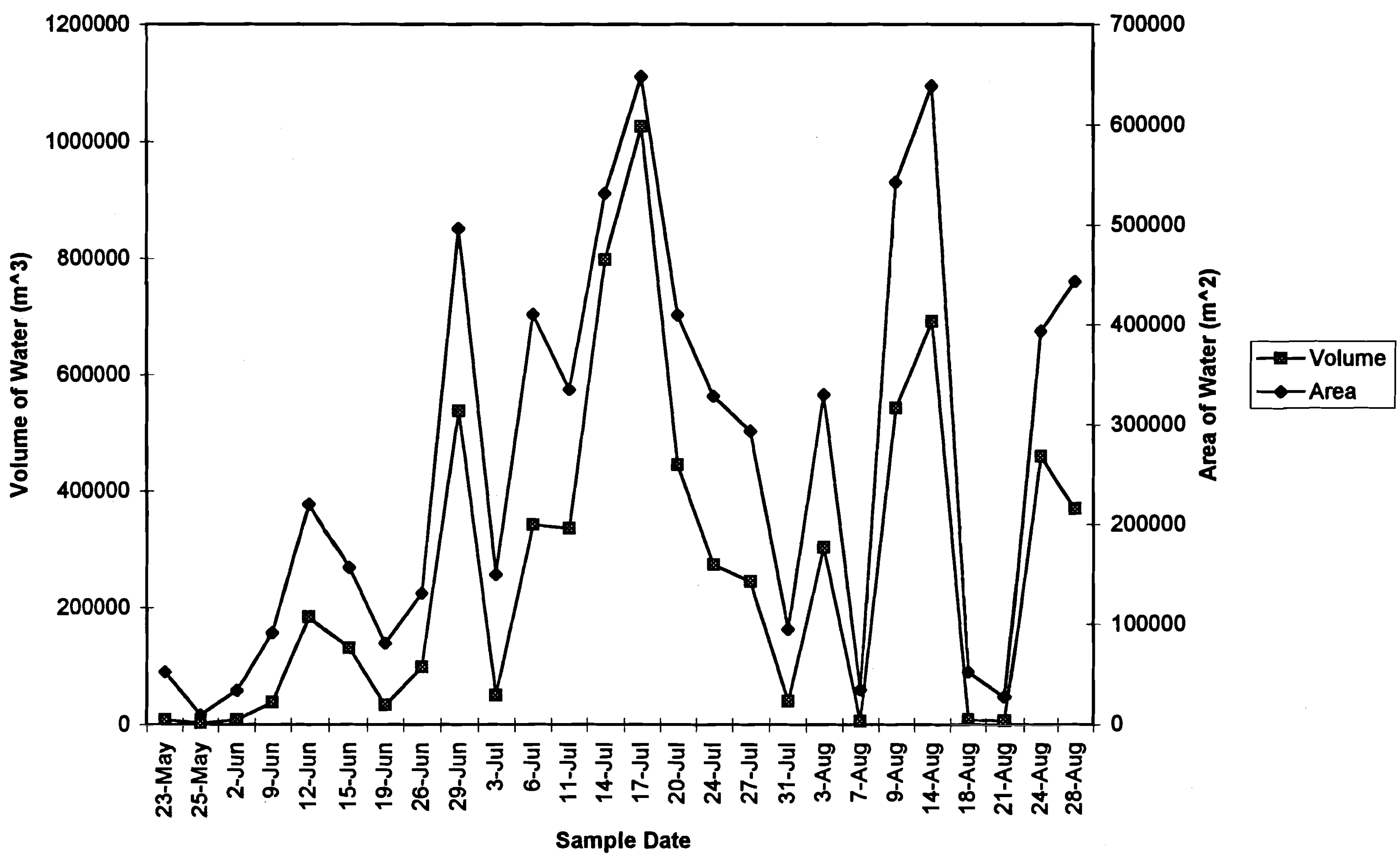

Figure 3. Approximate Mass of P in LGL, Summer 2000