Final Report

LITTLE ELKHART LAKE WATER LEVEL MANAGEMENT PROJECT

for

LITTLE ELKHART LAKE REHABILITATION DISTRICT

May 9, 1997

Project No.: 1964200-350

TABLE OF CONTENTS

Little Elkhart Lake Water Levels Management Project
Little Elkhart Lake

Chapter 1 - Introduction

History of Water Level Fluctuations 1-1

Chapter 2 - Overview of Project Area

Overview of Lake Characteristics 2-1

Watershed Characteristics 2-3

Surface Water Drainage 2-3

Geology and Soils 2-3

Groundwater Flow 2-5

Chapter 3 - Hydrologic Analysis

Introduction 3-1

Hydrologic Analysis 3-1

Effect of Local Groundwater Wells 3-6

Conclusions 3-7

Chapter 4 - Water Level Management Alternatives

Introduction 4-1

Changes in Operation of the High Water Outlet 4-1

Extension of Piers 4-2

Lake Bottom Sealing of Groundwater Outflow Areas 4-2

Dredging of Shallow Bays 4-6

Dredging of Navigational Channels 4-9

Water Supply Augmentation Using Deep Aquifer Well(s) 4-9

Chapter 5 - Recommendations

Introduction 5-1

Conclusion and Recommendation 5-1

Regulatory Approvals 5-1

Grant Opportunities 5-2

Implementation Sequence 5-2

References

Appendix A: Little Elkhart Lake Water Budget

Appendix B: Probibility Curve of Low Water Levels.

TABLE OF CONTENTS

Tables

2.1 Physical Characteristics of Little Elkhart Lake 2-1

3.1 Little Elkhart Lake Available Stage Measurements 3-4

3.2 Average Water Inputs and Outputs Little Elkhart Lake 3-6

3.4 Drawdown Time for Outlet Pipe During Large Storms..3-7

4.1 Cost of Clay Liner for Sealing Groundwater Discharge Areas 4-6

4.2 Sediment Volumes and Cost of Dredging Shallow Areas on Little Elkhart Lake 4-6

4.3 Cost of High Capacity Well Installation.. 4-10

Figures

2.1 Little Elkhart Lake Topographic Map 2-2

2.2 Underlying Strata of Sheboygan County 2-4

2.3 Little Elkhart Lake Groundwater Flow Directions 2-6

3.1 Little Elkhart Lake Simulated Lake Stage Fluctuation 3-5

4.1 Annual Precipitation/City of Plymouth 4-3

4.2 Annual Precipitation vs. Evaporation 4-4

4.3 Lake Bottom Contours 4-5

4.4 Bottom Sealing Areas 4-7

4.5 Potential Dredging Areas 4-8

4.6 Location of 3-Phase Power 4-11

CHAPTER 1

INTRODUCTION

History of Water Level Fluctuations

Little Elkhart Lake has experienced water level fluctuations dating back to pre-development time. As a "seepage" lake, the elevation of the water surface fluctuates with changes in groundwater levels. The lake level changes with long-range precipitation. During periods of wet weather, the lake elevation rises and during periods of drought, the lake level drops. Lake level information on the lake is limited, but records indicate the lake fluctuations have ranged as much as 4.6 feet in the last 25 years (Sheboygan Press, 1985).

During periods of high water levels, the lake community historically experienced problems with malfunctioning septic systems and property damage to near shore structures. During periods of low water, access by boats from shore is hindered by lack of water depth and excessive aquatic plant growth. In the early 1990s a sanitary sewer system was installed. In response to complaints from local residents, the Wisconsin Department of Natural Resources artificially pumped the lake down in 1975 and 1983. The artificial pumping lowered the lake 13 inches in 1975 and 12 inches in 1983. Despite the artificial pumping, the lake elevations continued to rise in the mid 1980s to a high of 2.5 feet above the ordinary high water level in the summer of 1986. To develop a long-term solution to the high water level problems, the Little Elkhart Lake Rehabilitation District, with assistance from the Town of Rhine, installed an outlet pipe on the east side of the lake in October, 1986. The outlet pipe discharges to Otter Creek and now keeps water levels from rising above an elevation of 885.43 feet above sea level (89.04 based on local datum).

In 1995, the outlet pipe's inlet section was damaged by shifting of the ground. The end section of the pipe in the lake was forced upward, preventing water from entering the pipe. As of May, 1997 the pipe end section is still in need of repair. The firm of R. A. Smith & Associates was hired in 1996 to conduct a three fold water level control project. The objectives of the project included the following elements:

1. Prepare a plan for permanent restoration of the lake outlet.

2. Determine the potential impact of private wells on water levels in Little Elkhart Lake.

3. Develop a long-range plan for managing high and low water levels on Little Elkhart Lake.

Objective 1 is addressed in a separate document of bidding plans and specifications for a new inlet section to the outlet pipe, and changes in the outlet control structure located in a manhole on the Camp Anokijig property. Implementation of the recommended changes to the outlet pipe is on hold until the issue is discussed at an annual meeting of the lake district.

Objectives 2 and 3 are addressed in this report. To address the concern for long-range water level management, a water budget for the lake was prepared for the period of 1967 through 1995. The long-range water budget will be used to determine potential changes in water elevation. The water budget for the lake is addressed in Chapter 3 of this report.

To control long-range water levels, the following management alternatives are evaluated in Chapter 4 of this report:

- Changes in operation of the high water outlet
- Extension of piers
- Lake bottom sealing of groundwater outflow areas
- Dredging of shallow bays
- Dredging of navagation channels
- Water supply augmentation using deep aquifer well(s)

Chapter 5 provides the final recommendations of the study and includes an implementation strategy for execution of the plan components.

This project was funded by the Little Elkhart Lake Rehabilitation District and the Wisconsin Department of Natural Resources through a Lake Planning Grant.

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CHAPTER 2

OVERVIEW OF PROJECT AREA

Overview of Lake Characteristics

PHYSICAL CHARACTERISTICS

Little Elkhart Lake is classified as a "seepage" lake by the Wisconsin Department of Natural Resources (DNR, 1991). The DNR describes seepage lakes as lakes that do not have an inlet or outlet and only have occasional overflow. The principal source of water is precipitation, surface runoff, and groundwater inflow. Lake levels in seepage lakes typically reflect groundwater levels and rainfall patterns and, therefore, may fluctuate seasonally (DNR, 1991). The lake is located in the Town of Rhine (Sections 33 and 34, T16N, R21E), Sheboygan County, Wisconsin. Table 2.1 lists various physical characteristics of Little Elkhart Lake.

Table 2.1.
Physical Characteristics of Little Elkhart Lake*

Characteristic	Amount
Lake surface area	54 acres
Total watershed area	550 acres
Watershed area (direct contributing areas only)	401 acres
Maximum depth	25 feet
Average depth	8 feet
Volume	144 million gallons (440 acre-feet)
Shoreline length	2.25 miles
Shoreline development	50 percent

* Compiled from lake survey and topo maps, and DNR (1991).

Figure 2.1 is a topographic map of the Little Elkhart Lake area. This map is dated April 25, 1989 and was obtained from the consulting engineering firm of Foth and Van Dyke.

FORMATION OF LAKE

The origin of the area surrounding Little Elkhart Lake, as stated by Alden (1918), is "While the basin itself is probably due to the melting of a great irregular mass of ice left buried by the glaciers, it is believed to be underlain by a considerable preglacial valley which extended southeastward and was occupied by the ancestral Sheboygan River." The glacial material in this area comes from both the Lake Michigan and Green Bay glaciers.

Figure 2.1.

Little Elkhart Lake topographic map.

LAKESHORE DEVELOPMENT

Development in Little Elkhart Lake's watershed mostly consists of low density residential units located on or near the lake's shoreline. As shown in Table 2.1, the shoreline is approximately 2.25 miles in length and is approximately 50% developed. According to the topographic map (Figure 2.1), there were less than 50 homes directly on the shoreline of the lake in addition to a YMCA camp, Camp Anokijig.

Watershed Characteristics

In addition to the homes on the lakeshore, the watershed also contains approximately 50 additional houses/buildings, a racetrack, a campground, forested land, and agricultural land. Currently, the residential areas in the watershed do not have storm sewers. All homes in the lake district are serviced by sanitary sewers and not septic systems. Homes outside the lake district are serviced by septic systems or holding tanks.

A typical slope in the watershed area ranges from 20 to 30 percent. Roughly 70% of the shoreline perimeter was classified by the Soil Conservation Service as having this range in slopes (Engel et. al., 1978). Elevations of land surface in the watershed range from 1070 feet above sea level down to the lake elevation of approximately 885 feet above mean sea level. This watershed is considered part of the Kettle Moraine.

Surface Water Drainage

As listed in Table 2.1, Little Elkhart Lake's total drainage area is 550 acres. However, 149 acres within the watershed boundary are internally drained and non-contributing. Therefore, the direct surface runoff contributing area is 401 acres. This seepage lake has no natural inlet or outlet. In October 1986, a PVC pipe outlet structure was constructed which discharges to Otter Creek. This structure was built to alleviate flooding problems experienced by property owners due to fluctuating lake elevations.

Geology and Soils

GEOLOGY

Little Elkhart Lake lies in an area of glacial drift underlain by Niagara dolomite bedrock (Alden, 1918). The depth of glacial drift ranges from 135 to 200 feet. Glacial material surrounding Little Elkhart Lake consists of end moraine (till, and stratified sand and gravel) to the north, and ground moraine (till; unstratified clay, silt, sand, gravel, and boulders) elsewhere (Skinner et. al., 1973). Figure 2.2 displays the underlying strata of Sheboygan County.

Figure 2.2.

Underlying strata of Sheboygan County
Source: Geological and Historical Atlas
of Sheboygan County, Wisconsin.

SOILS

Little Elkhart Lake and its watershed exist on two soil associations, Hochheim-Theresa association to the east and Casco-Fox-Rodman association to the west (Engel et. al., 1978). The associations are described in the soil survey of Sheboygan County as follows:

- Hochheim-Theresa:
  Well drained soils that have a subsoil of mainly clay loam or silty clay loam and are underlain by gravelly sandy loam glacial till.

- Casco-Fox-Rodman:
  Well drained to excessively drained soils that have a subsoil of mainly silty clay loam to sandy clay loam or gravelly sandy loam and are underlain by stratified gravel and sand outwash.

Groundwater Flow

Groundwater flow into and out of Little Elkhart Lake has been determined to play a major role in the hydrology of the lake as stated in DNR Lake Feasibility Study written in 1979. In addition, the report states that the groundwater drainage basin appears to follow the surface water drainage basin and that the lake exists as an extension of the groundwater table. Results from the study conducted by Vennie (1978) determined groundwater flow directions using observation wells located around the lake. Groundwater flow directions and the groundwater divide are shown in Figure 2.3. It can be seen that groundwater enters on the west side of the lake and exits the lake on the east side. At different times, flow was measured into and out of the lake (reverse flow) on the south side, west of the groundwater divide.

Figure 2.3.

Little Elkhart Lake groundwater flow directions.

CHAPTER 3

HYDROLOGIC ANALYSIS

Introduction

To understand the water level changes in Little Elkhart Lake and predict potential future changes, it is important to understand how water enters and leaves the lake. Little Elkhart Lake is a seepage lake. Therefore, to understand the changes in water level over time, we need to look at long-term changes in precipitation and evaporation. A hydrologic analysis is the first step in answering the question of what potential impact private wells have on the water level of Little Elkhart Lake. A detailed water budget was prepared for the lake and watershed. A spreadsheet was developed which estimates all of the inflows and outflows from the lake. This analysis evaluates annual surface runoff, evaporation, local well pumping, water discharged to the sanitary sewer, lake outflow through the outlet pipe, groundwater discharge and recharge, and lake storage. The spreadsheet model was then calibrated with available lake elevation data from various individuals and/or agencies. In addition, a low-elevation frequency analysis was performed on the available data to determine how often the lake may reach certain low levels.

Hydrologic Analysis

HYDROLOGIC METHOD

A water budget is a quantification of the hydrologic cycle (the process by which water moves in and out of the lake). For any one system, the sums of the volume of water coming into the system, leaving the system, and the change in volume of water retained in the system must equal zero to conserve mass. This summation of volumes is expressed in a general mass balance equation as follows:

$$P + Q_{in} - Q_{out} + G_{in} - G_{out} - E - T = \text{Change in Storage}$$

Where P is precipitation, Q_{in} and Q_{out} are surface water inflows and outflows, G_{in} and G_{out} are groundwater inflows and outflows, E is evaporation, T is plant transpiration, and Change in Storage is the change in volume of water retained in the system, such as in a lake. As lake storage changes, the water levels either rise or fall.

A water budget for Little Elkhart Lake was constructed on a spreadsheet (Appendix A). The above mass balance equation was edited and reorganized to reflect the physical conditions at Little Elkhart Lake. The new equation is,

$$P + Q_{in} + G_{in} - E - G_{out} - W_o - Q_{out} - Pump_{out} = \text{Change in Storage}$$

The additional terms, W_o and $Pump_{out}$, are the effects of pumping from local wells (well outflow) and water that was mechanically pumped out of the lake by the Wisconsin Department of Natural Resources in 1975 and 1983, respectively.

HYDROLOGIC PARAMETERS

Precipitation

Precipitation is the volume of water in the form of rainfall or snow which falls upon the lake area (rain depth times lake area). The precipitation depth data source is the National Oceanic and Atmospheric Administration (NOAA) weather station in the City of Plymouth. Data was available for the period October 1950 through September 1995.

Surface Water Inflow

There are no direct measurements of the surface water inflows into Little Elkhart Lake. To estimate the surface water inflow, the runoff depth from a similar watershed which has flow data was used to calculate an inflow rate. The runoff depth is the volume of flow divided by the surface area of the watershed.

The U.S. Geological Survey gauging station of the Sheboygan River at Sheboygan was selected for use in calculating the runoff depths in the Little Elkhart Lake watershed. The Little Elkhart Lake watershed is within the Sheboygan River watershed and overall has similar watershed characteristics. The period of record for the Sheboygan River gage at Sheboygan is June 1916 to September 1924, and October 1950 to the current year.

Evaporation/Transpiration

Little Elkhart Lake experiences water losses both through evaporation from open water areas and evapotranspiration from areas of emergent vegetation such as cattails. Evapotranspiration is the combination of evaporation and transpiration. There have been several studies measuring ratios between wetland evapotranspiration and free water surface evaporation. These ratios ranged from 0.38 to 1, to 3.0 to 1 (Idso, 1981). Some of the better studies and theoretical calculations indicate a ratio of around 0.85 to 1, showing less water loss with wetland vegetation (Idso, 1981). Plant transpiration water loss is countered by the reduction of air circulation and evaporation due to plant cover. For ease of calculation, wetland evapotranspiration and free water surface evaporation were considered equal.

Evaporation losses from Little Elkhart Lake were estimated using evaporation pan data. Evaporation pan data from the University of Wisconsin Agricultural Field Station at Arlington in Dane County, Wisconsin was used to calculate the evaporation on Little Elkhart Lake. A conversion ratio was needed to translate pan evaporation to free water surface evaporation. An annual average coefficient of 0.7 was used (Bras, 1990). Evaporation data was available for the period January 1965 through September 1995, and was the limiting source of data for this study.

Groundwater Outflow

Groundwater outflow is considered to be a large component of the water budget. Groundwater outflow is related to precipitation and watershed area as a percentage. The relationship is as follows: precipitation falls onto the watershed, which then seeps into the ground, flows into the lake, and then may flow out of the lake. This percentage was chosen as 30% based on past groundwater studies of the lake by Vinnie (1978), which relates to a net groundwater outflow. This means a higher percentage of precipitation may or may not enter the lake, but 30% of it leaves through groundwater outflow.

Well Outflow

The volume of water contained in Little Elkhart Lake is affected by the pumping of local wells around the lake. The average volume that flows out of the lake during a one-year period was calculated as 26 acre-ft/year. This value was used for each year during this study period. This calculation is discussed in detail in a subsequent section.

Surface Water Outflow

Surface water flows out of Little Elkhart Lake through a pipe outlet structure. Surface water only flows out of the lake during periods of high water level when the lake elevation reaches above 89.04 ft. DNR datum (885.43 ft. USGS datum). The outlet structure consists of a 10-inch PVC pipe with a control weir located in a manhole. Monthly outflow was calculated by using the preceding month's lake elevation, calculating an outflow using a culvert hydraulics computer software program entitled HY8, then multiplying this outflow by the number of days in the month, and lastly converting this into a volume per month. The development of the computer program HY8 was funded by the U.S. Department of Transportation Federal Highway Administration and described in report number FHWA-ED-878-101. In addition, the monthly outflow volume is limited to the amount of volume above the outlet pipe invert (i.e. the spreadsheet will not continue to calculate outflow when the lake level falls below the invert of the pipe outlet). However, since flow is only calculated on a monthly basis, this source of error (slight overestimate of flow) is probably minimal.

Pumping Outflow

The Wisconsin Department of Natural Resources mechanically pumped the lake down in 1975 and 1983. This was done during high water periods to help reduce flooding damages to property owners around the lake. These records were obtained from John Nelson at the DNR. Pumping occurred during May 1975 and November 1983. The lake was drawn down 13 inches in 1975 and 12 inches in 1983. Volume pumped was calculated by multiplying the surface area of the lake (54.0 acres) by the drawdown depth.

Storage

Storage volume in Little Elkhart Lake is controlled by the elevation of the outlet pipe structure, the shape of the lake basin, and precipitation. During dry conditions, the lake level may rescind below the outlet invert due to evaporation and groundwater losses. In the water budget, this reduction in lake level occurs when the inflows (precipitation and surface water inflow) are less than the outflows (evaporation, groundwater, pumping, etc.). The change in storage is carried over into the next month until subsequent inflows are sufficient to bring the storage volume back to the initial level.

The known storage value of 444 acre-feet used in the analysis was calculated from an April 1973 lake elevation reading of 87.70 feet DNR datum. The subsequent monthly change in storage was then calculated using the previously explained water budget equation. This change in storage was then added to the preceding month's storage to determine each current month's storage. This method was also used to back-calculate storage volumes to 1970.

DEVELOPMENT OF MONTHLY LAKE ELEVATIONS

Lake Elevation -Storage Relationship

A lake elevation versus storage relationship was developed for Little Elkhart Lake. A lake elevation /storage relationship shows how lake volume changes with change in water elevation. The relationship was developed by digitizing contour areas above the water surface from a one-foot topographic map and incorporating the lake elevation/storage curve developed on the DNR lake survey map. The lake survey map was prepared by the Wisconsin Department of Natural Resources in June 1974 and the topographic map used was prepared in April 1989. Contours are lines drawn on a map which represent the same elevation at each point on the line. The storage between two contours is found by averaging their surface areas and then multiplying by the difference in elevation of the two contours. The data was then plotted as lake elevation versus lake storage (volume). In the water budget analysis, lake elevation values were found using calculated values of storage and linearly interpolating between data points on the curve developed.

Calculated Stages

Monthly lake elevations were determined using the above methods for the period January 1970 through December, 1994. Values of storage prior to the initial storage value date of April 1973 were back-calculated from this point. The calculated values were then compared with actual lake elevation readings taken by various individuals and/or agencies. A date versus lake elevation plot is shown on Figure 3.1.

Figure 3.1 displays calculated lake stages with the lake outlet (which was in place in October 1986) and what the lake stages would be without the outlet. Actual lake elevation readings made by various individuals and/or agencies are shown as small squares on Figure 3.1 and are also listed in Table 3.1.

TABLE 3.1
Little Elkhart Lake Available Lake Elevation Measurements

	Elevation (ft)		
Date	**DNR**	**USGS**	**Source**
04/19/73	87.70	884.09	WDNR, lake map
04/30/86	91.03	887.42	WDNR, Vic Pappas
05/28/86	90.98	887.37	WDNR, Vic Pappas
10/09/86	91.18	887.57	Miller Engineering
05/04/88	89.31	885.70	WDNR, Vic Pappas
07/16/96	87.65	884.04	R. A. Smith & Associates, Inc.

Figure 3.1.

Little Elkhart Lake, simulated lake elevation fluctuation from January 1970 through September 1994.

Effect of Local Groundwater Wells

There are approximately 83 homes in the Little Elkhart Lake watershed. Of these 83 homes, 72 are located in the groundwater recharge area for the lake. Eleven homes and Camp Anokijig are located in the lake's groundwater discharge area and those wells do not effect the elevation of the lake.

The homes on Little Elkhart Lake are made up of both year-round homes and seasonal cottages. If we assume a worse case scenario (that all of the homes are used for year-round use) then we can estimate the maximum potential impact of local wells on lake elevation. An average single family home of 4 people uses approximately 70 gallons of water per person per day, or 280 gallons per household (Viessman and Hammer, 1993). With 72 homes in the groundwater recharge area, approximately 20,160 gallons of water is removed from the water table per day. Assuming use 365 days per year, the homes would remove 7,358,400 gallons per year, or 22.58 acre-feet per year of water.

To place this value in perspective to other water inputs and outputs, Table 3.2 summarizes the average water budget for Little Elkhart Lake.

TABLE 3.2
Average Water Inputs and Outputs Little Elkhart Lake

Source	Percent of inflow or outflow
INFLOW	
Precipitation	36.0%
Runoff/groundwater	64.0%
Total	100%
OUTFLOW	
Evaporation	16.0%
Groundwater outflow	79.1%
Private wells	4.8%
Total	100%

Source: R. A. Smith & Associates, Inc.

As can be seen, private wells only contribute 4.8 percent of the outflow of the lake. The change in lake storage caused by the loss of 1.88 acre-feet of water per month is equivalent to a change in lake elevation of 0.47 inches.

Ability of Outlet Pipe to Lower the Lake

To evaluate the ability of the outlet pipe to draw the lake down during large flood events, a hydraulic analysis of the pipe was conducted. The results of the analysis for the 2-, 10- and 100-year storms are summarized in Table 3.4.

TABLE 3.4
Drawdown Time for Outlet Pipe During Large Storms

Parameter	2-year	10-year	100-year
Peak Discharge (cfs)	75	245	515
Maximum Outflow (cfs)	0.30	1.40	2.56
Maximum Elevation*	89.24 (local datum) 885.63 (USGS)	89.60 (local datum) 885.99 (USGS)	90.15 (local datum) 886.54 (USGS)
Drawdown time	24 days	25-30 days	30-35days

Source: R. A. Smith & Associates, Inc.
* Note the conversion from local datum to USGS is 796.39. Elevation of the outlet pipe control is 89.04 local datum or 885.43 USGS.

Note that as the elevation of the lake goes up, the outflow through the outlet pipe increases due to extra pressure caused by the water head. During the 10- and 100-year storms, the pipe will be flowing under pressure (pipe submerged).

Analysis of Long Term Trends in Lake Elevation

To evaluate potential changes in lake elevation of Little Elkhart Lake, a low-water-elevation frequency analysis was performed. The analysis was conducted to try to predict how low the lake elevation could decline during periods of extreme drought and the frequency of this occurrence. This analysis was performed using monthly lake elevation values from the water budget for the period January 1970 through December, 1994. This analysis first ranks all of the monthly stages in ascending order, then calculates the probability of the lake elevation being equaled or exceeded using the following formula:

$$P = \frac{m}{n+1}(100)$$

where:

P = probability
m = rank
n = number

Results can be seen in Figure 1-B in Appendix B of this report. Extrapolation from the curve indicates that a lake elevation of approximately 78 feet (DNR datum), or 9-feet lower than the 1996 lake elevation, may be seen once every 1000 months, roughly 83 years. The plot also shows that approximately 79% of the time (over the 30 ± year period) the elevation of the lake would be below the existing pipe outlet structure.

Conclusions

Water elevations in Little Elkhart Lake are a reflection of local groundwater conditions, which reflect annual precipitation. As a seepage lake the elevation of the lake will fluctuate from year to year. High water problems have been solved by the installation of the high flow outlet pipe. Based on the analysis it is estimated that during severe and extended drought, which could happen once every 80 to 100 years, the lake level could drop as much as 9-feet below the levels observed in 1996.

The study indicates that local private wells are having a minor impact on the elevations of the lake and make up only 4.8 percent of the total outflow from the lake.

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CHAPTER 4

Water Level Management Alternatives

Introduction

Little Elkhart Lake has experienced water level fluctuations dating back to pre-development time. As a "seepage" lake, the elevation of the water surface fluctuates with changes in groundwater levels. The installation of the high level outlet pipe in 1986 has eliminated high water elevation problems. As outlined in Chapter 3, even during a 100-year storm the lake level will drop below the outlet pipe within 30 to 35-days. Only during extended periods of precipitation for several months will the high level outlet be needed.

One of the current issues on Little Elkhart Lake is one of managing the lake during periods of low water level. As outlined in Chapter 3, the lake level in theory can drop as much as 9-feet lower than the 1996 lake elevation during periods of extreme and extended droughts. During periods of low water levels on Little Elkhart Lake recreation use is hampered by shallow water depths and excess aquatic plant growth. During low water levels, lake residents along the west and south shores of the lake have trouble getting their boats to open water. The south bay of the lake along Wehmeyer Street has had a history of aquatic plant problems during low water levels that chokes the bay with vegetation, inhibiting boating and swimming.

To manage water levels during periods of extreme droughts, the following alternatives were evaluated:

- Changes in operation of the high water outlet
- Extension of piers
- Lake bottom sealing of groundwater outflow areas
- Dredging of shallow bays
- Dredging of navigation channels
- Water supply augmentation using deep aquifer well(s)

This chapter will discuss the advantages and disadvantages of each of the alternatives and their associated cost.

Changes in Operation of the High Water Outlet

In the fall of 1986, the Little Elkhart Lake Rehabilitation District installed a high water level outlet pipe on the east side of the lake. The outlet pipe discharges to Otter Creek, through a 10-inch plastic pipe. The operation of the pipe is controlled by a weir structure located in a manhole on the Camp Anokijig property. The weir structure is currently fixed in place and is not adjustable.

The high level outlet pipe only operates during periods of extended wet weather. Based on the analysis in Chapter 3, it is estimated that the lake level will be below the high level outlet pipe approximately 79% of the time. It has been questioned whether or not holding water back during periods of high water levels would help to maintain water levels during periods of drought. Based on a review of weather data for the Sheboygan County area, the alternative of holding water back does not seem feasible. Figure 4.1 illustrates the annual precipitation measured by the U.S. Weather Service at the City of Plymouth. As can be seen from Figure 4.1, high water levels are a result of a series of years with above normal precipitation.

The high water levels in the mid-1980s were the result of 10 years of precipitation above the 43 year average of 34.62 inches per year. Low water periods, such as those in the late 1950s and mid-1960s, were the result of extended periods of lower than average precipitation for several years in a row. Figure 4.2 illustrates precipitation at the City of Plymouth versus pan evaporation measured at Arlington, Wisconsin. As can be seen, during periods of low precipitation, evaporation rates reach their highest. It is unlikely that water held back during wet periods would be able to be maintained in the lake long enough to protect lake levels during extended droughts. The only thing holding water back may accomplish is reducing that rate at which the lake level would drop. The affect of the reduction would likely last only for a few weeks to months, not years as would be needed to maintain quality recreation on the lake at all periods.

Extension of Piers

During extended periods of drought when low lake levels inhibit boat access from shore, one option is to extend piers to deeper water. Figure 4.3 illustrates the bottom contour depths of Little Elkhart Lake. Based on the available lake map, the distance from a developed shoreline to the existing three-foot depth contour ranges from 75 to 150 feet along the south shore of the lake. If the lake level dropped an additional five feet during a period of extended drought, then the revised three foot contour along the south shore of the lake would be between 450 to 750 feet from a developed lot. Most piers on the lake are approximately 30 to 50 feet in length. Extension of piers during an extended drought would require the piers to be extended between 400 and 600 feet.

Under Wisconsin state law, riparian residents may extend their piers waterward under the following conditions, provided they do not interfere with the rights of others:

- to the length of their boat,
- to the 3-foot water depth contour, or
- to deeper water if required by the draft of the craft using the pier, which ever is greater.

The cost of extending a pier will vary depending on the needed length and type of pier. Due to the length that piers would have to be extended, this alternative does seem feasible.

Lake Bottom Sealing of Groundwater Outflow Areas

Groundwater discharge is the greatest source of water loss from Little Elkhart Lake. Groundwater discharge makes up 79.1% of all the water outflow from the lake on an annual basis. Sealing of the sand and gravel outflow areas would reduce the quantity of water that leaves the lake each year and, in theory, could help the lake retain more water inflow.

Figure 4.1

Annual Precipitation

Figure 4.2

Annual Precipitation vs. Evaporation

Figure 4.3

Lake Bottom Contours

Studies of groundwater flow in lakes indicate that in most situations groundwater flow takes place in a narrow band along the shoreline areas. Therefore, sealing of the entire bottom of the lake is not necessary. Figure 4.4 illustrates the areas of the lake that would need to be sealed to reduce groundwater outflow from the lake. Table 4.1 outlines the cost of placing a clay seal on the bottom of Little Elkhart Lake.

TABLE 4.1
Cost of Clay Liner for Sealing Groundwater Discharge Areas

Description	Cost
Mobilization	$1,000
Clay Liner	$44,300
Placement	$28,500
Coffer Dam	$20,000
Dewatering	$30,000
Total	**$123,800**

Source: R. A. Smith & Associates, Inc.

Installation of a clay liner on the bed of Little Elkhart Lake would require regulatory approval from the Wisconsin Department of Natural Resources. Installation of the clay liner would cover over existing sand and gravel near shore areas. The liner would cover over spawning areas for largemouth bass and various panfish. The loss of groundwater outflow from the lake may impact water levels in wetlands located southeast of the lake and elevations of water in the lake. Due to the potential environmental impacts of the placement of a clay liner on the bed of Little Elkhart Lake, it is unlikely that this alternative would receive regulatory approval and is therefore considered not feasible.

Dredging of Shallow Bays

An alternative to provide improved boat access during periods of low water levels would be to deepen shallow areas that have existing access problems. Under this alternative, shallow shorelines would be dredged at a 6 to 1 slope to a depth of five feet. Areas with historical access problems are illustrated on Figure 4.5. The navigational channel from the County boat launch would be dredged at the dimensions of 5-feet deep, 50-feet wide at the channel bottom, with 4 to 1 side slopes. Table 4.2 outlines the quantity of sediment and potential cost for dredging the problem areas based on current dredging cost ranges. Engineering and permits will add approximately 15% to the cost of sediment removal.

TABLE 4.2
Sediment Volumes and Cost Dredging Problem Areas
on Little Elkhart Lake

Location	Volume (cubic yards)	Cost ($9/yard+ engineering)
Boat Launch Navigational Channel	6,480	$67,068
A	4,841	$50,100
B	10,000	$103,500
C	5,000	$51,750

Source: R. A. Smith & Associates, Inc.

Figure 4.4

Bottom Sealing Areas

Figure 4.5

Potential Dredging Areas

Dredging could take place by either mechanical or hydraulic methods. The lake level of Little Elkhart Lake cannot be lowered without expensive pumping. Therefore, mechanical dredging methods would likely be limited to removal by hopper barges. A disposal site for the dredged material would need to be found within a short distance of the lake. To maintain reasonable costs, the disposal site would likely need to be within one mile of the lake.

Dredging of shallow areas would require a Chapter 30 permit from the Wisconsin Department of Natural Resources. An Environmental Impact Assessment would need to be prepared and published prior to issuance of any state permit. The potential project could disturb near shore fish spawning areas and reduce rooted aquatic vegetation that act as fish nursery zones. Large scale dredging permits are difficult to obtain and generally take 6 months to a year to acquire.

Dredging Navigational Channels

An alternative dredging option to a complete dredging of bays is to dredge navigational channels from the end of the piers to open water. The navigation channels would provide boat access to open water during periods of low water levels. Navigational channels would impact less aquatic habitat and would receive a more favorable regulatory response from the WDNR. A single navigational channel could be shared by more than one landowner to keep cost and disturbance to the lake to a minimum. The estimated cost of a 100-foot channel, 5-feet deep, 25-feet wide at the bottom, and with 4 to 1 side slopes would be approximately $7,000.

Water Supply Augmentation Using Deep Aquifer Well(s)

Water levels on Little Elkhart Lake could be maintained during low water periods by pumping of water from a deep aquifer. As shown on Figure 2-2, Little Elkhart Lake is underlain by several geologic formations. Of the formations, the Niagara Limestone and St. Peters Sandstone can produce high volumes of groundwater. On average, Little Elkhart Lake looses 39.12 acre-feet of water per month, or approximately 295 gallons per minute (gpm). Replacing the 295 gpm with well water would allow the lake community to maintain the lake at a more constant level. A well with a capacity of 500 gpm would provide a safety margin to allow water level maintenance under even the worst drought conditions.

Based on well logs for the Little Elkhart Lake area, a 500 gpm well would need to be drilled approximately 230 feet. The well would be drilled into the Niagara Limestone where availability of water is dependent on hitting a fracture in the stone. Depths of high capacity wells can vary in the Niagara Limestone from 200 to 500 feet. Other Wisconsin lakes that use high capacity wells to maintain water levels are Cedar Lake in Manitowoc County and Pretty Lake in Waukesha County.

The cost of installing a high capacity well is outlined in Table 4.3.

TABLE 4.3
Cost of High Capacity Well Installation

Item	Cost
Well	$26,000 to $31,000
Pump equipment	$20,000 to $25,000
On/off switch	$1,000
Fence and landscaping	$2,500
Total	**$49,500 to $59,500**

Source: Layne - Norhwest Inc.

Cost of operating the well will vary with weather conditions. The well would likely only be operated during the summer months. Average operating costs are estimated at approximately $1,500 per year.

The pumps for a high capacity well require 3-phase power to operate efficiently. Three phase power is available at the locations of the sanitary sewer lift stations. Figure 4.6 illustrates the location of the two lift stations located closest to the lake. The lift station east of Schwaller Drive is located at the county boat launch and may be subject to vandalism. The lift station located north of Wehmeyer Street provides a more secure location in a residential area. Locating the well at one of the lift station locations eliminates the cost of bringing in 3-phase power.

In addition to providing water to maintain lake levels, groundwater pumping may also improve the water quality of the lake. Groundwater is typically low in nutrients. The addition of nutrient poor water will dilute nitrogen and phosphorus concentrations from surface water runoff. Water quality monitoring of the lake in the late 1970s showed mean phosphorus concentrations of 0.04 mg/l. Depending on phosphorus concentrations in the groundwater, active dilution pumping at a rate of 500 gpm could reduce inlake total phosphorus levels to 0.02 to 0.03 mg/l. The result of dilution pumping would be reduced resuspension of bottom sediments, reduced algal concentrations and increased water clarity.

Figure 4.6

Location of 3-Phase Power

CHAPTER 5

RECOMMENDATIONS

Introduction

Little Elkhart Lake has experienced water level fluctuations dating back to pre-development time. As a "seepage" lake, the elevation of the water surface fluctuates with changes in groundwater levels. The installation of the high level outlet pipe in 1986 has eliminated high water elevation problems. One of the current issues on Little Elkhart Lake is one of managing the lake during periods of low water level. During periods of low water levels on Little Elkhart Lake, recreation use is hampered by shallow water depths and excess aquatic plant growth. During low water levels, lake residents along the west and south shore of the lake have trouble getting their boats to open water.

To manage water levels during periods of extreme droughts, the following alternatives were evaluated in Chapter 4:

- Changes in operation of the high water outlet
- Extension of piers
- Lake bottom sealing of groundwater outflow areas
- Dredging of shallow bays
- Dredging of navigational channels
- Water supply augmentation using deep aquifer well(s)

Conclusion and Recommendation

Of these alternatives, changes in operation of the high water outlet, and lake bottom sealing are not feasible. Dredging of shallow areas may be feasible, but regulatory approval of such projects is difficult. Extension of piers and dredging of navigational channels may be feasible. Water supply augmentation using a deep aquifer well appears to be the most feasible alternative to managing low water levels on Little Elkhart Lake during periods of extended drought. Therefore, installation of a 500 gallon per minute well is the recommended alternative. The well should be located at the sanitary lift station on Wehmeyer Street to take advantage of the available 3-phase electrical service. The well would be operated during summer periods when the lake level drops below the ordinary high water mark established by the Wisconsin Department of Natural Resources at 88.51 local datum (884.90 USGS datum). The cost of installing the well is estimated to range from $49,500 to $59,500. Operating costs are estimated at $1,500 per year.

Regulatory Approvals

Installation of a well that discharges at 500 gallons per minute will require a permit from the State of Wisconsin. Under Wisconsin Administrative Code NR 142.03, all wells that withdraw greater than 100,000 gallons per day for more than a 30-day period require a permit from the Wisconsin Department of Natural Resources.

Grant Opportunities

Installation of a high capacity well maybe eligible for a Wisconsin Lake Protection Grant. Lake Protection Grants are available for projects that protect or enhance the water quality of lakes. The grant can provide 75% of the cost of a project. To be eligible for this grant the project must provide water quality benefits. As outlined in Chapter 4, the proposed well will reduce inlake nutrient concentrations, as well as help maintain recreational use of the lake.

Dredging of the navigational channel at the County boat launch may be eligible for a Wisconsin Recreational Boating Facilities Program Grant from the Wisconsin Waterways Commission. The grant program can fund up to 60% of the cost of navigation channels that improve access from public boat launches. Private navigational channels are not eligible for this grant program.

Implementation Sequence

To implement the installation of a high capacity well and/or dredging of navigational channels, the following sequence of steps would need to be undertaken:

High Capacity Well

1. Conduct public informational meeting on project.
2. Obtain approval of the project at the annual meeting of the lake district.
3. Prepare application for a NR 142 permit for a high capacity well from the Wisconsin Department of Natural Resources.
4. Prepare bidding documents for the well installation.
5. Bid the project.
6. Prepare a financing plan for the project.
7. Award well installation contract.

Public and Private Navigational Channels

1. Conduct public informational meeting on project.
2. Obtain approval of the project(s) at the annual meeting of the lake district.
3. Hire engineering firm to conduct engineering feasibility study.
4. Conduct sampling of bottom sediment to determine physical characteristics, depths of soft sediment, and potential chemical contamination.
5. Identify methods of dredging.
6. Identify potential disposal sites.
7. Prepare necessary DNR water regulation permit applications and associated environmental impact documents.
8. Prepare final engineering plans and bidding documents.
9. Bid project(s) for construction.
10. Prepare a financing plan for the project.
11. Award contract for dredging and construction of necessary disposal sites.

The lake district could initiate a public project for dredging the navigational channel at the county boat launch. Under Wisconsin state law Chapter 30 construction of private navigational channels would need to initiated by the riparian landowners.

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APPENDIX A

Little Elkhart Lake Water Budget

APPENDIX B

Probability Curve of Low Water Levels