Hey and Associates, Inc.

CRYSTAL LAKE
WATER LEVEL MANAGEMENT PLAN

Sheboygan County

Prepared for:

Sanitary District No. 1 Towns of Rhine and Plymouth
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CHAPTER 1- INTRODUCTION

Crystal Lake is a clear, glacial kettle moraine lake located in central Sheboygan County. Historically, the lake has been regarded by riparian land owners, the surrounding community, and the Wisconsin Department of Natural Resources (WDNR) as a pristine natural resource with excellent water quality, high diversity of fish and aquatic plant communities offering numerous recreational opportunities. However, because Crystal Lake is classified as a *seepage lake*--meaning the lake does not have an inlet or outlet--the water quality of Crystal Lake, its ecosystem, and the lake water levels are heavily dependent on the land use practices within the watershed and the groundwater supply. Any alteration to the watershed or the groundwater resource will directly impact the water level of Crystal Lake.

In 1966, the Sanitary District No. 1 Towns of Rhine and Plymouth (the District) was formed to protect the environmental resources of the lake and the health and safety of the users of Crystal Lake. Increased water pollution, excessive weed growth, and navigational restrictions were the primary focus of the District at that time (Sanitary District No. 1 Towns of Rhine and Plymouth, 2006). Today the focus has shifted, as both the District and the surrounding residents have witnessed a constant decline in the lake water level. In 2006, the District by resolution, also assumed the role of an inland lake protection and rehabilitation district. The major fluctuations have resulted in concern for the future water quality and natural resources of the lake, as well as the ability of surrounding residents to utilize the waterbody for recreational purposes. Without evidence of severe drought conditions or low water levels on other adjacent lakes, it is speculated that some alteration to the groundwater supply has occurred.

Hey and Associates, Inc. was retained by the District to prepare a lake level management plan with the goal of determining what change(s) have occurred in the watershed and the hydrologic cycle that has directly impacted the water level of Crystal Lake. The plan includes evaluating the long-term fluctuations in water levels of Crystal Lake by preparing a detailed water budget for the period of January 1966 through September 2005. Alternatives to control long-term water levels are evaluated.

CHAPTER 2 – OVERVIEW OF THE PROJECT AREA

Overview of Lake Characteristics

Physical Characteristics

Crystal Lake is located in the Town of Rhine (Sections 31 and 32, T16N, R21E) in Sheboygan County, Wisconsin. As stated previously, Crystal Lake is classified as a seepage lake by the WDNR (WDNR, 1990). The WDNR describes seepage lakes as lakes that do not have an inlet or outlet and only have occasional overflow. The principal sources of water are precipitation, surface runoff, and groundwater inflow. The principle sources of outflow are evaporation and groundwater outflow. Lake levels in seepage lakes typically reflect groundwater levels and rainfall patterns and, therefore, may fluctuate seasonally (WDNR, 1991). Table 2.1 lists various physical characteristics of Crystal Lake.

Table 2.1
Physical Characteristics of Crystal Lake

Characteristic	Amount
Lake surface area	113.7 acres
Total watershed area	326 acres
Maximum depth	61 feet
Percentage of Lake less than 3 feet deep	11%
Percentage of Lake greater than 20 feet deep	47%
Average Depth	26 feet
Volume	2,967 acre-feet
Shoreline length	2.6 miles

Source: USGS topo map – Elkhart Lake Quad (1973), Sheboygan County DEM (2006), WDNR Lake Survey Map (1966), and Aron, et. al. (1989).

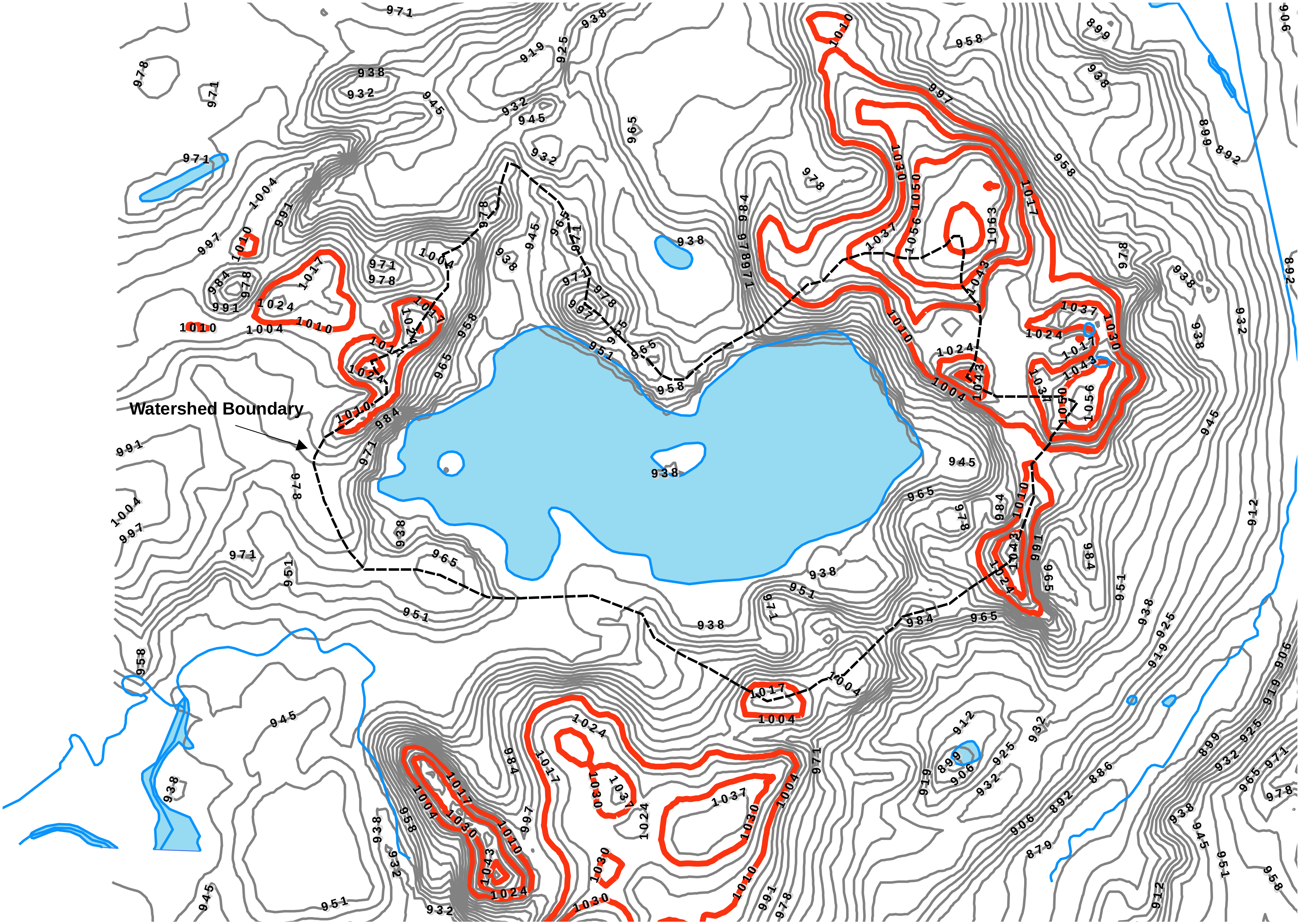
Figure 2.1 is a topographic map of the Crystal Lake area. This map was generated in ArcGIS using the Sheboygan County Digital Elevation Model.

Formation of Lake

The origin of the area surrounding Crystal 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 the Crystal Lake area comes from both the Lake Michigan and Green Bay glaciers.

Figure 2.1

Topographic Map of Crystal Lake



1,000 500 0 1,000 Feet

Hey and Associates, Inc.

Lakeshore Development

Development in Crystal Lake's watershed mostly consists of residential dwellings located on or near the lake's shoreline. As shown in Table 2.1, the shoreline is approximately 2.6 miles in length and is intensively developed throughout. There are an estimated 226 properties, of which 40 percent are full-time residents and the remaining 60 percent inhabit their homes approximately 50 percent of the year.

Watershed Characteristics

The surface drainage area to Crystal Lake is fairly small relative to the surface area of the lake. In addition to the homes on the lakeshore, the watershed also contains open and forested land and natural wetland areas. In the mid 1970s, a sanitary sewer collection system was installed around Crystal Lake to improve the water quality of the lake. Therefore, all homes are serviced by sanitary sewers and not septic systems.

A typical slope in the watershed area ranges from 8 to 28 percent. Elevations of land surface in the watershed range from 1,070 feet above sea level down to the lake elevation of approximately 932 feet above mean sea level.

Surface Water Drainage

As listed in Table 2.1, Crystal Lake's total drainage area is 326 acres. This seepage lake has no natural inlet or outlet. Based on historical records, a canal was constructed in the late 1800s from Crystal Lake to the Mullet River to augment low river levels for a flour mill in Plymouth. However, during high-flow periods, the Mullet River would backflow into Crystal Lake resulting in poor water quality and undesirable fish being introduced into the lake (Pappas, 2003). Thus, the canal was back-filled in the late 1920s.

Geology and Soils

Geology

Crystal 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 Crystal 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).

Soils

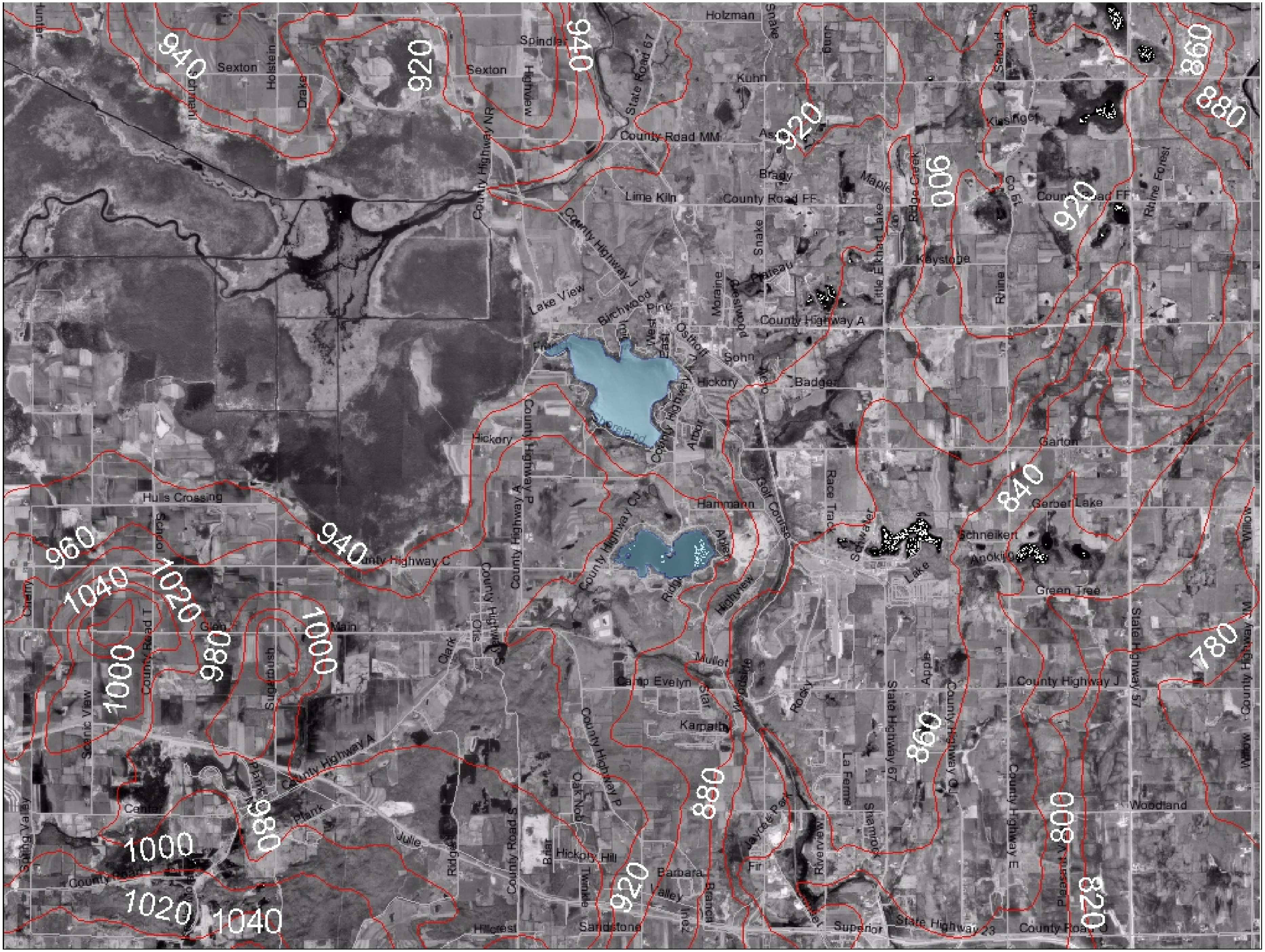
Crystal Lake and its watershed exist on the Casco-Fox-Rodman soil associations (Engel et. al., 1978). The association is described in the soil survey of Sheboygan County as "well drained to excessively drained soils that have a subsoil of mainly silty clay loam to sandy clay loam or gravelly sandy loam and are underlain by stratified gravel and sand outwash".

Groundwater Flow

Groundwater flow into and out of Crystal Lake has been determined to play a major role in the hydrology of the lake. Groundwater flow directions are shown in Figure 2.2, as mapped by the University of Wisconsin - Oshkosh (2004). It can be seen that groundwater enters on the west side of the lake and exits the lake on the north (flowing toward Elkhart Lake), the east (flowing toward La Budde Creek), and south side of the lake (flowing toward the Mullet River).

Figure 2.2

Groundwater Contour Map of Crystal Lake & Surrounding Area



Not to Scale

CHAPTER 3 – HYDROLOGIC ANALYSIS

Introduction

In order to understand the historical water level fluctuations of Crystal Lake and predict potential future changes, it is important to understand how water enters and leaves the lake. As stated previously, Crystal Lake is a seepage lake in which there is no direct inflow or outflow to the lake. Likewise, the elevation of the water surface is directly related to changes in the groundwater level. Therefore, the water level of Crystal Lake is a direct result of surface inflow from the watershed, precipitation on the lake's surface, groundwater inflow and outflow, and evaporation. The water level of the lake can also be directly affected by other mechanical means, such as high-capacity well withdrawal from the sand and gravel aquifer.

To understand how these components of the hydrologic cycle affect the water level over time, long-term changes in the hydrologic cycle need to be evaluated. A detailed water budget was prepared for the lake and watershed. A spreadsheet was developed that estimates all of the inflows and outflows from the lake. This analysis evaluates monthly precipitation and evaporation from the lake surface, surface runoff from the watershed, groundwater discharge and recharge, local well pumping, and lake storage. The spreadsheet model was then calibrated with available lake stage data from participants in WDNR's self-help lake monitoring program. This data was collected from September 1986 through September 2005.

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 Crystal Lake. As lake storage changes, the water level will either rise or fall.

A water budget for Crystal Lake was constructed using a spreadsheet methodology. The above mass balance equation was modified to reflect the physical conditions at Crystal Lake. The equation utilized in the budget is as follows:

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

The additional term, Wr_o, is the effect of pumping from local residential wells (well outflow). The surface outflow term, Q_{out}, is not included in the analysis because there is no direct outflow from Crystal Lake. Likewise, plant transpiration, T, was assumed to be negligible for this analysis.

Hydrologic Parameters

Precipitation

Precipitation is the volume of water in the form of rainfall or snow which falls upon the lake area (rain depth multiplied by 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 March 2006.

Surface Water Inflow

There are no direct measurements of the surface water inflows into Crystal 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 Crystal Lake watershed. The Crystal 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 September 2005, and a limiting source of data for this study.

Evaporation/Transpiration

Crystal Lake experiences water losses through both 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 3.0. Some of the better studies and theoretical calculations indicate a ratio of around 0.85, showing less water loss with wetland vegetation. 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 Crystal Lake were estimated using evaporation pan data. Evaporation pan data from the Wisconsin Agricultural Field Station at Marshfield (Marshfield Exp Farm) in Wood County, Wisconsin was selected to calculate the evaporation on Crystal Lake. This location was used because the pan evaporation during the months of May through October at Crystal Lake closely resembled the pan evaporation data from May through October at Marshfield (NOAA Technical Report NWS 33, Map 1 of 4, and NWS 34, Table I). For the months in which no evaporation data was measured at Marshfield, the estimated average monthly pan evaporation for Milwaukee was used as an estimate. The monthly means at Milwaukee were computed from the meteorological measurements using a form of the Penman Equation. Milwaukee was selected because the annual pan evaporation at Crystal Lake closely resembles the annual pan evaporation estimated at Milwaukee (NOAA TRNWS 33, June, 1982, and NOAA TRNWS 34, December, 1982).

A conversion ratio was required to translate the pan evaporation measurements to free water surface evaporation. An annual average coefficient of 0.782 was selected for Crystal Lake (NOAA TRNWS 33, June, 1982). Evaporation data was available for the period January 1965 through December 2005.

Well Outflow

The volume of water contained in Crystal Lake and the water elevation of the lake is directly affected by the pumping of local wells around the lake. The well outflow in the water budget equation represents the loss of volume that is withdrawn from Crystal Lake by riparian residential wells users. Before the installation of the sanitary sewer system in the mid 1970s, groundwater that was withdrawn from the Crystal Lake aquifer was recycled back into the groundwater. However, with the implementation of the sanitary sewer system, groundwater that was withdrawn from the aquifer for residential use is now discharged to the Glenbeulah wastewater treatment plant. The treated wastewater is discharged ultimately to the Mullet River. Therefore, this volume is a permanent loss of groundwater.

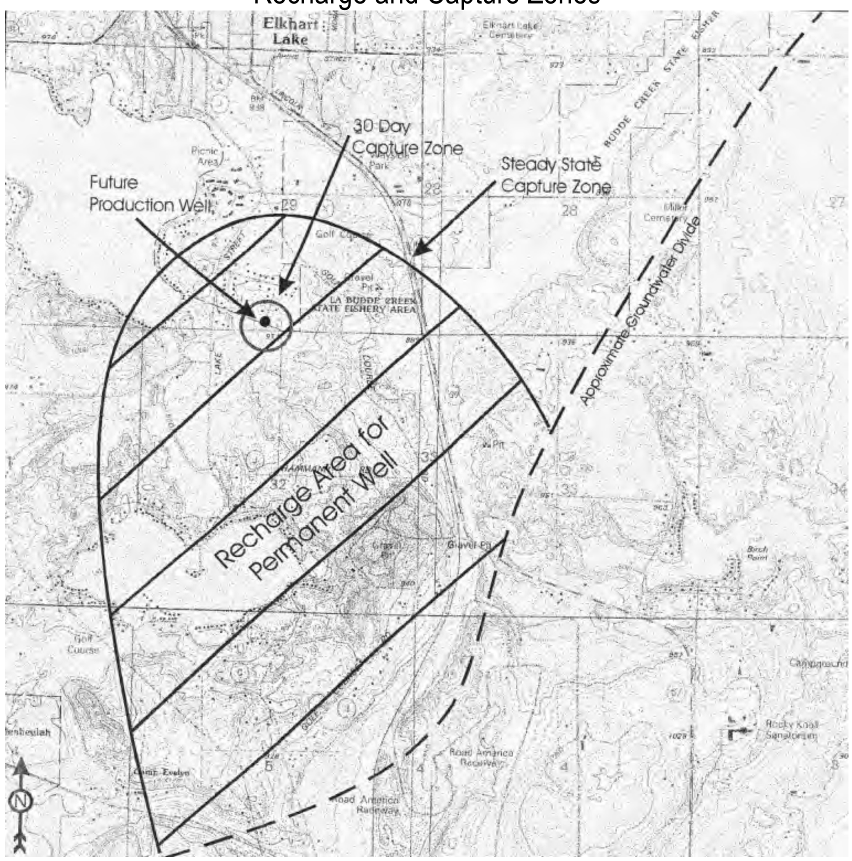
From the time that the sanitary sewer was installed in mid-1970s until average daily flows for Crystal Lake became available in January 1984, the volume of water withdrawn by residential users was determined using an average household water usage estimate. There are approximately 226 homes in the Crystal Lake watershed. For the purpose of this study, it was assumed that all of these homes are located in the groundwater recharge area for the lake. Of the 226 homes, it was estimated that 40 percent of the residents occupy their homes year-round, while the remaining 60 percent occupy their homes 50 percent of the year. 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 226 homes in the groundwater recharge area, approximately 44,295 gallons of water is removed from the water table per day, or 4.08 acre-feet per month of water. This value was used and applied to the budget from June 1970 until December 1983. For the months of January 1984 through September 2005, an average monthly volume was calculated based on daily average values provided by the wastewater treatment plant. The average monthly volume of groundwater outflow from January 1984 to September 2005 is 4.16 acre-feet (1.36 million gallons).

Groundwater Outflow

Groundwater outflow is considered to be a significant factor in the water budget. Typically, groundwater outflow is related to precipitation and watershed area as a percentage. Past groundwater studies indicate that the percentage relating the precipitation and watershed area to net groundwater outflow is approximately 30% (Vennie 1978). However, this is not the case for Crystal Lake. In this analysis, groundwater outflow represents a loss of groundwater that is due to additional source(s) that are suspect but remain to be fully proven. High-capacity well(s) service surrounding commercial and/or municipal users who are withdrawing significant volumes of groundwater from the aquifer that recharges Crystal Lake. The challenge lies in defining which user(s) are contributing to the continual drawdown of the lake.

Pumping records from the surrounding municipal wells are available, including Elkhart Lake Waterworks and Glenbeulah Waterworks. Elkhart Lake Waterworks has two operating wells, well #1 and #3, that have been permitted by the WDNR as high capacity wells. Based on the monthly pumpage reports submitted to the WDNR by Elkhart Lake Waterworks, well #3 began to withdraw groundwater in April 2002. This well is located approximately 3,750 feet north of Crystal Lake and its recharge area and capture zone incorporates the majority of Crystal Lake according to the report prepared for the Well Site Approval Request for the Village of Elkhart Lake conducted by Layne Water Resource Group, June 12, 1998 (see Figure 3.1). It has a total depth of 293 feet, and is also located in the sand and gravel aquifer according to WDNR Wisconsin Well Construction Reports. Before the well was put into use, it was estimated that well #3 would function as a supplement to the existing water supply, providing up to 33 million gallons per year (8.5 ac-ft/mo) to the increasing population (Layne Water Resource Group, date unknown). Based on actual pumping records, well #3 pumps an average total monthly volume of 7.1 ac-ft/mo. With the level of Crystal Lake *greatly* dependent on groundwater levels, this is a significant volume of groundwater outflow that can greatly impact the water level if there is not an equivalent volume of water recharging the aquifer. The other municipal well is at the Glenbeulah Waterworks Facility; however, the well that serves the facility is located in the deep limestone/dolomite aquifer and has a normal pumping rate of 0.62 acre-feet per day.

Figure 3.1
Elkhart Lake Well #3
Recharge and Capture Zones



Source: Layne Water Resource Group, June 12, 1998.

Numerous other commercial wells exist around Crystal Lake. Within a nine square-mile radius, six high-capacity well users exist as summarized in Table 3.1. These users include Camp Eveyln, Elkhart Lake's Road American, Crystal Lake Golf Course, Quit-Qui-Oc Golf Course, Knowles Manufacturing, and Crystal Lake Crushed Stone (WDNR, 2006). However prior to 2007, these private users of groundwater were not required to submit pumping records to the WDNR (with the likelihood that there will not be quality data available for many years to come according to the WDNR Bureau of Drinking Water & Groundwater). Therefore, the only data available for the wells at the present time includes the approved capacity, the normal pumping rate, the maximum pumping rate, general well information and geology information, the date that the well was approved by WDNR, and the completed construction date. In some instances, even this information is unavailable. However, it can be determined from the WDNR Wisconsin Well Construction Reports that two of the wells serving Camp Evelyn are located in the sand and gravel aquifer.

Due to the unknown variables of the commercial wells, these wells were also excluded from the water budget as a known groundwater outflow source. Without detailed groundwater mapping and aquifer information, exact location of the well, comprehensive pumping records, and other key information about the well, the variable of groundwater outflow remains an unknown in the water budget and can only be estimated from a mass balance of know inflow and outflows and change in lake stage (storage).

Storage

Storage volume in Crystal Lake is controlled by the shape of the lake basin and precipitation. During wet conditions, the lake level may rise due to precipitation, stormwater runoff, and groundwater inflow. During dry conditions, the lake level may drop due to evaporation and groundwater losses. Since 2002, concerned riparian owners and surrounding residents have witnessed the later, as the elevation of the lake continually declines over time.

Although lake level information on Crystal Lake is limited, some lake level information is available through the WDNR self-help lake monitoring program. Water level observations were made from April 1986 through October 2005 by several volunteers, while lake depth readings were also collected from 1990 through 2003 by a riparian resident. However, both sources of record lack datum information. Therefore, the known stage of 931.69 (Composite Surveying and Mapping, Sept. 14, 2004) (Appendix B) in September 2004 was used to convert each measurement to an estimated lake elevation at different periods in time (Appendix A).

Due to multiple unknown variables in this analysis, storage prior to April 1986 cannot be calculated until more definite groundwater outflow data is obtained.

Global Warming

Global Warming is an additional factor that may influence the water level of Crystal Lake that was not accounted for in the water budget calculation. It was not included due to the complexity and the difficulty of quantifying its impact lake levels.

Current science has proven that global warming is a “real” problem with “real” consequences. The increase in greenhouse gases such as water vapor, carbon dioxide, and methane has directly impacted the global climate, affecting the earth’s temperatures, aridity, precipitation, and the environment--to list a few. However, predicting how much the future temperature will change and what impact the climatic change will have on water levels is still questionable and difficult to define. The Environmental Protection Agency predicts that the water resources of Wisconsin will be affected. Specifically, “evaporation from streams and lakes is likely to increase with a warmer climate *resulting* in lower river flow and lower lake levels, particularly in summer”. Additionally, “if streamflow and lake levels drop, groundwater also could be reduced….which could harm the health of Wisconsin’s lakes and streams” (EPA, 1999). Thus, global warming could be another parameter contributing to the declining water level of Crystal Lake, but one that cannot be quantified in the water budget.

Table 3.1
High Capacity Well Summary Within a 9-square mile Radius of Crystal Lake

High Capacity Well Name	Well Permit #	Date Approved	Date Completed	Aquifer	Approved Capacity (gpd)	Normal Pumping Rate (gpd)	Maximum Pumping Rate (gpd)	Total Depth of Well (feet)	Pumping Water Level (feet)	Depth to Rock (feet)	Notes
Camp Eveyln (Main Well #3)	3242	12/14/2000	Unknown	Sand/Gravel	54,720	15,000	54,000	165	Unknown	Unknown	Approval Date given after installation date.[2]
Camp Eveyln (Lake House #4)	3243	12/14/2000	Unknown	Sand/Gravel	14,400	1,000	14,000	109	Unknown	Unknown	Approval Date given after installation date.[2]
Camp Eveyln (Well #5 Caretaker)	3244	12/14/2000	1/31/2001	Limestone/Dolomite	28,800	2,000	29,000	201	50	99	
Camp Eveyln (Replacement for Well #6)	3245	12/14/2000	2/1/2001	Limestone/Dolomite	72,000	20,000	72,000	222	40	112	Approval Date given after installation date.[2]
Road America	1828	4/16/1996	5/31/1996	Limestone/Dolomite	93,600	15,000	94,000	560	Unknown	207	
Road America	86413	3/11/1985	4/11/1985	Limestone/Dolomite	100,800	1,000	10,000	580	320	230	
Road America	3110	4/10/2000	4/21/2000	Limestone/Dolomite	93,600	30,000	93,000	440	135	115	
Crystal Lake Golf Course	840	10/13/1992	Unknown	Unknown	360,000	70,000	90,000	Unknown	Unknown	Unknown	
Quit-Qui-Oc Golf Course	31305	11/17/1982	2/17/1983	Limestone/Dolomite	288,000	20,000	288,000	432	52	334[2]	
Quit-Qui-Oc Golf Course	3152	5/31/2000	Unknown	Unknown	432,000	288,000	430,000	Unknown	Unknown	Unknown	
Quit-Qui-Oc Golf Course	3266	1/29/2001	3/14/2001	Limestone/Dolomite	99,360	33,000	99,000	380	Unknown	49	
Elkhart Lake Village Utility Well #1	86466	11/18/1935	Unknown	Limestone/Dolomite	979,200	192,000	979,000	526	159	235	
Elkhart Lake Village Utility Well #2	86467	10/19/1955	Unknown	Limestone/Dolomite	576,000	170,000	576,000	525	110.2	217	Filled/ Permanently Abandoned[2]
Elkhart Lake Village Utility Well #3	2331	5/10/1999	11/10/1999	Sand/Gravel	Unknown	Unknown	2,160,000[1] (design capacity)	293	118	Unknown	
Village of Glenbeulah Utility	86468	Unknown	Unknown	Limestone/Dolomite	403,200	202,000	404,000	430	100	130	
Knowles Manufacturing	86412	8/24/1984	Unknown	Limestone/Dolomite	432,000	1,000	1,000	428	Unknown	129	Inactive but not abandoned[2]
Crystal Lake Crushed Stone[1]	1576	4/5/1995		Sandy Shale/St. Peter				1125		150	

Source: Unless otherwise noted :WDNR Bureau of Drinking Water & Groundwater, *Water Well Data for Wisconsin Well Construction Reports*, January 2006.
[1]Per conversation with Kevin Shurilla of the WDNR.
[2]Sanitary District No. 1 Towns of Rhine and Plymouth, February 15, 2007.

Water Budget Results

The following discussion presents the results of the water budget analysis. As stated previously, the lake water surface elevations were calculated from April 1986 through October 2005.

A date versus lake elevation plot is shown on Figure 3.2 for the period April 1986 through October 2005. Also included on the plot is a trend line that demonstrates the overall trend of the lake level over the past two decades.

Figure 3.2
Crystal Lake Water Level from
April 1986 to October 2005

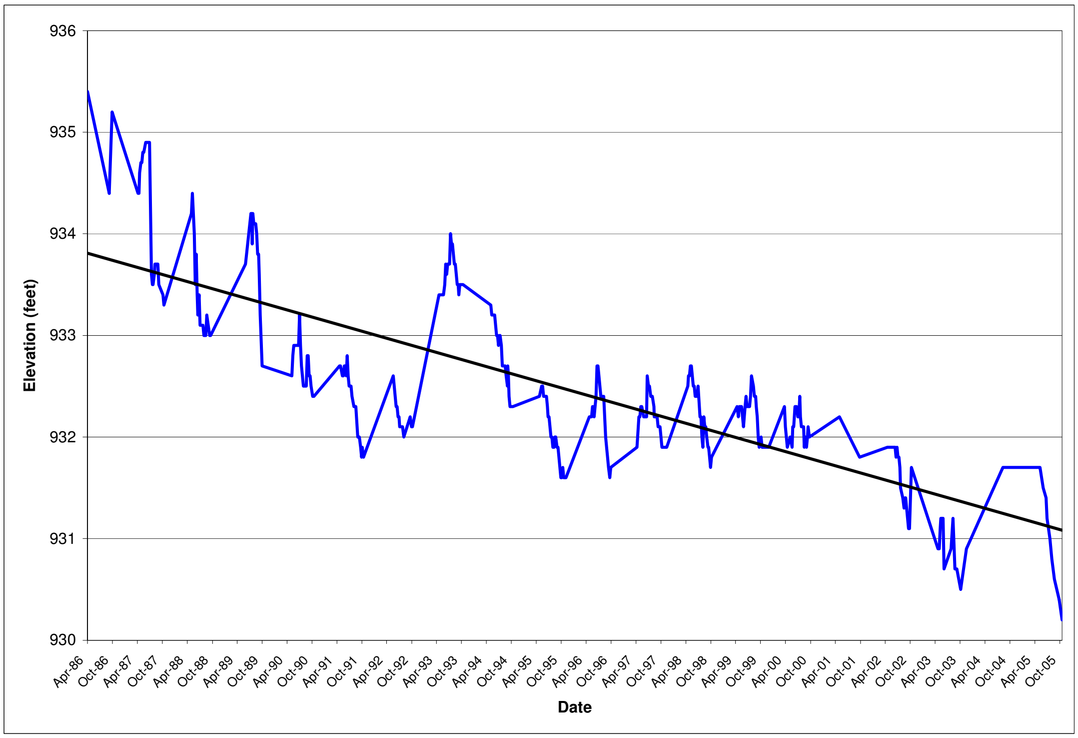


Figure 3.2 confirms riparian land owners and surrounding residents concern over the years that the water level of Crystal Lake is continually declining over time. During the study period lake levels have dropped between two to five feet, depending on the datum used. More specifically, the lake has lost between 230 and 590 acre-feet of water between the spring of 1986 and fall of 2005.

The following Figures 3.3 through 3.6 illustrate the historical trends of the known parameters of precipitation, surface runoff and groundwater inflow, evaporation, and residential well usage. In order to determine if there was a change in these parameters over time, a comparison of the minimum, maximum, mean, and standard deviation were plotted for two periods of time: 1) for the years of 1966 to 1986, in which lake level was not monitored, and 2) for the years of 1986 to 2005, in which lake level data is available. If the box plots are similar for the two periods examined, it can be concluded that the parameter has not changed significantly over time and; therefore, is not the reason for the decline in lake level.

Figure 3.3
Crystal Lake Precipitation

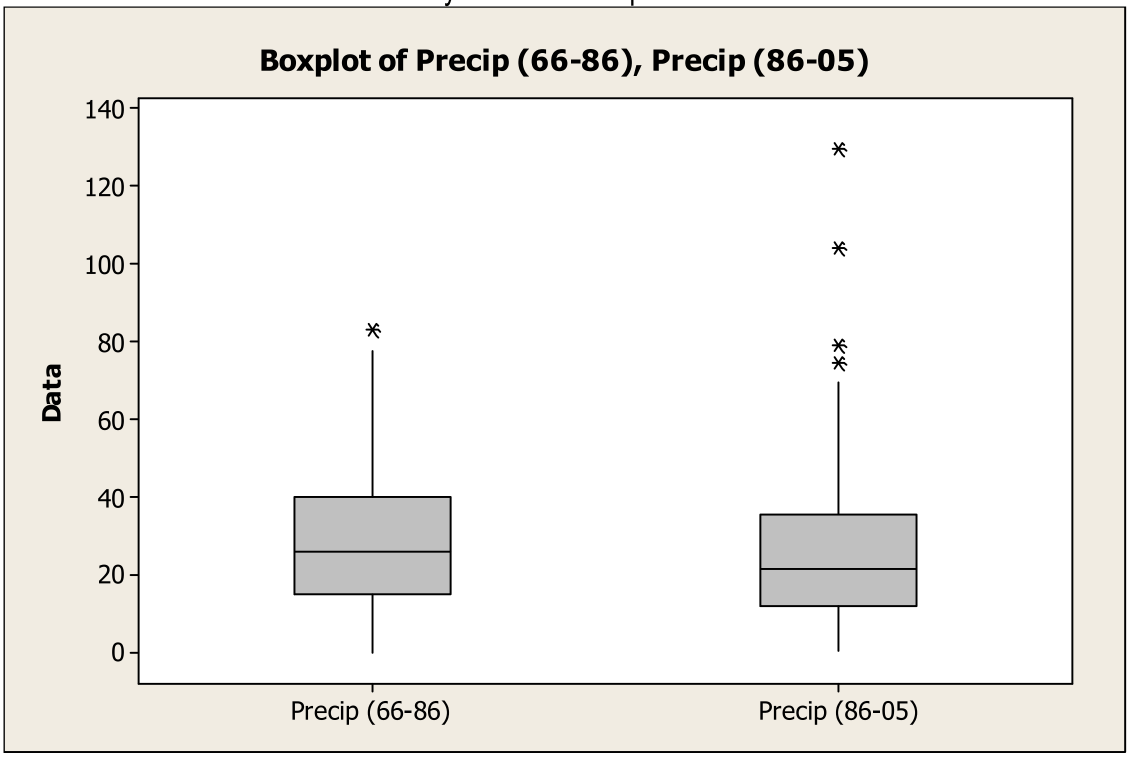


Figure 3.4
Crystal Lake Surface Runoff and Groundwater Inflow

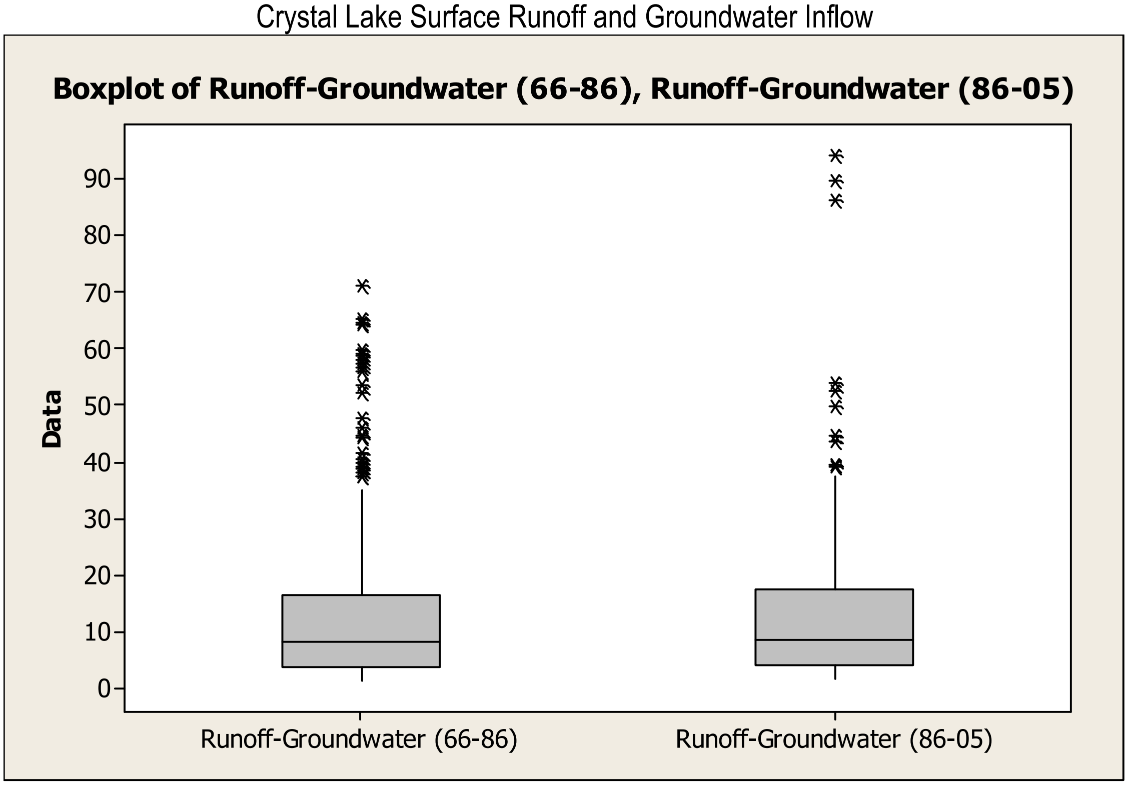
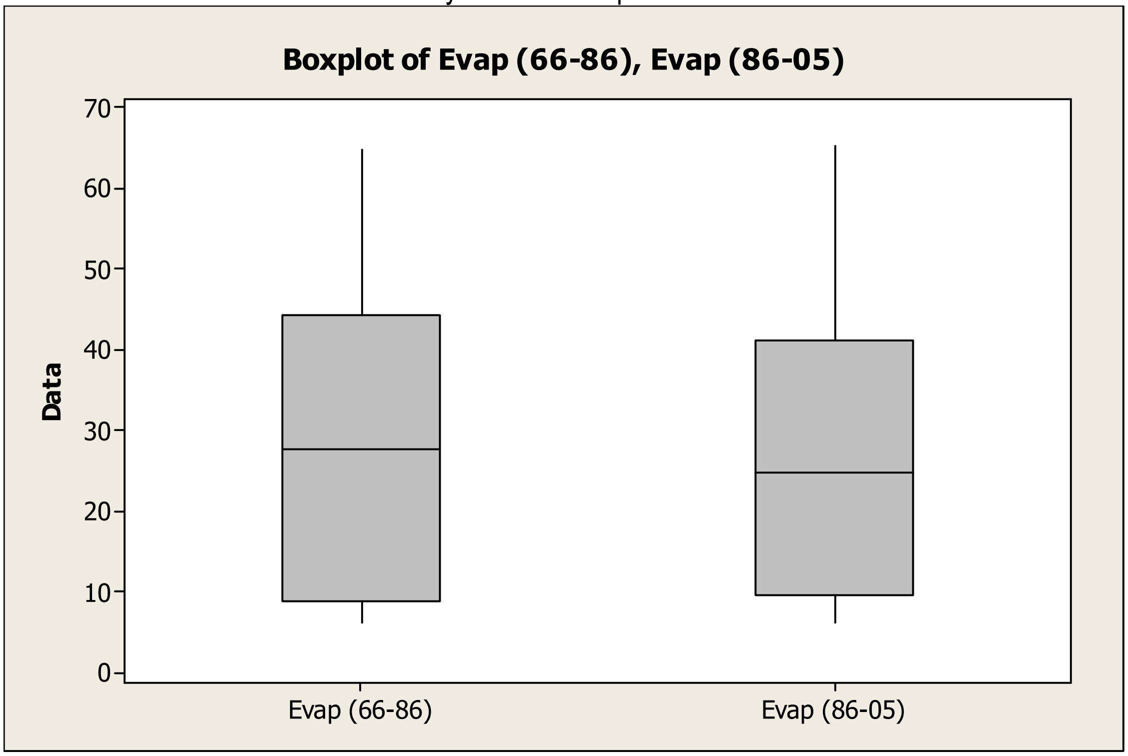


Figure 3.5
Crystal Lake Evaporation



Figures 3.3 through 3.5 prove that precipitation, surface runoff, groundwater inflow, and evaporation have not changed between the periods of 1966-1986 and 1986-2005

In the mid 1970s a sanitary sewer was installed around Crystal Lake to deal with malfunctioning septic systems. While this sewer eliminated a potentially serious source of groundwater and lake pollution, the sewer also became a pathway to export water out of the Crystal Lake watershed. Groundwater pumped by private wells prior to the sewer installation was returned to the groundwater through the septic system. Today this groundwater is exported away from the lake by the sewer and is discharged downstream of the lake near the Village of Glenbeulah. Monitoring of monthly sewer flow from 1984 through the present indicates that the sewer on average discharges 4 acre-feet of water per month out of the Crystal Lake Watershed (Figure 3.6). While this amount appears relatively small, it is enough to result in a long-term loss of water from the lake watershed.

Figure 3.7 illustrates a comparison of the average lake inflow and outflows for the periods of 1966 through 1975 prior to the installation of the sanitary sewer, and periods of 1975 through 2005 following the sewer installation. Precipitation, evaporation and runoff are based on locally measured data. Net groundwater outflow was based on a mass balance of known inflows and outflows. A major change between these two periods of time is the loss of 4 acre-feet per month of flow to the sanitary sewer. The increase in lake outflow results in a negative change in lake storage of approximately 1.98 acre-feet per month. This change in lake storage in recent years is the cause of declining lake levels.

Figure 3.6
Monthly Sanitary Sewer Flow from Crystal Lake Watershed

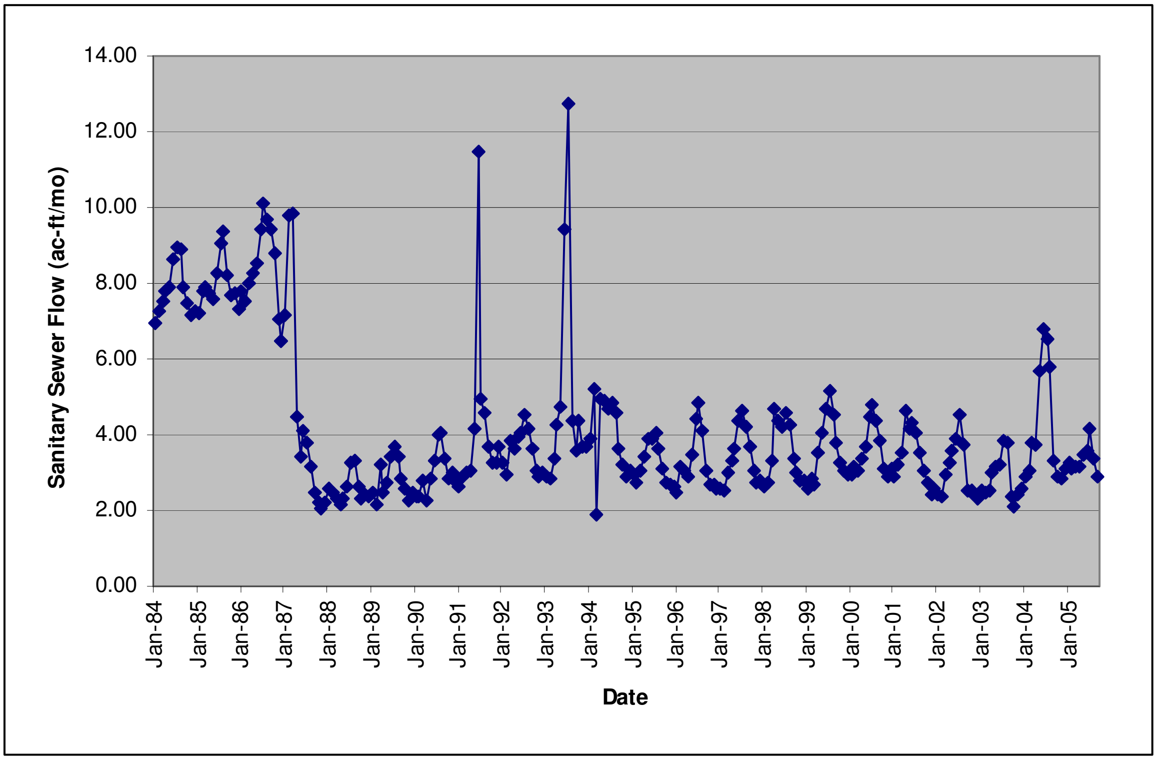
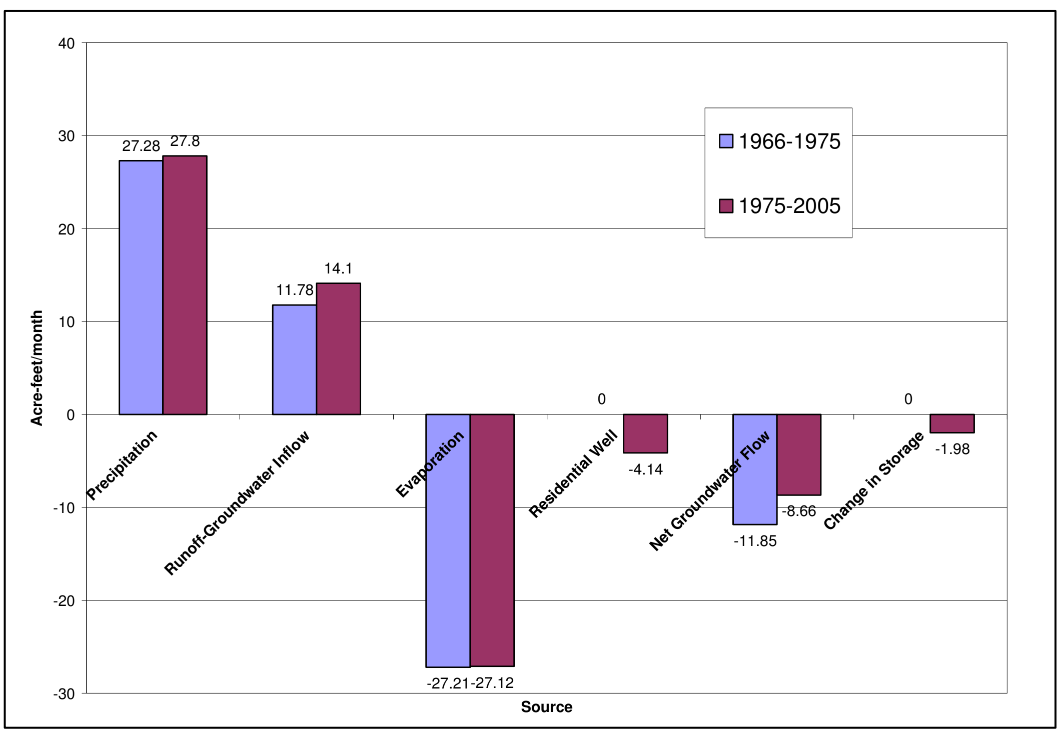
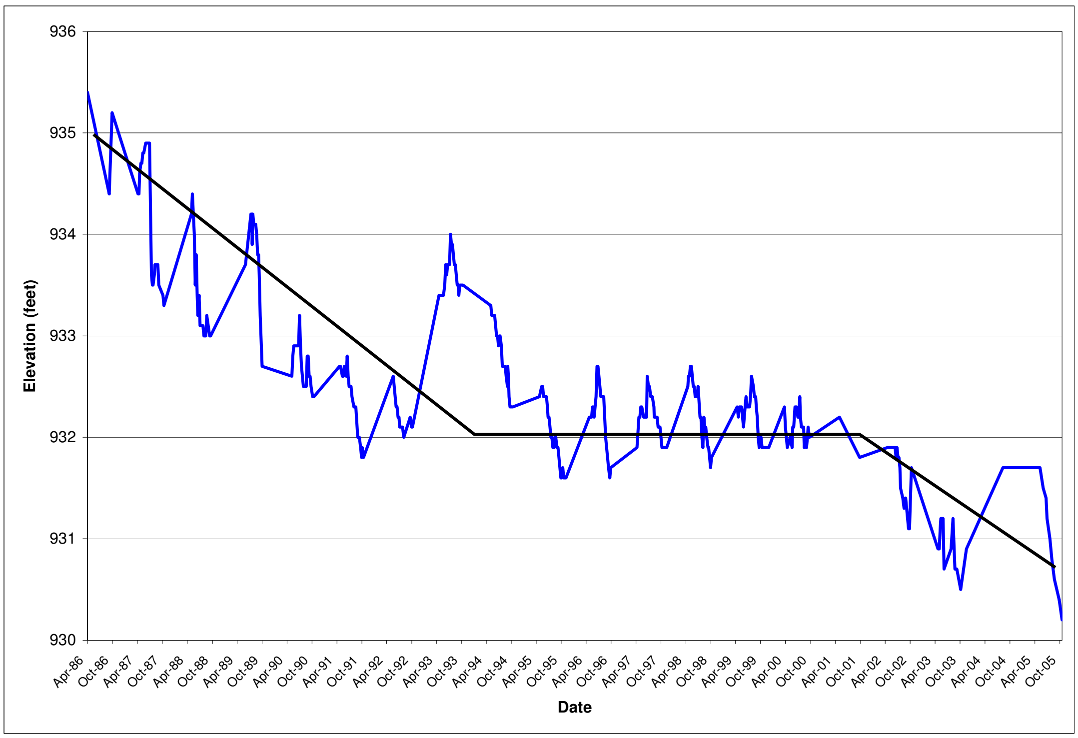


Figure 3.7
Average Monthly Inflow and Outflow for Crystal Lake
Before and After Installation of the Local Sanitary Sewer



Loss of water through the discharge of groundwater to the sanitary sewer system by residential well use may not be the only source of the declining water levels in Crystal Lake. If we look closer at Figure 3.2 we see there are actually three periods of recent lake level decline within the period of record as highlighted in Figure 3.8. From 1986 to 1994 we see a decline that is likely predominantly due to the sanitary sewer discharge. From 1994 to early 2002 the drop in lake level flattens out, and a second drop again begins in 2002 through the present.

Figure 3.8
Crystal Lake Water Level from
September 1986 to September 2005



In recent years, several new high capacity wells have been installed within the groundwater drainage area of Crystal Lake. Within a nine square-mile radius, six high-capacity well users exist. These users include Camp Eveyln, Elkhart Lake's Road American, Crystal Lake Golf Course, Quit-Qui-Oc Golf Course, Knowles Manufacturing, and Crystal Lake Crushed Stone (WDNR, 2006). The wells of particular interest are those that have been installed above the shale bed rock layer or within the sand and gravel aquifer occupied by Crystal Lake, and whose installation dates correspond to the recent changes in lake elevation. Figure 3.9 illustrates the depth and pumping capacity for the two wells located at Camp Eveyln and the Village of Elkhart Lake Well #3, located just north of Crystal Lake, the only wells with available data. The dates of these well installations are illustrated on Figure 3.10. A study by Layne-Northwest on the Village of Elkhart Lake's Well #3 indicates that Crystal Lake is within the recharge and capture zone of this municipal well. The installation of these new high capacity wells in 2002 may be a partial cause of the second decline in lake level shown in Figure 3.8.

Figure 3.9
Depth of Crystal and Elkhart Lakes Compared to
Four High Capacity Wells Located Near the Lakes with Known Depth Information

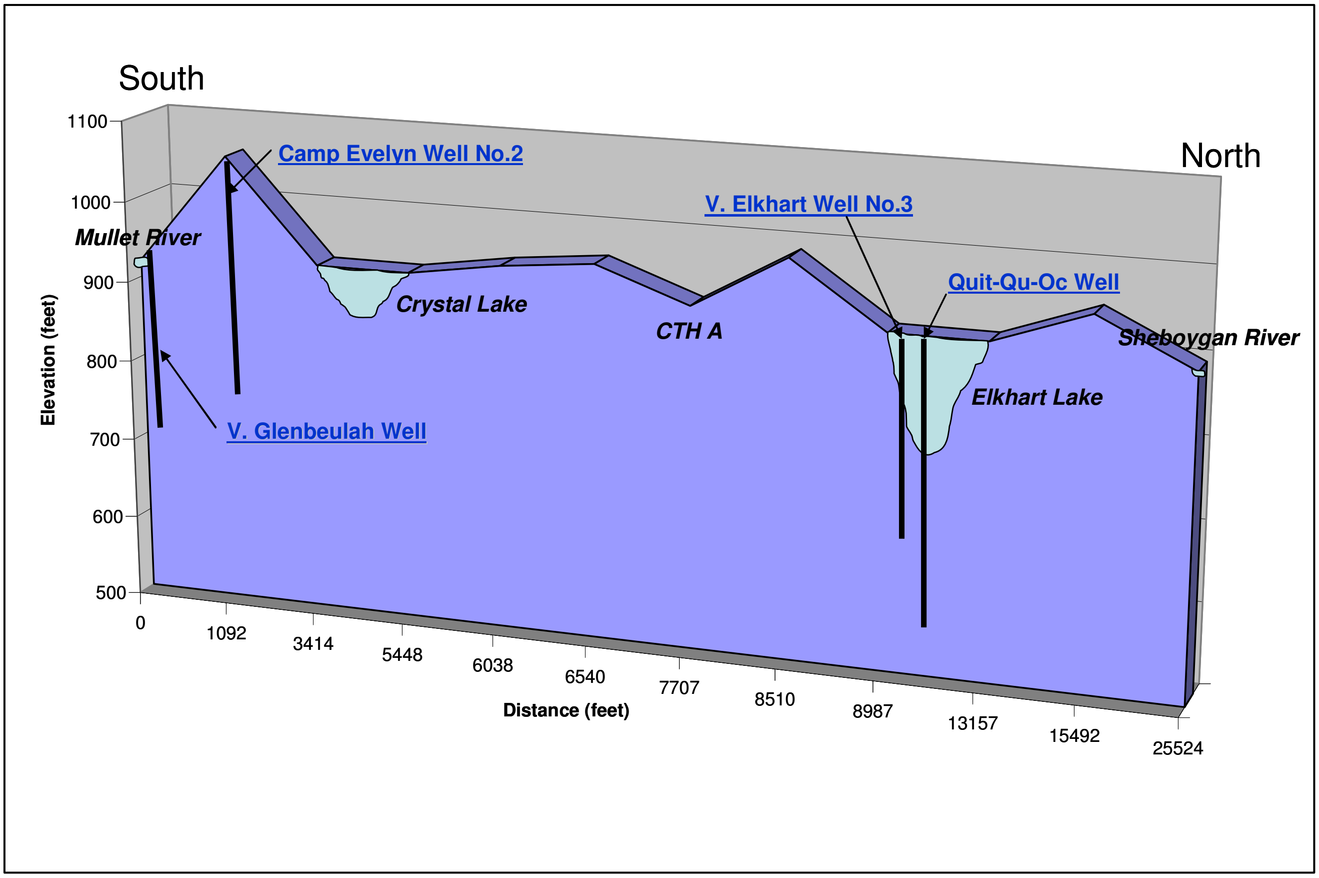
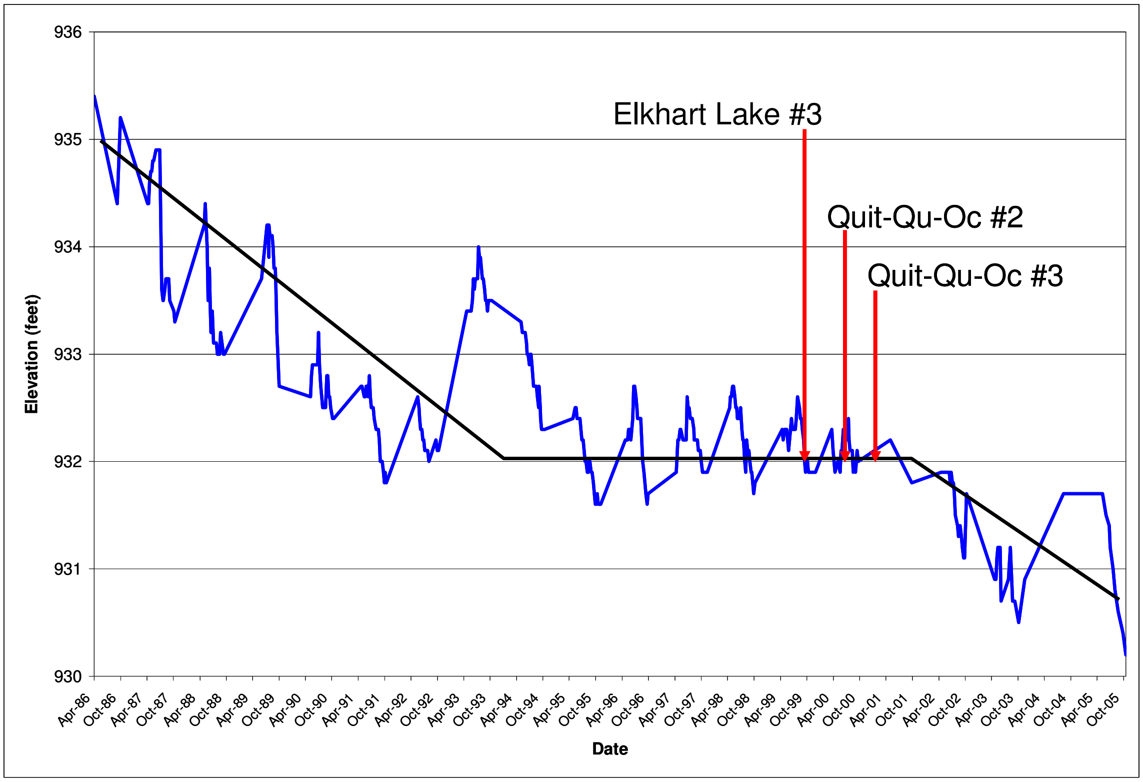


Figure 3.10
Relationship of Date of High Capacity Well Installation
To Changes in Crystal Lake Level



Conclusion

Crystal Lake is experiencing a continual decline in lake level. This decline is not attributed to any changes in precipitation, surface runoff, groundwater inflow, or lake surface evaporation. On a long-term basis the lake is losing approximately 1.98 acre-feet per month of lake storage. Part of the long-term loss is due to the installation of the sanitary sewer system around the lake that now exports water from the lake watershed which once was returned through septic systems. The declining lake levels may also be influenced by the installation of high capacity wells that are located within the lake's groundwater recharge area. Unfortunately, limited information is available about the groundwater aquifer in which Crystal Lake resides and high capacity well uses to answer what impact high capacity wells are having at this time. What can be concluded is that without a reduction in water export or artificial increase in water import, Crystal Lake water elevations will not naturally return to normal levels and may continue to decline.

CHAPTER 4 – WATER LEVEL MANAGEMENT ALTERNATIVES

Introduction

The focus of this study was to address the current problem of managing Crystal Lake during periods of low water level. The Sanitary District, surrounding riparian owners, and other users of the lake have increasing concerns regarding the continual decrease in water level that has plagued the lake over recent years. As outlined in Chapter 3, the lake has dropped to the lowest level seen during the twenty-year period lake level data is avialable (Figure 3.1). During recent years, the lake bottom has been completely exposed for extended periods of time, extending out as much as 50 to 100 feet from the shoreline (Figure 4.1). These periods of low water level on Crystal Lake have made it difficult for lake residents to get their boats to open water and have hampered recreational use due to shallow water depths. Many are also concerned about the impact on the aquatic vegetation and fish community and the water quality and temperature due to the decrease in lake level.

As outlined in Chapter 3, the decline in lake levels is not the results of natural weather fluctuations and is likely due to the artificial export of water through the sanitary sewer system and potentially high capacity wells in the area. Without a reduction in water export or artificial increase in water import, Crystal Lake water elevations will not naturally return to normal levels and may continue to decline.

Figure 4.1
Exposed Lake Bottom on the Northwest Shore during Period of Low Water Level during the fall, 2005


Source: Sanitary District No. 1 Towns of Rhine and Plymouth, 2005.

Water level management alternatives for Crystal Lake fall into there categories:

1. Alternatives to adjust to lower lake levels
2. Reductions in water exports
3. Increases in water imports

Alternatives to Adjust to Lower Lake Levels

Under this set of alternatives residents of Crystal Lake would adjust property conditions to live with permanently lower lake levels. To utilize the lake at its present and potentially lower lake level, piers, shore station, and boat houses, which have existed for decades, would have to be moved to accommodate the new shoreline. The new shoreline which is recently exposed, may over periods of time begin to erode under natural wave and ice movement, requiring new shore protection to be installed at the new shoreline location. The cost of these shoreline adjustments would run in the millions of dollars.

Moving the shoreline of to a new location further from shore may be physically possible, by doing so legally under Wisconsin Law may be difficult. Under the "Doctrine of Riparian Rights" riparian landowners of natural lakes only own property to the "Ordinary High Water Mark" (OHWM) (*Wisconsin Envtl. Decade v. Public Service Commission, 69 Wis. 2d 1, 230 N.W.2d 243(1975)*). The bed of natural lakes in Wisconsin is owned by the general public. The OHWM defines the natural boundary between private land and public waters. The OHWM is an erosion line, vegetation transition line or water line on structures that defines the elevation of a lake's long-term average lake level. Since Crystal Lake's is in a period of transition, there is a serious legal question; "What is the OHWM?" Under Wisconsin law, riparian owners can move their piers and shore stations onto lake beds to accommodate access to open water during periods of low lake levels; however, placement of shore protection or other permanent structures below the OHWM requires permission from the state. Some structures can be allowed through permits from the Wisconsin Department of Natural Resources, other require permission of the state legislature.

Under the alternative of living with lower lake levels, Crystal Lake would have less shallow littoral zone. This shallow littoral zone, which is the flat shelf along the lake shore, is where most fish, aquatic plants and other aquatic life reside. With less littoral area, the fishery of Crystal Lake may be altered, shifting from a community dominated by littoral zone species such as pan fish and bass to one dominated more by deep open water species such as crappie. The impacts of these changes on the ecology and water quality of the lake are unknown.

Living with permanently lower lake levels does not appear to be a feasible alternative for an established lake community with millions of dollars in property improvements and a lake ecosystem that has been in balance for thousands of years. This alternative is felt to be unfeasible for the given situation.

Reductions in Water Exports

As outlined in Chapter 3, at present, Crystal Lake water outputs exceed water inputs resulting in continued lowering of lake levels. Chapter 3 outlines that water inputs through rainfall, runoff and groundwater inflow have generally remained the same over the past 40 years of available records. What has changed at Crystal Lake is that exports have increased.

The installation of the sanitary sewer presently exports an average of 4 acre-feet per month of water used by residential homes, which once returned this water to the lake through septic systems. Unfortunately in the past, water that was discharged through septic systems was likely contaminated with nutrients, bacteria and household pollutants. Crystal Lake sits in a glacial deposit of pure sand and gravel, which provides a poor media for properly operating septic systems. Many homes on Crystal Lake are located on lots too small for conventional septic systems to be constructed. Elimination of the sanitary sewer system and a return to traditional onsite treatment systems of the past would likely result in increased contamination of the groundwater, lake recharge water and drinking water of the Crystal Lake area.

Also outlined in Chapter 3, is the question as to whether or not the installation of several high capacity wells in the Crystal Lake recharge area may be also effecting water levels. Further studies would be needed to determine the impacts of these wells. One well in question is the Village of Elkhart Municipal Well #3. This well serves a municipal water system, moving this well to a new location or deeper aquifer to reduce potential impacts to Crystal Lake would not be an easy or inexpensive operation. Elimination of high capacity wells from the Crystal Lake groundwater recharge area should be explored as a part of a multi-pronged program to correct lake level problems; however, without further analysis, this is likely not a feasible short-term solution.

Increases in Water Imports

Today water exports exceed water inputs to Crystal Lake resulting in continuing declining lake levels. One alternative to changing this water in-balance is to artificially increase water inputs. Increasing water inputs to the lake watershed could be accomplished through several means including, but not limited to:

1. Returning treated wastewater to the lake watershed.
2. Pumping water from the shallow aquifers near the Mullet River that now receive treated Crystal Lake wastewater.
3. Installation of a recharge well.

These days, residential water used by Crystal Lake residents is piped through a sanitary sewer system to a treatment plant near the Village of Glenbeulah. The water is treated in a state-of-the-art treatment and discharged in a series of infiltration seepage cells that feeds springs along the Mullet River. The water does not return to the Crystal Lake recharge area and, in effect, is exported downstream to the Mullet River. One alternative that has been used in other areas of the country is to return reclaimed wastewater back to the recharge zone where it was taken and infiltrate this water through the use of infiltration cells or spray irrigation. To return water from the treatment plant to the lake recharge area would require construction of a pumping station and approximately 2,500 feet of pipeline.

As outlined above, these days Crystal Lake's residentially-used water is piped, treated and discharged into a series of seepage cells that artificially feed springs along the Mullet River. Now, because of the wastewater treatment plant in Glenbeulah, the Mullet River carries a much higher base flow than historically. Returning a portion of the artificially-increased base flow from the Mullet River to Crystal Lake could resolve lake level problems. Only 1.25 acre-feet per month, on average, would be required to eliminate the current lake deficit. This amounts to less than 0.03 cfs of flow from the Mullet River.

The Mullet River is a coldwater trout stream that relies on a constant cold water base flow to maintain its balanced fishery. The Wisconsin Department of Natural Resources has raised concerns that any removal of water from the Mullet River could impact the coldwater fishery. However, in May 1993 the U.S. Geological Survey measured a base flow in the Mullet River near Plymouth at 7.86 cfs (USGS, 1996). The amount of water needed to maintain Crystal Lake's water levels is less that a 0.4% of the river's base flow. The removal this small amount of water from the river would likely have little or no measurable impact to the existing fishery. Guidelines could be put in place to limit pumping only during periods of adequate base flow to protect the fishery. To implement this alternative, a shallow well would need to be installed in the sand and gravel near the river, and a pipeline and pumping station installed.

The last alternative for artificially increasing water inputs to Crystal Lake would be the installation of a recharge well. As outlined in Chapter 3, the mean average deficit of water per month is about 1.25 acre-feet. A well that could produce a few hundred gallons per minute could easily make-up for the current water deficit and help maintain water levels. A larger supply that could allow some flushing of the lake would help maintain high water quality and prevent stagnant conditions. To size a proper well, an analysis of pump sizes and on/off cycling times would be needed to determine the most cost-effective option from an operation and energy consumption standpoint.

The alternative of constructing a recharge well has been explored by the District in the recent past to maintain water levels by pumping water from a deep aquifer. However, the WDNR denied the permit application because the proposed site did not meet the minimum distance requirement to the Mullet River, a local trout stream. Crystal Lake sits on top of a groundwater recharge area that also feeds several important groundwater nourished resources, including several wetlands, Big Elkhart Lake and the Mullet River. Placement of a new well in the recharge area of all these important resources would need to be done with care. However, it needs to be kept in mind that as the levels of Crystal Lake drop, so does the groundwater export from the lake. Downstream resources that are fed by Crystal Lake are also likely being impacted by the change in lake levels. Imports of water to Crystal Lake would also help recharge other locally connected groundwater resources.

Conclusion

As discussed above, the decline in lake levels at Crystal Lake is not the result of natural weather fluctuations and is likely due to the artificial export of water through the sanitary sewer system and potentially high capacity wells in the area. Without a reduction in water export or artificial increase in water import, Crystal Lake water elevations will not naturally return to normal levels and may continue to decline.

Living with the new lower lake levels by reconfiguring the development along the shoreline is not a feasible option as it disrupts millions of dollars in existing property improvements and may cause long-term impacts to the ecology of the lake. While efforts should be made to reduce exports of water from the watershed through water conservation by home owners, it is likely that this effort will not produce any short-term solutions and should be considered only as a component of a long-range strategy.

To return Crystal Lake levels to normal condition in the near future, the only feasible alternative at this time is to artificially increase water inputs to the lake through return of treated wastewater to the lake watershed by either pumping from the Mullet River, or installing a recharge well. Without a detailed cost analysis, installing a recharge well is likely the most cost-effective alternative.

Siting of the well to minimize potential impacts to other resources will require a more detailed understanding and analysis of the local groundwater system in the area. At the moment, little information on the local groundwater system is available. The following chapter will outline recommendations to acquire better information on the local groundwater system.

CHAPTER 5 – RECOMMENDATIONS

As discussed in the previous analysis, the decline in lake levels at Crystal Lake is not the result of natural weather fluctuations and is likely due to the artificial export of water through the sanitary sewer system and potentially high capacity wells in the area. Without a reduction in water export or artificial increase in water import, Crystal Lake water elevations will not naturally return to normal levels and may continue to decline. With low lake levels, the recreation use opportunities on the lake are hampered and negative impacts to the lake ecology are possible.

The causes of the lake level decline at Crystal Lake appear to be man-made and are the result of too many users of a limited groundwater resource that maintains the lake. The restoration of lake levels at Crystal Lake is going to take a several-pronged, long-term strategy to manage the limited groundwater resources in the area. The multi-pronged approach will require:

1. A better understanding of the groundwater system that feeds Crystal Lake, Big Elkhart Lake, and the Mullet and Sheboygan Rivers.
2. A reduction in water withdraws from the local aquifer and tighter controls on future withdraws.
3. Artificial recharge of groundwater losses that are already in place and cannot be controlled.

Better Understanding of Local Groundwater System

To develop a long-term management strategy for groundwater resources in the Crystal Lake area is going to require a better understanding of the local groundwater system. Today the information on the local groundwater system is limited. The following is an outline of the steps that are required to develop a better understanding of the groundwater system and their potential costs:

1. Develop a detailed map of the local aquifer, including geologic layers, water transmitting capacities, and water tables.

   In 2004 the University of Wisconsin-Oshkosh produced a map of the groundwater table in northeastern Sheboygan County for the Elkhart Lake Improvement Association (Figure 2.2). The map was produced from available well logs of private wells obtained from the Wisconsin Geological and Natural History Survey (WGNHS). The logs include information on depth to groundwater. Few logs include the elevation of the ground surface or water table. To determine water level from the depth to water table information provided in the well logs, the elevation of each well was determined from USGS topographical maps which have 10-foot contour intervals and an accuracy of ± 5 feet. To stay within the degree of accuracy of the available data, the water table contours were mapped at a 20-foot contour. Due to the steep topography on the study area, 20-foot contours provide inadequate data for a detailed groundwater analysis.

   Today Sheboygan County Planning Department has 2-foot contour maps available for the Crystal Lake area. Use of the new topographic maps combined with better location data on local well locations could be used in combination with the WGNHS well logs to produce a three-dimensional map of the shallow groundwater system in northeastern Sheboygan County. The cost of this mapping effort is estimated at $7,000.

2. Produce a three-dimensional groundwater model for the Crystal Lake area that would allow evaluation of various management alternatives.

   Using the data from the above groundwater table, mapping a computer model of the local aquifer system could be developed. The model could be used to identify the potential benefits and negative impacts of various management alternatives. The model could be used to identify the potential impacts of local high capacity wells and, if their use was modified, what impacts it could have on Crystal Lake's levels. The model could be used to identify potential locations for a recharge well. With adequate calibration, the model could evaluate impacts of management changes to Crystal Lake as well as Big Elkhart Lake and the Mullet and Sheboygan Rivers. Estimated cost for preparation and calibration of an adequate groundwater model to evaluate management strategies for the Crystal Lake area is $25,000 to $30,000.

3. As part of the calibration of any groundwater model, calibration data is needed. To gather adequate calibration data, the following monitoring programs should be started:

   (a) Install monitoring wells within the watershed in order to define the subsoils, determine the subsoil hydraulic conductivity, and to quantify the groundwater levels. The mapping outlined in Item 1 above should be used to determine the number and location of the needed monitoring wells. Assuming the installation of 4 monitoring wells, their cost would be approximately $3,500 to $5,000.

   (b) Install a series of electronic staff gauges to monitor the fluctuation of the lake and stream elevations in the area over time. The data logger can be programmed to automatically collect stage readings on daily time interval and stored until the data is downloaded. The gauge readings can then be converted into an elevation based on an established USGS bench mark. To provide adequate data to calibrate a regional groundwater model, gauges should be installed at Crystal Lake, Big Elkhart Lake, the Mullet River and Sheboygan Marsh. Cost of installing four gauges, including equipment, installation and surveying would be approximately $4,600.

Control of Groundwater Withdraws Within the Crystal Lake Watershed

Efforts should be made to minimize unnecessary and potentially harmful groundwater withdraws from the Crystal Lake recharge area. The above analysis indicates that Crystal Lake water levels are in a delicate balance with inflow and outflows. Even minor changes in flow rates have dramatic effects on lake levels. To protect lake levels at Crystal Lake, the following activities should take place:

1. No new high capacity well should be installed within the recharge area of Crystal Lake without a detailed analysis to document no potential negative impacts. The analysis should be conducted and certified by a Wisconsin licensed Hydrologist or Geologist.
2. Existing high capacity wells within the Lake's recharge area should be examined for their potential impacts to Crystal Lake elevations using the aquifer model described above. If the wells are determined to have an adverse impact, an analysis should be conducted to see if an alternative source of water could be used and a strategy for modifying or eliminating the well should be implemented.

3. The smart growth plans for the Townships of Plymouth and Rhine should prohibit any large ground or surface water users, such as golf courses, vegetable growers, bottling plants, etc. that would impact local groundwater levels.
4. The groundwater recharge areas of Crystal Lake and Big Elkhart Lake are overlapping. Residents of both lake communities should consider creating a non-profit trust to purchase development and water rights within the combined groundwater recharge area.
5. Water conservation measures should be utilized whereever feasible within the Crystal Lake groundwater recharge area, including uses by residential home owners, commercial operations, recreational facilities, and agriculture. Activities such as watering large landscaped areas (for instance, golf courses) should be kept to a minimum. The following web page offers a number of tips on conserving water: http://www.wateruseitwisely.com/100ways/ne.shtml.

Artificial Recharge of Groundwater

The Crystal Lake water budget is in imbalance, with exports exceeding imports. The result has been continually decreasing water levels that will not return to normal without the intervention of man. To return Crystal Lake to normal levels, inflow levels need to be artificially increased. Chapter 4 outlines several options to increase inflow rates. At this time, the most cost-effect alternative appears to be installation of a recharge well.

Currently, the elevation of Crystal Lake is significantly below normal lake levels. Low lake levels are not only an inconvenience to lake residents, but also could affect the ecology of the lake in the long-term. At this time, installation of a recharge well should be implemented to return lake levels to a more normal range.

Conclusion

Implementation of the above recommendations is going to take the combined efforts of local, county, and state government. The water level problems at Crystal Lake are the result of too many users of a limited water supply. To implement the above recommendations a task force made up the Crystal Lake Sanitary District, Crystal Lake Property Owners Association, Townships of Plymouth and Rhine, Villages of Elkhart Lake and Glenbeulah, Sheboygan County Planning Department, and Wisconsin Department of Natural Resources should be formed. The purpose of the group will be to identify funding source for project implementation, explore cooperative opportunities, and facilitate changes in local regulations and state permitting programs.

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APPENDIX A

WATER LEVEL ELEVATIONS FOR CRYSTAL LAKE

Surface Water Elevations for Crystal Lake Wisconsin
Estimated using known elevation and WDNR Self-Help Monitoring Data

Date	Water Level Elevation
4/1/86	935.4
9/7/86	934.4
9/28/86	935.2
4/5/87	934.4
4/12/87	934.4
4/18/87	934.6
4/26/87	934.7
5/3/87	934.7
5/10/87	934.8
5/17/87	934.8
5/31/87	934.9
6/14/87	934.9
6/28/87	934.9
7/12/87	933.6
7/19/87	933.5
7/24/87	933.5
8/2/87	933.6
8/9/87	933.7
8/16/87	933.7
8/23/87	933.7
8/30/87	933.7
9/5/87	933.5
10/4/87	933.4
10/11/87	933.3
4/30/88	934.2
5/8/88	934.4
5/22/88	934.0
5/28/88	933.5
6/5/88	933.8
6/12/88	933.4
6/15/88	933.2
6/26/88	933.4
7/3/88	933.1
7/10/88	933.1
7/17/88	933.1
7/24/88	933.1
7/31/88	933.0
8/7/88	933.0
8/14/88	933.0
8/21/88	933.2
9/11/88	933.0
9/17/88	933.0
6/1/89	933.7
7/21/89	933.9
7/9/89	934.2
7/16/89	934.2
7/23/89	934.2
7/30/89	934.1
8/7/89	934.1
8/14/89	934.1
8/21/89	934.0
8/27/89	933.8

Date	Water Level Elevation
9/4/89	933.8
9/10/89	933.6
9/17/89	933.2
10/1/89	932.7
5/6/90	932.6
5/13/90	932.8
5/20/90	932.9
5/29/90	932.9
6/17/90	932.9
6/24/90	932.9
7/1/90	933.2
7/8/90	932.9
7/15/90	932.7
7/22/90	932.6
7/29/90	932.5
8/5/90	932.5
8/12/90	932.5
8/19/90	932.5
8/26/90	932.8
9/2/90	932.8
9/9/90	932.6
9/16/90	932.6
9/23/90	932.5
10/6/90	932.4
10/14/90	932.4
4/20/91	932.7
4/27/91	932.7
5/12/91	932.6
5/19/91	932.6
5/26/91	932.7
6/2/91	932.7
6/9/91	932.6
6/16/91	932.8
6/23/91	932.6
6/30/91	932.5
7/13/91	932.5
7/21/91	932.4
8/3/91	932.3
8/11/91	932.3
8/18/91	932.3
8/24/91	932.2
9/1/91	932
9/14/91	932
9/22/91	931.9
9/29/91	931.8
10/5/91	931.9
10/13/91	931.8
5/17/92	932.6
5/25/92	932.5
5/31/92	932.4
6/7/92	932.3
6/14/92	932.3

Date	Water Level Elevation
6/21/92	932.2
6/28/92	932.2
7/5/92	932.1
7/12/92	932.1
7/19/92	932.1
7/26/92	932.1
8/3/92	932.0
9/20/92	932.2
9/29/92	932.1
10/7/92	932.1
4/19/93	933.4
5/16/93	933.4
5/22/93	933.4
5/31/93	933.5
6/6/93	933.7
6/13/93	933.6
6/20/93	933.7
7/4/93	933.7
7/11/93	934.0
7/18/93	933.9
7/25/93	933.9
8/1/93	933.8
8/8/93	933.7
8/15/93	933.7
8/22/93	933.6
8/29/93	933.5
9/5/93	933.5
9/12/93	933.4
9/19/93	933.5
9/26/93	933.5
10/3/93	933.5
10/11/93	933.5
5/2/94	933.3
5/10/94	933.2
5/16/94	933.2
5/23/94	933.2
5/31/94	933.2
6/8/94	933.1
6/14/94	933.0
6/21/94	933.0
6/28/94	932.9
7/5/94	933.0
7/10/94	933.0
7/18/94	932.9
7/27/94	932.7
8/16/94	932.7
8/23/94	932.6
9/1/94	932.5
9/3/94	932.7
9/8/94	932.6
9/11/94	932.5
9/14/94	932.4
9/21/94	932.3
9/29/94	932.3
10/5/94	932.3
10/12/94	932.3

Date	Water Level Elevation
4/25/95	932.4
5/11/95	932.5
5/18/95	932.5
5/25/95	932.4
6/1/95	932.4
6/8/95	932.4
6/13/95	932.4
6/20/95	932.3
6/27/95	932.2
7/5/95	932.2
7/12/95	932.1
7/18/95	932
7/26/95	932
8/2/95	931.9
8/10/95	931.9
8/15/95	932
8/22/95	932
8/30/95	931.9
9/7/95	931.9
9/14/95	931.8
9/20/95	931.7
9/27/95	931.6
10/4/95	931.6
10/12/95	931.7
10/18/95	931.6
10/25/95	931.6
11/6/95	931.6
4/23/96	932.2
5/2/96	932.2
5/9/96	932.2
5/16/96	932.3
5/23/96	932.3
5/30/96	932.2
6/6/96	932.3
6/13/96	932.4
6/19/96	932.7
6/27/96	932.7
7/4/96	932.6
7/11/96	932.5
7/17/96	932.4
7/25/96	932.4
7/31/96	932.4
8/8/96	932.4
8/15/96	932.2
8/21/96	932
8/29/96	931.9
9/5/96	931.8
9/12/96	931.7
9/20/96	931.6
9/27/96	931.7
4/9/97	931.9
4/22/97	932.2
4/29/97	932.2
5/6/97	932.3
5/12/97	932.3
5/27/97	932.2

Date	Water Level Elevation
6/2/97	932.2
6/10/97	932.2
6/17/97	932.2
6/23/97	932.6
7/1/97	932.5
7/8/97	932.5
7/16/97	932.4
7/23/97	932.4
7/30/97	932.4
8/9/97	932.3
8/13/97	932.2
8/27/97	932.2
9/3/97	932.2
9/10/97	932.1
9/17/97	932.1
9/24/97	932.1
10/1/97	932.0
10/8/97	931.9
10/22/97	931.9
10/29/97	931.9
11/5/97	931.9
11/12/97	931.9
4/14/98	932.5
4/20/98	932.6
4/27/98	932.6
5/4/98	932.7
5/11/98	932.7
5/19/98	932.6
5/26/98	932.5
6/2/98	932.5
6/8/98	932.4
6/15/98	932.4
6/23/98	932.4
6/30/98	932.5
7/8/98	932.3
7/14/98	932.2
7/20/98	932.2
7/28/98	932.0
8/4/98	931.9
8/11/98	932.2
8/18/98	932.1
8/25/98	932.1
9/1/98	932.0
9/9/98	931.9
9/15/98	931.9
9/22/98	931.8
9/29/98	931.7
10/7/98	931.8
4/12/99	932.3
4/21/99	932.2
4/29/99	932.3
5/7/99	932.3
5/14/99	932.3
5/21/99	932.2
5/28/99	932.1
6/8/99	932.3

Date	Water Level Elevation
6/15/99	932.4
6/22/99	932.3
6/29/99	932.3
7/6/99	932.3
7/13/99	932.3
7/20/99	932.4
7/27/99	932.6
8/10/99	932.5
8/17/99	932.4
8/24/99	932.4
8/25/99	932.4
8/31/99	932.3
9/7/99	932.2
9/14/99	932
9/21/99	931.9
10/5/99	932
10/12/99	931.9
10/26/99	931.9
11/2/99	931.9
11/16/99	931.9
11/29/99	931.9
3/22/00	932.3
3/30/00	932.1
4/12/00	931.9
5/3/00	932
5/17/00	931.9
5/24/00	932.1
5/31/00	932.1
6/8/00	932.3
6/14/00	932.3
6/21/00	932.3
6/29/00	932.2
7/6/00	932.2
7/13/00	932.4
7/19/00	932.2
7/26/00	932.1
8/2/00	932.1
8/10/00	932.1
8/16/00	931.9
8/23/00	932
9/1/00	931.9
9/8/00	932
9/13/00	932.1
9/21/00	932
5/1/01	932.2
9/26/01	931.8
4/16/02	931.9
4/24/02	931.9
5/15/02	931.9
5/24/02	931.9
5/30/02	931.9
6/6/02	931.9
6/12/02	931.9
6/19/02	931.8
6/26/02	931.9
7/4/02	931.8

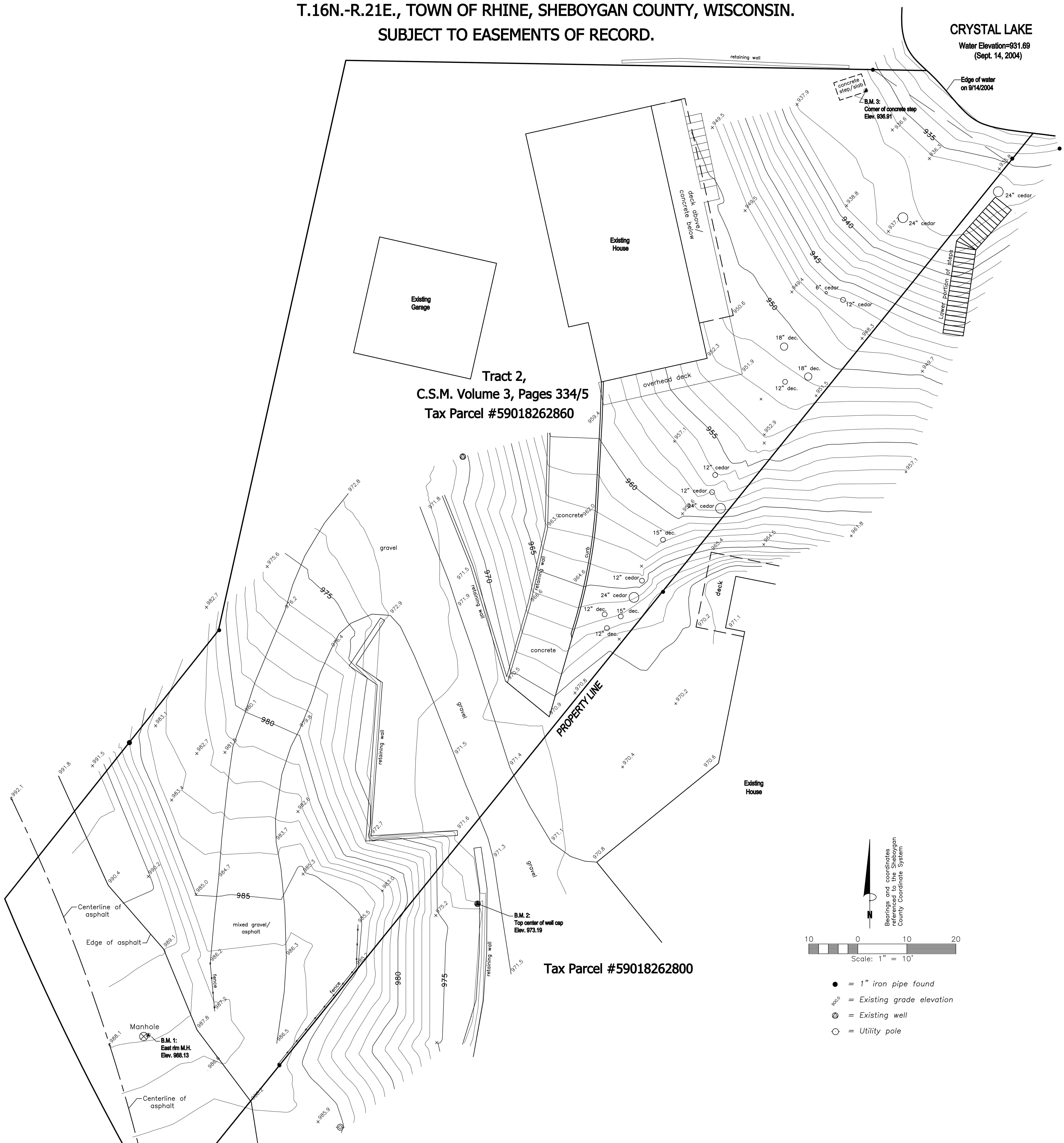
Date	Water Level Elevation
7/11/02	931.8
7/17/02	931.7
7/23/02	931.5
8/7/02	931.4
8/16/02	931.3
8/23/02	931.4
8/27/02	931.4
9/4/02	931.3
9/11/02	931.2
9/19/02	931.1
9/26/02	931.1
4/22/03	930.9
5/1/03	930.9
5/8/03	931.1
5/14/03	931.2
5/20/03	931.2
5/29/03	931.2
6/5/03	930.7
7/27/03	930.9
8/10/03	931.2
8/25/03	930.7
9/8/03	930.7
10/6/03	930.5
11/16/03	930.9
8/11/04	931.7
8/31/04	931.7
9/14/04	**931.7**
10/10/02	931.7
5/8/05	931.7
5/31/05	931.5
6/22/05	931.4
6/29/05	931.2
7/19/05	931.0
8/2/05	930.8
8/23/05	930.6
9/27/05	930.4
10/16/05	930.2

APPENDIX B

TOPOGRAPHIC SURVEY BY COMPOSITE SURVEYING AND MAPPING

Topographic Survey
for
Counselman & Associates

PART OF LOTS 14 AND 15, BLOCK 3, RESUBDIVISION OF CRYSTAL LAKE PARK, SECTION 31, T.16N.-R.21E., TOWN OF RHINE, SHEBOYGAN COUNTY, WISCONSIN.
SUBJECT TO EASEMENTS OF RECORD.



Project Benchmark:

Sheboygan County GPS Monument #061521, located 40 feet east of CTH P, and CTH A, and 230 feet south of CTH C
Elevation = 974.37

Coordinate/Bearing reference:

1) South 1/4 corner of Section 31, T.16N.-R.21E., 1" iron pipe found (N196379.634, E134921.915)
2) Southwest corner of Section 31, T.16N.-R.21E., P.K. nail found (N196440.692, E132356.299)

Compsite
Surveying & Mapping
Oostburg, Wisconsin
(920) 564-6812

/ / 20

John M. DuMez - Reg. Land Surveyor S-2267

If the surveyor's seal and signature is not red colored, the drawing is a copy that should be assumed to contain unauthorized alterations. The certification contained on this document shall not apply to copies.

FILE: c:\dwg\counslmn\rasp904.dwg
DRAWN BY: jdm
PROJECT: 2388