CITY OF MUSKEGO

Results of Water Stage Monitoring for Big Muskego Lake South Inlet Ditch

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Ruekert·Mielke

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Background:

Several residents along Loomis Drive have expressed concern to the City of Muskego regarding nuisance flooding within the watershed of a ditch system southeast of Big Muskego Lake. In order to characterize the high water conditions and help understand the causes, the City of Muskego commissioned a study in 2009 to perform a brief geomorphic assessment and collect water level data. Data was collected in 2009 and 2010 and included water surface elevations at three (3) locations and rainfall data. The rainfall gage was set at the fire station on Loomis Drive and the water level gages were set on the South Inlet Ditch to Big Muskego Lake as shown in Figure 1:

1) near the Loomis Drive residents on the 'East Lateral'
2) at the confluence between the East Lateral Ditch and the mainstem of the South Inlet Ditch, and
3) downstream of Loomis Road within the mainstem of the South Inlet Ditch at the Muskego Lakes Country Club golf course.

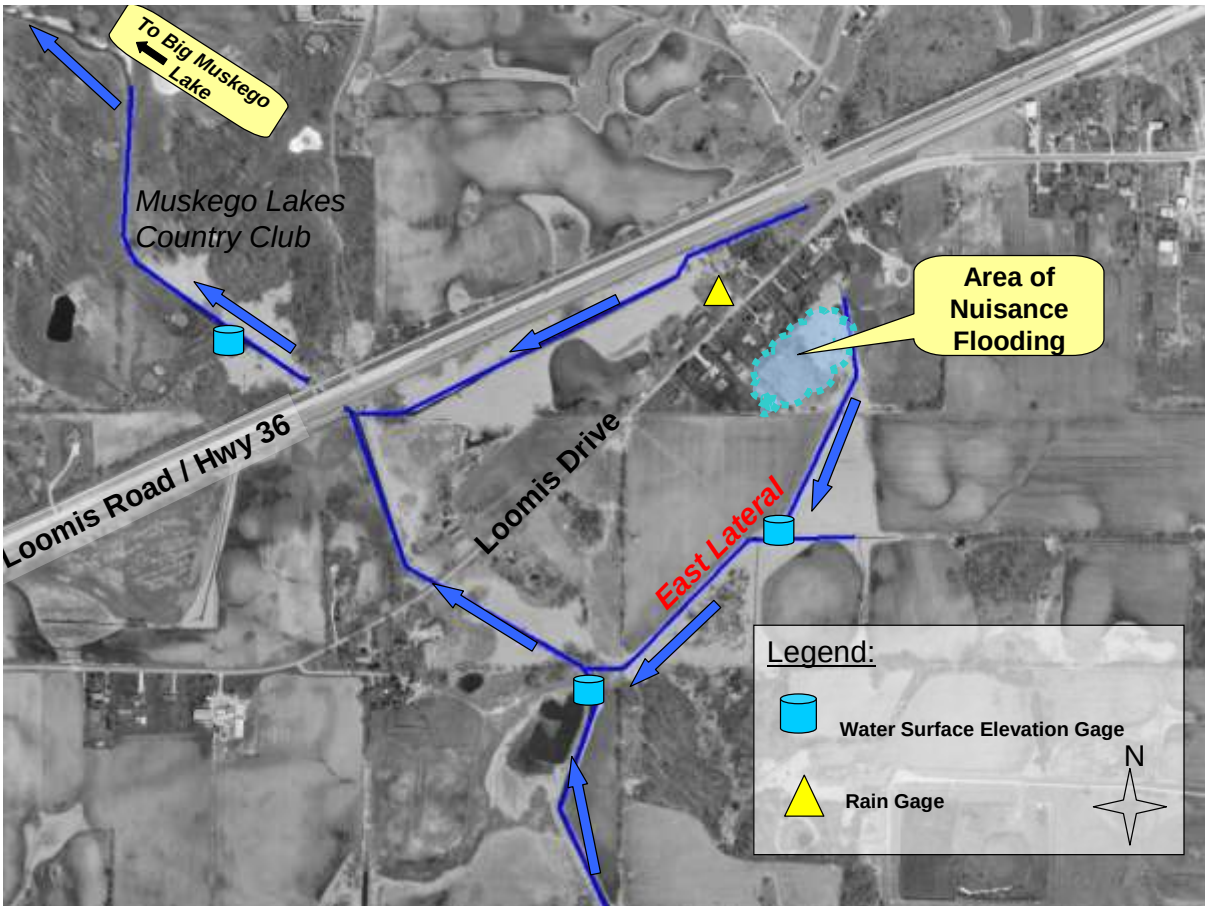


Figure 1. Water Surface Gage and Rainfall Gage Locations for South Inlet Ditch to Big Muskego Lake Study

The area is not a 'mapped floodplain' however; downstream of Loomis Road (Hwy 36) at the Muskego Lakes Country Club the 100-yr flood elevation is 774.0. The regulatory floodplain limits and project setting are described in Technical Memorandum No. 1 dated September 4, 2009 (Rye, 2009) included as Appendix B of this report. Recent flooding in 2010 came within about 0.5 ft of the mapped floodplain elevation at the country club.

The locally recorded highest water surface over the last two years at the residences on Loomis Drive occurred on July 23, 2010. This elevation was established by a pin flag set by a resident that estimated the high water level. This pin flag was later surveyed in by Ruekert and Mielke Associates (RMA) to be at elevation 774.20. However, immediately downstream of these homes at the 'Upstream' gage a maximum water surface elevation of 774.53 on that same date. Hence, the *maximum* water surface elevation at the Loomis Drive was likely higher than the estimated pin flags showed.

Perhaps as important to the residents as the peak water surface elevation, higher water surface elevations have not receded very 'quickly'. Since there is very little area direct contributing upstream of these sites (essentially the backyards of the homes and some other local areas) there are two logical explanations for the sustained high water elevations:

1) ***Poor surface drainage*** - there is a blockage in the downstream conveyance system that does not allow water to discharge, ***or***
2) ***High water table*** - the high water elevations are due to high local water table elevations

If the high water elevations are due to poor surface drainage, water may be backing up within the ditch system. This would occur if there is insufficient flow in the ditch because of a restriction or high resistance. If this were the case, then dredging may be useful. However, it will still be important to dredge the right area to the right elevation to get the best return on investment. In other words, it will not be helpful if you dredge upstream or downstream of the constriction.

If there is little difference between the water surface elevation of Big Muskego Lake and the ditches / area of nuisance flooding then the high water elevations can be attributable to a high water table. If the high water elevations at Loomis Drive are due to high water table conditions, dredging would not be helpful.

Methods

Additional details of the gage types and local settings are provided in previously mentioned Technical Memorandum No. 1 (Rye, 2009).

Over 200,000 data points of incremental rainfall and water surface elevation were collected in the open water seasons of 2009 and 2010. WLU16 Global Water data loggers were used to collect water elevations. Overall, these performed well. However, in 2009 the loggers at the pedestrian bridge and the upstream ditch became clogged and had to be reconstructed. In 2010 the upstream ditch data logger was destroyed, apparently by farming activity (perhaps cutting hay or other activity). This appears to have occurred on July 29, 2010. Since most of the rainfall occurred prior to July 29, 2010 the collected data remains valuable in understanding the behavior of the ditch system. Water surface elevations of Big Muskego Lake were collected by the City of Muskego and the U.S Geological Survey (USGS). In addition, as mentioned above, high water elevations were surveyed by Ruekert-Mielke Associates (RMA). Additional notes on the precision of the collected data are provided as Appendix A.

Data was collected for the following period(s):

Table 1. Collected Data Period of Record for South Inlet Ditch to Big Muskego Lake Study

	2009		2010	
Site	***Beginning Date***	***End Date***	***Beginning Date***	***End Date***
Big Muskego Lake	July 18, 2007	September 24, 2009	June 3, 2010	December 8, 2010
Golf Course	July 25, 2009	December 10, 2009	April 2, 2010	November 5, 2020
Bridge	September 5, 2009	December 11, 2009	April 2, 2010	November 5, 2010
Upstream	July 8, 2009	November 7, 2009	April 12, 2010	July 29, 2010
RAIN GAGE	July 8, 2009	December 11, 2009	April 2, 2010	September 17, 2010

Results

Rainfall Data:

Rainfall data was collected in 2009 and 2010 and is summarized below in Table 2.

Table 2. Summary of Collected Rainfall Data

	Average Muskego Precipitation Amount[1] (inches)	2009 (July 8, 2009 to December 11, 2010)		2010 (April 2, 2010 to September 17, 2010)	
		Precipitation Amount (inches)	Departure from Monthly Average (inches)	Precipitation Amount (inches)	Departure from Monthly Average (inches)
January	1.48	*No data*	*n/a*	*No data*	*n/a*
February	1.31	*No data*	*n/a*	*No data*	*n/a*
March	2.28	*No data*	*n/a*	*No data*	*n/a*
April	3.53	*No data*	*n/a*	0.42	**-3.11**
May	3.02	*No data*	*n/a*	0.12	**-2.90**
June	3.78	*No data*	*n/a*	0.11	**-3.67**
July	3.83	0.73 *(partial month)*	**-3.10** *(partial month)*	7.75	**+3.92**
August	4.77	3.02	**-1.75**	1.63	**-3.14**
September	3.52	0.0	**-3.52**	0.77 *(partial month)*	*n/a*
October	2.62	4.34	***-1.72***	*No data*	*n/a*
November	2.63	1.84	***-0.79***	*No data*	*n/a*
December	1.87	0.16 *(partial month)*	*n/a*	*No data*	*n/a*
Total Rainfall Depth (inches)	**36.64**	**10.09**		**10.62**	

(1) Source: The Weather Channel (www.weather.com)

As previously mentioned, additional information on data precision is provided in Appendix A. Overall, 2009 was a relatively dry year. 2010 was also a relatively dry year, with the noted exception of the very large rainfall event in late July. Over 5 inches of rainfall fell between July 22-24, 2010. Additional information on this large rainfall event in July 2010 is provided in Appendix C and additional data plots including the incremental and cumulative data plots for 2009 and 2010 are provided in Appendix D.

Water Surface Elevations

Big Muskego Lake

Gage heights were obtained from the United States Geological Survey (USGS) and the City of Muskego for Big Muskego Lake at the dam outlet. A gage zero was estimated based upon surveys performed by the Reukert Mielke Associates (RMA). As described in Appendix A, this is different than the gage zero reported by the USGS. However, using the RMA gage zero assures that the lake elevations are appropriately relevant to the water surface elevation data collected in the South Inlet Ditch. The lake elevations are shown along with the water surface elevations in Figures 2 through 6.

Data Loggers within Ditch System

The results of the data loggers within the ditch system in 2009 and 2010 are shown below in Figures 2 through 6. The tail of the "Upstream" data logger in late July 2010 (after the peak elevation has been reached) is much steeper than expected (see Figure 4). There is precedence for this as the receding limb of the hydrograph in 2009 also had a steep recession limb. Figure 5 is a detail of September 2009 low water conditions. Of interest in this graph is that the lake elevation is *higher* than the water surface elevation at the "Upstream" gage site.

The time or rate that the water surface elevation drops after a large rainfall or runoff event is termed the 'recession limb'. Review of recession limbs of the South Inlet Ditch in Figures below generally show a consistent slope.

High Water Profiles

The highest recorded values, water surface profiles, and slopes are shown below in Table 3 and shown in Figure 7. Note that the water surface elevation at the 'Homes' is shown as 774.2, however, as mentioned above, the unrecorded *maximum* elevation was likely higher. Note the highest recorded water surface elevation is presented during the highest events in 2009 and 2010 and the water surface elevation at a specific time (≈ 19:00) is presented for the other events in 2010. The computed slopes appear consistent with observed conditions. Lake elevations were not available for two of the events analyzed. However, the computed water surface slopes are similar for the higher flows analyzed.

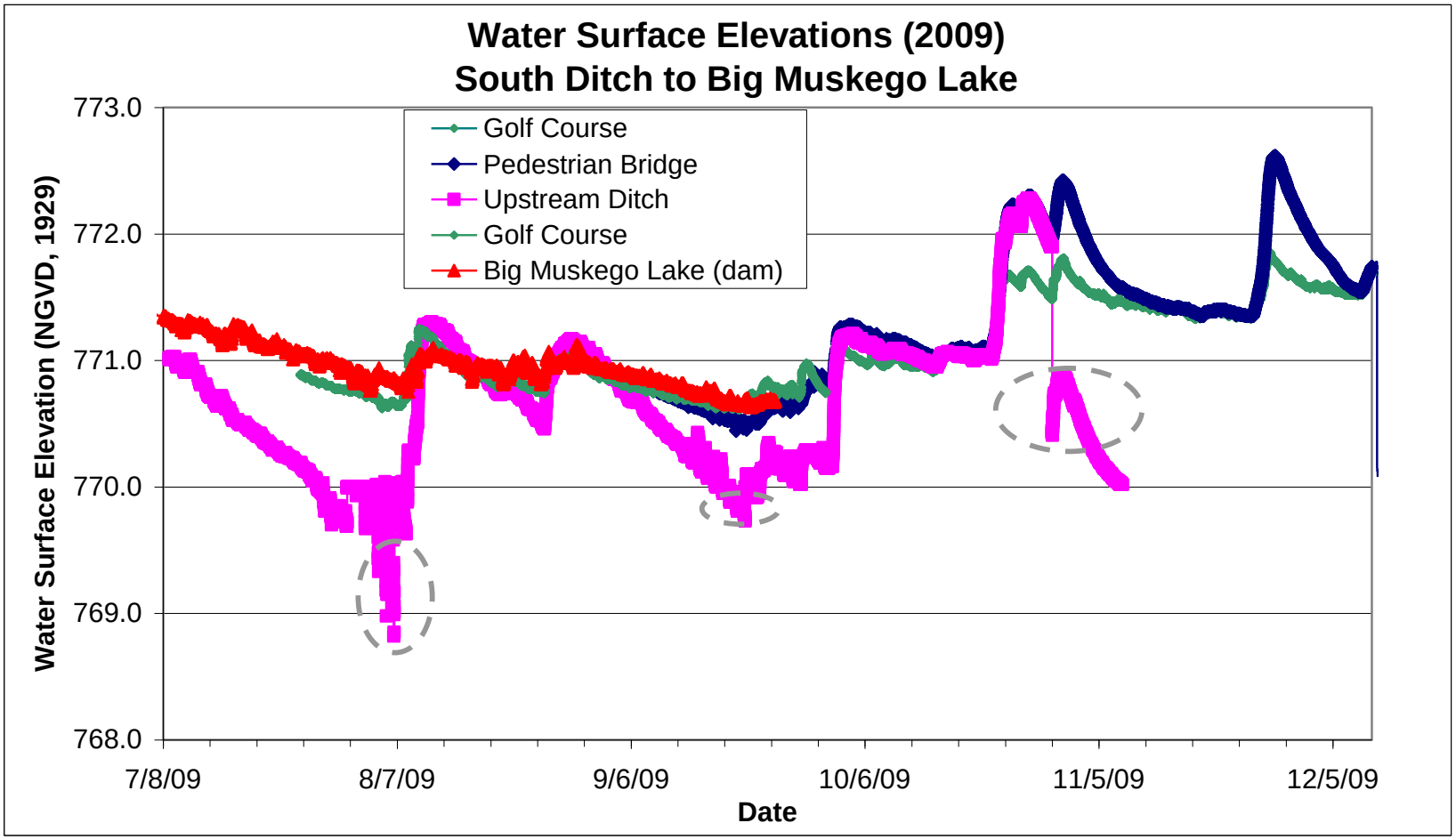


Figure 2. 2009 Water Surface Elevations
(Note: data in circled area should be considered with some caution)

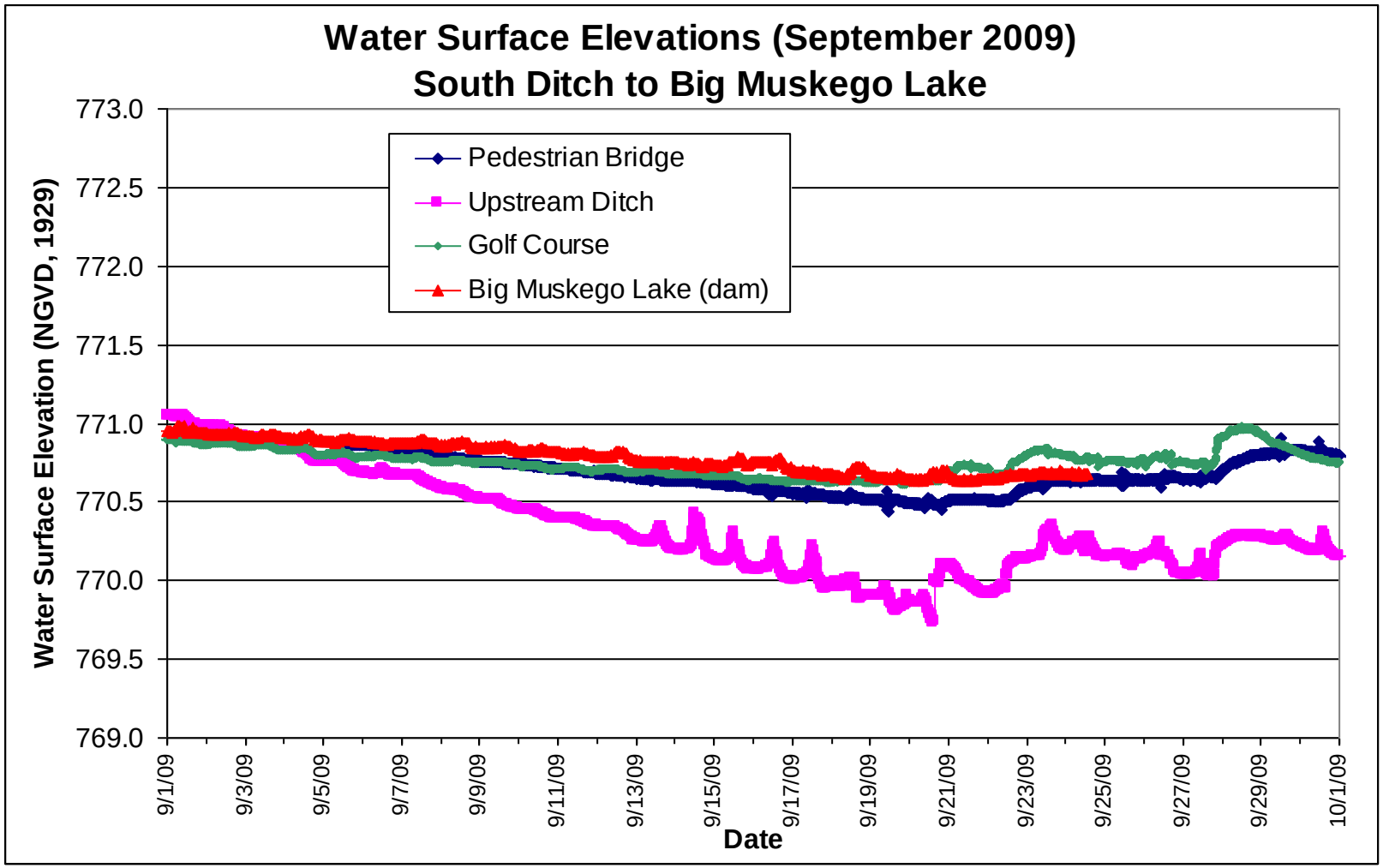


Figure 3. September 2009 Water Surface Elevations (Low Water Conditions)

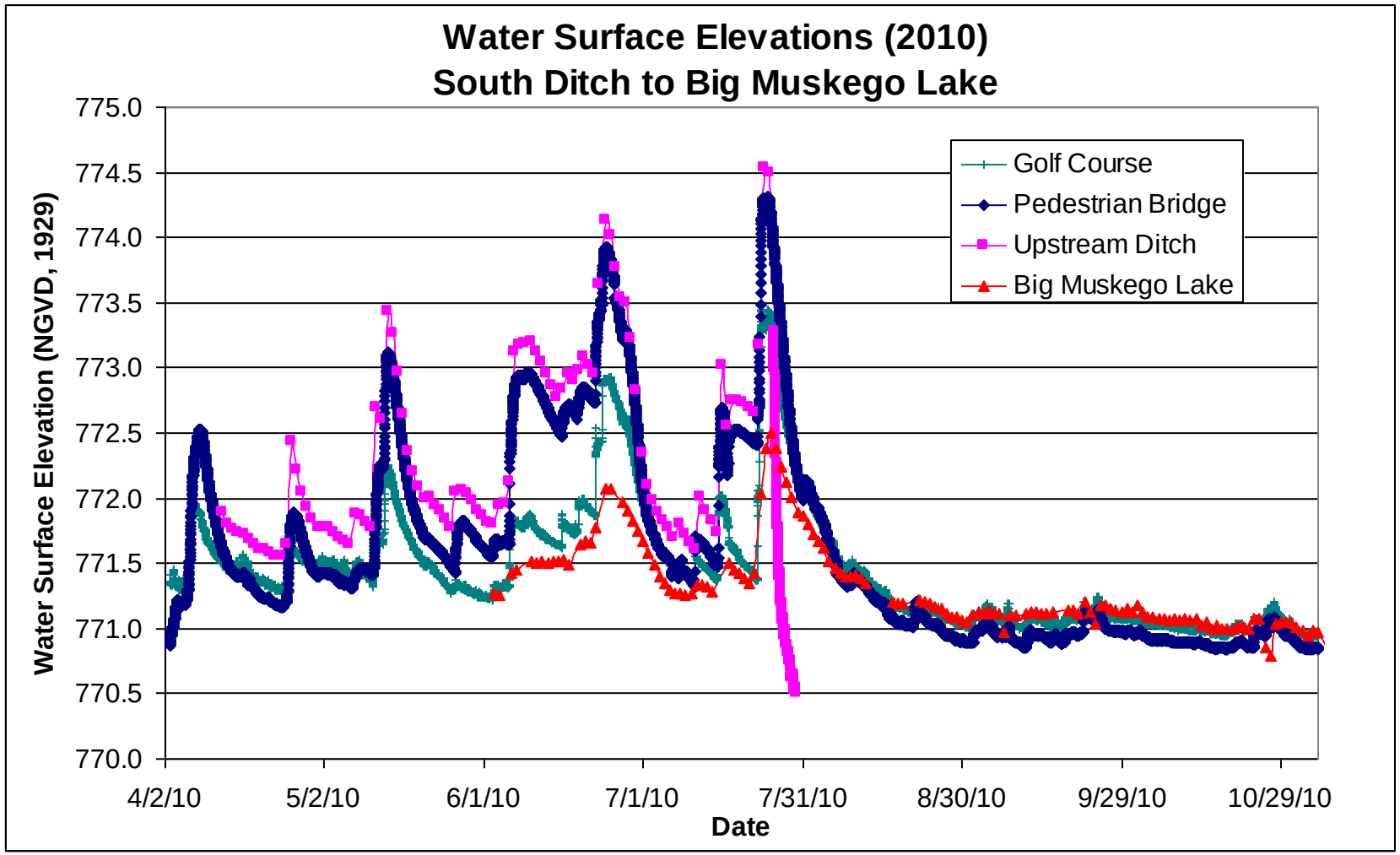


Figure 4. 2010 Water Surface Elevations

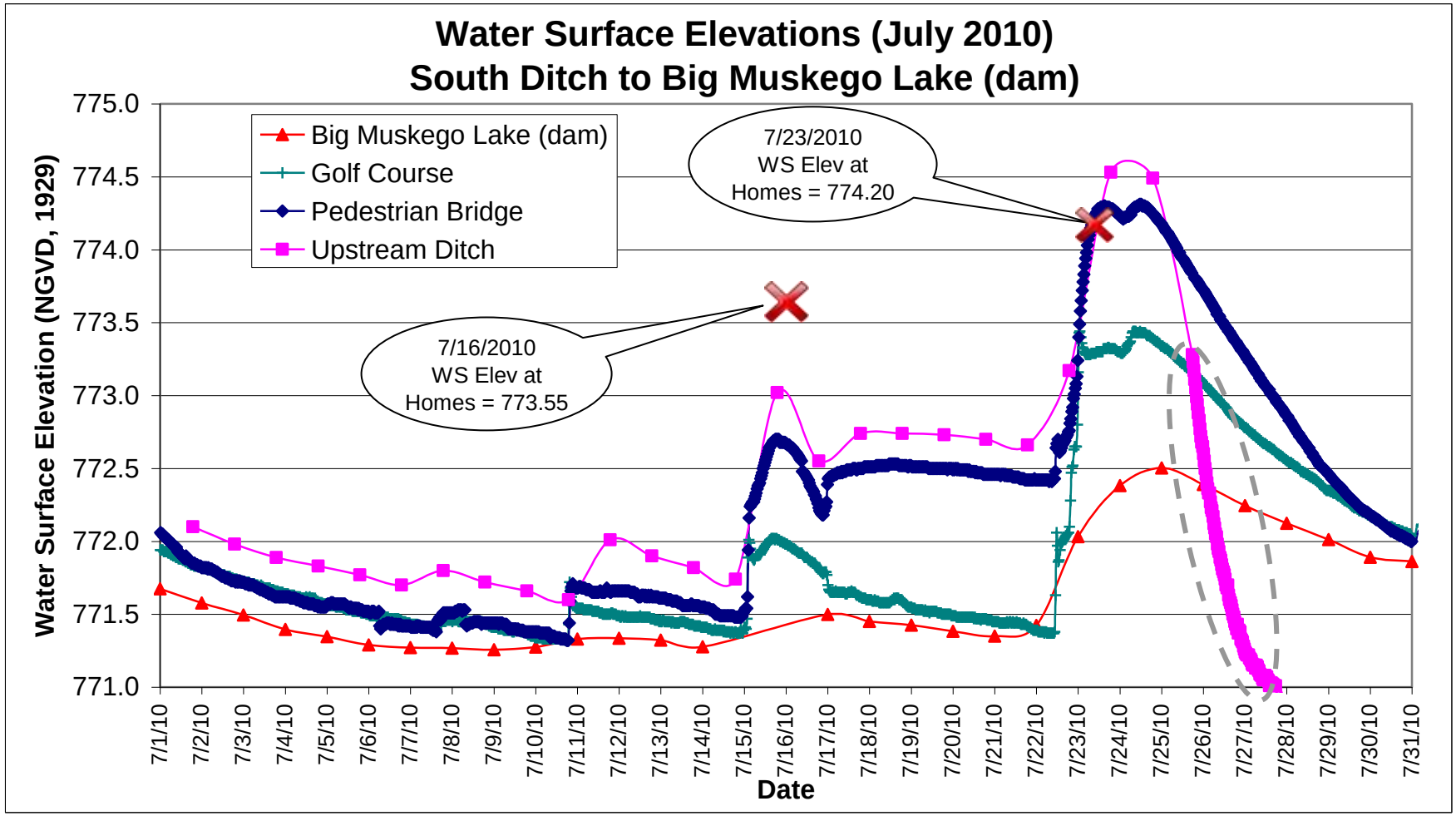


Figure 5. July 2010 Water Surface Elevations (Flood Conditions)
(Note the surveyed elevations at the homes on Loomis Drive on 7/16 and 7/23 – the recession limb within the circled area should be considered with some caution)

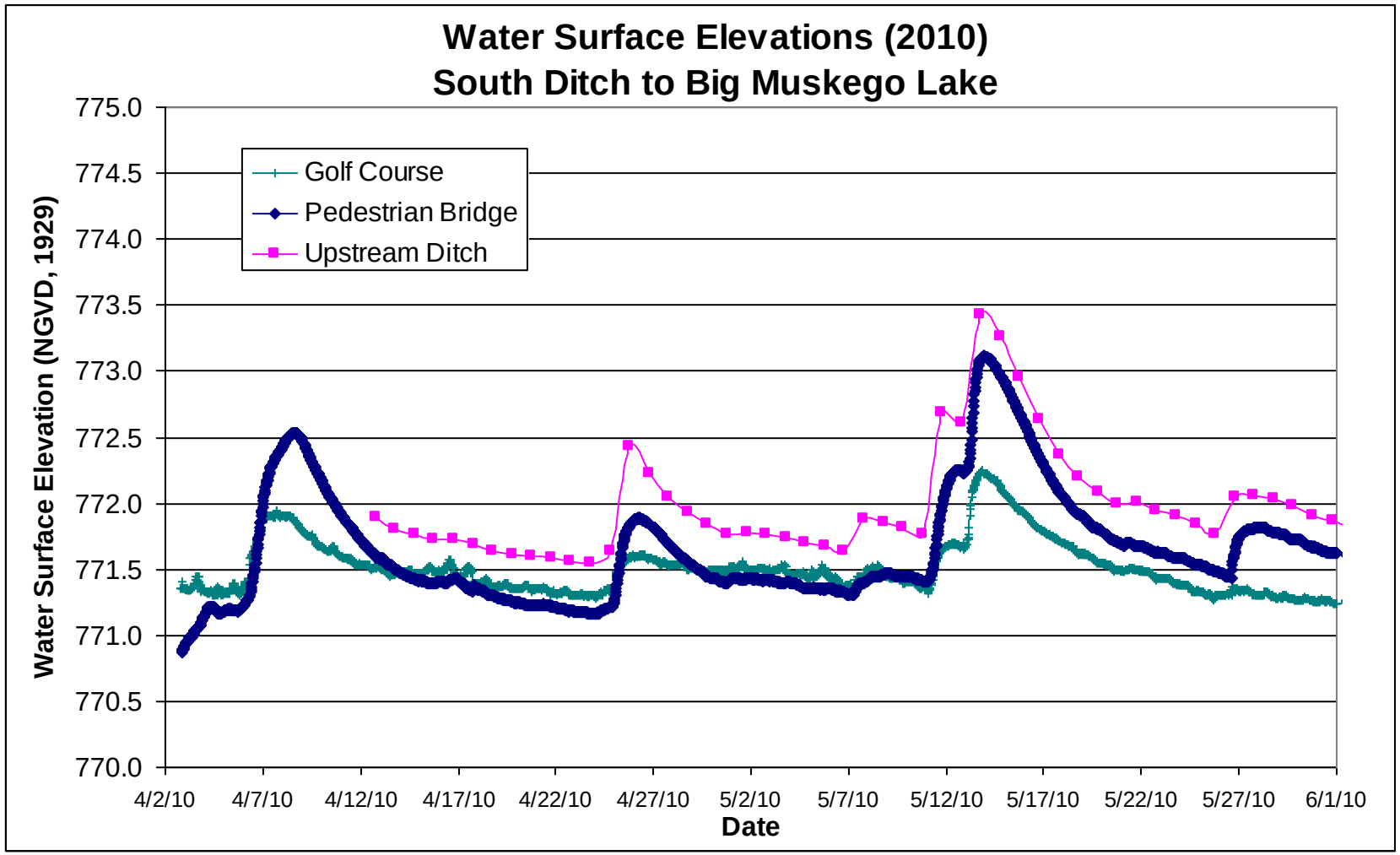


Figure 6. April and May 2009 Water Surface Elevations

Table 3. South Inlet Ditch High Water Surface Profiles

Location	Station (ft)	October 26-28, 2009 (highest recorded elevation in 2009)			May 13, 2010 ≈ 19:00			June 10, 2010 ≈ 19:00			July 16, 2010 ≈ 19:00			July 23-24, 2010 (highest recorded elevation in 2010)		
		Water Surface Elevation (ft)	Difference in Water Surface Elevation (ft)	Slope (ft / ft)	Water Surface Elevation (ft)	Difference in Water Surface Elevation (ft)	Slope (ft / ft)	Water Surface Elevation (ft)	Difference in Water Surface Elevation (ft)	Slope (ft / ft)	Water Surface Elevation (ft)	Difference in Water Surface Elevation (ft)	Slope (ft / ft)	Water Surface Elevation (ft)	Difference in Water Surface Elevation (ft)	Slope (ft / ft)
Big Muskego Lake	0							771.52			771.43			772.50		
Golf Course	4,200	771.71			772.24			771.76	0.24	0.00010	771.81	0.38	0.00015	773.44	0.94	0.00022
Bridge	6,700	772.21	0.50	0.00020	773.10	0.86	0.00034	772.88	1.12	0.00045	772.23	0.42	0.00017	774.31	0.87	0.00035
Upstream	*8,000*	772.28	0.07	0.00005	773.43	0.33	0.00025	773.12	0.24	0.00018	772.55	0.32	0.00025	774.53	0.22	0.00017
Homes	9,300													*774.2*	-0.33	-0.00025

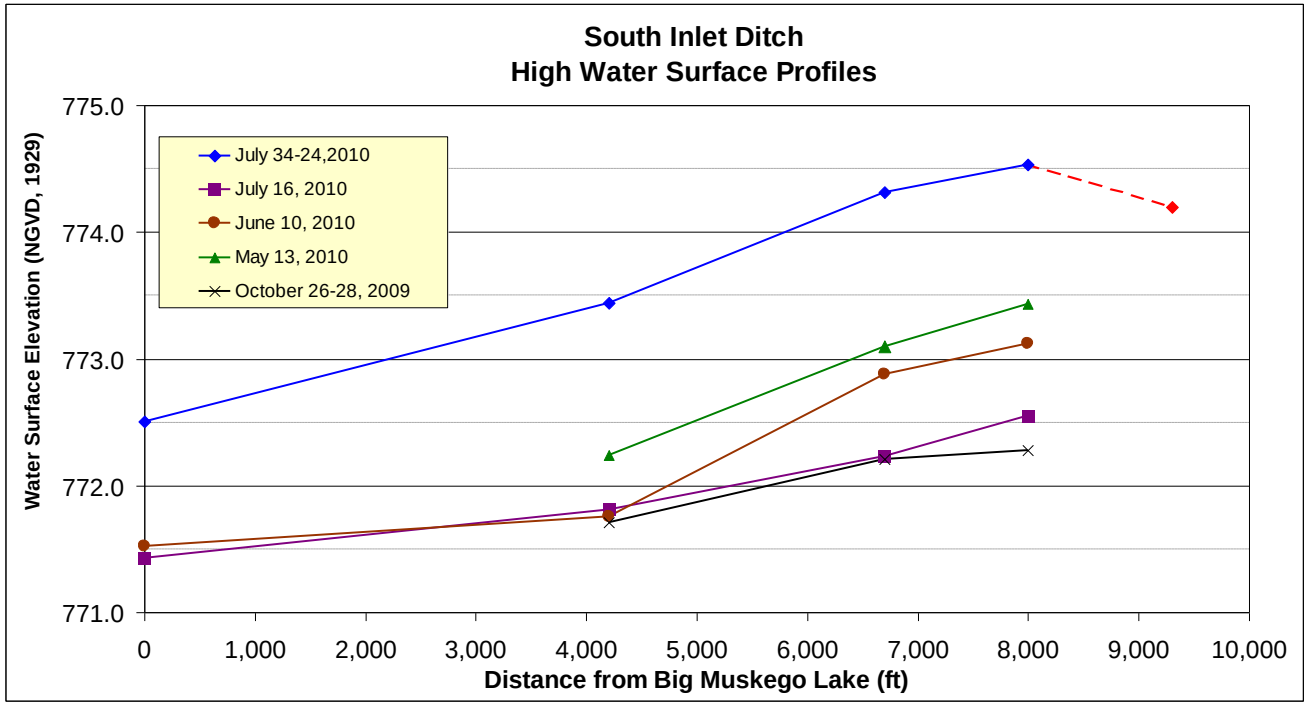


Figure 7. High Water Surface Profiles

Conclusions

The residents indicate that the sustained high water elevations had not historically been an issue. This could be attributed to a change in:

- hydrologic conditions
  - it just been wetter recently or
  - the land use has changed so there is more runoff
- hydraulic conditions
  - decrease in the surface drainage efficiency / the ditch system has filled in or there is more resistance
- subsurface drainage efficiency
  - something has occurred that has modified the water table flow patterns
- the attention paid to local high water levels
  - it was actually this high, but no one noticed - different people using the property differently or people have forgotten

Each of these possibilities will be briefly discussed below. Taking the last possibility first, residents near a waterbody often have short memories, have only lived in a neighborhood for a short time, or simply have not experienced some of the natural fluctuations or large events associated with a lake, wetland, or stream. However, in this case many of the present landowners have lived in the neighborhood for a number of years. In addition, there have *not* been a lot of changes in local land use (new houses built or changes in the backyard land uses that would change peoples' perspectives). There is little historic data available to document a misconception of changing conditions. Hence, the residents' contention of a changed condition may be with merit and worth additional consideration.

There have been some changes in the hydrologic conditions within the watershed in the last twenty years. The construction of the Emerald Park Landfill within the South Inlet Ditch watershed has likely increased the runoff volume. However, the facility has a stormwater management plan that should address some of these changes. Additional housing construction in the Big Muskego Lake and South Inlet Ditch watershed has also likely increased the runoff volume. However, the City has a stormwater management plan to address these changes in land use. In summary, although a detailed investigation or analysis has not been performed as part of this study, *it is generally assumed that the existing land use controls and stormwater management plans adequately address the impacts of development on the stormwater runoff volume.*

In addition to changes in the land use, the recent hydrologic conditions may be wetter than historically. As described in Technical Memorandum No. 1 in Appendix B, it is possible to use the average water surface elevation of Windy Lake as a surrogate for the annual runoff yield. Some care must be taken in the use of this data because Windy Lake is a managed outlet. However, there is some historic data and the annual average can be useful in making some assumptions whether a year has generally been wet or dry. A graph was presented in Technical Memorandum No. 1 and has been updated for this report as Figure 7. A 3-year moving average

trend line has been added to show overall trends. There is no statistical reason to use a 3-year moving average over any other return frequency. However, moving average trend lines of different frequency all show the same recent increase in the average water surface elevation of Wind Lake. If the Wind Lake average annual elevation is considered an appropriate surrogate for the annual watershed yield (runoff volume) it would indicate that the seven years have been wetter than the previous decade. This does not take into account how or when the precipitation fell so it must be considered with some caution. *However, it appears the hydrologic conditions over the last several years are wetter than the previous decade.*

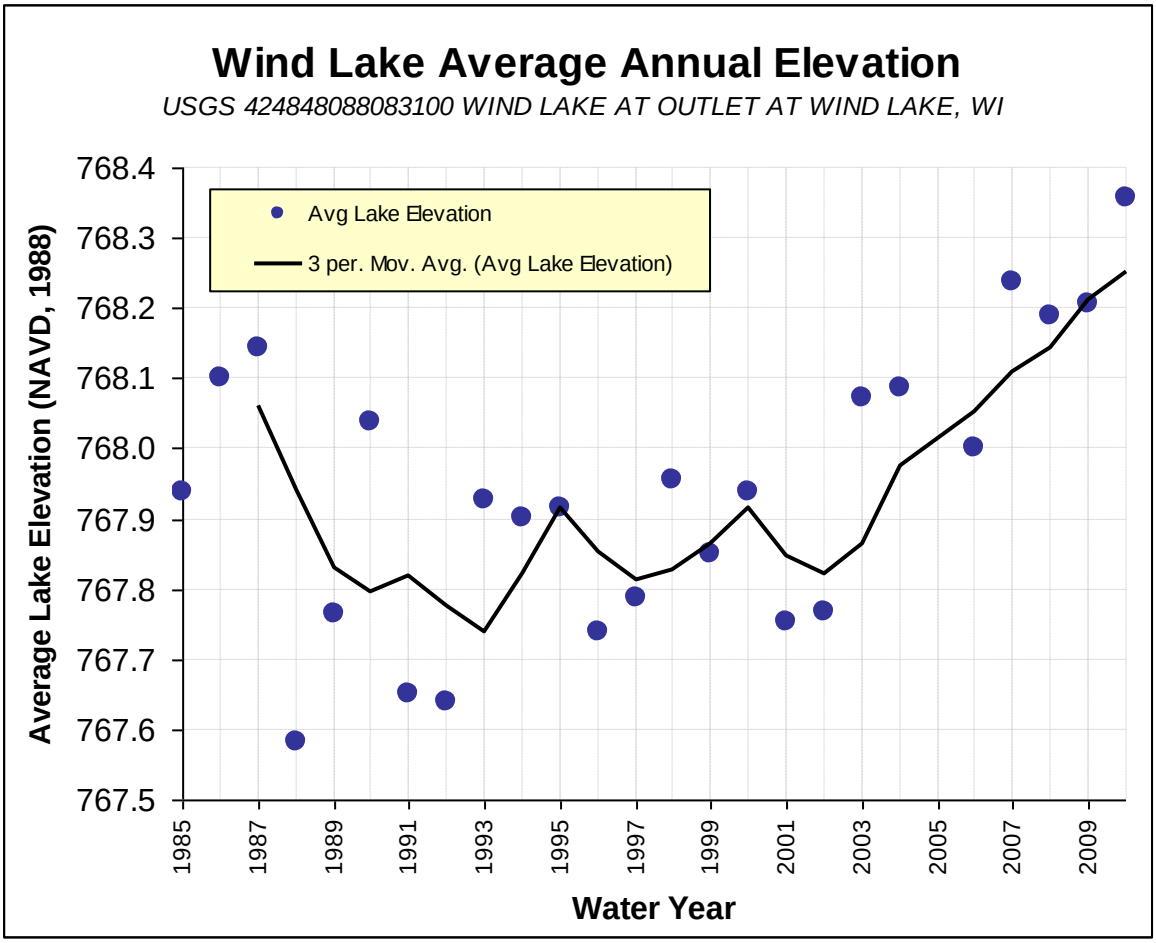


Figure 7. Wind Lake Annual Elevation (Updated since Tech Memo 1)
with 3-year moving average trend line (note the trend to a wetter condition since 2003)

Figure 8 shows the daily water surface elevations between 2007 and 2010 for Big Muskego Lake.

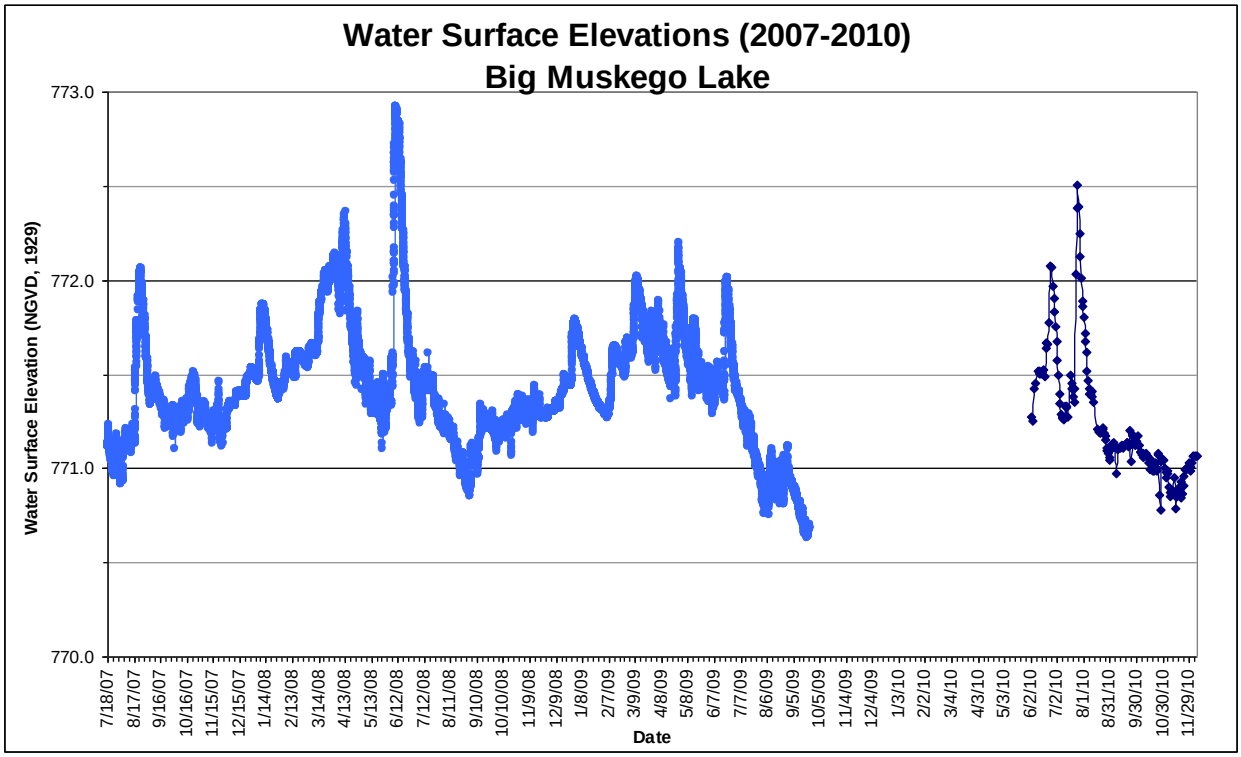


Figure 8. Big Muskego Lake Water Levels (2007-2010)
Note: gage zero used was surveyed by RMA as referenced in the report above (different than the USGS gage zero)

Figure 9 shows the annual minimum, mean, and maximum water surface elevations for Big Muskego Lake. The data is presented for the water year which runs from October 1 to September 30 of the next year. The recorded range for the period of record is 3.88 ft (maximum of 772.33 and a minimum of 768.45). However, the minimum was the result of a lake drawdown as part of a lake restoration effort in 1996 and 1997.

Comparison of 2009 and 2010 data for Big Muskego Lake with historic data indicates that lake levels were higher than more recent years, but generally consistent with conditions in the late 1990's. Overall, Figure 9 shows that the annual fluctuation of Big Muskego Lake is approximately 1.5 ft and is relatively consistent through the period of record. Figure 9 also includes a 3-year moving average shown for illustrative purposes.

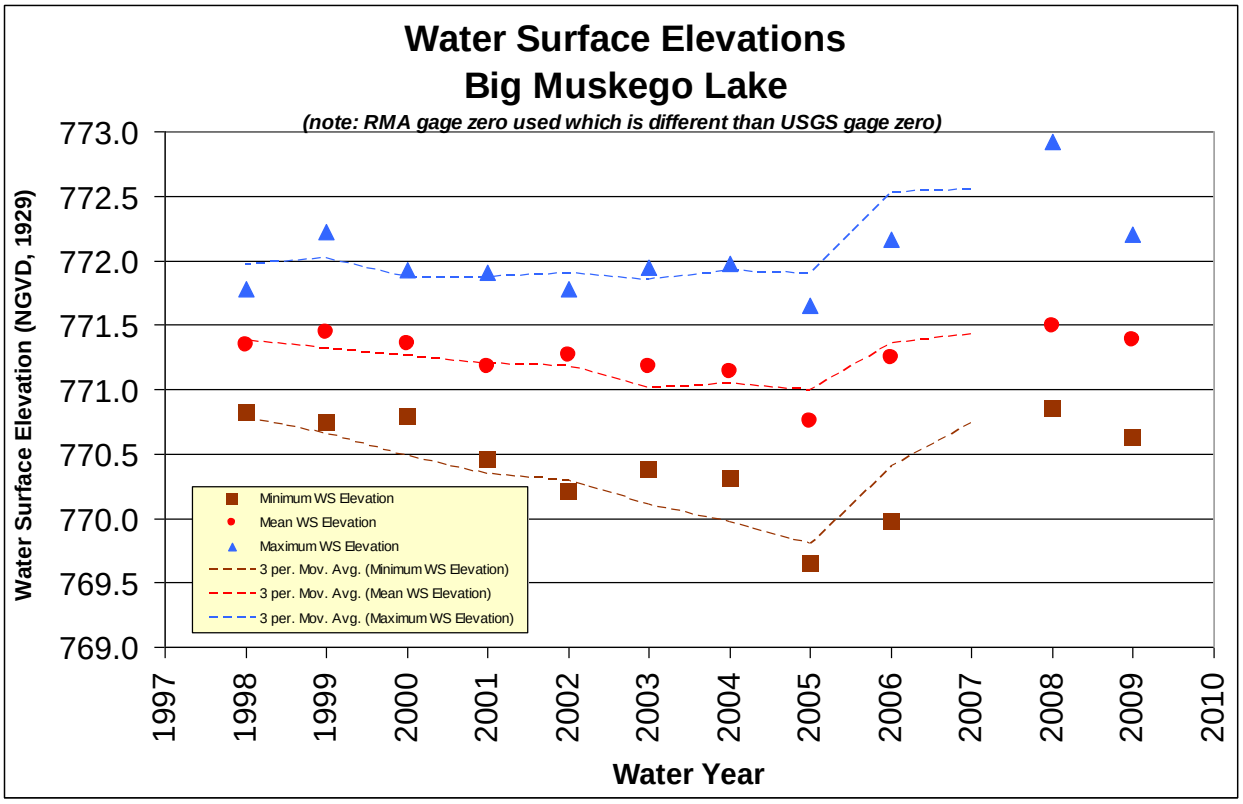


Figure 8. Big Muskego Lake Water Levels (1998-2009)
Annual Minimum, Mean, and Maximum Water Surface Elevations

The purpose of the water level gaging effort was to provide some additional insight on the hydraulic efficiency of the ditch system under flooding conditions. The slope of the water surface profile is very flat. The computed hydraulic slope of approximately 0.0002 ft/ ft (or 0.02%) in Table 4 is equivalent to about ¼ inch every 100 ft or about 1 ft per mile. The hydraulic efficiency of a drainage system can be evaluated based upon the amount of head loss over the reach length. If there is a lot of resistance to the flow because of roughness, high slope, or small flow area, there will be more head loss and a larger water surface slope. Conversely, the hydraulic gradient of the South Inlet Ditch is very low. It is relatively consistent throughout the reaches there is little resistance to flow and no large obstruction (such as a severely undersized culvert) is apparent. *Based upon this understanding, it does not appear dredging will significantly increase the overall efficiency of the drainage system.*

As discussed above, the computed water surface sloped indicated the existing crossings do not appear to be a restriction in the drainage system. The one exception may be the field crossing immediately downstream of the nuisance flooding area at Loomis Drive (see Figure 9). While there is relatively little flow through this culvert, it is considered in poor condition and is likely the local control for some of the backyard drainage. Although there is little flow through the culvert that would necessitate its replacement, there is the possibility that the culvert can become plugged with debris and ice. Hence, its replacement could provide some help in draining of the backyard area.

Figure 9. Existing field crossing of East Lateral just downstream of area of nuisance flooding

The final possibility is a change in the subsurface drainage efficiency. As described in Technical Memorandum No. 1 (Appendix B) the general water table flow is to the east-southeast. The landfill is located in the southern portion of the watershed and the overburden could change the local water table flow patterns. However, the available mapping of the regional groundwater flow indicates the flow is generally to the east and it is assumed the land fill should not have affected the water table. It is likely that review of existing monitoring at the landfill site (considered beyond the scope of this project) would confirm this assumption. The Big Muskego Lake outlet has not been modified recently and there are no other known projects that may have significantly changed the local / regional groundwater flow patterns. Hence, it is considered that it is unlikely there has been a change in the local or regional groundwater flow patterns.

In conclusion, the existing drainage system appears to be relatively efficient. The high water elevations experienced in the backyards of Loomis Drive appear to be due higher elevations in Big Muskego Lake and the groundwater table. It appears these recent higher water surface elevations may be due to wetter hydrologic conditions than were experienced in the previous decade.

Recommendations

Based upon the results of this study, the following recommendations are provided for consideration:

- Dredging of the ditch system is not recommended based upon the results this study.

- The field crossing immediately downstream of the nuisance flooding should be replaced. It is recommended that the culvert be 'oversized' to accommodate potential debris, ice, and to ensure it is not the hydraulic control. Since it is simply used as a field crossing without utilities, it is anticipated that a 36-inch corrugated metal pipe or similar pipe(s) would be a cost-effective measure to provide some benefit to the property owners. As mentioned above, it would be important to ensure the invert is sufficiently depressed so that it does not become the hydraulic control.

- The City may want to consider continuing to monitor the ditch system to further evaluate its efficiency.

References:

Rye, Marty E., 2009. *Technical Memorandum No. 1 – Watershed Description and Geomorphic Assessment, Big Muskego Lake South Inlet Ditch, City of Muskego*. Memorandum to Mr. Ken Ward from Marty Rye dated September 4, 2009. Concord Ecological Engineering.

Rye, Marty E., 2010. *Technical Memorandum No. 3 – Brief Summary of July 22-24, 2010 Rainfall Event, City of Muskego*. Memorandum to Mr. Ken Ward from Marty Rye dated July 26, 2010. Concord Ecological Engineering.

http://www.weather.com/outlook/travel/vacationplanner/wxclimatology/monthly/graph/53150

Appendix A
Some Notes on Study Precision

Data or analysis results are far too often presented to decision-makers without the appropriate context of their precision. For example flood elevations can be presented to the nearest 1/100th of a foot (or about 1/8 or an inch), yet to adequately manage risk we need to understand how fanciful this prediction may be. In other words, we may manage our risk differently if we understood that the actual flood elevation was perhaps within a foot as opposed to 1/8 of an inch. This is especially important to keep in mind when dealing with natural or biologic systems.

All studies, models, and analyses have limits of precision. The discussion below provides some insight into the uncertainty and error associated with the study.

<u>Uncertainty and Sources of Error:</u>
Like real world processes, data is often a bit messy. 'Uncertainty' describes the natural variability of a known value, while 'error' is considered the *inability* to measure the value something that can be known.

'Uncertainty'
For example there is 'uncertainty' because of natural variation in water surface elevations. The water surface elevations can change with discharge. Discharge in a stream is not constant. Small variations of discharge over small timesteps are related to eddy formation as the water 'pulses' downstream. Surface elevations can also vary because of small waves because of wind, turbulence at high flow, or in a smaller temporal and spatial scale due to debris flow or other obstructions.

There is also a great deal of uncertainty related to rainfall. Rainfall intensity varies considerably over time and space. Our personal experience, as well as detailed analytical studies, confirms that there are large differences in rainfall depths. Depending upon storm characteristics, large rainfall can occur in one area and there can be no rain a mile away.

'Error'
Error can be attributed to limitations in the equipment, analytical processes, and simply mistakes. In this study 'error' can describe the accuracy of the equipment used. The rainfall gage only measured the rainfall depth to 0.01 inches, but at times there may have been a rainfall of 0.005 inches that would not have been collected. Additionally, it takes approximately 0.2 seconds for the tipping bucket to complete a cycle, so, some rainfall depth is lost for very intense storms. High winds during a storm can also reduce the efficiency of the rainfall gage. Finally, vandalism or tampering with the gage (or datalogger) can occur at remote sites. All of these elements contribute to error in the collected rainfall data.

Additionally, the elevations of the water in the ditch and lake were collected at an hourly or daily interval. However, the extreme maximum may have occurred in between these time steps. The amount of sediment in the water column can slightly change the density of the water column

(and hence, the weight of water) above the datalogger. Though the datalogger manufacturer does not indicate there should be a problem in surface waters, large sediment concentrations can also plug up the diaphragm of the datalogger causing it to lose functionality. Finally, the datalogger can 'drift' from the calibration conditions. Hence, there is an error in the reported value that will increase with increasing drift from the calibrated condition.

Study Objectives

The data precision and related investment or expense must be directly related to the management question. The goal of a model or data collection is to be efficient and be as simple as possible….but no more. Ultimately the purpose of the data collection was to:

1. *understand how the existing system works, and*
2. *determine whether dredging or other activity might alleviate the nuisance flooding concerns of the Loomis Drive residents.*

The collected data provides information to address these questions. More dataloggers, collection of more data points, more precise equipment or a more elaborate physical construction may have allowed more precise or voluminous numerical reporting. However, all of these have a related expense and the goal is to get the *right* type and amount of data to answer the management questions.

In other words, if we know the water surface elevation to the 0.001 ft (or 1/64th of inch) may be attainable with considerably more investment. However, that level of accuracy is not reasonable or needed because the waves from a slight wind are larger than 0.001 ft. In addition, knowing the water surface elevation to 0.001 ft would not be any more helpful in making our management decision.

Summary of Data Collection Issues

Data, as with a model, must be reviewed to see, "*Does this make sense?".* This process is often termed 'quality control'. A summary of the quality control review of the collected data is summarized below.

Rainfall Data

As previously described rainfall data was collected in 2009 and 2010 using a tipping bucket rain gage at the fire station on Loomis Drive. Quality control review was based upon 3 questions:

1) *How does the rainfall data compare to 'average' conditions?*
2) *Does the rainfall data correlate well to the water level data?*
3) *How does the rainfall data compare to other nearby rainfall gage(s)?*

Data for average conditions for Muskego was obtained from 'The Weather Channel' and is presented in Table 1 of the report text and Table A-1 below. The results of the rainfall data collection were compared to National Climate Data Center (NCDC) information obtained from the National Oceanic Atmospheric Administration (NOAA) for Madison and Milwaukee. The Milwaukee gage is less than 15 miles away at the General Mitchell Airport. The departure from average conditions and mutual comparisons are shown in Tables A-2 through Table A-4.

Table A-1. Comparison of Muskego and Milwaukee Monthly Precipitation Data

(All Precipitation Depths are in Inches)

	Muskego					***Milwaukee(3)***				
		2009		***2010***			***2009***		***2010***	
	Average Muskego Precipitation Depth(1)	Precipitation Depth(2)	Departure from Monthly Average	Precipitation Depth(2)	Departure from Monthly Average	Average Milwaukee Precipitation Depth	Precipitation Depth	Departure from Monthly Average	Precipitation Depth	Departure from Monthly Average
January	1.48	No data	n/a	No data	n/a	1.85	0.97	-0.88	0.62	-1.23
February	1.31	No data	n/a	No data	n/a	1.65	2.31	0.66	0.67	-0.98
March	2.28	No data	n/a	No data	n/a	2.59	3.68	1.09	0.83	-1.76
April	3.53	No data	n/a	0.42	-3.11	3.78	4.50	0.72	3.42	-0.36
May	3.02	No data	n/a	0.12	-2.90	3.06	2.56	-0.50	3.47	0.41
June	3.78	No data	n/a	0.11	-3.67	3.56	5.44	1.88	6.93	3.37
July	3.83	0.73 *(partial month)*	-3.10 *(partial month)*	7.75	3.92	3.58	0.71	-2.87	10.93	7.35
August	4.77	3.02	-1.75	1.63	-3.14	4.03	4.04	0.01	1.52	-2.51
September	3.52	0	-3.52	No data	n/a	3.30	1.57	-1.73	2.58	-0.72
October	2.62	4.34	1.72	No data	n/a	2.49	5.57	3.08	1.66	-0.83
November	2.63	1.84	-0.79	No data	n/a	2.70	1.80	-0.90	1.78	-0.92
December	1.87	0.16 *(partial month)*	n/a	No data	n/a	2.22	2.68	0.46	1.57	-0.65
TOTAL	***34.64***					***34.81***	***35.83***	***1.02***	***35.98***	***1.17***

(1) Source: The Weather Channel (www.weather.com)
(2) Source: South Inlet Ditch to Big Muskego Lake Study
(3) Source: National Climatic Data Center (NCDC) http://www.weather.gov/climate/index.php?wfo=mkx

Table A-2. Comparison of Muskego - Milwaukee Departures from Average Conditions

(All Precipitation Depths are in Inches)

	2009			2010		
	Muskego Departure from Normal Monthly Precipitation Depth	***Milwaukee*** Departure from Normal Monthly Precipitation Depth	***Difference (Muskego - MIlwaukee)***	***Muskego*** Departure from Normal Monthly Precipitation Depth	***Milwaukee*** Departure from Normal Monthly Precipitation Depth	***Difference (Muskego - MIlwaukee)***
January	n/a	-0.88	*n/a*	n/a	-1.23	*n/a*
February	n/a	0.66	*n/a*	n/a	-0.98	*n/a*
March	n/a	1.09	*n/a*	n/a	-1.76	*n/a*
April	n/a	0.72	*n/a*	-3.11	-0.36	***-2.75***
May	n/a	-0.50	*n/a*	-2.90	0.41	***-3.31***
June	n/a	1.88	*n/a*	-3.67	3.37	***-7.04***
July	-3.10 *(partial month)*	-2.87	*n/a*	3.92	7.35	***-3.43***
August	-1.75	0.01	***-1.76***	-3.14	-2.51	***-0.63***
September	-3.52	-1.73	***-1.79***	n/a	-0.72	*n/a*
October	1.72	3.08	***-1.36***	n/a	-0.83	*n/a*
November	-0.79	-0.90	***0.11***	n/a	-0.92	*n/a*
December	n/a	0.46	*n/a*	n/a	-0.65	*n/a*
TOTAL	N/A	1.02	N/A	N/A	1.17	N/A

Table A-3. Madison Departures from Average Conditions for 2009 and 2010 (1)

(All Precipitation Depths are in Inches)

		2009		2010	
	Average Madison Precipitation Depth (inches)	Precipitation Depth	Departure from Monthly Average	Precipitation Depth	Departure from Monthly Average
January	1.25	0.54	-0.71	0.88	-0.37
February	1.28	1.91	0.63	1.02	-0.26
March	2.28	6.91	4.63	0.71	-1.57
April	3.35	4.43	1.08	3.65	0.30
May	3.25	3.68	0.43	3.79	0.54
June	4.05	4.17	0.12	8.38	4.33
July	3.93	1.94	-1.99	7.98	4.05
August	4.33	2.49	-1.84	3.92	-0.41
September	3.08	4.68	1.60	2.65	-0.43
October	2.18	3.80	1.62	2.30	0.12
November	2.31	1.32	-0.99	1.09	-1.22
December	1.66	3.20	1.54	1.49	-0.17
TOTAL	***32.95***	***39.07***	***6.12***	***37.86***	***4.91***

(1) Source: National Climatic Data Center (NCDC) http://www.weather.gov/climate/index.php?wfo=mkx

Table A-4. Comparison of Milwaukee - Madison Departures from Average Conditons

(All Precipitation Depths are in Inches)

	2009			2010		
	Madison	Milwaukee	***Difference***	Madison	Milwaukee	***Difference***
January	-0.71	-0.88	***0.17***	-0.37	-1.23	***0.86***
February	0.63	0.66	***-0.03***	-0.26	-0.98	***0.72***
March	4.63	1.09	***3.54***	-1.57	-1.76	***0.19***
April	1.08	0.72	***0.36***	0.30	-0.36	***0.66***
May	0.43	-0.50	***0.93***	0.54	0.41	***0.13***
June	0.12	1.88	***-1.76***	4.33	3.37	***0.96***
July	-1.99	-2.87	***0.88***	4.05	7.35	***-3.30***
August	-1.84	0.01	***-1.85***	-0.41	-2.51	***2.10***
September	1.60	-1.73	***3.33***	-0.43	-0.72	***0.29***
October	1.62	3.08	***-1.46***	0.12	-0.83	***0.95***
November	-0.99	-0.90	***-0.09***	-1.22	-0.92	***-0.30***
December	1.54	0.46	***1.08***	-0.17	-0.65	***0.48***
TOTAL	***6.12***	***1.02***	***5.10***	***4.91***	***1.17***	***3.74***

As can be seen from Tables A-1 through A-4, several months were less than average conditions. These are summarized below in Table A-5 which shows that 7 of 9 months were below average in Muskego, 4 of 9 months were below average in Milwaukee, and 3 of 9 months were below average in Madison.

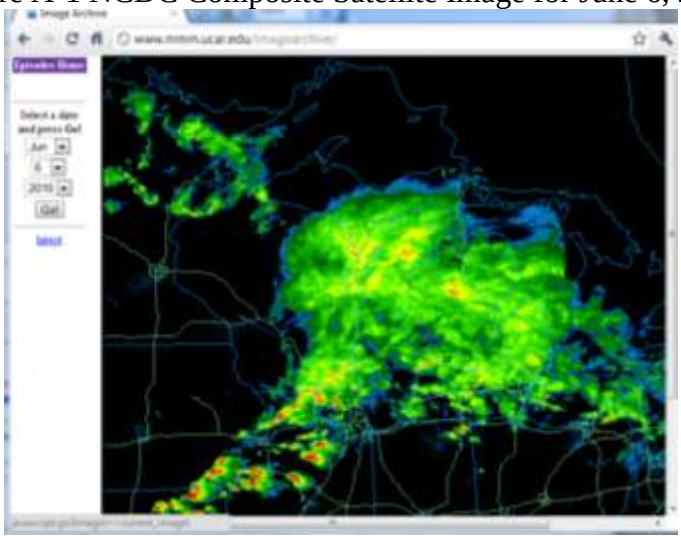
Table A-5. Comparison of Rainfall Departure from Average Monthly Values at 3 Gages

Complete Month	Muskego	Milwaukee	Madison
August 2009	Less	~ Equal	Less
September 2009	Less	Less	More
October 2009	More	More	More
November 2009	Less	Less	Less
April 2010	Less	Less	More
May 2010	Less	More	More
June 2010	Less	More	More
July 2010	More	More	More
August 2010	Less	Less	Less

The combined average depth of precipitation from April through June of 2010 at Muskego is over 10 inches, while the measured value is less than 1 inch. Hence, there is a 9.7 inch precipitation deficit for Muskego. In comparison, Milwaukee was 3.4 inches below average and Madison was 5.2 inches above average.

No rainfall was recorded in the last two weeks of May 2010. Yet the water level in the ditch and the lake rose over a foot in the last week of May and behaved in a manner consistent with a rainfall event. Similarly there was very little rainfall collected in early June of 2010 at the Muskego site, however, the water levels in the Muskego ditch system indicate a rainfall event occurred within the watershed on June 6, 2010. It is possible that rain could have fallen within the watershed, but missed the gage site. Review of the radar images from the NCDC for June 6 shows a large event that likely covered the area (see below in Figure A-1).

Figure A-1 NCDC Composite Satellite Image for June 6, 2010



In September 2009, no precipitation was recorded at the Muskego site. However, the water levels in the ditch and Big Muskego Lake show a long drawdown without a rainfall event. In addition, Milwaukee was also well below average.

Other rainfall events and the large event between July 22-24, 2010 (see Technical Memorandum No. 3 in Appendix C) are captured by the rainfall gage.

In conclusion, the rainfall gage at Muskego for the study did a good job collecting data for most of the record, and most importantly, the large event in late July 2010. The gage did not record anticipated rainfall events in May and June 2010. While it is possible that rain did not fall at the specific gage site (but elsewhere in the watershed) in May and June 2010, it seems unlikely. The tipping bucket rain gage and recorder is relatively simple and there is little opportunity for technical failure. Hence, the lack of rainfall data for this period is unexplained.

Water Level Data

As previously described, water levels in the ditches were measured using data loggers and the lake levels were measured at the outlet dam. The manufacturer indicated that the data loggers are constructed to perform in the site conditions of the study. However, the data loggers became plugged on three occasions with sediment and needed to be re-calibrated. In addition, the data logger at the 'Upstream Ditch' site was destroyed in late summer 2010. It is assumed that it was destroyed by farm equipment because it was destroyed when ditches are typically cut for hay.

The gage zero was calculated by surveying the water surface elevation and comparing that value for the recorded gage height at the same time. For example:

July 16, 2010 at 9:44 am surveyed water surface elevation = 771.88 ft
July 16, 2010 at 9:34 am the recorded gage height = 1.59 ft
So, gage zero = 771.88 – 1.59 = 770.29 ft

The water surface was surveyed several times in 2009 and 2010, hence the gage zero could be calculated or checked several times. Review of these calculations reveal some variance. This can be attributed to difficulty in measuring the water surface elevation (generally within a few hundredths of a foot), some limitations or error in the survey equipment or process, minor fluctuation in the data logger elevation, and some drift in the electronics of the data logger. As a result of this the gage zero ranged within a couple of tenths.

The water surface elevation at the Big Muskego Lake outlet was surveyed twice in 2010. The gage height was recorded by the USGS. The gage zero is reported by the USGS to be 760.0. The converted gage zero using the survey data was 759.48 and 759.56 accordingly. The difference between the USGS gage zero and the surveyed gage zero may be attributable to differences in the base benchmark information that is referenced (even though they are the same datum plane). The difference between the two surveyed gage zero elevation (0.08 ft) is an example of the error and uncertainty associated with measuring water surface elevations.

In conclusion, the water surface elevations are considered to generally within approximately a tenth of a foot.

Appendix B

Technical Memorandum No. 1

Concord Ecological Engineering, Inc

N6424 High Mound Road
Concord, WI 53178
Ph (262) 443-9980
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Technical Memorandum

To: Ken Ward, P.E. Project Manager - Ruekert and Mielke Associates

From: Marty Rye, P.E., CFM - Concord Ecological Engineering, Inc.

CC: Dave Simpson, P.E., Muskego City Engineer / Coordinator of Public Works Projects

Date: September 4, 2009

Re: Technical Memorandum No. 1 – Watershed Description and Geomorphic Assessment, Big Muskego Lake South Inlet Ditch, City of Muskego

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Problem Definition:

Several residents along Loomis Drive have expressed concern to the City of Muskego regarding nuisance flooding within the watershed of a ditch system southeast of Big Muskego Lake. In addition high water levels have caused inconveniences and damages to the Muskego Lakes Country Club golf course (Rye, 2009). In response to these concerns, the City of Muskego has commissioned a study to provide additional understanding of the hydrologic, hydraulic, and fluvial geomorphic processes in the watershed. This understanding will provide the basis for developing an approach to address the issues in the future.

Executive Summary:

A brief summary of this technical memorandum is provided below:

- The ditch system is stable, free of obstructions, and there is no major erosion.
- The dimensions of the ditch are a function of the chosen excavation limits as opposed to the reflection of natural fluvial processes. There appears to be little sediment supply, transport, or deposition.
- The project area is generally flat, with tight soils, a relatively high water table that flows from Big Muskego Lake to the southeast toward the Root River valley and then eventually to Lake Michigan. It is the remnant of a historic lake (lacustrine deposition).
- The water surface elevation collected on the date of the survey indicated essentially a flat water surface from the lake upstream through the limits of assessment.
- Review of data from the U.S. Geological Survey at Wind Lake indicates that 2007 and 2008 were wetter than previous years.
- There are three (3) water surface data loggers and one (1) tipping bucket rain gage installed on the ditch system.

DRAFT

Background:

Physical Setting:

The watershed for the ditch system is approximately 2,390 acres (3.7 square miles) and extends to the south into Racine County as shown in Figures 1. The flow is generally to the north and there are several laterals or tributaries to the main ditch system. It flows into Big Muskego Lake which is a eutrophic shallow lake / type 5 wetland approximately 2,260 acres in size (WDNR, 1991). It is described as a *"shallow bod*[y] *of water, now rapidly being extinguished by the immense swamps that surround them*." (Martin, 1965). It is controlled by a concrete weir and small slide gate at its outlet as shown in Figure 3 whose operation was taken over in 1965 by the City of Muskego. The outlet elevation is listed as 771 on the USGS quadrangle (unknown reference benchmark / datum plane – though generally 1929 datum plane) as shown in Figure 4. Flow from Big Muskego Lake continues south until it eventually drains into the Fox River.

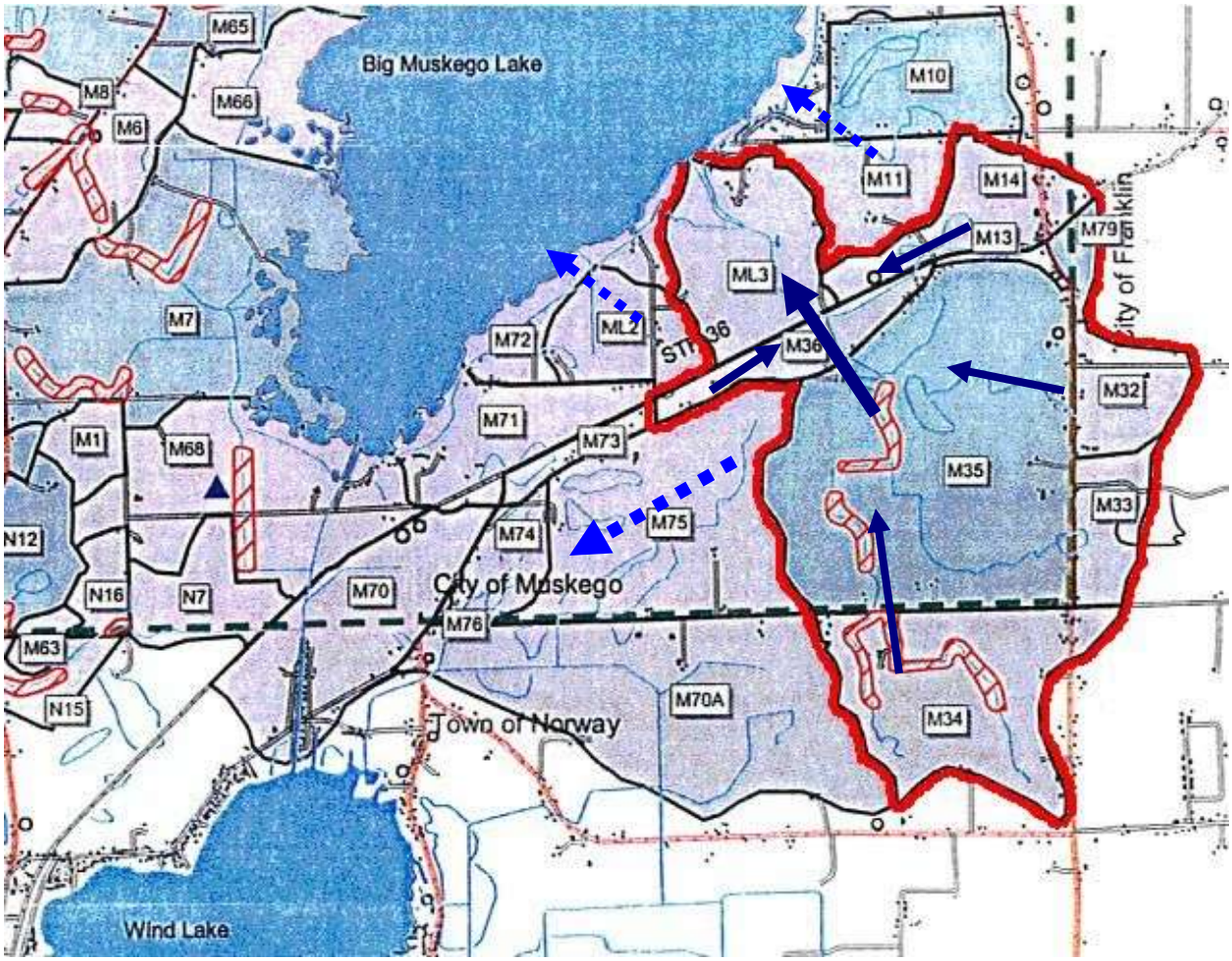


Figure 1 . Big Muskego Lake South Ditch Drainage Area
Source: Muskego Surface Water Management Plan (Earth Tech, 1998)

Figure 2. Big Muskego Lake Outlet

Figure 3. USGS Quadrangle Map Showing General Ground / Muskego Lake Elevations

General Description of Geology:
The glacial history is generally described in Southeastern Wisconsin Regional Planning Commission (SEWRPC) Technical Report 37 (SEWRPC, 2002) which states, "*There is evidence of several stages of glaciation in the Region. The last and most influential in terms of present physiography and topography was the Wisconsin stage, which is believed to have ended in the Region about 11,000 years ago.*" The general physiographic features of the area are shown below in Figure 4 and of the project area in detail in Figure 4a. As can be seen from these figures, the project area is shown as part of the "level organic" region.

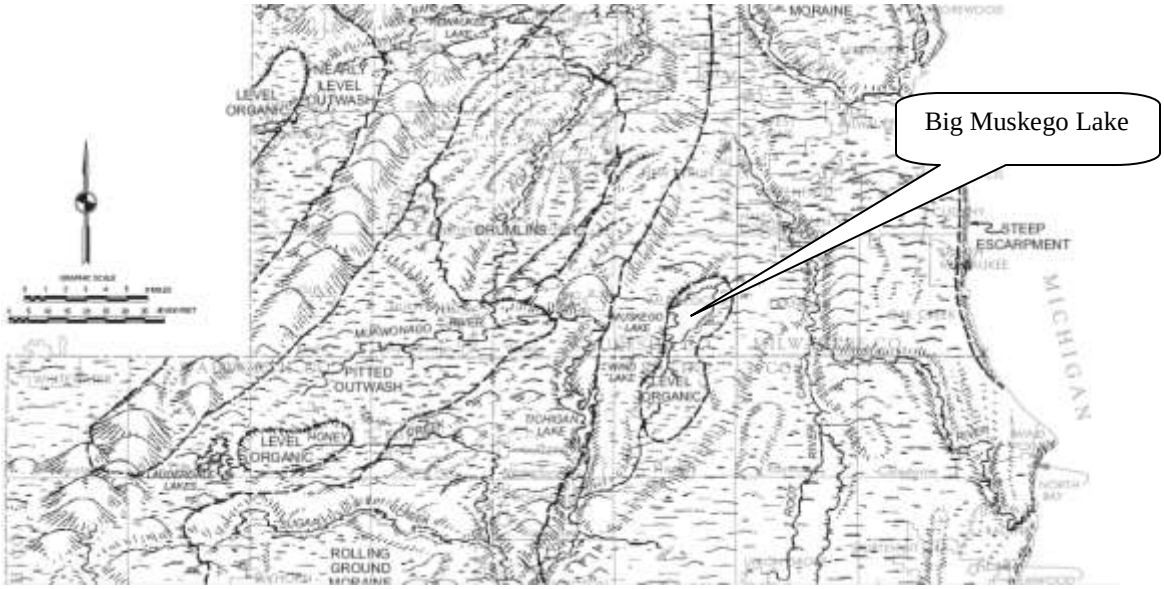


Figure 4. Physiographic Features of the Area (from Figure 8 in SEWRPC, 2002)

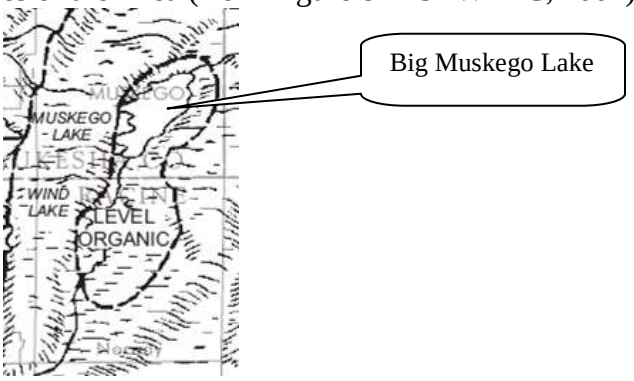


Figure 4a. – Detail of Project Areas shown in Figure 4

The depth to bedrock in the area appears to be over 200 ft.

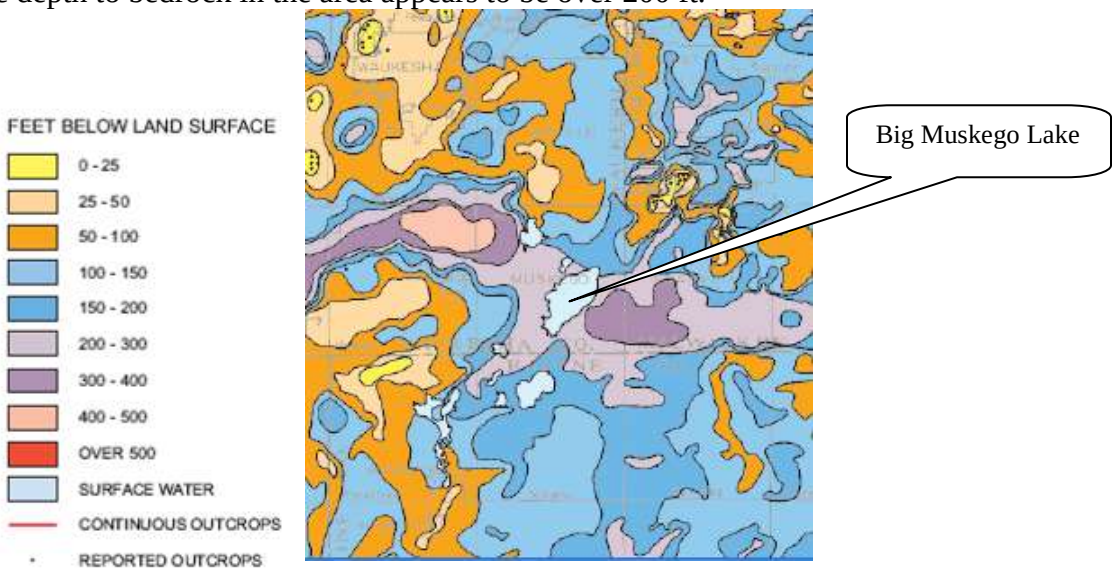


Figure 5 – Depth to Bedrock (source: SEWRPC, 2002)

Soils:
The soils of the watershed are described in the Soil Survey of Milwaukee and Waukesha County (USDA, 1971). The watershed is dominated by the Montgomery-Martinton-Mequon-Hebron-Saylesville soil association as shown in Figure 6

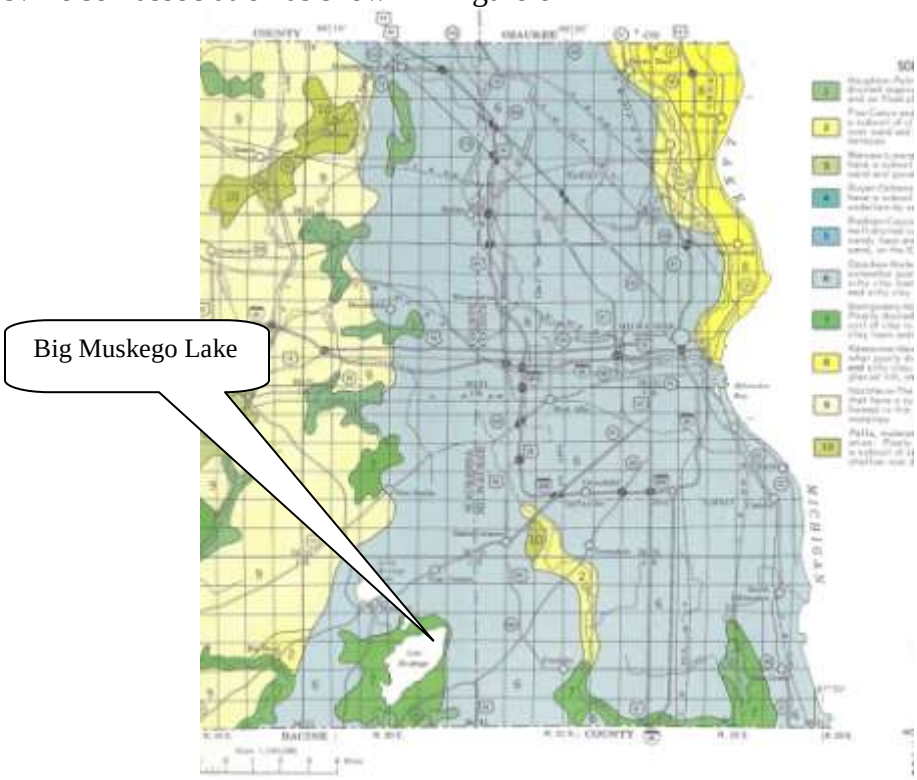


Figure 6. General Soil Map (USDA, 1971)

This association is described as *"poorly drained to well-drained soils that have a subsoil of clay to clay loam; formed in silty clay or silty clay loam sediments, in old lakebeds"*. The clay soil is a result of deposition of sediment in a glacial lakebed (a larger version of Big Muskego Lake).

The land near the residents expressing concern near Loomis Drive is dominated by gently sloping (1-3 percent) Martinton silt loam (MgA) and Sawmill silt loam (SgA). These soils are described has having a seasonally high water table (1 to 3 ft from the surface) and relatively low permeability. The native vegetation of the Martinton soils were "*mainly water-tolerant grasses, but it included a few scattered oak and elm trees*". The Sawmill series' native vegetation "*was water-tolerant grasses and sedges*" and it is generally described as "*silty alluvium, are poorly drained, and are subject to flooding*". Both of these soil series contain clay components.

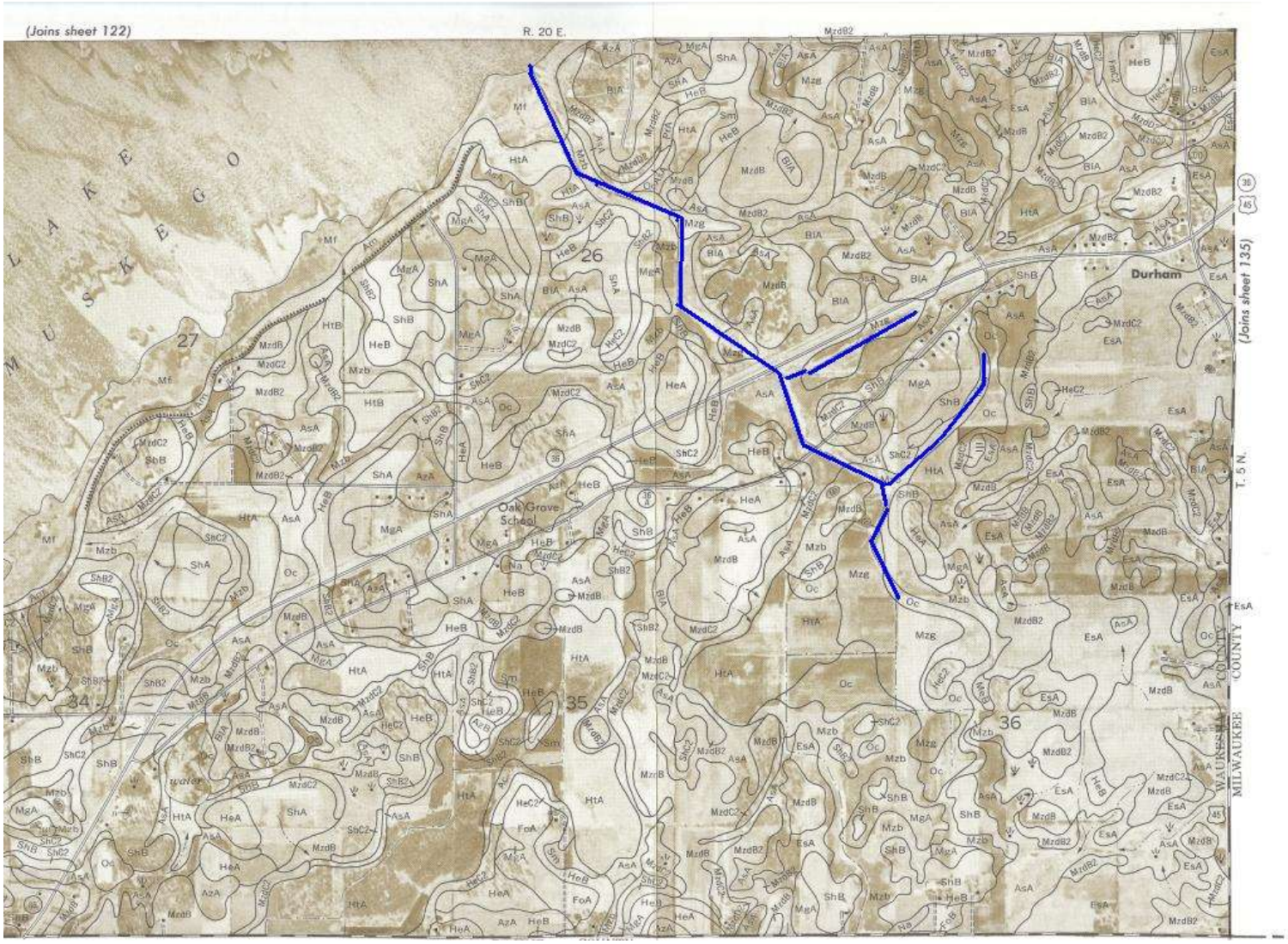


Figure 7. Soils near Loomis Drive (USDA, 1971) – with ditch section highlighted

Local Water Table / Groundwater Elevations and Gradient:
The water table elevations are shown in Figure 8 (Waukesha, 2009). This map was developed by the Wisconsin Geological and Natural History Survey staff (date of mapping listed as 1996 through 1998) from "field notes and other sources of information (See SEWRPC Technical Report Number 37, "Groundwater Resources of Southwestern Wisconsin")". As can be seen from this figure, the general flow pattern is to the east / southeast from Big Muskego Lake (with a listed outlet elevation of 771). The general flow is to the Root River Valley and eventually discharging into Lake Michigan which has a general range of elevation between 575.1 and 585.5 (USACE, 2009).

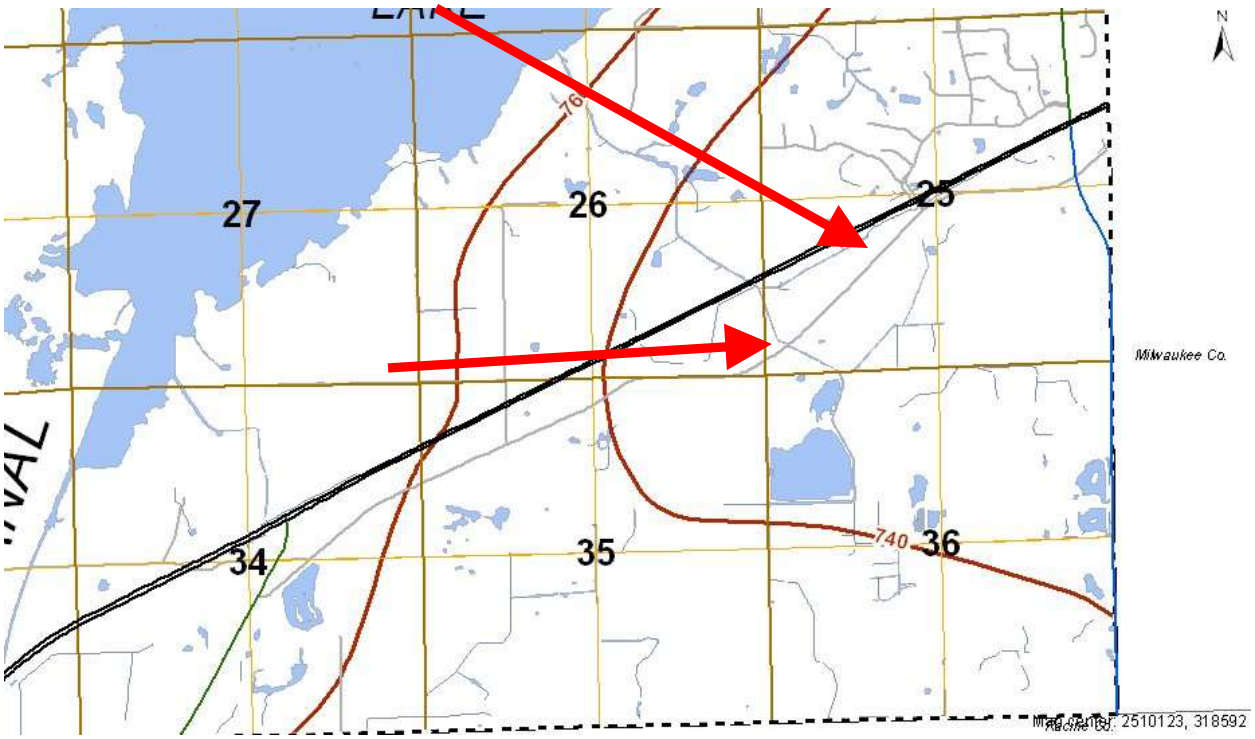


Figure 8. Local Water Table Elevations / Flow Patterns (Waukesha, 2009)

Land Use:
Pre-contact vegetation consisted of an oak savannah. The area was settled in the mid 19th century and cleared for farming. The majority of the drainage area is presently farmed in row crop or grasses. There is a golf course (Muskego Lake Country Club), landfill, and residential housing also within the watershed.

Summary of Previous Studies / Available Information:

Surface Water / Local Water Table Elevation Data

There are no known active gages on the ditch system / watershed. However, there were several staff gages noted during the field visit. One of them is near the "bridge" data collector described below. The data from these gages and local piezometers (assumed to be associated with the landfill) were unavailable with one exception.

Historic readings from a well were provided by the Emerald Park Landfill. The data was labeled from a well "MW-001A". It is unknown what formation the well is completed. However, sporadic data is available from 1988 to 2007 and is summarized in Table 1 below.

Table 1. Data from local monitoring well near landfill
Source: Veolia Environmental Services, Inc.

Value	**Elevation (Unknown Datum)**	**Date**
Highest Recorded	812.75	5/22/1996
Lowest Recorded	762.64	3/22/2007
Range (ft)	50.11	-----

Note: a value of 739.39 was eliminated as a probable error in the data

The very large range of values (over 50 ft) indicates this may be reflective of local landfill operations and not necessarily reflective of regional groundwater patterns. It is unlikely the regional water table fluctuates this much and the data should be applied with caution.

There is also a gage at the outlet of Big Muskego Lake. As with the staff gages within the ditch system, data associated with this gage has not been found to date.

The U.S. Geological Survey (USGS) maintains a gage at Wind Lake downstream of Big Muskego Lake. This collects daily lake level readings. Partial data is available from 1985 to present and average annual gage heights (or lake levels) are available since 1992. This information is useful in determining general trends and is essentially a surrogate for the *volume of runoff* within a watershed. Since the downstream portion of the ditch system is a lake the volume of runoff controls its elevation (and hence has a major impact on the elevation within the ditch) and is relative to this study. As can be seen from Figure 8 below, there has been a general upward trend in water surface elevations at Wind Lake. Of note is the highest average annual lake elevation was recorded in 2007.

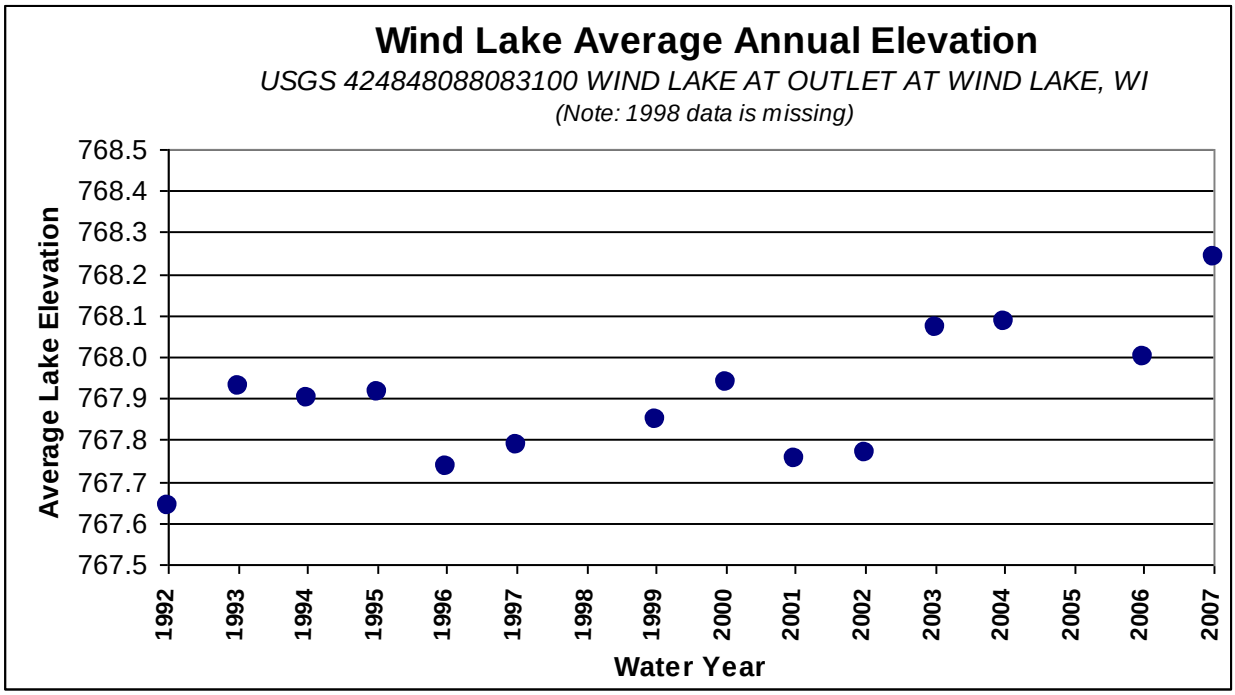


Figure 9. Average Annual Elevation of Wind Lake (USGS, 2009)

The instantaneous highest peak elevation was recorded as 770.02 (gage height of 9.98) on January 2, 1996. However, this occurred during the drawdown of Big Muskego Lake which occurred between October 1995 and April 1997 and summarized below (James, 2001).

Table 2. Summary of Big Muskego Lake Drawdown

Action	Date
Initiated Drawdown	October 1995
First Phase of Drawdown (lowered 0.5 meters)	December 1995 – mid-July 1996
Second Phase of Drawdown (lowered 0.5 meters)	July 1996 – January 1997
Begin Refilling Process	Late winter / early spring 1997
Lake is Refilled	April 1997

Daily data for the 2008 water year is shown below indicates the highest recorded elevation was nearly reached on June 14, 2008 at elevation 769.9 (gage height of 9.86) as shown in Figure 9. Since water years 1996 and 1997 should be considered an anomaly due to the Big Muskego Lake drawdown and re-filling, the highest recorded elevation under "normal operating conditions" actually occurred in 2008.

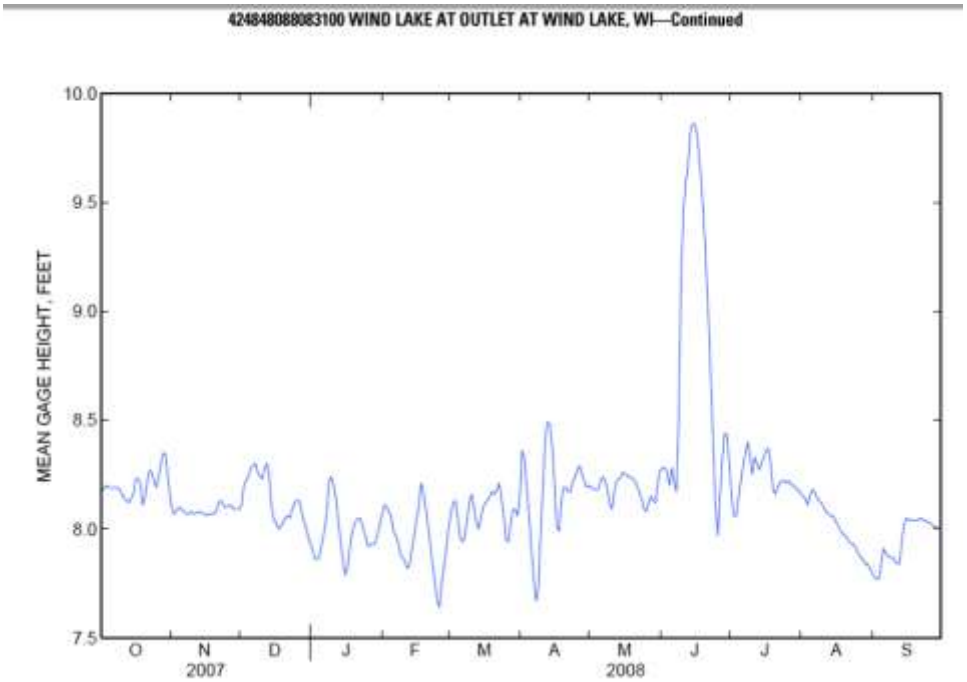


Figure 10. Wind Lake Gage Height for Water Year 2008
(Note: Gage Height = 760.04…….so, gage height 9.0 = 769.04)

The summer of 2009 continues to be above average as shown below in Figure 10.

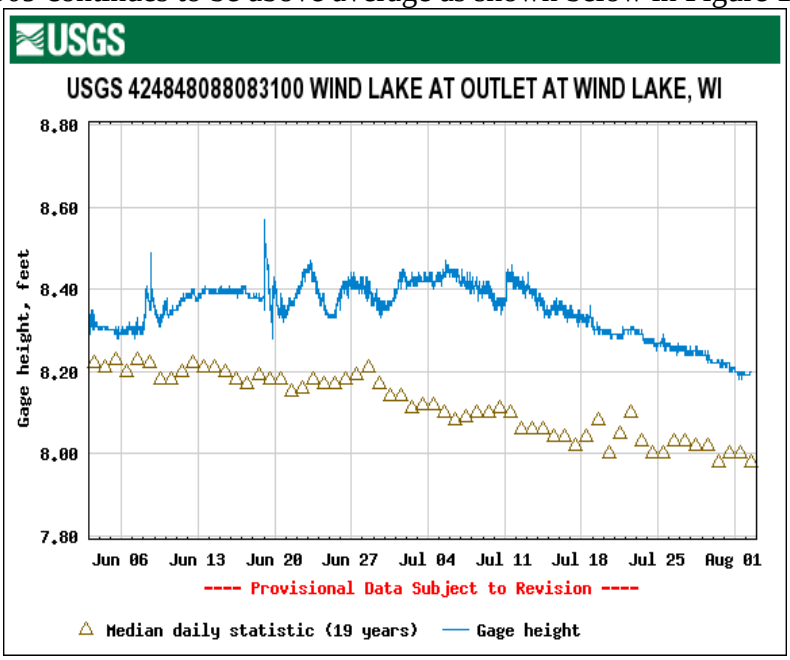


Figure 11. Wind Lake Data for the Summer of 2009

Other Studies

In addition to the previously mentioned studies, the following studies / investigations are known:

- A comprehensive study of the Fox River basin was completed in 1969 and some of the information within that report was included in this memorandum. The information in the is report tended to be directed to a larger scale and there was little specific information related to the drainage system under study.

- As part of the National Flood Protection Act (NFPA), a regulatory floodplain has been established that delineates the "100-yr floodplain" from Big Muskego Lake as elevation 774. However, the limits of the zoning and detailed study do not extend south of Loomis Road.

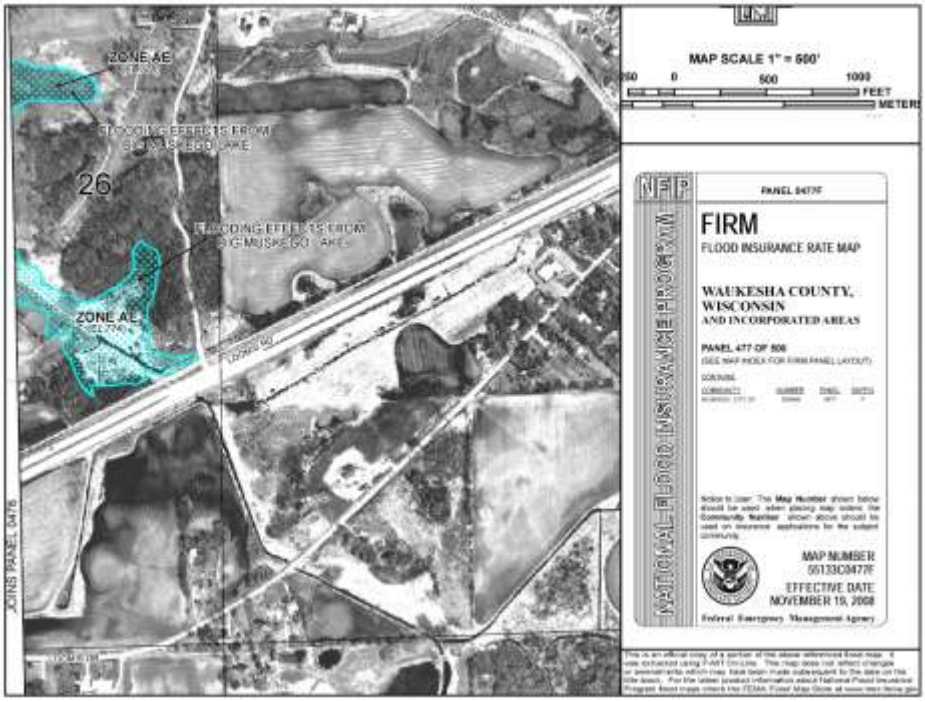


Figure 12. FEMA 'Firmette' of Project Area

- It is assumed there have been historic studies developed for the landfill siting (and subsequent expansion). The staff gages are assumed to have been part of these efforts.

- A brief oral history was provided by City staff and one of the residents on Loomis Drive. There are nuisance flooding concerns along the 'backyards' of residents on Loomis Drive including the homestead keeping horses along the mainstem of the ditch. These flooding concerns have been more pronounced in the last 2-3 years. Additional details may be provided by subsequent conversations with long-time residents.

- Background information provided by Ruekert-Mielke regarding drainage in the area, including:
    - Minutes of 9/1/1994 City of Muskego Emerald Park Landfill Standing Committee which includes discussions regarding the maintenance of the ditch which include the following comments (Muskego, 1994).
        - The ditch was last cleaned out in the 1960's
        - The City used to clean it out and levy the expense to property owners
        - It was confirmed that there has always been flooding issues in the area due to the low nature of the land – which is why one resident constructed a berm
        - It was stated the Big Muskego Lake dam *height* had not changed since the 1920's
        - Impacts to the wetlands were recognized as an issue / concern
        - The ditch condition was summarized, including:
            - The ditch is very flat with a slope of less than a foot per mile
            - The (old) box culvert under Hwy 36 were a concern
            - The wooden foot / snowmobile bridge downstream of Hwy 36 was recognized as a potential restriction
            - The golf course had dredged out the ditch and "*there is almost no fall to make the water drain from one to the other*"
            - There was discussion regarding the transition between the ditch outlet and the lake
    - Results of an August 28, 1994 survey with the following observations (Ruekert-Mielke, 1994):
        - The water surface is flat between Big Muskego Lake and Loomis Drive (old Loomis Road)
        - There is about a foot of difference in the water surface between Loomis Drive and a point *approximately* 2800 ft upstream of the crossing (within the landfill property) – however, the ditch elevation was flat. So, there was approximately 0.3 ft of standing water at Loomis Drive, while there was approximately 1.3 ft of standing water upstream at the landfill.
        - There was no flow stated as part of the survey
    - Summary of 1997 ditch improvement project (Ward, 1997) which included:
        - Replacement of the Hwy 36 culvert
        - Minor dredging upstream
        - It was noted the 'canal' was originally constructed in 1945
    - Engineering plans for the dredging of approximately 800 ft of channel upstream of Old Loomis Road crossing to a bottom elevation of 770.0 (Ruekert-Mielke, 1996). The plans show minor changes to the invert elevation, hence, it is assumed the project widened the channel bottom.

- Report on the Southeast Drainage Canal Tributary to Big Muskego Lake (Ward, 1994) which summarizes an investigation of the ditch system which states:
    - There may be an ice ridge at the mouth of the canal that impedes flow
    - The foot (snowmobile) bridge downstream of Hwy 36 impedes flow
    - There is a shallow ditch bottom between Hwy 36 and Old Loomis Road
    - There are twin culverts above the confluence of the East Lateral and the mainstem of the ditch that should be removed after the downstream issues are addressed *(note: it appears these have been removed and replaced with a bridge – location of water level logger for this investigation).*

- The City of Muskego has a Stormwater Management Plan completed in 1999 that provided additional information on the local drainage and guidance for development of the City.

<u>Anthropogenic Modification to Drainage System:</u>
The ditch system appears on historic aerial photos and although there is not a formal drainage district, it is recognized as an area of significant farm drainage activity in the Comprehensive Plan for the Fox River Watershed (SEWRPC, 1969) as shown below in Figure 13.

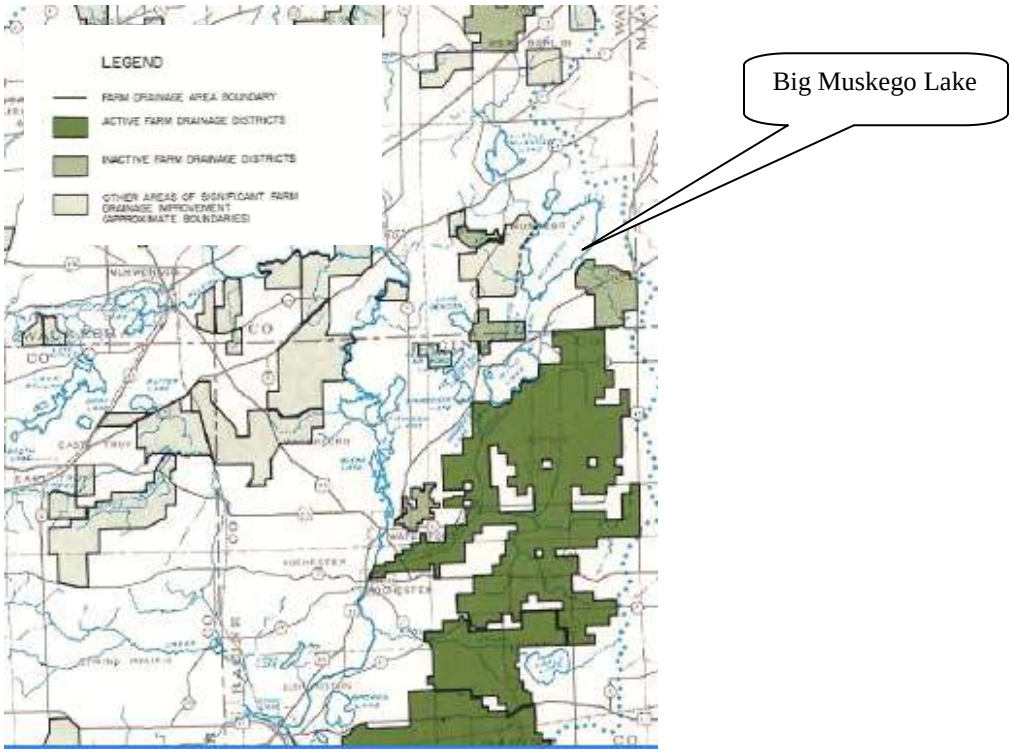


Figure 13. Drainage Activity as Shown in (SEWRPC, 1969)

In addition to the agricultural and residential land development activity mentioned above, additional modifications are discussed within the reach summaries and in summary of 'Other Studies' provided above.

Results of Qualitative Fluvial Geomorphic Assessment:

The characteristics and variability of stream systems can be *generally* described by their hydrologic, geomorphic, and vegetative regimes (Montgomery, 2003). Streams can be separated into reaches based upon differences in these regimes and the management issues which drive the analysis. The ditch system analyzed herein does not lend itself to these traditional modes of description and is generally homogeneous through the observed reaches. A field survey was performed on July 8, 2009. The weather was sunny and it had not rained for several days. While not specifically measured, the discharge in the ditch at the time of the survey was observed to be essentially 0 cfs. The outlet dam of Big Muskego Lake was also observed. The slide gate on the left bank was partially opened and the flow out of the lake was estimated to be less than 3 cfs. There was some floating bog noted on or near the outlet dam. The presence of these bog mats can impact the effective weir length and outlet rating curve of the dam. Hence, review of historic and future discharge estimates should take this into consideration.

Based upon the field review, the following statements can be made about the entire stream (ditch) length:

- **The system has been excavated**. It's existence, width and depth are dependant upon the excavated dimensions. While the width varies, it is much wider than may be expected in a natural system associated with the drainage area and hydrologic setting. It's main purpose appears to have been / continues to be to provide drainage to surrounding upland uses. Hence, it can generally be termed a 'ditch'.
- **The ditch is flat.** There is very little slope on the ditch system. A detailed invert slope was not determined. However, water surface elevations were collected throughout the observed reaches. The hydraulic gradient (water surface slope) was essentially zero. In fact, there was some negative slope on the water surface at some locations. This may due to inherent inaccuracies associated with attempting to estimate the water surface elevations and subtle differences in local soil transmisitivities (some water can soak into the banks). The flat slopes can be expected based upon the general setting as described above.
- **The banks are stable**. The ditch is a very low energy system that is generally overwidened by excavation and the banks are generally well-vegetated. The was no erosion of the banks noted during the site investigation. In addition, the ditch bottom is generally covered with submerged aquatic vegetation.
- **There is very little 'in-stream' habitat**. The system is really lotic (stream-like) rather it can generally be described as a backwater of Big Muskego Lake. There are no riffles, pools, or other characteristics associated with stream conditions. In addition there is essentially no large wood within the ditch system that provide habitat complexity.
- **There is limited hydraulic resistance**. The channel is generally smooth and free of hydraulic obstructions (woody debris jams, beaver dams, etc.).
- **The ditch is aggradional (filling in).** There is very little bed load sediment in this low energy system. No bar formation was observed and there was little bank sediment supply from the main channel or tributaries. The bed is filling in with sediment from local fields and accumulation of detritus from in channel vegetation. This appears to be a relatively slow process.

Selected Photos / Notes from Geomorphic Site Investigation:

The following selected photos and notes from the fluvial geomorphic site investigation are provided below. An ArcMap coverage with the photos and locations is provided separately from this memorandum to the City for their records and future use. The stream (ditch) is generally pretty homogeneous through the inspected reach, but it has been separated into 4 distinct reaches for the purposes of this memorandum. These reaches are shown below in Figure 13.

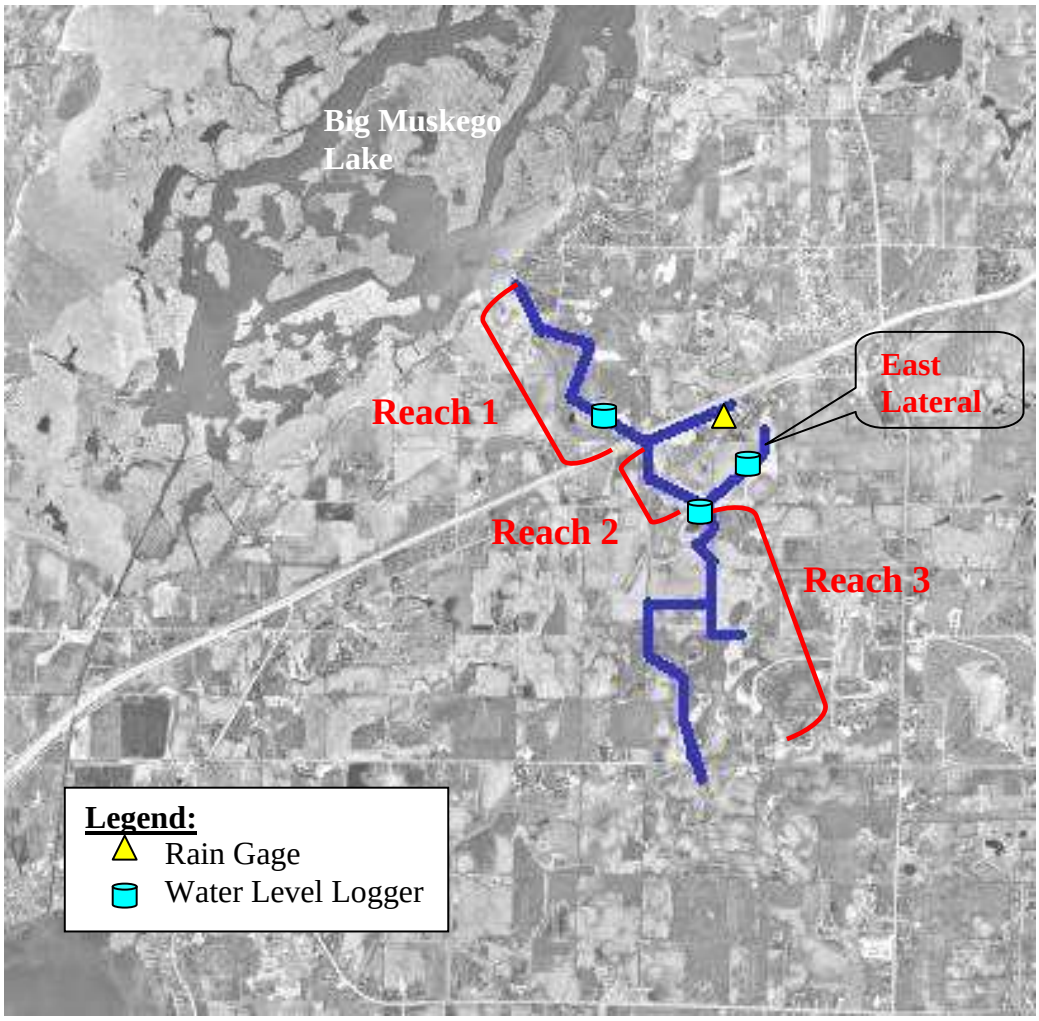


Figure 14. Reaches of Ditch System

Reach 1: Mouth to Trail Crossing north of Hwy 36

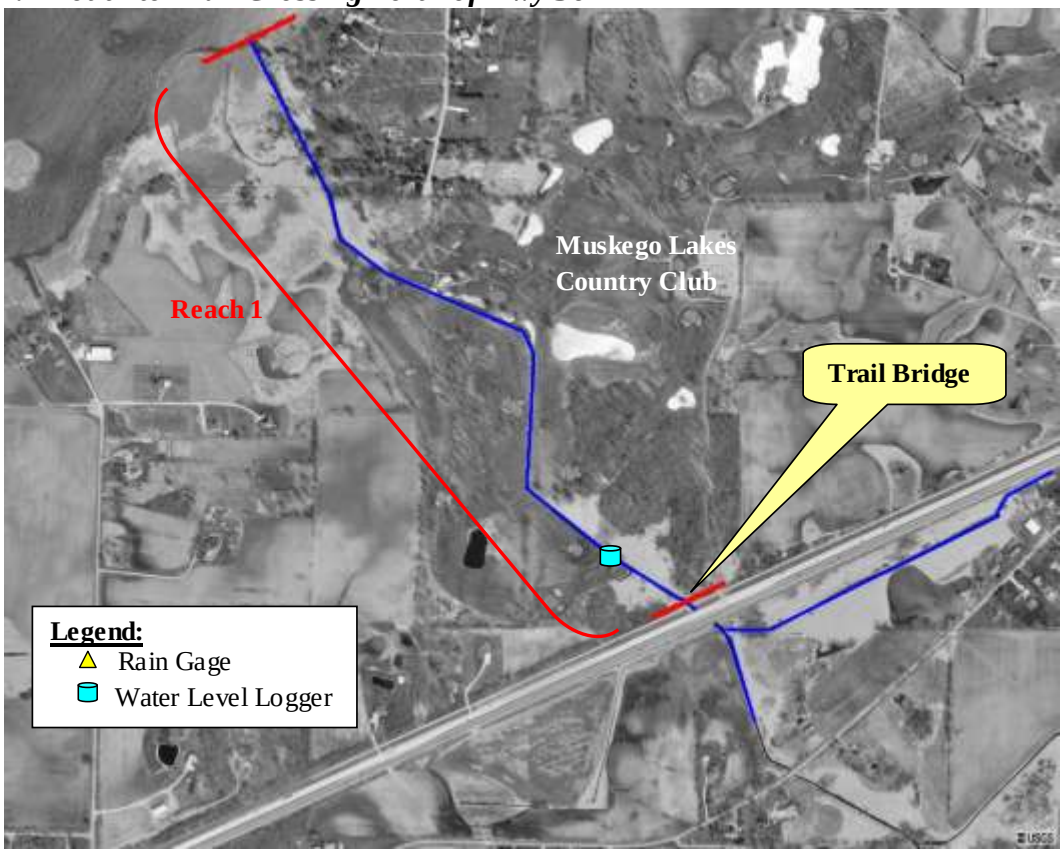


Figure 15. Aerial Photo of Reach 1

Description of Reach 1

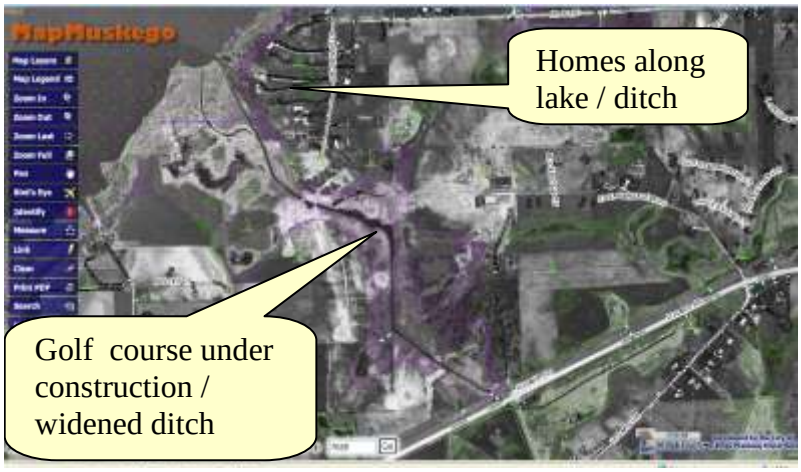
Reach 1 extends from the mouth to the trail bridge downstream of Loomis Road. As described above, the ditch section appears as a straightened constructed alignment on the 1941 aerial photo. The direct land use remains dominated by open space / agricultural use. The Muskego Lakes Country Club appears under construction in the 1970 aerial photo. As a part of this construction the ditch section was widened.

The discharge on the date of survey (July 8, 2009) was very close to 0 cfs. Hence, the surveyed water surface elevation throughout the reach was the same as Big Muskego Lake. The reach hydraulics appear to be dominated by Big Muskego Lake. The constructed section is overwidened and deepened due to excavation. There were no observed spoil banks (though there may be some downstream of the golf course on the left bank facing downstream). There was no woody debris observed in the reach. The channel is covered with rooted aquatic vegetation indicating very low flow velocities. The channel is crossed several times with private crossings. The crossings in the golf course do not appear to be an impedance to flow because the low member is near the top of the bank and the wide / well connected floodplain. One private crossing downstream of the golf course could impede 'intermediate' flood flows as a blockage to flow and reduction in channel capacity (see photos in Figure 19).

The riparian cover is dominated by grasses. These are mown to the water's edge in portions of the golf course and some private lawns downstream of the golf course. However, there is no observed erosion and the banks are stable.

Selected Aerial Photos / Modifications to Reach 1

1941



1970

2005

Figure 16. Selected Aeerial Photos of Reach 1

Selected Photos of Reach 1: Mouth to Trail Crossing north of Hwy 36

Figure 17. Mouth of System at Big Muskego Lake

Figure 18. Upstream of Mouth of System at Big Muskego Lake – Photo taken facing upstream

Figure 19. Downstream of Golf Course – Photo taken facing upstream – note private crossing

Figure 20. Downstream of Golf Course Photo taken facing downstream

Figure 21. Facing downstream from Golf Course Limit (bridge)

Figure 22. Facing upstream from Golf Course Limit (from bridge)

Selected Photos of Reach 1: Mouth to Trail Crossing north of Hwy 36

Figure 23. System within Golf Course – facing downstream – note: widened section

Figure 24. System within Golf Course – facing upstream – note: widened section in foreground

Figure 25. Section within Golf Course
Note straightened section, no ditch spoil, mowed to edge Photo taken facing upstream

Figure 26. Section within Golf Course
*Note: Crossings in background (no real impedance to flow)*Photo taken facing downstream

Figure 27. Facing downstream from the Water Level Data Collector

Figure 28. Facing downstream – Trail bridge in foreground. *Note: low member elevation collected during the site investigation*

Reach 2: Trail Crossing north of Hwy 39 to "Bridge" / Confluence with East Lateral

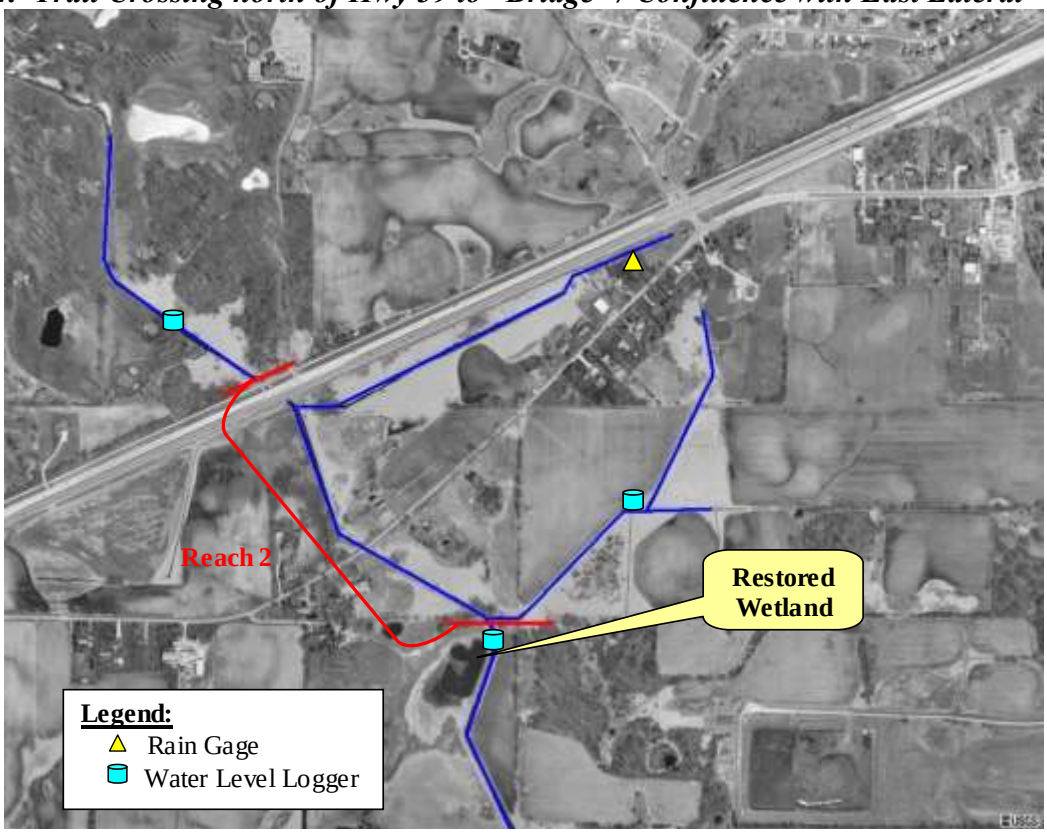


Figure 29. Aerial Photo of Reach 2

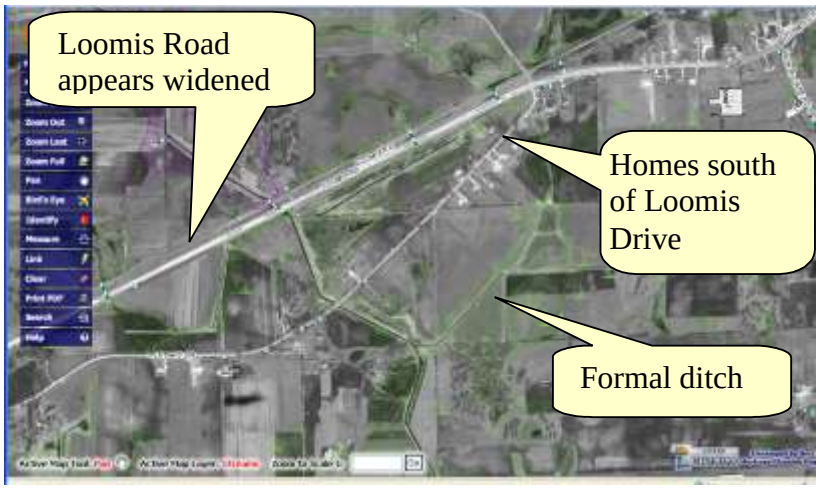
Description of Reach 2

Reach 2 extends from the foot / snowmobile bridge downstream of Hwy 36 to the confluence of the mainstem with the East Lateral. The constructed ditch section has been modified in the late 1990's with the replacement of the culvert beneath Hwy 36 and the minor dredging project. There is a ditch lateral that enters the reach from the northeast and another from the southwest. The southwest lateral drains land between Hwy 36 and Old Loomis Road. The northeast lateral drains land a portion of land north of Hwy 36. These tributaries or laterals express the same characteristics as the mainstem. In short, they are straightened, low-energy excavated channels, whose banks are stable and dominated by grasses.

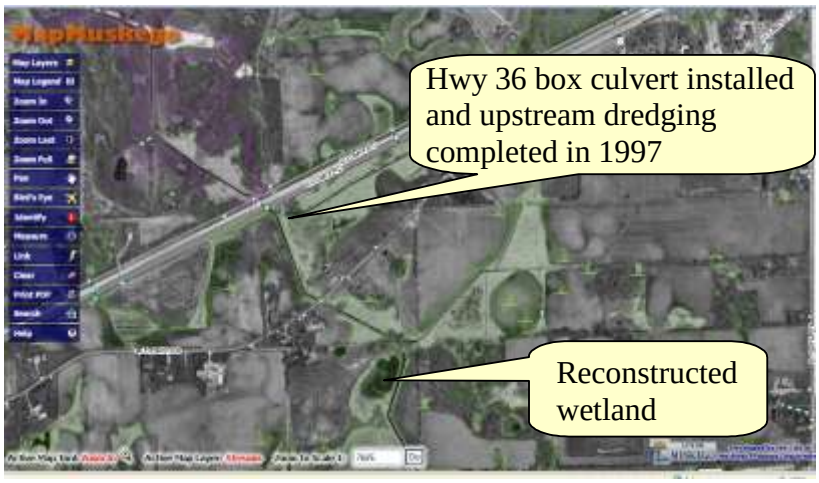
The discharge on the date of survey (July 8, 2009) was very close to 0 cfs. Hence, the surveyed water surface elevation throughout the reach was the same as Big Muskego Lake. As with Reach 1, the reach hydraulics appear to be dominated by Big Muskego Lake. The constructed section is overwidened and deepened due to excavation. There were no observed spoil banks. There was no woody debris observed in the reach. The channel is covered with rooted aquatic vegetation indicating very low flow velocities. The footbridge/ snowmobile crossing appears to restrict hydraulic conveyance at high flows and may have an impact on upstream flood to elevations during infrequent runoff events. This may increase the upstream flood damage potential. The modification (raising) of this bridge should be considered to reduce upstream flood damage potential. A more detailed study would be needed to evaluate the benefits and design of a modified crossing.

Selected Aerial Photos / Modifications to Reach 2 and East Lateral

1941



1963



2000

Figure 30. Selected Aerial Photos of Reach 2 and East Lateral

Selected Photos of Reach 2: Trail Crossing north of Hwy 36 to East Lateral Confluence

Figure 31. Downstream end of Loomis Road crossing (Hwy 36)

Figure 32. Upstream end of Loomis Road (Hwy 36) crossing

Figure 33. Facing upstream from Loomis Road (Hwy 36) crossing – note the branch to the lateral between old and new Loomis in the background

Figure 34. Facing upstream from Loomis Road (Hwy 36) – section between Loomis Drive and Loomis Road (old and new Loomis)

Figure 35. Facing west (downstream) from the Fire Station at Loomis Drive – ditch tributary

Figure 36. Facing downstream from Loomis Drive (old Loomis)

Selected Photos of Reach 2: Trail Crossing north of Hwy 39 to East Lateral Confluence

Figure 37. Upstream side of Loomis Drive crossing

Figure 38. Facing upstream from Loomis Drive crossing

East Lateral: Confluence with Mainstem to Limit south of Loomis Drive

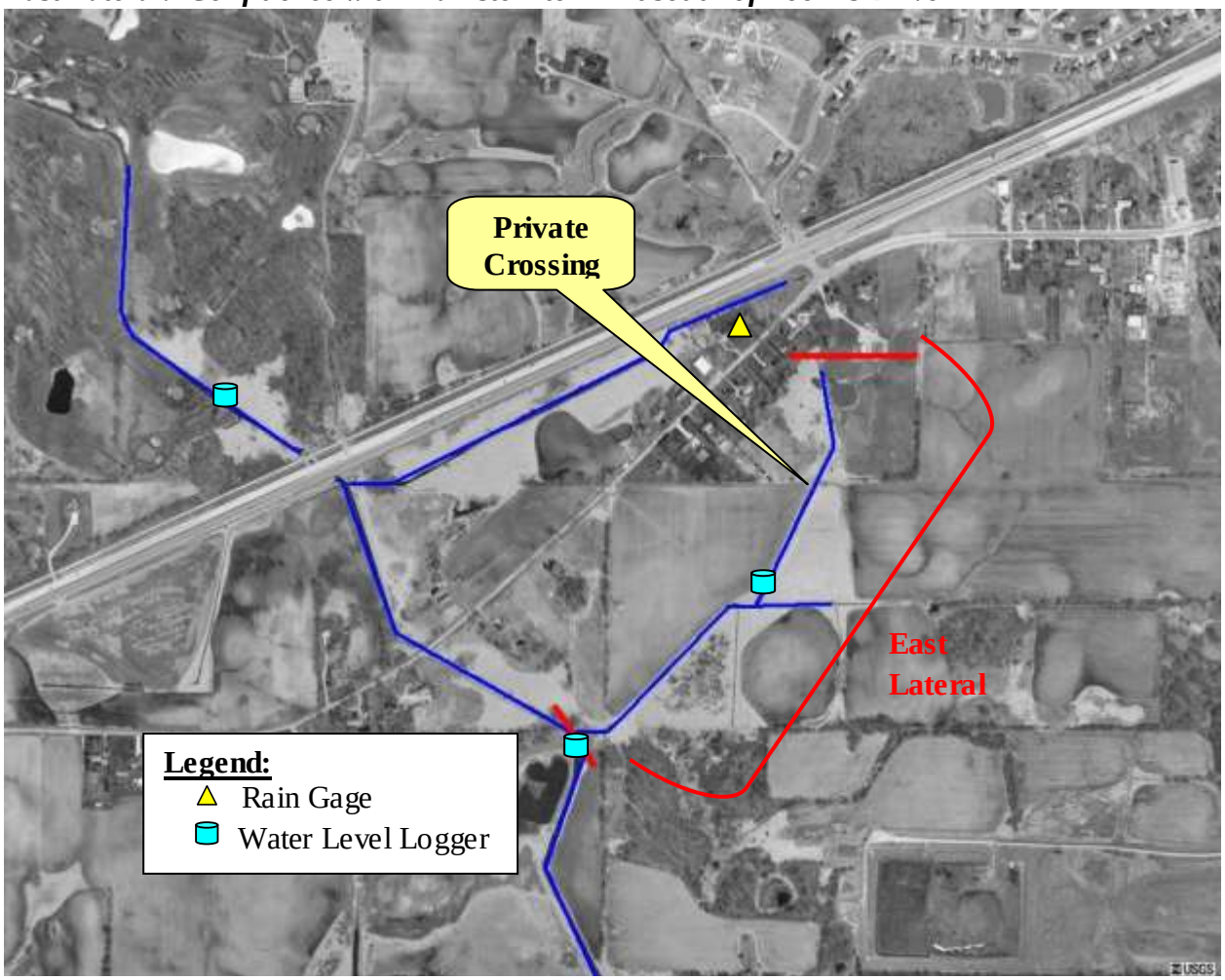


Figure 39. Aerial Photo of East Lateral

Description of East Lateral:
The East Lateral flows to the southwest to the mainsteam near the water level logger shown in Figure 39. There are several minor laterals that discharge into the mainstem. The mainstem splits to the north (termed northern minor arterial in photos below) near the water level logger. This northern branch drains the 'backyards' of the homes on Old Loomis Road (Loomis Drive). The water level in this branch have been the subject of concern to local residents.

Overall, the East Lateral is consistent with the other reaches in the system. It is a constructed, over-widened, low-energy ditch system with little erosion and whose banks are dominated by grasses. There is a private crossing of the lateral that is in disrepair and may impede some flood flows. Consideration should be given to the removal / replacement of this crossing. Overall, the land used within this catchment has been consistently agricultural in the last century. There were no signs of deposition or significant erosion in the lateral. The flow is intermittent and was near 0 cfs on the date of the survey. The measured elevation on the date of the survey was consistent with the elevation in the mainstem. Some additional history on the maintenance of the ditch is provided in the 'Other Studies' section of this report.

Selected Photos of East Lateral:

Figure 40. Facing downstream near the confluence with the mainstem - note presence of rooted aquatic vegetation and algae

Figure 41. Facing upstream near the confluence with the mainstem – note cornfield in left background

Figure 42. Facing downstream – upstream of confluence with mainstem

Figure 43. Same location as Figure 42 – facing upstream

Figure 44. Facing downstream (west) near water level data logger

Figure 45. Facing east (upstream) of minor eastern lateral near water level data logger

Selected Photos of East Lateral:

Figure 46. Facing downstream northern minor lateral (from water level data logger to private crossing as shown in Figure 39)

Figure 47. Facing upstream northern minor lateral (from water level data logger to private crossing as shown in Figure 39)

Figure 48. Private crossing in foreground

Figure 49. Private crossing on northern minor lateral of East Lateral (see Figure 39)

Figure 50. Facing upstream from private crossing (northern minor lateral)

Figure 51. Excavated pond at headwater of northern minor lateral

Reach 3: Trail crossing north of Hwy 39 to "Bridge" / Confluence with East Lateral

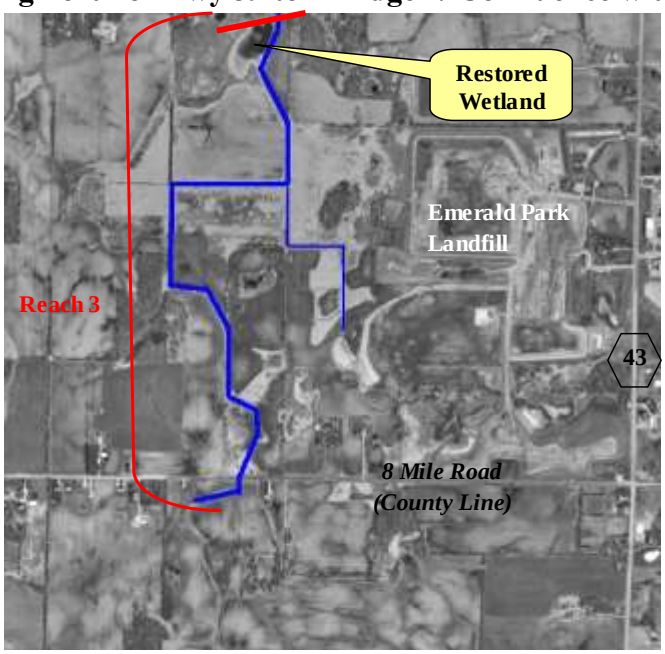


Figure 52. Aerial Photo of East Lateral

Description of Reach 3

Reach 3 is hydraulically and geomorphically similar to the downstream reaches. It is generally a constructed, low-energy, over-widened system with stable banks dominated by grasses. There were no signs of bar development, or other depositional features and it appeared the sediment load is dominated by silt. The bottom of the channel covered with submerged aquatic vegetation.

Discharge is intermittent with the exception of the standing backwater from Big Muskego Lake and standing water from the local water table. The major land use change occurred in the mid-1990's with the construction of the Emerald Park Landfill. The construction of the facility likely increased the runoff volume through the reduction of infiltration capacity. Some of this loss can also be mitigated with the conversion of some cropped agriculture has changed to grass cover. As the downstream reaches appear to be dominated by the Big Muskego Lake elevations, the land use change may not have had an effect on the downstream flood damage potential.

The water surface elevation taken on the date of the survey indicated a flat (or even slightly lower) elevation than the downstream water surface elevations. There are several staff gages within these reaches. Data for these gages has not been obtained for this investigation. The integrity and manager of this data is unknown.

There is a wetland complex near the downstream limits of the reach. The water surface elevation of the wetland and the ditch were the same on the date of the survey. The separating berm between the wetland and the ditch was historically lowered to improve hydraulic connectivity. The upstream portion of the watershed is presently undergoing some land use change with residential development.

Selected Photos of Reach 3 Trail Crossing north of Hwy 36 to East Lateral Confluence

Figure 54. Facing downstream from trail bridge at water level data logger

Figure 55. Water level data logger site

Figure 56. Staff gage at water level data logger site

Figure 57. Facing upstream from water level data logger site
(note wetland in background right)

Figure 58. Wetland complex near water level data logger site

Figure 59. Facing downstream
(note water tower in background left)

Selected Photos of Reach 3 Trail Crossing north of Hwy 39 to East Lateral Confluence

Figure 60. Facing downstream of mainstem (note transmission line)

Figure 61. Facing upstream of minor lateral extending to the south (note landfill in background left)

Figure 62. Facing downstream

Figure 63. Facing upstream

Figure 64. Facing downstream from Church Union Drive (corporate limits)

Figure 65. Facing upstream from Church Union Drive (corporate limits)

Description of Additional Field Data Being Collected:
In order to understand the drainage system, additional information is being collected during the open-water season.

1. **Precipitation data**: A Global Water Tipping Bucket Rain Gage with a WL data logger has been placed at fire station on Loomis Drive. The data collector has been set to retain rainfall depths at 5-minute intervals. Hence, rainfall intensity and overall storm depth will be available to evaluate water surface elevation data described below.

Figure 66. Tipping Bucket Rain Gage at Loomis Fire Station

2. **Big Muskego Lake water surface elevation:** City of Muskego staff (Tom Zagar) is collecting daily water surface elevation from a gage at the lake outlet dam. The lake has a significant impact on the hydraulics of the ditch system under study. It is the 'tailwater' control of the system and will be compared to water surface elevation data collected within the ditch system.

3. **Water surface elevation data within the ditch system:** Water surface elevation data is being collected at three sites along the ditch system using WLU16 Global Water data loggers. The data collectors have been set to retain water surface elevations at 15-minute intervals and 'synched' with the rainfall data being collected at the fire station.

Figure 67. Gage Site 1: Muskego Lakes Country Club

Figure 68. Gage Site 2: Old Sod Farm / Restored Wetland Site

Figure 69. Gage Site 3: Loomis Drive Ditch Lateral
(Photo on left facing downstream from the gage location, and photo on right a detail of the probe to the remnant pool)

4. **High water elevations near Loomis Drive:** During the field investigation a resident of Loomis Drive volunteered to set 'pin-flags' at high water elevations observed on his property. These can be 'tied into' the water surface elevations collected within the ditch system and Big Lake Muskego using GPS survey equipment and also related to precipitation data.

Recommendations:

As a result of the investigation to date, the following recommendations are provided for consideration.

1. Continue to collect data at stations provided
2. Survey high water elevations at the Loomis properties as they occur
3. Evaluate and report on collected data in late 2010
4. Meet with City and Wisconsin Department of Natural Resources to discuss results of this technical memorandum and confirm management objectives

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Appendix C

Technical Memorandum No. 3

Concord Ecological Engineering, Inc

N6424 High Mound Road
Concord, WI 53178
Ph (262) 443-9980
www.concord-ecoeng.com

Technical Memorandum

To: Ken Ward, P.E. Project Manager - Ruekert and Mielke Associates
From: Marty Rye, P.E., CFM - Concord Ecological Engineering, Inc.
CC: Dave Simpson, P.E., Muskego City Engineer / Coordinator of Public Works Projects
Date: July 26, 2010
Re: Technical Memorandum No. 3 – Brief summary of July 22-24, 2010 Rainfall Event, City of Muskego

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As part of a the Big Muskego Lake South Inlet ditch assessment a Global Water Tipping Bucket Rain Gage with a WL data logger has been placed at fire station on Loomis Drive. The data collector has been set to retain rainfall depths at 5-minute intervals.

Figure 1. Tipping Bucket Rain Gage at Loomis Fire Station

Data was retrieved from the data collector on July 25, 2010. This included data for the recent large rainfall event that occurred between July 22 and July 24, 2010. A brief summary of the data is provided below for your information.

- Total Rainfall Depth July 22 – July 24, 2010 = 5.66 inches (see Figure 2)
- The majority of the rainfall fell in three events measuring 1.77, 2.91, and 0.7 inches (see Figures 3-5)
- The two most intense periods of rainfall occurred on
    - Morning of July 22, 2010 (1.36 inches in 30 minutes) and
    - Evening of July 22, 2010 (0.58 inches in 10 minutes)
- The highest daily (24-hour) rainfall depth was 4.92 inches from about 9 am on July 22 to 9 am July 23, 2010

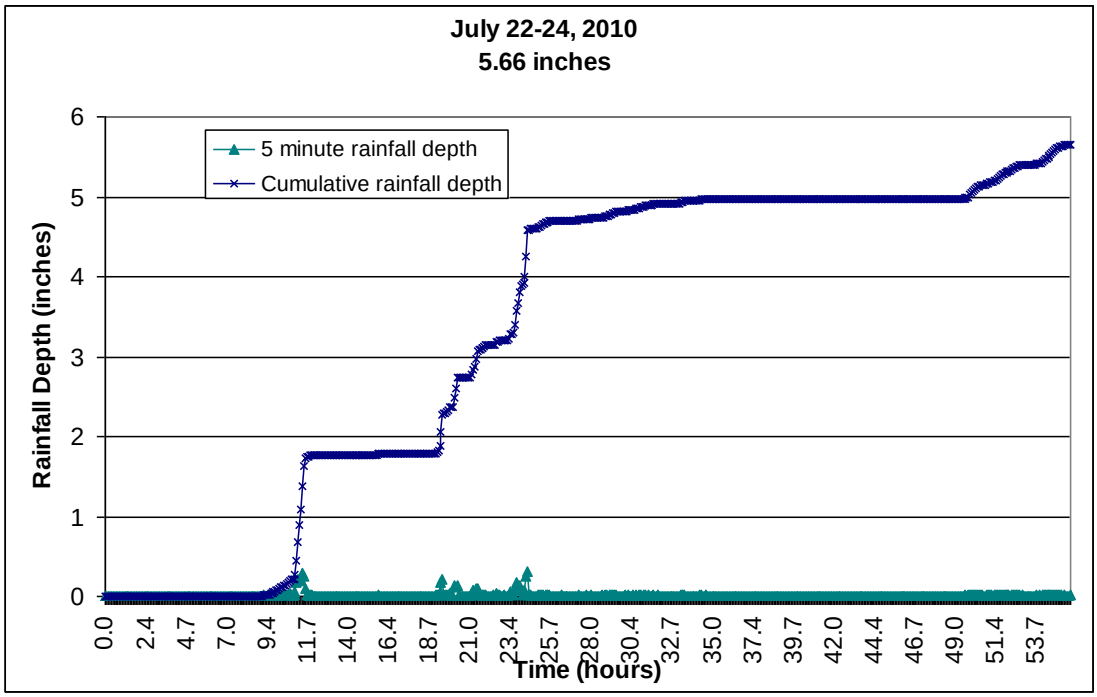


Figure 2. Muskego Rainfall – July 22-24, 2010

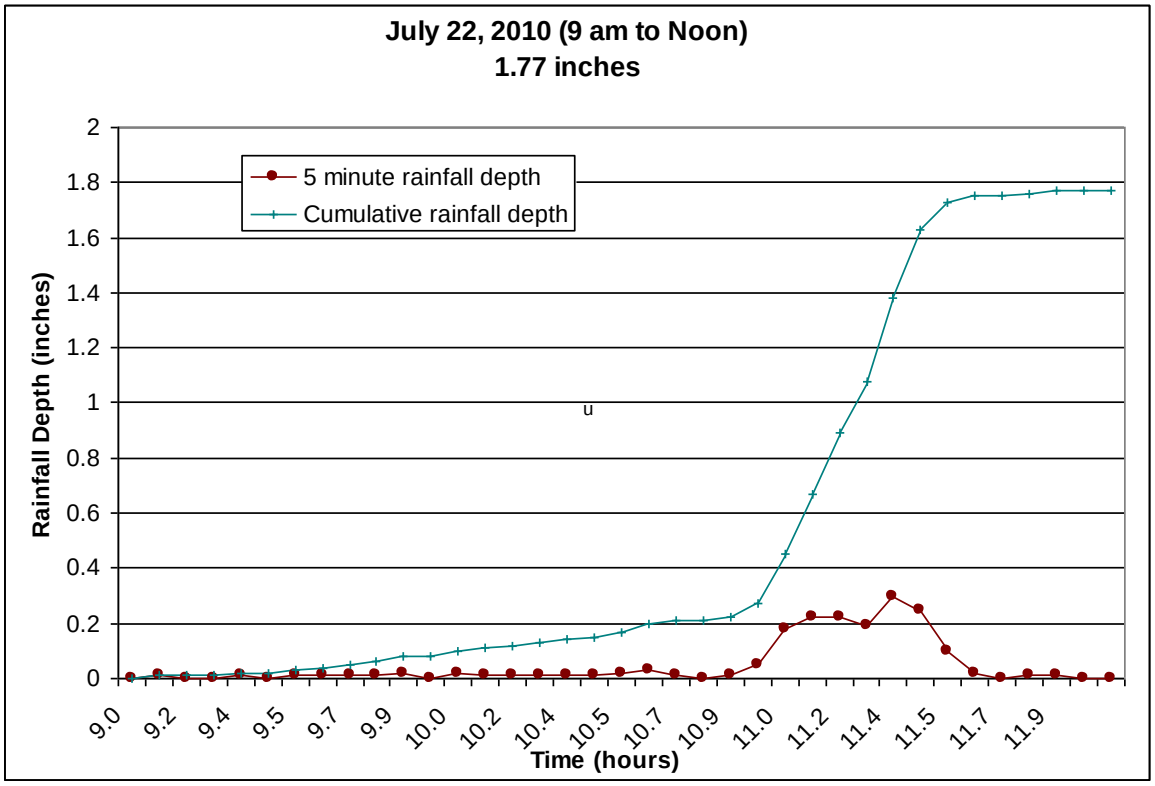


Figure 3. Muskego Rainfall – Morning of July 22, 2010

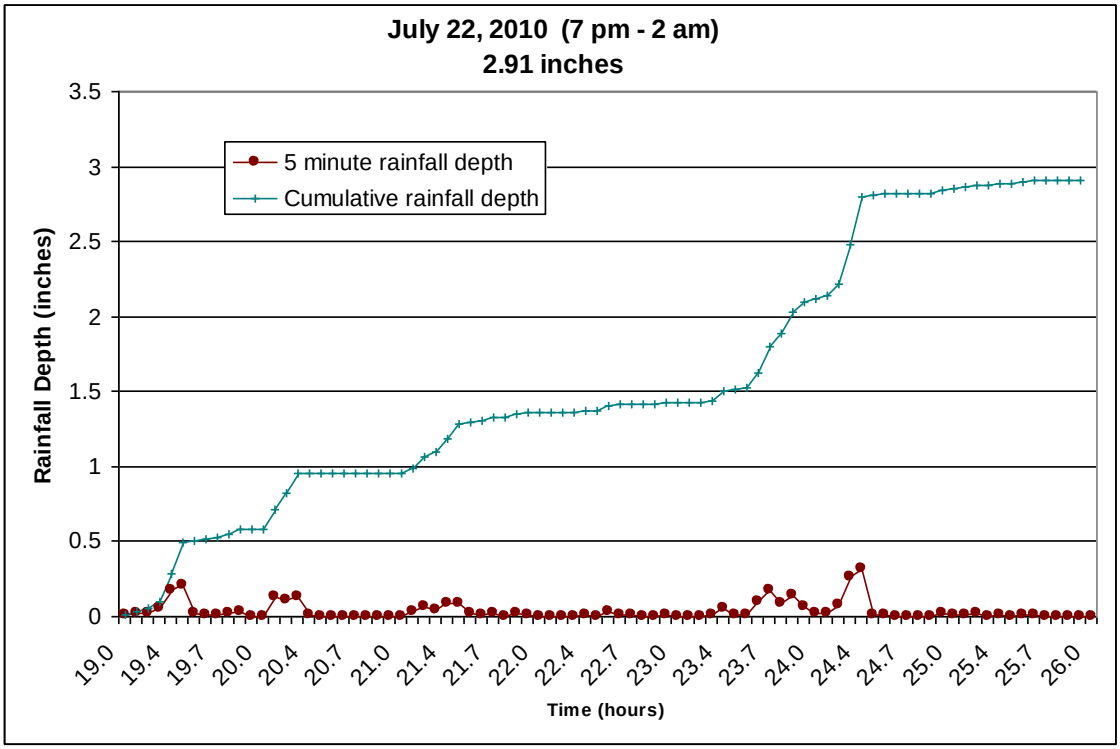


Figure 4. Muskego Rainfall – Evening of July 22, 2010

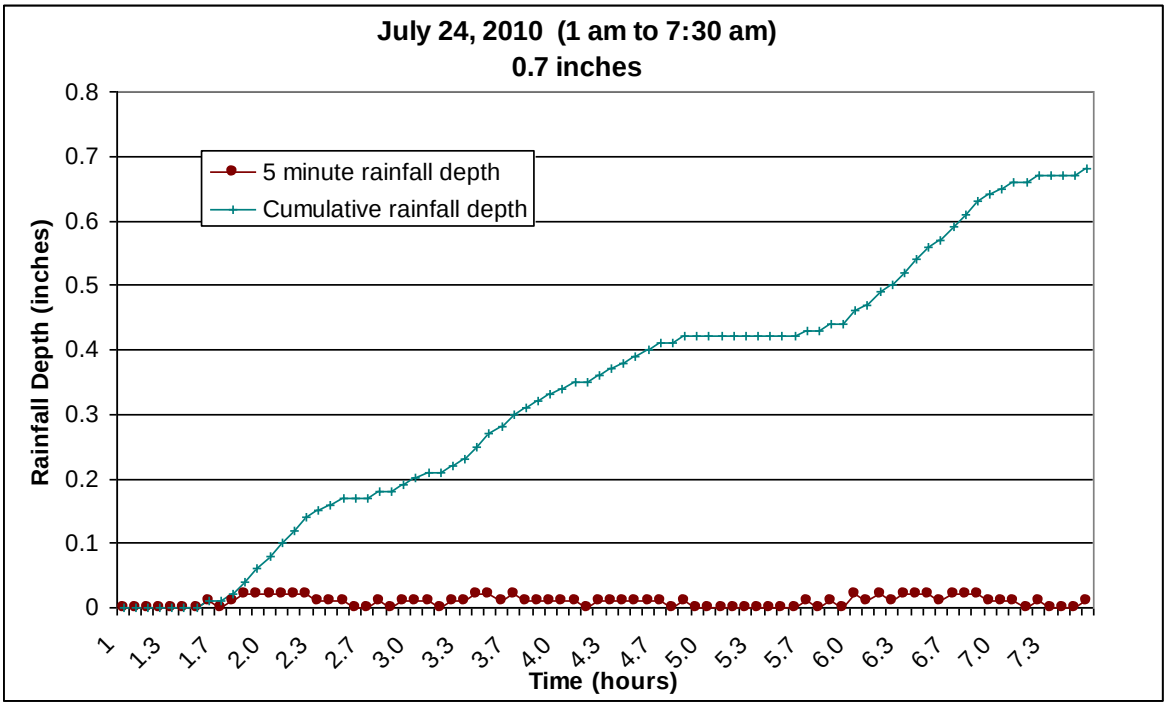


Figure 5. Muskego Rainfall – Early Morning of July 24, 2010

Appendix D

Additional Plots of Rainfall Data

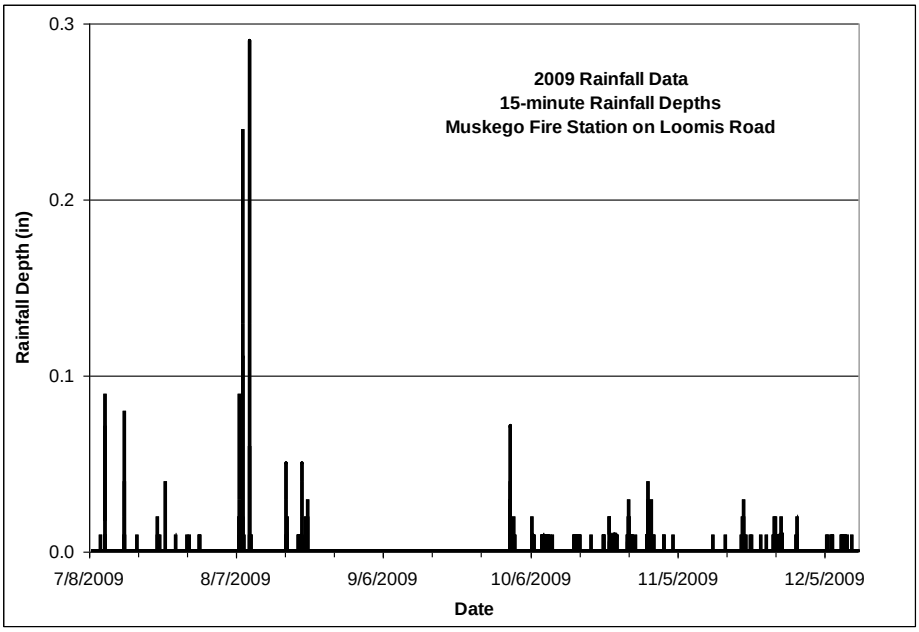


Figure D-1. 2009 Incremental Rainfall Depths

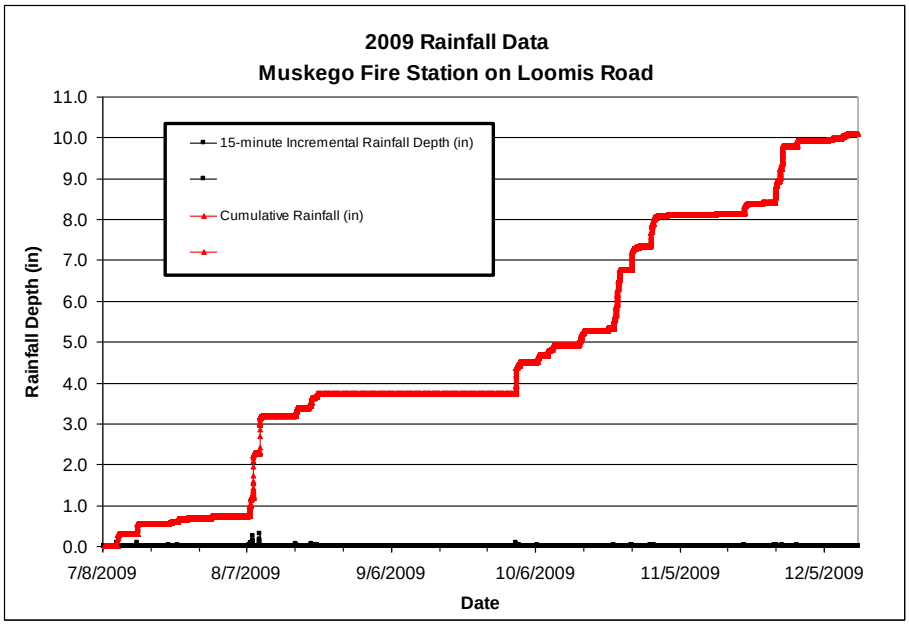


Figure D-2. 2009 Cumulative Rainfall Depths

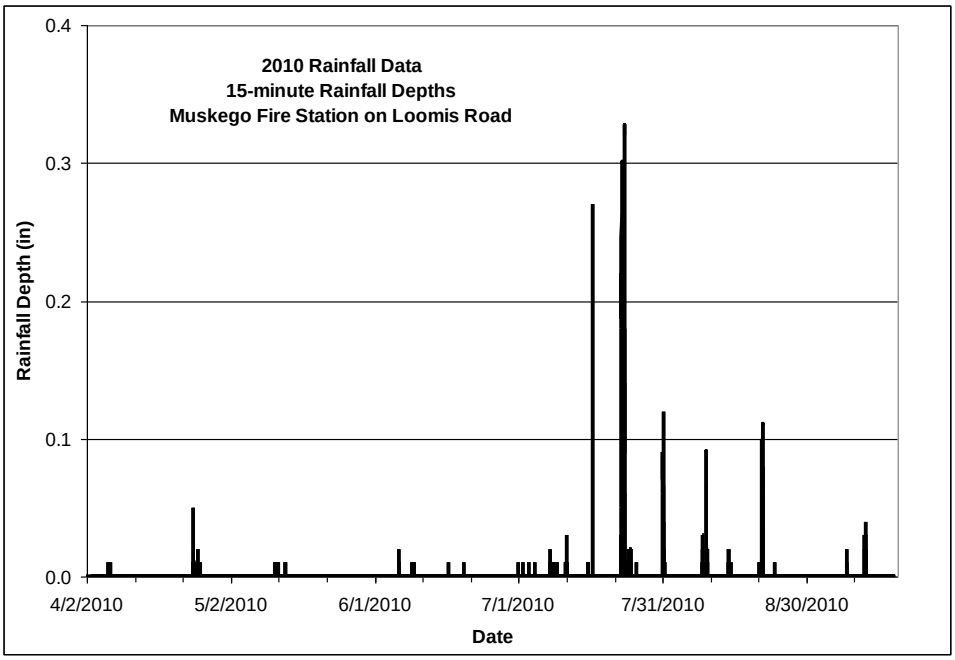


Figure D-3. 2010 Incremental Rainfall Depths

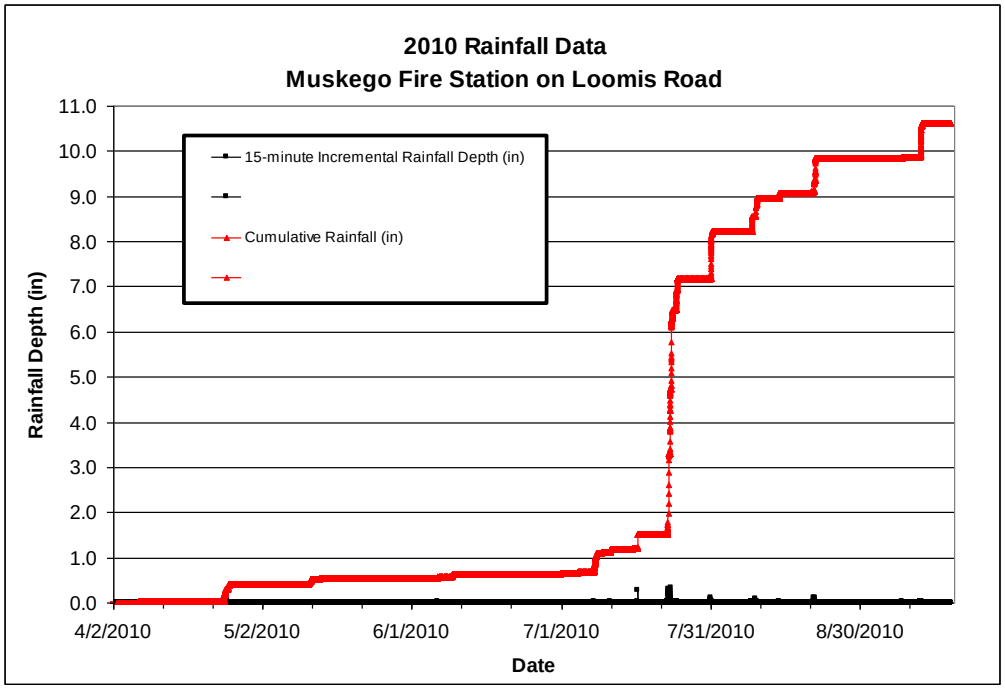
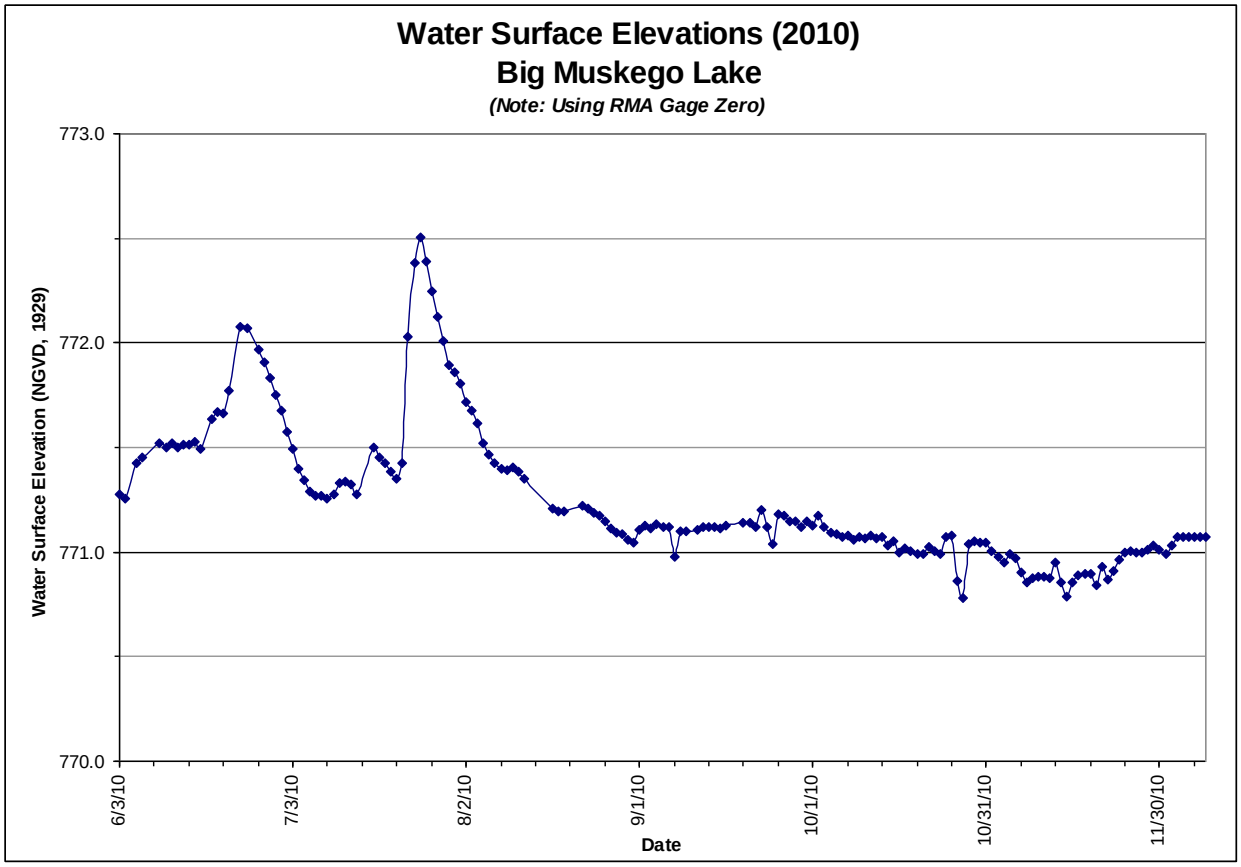


Figure D-4. 2010 Cumulative Rainfall Depths

Appendix E

Additional Plot of Big Muskego Lake



Appendix F

Water Temperature Plots of South Inlet Ditch to Big Muskego Lake

In addition to water surface elevations, water temperature data was collected at the pedestrian bridge site. The results of this data collection are shown below in Figures D-5 and D-6.

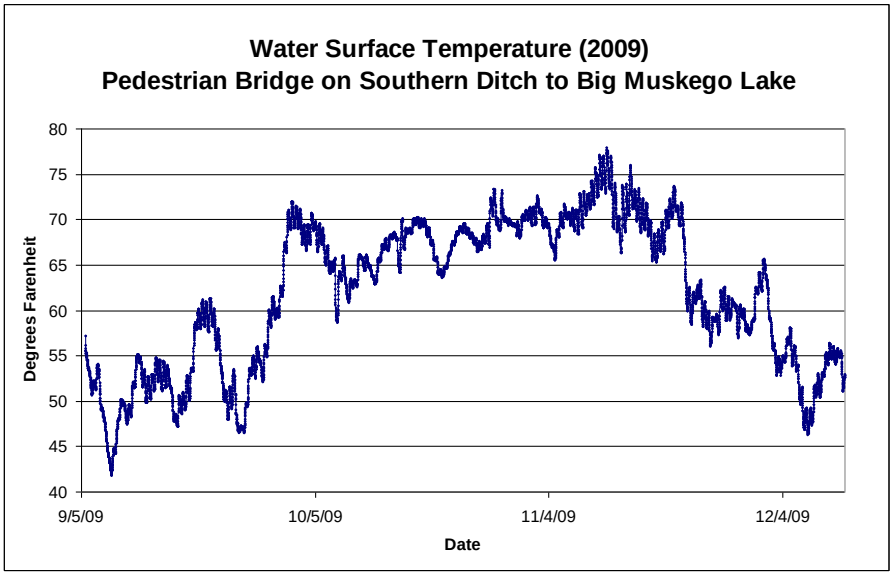


Figure D-5. 2009 Water Temperatures of Southern Ditch at Bridge

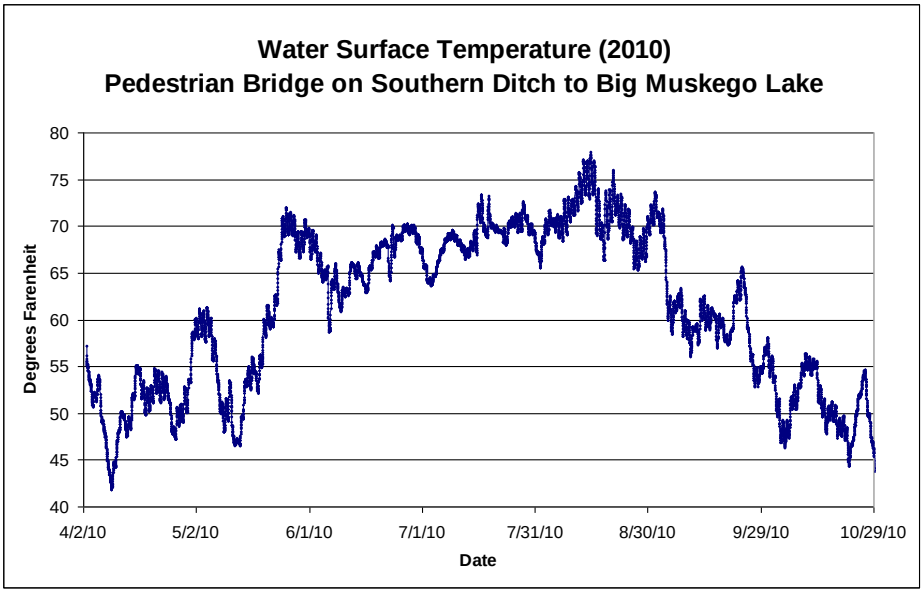


Figure D-6. 2010 Water Temperatures of Southern Ditch at Bridge