The Miljala Channel of Rock Lake

Sediment Control and Water Quality Improvement

Water Resources Management Workshop
Nelson Institute for Environmental Studies
University of Wisconsin-Madison

2012

The Water Resources Management (WRM) Master's degree program is housed within the Nelson Institute for Environmental Studies at the University of Wisconsin-Madison (UW). The program provides students with the opportunity to engage in a year-long practicum that investigates a real-world problem related to water resources in Wisconsin. WRM graduate students gain experience working with natural resource and engineering professionals in a hands-on setting that involves coordination of various stakeholder groups within a community. Students spend their fall semester planning the project, followed by field work and data analysis in the ensuing spring and summer. Late summer and early fall of the following year are reserved for preparing a report of the study's findings for the public. Graduate students within the WRM program must complete the practicum in order to obtain a Master's degree from the university.

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Preface

Since the 1960's, Water Resources Management (WRM) students have taken on a myriad of water resource management issues within various social settings, ranging from Native American reservations in rural northern Wisconsin to problems that arise in urban watersheds. The practicum experience gives students the tools and training that they need to obtain employment in this evolving, interdisciplinary field.

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Executive Summary

Sedimentation and water quality problems have long been an issue for Lake Mills residents living on or near the Miljala Channel, a small inlet on the western shore of Rock Lake. Expensive and frequent dredging has been required, and the permit for the turbidity curtain installed in the channel will soon expire. The Rock Lake Improvement Association (RLIA), in partnership with private consultants and the Jefferson County Land and Water Conservation Department (LWCD), conducted a 2009-2010 study that reported phosphorus and bacterial concentrations above state and federal limits. The study identified an agricultural drainage ditch that drains most of the watershed as the major source of sediment and water quality problems.

This report presents research conducted by the University of Wisconsin (UW)-Madison Water Resources Management (WRM) practicum in 2011 and 2012, as part of a Wisconsin Department of Natural Resources (DNR) lake planning grant secured by the RLIA. Our goals were to collect additional information about the sources of contaminants and the hydrology of the watershed. This information will provide the basis for an engineering design and help stakeholders make an informed decision on management practices.

The research included phosphorus and bacterial sampling during both stormflow and baseflow conditions, grain size analysis of sediments collected behind the turbidity curtain, automated monitoring of water levels in the drainage ditch and in shallow monitoring wells, and computer modeling of runoff. Because of the drought, we were unable to observe and characterize many runoff-producing storms. Plans for in-stream sediment monitoring and baseflow computer modeling had to be abandoned. Nevertheless, we were able to draw some conclusions as to the source of contaminants and strategies for management.

Here are a few of our conclusions:

- Phosphorus and bacterial levels in the drainage ditch remained high during the study period and are likely to persist without changes in management.
- Septic or sewer leaks and groundwater can be ruled out as sources of contaminants.
- Manure applied to farm fields is a likely source of both phosphorus and bacteria, although wildlife could also be a contributor.
- A large proportion of the sediment was found to be fine sand, which suggests that most of the sediment is eroded and transported during heavy rains (greater than 1 inch) rather than during baseflow.
- Infiltration tests, well monitoring, and flow monitoring showed that soils in the area have a high capacity to infiltrate rainfall, especially the Houghton muck, making surface runoff minimal and suggesting that ponds or wetlands for sediment control could be smaller than previously assumed. Preliminary estimates suggest that 2-3 acres may be sufficient for effective treatment.

The following recommendations for future action address the environmental concerns of the Miljala Channel watershed through farm field management changes, the restoration of wetlands, measures to minimize bank erosion, and suggested regulatory standards to address future development. Implementing these recommendations will only require a modest land area, making them likely to be acceptable to private landowners. Wetland restoration in Korth Park is key because of its potential not only to improve water quality but to provide recreational and habitat benefits.

Farm Field Management Changes

1. Update the nutrient management plan of the farm field south of Shorewood Hills Road to reduce phosphorus and bacteria associated with manure application. Specifically, we recommend an update to the phosphorus index based on distance to the drainage ditch, accompanied by an amended manure application plan if warranted.

2. Plant denser vegetation in the buffer strip adjacent to the farm field south of Shorewood Hills Road to reduce runoff velocity and allow for nutrient, bacterial and sediment interception.

Wetland Restoration

3. Restore shallow marsh wetlands in at least two sections of the ditch to control nutrients, sediment, and bacteria.

4. Control the velocity of peak flows during precipitation events to minimize bank erosion and re-suspension of deposited sediment. In areas where wetland restoration is not possible, reduce bank erosion through streambank stabilization, upstream detention, check dams, or similar control structures .

Regulatory Changes

5. Update local regulatory development standards to reduce runoff potential of future development projects, as outlined in Wisconsin Administrative Code Chapter NR 151.121-129.

Chapter 1: Introduction

Project Area

The Miljala Channel is a small inlet on the southwest corner of Rock Lake in Lake Mills, Wisconsin (WI). The Miljala Channel watershed has an area of 178 acres and drains into the southwest portion of Rock Lake (Figure 1.1). Land cover includes agricultural land, grassland, restored prairie plantings, forest, wetlands, and residential development (RLIA, 2011). Agricultural activity in the area commenced around 1880 when the Korth family settled the land, and continues today on a large portion of the land area in the watershed. A ditch was created in the early 1950's to drain agricultural land through the central part of the watershed. In 1957 the Miljala Channel was created to provide lake access to new homes. In 2000, Korth Park was established in the southeast corner of the watershed (approximately one-third of the park's 89 acres are within the watershed), and included a native prairie restoration. Residential dwellings encompass approximately 19 acres and include parts of the Shorewood Hills and Cedar Lane subdivisions, along with some isolated properties in other areas.

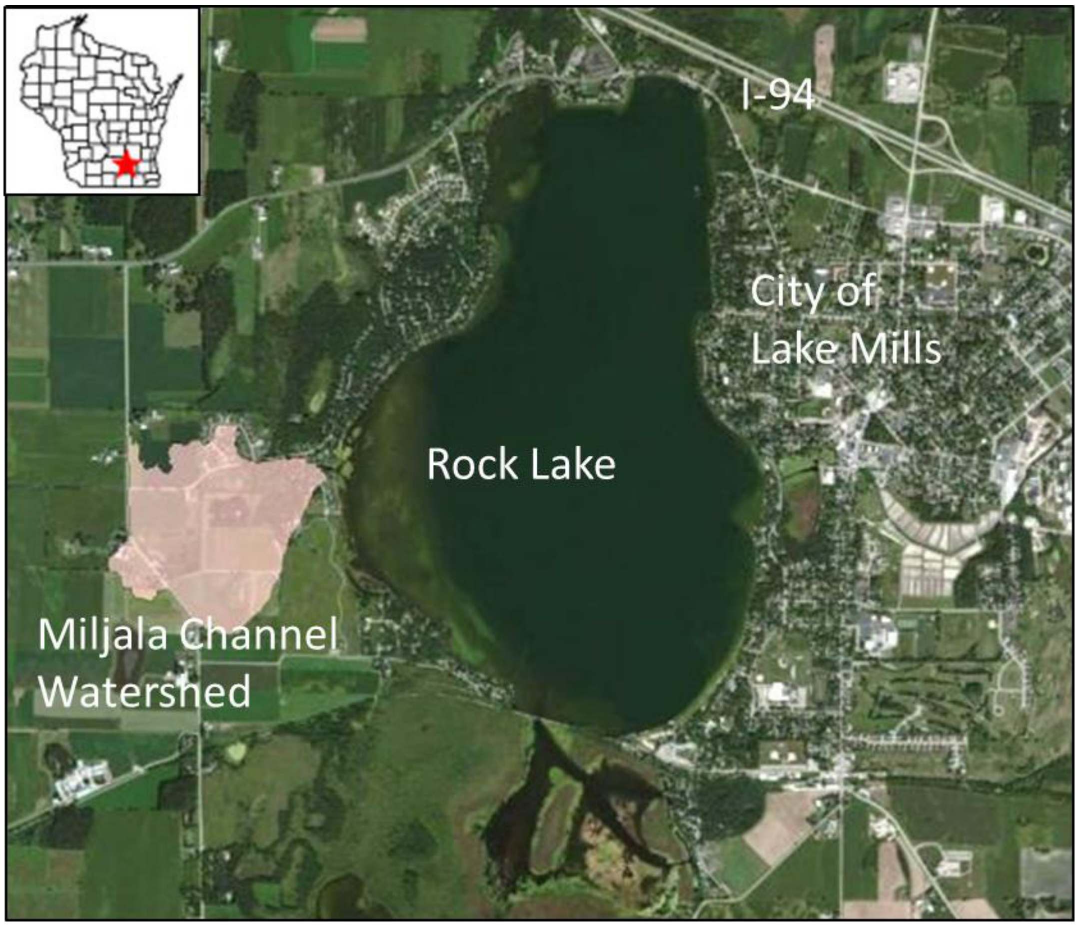


Figure 1.1 Location of Study Area

Introduction to Problem

Sedimentation, phosphorus loading, and bacterial contamination have been an ongoing concern in the Miljala Channel. Since 1998, seven separate dredgings and the installation of a sediment curtain have been performed to maintain channel navigability and boat access to the lake. A report, *Water Quality Monitoring and Evaluation of Pollutant Sources within the Southwest Subwatershed of Rock Lake* — compiled by the Rock Lake Improvement Association (RLIA), Jefferson County Land and Water Conservation Department (LWCD), and private consulting firms — has identified a drainage ditch created for agricultural purposes as the source of the phosphorus and bacteria laden sediment loads to the channel. This groundwater-fed ditch was excavated in the mid 1950's and drains a significant portion of the watershed through a former wetland and into the channel.

In addition to frequent observation of phosphorus and bacterial concentrations above state and federal limits, the RLIA study concluded that muck soil — originating from the bottom and sides of the ditch — was the primary component of sediment deposition occurring in both baseflow and stormflow events. The primary consulting firm, Underwater Habitat Investigations, LLC, recommended that the RLIA continue the project by conducting an initial engineering assessment based on their findings.

On May 1, 2010, the RLIA applied for a Wisconsin Department of Natural Resources (DNR) Lake Planning Grant to facilitate the development of a watershed management plan. The application for a large-scale planning grant was approved by the DNR and provides 75% of the funding for this project, with the remaining 25% in match funds provided by the RLIA and the UW-Madison Nelson Institute for Environmental Studies (RLIA, 2010). Initial provisions of the grant assigned the WRM workshop with tasks, including data collection and analysis to be used for the creation of a report. Specific responsibilities included identification of pollution sources, monitoring of water levels and flows in the ditch and turbidity at the Cedar Lane culvert, manual sampling of sediment and phosphorus loading at different ditch stages and discharges, systematic surveying of accumulated sediment thickness in the channel, and reviewing historical information on sediment accumulation and dredging in the channel since its construction in the 1950's. The WRM workshop was also asked to conduct bacterial source tracking to determine the presence or absence of human sewage contamination in the channel. Finally, WRM students were charged with expanding public participation in order to engage stakeholders during the project (Gaffield, 2011).

Beginning in September 2011, WRM students worked in conjunction with the Jefferson County LWCD, Montgomery Associates:Resource Solutions (MARS), and the RLIA to complete an in-depth survey of the hydrology, hydrogeology and ecology of the landscape. The survey was conducted in order to provide stakeholders with the additional site data required to select a comprehensive solution to the issues plaguing the Miljala Channel (Figure 1.2).

History of the Area

The Town of Lake Mills was established in 1845 on the west side of Rock Lake, across from the City of Lake Mills that was established only a few years earlier. Both were at least partly ushered in with the railroad that still runs across the southern edge of Rock Lake. In addition to farming, the town served largely as a place for vacation homes or cottages because of the scenic view and recreational opportunities provided by the lake. This changed somewhat after World War II when more year-round residents settled the area. Permanent houses were built near the lakeside allowing more people to take advantage of the chance to fish, swim, and otherwise enjoy

Rock Lake. In the 1960's, the town was connected to the sewer system of the City of Lake Mills. The 1970's and 1980's brought a housing boom to the area, with even more calling the town home. The most recent census for the Town of Lake Mills shows a population of just over 2,000 residents.

The land that now makes up Korth Park and borders the southern end of the ditch was first settled by C.W. Korth in 1880 (Figure 1.3). A sizable portion of the land, approximately 100 acres, was used as a cow pasture until about 1956. Cows were known to sink their hooves into the muck and occasionally fall into the ditch after it was built. The Korth family also grew crops that were largely used as feed, including corn, oats, and hay, on the drier areas of the land.

In 1910, to facilitate the growth of those crops, drain tiles were placed on the southern end of the Korth property in what is now a prairie. In that same year, the United States Geological Survey created a topographic map that showed the extent of wetlands in the area (Figure 1.4).

According to the map, a large swath of wetlands existed in the area where the Miljala Channel and the ditch now reside, just north and west of the drumlins. There was also a small patch of wetland shown just south of Korth Lane, which today is a pond (surface site 4 in this report). It had been a very marshy area that neighborhood children would cross in the winter to reach their bus stop, but had to be avoided when the land thawed in the spring. In the early 1970's, the

Figure 1.2 Location of Study Area and Sampling Points

Strasburgs, who owned this land at the time, laid drain tile and a culvert under the road to facilitate drainage. Today that tile is likely broken up. Though there is likely little flow from this area towards the ditch, it has twice been observed that water flowed out of the drain tile towards the ditch. Both observations occurred in early spring.

Around 1951, a ditch was built on the northern edge of the Korth property with funds from the Korths and two other landowners along the property line. The purpose of this ditch was to facilitate the draining of lands to increase viable cropland. When initially dug, the ditch was approximately 8 to 10 feet deep and 10 to 12 feet wide, with a steep slope. Spoils were placed just to the sides of the ditch itself. The three landowners only gained 10, 6, and 12 acres of farmland respectively, which was not enough to justify the costs of dredging the ditch. Years later, more ditching was completed in the southwestern part of the watershed near the corner of Highway S and Korth Lane; however, the land here remained too wet to farm (Korth, 2012). The ditch, after it was built, immediately began to erode.

In 1956 and 1957, the Miljala Channel was constructed at the confluence of the ditch and Rock Lake. It was created by a developer with the intention of selling lots around it and offered a means of boat access to Rock Lake for those new homes.

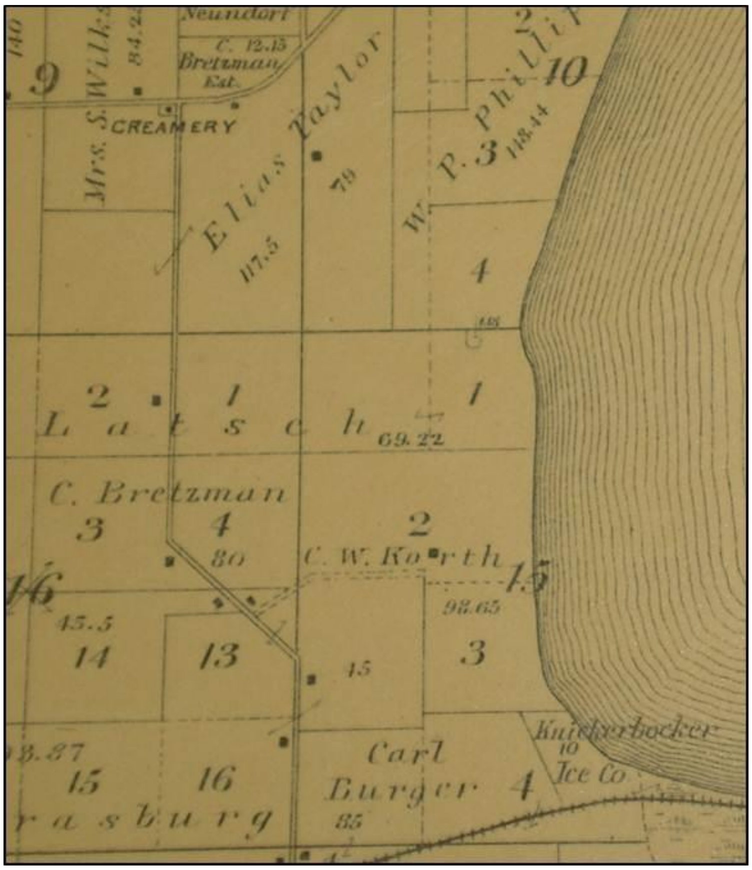


Figure 1.3 Plat Map

Along with the inland dredging to create the channel itself, approximately 1,300 feet of shoreline on Rock Lake, around the mouth of the channel, was dredged. Around this same time, Shorewood Hills Road was straightened, and Cedar Lane was constructed. Shorewood Hills Road runs down from Shorewood Hills west of the channel and then curls south. Upon completion, the channel was quite deep and its waters were clear; a perfect swimming spot for local children (Korth, 2012). Almost immediately, however, the channel began to fill with sediment. Though the northwestern area of the watershed was not considered a major runoff contributor, a culvert was built under Shorewood Hills Road (surface site 8 in this report). Later this was connected to the main ditch to the south.

By August 1998, the Miljala Channel was principally non-navigable due to the amount of sediment nearly filling it completely. Dredging was performed to remove this sediment, which totaled 6,000 cubic yards, 3,000 cubic yards of which were removed from between the Cedar Lane culvert and the point where the channel turns towards Rock Lake. The rest of the sediment was dredged between that turn and the lake. The sediment removed was placed on farmland near the drainage ditch, in an area within the watershed agreed upon with the Wisconsin DNR (RLIA, 2011).

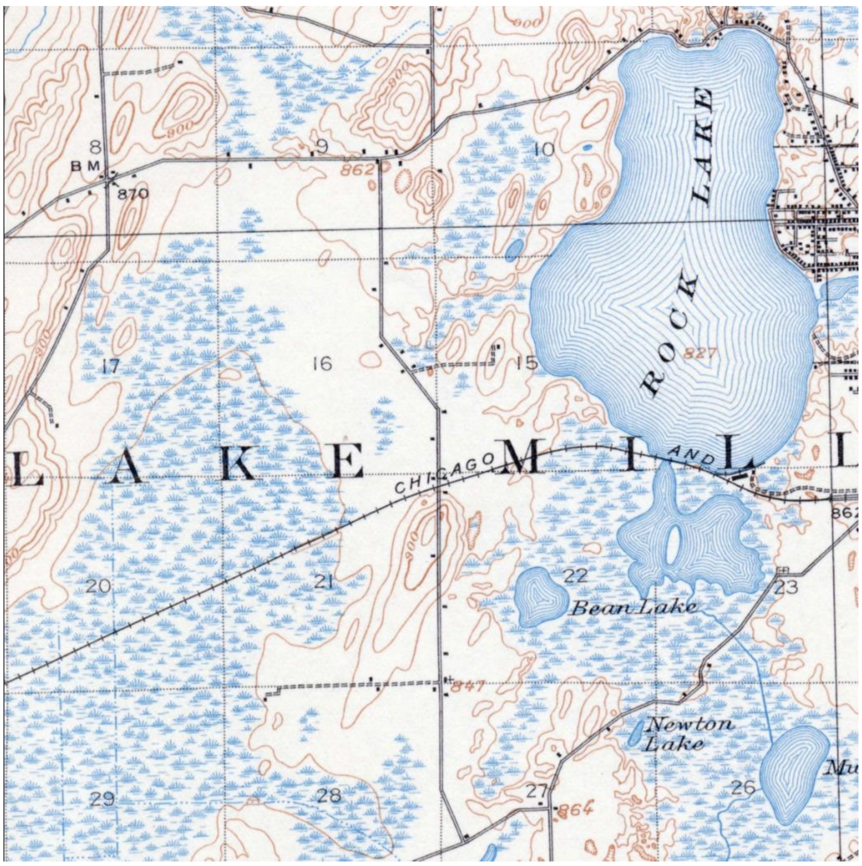


FIGURE 1.4 ROCK LAKE TOPOGRAPHY, 1910

The sedimentation problem in the channel continued in subsequent years, prompting further dredging in March 2005 and August 2009. Each time a backhoe was used near the Cedar Lane culvert, and the amounts removed were 500 and 700 cubic yards, respectively. Residents noted that approximately three feet of sediment appeared near the culvert between the 2005 dredging and the fall of 2007 and that about three feet more was deposited by the summer of 2008. It is notable that there was rather high precipitation in those years. After the dredge in 2009, a permit was granted by the DNR for a turbidity curtain to block sediment from moving through the channel. The curtain was eventually installed across the channel, 30 feet away from the culvert. In 2012, the permit was granted a two year extension through August 2014.

In the late 1980's, land on the Korth property on Cedar Lane was subdivided and lots were sold. Houses were built in the late 1980's and early 1990's along the road, though it should be noted that houses on the last north-south stretch of Cedar Lane are not within the watershed. Another subdivision emerged in the mid-1990's north of Shorewood Hills Road. Shorewood Meadows Drive subdivision includes a dozen homes that lie within the watershed and drain through the road culvert at surface site 8 (SS8) and into the drainage ditch.

In 2000, Dave Korth sold his remaining property to Jefferson County to create Korth Park (RLIA, 2001). After the park was established, ecosystem restorations were undertaken, including many acres of prairie, the shoreline of Rock Lake, an area of oak savannah, and a wetland restoration near Rock Lake. Additionally, Korth Lane was improved and other aspects of the park were built, including a parking lot, a shelter with indoor restrooms, and various nature trails, including one connecting to the Glacial Drumlin Trail to the south (RLIA, 2012). There are ongoing plans to further improve the ecosystems found within Korth Park in the future. As for the rest of the watershed, there is still farming in the northwest corner of the watershed and to the south of Korth Lane, though that area typically no longer drains past the road, and far fewer houses are being built in recent years as compared to the 1990's.

Chapter 2: Methodology and Results

Overview of Methods

Building on the 2009 and 2010 data published in the 2011 RLIA Report, we continued to monitor water quality in the ditch and in the navigation channel from October 2011 through October 2012. Our surface water sampling sites (SS1 through SS9) are shown in Figure 2.1.

In addition to seven sampling spots along the ditch and one sampling spot from a dock in the middle of the navigation channel (SS9), we sampled a farm pond south of Korth Lane (SS4) that is believed to drain to the ditch during wet years. We used field kits (Chemets) to regularly measure phosphate as well as other data needed for context and quality assurance, including: water temperature, air temperature, specific conductance (which measures dissolved minerals), pH, and dissolved oxygen. Since groundwater is typically cooler in summer, lower in oxygen, and higher in dissolved minerals than rainwater, this information is also useful for determining the relative contribution of groundwater and surface water to flows over time. We collected samples of bacteria and phosphorus from a subset of these sites, in both spring and summer and during both low-flow conditions and after rainfall, for laboratory analysis.

In order to better understand groundwater flow patterns in former wetlands, and to rule out groundwater as a source of contaminants, we installed nine piezometers (shallow groundwater-monitoring wells) constructed of a 2 foot length of well screen (1 inch PVC pipe with slots to admit water). The locations of our monitoring wells (designated MW1 through MW9) are shown in Figure 2.2.

Piezometers were typically installed in closely-spaced pairs ("nests") with one screened in the Houghton muck and another screened in the underlying silty clay to allow for measurement of vertical flow. Water levels in the wells were monitored as part of our biweekly sampling, and data loggers were installed in several wells during the summer.

We collected samples of the sediment accumulated behind the turbidity curtain and analyzed the grain size distribution to make some inferences about the sources of sediment and sediment transport (Figures 2.3 and 2.4).

A data logger was installed above the Cedar Lane culvert to continuously monitor the water level and flow in the ditch. Together with infiltration tests and slug tests to determine soil properties, this information was used to inform a computer rainfall-runoff model. Our understanding of the hydrology helped us interpret the results of water quality sampling and can provide the basis for the design of management alternatives.

Sediment Deposition

Sediment Source Objective

Sedimentation is a nuisance for homeowners in the Miljala Channel who must pay for frequent dredging. Sediment also carries contaminants like phosphorus and bacteria that can be released into the water. Our goal was to identify the primary sources and method of delivery of sediment accumulated in the channel. In addition, we sought to test the conclusions presented by previous consultants. In doing this, we hoped to inform the RLIA and other stakeholders of management solutions that could reduce sediment deposition and maintenance costs to landowners.

Figure 2.1 Aerial View of Surface Water Sites (SS1-SS9) and Monitoring Wells (MW1-MW9) Within the Miljala Channel.

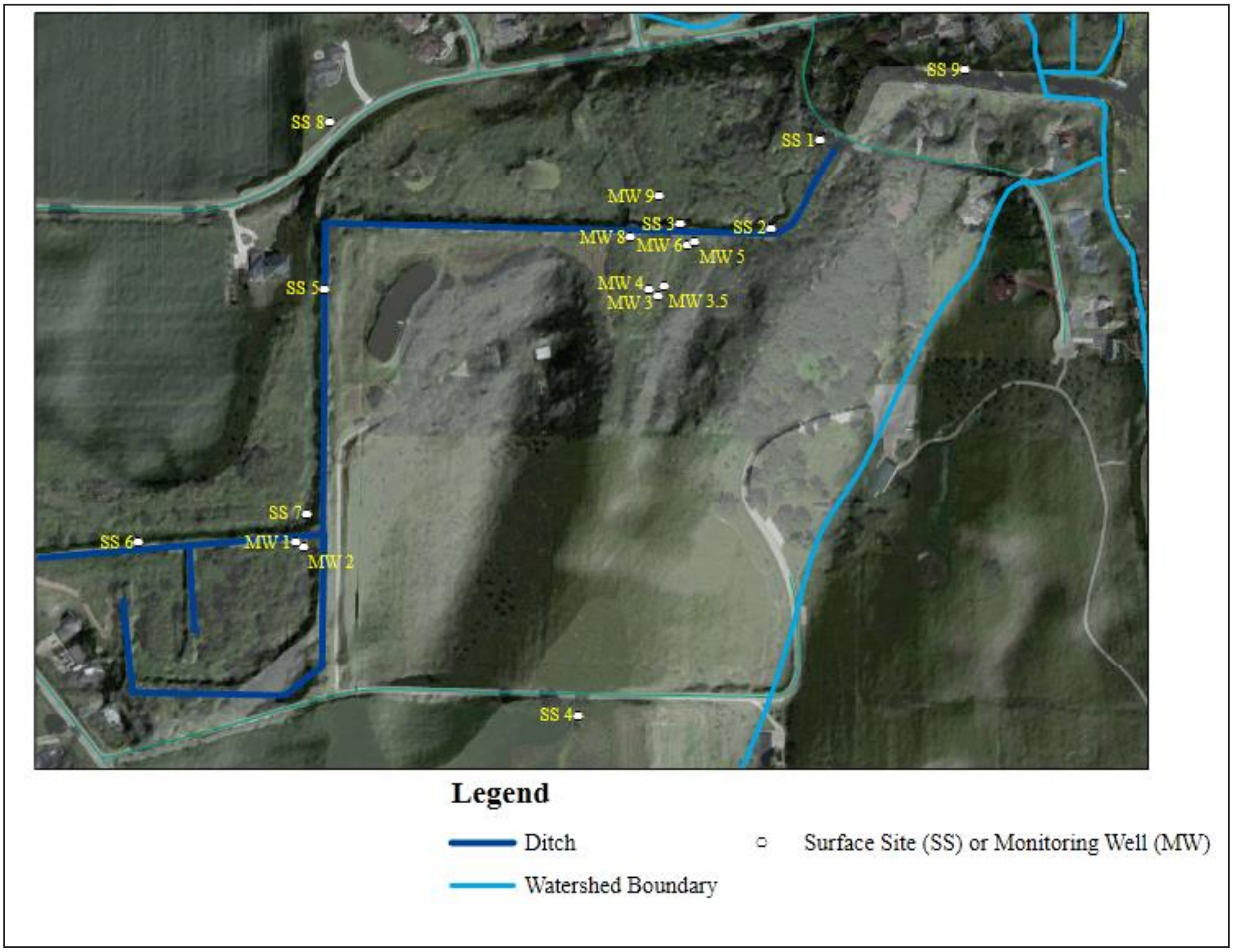


Figure 2.2 Map of Surface Sites and Monitoring Wells Within the Miljala Channel Watershed.

Sediment Source Investigation

The previous study concluded that the bottom and sides of the drainage ditch are the primary source of sediment. We began to question this conclusion after analyzing the particle size distribution of the sediment trapped behind the turbidity curtain and finding a large proportion of sand. Three cores were taken just prior to dredging in October 2011, with grain sizes separated by sieve, dried, and weighed. Although the Houghton Muck soil that forms the banks of the drainage ditch is composed mostly of organic matter, the material deposited behind the turbidity curtain was only 10% organic matter, with 14% coarse sand, 58% fine sand, and 18% silt and clay by total mass collected (Appendix D, Table D.1 and Figure D.1). A second set of samples collected in July 2012 showed similar results: 6% organic matter, 6% coarse sand, 62% fine sand, and 26% silt and clay (Appendix D, Table D.2 and Figure D.2).

Having observed small gullies below the culvert at Shorewood Hills Road, we considered that runoff from the Shorewood Meadows subdivision could lead to erosion of mineral soil. A crest-stage recorder was installed at the culvert to measure the maximum depth of water moving through the culvert during a rainstorm. Surprisingly, the subdivision was not a significant source of runoff during 2012. Flows were never high enough to obtain meaningful results from the crest stage recorder. Only on two dates was there any evidence that water had moved through the culvert at all; on other occasions, when we arrived during or just after a rainfall, the barrel of the culvert was dry or blocked with debris and the soil near the entrance was cracked. While drought was certainly a factor, the use of grass swales for drainage, rather than curb-and-gutter, means that the amount and velocity of runoff from the subdivision is much lower than would be observed from a similar area with traditional curb-and-gutter. Infiltration tests showed that the soil is quite permeable (Table 2.1). The subdivision could still be a source of runoff in wet years when frequent rains cause the soil to become saturated.

Figure 2.3 Sediment Core Samples. Photo Credit: Steve Neary, 8/21/12

Figure 2.4 Taking the Second Round of Sediment Cores. Pictured are Tom Beneke and Steve Neary. Photo Credit: Megan Phillips, 7.11.12

Road sand applied for traction in winter is another possible source. It was not possible to quantify the amount of road sand applied due to an inconsistent spreading mechanism used by the contractor. WRM students did notice sand collecting along the shoulders of Cedar Lane on July 18, 2012, following heavy rains. While this may be a contributing factor, our observations of sand settling out below the culvert outlet after heavy rains would suggest that the majority of sand originates from or passes through the ditch.

Sand is exposed in the bed of the ditch upstream of SS2 and downstream of SS5 (Figure 2.5). The steep, eroding banks upstream of SS2 also have a high sand content. A silty clay layer underlies the Houghton muck and may be exposed in places. We conducted an erosion survey in April 2012 and found extensive areas of exposed banks throughout the east to west section of the ditch. We have also observed signs of erosion and deposition in the crop field south of Shorewood Hills Drive; since manure is applied to this field, sediment transported from the field would also carry bacteria and sediment.

Ultimately, our findings do not contradict the conclusions of the previous report that the bottom and sides of the ditch are the major source of sediment. However, the particle size analysis clearly shows that a large part of the sediment is transported during infrequent storms rather than during baseflow. This observation is consistent with the higher velocity of flow needed to erode fine sand and keep it from settling out.

We installed a data logger to take continuous flow measurements at the Cedar Lane culvert from March through October of 2012. Figure 2.6 shows a hydrograph from spring 2012 that includes the largest peak flow observed during the study period. A sharp peak in the hydrograph indicates direct runoff from the land surface, while a gradual release of water

Table 2.1 Infiltration Rate for Top Layer of Soil in Inches Per Hour.

Soil type	Mean	Standard deviation
Casco loam	0.90	1.11
Fox loam	0.46	0.29
Fox silt loam	0.27	0.18
Houghton muck	2.18	1.00
Houghton muck (when excessively dry)	0.16	0.14
Kidder loam	0.36	0.44
Matherton silt loam	0.30	0.17
Otter silt loam	0.75	NA
Rotamer loam	0.87	0.40
Virgil silt loam	0.21	0.13

Figure 2.5 Sandy Soil Near SS2. Photo credit: Steve Neary, 10.5.12

over the course of several days indicates release of groundwater in the form of baseflow. Baseflow can be distinguished from runoff by the slope of the recession hydrograph after a rain event, as shown in Figure 2.8. Groundwater is the dominant source of flow in the ditch, and the amount and velocity of flow is typically quite low. Runoff peaks were only observed after heavy rainfall of greater than 1 inch or after a significant cumulative rainfall within a week. The sand component of the sediment is likely moved during these events.

The particle size distribution is good news for management of sediment. Sands settle quickly, so even a small sedimentation basin or other management practice will be able to capture a large proportion of the sediment loading currently clogging the Miljala Channel.

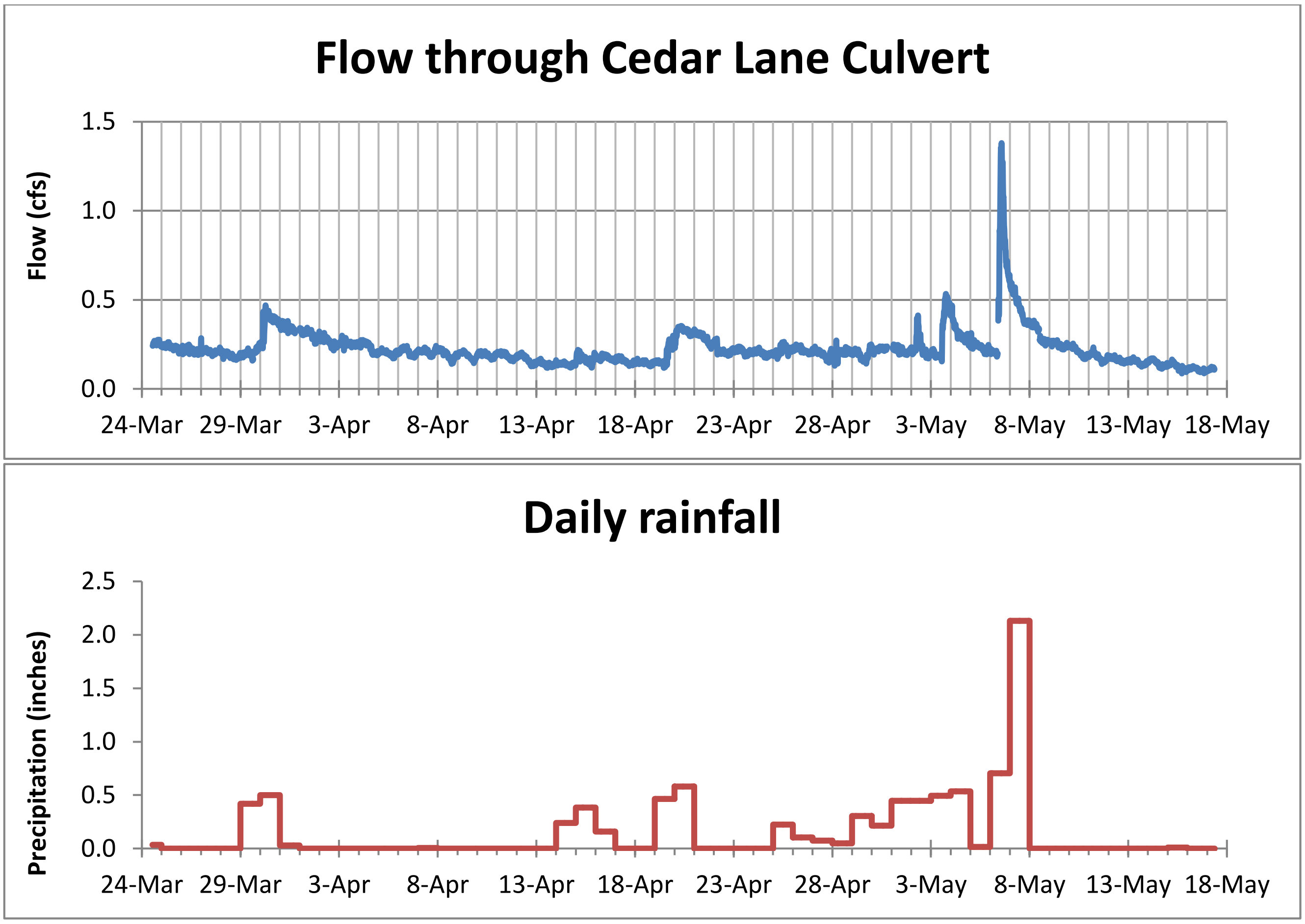


Figure 2.6 Example of Continuous Flow Data Collected at Cedar Lane Culvert.

Figure 2.7 SS8 After a Large Spring Storm (left). There was evidence of some ponded water in front of the culvert, but the crest stage gage results were inconclusive (right). Photo credit: Steve Neary, 5.11.12

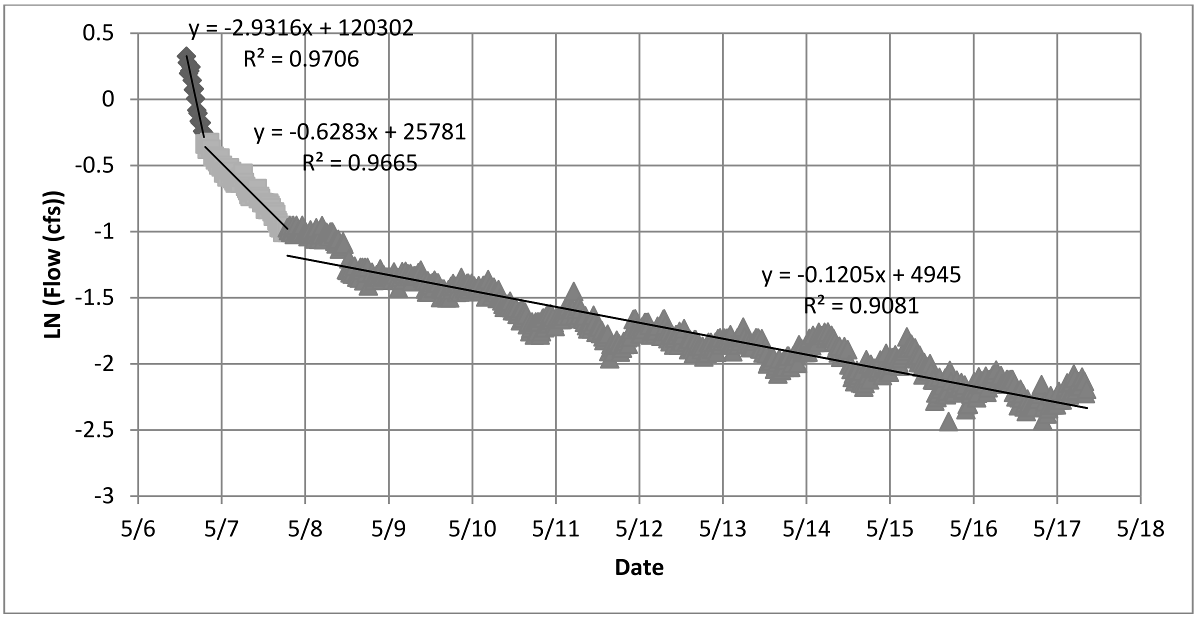


Figure 2.8 Hydrograph Recession After 1.77 inch Storm, Plotted on Log Scale. The change in slope indicate a shift from quickflow to baseflow.

Figure 2.9 Bank Erosion and Deposited Sediment Were Common Along the Ditch After Heavy Precipitation Events During the Study Period. Photo Credit: Steve Neary, 5.11.12

Figure 2.10 Steep, Eroding and Undercut Banks Found Along the Ditch in Several Places. Sand is also prevalent in the ditch, particularly in bends where velocity slows enough to force it from the water column. Photo credit: Steve Neary, 12.2.11

Phosphorus Transport

Phosphorus occurs naturally as a constituent of water as well as an input from anthropogenic sources. Natural occurrences of phosphorus derive from a number of sources, including the weathering of phosphorus-bearing rocks and mineral deposits. Anthropogenic sources of phosphorus in natural waters include fertilizers, human and industrial waste, and an anti-corrosion agent used in municipal water treatment to combat the corrosion of copper plumbing materials. Excess phosphorus in natural systems can cause the extensive growth of algal blooms that decrease oxygen levels in water and bring about serious environmental problems (eutrophication).

Water quality standards for surface waters protecting fish and aquatic life have a maximum total phosphorus (TP) level of 0.075 milligram per liter (mg/L) (75 ug/L) (Chapter NR 102.06 Wisconsin Administrative Code). Due to the high quality of Rock Lake, a total phosphorus level of 0.075 mg/L is a reasonable standard of phosphorus to maintain in the Miljala Channel watershed. Further research into the source and extent of phosphorus loading in Rock Lake is warranted due to the potential environmental degradation associated with excessive phosphorus.

Figure 2.11 Eutrophication Behind the Sediment Curtain. Photo credit: Steve Neary, 6.26.12

Phosphorus Objective

Elevated phosphorus levels in both the Miljala Channel and the ditch leading to it have led to further investigation into the quantity and sources of phosphorus entering the channel. Previous studies have shown phosphorus sampling results at concentrations higher than statewide mean values for streams, though these values were based on limited data. A more comprehensive study of the phosphorus concentrations in groundwater, surface water and deposited sediment is needed to determine effective measures to reduce phosphorus inputs.

Phosphorus Source Investigation

Total phosphorus and dissolved orthophosphate samples were collected and analyzed on multiple dates from September 17, 2011 to October 14, 2012. Total phosphorus is the sum of all forms of phosphorus in a sample. Dissolved orthophosphate is the soluble phosphorus portion of total phosphorus that is within solution and available for biological uptake. Samples were taken from surface sites and from monitoring wells to determine inputs from groundwater

Table 2.2 Surface Site Phosphorus Results for Four Dates at Sites Sampled in the Miljala Channel Watershed.

	Total Phosphorus (mg/L)				Dissolved Orthophosphate (mg/L)			
Site	04/12/12	08/07/12	08/16/12 *	10/14/12 *	04/12/12	08/07/12	08/16/12 *	10/14/12 *
SS 7	0.442	0.380	0.724		0.340	0.274	0.640	
SS 5		0.235	0.543	0.673		0.150	0.640	0.546
SS 3		0.141	0.466	0.480		0.103	0.346	0.355
SS 1	0.185	0.146	0.525	0.457		0.095	0.296	0.317
SS 9		0.052	0.078			0.013	ND	

*Storm sample date

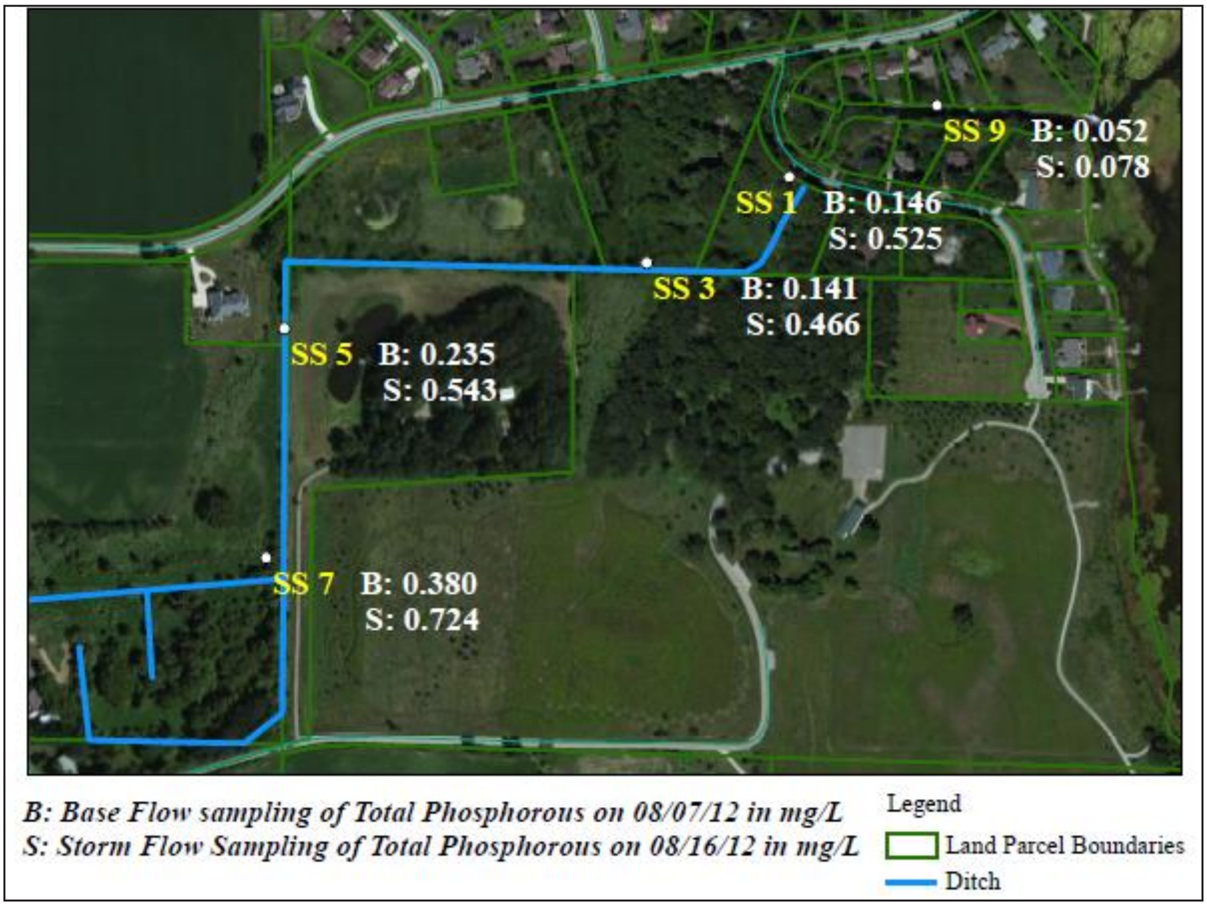


Figure 2.12 Map Showing Surface Site Phosphorus Results at Sites Sampled Within the Miljala Channel Watershed.

sources and their relation to surface water concentrations. Spatial variation in phosphorus loading was possible given the locations of surface water sampling sites and monitoring wells. Samples were taken during both baseflow and stormflow conditions to identify trends relating to rainfall events and increased flow rates.

Surface water total phosphorus (TP) concentrations throughout the ditch were often above the established criteria, as seen in Table 2.2. Raw data for total phosphorus and dissolved orthophosphate samples collected and analyzed on multiple dates from September 17, 2011 to August 16, 2012 can be found in Appendix D (Tables D.3 and D.4, and Figures D.3 and D.4). The data suggest that upstream reaches of the ditch are significant contributors to phosphorus loading, increasing the potential for harmful algal blooms in the Miljala Channel and Rock Lake (Table 2.2).

Sampling results also indicate that groundwater is not a major driver of elevated phosphorus concentrations during storm events. Laboratory analyses of all samples from monitoring wells revealed dissolved orthophosphate concentrations below 0.046 mg/L, which is about an order of magnitude lower than values obtained at surface sites. Though water reaching the ditch during baseflow conditions is primarily groundwater, the major contributor of phosphorus is runoff from storm events. Therefore, more focus should be given towards improving surface water quality by exploring runoff sources (Table 2.3).

Surface water phosphorus levels were highest in upstream reaches near surface sites 5 and 7 (SS5, SS7) during base flow and storm flow conditions (Table 2.2 and Figure 2.12). Such drastic differences in phosphorus results are partially caused by dilution from groundwater during baseflow conditions, which contributes to lower phosphorus concentrations observed downstream. Another reason for the differences observed are high phosphorus levels that leach out from the soil as well as deposited sediment in the ditch bottom. For instance, surface water dissolved orthophosphate constituted 62.7% of the total phosphorus results during base flow and 77.6% during storm flow, respectively. This suggests that there is more soluble phosphorus being transported in the system than particulate phosphorus.

Baseline phosphorus loading rates were calculated based on results obtained from lab analyses on August 7, 2012. Results show that total phosphorus and dissolved orthophosphate loading are higher at SS5 (64.4% and 63.2%) than SS1 (35.6% and 36.8%), respectively. These data add supporting evidence to the notion that upstream reaches are greater

Figure 2.13 Silt and Muck Soil Were Observed Suspended in the Water Column During Low Flow Conditions. Photo Credit: Steve Neary, 2.29.12

Table 2.3 Well Phosphorus Results for Three Dates Sampled in the Miljala Channel Watershed.

Site	Dissolved Orthophosphate (mg/L)		
	04/12/12	08/07/12	8/16/2012*
MW 1	0.037	0.046	0.036
MW 2	0.009	0.023	0.021
MW 8	0.024		0.019
MW 4	0.004		
MW 5	ND		
MW 6	ND		

* Storm sample date

contributors of phosphorus into the ditch. Storm flow phosphorus loading data were not obtained.

Precipitation events also contribute to increases in surface water phosphorus concentrations. This is manifested through the coupling of precipitation driven surface runoff and a minimal decrease in groundwater phosphorus concentration, as seen in Table 2.2 and Table 2.4. Larger storms produce an increased volume of overland flow and interflow that contribute to surface runoff. These increases in runoff cause more phosphorus to be removed from the land surface and transferred to the ditch.

A calculated phosphorus index (P index) can help with managing phosphorus runoff from cropland. Soil on the farm field north of SS7 and west of SS5 falls within the acceptable limit according to the DNR (P index = 5), even though elevated levels of phosphorus were observed on the field (129 mg/L). The P index for a field is determined using the distance to the closest navigable waterway. The distance chosen for this field's plan was in the range 301-1000 feet, which is above the range that should be used to calculate the field's P index (0-300 feet) considering the closest distance to the ditch is about 195 feet. Recalculation of the P index for this field in particular will likely place the P index above the acceptable limit, requiring a reduction in phosphorus-containing fertilizer applied to the field. Lowering phosphorus inputs on the field would likely reduce levels of soluble phosphorus reaching the ditch.

Table 2.4 Percent of Dissolved Orthophosphate Contained in Samples Collected on Four Dates in the Miljala Channel Watershed.

	% of Dissolved Orthophosphate in Water			
Site	**04/12/12**	**08/07/12**	**08/16/12 ***	**10/14/12 ***
SS 7	76.923	72.105	88.398	
SS 5		63.776	100.000	81.129
SS 3		73.050	74.249	73.958
SS 1		65.068	56.381	69.365
SS 9		25.000	ND	

* Storm sample date

Table 2.5 Total Phosphorus Percentage of Loadings to Channel Based on Sampling on August 7, 2012.

	Parameter				
Site	**Total Phosphorus (mg/L)**	**Flow (cfs)**	**Total Phosphorus (lbs/day)**	**Incremental Total Phosphorus Load (lbs/day)**	**%**
SS 5	0.235	0.056	0.071	0.071	64.4
SS 1	0.146	0.140	0.110	0.039	35.6

Table 2.6 Dissolved Orthophosphate Percentage of Loadings to Channel Based on Sampling on August 7, 2012.

	Parameter				
Site	**Dissolved Orthophosphate (mg/L)**	**Flow (cfs)**	**Dissolved Orthophosphate (lbs/day)**	**Incremental Dissolved Orthophosphate Load (lbs/day)**	**%**
SS 5	0.150	0.056	0.045	0.045	63.2
SS 1	0.095	0.140	0.072	0.026	36.8

Bacterial Contamination

Thermotolerant coliform bacteria (formerly termed fecal coliform bacteria), including *E. coli* among others, are commonly used as indicator organisms to assess bacterial contamination in natural waters. The presence of thermotolerant coliforms, or *E. coli*, in natural waters indicates fecal contamination and may signal the presence of pathogens that can cause gastrointestinal illness when found in high concentration. Because of this hazard, the United States Environmental Protection Agency (EPA) has developed standards for measuring and monitoring indicator organisms in water. In accordance with the Clean Water Act, Wisconsin has established maximum regulatory concentrations, using *E. coli* as the target indicator organism for recreational use of water bodies, at 235 colonies per 100 mL (EPA, 2003).

Although there are many different processes by which bacteria may be introduced into an environmental system, non-point sources are recognized as the major cause of bacterial contamination in waterways. In most cases, agricultural practices are the primary contributor (Diaz et al., 2009). Bacterial monitoring is important for both environmental and public health reasons. Rainfall events mobilize bacteria by generating runoff. The subsequent bacterial transport into ground and surface water environments can potentially affect ecosystem function. When present in surface waters used for human consumption or recreation, bacteria can also pose a risk to public health (Boutilier et al., 2009).

Bacterial Objective

The presence of coliform bacteria in the watershed has been documented by previous consultants. Sampling in 2009 and 2010 revealed that both *E. coli* and thermotolerant coliform bacteria were present in the ditch at levels above EPA standards for direct human contact through activities like swimming or water skiing. As a result, a secondary objective of this project was to investigate the source(s), loading and route of transport of coliform bacteria through the watershed and ultimately into Rock Lake. Identifying the source(s) of bacteria was of particular interest given the number of possible sources within the watershed. Potential sources include septic systems, a closed manure pit, agriculturally related fertilizer application, domestic animals, and wildlife. One main goal was to differentiate between these potential sources and to identify bacterial origin as either human or animal.

Bacterial Source Investigation

Bacterial sampling was conducted based on hydrologic transport within the watershed in order to distinguish between potential sources and to determine the occurrence and source of any human waste material within the watershed. Analyses were conducted for *E. coli* and fecal coliform bacteria, which both serve as indicators for the presence of human and animal fecal material. These bacteria are known to be associated with other harmful bacteria and viruses and therefore are sentinels for human health risk (RLIA, 2011).

Samples were collected during both baseflow and stormflow conditions to determine any differences in concentration between varying types of flow events. Increased concentration during a stormflow event could indicate manure runoff from nearby agricultural fields or local animal populations. Decreased concentration during a stormflow event could indicate a groundwater source, possibly from septic tank leakage or legacy contamination from a large manure pit removed in 2009 (Figure 2.14).

Sampling in the spring and summer of 2012 provided several insights into the abundance and source(s) of fecal coliform and *E. coli* bacteria in the watershed. *E. coli* and fecal coliform continue to persist in both the ditch and the channel, and have been found in excess of EPA standards for increased health risk to humans. Standards for the presence of fecal coliform and *E. coli* are 200 and 235 colonies per 100 mL, respectively (RLIA 2011).

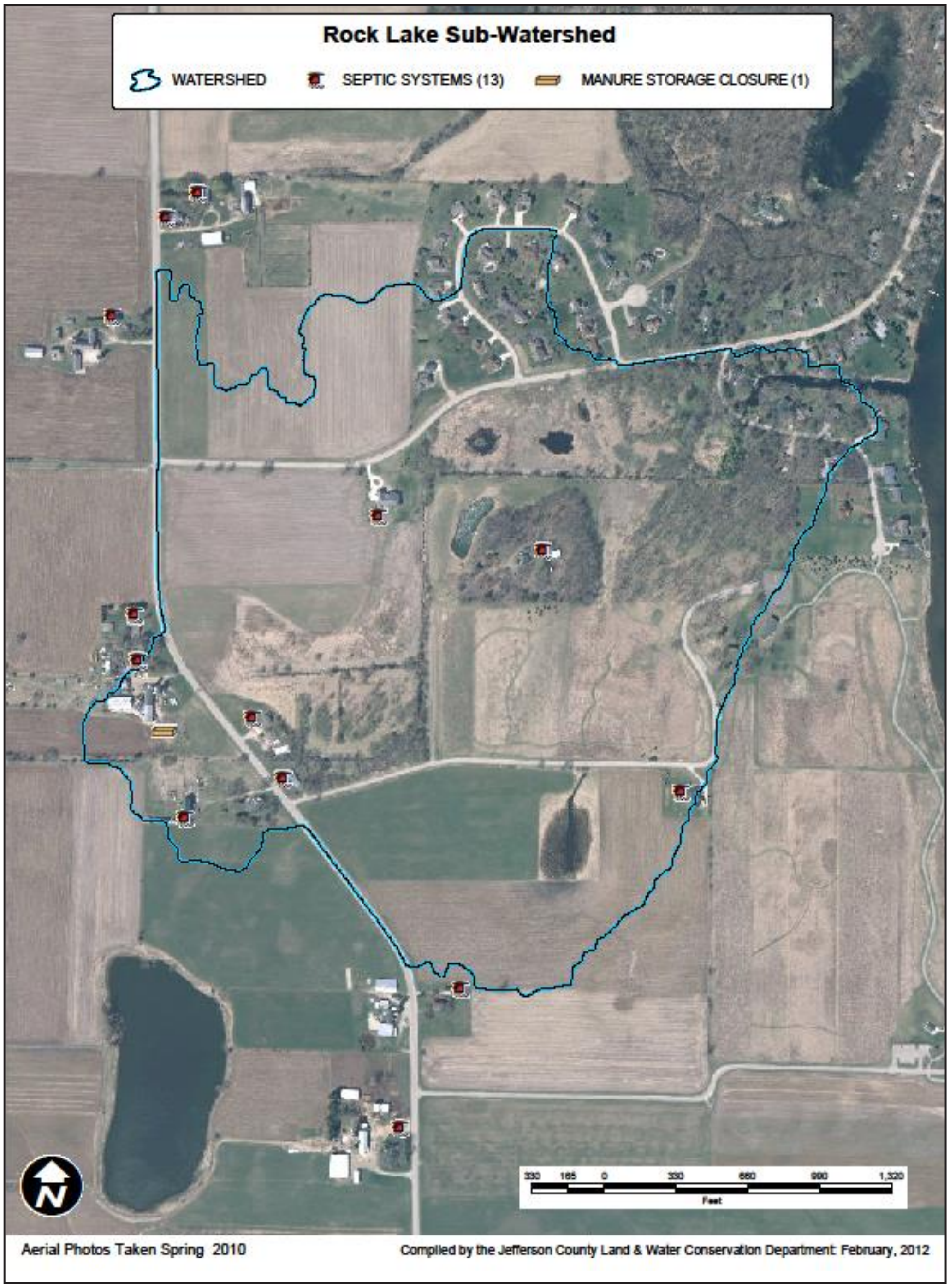


Figure 2.14 Septic Survey Map. Included are locations of septic systems and a previously removed manure pit within the watershed. Source: Jefferson County Land and Water Conservation Department.

The first key point is that groundwater does not appear to be the primary bacterial source. It is unlikely that leaky septic systems, sewers, or legacy contamination from manure pit removal in 2009 are the cause of contamination. Data from sampling in 2009, 2010 and 2012 indicates that fecal coliform and *E. coli* are more abundant during the peak growing season (mid-late summer) than in spring or late fall (Figures 2.15 and 2.16). In addition, bacterial concentrations showed a marked increase during storm events that produce substantial surface runoff. These fluctuations suggest that groundwater inputs are not providing a constant supply of bacteria to the ditch.

Sampling data also show a significant drop in bacterial colonies in 2010 as compared to 2009 and 2012 (Figure 2.15). The initial theory was that this drop in bacterial concentration was correlated with the manure spreading cycle of the agricultural field located directly west of SS5. The theory is based on documentation that manure applied to agricultural fields can result in surface runoff containing elevated bacterial concentrations (Brooks et al., 2009, Collins, 2004); thus, it seemed plausible that the field is a likely source of bacteria in the watershed. This particular field is row-cropped and chicken manure is applied in approximately 2 to 3 year intervals. According to this field's nutrient management plan, chicken manure was spread in both 2010 and 2012 at a rate of 2 tons per acre.

As a result, it is unlikely that manure spreading is the only source of bacterial contamination in the watershed. Dr. Sharon C. Long, a UW professor and Director of Environmental Microbiology with the Wisconsin State Laboratory of Hygiene, suggested that infrequent rainfall events this year may have allowed high ditch and channel bacterial concentrations to accumulate in the soil. Frequent rain events flush bacteria from the soil and serve to reduce overall population numbers (Long, 2012). During 2010 there was far more precipitation than 2009 or 2012, particularly during warm summer months (Table 2.7). Frequent and intense rain events in June and July of 2010 may have served to flush bacteria from the soil, thereby reducing ditch and channel concentrations that year.

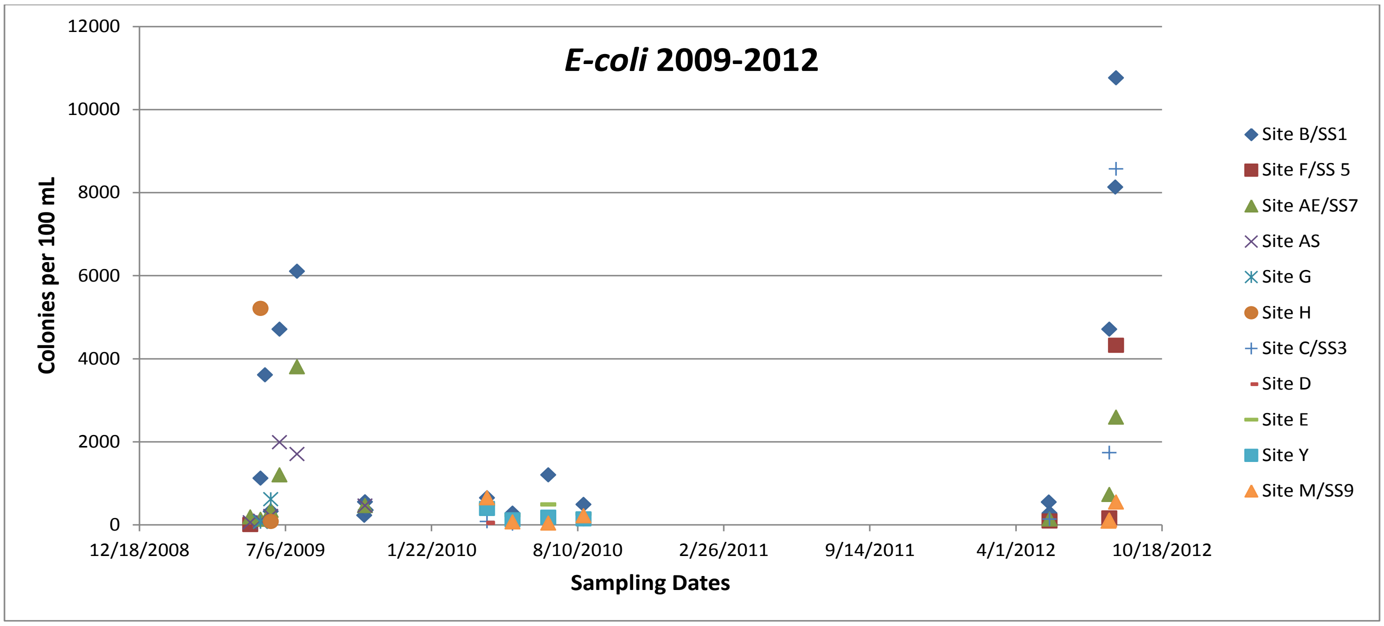


Figure 2.15 *E. coli* Concentrations (per 100 mL sample) from Select Sampling Dates in 2009-2012.

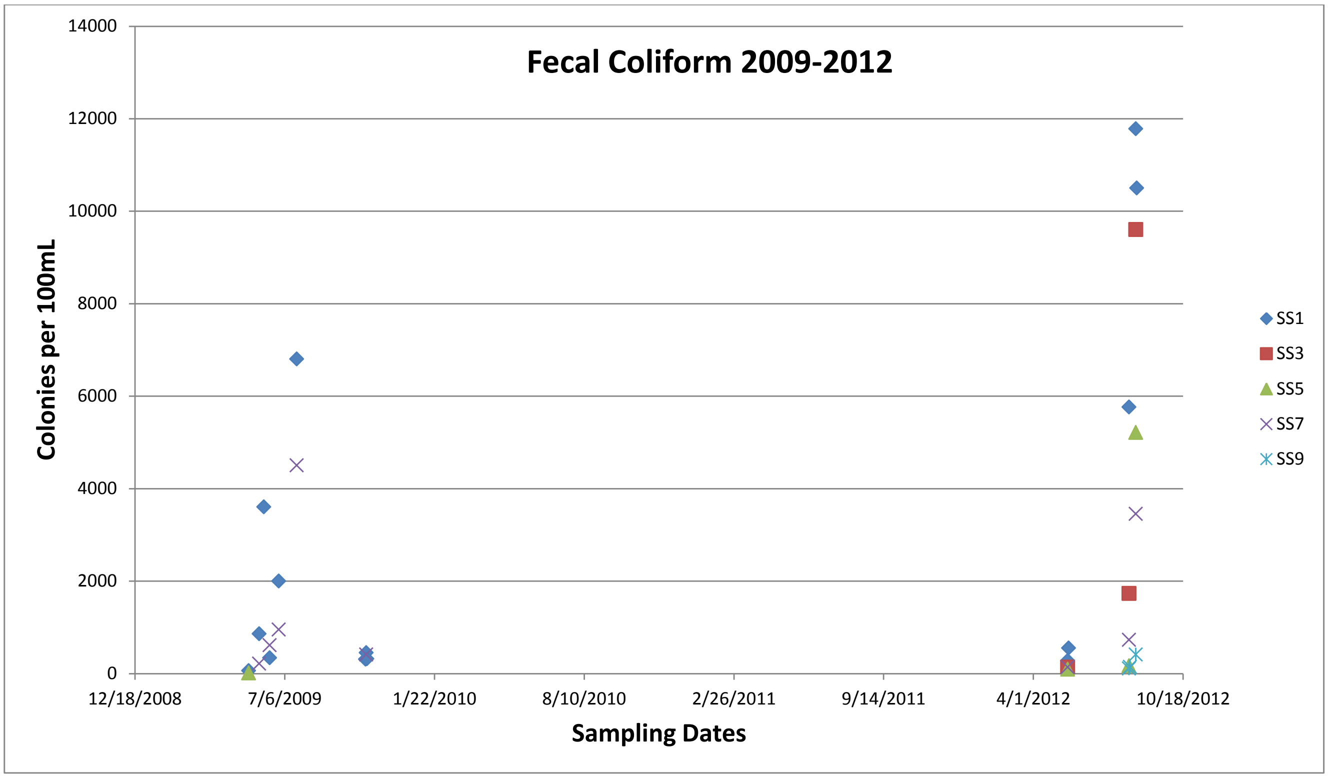


Figure 2.16 Fecal Coliform Concentrations (per 100 mL sample) from Select Sampling Dates in 2009-2012.

Table 2.7 Rainfall (inches) by Month in 2009, 2010, and 2012 at Station 474482 in Lake Mills, WI. Source: National Oceanic and Atmospheric Administration, National Climatic Data Center (http://www.ncdc.noaa.gov).

Year	Apr	May	Jun	Jul	Aug
2009	4.67	3.36	4.11	2	3.21
2010	4.09	4.61	10.38	7.23	3.62
2012	2.84	4.55	0.34	4.78	2.27

Another likely source of bacteria in the watershed is wildlife. It is well known that wildlife feces are a contributor to the presence of *E. coli* and fecal coliform in wetland and other naturally occurring ecosystems (Gordon and Cowling, 2003, Whitman et al., 2006). Numerous mammalian and avian species were observed in the area over the course of the study period, including deer, sandhill cranes, mallards and muskrats (Figure 2.17). In addition, a dead raccoon was discovered near the ditch at SS5 in June 2012.

In conclusion, it is likely that persistence of bacteria in the watershed is a result of regular contributions from wildlife feces as well as the spreading of manure for agricultural purposes. Once introduced into a system through fecal contamination, bacteria are able to persist outside of a host, forming colonies on both soil and suspended sediment (Byappanahalli et al., 2003). Numerous studies (Brooks et al., 2009, Byappanahalli et al., 2003, Tomer et al., 2010) found that surface runoff containing suspended sediment is a significant source of *E. coli*, and this is the likely method of delivery to the ditch and adjacent soil.

There is also a possibility that the watershed may be a source of naturally occurring bacteria. Some studies (Byappanahalli et al., 2003, Power et al., 2005) have suggested that *E. coli* may be capable of occurring in water or wet soil without any type of animal origin, possibly even persisting year-round (Whitman et al., 2006). Infrequent summer precipitation events may provide optimal conditions for continued bacterial persistence as well (Long, 2012). Genetic testing of bacteria in the watershed could help rule out a human source of bacteria, but would not distinguish between bacteria from chicken manure and natural sources.

Figure 2.17 Animal Tracks are Evident and Ubiquitous Throughout the Watershed, Indicating a Perennial Bacteria Source. Photo credit: Steve Neary, 1.27.12

Hydrology

The 2011 report described several management alternatives that could either prevent stream bank erosion, such as bank stabilization or ditch plugs, or that could trap pollutants, such as wetland restoration or sedimentation basins. As part of the Lake Planning Grant, Montgomery Associates:Resource Solutions will be further developing engineering solutions and working with landowners and the RLIA to evaluate alternatives. However, in order to determine the required size of sedimentation basins or wetlands, information on peak flows and runoff volume is needed. A better understanding on the sources and flows of groundwater, as well as soil parameters such as hydraulic conductivity, will help to assess the impacts of practices such as ditch plugs on the water table. Our goal in monitoring and computer modeling of surface and groundwater hydrology was to provide a preliminary assessment of the feasibility of management alternatives, and to provide data for further evaluation and engineering of solutions.

Groundwater monitoring

We installed data loggers in several wells to track groundwater levels, and compared those to flows in the ditch (Figure 2.18). Our hope was to find a strong relationship between groundwater storage in the Houghton Muck, as reflected by the height of the water table, and groundwater discharge to the ditch that could be used to model baseflow, but the correlation was weak (Figure 2.19).

However, well monitoring did reveal more about groundwater sources and flow paths (Figure 2.20). The significance of evapotranspiration to the water budget is clear from the daily fluctuations in water levels observed in both wells and the ditch. The role of glacial drumlins to recharge and store groundwater was evident from nearby monitoring wells MW5 and MW6. Those wells showed consistently higher water levels than wells farther from the drumlin and levels in those wells declined more slowly during the drought.

Figure 2.18 Recording Groundwater Elevation at MW5. Pictured are Ian Anderson, Maria Garcia de la Serrana, and Steve Neary. Photo credit: Patricia Cicero, 3.9.12

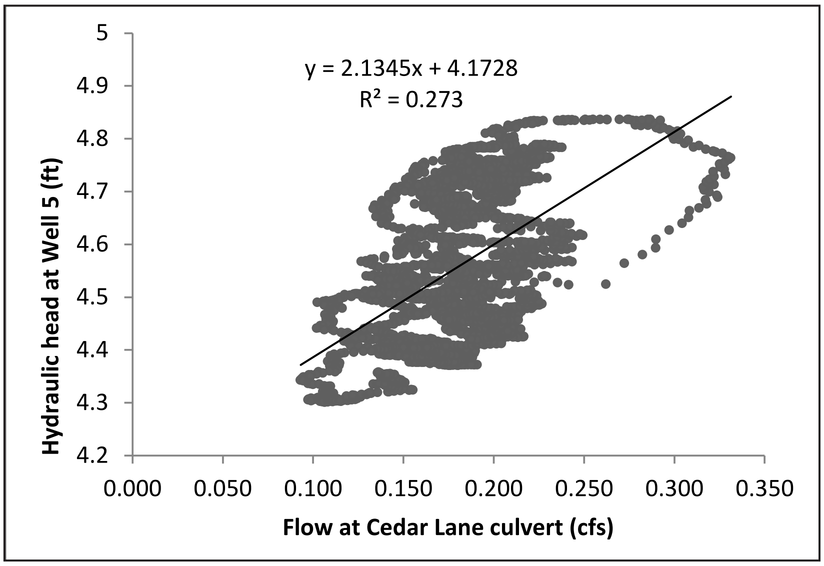


Figure 2.19 Poor Correlation Between Water Table and Groundwater Discharge to Ditch.

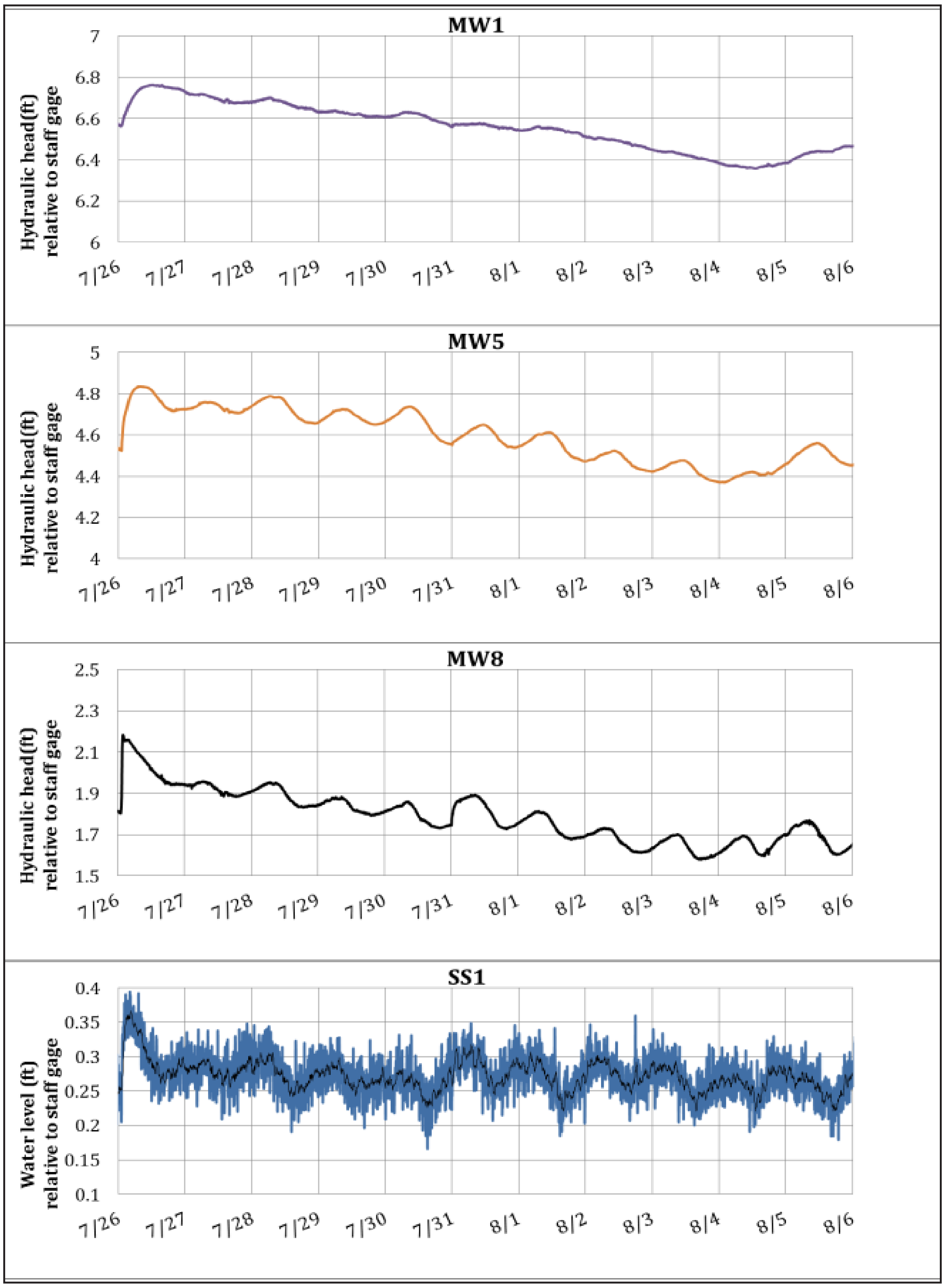
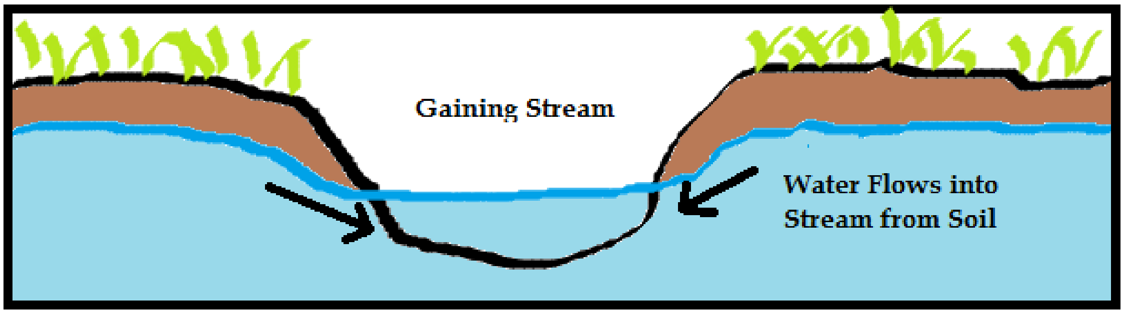


Figure 2.20 Comparison of Well Levels and Stream Levels.

In areas where there was little hydraulic connection to the drumlins, such as MW3, MW4, and MW8, the water table can drop below the elevation of the ditch and the area becomes a losing reach (Figure 2.21). Flows in the ditch and water tables in upstream wells (MW 1 and 2) declined very slowly. At the same time specific conductance, a measure of dissolved minerals, measured in the ditch increased to a new level, indicating either potential inputs of ions from an anthropogenic source or an increase in groundwater contributions with longer residence time. This indicates upper reaches of the ditch receive groundwater inputs from outside the surface watershed (Figure 2.22).

A regional map of the water table and county geology maps (Boreman and Trotta, 1975) support this interpretation. Recharge zones in areas of limestone bedrock or limestone gravel contribute both water and dissolved minerals to the upper reaches of the ditch. Groundwater is a significant water input into the system and all management strategies must incorporate its continuous input in their calculations. Regional groundwater flow keeps the soil wetter than would be predicted by precipitation within the watershed alone and will stabilize water levels in ponds, wetlands, or other management practices.



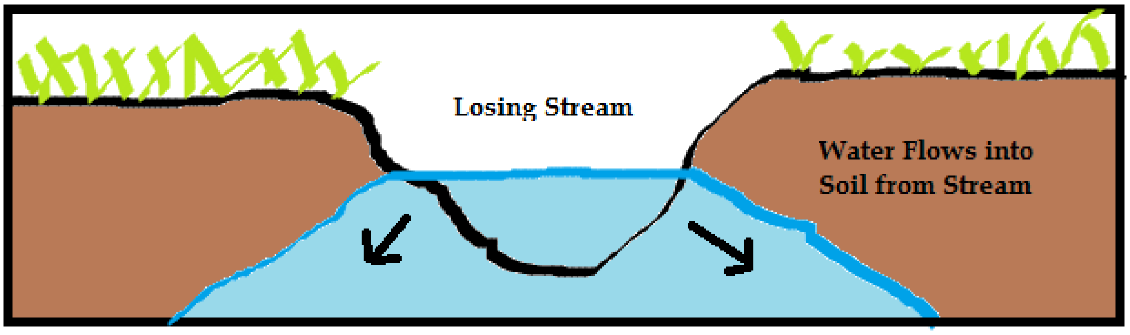


Figure 2.21 Gaining Streams Have Higher Water Table Elevations Within Wells Than Stream Stage Elevations. In this instance, water flows from the groundwater into the stream. Losing streams have flow out of the stream into the ground. Water table elevations lower than stream stage elevations indicate losing reaches.

Modeling ditch drainage and impacts of drainage plugs

Muck soils are difficult to drain because of their high water holding capacity and relatively low hydraulic conductivity (Boelter, 1972). Despite the installation of the ditch, upper reaches of the watershed remained too wet to farm most years, according to Dave Korth (2012). The influence of a drainage ditch or drain tile running through a wetland can be modeled using the van Schilfgaarde equation, as described in Appendix C. Starting from a fully saturated soil — as may occur in spring snowmelt — the soil drains rapidly near the ditch and more slowly with increasing distance. Beyond some threshold distance — the lateral effect — drainage is slow enough that it would take 14 days to drain the top foot of the soil, meeting the U.S. Army Corps of Engineers technical definition of wetland hydrology. Lateral effect is illustrated in Figure 2.23.

A similar approach is used by regulators to determine whether a ditch will impact nearby protected wetlands. The Minnesota Board of Water and Soil Resources (2012) has published setback distances for peat and muck soils based on field observations

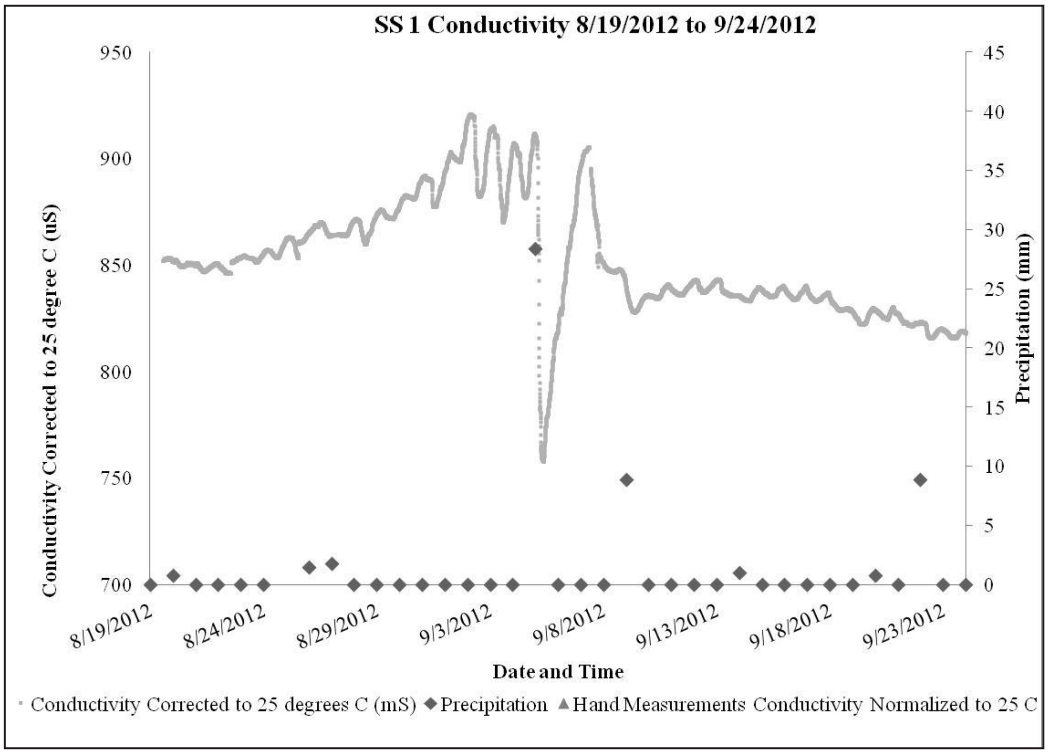


Figure 2.22 Conductivity and Precipitation Data Show Impacts When No Precipitation Occurs.

reported in the scientific literature; these are shown alongside lateral effect calculated for the site in Table 2.8.

Lateral effect is a crude way to delineate the wetland area effectively drained by a drainage ditch. It also provides a crude way to assess the impacts of proposed engineering solutions on landowners. For example, if a ditch plug or wetland causes 1 foot of water to be backed up into a 4 foot ditch that drains a farm field, or the ditch is made 1 foot shallower as part of bank stabilization, then we would expect the width of land effectively drained in a wet spring to be reduced 5-10 feet.

As Table 2.8 shows, a single drainage ditch in muck has a limited influence on the water table, especially when the ditch is shallow. Whether wet conditions are actually present outside that zone in a given year depends on precipitation patterns and evapotranspiration. Additional factors that could influence water table elevation are vertical groundwater movement from a deeper aquifer and surface depressions that allow for ponding of runoff. As described above, there is evidence for regional groundwater inflows in the upper reaches of the ditch that could reduce its effectiveness. Either of these factors could explain the presence of cattails within 40 feet of the ditch near SS7.

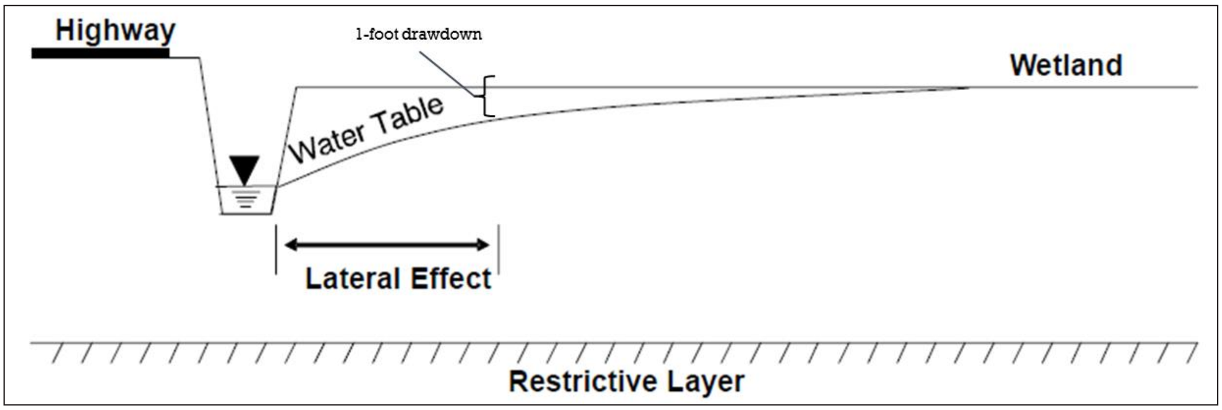


Figure 2.23 Lateral Effect Illustration. Lateral effect is the distance from the ditch that Is adequately drained within some critical period (adapted from Skaggs et al. 2005).

Table 2.8 Lateral Effect of a Drainage Ditch in Muck Soil.

Depth of ditch	Lateral effect based on van Schilfgaarde equation	Setback distance based on field observations reported in literature
2'	38'	40'
3'	48'	60'
4'	53'	70'
5'	56'	80'

Modeling Runoff and Peak Flow in the Ditch

Runoff volume and peak flows are important information for engineering of detention ponds and other management practices. We continuously monitored flows in the ditch at the Cedar Lane culvert from March through September of 2012. The highest peak flow measured during this period was 1.38 cfs, in response to an intense 1.77 inch storm on May 6. On August 19, 2007, the weather station in Lake Mills measured a 24-hour rainfall of 5.77 inches, the largest in its 115 year record (WSCO, 2009). Although we do not have flow data for this event, residents reported that the water in the ditch rose above the Cedar Lane culvert but did not overtop the road. Ponding and flow through the culvert was modeled in HydroCAD to determine the maximum water level associated with a range of peak inflows. The stage-storage relationship of the area behind the culvert was determined in Geographic Information Systems (GIS) from the 16 foot digital elevation model. Based on this simulation, peak flow through the ditch would have been somewhere in the range of 40-70 cubic feet per second (cfs) (Figures 2.24 and 2.25).

In the previous RLIA report (RLIA, 2011), consultants modeled peak stormflow using the methods outlined in the Natural Resources Conservation Service publication, TR-55 Urban Hydrology for Small Watersheds. This approach, widely used for stormwater engineering, uses landcover, soil type, and flow path characteristics to determine the volume and peak flows produced from a given precipitation depth and rainfall distribution. Runoff depends on both the amount and intensity of rainfall, so it can be misleading to compare a design storm, such as the 2 year, 24-hour rainfall to a real event that may have a different intensity of rainfall. Nonetheless, the peak flows published in the previous report seem unreasonably high, an order of magnitude larger than what has been observed in comparable storms (Figure 2.24).

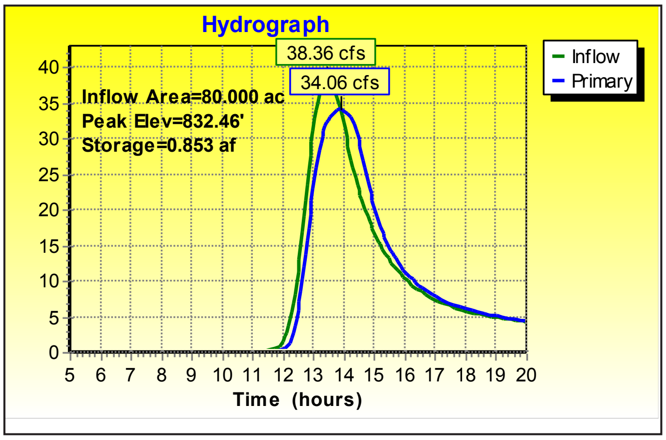


Figure 2.24 Peak Flow Sufficient to Submerge Cedar Lane Culvert (elevation 832.26).

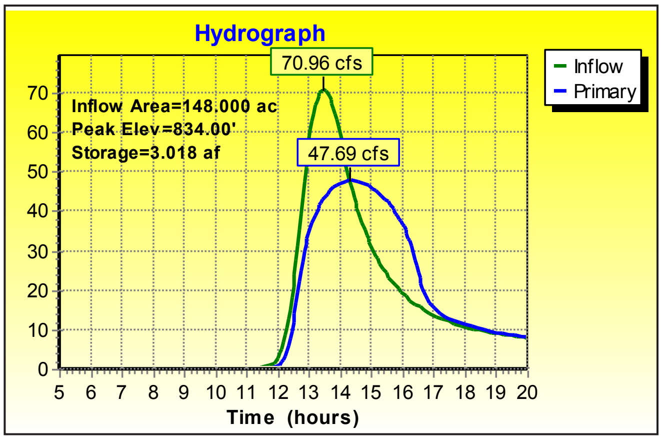


Figure 2.25 Peak Flow Sufficient to Overtop Cedar Lane (elevation <834).

Figure 2.26 A Drain Tile Connecting SS4 and the Ditch Emerges From a Thick Mat of Duckweed on the Pond at SS4. We did not observe water above this tile during the study period, indicating that this portion of the watershed does not normally contribute directly to the flow in the ditch. Photo credit: Steve Neary, 3.21.12

Figure 2.27 Sampling Accumulated Water Flowing Through the Culvert at SS8. This was the largest amount of water observed here during the study period. Pictured is Cody Meier. Photo credit: Steve Neary, 2.29.12

Figure 2.28 The Pond at SS4 Completely Dried Up for the Bulk of the Summer. Photo credit: Steve Neary, 6.20.12

Figure 2.29 A Gully Runs from the South End of the Culvert at SS8 to the Main Stem of the Ditch. Water was only observed here during snowmelt and after larger precipitation events. Pictured is the confluence of the gully flowing from SS8 and the main stem of the ditch. Note the eroded deer crossing in the center of the photo. Photo credit: Steve Neary, 2.29.12

Details were not given in the previous report, but there are several reasons why a TR-55 model might overestimate runoff.

A) A large portion of the runoff does not normally reach the ditch (Figure 2.30). Catchment 1 drains into the Miljala channel below the culvert. The 7.5 acres of the field in Catchment 11 drain to a closed depression which would have to overtop Shorewood Hills Drive to drain surface water. Catchment 12, which includes 28 acres south of Korth Lane, drains to a farm pond. Only in wet years does the pond get high enough to reach the

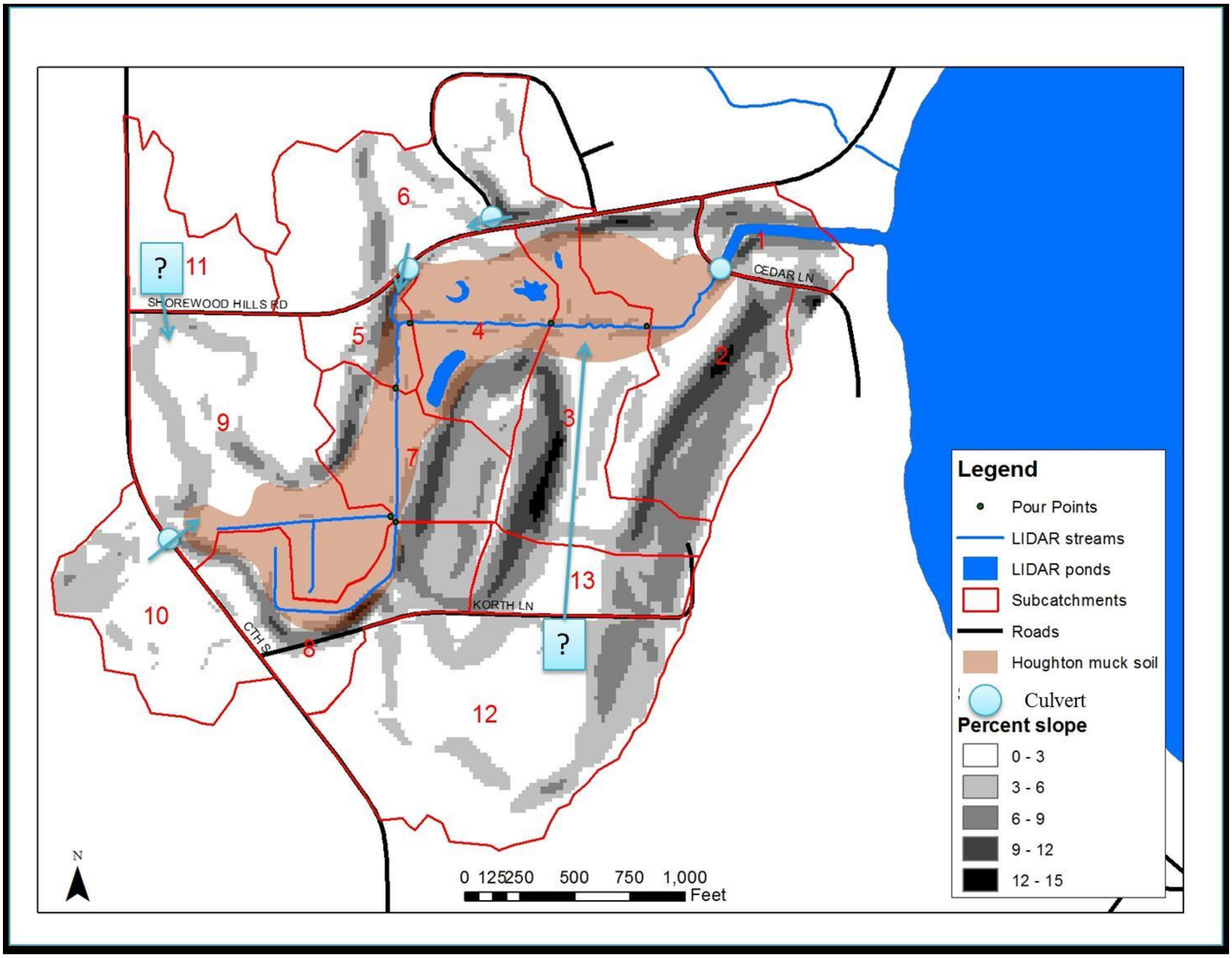


Figure 2.30 Subwatersheds Delineated in GIS. Numbers 11, 12, and 13 do not contribute runoff to ditch under normal conditions.

overflow drain and discharge into the ditch (Cicero, 2012). Catchment 13 is a 7 acre closed depression. The condition of the drain tiles that once drained it is uncertain. Catchment 4 includes several scrapes which could store runoff.

B) Most of the watershed has moderately permeable soils and limited impervious surfaces and so produces little runoff. This should be reflected in the curve numbers selected for the model. The Natural Resource Conservation Service (NRCS) Soil Survey (accessed 2011) classifies most of the soils in the watershed as moderately permeable (hydrologic class B). When drained, soggy wetland soils become moderately permeable — Waucosta silt loam is hydrologic group B — to highly permeable — Houghton muck is hydrologic group A. Our infiltration tests have also confirmed this pattern.

C) Because of their low slope, high infiltration rate, and water holding capacity, the muck soils surrounding the ditch have the potential to absorb much of the runoff from adjacent mineral soils. The exceptions to this pattern are the Shorewood Meadows subdivision (catchment 6) and the farm pond south of Korth Park (catchment 12), which drain directly to the ditch. Catchments 5 and 8 have steep slopes draining up to the ditch, so infiltration is limited.

The first two points were taken into account in the development of our TR-55 model in HydroCAD. Drained muck soils are treated as highly permeable (hydrologic soil group A) and contributing area is reduced. Drought prevented us from observing a clear relationship between water tables in the muck and flow in the ditch. Details of parameter selection for the model are shown in Appendix E. An alternate model incorporating groundwater storage and release from the muck soils was planned, but could not be completed due to data limitations imposed by the drought.

While incorporating these changes into a TR-55 model does produce more reasonable results that could provide the starting point for engineering, they should not be seen as a definitive. TR-55 is an event-based model, modeling the response of a system to a given storm without regard to antecedent moisture conditions in the soil, the level of the water table, or the water level in ponds. While this is the standard for stormwater engineering in urban areas, it has limitations for this particular watershed. As has become clear from our monitoring, these factors can be very significant in determining the peak flow, or whether any runoff is produced at all. Incorporating these factors using continuous modeling of groundwater and surface water flows is a difficult undertaking that is beyond the scope of a project of this nature.

Size and effectiveness of ponds or wetlands for sediment control

Because peak flows in the ditch are smaller than previously believed, estimates for the size of water quality treatment practices can also be revised downward. The previous report recommended that a treatment wetland should be 3-5% of the watershed area — 5.6 to 9.4 acres in size. This is probably an overestimate, first because the area that normally contributes runoff to the ditch is smaller than 180 acres, and second because this rule of thumb is likely based on more urbanized watersheds. A 2-3 acre detention pond was recommended based on an outdated standard — 5 micron control for the 1.5 inch storm.

Revised DNR standards for wet detention ponds call for the sediment treatment up to the one-year, 24-hour storm, which for southern Wisconsin is 2.25 inches (DNR, 2007). Modeling shows that this storm would generate 2.63 acre-feet of runoff and a peak discharge of 8 cfs. A sedimentation pond can completely trap all particles that settle out of the active storage zone faster than they are swept to the outlet; therefore, the minimum area (S_a) of the permanent pond depends on the peak outflow (q_o) during the design storm and the particle settling velocity (v_s) of the target sediment class, plus a safety factor.

$$S_a = 1.2 * (q_o / v_s)$$

The DNR (2007) found that removal of particles of 3 microns in diameter is needed to achieve 80% reduction of total suspended solids (TSS) in urban areas. A standard of 6 microns is needed for 60% reduction, and a standard of 12 microns can achieve 40% TSS reduction. Removal efficiencies in this watershed will undoubtedly be higher, since even a 20 micron standard can control the fine and coarse sand that makes up greater than 60% of the accumulated sediment below the culvert. Muck has an average settling velocity of 7.9e-4 ft/s and a minimum settling velocity of 5.4e-5 ft/s (Marttila and Klove, 2008), so while a 12 micron standard would control more than half the muck, a 5 micron standard would be needed to provide complete control.

Table 2.9 shows the minimum pond areas required to achieve various standards of sediment control. While the surface area of the permanent pond can be reduced by constraining the peak outflow, this requires more "live" storage — the volume of runoff detained during a storm. The minimum area of the temporary pool shown in Table 2.9 is determined either by the minimum slope needed for bank stability (3:1) or by the volume and depth of live storage (Atemporary = (2*VWQV/D) - Apermanent).

While a temporary storage depth of up to 3 feet can be practical for a detention pond, large fluctuations in water level can kill sensitive plant species. In revising his 15 year old standards for the design of stormwater wetlands, Scheueler (2012) recommended that the live storage, or "bounce," during the design storm should be no more than one foot, while cautioning that any bounce at all can favor invasive species. Tables 2.10 and 2.11 show the area of ponding needed to treat to a given standard while minimizing the bounce. This shows that a three acre wetland can provide high sediment control — without even accounting for the additional water quality benefits of vegetation — while avoiding bounce that favors invasive species.

Table 2.9 Minimum Pond Areas to Treat 1-Year, 24-Hour Storm With 3 Inch Bounce.

Sediment control standard	Settling velocity (ft/s)	Peak outflow (cfs)	Surface area of permanent pool (acres)	Live storage volume (acre-ft)	Depth of temporary pool "bounce" (ft)	Surface area of temporary pool (sq. ft)
20 micron	1.20E-03	4.00	0.09	0.74	3.00	0.40
12 micron	2.95E-04	4.00	0.37	0.74	3.00	0.44
5 micron	7.30E-05	4.00	1.51	0.74	3.00	1.65
3 micron	1.91E-05	4.00	5.77	0.74	3.00	6.03

Table 2.10 Wetland Area to Treat 1-Year, 24-Hour Storm With 1 Inch Bounce.

Sediment control standard	Settling velocity (ft/s)	Peak outflow (cfs)	Surface area of permanent pool (acres)	Live storage volume (acre-ft)	Depth of temporary pool "bounce" (ft)	Surface area of temporary pool (sq. ft)
20 micron	1.20E-03	6.40	0.15	0.47	1.00	0.79
12 micron	2.95E-04	6.40	0.60	0.47	1.00	0.63
5 micron	7.30E-05	6.40	2.42	0.47	1.00	2.47
3 micron	1.91E-05	6.40	9.23	0.47	1.00	9.34

Table 2.11 Wetland Area to Treat 1-Year, 24-Hour Storm With No Bounce.

Sediment control standard	Settling velocity (ft/s)	Peak outflow (cfs)	Surface area of permanent pool (acres)	Live storage volume (acre-ft)	Depth of temporary pool "bounce" (ft)	Surface area of temporary pool (sq. ft)
20 micron	1.20E-03	8.00	0.18	0.00	0.00	0.18
12 micron	2.95E-04	8.00	0.75	0.00	0.00	0.75
5 micron	7.30E-05	8.00	3.02	0.00	0.00	3.02
3 micron	1.91E-05	8.00	11.54	0.00	0.00	11.54

Community Input

Given that the outcome of this project will affect a diverse group of stakeholders, it was important to offer opportunities for public engagement as the project progressed. The WRM student cohort worked in collaboration with the RLIA to facilitate public meetings in Lake Mills throughout the study, at which concerned citizens were provided a forum to have their questions answered and concerns acknowledged. Encouragement of public participation in the planning phase of a long-term project fosters a sense of ownership within the community. This in turn increases the likelihood of a successful resolution to identified problems.

Spring 2012 Annual Meeting

The WRM cohort held a meeting on April 19, 2012, along with Patricia Cicero from Jefferson County Land and Water Conservation, Steve Gaffield of Montgomery and Associates: Resource Solutions, and the RLIA. The meeting was held at Lake Mills' Community Center with approximately 40 attendees. The meeting objective was a face-to-face interaction with local residents in order to discuss the direction of the project and provide a forum for public input.

The presentation touched on many topics, including phosphorus and bacterial inputs, sediment transport, watershed hydrology, and potential management solutions. The findings presented at this first meeting were very preliminary due to the exploratory nature of the project at that time. The WRM students explained their intent to concentrate sampling efforts in areas that were likely contributors of phosphorus and bacteria to the system, which would allow for the identification of representative points throughout the watershed. It was important to convey this strategy to the community to demonstrate that sending samples to the State Lab of Hygiene for analysis was the most efficient use of funding.

Figure 2.31 Steve Neary Facilitating a Question and Answer Session After a Public Meeting in Spring 2012.

Figure 2.32 Dan Haug Presents Findings of Previous Consultant's Reports at the Rock Lake Improvement Association Annual Meeting in Lake Mills. Photo Credit: Maria Garcia de la Serrana, 4.18.12

Following the presentation, the audience was given an opportunity to ask questions or provide input regarding what they would like to see from the project. Steve Neary, a WRM student, was the emcee for this session, with questions fielded by WRM students as well as by representatives from participating organizations.

The most common questions:

1. Who/what organization will pay for the implementation of the management solution?

2. How could sand be the biggest contributor to the channel sediment deposition when muck is more often observed moving during baseflow by residents?

General comments/concerns:

1. Will the sediment plume that forms beyond the channel after rain events be addressed?

2. The need to preserve the biodiversity within the channel. For example, an electroshock sampling identified poor fish species diversity in the channel.

3. Residents with waterfront property expressed a sense of urgency to devise a management solution to the sedimentation problem. During the 1998 dredging of the entire channel, homeowners were told that they would not need to dredge again for another 40 years. However, smaller dredges have already been done in 2005, 2009, and 2011. The cost of dredging the channel has become unsustainable and raising money to conduct subsequent dredges has become more difficult over the years.

The outcome:

The meeting brought people together who have been working towards a solution to this problem for many years. It provided stakeholders an open forum

Figure 2.33 Steve Gaffield (MARS) and Larry Clark (RLIA) Introduce the Water Resources Management Students to Rock Lake and the Miljala Channel on their First Visit to Korth Park. Photo credit: Steve Neary, 9.16.11

to voice their opinion and hear opinions of their neighbors. The meeting also provided an opportunity to pose questions to the consultants, students and natural resource managers working to alleviate the problems within the Miljala Channel and surrounding watershed.

Rock Lake Improvement Association Annual Meeting

Each year, federally-recognized nonprofit organizations are required to hold an annual meeting. RLIA hosted their event on August 25, 2012 in Lake Mills. The event was attended by approximately fifty people, including RLIA members, WRM cohort students and advisors, and other interested members from the community. WRM students gave a short presentation highlighting recent findings, as well as a proposed restoration option for a portion of the watershed. Students provided attendees with the opportunity for questions and comments:

Is muck the prominent sediment deposited in the channel? Recently analyzed soil cores demonstrated that the sediment was approximately 65% fine sand.

It was mentioned that dredging a wetland would be a part of the solution to the problem. Would dredging in a sensitive wetland area be an issue? Wetland maintenance occasionally requires periodic dredging. The maintenance schedule would be a function of how much sediment is coming in.

Is phosphorus coming into the lake still going to be an issue? Phosphorus can be taken up to some degree by the wetland vegetation.

How old is the sediment that was analyzed in the cores? The sediment cores that were taken this summer contained sediment accumulated after the dredging in October 2011.

Are there visible signs of erosion anywhere throughout the ditch? WRM students have seen some ephemeral gullies and eroded

Figure 2.34 Cody Meier and Katie Van Gheem Present Findings and Restoration Options at the Rock Lake Improvement Association Annual Meeting in Lake Mills. Photo Credit: Megan Phillips, 8.25.12

stream banks. These will require stabilization efforts in areas that have steep slopes. Sediment does not come from a single location, but rather from a number of eroding areas. A wetland would trap sediment and slow pollutant transport. Some drainage capacity must be maintained in the upland area. The ideal wetland site would be near Korth Park.

What will a wetland restoration accomplish? Phosphorus binds to soil particles which would be trapped within a wetland.

Following the presentation, a group of WRM students held a "wetland walk" that showcased several monitoring wells and sampling sites, as well as the crest stage gage constructed by students earlier in 2012.

Chapter 3: Recommendations

The following section contains a suite of recommendations that we believe will appropriately address the environmental concerns of the Miljala Channel watershed. These suggestions are based on careful analysis of baseline data, collected over the last 12 months, related to the hydrology, hydrogeology, and ecology of the site. We believe these recommendations can be implemented in a way that will be acceptable to private landowners. Implementation of these recommendations will not only meet the objectives outlined in the beginning of this report, but will serve to enhance the quality of life of Lake Mills residents and enhance the recreational and ecological value of Korth Park.

Farm Field Management Changes

1. Update the nutrient management plan of the farm field south of Shorewood Hills Road to reduce phosphorus and bacteria associated with manure application. Specifically, we recommend an update to the phosphorus index based on distance to the drainage ditch, accompanied by an amended manure application plan if warranted.

2. Plant denser vegetation in the buffer strip adjacent to the farm field south of Shorewood Hills Road to reduce runoff velocity and allow for nutrient, bacterial and sediment interception.

Wetland Restorations

3. Restore shallow marsh wetlands in at least two sections of the ditch to control nutrients, sediment, and bacteria.

4. Control the velocity of peak flows during precipitation events to minimize bank erosion and re-suspension of deposited sediment. In areas where wetland restoration is not possible, reduce bank erosion through streambank stabilization, upstream detention, check dams, or similar control structures.

Regulatory updates

5. Update local regulatory development standards to reduce the runoff potential of future development projects, as outlined in Wisconsin Administrative Code Chapter NR 151.121-129.

Farm Field Recommendations

We identified the primary source of the phosphorus as chicken manure applied to a farm field directly west of SS5. While the nutrient management plan for this field had been approved by the DNR, its phosphorus index had been computed based on distance to Rock Lake. We recommend an update to the phosphorus index based on distance to the drainage ditch, accompanied by an amended manure application plan if warranted. The landowner has expressed a willingness to change his nutrient management plan. This will reduce phosphorus and bacterial loading to the lake in the long-term.

Figure 3.1 An Erosional Gully in the Farm Field South of Shorewood Hills Road. Photo credit: Steve Neary, 5.31.12

However, because of high phosphorus levels in the soil, the field will continue to leach phosphorus into the ditch for the short-term. This loading could be further reduced by planting and maintaining denser vegetation in the buffer strip adjacent to the field. The current vegetation is sparse, shallow-rooted, and annual. Dense, deep-rooted perennial vegetation can better intercept phosphorus associated with sediment erosion and take up more dissolved phosphorus from the soil.

Wetland Restoration Recommendations

Neither of the first two recommendations can address the mobilization of contaminated sediment (Figure 3.2) that has settled in the ditch bottom, or the downstream source of bacteria — possibly from wildlife or from bacteria free-living in the soil. They do little to address the sediment problem, which includes bed and bank erosion in the ditch (Figure 3.3). A wetland restoration can effectively treat all three pollutants of concern: sediment, phosphorus , and bacteria.

Sediment Control

The principal function of the restored wetland would be to slow the velocity of water moving through the watershed during both baseflow and stormflow events. High velocity flows have shown to be a significant source of bank erosion. Reducing the velocity of water moving through the system will reduce erosion and cause any suspended sediment to settle out before reaching the Miljala Channel.

Phosphorus Control

Emergent vegetation in the wetland contributes to the control of suspended sediment by impeding flow and causing sediment to drop out of the water

Figure 3.2 Sand Deposition at the Culvert Outlet Into Miljala Channel. Photo credit: Steve Neary, 10.5.12.

Figure 3.3 Vegetation Was Cut on the Steep Banks Above the Culvert Outlet to the Miljala Channel. To prevent further erosion, these banks should remain vegetated throughout the year. Photo credit: Steve Neary, 8.22.12

column. The phosphorus attached to suspended sediment is thus removed from the water column. Wetland vegetation also serves to control phosphorus by acting as a sink. In this process, phosphorus is taken up by roots and sequestered into plant tissue where it remains until it is slowly released by decomposition processes. Under the anaerobic conditions that occur in wetland soils, decomposition can be very slow — this buildup of organic matter in wetlands produced the muck soils found in the lowlands of the watershed.

Bacteria Control

A shallow marsh wetland restoration would also address the problem of coliform bacteria in several ways. First, wetlands have been shown to have a high potential for retention of coliform bacteria (Knox et al., 2008). Since the wetland vegetation slows the velocity of water flowing through it, the residence time of water in a wetland increases. This means that it takes much longer for bacteria introduced into a system through runoff to reach the outlet of a wetland. During this time, bacteria are susceptible to predation and sorption to sediment and vegetation (Gerba et al., 1999). Bacteria attached to re-suspended sediment are subject to these same processes. Direct sunlight can also affect coliform inactivation and persistence. It has been shown that areas of shallow open water allow for exposure to ultraviolet radiation that can kill coliform bacteria (Gerba et al., 1999).

A wetland restoration would also create habitat and recreational benefits not addressed in the project objectives. A shallow marsh wetland would increase the attractiveness of the watershed for wildlife, particularly waterfowl that use these wetlands during migratory periods. An increased wildlife presence would likely increase park visitation by bird enthusiasts and the wetland itself would present an opportunity for an interpretive trail throughout the site.

Feasibility of Wetland Restoration

The site itself presents a perfect canvas for a wetland restoration. Feasibility of wetland restoration is highest where wetlands have been previous drained, where hydric soils are present, and where hydrology can be easily restored (Miner et al., 2003). Soils, topographic maps, and landowner accounts all confirm that the site was a permanent wetland prior to human settlement. The year-round discharge of groundwater ensures that adequate water will be present to support wetland plants if drainage is restricted. Wetland experts we spoke with commented that the intact wetland soils at the site would increase the probability of success.

Vegetation surveys of the watershed also indicate the presence of wetland flora (Table 3.1). In many cases, hydric soils will maintain a seed bank of wetland plant species that germinate when the soil is disturbed (Galatowitsch and van der Valk, 1995). While sites that have been drained and cultivated for more than 20 years have much smaller seed banks with fewer species than do recently drained wetlands (Wienhold and Van der Valk, 1989), it is possible that a native seed bank would contribute to the re-vegetation component of a wetland restoration. Germination studies should be executed prior to any proposed seeding plans in order to determine the viability of seeds stored in wetland soils.

Site vegetation is currently dominated by reed canary grass, an invasive species (Figure 3.4). To establish more diverse vegetation and maximize habitat benefits, reed canary grass would have to be controlled, except in locations of permanent standing water. Sod scraping with a bulldozer can be effective and can expose the seed bank, or some combination of well-timed mowing, herbicide application and burning can be used (WRCWG, 2009). Since high phosphorus levels, sediment deposition, and water level fluctuations favor invasive species like reed canary grass and narrow–leaf or hybrid cattails, this could be an uphill battle. Wetland restoration is often

Table 3.1 Miljala Channel Watershed Plant Species List. These species were observed over the course of the project period. A comprehensive vegetation survey should be conducted prior to implementation of any restoration activity.

Plant Species List	
Herbaceous	
Angelica	*Angelica atropurpurea*
Aster	*Aster spp.*
Bottlebrush sedge	*Carex comosa*
Burdock	*Arctium lappa*
Cattail	*Typha spp.*
Creeping charlie	*Glechoma hederacea*
Cup plant	*Silphium perfoliatum*
Cursed buttercup	*Ranunculus sceleratus*
Dame's rocket	*Hesperis matronalis*
Duck potato	*Sagittaria lancifolia*
Duckweed	*Lemna minor*
Garlic mustard	*Alliaria petiolata*
Giant ragweed	*Ambrosia trifida*
Marsh goldenrod	*Solidago uliginosa*
Marsh milkweed	*Asclepias incarnata*
Muskgrass	*Chara spp.*
Owlfruit sedge	*Carex stipata*
Prairie cord grass	*Spartina pectinata*
Reed canary grass	*Phalaris arundinacea*
Soft stem bulrush	*Schoenoplectus tabernaemontani*
Sticky bedstraw	*Galium aparine*
Stinging nettle	*Urtica dioica*
Sweet cicely	*Myrrhis odorata*
Wild Iris	*Iris versicolor*

Woody	
American elm	*Ulmus americana*
Bebb's willow	*Salix bebbiana*
Black willow	*Salix nigra*
Box elder	*Acer negundo*
Buckthorn	*Rhamnus cathartica*
Cottonwood	*Populus deltoides*
Green ash	*Fraxinus pennsylvanica*
Honeysuckle	*Lonicera spp.*
Quaking aspen	*Populus tremuloides*
Red osier dogwood	*Cornus stolonifera*
Sandbar willow	*Salix exigua*
Weeping willow	Salix babylonica
White pine	*Pinus strobus*

promoted as providing both species diversity and water treatment benefits, without an acknowledgement that these objectives can sometimes be in conflict (Zedler, 2000). However, there is certainly some habitat value of even a stand of cattails, and the restoration plan could target planting and invasive species control efforts to less-impacted areas.

To remove invasive species and expose the native seed bank, wetland expert Jeff Nania recommended a strategy that included plugging the ditch with the dredge spoils, scraping off the reed canary sod, and lightly regrading the landscape to match pre-development contours. Deep ponds have limited habitat benefit and are no longer recommended. Nania emphasized the importance of an equipment operator experienced in wetland restoration for making critical on-site adjustments.

One final element crucial to the success of any project implemented in the watershed is community involvement. A wetland restoration will require full utilization of community resources, including communication, labor, and financing. The master plan for the site should be adaptive in nature, with a built in strategy for assessing

Figure 3.4 The Buffer Strip between SS5 and SS7 was Essentially Monoculture Patches of Reed Canary Grass and Stinging Nettle. Photo credit: Steve Neary, 6.26.12

progress and project objectives during every step of the process. The community must be included in the assessment process to ensure that their needs are being met in an efficient and cost effective manner. An adaptive plan allows for changes to be made if these needs are not being met or if unforeseen circumstances arise that were not accounted for in the original plan. Community involvement in all phases of this project (planning, implementation, maintenance) is required in order to ensure its long term sustainability.

Locations of Wetlands and Impact on Landowners

A wetland restoration is only feasible with the cooperation of affected landowners. Wetland restoration may be compatible with some uses of the properties — for example, hunting or harvesting of marsh hay. However, several landowners may want to maintain drainage to allow for farming, for development, or for ATV/snowmobile use. Unless they are willing to sell land or easements, restoring all 28 acres of hydric soils to wetland is not a viable option. However, as

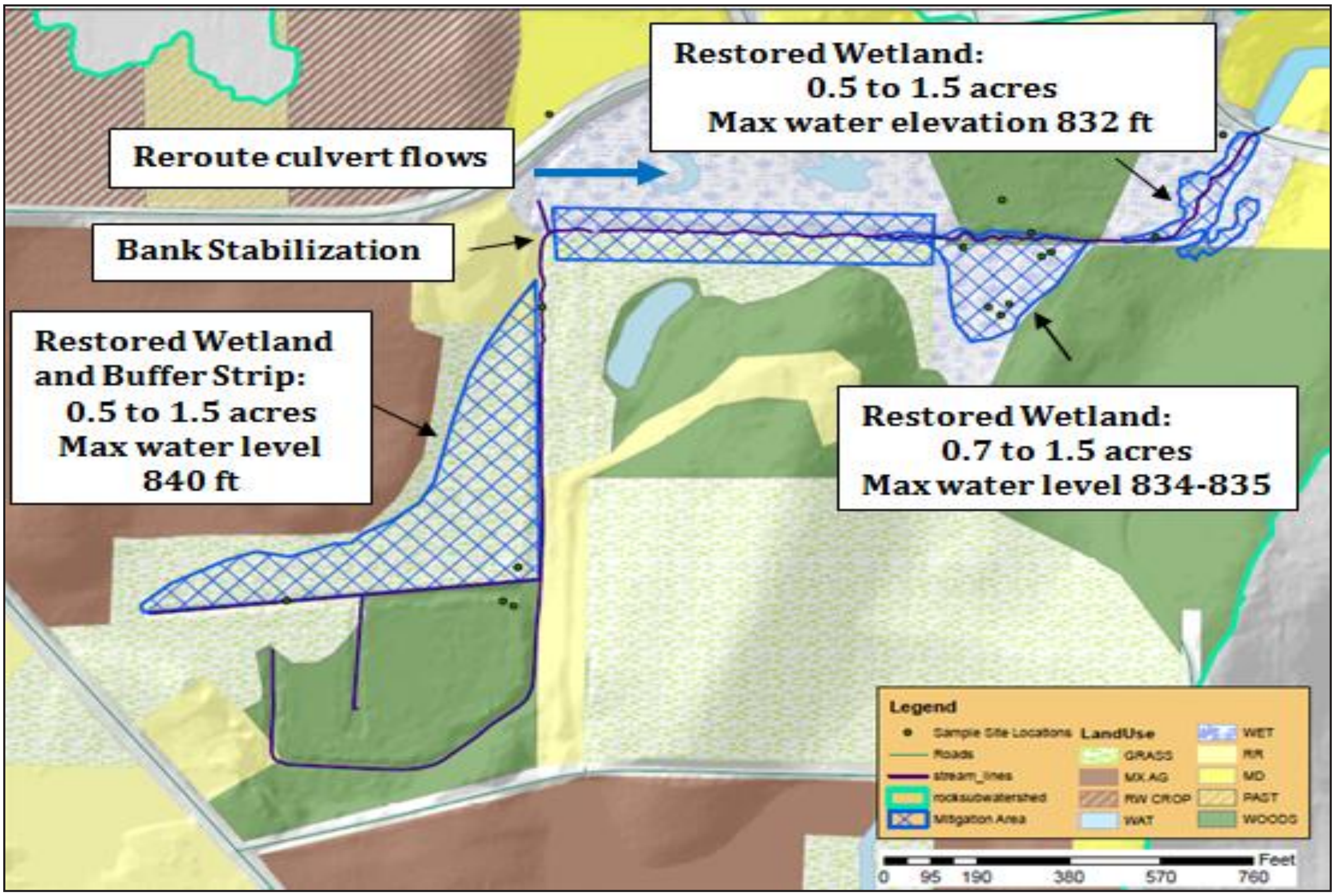


Figure 3.5 Possible Locations for Management Practices.

described in the Hydrology section, only 3 acres of wetland are needed to provide effective sediment control, and there is sufficient slope on the site so that impounding water at one location can still allow for drainage of upstream areas. Consultation with landowners and more detailed engineering are necessary to identify the best locations for wetlands, but a few possible sites are shown in Figure 3.5.

Immediately upstream of the Cedar Lane culvert, the ditch is shallow and the ground around it is usually saturated; the area is already a designated wetland. The owners of the out lot, Hope and Steve Oosdik, have little use for it other than storage on the uplands and may be open to further restoration. Plugging the ditch will prevent further undercutting of the banks. Establishing open water areas necessary for sedimentation and bacterial control will require a control structure at the culvert. Dikes may be impractical because of the soil type, but with excavation and a control structure, 0.5 to 1.5 acres of shallow emergent marsh could be created. The low elevation of the road and presence of trees puts some constraints on more ambitious plans.

Because of the potential to enhance habitat values in Korth Park, a wetland restoration along that stretch of the ditch is especially appealing. A low area of giant ragweed could be scraped to create 0.7 acres of shallow emergent marsh. If neighboring landowners are interested in participating, this could be expanded. Some water could be backed up into the ditch with minimal impacts on drainage of upstream parcels.

A third location is upstream of SS7. The loose sediment in the bed of the upper reaches of the channel has the potential to wash out in large rain events. Plugging the ditch and routing flows into a wetland would slow flows and prevent this from happening. A wetland here could also reduce downstream bank erosion by reducing velocity and volume of stormflow. One possible location for the wetland is in the buffer strip surrounding farmland, since the area is intended to be used for phosphorus treatment and already supports cattails. A soil test should be conducted before installing a wetland as manure-impacted soils have been known to release phosphorus to the water in anoxic wetland conditions, depending on soil properties (Pant et al., 2002).

This area is all private property, very flat, and used for ATV and snowmobile trails. To minimize impacts to landowners, the outlet can be designed so that surface water in the ditch drains down between large rain events. This fluctuation in the water table, or bounce, is incompatible with a diverse wetland community; however, a cattail marsh could be established — some are already present. Or since this area has not been effectively drained by the ditch, this could be an area to discuss the purchase of easements for a permanent wetland.

Design Considerations for a Restored Wetland

Since too large a fluctuation in the water level, or "bounce," can kill desirable species and promote invasive species, the outlets and control structures must be designed differently from ponds where temporary detention of water after a storm is a major consideration. This does increase the area necessary for effective treatment, but as described in the Hydrology section, a 3 acre wetland with no bounce could still provide 5 micron control in the 1-year, 24-hour storm.

Accumulated sediment will reduce the effectiveness of ponds or wetlands. A forebay can be designed to trap coarse sediment and allow for ease of maintenance — these are typically four feet deep with a concrete or gravel bottom. Vehicular access may be a challenge. Otherwise, deeper pools within the pond or wetland must be designed with enough volume to store sediment over a 10-20 year timeframe. If multiple wetlands are installed, the sediment load per area may be small enough that sediment could be allowed to accumulate without maintenance, although this will have impacts on the succession of the plant community over time and require adaptive management.

For wetlands to be effective in sediment control, it is important to prevent scouring and re-suspension of trapped sediments during high flow events. This can be done by having deeper ponds for sediment storage, designing for alternate flow routes in high events, or by providing enough storage to limit velocity during large events. In addition, much of the sediment erosion in this watershed may occur during large events. This is the case in drained peat-lands, where special control structures, have proved successful in controlling sediment loads (Marttila et al., 2010). The special control structures allow for unimpeded low flows and normal drainage while also providing back up for water during floods An additional option to limit high flows is to create temporary detention ponds, or infiltration basins, to intercept runoff from contributing areas such as the Shorewood Hills culvert. To avoid erosion of muck soils, surface velocity above 0.06 m/s (or 0.15 m/s in a small ditch) should be avoided (Martilla et al., 2008).

Changes to Regulatory Development Standards

Maintaining infiltration performance standards for runoff management of new development and re-development sites is important, as regulation and enforcement are required to adequately maintain pre-development conditions. Peak runoff discharge rates are maintained to pre-development, good hydrologic conditions for appropriate land covers, as identified in TR-55 or an equivalent methodology (Chapter NR 151.12 Wisconsin Administrative Code). If infiltration performance standards are not correctly regulated, large runoff events can lead to increased water volume, pollutants, and sediment reaching the outlet of the impacted watershed.

Infiltration standards were examined using Chapter NR 151 of the Wisconsin Administrative Code and the Town of Lake Mills ordinances. Chapter NR 151.121-129 was updated in January 2011, with any construction prior to January 2011 being regulated under NR 151.12- post-construction performance standard for new development and redevelopment (Lowndes, 2012). According to NR 151.12:

> Peak discharge regulations for Wisconsin lands developed prior to January 2011 shall employ Best Management Practices (BMPs) to maintain two-year, 24-hour design storms with a type II distribution with sufficient management to infiltrate at least 90 percent of pre-development infiltration volume and 25 percent of post-development runoff volume for residential developments and 60 percent of pre-development infiltration volume and 10 percent of post-development runoff volume for subdivisions only, respectively (Chapter NR 151.12 Wisconsin Administrative Code).

However, Wisconsin lands developed after January 2011 (NR 151.123-124) shall:

> Employ BMPs to maintain one-year, 24-hour and 2-year, 24-hour pre-development peak runoff discharge rates with low imperviousness areas (development up to 40 percent connected imperviousness) infiltrating at least 90 percent of pre-development infiltration volume, moderate imperviousness areas (>40-80 percent connected imperviousness) 75 percent, and high impervious areas (>80 percent connected imperviousness) 60 percent, respectively (Chapter NR 151.121-129 Wisconsin Administrative Code).

The Town of Lake Mills regulates runoff rates under the land and subdivisions regulations (5-4-5 Town of Lake Mills - Land and Subdivision Regulations). Presently, peak runoff rates are regulated to maintain ten-year storm events. We recommend that Lake Mills update this ordinance to include one-year, 24-hour and two-year, 24-hour storms. Examining only ten-year storm events leaves out numerous low floods that occur from storms with a shorter return period, which, due to their greater frequency, are a likely contributor to increased sedimentation. Ordinances of impervious areas and infiltration volumes in the Town of Lake Mills have been implemented to allow development of impervious surfaces up to 20 percent (low impervious areas) and control 90 percent of post construction runoff (5-4-5 Town of Lake Mills - Land and Subdivision Regulations). The Town of Lake Mills should update their ordinances to 90 percent of pre-development runoff volume, rather than 90 percent of post construction, because runoff rates may greatly increase post-development; analyzing only post-development conditions is insufficient when trying to maintain natural conditions.

Glossary

anthropogenic – man-made, or relating to human impacts on nature

baseflow – lower flows, associated with groundwater, that slowly reach the stream

drumlin – an elongated hill formed by glaciers

evapotranspiration – includes water that evaporates from the soil, standing water, or leaf surfaces, as well as water that passes through plants

infiltration – the portion of precipitation that soaks into the soil

interflow – rapid horizontal movement of water in the unsaturated zone of the soil

invasive species – an introduced plant or animal species which aggressively displaces native wildlife or otherwise disrupts the ecosystem

overland flow, or runoff – the portion of precipitation that runs across the land surface

reach – a section of a stream; groundwater flows into a gaining reach and out of a losing reach

recharge – the portion of precipitation that reaches the water table, or saturated portion of the soil

residence time – the average amount of time that a particle spends in a given part of a system

saturated zone – groundwater; portion of the soil or rock in which the pores are completely filled with water

stage – the water level above an arbitrary point, such as zero on a staff gage

stormflow – higher flows associated with water that rapidly reaches the stream through overland flow and interflow

thermotolerant coliform bacteria – a group of bacteria that include species found in the guts of humans and other warm-blooded animals, and therefore useful as an indicator of potential fecal contamination

transpiration – water that evaporates from the open pores of leaves and stems, driving water movement in a plant

unsaturated zone – portion of soil or rock in which the pores are only partially filled with water

watershed, subwatershed, or catchment – an area of land that all drains to the same point

References

Alhakimi, S.A. (2002) The extent and boundaries of extinct Lake Scuppernong , Jefferson County , southeastern Wisconsin. University of Wisconsin-Milwaukee Dissertations.

Boelter, D.H. (1972) Water table drawdown around an open ditch in organic soils. Journal of Hydrology 15 (4): 329–340.

Borman, R.G. and Tratta, L C. (1976) Ground-water resources and geology of Jefferson County, Wisconsin. Wisconsin Geological and Natural History paper: 37 pp.

Boutilier, L., Jamieson, R., Gordon, R., Lake, C., and Hart, W. (2009) Adsorption, sedimentation, and inactivation of *E. coli* within wastewater treatment wetlands. Water Research 43: 4370 – 4380.

Brooks, J.P., Adeli, A., Read, J.J., and McLaughlin, M.R. (2009) Rainfall simulation in greenhouse microcosms to assess bacterial-associated runoff from land-applied poultry litter. Journal of Environmental Quality 38: 218-229.

Byappanahalli, M., Fowler, M., Shively, D., and Whitman, R. (2003) Ubiquity and persistence of Escherichia coli in a midwestern coastal stream. Applied and Environmental Microbiology 69: 4549–4555.

Cicero, P. (2012) Personal interview. October 2, 2012.

Clayton, L., Attig, J.W., Mickelson, D.M., and Johnson, M.D. (1992) Glaciation of Wisconsin. Wisconsin Geological and Natural History Survey, Educational Series 36: 4 p.

Cohen, J.G. (2004) Natural community abstract for emergent marsh. Michigan Natural Features Inventory, Lansing, MI.

Collins, R. (2004) Fecal contamination of pastoral wetlands. Journal of Environmental Quality 33: 1912–1918.

Curtis, J.T. (1959) Vegetation of Wisconsin: an ordination of plant communities. University of Wisconsin Press, Madison, WI. 657 pp.

Diaz, Francisco J., O'Geen, A.T., and Dahlgre, R.A. (2010) Efficacy of constructed wetlands for removal of bacterial contamination from agricultural return flows. Agricultural Water Management, 97. 1813 – 1821.

DeSzalay, F.A. and Cassidy, W. (2004) Effects of muskrat (Ondatra zibethicus) lodge construction on invertebrate communities in a Great Lakes coastal wetland. American Midland Naturalist 146: 300-310.

Feinstein, D.T., Hart, D.J., Eaton, T.T., Kroheiski, J.T. and Bradbury, K.R. (2004) Regional aquifer model for southeastern Wisconsin. Wisconsin Geological and Natural History Survey, Open File Report 2004-01.

Fetter, C.W. (1994) Applied hydrogeology, third edition. McMillian College Publishing Co. New York, NY.

Fulford, J.M. (1998) User's guide to the US Geological Survey culvert analysis program.

Galatowitsch, S.M and van der Valk, A.G. (1995) Natural revegetation during restoration of wetlands in the southern prairie pothole region in North America. In Restoration of Temperate Wetlands (B.D. Wheeler, S.C. Shaw, W.J. Fojt, R.A. Robertson, eds.). John Wiley and Sons, New York, NY. 562 pp.

Galatowitsch, S.M. and van der Valk, A G. (1994) Restoring prairie wetlands: an ecological approach. Iowa State University Press, Ames, IA. 246 pp.

Gaffield, S. (2011) Scope modification for Rock Lake Improvement Association lake planning grants, MARS project number 1511. Montgomery Associates:Resource Solutions. Retrieved from http://www.rocklake.org/docs/articles/grantRe-scope6_11.pdf. Accessed December 8, 2012.

Gerba, C.P, Thurston, J.A, Falabi, J.A, Watt, P.M, and Karpiscak, M.M. (1999) Optimization of artificial wetland design for removal of indicator micro-organisms and pathenogenic protozoa. Water Science Technology 40: 363-368.

Glacial Heritage Area. (2011) Master plan. Wisconsin Department of Natural Resources. DNR Publication Number: LF – 050 – 2011. Retrieved from www.dnr.wi.gov/master_planning/. Accessed December 8, 2012.

Gordon, D.M, and Cowling, A. (2003) The distribution and genetic structure of Escherichia coli in Australian vertebrates: host and geographic effects. Microbiology 149:3575–3586.

Jefferson County Zoning Ordinance No. 11, Effective January 15, 1975. Last Amended May 7, 2012.

Kennedy, E.J. (1984) Discharge ratings at gaging stations. US Government Printing Office. Retrieved from http://www.comm-tec.com/Library/technical_papers/USGS/TWRI_3-A10.pdf. Accessed December 8, 2012.

Knox, A.K., Dahlgren, R.A., Tate, K.W., and Atwill, E.R. (2008) Efficacy of natural wetlands to retain nutrient, sediment and microbial pollutants. Journal of Environmental Quality 37: 1837-1846.

Korth, D. (2012) Personal interview. October 6, 2012.

Long, S. (2012) Personal interview. September 7, 2012.

Lowndes, M.A. (2012). Personal interview. August 21, 2012.

Marttila, H., and Kløve, B. (2008) Erosion and delivery of deposited peat sediment. Water Resources Research 44 (6): W06406.

Marttila, H, Vuori, K-M., Hökkä, H., Jämsen, J., and Kløve, B. (2010) Framework for designing and applying peak runoff control structures for peatland forestry conditions. Forest Ecology and Management 260 (8): 1262–1273.

Miner, J., Miller, J., and Fucciolo, C. (2003) A hydrogeologic procedure for evaluating wetland restoration and creation sites. Champaign, IL: Illinois State Geological Survey, Wetlands Geology Section.

Minnesota Board of Water and Soil Resources. (2012) BWSR guidance concerning NRCS-developed drainage setback tables. Retrieved from http://www.bwsr.state.mn.us /wetlands/delineation/Drainage_setback_guidance.pdf. Accessed October 22, 2012.

Mitsch, W.J. and J.G. Gosselink. (2007) Wetlands. John Wiley and Sons, Inc, Hoboken, NJ. 582 pp.

National Oceanic and Atmospheric Administration. (2012) Climate data online. Retrieved from http://www.ncdc.noaa.gov/cdo-web/#t. Accessed December 8, 2012.

Pant, H.K., Nair, V.D., Reddy, K.R., Graetz, D.A., and Villapando, R.R. (2002) Influence of flooding on phosphorus mobility in manure-impacted soil. Journal of Environmental Quality31 (4): 1399–1405.

Petraszak, A. (2011) A summary of the current lake planning grants. Making Waves. Retrieved from http://www.rocklake.org/docs/articles/GrantSummary.pdf. Accessed December 8, 2012.

Power, M.L., Littlefield-Wyer, J., Gordon, D.M., Veal, D.A., and Slade, M.B. (2005) Phenotypic and genotypic characterization of encapsulated Escherichia coli isolated from blooms in two Australian lakes. Environmental Microbiology 7: 631–640.

Rock Lake Improvement Association. (2012) Korth Park master plan. Retrieved from http://www.rocklake.org/info/korthprk/index/index.html accessed October 2012.

Rock Lake Improvement Association. (2011) Water quality monitoring and evaluation of pollutant sources within the southwest watershed of Rock Lake.

Rock Lake Improvement Association. (2010) Lake planning grant application, development of management plan: Miljola channel tributary. Retrieved from http://www.rocklake.org /docs/reports/8_2010%20LPG%20ManagePlan%20(Revised%209-10-10).pdf. Accessed December 8, 2012.

Rock Lake Improvement Association. (2001) Korth Park, on Rock Lake, Lake Mills, Wisconsin: 2001 master plan. Retrieved from http://www.rocklake.org/info/korthprk/index /index.html. Accessed December 8, 2012.

Schueler, T. (2012) Design choices for stormwater wetlands. Retrieved from http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/01 /wetland20design20choices1.pdf. Accessed October 28, 2012.

Soil Survey Staff, Natural Resources Conservation Service. (2011) Web soil survey. Retrieved from http://websoilsurvey.nrcs.usda.gov/. Accessed October 18, 2011.

Staff, M. (2012) Personal Communication. September 20, 2012.

Tomer, M.D., Wilson, C.G., Moorman, T.B., Cole, K.J., Heer, D., and Isenhart, T.M. (2010) Source-pathway separation of multiple contaminants during a rainfall-runoff event in an artificially drained agricultural watershed. Journal of Environmental Quality 39: 882-895.

United States Department of Agriculture. (2012) National cooperative soil survey: Houghton series description. Retrieved from https://soilseries.sc.egov.usda.gov/OSD_Docs/ H/HOUGHTON.html. Accessed May 12, 2012.

United States Department of Agriculture. (2011) Soils. Retrieved from https://soilseries.sc.egov.usda.gov/OSD_Docs/H/HOUGHTON.html. Accessed December 8, 2012.

United States Environmental Protection Agency. (2005) Protecting water quality from agricultural runoff. EPA-841-F-05-001.

United States Environmental Protection Agency. (2003) Bacterial water quality standards for recreational waters. EPA-823-R-03-008.

University of Wisconsin. (2012) Botany department website. Retrieved from http://botit.botany.wisc.edu/Resources/Vegetation/Wetlands_I_Plants/. Accessed December 8, 2012.

Vandewalle and Associates Inc. (2011) Farmland preservation plan map for Jefferson County agricultural preservation and land use plan.

Verry, E.S., Boelter, D.H., Paivanen, J., Nichols, D.S., Malterer, T., and Gafni, A. (2011) Physical properties of organic soils. In Peatland biogeochemistry and watershed hydrology at the Marcell Experimental Forest. Boca Raton, FL: CRC Press: 135-176.

Waller, D.M., and Alverson, W.S. (1997) The white-tailed deer: keystone herbivore. Wildlife Society Bulletin 25(2): 217-226.

Welsh, J. (2012) Personal interview. September 9, 2012.

Whitman, R.L., Nevers, M.B., and Byappanahalli, M.N. (2006) Examination of the watershed-wide distribution of Escherichia coli along Southern Lake

Michigan: an integrated approach. Applied and Environmental Microbiology 72: 7301–7310.

Wienhold, C.E., and van der Valk, A.G. (1989) The impact of duration of drainage on the seed banks of northern prairie wetlands. Canadian Journal of Botany (67): 1878-1884.

Wisconsin Department of Natural Resources. (2012) Surface water data viewer. Retrieved from http://dnrmaps.wi.gov/imf/imf.jsp?site=SurfaceWaterViewer. Accessed on 8/10/12.

Wisconsin Department of Natural Resources. (2012) Endangered resources. Retrieved from http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER056WI. Accessed Dec 8, 2012.

Wisconsin Department of Natural Resources. (2007) Conservation practice standard 1001: wet detention pond. Retrieved from http://dnr.wi.gov/topic/stormwater/documents /WetPondStd1001.pdf. Accessed December 8, 2012.

Wisconsin Department of Natural Resources Wetland Management Team. (2003) Reversing the loss: a strategy for protecting and restoring wetlands in Wisconsin. Retrieved from http://dnr.wi.gov/topic/wetlands/documents/reversingloss08_final.pdf. Accessed December 8, 2012.

Wisconsin Reed Canary Grass Management Working Group. (2009) Reed Canary Grass (Phalaris arundinacea) management guide: recommendations for landowners and restoration professionals.

Wisconsin State Climatology Office. (2009) 24-hr Maximum precipitation extremes at Wisconsin stations. Retrieved from: http://www.aos.wisc.edu/~sco/clim-history/stations/WI_STA-R-24EX.html. Accessed October 25, 2012.

Zedler, J.B. (2000) Progress in wetland restoration ecology. Trends in Ecology & Evolution 15 (10) (October 1): 402–407.

Zimmerman, F.R. (1953) Waterfowl habitat surveys and food habit studies 1940-1943. Wisconsin Conservation Department Report R.R. Project 6-R. Mimeo. 176 pp.

Appendix A: Future Project Funding

Future Project Funding

The restoration, enhancement and reclamation of wetlands are all growing priorities for communities across Wisconsin and the country. Funding is needed to finance a solution that limits sediment deposition and surface runoff containing phosphorus and bacteria in the watershed. A number of state, federal, and non-governmental agencies provide funding opportunities that may be used to implement the solutions put forth in this report. Members of the WRM cohort met with both governmental and non-governmental agencies to discuss future funding opportunities and potential partnerships. Jim Welsh from Natural Heritage Land Trust and Susan Graham at the Wisconsin DNR both provided invaluable information related to funding sources and also offered advice on how to proceed with different options. For example, DNR grant applications are often more competitive if the organization seeking funding meets with a DNR staff person prior to the submission of the application to devise a framework for the project and to gain insight on how to strengthen the organization's application. For the purposes of this report, we have divided funding into six main categories: (1) planning grants, (2) wetland and water body restoration grants, (3) wildlife improvement grants, (4) agricultural improvement grants, (5) general conservation grants, and (6) non-governmental assistance.

Keys to Funding Success

After meeting with individuals with expertise in the field and investigating projects similar to the Miljala channel project, it is evident that there are a few key factors that can lead to funding success.

First, the project needs to create partnerships and alliances across the spectrum. We see great potential in the relationship between RLIA, the Jefferson County Soil and Water Conservation Department, and UW-Madison. However, expanded partnerships would make the project more competitive to grant reviewers. For instance, Jim Welsh, Executive Director at Natural Heritage Land Trust, pointed out that Korth Park is already slated for expansion in the Glacial Heritage Area. The Glacial Heritage Area is a large coalition of both governmental and nongovernmental agencies and individuals that have preliminarily mapped out conservation goals and strategies for the southern Wisconsin region. The fact that Korth Park has already been highlighted as a high priority restoration initiative by a large number of conservation minded groups with a history of successful project completion is promising for grant acquisition. In the future, it would be helpful for groups like RLIA, the Jefferson County Soil and Water Conservation Department, Glacial Heritage Area, and local land trusts or other conservation planning organizations, to meet and build integrity in the project through documented conversation and planning.

Additionally, if RLIA is going to apply for and acquire grant funding, the organization needs to have a strong history of project success. RLIA must document that it can organize and execute conservation projects, supply adequate volunteer matching hours, and rally support from the local community by obtaining letters of support from municipalities, conservation groups, and others. The RLIA garlic mustard pulling events are a great example of a project that a funding organization would like to see. However, these types of projects need to be documented, and it would be ideal if there were tangible evidence of long term improvement at the project site.

Planning and Management Grants

Planning grants provide the funding to set a project in motion. This funding would provide the Miljala Channel project with the resources to contract restoration technicians to draft detailed plans of what the proposed solution will realistically entail (which will greatly depend on the agreed upon solution). Planning grants are generally less than $10,000, but, in addition to allowing the development of project plans, they can also make future grant funding applications more robust and increase the likelihood of acquiring funding to later implement the plans.

Management grants delve into more depth than planning grants and allow for implementation of a larger scale project (up to $100,000). Students from the WRM cohort had the opportunity to meet with Susan Graham, a local DNR Lake Management Grant Specialist, to learn how this funding avenue may be helpful for RLIA. This type of grant requires a 25% local share, which can be accounted for directly in dollars or indirectly via volunteer hours and donations. The annual deadline for this grant application is May 1. The application narrative should focus on the Miljala Channel's impact on Rock Lake at large to ensure that the scope of the project is wide and benefits the entire community. These grants are competitive and Susan Graham recommended consulting with her throughout the application process.

Wetland/Waterbody Restoration Grants

Wetland/waterbody restoration grants are those that are specific to the reclamation, restoration, or creation of wetlands and/or small waterbodies. Wetlands and waterbodies can provide additional wildlife habitat benefits.

After Congress passed the 2002 Farm Bill, large amounts of federal funding became available for wetland restoration programs. The Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) offices for Jefferson County could provide a list of incentive programs, including those listed below:

1. The U.S. Department of Agriculture Natural Resources Conservation Services (USDA-NRCS) created a "List of Eligible Practices and Payment Schedule" in November 2010 to outline the purpose and applicability for practices eligible to receive funding. Two of these programs, Wetland Creation 658 and Wetland Restoration 657, may be applicable for the project.

   a. The Wetland Creation 658 applies to sites where no natural wetland occurred or where a wetland exists or existed. For shallow water areas with an average depth less than 12 inches, $3,765 per acre may be received. For a shallow water area with average depth from 12 to 24 inches, $6,803 per acre may be received. The site must be maintained for a span of 15 years after installation.

b. The Wetland Restoration 657 applies to sites with hydric soils that were drained or altered and are capable of storing water for the development of a wetland system. The same compensation from Wetland Creation 658 is available. The program does not apply to existing non-degraded wetlands with intact native plant communities. Again, the practice must be maintained for a lifespan of 15 years after the year of installation.

2. The Wetlands Reserve Program (WRP) within the USDA-NRCS is a voluntary program seeking to restore and protect wetlands on private property. Landowners receive financial support from USDA-NRCS in exchange for restoring wetlands that have been drained for agriculture.

   a. An easement option is available in which the USDA pays 100 percent of the easement value and up to 100 percent of the restoration costs.

3. The U.S. Fish and Wildlife Service Division of Bird Habitat created North American Wetlands Conservation Act Grants to provide matching grants to organizations that have developed partnerships to carry out wetland conservation. Since 1996, 25 projects have been approved in Wisconsin alone, receiving a total of $1.13 million in grants. In 2008, the Wisconsin projects included: Love Lake Springs (Burnett County), a 37 acre site awarded $75,000 with $527,463 in matching funds; Meadow Valley Flowage (Juneau County), a 600 acre site awarded $75,000 with $87,500 matching funds; and the Northwest Wisconsin Wetland and Grassland Program of Polk, Burnett and St. Croix counties, which will restore and enhance 638 acres of wetlands, awarded $75,000 with matching funds of $75,000. The application deadline is March 1.

4. Five Star Restoration Program provides grants with awards ranging from $10,000 to $40,000 per project. It was established by the EPA to promote work on community-based wetlands restoration projects. Its objective is to engage five or more partners in each project to contribute funding and assistance. The application process is online through the National Fish and Wildlife Foundation website. Applications open in late fall and are accepted until early March. Awards are made in late spring. Since 1999, 10 projects in Wisconsin have been awarded grants ranging from $6,400 to $20,000.

5. Freshwater Future Grant Programs provide four different grants. Perhaps the most useful grant for this project would be the Project Grant Program. Awards range from $500 to $3,500. The deadline for spring is March 31 and fall is September 30.

Wildlife Improvement Grants

Wildlife improvement grants are categorized as those whose ultimate goal is the benefit of some organism(s) and/or its habitat. Grants in the section seek projects that add to the long term viability of certain wildlife.

1. United States Fish and Wildlife Service, Partners for Fish and Wildlife Program: The group works with private landowners and can provide funding for private landowners doing restoration work on their property.

2. Natural Resources Foundation, Besadny Grant Program: The C.D. Besadny Conservation Grant Program provides matching grants for small-scale projects that promote the responsible stewardship of Wisconsin's natural resources at the local level by providing funding ranging from $100 to $1,000. Grants must be matched 100% by the recipient organization. Applications must be received by January 15th of the year which the grants are awarded; funds are awarded in early March.

3. Upper Mississippi River Watershed Fund (UMRWF): Lake Mills lies within the Upper Mississippi River Watershed and thus qualifies for this program. The UMRWF is a partnership between the USDA Forest Service and the National Fish and Wildlife Foundation. This project could address three of the five funding priorities listed for the grant: loss of migratory bird habitat, regeneration of bottomland hardwoods, and establishment of riparian forest buffers to enhance water quality and aquatic habitat.

Grant awards range from $15,000 to $75,000 and require match that is non-federal in origin. Pre-proposals are due on April 15 and the full proposal is due on June 15, with each being submitted online at the Nation Fish and Wildlife Foundation's website.

Agricultural Improvement Grants

Agricultural improvement grants are those that target farmland and the improvement of farm practices to achieve some conservation goal. These grants could be applied for in addition to work done directly in the Miljala Channel. Agricultural grants could be used to mitigate sediment/bacteria/nutrient problems within the greater Miljala watershed area.

1. Conservation Reserve Program (CRP) is a federal effort in which landowners receive incentive and cost share payments for installing long-term conservation practices. The site must be located in designated Statewide Conservation Resource Enhancement Program Priority Areas.

2. Conservation Resource Enhancement Program (CREP) is a subset of the CRP program; CREP projects are state sponsored provisions of the USDA. The CREP program pays landowners to install filter strips along waterways or to return continually flooded fields to wetlands. Options for enrollment are through either a 15 year agreement or a perpetual easement. Incentives to do so include cost sharing of conservation practice installation, up front payments, and annual soil rental payments. The payment is 1.5 times the annual rent rate for a 15 year contract or 12 times the annual rent rate for a permanent easement. On average, participants have received payments of $2,000 per acre for 15-year contracts and $2,850 per acre for perpetual conservation easements, over an agreed upon timeframe. Eligible lands must be within 150 feet of an eligible stream or water body. Both of these programs are voluntary.

* For more information see Appendix C of *Jefferson County Farmland Preservation Report*, UW-URPL 2007

General Conservation Grants

General conservation grants are those that can be applied to most of the proposed solutions and to any area in need of funding. These grants are targeted at general improvement of conservation areas.

The Wisconsin Wetlands Association has done an excellent job of regularly posting notices of such opportunities. Their website, wisconsinwetlands.org/funding, provides a list of applicable funding sources. Listed below are a few sources that would be applicable for the restoration/enhancement of the potential Korth Park wetlands suggested by this report.

North American Wetlands Conservation Act Grants

The act provides matching grants to organizations that have developed partnerships to carry out wetland conservation. Since 1996, 25 projects have been approved in Wisconsin alone, receiving a total of $1.13 million in grants. In 2008, the Wisconsin projects were: Love Lake Springs (Burnett County), a 37 acre site awarded $75,000 with $527,463 in matching funds; Meadow Valley Flowage (Juneau County), a 600 acre site awarded $75,000 with $87,500 matching funds; and the Northwest Wisconsin Wetland and Grassland Program of Polk, Burnett and St. Croix counties that will restore and enhance 638 acres of wetlands, awarded $75,000 with matching funds of $75,000. The application deadline is March 1.

Non-Governmental Assistance

The following are agencies that may provide financial assistance or partnerships for a wetland restoration project.

Wisconsin Waterfowl Association

Wisconsin Waterfowl Association has restored thousands of acres of wetland and upland habitat with their top priority being restoration of Wisconsin's wildlife habitat. Wisconsin Waterfowl Association is always seeking good habitat restoration projects within the state of Wisconsin.

Ducks Unlimited, Inc.

This non-profit organization provides assistance for managing lands as wildlife habitat, including cost-sharing assistance, engineering services, and on-site surveys for wetland restoration. Funds are administered through the MARSH program, operated cooperatively with the DNR. The program will match funds for projects benefiting waterfowl and their habitat and provides cost sharing for wetland restoration on private land.

Natural Heritage Land Trust

This organization works with private landowners to purchase easements on land in priority conservation areas across the state. Many of these purchases are made in conjunction with an agreement with local counties to enhance recreational opportunities for the public, including the installation of interpretative trails, boat landings, and other amenities.

Appendix B: Geology and Zoning

Rock Lake Regional Geology

The geology of Jefferson County is primarily influenced by bedrock geology, erosion, and deposition. Specifically, erosional and glacial episodes radically changed the bedrock, hydrology, and surface features of the area. Bedrock topography in Jefferson County is relatively flat, with highest and lowest elevations in the northwest and southeast corners of the county, respectively (Boreman and Trotta, 1975). The dolomitic Sinnipee group underlies glacial deposits throughout much of the county (Feinstein et al., 2004). Within the area surrounding Rock Lake, stream channels cut through the Sinnipee group creating valleys and exposing underlying formations. St. Peter Sandstone, Prairie du Chien Dolomite and Cambrian Sandstones were uncovered and now form the uppermost bedrock formations in stream cut valleys (Boreman and Trotta, 1975).

During the glacial period, moraines and drumlins were formed when unconsolidated sediment was deposited throughout the region. Glacial Lake Scuppernong was formed from melt water during glacial recession. The lake deposited silty-clay sediment in the valleys and between drumlins. Lake elevations corresponded to the Lake Mills and Green Lake Moraines at elevations of 855 and 840 feet, respectively (Alhakimi, 2002).

The Miljala Channel watershed is located on the upper edge of a bedrock valley. The St. Peter Sandstone is the upper bedrock unit underlying glacial

Figure B.1 Infiltrating Meltwater in the Field Between Two Drumlins. A drain tile connecting SS4 to the ditch runs along this field (right hand side of this picture). Photo credit: Steve Neary, 2.29.12

material. A bedrock valley drops to the north, south, and west of the lake. Galena and Platteville formations are present on the opposite side of the bedrock valley to the north and south of Rock Lake (Boreman and Trotta, 1975). Generally, the water table has local highs in locations where Galena and Platteville formations are present. Therefore, water flows north and south toward the watershed before turning to flow east into Rock Lake.

Groundwater flow decreases where the valleys are filled with low permeability lacustrine sediment deposited in Glacial Lake Scuppernong. Well logs report depths of lacustrine, silty-clay sediment up to 100 feet below the land surface. Along Highway S there is a regional high in groundwater elevation with a decrease in water table elevation corresponding to a decrease in land elevation toward Rock Lake. Where elevation drops quickly, groundwater enters the system where the lacustrine sediment surface dips below regional groundwater levels. This creates the conditions necessary for an accumulation of dead plant tissue and results in the formation of the highly decomposed, organic Houghton Muck soil present within the watershed today.

Zoning in the Miljala Channel Watershed

One way Jefferson County protects its waterways is through designation of Shoreland - Wetland zones. These include all areas within 1,000 feet of the "ordinary high water mark of navigable lakes" and "300 feet of ordinary high water mark of navigable rivers" (Jefferson County Zoning Ordinance No. 11, 2012). Because the ditch is not considered navigable, the Miljala Channel watershed does not have a significant area zoned as Shoreland – Wetland (Staff, 2012). Unless a landowner requests rezoning to Natural Resource, the county does not have the ability to designate land as a Shoreland – Wetland zone (Cicero, 2012). Instead, at the state level, the DNR has the power to protect the wetlands through permit enforcement. As seen in Figure B.2, a small section of the watershed is currently identified as a wetland according to the DNR. Although not delineated as a "special wetland planning" area, a much larger portion of land in the watershed has been recognized as having wetland indicator soils and as a potentially restorable wetland (DNR, 2012). Since no waters within the watershed are considered navigable, there is no federal jurisdiction over these waters.

Flood Hazard Boundary maps, adopted by Jefferson County, determine the extent of the flood plain of rivers or streams in Jefferson County. Portions of land immediately adjacent to the channel have been designated as a flood plain, but they do not comprise any portion of the drainage ditch area, despite a hydrologic connection to the lake.

Zoning plays a key role in establishing guidelines for land use. According to Jefferson County, the Miljala Channel Watershed is currently zoned, in order from greatest to least number of acres, as agricultural, rural residential, residential – sewered, agricultural transition, and natural resources (Figure B.3).

Under the Jefferson County Farmland Preservation and Land Use Plan, agricultural land is designated exclusively as farmland and agricultural preservation area. The community has prioritized preservation of this land for farming, over residential development, due to soil suitability for cropland (Jefferson County Zoning Ordinance No. 11, 2012). Both types of residential zoning allow for construction of single family residences; however, sewered residential lots are located in the City of Lake Mills sewer system and rural residential lots are larger lots that may contain septic systems (Jefferson County Zoning Ordinance No. 11, 2012). Agricultural Transition lands are areas within the 15 year growth plan for the City of Lake Mills. These lands are currently open space, but may be developed in the future (Jefferson County Zoning Ordinance No. 11, 2012). The small area designated as a Natural Resources area does not allow for future

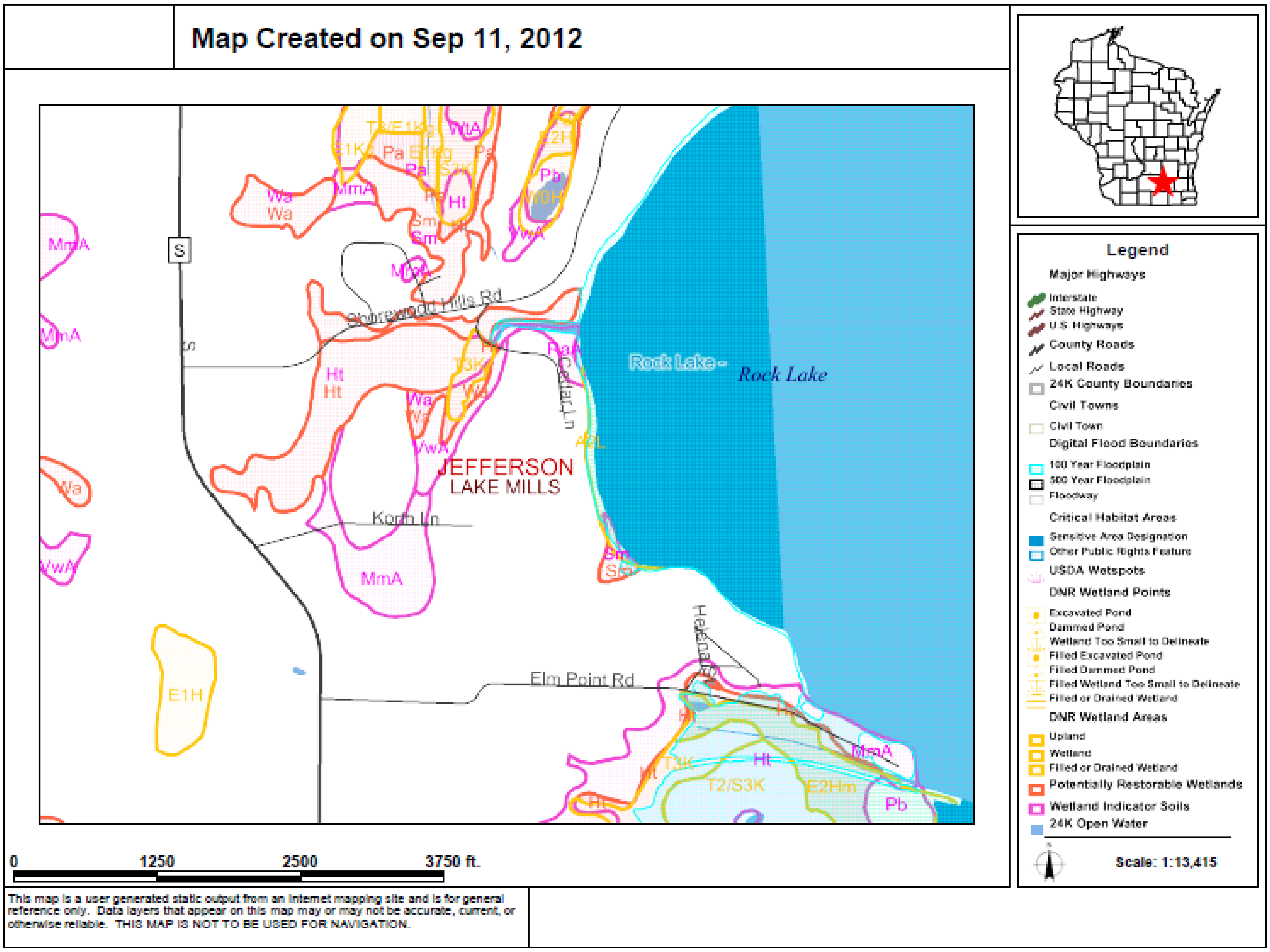


Figure B.2 Wetland Soil and Floodplain Map for the Miljala Channel Watershed. Red areas indicate Houghton Muck soils, pink designates wetland indicator soils, and gold areas within the watershed are zoned as wetland. Teal areas indicate the 100 year floodplain designation.

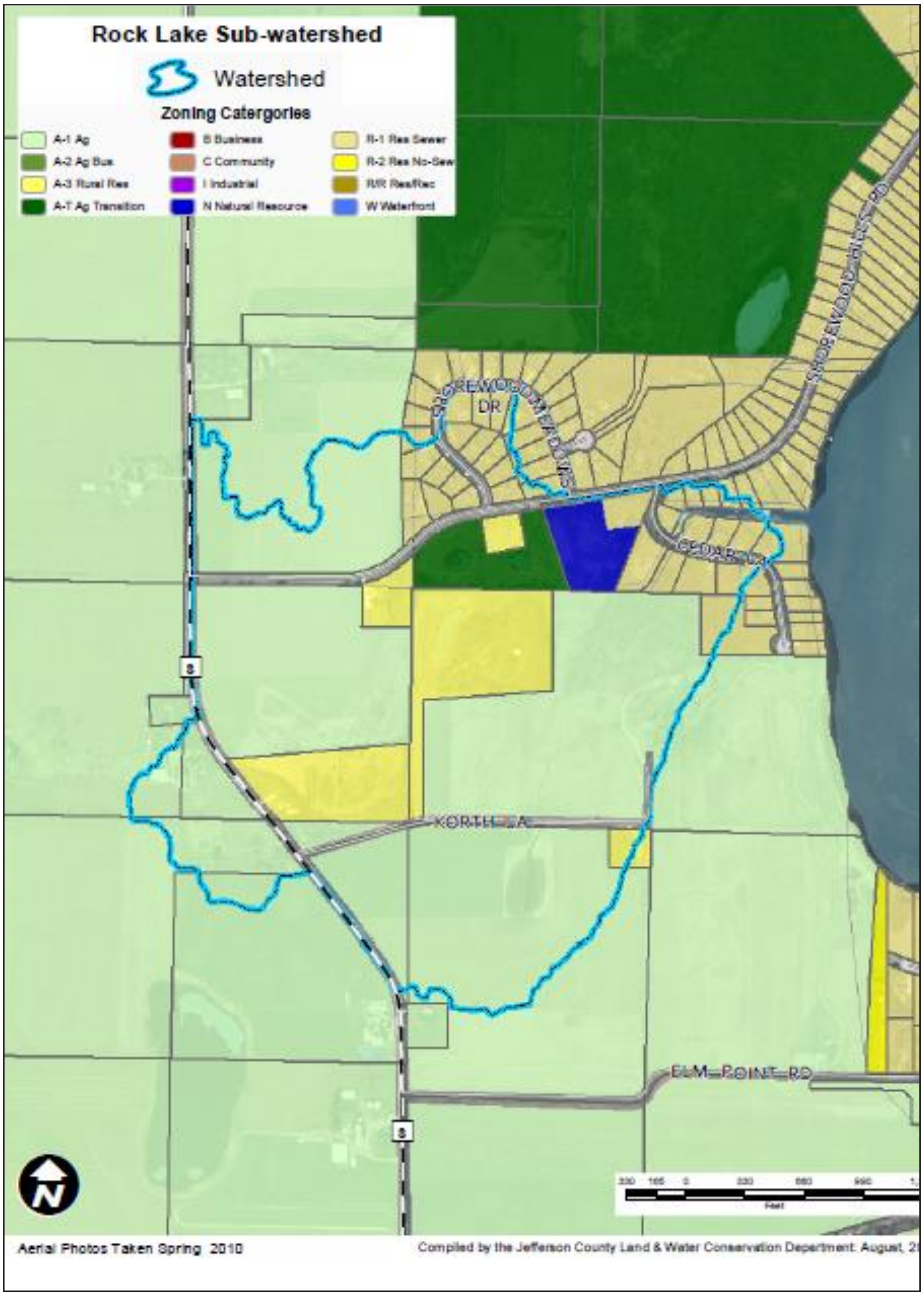


Figure B.3 Zoning Designations in the Miljala Channel Watershed.

development. Jefferson County Zoning Ordinance No. 11 identifies Natural Resources areas as sensitive areas "due to ground water, the presence of significant wildlife habitat and natural vegetation or the need to protect water quality" (2012). These zoning designations support and allow landowners to preserve current land uses within the Miljala Channel watershed. However, zoning "overlays" can further restrict use at a state, county, or township scale.

Landowners can request rezoning of their lands to a new designation, although the Jefferson County Planning and Zoning Committee has the ability to deny rezoning requests based on soil or land suitability (Staff, 2012). At the request of landowners, areas with wetland indicator soils may be identified as wetlands by the DNR and would then be regulated under state law (Staff, 2012).

Environmental corridors also play a significant role in supporting conservation and communicating potential land use hazards. According to the Jefferson County Zoning Ordinance No. 11, these corridors include "public-owned park, recreation, and conservancy lands, water bodies and wetlands mapped as part of the Wisconsin DNR Wetland Inventory, 100-year floodplains based upon Federal Emergency Management Agency (FEMA) maps or contiguous woodlands over 10 acres in size" (2012). As Figure B.3 depicts, the Miljala Channel watershed's environmental corridor includes a small designated wetland (DNR, 2012).

It is important to note that Rock Lake has been identified as an outstanding to exceptional lake by the DNR, and the area where this channel drains has been identified as a sensitive lake area and a public rights feature of the state (Figure B.4). Past runoff from the

Figure B.4 Rock Lake and the No-Wake Zone Located Near the Outlet of the Miljala Channel. This sensitive area supports a community of bulrush plants that provides critical habitat for fish, insects, and migrating waterfowl. Photo credit: Steve Neary, 9.16.11.

drainage ditch has not adversely impacted the plant life within this protected area of the lake (Cicero, 2012). This may be due to the protection offered by the sediment deposition in the channel.

The county is currently in the process of rezoning the area, with a projected completion date in 2013. The county should consider not only how an individual landowner will be affected, but how the neighborhood and lake will be impacted, and create codes and zoning to reflect the needs of the greater community.

Appendix C: Methodology

Sediment Analysis Procedure

During each coring event, multiple samples were taken at varying locations behind the turbidity curtain to ensure a representative sampling of accumulated sediment. At each coring site, a 6-7 inch long PVC pipe, with a 1.25 inch diameter, was lowered into the accumulated sediment. As each pipe reached the bottom of the channel, a rubber stopper was inserted into the top to create suction and secure the sediment core within the pipe. Each core was then carefully removed from the water and the bottom end was wrapped in cheese cloth. The cheese cloth was applied to allow for water drainage while retaining all sediment within.

After a drainage period of 1-2 weeks, sediment cores were forced from the pipes using a metal disc and rod. Samples were then placed in a dish of known mass and dried at 105° C for at least 24 hours to burn off any remaining moisture. The mass of the dried samples was then recorded. Next, the samples

Figure C.1 Routine Water Sampling at SS2. Pictured are Steve Neary, Ian Anderson, Maria Garcia de la Serrana, and Katie Van Gheem. Photo credit: Patricia Cicero, 3.9.12

were placed in an oven at 450°C for 24 hours to burn off any organic matter. Each sample mass was recorded again and compared to the previous weighing to determine the mass of organic matter that was burned off. Following the second burn, samples were gently disaggregated using a mortar and pestle to eliminate any clumping that occurred during the drying process. Each sample was then passed through a series of sieves, 125 and 500 microns, which separated the remaining sediment into coarse sand, fine sand and silt/clay fractions. The mass of each fraction was recorded and combined with previously recorded organic matter mass to determine the particle size distribution of each sample.

Dissolved Orthophosphate and Total Phosphorus Sampling Procedure

Samples were collected on two days during baseflow and two days during stormflow events. Sample bottles were labeled with the date, time, sampling point identification (storet number), and county. At each sampled surface site, dissolved orthophosphate and total phosphorus samples were collected. At each sampling site, bottles were placed facing upstream in flowing water halfway down the water column and filled to the neck. Contact with the stream bottom was avoided to prevent sediment contamination. Dissolved orthophosphate samples were also collected from monitoring wells using a peristaltic pump. The pump's collection hose was rinsed thoroughly with deionized water between samples.

Dissolved orthophosphate samples were taken in 60 (milliliter) mL bottles with no chemical preservation. Total phosphorus samples were taken in 250 mL bottles with sulfuric acid chemical preservation. After acidification, total phosphorus samples were field tested using litmus paper to ensure proper fixation with pH levels at or below two. Samples were put on ice and delivered to the Wisconsin State Laboratory of Hygiene (WSLH) within 24 hours of collection.

Bacterial Sampling Procedure

Sampling was conducted at surface sites on several dates in 2012. Samples were taken in sealed 100 mL bottles provided by the WSLH. Before each sampling session, all bottles were labeled with date and location. Time was also written on the bottle immediately before each sample was taken. Once the seal was removed, the cap was taken from the bottle and placed on the ground with the inside of the cap facing upwards to prevent any contamination from contact with the soil or human hands. Each bottle was then lowered into the center of the stream, about halfway between the water surface and the ditch bottom with the mouth of the bottle facing upstream. Care was taken not to disturb the stream bed during the sampling process. The bottle was then filled to the fill line, removed from the stream, and capped immediately. Once capped, the samples were placed on ice in a portable cooler and delivered to the WSLH within six hours of collection. Samples were analyzed at the WSLH for *E. coli* and fecal coliform concentrations using the culture method.

Figure C.2 Sampling for Conductivity in Surface and Groundwater. Pictured are Dan Haug and Ian Anderson. Photo credit: Steve Neary, 4.13.12

For each sampling session, one duplicate and one replicate were sampled at different surface sites. A 250 mL bottle was used for the replicates; two 100 mL bottles were used for duplicates. The purpose of these samples was to rule out any error occurring during processing and analysis.

Hydraulic Conductivity

Hydraulic conductivity is multiplied by the slope or gradient of the water table to determine the rate at which water will move through each type of sediment within the watershed. This value, called the specific discharge, is extremely important, as the product of specific discharge multiplied by aquifer height can estimate the amount of water moving through the aquifer both in storm events and baseflow (Figure C.2).

Infiltration Test Procedure

Infiltration tests were conducted in the soils of the Miljala Channel watershed in order to determine infiltration capacities (Figure C.3). Different soil types with varying cover types were tested to provide

Figure C.3 Soil Infiltration Test. Conducted by Mike Draper. Photo credit: Steve Neary, 6.15.12

a more precise measurement of infiltration rates in varying locations around the field site. Soils are divided by mapped soil unit, and subdivided by cover type and slope class. Each unique combination of soil, land cover, and slope is given a number which, when mapped using Geographic Information Systems (GIS), allows a clear picture of soil spatial relationships and is used to determine where infiltration tests should be conducted.

After conducting numerous infiltration tests across the diverse watershed landscape, results confirmed our hypothesis that flow through the muck was the main driver of baseflow to the ditch. Infiltration capacities of the various loam and silt loam soil types ranged from 0.21 inches per hour to 0.90 inches per hour. The average infiltration capacity of the Houghton Muck was 2.18 inches per hour with a range of 1.05 to 3.31 inches per hour. It is worth noting that when excessively dry, the Houghton Muck became moderately hydrophobic and the average hydraulic conductivity value fell to 0.16 inches per hour.

Infiltration tests were conducted using a Decagon Devices Minidisk Infiltrometer. This device has a mariotte tube with a sintered steel disk at its base, which allows slow seepage of water into the adjacent tube, upon which the device is placed. An attached bubble chamber with a suction control tube applies the tension needed to control the speed of infiltration.

Slug Test Procedure

Much of the landscape adjacent to the ditch consists of Houghton Muck on top of a silty-clay lacustrine deposit. The lacustrine deposit has a low hydraulic conductivity that allows only a small amount of water to flow through the aquifer. In comparison, the muck has a high hydraulic conductivity that allows water to flow quickly through the system, except in cases of extreme drought. The hydraulic conductivity of the muck is the primary diver of flow into the ditch, due to baseflow originating in surrounding uplands and the high infiltration capacity of the muck. Therefore, efforts were focused on acquisition of an accurate value for muck hydraulic conductivity. One method used to measure hydraulic conductivity is the Hvorslev slug test.

Slug tests were conducted by placing a “slug,” a small weighted cylinder of a known volume, into a well. Water levels were then recorded at 30 second intervals for approximately 40 minutes. The rate at which the water returns to its initial elevation indicates how quickly water moves through the aquifer. Tests were conducted at MW8, MW5, and MW1 with values of 0.230, 0.735, and 0.037 feet per day, respectively. These values fall within the expected range for this soil type, and therefore are believed to be representative of the muck.

Water Elevation and Flow Measurement Procedure

Two different systems were used to measure groundwater levels in the wells. The first method featured simple hand measurements, taken from January through November 2012. An electric tape was lowered into a well and depth to water was recorded. Water elevation was determined by subtracting the depth to water from the top of the well casing to water from the surveyed top of casing relative to 0.00 feet on the staff gauge.

The second method involved continuous measurements taken with a Solinst Datalogger from May through November 2012. This device measures the pressure under the water to determine how much water is above a location on the datalogger. Water pressure was corrected for barometric pressure using a non-submerged barometric pressure transducer in MW6. Water elevations for continuous data were measured, using the same procedure as electric tape measurements, to find pressure transducer elevation prior to removal. Pressure transducer elevation was used to find water elevation throughout the deployment. Water elevations were verified with hand measurements.

A Hobo data logger was installed 3 feet upstream of the Cedar Lane culvert to measure the water level in the ditch. The logger was placed into well-screen sunk into the ditch bottom and secured with rebar. The pressure readings were corrected for atmospheric pressure using data from the nearest weather station (Watertown, WI), and converted to a water depth above the sensor. The top of casing was surveyed relative to the staff gage and the sensor was kept at a constant elevation. Uncertainty in the water level measurements was calculated to be 0.05 feet. The Hobo sensor collected data at 5 minute intervals from March 24 to June 26, 2012. After June 26, it was replaced with a Solinst Levellogger that was automatically calibrated with a Solinst Barologger installed nearby at the site.

To convert water level measured in the ditch to stream flow, a rating curve was developed for the site (Figure C.5). Discharge through the Cedar Lane culvert was measured for a range of water levels by placing a basin of known volume under the culvert outlet and measuring the time to fill with a stopwatch. Each flow measurement is the average of at least three trials. Additional measurements taken in 2009, with a March McBerny FlowMate and a Swoffer Model 2100 current meter, were also included (RLIA, 2011). A rating curve is typically expressed as a power function of the form $Q = P\ (G\text{-}e)^b$ where G is the gage height, P and b are constants, and e is the gage height of zero flow — in this case 0.09 feet, the height of the culvert invert (Kennedy, 1984).

Figure C.4 Conducting a Landscape Survey to Gain Accurate Elevation Data for Monitoring Wells and the Stage Recorder. Pictured are Tom Beneke and Josh Bohnert. Photo credit: Steve Neary, 3.9.12

The rating curve includes flow measurements from 0.3 feet to 0.5 feet on the staff gage. While this may be valid for the range of stages observed in 2012 (between 0.1 and 0.9 feet), it should not be used to extrapolate above bankfull storage (around 2 feet), as the stage-storage relationship may change. One way to determine flows at higher stages would be to produce a rating curve using the Culvert Analysis Program developed by the United States Geological Survey (USGS) for solving complex culvert flow equations (Fulford, 1998).

Rain data were collected from two sources: the National Oceanic and Atmospheric Administration (NOAA) and University of Wisconsin Department of Atmospheric Oceanic and Space Sciences (UW AOSS) (NOAA, 2012). Hourly rainfall accumulation for Madison, Wisconsin was taken from the AOSS, and total daily rainfall was taken from the NOAA. Total daily rainfall accumulation was measured locally in Lake Mills, just east of the watershed across Rock Lake. Hourly rainfall accumulation was measured in Madison and provided an estimate of storm intensity and behavior. These values were assumed to be offset by traveling time to Lake Mills, located 30 miles to the east.

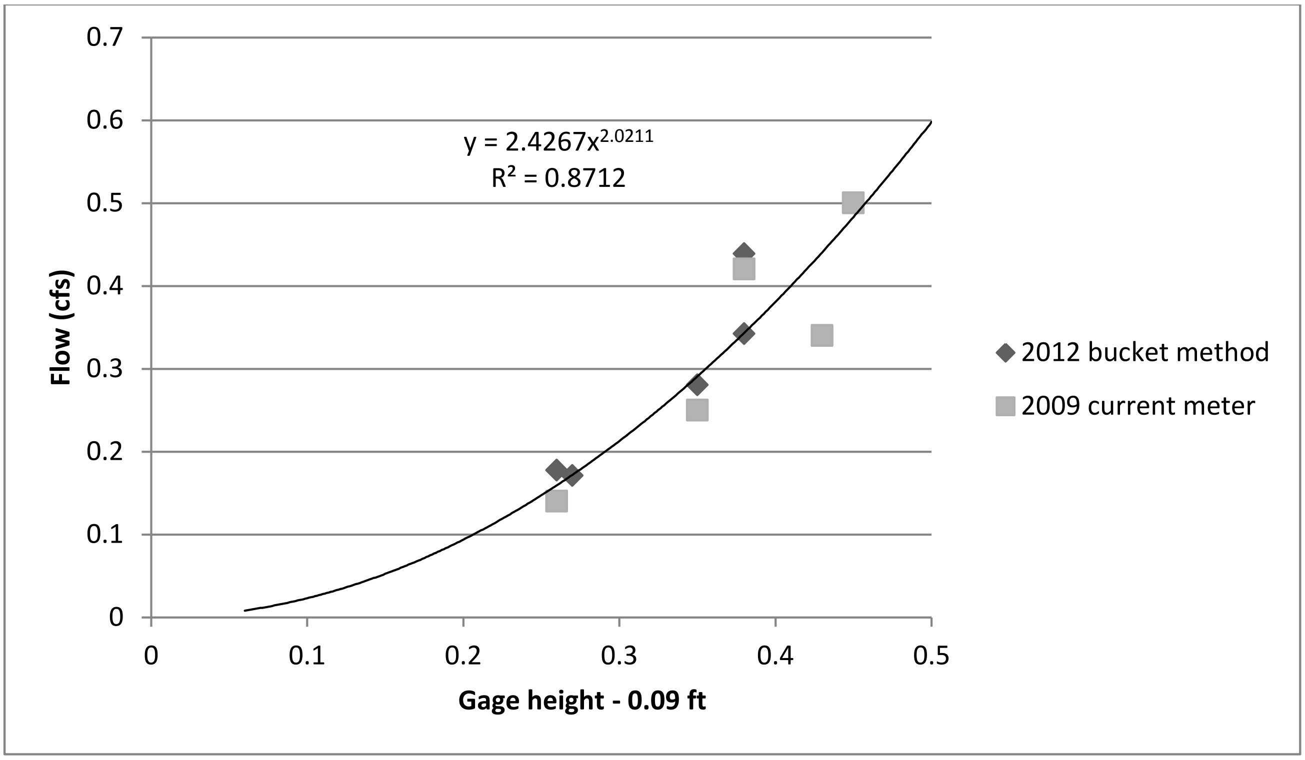


FIGURE C.5 RATING CURVE FOR THE DITCH AT CEDAR LANE CULVERT. $Q=2.4267(G-0.09)^{2.0211}$

Crest Stage Gage Construction

The crest stage gage consisted of a two inch PVC pipe, a cap, a small metal screen and a wooden meter stick. Before installation, six bore-holes were inserted to the base of the pipe, with five of them being arranged at 30 degree angles for intake and one exit hole located on the opposite end of the pipe (Figure C.7). Next, the cap was fastened to the top of the pipe and two vent holes were drilled through the cap and the pipe. In addition to venting, this helps to line up the cap correctly after subsequent removal.

A small metal screen was cut in a circular shape and a slit was cut in the middle in order to slide the meter stick through the screen. The screen was placed two inches from the base of the meter stick. After fitting the screen, the meter stick was fastened to the top cap using a small nail. Finally, as the meter stick was slowly inserted into the pipe, crushed cork and Styrofoam were gently poured onto the top of the screen.

The gage was placed in front of the culvert at SS8 in order to gain insight into the amount of surface runoff originating from the Shorewood Hills subdivision. The gage was installed by pounding the pipe into the ground such that the bottom of the meter stick was flush with the soil surface and the intake holes were facing the direction of flow. The top of the cap was also measured in relation to a known datum using field survey equipment. Results from the gage proved to be inconclusive. Drought conditions during the summer were thought to have contributed to minimal flow from the subdivision. Future testing at this site should be conducted during storm events with considerable antecedent soil moisture.

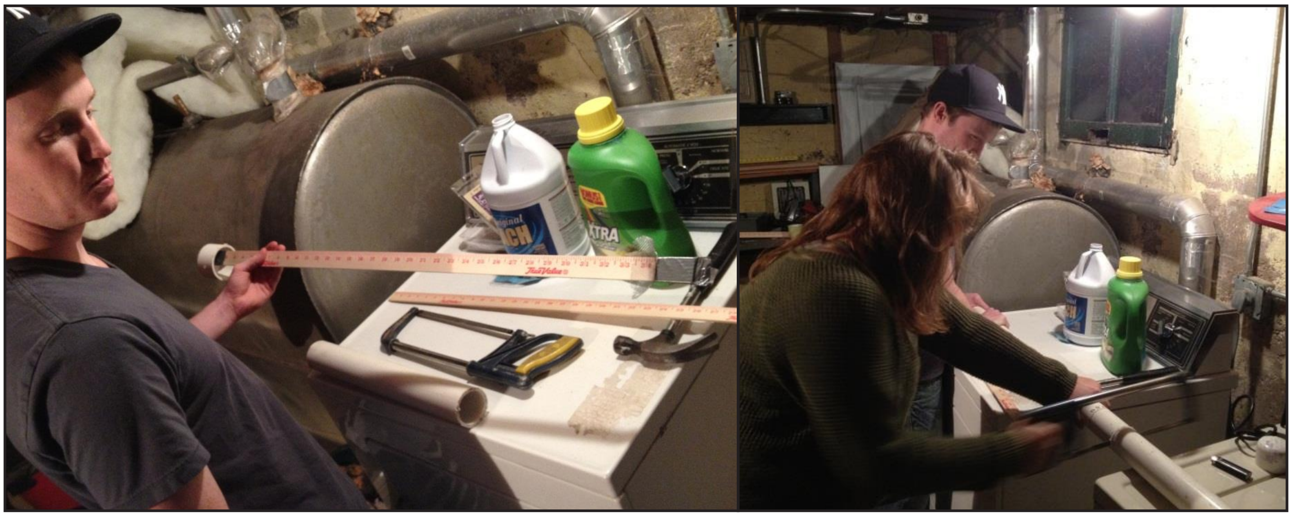


Figure C.6 Constructing the Crest Stage Gage. Pictured are Cody Meier and Megan Phillips. Photo credit: Steve Neary, 3.27.12

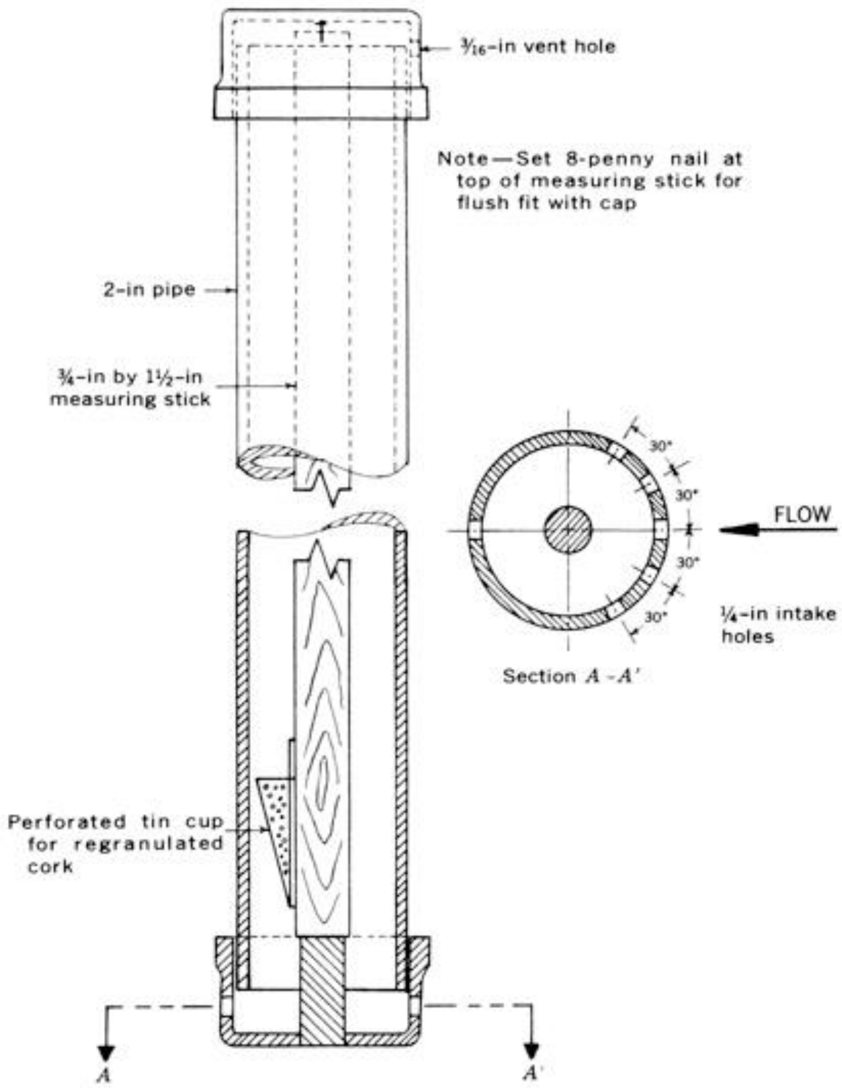


Figure C.7 Crest Stage Gage Diagram. Source: U.S. Geological Survey (usgs.gov).

Geographic Data and Analysis

The following GIS (Geographic Information Systems) layers were obtained from Jefferson County Land Information Office:

-2004/2005 two-foot contours

-2006 land use

-2006 soils

-2009 parcels

-2009 roads

The source and age of the following layers could not be verified:

-3 foot resolution hillshade map

-17.17 foot resolution digital elevation model

-LIDAR streams and ponds

-Watershed boundaries

Additionally, GPS coordinates for monitoring wells, sampling sites, and areas of soil erosion were collected. These were incorporated into GIS layers for mapping.

Watersheds were delineated from the 17.17 digital elevation model (DEM) and LIDAR stream network with ArcMap 10.0 using the procedure outlined in Maidment and Olivera (2002). Because spatial resolution of the DEM was too low to capture the ditch network, this feature was “burned” into the DEM from the LIDAR stream data. Pour points were selected by hand at culvert locations, above forks in the drainage network, and above the proposed location of a wetland restoration in Korth Park. Identification of watersheds with GIS tools requires “filling” depressions in the DEM — this was done for 3-foot depressions for use with pour points and 1-foot depressions to identify large closed basins. These files were combined, vectorized, and boundaries corrected upon comparison with two-foot contours.

Appendix D: Results

Sediment Analysis

Table D.1 Grain Size Distribution of Sediment Cores Taken from the Miljala Channel in October 2011.

Cup #	Core #	Cup Weight (g)	Weight (g) before burn	Weight (g) After H20 Burn (105°c)	Weight (g) After OM/Peat Burn (440°c)	OM/Peat (g)	% OM/Peat	Coarse Sand (g)	% Coarse Sand	Fine Sand (g)	% Fine Sand	Silt/Clay (g)	% Silt/Clay	Total %
1a	1	18.80	25.00	9.03	6.84	2.19	24.26	0.10	1.06	2.05	22.74	4.36	48.27	96.33
1b	1	19.80	25.00	8.52	6.22	2.30	26.98	0.07	0.83	1.36	15.91	4.71	55.24	98.96
Total 1				17.55		4.49	25.58	0.17	0.95	3.41	19.42	9.06	51.65	97.61
2a	2	20.30	25.00	17.10	16.26	0.85	4.95	1.54	9.02	11.83	69.14	2.80	16.35	99.47
2b	2	20.20	25.00	16.87	15.91	0.96	5.71	1.75	10.34	11.44	67.79	2.59	15.34	99.18
Total 2				33.97		1.81	5.33	3.29	9.68	23.26	68.47	5.39	15.85	99.33
4a	4 (top)	19.60	25.00	7.47	4.38	3.09	41.33	0.14	1.84	0.96	12.81	3.32	44.45	100.42
4b	4 (top)	21.30	25.00	7.82	4.69	3.13	40.01	0.24	3.07	1.56	19.91	2.74	35.06	98.06
Total 4 Top				15.28		6.21	40.65	0.38	2.47	2.51	16.44	6.06	39.65	99.21
4c	4 (mid)	21.00	25.00	15.44	14.18	1.26	8.16	2.20	14.25	9.48	61.36	2.47	15.98	99.75
4d	4 (mid)	20.50	25.00	19.20	18.61	0.59	3.09	3.17	16.53	13.61	70.87	1.55	8.06	98.54
Total 4 Mid				34.64		1.85	5.35	5.37	15.51	23.08	66.63	4.01	11.59	99.08
4e	4 (btm)	19.70	25.00	21.94	21.93	0.02	0.08	5.52	25.13	15.63	71.24	0.69	3.12	99.58
4f	4 (btm)	19.00	25.00	21.62	21.60	0.02	0.08	5.72	26.45	15.17	70.17	0.66	3.04	99.75
Total 4 Btm				43.56		0.04	0.08	11.24	25.79	30.80	70.71	1.34	3.08	99.66
Total 4				93.49		8.10	8.66	16.99	18.17	56.40	60.33	11.42	12.21	99.37
Total Cores				145.00		14.40	9.93	20.44	14.10	83.07	57.29	25.86	17.84	99.15

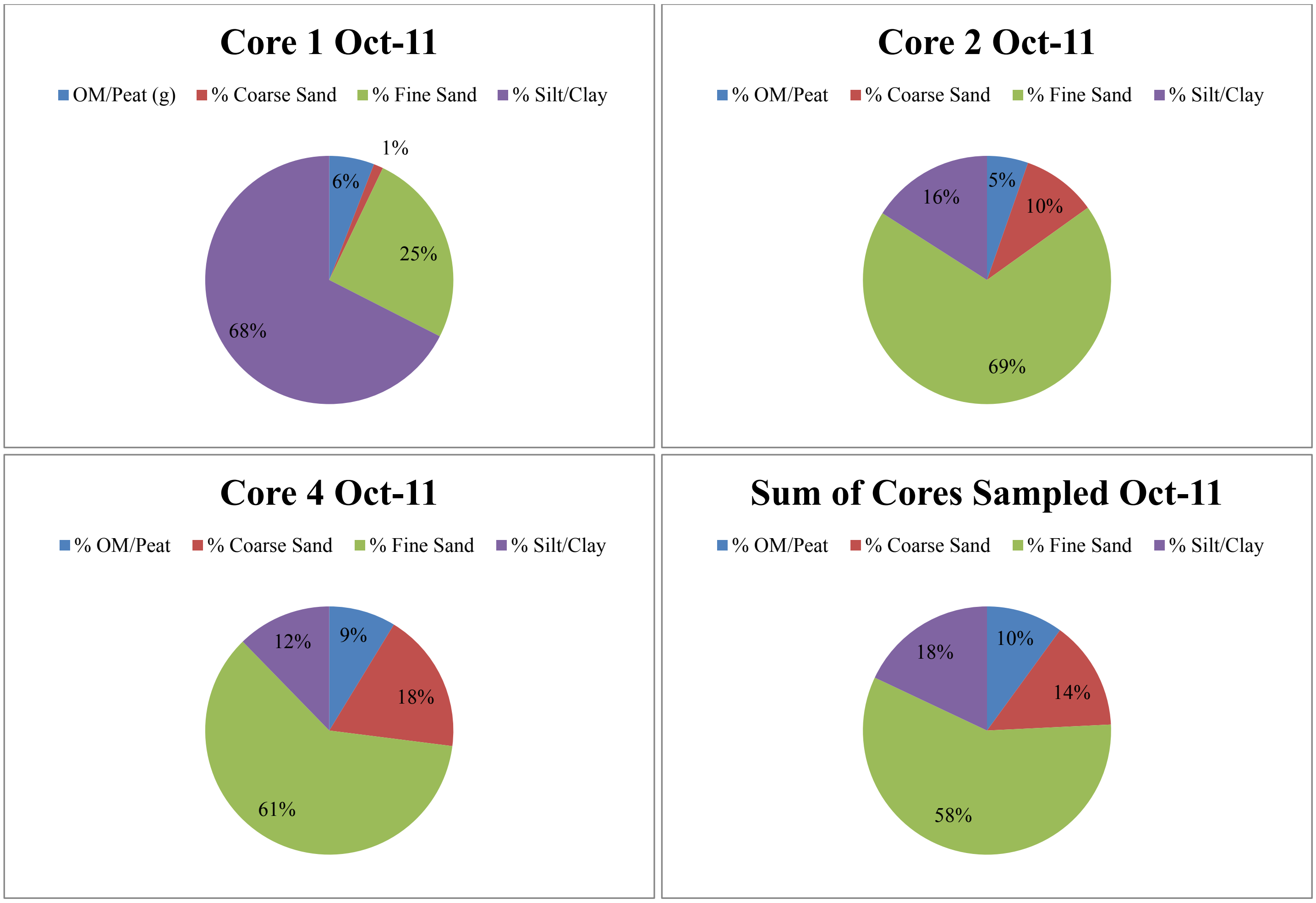


Figure D.1 Grain Size Distribution (percent by mass) of Sediment Cores Taken in October 2011.

Table D.2 Grain Size Distribution of Sediment Cores Taken from the Miljala Channel in July 2012.

Cup #	Core #	Cup Weight (g)	Weight (g) before burn	Weight (g) After H20 Burn (105°C)	Weight (g) After OM/Peat Burn (440°C)	OM/Peat (g)	% OM/Peat	Coarse Sand (g)	% Coarse Sand	Fine Sand (g)	% Fine Sand	Silt/Clay (g)	% Silt/Clay	Total %
1	1	123.20	765.90	137.10	138.33	0.00	0.00	3.56	2.60	73.60	53.68	59.80	43.62	99.89
2	2	99.06	606.88	442.14	428.44	13.70	3.10	18.85	4.26	319.38	72.23	88.07	19.92	99.51
3	3	37.19	225.21	149.31	139.81	9.50	6.36	25.72	17.23	96.73	64.78	16.13	10.80	99.17
4	4	62.20	289.10	117.30	91.40	25.90	22.08	3.09	2.63	39.45	33.64	48.64	41.47	99.82
5	5	30.97	52.43	16.03	11.03	5.00	31.20	1.15	7.19	4.93	30.76	4.87	30.41	99.57
Total				861.88	809.02	54.10	6.30	52.37	6.10	534.09	62.24	217.51	25.35	100.00

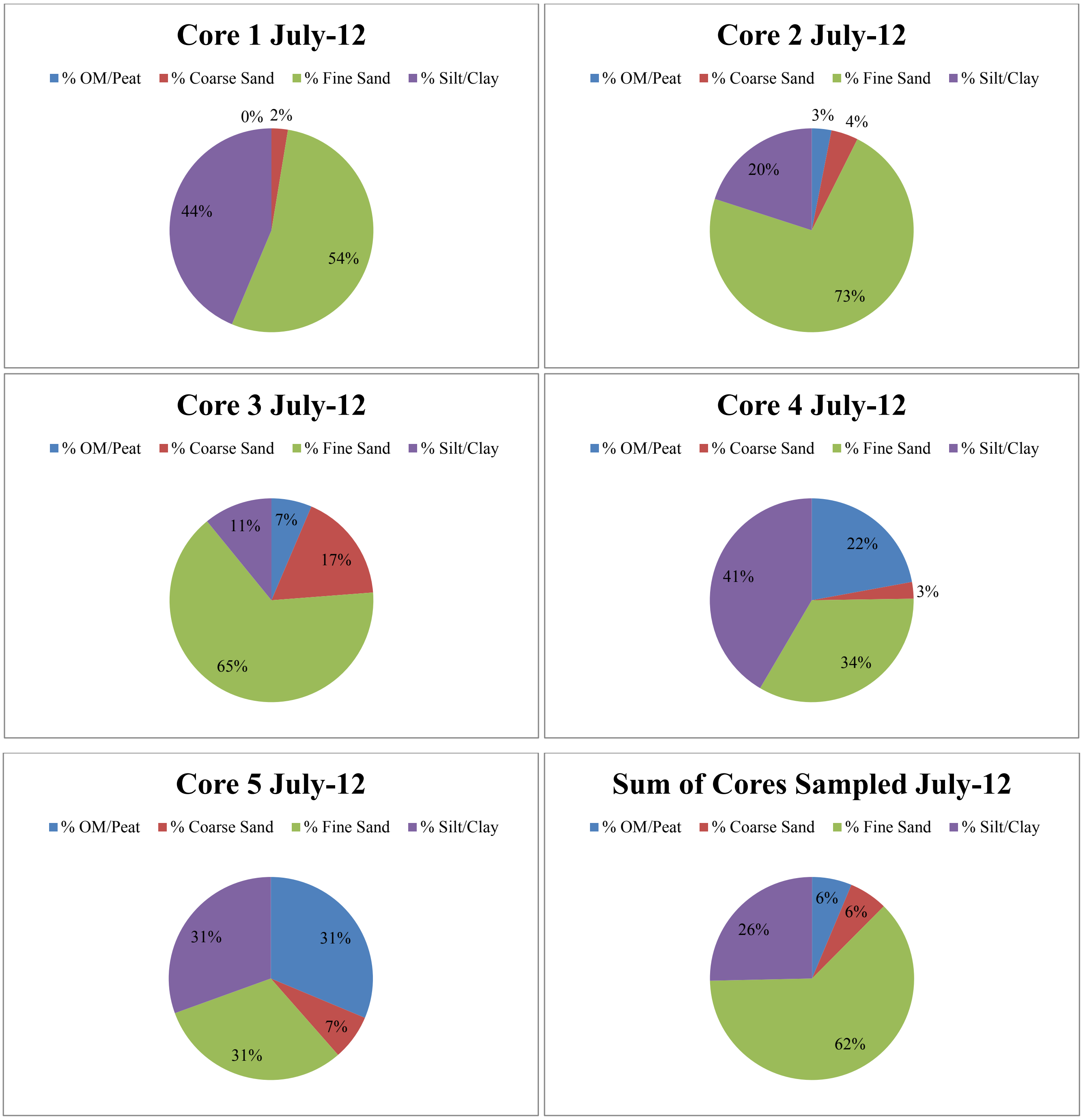


Figure D.2 Grain Size Distribution (percent by mass) of Sediment Cores Taken In July 2012.

Phosphorus Sampling

Table D.3 Raw Surface Site Phosphorus Data Obtained from Sampling September 17, 2011 to August 16, 2012 Using Chemets.

Total Phosphorus (mg/L)

Site	09/17/11	10/07/11	10/21/11	11/04/11	01/27/12	02/01/12	02/10/12	02/29/12	03/09/12	03/21/12	03/29/12	04/13/12	04/25/12	05/08/12	05/17/12	05/24/12	05/31/12	06/11/12	06/22/12	07/18/12	08/07/12	08/16/12
SS 6								2.50	1.00	4.50	10	0.8	5	3.5	6	10	7					
SS 7								0.80		0.50	3	1	0.3	1.6	1	1	0.9	1.5	1	5	2	3
SS 5	0.80	0.60	0.40	0.05		0.05	0.00	0.40	0.30	0.80	0.3	0.5	0.3	1.5	0.5	0.45	0.7	1.5	0.6		0.8	3
SS 8								0.60						1.5								
SS 4	4.50	0.20	0.04	0.10				0.90	0.15	1.50	0.1	0.2	0.1	0.8		7						
SS 3	0.30	0.60	0.40	0.30	0.05	0.15	0.00	0.50	0.10	0.60	0.1	0.5	0.3	0.8	0.2	0.3	0.5	0.7	0.2	1.5	0.4	1.5
SS 2	0.50	2.00	0.40	0.30	0.05	0.05		0.50	0.10	0.50	0.1	0.6	0.4	0.8	0.2	0.3	0.5	0.9	0.3	1.1		
SS 1	0.35	0.70	0.30	0.30	0.10	0.10	0.00	0.35	0.50	0.40	0.1	0.3	0.6	0.8	0.1	0.3	0.8	0.6	0.4	1	0.4	1.5
SS 9																					0.15	0.15

Table D.4 Raw Well Phosphorus Data Obtained from Sampling September 17, 2011 to August 16, 2012 Using Chemets.

Site	Total Phosphorus (mg/L)							
	01/27/12	02/01/12	03/09/12	03/21/12	03/29/12	05/24/12	08/07/12	08/16/12
MW 1	0.00	0.10	0.05		0.1	0	0.1	0.2
MW 2	0.00		0.10		0.1	0.25	0.2	0.2
MW 8	0.10		0.20					
MW 4	0.05		0.05		0.1			
MW 5	0.10		0.10		0.05	1		
MW 6	2.00		0.05		0.05			

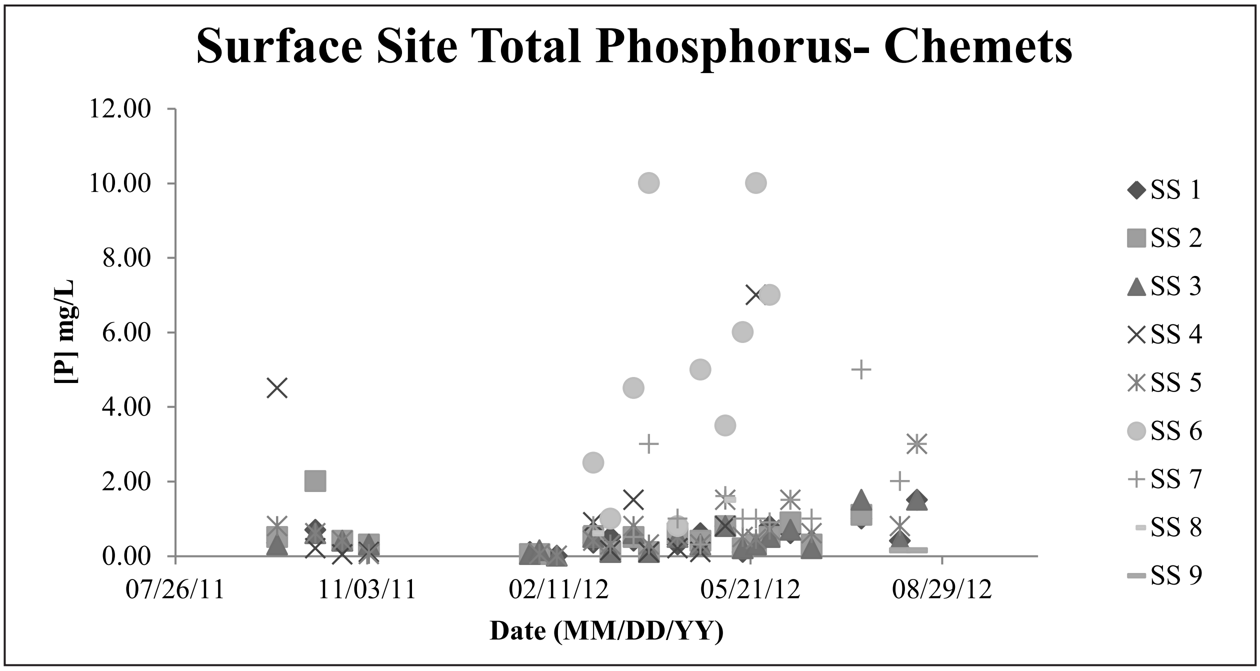


Figure D.3 Surface Site Total Phosphorus Results for Samples Collected and Analyzed Using Chemets on Multiple Dates from September 17, 2011 to August 16, 2012. Few samples were obtainable due to low water table levels caused by the Summer 2012 drought.

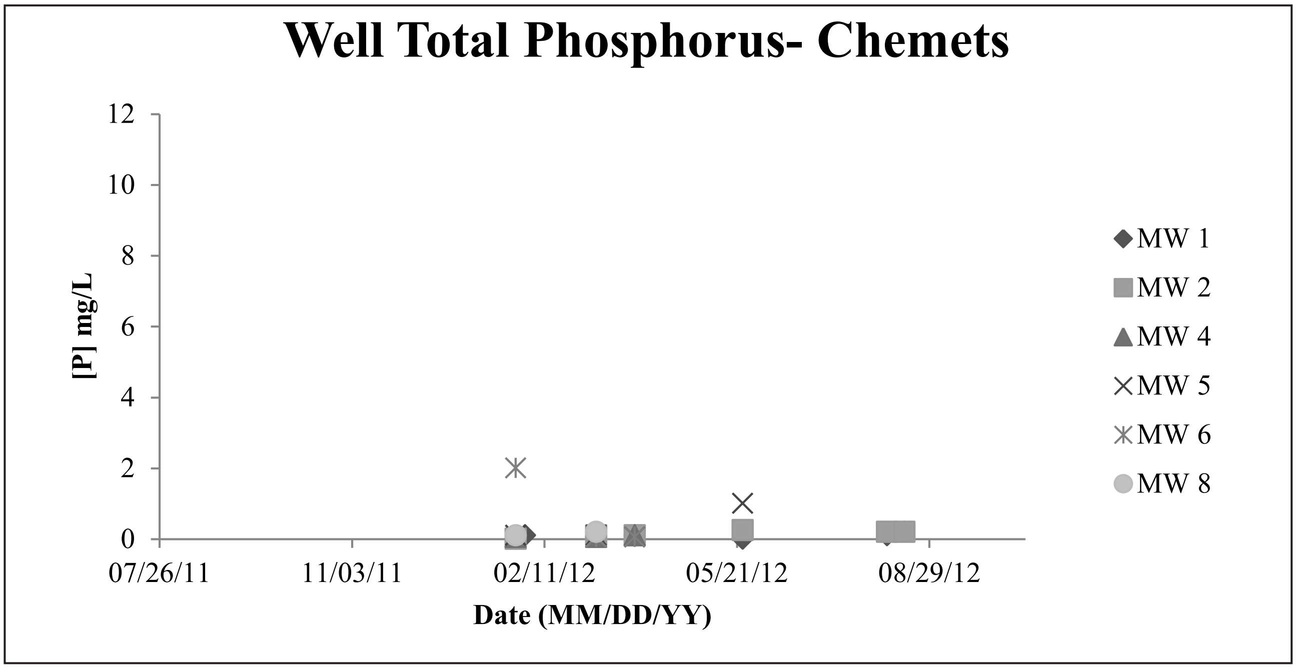


Figure D.4 Well Total Phosphorus Results for Samples Collected and Analyzed Using Chemets On Multiple Dates from September 17, 2011 to August 16, 2012. Few samples were obtainable due to low water table levels caused by the Summer 2012 drought.

Table D.5 *E. coli* Concentrations of Samples Taken on Three Dates in 2012. Samples Were Processed and Analyzed at the Wisconsin State Laboratory of Hygiene.

Site	*E-coli* (colonies/100 mL)		
	05/17/12	**08/07/12**	**08/16/12**
SS 7	135	727	2,590
SS 5	93	166	4,320
SS 3	138	1,733	8,570
SS 1	548	4,710	10,760
SS 1 (duplicate)	276		8,130
SS 9		83	548
SS 9 (duplicate)		111	

Table D.6 Fecal Coliform Concentrations of Samples Taken on Three Dates in 2012. Samples Were Processed and Analyzed at the Wisconsin State Laboratory of Hygiene.

Site	*E-coli* (colonies/100 mL)		
	05/17/12	**08/07/12**	**08/16/12**
SS 7	135	727	2,590
SS 5	93	166	4,320
SS 3	138	1,733	8,570
SS 1	548	4,710	10,760
SS 1 (duplicate)	276		8,130
SS 9		83	548
SS 9 (duplicate)		111	

Table D.7 Water Table Elevation Measurements Taken With an Electric Tape.

Monitoring Well Water Table Elevations (ft)									
Site	1/25/2012	1/27/2012	2/1/2012	2/3/2012	2/10/2012	3/9/2012	3/27/2012	3/29/2012	4/10/2012
MW 1	10.82	10.81	10.77	10.78			10.79		10.68
MW 2	10.91	10.81	11.18	10.77			10.84	10.75	10.69
MW 3	4.34	4.52	4.88	4.66	4.20		4.46	4.32	4.13
MW 3.5			4.80	4.59	4.17		4.44	4.34	4.17
MW 4	4.19	2.84	4.11	3.55	4.09		4.56	3.18	4.14
MW 5	4.92	4.98	5.03	5.01	4.99		5.12	5.09	5.09
MW 6	6.08	5.71	6.11	6.09	6.00		6.2	6.19	5.87
MW 8	3.77	3.71	3.90	3.86	3.73		3.97	3.92	3.82
MW 9	5.10		5.21	5.41			5.39	5.34	5.22
Monitoring Well Water Table Elevations (ft)									
Site	4/12/2012	4/24/2012	4/27/2012	5/8/2012	5/11/2012	5/21/2012	5/24/2012	5/31/2012	6/11/2012
MW 1		10.72		10.84	10.76	10.33	10.29	10.32	9.93
MW 2		10.75		10.85	10.76	10.35	10.33	10.37	9.97
MW 3		4.3		5.01	4.61	3.87	3.72	3.75	
MW 3.5		4.3		4.99	4.59	3.85	3.71	3.76	3.63
MW 4		4.36		5.12	4.66	3.88	3.45	3.72	3.04
MW 5		5.08		5.28	5.19	4.95	4.93	5.04	4.55
MW 6		5.94		6.21	6.23	5.81	5.84	5.9	5.57
MW 8		3.89		2.03	3.97	3.53	3.42	3.5	2.83
MW 9		5.6		5.67	5.39	4.93	4.83	4.69	4.13

Table D.7 continuted **Water Table Elevation Measurements Taken With an Electric Tape.**

Monitoring Well Water Table Elevations (ft)									
Site	6/12/2012	6/13/2012	6/14/2012	6/26/2012	6/27/2012	6/28/2012	7/11/2012	7/15/2012	7/18/2012
MW 1	9.87	9.86	10.17	9.6	9.59		9.35		9.35
MW 2				9.73			9.48		9.46
MW 3				3.02					
MW 3.5				3.61					3.59
MW 4				1.96					-0.83
MW 5				4.13			3.93	4.02	3.99
MW 6				5.17		5.04	4.59	4.84	4.94
MW 8				2.57	2.53	2.49	2.41	2.41	2.56
MW 9			3.98	3.48					

Monitoring Well Water Table Elevations (ft)							
Site	7/24/2012	07/25/12	8/7/2012	08/08/12	8/16/2012	09/07/12	09/25/12
MW 1		10.07	9.9	9.81	10.58	9.95	10.19
MW 2		9.91	9.86	10.63	10.18	10.23	
MW 3							
MW 3.5	3.58						
MW 4	-0.63				-0.97		
MW 5	4.39	4.38		4.1	4.84	3.99	4.224
MW 6		5.14		4.97	5.75	5.23	5.1
MW 8	2.68	2.48		2.28	2.95	2.24	2.24
MW 9							

Appendix E: Hydrologic Modeling

Lateral Effect Calculations

Lateral effect was calculated with the van Schilfgaarde Equation, as described in Verry et al. (2011), using the ND Drain Scope and Effect software. Hydraulic conductivity is based on slug tests conducted in wells screened in the muck layer. Drainable porosity is based on the lower bound reported for muck soils in the literature (Verry et al., 2011). The muck ranges from 4-6 feet in depth, and the underlying lacustrine layer has a hydraulic conductivity an order of magnitude lower. Depth of the ditch to typical spring water level ranges from 2 feet in the upper and lower reaches to 4 feet in middle reaches.

2' ditch

DRAINABLE POROSITY, f = 0.08

HYDRAULIC CONDUCTIVITY ABOVE DRAIN, Ka = 0.3 in/hr

HYDRAULIC CONDUCTIVITY BELOW DRAIN, Kb = 0.3 in/hr

INITIAL WATER LEVEL HEIGHT OVER BARRIER, h1 = 6.0 feet

FINAL WATER LEVEL HEIGHT OVER BARRIER, h2 = 5.0 feet

DRAIN HEIGHT OVER BARRIER, h3 = 4.0 feet

DRAIN DEPTH BELOW GROUNDLINE, h4 = 2.0 feet

EFFECTIVE RADIUS OF DRAIN, Re = 1.00 feet

TIME FOR WATER DRAWDOWN, T = 14.0 days

----

van Schilfgaarde Equation: LATERAL EFFECT 38.0 FT

3' ditch

DRAINABLE POROSITY, f = 0.08

HYDRAULIC CONDUCTIVITY ABOVE DRAIN, Ka = 0.3 in/hr

HYDRAULIC CONDUCTIVITY BELOW DRAIN, Kb = 0.3 in/hr

INITIAL WATER LEVEL HEIGHT OVER BARRIER, h1 = 6.0 feet

FINAL WATER LEVEL HEIGHT OVER BARRIER, h2 = 5.0 feet

DRAIN HEIGHT OVER BARRIER, h3 = 3.0 feet

DRAIN DEPTH BELOW GROUNDLINE, h4 = 3.0 feet

EFFECTIVE RADIUS OF DRAIN, Re = 1.00 feet

TIME FOR WATER DRAWDOWN, T = 14.0 days

----

van Schilfgaarde Equation: LATERAL EFFECT 47.6 FT

4' Ditch

DRAINABLE POROSITY, f = 0.08

HYDRAULIC CONDUCTIVITY ABOVE DRAIN, Ka = 0.3 in/hr

HYDRAULIC CONDUCTIVITY BELOW DRAIN, Kb = 0.3 in/hr

INITIAL WATER LEVEL HEIGHT OVER BARRIER, h1 = 6.0 feet

FINAL WATER LEVEL HEIGHT OVER BARRIER, h2 = 5.0 feet

DRAIN HEIGHT OVER BARRIER, h3 = 2.0 feet

DRAIN DEPTH BELOW GROUNDLINE, h4 = 4.0 feet

EFFECTIVE RADIUS OF DRAIN, Re = 1.00 feet

TIME FOR WATER DRAWDOWN, T = 14.0 days

----

van Schilfgaarde Equation: LATERAL EFFECT 53.1 FT

5' ditch

DRAINABLE POROSITY, f = 0.08

HYDRAULIC CONDUCTIVITY ABOVE DRAIN, Ka = 0.3 in/hr

HYDRAULIC CONDUCTIVITY BELOW DRAIN, Kb = 0.3 in/hr

INITIAL WATER LEVEL HEIGHT OVER BARRIER, h1 = 6.0 feet

FINAL WATER LEVEL HEIGHT OVER BARRIER, h2 = 5.0 feet

DRAIN HEIGHT OVER BARRIER, h3 = 1.0 feet

DRAIN DEPTH BELOW GROUNDLINE, h4 = 5.0 feet

EFFECTIVE RADIUS OF DRAIN, Re = 1.00 feet

TIME FOR WATER DRAWDOWN, T = 14.0 days

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van Schilfgaarde Equation: LATERAL EFFECT 56.0 FT

HydroCAD Model Results

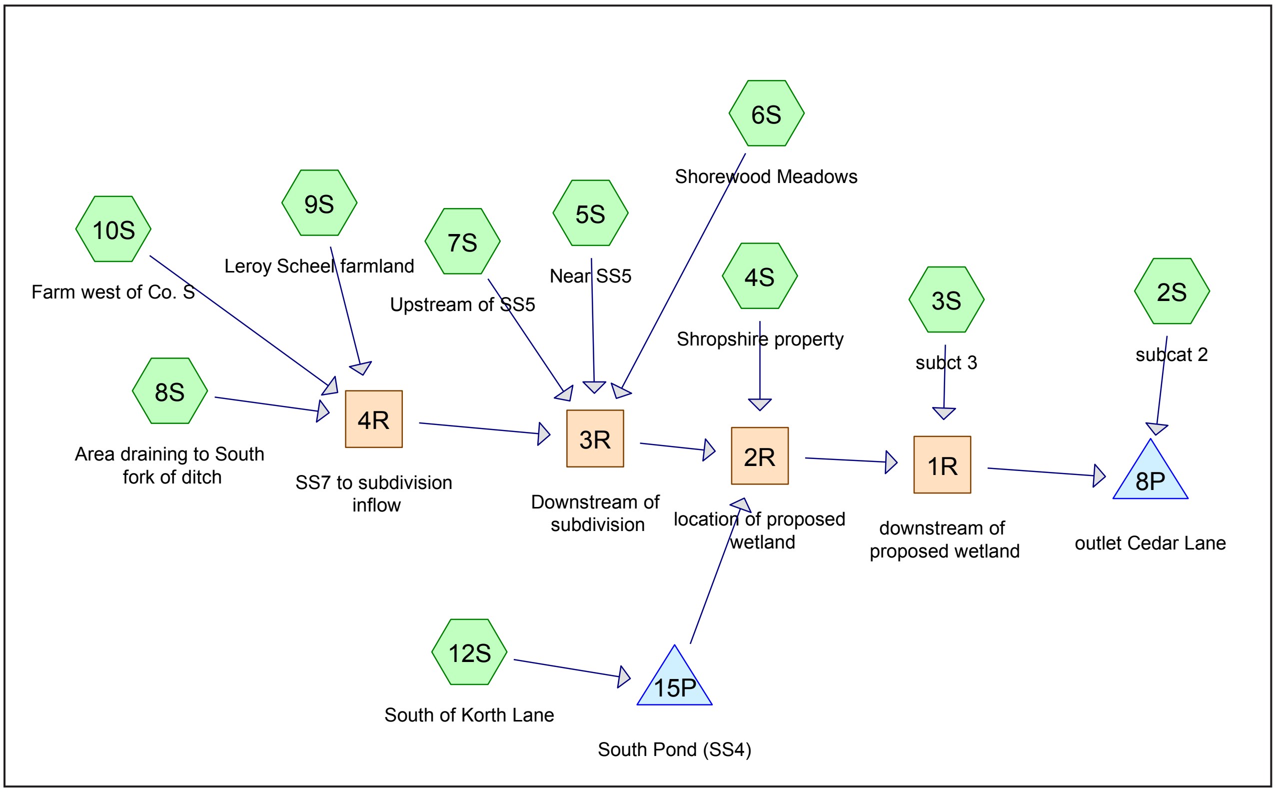

Figure E.1 Diagram of Catchments (S), Reaches (R), and Ponds or Outlets (P) in HydroCAD Model.

Time span=5.00-50.00 hrs, dt=0.05 hrs, 901 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: subcat 2	Runoff Area=20.110 ac 6.17% Impervious Runoff Depth=0.19" Flow Length=1,454' Tc=23.8 min CN=60 Runoff=1.40 cfs 0.324 af
Subcatchment 3S: subct 3	Runoff Area=16.300 ac 2.12% Impervious Runoff Depth=0.15" Flow Length=1,431' Tc=19.8 min CN=58 Runoff=0.66 cfs 0.204 af
Subcatchment 4S: Shropshire property	Runoff Area=11.020 ac 3.52% Impervious Runoff Depth=0.04" Flow Length=480' Tc=17.7 min CN=51 Runoff=0.05 cfs 0.038 af
Subcatchment 5S: Near SS5	Runoff Area=3.990 ac 6.14% Impervious Runoff Depth=0.32" Flow Length=827' Tc=19.9 min CN=65 Runoff=0.88 cfs 0.108 af
Subcatchment 6S: Shorewood Meadows	Runoff Area=18.600 ac 16.61% Impervious Runoff Depth=0.65" Flow Length=2,056' Tc=25.8 min CN=74 Runoff=10.04 cfs 1.004 af
Subcatchment 7S: Upstream of SS5	Runoff Area=9.730 ac 2.30% Impervious Runoff Depth=0.27" Flow Length=1,129' Tc=20.6 min CN=63 Runoff=1.47 cfs 0.217 af
Subcatchment 8S: Area draining to South fork of ditch	Runoff Area=9.050 ac 11.14% Impervious Runoff Depth=0.39" Flow Length=1,552' Tc=59.8 min CN=67 Runoff=1.25 cfs 0.291 af
Subcatchment 9S: Leroy Scheel farmland	Runoff Area=17.750 ac 5.45% Impervious Runoff Depth=0.74" Flow Length=1,759' Tc=31.5 min CN=76 Runoff=9.87 cfs 1.091 af
Subcatchment 10S: Farm west of Co. S	Runoff Area=11.300 ac 0.00% Impervious Runoff Depth=0.57" Flow Length=1,951' Tc=54.5 min CN=72 Runoff=2.95 cfs 0.532 af
Subcatchment 12S: South of Korth Lane	Runoff Area=27.920 ac 2.22% Impervious Runoff Depth=0.78" Flow Length=873' Slope=0.0102 '/' Tc=21.1 min CN=77 Runoff=21.97 cfs 1.825 af
Reach 1R: downstream of proposed wetland	Avg. Flow Depth=1.83' Max Vel=1.13 fps Inflow=12.12 cfs 3.485 af n=0.070 L=650.0' S=0.0025 '/' Capacity=62.47 cfs Outflow=11.88 cfs 3.485 af
Reach 2R: location of proposed wetland	Avg. Flow Depth=1.41' Max Vel=1.63 fps Inflow=11.85 cfs 3.281 af n=0.070 L=435.0' S=0.0069 '/' Capacity=102.96 cfs Outflow=11.77 cfs 3.281 af
Reach 3R: Downstream of subdivision	Avg. Flow Depth=1.59' Max Vel=1.38 fps Inflow=12.41 cfs 3.243 af n=0.070 L=580.0' S=0.0043 '/' Capacity=81.40 cfs Outflow=11.83 cfs 3.243 af
Reach 4R: SS7 to subdivision inflow	Avg. Flow Depth=1.80' Max Vel=0.76 fps Inflow=12.17 cfs 1.914 af n=0.100 L=920.0' S=0.0022 '/' Capacity=25.37 cfs Outflow=9.19 cfs 1.914 af
Pond 8P: outlet Cedar Lane	Inflow=12.40 cfs 3.810 af Primary=12.40 cfs 3.810 af
Pond 15P: South Pond (SS4)	Peak Elev=843.59' Storage=79,507 cf Inflow=21.97 cfs 1.825 af Outflow=0.00 cfs 0.000 af

Table E.1 Summary of Contributing Area, Curve Number, and Time of Concentration for Each Catchment and Reach. Runoff volumes are for a 1.77 inch storm.

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.130	75	(5S)
1.840	68	1 acre lots, 20% imp, HSG B (8S)
10.380	70	1/2 acre lots, 25% imp, HSG B (2S, 6S)
0.110	61	1/4 acre lots, 38% imp, HSG A (2S)
2.970	75	1/4 acre lots, 38% imp, HSG B (2S, 3S, 4S, 7S, 9S)
6.680	49	50-75% Grass cover, Fair, HSG A (3S, 4S, 5S, 7S)
10.660	69	50-75% Grass cover, Fair, HSG B (2S, 3S, 4S, 7S, 9S)
1.460	61	>75% Grass cover, Good, HSG B (10S)
8.070	35	Brush, Fair, HSG A (2S, 3S, 4S)
1.610	56	Brush, Fair, HSG B (2S, 3S, 5S)
2.760	75	Catchment 10, row crops (10S)
6.510	74	Farmsteads, HSG B (10S)
0.470	76	Gravel roads, HSG A (7S)
3.010	58	Meadow, non-grazed, HSG B (8S)
0.470	69	Pasture/grassland/range, Fair, HSG B (6S)
2.430	61	Pasture/grassland/range, Good, HSG B (12S)
7.290	89	Paved roads w/open ditches, 50% imp, HSG B (2S, 3S, 4S, 5S, 6S, 8S, 9S, 12S)
24.560	75	Row crops, contoured, Good, HSG B (5S, 6S, 7S, 9S)
26.510	78	Row crops, straight row, Good, HSG B (8S, 12S)
0.320	75	Small grain, straight row, Good, HSG B (10S)
0.680	98	Water Surface, 0% imp, HSG A (4S)
0.350	98	Water Surface, HSG B (3S, 12S)
5.050	36	Woods, Fair, HSG A (2S, 3S, 4S, 7S)
7.070	60	Woods, Fair, HSG B (3S, 4S, 7S, 10S)
1.370	43	Woods/grass comb., Fair, HSG A (5S, 8S)
12.010	65	Woods/grass comb., Fair, HSG B (2S, 4S)
145.770	**68**	**TOTAL AREA**

Figure E.2 Curve Numbers Based on Field Assessment of GIS Landcover Data.

Summary for Subcatchment 10S: Farm west of Co. S

Runoff = 0.74 cfs @ 12.74 hrs, Volume= 0.190 af, Depth= 0.20"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

	Area (ac)	CN	Description
*	2.760	75	Catchment 10, row crops
	1.460	61	>75% Grass cover, Good, HSG B
	6.510	74	Farmsteads, HSG B
	0.320	75	Small grain, straight row, Good, HSG B
	0.250	60	Woods, Fair, HSG B
	11.300	72	Weighted Average
	11.300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
18.1	100	0.0057	0.09		**Sheet Flow, Past farmstead from south** Grass: Short n= 0.150 P2= 2.57"
24.5	776	0.0057	0.53		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	30	0.0200	6.94	49.05	**Pipe Channel, CMP_Round 36" (not measured)** 36.0" Round Area= 7.1 sf Perim= 9.4' r= 0.75' n= 0.025 Corrugated metal
1.3	230	0.0400	3.00		**Shallow Concentrated Flow, wetland near SS6** Grassed Waterway Kv= 15.0 fps
10.5	815	0.0012	1.29	100.93	**Trap/Vee/Rect Channel Flow, North Fork of ditch** Bot.W=20.00' D=3.00' Z= 2.0 '/' Top.W=32.00' n= 0.070 Sluggish weedy reaches w/pools
54.5	1,951	Total			

Summary for Subcatchment 8S: Area draining to South fork of ditch

Runoff = 0.18 cfs @ 13.03 hrs, Volume= 0.081 af, Depth= 0.11"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
3.010	58	Meadow, non-grazed, HSG B
1.960	78	Row crops, straight row, Good, HSG B
0.960	43	Woods/grass comb., Fair, HSG A
1.840	68	1 acre lots, 20% imp, HSG B
1.280	89	Paved roads w/open ditches, 50% imp, HSG B
9.050	67	Weighted Average
8.042		88.86% Pervious Area
1.008		11.14% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
49.0	1,140	0.0010	0.39	2.33	**Channel Flow, south fork** Area= 6.0 sf Perim= 8.0' r= 0.75' n= 0.100 Very weedy reaches w/pools
7.0	100	0.0600	0.24		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.57"
3.8	312	0.0385	1.37		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
59.8	1,552	Total			

Summary for Subcatchment 9S: Leroy Scheel farmland

Runoff = 3.23 cfs @ 12.33 hrs, Volume= 0.446 af, Depth= 0.30"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
14.960	75	Row crops, contoured, Good, HSG B
1.760	89	Paved roads w/open ditches, 50% imp, HSG B
0.230	75	1/4 acre lots, 38% imp, HSG B
0.800	69	50-75% Grass cover, Fair, HSG B
17.750	76	Weighted Average
16.783		94.55% Pervious Area
0.967		5.45% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.0190	0.31		**Sheet Flow, catchment 9 flow path** Cultivated: Residue<=20% n= 0.060 P2= 2.57"
8.3	620	0.0190	1.24		**Shallow Concentrated Flow,** Cultivated Straight Rows Kv= 9.0 fps
6.7	309	0.0120	0.77		**Shallow Concentrated Flow, cattails and weeds** Short Grass Pasture Kv= 7.0 fps
11.1	730	0.0019	1.10	19.75	**Trap/Vee/Rect Channel Flow, north fork of ditch** Bot.W=5.00' D=2.00' Z= 2.0 '/' Top.W=13.00' n= 0.070 Sluggish weedy reaches w/pools
31.5	1,759	Total			

Summary for Subcatchment 7S: Upstream of SS5

Runoff = 0.07 cfs @ 13.11 hrs, Volume= 0.044 af, Depth= 0.05"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
3.470	69	50-75% Grass cover, Fair, HSG B
1.080	75	Row crops, contoured, Good, HSG B
0.590	75	1/4 acre lots, 38% imp, HSG B
0.790	60	Woods, Fair, HSG B
3.260	49	50-75% Grass cover, Fair, HSG A
0.470	76	Gravel roads, HSG A
0.070	36	Woods, Fair, HSG A
9.730	63	Weighted Average
9.506		97.70% Pervious Area
0.224		2.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.0	100	0.0800	0.12		**Sheet Flow, prairie** Grass: Bermuda n= 0.410 P2= 2.57"
5.7	490	0.0816	1.43		**Shallow Concentrated Flow, prairie** Woodland Kv= 5.0 fps
0.9	539	0.0100	9.64	347.15	**Trap/Vee/Rect Channel Flow,** Bot.W=3.00' D=4.00' Z= 1.5 '/' Top.W=15.00' n= 0.025
20.6	1,129	Total			

Summary for Subcatchment 5S: Near SS5

Runoff = 0.06 cfs @ 12.53 hrs, Volume= 0.026 af, Depth= 0.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

	Area (ac)	CN	Description
	0.700	75	Row crops, contoured, Good, HSG B
*	1.130	75	
	0.070	56	Brush, Fair, HSG B
	0.490	89	Paved roads w/open ditches, 50% imp, HSG B
	1.190	49	50-75% Grass cover, Fair, HSG A
	0.410	43	Woods/grass comb., Fair, HSG A
	3.990	65	Weighted Average
	3.745		93.86% Pervious Area
	0.245		6.14% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	100	0.0100	0.24		**Sheet Flow, west side of house** Cultivated: Residue<=20% n= 0.060 P2= 2.57"
4.2	412	0.0533	1.62		**Shallow Concentrated Flow, weedy slopes behind house** Short Grass Pasture Kv= 7.0 fps
8.8	315	0.0003	0.60	21.47	**Trap/Vee/Rect Channel Flow,** Bot.W=3.00' D=4.00' Z= 1.5 '/' Top.W=15.00' n= 0.070 Sluggish weedy reaches w/pools
19.9	827	Total			

Summary for Subcatchment 6S: Shorewood Meadows

Runoff = 2.86 cfs @ 12.26 hrs, Volume= 0.385 af, Depth= 0.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
8.260	70	1/2 acre lots, 25% imp, HSG B
0.470	69	Pasture/grassland/range, Fair, HSG B
7.820	75	Row crops, contoured, Good, HSG B
2.050	89	Paved roads w/open ditches, 50% imp, HSG B
18.600	74	Weighted Average
15.510		83.39% Pervious Area
3.090		16.61% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.2	100	0.0310	0.18		**Sheet Flow, lawns** Grass: Short n= 0.150 P2= 2.57"
15.1	1,549	0.0130	1.71		**Shallow Concentrated Flow, grass swales** Grassed Waterway Kv= 15.0 fps
1.5	407	0.0147	4.54	22.70	**Channel Flow, culvert and gully** Area= 5.0 sf Perim= 10.0' r= 0.50' n= 0.025 Earth, clean & winding
25.8	2,056	Total			

Summary for Subcatchment 4S: Shropshire property

Much of runoff goes to scrape. Should this be modeled?

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[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
0.060	69	50-75% Grass cover, Fair, HSG B
0.600	75	1/4 acre lots, 38% imp, HSG B
0.800	65	Woods/grass comb., Fair, HSG B
1.740	60	Woods, Fair, HSG B
0.320	89	Paved roads w/open ditches, 50% imp, HSG B
1.870	49	50-75% Grass cover, Fair, HSG A
0.680	98	Water Surface, 0% imp, HSG A
4.240	35	Brush, Fair, HSG A
0.710	36	Woods, Fair, HSG A
11.020	51	Weighted Average
10.632		96.48% Pervious Area
0.388		3.52% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.8	100	0.0800	0.12		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 2.57"
3.9	380	0.1070	1.64		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
17.7	480	Total			

Summary for Subcatchment 3S: subct 3

Runoff = 0.03 cfs @ 24.00 hrs, Volume= 0.019 af, Depth= 0.01"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
6.110	69	50-75% Grass cover, Fair, HSG B
0.410	75	1/4 acre lots, 38% imp, HSG B
1.020	56	Brush, Fair, HSG B
4.290	60	Woods, Fair, HSG B
0.280	89	Paved roads w/open ditches, 50% imp, HSG B
0.360	49	50-75% Grass cover, Fair, HSG A
0.050	98	Water Surface, HSG B
2.030	35	Brush, Fair, HSG A
1.750	36	Woods, Fair, HSG A
16.300	58	Weighted Average
15.954		97.88% Pervious Area
0.346		2.12% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.8	100	0.1200	0.21		**Sheet Flow,** Grass: Dense n= 0.240 P2= 2.57"
5.4	550	0.0580	1.69		**Shallow Concentrated Flow, Korth prairie** Short Grass Pasture Kv= 7.0 fps
4.6	550	0.0180	2.01		**Shallow Concentrated Flow, weedy lowland** Grassed Waterway Kv= 15.0 fps
2.0	231	0.0030	1.89	67.91	**Trap/Vee/Rect Channel Flow,** Bot.W=3.00' D=4.00' Z= 1.5 '/' Top.W=15.00' n= 0.070
19.8	1,431	Total			

Summary for Subcatchment 2S: subcat 2

Runoff = 0.06 cfs @ 15.65 hrs, Volume= 0.045 af, Depth= 0.03"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
2.120	70	1/2 acre lots, 25% imp, HSG B
1.140	75	1/4 acre lots, 38% imp, HSG B
0.520	56	Brush, Fair, HSG B
11.210	65	Woods/grass comb., Fair, HSG B
0.470	89	Paved roads w/open ditches, 50% imp, HSG B
0.220	69	50-75% Grass cover, Fair, HSG B
0.110	61	1/4 acre lots, 38% imp, HSG A
1.800	35	Brush, Fair, HSG A
2.520	36	Woods, Fair, HSG A
20.110	60	Weighted Average
18.870		93.83% Pervious Area
1.240		6.17% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.1	100	0.1100	0.14		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 2.57"
2.9	286	0.1100	1.66		**Shallow Concentrated Flow, down wooded hillslope** Woodland Kv= 5.0 fps
4.0	811	0.2300	3.36		**Shallow Concentrated Flow, woodland and streambanks** Short Grass Pasture Kv= 7.0 fps
4.8	257	0.0077	0.90	4.48	**Channel Flow,** Area= 5.0 sf Perim= 15.0' r= 0.33' n= 0.070 Sluggish weedy reaches w/pools
23.8	1,454	Total			

Summary for Subcatchment 12S: South of Korth Lane

Runoff = 7.74 cfs @ 12.18 hrs, Volume= 0.769 af, Depth= 0.33"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Type II 24-hr observed 1yr Rainfall=1.77"

Area (ac)	CN	Description
24.550	78	Row crops, straight row, Good, HSG B
2.430	61	Pasture/grassland/range, Good, HSG B
0.640	89	Paved roads w/open ditches, 50% imp, HSG B
0.300	98	Water Surface, HSG B
27.920	77	Weighted Average
27.300		97.78% Pervious Area
0.620		2.22% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	100	0.0102	0.24		**Sheet Flow,** Cultivated: Residue<=20% n= 0.060 P2= 2.57"
14.2	773	0.0102	0.91		**Shallow Concentrated Flow, through field to pond** Cultivated Straight Rows Kv= 9.0 fps
21.1	873	Total			

Summary for Pond 15P: South Pond (SS4)

Inflow Area = 27.920 ac, 2.22% Impervious, Inflow Depth = 0.33" for observed 1yr event
Inflow = 7.74 cfs @ 12.18 hrs, Volume= 0.769 af
Outflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Peak Elev= 842.95' @ 25.25 hrs Surf.Area= 57,638 sf Storage= 33,496 cf

Plug-Flow detention time= (not calculated: initial storage excedes outflow)
Center-of-Mass det. time= (not calculated: no outflow)

Volume	Invert	Avail.Storage	Storage Description
#1	842.00'	430,564 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
842.00	12,643	0	0
844.00	107,051	119,694	119,694
846.00	203,819	310,870	430,564

Device	Routing	Invert	Outlet Devices
#1	Device 2	844.33'	**9.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	842.00'	**9.0" Round Culvert** L= 1,542.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 842.00' / 834.00' S= 0.0052 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.44 sf

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=842.00' (Free Discharge)
↑**2=Culvert** (Controls 0.00 cfs)
↑**1=Orifice/Grate** (Controls 0.00 cfs)

Summary for Reach 4R: SS7 to subdivision inflow

Inflow Area =	38.100 ac,	5.18% Impervious, Inflow Depth = 0.23"	for observed 1yr event
Inflow =	3.66 cfs @	12.36 hrs, Volume=	0.717 af
Outflow =	2.37 cfs @	13.29 hrs, Volume=	0.717 af, Atten= 35%, Lag= 55.6 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.52 fps, Min. Travel Time= 29.7 min
Avg. Velocity = 0.16 fps, Avg. Travel Time= 96.4 min

Peak Storage= 4,218 cf @ 12.80 hrs
Average Depth at Peak Storage= 0.87'
Bank-Full Depth= 3.00' Flow Area= 25.5 sf, Capacity= 25.37 cfs

4.00' x 3.00' deep channel, n= 0.100 Very weedy reaches w/pools
Side Slope Z-value= 1.5 '/' Top Width= 13.00'
Length= 920.0' Slope= 0.0022 '/'
Inlet Invert= 839.00', Outlet Invert= 837.00'

Summary for Reach 3R: Downstream of subdivision

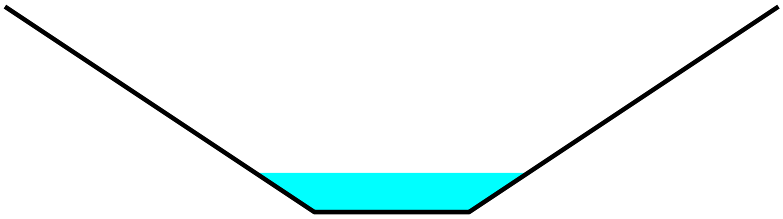
[61] Hint: Exceeded Reach 4R outlet invert by 0.28' @ 13.35 hrs

Inflow Area = 70.420 ac, 7.86% Impervious, Inflow Depth = 0.20" for observed 1yr event
Inflow = 3.15 cfs @ 13.23 hrs, Volume= 1.174 af
Outflow = 3.07 cfs @ 13.54 hrs, Volume= 1.174 af, Atten= 2%, Lag= 18.9 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.95 fps, Min. Travel Time= 10.2 min
Avg. Velocity = 0.34 fps, Avg. Travel Time= 28.5 min

Peak Storage= 1,886 cf @ 13.37 hrs
Average Depth at Peak Storage= 0.78'
Bank-Full Depth= 4.00' Flow Area= 36.0 sf, Capacity= 81.40 cfs

3.00' x 4.00' deep channel, n= 0.070 Sluggish weedy reaches w/pools
Side Slope Z-value= 1.5 '/' Top Width= 15.00'
Length= 580.0' Slope= 0.0043 '/'
Inlet Invert= 836.50', Outlet Invert= 834.00'



Summary for Reach 2R: location of proposed wetland

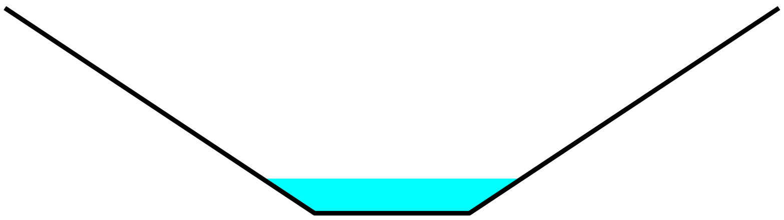
[62] Hint: Exceeded Reach 3R OUTLET depth by 0.01' @ 26.30 hrs
[79] Warning: Submerged Pond 15P Primary device # 2 OUTLET by 0.68'

Inflow Area = 109.360 ac, 5.98% Impervious, Inflow Depth = 0.13" for observed 1yr event
Inflow = 3.07 cfs @ 13.54 hrs, Volume= 1.174 af
Outflow = 3.05 cfs @ 13.74 hrs, Volume= 1.174 af, Atten= 1%, Lag= 11.7 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.11 fps, Min. Travel Time= 6.5 min
Avg. Velocity = 0.41 fps, Avg. Travel Time= 17.8 min

Peak Storage= 1,192 cf @ 13.63 hrs
Average Depth at Peak Storage= 0.68'
Bank-Full Depth= 4.00' Flow Area= 36.0 sf, Capacity= 102.96 cfs

3.00' x 4.00' deep channel, n= 0.070 Sluggish weedy reaches w/pools
Side Slope Z-value= 1.5 '/' Top Width= 15.00'
Length= 435.0' Slope= 0.0069 '/'
Inlet Invert= 834.00', Outlet Invert= 831.00'



Summary for Reach 1R: downstream of proposed wetland

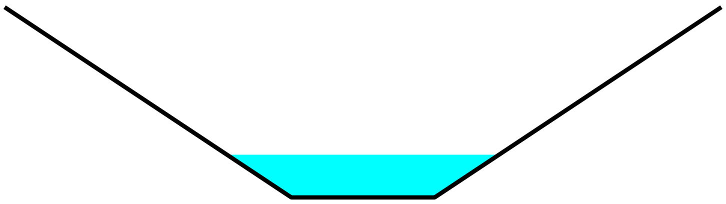
[62] Hint: Exceeded Reach 2R OUTLET depth by 0.25' @ 14.25 hrs

Inflow Area = 125.660 ac, 5.48% Impervious, Inflow Depth = 0.11" for observed 1yr event
Inflow = 3.05 cfs @ 13.74 hrs, Volume= 1.192 af
Outflow = 2.95 cfs @ 14.16 hrs, Volume= 1.192 af, Atten= 3%, Lag= 25.1 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-50.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.77 fps, Min. Travel Time= 14.0 min
Avg. Velocity = 0.28 fps, Avg. Travel Time= 38.1 min

Peak Storage= 2,476 cf @ 13.92 hrs
Average Depth at Peak Storage= 0.88'
Bank-Full Depth= 4.00' Flow Area= 36.0 sf, Capacity= 62.47 cfs

3.00' x 4.00' deep channel, n= 0.070 Sluggish weedy reaches w/pools
Side Slope Z-value= 1.5 '/' Top Width= 15.00'
Length= 650.0' Slope= 0.0025 '/'
Inlet Invert= 831.00', Outlet Invert= 829.35'



Appendix F: Site Visits

Sharon Long and Sharon Kluender

Members of the WRM cohort met with microbiologists Sharon Long and Sharon Kluender at the Wisconsin State Laboratory of Hygiene (WSLH) on multiple occasions throughout the course of the project. The purpose of these meetings was to discuss potential strategies for source identification and remediation of bacterial contamination in the watershed.

The first meeting was held on April 16, 2012. Topics discussed included land use in the watershed, sampling regime, and types of tests that could be conducted at the WSLH. The first recommendation was to conduct a septic survey in order to identify all possible bacterial sources in the watershed. Secondly, a sampling regime for *E. coli* and fecal coliform was determined. There would be four total sampling sessions, two each during baseflow and stormflow events. Samples would be taken at SS1, SS3, SS5, SS7, and SS9. In addition, one replicate and one duplicate test would be conducted for each sampling session to check for quality assurance. Other topics discussed at this meeting included natural bacterial population increase during summer months and community-based riparian zone management as a way to promote infiltration of bacteria-laden runoff before reaching the ditch.

After multiple sampling sessions during the summer, a second meeting at the WSLH was held on September 7, 2012. Bacterial concentrations were reviewed and a number of issues were discussed. Bacterial populations continued to persist above EPA standards throughout the ditch and channel, and it was determined that septic leakage is an unlikely source of bacterial contamination. Wildlife, and to some degree, manure, were determined to be the most prevalent sources of bacteria in the watershed. It was also noted that it is possible for bacteria to persist in ditch banks or bed load and can even reproduce outside of a human host. Further coliphage genotyping tests could be conducted to confirm that the bacterial source is indeed non-human. These tests are relatively new and have not been very successful in Wisconsin, however. Wetland restoration and riparian buffer maintenance were discussed as two potential methods for mitigation of unwanted bacterial growth. It was also noted that precipitation frequency and intensity can have a major impact on bacterial growth and transport through a system.

Quentin Carpenter

On May 17, 2012, the WRM cohort invited UW Madison Wetlands Ecology professor Quentin Carpenter to Korth Park for a wetland walk. The purpose of this walk was to better understand Miljala Channel watershed ecology. A walk of the ditch from SS1 to MW1 produced several interesting pieces of information about the watershed. First, Professor Carpenter helped to observe and identify a number of wetland plant species, including multiple sedges. Secondly, the existence of a thick silty-clay layer beneath loosely-settled muck soil at the bottom of the ditch between SS1 and SS5 was discovered. Professor Carpenter acknowledged this as a lacustrine deposit that likely formed the bottom of glacial Lake Scuppernong several thousand years ago.

The discovery of multiple groundwater discharge points between SS3 and SS5 was a third point of interest. These points are located on both sides of the ditch, with water being discharged from the Shropshire property as well as from the property to the north containing three wetland scrapes. Reddish brown water and soil at these discharge points indicates the presence of redoxomorphic activity, which is a defining characteristic of wetland soils (Mitsch and Gosselink, 2007). The WRM cohort also made an interesting discovery at SS5. A soil probe into the bed of the ditch produced a thick layer of relatively non-decomposed woody material. Professor Carpenter suggested that this was a remnant of a former Tamarack swamp.

Overall, the wetland walk with Professor Carpenter was very useful. He helped to identify many important features of the site that had not been explicitly determined at that point. He also advised that potential for a wetland restoration exists given the characteristics suggesting the presence of a former wetland.

Figure F.1 Groundwater Discharge (top) and Redoxomorphic Soils (bottom) Between SS3 and SS5. Identified by UW Madison Wetlands Ecology Professor, Quentin Carpenter, during a wetland walk. Both of these features are typical of wetlands. Photo credit: Steve Neary, 5.17.12

Jeff Nania and Peter Ziegler

On July 20, 2012, the WRM cohort met with wetland restoration experts Jeff Nania and Peter Ziegler to discuss the potential for restoration activities in the Miljala Channel watershed. The day began with the visiting professionals asking questions of the students to gain some insight into local soil and hydrologic conditions. Next, a site visit was conducted, beginning with the culvert at Cedar Lane (SS1) and moving upstream along the drainage ditch toward MW1. Along the way, soil conditions, drainage, and plant assemblages that might denote wetland conditions were identified.

Some of the key findings from the investigation included silty-clay mineral soil at one foot of depth in the north-central area of Korth Park. This soil contained redoxomorphic features, also known as mottling. The mottling indicates that soil is saturated for a good portion of the year and is often used as an informal field method of determining hydric soils and wetland boundaries. Also of note was the presence of a steady flow of water in the ditch, despite extreme drought conditions. This, coupled with a water temperature of ten degrees Celsius, indicates the strong influence of groundwater in the system.

In addition, WRM students searched for signs of overbank sediment transport, which would be the result of flooding that has exceeded the banks of the ditch and created drift lines on outlying areas. A cursory search revealed no such features, suggesting that the muck soil is capable of storing large volumes of water.

These observations led to Mr. Nania's suggestion that a wetland restoration project is likely to be successful if properly implemented. Mr. Nania and Mr. Ziegler agreed with the WRM group's optimism and cited hydric soils, wetland vegetation, groundwater contribution, and lack of overbank flooding as supporting evidence. They furthermore suggested that significant grant funding might be attainable to conduct a restoration project. Given that Mr. Nania has considerable grant application review experience, this gave the group reason for optimism.

Jim Welsh

Project members met with Natural Heritage Land Trust Executive Director Jim Welsh on September 9, 2012 to discuss opportunities for land acquisition, funding, and group collaboration for a Miljala Channel restoration project. Welsh noted that Korth Park had already been slated for expansion and conservation enhancements as part of the Glacial Heritage Area (GHA). The GHA is a united network of parks, cultural and historical sites, and wildlife and nature areas, located primarily in Jefferson and neighboring counties of southeast Wisconsin. The GHA is headed by a collaboration of governmental and non-governmental agencies. Furthermore, Mr. Welch suggests that any future conservation development plans on the Miljala Channel watershed should be communicated to the Jefferson County Parks Department early on.

The GHA master plan states, "[t]he Jefferson County Parks Department will take the lead on expanding the park, both to be able to provide a broader range of recreation activities and experiences as well as to

Figure F.2 Wetland Walk With Jeff Nania (center, back turned) and Peter Ziegler (not pictured). Chatting with a local landowner about the history of the area. Photo credit: Steve Neary, 7.20.12

adjoin the Glacial Drumlin Trail and the Lake Mills Wildlife Area" (GHA, 2011). Currently, 90 acres are owned by Jefferson County Parks, and the GHA's projected area for the park is 285 acres. Welsh suggested the RLIA should develop a mitigation plan for the watershed that includes the GHA and also use relationships with sponsor groups that have proven track records of successful project management and execution. Developing partnerships with other organizations will improve the integrity of grant applications for watershed improvement projects and land acquisition. Welsh expressed that he would be happy to offer support and answer any questions for RLIA as the project moves forward.

Appendix G: Ecosystem Model

Overview

During pre-settlement times, wetlands covered about 10 million acres of Wisconsin's total land area as non-continuous sections of land situated at or below the water table (DNR, 2003). These wetlands were located throughout the state, both in glaciated and non-glaciated regions. One common wetland ecosystem type is the Shallow Emergent Marsh (SEM). The SEM community is typically found on lowland sites that are poorly-drained and contain nutrient-rich, partially decomposed organic soils. These sites feature year-round standing water and can have both surface water and groundwater inputs while receiving a moderate amount of rainfall each year. SEMs are found among depressions in glaciated terrain, in places like lake beds, outwash plains, ground moraines, and end moraines (USDA, 2011). These wetlands were formed when decaying organic matter became saturated and began to accumulate over glacially deposited, impermeable layers of silt and clay. Due to the rich nature of these soils, much of the pre-settlement land supporting SEM was cleared for agricultural purposes (Mitsch and Gosselink 2007).

Community Structure, Species Abundance and Distribution

Due to the submerged nature of the SEM, species richness is low when compared to other plant community types in Wisconsin. Generally speaking, the most abundant species are sedges, rushes, reeds, cattails and other grass-like emergent plants (Curtis, 1959). As for species with less frequent occurrence, the relative abundance will most likely be site dependent (Tables G.1 and G.2). For a full list of typical species found in Wisconsin marsh ecosystems, consult Table G.3. Site factors influencing abundance and distribution are mostly related to site hydrology and geologic landscape setting.

The first main factor influencing species abundance and distribution is water input. SEMs are either fed by precipitation, groundwater, surface water, or a combination of the two. Precipitation-dependent marsh systems are nutrient poor and thus will contain fewer species that require an abundance of dissolved nutrients. Groundwater fed marsh systems have high levels of nutrients, which are contributed by slowly dissolving bedrock. In southern Wisconsin, groundwater is typically basic due to calcium released from limestone bedrock. Zimmerman (1953) created a gradient of emergent aquatic plant species based on several ranges of soluble calcium carbonate concentrations (Table G.4). Different species had optimum ranges in soft, medium hard, and very hard water. Surface water fed marsh systems are the most nutrient rich due to suspended sediment and nutrients contributed as a result of overland flow. Marshes located on landscapes with adjacent agricultural activity are prone to nutrient saturation due to runoff from fertilizer application and animal waste. These systems are frequently dominated by aggressive colonizers like cattails, reed canary grass and giant reed grass (Mitsch and Gosselink, 2007).

The second factor affecting species abundance and distribution is water depth, which closely correlates with the type of water input for a given site. Precipitation dependent marshes will have the greatest fluctuation in stage height due to the irregular nature of rain events. These sites will contain an abundance of species that can tolerate frequent wetting and drying and fewer species that require constant inundation. Groundwater fed marshes will have the most static stage height due to a perpetual source of water throughout the year. Species requiring year-round inundation are generally abundant in these systems. Surface water fed marshes fall in the middle of the stage fluctuation gradient. These systems generally have a peak stage after spring snowmelt that slowly decreases throughout the summer (Mitsch and Gosselink, 2007). In wet years these marshes can have water depth exceeding two feet, resulting in an abundance of species that float on the surface or have floating leaves.

Table G.1 Prevalent Species of Emergent Marsh Ecosystems in Wisconsin. Source: Vegetation of Wisconsin (Curtis, 1959).

Prevalent species of emergent aquatic communities

Species	*Pres.*	*Species*	*Pres.*
Eleocharis acicularis*	38%	S. americanus*	42%
Iris shrevei	29	S. validus*	49
Phragmites communis*	38	Sparganium eurycarpum*	51
Pontederia cordata*	51	Typha latifolia*	71
Sagittaria latifolia*	62	Zizania aquatica*	53
Scirpus acutus*	73		

* Species are also modal, since their presence values are higher here than in any other Wisconsin community.

Additional modal species, with their presence (%) values: Alisma plantago-aquatica (11), Carex aquatilis (9), Carex trichocarpa (2), Cyperus strigosus (2), Decodon verticillatus (11), Echinochloa walteri (7), Eleocharis calva (4), Eleocharis palustris (18), Glyceria borealis (2), Juncus torreyi (11), Lemna minor (67), Lemna trisulca (22), Ludwigia palustris (2), Ranunculus flabellaris (2), Ranunculus reptans (2), Sagittaria rigida (29), Scirpus fluviatilis (31), Scirpus heterochaetus (16), Sparganium americanum (2), Spirodela polyrhiza (9), Typha angustifolia (29), Utricularia vulgaris (22), Veronica anagallis-aquatica (2).

No. of stands 45.
Species density 11.
Total no. of species 80.
Index of Homogeneity 49.2%.
No. of modal species 33.
No. of prevalent modal species as % of total prevalents 90.8%.

Table G.2 Average Structure of Cattail Marsh Ecosystems in Southern Wisconsin. Source: Vegetation of Wisconsin (Curtis, 1959).

Average structure of southern cattail marshes

Species	*Frequency*	*Density per sq. m.*	*Species*	*Frequency*	*Density per sq. m.*
Lemna minor	100%	210.0	Typha latifolia	20	0.3
Typha angustifolia	95	27.7	Apocynum cannabinum	17	0.5
Utricularia vulgaris	93	130.2	Calamagrostis canadensis	17	3.1
Equisetum fluviatile	65	3.6	Carex hystericina	17	4.5
Eleocharis elliptica	53	70.9	Leersia oryzoides	17	2.0
Cicuta bulbifera	45	10.2	Salix interior	15	0.8
Scirpus americanus	40	33.1	Galium trifidum	13	1.7
Carex aquatilis	32	10.6	Carex stricta	13	5.5
Sagittaria latifolia	32	10.3	Rumex orbiculatus	11	0.2
Carex trichocarpa	23	7.9	Scirpus acutus	7	1.9
Lycopus uniflorus	23	5.8	Phragmites communis	7	3.1
Carex lanuginosa	20	1.1	plus six other species		

Table G.3 Full List of Plant Species Found in Emergent Marsh Ecosystems of Wisconsin. Source: Wisconsin DNR.

Latin Name	Common Name
Armoracia lacustris	Lake-cress
Alisma plantago-aquatica	Common Water-plantain
Apocynum cannabinum	Indian Hemp
Calamagrostis canadensis	Bluejoint Grass
Caltha natans	Floating Marsh-marigold
Carex aquatilis	Water Sedge
Carex hystericina	Bottlebrush Sedge
Carex languinosa	Wooly Sedge
Carex lenticularis	Shore Sedge
Carex stricta	Tussock Sedge
Carex trichocarpa	Hairy-fruit Sedge
Catabrosa aquatica	Brook Grass
Cicuta bulbifera	Bulb-bearing Water-hemlock
Cyperus strigosus	Straw-colored Flatsedge
Decodon verticillatus	Swamp Loosestrife
Didiplis diandra	Water-purslane
Echinochloa walteri	Water-millet
Echinodorus rostratus	Erect Burhead
Elatine triandra	Longstem Water-wort
Eleocharis acicularis	Needle Spike-rush
Eleocharis elliptica	Elliptic Spike-rush
Eleocharis equisetoides	Horsetail Spike-rush
Eleocharis erythropoda	Bald Spike-rush
Eleocharis flavescens	Capitate Spike-rush
Eleocharis palustris	Marsh Spike-rush

Latin Name	Common Name
Eleocharis quadrangulata	Square-stem Spike-rush
Eleocharis robbinsii	Robbins' Spike-rush
Epilobium strictum	Downy Willow-herb
Equisetum fluviatile	Water Horsetail
Galium palustre	Marsh Bedstraw
Galium trifidum	Three-petal Bedstraw
Glyceria borealis	Northern Mannagrass
Iris virginica v. shrevei	Blue Flag Iris
Juncus torreyi	Torrey's Rush
Leersia oryzoides	Rice Cut-grass
Lemna minor	Common Duckweed
Lemna trisulca	Star Duckweed
Ludwigia palustris	Marsh Purslane
Lycopus uniflorus	Northern Bugleweed
Myosotis laxa	Small Forget-me-not
Nuphar advena	Yellow Water Lily
Phragmites communis	Giant Reed Grass
Pontederia cordata	Pickerelweed
Ranunculus cymbalaria	Seaside Crowfoot
Ranunculus flabellaris	Yellow Water Crowfoot
Ranunculus gmelinii	Small Yellow Water Crowfoot
Ranunculus reptans	Creeping Spearwort
Rumex orbiculatus	Great Water Dock
Salix interior	Sandbar Willow
Sagittaria calycina	Long-lobe Arrowhead

Latin Name	Common Name
Saggitaria latifolia	Broadleaf Arrowhead
Saggitaria rigida	Sessile-fruited Arrowhead
Scirpus acutus	Hard-stem Bulrush
Scirpus americanus	Three-square Bulrush
Scirpus cyperinus	Wool Grass
Scirpus fluviatilis	River Bulrush
Scirpus heterochaetus	Slender Bulrush
Scirpus pallidus	Pale Bulrush
Scirpus torreyi	Torrey's Bulrush
Scirpus validus	Soft-stem Bulrush
Sparganium americanum	American Bur-reed
Sparganium eurycarpum	Common Bur-reed
Spirodela polyrhiza	Giant Duckweed
Typha angustifolia	Narrow-leaved Cattail
Typha x glauca	Hybrid Cattail
Typha latifolia	Broad-leaved Cattail
Utricularia vulgaris	Common Bladderwort
Veronica anagallis-aquatica	Water Speedwell
Zizania aquatic	Wild Rice

Table G.4 Hardness Preference Ranges for Common Emergent Species in Wisconsin. Source: Vegetation of Wisconsin (Curtis, 1959)

Emergent aquatics by water hardness classes

	% presence in		
	50 p.p.m. or less ($CaCO_3$)	50–150 p.p.m. ($CaCO_3$)	150 p.p.m. or more ($CaCO_3$)
Species with optimum in soft water			
Glyceria canadensis	8	6	0
Sagittaria latifolia	83	62	53
Scirpus cyperinus	17	6	0
Spartina pectinata	25	12	0
Species with optimum in medium hard water			
Scirpus validus	33	65	54
Sagittaria rigida	8	53	23
Eleocharis acicularis	42	47	31
Species with optimum in very hard water			
Iris virginica	17	24	39
Leersia oryzoides	8	18	39
Scirpus acutus	42	82	100
S. americanus	25	47	54
S. fluviatilis	8	35	54
Species with no pronounced optimum			
Eleocharis palustris	17	18	15
Pontederia cordata	58	59	46
Typha latifolia	67	71	77
Zizania aquatica	58	65	62
Phragmites communis	42	35	54

The spatial distribution of a given emergent species is generally random, although there are likely to be some patterns evident. Species capable of tolerating fluctuating water levels, such as sedges, are more likely to be found on fringe areas, while species that require constant inundation will be found in deeper spots within a marsh (Curtis, 1959). During intense precipitation events, sedimentation can occur that may create open pockets of exposed soil. These sites create a favorable environment for early colonizers like reed canary grass and smartweed (Figure G.1).

Another factor affecting the spatial distribution and structure of a SEM community is the method by which most of the plant species reproduce. Most of these plant species contain large underground functional structures used to anchor into water-logged soil. A second function of these structures is vegetative propagation. In this form of reproduction, the plants spread via underground stems, called rhizomes, that can move through the soil and send out new shoots as they move across the landscape. As a result, these species tend to grow in large clonal clumps that are all derived from a single plant. Vegetative propagation is very common and results in a high density per unit area within a species colony (Curtis, 1959).

While plant species tend to reproduce vegetatively once established in a marsh, they are also capable of reproducing via seed dispersal. Species like cattails can produce hundreds of seeds that are wind or animal disseminated. Over time, ungerminated seeds accumulate in the soil and create what is known as a seed bank. Wetland soils, also known as hydric soils, will very often have a natural seed bank containing seeds from many different wetland plants. When soil becomes exposed through erosion or other processes, favorable conditions will cause exposed seeds to germinate. This can be useful when attempting to restore or amend the vegetative community in a shallow marsh ecosystem (Galatowitsch and van der Valk, 1995).

Figure G.1 Early Colonizing Plants Are Able To Quickly Gain a Foothold in Deposited Sediment After a Storm Event.

Wildlife Community

The shallow emergent marshes of Wisconsin are considered one of the most valuable habitats for a number of avian species. They serve as a breeding and feeding ground for a large number of waterfowl species in North America. They also serve as a temporary stopping point for migratory birds on their annual migrations (Mitsch and Gosselink, 2007). Different bird species prefer specific parts of a marsh for various reasons, and thus marshes that contain a variety of plant species and habitats, or nesting substrates (open water, edge, emergent), will have the greatest avian species richness (Galatowitsch and van der Valk, 1994). SEM communities also provide valuable habitat for a number of other species including reptiles and amphibians (Figure G.2).

Ecological Processes

Disturbances

The disturbance regime in this community ecosystem type is one that occurs naturally but is also accelerated by humans in many cases. SEM communities in Wisconsin typically developed when glaciation created low, flat areas in the landscape that began to collect water from both above and below-ground sources. As water flowed in, these areas began to collect sediment that allowed for vegetation growth. Thus, the SEM ecosystem is a transitional community on the wetland succession gradient. Emergent vegetation slows down flow velocity and causes suspended particles to drop from the water column. Over the course of time, enough sediment can accumulate such that the water level in the marsh is no longer deep enough to support emergent aquatic vegetation. At this point, the marsh has transitioned into a wet prairie or sedge meadow (Curtis, 1959).

Humans can increase the frequency and intensity of disturbances in several ways. Because of Wisconsin's rich agricultural industry, many wetlands are located within proximity to some type of agricultural activity. Bare fields cleared for agriculture can contribute significant amounts of suspended sediment during

Figure G.2 A Pair of Sandhill Cranes Wandering the Fields Adjacent to SS4 (top), a Painted Turtle (top left), and an American Toad (bottom left). Photo credit: Steve Neary, 3.9.12

intense spring precipitation events. The suspended soil is often accompanied by fertilizers and pesticides that are applied to fields in order to improve crop production. As a result, sedimentation can occur more rapidly if a marsh is located proximate to these types of fields. In addition, increased nutrient input creates a favorable environment for invasive (both native and non-native) species like reed canary grass and giant reed grass that can aggressively take over a site and suppress growth of other species (Galatowitsch and van der Valk, 1994).

Another way that humans increase disturbance impact is through the creation of impervious surfaces. Rooftops, roads, driveways and sidewalks are all types of impervious surfaces. During precipitation events, these surfaces shed water at a greater rate than do naturally vegetated surfaces. This results in increased water volumes moving at higher rates through a watershed. Not only can the water carry unwanted elements such as lawn fertilizers or automobile fluids, but it can also increase soil erosion due to increased flow velocity.

Nutrient Cycling

One of the most important functions of a SEM, and wetlands in general, is nutrient cycling. Because water is present throughout the year, SEM communities have certain biogeochemical processes and pathways that dominate the system and are unique compared to upland or open water ecosystems. These processes occur within a marsh as well as between the marsh and its surrounding landscape.

One of the most important functions of a SEM is the ability to sequester and retain phosphorus (Mitsch and Gosselink, 2007). This is of particular importance in watersheds that contain agricultural activity, as manure and fertilizers can contribute phosphorus through overland flow and can lead to eutrophication of lakes and rivers (Galatowitsch and van der Valk, 1994). Soluble phosphorus has an affinity to bind with iron, calcium and magnesium; therefore, groundwater fed systems containing these elements will be more effective at sequestering phosphorus and rendering it unavailable for plant and algal growth (Mitsch and Gosselink, 2007).

Figure G.3 Canadian Geese Forge a Temporary Home at the South Edge of the Pond at SS4 (left) and Reed Canary Grass Begins to Form Around the Pond (right).

Shallow emergent marsh communities are also very important in the global nitrogen cycle. Nitrogen, like phosphorus, is a major component of runoff from agricultural fertilizers and animal waste. Excess available nitrogen can lead to eutrophication of waterways, and can also create favorable conditions for invasive species like narrow–leaf or hybrid cattails and reed canary grass. The main process occurring in a SEM is called denitrification, which is performed by bacteria in anaerobic conditions. The bacteria breakdown soluble nitrate (NO3-) and convert it into gaseous form (N2 or N20), effectively removing it from the aquatic system (Mitsch and Gosselink, 2007).

Figure G.4 Reed Canary Grass Emerges From Mats Formed by Tussock Sedge, a Native Wetland Plant, at SS4. Photo credit: Steve Neary, 3.18.12

Nutrients like phosphorus, nitrogen, and carbon can also be sequestered via wetland plant uptake. As dead plant material containing these nutrients accumulates in saturated or anaerobic conditions, decomposition occurs at a much slower rate than at upland sites. This allows for a significant amount of previously soluble nutrients to be tied up in organic materials or hydric soil. SEM communities that maintain a static stage height year round will be most effective at slowing decomposition. Lowering of the stage during summer months will expose previously inundated plant material and speed up decomposition, rendering nutrients available for plant uptake.

Species Interactions

Of all interspecies activity occurring within a SEM, the chief interaction is between the muskrat and the surrounding plant community. Muskrats can be considered the most important animal species to inhabit a SEM. They play a significant role in determining the distribution of plant species and the structure of the marsh in general. Muskrats construct large dwellings made out of mud and plant stems, usually cattails and bulrushes (Curtis, 1959). These dwellings typically emerge from the water, and serve as micro-habitat for sedges and other grass-like plants. Muskrats also consume a large amount of emergent vegetation, and in high densities are capable of creating large areas of open water that are devoid of vegetation (DeSzalay and Cassidy, 2004). In some cases, these areas are colonized by floating aquatic vegetation. The muskrat's significant influence has been thought to retard or even reverse succession in SEM communities (Curtis, 1959).

Human Use and Impact

Invasive Species

The introduction of invasive species is the most pronounced effect that humans can have on a SEM. Whether intended or not, the introduction of aggressive invasive species (native and non-native) can be devastating to the species diversity of a SEM. Plants like reed canary grass, giant reed grass, and narrow-leaved cattails are capable of tolerating a wide range of site types, but SEMs are particularly at risk due to their placement on the landscape and potential for surface runoff. Because they are located on low points in the landscape, SEMs will typically collect runoff containing suspended sediment and nutrients. Agricultural watersheds are the most vulnerable due to the presence of fertilizers and animal waste. As a result, there are plenty of nutrients and water available for plant growth, presenting a potential invader with an almost ideal situation for colonization. Intense precipitation events can cause excessive sedimentation that creates patches of deposited soil, creating an ideal habitat for a quick colonizer.

Most invasives become recognized as such because they have rapid population growth that causes a decline in the number and abundance of native species. The DNR reports that many marshes in the Southeast Glacial Plains region are becoming dominated by the invasive narrow-leaved cattail, which has the capability of altering the plant community in a marsh (2012). This happens when the invasive cattails out-compete the natives, due to their ability to produce rhizomes at a greater rate than other native species (Curtis, 1959). Thus, they are able to occupy a great amount of area in a short amount of time. In addition to extensive horizontal growth, invasives tend to have rapid vertical growth that prevents other adjacent plants from receiving full sunlight. Thick clonal stands tend to shade out the areas around them and create unfavorable growing conditions for other plants. Once these invasive species become well-established within a SEM, excessive human management is required for removal, and even then eradication is not guaranteed.

In addition to vegetative propagation, many invasive species are prolific seeders (e.g. cattails, grasses) that produce thousands of seeds per plant each year, increasing the odds of survival. These types of seeds are typically wind disseminated, which is virtually impossible to control. Seeds can accumulate in the seed bank, resulting in a return of undesirable species subsequent to eradication. One way to avoid colonization by invasives is to make sure that nearby forests, fields, and open lots are also free from these invaders. Removal of excess nutrient and sediment input is another way to prevent invasion. Buffer areas around a marsh are one way to achieve this.

Hunting

Hunting is one of the most popular outdoor activities in Wisconsin, and has deep rooted cultural significance throughout the state. Wisconsin has a waterfowl hunting season that occurs each fall (DNR, 2012). SEM communities in Wisconsin are an ideal location for waterfowl due to the abundance of food and habitat for nesting. In order to maintain a healthy waterfowl population that can support hunting pressure, it is imperative that enough habitat and food exist to sustain such a population.

Water Quality

One of the most valuable functions of a SEM is the ability to improve water quality. As mentioned before, a SEM is able to remove and sequester nutrients and suspended sediment that can be detrimental to surface waterways and groundwater used for human consumption. High plant growth rates and a variety of decomposition pathways also allow for an accumulation of organic matter that can lead to the permanent removal of chemicals (Mitsch and Gosselink, 2007). SEM systems provide a natural method of improving water quality for a variety of human uses, including recreation, agriculture and municipal water.

Appendix H: Well Construction

A series of 9 hand-augured wells and a staff gauge at the outflow of the ditch were used to identify the relationship between the water table and the ditch. The wells were located in the Houghton Muck (muck) and underlying silty-clay layer at five locations (Figure H.1). Plans to auger wells into other sections of the watershed were abandoned when soil sampling revealed an abundance of silty-clay soils with low permeability throughout the watershed. Thus, wells were not located outside of the muck soil type.

Well locations were chosen to best illustrate the water flow system within the watershed. Within the unconfined muck aquifer, water flows from areas with a higher to a lower water table elevation. Additionally, water table elevation will typically mimic surface elevation. Sandy substrates found in the glacial drumlins surrounding the watershed will typically transmit water more quickly than silt or clay (Figure H.1).

Well nests were used at three locations to identify vertical flow between the muck and silty-clay layers (Figure H.2). Since water flows from higher hydraulic head to lower hydraulic head, flow direction can be identified through a comparison of water elevation differences. Nested wells reveal how the muck interacts with the deeper aquifer below the silty-clay layer. If a component of the source water originated in a deeper aquifer, the well screened in the muck would have a lower water elevation than the well screened in the silty-clay layer (Hypothetical Water Table #1, Figure H.2). The inverse is a sign of water loss from the muck to the deeper aquifer (Hypothetical Water Table #3, Figure H.2). If there is no significant flow between the two aquifers, both water table elevations will be the same (Hypothetical Water Table #2, Figure H.2).

One well nest is located near the confluence of the two main channels at the headwaters of the ditch. The first well, MW1, was screened in the base of the

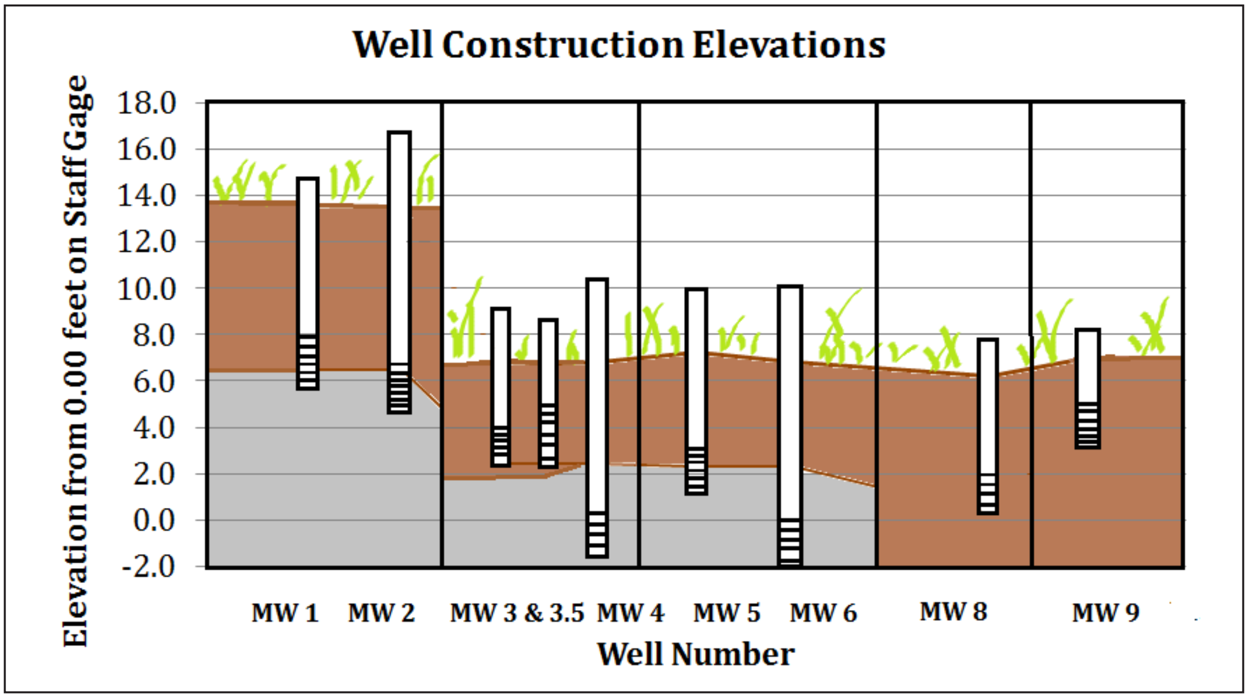


Figure H.1 Well Construction Diagram of the Wells Located in the Watershed. Grey represents the silty-clay layer and brown represents the Houghton Muck. All Elevations have been surveyed to 0.00 feet on the staff gage.

muck while MW2 was augured to the base of the silty-clay layer. These wells were placed at this location to determine water elevation within this section of the watershed and to identify potential pollutant sources from groundwater. Similar water elevations were observed at MW1 and MW2, despite being screened into different substrates. This indicates there is no flow of deep groundwater moving from the silt into the muck or flow into the deeper aquifer from the muck. These wells have the highest water elevation within the watershed by nearly five feet.

Downstream from the upper reach nest, MW8 was screened into the muck where the drain tile connected to SS4 enters the ditch. This location was chosen to monitor potential drain tile impact on water elevation changes or pollutant loading. MW8 typically had the lowest water elevation of all wells and appeared to reflect stream stage during rainfall events.

Located directly north of MW8 on the opposite side of the ditch, MW9 was also screened into the muck. Comparison of head values in these wells allowed for determination of the flow gradient into the ditch at this location. The location of MW 9 also provided

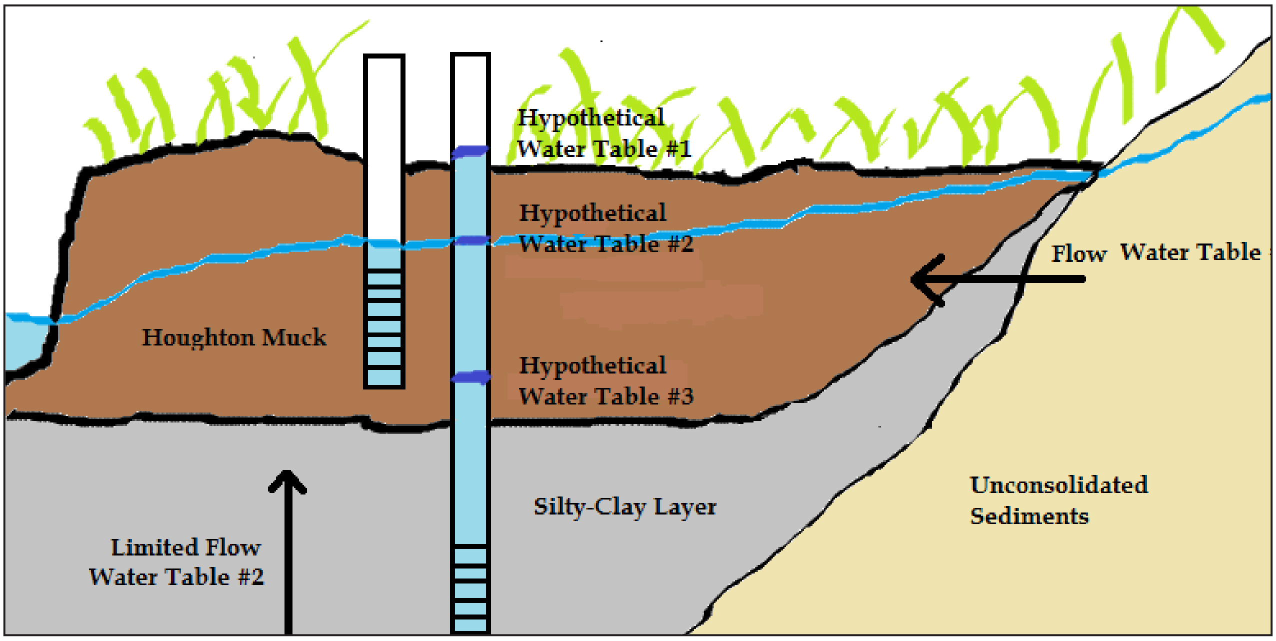


Figure H.2 Theoretical Vertical and Horizontal Contribution of Groundwater into the Ditch. Groundwater primarily flows into the watershed through horizontal flow from unconsolidated sediments where the silty-clay layer is thin or nonexistent. Vertical flow from under the muck soils is indicated by the relationship between wells within a well nest. If water levels are similar between both wells (hypothetical water table #2), there is minimal vertical flow. If water level is lower in the deeper well (hypothetical water table #3), then water flows downward out of the muck. If the inverse is true (hypothetical water table #1), water is flowing upward through the silty-clay layer into the muck. Typically, there is limited vertical flow through the bottom of the silty-clay layer.

the ability to sample groundwater input from the north side of the watershed for phosphorus and bacteria concentrations. Throughout the early portion of the study period MW9 had the second highest water elevations. In fact the water table was approximately 2 feet below the surface throughout much of this time period. Without rainfall the volume of water stored in the muck decreased and water levels dropped to below the bottom of the well.

Nested wells MW5 and MW6 were sited adjacent to a groundwater seep on the southern side of the ditch, east of MW8. This nest was installed to observe phosphorus and bacteria levels and groundwater flow entering the muck at this location. MW5 maintained water elevation consistently higher than surrounding wells throughout the drought period, demonstrating a significant, sustained groundwater source. Throughout the study period, MW5 and MW6 had a similar pattern of flow despite MW6's higher water elevation. This indicates upward flow through the silty-clay layer into the muck at this location (Figure H.3).

To examine flow further from the ditch, nested wells MW3, MW3.5, and MW4 were sited approximately 50 meters south of MW8, between two drumlins. MW3 and MW3.5 were screened in muck at two different elevations. MW 3 and MW 3.5 showed similar water elevations. MW4 was screened in the silty-clay layer to observe flow moving upward or downward through the silty-clay. The well nest consisting of MW3, MW3.5, and MW4 exhibited similar water elevations from January through June 2012. In July, the water table dropped below well screens in MW3 and MW3.5, and eventually dropped below MW4 due to a lack of recharge from groundwater inputs within this region (Figure H.4). Therefore the primary recharge mechanism within this region of the watershed is precipitation.

Water table elevation in wells located in the silty-clay layer followed similar patterns from June through May, at which point MW2 and MW6 continued to follow the same pattern while MW4 decreased in elevation until it fell below the well screen (Figure H.5). This may imply that MW4 was not augured as closely to the bottom of the silty-clay layer as were MW2 and MW6, or that it is not hydrologically connected to the same aquifer.

These data, along with regional groundwater flow maps (Boreman and Trotta, 1975), indicate that the primary baseflow source is a regional groundwater discharge from drumlins surrounding the muck soils. The assumption that groundwater inputs originate from all drumlins surrounding the muck would explain why MW9 decreased significantly and did not respond in the same fashion as MW5, as MW 9 is farther from the discharge location. The results also signify a lack of upward flow from the deeper aquifer throughout much of the watershed. Most importantly, these results demonstrate two important features. The first is the fundamental connection between precipitation and all water levels within this watershed. Second, there is a significant baseflow component to the system.

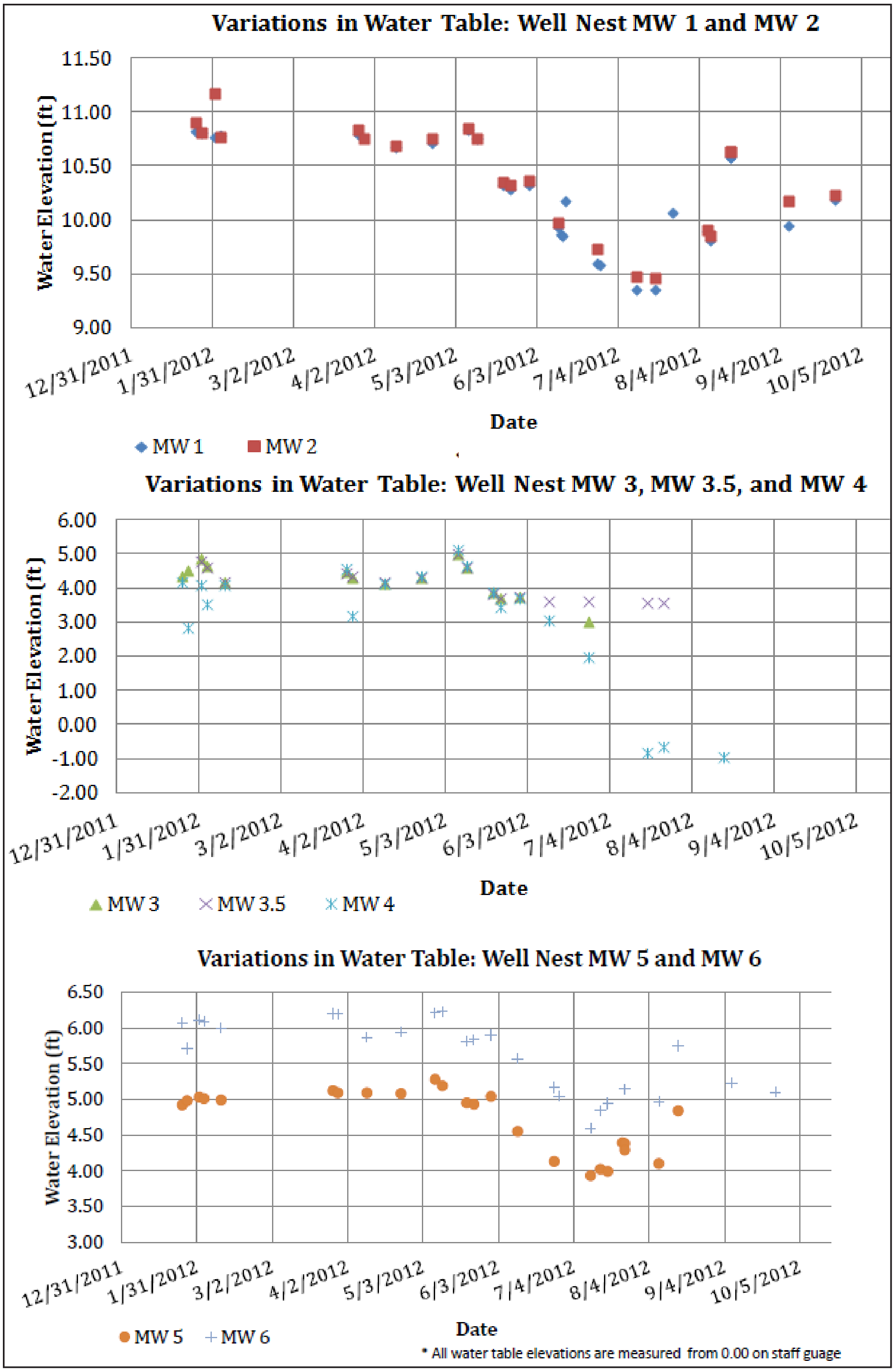


Figure H.3 Differences Between Groundwater Levels in the Three Well Nests.

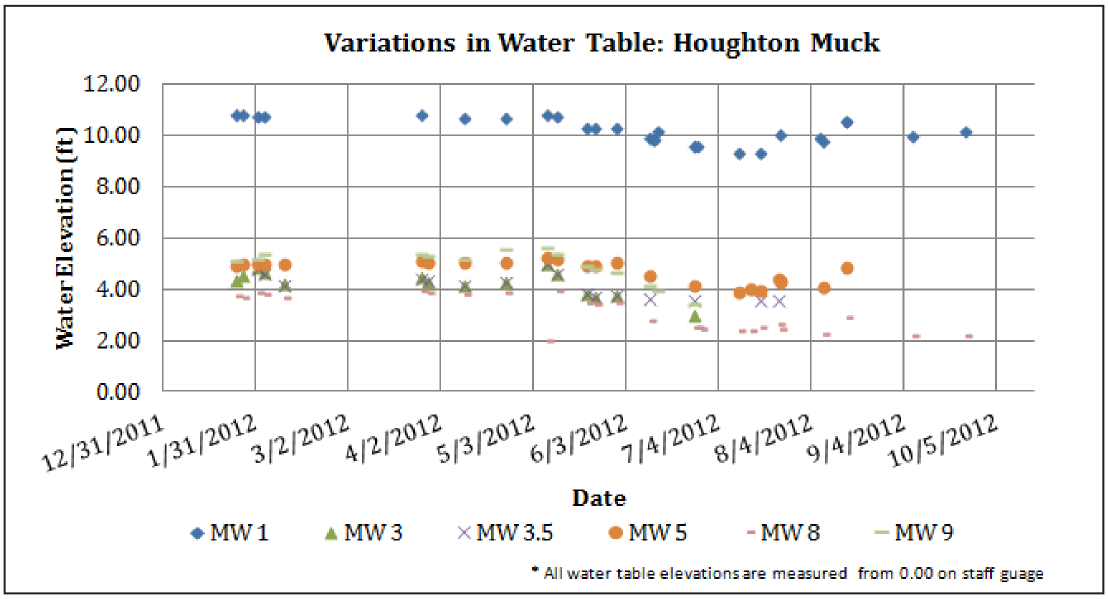


Figure H.4 Differences Between Groundwater Levels in Wells in Houghton Muck.

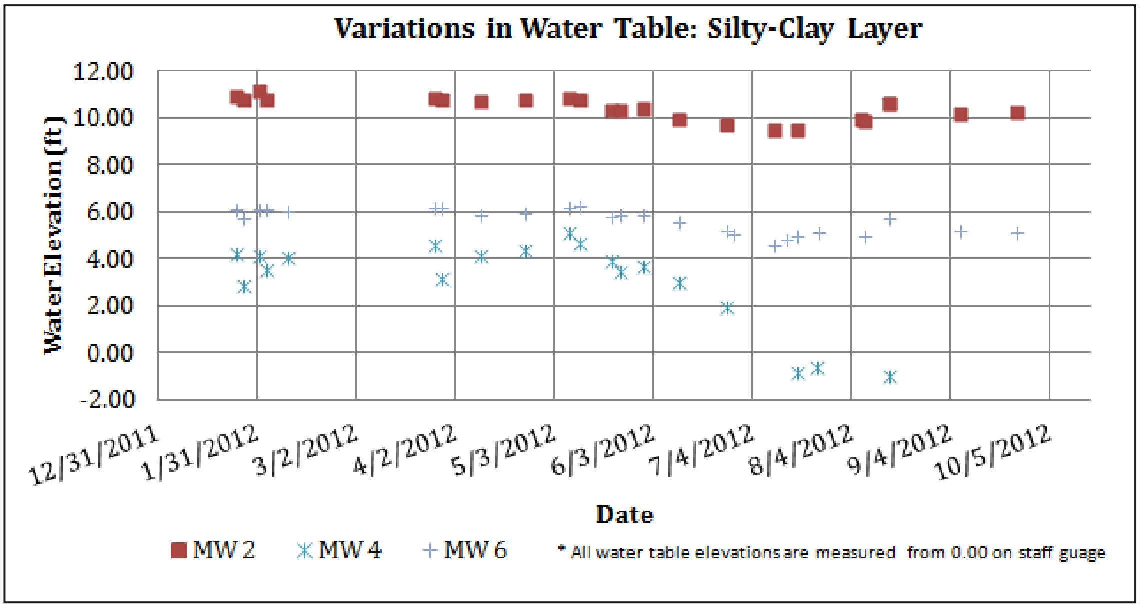


Figure H.5 Differences Between Groundwater Levels in Wells in Silty-Clay Layer.

Appendix I: Water Quality Measures

Water quality within the ditch has implications for the ecological health of the channel and the lake at large. Poor water quality within the lake has the potential to decrease shoreline property values and pose a threat to local tourism activities, including boating and fishing. Several water quality parameters were examined over the duration of the study in an attempt to pinpoint the source of pollution entering the ditch.

Water Temperature

Water temperature within a water body fluctuates on a daily and seasonal basis. Temperature plays a major role in determining the rate of aquatic chemical and biological processes, including bacterial and algal growth and metabolic rates of aquatic life. Most aquatic organisms tolerate a narrow thermal range and can be significantly impacted by storm water inputs related to increases in impervious surfaces typically seen in developing areas.

Water temperature was more variable at surface sites than within monitoring wells. Temperature generally became cooler with distance downstream due to continued groundwater input. Warmer temperatures were observed in surface water in the upper reaches of the ditch where low water levels and slow flow increased interception of solar radiation. Temperature also varied seasonally. The figures below depict monitoring results over the course of the project (Figure I.1, I.2, and I.3).

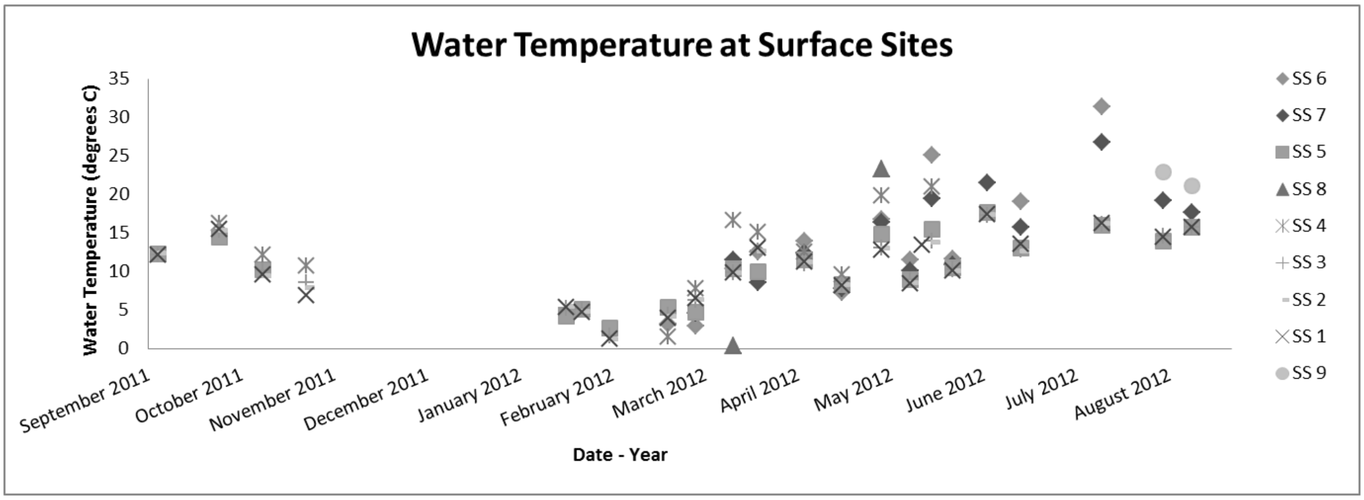


Figure I.1 Water Temperature (measured in degrees Celsius) Taken at the Surface Sites.

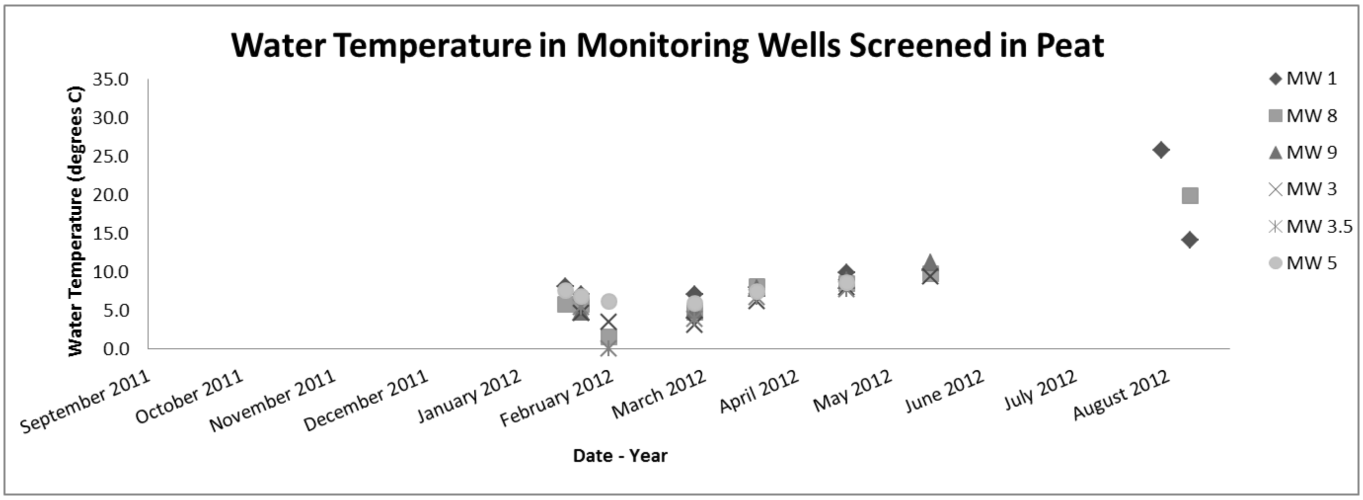


Figure I.2 Water Temperature (measured in degrees Celsius) Taken at the Monitoring Wells Screened in Peat Soils.

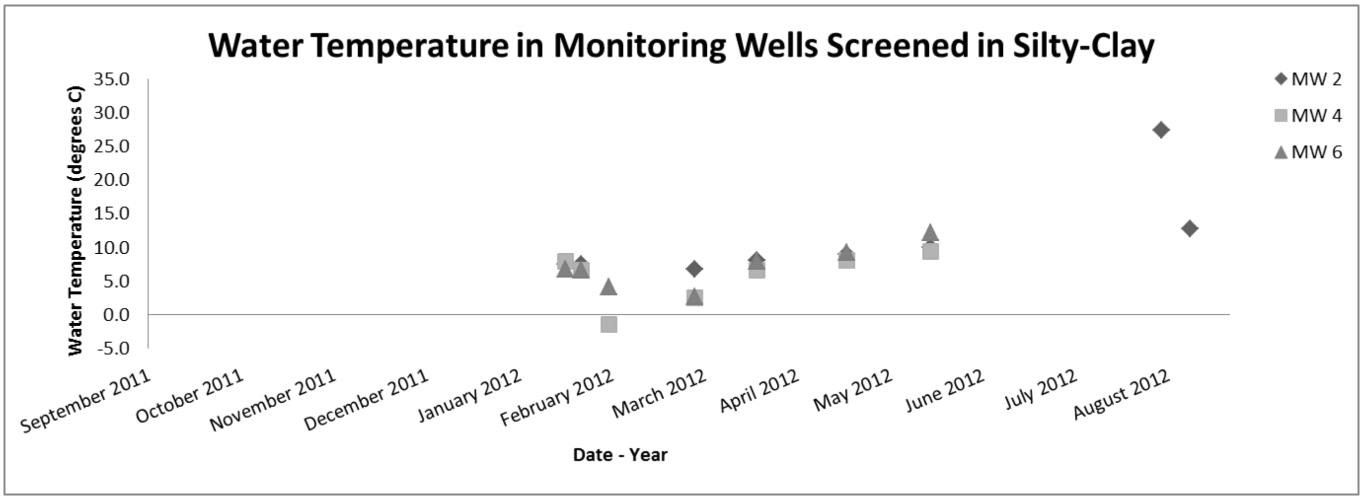


Figure I.3 Water Temperature (measured in degrees Celsius) Taken at the Monitoring Wells Screened in Silty-Clay Soils.

Dissolved Oxygen (D.O.)

Dissolved oxygen fluctuates on both a seasonal and diurnal, or 24-hour, cycle depending on the biological activity taking place within the water body. Many aquatic organisms are limited by oxygen levels within their respective habitats. For example, most fish species cannot tolerate oxygen levels less than 3.0 mg/L and, in Wisconsin, trout streams are classified as having 8-12 mg/L of oxygen available. It should also be noted that dissolved oxygen varies with water temperature. Colder water can hold more oxygen, thereby enhancing habitat for cold water fish species and the macroinvertebrates that they feed on.

Higher dissolved oxygen concentrations were observed at surface sites than within monitoring wells. This is due to the fact that the surface sites are subject to atmospheric exposure, which allows for the mixing of atmospheric oxygen at the air-water boundary. Sampling sites within the upper reaches of the watershed exhibited lower values of dissolved oxygen than sites in the lower portion of the watershed. One potential explanation for this trend is microbial reduction of oxygen within the soils. The trend could also be attributed to groundwater inputs low in dissolved oxygen. The figures below depict monitoring results over the course of the project. (Figures I.4, I.5, and I.6)

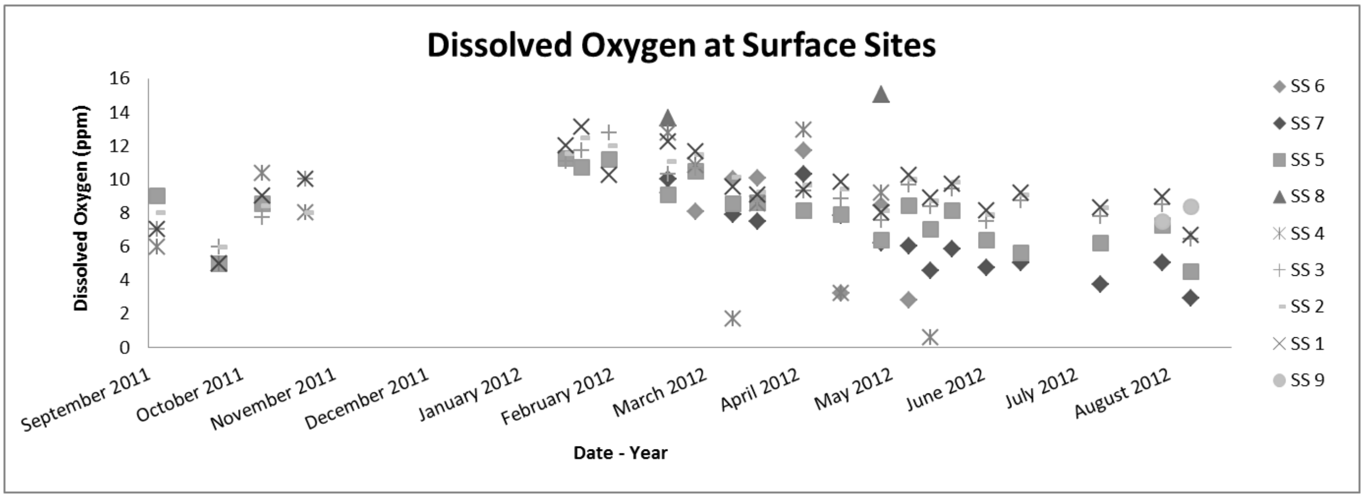


Figure I.4 Dissolved Oxygen (mg/L) Measurements Taken at the Surface Sites.

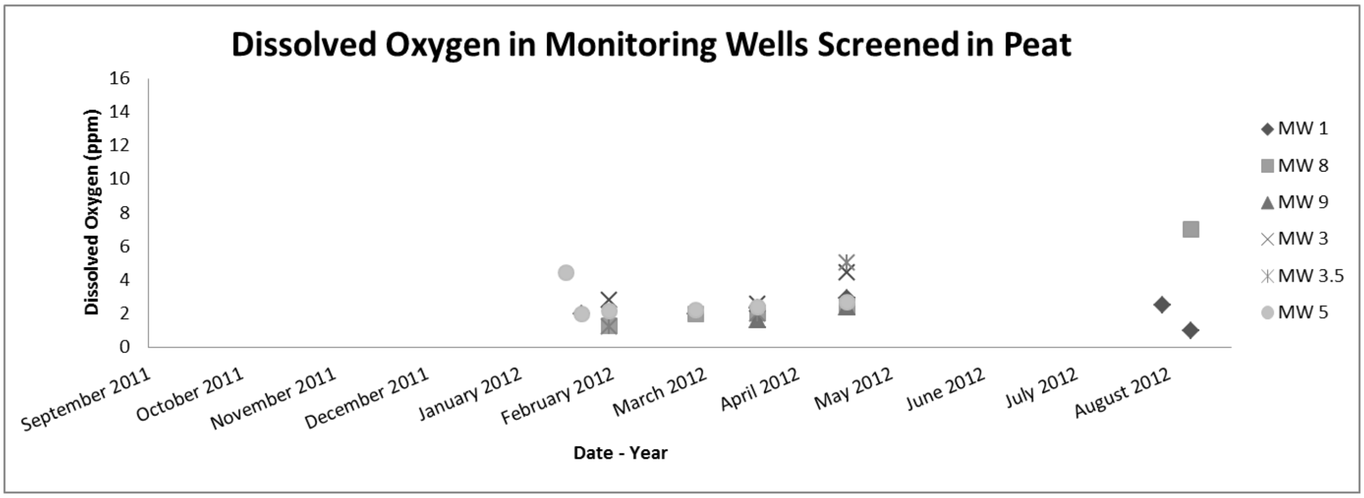


FIGURE I.5 DISSOLVED OXYGEN (MG/L) MEASUREMENTS TAKEN IN THE WELLS SCREENED IN PEAT SOILS.

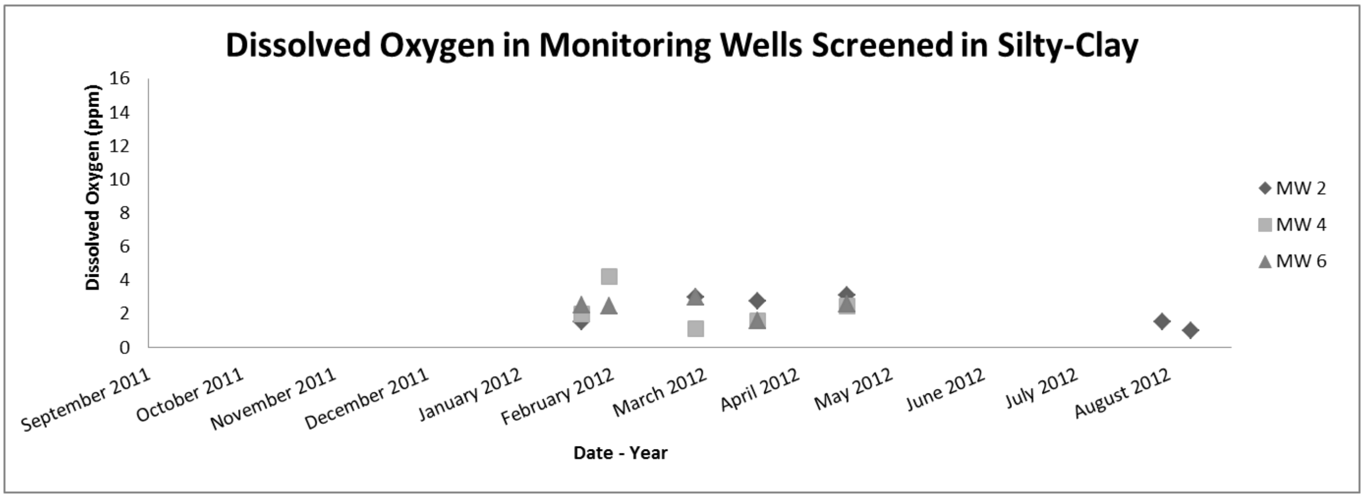


FIGURE I.6 DISSOLVED OXYGEN (MG/L) MEASUREMENTS TAKEN IN THE WELLS SCREENED IN SILTY-CLAY SOILS.

Conductivity

Conductivity in natural waters is affected by the concentration of anions (chloride, phosphate, nitrate, and sulfate) and cations (sodium, magnesium, calcium, iron) within a water body. Water temperature also has an impact on conductivity, which is why measurements are usually reported as "normalized at 25 degrees Celsius." Within moving water bodies, conductivity is generally correlated with regional geology. For example, when water is exposed to soluble minerals for prolonged periods of time, specific conductance will increase. This indicates that the longer it takes for water to move from infiltrating into the aquifer to flowing out of the aquifer, the higher the amount of anions will be present in the solution. Carbonate bedrock, limestone or dolostone, is an example of relatively soluble bedrock, so exposure to gravels or bedrock composed of these minerals for extended periods of time will usually result in water with higher conductivity.

Conductivity monitoring results were obtained over the course of the project (Figures I.7, I.8, and I.9).

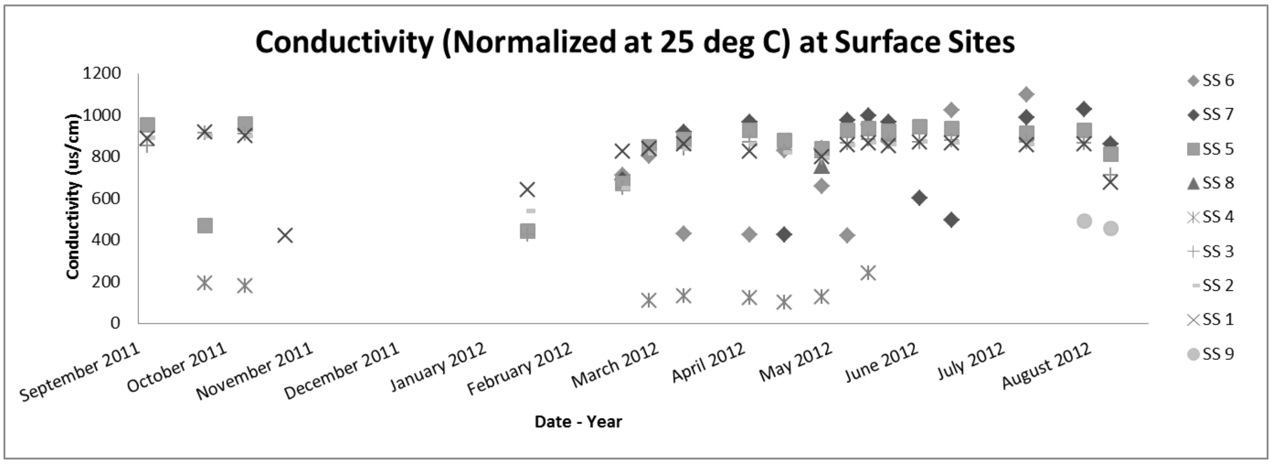


Figure I.7 Conductivity Measurements Taken at the Surface Sites.

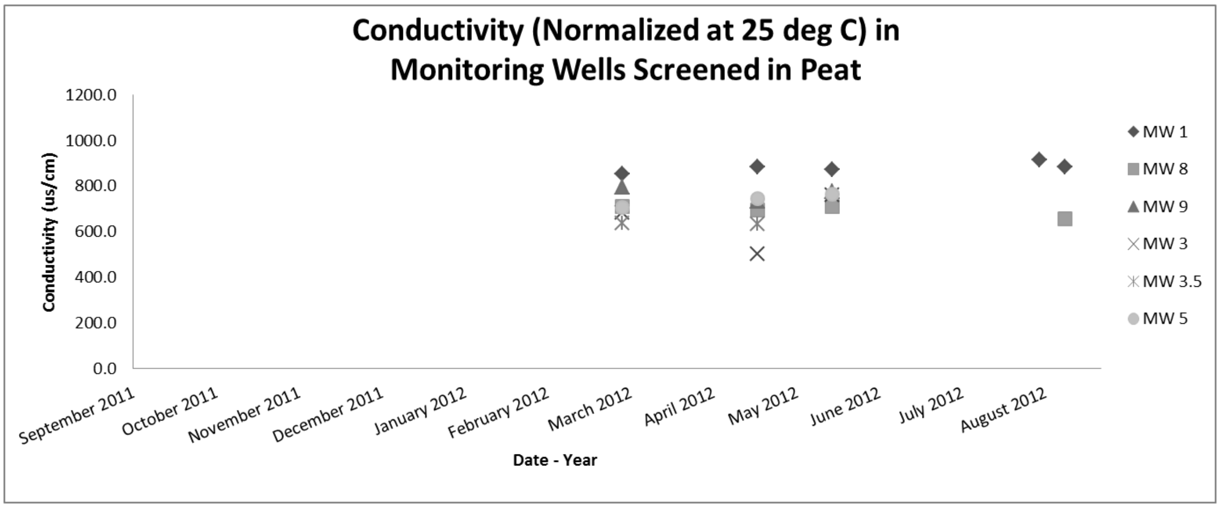


Figure I.8 Conductivity Measurements Taken in the Wells Screened in Peat Soils.

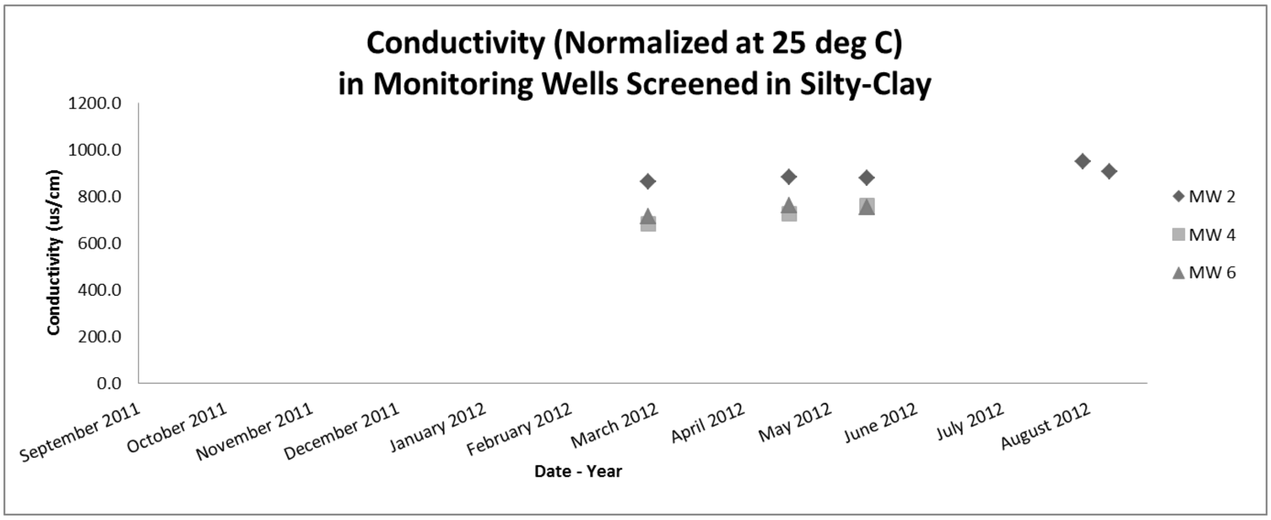


Figure I.9 Conductivity Measurements Taken in the Wells Screened in Silty-Clay Soils.

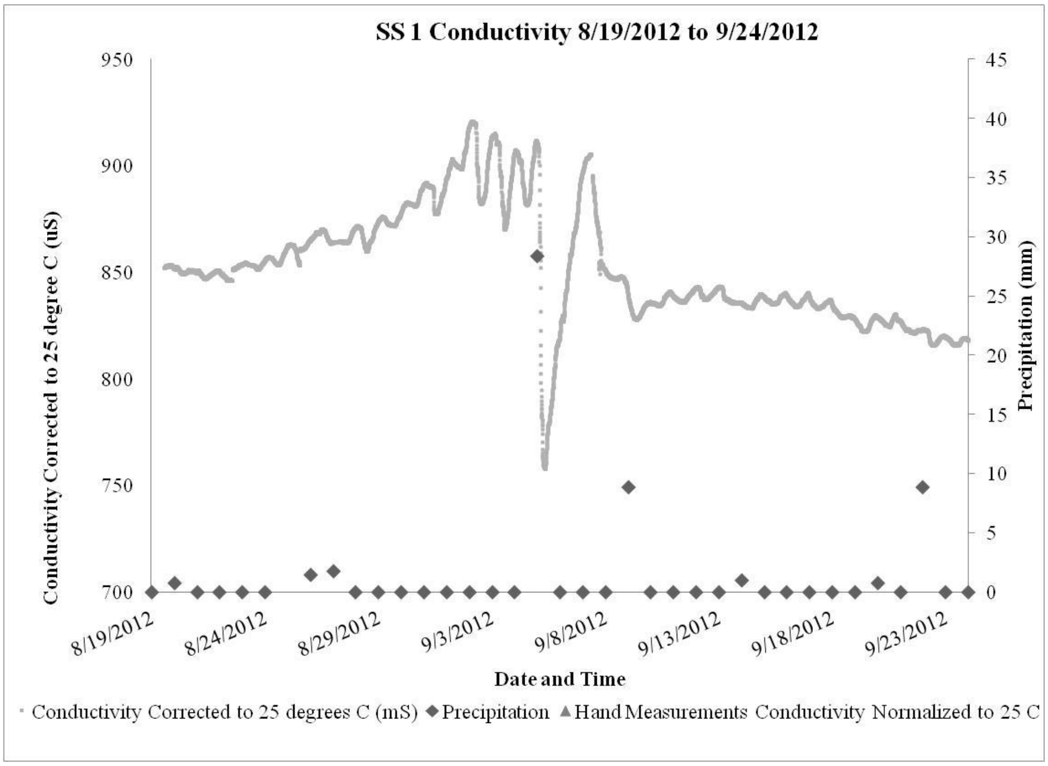


Figure I.10 Conductivity and Precipitation Data Collected Showing the Impacts of Rainfall on Conductivity Levels.

Continuous Data - Conductivity increase is typically associated with longer exposure to mineral substrates, typical of long flow paths through groundwater systems. Conductivity typically decreases during precipitation events due to limited ion concentrations in rainwater. Figure I.10 shows a quick decrease in conductivity then a slower increase back to normal levels. Normal levels of conductivity occur when ions are in equilibrium in the water, with mineral dissociation occurring until this equilibrium is reached (Figure I.10).

In the absence of precipitation, increases in conductivity followed by constant levels show groundwater inputs from deeper reservoirs (Figure I.11). Decreases during precipitation events demonstrate shallower aquifer contribution to the system. This indicates a deep groundwater contribution driving flow during dry periods. Deep groundwater contributions likely originate south of the watershed, as "yellow gravel," or dolomite gravel, is reported in well logs there. Groundwater originating north of the watershed would have lower conductivity, as well logs indicate primarily sand deposits within this region.

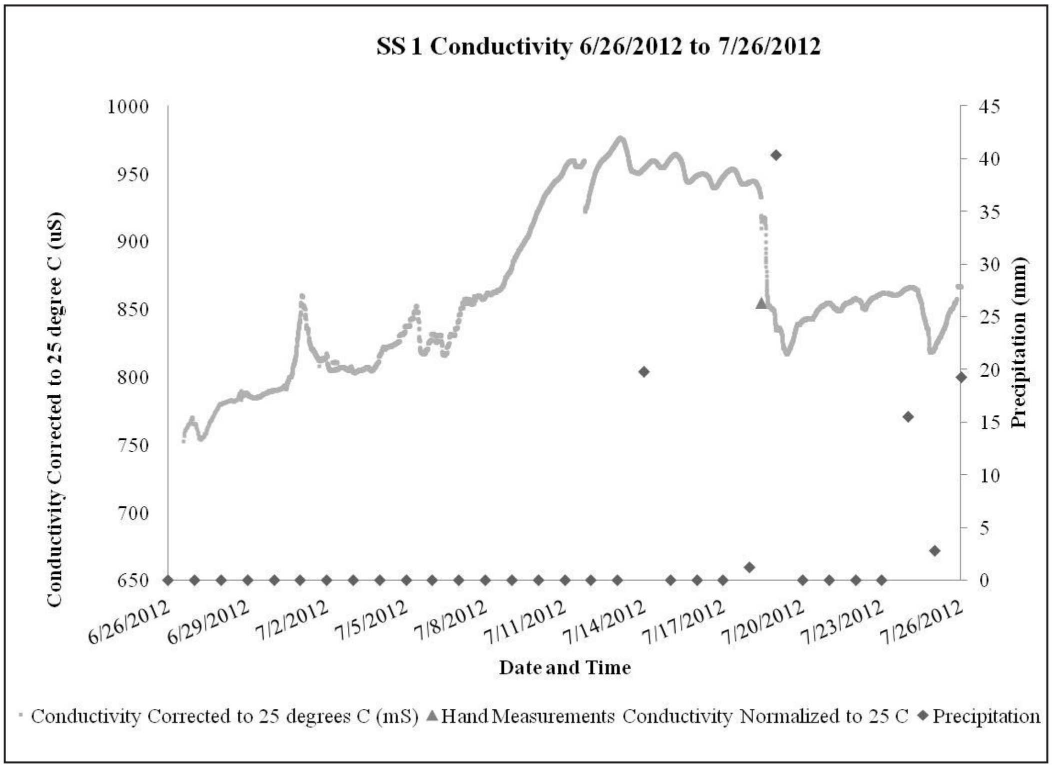


Figure I.11 Conductivity and Precipitation Data Collected Showing the Impacts on Conductivity Levels When No Precipitation Occurs.

Non continuous data - Higher conductivity levels are typical of deep groundwater input, as found at the confluence of the two upper reaches near MW1 and MW2. Groundwater elevation at this location maintained near static levels through time, despite limited rainfall throughout the summer. Deep groundwater input is also evident at MW5 and MW6, where a slight elevation in conductivity was observed. This conclusion is supported by sustained water elevations in these wells, despite decreases in MW 3, MW 3.5, MW 4, and MW 9, all of which are located at a greater distance from drumlins.

Overall, conductivity decreases were observed in both monitoring wells and at surface sites as one moves downstream in the watershed. Levels are higher at surface sites than in wells, which could be attributed to chemical reactions occurring in anaerobic environments typical of wetland areas with high organic content. Higher levels at surface sites also indicate that groundwater inflow occurs from the sides of the aquifer rather than up through the silty-clay layer. This is not conclusive, however, considering that clay can typically cause the same changes. Nested well samples indicate that proximate locations have comparable conductivity values, regardless of substrate.

pH

The typical range of pH in natural waters is 6-8. It should be noted that pH is on a logarithmic scale, therefore a decrease in pH by one increment results in a tenfold increase in acidity. pH values are affected by occurrences such as atmospheric deposition in the form of acid rain, weathering of nearby rock, and discharge from wastewater treatment facilities. A low pH value (less than 5) can allow for toxic compounds to mobilize within a water body and be available for uptake by plants and animals, potentially resulting in adverse impacts to aquatic life (including reduced biodiversity) and human health (including biomagnification of toxic compounds in game fish).

Surface sites exhibited more variability in pH than monitoring wells. The majority of wells had pH values near 7, which is typical of groundwater fed wetlands. MW1 and MW5 exhibited higher pH values than the other wells, which is likely due to their proximity to groundwater input sources. Daily and seasonal fluctuations in pH may be caused by natural variations in photosynthesis in the ditch. The process of photosynthesis uses hydrogen ions, which reduces stream hydrogen concentration and thereby slightly increases the measured pH value. The processes of decomposition and respiration have the opposite effect. Overall, measured pH values are highest during the day, especially during the growing season when photosynthesis is at its maximum. In anaerobic environments with abundant organic material, (typical wetland conditions) pH levels are controlled primarily through microbial reduction.

It should be noted that these measurements are sensitive to sampling error due to the calibration process, which must be conducted prior to use of the probe. Figures I.12, I.13, and I.14 depict monitoring results over the course of the project.

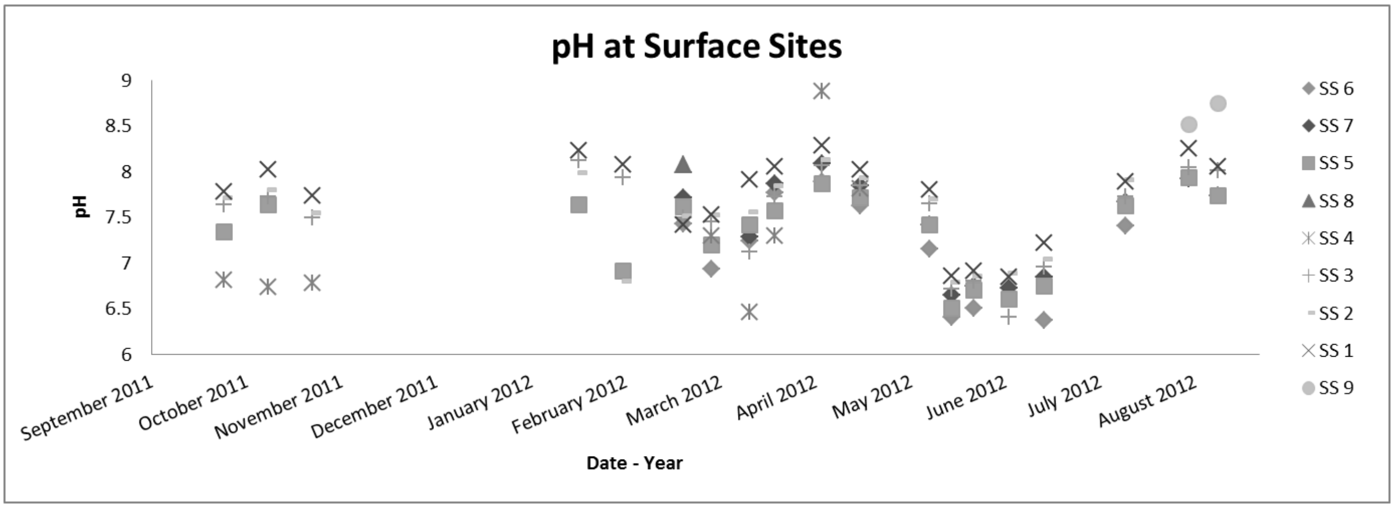


Figure I.12 pH Measurements at the Surface Sites.

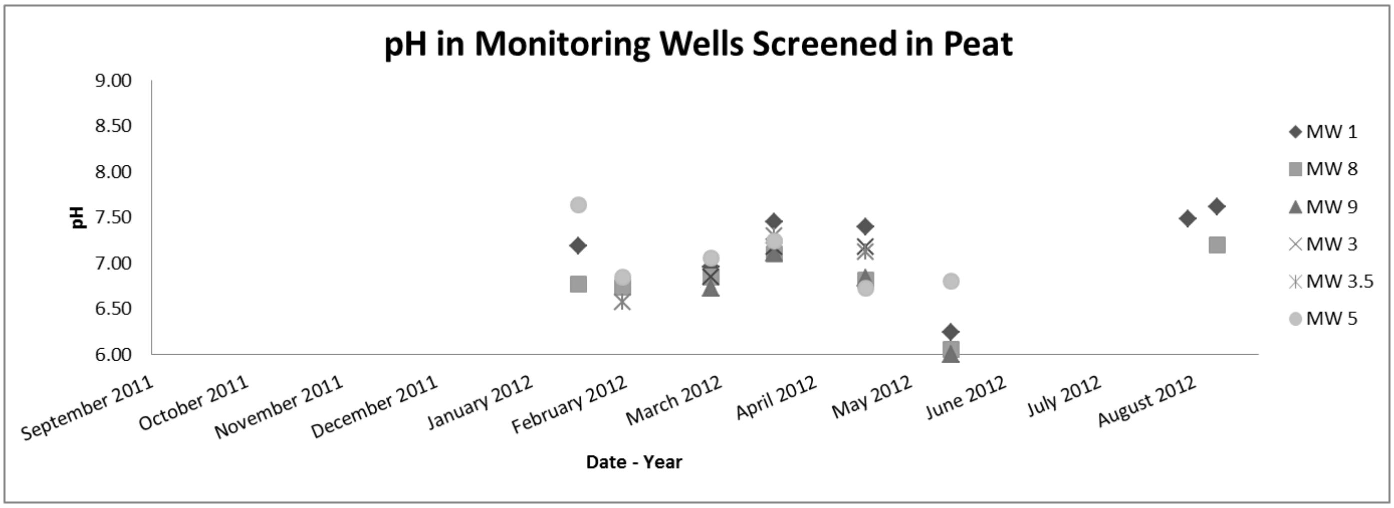


Figure I.13 pH Measurements Taken in the Wells Screened in Peat Soils.

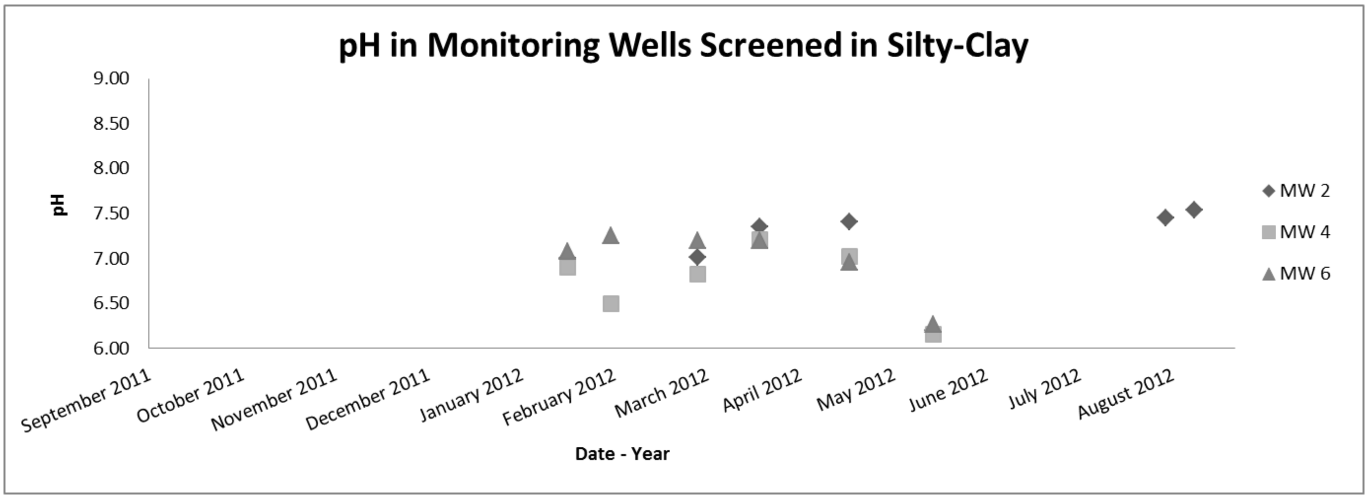


Figure I.14 pH Measurements Taken in the Wells Screened in Silty-Clay Soils.