Feasibility Study
Wetland 639W
Outlet Modifications
FINAL REPORT

Wenck File #1240-83

Prepared for:

SHINGLE CREEK
WATERSHED MANAGEMENT
COMMISSION

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

July 2011

Wenck
Engineers • Scientists

Table of Contents

<u>TABLES</u>

Table of Contents (Cont.)

FIGURES

APPENDICES

1.0 Introduction

1.1 BACKGROUND

The Shingle Creek Watershed Management Commission (SCWMC) and the cities of Brooklyn Center and Crystal have for a number of years investigated ways to improve the Twin Lake chain of lakes. Modeling of the lakes' watershed and water quality testing at outfalls into the lakes in 1999 suggested that the part of the watershed that outlets through Wetland 639W, a large wetland complex on the north side of Upper Twin Lake (Figures 1.1, 1.2) was exporting more phosphorus to the lake than would be expected for the land uses in the watershed. More detailed monitoring upstream and downstream of the wetland conducted in 2002 confirmed that the wetland was the likely source of the excess phosphorus, but the exact mechanism causing that export was not known.

A network of storm sewers and a channel known locally as Twin Creek conveys stormwater from approximately 1,010 acres of fully developed mixed use land in the cities of Crystal, Brooklyn Center, Brooklyn Park, and New Hope to Wetland 639W (Figure 1.3). In addition, approximately 324 acres of land on the Crystal Airport drains overland to the wetland, which is located on property owned by the Metropolitan Airports Commission (MAC). Drainage is conveyed by sheet flow across the main basin of the wetland, and is discharged from the basin by Twin Creek to Upper Twin Lake.

Monitoring performed by the SCWMC in Twin Creek upstream and downstream of the wetland has found that total phosphorus concentration in the water discharged from the wetland is significantly greater than the concentration at the inlet, indicating that the wetland is discharging phosphorus. The phosphorus load discharged from the wetland into Upper Twin Lake is an estimated 25-35 percent of the total load of phosphorus to Upper Twin Lake, and a Total Maximum Daily Load (TMDL) study completed for the lake concluded that this phosphorus load contributes significantly to its impairment. Because Upper Twin is connected to Middle and Lower Twin, the nutrient-rich water from Upper Twin flows directly to those lakes and contributes to their Impaired Waters status. Reducing phosphorus load exported from Wetland 639W is the highest-priority action in the EPA-approved TMDL and MPCA-approved Twin and Ryan Lakes Nutrient TMDL Implementation Plan.

In 2008 the SCWMC received a $60,000 Section 319 grant from the Minnesota Pollution Control Agency (MPCA) to conduct additional monitoring, perform a diagnostic study, and complete a feasibility report detailing options for reducing phosphorus export from the wetland. The grant was matched with $30,000 from the cities of Brooklyn Center, Brooklyn Park, Crystal, and New Hope and $30,000 from the Commission. Additional monitoring was performed in

2008, and hydrological and hydraulic modeling and feasibility analysis performed in 2009. This report details findings, presents options for mitigating the phosphorus export, and makes a recommendation regarding the most feasible and cost-effective option. A Technical Advisory Committee composed of city, MPCA, DNR, and Metropolitan Airports Commission staff met periodically throughout the course of the study, and participated in the identification of the most feasible options.

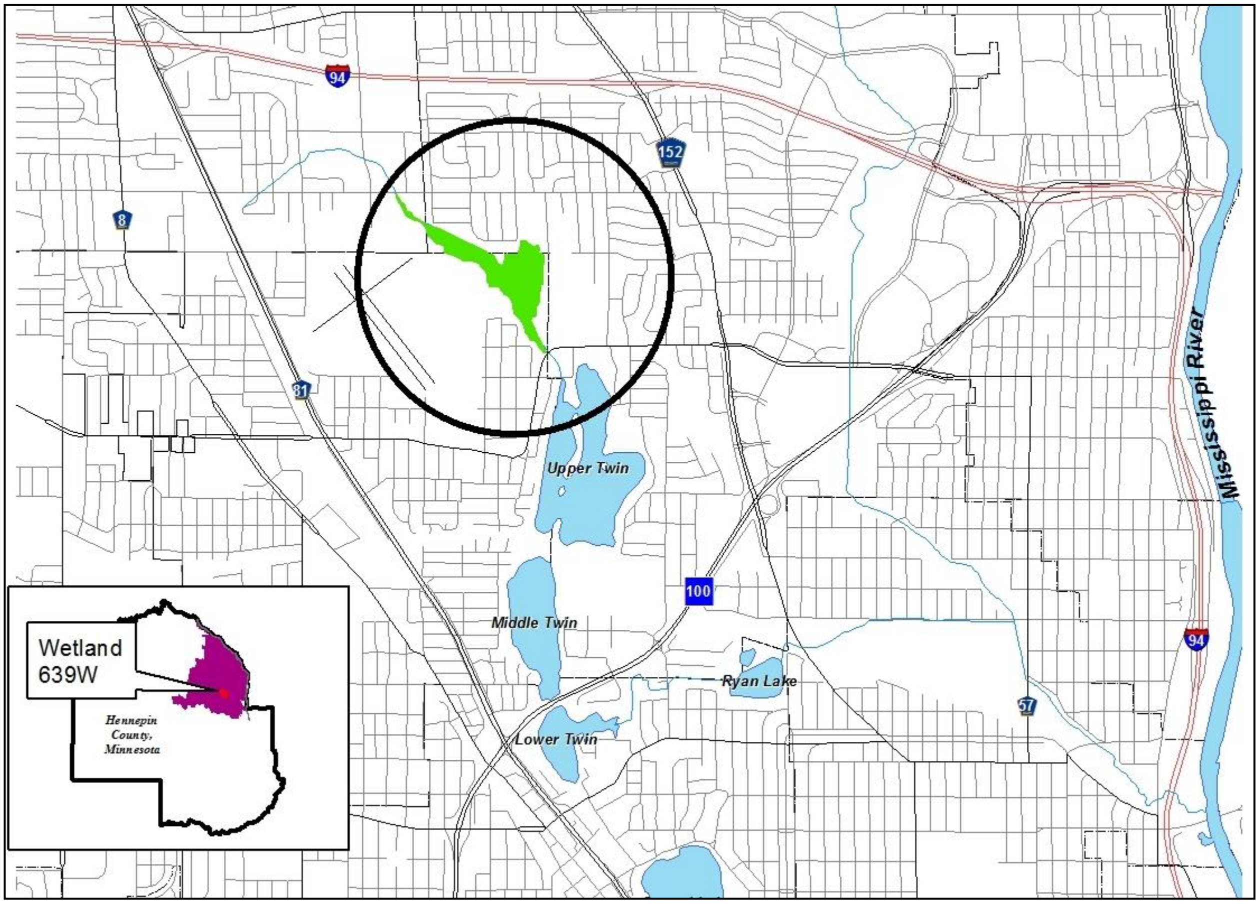


Figure 1.1. Wetland 639W location.

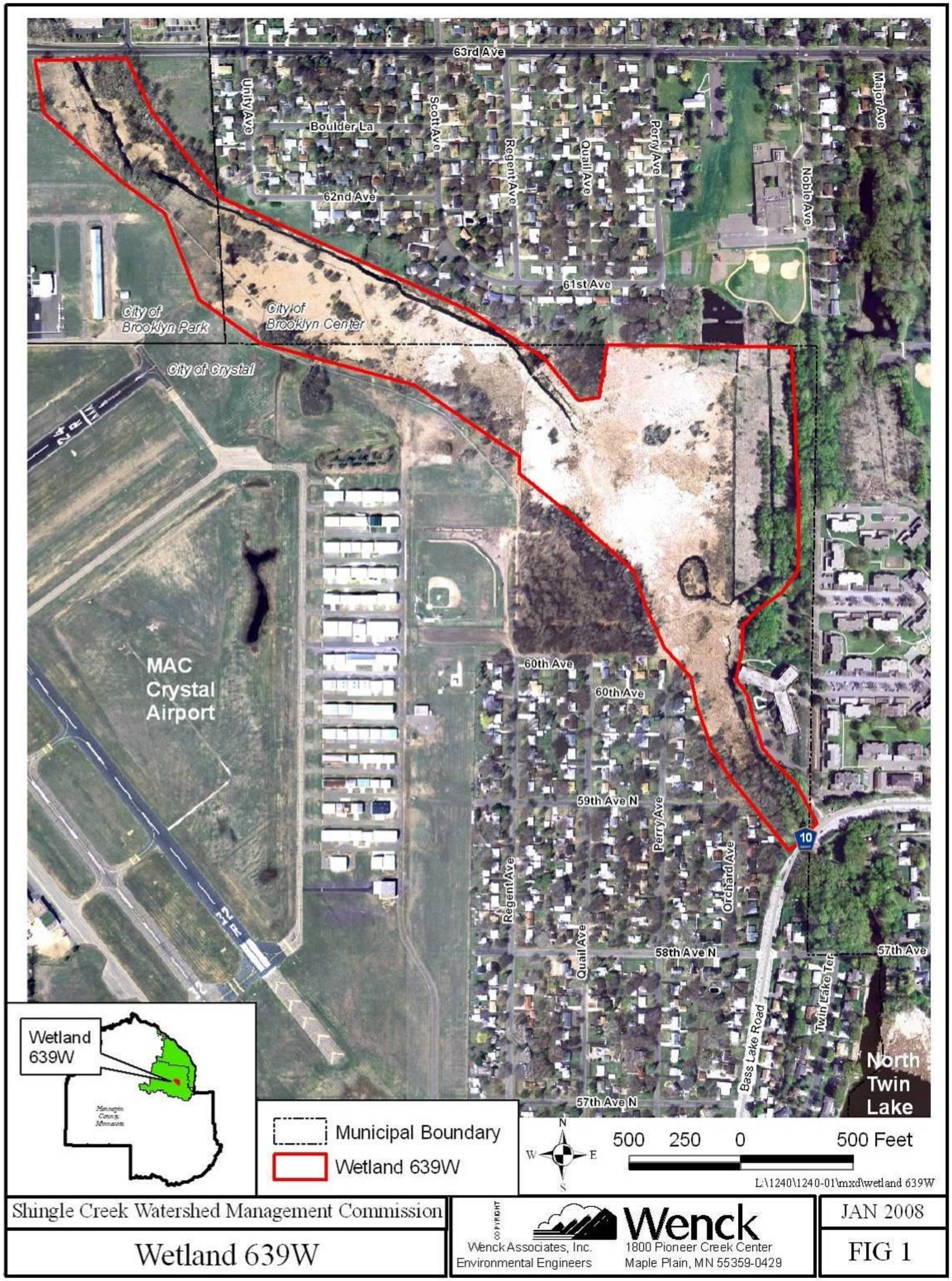


Figure 1.2. Wetland 639W.

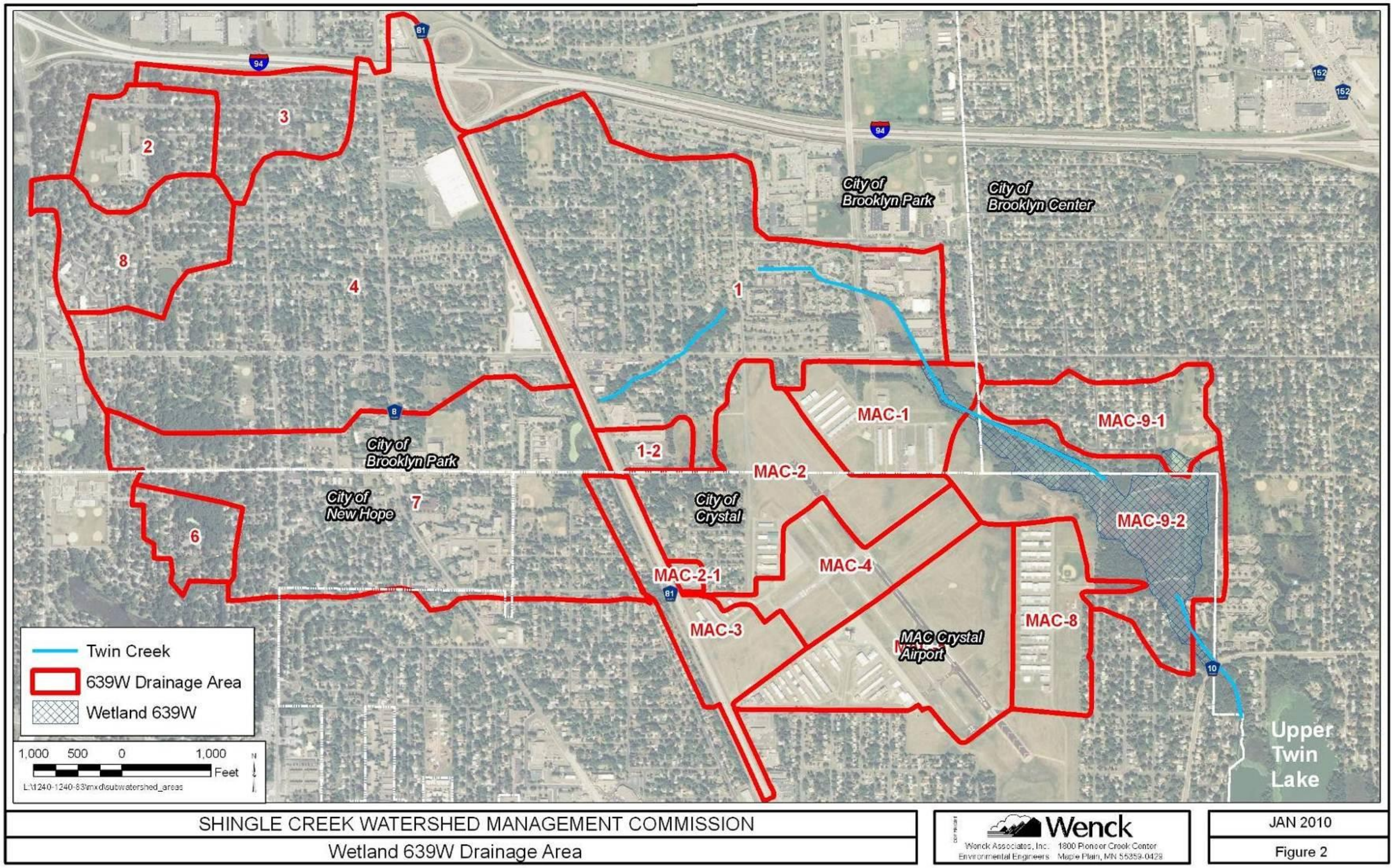


Figure 1.3. Wetland 639W contributing drainage area.

1.2 HISTORY

Little is known about the pre-settlement conditions in Wetland 639W. A wetland in the general vicinity is depicted on the original Public Land Survey and other early maps (Figures 1.4-1.6), although the size and extent of the wetland varies, probably based on the quality of information available to the mapmaker. Several of these early maps show the outlet of Wetland 639W discharging to Upper Twin Lake. None shows a natural channel conveying drainage to Wetland 639W, although maps of the time rarely showed intermittent streams.

Figure 1.4. Extracts from the 1854 Public Land Survey.

The figure above shows Wetland 639W as a "bulge" extending from off the map into Section 33. The figure below shows the south end of Wetland 639W and its outlet, Twin Creek.

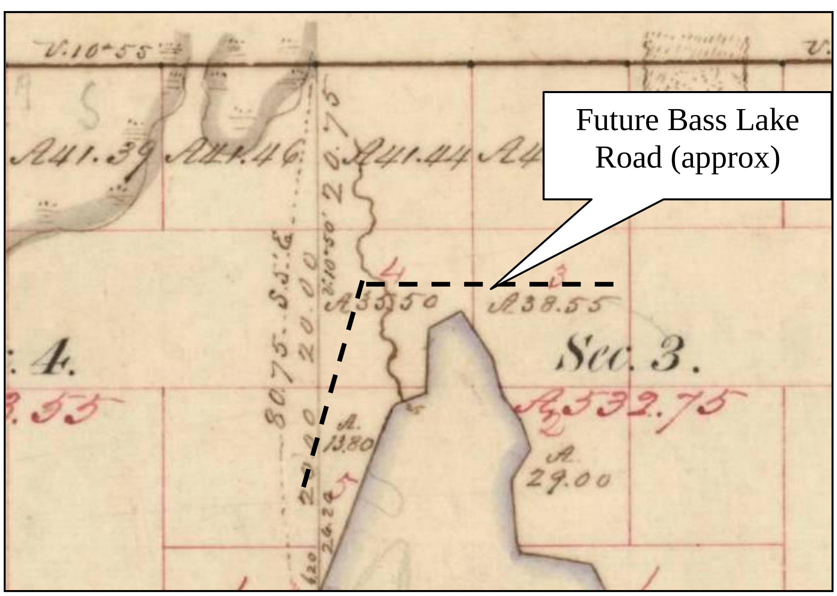


Figure 1.5. 1874 Illustrated Atlas of Hennepin County.

The 1874 Hennepin County Atlas (above) and 1902 USGS quad map (below) show Wetland 639W, but no channel from the north and west conveying drainage to the wetland.

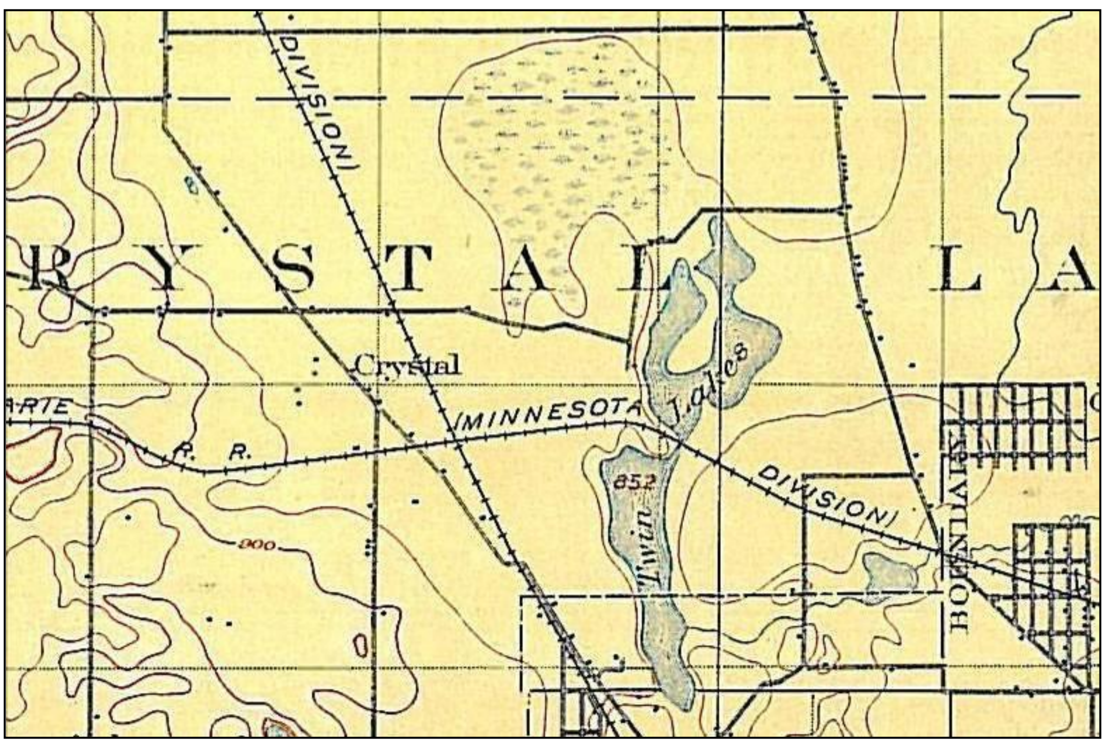


Figure 1.6. 1902 USGS topographic quad map.

By the early Twentieth Century, the area to the north and west of Wetland 639W was in agricultural production, and it is likely that ditches and channels had been dug and dredged to convey runoff from the north and west to the wetland and then into Upper Twin Lake. The 1947 aerial photograph shown in Figure 1.6 is overlaid with the modern street layout for context. The red outline shows the general boundary of modern Wetland 639W. The photo shows a straight agricultural ditch angling from 63rd Avenue in the northwest corner of the photo, then traversing through the wetland and outletting in the southeast corner of the photo into Upper Twin Lake. Other straight agricultural ditches are also present, and what is now the Crystal Airport contains a number of small wetlands.

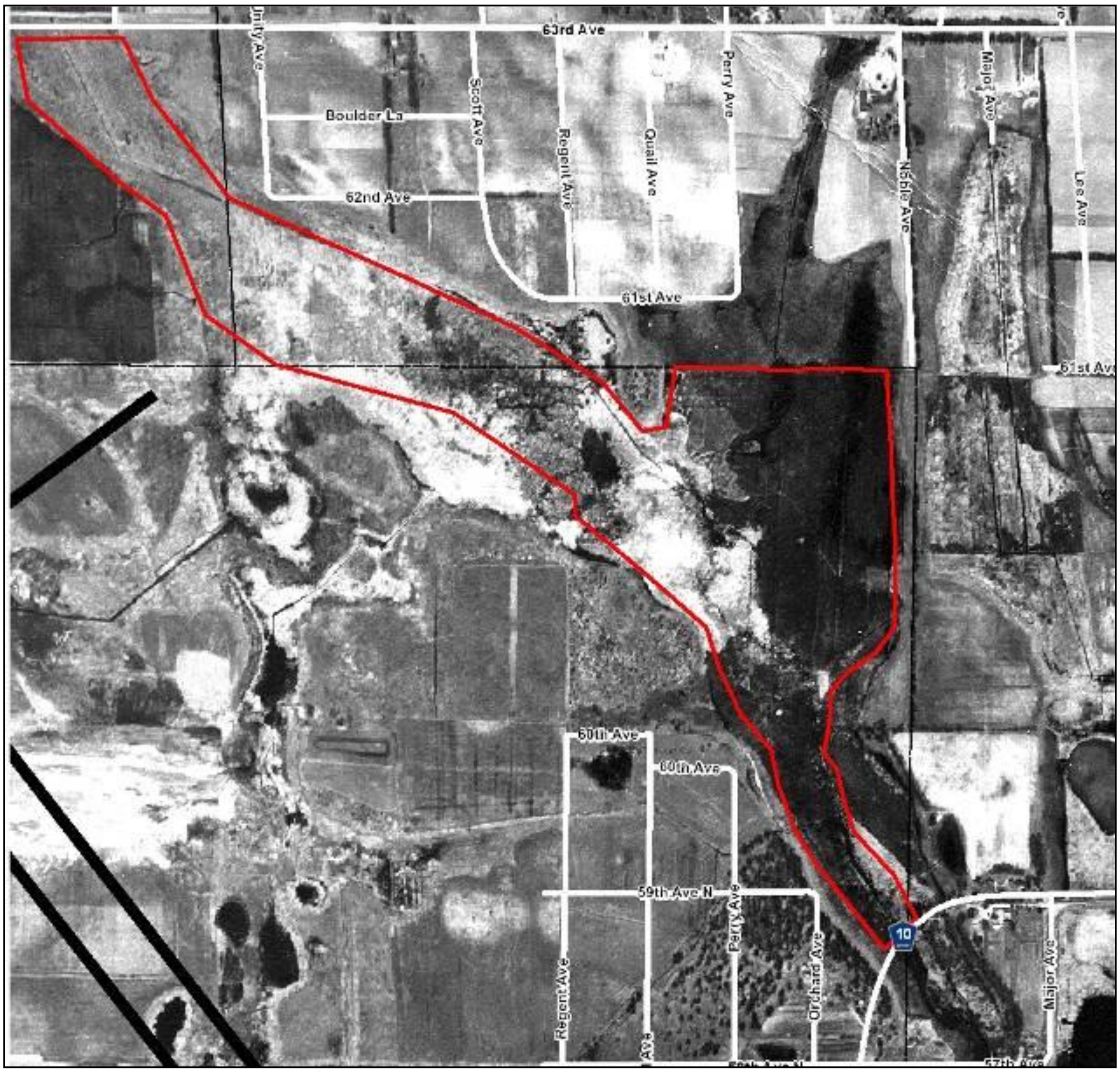


Figure 1.7. 1947 aerial photo of wetland 639W.
Photo is overlayed with the modern street system and the approximate modern limits of the wetland outlined in red.

1.3 EFFECTS OF DEVELOPMENT ON WETLANDS

Development, including both conversion from native prairie and savanna to agriculture and from agriculture to urban development, has fundamentally altered Wetland 639W.

The first major impact is the change from its natural hydroperiod. Unaltered wetlands obtain their hydrologic inputs from groundwater discharges (a discharge wetland), from precipitation and local drainage (a recharge wetland), or a combination of both sources. These inputs ebb and flow depending on annual precipitation, and these measured pulses sustain a wide variety of plants and wildlife. As development occurs, the increase in impervious surface generates more stormwater runoff and decreases infiltration to the local groundwater table.

In the past it was common to route agricultural or stormwater runoff to wetlands, and often to dredge channels through the wetland to hasten the flow of runoff through the system. As urbanization occurred, storm sewers were routed to the nearest water, which was often a wetland. Thus, instead of moderate pulses of small volumes of runoff to the wetland, a large volume of runoff is conveyed to and through the wetland. In addition, channels dredged to and through wetlands are hydraulic conduits that drain the wetland.

This is the case for Wetland 639W. As discussed in the previous section, historical maps and aerial photos show the progression from an unaltered wetland to a ditched wetland receiving runoff from first agricultural ditches and then storm sewers. The extent of the wetland has also been reduced.

The second major impact to agricultural and urban wetlands is that the increased inputs of stormwater contain sediment and phosphorus that impacts the wetland vegetation, which becomes dominated by species such as cattails and reed canary grass that are tolerant of the new hydroperiod and degraded water quality. This not only decreases biodiversity in the wetland, the heavy cattail growth increases evapotranspiration from the wetland, further drawing down surficial groundwater elevation. The high phosphorus loads in the runoff adsorb to wetland soils faster than it can be taken up, and soils become increasingly saturated with phosphorus. The wetland becomes less able to assimilate phosphorus and more likely to export phosphorus. This appears to be the case with Wetland 639W.

2.0 Monitoring

Stream monitoring at the inflow and outflow of the wetland was conducted in 2002. In 2008 the SCWMC replicated the 2002 stream monitoring, adding a midpoint monitoring station and also tracking groundwater levels in and near the wetland. Soil cores taken from the wetland were also analyzed for phosphorus fractionation.

2.1 STREAM MONITORING

Flow and water quality monitoring was conducted at the locations shown in Figure 2.1. 2008 was a very dry year (total annual precipitation = 20.5”, compared to 28”-32” in an average year). In the spring and in the fall there was water in the channel at all three locations, but throughout the summer for the most part the stream was dry.

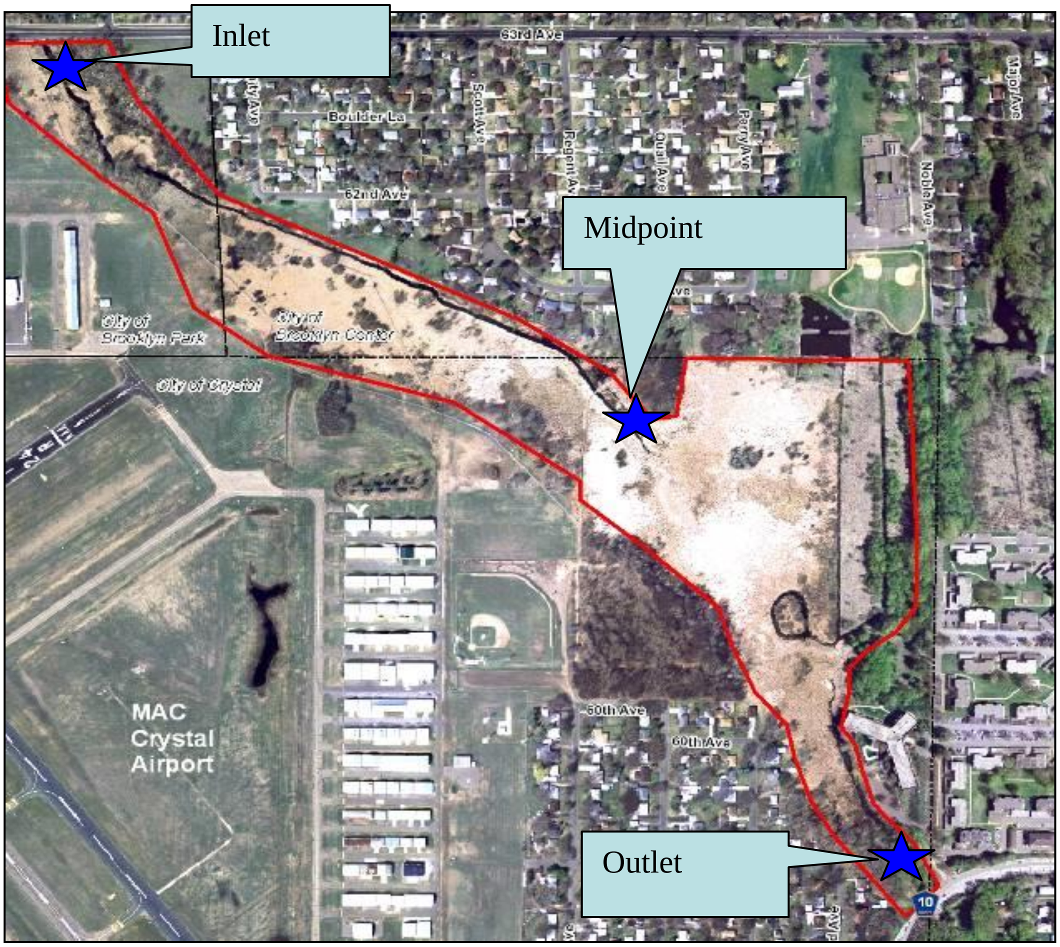


Figure 2.1. 2002 and 2008 stream monitoring locations.

Table 2.1 below shows the 2008 stream monitoring results. In July and August there was no flow in the channel. The total phosphorus concentrations are shown on Figure 2.2.

Table 2.1. 2008 stream monitoring results.

Project Station ID	Date	Military Time	Flow (cfs)	Solids, Total Suspended Volatile (mg/L)	Solids, Total Suspended (TSS) (mg/L)	Phosphorus, orthophosphate as P (mg/L)	Phosphorus, Total as P (mg/L)
SW-1 Outlet	5/5/2008	10:00	0.405	<10	19	0.021	0.110
	5/20/2008	10:00	0.433	<10	<10	0.038	0.240
	6/16/2008	9:45	0.439	<10	<10	0.160	0.410
	7/29/2008	10:25	0.000	N/A	N/A	N/A	N/A
	8/14/2008	9:45	0.000	N/A	N/A	N/A	N/A
	8/29/2008	11:50	0.215	<10	5.5	0.085	0.350
	9/24/2008	11:00	0.000	10	10	0.180	0.610
	10/13/2008	16:05	0.000	<10	15	0.052	0.430
SW-2 Midpoint	5/5/2008	10:30	0.411	<10	<10	0.022	0.089
	5/20/2008	11:30	0.226	<10	<10	0.035	0.078
	6/16/2008	10:45	0.484	<10	<10	0.170	0.370
	7/29/2008	11:35	0.000	N/A	N/A	N/A	N/A
	8/14/2008	13:30	0.000	N/A	N/A	N/A	N/A
	8/29/2008	12:00	0.119	12	32	0.030	0.260
	9/24/2008	11:15	0.255	<10	<10	0.046	0.150
	10/7/2008	11:15	2.081	<10	<10	0.044	0.120
	10/13/2008	15:20	0.667	<10	<10	0.075	0.180
SW-3 Inlet	5/5/2008	11:00	0.078	<10	<10	0.041	0.140
	5/20/2008	12:30	0.094	<10	<10	0.075	0.160
	6/16/2008	13:00	0.106	14	<10	0.170	0.340
	7/29/2008	12:40	0.000	N/A	N/A	N/A	N/A
	8/14/2008	12:45	0.000	N/A	N/A	N/A	N/A
	8/29/2008	12:30	0.050	<10	7	0.069	0.250
	9/11/2008	13:00	0.068	<10	<10	0.160	0.500
	9/23/2008	18:30	5.915	10	20	0.100	0.180
	9/24/2008	11:30	0.075	11	<10	0.084	0.170
	10/7/2008	11:55	2.030	<10	<10	0.075	0.140
	10/13/2008	14:45	1.247	<10	<10	0.160	0.250

N/A = not available. No grab sample was taken as there was no recordable flow in the channel.

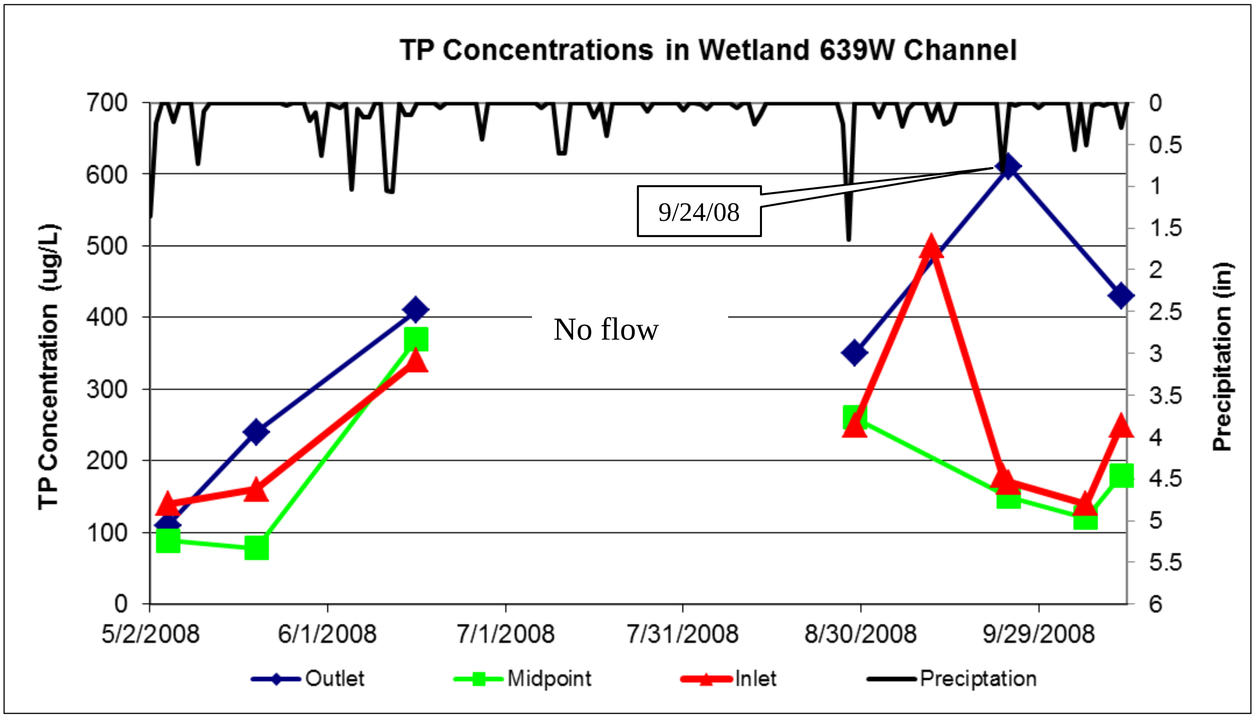


Figure 2.2. Total phosphorus concentrations in the channel.
Note: SW-1 is the outlet, SW-2 is the midpoint, and SW-3 is the inlet of the wetland.

The concentration at the outlet typically exceeds concentration at other monitoring stations. After virtually no rain in July and August, 1.9" of rain fell August 27-28 and another 0.8" fell on September 23. Figure 2.2 shows a high pulse of phosphorus discharged from the wetland after that rain event.

Table 2.2. 2008 stream monitoring summer averages.

Location	Parameter	N	Min	Max	Mean
Inlet	Sampled flow	9	0.075	5.915	0.878
	TSS (ug/L)	9	<10	20	10.8
	VSS (ug/L)	9	<10	14	10.5
	TP (ug/L)	9	0.14	0.5	0.237
	OP (ug/L)	9	0.041	0.16	0.104
Midpoint	Sampled flow	7	0.119	2.081	
	TSS (ug/L)	7	<10	32	13.1
	VSS (ug/L)	7	<10	12	10.3
	TP (ug/L)	7	0.078	0.37	0.178
	OP (ug/L)	7	0.022	0.17	0.06
Outlet	Sampled flow	6	0.215	0.439	0.187
	TSS (ug/L)	6	5.5	19	11.6
	VSS (ug/L)	6	<10	10	10
	TP (ug/L)	6	0.11	0.61	0.358
	OP (ug/L)	6	0.021	0.18	0.089

Table 2.3. Summer average results for 2002 monitoring compared to 2008 results.

Location	Parameter	2002	2008
Inlet	Sampled flow (cfs)	11.6	0.88
	TSS (mg/L)	13.4	10.8
	VSS (mg/L)	7.2	10.5
	TP (mg/L)	0.15	0.24
	OP (mg/L)	0.06	0.10
Mid-point	Sampled flow (cfs)	n/a	0.47
	TSS (mg/L)	n/a	13.1
	VSS (mg/L)	n/a	10.3
	TP (mg/L)	n/a	0.18
	OP (mg/L)	n/a	0.06
Outlet	Sampled flow (cfs)	7.75	0.19
	TSS (mg/L)	50.3	11.6
	VSS (mg/L)	29.8	10.0
	TP (mg/L)	0.36	0.36
	OP (mg/L)	0.12	0.09

Note: Annual precipitation in 2002 was 43.3" and in 2008 was 20.5", compared to annual average of 28"-32"

2.2 GROUNDWATER LEVEL MONITORING

Groundwater plays an essential role in wetland hydrology. Some wetlands receive a significant contribution from groundwater, while others discharge into groundwater. Many wetlands are a combination of discharge-recharge, depending on the season. Groundwater also plays an important role in wetland biogeochemistry. Wetlands transform and store phosphorus when plants uptake nutrients from the soil and from surface water. When the plants senesce and the remains accumulate in the wetland, the stored phosphorus becomes bound in the poorly degraded plant material or peat (Mitch and Gosselink 2000). Peat stores phosphorus because the mineralization of the plant material is slow in the anoxic water of the wetland. When wetland soils are not saturated with water, the plant biomass is quickly broken down in the oxygenated conditions, increasing the rate of mineralization and making more phosphorus available for release.

As part of the 2008 monitoring, groundwater elevation was monitored at various locations as a measure of soil saturation and to better understand how groundwater flows through the wetland. Figure 2.3 shows the locations where piezometers tracked changes in groundwater elevation, some throughout the entire monitoring period, and others for shorter periods or as part of a short-term monitoring of a transect across the wetland. Figures 2.5 – 2.10 show the monitoring record at MW-1 through MW-6. Precipitation is also shown in these figures.

Two things are striking about the monitoring records at MW-1, 2, 3, and 6. First and most obvious is the steep decline in groundwater elevation that starts in the spring and continues to about the end of October. There are occasional ticks upward following rain events, but the elevation immediately starts to decline again. The second and less obvious feature is that by October the groundwater elevations, while varying with precipitation, generally level off. A wetland that is discharging to groundwater would decline at a relatively steady rate, and at a slower rate than what was measured during the summer.

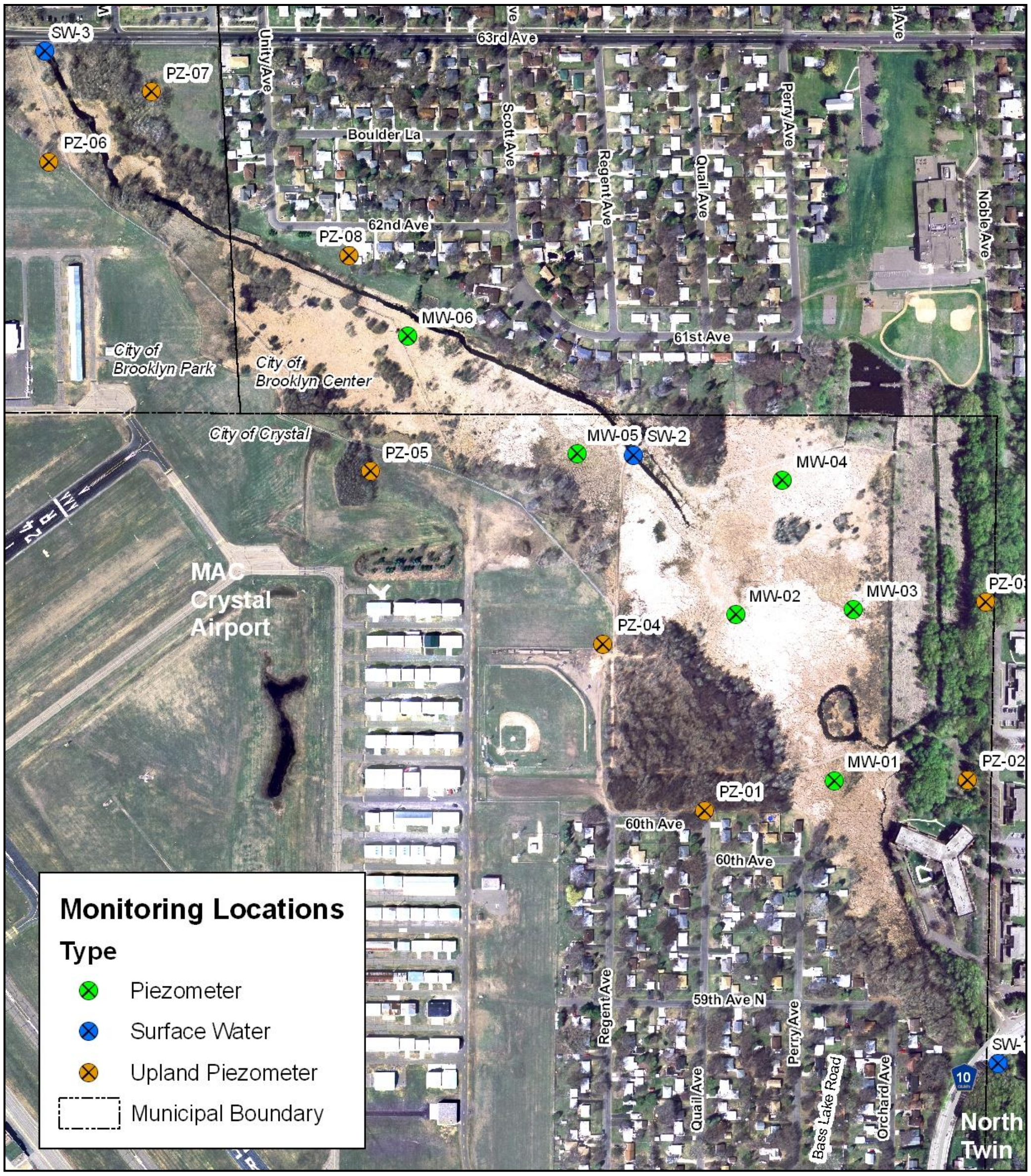


Figure 2.3. 2008 groundwater elevation monitoring locations.

The groundwater elevations and transects indicate that the general movement of groundwater in the wetland is from all directions to the central basin (Figure 2.4). The stream in the upper part of the wetland appears to be losing, or contributing streamflow to groundwater, which is then conveyed to the central basin. This movement of groundwater to the central basin could be expected to stabilize groundwater elevations at that point. However, the elevations at MW-1 and MW-2 in the central basin indicate that groundwater elevations there drop just as or even more rapidly as elevations elsewhere in the wetland.

Clearly there is some factor other than groundwater discharge that is causing the steep declines in groundwater elevation in the central basin of Wetland 639W.

The central basin of the wetland is vegetated with dense cattail growth. Cattails have a high evapotranspiration crop coefficient, meaning they use a lot of water. During periods of lower precipitation and runoff, when there is little to no standing surface water, cattails rely on groundwater for the water necessary for photosynthesis. 2008 was a very low precipitation year, and the piezometers measured a 2-3 foot drop in surficial groundwater over the summer growing season. The main basin of the wetland experienced extended periods of soil dryness, so then when rain events did occur, pulses of phosphorus were discharged from the wetland to the lake (Figure 2.2). These pulses were high in orthophosphate (Table 2.1), which is the form of phosphorus that is most readily available for plant uptake and which fuels lake algal blooms.

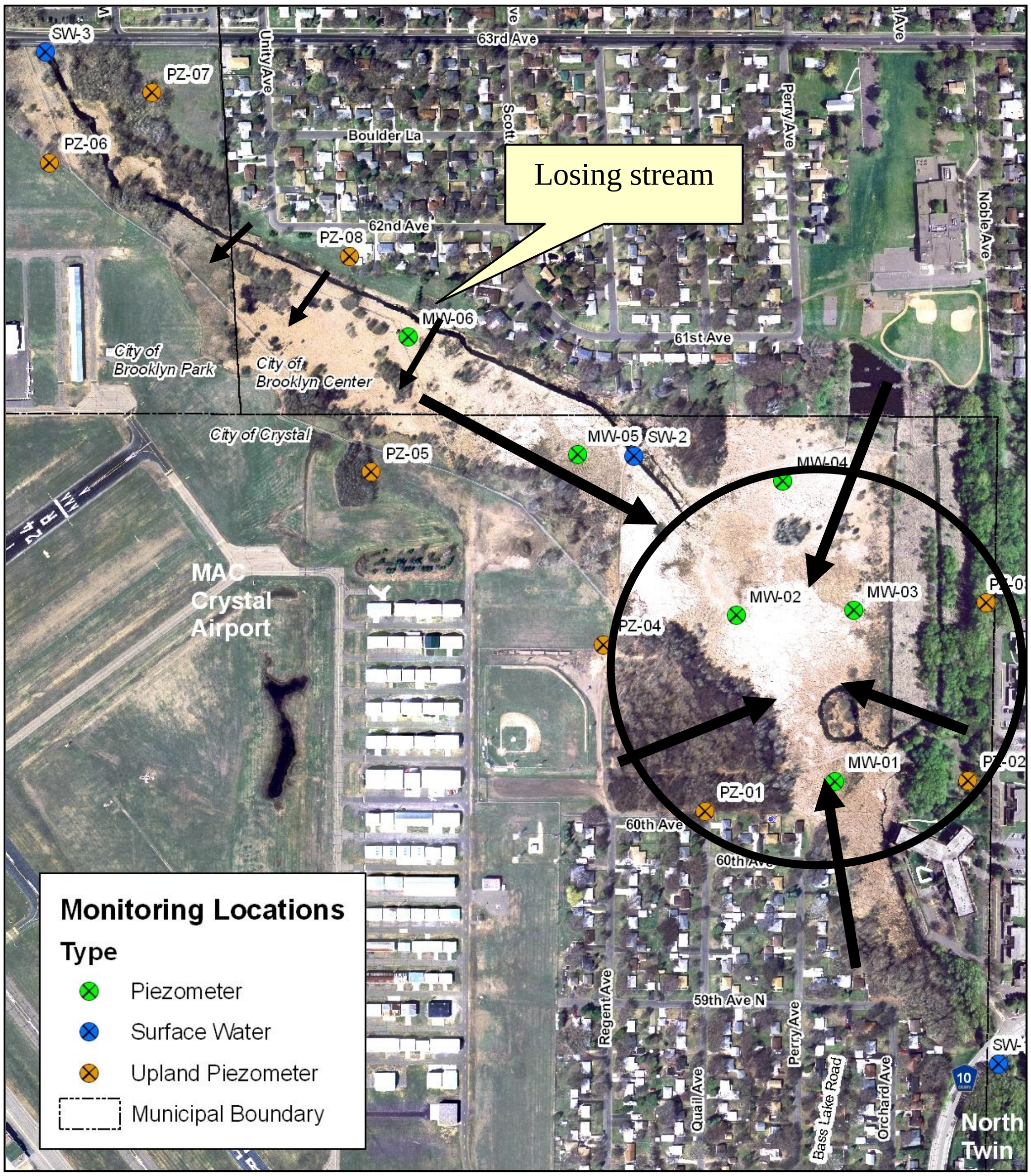


Figure 2.4. Surficial groundwater movement in 2008.

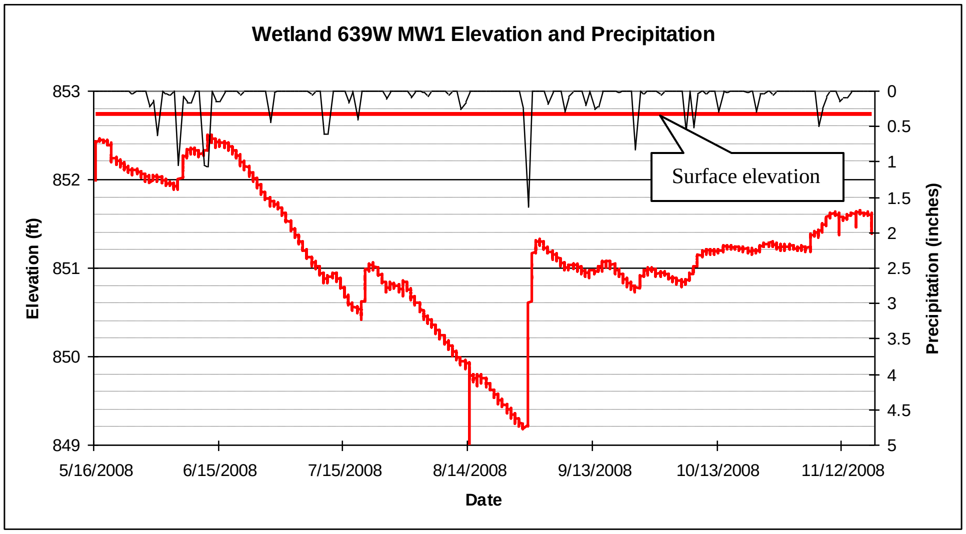


Figure 2.5. Groundwater elevation at monitoring well 1.

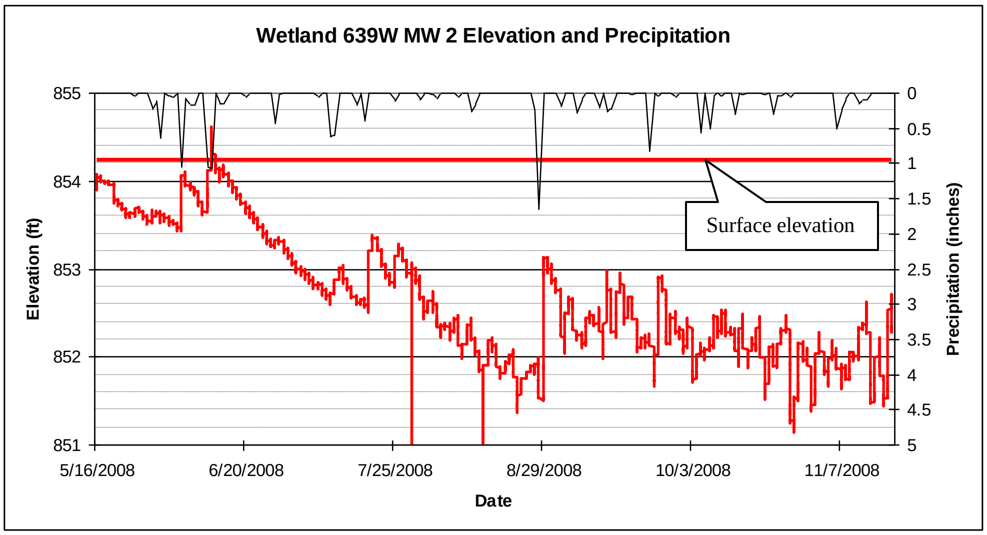


Figure 2.6. Groundwater elevation at monitoring well 2.

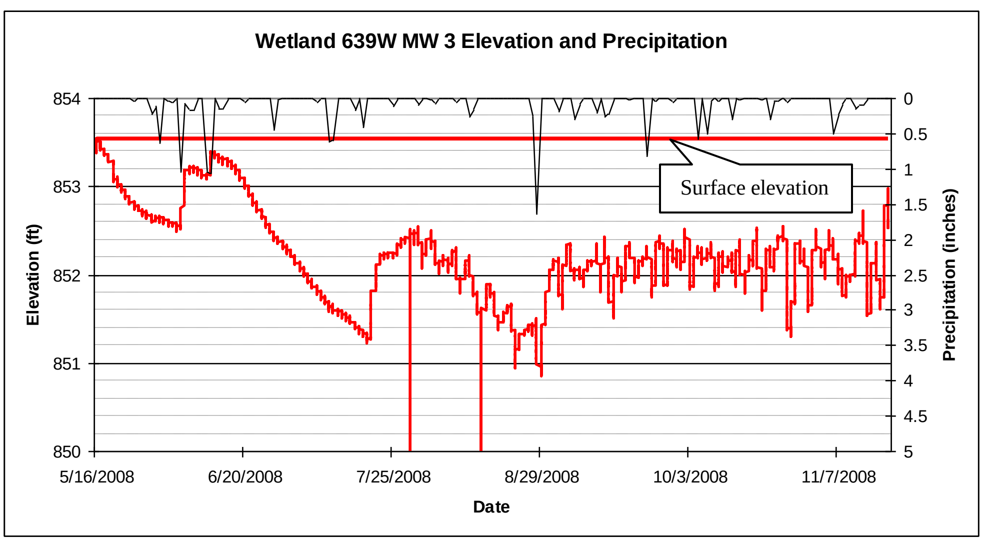


Figure 2.7. Groundwater elevation at monitoring well 3.

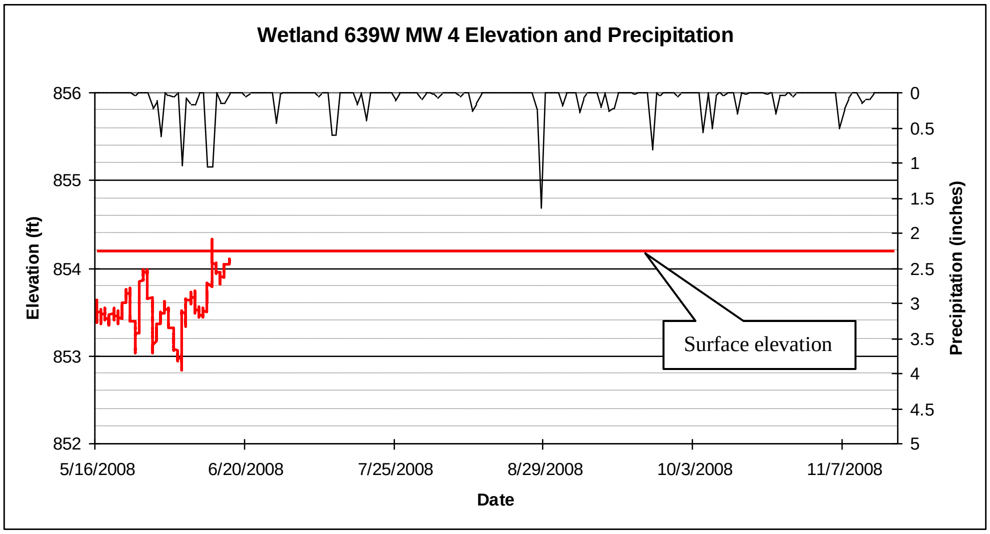


Figure 2.8. Groundwater elevation at monitoring well 4.

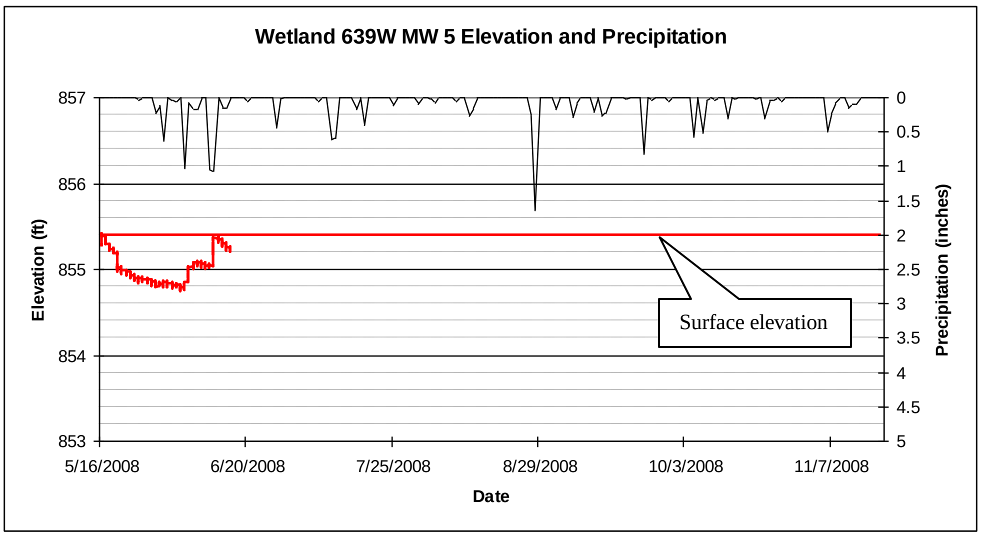


Figure 2.9. Groundwater elevation at monitoring well 5.

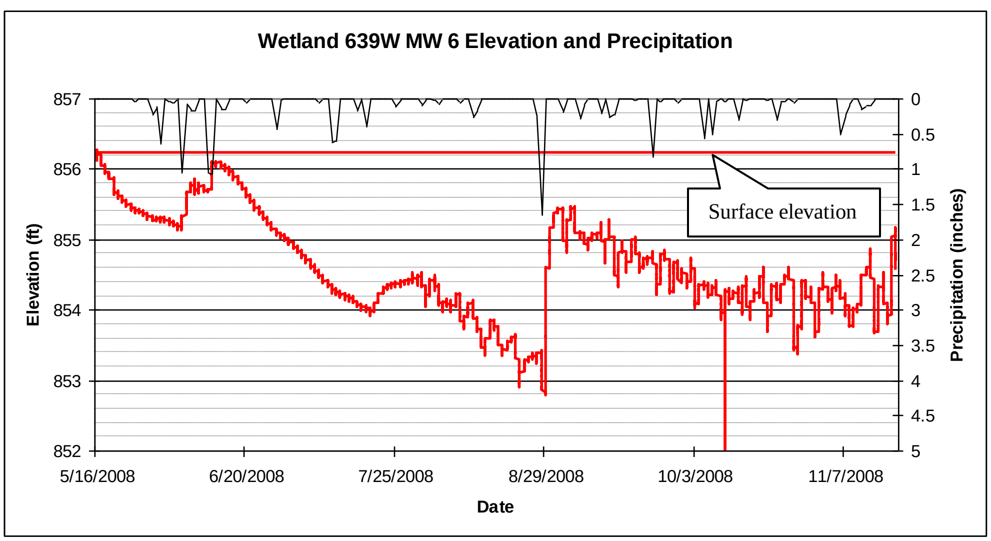


Figure 2.10. Groundwater elevation at monitoring well 6.

2.3 SOIL CHEMISTRY

Wetland soils serve as the medium in which chemical transformations take place and are the primary storage of available chemicals. Composition of a wetland's soil is dependant on both the parent material and the extent and duration of its saturation with water (Reddy and Delaune 2008).

The nature and extent of chemical transformation in wetlands is dependant on the chemical composition of the wetland organic and mineral soils. As the wetland becomes saturated, pore spaces in the soil fill with water and oxygen is no longer able to diffuse through, causing anaerobic or reduced conditions. The chemical transformation in the wetland is then driven by the redox potential of the wetland soils (Mitsch and Gosselink 2000).

To better understand the chemical transformations occurring in Wetland 639W, soil cores taken at several monitoring well locations were analyzed by US Army Corps of Engineering staff at the Eau Galle Aquatic Ecology Laboratory in Spring Valley, Wisconsin. Sequential phosphorus fractionation was performed to determine the types of transformations occurring in the wetland.

In general, the soil cores were relatively high in organic content. The iron-bound phosphorus fraction was fairly high at monitoring sites MW-1, MW-2, MW-3, and MW-6 (Table 2.4 and Figure 2.11). This indicates that oxygen dynamics may be an important factor in the release of phosphorus from the wetland sediments. In addition, the testing revealed high concentrations of total phosphorus in the soil cores, which is indicative of saturation. The cores also exhibited a fairly low refractory component, which is indicative of high mineralization potential.

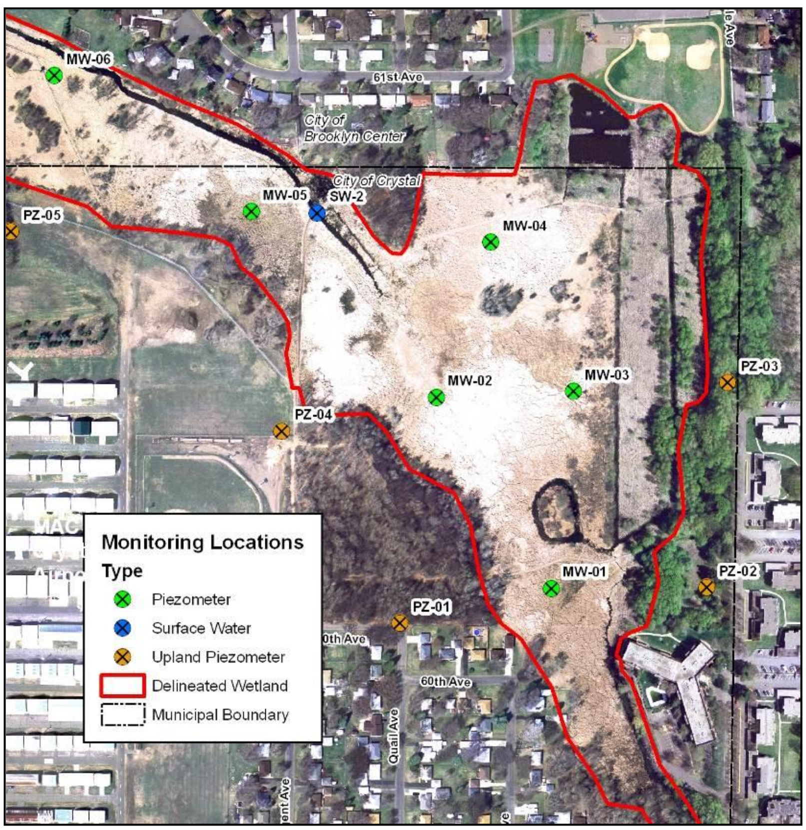


Figure 2.11. Sediment core locations.

Table 2.4. Sediment soil chemistry results from cores taken when drilling groundwater monitoring wells.

Station	Moisture Content (%)	Sediment Density (g/mL)	Loss-on-Ignition (%)	Loosely-bound P (mg/g DW)	Iron-bound P (mg/g DW)	Iron-bound P (mg/g FW)	Calcium-bound P (mg/g DW)	Refractory organic P (mg/g DW)	Total P (mg/g DW)	Total N (mg/g DW)
MW-1-U6	77.9	0.104	61.1%	0.022	0.513	0.113	0.015	0.060	1.750	18.478
MW-1-M6	81.2	0.130	73.5%	0.006	0.111	0.021	0.028	0.076	1.120	22.616
MW-1-L6	84.1	0.097	83.5%	0.002	0.072	0.011	0.015	0.097	0.767	21.884
MW-2-U6	73.2	0.157	62.2%	0.022	0.617	0.165	0.050	0.201	2.132	21.717
MW-2-M6	70.5	0.179	60.9%	0.008	0.195	0.058	0.020	0.246	1.602	22.680
MW-2-L6	72.2	0.152	59.8%	0.020	0.148	0.041	0.047	0.157	1.285	20.918
MW-3-U6	76.0	0.104	65.7%	0.028	0.615	0.148	0.075	0.129	2.283	24.078
MW-3-M6	80.0	0.076	78.9%	0.021	0.166	0.033	0.045	0.131	1.046	25.050
MW-3-L6	79.9	0.116	76.9%	0.012	0.114	0.023	0.077	0.160	0.887	22.310
MW-4-U6	73.6	0.135	60.0%	0.014	0.132	0.035	0.062	0.197	1.464	20.291
MW-4-M6	71.9	0.138	58.5%	0.025	0.095	0.027	0.074	0.176	1.017	16.926
MW-4-L6	72.1	0.132	59.1%	0.014	0.107	0.030	0.076	0.146	1.046	18.327
MW-5-U6	70.1	0.132	48.7%	0.021	0.202	0.060	0.078	0.058	1.283	16.177
MW-5-M6	67.1	0.134	51.8%	0.021	0.135	0.044	0.048	0.139	0.941	11.977
MW-5-L6	71.1	0.149	62.1%	0.020	0.122	0.035	0.044	0.094	0.932	16.859
MW-6-U6	62.9	0.133	43.2%	0.046	0.840	0.311	0.173	0.195	2.743	14.338
MW-6-M6	60.9	0.199	45.1%	0.036	0.567	0.222	0.254	0.126	3.020	15.038
MW-6-L6	69.5	0.185	48.1%	0.057	0.734	0.224	0.229	0.168	2.595	13.887

Note: U6 means the upper 6” of the core; M6 is the middle 6”, and L6 is the lower 6”. U6 is closest to the surface.

3.0 Conclusions and Recommendation

3.1 HYPOTHESES

Prior to undertaking the 2008 monitoring, the Commission hypothesized that one or more of the following conditions was causing the export of phosphorus from the wetland.

1. Stormwater is conveyed through the upper wetland in a channel. At the wetland midpoint, just above the central wetland basin, the channel disappears and the flow diffuses into sheet flow. This sheet flow moves more slowly across the wetland basin, and becomes deoxygenated as vegetation and soils capture and use the dissolved oxygen. Anoxia at the soil-water interface across the wetland breaks electrochemical bonds and releases phosphorus from the mineral soils.
2. The wetland vegetation and soil dries out in summer, becoming friable. Periodic large events mobilize and flush organic material and detached soil particles out of the wetland and into the lake.
3. The wetland soils have reduced ability to bind phosphorus due to the transport of sediment and nutrients to the wetland from historic agricultural and current urban stormwater.

3.2 CONCLUSIONS

A detailed analysis of the monitoring data presented above and observation of conditions in Wetland 639W suggests that the likely reason phosphorus is released from the wetland is the de-saturation of the central basin during the summer, likely by the dense cattails that dominate the basin.

This drying out has two effects. First, during the periods when groundwater is drawn down and is no longer saturated with water, the soil may become aerobic, and mineralize faster than it would were it saturated. The soil core data discussed in Section 2.3 above indicated that the soil has a high mineralization potential. Thus, instead of tying up organic phosphorus in slowly decomposing peat, the phosphorus is transformed into an inorganic form that is bound with iron as ferric phosphate. The sequential phosphorus fractionation on the soil cores revealed a high iron-bound fraction in the cores. When the soil becomes flooded again, the ferric iron is reduced to more soluble ferrous compounds that are released into the water column and discharged in outflow from the wetland. The channel monitoring data showed a high concentration of phosphorus at the outlet when a rain event in September refilled the wetland following a dry summer. Second, the vegetation and soil become friable, and as noted in the initial hypotheses, stormwater sheet flowing across the wetland mobilizes the organic material and mineralized soil particles and conveys them and the associated phosphorus load downstream to Upper Twin Lake.

3.3 REMEDIES

The Commission and the Technical Advisory Committee (TAC) considered several options to reduce the phosphorus export from the wetland. Some of these were identified but not seriously considered as they were considered infeasible for cost, maintenance, or regulatory reasons as described in Table 3.1. The most promising options, options 2 and 3, were studied in more detail. The preferred option is a combination of the two approaches.

Table 3.1. Options to reduce phosphorus export from Wetland 639W.

Option	Implementation Considerations
1. Bypass all flow around the wetland	Option would eliminate all surface water inputs from the upper watershed, leaving only direct runoff from the surrounding watershed, groundwater inputs, and precipitation. This would significantly affect the wetland's hydroperiod and change the wetland type, likely requiring wetland mitigation. May be difficult to obtain a permit.
2. Bypass high flows allowing low flows to pass	Would eliminate the most damaging high flows but allow low flows to continue, reducing the impact to the wetland hydroperiod.
3. Revise wetland outlet to retain water in the wetland	Needs to be carefully designed to avoid creating areas of permanent open water that would be attractive to waterfowl and other aviation nuisances.
4. Excavate storage cells in the wetland to slow rate of flow	Would create areas of permanent open water that would be attractive to waterfowl and other aviation nuisances.
5. Soil amendment	Does not address the cause of soil mineralization problem, would have to be reapplied periodically.
6. Remove cattails and excavate mineralized soils	Expensive, would change wetland type, likely requiring wetland mitigation. Would lower wetland surface elevation creating areas of permanent open water.
7. Chemical treatment of effluent	Expensive, an ongoing cost for operations, needs a flocculation basin that would periodically have to be dredged and the material disposed.
8. Chemical treatment within the wetland	Alum columns, limestone berms, etc. Minimally effective considering the volume of water passing through.
9. Reduce peak rates from upper watershed	Very long term, also needs to be done carefully to avoid creating open-water habitat.

3.4 RECOMMENDED OPTION

The recommended option is to modify the outlet of Wetland 639W to limit outflow so that the wetland stays as wet as possible, reducing the periods of soil dryness. This would be accomplished through the construction of a sheet pile weir along the "bottom" of the wetland. This weir would be set at elevation 856.0, approximately two feet above the ground elevation. Figure 3.1 shows a schematic drawing of the proposed modified outlet. A new outlet set at elevation 855.5 would be constructed at a point upstream of the central wetland basin. This new outlet would discharge into a new channel to be constructed at the edge of the upland wooded area adjacent to the wetland. The channel would outlet through an existing swale downstream of the sheet pile weir. Figure 3.2 shows the general location of the new channel.

Water would be stored in the wetland until the elevation exceeds 855.5, at which point the upper outlet would begin to discharge into the channel. Hydrologic and hydraulic modeling indicate that channel discharge and storage in the wetland between elevations 855.5 and 856.0 can accommodate up to a 1.5 inch event. When the basin is full (i.e., at elevation 855.5), events greater than 1.5 inches will be discharged both through the channel and over the top of the sheet pile weir. Modeling is discussed in more detail below.

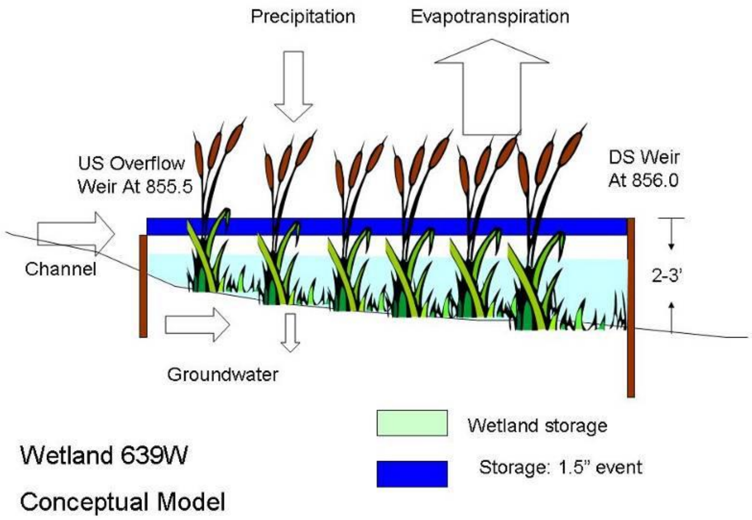


Figure 3.1. Conceptual cross section of proposed sheet pile weir and new outlet.

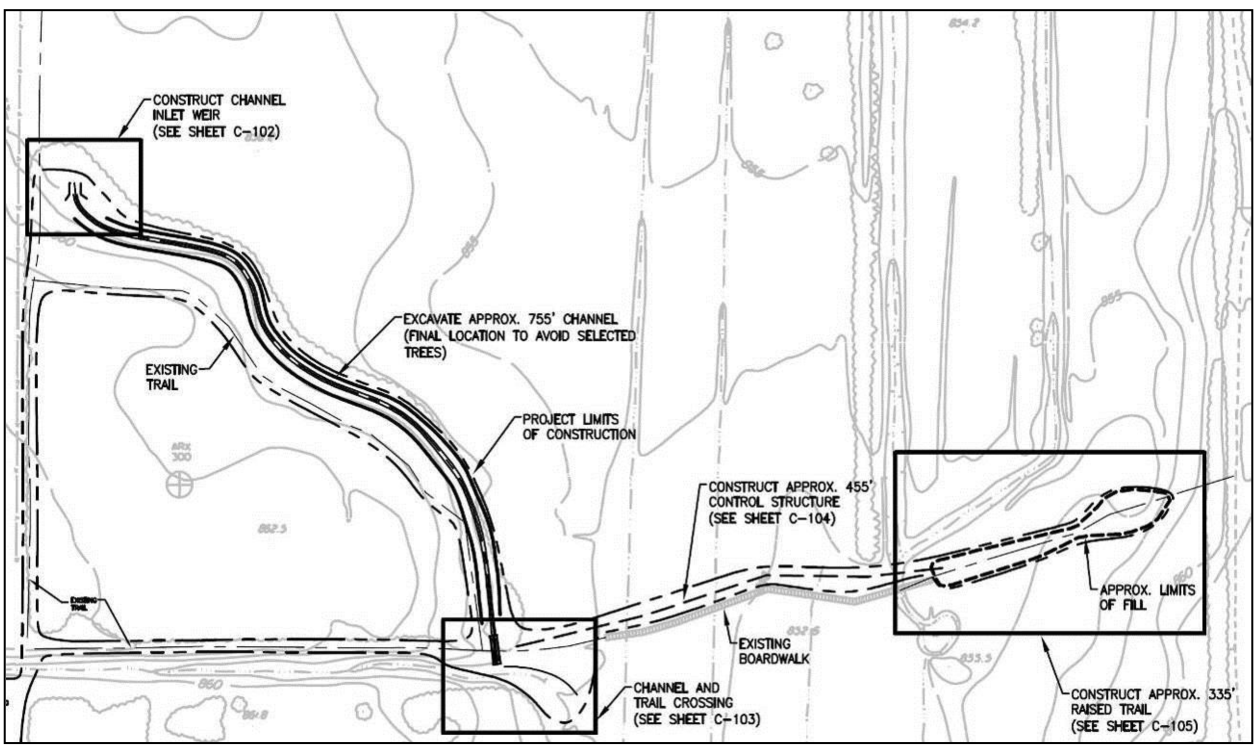


Figure 3.2. Conceptual layout of recommended outlet modification.

3.4.1 Modeling

Hydrologic and hydraulic modeling were completed to assess the impact of various improvement scenarios on flow through the wetland and on wetland elevations. The P8 model prepared for the Twin and Ryan Lakes Nutrient TMDL and the Shingle Creek watershed SWMM model were used in this analysis. The SWMM model hydrology is well-calibrated to watershed runoff measured at various locations throughout the watershed during the development of the Shingle Creek chloride TMDL. P8 hydrology was calibrated to the SWMM model and the pollutant loading was calibrated to Twin Creek water quality data collected in 2002 and 2008. P8 output is shown in Appendix A.

Once the models were calibrated the proposed new sheet pile weir, outlet structure, and outlet channel were added. The models were then used to optimize the design details of the weirs and evaluate the impact of the revised outlets on wetland hydrology. Figures 4.1 and 4.2 below show the hydrographs for the 2-year event and the 100-year event respectively assuming the basin is "full" (i.e., at 855.5) as a starting condition. The hydrographs show the elevation of water in the basin at Node SW-2, which is the sheet pile weir. The 2-year event hydrograph shows that the wetland very slightly overtops the weir, and then the basin is drawn down to the starting conditions in a few days. The 100-year event hydrograph shows the weir overtopped and flowing for about one day, and then drawing down the second day.

Figures in Appendix A show a ten year precipitation record run through the SWMM model. Captions indicate the annual precipitation, where average is 28-33 inches per year. The starting condition on January 1 for each run is a "full" basin. Elevations between 855.5 and 856.0 indicate water being discharged through the channel, while elevations below 855.5 indicate no water being discharged through the channel. Elevations above 856.0 indicate water being discharged both through the channel and over the top of the sheet pile weir.

3.4.2 Storage and Potential for Open Water

Installation of the sheet pile weir will increase storage in the central basin. Because of the proximity to the Crystal Airport, it is of prime importance to prevent the creation of open water that would attract waterfowl. The central basin of the wetland is currently vegetated mainly with dense cattails several feet in height interspersed with higher elevation areas of scrub shrubs and trees. There are some pockets with less dense cattail growth. During large events lower areas of the basin may for short periods contain up to a foot of standing water, compared to field observations that the wetland currently rarely contains more than six inches of standing water. It is unlikely that any significant new open water will be created in the main basin as the height of the standing cattails well exceed the potential standing water depth.

There is a possibility that pockets of open water may be created in the lower basin immediately adjacent to the sheet pile weir. This area is a foot lower in elevation from the central basin, and may contain 1-2 feet of standing water on a continuing basis. This may cause changes in vegetation that might result in open water. However, these low areas are small in size and are surrounded by higher ground that could be expected to remain vegetated with cattails, limiting attractiveness to waterfowl.

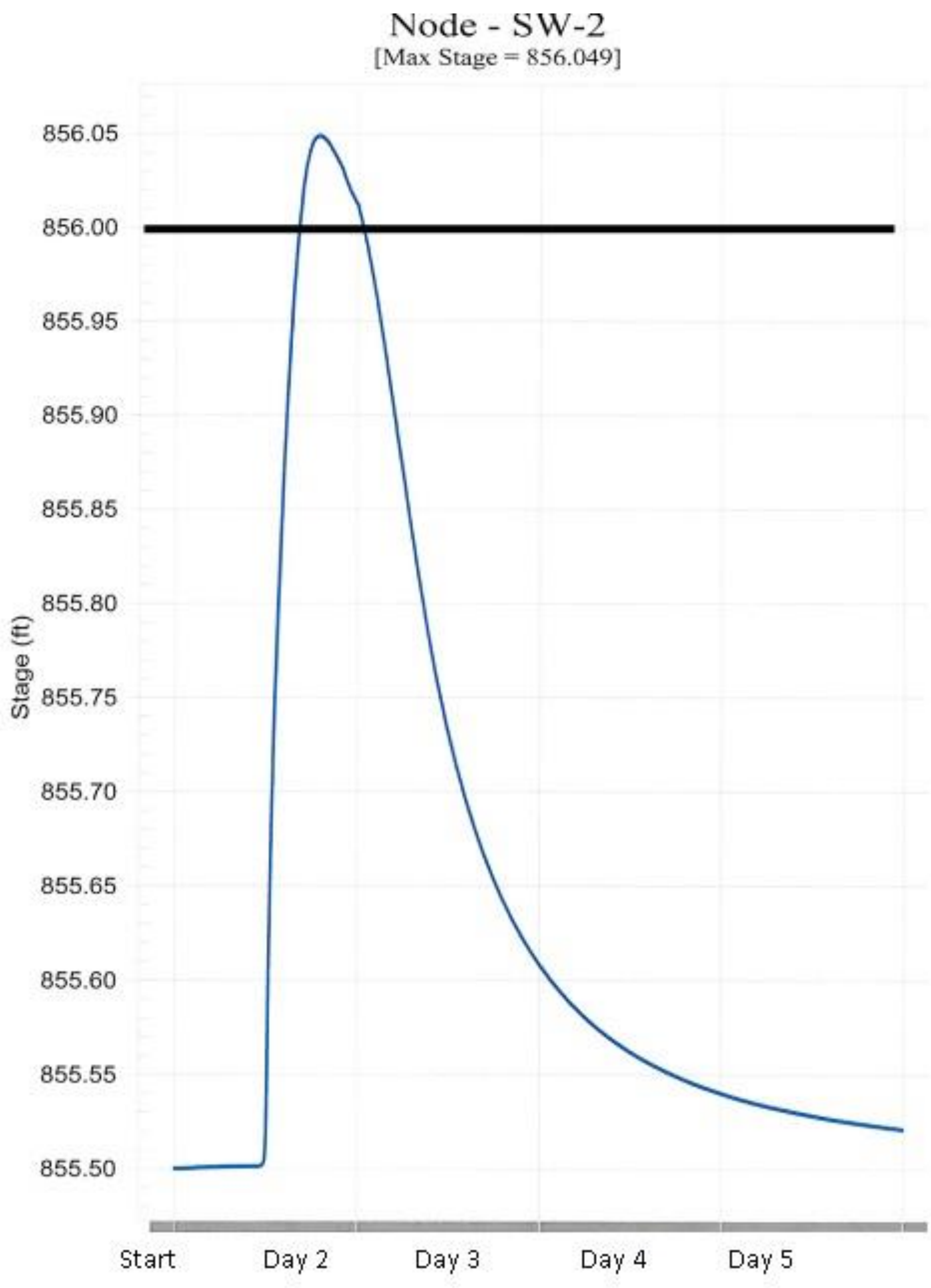


Figure 3.3. Hydrograph, 2- year event at Node SW-2, the sheet pile weir. Flow just overtops the downstream weir set at 856.0.

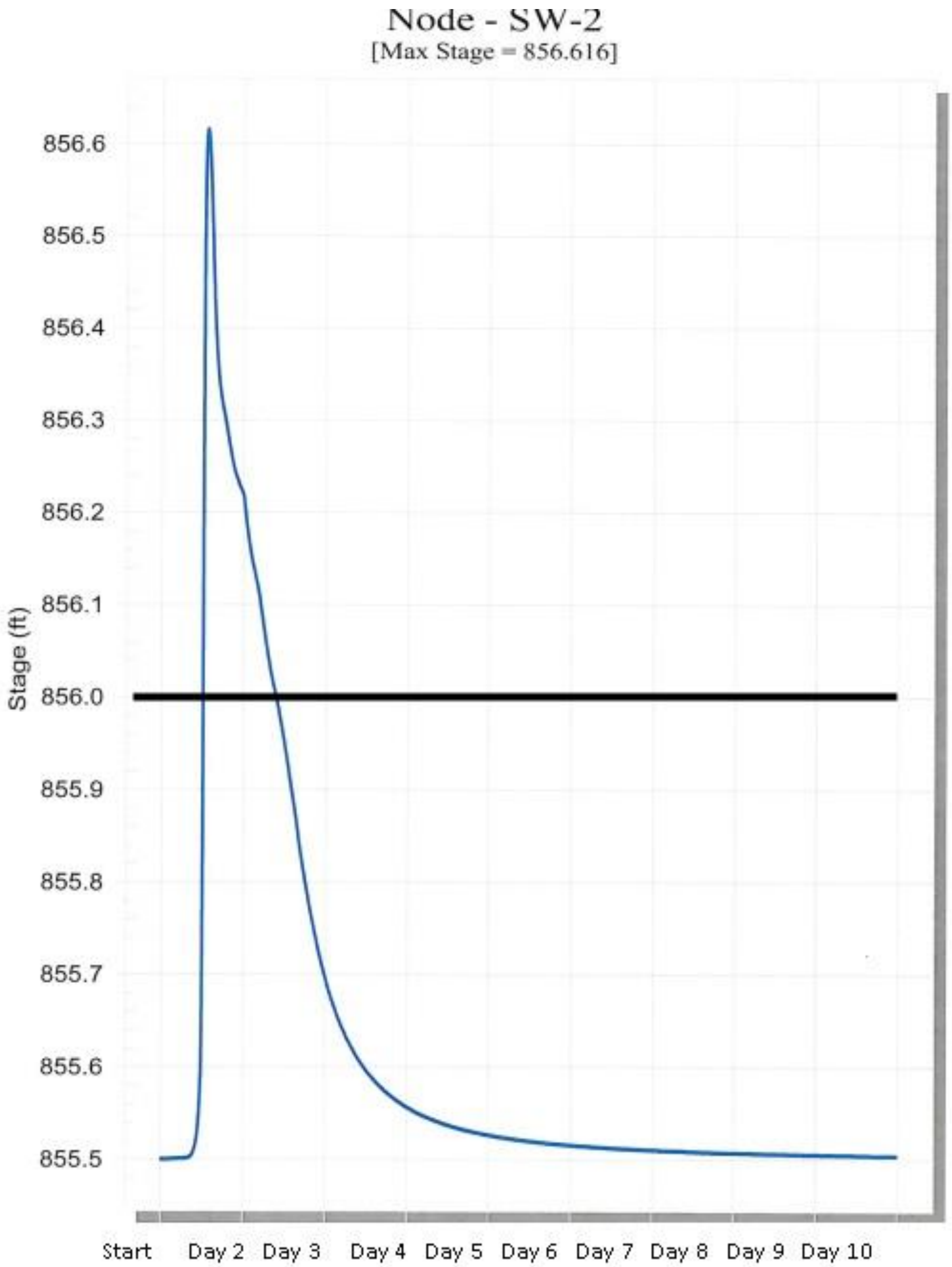


Figure 3.4. Hydrograph, 100-year event for Node SW-2, the sheet pile weir. Flow overtops the downstream weir for approximately one day and then is drawn down by the next day.

The wettest year in this period was 2002, where the model predicts the sheet pile weir would have been overtopped five times. However, even during that wet year there were periods when the wetland elevation would have fallen below the outlet elevation and there would have been no flow in the channel. The "bounce," or change in wetland elevation due to a precipitation event, is estimated to be less than one foot during this period of record.

3.5 COST AND PERFORMANCE

Previous study and the Twin and Ryan Lakes Nutrient TMDL estimated that Wetland 639W exports between 600-800 pounds of total phosphorus annually, depending on the amount of precipitation received. The goal of this project is to reduce phosphorus export by an average 300 pounds per year. This would accomplish a significant fraction of the approximately 750 pound annual total phosphorus wasteload reduction required to Upper Twin Lake. Because Middle Twin Lake is connected to Upper Twin Lake through a short channel, improving Upper Twin Lake will have a beneficial effect on Middle Twin.

3.5.1 Pollutant Load Removals

Runoff volume data generated by the P8 model was used to estimate the annual pollutant load under various scenarios. To provide an upper and lower range, actual water quality data from the 2002 (wet year) and 2008 (dry year) monitoring were with the P8 modeled volumes to estimate the outflow loads. A third estimate was made using the modeled annual runoff volume averaged over the ten year precipitation record. These load estimates are shown in Table 3.2, indicating the preferred option, Option 3, meets the removal goal of 300 pounds per year.

For the “No Build” option, which is the current condition, modeled total annual discharge from the wetland was multiplied by the observed summer average TP concentration at the outlet to obtain the estimated outflow load. For the “Sheet Pile (SP) Weir Only” option, which includes only the outlet modification and does not include the bypass channel, the modeled total annual discharge over the top of the weir was multiplied by the observed summer average TP concentration at the outlet to obtain the estimated outflow load.

For the “Bypass + Sheet Pile Weir” option, which is the recommended option, the estimated outflow load is the sum of two loads. The modeled total annual discharge over the top of the weir was multiplied by the observed summer average TP concentration at the outlet to obtain the annual load. The modeled total annual discharge through the bypass weir was multiplied by the observed summer average at the midpoint of the wetland to obtain the annual load.

Table 3.2. Estimated phosphorus export load reductions for each of the three Wetland 639W options.

Year	Option	P8 Volume (a-f/yr)	Monitored Avg TP Concentration (mg/l)	Annual Load Wetland Outflow (kg/yr)	Annual Load Reduction (kg/yr)	Annual Load Reduction (lb/yr)
2002 Wet Year 43.8” precip	1. No build	1,057	0.364	474.6	0	0
	2. SP weir only	846	0.364	379.7	94.9	209
	3. Bypass + weir	846		160.8	313.8	690
	Bypass	814	0.146	146.6		
	Flow over weir	32	0.364	14.2		
2008 Dry Year 22.7” precip	1. No build	647	0.403	321.7	0	0
	2. SP weir only	467	0.403	232.2	89.5	199
	3. Bypass + weir	478		157.4	164.2	365
	Bypass	478	0.267	157.4		
	Flow over weir	0	0.403	0		

Year	Option	P8 Volume (a-f/yr)	Monitored Avg TP Concentration (mg/l)	Annual Load Wetland Outflow (kg/yr)	Annual Load Reduction (kg/yr)	Annual Load Reduction (lb/yr)
Average	1. No build	852	0.384	403.1	0	0
	2. SP weir only	656	0.384	310.5	92.6	206
	3. Bypass + weir	662		172.1	231	513
	Bypass	646	0.207	164.5		
	Flow over weir	16	0.384	7.5		

Note: Concentrations used for 2002 and 2008 are the monitored summer average concentration; for the average the concentration is the average of the 2002 and 2008 monitoring results. The No Build, SP weir only, and flow over weir option concentrations are at the outlet of the wetland. Concentrations used for the bypass option are the summer average at the midpoint of the wetland, near where the bypass weir would be located.

3.5.2 Estimated Cost Effectiveness

Table 3.3 below is summary of construction cost (excluding engineering and other costs), and an estimated cost per pound of phosphorus removed.

Table 3.3. Estimated costs, load reductions, and cost per pound removed for Wetland 639W design options.

	Estimated Cost	Load Reduction (lbs) and Cost per Pound		
		Wet Year	Dry Year	Average
1. No build	$0	0 $0	0 $0	0 $0
2. Sheet pile weir only	$325,000	209 $1,555	199 $1,633	206 $1,578
3. Bypass + sheet pile weir				
To east	$590,000	690 $855	365 $1,616	513 $1,150
To west (pipe)	$890,000	690 $1,290	365 $2,438	513 $1,735
To west (channel)	$410,000	690 $594	365 $1,123	513 $799
To south (pipe)	$770,000	690 $1,116	365 $2,110	513 $1,501

3.5.3 Ongoing Operations and Maintenance

The City of Crystal has agreed to take on responsibility for ongoing operations and maintenance of the weirs and channel. These activities are expected to include but not be limited to:

- Routine inspection of weirs, outfalls, and the channel.
- Removal of debris accumulated on the weirs or blocking the outfalls.
- Removal of trees, woody debris, sediment deltas, and other blockages in the outlet channel.
- Maintenance, repair, and replacement as necessary of weirs, outfalls, and the channel.

3.5.4 Estimated Cost and Funding

The following is a summary of the estimated costs and funding sources for this project. An MPCA Section 319 grant to assist with construction funding extends through August 29, 2014. The benefitting cities include Brooklyn Center, Brooklyn Park, Crystal, and New Hope. Those cities have not yet reached an agreement on cost sharing between the partners. Because the project is located mostly in Crystal, Crystal has agreed to be the lead agency and to manage the construction project if approved.

Costs		
Construction		$410,000
Contingency		85,000
Final Design and Construction Engineering		50,000
Followup Monitoring and Reporting		25,000
	Total	$570,000
Funding		
MPCA Section 319 Grant		$300,000
Shingle Creek WMC		142,500
Cities		127,500
	Total	$570,000

4.0 Literature Cited

American Society of Civil Engineers (ASCE). 1996. Hydrology Handbook. Manuals and Reports on Engineering Practice No. 28. Second Edition.

Mitsch, W. and J. Gosselink. 2000. Wetlands. New York: John Wiley & Sons. Third Edition.

Reddy, K.M and R.D. Delaune. 2008. Biogeochemistry of Wetlands: Science and Applications. Boca Raton, FL: CRC Press.

Appendix A Hydrologic and Hydraulic Modeling Output

Wetland 639W P8 Modeling Results

Flow and Total Phosphorus 1998-2008

Device	Total Volume (Ac-ft)	Total TP Load (lbs/yr)	Average Concentr. (ppm)	Average Flow (cfs)	Average TP Load (lbs/yr)
OVERALL	11,823.31	6,843.09	0.213	1.506	631.33
WS 1	2,832.88	2,235.96	0.290	0.361	206.29
WS 2	365.22	279.35	0.281	0.047	25.77
WS 3	363.26	277.77	0.281	0.046	25.63
Pond 6	158.70	59.62	0.138	0.020	5.50
Pond 7	2,348.20	1,224.73	0.192	0.299	112.99
Pond 8	872.31	329.56	0.139	0.111	30.41
WS 4	3,918.17	2,716.68	0.255	0.499	250.64
MAC-1	422.49	313.86	0.273	0.054	28.96
MAC-2	329.23	224.07	0.250	0.042	20.67
MAC-4	420.90	324.07	0.283	0.054	29.90
MAC-5	857.57	651.71	0.280	0.109	60.13
Pond MAC-9-1A	284.63	138.25	0.179	0.036	12.76
MAC-9-2	273.20	145.92	0.197	0.035	13.46
BNSF Pond	6,257.38	2,774.85	0.163	0.797	256.00
Pond 1-2	6,387.10	2,836.51	0.163	0.813	261.69
SW - 3	9,235.30	5,079.52	0.202	1.176	468.63
Pond MAC-9-1B	281.06	102.46	0.134	0.036	9.45
Total	11,823.31	6,843.09	0.213	1.506	631.33

Note: "Total Volume" and "Total TP Load" is the sum of 1998-2008 output, based on the actual precipitation record during that period, and using the NURP50 particle file for average urban runoff. "Average Flow" and "Average Load" are annual average over that period

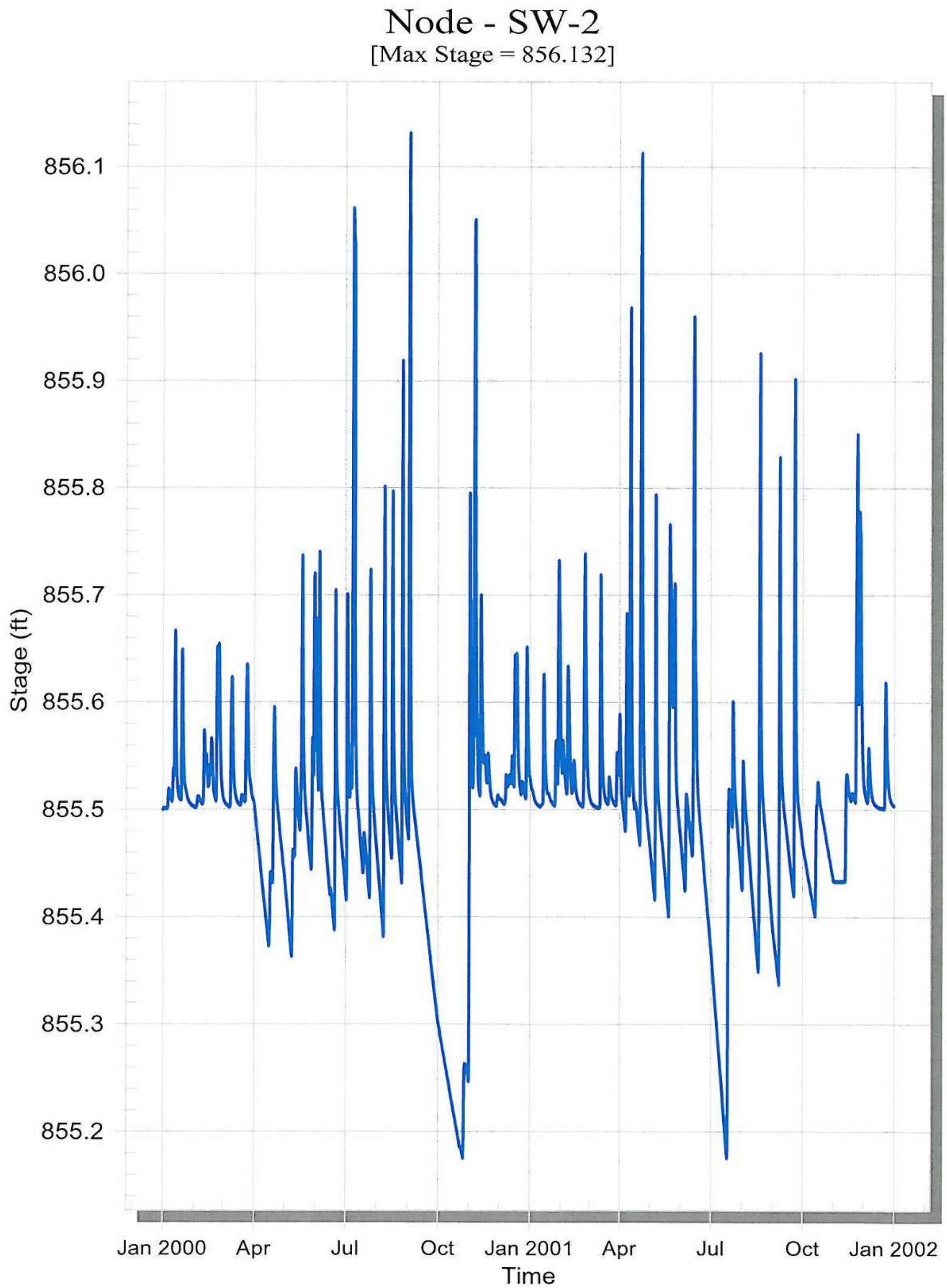
Year	Flow (ac-ft)	TP Load (lbs)	TP Conc (ppm)
1998	1,014	618	0.224
1999	968	580	0.22
2000	1,338	744	0.205
2001	1,258	689	0.202
2002	1,416	784	0.204
2003	978	536	0.202
2004	1,045	605	0.213
2005	1,137	668	0.216
2006	987	601	0.224
2007	938	544	0.213
2008	647	437	0.248
Average	**1,066**	**619**	**0.216**

Wetland 639W XP-SWMM Results

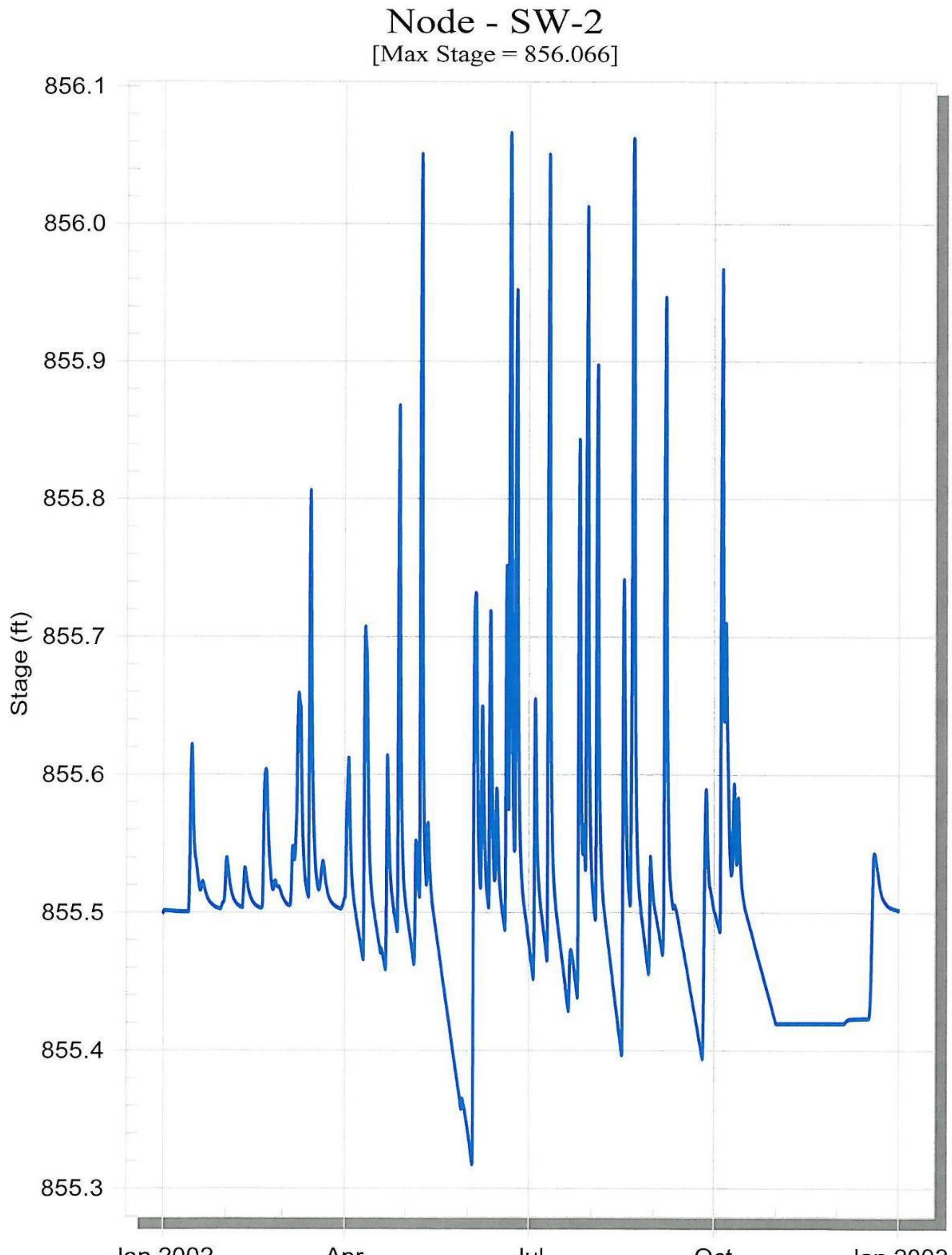
Event/Year	1.5 Inch	2 Year	10 Year	100 Year	1999	2000-2001	2002	2003 - 2004	2005-2006	2007	2008	10 Year	
Precipitation (in)	1.5	2.7	4.1	5.9	31.1	35.0 - 35.8	43.8	28.4 - 32.4	38.3 - 33.7	28.6	22.7	Total (af)	Average (af)
Bypass Model													
Peak Bypass Flow (cfs)	28	35	41	41	28	32	30	37	34	28	19		
Bypass Volume (af)	55	68	74	67	687	1,756	1,087	1,339	1,762	696	478	7,805	780
SP Weir Peak Flow (cfs)	16	169	370	443	9	47	17	206	79	18	0		
SP Weir Volume (af)	6	75	171	282	8	110	38	334	127	14	0	631	63
Peak Wetland Elev.	856.1	856.3	856.6	857.4	856.0	856.1	856.1	856.6	856.2	856.1	855.8		
SP Weir Only Model													
SP Weir Peak Flow (cfs)	NA	260	414	453	40	80	46	232	113	47	29		
SP Weir Volume (af)	NA	145	246	349	688	1,846	1,120	1,652	1,885	700	467	8,357	836
Peak Wetland Elev.	NA	856.4	856.7	857.5	856.1	856.2	856.1	856.6	856.2	856.1	856.1		

SWMM Output Hydrographs, Ten Year Period of Record Precipitation

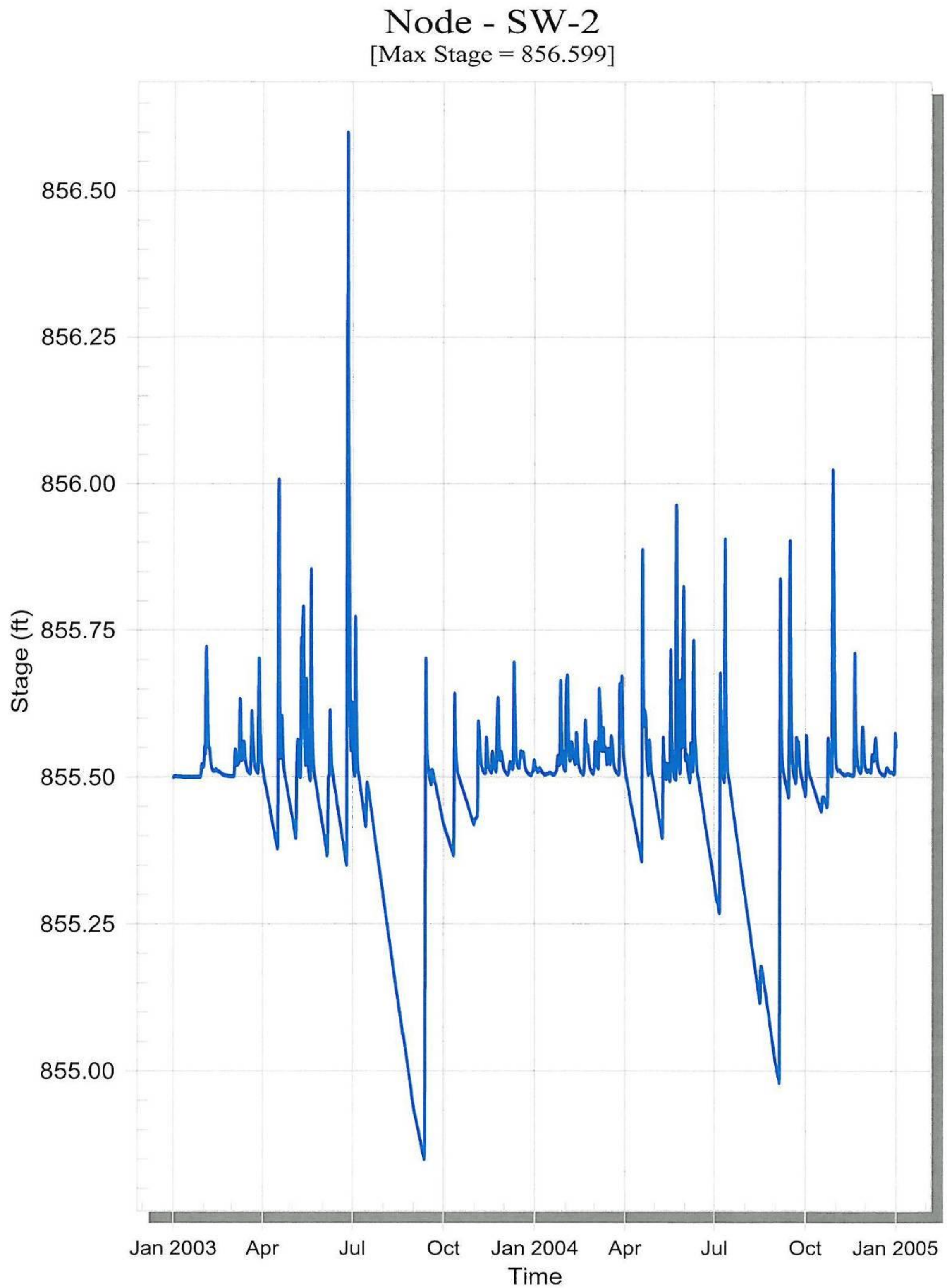
These figures show a ten year precipitation record run through the SWMM model at Node SW-2, which is the proposed sheet pile weir at the wetland outlet. Captions indicate the annual precipitation, where average is 28-33 inches per year. The starting condition on January 1 for each run is a “full” basin. Elevations between 855.5 and 856.0 indicate water being discharged through the channel, while elevations below 855.5 indicate no water being discharged through the channel. Elevations above 856.0 indicate water being discharged both through the channel and over the top of the sheet pile weir.



2000 precipitation = 34.1 inches; 2001 = 39.8 inches

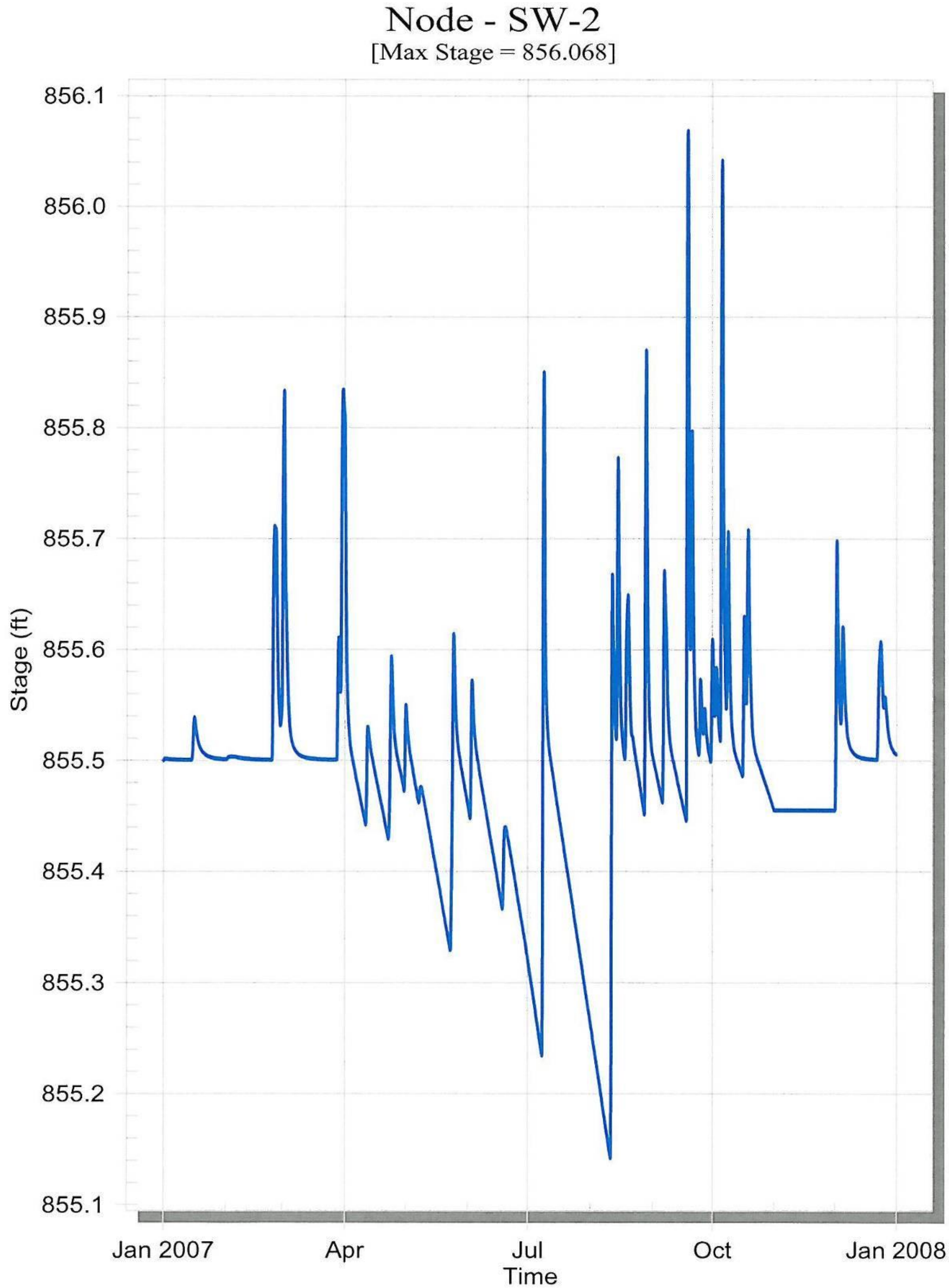


2002 precipitation = 46.7 inches.

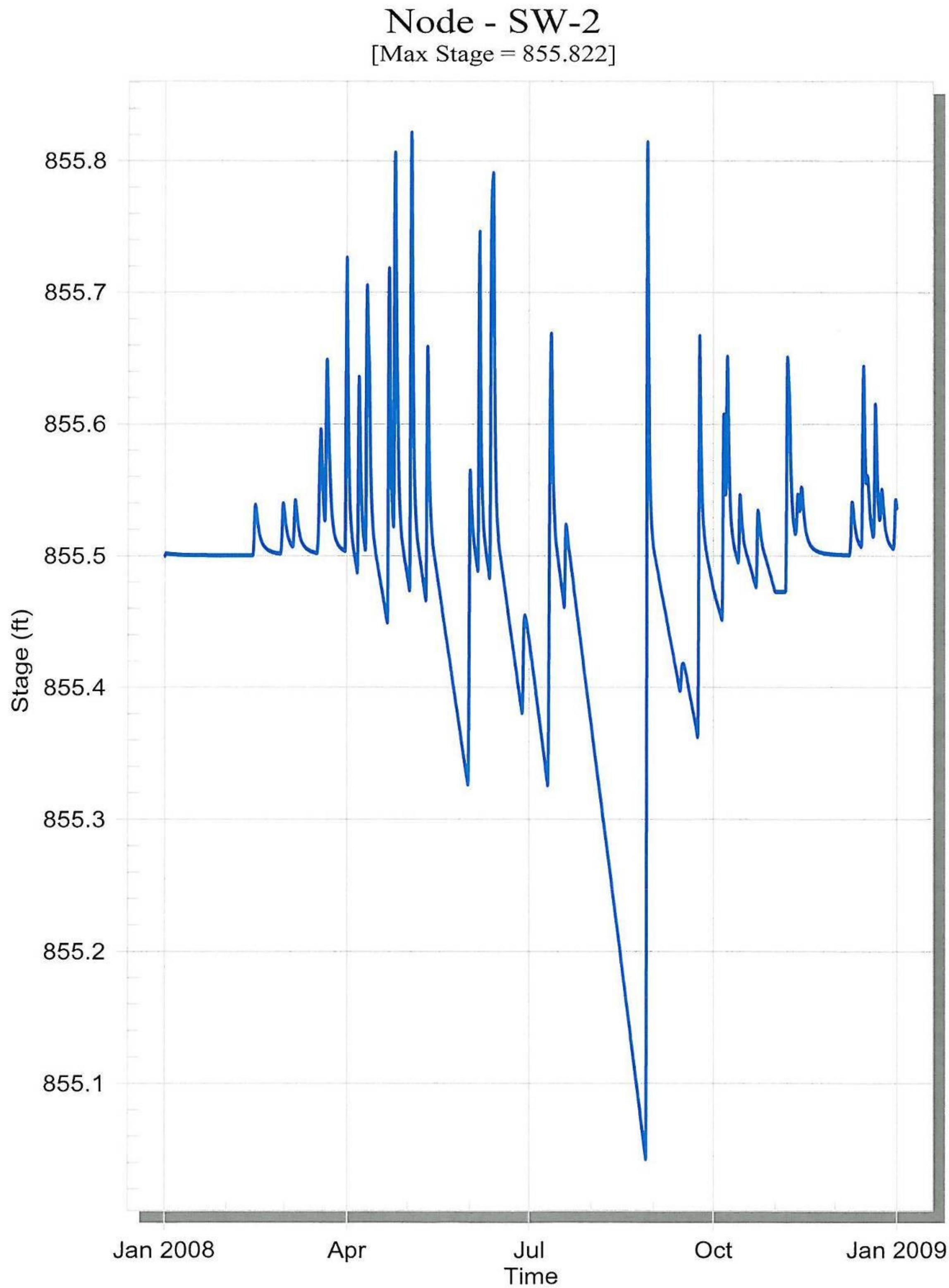


2003 precipitation = 27.1 inches; 2004 = 35.1 inches.

2005 precipitation = 39.2 inches; 2006 = 33.0 inches.



2007 precipitation = 33.0 inches.



2008 precipitation = 20.5 inches.