Basis of Design
Thurston Pond Restoration Project
MDEQ Tracking Code: 2005-0114

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on behalf of  
Ann Arbor Public School District  
September 8, 2008

Submitted to:  
Michigan Department of Environmental Quality  
http://www.michigan.gov/deq  
Environmental Science and Services Division
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1.0 EXECUTIVE SUMMARY
Thurston Pond is a shallow (2-6 feet deep) pond dug out of an existing wetland back in the late 1960s on the northeast side of Ann Arbor, Michigan. This pond is located in the upper subwatershed of Millers Creek (Figure 1) and was initially identified as a stormwater retrofit opportunity in the Millers Creek Watershed Improvement Plan (refer to: http://www.aamillerscreek.org). The pond is underlain by clay but may be receiving and/or discharging groundwater. On an annual basis the pond receives little surface water runoff. The pond’s water surface elevation appears to be mainly a function of the net balance between precipitation and evapotranspiration. There may have been or may still be another water loss route, such as sump pumps, that is contributing to recent low water conditions. Homeowners along the pond claim that at the same time the water level is dropping the pond is also filling in with sediment and decaying plants. However, sediment sampling found the thickness of the unconsolidated sediment lying on the clay bottom averages only 1 – 1.5 feet. Interestingly, five out of seven samples found that this material is predominantly (>86% by weight) inorganic material. Two samples were predominantly organic, approximately 63% by weight. Residents who have lived by the pond since its construction claim that sediment washed into the pond either during construction of the pond or during construction of the Orchard Hills/Maplewood subdivisions and has been there ever since.

Water quality sampling conducted in the pond and in the storm sewer around the pond, showed that the pond is eutrophic to hypereutrophic and that total phosphorus concentrations were higher in the pond (average = 286 ug/L) than in the storm water (average = 87 ug/L). Chlorophyll a concentrations ranged between 35 – 290 mg/m³, with an average of 124 mg/m³. Secchi disk depth never exceeded 11-inches and was often shallower. Thurston Pond has a long fetch and that characteristic combined with carp, turtles and waterfowl in the pond can re-suspend unconsolidated sediments.

The original concept for the pond restoration was 1) to bring in more stormwater by altering inlet connections at Clague Middle School and off of Georgetown Street; 2) altering the outlet to release flows at a low, constant rate and 3) installing a constructed floating wetland aeration system (Ocean Arks Restorer) to primarily remediate (digest) sediments in-place. Stormwater from both inlets would be first treated by swirl concentrators installed in the street. The City of Ann Arbor has agreed to maintain these swirl concentrators in perpetuity (see Maintenance Appendix). The inlet and outlet changes would likely raise the average water surface elevation by a foot or more and achieve a more regular, sustained outlet flow.

However, a topographic and bathymetric survey in conjunction with an XP-SWMM model of the pond, found that any modification that would bring in more storm water through the Georgetown inlet would also increase the chances of
street flooding. An alternate inlet location, on Bluett Street, was selected. While this location drains approximately 54% of the watershed drained by the Georgetown location, it does provide an easement for utility use. This location also necessitates the installation of new storm sewer to divert flows from the Bluett storm sewer to Thurston Pond.

In addition, all the available research on the Restorer technology indicates that the most successful applications and greatest sediment remediation potential is for sediments high in organic matter (OM). As noted above, the majority of the Thurston sediment samples have a very low OM content. In addition, when this concept was presented to the public, a strong consensus against its use arose. Residents thought the system was unappealing in appearance, would be difficult to maintain and operate and difficult to protect from vandalism. Lastly, the Project Team’s opinion was the system would also do little to mitigate the impacts of sediment and associated nutrient resuspension.

Alternatives to the Restorer technology include alum treatment and removal and disposal of sediment. Alum treatment will not mitigate the impacts of sediment resuspension nor is the use of chemical additives appealing. Sediment removal is an attractive alternative for a number of reasons. Firstly, a berm installed on the west side of the pond to keep pond levels higher has been sinking and needs to be built back up. Secondly, interest in restoring an oak savannah between Thurston School and the pond has been gaining momentum both with residents and Ann Arbor Public School officials. This restoration area is immediately adjacent to the pond with sufficient area to hold most of the removed sediment. Both the proposed oak savannah and existing berm could use the fill. Preliminary sediment sampling shows that volatile organic compounds (VOCs), polyaromatic hydrocarbons (PAHs), pesticides, and herbicides are all below detection. Of the three heavy metals tested, cadmium, chromium and lead all were well below MDEQ generic clean-up criteria except chromium, which exceeded the groundwater/surface water interface criteria (criteria = 3,300 ug/kg; average sediment concentration = 8,000 ug/kg). While more sediment testing is needed to determine suitability for re-use on site, the removal and re-use of this material would be a mutual benefit for the pond and the surrounding area.

The final project design has undergone a number of changes. Originally, the design included outlet revisions (low flow orifices) that were later taken out. The orifices are now being added back to the design as an addendum to the construction drawings (See Figure 2 below). The construction drawings are included in Design Drawings Appendix.
Figure 1. Millers Creek Watershed with Thurston Pond to the north (from the Millers Creek Watershed Improvement Plan)
Figure 2. Proposed Thurston Pond Outlet Revisions (to be issued as an addendum to the construction documents)
2.0 PROJECT DEFINITION AND BACKGROUND

This project has been subject to a number of fits and starts as practical constraints and Michigan Department of Environmental Quality (MDEQ) funding constraints changed the course of the project and delayed the final outcomes. These issues delayed the project by more than a year.

As will be described in more detail in later sections of this report, two critical issues – bringing in more storm water and managing pond sediments were the practical constraints that created uncertainties both about achieving the project outcomes and securing reimbursement from MDEQ under the Clean Water Act 319 grant that is partially funding this project. Sediment quality testing for this project indicated that the floating, aerated wetland originally proposed in the grant application would not substantially oxidize pond sediments. Hydraulic modeling indicated that bringing in more water through the main, existing pond inlet from Georgetown would likely create more street flooding. Both concepts were dropped from further consideration near the outset of this project.

Significant project delays occurred while MDEQ debated using grant funds for building a new inlet to the pond and potentially dredging the pond. Eventually, MDEQ approved the use of grant funds for the new inlet but not for dredging. Dredging, for this project, is considered a maintenance activity and therefore not reimbursable under the grant.

Another delay occurred while a draft of this design basis was submitted to and reviewed by MDEQ the winter of 2007-2008. Without the removal of the existing pond sediments, there is a concern that outflows from the pond may increase rather than decrease downstream phosphorus loads. After a preliminary review of the draft design basis, MDEQ gave the project team the go-ahead to finish final design.

We have recently added a catch basin filter in the pond outlet that should improve overall phosphorus and sediment removal capacities (Refer back to Figure 2 above). Also, the Thurston Nature Center Committee (TNCC) is determined to dredge the pond. While a volunteer organization, the TNCC is strongly committed to preserving the pond and is the lead organization for managing the pond and the natural restored areas around the pond. We believe this suite of activities will substantially decrease overall phosphorus loads from this subwatershed of Millers Creek. This improvement is in addition to the higher water levels in the pond and a more controlled release of storm water to Millers Creek that will help mediate peak flows on the stream bed and banks downstream.
2.1 **Project Objectives**

The goal of the Thurston Pond Restoration Project is to create a pond with greater habitat diversity dominated by emergent macrophytes that discharges cleaner water, more frequently to Millers Creek. A secondary goal is to regain the pond as an object of study for the Ann Arbor Public Schools District (AAPSD). These goals will be accomplished by:

- Altering the existing pond inlets to bring more (treated) storm water, more frequently into the pond
- Installing underground proprietary BMP treatment devices (swirl concentrators) on these inlets before they discharge to the pond, and
- Retrofitting the existing pond outlet to allow for controlled and filtered release of water above the permanent water level

Originally, the plan for Thurston Pond was to install a floating, aerated treatment wetland system to primarily remediate (digest) sediments in-place. However, a geotechnical evaluation (See Monitoring Appendix) indicated that most of the sampled sediment is primarily inorganic (~90% inorganic). The success of sediment digestion is a direct function of the sediment organic fraction. After testing, our recommendation which received concurrence from the project steering committee, was against installation of this system.

One other important adjustment from the original proposal is a change in the inlets where the proposed retrofits will occur. Originally, we had proposed to bring in more storm water from the Georgetown and Clague School inlets. However, XP-SWMM modeling showed that the only way to bring in substantially more storm water from Georgetown would also likely increase the possibility of street flooding in Georgetown. This inlet was abandoned and an alternate location was recommended off of Bluett, through a City easement.

Currently, almost all storm water in the neighborhoods north of Thurston Pond bypasses the pond and is discharged directly into Millers Creek (refer to Figure 1). The data needed for understanding water quality will be generated by pond dry weather and wet weather water quality surveys. The objectives of the water quality monitoring for Thurston Pond are:

1) Develop an understanding of existing Thurston Pond water quality. This includes dry and wet weather monitoring of temperature, conductivity, dissolved oxygen (DO), pH, Secchi Disk Transparency (pond only), conductivity (COND), total phosphorus (TP), orthophosphate (PO4), total nitrogen (TN), total kjeldahl nitrogen (TKN), chlorophyll a (pond only), total copper and total zinc.
2) Develop an understanding of the existing stormwater run-off water quality. This includes measuring the storm sewer event mean concentrations (EMCs) of all the parameters listed above, unless otherwise noted.

3) Evaluate the impacts of the proposed BMP installations on pond and storm sewer water quality. This will include comparison of pre-construction and post-construction storm sewer pollutant EMCs and loads and pond water quality.

4) Evaluate the hydrologic impact of re-directing additional storm water from the storm sewer into Thurston Pond, on Millers Creek.

5) Strengthen the local environmental awareness and constituency by developing a volunteer pond monitoring program.

2.2 Project Site Background

Thurston Pond is an 8.4-acre shallow pond at the headwaters of Miller’s Creek (refer to Figure 1) in Ann Arbor, Michigan and an integral part of the Thurston Nature Center (TNC) owned by Ann Arbor Public Schools (AAPS). In 1968, the TNC became only the second Conservation Education Reserve designated by the Michigan Department of Natural Resources. At one time, Thurston Pond was the headwaters of Millers Creek. Storm sewer constructed in 1963 for the Bromley and Orchard Hills neighborhoods now carries most of the drainage around the pond quickly and without upstream detention to the first open channel reach in Millers Creek. During the summer this reach is often stagnant and consistently has the highest phosphorus and *Escherichia coli* (*E. coli*) concentrations found in the creekshed.

Miller’s Creek has a 2.4 square mile watershed and is the smallest named tributary of the Huron River located in the fastest growing area in Ann Arbor. The Miller’s Creek watershed has been identified as a contributor to two Total Maximum Daily Loads (TMDLs) on the Huron River. One TMDL is for phosphorus in the middle Huron and the other is for *E. coli* on Geddes Pond (at the mouth of Millers Creek) on the Huron River.

Currently, the pond water depth ranges between 1 – 6 feet, with an average depth of approximately 2.5 feet (see Monitoring Appendix). The water level is typically more than a foot below the overflow elevation. Over time, with lack of flushing, the occasional untreated storm sewer discharge, direct drainage from adjacent yards, and internally generated load, the pond has been experiencing eutrophication. The pond has been slowly disappearing and in the summer the water column is dominated by algae. The pond used to be part of the environmental education curriculum of adjacent Thurston Elementary School. But over the last several years the decline in density and diversity of aquatic life has prompted AAPSD to take the pond off their list of field trip sites. Thurston
students are now bussed to other pond sites for outdoor environmental education.

2.2.1 Project Site History

Prior to the construction of Bromley and Orchard Hills subdivisions the land surrounding the pond was predominantly agricultural. At that time the pond did not exist. Rather, an aerial photograph from 1940 shows a low lying wetland depression (Figure 3), similar in shape to the present day pond. Construction activities in the 1960’s significantly changed the hydrology and transformed the marsh into a shallow pond. With the additional runoff after the area was developed, the marsh was deepened to function as a stormwater holding basin. Present day sediment accumulations overlay the native soils and range from 1 to 2 feet. A geotechnical investigation found that most of the sampled sediment is inorganic (refer to Findings section below)

A group of six University of Michigan graduate students adopted the site for their master thesis (“Thurston Nature Center Analysis And Ecosystem Management Plan,” May 1997). The thesis detailed existing conditions and proposed three alternative long-term trajectories for the pond, including wetland restoration, pond restoration and a “do nothing,” alternative. The Thurston Nature Center Committee, a dedicated group of volunteer caretakers, has since decided upon pond restoration (see TNCC Plan Appendix).

Figure 3. Pre-Development Thurston “Pond” (red arrow indicates approximate pond location)

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1 Ennett, K., Givinsky S., Howard J., McKenney E., Moore S., Siriamnauyapas W.; The University of Michigan School of Natural Resources and Environment, May 1997; “Thurston Nature Center Analysis And Ecosystem Management Plan”
3.0 STUDY INTENT
The overall goal of this basis of design is to demonstrate that the proposed pond and storm sewer improvements will result in a deeper pond with better water quality. Monitoring includes pre- and post-construction pond water depths, water quality, storm water quality and flows, and downstream Millers Creek hydrology. Improvements in Millers Creek hydrology will be evaluated by developing pre- and post-construction rainfall versus flow response relationships with data from rain and flow meters.

3.1 Methods

3.1.1 Hydrology
A staff gage, level logger and automated rain gage were installed at the pond. The sampling regime included regularly scheduled pond monitoring and wet weather monitoring. Wet weather monitoring was conducted in the storm sewer around the pond (see Figure 4 below).

The level logger (with a barlogger for pressure correction) was installed on the staff gage in a perforated PVC stilling well. The logger recorded pond level once every fifteen minutes. A rain gage was also attached to the staff gage (to discourage vandalism) and recorded rainfall in 5-minute intervals.

A transducer and staff gage were already installed as part of the Millers Creek Watershed Improvement Plan (MCWIP) in 2002 on Pfizer’s property just downstream of Plymouth Road (aka “the Plymouth station”) and the outlet for the storm sewer carrying flows from the Thurston Pond area (Figure 4). The stage-discharge curve at this gage was developed as part of the MCWIP with 9 measurements that spanned a wide range of flow rates. There is also a rain gage located in a large wetland Pfizer restored on Huron River Drive just before the inception of the MCWIP. These are continuous recording gages that are maintained and downloaded regularly by the Huron River Watershed Council (HRWC). Data from these gages was provided by Pfizer and HRWC for use on this project.

The existing, calibrated XP-SWMM model of Millers Creek was used to analyze the pre- and post-construction impacts of storm events on the water levels in the pond. A schematic of the hydraulic model and the description of the original Millers Creek model calibration from Chapter 4 of the MCWIP are included in the Modeling Appendix. The model total event flow volumes in the storm sewer in Bluett Road were checked against the total event volumes measured in the storm sewer during the wet weather monitoring.

A simplified, spreadsheet water balance model was used to forecast pond water levels over an average rainfall (32 inches of rain) year (1991). Correlations were
created between design event rainfall depths and the XP-SWMM model results for pre- and post-construction water level increases in the pond. This correlation is used as the surrogate for the combined rain and runoff inputs to the water balance model. The water balance model was also tested against the water level data collected during the Summer 2006.

3.1.2 Water Quality Sampling
The main objective of the project water quality sampling is to obtain comparable data for pre- and post construction conditions in Thurston pond and the storm sewer downstream from the pond. The water quality parameters include temperature, pH, dissolved oxygen (DO), secchi disk transparency (pond only), conductivity (COND), total phosphorus (TP), orthophosphate (PO4), total nitrogen (TN), total kjeldahl nitrogen (TKN), chlorophyll a (pond only), total copper and total zinc (See Table 1 below). A secondary objective is to evaluate downstream impacts on the flow regime of Millers Creek. Also, the pond monitoring will be conducted by a group of trained volunteers. The final objective is to educate this group of volunteer monitors about water quality issues and strengthen the local environmental constituency.

3.1.3 Pond Water Quality Monitoring
Pre-construction sampling was conducted between June 2006 and October 2006. The project was going to be broken into three phases, including pre-construction, post-construction, and pre-wetland system installation. The current plan is to do one season of pre-construction, and one season of post-construction monitoring.

Pond monitoring with the field meters occurred on a weekly basis from two locations on the pond; at the southern end at the inlet off Georgetown, and at the northern end, near Yorktown (see Figure 4). Volunteers measured the temperature, pH, DO, conductivity and secchi disk depth using hand-held meters. Volunteers also grabbed one weekly water quality sample for analysis by RTI Laboratories. The total number of pond water quality samples for laboratory analysis for the summer monitoring period ranged between 16 and 18, depending on the parameter. In addition, at least 2 duplicates and 2 trip blanks were run for the summer monitoring period.

Surface grab sampling was used for collecting water quality samples in Thurston Pond. Samples were collected from the shore in an open container from a single point at, or near the water surface (Figure 5). If the water depth was less than 1.5 ft, the measurements were made at a depth equal to one-third of the total depth measured from the water surface. However, if the depth was greater than 1.5 ft, temperature, pH, conductivity, and DO were measured at approximately 1 ft below the water surface. Field personnel used a hand-held probe to measure DO, pH, temperature and conductivity of individual grab samples from all locations. A field sampling standard operating procedure (SOP), equipment list,
field data sheet, chain of custody form and field meter SOPs are included in the Monitoring Appendix.

### Table 1. Water Quality Testing Parameters and Ranked Priority

<table>
<thead>
<tr>
<th>Test Results Obtained</th>
<th>Test</th>
<th>Description</th>
<th>Rank</th>
<th>Sampling/Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Field</td>
<td>Temperature</td>
<td>Using held-probe in-situ water samples are tested for temperature and recorded by hand.</td>
<td>P</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>Using held-probe in-situ water samples are tested for pH, and recorded by hand.</td>
<td>P</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>DO</td>
<td>Using held-probe in-situ water samples are tested for dissolved oxygen content, and recorded by hand.</td>
<td>P</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Secchi Disk Transparency</td>
<td>An 8 inch (20 cm) diameter disk with alternating and alternating black and white pattern, which is placed into the water until it is no longer visible. The depth at which this transition occurs is recorded by hand.</td>
<td>P</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Conductivity</td>
<td>Using held-probe in-situ water samples are tested for conductivity and recorded by hand.</td>
<td>S</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Staff Gauge</td>
<td>Read and record staff gage reading</td>
<td>P</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Aquatic Vegetation Survey</td>
<td>Consultant and volunteer to perform aquatic vegetation coverage estimate</td>
<td>S</td>
<td>C/V</td>
</tr>
<tr>
<td>Laboratory Testing</td>
<td>TP</td>
<td>Pond grab and automated sampler composite sample (EMC)</td>
<td>P</td>
<td>V/L</td>
</tr>
<tr>
<td></td>
<td>PO4</td>
<td>Pond grab and automated sampler composite sample (EMC)</td>
<td>P</td>
<td>V/L</td>
</tr>
<tr>
<td></td>
<td>TN</td>
<td>Pond grab and automated sampler composite sample (EMC)</td>
<td>P</td>
<td>V/L</td>
</tr>
<tr>
<td></td>
<td>TKN</td>
<td>Pond grab and automated sampler composite sample (EMC)</td>
<td>P</td>
<td>V/L</td>
</tr>
<tr>
<td></td>
<td>Chlorophyll a</td>
<td>Pond grab sample only</td>
<td>P</td>
<td>V/L</td>
</tr>
<tr>
<td></td>
<td>Total Copper</td>
<td>Pond grab and automated sampler composite sample (EMC)</td>
<td>S</td>
<td>V/L</td>
</tr>
<tr>
<td></td>
<td>Total Zinc</td>
<td>Pond grab and automated sampler composite sample (EMC)</td>
<td>S</td>
<td>V/L</td>
</tr>
</tbody>
</table>

v = volunteer, c = consultant, l = lab
P = Primary parameter
S = Secondary parameter
Figure 4. Thurston Pond Monitoring Locations
Following the stormwater re-routing and BMP retrofit, pond depths will likely range from 2-4 feet with a few holes as much as 6-feet deep. There is a possibility that the sediment-water interface could go anoxic and sediments release adsorbed phosphorus into the water column. Some DO profiling was done at the Georgetown inlet area (the deepest area of the pond). As part of the monitoring, DO was measured just above the sediment-water interface at less than 0.5 mg/L so a sample was grabbed at this depth and analyzed for total phosphorus.

3.1.4 Wet Weather Monitoring

The wet weather monitoring consisted of automated depth and water quality sampling at one location on Bluett Road and one location just downstream of the Clague School outlet (refer to Figure 4 above). Modeling has shown that for pre-construction conditions the pond rarely produces any outflow (less than once a year). The wet weather water quality parameters are the same ones proposed for the pond monitoring, except for chl a (measured in the pond only).

A wet weather event was defined as at least 0.25 inches of rainfall over a twenty-four hour period. Ideally, a wet weather event was preceded by at least 72 hours of dry weather (<0.05 inches of precipitation). However, due to the need to capture as many rainfall events between June and August as possible, the 72-hour antecedent dry weather requirement may be waived for some events.

An Isco model 3700 automatic sampler was used for grabbing water quality samples in the storm sewer. Samplers were set in existing manholes and programmed to begin their sampling routine at a pre-determined water depth, approximately 0.1 feet and 0.2 feet. An Isco submerged probe monitored the flow and depth and when set levels were reached, triggered the sampler to begin
its sampling routine. The sampling routine was time-paced grab sampling. The
time intervals varied at set points to provide increased sampling frequency during
peak flow and decreased sampling frequency during decreasing flows. The data
was downloaded after rain events which were large enough to trigger the
sampler to collect samples.

Samples grabbed by the auto sampler were stored in individual bottles. The
individual grab samples were used to create a composite sample in a single
bottle using the flow-proportioning method. In this manner, more weight
(volumetrically speaking) is given to the concentrations occurring during high flow
rather than at low flow. This assures that the mass of pollutant in each grab is
fairly represented in the composite. The composite represents the flow-weighted
average concentration taken over the whole event or monitoring period. The
result is referred to as the event mean concentration (EMC) and is the
recommended concentration unit for analysis by the ASCE/EPA joint project on
urban stormwater BMP performance analysis (GeoSyntec, et.al., 2001). The
composite samples were sent to RTI Laboratories for the required testing.

3.1.5 Bathymetry Survey
Pond bathymetry was surveyed by running transects across the pond. Both
depth to top of the unconsolidated sediment and to refusal were recorded. Inlet
and outlet information and topography around the immediate pond perimeter
were also collected. The pond bathymetry survey is included in the Monitoring
Appendix.

3.1.6 Sediment Survey
The objectives of the sediment sampling were to characterize and assess the
thickness of the bottom sediment overlying the native clay within the pond,
determine the organic/inorganic fraction of these samples and determine the
concentrations on priority pollutants in the sediment samples.

Sediment sample locations were selected following the bathymetry survey.
Locations were selected to capture a range of sediment depths and spacing
around the pond. Samples were collected manually by Soils and Materials
Engineers (SME) on March 7, 2006 by advancing a 4-foot macro core sampler
into the pond sediment from a flat bottom boat platform (see Figure 6 below). Six
of the samples were submitted for laboratory analysis of total phosphorus,
ammonia, nitrate, nitrite, iron and manganese. Two samples in the immediate
vicinity of the Clague and Georgetown inlets were submitted for laboratory
analysis of pesticides, herbicides, volatile organic compounds (VOCs),
polynuclear aromatic hydrocarbons (PAHs), cadmium, chromium and lead. The
sediment samples were analyzed by Fibertec Environmental Services in Holt,
Michigan. Results were compared to MDEQ Part 201 Cleanup Criteria. The data
and map of sediment sampling locations are included in the Monitoring
Appendix.
Figure 6. Sediment Sampling on Thurston Pond
4.0 FINDINGS

The topographic survey and XP-SWMM model results demonstrate that there is little annual flow contribution from the Georgetown inlet and the Clague inlet. In fact, the Georgetown inlet is always completely submerged. There is some evidence to suggest that the Georgetown inlet has settled significantly since the pond was excavated out years ago (See Figure 7 below). The model shows that only a storm event somewhere between the 10-year design and 100-year design event size causes overflow in the Georgetown inlet.

The Clague inlet is fed by two stormwater lines, one that drains a yard drain on the southeast side of the school and one that carries overflow from a manhole that captures the school parking lot runoff on the southwest side of the school. The line that carries flow to the pond inlet is set almost a foot higher than the storm sewer that carries flow out into Bluett and eventually down to the outlet on Millers Creek below Plymouth Road.

Although there were problems with the collected water level data from the pond, a simplified water balance model, flow data from Millers Creek and anecdotal evidence suggests that at the time of the monitoring there may have been another unaccounted loss route for pond water. Visual inspection suggests there is rarely any flowing water in the pond outlet. The unknown loss route would have to be a subsurface loss. However, the general groundwater flow is likely towards Millers Creek. Inspection of recorded pond water level and Millers Creek flow data suggests that some recorded water level losses exceeded estimated evapotranspiration rates and Millers Creek base flows combined.

Some possible explanations for these discrepancies include erroneous water level data, groundwater seepage into sanitary sewer or groundwater flowing beneath Millers Creek. Another explanation is that the sinking berm on the pond’s west side is allowing water to get behind the berm and there is an area behind the berm that is permeable enough to create a significant loss route. Part of this project will raise the elevation of the berm back to its original design to cut off this potential loss route. No matter the loss route, any additional water brought in with stormwater inflows from this project will help increase water levels in the pond.

The borings show a fairly homogeneous bottom layer of clay. Anecdotal evidence also suggests that following the original construction work, the pond was completely underlain by clay. It is hard to know at this time if this clay layer has been penetrated and if this penetration is now a loss route.
Figure 7. Thurston Pond (1969) looking southwest. Georgetown inlet pipes on left side of the picture (these pipes are now submerged)

4.1 Hydrology

For the most part, the relationships found between temperature, rainfall, pond water levels, flow in the storm sewer in Bluett and at Clague and flow in Millers Creek showed expected trends. For instance, Thurston Pond never overflowed (nor did the water balance model predict any overflows) during the Summer 2006 monitoring period and for many days out of the summer, little to no flow was recorded in Millers Creek. However, the conversion of absolute recorded pressure to pond water depths corrected for barometric pressure, did not appear to yield consistent results. The deployment of two different manufacturers’ sensors for absolute pressure and barometric pressure appeared to unnecessarily complicate the data conversion to pond depths and may have led to erroneous measurements.

The XP-SWMM model was used to forecast flows into the pond and pond water level changes due to rainfall for both pre- and post-construction conditions. The results from this model were also used as inputs to a simplified water balance model to look at pond water level changes over an average water year. The water balance model appears to corroborate the finding that there are problems with the measured water surface elevation data. The model results also suggest there may be or have been another water loss route from the pond that impacts the water surface elevation. This water loss route may be through cracks in storm or sanitary sewer or may have been sump pumps that at the time of monitoring were discharging to sanitary sewer. All sump pumps have now been disconnected as part of the City of Ann Arbor’s sump pump disconnection program. As of the submittal of this design basis, we are also re-deploying a recently purchased water level logger with built-in barometric pressure and temperature compensation to check pond water levels again.
4.1.1 Thurston Pond Water Levels and Millers Creek Flows

The absolute pressure and barometric pressure-corrected readings converted to water depths for Thurston Pond are shown in Figure 8 below. Also shown is the corrected water balance estimates for pond water depths over the same period. The water balance model inputs were created from the XP-SWMM model estimates for changes in pond water level due to rainfall and runoff estimates for design rain events (0.25 in, 0.5 in, 1-year, 2-year, 5-year, 10-year, and 100-year). These inputs were developed by correlating the total rainfall by event with the estimated rise in pond level (see Figure 9 below).

We used the HOBO Onset Water Level Logger for measuring absolute pressure and the Solinst Barologger to correct absolute pressure for atmospheric (barometric) pressure. Using the corrections specified by the manufacturers appears to lead to results that could not be explained. For instance, the plot of barometric pressure-corrected data shows water level rises during periods without rainfall. We have recently purchased a self-corrected water level logger (Winter, 2007) and will deploy it at the time of submittal for this design basis.

Millers Creek baseflows measured at the Plymouth gage at the beginning of the Summer 2006 ranged roughly between 0.1 cfs and 0.2 cfs. The month of July 2006 there were quite a few days where the flow was virtually zero. The possibility of the lack of flow at the Plymouth station was confirmed visually during the field work for the MCWIP. There are definitely periods when the flow at that station essentially drops to zero. The meter stopped functioning the second
week of August, 2006 but was back up and running the beginning of September, 2006. However, the base flows appeared to jump up to the 0.5 cfs to 0.8 cfs range after re-deployment of the transducer. This may have been a result of changing the depth of the transducer at the monitoring location at the time of re-deployment or simply have been more baseflow. However, the large jump in baseflow remains suspicious.

![Graph showing correlations between total event rainfall and estimated Thurston Pond water level rise for Pre- and Post-Construction conditions. The graph includes three lines: Pre-, Adj-Pre-, and Post-, with corresponding equations: $y=4.2901x$, $R^2 = 0.982$ for Pre-construction; $y=2.9449x$, $R^2 = 0.988$ for Adj-Pre-construction; and $y=2.3x$ for Post-construction.]

**Figure 9.** Correlations between total event rainfall and estimated Thurston Pond water level rise for Pre- and Post-Construction conditions (adjusted-Pre-construction scenario revised to match maximum water elevation rise from pond water level data)

### 4.1.2 Pond Water Balance Model

The water balance input was derived from the correlation between total event rainfall and the XP-SWMM-predicted change in water surface elevation. The XP-SWMM model accounts for both the total rainfall that falls on the pond and the total runoff coming into the pond (refer to Figure 9 above). This model was checked against the measured water surface elevation data during the 2006 monitoring period. However, the model results could not be adjusted to match all the variations in the measured data. The model was, however, adjusted so that the model results approximated the maximum recorded pond rise during that period (the September 12-13 event). It was felt that the possible error associated with the conversion issues between absolute and barometric pressure would be minimized during this relatively large event and rise in pond elevation.

This adjustment to approximate the data required a decrease in the water level rise correlation created with XP-SWMM of approximately 22% (from $y = 2.9449x$ to $y=2.3x$, where $y =$ pond rise in inches and $x =$ total rainfall in inches). However, the model could still not duplicate the drastic decrease in water level, for instance, over the period between 9/30 and 10/2 (refer back to Figure 8). This
decrease would require a constant loss of more than 2.5 cfs over and above the evapotranspiration (ET) loss in the pond, far exceeding base flows in Millers Creek during that period.

It is not entirely clear why this downward adjustment is necessary. The XP-SWMM model does not show any runoff entering the pond until the rainfall surpasses the 10-year event size (3.5 inches over 24 hours). Theoretically, the water balance for Thurston Pond is almost entirely met by the net differences between precipitation and evapotranspiration over the pond itself.

Millers Creek flow at the Plymouth station for 2006 has been collected and collated for the pre-construction monitoring of this project. Figure 10 below is an example of the kind of analyses we will use to determine potential impacts of this project on downstream flows.

![Figure 10. Relationship of Total Daily Rainfall and Total Daily Flow in Millers Creek at the Plymouth Station](image)

### 4.2 Pond Water Quality
Thurston Pond’s metabolism can be clearly characterized as eutrophic and based on trophic system cut-offs for chlorophyll a (chl a) established by
limnologists, it verges on hypereutrophic (see: Table 2 below from: Wetzel, R.G., 1975. Limnology, 2nd Ed., Saunders College Publishing, Philadelphia). This is an ecosystem with extremely high productivity (See Figure 11 below). However, based on the hydrologic analyses, it appears that most of the pond phosphorus is from internal loading. On average, over 90% of the pond phosphorus is bound up as particulate and is probably associated with organic matter (see Table 3 and Figure 12). In fact, the ratio of total phosphorus to dissolved phosphorus increases almost in direct proportion to the increase in algal production as expressed by chl a.

The only measured dissolved oxygen (DO) concentrations lower than 1 mg/L were in the deepest hole in the pond near Station 1. Concentrations between 0.25 mg/L and 0.45 mg/L were found at about the sediment-water interface in about 4-5 feet of water. Measured total and dissolved phosphorus at this depths were 410 and 41 ug/L, respectively.

Table 2. General Lake Trophic Classification (Wetzel, 1975)

<table>
<thead>
<tr>
<th>Lake Productivity Classification</th>
<th>Total Phosphorus μg/L</th>
<th>Chlorophyll a (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligotrophic</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Mesotrophic</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>Eutrophic</td>
<td>84</td>
<td>14</td>
</tr>
<tr>
<td>Hypereutrophic</td>
<td>&gt;750</td>
<td>100-150</td>
</tr>
</tbody>
</table>

Figure 11. Thurston Pond water temperature and Chlorophyll a concentrations at Stations 1 and 2 from June through September 2006.
The secchi disk depths are very shallow (see Table 3a below) and are likely due both to the very high system productivity and to suspended sediment. The pond is shallow, has a relatively long fetch and is also populated by carp, geese and snapping turtles, all species with a tendency to re-suspend sediment. Wetzel (1975) notes that phosphorus release from sediments can roughly double if the sediments are disturbed by agitation from turbulence.

The pond pH is on the basic side, but all of the pH readings were taken during the day and may reflect the impact of algal photosynthesis. Dissolved oxygen actually tends to stay high (> 5 mg/L) which is probably due to the shallow water depths and a high transfer rate of oxygen at the atmosphere-water interface. It also appears most of the nitrogen is part of dissolved organic matter (as measured by Total Kjeldahl Nitrogen (TKN)).

Copper and zinc concentrations were measured in the pond as well (see Table 3 and Figure 13 below). While we do not believe the pond receives much storm water, the copper and zinc concentrations in the pond are roughly equivalent to the concentrations measured in the storm water (see following section) around the pond. Because the pond rarely overflows, anything that gets into the pond can have a very long turnover time. One explanation for the roughly equivalent metal concentrations is that additions of copper and zinc back when the pond was used for storm water on a more ad hoc basis have mostly remained in place. This hypothesis is bolstered by the highly inorganic nature of the unconsolidated sediment found in the cores and the apparently low volume of incoming stormwater.

<table>
<thead>
<tr>
<th>Temp (Celsius)</th>
<th>Secchi Disk Depth (inches)</th>
<th>pH</th>
<th>DO (mg/L)</th>
<th>Cu (ug/L)</th>
<th>Zn (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Average</td>
<td>24</td>
<td>7</td>
<td>9.0</td>
<td>10.1</td>
<td>44</td>
</tr>
<tr>
<td>Maximum</td>
<td>32</td>
<td>11</td>
<td>9.9</td>
<td>19.6</td>
<td>97</td>
</tr>
<tr>
<td>Minimum</td>
<td>10</td>
<td>3</td>
<td>8.0</td>
<td>3.2</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chlorophyll a (mg/m³)</th>
<th>TP (ug/L)</th>
<th>PO4 (ug/L)</th>
<th>TKN (mg/L)</th>
<th>NO3 (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Average</td>
<td>124</td>
<td>286</td>
<td>28</td>
<td>7.81</td>
</tr>
<tr>
<td>Maximum</td>
<td>290</td>
<td>440</td>
<td>120</td>
<td>18.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>35</td>
<td>91</td>
<td>5</td>
<td>2.00</td>
</tr>
</tbody>
</table>
Figure 12. Thurston Pond Total Phosphorus and Orthophosphate concentrations at Stations 1 and 2 from June through September 2006.

Figure 13. Thurston Pond Copper and Zinc concentrations at Stations 1 and 2 from June through September 2006.
4.3 *Wet Weather Monitoring*

The wet weather monitoring captured the storm sewer flow and water quality characteristics of six separate events, with all but one event preceded by at least 48 hours of dry weather with a total rainfall greater than 0.25 inches for all events (see Table 4 and Table 5 below).

When the measured total flows through the Bluett storm sewer are plotted against the XP-SWMM-estimated flow through the storm sewer there is a divergence between the two sets of volumes, but the divergence is not consistent and may simply be due to the vagaries of the actual event hyetographs as opposed to the consistent SCS Type-II design event 24-hour hyetographs run in XP-SWMM (See Figure 14 below).

<table>
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<tr>
<th>Characteristic</th>
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<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7/11</td>
</tr>
<tr>
<td>Duration</td>
<td>(hours)</td>
<td>14</td>
</tr>
<tr>
<td>Antecedent Dry Period</td>
<td>(days)</td>
<td>4.2</td>
</tr>
<tr>
<td>Total Rain</td>
<td>(in)</td>
<td>0.96</td>
</tr>
<tr>
<td>Peak Hourly Rainfall</td>
<td>(in/hr)</td>
<td>0.49</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Units</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>7/11</td>
</tr>
<tr>
<td>Bluett Peak Flow</td>
<td>(cfs)</td>
<td>1.50</td>
</tr>
<tr>
<td>Bluett Total Flow</td>
<td>(cf)</td>
<td>5,669</td>
</tr>
<tr>
<td>Clague Peak Flow</td>
<td>(cfs)</td>
<td>0.77</td>
</tr>
<tr>
<td>Clague Total Flow</td>
<td>(cf)</td>
<td>5,326</td>
</tr>
</tbody>
</table>

The wet weather event mean concentrations (EMCs) are summarized in Table 6 below. This table is broken up into three pieces – the first being the combined statistics of all the collected EMCs, the second is for the Bluett storm sewer results alone and the third the Clague Middle School results along.

These wet weather EMCs fall right in line with estimates from other studies. For instance, the total suspended solids, total copper and total zinc concentrations are very close to the EMCs estimated for low and medium residential land use areas for the Rouge River National Wet Weather Demonstration Project\(^2\). The total phosphorus and orthophosphate EMCs are actually closer to the Rouge River EMCs for urban open and agricultural land uses.

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\(^2\) Rouge River National Wet Weather Demonstration Project, 1996. Preliminary Pollutant Loading Projections for Rouge River Watershed and Interim Non Point Source Pollution Control. RPO-NPS-TR07.00; Table 3.4.
Figure 14. Total Measured and Pre-Construction XP-SWMM-Predicted Flow through the Bluett Storm Sewer based on rainfall event size

Table 6. Monitored Wet Weather Water Quality

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Count</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>(ug/L)</td>
<td>12</td>
<td>22</td>
<td>73</td>
<td>3</td>
</tr>
<tr>
<td>Zinc</td>
<td>(ug/L)</td>
<td>12</td>
<td>48</td>
<td>76</td>
<td>25</td>
</tr>
<tr>
<td>TSS</td>
<td>(mg/L)</td>
<td>12</td>
<td>21</td>
<td>110</td>
<td>0.5</td>
</tr>
<tr>
<td>TP</td>
<td>(ug/L)</td>
<td>12</td>
<td>87</td>
<td>180</td>
<td>18</td>
</tr>
<tr>
<td>OP</td>
<td>(ug/L)</td>
<td>12</td>
<td>50</td>
<td>130</td>
<td>5</td>
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</tbody>
</table>

**Bluett**

<table>
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<tr>
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<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>(ug/L)</td>
<td>6</td>
<td>17</td>
<td>69</td>
<td>3</td>
</tr>
<tr>
<td>Zinc</td>
<td>(ug/L)</td>
<td>6</td>
<td>46</td>
<td>76</td>
<td>25</td>
</tr>
<tr>
<td>TSS</td>
<td>(mg/L)</td>
<td>6</td>
<td>22</td>
<td>110</td>
<td>0.5</td>
</tr>
<tr>
<td>TP</td>
<td>(ug/L)</td>
<td>6</td>
<td>116</td>
<td>180</td>
<td>44</td>
</tr>
<tr>
<td>OP</td>
<td>(ug/L)</td>
<td>6</td>
<td>76</td>
<td>130</td>
<td>44</td>
</tr>
</tbody>
</table>

**Clague**

<table>
<thead>
<tr>
<th></th>
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<th>Count</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>(ug/L)</td>
<td>6</td>
<td>27</td>
<td>73</td>
<td>3.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>(ug/L)</td>
<td>6</td>
<td>49</td>
<td>66</td>
<td>30</td>
</tr>
<tr>
<td>TSS</td>
<td>(mg/L)</td>
<td>6</td>
<td>20</td>
<td>60</td>
<td>0.5</td>
</tr>
<tr>
<td>TP</td>
<td>(ug/L)</td>
<td>6</td>
<td>59</td>
<td>110</td>
<td>18</td>
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<tr>
<td>OP</td>
<td>(ug/L)</td>
<td>6</td>
<td>24</td>
<td>63</td>
<td>5</td>
</tr>
</tbody>
</table>
4.4 **Sediment Quality**

Sediment at four of the six locations (S1, S2, S3, and S5) consisted of unconsolidated sandy or silty clay with some silt and/or trace to some sand and/or gravel. Sediment at S4 and S6 consisted of primarily unconsolidated fine to coarse sand with some silt and trace to some clay. Consolidated native sandy clay was encountered beneath the sediments at S1 through S5 and S7. Particle Size Distribution Reports for S1 through S7 are included in the Monitoring Appendix.

In general, sediment in the western portion of the pond, represented by samples S4 through S6, appeared coarser than the sediments in the eastern portion of the pond. The sediment thickness ranged from nine inches at S3 to 36 inches at S6. SME was unable to advance the macrocore beyond 36 inches at S6. Sediment thicknesses measured during sampling activities can be found in the Monitoring Appendix.

Table 7 below presents a summary of the laboratory results for organic content, loss by wash, iron, manganese, nitrogen ammonia, nitrogen nitrate, nitrogen nitrite, and total phosphorus. In summary, organic content in clay samples was reported at 1.8% (S7) and 2.1% (S1). Organic content in sediment samples ranged from 7.4% (S5) to 64% (S4). Loss by wash for clay was 54.8% (S1) and 66.3% (S7). Loss by wash for sediment ranged from 25.4% (S6) to 97.1% (S2). Concentrations of total phosphorus in sediment samples ranged from 130,000 parts per billion (µg/kg) to 630,000 µg/kg. Concentrations of ammonia in sediment ranged from 37,000 µg/kg to 430,000 µg/kg. No concentrations of nitrate or nitrite were detected in sediment samples above the reporting limit of 10,000 µg/kg.

Table 8 below compares the laboratory results from sediment samples S1 and S5 for volatile organic compounds (VOCs), polyaromatic hydrocarbons (PAHs), pesticides, herbicides, cadmium, chromium, and lead to the Michigan Department of Environmental Quality (MDEQ) Part 201 Generic Residential Cleanup Criteria and Screening Levels of the Administrative Rules for Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, dated January 23, 2006. Concentrations of cadmium, chromium, and lead were detected above reporting limits, but below MDEQ Part 201 Generic Residential Cleanup Criteria. No concentrations of VOC, PAHs, herbicides, or pesticides were detected above laboratory reporting limits in analyzed samples.

Results from S1 and S5 collected from near the storm water inlets indicate re-use of sediment on-site would be acceptable. Results from S1 and S5 also indicate sediment disposal at a Type II landfill would likely be acceptable. However, additional waste characterization analyses may be required by a selected disposal facility. Also, additional sediment sampling and laboratory testing would
be necessary to place dredged sediment from Thurston Pond at a location off-site other than a Type II landfill.

Table 7. Organic content, nutrient, iron and manganese concentrations of Thurston Pond sediment samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S1 Sediment 3/7/06</th>
<th>S1 Clay 3/7/06</th>
<th>S2 Sediment 3/7/06</th>
<th>S3 Sediment 3/7/06</th>
<th>S4 Sediment 3/7/06</th>
<th>S5 Sediment 3/7/06</th>
<th>S6 Sediment 3/7/06</th>
<th>S7 Clay 3/7/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Content</td>
<td>12.0%</td>
<td>2.1%</td>
<td>13.7%</td>
<td>11.3%</td>
<td>64.0%</td>
<td>7.4%</td>
<td>62.8%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Loss by Wash</td>
<td>53.2%</td>
<td>54.8%</td>
<td>97.2%</td>
<td>69.2%</td>
<td>33.5%</td>
<td>55.3%</td>
<td>25.4%</td>
<td>66.3%</td>
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<tr>
<td>Iron</td>
<td>15,000,000</td>
<td>NA</td>
<td>20,000,000</td>
<td>10,000,000</td>
<td>9,600,000</td>
<td>1,600,000</td>
<td>20,000,000</td>
<td>NA</td>
</tr>
<tr>
<td>Manganese</td>
<td>100,000</td>
<td>NA</td>
<td>200,000</td>
<td>110,000</td>
<td>77,000</td>
<td>120,000</td>
<td>20,000</td>
<td>NA</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>74,000</td>
<td>NA</td>
<td>430,000</td>
<td>73,000</td>
<td>300,000</td>
<td>37,000</td>
<td>230,000</td>
<td>NA</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>&lt;10,000</td>
<td>NA</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>NA</td>
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<tr>
<td>Nitrite-N</td>
<td>&lt;10,000</td>
<td>NA</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
<td>&lt;10,000</td>
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<tr>
<td>Phosphorus</td>
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<td>130,000</td>
<td>230,000</td>
<td>210,000</td>
<td>NA</td>
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</tbody>
</table>

NOTES:
(1) Concentrations reported in ug/kg (parts per billion or ppb), unless otherwise noted.
(2) NA = Not analyzed.
(3) Sediment = unconsolidated sample; Clay = consolidated sample

Table 8. Priority pollutant concentrations of Thurston Pond sediment samples

<table>
<thead>
<tr>
<th>Constituent</th>
<th>MDEQ Part 201 Generic Residential Cleanup Criteria, January 23, 2006</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drinking Water Protection Criteria</td>
<td>Groundwater/Surface Water Interface Protection</td>
</tr>
<tr>
<td>VOCs</td>
<td>CS</td>
<td>CS</td>
</tr>
<tr>
<td>PAHs</td>
<td>CS</td>
<td>CS</td>
</tr>
<tr>
<td>Herbicides</td>
<td>CS</td>
<td>CS</td>
</tr>
<tr>
<td>Pesticides</td>
<td>CS</td>
<td>CS</td>
</tr>
<tr>
<td>Cadmium</td>
<td>6,000</td>
<td>3,000</td>
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<tr>
<td>Chromium (total)</td>
<td>30,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Lead (total)</td>
<td>700,000</td>
<td>2,500,000</td>
</tr>
</tbody>
</table>

NOTES:
(1) Concentrations reported in ug/kg (parts per billion or ppb) unless otherwise noted.
(2) Analytical results were compared to the MDEQ Part 201 Generic Cleanup Criteria and Screening Levels for residential site use, dated January 23, 2006.
(3) ID = Inadequate data to develop criterion.
(4) NA = Not analyzed.
(5) NLV = Hazardous substance is not likely to volatilize under most conditions.

4.5 Forecast Improvements

We utilized the runoff water quality measurements and the water balance model to estimate the volume of additional treated runoff into the pond, the potential change in annual water surface elevations and the potential water quality improvements in terms of downstream phosphorus loading to Millers Creek and to the Huron River. While there are still questions about the lower than predicted water levels in the pond for existing conditions, these questions do not affect the total predicted additional annual volume of water forecast to enter the pond following implementation of the improvements. Approximately 9 million additional cubic feet of water is forecast to enter the pond after the new inlet is constructed. This is an additional 9 million cubic feet of runoff captured in the pond that will result in increases to the pond water surface elevation and number of pond discharges and decreases in peak runoff rates in Millers Creek (see Figure 15 below). Even if the increased water input does not result in significant additional overflows into Millers Creek, from a non-point source pollution control...
perspective, this would be an even better scenario for reducing pollutant loads to the creek and the Huron River.

**Figure 15. Forecast Improvements in Thurston Pond Water Surface Elevation following implementation of design**

Our evaluation of reductions in phosphorus (P) loading to Millers Creek compares estimates of the existing runoff load from the watershed area being redirected to Thurston Pond, the existing potential pond outflow load, and three scenarios of potential future loads.

The total existing watershed P load estimate was derived from the watershed annual P loading estimates (0.66 lbs P/ac/yr) for the Plymouth subwatershed developed from the calibrated MCWIP model and the total area now re-directed to the pond for all runoff events (~44 acres). The load from the estimated annual pond outflow was derived from the pond water balance model overflow estimates and the average pond total P concentration found during the sampling of 2006.

The potential future load estimates included: 1) a scenario where the total predicted future P load was set equal to the total average annual outflow predicted in the water balance model (~9 million cubic feet) times the average pond total P concentration (286 ug/L) found during the 2006 sampling; 2) a scenario where that P load is reduced by running it through a filter installed at the existing outlet (refer back to Figure 2) and all the particulate P was captured (with an assumed total P to dissolved P ratio of 85%) and 3) where the P load was reduced by running it through the outlet filter and all the particulate P was captured (with an assumed total P to dissolved P ratio of 95%).
The results of these loading scenarios are summarized in Table 9 below. The estimated existing watershed runoff and pond outflow P loads are 30 and 39 pounds, respectively. This means that the watershed generates on average 30 pounds of P in the runoff. Because most of this runoff never gets into the pond, this is load directly to Millers Creek. The pond outflow load assumes that roughly 1 million cubic feet of pond overflow makes it to the creek. Given the apparent, systematic over-estimate of pond outflows by the modeling for this project, this outflow estimate is likely high. Therefore, the average annual total P load from the pond and its watershed likely ranges between 30 – 69 pounds of P.

For the proposed conditions scenarios, we bracketed a range of scenarios for total P removal. The first scenario assumes no internal pond P load is discharged from the pond and that the pond removes 80% of the total watershed load for a total pond-watershed load of 11 pounds of P annually. Currently, this scenario is over-optimistic. However, it is included here because the residents and the TNCC are very interested in removing the unconsolidated pond sediments. These unconsolidated sediments are likely the source of the internal P loading. They are currently looking at all their external funding options to find a cost-effective way to remove these sediments.

For the last two proposed conditions scenarios, we assumed that the proposed outlet filter captured almost all the particulate P that went out in the approximately 9 million cubic feet of pond water predicted to leave the pond following construction of the improvements. These scenarios assume that the particulate P fraction ranges between 85% and 95% of the total P in the pond. The data (see Section 4.2 above) bear out this range of particulate P. In fact, those periods when the pond P concentrations are the highest, are also the periods when the algal production is the highest and the ratio of particulate P to dissolved P is also the highest. During these periods almost all the P is associated with algal biomass. With these two scenarios total P loading from the pond and its watershed to Millers Creek ranges between 9 and 18 pounds on an annual basis. Even if these estimates are also optimistically high, and we assumed an additional 25% loss of P to the creek, the total P load ranges between roughly 12 – 23 pounds. Taken together, the range of projected total existing loads and future loads, equates to an overall percentage removal of 60% of total annual P or an additional 18 – 41 pounds of P removed annually. If for some reason, the improvements do not result in overflows on an average basis, and even assuming that there is little to no overflow now, these improvements would still result in roughly an additional 30 pounds of P removed annually.

Table 9. Estimated Pre- and Post-Construction Total Phosphorus Loads Entering and Exiting Thurston Pond

<table>
<thead>
<tr>
<th>Condition</th>
<th>Phosphorus Load Scenario</th>
<th>Total Annual P Load (lbs P/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>Runoff Load from Thurston Watershed</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Existing Pond Outflow (based on modeled 1991 outflow)</td>
<td>39</td>
</tr>
<tr>
<td>Proposed</td>
<td>P Load from Thurston Pond assuming no internal load</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>P Load from Thurston Pond assuming 90% removal of TP</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>P Load from Thurston Pond assuming 95% removal of TP</td>
<td>9</td>
</tr>
</tbody>
</table>
5.0 MAINTENANCE

The City of Ann Arbor (“The City”) has already agreed to maintain the swirl concentrators to be installed at the Clague Middle School and at the new inlet off of Bluett (See Maintenance Appendix). The City will put these units into their regular maintenance schedule and they will be vectored out once every year or so.

The TNCC have also agreed verbally to remove the collected sediment in the pond outlet filter on an annual basis (refer back to Figure 2). A letter from the TNCC is expected to confirm this arrangement and when received will be forwarded on to complete this submittal package.

Maintenance for the pond outlet will consist of pulling up the filter and disposing of the captured sediment off-site. This filter is simply held in place by the catch basin outlet grate. The grate would need to be unbolted, lifted off and rebar slipped into the filter loops to lift the filter up. The filter sack can then be removed and emptied off site. This material would likely be good fertilizer and should be used in an area that cannot runoff into adjacent waterbodies.

Maintenance of the planted area around the outlet will be performed by the construction contractor for the first year after planting. After this first year, the plants and seed should be sufficiently established to warrant very little attention after this period. If any attention is needed for outlet stabilization, the TNCC which maintains the pond grounds now, will address.