Como Regional Park Stormwater BMPs Feasibility Study

Capitol Region Watershed District
Saint Paul, MN

June 28, 2018

Como Regional Park Stormwater BMPs Feasibility Study

BY CAPITOL REGION WATERSHED DISTRICT

Project conducted in partnership with:
City of St. Paul

Partial funding provided by:
Clean Water Land & Legacy Amendment

Report prepared by:
Houston Engineering Inc.

Saint Paul, Minnesota
6/28/2018

TECHNICAL REPORT:
COMO REGIONAL PARK STORMWATER BMPS
FEASIBILITY STUDY.

CAPITOL REGION WATERSHED DISTRICT

June 28, 2018

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of Minnesota.

Greg Bowles

Greg Bowles, P.E.
License Number 41929

6/28/2018

Date

Houston Engineering, Inc.
6901 E Fish Lake Rd., Suite 140
Maple Grove, MN 55369
Phone # 763.493.4522

HEI Project No. 6475-0019

TABLE OF CONTENTS

APPENDICES

Appendix A – Geotechnical Evaluation Report

Appendix B – Preliminary Concept BMP Alternatives

- Narrative Description
- Concept Design Sketches

Appendix C – Additional Concept BMP Alternative Data

- NW Pond Fact Sheet
- NW Pond Concept Design
- Opinion of Probable Cost

1 INTRODUCTION

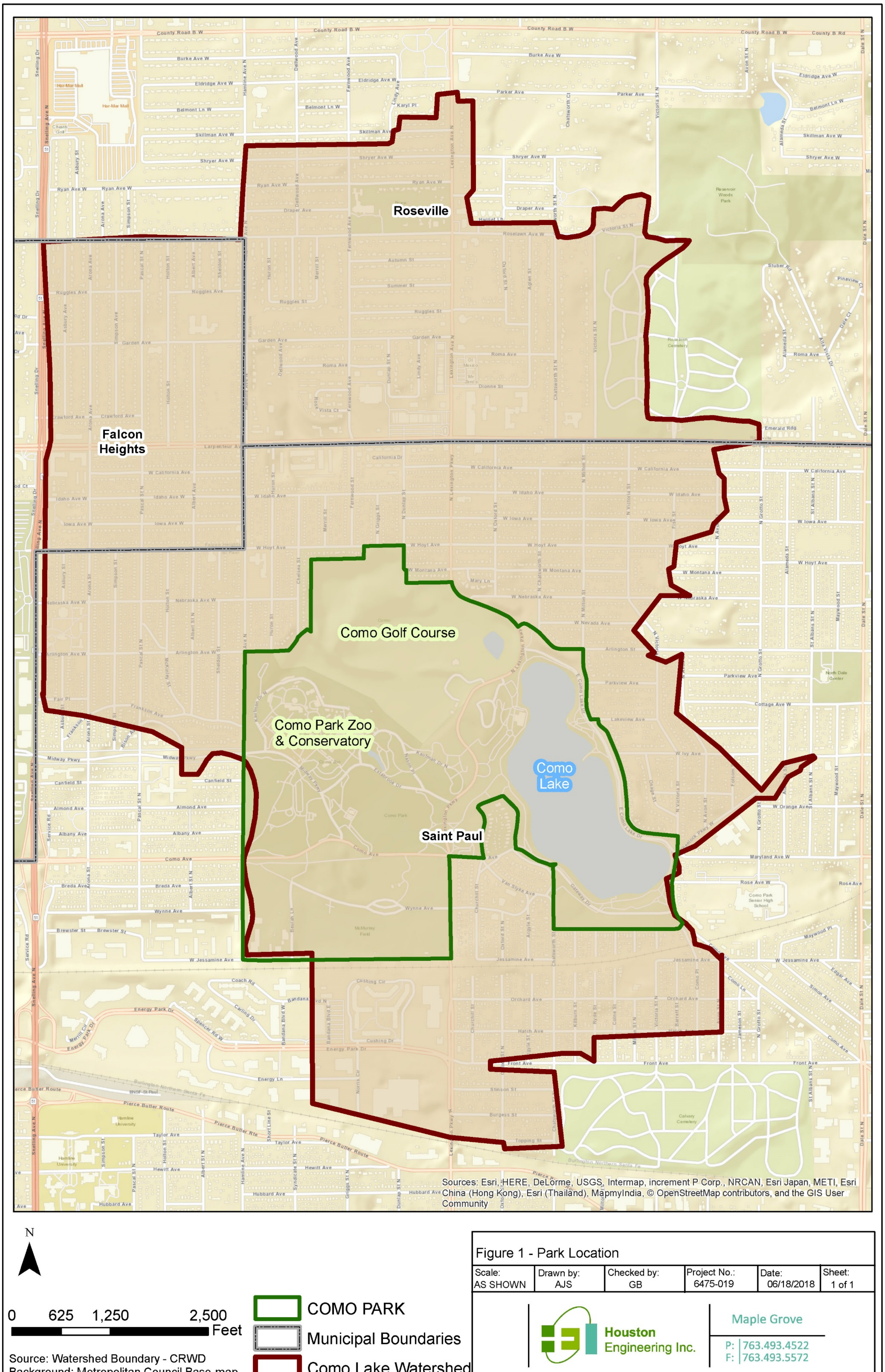
The Capitol Region Watershed District (CRWD) has initiated this study to assess the feasibility of stormwater management options within Como Regional Park, located in St. Paul, MN. Como Lake is the water resource of concern within the park and is impaired for total phosphorus (TP)[1]. Como Park is an opportune location for stormwater treatment, for both runoff in and outside of the park, due to its position within the Como Lake watershed and open greenspace, See **Figure 1**.

1.1 PROJECT BACKGROUND

In 2016, CRWD and Houston Engineering, Inc. (HEI) completed an inventory of stormsewers within Como Park, documented constructed stormwater best management practices (BMPs) within the Como Lake watershed, and analyzed the existing pollutant loads delivered to Como Lake[2]. A stormwater master plan is currently being developed to manage stormwater within the park. In this effort, large-scale regional treatment BMPs have been identified as a more cost-effective approach for stormwater treatment when compared to a site-by-site treatment approach. The regional BMPs have the benefit of treating runoff from both within and outside of Como Park to both improve water quality to Como Lake[3]. Due to the timing of planned projects within the park, the BMP feasibility assessment has been expedited for collaboration purposes[4]. The planned projects consist of parking lot improvements at Como Golf Course, parking lot improvements north and south of Como Park Pavilion, and reconstruction of exhibits within Como Zoo.

There are many stakeholders involved in the project (project partners). These partners include CRWD; the City of St. Paul Public Works; and the City of St. Paul Parks and Recreation, which includes Como Regional Park, Como Golf Course, and Como Park Zoo and Conservatory.

Figure 1 – Como Regional Park and Como Lake Subwatershed Location



1.2 Project Goals and Objectives

The project partners have a shared goal of protecting and improving Como Lake as a water resource. The project partners have previously agreed upon goals and objectives for the Como Regional Park Stormwater Master Plan. The goals and objectives for this project align with the stormwater master plan efforts by providing regional treatment for collaboration opportunities. The following goals will apply to the development of BMP conceptual designs in this project:

Goal 1 – Improve Como Lake water quality by developing conceptual BMP options ready for final design and implementation.

- **Objective 1** – Achieve a level of treatment that equals a 1.1-inch volume reduction in water leaving the tributary impervious area and entering the BMP. This includes any future planned impervious area and may be done collectively through BMP treatment trains.
- **Objective 2** – Develop and prioritize BMPs based on cost-effectiveness of treatment and timing of park improvement projects.
- **Objective 3** – Explore BMPs that target reduction of total phosphorous (TP) and total suspended solids (TSS).

Goal 2 – Maintain or improve the function and aesthetics of Como Park, its programing, and its amenities, particularly Como Golf Course.

- **Objective 1** – Provide visually appealing surface BMPs that will be viewed as an amenity by park visitors
- **Objective 2** – Integrate BMPs into the current function of Como Park. For Como Golf Course in particular, ensure that any changes to the layout, play, and difficulty of the course improve the golfing experience for visitors.

2 Feasibility Analysis

Ten locations within Como Park were evaluated for placement of BMPs to treat stormwater. Subsequently, six of the ten locations were selected for feasibility analysis and concept BMP designs. See **Figure 2** for a map of these locations. Como Park has many advantages for stormwater management design at these locations. Multiple locations have existing ponds or are adjacent to collector stormsewer lines. Many of these locations were chosen for their location relative to anticipated park improvement projects so that the BMPs may be used to treat the upcoming projects. Priority was placed on the feasibility of designs that would collect and treat runoff from a larger, regional area.

2.1 BMP Identification and Design

2.1.1 Data Collection

Various information was collected to determine the feasibility of BMP implementation. Relevant data was reviewed from the previous projects and data gaps were identified and sent to the appropriate project partners, who responded with available information. A planning level Gopher One Call was submitted and review for any major utilities that would affect the function or construction of a BMP. Next, 13 soil borings were taken across anticipated infiltration BMP locations and a detailed geotechnical report can be found in **Appendix A**.

Figure 2 - Locations Selected for BMP Analysis with Stormsewer

A survey was completed to capture missing stormsewer data and identify any utilities that were marked during the soil boring utility locate. Lastly, it was determined that an on-site walk through with the project partners would be useful to receive input at particular locations as well as gain perspective and understanding of the site's current function within Como Park and Golf Course.

2.1.2 CONCEPTUAL BMP DESIGN CONSIDERATIONS AND IDENTIFICATION

The BMP type was chosen based on site characteristics, site constraints, and BMP performance. In terms of BMP performance, volume reduction (e.g. infiltration and reuse) were regarded as a preferred stormwater treatment option. The soil borings and estimated seasonal high groundwater determined if infiltration was feasible at a particular location. Seven of the 13 soil borings were also screened for environmental contaminants (Diesel Range Organics [DRO] and Volatile Organic Compounds [VOC]). VOCs were not detected in any of the screened borings. DRO concentrations were detected at three locations with the detected concentrations and limits shown in **Table 1** and **Figure 2**. It is recommended that infiltration not be used as a treatment mechanism at these locations; rather, treatment practices should be lined with impermeable material to prevent contaminates from entering groundwater, as indicated in the conceptual designs.

Table 1 - Results of the Environmental Screening of Soil Borings

Soil Boring ID	Soil Boring Location	Detected DRO Conc. (mg/kg)	MPCA Unregulated Fill DRO Conc. Limit [5] (mg/kg)
ST-5	Just SW of the Golf Course Parking Lot	47.3	100
ST-10	Within the parking lot south of the pavilion, on the NW side	95.7	100
ST-12	In the greenspace north of the parking lot north of the pavilion	5,960	100

Iron-enhanced sand filtration (IESF) BMPs were specifically identified to be assessed at multiple locations due to their improved removal of dissolved phosphorus. Particular attention was given to IESF benches retrofit into existing ponds. It is essential to allow IESFs to 'rest' (or dry) for a period of time to avoid anoxic conditions within the filter (anoxic conditions will release bound phosphorus).

Designs for all BMP types were based on criteria from the Minnesota Stormwater Manual[6]. The capacities of the concept designs were designed to achieve the 1.1-inch volume reduction goal within Como Park (see **Section 2.2.1**), except for the NW Pond. For BMP locations where the goal could not be met, the BMP was maximized to a reasonable sized area, depending on site conditions.

HEI analyzed the sites and brainstormed various types and layouts of BMPs based on the project goals and objectives, BMP design criteria, available and collected data, and CRWD input.

2.2 PRELIMINARY CONCEPT BMP ALTERNATIVES

An initial list of BMP descriptions and sketches were presented to CRWD for input and preference on BMP selection. After receiving CRWD feedback, the BMPs were further developed into the following preliminary concept BMP alternatives, provided in **Appendix B**. The preliminary concept BMP alternatives are summarized in **Table 2**.

Table 2 – Preliminary Concept BMP Alternatives

Preferred BMP ID	Preliminary BMP ID	BMP Type	Description
Northwest Golf Pond Location			The stormwater pond at the northwest end of the golf course currently treats diverted runoff from an upstream stormsewer.
NW Pond IESF Bench	**NW Pond 1**	**IESF bench**	The opportunity exists to retrofit the pond with an IESF bench to provide additional treatment of dissolved phosphorus. (See **Section 3.1** for details.)
Golf Parking Lot Pond Location			The golf course parking lot currently drains to an irregular shaped pond (between the greens for Hole 15 and Hole 18) via stormsewer. Further, there is a trunk stormsewer that passes underneath the parking lot which could be used to divert runoff for regional treatment.
Golf Lot IESF Bench	**Golf Lot 1**	**IESF Bench**	The trunk stormsewer would be diverted to an existing pretreatment basin, through a channel waterway, and into the existing pond, which will be retrofit with an IESF bench that drains to the larger pond to the northeast. (See **Section 3.1** for details.)
--	Golf Lot 2	IESF Ditch Check	Using the same diversion and watercourse as Golf Lot IESF Bench, this BMP would use a series of check dams with replaceable IESF inserts. This is a newer BMP type that has recently been studied by the University of Minnesota.
--	Golf Lot 3	Rain Gardens	Local runoff from the golf course parking lot will be treated by rain gardens located in islands in the parking lot and greenspace west of the lot. DRO was detected in this location at boring ST-5, therefore bio-filtration with a liner is recommended.
East Golf Ponds Alternate Location			Currently, the two east ponds in the golf course receive diverted runoff from hundreds of acres in the watershed, which is then pumped to Como Lake.
--	East Ponds 1a	IESF Bed	This BMP would direct a fraction of the pumped water to IESF beds on the east side of Lexington Ave. A valve would be installed to direct flows to alternate the use of each IESF bed and allow them to rest.
--	East Ponds 1b	IESF Bed	Similar to East Ponds IESF Bed 1, this option would use a holding tank on the east side of Lexington store the pumped runoff and better regulate the usage of the IESF bed.
--	East Ponds 1c	IESF Bed	Similar to East Ponds IESF Bed 1, this option would install a separate wet well and pump in the pond, if use of the existing pumps is not favorable.
Como Zoo Regional Location			This location would collect regional stormwater runoff from Como Zoo as well as runoff from the residential area upstream of the zoo. Four soil borings were taken at this location. Only soil boring number 1, near the existing Zoo infiltration basin, showed suitable conditions for infiltration.
--	Zoo 1a	Filtration Basin	The stormsewer could be treated by a filtration basin. This would require moving the Hole 8 white tee-box, and the reconstruction of the trunk stormsewer in order to raise the invert elevation to be able to discharge filtered water to downstream stormsewer.
Zoo 1 – Filtration Basin	**Zoo 1b**	**Filtration Basin**	Similar to Zoo Filtration Basin 1, this option installs a smaller pipe parallel the trunk stormsewer. (See **Section 3.1** for details.)
Zoo 2 – Infiltration Basin	**Zoo 2**	**Infiltration Basin**	There is an existing infiltration basin adjacent to the zoo stormsewer, which captures a small portion of the zoo. This basin could be expanded, to receive runoff from the zoo stormsewer. The size of the basin is limited by steep slopes and the Hole 7 fairway. (See **Section 3.1** for details.)
--	Zoo 3	Underground Infiltration	Because of the limited space for surface infiltration, an underground system could be considered under the Hole 7 fairway. A pretreatment basin would be provided at existing infiltration basin.
--	Zoo 4	Underground Infiltration	Similar to Zoo 3 underground, but the location of the pretreatment basin could be moved to near the Hole 8 tee-boxes.
Zoo Combo	Zoo 1b & Zoo 2	**Infiltration & Filtration Basins**	Combine Zoo 1 and Zoo 2 into a treatment train. (See **Section 3.1** for details.)
Pavilion North Location			The parking lot north of the pavilion was identified as another potential location to treat the trunk stormsewer which runs through the park. However, it was determined that the trunk stormsewer was too low, relative to the lake, to provide regional treatment.
Pavilion North Rain Gardens	**Pavilion North 1**	**Rain Gardens**	Rain gardens would provide treatment to the pavilion north parking lot. Bio-filtration with a liner is recommended due to soils and high DRO levels detected at boring ST-12. (See **Section 3.1** for details.)
Pavilion South Parking Lot Location			Soil boring number 8 (more southern boring in the parking lot) and potentially boring 9 (east of the parking lot) were suitable for infiltration. Boring 10 (more northern boring in the parking lot) showed suitable soils, but DRO was detected 5-7 feet below grade. Soil Boring number 6 (southeast of the fountain) was suitable for infiltration.
Pavilion South Parking Lot	**Pavilion South 1**	**Infiltration & Filtration Swale**	This alternative is a treatment train of an infiltration swale overflowing to a filtration basin. The parking lot would sheet flow to curb cuts that would lead to a bio-infiltration swale. Runoff that is not captured in the infiltration swale would overflow to a filtration basin. (See **Section 3.1** for details.)

Preferred BMP ID	Preliminary BMP ID	BMP Type	Description
Pavilion South Regional Location			This location provides an area for regional treatment within Como Park. There are challenges in this area due to the high usage of this park space, utilities, the depth of stormsewer and the large contributing drainage area. The more simple options were first analyzed, which lead to the exploration of other, more expensive BMP alternatives.
--	Pavilion South 2a	Infiltration Basin	This concept was developed to show the approximate area of a surface infiltration BMP, sized to treat the goal of 1.1-inches of runoff from impervious surface within the drainage area. This alternative is likely infeasible due to the large amount of park area that is required, and the extensive lowering of the ground surface elevation.
--	Pavilion South 2b	Infiltration Basin	This concept was developed to show the approximate area of a surface infiltration BMP, sized to treat 0.5-inches of runoff from impervious surface in the drainage area. This option does not meet the 1.1-inch goal, but results in a more manageable treatment area required. Various arrangements of surface infiltration basins may be explored.
Pavilion South Regional 1 – Reuse/UG Infilt.	**Pavilion South 3**	**Reuse / Underground Infiltration**	With an underground infiltration concept, maintaining separation from the seasonal high groundwater restricts the options for its location. The seasonal high groundwater is assumed to be near the Ordinary High Water (OHW) elevation of the lake (881.4). The simplest solution is to capture water from the stormsewer further upstream (west). Reuse could also be considered with this alternative. (See **Section 3.1** for details.)
--	Pavilion South 4a	Infiltration Stream	Runoff from the stormsewer to the southwest can be treated through an infiltration design consisting of an intermittent stream, plantings, landscaping, weir structures to provide storage, and infiltration throughout the system (see example photo below). A normally dry, rock stream bed would meander through the park three to five feet below the existing ground elevation. During rain events, weirs or ditch checks would store runoff in the 'floodplain' of the stream, and runoff would subsequently infiltrate.
Pavilion South Regional 2 – Recirculating Infilt. Stream	**Pavilion South 4b**	**Recirculating Infiltration Stream**	This alternative builds on the infiltration stream design, but includes underground storage and recirculation for the purpose of providing more volume to infiltration through the stream. (See **Section 3.1** for details.)
--	Pavilion South 5	IESF Bed	This alternative consists of a holding tank or pond to collect the regional runoff. Runoff would then be pumped to a set of IESF beds.

** **Bold BMP Alternatives** indicate the preferred alternatives selected for further analysis and concept design

2.3 Selection of Preferred BMP Alternatives

A meeting was held CRWD on February 2nd, 2018, in which the twenty-one preliminary concept BMP alternatives were presented and discussed. Several BMPs and locations were eliminated from consideration, as discussed below. As a result of the meeting, nine BMPs were selected for further conceptual design and assessment, which are identified by the Preferred BMP ID in **Table 2**.

The southern golf course pond (South Golf Pond) does not currently receive runoff from the trunk storm sewers. It is also land-locked with an approximate normal water elevation (871.2) well beneath the water surface elevation of Como Lake (879.9), therefore, there is no opportunity to install a gravity outlet pipe. Treatment at this location would require routing additional runoff to the pond, treating it, and installing a pump to drawdown water elevation of the pond. It is noted that there are localized flooding concerns in the golf course due to the lack of an outlet, but because the pond is land locked, it is not contributing pollutants to Como Lake. Therefore, treatment at this location would not provide additional water quality benefit to Como Lake and thus does not meet the goals of this study. For this reason, BMP alternatives were not further pursued at the South Golf Pond.

At the East Golf Ponds locations, no BMP alternative was selected for preliminary concept design. There are concerns with the potential treatment of groundwater, since the elevation of these ponds is below the elevation of the lake. Options to retrofit either of the two east golf course ponds with an IESF bench were not pursued due to issues with altering the pond elevations. Another alternative at the East Golf Ponds location was to include pumped IESF beds on the east side of Lexington, across from the ponds. These alternatives were also not pursued because of limited available space and high pedestrian traffic within the park and golf course at this location.

2.4 Assessment Methods

The nine concept BMP alternatives were refined and assessed for water quality performance. Construction and maintenance costs were estimated for the life of the BMP.

2.4.1 Volume Reduction

As an initiative in the Como Park Stormwater Master Plan efforts, a Volume Reduction Memo[4] was previously drafted to outline the process and determinations used to define volume reduction within Como Park based on CRWD permitting rules. The method set forth in that document was used in this study to determine the 1.1-inch volume reduction goals. The BMP water quality treatment volume was then compared to the volume reduction goals within and outside of Como Park.

2.4.2 Water Quality Modeling and Assessment

The Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (P8) Urban Catchment Model software program was used to model water quality inflow and removals through the proposed BMPs. P8 simulates rainfall, pollutant loading, and runoff from the watershed and subsequently routes the runoff through water quality treatment features that simulate pollutant particle removal. The existing P8 model from previous studies was modified with the BMP alternatives to determine the reduction of TSS, TP, and volume each would provide. For more information on the development of the existing conditions model, see the *Como Park Stormwater Inventory and Watershed Analysis* Report [2].

Because many of the concept BMPs are in a treatment train (i.e., a downstream feature that also removes pollutants), the BMP removals cannot be simply calculated at the BMP. For example, introducing a BMP upstream of a pond will reduce the amount of pollutants to the pond and, therefore, reduce the pollutants the pond removes. To account for these treatment train effects, the removals of the BMPs were quantified by reduction of TSS, TP, and volume to the resource of concern (Como Lake) and compared to existing conditions at the resource of concern. Further, percent removals are based on the total load from the BMP drainage area, rather than the inflow to the BMP. This is because some of the BMPs will capture a fraction of the annual inflow and the remaining flow in large storms will bypass the BMP.

IESFs introduce iron into a sand filter to increase the removal of dissolved phosphorus through chemical sorption. To model this removal, the CRWD particle file was modified, which specifies removal percentages at various particle sizes. The dissolved fraction (P0%) filtration efficiency was changed from 50% to a value of 70%. This is consistent with 70% dissolved phosphorus removal, conservatively selected from a study of sand filter benches in a 2010 Saint Anthony Falls Laboratory (SAFL) report[7]. Actual dissolved phosphorus removal percentages for monitored locations in the report vary in range from 30%-90%, while dissolved phosphorus capture was greater than 50%.

2.4.3 Cost Estimate

A preliminary opinion of probable costs (OPC) for construction, engineering, administrative, and annual maintenance costs were estimated to determine total BMP implementation costs over a 30 year period. The estimates are approximate and should not be used for bidding or construction. They were developed without the benefit of detailed designs and are not intended to encompass all bid items. Also, the presence of groundwater, significant utilities, access issues, or other unanticipated factors could inflate the cost higher than estimated. Therefore, a 30% contingency was added to each estimate, and the actual costs should be expected to vary. Engineering design and administrative costs were estimated at 25% of the OPC.

Long-term maintenance of BMPs is critical to ensuring that they continue to perform as designed. The proposed BMPs will require periodic sediment removal, inspection, mowing, and/or repair. To estimate the annual average cost for long-term maintenance, methods from five sources (Chisago SWCD, 2011; EPA, 1999; Schueler et. al., 1992; WCD, 2014; WERF, 2013)[8] were applied and averaged over each BMP Type. It is expected that the IESF benches (at the Golf Lot and NW Pond) will have a reduced life-span due to high loading of runoff. Because the volume of water treated by the IESF is undersized when compared to 1.1” of runoff over the drainage area (which is the design standard), higher frequency storms will be treated by a relatively smaller IESF area. As a result, the dissolve phosphorus loading to the IESF will be higher than if the IESF was able to meet the 1.1” runoff volume and the phosphorus sorption capacity of the iron will likely not meet standard 30 year design life of the BMP. Therefore, the life cycle was reduced from 30 years to 20 years for these BMPs.

2.4.4 Cost-Benefit Analysis

A lifetime cost-benefit analysis was performed for the preferred BMPs. The total estimated lifetime cost of each BMP was annualized and then normalized by it's annual TP removal which results in a cost per pound of TP removed. The metric used for determining benefit was TP because of Lake Como's impairment. The assessed BMPs can then be compared and prioritized to determine the most cost-effective practices. Many of the BMPs provide exceptional value (less than $1,000/lb TP). These lower costs-benefit values (more cost-effective) are attributed to efficiencies of the regional BMP, above ground practices, existing infrastructure, and retrofitting BMPs (as opposed to constructing a completely new BMP). The BMP alternatives (including Alternative Treatment Train Combinations) were prioritized by the Cost-Benefit Rank as shown in **Table 3** and are further discussed in **Section 3.2**.

3 Results

3.1 Concept BMP Alternatives

The nine concept BMPs alternatives were presented to the project partners on March 23rd, 2018. **Appendix C** includes descriptions and discussion of the BMPs at each location, concept sketches, and OPCs of the alternatives which were presented at the meeting. Also included in the analysis and discussion are three scenarios of treatment trains. The results are described below and summarized in **Table 3**, which tabulates the BMP volume reductions, removals, and costs as well as ranks the BMP alternatives based on the annualized cost to remove TP.

NW Pond IESF Bench

Description - The NW Golf Pond as shown in **Figure 2** is a 1.75-acre pond that was built for stormwater treatment in 2007 and also serves as a feature to Como Golf Course. The pond captures runoff from 157 residential acres northwest of the Como Golf Course. In addition, the pond receives inflow which is pumped from Gottfrieds Pit, a pond with a 521-acre drainage area of residential and commercial land. Although the pond provides significant TSS removal there is opportunity for additional treatment of dissolved phosphorus through retrofitting the pond with an IESF bench. The sand bench would be cut into the existing grade along Hole 3 and is recommended to be an out-of-play golfing hazard due to the tendency of IESFs to form ridged clumps. An automated control valve will be included to bypass flows from Gottfrieds Pit in order to let the filter dry. The valve could be included at the pond outlet or at the upstream diversion structure.

Additional Design Considerations - Runoff from Gottfrieds Pit is pumped into a stormsewer that is captured by the NW Pond and routed downstream through the large trunk sewer in the golf course. It is understood that this pumping can occur for days after a rain event. This brings a unique challenge to designing an IESF due to the drying requirements of an IESF to avoid anoxic conditions. Preliminary conceptual design of the NW Pond IESF utilized automated valves to divert water away from the IESFs during required drying times[1]. There are multiple possible configurations of an automated valve that could be explored, including locating the valve in the diversion structure or at the pond outlet. Further, the following ideas may encourage the drying of IESFs:

- Lining the bottom of the sand bed,
- Drawing the pond down further than the IESF bed surface,
- Sloping the bottom of the IESF to the drain tile, and
- Incorporating edging along the pond-filter interface.

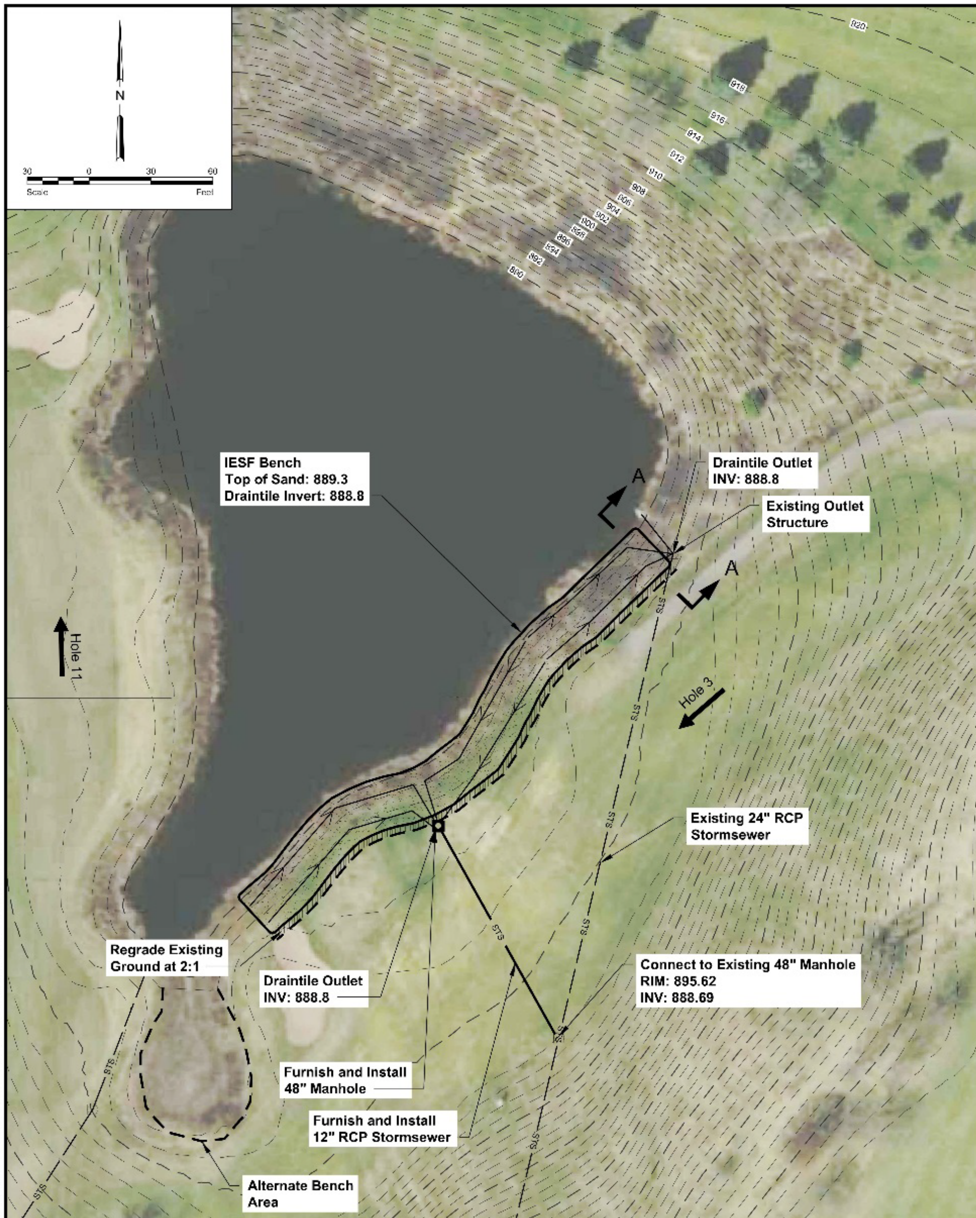
Extensive maintenance is required for IESF benches. It is recommended that an operation and maintenance plan be drafted, which can define the level of maintenance required for this BMP.

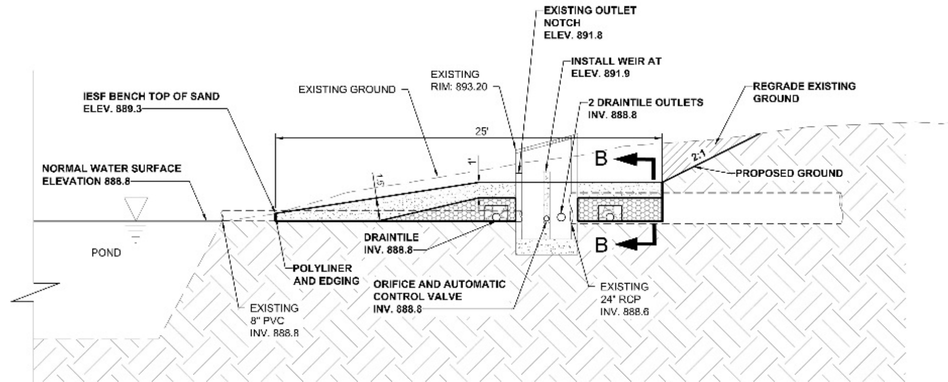
Results and Analysis – This alternative captures the most TP of any single BMP (excluding the treatment trains) and also provides the largest water quality treatment volume (3.60 ac-ft; three times larger than the next largest BMP alternative analyzed). The pond does not treat any impervious area within the park that counts toward the 1.1-inch volume reduction goal. The play of the golf course would be affected by the IESF (30 feet total width, compared to the existing 15 to 25 feet width vegetated buffer), but the location and size of the IESF could be adjusted to fit the needs of the golf course.

NW Pond IESF Bench	
Meets 1.1-inch volume reduction goal w/in Como Park	N/A
TP Removed (lb/yr)	31
Construction Engineering & Admin. Cost Est.	$359,311
20-yr Annualized Cost-Benefit ($/lb TP)	$923
Cost-Benefit Rank	7 of 12

[1] P8 does not have the ability to model a user defined inflow or time dependent flow changes (i.e. the opening and closing of a valve which are proposed in the NW Pond IESF and Golf Lot IESF). In order to incorporate the modeling of automated valves during the analysis, the pumping from Gottfrieds Pit was not routed to the IESFs.

Figure 2 – NW Pond IESF Bench

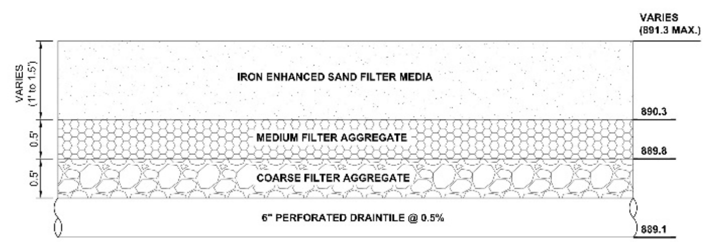




SECTION A-A
NOT TO SCALE

WATER LEVELS TABLE

	EXISTING	PROPOSED
OVERFLOW	893.2	893.2
WQL (WEIR)	NA	891.9
NOTCH IN MH	891.8	891.8
NWL (AUTOMATIC CONTROL VALVE)	888.8	888.8



IESF AGGREGATE GRADING LAYOUT (SECTION B-B)
NOT TO SCALE

No.	Revision	Date	By

PRELIMINARY
Not for Construction

Houston Engineering Inc.
Fargo
P: 701.237.5065
F: 701.237.5101

Drawn by	Date			
HRR	3-9-2018	COMO REGIONAL PARK STORMWATER BMPS FEASIBILITY STUDY	NORTHWEST POND CONCEPT DESIGN	SHEET
Checked by GB	Scale AS SHOWN	CAPITAL REGION WATERSHED DISTRICT	PROJECT NO. 6745-019	1 of 1

Golf Lot IESF Bench

Description - The golf course parking lot drains through stormsewer flowing northeast to an irregular shaped pond located between the greens for Hole 15 and Hole 18. That pond would be retrofitted with an IESF bench. Further regional treatment (which includes Como Zoo) would be provided by bulkheading the current diversion from the trunk stormsewer to the east ponds and providing a new diversion to an existing basin for pre-treatment. The diverted runoff would flow through the existing waterway, over the waterfall feature, and into the IESF retrofit pond. This alternative gives the golf course an opportunity to revitalize its Hole 18 waterfall feature. **Figure 3** shows the concept plan for enhancing this pond.

Additional Design Considerations - Runoff from Gottfrieds Pit is pumped into a stormsewer that is captured by the NW Pond and routed downstream through the large trunk sewer in the golf course. A diversion of the trunk sewer flow could be constructed so that a portion of the flow to reaches this BMP. Similar to the NW Pond IESF Bench, this brings a unique challenge to designing an IESF due to the drying requirements. Conceptual design of the Golf Pond IESF utilized automated valves to divert water away from the IESFs during required drying times. The operation of the upstream NW Pond IESF Bench automated valve, could also affect the operation of this BMP's automated valve. Further, the following ideas may encourage the drying of IESFs:

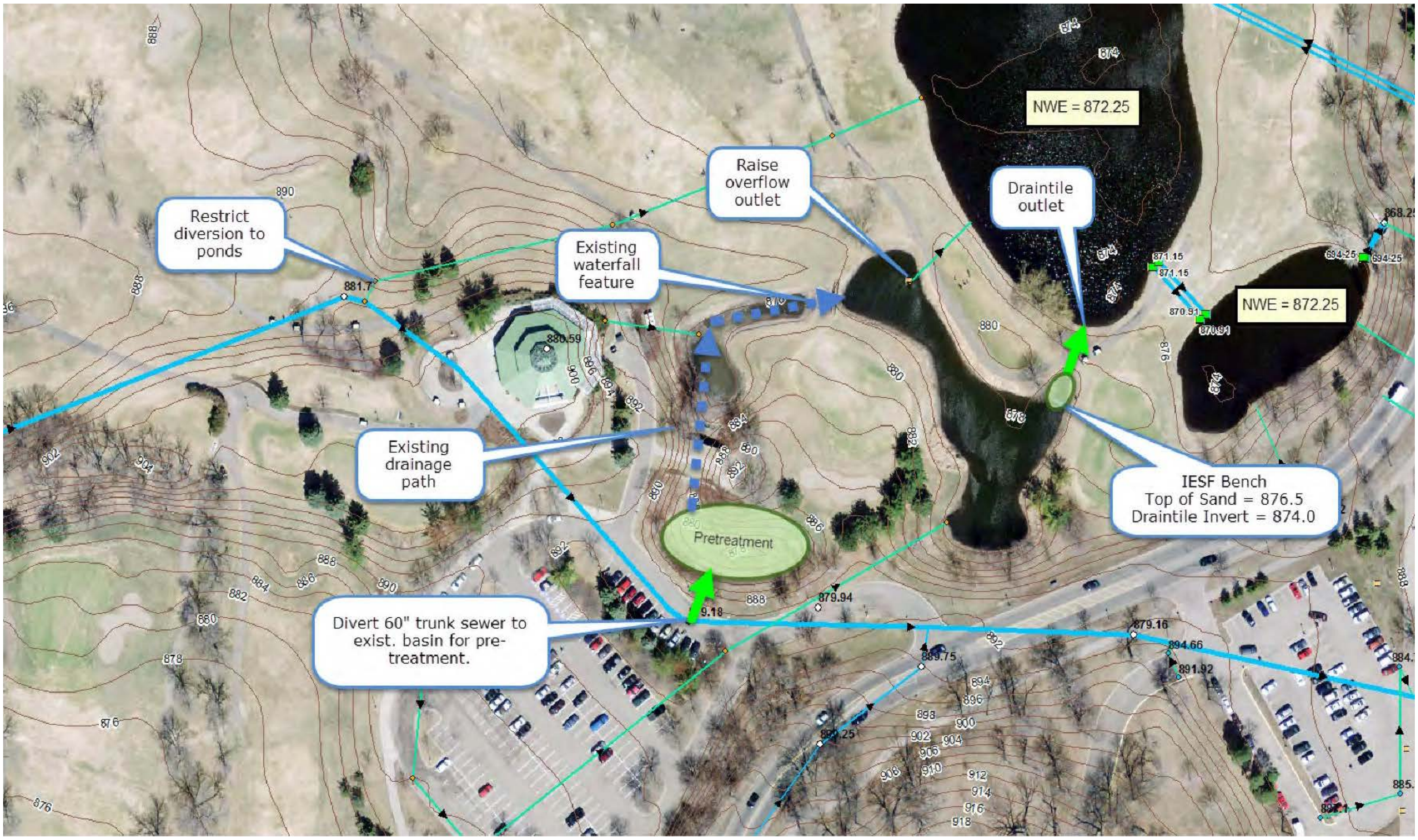
- Lining the bottom of the sand bed,
- Drawing the pond down further than the IESF bed surface,
- Sloping the bottom of the IESF to the drain tile, and
- Incorporating edging along the pond-filter interface.

Extensive maintenance is required for IESF benches. It is recommended that an operation and maintenance plan be drafted, which can define the level of maintenance required for this BMP.

Results and Analysis – The 1.1-inch volume reduction goal within the park is not met by this alternative alone, but could be met in a treatment train. The Golf Lot Pond IESF Bench collects the largest drainage area of the preferred BMP alternatives and treats a large amount of TP at a good cost-benefit price (although this is not reflected in the cost-benefit rank due to the abundance of cost-effective options, see **Section 2.4.4**). Retrofitting the golf course lot pond with an IESF will have little effect on the play of golf, as the BMP is proposed to be built into the pond area.

Golf Lot IESF Bench	
Meets 1.1-inch volume reduction goal w/in Como Park	No
TP Removed (lb/yr)	23.9
Construction Engineering & Admin. Cost Est.	$279,460
20-yr Annualized Cost-Benefit ($/lb TP)	$931
Cost-Benefit Rank	9 of 12

Figure 3 – Golf Lot IESF Bench



Zoo 1 - Filtration Basin

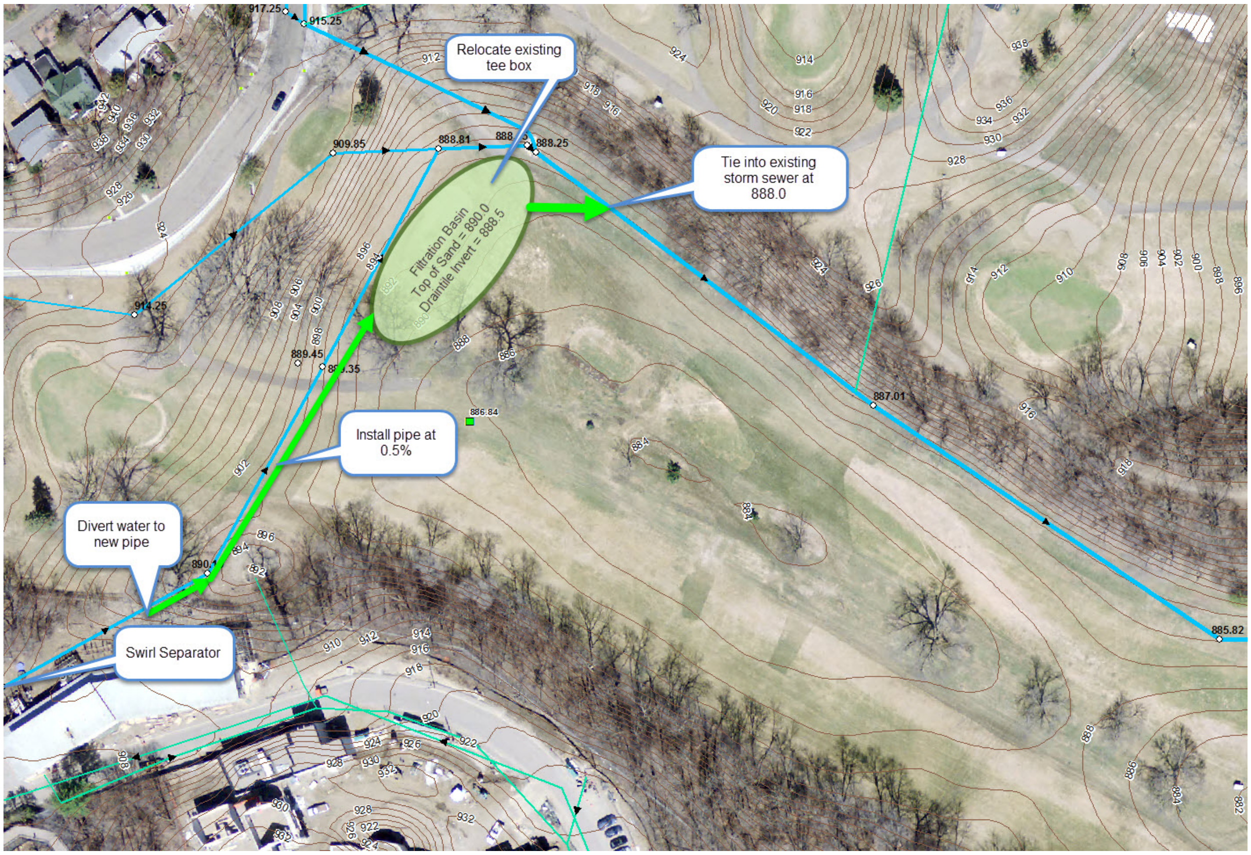
Description - Runoff could be diverted through a new, smaller stormsewer at a flatter grade to provide sufficient flow to the filtration BMP. Pretreatment could be provided by a hydrodynamic separator in an accessible, upstream manhole. **Figure 4** below shown the concept plan for this filtration basin.

Additional Design Considerations - Robust pretreatment should be considered due to the large drainage area and high sediment loading. The filtration basin could be landscaped with grass bottom, sand, plantings, or other features for aesthetics.

Results and Analysis – The 1.1-inch volume reduction goal within the park is not met by this alternative. Relocating the Hole 8 white tee box would be required with this BMP alternative.

Zoo 1 Filtration Basin	
Meets 1.1-inch volume reduction goal w/in Como Park	No
TP Removed (lb/yr)	16.1
Construction Engineering & Admin. Cost Est.	$266,936
30-yr Annualized Cost-Benefit ($/lb TP)	$927
Cost-Benefit Rank	8 of 12

Figure 4 – Zoo 1 Filtration Basin



Zoo 2 - Infiltration Basin

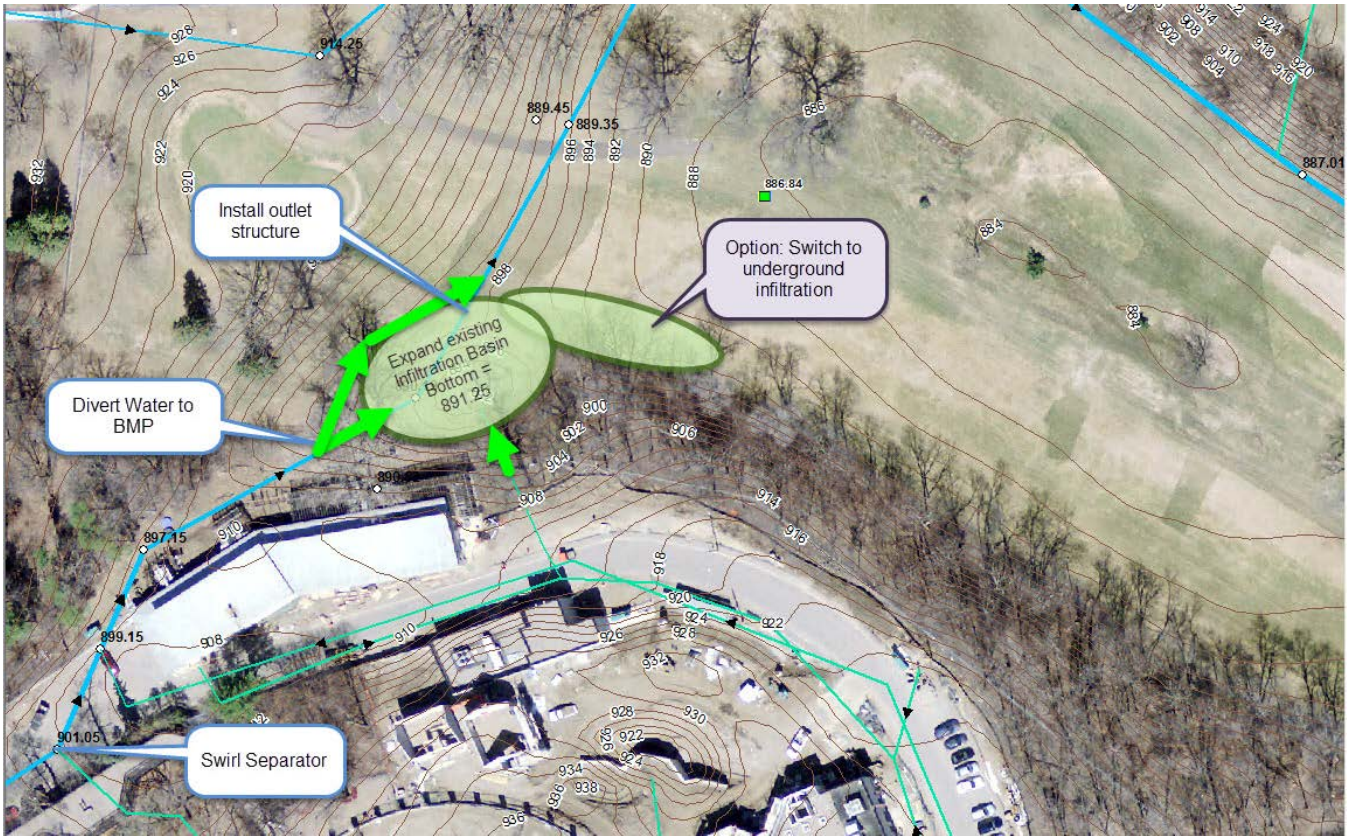
Description – There is an existing infiltration basin in this location that serves as treatment for the zoo's polar bear exhibit. There is opportunity to capture and treat regional flow from the adjacent trunk stormsewer by diverting sewer flow and expanding the basin. The basin expansion would include a narrow (10 to 20 feet wide) swale along the tree line south of the fairway for Hole 7. Pretreatment would be provided by a hydrodynamic separator in an accessible, upstream manhole. **Figure 5** shows the expanded basin.

Additional Design Considerations - Robust pretreatment should be considered due to the large drainage area and high sediment loading. An alternative design could consist of utilizing underground infiltration to achieve similar removals (not evaluated).

Results and Analysis – The 1.1-inch volume reduction goal within the park is not met by this alternative alone, but could be met in a treatment train. This alternative provides the highest ranked (lowest cost-benefit) of all the alternatives analyzed and provides a significant amount of TP removal.

Zoo 2 - Infiltration Basin	
Meets 1.1-inch volume reduction goal w/in Como Park	No
TP Removed (lb/yr)	18.7
Construction Engineering & Admin. Cost Est.	$176,978
30-yr Annualized Cost-Benefit ($/lb TP)	$380
Cost-Benefit Rank	1 of 12

Figure 5 – Zoo 2 - Infiltration Basin



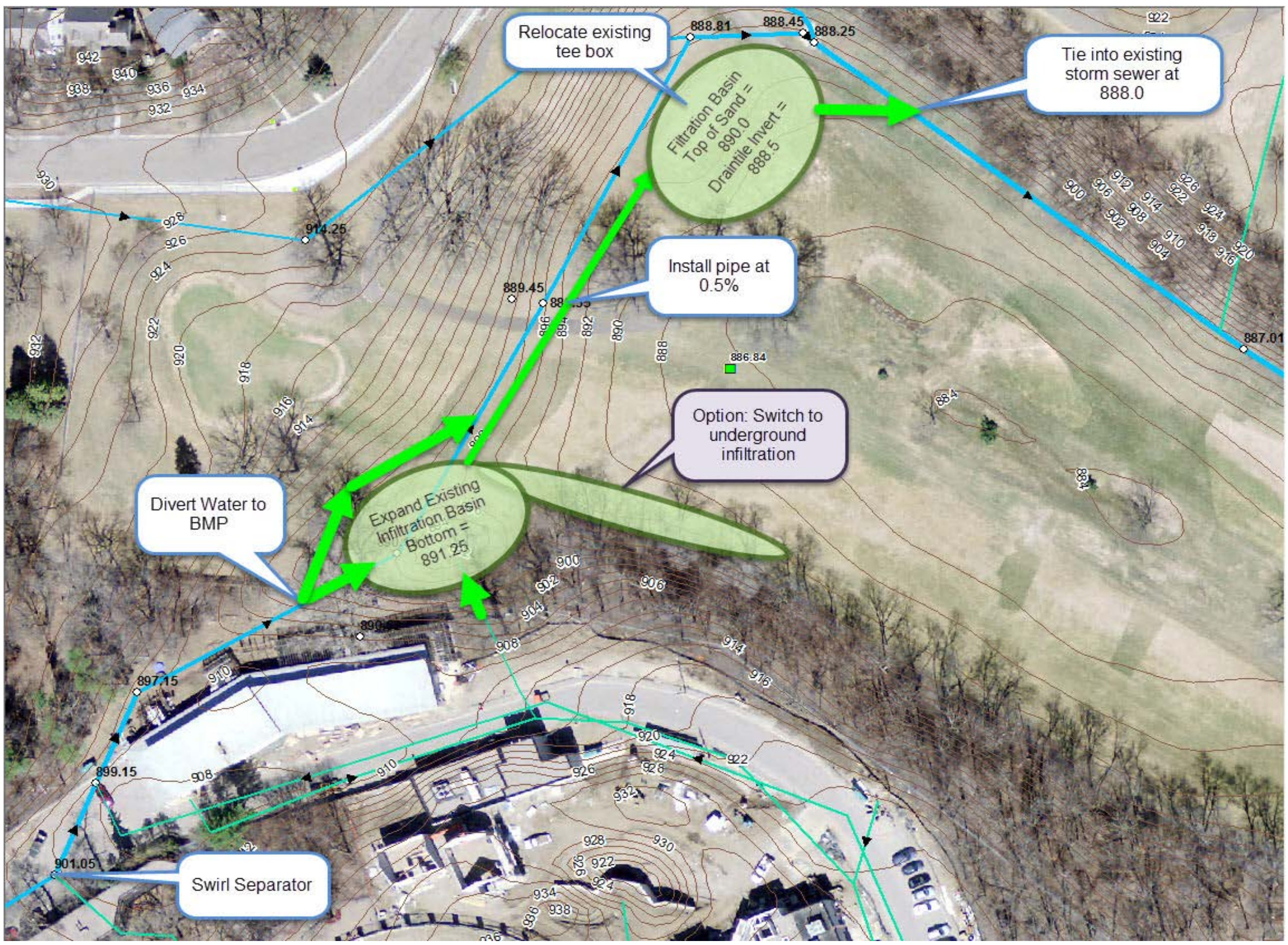
Zoo Combination (Zoo Combo)

Description - This alternative as showing in **Figure 6** combines the Zoo 2 Infiltration Basin and the Zoo 1 Filtration Basin which will capture overflow from the infiltration basin in order to treat a larger volume of runoff.

Results and Analysis – The 1.1-inch volume reduction goal within the park is not met by this alternative alone (not met as shown, but additional detail in the design may achieve the 0.08 ac-ft of volume reduction to meet the goal), but could be met in a treatment train. When considering the addition of the Zoo 1 Filtration Basin in series with the Zoo 2 Infiltration Basin (Zoo Combo), the TP removal is marginally increased by 6.2 lbs. That increase in removal would cost an estimated $1,257/lb of TP. This shows that the additional treatment is not as cost-effective as either BMP on their own, but the total treatment achieved by Zoo Combo is more cost-effective than Zoo 1 on its own.

Zoo Combination	
Meets 1.1-inch volume reduction goal w/in Como Park	No
TP Removed (lb/yr)	24.9
Construction Engineering & Admin. Cost Est.	$369,074
30-yr Annualized Cost-Benefit ($/lb TP)	$827
Cost-Benefit Rank	4 of 12

Figure 6 – Zoo Combination



Pavilion North Raingardens

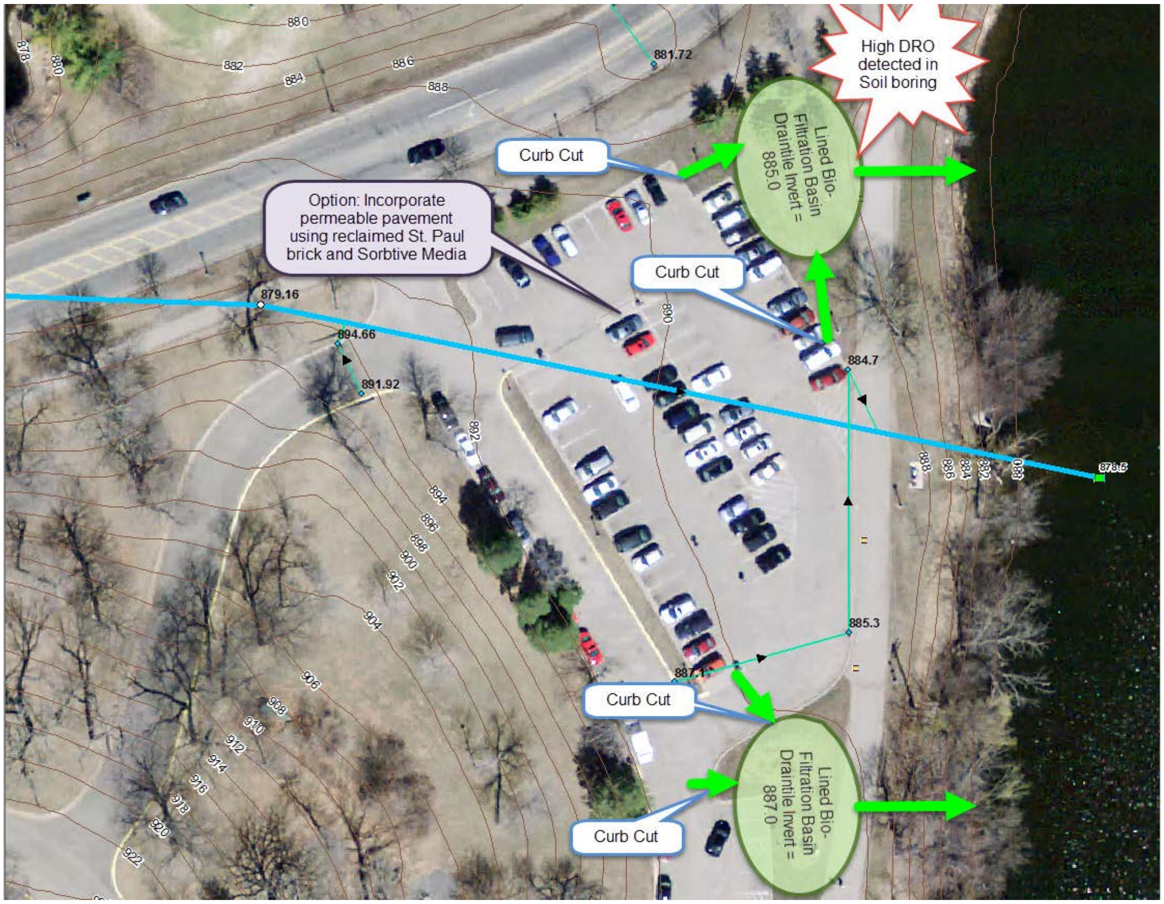
Description - Raingardens shown in **Figure 7** would be located near the parking lot to capture runoff. The parking lot would be regraded, and curb cuts would be added to allow runoff to enter the lined bio-filtration basins. A poly liner would be used within the basins due to soils and high DRO levels detected at 10-12 feet of depth.

Additional Design Considerations – Other BMP alternatives that were discussed in this location are permeable pavers or other permeable hardscape, tree trenches, and/or proprietary filtration media for dissolved phosphorus removal.

Results and Analysis – Regional treatment was evaluated at this location, but deemed infeasible due to the low invert of the trunk stormsewer relative to the normal water elevation of Como Lake. The lack of regional treatment and high maintenance cost of raingardens results in the worst cost-benefit of the BMP alternatives. However, this alternative, along with other treatment options, should be considered in reconstruction of the parking lot – which could require stormwater treatment as it meets the 1.1-inch volume reduction goal.

Pavilion North Raingardens	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	2.0
Construction Engineering & Admin. Cost Est.	$123,708
30-yr Annualized Cost-Benefit ($/lb TP)	$3,478
Cost-Benefit Rank	12 of 12

Figure 7 – Pavilion North Raingardens



Pavilion South Parking Lot Infiltration/Filtration Swale

Description - This concept BMP is an infiltration swale overflowing to a swale with filtration (including underdrain). The ability for infiltration will depend on further soil analysis due to variability in the soil borings collected in this study. The parking lot would sheet flow to curb cuts that would lead to a bio-infiltration/filtration swale with possible terraced seating (see photo in **Figure 8**).

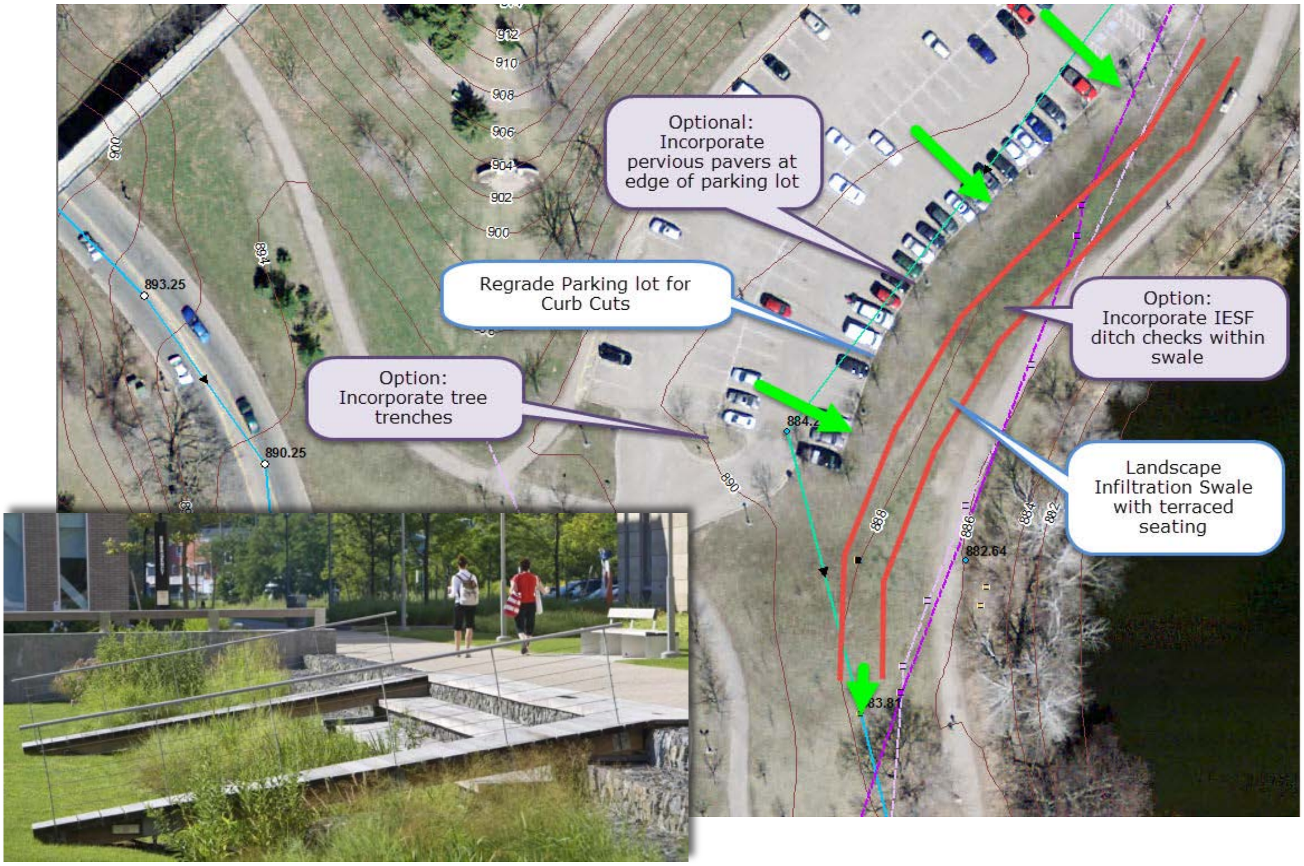
Additional Design Considerations -

- Option to include iron-enhanced ditch check filtration practices
- Option to include pervious pavers or tree trenches in parking lot; incorporating other BMPs will allow for a smaller infiltration/filtration swale.

Results and Analysis – This alternative ranked high in the cost benefit analysis. A large contributor to this is the lower maintenance estimate for infiltration practices. If plantings are included resulting in a feature more closely representing a raingarden, the cost of maintenance could rise. Creative BMP designs could accommodate high pedestrian traffic and provide an amenity to the park.

Pavilion South Parking Lot	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	4.5
Construction Engineering & Admin. Cost Est.	$93,351
30-yr Annualized Cost-Benefit ($/lb TP)	$832
Cost-Benefit Rank	5 of 12

Figure 8 – Pavilion South Parking lot Infiltration/Filtration Swale



Pavilion South Regional 1 - Reuse & Underground Infiltration

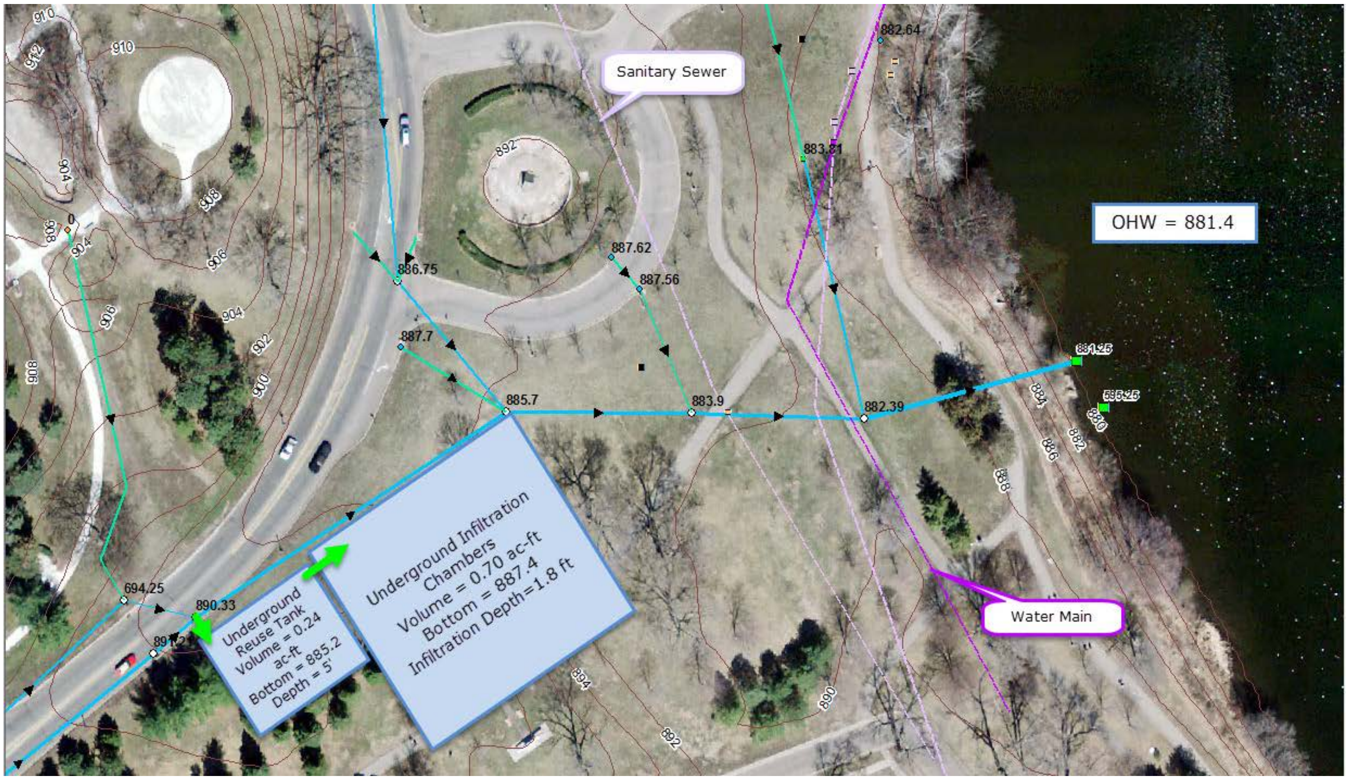
Description - With an underground infiltration concept, maintaining separation from the seasonal high groundwater restricts the options for it's location. The seasonal high groundwater is assumed to be near the Ordinary High Water (OHW) elevation of the lake (881.4). The simplest solution is to capture water from the upstream southwest stormsewer, as shown in **Figure 9**. The concept shown is to combine the underground infiltration gallery with underground storage for water reuse.

Additional Considerations - If water reuse is desired, there would need to be a water demand. The water demand could be irrigating this area of the park, a type of filling station for watering vehicles, or using the reuse stormwater for fountains or other water features.

Results and Analysis – The alternative does meet the 1.1-inch volume reduction goal and removes a high amount of TP, but since the system is underground the cost will be relatively higher than surface BMPs. The BMP size and cost could be reduced by implementing surface BMPs within the drainage area to reduce the required volume of the underground BMP. The impacts to the park consist of loss of trees, but the usable park space is maintained.

Pavilion South Regional 1	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	21.2
Construction Engineering & Admin. Cost Est.	$1,039,672
30-yr Annualized Cost-Benefit ($/lb TP)	$2,172
Cost-Benefit Rank	10 of 12

Figure 9 – Pavilion South Regional 1 – Reuse & UG Infiltration



Pavilion South Regional 2 – Recirculating Infiltrating Stream

Description - Runoff from the stormsewer to the southwest can be treated through a design consisting of 3 features outlined below. Each feature is sized to capture approximately one third of the 1.1" volume reduction goal for the purpose of this study.

Storage Tank – Runoff could first be captured by a large underground storage tank. Pretreatment would be provided in the storage tank, or, alternatively, by an upstream hydrodynamic separator for ease of maintenance. The underground storage would retain runoff that would then be pumped to the upstream end of the infiltrating stream (see below) and 'recirculated' through the meandering-infiltration stream or allowed to infiltrate via underground infiltration.

Meandering-infiltrating stream – An infiltration design consisting of an intermittent meandering stream, plantings, landscaping, weir structures to provide storage, and infiltration throughout the stream corridor (see example photo in **Figure 10**). A normally dry, rock stream bed would meander through the park at about two feet below the existing ground elevation. During rain events, stone weirs would store runoff in the 'floodplain' of the stream, and runoff would subsequently infiltrate. Runoff which would not infiltrate in the stream would overflow into a recirculation manhole, which would pump water to the upstream end of the stream. The cycle would continue until all of the runoff in the system is infiltrated. This would provide a water feature amenity as the stream bed would be flowing with water after the rain event is over. The benefits of this system is that it provides treatment for a greater volume of water, while providing an amenity to Como Park.

Underground Infiltration – To provide additional treatment and flexibility, an underground infiltration system could be installed. Plumbing would allow the recirculation tank to pump water into the infiltrating stream or the underground infiltration system.

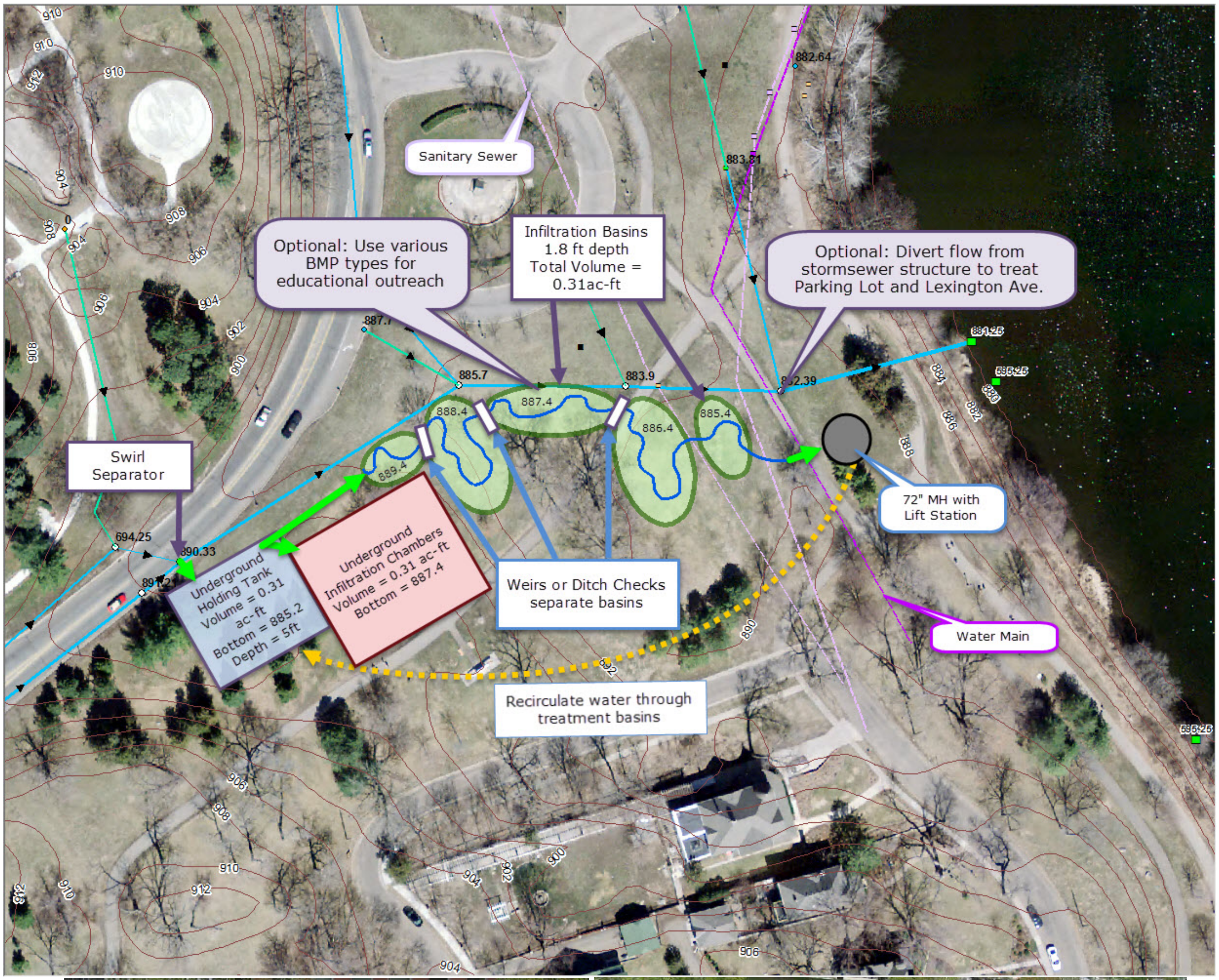
Additional Design Considerations -

- There are many possible configurations of this BMP that can be further explored to maximize treatment efficiency.
- As an option to showcase different types of stormwater treatment BMPs, a treatment train of various BMP types could be implemented for education and outreach. Further, with the recirculation system, the stored water could be used for live-action demonstrations or research purposes.
- If drawdown requirements are a concern, the recirculation system could be used with a filtration BMP, allowing for faster drawdown time.
- The holding tank could double as a stormwater reuse system.

Results and Analysis – Even with the complexity of the recirculation system, the cost-benefit is similar to the Pavilion South Regional 1 with the same removals. This is attributed to the surface features reducing the underground storage required, thereby off-setting the high cost of underground treatment. Some usable park space is lost due to the stream corridor, but that loss is minimal compared to the other surface BMPs in the preliminary alternatives analysis. Further, surface BMPs will better promote educational opportunities.

Pavilion South Regional 2	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	21.2
Construction Engineering & Admin. Cost Est.	$1,130,676
30-yr Annualized Cost-Benefit ($/lb TP)	$2,363
Cost-Benefit Rank	11 of 12

Figure 10 – Pavilion South Regional 2 – Recirculating Infiltrating Stream



Alternative Treatment Train Combinations

Description – Three treatment train options were analyzed in order to maximize volume reduction and TP removal. Mass of TSS or TP removed by BMP treatment trains (or combination of BMPs in series) cannot be simply added, because removals from the upstream BMP will affect the efficiency of the downstream BMP. Therefore, the treatment train alternatives were modeled separately to determine removals as seen by the downstream resource (Como Lake). The alternatives include different combinations of the BMPs proposed for Como Zoo and Golf course.

Results and Analysis – The Zoo 2 & Golf Parking Lot treatment train is the most efficient of the three analyzed, while The Zoo Combination & Golf Parking Lot treatment train is less efficient as shown by the higher benefit cost than both of the individual BMPs by themselves. The Zoo 2, Golf Parking Lot & Northwest Golf Course Pond option is the second most cost-effective treatment train, and removes significantly more TP than the Zoo 2 & Golf Lot treatment train.

Golf Lot & Zoo Combo	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	43.6
Construction Engineering & Admin. Cost Est.	$648,534
30-yr Annualized Cost-Benefit ($/lb TP)	$853
Cost-Benefit Rank	6 of 12

Zoo 2 & Golf Lot	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	37.5
Construction Engineering & Admin. Cost Est.	$456,438
30-yr Annualized Cost-Benefit ($/lb TP)	$633
Cost-Benefit Rank	2 of 12

Zoo 2, Golf Lot & NW Pond	
Meets 1.1-inch volume reduction goal w/in Como Park	Yes
TP Removed (lb/yr)	58.3
Construction Engineering & Admin. Cost Est.	$815,749
30-yr Annualized Cost-Benefit ($/lb TP)	$773
Cost-Benefit Rank	3 of 12

3.2 Summary and Discussion of Results

Table 3 tabulates the BMP volume reductions, removals, and costs as well as ranks the BMP alternatives based on the annualized cost to remove TP.

Table 3 - Concept BMP Alternatives Performance and Efficiency Table

BMP Name	BMP Type	Drainage Area (ac)	BMP Size (sq-ft)	Volume Reduction: 1.1" Volume Reduction Goal (ac-ft)	Volume Reduction: 1.1" Goal w/in Como Park (ac-ft)	Volume Reduction: BMP WQ Treatment Volume (ac-ft)	BMP Removals: TP (lb/yr)	BMP Removals: TP %	BMP Removals: TSS (lb/yr)	BMP Removals: TSS %	BMP Removals: Volume (ac-ft/yr)	BMP Removals: Volume %	Volume Treated[7] (ac-ft/yr)	Volume Treated[7] %	Cost: Construction, Engineering & Admin	Cost: Annual Maintenance	Cost: Annualized 30-yr Life-Cycle Cost	30-yr Annualized Cost-Benefit ($/lb TP)	Cost-Benefit Rank
NW Pond	IESF Bench	153.2[4]	6,200	4.42	0.00	3.60[1]	31	28%	2517	5%	0.0	0%	93.7	87%	$359,311	$14,372	$28,657	923[3]	7[3]
Golf Lot	IESF Bench	278.6[4]	1,480	6.58	1.18[5]	0.55[1]	23.9	20%	872	3%	0.0	0%	54.2	37%	$279,460	$11,178	$22,288	931[3]	9[3]
Zoo 1	Filtration Basin	62.0	9,800	1.91	0.93	0.20[2]	16.1	37%	3882	21%	0.0	0%	35.8	82%	$266,936	$9,183	$14,897	927	8
Zoo 2	Infiltration Basin	63.2	13,420	1.91	0.93	0.65	18.7	40%	3136	16%	24.5	52%	27.8	59%	$176,978	$1,841	$7,102	380	1
Zoo Combo	Filtration Basin & Infiltration Basin	63.2	23,220	1.91	0.93	0.85[2]	24.9	53%	4877	25%	24.3	52%	40.4	86%	$369,074	$12,696	$20,597	827	4
Pavilion North	Rain Gardens	3.4	2,875	0.10	0.10	0.07[2]	2	62%	1133	91%	0.0	0%	3.1	92%	$123,708	$4,256	$6,904	3478	12
Pavilion South Parking Lot	Infiltration and Filtration Swale	7.4	9,200	0.15	0.15	0.15[2]	4.5	84%	2438	91%	3.4	74%	4.2	91%	$93,351	$971	$3,746	832	5
Pavilion South Regional 1	Reuse Tank and Underground Infiltration	68.7	26,180	0.94	0.94	0.94	21.2	63%	13081	66%	15.2	66%	15.2	66%	$1,039,672	$17,466	$46,067	2172	10
Pavilion south Regional 2	Infiltration Stream and Underground Infiltration	68.7	29,000	0.94	0.94	0.94	21.2	63%	12957	66%	15.4	67%	15.4	67%	$1,130,676	$18,995	$50,100	2363	11
Alternative Treatment Train Combinations																			
Golf Lot & Zoo Combo	Treatment Train	278.6[4]	24,700	6.58	1.18[5]	1.40[6]	43.6	38%	4650	18%	24.2	17%	86.0	61%	$648,534	$23,875	$37,216[3]	853[3]	6
Zoo 2 & Golf Lot	Treatment Train	278.6[4]	14,900	6.58	1.18[5]	1.20[6]	37.5	34%	3309	13%	24.3	16%	73.4	50%	$456,438	$13,019	$23,721[3]	633[3]	2
Zoo 2, Golf Lot & NW Pond	Treatment Train	278.6[4]	21,100	6.58	1.18[5]	4.80[6]	58.3	32%	5068	8%	8.3	5%	180.7	109%[8]	$815,749	$27,391	$45,088[3]	773[3]	3

1. Volume after the multiplier of 0.8 was applied for iron enhanced filtration
2. Volume after the multiplier of 0.55 was applied for filtration
3. A 20-year annualized benefit was used for the IESF BMPs due to high loading rates
4. The value shown does not include GottFrieds Pit (513.0 acres), which drains to this BMP but may not be treated
5. The Golf Parking Lot 1.1" Goal is 0.18; most of the remaining 1.1" goal within the park is from Como Zoo.
6. Sum of BMP WQ Treatment Volumes included in the Treatment Train
7. Includes volume infiltrated or filtrated through the BMP
8. The Treated Volume is greater than 100% because treated runoff from the NW Pond IESF is treated again by the Golf Lot IESF

3.2.1 PROJECT OBJECTIVES

The results were reviewed in light of the quantifiable objectives under Goal 1 of the project, and are highlighted are below:

- The BMPs that meet the 1.1-inch volume reduction goal of their respective drainage areas within Como Park are:
  - Pavilion North Rain Gardens (can adjust size with parking lot reconstruction)
  - Pavilion South Parking Lot
  - Pavilion South Regional 1
  - Pavilion South Regional 2
  - Golf Lot-Zoo Combo Treatment Train
  - Zoo 2-Golf Lot Treatment Train
  - Zoo 2-Golf Lot- NW Pond Treatment Train
- Zoo 2 Infiltration is the most cost-effective BMP identified for TP removal ($380/lb/yr).
- Pavilion South Regional 1 and 2 remove the most TSS (approximately 13,000 lbs/yr TSS)
- Zoo 2-Golf Lot-NW Pond treatment train removes the most TP (58.3 lbs/yr), at an exceptional value ($773/lb TP) and the NW Pond removes the most TP of the single (non-treatment train) BMPs (31.0 lbs/yr TP).

3.2.2 TREATMENT TRAIN CONSIDERATIONS

The three treatment train combinations that were analyzed are the Golf Lot-Zoo Combo, Zoo 2-Golf Lot, and Zoo 2-Golf Lot-NW Pond. Because these BMPs are in series, the removals of each individual BMP are not simply additive. The multiple goals of the project make assessing the results a type of balancing act of prioritizing goals, namely TP removal, cost, and volume reduction goals. When considering the treatment train BMP combinations, the following are important observations:

- Combining filtration BMP in series is generally not preferred because the water filtered in the upstream filtration BMP would be filtered a second time in the downstream filtration BMP. However, in the case of the treatment trains modeled, there is a considerable amount of additional untreated runoff that is treated by the downstream filtration BMP.
- When considering Zoo 2-Golf Lot vs. Golf Lot-Zoo Combo, the TP removal is marginally increased by 6.1 lbs with the addition of the Zoo Filtration Basin (Golf Lot-Zoo Combo). That increase in removal would cost an estimated $13,495 annually, or $2,212/lb of TP. This shows that the addition of the Zoo Filtration Basin to the Zoo 2-Golf Lot treatment train is relatively less cost-effective than other options.
- Zoo 2-Golf Lot-NW Pond treatment train:
  - First, it should be noted that the Golf Lot treats less TP, even though it has a larger drainage area. This is because the NW Pond is a larger IESF with more storage in the larger pond.
  - Second, the Zoo Infiltration Basin in series with the Golf Lot IESF is an excellent combination as the overflow from the undersized infiltration basin will flow to the Golf Lot IESF. If more treatment is desired, the addition of the NW Pond could provide an increase of 20.8 lbs TP at a relatively low cost (ranked 3rd overall).
  - Finally, in the treatment train as modeled, the Golf Lot IESF is essentially double treating the filtered water from the NW Pond IESF (as shown by the Volume Treated column over 100% of the inflow). This is not desirable because of the inefficient treatment and it may not allow the IESF to dry. However, because automated valves are proposed for both the NW Pond IESF and the Golf Lot IESF, flow from Gottfrieds Pit could bypass the NW Pond IESF (via an

automated valve, which could occur after 48 hours of inundation), and could also bypass the Golf Lot IESF (via an automated valve).

3.3 Recommendation

This study shows feasible designs and water quality analysis for many locations throughout Como Regional Park that will provide regional treatment of stormwater from within the park and areas outside of the park. Technical analysis of results related to the project goals and objectives (as discussed in **Section 3.2**) will help determine the recommendation of proposed BMPs for implementation.

There are other less technical factors that also determine the selection of proposed BMPs. These factors include the benefits of regional practices, collaboration between entities, anticipated park improvement projects, and scheduling/timing of the planned projects. The locations analyzed were selected with these purposes in mind. The following park improvement projects are anticipated to occur in the near future and are within the drainage areas of the concept BMP alternatives: Pavilion north parking lot, pavilion south parking lot, golf course parking lot, and projects within Como Zoo. It is understood that Como Zoo is the most immanent anticipated park improvement project.

The Zoo 2 Infiltration Basin is the highest ranked alternative in terms of annualized cost-benefit ($/lb TP), and also treats upstream planned projects within the zoo[2]. Therefore, Zoo 2 would be the highest recommend alternative. However, Zoo 2 does not meet the 1.1-inch volume reduction goal within the park. If the 1.1-inch volume reduction goal for Como Zoo is to be met, a treatment train combination of BMPs is needed. Zoo 2-Golf Lot treatment train meets the 1.1-inch goal for both the Como Zoo and the golf course parking lot, and also is the second highest ranked alternative. Because of this, and the fact that Zoo 2-Golf lot meets the project goals and objectives, it should be considered a priority for implementation.

If more treatment is desired, the next most cost-effective step is to include the NW Pond in the treatment train, which was analyzed as the Zoo 2-Golf Lot-NW Pond treatment train and is ranked third. This combination removes the highest amount of TP of the alternatives analyzed and provides exceptional benefit.

For the pavilion north location, since it is infeasible to treat regional flows, it is best that any improvement project re-evaluate the treatment options for the goals of that project.

Lastly, the pavilion south parking lot and regional alternatives can meet the 1.1-inch volume reduction goal. Many options were considered in the feasibility analysis to provide combined treatment of the regional stormsewer as well as the pavilion south parking lot. The Pavilion South Regional 2 preferred alternative can treat both the regional and parking lot flows. This alternative is more expensive due to the recirculation and underground features but is the recommended project to consider if regional treatment and other ancillary benefits are desired. Apart from regional treatment, the Pavilion South Parking Lot BMP alterative provides a cost-effective solution for treatment of the anticipated improvement of the parking lot.

---

[2] It should also be noted that all the BMPs that treat runoff from Como Zoo also capture runoff from other areas. In other words, in an actual 1.1-inch rain event, the BMPs' volume will capture a fraction of runoff from Como Zoo and a fraction of runoff from areas outside the Zoo and Park.

4 References

[1] *Como Lake TMDL*, Capitol Region Watershed District and Emmons & Olivier Resources, Inc. October 2010.

[2] *Como Park Stormwater Inventory and Watershed Analysis.* Capitol Region Watershed District (CRWD) and Houston Engineering Inc. (HEI). 2016.

[3] *Como Lake Watershed Load Reductions.* Draft Technical Memorandum. Capitol Region Watershed District (CRWD) and Houston Engineering Inc. (HEI). Dated May 25, 2017.

[4] *Como Park Volume Reduction Goal.* Draft Technical Memorandum. Capitol Region Watershed District (CRWD) and Houston Engineering Inc. (HEI). Dated May 25, 2017.

[5] *Best Management Practices for the Off-Site Reuse of Unregulated Fill*, Minnesota Pollution Control Agency (MPCA), February 2012.

[6] Structural stormwater Best Management Practices. (2017, October 31). *Minnesota Stormwater Manual*. Retrieved, 2017-2018 from https://stormwater.pca.state.mn.us/index.php?title=Structural_stormwater_Best_Management_Practices&oldid=34005.

[7] *Performance Assessment of an Iron-Enhnaced Sand Filtration Trench for Capturing Dissolved Phosphorus*. Erickson A., Gulliver J., St. Anthony Falls Laboratory (SAFL). November 10,2010.

[8] Chisago Soil and Water Conservation District (SWCD). 2011. *City of Center City: Stormwater Retrofit Assessment.*

Environmental Protection Agency (EPA). August 1999. Strassler, E. et al. *Preliminary Data Summary of Urban Storm Water Best Management Practices*. Chapter 6. EPA-821-R-99-012.

Schueler, Thomas R., Peter A. Kumble, and Maureen A. Heraty. 1992. *A current assessment of urban best management practices: techniques for reducing non-point source pollution in the coastal zone.* Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, D.C.

Washington Conservation District (WCD). October, 15, 2014. *Wilmes Lake Subwatershed Retrofit Analysis.* Prepared for the South Washington Watershed District.

Water Environment Research Foundation (WERF). 2013. Pomeroy, C.A., et al. *User's Guide to the BMP SELECT Model, Version 2.0.* Prepared by ACR, Colorado State University, University of Utah, and WERF.

APPENDIX A

GEOTECHNICAL EVALUATION REPORT

Preliminary Geotechnical Evaluation Report

Como Stormwater BMPs
1225 Estabrook Drive
Saint Paul, Minnesota

Prepared for

Houston Engineering, Inc.

Professional Certification:
I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of Minnesota.

Tyler J. Reich, PE
Project Engineer
License Number: 54944
January 15, 2018

TYLER JAMES ROWE REICH
LICENSED PROFESSIONAL ENGINEER
54944
STATE OF MINNESOTA

Project B1712486

Braun Intertec Corporation

BRAUN INTERTEC
The Science You Build On.

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

January 15, 2018

Project B1712486

Mr. Alexander Schmidt
Houston Engineering, Inc.
1401 21st Avenue North
Fargo, ND 58102

Re: Preliminary Geotechnical Evaluation
Como Stormwater BMPs
1225 Estabrook Drive
Saint Paul, Minnesota

Dear Mr. Schmidt:

We are pleased to present this Preliminary Geotechnical Evaluation Report for the Como Stormwater BMP feasibility project at the above referenced site.

Thank you for making Braun Intertec your geotechnical consultant for this project. If you have questions about this report, or if there are other services that we can provide in support of our work to date, please contact Tyler Reich at 612.418.6116 (treich@braunintertec.com).

Sincerely,

BRAUN INTERTEC CORPORATION

Tyler J. Reich, PE
Project Engineer

Colette Brandenburg for:
Daniel B. Mahrt, PE
Associate Principal – Principal Engineer

Table of Contents

BRAUN INTERTEC

A. Introduction

A.1. Project Description

This Preliminary Geotechnical Evaluation Report addresses the proposed design and construction of stormwater best management practices (BMPs) at the Como Park Golf Course located at 1225 Estabrook Drive in Saint Paul, Minnesota. Details of the project components were not available at the time of this report and a more comprehensive geotechnical exploration may be required during future phases of this project.

A.2. Purpose

The purpose of our preliminary geotechnical evaluation is to characterize subsurface geologic conditions at selected exploration locations and evaluate their impact on the design and construction of potential stormwater BMPs.

A.3. Scope of Services

We performed our scope of services for the project in accordance with our Proposal for a Preliminary Geotechnical Evaluation, dated December 12, 2017, and authorized on December 14, 2017. The following list describes the geotechnical tasks completed in accordance with our authorized scope of services.

- Reviewing background information.

- Staking and clearing the exploration location of underground utilities. Houston Engineering selected and we staked the new exploration locations. We acquired the surface elevations and locations with GPS technology using the State of Minnesota's permanent GPS base station network. The Soil Boring Location Sketch included in the Appendix shows the approximate locations of the borings.

- Performing 13 standard penetration test (SPT) borings, denoted as ST-1 to ST-13 to nominal depths of 21 to 26 feet below grade across the site.

- Performing environmental screening at 7 of the selected boreholes (ST-5, ST-6, ST-8, ST-10, ST-11, ST-12, and ST-13).

- Performing laboratory testing on select samples to aid in soil classification and engineering analysis.

- Preparing this report containing a boring location sketch, logs of soil borings, a summary of the soils encountered, results of laboratory tests, results of our environmental screening, and recommendations for stormwater improvements.

B. Results

B.1. Geologic Overview

The Ramsey County geologic atlas indicates that the site is underlain with glacial outwash sands. We based the geologic origins used in this report on the soil types, in-situ and laboratory testing, and available common knowledge of the geological history of the site. Because of the complex depositional history, geologic origins can be difficult to ascertain. We did not perform a detailed investigation of the geologic history for the site.

B.2. Boring Results

Table 1 provides a summary of the soil boring results, in the general order we encountered the strata. Please refer to the Log of Boring sheets in the Appendix for additional details. The Descriptive Terminology of Soil sheet in the Appendix includes definitions of abbreviations used in Table 1.

Table 1. Subsurface Profile Summary*

Strata	Soil Type - ASTM Classification	Range of Penetration Resistances	Commentary and Details
Pavement section			▪ Encountered only at boring locations ST-8, ST-10, and ST-11. ▪ Overall thickness ranges from 9 to 15 inches. ▪ Bituminous thickness 3 to 11 inches. ▪ Aggregate base is 6 to 12 inches when encountered.
Topsoil fill	SM, OL, CL		▪ Encountered at all boring locations without pavement. ▪ Predominantly SM. ▪ Dark brown to black. ▪ Thicknesses at boring locations varied from about 1 to 13 inches. ▪ Moisture condition generally moist or wet.
Fill	SM, SP, ML	3 to 28 BPF	▪ Encountered at all boring locations except ST-2 and ST-4. ▪ Predominantly SM. ▪ General penetration resistance of 8 to 20 BPF. ▪ Moisture condition generally moist. ▪ General thicknesses at boring locations varied from 4 to 9 feet where encountered. ▪ Extended to a depth of 23 feet at boring ST-12.
Swamp deposits	OL, SM, CL	Weight of Hammer to 8 BPF	▪ Encountered at boring locations ST-2 to ST-5, ST-7, ST-9, and ST-12. ▪ Predominantly organic silt. ▪ Thicknesses at boring locations varied from 3 to 18 feet when encountered. ▪ Extended to termination depth of boring ST-12.
Lacustrine	ML	1 to 10 BPF	▪ General penetration resistance of 2 to 4 BPF. ▪ Moisture condition generally wet. ▪ Extended to termination depth of borings ST-4 and ST-7.
Glacial deposits	SP, SP-SM, SM	4 to 44 BPF	▪ General penetration resistance of 8 to 12 BPF. ▪ Variable amounts of gravel. ▪ Moisture condition generally moist. ▪ Extended to termination depth of borings ST-1 to ST-3, ST-5, ST-6, ST-9, ST-10, and ST-13.
	CL	10 to 20 BPF	▪ General penetration resistance of 14 BPF. ▪ Moisture condition generally wet. ▪ Extended to termination depth of borings ST-8 and ST-11.

*Abbreviations defined in the attached Descriptive Terminology of Soil sheet.

For simplicity in this report, we define existing fill to mean existing, uncontrolled, or undocumented fill.

B.3. Groundwater

Table 2 summarizes the depths where we observed groundwater; the attached Log of Boring sheets in the Appendix also include this information and additional details.

Table 2. Groundwater Summary

Location	Surface Elevation	Measured or Estimated Depth to Groundwater (ft)	Corresponding Groundwater Elevation (ft)
ST-1	892	19	873
ST-2	888.4	17	871 1/2
ST-3	890.4	18.5	872
ST-4	884.3	---	---
ST-5	886.2	15	871
ST-6	891.5	15	876 1/2
ST-7	888.4	19	869 1/2
ST-8	889.9	11	879
ST-9	888.2	14	874
ST-10	890	13	877
ST-11	890.2	---	---
ST-12	889.6	---	---
ST-13	889.7	14	875 1/2

Our experience with similar soil indicates that seasonal and annual fluctuations of groundwater should be anticipated.

B.4. Laboratory Test Results

Our mechanical analyses indicated that the poorly graded sand with silt contained 5.8 to 10.2 percent silt and clay by weight. The sandy lean clay sample tested contained 68 percent silt and clay by weight.

Moisture contents of the sandy soils varied from 4.3 to 4.7 percent, indicating that the material was likely below its optimum moisture content. The moisture content of the clayey sample tested was 16 percent.

B.5. Environmental Screening Results

Soil samples were generally collected from depths at intervals where elevated PID measurements were observed in the field. If elevated PID readings were not observed, the soil samples were collected from the depth most likely to be impacted based on the potential contaminant source.

Samples were submitted to Pace Analytical, Montana and analyzed for a combination of the following parameters:

- Volatile Organic Compounds (VOCs) using EPA Method 8260B
- DRO using Method WI MOD DRO

PID field screening results were recorded for soil samples collected from borings ST-5, ST-6, ST-8, ST-10, ST-11, ST-12, and ST-13. Soil samples collected at borings ST-5, ST-6, ST-8, ST-10, ST-11, and ST-13 showed organic vapor concentrations below 1 part per million (ppm), which are considered to be general background readings. PID values from soil boring ST-12 showed a PID value of 3.9 at a depth of 12 1/2 feet, decreasing to 1 ppm or less at in every other sample. A summary of the PID field screening results are included on the boring logs.

VOC’s were not detected from any sample collected on site. DRO was detected in soil samples collected at ST-5 (5-7 feet below grade), ST-10 (5-7 feet below grade) and ST-12 (10-12 feet below grade). Concentrations of DRO in soil samples collected at ST-5, ST-10, and ST-12 were 47.3 milligram per kilogram (mg/kg), 95.7 mg/kg, and 5,960 mg/kg, respectively.

C. Preliminary Recommendations

C.1. Discussion

The results of this evaluation will be used to select suitable areas for potential stormwater BMPs. A more thorough geotechnical investigation may be necessary after there have been developments in the design phase of this project.

C.2. Stormwater

We estimated infiltration rates for some of the soils we encountered in our soil borings, as listed in Table 3. These infiltration rates represent the long-term infiltration capacity of a practice and not the capacity of the soils in their natural state. Field testing, such as with a double-ring infiltrometer (ASTM D3385), may justify the use of higher infiltration rates. However, we recommend adjusting field test rates by the appropriate correction factor, as provided for in the Minnesota Stormwater Manual or as allowed by the local watershed. We recommend consulting the Minnesota Stormwater Manual for stormwater design.

Table 3. Estimated Design Infiltration Rates Based on Soil Classification

Soil Type	Infiltration Rate* (inches/hour)
Gravels and gravelly sands	1.63
Sands with less than 12 percent fines, poorly graded or well graded sands	0.8
Silty sands, silty gravelly sands	0.45
Silts, silty, or clayey fine sands	0.2
Clays	0.06

*From Minnesota Stormwater Manual. Rates may differ at individual sites.

Fine-grained soils (silts and clays), topsoil, or organic matter that mixes into or washes onto the soil will lower the permeability. The contractor should maintain and protect infiltration areas during construction. Furthermore, organic matter and silt washed into the system after construction can fill the soil pores and reduce permeability over time. Proper maintenance is important for long-term performance of infiltration systems.

This geotechnical evaluation does not constitute a review of site suitability for stormwater infiltration or evaluate the potential impacts, if any, from infiltration of large amounts of stormwater.

D. Procedures

D.1. Penetration Test Borings

We drilled the penetration test borings with an ATV-mounted core and auger drill equipped with hollow-stem auger. We performed the borings in general accordance with ASTM D6151 taking penetration test samples at 2 1/2- or 5-foot intervals in general accordance to ASTM D1586. The boring logs show the actual sample intervals and corresponding depths.

We sealed penetration test boreholes meeting the Minnesota Department of Health (MDH) Environmental Borehole criteria with an MDH-approved grout. We will forward a sealing record for those boreholes to the Minnesota Department of Health Well Management Section.

D.2. Exploration Logs

D.2.a. Log of Boring Sheets

The Appendix includes Log of Boring sheets for our penetration test borings. The logs identify and describe the penetrated geologic materials, and present the results of penetration resistance and other in-situ tests performed. The logs also present the results of organic vapor screening, laboratory tests performed on penetration test samples, and groundwater measurements.

We inferred strata boundaries from changes in the penetration test samples and the auger cuttings. Because we did not perform continuous sampling, the strata boundary depths are only approximate. The boundary depths likely vary away from the boring locations, and the boundaries themselves may occur as gradual rather than abrupt transitions.

D.2.b. Organic Vapor Measurements

Soils samples recovered from the soil borings were visually and manually classified in the field by an environmental technician using ASTM D 2487 “Unified Soils Classification System” and ASTM D 2488 “Recommended Practice for Visual and Manual Description of Soils.” In addition, the recovered soil samples from each boring location were screened by headspace method for the presence of organic vapors using a photoionization detector (PID). The PID was equipped with a 10.6-electron-volt lamp and calibrated to a 100 parts per million (ppm) isobutylene standard.

D.2.c. Geologic Origins

We assigned geologic origins to the materials shown on the logs and referenced within this report, based on: (1) a review of the background information and reference documents cited above, (2) visual classification of the various geologic material samples retrieved during the course of our subsurface exploration, (3) penetration resistance and other in-situ testing performed for the project, (4) laboratory test results, and (5) available common knowledge of the geologic processes and environments that have impacted the site and surrounding area in the past.

D.3. Material Classification and Testing

D.3.a. Visual and Manual Classification

We visually and manually classified the geologic materials encountered based on ASTM D2488. When we performed laboratory classification tests, we used the results to classify the geologic materials in accordance with ASTM D2487. The Appendix includes a chart explaining the classification system we used.

D.3.b. Laboratory Testing

The exploration logs in the Appendix note most of the results of the laboratory tests performed on geologic material samples. We performed the tests in general accordance with ASTM procedures.

D.4. Groundwater Measurements

The drillers checked for groundwater while advancing the penetration test borings, and again after auger withdrawal. We then filled the boreholes, as noted on the boring logs.

E. Qualifications

E.1. Variations in Subsurface Conditions

E.1.a. Material Strata

We developed our evaluation, analyses, and recommendations from a limited amount of site and subsurface information. It is not standard engineering practice to retrieve material samples from exploration locations continuously with depth. Therefore, we must infer strata boundaries and thicknesses to some extent. Strata boundaries may also be gradual transitions, and project planning should expect the strata to vary in depth, elevation, and thickness away from the exploration locations.

Variations in subsurface conditions present between exploration locations may not be revealed until performing additional exploration work, or starting construction. If future activity for this project reveals any such variations, you should notify us so that we may reevaluate our recommendations. Such variations could increase construction costs, and we recommend including a contingency to accommodate them.

E.1.b. Groundwater Levels

We made groundwater measurements under the conditions reported herein and shown on the exploration logs, and interpreted in the text of this report. Note that the observation periods were relatively short, and project planning can expect groundwater levels to fluctuate in response to rainfall, flooding, irrigation, seasonal freezing and thawing, surface drainage modifications, and other seasonal and annual factors.

E.2. Use of Report

This report is for the exclusive use of the addressed parties. Without written approval, we assume no responsibility to other parties regarding this report. Our evaluation, analyses, and recommendations may not be appropriate for other parties or projects.

E.3. Standard of Care

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

Appendix

DENOTES APPROXIMATE LOCATION OF STANDARD PENETRATION TEST BORING

BRAUN INTERTEC
The Science You Build On.
11001 Hampshire Avenue S
Minneapolis, MN 55438
952.995.2000
braunintertec.com

Drawing Information

Project No:	B1712486
Drawing No:	B1712486
Drawn By:	BJB
Date Drawn:	12/6/17
Checked By:	TR
Last Modified:	12/26/17

Project Information

Como Stormwater BMPs

1225 Estabrook Drive

Saint Paul, Minnesota

Soil Boring Location Sketch

F:\2017\B1712486.dwg,Geotech,12/26/2017 11:04:31 AM

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-1**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

Elev. feet 892.0	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
890.9	1.1	FILL	FILL: Silty Sand, fine- to medium-grained, dark brown, moist. (Topsoil Fill)			
888.0	4.0	FILL	FILL: Silty Sand, fine- to medium-grained, brown, moist.	8		
883.0	9.0	SP	POORLY GRADED SAND, fine- to medium-grained, brown, moist, very loose to loose. (Glacial Outwash)	4 9		
871.0	21.0	SP	POORLY GRADED SAND, fine- to coarse-grained, with Gravel, brown, moist to waterbearing, loose to medium dense. (Glacial Outwash)	7 13 8 5	∇	An open triangle in the water level (WL) column indicates the depth at which groundwater was observed while drilling. Groundwater levels fluctuate.
			END OF BORING. Water observed at 19 feet with 7 1/2 feet of hollow-stem auger in the ground. Water observed at 19 feet with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 9 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-2**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier	METHOD: 3 1/4" HSA, Autohammer	DATE: **12/11/17**	SCALE: **1" = 4'**

Elev. feet 888.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
888.2	0.2	TS	ORGANIC CLAY, black, wet. (Topsoil)			
882.4	6.0	OL	ORGANIC CLAY, black, wet, rather soft. (Swamp Deposit)	4 5		
879.4	9.0	SM	SILTY SAND, fine-grained, trace organics, brown, moist. (Glacial Outwash)	7		
876.4	12.0	ML	SILT, gray, wet, rather soft. (Lacustrine)	5		
870.4	18.0	SM	SILTY SAND, fine- to coarse-grained, with Gravel, with Clay lenses, brown, wet to waterbearing, very loose to loose. (Glacial Outwash)	6 4	▽	
867.4	21.0	SP	POORLY GRADED SAND, medium- to coarse-grained, with Gravel, brown, waterbearing, loose. (Glacial Outwash)	8		
			END OF BORING. Water observed at 17 feet with 19 1/2 feet of hollow-stem auger in the ground. Water observed at 17 feet with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 7 1/2 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.			

(See Descriptive Terminology sheet for explanation of abbreviations)

BRAUN℠ INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-3**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

Elev. feet 890.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
889.6	0.8	FILL	FILL: Sandy Lean Clay, dark brown, wet. (Topsoil Fill)			
886.4	4.0	FILL	FILL: Silt, brown, wet.	6		
881.4	9.0	OL	ORGANIC CLAY, black, wet, soft. (Swamp Deposit)	3 3		
878.4	12.0	SM	SILTY SAND, fine- to medium-grained, slightly organic, black, wet, very loose. (Swamp Deposit)	2		
872.4	18.0	ML	SILT, gray, wet, very soft to rather soft. (Lacustrine)	1 5		
869.4	21.0	SP	POORLY GRADED SAND, fine- to coarse-grained, with Gravel, brown, waterbearing, medium dense. (Glacial Outwash)	13	▽	

END OF BORING.

Water observed at 18 1/2 feet with 19 1/2 feet of hollow-stem auger in the ground.

Water observed at 18 1/2 feet with 19 1/2 feet of hollow-stem auger in the ground.

Water not observed to cave-in depth of 11 1/2 feet immediately after withdrawal of auger.

Boring then backfilled with bentonite grout.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-4**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier	METHOD: 3 1/4" HSA, Autohammer	DATE: **12/11/17**	SCALE: **1" = 4'**

Elev. feet 884.3	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
884.1	0.2	FILL	FILL: Lean Clay, black, wet. (Topsoil Fill)			
		OL	ORGANIC CLAY, fine- to medium-grained, black, wet, soft. (Swamp Deposit)	3		
				WH		
				3		
875.3	9.0	OL	ORGANIC CLAY, trace shells, black, wet, soft to rather soft. (Swamp Deposit)	4		
				4		
				2		
866.3	18.0	ML	SILT, gray, wet, rather soft. (Lacustrine)	5		
863.3	21.0		END OF BORING. Water not observed with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 5 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486 GEOTECHNICAL EVALUATION Como Stormwater BMPs 1225 Estabrook Drive St. Paul, Minnesota	BORING: ST-5 LOCATION: See attached sketch.

DRILLER: B. Kammermeier	METHOD: 3 1/4" HSA, Autohammer	DATE: 12/11/17	SCALE: 1" = 4'

Elev. feet 886.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	PID ppm	Tests or Notes
886.1	0.1	FILL	FILL: Silty Sand, fine- to medium-grained, trace roots, dark brown, moist. (Topsoil Fill)				
		FILL	FILL: Silty Sand, fine- to medium-grained, with Gravel, dark brown, moist.	24		0.4	
				24		0.5	
879.2	7.0	OL	ORGANIC CLAY, black, wet, medium. (Swamp Deposit)	7		0.6	
877.2	9.0	SM	SILTY SAND, fine- to medium-grained, with Gravel, black, moist, loose. (Swamp Deposit)	5		0.4	
874.2	12.0	ML	SILT, gray, wet, rather soft. (Lacustrine)	4		0.2	
872.2	14.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, with Gravel, brown, waterbearing, loose. (Glacial Outwash)	10	∇	0.2	
				10		0.2	
865.2	21.0		END OF BORING. Water observed at 15 feet with 15 feet of hollow-stem auger in the ground. Water observed at 18 1/2 feet with 20 feet after last sample. Water not observed to cave-in depth of 6 1/2 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-6**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet 891.5	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	PID ppm	Tests or Notes
891.2	0.3	FILL	FILL: Silty Sand, fine- to medium-grained, trace roots, dark brown, moist. (Topsoil Fill)					
		FILL	FILL: Poorly Graded Sand with Silt, fine- to medium-grained, brown, moist.	28			0.1	
				13				
884.5	7.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, with Clay seams, brown, moist to wet, loose to medium dense. (Glacial Outwash)	14		5	0.4	p200 = 8%
				9			0.2	
				12			0.1	
877.5	14.0	SM	SILTY SAND, fine- to medium-grained, with Gravel, brown, wet to waterbearing, loose. (Glacial Outwash)	8	▽		0.1	
873.5	18.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, with Gravel, brown, waterbearing, loose. (Glacial Outwash)	5			0.1	
870.5	21.0		END OF BORING.					

Water observed at 15 feet with 15 feet of hollow-stem auger in the ground.

Water observed at 17 feet with 20 feet after last sample.

Water not observed to cave-in depth of 7 feet immediately after withdrawal of auger.

Boring then backfilled with bentonite grout.

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-7**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

Elev. feet 888.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
888.1	0.3	SM	SILTY SAND, fine- to medium-grained, trace roots, dark brown, moist.			
		FILL	FILL: Silty Sand, fine- to medium-grained, with Gravel, trace organics, dark brown.	27		
				10		
882.4	6.0	OL	ORGANIC CLAY, trace shells, black, wet, rather soft. (Swamp Deposit)	4		
				4		
876.4	12.0	SM	SILTY SAND, fine- to medium-grained, trace shells, black, wet, rather soft. (Swamp Deposit)	5		
874.4	14.0	OL	ORGANIC CLAY, trace shells, dark gray, wet, very soft. (Swamp Deposit)	WH		
870.4	18.0	ML	SILT, gray, wet, soft. (Lacustrine)		▽	
				2		
867.4	21.0		END OF BORING.			

Water observed at 19 feet with 19 1/2 feet of hollow-stem auger in the ground.

Water observed at 19 feet with 19 1/2 feet after last sample.

Water not observed to cave-in depth of 5 1/2 feet immediately after withdrawal of auger.

Boring immediately backfilled with bentonite grout.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486 GEOTECHNICAL EVALUATION Como Stormwater BMPs 1225 Estabrook Drive St. Paul, Minnesota	BORING: ST-8 LOCATION: See attached sketch.

DRILLER: B. Kammermeier	METHOD: 3 1/4" HSA, Autohammer	DATE: 12/11/17	SCALE: 1" = 4'

Elev. feet 889.9	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	PID ppm	Tests or Notes
889.2	0.8	PAV	3 inches of bituminous over 6 inches of aggregate base.					
		FILL	FILL: Poorly Graded Sand, with organics, with Gravel, brown to dark brown, moist.	8			0.1	
				8			0.1	
883.9	6.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, with Gravel, brown, moist, medium dense. (Glacial Outwash)	17		5	0.2	p200 = 10%
				13	▽		0.2	
877.9	12.0	GP	POORLY GRADED GRAVEL, fine- to coarse-grained, with Sand, brown, waterbearing, loose. (Glacial Outwash)	7			0.1	
				5			0.1	
871.9	18.0	CL	LEAN CLAY, reddish brown, wet, rather stiff. (Glacial Till)	10			0.3	
868.9	21.0		END OF BORING. Water observed at 11 feet with 12 1/2 feet of hollow-stem auger in the ground. Water observed at 16 1/2 feet with 20 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 7 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.					

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN℠ INTERTEC

LOG OF BORING

(See Descriptive Terminology sheet for explanation of abbreviations)

Braun Project B1712486 **GEOTECHNICAL EVALUATION** **Como Stormwater BMPs** **1225 Estabrook Drive** **St. Paul, Minnesota**	BORING: **ST-9** LOCATION: See attached sketch.

DRILLER: B. Kammermeier	METHOD: 3 1/4" HSA, Autohammer	DATE: **12/11/17**	SCALE: **1" = 4'**

Elev. feet 888.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
887.9	0.3	FILL	FILL: Silty Sand, fine- to medium-grained, trace roots, dark brown, moist. (Topsoil Fill)			
879.2	9.0	FILL	FILL: Silty Sand, fine- to medium-grained, trace asphalt debris at 3 feet, trace organics, brown, moist.	14 5 3		
876.2	12.0	CL	LEAN CLAY, trace shells, dark gray, wet, soft. (Swamp Deposit)	3		
870.2	18.0	SP	POORLY GRADED SAND, fine- to medium-grained, with Gravel, gray, waterbearing, medium dense to dense. (Glacial Outwash)	44 11	∇	
867.2	21.0	SP	POORLY GRADED SAND, medium- to coarse-grained, with Gravel, gray, waterbearing, very loose. (Glacial Outwash)	4		
			END OF BORING. Water observed at 15 feet with 15 feet of hollow-stem auger in the ground. Water observed at 14 feet with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 6 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.			

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-10**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet 890.0	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	PID ppm	Tests or Notes
888.8	1.3	PAV	3 inches of bituminous over 12 inches of aggregate base.					
884.0	6.0	FILL	FILL: Silty Sand, fine- to medium-grained, brown, moist.	19			0.1	
				6			0.2	
881.0	9.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, trace Gravel, brown, moist, medium dense. (Glacial Outwash)	11		4	0.7	p200 = 6%
878.0	12.0	SP	POORLY GRADED SAND, fine- to coarse-grained, with Gravel, dark brown, moist, medium dense. (Glacial Outwash)	15			0.3	
872.0	18.0	SP-SM	POORLY GRADED SAND with SILT, medium- to coarse-grained, with Gravel, brown, waterbearing, loose to medium dense. (Glacial Outwash)	12	▽			
				6			0.2	
869.0	21.0	SP-SM	POORLY GRADED SAND with SILT, fine- to coarse-grained, with Gravel, gray, waterbearing, medium dense. (Glacial Outwash)	29			0.3	

END OF BORING.

Water observed at 13 feet with 15 feet of hollow-stem auger in the ground.

Water observed at 17 feet with 20 feet of hollow-stem auger in the ground.

Water not observed to cave-in depth of 6 1/2 feet immediately after withdrawal of auger.

Boring then backfilled with bentonite grout.

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-11**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier	METHOD: 3 1/4" HSA, Autohammer	DATE: 12/11/17	SCALE: 1" = 4'

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet 890.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	PID ppm	Tests or Notes
889.2	1.0	PAV	11 inches of bituminous.					
886.2	4.0	FILL	FILL: Poorly Graded Sand with Silt, fine- to medium-grained, with Gravel, brown, moist.	7			0.2	
869.2	21.0	CL	SANDY LEAN CLAY, trace Gravel, brown, wet, very stiff. (Glacial Till)	14		16	0.1	p200 = 68%
				14			0.1	
				20			0.1	
				14			0.0	
				14			0.0	
				11			0.1	

END OF BORING.

Water not observed with 19 1/2 feet of hollow-stem auger in the ground.

Water not observed to cave-in depth of 2 feet immediately after withdrawal of auger.

Boring then backfilled with bentonite grout.

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-12**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

Elev. feet 889.6	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	PID ppm	Tests or Notes
889.4	0.3	FILL	FILL: Silty Sand, fine- to medium-grained, trace roots, dark brown, moist. (Topsoil Fill)				
		FILL	FILL: Silty Sand, fine- to coarse-grained, with Gravel, trace Clay, dark brown to gray, moist to wet.	17		0.1	
				13			
				6		0.2	
				6		1.0	
				6		3.9	
				7		1.0	
				7		0.2	
866.6	23.0	OL	ORGANIC CLAY, black, wet, medium. (Swamp Deposit)	8		0.2	
863.6	26.0		END OF BORING. Water not observed with 24 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 6 feet immediately after withdrawal of auger. Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

BRAUN INTERTEC

LOG OF BORING

Braun Project B1712486
GEOTECHNICAL EVALUATION
Como Stormwater BMPs
1225 Estabrook Drive
St. Paul, Minnesota

BORING: **ST-13**

LOCATION: See attached sketch.

DRILLER: B. Kammermeier | METHOD: 3 1/4" HSA, Autohammer | DATE: **12/11/17** | SCALE: **1" = 4'**

Elev. feet 889.7	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	PID ppm	Tests or Notes
889.2	0.5	FILL	FILL: Silty Sand, fine- to medium-grained, trace roots, dark brown, moist. (Topsoil Fill)					
885.7	4.0	FILL	FILL: Silty Sand, fine- to medium-grained, with Gravel, brown, moist.	6			0.1	
880.7	9.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, with Gravel, brown, moist, medium dense. (Glacial Outwash)	13		4	0.1	p200 = 10%
				14			0.1	
877.7	12.0	ML	SILT, white, wet, soft. (Lacustrine)	2			0.2	
875.7	14.0	ML	SILT, gray, wet, rather stiff. (Lacustrine)	10			0.2	
868.7	21.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, with Gravel, brown, waterbearing, loose to medium dense. (Glacial Outwash)	18	▽		0.2	
				8			0.1	

END OF BORING.

Water observed at 15 feet with 15 feet of hollow-stem auger in the ground.

Water observed at 19 1/2 feet with 20 feet after last sample.

Water not observed to cave-in depth of 7 feet immediately after withdrawal of auger.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2017\12486.GPJ BRAUN_V8_CURRENT.GDT 1/15/18 11:04

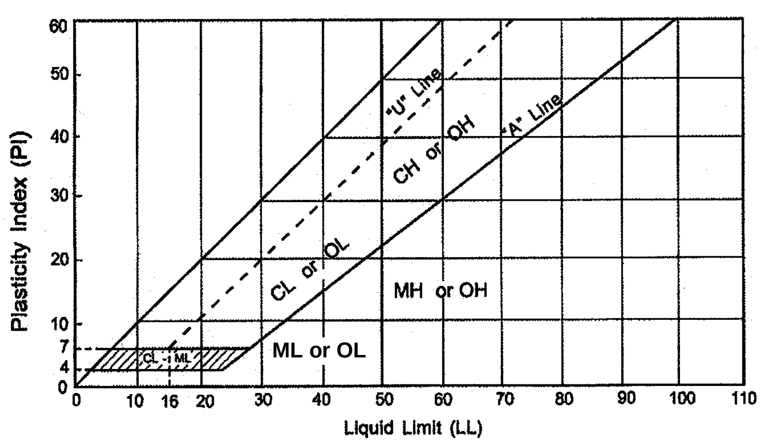
BRAUN INTERTEC

Descriptive Terminology of Soil

Standard D 2487
Classification of Soils for Engineering Purposes
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [a]				Soils Classification: Group Symbol	Soils Classification: Group Name [b]
Coarse-grained Soils more than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines [e]	$C_u \geq 4$ and $1 \leq C_c \leq 3$ [c]	GW	Well-graded gravel [d]
			$C_u < 4$ and/or $1 > C_c > 3$ [c]	GP	Poorly graded gravel [d]
		Gravels with Fines More than 12% fines [e]	Fines classify as ML or MH	GM	Silty gravel [d f g]
			Fines classify as CL or CH	GC	Clayey gravel [d f g]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines [i]	$C_u \geq 6$ and $1 \leq C_c \leq 3$ [c]	SW	Well-graded sand [h]
			$C_u < 6$ and/or $1 > C_c > 3$ [c]	SP	Poorly graded sand [h]
		Sands with Fines More than 12% [i]	Fines classify as ML or MH	SM	Silty sand [f g h]
			Fines classify as CL or CH	SC	Clayey sand [f g h]
Fine-grained Soils 50% or more passed the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line [j]	CL	Lean clay [k l m]
			PI < 4 or plots below "A" line [j]	ML	Silt [k l m]
		Organic	(Liquid limit - oven dried) / (Liquid limit - not dried) < 0.75	OL	Organic clay [k l m n]
				OL	Organic silt [k l m o]
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay [k l m]
			PI plots below "A" line	MH	Elastic silt [k l m]
		Organic	(Liquid limit - oven dried) / (Liquid limit - not dried) < 0.75	OH	Organic clay [k l m p]
				OH	Organic silt [k l m q]
Highly Organic Soils		Primarily organic matter, dark in color and organic odor		PT	Peat

a. Based on the material passing the 3-inch (75mm) sieve.
b. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders or both" to group name.
c. $C_u = D_{60}/D_{10}$ $C_c = \frac{(D30)^2}{D_{10} \times D_{60}}$
d. If soil contains ≥15% sand, add "with sand" to group name.
e. Gravels with 5 to 12% fines require dual symbols:
   GW-GM well-graded gravel with silt
   GW-GC well-graded gravel with clay
   GP-GM poorly graded gravel with silt
   GP-GC poorly graded gravel with clay
f. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
g. If fines are organic, add "with organic fines: to group name.
h. If soil contains ≥15% gravel, add "with gravel" to group name.
i. Sand with 5 to 12% fines require dual symbols:
   SW-SM well-graded sand with silt
   SW-SC well-graded sand with clay
   SP-SM poorly graded sand with silt
   SP-SC poorly graded sand with clay
j. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
k. If soil contains 10 to 29% plus No. 200, add "with sand" or "with gravel" whichever is predominant.
l. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI ≥ 4 and plots on or above "A" line.
o. PI < 4 or plots below "A" line.
p. PI plots on or above "A" lines.
q. PI plots below "A" line.



Laboratory Tests

DD	Dry density, pcf	**OC**	Organic content, %
WD	Wet density, pcg	**S**	Percent of saturation, %
MC	Natural moisture content, %	**SG**	Specific gravity
LL	Liquid limit, %	**C**	Cohesion, psf
PL	Plastic limits, %	**Ø**	Angle of internal friction
PI	Plasticity index, %	**qu**	Unconfined compressive strength, psf
P200	% passing 200 sieve	**qp**	Pocket penetrometer strength, tsf

Particle Size Identification

Boulders................. over 12"
Cobbles .... 3" to 12"
Gravel
  Coarse .... 3/4" to 3"
  Fine................ No. 4 to 3/4"
Sand
  Coarse .... No. 4 to No. 10
  Medium .... No. 10 to No. 40
  Fine................ No. 40 to No. 200
Silt .... <No. 200, PI< 4 or below "A" line
Clay .... <No. 200, PI ≥ 4 and on or about "A" line

Relative Density of Cohesionless Soils

Very Loose............ 0 to 4 BPF
Loose..................... 5 to 10 BPF
Medium dense .... 11 to 30 PPF
Dense .... 31 to 50 BPF
Very dense............ over 50 BPF

Consistency of Cohesive Soils

Very soft................ 0 to 1 BPF
Soft .... 2 to 3 BPF
Rather soft .... 4 to 5 BPF
Medium .... 6 to 8 BPF
Rather stiff .... 9 to 12 BPF
Stiff .... 13 to 16 BPF
Very stiff................. 17 to 30 BPF
Hard....................... over 30 BPF

Drilling Notes

Standard penetration test borings were advanced by 3 1/4" or 6 1/4" ID hollow-stem augers, unless noted otherwise. Jetting water was used to clean out auger prior to sampling only where indicated on logs. All samples were taken with the standard 2" OD split-tube samples, except where noted.

Power auger borings were advanced by 4" or 6" diameter continuous flight, solid-stern augers. Soil classifications and strata depths were inferred from disturbed samples augered to the surface, and are therefore, somewhat approximate.

Hand auger borings were advanced manually with a 1 1/2" or 3 1/4" diameter auger and were limited to the depth from which the auger could be manually withdrawn.

BPF: Numbers indicate blows per foot recorded in standard penetration test, also known as "N" value. The sampler was set 6" into undisturbed soil below the hollow-stem auger. Driving resistances were then counted for second and third 6" increments, and added to get BPF. Where they differed significantly, they are reported in the following form: 2/12 for the second and third 6" increments, respectively.

WH: WH indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

WR: WR indicates the sampler penetrated soil under weight of rods alone; hammer weight, and driving not required.

TW: TW indicates thin-walled (undisturbed) tube sample.

Note: All tests were run in general accordance with applicable ASTM standards.

APPENDIX B

PRELIMINARY CONCEPT BMP ALTERNATIVES

1-29-2018

Preliminary BMP Alternatives

Como BMP Feasibility Study

Bold Numbered BMPs have sketches associated

Golf Lot

1) **IESF bench in irregular shaped pond**
   - Pretreatment in existing basin
   - The golf course would have a chance to revitalize waterfall feature and upstream basin
2) **Horizontal IESF**
   - Check dam with a replaceable IESF vertical insert
3) **Local rain gardens in parking island and greenspace to the west**
   - DRO detected (at 5-7 foot depth), below MPCA limit for 'unregulated fill'. Recommend using bio-filtration with a liner to prevent groundwater contamination.

East Ponds

Silty soils layer in boring limits the use of infiltration.

1) **Pump and treat IESFs east of Lexington**
   a) **Use existing lift station**
   b) **Underground holding tank after existing lift station; pump from holding tank to surface IESF**
   c) **Install new wet well and lift station, bore new pressure line under road**

South Pond

None

NW Pond

1) **IESF bench with optional automated drawdown valve**
   a) Various designs for IESF benches will result in different normal water level for the pond. Changing the pond normal water level will also affect the inundation periods of the adjacent fairways.

Zoo Regional

Four soil borings were taken at this location. Only soil borings number 1, near the existing Zoo infiltration basin, showed suitable conditions for infiltration.

1) **Hole 8 filtration basin**
   a) **Reconstruct upstream stormsewer at a flatter grade to provide sufficient fall for filtration BMP**
   b) **Install new, smaller parallel stormsewer upstream at a flatter grade to provide sufficient fall for filtration BMP**
2) **Expand existing infiltration basin and incorporate regional inflows**
3) **Expand existing infiltration basin and incorporate regional inflows as pretreatment to an underground infiltration structure.**
4) **Install a pretreatment basin near the Hole 8 tee box, and route runoff to an underground infiltration structure.**

Pavilion North

1) Local rain gardens

- Use lined bio-filtration due to soils and high DRO levels detected at 10-12 feet of depth
- 60-inch trunk sewer is too low to provide a regional gravity infiltration or filtration BMP.

Pavilion South

Soil boring number 6 (southeast of the fountain) and boring 8 (more southern boring in the parking lot) and potentially boring 9 (east of the parking lot) were suitable for infiltration. Boring 10 (more norther boring in the parking lot) showed suitable soils, but DRO was detected 5-7 feet below grade.

1) Infiltration swale and filtration basin for parking lot

- This concept BMP is a treatment train of a infiltration swale overflowing to a filtration basin. The parking lot would sheet flow to curb cuts that would lead to a bio-infiltration swale with terraced seating (see example photo below). Runoff that is not captured in the infiltration swale will overflow to a filtration basin.
- Option to include iron-enhanced filtration practices
- Option to include pervious pavers in parking lot

2) Surface Infiltration Basin

a) Sized to 1.1-inch goal

- This concept shows the approximate area of a surface infiltration BMP, sized to treat the goal of 1.1-inches of runoff from impervious surface in the drainage area. This alternative is likely infeasible due to the large amount of park area that is required, and the extensive lowering of the ground surface elevation. This lead to the exploration of other, more expensive BMP alternatives.

b) Sized to 0.5-inch treatment

- This concept shows the approximate area of a surface infiltration BMP, sized to treat 0.5-inches of runoff from impervious surface in the drainage area. This option does not meet the 1.1-inch goal, but results in a more manageable area required. Various arrangements of surface infiltration basins may be explored.

3) Underground Infiltration Gallery

- With an underground infiltration concept, maintaining separation from the seasonal high groundwater restricts the options for its location. The seasonal high groundwater is assumed to be near the Ordinary High Water (OHW) elevation of the lake (881.4). The simplest solution is to capture water from the stormsewer shown.

- The concept shown is to combine the underground infiltration with underground storage for water reuse. There are questions surrounding the demand for a water reuse BMP:
  - Is Como Park interested in irrigating this area of the park?
  - What does Como Park use to irrigate their plants, gardens, etc. currently? Would there be interest or need to use a type of stormwater filling station, for watering vehicles?
  - Potentially use reuse water for the fountain, or other water features.

4) Meandering infiltrating stream corridor with weirs

a) **Infiltrating Stream -** Runoff from the stormsewer to the southwest can be treated through an infiltration design consisting of an intermittent stream, plantings, landscaping, weir structures to provide storage, and infiltration throughout the system (see example photo below). A normally dry, rock stream bed would meander through the park three to five feet below the existing ground elevation. During rain events, weirs or ditch checks would store runoff in the 'floodplain' of the stream, and runoff would subsequently infiltrate.

b) **Recirculating infiltration stream BMP -** The system above could include additional treatment by incorporating a large underground storage (or pond) downstream of the BMP. The underground storage would capture untreated runoff that would then be pumped to the upstream end of the stream and 'recirculated' through the infiltration BMP. Recirculated water will infiltrate or continue down the stream into the storage, and the cycle will continue until all of the runoff in the system in infiltrated. This would provide a water feature amenity as the stream bed would be flowing with water after the rain event is over. The benefit is treatment for a greater volume of water, while providing an amenity to Como Park.

Additional Ideas:

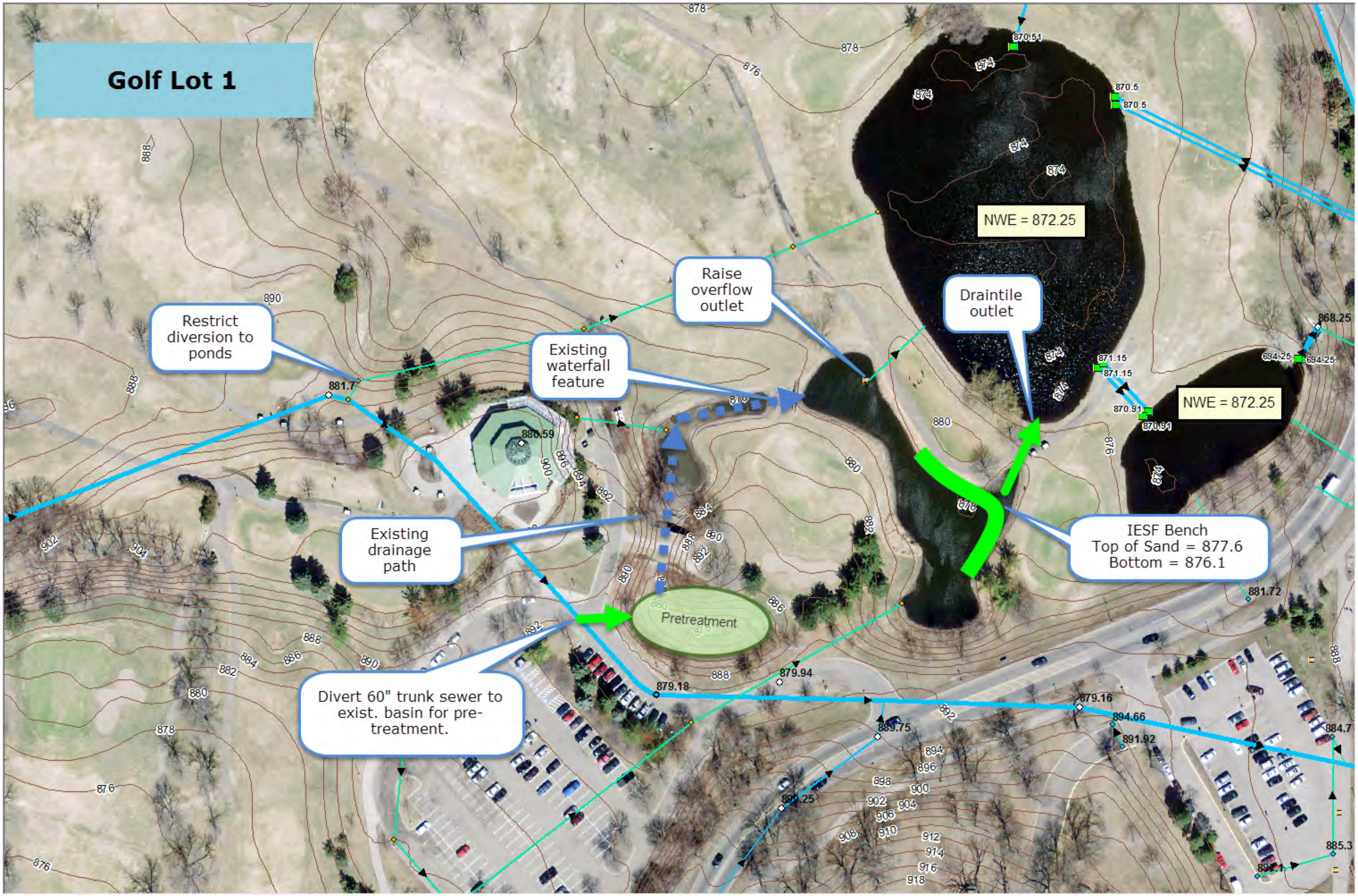
- As an option to showcase different types of stormwater treatment BMPs, a treatment train of various BMP types could be implemented for education and outreach. Further, with the recirculation system, the stored water could be used for live-action demonstrations or research purposes.
- If drawdown requirements are a concern, the recirculation system could be used with a filtration BMP, allowing for a faster drawdown time.
- The holding tank could double as a stormwater reuse system.
- The alternative could also use filtration to treat the water entering the holding tank, and subsequently used for a stormwater-waterpark. You see the water being treated that is used in the stormwater-waterpark!

5) Holding tank and pump for surface IESF; or UG IESF

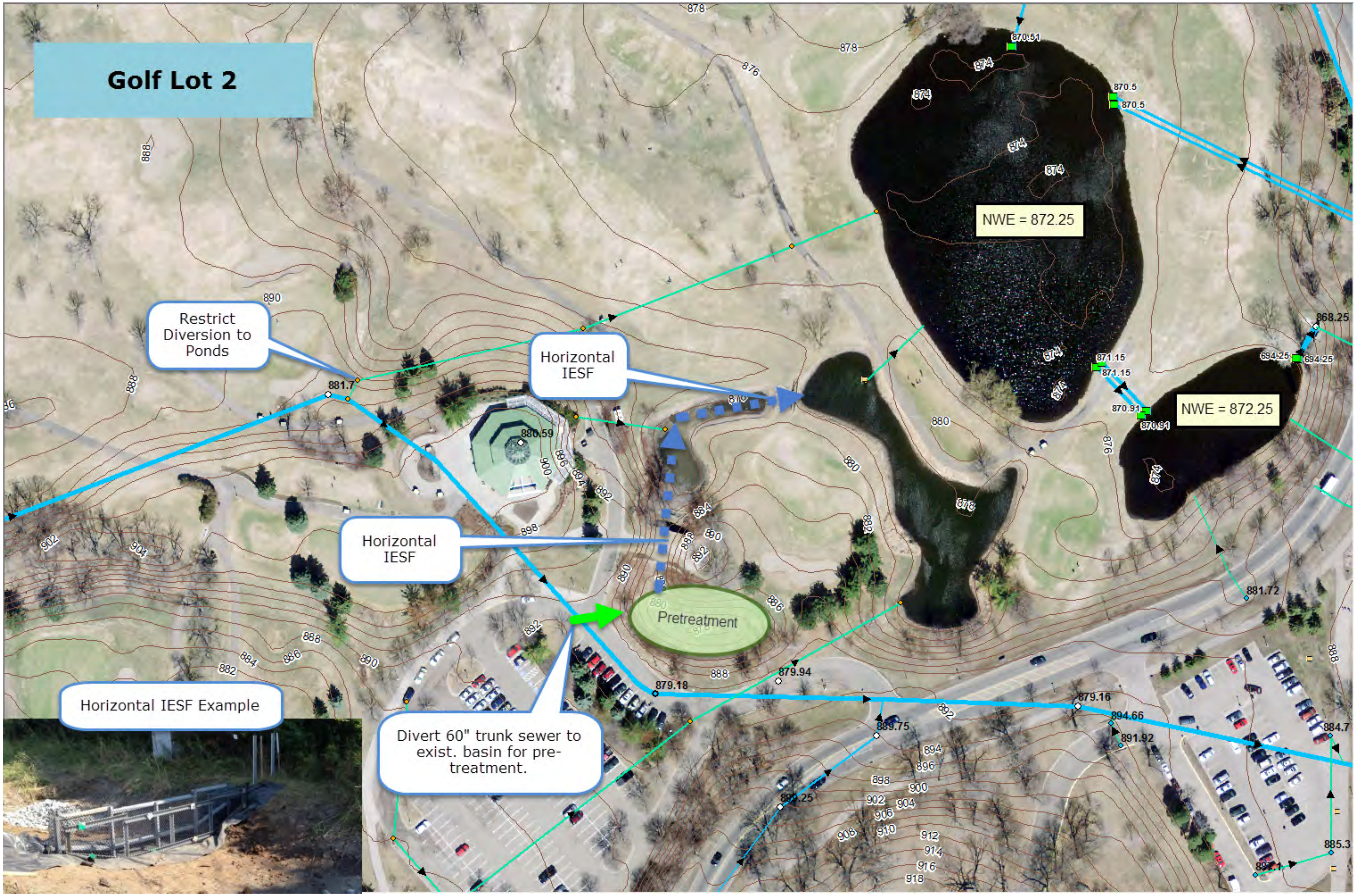
Pavilion South Comparison Table

Option	Treatment Volume Goal 1.1” over impervious area (Ac-Ft)	Attainable Treatment Volume (Ac-Ft)	Ease of Long-Term Maintenance	Construction Cost
Pavilion South 1: Swale to Filtration Basin	0.2	0.2	Difficult	Medium
Pavilion South 2a: 1.1" Infiltration Basin	1.2	1.2	Medium	Medium
Pavilion South 2b: 0.5" Infiltration Basin	1.2	0.6	Medium	Medium
Pavilion South 3: Underground Infiltration	1.2	0.9	Difficult	High
Pavilion South 4a: Train of Infiltration Basins	1.2	0.3	Difficult	Medium
Pavilion South 4b: Train of Infiltration Basins (Recirculating)	1.2	1.2	Difficult	High
Pavilion South 5: Underground Tank pumps to IESF	1.2	1.0	Difficult	High

Appendix B - Preliminary Concept BMP Alternatives

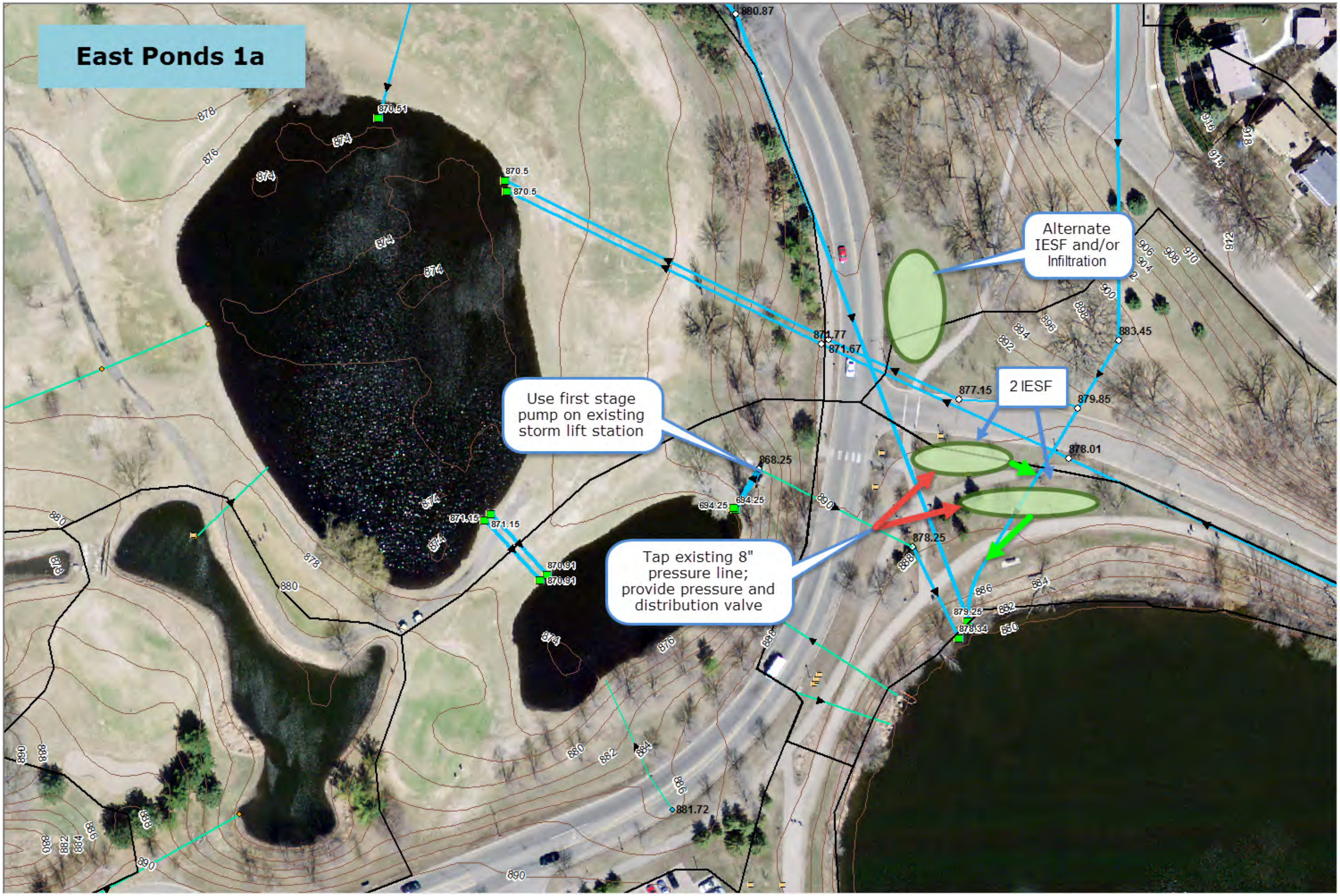


Appendix B - Preliminary Concept BMP Alternatives



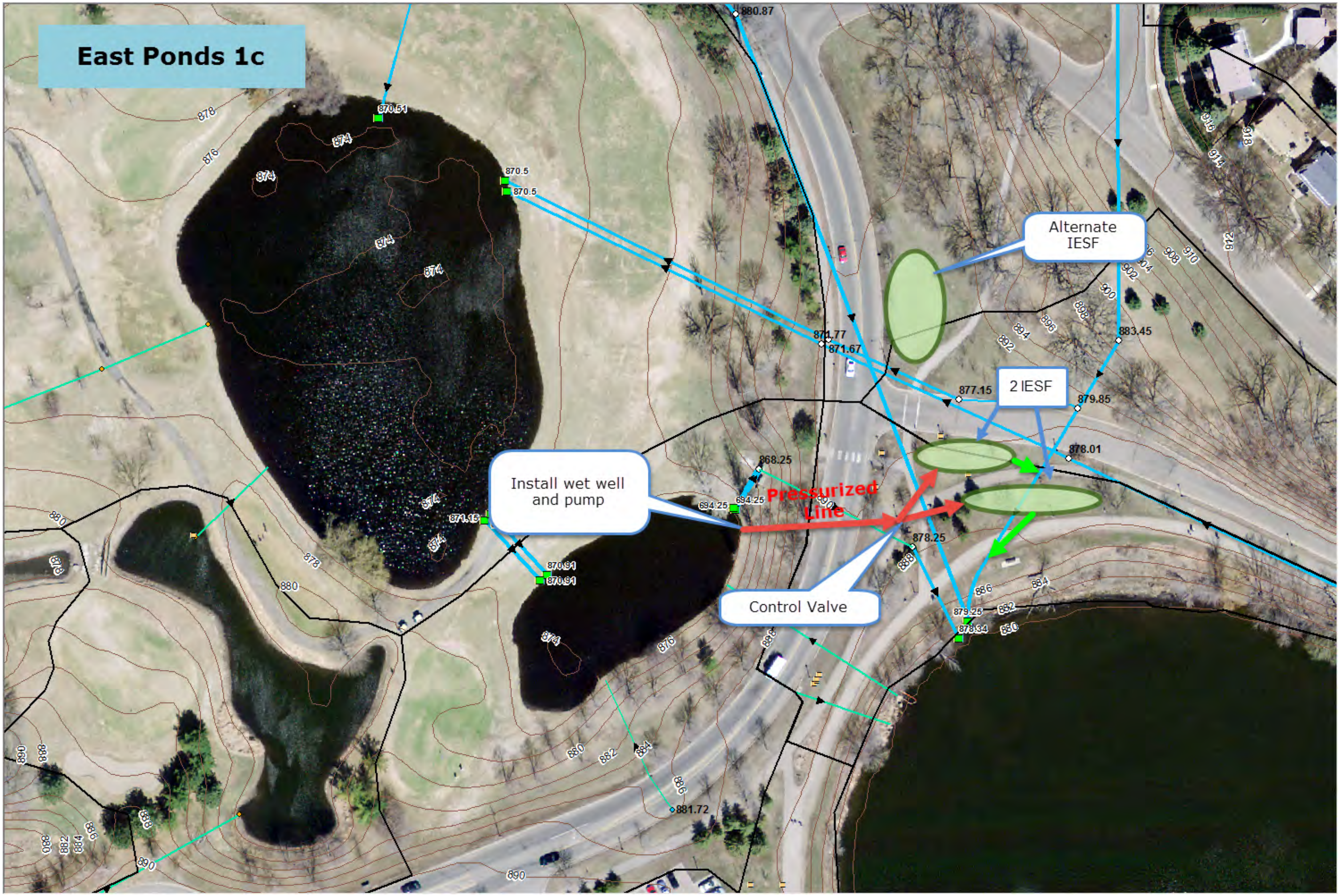
Appendix B - Preliminary Concept BMP Alternatives

Appendix B - Preliminary Concept BMP Alternatives

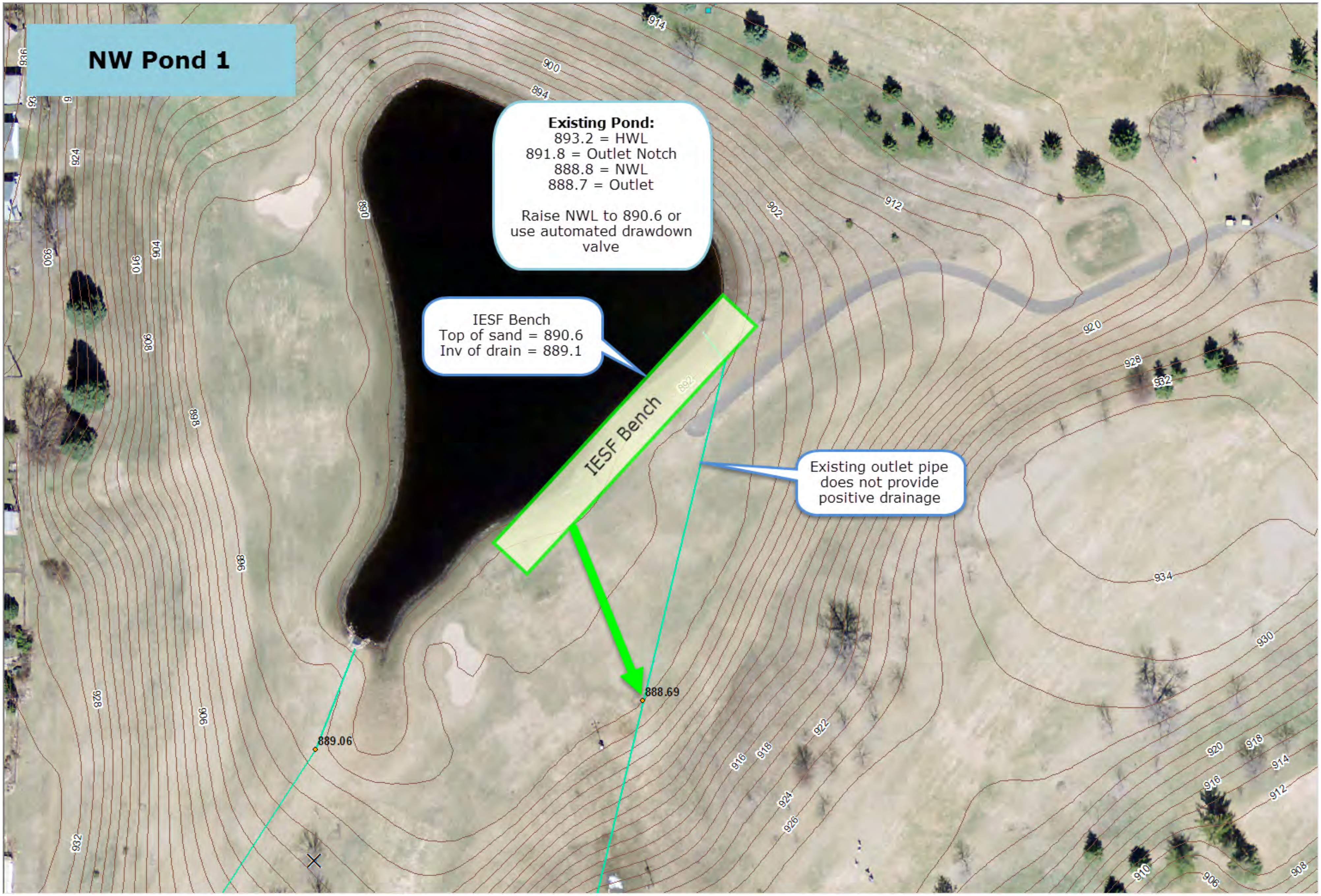


Appendix B - Preliminary Concept BMP Alternatives

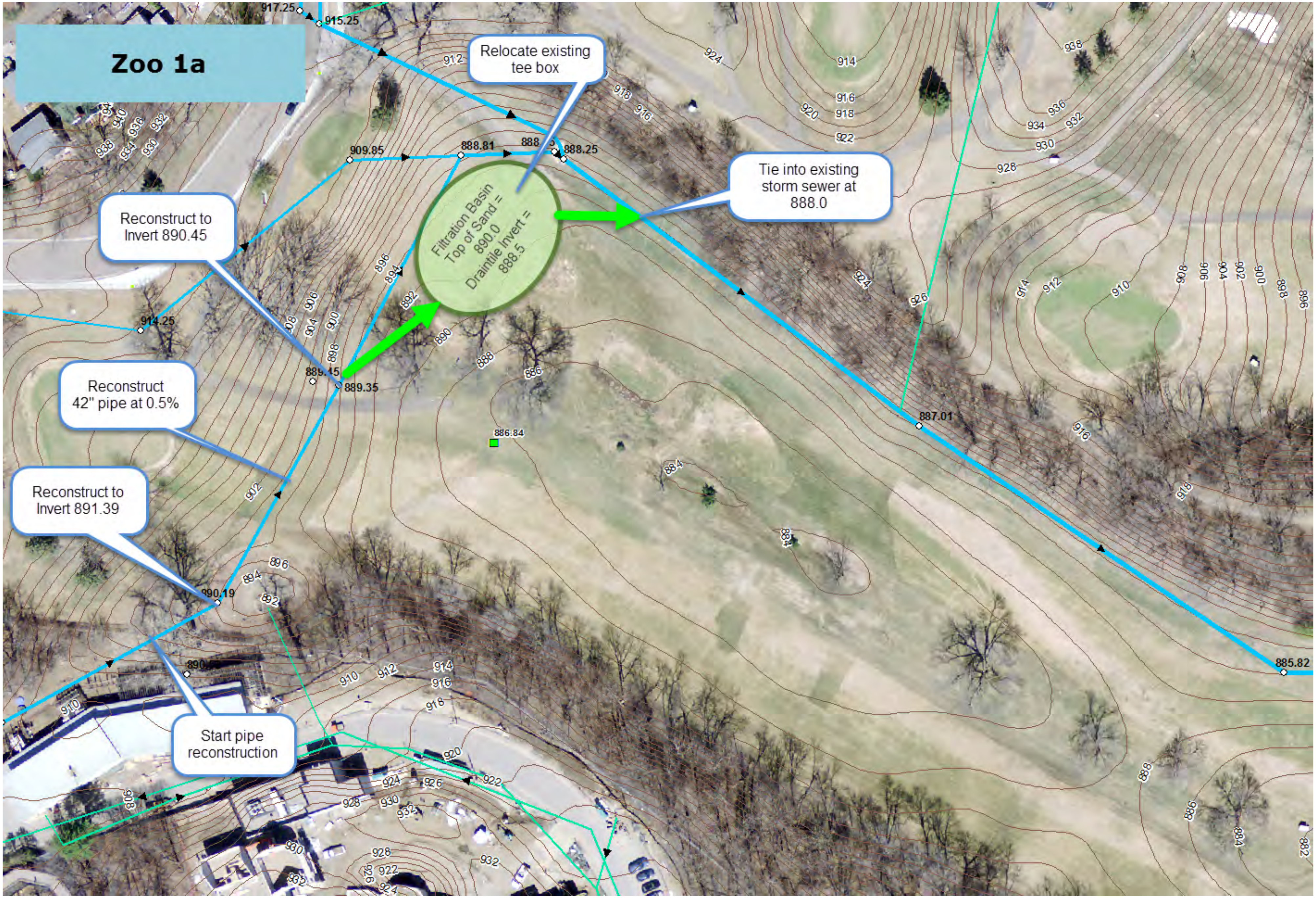
Appendix B - Preliminary Concept BMP Alternatives



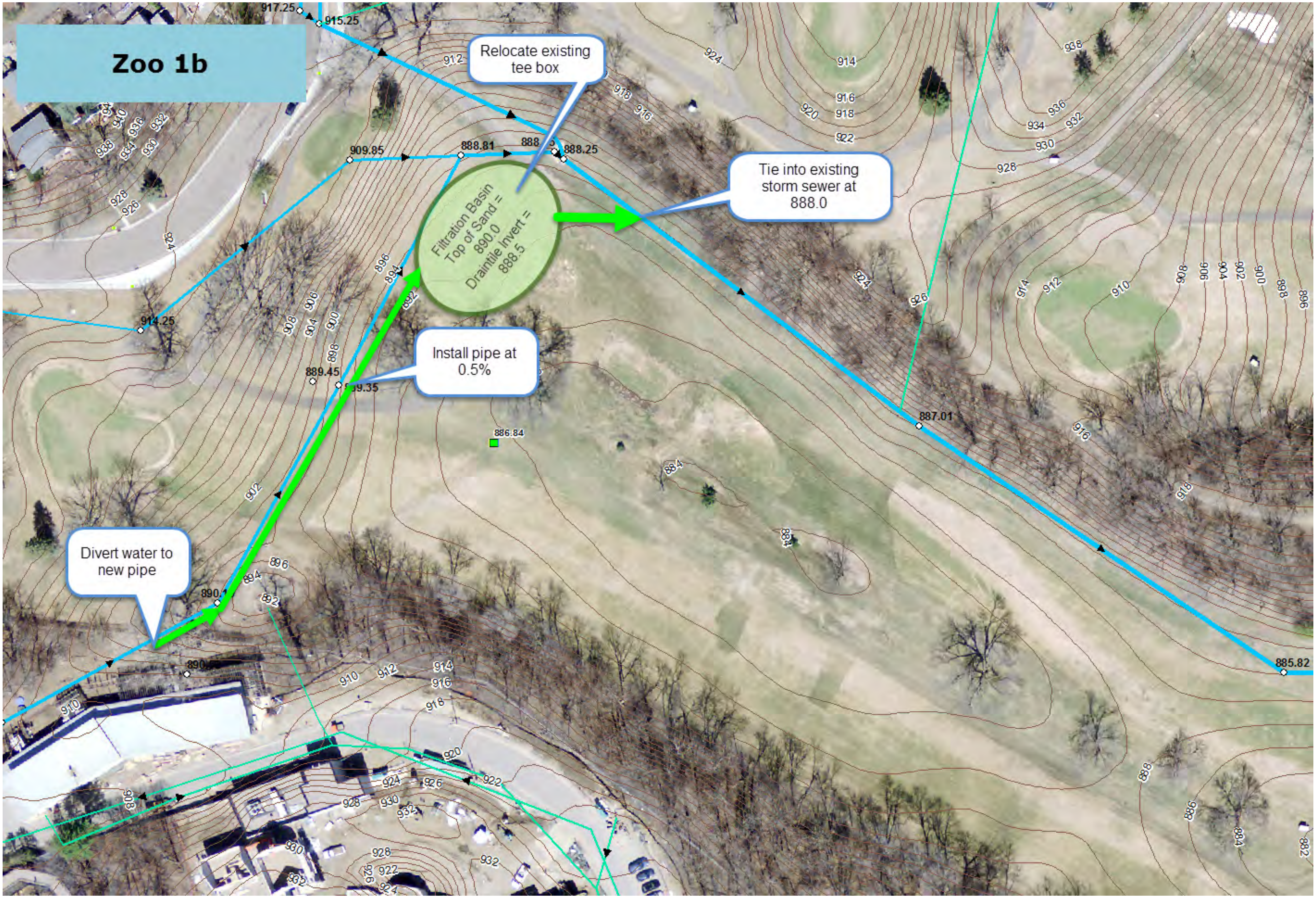
Appendix B - Preliminary Concept BMP Alternatives



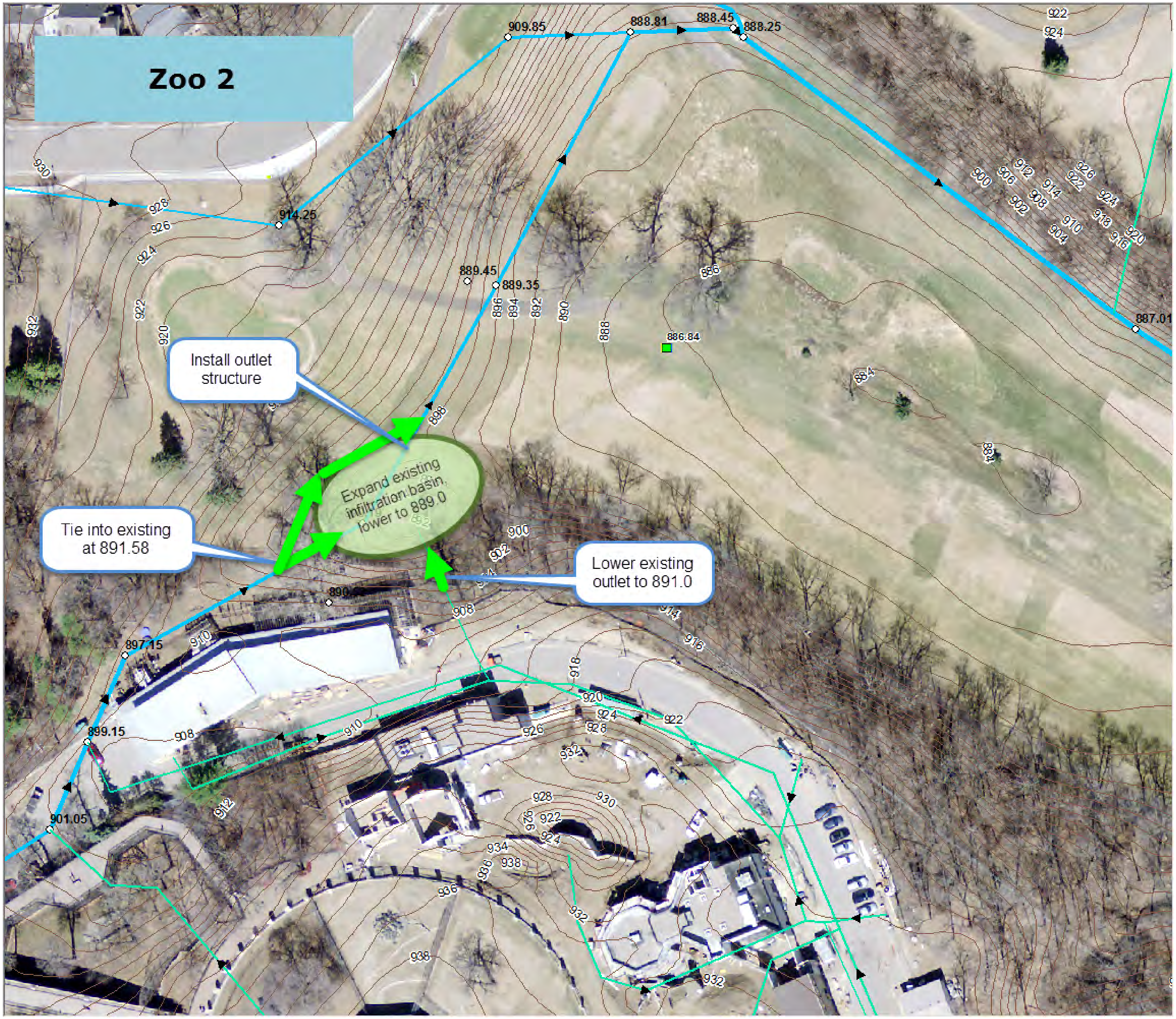
Appendix B - Preliminary Concept BMP Alternatives



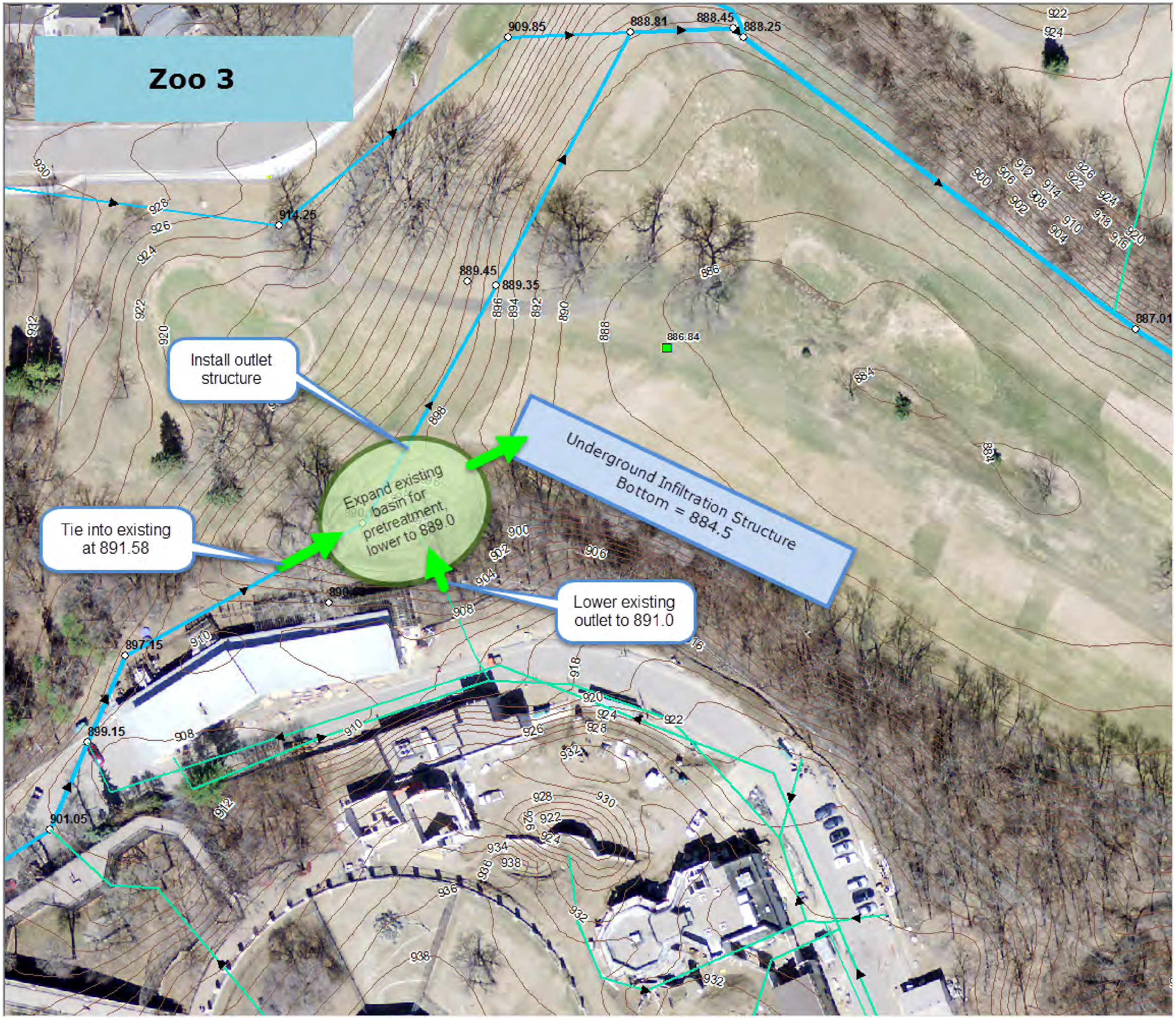
Appendix B - Preliminary Concept BMP Alternatives



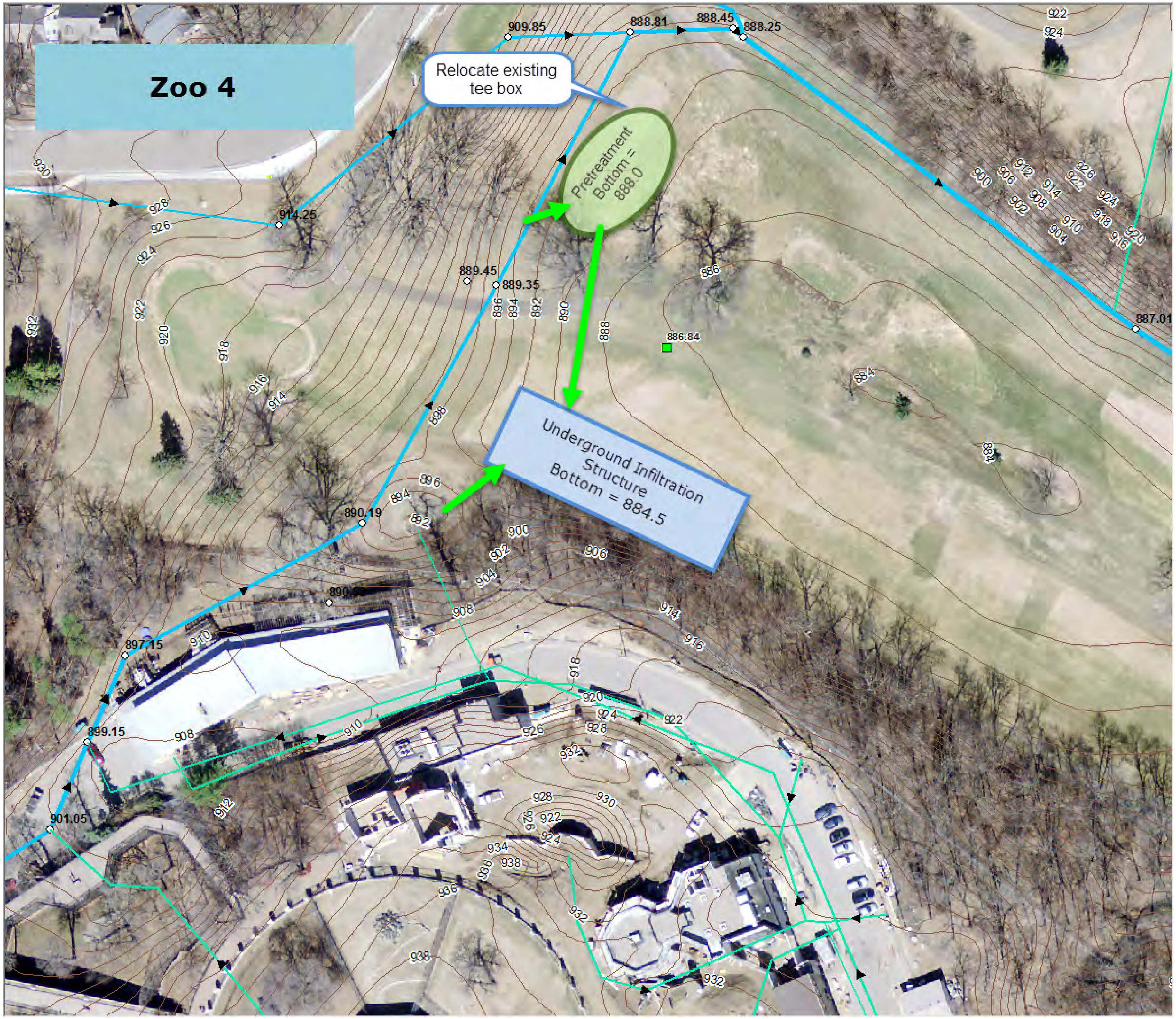
Appendix B - Preliminary Concept BMP Alternatives



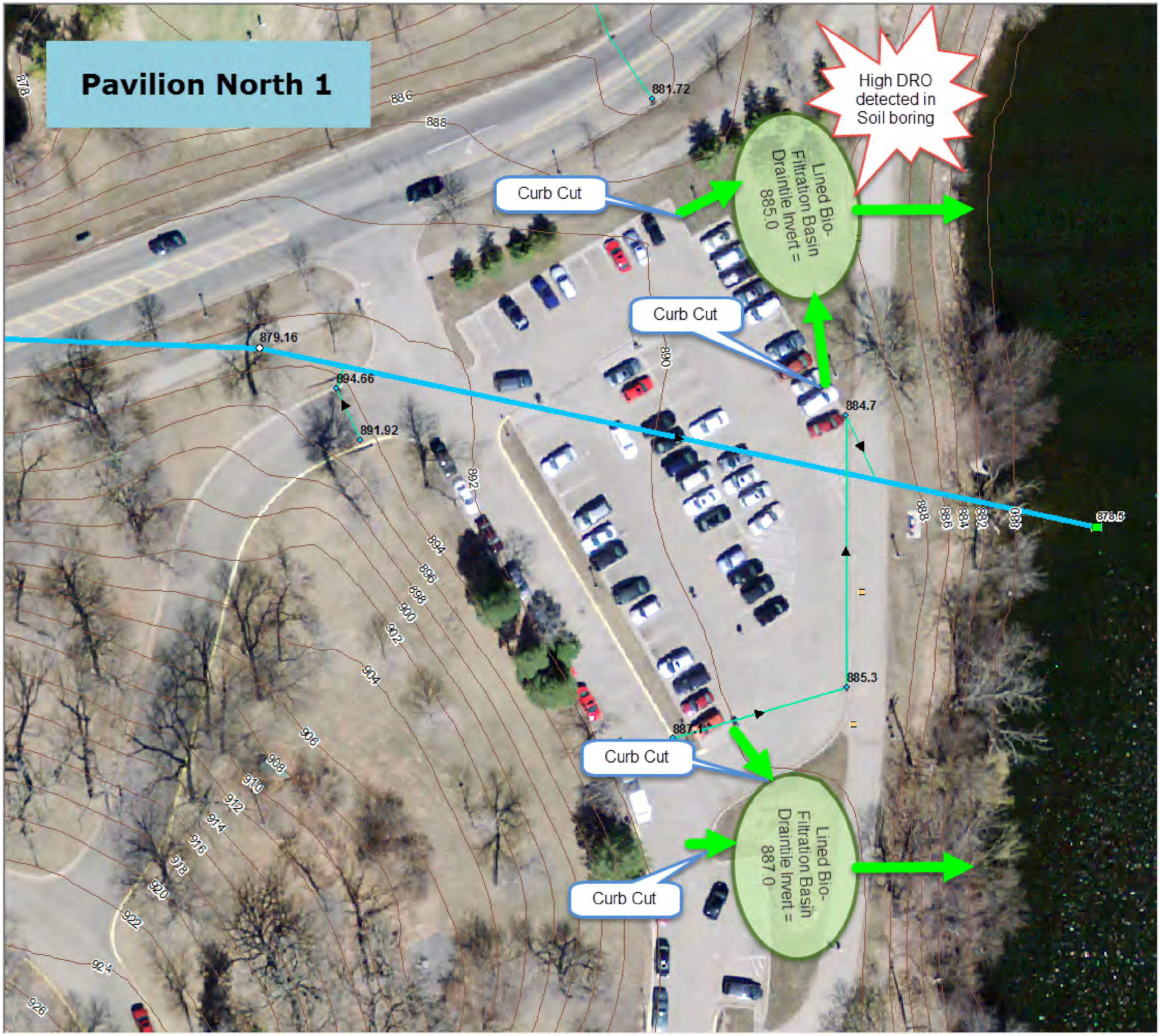
Appendix B - Preliminary Concept BMP Alternatives



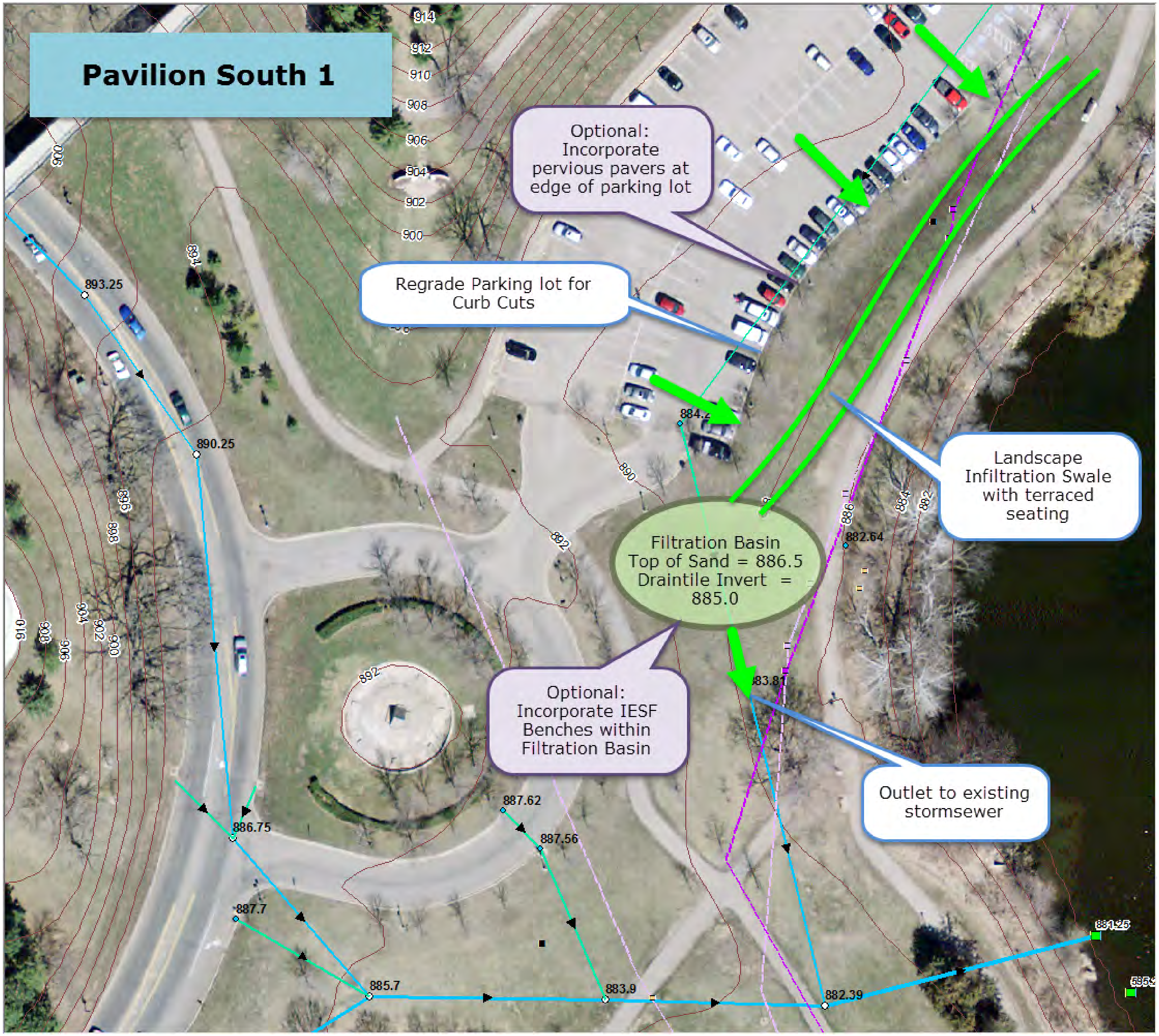
Appendix B - Preliminary Concept BMP Alternatives



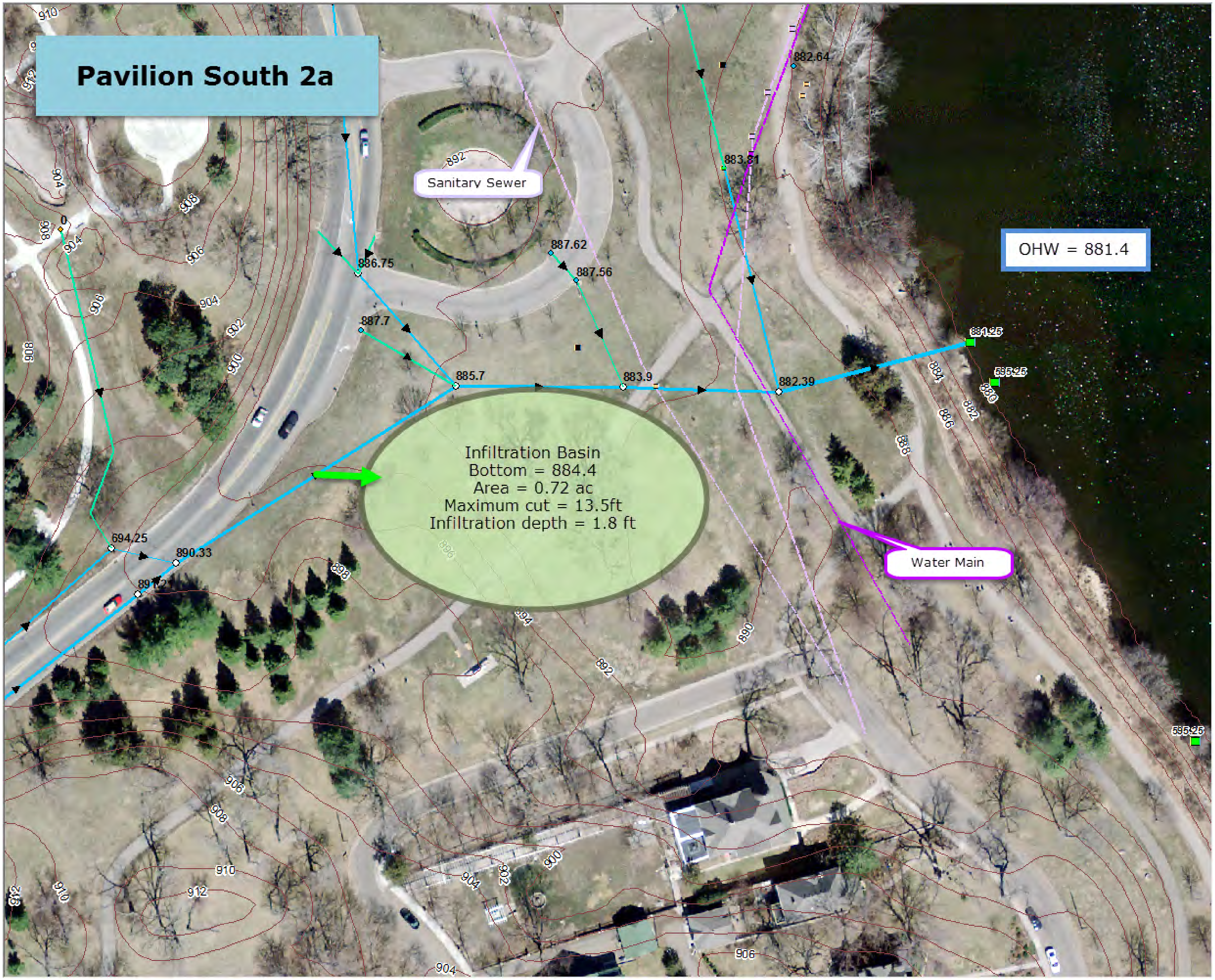
Appendix B - Preliminary Concept BMP Alternatives



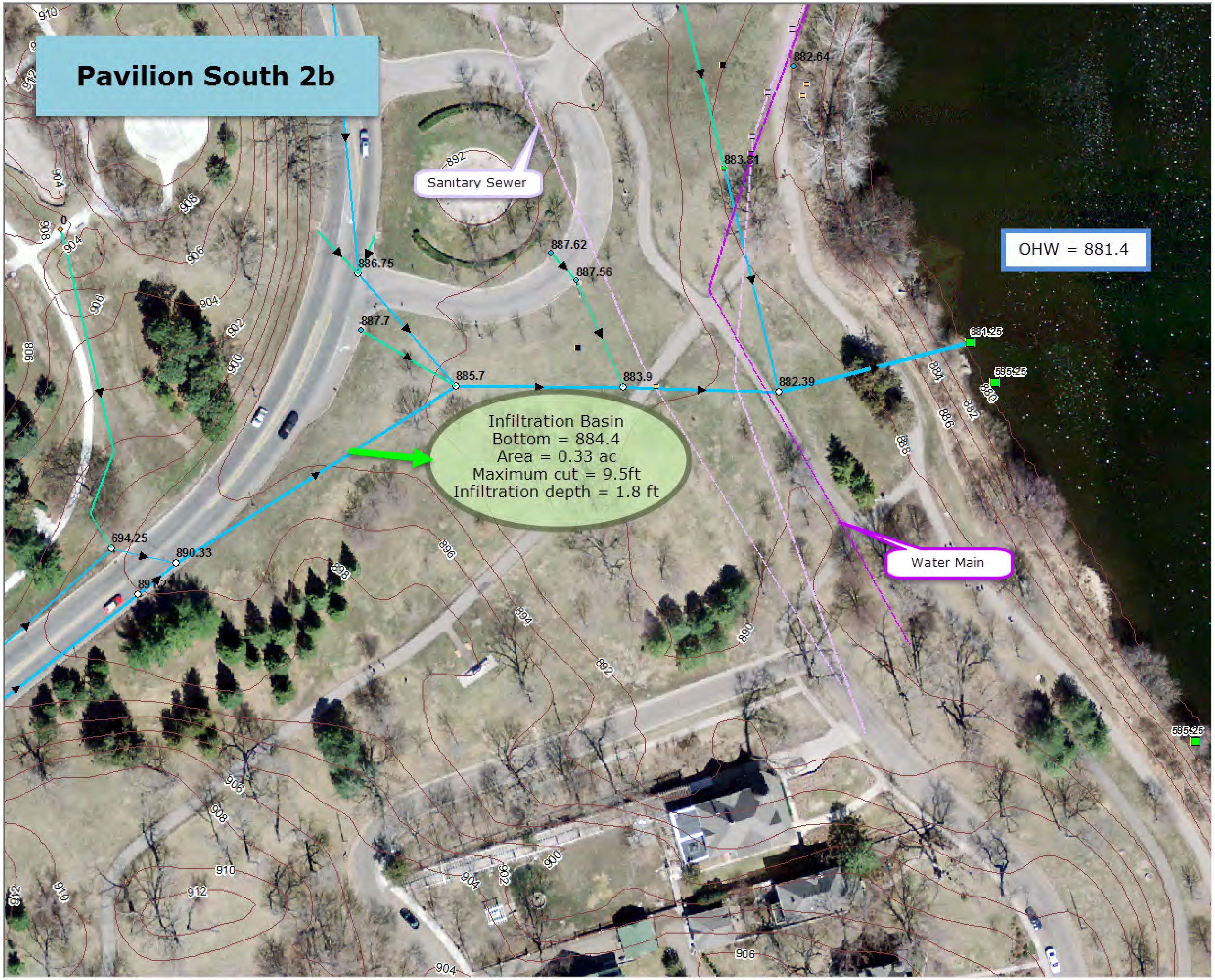
Appendix B - Preliminary Concept BMP Alternatives



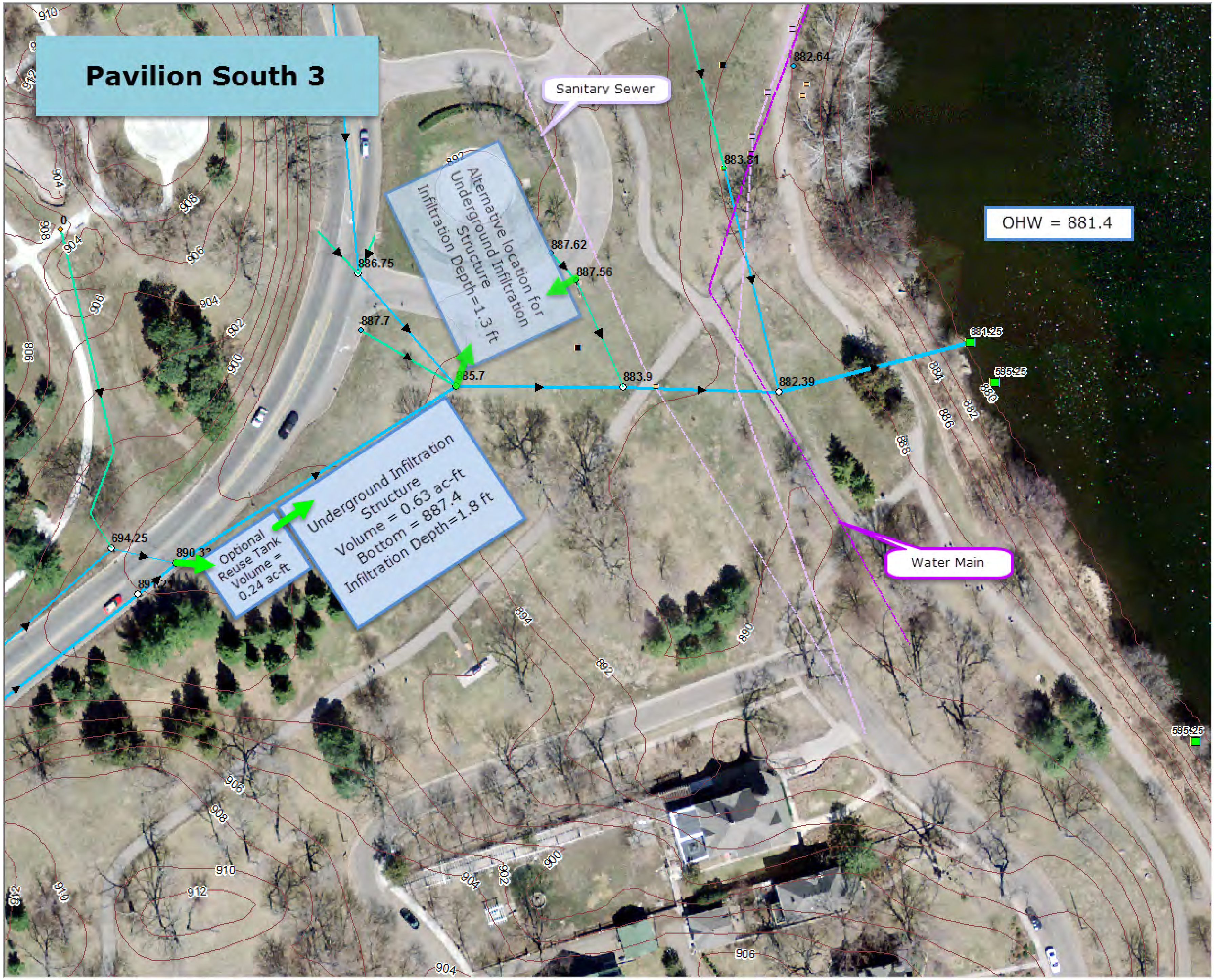
Appendix B - Preliminary Concept BMP Alternatives



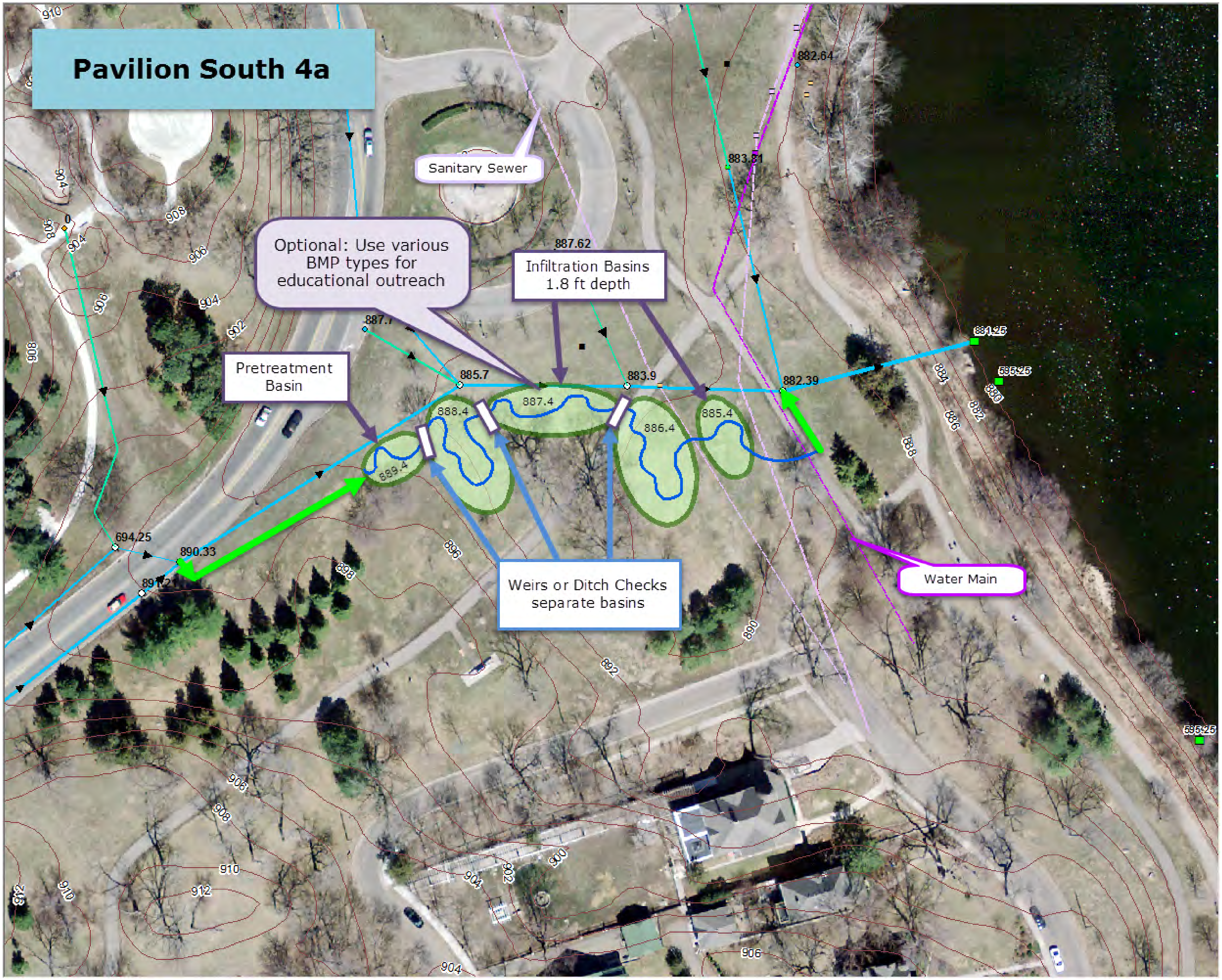
Appendix B - Preliminary Concept BMP Alternatives



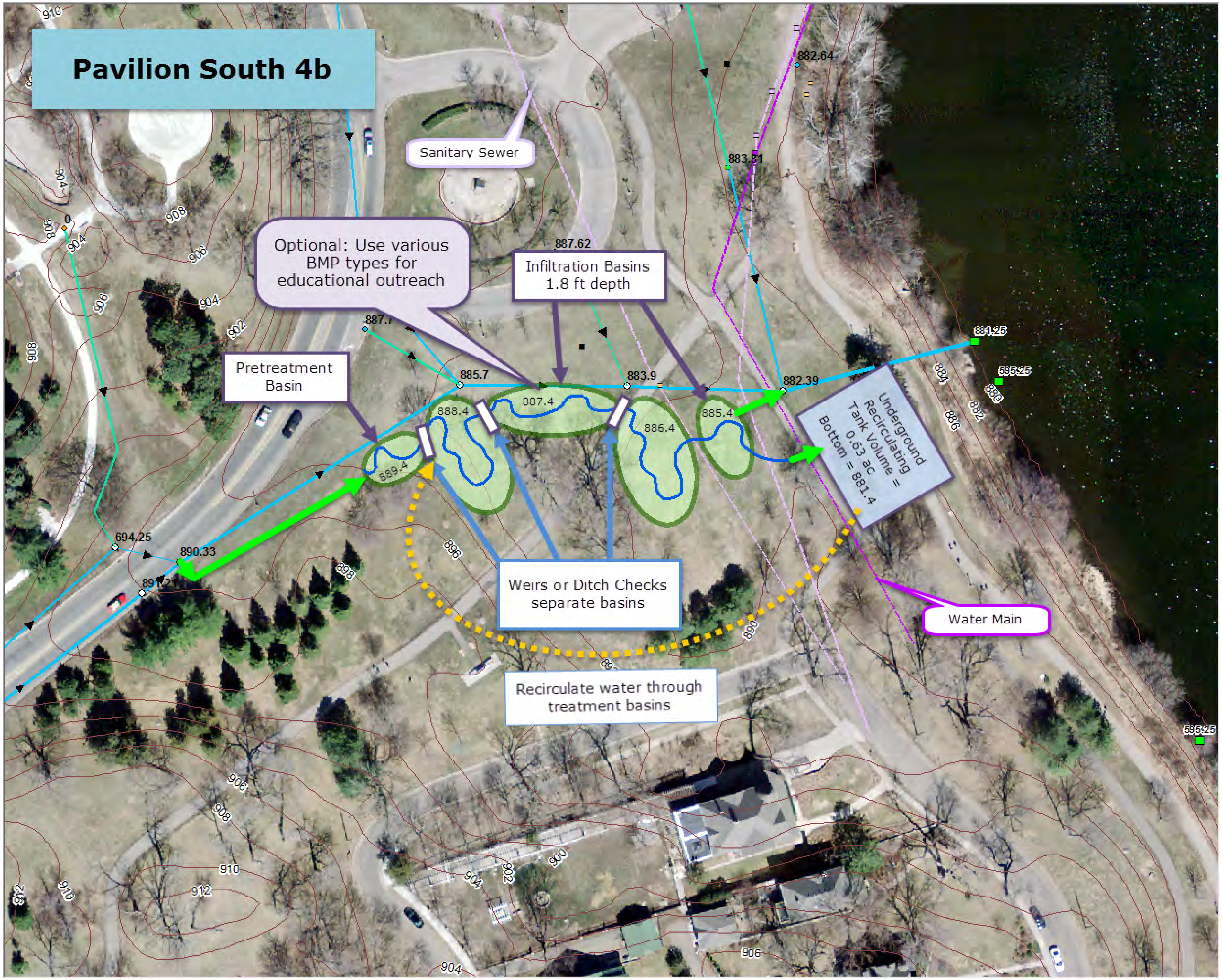
Appendix B - Preliminary Concept BMP Alternatives



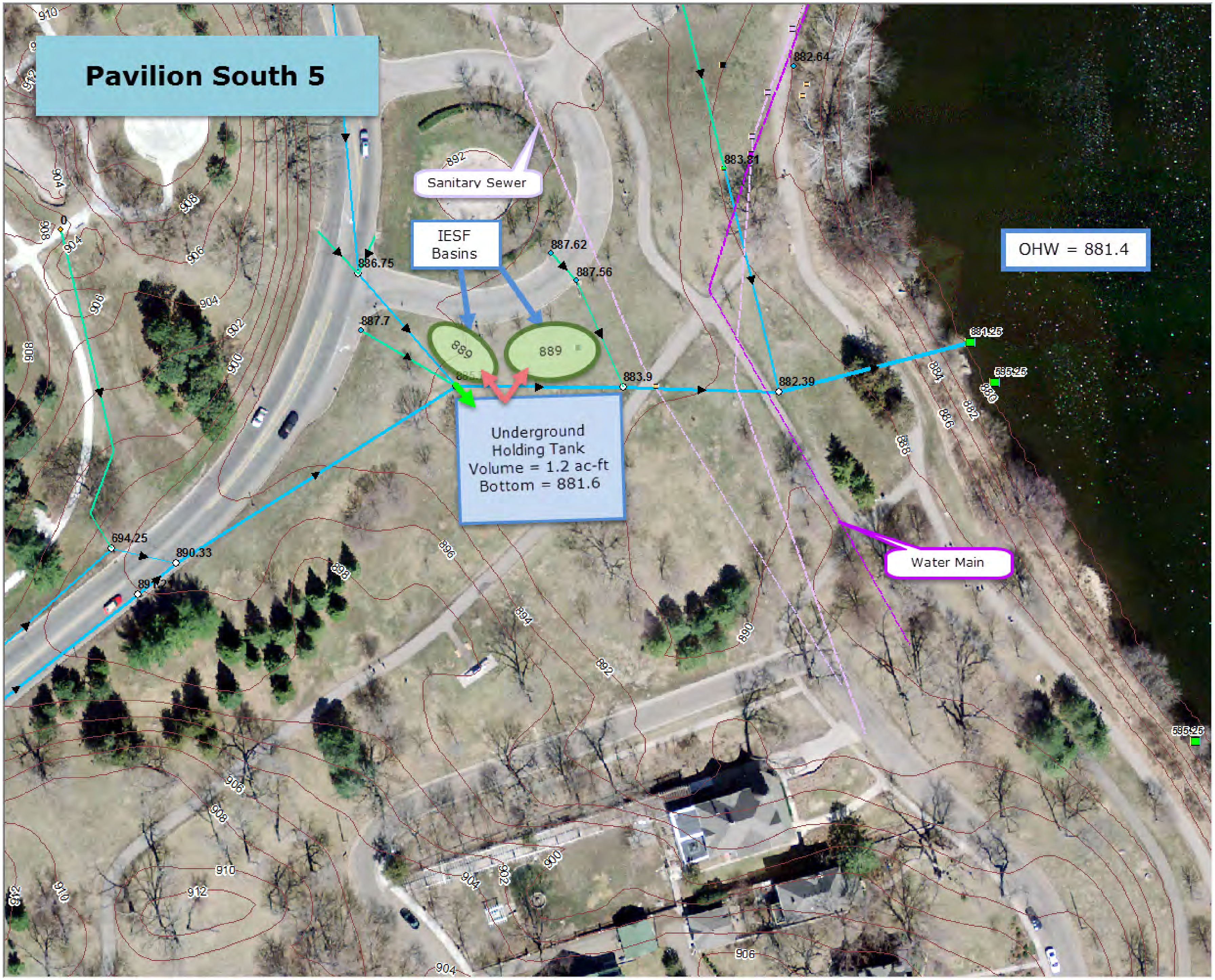
Appendix B - Preliminary Concept BMP Alternatives



Appendix B - Preliminary Concept BMP Alternatives



Appendix B - Preliminary Concept BMP Alternatives



APPENDIX C

ADDITIONAL CONCEPT BMP ALTERNATIVE DATA

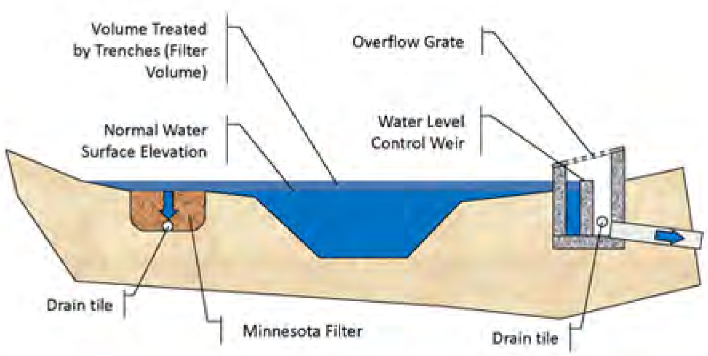
NW GOLF POND – IESF BENCH

Location: Como Golf Course pond at Hole 3 and Hole 11

BMP Type: Iron Enhanced Sand Filter bench retrofit to pond

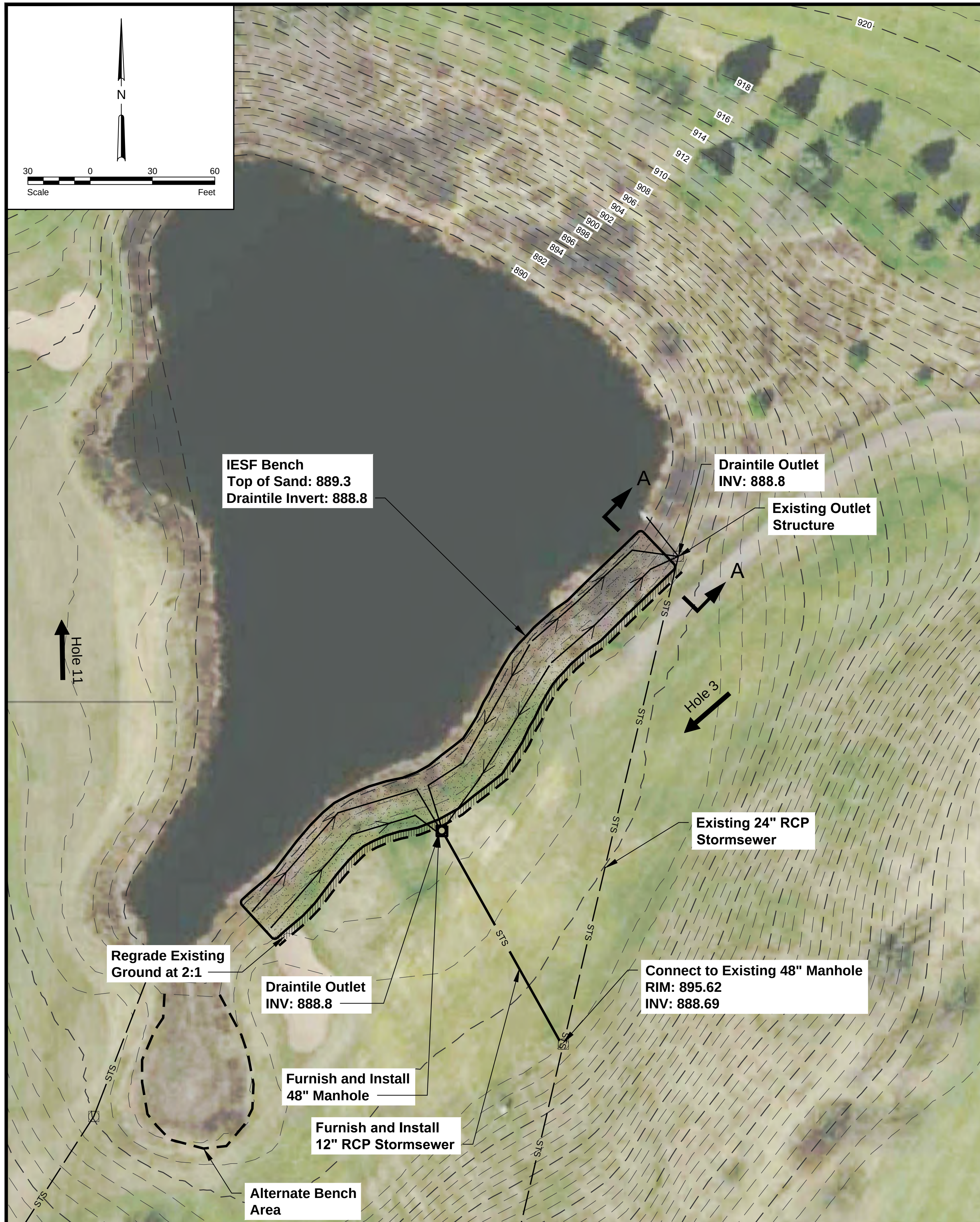
666 acres Catchment Area | 3.6 ac-ft Treatment Volume | 31 lb Increase in Annual TP Removal

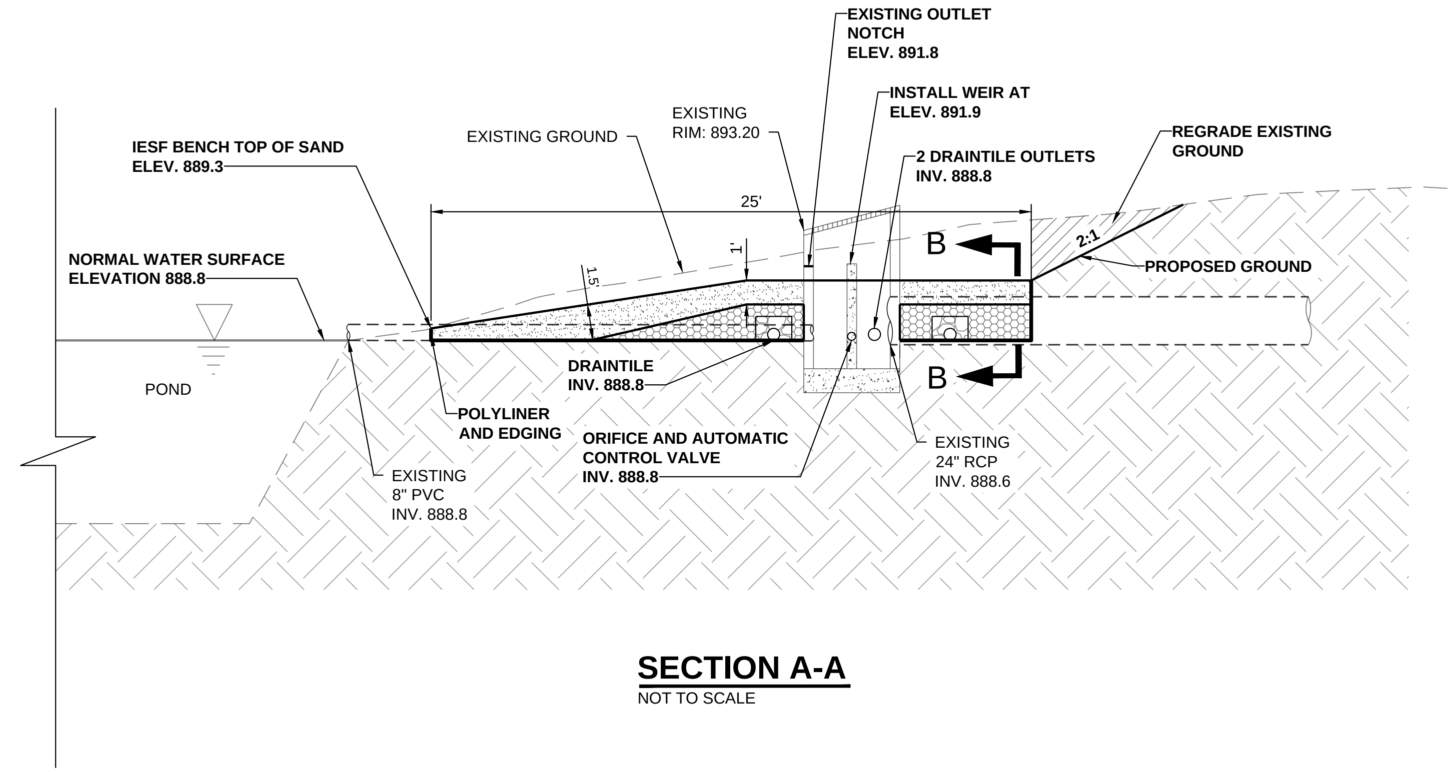
The NW Golf Pond is a 1.75-acre pond that was built for stormwater treatment in 2007 and also serves as a feature to Como Golf Course. The pond captures runoff from 157 residential acres northwest of the Como Golf Course, and currently also receives inflow which is pumped from Gottfrieds Pit, a pond with a 521-acre drainage area of residential and commercial land. Although the pond provides significant TSS removal there is opportunity for additional treatment of dissolved phosphorus through retrofitting the pond with an IESF bench. The sand bench would be cut into the existing grade along Hole 3 and would be an out-of-play golfing hazard due to the tendency of IESFs to form ridged clumps. An automated control valve will be included to bypass flows from Gottfrieds Pit in order to let the filter rest (dry). The valve could be included at the pond outlet or at the upstream diversion structure.



	BMP Name	**NW Pond 1**		
	BMP Type	IESF Bench		
	Drainage Area (ac)	666.2		
	BMP Size (sq-ft)	6,200		
Volume Reduction	1.1" Volume Reduction Goal (ac-ft)	4.42		
	1.1" Goal w/in Como Park (ac-ft)	0.0		
	BMP WQ Treatment Volume (ac-ft)[1]	3.60		
BMP Removals[2]		Retrofit Increase		Retrofit + Existing
	TP (lbs/yr)[3]	31.0	28%	81.9
	TSS (lbs/yr)	2,517	5%	45,766
	Volume (ac-ft/yr)	0	0%	0
Cost	Construction, Engineering & Admin[4]	$359,311		
	Annual Maintenance[5]	$14,372		
	Annualized 20-yr life-cycle	$28,657		
	20-yr Annualized Cost-Benefit for IESF Retrofit ($/lb TP)	**923**		

[1] Volume of water treated by the IESF bench multiplied by 80% filtration credit.
[2] Existing and proposed conditions were modeled without the inflow from Gottfrieds Pit to better simulate the automated valve bypass, results may vary depending on the configuration of the automated valve.
[3] Dissolved phosphorus removal was adjusted to 70% to account for the iron sorption of phosphorus (Erickson, Gulliver; 2010).
[4] Engineering and administration costs were estimated as 25% of the construction cost.
[5] Estimated as 5% of the construction cost.



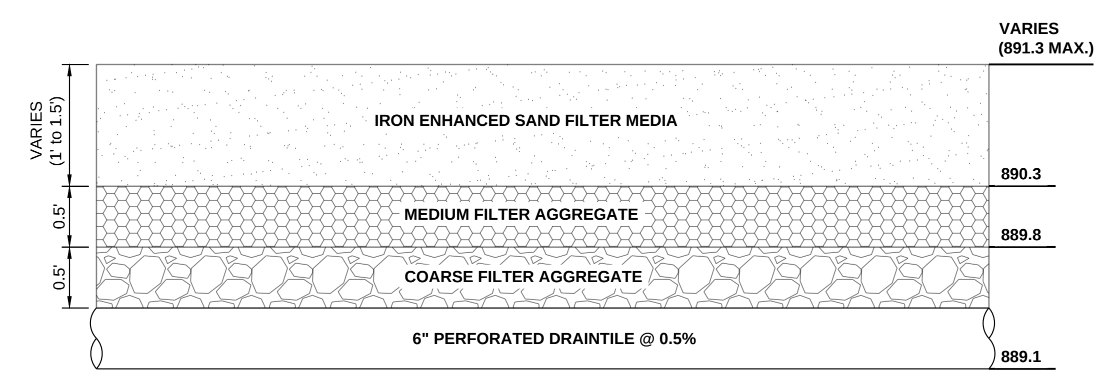


SECTION A-A

NOT TO SCALE

WATER LEVELS TABLE

	EXISTING	PROPOSED
OVERFLOW	893.2	893.2
WQL (WEIR)	NA	891.9
NOTCH IN MH	891.8	891.8
NWL (AUTOMATIC CONTROL VALVE)	888.8	888.8



IESF AGGREGATE GRADING LAYOUT (SECTION B-B)

NOT TO SCALE

No.	Revision	Date	By

PRELIMINARY
Not for Construction

Houston Engineering Inc.

Fargo
P: 701.237.5065
F: 701.237.5101

Drawn by	Date	Checked by	Scale
HRR	3-9-2018	GB	AS SHOWN

COMO REGIONAL PARK STORMWATER BMPS
FEASIBILITY STUDY
CAPITAL REGION WATERSHED DISTRICT

NORTHWEST POND
CONCEPT DESIGN
PROJECT NO. 6745-019

SHEET
1 of 1

H:\Maple Grove\JBN\6400\6475\17_6475_019\CAD\Exhibits\Exhibit Layout 1.dwg-NW Pond-3/9/2018 5:41 PM-(hrollin)

Engineer's Preliminary Cost Estimate
BMP - NW Pond Iron Enhanced Sand Filter Bench
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 15,000.00	$ 15,000.00
2	Clearing and Grubbing	LS	1	$ 500.00	$ 500.00
3	Excavation (P)	CY	880	$ 6.00	$ 5,280.00
4	Haul & Dispose of Soil (P)	CY	880	$ 12.00	$ 10,560.00
5	6" PVC Perforated Pipe Drain (pipe and cleanouts)	LF	590	$ 15.00	$ 8,850.00
6	12" RCP Stormsewer (pipe and bedding)	LF	114	$ 50.00	$ 5,700.00
7	48" Stormsewer Structure	EA	1	$ 4,500.00	$ 4,500.00
8	Sand Filter Edging (Plastic)	LF	588	$ 10.00	$ 5,880.00
9	Install Weir in Existing Manhole	EA	1	$ 1,500.00	$ 1,500.00
10	Coarse Filter Aggregate	CY	30	$ 70.00	$ 2,100.00
11	Medium Filter Aggregate	CY	197	$ 70.00	$ 13,790.00
12	Fine Filter Aggregate	CY	320	$ 60.00	$ 19,200.00
13	Iron Filings (5% by weight of Fine Filter Aggregate)	TON	28	$ 1,500.00	$ 42,525.00
14	Polyliner Material	SY	840	$ 2.50	$ 2,100.00
15	Automatic Valve Vault	EA	1	$ 70,000.00	$ 70,000.00
16	Seeding	AC	0.4	$ 1,500.00	$ 629.71
17	Hydromulch	AC	0.4	$ 7,500.00	$ 3,000.00
18	Golf Course Restoration	LS	1.0	$ 5,000.00	$ 5,000.00
19	Erosion Control (construction entrance, silt fence, bioroll)	LS	1.0	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 221,114.71
Construction Contingencies (30%)					$ 66,334.41
Total Construction Cost					**$ 287,449.13**
Engineering and Administration (25%)					$ 71,862.28
Non-Construction Cost					**$ 71,862.28**
Total Estimated Project Cost					**$ 359,311.41**
Operation and Maintenance					$ 14,372.46

Assumptions:

Engineer's Preliminary Cost Estimate
BMP - Golf Parking Lot Pond IESF Bench
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 20,000.00	$ 20,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Grading (pond berm, IESF)	LS	1	$ 3,000.00	$ 3,000.00
4	Common Borrow (CV)	CY	150	$ 30.00	$ 4,488.89
5	Stone to Stabilize Existing Channel	CY	83	$ 150.00	$ 12,500.00
6	Reconstruct Waterfall	LS	1	$ 5,000.00	$ 5,000.00
7	Reconstruct Overflow Outlet	LS	1	$ 2,500.00	$ 2,500.00
8	Grout Existing Diversion	LS	1	$ 500.00	$ 500.00
9	Diversion Weir in Existing MH	LS	1	$ 2,000.00	$ 2,000.00
10	6" PVC Perforated Pipe Drain (pipe and cleanout)	LF	100	$ 15.00	$ 1,500.00
11	12" RCP Stormsewer (pipe and bedding)	LF	90	$ 50.00	$ 4,500.00
12	Sand Filter Edging	LF	175	$ 10.00	$ 1,750.00
13	Medium & Coarse Filter Aggregate	CY	55	$ 70.00	$ 3,837.04
14	Fine Filter Aggregate	CY	55	$ 60.00	$ 3,288.89
15	Iron Filings	TON	5	$ 1,500.00	$ 7,400.00
16	Polyliner Material for IESF Lining	SY	213	$ 2.50	$ 532.64
17	Automatic Valve Vault	LS	1	$ 70,000.00	$ 70,000.00
18	Pavement/Aggregate/Curb Reconstruction	SY	58	$ 100.00	$ 5,777.78
19	Golf Course Restoration	LS	1	$ 15,000.00	$ 15,000.00
20	Seeding	AC	0.1	$ 1,500.00	$ 150.00
21	Hydromulch	AC	0.1	$ 7,500.00	$ 750.00
22	Erosion Control (construction entrance, silt fence, bioroll)	LS	1	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 171,975.23
Construction Contingencies (30%)					$ 51,592.57
Total Construction Cost					**$ 223,567.80**
Engineering and Administration (25%)					$ 55,891.95
Non-Construction Cost					**$ 55,891.95**
Total Estimated Project Cost					**$ 279,459.75**
Operation and Maintenance					$ 11,178.39

Assumptions:

Engineer's Preliminary Cost Estimate
BMP - Zoo 1 Filtration Basin
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 10,000.00	$ 10,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Excavation (P)	CY	1280	$ 6.00	$ 7,680.00
4	Haul & Dispose of Soil (P)	CY	1180	$ 12.00	$ 14,160.00
5	6" PVC Perforated Pipe Drain (pipe and cleanout)	LF	340	$ 15.00	$ 5,100.00
6	12" RCP Stormsewer (pipe and bedding)	LF	476	$ 50.00	$ 23,800.00
7	48" Stormsewer Structure	EA	2	$ 4,500.00	$ 9,000.00
8	60" Stormsewer Structure	EA	1	$ 6,000.00	$ 6,000.00
9	Landscaping	LS	1	$ 7,500.00	$ 7,500.00
10	Relocate Tee Box	LS	1	$ 2,000.00	$ 2,000.00
11	Filter Aggregate	CY	544	$ 70.00	$ 38,111.11
12	Outlet Structure	EA	1	$ 6,500.00	$ 6,500.00
13	Hydrodynamic Separator	EA	1	$ 20,000.00	$ 20,000.00
14	Golf Course Restoration	LS	1	$ 5,000.00	$ 5,000.00
15	Seeding	AC	0.2	$ 1,500.00	$ 319.49
16	Hydromulch	AC	0.2	$ 7,500.00	$ 1,597.45
17	Erosion Control (construction entrance, silt fence, bioroll)	LS	1.0	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 164,268.05
Construction Contingencies (30%)					$ 49,280.42
Total Construction Cost					**$ 213,548.47**
	Engineering and Administration (25%)				$ 53,387.12
Non-Construction Cost					**$ 53,387.12**
Total Estimated Project Cost					**$ 266,935.59**
Operation and Maintenance					$ 9,182.58

Engineer's Preliminary Cost Estimate
BMP - Zoo 2 Expanded Infiltration Basin
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 10,000.00	$ 10,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Excavation (P)	CY	1733	$ 6.00	$ 10,396.67
4	Haul & Dispose of Soil (P)	CY	962	$ 12.00	$ 11,548.89
3	Grading	CY	770	$ 4.00	$ 3,081.48
5	Remove Existing Stormsewer Structure	LS	1	$ 1,000.00	$ 1,000.00
6	12" RCP Stormsewer (pipe and bedding)	LF	40	$ 50.00	$ 2,000.00
7	60" Stormsewer Structure	EA	2	$ 6,000.00	$ 12,000.00
8	48" Stormsewer Structure	EA	1	$ 4,500.00	$ 4,500.00
9	Install Weir Diversion Structure	EA	1	$ 2,000.00	$ 2,000.00
10	Salvage and Relocate Existing Stormsewer	LF	125	$ 80.00	$ 10,000.00
11	Hydrodynamic Separator	EA	1	$ 20,000.00	$ 20,000.00
12	Golf Course Restoration	LS	1	$ 5,000.00	$ 5,000.00
13	Restructure Existing Outlet	LS	1	$ 1,500.00	$ 1,500.00
14	Seeding	AC	0.9	$ 1,500.00	$ 1,397.07
15	Hydromulch	AC	0.9	$ 7,500.00	$ 6,985.37
16	Erosion Control (construction entrance, silt fence, bioroll)	LS	1	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 108,909.48
Construction Contingencies (30%)					$ 32,672.84
Total Construction Cost					**$ 141,582.32**
Engineering and Administration (25%)					$ 35,395.58
Non-Construction Cost					**$ 35,395.58**
Total Estimated Project Cost					**$ 176,977.90**
Operation and Maintenance					$ 1,840.57

Assumptions:

Engineer's Preliminary Cost Estimate
BMP - Zoo Combination Filtration Basin and Expanded Infiltration Basin
3/19/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 20,000.00	$ 20,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Remove Existing Stormsewer Structure	LS	1	$ 1,000.00	$ 1,000.00
4	Excavation (P)	CY	3010	$ 6.00	$ 18,060.00
5	Haul & Dispose of Soil (P)	CY	2140	$ 12.00	$ 25,680.00
6	6" PVC Perforated Pipe Drain (pipe and cleanout)	LF	340	$ 15.00	$ 5,100.00
7	12" RCP Stormsewer (pipe and bedding)	LF	398	$ 50.00	$ 19,900.00
8	Relocate Tee Box	LS	1	$ 2,000.00	$ 2,000.00
9	Weir Diversion Structure	LS	1	$ 2,000.00	$ 2,000.00
10	48" Stormsewer Structure	Each	1	$ 4,500.00	$ 4,500.00
11	60" Stormsewer Structure	EA	3	$ 6,000.00	$ 18,000.00
13	42" RCP Stormsewer	LF	25	$ 120.00	$ 3,000.00
14	Salvage and Relocate Existing Stormsewer	LF	125	$ 80.00	$ 10,000.00
15	Filter Aggregate	CY	544	$ 70.00	$ 38,111.11
16	Hydrodynamic Separator	Each	1	$ 20,000.00	$ 20,000.00
17	Restructure Existing Outlet of Infiltration Basin	LS	1	$ 1,500.00	$ 1,500.00
18	Outlet Structure	EA	1	$ 6,500.00	$ 6,500.00
19	Landscaping	LS	1	$ 7,500.00	$ 7,500.00
20	Golf Course Restoration	LS	1	$ 7,000.00	$ 7,000.00
21	Seeding	AC	1.1	$ 1,500.00	$ 1,628.55
22	Hydromulch	AC	1.1	$ 7,500.00	$ 8,142.73
23	Erosion Control (construction entrance, silt fence, bioroll)	LS	1	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 227,122.39
Construction Contingencies (30%)					$ 68,136.72
Total Construction Cost					**$ 295,259.11**
Engineering (25%)					$ 73,814.78
Non-Construction Cost					**$ 73,814.78**
Total Estimated Project Cost					**$ 369,073.89**
Operation and Maintenance					$ 12,696.14

Assumptions:

Engineer's Preliminary Cost Estimate
BMP - Pavilion North Rain Gardens
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Excavation (P)	CY	540	$ 6.00	$ 3,240.00
4	Haul & Dispose of Soil (P)	CY	540	$ 12.00	$ 6,480.00
5	Grout Existing Stormsewer	Each	3	$ 500.00	$ 1,500.00
6	Pretreatment	Each	4	$ 2,000.00	$ 8,000.00
7	Polyliner Material	SY	460	$ 2.50	$ 1,150.00
8	Concrete Curb Cut (4')	Each	4	$ 500.00	$ 2,000.00
9	Pavement Reconstruction	SY	50	$ 50.00	$ 2,500.00
10	Engineered Soil	CY	270	$ 30.00	$ 8,100.00
11	Filter Aggregate	CY	110	$ 70.00	$ 7,700.00
12	Raingarden Plantings	SY	160	$ 60.00	$ 9,583.33
13	6" PVC Perforated Pipe Drain (pipe and cleanout)	LF	110	$ 20.00	$ 2,200.00
14	Outlet structure	Each	2	$ 2,000.00	$ 4,000.00
15	12" RCP Stormsewer (pipe and bedding)	LF	100	$ 50.00	$ 5,000.00
16	Riprap	CY	21	$ 80.00	$ 1,688.89
17	Seeding	AC	0.05	$ 1,500.00	$ 80.92
18	Hydromulch	AC	0.05	$ 7,500.00	$ 404.61
19	Erosion Control (construction entrance, silt fence, bioroll)	LS	1	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 76,127.76
Construction Contingencies (30%)					$ 22,838.33
Total Construction Cost					**$ 98,966.09**
Engineering and Administration (25%)					$ 24,741.52
Non-Construction Cost					**$ 24,741.52**
Total Estimated Project Cost					**$ 123,707.61**
Operation and Maintenance					$ 4,255.54

Assumptions: St. Paul Parks will reconstruct and regrade parking lot, no contamination clean-up

Engineer's Preliminary Cost Estimate
BMP - Pavilion South Infiltration and Filtration Swale
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Excavation (P)	CY	420	$ 6.00	$ 2,520.00
4	Haul & Dispose of Soil (P)	CY	420	$ 12.00	$ 5,040.00
5	Remove Existing Stormsewer	LF	140	$ 15.00	$ 2,100.00
7	Concrete Curb Cut	EA	3	$ 500.00	$ 1,500.00
8	Concrete Flume from Curb Cut to Swale	LF	62	$ 40.00	$ 2,480.00
9	Pretreatment (Rain-Guardian)	EA	3	$ 1,500.00	$ 4,500.00
10	6" PVC Perforated Pipe Drain (pipe and cleanout)	LF	620	$ 15.00	$ 9,300.00
14	Raingarden Plantings	SY	156	$ 60.00	$ 9,333.33
15	Landscaping	LS	1	$ 5,000.00	$ 5,000.00
16	Connect to Existing Stormsewer	LS	1	$ 1,000.00	$ 1,000.00
17	Riprap (outlet of flumes)	CY	5	$ 80.00	$ 373.33
18	Seeding	AC	0.2	$ 1,500.00	$ 300.00
19	Hydromulch	AC	0.2	$ 7,500.00	$ 1,500.00
20	Erosion Control (construction entrance, silt fence, bioroll)	LS	1.0	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 57,446.67
Construction Contingencies (30%)					$ 17,234.00
Total Construction Cost					**$ 74,680.67**
Engineering and Administration (25%)					$ 18,670.17
Non-Construction Cost					**$ 18,670.17**
Total Estimated Project Cost					**$ 93,350.83**
Operation and Maintenance					$ 970.85

Assumptions: St. Paul Parks will reconstruct and regrade parking lot

Engineer's Preliminary Cost Estimate
BMP - Pavilion South Reuse Tank and Underground Infiltration
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 32,000.00	$ 32,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Excavation (P)	CY	10528	$ 6.00	$ 63,167.98
4	Haul & Dispose of Soil (P)	CY	3158	$ 12.00	$ 37,897.62
	Backfill Material (P)	CY	7370	$ 4.00	$ 29,479.45
6	Underground Stormwater Holding Tank (Reuse)	CF	13286	$ 11.00	$ 146,143.80
8	Underground Stormwater Infiltration Chambers	CF	30492	$ 4.00	$ 121,968.00
9	Washed Rock Material for Infiltration Chambers	CY	1800	$ 57.00	$ 102,600.00
10	Pump System for Irrigation	EA	1	$ 40,000.00	$ 40,000.00
11	Control System for Irrigation	LS	1	$ 12,000.00	$ 12,000.00
12	Hydrodynamic Separator	EA	1	$ 20,000.00	$ 20,000.00
13	12" RCP Stormsewer (pipe and bedding)	LF	30	$ 50.00	$ 1,500.00
14	Diversion Weir in Existing MH	LS	1	$ 1,500.00	$ 1,500.00
15	Pavement Reconstruction	SY	313	$ 50.00	$ 15,661.11
16	Seeding	AC	0.9	$ 1,500.00	$ 1,396.70
17	Hydromulch	AC	0.9	$ 7,500.00	$ 6,983.52
18	Erosion Control (construction entrance, silt fence, bioroll)	LS	1.0	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 639,798.19
Construction Contingencies (30%)					$ 191,939.46
Total Construction Cost					**$ 831,737.64**
Engineering and Administration (25%)					$ 207,934.41
Non-Construction Cost					**$ 207,934.41**
Total Estimated Project Cost					**$ 1,039,672.05**
Operation and Maintenance					$ 17,466.49

Assumptions: Underground stormwater structure prices based on McMurray Field project

Engineer's Preliminary Cost Estimate
BMP - Pavilion South Infiltration Stream and Underground Infiltration
3/9/2018

No.	Bid Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 35,000.00	$ 35,000.00
2	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
3	Excavation (P)	CY	6550	$ 6.00	$ 39,300.00
4	Haul & Dispose of Soil (P)	CY	2430	$ 12.00	$ 29,160.00
5	Backfill Material (P)	CY	4120	$ 4.00	$ 16,480.00
6	Underground Stormwater Holding Tank (Recirculation)	CF	17060	$ 11.00	$ 187,660.00
7	Underground Stormwater Infiltration Chambers	CF	13649	$ 4.00	$ 54,595.20
8	Washed Rock Material for Infiltration Chambers	CY	806	$ 57.00	$ 45,913.50
9	Pump System for Recirculation	EA	2	$ 40,000.00	$ 80,000.00
10	Control System for Recirculation	LS	1	$ 12,000.00	$ 12,000.00
11	72" Manhole with Lift Station for Recirculation	LS	1	$ 15,000.00	$ 15,000.00
12	Install Weir in Existing Manhole	LS	1	$ 1,500.00	$ 1,500.00
13	Riprap	CY	17	$ 80.00	$ 1,333.33
14	Streambed Stone	CY	200	$ 150.00	$ 30,000.00
15	Outlet Structure (at outlet of stream)	LS	1	$ 6,500.00	$ 6,500.00
16	Automatic Valve Vautl	EA	1	$ 20,000.00	$ 20,000.00
17	8" PVC Distribution Pipe	LF	450	$ 60.00	$ 27,000.00
18	12" RCP Stormsewer (pipe and bedding)	LF	40	$ 50.00	$ 2,000.00
19	6" PVC Perforated Drain	LF	522	$ 15.00	$ 7,830.00
20	Pavement Reconstruction	SY	213	$ 50.00	$ 10,638.89
21	Raingarden Plants	SY	339	$ 30.00	$ 10,180.97
22	Landscaping	LS	1	$ 16,000.00	$ 16,000.00
23	Stone Weirs	EA	4	$ 2,500.00	$ 10,000.00
24	Hydrodynamic Separator	EA	1	$ 20,000.00	$ 20,000.00
25	Seeding	AC	1.1	$ 1,500.00	$ 1,701.45
26	Hydromulch	AC	1.1	$ 7,500.00	$ 8,507.23
27	Erosion Control (construction entrance, silt fence, bioroll)	LS	1.0	$ 5,000.00	$ 5,000.00
Construction Subtotal					$ 695,800.56
Construction Contingencies (30%)					$ 208,740.17
Total Construction Cost					**$ 904,540.73**
Engineering (25%)					$ 226,135.18
Non-Construction Cost					**$ 226,135.18**
Total Estimated Project Cost					**$ 1,130,675.92**
Operation and Maintenance					$ 18,995.36

Assumptions: Underground stormwater structure prices based on McMurray Field project

Engineer's Preliminary Cost Estimate
BMP - Zoo Combination and Golf Parking Lot Treatment Train
3/9/2018

Golf Lot Construction Subtotal	$	171,975.23
Zoo Combo Construction Subtotal	$	227,122.39
Construction Contingencies (30%)	$	119,729.29
Total Construction Cost	**$**	**518,826.91**
Engineering and Administration (25%)	$	129,706.73
Non-Construction Cost	**$**	**129,706.73**
Total Estimated Project Cost	**$**	**648,533.64**
Operation and Maintenance	$	23,874.53

Assumptions:

Engineer's Preliminary Cost Estimate
BMP - Zoo 2 and Golf Parking Lot Treatment Train
3/15/2018

Golf Lot Construction Subtotal	$	171,975.23
Zoo 2 Construction Subtotal	$	108,909.48
Construction Contingencies (30%)	$	84,265.41
Total Construction Cost	**$**	**365,150.12**
Engineering and Administration (25%)	$	91,287.53
Non-Construction Cost	**$**	**91,287.53**
Total Estimated Project Cost	**$**	**456,437.65**
Operation and Maintenance	$	13,018.96

Assumptions:

Engineer's Preliminary Cost Estimate
BMP - Zoo 2, Golf Parking Lot and NW Pond Treatment Train
3/15/2018

Golf Lot Construction Subtotal	$	171,975.23
Zoo 2 Construction Subtotal	$	108,909.48
NW Pond Construction Subtotal	$	221,114.71
Construction Contingencies (30%)	$	150,599.83
Total Construction Cost	**$**	**652,599.24**
Engineering and Administration (25%)	$	163,149.81
Non-Construction Cost	**$**	**163,149.81**
Total Estimated Project Cost	**$**	**815,749.06**
Operation and Maintenance	$	27,391.42

Assumptions: