RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Feasibility Report

Silver Lake Subwatershed SiL_2 Water Quality Improvement Project

Prepared for
Riley Purgatory Bluff Creek Watershed District

December, 2018

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Contents

List of Tables

List of Figures

List of Appendices, Attachments, or Exhibits

Certifications

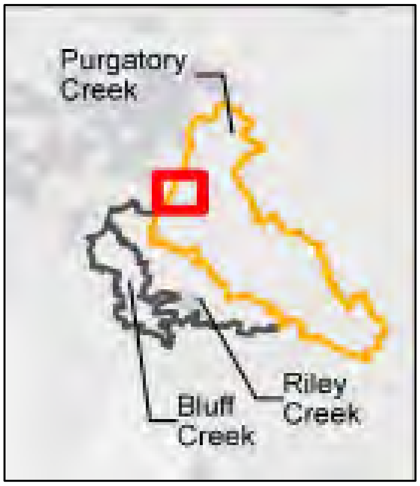
I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

December 5, 2018	
Scott Sobiech PE #: 41338	Date

December 5, 2018	
Brandon Barnes PE #: 49540	Date

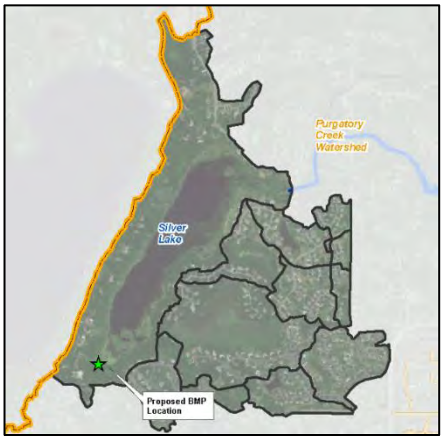
Executive Summary

This study was completed to evaluate proposed actions within subwatershed Silver_Lake, SiL_2 to improve the water quality in Silver Lake, located in the city of Chanhassen, Minnesota. The site was identified in the 2017 UAA as a location for a BMP to reduce the phosphorus loading to Silver Lake. This site presents several design and maintenance challenges including, but not limited to, drainage patterns, tree canopy, and topography.



Site within Purgatory watershed

Five best management practices (BMPs), in conjunction with the stabilization of an existing ravine to Silver Lake, were identified that would minimize site impacts (both wetland and upland), could be constructed primarily on publically owned property, and have comparably low maintenance costs. BMPs evaluated included both proprietary and non-proprietary BMPs including:



Location of proposed water quality BMP

non-proprietary BMPs

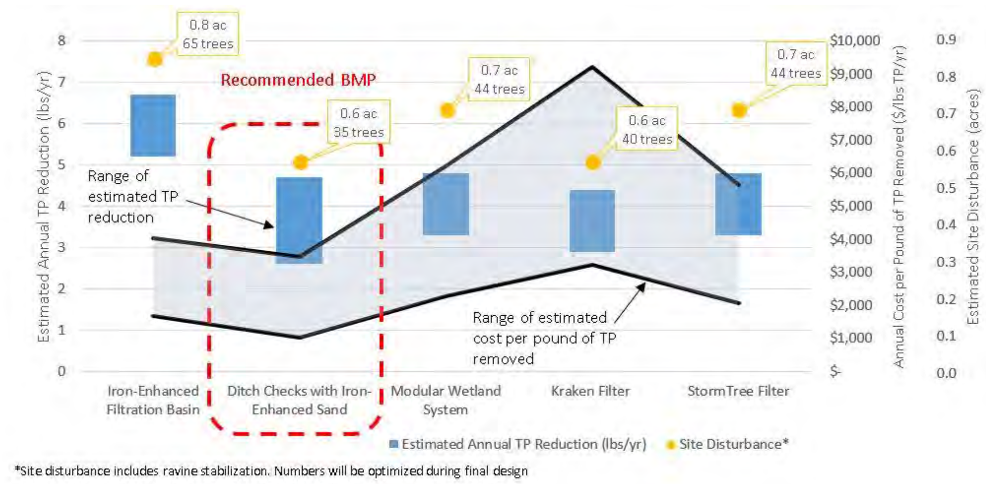
- Ditch checks with iron-enhanced sand
- Iron-enhanced filtration basin with underdrain

proprietary BMPs

- Modular Wetland Systems (MWS) – BioClean (or similar)
- Kraken Filter – BioClean
- StormTree – StormTree (or similar)


Eroded ravine downstream of road drainage

An evaluation for each BMP was completed which considered water quality benefits, regulatory approvals, affected property owners, wetland and upland impacts, and cost to construct and maintain.



Of the five BMPs evaluated, ditch checks with iron-enhanced sand have the lowest annualized cost per pound of phosphorus removed.

Based on the results of the evaluation, potential upland, wetland, and tree impacts, as well as the cost per pound of phosphorous removed, a combination of ditch checks with iron-enhanced sand and ravine stabilization are feasible BMPs for the site. The recommended iron-enhanced ditch checks, in conjunction with the ravine stabilization, minimize adverse impacts and erosion potential to natural resources in the area and will help improve and protect the water quality in Silver Lake. The results indicate the BMPs would reduce the phosphorus loading to Silver Lake by 2.6 to 4.7 pounds annually costing about $1,640 (ranging from $1,020 to $3,460) per pound of phosphorus removed when long-term maintenance is considered over a 30 year period.

The engineer's opinion of probable cost for the design, permitting, and construction of iron-enhanced ditch checks and ravine stabilization is estimated at $122,000 with a potential range of $98,000 to $183,000 based on the feasibility level of design. Water quality BMPs require ongoing maintenance and operation to provide the intended water quality benefits. As additional site-specific information (e.g., soil borings) becomes available in the next stage of design, the proposed configuration, cost, performance of the iron-enhanced ditch checks, number trees affected, and maintenance considerations could change. The District will also need to collaborate closely with the city of Chanhassen to ensure long-term maintenance of the project.

1.0 Context and Goals for this Ecological Enhancement Plan

This report summarizes the proposed actions within subwatershed Silver_Lake, SiL_2 to improve the water quality in Silver Lake, located in the city of Chanhassen, Minnesota. Figure 1-1 illustrates the Silver Lake watershed and drainage patterns of SiL_2 and the contributing subwatersheds. This report is prepared under the direction of the Board of Managers of the Riley-Purgatory-Bluff Creek Watershed District.

The Riley-Purgatory-Bluff Creek Watershed District (RPBCWD or District) was established by the Minnesota Water Resources Board in 1969, acting under authority of the Watershed Law. As charged by the law and the order establishing the District, the general purpose of the District is to protect public health and welfare and to provide for the provident use of natural resources through planning, flood control, and conservation projects.

The District is located in the southwestern portion of the Twin Cities Metropolitan Area, encompassing an area of nearly 50 square miles. There are three major subwatersheds within the District—Riley Creek, with a watershed area of 10.0 square miles; Purgatory Creek (31.4 square miles), and Bluff Creek (5.9 square miles). All three creeks discharge to the Minnesota River. Stormwater management and development were guided by the District's 1973 Overall Plan, revised in May 1996 and February 2011 in accordance with the Metropolitan Surface Water Management Act and Watershed Law (Minnesota Statutes Chapters 103B and 103D). In 2013 the District completed a major amendment to the 2011 Plan. This was approved by the Board of Water and Soil Resources (BWSR) in early 2014 and is the current guiding document of the District (the Plan).

The Lotus, Silver, Duck, Round, Mitchell, Red Rock use attainability analysis (UAA) was prescribed by the 1996 Riley-Purgatory-Bluff Creek Watershed District Water Management Plan. The Silver Lake UAA was updated in March 2017 as part of *the Lotus, Silver, Duck, Round, Mitchell, Red Rock Use Attainability Analysis Update; Lake Idlewild and Staring Lake Use Attainability Analysis; and Lower Purgatory Creek Stabilization Study* and includes recommended remedial measures to improve the water quality (Barr Engineering, 2017).

The UAA provides the scientific foundation for lake-specific management plans that will preserve existing—or achieve potential—beneficial uses of the lakes. The UAA is a structured, scientific assessment of the factors affecting attainment of a beneficial use under both current and ultimate watershed development conditions. "Use Attainment" refers to achievement of water quality conditions that support lake-specific uses such as swimming, fishing, wildlife habitat, and aesthetic viewing.

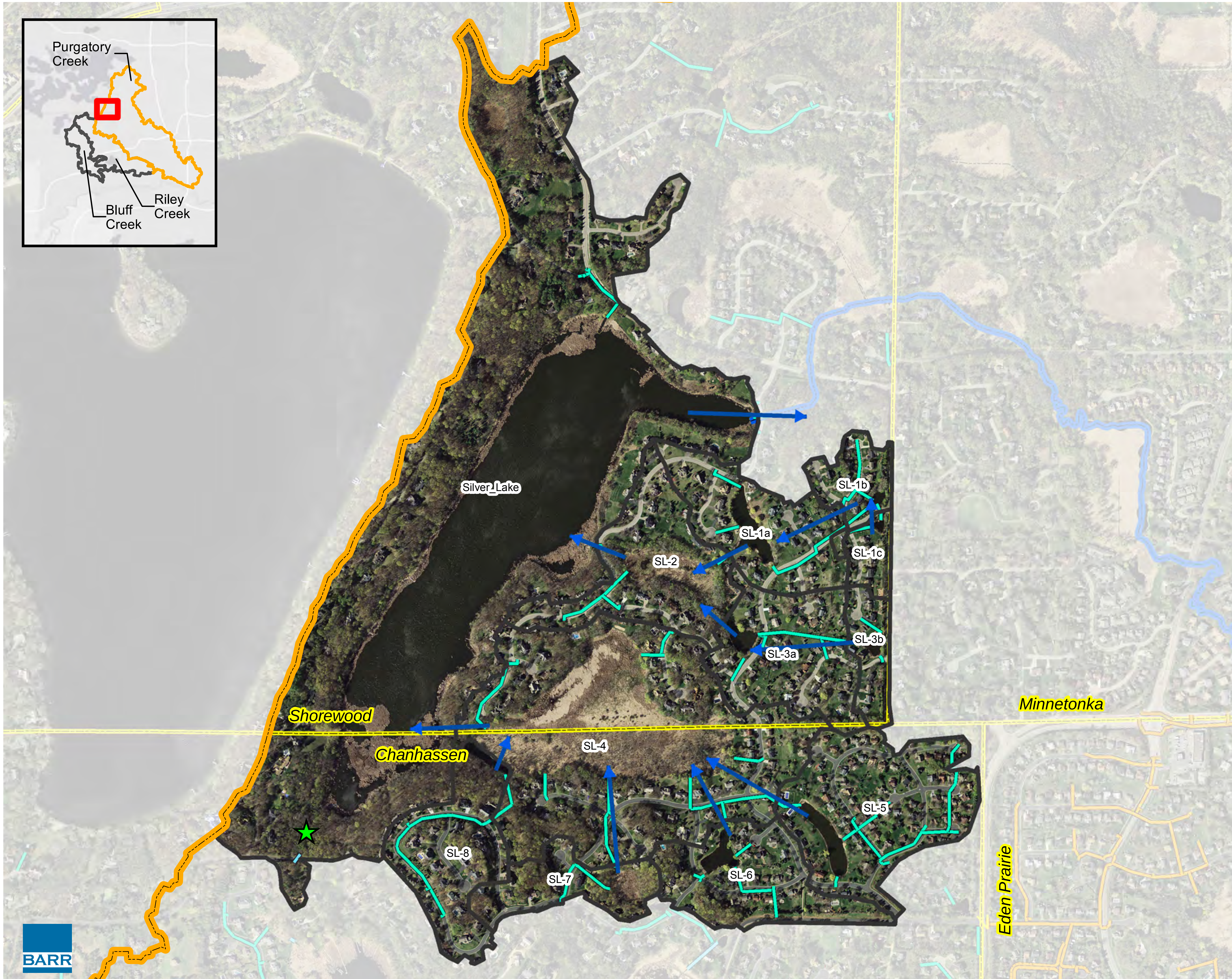
The 2017 UAA Update was completed with the goal of: (1) assessing the water quality of major lakes in the Purgatory watershed based on more recent physical, chemical, and biological data, (2) improving the understanding of current water quality concerns in the lakes, and (3) identifying best management practices (BMPs) to improve and protect the lakes' water quality and increase the likelihood of them being removed from the Minnesota Pollution Control Agency's (MPCA) list of impaired waters list for excess nutrients. The overarching purpose of the UAA update was to identify and evaluate BMPs that can be implemented to improve and/or protect the lakes' water quality and achieve the long-term vision of sustainable uses, as outlined in the District's Plan.

The District's Plan articulates the long-term vision of sustainable uses for each of its water bodies. Achieving this vision will result in:

- Waters dominated by diverse native fish and plant populations.
- Lakes with water clarity of 2 meters or more.
- Delisting of half of all impaired (303d) lakes or stream reaches.
- An engaged and educated public and scientific community that participates in adaptive management activities.
- Regulatory recommendations necessary for municipal, county, and state authorities to sustain the achieved conditions.

SILVER LAKE WATERSHED AND FLOW PATTERNS

FIGURE 1-1



- Potential BMP Location
- Flow Directions
- Silver Lake Subwatersheds
- Purgatory Creek Watershed
- Storm Sewer
- Municipal Boundaries

N

0 220 440 880 1,320 1,760 Feet

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

1.1 Vision, Approach and SiL_2 Project Goals

The 2017 UAA update identified the Silver Lake subwatershed SiL_2 as a targeted location within the Silver Lake watershed to reduce the phosphorus loading and improve the water quality of Silver Lake. The UAA indicates that runoff from approximately 13.5 acres drains through the location of the potential stormwater treatment system. The UAA suggests that an iron enhanced sand filtration system treating discharge from Pleasantview Road and Ridge Road would be approximately 0.4 acres at the surface with the potential to reduce the annual phosphorus loading to Silver Lake by 6.3 pounds. The UAA suggests a cost-benefit of about $4,530 per pound of TP removed, assuming the BMP functions for 30 years. Figure 1-2 shows the location of the proposed iron-enhanced sand BMP in the UAA report.

The District ordered this feasibility study to evaluate the viability of constructing a BMP to treat runoff from Pleasantview Road and Ridge Road, and to identify if an iron enhanced sand filtration system would be the preferred BMP for the site. This study evaluates the feasibility of other stormwater BMPs, as well. Estimated total phosphorus removals and engineer’s opinion of project costs were determined for five feasible BMPs.

PROPOSED BMP LOCATION FOR SILVER LAKE, SiL_2

FIGURE 1-2

UAA Drainage Area to BMP

Approximate BMP Location

National Wetland Inventory Delineation

Hennepin County 2011 Contours (NGVD29)

10-Foot Contour

2-Foot Contour

N

0 55 110 220 330 440 Feet

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

1.2 Silver Lake Water Quality Goals and Current Lake Conditions

The MPCA lake eutrophication criteria establish water quality standards for lakes based on total phosphorus, chlorophyll *a*, and Secchi disc transparency (Minnesota Pollution Control Agency, 2017). The standards are based on the geographic location of the water body (and associated ecoregion) and its depth (shallow vs. deep lakes). The growing season average Total Phosphorus (TP) concentration (115 µg/L) for Silver Lake based on measurements collected by RPBCWD consistently failed to meet the MPCA water quality standards. The most recent growing-season average TP concentration in year 2017 was calculated as 58 µg/L which is the only year that meets the MPCA goal of ≤60 µg/L, and the lowest growing season average concentration on record since concentrations were recorded beginning in 1996. The next lowest growing season average was 72 µg/L in 2011. TP concentrations reached a maximum value of 215 µg/L in 2000.

Historically Chl-a concentrations in Silver Lake have exceeded the District goal of 20 µg/L every year on record (Barr Engineering, 2017). The 2015 growing season average concentrations was 36 µg/L, this was lowest value on record. The highest average value recorded was 220 µg/L in 2000.

Historical Secchi depths in Silver Lake have not achieved the MPCA goal of ≥1.0 meter. The only growing season average on record to meet the MPCA goal for Secchi depth was in 2017 and was 1.72 meters. This was the highest (best) value on record. The lowest (worst) value calculated was 0.22 meters in 2000.

An in-lake model was used to determine TP load reductions needed to meet the water quality goal for Silver Lake. Table 1-1, from the UAA, shows the measured and modeled growing season average (June – September) concentration, the TP load to the lake under existing conditions, the water quality goal, the TP loading capacity for meeting the water quality standard, and the required percent reduction needed to meet the TP goal (Barr Engineering, 2017). Under existing conditions, Silver Lake is not meeting the MPCA’s water quality goal for a shallow lake of 60 µg/L. Modeled and measured growing season average concentrations in the lake surfaces waters for the 2015 water year was 91 µg/L and 85 µg/L respectively. The estimated TP load under existing conditions was 214 pounds for the 2015 water year. To achieve the TP goal the load to Silver Lake would need to be reduced to 179 pounds, resulting in a 16% TP load reduction.

Table 1-1 Silver Lake estimated load reductions required to meet TP water quality goal for 2015 water year[1]

Measured growing season average TP concentration (µg/L)	Modeled growing season average TP concentration (µg/L)	Estimate 2015 TP loading rate (lbs/yr)	TP concentration goal (µg/L)	Estimated Loading Capacity to meet WQ goal (lbs/yr)	Percent reduction needed to achieve goal (%)
85	91[2]	214	60	179	16%

Note(s):
(1) Values cited from the Lotus, Silver, Duck, Round, Mitchell, Red Rock Use Attainability Analysis Update (Barr Engineering, 2017)
(2) Volumetric average concentration for entire water column

2.0 Existing Conditions

2.1 Silver Lake Watershed and Lake Description

Silver Lake is one of two headwater lakes to Purgatory Creek. Silver Lake lies mostly within the boundaries of the city of Shorewood with the southern part of the watershed in the city of Chanhassen. The watershed area contributing runoff to Silver Lake is 407 acres including the lake surface area of 71 acres (Figure 1-1). The majority of the Silver Lake watershed is covered by single family detached residential land use (72%) (Barr Engineering, 2017). Single family detached residential classification has approximately 35% total impervious area and 20% directly connected impervious area.

Table 2-1 provides a summary of the physical characteristics for Silver Lake. Silver Lake has an open-water surface area of approximately 71 acres. The lake is shallow, with a maximum depth of approximately 14 feet and mean depth of approximately 5 feet. The lake area, depth, and volume depend on the water level of the lake, which has been observed to vary between a high measurement of 901.03 feet (2012) to a low measurement of 894.78 feet (1972). Since 2011 water levels in Silver Lake have averaged 899.3 feet. The outlet of Silver Lake is a control structure that feeds into Purgatory Creek with a control elevation of 898.54. At the average water elevation of 899.3 feet the total water volume in Silver Lake is 190 acre-ft.

Table 2-1 Silver Lake physical parameters

Lake Characteristic	Silver Lake
Lake MDNR ID	27-0136-00
MPCA Lake Classification	None
Water Level Control Elevation (feet)	898.54
Average Water Elevation (feet) (1)	899.3
Surface Area (acres)	71
Mean Depth (feet)	5
Maximum Depth (feet)	14
Littoral Area (acres)	71
Volume (at normal water elevation) (acre-feet)	190
Thermal Stratification Pattern	polymictic
Estimated Residence Time (years) – 2014-2015 climatic Conditions	0.9
Total Watershed Area	407(2)
Subwatershed Area (acres)	407(2)
Trophic Status Based on 2015 Growing Season Average Water Quality Data	Hypereutrophic
Note(s): (1) Average water elevation 1911-2015. (2) Watershed area includes surface area of lakes.	

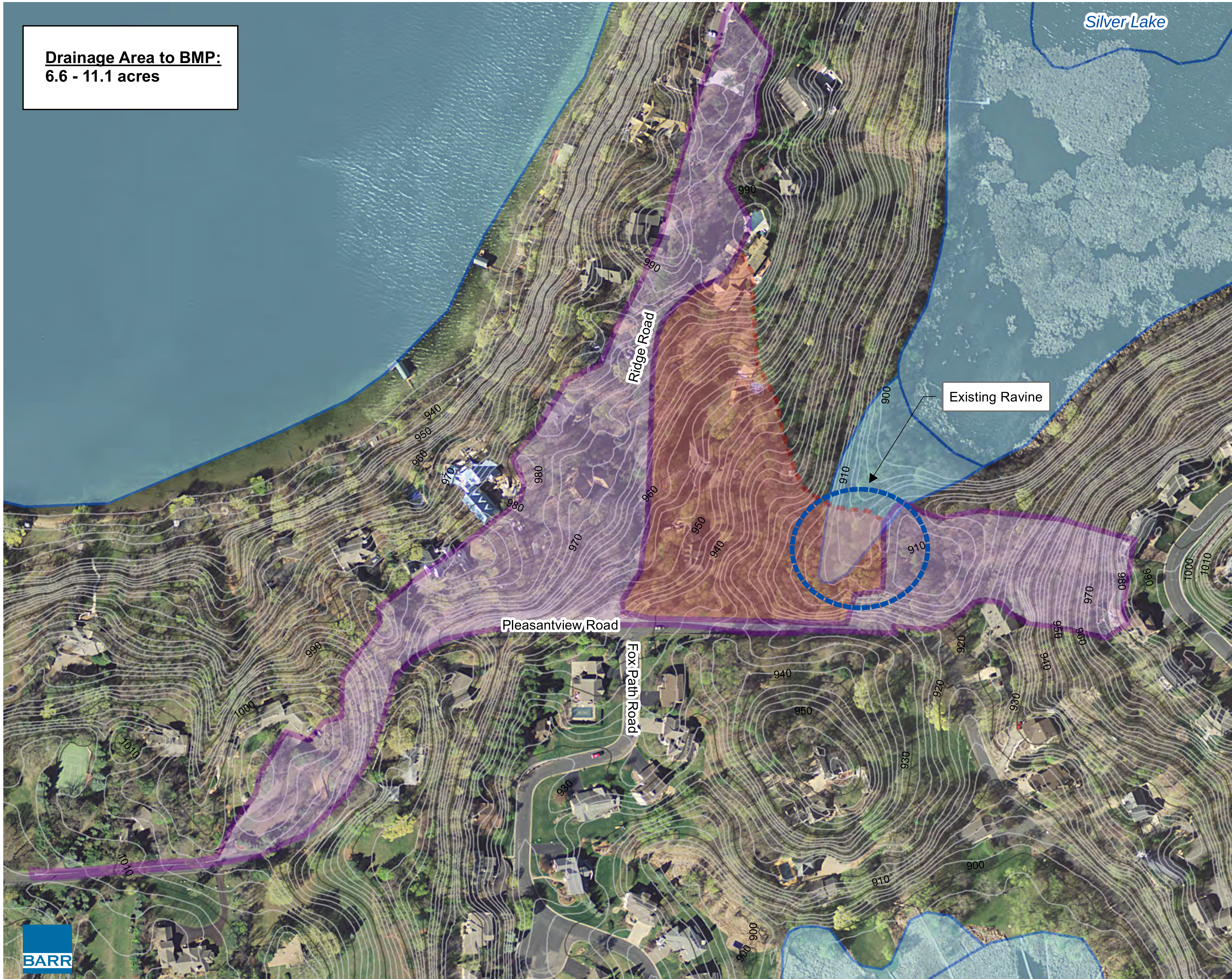
2.2 Project Area Watershed

The 2017 UAA estimated the drainage area to the proposed BMP in the SiL_2 subwatershed to be 13.5 acres. During this feasibility study, the drainage area was refined. The drainage area tributary to the proposed BMP varies between 6.6 and 11.1 acres depending on the location of the BMP. Figure 2-1 illustrates how the location of the BMP affects the contributing drainage area, as indicated by the yellow delineated watershed. A BMP located along Pleasantview Road does not receive drainage from the wooded area to the north near Silver Lake (**A.**). A BMP located within the ravine will receive additional drainage west of the ravine (**B.**). A BMP located near the ravine with an inlet along Pleasantview Road will receive additional drainage to the east (**C.**).

A. BMP by Pleasantview Road **B.** BMP in ravine **C.** BMP east of ravine

Figure 2-1 BMP Location Alternatives

A high-level comparison of the drainage area based on the BMP location is shown in Figure 2-2. Depending on the BMP location, the total phosphorus loading and resulting total potential load, may be less than estimates in the UAA. The land use classification of the SiL_2 watershed is mostly single family residential detached with approximately one-third or one-quarter of the watershed consisting of preserve or wetland (depending on BMP location).



TRIBUTARY DRAINAGE AREA

FIGURE 2-2

- Drainage Area to BMP
- Additional Drainage Area to BMP Located in Ravine
- Approximate BMP Location
- National Wetland Inventory Delineation

Hennepin County 2011 Contours (NGVD29)

- 10-Foot Contour
- 2-Foot Contour

N

0 55 110 220 330 440 Feet

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

2.3 Vegetation

The project site consists of dense herbaceous vegetation with a tree canopy of patchy oak/mixed-hardwood. There is a steep slope off Pleasantview Road (**B.** in Figure 2-3) down to the start of an eroded ravine which drains to Silver Lake. The depressed area (**A.** in Figure 2-3) surrounding the ravine is relatively flat and well-vegetated.

A. Project site looking north from Pleasantview Road

B. Project site looking south up to Pleasantview Road

Figure 2-3 Site Vegetation

2.4 Site Erosion

The banks and sides of the existing ravine are eroded, exposing tree roots and silty soil (**A.** in Figure 2-4). The ravine substrate consists of mainly gravel and sand at the upstream end, shifting to mainly sand and silt at the flatter, downstream end near Silver Lake (**B.** in Figure 2-4). Runoff reaches the ravine by flowing to a low point along Pleasantview Road where it overtops and flows down the steep road bank and enters the ravine (**C.** in Figure 2-4). These characteristics of the existing ravine result in additional TP and TSS loading above the estimated watershed load.

A. Ravine erosion at upstream end near Pleasantview Road

B. Ravine erosion at downstream end near Silver Lake

C. Low spot along Pleasantview Road where runoff enters ravine

Figure 2-4 Ravine Erosion

3.0 Preliminary BMP Screening

Selection of feasible stormwater BMPs occurs by considering a holistic approach that accounts for unique site constraints, operation and maintenance, environmental concerns, effectiveness, and overall cost. When evaluated individually, there may be several BMPs that meet that meet the recommendations from the UAA. However, when multiple potential BMPs are compared, more feasible options may be identified. The first step to identify feasible BMPs for the Sil_2 watershed was to complete a high-level qualitative screening. The screening compares several BMPs based on site specific requirements including minimizing site impacts (both wetland and upland), could be constructed primarily on publically owned property, and have comparably low maintenance costs. In this analysis, six non-proprietary treatment devices (Table 3-1) and ten pre-fabricated treatment devices (Table 3-2) were identified as part of this initial high-level screening. The tables list each BMP considered and summarize associated performance, estimated footprint, maintenance, design concerns, and schematic. Devices which were similar in design and approach were grouped together and are summarized in Table 3-1 and Table 3-2. The differences between treatment devices presented in the tables were used to identify five potentially feasible BMPs for the site, which are listed below and highlighted in green in Table 3-1 and Table 3-2. BMPs that were not identified for further evaluation are highlighted in red.

3.1 Non-Proprietary Devices

For this evaluation, a non-proprietary BMP is defined as a BMP that a contractor could construct without purchasing a pre-fabricated system from a third party manufacture. Examples of non-proprietary BMPs are iron enhanced sand filtration, infiltration, woodchip bioreactors, and biofiltration. Both proprietary and non-proprietary options were considered. Two BMPs were identified based on nutrient reduction performance, device footprint and site constraints, and maintenance requirements. The most feasible non-proprietary BMPs for the site are listed below.

- Iron-enhanced filtration basin with underdrain
- Ditch checks with iron-enhanced sand

3.2 Pre-Fabricated Devices

In addition to non-proprietary devices, ten different pre-fabricated treatment devices were also considered. The differences between treatment devices presented in Table 3-2 were used to identify the following three potentially feasible pre-fabricated BMPs for the site.

- Modular Wetland Systems (MWS) – BioClean (or similar)
- Kraken Filter – BioClean
- StormTree – StormTree (or similar)

3.3 Preliminary BMP Screening Summary

The following five BMPs were identified for further evaluation. The BMPs selected include both pre-fabricated devices as well as non-propriety BMPs:

- Iron-enhanced filtration basin with underdrain
- Ditch Checks with iron-enhanced sand
- Modular Wetland Systems (MWS) – BioClean (or similar)
- Kraken Filter – BioClean
- StormTree – StormTree (or similar)

Each potential BMP identified was further evaluated to identify the anticipated nutrient removal, and identify a system that would fit within city-owned parcels, maximize TP reduction, minimize project cost, and minimize site impacts. Each conceptual design is discussed in Section 4.0.

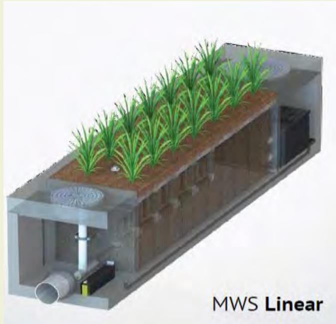
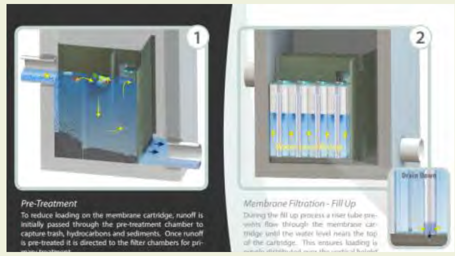
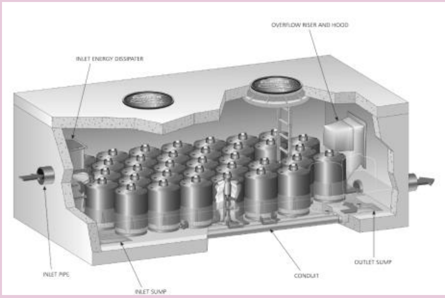
Table 3-1 Non-Proprietary BMP Evaluation Matrix

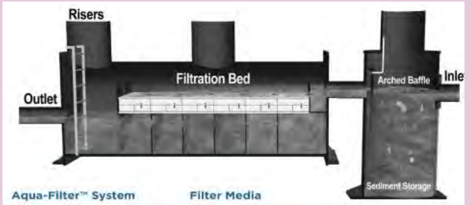
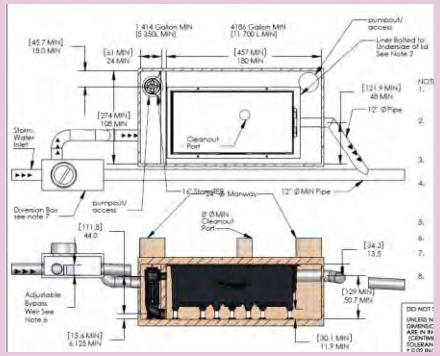
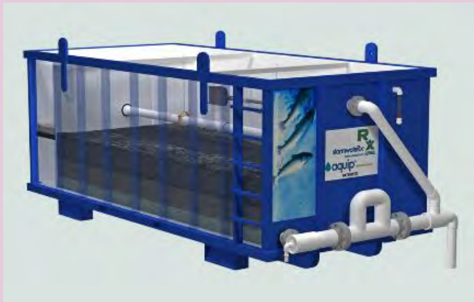
Device Name	Description	Average Performance and Features	Approximate Device Footprint for Sil_2 Watershed	Typical Maintenance	Design Concerns	Schematic
Woodchip Bioreactor[1]	A woodchip bioreactor routes drainage through a buried trench filled with woodchips. Woodchip bioreactors can be used in conjunction with a high flow bypass for large storm events. Woodchip bioreactors require 12 hours of contact time before leaving the system.	TP Removal: 53-79% TN Removal: 15-60% (Nitrate) Research of TP performance is still on-going.	40,000 sf to treat 2.0 cfs[5] flowrate.	Periodic inspection of inlet and outlet structures and occasional addition of woodchip material to maintain the design depth of the bioreactor. Approximately 10+ year lifespan of woodchip media.	Research for nutrient removal performance is still on-going. Long contact time (+12 hr) results in very large footprint.	 Construction of trench for woodchip bioreactor. Photograph from presentation "Anaerobic Woodchip Bioreactors Under Minnesota Conditions," courtesy of Andy Ranaivoson, University of Minnesota
Woodchip Bioreactor in combination with upstream placed iron-enhanced phosphorus filter[2]	Adding an upstream phosphorus filter to a woodchip bioreactor in a separate chamber can increase TP reduction.	TP Removal: 88% TN Removal:15-60% Research of TP performance is still on-going.	40,000 sf to treat 2.0 cfs[5] flowrate.	Periodic inspection of inlet and outlet structures and occasional addition of woodchip material to maintain the design depth of the bioreactor. Approximately 10+ year lifespan of woodchip media.	Research for nutrient removal performance is still on-going. Long contact time (+12 hr) results in very large footprint.	See photo above
Biofiltration/ Bioretention basin with underdrain	Planting soil engineered media with sand trench and draintile. Pre-treatment sump can be used upstream of basin.	TP Removal: 44% TN Removal: 50% TSS Removal: 80%	9,500 sf to capture 1.1 inches off the watershed impervious area. Maximum above ground storage depth of 1.0 ft.	Pruning and weeding as needed. Stabilize and replace mulch as needed. Remove sediment from pre-treatment systems annually. Clean out of the underdrain system as needed.	Larger footprint than pre-fabricated devices considered. Lower removal efficiencies for nutrients than other pre-fabricated devices, iron-enhanced filters, and spent lime filters. May be difficult to establish desired vegetation, requiring more O&M relative to an IES basin.	 Bioretention rain garden at American Legion, Roseville, MN. Designed by Barr Engineering.
Iron-Enhanced Sand (IES) Filter with underdrain	Iron-enhanced sand media with draintile. Pre-treatment sump can be used upstream of basin.	TP Removal: 77% TN Removal: 35% TSS Removal: 85%	2,800-15,400 sf for 22-33 min contact time and 2 cfs[5] flowrate.	Periodic inspection of inlet and outlet structures, clean out of the underdrain system, and occasional addition of filtration media to maintain the design depth of media. Approximately 35 year lifespan of media.	IES ditch checks must drawdown completely so as not to go anoxic. Potential to go anoxic and must be accounted for in the design to prevent the release of phosphorus. Larger footprint than pre-fabricated devices considered.	 Iron enhanced sand filter basin, Maplewood, MN. Designed by Barr Engineering.

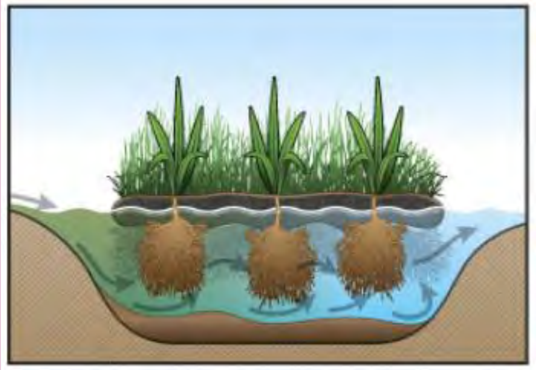
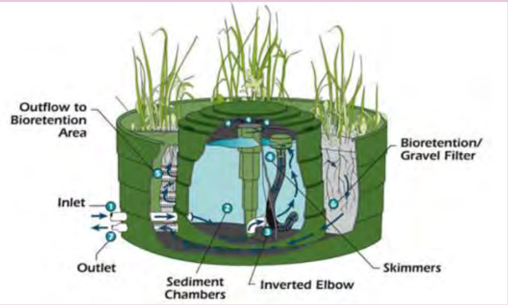
Device Name	Description	Average Performance and Features	Approximate Device Footprint for Sil_2 Watershed	Typical Maintenance	Design Concerns	Schematic
Spent Lime Filter with underdrain[3]	Spent Lime filter media with draintile. Pre-treatment sump can be used upstream of basin.	TP Removal: 65% Research of TP removal performance is still on-going.	2,200-3,100 sf for 5-15 min contact time and 2 cfs[5] flowrate.	Routine inspection of inlet and outlet structures, annual mixing of the lime material to maintain porosity and hydraulic conductivity, and occasional addition of spent lime to maintain the design depth of media. Clean out of the underdrain system as needed. Long lifespan of media.	Research for nutrient removal performance is still on-going. Larger footprint than pre-fabricated devices considered.	 Lake Susan Spent Lime filter in Chanhassen, MN. Designed by Barr Engineering.
Ditch Checks with Iron-Enhanced Sand[4]	Ditch checks along existing ravine with IES embedded within. High flows will move over ditch checks without dislodging media.	TP Removal: 30-50% TN Removal: 35% TSS Removal: 85% Research of performance is still on-going.	4,500-25,000 sf for 22-33 min contact time and 3.2 cfs[5] flowrate. Total required area will be divided by the number of ditch checks used.	Periodic inspection of ditch checks and occasional addition of filtration media to maintain the design depth of media. Approximately 35 year lifespan of media.	IES ditch checks must drawdown completely so as not to go anoxic. Potential to go anoxic and must be accounted for in the design to prevent the release of phosphorus. Research of performance is still on-going. Potential to be located within a delineated wetland.	 Construction of an iron-enhanced ditch check from presentation "Iron-enhanced Ditch Checks in Roadside Drainage Ditches Can Mitigate Runoff," courtesy of Poornima Natarajan, University of Minnesota

1 - Christianson, Laura E. and Helmers, Matthew J., "Woodchip Bioreactors for Nitrate in Agricultural Drainage" (2011). Agriculture and Environment Extension Publications. 85.
2 - Christianson, Laura E. and Lepine, C., "Denitrifying woodchip bioreactor and phosphorus filter pairing to minimize pollution swapping" (2017). Water Research.
3 - Barr Engineering. (2014). Lake Susan Subwatersheds LS-2.4/LS-2.12 Water Quality Improvement Project.
4 - Erickson, A., Gulliver, J., & Weiss, P. (2012). Capturing phosphates with iron enhanced sand filtration. Water Research.
5 – The approximate 1-year peak runoff rate from the Sil_2 watershed ranges from 2 cfs with a 6.64 acre drainage area to 3.2 cfs with an 11.1 acres drainage area.

Table 3-2 Pre-fabricated BMP Evaluation Matrix

Device Name and *Manufacturer*	**Description**	**Average Performance and Features**	**Approximate Device Footprint**	**Typical Maintenance**	**Design Concerns**	**Schematic**
Modular Wetland Systems (MWS) *BioClean* Nutrimax Engineered Wetlands BioFilter *Suntree* FocalPoint Biofiltration Systems *Construction Eco Services*	These devices are stormwater treatment systems consisting of biofiltration via horizontal flow. Flow can enter system via a curb inlet. System has a pre-treatment cartridge and overflow pipe for large events. An open bottom for infiltration is possible.	TP Removal: 60-87%[1] Hydrocarbons: 90%[1] TSS Removal: 80-90%[1] OP Removal: 67%[1] TN Removal: 47%[1]	Concrete-lined vault may range from 4-8'W x 15-16'L x 2-5' D. Device can have open bottom for infiltration purposes. Can treat maximum flow rates ranging from 0.175 - 0.462 cfs.	Clean pre-treatment chamber by hand or with a standard vacuum truck. Only periodic replacement of media in the pre-filter cartridges is required for long term operation. No need to routinely replace or maintain biofiltration media.	Low maximum allowable flow rate through system could prevent treatment of high volume storms. Installation along road may be infeasible due to width requirements, and existing topography north of the road. Proprietary media is more expensive than locally sourced media. Concrete structure is additional construction cost.	
Kraken Filter *BioClean*	Underground vault with a pre-treatment chamber. Treatment occurs through membrane cartridges. This stormwater treatment device can treat high flows with the option of high flow bypass. Drain down eliminates standing water in the system.	TP Removal: > 50%[2] TSS Removal: 89%[2] Metals Removal: > 50%[2] TPH Removal: 90%[2] Trash Removal: 99%[2]	Concrete-lined vault approximately 8'W x 16'L x 6'D Contains 97-114 cartridges. Can treat a maximum flow rate of 2.88 cfs.	No granular media to replace. Membrane filter cartridges can be removed and cleaned by hand with a hose. Maintenance consists of removing debris from the pre-treatment sump with a standard sump vacuum or vactor truck.	Installation adjacent to road may be infeasible given width requirements. Device must be buried making sure to allow for sufficient elevation to drain BMP to nearby ravine. Higher construction and maintenance cost than non-prefabricated BMPs. Filters must be replaced every few years. Device is not visible - no educational or aesthetic component.	
Up-Flo® Filter *Hydro International* StormFilter *Contech* Perk Filter™ *Kristar* SorbtiveFilter *Imbrium*	Stormwater treatment structures that house rechargeable, media-filled cartridges, trapping particulates and absorbing pollutants. Stormwater enters a cartridge, percolates horizontally through the cartridge's filter media and collects in the center tube before exiting the system. Often the filtration unit is preceded by a pre-treatment sump and has options for high flow bypass.	TP Removal: 60-82%[3,4,5] TSS Removal: 80-98%[3,4,5] TN Removal: 50%[5]	Concrete-lined vaults may range from approximately 8-10'W x 16-24'L x 3-5'D. Can treat maximum flow rates ranging from 1.2 - 3.75 cfs.	Maintenance consists of removing debris from the pre-treatment sump with a standard sump vacuum or vactor truck. Replacement of cartridges is needed approximately once per year. No heavy-lifting equipment is required.	Requires multiple feet (> 2.0 ft.) of head between inlet and outlet of system. Head differential between inlet and outlet may be too large to discharge to nearby ravine. Installation adjacent to road is infeasible given width requirements. Replacement of cartridges is needed approximately once per year. Device is not visible - no educational or aesthetic component.	

Device Name and ***Manufacturer***	Description	Average Performance and Features	Approximate Device Footprint	Typical Maintenance	Design Concerns	Schematic
Filterra Bioretention *Contech* StormTree *StormTree*	Stormwater runoff enters the Filterra system through a curb-inlet opening and flows through a specially designed filter media mixture contained in a landscaped concrete container. Stormwater runoff flows through the media and into an underdrain system at the bottom of the container, where the treated water is discharged.	TP Removal: 63-70%[6,7] TSS Removal: 85-86%[6,7] TN Removal: 34-48%[6,7]	Sizing guidance not readily available from manufacturer web page. For StormTree: Device can treat 1.09 acres (0.34 cfs min.) with 9'x17' box using proprietary media with a 50 in/hr infiltration capacity.	Contech provides a first year of included maintenance consisting of a maximum of two scheduled visits. Additional maintenance may be necessary depending on sediment and trash loading. Ongoing maintenance involves cleaning biofiltration bay with landscape tools (rake and shovel).	Installation adjacent to road may be infeasible given width requirements. Requires additional underground storage unit upstream of filter. Concrete structure may prevent tree growth and adds an additional, unnecessary cost. StormTree unit has open bottom and open sides to allow tree growth.	
AquaFilter™ *AquaShield*	Flow-through water quality device custom designed to remove fine-grained sediment, heavy metals bound to particulate matter and residual oil by utilizing a treatment train approach. AquaFilter™ technology incorporates a hydrodynamic separation chamber (Aqua-Swirl™) for pretreatment and a separate chamber to provide filtration treatment.	TP Removal: 96%[8] TSS Removal: 96%[8]	Sizing guidance not readily available from manufacturer webpage.	Inspection and maintenance activities are performed from the surface. A vacuum truck is typically used to perform maintenance on the swirl chamber while filter replacement requires personnel entry to the filtration chamber.	Expensive to replace filters. Requires entry into filtration chamber. Installation at curb may be infeasible given width requirements.	
BioSTORM® *BioMicrobics*	Pre-engineered stormwater treatment system removes trash, sediment, oil and other pollutants from stormwater runoff. The BioSTORM®'s unique off-line design consists of a patented StormTEE® self-cleaning deflector screen and a modular separation/coalescing unit, all housed in readily-available precast concrete tanks.	TSS Removal: 90%[9] No nutrient removal provided by device.	Sizing guidance not readily available from manufacturer webpage.	Annual vacuum pumping of the oil floating inside the BioSTORM® separation module. Annual pumping out of the solids from each tank or compartment. To clean the StormTEE® deflector screen, raise and lower the internal swab to dislodge any debris that may be stuck to the screen.	No nutrient removal provided by device. Expensive and labor intensive maintenance. Requires annual pumping out of the solids from each tank or compartment. Installation at curb may be infeasible given width requirements.	
Aquip *stormwateRx*	Enhanced media filtration system for industrial stormwater application. Media housed in concrete vault.	TP Removal: 75%[10] TSS Removal: 80%[10]	Device requires 3' 9" of drop between inlet and outlet. Treats up to 1.7 cfs with a 13'W by 52'L device.	Device is a passive, underground system with no moving parts. Maintenance requirements not provided on webpage.	Used for industrial applications. Installation at curb is infeasible given width requirements. Head differential between inlet and outlet may be too large to discharge to nearby ravine.	

Device Name and ***Manufacturer***	Description	Average Performance and Features	Approximate Device Footprint	Typical Maintenance	Design Concerns	Schematic
BioHaven® Floating Islands *Floating Island International*	BioHaven® Floating Islands are patented biomimetic, self-sustaining floating treatment wetlands. The islands typically use a combination of microbial and plant growth to effectively take up, precipitate and/or filter nutrients and other pollutants from water. The islands can be anywhere up from 100 square feet and beyond by linking the islands together.	TP Removal: 42-91%[11] TSS Removal: 54-93%[11] TN Removal: 40-87%[11]	No information of sizing guidance on webpage.	Invasive species are expected to grow on the islands. Access to perform vegetative maintenance requires additional equipment. Mechanical removal of invasive species would be required. As the floating treatment wetlands absorb suspended solids and develops a biofilm, the absorption rate declines. For the floating wetland to continue to function as a biofilter, the entire wetland would have to be removed from the water, allowed to drain, and the matrix beneath the island would have to be rinsed off into an approved area to not allow the suspended solids to reenter the water body.	Device requires extensive plant maintenance. Lifespan is unproven. Device does little to reduce algal growth. Device would not treat watershed upstream of Silver Lake, as it would be placed within the lake.	
StormTreat Systems *StormTreat*	StormTreat Systems (STS) are proprietary stormwater runoff treatment technology pods offering high quality pollutant removal performance through sedimentation and filtration with adsorption mechanisms.	TP Removal: 50%[12] TSS Removal: 93%[12] TN Removal: 73%[12]	Tank width: 9.75-ft Tank height: 4-ft Would require 10 units to treat 2.11 acres of impervious. Approximately 1,000-1,500 sf surface area.	Maintenance of STS is limited to annual plant maintenance and monitoring of sediment depth within the chambers. The sediment pumping schedule varies from site to site but is generally needed only every 2-3 years. Sediment removal procedures are similar to traditional catch basin clean-outs, using standard equipment and technique resulting in convenience and low cost.	Proprietary tank requires specialty shipping from Massachusetts as no local representative exists. System looks unusual and industrial after installation. Device must be installed at bottom of depression near existing ravine. Configuration may not allow proper drainage from outlet of BMP to the nearby ravine. System would not fit adjacent to existing road.	

1 - BioClean Environmental. (2015). Modular Wetlands Advanced Stormwater Biofiltration: MWS Linear. Modular Wetland Systems, Inc.
2 - BioClean Environmental. (2015). The Kraken Filter.
3 - HydroInternational (2018). Up-Flo Filter.
4 - Imbrium. Sorbtive Media. http://www.imbriumsystems.com/stormwater-treatment-solutions/sorbtive-media.
5 - Contech Engineered Solutions. The Stormwater Management StormFilter® Solutions Guide.
6 - Contech Filterra Bioscape. http://www.conteches.com/products/stormwater-management/biofiltration-bioretention/filterra/filterra%20-%208830672-configurations
7 - StormTree. (2017). StormTree. Retrieved December 11, 2017, from http://www.storm-tree.com/
8 - AquaShield Water Treatment Solutions. Aqua-Filter. http://www.aquashieldinc.com/--aqua-filter.html.
9 - BioMicrobics. BioSTORM Stormwater Treatment Systems. http://www.biomicrobics.com/products/biostorm-stormwater-treatment-systems/
10 - stormwateRx. Aquip®. http://stormwaterx.com/stormwaterx_products/aquip/
11 - BioHaven® Floating Islands. http://www.floatingislandinternational.com/products/biohaven-technology/
12 - StormTreat Systems. http://stormtreat.com/configuration/specifications.php

4.0 Evaluated Best Management Practices

The following five BMPs were evaluated: (1) ditch checks with iron-enhanced sand, (2) an iron-enhanced filtration basin with underdrain, (3) the BioClean Modular Wetland Systems (MWS), (4) the BioClean Kraken Filter, and (5) the StormTree filter. Each of these BMPs are described in the following sections.

4.1 Iron-Enhanced Filtration Basin

Iron-enhanced filtration consists of mixing iron filings or steel wool with a filtration media (i.e., sand). Filtration through the sand (or other filtration media) removes the particulate phosphorus, while the iron filings, which form iron oxide when rusted, increase the removal of dissolved phosphorus. When water containing dissolved phosphorus contacts the iron oxide, the dissolved phosphorus is removed from the stormwater through surface sorption. Figure 4-1 includes photographs of iron-enhanced sand filtration systems.

Construction of Beam Avenue iron-enhanced sand filtration system (Ramsey-Washington Metro Watershed District, 2017).

Iron-enhanced sand filtration system near Beam Avenue following a rainfall event (Ramsey-Washington Metro Watershed District, 2017).

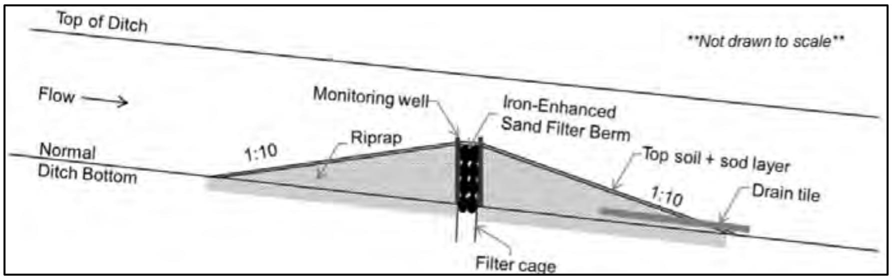
Figure 4-1 Photographs of iron-enhanced sand filtration system

The use of iron-enhanced filtration in stormwater management is recognized by the MPCA and included as a BMP in the *Minnesota Stormwater Manual* (Minnesota Pollution Control Agency, 2015). Monitoring data reported in the *Minnesota Stormwater Manual* has shown promising results for the removal of both total and dissolved phosphorus. Total phosphorus removal through the system ranges from 70-77 percent (Minnesota Pollution Control Agency, 2015).

Use of iron-enhanced filtration was identified to target the removal of soluble phosphorus in the Silver Lake watershed. A relatively short contact time (20–30 minutes) is required for the surface sorption to bind phosphorus to the iron oxide on the iron filings. However, the filtration media must dry out between rainfall events to prevent anoxic conditions within the filter which can release phosphorus. Therefore, the filter must be drawn down within 48 hours of a rainfall event. This means the BMP footprint must be designed proportionally to the volume of water to be treated. The estimated lifespan of the iron material is approximately 35 years, although this has not been confirmed in the field (Erickson, Gulliver, & Weiss, 2012). Deposition of buildup of organic matter on the filter can adversely impact system performance. Periodic maintenance activities are required, including inspection of inlet and outlet structures, cleanout of the underdrain system, and occasional addition or replacement of filtration media to maintain the design depth (i.e., contact time) of the material.

4.2 Ditch Checks with Iron-Enhanced Sand

Ditch checks are primarily constructed across swales or drainage ditches to counteract erosion by reducing water flow velocity. Utilizing ditch checks along the existing ravine will prevent future scouring and channel erosion, addressing the need for ravine stabilization. A recent University of Minnesota study in conjunction with MNDOT and the city of Roseville roadway projects has shown that combining iron-enhanced sand filter media in ditch checks along swales can filter out both particulate and dissolved pollutants (Natarajan & Gulliver, 2015). As shown in Figure 4-2, the iron-enhanced swale ditch check incorporates filtration media consisting of gravel, sand and iron as the adsorptive media to retain phosphate and dissolved metals. As water flows through the swale, the particulates filter out and the dissolved pollutants are retained by the iron-enhanced media in the ditch check.



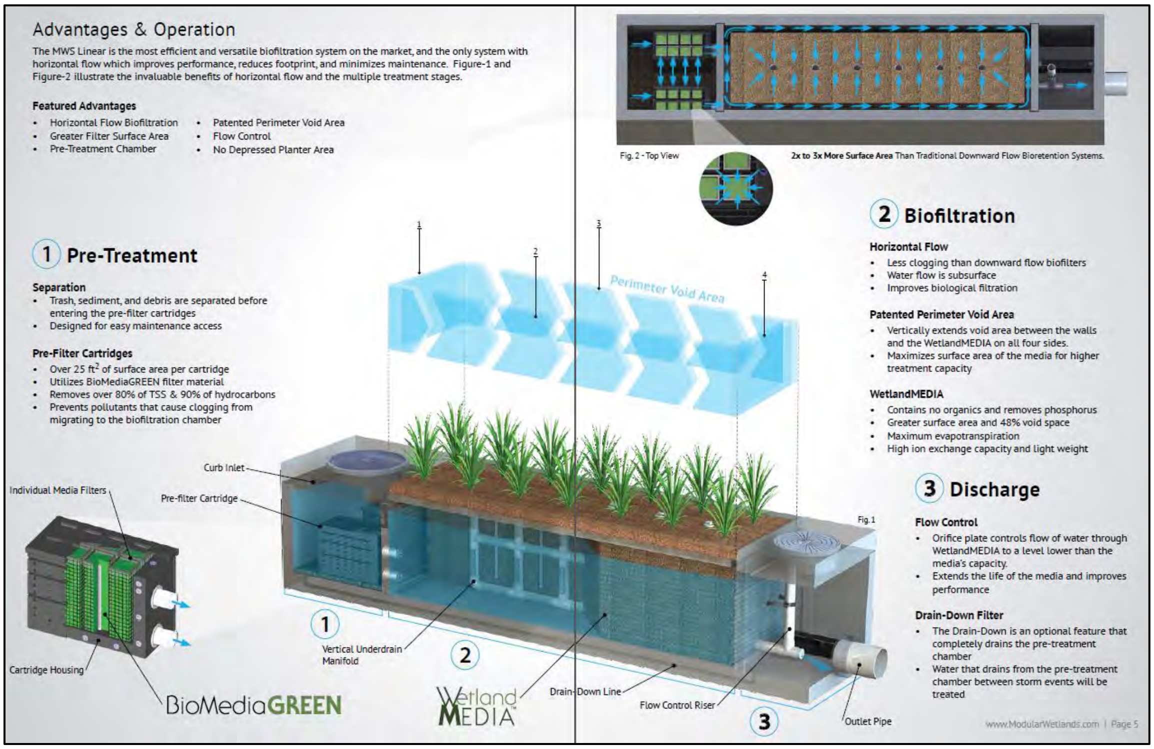
Schematic of iron-enhanced ditch checks used in University of Minnesota study on a highway drainage swale in Stillwater, MN (Natarajan & Gulliver, 2015).

Figure 4-2 Schematic of an iron-enhanced swale ditch check

As is the case for the iron-enhanced filtration basin, the iron-enhanced ditch checks must be drawn down within 48 hours of a rainfall event. Total phosphorus removal through the system ranges from 70-77 percent (Minnesota Pollution Control Agency, 2015), and the preferred contact time is 20-30 minutes.

4.3 Modular Wetland Systems (MWS) – BioClean

The Linear Modular Wetland System (MWS), by BioClean, increases filtration capacity for a given surface area by utilizing horizontal flow. This allows for a smaller footprint and higher treatment capacity than traditional vertical filtration BMPs (like the filtration basin). The MWS incorporates a pre-treatment chamber that includes separation and pre-filter cartridges allowing for a high particulate reduction capacity (Figure 4-3). The pre-treatment chamber reduces maintenance costs and improves the filter performance. The curb-type configuration shown in Figure 4-4 is the only feasible design for the site and requires some curb and gutter roadwork along Pleasantview Road in order to convey runoff into the filter. This device has the capacity to treat 0.115 cfs through the filter and the manufacture indicates the filter will remove approximately 64% of TP and 85% of TSS from influent runoff (BioClean Environmental, 2015).



Modular Wetland System brochure from BioClean (BioClean Environmental, 2015).

Figure 4-3 Schematic of the Modular Wetland System filtration chamber

Schematic of Modular Wetland System – Linear with upstream underground storage vault (BioClean Environmental, 2015).

Figure 4-4 Schematic of the Linear Modular Wetland System with curb inlet

4.4 Kraken Filter

The Kraken Filter, by BioClean, is an engineered stormwater membrane filter that provides treatment for high flow rates (up to 2.88 cfs) using a number of filter cartridges. The membrane filter cartridges do not contain granular media and must be removed and cleaned by hand. The Kraken has a built-in pre-treatment chamber (A) which is designed to dry out between storm events. Runoff first passes through the pre-treatment chamber, moving to the membrane filter where it fills up the outer chamber (B). Once water reaches the top of the chamber, it flows down through the filter membrane (C), collecting in the underdrain, and flowing to the discharge chamber. High flows pass over the high-flow weir directly to the discharge chamber (D). Figure 4-5 depicts this process.

A **B** **C** **D**

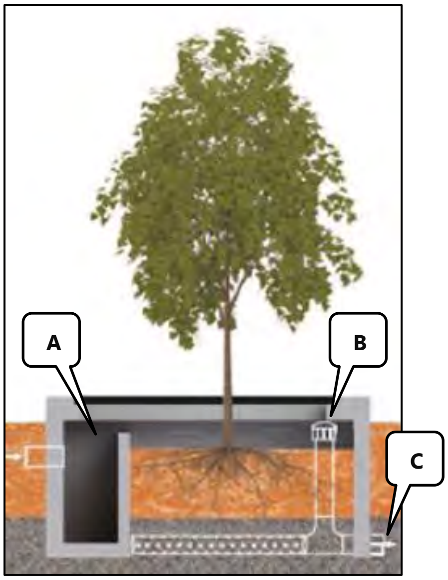
Schematic of Kraken Filter treatment train from BioClean (BioClean Environmental, 2015).

Figure 4-5 Schematic of the Kraken Filter

The largest model can treat 2.88 cfs and has an internal storage volume of 48 cubic-feet. The manufacture indicates that the device can remove 50% of TP and 89% of TSS from influent runoff (BioClean Environmental, 2015). The device configuration requires some curb and gutter roadwork in order to convey runoff into an inlet upstream of the filter. The device would be buried and could discharge into the existing ravine via an outlet pipe.

4.5 StormTree

StormTree is a stormwater management system that integrates street trees to collect and remove pollutants from stormwater runoff. StormTree is an open concrete box, therefore the amount of runoff treated is not constrained to the dimensions of a concrete structure. StormTree relies on direct infiltration, as well as an expanded engineered media layer to treat larger drainage areas. As shown in Figure 4-6, the system can be fabricated with an interior sump and catch basin (A) providing pre-treatment by the collection of particulate matter. High flow bypass (B) and an underdrain outlet pipe (C) are standard features with all StormTree models. The high flow bypass feature reduces the potential for surcharge or backup of incoming runoff during high intensity rain events. The underdrain conveys high flows which do not infiltrate to an outlet pipe to the ravine.



StormTree schematic with open box system and pre-treatment chamber.

Figure 4-6 Schematic of the StormTree device with inlet entry and pre-treatment sump

The largest model has a surface area of approximately 200 square feet, which the manufacture estimates, can treat 0.34 cfs, and can be placed in conjunction with an upstream storage vault to hold runoff during large events. The device claims to remove 63% of TP and 85% of TSS from influent runoff (StormTree, 2017). The device configuration requires some curb and gutter roadwork in order to convey runoff into an inlet upstream of the filter.

5.0 Conceptual Design Alternatives

Five conceptual designs for a stormwater BMP were considered:

- Conceptual Design 1 – Iron Enhanced Sand Basin with Underdrain
- Conceptual Design 2 – Ditch Checks with Iron Enhanced Sand
- Conceptual Design 3 – Linear Modular Wetland System (BioClean)
- Conceptual Design 4 – Kraken Filter (BioClean)
- Conceptual Design 5 – StormTree (StormTree)

Each conceptual design is discussed in more detail below. The goal for each of the conceptual designs was to identify a BMP that would fit within the existing city-owned parcels and minimize site impacts and project cost.

5.1 Conceptual Design 1 – Iron Enhanced Sand Basin with Underdrain

Conceptual Design 1 is shown in Figure 5-1. The proposed location of the filtration basin is north of Pleasantview Road along the east side of the existing ravine; it is located in the upland area to minimize impacts to the existing wetland. The selected location would minimize removal of large trees, but would require removal of some brush and small trees. This design requires minor roadwork and the construction of a sump inlet to pretreat runoff from Pleasantview and Ridge Roads. An outlet pipe from the sumped catch basin will direct flows into the filtration basin where a series of draintile will convey filtered runoff into the existing ravine.

The filtration system was sized to treat 1.1 inches off the impervious drainage area with a minimum of 1.5 feet of sand media. This results in a design discharge rate of 0.33 cfs (assuming an infiltration rate of 1.63 in/hr through the sand media). The design discharge rate allows the filter to draw down within 48 hours of a rainfall event to prevent the filtration media from becoming anoxic, and potentially releasing phosphorus. This design would treat approximately 84 percent of the flow passing through this location. The filtration media would be comprised of a mixture of sand and iron filings. It is anticipated that the iron filings would be 5 percent by weight of the filtration media. An underdrain would be located below the filtration media to convey filtered stormwater to the proposed outlet structure.

The ravine would be stabilized so as to reduce channel and bank erosion, slow flow velocities, and minimize downstream pollutant loading. Stabilization methods include: widening the existing ravine channel, regrading and flattening side slopes, and placing vegetated turf reinforcement mat (TRM) along the ravine banks and channel bed.

Soil borings were not completed as part of this feasibility evaluation, when additional information is available, an impermeable geomembrane maybe required below the underdrain to prevent groundwater from seeping into the filtration system. High flows would exit the basin via an outlet structure. The outlet structure pipe would drain to the existing ravine downstream of the basin.

The filtration system in Conceptual Design 1 could be constructed entirely within city-owned property. However, coordination with the property owner at 6285 Ridge Road would be required to restore the ravine upstream of the proposed filtration basin.

5.1.1 Anticipated Water Quality Improvements

The calibrated Silver Lake P8 model developed for the 2017 UAA report was used to define the phosphorus loading from the Silver Lake watershed. The method to calculate additional phosphorus loading from the eroded ravine is similar to that of the Creek Restoration Action Strategy for Upper Riley Creek (Barr Engineering, 2017). After the drainage area to the proposed BMP location was refined based on BMP location, the performance of Conceptual Design 1 was evaluated, estimating the average annual volume of runoff treated by the proposed BMP and the associated phosphorus removals.

The estimated ravine stabilization benefits are shown in Table 5-1. Due to limited historic erosion data, a range of TP released under existing and proposed conditions is provided. The difference between the TP released under existing and proposed conditions, which ranges from 1.0 lb/yr to 2.5 lbs/yr, is used to quantify the TP reduction benefit of stabilizing the ravine.

Table 5-1 Total phosphorus removal by ravine stabilization

Condition	Estimated Bank Erosion - Low (1) (feet per year)	Estimated Bank Erosion - High (1) (feet per year)	Estimated Average Bank Height (ft)	Ravine Length (ft)	Erosion - Low (tons/yr)	Erosion - High (tons/yr)	TP Released - Low (2) (lbs/yr)	TP Released - High (2) (lbs/yr)
Existing	0.03	0.10	2.5	385	1.5	4.2	1.5	5.0
Proposed	0.01	0.05	2.5	385	0.5	2.5	0.5	2.5

Note(s):

(1) High and low erosion estimates were based on Table 1 in WI NRCS Field Office Technical Guide (Wisconsin Natural Resources Conservation Service, 2003). Erosion under existing conditions was estimated based on field visit.

(2) A soil texture correction factor of 1.0 is used for silty soils according to Exhibit 2 of the MI DEQ Training Manual (Michigan Department of Environmental Quality, 1999).

The performance of the conceptual design was evaluated for the same 30-year period (1986 through 2015) used in the 2017 UAA. As shown in Table 5-2 the estimated average annual total phosphorus removal for Conceptual Design 1 was 5.2 to 6.7 pounds/year (63% to 82% of influent TP).

Table 5-2 Total phosphorus removal by Conceptual Design 1

TP Loading from Drainage Area (lbs/yr)	TP Loading from Existing Ravine (lbs/yr)	TP Routed to BMP (lbs/yr)	TP Bypassing BMP(1) (lbs/yr)	TP Removed by Conceptual Design 1 (lbs/yr)	Percentage Removed by Conceptual Design 1(2) (%)
6.7	1.5 – 5.0	6.0	0.7	5.2 – 6.7	63 – 82%

Note(s):

(1) Column 4 = Column 1-Column 3

(2) Column 6 = (Column 5)/(Column 1+Column 2)

5.1.2 Engineer's Opinion of Probable Cost

The Engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. Based on the current level of design, the cost range for construction, planning engineering and design, permitting, construction management, and contingency is estimated as $263,000 to $492,000. Maintenance requirements for Conceptual Design 1 include yearly site inspections and maintenance of vegetation surrounding the BMP. Replacement of the sand media is required every 15 years. This level of maintenance equates to an annual cost of approximately $3,060 ($2,550 to

$4,590), or a 30-year lifecycle cost of $91,700 ($76,400 to $137,500). Considering both the principal and maintenance costs equates to an annual cost of $2,350 per pound of phosphorus removed ($1,670 to $4,040).

Appendix A includes a detailed discussion including assumptions used to determine the Engineer's opinion of probable cost for Conceptual Design 1.

5.1.3 Wetland and Upland Impacts

The total area of disturbance for the proposed BMP is approximately 0.8 acres. This area includes the footprint of the infiltration basin as well as grading extents required to stabilize the ravine. Based on the tree survey and wetland delineation conducted on May 31, 2018, it is estimated that of the 0.8 total acres of disturbance, approximately 0.2 acres of the existing eroded wetland could be restored/enhanced. Sixty-five trees exist within the proposed BMP extents, 35 of which are located within the ravine stabilization extents. The number of trees impacted by the proposed BMP may change in the next phase of design as grading extents are optimized.

The city of Chanhassen is the wetland permitting authority for this project. The wetland located in the subwatershed is classified by the city as a preserve wetland.

The city's management strategy for preserve wetlands is to maintain the wetland without degrading existing functions, values, or wildlife habitat, and active management of the wetland maybe required to protect unique features. Based on available information, the modification of the ravine BMP area of disturbance are not anticipated to change the wetland type, functions, or wildlife habitat.

Conceptual Design 1 will result in permanent modifications to the existing ravine, because the ravine will be re-graded during stabilization efforts. It is anticipated that ravine stabilization will be designed such that permanent wetland impacts are avoided or minimized. Conceptual Design 1 will also result in permanent impacts to the existing upland vegetation. Construction of the iron-enhanced sand filtration system and ravine restoration would remove approximately 0.8-acres of existing dense brush and approximately 30 trees. Following construction, native grasses could be planted adjacent to the filtration system; however, the dense brush and trees could not be restored without impacting the functionality of the iron-enhanced sand filtration system.

5.1.4 Regulatory Approval

A grading permit for Conceptual Design 1 will be required by the city of Chanhassen. There may be temporary wetland impacts to restore the ravine.

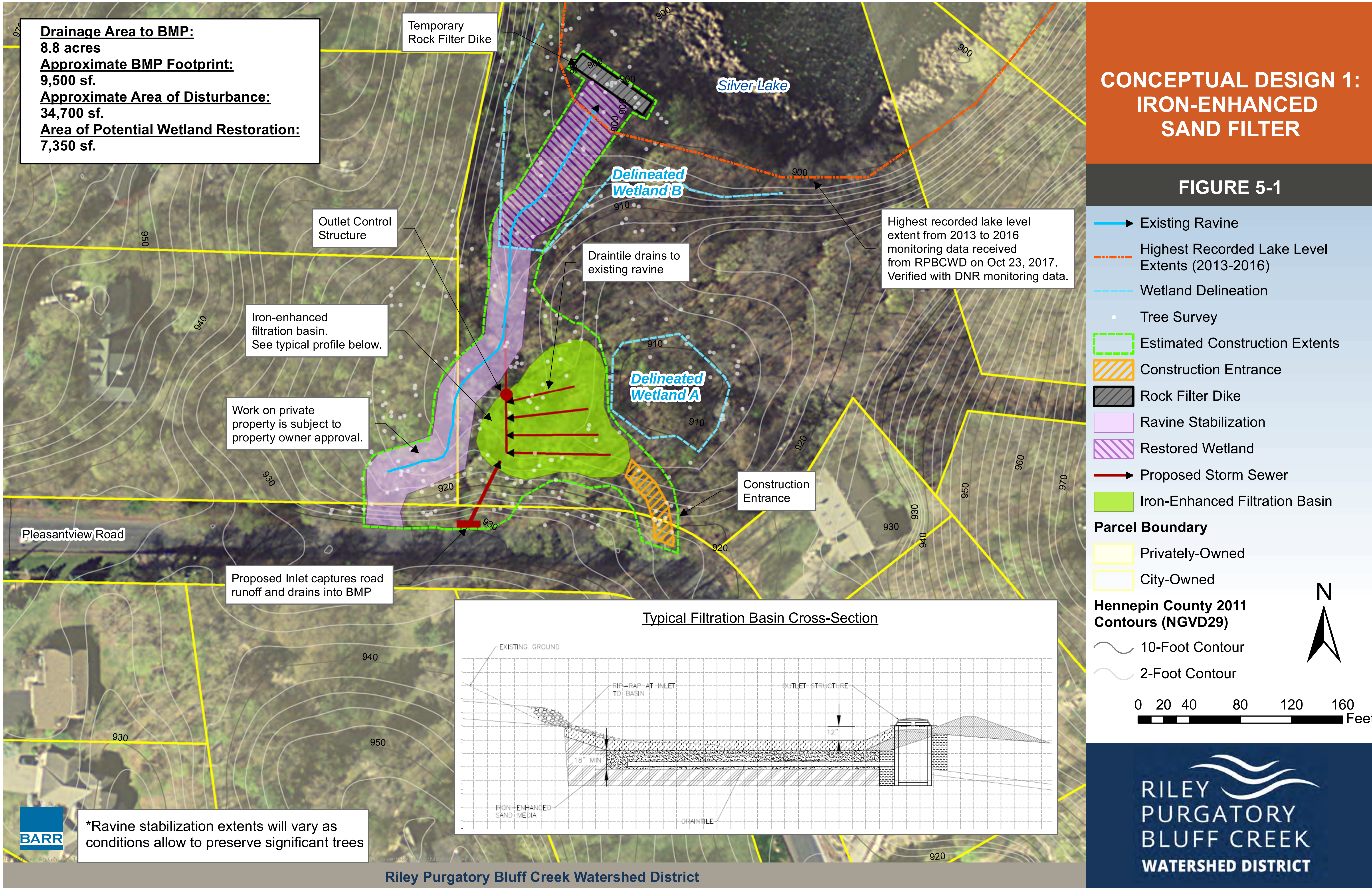
The MPCA regulates the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program. A NPDES permit is required for construction projects on less than 1 acre of soil that the MPCA determines pose a risk to water resources. Considering the location of the proposed BMP (adjacent to the drainage way), it is likely that a NPDES permit will be required. The MPCA will also require a stormwater pollution prevention plan.

The MnDNR regulates work below the ordinary high water level (OHW) of public waters. The OHW for Silver Lake is 898.1 feet (NGVD29). A detailed topographic survey was completed for this feasibility evaluation confirming that grading for the ravine restoration will occur below the OHW. Because work would occur below the OHW, approved under RPBCWD's regulatory framework is needed unless a project specific Public Water Work Permit is obtained from the MnDNR.

RPBCWD regulates the control of floodwater to ensure the preservation of floodplains and flood storage areas, improve water quality, preserve vegetation, alleviate identified erosion problems, ensure the preservation of wetland and creek buffers, and prevent erosion of shorelines and stream banks. A RPBCWD permit will be required, although the applicable rules will depend on the final site design and configuration. It is anticipated that a permit for Rule B – Floodplain Management and Drainage Alterations, Rule C – Erosion and Sediment Control, Rule D – Wetland and Creek Buffers, Rule F – Shoreline and Streambank Stabilization, and Rule J – Stormwater Management maybe required.

5.1.5 Affected Property Owners

With the exception of less than 0.1 acres of the upstream end of the ravine stabilization efforts, the proposed stormwater treatment BMP would be constructed completely within parcels owned by the city of Chanhassen or along the road right-of-way. Permission from the affected property owner at 6285 Ridge Road will be required to stabilize the ravine at the most upstream location just south of Pleasantview Road. An access and cooperative agreement with the City will be needed. During construction, access to the site could be via a construction entrance constructed off Pleasantview Road to the east of the site.



CONCEPTUAL DESIGN 1: IRON-ENHANCED SAND FILTER
FIGURE 5-1
Drainage Area to BMP: 8.8 acres
Approximate BMP Footprint: 9,500 sf.
Approximate Area of Disturbance: 34,700 sf.
Area of Potential Wetland Restoration: 7,350 sf.
Temporary Rock Filter Dike
Silver Lake
Delineated Wetland B
Delineated Wetland A
Outlet Control Structure
Draintile drains to existing ravine
Highest recorded lake level extent from 2013 to 2016 monitoring data received from RPBCWD on Oct 23, 2017. Verified with DNR monitoring data.
Iron-enhanced filtration basin. See typical profile below.
Work on private property is subject to property owner approval.
Construction Entrance
Pleasantview Road
Proposed Inlet captures road runoff and drains into BMP
*Ravine stabilization extents will vary as conditions allow to preserve significant trees
Typical Filtration Basin Cross-Section
EXISTING GROUND
RIP-RAP AT INLET TO BASIN
OUTLET STRUCTURE
12"
18" MIN
IRON-ENHANCED SAND MEDIA
DRAINTILE
Existing Ravine
Highest Recorded Lake Level Extents (2013-2016)
Wetland Delineation
Tree Survey
Estimated Construction Extents
Construction Entrance
Rock Filter Dike
Ravine Stabilization
Restored Wetland
Proposed Storm Sewer
Iron-Enhanced Filtration Basin
Parcel Boundary
Privately-Owned
City-Owned
Hennepin County 2011 Contours (NGVD29)
10-Foot Contour
2-Foot Contour
N
0 20 40 80 120 160 Feet
BARR
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
Riley Purgatory Bluff Creek Watershed District

5.2 Conceptual Design 2 – Ditch Checks with Iron Enhanced Sand

Conceptual Design 2 is shown in Figure 5-2. The proposed location of the ditch checks are along the existing ravine from Pleasantview Road north to Silver Lake. The proposed ditch checks are located outside of the existing delineated wetland. The design would minimize removal of existing trees and brush and requires minor roadwork and the construction of a sump inlet to pretreat runoff from Pleasantview and Ridge Roads. An outlet pipe from the sump catch basin would direct flows into the existing ravine. The existing ravine would be graded and widened to a bottom width of approximately 7.0 feet and a top width of approximately 10.0 feet. Up to five ditch checks would be placed along the ravine to reduce flow velocities and prevent further erosion and scouring. The ditch checks would be reinforced with 1.0 foot thick iron-enhanced sand lined with a geotextile liner, held in place within a metal cage. Class II rip-rap would be placed at a 5:1 slope around the filter arrangement.

The ravine would be stabilized similar to the method described in Section 5.1.

5.2.1 Anticipated Water Quality Improvements

The calibrated Silver Lake P8 model developed for the 2017 UAA report was used to define the phosphorus loading from the Silver Lake watershed. After the drainage area to the proposed BMP location was refined based on BMP location, the performance of Conceptual Design 2 was evaluated, estimating the average annual volume of runoff treated by the proposed BMP and the associated phosphorus removals. The ditch check performance was evaluated using a range of infiltration rates (0.8 and 1.6 inches per hour, simulating sedimentation and obstructions upstream of the ditch checks) and particle settling assumptions (particle removal scale factor of 0.3 and 0.5) behind the ditch checks. A particle removal scale factor of 0.3 assumes some settling of larger particles behind each ditch check; whereas, the remaining particles will be filtered through the IES or will overtop the ditch check. A particle scale factor of 0.5 assumes half of the larger particles will settle out behind each ditch check. An infiltration rate of 0.8 inches per hour assumes a 50% plugged sand media surface, since a typical infiltration rate of sand is approximately 1.6 inches per hour.

The estimated ravine stabilization benefits for Conceptual Design 2 are the same as those provided in Section 5.1.1 resulting in an estimated total phosphorus reduction between 1.0 and 2.5 lbs/yr.

A range of estimated average annual total phosphorus removed by Conceptual Design 2 was determined using the four scenarios shown in Table 5-3.

The performance of the conceptual design was evaluated for the same 30-year period used in the UAA (1986 through 2015). The estimated average annual total phosphorus removal for Conceptual Design 2 ranges from 2.6 to 4.7 pounds/year (27% to 36% of influent TP).

Table 5-3 Total phosphorus removal by Conceptual Design 2

Scenario	TP Loading from Drainage Area (lbs/yr)	TP Loading from Existing Ravine (lbs/yr)	TP Routed to BMP (lbs/yr)	TP Bypassing BMP(1) (lbs/yr)	TP Removed by Conceptual Design 2 (lbs/yr)	Percentage Removed by Conceptual Design 2(2) (%)
PSRF = 0.3 Infiltration = 0.8 in/hr	8.1	1.5 – 5.0	1.6	6.5	2.6 – 4.1	27 – 32%
PSRF = 0.3 Infiltration = 1.6 in/hr	8.1	1.5 – 5.0	1.7	6.4	2.7 – 4.2	28 – 32%
PSRF = 0.5 Infiltration = 0.8 in/hr	8.1	1.5 – 5.0	2.1	6.0	3.1 – 4.6	32 – 35%
PSRF = 0.5 Infiltration = 1.6 in/hr	8.1	1.5 – 5.0	2.2	5.9	3.2 – 4.7	33 – 36%

Note(s):
(1) Column 5 = Column 2-Column 4
(2) Column 7 = (Column 6)/(Column 2+Column 3)

5.2.2 Engineer's Opinion of Probable Cost

The Engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. Based on the current level of design, the cost range for construction, planning engineering and design, permitting, construction management, and contingency is estimated as $98,000 to $183,000. Maintenance requirements for Conceptual Design 2 include yearly site inspections and maintenance of sediment and vegetation surrounding the ditch checks. Replacement of the sand media is required every 15 years. This level of maintenance equates to an annual cost of approximately $1,930 ($1,550 to $2,900), or a 30-year lifecycle cost of $58,000 ($46,400 to $87,000). Considering both the principal and maintenance costs equates to an annual cost of $1,640 per pound of phosphorus removed ($1,020 to $3,460).

Appendix A includes a detailed discussion including assumptions used to determine the Engineer's opinion of probable cost for Conceptual Design 2.

5.2.3 Wetland and Upland Impacts

The total area of disturbance for the proposed BMP is approximately 0.6 acres. Using the wetland extents from the wetland delineation conducted in 2018, it is estimated that of the 0.6 total acres of disturbance, approximately 0.2 acres of the existing eroded wetland could be restored/enhanced. Thirty-five trees exist within the proposed ravine stabilization extents. The number of trees impacted by the proposed BMP may change in the next phase of design as grading extents are optimized.

The city of Chanhassen is the wetland permitting authority for this project, and the applicable wetland management guidelines are similar to Conceptual Design 1, discussed in Section 5.1.3.

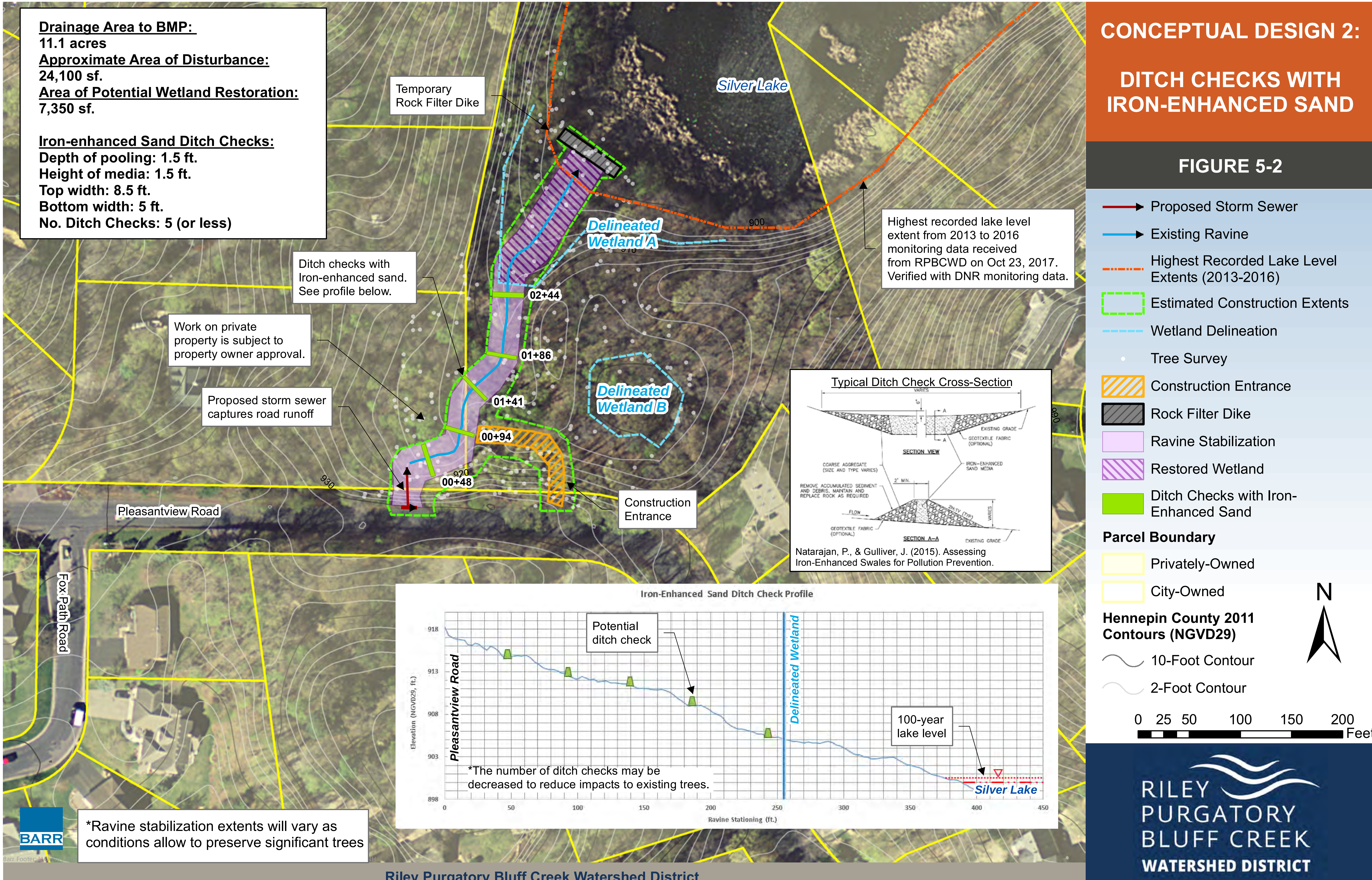
Conceptual Design 2 will result in permanent impacts to the existing ravine, because the ravine will be widened and re-graded during stabilization efforts. It is anticipated that ravine stabilization will be designed such that permanent wetland impacts are avoided or minimized. The re-grading of the ravine will remove existing brush and approximately 35 trees located within a 10 foot buffer of the channel centerline. Following construction, native grasses could be planted in and adjacent to the ravine at all locations except on the ditch checks.

5.2.4 Regulatory Approval

The permits required for Conceptual Design 2 will be similar to the permits required for Conceptual Design 1 discussed in Section 5.1.4.

5.2.5 Affected Property Owners

Less than 0.1 acres at the upstream end of the ravine stabilization efforts will affect a single residential property. Permission from the property owner would be required to construct the for upstream ditch checks. All other disturbed area is located within parcels owned by the city of Chanhassen or within road right-of-way. An access and cooperative agreement with the City will be needed. During construction, access to the site would be via a construction entrance constructed off Pleasantview Road to the east of the site.


CONCEPTUAL DESIGN 2:
DITCH CHECKS WITH IRON-ENHANCED SAND
FIGURE 5-2
Drainage Area to BMP:
11.1 acres
Approximate Area of Disturbance:
24,100 sf.
Area of Potential Wetland Restoration:
7,350 sf.
Iron-enhanced Sand Ditch Checks:
Depth of pooling: 1.5 ft.
Height of media: 1.5 ft.
Top width: 8.5 ft.
Bottom width: 5 ft.
No. Ditch Checks: 5 (or less)
Temporary Rock Filter Dike
Silver Lake
Delineated Wetland A
Delineated Wetland B
Highest recorded lake level extent from 2013 to 2016 monitoring data received from RPBCWD on Oct 23, 2017. Verified with DNR monitoring data.
Ditch checks with Iron-enhanced sand. See profile below.
Work on private property is subject to property owner approval.
Proposed storm sewer captures road runoff
Construction Entrance
02+44
01+86
01+41
00+94
00+48
900
910
920
930
Pleasantview Road
Fox Path Road
Typical Ditch Check Cross-Section
SECTION VIEW
SECTION A-A
Natarajan, P., & Gulliver, J. (2015). Assessing Iron-Enhanced Swales for Pollution Prevention.
Iron-Enhanced Sand Ditch Check Profile
Potential ditch check
Pleasantview Road
Delineated Wetland
100-year lake level
Silver Lake
*The number of ditch checks may be decreased to reduce impacts to existing trees.
Elevation (NGVD29, ft.)
918
913
908
903
898
0
50
100
150
200
250
300
350
400
450
Ravine Stationing (ft.)
Proposed Storm Sewer
Existing Ravine
Highest Recorded Lake Level Extents (2013-2016)
Estimated Construction Extents
Wetland Delineation
Tree Survey
Construction Entrance
Rock Filter Dike
Ravine Stabilization
Restored Wetland
Ditch Checks with Iron-Enhanced Sand
Parcel Boundary
Privately-Owned
City-Owned
Hennepin County 2011 Contours (NGVD29)
10-Foot Contour
2-Foot Contour
N
0 25 50 100 150 200 Feet
*Ravine stabilization extents will vary as conditions allow to preserve significant trees
BARR
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
Riley Purgatory Bluff Creek Watershed District

5.3 Conceptual Design 3 – Linear Modular Wetland System (BioClean)

Conceptual Design 3 is shown in Figure 5-3. The proposed location of the Modular Wetland System (MWS) is along the north side of Pleasantview Road. With the exception of the ravine stabilization, the proposed work is not located in the existing wetland. The design requires the removal of existing trees and brush along the north side of Pleasantview Road and requires minor roadway modifications and the construction of a curb and gutter inlet to direct runoff into the BMP. The MWS would be a 4-foot wide and 10-foot deep underground storage vault approximately 150 feet long along Pleasantview Road, providing 6,000 cubic-feet of runoff storage. The filtration chamber will have a surface footprint of approximately 4-feet wide by 17-feet long planted with native vegetation.

The proposed inlet will capture runoff from approximately 6.6 acres, conveying it into the underground storage chamber where water will filter through the filtration media. Once flow passes through the filtration chamber, an outlet pipe will convey flow back into the ravine.

The ravine would be stabilized similar to the method described in Section 5.1.

5.3.1 Anticipated Water Quality Improvements

The calibrated Silver Lake P8 model developed for the 2017 UAA report was used to define the phosphorus loading from the Silver Lake watershed. After the drainage area to the proposed BMP location was refined based on the BMP location, the performance of Conceptual Design 3 was evaluated, estimating the average annual volume of runoff treated by the proposed BMP and the associated phosphorus removals.

The estimated ravine stabilization benefits for Conceptual Design 3 are the same as those provided in Section 5.1.1 resulting in an estimated total phosphorus reduction of 1.4 lbs/yr.

The performance of the conceptual design was evaluated for the same 30-year period (1986 through 2015) used in the 2017 UAA. As shown in Table 5-4, the estimated average annual total phosphorus removal for Conceptual Design 3 is 3.3 to 4.8 pounds/year (46 to 48% of influent TP).

Table 5-4 Total phosphorus removal by Conceptual Design 3

RP Loading by Drainage Area (lbs/yr)	TP Loading from Existing Ravine (lbs/yr)	TP Routed to BMP (lbs/yr)	TP Bypassing BMP[(1)] (lbs/yr)	TP Removed by Conceptual Design 3 (lbs/yr)	Percentage Removed by Conceptual Design 3[(2)] (%)
5.4	1.5 – 5.0	3.6	1.9	3.3 – 4.8	46 – 48%

Note(s):

(1) Column 4 = Column 1-Column 3

(2) Column 6 = (Column 5)/(Column 1+Column 2)

5.3.2 Engineer's Opinion of Probable Cost

The Engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. Based on the current level of design, the cost range for construction, planning engineering and design, permitting, construction management, and contingency is estimated as $291,000 to $545,000. Maintenance requirements for Conceptual Design 3 include yearly filter inspection, maintenance of pre-treatment chamber, and yearly replacement of pre-treatment filter cartridges. This level of maintenance equates to an annual cost of approximately $1,550 ($1,290 to $2,330), or a 30-year lifecycle cost of $46,500 ($38,800 to $69,800). Considering both the principal and maintenance costs equates to an annual cost of $3,370 per pound of phosphorus removed ($2,280 to $6,210).

Appendix A includes a detailed discussion including assumptions used to determine the Engineer's opinion of probable cost for Conceptual Design 3.

5.3.3 Wetland and Upland Impacts

The total area of disturbance for the proposed BMP is approximately 0.7 acres. Using the tree survey and wetland extents from the wetland delineation described conducted in 2018, it is estimated that of the 0.7 total acres of disturbance, approximately 0.2 acres of the existing eroded wetland could be restored/enhanced. Thirty-five trees exist within the proposed ravine stabilization extents. The number of trees impacted by the proposed BMP may change in the next phase of design as grading extents are optimized.

The city of Chanhassen is the wetland permitting authority for this project, and the applicable wetland management guidelines are similar to Conceptual Design 1, discussed in Section 5.1.3.

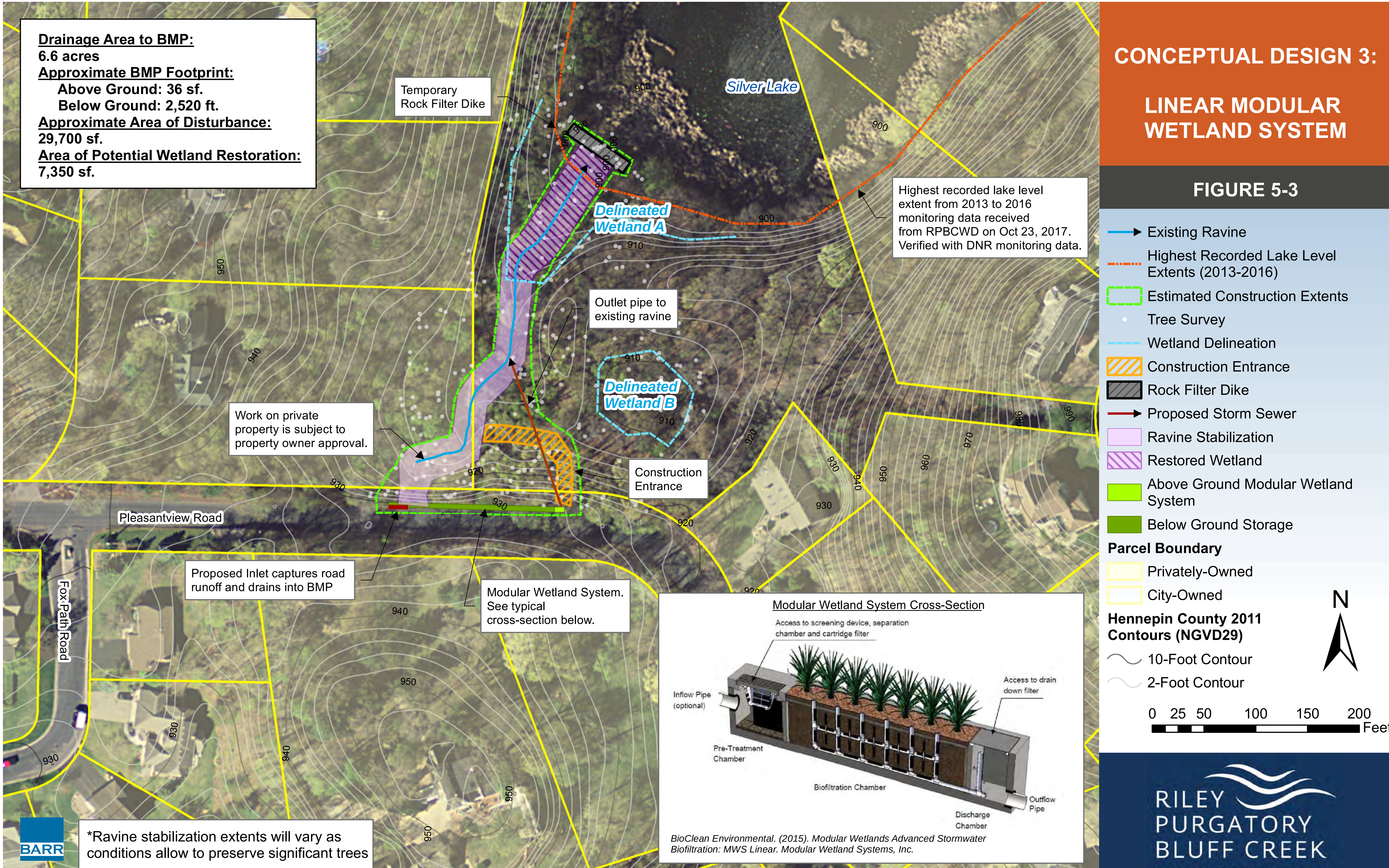
Conceptual Design 3 will result in permanent impacts to the existing ravine, because the ravine will be widened and re-graded during stabilization efforts. It is anticipated that ravine stabilization will be designed such that permanent wetland impacts are avoided or minimized. The installation of the MWS will remove existing brush and an additional 9 small trees located along Pleasantview Road. Following construction, native grasses and shrubs could be planted over all underground features and in the filtration chamber.

5.3.4 Regulatory Approval

The permits required for Conceptual Design 3 will be similar to the permits required for Conceptual Design 1 discussed in Section 5.1.4.

5.3.5 Affected Property Owners

Less than 0.1 acres at the upstream end of the ravine stabilization efforts will affect a single residential property. Permission from the property owner would be required to construct the for upstream ditch checks. All other disturbed area is located within parcels owned by the city of Chanhassen or within road right-of-way. An access and cooperative agreement with the City will be needed. During construction, access to the site would be via a construction entrance constructed off Pleasantview Road to the east of the site.



CONCEPTUAL DESIGN 3: LINEAR MODULAR WETLAND SYSTEM

FIGURE 5-3

5.4 Conceptual Design 4 – Kraken Filter (BioClean)

Conceptual Design 4 is shown in Figure 5-4. The proposed location of the Kraken Filter is along the north side of Pleasantview Road. With the exception of the ravine stabilization, the proposed work is not located in the existing wetland. The design requires the removal of existing trees and brush along the north side of Pleasantview Road and requires minor roadway improvements and the construction of a curb and gutter inlet to direct runoff into the BMP. The Kraken Filter will be constructed completely underground, requiring a minimum surface area of 160 square feet and a 3 foot depth.

The proposed inlet will capture runoff from approximately 6.6 acres, conveying it into the underground chamber where water will filter through the filtration media. Once flow passes through the filtration chamber, an outlet pipe will convey flow into the ravine.

The ravine would be stabilized similar to the method described in Section 5.1.

5.4.1 Anticipated Water Quality Improvements

The calibrated Silver Lake P8 model developed for the 2017 UAA report was used to define the phosphorus loading from the Silver Lake watershed. After the drainage area to the proposed BMP location was refined based on the BMP location, the performance of Conceptual Design 4 was evaluated, estimating the average annual volume of runoff treated by the proposed BMP and the associated phosphorus removals.

The estimated ravine stabilization benefits for Conceptual Design 4 are the same as those provided in Section 5.1.1 resulting in an estimated total phosphorus reduction of 1.4 lbs/yr.

The performance of the conceptual design was evaluated for the same 30-year period (1986 through 2015) used in the 2017 UAA. As shown in Table 5-5, the estimated average annual total phosphorus removal for Conceptual Design 4 is 2.9 to 4.4 pounds/year (42% of influent TP).

Table 5-5 Total phosphorus removal by Conceptual Design 4

TP Loading by Drainage Area (lbs/yr)	TP Loading from Existing Ravine (lbs/yr)	TP Routed to BMP (lbs/yr)	TP Bypassing BMP[1] (lbs/yr)	TP Removed by Conceptual Design 4 (lbs/yr)	Percentage Removed by Conceptual Design 4[2] (%)
5.4	1.5 – 5.0	4.6	0.9	2.9 – 4.4	42%

Note(s):

(1) Column 4 = Column 1-Column 3

(2) Column 6 = (Column 5)/(Column 1+Column 2)

5.4.2 Engineer's Opinion of Probable Cost

The Engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. Based on the current level of design, the cost range for construction, planning engineering and design, permitting, construction management, and contingency is estimated as $257,000 to $482,000. Maintenance requirements for Conceptual Design 4 include yearly filter inspection, maintenance of pre-treatment chamber, and replacement of filter cartridges every three years. This level of maintenance equates to an annual cost of approximately $7,100 ($5,900 to $10,630), or a 30-year lifecycle cost of $212,500 ($177,100 to $318,800). Considering both the principal and maintenance costs equates to an annual cost of $4,870 per pound of phosphorus removed ($3,230 to $9,200).

Appendix A includes a detailed discussion including assumptions used to determine the Engineer's opinion of probable cost for Conceptual Design 4.

5.4.3 Wetland and Upland Impacts

The total area of disturbance for the proposed BMP is approximately 0.6 acres. Using the tree survey and wetland extents from the wetland delineation conducted in 2018, it is estimated that of the 0.6 total acres of disturbance, approximately 0.2 acres of the existing eroded wetland could be restored/enhanced. Thirty-five trees exist within the proposed ravine stabilization extents. The number of trees impacted by the proposed BMP may change in the next phase of design as grading extents are optimized.

The city of Chanhassen is the wetland permitting authority for this project, and the applicable wetland management guidelines are similar to Conceptual Design 1, discussed in Section 5.1.3.

Conceptual Design 4 will result in permanent impacts to the existing ravine, because the ravine will be widened and re-graded during stabilization. It is anticipated that ravine stabilization will be designed such that permanent wetland impacts are avoided or minimized. The installation of the Kraken Filter will remove existing brush and an additional 5 small trees located along Pleasantview Road. Following construction, native grasses and shrubs could be planted over all underground features.

5.4.4 Regulatory Approval

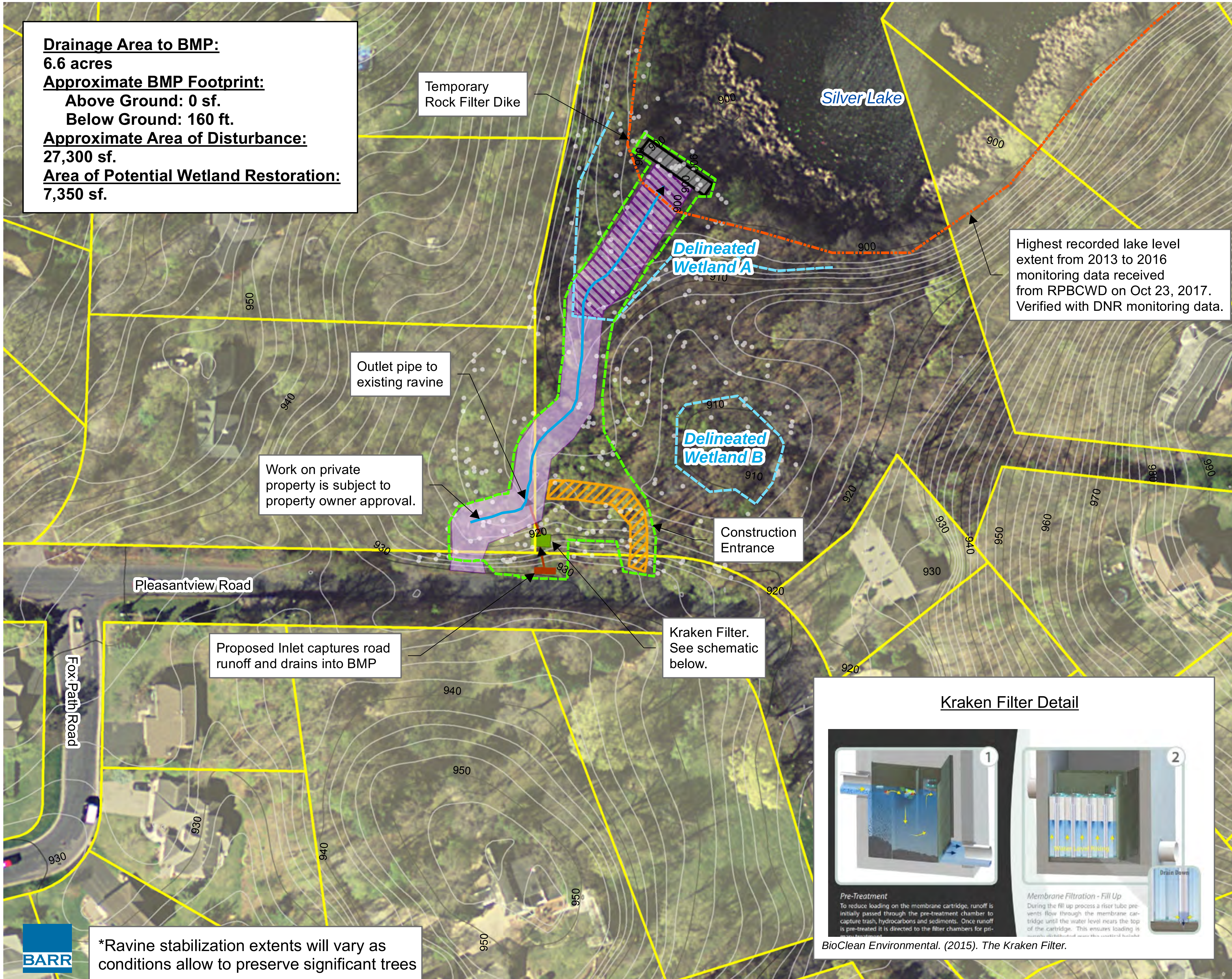
The permits required for Conceptual Design 4 will be similar to the permits required for Conceptual Design 1 discussed in Section 5.1.4

5.4.5 Affected Property Owners

Less than 0.1 acres at the upstream end of the ravine stabilization efforts will affect a single residential property. Permission from the property owner would be required to construct the for upstream ditch checks. All other disturbed area is located within parcels owned by the city of Chanhassen or within road right-of-way. An access and cooperative agreement with the City will be needed. During construction, access to the site would be via a construction entrance constructed off Pleasantview Road to the east of the site.

CONCEPTUAL DESIGN 4: KRAKEN FILTER

FIGURE 5-4



BioClean Environmental. (2015). The Kraken Filter.

- Existing Ravine
- Highest Recorded Lake Level Extents (2013-2016)
- Estimated Construction Extents
- Wetland Delineation
- Tree Survey
- Construction Entrance
- Rock Filter Dike
- Ravine Stabilization
- Restored Wetland
- Proposed Storm Sewer

Parcel Boundary

- Privately-Owned
- City-Owned
- Below Ground Storage

Hennepin County 2011 Contours (NGVD29)

- 10-Foot Contour
- 2-Foot Contour

N

0 25 50 100 150 200 Feet

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

BARR

5.5 Conceptual Design 5 – StormTree (StormTree)

Conceptual Design 5 is shown in Figure 5-5. The proposed location of the StormTree filter is along the north side of Pleasantview Road. With the exception of the ravine stabilization, the proposed work is not located in the existing wetland. The design requires the removal of existing trees and brush along the north side of Pleasantview Road and requires minor roadway improvements and the construction of a curb and gutter inlet to direct runoff into the BMP. The StormTree filter requires a 4-foot wide and 10-foot deep underground storage vault approximately 150 feet along Pleasantview Road, providing approximately 6,000 cubic-feet of storage. The filtration chamber will have a surface footprint of approximately 200 square feet planted with a native trees.

The proposed inlet will capture runoff from approximately 6.6 acres, sending it into the underground storage chamber where water will filter through the filtration media at a maximum rate of 0.34 cfs. Once flow passes through the filtration chamber, an outlet pipe will convey flow to the ravine.

The ravine would be stabilized similar to the method described in Section 5.1.

5.5.1 Anticipated Water Quality Improvements

The calibrated Silver Lake P8 model developed for the 2017 UAA report was used to define the phosphorus loading from the Silver Lake watershed. After the drainage area to the proposed BMP location was refined based on the BMP location, the performance of Conceptual Design 5 was evaluated, estimating the average annual volume of runoff treated by the proposed BMP and the associated phosphorus removals.

The estimated ravine stabilization benefits for Conceptual Design 5 are the same as those provided in Section 5.1.1 resulting in an estimated total phosphorus reduction of 1.4 lbs/yr.

The performance of the conceptual design was evaluated for the same 30-year period (1986 through 2015) used in the 2017 UAA. As shown in Table 5-6, the estimated average annual total phosphorus removal for Conceptual Design 5 is 3.3 to 4.8 pounds/year (46 to 48% of influent TP).

Table 5-6 Total phosphorus removal by Conceptual Design 5

TP Loading from Drainage Area (lbs/yr)	TP Loading from Existing Ravine (lbs/yr)	TP Routed to BMP (lbs/yr)	TP Bypassing BMP(1) (lbs/yr)	TP Removed by Conceptual Design 5 (lbs/yr)	Percentage Removed by Conceptual Design 5(2) (%)
5.4	1.5 – 5.0	3.7	1.7	3.3 – 4.8	46 – 48%

Note(s):

(1) Column 4 = Column 1-Column 3

(2) Column 6 = (Column 5)/(Column 1+Column 2)

5.5.2 Engineer's Opinion of Probable Cost

The Engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. Based on the current level of design, the cost range for construction, planning engineering and design, permitting, construction management, and contingency is estimated as $266,000 to $498,000. Maintenance requirements for Conceptual Design 5 include yearly filter inspection, maintenance of pre-treatment chamber, maintenance of filter vegetation, mulch replacement, and tree replacement (once within a thirty year period). This level of maintenance equates to an annual cost of approximately $1,345 ($1,120 to $2,020), or a 30-year lifecycle cost of $40,400 ($33,600 to $60,600). Considering both the principal and maintenance costs equates to an annual cost of $3,070 per pound of phosphorus removed ($2,070 to $5,640).

Appendix A includes a detailed discussion including assumptions used to determine the Engineer's opinion of probable cost for Conceptual Design 5.

5.5.3 Wetland and Upland Impacts

The total area of disturbance for the proposed BMP is approximately 0.7 acres. Using the tree survey and wetland extents from the wetland delineation conducted in 2018, it is estimated that of the 0.7 total acres of disturbance, approximately 0.2 acres of the existing eroded wetland could be restored/enhanced. Thirty-five trees exist within the proposed ravine stabilization extents. The number of trees impacted by the proposed BMP may change in the next phase of design as grading extents are optimized.

The city of Chanhassen is the wetland permitting authority for this project, and the applicable wetland management guidelines are similar to Conceptual Design 1, discussed in Section 5.1.3.

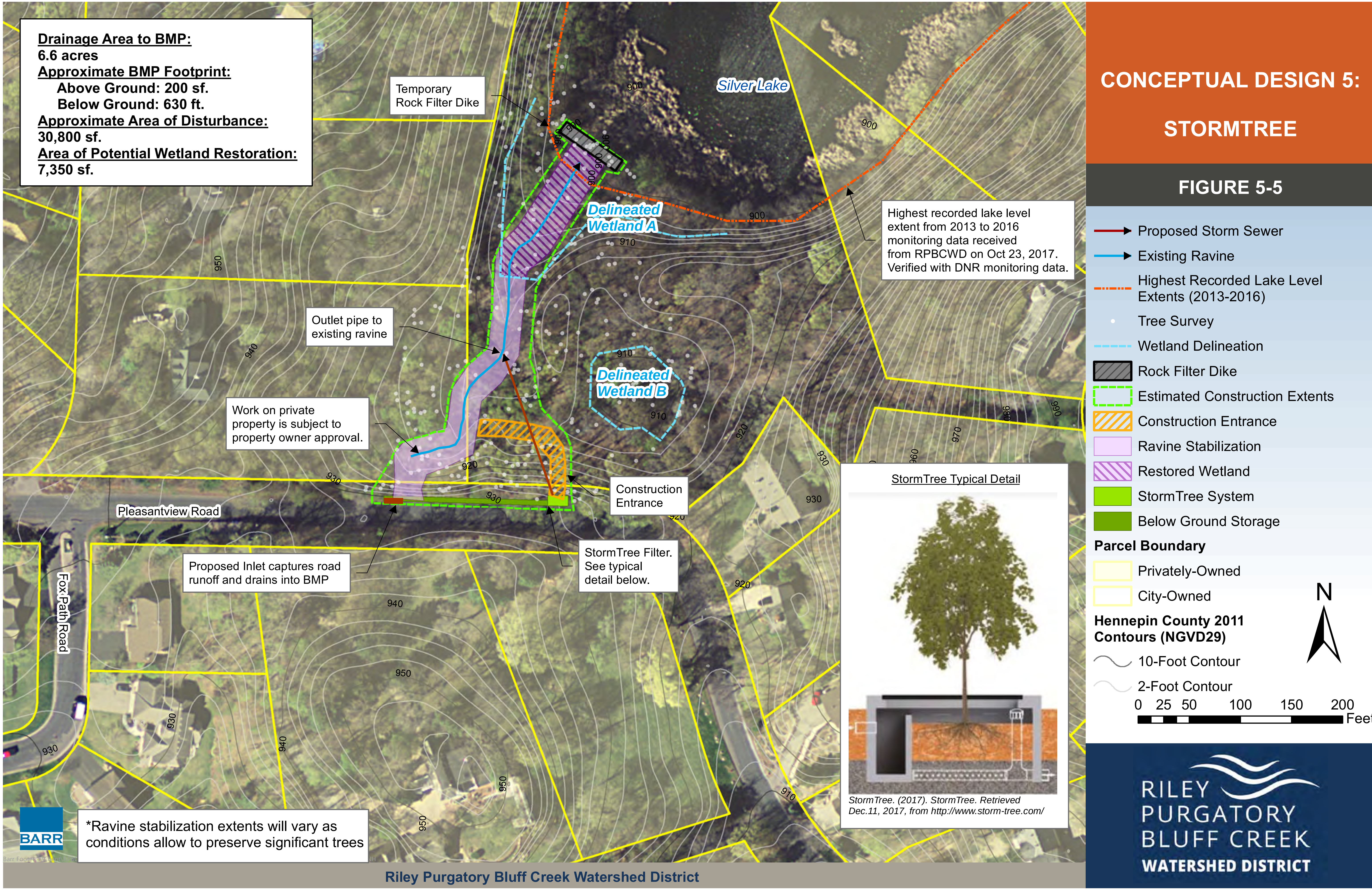
Conceptual Design 5 will result in permanent impacts to the ravine, because the ravine will be re-graded during stabilization. The installation of the StormTree filter will remove existing brush and an additional 9 small trees along Pleasantview Road and at the underground storage system. Following construction, native grasses and shrubs could be planted over all underground features, with a native tree planted in the filtration chamber.

5.5.4 Regulatory Approval

The permits required for Conceptual Design 5 will be similar to the permits required for Conceptual Design 1 discussed in Section 5.1.4.

5.5.5 Affected Property Owners

Less than 0.1 acres at the upstream end of the ravine stabilization efforts will affect a single residential property. Permission from the property owner would be required to construct the for upstream ditch checks. All other disturbed area is located within parcels owned by the city of Chanhassen or within road right-of-way. An access and cooperative agreement with the City will be needed. During construction, access to the site would be via a construction entrance constructed off Pleasantview Road to the east of the site.



CONCEPTUAL DESIGN 5:
STORMTREE
FIGURE 5-5
Drainage Area to BMP:
6.6 acres
Approximate BMP Footprint:
Above Ground: 200 sf.
Below Ground: 630 ft.
Approximate Area of Disturbance:
30,800 sf.
Area of Potential Wetland Restoration:
7,350 sf.
Temporary Rock Filter Dike
Silver Lake
Delineated Wetland A
Delineated Wetland B
Highest recorded lake level extent from 2013 to 2016 monitoring data received from RPBCWD on Oct 23, 2017. Verified with DNR monitoring data.
Outlet pipe to existing ravine
Work on private property is subject to property owner approval.
Construction Entrance
Pleasantview Road
Fox Path Road
Proposed Inlet captures road runoff and drains into BMP
StormTree Filter. See typical detail below.
StormTree Typical Detail
StormTree. (2017). StormTree. Retrieved Dec.11, 2017, from http://www.storm-tree.com/
*Ravine stabilization extents will vary as conditions allow to preserve significant trees
900
910
920
930
940
950
960
970
980
990
Proposed Storm Sewer
Existing Ravine
Highest Recorded Lake Level Extents (2013-2016)
Tree Survey
Wetland Delineation
Rock Filter Dike
Estimated Construction Extents
Construction Entrance
Ravine Stabilization
Restored Wetland
StormTree System
Below Ground Storage
Parcel Boundary
Privately-Owned
City-Owned
Hennepin County 2011 Contours (NGVD29)
10-Foot Contour
2-Foot Contour
N
0 25 50 100 150 200 Feet
BARR
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
Riley Purgatory Bluff Creek Watershed District

6.0 Conceptual Design Summary

Table 6-1 summarizes the estimated annual total phosphorus removal, site impacts, and Engineer's opinion of probable cost for each of the five conceptual designs considered.

Table 6-1 Summary of Silver Lake subwatershed, Sil_2, water quality management projects

Conceptual Design	Estimated Annual TP Reduction (lbs/yr)(1)	Wetland Impacts (acre)(6)	Upland Impacts (acre) (6)	Number of Impacted Trees(3,6)	Engineer's Opinion of Probable Cost ($)(4)	Anticipated Maintenance Cost over 30-year lifecycle ($)(5)	Annual Cost per Pound TP Removed ($/lbs TP/yr)(2)
	A	B	C	D	E	F	G = (E+F) / A / 30
Conceptual Design 1 Iron-Enhanced Filtration Basin	5.2 – 6.7	~0.2(3)	0.8	~65	$328,000 ($263,000 – $492,000)	$91,700 ($76,400 – $137,500)	$2,350 ($1,670 – $4,040)
Conceptual Design 2 Ditch Checks with Iron-Enhanced Sand	2.6 – 4.7	~0.2(3)	0.6	~35	$122,000 ($98,000 – $183,000)	$58,000 ($46,400 – $87,000)	$1,640 ($1,020 – $3,460)
Conceptual Design 3 Modular Wetland System	3.3 – 4.8	~0.2(3)	0.7	~44	$363,000 ($291,000 – $545,000)	$46,500 ($38,800 – $69,800)	$3,370 ($2,280 – $6,210)
Conceptual Design 4 Kraken Filter	2.9 – 4.4	~0.2(3)	0.6	~40	$321,000 ($257,000 – $482,000)	$212,500 ($177,100 – $318,800)	$4,870 ($3,230 – $9,200)
Conceptual Design 5 StormTree Filter	3.3 – 4.8	~0.2(3)	0.7	~44	$332,000 ($266,000 – $498,000)	$40,400 ($33,600 – $60,600)	$3,070 ($2,070 – $5,640)

Note(s):
(1) Estimated annual total phosphorus (TP) reduction is the removal with the BMP and ravine stabilization, the BMP performance was evaluated over a 30-year period (1986-2015).
(2) Based on a 30-year period. Includes estimated costs for permitting, engineering, and construction; and estimated annual operation and maintenance costs.
(3) A wetland delineation, topographic survey, and tree survey were performed on May 31, 2018.
(4) Estimate includes all BMP and ravine stabilization costs.
(5) Anticipated annual maintenance cost includes filter inspections, replacement and maintenance of filter media, replacement and maintenance of filter components, and BMP vegetation.
(6) Impacts to wetland area, upland area, and number of trees are approximate and will be optimized during the next phase of design.

Of the conceptual designs evaluated, the iron-enhanced filtration basin combined with the ravine stabilization has the highest upland impacts and will require the removal of almost twice as many trees as the other alternatives. The iron-enhanced ditch checks have a similar annual cost per pound of phosphorus removed as the basin, but has the least upland and tree impacts.

If the iron-enhanced ditch checks (i.e., Conceptual Design 2) is selected, modifications to further reduce upland and tree impacts can be made while still providing some phosphorus treatment before entering Silver Lake. With 5 ditch checks, the BMP has the potential to remove between 2.6 and 4.7 lbs/yr of phosphorus. If less than 5 ditch checks is desired, the total phosphorus reduction potential of the BMP will be reduced.

The optimization of the chosen design would need to be coordinated with the city of Chanhassen to ensure that the design meets the city's wetland management guidelines.

7.0 Schedule of Activities

Figure 7-1 summarizes an estimated schedule of anticipated tasks if the RPBCWD Board of Managers authorize final design of a water quality improvement project.

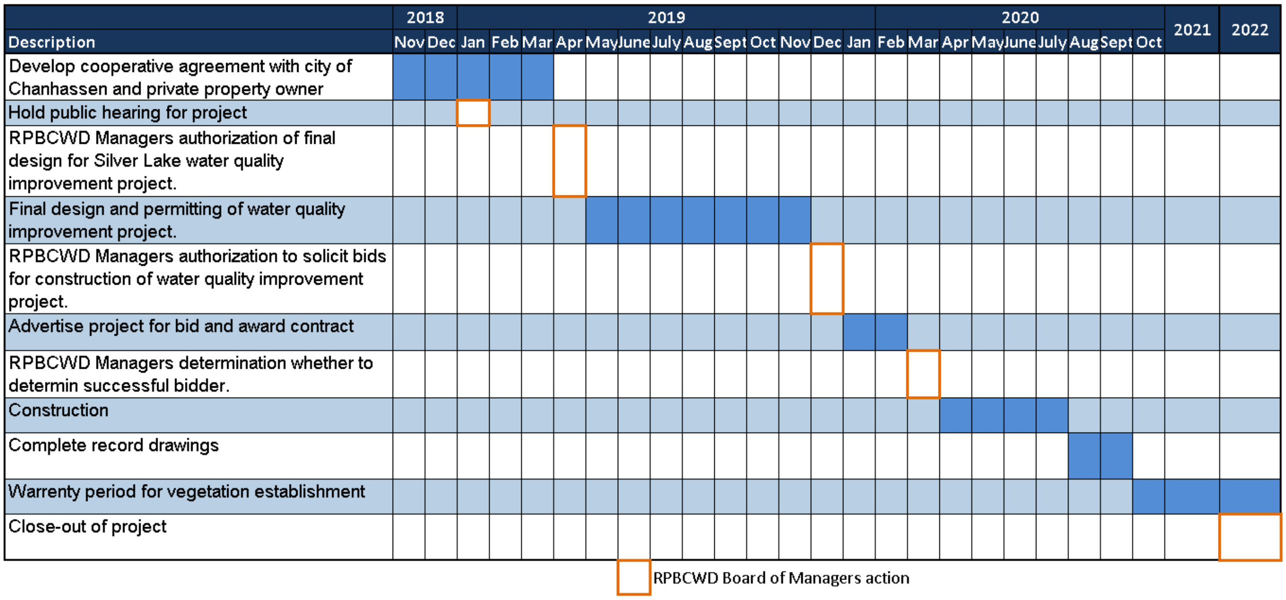


Figure 7-1 Potential Schedule of Activities

8.0 Agreements

Table 8-1 summarizes anticipated agreements required prior to construction of a water quality BMP.

Table 8-1 Summary of Anticipated Agreements

Description	Notes	Period	Lead Organization
Cooperative agreement between RPBCWD and city of Chanhassen	Cooperative agreement between RPBCWD and city of Chanhassen for activities related to construction and operation and maintenance of the BMP. The agreement would establish procedures for performing specific tasks, and define responsibilities of each organization.	2019	RPBCWD and city of Chanhassen
Access agreement with private property owner(s).	Agreement with residential property owner(s) to access residential property to construct the proposed BMP.	2019	RPBCWD

9.0 Financing & Work Plan

RPBCWD would finance design, permitting, construction, and monitoring of the proposed water quality BMP for 2 to 4 years following construction. The city of Chanhassen will be responsible for financing ongoing operation and maintenance activities following construction, including implementation of system modifications based on monitoring data collected by RPBCWD.

RPBCWD would lead the design, permitting, construction, and monitoring of a proposed water quality BMP. During final design RPBCWD would regularly coordinate with the City regarding design of project features that affect ongoing operation and maintenance of the BMP, access to city-owned property, and modifications to Pleasantview Road.

Following construction, city of Chanhassen staff will be responsible for annual operation and maintenance of the BMP. Roles and responsibilities are clarified below:

- RPBCWD will take the lead in developing a cooperative agreement with the city of Chanhassen to allow RPBCWD staff and contractors to access the site to construct a water quality BMP.
- Following construction, city of Chanhassen staff will be responsible for maintenance of BMP including vegetation removal within filtration BMPs, cleaning of pretreatment facilities, adding additional or replacing filtration material, and all other tasks necessary such that the BMP provides the intended nutrient removal.
- RPBCWD will monitor system performance for 2-4 years following construction. Monitoring results will be shared with the city of Chanhassen on an annual basis.
- RPBCWD will provide recommendations for system modifications to improve system performance based on monitoring data. The city of Chanhassen will be responsible for determining whether to modify the system within this period.
- The potential activities defined in the cooperative agreement between RPBCWD and the city of Chanhassen and potential responsible parties are summarized in Table 9-1.
- The anticipated primary points of contact are summarized in Table 9-2.

Table 9-1 Potential Activities Defined in Cooperative Agreement

Activity	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Construciton of water quality BMP and ravine stabilization	R																														
Annual inspection of water quality BMP and ravine		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Monitor performance of water quality BMP		R	R	R																											
Vegetation maintenance and sediment removal		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Iron-enhanced sand media replacement											C										C										

R = RPBCWD; C = city of Chanhassen

Table 9-2 Anticipated Primary Points of Contact

Organization	Name	Phone
RPBCWD	Claire Bleser	952.607.6512
city of Chanhassen	Paul Oehme	952.227.1168

10.0 Recommendation

Based on the results of the engineering assessment, potential site impacts, and phosphorous removed, Conceptual Design 2 — ditch checks with iron-enhanced sand placed within the stabilized ravine, is recommended as the most feasible BMP. The engineering assessment was based on information collected during a review of available data and preliminary site characterization.

Conceptual Design 2 is a feasible project, consistent with the 2017 UAA Plan for Silver Lake. This BMP combination presents the lowest impacts to natural resources in the area while also helping improve and protect the water quality in Silver Lake and waters located downstream.

The engineer opinion of probable cost for the design, permitting, and construction of Conceptual Design 2 is $122,000 with a potential range of $98,000 to $183,000 based on the current level of design. As plans and specifications for the recommended conceptual design are prepared, the District should continue to collaborate with city of Chanhassen staff about plan details. If the Board elects to pursue the project, it is recommended that coordination with the city of Chanhassen start in the near term to develop a cooperative agreement in advance of the project implementation. Over a 30-year period, long term maintenance will be needed which results in an anticipated annual cost per pound of phosphorus reduced of between $1,020 and $3,460.

Additionally, it is recommended that the RPBCWD monitor the iron-enhanced ditch checks and ravine stabilization for 2 to 4 years after construction. This monitoring will be used to optimize the system and evaluate the pollutant removal performance under typical annual variations.

11.0 References

Minnesota Pollution Control Agency. (2017, November 20). *Minnesota Administrative Rules: Chapter 7050, Waters of the State*. Retrieved from The Office of the Revisor of Statutes: https://www.revisor.mn.gov/rules/?id=7050&version=2017-12-14T11:07:06-06:00&format=pdf

Barr Engineering. (2017). *Creek Restoration Action Strategy – Upper Riley Creek Sediment.*

Barr Engineering. (2017). *Lotus, Silver, Duck, Round, Mitchell, Red Rock Use Attainability Analysis Update; Lake Idlewild and Staring Lake Use Attainability Analysis; and Lower Purgatory Creek Stabilization Study.*

BioClean Environmental. (2015). *Modular Wetlands Advanced Stormwater Biofiltration: MWS Linear.* Modular Wetland Systems, Inc.

BioClean Environmental. (2015). *The Kraken Filter.*

Erickson, A., Gulliver, J., & Weiss, P. (2012). *Capturing phosphates with iron enhanced sand filtration.* Water Research.

Michigan Department of Environmental Quality. (1999). *Pollutants Controlled Calculation and Documentation For Section 319 Watersheds Training Manual.* Lansing.

Minnesota Pollution Control Agency. (2015, May 5). *Overview for iron enhanced sand filter*. Retrieved December 11, 2017, from Minnesota Stormwater Manual: https://stormwater.pca.state.mn.us/index.php/Overview_for_iron_enhanced_sand_filter

Natarajan, P., & Gulliver, J. (2015). *Assessing Iron-Enhanced Swales for Pollution Preventi.*

Ramsey-Washington Metro Watershed District. (2017). *Sand Filter*. Retrieved from Ramsey-Washington Metro Watershed District: http://www.rwmwd.org/index.asp?SEC=58E60B76-2BA3-4B6D-A41C-7B8DC882B113&Type=B_BASIC

StormTree. (2017). *StormTree*. Retrieved December 11, 2017, from http://www.storm-tree.com/

Wisconsin Natural Resources Conservation Service. (2003). *Field Office Technical Guide: Streambank Erosion.*

Appendix A

Engineer's Opinion of Probable Cost

1.0 Cost Estimate

Engineer's opinions of probable costs for design, permitting, and construction were developed for each conceptual design. These opinions of costs, project reserves, contingency, documentation and discussion are intended to provide background information for feasibility alternatives assessment, analysis purposes and budget authorization by the RPBCWD. The cost of time escalation is not included in the opinions of probable cost. All costs are presented in 2017 US dollars.

Quantities were estimated with calculations based on available information presented in previous sections. Dimensions, areas, and volumes for construction were estimated using excel, GIS and manufacturer information.

Unit costs are based on recent bid prices, published construction cost index resources, and similar stormwater BMP projects. Unit process were developed and compared to similar project prices. Costs associated with Base Planning Engineering and Design (PED) are based on percentages of estimated construction cost and are within a range similar to those used in past projects designed by Barr. Costs associated with Construction Management (CM) are based on estimated costs to manage the construction process, based on Barr's experience with similar projects, but may change depending on the services that are provided during construction. The estimates also include Permitting and Regulatory Approvals, which is intended to account for additional planning, coordination, and mitigation costs that are likely to be incurred as the project is permitted with environmental agencies.

The opinions of cost include tasks and items related to engineering and design, permitting, and constructing each conceptual design. The opinions of cost do not include other tasks following construction of each alternative presented such as operations and maintenance, or monitoring.

Contingency used in these opinions of probable cost are intended to help identify an estimated construction cost amount for the minor items included in the current Project scope, but have not yet been quantified or estimated directly during the feasibility evaluation. Stated another way, contingency is the resultant of the pluses and minuses that cannot be estimated at the level of project definition that exists. The contingency includes the cost of ancillary items not currently itemized in the quantity summaries but commonly identified in more detailed design and required for completeness of the work. A 25% contingency is applied to the estimated construction cost to account for the costs of these items.

Industry resources for cost estimating (*AACE International Recommended Practice No. 18R-97, and ASTM E2516-06 Standard Classification for Cost Estimate Classification System*) provide guidance on cost uncertainty, depending on the level of project design developed. The opinion of probable cost for the alternatives evaluated generally corresponds to a Class 4 estimate characterized by completion of limited engineering and use of deterministic estimating methods. As the level of design detail increases, the level of uncertainty is reduced. Figure A-1 provides a graphic representation of how uncertainty (or accuracy) of cost estimates can be expected to improve as more detailed design is developed.

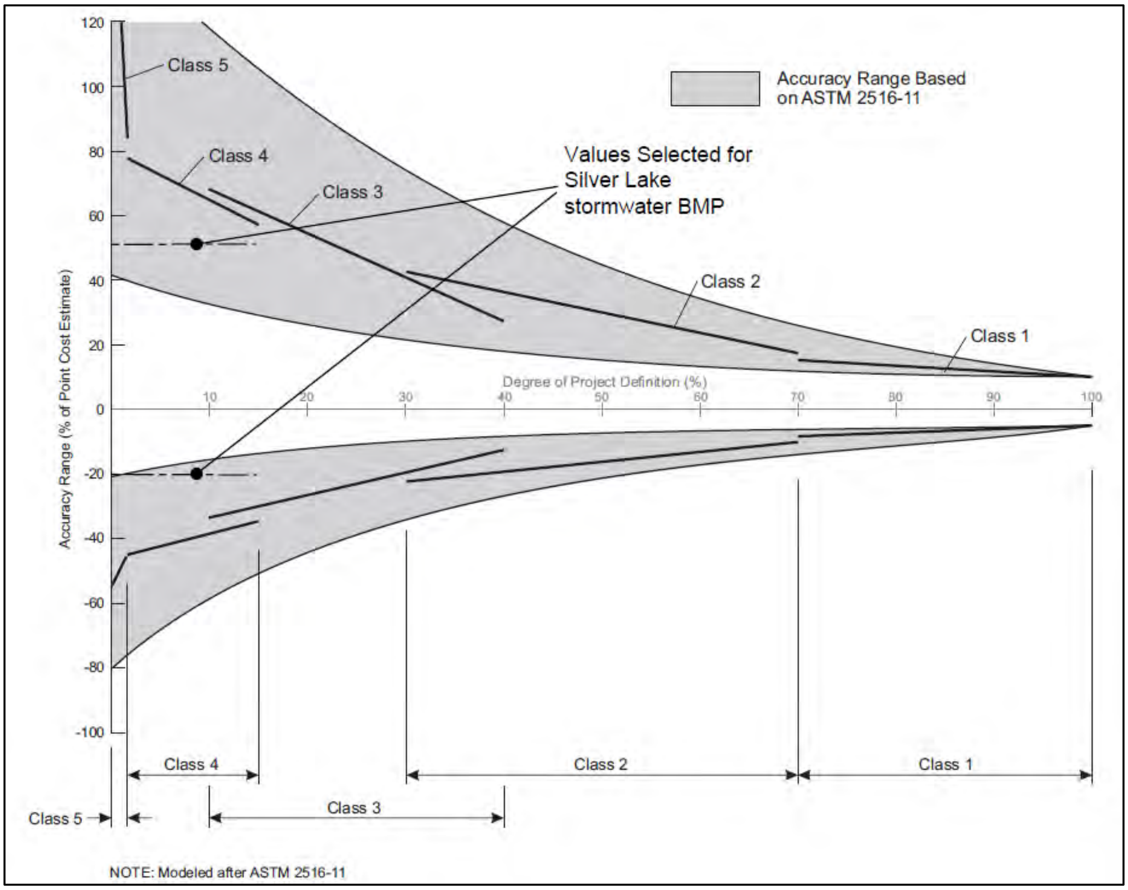


Figure A-1 Relationship between Cost Accuracy and Degree of Project Definition

At this early stage of design, the range of uncertainty of total project cost is high. Due to the early stage of design, it is standard practice to place a broad accuracy range around the point cost estimate.

The accuracy range is based on professional judgment considering the level of design completed, the complexity of the project, and the uncertainties in the project scope; the accuracy range does not include costs for future scope changes that are not part of the project as currently defined or risk contingency. The estimated accuracy range for this point estimate is -20% to +50%.

The opinion of probable cost provided in this memorandum is made on the basis of Barr Engineering's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. It is acknowledged that additional investigations and additional site specific information that becomes available in the next stage of design may result in changes to the proposed configuration, cost and functioning of project features. This opinion is based on project-related information available to Barr Engineering at this time and includes a conceptual-level feasibility design of the project. The opinion of cost may change as more information becomes available and further design is completed. In addition, because we have no control over the eventual cost of labor, materials, equipment or services furnished by others, or over the contractor's methods of determining prices, or over competitive bidding or market conditions, Barr Engineering cannot and does not guarantee that proposals, bids, or actual costs will not vary from the opinion of probable cost presented in this memorandum. If the RPBCWD wishes greater assurance as to the probable project cost, the RPBCWD should authorize further investigation and design of a selected alternative.

Table A-1 provides a comparison of the opinion of costs for each of the five alternatives. These costs assume that all work will be completed within City owned parcels or in private parcels where permission to work has been granted. These costs also assume that no purchase of additional easements will be required. Table A-3 through Table A-7 include opinion of cost for each design alternative.

Table A-1 Engineer's Opinion of Probable Cost – Feasibility Estimate Summary

Conceptual Design	Engineer's Opinion of Probable Cost ($)[1]
Conceptual Design 1 Iron-Enhanced Filtration Basin	$328,000 ($263,000 - $492,000)
Conceptual Design 2 Ditch Checks with Iron-Enhanced Sand	$122,000 ($98,000 - $183,000)
Conceptual Design 3 Modular Wetland System	$363,000 ($291,000 - $545,000)
Conceptual Design 4 Kraken Filter	$321,000 ($257,000 - $482,000)
Conceptual Design 5 StormTree Filter	$332,000 ($266,000 - $498,000)

Note(s):

(1) Approximate values based on available information. Soil borings are required during the next phase of design to identify existing soil characteristics and estimate the groundwater elevation. Estimate includes all BMP and ravine stabilization costs. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%.

The opinions of costs above do not include the cost to maintain the stormwater BMP following construction. The planning level cost to maintain each BMP over a 30 year period are provided in Table A-2.

Table A-2 Engineer's Opinion of Probable Maintenance Cost – Feasibility Estimate Summary

Conceptual Design	Engineer's Opinion of Probable Maintenance Cost Over a 30 Year Lifecycle ($)(1)
Conceptual Design 1 Iron-Enhanced Filtration Basin	$91,700 ($73,400 - $137,600)
Conceptual Design 2 Ditch Checks with Iron-Enhanced Sand	$58,000 ($46,400 - $87,000)
Conceptual Design 3 Modular Wetland System	$46,500 ($37,200 - $69,800)
Conceptual Design 4 Kraken Filter	$212,500 ($170,000 - $318,800)
Conceptual Design 5 StormTree Filter	$40,400 ($32,400 - $60,600)

Note(s):

(1) Anticipated maintenance cost includes annual filter inspections, replacement and maintenance of filter media, replacement and maintenance of filter components, and BMP vegetation evaluated over a 30-year period. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%.

2.0 References

American Society for Testing and Materials. 2006. ASTM E2516-06 Standard Classification for Cost Estimate Classification System. ASTM International, West Conshohocken, PA, DOI: 10.1520/E2516-06

Association for the Advancement of Cost Estimating. 2005. *AACE International Recommended Practice NO. 18R-97*, February 2, 2005

Table A-3 Engineer's Opinion of Probable Project Cost: Conceptual Design 1 - Iron Enhanced Filtration Basin

PREPARED BY: BARR ENGINEERING COMPANY	REV 1	SHEET: 1	OF 6
		BY: HNH	DATE: 10/1/2018
PRELIMINARY ENGINEERING REPORT		CHECKED BY: BJB	DATE:
ENGINEER'S OPINION OF PROBABLE PROJECT COST		APPROVED BY: SAS	DATE:
PROJECT: Silver Lake Stormwater BMP	ISSUED:		DATE:
LOCATION: City of Chanhassen, MN	ISSUED:		DATE:
PROJECT #: 23/27-0053.14-024	ISSUED:		DATE:
OPINION OF COST - SUMMARY	ISSUED:		DATE:

Engineer's Opinion of Probable Project Cost
Conceptual Design 1 – Iron Enhanced Filtration Basin
Silver Lake BMP

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$ 29,500	$29,500.00	1,2,3,4,5
B	Rock Erosion Control Construction Entrance	Each	1	$ 1,200	$1,200.00	1,2,3,4,5
C	Clearing & Grubbing	Acre	0.52	$ 15,000	$7,818.60	1,2,3,4,5
D	Erosion Control Silt Fence	L.F.	500	$ 2.75	$1,375.00	1,2,3,4,5
E	Erosion Control Blanket	S.Y.	2523	$ 2.50	$6,307.00	1,2,3,4,5
F	Riprap, MnDot Class III w/Type IV Geotextile	Ton	10	$ 125	$1,250.00	1,2,3,4,5
H	Remove/Replace Ex. Bit. Road	S.Y.	30	$ 85	$2,550.00	1,2,3,4,5
I	Common Excavation	C.Y.	1447	$ 40	$57,897.78	1,2,3,4,5
J	Site Restoration (Seed & Mulch)	Acre	0.52	$ 10,000	$5,212.40	1,2,3,4,5
K	12" HDPE Storm Sewer	L.F.	55	$ 75	$4,125.00	1,2,3,4,5
L	18" HDPE Storm Sewer	L.F.	45	$ 85	$3,825.00	1,2,3,4,5
M	Outlet Control Structure	Each	1	$ 2,500	$2,500.00	1,2,3,4,5
N	Curb and Gutter with Base	L.F.	30	$ 25	$750.00	1,2,3,4,5
O	Precast Concrete Catch Basin w/ 3-ft Sump	Each	1	$ 7,000	$7,000.00	1,2,3,4,5
Q	Backfill and Grading (Excav. Borrow)	C.Y.	190	$ 10	$1,900.00	1,2,3,4,5
R	Geotextile Liner	S.Y.	905	$ 1.75	$1,583.89	1,2,3,4,5
S	6" Under Drain Perforated Pipe	L.F.	400	$ 12	$4,800.00	1,2,3,4,5
T	10" Under Drain CPEP-DW Header Pipe	L.F.	40	$ 60	$2,400.00	1,2,3,4,5
U	Under Drain Fittings & Appurtanances	L.S.	1	$ 1,000	$1,000.00	1,2,3,4,5
V	Import Iron Enhanced Sand (5% iron by weight)	C.Y.	302	$ 45	$13,576.20	1,2,3,4,5
W	Pea Rock	C.Y.	121	$ 45	$5,430.48	1,2,3,4,5
CC	Rock Filter Dike	Tons	10	$ 55	$550.00	1,2,3,4,5
DD	F&I Turf Reinforcement Mat	S.Y.	800	$ 18	$14,400.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$177,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (25%)				$44,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$221,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$79,000.00	1,2,3,4,5,8
	PERMITTING & REGULATORY APPROVALS				$6,000.00	1,5,6,8
	CONSTRUCTION MANAGEMENT				$22,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$328,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$263,000.00**	5,7,8
		50%			**$492,000.00**	5,7,8

Notes

[1] Limited Design Work Completed (10 - 15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] No Soil Borings Available.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit from the City of Chanhassen, MN. If replacement/mitigation is required, the total cost may increase to approximately $20,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

BARR PREPARED BY: BARR ENGINEERING COMPANY	REV 1	SHEET: 2		OF	6
		BY:	HNH	DATE:	10/1/2018
PRELIMINARY ENGINEERING REPORT		CHECKED BY:	BJB	DATE:	
ENGINEER'S OPINION OF PROBABLE PROJECT COST		APPROVED BY:	SAS	DATE:	
PROJECT: Silver Lake Stormwater BMP	ISSUED:			DATE:	
LOCATION: City of Chanhassen, MN	ISSUED:			DATE:	
PROJECT #: 23/27-0053.14-024	ISSUED:			DATE:	
OPINION OF COST - SUMMARY	ISSUED:			DATE:	

Engineer's Opinion of Probable Project Cost
Conceptual Design 2 – Ditch Checks with Iron-Enhanced Sand
Silver Lake Stormwater BMP

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$ 9,900.00	$9,900.00	1,2,3,4,5
B	Rock Erosion Control Construction Entrance	Each	1	$ 1,200.00	$1,200.00	1,2,3,4,5
C	Clearing & Grubbing	Acre	0.27	$ 15,000.00	$4,050.00	1,2,3,4,5
D	Erosion Control Silt Fence	L.F.	500	$ 2.75	$1,375.00	1,2,3,4,5
E	Erosion Control Blanket	S.Y.	1307	$ 2.50	$3,267.00	1,2,3,4,5
G	Riprap, MnDot Class II w/Type IV Geotextile	Ton	13	$ 100.00	$1,322.22	1,2,3,4,5
I	Common Excavation	C.Y.	92	$ 40.00	$3,697.78	1,2,3,4,5
J	Site Restoration (Seed & Mulch)	Acre	0.27	$ 10,000.00	$2,700.00	1,2,3,4,5
K	12" HDPE Storm Sewer	L.F.	55	$ 75.00	$4,125.00	1,2,3,4,5
N	Curb and Gutter with Base	L.F.	30	$ 25.00	$750.00	1,2,3,4,5
O	Precast Concrete Catch Basin w/ 3-ft Sump	Each	1	$ 7,000.00	$7,000.00	1,2,3,4,5
V	Import Iron Enhanced Sand (5% iron by weight)	C.Y.	2.4	$ 45.00	$106.25	1,2,3,4,5
X	Metal Cages	Each	5	$ 925.00	$4,625.00	1,2,3,4,5
R	Geotextile Liner	S.Y.	18.9	$ 1.75	$33.06	1,2,3,4,5
W	Pea Rock	C.Y.	2.4	$ 45.00	$106.25	1,2,3,4,5
CC	Rock Filter Dike	Tons	10	$ 55.00	$550.00	1,2,3,4,5
DD	F&I Turf Reinforcement Mat	S.Y.	800	$ 18.00	$14,400.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$59,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (25%)				$15,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$74,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$35,000.00	1,2,3,4,5,8
	PERMITTING & REGULATORY APPROVALS				$6,000.00	1,5,6,8
	CONSTRUCTION MANAGEMENT				$7,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$122,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$98,000.00**	5,7,8
		50%			**$183,000.00**	5,7,8

Notes

[1] Limited Design Work Completed (10 - 15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] No Soil Borings Available

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit from the City of Chanhassen, MN. If replacement/mitigation is required, the total cost may increase to approximately $20,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

Table A-5 Engineer's Opinion of Probable Project Cost: Conceptual Design 3 – BioClean Modular Wetland System

PREPARED BY: BARR ENGINEERING COMPANY	REV 1	SHEET: 3	OF	6
BARR		BY: HNH	DATE:	10/1/2018
PRELIMINARY ENGINEERING REPORT		CHECKED BY: BJB	DATE:	
ENGINEER'S OPINION OF PROBABLE PROJECT COST		APPROVED BY: SAS	DATE:	
PROJECT: Silver Lake Stormwater BMP	ISSUED:		DATE:	
LOCATION: City of Chanhassen, MN	ISSUED:		DATE:	
PROJECT #: 23/27-0053.14-024	ISSUED:		DATE:	
OPINION OF COST - SUMMARY	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost
Conceptual Design 3– BioClean Modular Wetland System

Silver Lake Stormwater BMP

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$ 32,700.00	$32,700.00	1,2,3,4,5
B	Rock Erosion Control Construction Entrance	Each	1	$ 1,200.00	$1,200.00	1,2,3,4,5
C	Clearing & Grubbing	Acre	0.31	$ 15,000.00	$4,650.00	1,2,3,4,5
D	Erosion Control Silt Fence	L.F.	800	$ 2.75	$2,200.00	1,2,3,4,5
E	Erosion Control Blanket	S.Y.	1742	$ 2.50	$4,356.00	1,2,3,4,5
H	Remove/Replace Ex. Bit. Road	S.Y.	30	$ 85.00	$2,550.00	1,2,3,4,5
I	Common Excavation	C.Y.	296	$ 40.00	$11,835.56	1,2,3,4,5
J	Site Restoration (Seed & Mulch)	Acre	0.36	$ 10,000.00	$3,600.00	1,2,3,4,5
K	12" HDPE Storm Sewer	L.F.	150	$ 75.00	$11,250.00	1,2,3,4,5
N	Curb and Gutter with Base	L.F.	100	$ 25.00	$2,500.00	1,2,3,4,5
P	Precast Concrete Catch Basin	Each	1	$ 2,500.00	$2,500.00	1,2,3,4,5
Q	Backfill and Grading (Excav. Borrow)	C.Y.	175	$ 10.00	$1,750.00	1,2,3,4,5
Y	Modular Wetland System	Each	1	$ 75,000.00	$75,000.00	1,2,3,4,5
CC	Rock Filter Dike	Tons	10	$ 55.00	$550.00	1,2,3,4,5
DD	F&I Turf Reinforcement Mat	S.Y.	800	$ 18.00	$14,400.00	1,2,3,4,5
EE	Install Pre-Manufactured Device and Storage Tank	Each	1	$ 25,000.00	$25,000.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$196,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (25%)				$49,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$245,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$87,000.00	1,2,3,4,5,8
	PERMITTING & REGULATORY APPROVALS				$6,000.00	1,5,6,8
	CONSTRUCTION MANAGEMENT				$25,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$363,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$291,000.00**	5,7,8
		50%			**$545,000.00**	5,7,8

Notes

[1] Limited Design Work Completed (10 - 15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] No Soil Borings Available, Limited Field Investigation Completed, and no site survey.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit from the City of Chanhassen, MN. If replacement/mitigation is required, the total cost may increase to approximately $20,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

Table A-6 Engineer's Opinion of Probable Project Cost: Conceptual Design 4 - BioClean Kraken Filter

PREPARED BY: BARR ENGINEERING COMPANY	REV 1 SHEET: 4	OF 6	
	BY: HNH	DATE:	10/1/2018
PRELIMINARY ENGINEERING REPORT	CHECKED BY: BJB	DATE:	
ENGINEER'S OPINION OF PROBABLE PROJECT COST	APPROVED BY: SAS	DATE:	
PROJECT: Silver Lake Stormwater BMP	ISSUED:	DATE:	
LOCATION: City of Chanhassen, MN	ISSUED:	DATE:	
PROJECT #: 23/27-0053.14-024	ISSUED:	DATE:	
OPINION OF COST - SUMMARY	ISSUED:	DATE:	

Engineer's Opinion of Probable Project Cost
Conceptual Design 4– BioClean Kraken Filter
Lake Susan Stormwater BMP

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$28,700.00	$28,700.00	1,2,3,4,5
B	Rock Erosion Control Construction Entrance	Each	1	$1,200.00	$1,200.00	1,2,3,4,5
C	Clearing & Grubbing	Acre	0.31	$15,000.00	$4,650.00	1,2,3,4,5
D	Erosion Control Silt Fence	L.F.	800	$2.75	$2,200.00	1,2,3,4,5
E	Erosion Control Blanket	S.Y.	1742	$2.50	$4,356.00	1,2,3,4,5
H	Remove/Replace Ex. Bit. Road	S.Y.	30	$85.00	$2,550.00	1,2,3,4,5
I	Common Excavation	C.Y.	208	$40.00	$8,335.56	1,2,3,4,5
J	Site Restoration (Seed & Mulch)	Acre	0.36	$10,000.00	$3,600.00	1,2,3,4,5
K	12" HDPE Storm Sewer	L.F.	75	$75.00	$5,625.00	1,2,3,4,5
N	Curb and Gutter with Base	L.F.	100	$25.00	$2,500.00	1,2,3,4,5
P	Precast Concrete Catch Basin	Each	1	$2,500.00	$2,500.00	1,2,3,4,5
Q	Backfill and Grading (Excav. Borrow)	C.Y.	87.5	$10.00	$875.00	1,2,3,4,5
Z	Kraken Filter	Each	1	$70,000.00	$70,000.00	1,2,3,4,5
CC	Rock Filter Dike	Tons	10	$55.00	$550.00	1,2,3,4,5
DD	F&I Turf Reinforcement Mat	S.Y.	800	$18.00	$14,400.00	1,2,3,4,5
EE	Install Pre-Manufactured Device	Each	1	$20,000.00	$20,000.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$172,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (25%)				$43,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$215,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$78,000.00	1,2,3,4,5,8
	PERMITTING & REGULATORY APPROVALS				$6,000.00	1,5,6,8
	CONSTRUCTION MANAGEMENT				$22,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$321,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$257,000.00**	5,7,8
		50%			**$482,000.00**	5,7,8

Notes

[1] Limited Design Work Completed (10 - 15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] No Soil Borings Available, Limited Field Investigation Completed, and no site survey.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit from the City of Chanhassen, MN. If replacement/mitigation is required, the total cost may increase to approximately $20,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

Table A-7 Engineer's Opinion of Probable Project Cost: Conceptual Design 5 - StormTree Filter

BARR PREPARED BY: BARR ENGINEERING COMPANY	REV 1	SHEET: 5	OF	6	
		BY: HNH	DATE:	10/1/2018	
PRELIMINARY ENGINEERING REPORT		CHECKED BY: BJB	DATE:		
ENGINEER'S OPINION OF PROBABLE PROJECT COST		APPROVED BY: SAS	DATE:		
PROJECT: Silver Lake Stormwater BMP	ISSUED:		DATE:		
LOCATION: City of Chanhassen, MN	ISSUED:		DATE:		
PROJECT #: 23/27-0053.14-024	ISSUED:		DATE:		
OPINION OF COST - SUMMARY	ISSUED:		DATE:		

Engineer's Opinion of Probable Project Cost
Conceptual Design 5– StormTree Filter
Silver Lake Stormwater BMP

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$ 31,000.00	$31,000.00	1,2,3,4,5
B	Rock Erosion Control Construction Entrance	Each	1	$ 1,200.00	$1,200.00	1,2,3,4,5
C	Clearing & Grubbing	Acre	0.36	$ 15,000.00	$5,413.64	1,2,3,4,5
D	Erosion Control Silt Fence	L.F.	800	$ 2.75	$2,200.00	1,2,3,4,5
E	Erosion Control Blanket	S.Y.	1746.8	$ 2.50	$4,367.00	1,2,3,4,5
H	Remove/Replace Ex. Bit. Road	S.Y.	30	$ 85.00	$2,550.00	1,2,3,4,5
I	Common Excavation	C.Y.	296	$ 40.00	$11,835.56	1,2,3,4,5
J	Site Restoration (Seed & Mulch)	Acre	0.36	$ 10,000.00	$3,609.09	1,2,3,4,5
K	12" HDPE Storm Sewer	L.F.	150	$ 75.00	$11,250.00	1,2,3,4,5
N	Curb and Gutter with Base	L.F.	100	$ 25.00	$2,500.00	1,2,3,4,5
Q	Backfill and Grading (Excav. Borrow)	C.Y.	175	$ 10.00	$1,750.00	1,2,3,4,5
AA	StormTree Filter	Each	1	$ 32,500.00	$32,500.00	1,2,3,4,5
BB	Pre-Cast Concrete Underground Storage Vault	Each	1	$ 36,000.00	$36,000.00	1,2,3,4,5
CC	Rock Filter Dike	Tons	10	$ 55.00	$550.00	1,2,3,4,5
DD	F&I Turf Reinforcement Mat	S.Y.	800	$ 18.00	$14,400.00	1,2,3,4,5
FF	Install Storage Tank	Each	1	$ 25,000.00	$25,000.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$186,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (25%)				$47,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$233,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$70,000.00	1,2,3,5,8
	PERMITTING & REGULATORY APPROVALS				$6,000.00	1,5,6,8
	CONSTRUCTION MANAGEMENT				$23,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$332,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$266,000.00**	5,7,8
		50%			**$498,000.00**	5,7,8

Notes

[1] Limited Design Work Completed (10 - 15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] No Soil Borings Available, Limited Field Investigation Completed, and no site survey.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit from the City of Chanhassen, MN. If replacement/mitigation is required, the total cost may increase to approximately $20,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY		REV 1	SHEET:	6	OF	6
BARR			BY:	HNH	DATE:	10/1/2018
PRELIMINARY ENGINEERING REPORT			CHECKED BY:	BJB	DATE:	
ENGINEER'S OPINION OF PROBABLE O&M COST			APPROVED BY:	SAS	DATE:	
PROJECT: Silver Lake Stormwater BMP		ISSUED:			DATE:	
LOCATION: City of Chanhassen, MN		ISSUED:			DATE:	
PROJECT #: 23/27-0053.14-024		ISSUED:			DATE:	
OPINION OF COST - SUMMARY		ISSUED:			DATE:	

Engineer's Opinion of Probable Project Cost
30-Year Operation and Maintenance Costs
Silver Lake BMP

Cat. No.	ITEM DESCRIPTION	Conversion	Conceptual Design 1	Conceptual Design 2	Conceptual Design 3	Conceptual Design 4	Conceptual Design 5	NOTES
A	Vegetation Maintenance ($40/hr)	9 - 39 hrs/yr	$ 46,200	$ 46,200			$ 10,800	1,2,3,4, 6
B	Iron Enhanced Sand Filter Replacement ($45/C.Y.)	once every 10 years	$ 27,152	$ 213				1,2, 3, 6
C	MWS Pretreatment Filter Cartridges ($80/cartridge)	8 cartridges per year			$ 19,200			1,2, 5, 6
D	Vacuum Pre-Treatment Chamber ($150/hr)	3 hrs/yr			$ 13,500	$ 13,500	$ 13,500	1,2, 5, 6
E	Filter Inspection ($150/hr)	1 hr/yr			$ 4,500	$ 4,500	$ 4,500	1,2, 5, 6
F	Kraken Filter Cartridges ($100/cartridge)	152 cartridges every 3 years				$ 152,000		1,2, 5, 6
G	Tree Replacement ($500/tree)	once every 30 years					$ 500	1,2, 5, 6
H	Mulch Replacement ($300/replacement)	once every 3 years					$ 3,000	1,2, 3, 6
	O&M TOTAL COST		$ 73,400	$ 46,400	$ 37,200	$ 170,000	$ 32,300	
	CONTINGENCY (25%)		$ 91,700	$ 58,000	$ 46,500	$ 212,500	$ 40,400	
	ESTIMATED ACCURACY RANGE		**$ 73,400**	**$ 46,400**	**$ 37,200**	**$ 170,000**	**$ 32,400**	6
	(-20% to 50%)		**$ 137,600**	**$ 87,000**	**$ 69,800**	**$ 318,800**	**$ 60,600**	6

Notes

[1] Limited Design Work Completed (10 - 15%).

[2] Prices Based on Information Available at This Time.

[3] Estimate based on maintenance costs for similar BMPs conducted by Barr staff.

[4] Vegetation maintenance of Conceptual Design 5 is less than that of Conceptual Designs 1 and 2 as surface footprint is smaller.

[5] Estimate from manufacturer.

[6] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. Contingency is an allowance for the net sum of costs that will be in the Final O&M Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Operation and Maintenance Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency.