

Item 6A.
BCWMC 2-18-16
Appendices available online

Feasibility Report for Plymouth Creek Restoration Project - DRAFT

Plymouth, Minnesota

Prepared for
Bassett Creek Watershed Management Commission

February 2016



Feasibility Report for Plymouth Creek Restoration Project

Plymouth, Minnesota

Prepared for
Bassett Creek Watershed Management Commission

February 2016

Feasibility Report for Plymouth Creek Restoration Project

February 2016

Contents

1.0	Executive summary.....	1
1.1	Background.....	1
1.2	Site characteristics.....	1
1.3	Recommended stabilization project description.....	1
1.4	Project impacts and estimated costs.....	2
1.5	Recommendations.....	2
2.0	Background and objectives.....	3
2.1	Goals and objectives.....	3
2.1.1	Scope.....	3
2.1.1.1	Stream Stabilization Goals.....	5
2.1.2	Considerations.....	5
2.2	Background.....	5
2.2.1	Project area description.....	5
2.2.2	Past documents and activities addressing the project area.....	6
2.2.2.1	BCWMC Watershed Management Plan (2015).....	6
2.2.2.2	BCWMC Resource Management Plan (2009).....	6
2.2.2.3	Medicine Lake Excess Nutrients TMDL (2010).....	7
3.0	Site characteristics.....	8
3.1	Plymouth Creek Watershed.....	8
3.2	Stream characteristics.....	8
3.2.1	Surrounding land use.....	8
3.2.2	Stream geomorphic assessment.....	10
3.2.3	Historical channel alignment.....	10
3.2.4	Available hydrologic and hydraulic models.....	11
3.3	Site access.....	11
3.4	Phase I Environmental Assessment.....	11
3.5	Cultural and historical resources.....	12
3.6	Wetlands.....	12
4.0	Stakeholder input.....	13

4.1	Public stakeholder meetings	13
4.2	Technical stakeholder meeting	13
4.3	Technical stakeholder comments.....	13
5.0	Potential improvements.....	14
5.1	Description of stabilization alternatives.....	14
5.1.1	Hard armoring and bioengineering stream stabilization techniques.....	14
5.1.2	Stream stabilization techniques evaluated.....	15
5.1.3	Non-site-specific techniques and considerations	16
5.2	Recommended alternatives for stabilization	17
5.2.1	Sites 1 and 2	19
5.2.2	Site 3.....	19
5.2.3	Site 4.....	19
5.2.4	Site 5.....	19
5.2.5	Sites 6, 7, 8, and 9.....	20
5.2.6	Site 10	20
5.2.7	Sites 11 through 13	20
5.2.8	Site 14	20
5.2.9	Sites 15, 16, and 17.....	20
5.2.10	Sites 18 and 19	21
5.2.11	Site 20	21
5.2.12	Site 21	21
6.0	Project impacts	26
6.1	Easement acquisition.....	26
6.2	Permits required for the project	26
6.3	Water quality impacts.....	28
6.4	Other project impacts	31
7.0	Project cost considerations.....	32
7.1	Cost estimate.....	32
7.1.1	Temporary easements	32
7.1.2	Off-site sediment disposal.....	33
7.1.3	Wetland mitigation.....	33
7.1.4	Tree replacement and revegetation.....	33
7.1.5	30-year cost.....	33
7.1.6	Annualized pollutant reduction cost	34

7.1.7	Miscellaneous costs.....	34
7.2	Funding sources.....	34
7.3	Project schedule.....	34
8.0	Alternatives assessment and recommendations.....	36
9.0	References.....	38

List of Tables

Table 2-1	BCWMC channel restoration projects.....	7
Table 5-1	Plymouth Creek feasibility study alternatives summary.....	25
Table 6-1	Potential permit requirements by work site.....	28
Table 6-2	Estimated existing bank erosion and pollutant loading by site.....	30
Table 7-1	Plymouth Creek recommended alternatives cost estimates.....	35
Table 8-1	Plymouth Creek recommended alternatives cost summary.....	37

List of Figures

Figure 2-1	Plymouth Creek Feasibility Study Project Area.....	4
Figure 3-1	Plymouth Creek Watershed Land Use.....	9
Figure 5-1	Plymouth Creek Potential Stabilization Sites.....	18
Figure 5-2	Plymouth Creek Study Reach 1 Recommended Alternatives.....	22
Figure 5-3	Plymouth Creek Study Reach 2 Recommended Alternatives.....	23
Figure 5-4	Plymouth Creek Study Reach 3 Recommended Alternatives.....	24

List of Appendices

Appendix A	2015 Erosion Site Photos
Appendix B	Historical Aerial Photos
Appendix C	Phase I Assessment
Appendix D	Cultural and Historical Resources
Appendix E	Wetland Delineation
Appendix F	Stream Stabilization Technique Examples
Appendix G	Detailed Alternative Assessments
Appendix H	Detailed Alternative Cost Estimates

Certifications

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

Jeff Weiss
PE #: 48031

Date

1.0 Executive summary

1.1 Background

The Bassett Creek Watershed Management Commission's (BCWMC) 2015 Watershed Management Plan (Plan) addresses the need to restore stream reaches damaged by erosion or affected by sedimentation. Section 3.4 of the Plan describes the issue and the benefits of stream restoration, and Section 4.2.5 describes the Commission's policies related to streambank restoration and stabilization.

This study examines the feasibility of stabilizing sites along Plymouth Creek within Plymouth Creek Park and between Fernbrook Lane North and Annapolis Lane North, collectively referred to as the project area (see Figure 2-1). The Plan's 10-year Capital Improvement Program (CIP) includes this project, which will be completed in 2017 and 2018 through an ad valorem tax levied by Hennepin County on behalf of the BCWMC.

1.2 Site characteristics

The project area along Plymouth Creek extends approximately 2,800 feet, including approximately 1,700 feet within the Plymouth Creek Park and 1,100 feet between Fernbrook Lane North and Annapolis Lane North. Three reaches have been identified for this feasibility study, based on physical and geomorphic distinguishing features (see Figure 2-1). Reaches 1 and 2 are within Plymouth Creek Park, a city park that includes ballfields, an event center, and a disc golf course adjacent to the creek. Reach 3 includes the area between Fernbrook Lane North and Annapolis Lane North.

Within Reach 1 the stream is relatively straight, with the appearance of it being in part a result of historical channelization or ditching, and the stream is over-widened with only a small available floodplain. In Reach 2 the stream meanders through an open wetland area; however, the channel is moderately incised and may not access the floodplain with appropriate frequency. Reach 3 is densely forested with a more sinuous stream channel and includes several locations where meander bends are eroding the valley walls or have an extremely tight (and likely unstable) meander radius. Additional description of the stream geomorphic characteristics, channel alignment, and watershed land use is provided in Section 3.0.

A Phase I Environmental Site Assessment (Phase I) was completed for the project area in November 2015 and is included as Appendix C. The Phase I did not identify any recognized environmental conditions (i.e., the presence or release of any hazardous substances or petroleum products). Therefore, none of the project area is anticipated to require special soils management or corrective action during restoration.

Portions of Plymouth Creek and fringe wetlands in the project area were delineated in September 2015; the delineation report is included as Appendix E. Wetlands delineated in the project area totaled approximately 0.6 acres and were made up of seasonally flooded basin and wet meadow communities.

1.3 Recommended stabilization project description

This feasibility study evaluates a variety of alternatives for stabilizing up to 21 sites along Plymouth Creek within the project area. The measures considered for potential implementation include the following:

- Re-meandering the stream channel
- Restoring the vegetative buffer
- Re-connecting the stream with its floodplain
- Installing a variety of stream stabilization measures, including riprap, root wads and toe wood, vegetated reinforced soil stabilization (VRSS), rock or log vanes, and stone toe protection
- Removing large woody debris

The recommended stabilization measures include a combination of bioengineering and hard armoring techniques and are discussed in Section 5.2 and shown in Figure 5-2, Figure 5-3, and Figure 5-4.

Additional details for all stabilization alternatives considered for this study are provided in Appendix G.

1.4 Project impacts and estimated costs

Potential impacts from the stabilization project are discussed in Section 6.0 and include temporary impacts to wetlands, disc golf course usage, tree loss, and bat habitat. Of these, the most significant consideration for the project is the need to manage disc golf course usage to achieve the desired establishment of ground cover vegetation along the stabilized stream banks and riparian corridor.

The proposed project will result in reduced stream bank erosion and, therefore, reduced sediment and phosphorus loading to Plymouth Creek and all downstream water bodies, including Medicine Lake, the Mississippi River, and Lake Pepin. Estimates of existing erosion rates and pollutant loading are presented in Section 6.3. The total reduction in pollutant loading as a result of the project is estimated as 90,800 pounds per year total suspended sediment and 52.2 pounds per year total phosphorus. The majority of this load reduction will be achieved by stabilizing the eroding banks in Reaches 2 and 3.

The feasibility-level opinion of cost for implementing all of the identified measures for the 2017 Plymouth Creek Restoration Project is \$766,000, as shown in Table 8-1. This total includes \$479,000 for construction; \$144,000 for construction contingency; and \$144,000 for engineering design, permitting, and construction observation. The costs result in a 30-year annualized cost of approximately \$1,000 per pound of phosphorus reduction and approximately \$0.57 per pound of TSS reduction. The methodology and assumptions used for the cost estimates are discussed in Section 7.0, and detailed cost estimates for all stabilization alternatives considered for this study are provided in Appendix H.

1.5 Recommendations

Stabilization and restoration of stream banks within the project area will provide water quality improvement by 1) repairing actively eroding sites and 2) preventing erosion at other sites by installing preemptive measures to protect existing stream banks. We recommend that the opinion of cost identified in this study be used to develop a levy request for this project and that it proceed to the design and construction phase.

2.0 Background and objectives

The BCWMC's 2015 Watershed Management Plan (Plan, Reference (1)) addresses the need to restore stream reaches damaged by erosion or affected by sedimentation. Section 3.4 of the Plan describes the issue and the benefits of stream restoration, and Section 4.2.5 describes the Commission's policies related to streambank restoration and stabilization. The Plan's 10-year CIP includes streambank restoration and stabilization projects.

This feasibility study follows the protocols developed by the U.S. Army Corps of Engineers (USACE) and the BCWMC for projects within the BCWMC Resource Management Plan (RMP). Although the portion of this project area located upstream of Fernbrook Lane North is not included in the RMP, it otherwise fits with the intent of the RMP due to its proximity and similarity to the other stream projects included in the RMP.

The City of Plymouth requested restoration of sites along Plymouth Creek within Plymouth Creek Park (between the access road crossing to Plymouth Creek Center and Fernbrook Lane North) and between Fernbrook Lane North and Annapolis Lane North (see Figure 2-1) be added to the BCWMC CIP, and this project is currently listed in the BCWMC CIP. This study examines the feasibility of this restoration work. It was developed with input from the City of Plymouth, who owns or maintains easements to nearly all property adjacent to the creek.

Sites within the project area would be restored as a group, with design and construction costs included in the BCWMC 2017 CIP.

2.1 Goals and objectives

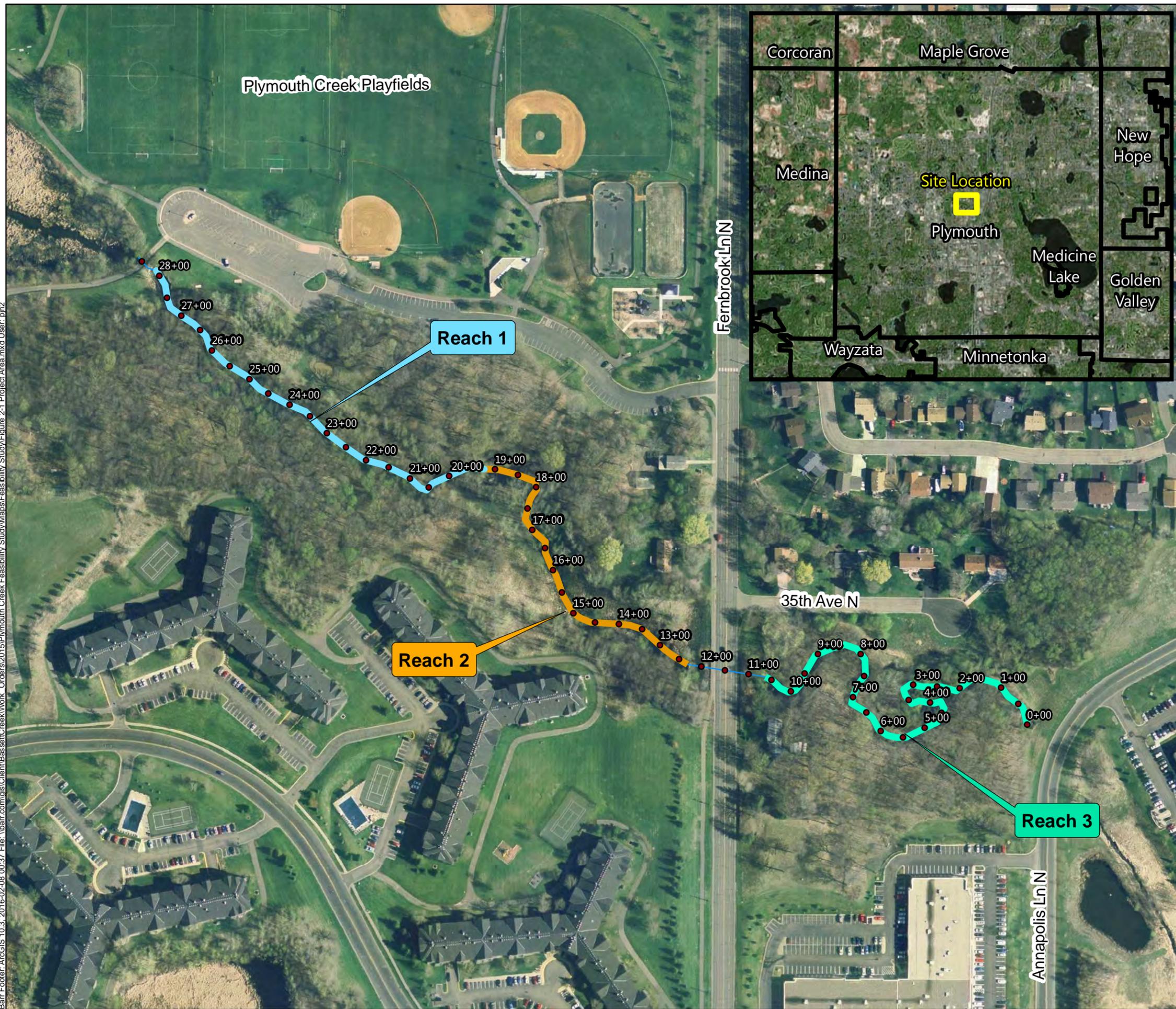
The objectives of this study are to:

1. Review the feasibility of implementing stream bank stabilization measures and re-establishing desirable vegetation within the project area along Plymouth Creek.
2. Develop conceptual designs.
3. Provide an opinion of costs for measures that could potentially be used at each erosion site.

2.1.1 Scope

The portion of Plymouth Creek located between Fernbrook Lane North and Annapolis Lane North was identified by the City of Plymouth as suffering from stream bank and channel erosion and included in the BCWMC 2009 RMP. The RMP recommended that a feasibility study be completed for this portion of the project area to identify effective restoration measures for the stream. The project area upstream of Fernbrook Lane North has many of the same issues identified downstream and was included in the CIP as a candidate for stabilization.

Barr Footer: ArcGIS 10.3. 2016-02-08 00:37 File: \\barr.com\isis\client\BassettCreek\Work_Orders\2015\Plymouth_Creek_Feasibility_Study\Maps\Figure 2-1 Project Area.mxd User: plh2



Legend

- Non-Reach Creek
- Reach 3
- Reach 2
- Reach 1



Feet
100 0 100 200



Meters
30 0 30 60





Figure 2-1
 PLYMOUTH CREEK STUDY PROJECT AREA
 Plymouth Creek Feasibility Study
 Bassett Creek Watershed
 Management Commission

2.1.1.1 Stream Stabilization Goals

The goals of the stream stabilization project are to:

- Reduce sediment loading to Plymouth Creek and improve downstream water quality by stabilizing eroding banks.
- Preserve natural beauty along Plymouth Creek and contribute to natural habitat quality and species diversification by planting eroded areas with native vegetation.
- Prevent future channel erosion along the creek and subsequent degradation of water quality downstream by establishing a stable channel dimension, pattern, and profile.
- Seek opportunities to enhance vegetation and habitat within the project area.

2.1.2 Considerations

Key considerations for stabilization approaches included:

- Minimizing flood impacts to adjacent landowners by ensuring that project features do not increase flood elevations.
- Maintaining the functionality of the Plymouth Creek Park disc golf course.
- Maintaining existing floodplain storage.
- Minimizing tree loss where possible.

The considerations listed above played a key role in determining final recommendations and their continued consideration will be required through final design.

2.2 Background

2.2.1 Project area description

The entire Plymouth Creek project area (Figure 2-1) extends approximately 2,800 feet from Annapolis Lane North on the downstream end to approximately 1,700 feet upstream of Fernbrook Lane North on the upstream end. The upstream boundary of the project area is a flood-control structure. Originally known as the Central Park Pond Outlet, this structure runs under an access road that connects the Plymouth Creek Park parking lot on the north and the Plymouth Creek Center on the south.

The project area is divided into three reaches shown on Figure 2-1 and discussed in Section 3.2. Land immediately adjacent to Reaches 1 and 2 is predominantly occupied by a disc golf course. Reach 1 has heavy tree cover and sparse vegetation below the canopy, in part due to traffic from the course. Reach 2 is a mix of tree cover and a grassy riparian area. The land adjacent to Reach 3 primarily comprises a wooded valley on both sides of the creek, adjacent to a residential neighborhood.

The BCWMC Engineer walked the entire project area in September 2015 and identified sites with bank erosion, scour, and/or bank failure. Additional site visits were conducted in October and November 2015

to meet with stakeholders, check conceptual stabilization alternatives, and observe the creek during different flow conditions. Photos of identified bank erosion locations are included in Appendix A; the sites presented in this report are considered the most important locations for stabilization to meet the BCWMC goals and objectives.

Stream bank erosion is a natural process that occurs at some rate on all alluvial channels, and the natural erosion rate can be accelerated by local and regional changes in land use and hydrology. The bank erosion and bank failures throughout the project area appear to be caused by a combination of natural stream erosion processes, problems associated with changing watershed hydrology, direct historical impacts to the stream channel, and effects of riparian land use. Of the 5,600 feet of stream bank in the project area, approximately 2,850 feet (more than half) showed some degree of erosion. The sediment load from the erosion and scour increases phosphorus loads to downstream water bodies, decreases the clarity of water in the stream, destroys aquatic habitat, and reduces the discharge capacity of the channel.

Stable stream channels are often said to be in a state of “dynamic equilibrium” with their watersheds, adjusting to changes in the watershed hydrology. It may take many years or decades for a stream to fully adjust to a rapid change in watershed hydrology. The use of best management practices (BMPs) helps reduce the impact of development projects on streams. Nonetheless, development and land use changes fundamentally change the hydrology of the watershed. These changes to hydrology often include increased magnitude and frequency of high-flow events, which subsequently increases erosion rates. In addition, the heavy use of the disc golf course in the riparian area of Reaches 1 and 2 has decreased groundcover on the stream banks and adjacent wooded areas, increasing the potential for erosion.

2.2.2 Past documents and activities addressing the project area

2.2.2.1 BCWMC Watershed Management Plan (2015)

The 2015 BCWMC Watershed Management Plan (Reference (1)) addresses the need to restore stream reaches damaged by erosion or affected by sedimentation. Prior to 2007, the costs for channel stabilization projects were covered by a fund established by the BCWMC. However, as authorized, this fund was not sufficient to cover the costs of all the restoration projects identified. In January 2007 the BCWMC’s Technical Advisory Committee recommended that the Commission add stream channel restoration projects to the Commission’s 10-year CIP. The BCWMC then identified and prioritized potential channel restoration projects by stream reach and prepared cost estimates. Larger projects were added to the CIP in May 2007. These included the Main Stem of Bassett Creek, the North Branch of Bassett Creek, the Sweeney Lake Branch of Bassett Creek, and Plymouth Creek—reaches with increased stream bank erosion, streambed aggradation, or scour. The current Plymouth Creek project is included in the BCWMC’s 10-year CIP for construction in 2017-2018.

2.2.2.2 BCWMC Resource Management Plan (2009)

The BCWMC completed a Resource Management Plan in July 2009 (Reference (2)) for water quality improvement projects scheduled for design and construction between 2010 and 2016. The goal of the RMP was to streamline the USACE permitting process for these projects. Although only a portion of the

Plymouth Creek project area is included in the RMP, given its proximity and similarity to other stream RMP projects, this feasibility study follows the same USACE/BCWMC protocols.

Table 2-1 presents completed and future restoration projects included in the BCWMC CIP, along with their estimated start dates and costs.

Table 2-1 BCWMC channel restoration projects

Creek Project	Target Project Start	Estimated Project Cost
Sweeney Lake Branch	2008 (complete)	\$386,000 ⁽¹⁾
Plymouth Creek, Reach 1	2010 (complete)	\$965,000 ⁽¹⁾
Bassett Creek Main Stem, Reach 2 (Crystal border to Regent Ave.)	2010 (complete)	\$636,000 ⁽¹⁾
Bassett Creek Main Stem, Reach 1 (Duluth St. to Crystal Border)	2011 (complete)	\$580,200 ⁽¹⁾
North Branch	2011 (complete)	\$834,900 ⁽¹⁾
Bassett Creek Main Stem 2012 (Golden Valley Road to Irving Ave. No.)	2012 (complete)	\$856,000 ⁽²⁾
Bassett Creek Main Stem 2015 (10 th Ave. to St. Croix Ave. (2015-CR))	2015 (underway)	\$1,503,000 ⁽³⁾
Plymouth Creek, from Annapolis Lane to 2,500 feet upstream (west) of Annapolis Lane (2017CR-P)	2017 (underway, this study)	\$600,000 ⁽³⁾
Bassett Creek Main Stem 2017, (Cedar Lake Rd to Irving Ave. (2017CR-M))	2017 (feasibility study underway)	\$800,000 ⁽³⁾

(1) Costs as estimated in revised 2011 CIP

(2) Costs as estimated in 2011 BCWMC Watershed Management Plan amendment

(3) Costs as estimated in 2015–2025 CIP—Table 5-3 in the 2015 BCWMC Watershed Management Plan

2.2.2.3 Medicine Lake Excess Nutrients TMDL (2010)

Medicine Lake, the downstream receiving water body for Plymouth Creek, is listed as impaired for excess nutrients (Reference (3)). The BCWMC and the Minnesota Pollution Control Agency (MPCA) prepared a Total Maximum Daily Load (TMDL) study and implementation plan for the lake in 2010 (References (4) and (5)). The TMDL study found that Plymouth Creek is a significant source of total phosphorus (TP) loading to the lake because Plymouth Creek drains the majority of the lake’s watershed; phosphorus loading to the lake is primarily from stormwater. Existing total phosphorus loading to the lake from Plymouth Creek is estimated to be 2,360 pounds per year TP, or 52% of the total load to Medicine Lake. This project is expected to reduce the loading by approximately 52.2 pounds per year TP (see Section 6.3).

The TMDL implementation plan (Reference (5)) estimated that a load reduction of 1,287 pounds per year TP from the Medicine Lake watershed is necessary to meet the nutrient Waste Load Allocation for the lake. Erosion control and streambank restoration along Plymouth Creek was estimated to provide a potential annual reduction in TP loading of 711 pounds. The cost for the load reduction from streambank restoration was estimated at \$500 to \$5,000 per pound TP.

3.0 Site characteristics

3.1 Plymouth Creek Watershed

The watershed area tributary to the project area along Plymouth Creek is approximately 2,900 acres and drains portions of the City of Plymouth (Figure 3-1). The watershed is nearly fully developed; existing land use includes single-family residential, commercial/industrial, highway, parks and undeveloped land, multi-family residential, and water surface. Exact percentages for land-use type in this subwatershed have not been determined.

3.2 Stream characteristics

The project area along Plymouth Creek (Figure 2-1) extends approximately 2,800 feet, including approximately 1,700 feet within the Plymouth Creek Park and 1,100 feet between Fernbrook Lane North and Annapolis Lane North. Three reaches have been identified for this feasibility study, based on physical and geomorphic distinguishing features as described in Section 3.2.2. Reach 1 extends approximately 950 feet from the upstream access road crossing and its control structure to a footbridge crossing the creek. Reach 2 extends approximately 750 feet from the footbridge to Fernbrook Lane North. Reach 3 includes the area between Fernbrook Lane North and Annapolis Lane North.

The Commission Engineer reviewed previously documented erosion sites and walked the entire project area to investigate the scale and severity of erosion problems, identify additional sites, and perform an initial qualitative geomorphic assessment.

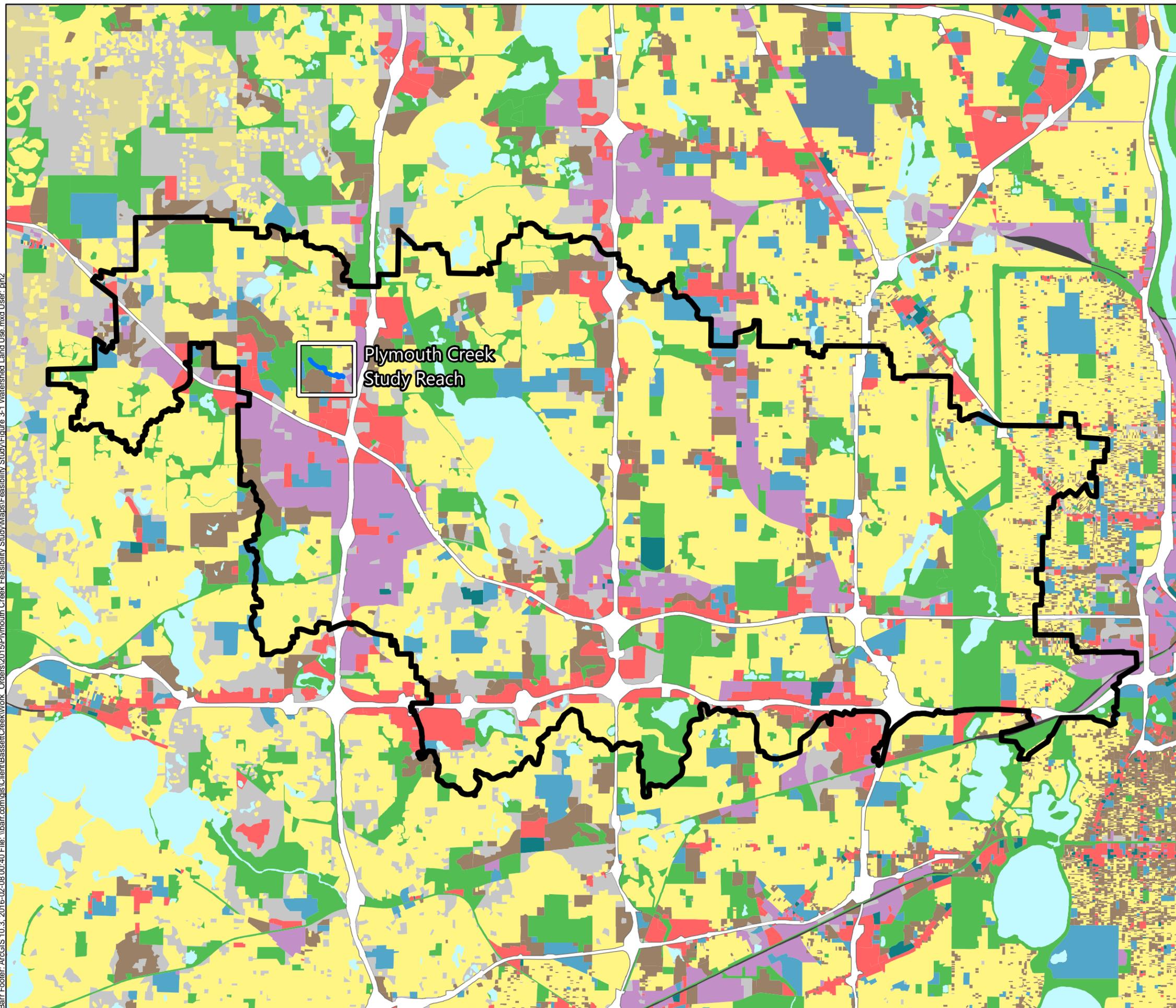
3.2.1 Surrounding land use

Reaches 1 and 2 are within Plymouth Creek Park, a city park that includes ballfields, an event center, and a disc golf course adjacent to the creek. The park also includes a large wetland upstream of the project area. Plymouth Creek flows through the wetland from northwest to southeast. Land use surrounding the park is primarily single-family residential on the north, commercial on the west, and apartment complexes on the south.

A residential neighborhood is adjacent to Reach 3 on the north and several office and light industrial complexes are to the south and east of Plymouth Creek. Throughout the reach, a wooded valley creates a buffer between the street and the creek.

According to 1947 aerial photography (see Appendix B), prior to urban development in the project area, the creek was surrounded by land cleared for agriculture.

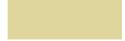
Barr Footer: ArcGIS 10.3. 2016-02-08 00:40 File: \\barr.com\gis\client\BassettCreek\Work_Orders\2015\Plymouth Creek Feasibility Study\Maps\Figure 3-1 Watershed Land Use.mxd User: ph2



Legend

-  Study Reach
-  Watershed Management Boundary

Metropolitan Council 2010 Generalized Landuse

-  Agricultural
-  Single Family Residential
-  Multifamily Residential
-  Commercial
-  Industrial
-  Institutional
-  Mixed Use
-  Park, Recreational or Preserve
-  Rights-of-Way (i.e., Roads)
-  Airport
-  Railway (inc. LRT)
-  Vacant or Unknown
-  Water

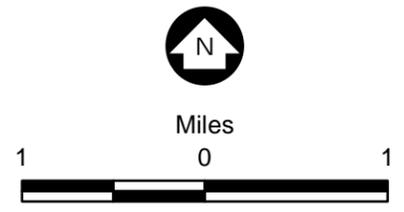


Figure 3-1

PLYMOUTH CREEK WATERSHED
 LAND USE/LAND COVER
 Plymouth Creek Feasibility Study
 Bassett Creek Watershed
 Management Commission

3.2.2 Stream geomorphic assessment

Within the project area, Plymouth Creek is a low-gradient, largely meandering stream that flows through a confined alluvial valley in the vicinity of Fernbrook Lane North. The project area is bounded on the upstream end by a wetland complex and a flood-level control structure (the "Central Park Pond Outlet") that together limit the amount of sediment that is conveyed into the project area from upstream. In the center and at the downstream end of the project area Plymouth Creek flows through two road culverts (one each at Fernbrook Lane North and Annapolis Lane North) that serve as grade control and limit flows during large floods.

The BCWMC Engineer performed a qualitative geomorphic assessment for the entire project area during a field visit; a detailed geomorphic assessment, aided by a channel survey, will be performed prior to detailed design. Within the project area Plymouth Creek has an approximate average bankfull depth of 2 feet, and an approximate bankfull width of 10 to 15 feet. Within Reach 1 the stream is relatively straight—in part a result of historical channelization or ditching. The channel appears to have a very mild slope through Reach 1, as indicated by long pools and short riffles with little apparent elevation change. With banks between 2 feet and 4 feet high, the stream does not appear to be incised in this reach but has little available floodplain due to a confined valley type. In Reach 2 the stream meanders through an open wetland area approximately 150 feet wide; however, the channel is moderately incised and may not access the floodplain with appropriate frequency. In addition, pockets of granular soils have facilitated bank erosion in some areas of Reach 2. Reach 3 is densely forested with a more sinuous stream channel and includes several locations where meander bends are eroding the valley walls or have an extremely tight (and likely unstable) meander radius. The presence of large woody debris, which directs flows towards the banks, is also causing stream bank erosion. A tight meander in the lower half of the reach is apparently being cut off.

3.2.3 Historical channel alignment

The stream alignment shown in pre-development aerial photos and maps is generally the same as under present conditions: Plymouth Creek passes through a confined valley for approximately 1 mile between upstream and downstream wetland areas. Available historical imagery for the project area can be found in Appendix B. Additional historical maps are included in the Phase I Environmental Site Assessment Report (Appendix C). Beginning with the 1947 aerial imagery of the project area, Plymouth Creek is seen in its approximate current alignment, including any portions that appear straightened or channelized due to low sinuosity and the presence of adjacent abandoned channels.

The apparent low migration rate may be attributed to the fact that the project area is relatively high in the Bassett Creek watershed and the clayey, cohesive soils are relatively resistant to erosion (especially when compared to non-cohesive sediment such as sand). A comparison of natural and historical wetland areas has not been completed; however, in general, wetlands and natural storage areas are better preserved in the outer suburbs than in the core cities and inner suburbs. As noted previously, there is a large wetland immediately upstream of the project area, which has likely provided natural storage during large flow events and reduced peak flows through the project area.

Unexpectedly, the historical images show that the very tight meander between Fernbrook Lane and Annapolis Lane has been present for many years. Tight meanders with a small radius of curvature are often unstable due to high erosive stresses on the outer banks of the meander (Reference (3)). There is notable erosion on the banks in existing conditions; however, the historical aerial images indicate that the migration rates within this area are relatively low.

3.2.4 Available hydrologic and hydraulic models

Hydrologic and hydraulic information is available for Plymouth Creek in the form of an XP-SWMM hydrologic model and an HEC-2 hydraulic model. The XP-SWMM model was produced by Barr Engineering Co. in 2012 for Bassett Creek and its contributing watersheds, as authorized by the BCWMC. The HEC-2 hydraulic model, produced in 1975 for a Housing and Urban Development (HUD) study of Plymouth Creek, was converted to HEC-RAS. The 2-year, 10-year, and 100-year, 24-hour discharges for Plymouth Creek produced by the 2012 Bassett Creek model were incorporated into the converted HEC-RAS model. Velocities within the stream channel vary from 1 foot per second (fps) to 5 fps for the 2-year event, 1 to 6 fps for the 10-year event, and 1 to 8 fps for the 100-year event. Lower velocities occur upstream, in the over-widened portion of the study area; highest velocities occur near the culvert crossing with Fernbrook Lane.

Final design efforts should include a topographic survey to create a more detailed hydraulic model through the project area. The detailed model should be used to confirm the range of anticipated velocities and assist in choosing final stabilization measures.

3.3 Site access

Because most of the sites in the project area are on public property (Plymouth Creek Park) or within City of Plymouth easements, construction access will be fairly straightforward. Relatively few obstacles or infrastructure elements block access to the proposed work areas. Potential site access locations and staging areas are presented in the figures in Section 5.2.

3.4 Phase I Environmental Assessment

In conformance with ASTM, International (ASTM) Practice E 1527-13A, a Phase I Environmental Site Assessment (Phase I) was completed for the project area in November 2015. A copy of the Phase I assessment is included in Appendix C. The Phase I study area encompassed properties most likely to affect soil within the project area: the 2,800-foot stretch of creek plus properties within 50 feet of the centerline of the creek. This collective grouping of properties is referred to as "the Property" for the purposes of the Phase I. The Phase I was a desktop study and did not include testing sample materials for contamination.

The Phase I did not identify any recognized environmental conditions (i.e., the presence or release of any hazardous substances or petroleum products in, on, or at the Property). Therefore, no areas of the Property are anticipated to require special soils management or corrective action during creek restoration.

The Phase I had one significant data gap, involving a parcel adjoining the creek. The owner of this parcel did not respond to a request for an interview (parcel 22-118-22-22-0030, to the east of Fernbrook Lane). It is recommended that an interview with this owner be conducted prior to commencement of any bank stabilization efforts on that parcel.

3.5 Cultural and historical resources

A reconnaissance survey of Reaches 1 through 3 (see Figure 2-1) was completed during October and November of 2015 to determine if any sites might require further investigation for cultural or historical importance. A records/literature search had previously been conducted at the Minnesota Historical Society. The field survey was completed by comparing historical aerial photographs to current conditions and by walking the relevant reaches to observe conditions on the ground. Regular shovel tests were also conducted to observe conditions below the soil surface. Results for all investigations were negative, indicating that there is little risk of disturbing a site with cultural or historical significance during construction. The full report of the archeological reconnaissance survey is included as Appendix D.

3.6 Wetlands

Portions of Plymouth Creek and fringe wetlands associated with the project area were delineated on September 22, 2015. The wetland delineation was established according to the Routine On-Site Determination Method specified in the USACE Wetlands Delineation Manual (1987 Edition) and the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Midwest Region (USACE, 2010). The delineation and assessment are necessary to meet the requirements of a USACE Section 404 Permit and the Wetland Conservation Act.

Two sections of Plymouth Creek and two fringe wetlands were delineated within the project area. Both sections of the creek were delineated as riverine systems, approximately 2,500 feet long (in total) and composed of both linear and meandering stream channel. Wetlands delineated along fringe areas of Plymouth Creek totaled approximately 0.6 acres and were made up of seasonally flooded basin (Type 1, PEMA) and wet meadow (Type 2, PEMB) communities.

A full summary of the wetland delineation, including figures and field data sheets, is in Appendix E.

4.0 Stakeholder input

4.1 Public stakeholder meetings

A public stakeholder meeting was held at Plymouth City Hall on October 26, 2015, at 7:00 p.m. During the meeting, preliminary design concepts were presented to local residents and users of the Plymouth Creek Park disc golf course. Attendees asked questions and provided some of their observations of the creek. There were no significant concerns raised about the project. Some attendees did indicate a strong desire to have the disc golf course remain in place, although the need for some disruption in access to the course during construction was acknowledged. One long-time resident, who lives adjacent to the creek, was able to validate the findings of historical images—that the tight meander upstream of Annapolis Lane has been in that pattern for many years.

4.2 Technical stakeholder meeting

A technical stakeholder meeting was held at the site on the afternoon of October 26, 2015. Attendees included representatives from the City of Plymouth, Bassett Creek Watershed Management Commission, USACE, Minnesota Department of Natural Resources (MDNR), and Barr Engineering Co. The attendees reviewed the design concepts for each of the three reaches and provided technical feedback. Items discussed included:

- Review of the project schedule and meeting objectives.
- Review of the erosion sites and other creek deficiencies.
- Review and discussion of the design concepts.
- Discussion of permit requirements for potential wetland impacts and stream meanders.
- Discussion of potential habitat improvements.

The meeting provided an opportunity to review the project site and discuss options, considering both ideal restoration scenarios and practical aspects of maintaining existing uses within Plymouth Creek Park. The USACE and MDNR expressed their preference for bioengineering techniques whenever possible. The City described the use of the disc golf course and its popularity. According to the City, it may be possible to realign holes on the course to minimize disturbance along the creek. It may also be possible to temporarily close holes to help re-establish vegetation on the banks; however, permanent closure of portions or all of the disc golf course is not an option. Additional specific outcomes of the discussion are incorporated into the appropriate sections below.

4.3 Technical stakeholder comments

Detailed comments on a draft version of this report were provided by City of Plymouth staff on February 1, 2016. Technical comments were also provided by MDNR staff on February 4, 2016. Comments pertaining to the feasibility study have been incorporated into this final report; additional review of the technical comments is recommended during final design.

5.0 Potential improvements

This section provides a summary of the alternatives for stabilization of Plymouth Creek. Section 5.1 includes a general description of the stabilization alternatives and techniques evaluated (see Appendix F for more detail). Section 5.2 provides a description of all of the sites and the recommended improvements for each site, which are shown in Figure 5-2 through Figure 5-4 and summarized in Table 5-1. Complete discussion of all stabilization alternatives considered for each site is provided in Appendix G.

Rather than presenting several stabilization alternatives for the entire project area or for each reach, the discussion in Section 5.2 focuses on the recommended stabilization measures at each site. Stabilization sites within each reach with similar characteristics and similar stabilization alternatives are discussed together.

Although the sites for stabilization are discussed here individually, final design for the project will likely result in a nearly continuous implementation of stabilization techniques through all three stream reaches. The stabilization sites identified in Figure 5-1 generally abut and overlap one another, although not all stream banks within each reach need stabilization and the recommended stabilization techniques may differ between adjacent sites.

5.1 Description of stabilization alternatives

When selecting alternatives for detailed design and construction, the BCWMC and the City of Plymouth may select differing approaches at each site (even sites with similar characteristics) to best meet the overall project goals. As a result, there are a large number of possible combinations of alternatives that would provide stabilization benefits throughout the entire project area. Furthermore, detailed design efforts may identify and include stabilization techniques or combinations of techniques that are not specifically included in this feasibility study.

5.1.1 Hard armoring and bioengineering stream stabilization techniques

Techniques for stream stabilization generally fall into two categories: hard armoring and bioengineering (also known as soft armoring). Hard armoring techniques include the use of engineered materials such as stone (riprap or boulders), gabions, and concrete to stabilize slopes and prevent erosion. Bioengineering techniques employ biological and ecological concepts to control erosion, using vegetation or a combination of vegetation and construction materials, including logs and boulders. Techniques that do not use vegetative material but are intended to achieve stabilization of natural flow patterns and create in-stream habitat, such as boulder or log vanes, are generally included under the umbrella of bioengineering.

Hard armoring and bioengineering techniques present different challenges, costs, and benefits for stream stabilization design. Hard armoring methods are viewed as standard and time-tested and typically have a longer life span due to the permanence of the materials used. Hard armoring is usually effective in preventing erosion where it is installed; however, placement must consider downstream impacts, understanding that the armoring may push the erosive stresses downstream. Hard armoring typically

requires little maintenance; however, if the armoring fails, maintenance or replacement can be expensive, particularly if the armoring materials need to be removed from the site.

Bioengineering techniques maintain more of a stream's natural function and provide better habitat and a more natural appearance than hard armoring. If vegetation is well-established this approach can also be self-maintaining. Due to biodegradation of construction materials and variable vegetation establishment success, it is typically assumed that bioengineering installations have a shorter life span and may need more frequent (if less expensive) maintenance, particularly as the vegetation is becoming established. Compared to hard armoring, the success of bioengineering techniques is more dependent on the skill of the designer and installer—sometimes making bioengineering construction more expensive.

Technical stakeholders for this Plymouth Creek feasibility study, including the USACE and MDNR, expressed a preference for bioengineering over hard armoring for stream stabilization where possible. In addition, the current BCWMC Watershed Management Plan (see Section 4.2.5 of Reference (1)) states: "recognizing their benefits to biodiversity and more natural appearance, the BCWMC will strive to implement stream and streambank restoration and stabilization projects that use soft armoring techniques (e.g., plants, logs, vegetative mats) as much as possible and wherever feasible."

5.1.2 Stream stabilization techniques evaluated

The following stream stabilization techniques were evaluated for stabilizing Plymouth Creek within the project area. Example figures and additional descriptions for selected techniques are included in Appendix F.

Hard armoring techniques evaluated

- Riprap-lined channel—riprap throughout an entire channel cross section to control stream bed elevations and prevent fluvial erosion
- Stone toe protection—riprap or other stones along the lower portion of a stream bank to protect against fluvial erosion
- Riprap slope stabilization—riprap along a steep slope to protect against fluvial erosion and prevent undercutting and slumping
- Concrete swale—concrete channel below culvert outlet to protect ground from scour

Bioengineering techniques evaluated

- Re-meander—stream channels that are redirected into a historical or newly constructed meandering pattern to add stream length, establish a sustainable meander pattern, add aquatic habitat, and reconnect flood flows to the floodplain
- Meander cutoff—stream channels that are redirected into a shortened pattern by removing meander bends, decreasing problematic bank erosion and accelerating natural processes of channel migration

- Active floodplain/vegetated bench—modifications made to the stream cross section to increase floodplain connectivity and decrease erosive stress during flood flows; can involve construction of a soil bench, lowering an existing bench, and/or raising the channel bed
- Boulder or log vane—boulders or large logs embedded in the stream bank and extending partially (“vanes”) or entirely across the stream (“cross vanes”) to achieve one or more of the following goals: re-direct flows away from banks, encourage sediment deposition in selected areas, control stream bed elevations, and create scour pool habitat features
- Constructed riffle—gravel or cobble material installed in the stream bed to create natural flow patterns/varied habitat features and, frequently, to control stream bed elevations
- Mobile culvert substrate—gravel, cobble, or boulder material installed in the bed of a culvert to maintain sediment transport, create varied flow patterns, facilitate aquatic organism passage, and control stream bed elevations
- Vegetated buffer—native vegetation established along a stream bank or overbank area to stabilize bare soils and increase resistance to fluvial erosion
- Vegetated reinforced slope stabilization (VRSS)—soil lifts created with long-lasting, biodegradable fabric and vegetated to stabilize steep slopes and encourage establishment of root systems for further stabilization
- Root wads or toe wood—tree trunks with the root ball attached, installed either singly (root wads) or in conjunction with additional large woody debris and VRSS (toe wood) to achieve one or more of the following goals: increase bank roughness and resistance to erosion, create undercut/overhanging bank habitat features, re-direct flows away from banks, and provide a bench for establishment of riparian vegetation

5.1.3 Non-site-specific techniques and considerations

Due to the public park setting and traffic from a popular disc golf course, there are techniques and considerations that are not specific to individual erosion sites.

Management of revegetated areas: Regardless of the specific techniques chosen to stabilize individual sites, there will be areas that will be revegetated during construction. During the development of this study, the Plymouth Parks and Recreation Department staff have described usage of the disc golf course and potential issues with managing foot traffic in revegetated areas, and the City has recommended a discussion with the Commission regarding the extent of revegetation to ultimately be included with this project.

The concepts developed in this report include a line-item for a project-wide approach to manage foot traffic within the revegetation areas to make the efforts more effective, and it is assumed the project-wide approach will use a combination of fencing (temporary or permanent), signage, designated walking paths, and disc retrieval poles already available on the course. The final design should include close coordination

with the Plymouth Parks and Recreation Department to develop a long-term means to manage and/or exclude foot traffic from revegetated areas.

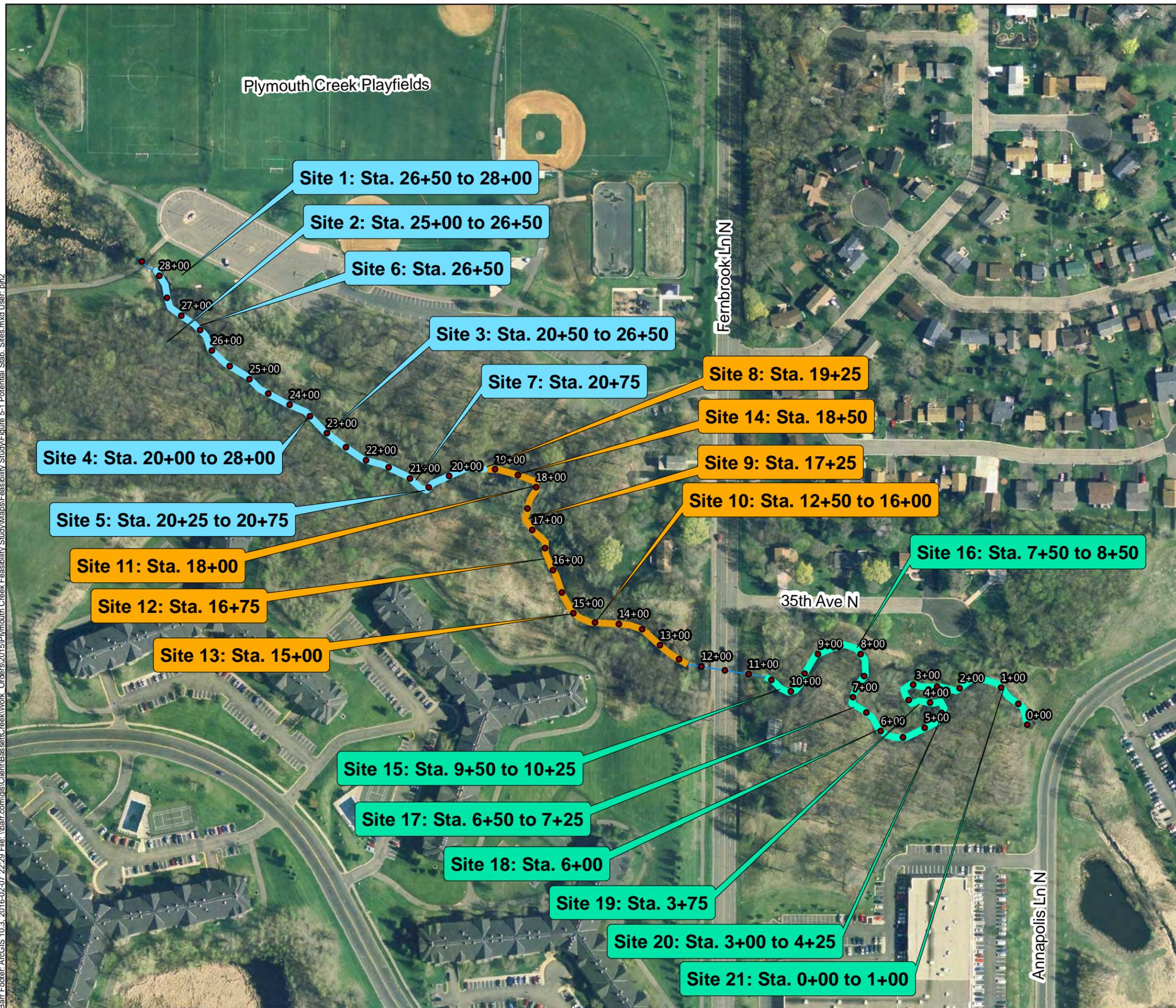
Educational Signage: The public setting provides an opportunity to educate park users about riparian ecology and the efforts of the BCWMC and City of Plymouth to improve water quality by stabilizing erosion sites. It will also provide a means to encourage disc golfers to use the retrieval poles and stay out of the revegetation areas.

5.2 Recommended alternatives for stabilization

The following discussion is organized by location within each reach, referred to as “stabilization sites.” The stabilization sites for the entire project area are shown in Figure 5-1. Stabilization sites within each reach with similar characteristics and stabilization alternatives are discussed together in the following sections. Recommended stabilization alternatives for each reach are shown in Figure 5-2 (Reach 1), Figure 5-3 (Reach 2), and Figure 5-4 (Reach 3). Complete discussion of the stabilization alternatives considered for each site is included in Appendix G.

The final project will consist of a combination of the alternatives discussed in Appendix G. The alternatives recommended for the final design are summarized in the following sections. The advantages and disadvantages of the recommended stabilization alternatives are summarized in Table 5-1. Alternatives that could be implemented in combination were chosen if they presented cost-effective pollutant loading reductions (see Sections 6.0 and 7.0) without producing significant impacts to surrounding land uses. In cases where only one alternative could be implemented, priority was given to options that were innovative, cost-effective, and used natural materials. The ability of alternatives to improve stream habitat and vegetative surroundings (identified as priorities in stakeholder meetings) was also taken into consideration in choosing the final alternatives.

Barr Footer: ArcGIS 10.3. 2016-02-07 22:29 File: \\barr.com\gis\client\BassettCreek\Work_Orders\2015\PlymouthCreek\Feasibility Study\Maps\Feasibility Study\Figure 5-1 Potential Stab. Sites.mxd User: ph2



Legend

- Non-Reach Creek
- Reach 3
- Reach 2
- Reach 1

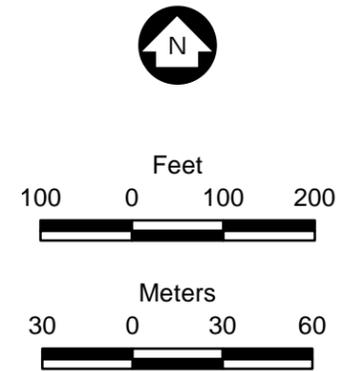


Figure 5-1

PLYMOUTH CREEK POTENTIAL STABILIZATION SITES
 Plymouth Creek Feasibility Study
 Bassett Creek Watershed Management Commission

5.2.1 Sites 1 and 2

Sites 1 and 2 consist of a relatively straight reach that appears to have straightened over time due to low sinuosity and the presence of abandoned meanders from Station 26+50 to 28+00 (Site 1) and 25+00 to 26+50 (Site 2), shown on Figure 5-2. The existing stream between the historical channels has some bare lower stream banks; a footbridge for the disc golf course crosses the stream. The erosion on the banks of the existing channel is relatively minor.

Recommended alternative summary (Alternatives 1C and 2C): Install root wads and log vanes to stabilize eroding areas. Use log vanes to reshape the channel bottom and narrow the low-flow channel while maintaining the overall channel cross section. Establish vegetation on bare banks.

5.2.2 Site 3

Site 3 consists of an over-widened stream channel with a small active floodplain. It extends from Station 20+50 to 26+50, as shown on Figure 5-2. There are many areas where sediment is being deposited near the banks and the channel is beginning to narrow. Due to the wide channel bottom, water depth is very low during low-flow conditions, resulting in poor aquatic habitat. The channel banks are bare and the dense tree canopy overhead creates consistent shade along the stream channel.

Recommended alternative summary (Alternatives 3B and 3C): Install log vanes and reshape the channel bottom to narrow the low-flow channel while maintaining the overall channel cross section. Use one or more log cross vanes to provide grade control and prevent downcutting. Vegetate existing bare upper banks above the bankfull flow elevation with shade-tolerant trees, shrubs, and seed mixes. This alternative will benefit from a project-wide plan to establish vegetation while managing foot traffic from the disc golf course.

5.2.3 Site 4

Site 4 includes overbank areas on both sides of the creek, but primarily on the south (Figure 5-2), outside of the stream channel areas described above for Site 3. Due to the heavy use of the disc golf course, this area is largely unvegetated, resulting in significant sediment transfer from the bare ground to the stream.

Recommended alternative summary (Alternative 4A): Install vegetation to create additional vegetated buffer areas on both sides of the creek. This recommendation is contingent on the implementation of a plan to establish vegetation and manage disc golf traffic.

5.2.4 Site 5

Site 5 is near the downstream end of Reach 1 (see Figure 5-2). A steep eroding outer bank is present near this site. The high clay content of the soils limits the rate of bank migration, but stabilizing the bank would remove a source of sediment to the stream and improve its aesthetics near a footbridge crossing.

Recommended alternative summary (Alternative 5B): Install bioengineering in the form of VRSS in front of the existing bank to minimize grading into the bank and create a bankfull bench in front of the bank.

5.2.5 Sites 6, 7, 8, and 9

Four pedestrian bridges used by disc golfers are located within Reach 1 (Sites 6 and 7, Figure 5-2) and Reach 2 (Sites 8 and 9, Figure 5-3). Erosion around the bridge abutments is present at all four bridges.

Recommended alternative summary (Alternatives 6A through 9A): Install hard armor (riprap) around each abutment and log vanes upstream of each abutment to direct flow to the center of the river and encourage sedimentation around the bridge abutments.

5.2.6 Site 10

Site 10 includes much of the stream channel located in the downstream half of Reach 2 (see Figure 5-3). The stream bed in this section appears to be mildly incised, resulting in limited access to the floodplain. Incised streams often have greater-than-average erosion; unlike streams that are well-connected to the floodplain, they do not effectively transfer flood energy. The excess energy causes bank erosion, suggesting the erosion at this site may continue to worsen. If the channel incision migrates upstream, additional banks and lengths of stream may be more prone to erosion.

Recommended alternative summary (Alternatives 10C and 10D): Raise the channel bed elevation with boulder cross vanes or constructed riffles to act as localized grade control and improve connectivity of flood flows with the floodplain. Lower portions of the floodplain adjacent to the stream channel as needed to improve connectivity of flood flows with the floodplain and maintain the existing flood profile.

5.2.7 Sites 11 through 13

Eroding banks are present in several locations in Reach 2. Sites 11 through 13 are located within the section of Plymouth Creek addressed in Site 10 (see Figure 5-3). Stabilization of these sites could be performed instead of or in conjunction with one of the alternatives described for Site 10.

Recommended alternative summary (Alternatives 11B through 13B): Install root wads around eroding bends to direct flow to the center of the stream and grade the eroding bank to a more stable slope.

5.2.8 Site 14

Site 14 includes the outfall from a 12-inch-diameter PVC pipe draining from the Plymouth Creek Park parking area to Plymouth Creek (see Figure 5-3). The outfall of this pipe has limited stabilization and is causing sediment to erode into the creek.

Recommended alternative summary (Alternative 14A): Install riprap from the pipe outlet to the stream.

5.2.9 Sites 15, 16, and 17

Steep eroding banks are present in three locations within Reach 3, as shown on Figure 5-4. In these locations, the bend radius is not overly tight, but the stream channel is cutting into high valley walls, causing bank failures, and undercutting trees.

Recommended alternative summary (Alternatives 15C, 16C, and 17B): Install toe wood (root wads and large woody debris) around the first two eroding bends (Sites 15 and 16) to increase roughness of the lower banks and establish a vegetated bench at the toe of the high, eroding banks. Install boulder or log vanes around the third eroding bend (Site 17) to direct flow to the center of the stream.

5.2.10 Sites 18 and 19

Large woody debris is present in two primary locations within the stream (see Figure 5-4). The debris causes jams within the stream—redirecting flow towards the banks, which causes bank erosion.

Recommended alternative summary (Alternatives 18A and 19A): Remove existing large woody debris from the stream.

5.2.11 Site 20

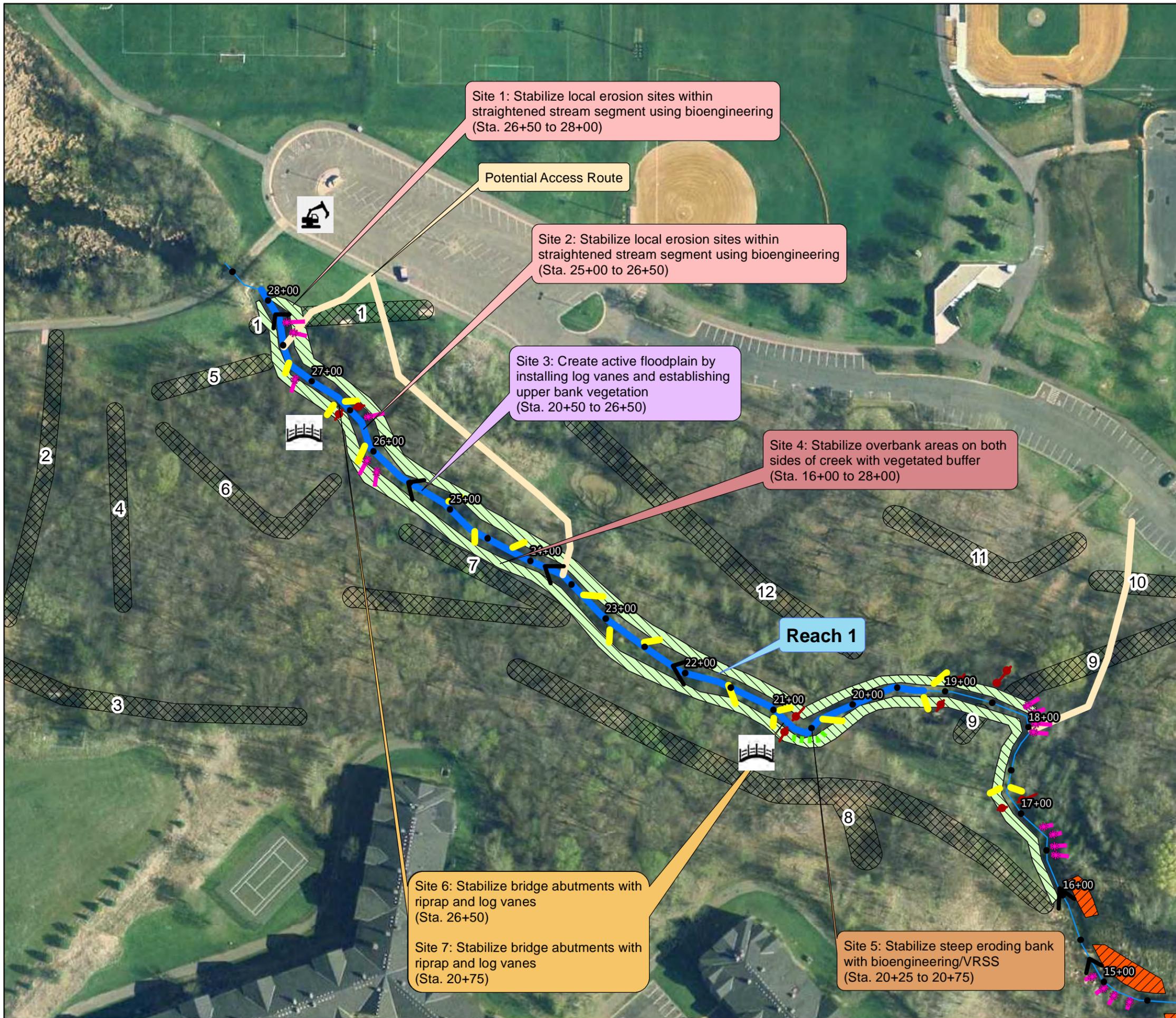
A tight meander is present within the downstream half of Reach 3 (Station 3+00 to 3+50 on Figure 5-4). The meander radius is overly small, making the bend unstable and contributing to significant erosion of the outer bank. In addition, the meander is being cut off at the upstream bend (Station 4+25).

Recommended alternative summary (Alternative 20D): Change the stream channel alignment upstream of the cutoff and the tight meanders (from approximately Station 3+00 to 6+25) to create meanders with stable curvature. Install toe wood (root wads and large woody debris) around the eroding bends (Station 3+00 to 3+50 and 4+00 to 4+50) and boulder or log vanes to increase roughness of the lower banks and establish a vegetated bench at the toe of the high, eroding banks.

5.2.12 Site 21

Similar to Site 3 in Reach 1, Site 21 consists of an over-widened stream channel without an active floodplain (see Figure 5-4).

Recommended alternative summary (Alternative 21B): Install log vanes and reshape the channel bottom to narrow the low-flow channel while maintaining the overall channel cross section.



Legend

- Riprap
- Rootwads
- Vanes
- VRSS
- Construction Access
- Vegetated Buffer
- Pedestrian Bridge
- Culvert Outfall
- Construction Staging Location
- Disc Golf Fairway

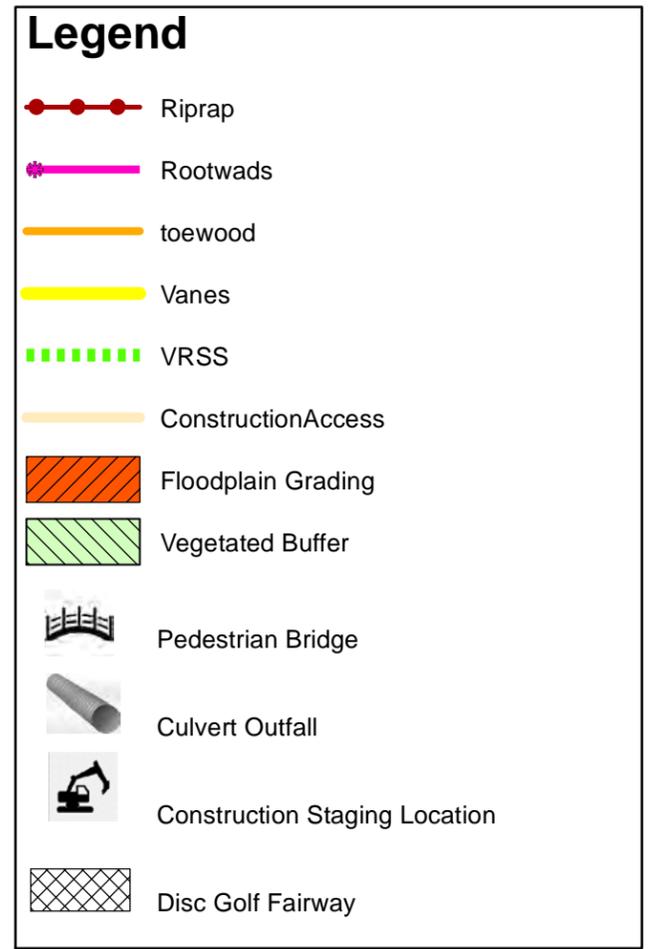
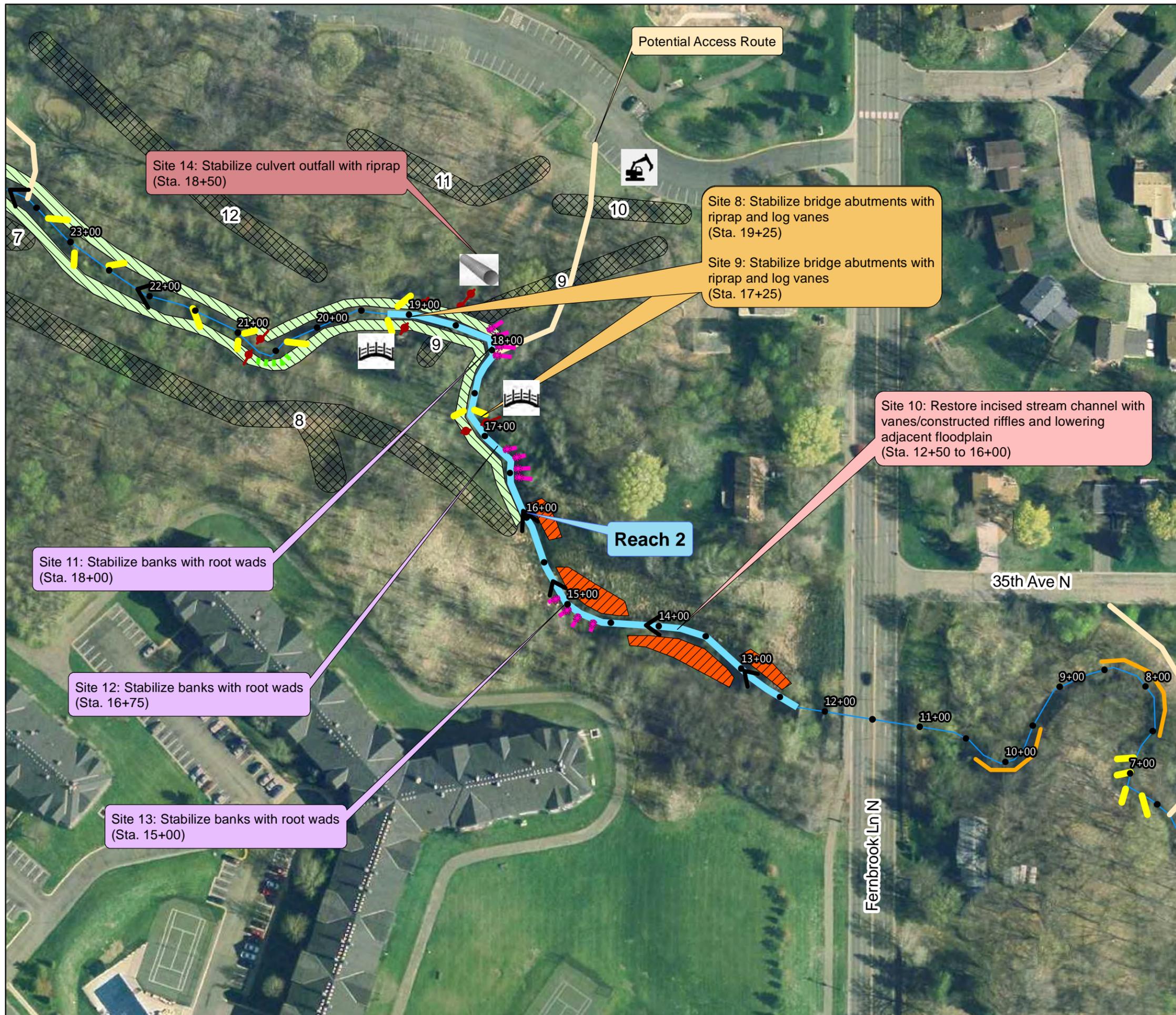
Note: Temporary closures to disc golf course may be necessary during construction.

N

Feet

100 0 100 200

Figure 5-2
 PLYMOUTH CREEK REACH 1
 RECOMMENDED ALTERNATIVES
 Plymouth Creek Feasibility Study
 Bassett Creek Watershed
 Management Commission



Note: Temporary closures to disc golf course may be necessary during construction.

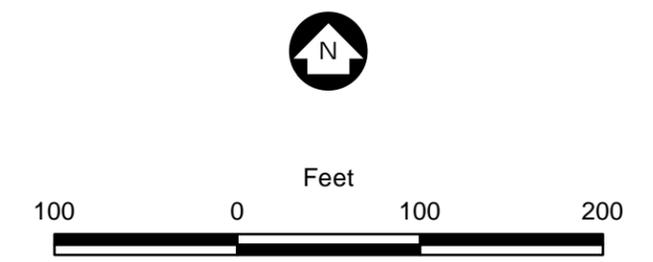


Figure 5-3

PLYMOUTH CREEK REACH 2
 RECOMMENDED ALTERNATIVES
 Plymouth Creek Feasibility Study
 Bassett Creek Watershed
 Management Commission

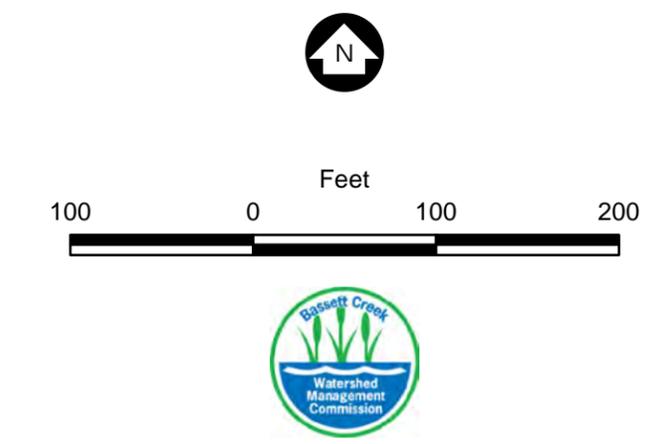
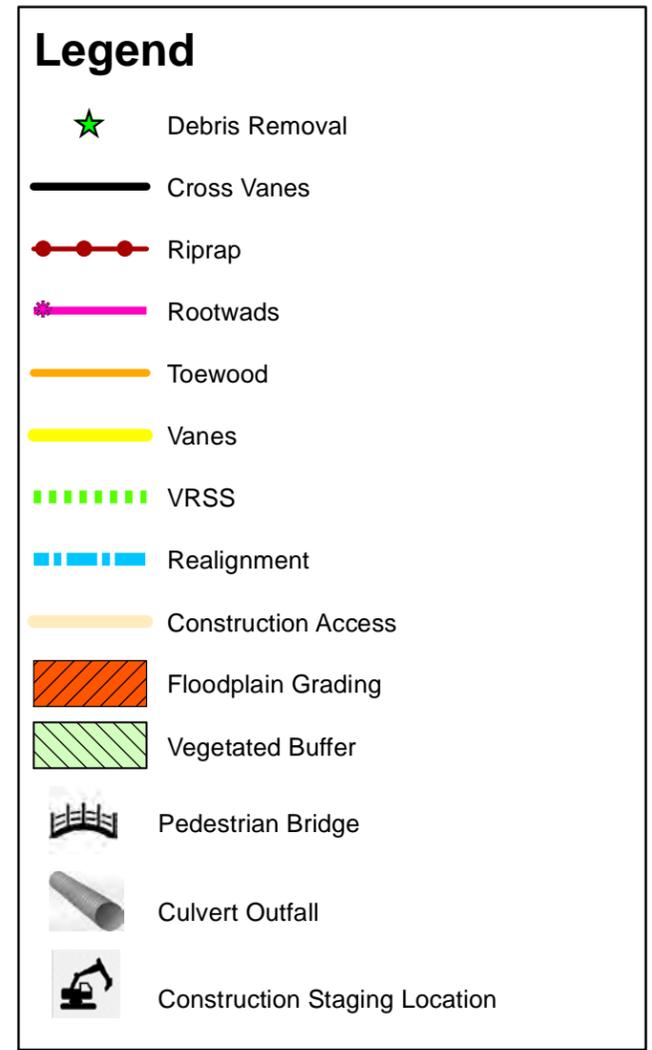
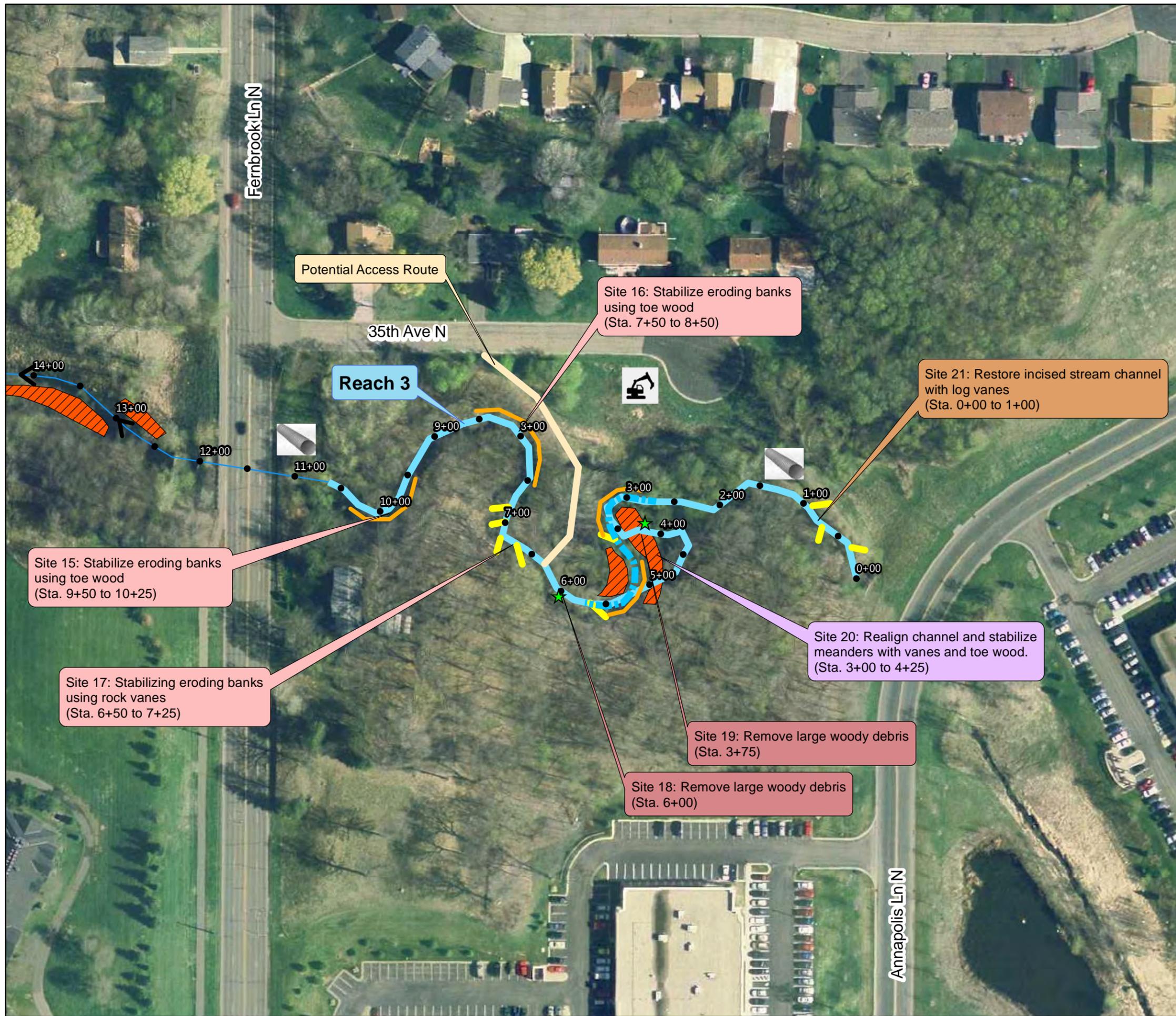


Figure 5-4
 PLYMOUTH CREEK REACH 3
 RECOMMENDED ALTERNATIVES
 Plymouth Creek Feasibility Study
 Bassett Creek Watershed
 Management Commission

Table 5-1 Plymouth Creek feasibility study recommended alternatives summary

Reach	Site	Alternative	Alternative Description	Advantages	Disadvantages
Reach 1	Site 1	Alternative C	Stabilize erosion areas with root wads, log vanes, and vegetation	Contributes to habitat, provides grade control, and utilizes materials generated on site.	Does not use historic channels, vegetation limited to shade-tolerant species.
Reach 1	Site 2	Alternative C	Stabilize erosion areas with root wads, log vanes, and vegetation	Contributes to habitat, provides grade control, and utilizes materials generated on site.	Does not use historic channels, vegetation limited to shade-tolerant species.
Reach 1	Site 3	Alternative B	Install log vanes within reach	Improves habitat by deepening channel, provides grade control, reduces upper bank stress.	Does not create vegetated floodplain.
Reach 1	Site 3	Alternative C	Upper bank vegetation	Improves aesthetics of stream bank, reduces erosion.	Requires careful coordination with disc golf users, vegetation limited to shade-tolerant species.
Reach 1	Site 4	Alternative A	Establish vegetated buffer	Improves aesthetics of riparian area, reduces erosion.	Requires careful coordination with disc golf users, vegetation limited to shade-tolerant species.
Reach 1	Site 5	Alternative B	Vegetate steep, eroding bank with VRSS	Contributes to habitat, improves aesthetics.	More costly to install, vegetation limited to shade-tolerant species.
Reach 1	Site 6	Alternative A	Stabilize bridge abutments with riprap and log vanes	Reduces erosion, reduces erosive pressure on abutments for added protection.	Riprap does not provide natural habitat, more complex design.
Reach 1	Site 7	Alternative A	Stabilize bridge abutments with riprap and log vanes	Reduces erosion, reduces erosive pressure on abutments for added protection.	Riprap does not provide natural habitat, more complex design.
Reach 2	Site 8	Alternative A	Stabilize bridge abutments with riprap and log vanes	Reduces erosion, reduces erosive pressure on abutments for added protection.	Riprap does not provide natural habitat, more complex design.
Reach 2	Site 9	Alternative A	Stabilize bridge abutments with riprap and log vanes	Reduces erosion, reduces erosive pressure on abutments for added protection.	Riprap does not provide natural habitat, more complex design.
Reach 2	Site 10	Alternative C	Raise channel bed using cross vanes/constructed riffles	Reduces bed and bank erosion, improves stream access to floodplain.	Decreases already shallow slope, does not address stream cross-section in other locations.
Reach 2	Site 10	Alternative D	Lower adjacent floodplain	Improves stream access to floodplain, improves buffer habitat, reduces flood elevation.	Significant disturbance of wetland, may require significant grading, requires coordination with sanitary manholes.
Reach 2	Site 11	Alternative B	Stabilize banks with root wads	Reduces bank erosion, improves in-stream habitat, utilizes materials generated on site.	Requires tree removals, more complex design.
Reach 2	Site 12	Alternative B	Stabilize banks with root wads	Reduces bank erosion, improves in-stream habitat, utilizes materials generated on site.	Requires tree removals, more complex design.
Reach 2	Site 13	Alternative B	Stabilize banks with root wads	Reduces bank erosion, improves in-stream habitat, utilizes materials generated on site.	Requires tree removals, more complex design.
Reach 2	Site 14	Alternative A	Stabilize culvert outfall with hard armor	Inexpensive, effectively stabilizes outfall from erosion.	Does not provide natural habitat, not aesthetically pleasing.
Reach 3	Site 15	Alternative C	Install bank stabilization measures at eroding banks using toe wood	Stabilizes bank and reduces stress and erosion, provides habitat, utilizes materials generated on site.	Installation can be challenging, useful life is less than other options, requires significant woody debris.
Reach 3	Site 16	Alternative C	Install bank stabilization measures at eroding banks using toe wood	Stabilizes bank and reduces stress and erosion, provides habitat, utilizes materials generated on site.	Installation can be challenging, useful life is less than other options, requires significant woody debris.
Reach 3	Site 17	Alternative B	Install 4 rock vanes for bank protection	Reduces erosive stress and bank erosion, improves in-stream habitat.	Can result in increases in flood elevations, less effective at high flows.
Reach 3	Site 18	Alternative A	Remove large woody debris	Reduces flooding potential and bank erosion.	Decreases stream roughness and may increase flow velocity.
Reach 3	Site 19	Alternative A	Remove large woody debris	Reduces flooding potential and bank erosion.	Decreases stream roughness and may increase flow velocity.
Reach 3	Site 20	Alternative D	Realign channel and stabilize meanders with vanes and toe wood	Stabilizes bank and reduces stress and erosion, provides habitat, utilizes materials generated on site, improves cross section stability.	Reduces stream length and increases stream slope, installation can be challenging, useful life is less than other options, requires significant woody debris.
Reach 3	Site 21	Alternative B	Install log vanes within reach	Improves habitat by deepening channel, provides grade control, reduces upper bank stress.	Does not create vegetated floodplain.

6.0 Project impacts

This section discusses the impacts of a stabilization project, including the land ownership and permitting requirements and the estimated pollution reduction resulting from each alternative.

6.1 Easement acquisition

Nearly all of the proposed work sites are located on City of Plymouth property, or within existing easements. Temporary construction easements are not included in the opinion of cost and are not expected to have significant effect on cost along the City property. A small piece of Reach 3 may require an easement or temporary right of entry; however, the property impact is minor and not anticipated to cause significant issues. The property's owner attended the public stakeholder meeting and expressed support for the project; it is assumed this owner will be willing to work with the City on an easement agreement.

6.2 Permits required for the project

The proposed project will require 1) a Clean Water Act Section 404 permit from the USCAE, or Letter of Permission under a General Permit, and Section 401 certification from the Minnesota Pollution Control Agency (MPCA), 2) compliance with the Minnesota Wetland Conservation Act, 3) a Construction Stormwater General Permit from the MPCA and compliance with the MPCA's guidance for managing dredged materials, 4) a Public Waters Work Permit from the MDNR, 5) compliance with Minnesota environmental review rules, and 6) a grading permit from the City of Plymouth.

Section 404 Permit

According to Section 404 of the Clean Water Act (CWA), the USACE regulates the placement of fill into wetlands if they are hydrologically connected to a Water of the United States. In addition, the USACE may regulate all proposed wetland alterations if any wetland fill is proposed. The MPCA may be involved in wetland mitigation requirements as part of the CWA Section 401 water quality certification process for the 404 Permit.

As discussed in Section 2.2.2.2, the BCWMC developed its Resource Management Plan (RMP), with the goal of completing a conceptual-level USACE permitting process for proposed projects. The RMP was submitted to the USACE in April 2009 and revised in July 2009. This feasibility study follows the protocols for projects within the BCWMC RMP.

The USACE 404 permit requires a Section 106 review for historic and cultural resources. The results of the archeological reconnaissance study are included as Appendix D. If more detailed information is requested by the State Historic Preservation Office (SHPO), a Phase I Archeological Survey may need to be completed. A Phase I Archeological Survey can be completed in 45 days or less during a frost-free period. The USACE staff anticipates that the 404 permit review and approval process could require 120 days to complete.

Minnesota Pollution Control Agency (MPCA) Permits

Construction of the proposed project will require a National Pollutant Discharge Elimination System/State Disposal System Construction Stormwater (CSW) General Permit issued by the MPCA. The CSW permit will require the preparation of a stormwater pollution prevention plan that explains how stormwater will be controlled within the project area during construction.

Based on the findings of the Phase I Environmental Assessment (Appendix C), it is not anticipated that environmental impacts such as contaminated soil and debris will be encountered during stream restoration activities; therefore it is not anticipated that the project will require additional permits for disposing of contaminated soil. In the unlikely event that environmental impacts are encountered during the creek restoration earthwork, contaminated materials will need to be handled and managed appropriately. The response to discovery of contamination typically includes entering the MPCA's voluntary program. In accordance with MPCA guidance, a construction contingency plan could be prepared for the project. This would include specifying initial procedures for handling potentially impacted materials, collecting analytical samples, and working with the MPCA to determine a method for managing impacted materials.

Public Waters Work Permit

The MDNR regulates projects constructed below the ordinary high water level of public waters, watercourses, or wetlands, which alter the course, current, or cross section of the water body. Public waters regulated by the MDNR are identified on published public waters inventory maps. Plymouth Creek is a public watercourse, so the proposed work will require a MDNR public waters work permit.

Minnesota Environmental Assessment Worksheet

The Minnesota administrative rules (MN Rules 4410.4300) require the preparation of an Environmental Assessment Worksheet (EAW) for any project that will "change or diminish the course, current, or cross-section of one acre or more of any public water or public waters wetland." Depending on the amount of grading within the floodplain required for final design of Site 10 (see Section 5.2.6), the proposed work may disturb more than one acre along Plymouth Creek and the adjacent wetlands. Therefore the proposed work may require preparation of an EAW to be submitted to the Minnesota Environmental Quality Board (MEQB).

Minnesota Wetland Conservation Act

The Minnesota Wetland Conservation Act (WCA) regulates the filling and draining of wetlands and excavation within Type 3, 4, and 5 wetlands—and may regulate any other wetland type if fill is proposed. The WCA is administered by local government units (LGU), which include cities, counties, watershed management organizations, soil and water conservation districts, and townships. The City of Plymouth is the LGU for the entire project area. The Minnesota Board of Water and Soil Resources (BWSR) oversees administration of the WCA statewide.

As described in Minnesota rules 8420, WCA is not applicable to the types of wetland impacts that will be a part of this project and a permit related to wetland impacts will not be required; however the LGU will have the final determination.

MDNR may determine that the project area qualifies as a public waters wetland and require permitting. The proposed project will involve grading existing stream banks and excavation in a wetland floodplain to provide better floodplain connection. This type of work can generally be considered self-mitigating and/or enhancing existing wetlands, and therefore, is not expected to require wetland mitigation.

Local Permits

The City of Plymouth will require a permit for grading work within the City’s jurisdiction. The City’s requirements should be reviewed within the context of the specific work to be performed at each site.

Table 6-1 shows the list of expected permitting agencies for each reach. This list is only an estimate; each reach should be scoped for permits as the site construction details are developed.

Table 6-1 Potential permit requirements by work site

Reach Number	Agencies Who May Require Permits
1	City of Plymouth, MDNR, MPCA, MEQB, USACE
2	City of Plymouth, MDNR, MPCA, MEQB, USACE
3	City of Plymouth, MDNR, MPCA, MEQB, USACE

6.3 Water quality impacts

The proposed stabilization measures will result in reduced stream bank erosion and, therefore, reduced sediment and phosphorus loading to Plymouth Creek and all downstream water bodies, including Medicine Lake, the Mississippi River, and Lake Pepin. The existing stream bank erosion rate (in units of feet per year) for each stabilization site has been estimated based on a field assessment method known as the Bank Assessment for Non-Point Source Consequences of Sediment (BANCS) model (Reference (3)).

The BANCS model uses two erosion-estimation tools to develop risk ratings for the Bank Erosion Hazard Index (BEHI) and the Near-Bank Stress (NBS). The BEHI rating evaluates the susceptibility of a segment of stream bank to erosion as a result of multiple processes: surface erosion, fluvial entrainment, and mass erosion (wasting). The NBS rating characterizes the energy distribution against a segment of stream bank; disproportionate energy distribution in the near-bank region can accelerate bank erosion. The BEHI and NBS estimation tools are applied in a field assessment for each segment of stream bank potentially contributing sediment to the stream channel. The Commission Engineer performed BEHI and NBS assessments for multiple segments of Plymouth Creek during site visits in September 2015.

The field-determined BEHI and NBS ratings for each site along Plymouth Creek are shown in Table 6-2. Sites in Reach 1 and the upstream portions of Reach 2 are generally rated “very low” or “low” for BEHI due to the clay soils in the stream banks, which limit bank erosion. Most sites in Reach 2, where the soils are

more granular and the banks somewhat higher, are rated “moderate” for BEHI. Most sites in Reach 3 are also rated moderate due to higher eroding banks. For NBS, sites in all reaches are rated low—except for sites with localized stresses due to tight meander bends or flow obstructions (bridge abutments or woody debris). The only site rated high for NBS is Site 20, which has an overly tight meander.

To convert BEHI and NBS ratings into a stream bank erosion rate estimate, the BANCS model relies on measured bank erosion data to develop relationships applicable to various hydrologic and geologic conditions. No such relationship is currently available for Minnesota; this feasibility study uses relationships developed from data collected in sedimentary and metamorphic geologic regions in Colorado (Figure 5-34 of Reference (3)). The estimated bank erosion rate for each stabilization site is shown in Table 6-2; estimated erosion rates range from 0.02 feet per year to 0.40 feet per year.

The estimated total sediment load from bank erosion is calculated using the approximate dimensions of the eroding stream banks at each site. The effects of stabilization alternatives on water quality are estimated based on the assumption that each stabilization alternative successfully addresses erosion at the site and brings erosion to a low rate, representative of a stable stream in this geologic setting. For this analysis, a stable low erosion rate is assigned a nominal value of 0.01 feet per year due to the clay soils in Sites 1-5 and 0.04 feet per year at the remainder of the sites. The resulting estimated sediment load reduction for stabilization at each site is shown in Table 6-2. The corresponding reduction of total suspended sediment (TSS) and total phosphorus (TP) load are calculated using an estimation tool developed by BWSR (Reference (4)) and shown in Table 6-2. The BWSR tool assumes that all eroded sediment becomes TSS, which is conservative because eroded sand and gravel typically is not suspended but is transported as bedload. Given the high clay content in the banks throughout the project area, this assumption is reasonable. The BWSR tool also assumes that TP load is equivalent to 1.15 pound TP per pound of eroded sediment.

The total reduction in pollutant loading as a result of stabilizing the sites within the project area is estimated as 90,800 pounds per year TSS and 52.2 pounds per year TP. The majority of this load reduction will be achieved by stabilizing the eroding banks in Reaches 2 and 3. The load reduction achieved by the project may assist in meeting the load reduction goals for TP described in the Medicine Lake Excess Nutrients TMDL Implementation Plan (Reference (5), see Section 2.2.2.3), which include a goal of 711 pounds per year TP reduction from streambank stabilization along Plymouth Creek.

The pollutant loading and reduction computations completed were limited to analysis of the stream banks. Bare soils within the disc golf course also likely contribute some additional sediment loading to the stream; however quantification of the sediment loading from the disc golf course is not straightforward because slopes and amount of effective buffer between the fairways and the stream are variable. A consistent vegetative buffer along the creek will help intercept sediment in runoff from bare soils. In addition, trees removed for the project could be chipped on site and the wood chips placed on bare soils within the disc golf course to reduce sediment loading to the creek.

Table 6-2 Estimated existing bank erosion and pollutant loading by site

Reach	Site	Site Description	Site Length (1)(2)	Est. Avg. Bank Height (ft)	BEHI rating	NBS rating	Est. Erosion Rate ⁽³⁾ (ft/yr)	Est. Sed. Load ⁽⁴⁾ (ton/yr)	"Stable" Sed. Load ⁽⁵⁾ (ton/yr)	Est. Sed. Load Reduction (ton/yr)	TSS Reduction ⁽⁶⁾ (lb/yr)	TP Reduction ⁽⁶⁾ (lb/yr)
Reach 1	Site 1	Historically straightened with bare lower banks	142	2.5	Very low	Low	0.02	0.3	0.2	0.2	340	0.20
Reach 1	Site 2	Historically straightened with bare lower banks	164	2.5	Very low	Low	0.02	0.4	0.2	0.2	390	0.23
Reach 1	Site 3	Straight channel, over-wide with bare upper banks	600	2.5	Very low	Low	0.02	2.9	1.4	1.4	2,890	1.7
Reach 1	Site 4	Overbanks adjacent to Site 3, bare ground	800	2.5	Very low	Low	0.02	3.9	1.9	1.9	3,850	2.2
Reach 1	Site 5	Steep eroding bank at meander bend	60	4	Moderate	Low	0.15	1.7	0.1	1.6	3,240	1.9
Reach 1	Site 6	Pedestrian bridge with erosion at abutments	10	3	Low	Moderate	0.08	0.2	0.1	0.1	230	0.13
Reach 1	Site 7	Pedestrian bridge with erosion at abutments	10	3	Low	Moderate	0.08	0.2	0.1	0.1	230	0.13
Reach 2	Site 8	Pedestrian bridge with erosion at abutments	10	3	Low	Moderate	0.08	0.2	0.1	0.1	230	0.13
Reach 2	Site 9	Pedestrian bridge with erosion at abutments	10	3	Low	Moderate	0.08	0.2	0.1	0.1	230	0.13
Reach 2	Site 10	Mildly incised stream channel upstream of Fernbrook Lane	350	3.5	Moderate	Low	0.15	2.0	0.5	1.5	2,970	1.7
Reach 2	Site 11	Eroding bank at meander bend	90	3.5	Moderate	Low	0.15	2.3	0.6	1.7	3,340	1.9
Reach 2	Site 12	Eroding bank at meander bend	90	3.5	Moderate	Low	0.15	2.3	0.6	1.7	3,340	1.9
Reach 2	Site 13	Eroding bank at meander bend	90	3.5	Moderate	Low	0.15	2.3	0.6	1.7	3,340	1.9
Reach 2	Site 14	Outfall from parking area drainage pipe with erosion	90	1	Moderate	Low	0.15	1.3	0.3	1.0	1,910	1.1
Reach 3	Site 15	High eroding bank at meander bend	100	6	Moderate	Moderate	0.25	7.2	1.2	6.1	12,130	7.0
Reach 3	Site 16	High eroding bank at meander bend	100	6	Moderate	Moderate	0.25	7.2	1.2	6.1	12,130	7.0
Reach 3	Site 17	High eroding bank at meander bend	100	6	Moderate	Moderate	0.25	7.2	1.2	6.1	12,130	7.0
Reach 3	Site 18	Large woody debris jam with bank erosion	10	2	Low	Moderate	0.08	0.2	0.1	0.1	150	0.09
Reach 3	Site 19	Large woody debris jam with bank erosion	10	2	Low	Moderate	0.08	0.2	0.1	0.1	150	0.09
Reach 3	Site 20	Tight meander with eroding bank and developing cutoff	150	4	Moderate	High	0.40	11.6	1.2	10.4	20,800	12.0
Reach 3	Site 21	Straight channel, over-wide with bare upper banks	80	4	Moderate	Low	0.15	4.6	1.2	3.4	6,780	3.9
Totals								58.4	13.0	45.4	90,800	52.2

(1) For site lengths in *italics*, bank erosion is estimated to occur along both banks (total length of eroding bank is double the site length).

(2) Sites 11-13 are included within Site 10; bank erosion length for Site 10 assumes Sites 11-13 are stabilized separately.

(3) Erosion rates derived from Colorado BEHI/NBS data for sedimentary/metamorphic geology, Figure 5-34 of Reference (3).

(4) Calculated as length (ft) x height (ft) x erosion rate (ft) / 27 (ft³/cy) x 1.3 (ton/cy).

(5) Estimated from a representative very low BEHI, very low NBS erosion rate of 0.01 ft/yr for Sites 1-5. Estimated from a representative low BEHI, low NBS erosion rate of 0.04 ft/yr for Sites 6-21.

(6) Calculated from equations in Reference (4), TSS reduction of 1.0 lb/lb sediment, TP reduction of 1.15 lb/ton sediment.

6.4 Other project impacts

Tree Loss

The proposed project includes the removal of approximately 100–150 trees; the final number will depend on the alternatives selected. All of the trees are located in areas where bank grading or site access will be necessary. A detailed tree inventory should be completed during the final design process with the goal of identifying specific trees to remove and save. Required tree removals should target dying or diseased and undercut trees first, followed by less desirable or disease susceptible species such as box elder, cottonwood, and ash. Close coordination with the City of Plymouth forestry department will be important. Public stakeholder input on tree loss will also be sought.

Many of the trees removed for the project are proposed to be reused on site as part of stream stabilization measures. Trees not used for bank stabilization could be chipped and placed on bare soils in heavily used portions of the disc golf course to reduce sediment generation during runoff events.

Impacts to Bats

Preservation of bat species in Minnesota has recently become an important issue. White Nose Syndrome (WNS) has been attributed to the deaths of millions of bats in recent years across the United States, and all four species that hibernate in Minnesota are susceptible to the disease (Reference (5)). Bats typically hibernate in sheltered areas such as caves, but some bats nest in trees during summer months. Extensive tree removals are to be avoided when bats are not hibernating to avoid inadvertently destroying nests. During final design, there should be additional consultation with the US Fish and Wildlife Service or MDNR regarding the timing of tree removals and the potential impacts to bats.

Sanitary Sewer

A sanitary sewer trunk line for the City of Plymouth runs through the stream valley. The pipe is buried approximately 15–20 feet below the ground surface; however, four manholes are located at the surface in the vicinity of Reaches 1 and 2. The final project design should avoid disturbance of these manholes, if possible, and unobstructed access to the manholes for maintenance purposes should be maintained. Prior to final design for this project, the City of Plymouth should determine whether any sewer maintenance near Plymouth Creek is necessary so that impacts to the project area can be minimized, if possible.

Impacts to Plymouth Creek Park

Due to the proximity of the disc golf course to some of the stabilization sites in Reaches 1 and 2, temporary closures of portions of the course will likely be necessary during construction to ensure the safety of park users. Plymouth Park and Recreation Department staff have indicated that a temporary closing (up to of a year) specific disc golf holes may be acceptable to achieve initial vegetation establishment in the riparian areas. Multi-year or permanent hole or course closures would not be acceptable and were not considered as part of this project.

7.0 Project cost considerations

This section presents a screening-level cost estimate of the evaluated alternatives, discusses potential funding sources, and provides an approximate project schedule.

7.1 Cost estimate

The cost estimate is a Class 4 feasibility-level cost estimate as defined by the American Association of Cost Engineers International (AACI International) and uses the assumptions listed below and detailed in the following sections.

- The cost estimate assumes a 30% construction contingency.
- Costs associated with design, permitting, and construction observation (collectively “engineering”) is assumed to be 30% of the estimated construction costs (excluding contingency).
- Construction easements may be necessary to construct the project; however, the cost is expected to be negligible.
- Additional work may be required to determine if cultural and/or historical resources are present at any project site.

The total construction and 30-year cost estimates for each recommended stabilization alternative are summarized in Table 7-1. Detailed cost-estimate tables for all alternatives considered are provided in Appendix H.

The Class 4 level cost estimates have an acceptable range of between -15% to -30% on the low range and +20% to +50% on the high range. Based on the development of concepts and initial vetting of the concepts by the City of Plymouth and MDNR, it is not necessary to utilize the full range of the acceptable range for the cost estimate; and we assume the final costs of construction may be between -20% and +30% of the estimated construction budget. The assumed contingency for the project (30%) incorporates the potential high end of the cost estimate range.

For the recommended stabilization alternatives presented in Table 7-1, the total estimated construction cost is \$479,000. The Class 4 level cost estimate range for the construction costs is \$383,000 to \$623,000. The total capital cost is estimated as \$766,000, which includes estimated construction costs of \$479,000, plus \$144,000 each for construction contingency and engineering (all costs rounded to the nearest \$1,000).

7.1.1 Temporary easements

Most of the project is located on property owned by the City of Plymouth or in areas where the City has access easements. The costs associated with temporary construction easements, if required, are typically negligible; no costs for temporary construction easements are included in this estimate.

7.1.2 Off-site sediment disposal

Some alternatives assume off-site disposal of excavated sediment. Based on the results of the Phase I assessment (Appendix C), it is assumed that a Phase II assessment of bank material will not be necessary and that sediment disposed off-site will not require additional testing or special disposal as hazardous or dredged material. As such, these costs are not included in this estimate.

7.1.3 Wetland mitigation

Stream banks are considered to be wetlands and disturbing the banks as part of a restoration project is a temporary wetland impact. However, because the purpose of stream bank repair and restoration is to create a stable bank that can support a riparian ecosystem, the impacts are considered to be self-mitigating. Therefore, stream bank restoration projects do not typically require additional costs for wetland mitigation. The costs of wetland mitigations associated with the grading recommended for Site 10 are not included in the cost estimate.

7.1.4 Tree replacement and revegetation

It is assumed that the City of Plymouth will determine where tree replacements will be desired (based on estimated tree removals and long-term plans for the park land) during final design. For the cost estimate, tree replacements are assumed only for Reach 3 and other areas not directly a part of the disc golf course. Discussions with the City have indicated that tree removals associated with the project may open the canopy in such a way that provides benefits for reestablishing vegetation and, as such, tree replacements along the disc golf course may not be desirable. Because many of the stabilization sites have significant shade cover, the costs of shade-tolerant species (shrubs and grasses), appropriate site preparation, seeding, and maintenance to establish the vegetation are included in the cost estimate.

7.1.5 30-year cost

The 30-year cost for each alternative is based on anticipated maintenance and replacement costs. For alternatives with an estimated life span less than 30 years, significant maintenance is assumed to occur at the end of the estimated life span shown in Table 7-1. It is assumed to equal 50% of the original construction cost for hard armoring alternatives and 25% of the original construction cost for bioengineering alternatives. Annual maintenance estimates are based on maintenance costs associated with the initial "establishment" period; 50% is assumed for vegetation-only alternatives (Alternatives 3C and 4A) and 25% for all other alternatives. For the recommended stabilization alternatives presented in Table 7-1, the estimated cost of annual maintenance is \$5,900 (2016 dollars).

The 30-year cost for each alternative is calculated as the future worth of the initial capital cost (including contingency and engineering costs) plus the future worth of annual maintenance and significant maintenance at the end of the alternative life span. A 3% rate of inflation is assumed. The annualized cost for each alternative is calculated as the value of 30 equal, annual payments of the same future worth as the 30-year cost. For the recommended stabilization alternatives presented in Table 7-1, the estimated total 30-year cost is \$2,540,000; the equivalent annualized cost is \$52,100.

7.1.6 Annualized pollutant reduction cost

Estimated annual loading reductions for TSS and TP are included for each recommended alternative in Table 7-1. The loading reductions are based on the assumption that each alternative is successful in reducing bank erosion at each site to a nominal rate of 0.01 or 0.04 feet per year—representative of a well-vegetated stable bank with very low to low near-bank erosive stress (see Section 6.3). The annualized pollutant-reduction cost for each alternative is the annual load reduction divided by the annualized 30-year cost. Annualized pollutant-reduction costs for all alternatives considered in this study are provided in Appendix H.

Annualized costs for TP removal for the recommended alternatives range from \$380 per pound TP to \$8,650 per pound TP. Most of the high-cost alternatives are associated with relatively inexpensive construction that will have minimal impact on the pollutant loading from the project area, such as stabilizing bridge abutments at Sites 6 through 9 or removing large woody debris at Sites 18 and 19. Alternatives that are estimated to have the most cost-effective pollutant reductions include stabilizing eroding bends in multiple locations with root wads, toe wood, and vanes (Sites 11 through 13 and 15 through 17) and stabilizing the downstream-most site (Site 21) with log vanes.

For the recommended stabilization alternatives presented in Table 7-1, the estimated total annualized pollutant reduction costs are \$1,000 per pound TP and \$0.57 per pound TSS. For reference, the Medicine Lake TMDL Implementation Plan (Reference (5)) assumed a pollutant reduction cost ranging from \$500 to \$5,000 per pound TP.

7.1.7 Miscellaneous costs

Most site costs include miscellaneous items needed during construction (e.g., a rock construction entrance, a filter dike to control in-stream sediment disturbance, and restoration of access paths). Based on previous project experience, the estimate for each alternative includes some costs that could be applied to these miscellaneous items.

7.2 Funding sources

The City of Plymouth proposes to use BCWMC CIP funds to pay for this project. The source of these funds is an ad valorem tax levied by Hennepin County over the entire Bassett Creek watershed.

7.3 Project schedule

The design of this project is scheduled to begin in 2016. The construction work will likely be completed during the fall and winter of 2017. This would require the BCWMC to hold a public hearing and order the project in time to submit its ad valorem tax levy request to Hennepin County. If project construction is scheduled for fall or winter, spring or summer 2017 bidding is recommended. This will allow contractors to acquire necessary quantities of plants and seeds at a reasonable price. In the intervening time, the City will gather public input, prepare the final design, and obtain permits.

Table 7-1 Plymouth Creek recommended alternatives cost estimates

Reach	Site	Alternative	Alternative Description	Construction Cost Estimate ⁽¹⁾	Construction Contingency ⁽²⁾	Engineering ⁽³⁾	Capital Cost Estimate ⁽⁴⁾	Annualized Cost ⁽⁵⁾	TP Loading		TSS Loading	
									Load Reduction (lb/yr)	Cost/lb Reduced ⁽⁶⁾	Load Reduction (lb/yr)	Cost/lb Reduced ⁽⁶⁾
Reach 1	Site 1	Alternative C	Stabilize erosion areas with root wads, log vanes, and vegetation	\$ 16,080	\$ 4,820	\$ 4,820	\$ 25,700	\$ 1,700	0.20	\$ 8,650	340	\$ 5.00
Reach 1	Site 2	Alternative C	Stabilize erosion areas with root wads, log vanes, and vegetation	\$ 10,810	\$ 3,240	\$ 3,240	\$ 17,300	\$ 1,200	0.23	\$ 5,290	390	\$ 3.08
Reach 1	Site 3	Alternative B	Install log vanes within reach	\$ 31,450	\$ 9,440	\$ 9,440	\$ 50,300	\$ 3,400	1.66	\$ 3,370	2,890	\$ 1.94
Reach 1	Site 3	Alternative C	Upper bank vegetation	\$ 14,150	\$ 4,250	\$ 4,250	\$ 22,700	\$ 2,200				
Reach 1	Site 4	Alternative A	Establish vegetated buffer	\$ 14,840	\$ 4,450	\$ 4,450	\$ 23,700	\$ 2,200	2.21	\$ 990	3,850	\$ 0.57
Reach 1	Site 5	Alternative B	Vegetate steep, eroding bank with VRSS	\$ 20,480	\$ 6,140	\$ 6,140	\$ 32,800	\$ 2,600	1.86	\$ 1,400	3,240	\$ 0.80
Reach 1	Site 6	Alternative A	Stabilize bridge abutments with riprap and log vanes	\$ 7,940	\$ 2,380	\$ 2,380	\$ 12,700	\$ 1,000	0.13	\$ 7,530	230	\$ 4.35
Reach 1	Site 7	Alternative A	Stabilize bridge abutments with riprap and log vanes	\$ 7,940	\$ 2,380	\$ 2,380	\$ 12,700	\$ 1,000	0.13	\$ 7,530	230	\$ 4.35
Reach 2	Site 8	Alternative A	Stabilize bridge abutments with riprap and log vanes	\$ 7,940	\$ 2,380	\$ 2,380	\$ 12,700	\$ 1,000	0.13	\$ 7,530	230	\$ 4.35
Reach 2	Site 9	Alternative A	Stabilize bridge abutments with riprap and log vanes	\$ 7,940	\$ 2,380	\$ 2,380	\$ 12,700	\$ 1,000	0.13	\$ 7,530	230	\$ 4.35
Reach 2	Site 10	Alternative C	Raise channel bed using cross vanes/constructed riffles	\$ 20,970	\$ 6,290	\$ 6,290	\$ 33,600	\$ 2,600	1.71	\$ 3,460	2,970	\$ 1.99
Reach 2	Site 10	Alternative D	Lower adjacent floodplain	\$ 35,230	\$ 10,570	\$ 10,570	\$ 56,400	\$ 3,300				
Reach 2	Site 11	Alternative B	Stabilize banks with root wads	\$ 11,750	\$ 3,530	\$ 3,530	\$ 18,800	\$ 1,300	1.92	\$ 680	3,340	\$ 0.39
Reach 2	Site 12	Alternative B	Stabilize banks with root wads	\$ 11,750	\$ 3,530	\$ 3,530	\$ 18,800	\$ 1,300	1.92	\$ 680	3,340	\$ 0.39
Reach 2	Site 13	Alternative B	Stabilize banks with root wads	\$ 11,750	\$ 3,530	\$ 3,530	\$ 18,800	\$ 1,300	1.92	\$ 680	3,340	\$ 0.39
Reach 2	Site 14	Alternative A	Stabilize culvert outfall with hard armor	\$ 6,710	\$ 2,010	\$ 2,010	\$ 10,700	\$ 800	1.10	\$ 730	1,910	\$ 0.42
Reach 3	Site 15	Alternative C	Install bank stabilization measures at eroding banks using toe wood	\$ 48,740	\$ 14,620	\$ 14,620	\$ 78,000	\$ 5,300	6.98	\$ 760	12,130	\$ 0.44
Reach 3	Site 16	Alternative C	Install bank stabilization measures at eroding banks using toe wood	\$ 48,740	\$ 14,620	\$ 14,620	\$ 78,000	\$ 5,300	6.98	\$ 760	12,130	\$ 0.44
Reach 3	Site 17	Alternative B	Install 4 rock vanes for bank protection	\$ 23,010	\$ 6,900	\$ 6,900	\$ 36,800	\$ 2,800	6.98	\$ 400	12,130	\$ 0.23
Reach 3	Site 18	Alternative A	Remove large woody debris	\$ 3,670	\$ 1,100	\$ 1,100	\$ 5,900	\$ 400	0.09	\$ 4,520	150	\$ 2.67
Reach 3	Site 19	Alternative A	Remove large woody debris	\$ 3,670	\$ 1,100	\$ 1,100	\$ 5,900	\$ 400	0.09	\$ 4,520	150	\$ 2.67
Reach 3	Site 20	Alternative D	Realign channel and stabilize meanders with vanes and toe wood	\$ 92,380	\$ 27,710	\$ 27,710	\$ 147,800	\$ 8,500	11.96	\$ 710	20,800	\$ 0.41
Reach 3	Site 21	Alternative B	Install log vanes within reach	\$ 13,430	\$ 4,030	\$ 4,030	\$ 21,500	\$ 1,500	3.90	\$ 380	6,780	\$ 0.22
Project-wide			Educational signage	\$ 2,500	\$ 750	\$ 750	\$ 4,000	-	-	-	-	-
Project-wide			Foot traffic management (temp. fencing and wood chip paths)	\$ 5,000	\$ 1,500	\$ 1,500	\$ 8,000	-	-	-	-	-
Project Totals*:				\$ 479,000	\$ 144,000	\$ 144,000	\$ 766,000	\$ 52,100	52.2	\$ 1,000	90,800	\$ 0.57

* Costs may not sum due to rounding.

(1) A Class 4 screening-level opinion of probable cost, as defined by the American Association of Cost Engineers International (AACI International), has been prepared for these alternatives. The opinion of probable construction cost provided in this table is based on Barr's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project.

(2) Assumed 30% contingency on construction costs.

(3) Assumed 30% of construction costs for design, permitting, and administration.

(4) Includes estimated initial construction cost (with 30% contingency) and design, permitting, and administration costs (30% of construction cost).

(5) Future value of capital cost, annual maintenance cost, and major maintenance cost at end of expected life span, annualized to 30-year value assuming 3% inflation rate.

(6) Annualized cost divided by estimated annual pollution load reduction.

8.0 Alternatives assessment and recommendations

The final project will consist of a combination of the alternatives discussed in Appendix G. The costs of the alternatives recommended for the final design are summarized in Table 8-1. Alternatives that could be implemented in combination were chosen if they presented cost-effective TP and TSS loading reductions without producing significant impacts to surrounding land uses. In cases where only one alternative could be implemented, priority was given to options that were innovative, cost-effective, and used natural materials. The ability of alternatives to improve stream habitat and vegetative surroundings (identified as priorities in stakeholder meetings) was also taken into consideration in choosing the final alternatives.

Stabilization and restoration of stream banks within the project area will provide water quality improvement by 1) repairing actively eroding sites and 2) preventing erosion at other sites by installing preemptive measures to protect existing stream banks.

Using the recommended alternatives, design and construction costs for restoration of this section of Plymouth Creek total approximately \$766,000, or about \$275 per foot of stabilized stream. This is in the lower third of the range of costs associated with the feasible alternative combinations evaluated in Appendix H (from \$506,000 to \$1,153,000) and represents cost-effective stream stabilization with an emphasis on bioengineering techniques where possible. Costs for stream stabilization projects of similar scale often range between \$250 and \$400 per foot; costs associated with the high end of this range are often associated with rapid planning-level cost estimates. Therefore, the anticipated cost for stabilizing this reach of Plymouth Creek is on the lower end of typical price ranges for the recommended work.

The total estimated project capital cost of \$766,000 includes an estimated \$479,000 in construction costs, \$144,000 in construction contingency, and \$144,000 design, permitting, and construction observation costs (all costs rounded to the nearest \$1,000). We recommend that these costs be used to develop a levy request for this project and that it proceed to the design and construction phase.

Table 8-1 Plymouth Creek recommended alternatives cost summary

Reach	Construction Cost Estimate (1)	Construction Contingency (2)	Engineering (3)	Capital Cost Estimate (4)	Annualized Cost ⁽⁵⁾	TP Loading		TSS Loading	
						Load Reduction (lb/yr)	Cost/lb Reduced ⁽⁶⁾	Load Reduction (lb/yr)	Cost/lb Reduced ⁽⁶⁾
Reach 1	\$ 123,700	\$ 37,100	\$ 37,100	\$ 197,900	\$ 15,300	6.43	\$ 2,380	11,170	\$ 1.37
Reach 2	\$ 114,000	\$ 34,200	\$ 34,200	\$ 182,500	\$ 12,600	8.82	\$ 1,430	15,360	\$ 0.82
Reach 3	\$ 233,600	\$ 70,100	\$ 70,100	\$ 373,900	\$ 24,200	36.97	\$ 650	64,270	\$ 0.38
Educational signage	\$ 2,500	\$ 750	\$ 750	\$ 4,000	–	–	–	–	–
Foot Traffic Mgt.	\$ 5,000	\$ 1,500	\$ 1,500	\$ 8,000	–	–	–	–	–
Project Totals*:	\$ 479,000	\$ 144,000	\$ 144,000	\$ 766,000	\$ 52,100	52.2	\$ 1,000	90,800	\$ 0.57

* Costs may not sum due to rounding.

(1) A Class 4 screening-level opinion of probable cost, as defined by the American Association of Cost Engineers International (AACI International), has been prepared for these alternatives. The opinion of probable construction cost provided in this table is made based on Barr’s experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project.

(2) Assumed 30% contingency on construction costs.

(3) Assumed 30% of construction costs for design, permitting, and administration.

(4) Includes estimated initial construction cost (with 30% contingency) and design, permitting, and administration costs (30% of construction cost).

(5) Future value of capital cost, annual maintenance cost, and major maintenance cost at end of expected life span, annualized to 30-year value

(6) Annualized cost divided by estimated annual pollution load reduction.

9.0 References

1. **Bassett Creek Watershed Management Commission.** 2015 Watershed Management Plan. September 2015.
2. —. Resource Management Plan for Basset Creek Watershed Management Commission Proposed Water Quality Improvement Projects 2010 - 2016. 2009.
3. **Minnesota Pollution Control Agency.** *2014 Proposed Impaired Waters List.* [<https://www.pca.state.mn.us/sites/default/files/wq-iw1-47.pdf>]. April 2014.
4. **Minnesota Pollution Control Agency and Bassett Creek Watershed Management Commission.** *Medicine Lake Excess Nutrients Total Maximum Daily Load.* November 2010.
5. —. *Medicine Lake Excess Nutrients Total Maximum Daily Load Implementation Plan.* September 2010.
6. **Rosgen, D.L.** *Watershed Assessment of River Stability and Sediment Supply (WARSSS).* Fort Collins, CO : Wildland Hydrology Books, 2006.
7. **Minnesota Board of Water and Soil Resources (MN BWSR).** Pollution Reduction Estimator - Water Erosion - Excel Version. [http://www.bwsr.state.mn.us/elinkupdate/Pollution_Reduction_Calculator_Manual.pdf]. 2010.
8. **Minnesota Department of Natural Resources.** White-nose Syndrome and Minnesota's bats. [<http://www.dnr.state.mn.us/wns/index.html>]. 2015.