G. Detailed alternatives for stabilization

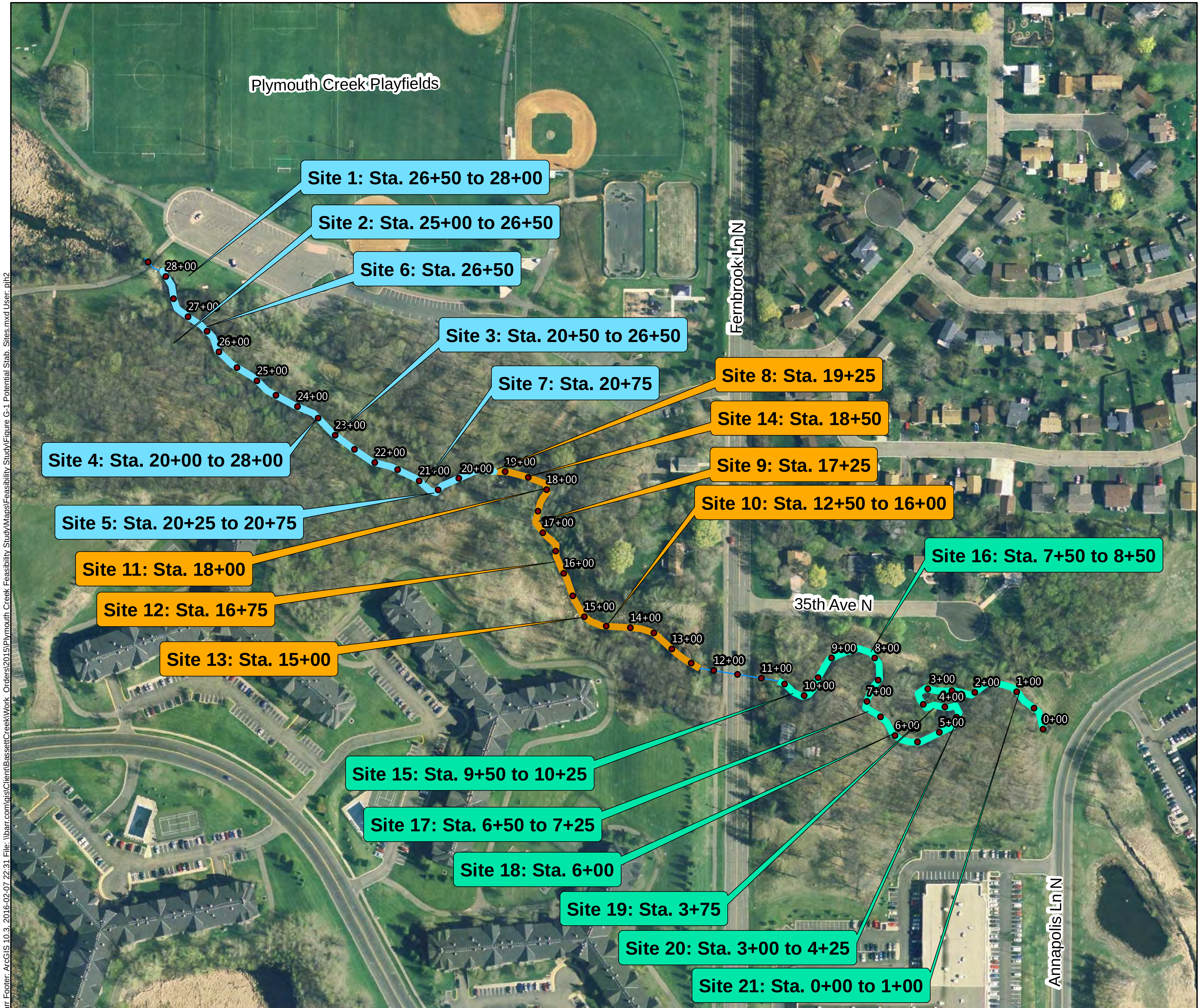
The following discussion is organized by location within each reach, referred to as "stabilization sites." The stabilization sites for the entire project area are shown in Figure G-1. Potential stabilization alternatives for each reach are summarized in Figure G-2 through Figure G-4 and in Table G-1. Stabilization sites within each reach with similar characteristics and stabilization alternatives are discussed together.

For each stabilization site (or group of sites), the following discussion includes:

- A brief description of the site characteristics.
- The issues to be addressed.
- Potential feasible alternatives for stabilization, with the advantages and disadvantages of each.
- A brief description of alternatives deemed infeasible after consideration.

A variety of factors or combinations of factors may make a "do-nothing" option viable for an individual site; however, it may not be cost-effective—particularly if the intent is to stabilize the site in the near future. If a "do-nothing" approach is ultimately chosen for a particular site, the potential need for future site stabilization should be evaluated. This evaluation should consider whether likely access routes could damage the measures already installed.

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 G-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.



Legend

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

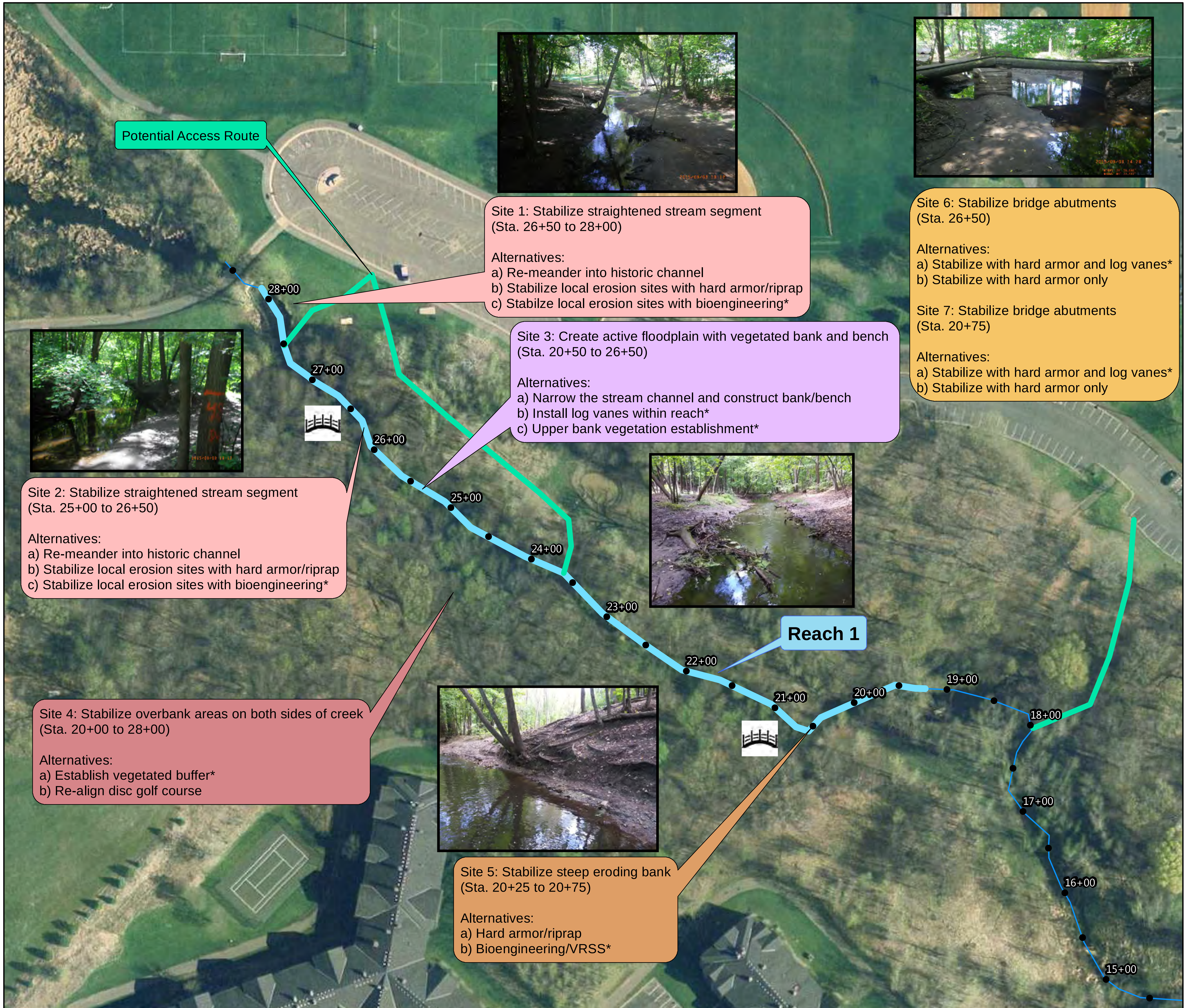
N

Feet
100 0 100 200

Meters
30 0 30 60

Figure G-1

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



Reach 1

Issues: Appears to be historically straightened; channel is overwide with bare banks. Significant bare overbank areas due to disc golf usage. High clay content of soils helps reduce bank movement.

Constraints: Restoration must be compatible with disc golf course; need for bridge crossings. Narrow valley and low slope limit meandering potential. Deep shade limits vegetation options.

Legend

Pedestrian Bridge

Culvert Outfall

Note: Individual alternatives are defined as a, b, or c for many of the sites. One or more alternatives will be chosen for each site.

*Indicates recommended alternative

N

Feet

100 0 100 200

Meters

30 0 30 60

Figure G-2

PLYMOUTH CREEK REACH 1 ALTERNATIVES
Plymouth Creek Feasibility Study
Bassett Creek Watershed
Management Commission

Barr Footer: ArcGIS 10.3, 2016-02-07 22:04 File: \\barr.com\gis\Client\BassettCreek\Work_Orders\2015\Plymouth Creek Feasibility Study\Maps\Feasibility Study\Figure G-2 Reach 1 Alternatives.mxd User: pjh2

G.1 Sites 1 and 2

Sites 1 and 2 (shown in Photo 1 and 2 in Appendix A) consist of a relatively straight reach that appears to have straightened over time as evidenced by the 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 G-2. The abandoned channels have vegetated banks and are situated at an elevation above typical flow levels in Plymouth Creek. The abandoned stream section in Site 1 no longer conveys flow during most flow events; however, the section in Site 2 is active during flood events. 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. Immediately upstream of Site 1, the existing water level control structure impedes sediment flow through Plymouth Creek and may represent a "clear water" discharge that could potentially increase scour through the downstream reaches.

Alternatives 1A and 2A—Re-meander into historical channel

Alternative summary: Re-meander the stream into the historical channels.

Advantages: Re-meandering will improve habitat by adding stream length, improve stream aesthetics, reduce erosion by slowing water flow, and improve water quality through stream bank stabilization.

Disadvantages: Lengthening the stream will decrease the already mild slope and may reduce stream conveyance and sediment transport capacity. Tree removals will be necessary at both Site 1 and Site 2. Hydraulic modeling will be required during final design to ensure the flood profile is not impacted. The foot bridge between the sites will likely need to be replaced or realigned to avoid adverse impacts from an altered flow pattern.

Feasibility: This alternative is feasible given the existence of the historical channels and the ability for the existing footbridge between these sites to be realigned, if necessary; however, it may be more cost effective to consider this option when the footbridge needs to be replaced.

Alternatives 1B and 2B—Stabilize local erosion sites with hard armor/riprap

Alternative summary: Install riprap along the outer banks to reduce the sediment loading and loss of bank.

Advantages: Riprap is relatively inexpensive, effective in reducing bank erosion, and can be resilient to large flood events if properly designed.

Disadvantages: Stabilizing the stream channel in-place does not take advantage of the existing historical meander channels and may be less aesthetically pleasing, especially for Site 2 where a disc golf tee box is adjacent to the historical channel. Hard armoring does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the riprap, maintenance costs tend to be higher than for bioengineering techniques.

Feasibility: This alternative is feasible if detailed modeling indicates there are high velocities at these sites and bioengineering options are determined to be infeasible.

Alternatives 1C and 2C—Stabilize local erosion sites with bioengineering

Alternative summary: 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.

Advantages: Bank stabilization with bioengineering techniques will improve aesthetics of the stream, reduce erosion by directing flow away from stream banks, and improve water quality through stream bank stabilization. One or more log vanes can extend across the entire channel to provide grade control and prevent downcutting due to the clear water discharge from the upstream control structure. The cost of bioengineering within these reaches is comparable to hard armoring and significantly lower than re-meandering.

Disadvantages: Stabilizing the stream channel in-place does not take advantage of the existing historical meander channels and may be less aesthetically pleasing, especially for Site 2 where a disc golf tee box is adjacent to the historical channel. Due to the shady conditions, vegetation will be limited to shade-tolerant species. The combination of extreme shade and disc golf traffic may hinder establishment of vegetation.

Feasibility: Shade-tolerant species are available and the stream banks can be feasibly vegetated.

Sites 1 and 2 infeasible alternatives

The creation of additional stream channels outside of the historical meanders is not considered feasible due to impacts to the disc golf course and significant grading/tree removal.

Sites 1 and 2 recommendations

Although re-meandering is feasible for Sites 1 and 2, Alternatives 1A and 2A have a high estimated cost, compared to the alternatives for stabilizing the stream in its current location. In addition, the tree removals and foot bridge realignment that would be necessary for the re-meandering alternatives are significant disadvantages. Given the expressed preference of the BCWMC and permitting agencies for bioengineering solutions, Alternatives 1C and 2C are recommended.

G.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 G-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. Photo 3 in Appendix A illustrates a typical portion of this site.

Alternative 3A—Narrow stream channel and construct floodplain bench

Alternative summary: Narrow the stream channel by grading to establish a vegetated floodplain bench within the existing channel alignment; offset decreased channel cross section by cutting back the existing high banks. This alternative would include upper-bank vegetation as described in Alternative 3C.

Advantages: Narrowing the channel will deepen it during low flow, providing improved habitat. It will also create a larger floodplain and vegetated stream buffer soon after construction.

Disadvantages: Narrowing the channel will require significant grading—excavating from the upper banks to create a floodplain while maintaining the overall channel conveyance. To achieve the desired channel shape tree removals will likely be required in some locations. Hydraulic modeling will be required during final design to ensure the flood profile is not impacted.

Feasibility: If the design of the narrowed channel can maintain existing flood elevations, this alternative is technically feasible, although it will require significant and costly grading. The overall feasibility of this alternative depends on whether the work can be completed without removing a significant number of trees.

Alternative 3B—Install log vanes

Alternative summary: Install log vanes and reshape the channel bottom to narrow the low-flow channel while maintaining the overall channel cross section. The logs for this alternative would be obtained by removing trees leaning over and at high risk of falling into the creek. Pre-emptively removing the trunks but leaving the stumps and roots will prevent localized erosion—both on the bare bank where the tree might fall and on other banks which would, subsequently, receive redirected flows. This alternative will also include upper-bank vegetation as described in Alternative 3C.

Advantages: Narrowing the low-flow channel with log vanes will provide improved habitat by deepening the channel during low flows and reduce the stress on the upper banks during high flows. Natural materials available onsite will be used for much of the log vane construction and prevent future erosion. One or more log cross vanes can extend across the entire channel to provide grade control and prevent downcutting due to the clear water discharge from the upstream control structure.

Disadvantages: The bench created by the log vanes will remain below the bankfull flow elevation. Depending on the available light at a given location and the frequency of inundation, vegetation on the low benches may be thin. Exposed soil may be less aesthetically pleasing than a vegetated floodplain.

Feasibility: Providing the design of the narrowed channel can maintain existing flood elevations, this alternative is feasible.

Alternative 3C—Upper-bank vegetation establishment

Alternative summary: Vegetate existing bare upper banks above the bankfull flow elevation with shade-tolerant trees, shrubs, and seed mixes. This alternative would be implemented in conjunction with Alternative 3A or 3B.

Advantages: Establishing perennial vegetation will improve aesthetics of the stream and reduce erosion from flood flows or overland flow entering the stream.

Disadvantages: Due to the shady conditions, suitable species will need to be selected carefully; site preparation, seeding, and establishment maintenance will need to be tailored to the site.

Feasibility: Shade-tolerant species are available and the upper banks can be vegetated; relatively frequent maintenance may be required due to the impacts of disc golf activity. This alternative also requires the cooperation of disc golfers to stay off newly established vegetation.

Infeasible alternatives

Re-meandering Plymouth Creek throughout Site 3 is not considered feasible due to the impact on the adjacent disc golf course. In addition, considering the existing topography and high overbank areas, establishing a meandering stream channel and floodplain would require significant and prohibitively costly excavation and tree removal.

Narrowing the stream channel by importing soil or rock and without excavating the existing high banks is not considered feasible due to the inevitable increase in the flood profile, not permitted by BCWMC policies. In addition, shifting the stream type to a narrow step-pool channel with limited floodplain is not considered feasible due to the low stream slope that will not facilitate creation of step-pool features.

Given the City's desire to maintain a natural stream channel through the Plymouth Creek Park and BCWMC policies preferring bioengineering techniques, lining Plymouth Creek with riprap to decrease bank erosion is also infeasible.

Site 3 recommendations

Alternative 3B is recommended for stabilizing the stream bed and lower banks of Site 3 because it will require minimal tree removals/grading and will use natural materials available onsite. Removing trees leaning over and at high risk of falling into the channel will also prevent localized erosion. Alternative 3C is recommended for stabilizing the upper banks and providing long-term natural aesthetics to the stream corridor. These two alternatives, implemented together, will stabilize and establish natural vegetation along approximately one-quarter of the entire project area.

G.3 Site 4

Site 4 includes overbank areas on both sides of the creek, but primarily on the south (Figure G-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 (see Photo 4 in Appendix A).

Alternative 4A—Establish vegetated buffer

Alternative summary: Install low fencing or other markers and shade-tolerant vegetation to establish a vegetative buffer on the creek banks, while allowing for controlled or stabilized stream access points so as to not inhibit the use of the disc golf course.

Advantages: A vegetated buffer will improve water quality in the stream by separating disc golf foot traffic from the stream, thereby reducing bank erosion and removing sediment from overland runoff entering the stream. The buffer will also result in improved aesthetics near the stream and provide an opportunity to educate park users on natural buffers and stream bank stability.

Disadvantages: Suitable, shade-tolerant species will need to be carefully selected; site preparation, seeding, and maintenance will need to be tailored to the location. The vegetated buffer and any fencing will inconvenience disc golf course users and may require user education and cooperation as well as frequent maintenance.

Feasibility: Shade-tolerant species are available and a vegetated buffer can be feasibly established; relatively frequent maintenance may be required due to the impact of disc golf course users.

Alternative 4B—Realign disc golf course

Alternative summary: Realign portions of the Plymouth Creek Park disc golf course to reduce the potential for golfers to enter the creek by placing pins away from the stream and eliminating holes that cross the stream. This alternative could be implemented alone or in conjunction with Alternative 4A. This alternative would also include upper-bank vegetation, as described for Alternative 4C.

Advantages: Placing pins away from the stream will cause golfers to throw away rather than toward the stream and reduce foot traffic on the stream banks. Some degree of hole realignment may be possible without tree removal or additional grading.

Disadvantages: Separating play from the stream channel by realigning holes may decrease some users' enjoyment of the natural amenities of the course. Any major adjustments to hole placement (for example, to decrease the overall density of the course) will require clearing and/or tree removal and may be relatively costly.

Feasibility: This alternative is feasible only if it can be done with minimal tree removal and provides an opportunity for public involvement in the stabilization of Plymouth Creek.

Site 4 recommendations

Establishing vegetated buffers on the overbank areas along Site 4 will maintain continuity with the upper-bank vegetation recommended for Site 3 (Alternative 3C), while allowing continued disc golf course usage. Alternative 4A is recommended.

G.4 Site 5

Site 5 is near the downstream end of Reach 1 (see Figure G-2 and Photo 5 in Appendix A). 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.

Alternative 5A—Stabilize with hard armor/riprap

Alternative summary: Install riprap or boulders along the lower slope of the outer bank to reduce the sediment loading and loss of bank.

Advantages: Riprap is relatively inexpensive and effective in reducing bank erosion; if properly designed it can be resilient to large flood events.

Disadvantages: Hard armoring does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the riprap, maintenance costs tend to be higher than for bioengineering techniques.

Feasibility: This alternative is feasible if bioengineering alternatives cannot be used.

Alternative 5B—Stabilize with VRSS

Alternative summary: Install bioengineering in the form of VRSS to encourage vegetative growth along the outer bank. Install VRSS in front of the existing bank to minimize grading into the bank.

Advantages: VRSS is aesthetically pleasing after the vegetated banks begin to thrive and uses renewable materials. If properly designed and installed, VRSS can be resilient to large flood events.

Disadvantages: Suitable, shade-tolerant species will need to be selected; site preparation, seeding, and maintenance will need to be tailored to the location. VRSS is more costly to install than hard armoring alone.

Feasibility: Shade-tolerant species are available and the VRSS area can be feasibly vegetated, though relatively frequent maintenance may be required during the vegetation-establishment period.

Infeasible alternatives

Re-grading of the stream bank to reduce the steep slope is not considered feasible. The regrading would remove several trees and reduce the areas available for the disc golf course.

Site 5 recommendations

Given the expressed preference of the BCWMC and permitting agencies for bioengineering solutions, Alternative 5B is recommended.

G.5 Sites 6, 7, 8, and 9

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

Alternatives 6A through 9A—Stabilize with hard armor and log vanes

Alternative summary: 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.

Advantages: Riprap around each abutment will reduce erosion during high flows, while log vanes will reduce the erosive pressure on the abutments.

Disadvantages: Hard armor around bridge abutments does not appear natural or provide quality in-stream habitat. Adding log vanes to the bridge locations will add complexity and require more detailed design and construction oversight to achieve the desired flow patterns.

Feasibility: This alternative is feasible.

Alternative 6B through 9B—Stabilize with hard armor only

Alternative summary: Install hard armor (riprap) around each abutment.

Advantages: Riprap around each abutment will reduce erosion during high flows and will not require any in-stream work. Installing only riprap will cost less than combining riprap with log vanes.

Disadvantages: Armoring only the bridge abutments without reducing the erosive pressure by redirecting the flow may result in failure of the riprap or additional maintenance after large flood events. In addition, hard armor around bridge abutments does not appear natural or provide quality in-stream habitat.

Feasibility: This alternative is feasible.

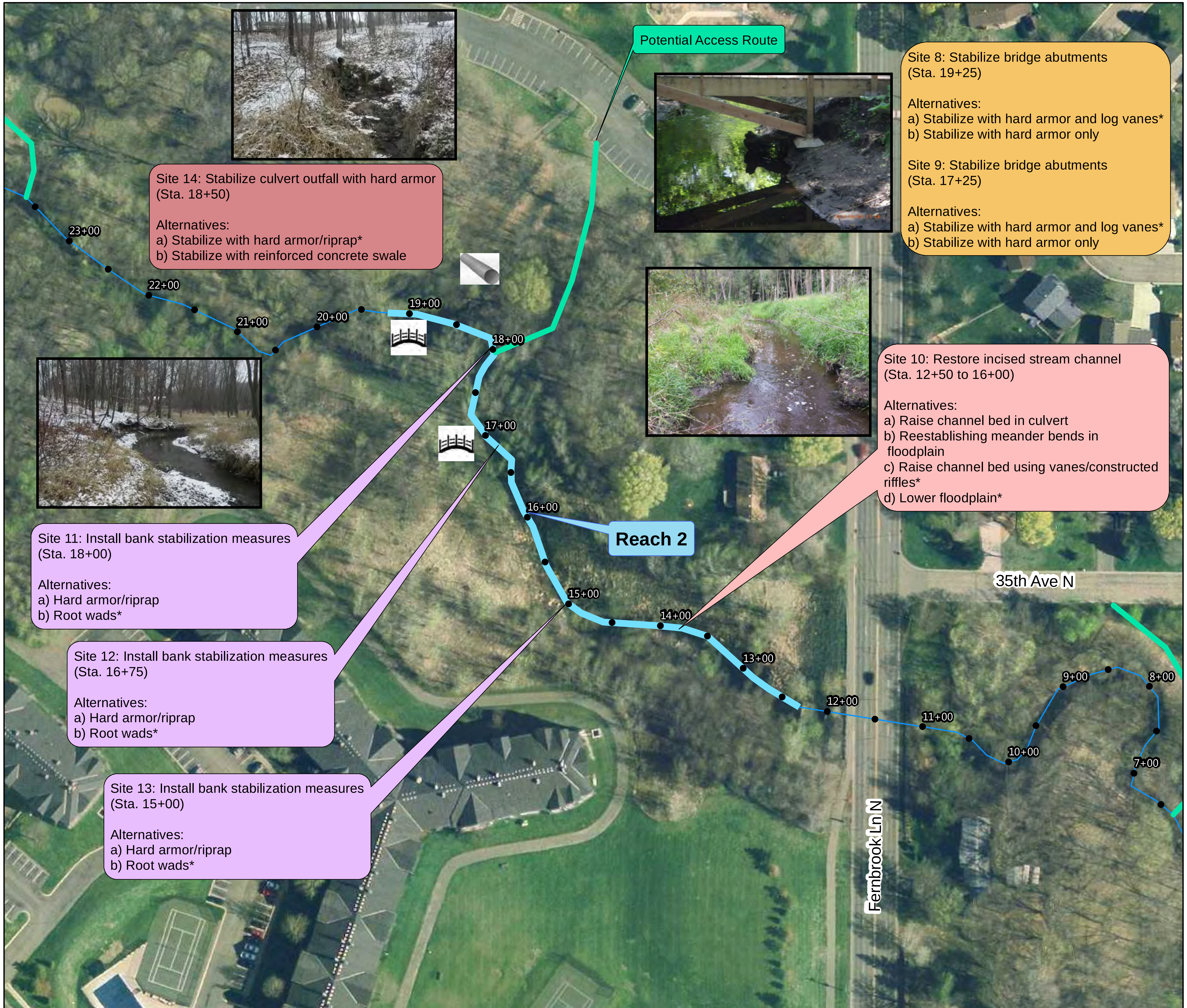
Infeasible alternatives

The cost of new footbridges—relative to the low consequences of erosion-related failure—is high. This makes widening the footbridges to put the abutments away from the channel on the floodplain infeasible.

Installing log vanes upstream of the abutment without riprap is not considered feasible. This would not provide the abutments with the required level of protection, especially during larger flow events.

Sites 6 through 9 recommendations

Alternatives 6A through 9A are recommended for stabilizing the pedestrian bridge abutments; both will improve resistance of the abutments to high flows and reduce the erosive pressure by redirecting flows toward the center of the stream.



Reach 2

Issues: Erosion of the stream bed (incision) has resulted in limited access to floodplain. Incision perhaps due to culvert grade on downstream end of reach. Pockets of granular soils prone to bank erosion.

Constraints: Culvert limits flow in floods. Nearby home impacted if flood levels increase. Low slope. Sanitary sewer manholes should be avoided and access to these manholes should be maintained.

Legend

Pedestrian Bridge

Culvert Outfall

Note: Individual alternatives are defined as a, b, c, or d for many of the sites. One or more alternatives will be chosen for each site.

*Indicates recommended alternative

N

Feet

100 0 100 200

Meters

30 0 30 60

Figure G-3

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

Barr Footer: ArcGIS 10.3, 2016-02-07 22:09 File: \\barr.com\gis\Client\BassettCreek\Work_Orders\2015\Plymouth Creek Feasibility Study\Maps\Feasibility Study\Figure G-3 Reach 2 Alternatives.mxd User: pjh2

G.6 Site 10

Site 10 includes much of the stream channel located in the downstream half of Reach 2 (see Figure G-3). The stream bed in this section appears to be mildly incised (see Photo 8 in Appendix A), resulting in limited access to the floodplain. In addition, pockets of granular soils have facilitated bank erosion in some areas. 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.

Residential property exists on the downstream portion of the reach and cannot be further impacted by floodwaters. A portion of the overbank in this reach is defined as wetland (see Appendix E), which will necessitate additional permitting to ensure any impacts are mitigated.

Alternative 10A—Raise culvert bed elevation

Alternative summary: Add riprap and gravel to the bed of the culvert (grout select cobbles into place if necessary) under Fernbrook Lane North to act as a grade control and increase the bed elevation in the stream through Site 10. At the request of the MDNR, the culvert was installed 1 foot lower than the previous culvert, with the intent that it would fill with sediment and have a natural bottom. While a portion of the culvert has accumulated sediment, a natural bottom has not been fully established.

Advantages: Raising the stream bed in the Fernbrook Lane North culvert will decrease the slope of the creek and allow for improved access to the floodplain. This alternative will be relatively low-cost and may increase the ability of aquatic organisms to move through the culvert during low-flow conditions. It is assumed that a natural substrate will gradually accumulate in the culvert; this alternative would speed up the process.

Disadvantages: If too much material is added to the culvert bottom, its conveyance would be altered and the upstream flood profile could be affected.

Feasibility: Providing the design of the culvert can maintain existing flood elevations, this alternative is feasible.

Alternative 10B—Re-meander on floodplain

Alternative summary: Construct a meandering stream channel through the existing floodplain to improve connectivity of flood flows with the floodplain.

Advantages: The additional meander bends in the floodplain would allow for increased habitat by adding stream length and improve the aesthetics within this reach. The new channel will be constructed with a geomorphically appropriate cross section, which will help ensure ongoing channel stability.

Disadvantages: Adding stream length and raising the bed elevation of the stream will decrease the stream slope, reduce conveyance, and could affect the upstream flood profile. Hydraulic modeling will be required during final design to ensure the flood profile is not impacted. Impacts to the flood elevation could be offset by lowering the floodplain as described in Alternative 10D. In addition, construction of a new channel through the existing wetland floodplain may require mitigation for wetland impacts. Two sanitary manholes exist within this site. The re-meander must not impede vehicle access to the manholes or increase the potential for fluvial erosion around the manholes.

Feasibility: This alternative is feasible; however, there are multiple obstacles. It will be difficult to find a reasonable way to re-meander the stream while maintaining necessary vehicle access to the sewer manholes. This option will also be relatively costly compared to the other alternatives.

Alternative 10C—Raise channel bed with vanes/riffles

Alternative summary: 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.

Advantages: The installation of cross vanes would facilitate sedimentation upstream of the cross vanes and naturally raise the stream bed without construction of an entirely new channel. If properly designed and constructed, cross vanes could also help direct flow away from existing eroding banks. This alternative will have reduced wetland impacts compared to Alternative 10B.

Disadvantages: Similar to Alternative 10B, raising the bed elevation could affect the upstream flood profile. Hydraulic modeling will be required during final design, and impacts could be offset by lowering the floodplain as described in Alternative 10D. In addition, this alternative will not alter the stream cross section if it is found to be overly wide in areas away from the installed vanes or riffles.

Feasibility: Providing that the design of the vanes or riffles can maintain existing flood elevations, this alternative is feasible.

Alternative 10D—Lower floodplain

Alternative summary: Lower portions of the floodplain adjacent to the stream channel to improve connectivity of flood flows with the floodplain and maintain the existing flood profile. This alternative may be used alone or in combination with Alternative 10B or 10C.

Advantages: Improved access to the floodplain creates fertile overbank areas for vegetation associated with the stream buffer and improves habitat in the buffer. Additionally, a lowered floodplain will produce increased flood storage and could lower the design flood profile.

Disadvantages: Lowering the floodplain within this reach will impact a delineated wetland. Additional permitting may be required to ensure the wetland impacts are mitigated or are determined to be self-mitigating. Due to the volume of soil to be removed, this alternative may be more costly than alternatives addressing the stream channel alone. Any grading work within the floodplain must not disturb the existing sanitary manholes and should provide vehicle access to the manholes.

Feasibility: This alternative is feasible and may allow for feasible construction of Alternative 10B or 10C. Based on feedback from the technical stakeholder meeting, permitting of the wetland impacts is not anticipated to be a significant obstacle.

Infeasible alternatives

Due to the relatively recent replacement of the culvert under Fernbrook Lane North by the City, any further replacement of the culvert or addition of culverts on the floodplain are considered infeasible.

Site 10 recommendations

Re-meandering the stream channel through Site 10 would require significant excavation, both for the new channel and to maintain flood flow capacity by lowering the floodplain. It may also conflict with the existing sanitary manhole in the area. Alternative 10C is recommended for this site because it provides many of the same benefits at a lower cost; in addition, fewer boulder vanes may be needed if the design is coordinated with stabilization of Sites 11 through 13. Alternative 10D is also recommended because some degree of increased flood flow capacity will likely be needed to offset the raised channel bed elevation.

G.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 G-3). Stabilization of these sites could be performed instead of or in conjunction with one of the alternatives described for Site 10. The eroding banks at these sites are shown in Photo 10 through Photo 12 of Appendix A.

Alternatives 11A through 13A—Stabilize with hard armor/riprap

Alternative summary: Install riprap along the outer banks to reduce the sediment loading and loss of bank.

Advantages: Riprap is relatively inexpensive, effective in reducing bank erosion, and if properly designed can be resilient to large flood events.

Disadvantages: Hard armoring does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the riprap, maintenance costs tend to be higher than for bioengineering techniques.

Feasibility: This alternative is feasible if bioengineering techniques are not possible.

Alternatives 11B through 13B—Stabilize with root wads

Alternative summary: Install root wads around eroding bends to direct flow to the center of the stream.

Advantages: Root wads will reduce the erosive stress on the outer banks, reduce bank erosion, and allow vegetation to become established. Root wads also create scour pools and cover that can increase habitat diversity within the stream. Trees will likely need to be removed to gain access to these banks, providing a source for the root wads.

Disadvantages: Root wads will require removing trees; however, bank access is likely to require tree removal regardless of the technique. Adding root wads to the outer banks will add complexity and require more detailed design and construction oversight to achieve the desired flow patterns.

Feasibility: This alternative is feasible provided root wads would not require unnecessary tree removal.

Sites 11 through 13 recommendations

Given the expressed preference of the BCWMC and permitting agencies for bioengineering solutions, Alternatives 11B through 13B are recommended. As discussed in Section G.6 for Site 10, the required number of root wad may be reduced during final design if selected vane locations for Alternative 10C can meet the objectives of both raising the channel bed elevation and stabilizing meander bends.

G.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 G-3). The outfall of this pipe has limited stabilization and is causing sediment to erode into the creek (see Photo 13 in Appendix A).

Alternative 14A—Stabilize with hard armor/riprap

Alternative summary: Install riprap from the pipe outlet to the stream.

Advantages: Riprap is relatively inexpensive, effective in reducing erosion, and if properly designed can be resilient to large flood events. Riprap is the primary stabilization technique for pipe outlets due to its effectiveness at protecting against the high anticipated velocities and associated shear stresses from the outlet.

Disadvantages: Hard armoring does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the riprap, maintenance costs tend to be higher than for bioengineering techniques.

Feasibility: This alternative is feasible.

Alternative 14B—Stabilize with reinforced concrete swale

Alternative summary: Install a reinforced concrete swale from the pipe outlet to the stream.

Advantages: A concrete swale is highly effective in eliminating erosion at pipe outlets. If designed correctly, the swale can have a long life expectancy.

Disadvantages: A concrete swale does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the swale, maintenance costs tend to be higher than for bioengineering techniques.

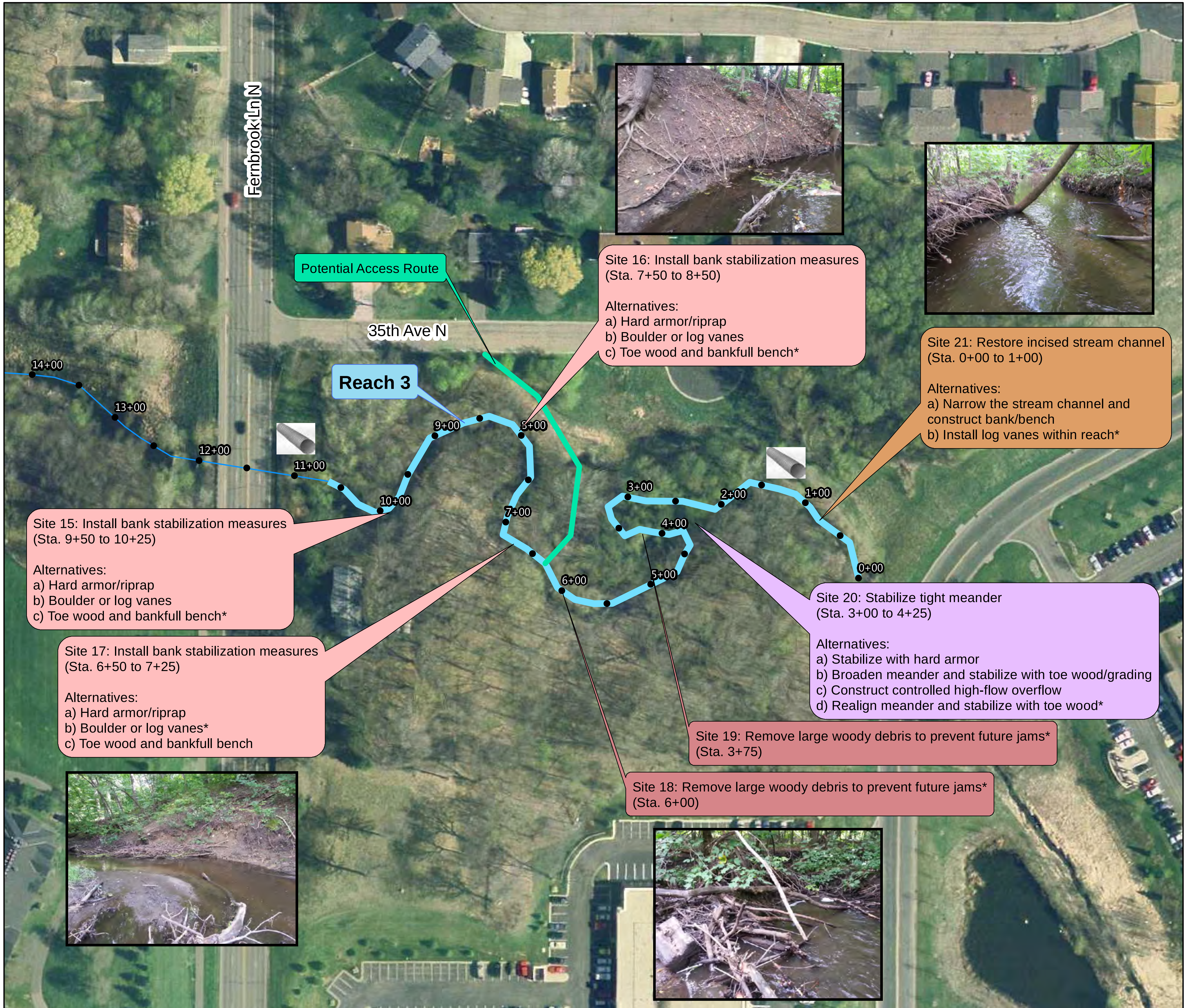
Feasibility: This alternative is feasible.

Infeasible alternatives

Due to the high anticipated velocities associated with the pipe outfall and the expense of replacing a failed pipe, bioengineering techniques are not typically used at sites like this.

Site 14 recommendations

Alternative 14A is recommended to maintain consistency with techniques used elsewhere within the project area (riprap rather than concrete armoring).



Reach 3

Issues: Several large eroding outer banks. Significant woody debris causing jams that redirect flow at banks. Unstable tight meander in downstream third in the process of being cut off.

Constraints: Narrow valley and low slope limit meandering potential, Deep shade limits vegetation options. Meander cutoff and loss of stream length could be permitting issue. Some existing trees may need preservation, inhibiting work access in their vicinity.

Legend

Pedestrian Bridge

Culvert Outfall

Note: Individual alternatives are defined as a, b, or c for many of the sites. One or more alternatives will be chosen for each site.

***Indicates recommended alternative**

N

Feet

100 0 100 200

Meters

30 0 30 60

Figure G-4

PLYMOUTH CREEK REACH 3 ALTERNATIVES
Plymouth Creek Feasibility Study
Bassett Creek Watershed
Management Commission

Barr Footer: ArcGIS 10.3, 2016-02-07 22:12 File: \\barr.com\gis\Client\BassettCreek\Work_Orders\2015\Plymouth Creek Feasibility Study\Maps\Feasibility Study\Figure G-4 Reach 3 Alternatives.mxd User: pjh2

G.9 Sites 15, 16, and 17

Steep eroding banks are present in three locations within Reach 3, as shown on Figure G-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 (see Photo 14 through Photo 16 in Appendix A).

Alternatives 15A through 17A—Stabilize with hard armor

Alternative summary: Install riprap along the outer banks to reduce the sediment loading and loss of bank.

Advantages: Riprap is relatively inexpensive, effective in reducing bank erosion, and if properly designed can be resilient to large flood events.

Disadvantages: Hard armoring does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the riprap, maintenance costs tend to be higher than for bioengineering techniques. High erosive stress will continue to act at the toe of the steep banks, especially in high flows.

Feasibility: This alternative is feasible if suitable bioengineering alternatives are not identified.

Alternatives 15B through 17B—Stabilize with boulder or log vanes

Alternative summary: Install boulder or log vanes around eroding bends to direct flow to the center of the stream.

Advantages: Boulder or log vanes will reduce the erosive stress on the outer banks, reduce bank erosion, and allow for establishment of vegetation. Vanes also create mid-channel scour pools that can increase habitat diversity within the stream.

Disadvantages: Depending on their design, vanes can increase the upstream flood profile; hydraulic modeling will be required during final design to ensure that flood impacts are acceptable. Adding vanes to the outer banks will add complexity and require more detailed design and construction oversight to achieve the desired flow patterns. High erosive stress will continue to act at the toe of the steep banks during high flows.

Feasibility: This alternative is feasible.

Alternatives 15C through 17C—Stabilize with toe wood

Alternative summary: Install toe wood (root wads and large woody debris) around eroding bends to increase roughness of the lower banks and establish a vegetated bench at the toe of the high, eroding banks.

Advantages: Toe wood, constructed from natural materials at the project site, is effective in reducing stream bank erosion. Select trees can be removed within this reach to thin the cover and facilitate understory growth and provide material for the toe wood. The in-stream root wads create habitat complexity, while the vegetated bench separates the area of high erosive stress from the steep outer banks.

Disadvantages: Toe wood installation is more challenging than hard armoring and will require additional construction oversight to achieve the desired flow patterns. The longevity of toe wood depends on the woody material being consistently submerged (less potential for rotting) and successful establishment of vegetation along the bench. Toe wood becomes less cost effective if sufficient material is not available onsite.

Feasibility: This alternative is feasible, provided that sufficient woody material can be harvested from within the reach without excessive tree removal.

Infeasible alternatives

Stabilizing the high eroding banks with grading or VRSS is considered infeasible due to the number of trees that would need to be removed to grade the banks to a stable slope. Due to the shady conditions, establishing stabilizing vegetation for VRSS would be difficult.

Sites 15 through 17 recommendations

Although Sites 15 through 17 share many characteristics, the meander bends do not need to be stabilized using identical techniques. Hard armoring methods are not preferred, but there may not be sufficient woody material available to stabilize all three bends with toe wood; the optimal solution may require a combination of toe wood and vane techniques. Accordingly, Alternatives 15C, 16C, and 17B are recommended. Site 17 has the largest meander radius, making it the best candidate for stabilization with boulder or log vanes.

G.10 Sites 18 and 19

Large woody debris is present in two primary locations within the stream (see Figure G-4 and Photos 18 and 19 in Appendix A). The debris causes jams within the stream—redirecting flow towards the banks, which causes bank erosion.

Alternatives 18A and 19A—Remove large woody debris

Alternative summary: Remove existing large woody debris from the stream.

Advantages: Removal of the debris will allow the stream to flow naturally and reduce the stream bank erosion. It will also reduce flooding potential by removing the flow blockages.

Disadvantages: Woody debris removal will decrease the effective roughness of the stream channel and may cause increased flow velocities. Increased flow velocities in the absence of other restoration or stabilization measures could increase bank erosion.

Feasibility: This alternative is feasible and may provide a source of woody material for Alternatives 15C through 17C (toe wood), but it should not be pursued apart from other stabilization measures within Reach 3.

Sites 18 and 19 recommendations

Alternatives 18A and 19A are recommended.

G.11 Site 20

A tight meander is present within the downstream half of Reach 3 (Station 3+00 to 3+50 on Figure G-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). Photo 19 in Appendix A shows the developing cutoff.

Alternative 20A—Stabilize with hard armor

Alternative summary: Install riprap along the outer banks of both the tight meander (Station 3+00 to 3+50) and the upstream meander (Station 4+00 to 4+50) to reduce sediment loading and loss of bank and prevent meander cutoff.

Advantages: Riprap is relatively inexpensive, effective in reducing bank erosion, and if properly designed can be resilient to large flood events.

Disadvantages: Hard armoring does not encourage vegetative growth and does not appear natural or provide quality in-stream habitat. If erosion occurs around or behind the riprap, maintenance costs tend to be higher than for bioengineering techniques. High erosive stress will continue to act at the toe of the steep bank, especially in high flows, and the tendency for the stream to cutoff the meander will remain.

Feasibility: This alternative is feasible if bioengineering methods are not possible.

Alternative 20B—Stabilize with toe wood and grading to broaden meander

Alternative summary: 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) to increase roughness of the lower banks and establish a vegetated bench at the toe of the high, eroding banks. Use the toe wood bench to increase the meander radius by excavating a new channel, as necessary. Depending on the final channel alignment, boulder or log vanes may be used to decrease the length of toe wood required.

Advantages: This alternative retains the general meander pattern of the stream and can be designed to have minimal impact on the overall stream length. Toe wood is effective in reducing stream bank erosion, using natural sources of materials at the project site. Select trees can be removed within this reach to thin the cover, facilitate understory growth, and provide material for the toe wood. The in-stream root wads create habitat complexity, while the vegetated bench separates the area of high erosive stress from the steep outer banks.

Disadvantages: Due to the tight project limits in this area, the stream will still have relatively tight bends. This may, eventually, result in a cutoff loop regardless of stabilization efforts. Hydraulic modeling will be required during final design to ensure that flood impacts are acceptable. Toe wood installation is more challenging than hard armoring and will require additional construction oversight to achieve the desired flow patterns. The longevity of toe wood depends on the woody material being consistently submerged (less potential for rotting) and successful establishment of vegetation along the bench. A significant number of trees would need to be removed for grading and to ensure that enough material is available for toe wood.

Feasibility: This alternative is feasible, provided that sufficient woody material is available and that design of the adjusted meander pattern can maintain existing flood elevations.

Alternative 20C—Create controlled high-flow overflow

Alternative summary: Stabilize the area forming a natural cutoff (from approximately Station 2+25 to 4+25) with an armored overflow channel that could be used during flood events to prevent the stream from completing the meander cutoff. A grade-control structure made of fieldstone could direct flow through the area during flood events. This alternative could be combined with Alternative 20A or 20B to stabilize the remaining tight meander, which would continue to convey flow during low- to average-flow conditions.

Advantages: Stabilizing the natural overflow while retaining the existing low-flow channel will maintain the existing stream length and habitat while preventing uncontrolled stream migration and corresponding erosion. Installation of riprap or logs in this area would be relatively inexpensive and could be designed for stability during high flows.

Disadvantages: Hydraulic modeling will be required during final design to ensure that flood impacts are acceptable. If stabilization measures are not taken on the surrounding meander bends (Alternative 20A or 20B), the high-flow overflow could be flanked by erosion and the stream could experience an abrupt avulsion or change of course. This option will need to be approved by the MDNR. Monitoring information may need to be provided to address their concern that the design might result in the loss of habitat.

Feasibility: This alternative is feasible, provided that design of the high-flow overflow and any additional meander stabilization measures can maintain existing flood elevations.

Alternative 20D—Realign channel to stabilize and broaden meander

Alternative summary: 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 and boulder or log vanes around both meander bends to stabilize the outer banks and create a bankfull bench.

Advantages: Creating a stable channel pattern will ensure long-term stability and reduce the risk of meander cutoff or avulsion. Toe wood and vanes are effective in reducing stream bank erosion, using natural sources of materials at the project site. Select trees can be removed within this reach to thin the cover, facilitate understory growth, and provide material for the toe wood. The in-stream root wads create habitat complexity, while the vegetated bench separates the area of high erosive stress from the steep outer banks.

Disadvantages: Changing the stream alignment will result in a reduction in overall stream length by approximately 100 feet, which will increase the stream slope. Hydraulic modeling will be required during final design to ensure that flood impacts are acceptable. Toe wood installation is more challenging than hard armoring and will require additional construction oversight to achieve the desired flow patterns. The longevity of toe wood depends on the woody material being consistently submerged (less potential for rotting) and successful establishment of vegetation along the bench. A significant number of trees would need to be removed for grading and to ensure that enough material is available for toe wood.

Feasibility: Based on feedback from MDNR that reductions in stream length may be acceptable in order to increase stability and long-term habitat value of the stream, this alternative is feasible. Final design will need to verify that sufficient woody material is available and that design of the adjusted meander pattern can maintain existing flood elevations.

Infeasible alternatives

Stabilizing this meander with boulder or log vanes alone is not considered feasible due to the low meander radius. In conditions with very tight meander bends, installation of vanes to redirect flow is sensitive to minor error and unexpected outcomes, and this alternative would not address the tendency of the stream to cutoff the meander.

Site 20 recommendations

Alternative 20D is recommended to prevent uncontrolled stream avulsion, reduce erosion from the tight meander banks, and increase the long-term habitat value of the stream. This alternative will be significantly more expensive than stabilizing the meander with hard armoring, but will provide long-term benefits to the channel stability, stream habitat, and natural character of Plymouth Creek in Reach 3. Coordination with MDNR and other permitting agencies will be required throughout the final design process to ensure that the reduction in stream length is acceptable.

G.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 G-4 and Photo 20 in Appendix A).

Alternative 21A—Narrow stream channel and construct floodplain bench

Alternative summary: Narrow the stream channel by grading to establish a vegetated floodplain bench within the existing channel alignment; offset the decreased channel cross section by cutting back the existing high banks.

Advantages: Narrowing the channel will provide improved habitat by deepening the channel during low flows and create an active (if narrow) floodplain and vibrant stream buffer soon after construction.

Disadvantages: Creating a floodplain without decreasing the overall conveyance of the narrowed channel will require significant grading and excavation from the existing upper banks. Tree removals will likely be required in some locations to achieve the desired channel shape. Hydraulic modeling will be required during final design to ensure the flood profile is not impacted.

Feasibility: Providing that the design of the narrowed channel can maintain existing flood elevations, this alternative is feasible, although it will require significant and costly grading.

Alternative 21B—Install log vanes

Alternative summary: Install log vanes and reshape the channel bottom to narrow the low-flow channel while maintaining the overall channel cross section.

Advantages: Narrowing the low-flow channel with log vanes will provide improved habitat by deepening the channel during low flows and reduce the stress on the upper banks during high flows. Natural materials available onsite could be used for much of the log vane construction.

Disadvantages: The bench created by the log vanes will remain below the bankfull flow elevation and periodic inundation will prevent establishment of vegetation. The exposed soil creek bottom may be less aesthetically pleasing than a vegetated floodplain.

Feasibility: Providing that the design of the narrowed channel can maintain existing flood elevations, this alternative is feasible.

Infeasible alternatives

Narrowing the stream channel by importing soil or rock and without excavating the high banks is not considered feasible due to the inevitable increase in the flood profile, which is not permitted by BCWMC policies.

The preference of stakeholders to maintain a natural stream channel makes lining Plymouth Creek with riprap infeasible.

Site 21 recommendations

Alternative 21B is recommended for stabilizing the stream bed and lower banks of Site 21 because it will require minimal tree removal and grading and utilize natural materials available onsite. Alternative 21C is recommended for stabilizing the upper banks and providing long-term natural aesthetics to the stream corridor.

Table G-1 Plymouth Creek feasibility study alternatives summary

Reach	Site	Alternative	Alternative Description	Advantages	Disadvantages	Rec.?
Reach 1	Site 1	Alternative A	Remeander into historic channels	Adds habitat by adding stream length, improves aesthetics and water quality.	Decreases already shallow slope, requires tree removals.	N
Reach 1	Site 1	Alternative B	Stabilize erosion areas with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not use historic channels, does not provide natural habitat, less aesthetically pleasing.	N
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.	Y
Reach 1	Site 2	Alternative A	Remeander into historic channels	Adds habitat by adding stream length, improves aesthetics and water quality.	Decreases already shallow slope, requires tree removals.	N
Reach 1	Site 2	Alternative B	Stabilize erosion areas with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not use historic channels, does not provide natural habitat, less aesthetically pleasing.	N
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.	Y
Reach 1	Site 3	Alternative A	Narrow channel for approx. 800'	Improves habitat by deepening channel, improves access to floodplain.	Requires significant grading and tree removals.	N
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.	Y
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.	Y
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.	Y
Reach 1	Site 4	Alternative B	Realign disc golf course	Reduces or removes foot traffic pressure on banks.	May decrease natural amenities of course, may require clearing.	N
Reach 1	Site 5	Alternative A	Stabilize steep, eroding bank with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing.	N
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.	Y
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.	Y
Reach 1	Site 6	Alternative B	Stabilize bridge abutments with riprap only	Reduces erosion, less complex design.	Riprap does not provide natural habitat, requires more riprap.	N
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.	Y
Reach 1	Site 7	Alternative B	Stabilize bridge abutments with riprap only	Reduces erosion, less complex design.	Riprap does not provide natural habitat, requires more riprap.	N
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.	Y
Reach 2	Site 8	Alternative B	Stabilize bridge abutments with riprap only	Reduces erosion, less complex design.	Riprap does not provide natural habitat, requires more riprap.	N
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.	Y
Reach 2	Site 9	Alternative B	Stabilize bridge abutments with riprap only	Reduces erosion, less complex design.	Riprap does not provide natural habitat, requires more riprap.	N
Reach 2	Site 10	Alternative A	Raise stream bed in Fernbrook Lane North culvert	Low cost, improves stream access to floodplain.	Reduces culvert conveyance and may affect flood elevations.	N
Reach 2	Site 10	Alternative B	Create meanders in open area to add 70' of stream length	Improves habitat by adding stream length, improves stream access to floodplain, creates stable cross-section.	Decreases already shallow slope, increases wetland impacts, requires coordination with sanitary manholes.	N

Table G-1 Plymouth Creek feasibility study alternatives summary

Reach	Site	Alternative	Alternative Description	Advantages	Disadvantages	Rec.?
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.	Y
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.	Y
Reach 2	Site 11	Alternative A	Stabilize eroding banks with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing.	N
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.	Y
Reach 2	Site 12	Alternative A	Stabilize eroding banks with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing.	N
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.	Y
Reach 2	Site 13	Alternative A	Stabilize eroding banks with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing.	N
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.	Y
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.	Y
Reach 2	Site 14	Alternative B	Stabilize culvert outfall with concrete swale	Effectively stabilizes outfall from erosion, long life expectancy.	Does not provide natural habitat, not aesthetically pleasing.	N
Reach 3	Site 15	Alternative A	Install bank stabilization measures at eroding banks using hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing, does not reduce erosive stress.	N
Reach 3	Site 15	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.	N
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.	Y
Reach 3	Site 16	Alternative A	Install bank stabilization measures at eroding banks using hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing, does not reduce erosive stress.	N
Reach 3	Site 16	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.	N
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.	Y
Reach 3	Site 17	Alternative A	Install bank stabilization measures at eroding banks using hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing, does not reduce erosive stress.	N
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.	Y
Reach 3	Site 17	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.	N
Reach 3	Site 18	Alternative A	Remove large woody debris	Reduces flooding potential and bank erosion.	Decreases stream roughness and may increase flow velocity.	Y
Reach 3	Site 19	Alternative A	Remove large woody debris	Reduces flooding potential and bank erosion.	Decreases stream roughness and may increase flow velocity.	Y
Reach 3	Site 20	Alternative A	Stabilize with hard armor	Inexpensive, effective at reducing bank erosion, resilient to large flood events.	Does not provide natural habitat, less aesthetically pleasing, does not reduce erosive stress.	N

Table G-1 Plymouth Creek feasibility study alternatives summary

Reach	Site	Alternative	Alternative Description	Advantages	Disadvantages	Rec.?
Reach 3	Site 20	Alternative B	Stabilize with toe wood and grading to broaden meander	Stabilizes bank and reduces stress and erosion, provides habitat, utilizes materials generated on site, maintains existing stream length.	Installation can be challenging, useful life is less than other options, requires significant woody debris.	N
Reach 3	Site 20	Alternative C	Controlled overflow, install grade control structure downstream	Stabilizes active meander cutoff, maintains existing stream length.	Can be flanked by erosion and stream avulsion.	N
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.	Y
Reach 3	Site 21	Alternative A	Narrow channel for approx. 80'	Improves habitat by deepening channel, improves access to floodplain.	Requires significant grading and tree removals.	N
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.	Y