Stream Condition Assessment Memorandum

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1 Introduction

The Town of Wilbraham is located in Hampden County, Massachusetts and bordered by the Chicopee River to the north and the City of Springfield to the west. Hydrology within the town is characterized by tributaries originating in the Wilbraham Mountains to the east and flowing through low-lying wetland areas towards the Chicopee and Connecticut Rivers to the north and west, respectively.

As is the case with most modern-day communities, impervious urban development has altered pre-development hydrology within the Town, increasing stormwater runoff flows. When streams receive increased stormwater runoff flows, the resulting rapid changes in stream geomorphology and hydraulics can lead to instability of the stream channel and banks[1]. Erosion of a stream channel and banks, which is a natural process that can be accelerated by instability[2,3], can negatively impact both aquatic habitats[4] and adjacent communities. Therefore, understanding causes of stream instability and implementing stream restoration techniques can reduce risks to aquatic ecosystems and adjacent communities.

The Town identified five reaches within two streams that appear to present higher risks to the community. Reaches were identified based on the visual severity of bank erosion or historic flooding (i.e., probability of failure) and proximity to adjacent Town-owned facilities, infrastructure, or buildings (i.e., consequence of failure). Together with the Town, Tighe & Bond visited each stream reach and performed a cursory assessment of geomorphic processes

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[1] EPA, February 2024. Urbanization - Stormwater Runoff. https://www.epa.gov/caddis/urbanization-stormwater-runoff#:~:text=It%20alters%20channel%20morphology%2C%20generally,water%20velocity%20and%20shear%20stress. Accessed May 7, 2024.

[2] USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

[3] Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union. https://wildlandhydrology.com/resources/docs/River%20Restoration%20and%20Natural%20Channel%20Design/Rosgen_2011_Natural_Channel_Design.pdf

[4] NOAA Fisheries, February 2024. River Habitat. https://www.fisheries.noaa.gov/national/habitat-conservation/river-habitat#:~:text=Habitat%20Loss,and%20can%20lead%20to%20flooding. Accessed May 7, 2024.

and stream conditions. This assessment was used to recommend conceptual restoration solutions for long-term channel and bank stability, including permitting considerations and opinions of probable cost.

The following attachments are included with this memorandum:

- Attachment A contains figures depicting an aerial overview of the five stream reaches
    - Figure 1 is a locus map of the stream reaches evaluated
    - Figure 2 is a locus map of Stream A, the Unnamed Tributary at Woodland Dell Cemetery
    - Figure 3 is a locus map of Stream B, the Unnamed Tributary at Rice Drive
- Attachment B contains a selection of typical details for channel and bank stabilization
- Attachment C contains Stream Classification References
- Attachment D contains Bank Erosion Hazard Index (BEHI) analysis worksheets
- Attachment E contains Opinions of Probable Cost for recommended stream restoration projects

2 Project Site Description

Tighe & Bond visited the identified five reaches on two streams with the Town on March 20, 2024. Each stream was separated into reaches based on location, in-stream features, and geomorphological characterization. A description of each stream and separate reaches within each stream is detailed below.

2.1 Stream A: Unnamed Tributary at Woodland Dell Cemetery

Stream A is a perennial stream that borders the southern edge of the Woodland Dell Cemetery with a bankfull width of approximately 13 feet, flowing east to west towards Woodland Dell Road. Another perennial stream flows from southeast to northwest and crosses Brookmont Drive through a culvert. The confluence of the two streams is located north of 18 Brookmont Drive. Downstream of the confluence, the stream flows through several recently constructed culvert crossings under private driveways, then enters a nearly 800-foot long culvert that crosses under Main Street. The study area was separated into three reaches:

- **Reach A1** is approximately 910 feet long and located just south of the Cemetery and upstream of the confluence
- **Reach A2** is approximately 310 feet long and located downstream of the confluence
- **Reach A3** is approximately 490 feet long and located upstream of the confluence and crossing underneath Brookmont Drive

Reaches A1 and A3 are characterized by steep banks, with notable bank failures observed adjacent to the Cemetery and downstream of the Brookmont Drive culvert. The culvert through Brookmont Drive is under consideration for rehabilitation or replacement as part of the Culvert Asset Management Plan and conveys Reach A3 toward the confluence. Downstream of Reach A2, the Town noted that natural debris is often removed from the trash rack at the Main Street Culvert entrance.

2.2 Stream B: Unnamed Tributary at Rice Drive

Stream B is a perennial stream with bankfull widths ranging from 13 feet to 17 feet, flowing east to west through the Rice Nature Preserve, along the northern border of Highmoor Drive residential properties, then along the edge of the Rice Drive cul-de-sac. A confluence with another unnamed tributary flowing from the north is located at the Rice Drive cul-de-sac. Downstream of this confluence, the stream is conveyed through a privately-owned culvert under the driveway at 14 Rice Drive, then flows through a generally straight channel along the northern border of Rice Drive residential properties and towards a crossing through Main Street. The stream ultimately enters a wetland area and converges with Sawmill Brook. The study area was separated into two reaches:

- **Reach B1** is approximately 1590 feet long and located in the wooded area upstream of Rice Drive
- **Reach B2** is approximately 910 feet long and located along the Rice Drive cul-de-sac and includes the confluence, driveway culvert, and straight channel

Reach B1 is generally bending and characterized by steep banks. Reach B2 encroaches close to neighboring properties and roadways. Issues with erosion in Reach B2 prompted the Town to install pre-cast concrete blocks armoring along the edge of the Rice Drive cul-de-sac.

Undermining of the concrete blocks was observed. The confluence upstream of the 14 Rice Drive culvert is an open basin with undefined channels and contains deposited sediment. The 14 Rice Drive culvert was observed to be failing, with bare soils present and visible erosion of the fill material between the driveway and the culvert. Reach B2 meanders for approximately 430 feet before straightening into what appears to be a constructed channel along the northern edge of the Rice Drive residential properties. The Town has observed backyard flooding in this area.

3 Geomorphologic Assessment

River stability is the ability of a stream to transport flows and sediment produced by its watershed, over time in the present climate, such that the stream channel maintains its dimensional pattern and profile without excessive aggradation or degradation[5]. Inventory and evaluation of stream stability requires an understanding of the cause of the impairment to the stream. A geomorphological assessment, including characterization of a stream channel and banks, can help determine the cause of impairment, anticipate how the stream may potentially evolve over time, and inform recommendations for stream restoration solutions.

Tighe & Bond performed a cursory geomorphologic assessment of the five reaches in accordance with Natural Channel Design Phase II[6,7]. This phase of the Natural Channel Design approach includes geomorphic characterization of the stream, which includes identification of the Valley Type and Stream Type, and a hydrologic analysis, which includes examination of regional regression curves or stream gage data. The geomorphologic assessment included the following tasks:

- Collecting field data and geospatial data
- Classifying the valley type and stream type for each reach, based on the Rosgen Classification of Natural Rivers
- Assessing the bank erosion hazard index (BEHI) for each reach
- Recommending a priority level for improvements at each reach

[5] Rosgen, D.L., 2001. A Stream Channel Stability Assessment Methodology. Wildland Hydrology, Pagosa Springs, CO. https://wildlandhydrology.com/resources/docs/Assessment/Rosgen_2001_Channel_Stability.pdf

[6] USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

[7] Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union. https://wildlandhydrology.com/resources/docs/River%20Restoration%20and%20Natural%20Channel%20Design/Rosgen_2011_Natural_Channel_Design.pdf

3.1 Data Collection

Field data collection by Tighe & Bond for the geomorphologic assessment was performed on March 20, 2024. This included collection of channel and bank dimensions, materials, and indicators of erosion at point locations within the three identified stream reaches.

Each point location was assigned a unique identifier within each stream and reach. For example, the third point location within Reach A2 would be called Point A2-3. Additional geospatial data from publicly available GIS databases was obtained to support field data.

The point locations where data was collected are shown on Figures 2 and 3 in Attachment A. A summary of data collection sources is shown on Table 3-1.

TABLE 3-1
Data Sources

Item	Source
USGS Streamstats Program (v. 4.20.1)	https://streamstats.usgs.gov/ss/
Elevation Terrain	Information (MassGIS) 2015 LiDAR Dataset, available online at: https://maps.massgis.digital.mass.gov/MassMapper/MassMapper.html
Field Data Collection	Tighe & Bond and the Town of Wilbraham, March 20, 2024

3.2 Valley and Stream Classification

Each reach was classified using the Valley Type and Stream Type to better understand the geomorphologic processes that impact stream stability. Based on Natural Channel Design guidelines,[8,9] Valley Type is a distinct characterization of a valley based on side slopes, materials, and geologic characteristics that influence the shape of the valley, and Stream Type is a distinct characterization of a stream based on stream dimensions, stream pattern, stream profile, and channel materials. The criteria used to determine the Valley Type and Stream Type for each reach are defined on Table 3-2. These criteria were estimated using data collected at point locations in the field and from GIS databases. Definitions of the evaluated criteria are presented in Table 3-2.

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[8] USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

[9] Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union. https://wildlandhydrology.com/resources/docs/River%20Restoration%20and%20Natural%20Channel%20Design/Rosgen_2011_Natural_Channel_Design.pdf

TABLE 3-2
Definitions of Valley and Stream Classification Criteria

Item	Definition/Source
Sinuosity	Sinuosity (K) = Stream Length (Ls) / Valley Length (Lv) Estimated using orthographic imagery and LiDAR elevation terrain to determine stream planform and GIS tools to measure Ls and Lv.
Slope	Slope of the stream channel. Obtained elevations from LiDAR elevation terrain and used GIS tools to estimate stream length.
Single/Multi-thread	If a stream system consists of a single channel or multiple channels. Observed in the field.
Entrenchment Ratio	Entrenchment Ratio = Flood Prone Area Width / Bankfull Width. Measured Flood Prone Area Width and Bankfull Width in the field.
Width/Depth Ratio	Width/Depth Ratio = Bankfull Width / Bankfull Depth. Measured in the field.
Channel Material	Bedrock, boulders, cobble, gravel, sand, silt/clay. Observed in the field.
Bank Material	Bedrock, boulders, cobble, gravel, sand, silt/clay. Observed in the field.
Valley Type[9,10]	Distinct characterization of a valley based on applying the criteria above to classification keys used in Natural Channel Design
Stream Type[9,10]	Distinct characterization of a stream based on applying the criteria above to classification keys used in Natural Channel Design

A summary of geomorphologic characterization within each reach is as follows:

- **Reach A1** – This cobble-lined stream has a steep channel slope and banks, appears to be entrenched, and has a low width to depth ratio. As such, this reach may be classified as an A1 type stream. The A stream type typically consists of step pools and has a low sediment storage potential. Channel stability is impacted by organic debris obstructing flow.
- **Reach A2** – Downstream of the confluence, the channel becomes less steep, moderately entrenched, and lined with gravel. As such, this reach may be classified as either a B4 or G4 stream type, indicating that the stream may be in the process of succeeding from a stable, type B stream to a less stable type G stream, becoming more entrenched and less stable over time.
- **Reach A3** – Quantitative measurements were not collected along this reach, and therefore, this reach was not included on Table 3-3. However, the reach was visited in the field and qualitative observations were recorded. Due to its steep slope and visible step pools, this reach is likely an A type stream.
- **Reach B1** – Though located within a Type I valley with steep slopes, this reach may be classified as a type B4a stream due to its moderate width to depth ratios, moderately entrenched channel, and steeper slopes. The channel materials vary and

consist of gravel, sand, and cobbles depending on the location. Type B streams are typically stable. However, upland erosion above the flood-prone area was also observed.

- **Reach B2** – This channel has been modified from its natural form due to the sedimentation basin upstream of the 14 Rice Drive culvert, increased velocities downstream of the culvert, and channel straightening parallel to Rice Drive. A moderately sinuous, slightly entrenched portion of the stream exists between the culvert and the straightened section. This portion of the stream can be classified as a Type C3b channel.

Attachment C shows the classification keys used in Natural Channel Design to determine valley and stream type for each reach. Classification criteria are summarized in Table 3-3.

TABLE 3-3
Summary of Valley and Stream Classification

Stream Classification Criteria	**Value at Each Point Location[1]**						
	A1-1	**A2-1**	**B1-1**	**B1-2**	**B1-3**	**B2-1**	**B2-2**
Sinuosity (ft/ft)	1.20	1.27	1.27	1.27	1.27	1.20	1.20
Slope (ft/ft)	0.07	0.03	0.04	0.04	0.04	0.03	0.03
Bankfull Width (ft)	13.0	13.0	13.0	16.0	12.0	4.5[4]	17.0
Bankfull Depth (ft)	2.0	1.5	2.0	1.5	1.3	1.8	1.4
Single/Multi-thread	Single Thread	Single Thread	Single Thread	Single Thread	Single Thread	Single Thread	Single Thread
Entrenchment Ratio (ft/ft)	1.35	1.54	1.81	1.56	2.08	2.89	2.47
Width/Depth Ratio (ft/ft)	6.50	8.67	6.50	10.67	9.02	2.45	12.00
Channel Material	Cobble	Gravel	Gravel & Some Cobbles	Sand & Gravel	Gravel	Gravel	Cobbles
Valley Type[3]	I	I	I	I	I	V	V
Stream Type[3]	A1	B4 or G4	B4a	B4a	B4a	N/A[2]	C3b

[1]Quantitative measurements were not collected within Reach A3, but the Rosgen Stream Type could be estimated using qualitative observations described in this section.
[2]This reach did not meet the criteria of any Rosgen Stream type.
[3]Based on Valley Type and Stream Type classification keys used in Natural Channel Design.
[4]This measurement is considered an outlier because it is located in a constricted channel downstream of the 14 Rice Drive culvert.

3.3 Bank Erosion Hazard Index (BEHI) Analysis

The BEHI analysis evaluates the susceptibility to erosion from multiple stream erosional processes. The output of this analysis is an adjective rating, from very low to extreme, characterizing the rate of bank erosion. The BEHI model is process based and therefore does not isolate individual processes of erosion but integrates multiple variables to create a combined erosional assessment. Annual erosion rates were not calculated as part of this analysis. Definitions of BEHI Analysis variables are described in Table 3-4.

TABLE 3-4
Definitions of BEHI Analysis Criteria

BEHI Criteria	BEHI Criteria
Study Bank Height Ratio	Study bank height (the distance between the bankfull elevation and the top of the study bank) divided by the bankfull height (distance between the water surface elevation and the bankfull elevation)
Root Depth Ratio	Root depth, or the length of visible roots on the study bank, divided by the study bank height
Weighted Root Density	Approximate percentage area of the study bank covered in roots multiplied by the root depth ratio
Bank angle	Angle of the study bank from horizontal, rotating inwards towards the stream channel
Surface Protection	Approximate percentage area of the study bank protected by boulders, logs, or infrastructure
Bank Material	Adjustment to the BEHI adjective rating based on observed bank materials
Stratification of Bank Material	Adjustment to the BEHI adjective rating based on the position of unstable layers in relation to bankfull stage
Adjective Rating	Bank erosion hazard index rating of Very Low, Low, Moderate, High, Very High, or Extreme

BEHI analysis criteria were collected in the field and calculated using worksheets included in Attachment D. A summary of BEHI analysis criteria and the adjective rating of bank erosion severity is summarized in Table 3-5. A summary of bank erosion trends in each reach is as follows:

- **Reach A1** – Although this ravine-like reach has very steep banks, bedrock was present along the banks, which indicates that this reach has a very low risk for bank erosion.
- **Reach A2** – Downstream of the confluence, the stream banks are composed of sand and gravel, and generally have less protection from rock, boulders, and vegetation than upstream of the confluence.
- **Reach A3** – Quantitative measurements were not collected along this reach, and therefore, this reach was not included on Table 3-4. However, the reach was visited in the field and qualitative observations were recorded. Upstream of and downstream of the culvert, bare sandy soils were observed, indicating the likelihood of a higher bank erosion rate on the banks upstream and downstream of the culvert.
- **Reach B1** – High to extreme levels of bank erosion were observed at this reach due to bare sands and gravels present on the banks, high study bank height ratios, and

low surface protection. Runoff from upland properties appears to be contributing to erosion above the flood-prone-area.

- **Reach B2** – Downstream of the 14 Rice Drive Culvert, it is likely that increased outlet velocities have caused bank erosion at the culvert outlet. Further downstream, however, the sand and gravel banks are protected by cobbles and vegetation, only exhibiting moderate levels of bank erosion.

TABLE 3-5
Summary of BEHI Analysis

BEHI Criteria	**Value at Each Point Location[1]**						
	A1-1	**A2-1**	**B1-1**	**B1-2**	**B1-3**	**B2-1**	**B2-2**
Study Bank Height Ratio	11.4	6.0	1.7	2.6	6.0	5.7	4.0
Root Depth Ratio	0.1	0.2	0.6	0.2	0.2	0.1	0.4
Weighted Root Density	8.0%	3.6%	3.0%	2.5%	4.0%	3.8%	3.8%
Bank angle	100°	55°	43°	45°	30°	45°	30°
Surface Protection	20%	5%	5%	10%	5%	10%	40%
Bank Material	Gravel & Bedrock	Sand & Gravel	Sand & Gravel	Sand & Gravel	Sand	Sand	Sand
Stratification of Bank Material	None	None	None	None	None	None	None
BEHI Adjective Rating	Very Low	High	High	Very High	Extreme	Extreme	Very High

[1]Detailed measurements were not collected within Reach A3, but qualitative observations related to bank erosion are described in this section.

3.4 Hydrologic Data

Tighe & Bond utilized USGS Stream Stats to obtain representative baseflow[10], bankfull flow[11], and the 2-, 5-, 10-, 25-, 50-, and 100-year return frequency storm event flows[12] at each bank failure location. These flows are identified in Table 3-6.

TABLE 3-6
Predicted Hydrologic Flows for Each Reach

Flow ID[10,11,12]	Flow (cfs)				
	A1	**A2**	**A3**	**B1**	**B2**
Baseflow*	0.27	0.73	0.44	0.47	0.64
Bankfull Flow	24.0	45.9	30.0	41.2	47.6
2-year	20.4	44.5	30.0	31.5	38.4
5-year	35.2	75.8	51.4	53.9	65.3
10-year	47.4	101	69.0	72.3	87.3
25-year	65.6	139	95.3	99.7	120
50-year	81.1	172	117	123	148
100-year	97.9	206	142	148	177

*Baseflow assumed to be the 50% duration flow.

[10] Ries, K.G., III, 2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p.
[11] Bent, G.C., and Waite, A.M.,2013, Equations for estimating bankfull channel geometry and discharge for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2013–5155, 62 p.
[12] Zarriello, P.J., 2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156, 99 p.

4 Permitting

Stream restoration projects may require permits under the following regulatory programs. Permitting needs will depend on site-specific conditions, the selected design, and impact areas.

- **Wetlands Protection Act Notice of Intent/Order of Conditions –** Stream restoration projects are assumed to involve work within jurisdictional resource areas regulated by the Massachusetts Wetlands Protection Act (WPA; *M.G.L. c*. *131*, § *40*) and implementing regulations (310 CMR 10.00). It is assumed that a Notice of Intent (NOI) filing would be required with the Wilbraham Conservation Commission and MassDEP.
- **Massachusetts Environmental Policy Act (MEPA) –** Depending on the project, review thresholds set forth by MEPA (defined under 301 CMR 11.03) may be exceeded and the preparation and submittal of an Environmental Notification Form (ENF) could be required. MEPA review involves submission of an ENF to the Office of Energy and Environmental Affairs (EEA), public notice requirements, a site visit, and response to comments resulting from the public comment period. If the site it located within one miles of an EJ community and a MEPA review threshold is triggered, then an Environmental Impact Report (EIR) will also be required.
- **Massachusetts Endangered Species Act (MESA) Review –** Depending on the stream reach location, *Priority Habitats of Rare Species* or *Estimated Habitats of Rare Wildlife* may be present. If present, the project may be subject to a MESA Project Review. Rare Species Information Request would likely also need to be submitted the Massachusetts Natural Heritage and Endangered Species Program (NHESP) to verify the species identified within the project area to guide project design and best management practice development.
- **Chapter 91 Waterways License –** Projects involving activities that may results in changes to stream geometry may require Chapter 91 licensing, if the stream is considered a jurisdictional waterway under Chapter 91 of the Massachusetts Public Waterfront Act and implementing regulations at 310 CMR 9.00. Waterways, including all submerged lands lying below the high water mark of any non-tidal river or stream on which public funds have been expended for stream clearance, channel improvement, or any form of flood control or prevention work, either upstream or downstream within the river basin, except for any portion of any such river or stream which is not normally navigable during any season, by any vessel including canoe, kayak, raft, or rowboat are jurisdictional.
- **Section 401 Water Quality Certification –** A Section 401 Water Quality Certification (WQC) may be required for stream restoration projects if any project results in either in a loss of 5,000 square feet cumulatively of Bordering or Isolated Vegetated Wetlands and Land Under Water, the amount of any proposed dredging is greater than 100 cubic yards, or if any of the other thresholds listed in 314 CMR 9.04 are met. If impact areas do not exceed these thresholds, the WPA Order of Conditions will serve as the 401 WQC.
- **Section 404 Army Corps Pre-Construction Notification –** Stream restoration projects will involve work within Wetlands and Waters of the United States regulated under Section 404 of the Clean Water Act. The Corps' General Permits (GP) for Massachusetts cover specific activities within the limits of Corps' jurisdiction as stated in each of the activity General Permits. The total temporary and permanent impact area is used to determine if a project is eligible for Self-Verification, Pre-Construction Notification, or Individual Permit coverage. It is assumed that most, if not all, of the projects would require a permit application to submitted to the Corps.

In addition to environmental factors, the MA General Permit requires notification of the State Historic Preservation Officer (SHPO), Tribal Historic Preservation Officers (THPOs), and the Massachusetts Board of Underwater Archaeological Resources (MABUAR) per Section 106 of the National Historic Preservation Act, which could take place as part of the MHC PNF submittal discussed below.

Massachusetts Historic Commission – Any new construction projects or renovations to existing structures that require funding, licenses, or permits from any state or federal governmental agencies must be reviewed by the State Historic Preservation Officers, including MHC, MABUAR, and pertinent THPOs for impacts to historic and archaeological properties in accordance with Section 106 of the National Historic Preservation Act of 1966 and 950 CMR 71. The purpose of this review is to ensure that projects minimize or mitigate adverse effects to properties listed in the National and/or State Register of Historic Places. It is assumed that a Project Notification Form (PNF) will need to be completed and submitted to relevant parties for all replacement projects.

5 Recommendations

Based on field observations and the geomorphic assessment, Tighe & Bond used a Rosgen Priority Level approach[13] to recommend stream restoration techniques for impaired areas within the observed stream reaches. This approach classifies stream restoration projects into four distinct categories based on bank stabilization needs, site constraints, and economic constraints. Categories 1, 2, and 3 involve methods that require redesigning the channel, while Category 4 involves installation of in-stream structures and bioengineering within the existing channel and banks. The four categories for stream restoration projects are described below:

- Category 1 – Creates a new stable channel, reconnected to existing floodplain, more expensive
- Category 2 – Creates a new stable channel, excavate new floodplain, more expensive
- Category 3 – Creates step-pool channel within planform of existing channel, excavate new floodplain, more expensive
- Category 4 – In-place channel stabilization with in-stream structures and bioengineering, less expensive. Examples of in-place channel stabilization are listed below. Standard details for items noted with an asterisk (*) are included in Attachment B.
    - In-stream Structures, including root wads*, log vanes, rock cross vanes*, J-hooks, and stone toe*

[13] Rosgen, D.L., 1997. A Geomorphological Approach to Restoration of Incised Rivers. In: Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, S.S.Y. Wang, E.J. Langendoen, and F.D. Shields (Editors). University of Mississippi, Oxford, Mississippi. https://wildlandhydrology.com/resources/docs/River%20Restoration%20and%20Natural%20Channel%20Design/Rosgen_1997_Updated_Figures.pdf

- Bioengineering practices, including brush mattress, brush layers, live stakes, fabric encapsulated soil lifts*, fascines*, transplants, and erosion control matting*

In addition to recommendations for channel design, in-stream structures, or bioengineering outlined within the Rosgen Priority Level approach, Tighe & Bond developed recommendations associated with stream restoration work, such as studies and analysis, maintenance, or coordination with potential future work.

Tighe & Bond assumed that recommendations would be completed as a single stream restoration project within each reach. Under this assumption, opinions of probable cost were developed for each reach. For reaches where maintenance is recommended in lieu of a stream restoration project, a yearly capital cost was provided. Opinions of probable cost are summarized in Section 6.

Projects can be prioritized based on the severity of bank failure or channel instability (i.e., probability of failure) and the proximity of the issue to critical infrastructure, buildings, or resources (i.e., consequence of failure). As such, projects were assigned to be high priority, moderate priority, or low priority. Planning for high priority projects should begin in the next five years. Moderate priority project sites should be monitored frequently to document deterioration, resident complaints, and plan a stream restoration project if conditions worsen or once high priority restoration is addressed. Low priority project sites should be monitored annually to document deterioration, resident complaints, and plan a stream restoration project if conditions worsen. For reaches where maintenance is recommended in lieu of a stream restoration project, a recommended frequency for maintenance was provided.

5.1 Reach A1

While the channel is entrenched and disconnected from floodplain, the banks appear stable because they are composed of mostly bedrock. Type A streams like this one are less likely to evolve into other stream types, but are susceptible to downcutting (i.e., degradation of the channel) caused by large woody debris. Regular removal of large woody debris from the stream can reduce stream instability, although smaller organic and woody debris may slow velocities and provides habitat. This reach does not require the intervention of stream restoration techniques, but could benefit from occasional maintenance. A summary of recommendations within this reach is as follows:

- **Channel Design (Categories 1, 2, or 3):** None
- **In-stream Structures & Bioengineering (Category 4):** None
- **Other Recommendations:** Perform periodic maintenance. Monitor for organic debris, such as tree trunks, and periodically remove large flow obstructions.
- **Studies & Analyses:** None
- **Cost range:** $1,000 - $5,000 per year, using Town personnel labor
- **Priority:** Monitor yearly, or after storm events equal to or larger than a 2-year return frequency storm event.

5.2 Reach A2

The stream type classification between a type B and type G stream indicates that this reach may evolve into a less stable channel over time. Category 4 stabilization adjacent to the Cemetery, including in-place channel stabilization structures and bioengineering, may preventatively reduce bank erosion and damage to the Cemetery. Therefore, recommendations include installing in-stream structures, such as cross-vanes, boulders, and root wads, to continue to direct flow away from the Cemetery, and installing bioengineering features, such as fabric matting and live stakes, to promote bank stability during high flow events. A hydrologic and hydraulic analysis should be performed to determine design flows and shear stresses for bank stabilization design. Due to its preventative nature, this work is currently low priority, but that priority could increase if conditions worsen. A stream restoration project that includes these recommendations can be summarized as follows:

- **Channel Design (Categories 1, 2, or 3):** None
- **In-stream Structures & Bioengineering (Category 4):**
  - 50-100 feet of Fabric Encapsulated Soil Lifts (See Detail B-1 in Attachment B)
  - 3-5 Rootwads (See Detail B-2 in Attachment B)
  - 50-100 feet of Stone Toe Slope (See Detail B-3 in Attachment B)
  - 100-500 square feet of fabric matting with live stakes (See Detail B-4 in Attachment B)
  - 2-3 Cross Vanes (See Detail B-6 in Attachment B)
- **Other Recommendations:** None
- **Studies & Analyses:** Hydrologic & Hydraulic Analysis
- **Cost range:** $500,000 - $700,000
- **Priority:** Low

5.3 Reach A3

Reach A3 has steep banks is located adjacent to residential properties, with apparent bank erosion upstream and downstream of the Brookmont Drive culvert. As such, Category 4 bank stabilization techniques are recommended the vicinity of the Brookmont Drive culvert. This includes installation of in-stream structures, such as cross-vanes and root wads, to direct flow away from adjacent properties, and to install bioengineering features, such as fabric encapsulated soil lifts and live stakes, to promote bank stability. A hydrologic and hydraulic analysis would be recommended to determine design flows and shear stresses along the channel. If the Brookmont Drive culvert is rehabilitated or replaced as part of the Culvert Asset Management program, coordinating stream restoration work with culvert restoration work may result in cost savings. Stream restoration recommendations are moderate priority due to the adjacent residential properties and the roadway. Therefore, these recommendations should be completed in the next 5 to 10 years, or when the Brookmont Drive culvert is rehabilitated or replaced. A stream restoration project that includes these recommendations can be summarized as follows:

- **Channel Design (Categories 1, 2, or 3):** None
- **In-stream Structures & Bioengineering (Category 4):**
  - 100-200 feet of Fabric Encapsulated Soil Lifts (See Detail B-1 in Attachment B)
  - 3-5 Rootwads (See Detail B-2 in Attachment B)
  - 100-200 feet of Stone Toe Slope (See Detail B-3 in Attachment B)
  - 100-500 square feet of fabric matting with live stakes (See Detail B-4 in Attachment B)
  - 2-3 Cross Vanes (See Detail B-6 in Attachment B)

- **Other Recommendations:** None
- **Studies & Analyses:** Hydrologic & Hydraulic Analysis
- **Cost range:** $600,000 - $800,000
- **Priority:** Moderate

5.4 Reach B1

The stream pattern and profile within this reach is generally stable, with some point locations of extreme erosion. Category 4 stabilization, including installation of in-stream structures and bioengineered stabilization techniques, would be recommended within this reach. One area of extreme erosion exists on the full height of the bank behind a residential property (Point Location B1-2). This area of erosion has likely formed due to upland stormwater runoff. Therefore, slope stabilization at Point Location B1-2 is a high priority and should be addressed within the next 5 years. Slope stabilization recommendations include installing bioengineering features, such as fabric matting, armoring, and live stakes. These improvements will reduce downstream sediment transport and mitigate potential slope failure encroachment on residential property. We recommend monitoring the Main Street Culvert for erosion and sedimentation issues. A stream restoration project that includes slope stabilization at Point Location B1-2 can be summarized as follows:

- **Channel Design (Categories 1, 2, or 3):** None
- **In-stream Structures & Bioengineering (Category 4):**
    - 200-300 feet of Fabric Encapsulated Soil Lifts (See Detail B-1 in Attachment B)
    - 3-5 Rootwads (See Detail B-2 in Attachment B)
    - 200-300 feet of Stone Toe Slope (See Detail B-3 in Attachment B)
    - Rip-rap slope covered with 100-200 square feet of fabric matting and live stakes (See Detail B-4 in Attachment B)
    - 3-4 Cross Vanes (See Detail B-6 in Attachment B)
- **Other Recommendations:** Monitor the Main Street culvert for clogging and sedimentation issues
- **Studies & Analyses:** None
- **Cost range:** $500,000 - $600,000
- **Priority:** High, complete in next 5 years

5.5 Reach B2

There is an opportunity to define a stable channel upstream of the 14 Rice Drive culvert and replace the undermined precast concrete bank armoring with a natural channel design. As such, a combination of Category 2 and Category 4 design is recommended. This includes performing a reference reach survey within Reach B1 reach to determine a stream pattern and profile for the new channel, performing a hydrologic and hydraulic analysis to determine design flows and shear stresses along the channel, constructing a new channel, installing in-stream structures, such as cross-vanes, boulders, and root wads, installing bioengineering features, such as fabric encapsulated soil lifts and live stakes, and ideally replacing the failing culvert at 14 Rice Drive. Due to its proximity to public roadways and residential properties, these improvements are a moderate priority and could be completed in the next 5 to 10 years.

A stream restoration project that includes these recommendations can be summarized as follows:

- **Channel Design (Categories 1, 2, or 3):** Design new meandering channel (Category 2) and excavate additional floodplain
- **In-stream Structures & Bioengineering (Category 4):**
    - 200-300 feet of Fabric Encapsulated Soil Lifts (See Detail B-1 in Attachment B)
    - 5-7 Rootwads (See Detail B-2 in Attachment B)
    - 200-300 feet of Stone Toe Slope (See Detail B-3 in Attachment B)
    - 300-600 square feet of fabric matting with live stakes (See Detail B-4 in Attachment B)
    - 3-5 Cross Vanes (See Detail B-6 in Attachment B)
- **Other Recommendations:** Consider replacement of culvert at 14 Rice Drive (not included in cost range)
- **Studies & Analyses:** Reference reach survey of Reach B1, Hydrologic & Hydraulic Analysis
- **Cost range:** $800,000 - $1,000,000

  Priority: Moderate

6 Opinion of Probable Cost

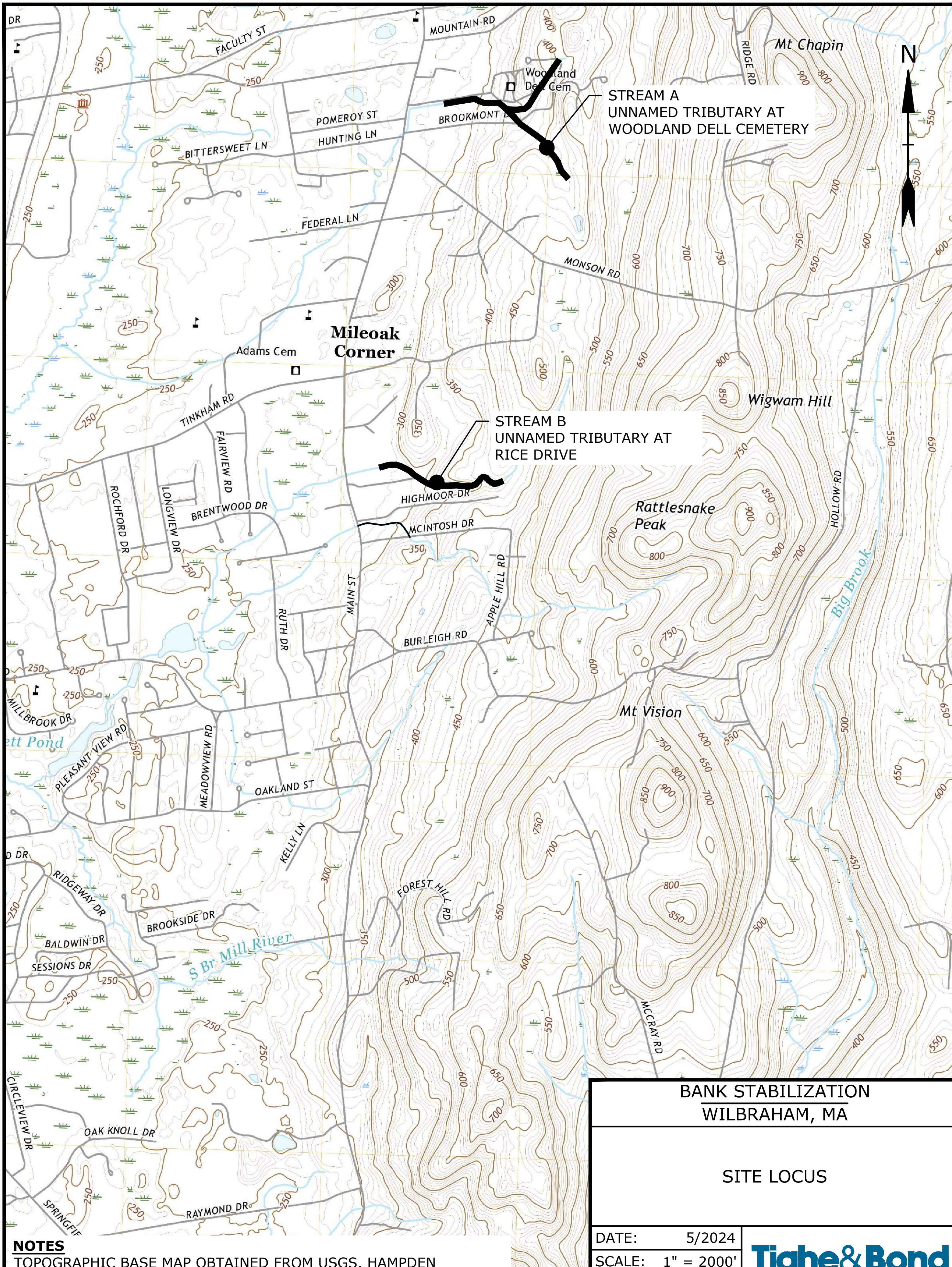
The following opinion of probable costs has been developed for the recommendations noted above. The probable construction costs are an approximation based on limited investigations and our experience on other similar sized projects and are not based on detailed quantity takeoffs or designs. Once further detailed investigations are performed, the scope of work may change, affecting the actual construction costs. The estimates include engineering, permits, access coordination, and contingencies where applicable. Detailed opinions of probable costs for stream restoration projects are included as Attachment E.

Item		**Probable Cost Range[1]**
Reach A1	Periodic maintenance	$1000/year - $5000/year
Reach A2	Stream Restoration with bioengineering and in-stream structures (Low Priority)	$500,000 - $700,000
Reach A3	Stream Restoration with Bioengineering and in-stream structures (Moderate Priority)	$600,000 - $800,000
Reach B1	Slope Stabilization with Bioengineering (High Priority)	$500,000 - $600,000
Reach B2	Stream Restoration with channel design, bioengineering, and in-stream structures (Moderate Priority)	$800,000 - $1,000,000
Yearly Maintenance Total		**$1000/year - $5000/year**
Stream Restoration Project Total		**$2,400,000 - $3,100,000**

[1]This is an engineer's Opinion of Probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

\\tighebond.com\data\Data\Projects\W\W1929 Wilbraham\035 MVP Culvert Assessment Program\Reports\Bank Stabilization Memo\Wilbraham_BankStabilization_Memo.docx

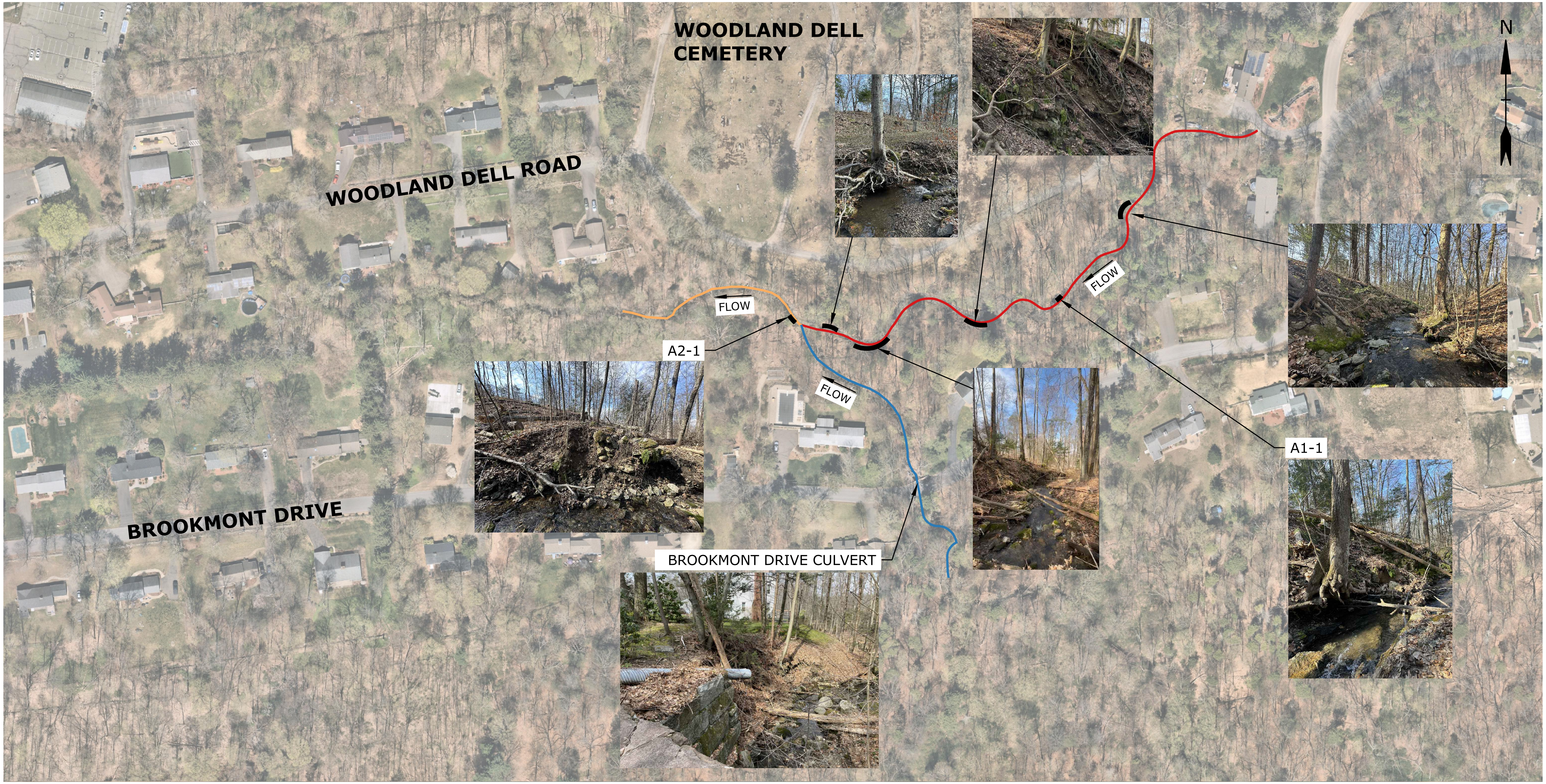
ATTACHMENT A
Locus Figures



BANK STABILIZATION WILBRAHAM, MA	
SITE LOCUS	
DATE: 5/2024	Tighe&Bond
SCALE: 1" = 2000'	
FIGURE: A-1	

NOTES

TOPOGRAPHIC BASE MAP OBTAINED FROM USGS, HAMPDEN QUANDRANGLE, MA, CT, DATED 2021



LEGEND:

APPROXIMATE LOCATION OF OBSERVED BANK EROSION

STREAM REACH A1

STREAM REACH A2

STREAM REACH A3

BANK STABILIZATION
WILBRAHAM, MA

STREAM A
UNNAMED TRIBUTARY AT WOODLAND DELL CEMETERY
LOCUS MAP

DATE:	April 2024
SCALE:	NO SCALE
FIGURE	A-2

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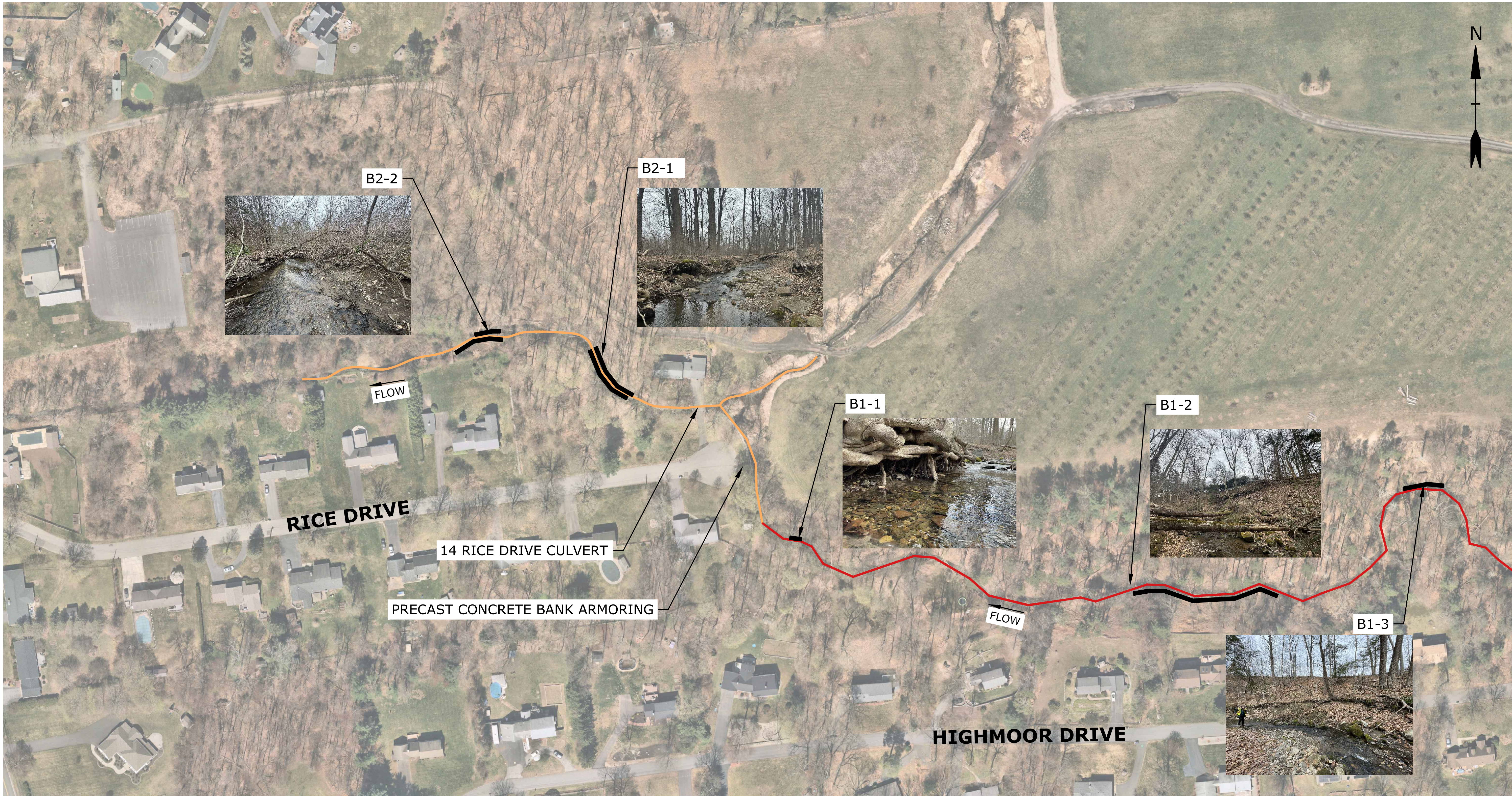

LEGEND:

- APPROXIMATE LOCATION OF OBSERVED BANK EROSION
- STREAM REACH B1
- STREAM REACH B2

BANK STABILIZATION
WILBRAHAM, MA

STREAM B
UNNAMED TRIBUTARY AT RICE DRIVE
LOCUS MAP

DATE: April 2024
SCALE: NO SCALE
FIGURE A-3

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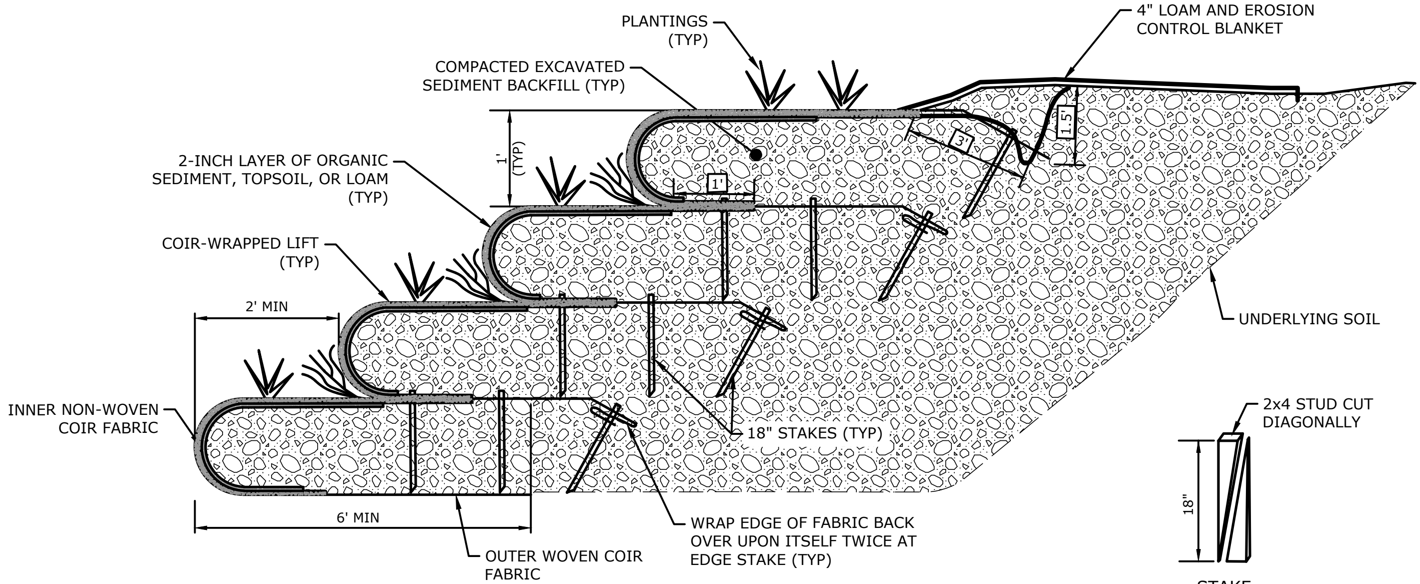
ATTACHMENT B

Typical Bank Stabilization Details



STAKE

ENCAPSULATED SOIL LIFT

NO SCALE

NOTES:

1. INSTALL ENCAPSULATED SOIL LIFTS FROM DOWNSTREAM TO UPSTREAM, WITH UPSTREAM COIR FABRIC OVERLAPPING DOWNSTREAM FABRIC BY 18" MINIMUM.

2. USE SANDBAGS, T IMBER FORM, OR OTHER AS NECESSARY TO FORM FACE OF LIFT AND KEEP LOWER LIFTS SUFFICIENTLY DRY FOR INSTALLATION AND COMPACTION.

3. PROTECT FROM DAMAGE WHEN CONSTRUCTED BELOW TEMPORARY ACCESS ROAD OR NEAR OTHER WORK.

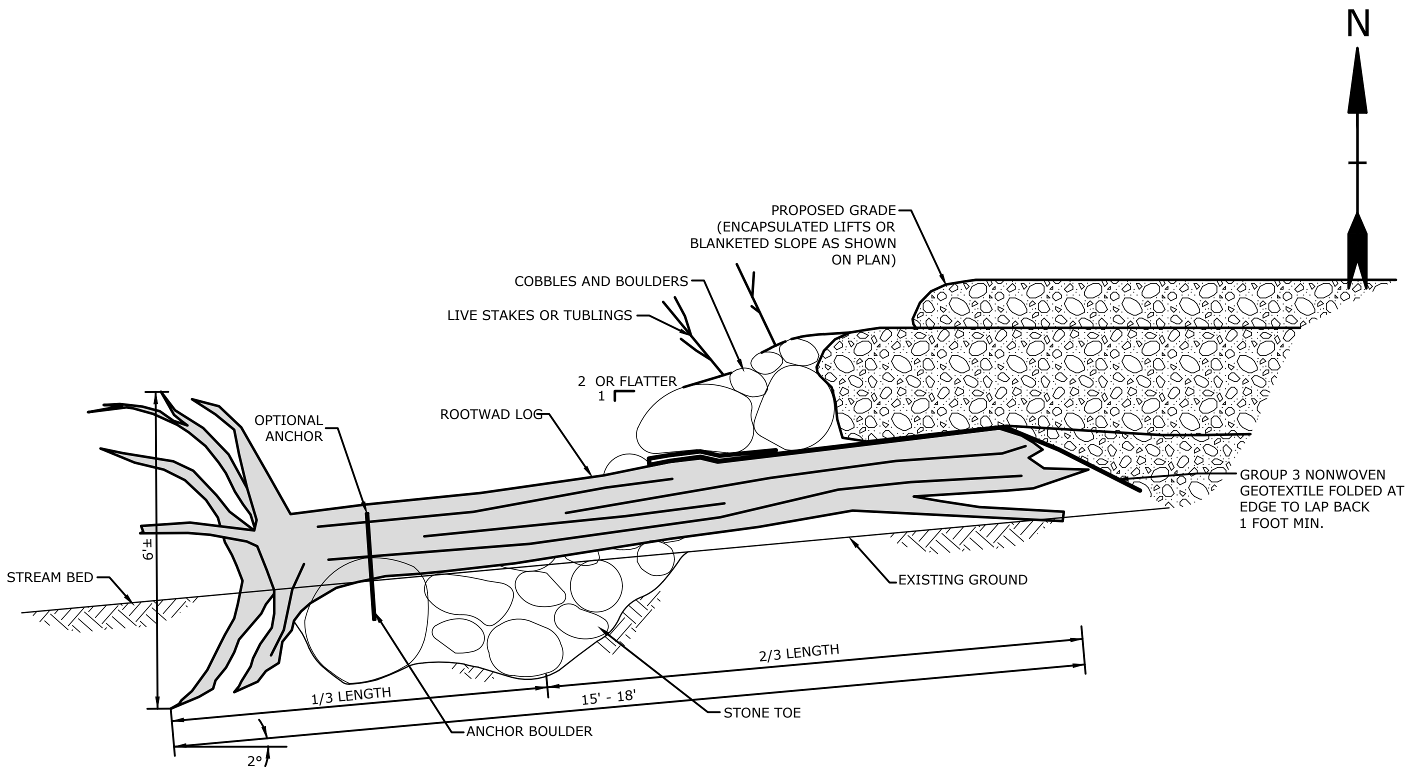
PHOTO - FABRIC ENCAPSULATED SOIL LIFT EXAMPLE

BANK STABILIZATION DETAILS
WILBRAHAM, MA

FABRIC ENCAPSULATED SOIL LIFT

DATE:	5/2024
SCALE:	NO SCALE
FIGURE:	B-1

Tighe&Bond



ROOTWAD

NO SCALE

NOTES:

1. DRAPE GEOTEXTILE AROUND ROOTWAD LOG AND PACK SOIL BELOW LOG FOR A TIGHT FIT.

2. ROOTWAD LOG TO HAVE 15 TO 24 INCH DIAMETER TRUNK, INTACT ROOT DIAMETER OF 6 FEET AND TO BE A ROT-RESISTANT SPECIES (BLACK LOCUST, WHITE OAK, CEDAR, BLACK WALNUT, OR APPROVED EQUAL).

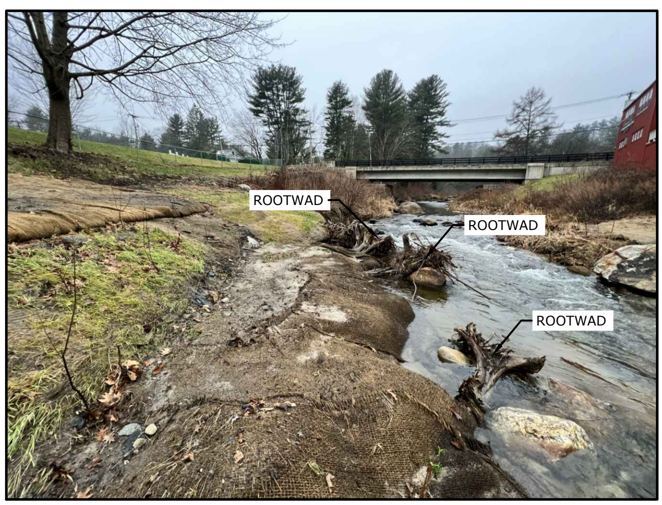


PHOTO - ROOTWAD EXAMPLE

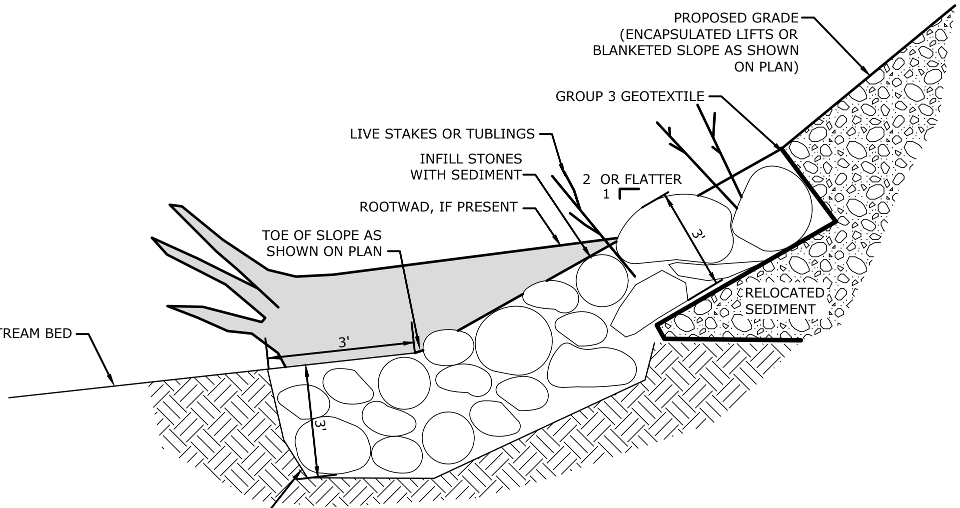
BANK STABILIZATION DETAILS
WILBRAHAM, MA

ROOTWAD

DATE:	5/2024
SCALE:	NO SCALE
FIGURE:	B-2

Tighe&Bond

N



STONE TOE SLOPE
NO SCALE

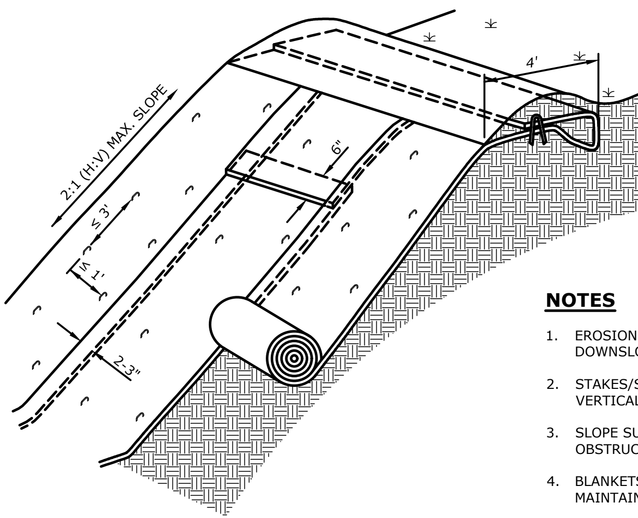
PHOTO - STONE TOE SLOPE EXAMPLE

BANK STABILIZATION DETAILS
WILBRAHAM, MA

STONE TOE SLOPE

DATE:	5/2024
SCALE:	NO SCALE
FIGURE:	B-3

Tighe&Bond



EROSION CONTROL BLANKET
NO SCALE

NOTES

1. EROSION CONTROL BLANKET SHALL BE INSTALLED VERTICALLY DOWNSLOPE.
2. STAKES/STAPLES SHALL BE PLACED NO MORE THAN 3 FEET APART VERTICALLY, AND 1 FEET APART HORIZONTALLY.
3. SLOPE SURFACE SHALL BE FREE OF STICKS, ROCKS, AND OTHER OBSTRUCTIONS.
4. BLANKETS SHALL BE ROLLED OUT LOOSELY AND STAKED/STAPLED TO MAINTAIN DIRECT SOIL CONTACT. DO NOT STRETCH THE BLANKETS.
5. EROSION CONTROL BLANKET SHALL BE ALL NATURAL BIODEGRADABLE WITH A MINIMUM 24 MONTH DECOMPOSITION RATE.
6. STAKE BLANKET IN PLACE, CUT HOLES THROUGH LAYERS, THEN DIG THE PLANTING HOLES IN THE SOIL. STAPLE AROUND PLANT EVERY 1 FT.
7. EXCAVATE A 1 FT WIDE BY 1 FT DEEP TRENCH ALONG THE TOP OF THE SLOPE. THE TRENCH CHALL RUN ALONG THE LENGTH OF THE INSTALLATION. STAPLE BLANKET ALONG BOTTOM OF TRENCH, FILL WITH COMPACTED SOIL, OVERLAP BLANKET TOWARDS TOE OF SLOPE, AND SECURE WITH STAPLES EVERY 2 FT.

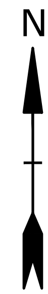
N

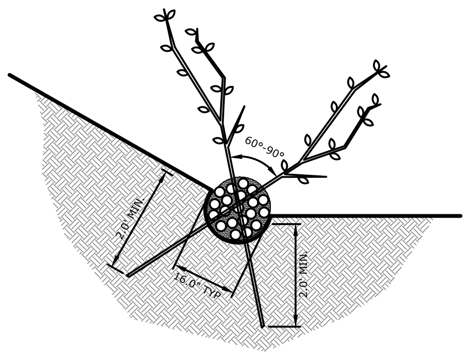
BANK STABILIZATION DETAILS
WILBRAHAM, MA

EROSION CONTROL BLANKET

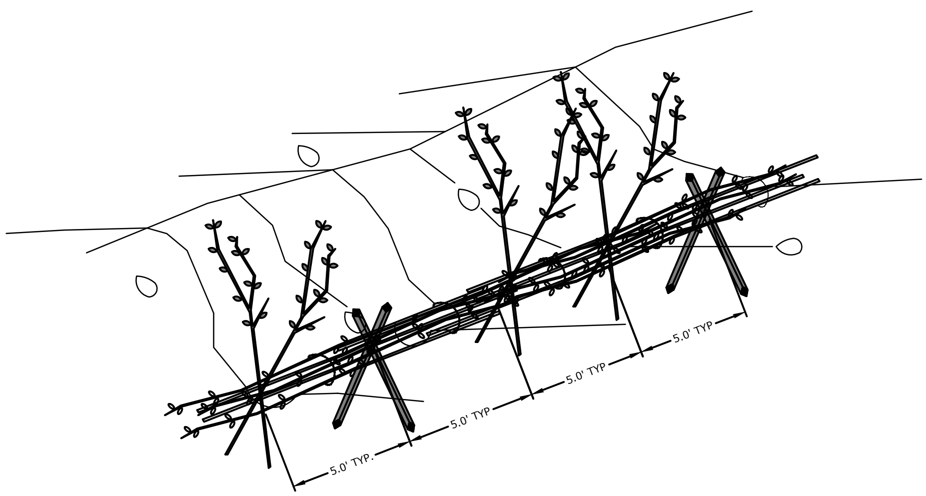
DATE:	5/2024
SCALE:	NO SCALE
FIGURE:	B-4

Tighe&Bond





SECTION
WILLOW FASCINE DETAIL
NO SCALE



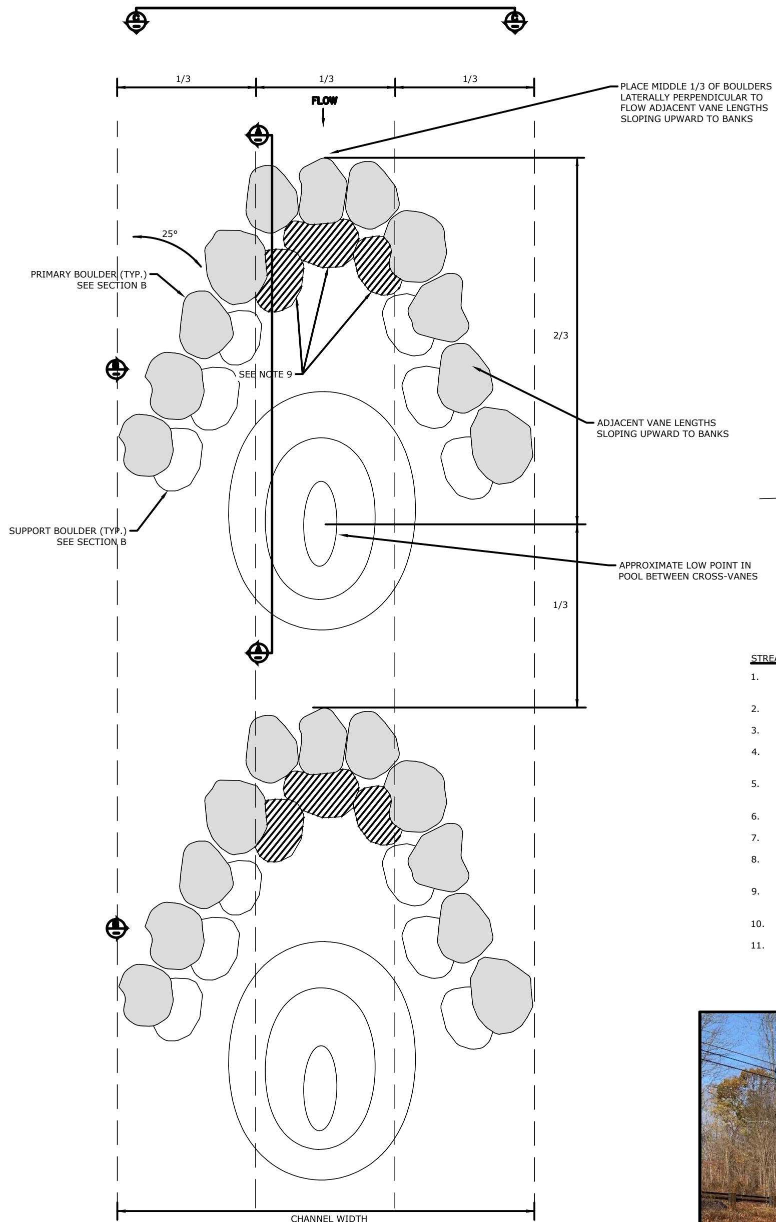
ISOMETRIC
WILLOW FASCINE DETAIL
NO SCALE

BANK STABILIZATION DETAILS
WILBRAHAM, MA

WILLOW FASCINE

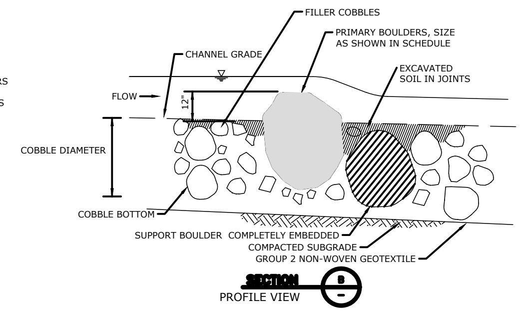
DATE:	5/2024
SCALE:	NO SCALE
FIGURE:	B-5

Tighe&Bond

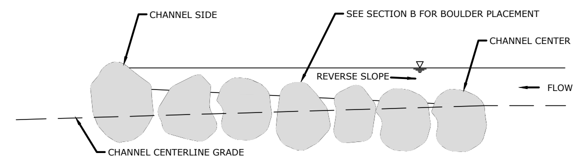


PLAN VIEW

CROSS-VANE DETAIL
NO SCALE



SECTION B
PROFILE VIEW

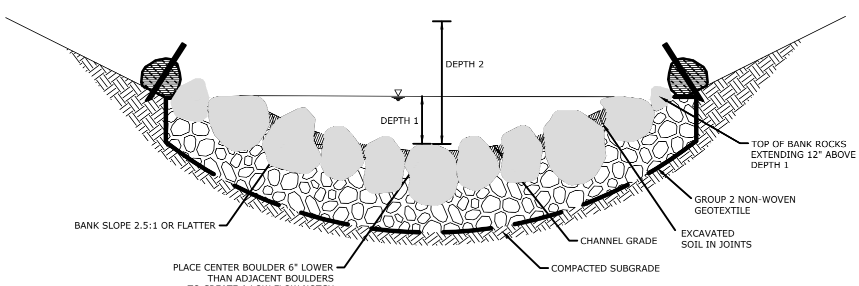


SECTION A
PROFILE VIEW

STREAM CHANNEL RESTORATION NOTES:

1. USE WEATHERED SUBANGULAR OR ROUNDED COBBLES AND BOULDERS FOR STREAM CHANNELS AND CROSS VANES.
2. COBBLE LAYER THICKNESS AS SHOWN IN SECTION B.
3. ALIGN LONG AXIS OF BOULDER PARALLEL TO STREAM FLOW.
4. PLACE EXCAVATED MATERIAL OVER COBBLES AND BOULDERS AND MECHANICALLY WORK SMALLER MATERIAL INTO VOIDS UNTIL VOIDS ARE FILLED.
5. PROVIDE SUDDEN VERTICAL UNDULATIONS IN COBBLE BOTTOM OF APPROXIMATELY 6 INCHES AT INTERMEDIATE POINTS BETWEEN CROSS VANES BOULDERS TO FORM SMALL STEP POOLS.
6. GENERALLY ALIGN CHANNEL TO LINES AND GRADES SHOWN ON SITE PLAN.
7. CONTROL WATER DURING CONSTRUCTION USING A STREAM BYPASS IN ONE OR MORE PHASES.
8. SCOUR POOL IS TO BE ALLOWED TO FORM NATURALLY WHEN CROSS-VANE IS INSTALLED IN A LOCATION THAT DOES NOT REQUIRE A COBBLE BOTTOM.
9. ONLY HATCHED SUPPORT BOULDERS ARE TO BE INSTALLED IN AREAS THAT ARE CALLED OUT TO HAVE A COBBLE STREAMBED.
10. CROSS-VANE DEPTH MEASUREMENTS MEASURED FROM THE CHANNEL INVERT TO THE TOP OF THE BOULDERS.
11. DOWNSTREAM CROSS-VANE POOL DEPTH TO BE GRADED TO BETWEEN 0.5' AND 1.0' BELOW CHANNEL CENTERLINE GRADE WITH THE LOWEST DEPTH OCCURRING APPROXIMATELY 2/3 FROM THE TOP OF THE CROSS-VANE

PHOTO - CROSSVANE EXAMPLE



SECTION C
CROSS SECTION VIEW

BANK STABILIZATION DETAILS
WILBRAHAM, MA

CROSSVANE

DATE:	5/2024
SCALE:	NO SCALE
FIGURE:	B-6

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ATTACHMENT C

Rosgen Stream Classification References

Table 11–1 Valley types used in geomorphic characterization

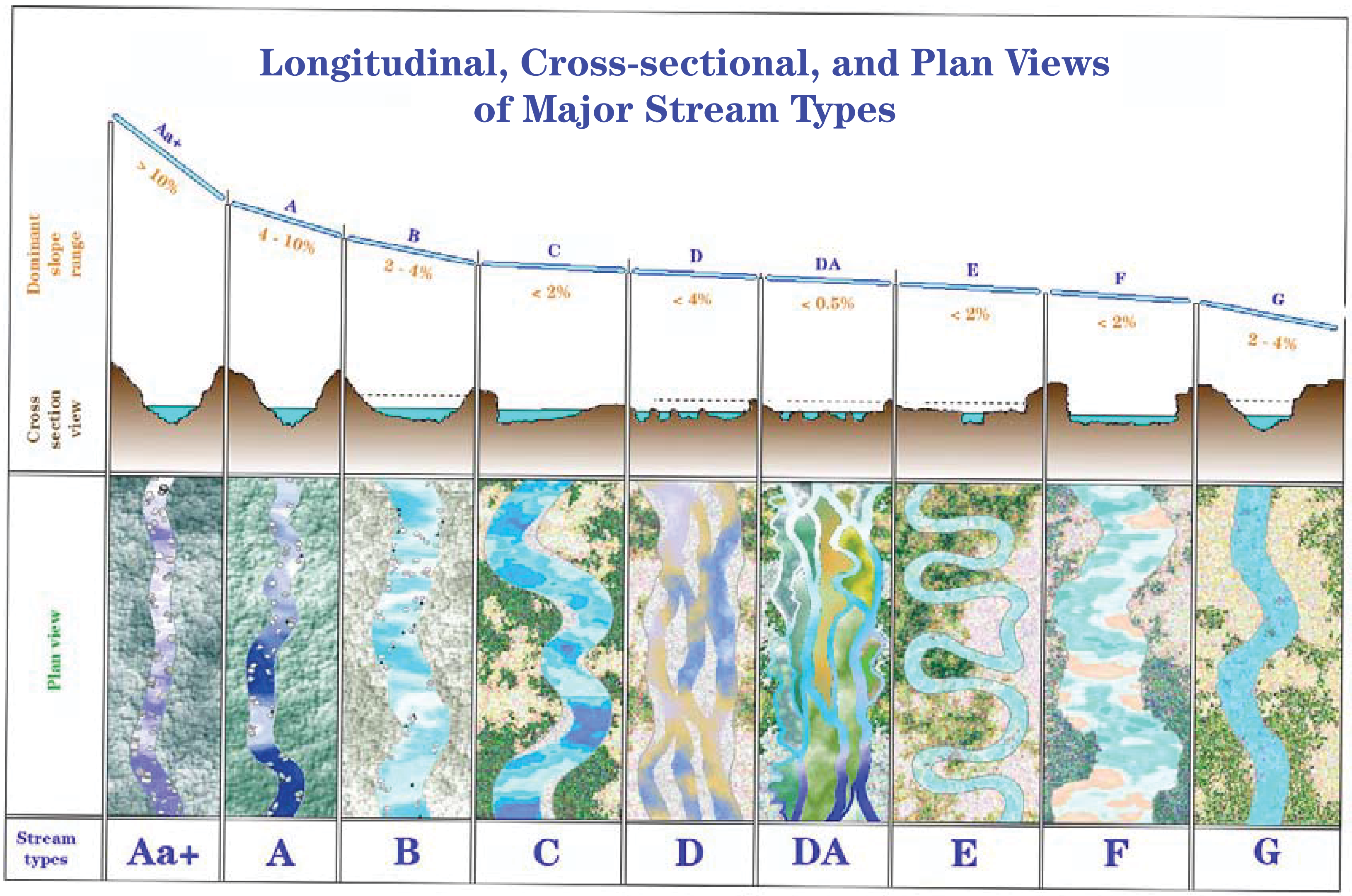
Valley types	Summary description of valley types
I	Steep, confined, V-notched canyons, rejuvenated side slopes
II	Moderately steep, gentle-sloping side slopes often in colluvial valleys
III	Alluvial fans and debris cones
IV	Gentle gradient canyons, gorges, and confined alluvial and bedrock-controlled valleys
V	Moderately steep, U-shaped glacial-trough valleys
VI	Moderately steep, fault, joint, or bedrock (structural) controlled valleys
VII	Steep, fluvial dissected, high-drainage density alluvial slopes
VIII	Wide, gentle valley slope with well-developed flood plain adjacent to river and/or glacial terraces
IX	Broad, moderate to gentle slopes, associated with glacial outwash and/or eolian sand dunes
X	Very broad and gentle valley slope, associated with glacio- and nonglacio-lacustrine deposits
XI	Deltas

REFRENCES

USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union.

Figure 11–2 Broad-level stream classification delineation showing longitudinal, cross-sectional, and plan views of major stream types

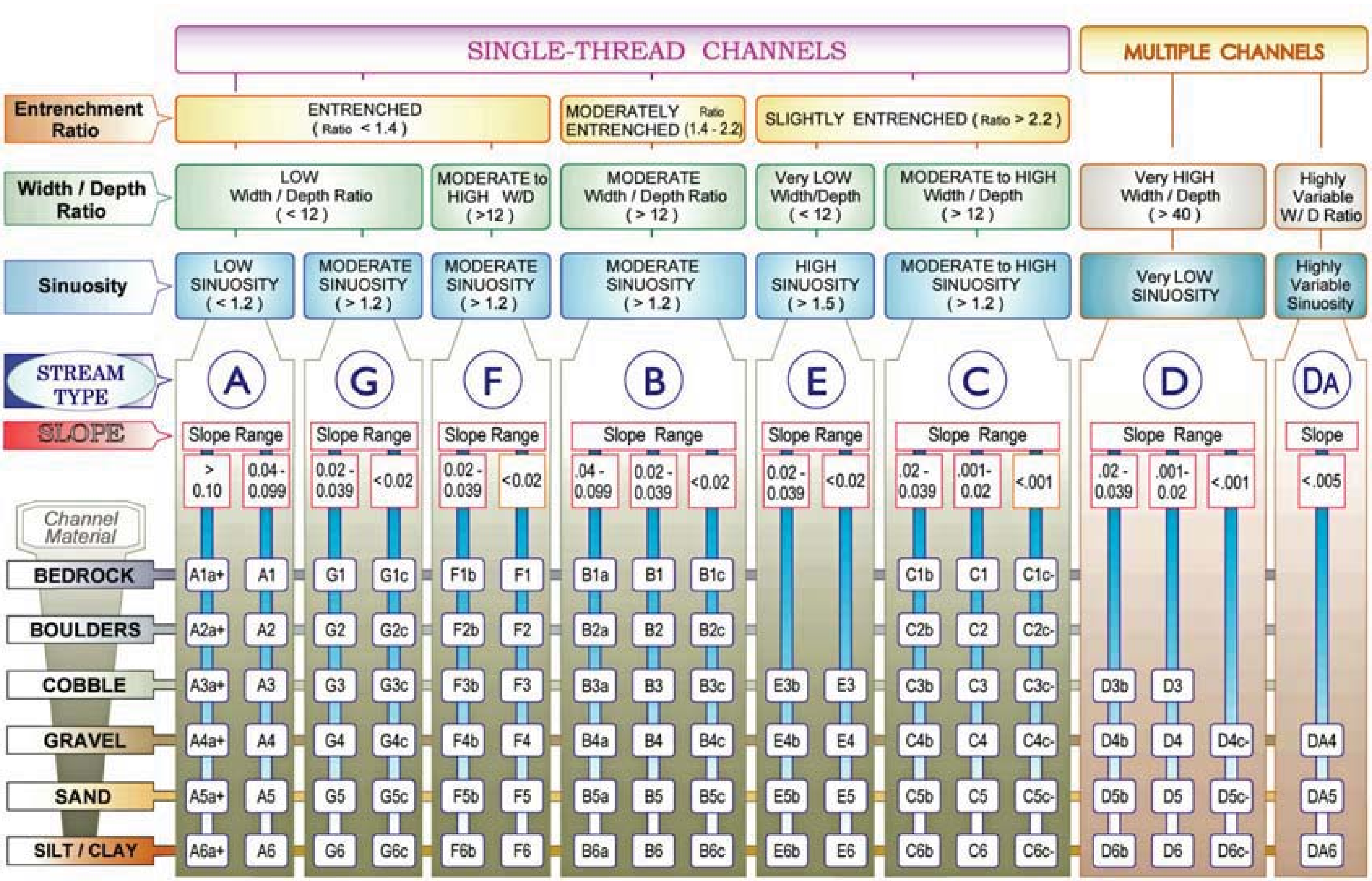


REFRENCES

USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union.

Figure 11–3 Classification key for natural rivers



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

REFRENCES

USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union.

Table 11–2 General stream type descriptions and delineative criteria for broad-level classification (level 1)

Stream type	General description	Entrench-ment ratio	W/d ratio	Sinuosity	Slope	Landform/ soils/features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock, or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls
A	Steep, entrenched, cascading, step-pool streams. High energy/ debris transport associated with depositional soils. Very stable if bedrock or boulder-dominated channel	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step-pool bed morphology
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Very stable plan and profile. Stable banks	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition and/or structural. Moderate entrenchment and width-to-depth ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools
C	Low gradient, meandering, point bar, riffle/pool, alluvial channels with broad, well-defined flood plains	>2.2	>12	>1.2	<.02	Broad valleys with terraces, in association with flood plains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/ pool bed morphology
D	Braided channel with long-itudinal and transverse bars. Very wide channel with eroding banks	n/a	>40	n/a	<.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment with abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bed load and bank erosion
DA	Anastomizing (multiple channels) narrow and deep with extensive, well-vegetated flood plains and associated wetlands. Very gentle relief with highly variable sinuosities and width-to-depth ratios. Very stable streambanks	>2.2	Highly variable	Highly variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomized (multiple channel) geologic control creating fine deposition with well-vegetated bars that are laterally stable with broad wetland flood plains. Very low bed-load, high wash load sediment
E	Low gradient, meandering riffle/pool stream with low width-to-depth ratio and little deposition. Very efficient and stable. High meander width ratio	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with flood plains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width-to-depth ratios
F	Entrenched meandering riffle/pool channel on low gradients with high width-to-depth ratio	<1.4	>12	>1.2	<.02	Entrenched in highly weathered material. Gentle gradients with a high width-to-depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology
G	Entrenched gully step-pool and low width-to-depth ratio on moderate gradients	<1.4	<12	>1.2	.02 to .039	Gullies, step-pool morphology with moderate slopes and low width-to-depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials (fans or deltas). Unstable, with grade control problems and high bank erosion rates

REFRENCES
USDA NRCS, August 2007. Part 654 National Engineering Handbook, Chapter 11 Rosgen Geomorphic Channel Design. https://semspub.epa.gov/work/01/557060.pdf

Rosgen, D.L. (2011). Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In A. Simon, S.J. Bennett, & J.M. Castro (Eds.), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, Geophysical Monograph Series 194, pp. 69–93. Washington, D.C.: American Geophysical Union.

ATTACHMENT D
BEHI Analysis Worksheets

Bank Erosion Hazard Index (BEHI)

Stream: **A , Unnamed Tributary** Location: **A1-1, South east of Woodland Dell Cemetery**

Station: **n/a** Observers: **JF, CD**

Date: **3/20/2024** Stream Type: **A1** Landscape Type:

Study Bank Height to Bankfull Height (C) — BEHI Score (Fig. 3-7)

Study Bank Height (ft) =	18.00 (A)	Bankfull Height (ft) =	1.58 (B)	(A) / (B) =	11.39 (C)	9.0

Root Depth to Study Bank Height (E)

Root Depth (ft) =	2.00 (D)	Study Bank Height (ft) =	18.00 (A)	(D) / (A) =	0.11 (E)	8.0

Weighted Root Density (G)

Root Density as % =	75% (F)	(F) × (E) =	8% (G)	9.0

Bank Angle (H)

Bank Angle as *Degrees* =	100 (H)	10.0

Surface Protection (I)

Surface Protection as % =	20% (I)	7.0

Bank Material Adjustment:

- **Bedrock** (Overall *Very Low* BEHI)
- **Boulders** (Overall *Low* BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

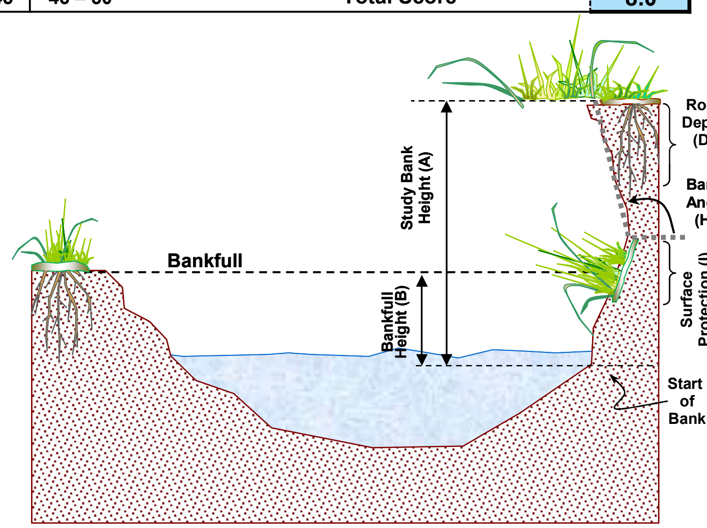
Bank Material Adjustment: -35

Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **Very Low** — **8.0**



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

Bank Erosion Hazard Index (BEHI)

Stream: **A, Unnamed Tributary** Location: **A2-1, South of Woodland Dell Cemetary**

Station: **n/a** Observers: **JF, CD**

Date: **3/20/2024** Stream Type: **B4 or G4** Landscape Type:

					BEHI Score (Fig. 3-7)
Study Bank Height to Bankfull Height (C)					
Study Bank Height (ft) =	5.50 (A)	Bankfull Height (ft) =	0.92 (B)	(A) / (B) = 6.00 (C)	1.5
Root Depth to Study Bank Height (E)					
Root Depth (ft) =	1.00 (D)	Study Bank Height (ft) =	5.50 (A)	(D) / (A) = 0.18 (E)	1.0
Weighted Root Density (G)					
		Root Density as % =	20.00 (F)	(F) × (E) = 3.64 (G)	9.5
Bank Angle (H)					
			Bank Angle as *Degrees* =	55 (H)	3.5
Surface Protection (I)					
			Surface Protection as % =	5% (I)	10.0

Bank Material Adjustment:

Bedrock (Overall *Very Low* BEHI)

Boulders (Overall *Low* BEHI)

Cobble (Subtract 10 points if uniform medium to large cobble)

Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

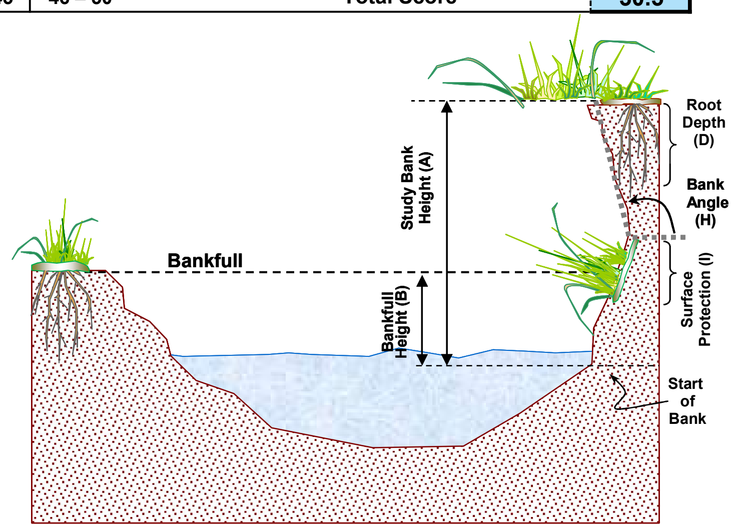
Bank Material Adjustment: 5

Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **High** / **30.5**



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

Bank Erosion Hazard Index (BEHI)

Stream:	B, Unnamed Tributary	Location:	B1-1, East of Rice Drive
Station:	n/a	Observers:	JF, CD
Date:	3/20/2024	Stream Type: B4a	Landscape Type:

BEHI Score (Fig. 3-7)

Study Bank Height to Bankfull Height (C)

Study Bank Height (ft) =	2.50 (A)	Bankfull Height (ft) =	1.50 (B)	(A) / (B) =	1.67 (C)	7.0

Root Depth to Study Bank Height (E)

Root Depth (ft) =	1.50 (D)	Study Bank Height (ft) =	2.50 (A)	(D) / (A) =	0.60 (E)	3.5

Weighted Root Density (G)

Root Density as % =	5.00 (F)	(F) × (E) =	3.00 (G)	9.0

Bank Angle (H)

Bank Angle as *Degrees* =	43 =(H)	3.0

Surface Protection (I)

Surface Protection as % =	5% (I)	10.0

Bank Material Adjustment:

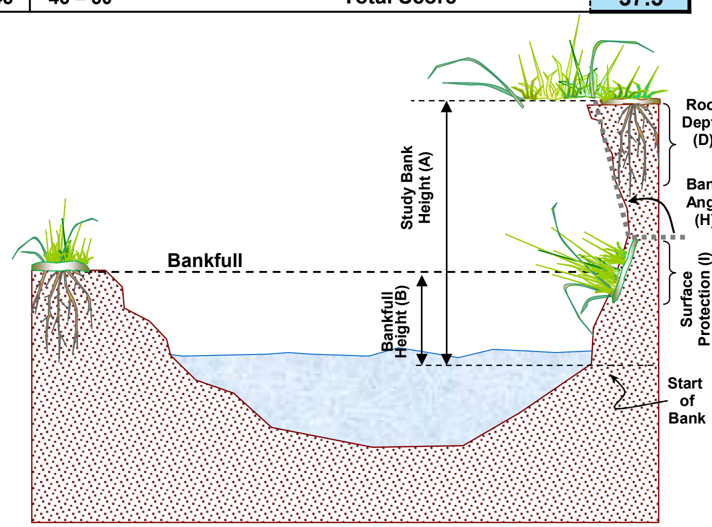
- **Bedrock** (Overall *Very Low* BEHI)
- **Boulders** (Overall *Low* BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

Bank Material Adjustment: 5

Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **High** — **37.5**



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

Bank Erosion Hazard Index (BEHI)

Stream: **B, Unnamed Tributary** Location: **B1-2, East of Rice Drive**

Station: **n/a** Observers: **JF, CD**

Date: **3/20/2024** Stream Type: **B4a** Landscape Type:

						BEHI Score (Fig. 3-7)
Study Bank Height to Bankfull Height (C)						
Study Bank Height (ft) =	3.00 (A)	Bankfull Height (ft) =	1.17 (B)	(A) / (B) =	2.56 (C)	9.0
Root Depth to Study Bank Height (E)						
Root Depth (ft) =	0.50 (D)	Study Bank Height (ft) =	3.00 (A)	(D) / (A) =	0.17 (E)	7.5
Weighted Root Density (G)						
		Root Density as % =	15.00 (F)	(F) × (E) =	2.50 (G)	10.0
Bank Angle (H)						
				Bank Angle as *Degrees* =	45 (H)	3.0
Surface Protection (I)						
				Surface Protection as % =	10% (I)	10.0

Bank Material Adjustment:

Bedrock (Overall *Very Low* BEHI)

Boulders (Overall *Low* BEHI)

Cobble (Subtract 10 points if uniform medium to large cobble)

Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

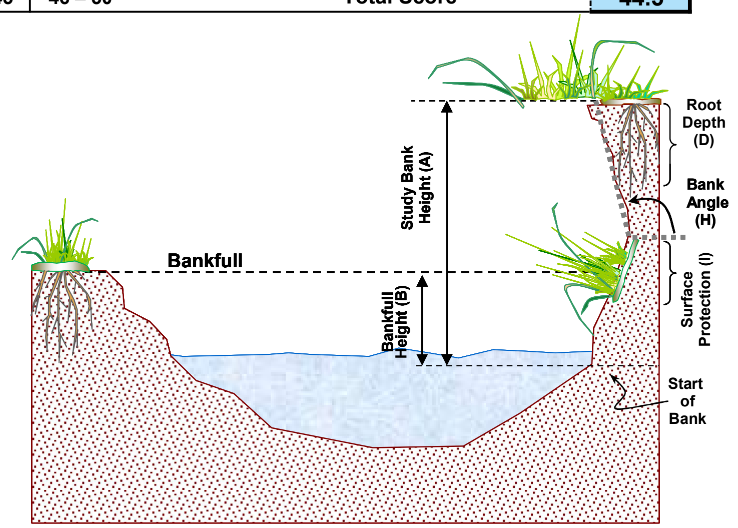
Bank Material Adjustment: 5

Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **Very High** — **44.5**



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

Bank Erosion Hazard Index (BEHI)

Stream: **B, Unnamed Tributary** Location: **B1-3, East of Rice Drive**

Station: **n/a** Observers: **JF, CD**

Date: **3/20/2024** Stream Type: **B4a** Landscape Type:

				BEHI Score (Fig. 3-7)
Study Bank Height to Bankfull Height (C)	Study Bank Height (ft) = 5.00 (A)	Bankfull Height (ft) = 0.83 (B)	(A) / (B) = 6.02 (C)	10.0
Root Depth to Study Bank Height (E)	Root Depth (ft) = 1.00 (D)	Study Bank Height (ft) = 5.00 (A)	(D) / (A) = 0.20 (E)	7.0
Weighted Root Density (G)		Root Density as % = 20.00 (F)	(F) × (E) = 4.00 (G)	10.0
Bank Angle (H)			Bank Angle as *Degrees* = 30 (H)	3.0
Surface Protection (I)			Surface Protection as % = 5% (I)	10.0

Bank Material Adjustment:

- **Bedrock** (Overall *Very Low* BEHI)
- **Boulders** (Overall *Low* BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

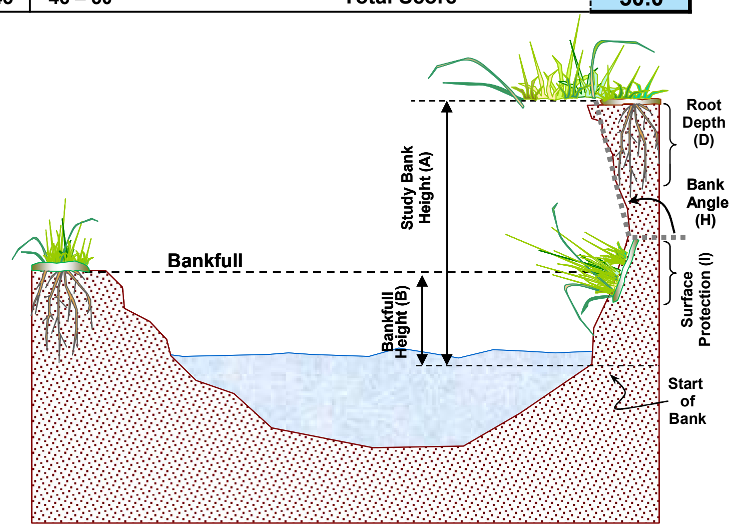
Bank Material Adjustment: 10

Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **Extreme** **50.0**



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

Bank Erosion Hazard Index (BEHI)

Stream: **B, Unnamed Tributary** Location: **B2-1, West of Rice Drive**

Station: **n/a** Observers: **JF, CD**

Date: **3/20/2024** Stream Type: **NA** Landscape Type:

Parameter	Input 1	Input 2	Ratio	BEHI Score (Fig. 3-7)
Study Bank Height to Bankfull Height (C)	Study Bank Height (ft) = 8.00 (A)	Bankfull Height (ft) = 1.42 (B)	(A) / (B) = 5.65 (C)	10.0
Root Depth to Study Bank Height (E)	Root Depth (ft) = 0.50 (D)	Study Bank Height (ft) = 8.00 (A)	(D) / (A) = 0.06 (E)	10.0
Weighted Root Density (G)	Root Density as % = 60.00 (F)		(F) × (E) = 3.75 (G)	10.0
Bank Angle (H)	Bank Angle as *Degrees* = 45 (H)			3.0
Surface Protection (I)	Surface Protection as % = 10% (I)			10.0

Bank Material Adjustment:

Bedrock (Overall *Very Low* BEHI)

Boulders (Overall *Low* BEHI)

Cobble (Subtract 10 points if uniform medium to large cobble)

Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

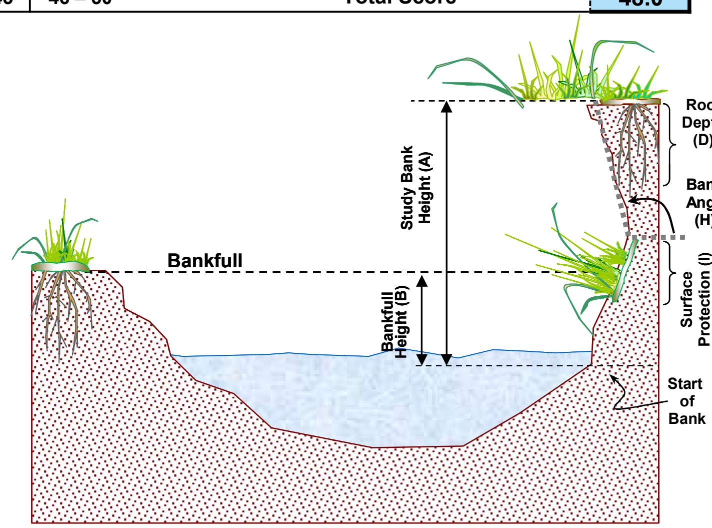
Bank Material Adjustment: 5

Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **Extreme** 48.0



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

Bank Erosion Hazard Index (BEHI)

Stream: **B, Unnamed Tributary** Location: **B2-2, East of Rice Drive**

Station: **n/a** Observers: **JF, CD**

Date: **3/20/2024** Stream Type: **C3b** Landscape Type:

Parameter	Inputs	Calculation	Result	BEHI Score (Fig. 3-7)
Study Bank Height to Bankfull Height (C)	Study Bank Height (ft) = 4.00 (A); Bankfull Height (ft) = 1.00 (B)	(A) / (B) =	4.00 (C)	10.0
Root Depth to Study Bank Height (E)	Root Depth (ft) = 1.50 (D); Study Bank Height (ft) = 4.00 (A)	(D) / (A) =	0.38 (E)	5.0
Weighted Root Density (G)	Root Density as % = 10.00 (F)	(F) × (E) =	3.75 (G)	9.0
Bank Angle (H)	Bank Angle as *Degrees* =		30 (H)	3.0
Surface Protection (I)	Surface Protection as % =		40% (I)	5.0

Bank Material Adjustment:

- **Bedrock** (Overall *Very Low* BEHI)
- **Boulders** (Overall *Low* BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

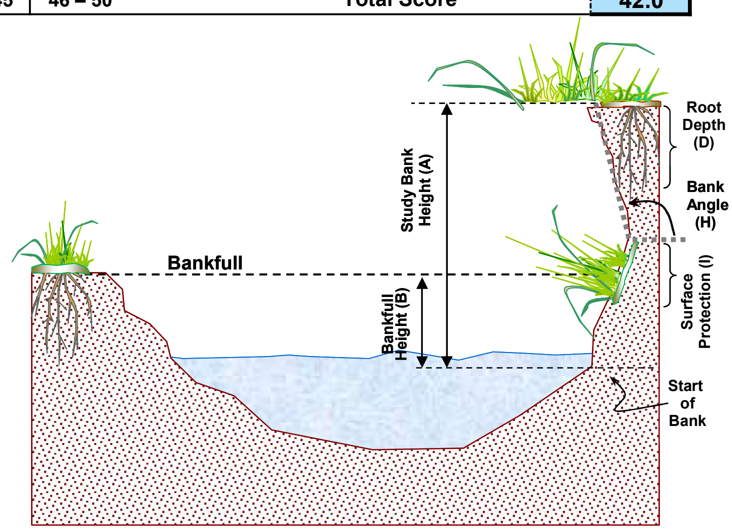
Bank Material Adjustment: 10

Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull: 0

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **Very High** 42.0



Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

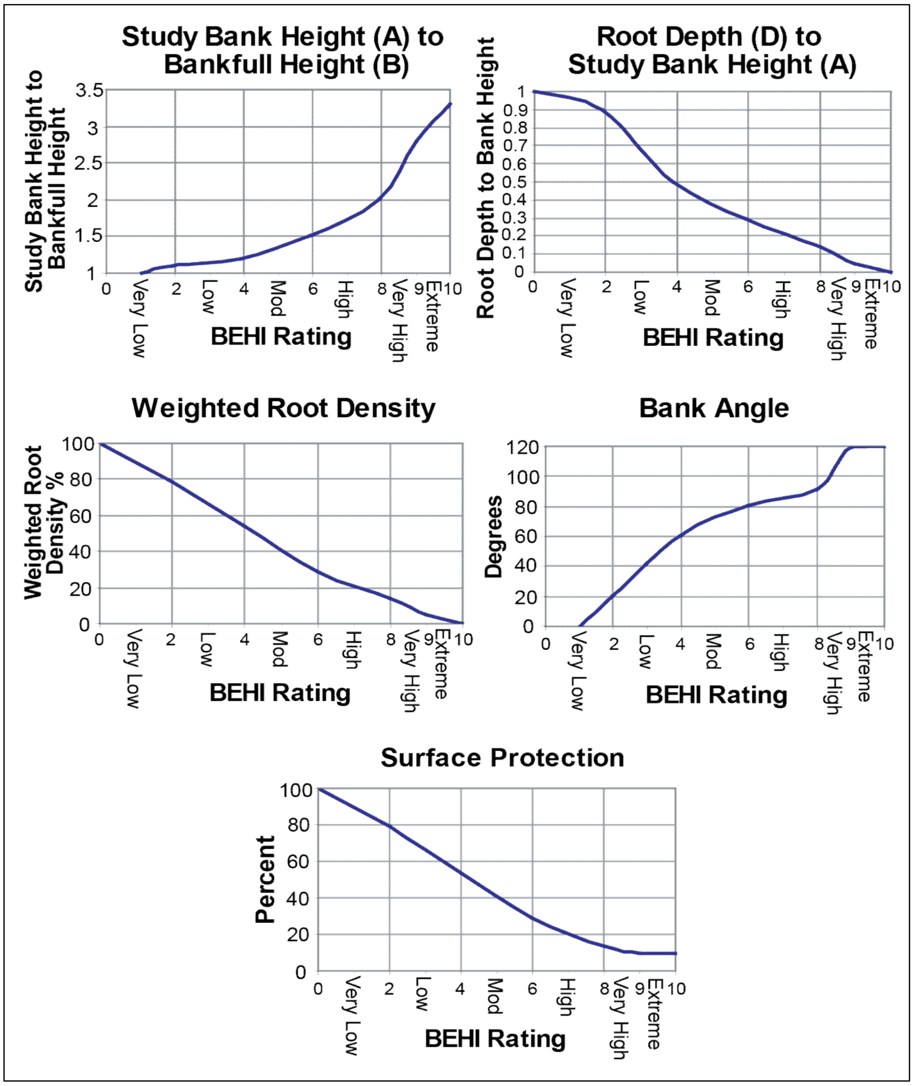


Figure 3-7. Streambank erodibility criteria showing conversion of measured ratios and bank variables to a BEHI rating (Rosgen, 1996, 2001b, 2006b). Use **Worksheet 3-11** to determine BEHI score.

Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In Proceedings of the seventh federal interagency sedimentation conference (Vol. 2, No. 2, pp. 9-15). Subcommittee on Sedimentation Reno, NV.

ATTACHMENT E

Opinion of Probable Cost

CONCEPTUAL OPC - REACH A2 STREAM RESTORATION	Budgetary Cost
June 2024	
Preliminary Design (6 months)	
Basemap Development	$5,000
Wetland Delineation	$5,000
Bathymetry	$5,000
Environmental Due Diligence	$2,500
Sediment Samples (2 per site min)	$2,000
Data Compilation	$5,000
Sediment Management Plan	$3,000
Permit-level Design Drawings	$25,000
Hydrologic & Hydraulic Analysis	$15,000
Planning Contingency (10%)	$6,750
Preliminary Design Subtotal (Rounded to nearest $1k)	*$74,000*
Permitting (18 months)	
NHESP	$3,000
MHC	$3,000
MEPA	$30,000
401	$8,000
404	$8,000
NOI	$15,000
Permitting Contingency (10%)	$6,700
Permitting Subtotal (Rounded to nearest $1k)	*$74,000*
Final Design and Bidding (2 months)	
Access Coordination	$10,000
Final Design	$25,000
Specifications	$10,000
Bidding Assistance	$15,000
Final Design Contingency (10%)	$6,000
Final Design Subtotal (Rounded to nearest $1k)	*$66,000*
Design and Permitting Subtotal	*$214,000*
Construction (6 months)	
Clearing	$50,000
Temporary Stream Crossing	$20,000
Erosion Controls	$5,000
Establish Access	$20,000
Earthwork	$40,000
Boulders	$6,000
Stone Toe	$16,000
Rootwads	$5,000
Grade Control/Cross-vanes	$15,000
FES lifts	$30,000
Landscaping	$10,000
Mob/demob	$11,000
General Conditions	$34,000
Construction Engineering (12%)	$31,000
Construction Contingency (20%)	$52,000
Construction Subtotal (Rounded to nearest $1k)	*$345,000*
Materials & Bidding Contingency (20%)	*$69,000*
Grand Total	**$628,000**
SAY	**$500,000 - $700,000**

The probable costs are an approximation based on limited investigations and our experience on other similar projects and are not based on detailed quantity takeoffs or designs. Once further detailed investigations are performed, the scope of work may change, affecting actual costs. Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the work will not vary from this estimate of the probable cost.

CONCEPTUAL OPC - REACH A3 STREAM RESTORATION	**Budgetary Cost**
June 2024	
Preliminary Design (6 months)	
Basemap Development	$5,000
Wetland Delineation	$5,000
Bathymetry	$5,000
Environmental Due Diligence	$2,500
Sediment Samples (2 per site min)	$2,000
Data Compilation	$5,000
Sediment Management Plan	$3,000
Permit-level Design Drawings	$25,000
Hydrologic & Hydraulic Analysis	$15,000
Planning Contingency (10%)	$6,750
Preliminary Design Subtotal (Rounded to nearest $1k)	*$74,000*
Permitting (18 months)	
NHESP	$3,000
MHC	$3,000
MEPA	$30,000
401	$8,000
404	$8,000
NOI	$15,000
Permitting Contingency (10%)	$6,700
Permitting Subtotal (Rounded to nearest $1k)	*$74,000*
Final Design and Bidding (2 months)	
Access Coordination	$10,000
Final Design	$25,000
Specifications	$10,000
Bidding Assistance	$15,000
Final Design Contingency (10%)	$6,000
Final Design Subtotal (Rounded to nearest $1k)	*$66,000*
Design and Permitting Subtotal	*$214,000*
Construction (6 months)	
Clearing	$50,000
Temporary Stream Crossing	$20,000
Erosion Controls	$5,000
Establish Access	$20,000
Earthwork	$40,000
Boulders	$6,000
Stone Toe	$16,000
Rootwads	$5,000
Grade Control/Cross-vanes	$25,000
FES lifts	$60,000
Landscaping	$10,000
Mob/demob	$13,000
General Conditions	$41,000
Construction Engineering (12%)	$37,000
Construction Contingency (20%)	$62,000
Construction Subtotal (Rounded to nearest $1k)	*$410,000*
Materials & Bidding Contingency (20%)	*$82,000*
Grand Total	**$706,000**
SAY	**$600,000 - $800,000**

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CONCEPTUAL OPC - REACH B1 STREAM RESTORATION	**Budgetary Cost**
June 2024	
Preliminary Design (6 months)	
Basemap Development	$5,000
Wetland Delineation	$5,000
Environmental Due Diligence	$2,500
Sediment Samples (2 per site min)	$2,000
Data Compilation	$5,000
Permit-level Design Drawings	$20,000
Hydrologic & Hydraulic Analysis	$2,000
Planning Contingency (10%)	$4,150
Preliminary Design Subtotal (Rounded to nearest $1k)	*$46,000*
Permitting (18 months)	
NHESP	$3,000
MHC	$3,000
MEPA	$30,000
NOI	$15,000
Permitting Contingency (10%)	$5,100
Permitting Subtotal (Rounded to nearest $1k)	*$56,000*
Final Design and Bidding (2 months)	
Access Coordination	$10,000
Final Design	$20,000
Specifications	$10,000
Bidding Assistance	$15,000
Final Design Contingency (10%)	$5,500
Final Design Subtotal (Rounded to nearest $1k)	*$61,000*
Design and Permitting Subtotal	*$163,000*
Construction (6 months)	
Clearing	$25,000
Erosion Controls	$5,000
Establish Access	$20,000
Earthwork	$10,000
Stone Toe	$24,000
Rootwads	$5,000
Grade Control/Cross-vanes	$20,000
FES lifts	$90,000
Landscaping	$10,000
Mob/demob	$10,000
General Conditions	$33,000
Construction Engineering (12%)	$30,000
Construction Contingency (20%)	$50,000
Construction Subtotal (Rounded to nearest $1k)	*$332,000*
Materials & Bidding Contingency (20%)	*$66,400*
Grand Total	**$561,400**
SAY	**$500,000 - $600,000**

The probable costs are an approximation based on limited investigations and our experience on other similar projects and are not based on detailed quantity takeoffs or designs. Once further detailed investigations are performed, the scope of work may change, affecting actual costs. Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the work will not vary from this estimate of the probable cost.

CONCEPTUAL OPC - REACH B2 STREAM RESTORATION	**Budgetary Cost**
June 2024	
Preliminary Design (6 months)	
Basemap Development	$5,000
Wetland Delineation	$5,000
Bathymetry	$5,000
Refrence Reach	$10,000
Environmental Due Diligence	$2,500
Sediment Samples (2 per site min)	$2,000
Data Compilation	$5,000
Sediment Management Plan	$3,000
Permit-level Design Drawings	$30,000
Hydrologic & Hydraulic Analysis	$15,000
Planning Contingency (10%)	$8,250
Preliminary Design Subtotal (Rounded to nearest $1k)	*$91,000*
Permitting (18 months)	
NHESP	$3,000
MHC	$3,000
MEPA	$30,000
401	$8,000
404	$8,000
NOI	$15,000
Permitting Contingency (10%)	$6,700
Permitting Subtotal (Rounded to nearest $1k)	*$74,000*
Final Design and Bidding (2 months)	
Access Coordination	$10,000
Final Design	$30,000
Specifications	$10,000
Bidding Assistance	$15,000
Final Design Contingency (10%)	$6,500
Final Design Subtotal (Rounded to nearest $1k)	*$72,000*
Design and Permitting Subtotal	*$237,000*
Construction (6 months)	
Clearing	$50,000
Temporary Stream Crossing	$20,000
Erosion Controls	$10,000
Establish Access	$20,000
Earthwork	$100,000
Boulders	$6,000
Stone Toe	$24,000
Rootwads	$7,000
Grade Control/Cross-vanes	$25,000
FES lifts	$90,000
Landscaping	$10,000
Mob/demob	$18,000
General Conditions	$57,000
Construction Engineering (12%)	$46,000
Construction Contingency (20%)	$76,000
Construction Subtotal (Rounded to nearest $1k)	*$559,000*
Materials & Bidding Contingency (20%)	*$111,800*
Grand Total	**$907,800**
SAY	**$800,000 - $1,000,000**

The probable costs are an approximation based on limited investigations and our experience on other similar projects and are not based on detailed quantity takeoffs or designs. Once further detailed investigations are performed, the scope of work may change, affecting actual costs. Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the work will not vary from this estimate of the probable cost.