Geomorphic Assessment and Restoration Recommendations for Five Streams in Falmouth, Maine

Prepared for

Town of Falmouth (Maine)

Norton Brook in Falmouth, ME

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EXECUTIVE SUMMARY

A fluvial geomorphic assessment was completed of five streams in Falmouth, Maine: Chenery Brook, Hobbs Brook, Norton Brook, Mill Creek, and Webes Creek. The assessment was completed to determine what restoration actions might be taken to remove Hobbs Creek from Maine's impaired streams list and ensure the other four streams are not listed as urban-impaired streams by the Maine Department of Environmental Protection. The findings were used to identify the impacts of urbanization on channel morphology and physical aquatic habitat in order to develop conceptual restoration options that will address the identified underlying causes for stream degradation. In total, 30 distinct geomorphic reaches of uneven lengths were delineated on the five streams with breaks between reaches occurring where the character of the valley or channel changes abruptly. Many of the reach breaks are at stream crossings where undersized culverts often disrupt the continuity of geomorphic, hydraulic, and ecological processes.

Human activities in the watershed have impacted the five assessed streams to varying degrees and extents. In-stream wood is an important element of high-quality physical aquatic habitat on streams in temperate climates. While the riparian zones on the five streams are well forested in most areas, long sections of even the most densely forested reaches are devoid of wood and may reflect past land clearance activities from decades ago. Streams that have had predominately forested watersheds for decades, such as Chenery Brook, Mill Creek, and Norton Brook, have more wood in the channel than watersheds that have become less forested through time (e.g., Webes Creek) or have only recently become reforested (e.g., Hobbs Brook). Forests take time to mature sufficiently for trees to begin decaying and naturally falling into the stream channel. In-stream wood levels in even the most forested of the five assessed streams are still below levels in pristine watersheds and will take decades to noticeably improve naturally. Therefore, the associated habitat benefits of in-stream wood could be more rapidly restored through "chop and drop" wood addition projects in remote areas or anchored wood additions using log sills, isolated logs, and log jams near stream crossings and other developments.

Multiple undersized stream crossings are present along the five assessed streams with at least one such crossing on each stream. Undersized crossings are unable to convey large flow discharges without impounding flow, upsetting the natural hydrological, geomorphological, and ecological continuity of the stream. Large wetland complexes dominated by low growing alders have formed upstream of undersized crossings on all five streams (e.g., upstream of Johnson Road on Norton Brook), although natural wetlands may have existed in some of these areas prior to the crossings' presence. Since the backwatering upstream of a culvert leads to deposition, flows exiting the culvert outlet are sediment starved and scour downstream of the undersized culverts is sometimes severe, exposing a hardpan clay on the stream bottom and eroding banks. The most dramatic scouring is present downstream of the railroad culvert on Chenery Brook, although the highest priority for a culvert replacement is at the Northbrook Drive culvert on Norton Brook where the headwall is damaged and the road could potentially be overtopped by severe backwatering during a large storm. The best restoration measure to address the impact of the undersized crossings is to replace them with geomorphically compatible structures that have a width at least equivalent to the stream channel and also provide for relief culverts where wide floodplains are present. Larger structures may take years to replace given the high cost, so log crib walls and log sills could be used in the interim to address the impacts of bank and bed scour, respectively, at the undersized culvert outlets.

Past direct human activities on or near the stream channel continue, at least locally, to constrain the stream's adjustment and impact channel morphology. An old dam on Mill Creek blocks the sinuous natural flow path with the stream now flowing through a deep eroding gully around the dam's flank. Artificial fill on the floodplain at two or more locations on Norton Brook constrains channel migration and the development of a more natural sinuous planform. On the most upstream reach of Webes Creek, channel constraints by fill has caused erosion of the opposite bank and exposure of a manhole along the sewer line paralleling the length of the stream. Portions of the five streams were likely straightened in the past and the resulting higher flow velocities tend to be associated with the exposure of a habitat-poor hardpan clay on the stream bottom. Ideally, these various constraints to channel adjustment can be removed as part of restoration efforts (e.g., fill removal), so natural conditions can develop and be sustained over time. Elsewhere, log jams and other restoration structures could be constructed to more immediately improve aquatic habitat and encourage meander redevelopment along straightened reaches.

Human development within the watersheds of the five streams has increased over time, particularly in the Webes Creek watershed. Little evidence was seen on the five streams that excess runoff from impervious surfaces or concentration of runoff was having a direct impact on the stream channels. However, concentration of runoff along Route 1 has resulted in the erosion of a small gully that has led to deposition of a delta into Chenery Brook at the mouth of the gully. The excess runoff from development could, however, be indirectly contributing to erosion of the bed and banks more directly related to other human activities (e.g., undersized crossings). In-stream efforts to address these issues could include reclamation of the floodplain through the removal of artificial fill and the addition of in-stream wood, both of which should reduce flood flow velocities potentially enhanced from excess (and the concentration) of runoff.

Despite the human influences on the five streams, natural conditions still exert a strong influence. A great length of all five streams flow through stiff fine-grained glaciomarine clays and silts (i.e., hardpan), leading to channels with a low width:depth ratio (i.e., relatively deep and narrow) and high sinuosity with sometimes very tight meanders developing. Wood in the channel is typically associated with positive habitat attributes such as cover, flow complexity, and the deposition of sediment above the hardpan clay. These natural conditions indicate that restoration efforts focused on removing constraints to natural processes and increasing wood loading in the stream channels will lead to sustainable habitat improvements that will keep the streams from being listed as urban impaired by the State of Maine.

1.0 INTRODUCTION

The following report presents the findings and recommendations resulting from a fluvial geomorphic assessment of five streams in Falmouth, Maine (listed in alphabetical order): Chenery Brook, Hobbs Brook, Mill Creek, Norton Brook, and Webes Creek (Figure 1). Hobbs Brook is in a separate watershed in a rural setting that drains to the Piscataqua River, whereas Chenery Brook, Norton Brook, and Webes Creek are tributaries to Mill Creek that drains directly into Mussel Cove. The watersheds of Hobbs Brook, Chenery Brook, and Norton Brook extend into the neighboring Town of Cumberland but the geomorphic assessment was restricted to Falmouth alone.

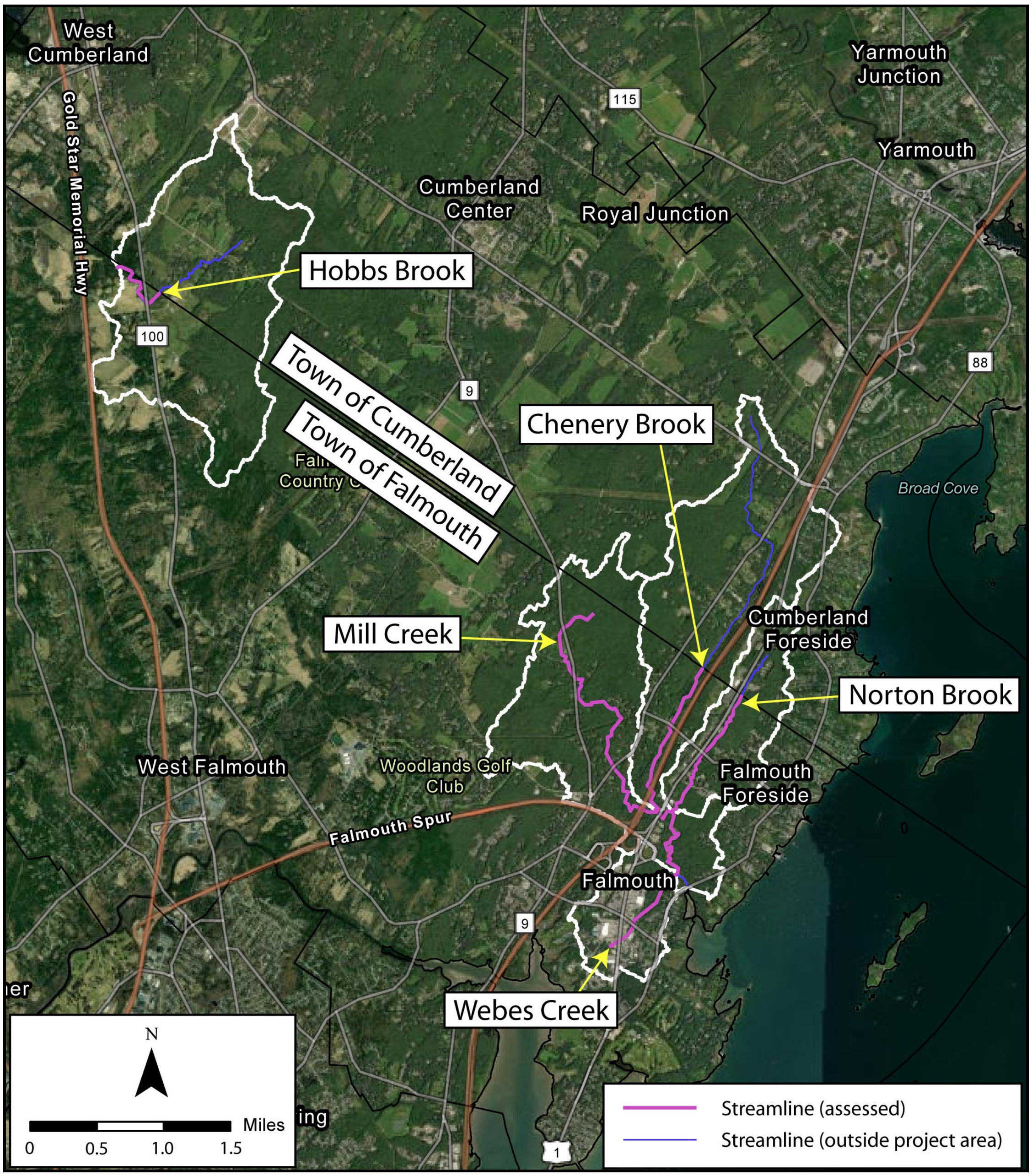

Figure 1. Map showing the location of the five assessed streams and their surrounding watersheds.

The five assessed streams are either impaired (Hobbs Brook) or could potentially be listed as urban impaired by the Maine Department of Environmental Protection (DEP), and, as a result of a listing, the streams would face stricter stormwater discharge requirements (Web citation 1). The geomorphic assessment of each stream was completed to: 1) establish the current condition of the streams and the natural and human factors, past and present, influencing those conditions; 2) determine whether excess stormwater and sediment runoff from development in the surrounding watersheds and other human activities are causing habitat and water quality degradation in the streams; and 3) identify and develop conceptual restoration projects that will sustainably enhance aquatic habitat, macroinvertebrate assemblages, and fish populations. The conceptual restoration projects are intended to ensure that the streams meet DEP's designated stream class and, as a result, either prevent the stream's from being listed as urban impaired or remove the existing impaired listing on Hobbs Brook.

The geomorphic assessment consisted of five technical tasks: 1) review of background materials including previous reports, soils maps, and surficial geology maps; 2) historic assessment of channel and watershed changes using topographic maps and aerial photographs; 3) a rapid geomorphic assessment of the stream channels; 4) a detailed assessment including mapping of channel features and topographic surveying of channel dimensions; and 5) development of conceptual restoration designs. Each component of the assessment was similarly completed on all five streams. The results for each of these technical tasks are discussed below.

2.0 BACKGROUND REVIEW

The background review of existing materials consisted of an evaluation of previous reports, topographic maps, and surficial geology maps relevant to understanding the natural conditions and human activities influencing conditions on the five assessed streams. The most significant findings resulting from the background review include:

- Timber was an important part of Falmouth's economy in the 1700s (Web citation 2). Lumber mills operated on the Presumpscot and Piscataqua Rivers as well as Mussel Cove. In addition, Falmouth was an important supplier of white pine for use as masts by the British navy. While no mention of the five assessed streams is mentioned in the History of Falmouth Maine (Web citation 2), logs in the 1700s were moved along streams, so log drives on the five streams could very well have occurred to supply timber for the lumber mills and British ships. Mill Creek, given its name and size, might have had mills and associated dams even upstream of its confluence at Mussel Cove known to have mills;

- Interstate 295 was completed through Falmouth in 1961 (Web citation 3) with construction presumably beginning in the 1950s. I-295 crosses both Mill Creek and Chenery Brook and, for some distance, closely approaches and parallels Chenery Brook. As a result, I-295 may be causing an impact on portions of Mill Creek and Chenery Brook;

- The first railroad came through Falmouth in 1848 (Web citation 4). Since two rail lines pass through Falmouth, some uncertainty remains as to whether the line that crosses Chenery Brook and Mill Creek was operational in 1848 or sometime after but before 1889 as the railroad appears on a topographic map surveyed that year (Web citation 5). The rail line crossings and proximity of the rail grade to the stream in other locations has likely locally impacted both streams for more than a century;

- The level of riparian zone disturbance (within the Town of Falmouth) varies between the five streams with: a) 26 percent disturbance along Chenery Brook, b) six percent along Hobbs Brook, c) 15 percent along Mill Creek, d) 12 percent along Norton Brook, and e) 44 percent along Webes Creek (Web citation 1). The amount of wood in the five assessed stream channels may be, at least partially, related to the levels of disturbance within the associated riparian zones. Streams with wood in the channel generally have higher fish populations (Flebbe, 1999), a greater abundance and richness of macroinvertebrates (Bond et al., 2006), and more complex physical habitat (Benke and Wallace, 2003);

- Topographic maps available for download and use in Google Earth (Web citation 6) reveal features useful in anticipating stream conditions and controls. Chenery Brook and Norton Brook are separated by an elevated narrow linear ridge, all three of which parallel each other. The ridge is likely composed of bedrock and suggests that ledge might be exposed along these two streams as well as Mill Creek that crosses the southern nose of the ridge near the confluence of Chenery Brook. Ledge is less likely to be found on Webes Creek and Norton Brook. The lower end of Mill Creek is highly sinuous and flows through a tidal marsh before reaching Mussel Cove downstream of Route 1. Given that Norton Brook and Webes Creek enter Mill Creek downstream of Route 1, tides may influence the lower ends of these two streams as well;

- Surficial geology maps show that large portions of Chenery Brook, Norton Brook, and Webes Creek flow through the Presumpscot Formation, a gray to bluish-gray marine silt and clay (Web citation 7 – Portland East Quadrangle), suggesting that a compacted, or hardpan, silt and clay may be occasionally exposed on the bed and banks of these streams (referred to as a hardpan clay throughout the report). Similar conditions likely exist on Mill Creek from a short distance upstream of the Chenery Brook confluence down to the Norton Brook confluence, although the Presumpscot Formation is mapped as just a thin veneer over bedrock upstream of the Chenery Brook confluence, so ledge is also likely present along the channel in this area. Glacial till, an admixture of clay, silt, sand, gravel, and even boulders, is mapped along the upper portion of Mill Creek and is also found as a thin veneer over bedrock in upland areas along the edges of Chenery Brook and Norton Brook, so a gravel or coarser substrate derived from the till or bedrock is possible on these three streams. A coarse substrate on Webes Creek is less likely to be found as the entire length of the stream is within the Presumpscot

Formation. Like Mill Creek, Hobbs Brook is entirely within the Presumpscot Formation (Web citation 7 – Cumberland Center Quadrangle), so a coarse substrate is unlikely but hardpan clay on the bed or banks should be expected.

3.0 HISTORICAL ASSESSMENT

The historical assessment of the five streams consisted of: a) a visual inspection of historical aerial photographs and topographic maps to identify changes in channel position and b) a GIS analysis of land use changes in each watershed.

3.1 Channel changes

Topographic maps of the five streams are available back to maps surveyed in 1889 (and published in the early 1890s) and can be compared with other historical topographic maps from 1916, 1941, and 1956 (Web citation 8) as well as the most recent topographic map from the 1980s available for viewing in Google Earth (Web citation 6). The resolution of the 1890s topographic maps is poor, so uncertainty remains as to whether the minor changes discussed below are actually on-the-ground changes or merely artifacts of comparing maps of different resolution. Two examples are the apparent a) development of high amplitude meanders in the tidal marshes of lower Mill Creek and b) shift at the confluence of Norton Brook shown on the 1890s maps as first joining Chenery Brook before entering Mill Creek. If these changes really did occur, they would have happened prior to 1916 but they are more likely only artifacts of different mapping methods and resolution rather than actual changes. If Norton Brook did flow into Chenery Brook in the past, then the construction of Route 1 with a high road grade between the two streams would be the most plausible explanation for the change. However, Route 1 wasn't constructed in Maine until 1926 (Web citation 9) and, therefore, after the apparent change in position of the Norton Brook confluence. The only more definitive change observed is that the position of upper Mill Creek on the 1980s topographic map differs from its current position in the large flat wooded area downstream of Long Creek Way; whether the channel was rerouted or whether the map shows Mill Creek following a preexisting tributary rather than what is now defined as Mill Creek is uncertain. Other minor changes have possibly occurred but the resolution of the maps are insufficient to identify such changes on these relatively small streams.

Aerial photographs of the five streams are available on Google Earth back to 1996 and Earth Explorer back to 1940 (Web citation 10). Unfortunately, the streams are too small, the banks generally well forested, and the resolution of the aerial photographs frequently too poor to discern channel changes over time. The aerial photographs do show the riparian zones of the Mill Creek watershed have largely remained forested through the photographic record despite increasing development in the watershed. The aerial photographs were also useful in identifying land use changes in the watersheds (see Section 3.2 below).

3.2 Watershed land use changes

Watershed land use changes can cause impacts to the channel by altering the amount of runoff and sediment delivered to the channel during storm events. A rapid decline in biotic diversity occurs on urban streams where more than 10 percent of the watershed is covered with impervious surfaces (Klein, 1979). Urbanization also impacts the physical characteristics of streams in several ways including increases in channel size, greater bed and bank erosion, and more simplified channel morphology (e.g., loss of pools, less in-stream wood) (McBride and Booth, 2005).

How the amount of forested, open land, and, in particular, developed land has changed through time was determined by hand digitizing the limits of each land use type within the watersheds of the five assessed streams on aerial photographs from 1940, 1960, 1975, 2006, and 2022 (Appendix 1). While the field assessments of the streams themselves included only those portions of the streams within the Falmouth town limits, the land use mapping included the entire area of the watersheds, even those portions of Chenery Brook, Hobbs Brook, and Norton Brook (and as a consequence Mill Creek as well) that extend into the Town of Cumberland. Maps are provided only for the Hobbs Brook and Mill Creek watersheds with the watershed limits of Chenery Brook, Norton Brook, and Webes Creek clearly demarcated on the Mill Creek watershed maps. The data on land use changes displayed in Figure 2 and Table 1 separate out the results for these three subwatersheds, while the data for Mill Creek includes both the data for these three subwatersheds and the additional areas outside the limits of those subwatersheds.

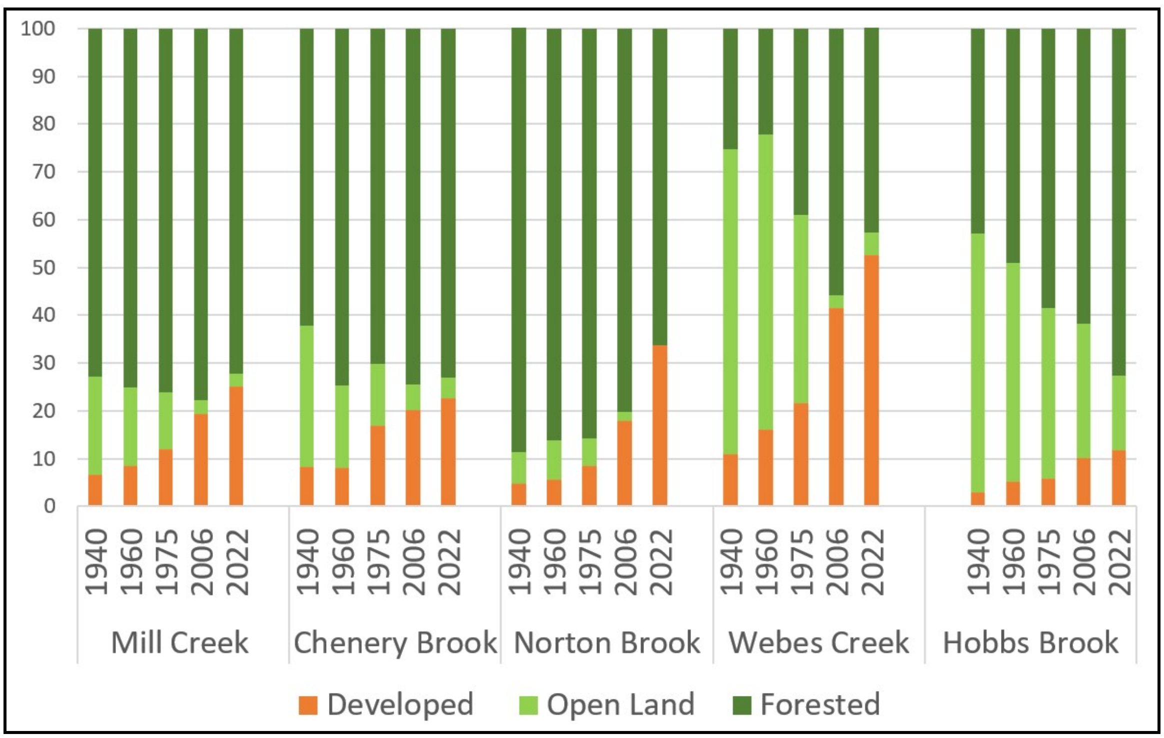

Figure 2. Land use changes through time by percentage of watershed area on the five assessed streams.

Stream/Land use	Drainage area (mi^2)	Percent of watershed (year) 1940	1960	1975	2006	2022	Total change (%) 1940-2022	Period of Greatest Change
Chenery Brook*	2.0648							
Forest		62.1	74.8	70.2	74.6	73	17.6	1940-1960
Open lands		29.6	17.2	13	5.2	4.4	-85.1	1975-2006
Developed		8.3	8	16.8	20.2	22.6	172.3	1960-1975
Hobbs Brook	2.3498							
Forest		42.9	49	58.4	61.7	72.7	69.5	1975-2006
Open lands		54.1	45.8	35.7	28	15.6	-71.2	1975-2006
Developed		3	5.2	5.9	10.2	11.7	290.0	1975-2006
Mill Creek	5.3234							
Forest		72.7	75.1	76.2	77.6	72.2	-0.7	2006-2022
Open lands		20.6	17.4	11.8	3	2.7	-86.9	1975-2006
Developed		6.6	8.5	12	19.3	25.1	280.3	1975-2006
Norton Brook*	0.7863							
Forest		88.8	86.3	85.8	80.2	66.3	-25.3	1975-2006
Open lands		6.6	8.1	5.8	1.8	0	-100.0	1975-2006
Developed		4.7	5.6	8.4	18	33.7	617.0	1975-2006
Webes Creek*	0.5419							
Forest		25.3	22.1	39.1	55.9	42.9	69.6	1960-1975
Open lands		63.7	61.8	39.2	2.5	4.7	-92.6	1975-2006
Developed		11	16.1	21.7	41.6	52.5	377.3	1975-2006

* These streams are smaller subwatersheds within the Mill Creek watershed

Table 1. Land use changes through time on the five assessed streams.

Three land use categories were mapped: forested lands, open lands, and developed lands. Forested lands are those areas of large contiguous tree growth. Open lands include agricultural areas, open fields that may or may not be in agricultural production, and wetland/marsh areas. Developed lands are those areas where homes, commercial developments, and roadways are concentrated. While changes in the amount of developed lands serve as a proxy for changes in the amount of impervious surface area, the total percentage of impervious surface area is likely much less than the percentage of developed lands that also includes small patches of open space, trees, etc. Further refinement of the land use mapping, such as carefully mapping impervious surface areas, was not possible given the resolution and clarity of the older aerial photographs.

With only minor exceptions, the amount of agricultural land (including open fields and marsh land that might not be in production) has decreased over time in each of the five watersheds, while the amount of developed land has increased (Figure 2 and Table 1). The percentage increase in developed land has been significant in the Mill Creek watershed with most of the increase occurring after 1975 (Table 1). The increases in development have been most significant in the Webes Creek subwatershed, particularly in the upper watershed (Appendix 1). As a result, a greater percentage of the watershed in the upper portion of Webes Creek will be covered with impervious surfaces and, therefore, the channel is more likely to be impacted by excess runoff. Development in the other watersheds is not only less significant overall but also less concentrated, so is less likely to cause an impact. However, development activities directly on the streams, regardless of the overall percentage of imperviousness in the watersheds, could impact the streams (e.g., road crossings).

Mill Creek, Chenery Brook, and Norton Brook have remained well forested since 1940 (Figure 2 and Table 1). Despite recent losses in forest cover to development, that development has largely avoided the riparian zone (Appendix 1), so considerable in-stream wood might be present in these stream channels. In contrast, while Hobbs Brook has seen the greatest increase in forest cover since 1940, less in-stream wood may be present because the forest is less mature and fewer trees dying and falling into the stream channel as would be expected in an older forest stand.

4.0 RAPID GEOMORPHIC ASSESSMENT

As part of the Rapid Geomorphic Assessment completed in Fall 2023, each of the five streams were subdivided into reaches of uneven length. Each reach is a relatively homogeneous length of stream channel that has a character distinct from adjacent reaches or is separated from an adjacent reach by a structure (e.g., culvert) or land feature (e.g., tributary confluence) that significantly alters the channel morphology upstream and/or downstream. The reaches on each stream are numbered sequentially from the upstream end and given a prefix letter to identify the stream (the first letter of the stream's name) such that Reach N1 is the most upstream reach on Norton Brook. See Appendix 2 for maps of all of the reach locations on the five streams. Some of the streams extend into the neighboring town of Cumberland, but the assessments and the reach numbering are restricted to Falmouth. Delineating the reaches and characterizing the morphological conditions present in each reach are critical for identifying the natural and human factors potentially responsible for observed channel instabilities and degraded aquatic habitat.

Reaches that share similar traits are referred to as "like-reaches" and an understanding of channel response or effective restoration techniques gained in one reach may apply to other "like-reaches". See Table 2 (placed at the end of the report) for details on the location, length, and characteristics of each reach. The breaks between reaches occur at observable changes resulting from various natural and human conditions such as a change in channel confinement, channel gradient, or human alteration of the channel such as at a culvert. Typically, these reach breaks, whether at natural or human features, represent grade controls whereby channel adjustments in adjacent reaches cannot migrate upstream or downstream due to constraints at the reach breaks themselves. Consequently, the most dramatic channel adjustments often occur immediately adjacent to the reach breaks.

The rapid geomorphic assessment was conducted on all of the delineated reaches on the five streams using an adaptation of EPA's *Streamwalk* protocol developed by Maine Inland Fisheries and Wildlife (Appendix 3). The rapid geomorphic assessment uses visible physical characteristics of the stream to identify whether the stream is undergoing morphological adjustments associated with aggradation (e.g., presence of bars, siltation in pools), degradation (e.g., headcuts, elevated tree roots), widening (e.g., leaning trees, erosion on both sides of channel), or planform changes (e.g., cut-off channels, formation of islands). Depending on the total number of features observed that are indicative of these adjustments, the stream is characterized as either "in adjustment" (i.e., numerous observed features), "transitional/stressed" (i.e., some observed features), or "in regime" (i.e., very few or no observed features) (Appendix 3).

Reaches "in regime" are considered geomorphically stable (i.e., in equilibrium) and are taken to represent the natural state of the channel that would emerge in the absence of human impacts. In contrast, reaches categorized as "stressed" or "in adjustment" are considered to be responding to varying degrees to human influences (e.g., channel straightening) or natural events (e.g., floods). However, the scores are based on the presence or absence of certain features and not how well developed those features are. Consequently, a clearly degrading reach evidenced by dramatic increases in bank height may still classify as "in regime" if none of the other characteristic features of degradation are present. Furthermore, some unaltered stream reaches are naturally dynamic and the resulting complexity is important for ecosystem health, so the presence of some of the assessed features does not necessarily imply unstable or undesirable conditions. Consequently, the results of the rapid geomorphic assessment are best corroborated by a qualified professional (i.e., fluvial geomorphologist) and/or more detailed assessments.

Of the 30 total assessed reaches on all five streams, only one, on Norton Brook, rates as "in adjustment", eight are classified as "transitional/stressed", and 21 are considered "in regime" (Appendix 1). These results accurately reflect the overall good and intact morphological condition of all five streams and suggest current conditions do not represent a great departure from what might be expected naturally. While human alterations of the channel are causing localized impacts, systemic channel responses extending across multiple reaches or even the full length of individual reaches are not present. Consequently, stream restoration efforts on the five streams addressing the localized impacts observed are likely to have a greater chance of success.

The overall reach conditions recorded on the rapid geomorphic assessment forms (Appendix 3) do not accurately capture all of the localized channel adjustments occurring on the streams, Consequently, a brief description of each reach from upstream to downstream on all five streams (presented in alphabetical order) is provided below with ideas for potential restoration projects where appropriate. Table 2 provides a summary of the conditions and potential restoration options for each reach. A priority rating is given to provide a sense as to how important the project is to complete for improving geomorphic and habitat function, and a complexity rating is given to indicate how difficult the project will be to complete in terms of access and perceived landowner willingness among other considerations (although likely costs are indicated in a separate column. A priority/complexity rating of high/low is ideal as great benefit can accrue relatively easily, whereas a low/high rating would require great effort with little benefit.

4.1 Chenery Brook

Reach C1 – Cumberland town line to railroad culvert

Much of the reach is likely impacted during large storms by flow impoundment upstream of the undersized railroad culvert at the downstream end that may also enhance development of the high amplitude meanders, relatively deep and narrow channel morphology (i.e., low width:depth ratio), and fine-grained substrate (i.e., sand and silt) that characterize the low-gradient reach. Bank erosion and undermined trees are present where the meander apices impinge on the higher slopes of clay along the valley's edge with narrow sandy point bars observed on the inside bends of the tight meanders Figure 3a). Numerous small logs in the channel create flow complexity where present (Figure 3b). More and larger wood would likely be in the channel if the riparian vegetation consisted of larger trees rather than the shrubs and grasses present under the power line under which the stream flows for most of the reach.

Given the limited access to the reach, "chop and drop" wood additions (i.e., directionally felling standing trees into the steam) could increase wood loading and flow complexity in those areas where the stream moves away from the power line and tall mature trees are present.

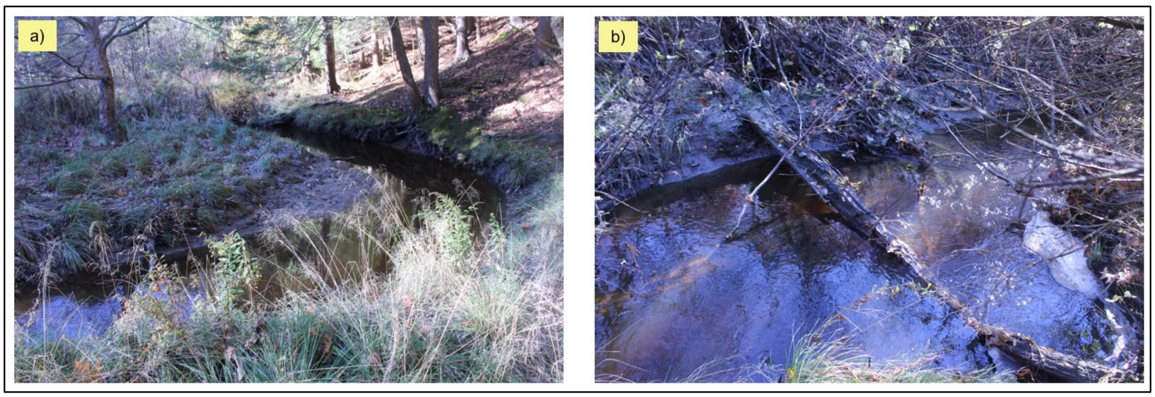

Figure 3. Reach C1 exhibits a) bank erosion where meander apices impinge on higher banks and b) flow complexity where wood is present in the channel.

Reach C2 – Railroad culvert to widened floodplain with sinuous channel

Severe scour of the banks is evident at the outlet of the railroad culvert (Figure 4a) with the bed substrate stripped away to hardpan clay and a large cobble bar formed downstream that has infilled the channel, forcing the channel to shift into an eroding bank. Beyond the scour area, the channel has been artificially straightened against the I-295 road grade, perhaps resulting in the cutting off of a now abandoned meander that is located just upstream of a constricting ridge of higher ground on the right bank floodplain (looking downstream). The straightened channel has a sandy substrate for most of its length and minimal wood, pools, and flow complexity are present (Figure 4b). The high road grade of Interstate 295 is composed of large boulders at its base, but the right bank floodplain is quite wide in most areas. The floodplain is forested with mature trees, providing a good canopy despite only a few mature trees on the I-295 road grade.

Given the limited access to the reach, "chop and drop" wood additions could increase wood loading and flow complexity along the straightened channel that comprises nearly the entire length of the reach. Wood additions are likely to immediately improve flow complexity and pool depths where the substrate is sandy. The leaning trees downstream of the railroad culvert (Figure 4a) indicate scour is ongoing and could be treated, if access routes are identified, with log cribbing to reduce erosion and fine sediment inputs into the channel. Low log sills could be placed on the channel bed to redirect flow away from the scoured banks and trap sediment to provide a substrate above the hardpan clay. Larger marginal log jams could be built along the straightened channel to encourage meander development.

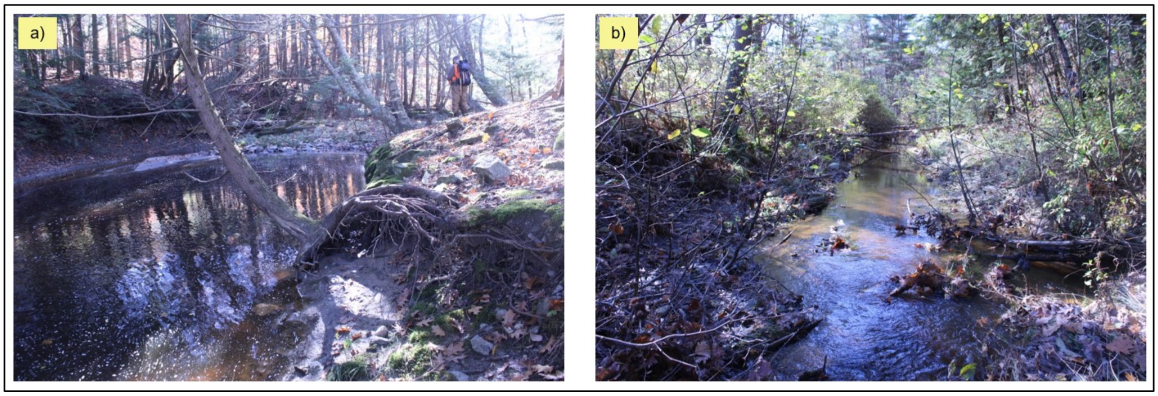

Figure 4. Reach C2 a) exhibits severe scour downstream of the railroad culvert and beyond the scour b) is artificially straightened with minimal wood, pools, and flow complexity in the channel.

Reach C3 – From start of widened floodplain with sinuous channel to Johnson Road

As the channel moves away from the I-295 road grade and the straightened portion of the channel ends, a more sinuous channel emerges with the meanders sometimes impinging on natural higher ground along the left bank (Figure 5a). Numerous tall standing dead trees are present on the floodplain, many of which have fallen into the channel to form log jams and good flow complexity (Figure 5b). Beaver activity was observed in the reach and is partially responsible for the abundance of wood in the channel. The dead standing trees suggest the area was previously impounded, but such ponding likely ended approximately five years ago based on the size of new saplings now growing on the floodplain. A small dam and upstream pond is present just upstream of Johnson Road near a residential property, although another unknown reason (perhaps beaver activity) is considered responsible for impounding the entire reach. The Johnson Road culvert is nearly as wide as the channel and no deposition is present upstream that would suggest backwatering is occurring upstream of the culvert.

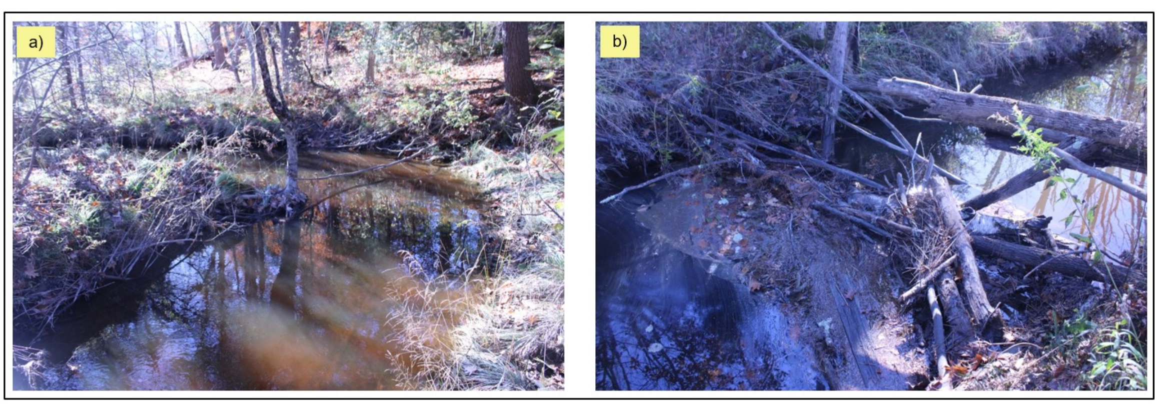

Figure 5. Reach C3 is a) more sinuous than Reach C2 and b) loaded with large fallen wood that forms log jams and good flow complexity.

Stream conditions are good through most of the reach, but removal of the dam and associated rock work is recommended, assuming permission is granted by the landowners who do not seem to currently occupy or use the property.

Reach C4 – Johnson Road to area of increasing confinement

An 8-inch diameter gas line crosses the stream just downstream of the Johnson Road, but no significant scour is present at the culvert outlet that would threaten the pipeline. The high left bank just downstream of the gas pipeline is unstable (Figure 6a). A gravel substrate is present near the gas pipeline, perhaps associated with the pipeline or erosion from the high bank. The stream quickly transitions to a sinuous channel downstream with a low width:depth ratio and clay banks. Abundant small wood has created multiple log jams and beaver dams (Figure 6b), creating good flow complexity; a side channel has been carved into the wide floodplain where impounded flow behind one log jam overtopped the bank. The presence of two adjacent sharp right angle bends in the channel may indicate the reach was channelized in the past. The floodplain is well vegetated with shrubs dense enough to provide a good canopy over the narrow stream. The absence of tall mature trees suggest the floodplain is inundated for extended periods.

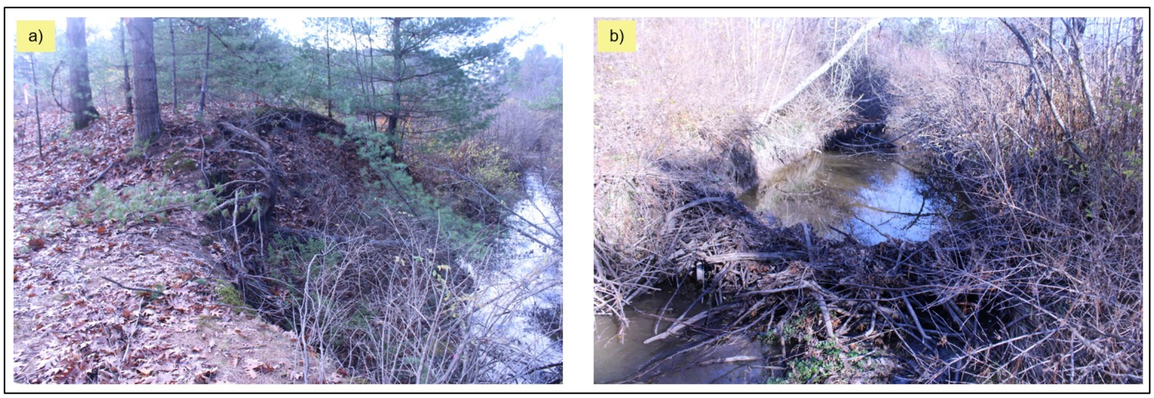

Figure 6. Just downstream of the gas pipeline a) the high bank is eroding, while further downstream b) numerous log jams and beaver dams are present in the channel.

Given the good condition of the stream, poor access, and lack of tall mature trees for chop and drop, restoration is not critical nor practical for much of the reach. Outreach to the landowner is recommended to discuss conservation, so the reach can remain undisturbed. Bank stabilization of the high bank just downstream of the gas pipeline could be completed with log cribbing but is not considered essential as the pipeline is not considered threatened by the erosion (Figure 6a).

Reach C5 – From area of increasing confinement to I-295 culvert

Although Reach C5 maintains a sinuous channel in parts, the floodplain narrows considerably as higher ground approaches closer to the channel from both sides (Figure 7a) with some erosion along the higher banks. A cobble substrate is present where the channel impinges on the high ground. A cobble substrate is present for 150ft upstream of the I-295 culvert and suggests no backwatering is occurring upstream of the appropriately sized culvert. A large beaver dam is impounding much of the reach with abundant leaves floating on the stagnant water in the channel (Figure 7b) with a second smaller beaver dam just downstream. Additional logs and branches that have fallen into the channel also improve flow complexity. Tall trees are present on the high ground and provide some canopy over the channel (Figure 7b) with lower shrubs still dominating the floodplain vegetation (Figure 7a) as in Reach C4.

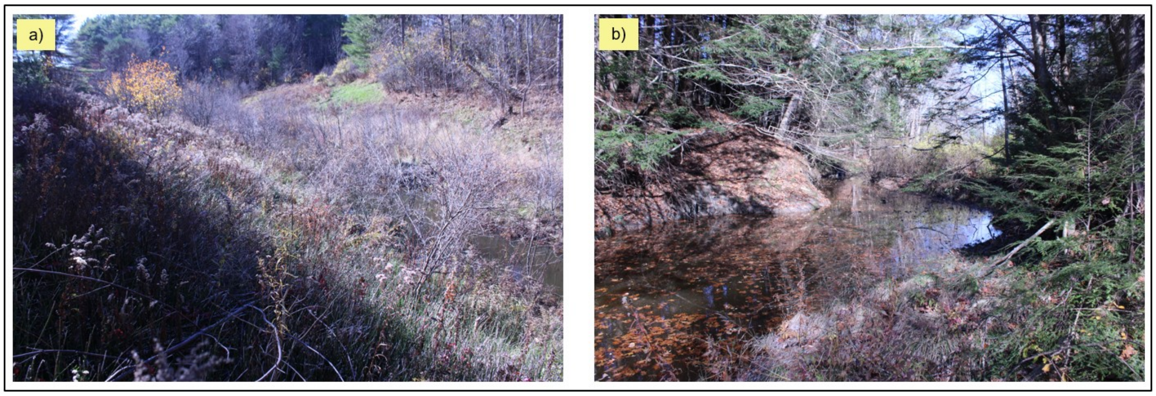

Figure 7. Reach C5 has a) a narrower floodplain as high ground on both sides converge and b) a lengthy impounded area upstream of a large beaver dam.

Given the good condition of the stream and poor access, restoration is not critical nor practical for much of the reach. Outreach to the landowner is recommended to discuss conservation, so the reach can remain undisturbed. With tall trees on the high ground in close proximity to the channel (Figure 7b), chop and drop could be performed along portions of the reach to further improve flow complexity.

Reach C6 – I-295 culvert to sharp bend on high right bank

Immediately downstream of the I-295 culvert, Chenery Brook is narrowly confined by 8-foot high banks on both sides of the channel (Figure 8a). Ledge extends high up the left bank near the culvert, but is found only at the base of the bank further downstream with clay of the Presumpscot Formation above. The high right bank is largely composed of the glaciomarine clay with some sloughing close to the culvert. However, severe scour is not observed, because the culvert is nearly as wide as the channel. The right bank remains confining throughout the reach but a floodplain emerges on the left bank near the downstream end of the reach with a vegetated overflow channel present. Within the channel, a cobble substrate is present through the confined reach and becomes finer downstream with sand bars along the channel margins, including on the inside of the sharp bend at the downstream end of the reach (Figure 8b). The sand bar formation coincides with the emergence of the left bank floodplain and backwatering upstream of the sharp bend. A beaver dam and other wood are present in the channel but the wood is not abundant. A few mature trees are growing on both banks and provide some canopy over the stream channel.

Chop and drop wood additions could increase flow complexity in this short reach, but is a low priority given the existing in-stream wood and beaver dam.

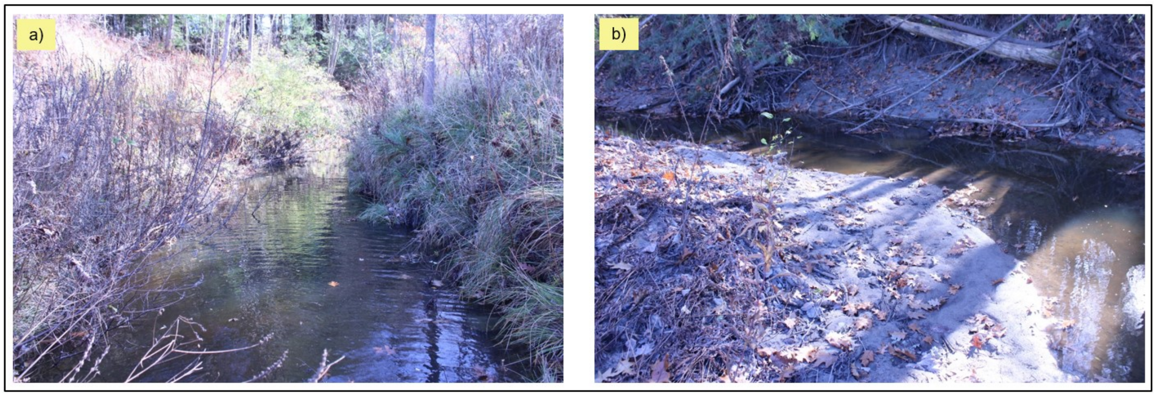

Figure 8. C6 is a) confined at the upstream end with b) sand bars present further downstream where at a sharp bend at the downstream end of the reach.

Reach C7 – Sharp bend on high right bank to Mill Creek confluence

Reach C7 is highly sinuous with a sandy substrate and eroding banks on the outside bend of meanders (Figure 9a). A wide floodplain is present but the channel occasionally impinges on the high banks along the back edge of the floodplain. A former channel is present on the floodplain at the upstream end of the reach and along with two close by sharp right angle bends in the channel suggest the channel's position may have been altered in the past by humans. The presence of wide sand bars, leaning trees along undermined and eroding banks, and abundant wood in the channel indicate the channel is dynamic and the meanders actively migrating. While the channel has a low width:depth ratio in places as a result of the meander migration and bar deposition, flow complexity is good, pools are formed around logs in the stream, and a well developed canopy covers nearly the entire reach due to the mature forested floodplain. A cobble bar has formed at the mouth of a small tributary (Figure 9b) that is actively eroding from runoff concentrated along Route 1.

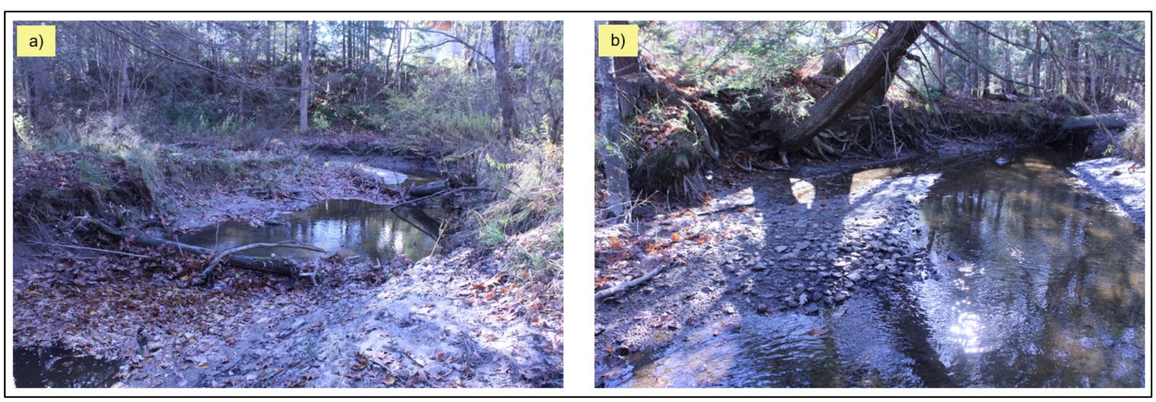

Figure 9. Reach C7 has a) a sinuous channel with abundant wood, bars, and undermined and eroding banks and b) a cobble bar formed at the mouth of an eroding gully off of Route 1.

Reach C7 is currently in good condition, so restoration in the channel is a low priority, although chop and drop and reactivating the abandoned channel could increase flow complexity and reduce sediment inputs from the high banks, respectively. A higher restoration priority would be to add wood to the eroding gully off of Route 1 to reduce the erosion and trap sediment before reaching Chenery Brook.

4.2 Hobbs Brook

Reach H1 – Cumberland town line to Gray Road

Reach H1 is characterized by a sinuous sand-bed channel with a low width:depth ratio flowing through an alder and cattail dominated wetland (Figure X). Flow in the channel was stagnant at the time of the assessment during low-flow conditions. Backwatering upstream of the Gray Road culvert may enhance the wetland conditions that would likely persist even in the absence of the culvert. A gas pipeline crosses the channel and wetland immediately upstream of the culvert. Few mature trees are growing along the channel nor was wood observed in the channel, although the channel was closely inspected only at its downstream end at Gray Road.

Restoration is not recommended for Reach H1 given the persistent wetland conditions and no perceived threat to the gas pipeline, Gray Road, or other nearby infrastructure (e.g., adjacent residential homes).

Figure 10. Reach H1 has a low width:depth ratio as it flows through a wetland.

Reach H2 – Gray Road to high confining left bank

A scour pool lined with cattails is present at the outlet of the 10-foot wide and 4-foot high Gray Road culvert (Figure 11a); the culvert closely matches the channel's dimensions but does block floodplain/wetland conveyance, so has a scouring effect at high flows. The banks throughout the reach are composed of the Presumpscot Formation with the clay forming a hardpan substrate on the channel bottom where not covered by a thin bed of gravel along riffles or soft fine sediment and organics in areas of more stagnant flow. A few isolated boulders are seen throughout the upper half of the reach and may be associated with past farming activities. A low discontinuous floodplain is inset within a higher continuous floodplain, suggesting channel incision occurred in the reach. The sinuous channel with a low width:depth ratio has little in-stream wood with only a few mature trees growing along the channel that passes through open fields (Figure 11b).

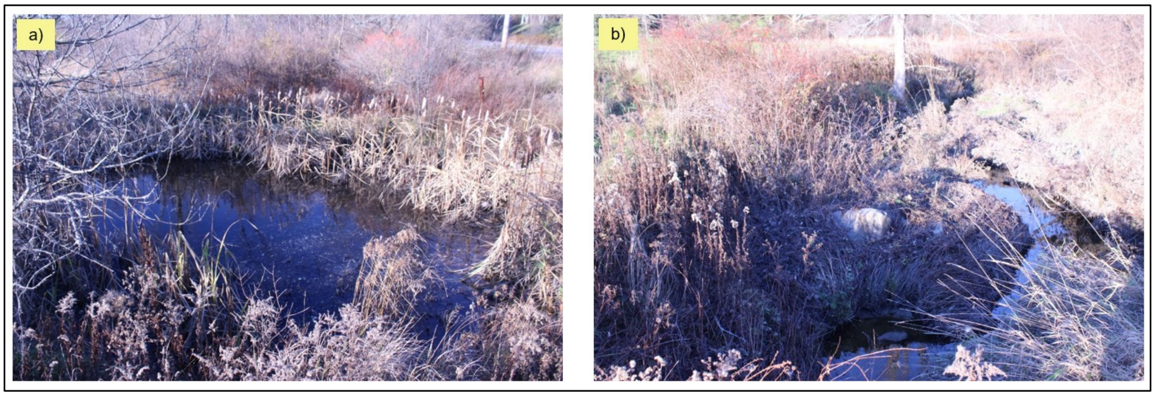

Figure 11. Reach H2 has a) scour pool at the outlet of the Gray Road culvert, but further downstream is b) a sinuous channel with little in-stream wood.

Flow complexity could be increased and sediment deposition enhanced above the exposed hardpan clay substrate through wood additions such as low log sills. Chop and drop could be used in the lower third of the reach where the approaches uplands with mature trees. Any restoration activities would first require the permission of the landowner.

Reach H3 – From high confining left bank to Piscataqua River confluence

Reach H3 is a relatively straight channel that flows along a high surface on the left bank with only a narrow floodplain before encountering higher ground on the right bank as well (Figure 12a). The channel has a soft substrate and very low banks perhaps due to infilling by fine sediments associated with past ponding caused by a fallen large tree crossing the channel downstream that was further jammed up by small branches emplaced, in part, by beaver (Figure 12b). The highwater mark of the impoundment is demarcated along the high left bank by a color change on the ground (marked by red arrows on Figure 12a) with a thin gray film of fine silt draping the lower slope and right bank floodplain. The impoundment has since drained as the channel has migrated around the fallen tree. One small tree has fallen across the channel within the formerly impounded area (at red arrow furthest to right in Figure 12a) and may act as a log sill to improve flow complexity within this upper portion of the reach with otherwise little wood. The channel is better defined with higher banks downstream of the formerly impounded area. While few mature trees are found on the narrow floodplain, particularly in the impounded area, forest growth on the higher adjacent surfaces provides a good canopy over the entire channel (Figure 12).

Given the relatively undisturbed condition of the stream, restoration is not critical for much of the reach. Outreach to the landowner is recommended to discuss conservation, so the reach can remain in a fairly pristine condition. With landowner permission, Reach H3 would be an excellent candidate for chop and drop given the large stand of mature trees growing on the high ground near the channel and the upper portion of the reach that is largely devoid of in-stream wood (Figure 12a).

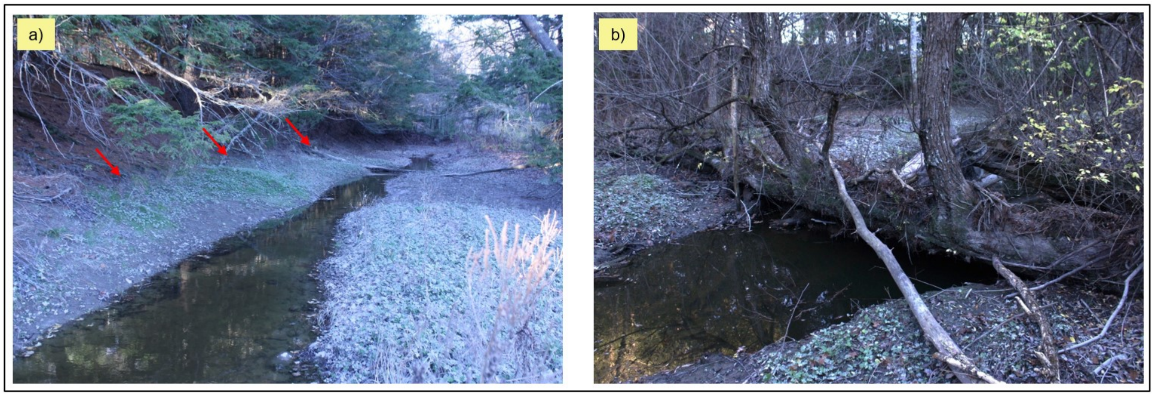

Figure 12. The upper portion of Reach H3 was a) impounded by b) a fallen large tree jammed with smaller branches further downstream.

4.3 Mill Creek

Reach M1 – Route 9 to Olde Blackwood Way

Immediately below Route 9, Reach M1 flows in a well defined sinuous channel (Figure 13a) with a substrate of clean pea-sized gravel. Within 250 ft of Route 9, the channel quickly transitions into a wetland with a poorly defined channel that comprises most of the reach's length. The impounded flow condition is enhanced by a small culvert passing under a private driveway but wetland conditions are present on both sides of the culvert. A well defined channel reemerges as the channel becomes increasingly confined by higher ground. The channel, behind a residential home, appears to have been altered by human activity with a large meander cutoff and the channel now straight. At the downstream end, a sharp right angle bend is present (Figure 13b) at the edge of Olde Blackwood Way as part of a realignment of the channel to flow through the culvert. In-stream wood is creating good flow complexity at the downstream end of the reach with jams forming as leaves and smaller branches are trapped behind larger fallen trees. A mature forested buffer is growing at the upstream and downstream ends of the reach (Figure 13). The channel through the wetland area is bordered by low growing alders.

The private driveway culvert could be enlarged to reduce backwatering in the wetland area. The culvert under Olde Blackwood Way could be repositioned to better align with the preexisting flow path and, thus, eliminate the sharp bend (Figure 13b) that could create erosion problems by the road during a large storm. Chop and drop or wood additions could be used to increase flow complexity at the upstream and downstream ends of the reach, but will require landowner permission.

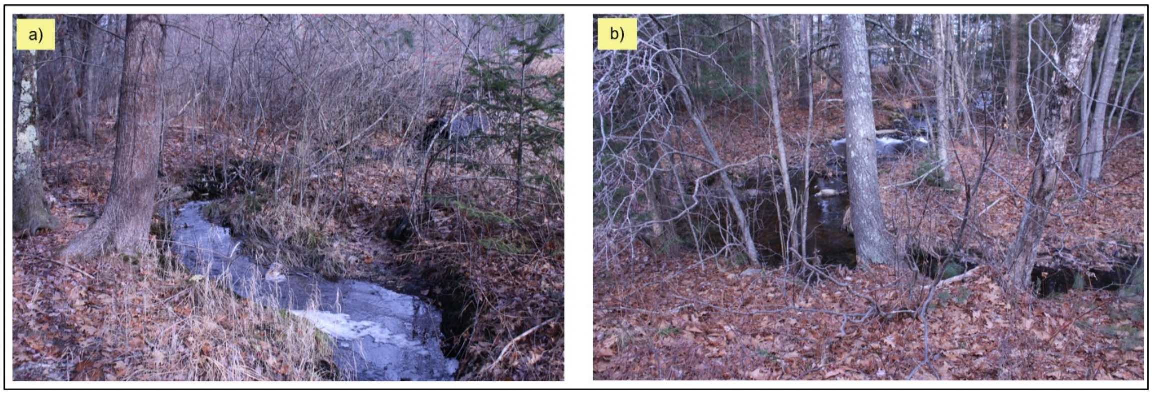

Figure 13. The upper part of Reach M1 has a) a well defined sinuous channel while the end of the reach has b) a sharp bend indicating the channel was realigned to pass through the culvert.

Reach M2 – Olde Blackwood Way to Route 9

Minor bank scour has occurred at the outlet of the undersized double culvert under Olde Blackwood Way. The straightened channel behind the home and barn in the upper reach has a high width:depth ratio with little in-stream wood. An abandoned meander is present on the right bank (Figure 14a) that extends upstream to Olde Blackwood Way and aligns with the sharp bend in Reach M1 (Figure 13b from reach M1), suggesting the main flow path was moved as part of road construction or prior human activity. Downstream of a small culvert under a field road, the stream transitions into a wetland area dominated by cattails and alders with the straightened channel eventually approaching and then flowing along Route 9 at the end of the reach (Figure 14b). The stream passes through a culvert under Paddington Way before taking a sharp left turn into the culvert under Route 9 that is set a bit low (but does not appear to be problematic). A large tributary enters the stream immediately upstream of the Route 9 culvert. Given the fields behind the home and barn in the upper reach and low shrubs in the wetland, very few large mature trees are present along the channel to provide canopy cover or a long-term source for wood recruitment into the stream for improved habitat and flow complexity.

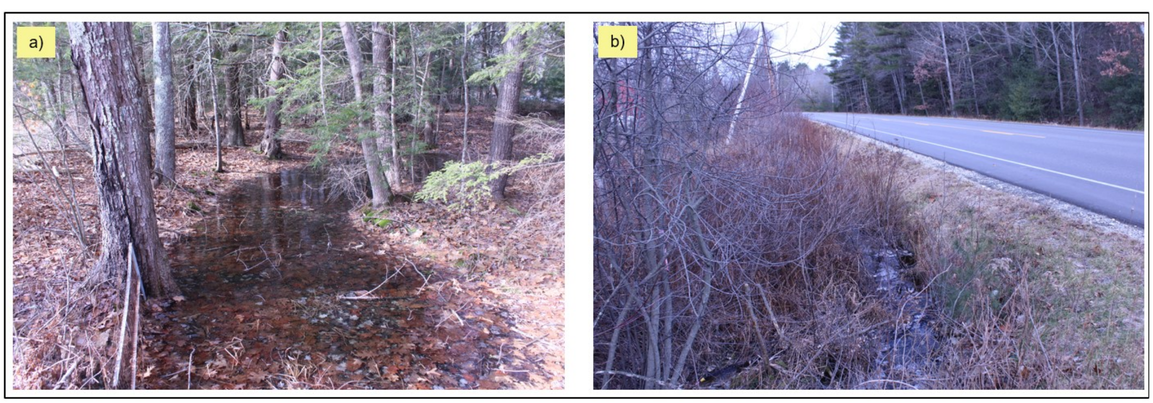

Figure 14. Reach M2 a) has an abandoned meander in the upper reach and b) flows along Route 9 at the downstream end of the reach.

Restoration opportunities include replacing the field road with a larger culvert or ford and realigning the stream to avoid a sharp bend entering the Route 9 culvert. The channel could be realigned to reestablish flow in the old meander and eliminate the hard bend in Reach M1 (Figure 13b from Reach M1), but this would require moving the culvert under Olde Blackwood Way. If this proves insurmountable, then another option would be to place a relief culvert under the road at the sharp bend, so flood flows can pass into the old meander and reduce some of the erosive force on the road grade. Wood could be added to the channel in the form of low log sills to improve flow complexity without increasing flooding, so could be palatable to the landowner who would need to provide permission for the project.

Reach M3 – Route 9 to Long Creek Way

The Route 9 culvert outlets at a sharp bend and flows directly into a left bank composed of ledge and, given the sharp bends at both the inlet and outlet of the culvert, suggests significant modifications to the channel alignment occurred during the construction of Route 9. An overflow chute has formed on the left bank floodplain just beyond the ledge outcrop. The channel flows across a wide floodplain that is slightly constrained by artificial fill on the right bank on which homes have been built along Route 9. The channel has a high width:depth ratio and the upper part of the reach may have been artificially straightened in the past, but three high amplitude meanders have formed in the lower reach (Figure 15a), likely due to a combination of flow impoundment downstream and clay bank materials. The channel substrate contains pea gravel at the upstream end but is predominately sand before reaching the downstream end with occasional small sand bars present along the margins of the channel. For short lengths, in-stream wood is creating good flow complexity with minor flow impoundment upstream, cascading flow over logs, and overflow onto the floodplain (Figure 15b). However, in general, the amount of wood in the channel is minimal despite the forested floodplain with numerous tall mature trees providing a full canopy over the channel. The undersized culvert at the downstream end is paired with an additional small culvert set at the floodplain elevation.

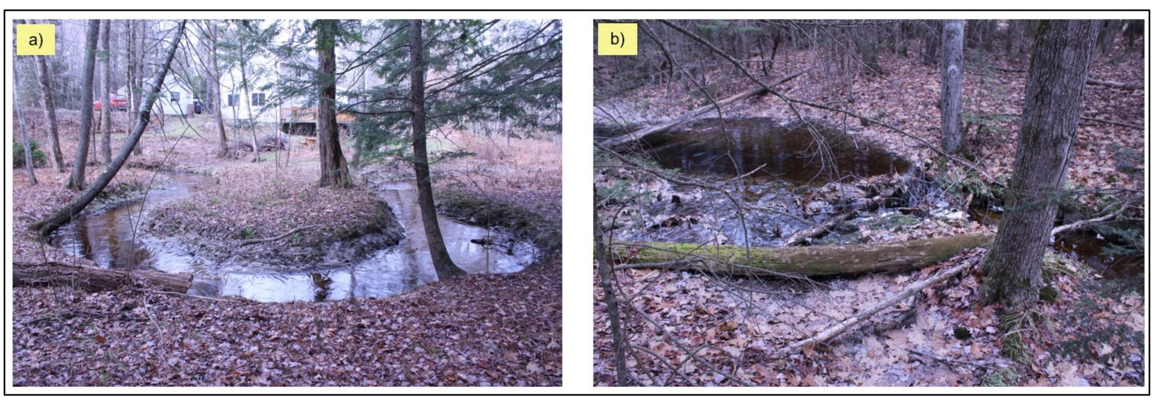

Figure 15. Reach M3 has a) high amplitude meanders and b) good flow complexity where wood is present.

Resizing the Long Creek Way culvert will be simpler than realigning the Route 9 culvert given the size of the roadways. Naturally, wood loading in the forested channel will increase slowly as the forest ages, but a chop and drop project will lead to immediate aquatic habitat improvements. The artificial fill on which several homes and yards are situated is not a severe channel constraint so need not be removed.

Reach M4 – Long Creek Way to the bedrock falls

Reach M4 has a sinuous channel with a substrate ranging in size from pea gravel to sand. The upper reach has a low width:depth ratio and relatively high banks due to minor incision, in part associated with scour at undersized culverts at Long Creek Way and a private driveway, that transitions to a channel with a higher width:depth ratio, lower banks, evidence of abandoned meanders on the floodplain, and greater sinuosity. High amplitude meanders, similar to Reach M3 (Figure 15a for Reach M3), become more frequent downstream as the stream becomes backwatered upstream of the bedrock falls. A few small sand bars have formed along the margins of the channel. While wood is largely absent from the channel despite a well forested buffer with several tall mature trees (Figure 16a), wood that is present, even very small pieces, help to trap sand and fine gravel (Figure 16b) and create good flow complexity.

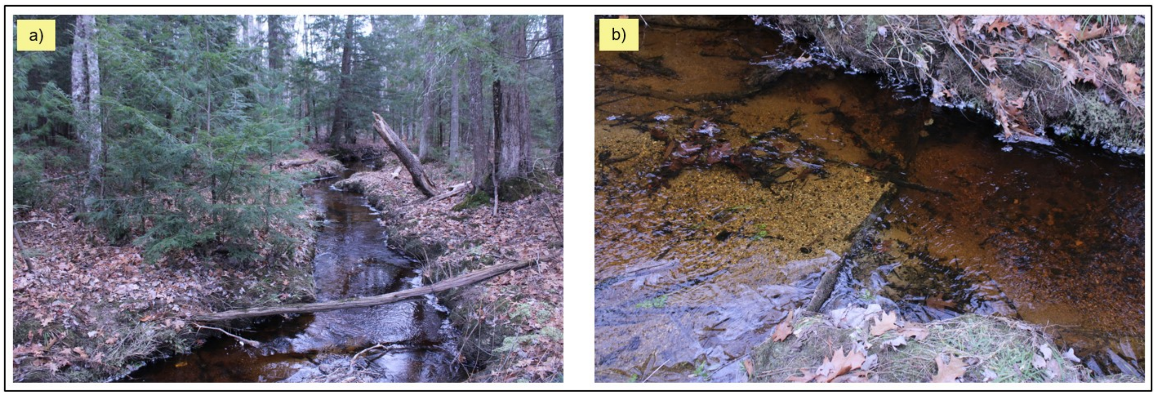

Figure 16. Wood is a) largely absent from Reach M4 despite a well forested buffer but, where present, b) even small pieces of wood help trap sediment.

Replacing the two undersized culverts at the upstream end of the reach will improve sediment transport continuity and reduce scour. One is under a small road and the other a private driveway. These projects are likely feasible but they are not creating major problems so are considered a low priority. Greater improvements reach wide would be achieved by completing chop and drop wood additions that would immediately improve aquatic habitat. This is a long wooded reach that should be a high priority for land conservation as conditions will improve over time if no actions are taken.

Reach M5 – From the bedrock falls to the transmission line

Reach M5 is characterized by a channel confined by high banks and a series of small bedrock waterfalls (Figure 17a) separated by steep sections with large boulders and, in places, bifurcated flow around islands. At the base of one falls, a side channel has formed where flow escapes the main channel at high flow. The channel widens dramatically for a short distance where the high banks recede away from the channel, leading to a wide low-gradient area backwatered behind additional bedrock falls downstream. A large sand delta has formed where a small tributary enters this ponded section (Figure 17b). Minimal wood is in the channel that is likely difficult to retain in the steeper confined sections dominating the reach. A well forested buffer with tall trees provides a full canopy throughout the reach.

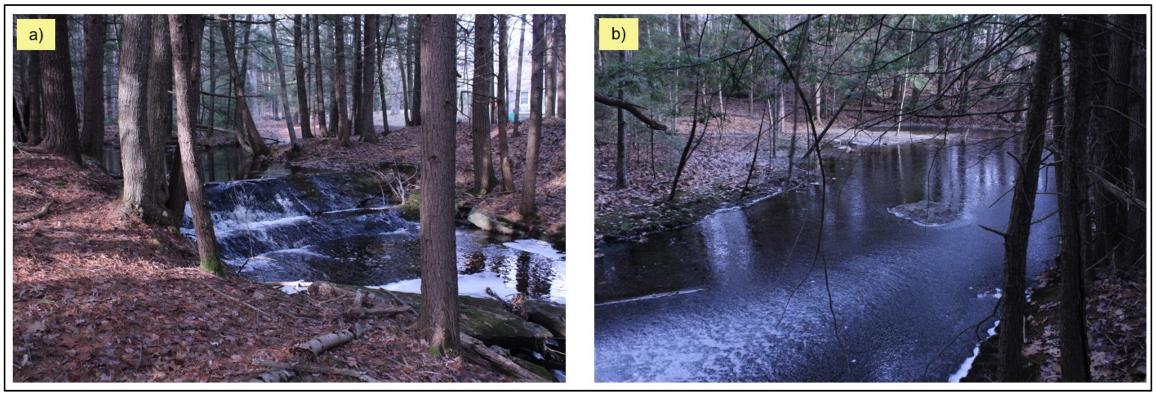

Figure 17. Reach M5 has a series of a) bedrock falls with an intervening b) a wide low-gradient backwatered area with a sand delta at a tributary confluence.

Reach M5 is in excellent condition with limited need for restoration. Chop and drop could be completed in the short wider section where wood is more likely to be retained without anchoring but is considered a low priority.

Reach M6 – From the transmission line to Middle Road

Reach M6 is largely a sinuous channel with a high width:depth ratio, eroding banks, and, in most locations, a wide floodplain. The channel occasionally bifurcates around islands. A hardpan clay outcrops on the stream bottom in many places while in others a cobble and gravel substrate is present with bedrock occasionally observed. In some areas, the gravel particles are actually composed of clay derived from the hardpan (referred to as rip-up clasts of clay). Small bedrock steps are present at the lower end of the reach. An old remnant dam occurs within the reach (Figure 18a) with the stream having carved a deep gully through high banks of clay around the flanks of the dam with trees falling and/or slowly sliding into the channel from the top of the gully walls (Figure 18b). The gully is straight but the original sinuous channel is still present downstream of the dam. Numerous log jams fully or partially cross the channel, although long sections are devoid of wood despite the forested floodplain that provides a full canopy over the channel along the entire reach. The elliptical-shaped culvert at the downstream end of the reach spans the entire width of the channel, so no signs of backwatering (i.e., excessive deposition of fine sediment) are present.

In addition to chop and drop through the entire reach to supplement the existing in-stream wood and enhance aquatic habitat, the remnant dam (Figure 18a) could be removed and the channel realigned into the former sinuous channel to prevent further fine sediment from eroding from the clay banks through the deep gully (Figure 18b). A lot of wood could be placed in the gully to prevent further erosion but could remain as an overflow channel during large floods. The gully could be Given that the Middle Road culvert already closely matches the channel's width, no action needs to be taken.

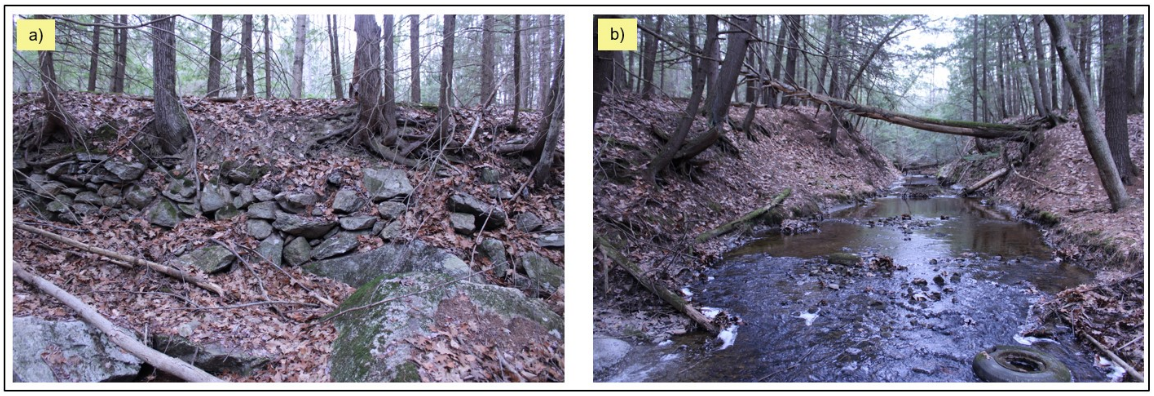

Figure 18. Reach M6 has a) an old dam with b) a gully carved through clay around the dam's flank.

Reach M7 – Middle Road to downstream end of the bedrock gorge

No scour is present downstream of the Middle Road culvert outlet, but a large gravel bar has formed just downstream (Figure 19a) that is more likely the result of backwatering upstream of some bedrock falls (Figure 19b) than due to impacts associated with the culvert. Most of the reach flows through a confined bedrock gorge with periodic low bedrock falls. A rocky channel with a high width:depth ratio is present in lower gradient sections in between the falls. An old remnant dam is at the top of one of the falls. Wood is abundant in the channel with several log jams present (Figure 19b) with a well forested buffer present providing a full canopy over the channel throughout the reach.

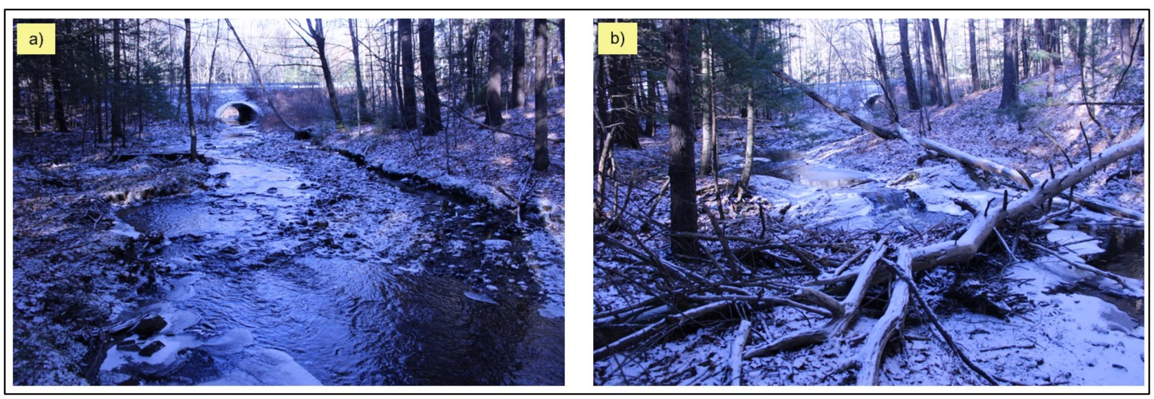

Figure 19. At the outlet of the Middle Road culvert a) a large gravel bar has formed but is more likely related to b) the bedrock falls just downstream.

Reach M7 is in excellent condition with no need for restoration. The old remnant dam is having no morphological impact and can remain in place. Abundant wood is already in the channel, so chop and drop would provide little added benefit. Attempting to conserve the land around the channel through the reach would prevent future development that might threaten the stream's excellent condition. Discussions with the landowner at the upstream end of the reach indicated his interest in conserving his parcel, so outreach to him might prove beneficial.

Reach M8 – From downstream end of the bedrock gorge to the railroad crossing

As the channel becomes less confined at the downstream end of the bedrock gorge, the expansion of flow has created a bifurcated channel with one of the channels creating a large meander (Figure 20a). Further downstream, a single wide channel forms with minimal in-stream wood (Figure 20b). The left bank of the channel at the downstream end flows against the railroad grade and approaches the railroad culvert at a right angle, although no observable impact is associated with this sharp approach angle. A forested buffer provides a canopy over the entire reach, including along the railroad grade.

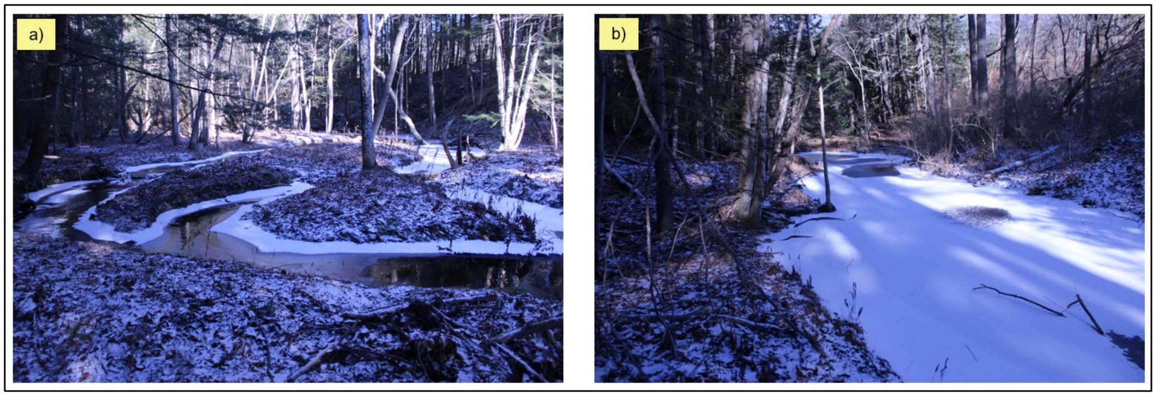

Figure 20. a) The stream bifurcates around an island at the upstream end of Reach M8 but becomes b) a wide single-thread channel at the downstream end (railroad grade on right side of photo).

Chop and drop is recommended along the reach to immediately improve wood loading and aquatic habitat. Given the railroad culvert just downstream, a log strainer should be built to catch any mobile wood to prevent blockage at the inlet of the culvert. While better realigning the railroad culvert with the stream would restore full geomorphic function, implementation would likely be cost prohibitive and no significant negative impacts resulting from the poor alignment are evident.

Reach M9 – Railroad crossing to I-295

Significant scour is present at the outlet of the railroad culvert with erosion leaving boulders in the channel that formerly lined the bank for protection (Figure 21a). The reach is characterized by high-amplitude meanders where scour on the outside bends of meanders is relatively minor. Near the downstream end of the reach, the channel takes a sharp bend and becomes straighter where approaching and then flowing against a high bank. At the end of the high bank, the channel takes another sharp bend (against more high ground opposite the high bank) that is severely scoured (Figure 21b) and then encounters a jumble of large boulders that partially block the channel before entering the I-295 culvert. The origin of the boulders is uncertain and could be natural or placed by humans (either part of a remnant dam or the result of I-295 construction). The double culvert under I-295 appears well sized and no evidence of backwatering was observed. Aside from the boulders at the downstream and upstream (Figure 21a) ends, the substrate is largely composed of sand. Limited wood is found in the channel and large trees are found only on the higher slopes with smaller trees and shrubs present on the floodplain.

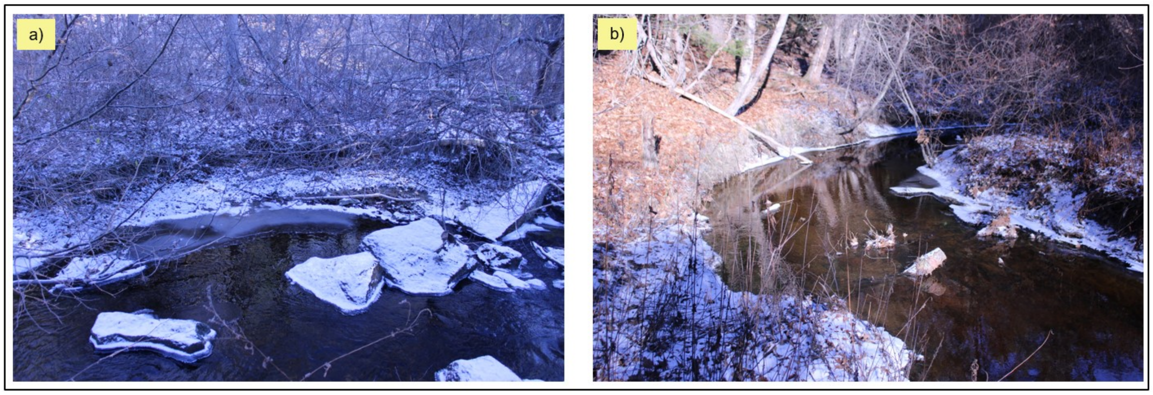

Figure 21. Scour in Reach M9 is most severe a) at the outlet of the railroad culvert and b) at a sharp bend against a high bank.

Access to this reach between the railroad and I-295 would be difficult, so the only practical restoration alternative would be to conduct limited chop and drop where sufficient tall trees are available. If access were available, removal of the boulders partially blocking the channel upstream of the I-295 culvert is recommended if they are determined to be unnatural. Scour at the railroad culvert outlet is likely to continue unless the culvert can be resized, a likely cost-prohibitive endeavor.

Reach M10 – I-295 to Route 1

No scour is evident at the outlet of the double culverts passing under I-295 that, together, closely match the width of the channel. No signs of fine sediment deposition are seen upstream of the Route 1 box culvert at the downstream end of the reach, a structure that also closely matches the width of the channel. The sinuous channel between the culverts, flows across a narrow floodplain and occasionally impinges on the high banks on the back edge of the floodplain. A channel-spanning bridge crosses the stream where a private driveway passes over the channel, but the rock armor protecting the bridge abutments constricts the channel slightly (Figure 22a). In-stream wood includes a log sill crossing the channel that is trapping pea-gravel upstream and creating flow complexity as water passes over the log (Figure 22b). Elsewhere, a fallen tree spanning the channel at the floodplain level has caught wood underneath to create a log jam blocking the entire channel. Only a partial canopy shades the channel as only a few large trees are present on the floodplain dominated by low growing shrubs.

Some chop and drop could be completed in the reach but the number of available trees is limited and considerable in-stream wood is already present. While the bridge (Figure 22a) fully spans the channel, pulling back some of the armor to reduce or eliminate the constriction of the channel is recommended if approval is given by the landowner. The culverts at the upstream and downstream end closely match the channel width and show no signs of morphological adjustment, so, while not ideal, are a low priority for replacement.

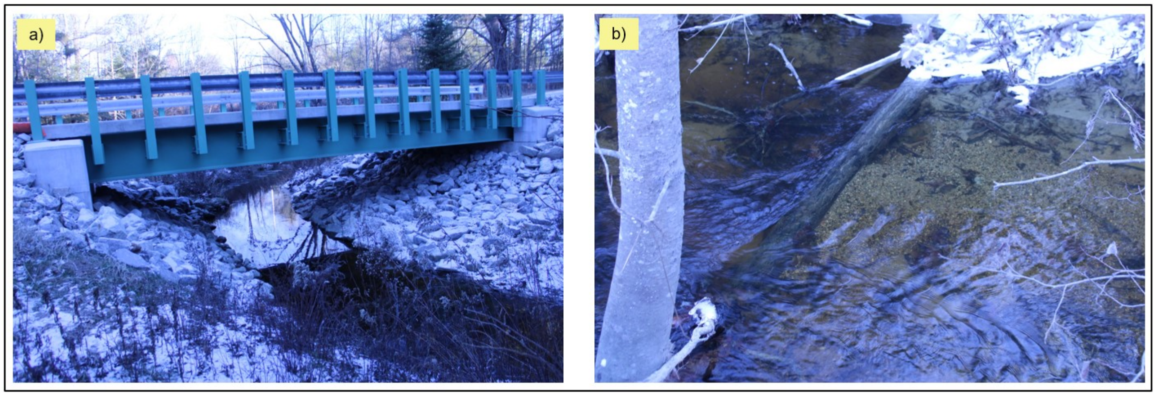

Figure 22. a) a bridge crossing the channel spans the channel but the rock armor partially constricts the channel and b) a log sill is trapping pea-gravel upstream and creating flow complexity.

Reach M11 – Route 1 to Foreside Road

The entire length of Reach M11 is tidally influenced. The reach is initially confined by high banks of clay but downstream of the Norton Brook confluence opens up onto a wide tidal marsh with broad high-amplitude meanders traversing nearly the entire width of the marsh (Figure 23a). The channel just below the Norton Brook confluence appears to have been artificially straightened with a low berm at the top of the right bank and higher ground along the left bank. Daily fluctuations of the water level leads to sapping erosion of the fine-grained bank material along the entire reach with erosion most severe on the outside bends of meanders but occurring nearly everywhere as evidenced by the unvegetated banks and materials slumping into the channel. A sewer line runs along the edge of the marsh for much of the reach's length on the right bank at the base of the uplands. While the sewer line is for the most part quite distant from the channel, at least one manhole has largely become exposed by erosion on the outside bend of a meander (Figure 23b) and others are close to the bank. Wood in the upper confined reach is fairly abundant due to erosion of the high slopes but is much more limited downstream where the channel occasionally impinges on the uplands. The substrate is fine-grained, often rippled, sand. A forested canopy is restricted to the upper reach and the few areas where the channel flows near the uplands.

The exposed manhole (Figure 23b) could be protected from further erosion by constructing a marginal log jam around it such that the structure would be in the center of the jam. A series of log jams should be constructed along the eroding meander bend to prevent outflanking of the manhole protection structure. Similarly, a series of log jams could be built along the left bank of the straightened section to encourage meander growth across the marsh. Berm removal should accompany this restoration effort. Additional log structures could be built for habitat enhancement where the channel approaches the uplands, but would not look particularly natural if built in the center of the marsh where wood is unlikely to naturally collect.

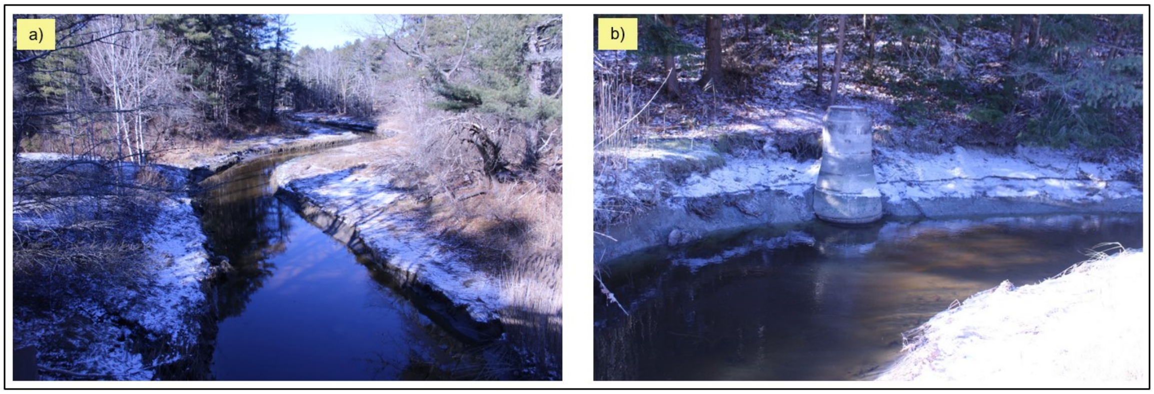

Figure 23 Reach M11 is characterized by a) broad meanders across the marsh that have b) exposed a manhole through bank erosion in at least one location.

4.4 Norton Brook

Reach N1 – Cumberland town line to behind Street Cycles store

The upstream end of the reach is slightly incised, and the channel's position appears to have recently shifted along a short section (e.g., tree root crossing over the channel, tree growing in center of channel, headcut on small tributary). Elsewhere, a shift in the channel's position is ongoing as flow is split around an island with one channel showing signs of abandonment (e.g., accumulating fine sediments and organics). These changes in channel position indicate the stream is dynamic. Throughout the reach the channel is sinuous (Figure 24a) and becomes less incised downstream. High-amplitude meanders are present, particularly at the downstream end of the reach where the floodplain is constricted by the placement of artificial fill at the Street Cycles building. Where the outside bends of meanders occasionally impinge on the uplands at the edge of the floodplain, mass failures can occur. A portion of the channel may have been straightened behind the Invisible Fence Building, although meanders are naturally reforming along this section. A sand substrate characterizes the entire reach with small point bars of sand on the inside bends of meanders and overbank sand deposits occasionally observed on the floodplain along the margins of the channel. Numerous log/stick jams and isolated wood is present in the channel and pools are carved in association with this wood. The channel flows through a well-forested floodplain providing a full canopy over the channel (Figure 24).

The reach is largely in excellent condition with dynamic changes, flow complexity, and plentiful wood to ensure numerous habitat types in close proximity. Additional wood could be added through chop and drop in areas with low wood loading but given the present condition, this is considered a low priority. Bank erosion (Figure 24b) is not prevalent and need not be treated as no infrastructure is threatened and contributes wood and sediment to the channel that sustain the dynamic nature of the stream. The stream, or at least the land on the left bank, is already conserved and under the control of a local land trust.

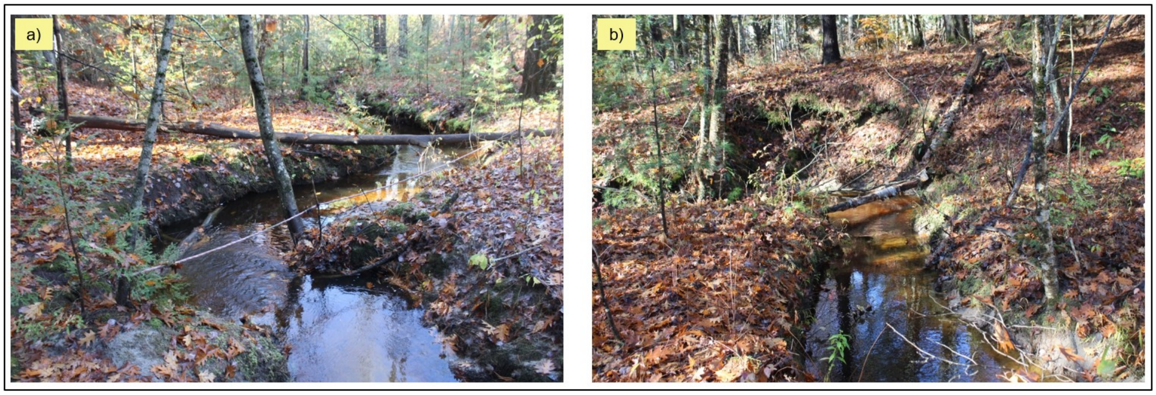

Figure 24. Reach N1 is a) a sinuous channel with b) erosion where channel impinges on uplands.

Reach N2 – From behind Street Cycles store to Johnson Road

Reach N2 is only slightly sinuous and may have been artificially straightened in the past, in part, and is now naturally reforming incipient meanders (Figure 25a). A portion of the straight channel flows against artificial fill extending 50 ft out onto the floodplain behind the Street Cycles building. Two steps in the stream profile occur along this section, one composed of broken asphalt pieces and the other of boulders presumably both derived from the fill. The artificial fill extends downstream to just upstream of the European Bakery and Tea Room where the floodplain widens out again. The substrate is sandy with some gravel, perhaps derived from the fill. Limited wood is found in the channel, because the floodplain is dominated by shrubs with few tall trees, providing a dense low canopy over the stream channel (Figure 25b). The density of the shrubs increases downstream, perhaps, in part, due to the backwatering effects upstream of the Johnson Road culvert that does not include any relief culverts across the wide floodplain.

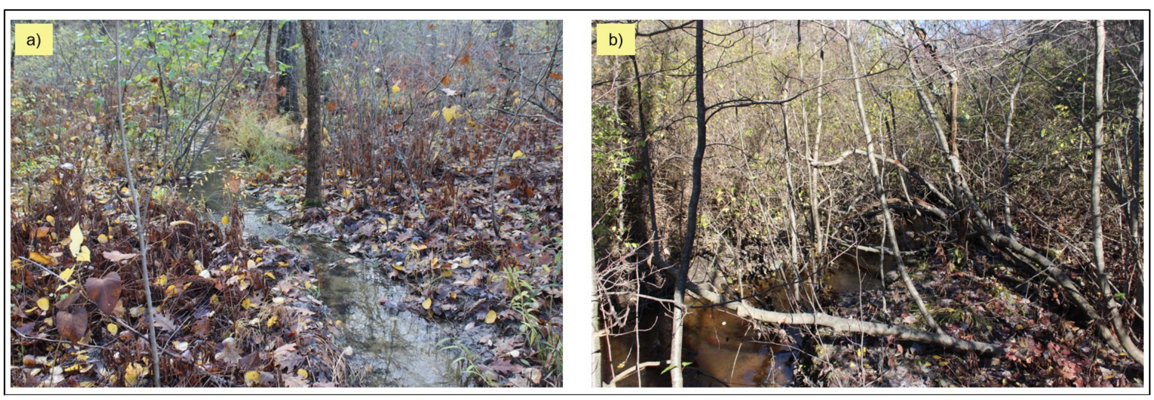

Figure 25. Reach N2 a) may have been artificially straightened with incipient meanders now naturally reforming and b) has a dense growth of shrubs providing a low canopy over the channel.

Wood additions in the channel could increase flow complexity and encourage further meander development, but access might be difficult given the dense vegetative growth. The artificial fill could be removed behind the Street Cycles store to restore the natural floodplain width, but would disrupt the existing business given the current use on the fill surface. While the Johnson Road culvert closely matches the width of the channel, floodplain relief culverts should be added under Johnson Road to reduce backwatering during large storm events and allow for the growth of a forested floodplain that would, over decades, provide a supply of wood into the channel.

Reach N3 – Johnson Road to Northbrook Drive

Scour downstream of the undersized Johnson Road culvert has created a slight perching at the outlet, exposed the geotextile fabric placed under the riprap on the bank, and caused erosion downstream of the riprap. The first 200 ft of the reach are a dense thicket of shrubs across a wide floodplain similar to Reach N2 (Figure 25b from Reach N2) but quickly transitions downstream to a narrower floodplain confined by high forested bedrock-controlled uplands. Possible remnants of an old dam where placed rocks extend up the higher slopes is present near where the natural confinement begins. The channel is slightly incised with high amplitude meanders further downstream (Figure 26a) that have likely formed due to backwatering upstream of bedrock falls just downstream (Figure 26b). A mass failure is present on the high left bank at a sharp bend at the downstream end of the falls but does not threaten any infrastructure. While a rocky substrate is found through much of the reach, a hard-pan clay is exposed on the channel's bed and banks between the base of the falls and the Northbrook Drive culvert. The gabion headwall above the Northbrook Drive culvert at the downstream end of the reach is failing (i.e., leaning and sliding down the slope) and needs to be fixed to prevent the culvert from becoming blocked. In-stream wood is present in the reach but is not plentiful despite a well forested buffer with a full canopy through most of the reach (Figure 26).

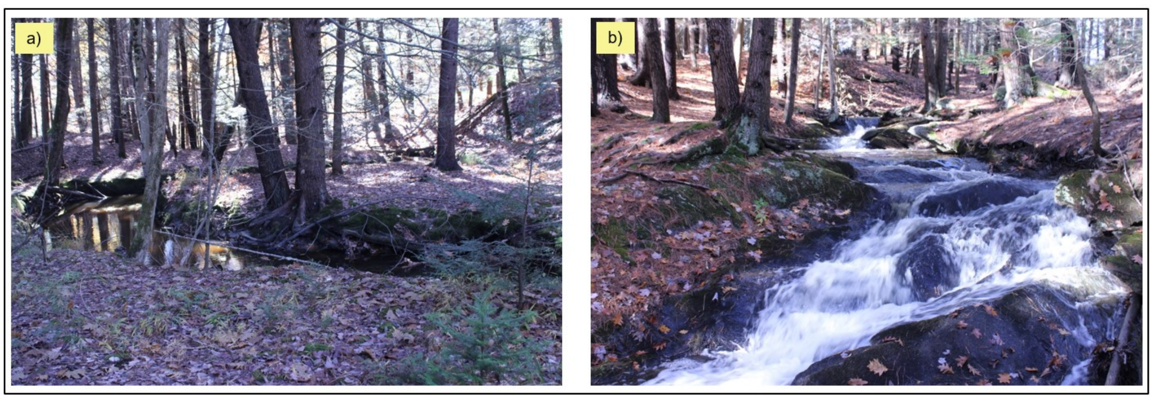

Figure 26. In Reach N3, a) high-amplitude meanders have formed b) upstream of bedrock falls.

The scour around the riprap downstream of the Johnson Road culvert could be replaced with log cribbing, but, as mentioned above for Reach N2, adding floodplain relief culverts is the best solution for reducing scour and restoring geomorphic function at the crossing. Wood additions through chop and drop would improve flow complexity and trap sediment and cover the exposed hardpan clay, but should be anchored in place given the proximity to the Northbrook Drive culvert. The headwall at the Northbrook Drive culvert needs to be repaired and the undersized structure enlarged to at least match the full width of the channel and perhaps also include floodplain relief culverts.

Reach N4 – Northbrook Drive to Mill Creek confluence

The headwall at the outlet of the Northbrook Drive culvert has similar, but not as severe, problems as the inlet as described above for Reach N3. A scour pool and eroding banks just downstream of the outlet are resulting from the undersized nature of the culvert. The channel through the reach is slightly incised with high-amplitude meanders (Figure 27a) that are most prevalent at possible backwatering sites such as upstream of the Mill Creek confluence (with tidal influence) and upstream of an apparent old crossing to the gravel pit where fill blocks the floodplain (with two old displaced culvert pipes remain in the stream nearby). Significant deposition is occurring locally even on the outside bend of a meander where a tributary enters and a large log helps trap the sediment (Figure 27b). Plenty of wood is in the channel, particularly where meanders impinge on higher slopes and cause mass failures. However, long stretches of stream have no wood (Figure 27a). A wide forested floodplain is present throughout the reach with a full canopy over the channel, although the floodplain is blocked at the inferred crossing to the gravel pit and constricted by artificial fill on which the Sullivan Tire store is built.

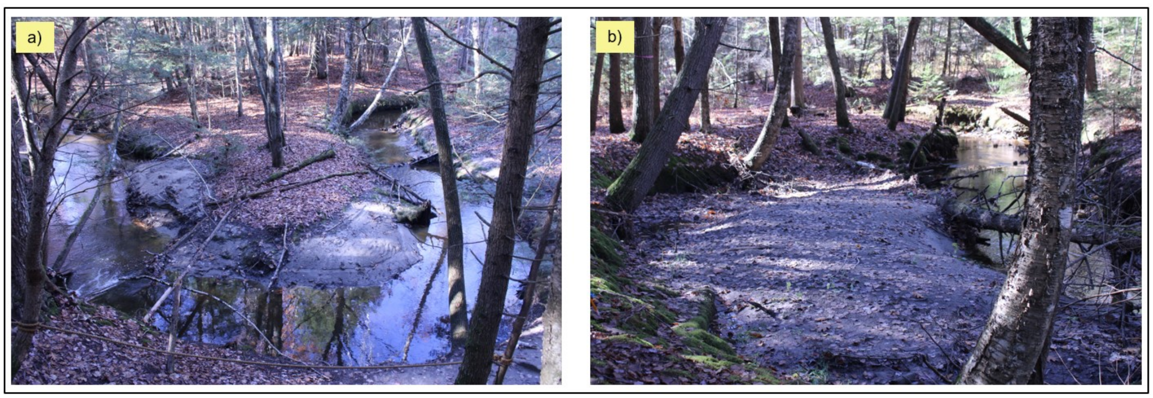

Figure 27. a) High-amplitude meanders and b) sand deposition (even on the outside bends of meanders) characterize Reach N4.

The simplest and most effective restoration approach is to complete chop and drop to improve flow complexity, although the stream condition is good throughout the reach so is a low priority. Repairs to the Northbrook Drive culvert and addition of floodplain culverts was already considered for Reach N3 (see above and Table 2d). The removal of floodplain fill and the culvert pipes at the old gravel pit crossing are a high priority but may be difficult to access.

4.5 Webes Creek

Reach W1 – Culvert by Ace Hardware store to Depot Road

Webes Creek drains the most heavily developed portion of Falmouth (Figure 2, Table 1, and Appendix 1). The upper portion of Reach W1 is straight and confined by high banks of natural clay and is further constrained on the right bank by brush, wood pallets, and concrete blocks discarded over the edge by the greenhouse operations situated on top of the bank (Figure 28a). Bank erosion is located directly across from the area of greatest constriction where the channel has shifted towards the left bank, exposing the base of a manhole along the sewer line that parallels the length of Webes Creek (Figure 28b). A floodplain is present at the lower end of the reach and the channel becomes slightly sinuous. The double culvert under Depot Road is backwatering the channel upstream where the substrate becomes increasingly soft. Upstream in the confined area the substrate is rocky in places but much of the gravel component consists of rip-up clasts of clay derived from those areas where a hardpan substrate is exposed. Aside from small branches, no wood is present in the channel. The floodplain is dominated by shrub vegetation with few tall trees, so the canopy over the stream is limited.

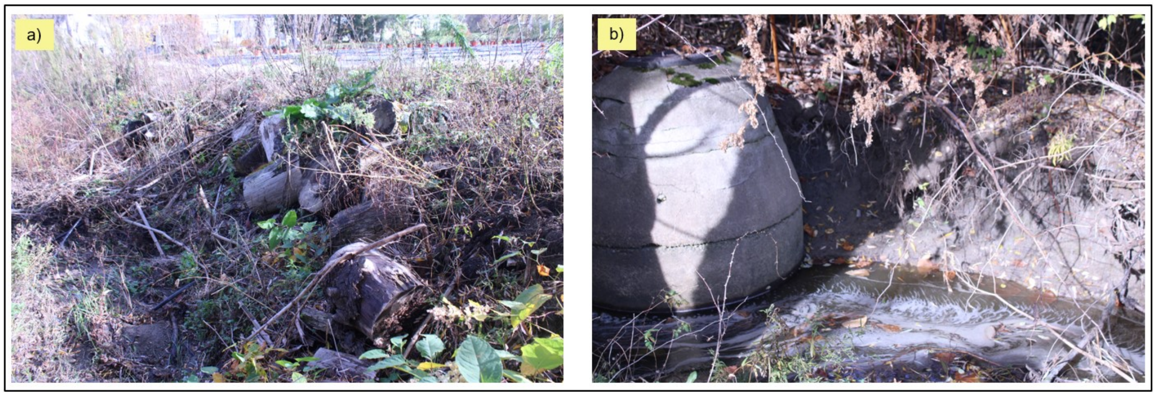

Figure 28. In Reach W1 a) stumps, branches, and other fill on the right bank have constricted the channel and shifted the channel towards the left bank where b) erosion around a manhole is occurring.

Removal of the largely organic fill on the right bank will reduce flow constriction and reclaim a narrow strip of floodplain in the confined upper reach. After fill removal, the channel could be rerouted away from the eroding manhole with marginal log jams built around the structure as well as upstream and downstream. Low log sills crossing the channel through the reach could trap more sediment and organics on the stream bottom and reduce the percentage of the bed that is either hardpan or clay rip-up clasts. Resizing the Depot Road culvert would reduce backwatering on the floodplain upstream and allow for a planting project to encourage the growth of taller trees that will ultimately provide a better canopy over the channel and supply wood to the channel over time.

Reach W2 – Depot Road to the end of the lawn

Reach W2 is a short reach running the length of a grassy lawn on a residential property downstream of Depot Road. The slightly sinuous channel flows against a higher bank of clay on the left bank and was likely artificially straightened in order to create a larger lawn. Natural incipient meanders are reforming along the straightened channel (Figure 29a). Scour at the outlet of the Depot Street has displaced riprap to form a large cobble bar (Figure 29b). Just downstream, a long narrow section of the lawn has slumped down the bank due to scour (Figure 29b). The erosion continues through the upper half of the reach. Downstream of the cobble bar, a hardpan clay is largely exposed on the stream bed with minimal substrate of fines and gravel. A 6-inch pipe crosses the channel and connects to the sewer line and rests on the channel bed causing a minor flow impoundment and accumulation of organic material (i.e., leaves and small branches) upstream. With a lawn on the right bank and largely shrubs on the right bank, a canopy over the channel is largely absent and no large wood is present in the channel.

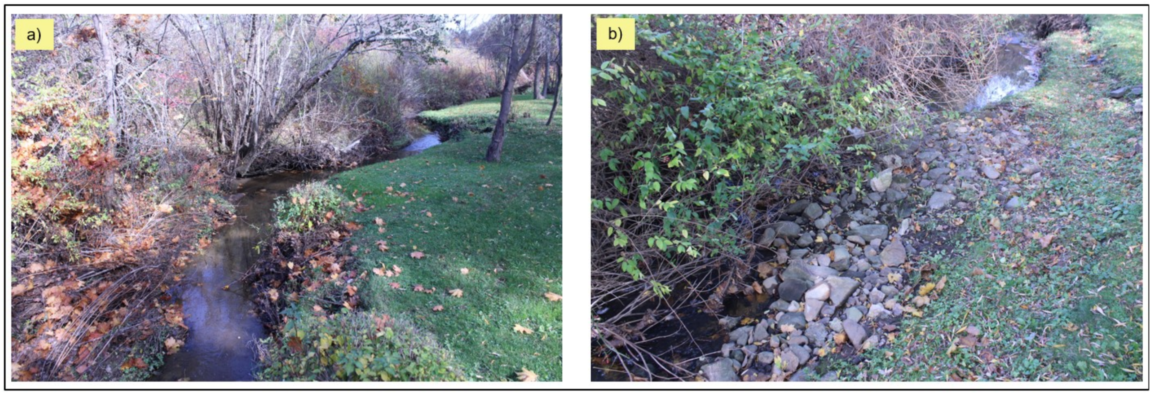

Figure 29. Reach W2 flows a) in a straightened channel now naturally reforming meanders along the edge of the lawn with b) a large cobble bar and eroding banks downstream of the Depot Road culvert.

Enlarging the Depot Road culvert would greatly reduce the scour and erosion observed in the upper portion of Reach W2. Log sills could be spaced throughout the reach to help trap sediment and cover the hardpan clay while increasing flow complexity. The eroding banks could be protected with log cribbing. The pipe crossing the channel needs to be either removed (if no longer in use) or protected with a full channel spanning log jam and log cribbing along the banks to prevent damage from the impact of rocks, wood, or debris carried by high flows. A more holistic approach to many of these problems might be to recreate the broader meanders across the lawn that were likely present naturally. All of these restoration options will require landowner permission to implement with recreating meanders requiring removal of part of the lawn, so unlikely to be supported.

Reach W3 – From the end of the lawn to the next lawn downstream on the right bank

The upper portion of Reach W3 is a sinuous unconfined channel with bank erosion on the outside bends of meanders, especially where they impinge on the higher uplands, and significant sand deposition on the inside bends (Figure 30a). The channel becomes straighter downstream despite a wide floodplain, so was perhaps artificially straightened in the past. A dense growth of shrubs overhangs the channel close to the water surface and supplies small branches to form numerous jams that divert flow into side channels and create small steps in the longitudinal profile (Figure 30b). The channel's banks are very low and poorly defined, especially upstream of jams. The sewer line runs along the reach on the left bank but does not directly impinge on the channel. The channel substrate consists of a clay hardpan that is sometimes covered by a thin layer of clay rip-up clasts or thick muck upstream of jams.

Access to the reach is poor, although an access path is maintained along the sewer line off the left bank. Clippings of shrubs were seen along the access path and could be bundled together with twine and placed in the stream to form additional steps like seen naturally (Figure 30b). At minimal cost, this could further enhance flow complexity and trap sediment to cover the hardpan clay where exposed. Eroding banks at the upstream end of the reach are supplying the sediment that could provide this substrate above the hardpan, so bank stabilization is not recommended as no infrastructure is threatened.

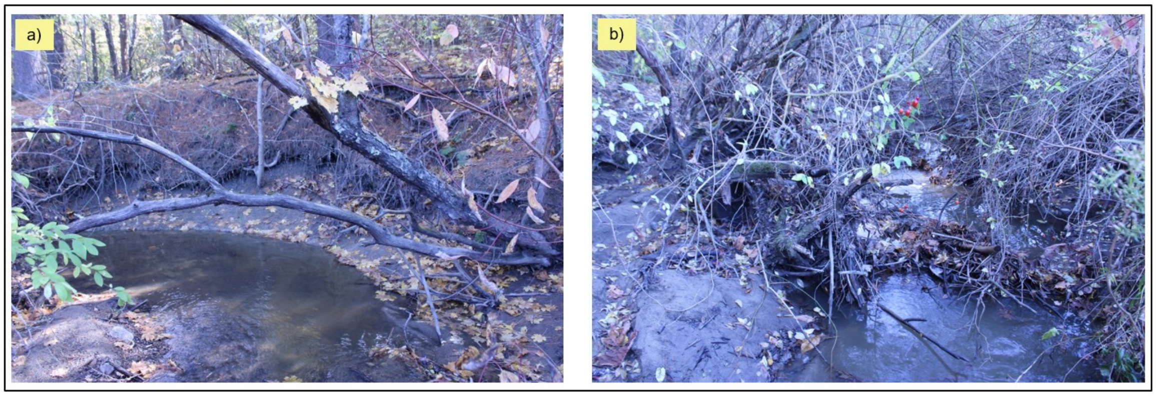

Figure 30. Reach W3 is a) sinuous with erosion on the outside bends of meanders and sand deposition on the inside bends in the upper part of the reach while b) flow complexity is maintained in the straighter downstream part of the reach by jams formed by small sticks.

Reach W4 – From the next lawn downstream on the right bank to open meadowy area

Reach W4 is a short straight reach where the channel banks become better defined as the large residential lawns on the right bank slope down to the channel from the uplands. The floodplain is considerably narrower on the left bank compared to Reach W3 upstream. Localized bank erosion is occurring and undermining trees (Figure 31a). Multiple large trees have fallen across the channel and are partially blocking flow (Figure 31b). Flow is stagnant through the reach due to either (or both) blockages by fallen trees or backwatering upstream of the Mill Creek confluence. Shrub vegetation and lawns dominate the top of the banks but some large trees provide a partial canopy over the channel.

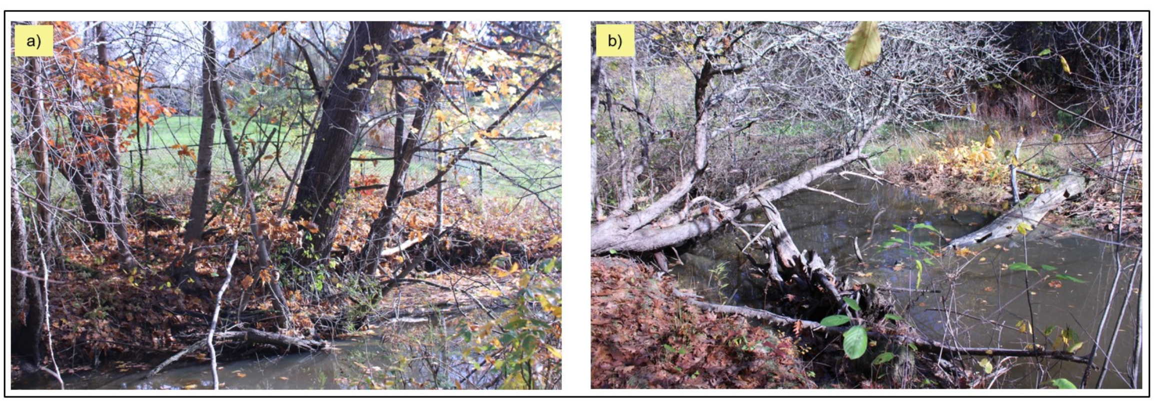

Figure 31. In Reach W4 a) localized erosion is undermining trees that ultimately b) causes large trees to fall across the channel.

No in-stream restoration recommendations are available. Residential property owners might be approached to discuss the environmental benefits of planting a buffer of trees and/or shrubs along the edge of the channel where lawns now extend to the top of the right bank.

Reach W5 – From the open meadowy area to Mill Creek confluence

Reach W5 is a tidal marsh backwatered by tides moving up from Mill Creek. The high-sinuosity channel has a low width:depth ratio with the banks nearly submerged at high tide (Figure 32a). The sewer line runs along the edge of the marsh and the channel approaches a manhole at the outside bend of one meander but is not impacted by erosion. A broken concrete bridge crosses the channel (Figure 32b) in line with an access road coming down the slope from the uplands on the right bank, so might have been used for access to the sewer line. No adverse channel response is apparent due to the bridge blocking the channel with low velocity flows likely passing over the structure at higher tides and stream flows. No significant in-stream wood was observed in the reach. Large trees growing on the uplands bordering the marsh provide minimal canopy where the meanders approach the edge of the marsh as no shrubs or trees are growing in the marsh bordering the channel.

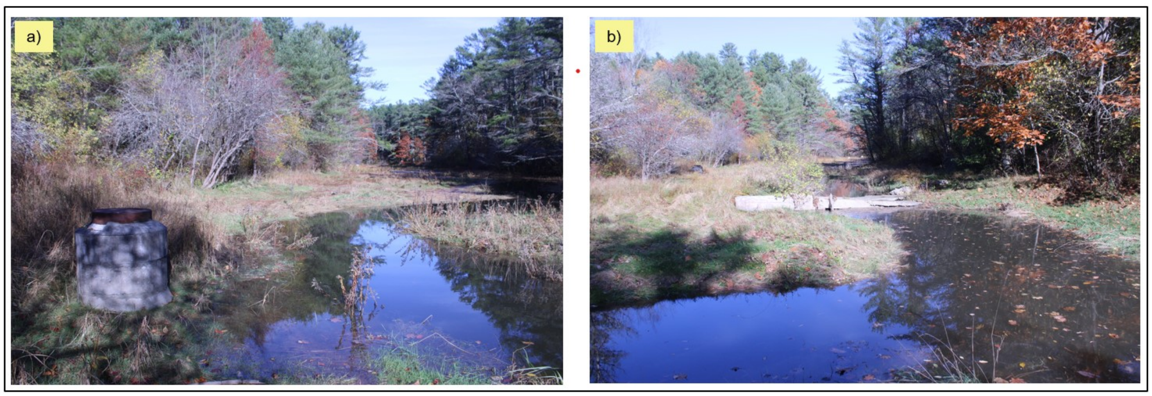

Figure 32. In Reach W5, a) meanders approach the sewer line at the edge of the marsh and b) a collapsed concrete bridge crosses the channel.

No restoration is needed in Reach W5, but the concrete bridge could be removed to improve the aesthetic and to fully restore geomorphic function in this tidally dominated reach. Monitoring should periodically be conducted to be sure erosion does not threaten the manholes near the channel on the left bank.

5.0 DETAILED GEOMORPHIC ASSESSMENT

A more detailed assessment of the five streams was completed by: 1) mapping important channel features observed while traversing the length of the streams and 2) surveying channel dimensions and conditions at 10 representative sites (generally two sites per stream). The results of the mapping and surveying are described below.

5.1 Channel features mapping

A number of channel features were mapped where observed along the streams including in-stream wood and areas of bank erosion. (In some areas with thick shrub vegetation, walking directly in the channel was sometimes difficult, so the mapping missed some features over short distances.) Table 3 provides a summary of these and other mapped features with the locations provided as ArcGIS shapefiles in the digital supplement to this report. Key features are described below individually. The GIS data could be queried further to determine if associations exist between features such as whether deep pools are associated with in-stream wood.

	Chenery Brook		Hobbs Brook		Mill Creek		Norton Brook		Webes Creek	
Mapped features	**Total**	**Per mile**	**Total**	**Per mile**	**Total**	**Per mile**	**Total**	**Per mile**	**Total**	**Per mile**
Instream habitat features										
Large wood (includes log jams)	169	129	19	30	244	64	164	123	26	30
Log jams	20	15	1	2	28	7	22	16	6	7
Deep pools	12	9	1	2	42	11	14	10	2	2
Beaver dams	4	3	0	0	0	0	0	0	0	0
Channel stability/Sediment loading										
Grade controls	0	0	0	0	15	4	3	2	0	0
Mass failures	1	1	0	0	1	0	3	2	0	0
Eroding banks	35	27	5	8	41	11	12	9	13	15
Sand/gravel bars	21	16	11	17	37	10	14	10	6	7
Migration features										
Avulsions	0	0	0	0	1	0	2	1	0	0
Flood chutes	12	9	0	0	9	2	8	6	1	1
Oxbows/cutoffs	2	2	0	0	1	0	3	2	0	0
Stream crossings (bridges/culverts)	3	2	2	3	14	4	2	1	2	2

Table 2. Summary of mapped channel features. The assessed length of Chenery Brook was 1.3 mi, Hobbs Brook was 0.6 mi, Mill Creek was 3.8 mi, Norton Brook was 1.3 mi, and Webes Creek was 0.9 mi.

Wood serves as a proxy for good aquatic habitat in streams given its association with higher fish populations (Flebbe, 1999), a greater abundance and richness of macroinvertebrates (Bond et al., 2006), pools (Montgomery et al., 1995), and more complex physical habitat in general (Benke and Wallace, 2003). All five streams have in-stream wood, including log jams that span the channel. Given the narrowness and small size of the streams, particularly at their upstream ends, these log jams are often formed by small branches and sticks derived from alders and other shrubs growing along its banks. Although perhaps not adequately reflected in the mapping data, the log jams and other in-stream wood tend to be closely associated with complex flow patterns, pools, and the accumulation of organic rich fine sediments (over a clay hardpan) that can serve as a food source for macroinvertebrates. Chenery Brook and Norton Brook have considerably more wood per stream mile compared to the other three streams (Table 3). However, the frequency of wood on Chenery Brook and Norton Brook is still well below the more than 200 pieces/mile targeted by fisheries biologists for even small New England streams (Kratzer and Warren, 2013). Therefore, the channel features mapping reveals a need for increased wood loading on the five assessed streams, even those in well forested areas with locally excellent habitat conditions such as Norton Brook.

Mass failures, and bank erosion in general, on the streams are not significant. While numerous areas of erosion are observed along the streams, they tend to be of short length and are often associated with the outside bends of high-amplitude meanders where they impinge on higher banks of the uplands at the back edge of the streams' floodplains. Trees growing on the bank collapse into the streams at these locations, so the erosion serves as a source of wood inputs to the stream channels. Mass failures and severe bank scour were also observed at the outlet of several undersized culverts, most notably the railroad culvert on Chenery Brook and the Depot Street culvert on Webes Creek. The bank scour associated with undersized culverts is localized and does not extend far downstream. The erosion observed on the five streams is largely part of natural channel processes (e.g., outer bend of a meander) or is localized around undersized culverts. Long continuous areas of erosion associated with a major basin-wide disturbance, such as urbanization, are not observed. The short discontinuous mass failures and bank erosion revealed through the channel features mapping are largely consistent with a natural sinuous stream generating the periodic inputs of sediment and wood necessary to sustain a dynamic stream channel with good flow complexity and a channel substrate of sediment (rather than a hardpan clay stream bottom).

In contrast to the presence of in-stream wood, hardpan clay exposed on the stream bottom is a proxy for poor aquatic habitat quality (but was not mapped as part of the channel features mapping). All five streams have formed in valleys primarily, if not exclusively, floored by the Presumpscot Formation. Therefore, exposure of the hardpan on the bed of the channel is an indication that flow velocities in that area are too strong to retain and accumulate sediment. Without sediment and organic matter on the stream bottom, a substrate for macroinvertebrate colonization and feeding will be lacking. Even a thin layer of sediment, as is the case in many areas on the assessed streams, would represent greatly improved habitat compared to the bare hardpan. An exposed hardpan on the stream bed was observed in several locations on all five streams. Exposed hardpan tends to be located where stream velocities are high and/or where sediment is limited such as at the outlets of undersized culverts or downstream of bedrock falls. While short distances of hardpan may be exposed immediately downstream of log jams, this is balanced by longer sections upstream where sediment, sometimes considerable amounts, tends to accumulate.

5.2 Topographic surveying

Topographic surveying was completed along portions of ten reaches. Three surveys were conducted on Norton Brook (Reaches N1, N2, and N3), two each on Chenery Brook (two adjacent sites surveyed in Reach C2), Hobbs Brook (Reaches H2 and H3) and Mill Creek (Reaches M6 and M11), and only one on Webes Creek (Reach W1). The surveys were conducted to establish the channel's (bankfull) dimensions (i.e., width, depth, sinuosity, and slope) and allow for comparisons between sites to document how the dimensions vary between more natural conditions and various settings altered by human impacts (e.g., outlet of an undersized culvert). The survey data is summarized in Table 4 with plots of the planviews, cross sections, and longitudinal profiles of each site provided in Appendix 4. The survey data was also used to develop conceptual restoration designs, so further details about the surveys are discussed along with the developed designs in Section 6.0 below.

Stream	Reach number	Cross section	Bankfull width (ft)	Mean depth (ft)	Max depth (ft)	Width/ depth	Channel gradient	Sinuosity
Chenery Brook	C2a	1	18.4	2.89	4.71	6.4	0.0048	1.107
	C2a	2	43.2	2.89	4.35	14.9	0.0048	1.107
	C2a	3	45.1	1.23	3.01	36.7	0.0048	1.107
	C2b	4	19.8	2.24	2.63	8.8	0.0025	1.044
	C2b	5	22.8	2.12	3.49	10.7	0.0025	1.044
	C2b	6*	26.1	0.95	1.25	27.5	0.0025	1.044
Hobbs Brook	H2	1	31.3	0.76	2.51	41.4	0.0014	1.230
	H2	2	16.1	0.69	2.13	23.4	0.0014	1.230
	H2	3	15.7	0.95	2.61	16.6	0.0014	1.230
	H3	4	32.3	0.64	1.82	50.5	0.0006	1.162
	H3	5	23.6	0.60	1.54	39.4	0.0006	1.162
	H3	6	16.6	0.79	1.90	21.1	0.0006	1.162
Mill Brook	M6	1	16.0	1.88	2.44	8.5	0.0042	1.051
	M6	2	21.9	1.50	1.68	14.6	0.0042	1.051
	M11	1	24.7	3.38	4.86	7.3	0.0004	1.097
	M11	2	22.5	3.74	5.86	6.0	0.0004	1.097
Norton Brook	N1	1	12.7	1.69	3.22	7.5	0.0041	1.357
	N1	2	17.2	1.52	3.09	11.3	0.0041	1.357
	N1	3	14.2	1.97	2.83	7.2	0.0041	1.357
	N2	1	10.5	1.24	2.08	8.5	0.0057	1.632
	N2	2	15.7	1.14	3.42	13.8	0.0057	1.632
	N2	3	7.9	1.56	2.87	5.0	0.0057	1.632
	N3	1	23.4	2.16	2.93	10.8	0.0499	1.122
	N3	2	16.1	2.24	2.92	7.2	0.0499	1.122
	N3	3	13.4	2.06	3.65	6.5	0.0499	1.122
Webes Creek	W1	1	15.6	1.73	2.73	9.0	0.0087	1.118
	W1	2	20.5	1.08	2.59	19.0	0.0087	1.118
	W1	3	9.1	1.45	1.97	6.3	0.0087	1.118

* Transect crosses abandoned meander/oxbow channel

Table 4. Summary of survey data.

6.0 CONCEPTUAL RESTORATION PLANS

All of the topographic survey sites (see Section 5.2 above) were also locations for which conceptual restoration designs were developed. The survey data provide the necessary detail on channel dimensions to develop viable conceptual restoration plans, although issues regarding machine access (that might be difficult though not insurmountable) in some instances are not addressed. The chosen survey/restoration sites were selected for their potential to: 1) restore natural fluvial processes, 2) address channel instability and habitat degradation, and, as a whole, 3) exemplify a range of restoration strategies that might be effective for "like-reaches" elsewhere on the five assessed streams. The restoration plans span a range of complexities from relatively simple and inexpensive approaches that do not require heavy machinery to more complex and expensive strategies.

The ten conceptual restoration designs are described further below and presented in Appendix 4 with the associated survey data. Restoration ideas for other reaches for which concepts have not been developed (see Table 2) and are considered too expensive or complex to be completed for environmental purposes only (e.g., culvert replacements at major roads) should be placed on a "watch list" such that when funding becomes available for other purposes (e.g., improve safety of an aging culvert), these "watch list" restoration ideas can be presented to the project designers to ensure that the environmental concerns at these sites are simultaneously considered (for example, see Section 6.1 below).

6.1 Reach C2a: Log crib walls and log sills

Reach C2 on Chenery Brook begins at the outlet of the railroad culvert. A continuous two-part survey was completed from the railroad culvert outlet to an area where the channel becomes confined between natural uplands on the right bank and the I-295 road grade on the left bank (Appendix 4). The upper portion of the surveyed area (Reach C2a) documents the scour and deposition occurring at the outlet of the undersized railroad culvert, while the downstream end of the survey area (see Reach C2b below) characterizes an artificially straightened channel and the associated abandoned meander upstream of the valley constriction.

Severe scour at the outlet of the railroad culvert (Figure 4a) has more than doubled the channel width relative to unaffected areas (compare Cross Section 2 in Reach C2a with Cross Section 4 in Reach C2b in Table 4 and Appendix 4). The bed of the channel immediately downstream of the outlet has been stripped of sediment, exposing the hardpan clay underneath. The material scoured from the bed and banks of the channel have been redeposited downstream to form a large gravel bar that has caused a shift in the channel's position and further widening of the channel (Reach C2a Cross Section 3). Scouring of the right bank continues along the new channel. This scour, deposition, and channel migration is in response to a 67 percent constriction of the channel caused by the undersized railroad culvert (Appendix 4 – see Cross Section 1 in Reach C2a).

The only long-term sustainable manner of addressing the scour at the outlet of the railroad culvert is to replace the structure with a crossing that at least matches the width of the channel. However, a culvert replacement is not considered as part of the conceptual design here, because the project is considered a "watch list" project on Table 2 given the expected high cost, complexity, and long timeframe required to implement such a project along the rail line. A conceptual design of a culvert replacement is provided for Reach N3 at Northbrook Drive (see Section 6.9 below).

A more feasible short-term solution to address the environmental and geomorphic impacts of the scour at the outlet of the railroad culvert would be to construct log crib walls along the eroding banks to save the undermined trees along the edge of the bank and to reduce the introduction of fine sediment to the channel (Appendix 4). Additionally, log sills could be placed on the bed of the channel to locally reduce flow velocities that will trap sediment above the hardpan clay, narrow the channel, and improve substrate conditions for macroinvertebrate colonization. Ideally, these log structures would be constructed with heavy machinery but given the difficulty in accessing the site and the forested nature of the site, the work could be completed with hand tools (e.g., grip hoists) with the trees sourced on site. The use of log crib walls and log sills would also be appropriate for similar "like reaches" where scour is occurring at the outlet of culverts such as Reach N3, Reach N4, and Reach W2. These same locations would also be appropriate for culvert replacements given that the cause of the scouring at these sites relates to the undersized nature of the stream crossing structures.

6.2 Reach C2b: Boulder-supported log jams

Reach C2b, just downstream of Reach C2a, is an artificially straightened channel flowing against the high I-295 road grade on the left bank with boulders at the base (Appendix 4). The straightened channel extends downstream for a long distance beyond the surveyed area. A floodplain is present on the right bank that pinches down to nothing at the downstream end of the surveyed area due to a spur of high ground that encroaches on the channel. An abandoned meander is present on the right bank floodplain that was likely originally formed as a result of backwatering upstream of the constricting spur (Appendix 4 – see planview and Cross Section 6) . Abandonment of the meander presumably occurred when the channel was artificially straightened, possibly at the time of I-295 construction. The bed of the meander is elevated above the bed of the active and straightened channel due to slight incision below the floodplain. As a consequence, only larger flows now enter the abandoned meander.

Although the width:depth ratio of the straightened channel is not as high as in Reach C2a (Table 4), straightened channels typically have poor habitat due to wide channels without confining bars at low flow. Consequently, summertime flow depths are low and flow complexity minimal. To restore more natural conditions, a series of boulder-supported log jams could be built along the margins of the artificially straightened channel (even beyond the surveyed area) to increase flow complexity, provide cover habitat, and promote sediment deposition to narrow the channel (Appendix 4). By alternating the bank on which the log jams are built, meanders could be encouraged to form by redirecting flow into the bank across from each jam. Ultimately, this would improve substrate particle size segregation (i.e., reduce embeddedness) and increase pool depths. If boulders from the base of the I-295 road grade could be repurposed, then the log jams could be constructed with hand tools only, given the difficulty of accessing the site with heavy machinery, but the use of heavy machinery would be preferable. Boulder-supported log jams could also be used on other artificially straightened reaches such as Reach N2 and Reach W2.

6.3 Reach H2: Riparian plantings and isolated wood additions

Reach H2 flows through an open field with a poor riparian canopy. Most of the reach has a relatively low width:depth (i.e., less than 25.0) (Table 4 – see Cross Sections 2 and 3) and may be slightly incised as a narrow discontinuous floodplain is inset below a wider more continuous flat surface (considered to be the historic floodplain). The channel has good sinuosity (Appendix 4 – see planview) but the lack of wood in the channel is limiting flow complexity and sediment accumulation on the stream bed, so hardpan clay is exposed in places.

With landowner agreement, perhaps assisted by NRCS programs to compensate the landowner for lost productivity, the planting of riparian zone trees to a minimum width of 35 ft from the top of the stream bank would improve the canopy and provide a source of wood over time (Appendix 4). For more immediate improvements (and perhaps more acceptable to the landowner), the placement of isolated wood buried in the channel with root wads exposed on the channel bed or in the form of low log sills running across the channel would both enhance flow complexity, provide cover habitat, and encourage sediment deposition to create a substrate over the hardpan clay for macroinvertebrate colonization. Boulders already in the channel could be repurposed to help anchor some of the structures. The implementation could be completed with hand tools, but access for heavy machinery would not be problematic with permission from the landowner. Riparian plantings would also be effective in those reaches without tall trees growing along the stream such as Reach M2 (with landowner permission) and Reach N2 (with resizing of the Johnson Road culvert).

6.4 Reach H3: Chop and drop wood additions

For most of Reach H3, the channel is largely infilled by fine sediment that was deposited in the channel and across the narrow floodplain when flow was impounded behind a fallen tree later plugged with smaller branches by beaver (Figure 12). As a result, the channel has minimal depth and a resulting high width:depth (Table 4 – see Cross Sections 1 and 2). Based on the deposition line at the back edge of the floodplain (Figure 12a), the depth of the impoundment above the floodplain level was 2.0 ft (Appendix 4 – see cross sections). Now that the impoundment has drained, conditions are slowly recovering with greater channel depth and lower width:depth ratios closer to the fallen tree. The lack of in-stream wood within the formerly impounded area may be slowing the rate of recovery.

Adding wood to the channel through the chop and drop method within the formerly impounded area (Appendix 4) will improve cover habitat where little is present now and generate flow complexity to help remove the built up fine sediment in the channel. The possibility exists the added wood could also impound flow. Although impounded flow is not considered an issue, the application of chop and drop could be at a lower density (one key log every 6 to 8 channel widths compared to a more typical wood loading of every 3 or 4 channel widths) to reduce the potential for impounding flow. The reach is in excellent condition currently and discussing with the landowner the potential for placing the land in conservation would ensure a long-term supply of wood reaches the channel from the forested riparian zone. Chop and drop is a technique that could be applied to most forested reaches on all five of the assessed streams to supplement existing in-stream wood even where conditions are already excellent such as Reach M4 and Reach N1.

6.5 Reach M6: Dam removal and channel realignment

The topographic survey of Reach M6 was conducted in the vicinity of the old dam and includes both the existing channel and the old channel across which the dam was originally built (Appendix 4 – see planview). The stacked stone of the dam fills in a gap between ledge on both flanks of the structure. The dam was 10 ft high above the old channel bed that is still visible downstream of the dam. Upstream, the original channel is not present, perhaps due to infilling of the channel through sediment deposition. The current channel formed by eroding through Presumpscot Formation clay beyond the bedrock ledge on the right flank of the dam (looking downstream), perhaps at a low area that was overtopped during a large flood. The bankfull width of the narrow gully formed from the outflanking of the dam is less than the width of the former channel blocked by the dam (Appendix 4 – see cross sections) and remains confined by high banks of clay, whereas the former channel has access to a wide floodplain (Appendix 4 – compare Cross Sections 1 and 2). Without restoration, the channel through the gully area is likely to widen over time until matching the former channel's width with the high banks continuing to erode.

As self-stabilization of the high eroding banks through the gully may take decades, removal of the dam and realignment of the creek back into its former channel and wide floodplain (Appendix 4) would reduce flow energy in the immediate vicinity and reduce fine sediment loading to downstream areas. Large wood, potentially through chop and drop, could be placed in the gully (to be abandoned by realigning the channel) to prevent the channel from reoccupying the area but still providing an overflow channel during high flows to reduce flow energy in the reactivated channel. Access for heavy machinery would be relatively easy from the end of Chandler Drive as long as one of the residential homeowners agrees to having an excavator traverse the edge of their lawn. To avoid trucking off site, the rocks of the dam could be repurposed as boulder clusters or for anchoring logs placed in the realigned channel and/or set aside in an upland area. The old dam is rather unique for the five assessed streams, so no "like reaches" exist where dam removal and channel realignment could also be used. The only other possible remnant dams observed were in Reach M7 and N3, neither of which are causing issues necessitating removal.

6.6 Reach M11: Berm removal and marginal log jams

The surveyed area of Reach M11 includes the apparently straightened section of channel with a low berm along the right bank (Appendix 4 – see Cross Section 1). The straightened section begins near the confluence of Norton Brook and continues downstream to include part of a broad meander that is forming where the marsh widens. The difference in sinuosity between the broad meander and the straightened section is clear in planview (Appendix 4).

The natural morphology of the creek through the tidal marsh is a highly sinuous meandering form. The berm along a straightened section of channel where the survey was conducted suggests the straightening was completed by humans. To restore the more natural sinuous conditions, the berm could be removed and several marginal log jams constructed along the left bank to divert flow into the opposite bank to encourage meander growth along the straightened section (Appendix 4). To have the desired effect, the log jams would need to protrude out into the channel about 50 percent of its width, or approximately 12 ft with each log jam spaced about five times the protrusion distance or 60 ft. The log jams would ideally be anchored with vertical and horizontal log piles, but the exact method of securing the structures would occur in a later design phase. The log jams would look natural given that the left bank runs at the edge of the forested uplands. Smaller boulder-supported log jams were recommended for Reach C2b. Given the generally small size of the five assessed streams, the larger more robust marginal log jams suggested for Reach M11 are not considered appropriate elsewhere on the five streams.

6.7 Reach N1: Chop and drop

The sinuous channel (Appendix 4 – see planview) flowing on a forested floodplain in Reach N1 has a very low width:depth ratio of less than 12.0 (Table 4), both consistent with a stream flowing through hardpan clay that is exposed along the stream. The low width:depth ratio is also consistent with channel incision, although the presence of sand deposits along the edge of the channel at or near the floodplain level would indicate no, or only slight, incision has occurred. While numerous small log jams and isolated pieces of wood are found in the survey area and throughout the reach as a whole, long sections have no in-stream wood and the total loading is considered far below target levels (Kratzer and Warren, 2013).

Conditions are currently very good through much of Reach N1 and is largely free of human constraints (i.e., only minor amounts of fill at the back edge of the floodplain), so, in many respects, Reach N1 can be considered a reference reach for understanding how all five of the assessed streams may have appeared prior to human alterations of the channels and surrounding watersheds. That said, wood loading in the streams could be higher. Chop and drop wood additions could be completed to add wood to the channel (Appendix 4) where long sections of the stream currently do not have in-stream wood. The floodplain is well forested and wood will slowly be recruited to the channel as the forest matures. The chop and drop projects would more immediately improve flow complexity, cover habitat, and increase deposition in the channel to remedy the slight incision that may have occurred along the channel. Given the maturing forest, the benefits of the chop and drop project will be sustainable as future wood recruitment will replace the felled trees over a few decades. Many well forested reaches with low levels of in-stream wood are found on the five assessed streams, all of which would be good candidates for chop and drop projects such as portions of Reach N3 and Reach N4.

6.8 Reach N2: Fill removal

The survey of Reach N2 was conducted at the upstream end of the reach and includes a portion of Reach N1 in order to document the constriction of the floodplain by artificial fill and the change from a highly sinuous channel upstream in Reach N1 to the straighter configuration of N2 (Appendix 4 – see planview). The top of the fill on the right bank is more than 5.0 ft higher than the floodplain on the left bank (Appendix 4 – see Cross Section 3). The differences in channel dimensions between the sinuous channel upstream and the artificially straightened channel downstream are distinct (Table 4 – compare Cross Sections 1 and 3). The straightening and the constraint of the channel flowing against the elevated coarse artificial fill has resulted in a narrower channel with a lower width:depth ratio than the more natural conditions upstream. Straightened channels typically have a higher width:depth ratio than natural unaltered channels (Simon, 1989), so the opposite trend in this case suggests that the straightening occurred recently enough that the channel has yet to respond and/or the coarser fill material is inhibiting the widening into the right bank. Future widening, however, should be expected if no restoration occurs but may require a large flow event to be initiated.

The artificial fill on the right bank at the upstream end of Reach N2 has significantly narrowed the natural floodplain and its removal (Appendix 4) will restore the full floodplain width, eliminate constraints to channel adjustment, and reduce flood flow velocities in the channel. While full fill removal would be ideal, the presence of an active commercial property on the fill may preclude that; however, even partial removal would be helpful and is more likely to be considered by the landowner. In-stream restoration activities could be completed with fill removal or on its own if the landowner does not permit fill removal. Isolated logs could be placed in the channel to improve flow complexity and log placements on the restored floodplain (if the fill is removed) would prevent scour of the surface and serve as nurse logs for the growth of trees. Boulder-supported log jams could be used to encourage the growth of meanders along the straightened channel in a manner as described above for Reach C2b (see Appendix 4 and Section 6.2). Fill removal could also be used in Reaches N1 (although the fill does not constrict the floodplain as significantly) and N3 where fill for the old road to the gravel pit (see Section 4.4 above) appears to completely block the floodplain.

6.9 Reach N3: Culvert replacement

The overall slope of the surveyed portion of Reach N3 is quite high (0.05 – see longitudinal profile in Appendix 4) due to the bedrock ledges at the upstream end. Just upstream of the culvert, the gradient is much lower with only a narrow floodplain present before rising up to higher banks (Appendix 4 – Cross Section 3). As a result, backwater from the undersized culvert under Northbrook Drive could rise quite high given the limited space to store floodwaters between the high banks and bedrock ledges upstream. The culvert constricts the channel by 75 percent (Table 4 and Appendix 4 – see Cross Section 3). Detailed hydraulic modeling is needed to establish the potential risk of backwatering during a large runoff event overtopping the road.

The gabion headwall above and around the Northbrook Drive culvert is sliding and rotating down the slope above the culvert (Figure 33) and could potentially block portions of the inlet and greatly worsen the backwater effect. A culvert replacement with a larger structure spanning at least 1.2 times the bankfull width (or 16.1 ft based on a bankfull width of 13.4 ft – see Table 4) should be a high priority with additional relief culverts set at the floodplain level to eliminate the channel constriction and minimize backwatering during even the largest flows (Appendix 4). The gabion headwall should be replaced at the same time to prevent any threat of blocking the culvert inlet that would also be greatly minimized by the enlarged structure. A structure spanning the entire channel, ideally a bridge that also spans the entire narrow floodplain, will better pass sediment and wood, thereby reducing the geomorphic impact of the stream crossing. Replacing undersized culverts with wider crossings could also be completed at the downstream end of Reaches C1, M1, N2, and W1 among others.

Figure 33. Gabion baskets on the headwall of Northbrook Drive are sliding down slope above the culvert inlet.

6.10 Reach W1: Manhole protection and fill removal

Reach W1 is immediately downstream of extensive commercial development in the watershed and begins at a culvert draining this area. The upper portion of the reach is confined, to some degree by artificial fill on the left bank, and, as a result, the channel is wider and deeper than the unconfined lower portion of the reach (Table 4 and Appendix 4 – compare Cross Sections 2 and 3). The confining fill and resulting strong confined flows are responsible for stripping the substrate down to a hardpan clay and redirecting flow into the opposite bank where a sewer manhole has been exposed. The wide floodplain downstream prevents in-channel flow velocities from increasing beyond that of the bankfull flow and prevents channel widening and deepening.

While extensive earthen fill might be on the right bank of the channel, a considerable amount of brush and other material has more obviously been placed over the right bank and further constrained the channel. This fill should be removed to restore at least a narrow portion of the floodplain (Appendix 4) and reduce flow velocities responsible for bank erosion and a hardpan clay substrate. These issues should also be more directly addressed with log sills placed along the channel to help trap sediment above the substrate and a log jam constructed around the manhole exposed by erosion to prevent damage and to encourage the channel back into its original path along the right bank. After removing fill from the right bank, the slope should be sloped back and treated with a bioengineering solution, such as fascine bundles and willow plantings, to encourage vegetative growth that over time will provide a canopy over the stream channel and a long-term source of in-stream wood as the trees mature.

7.0 CONCLUSIONS

Centuries of human activities in and around the five assessed streams in Falmouth, Maine have, at least locally, constrained natural processes and degraded habitat quality. In-stream and floodplain activities by humans include the construction of dams, placement of artificial fill on the floodplains, artificial straightening of the channels, and building of undersized stream crossings. Along with the indirect contribution of excess (and the concentration of) runoff from developed areas of the watershed (particularly Webes Creek), these various human activities have led to the degradation of aquatic habitat as reflected in low wood loadings in the streams, exposure of a hardpan clay on the stream bottom, eroding stream banks, and areas of impounded flow with wetland rather than fluvial characteristics. While most of the streams' length are largely stable, the generally short lengths of degraded habitat, in the immediate vicinity of an undersized culvert for example, lead to the isolation of larger areas of good habitat found along the five streams.

Conceptual restoration designs have been developed to address the human impacts observed on the five streams. In areas with low wood loadings and far from any infrastructure, the "chop and drop" approach of directionally felling trees into the stream channel represents the quickest, cheapest, and most effective approach to improve cover habitat, flow complexity, and retention of sediment on the stream bed (where hardpan clay is now exposed). Constructed marginal log jams or smaller boulder-supported log jams can be used to encourage meander growth along artificially straightened channels, while log crib walls are recommended for addressing bank scour at the outlet of undersized culverts. Where these larger wood structures are not practical, isolated logs and log sills can be utilized to improve habitat conditions with minimal impact to the existing channel morphology or nearby infrastructure. The various wood-based measures proposed will provide immediate habitat improvements. Sustaining those improvements, however, will depend on removing constraints to natural channel adjustment such as the resizing of culverts narrower than the stream channel (with the culvert at Northbrook Drive on Norton Brook being the highest priority), removal of the dam on Mill Creek, and artificial fill removal (with fill at the upstream end of Webes Creek being a high priority). Only through a continued effort over time, starting with the easiest and most inexpensive efforts first while the capacity is developed to address the larger projects, can the Town of Falmouth avoid the streams being listed as urban impaired by the Maine

Department of Environmental Protection. The natural conditions on the streams, particularly the bed and banks composed of the fine-grained silts and clays of the Presumpscot Formation, ensure the streams will respond rapidly and positively to the restoration efforts.

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TABLE 2
(Reach summary)

Table 2a. Summary of reach characteristics and restoration options for Chenery Brook.

a)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
C1	Cumberland town line to railroad culvert	1,075	- Floodplain access - Shrubs for canopy - Narrow channel - Small log jams - Fine substrate	- Undersized culvert - Partial forest buffer removal	1) Chop and drop 2) Replace undersized culvert at downstream end	1) Very low ($25k) 2) Watch list (> $1 million)	1) Mod./Low 2) High/High	
C2	Railroad culvert to widened floodplain with sinuous channel	854	- Severe scour at culvert outlet - Largely fine substrate - Minimal wood in channel	- Channel straightening - Flows along I-295 road grade	1) Chop and drop 2) Log sills, crib walls, and/or log jams	1) Very low ($25k) 2) Low ($100k)	1) Mod./Low 2) Mod./High	
C3	Widened floodplain wirh sinuous channel to Johnson Road	1,422	- Floodplain access with sinuous channel - Drowned dead trees - Beaver activity - Abundant wood in channel	- Small dam and associated pond - Johnson Rd culvert but sufficiently sized	1) Dam removal	1) Moderate ($120k)	1) Mod./Mod.	
C4	Johnson Road to area of increasing confinement	2,208	- Sinuous channel - Small log jams - Predominately fine substrate - Canopy of small shrubs	- Gas pipeline crossing - Straightening (?)	1) Land conservation 2) Bank stabilization	1) Very low ($50k) 2) Low ($100k)	1) Mod./Mod. 2) Low/Mod.	

Table 2a (continued). Summary of reach characteristics and restoration options for Chenery Brook.

a)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
C5	Area of increasing confinement to I-295 culvert	1,141	- Narrow floodplain - Cobble substrate in places - Beaver dam with large impoundment - Mature trees on nearby uplands	- I-295 culvert but no backwatering evident	1) Land conservation 2) Chop and drop	1) Very low ($50k) 2) Very low ($25k)	1) Mod./Mod. 2) Low/Low	
C6	I-295 culvert to sharp bend on high right bank	556	- Upper reach confined - Ledge outcropping on left bank - Sloughing right bank of clay - Floodplain and sand bars in lower reach	- Abandoned channel and sharp bend suggest straightening	1) Chop and drop	1) Very low ($25k)	1) Mod./Low	
C7	Sharp bend on high right bank to Mill Creek confluence	903	- Floodplain access - Good tree canopy - Abundant wood - Sinuous dynamic planform - Predominately sandy substrate	- Straightening (?) - Concentrated runoff in small gully from Route 1	1) Chop and drop 2) Reactivate abandoned channel 3) Wood additions in small gully	1) Very low ($25k) 2) Mod. ($150k) 3) Low ($50k)	1) Low/Low 2) Low/Mod. 3) High/Low	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs
† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site
Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2b. Summary of reach characteristics and restoration options for Hobbs Brook.

b)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
H1	Cumberland town line to Gray Road	601	- Marsh lands with dense shrubs - Low width:depth channel - Fine substrate	- Undersized culvert at downstream end - Gas pipeline crosses just upstream of culvert	1) Replace undersized culvert	1) Watch list ($300k)	1) Mod./Mod.	
H2	Gray Road to high confining left bank	1,593	- Scour at culvert outlet - Clay hardpan substrate - Minimal wood in channel - Sinuous low width:depth channel	- Straightening (?) - Clearance of riparian zone - Boulders in channel	1) Chop and drop 2) Log sills	1) Very low ($25k) 2) Very low ($45k)	1) High/Low 2) High/Low	
H3	High confining left bank to Piscataqua River confluence	1,121	- Narrow floodplain - Upper half imounded by fallen tree jammed with branches - Good forest canopy - Minimal wood in channel	- None evident directly in channel	1) Land conservation 2) Chop and drop	1) Very low ($50k) 2) Very low ($25k)	1) Mod./Mod. 2) Low/Low	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2c. Summary of reach characteristics and restoration options for Mill Creek.

c)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
M1	Route 9 to Olde Blackwood Way	1,599	- Sinuous channel at upstream and downstream ends - Alder wetland in middle of reach - Small log jams - Good canopy	- Undersized culverts - Channel realignment	1) Chop and drop 2) Replace both undersized culverts	1) Very low ($25k) 2) Moderate ($150k)	1) Mod./Low 2) Mod./Mod.	
M2	Olde Blackwood Way to Route 9	814	- Channel with high width:depth ratio - Abandoned meander on right bank - Little in-stream wood - Wetland at end of reach	- Channel straightening - Undersized and poorly aligned culverts	1) Provide relief culvert or reactivate meander 2) Realign and resize culverts 3) Low log sills	1) Moderate ($100k) or high ($200k) 2) High ($200k) 3) Low ($50k)	1) Mod./Mod. 2) Mod./High 3) Mod./Low	
M3	Route 9 to Long Creek Way	1,133	- High amplitude meanders downstream - Gravel/sand substrate - High width:depth channel - Minimal wood in channel despite forest	- Channel realigned at Route 9 - Fill blocks portion of floodplain - Straightening (?) at upstream end - Undersized culvert	1) Chop and drop 2) Resize Long Creek Way culvert	1) Very low ($25k) 2) Moderate ($100k)	1) Low/Low 2) Mod./Low	
M4	Long Creek Way to the bedrock falls	2,286	- High amplitude meanders downstream - Gravel/sand substrate - Low to high width:depth channel - Minimal wood in channel despite forest	- Undersized culvert under private driveway	1) Land conservation 2) Chop and drop 3) Resize driveway culvert	1) Low ($75k) 2) Low ($100k) 3) Low ($50k)	1) High/Mod. 2) Mod/Low 3) Low/Low	

Table 2c (continued). Summary of reach characteristics and restoration options for Mill Creek.

c)

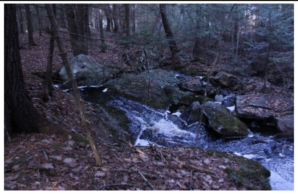
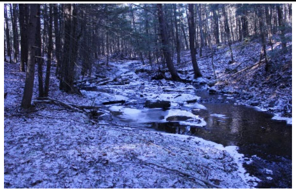
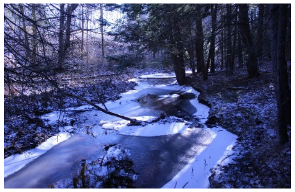
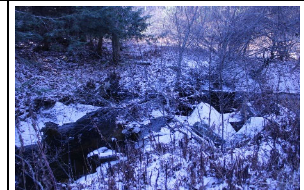
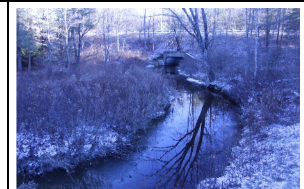
Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
M5	Bedrock falls to the transmission line	536	- Confined channel - Bedrock falls - Large sand bar in low gradient area - Well forested buffer	- None evident directly in channel	1) Chop and drop in low gradient area	1) Very low ($20k)	1) Low/Low	
M6	Transmission line to Middle Road	2,315	- Sinuous high width:depth channel - Hardpan clay substrate common - Well forested buffer - Numerous log jams - Narrow floodplain	- Remnant dam - Middle Road culvert (but not undersized)	1) Chop and drop 2) Remove dam and realign channel	1) Very low ($30k) 2) High ($250k)	1) Mod./Low 2) High/Mod.	
M7	Middle Road to downstream end of bedrock gorge	1,204	- Confined channel - Low bedrock falls - Cobble substrate and bars in low gradient areas - Abundant in-stream wood and good buffer	- Remnant dam - Middle Road culvert (but not undersized)	1) Land conservation	1) Very low ($40k)	1) High/Mod.	
M8	Downstream of bedrock gorge to railroad culvert	511	- Bifurcated channel where flow expands - High width:depth - Minimal in-stream wood - Good forested buffer	- Poorly aligned culvert - Flow along railroad grade	1) Chop and drop w/ log strainer 2) Resize and realign culvert	1) Very low ($30k) 2) Watch list (> $1 million)	1) Mod./Mod. 2) Low/High	

Table 2c (continued). Summary of reach characteristics and restoration options for Mill Creek.

c)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
M9	Railroad culvert to I-295 culvert	1,116	- Sinuous with high amplitude meanders - Sand substrate - Straight along high bank - Minimal wood & poor buffer on floodplain	- Riprap at railroad culvert outlet - Large boulders in channel upstream of I-295 culvert (see photo)	1) Chop and drop 2) Remove boulders	1) Very low ($25k) 2) Low ($60k)	1) High/Low 2) Low/High	
M10	I-295 culvert to Route 1 culvert	837	- Sinuous channel - Narrow floodplain - Significant in-stream wood -Low shrubs on floodplain	- Riprap under bridge constricts channel - Culverts at both ends but both match channel width	1) Chop and drop 2) Pull back riprap to alleviate constriction	1) Very low ($20k) 2) Very low ($20k)	1) Low/Low 2) Mod./Mod.	
M11	Route 1 culvert to Foreside Road bridge	5,537	- Tidally influenced - High amplitude meanders across marsh - Minimal wood - Fine substrate - Eroding banks	- Straightening and berming in short section - Sewer line at edge of floodplain w/ channel imipinging at one spot	1) Berm removal & log jams to encourage meander growth where straightened 2) Bank protection with logs where near sewer line	1) High ($250k) 2) Mod. ($200k)	1) Low/Mod. 2) High/Mod.	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2d. Summary of reach characteristics and restoration options for Norton Brook.

d)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
N1	Cumberland town line to behind Street Cycles store	1,868	- Dynamic sinuous channel - Low width:depth channel - Sand substrate - Multiple log jams w/ forested floodplain	- Straightening (?) - Floodplain partially constricted by fill	1) Chop and drop	1) Very low ($25k)	1) Low/Low	
N2	Behind Street Cycles store to Johnson Road culvert	1,316	- Channel flows against fill at upstream end - Wide marshy floodplain downstream - Minimal wood in channel - Low sinuosity	- Straightening (?) - Floodplain partially constricted by fill - Johnson Rd culvert	1) Log sills and jams 2) Remove fill 3) Add relief culverts at Johnson Road	1) Low ($100k) 2) Mod. ($200k) 3) High ($250k)	1) Mod./Mod. 2) Mod./High 3) High/High	
N3	Johnson Road culvert to Northbrook Drive culvert	1,541	- Rocky substrate above hardpan clay - Bedrock confinement - Minimal wood - Sinuous above falls - Headwall above culvert inlet collapsing	- Remnant dam (?) - Riprap at culverts - Johnson Rd culvert	1) Log cribbing to replace riprap 2) Repair and resize Northwood Dr culvert 3) Anchored chop and drop	1) Low ($100k) 2) High ($250k) 3) Very low ($40k)	1) High/Low 2) High/Mod. 3) Mod./Low	
N4	Northbrook Drive culvert to Mill Creek confluence	1,338	- Sinuous channel across wide floodplain - Sandy substrate and large sand bars - Good forest canopy - In-stream wood common	- Fill across floodplain at old crossing to quarry - Fill constricts floodplain at Sullivan Tire - Scour at culvert outlet	1) Chop and drop 2) Remove fill crossing floodplain at old quarry access	1) Very low ($25k) 2) High ($250k)	1) Low/Low 2) High/High	

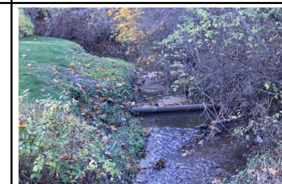
* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2e. Summary of reach characteristics and restoration options for Webes Creek.

e)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
W1	Culvert by Ace Hardware store to Depot Road	703	- Floodplain access at downstream end - Confined by clay and fill upstream - Limited wood and canopy - Hardpan clay on bed	- Undersized culverts - Fill constricts channel - Manhole exposed by erosion - Forest buffer removed	1) Remove fill and log jams to protect manhole 2) Log sills to trap sediment over clay 3) Resize Depot Rd culvert	1) High ($200k) 2) Low ($40k) 3) High ($250k)	1) High/Mod. 2) High/Mod. 3) High/High	
W2	Depot Road culvert to end of the lawn	257	- Severe scour at culvert outlet - Minor sinuosity - Hardpan clay on bed - Minimal buffer and in-stream wood	- Channel straightening - Pipe crosses channel - Severe scour at culvert outlet - Forest buffer rremoved	1) Log cribbing for bank protection 2) Log sills to trap sediment over clay 3) Remove pipe or protect w/ log jam 4) Recreate meanders	1) Very low ($40k) 2) Very low ($40k) 3) Moderate ($120k) 4) High ($300k)	1) High/Low 2) Mod./Mod. 3) High/Mod. 4) Mod./High	
W3	End of the lawn to the next lawn downstream on the right bank	1,211	- Upstream end sinuous - Low banks downstream - Hardpan clay exposed in areas - Jams w/ sticks derived from thick shrub buffer	- Straightening (?)	1) Bundle clippings to form jams	1) Very low ($10k)	1) Mod./Low	
W4	Next lawn downstream on the right bank to open meadowy area	391	- Straight channel with better defined banks - Bank erosion causing large trees to fall into channel - Stagnant flow - Poor canopy	- Straightening (?)	1) Buffer planting along edge of lawnss	1) Very low ($25k)	1) High/Mod.	
W5	Open meadowy area to Mill Creek confluence	983	- Tidally influenced - High amplitude meanders across marsh - Minimal wood and poor canopy - Fine substrate - Low width:depth	- Straightening (?) at upstream end - Concrete bridge collapsed in channel - Channel approaching sewerline	1) Remove collapsed bridge	1) Low ($75k)	1) Low/Mod.	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

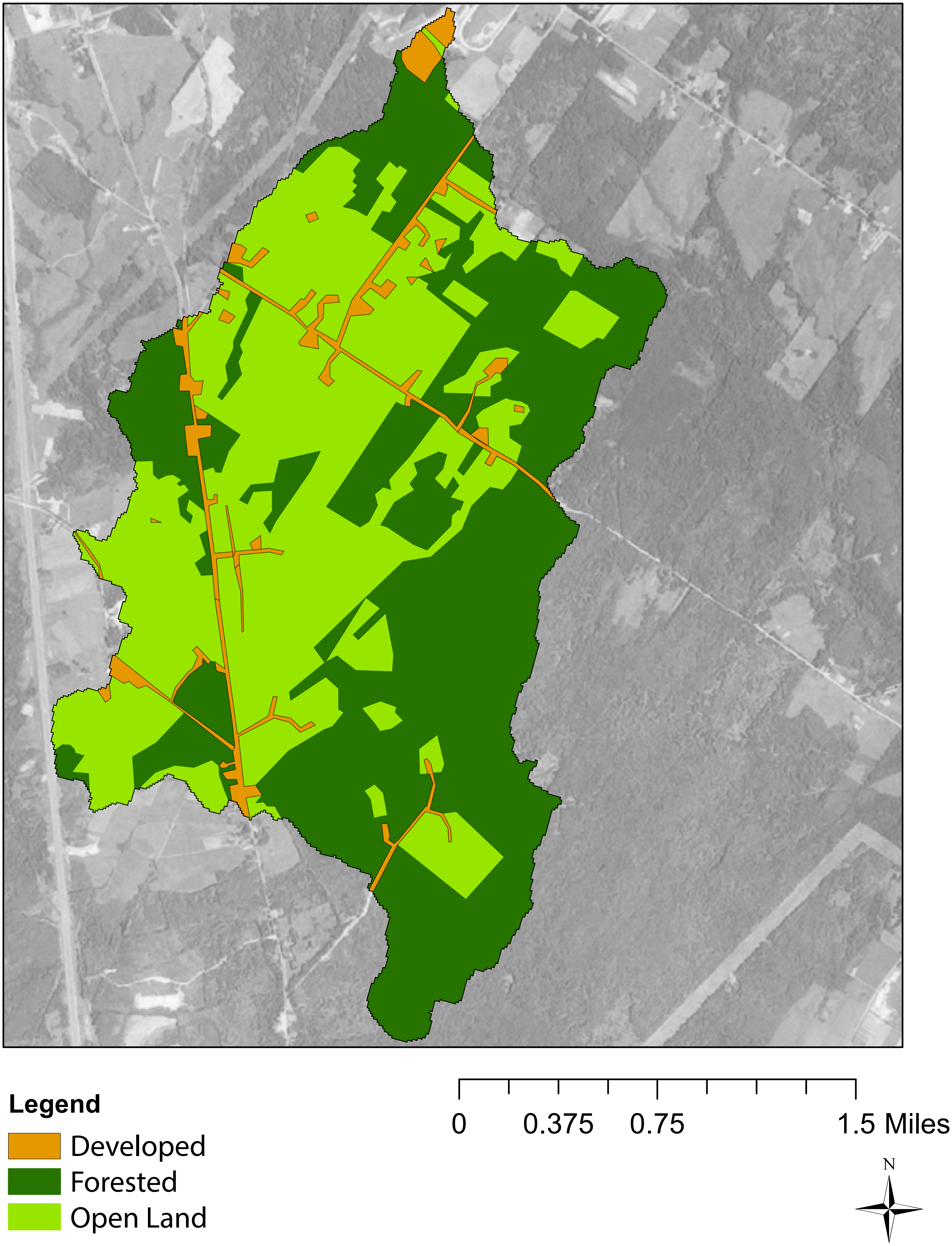
Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

APPENDIX 1
(Land use maps)

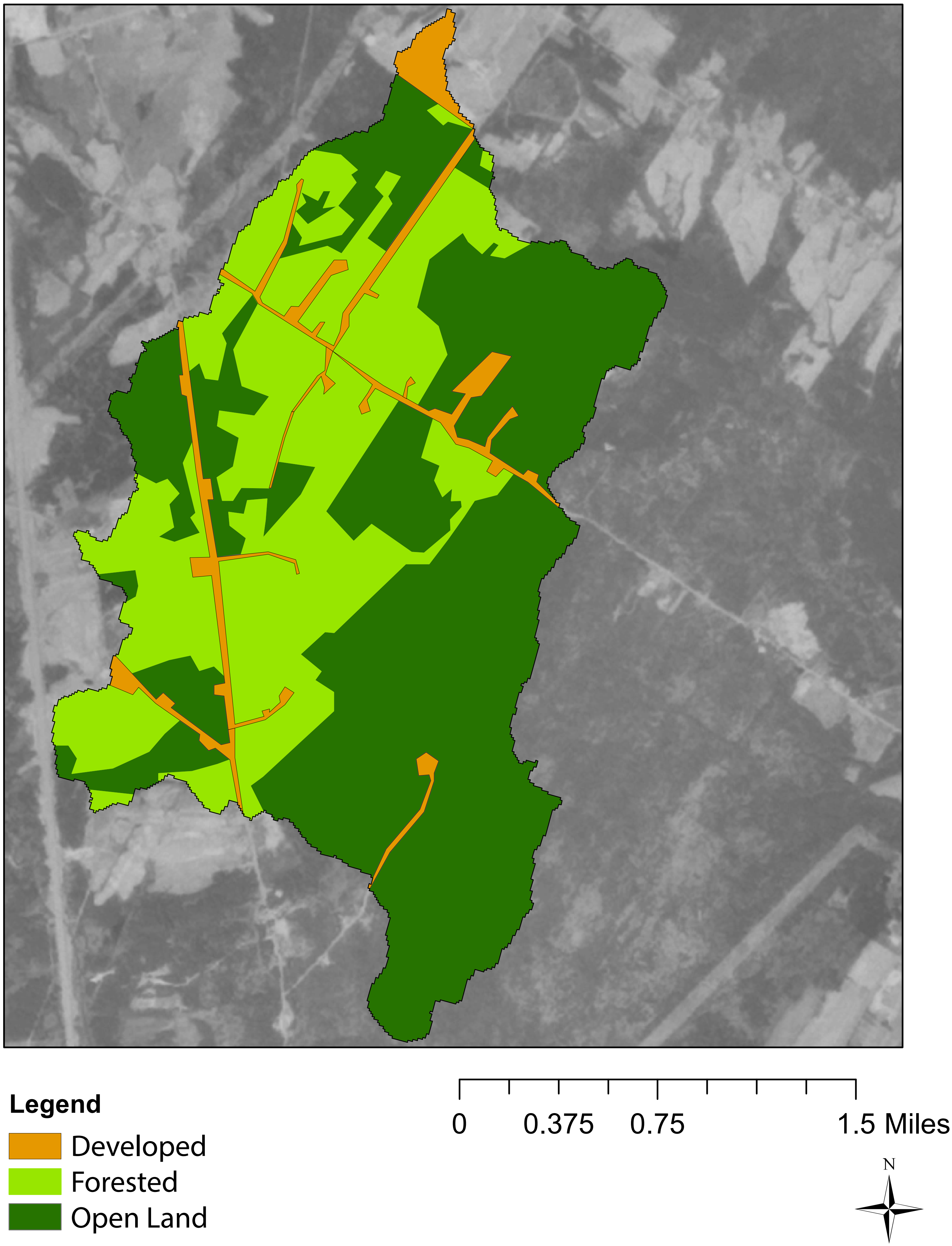
1940 Land Use for Hobbs Brook

Field Geology Services
Fluvial Geomorphology

1960 Land Use for Hobbs Brook

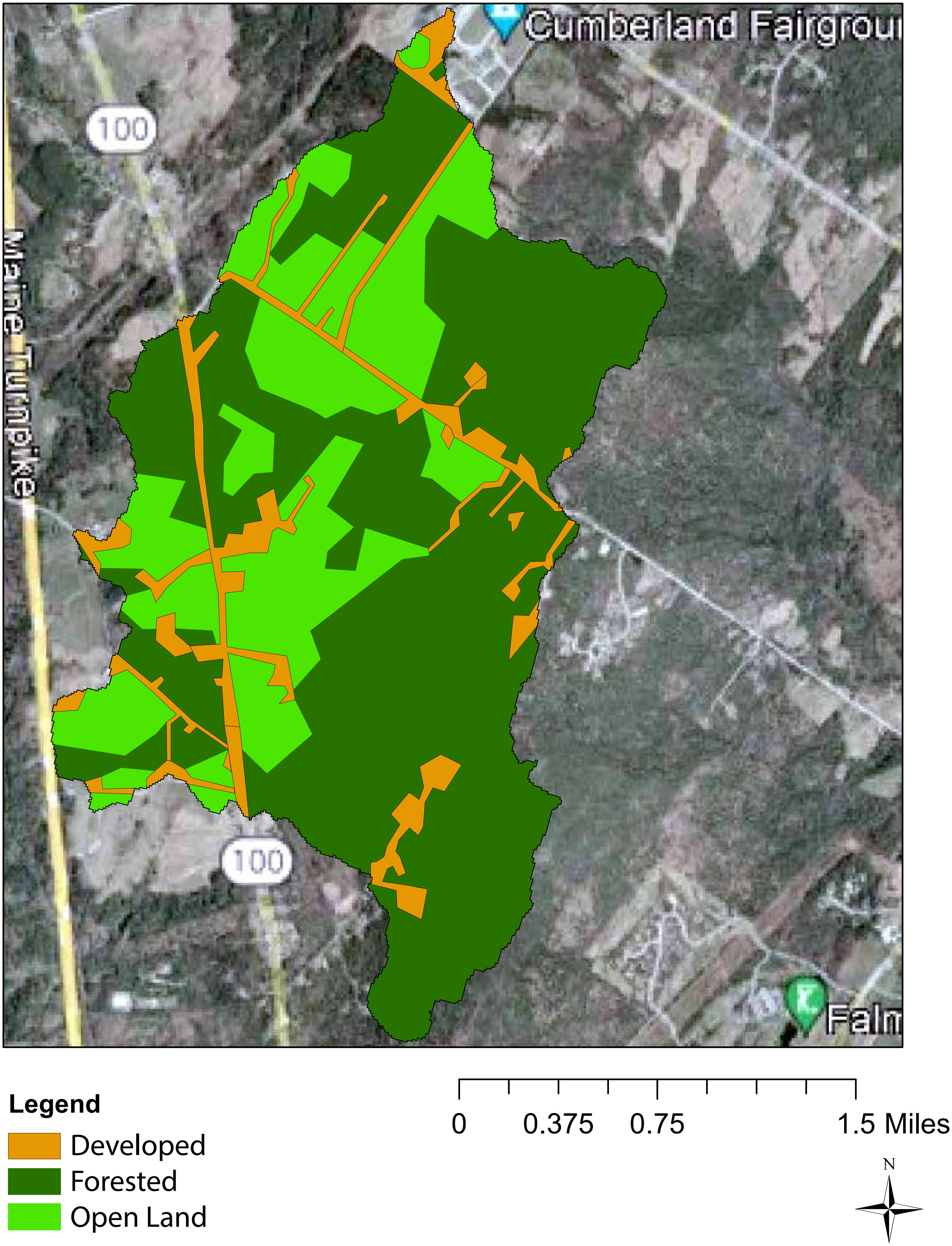


1975 Land Use for Hobbs Brook



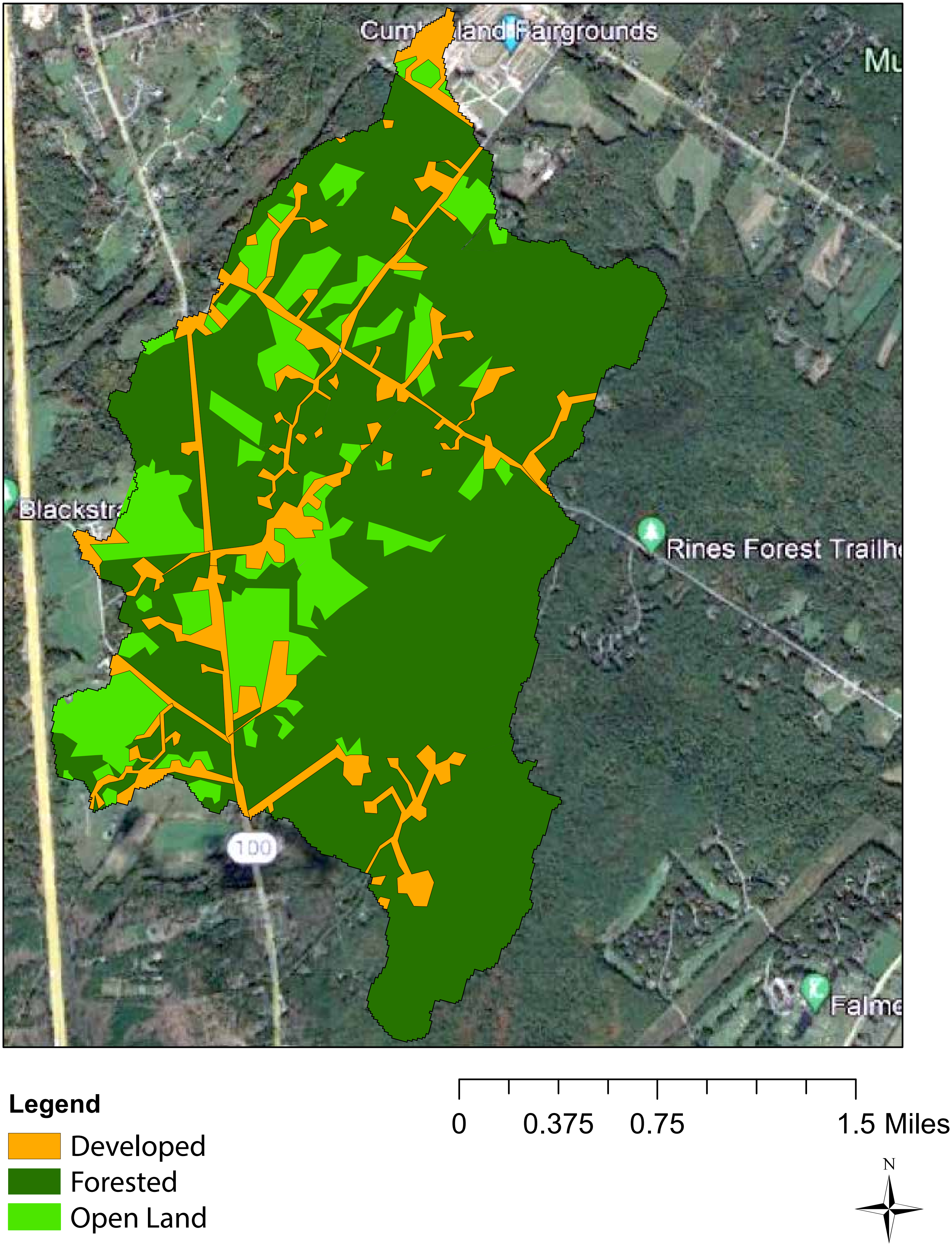
Field Geology Services
Fluvial Geomorphology

2006 Land Use for Hobbs Brook



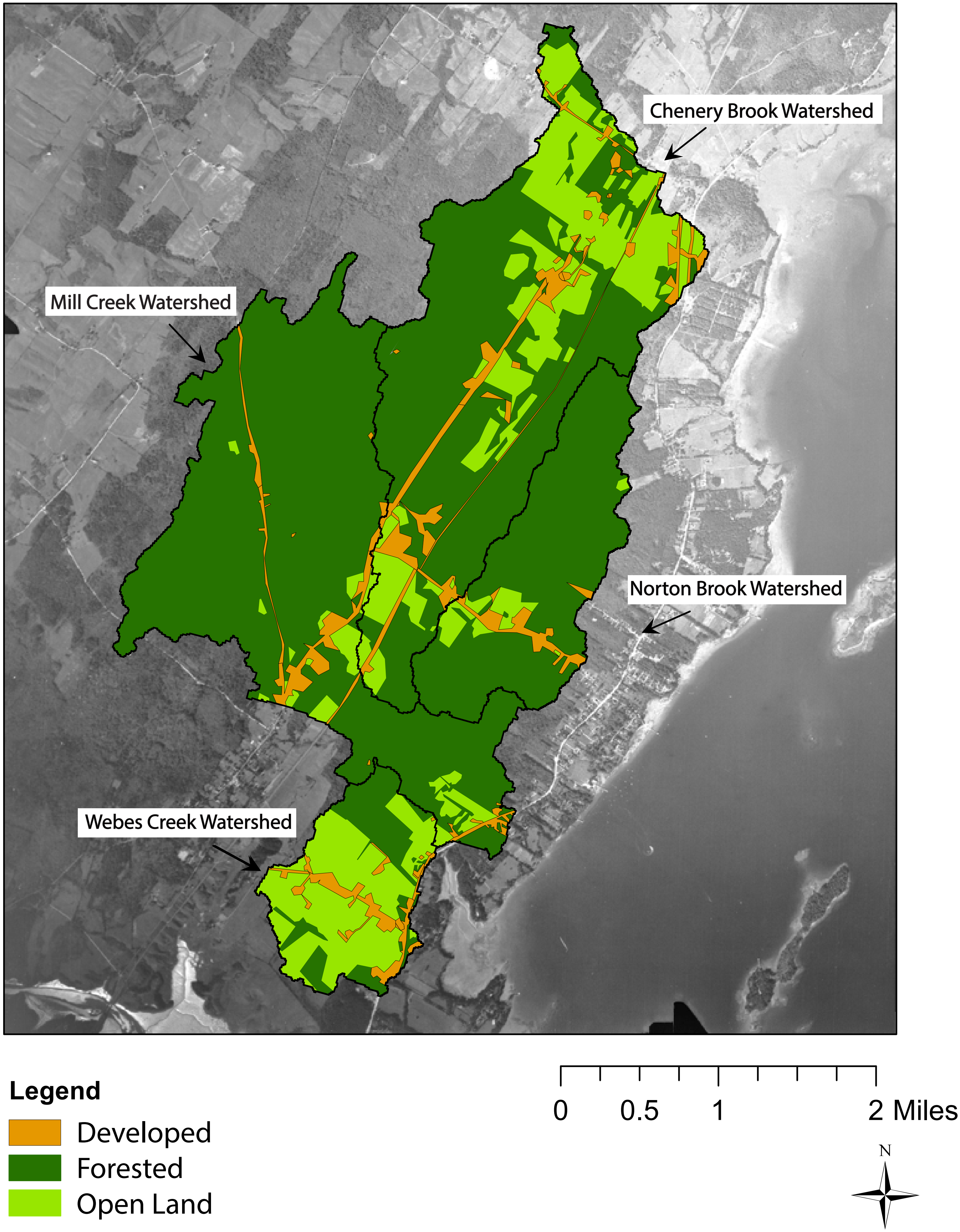
Field Geology Services
Fluvial Geomorphology

2022 Land Use for Hobbs Brook

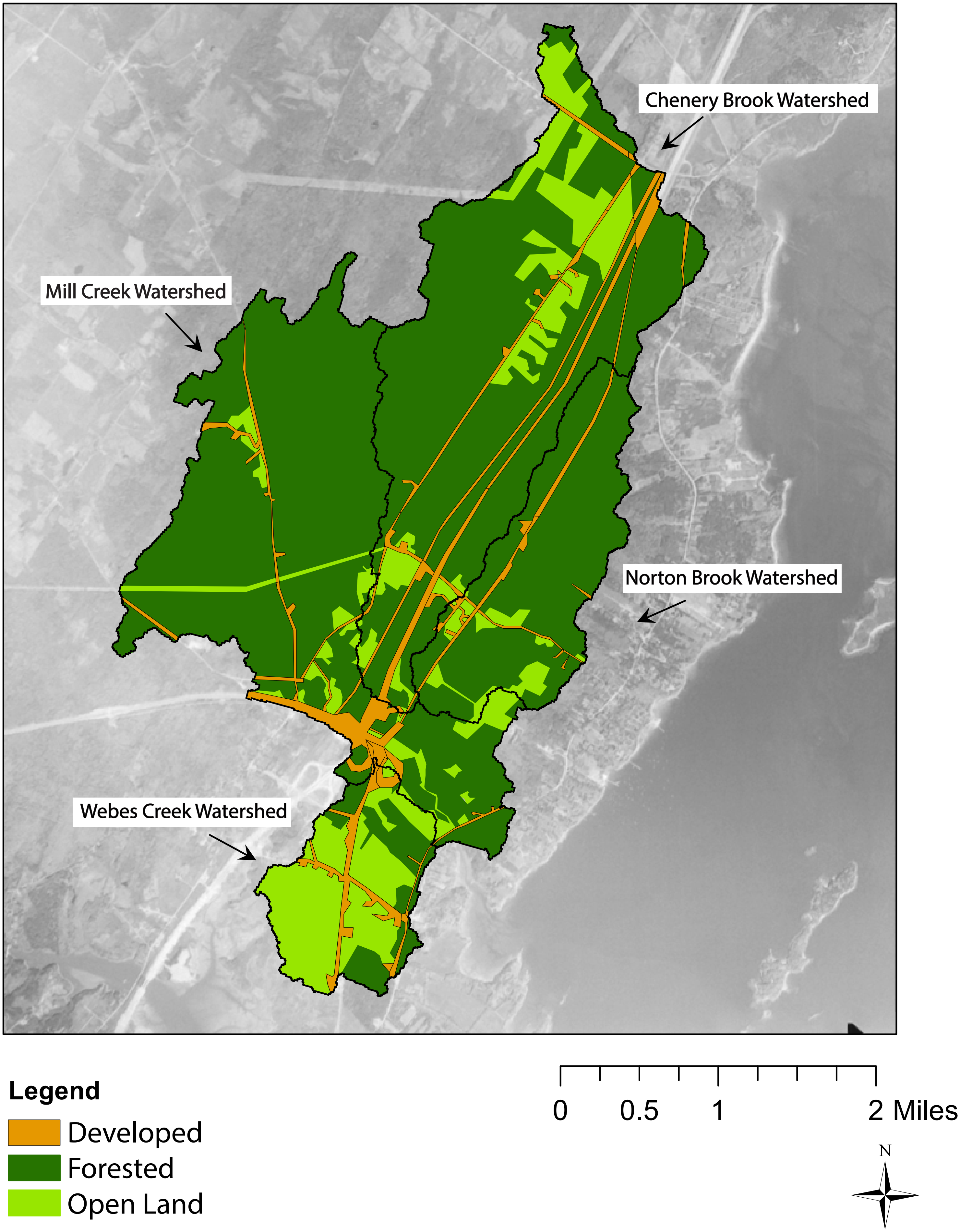


Field Geology Services
Fluvial Geomorphology

1940 Land Use for Mill Creek



1960 Land Use for Mill Creek

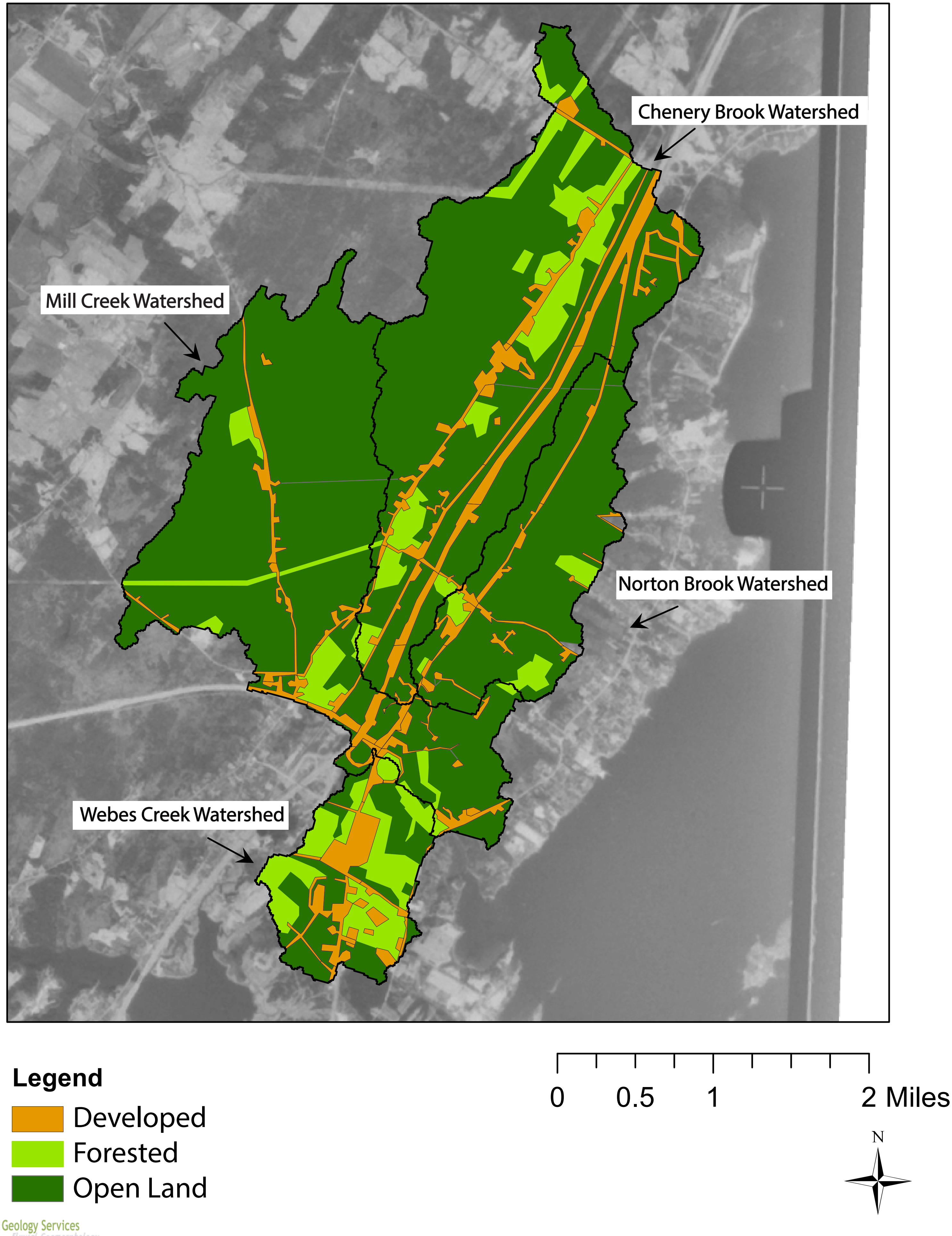


Legend

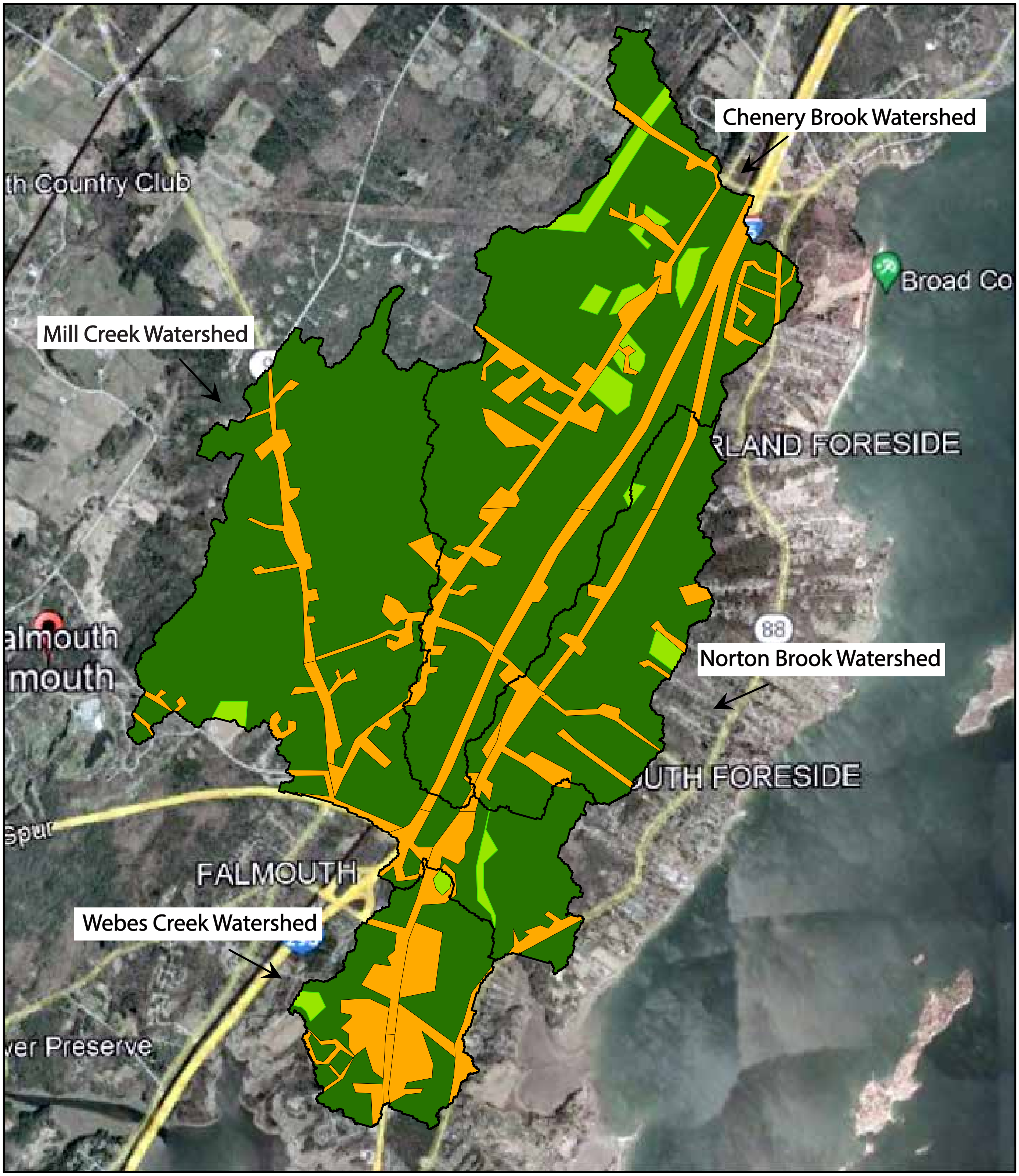
- Developed
- Forested
- Open Land

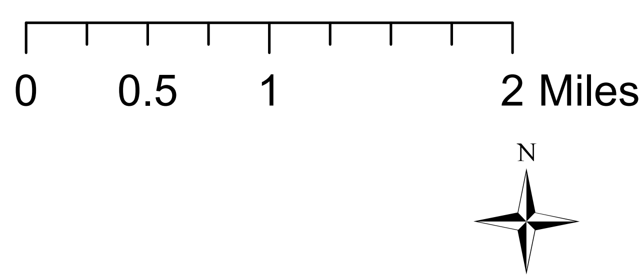
Field Geology Services
Fluvial Geomorphology

1975 Land Use for Mill Creek



2006 Land Use for Mill Creek



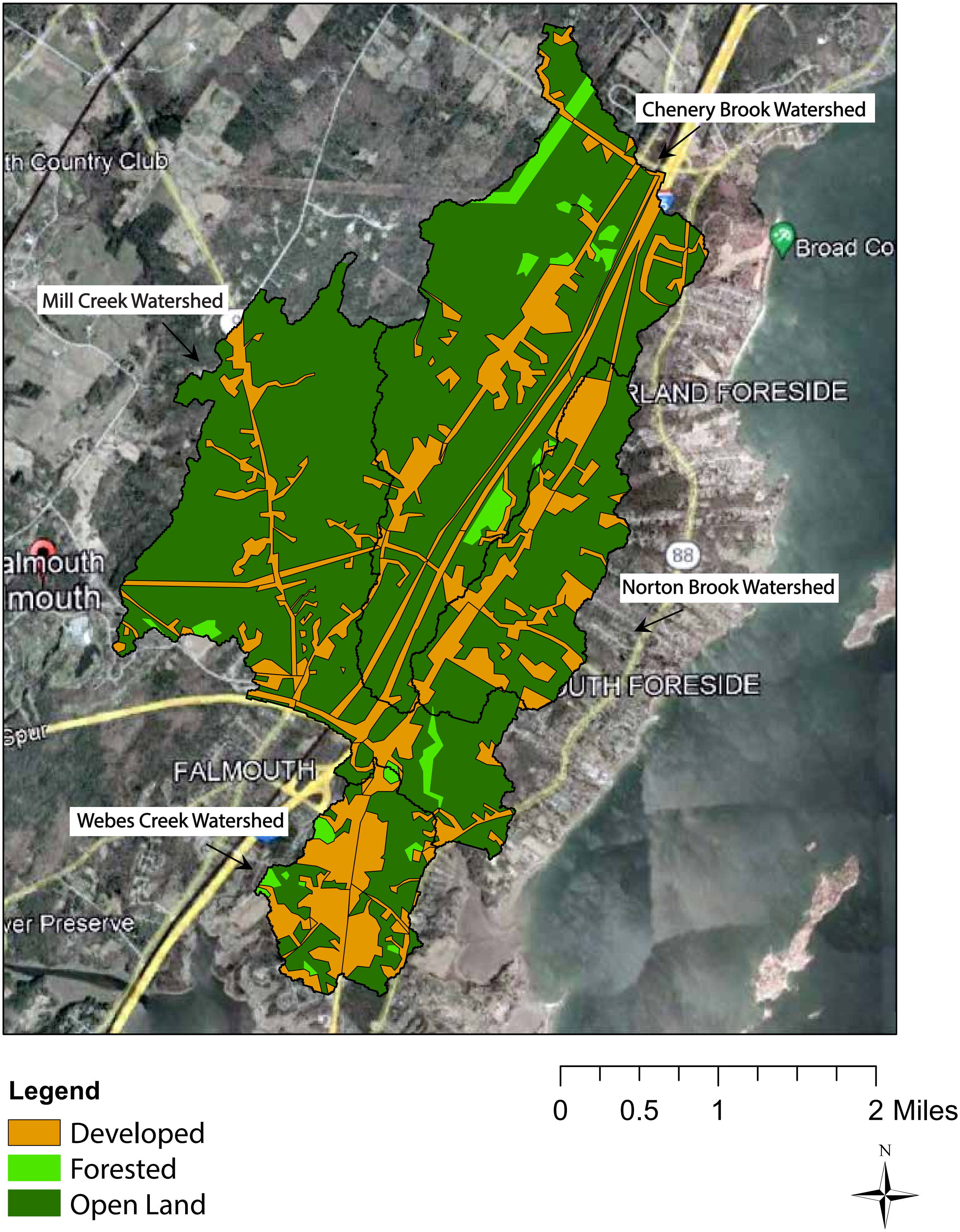


Legend

- Developed
- Forested
- Open Land

Field Geology Services
Fluvial Geomorphology

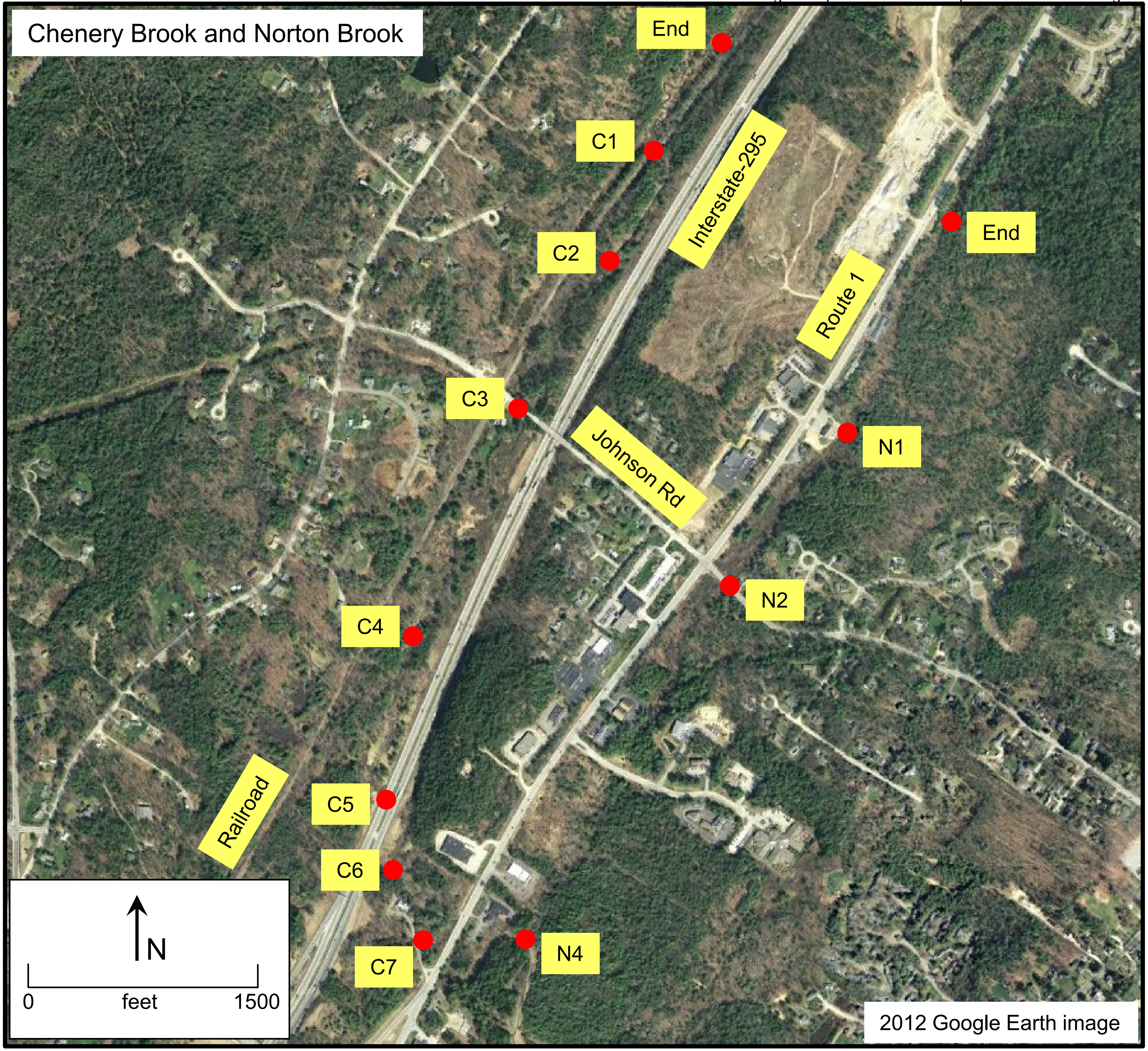
2022 Land Use for Mill Creek



Field Geology Services
Fluvial Geomorphology

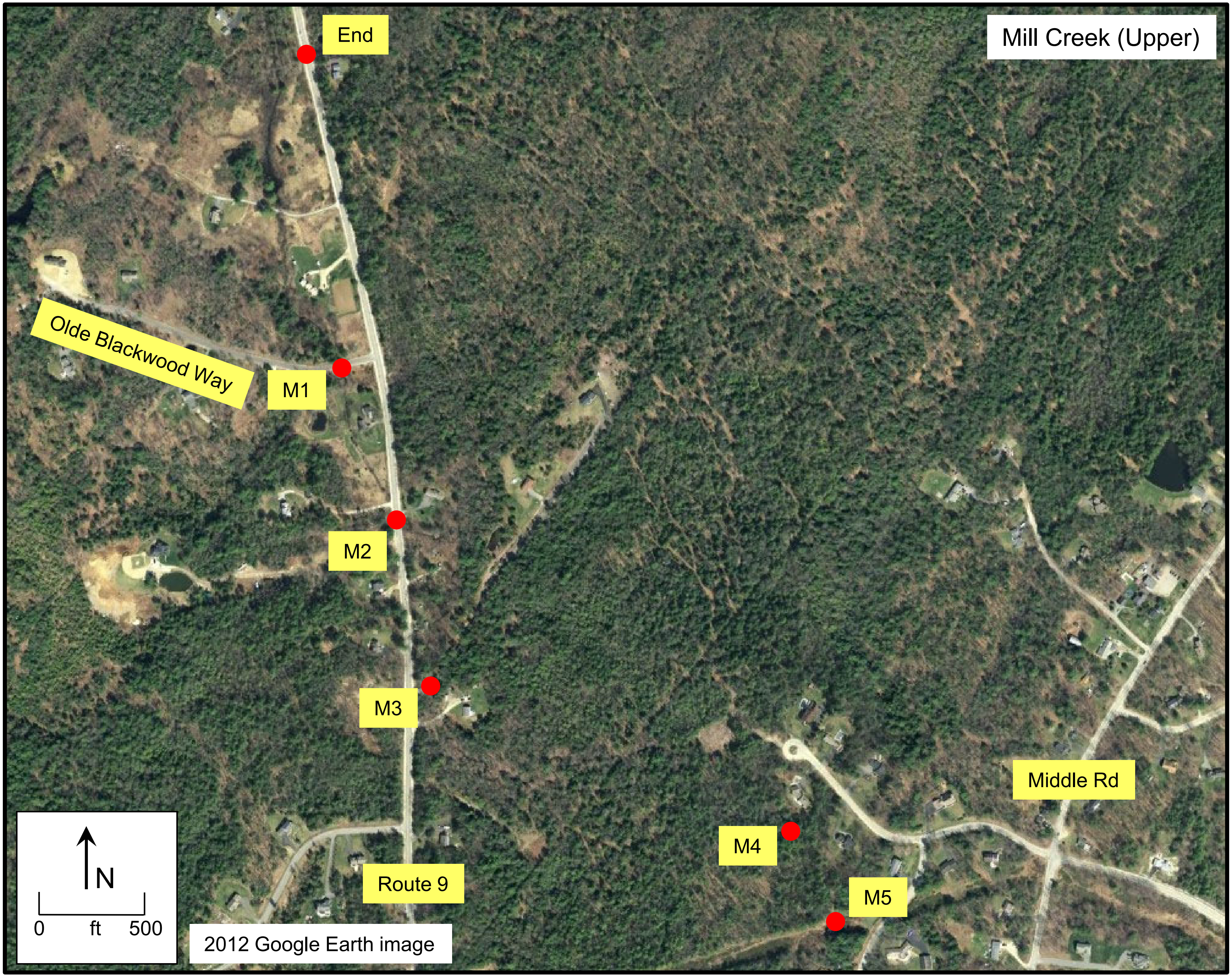
APPENDIX 2

(Reach location maps)



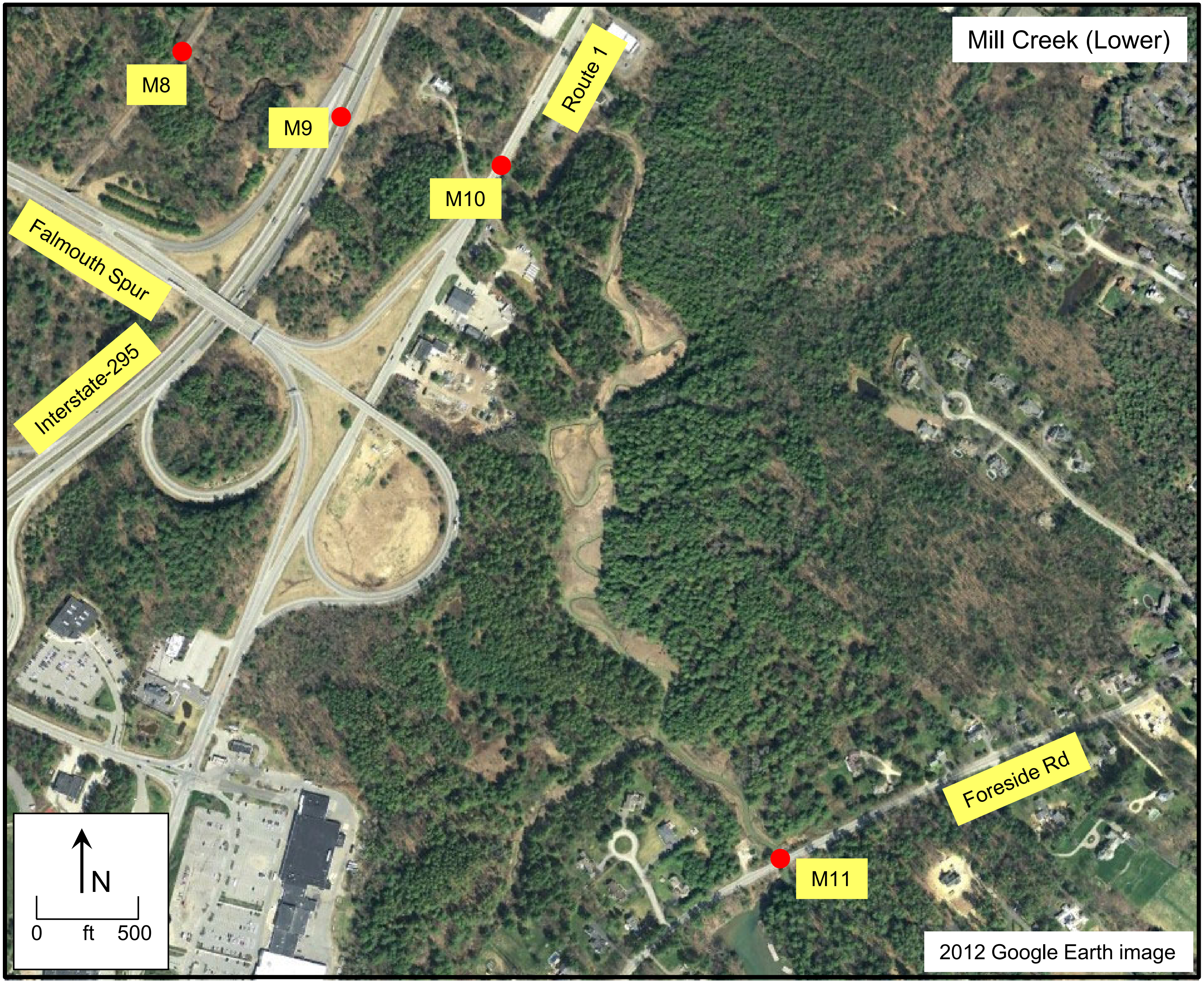
Appendix 2. Reach location map for Chenery Brook and Norton Brook.

Appendix 2. Reach location map for Hobbs Brook.



Appendix 2. Reach location map for Mill Creek (Upper).

Appendix 2. Reach location map for Mill Creek (Middle).



Appendix 2. Reach location map for Mill Creek (Lower).

Field Geology Services
Fluvial Geomorphology

Appendix 2. Reach location map for Webes Creek.

APPENDIX 3

(Rapid Geomorphic Assessment forms)

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 1 ***Recorder:*** NickMiller, JohnField
Location: Cumberland town line to RR Xing ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	5	4	0.44

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.17

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 2 ***Recorder:*** Nick Miller, John Field
Location: Railroad culvert to widened floodplain with sinuous channel ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	4	5	0.56

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.28

Condition: Transitional or stressed

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 3 ***Recorder:*** Nick Miller, John Field
Location: From start of widened floodplain with sinuous channel to Johnson Road ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	4	5	0.56

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.20

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 4 ***Recorder:*** NickMiller, JohnField
Location: Johnson Rd to area of increasing confinement ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded		x	
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone	x		
		Sum of Indices:	4	5	0.56
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =

- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.24

Condition: Transitional or stressed

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 5 ***Recorder:*** NickMiller, JohnField
Location: Area of increasing confinement to I-295 culvert ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.15

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 6 ***Recorder:*** NickMiller, JohnField
Location: I-295 culvert to Sharp bend at high RB ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	***Description***	***No***	***Yes***	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	5	4	0.56

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.20

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 7 ***Recorder:*** NickMiller, JohnField
Location: Sharp bend at high RB to Mill Brook confluence ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	2	7	0.78

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.33

Condition: Transitional or stressed

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 11/7/2022 ***Sample ID:*** Hobbs Brook Reach 1 ***Recorder:*** Nick Miller, John Field

Location: US of Gray Rd to Upstream Town Line ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	***Description***	***No***	***Yes***	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 11/7/2022 ***Sample ID:*** Hobbs Brook Reach 2 ***Recorder:*** Nick Miller, John Field
Location: Gray Rd to High confining LB ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	6	9	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.08

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 11/7/2022 ***Sample ID:*** Hobbs Brook Reach 3 ***Recorder:*** NickMiller, JohnField
Location: High confining LB to Piscataqua River confluence ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	6	3	0.33

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.15

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 1 ***Recorder:*** NickMiller, JohnField
Location: Route 9 to Olde Blackwood Way ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	Places
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.125

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel		x	some
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.094

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 2 ***Recorder:*** NickMiller, JohnField
Location: Olde Blackwood Way to Route 9 ***Crew:***

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.028

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 **Sample ID:** Mill Creek Reach 3 **Recorder:** NickMiller, JohnField
Location: Route 9 to Long Creek Way **Crew:**

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	Description	No	Yes	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.125

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.159

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 4 ***Recorder:*** Nick Miller, John Field
Location: Long Creek Way to the bedrock falls ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.0275

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 **Sample ID:** Mill Creek Reach 5 **Recorder:** Nick Miller, John Field
Location: From the bedrock falls to the transmission line **Crew:**

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	Description	No	Yes	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.10

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 6 ***Recorder:*** Nick Miller, John Field
Location: From the transmission line to Middle Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	6	3	0.33

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases		x	
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	5	2	0.29

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.29

Condition: Transitional or stressed

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 **Sample ID:** Mill Creek Reach 7 **Recorder:** NickMiller, JohnField
Location: Middle Rd to downstream end of bedrock gorge **Crew:**

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	3	0.22

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)		x	
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.19

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 8 ***Recorder:*** NickMiller, JohnField

Location: From downstream end of bedrock gorge to the railroad crossing ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)		x	
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	4	3	0.43

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =

SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.11

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 9 ***Recorder:*** Nick Miller, John Field

Location: RR crossing to I-295 ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)		x	
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.13

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 10 ***Recorder:*** Nick Miller, John Field
Location: I-295 to Rt 1 ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.125

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.03

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 11 ***Recorder:*** NickMiller, JohnField
Location: Rt 1 to Foreside Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone	x		
		Sum of Indices:	5	4	0.44

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	6	1	0.14

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle		x	
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach		x	
	8	Fracture lines along top of bank	x		
		Sum of Indices:	4	4	0.50

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0.27

Condition: Transitional or stressed

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Norton Brook Reach 1 ***Recorder:*** NickMiller, JohnField
Location: Cumberland town line to behind Street Cycles store ***Crew:***

Form/ Process	Num	Geomorphic Indicator – Description	Present – No	Present – Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone		x	
		Sum of Indices:	6	3	0.33

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed		x	
	3	Bank height increases		x	
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	4	3	0.43

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	4	4	0.50

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form		x	
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form		x	
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	3	4	0.57

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.46

Condition: In adjustment

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/27/2022 ***Sample ID:*** Norton Brook Reach 2 ***Recorder:*** NickMiller, JohnField
Location: From behind Street Cycles store to Johnson Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	7	2	0.22

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.13

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	4	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.12

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/27/2022 ***Sample ID:*** Norton Brook Reach 3 ***Recorder:*** Nick Miller, John Field
Location: Johnson Rd to Northbrook Dr ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone		x	
		Sum of Indices:	6	3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	6	1	0.14
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =

SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.25

Condition: Transitional or stressed

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/27/2022 ***Sample ID:*** Norton Brook Reach 4 ***Recorder:*** Nick Miller, John Field
Location: Northbrook Dr to Mill Creek confluence ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	5	4	0.44

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	6	1	0.14

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)		x	
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.31

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 1 ***Recorder:*** Nick Miller, John Field
Location: Culvert at Ace Hardware to Depot Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.06

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 Data Collection Form – RGA

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 **Sample ID:** Webes Creek Reach 2 **Recorder:** NickMiller, JohnField
Location: Depot Rd to the end of the lawn **Crew:**

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	Description	No	Yes	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded		x	
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends		x	
	5	Toe erosion on both sides of channel through riffle		x	
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach		x	
	8	Fracture lines along top of bank		x	
		Sum of Indices:	3	5	0.63
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.21

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 3 ***Recorder:*** Nick Miller, John Field
Location: From end of the lawn to next lawn on RB DS ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score *
	Num	*Description*	*No*	*Yes*	
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials		x	
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	2	7	0.78

Form/ Process	Num	Description	No	Yes	Score
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Form/ Process	Num	Description	No	Yes	Score
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.20

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 4 ***Recorder:*** NickMiller, JohnField
Location: 1st lawn DS to Open meadowy backwater area ***Crew:***

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
- **SI ≤ 0.20 = *in regime***
- **SI 0.21 – 0.40 = *transitional or stressed***
- **SI ≥ 0.41 = *in adjustment***

Stability Index: 0

Condition: In regime

Field Geology Services *Fluvial Geomorphology*

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 5 ***Recorder:*** Nick Miller, John Field
Location: Open meadowy backwater area to Mill Creek confluence ***Crew:***

1st

Form/ Process	Num	Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0

Condition: In regime

Field Geology Services Fluvial Geomorphology

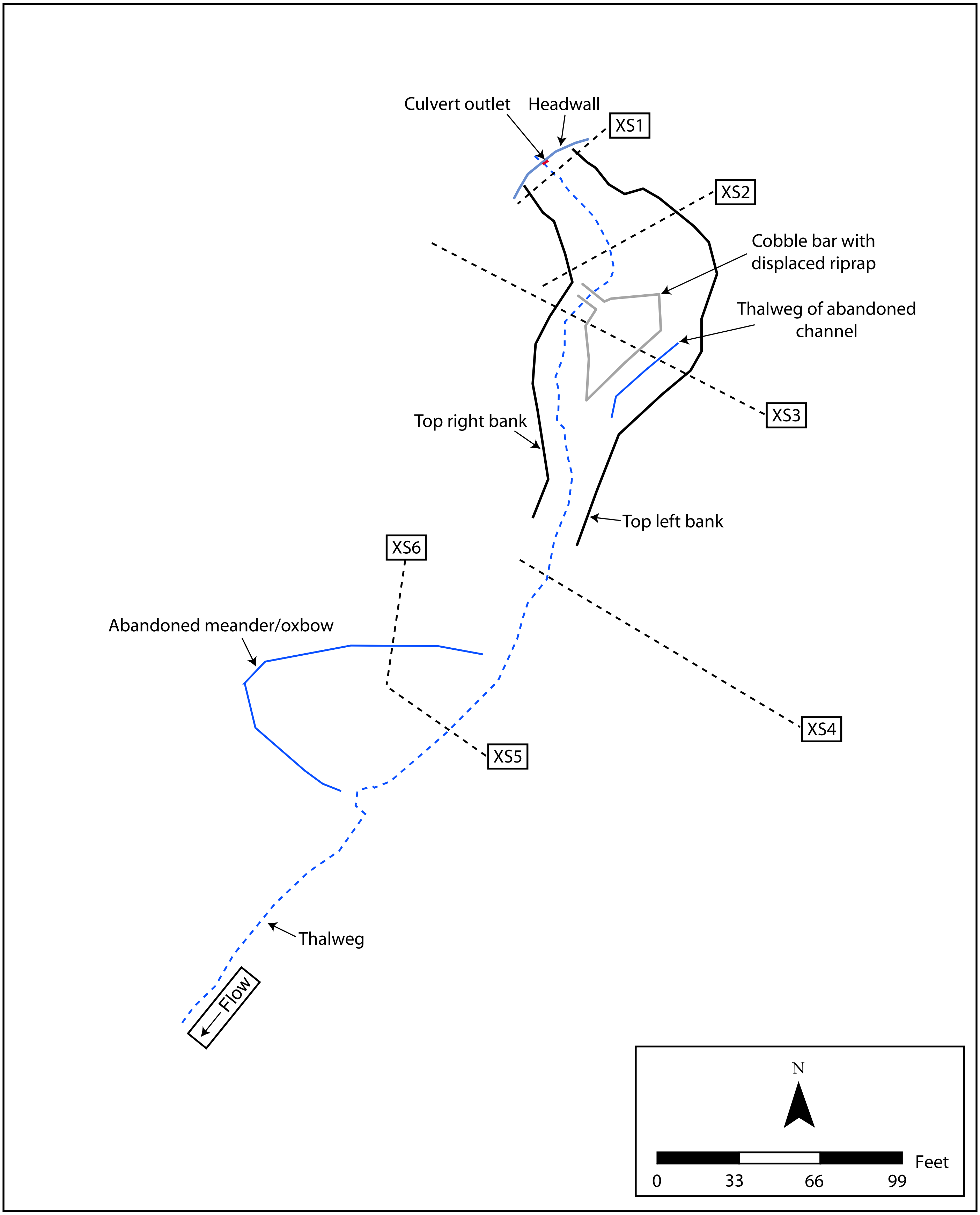
Appendix 2. Rapid geomorphic assessment data sheet.

APPENDIX 4

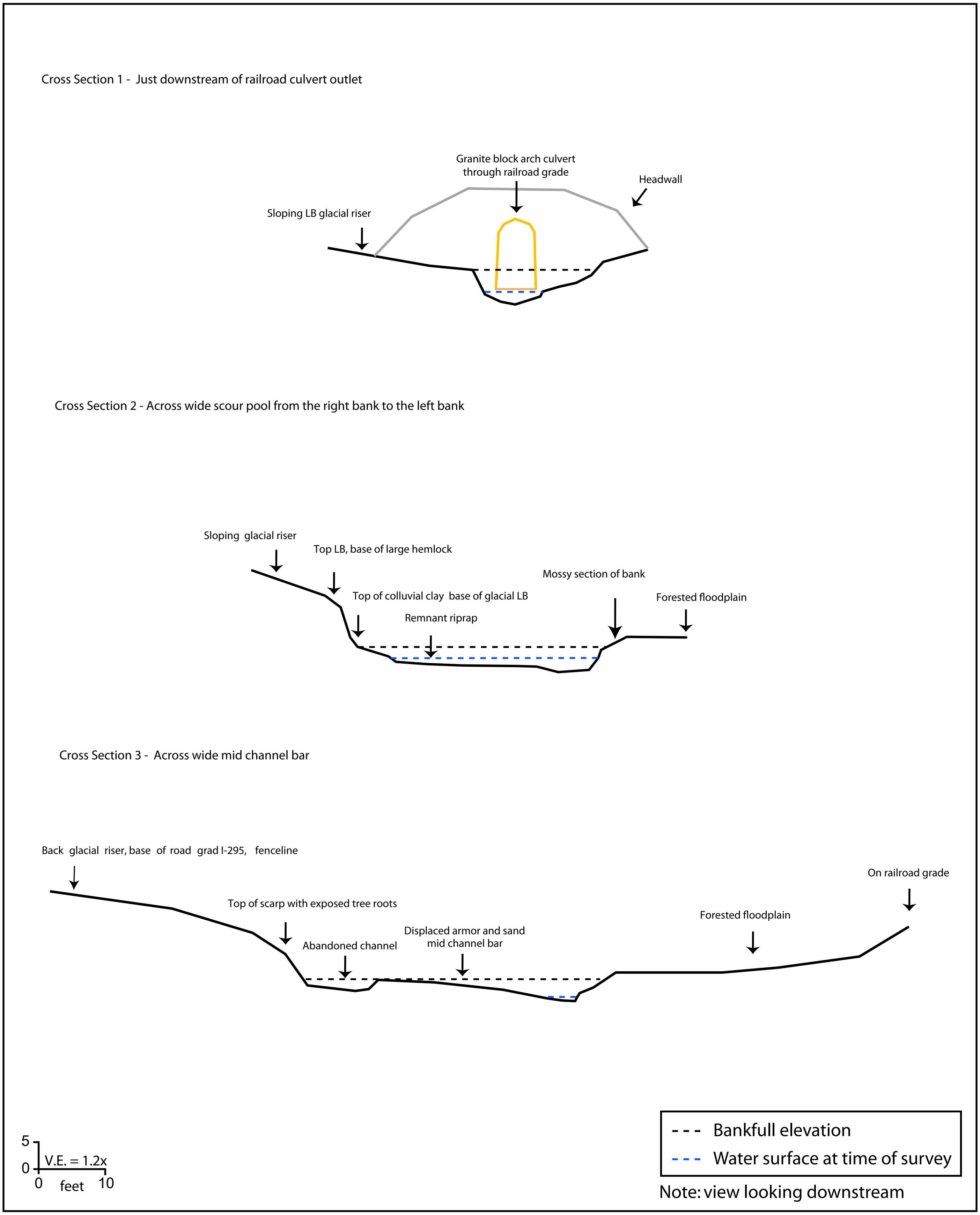
(Survey data and conceptual design packets)

Chenery Brook – Reach C2a

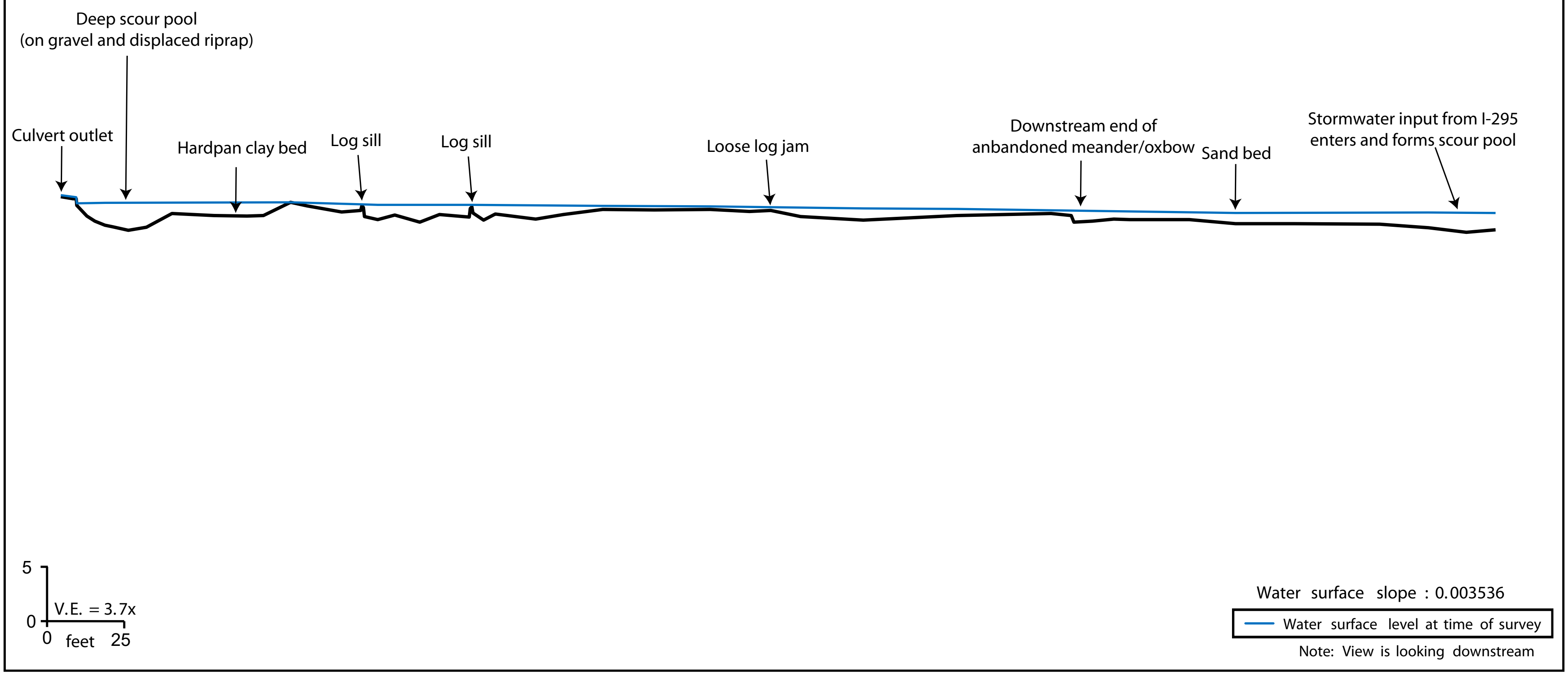
Survey Data and Conceptual Restoration Design



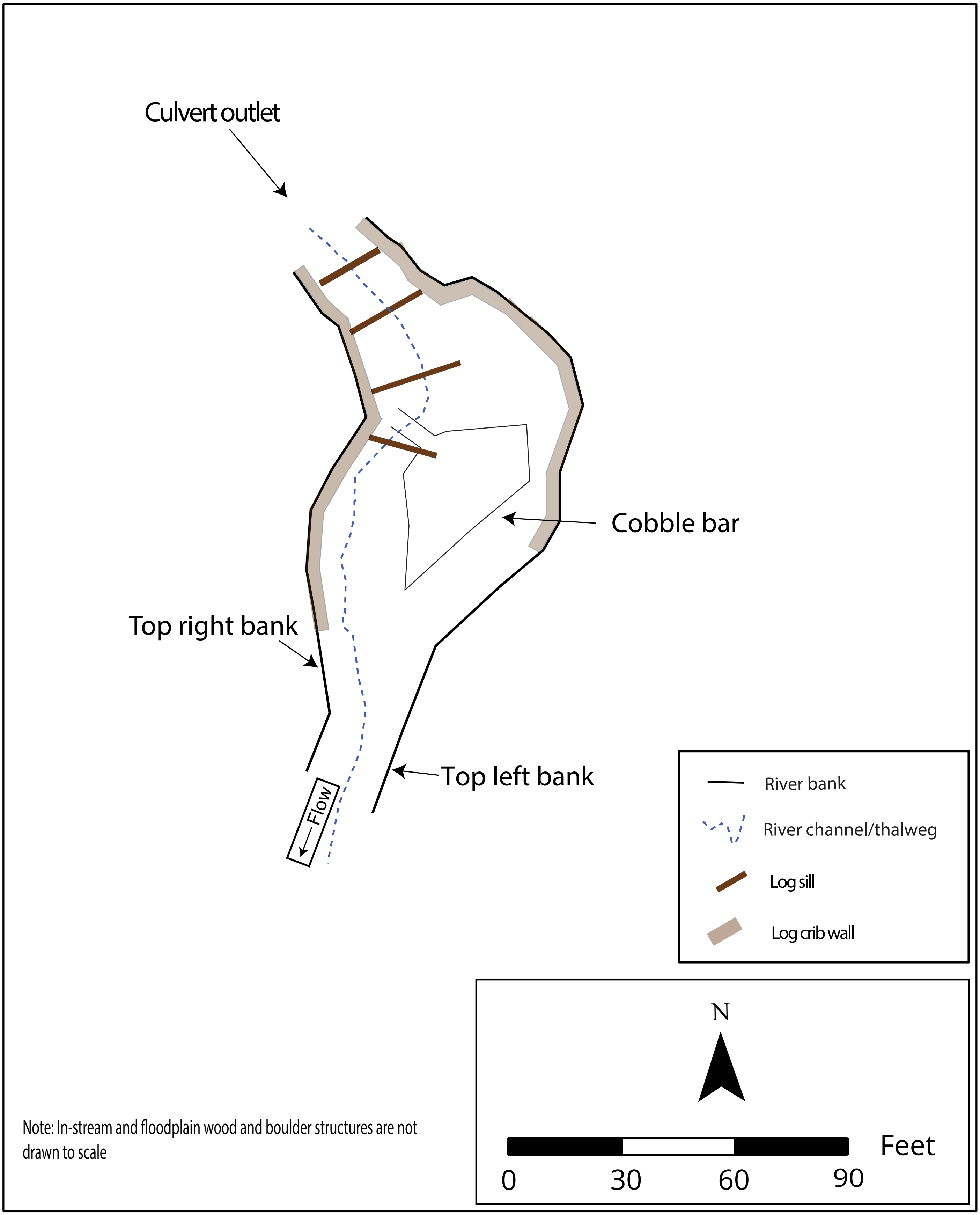
Chenery Brook - Surveyed plan view. Reaches C2a and C2b.



Chenery Brook - Surveyed cross sections. Reach C2a.

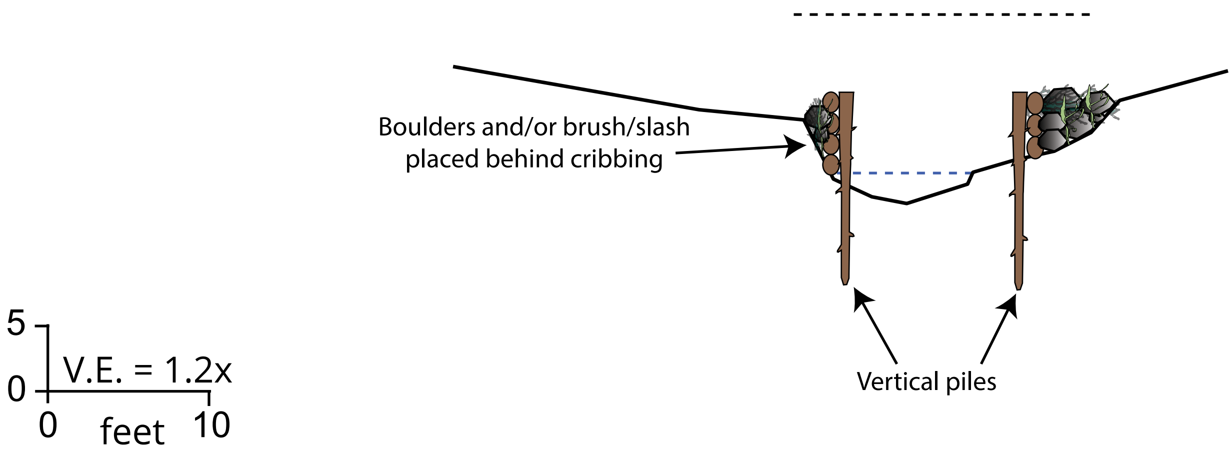


Chenery Brook - Longitudinal profile. Reaches C2a and C2b.

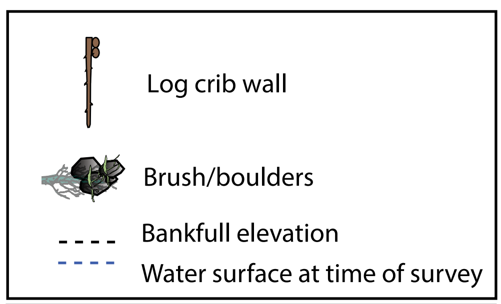


Chenery Brook - Proposed planview. Reach C2a.

Cross Section 1
Log Crib Wall



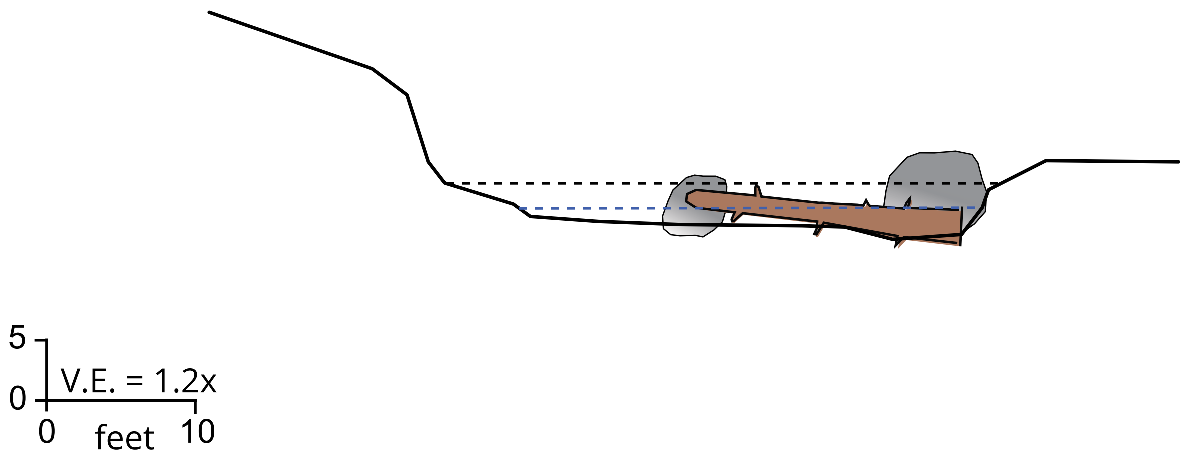

Example of crib wall on Sunday River, ME



Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chenery Brook - Proposed Condition for Cross Section 1. Reach C2a.

Cross Section 2
Log Sill



Natural log sill on Clesson Brook, MA

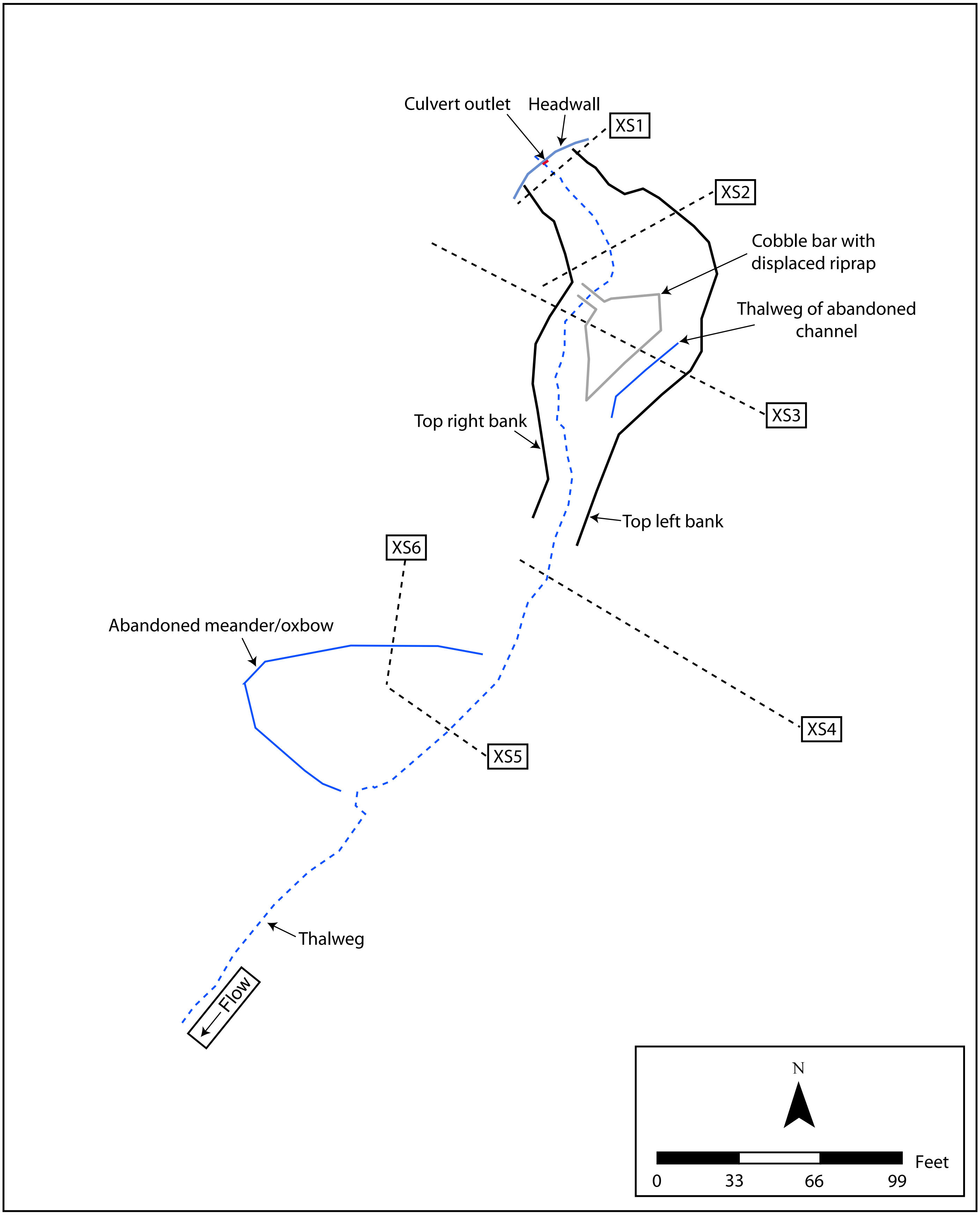
Boulder
Log
Bankfull elevation
Water surface at time of survey

Note: view looking downstream
Note: Structural elements are schematic and not to scale

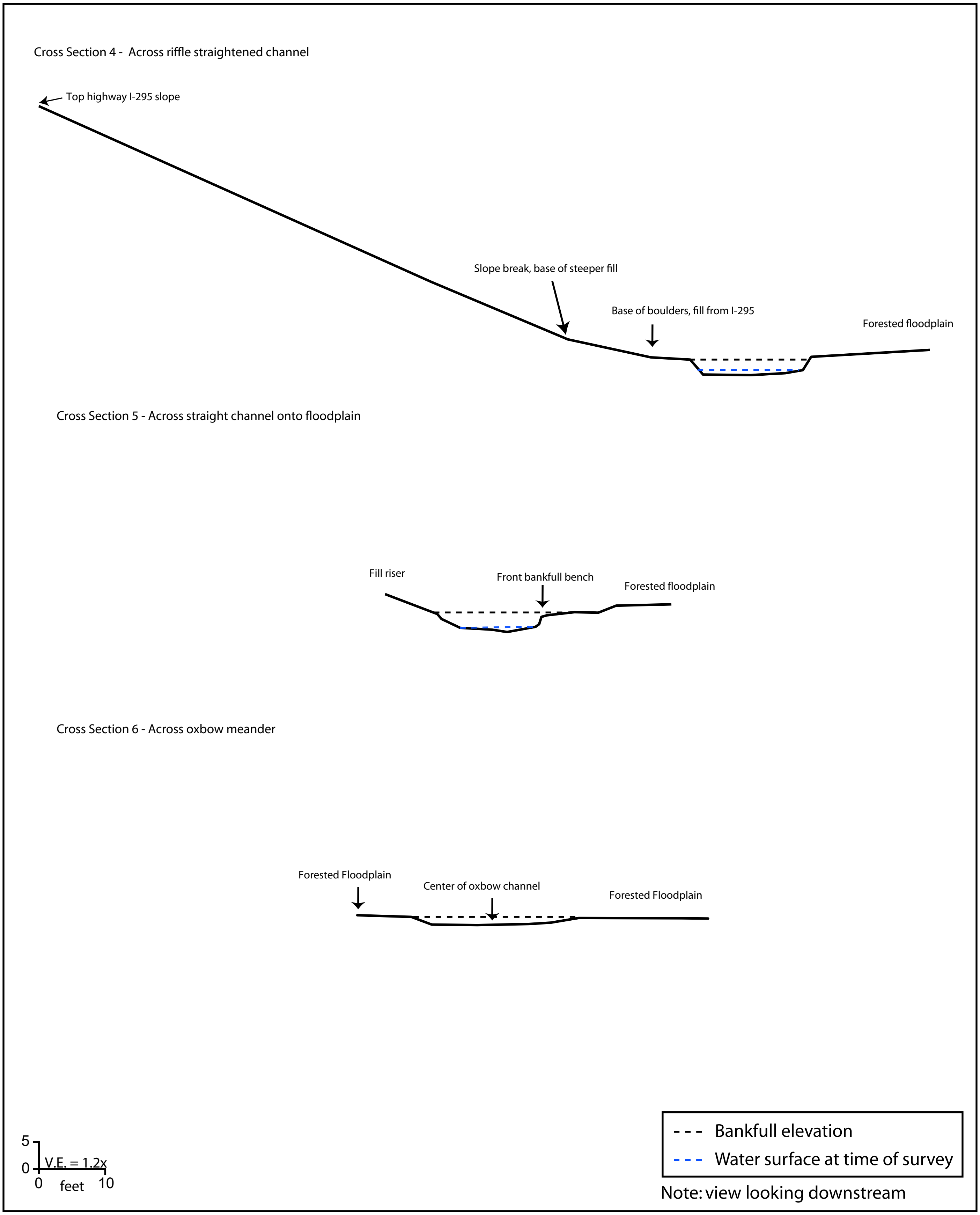
Chenery Brook - Proposed Conditions for Cross Section 2. Reach C2a.

Chenery Brook – Reach C2b

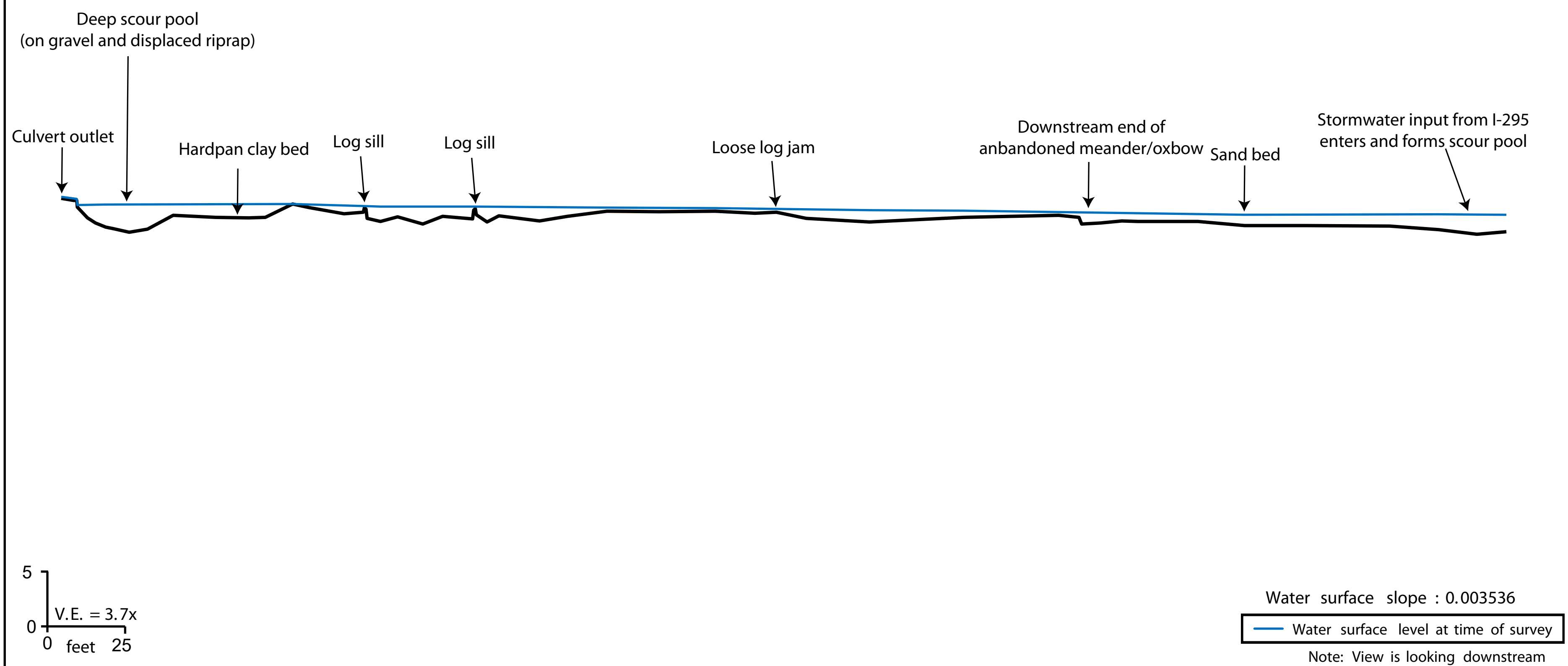
Survey Data and Conceptual Restoration Design



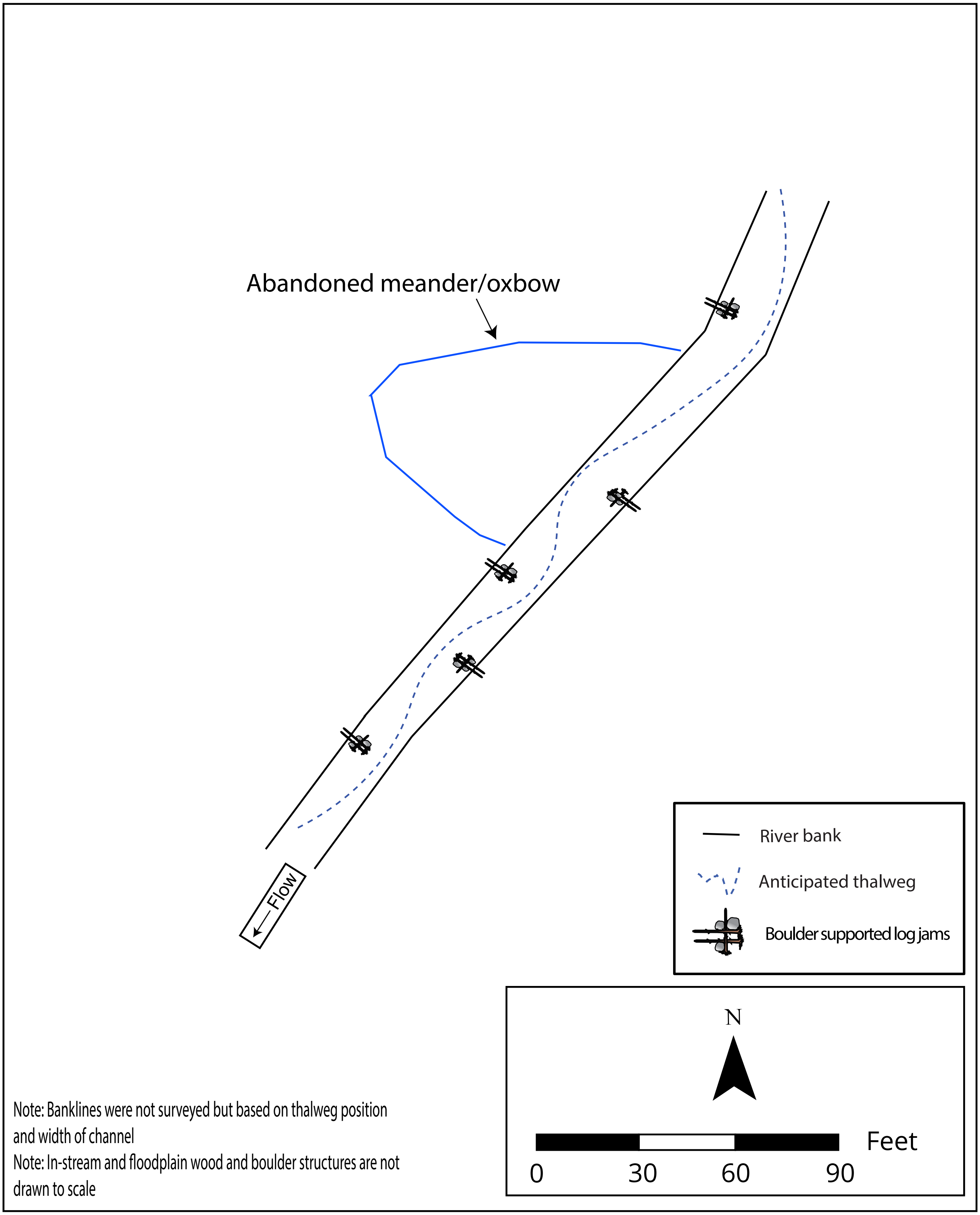
Chenery Brook - Surveyed plan view. Reaches C2a and C2b.



Chenery Brook - Surveyed cross sections. Reach C2b.

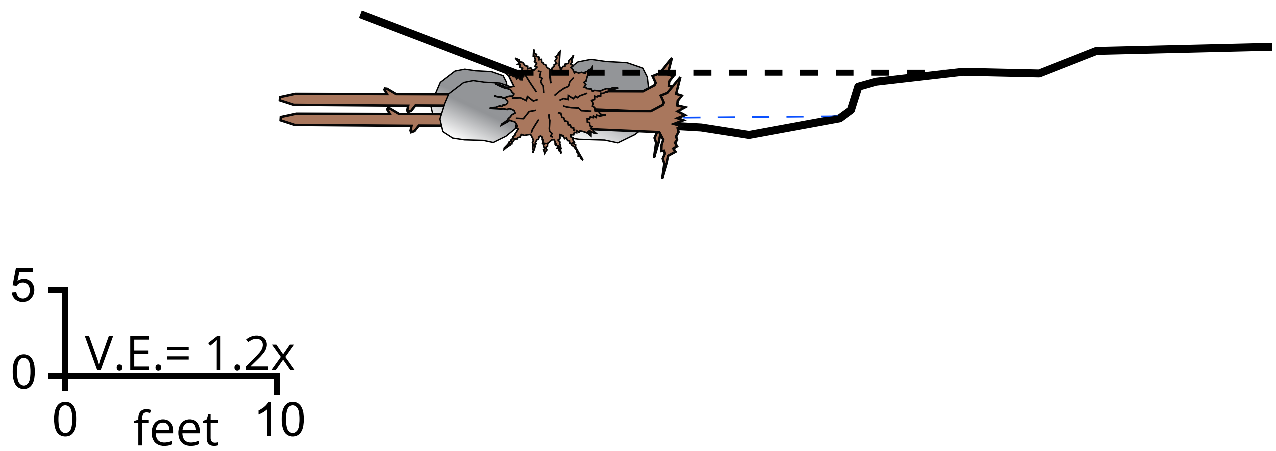


Chenery Brook - Longitudinal profile. Reaches C2a and C2b.

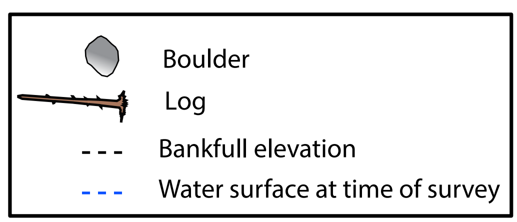


Chenery Brook - Proposed planview. Reach C2b.

Cross Section 5
Boulder Supported Log Jam




Boulder supported log Jam in Houlton, ME

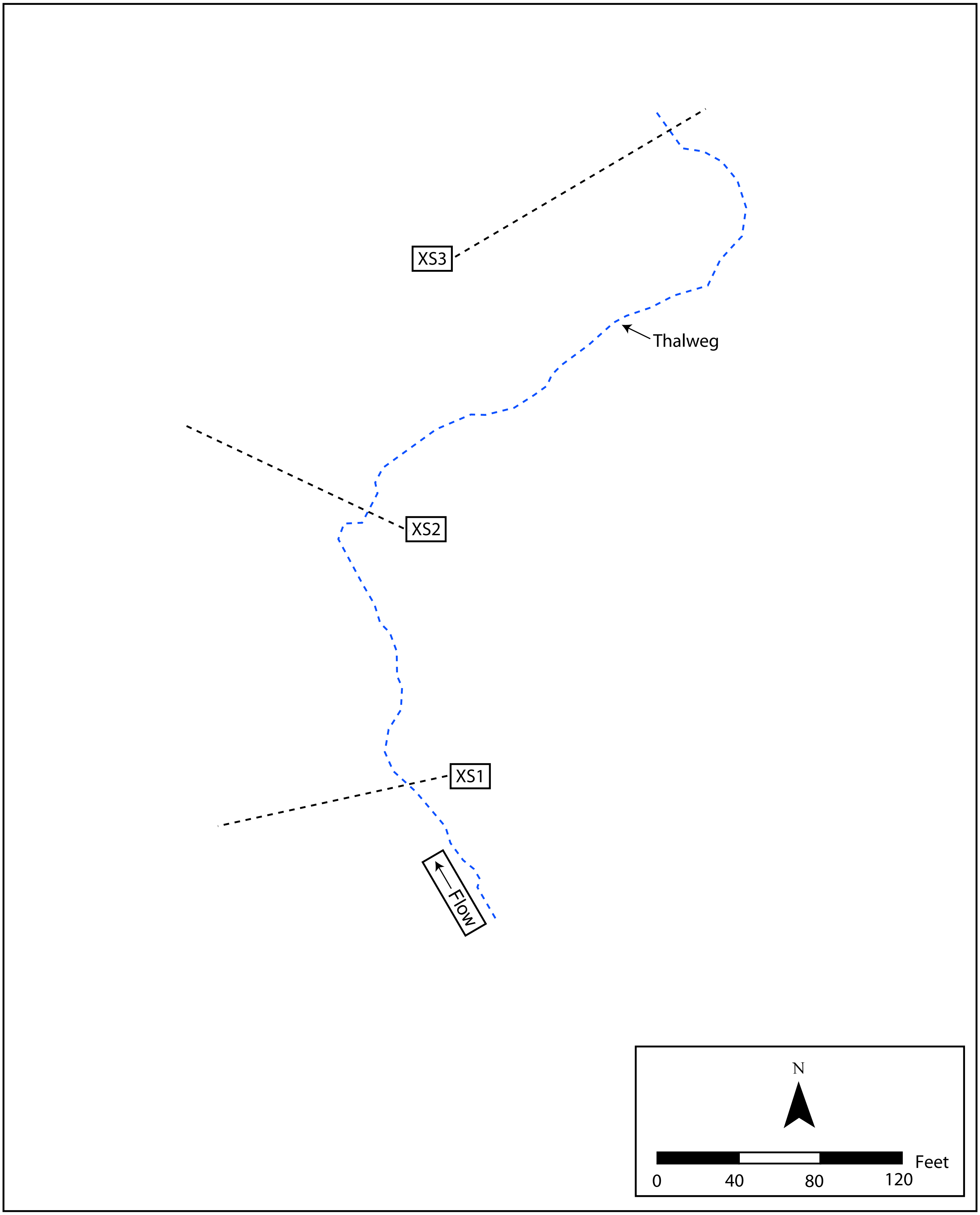


Note: view looking downstream
Note: Structural elements are schematic and not to scale

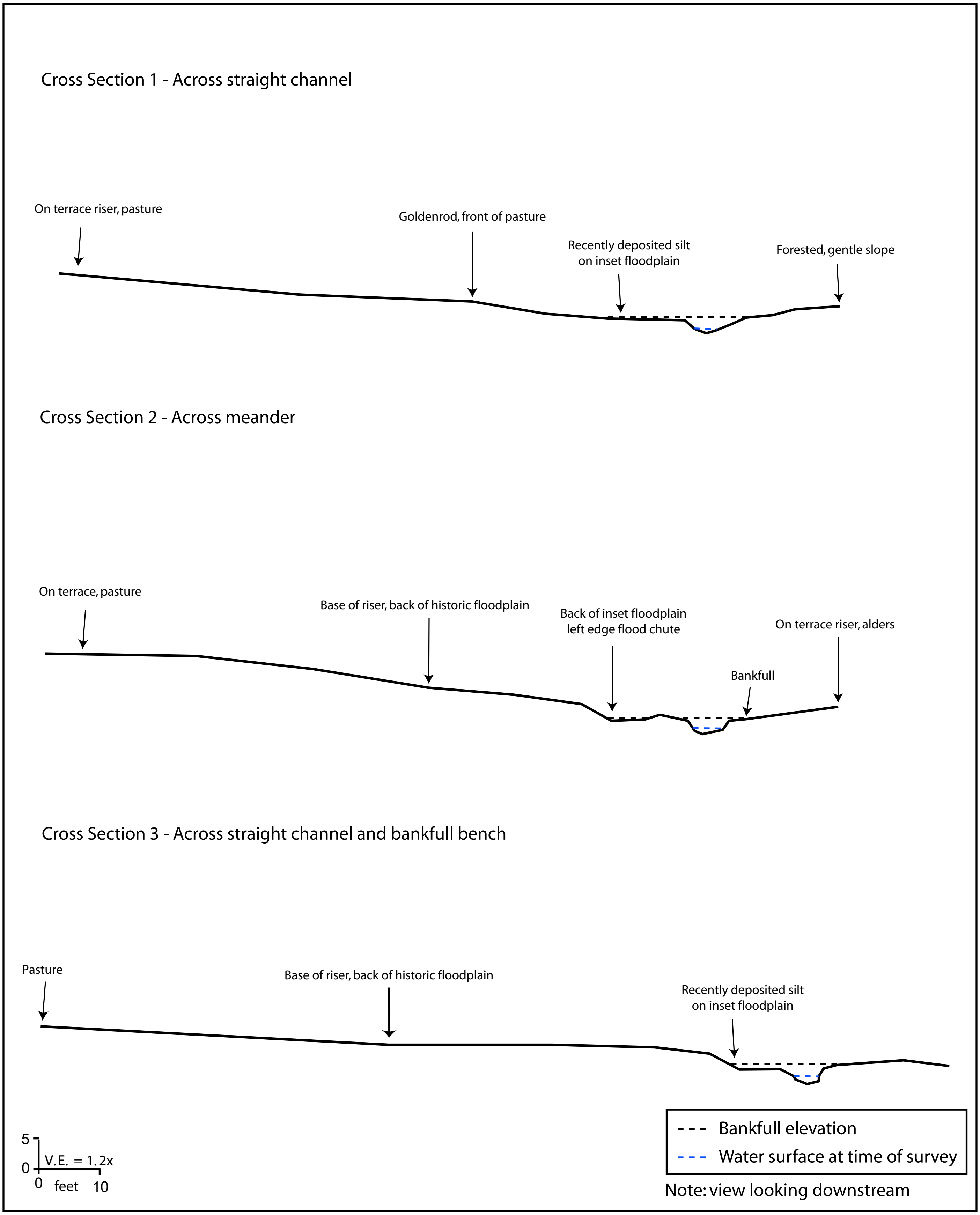
Chenery Brook - Proposed conditions for Cross Section 5. Reach C2b.

Hobbs Brook – Reach H2

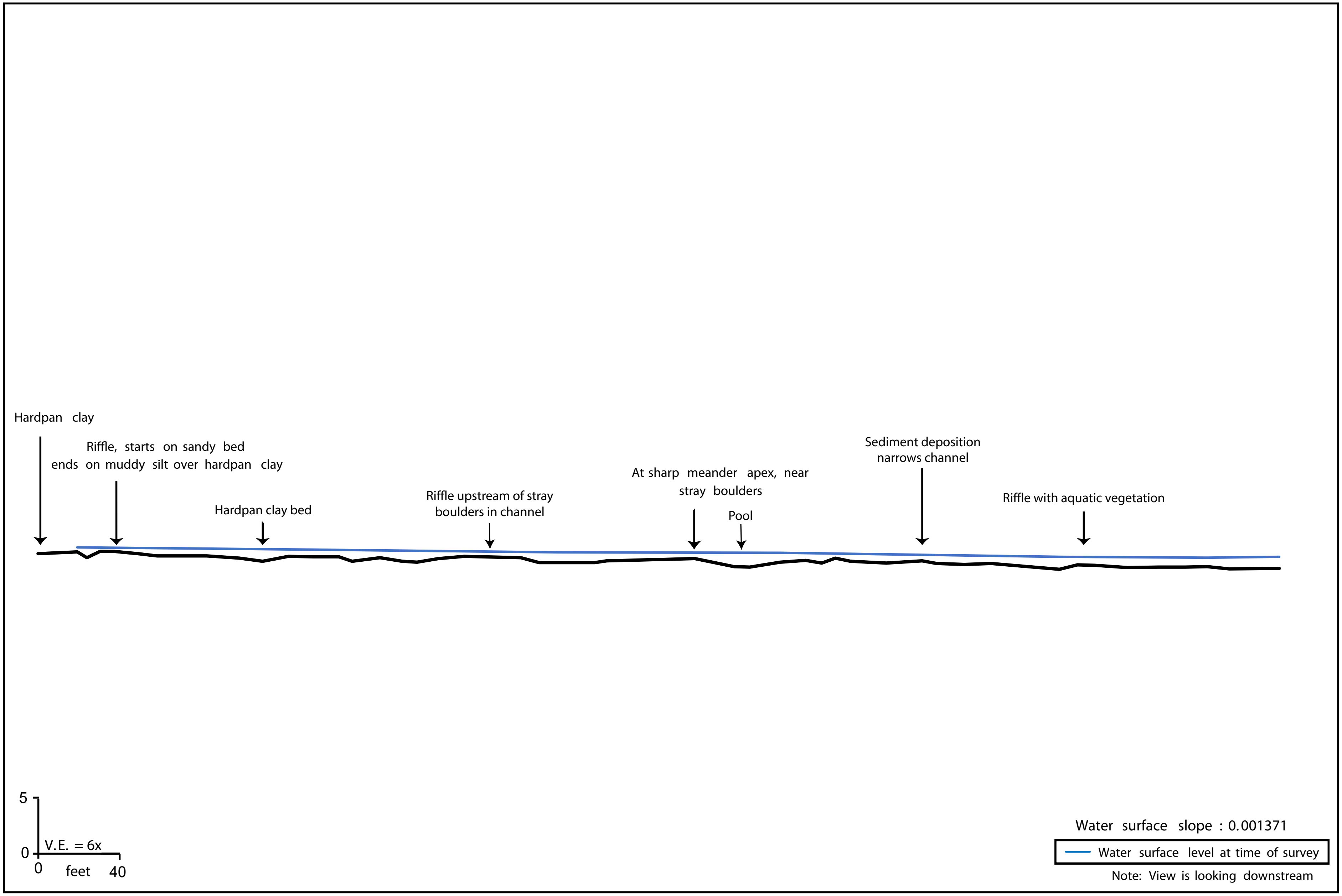
Survey Data and Conceptual Restoration Design



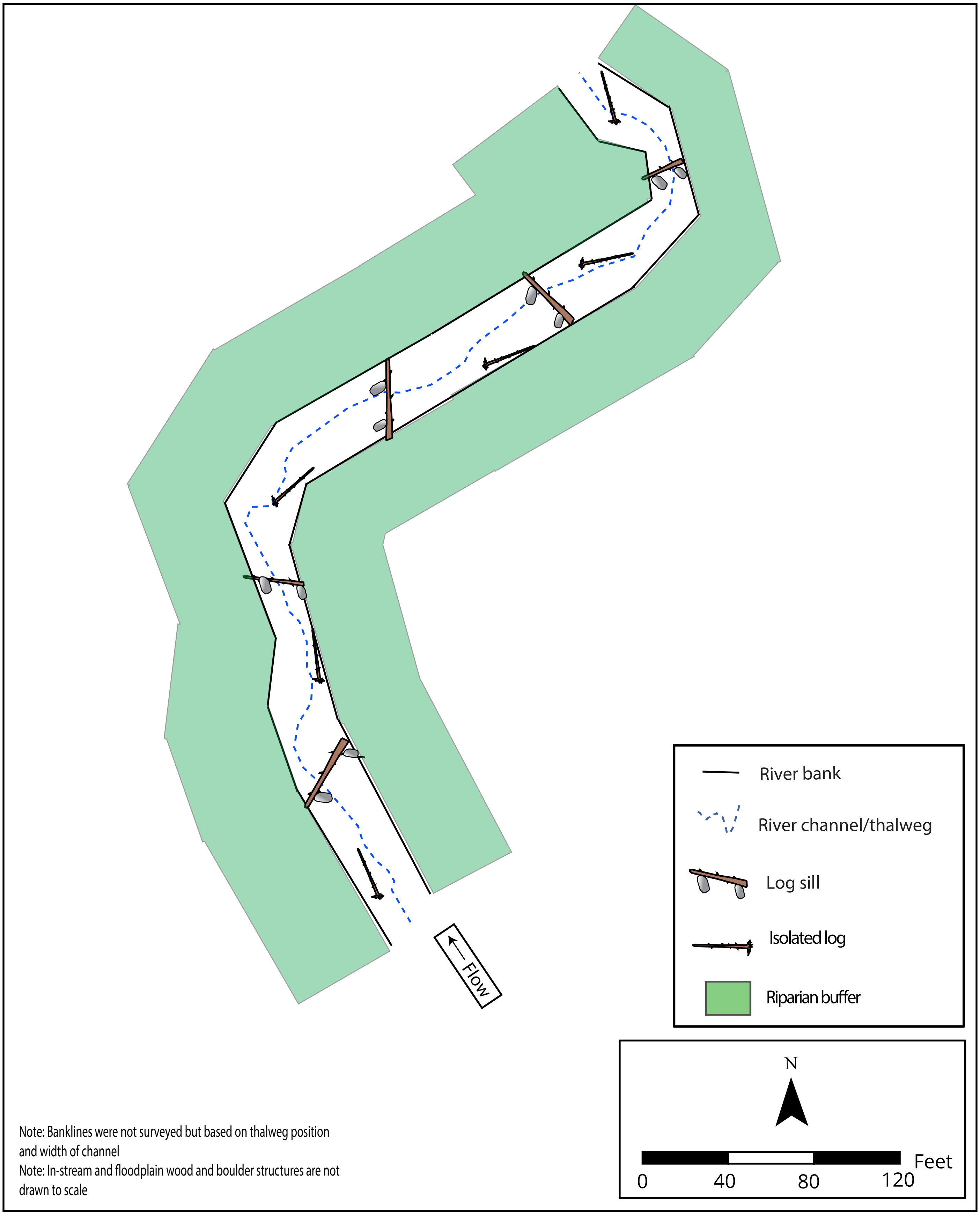
Hobbs Brook - Surveyed plan view. Reach H2.



Hobbs Brook - Surveyed cross sections. Reach H2.

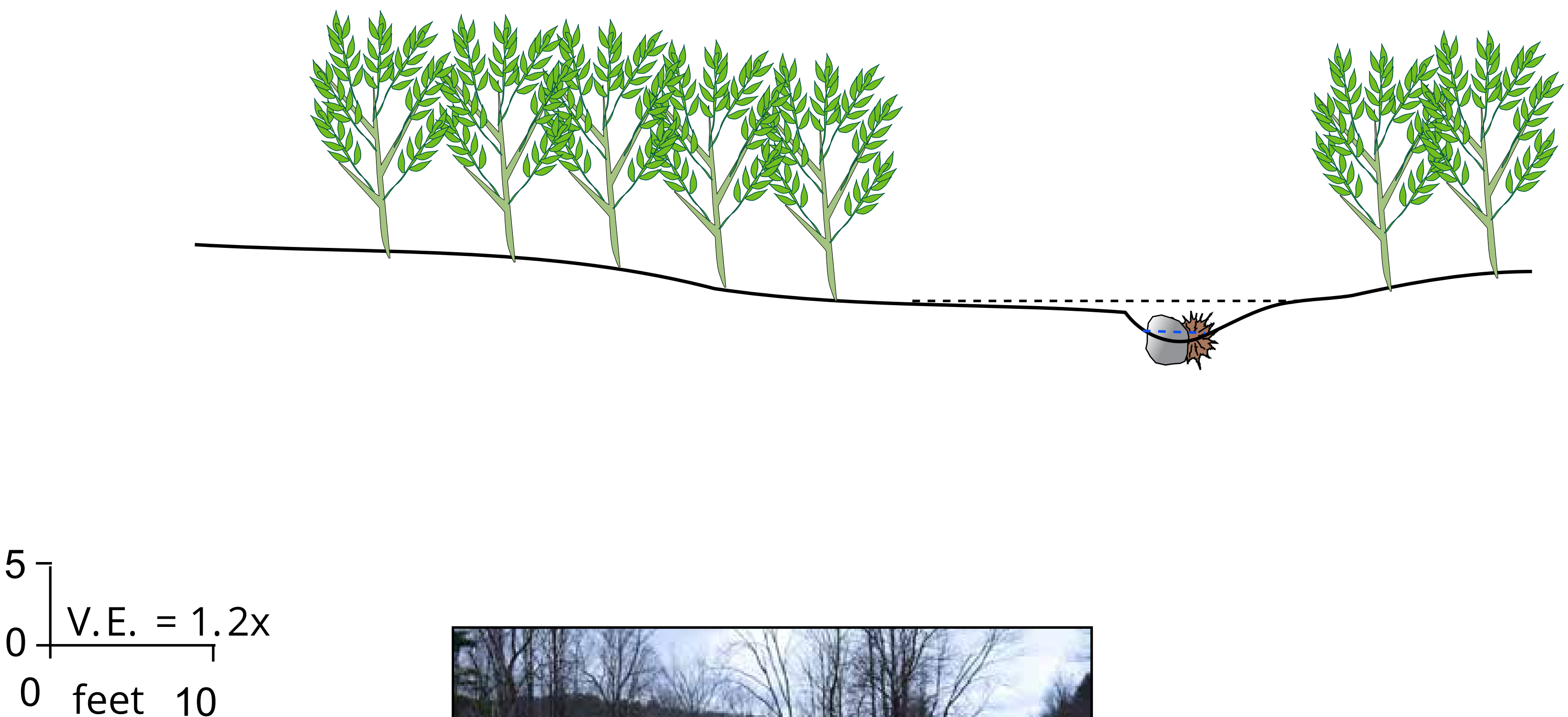


Hobbs Brook - Longitudinal profile. Reach H2.



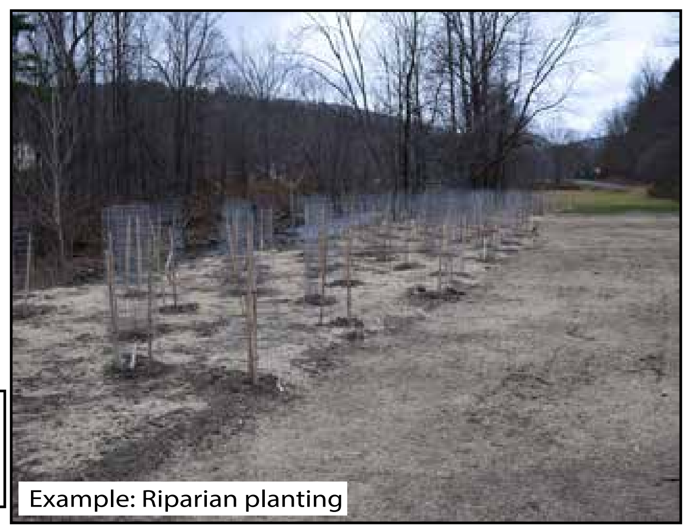
Hobbs Brook - Proposed planview. Reach H2.

Cross Section 1
Isolated Log
Riparian Buffer Planting



- Boulder
- Log
- Willows (riparian buffer)
- Bankfull elevation
- Water surface at time of survey

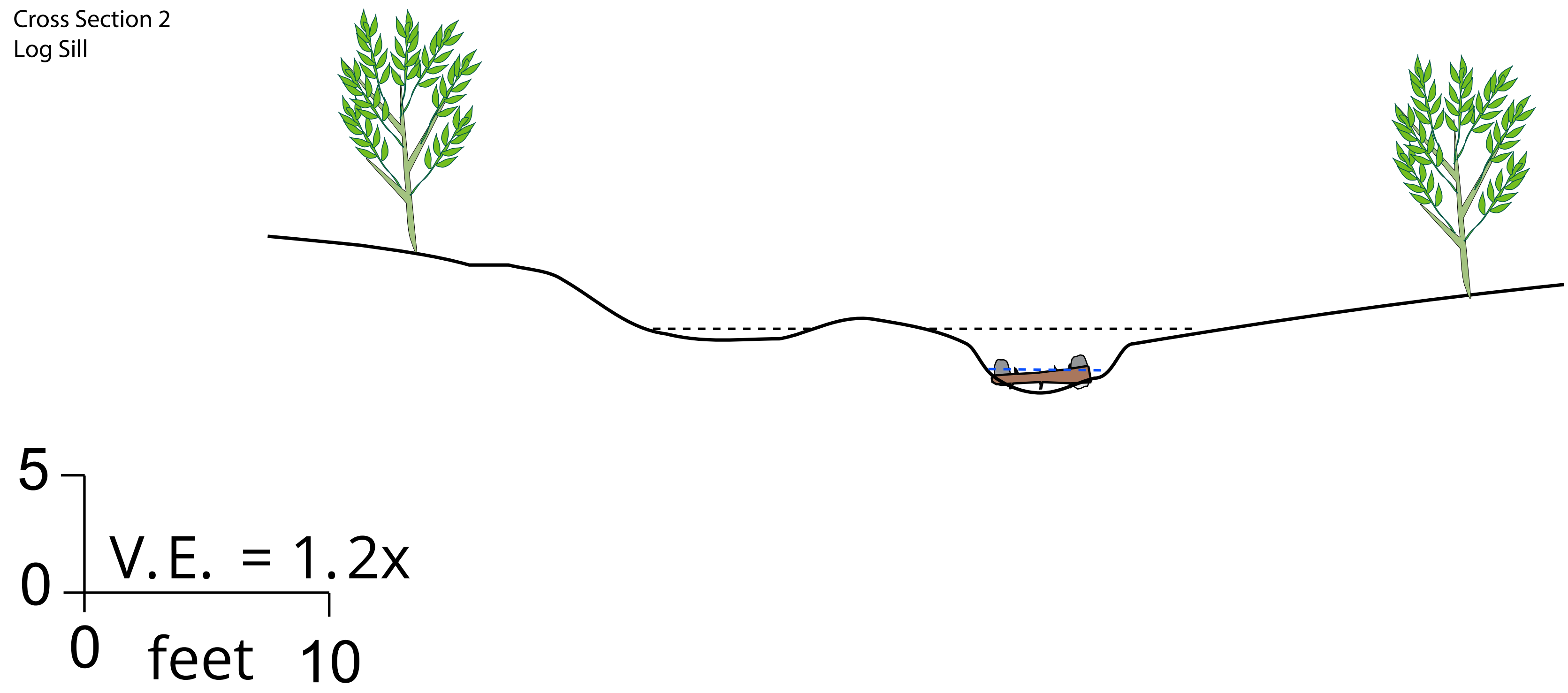
Note: view looking downstream
Note: Structural elements are schematic and not to scale



Example: Riparian planting

Example photo: Isolated log

Hobbs Brook - Proposed conditions for Cross Section 1. Reach H2.

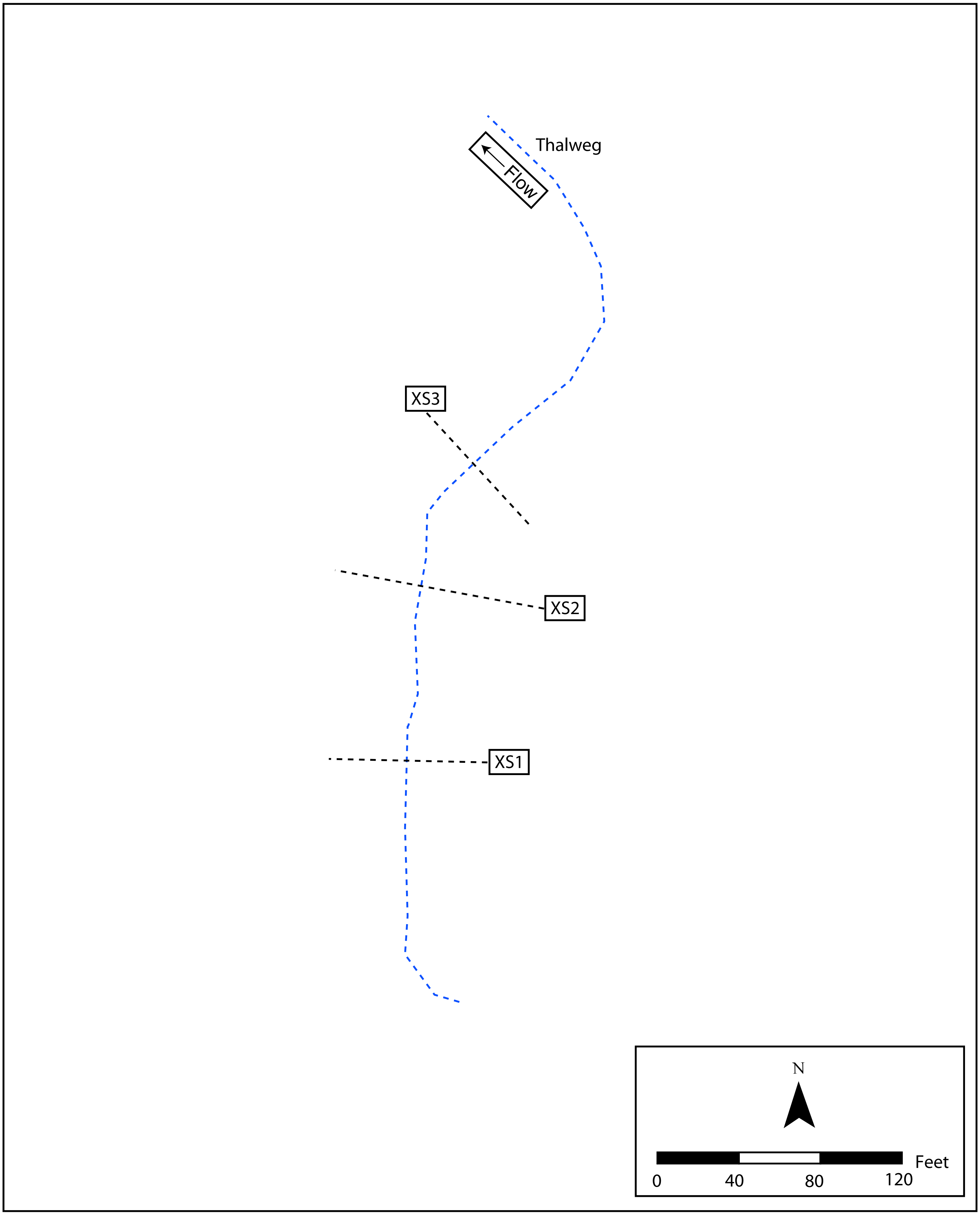


Natural log sill on Clesson Brook, MA

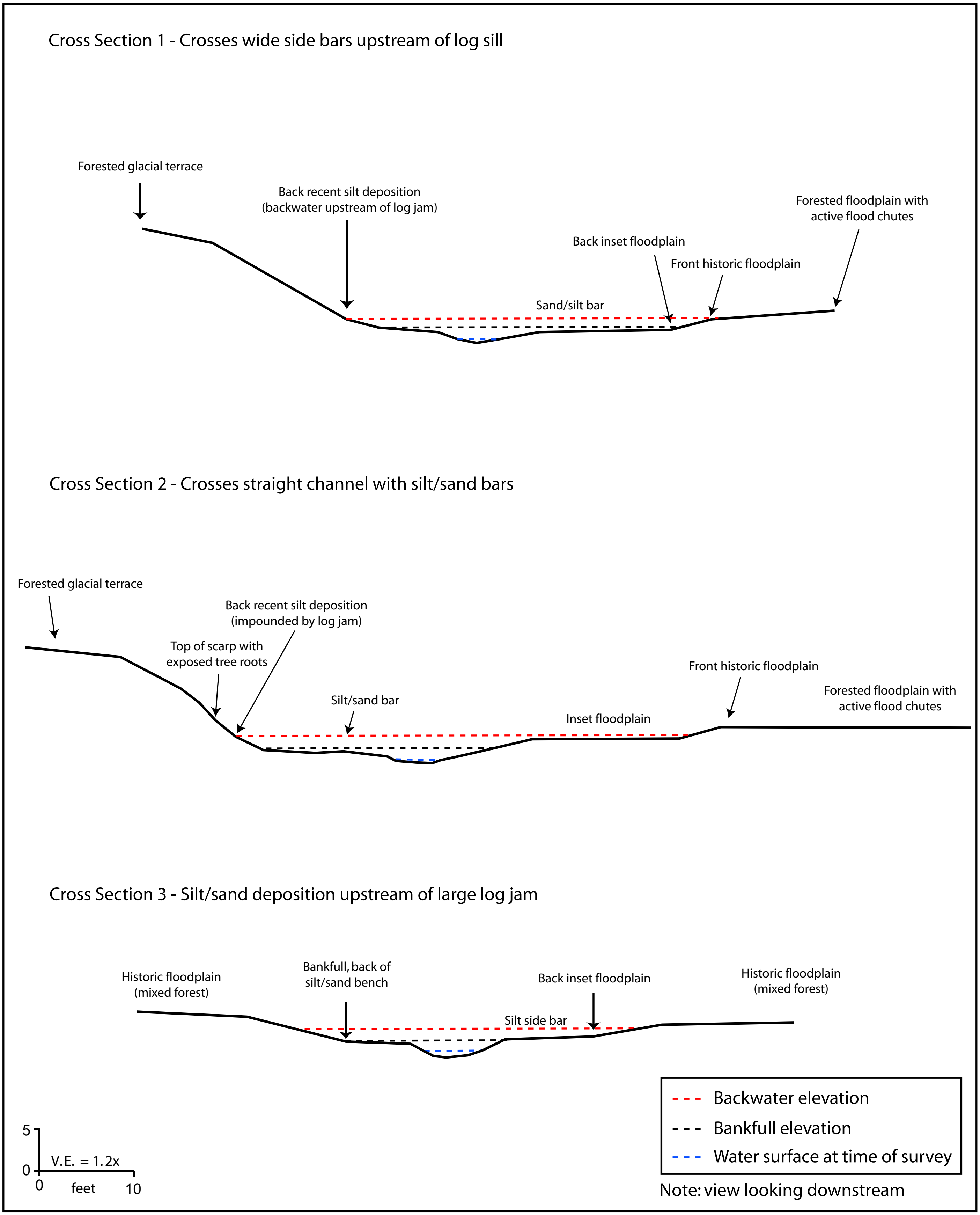
Hobbs Brook - Proposed conditions for Cross Section 2. Reach H2.

Hobbs Brook – Reach H3

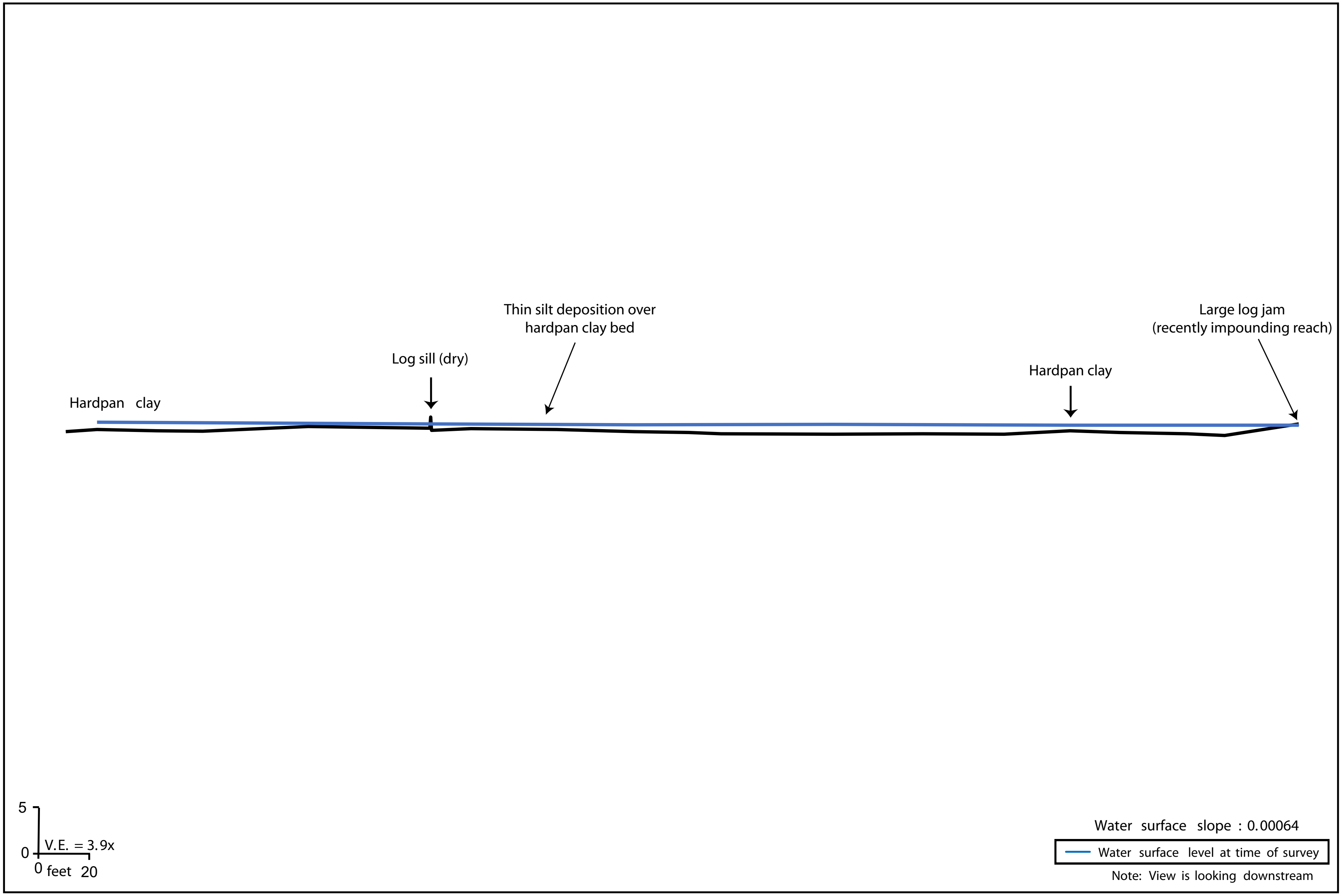
Survey Data and Conceptual Restoration Design



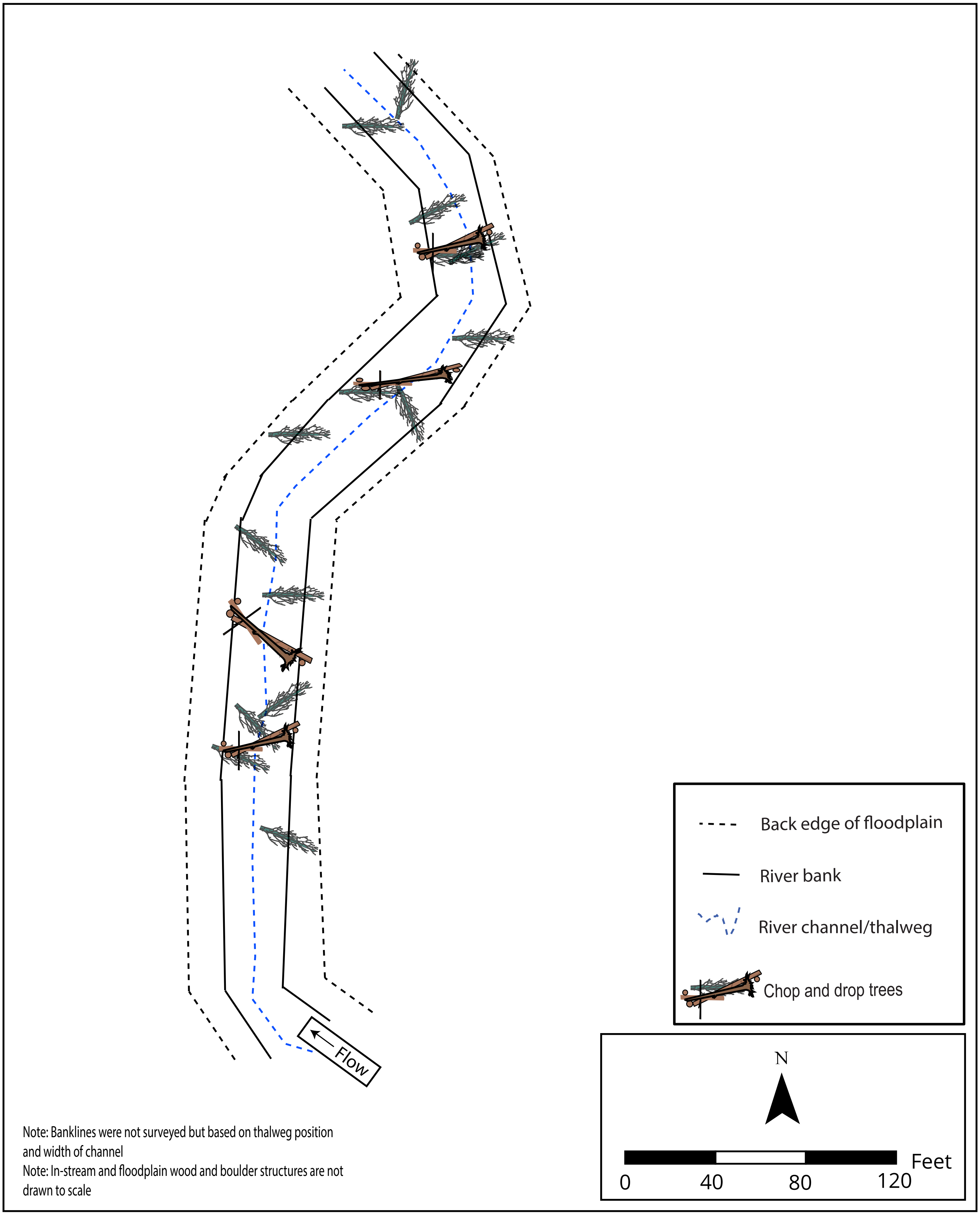
Hobbs Brook - Surveyed plan view. Reach H3.



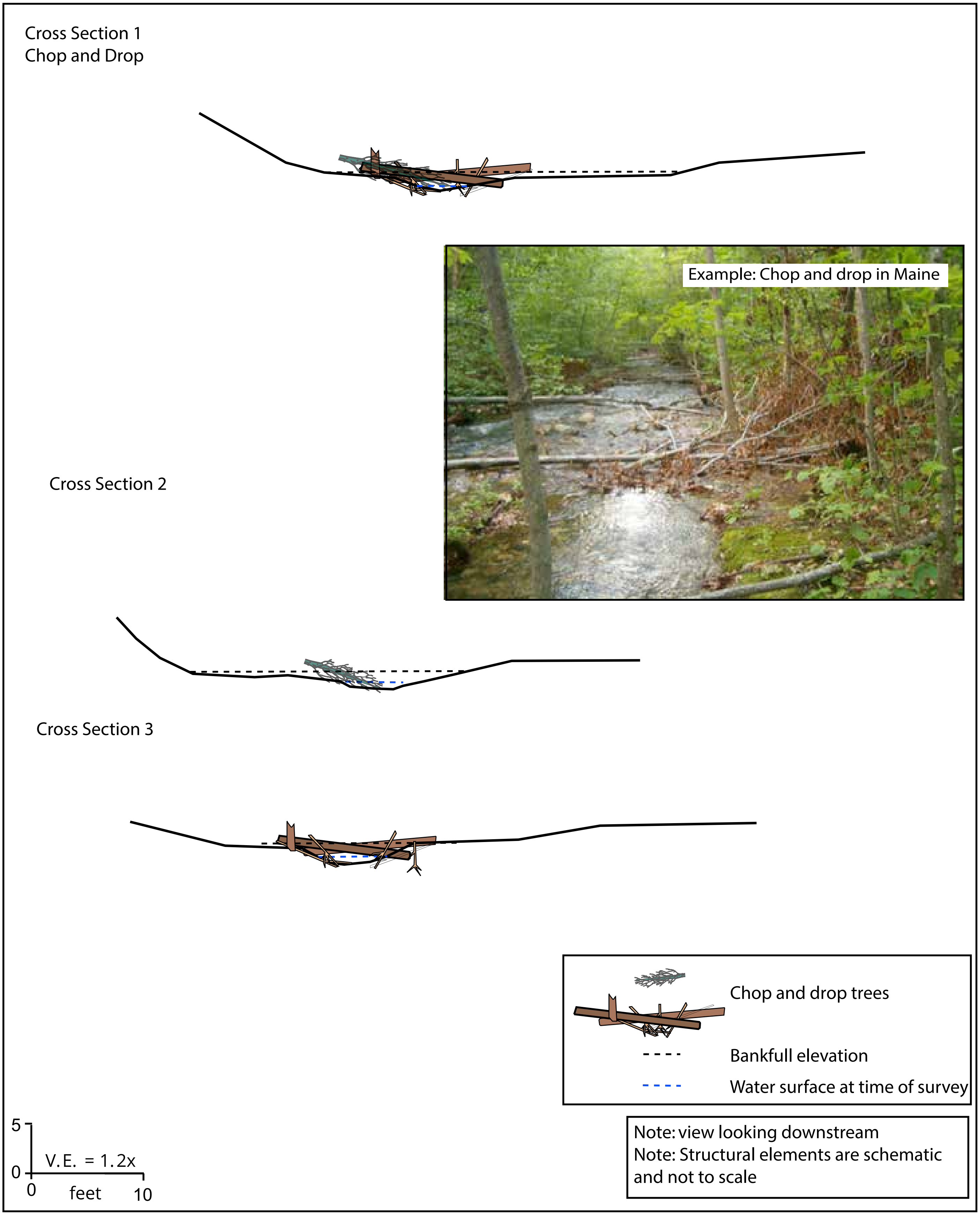
Hobbs Brook - Surveyed cross sections. Reach H3.



Hobbs Brook - Longitudinal profile. Reach H3.



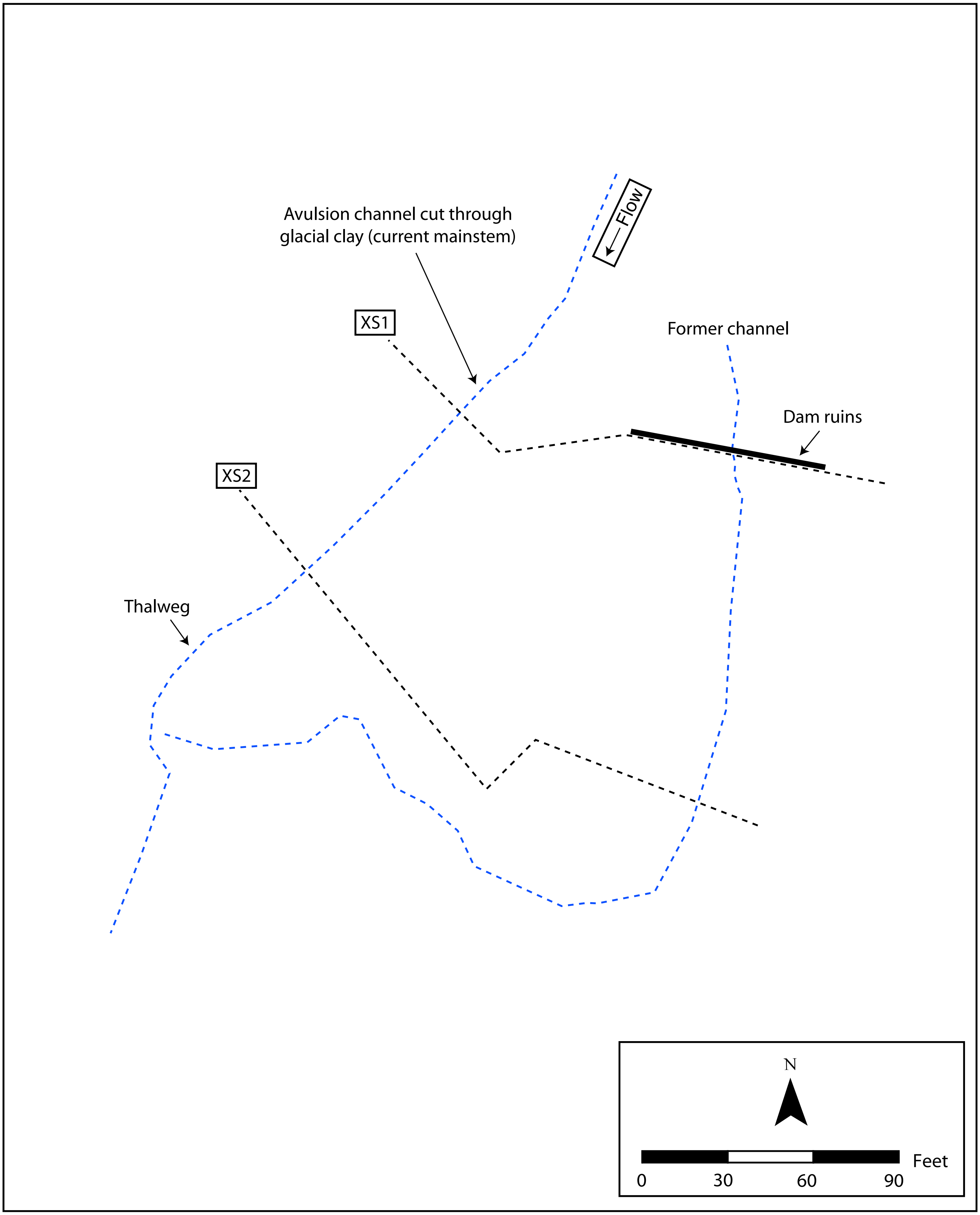
Hobbs Brook - Proposed planview. Reach H3.



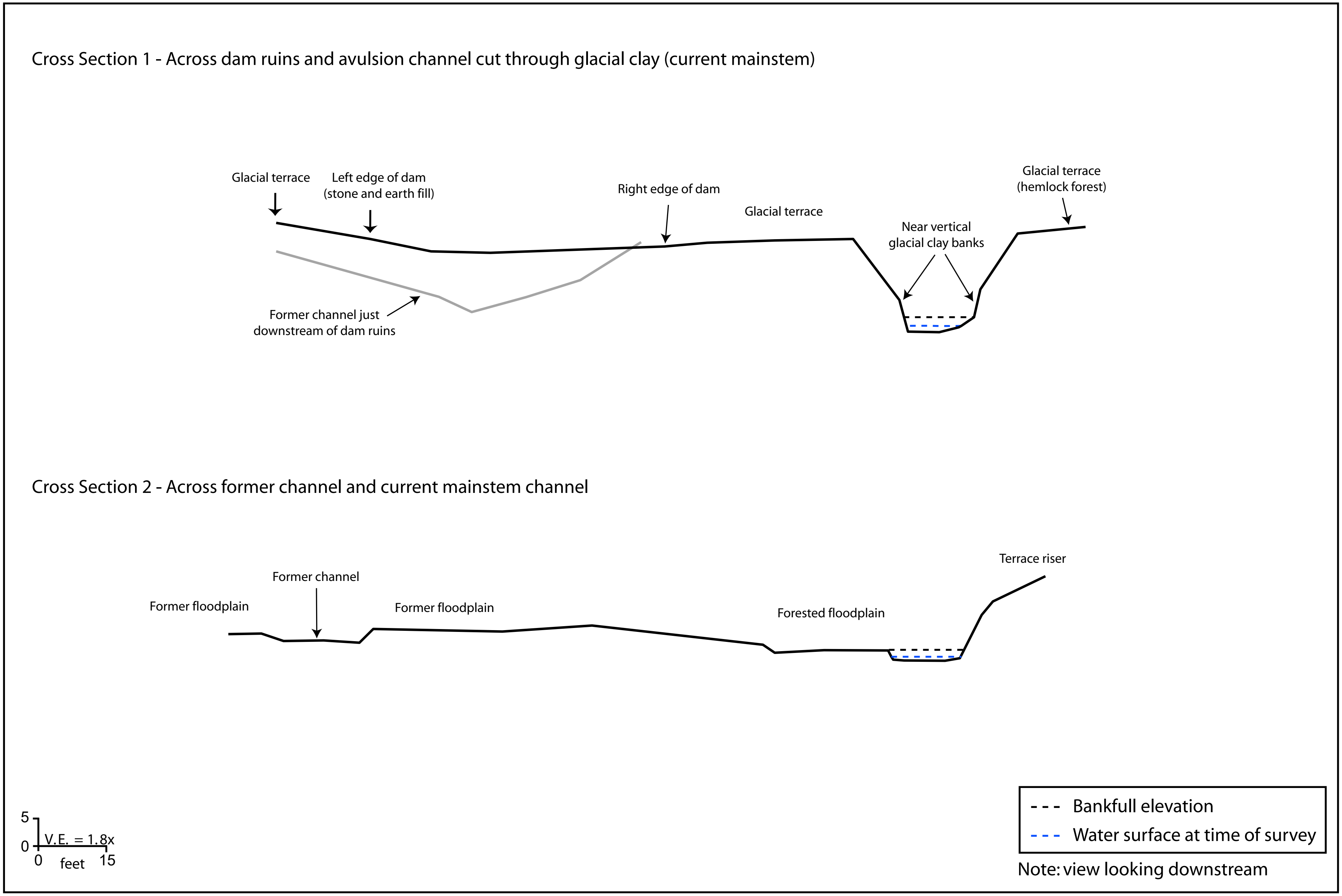
Hobbs Brook - Proposed conditions for cross sections. Reach H3.

Mill Creek – Reach M6

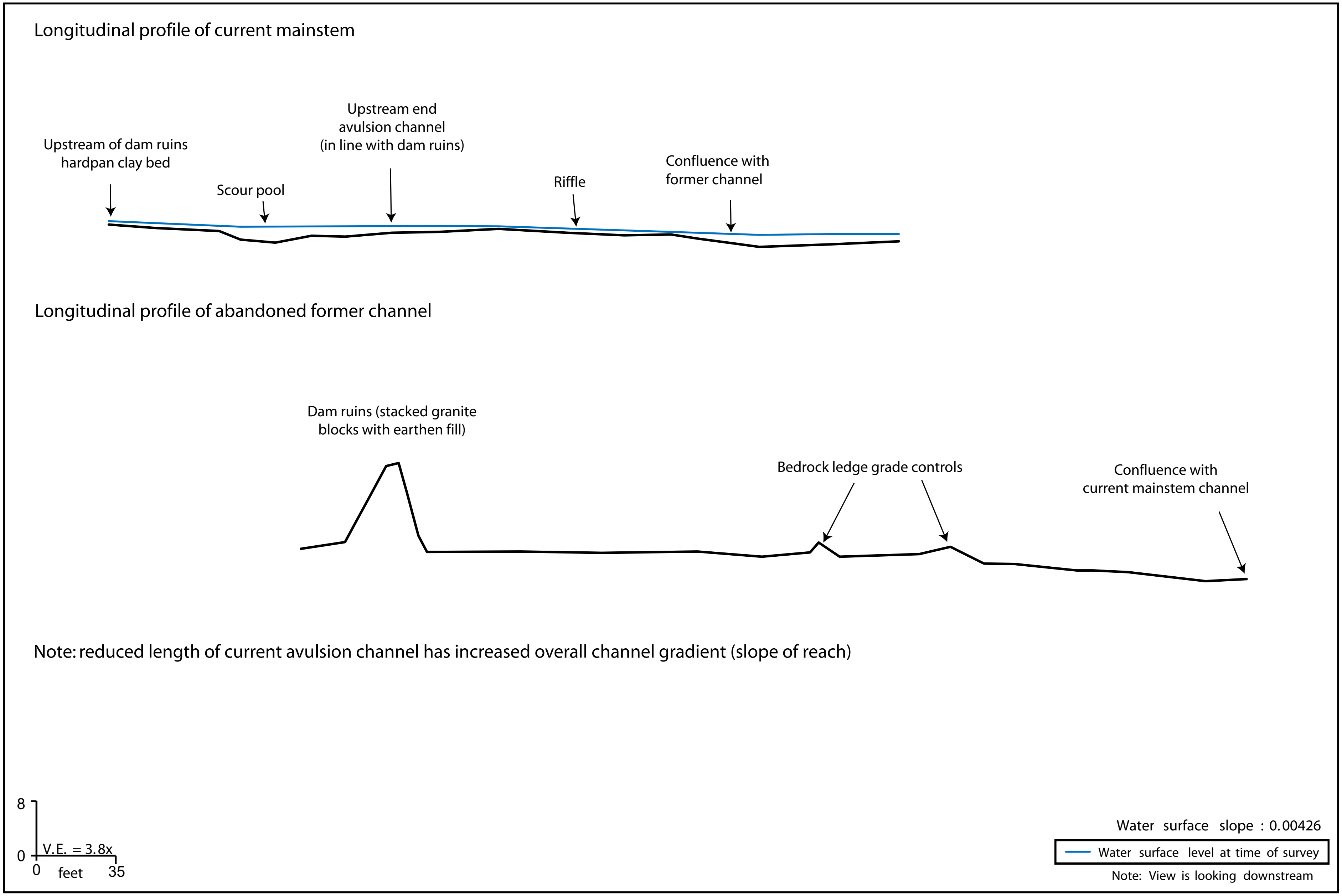
Survey Data and Conceptual Restoration Design



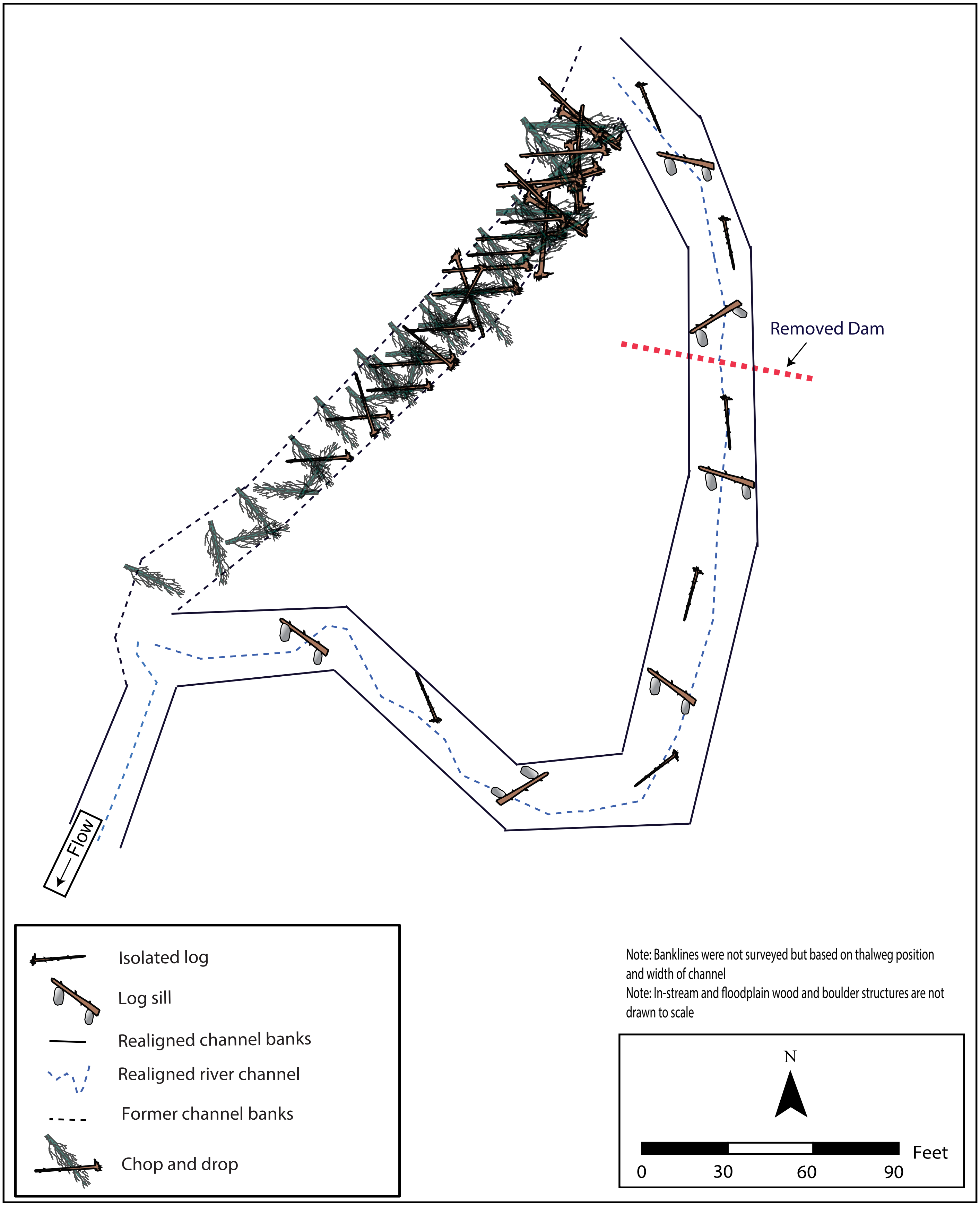
Mill Creek - Surveyed plan view. Reach M6.



Mill Creek - Surveyed cross sections. Reach M6.

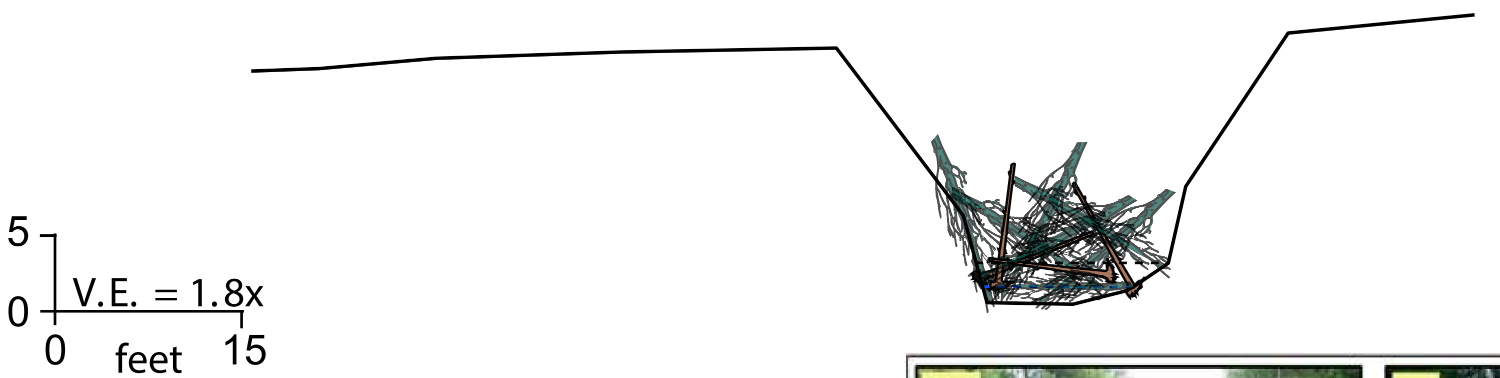


Mill Creek - Longitudinal profile. Reach M6.



Mill Creek - Proposed planview. Reach M6.

Cross Section 1
Chop and Drop for Channel Realignment

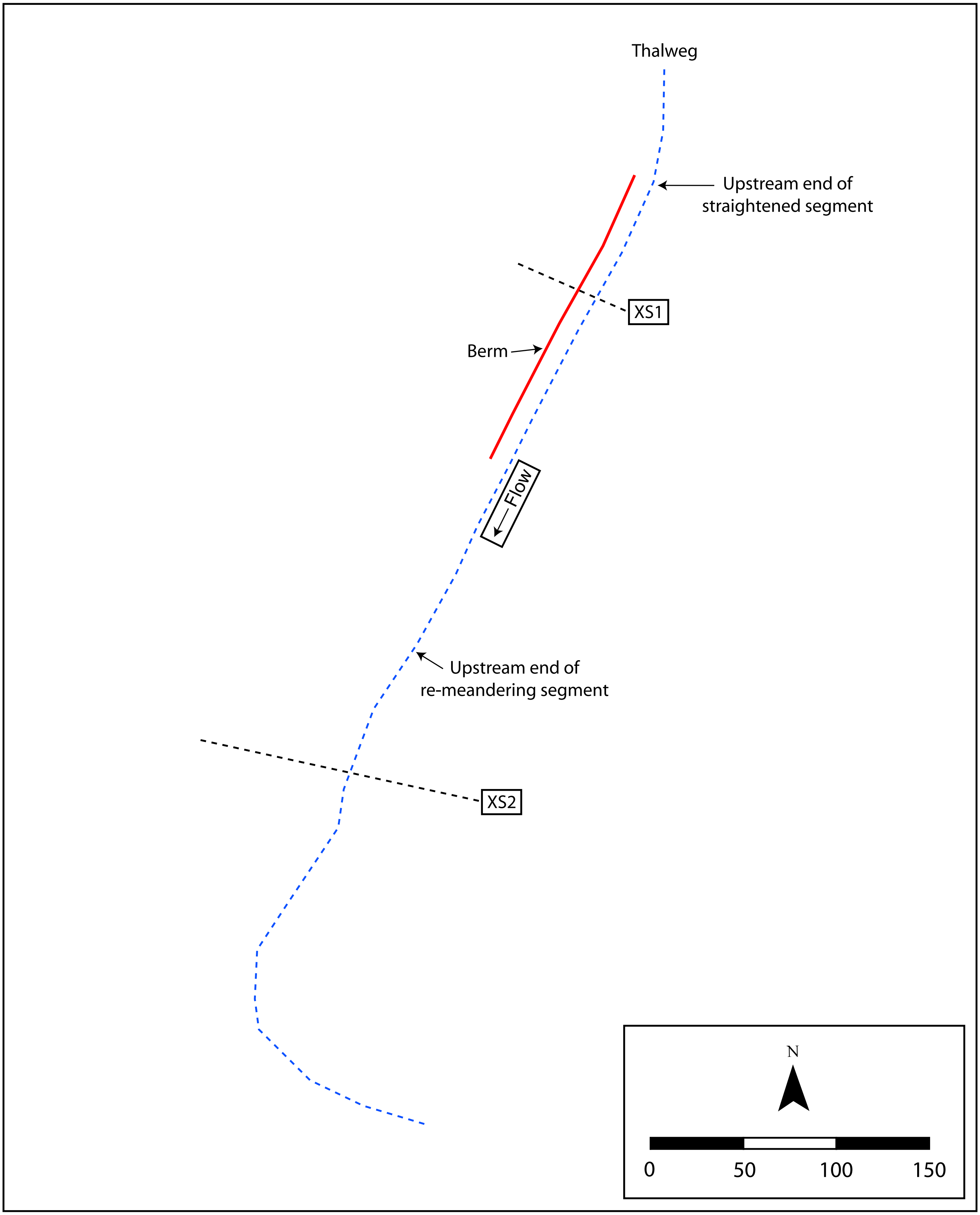


Note: view looking downstream
Note: Structural elements are schematic and not to scale

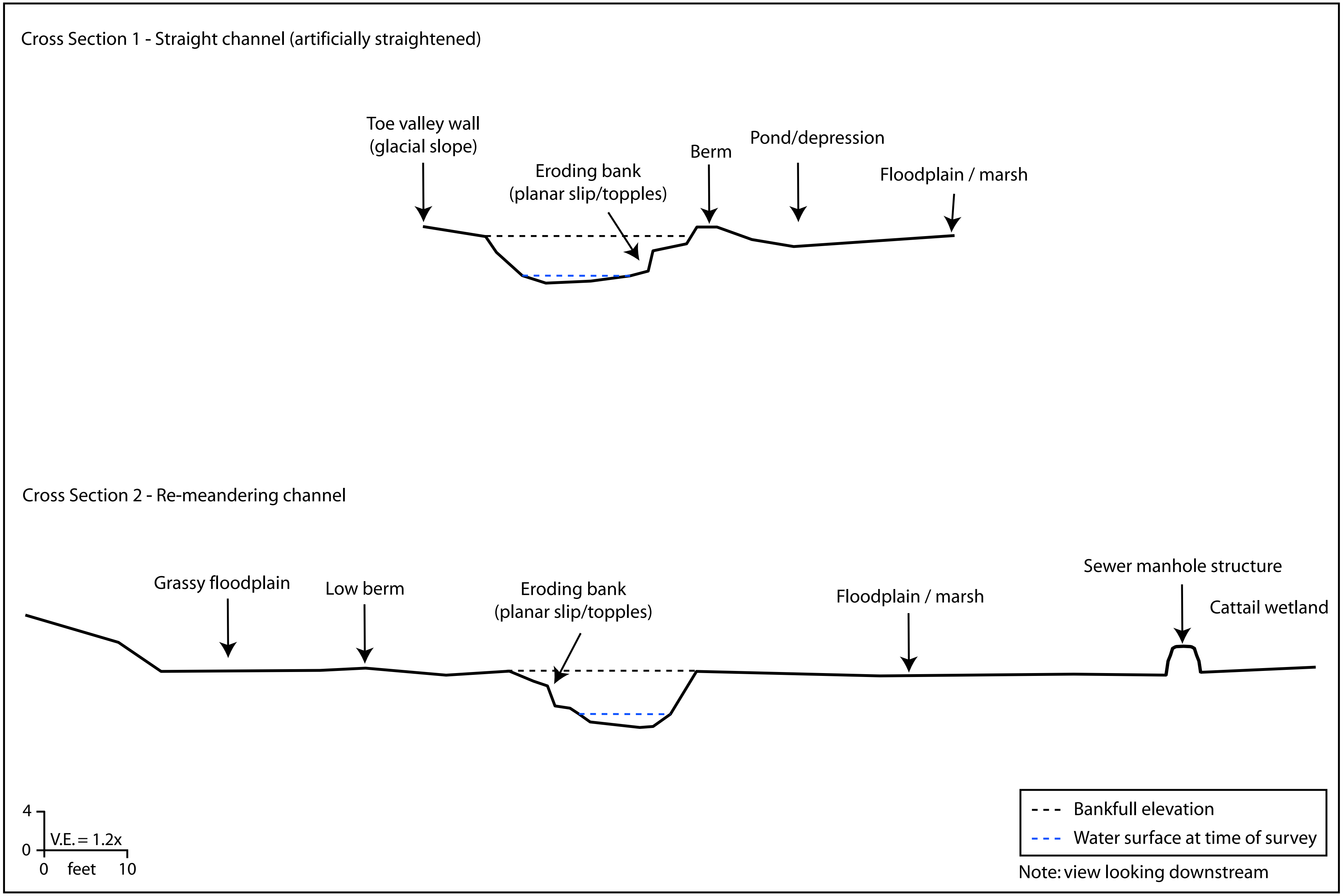
Mill Creek - Proposed conditions for Cross Section 1. Reach M6.

Mill Creek – Reach M11

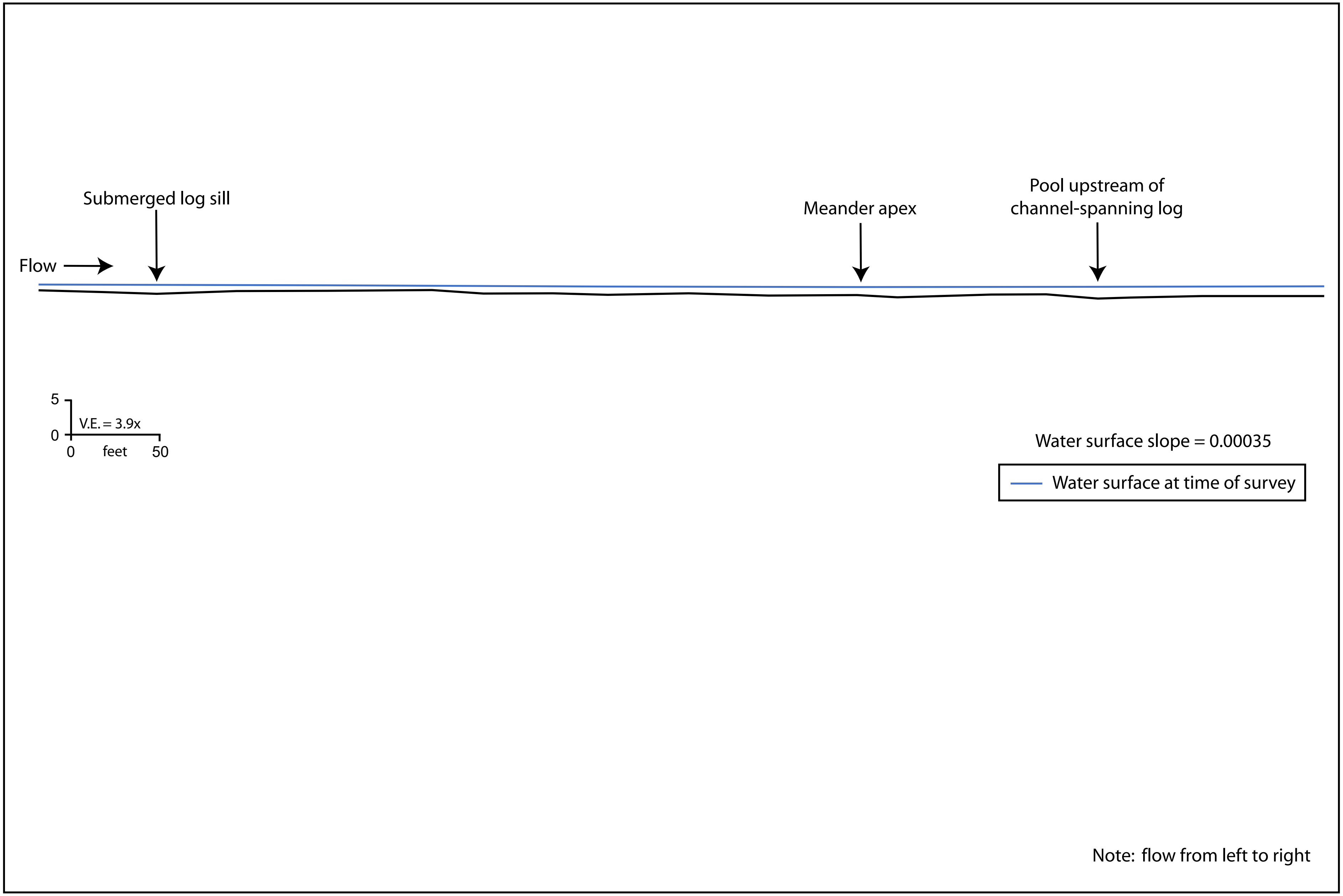
Survey Data and Conceptual Restoration Design



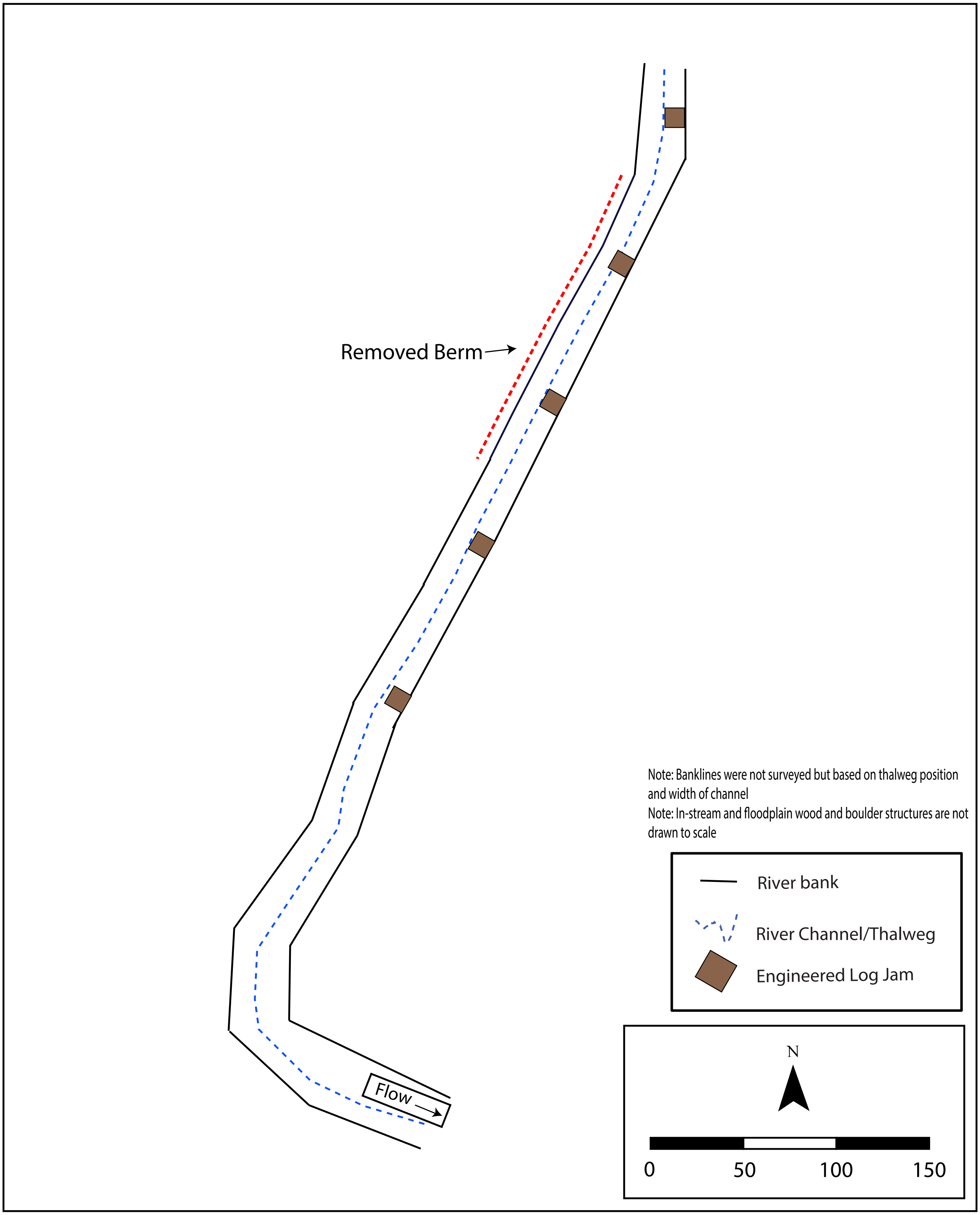
Mill Creek - Surveyed cross sections. Reach M11.



Mill Creek - Surveyed cross sections. Reach M11.

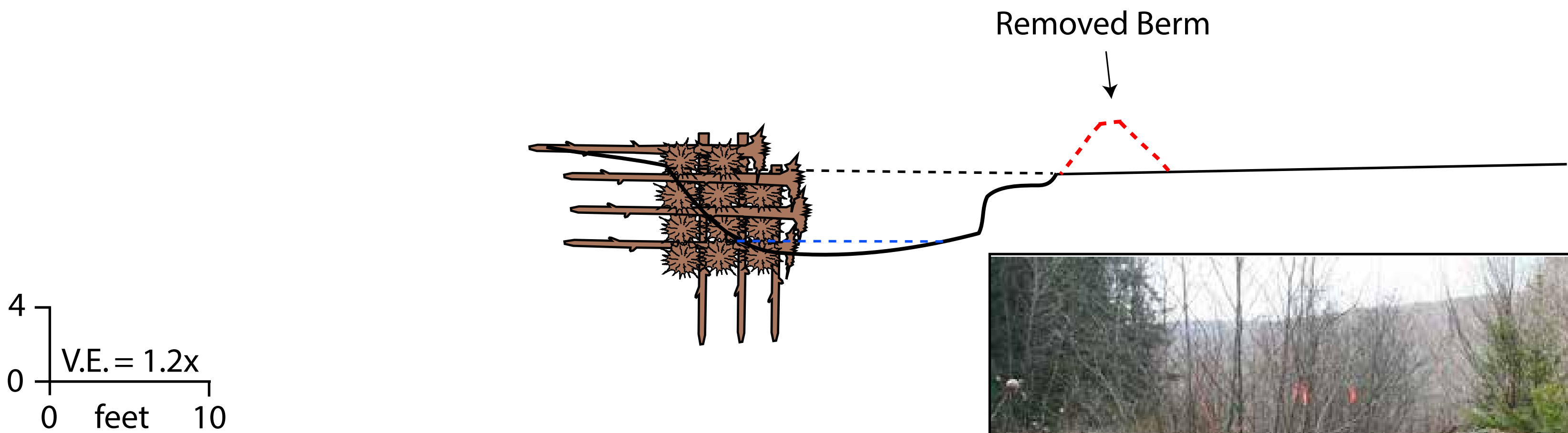


Mill Creek - Longitudinal profile. Reach M11.



Mill Creek - Proposed planview. Reach M11.

Cross Section 1
Engineered Log Jam




Example: Berm removal on Nash Stream, NH


Example: Marginal log jam in Stark, NH

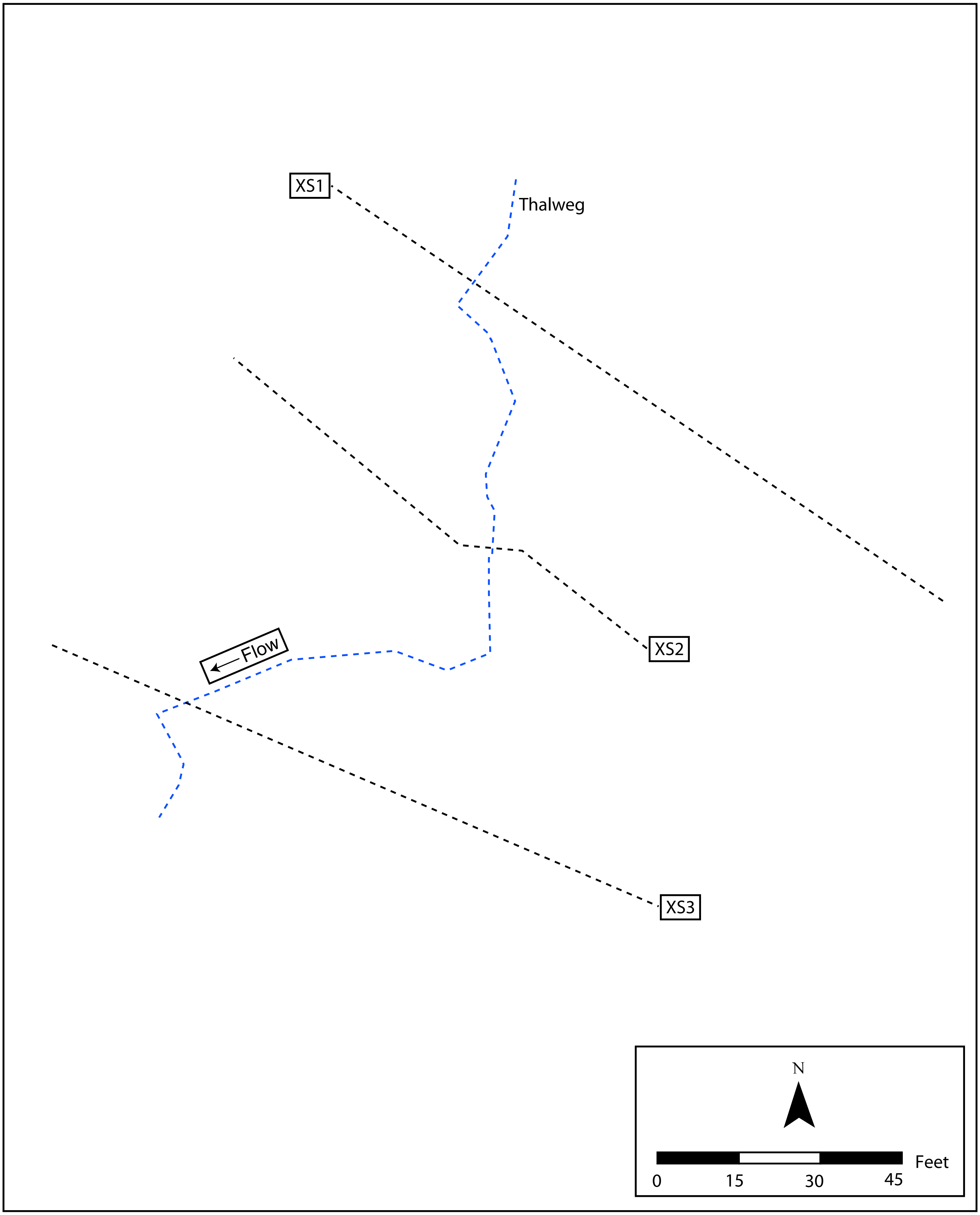
Note: view looking downstream
Note: Structural elements are schematic and not to scale

Root Wad
Bankfull elevation
Water surface at time of survey

Mill Creek - Proposed conditions for Cross Section 1. Reach M11.

Norton Brook – Reach N1

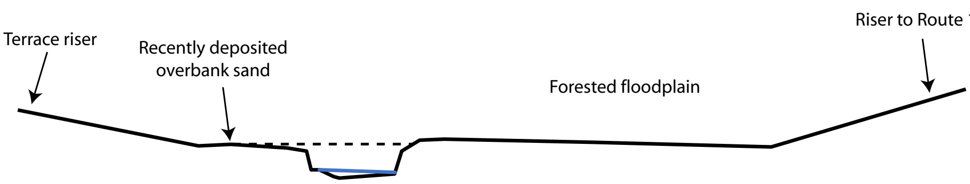
Survey Data and Conceptual Restoration Design



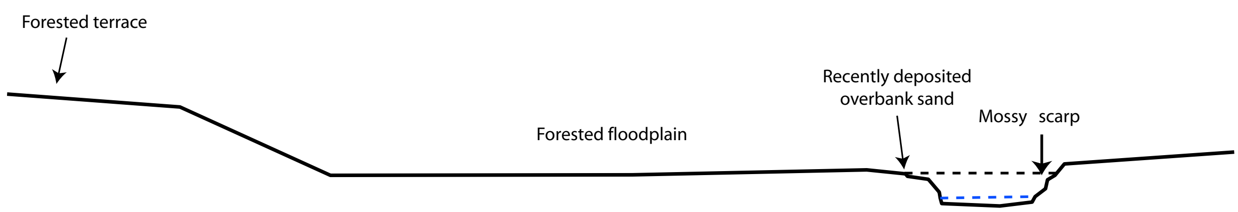
Norton Brook - Surveyed plan view. Reach N1.

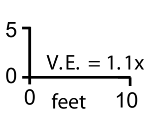
Cross Section 1 - Across wide floodplain and straight riffle

Cross Section 2 - Across sand bed channel with overbank sand deposition



Cross Section 3 - Crosses channel at meander apex

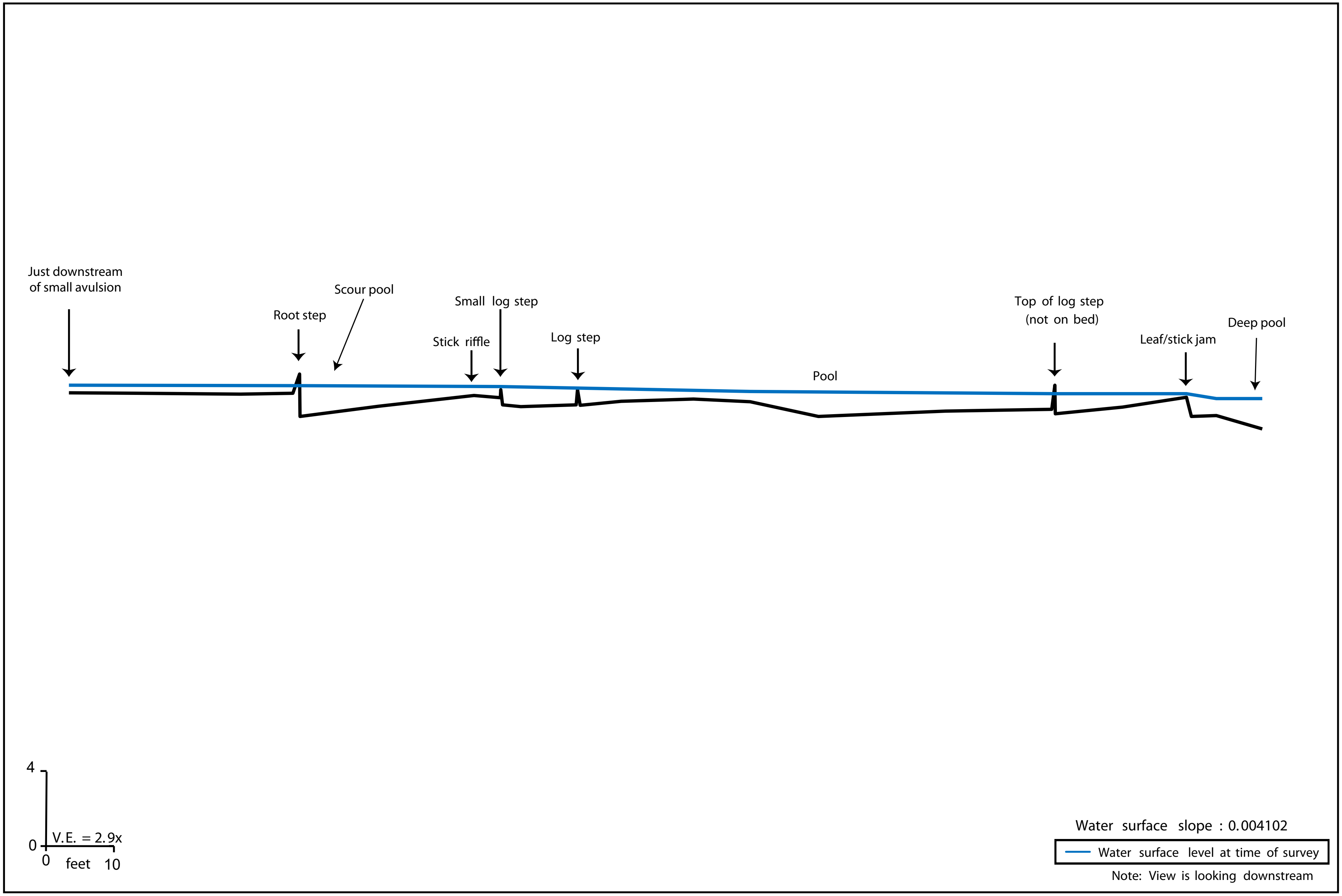




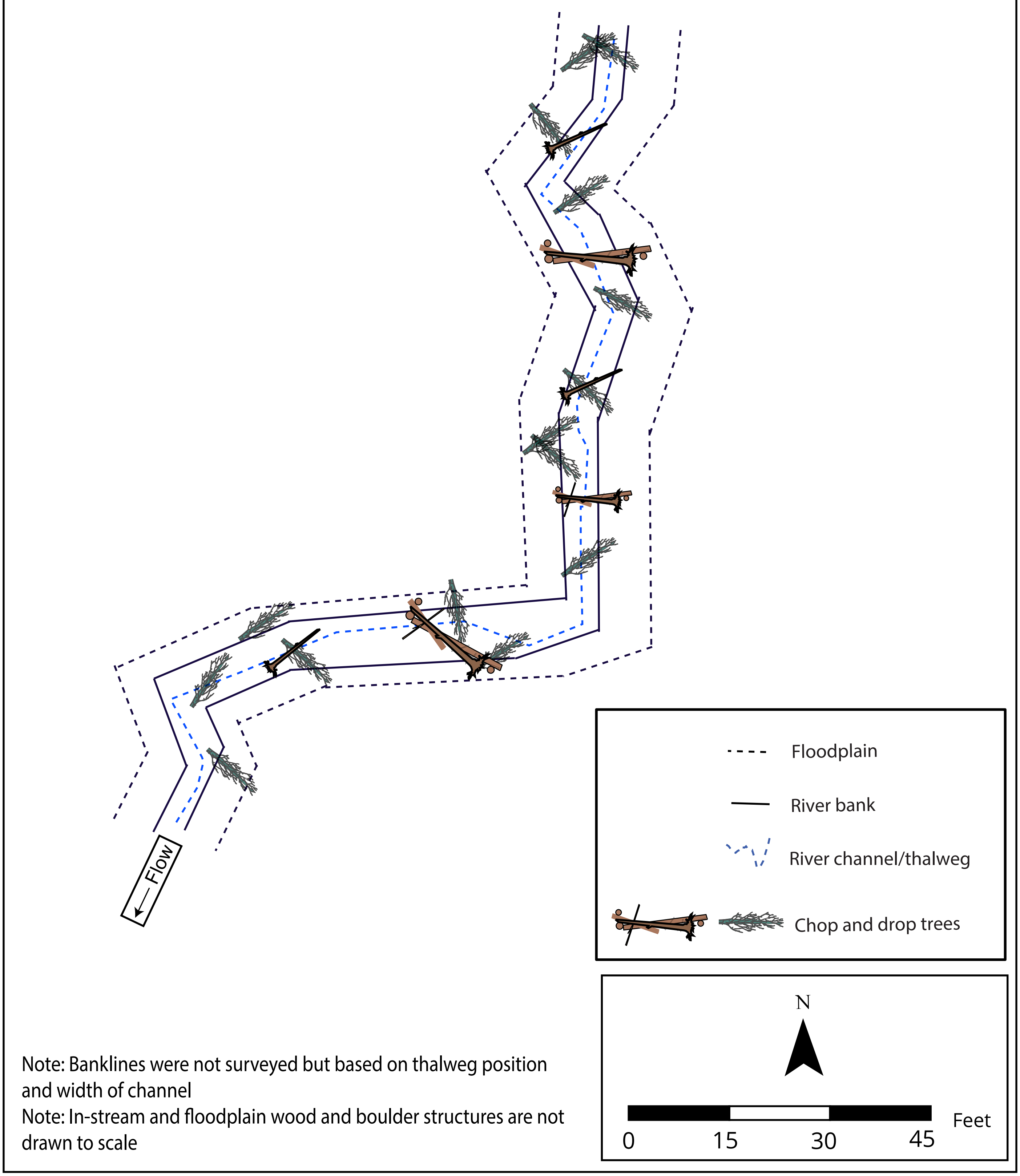
--- Bankfull elevation
--- Water surface at time of survey

Note: view looking downstream

Norton Brook - Surveyed cross sections. Reach N1.



Norton Brook - Longitudinal profile. Reach N1.

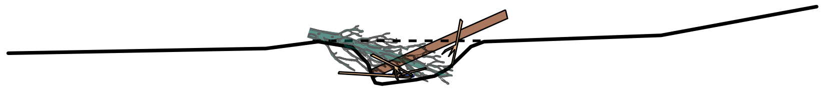


Note: Banklines were not surveyed but based on thalweg position and width of channel
Note: In-stream and floodplain wood and boulder structures are not drawn to scale

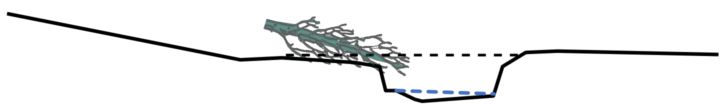
Norton Brook - Proposed plan view. Reach N1.

Chop and Drop

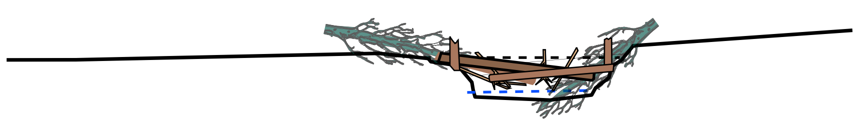
Cross Section 1

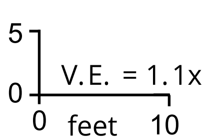


Cross Section 2



Cross Section 3





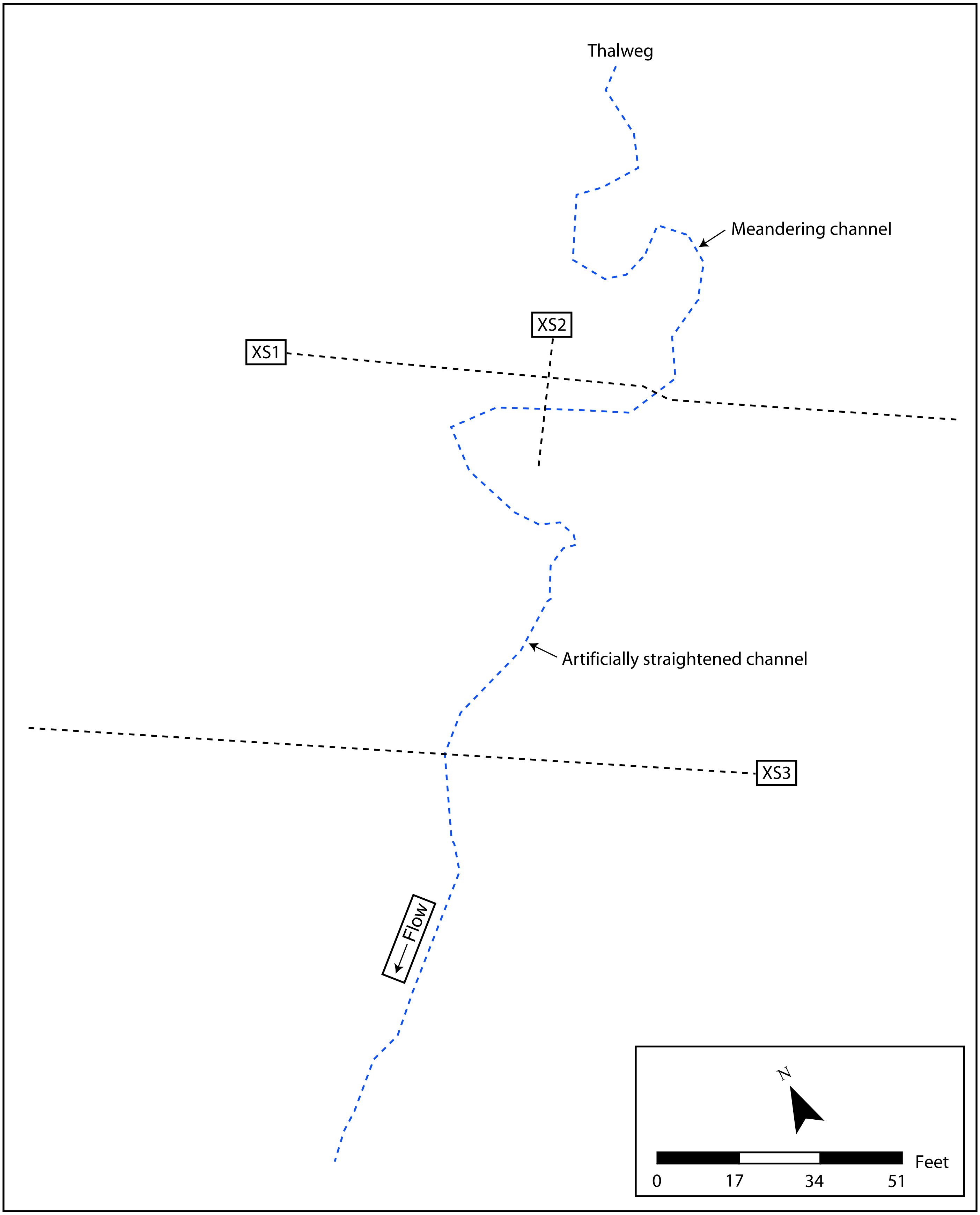
Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chop and drop trees
Bankfull elevation
Water surface at time of survey

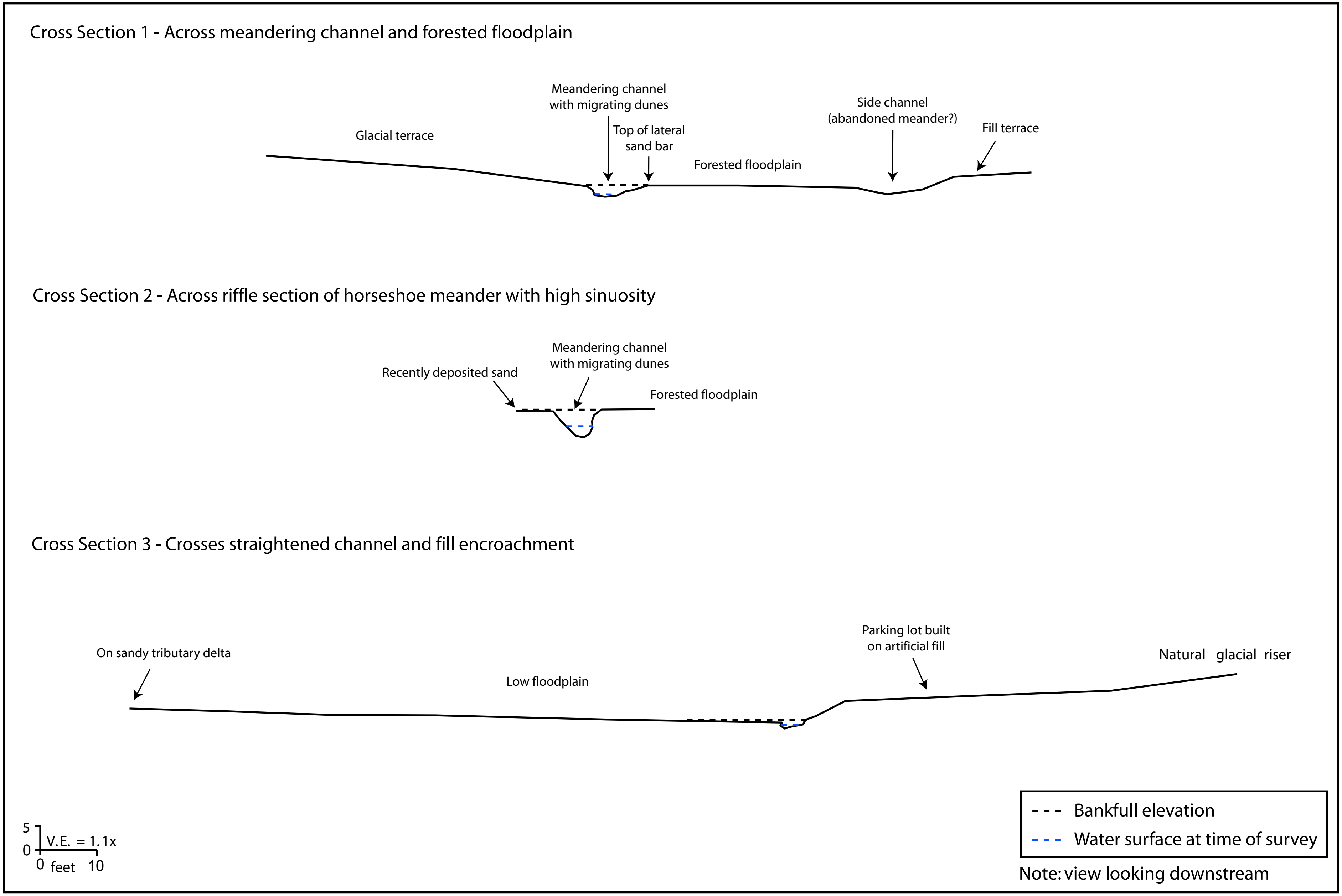
Norton Brook - Proposed conditions for cross sections 1-3. Reach N1.

Norton Brook – Reach N2

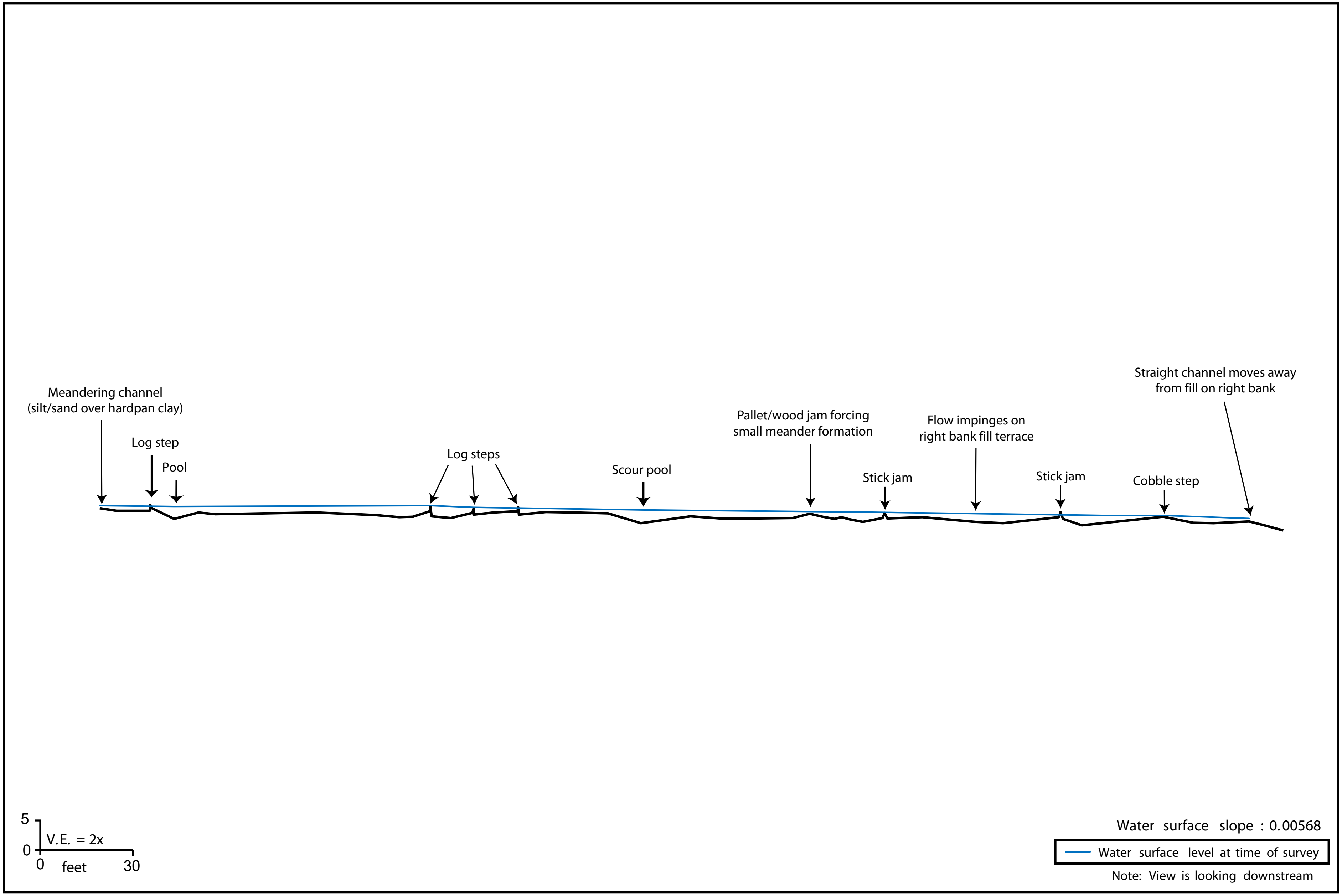
Survey Data and Conceptual Restoration Design



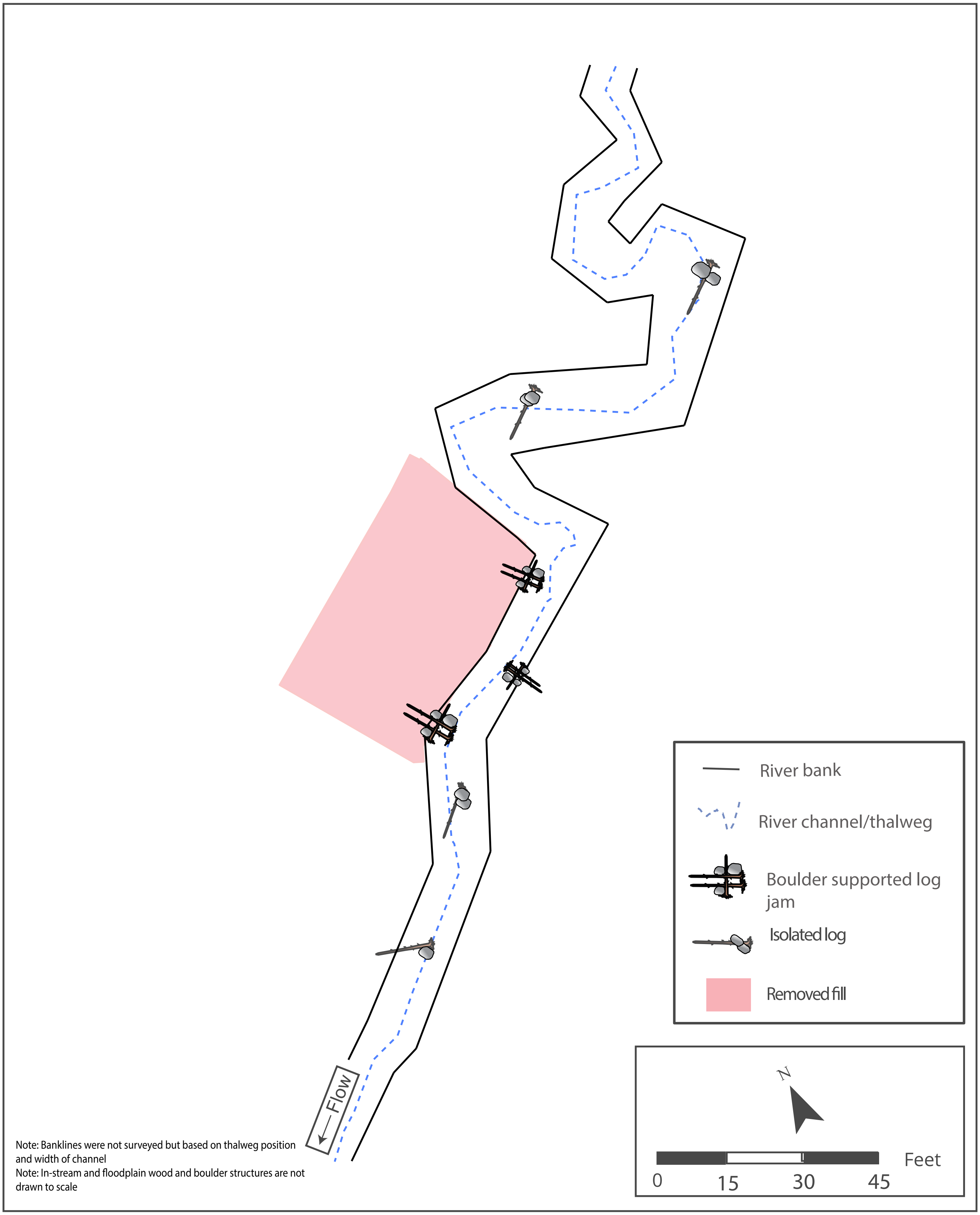
Norton Brook - Surveyed plan view. Reach N2.



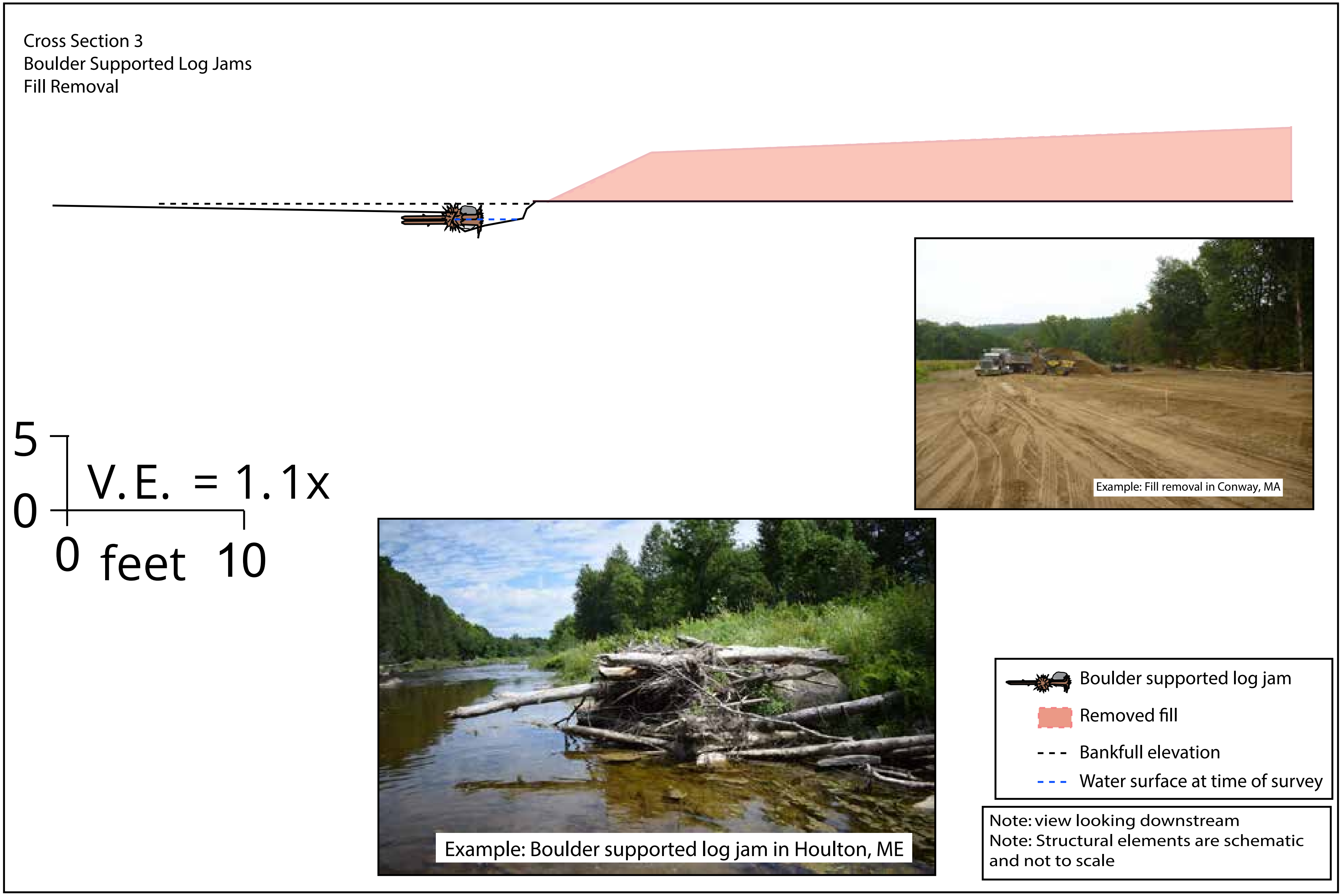
Norton Brook - Surveyed plan view. Reach N2.



Norton Brook - Longitudinal profile. Reach N2.



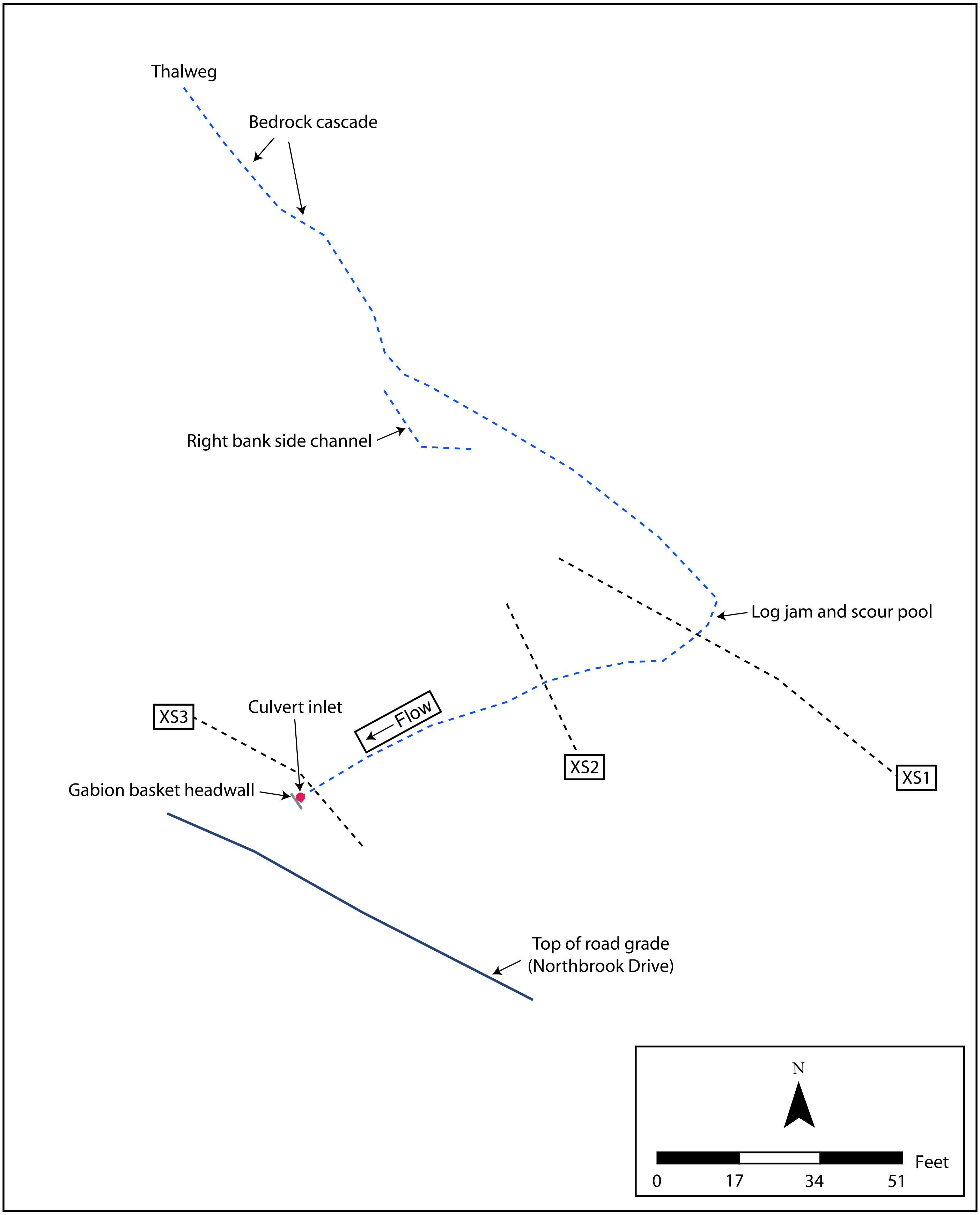
Norton Brook - Proposed plan view. Reach N2.



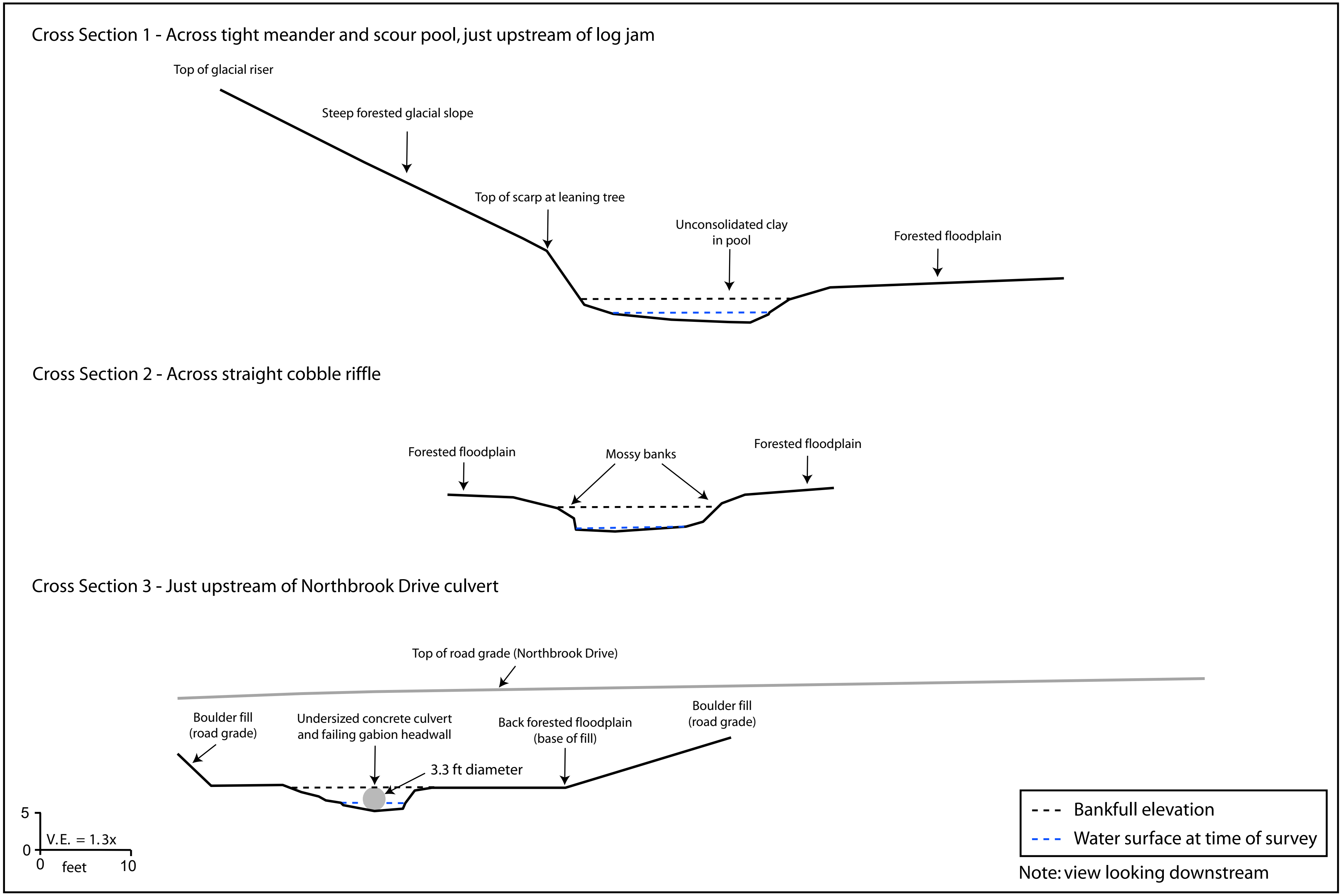
Norton Brook - Proposed conditions for Cross Section 3. Reach N2.

Norton Brook – Reach N3

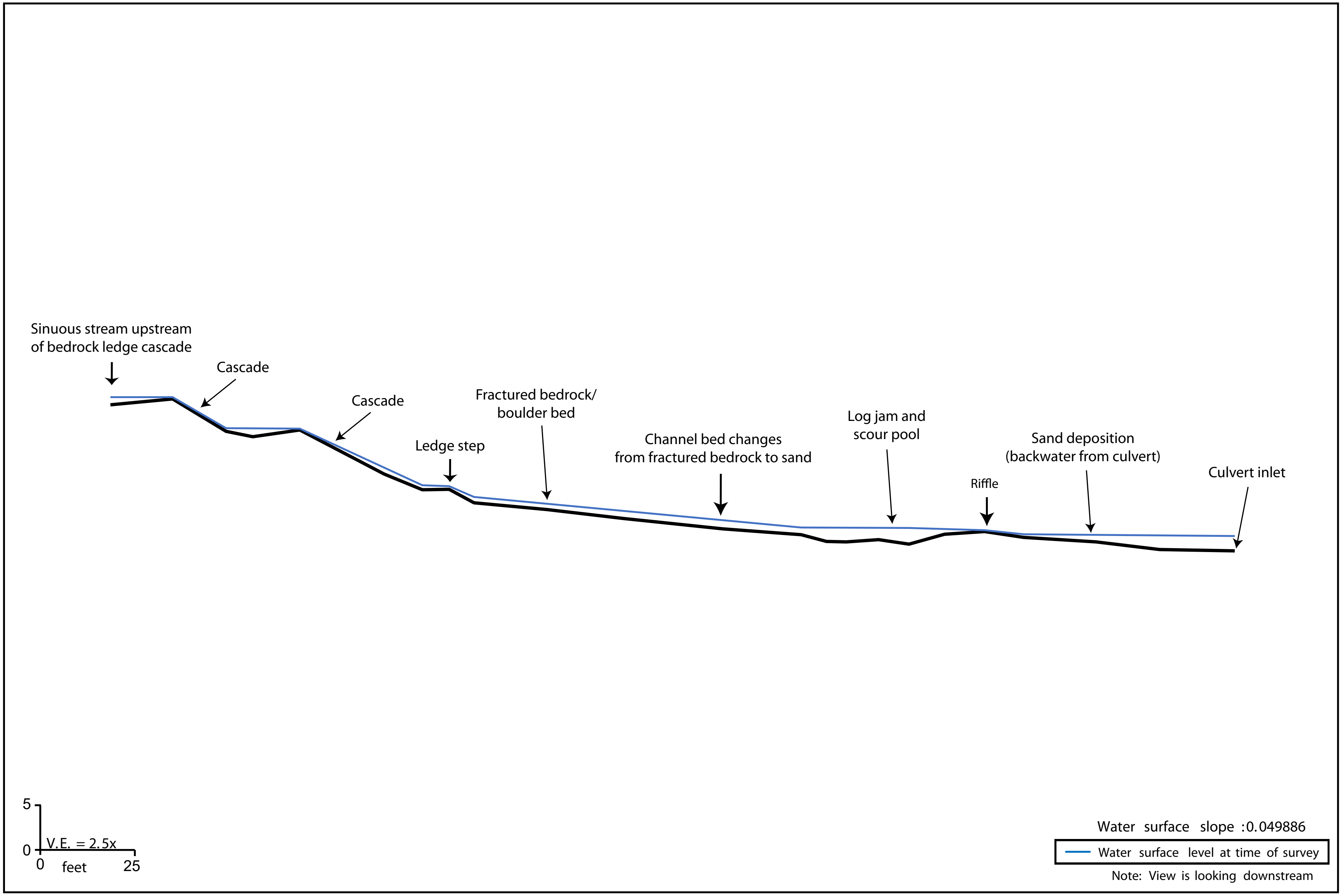
Survey Data and Conceptual Restoration Design



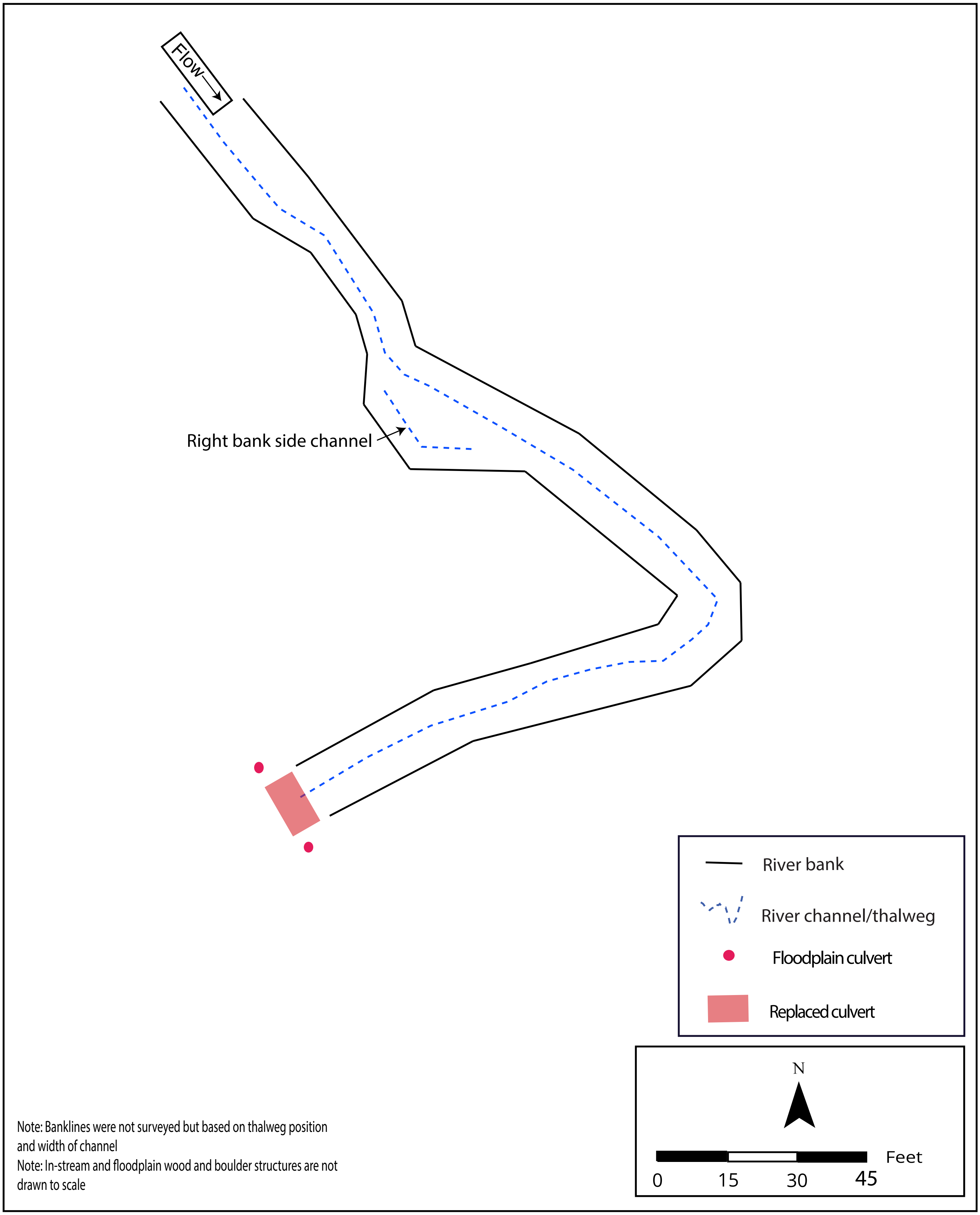
Norton Brook - Surveyed plan view. Reach N3.



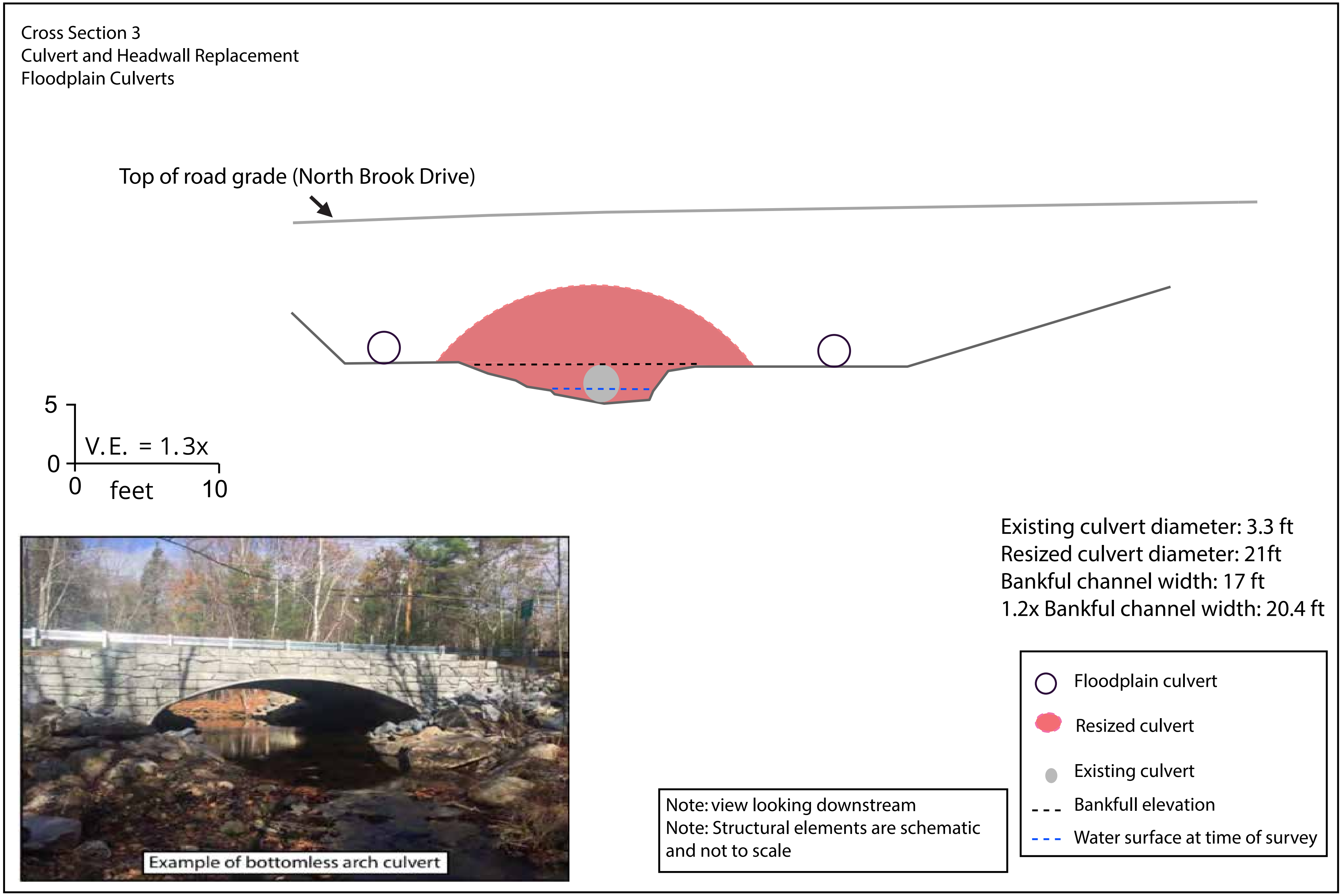
Norton Brook - Surveyed cross sections. Reach N3.



Norton Brook - Longitudinal profile. Reach N3.



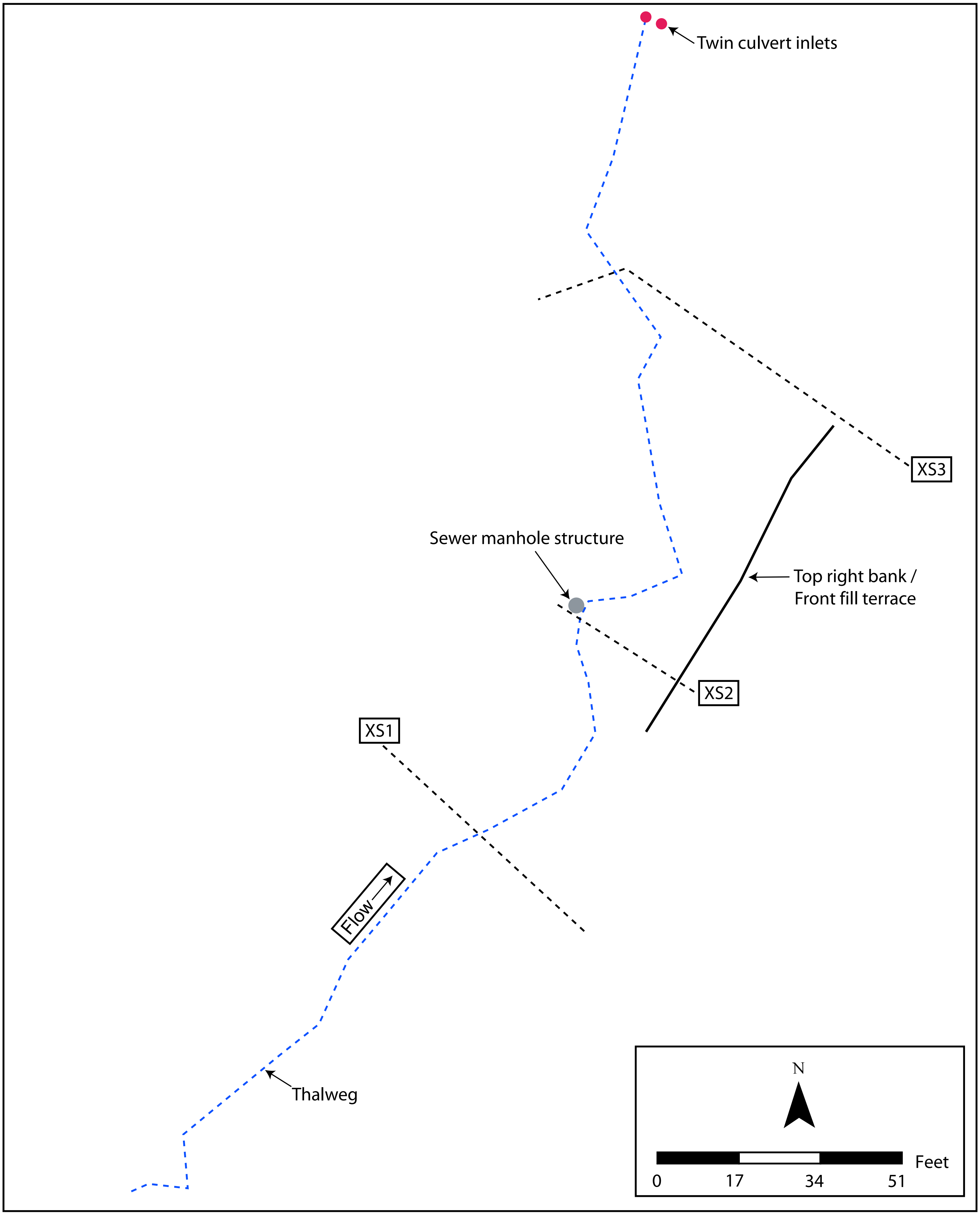
Norton Brook - Proposed plan view. Reach N3.



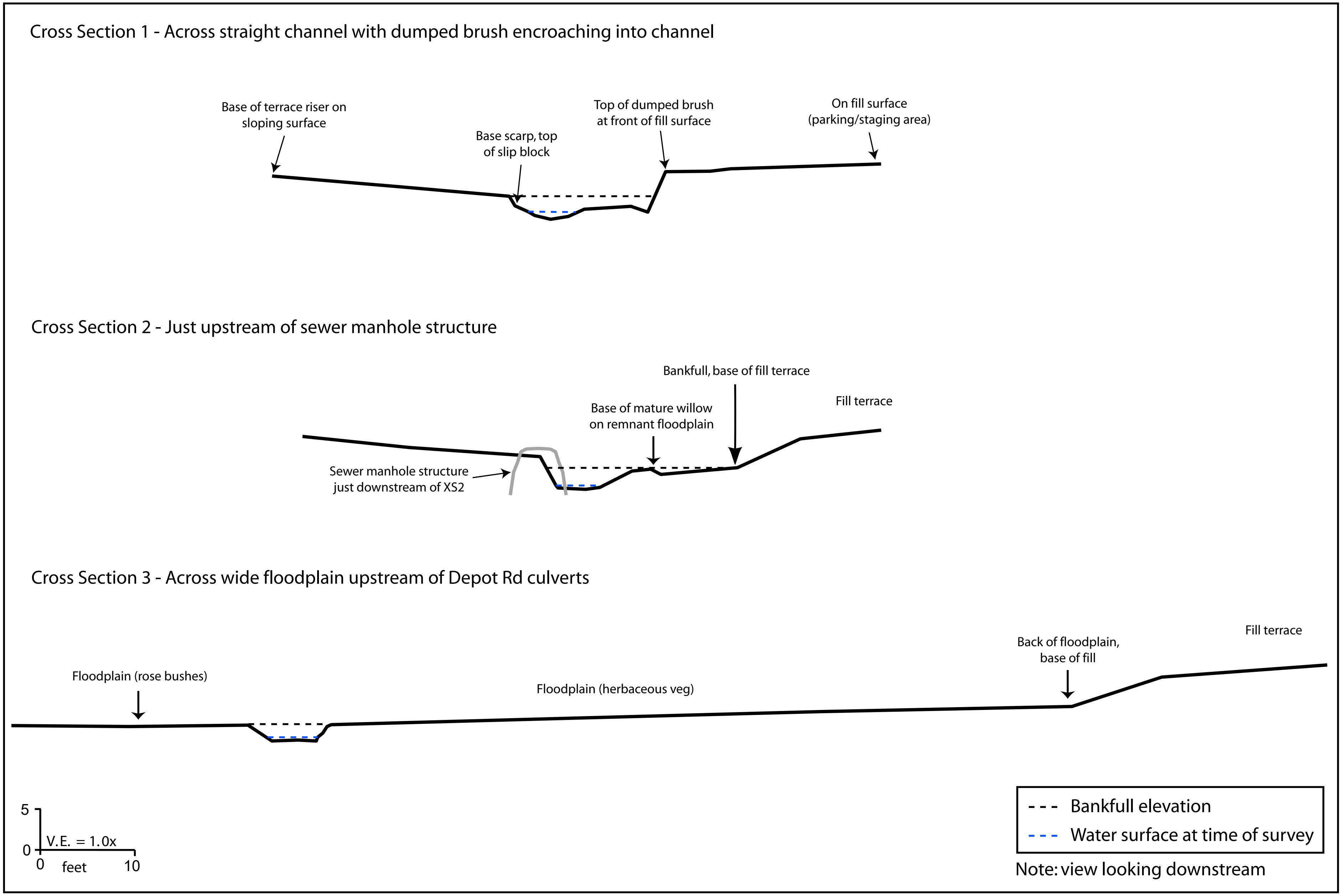
Norton Brook - Proposed condition for Cross Section 3. Reach N3.

Webes Creek – Reach W1

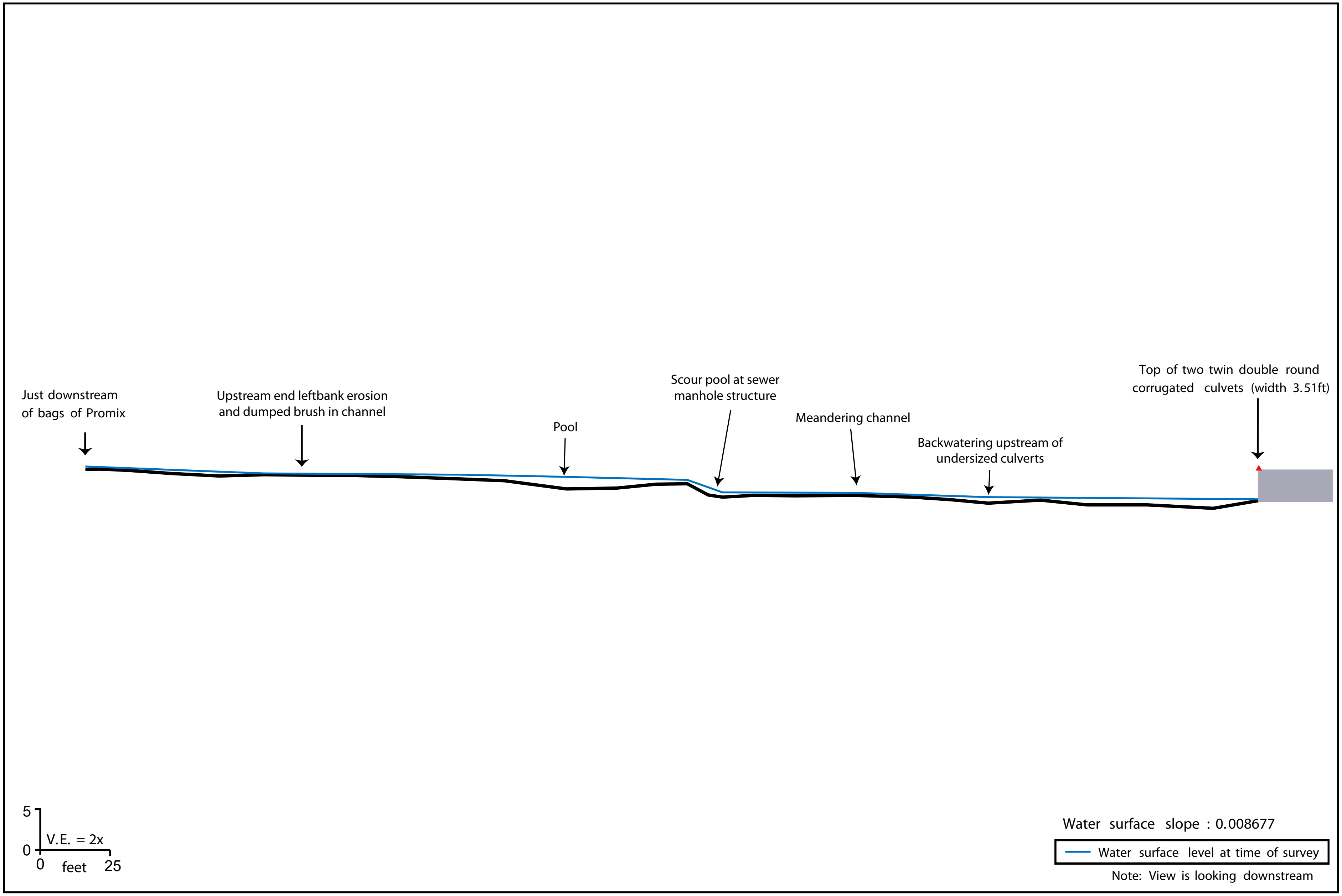
Survey Data and Conceptual Restoration Design



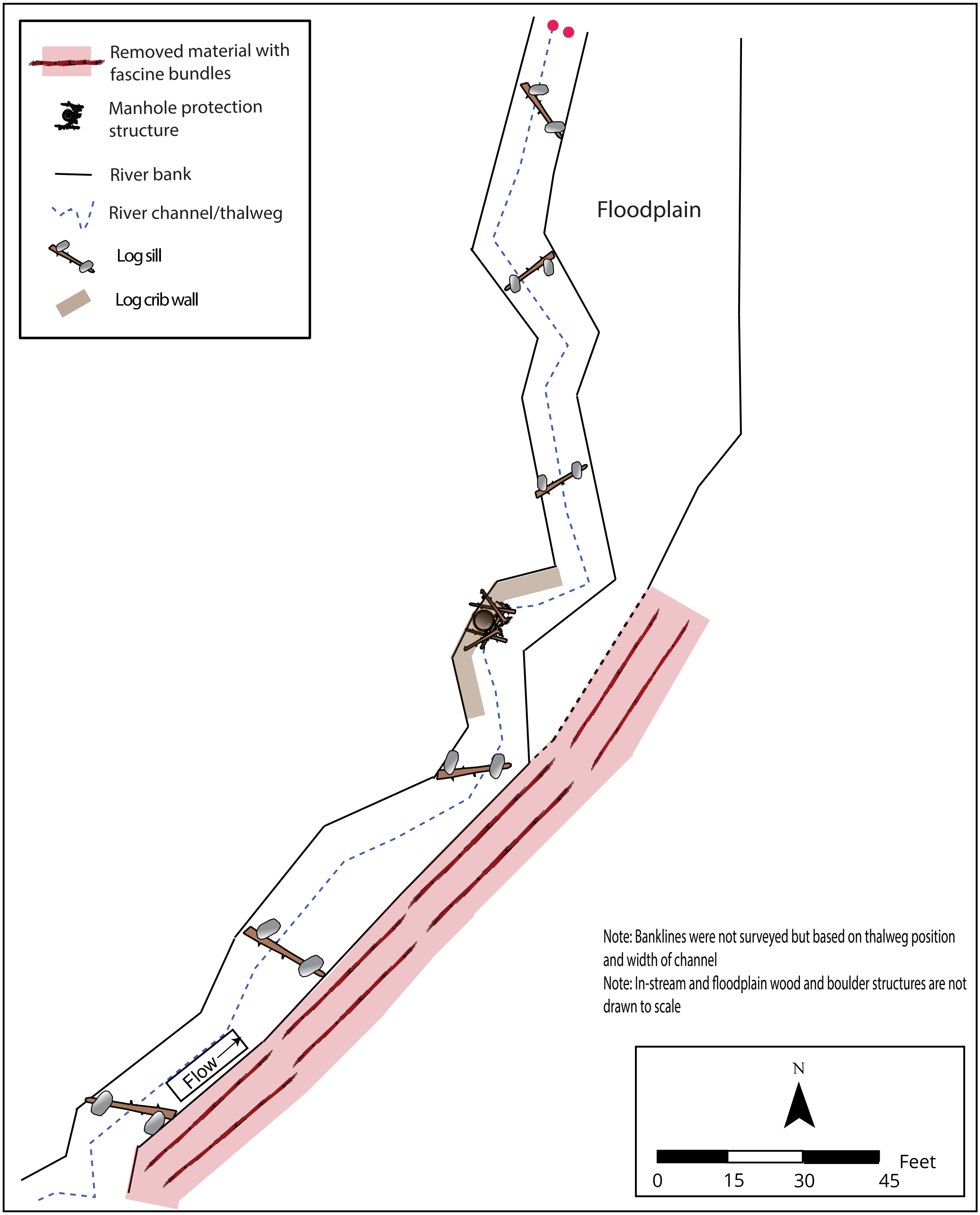
Webes Creek. Surveyed planview. Reach W1.



Webes Creek - Surveyed cross sections. Reach W1.

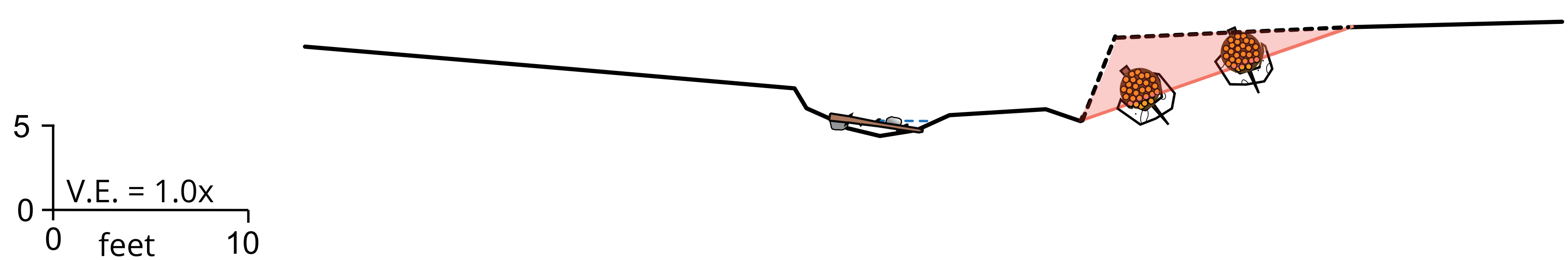


Webes Creek - Longitudinal profile. Reach W1.

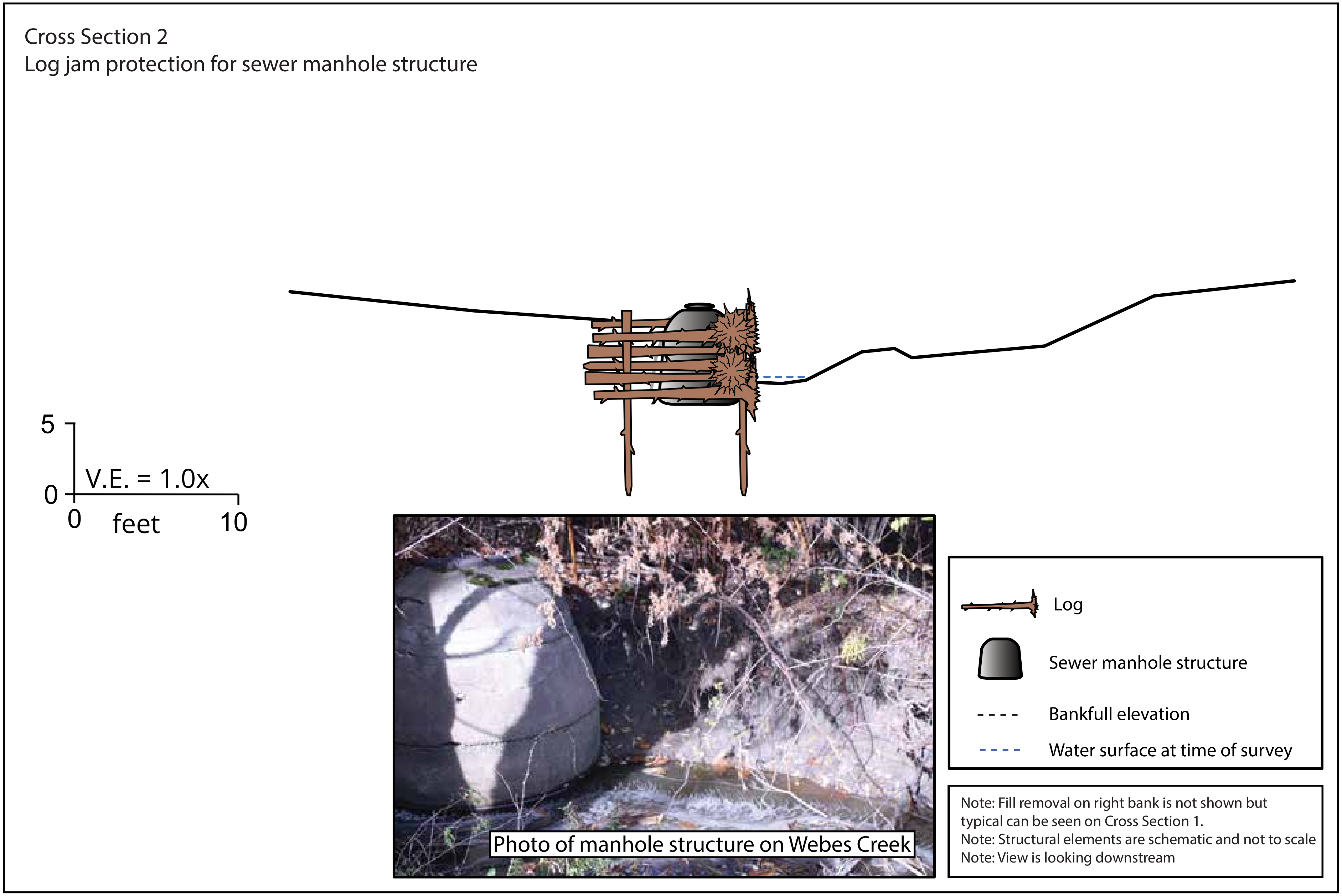


Webes Creek. Proposed Planview. Reach W1.

Field Geology Services
Fluvial Geomorphology



Webes Creek - Proposed conditions at Cross Section 1. Reach W1.



Webes Creek - Proposed conditions at Cross Section 2. Reach W1.