Phase 2 Geomorphic Assessment of the Batten Kill, Vermont

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Executive Summary

A Phase 2 geomorphic assessment of the Batten Kill mainstem and the lower reaches of 9 major tributaries was completed in Summer 2004. The results of the Phase 2 assessment document the morphological impacts of human land use on the river system (e.g., berming and channelization) identified during the previously completed Phase 1 assessment. Extensive straightening on more than 40 percent of the Batten Kill mainstem over 80 years ago has created wide, shallow, slightly incised channels with a plane bed morphology. While largely unchanging during low to moderate flows, the straightened channels are regaining sinuosity during large floods when debris blocks the channel and flow "breaks out" onto the floodplain with sufficient force to scour a new meander bend into the floodplain surface. Habitat conditions are improved in these areas of flow, sediment, and energy attenuation as evidenced by better particle size segregation, multiple velocity patterns, and deeper pools.

Nearly continuous berming is present along both banks on 4 of the 6 tributaries draining from the Green Mountains on the eastern side of the watershed: Mad Tom Brook, Bourn Brook, Lye Brook, and Roaring Branch. This berming was in response to watershed wide flooding in June 1973 but evidence exists for an earlier berming episode, perhaps following the 1936 flood. The berms still confine flows at nearly twice the bankfull depth or more, so the tributary channels have been unable to adjust to smaller "bankfull" flows. Consequently, habitat remains degraded and the channel unable to return to an equilibrium condition. Tributaries draining the Taconic Mountains generally have a stable equilibrium morphology with very little human alteration. This results from bedrock controls and valley confinement by glacial deposits – conditions not as widely present on the more disturbed Green Mountain tributaries.

The original process of berming along the tributaries in the early 1970's most likely had a direct, perhaps significant, watershed wide impact on instream habitat. Flow confinement by berms on the Green Mountain tributaries prevents flow from crossing the alluvial fan surfaces at the lower ends of the Green Mountain tributaries, as occurred prior to human settlement of the region. Although removing berms in many localities would put property at greater risk, opportunities should be sought, far from any developments, where berm removal would allow flow to escape onto the alluvial fan surface. Restoration such as this could improve habitat while simultaneously reducing the risk of a berm failure in a more populated area. Straightened channel segments on the mainstem are prone to flow escaping the channel and creating new meanders bends across the floodplain. Mimicking this process as part of restoration efforts in the watershed will speed up the natural recovery of channel sinuosity, improve physical habitat conditions, and reduce the likelihood of an unplanned "break out" across the floodplain that could adversely impact landowners along the river. By identifying how stream channels are adjusting to human impacts in the Batten Kill watershed, the Phase 2 assessment results can be used to select restoration opportunities that will not only improve habitat, but do so in a way that will bring the channel closer to a sustainable equilibrium condition.

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Introduction

A Phase 2 geomorphic assessment of the Batten Kill mainstem and the lower reaches of 9 major tributaries was completed in Summer 2004. This work is a follow up to earlier geomorphic studies, including a Phase 1 assessment and several Phase 3 assessments at different sites along the mainstem. This earlier work was completed between 2000-2003. The results of the Phase 2 assessment document the morphological impacts of human land use on the river system (e.g., berming and channelization) identified during the Phase 1 assessment. The Phase 2 reports are presented in Tables 1 and 2 with supporting documentation presented in Appendix 1 (included as a CD), including ArcView shapefiles, drafted cross sections, and ground photographs separated by reach. The shapefiles record the location of reach and segment breaks, cross section and pebble count locations, bank erosion and revetment sites, berms, flood chutes, channel avulsions, and grade controls. An improved understanding of past channel responses revealed in the Phase 2 data will help in the selection, implementation, and management of future restoration projects.

The Phase 2 assessment encompassed an analysis of 30 reaches, including the 13 reaches on the mainstem, 3 reaches each on the Green River and the West Branch, 2 reaches each on Roaring Branch, Lye Brook, Bourn Brook, and Mad Tom Brook, and 1 reach each on Warm Brook, Munson Brook, and Bromley Brook (Figure 1; Appendix 1). Some of the reaches were further subdivided into segments where human impacts have altered the naturally occurring channel morphology or subreaches where natural conditions were sufficiently different than originally identified during the Phase 1 assessment (Figure 1). All of the tributary reaches analyzed are the downstream most reaches for each particular tributary. The original Phase 1 reach delineation mistakenly considered Bromley Brook the continuation of Bourn Brook such that the second reach on Bourn Brook is actually considered a secondary tributary to Bourn Brook. For simplicity, the original reach numbering was maintained as part of this assessment but a note of the mistake added to the appropriate records on the Phase 2 DMS file. The following report is divided into separate discussions of the 13 mainstem reaches and the 17 analyzed tributary reaches.

Mainstem Assessment

The mainstem Batten Kill can be separated into 4 separate ***cells*** of influence with the upstream most portion of each cell representing a rejuvenation point that in many respects behaves as a grade control (Figure 2). Coarse sediment introduced into the channel at the rejuvenation points significantly alter channel morphology compared to points immediately upstream. While watershed-scale events such as deforestation would impact the entire river system, more localized perturbations, such as channel straightening, occurring within one cell are unlikely to cause morphological adjustments in another cell. Consequently, each cell acts like a separate river system with the rejuvenation point at the upstream end serving as a source region with points downstream transferring this sediment to a response zone at the lowest portion of each cell. Accompanying a downstream decrease in slope in each cell is a general increase in sinuosity, decrease in width:depth ratio, and a decrease in substrate particle size, but these trends are frequently disturbed by past human activities in the channel (e.g., straightening). Identification of these separate cells of influence along the river system, therefore, provides a means for anticipating the type and extent of channel adjustments that might occur in response to human land use or natural events along the river.

The location of cells on the Batten Kill can be recognized by charting downstream changes in the percentage of particles on the channel bed coarser than fine gravel (i.e., coarse gravel and coarser). Grain size decreases in a downstream direction within each cell and then increases rapidly at the rejuvenation point at the upstream end of the next downstream cell (Figure 3). While significant tributaries (e.g., Lye Brook and Green River), high eroding banks (e.g., below wastewater treatment facility in Manchester), and very broad valleys (e.g., Reach M8) complicate the simplistic model of gradual downstream reduction in grain size, these conditions are not significant enough to completely alter the channel morphology and create separate cells. Given that the purpose of the Phase 2 assessment is to identify how the stream channel is responding to natural events and human land use in the watershed, subdividing the river into separate cells provides a convenient means of discussing the assessment results.

Cell 1 – New York border to Roaring Branch confluence (Reaches M1-M4)

The Phase 1 assessment documented significant channel straightening along all 4 reaches (>75% of total stream length) within this cell (Figure 4) and a long history of gravel mining/dredging into at least the 1980’s is documented in Reach M4 near the Route 313 bridge in Arlington. Roads are present within the corridor of all 4 reaches with the river impinging against River Road and route 313 in M1-M3. While the river is causing erosion and maintenance problems along River Road at several locations, both roads closely follow the valley side slopes such that the roads are not causing a significant change in valley confinement. Land use in the river corridor is heavily agricultural and the riparian buffer is absent in many localities, particularly in Reach M3.

The impact of channel straightening on channel morphology was documented during the Phase 2 assessment. All 4 reaches have a nearly continuous plane bed morphology with deeper pools present only where the river flows against the higher banks of the valley side (or road embankments along the valley side), downstream of the Green River where sediment inputs from that tributary are constricting flow, and at bridges where flow is also constricted. Cross sections illustrate the generally wide, shallow, and incised morphology of the channel within this cell and absence of bar development (Figure 5). Despite the general lack of bar formation, sediment transport appears high through the reach because of upstream deposition and channel realignment upstream of the 2 bridges at the upstream and downstream end of River Road (Figure 6).

While the historic channel adjustments (e.g., incision and widening) in reaches M1-M4 resulting from channel straightening are largely complete, these reaches remain highly sensitive to future adjustments. Although portions of the straightened reaches have undergone a stream type departure from a “C” to an “F” type stream (Figure 5), these reaches are generally unchanging in their current late Phase II/early Phase III configuration (referring to Schumm’s channel evolutionary model) under low to moderate flows. However, during large flows, debris jams can block the channel and flow can escape out on the floodplain at a low spot along the bank. Under these conditions, channel aggradation and planform adjustments occur rapidly as new meanders form on the floodplain during Stage IV of the channel evolutionary process. The lack of a riparian buffer on the floodplain further increases the stream's sensitivity and susceptibility to these changes. The resulting flow and sediment attenuation across the floodplain at these "break out" points forms new meanders with large unvegetated point bars developing on the inside bend of the meanders (Figure 7). The resulting bankfull width in these attenuation zones (e.g., M3 Segment B) is similar to the straightened segments within the same reach (e.g., M3 Segment C)(Figure 8). Over time as fine sediment accretes on the point bar and vegetation becomes better established the bankfull width will ultimately become less than the straightened segments (i.e., as the channel evolves from a Stage IV to Stage V channel in the channel evolutionary model). Currently, even with a similar bankfull width, habitat conditions are better in the attenuation zones where there is a better segregation of particle sizes, greater variation in velocity-depth patterns, and deeper pools. The attenuation zones are areas of energy dissipation such that the reach as a whole becomes less sensitive to further "break outs" and channel adjustments.

Cell 2 –Roaring Branch confluence to Bourn Brook confluence (Reaches M5-M9)

Sediment inputs from Bourn Brook rejuvenate the stream at the upstream end of this cell with the sand and finer substrate immediately upstream of the confluence (Reach M10) replaced by a cobble substrate downstream (Reach M9). For much of Reach M9 the river has been straightened and pinned against glacial deposits along the right bank such that coarse material continues to be supplied to the channel downstream of Bourn Brook. Only downstream of the Lye Brook confluence(downstream end of Reach M9), which also supplies coarse sediment to the channel, does the substrate particle size begin to decline as the channel flows across a very broad valley with very little of its length flowing near the valley walls that might supply additional coarse sediment (Figure 3). Accompanying the downstream decrease in particle size is an increase in the natural sinuosity of the channel but this meandering is disrupted by channel straightening in many locations.

In addition to Reach M9, the Phase 1 assessment also documented significant channel straightening (i.e., high impact rating) in all of the other reaches in this cell. The straightening was likely completed to assist with draining wetlands that persist in portions of the very broad valleys within this cell. Land use within the river corridor is heavily agricultural but the riparian buffer is greater than 100 feet wide along 80 percent of all 5 reaches. In addition to the straightening, railroad construction resulted in meander cutoffs in Reach M5 and an artificial constriction of the valley in all 5 reaches of Cell 2 (Figure 9).

The impact of channel straightening on channel morphology was documented during the Phase 2 assessment and earlier Phase 3 assessments completed near the Ira Allen House in Reach M5 Segment C and D. Reach M5 was segmented into straightened portions (Segments A, C, and E) and portions where the original meanders are largely undisturbed (Segments B and D). The naturally meandering segments have a narrower bankfull width, shallower bankfull depth, lower width:depth ratio, and greater occurrence of point bars than adjacent straightened segments (Figure 10). Longitudinal profiles reveal that the well developed riffle-pool bed morphology in meandering areas is replaced by shallower and less numerous pools in straightened segments (Figure 11). These channel adjustments have resulted in degraded habitat conditions in the straightened segments with poorer pool development and less velocity-depth flow complexity. Sand substrate predominates in all segments of Reach M5 so particle size distribution is not altered by straightening.

Incision and widening associated with straightening appear to be a largely historic channel adjustment with the straightened reaches largely unchanging at the current time. The lower gradient and broader valley in Reaches M5-M8 means that flow attenuation, the creation of new meanders across the floodplain, and further channel adjustments are less likely to occur compared to the reaches in Cell 1. If such adjustments did occur during a large flow event, they would likely occur in the narrower Reach M6 or those portions of the broader valleys most severely constricted by the railroad where flow velocities would be greater. Flow attenuation, channel widening, and aggradation will more likely occur in Reach M9 because of the higher gradient and coarse sediment supply from Bourn Brook and high eroding banks along the channel (e.g., the bank below the water treatment facility in Manchester). Upstream of the Union Street bridge in Manchester (Reach M9), at the upstream end of Cell 2, a new meander was created where a debris jam blocked the straightened channel and flow scoured the floodplain as in Cell 1 (Figure 7).

Cell 3 –Bourn Brook confluence to Little Mad Tom Brook confluence (Reaches M10-M11)

While Little Mad Tom Brook itself provides some coarse sediment, the river also flows against high banks of glacial deposits along most of the length of Reach M11. Although no severe bare erosion spots exist along these high banks, coarse sediment is likely derived from these glacial deposits. Despite the presence of Dufresne Pond and small wetland areas upstream, a coarse substrate is maintained along the reach until the channel no longer flows against the high banks downstream of the Route 30 bridge in Manchester. Downstream of the bridge, grain size decreases rapidly with inputs from the West Branch having a minimal impact on the substrate particle size.

Unlike the significant straightening in Cells 1 and 2, no evidence for straightening exists in Reach M10 and only 15 percent of Reach M11 appears to have been straightened. The greatest human impact in Cell 3 documented during the Phase 1 assessment is urban development in the town of Manchester along the river’s right bank at the downstream end of Reach M11. The direct impact of these developments on river morphology, however, is probably minimal because the developments are situated on a low terrace above the river’s floodplain. The riparian buffer width is over 100 feet along greater than 85 percent of both reaches.

Only the short straightened sections of Reach M11 have experienced historic channel adjustments. As in Cells 1 and 2, the straightened sections have a wide, shallow, plane bed morphology with degraded habitat conditions compared to the unaltered areas. Reach M10 has several beaver dams present that create backwater areas punctuated by short falls or riffle as water flows over the dams. The beaver dams, as well as other debris in the reach, effectively trap fine to coarse gravel sediment. Flow escapes over the banks in the backwater areas creating split flows and side channels (Figure 11). The creation of side channels, flow velocity variations, and gravel deposits results in improved habitat conditions. Although the creation of side channels may lead to occasional channel avulsions during large events, Reach M10 should be considered geomorphically stable and could serve as a reference condition for the downstream ends of other cells where human activities have depleted the availability of wood in the channel and on the banks.

Cell 4 –Little Mad Tom Brook confluence to headwaters (Reaches M12-M13)

Channel straightening has occurred along nearly 60 percent of Reach M12 and also appears to be extensive in Reach M13 (although initially undocumented in the Phase 1 assessment). Roads and railroads occur along 70 percent of Reach M13 with several bridges and culverts crossing or in the channel in both reaches. Development within the corridor is minimal but the riparian buffer is absent along at least 75 percent of Reach M12 and 30 percent of Reach M13. A majority of the river’s flow is diverted into South Village Pond beginning in Reach M13 with the flow returning to the mainstem Batten Kill in Reach M12.

An approximately 400-foot long section near the downstream end of Reach M13 (upstream of the old railroad depot in East Dorset; Segment B) has been straightened with an old, carefully constructed, rock wall built along both banks. The channel is incised (incision ratio = 1.7) but the rock wall has arrested bank widening, so the channel remains relatively narrow (width:depth ratio = 9.2). Upstream of the rock wall, a large mid-channel bar is forming due to backwater ponding as the flow enters the constricted reach with the rock wall. Debris clogging the culvert under the railroad grade at the downstream end of Segment C has created, or at least enhanced, a wetland behind the railroad embankment. Neither Segment C nor Segment D, the short steep mountainous portion of the reach at the terminus of the mainstem, was analyzed in detail. Future channel adjustments in Reach M13 are unlikely as long as the culvert debris blockage, rock wall, and flow diversion are maintained. A railroad maintenance crew working on the day of the field assessment appeared to be clearing the debris from the culvert. With clearing of the culvert, continued growth of the gravel bar upstream of the rock wall might be expected to accompany larger flows.

Reach M12 is a “C” type stream by reference with Segment A remaining that way today. The upper portion of M12 (Segment B) has experienced straightening with flashboards placed along the low left bank in an attempt to keep flow from escaping across the floodplain. Where the flashboards are in disrepair, flow is spilling onto the floodplain even during low flow. Channel planform adjustments will likely accompany a larger flow event with more side channels created. Given the low gradient and broad valley, widespread scour and channel avulsion are unlikely. The planform changes should improve habitat conditions compared to the current straightened configuration (as the conditions return to those that currently exist in Segment A) and the lack of human development in the reach means that little, if any, infrastructure would be harmed by planform adjustments.

Summary of mainstem channel conditions

The major human influence on the Batten Kill mainstem has been channel straightening. While much of the main stem has experienced historic channel incision and widening in response to this straightening, the channel is, at present, generally unchanging during small to moderate flows as evidenced by the very low levels of bank erosion along its length (less than 2 percent). However, the straightened channel segments are inherently unstable during large flow events and are highly sensitive to channel widening and planform adjustments where sediment transport capacity decreases rapidly due to debris blockage or loss of flow confinement. At these locations, the channel has a tendency to "break out" across the floodplain by scouring a new meander loop into the floodplain while cutting off a short portion of the previously straightened channel (Figure 7). Evidence for this process is seen at 3 locations on the mainstem (Reach M1 Segment B, Reach M3 Segment B, and upstream end of Reach M9). Straight channel segments in steeper portions of reaches close to the rejuvenation points of each cell are the most sensitive to future "break outs" because of the associated higher stream power and sediment load. While portions of the channel have been straightened at the downstream ends of some cells, the lower gradient and sediment load makes these straightened segments less prone to "break outs". Habitat conditions are improved within the newly created meander loops due to a greater segregation of particle sizes, more variation in flow velocities, and deeper pools.

Tributary Assessment

A distinct difference exists in the character of tributaries emanating from the Green Mountains on the east side of the Batten Kill (i.e., Mad Tom Brook, Bourn Brook, Bromley Brook, Lye Brook, Roaring Branch, and Warm Brook) compared to those draining the Taconic Mountains on the west (i.e., West Branch, Munson Brook, and Green River). The morphological character of the tributaries within the same source region is very similar, so channel response to human land use and natural events in one tributary will likely be similar in another tributary draining from the same source area. Consequently, the discussion of the tributary assessment results below is subdivided by mountain range.

Taconic Mountain tributaries

Bedrock and valley side wall constraints are responsible for a lack of channel migration observed on historical aerial photographs during the Phase 1 assessment of Munson Brook and West Branch. Since the 1970's, a large scale channel avulsion or human diversion occurred on the alluvial fan at the terminus of Green River where no such valley constraints or grade controls exist. Development pressures are highest on the Taconic Mountain tributaries, especially the downstream ends of Munson Brook and West Branch in Manchester. Numerous road crossings are present on each tributary. Straightening of the channel is significant only on the lowest end of Green River (T1.01). The riparian buffer is greater than 100 feet wide along 85 percent of Munson Brook and upper West Branch (T6.02 and T6.03) but less than 10 percent on lower West Branch (T6.01) and lower Green River (T1.01).

Both Munson Brook and West Branch have waterfalls near the confluence with the Batten Kill (Figure 13). Their presence might demarcate a geological fault line bounding the west side of the valley. The waterfall on West Branch is in the center of Manchester and a small dam and mill building is situated on the falls. The stream flows downstream through a heavily developed portion of Manchester before reaching a low gradient area dominated by beaver dams at the confluence with the Batten Kill. The West Branch flows into Reach M10, which is similarly characterized by beaver dams that divert flow into habitat enhancing side channels. Beaver dams are also present on the lowest end of Munson Brook. Immediately upstream of the waterfalls on Munson Brook and West Branch the streams have only narrow floodplains, if any, with glacial sediments constricting the valleys and the streams frequently flowing along these nonalluvial materials (T5.01-B and T6.02-A). Wetlands with poorly defined channels characterize the areas further upstream (T5.01-C and T6.02-B) and were not analyzed in detail as part of this study. Munson Brook eventually rises steeply as a small drainage near the Southern Vermont Arts Center that was not studied in detail (T5.01-D). Upstream of the wetland area on West Branch near the town park in Manchester, the stream channel again becomes well defined with a deep pool occurring where the left bank flows against bedrock (T6.03). The channel otherwise has a more plane bed morphology with a berm on the left bank extending 630 feet upstream of the bedrock exposure. A linear depression on the right bank floodplain parallels the stream channel and may be the remnants of an old diversion channel leading to a mill or some other structure no longer visible. While West Branch continues upstream to Dorset, the Phase 2 assessment terminated at Reach T6.03.

Most of the urban development in Manchester occurs on low terraces, not the floodplain, so its direct impact on Munson Brook and West Branch is minimal. Active and historic channel adjustments on these two tributaries are mostly localized to either natural or artificial constrictions. Debris accumulating in the West Branch channel downstream of the Route 30 bridge (T6.02-A) has caused the upstream accumulation of fine sediment, precipitating the human excavation of a side channel to allow flow to circumvent the debris jam. Bridges and culverts crossing, or in, the channels, are responsible for downstream scour, which in places has been treated with bank armoring (Figure 14). Only further upstream on West Branch (T6.03) has channel straightening resulted in historic channel widening. Given the straightening, the broad floodplain with previous diversion channels and the presence of a levee would suggest the potential for future planform changes and widening as on the mainstem. The mature forest within the corridor and bedrock controls along the left bank, however, provide for better habitat conditions than observed along straightened reaches on the mainstem.

Green River, draining a slightly different rock type than the other 2 Taconic Mountain tributaries, is morphologically distinct. With no bedrock grade controls near the terminus of the tributary, a well developed alluvial fan exists. Historic planform changes reflect the potential for future changes, especially during larger events. The wide shallow plane bed morphology that characterizes the channel across the alluvial fan may represent an equilibrium condition in the absence of a well forested fan surface and woody debris in the channel. Sediment levels on the Green River are higher than the other 2 Taconic Mountain tributaries because of different lithologies and more confined valleys with steeper side slopes. Multiple mid-channel and point bars in T1.02 are causing localized bank erosion on outside bed of channels. Where the riparian buffer is present, habitat conditions are good with the introduction of debris. Poorer conditions are present where the buffer is absent, bank erosion is accelerated, and oversized unvegetated bars reduce cover. A delta bar emanating from Hamilton Hollow at the downstream endpoint of T1.03 has resulted in periodic dredging with the spoil piles placed on the opposite banks. This secondary tributary as well as high nonalluvial banks upstream in T1.03 serves as a source area for the sediments driving channel adjustments due to aggradation in downstream reaches (T1.01 and T1.02).

Green Mountain tributaries

The assessed reaches on the 4 primary Green Mountain tributaries are on well developed alluvial fans with multiple abandoned channels on their surfaces (Figure 15). Modest residential (Bourn and Lye Brooks) and commercial developments (Roaring Branch) are present on the fan surfaces. Although these developments are largely outside the river corridor mapped in the Phase 1 assessment, they are adjacent to abandoned channels that may have once been active hundreds of years ago. All of the channels on the primary tributaries have been nearly continuously straightened with the windshield survey revealing berms along the channel margins. The riparian buffer is over 100 feet wide along 80 percent of all the Green Mountain tributaries except for the lowest reach on Mad Tom Brook (T7.01) and Bourn Brook (T4.01) where the buffer is 100 feet wide on less than 60 percent and 40 percent of these reaches, respectively. Much of the stream corridor on Lye Brook, Bourn Brook, and Roaring Branch is forested but the Mad Tom Brook corridor is predominately agricultural. Bromley and Warm Brooks are secondary tributaries that flow onto the alluvial fan surfaces constructed by the primary tributaries into which they flow. Both commercial and residential developments are present along these 2 assessed secondary tributaries.

Nearly continuous berming is present along both banks on Bourn Brook, Lye Brook, and Roaring Branch and along the left bank of Mad Tom Brook (Figure 16). The berm on Lye Brook's left bank terminates where the channel has been placed along the bedrock valley side slopes. Only minor berming is present on the right bank of Warm Brook and no berms were observed on Bromley Brook. Numerous flood chutes are present at the termini of Warm Brook and Bromley Brook where they lose confinement and join Roaring Branch and Bourn Brook, respectively. An historical ground photograph found at the Arlington Public Library demonstrates that berming on Roaring Branch occurred shortly after the June 1973 flood, the largest flood on record since 1936 (Figure 17). The presence of double berms on Lye Brook (Figure 18) and patterns of vegetation growth on berms along Bourn Brook (Figure 19) suggest that widespread channelization occurred on all of the primary Green Mountain tributaries in response to the 1973 flood (Figure 18). The double berms on Lye Brook also indicate a prior history of channelization, perhaps related to the 1936 flood. In addition, a very large berm, protecting several homes, was more recently built on a short section of Lye Brook in conjunction with construction of the Route 7 bypass (Super 7).

Flow access to the alluvial fans at the lower ends of these tributaries is blocked by the berms, thereby increasing flow velocities and delivery of sediment to the Batten Kill mainstem while reducing the creation and maintenance of side channels on the alluvial fans. The lack of flow attenuation across the Roaring Branch alluvial fan is probably in part responsible for the severe erosion of a high bank of glacial deposits directly across from the Roaring Branch confluence (Figure 20). The integrity of the berms is sound in most locations and their height, more than or near twice the bankfull depth (Figure 18), mean that flow is confined at even large flows and the stream channel unable to adjust to smaller "bankfull" flows. Consequently, gravel bars remain unvegetated and the stream channel unable to completely "heal" (i.e., reach StageV of Schumm's Channel Evolution Model) from the 1973 flood, subsequent berming, and later floods (e.g., 1976). At the ends of berms (e.g., Bourn Brook) or where breaches are present in the berms (e.g., Lye Brook), flow escapes from the current channel and enters side channels that are being created in the surrounding forested areas. Habitat conditions are improved in these areas because deeper pools form where the escaping flow can scour around tree trunks and reduced flow velocities in the main channel can lead to revegetation of bars. While no breaches in the berms are currently present near human settlements, the presence of berms near settlements in other areas bespeaks to the potential hazards present on all of the Green Mountain tributaries if a berm was to fail during an extreme event.

Summary of tributary channel conditions

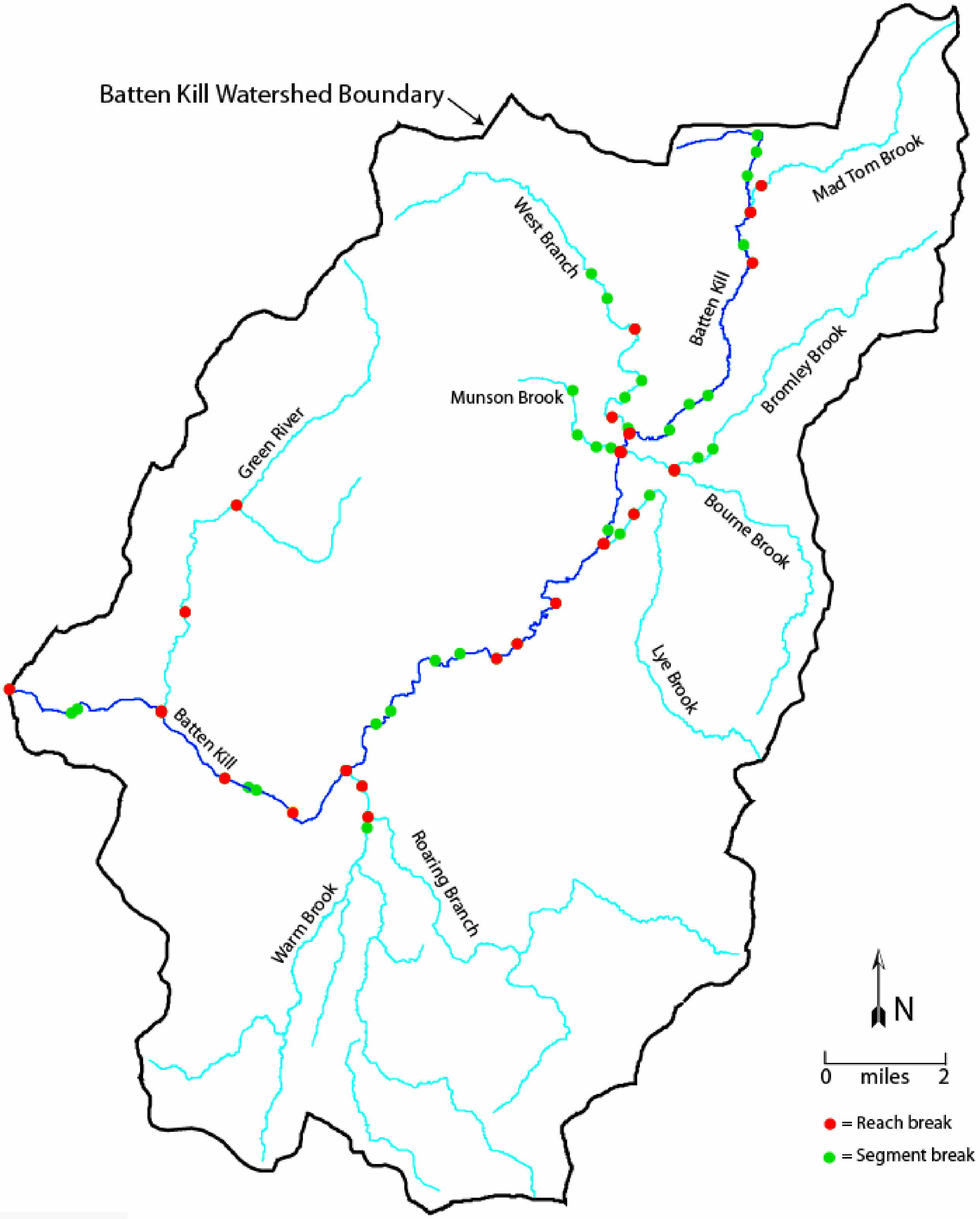
Differences between the Taconic and Green Mountains lead to morphological difference in the Batten Kill tributaries emanating from these 2 geological provinces. Tributaries draining the Taconic Mountains have largely stable channel configurations due to the existence of bedrock controls and channel confinement within higher banks of glacial deposits. The Green Mountain tributaries, in contrast, have experienced widespread historic channelization that has created instabilities that persist until today. Flow confinement by berms prevents the improvement of habitat conditions by maintaining a plane bed morphology and large unvegetated bars. While the berms do protect homes and other infrastructure during small to moderate flow events, a berm breach during a large flood could lead to serious damages.

Restoration Opportunities

Sinuosity is slowly returning to straightened reaches of the mainstem by forming new meanders at points of flow and sediment attenuation ("break outs") where the flow has been diverted by debris or has overtopped its banks (Figure 7). Locating additional attenuation assets elsewhere where natural flow conditions can be restored will hasten the process by which the channel regains sinuosity after being artificially straightened in the past. Restoration and management efforts of this sort would improve habitat, allow the stream to expend energy in undeveloped areas, and, consequently, reduce the risk of flood damage to human infrastructure elsewhere.

The original process of berming along the Green Mountain tributaries in the early 1970's, with heavy machinery in the channel, most likely had a direct, perhaps significant, watershed wide impact on instream habitat. Flow confinement by berms on the tributaries continues to prevent a full return to equilibrium conditions created when flow crosses the alluvial fan surfaces found at the lower ends of the Green Mountain tributaries. Although removing berms in many localities would put property at greater risk, opportunities should be sought, far from any developments, where berm removal would allow flow to escape onto the alluvial fan surface. Restoration such as this would have several advantages: 1) create side channel habitat on the alluvial fans; 2) reduce peak flow velocities within the formerly confined tributary, thereby permitting revegetation of gravel bars; 3) reduce the risk of berms catastrophically failing in other areas where property might be damaged; 4) allow the stream to expend additional energy before entering the mainstem; and 5) return the stream to a more natural flow regime. The implementation of restoration strategies on the tributaries and mainstem that run counter to traditional river management techniques will require a concerted education effort throughout the watershed that increases public understanding and support for restoration plans that can potentially improve fish habitat, reduce risks to human infrastructure, and return streams to a natural equilibrium condition by hastening the natural channel evolutionary process.

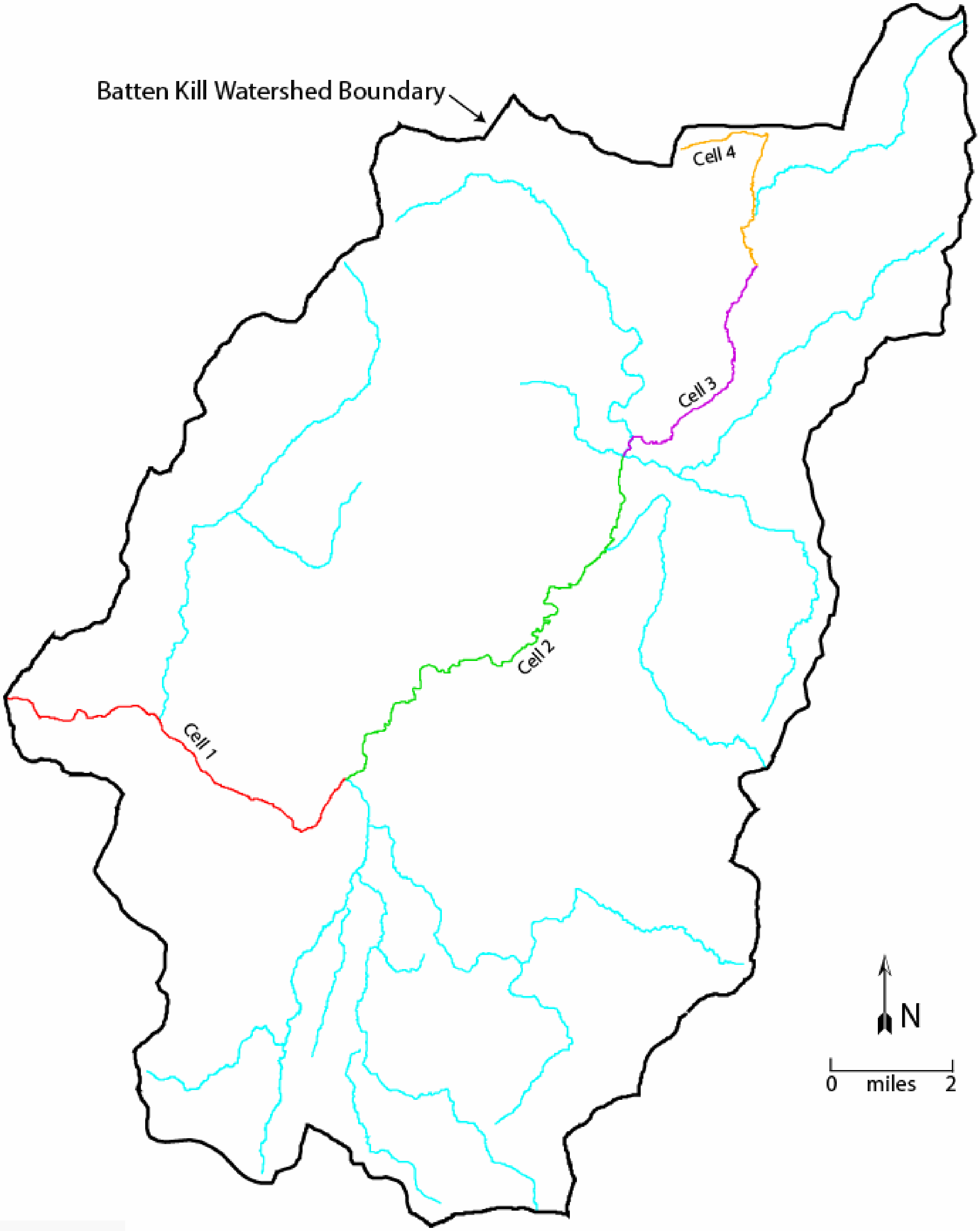
Location of Phase 2 Reach and Segment Breaks



Field Geology Services
Fluvial Geomorphology

Batten Kill Phase 2 Assessment - Figure 1

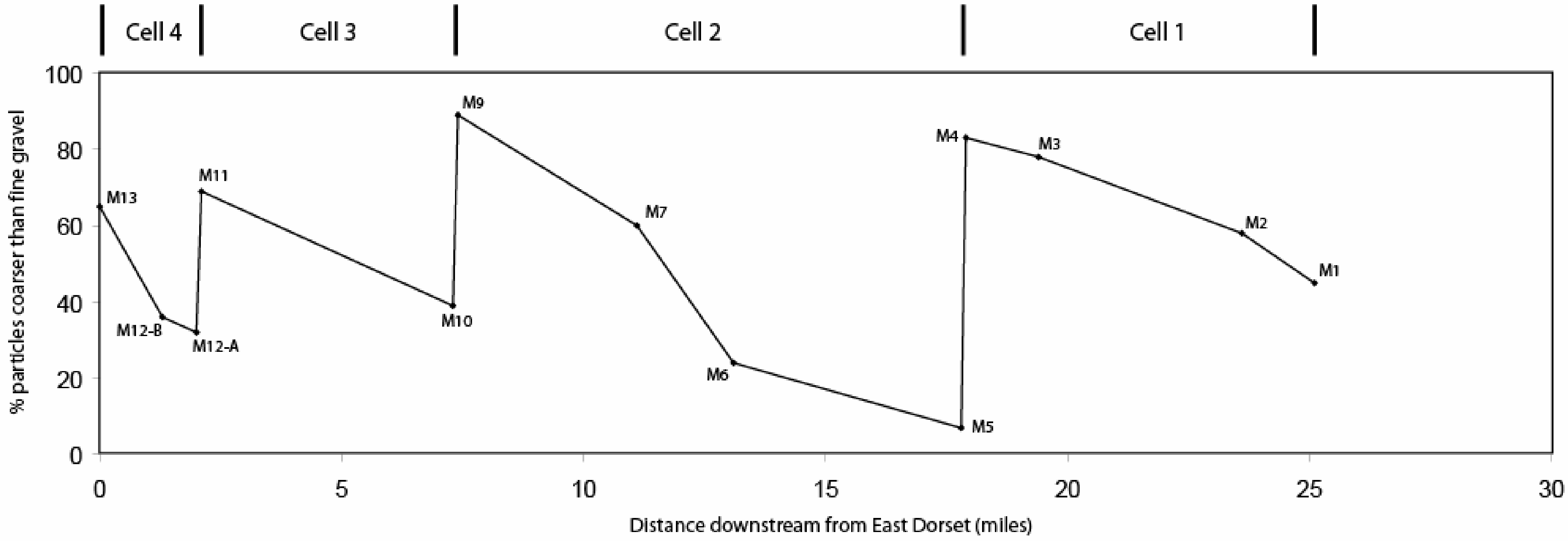
Location of Separate Cells of Influence



Field Geology Services
Fluvial Geomorphology

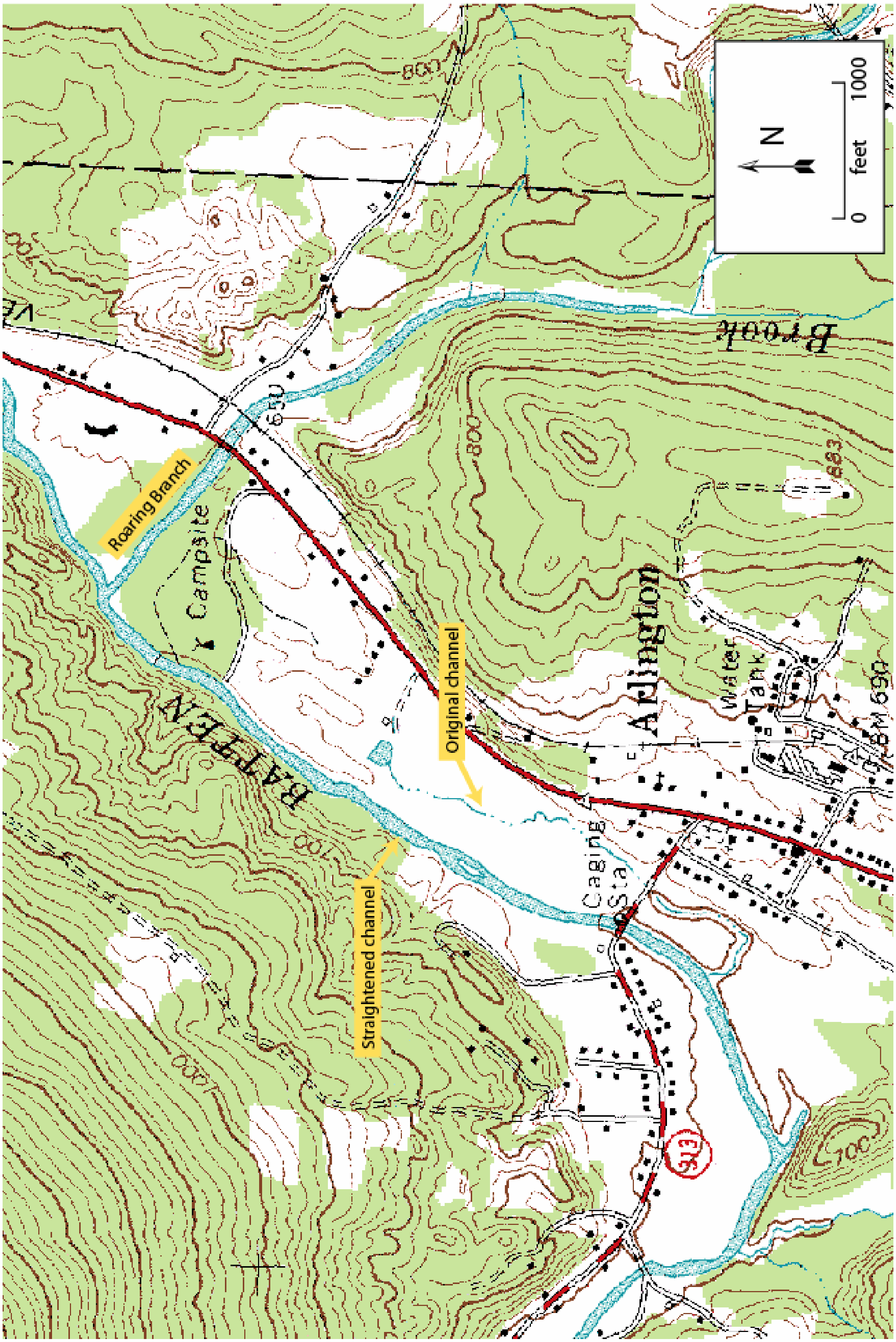
Batten Kill Phase 2 Assessment - Figure 2

Downstream Changes in Substrate Particle Size



Batten Kill Phase 2 Assessment - Figure 3

Straightened Channel Downstream of Roaring Branch



Batten Kill Phase 2 Assessment - Figure 4

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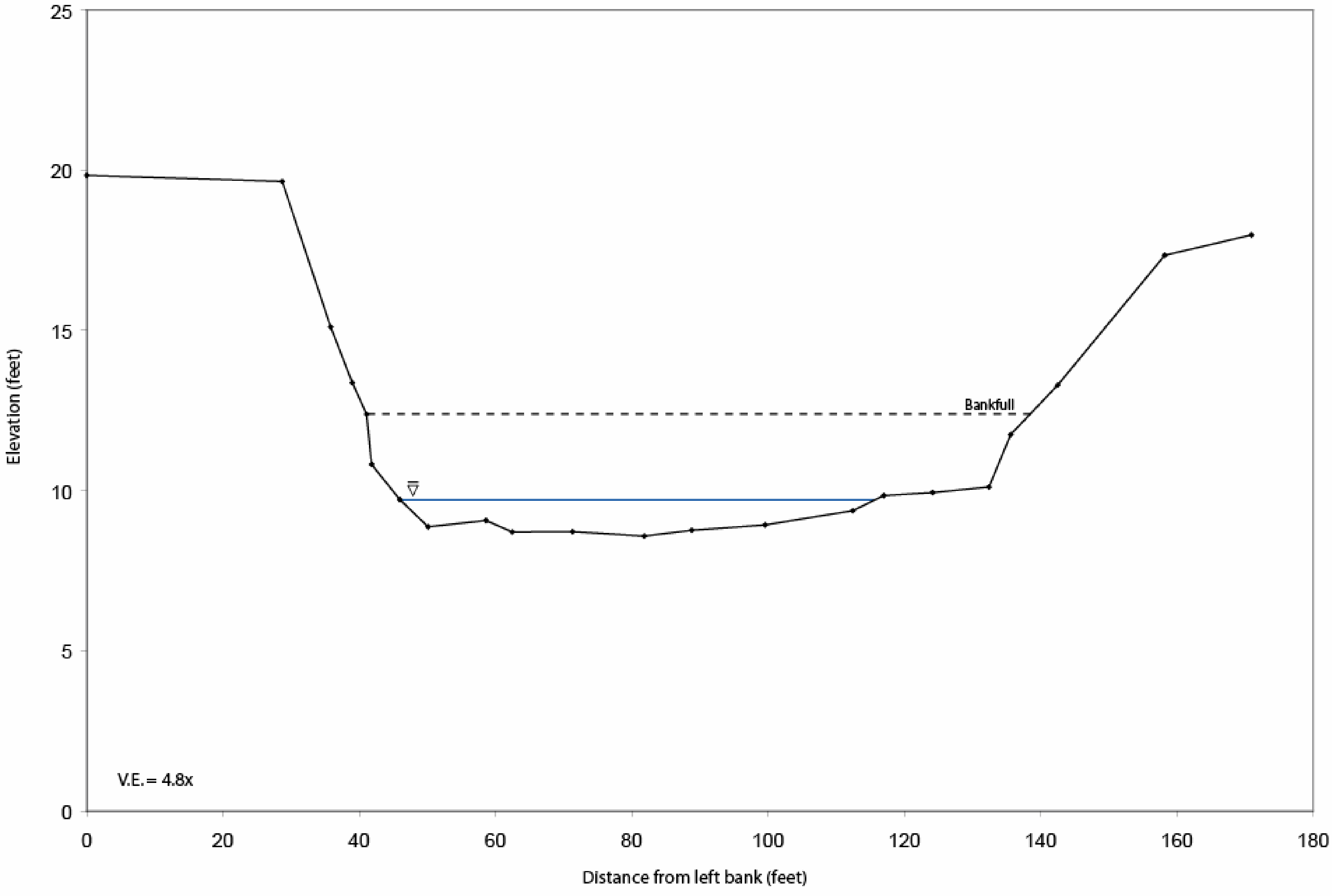
Cross Section of Straightened Channel in Reach M2



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Batten Kill Phase 2 Assessment - Figure 5

Bar Deposition and Channel Realignment Upstream of Bridge in Reach M4

Note: View looking upstream from Rochester Bridge

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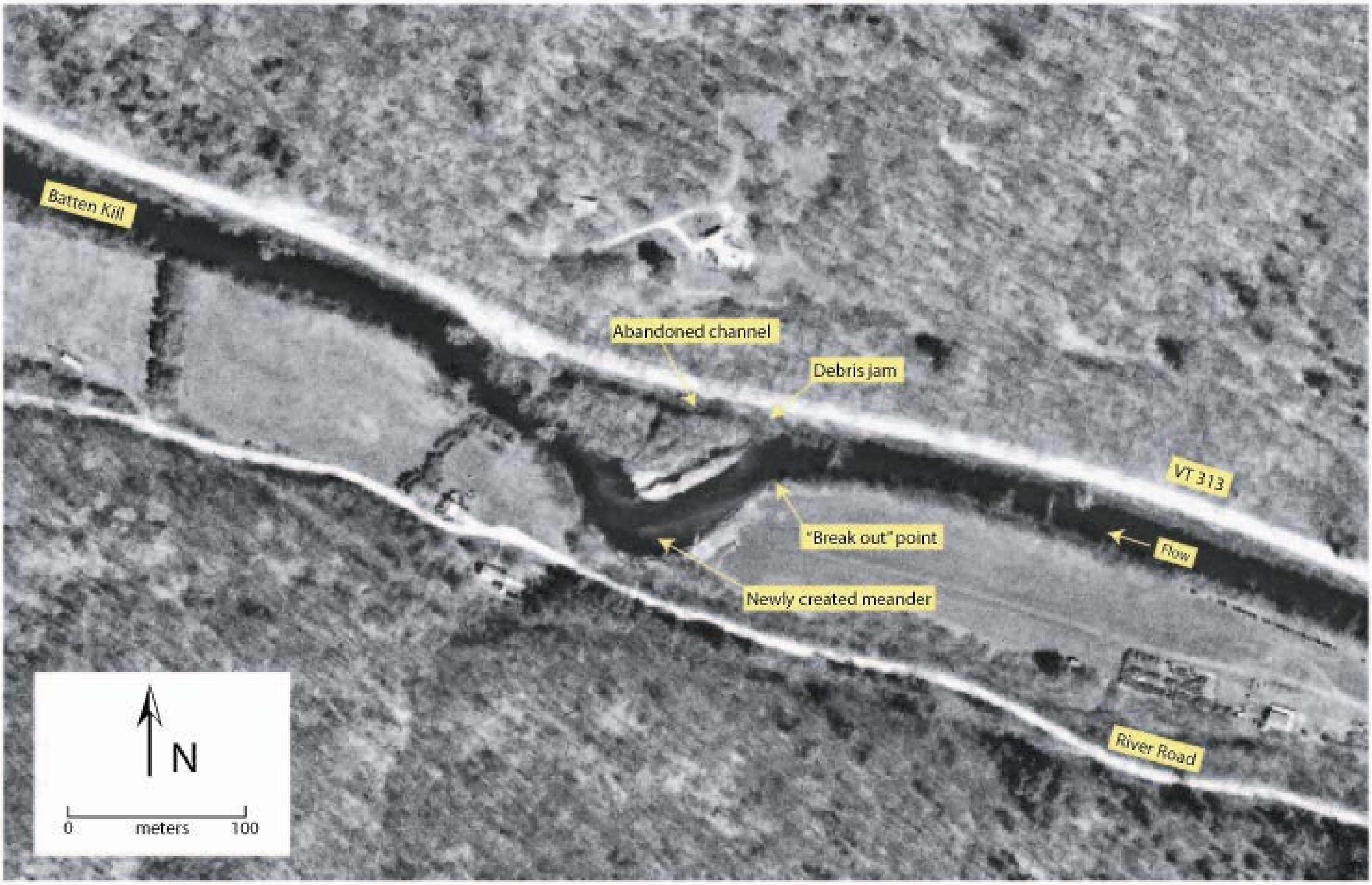
Batten Kill Phase 2 Assessment – Figure 6

New Meander Created at “Break Out” Point (Reach M3 Segment B)



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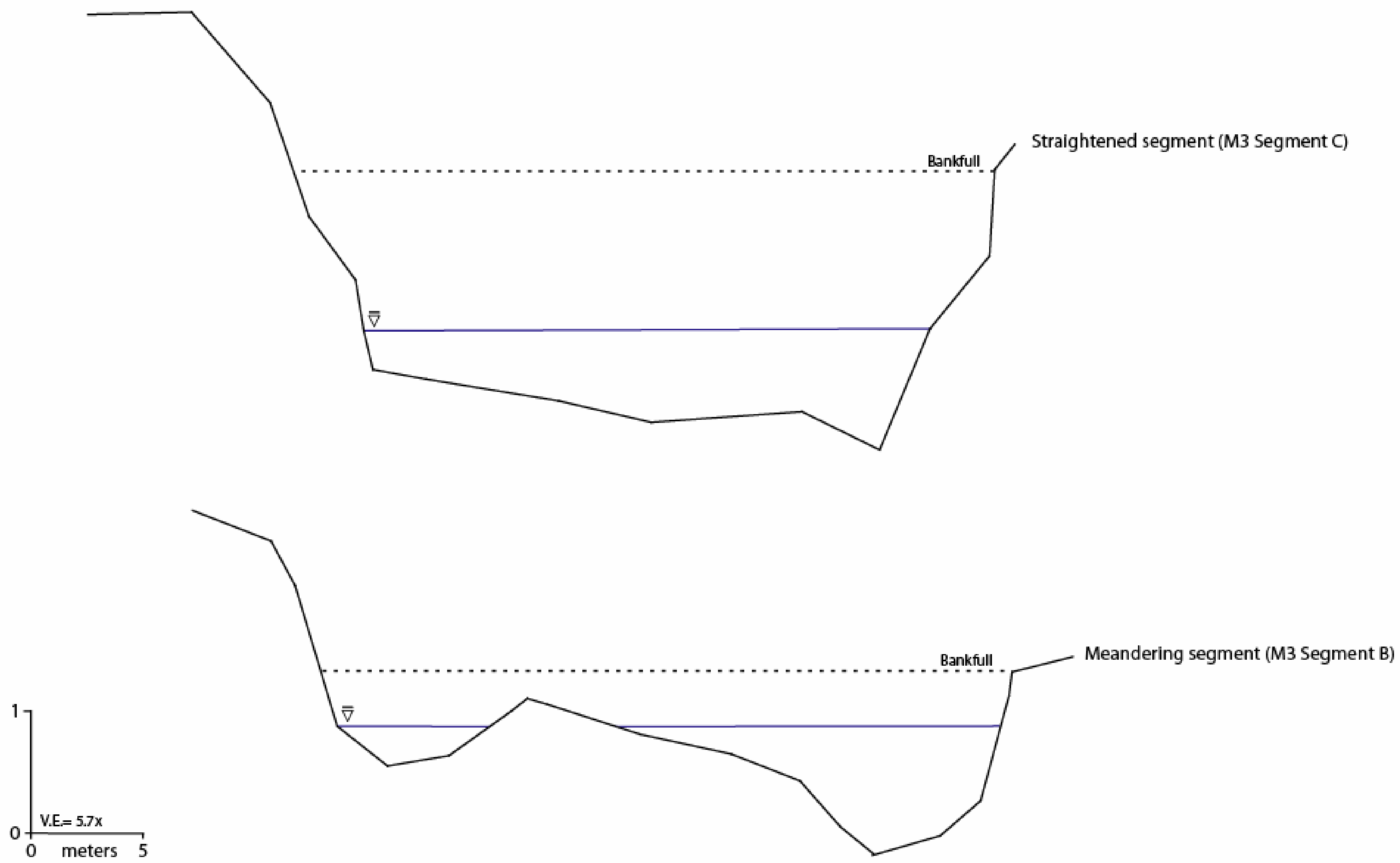
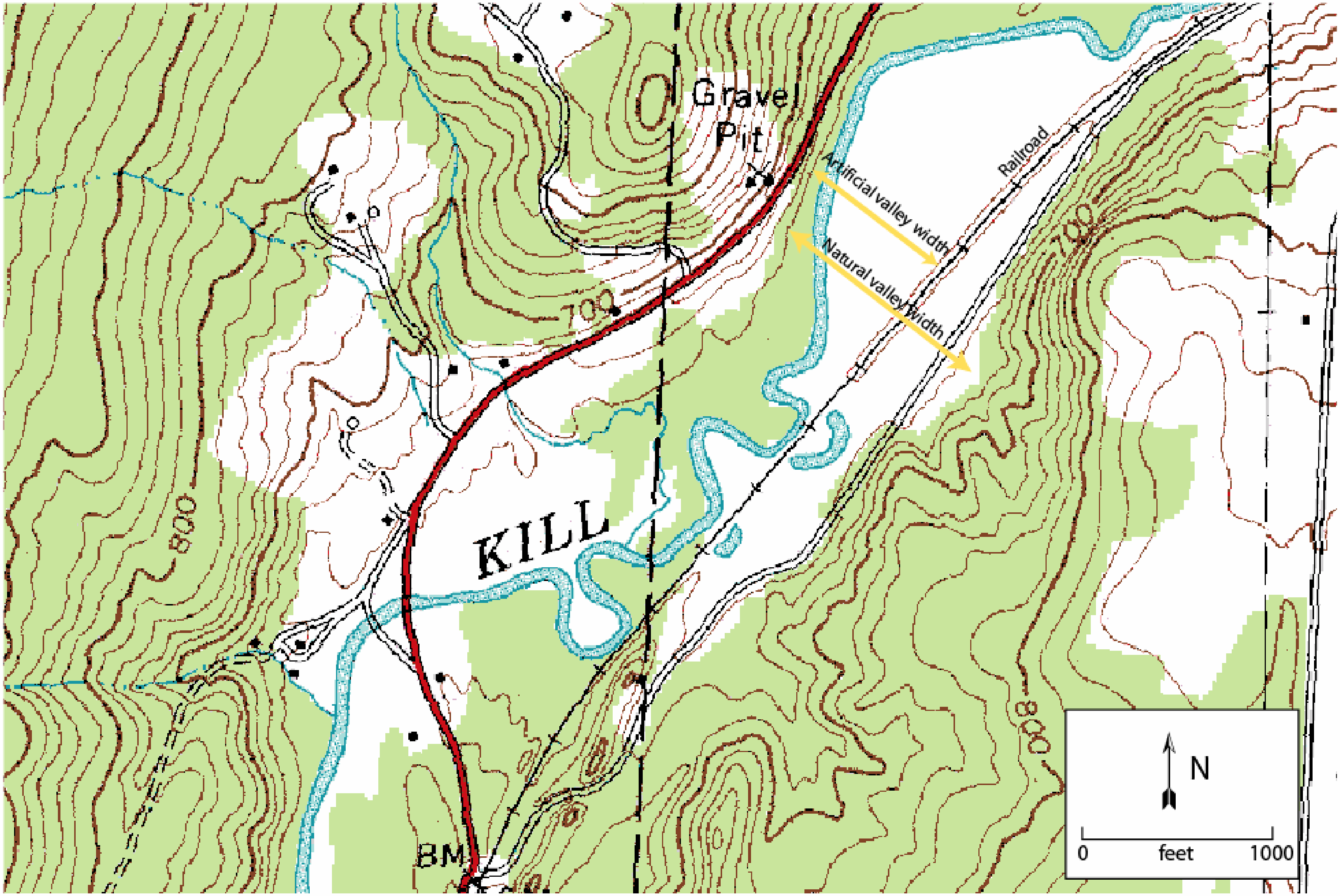
Batten Kill Phase 2 Assessment – Figure 7

Comparison of Straightened and Meandering Channel Bankfull Widths



Batten Kill Phase 2 Assessment - Figure 8

Railroad Impacts on Valley Width and Meander Geometry (Reach M5-B)



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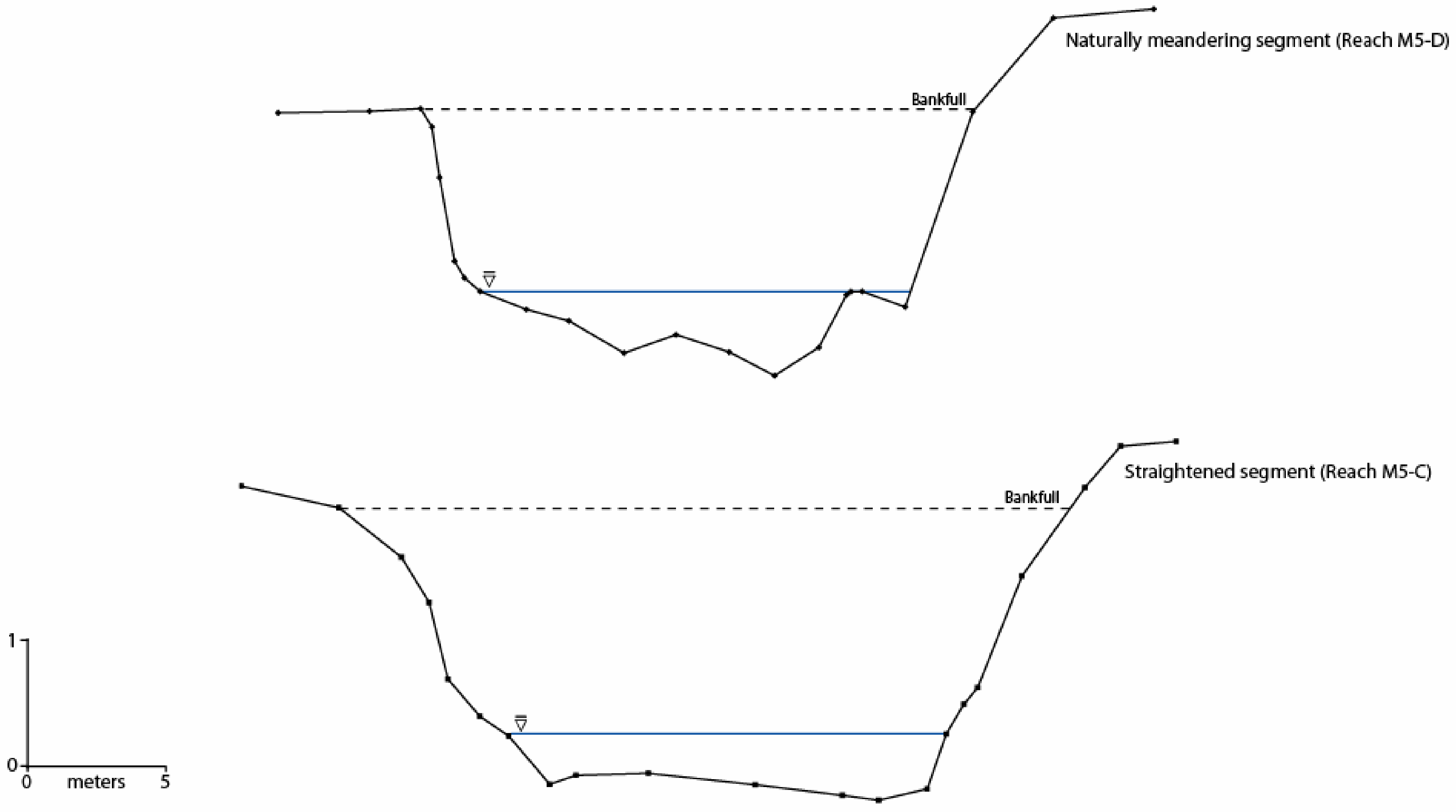
Batten Kill Phase 2 Assessment - Figure 9

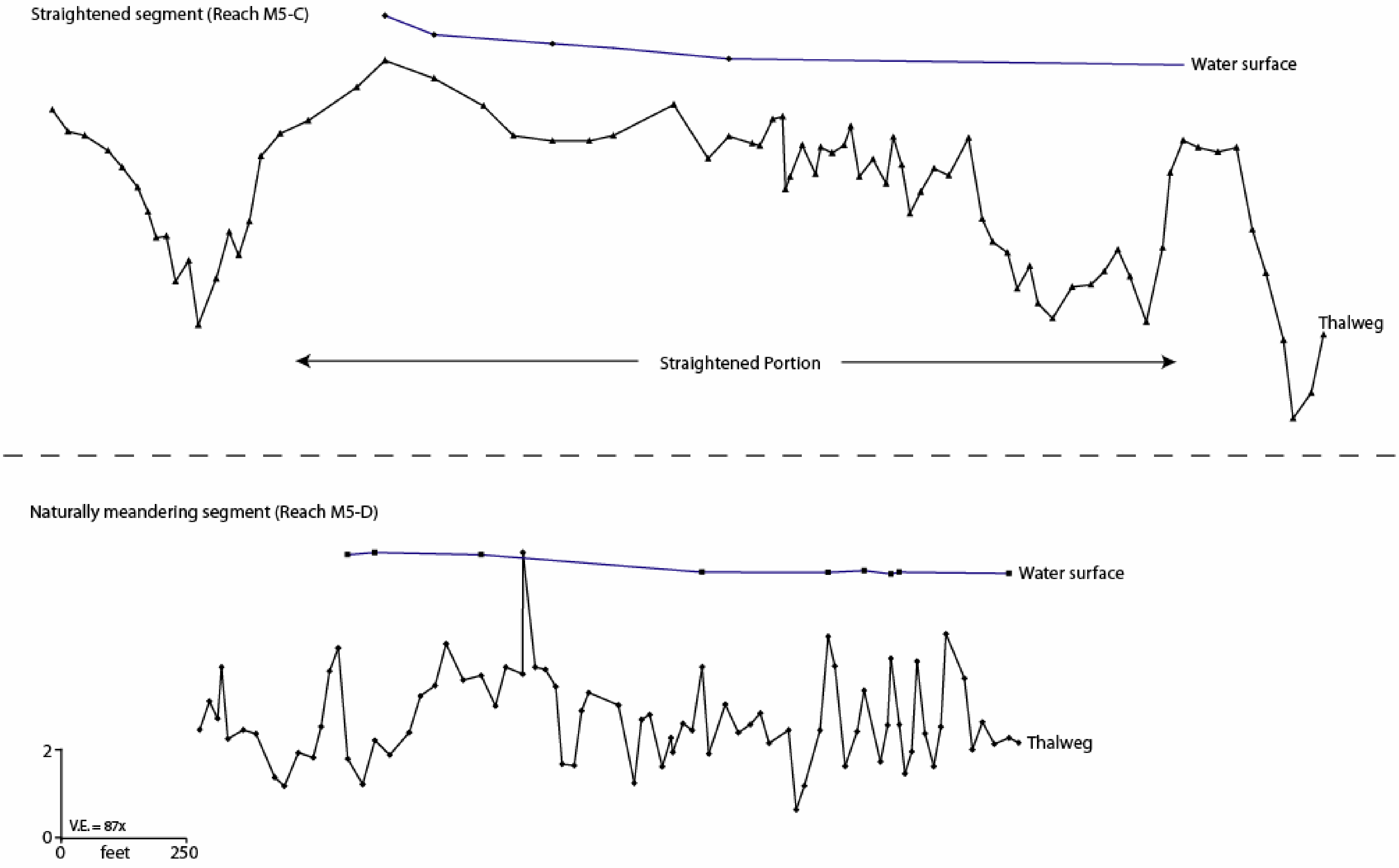
Increased Bankfull Width in Straightened Channel



Field Geology Services

Batten Kill Phase 2 Assessment - Figure 10

Longitudinal Profile of Straightened and Meandering Channels



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Batten Kill Phase 2 Assessment - Figure 11

Flow Splitting in to Side Channel (Reach M10)

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Batten Kill Phase 2 Assessment – Figure 12

Waterfall on Munson Brook (Reach T5.01-A)

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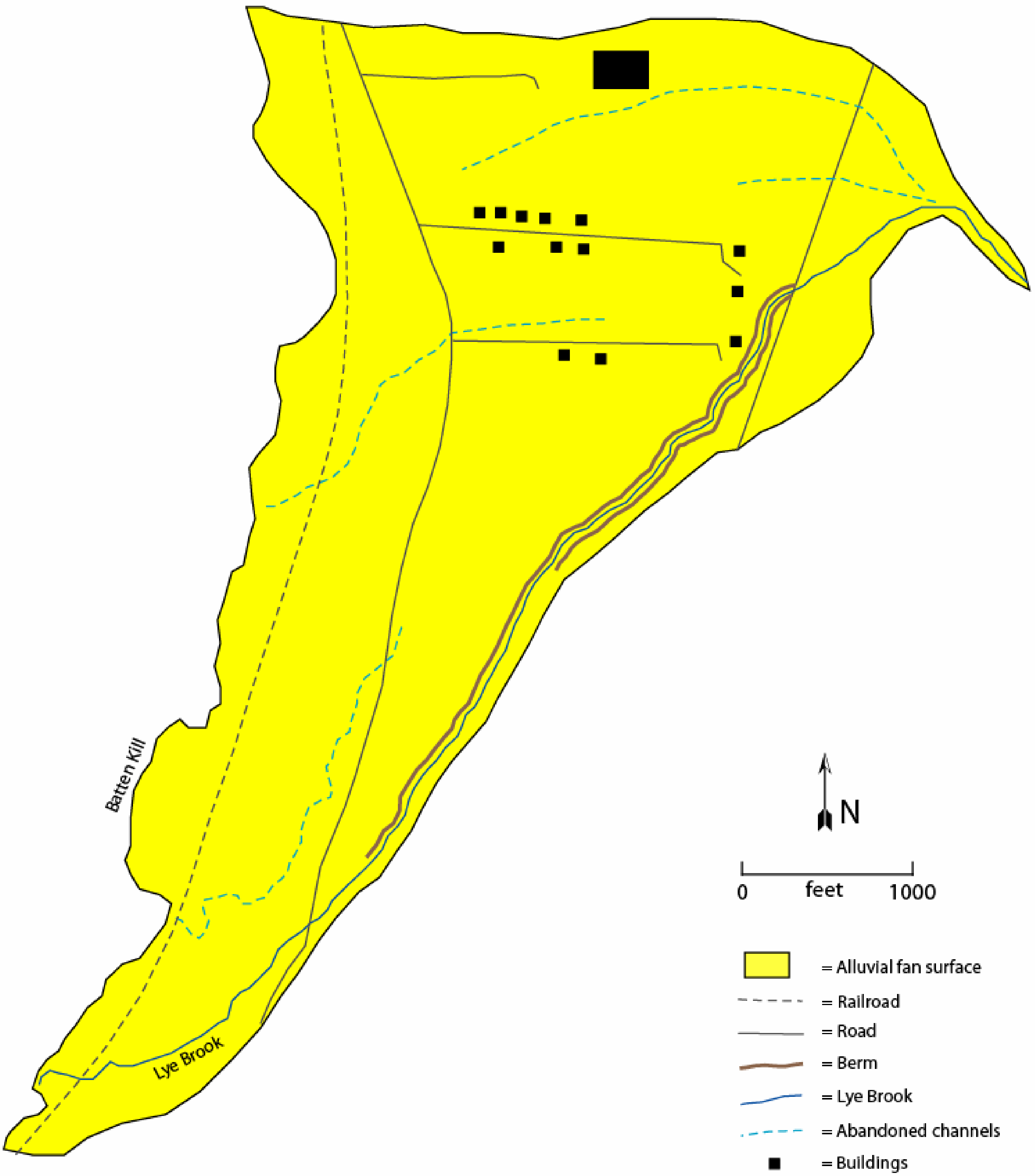
Batten Kill Phase 2 Assessment – Figure 13

Bank Armoring Downstream of Culvert (Reach T5.01-B)

Batten Kill Phase 2 Assessment – Figure 14

Lye Brook Alluvial Fan

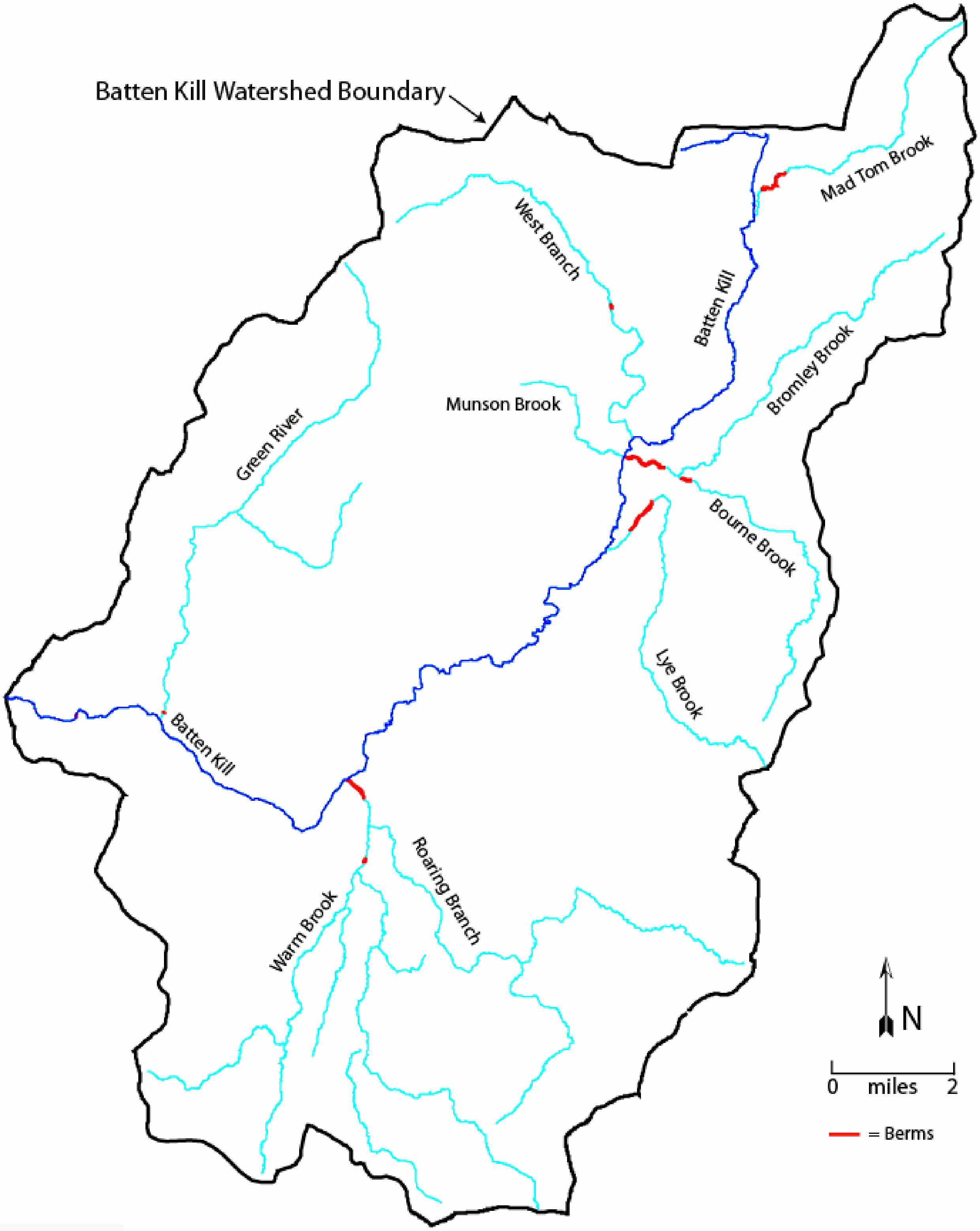


Note: Batten Kill mainstem flows along western edge of alluvial fan surface

Field Geology Services

Batten Kill Phase 2 Assessment - Figure 15

Location of Tributary Berms on Assessed Reaches



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Batten Kill Phase 2 Assessment - Figure 16

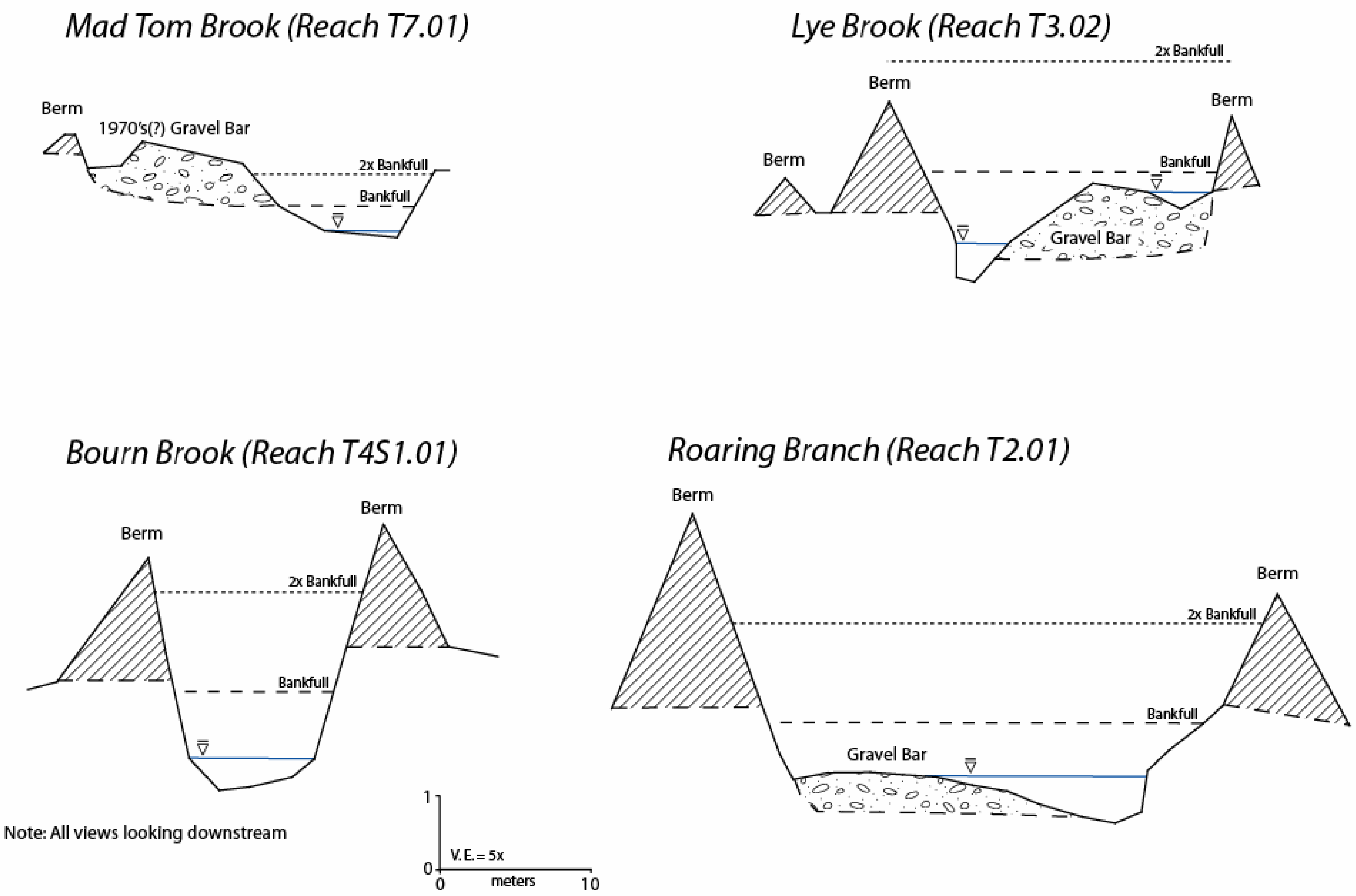
Berm Construction on Roaring Branch Following 1973 Flood

PRATT SidE

MEAR'S SidE

Flood WoRK on BRANCH · OCT. 7, 1973.

Cross Sections of Berms on Green Mountain Tributaries



Note: All views looking downstream

Field Geology Services

Batten Kill Phase 2 Assessment - Figure 18

Patterns of Vegetation Growth on Bourn Brook Berm

Note: Old dieing tree in center of photo was stressed when base was buried during berm construction. All healthy trees growing on berm are less than 30 years old.

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Batten Kill Phase 2 Assessment – Figure 19

High Eroding Bank Across from Roaring Branch Confluence

Note: View looking upstream on Batten Kill

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Batten Kill Phase 2 Assessment – Figure 20

Table 1 - Summary of Phase 2 stream geometry

Stream Geometry Data

Battenkill River

		Phase 2 Stream Type					Phase 1 Data		Phase 2 Channel Data											
Reach	Seg- ment	Stream Type	Bed Material	Bedform	Subcl. Slope	Sub Rch?	Slope	Channel width	Bankfull width	Max. depth	Mean depth	Floodpr. width	Low Bank Ht	W/D Ratio	Entrench- ment	Incision Ratio	Stage Evol.	Evol. Model	RGA Cond.	RHA Cond.
M01	A	C	Gravel	Plane Bed	c	No	0.3	144.0	117.0	7.3	6.8	6.8	7.3	17.2	8.5	1.0	III	F	Good	Fair
M01	B	C	Gravel	Riffle-Pool	c	No	0.3	144.0	162.0	6.0	3.9	3.9	6.0	41.5	6.2	1.0	IV	F	Fair	Fair
M01	C	C	Gravel	Plane Bed	c	No	0.3	144.0	117.0	7.3	6.8	6.8	7.3	17.2	8.5	1.0	III	F	Good	Fair
M02	0	C	Gravel	Plane Bed	c	No	0.3	130.4	91.0	4.5	4.0	4.0	10.0	22.8	8.3	2.2	III	F	Fair	Good
M03	A	C	Gravel	Plane Bed	c	No	0.1	127.9	102.0	7.3	5.3	5.3	8.0	19.2	4.3	1.1	III	F	Good	Fair
M03	B	C	Gravel	Plane Bed	c	No	0.1	127.9	102.0	8.1	6.1	6.1	8.2	16.7	4.3	1.0	III	F	Good	Good
M03	C	C	Gravel	Plane Bed	c	No	0.1	127.9	102.0	7.3	5.3	5.3	8.0	19.2	4.3	1.1	III	F	Good	Fair
M04	0	C	Gravel	Plane Bed	c	No	0.4	127.2	111.0	5.5	3.3	3.3	7.2	33.6	11.1	1.3	III	F	Good	Fair
M05	A	E	Gravel	Riffle-Pool	c	No	0.1	99.9	86.0	7.7	7.1	7.1	7.7	12.1	10.2	1.0	III	F	Good	Fair
M05	B	E	Gravel	Riffle-Pool	c	No	0.1	99.9	64.0	6.9	6.2	6.2	6.9	10.3	13.8	1.0	I	F	Good	Good
M05	C	E	Gravel	Riffle-Pool	c	No	0.1	99.9	86.0	7.7	7.1	7.1	7.7	12.1	10.2	1.0	III	F	Good	Fair
M05	D	E	Gravel	Riffle-Pool	c	No	0.1	99.9	64.0	6.9	6.2	6.2	6.9	10.3	13.8	1.0	I	F	Good	Good
M05	E	E	Gravel	Riffle-Pool	c	No	0.1	99.9	86.0	7.7	7.1	7.1	7.7	12.1	10.2	1.0	III	F	Good	Fair
M06	0	E	Sand	Plane Bed	c	No	0.0	89.1	48.0	5.2	4.4	4.4	6.1	10.9	7.9	1.2	III	F	Good	Good
M07	0	E	Sand	Riffle-Pool	c	No	0.0	88.8	54.0	7.1	6.3	6.3	8.7	8.6	13.4	1.2	III	F	Good	Good
M08	0	E	Sand	Riffle-Pool	c	No	0.1	87.8	59.0	5.7	5.3	5.3	6.0	11.1	16.0	1.1	III	F	Good	Good
M09	A	C	Gravel	Plane Bed	c	No	0.5	78.8	67.0	3.6	3.1	3.1	3.6	21.6	12.9	1.0	III	F	Good	Fair
M09	B	C	Gravel	Plane Bed	c	No	0.5	78.8	67.0	3.6	3.1	3.1	3.6	21.6	12.9	1.0	III	F	Good	Fair
M10	0	E	Gravel	Riffle-Pool	c	No	0.7	75.8	38.0	3.1	2.4	2.4	3.1	15.8	5.0	1.0	I	F	Referen	Good
M11	A	E	Cobble	Riffle-Pool	c	No	0.3	45.1	42.0	4.3	3.6	3.6	4.3	11.7	10.7	1.0	I	F	Referen	Good
M11	B	E	Cobble	Riffle-Pool	c	No	0.3	45.1	38.2	3.3	2.6	2.6	3.3	14.7	11.8	1.0	III	F	Good	Fair
M11	C					No	0.3	45.1												
M11	D	E	Cobble	Riffle-Pool	c	No	0.3	45.1	24.2	5.3	3.5	3.5	5.3	6.9	18.6	1.0	I	F	Referen	Good
M12	A	C	Sand	Riffle-Pool	c	No	0.4	36.9	30.0	4.8	3.9	3.9	4.8	7.7	18.0	1.0	I	F	Referen	Good
M12	B	C	Gravel	Plane Bed	c	No	0.4	36.9	24.0	3.6	2.6	2.6	4.9	9.2	22.5	1.4	III	F	Good	Fair
M13	A	G	Gravel	Plane Bed	c	No	11.3	15.8	12.0	1.5	1.3	1.3	2.5	9.2	1.6	1.7	IId	F	Fair	Fair
M13	B	G	Gravel	Plane Bed	c	No	11.3	15.8	25.0	3.7	2.8	2.8	6.2	8.9	7.0	1.7	IId	F	Fair	Fair
M13	C					No	11.3	15.8												
M13	D					No	11.3	15.8												
T1.01	0	C	Gravel	Plane Bed	c	No	0.9	56.3	31.0	1.8	1.5	1.5	3.8	20.7	12.9	2.1	III	F	Fair	Fair
T1.02	0	C	Gravel	Plane Bed	c	No	1.3	53.7	59.0	4.0	3.6	3.6	4.0	16.4	5.1	1.0	III	F	Good	Fair

Table 1 (continued)

		Phase 2 Stream Type					Phase 1 Data		Phase 2 Channel Data											
Reach	Seg-ment	Stream Type	Bed Material	Bedform	Subcl. Slope	Sub Rch?	Slope	Channel width	Bankfull width	Max. depth	Mean depth	Floodpr. width	Low Bank Ht	W/D Ratio	Entrench-ment	Incision Ratio	Stage Evol.	Evol. Model	RGA Cond.	RHA Cond.
T1.03	0	B	Gravel	Plane Bed	c	No	0.7	40.8	37.0	2.4	1.1	1.1	2.4	33.6	1.4	1.0	I	F	Good	Good
T2.01	0	F	Cobble	Plane Bed	c	No	1.2	74.4	94.0	4.7	2.9	2.9	9.9	32.4	1.2	2.1	IV	F	Fair	Fair
T2.02	0	D	Cobble	Plane Bed	c	No	1.2	74.4	92.0	3.1	1.8	1.8	3.1	51.1	3.2	1.0	IV	D	Fair	Fair
T2S1.01	A	C	Gravel	Plane Bed	c	No	0.9	52.8	66.0	4.2	2.7	2.7	6.0	24.4	5.5	1.4	III	F	Fair	Fair
T2S1.01	B	C	Gravel	Riffle-Pool	c	No	0.9	52.8	41.0	2.8	2.1	2.1	4.6	19.5	8.8	1.6	III	F	Good	Fair
T3.01	A	E	Gravel	Plane Bed	c	No	0.8	31.4	27.0	3.8	3.5	3.5	3.8	7.7	41.8	1.0	III	F	Good	Fair
T3.01	B	E	Gravel	Plane Bed	c	No	0.8	31.4	27.0	3.8	3.5	3.5	3.8	7.7	41.8	1.0	IV	F	Good	Good
T3.02	A	F	Gravel	Plane Bed	b	No	3.3	29.8	65.0	4.0	2.3	2.3	7.5	28.3	1.1	1.9	IV	F	Fair	Fair
T3.02	B	G	Gravel	Plane Bed	b	No	3.3	29.8	52.0	8.9	6.0	6.0	13.2	8.7	9.6	1.5	IId	F	Fair	Fair
T4.01	0	F	Cobble	Plane Bed	b	No	2.3	40.0	46.0	4.1	3.3	3.3	8.4	13.9	1.2	2.0	IV	F	Fair	Fair
T4.02	A	C	Gravel	Plane Bed	c	No	6.0	27.3	47.0	3.3	2.5	2.5	3.3	18.8	4.3	1.0	III	F	Good	Fair
T4.02	B	C	Gravel	Plane Bed	c	No	6.0	27.3	47.0	3.3	2.5	2.5	3.3	18.8	4.3	1.0	I	F	Good	Fair
T4.02	C	C	Gravel	Plane Bed	c	No	6.0	27.3	38.0	2.6	1.7	1.7	3.1	22.4	5.3	1.2	III	F	Good	Fair
T4S1.01	0	F	Cobble	Plane Bed	a	No	1.8	28.7	36.0	4.7	4.2	4.2	10.6	8.6	1.2	2.3	III	F	Fair	Fair
T5.01	A	C	Bedrock	Bedrock	a	No	7.4	19.6	21.0	1.9	1.3	1.3	2.2	16.2	11.9	1.2	IId	F	Good	Good
T5.01	B	F	Cobble	Plane Bed	a	No	7.4	19.6	21.0	2.1	1.4	1.4	6.3	15.0	1.4	3.0	III	F	Good	Fair
T5.01	C					No	7.4	19.6												
T5.01	D					No	7.4	19.6												
T5.01	E					No	7.4	19.6												
T6.01	A	C	Sand	Riffle-Pool	c	No	2.6	45.7	25.0	1.8	1.0	1.0	1.8	25.0	10.0	1.0	I	F	Good	Good
T6.01	B	C	Gravel	Riffle-Pool	b	No	2.6	45.7	39.0	5.0	4.7	4.7	6.3	8.3	6.4	1.3	I	F	Good	Good
T6.02	A	C	Gravel	Riffle-Pool	c	No	0.6	44.8	25.0	1.9	1.4	1.4	1.9	17.9	16.0	1.0	I	F	Good	Good
T6.02	B					No	0.6	44.8												
T6.02	C					No	0.6	44.8												
T6.03	A	C	Gravel	Riffle-Pool	c	No	0.9	40.5	38.0	2.1	1.6	1.6	2.4	23.7	5.1	1.1	IV	F	Good	Good
T6.03	B					No	0.9	40.5												
T6.03	C					No	0.9	40.5												
T7.01	0	C	Gravel	Plane Bed	c	No	1.3	27.0	43.0	4.5	3.0	3.0	6.0	14.3	4.7	1.3	IV	F	Good	Fair
T7.02	0	C	Cobble	Plane Bed	b	No	4.6	25.8	37.0	3.6	3.1	3.1	3.6	11.9	10.8	1.0	III	F	Good	Fair

Table 2 - Summary of Phase 2 Rapid Geomorphic Assessment results

Rapid Geomorphic Assessment

Battenkill River

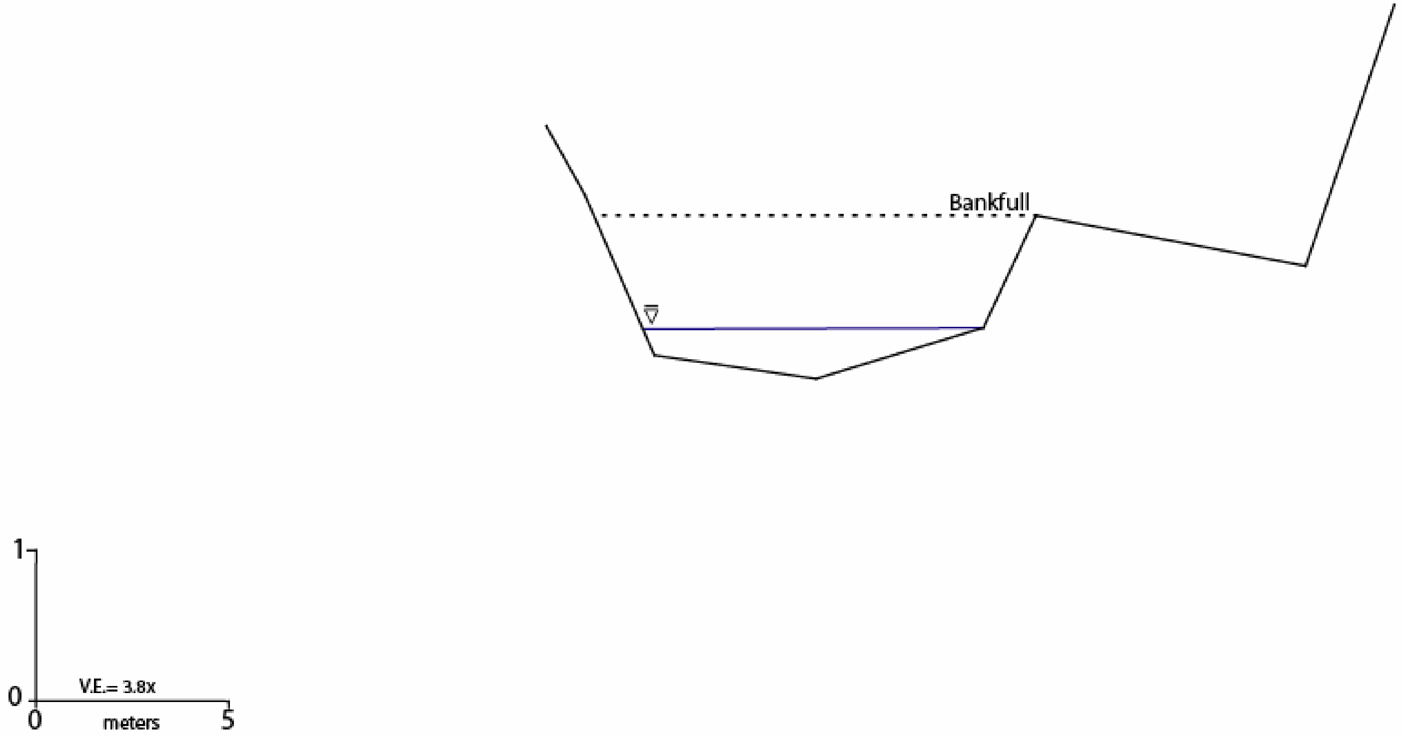
			Degradation			Aggradation			Widening		Planform				
Reach	Segment	Sub-Rch?	Score	STD	Historic	Score	STD	Historic	Score	Historic	Score	Historic	Geo. Score	Geo. Condition	Evol. Stage
M01	A	No	13	None	Yes	10	None	Yes	15	Yes	12	No	0.63	Good	III
M01	B	No	16	None	No	12	None	No	10	No	10	No	0.60	Fair	IV
M01	C	No	14	None	Yes	10	None	No	16	Yes	13	Yes	0.66	Good	III
M02	0	No	13	None	Yes	12	None		13	Yes	14		0.65	Fair	III
M03	A	No	13	None	No	12	None		15		13		0.66	Good	III
M03	B	No	10	None	No	13	None		15		7	No	0.56	Good	III
M03	C	No	13	None	No	12	None		15		13		0.66	Good	III
M04	0	No	13	None	Yes	10	None	No	14	Yes	15	Yes	0.65	Good	III
M05	A	No	15	None	Yes	15	None	No	17	No	14	No	0.76	Good	III
M05	B	No	17	None	No	16	None	No	17	Yes	14	No	0.80	Good	I
M05	C	No	15	None	Yes	15	None	No	17	No	14	No	0.76	Good	III
M05	D	No	17	None	No	16	None	No	17	No	14	No	0.80	Good	I
M05	E	No	15	None	Yes	15	None	No	17	No	14	No	0.76	Good	III
M06	0	No	16	None	No	16	None	No	18	No	16	No	0.83	Good	III
M07	0	No	14	None	No	17	None	No	17	No	17	No	0.81	Good	III
M08	0	No	14	None	No	15	None	No	16	No	14	No	0.74	Good	III
M09	A	No	13	None	Yes	13	None	No	15	Yes	14	No	0.69	Good	III
M09	B	No	13	None	Yes	13	None	No	15	Yes	14	No	0.69	Good	III
M10	0	No	18	None	No	17	None	No	19	No	19	No	0.91	Reference	I
M11	A	No	18	None	No	18	None	No	18	No	16	No	0.88	Reference	I
M11	B	No	13	None	No	13	None	No	15	No	16	No	0.71	Good	III
M11	C	No											0.00		
M11	D	No	18	None	No	18	None	No	18	No	16	No	0.88	Reference	I
M12	A	No	18	None	No	19	None	No	17	No	16	No	0.88	Reference	I
M12	B	No	11	Other	Yes	10	Other	No	16	Yes	15	Yes	0.65	Good	III
M13	A	No	7	C to G	Yes	13	None	No	14	Yes	14	No	0.60	Fair	IId
M13	B	No	7	C to G	Yes	13	None	No	14	Yes	14	No	0.60	Fair	IId
M13	C	No											0.00		
M13	D	No											0.00		
T1.01	0	No	5	C to F	Yes	10	None	No	10	Yes	11	No	0.45	Fair	III
T1.02	0	No	13	None	Yes	10	None	No	17	No	14	Yes	0.68	Good	III
T1.03	0	No	16	None	No	13	None	No	15	No	16	No	0.75	Good	I
T2.01	0	No	5	C to F	Yes	5	C to D	No	8	Yes	11	Yes	0.36	Fair	IV

Table 2 (continued)

Reach	Seg-ment	Sub-Rch?	Degradation			Aggradation			Widening		Planform		Geo. Score	Geo. Condition	Evol. Stage
			Score	STD	Historic	Score	STD	Historic	Score	Historic	Score	Historic			
T2.02	0	No	12	Other	No	4	C to D	No	9	No	13	No	0.48	Fair	IV
T2S1.01	A	No	12	None	Yes	9	None	No	14	No	15	Yes	0.63	Fair	III
T2S1.01	B	No	10	None	Yes	15	None	No	14	No	13	No	0.65	Good	III
T3.01	A	No	15	None	Yes	15	None	No	16	No	13	No	0.74	Good	III
T3.01	B	No	13	None	Yes	14	None	No	15	Yes	13	No	0.69	Good	IV
T3.02	A	No	11	C to F	Yes	10	None	No	10	Yes	11	Yes	0.53	Fair	IV
T3.02	B	No	11	C to G	Yes	10	None	No	11	Yes	11	Yes	0.54	Fair	IId
T4.01	0	No	5	C to F	Yes	5	C to D	No	8	Yes	13	Yes	0.39	Fair	IV
T4.02	A	No	13	None	Yes	14	None	No	16	No	12	No	0.69	Good	III
T4.02	B	No	13	None	No	15	None	No	17	No	14	No	0.74	Good	I
T4.02	C	No	14	None	No	14	None	No	14	No	15	No	0.71	Good	III
T4S1.01	0	No	5	C to F	Yes	10	None	No	13	Yes	12	Yes	0.50	Fair	III
T5.01	A	No	15	None	No	17	None	No	17	No	18	No	0.84	Good	IId
T5.01	B	No	5	C to F	No	15	None	No	15	No	18	No	0.66	Good	III
T5.01	C	No											0.00		
T5.01	D	No											0.00		
T5.01	E	No											0.00		
T6.01	A	No	17	None	No	15	None	No	17	No	15	No	0.80	Good	I
T6.01	B	No	15	None	No	15	None	No	17	No	17	No	0.80	Good	I
T6.02	A	No	16	None	No	14	None	No	17	No	16	No	0.79	Good	I
T6.02	B	No											0.00		
T6.02	C	No											0.00		
T6.03	A	No	16	None	No	16	None	No	17	No	17	No	0.83	Good	IV
T6.03	B	No											0.00		
T6.03	C	No											0.00		
T7.01	0	No	13	None	Yes	14	None	Yes	13	Yes	12	Yes	0.65	Good	IV
T7.02	0	No	14	None	No	10	None	No	15	No	14	No	0.66	Good	III

Appendix A

Mad Tom Brook T7.02 - Cross Section 1



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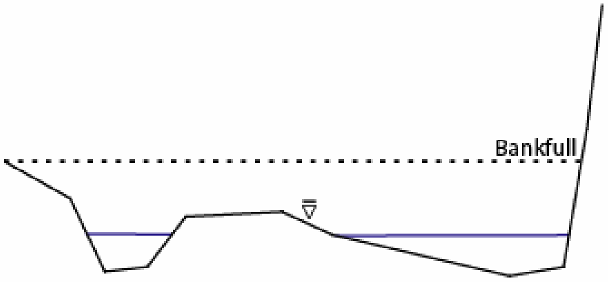
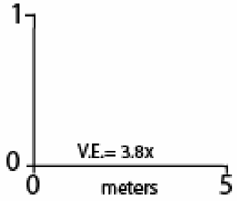
Mad Tom Brook T7.01 - Cross Section 3





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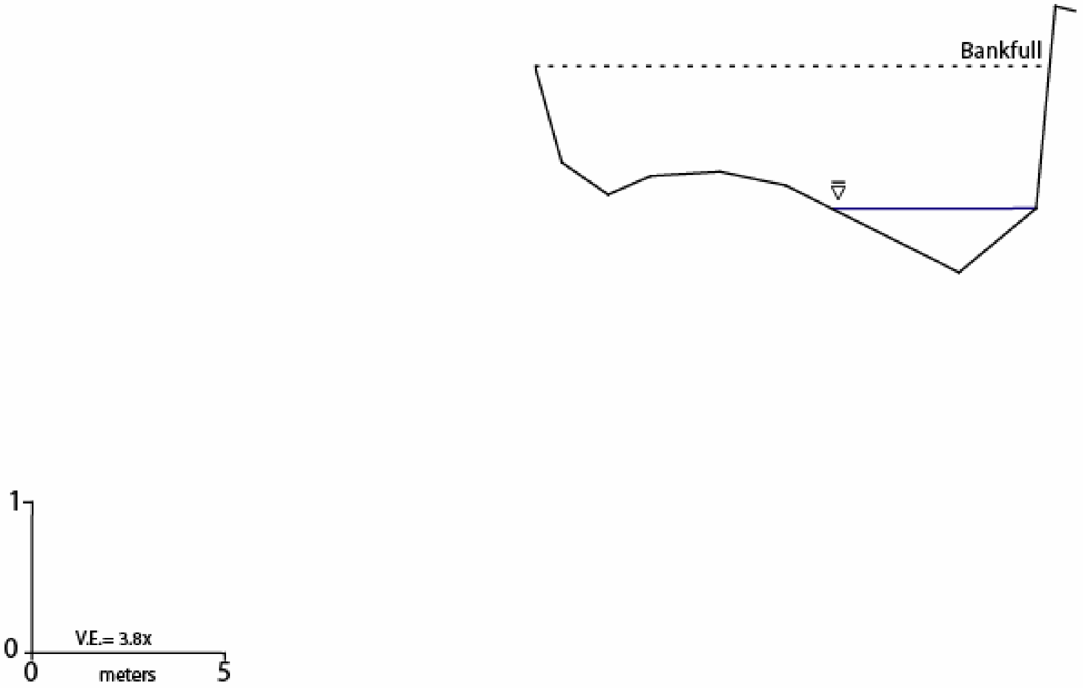
Mad Tom Brook T7.01 - Cross Section 2



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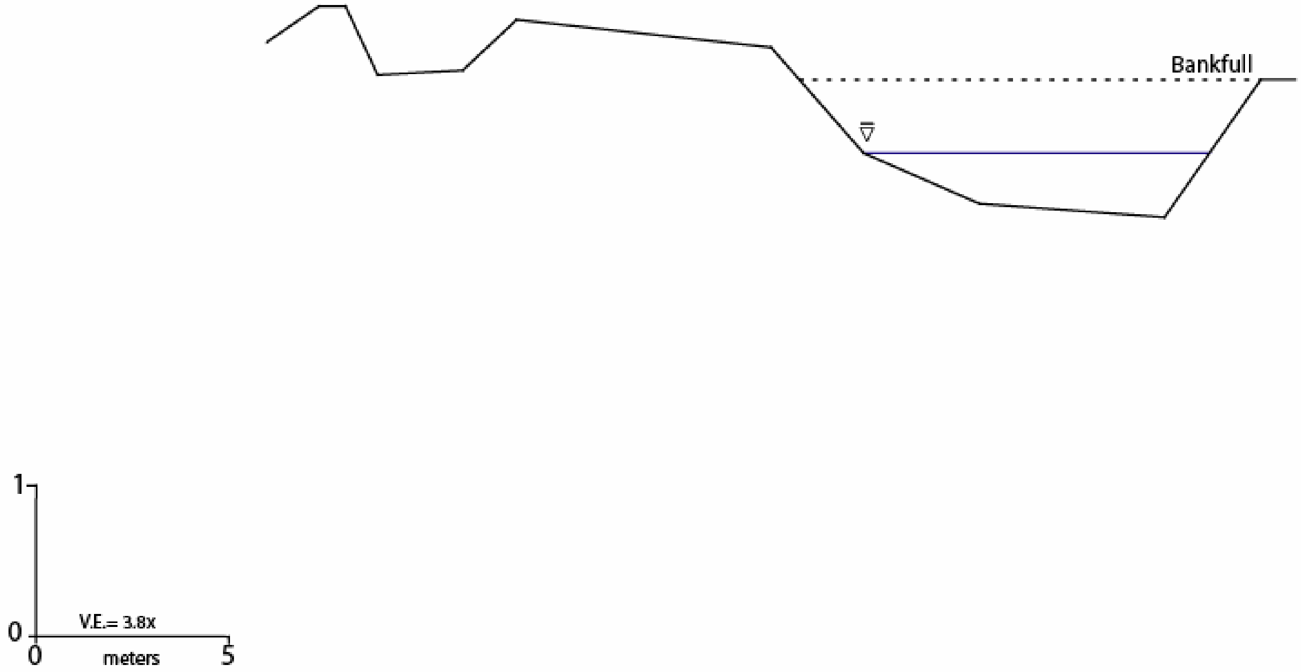
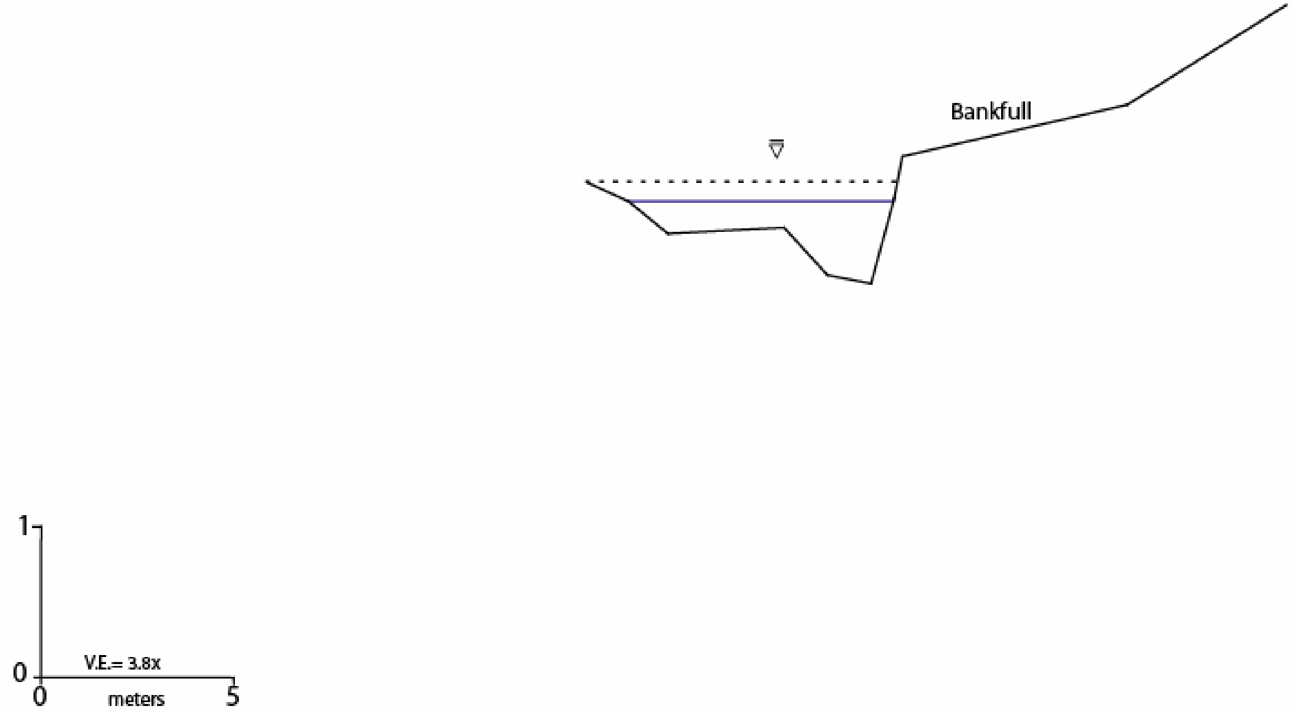
Fluvial Geomorphology

Mad Tom Brook T7.01 - Cross Section 1



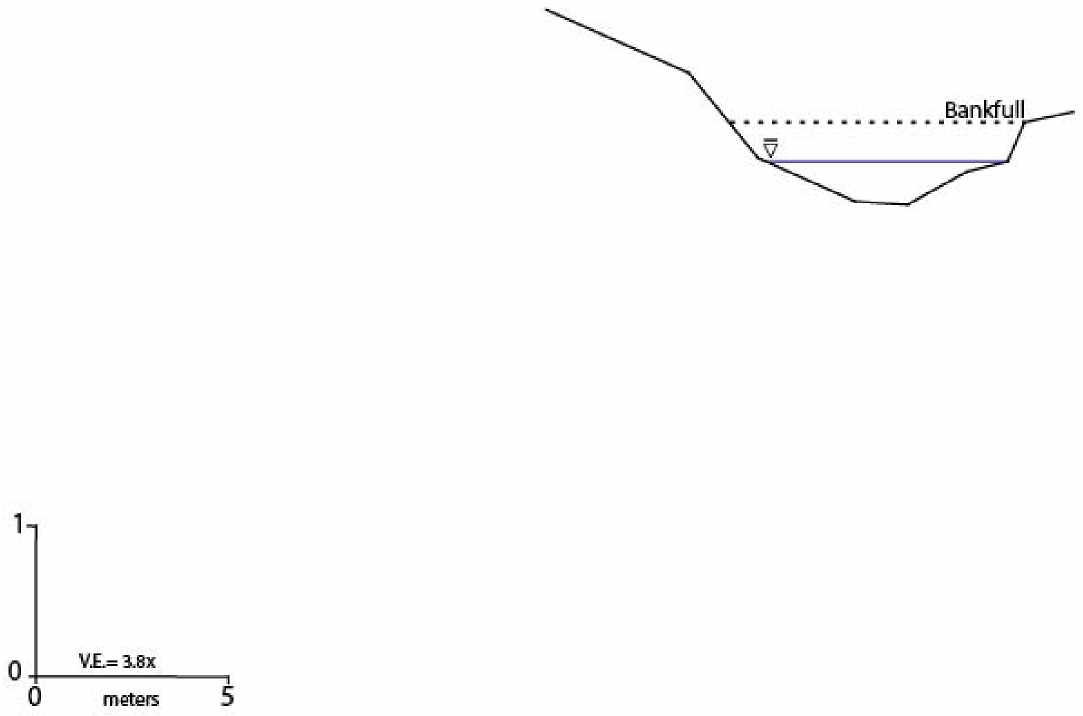
Field Geology Services
Fluvial Geomorphology

West Branch T6.02 - Cross Section 3



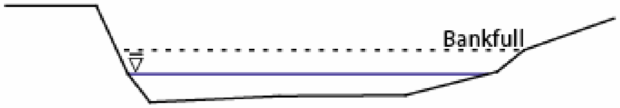
Field Geology Services
Fluvial Geomorphology

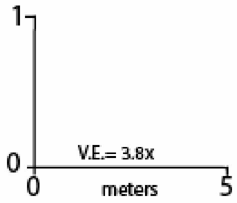
West Branch T6.02 - Cross Section 2



Field Geology Services
Fluvial Geomorphology

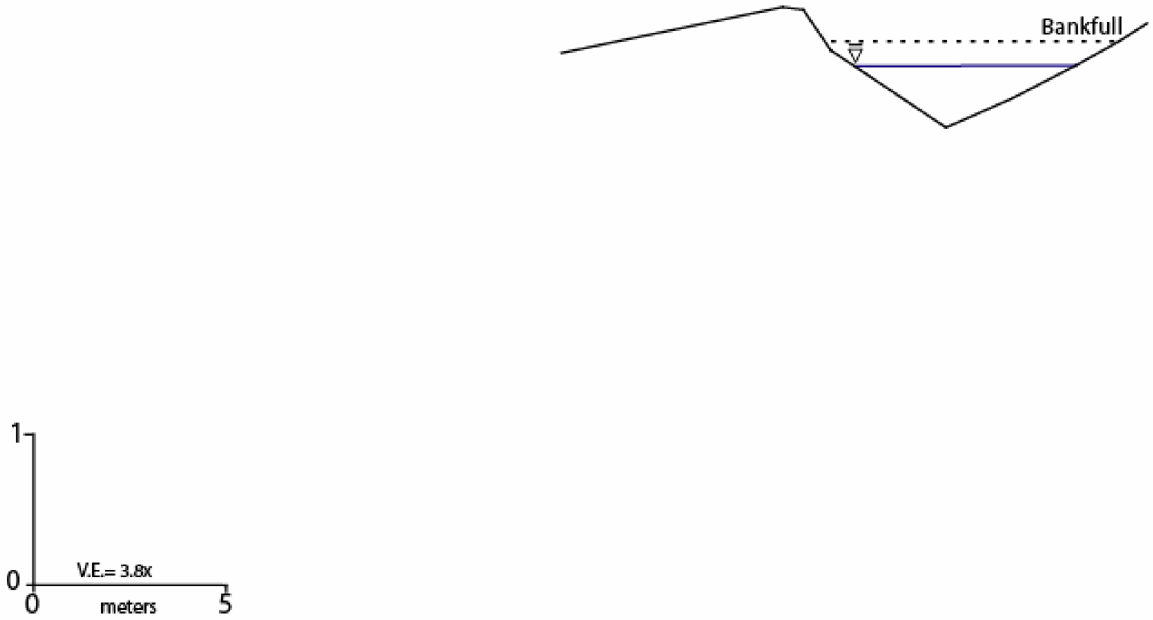
West Branch T6.02 - Cross Section 1



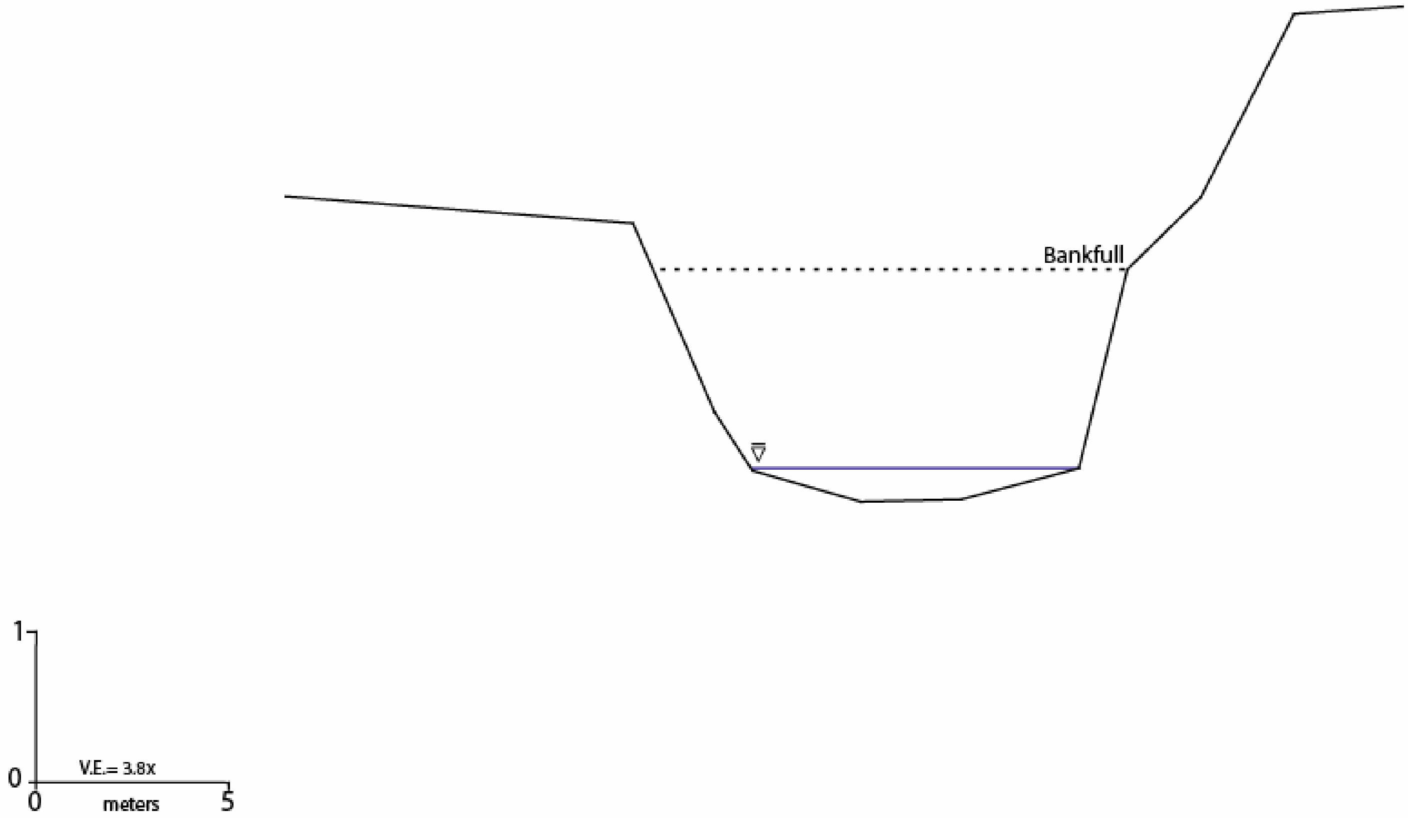


Field Geology Services
Fluvial Geomorphology

West Branch T6.01 - Cross Section 2

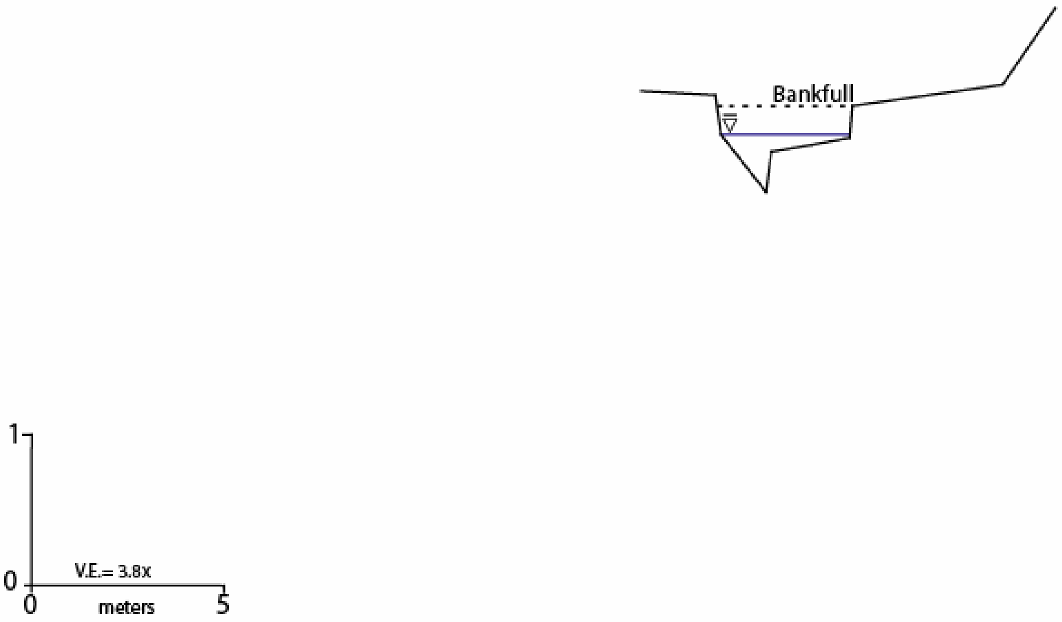


West Branch T6.01 - Cross Section 1



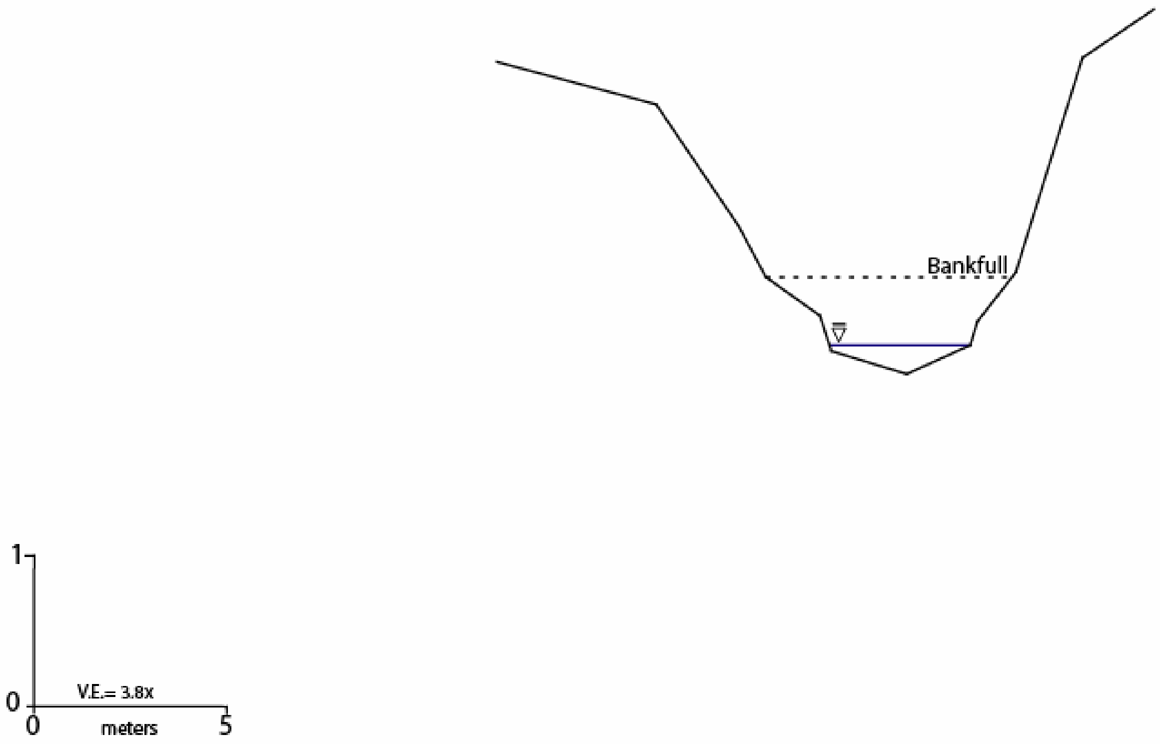
Field Geology Services
Fluvial Geomorphology

Munson Brook T5.01 - Cross Section 2



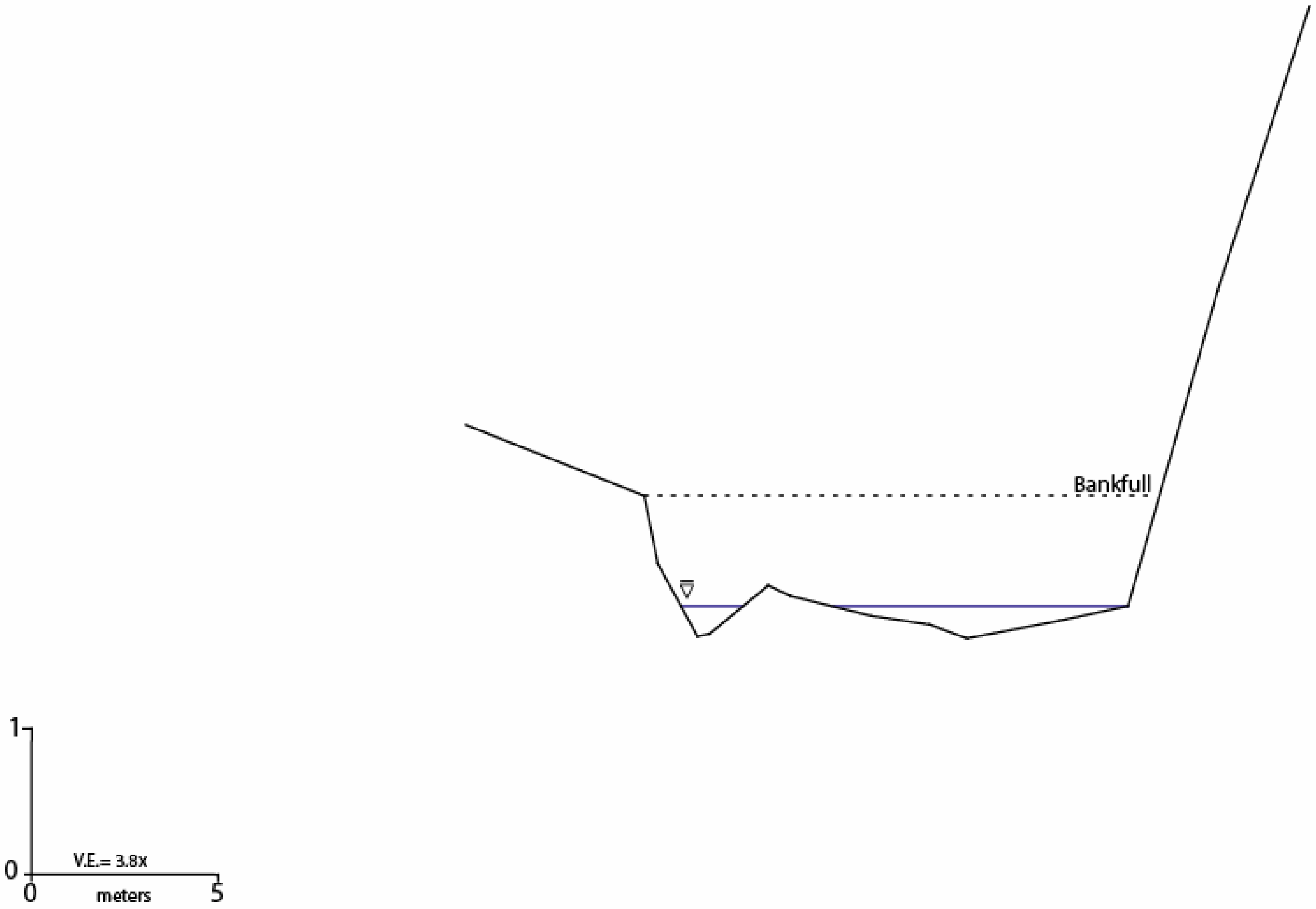
Field Geology Services
Fluvial Geomorphology

Munson Brook T5.01 - Cross Section 1



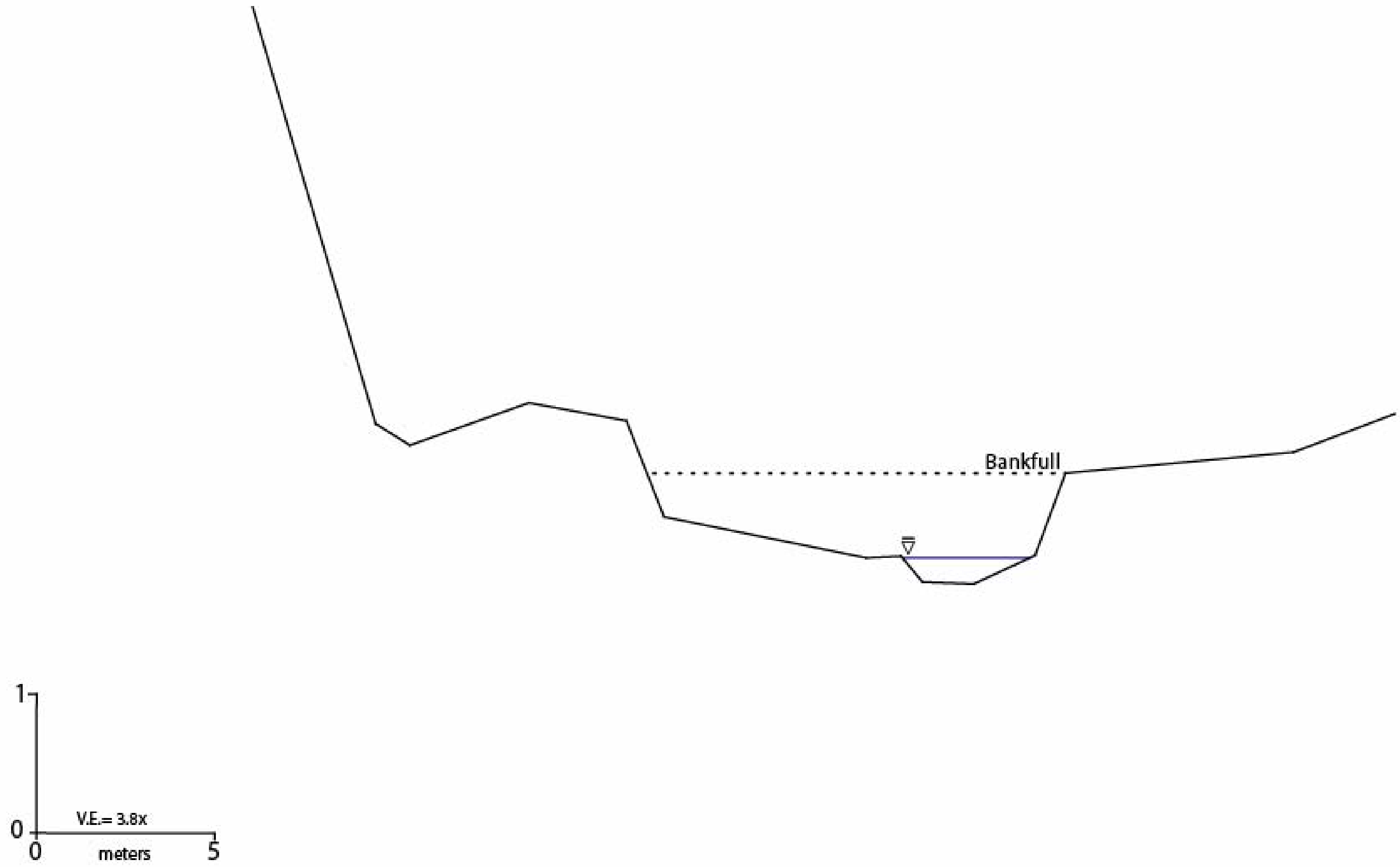
Field Geology Services
Fluvial Geomorphology

Bromley Brook T4.02 - Cross Section 2



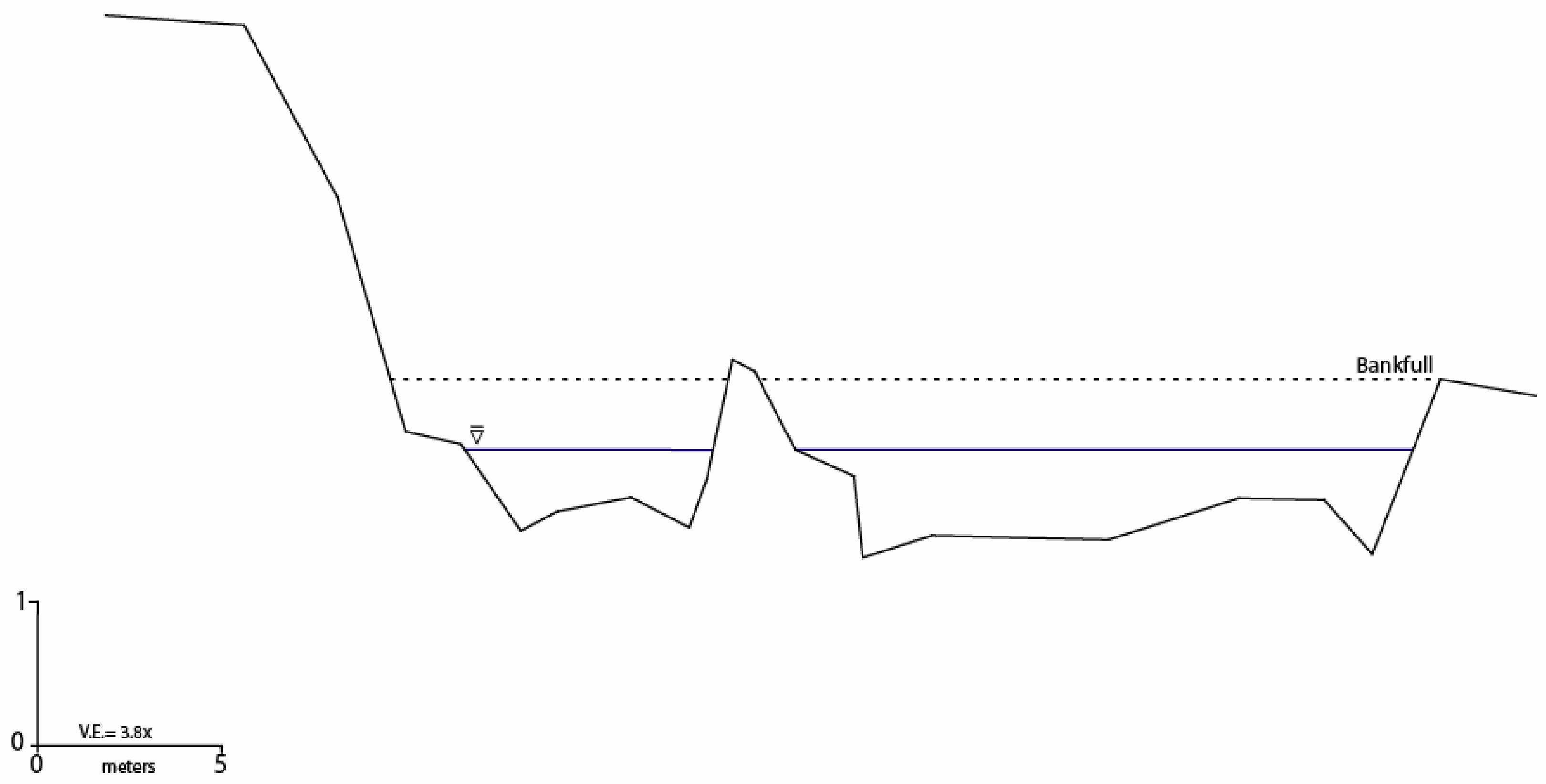
Field Geology Services
Fluvial Geomorphology

Bromley Brook T4.02 - Cross Section 1



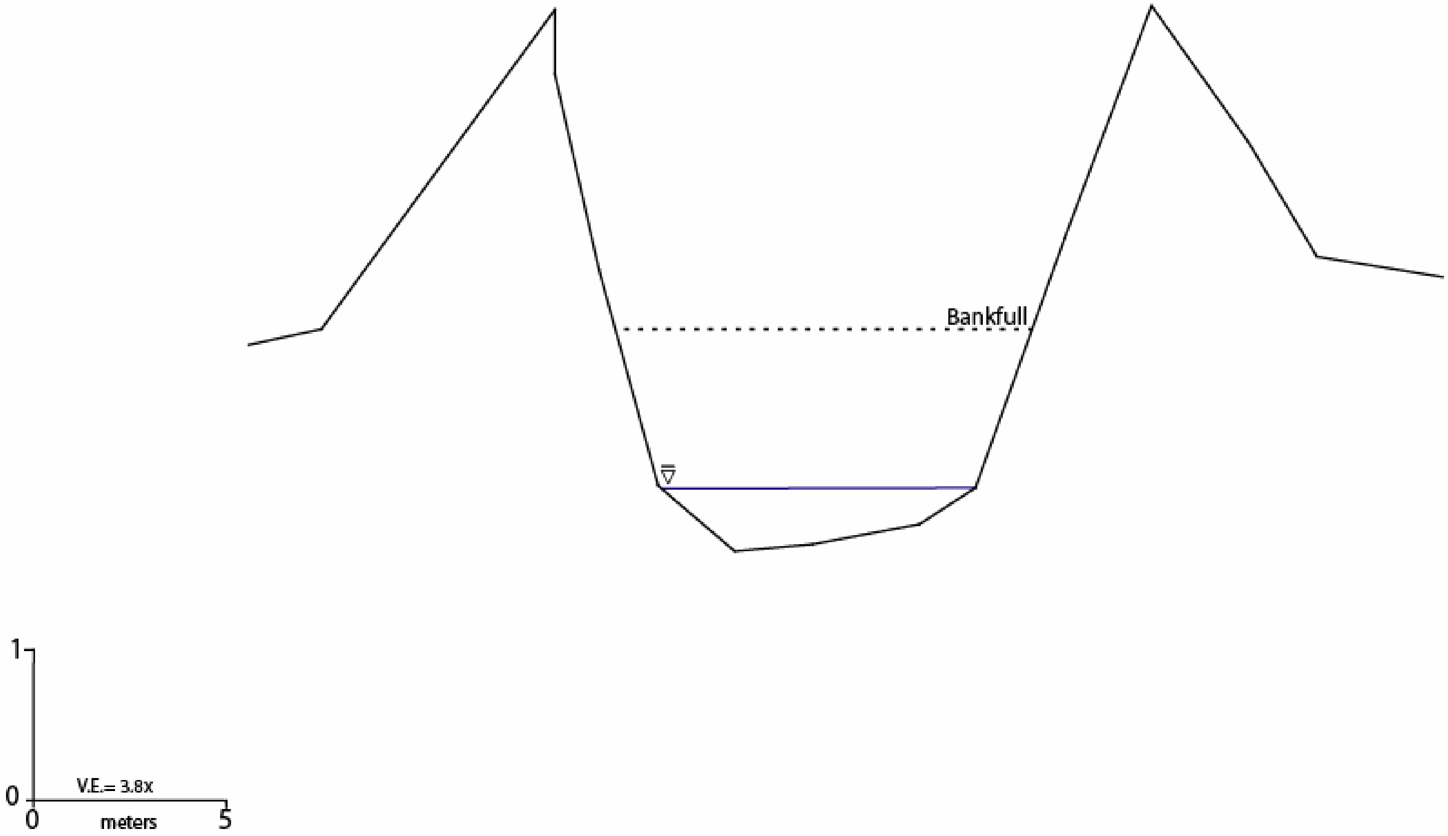
Field Geology Services
Fluvial Geomorphology

Bourne Brook T4S1.01 - Cross Section 2

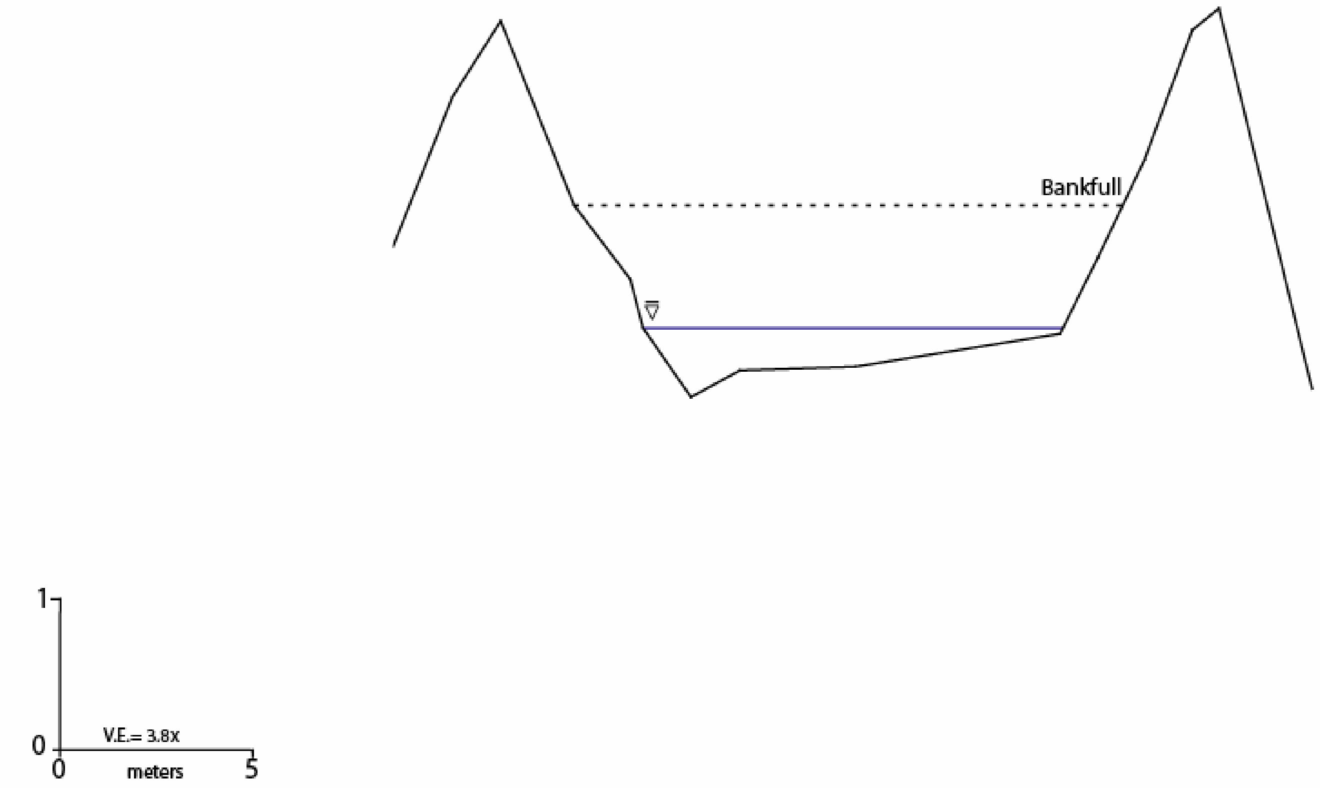


Field Geology Services
Fluvial Geomorphology

Bourne Brook T4S1.01 - Cross Section 1

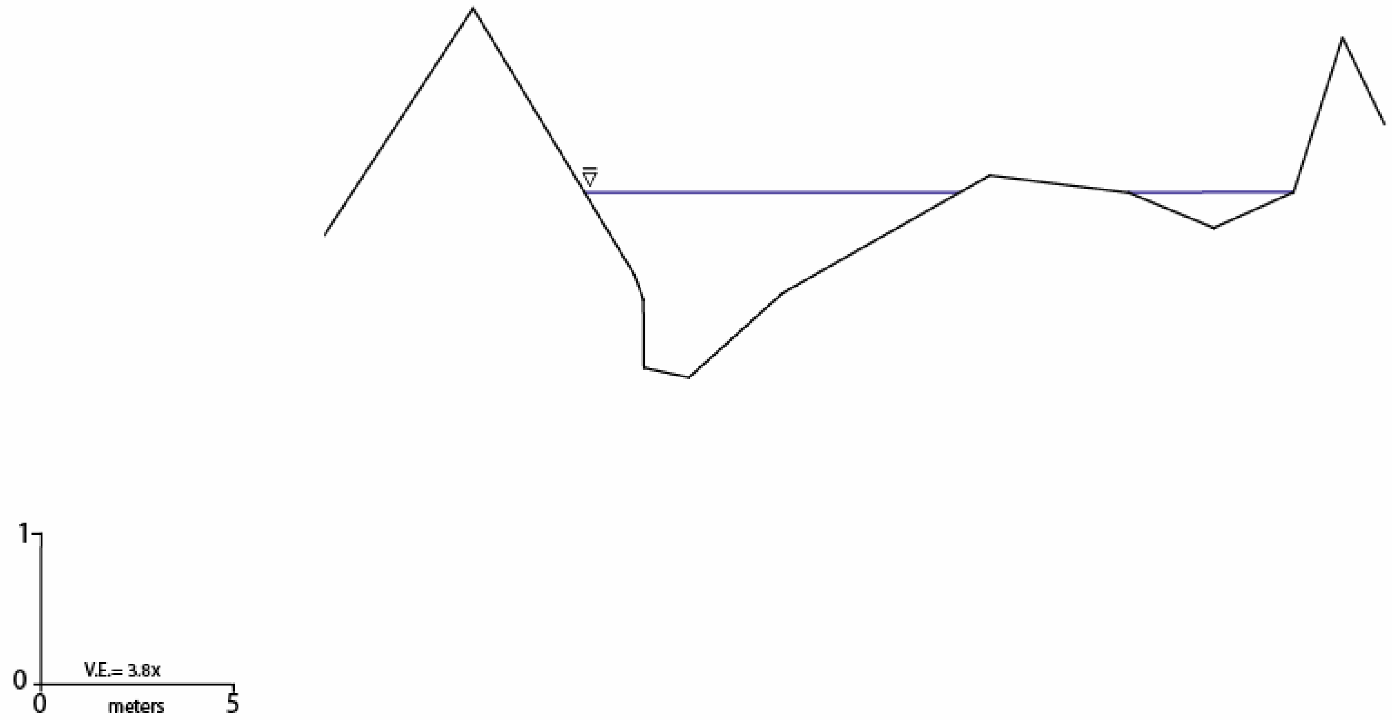


Bourne Brook T4.01 - Cross Section 3



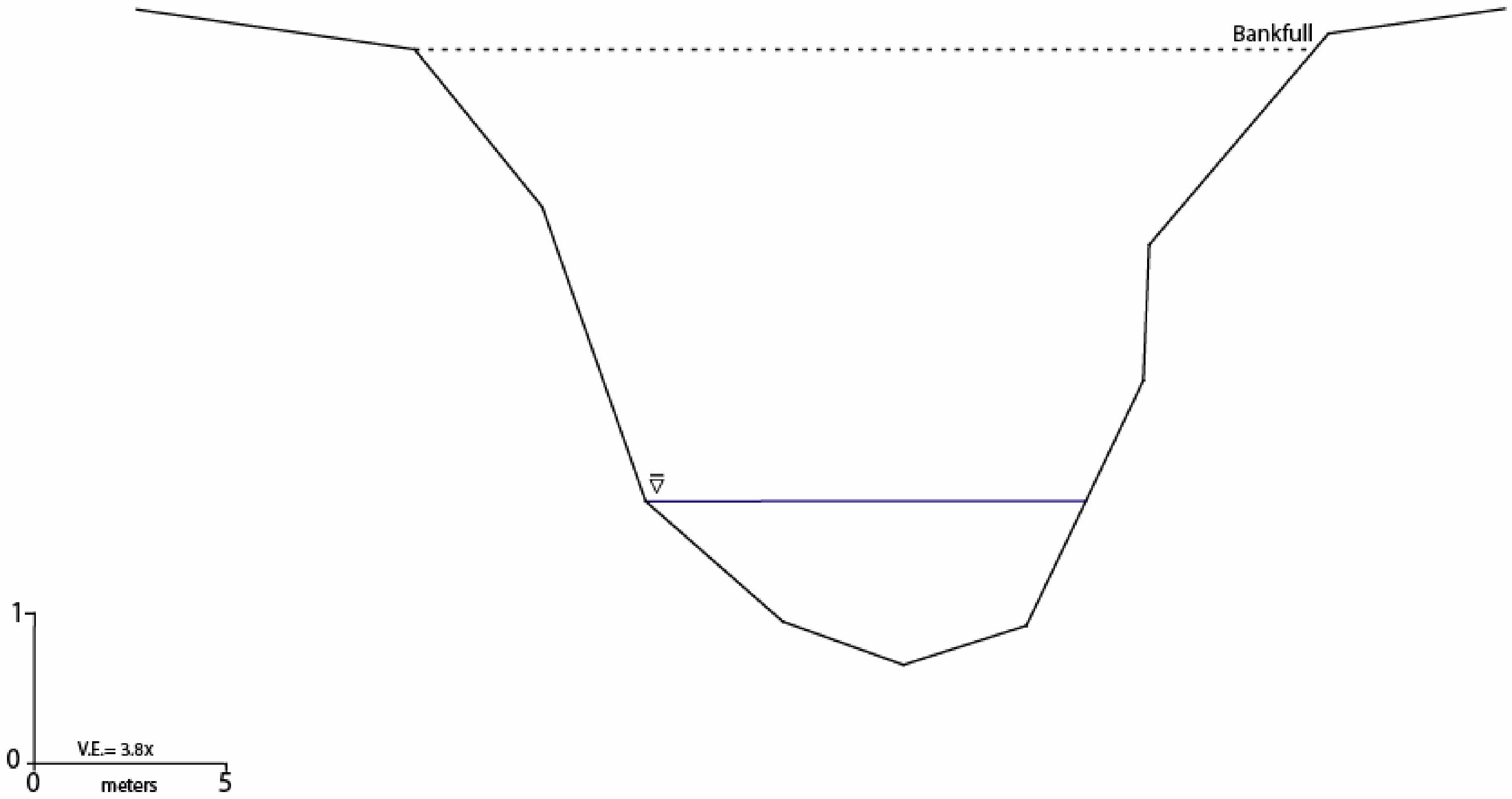
Field Geology Services
Fluvial Geomorphology

Lye Brook T3.02 - Cross Section 2



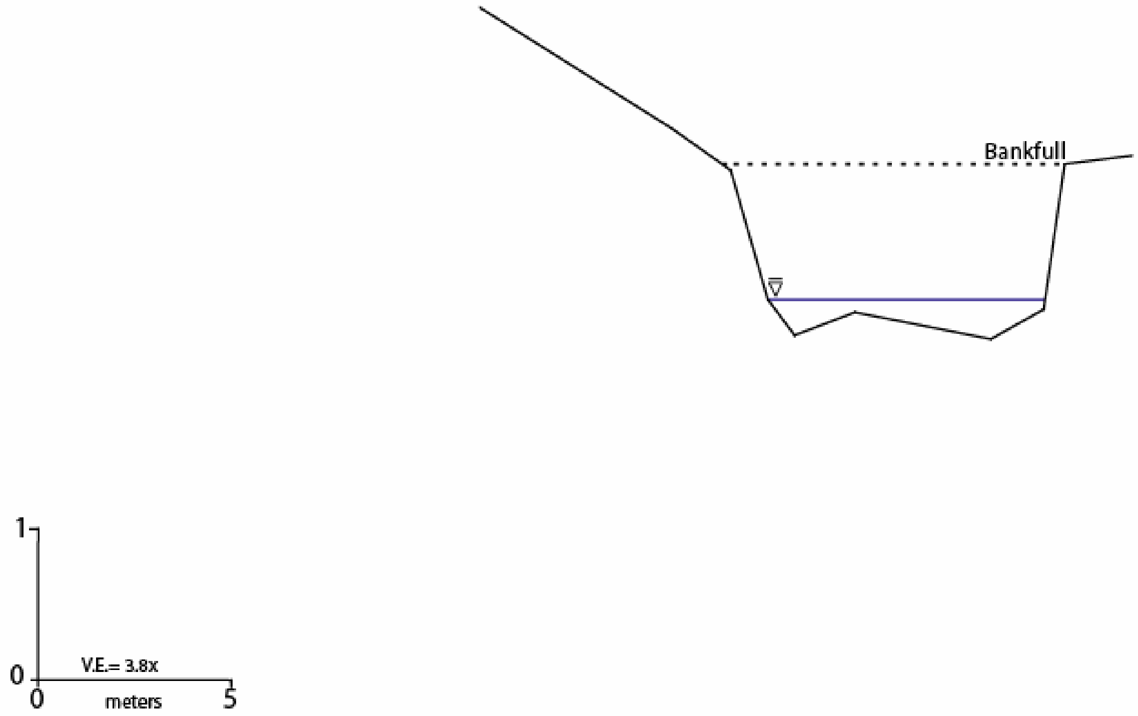
Field Geology Services
Fluvial Geomorphology

Lye Brook T3.02 - Cross Section 1



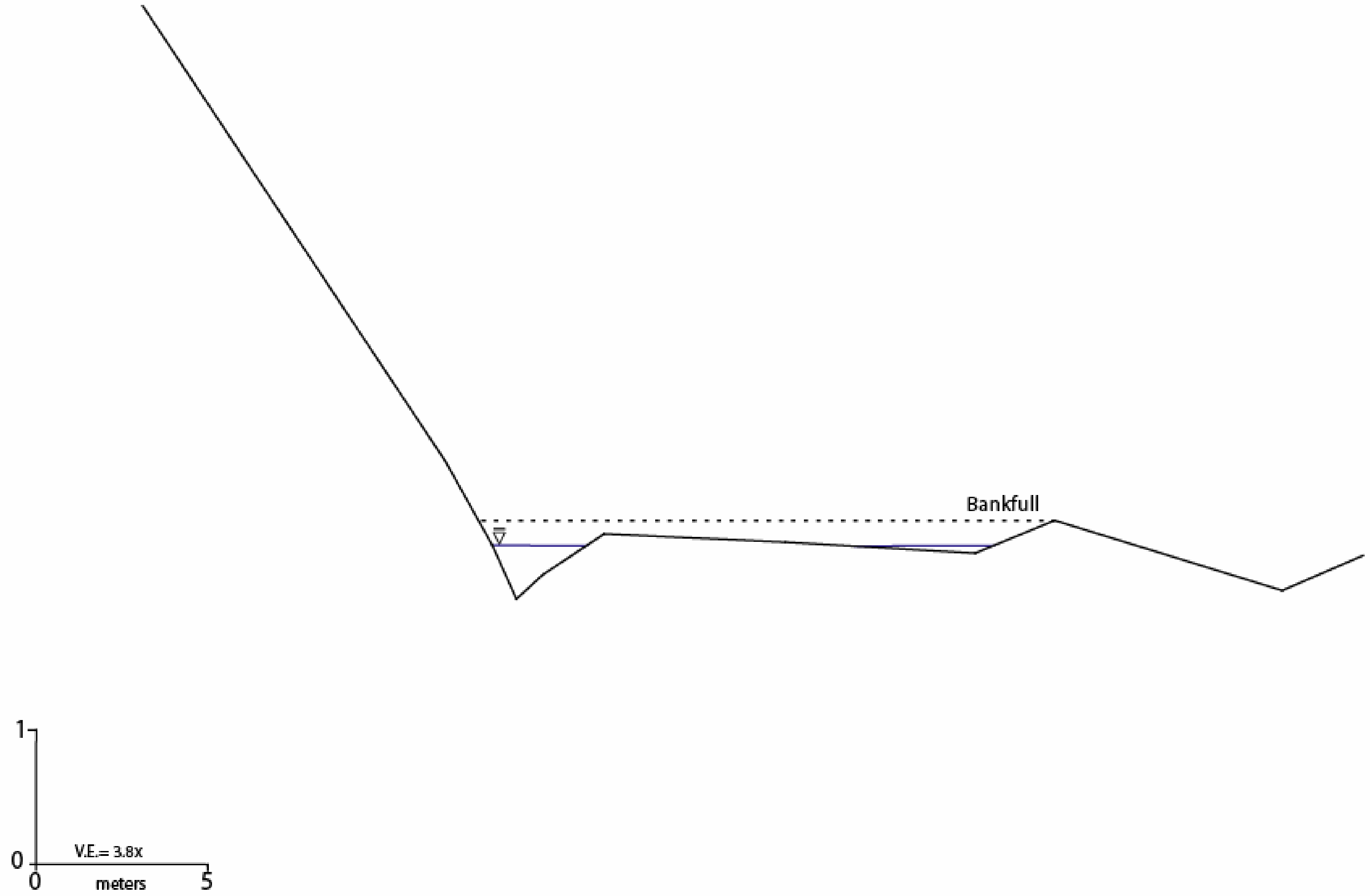
Field Geology Services
Fluvial Geomorphology

Lye Brook T3.01 - Cross Section 2



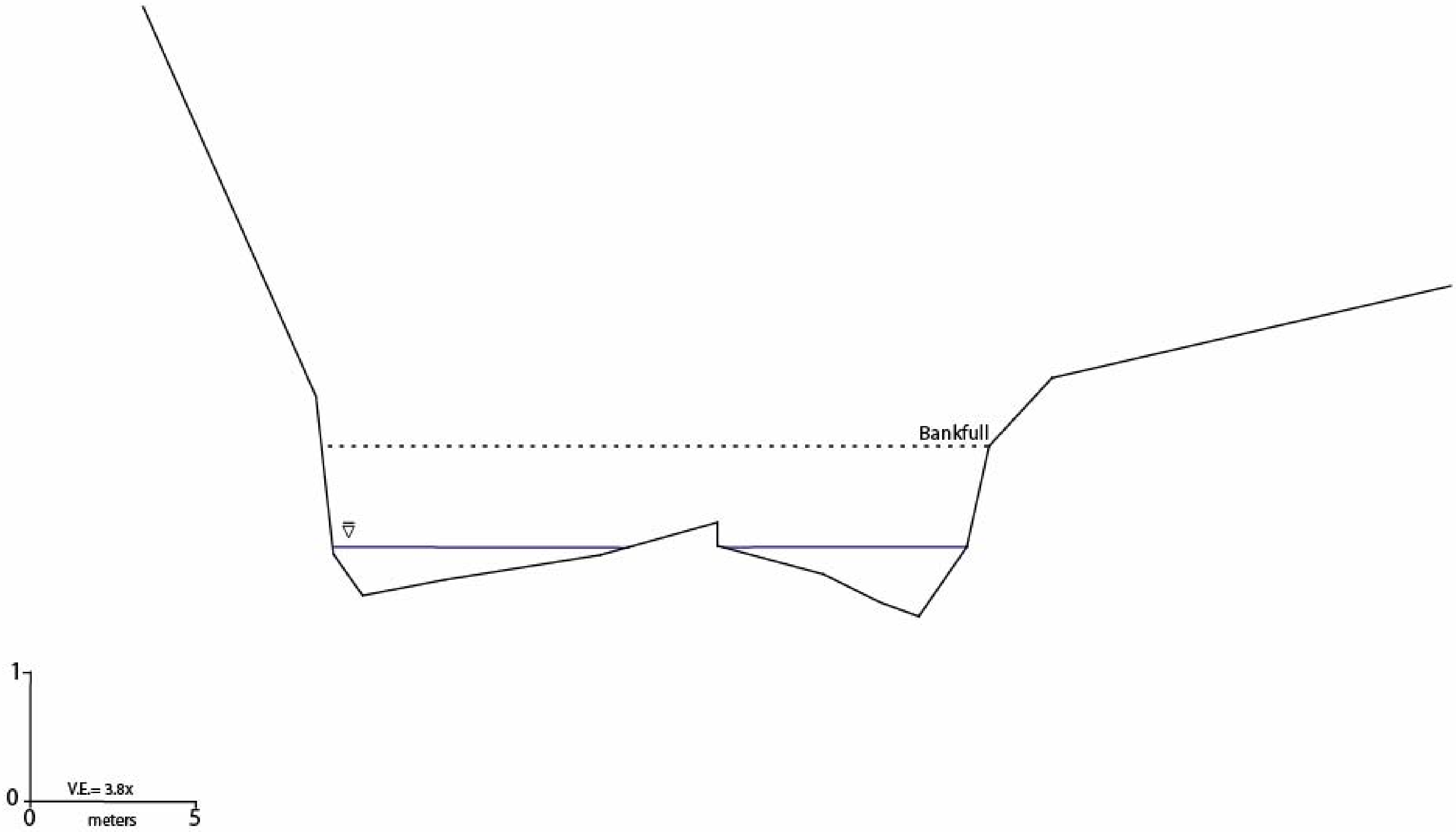
Field Geology Services
Fluvial Geomorphology

Lye Brook T3.01 - Cross Section 1



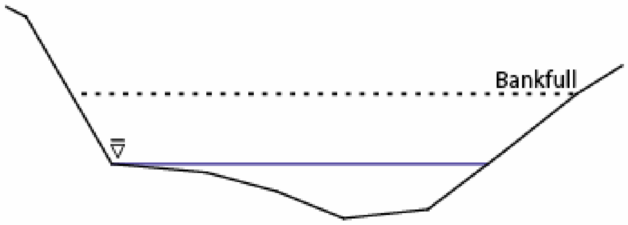
Field Geology Services
Fluvial Geomorphology

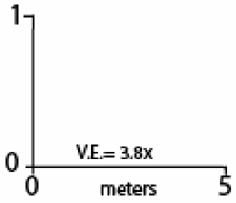
Warm Brook T2S1.01 - Cross Section 2



Field Geology Services
Fluvial Geomorphology

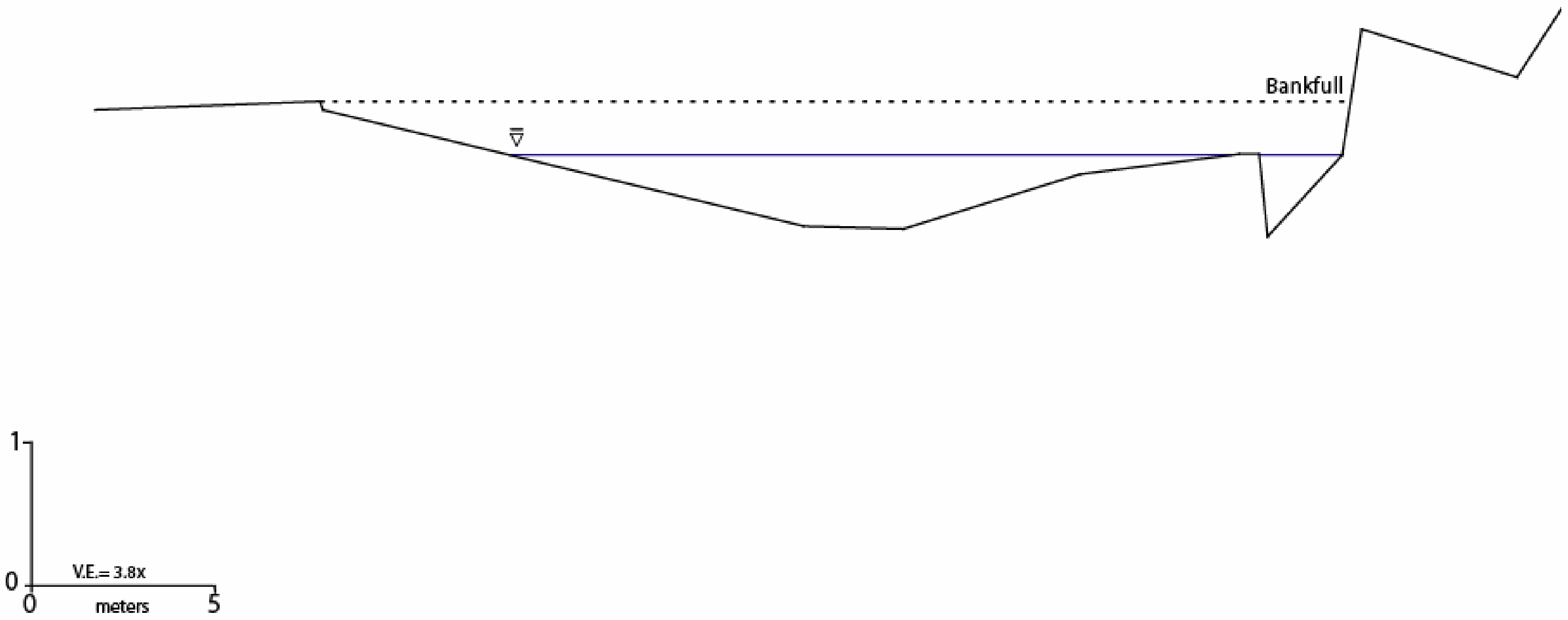
Warm Brook T2S1.01 - Cross Section 1





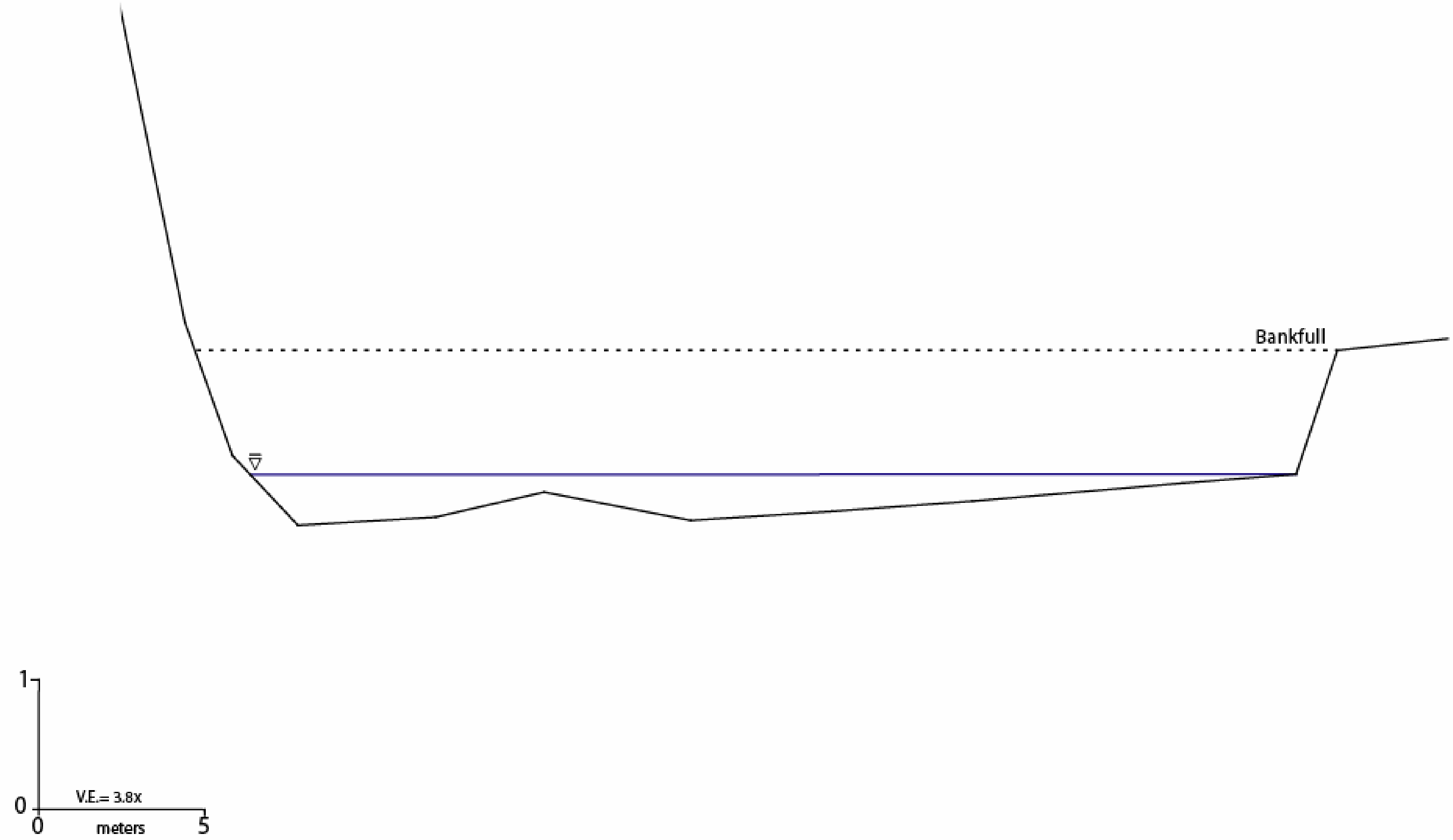
Field Geology Services
Fluvial Geomorphology

Roaring BranchT2.02 - Cross Section 2



Field Geology Services
Fluvial Geomorphology

Roaring BranchT2.02 - Cross Section 1



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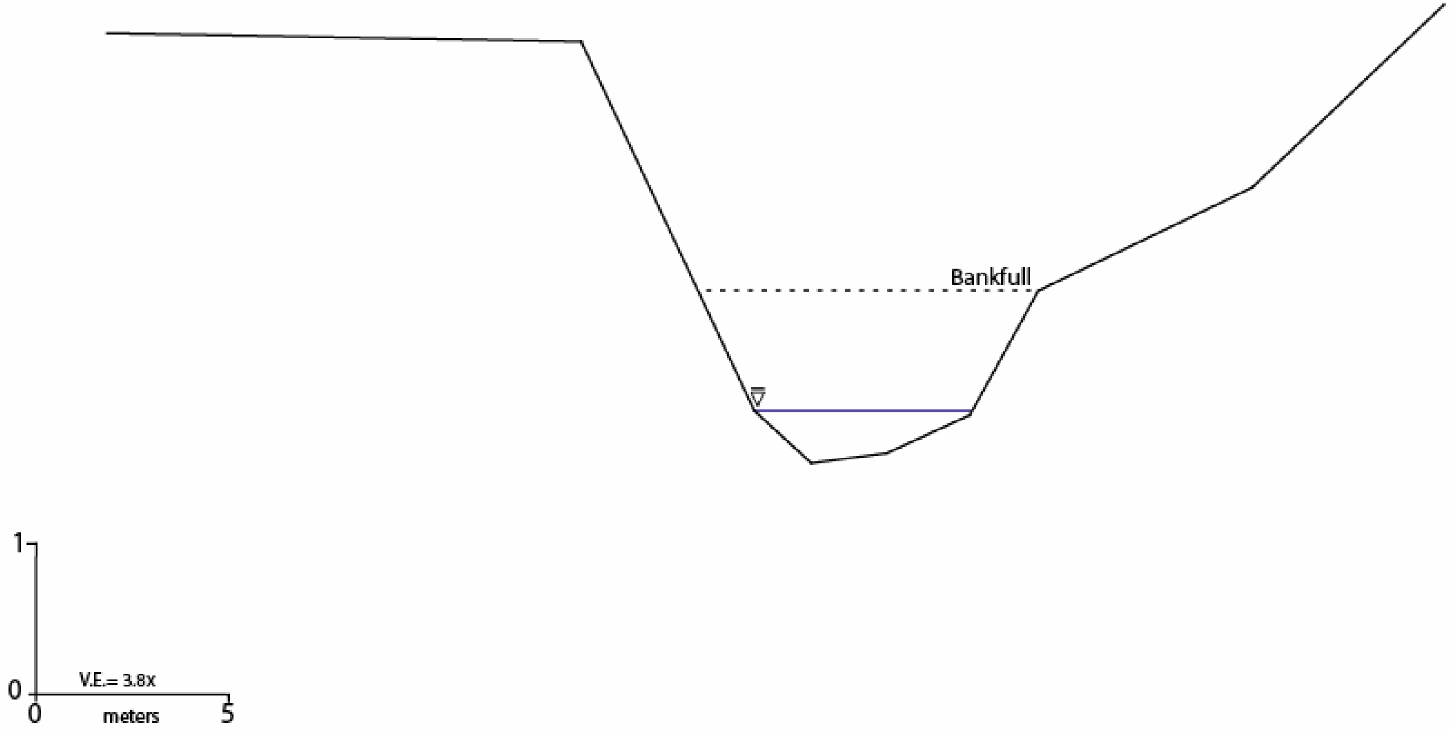
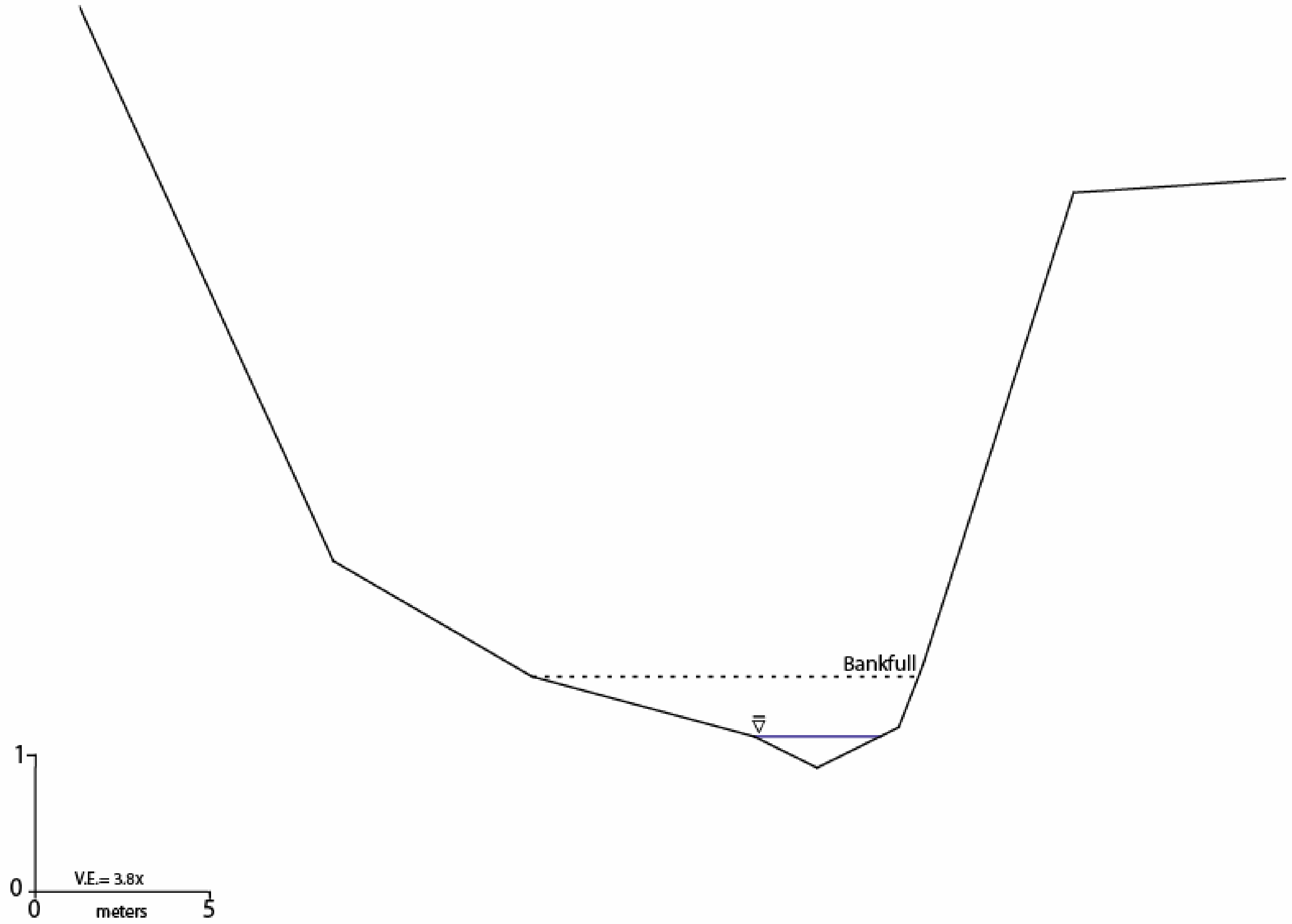
Fluvial Geomorphology

Green River T1.03- Cross Section 2



Field Geology Services
Fluvial Geomorphology

Green River T1.03- Cross Section 1



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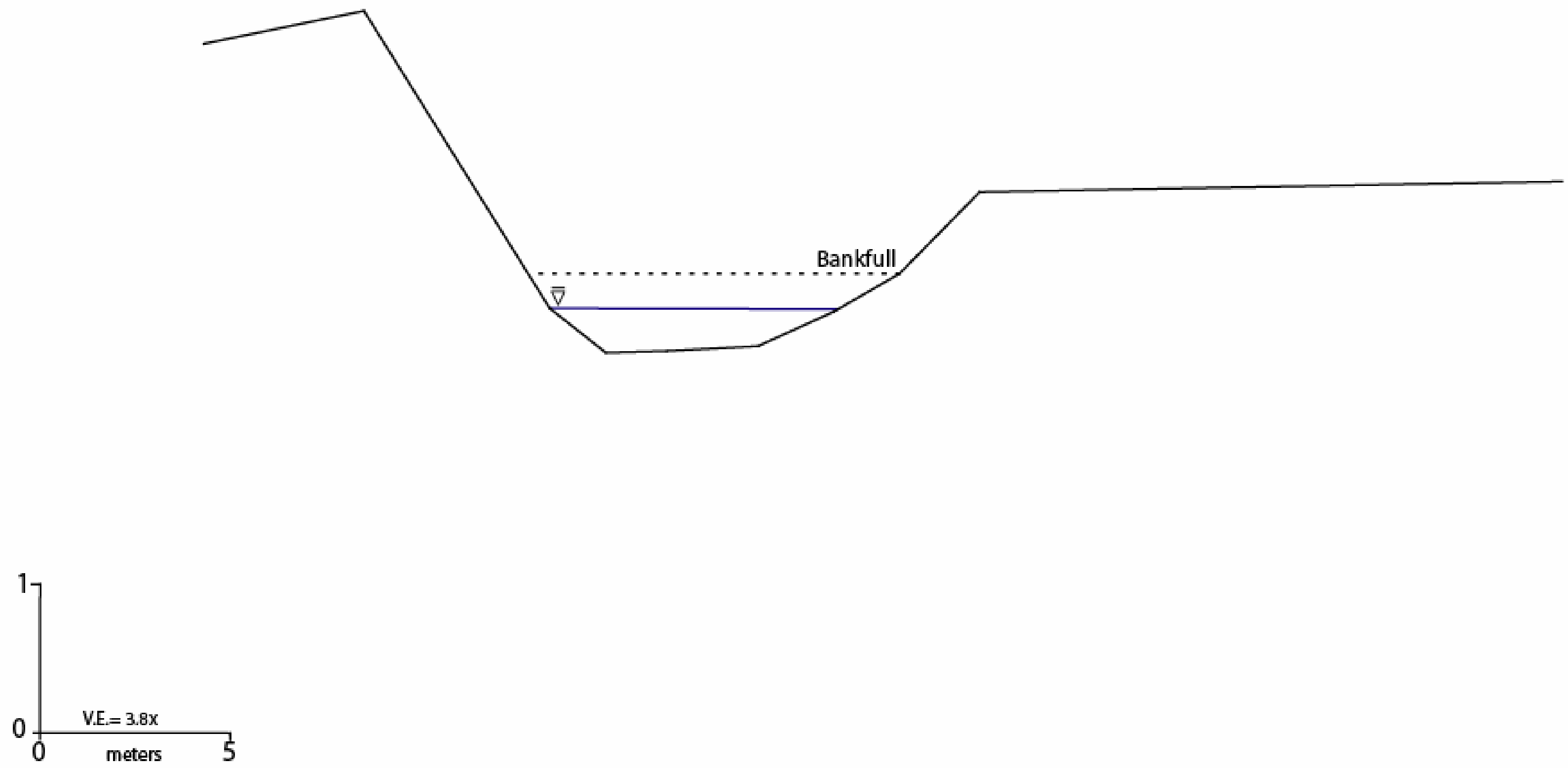
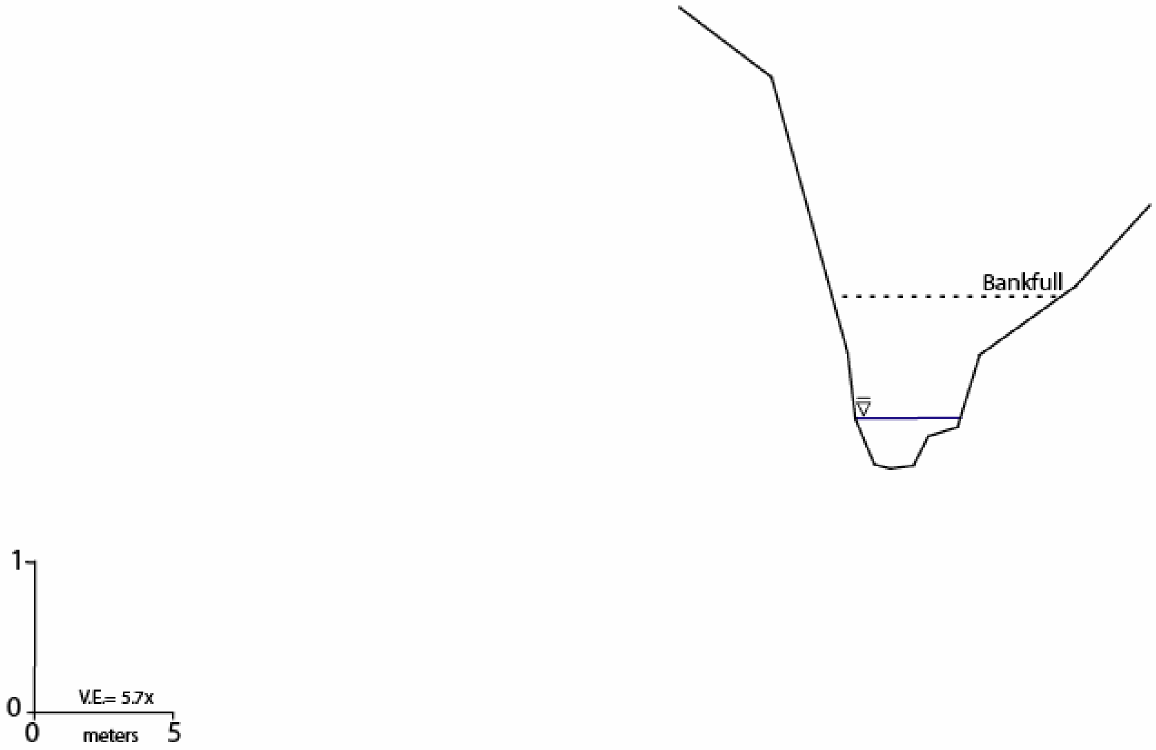
Fluvial Geomorphology

Green River T1.01- Cross Section 2



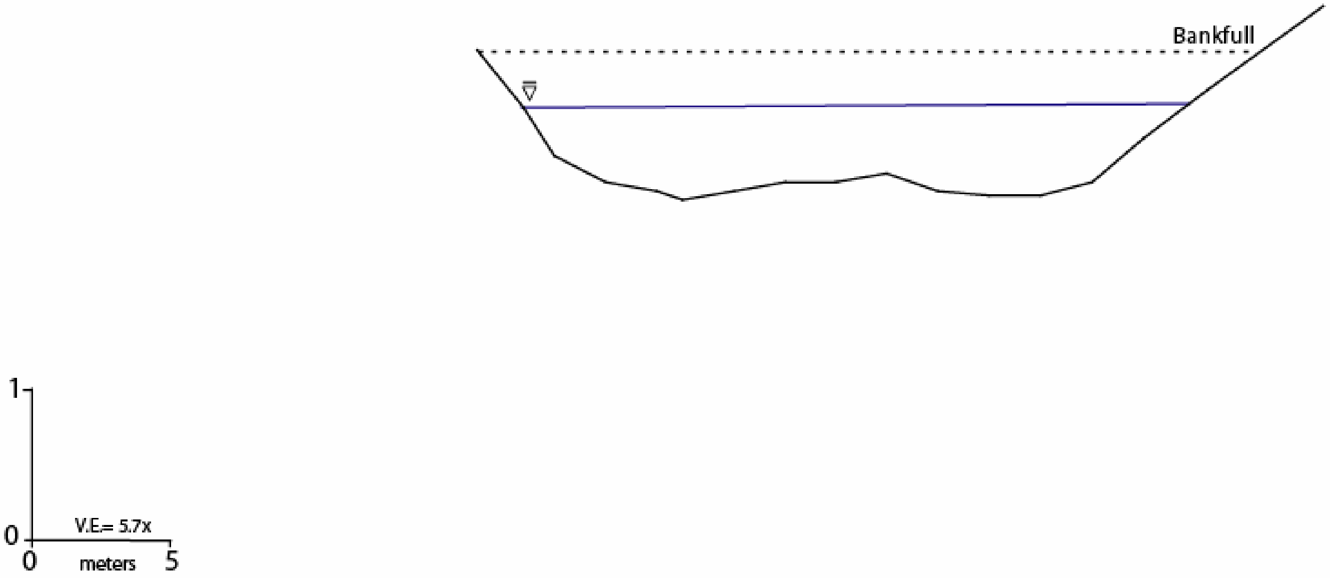
Field Geology Services
Fluvial Geomorphology

Battenkill M13 - Cross Section 2



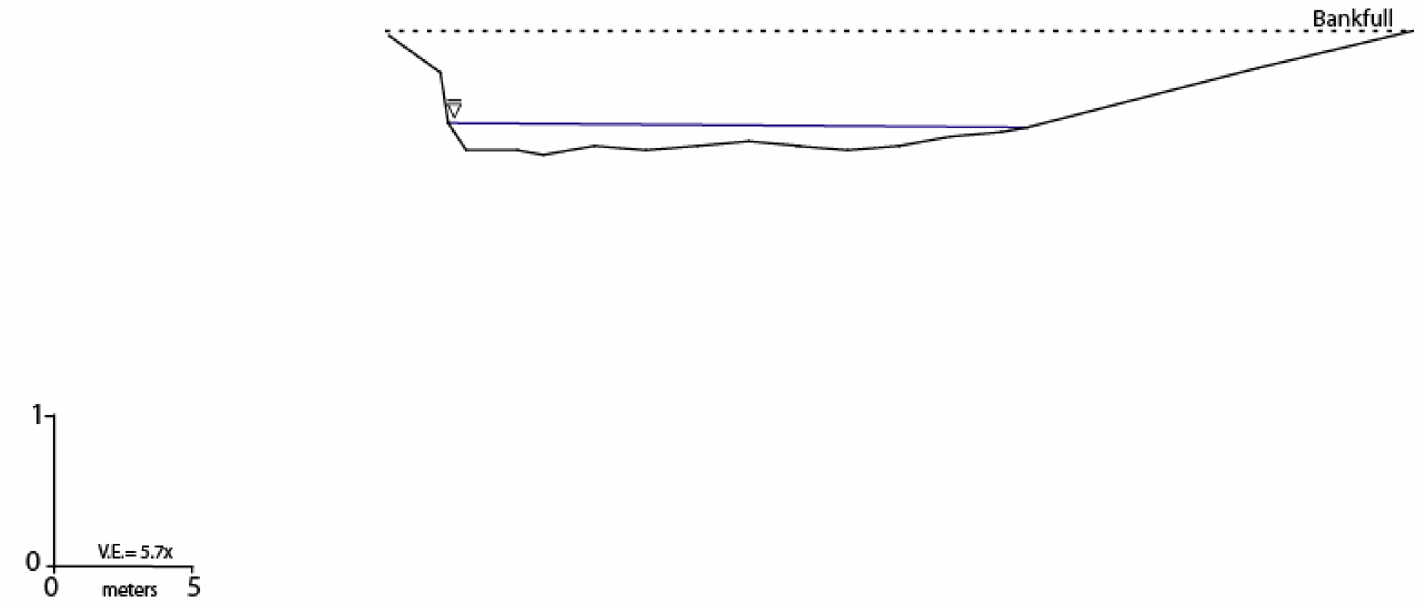
Field Geology Services
Fluvial Geomorphology

Battenkill M12 - Cross Section 2



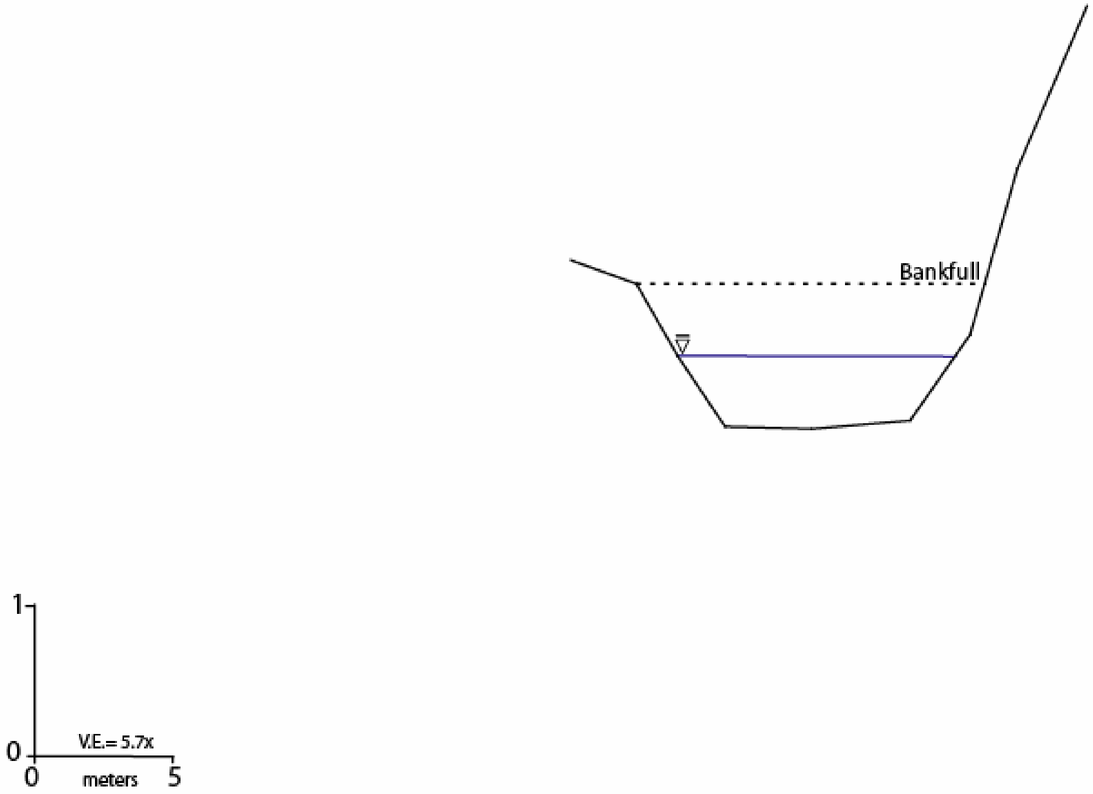
Field Geology Services
Fluvial Geomorphology

Battenkill M12 - Cross Section 1



Field Geology Services
Fluvial Geomorphology

Battenkill M11 - Cross Section 2



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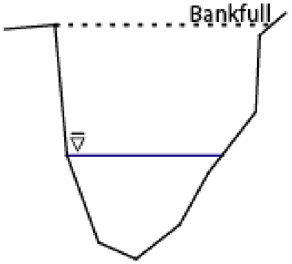
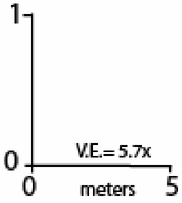
Fluvial Geomorphology

Battenkill M11 - Cross Section 1





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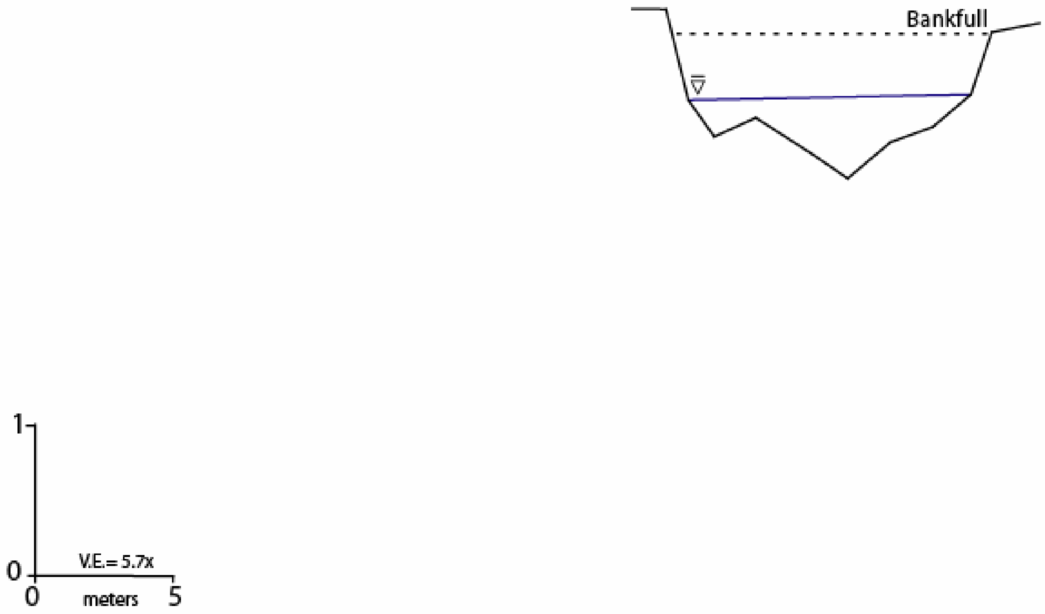
Fluvial Geomorphology

Battenkill M10 - Cross Section 1



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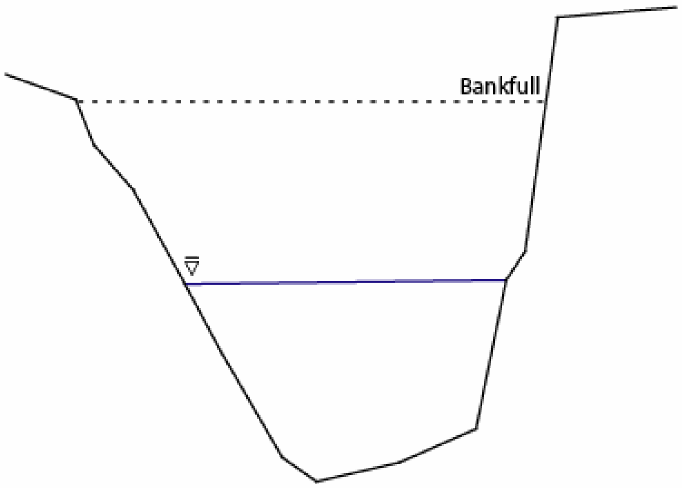
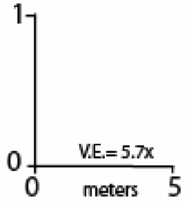
Fluvial Geomorphology

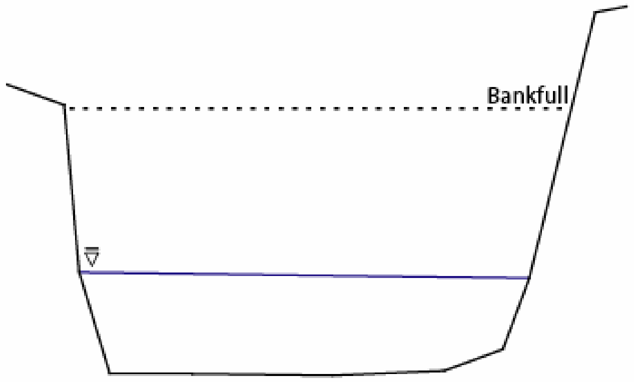
Battenkill M8 - Cross Section 2

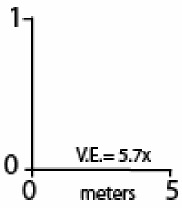




Field Geology Services
Fluvial Geomorphology

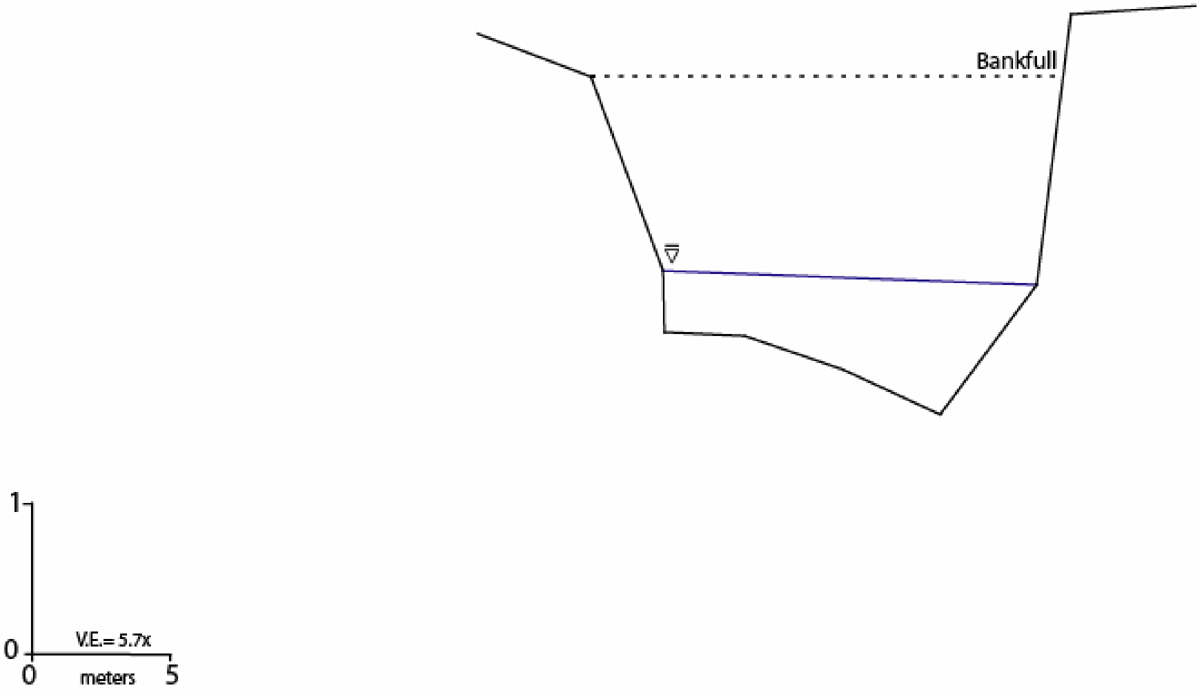
Battenkill M8 - Cross Section 1





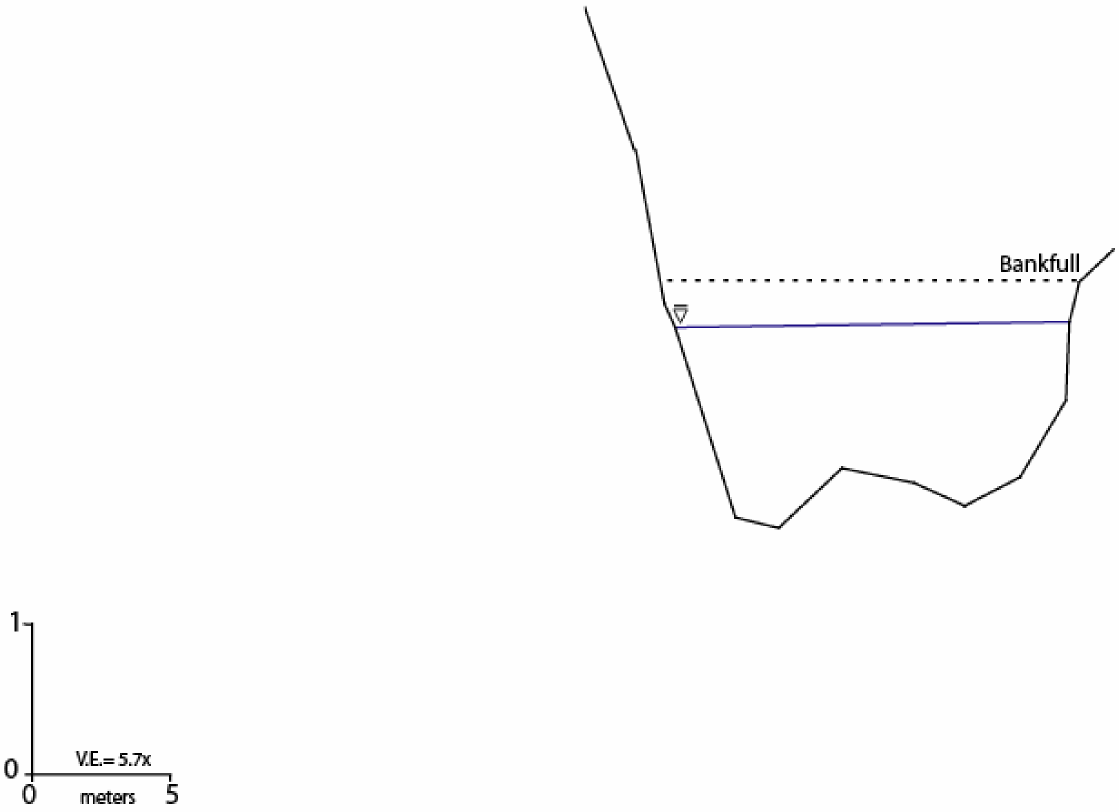
Field Geology Services
Fluvial Geomorphology

Battenkill M7 - Cross Section 1



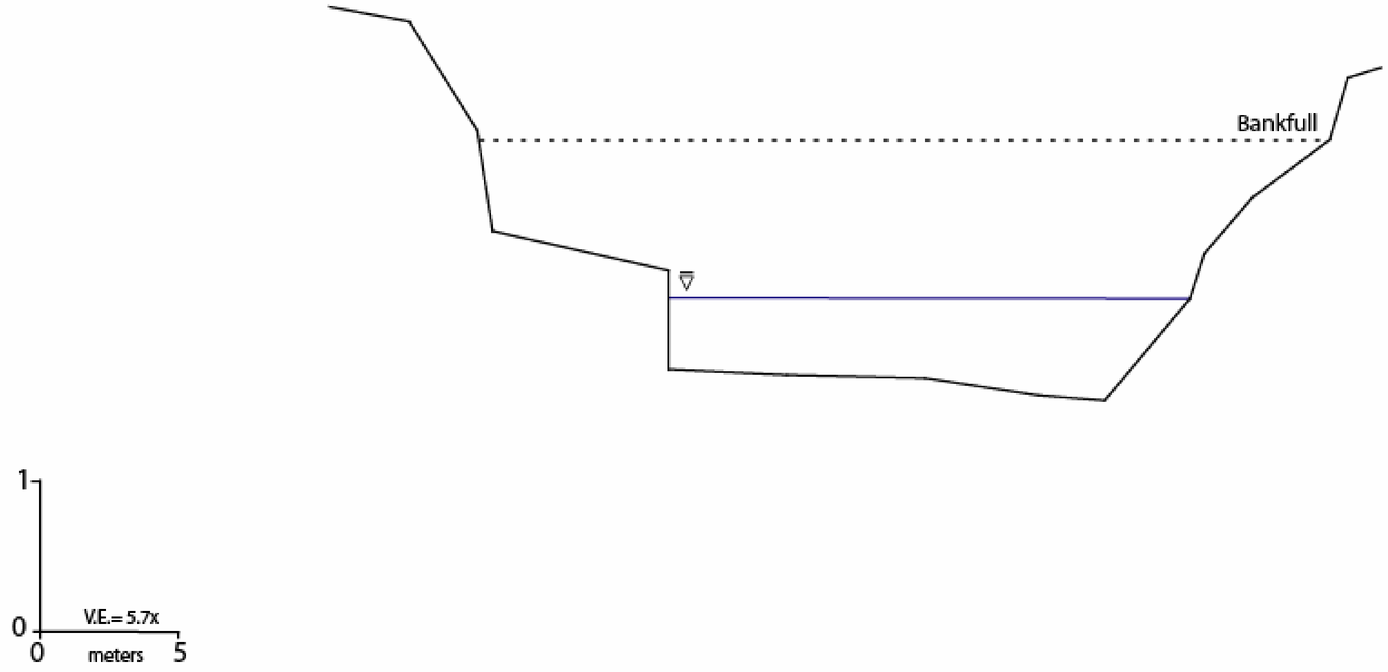
Field Geology Services
Fluvial Geomorphology

Battenkill M6 - Cross Section 1



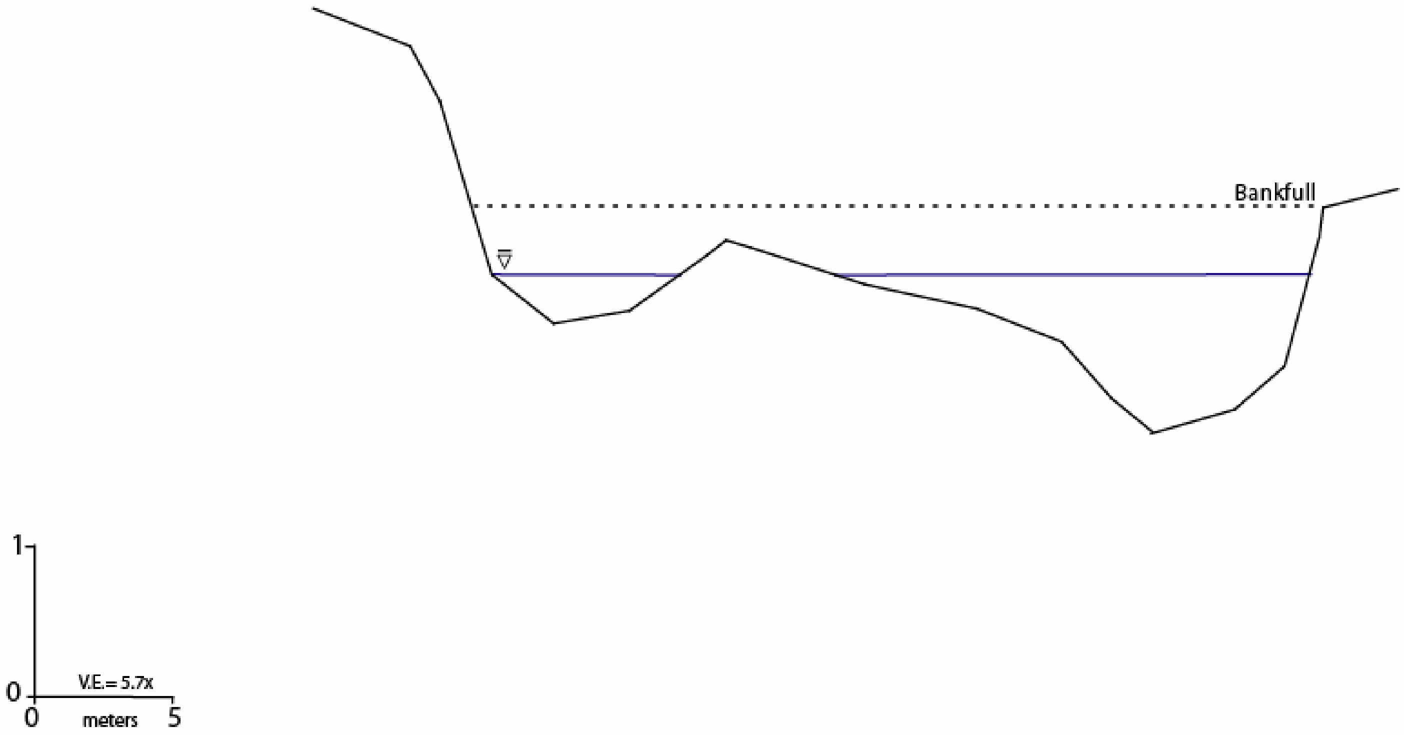
Field Geology Services
Fluvial Geomorphology

Battenkill M4 - Cross Section 2

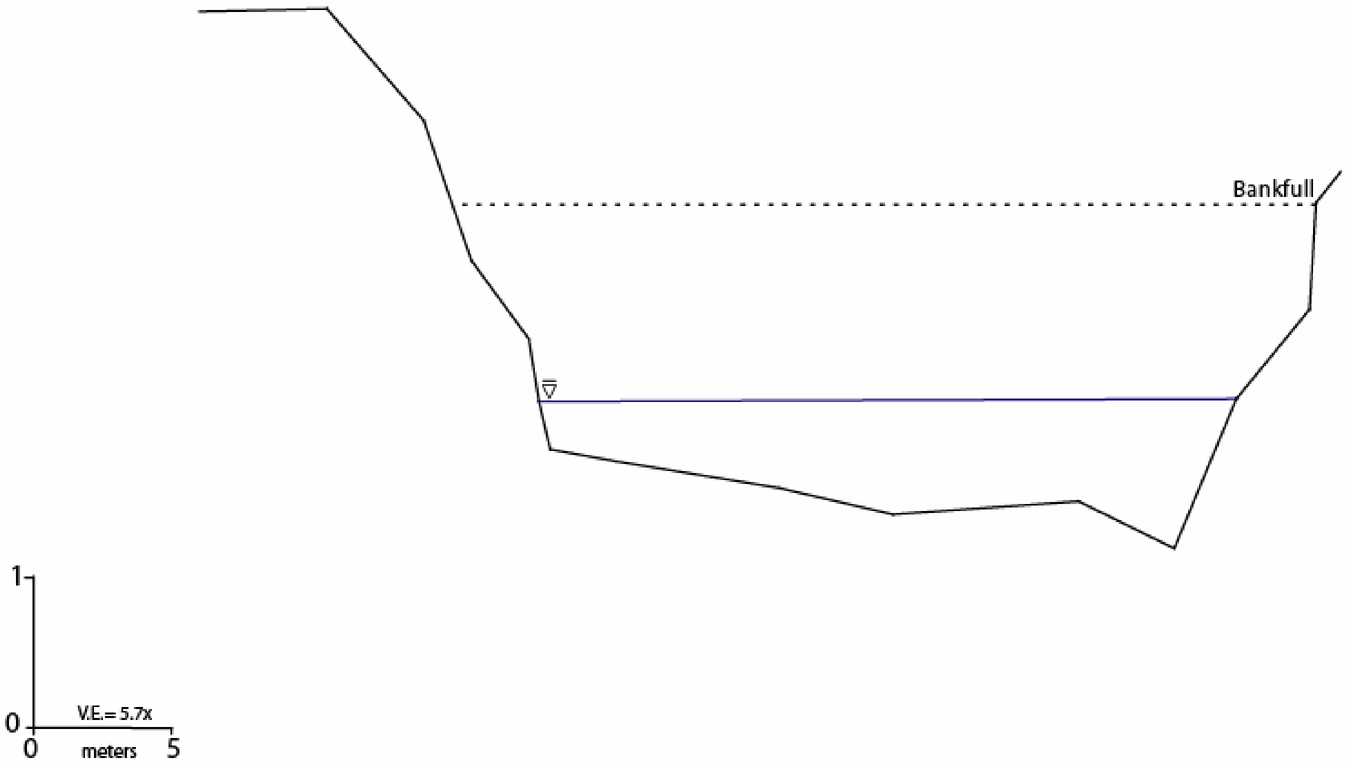


Field Geology Services
Fluvial Geomorphology

Battenkill M3 - Cross Section 2



Battenkill M3 - Cross Section 1



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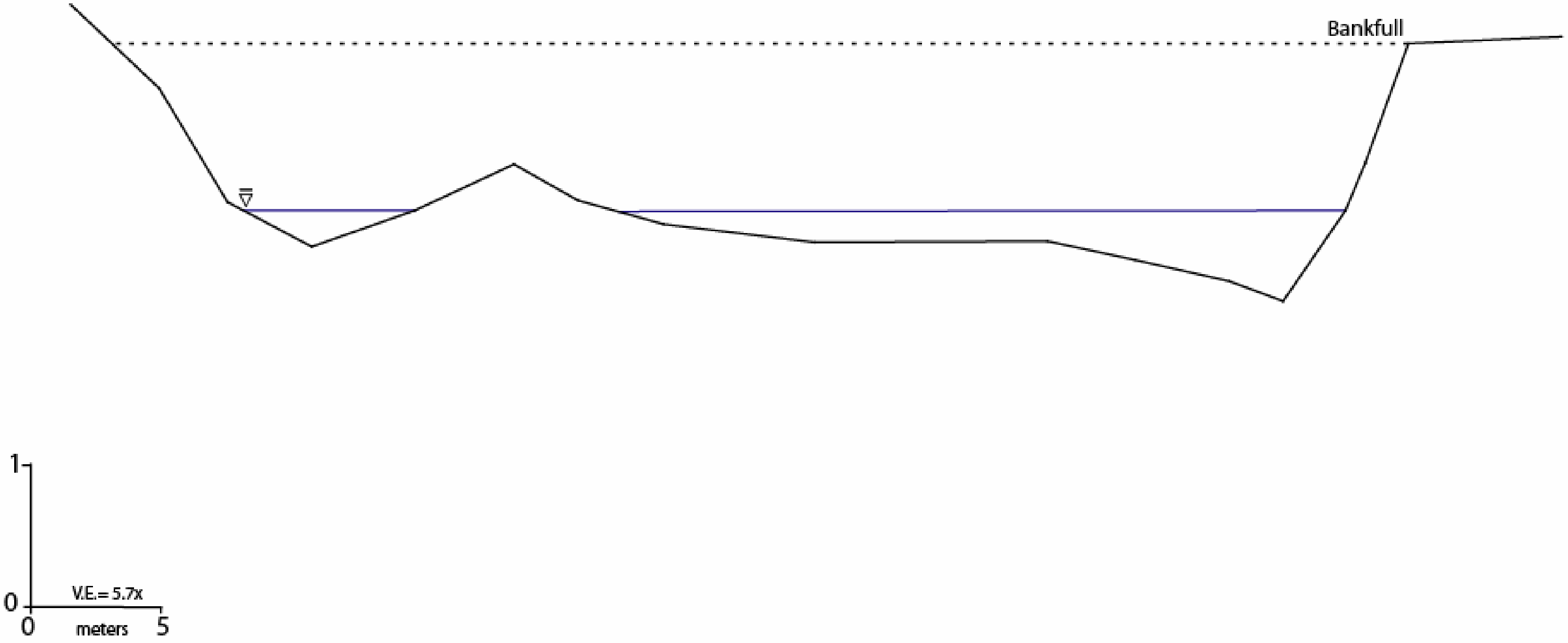
Battenkill M1 - Cross Section 3



Field Geology Services
Fluvial Geomorphology

Battenkill M1 - Cross Section 2