Gunstock Brook Watershed
Stream Geomorphic Assessment
Gilford, New Hampshire
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1.0 EXECUTIVE SUMMARY

A stream geomorphic assessment of Gunstock Brook was conducted by Bear Creek Environmental, LLC (BCE) in August 2011. The study was funded by the Samuel P. Pardoe Foundation and the Belknap County Conservation District. A planning strategy based on fluvial geomorphic science (see glossary at end of report for associated definitions) was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. The stream geomorphic assessment data can be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use alter the physical processes and habitat of rivers. The stream geomorphic assessment data will be used to help focus stream restoration activities within the watershed and assist with town planning.

The stream geomorphic assessment followed the Vermont Agency of Natural Resources Protocols that has been adopted by the New Hampshire Department of Environmental Services (NHDES). The Gunstock Brook watershed was divided into six reaches for the Phase 2 assessment (five on the main stem and one on a major tributary to Gunstock Brook), encompassing approximately six miles of stream channel. The most downstream 550 feet of the main stem was impounded and did not receive a full Phase 2 assessment. Bridge and culvert data collected by BCE were used to identify structures that have the potential to fail because of channel adjustments, are having a geomorphic impact on the stream, or are impeding aquatic organism passage.

Some problems in the Gunstock Brook watershed include undersized stream crossings, corridor encroachments, increased stormwater runoff from impervious surfaces, channel straightening associated with the construction of roads and development, lack of riparian buffers, mass failures, and degraded water quality through sediment loading. Several reaches of Gunstock Book and the major tributary have undersized culverts or bridges that are causing localized geomorphic instability and are reducing or impeding fish passage. Alteration of stream channels mostly in the downstream section of Gunstock Brook has caused major to extreme channel degradation resulting in a disconnection between the channel and adjacent floodplain. High quality streamside buffers are lacking along the many reaches where development is prevalent within the river corridor of Gunstock Brook. Despite all these impacts, there are areas within the watershed that still contain well forested river corridors as well as undeveloped wetland areas.

A list of 20 potential restoration and conservation projects was developed during project identification. Types of projects include: river corridor protection through conservation easements or adoption of fluvial erosion hazard zones, replacing undersized structures causing localized channel instability, improving riparian buffers, alternative analysis for dam removal and berm removal, remediation of erosion from a well discharge to improve water quality, and improved stormwater treatment.

2.0 BACKGROUND

The Belknap County Conservation District retained Bear Creek Environmental, LLC to conduct a Phase 2 Geomorphic Assessment within the Gunstock Brook Watershed. The Gunstock Brook watershed has a drainage area of approximately 9 square miles at the mouth, where the brook enters Sanders Bay of Lake Winnipesaukee (Figure 2.1). A summary of the geomorphic condition of Gunstock Brook and one major tributary is described in this report along with the identification of preliminary projects to be further developed. Stream geomorphic assessment data can be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use alter the physical processes of rivers.

A total of approximately six river miles were assessed using Phase 2 protocols, including five reaches on the main stem of Gunstock Brook and one reach on its major tributary. These six reaches (M01 through M05 and T2.01) were further divided into eighteen segments during the Phase 2 investigation based on changes in channel conditions identified during the field work. A segment is distinct in one or more of the following parameters: degree of floodplain encroachment or channel alteration, presence of grade controls, channel dimensions, channel sinuosity and slope, riparian vegetation and corridor conditions, and degree of flow regulation. Segments are assigned letters starting with "A" at the most downstream end of the reach. All segments were assessed except for the most downstream segment, which was impounded from Lake Winnipesaukee.

This study of the Gunstock Brook watershed utilized state-of-the-art Stream Geomorphic Assessment (SGA) protocols developed by the Vermont Department of Environmental Conservation (VTDEC). The SGA protocols are intended to be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use affect hydro-geomorphic processes at the landscape and reach scale, and how these changes alter the physical structure and biological habitat of rivers. The Vermont protocol includes three phases:

1. Phase 1 – Remote sensing and cursory field assessment;
2. Phase 2 – Rapid habitat and rapid geomorphic assessments to provide field data to characterize the current physical condition of a river; and
3. Phase 3 – Detailed survey information for designing "active" channel management projects.

BCE conducted a partial Phase 1 assessment of the Gunstock Brook watershed during spring 2011. This partial phase 1 assessment included breaking the watershed into reaches (sections of river that are similar), and characterizing the reaches in terms valley confinement (valley width) and valley slope. The fieldwork for the Phase 2 assessment was completed in August 2011 by BCE. Bridge and culvert assessments following the New Hampshire Stream Crossing Protocol were conducted on all assessed reaches. These field data were used to develop preliminary river restoration and protection projects presented in this report. Phase 3 surveys for active restoration projects, may be required at some point in the near future for project design and permitting. The Phase 1 and 2 stream geomorphic assessment data can be used by resource managers to develop fluvial erosion hazard (FEH) zones. FEH zoning ordinances are intended to prevent increased river encroachment in areas prone to fluvial erosion hazards to reduce property loss and damage, and encourage long-term river stability. Although the delineation of FEH zones were not part of this study, the data collected in 2011 can be used in the future to develop these zones.

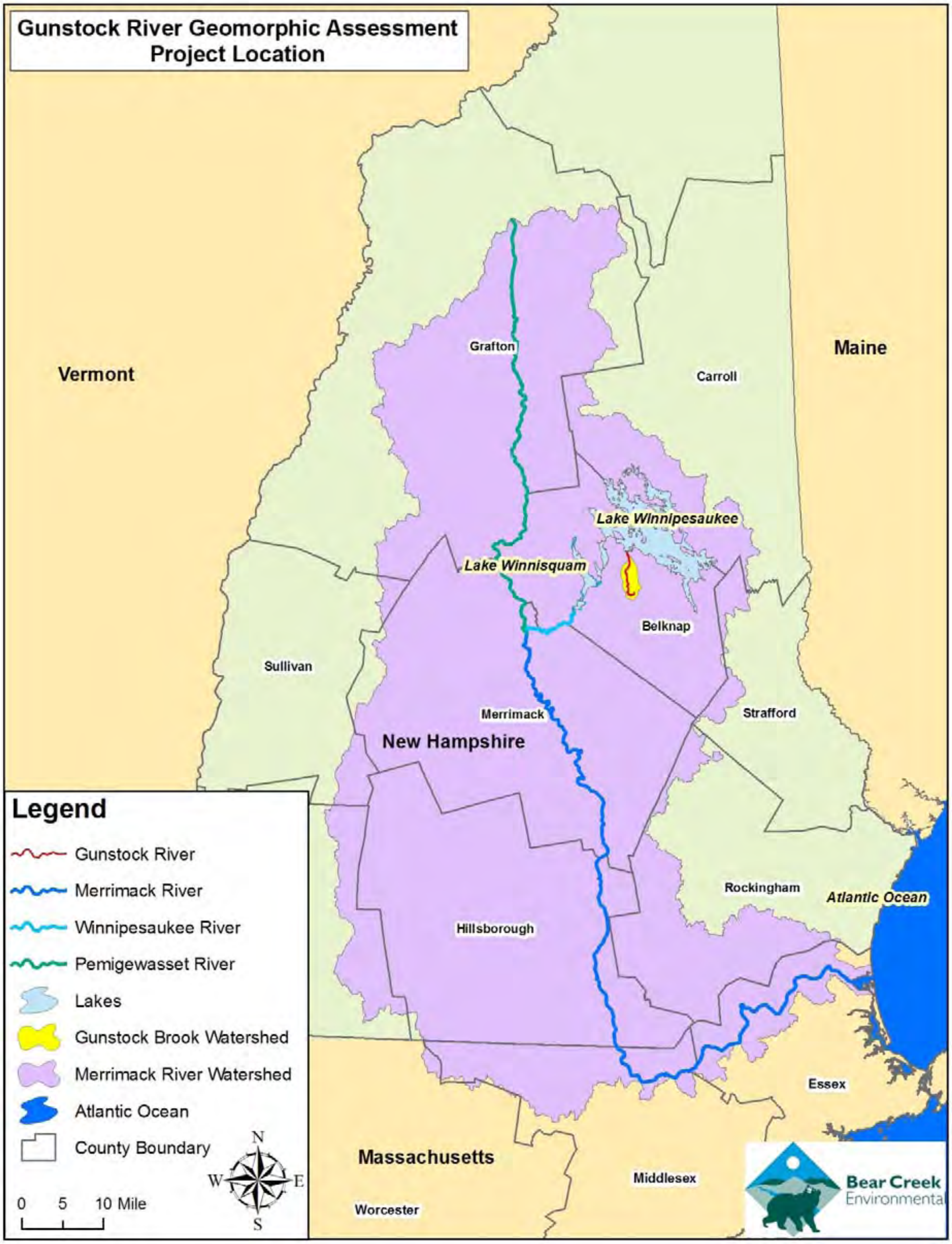

Figure 2.1 Project Location Map

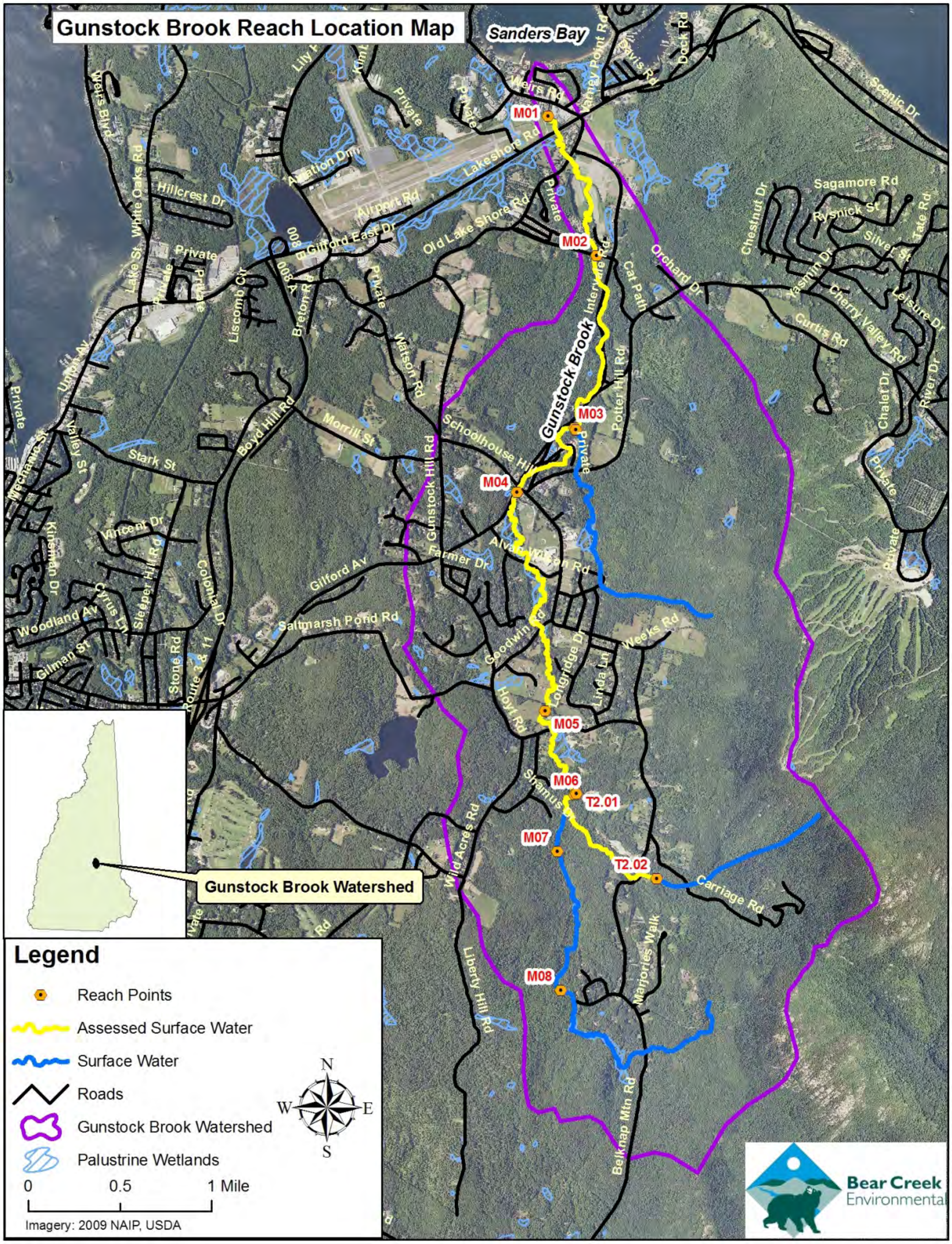

Figure 2.2 Gunstock Brook Reach Location Map

3.0 METHODS

A summary of the Phase 1, Phase 2, and Bridge and Culvert methodologies is provided in the following sections.

3.1 Phase 1 Methodology

The Phase 1 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 1 (Vermont Agency of Natural Resources 2007), and used version 4.59 of the Stream Geomorphic Assessment Tool (SGAT). SGAT is an ArcView extension. Phase 1, the remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called "windshield surveys". The Phase 1 assessment provides an overview of the general physical nature of the watershed. As part of the Phase 1 study, stream reaches are determined based on geomorphic characteristics such as: valley confinement, valley slope, geologic materials, and tributary influence. The stream centerline of Gunstock Brook was delineated using 2010 orthoimagery. In addition, a short section of stream channel behind the Gilford Town Hall was mapped using a submeter GPS unit to better understand the location that could not easily be discerned from the 2010 imagery.

3.2 Phase 2 Methodology

The Phase 2 assessment of the Gunstock Brook watershed followed procedures specified in the Vermont Stream Geomorphic Assessment (SGA) Handbook Phase 2 (Vermont Agency of Natural Resources, 2009), and used version 4.59 of the Stream Geomorphic Assessment Tool (SGAT) Geographic Information System (GIS) extension to index impacts within each reach. The geomorphic condition for each Phase 2 reach is determined using the rapid geomorphic assessment (RGA) protocol, and is based on the degree of departure of the channel from its reference stream type (Vermont Agency of Natural Resources, 2009). The study also used a new rapid habitat assessment (RHA) protocol (Vermont Agency of Natural Resources, 2008a; Milone and MacBroom, Inc, 2008c).

Reaches determined during Phase 1 were broken up further into segments for the Phase 2 geomorphic assessment as necessary. Topographic maps and orthophotos were used as a first cut in delineating segment breaks. The project team walked each reach to confirm preliminary segment breaks determined from reviewing topographic maps and orthophotos. The reaches were walked to the extent that conditions were suitable for walking and landowners had granted permission. Attributes that were considered when determining segment breaks include: grade controls, changes in channel dimensions, changes in dominant bed material, slope, entrenchment or sinuosity, signs of planform changes, presence of beaver dams, and evidence of aggradation and degradation. The bankfull width and depth were measured occasionally along the reach to track changes in bankfull dimensions. Once segment breaks were determined, the Phase 2 field forms were completed accordingly.

Valley walls delineated during Phase 1 were field verified using a range finder and submeter GPS unit (Trimble Geoexplorer 2008 series). Human caused changes in valley width due to permanent high embankments that serve as artificial valley walls were also mapped on field sketches with reference to topographic maps and/or orthophotographs. The valley walls were used to evaluate Phase 2 confinement. Adjacent terraces and valley walls were evaluated in terms of their proximity to the channel as outlined in the most current version of the Vermont Phase 2 SGA Handbook. The location, total height and height above water surface were recorded for channel spanning grade controls, both natural and human constructed.

Channel dimensions and bed substrate composition were measured at one to three representative locations within each segment. The channel dimensions and substrate composition were recorded on the Cross-section Worksheet and summarized on the Rapid Stream Assessment Field Notes form under Step 2. Stream type was evaluated based on the channel dimension data, bed substrate composition results, and confirmed channel slope. Dominant bed forms were determined based on the criteria set forth in the most recent version of the Vermont Phase 2 SGA Handbook.

Stream banks were evaluated in terms of their typical slope and dominant texture as outlined in the Vermont Phase 2 SGA Handbook. Areas of bank erosion, mass failures, and gullies were mapped and pertinent information regarding the height and length of such features was recorded. Areas lacking adequate riparian buffers (<25 feet) were mapped and notes were made about the types of vegetation comprising existing riparian buffers. River corridor encroachments including roads, railroads, improved paths, and development were mapped according to their locations, and the height of these encroachments was recorded. Notes were also taken concerning river corridor land use activities.

The locations of springs, seeps, small tributaries, adjacent wetlands, debris jams, beaver dams and channel constrictions were recorded and evaluated in terms of how they may be affecting channel flows. Locations of stormwater inputs from urban runoff, agricultural drainage and road ditching were noted to determine the extent of increased flow status during a storm event. Similarly, locations of flow regulations and water withdrawals were mapped to evaluate potential decreases in channel flows.

Depositional features were mapped to assess the sediment transport regime and storage capacity of the segment. Channel migration features were also mapped in order to determine the amount of channel planform adjustment the segment was undergoing. Sections of the stream where the channel does not appear to be following the natural path of the river and may have been straightened were noted, along with locations where material has been removed from the channel in order to assess the extent to which stream power and morphology have been altered. Steep riffles and headcuts were mapped and used as indicators of active geomorphic processes.

RHA and RGA field forms were completed for the Phase 2 reaches. The appropriate RHA and RGA forms were selected based on segment characteristics and scored according to the data collected from the field assessment. A segment score and corresponding condition were determined for both the RHA and the RGA. Additionally for the RGA, major geomorphic processes were identified, the stage of channel evolution was determined, and a stream sensitivity rating was assigned.

The RHA is used to evaluate the physical components of a stream (channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The RHA results can be used to compare physical habitat condition between sites, streams, or watersheds, and they can also serve as a management tool in watershed planning.

To assure a high level of confidence in the Phase 2 SGA data, strict quality assurance/quality control (QA/QC) procedures were followed by BCE. These procedures involved a thorough in-house review of all data, which took place during January 2012. The Project Team conducted the assessment according to the approved Quality Assurance procedures specified in the Phase 2 handbook.

A quality control review of the Gunstock Brook geomorphic assessment data by the New Hampshire Geological Survey was initiated by BCE to lay the ground work for the development of Fluvial Erosion Hazard (FEH) Zones, which are based on the Phase 1 and 2 stream geomorphic assessment data. Stream geomorphic assessment data and delineated FEH zones need to go through the standard QA review from the NHGS in order for the Department of Environmental Services (DES) to state the zones are consistent with the Department's protocols. Dave Jeffers, Regional Planner with the Lakes Regional Planning Commission has been working with the Gilford Hazard Mitigation Plan Update Committee. According to Mr. Jeffers, there may be local interest in using the stream geomorphic assessment data to develop FEH zones for Gunstock Brook.

Shane Csiki of the New Hampshire Geological Survey (NHGS) conducted a QA/QC review of the data collected by Bear Creek Environmental (BCE) for Gunstock Brook. At the end of January, 2012, the NHGS sent the first set of QA recommendations based on review of the GIS data. The NHGS recommended that changes be made to the stream centerline and the valley walls. Based on recommendations from NHGS, BCE updated the stream centerline using 2010 orthoimagery. The meander centerline and valley walls were also updated. NHGS reviewed the updated files for valley walls and stream centerline and then made further recommendations on February 6, 2012 referring to refining the valley walls and the stream centerline. Mr. Csiki accepted the revisions and provided a couple of additional comments. BCE conducted a field visit to verify valley wall locations on February 10, 2012. The valley walls and meander centerlines were updated once more and SGAT was rerun.

Following the review of GIS data, the NHGS reviewed the Phase 2 data excel spreadsheets. Mr. Csiki had questions/comments on four segments. These comments were addressed in a response document from BCE dated March 13, 2012. A second QA document was sent to BCE on 3/21/12 containing comments/questions on three segments on Gunstock Brook. BCE promptly responded (on March 28, 2012) to the comments and made necessary updates to the data. The Gunstock Brook stream geomorphic assessment data passed the

QA review by the NHGS, and these data are approved for use in developing FEH zones. The phase 2 QA comments and questions are provided at the end of Appendix A.

3.3 Bridge and Culvert Methodology

Bridge and culvert inventory and assessments were conducted by BCE during the Phase 2 assessment to determine if stream crossings were contributing to localized streambank erosion, sedimentation, and reduced fish passage. The New Hampshire Stream Crossing Protocol was followed. The Vermont Culvert Geomorphic Screening Tool (Milone and MacBroom, Inc., 2008a) and the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, Inc, 2008b) were used to identify culverts within the Gunstock Brook watershed that are highest priority for replacement/retrofit due to geomorphic incompatibility and/or for being potential barriers to movement and migration of aquatic organisms.

4.0 STREAM TYPES

Reference stream types are based on the valley type, geology and climate of a region and describe what the channel would look like in the absence of human-related changes to the channel, floodplain, and/or watershed. Table 1 shows the typical characteristics used to determine reference stream types (Vermont Agency of Natural Resources, 2009). Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems. Stream and valley characteristics including valley confinement, and slope were determined from digital United States Geological Survey (USGS) topographic maps (Table 2).

Table 1. Reference Stream Type

Stream Type	Confinement	Valley Slope	Bed Form
A	Narrowly Confined	Very steep > 6.5 %	Cascade
A	Confined	Very steep 4.0 - 6.5 %	Step-Pool
B	Confined or Semi-confined	Steep 3.0 – 4.0 %	Step-Pool
B	Confined, Semi-confined or Narrow	Moderate to Steep 2.0 – 3.0 %	Plane Bed
C or E	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <2.0 %	Riffle-Pool or Dune-Ripple
D	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <4.0 %	Braided Channel
F	Confined or Semi-confined	Moderate to Gentle <4.0 %	Variable

Table 2 lists the reference stream types for assessed reaches in the Gunstock Brook watershed. All reaches assessed for Phase 2 in the Gunstock Brook watershed are "C" channels by reference. Reference "C" channels have unconfined valleys with moderate to gentle valley slopes and moderate to high width to depth ratios and sinuosity. All the mainstem reaches, with the exception of M02 and M03, which are steeper, have an overall confinement type of very broad. Reaches M03 and T2.01 (on a tributary of Gunstock Brook) have slopes greater than 2.0 percent, and are therefore, assigned a subclass slope of "b". All reaches have a reference bedform of riffle-pool except for T2.01 which has a step-pool bedform. The reference reach characteristics were refined during the Phase 2 Assessment.

Table 2. Geomorphic Setting of Assessed Reaches

Stream	Reach ID	Reference Stream Type	Confinement	Valley Slope	Bedform
Gunstock Brook	M01	C	Very Broad	0.55	Riffle-Pool
	M02	C	Broad	1.99	Riffle-Pool
	M03	Cb	Broad	2.80	Riffle-Pool
	M04	C	Very Broad	0.66	Riffle-Pool
	M05	C	Very Broad	1.12	Riffle-Pool
Tributary to Gunstock Brook	T2.01	Cb	Very Broad	3.78	Step-pool

During the Phase 2 assessment, the six assessed reaches were broken into 18 segments based on detailed field observations. The existing stream type is based on channel dimensions measured during the Phase 2 assessment. The reference and existing stream type for each assessed reach/segment is included in Figures 4.1 and 4.2, respectively. Detailed segment summary data are provided in Appendix A. Table 3 summarizes the segment locations, and is included as reference for the reader.

Table 3. Description of Segment Locations

Stream	Segment ID	Description
Gunstock Brook	M01-A	From mouth to Lakeshore Road
	M01-B	From Lakeshore Road to Old Lakeshore Road
	M01-C	Old Lakeshore Road to one-half mile upstream of Old Lakeshore Road
	M01-D	One-half mile upstream of Old Lakeshore Road to east of cul-de-sac on Hampshire Drive
	M01-E	East of cul-de-sac on Hampshire Drive to Henderson Road crossing
	M02 - A	Henderson Road crossing to where brook becomes close to Intervale Rd
	M02-B	Brook runs parallel and in close proximity to Intervale Road
	M02-C	From just downstream of Intervale Road Crossing to tributary

Table 3. Description of Segment Locations		
Stream	**Segment ID**	**Description**
		confluence south of Cherry Valley Road
	M03-A	Tributary confluence south of Cherry Valley Road to upstream of Tannery Hill Road Covered Bridge
	M03-B	Just upstream of Tannery Hill Road Covered Bridge to Belknap Mountain Road crossing
	M04-A	Belknap Mountain Road crossing to approximately 1000 feet upstream of Goodwin Road crossing
	M04-B	About 1000 feet upstream of Goodwin Road crossing to east of Given Drive cul-de-sac
	M04-C	East of Given Drive cul-de-sac to tributary confluence about 1000 feet upstream of Hoyt Road crossing
	M05-A	Tributary confluence about 1000 feet upstream of Hoyt Road crossing to Hoyt Road crossing
	M05-B	Hoyt Road crossing to northeast of Bridget Circle
	M05-C	Northeast of Bridge Circle to confluence with tributary 2 (T2)
Tributary 2	T2.01-A	Confluence with Gunstock Brook to below sand pit
	T2.01-B	Below sand pit to just east of Belknap Mountain Road Crossing

For most of the segments on the Gunstock Brook main stem, the existing stream type is "C". All but two segments have the same reference and existing stream type. For the two most downstream assessed segments located downstream and upstream of Old Lakeshore Road, M01-B and M01-C, the existing stream type differs from the reference stream type and a stream type departure has taken place. A stream type departure occurs when the channel dimensions deviate so far from the reference condition that the existing stream type is no longer the reference stream type. In both segments M01-B and M01-C a stream type departure from a reference "C" channel with slight entrenchment to a "B" channel with moderate entrenchment has occurred due to channel straightening and downcutting of the channel.

These stream type departures represent a significant change in floodplain access and stability. Watersheds which have lost attenuation or sediment storage areas due to human related constraints are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrients to receiving waters, and lack the sediment storage and distribution processes that create and maintain habitat (Vermont Agency of Natural Resources, 2009).

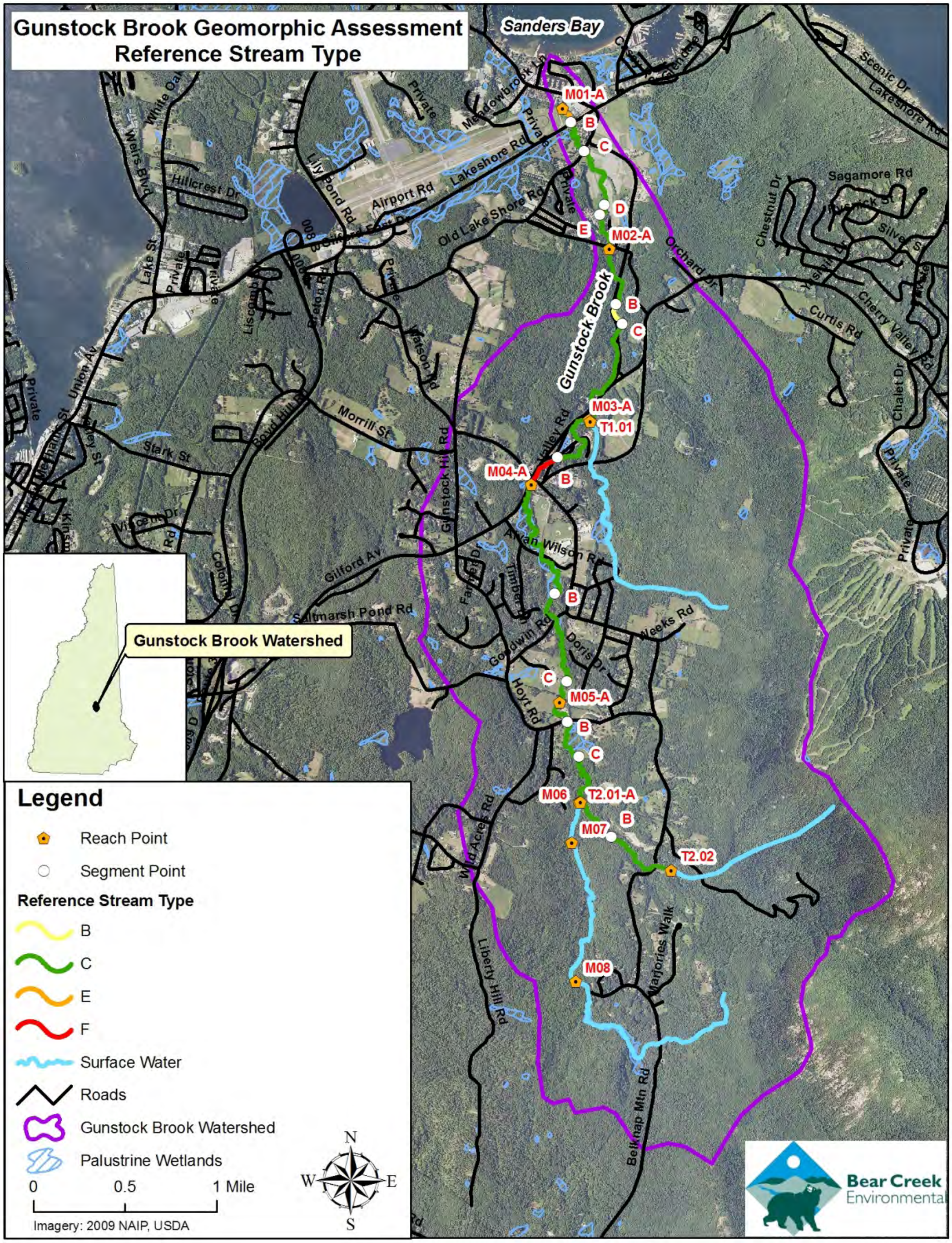

Figure 4.1 Gunstock Brook Reference Stream Types for Phase 2 Assessment

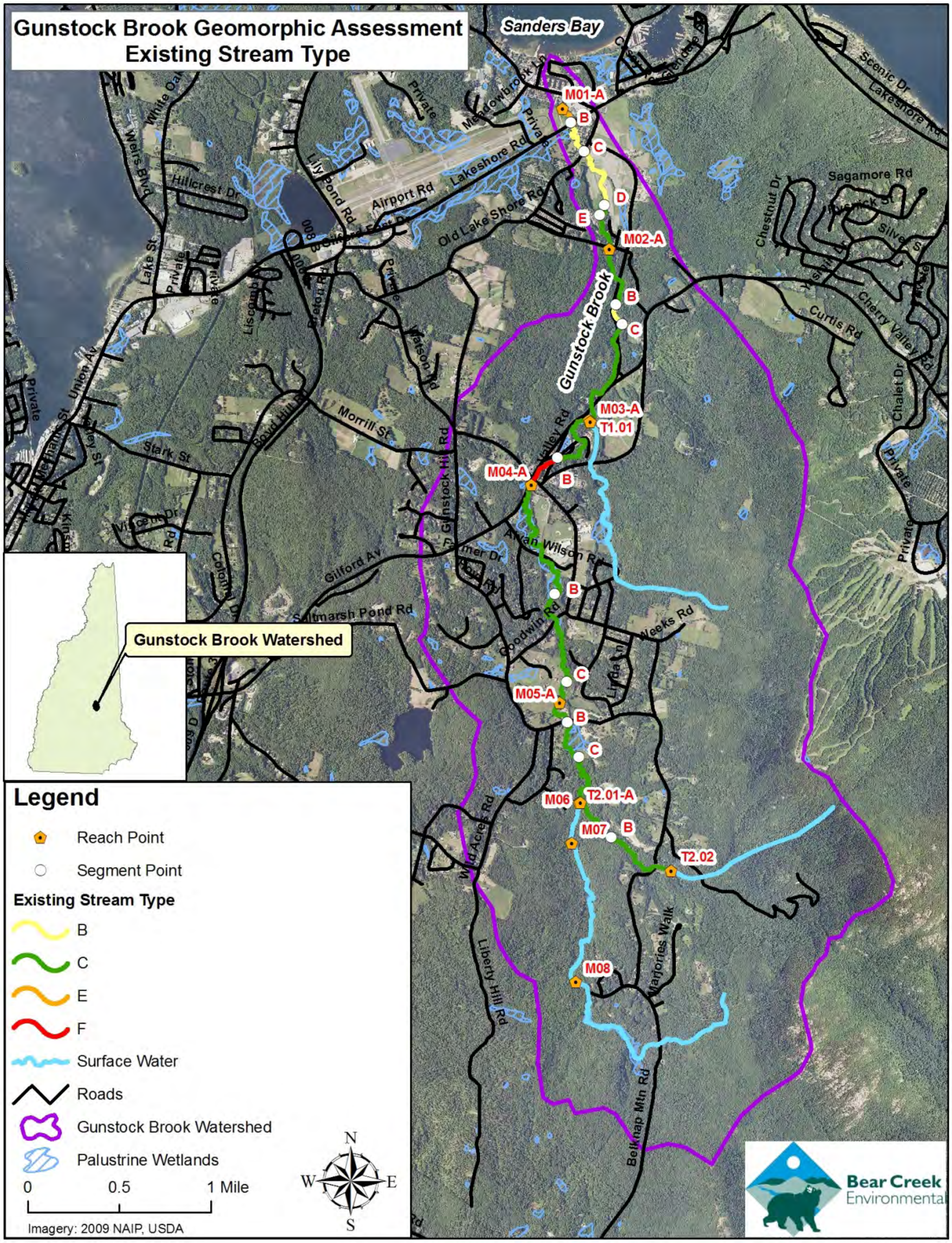

Figure 4.2 Existing Stream Type for Phase 2 Geomorphic Assessments

5.0 GEOMORPHIC CONDITION

The stream condition is determined using the scores on the rapid assessment field forms, and is defined in terms of departure from the reference condition. There are four categories to describe the condition (reference, good, fair and poor). These ratings are defined below.

- Reference – no departure
- Good – minor departure
- Fair – major departure
- Poor – severe departure

The existing geomorphic condition is depicted in Figure 5.1. Geomorphic condition is determined based on the degree (if any) of channel degradation, aggradation, widening and planform adjustment. Degradation is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. The planform of a channel is its shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other adjustment processes such as aggradation and widening. Channel widening occurs when stream flows are contained in a channel as a result of degradation or floodplain encroachment or when sediments overwhelm the stream channel and the erosive energy is concentrated into both banks.

Four segments along the main stem of Gunstock Brook are in “good” geomorphic condition (M02-B, M03-B, M04-A, and M05-B). In addition, the most downstream reach on the major tributary to Gunstock Brook (T2.01) is in “good” geomorphic condition. Two of the Gunstock Brook segments in “good” condition are located in higher gradient, more confined sections with step-pool bedform and cobble dominated substrate. The other two segments in “good” condition are surrounded by wetland, have healthy buffers, and minimal encroachments. All of the remaining segments except two, which have a “poor” condition (M02-A and M03-A), are in “fair” geomorphic condition. Segment M02-A, located upstream of the Henderson Road crossing is impacted by floodplain encroachments from Intervale Road and a undersized and poorly aligned bridge crossing at Intervale Road. The poor geomorphic condition of segment M03-A is related to extensive straightening of the channel and floodplain encroachment from development near the Gilford Town offices. In the areas that are in “poor” or “fair” condition, significant instream modifications and floodplain encroachment is common leading to an increase in stream power in the channel and a loss of functioning floodplains.

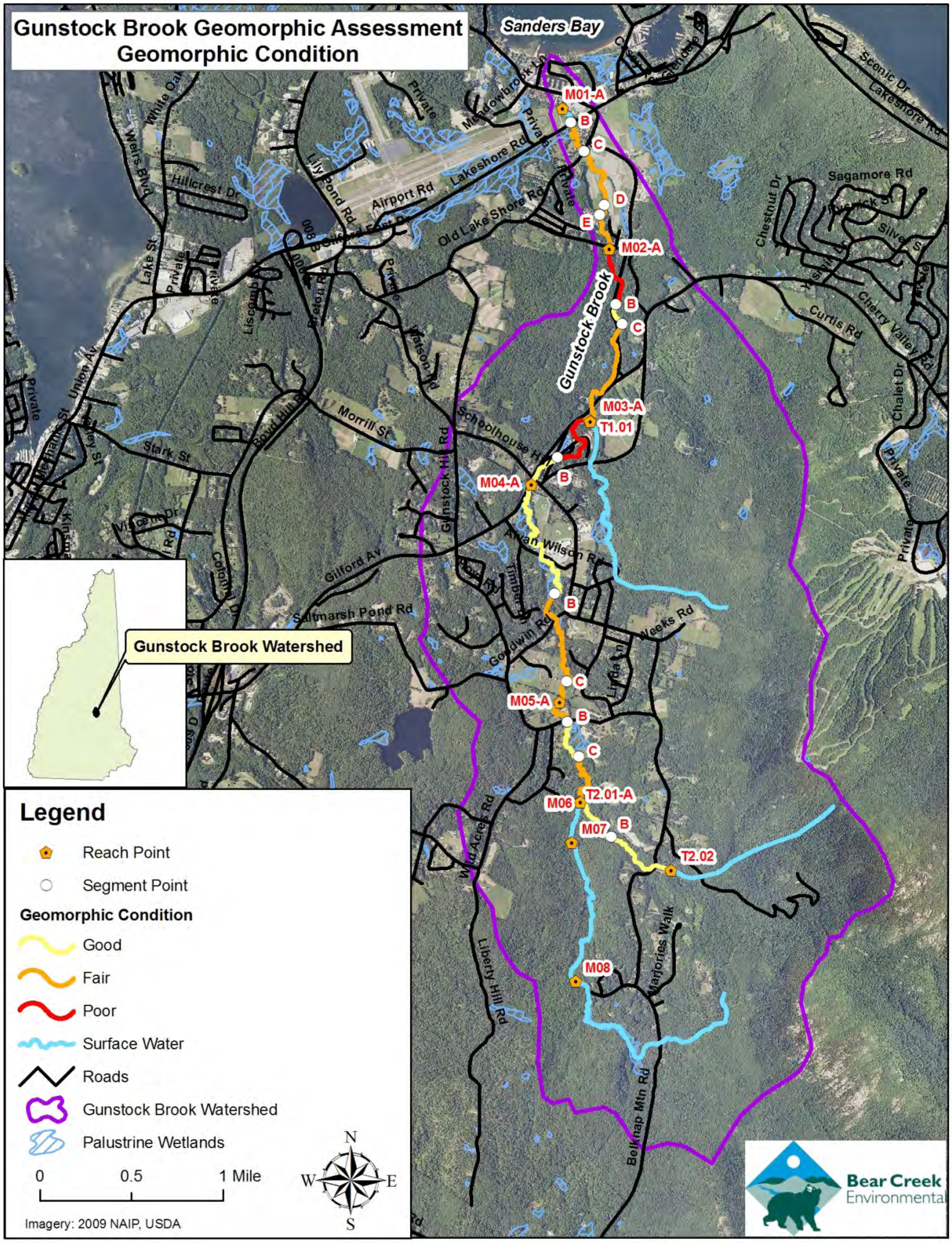

Figure 5.1. Phase 2 Geomorphic Condition of the Gunstock Brook Watershed

Functioning floodplains play a crucial role in providing long term stability to a river system. Natural and anthropogenic impacts may alter the equilibrium of sediment and discharge in natural stream systems and set in motion a series of morphological responses (aggradation, degradation, and widening and/or planform adjustment) as the channel tries to reestablish a dynamic equilibrium. Small to moderate changes in slope, discharge, and/or sediment supply can alter the size of transported sediment as well as the geometry of the channel; while large changes can transform reach level channel types (Ryan, 2001). Human-induced practices that have contributed to stream instability within the Gunstock Brook watershed include:

- Forest clearing
- Channelization and bank armoring
- Removal of woody riparian vegetation
- Floodplain encroachments
- Poor road maintenance and installation of infrastructure
- Loss of wetlands

These anthropogenic practices have altered the balance between water and sediment discharges within the Gunstock Brook watershed. Channel morphologic responses to these practices contribute to channel adjustment that may further create unstable channels. All three adjustment processes, aggradation, widening and planform migration as a result of historic degradation within the channel are present within the Gunstock Brook watershed.

The reach condition ratings of the Gunstock Brook watershed indicate that most of the reaches/segments are actively or have historically undergone a process of minor or major geomorphic adjustment. Many of the reaches studied in the Gunstock Brook watershed are undergoing a channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed. Table 4 below summarizes the channel evolution of each study reach and the primary adjustment processes that are occurring.

Both the "D" stage and "F" stage channel evolution models (Vermont Agency of Natural Resources, 2009; Vermont Agency of Natural Resources, 2004) are helpful for explaining the channel adjustment processes underway in the Gunstock Brook watershed. The "F" stage channel evolution model is used to understand the process that occurs when a stream degrades (incises). The common stages of the "F" channel evolution stage, as depicted in Figure 5.2 include:

- Stable (F-I) - a pre-disturbance period
- Incision (F-II) – channel degradation (head cutting)
- Widening (F-III) – bank failure
- Stabilizing (F-IV) – channel narrows through sediment build up and moves laterally building juvenile floodplain
- Stable (F-V) - gradual formation of a stable channel with access to its floodplain at a lower elevation

The "D-stage" channel evolution model applies to reaches where there may have been some minor historic incision; however, the more dominant active adjustment process is aggradation, which in turn leads to channel widening and planform adjustment. The D-stage adjustment process typically occurs in unconfined, low to moderate gradient valleys where the stream is not entrenched and has access to its floodplain or flood prone area at the 1-2 year flood stage.

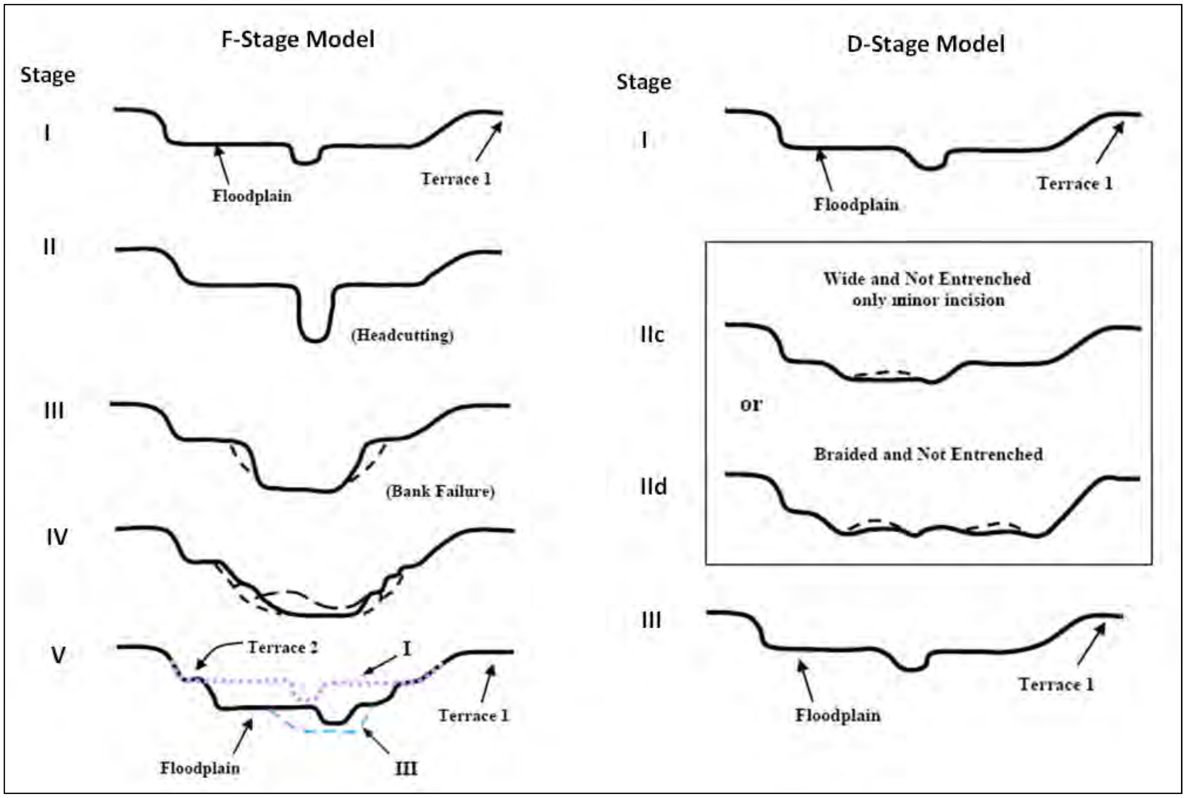

Figure 5.2 Typical channel evolution models for F-Stage and D-Stage (Vermont Agency of Natural Resources, 2009)

Table 4. Stream Type and Channel Evolution Stage							
Segment Number	**Entr. Ratio**	**Width to Depth Ratio**	**Incision Ratio**	**Reference Stream Type**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
Gunstock Brook							
M01-A	Not Assessed - Impounded						
M01-B	1.9	9.2	2.2	C4	B4c	F-II	**Aggradation** Widening Planform
M01-C	1.7	8.8	2.3	C4	B4c	F-II	Aggradation Widening Planform
M01-D	34	17	1.3	C4	C4	F-III	**Aggradation Widening** Planform

Table 4. Stream Type and Channel Evolution Stage

Segment Number	Entr. Ratio	Width to Depth Ratio	Incision Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
M01-E	2.4	34.1	1.8	C4	C4	F-III	**Aggradation** **Widening** Planform
M02-A	4.8	13.8	1.3	C3b	C3b	F-III	***Aggradation*** **Widening** ***Planform***
M02-B	1.4	13.8	1.0	B3	B3	F-I	Widening Planform
M02-C	2.5	19.3	1.0	C3	C3	F-III	Aggradation Widening **Planform**
M03-A	2.2	34.8	2.0	C3	C3	F-IV	***Aggradation*** **Widening** ***Planform***
M03-B	1.2	17.5	1.0	F3b	F3b	F-I	Aggradation **Planform**
M04-A	16.1	23.3	1.0	C4	C4	F-I	Aggradation Widening Planform
M04-B	5.2	10.4	1.3	C4	C4	F-II	**Aggradation** Widening **Planform**
M04-C	17.1	16.7	1.5	C4	C4	F-II	Aggradation Widening **Planform**
M05-A	10.1	10.8	1.5	C4	C4	F-II	Aggradation **Planform**
M05-B	19.4	18.7	1.0	C4	C4	D-IIc	**Aggradation** **Planform**
M05-C	11.3	22	1.0	C4	C4	D-IIc	**Aggradation** Widening **Planform**
Tributary to Gunstock Brook							
T2.01-A	13.2	14.2	1.1	C4b	C4b	D-IIc	**Aggradation** Widening **Planform**
T2.01-B	6.8	12.4	1.0	C4b	C4b	F-I	Planform

Italics and Bold Black lettering – denotes extreme adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process
Red denotes severe incision ratio
Blue denotes moderate incision ratio
Green denotes a stream type departure

When stream channels are altered through straightening, it can set this evolution process into motion and cause adjustment processes to occur. The bed erosion that occurs when a meandering river is straightened in its valley is a problem that translates to other sections of the stream. Localized incision will travel upstream and into tributaries, thereby eroding sediments from otherwise stable streambeds. These bed sediments will move into and clog reaches downstream, leading to lateral scour and erosion of the streambanks. Channel evolution processes may take decades to play out. Even landowners that have maintained wooded areas along their stream and riverbanks may have experienced eroding banks as stream channel slopes adjust to match the valley slopes. It is difficult for streams to attain a new equilibrium where the placement of roads and other infrastructure has resulted in little or no valley space for the stream to access or to create a floodplain.

In terms of the channel evolution model, two segments on Gunstock Brook in the vicinity of the Belknap Mountain Road crossing (M03-B and M04-A) are in stage I of the "F-stage" channel evolution model. This means these reaches have not undergone a channel incision process, and generally the sediment transport capacity is in equilibrium with the sediment load. The most upstream segment on the tributary to Gunstock Brook (T2.01-B), which has been relatively undisturbed is also in stage F-I. Segment M02-B, which flows close to Intervale Road, is a stream channel in stage F-1 whose reference stream type has been modified due to the placement of the road.

In contrast, many segments on the main stem have undergone historic degradation. These channels are either in stage F-II or F-III of the "F-stage" channel evolution model. Segments that have been heavily armored and/or extensively straightened (M01-B, M01-C, M04-B, M04-C, and M05-A) have lost access to the floodplain as a result of channel incision or floodplain filling. These segments have remained in stage F-II because the armoring has prevented the channel from widening. Stream power is increased within the channel due to the increased slope and loss of floodplain access.

The next stage (stage F-III) occurs when an entrenched channel widens and migrates laterally through bank erosion caused by the increased stream power. The following segments located in the first two reaches of Gunstock Brook are in stage F-III (M01-D, M01-E, M02-A and M02-C). Stage F-IV of the "F-stage" channel evolution model involves the channel stabilizing itself by changes in its migration pattern and building a new floodplain at a lower elevation. Only one segment, M03-A, on Gunstock Brook was in stage F-IV. This segment had undergone severe channel incision with a historic incision ratio of 2.0.

Three segments within the Gunstock Brook study area (T2.01-A, M05-B and M05-C) fall into the "D-stage" evolution model, where the more dominant active adjustment process is aggradation. This build up of sediment leads to channel widening and planform adjustment. In the D-IIc stage, the channel becomes extremely depositional. The channel width narrows through aggradation as bar features develop. Transverse (diagonal bars) may be common. The segments in stage D-IIc are not incised. The high number of diagonal bars and steep riffles indicate the segments are aggradational and the large number of flood chutes reflects planform adjustment. Segments T2.01-A (Tributary 2 near confluence with Gunstock Brook) , M05-B and M05-C (Hoyt Road crossing to confluence with Tributary 2) are currently acting as important attenuation segments for sediment and flood flows.

6.0 HABITAT CONDITION

Table 5 below shows a comparison of the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA). A summary of the rapid habitat assessment values for each reach/segment is included on page 2 of Appendix A. For seven of the 17 assessed segments, both the habitat score and the geomorphic score resulted in a "fair" rating. Four segments (M04-A, M05-B, T2.01-A and T2.01-B) had a rating of "good" for both habitat and geomorphic condition. Two of the segments (M02-A and M03-A) had a fair habitat condition, but a poor geomorphic condition. Segment M02-A is planebed by reference and therefore lacks key pool and riffle features that would provide good habitat. Many of the segments that had been straightened or had floodplain alterations lacked a strong riffle-pool bedform and the diversity of habitat features that this brings. Numerous segments had major intrusion into their river corridor from roads, and many segments had inadequate riparian buffers due to historic and/or recent land clearing. In most cases, the habitat score was similar to the geomorphic score, implying that the ecological health of Gunstock Brook is closely related to the geomorphic condition of the stream.

Table 5. Comparison of Habitat and Geomorphic Condition Gunstock Brook and Major Tributary

Segment Number	Habitat Score	Geomorphic Score	Habitat Condition	Geomorphic Condition
M01-B	0.43	0.49	Fair	Fair
M01-C	0.47	0.53	Fair	Fair
M01-D	0.53	0.55	Fair	Fair
M01-E	0.36	0.46	Fair	Fair
M02-A	0.61	0.33	Fair	Poor
M02-B	0.54	0.78	Fair	Good
M02-C	0.49	0.53	Fair	Fair
M03-A	0.56	0.26	Fair	Poor
M03-B	0.50	0.78	Fair	Good
M04-A	0.71	0.69	Good	Good
M04-B	0.73	0.53	Good	Fair
M04-C	0.54	0.56	Fair	Fair
M05-A	0.59	0.61	Fair	Fair
M05-B	0.73	0.66	Good	Good
M05-C	0.74	0.59	Good	Fair
T2.01-A	0.74	0.65	Good	Good
T2.01-B	0.78	0.83	Good	Good

7.0 BRIDGE AND CULVERT ASSESSMENT RESULTS

A total of 18 stream crossings (fourteen bridges and four culverts) within the Gunstock Brook watershed were evaluated using the New Hampshire Stream Crossing Protocol. The geomorphic compatibility and Aquatic organism passage (AOP) screening tools, photographs and Phase 2 constriction notes were used to prioritize structures for replacement/retrofit. The geomorphic compatibility ratings span the following range:

- Fully Compatible
- Mostly Compatible
- Partially Compatible
- Mostly incompatible
- Fully Incompatible

The VT AOP screening guide has the following four categories:

- Full AOP for all organisms
- Reduced AOP for all aquatic organisms
- No AOP for all aquatic organisms except adult salmonids
- No AOP for all aquatic organisms

Table 6 summarizes the data collected for the assessed structures within the Phase 2 study area. The final column of Table 6 includes a prioritization of structures for replacement or retrofit based on three criteria: structure width in relation to bankfull channel width, aquatic organism passage (AOP) and geomorphic compatibility, and notes from the Phase 2 study. One of three priorities for replacement was assigned (low, moderate or high). The following criteria explain the priority level assigned to each structure:

High Priority: Structures with spans of approximately 50 percent of the bankfull width or less, which are significantly impeding natural sediment transport. In general, culverts that have a geomorphic compatibility rating of fully incompatible or mostly incompatible are given a high priority. Culverts that are impeding the passage of aquatic organisms are automatically placed in the high priority category (e.g. free fall outlet) unless the habitat value in the vicinity of the structure is lacking.

Moderate Priority: Structures with spans less than 50 percent that are not causing significant geomorphic instability and structures with spans greater than 50 percent that are causing instability. Culverts that are resulting in reduced aquatic organism passage (e.g. do not have material throughout the structure or have a cascade outfall) result in at least moderate priority.

Low Priority: Stream crossing structures that are not included in either of the two categories above.

A total of eight structures were identified as high priority for replacement. Two of the high priority structures are culverts (Lakeshore Road and Town Garage Access Road) with no aquatic organism passage including adult salmonids. The Lakeshore Road Culvert was partially compatible and the Town Garage Access Road Culvert was mostly compatible. One of the high priority culverts (Trail to Lyman's) is mostly incompatible with reduced AOP. The most downstream Intervale Road crossing did not meet the criteria of high priority above, but was placed in the high priority category because of the poor alignment of the structure and the resultant impacts. The bridge at Old Lakeshore Road also did not meet the criteria for high priority but was placed in this category due to its poor condition. A private trail bridge in segment M04-B was placed in the high priority category since it is failing and a debris jam is currently obstructing part of the bridge. It appears that the bridge is not being used so removal is recommended instead of replacement. Two bridges (Intervale Road, upstream and Cherry Valley Road) are significantly undersized and therefore placed in the high priority category. The Cherry Valley Road Bridge has deteriorating footers (Figure 7.1)

Figure 7.1. The Cherry Valley Road Bridge has deteriorating footers.

Table 6
Gunstock Brook
Evaluation using Vermont Geomorphic Compatibility and AOP Screening Tools

Stream Name	Reach/ Segment Number	Road Name	Structure Type	Percent Bankfull Channel Width[1,2]	Aquatic Organism Passage (AOP)	Geomorphic Compatibility	Phase 2 Notes	Priority for Replacement or Retrofit
Gunstock Brook	M01-B	Lakeshore Road	Culvert	54	No AOP including adult salmonids	Partially Compatible	Scour below. Culvert is perched 1 foot and is free fall. Water depth in culvert is shallow.	High
	M01-B	Snowmobile Trail	Bridge	97	NA	NA	Just upstream of Lakeshore Road Culvert. Any issues are probably more due to Lakeshore Road culvert.	Not recommended
	M01-B	Old Lakeshore Road	Bridge	78	NA	NA	Deposition above and below. Bridge in poor condition. Deteriorating decking and center pier.	High
	M01-E	Henderson Road	Culvert	50	Reduced AOP	Mostly Incompatible	Ten years old according to landowner. Deposition above and below. Scour below and in structure. Erosion below box culvert on both sides.	Moderate
	M02-A	Intervale Road	Bridge	63	NA	NA	Poor alignment; Large mid-channel bar upstream of structure diverting flow to bank with mass failure. Deposition and scour below. Bedrock grade control within structure.	High
	M02-C	Intervale Road	Bridge	43	NA	NA	Scour below and poor alignment. Deterioration of abutments.	High
	M02-C	Cherry Valley Road	Bridge	46	NA	NA	Footers deteriorating. Deposition above and poor alignment.	High
	M03-A	Town Garage Access Road	Culvert	80	No AOP including adult salmonids	Mostly Compatible	Shallow water depth in culvert. Culvert is perched 1 foot and is a free fall.	High

Table 6
Gunstock Brook
Evaluation using Vermont Geomorphic Compatibility and AOP Screening Tools

Stream Name	Reach/ Segment Number	Road Name	Structure Type	Percent Bankfull Channel Width[1,2]	Aquatic Organism Passage (AOP)	Geomorphic Compatibility	Phase 2 Notes	Priority for Replacement or Retrofit
	M03-B	Tannery Hill Trail	Bridge	63	NA	NA	Deteriorating abutments. Scour below and deposition above.	Low
	M03-B	Belknap Mountain Road	Bridge	63	NA	NA	Perched dam 9 feet high under bridge. Deposition and scour above.	Low
	M04-A	Alvah Wilson Road	Bridge	83	NA	NA	Beaver dam close to structure. Guard rail and cement block on decking old. Rusted beams. Deposition below and poor alignment.	Low
	M04-B	Goodwin Road	Bridge	61	NA	NA	Scour above. Abundant failed armoring in channel.	Low
	M04-B	Private Trail	Bridge	79	NA	NA	Debris jam under bridge. Wooden bridge failing and does not seem to be used. Should be removed if not used.	High (Removal recommended)
	M05-A	Farm Bridge	Bridge	96	NA	NA	Wooden bridge.	Not recommended
	M05-A	Field Access Bridge	Bridge	83	NA	NA	Wooden bridge. Erosion and armoring failing on upstream end.	Low
	M05-A	Hoyt Road	Arch	117	NA	NA	Structure new and sized appropriately. Deposition below.	Not recommended
Unnamed Tributary to Gunstock Brook	T2.01-A	Trail to Lyman's	Culvert	31	Reduced AOP	Mostly Incompatible	Structure rusted on bottom and deformed. Deposition above and below. Scour pool below. Abundant right bank erosion on downstream end.	High
	T2.01-B	Belknap Mountain Road	Bridge	100	NA	NA	Riprap within structure.	Not recommended

[1]Shaded for bankfull width percentage less than 50%, [2]Percent bankfull width based on New Hampshire Hydraulic Geometry Curve; NA – not applicable for bridges and arches.

8.0 PRELIMINARY PROJECT IDENTIFICATION AND PRIORITIZATION

The stream reaches evaluated in this study present a variety of planning and management strategies which can be classified under one of the following categories: Active Geomorphic Restoration, Passive Geomorphic Restoration, and Conservation.

Active Geomorphic Restoration implies the management of rivers to a state of geomorphic equilibrium through active, physical alteration of the channel and/or floodplain. Often this approach involves the removal or reduction of human constructed constraints or the construction of meanders, floodplains or stable banks. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.

Passive Geomorphic Restoration allows rivers to return to a state of geomorphic equilibrium by removing factors adversely impacting the river and subsequently using the river's own energy and watershed inputs to re-establish its meanders, floodplains and equilibrium conditions. In many cases, passive restoration projects may require varying degrees of active measures to achieve the ideal results. Active riparian buffer revegetation and long-term protection of a river corridor is also essential to this alternative.

Conservation is an option to consider for protecting the riparian corridor from future development. Providing an easement on lands adjacent to surface waters reduces conflict and provides a long term solution to sediment storage and flood water attenuation needs.

There are a number of federal programs available for river restoration and protection. These programs are as follows:

- Conservation Reserve Enhance Program (CREP)
- Environmental Quality Incentives Program (EQUIP)
- Wildlife Habitat Incentives Program (WHIP)
- Wetland Reserve Program (WRP)

Conservation Reserve Enhancement Program

The USDA Farm Service administers a program called the Conservation Reserve Enhancement Program that helps agricultural producers to take farmland out of production in sensitive areas, such as river corridors. This helps to improve water quality and restore wildlife habitat.

- CREP can be either a 15 or 30 year contract to plant trees.
- 90% of the practice costs are covered with the remaining 10% either resting with the participants or could be paid by the US Partners for Fish and Wildlife. Examples of the practice costs include fencing, watering facilities, and trees. There are some costs that are capped, but generally all the practice costs can be paid through the program.
- To provide additional incentives to enroll in CREP, the program offers upfront and annual rental payments for the land where agricultural production is lost during the contract period.

Environmental Quality Incentives Program

EQUIP is a voluntary program available through the Natural Resources Conservation Service (NRCS) that provides financial and technical assistance to implement conservation practices to meet local environmental regulations. Owners of land in agricultural or forest production are eligible for the program. Contracts with landowners can be up to ten years in length.

Wildlife Habitat Incentives Program

WHIP is a voluntary program offered to landowners to improve wildlife habitat on their land. Owners of agricultural land, nonindustrial private forest land, and Native American land are eligible. Technical assistance and up to 75 percent cost-share is available to improve fish and wildlife habitat.

Wetland Reserve Program

WRP is a voluntary program offered by NRCS to landowners to protect, restore and enhance wetlands on their property. NRCS provides technical assistance and financial support for projects that establish long-term conservation and wildlife practices and protection.

8.1 Watershed-Level Opportunities

There are a number of watershed-level opportunities available to improve the geomorphic stability and water quality of the Gunstock Brook watershed. Watershed opportunities include the development and adoption of fluvial erosion hazard zones, improved stormwater treatment, and community stream clean-up activities.

FLUVIAL EROSION HAZARD ZONES

The purpose of defining Fluvial Erosion Hazard Zones is to prevent increases in man-made conflicts that can result from development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; and prohibit land uses and development in fluvial erosion hazard areas that pose a danger to health and safety. The basis of a Fluvial Erosion Hazard Zone is a defined river corridor which includes the course of a river and its adjacent lands. The width of the corridor is defined by the lateral extent of the river meanders, called the meander belt width, which is governed by valley landforms, surficial geology, and the length and slope requirements of the river channel. The width of the corridor is also governed by the stream type and sensitivity of the stream. River corridors, as defined by the Vermont Agency of Natural Resources (2008b), are intended to provide landowners, land use planners, and river managers with a meander belt width which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards. Information collected during the Phase 2 Assessment including reach sensitivity, reach condition, and stream type is used to develop these zones. Towns have the opportunity to work with the New Hampshire Department of Environmental Services

(NHDES) and regional planning commissions to develop fluvial erosion hazard zones to reduce conflicts within the river corridor. Additional information regarding Fluvial Erosion Hazard Zones is available on the NHDES website (http://des.nh.gov/organization/commissioner/pip/factsheets/geo/documents/geo-10.pdf) in the Environmental Fact Sheet (New Hampshire Department of Environmental Services, 2010a; and in Chapter 2.9 of the Innovative Land Use Planning and Techniques Handbook: New Hampshire Department of Environmental Services, 2010b).

STORMWATER

Stormwater runoff rates are of particular concern in urbanized and agricultural watersheds because stormwater runs off from impervious surfaces rather than naturally infiltrating the soil. The cumulative effect of the increased frequency, volume, and rate of stormwater runoff results in increases in wash-off pollutant loading to streams and destabilization of stream channels. Stormwater improvement projects to increase baseflow and decrease peak flow and sediment loading are recommended for the Gunstock Brook watershed. The details of project location are outlined in the reach level opportunities below.

8.2 Reach-Level Opportunities

A description of each reach/segment is provided in this section along with general recommendations for restoration and protection strategies. The reaches/segments are listed from downstream to upstream. The reaches are broken into sections based on the stream they are located in: Gunstock Brook main stem and Tributary to Gunstock Brook. Proposed project locations are provided on maps on pages 1 through 7 in Appendix B. Project locations where the Natural Resources Conservation District has recommended projects are also included on the maps. The Phase 2 stream geomorphic assessments provides a picture of the condition of the channel and the adjustment process, however, is not a comprehensive study for determining site specific actions. The Phase 2 study provides a foundation for project development, and additional work is recommended to further develop these projects.

Gunstock Brook Main Stem

Reach M01

The most downstream reach of Gunstock Brook (M01) starts about 600 feet downstream of Lakeshore Road (Route 11) and continues upstream approximately one mile to the Henderson Road crossing. Reach M01 has been broken up into five segments. The most downstream segment, M01-A, is about 600 feet long and is impounded by Lake Winnipesaukee (Figure 8.1). This segment was not fully assessed because of the lake influence. No potential projects were identified by BCE within this short segment.

Figure 8.1. Impounded segment M01-A

The Natural Resources Conservation Service (NRCS) has recommended a streambank stabilization project (SB6) along the banks of an impounded section of Gunstock Brook upstream of the Route 11B crossing (Winnipesaukee Gateway, 2012, http://winnipesaukeegateway.org/monitoring-the-lake/potential-restoration-sites-map). The NRCS has also evaluated two bank erosion areas that are located downstream of Lakeshore Road. These locations are shown on the map on page 1 of Appendix B. All three of these proposed bank stabilization areas are located downstream of the Gunstock Brook study area that received a full phase 2 assessment by BCE. For this reason, BCE does not have information to guide a decision about bank stabilization in this location.

Segment M01-B begins just upstream of the Lakeshore Road crossing and continues upstream for 1,200 feet until Old Lakeshore Road. Extreme degradation has occurred in this segment due to the extensive channel alteration, which has resulted in a stream type departure from a "C" stream to a "B" stream. Widening is being prevented by the abundant riprap (Figure 8.2). Riprap is graded rock that is used to stabilize banks. The bedform has been altered from riffle-pool to plane bed (i.e. lacks defined habitat features) due to the channel alterations. The geomorphic and habitat condition of Segment M01-B are both "fair". The lack of large woody debris, embedded channel, lack of riffle habitat, and the lack of vegetation on both banks and in buffers has led to the "fair" habitat condition.

Figure 8.2 Rock riprap in vicinity of measured cross section in M01-B.

Three potential projects have been identified by BCE in segment M01-B based on the Phase 2 study. The first project is the retrofit or replacement of a box culvert at the Lakeshore Road crossing, which is impeding fish passage (Project #1, Figure 8.3). Based on the Vermont AOP culvert screening tool, the AOP retrofit potential is medium for strong and moderate swimmers and low for weak swimmers. Additional studies are recommended to determine if the replacement or retrofit of the culvert makes more sense. Project #2 includes improving stormwater runoff to alleviate excess sediment into the stream (Figure 8.4). The third project involves a bridge at the Old Lakeshore Road crossing at the upstream end of M01-B. The Old Lakeshore Road crossing is in poor condition due to deteriorating decking and pier (Figure 8.5). This structure was placed in the high priority category for replacement. It is recommended that the bridge be replaced (Project #3) and special consideration be given to geomorphic compatibility including the span and alignment as part of the bridge design.

The Natural Resources Conservation Service (NRCS) has targeted two locations near the tennis courts and upstream of Lakeshore Road for possible bank stabilization work (Winnipesaukee Gateway, 2012, http://winnipesaukeegateway.org/monitoring-the-lake/potential-restoration-sites-map/). Site SB5-A is located on the western bank approximately 200 feet upstream of Lakeshore Road). The second location (Site SB5-B) is on the east bank about 400 feet upstream of Lakeshore Road. This section appears to have been historically riprapped and there are areas where erosion is occurring within the armored sections. This area has been straightened and the river is now finding a more sinuous course. There are trees and shrubs on the bank that would need to be removed to riprap the bank, and that action would reduce shading and possibly increase energy into the channel and banks below the stabilized section thereby causing bank erosion. It may be possible to plant additional trees back away from the bank to give them time to grow and establish root structure. If infrastructure, such as homes or the tennis courts are threatened, bank stabilization using rock armoring may be the only recourse to protect these investments. If a decision is made to armor the banks, a biotechnical approach is recommended, where the upper bank is sloped and planted and live cuttings are incorporated into the rock riprap. Existing large trees along the bank should remain to the extent feasible.

Figure 8.3. Perched box culvert at Lakeshore Road.

Figure 8.4 Sediment laden stormwater culvert along segment M01-B.

Figure 8.5. Deteriorating decking and pier of Old Lakeshore Road Bridge in Segment M01-B.

The next segment upstream, Segment M01-C, begins at the Old Lakeshore Road crossing and continues for 2,195 feet until the dominant corridor land use changes from hay and cropland to shrub/sapling. The channel in segment M01-C flows through a farm where a Conservation Reserve Enhancement Program (CREP) is currently underway to protect water quality through the establishment of a 35 foot buffer. Like M01-B, M01-C has undergone severe incision (ratio of 2.3) due to channel alteration, which has resulted in a stream type departure from a "C" stream to a "B". Rip-rap along channel banks has prevented widening. Both the RGA and RHA were scored as "fair". The "fair" habitat condition was attributed to a lack of large woody debris, channel incision, and the compromised condition of banks and the riparian corridor due to incomplete vegetation layers and buffer widths less than 50 feet.

Extensive erosion is occurring in the next segment, M01-D, indicating that it is in the widening stage. There is also abundant aggradation in this segment as seen through the presence of diagonal bars and steep riffles. Segment M01-D begins where the corridor land use is predominantly shrub/sapling and where incision is minor. The segment continues upstream for 654 feet until the dominant river corridor land use becomes residential. The geomorphic and habitat condition were both scored as "fair". The channel aggradation and widening contributed to the "fair" geomorphic condition, while lack of woody debris and the bank and buffer condition contributed to the "fair" habitat condition. Through most of the segment, the buffer is naturally regenerating.

There is a proposed NRCS project (SB4) in segment M01-D project (SB4) that involves streambank stabilization of a bank that is experiencing significant erosion (Figure 8.6). The river is currently in an adjustment process that will move it towards a stable or equilibrium condition through erosion and deposition of sediment. If allowed to continue in the current course, the river will eventually create a bankfull bench or floodplain at a lower elevation. It is understandable that the farmer is concerned about losing land in this location. If the farmer is amenable, a wide buffer of land could be taken out of production and the farmer could be compensated for this additional land through the CREP program. Problems associated with riprapping this section include loss of aquatic habitat, increased energy and erosion downstream of the riprapped section and loss of floodplain access. If the landowner and NRCS decide to move forward with riprapping the bank, a biotechnical approach is recommended. A biotechnical approach may include grading the upper bank and planting with trees as well as incorporating live cuttings such as willow into the rock toe.

Figure 8.6. Bank erosion (looking upstream) along Segment M01-D at proposed NRCS project SB4

Development within the river corridor is pronounced in segment M01-E. Approximately 30 percent of segment M01-E has been straightened and armored, which has led to major degradation of the stream channel. The extensive armoring is seen just downstream of Henderson Road on the east bank (Figure 8.7). The incision process has resulted in a loss of floodplain access and subsequent widening of the stream channel. Aggradation is a major adjustment process; there are numerous side bars and some diagonal bars and steep riffles. The habitat and geomorphic scores were both "fair". Japanese knotweed, an invasive plant, is present on both banks. Riffle embeddedness, limited vegetative cover on the eastern stream bank and altered riparian areas also contributed to the "fair" habitat condition.

In the center of M01-E, there is a stormwater retention pond in the western side of the river corridor (Figure 8.8). The retention pond is helping to alleviate the impact of stormwater drainage from the nearby development into Gunstock Brook. However, the buffer vegetation within the vicinity of the stormwater pond is predominantly herbaceous, which does not provide the best riparian condition. Approximately 180 feet downstream of the pond is another stormwater input that is causing localized erosion on the western stream bank, which is contributing sediment to the channel (Figure 8.9). It is recommended that the stormwater runoff in this location be improved to alleviate further sediment contribution to the channel (Project #4).

Figure 8.7. Segment M01-E just downstream of Henderson Road crossing with abundant riprap on east bank.

Figure 8.8. Stormwater Pond in the river corridor for M01-E.

Figure 8.9. Stormwater input causing localized erosion on streambank in M01-E.

Reach M02

Reach M02 begins just upstream of the Henderson Road crossing and continues for just over one mile until the confluence with a major tributary (T1). The majority of reach M02 is encroached upon by Intervale Road and Cherry Valley Road. The reach was broken up into three segments based on planform and slope and channel dimensions. Projects for reach M02 are shown on page 2 of Appendix B.

Segment M02-A is unique among all other segments in the Gunstock Brook study since its reference bedform is plane bed. Upstream of the Intervale Road crossing, there is a human caused change in confinement due to the encroachment of Intervale Road in the river corridor. Channel incision is minor in segment M02-A. However, abundant erosion indicates that the channel is widening. There are areas of channel braiding with islands and large depositional features causing major planform change. The geomorphic condition in M02-A is "poor" while the habitat condition is "fair", which was mostly a result of the river banks and riparian areas being impacted by erosion and road encroachment.

The Intervale Road Bridge is undersized and in poor alignment to the stream channel, which has resulted in a large mid-channel bar immediately upstream of the structure (Figure 8.10). The bar is diverting flow into the eastern bank into a mass failure (Figure 8.11). The replacement of the Intervale Road Bridge with a larger span and compatible alignment (Project #5) would improve the geomorphic stability of Gunstock Brook. The NRCS has recommended a streambank stabilization project (SB3) to arrest the mass failure and to reduce sediment loading into Gunstock Brook and Lake Winnipesaukee. The steep slope of the bank does not allow plants to grow in this location and trees are falling into the brook. If allowed to continue naturally, the bank would continue to erode and eventually reach a more stable slope that allows plant growth. Given the steep bank, this would take many years. BCE would recommend that a geotextile engineer be retained to evaluate if the mass failure should be remediated. As part of the evaluation of the site, engineers and river scientists should consider approaches to improve geomorphic compatibility through the design and installation of a bridge with a wider span and an improved alignment. Options may be available to reduce erosion at this site without hard armoring the steep bank.

Segment M02-B begins about 750 feet upstream of the most downstream Intervale Road crossing and continues until about 180 feet downstream of the second downstream Intervale Road crossing. The entire 653 foot length of the segment is encroached upon by Intervale Road, which has caused a change in confinement from very broad to semi-confined. The encroachment of the road has resulted in a modification of the reference stream type, which is now a cobble dominated "B" stream with a dominant bedform of step-pool (Figure 8.12). The road is now acting as the new valley wall and will prohibit the evolution of the channel back to the reference stream type of "C". The channel has not incised. A significant amount of riprap exists along the western bank, but much of it is failing. Geomorphic condition in the segment scored as "good" and the habitat condition was scored "fair". The lack of large woody debris cover in M02-B and the poor condition of the western banks and riparian areas led to the "fair" habitat condition for the segment.

Figure 8.10. Undersized and misaligned Intervale Road Bridge with mid-channel bar upstream in M02-A.

Figure 8.11. Mass failure along eastern bank just upstream of Intervale Road Bridge in M02-A.

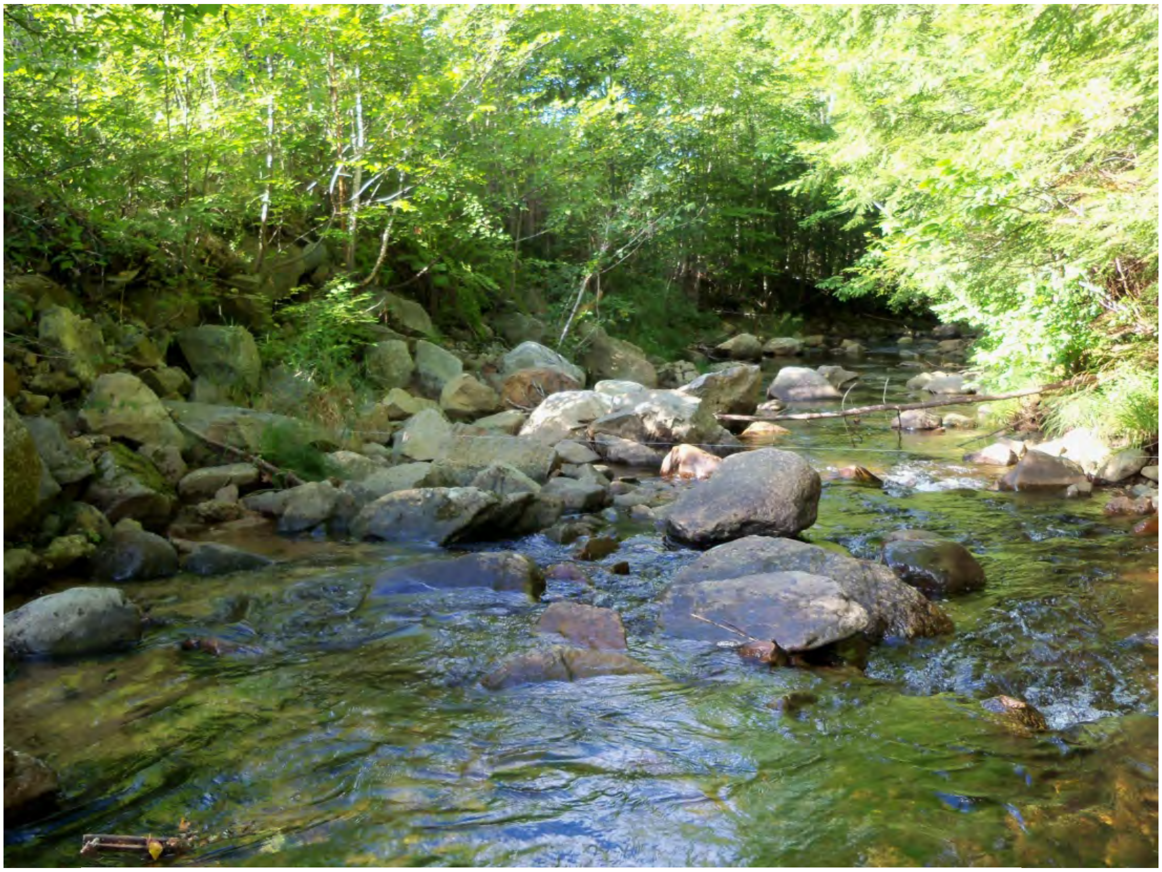

Figure 8.12. Cobble dominated "B" stream type and failing riprap in segment M02-B.

M02-C begins about 180 feet downstream of the most upstream Intervale Road crossing and continues for 3,470 feet until the confluence with the first major tributary to Gunstock Brook (T1). The RGA resulted in a geomorphic condition of "fair" for Segment M02-C. The floodplain has been encroached upon by Intervale Road and Cherry Valley Road throughout most of the segment and approximately half of the segment has been straightened. Floodplain access is variable in M02-C. For most of the segment the channel is not incised. However, there are areas where either the road encroachment or streamside berms have caused channel incision, which has resulted in a stream type departure (Figure 8.13). Widening is minor as is aggradation, although steep riffles and diagonal bars were observed (Figure 8.14). The overall habitat condition is "fair" predominantly due to the lack of woody debris cover, unsorted substrate, compromised riffle and pool features, and poor eastern bank and riparian area from the road encroachment. Japanese knotweed was observed along the bank by Intervale Road.

Projects that would benefit M02-C include berm removal, stormwater improvements, and replaceing undersized structures. The berm located upstream of the Intervale Road crossing could be removed to provide for better floodplain access (Project #8). A study is recommended to determine if this berm removal project would make Intervale Road more vulnerable to flooding. Stormwater from Intervale Road (Figure 8.15) is also a concern within Segment M02-C. Project #6 addresses improving stormwater runoff from Intervale Road into Gunstock Brook. The two bridges that cross Gunstock Brook in Segment M02-C (Intervale Road and Cherry Valley Road) are both noted as high priority for replacement due to being significantly undersized (Projects #7 and #9).

Figure 8.13. Straightening and road encroachment in Segment M02-C.

Figure 8.14. Diagonal bar in Segment M02-C.

Figure 8.15. Stormwater runoff from Intervale Road into M02-C.

M03

Reach M03 was divided into two segments to account for the presence of grade controls and variable channel dimensions in the upstream segment. The reach begins at the confluence with the first major tributary (T1) and continues until just upstream from the Belknap Mountain Road crossing. M03-A is 2,388 feet in length and the upper end of the segment ends just downstream of the covered bridge at Tannery Hill Trail. Segment M03-A flows through a broad valley and is a cobble dominated "C" stream with a riffle-pool bedform.

Road encroachment occurs along about half of the western bank in M03-A, which is armored along the most upstream section. There are three mass failures along the eastern bank totaling 113 feet in length. An incision ratio of 2.0 indicates that this segment has undergone extreme degradation, which has resulted in major widening and extreme aggradation and planform adjustment. The floodplain appears to have been filled in previous years along the town hall parking area. Downstream of the parking area, M03-A becomes extremely depositional with areas of braiding (Figure 8.16). A juvenile floodplain is forming.

Due to the geomorphic instability caused by channel degradation, the geomorphic condition of M03-A is "poor". The rapid habitat condition was "fair". The "fair" condition was due to riffle-pool habitat features, such as small pool size and cover, riffle spacing, and depositional features. Channel morphology (high width to depth and incision ratios) also contributed to the "fair" habitat condition.

The Town Garage Access Road crossing is the only road crossing within segment M03-A. The culvert at this crossing is mostly compatible in terms of geomorphic stability and was flagged as no aquatic organism passage including adult salmonids using the Vermont AOP screening tool. The structure is perched about one foot and is recommended for replacement or retrofit (Figure 8.17, Project # 10).

Stormwater runoff from the town garage parking lot is causing excess sediment into Gunstock Brook (Figure 8.18). Project # 11 would address the sediment loading by improving stormwater runoff from the parking area. Another project that would address sediment loading and runoff into Gunstock Brook (M03-A) is an investigation of an eroded swale (Figure 8.19) that is receiving discharge from a well (Project #12). Runoff from the swale is introducing significant sediment into Gunstock Brook (Figure 8.20).

Figure 8.16. Braided section of M03-A.

Figure 8.17. Perched culvert at Town Garage Access Road in Segment M03-A impeding aquatic organism passage.

Figure 8.18. Sediment laden stormwater runoff from Town Garage parking lot in M03-A.

Figure 8.19. Eroded swale in Segment M03-A.

Figure 8.20. Sediment from eroded swale in Segment M03-A.

Segment M03-B begins approximately 150 feet downstream of the Tannery Hill Bridge crossing and continues to just upstream of the Belknap Mountain Road crossing. The segment is 1,098 feet in length and the western bank is encroached upon by Cherry Valley Road. Approximately half of M03-B has been straightened using rock riprap on one or both banks. Bedrock grade controls throughout M03-B have prevented the bed from degrading and the extensive armoring is keeping the channel from widening. Despite the channel alterations and the proximity to Cherry Valley Road, M03-B is a cobble dominated natural "F" channel, with a slope of a "B" channel and a step-pool bedform (Figure 8.21). Some locations along the segment have a stream type of "B", but "F" is the predominant stream type. At the downstream end, Japanese knotweed is present along the western bank near the Gilford town hall.

Thanks to the stability the bedrock grade controls provide, Segment M03-B scored "good" for geomorphic condition. The habitat condition was "fair" due mostly to the condition of the western banks and the lack of connectively resulted from a dam under the Belknap Mountain Road crossing (Figure 8.22). The lack of woody debris cover in the segment also contributed to the "fair" habitat condition. Pool cover was good due to the boulders in the upper portion of the segment.

The dam under Belknap Mountain Road is impeding the passage of aquatic organisms. Downstream from the dam are rock walls lining the stream banks (Figure 8.23). The dam and rock walls are what is left of a sawmill that operated in the 1800s (Gilford Historic District Commission, 1990). During this time period, the dam impounded water up into Reach M04. The recreational area was called the Millpond and was used as a fishing and ice skating spot. Now the area contains tennis courts. An alternatives analysis is recommended to improve habitat connectivity at the former mill site and determine if it is feasible and beneficial to remove the dam and rock walls (Project #13). Historic preservation may be a consideration regarding removal of this dam.

Figure 8.21. Natural cobble dominated "Fb" channel in M03-B.

Figure 8.22. Dam at Belknap Mountain Road crossing in M03-B.

Figure 8.23. Rock walls downstream of the Belknap Mountain Road crossing in M03-B.

M04

Upstream of Belknap Mountain Road, Gunstock Brook becomes lower gradient. Reach M04 was divided up into three segments based on variable banks and buffers. The most downstream segment, M04-A, begins approximately 100 feet upstream of Belknap Mountain Road Bridge and continues for approximately one mile to where the river corridor becomes more forested and less shrub/sapling. The first 800 feet of Segment M04-A is encroached upon by Gilford Avenue where approximately 460 feet of the channel has been straightened. Due to its historic alteration, this section of Segment M04-A has high banks and is lacking habitat features (Figure 8.24). The segment then transitions into a channel that flows through wetland habitat with good floodplain access, which comprises the majority of the rest of the segment (Figure 8.25).

Figure 8.24. Straightened section of M04-A.

Figure 8.25. Typical wetland channel in M04-A.

Based on the Phase 2 assessment, both the geomorphic and habitat conditions of segment M04-A are "good". The stream type is a gravel dominated "C" stream which has not incised. Segment M0-4A is undergoing minor aggradation with some diagonal and point bars and limited planform change with the presence of an island. Abundant large woody debris, coarse particulate organic matter and deep pools that are providing suitable water depths for fish and amphibians has contributed to the "good" habitat condition. Alders are the dominant vegetation on the banks. Given the prime riparian condition and wetland habitat, a 1,890 foot length of Segment M04-A is recommended for conservation to protect it from future impacts and to maintain the function of the wetland it flows through (Project #14).

Approximately halfway through the segment heading upstream, Gunstock Brook flows past the Alvah Wilson Middle School and then continues under Alvah Wilson Road Bridge. There is currently a beaver dam within the structure that may cause some problems in the future for stream flow through the bridge (Figure 8.26). There are also two old abutments within M04-A which are constricting the stream channel. One abutment is in the downstream straightened section, but another one is located approximately 850 feet from the top of the segment (Figure 8.27).

Figure 8.26. Beaver dam within Alvah Wilson Road Bridge in M04-A.

Figure 8.27. Old abutment constricting the stream channel in M04-A.

Segment M04-B begins where the habitat changes from a shrub/sapling wetland channel to a 3,641 foot long channel flowing through a more forested area with some development. For much of the segment the banks are covered in moss and create some undercuts suitable for fish to obtain cover (Figure 8.28). The stream type is a gravel dominated "C" riffle-pool that has experienced minor incision. Aggradation is major throughout the reach with numerous depositional features including point, mid-channel, diagonal, and side bars as well as many steep riffles. As the sediment is working its way through the segment, planform change is major with one neck cut off and many flood chutes.

Figure 8.28. Moss covered undercut bank in M04-B.

One contributor to the sediment in this reach appears to be coming from tributaries (Figure 8.29) that are receiving stormwater runoff from Doris Drive residential development. During a rainstorm in August 2011, stormwater runoff was observed from Doris Drive and driveways (Figure 8.30) into tributaries of the mainstem (Figure 8.31). Improving the stormwater runoff from this area would be beneficial to reducing sediment loading into Gunstock Brook (Project #16).

A wooden bridge along Gunstock Brook is currently collapsing (Figure 8.32). Sediment and debris are blocking the bridge that does not appear to be in use. Removal of the bridge is recommended (Project #15).

Figure 8.29. Tributary contributing sediment to Gunstock Brook in Segment. M04-B.

Figure 8.30. Turbid stormwater runoff on Doris Drive on August 21, 2012.

Figure 8.31. Sediment loading from sandy tributary into M04-B.

Figure 8.32. Collapsing wooden bridge in M04-B.

The most upstream segment in Reach M04, M04-C, begins near the Given Drive development. The segment continues for 848 feet where there is a lack of buffer along about half the segment on the eastern side (Figure 8.33). The channel has also been straightened and armored in the downstream section (Figure 8.34). A channel avulsion (change in channel course) has occurred here leading to major planform adjustment. There is abundant erosion on the banks in places which lack riprap or a vegetated buffer. Planting of native trees and shrubs away from the bank in backyards of the Given Drive housing development would help to stabilize the bank as the channel migrates to reach its equilibrium state (Project #17).

M04-C is a gravel dominated "C" stream that has lost access to its floodplain through channel incision but has not yet widened. Armoring of the banks is increasing the stream power through the lower end of the segment. The loss of floodplain access has resulted in M04-C being a sediment transport reach as opposed to its natural condition as a depositional reach. The geomorphic condition of M04-C is "fair" due to the degree of channel alteration and resultant degradation. The habitat condition also scored as "fair" mostly as a result of poor buffers and riparian habitat on the eastern side, compromised bank condition and lack of vegetative cover, short riffles, and very little pool cover.

Figure 8.33. Lack of riparian buffer and streambank erosion in M04-C.

Figure 8.34. Channel alteration and streambank armoring in M04-C.

M05

Reach M05, the uppermost reach on Gunstock Brook, begins about 900 feet downstream of the Hoyt Road crossing and continues for 4,425 feet until the confluence with a major tributary of Gunstock Brook (T2). The reach was broken up into three segments due to variable channel dimensions and banks and buffers. Segment M05-A is 936 feet long and begins at a tributary confluence and continues until just upstream of the Hoyt Road crossing.

Dominant land use in the eastern corridor is hay but a small portion of lack of buffer on the western side is due to residential lawn. Two wooden bridges span the channel in Segment M05-A, but they are of low priority for replacement since they are close to the bankfull channel width and are causing little or no geomorphic instability. The Hoyt Road crossing is at the upstream end of the segment and is not recommended for replacement since it has an adequate width to accommodate channel flows and sediment. The Hoyt Road culvert was previously identified by NRCS as an undersized structure. According to Brian Denutte at the Gilford Dept. of public works, this undersized structure was replaced in 2007 by an arch.

The banks are well vegetated (Figure 8.35) along most of the segment except where there is no vegetated buffer by one of the bridges and the lawn on the western side. One major impact in M05-A is that it has been straightened at the downstream end for approximately one third of its length. The channel alteration most likely led to the major incision observed in M05-A. The channel has not yet widened. The stream type is a gravel dominated "C" stream with riffle-pool bedform. There is minor aggradation in the segment as observed through some steep riffles, diagonal bars, point bars, side bars, and mid-channel bars. Planform has changed somewhat due to the aggradation, but not as pronounced as in reaches upstream from here.

Both the geomorphic and habitat condition resulted in a "fair" score. The "fair" geomorphic condition was primarily due to the channel incision and channel alteration. Compromised riparian area on the eastern side due to the hay field, lack of abundant woody debris, and loss of floodplain access contributed to the "fair" habitat condition.

Figure 8.35. Well vegetated banks in M05-A.

The Natural Resource Conservation Service (NRCS) has investigated sediment loading upstream of Hoyt Road in the vicinity of Gunstock Brook segment M05-A (Winnipesaukee Gateway, 2012, http://winnipesaukeegateway.org/monitoring-the-lake/potential-restoration-sites-map/). The following actions have been recommended by the NRCS for this site (SB2):

1. Clean out existing sediment & erosion control structures.
2. Vegetate excavation sites not being used.
3. Re-establish woody vegetation within the brook's riparian buffer.

4. Replace undersized culvert at trail crossing.

Segment M05-B begins just upstream of the Hoyt Road crossing and continues for 1,433 feet until the riparian corridor becomes forested as opposed to shrub/sapling. The only area of channel straightening is at the downstream end of the segment near the Hoyt Road crossing. There are localized areas of rip-rap that is presently failing (Figure 8.36). Riparian buffers are in good shape in the segment with a width of greater than 200 feet in most locations.

Figure 8.36. Failing rip-rap in M05-B.

The stream type in segment M05-B is a gravel dominated "C" riffle-pool with good floodplain access. The habitat and geomorphic conditions are both good. The good geomorphic condition is due to the lack of incision and subsequent widening. The channel is in a state of aggradation that is causing planform change as seen through many flood chutes. The dominant active adjustment process is aggradation. Many steep riffles along with bar features were observed during the Phase 2 assessment. The good habitat condition is attributed to abundant pools, the well vegetated banks and buffers, and wide riparian area.

The most upstream Segment in M05, M05-C, begins where the riparian land use becomes forested and continues until the confluence with a major tributary of Gunstock Brook (T2). This segment has good floodplain access, well forested buffers and no channel alteration. However, sediment input to the segment has resulted in steep riffles and bar features (Figure 8.37) indicating major aggradation leading to abundant flood chutes (major planform change). Aggradation is the dominant adjustment process. A channel avulsion (Figure 8.38) and two debris jams are also present in Segment M05-C.

The RGA condition scored in the "fair" category due to the major aggradation and resultant planform adjustment. There was no incision in this Segment M05-C and the channel therefore has good access to its floodplain. The RHA scored in the "good" category mostly due to the nice undercut banks and pools (Figure 8.39) and well vegetated stream banks and riparian corridor. Given the high quality buffer and corridor conditions and habitat, it is recommended that Segments M05-B and M05-C be considered for conservation (Project #18). These two segments serve as key flood and sediment attenuation sections of Gunstock Brook and development within the corridor would jeopardize the ability for them to continue to provide flood and sediment retention.

Figure 8.37. Large diagonal bar showing major aggradation in M05-C.

Figure 8.38. Channel avulsion indicating major planform change in M05-C.

Figure 8.39. Deep pool and nice undercut bank in M05-C.

Major Tributary to Gunstock Brook

Reach T2.01

Reach T2.01 begins at the confluence with Gunstock Brook and was divided into two segments primarily based on variable confinement. The most downstream segment, T2.01-A, is a 1,482 foot long and extends to where valley width narrows. The stream type is a gravel dominated “C” channel with a slope of a “B” channel that has not experienced any channel alteration and is therefore not incised. Depositional features such as steep riffles, mid-channel bars, point bars, and side bars are common showing evidence of major aggradation. The aggradation (Figure 8.40) is primarily due to a drop in channel slope in this segment but may also be attributed to sediment input from the nearby gravel operation. Aggradation is the driving process in T2.01-A.

Major planform change has resulted from the aggradation in T2.01-A and can be seen as evidence from the many flood chutes and two neck cut-offs. Although there was significant deposition and planform adjustment in T2.01-A, the RGA scored in the low “good” category. High quality banks and buffers are present on both sides of the corridor in T2.01-A, which are wide and well vegetated. This contributed to the “good” score along with the lack of incision and widening. The RHA score of “good” in segment T2.01-A was primarily due to the abundant large woody debris and pools, and well vegetated and stable banks and buffers.

Figure 8.40. Depositional features in T2.01-A caused by drop in slope and perhaps upstream sediment source.

There is one stream crossing in T2.01-A that is significantly undersized and causing geomorphic instability. A culvert at a trail crossing (Figure 8.41) is in poor condition (rusted bottom and deformed) and has been given a high priority for replacement (Project #19) due to its reduced aquatic organism passage and geomorphic incompatibility. The replacement of this undersized structure is also a recommendation of NRCS (see page 51).

Figure 8.41. Undersized and rusted culvert in T2.01-A.

Segment T2.01-B begins where the valley becomes narrower and continues approximately ½ mile until 450 feet upstream of Belknap Mountain Road. Like T2.01-A, the banks and buffers are well forested in Segment T2.01-B. There has been no incision based on the cross section measured in this segment (Figure 8.42). Some banks are higher but this is more a function of natural floodplain variability than incision. There is very little erosion indicating that the segment is not widening. The stream type is a gravel dominated "C" channel with a slope of a "B" channel that has a dominant bedform of riffle-pool with a subdominant bedform of step-pool (upstream of Belknap Mountain Road). The channel is in the first stage of the channel evolution model, indicating it stable condition. All geomorphic processes were scored in the "good" or "reference" category. The lack of channel alteration, high quality banks and buffers, minor erosion and channel migration is indicative of the "good" geomorphic condition. The habitat condition also scored as "good" as a result of abundant pools, good hydrologic characteristics, nice undercut banks (Figure 8.43), and high quality banks and buffers.

Conservation of reach T2.01 is recommended to provide continued flood and sediment attenuation (Project #20). Flood and sediment attenuation is important to prevent further transport of sediment to Gunstock Brook.

Figure 8.42. Cross section in T2.01-B showing good floodplain access.

Figure 8.43. Nice undercut in T2.01-B providing cover for aquatic species.

8.3 Site Level Opportunities

Site specific projects were identified using the criteria outlined by the VANR in Chapter 6 – Preliminary Identification and Prioritization (Vermont Agency of Natural Resources 2010). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium. Project maps (Appendix B) have been developed for the Gunstock Brook watershed. These maps were created using indexed data from the Phase 2 Stream Geomorphic Assessments along with existing data available from the New Hampshire Geographically Referenced Analysis and Information Transfer System (GRANIT). Locations of potential projects included on the Lake Winnipesaukee website http://winnipesaukeegateway.org/monitoring-the-lake/potential-restoration-sites-map/ are also shown on the map.

A total of 20 projects were identified by BCE to promote the restoration or protection of channel stability and aquatic habitat in the Gunstock Brook watershed. The projects are broken down by category as follows: 3 conservation, 1 passive restoration (streamside plantings); 5 stormwater improvement projects; 11 active restoration (8 bridge or culvert replacement or retrofit projects, one alternative analysis for dam and rock wall removal, one berm removal/planform restoration project, and one investigation and alternatives analysis for well discharge into a swale that enters Gunstock Brook. Information from the Phase 2 stream geomorphic assessment and bridge and culvert assessments could be used to inform the Town of Gilford of which stream crossings are contributing to localized instability. The projects include:

Reach M01 – Gunstock Brook Mainstem (Refer to map on Page 1 of Appendix B)

- **Active Restoration** by replacing culvert impeding fish passage at Lakeshore Road (Project #1);
- **Stormwater Management** in the vicinity of Lakeshore Road (Project #2);
- **Active Restoration** by replacing bridge in poor condition at Old Lakeshore Road (Project #3);
- **Stormwater Management** of developed area west of Gunstock Brook off of Henderson Road (Project #4).

Reach M02 – Gunstock Brook Mainstem (Refer to map on page 2 of Appendix B)

- **Active Restoration** by replacing undersized and poorly aligned bridge at downstream Intervale Road crossing (Project #5);
- **Stormwater Management** of runoff from Intervale Road (Project #6);
- **Active Restoration** by replacing significantly undersized bridge at upstream Intervale Road crossing (Project #7);
- **Alternatives analysis** for berm removal to improve floodplain function just upstream of Intervale Road crossing (Project #8);
- **Active Restoration** by replacing significantly undersized bridge at Cherry Valley Road (Project #9).

Reach M03 – Gunstock Brook Mainstem (Refer to map on page 3 of Appendix B)

- **Active Restoration** by replacing perched culvert at the Town Garage Access Road (Project #10);
- **Stormwater Management** of runoff from Town Garage parking lot (Project #11);
- **Investigation** of eroded swale receiving well discharge (Project #12);
- **Active Restoration** by alternatives analysis of dam and rock wall removal (Project #13)

Reach M04 – Gunstock Brook Mainstem (Refer to maps on pages 4 and 5 of Appendix B)

- **Conservation** of the riparian corridor and wetland to maintain wetland function and to prevent further development that would reduce flood and sediment attenuation capacity (Project #14);
- **Active Restoration** by replacing undersized failing bridge along private trail where a debris jam is developing (Project #15 – Page 5 of Appendix B);
- **Stormwater Management** of Doris Drive residential development (Project #16);
- **Passive Restoration** by planting trees within the riparian corridor along the streambank at the Given Drive development to improve buffer conditions (Project #17).

Reach M05 – Gunstock Brook Mainstem (Refer to map on page 6 of Appendix B)

- **Conservation** of the riparian corridor to maintain stability and habitat (Project #18).

Major Tributary (T2) to Gunstock Brook (Refer to map on page 7 of Appendix B)

- **Active Restoration** by replacing significantly undersized and deteriorating culvert at trail crossing (Project #19);
- **Conservation** of the riparian corridor to provide shading of the brook and maintain sediment and flood attenuation areas (Project #20).

9.0 Next Steps

There are many opportunities to either restore Gunstock Brook and its major tributary to a stable condition. Preliminary reach level and site level projects have been identified and will form the bases for future project development. These preliminary projects include: conservation, streamside plantings, retrofit and/or replacement of stream crossings, berm removal, dam and/or rock wall removal, investigation of well discharge, and improving stormwater runoff. On the watershed level, the development and implementation of fluvial erosion hazard zones is recommended to avoid conflicts regarding land use and to save money spent on flood damage and river maintenance. The Town of Gilford could pursue the opportunity to work with the New Hampshire Department of Environmental Services and the Lakes Regional Planning Commission to develop fluvial erosion hazard zones for the land surrounding the Gunstock Brook mainstem and tributaries. The following are recommendations for next steps.

1. Complete a river corridor plan for the Gunstock Brook watershed to help guide project prioritization and development.
2. BCCD to meet with project partners including the Guildford Conservation Commission, Lake Regional Planning Commission, North County Resource Conservation & Development Area Council, Gilford Hazard Mitigation Update Committee, NRCS and the NHDES to discuss restoration and protection opportunities.
3. Provide outreach to private landowners and the public about the plan and potential projects.
4. Hire contractors (river scientists and engineers) to prepare project design and implementation strategies for selected high priority projects.
5. Work with regulatory agencies on project design and permitting.

For additional information about river restoration and protection opportunities within the Gunstock Brook watershed please contact:

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10.0 LIST OF ACRONYMS AND GLOSSARY OF TERMS

List of Acronyms

AOP – aquatic organism passage
BCE – Bear Creek Environmental, LLC
FEH – Fluvial Erosion Hazard Zone
GIS – Geographic Information System
GRANIT- New Hampshire Geographically Referenced Analysis and Information Transfer System
NHDES - New Hampshire Department of Environmental Services
NWI – National Wetlands Inventory
QA/QC – quality assurance/quality control
RHA- Rapid Habitat Assessment
RGA-Rapid Geomorphic Assessment
SGA – Stream Geomorphic Assessment
SGAT – Stream Geomorphic Assessment Tool
USGS – United States Geological Survey
VTDEC – Vermont Department of Environmental Conservation

Glossary of Terms

Adapted from:
Restoration Terms, by Craig Fischenich, February, 2000, USAE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg, MS 39180
And
Vermont Stream Geomorphic Assessment Handbook, Appendix Q, 2009, VT Agency of Natural Resources, Waterbury, VT. http://www.vtwaterquality.org/rivers/docs/assessmenthandbooks/rv_apxqglossary.pdf

Adjustment process – type of change that is underway due to natural causes or human activity that has or will result in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel plan form adjustment processes).

Aggradation - A progressive buildup or raising of the channel bed and floodplain due to sediment deposition. The geologic process by which streambeds are raised in elevation and floodplains are formed. Aggradation indicates that the stream discharge and/or bed load characteristics are changing. Opposite of degradation.

Alluvial fan – A fan-shaped accumulation of alluvium (alluvial soils) deposited at the mouth of a ravine or at the juncture of a tributary stream with the main stem where there is an abrupt change in slope.

Alluvial soils – Soil deposits from rivers.

Alluvium – A general term for detrital deposits made by streams on riverbeds, floodplains, and alluvial fans.

Avulsion – A change in channel course that occurs when a stream suddenly breaks through its banks, typically bisecting an overextended meander arc.

Bank Stability – The ability of a streambank to counteract erosion or gravity forces.

Bankfull channel depth - The maximum depth of a channel within a riffle segment when flowing at a bankfull discharge.

Bankfull channel width - The top surface width of a stream channel when flowing at a bankfull discharge.

Bankfull discharge - The stream discharge corresponding to the water stage that overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years and given its frequency and magnitude is responsible for the shaping of most stream or river channels.

Bar – An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an over wide channel.

Berms – Mounds of dirt, earth, gravel or other fill built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain.

Cascade – River bed form where the channel is very steep with narrow confinement. There are often large boulders and bedrock with waterfalls.

Channelization – The process of changing (usually straightening) the natural path of a waterway.

Culvert – A buried pipe that allows flows to pass under a road.

Degradation – (1) A progressive lowering of the channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation. (2) A decrease in value for a designated use.

Delta bar – A deposit of sediment where a tributary enters the mainstem of a river.

Depositional features – Types of sediment deposition and storage areas in a channel (e.g. mid-channel bars, point bars, side bars, diagonal bars, delta bars, and islands).

Diagonal Bar – Type of depositional feature perpendicular to the bank that is formed from excess sedimentation and within the channel and from the development of steep riffles.

Drainage Basin – The total area of land from which water drains into a specific river.

Dredging – Removing material (usually sediments) from wetlands or waterways, usually to make them deeper or wider.

Erosion – Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.

Floodplain – Land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.

Gaging Station – A particular site in a stream, lake, reservoir, etc., where hydrologic data are obtained.

Grade control - A fixed feature on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision; typically bedrock, dams or culverts.

Gradient – Vertical drop per unit of horizontal distance.

Habitat – The local environment in which organisms normally grow and live.

Headwater – Referring to the source of a stream or river.

Head cut – Sudden change in elevation or knickpoint at the leading edge of a gully

Incised River – A river that erodes its channel by the process of degradation to a lower base level than existed previously or is consistent with the current hydrology.

Islands – Mid-channel bars that are above the average water level and have established woody vegetation.

Lacustrine soils- Soil deposits from lakes.

Meander - The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.

Meander migration – The change of course or movement of a channel. The movement of a channel over time is natural in most alluvial systems. The rate of movement may be increased if the stream is out of balance with its watershed inputs.

Meander belt width – The horizontal distance between the opposite outside banks of fully developed meanders determined by extending two lines (one on each side of the channel) parallel to the valley from the lateral extent of each meander bend along both sides of the channel.

Meander wavelength - The lineal distance downvalley between two corresponding points of successive meanders of the same phase.

Meander wavelength ratio – The meander wavelength divided by the bankfull channel width.

Meander width ratio – The meander belt width divided by the bankfull channel width.

Mid-channel bar – Sediment deposits (bar) located in the channel away from the banks, generally found in areas where the channel runs straight. Mid-channel bars caused by recent channel instability are unvegetated.

Planform - The channel shape as if observed from the air. Changes in planform often involve shifts in large amount of sediment, bank erosion, or the migration of the channel.

Plane bed – Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed.

Point bar –The convex side of a meander bend that is built up due to sediment deposition.

Pool -- A habitat feature (section of stream) that is characterized by deep, low-velocity water and a smooth surface.

Reach - Section of river with similar characteristics such as slope, confinement (valley width), and tributary influence.

Restoration – The return of an ecosystem to a close approximation of its condition prior to disturbance.

Riffle - A habitat feature (section of stream) that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle-pool - Channel has undulating bed that defines a sequence of riffles, runs, pools, and point bars. Occurs in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys with well-established floodplains.

Riparian Buffer – The width of naturally vegetated land adjacent to the stream between the top of the bank and the edge of other land uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface.

Riparian Corridor – Lands defined by the lateral extent of a stream's meanders necessary to maintain a stable stream dimension, pattern, profile and sediment regime.

Segment – A relatively homogeneous section of stream contained within a reach that has the same reference stream characteristics but is distinct from other segments in the reach.

Sensitivity – The valley, floodplain and/or channel condition's likelihood to change due to natural causes and/or anticipated human activity.

Side bar – Unvegetated sediment deposits located along the margins or the channel in locations other than the inside of channel meander bends.

Step-pool – Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials. Often associated with steep channels in confined valleys.

Steep riflle – Associated with aggradation where sediment has dropped out to form a steep face of sediment on the downstream side.

Surficial sediment/geology – Sediment that lies on top of bedrock.

Tributary – A stream that flows into another stream, river, or lake.

Urban runoff – Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the receiving waters.

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