Bear Creek Environmental

River Corridor Plan
Moon Brook Watershed
Rutland City, Rutland Town, and Mendon, Vermont

March 20, 2008

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1.0 EXECUTIVE SUMMARY

The River Corridor Planning effort is sponsored by the Rutland Natural Resources Conservation District (RNRCD) with funding provided through a grant from the Agency of Natural Resources Clean and Clear Program. The Vermont Department of Environmental Conservation (DEC) River Management Program provided technical expertise and shared quality control/quality assurance responsibilities with Bear Creek Environmental. The River Corridor Plan (RCP) followed the Vermont Agency of Natural Resources River Corridor Planning Guide (Vermont Agency of Natural Resources, 2007c) and Draft 9 of Chapter 5 of the plan dated October 2, 2007. Information for the RCP came from the DEC, the Vermont Center for Geographic Information (VCGI), the City of Rutland, and field data collected by Bear Creek Environmental.

The primary objective of the RCP is to use stream geomorphic assessment data to identify and prioritize river corridor protection and restoration projects within the Moon Brook watershed in Rutland City, Rutland Town and Mendon. Stream Geomorphic Assessments following Agency of Natural Resources Protocols were completed for Moon and Mussey Brooks by Bear Creek Environmental during summer 2005. Bridge and culvert data collected during 2007 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.

The primary goal of the State of Vermont's River Management Program's is to "manage toward, protect, and restore the equilibrium conditions of Vermont's rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner." The RCP provides many opportunities for enhancing and restoring the Moon Brook Watershed at the community-level as well, including: improving water quality and biological integrity, returning the brooks to waters suitable for trout, increasing the recreation resource of the watershed, restoring river corridor functions, and reducing erosion and flood hazards.

At the watershed scale Fluvial Erosion Hazard (FEH) zones were identified in order to prevent increased encroachment in areas prone to fluvial erosion hazard; minimize property loss and damage; prohibit land uses and development that pose a danger to health and safety; and discourage the development of property that is unsuited for the intended purposes due to fluvial erosion hazards.

At the reach and site level scale, potential restoration and protection projects that would be compatible with geomorphic adjustments and managing the stream toward equilibrium conditions were identified. A list of 22 potential restoration and conservation projects was developed during project identification. Types of projects include: Protecting River Corridors, Planting and Improving Stream Buffers, Placing Streams in Former Channel Locations, Replacing Undersized Bridges and Culverts, Reducing the Number of Stream Crossings, Conducting Alternatives Analyses for Modifying On-stream Ponds, and Arresting Head Cuts.

2.0 LOCAL PLANNING PROGRAM OVERVIEW

2.1 RIVER CORRIDOR PLANNING TEAM

The river corridor planning team for the Moon Brook watershed is comprised of the Natural Resources Conservation District, the Agency of Natural Resources, Bear Creek Environmental, local municipalities and landowners. This planning effort is sponsored by the Rutland Natural Resources Conservation District (RNRCD) with Nanci McGuire as project Manager. Funding for the project is provided through a grant from the Clean and Clear Program. Shannon Pytlik from the Vermont River Management Section of the Vermont Agency of Natural Resources (VANR) provided technical guidance for this project. Other members of the river corridor planning team include: Alan Shelvey (City Engineer for Rutland City), Evan Pilachowski (Associate Engineer for Rutland City), Fred Nicholson (Stream Alterations Engineer, VANR), Mic Metz (Wetlands Scientist with VANR), Ethan Swift (Watershed Coordinator, Vermont Agency of Natural Resources), and Jim Pease (Analyst-Biologist with Stormwater Section, VANR).

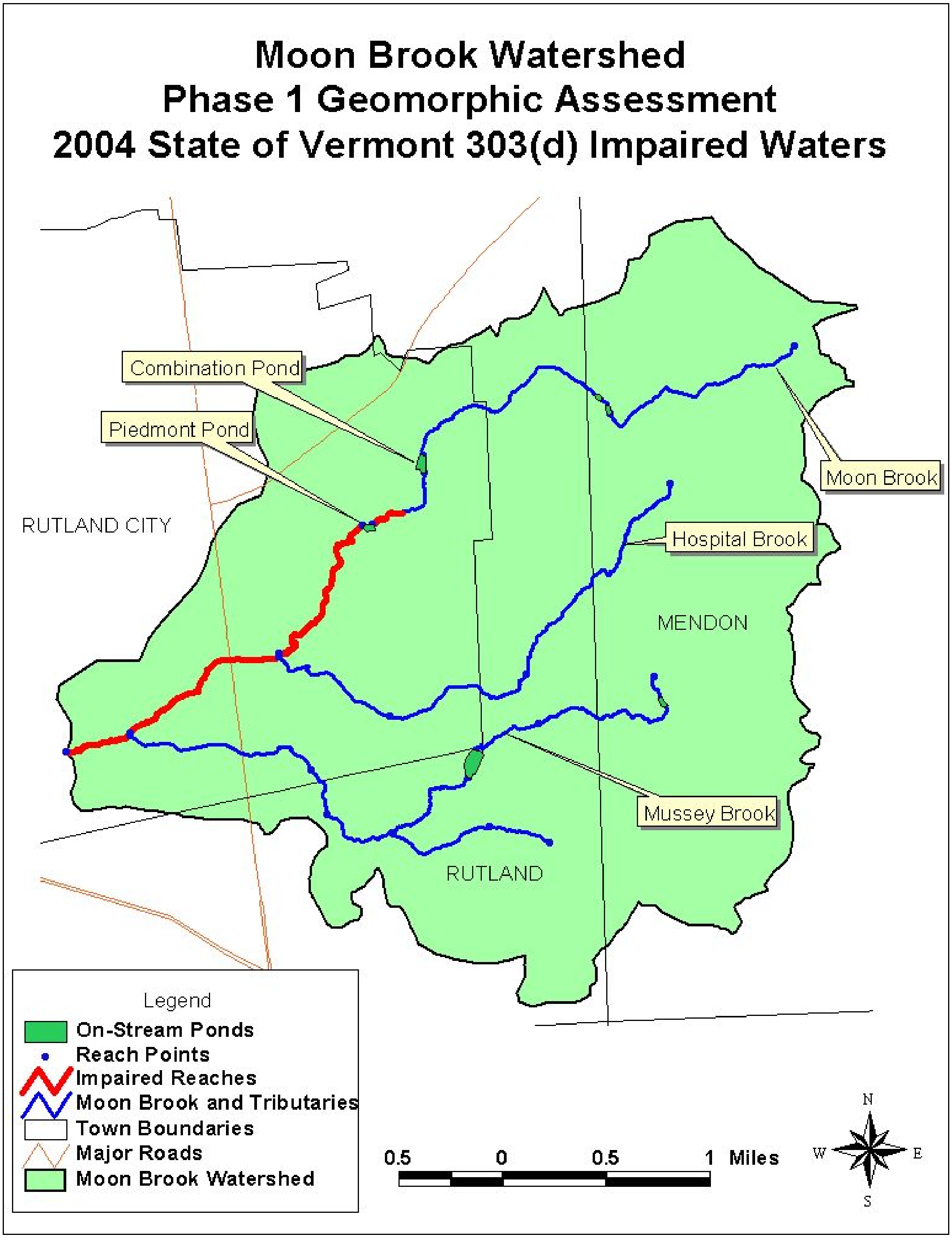


Figure 1. Moon Brook is on the State of Vermont 303 (d) List of Impaired Waters.

2.2 GOALS AND OBJECTIVES OF THE PROJECT

The Vermont Stormwater Section retained Bear Creek Environmental to conduct Phase 1 and 2 Stream Geomorphic Assessments of the Moon Brook Watershed in 2005. The primary goal of this study was to assess the geomorphic condition of Moon Brook and its major tributaries in order to address the segments. Moon Brook from the mouth to river mile 2.3 is listed on the State of Vermont 303(d) list of impaired waters (Vermont Department of Environmental Conservation, 2004 and 2006) due to stormwater runoff and erosion (Figure 1). The main objectives of the study were to provide an overview of the general physical characteristics of the watershed, to assess the impact of parameters such as land use, channel modification, floodplain modification, erosion and debris/ice-jam potential on each reach, and determine which reaches may be in channel adjustment. The primary objective of the Phase 2 Assessment was to provide the VTDEC with information that can be used for watershed planning and restoration activities.

In 2007, the RNRCD, as part of the grant with the Agency of Natural Resources hired Bear Creek Environmental to develop a River Corridor Management Plan for the Moon and Mussey Brooks. The primary objective of the River Corridor Management Plan is to use the Phase 1 and 2 Assessment data to identify and prioritize river corridor protection and restoration projects within the Moon Brook watershed. Bridge and culvert data collected during 2007 are being 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. Based on a list of potential projects developed during project identification, one project will be selected for further evaluation under the current grant.

2.2.1 State River Management Goals and Objectives

The State of Vermont's River Management Program has set out several goals and objectives that are supportive of the local initiative in the Moon Brook watershed. The state management goal is to, "manage toward, protect, and restore the fluvial geomorphic equilibrium condition of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner." (Vermont Agency of Natural Resources, 2007c) The objectives of the Program are to avoid damage to investments due to fluvial erosion hazards, to reduce sediment and nutrient loads, and to restore and protect aquatic and riparian habitat. Additionally, the Vermont River Management Program has set out to provide funding and technical assistance to facilitate an understanding of river instability and the establishment of well developed and appropriately scaled strategies to protect and restore river equilibrium.

2.2.2 Locals Goals and Objectives

A community-based river corridor management plan provides many opportunities for enhancing and restoring the Moon Brook Watershed. Some of the local goals are listed below:

- Improve the water quality and biological integrity of Moon Brook and Mussey Brook
- Return temperature regime of the brooks to waters suitable for trout
- Increase the recreational resource
- Restore river corridor functions
- Reduce erosion and flood hazards
- Protect existing flood and sediment attenuation areas

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

3.1.1 Watershed Description

Moon Brook is located within the Otter Creek watershed, part of the larger Lake Champlain-St. Lawrence River basin (Figure 2). Moon Brook and its tributaries account for roughly 9 mi^2 of the entire 1,100 mi^2 Otter Creek watershed. Moon Brook ranges from 2,386 ft in elevation on East Mountain at its eastern most headwaters to 510 ft at the confluence with Otter Creek, in the central part of the Otter Creek watershed, at the western edge of the Moon Brook basin. The topography of Moon Brook is generally mild, with the greatest changes in relief occurring in the uppermost headwaters of the basin.

3.1.2 Political Jurisdictions

Project reaches for Moon and Mussey Brooks are located in Rutland County Vermont within the towns of Rutland and Mendon as well as the City of Rutland. The Moon Brook watershed falls under the jurisdiction of the Rutland Regional Planning Commission.

3.1.3 Land Use

Moon Brook is located within a highly urbanized area in Rutland County, Vermont. The upper portions of the watershed are predominantly forested, but urban land use dominates throughout most of the mainstem reaches and lower reaches of the tributaries, with sparsely distributed agricultural parcels (Figure 3).

Historically much of the lower watershed was used for agriculture. A map of Rutland County, dated 1854, provides documentation that Mussey Brook originally flowed directly into the Otter Creek south of Park Street (Scott, 1854). It is thought to have been redirected to dry up lands for agricultural purposes (Shelvey, 2006). Today, Mussey Brook is a tributary to Moon Brook whose watershed is slightly less urbanized than Moon Brook's watershed. Reviews of orthophotos from the 1970s have shown that the Moon Brook watershed was dominated by urban, agricultural fields, forest, and shrub land at that time.

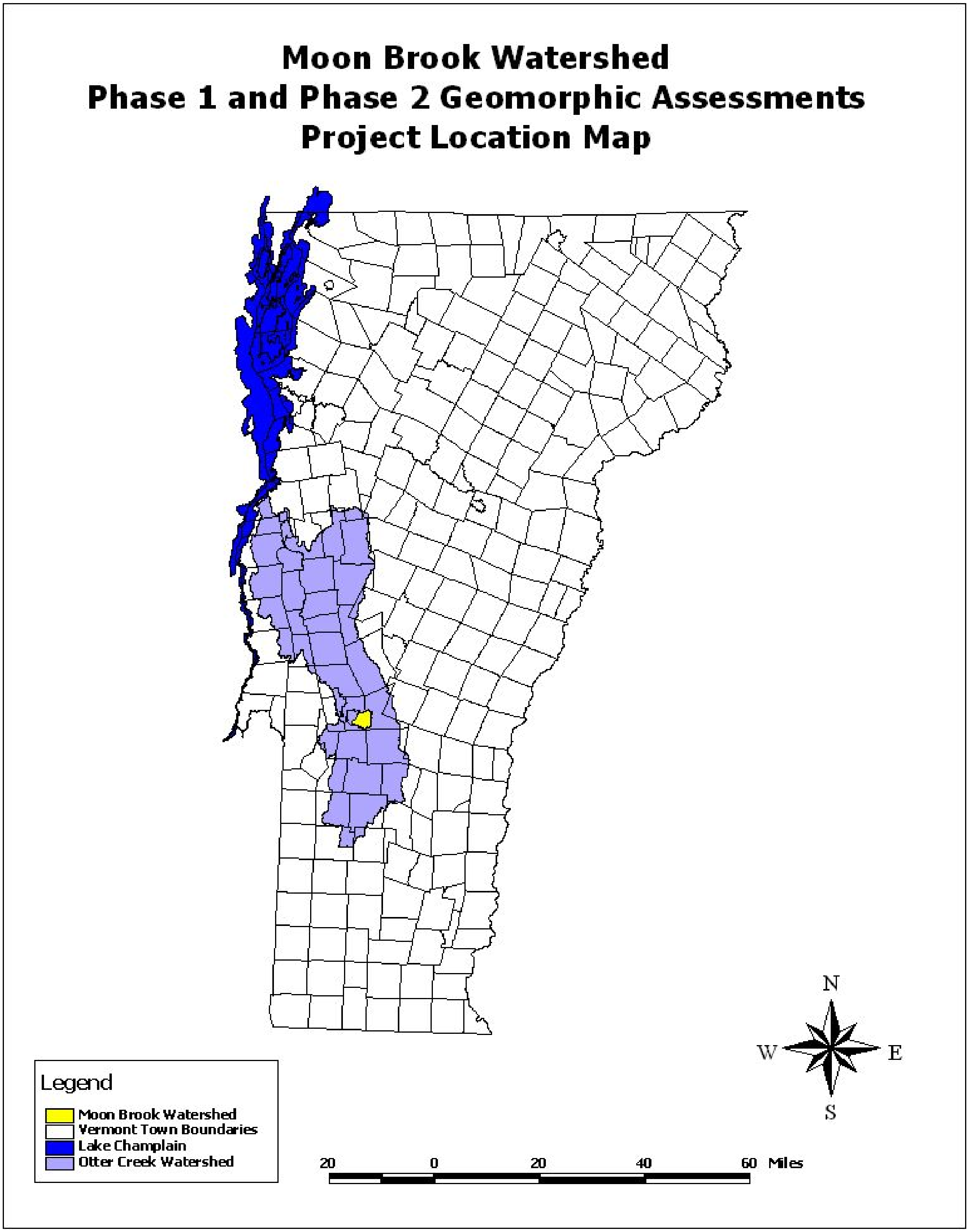


Figure 2: Project location map

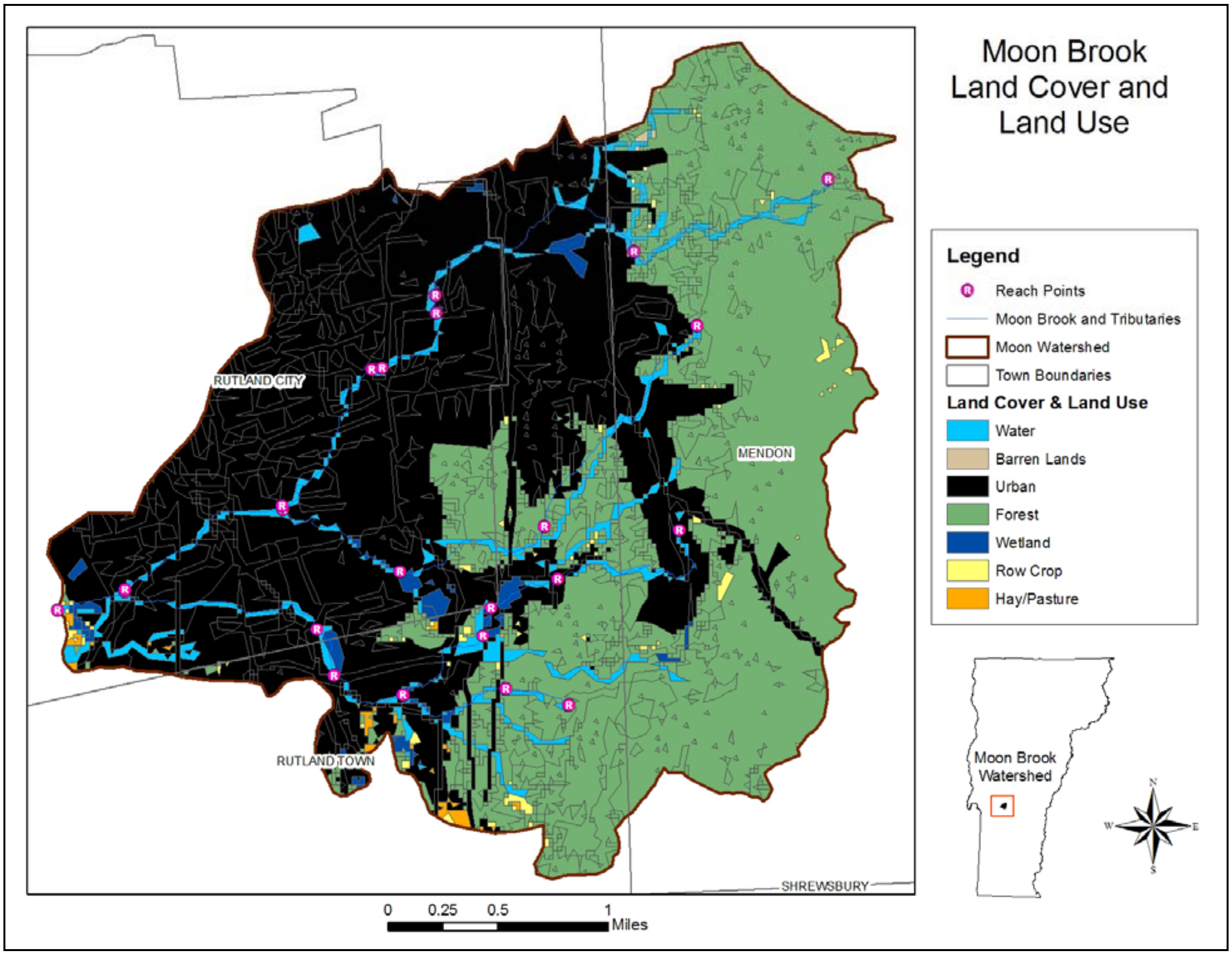


Figure 3. Land cover and land use for Moon Brook waters Geologic Setting

Rutland Town was founded in the late 1700s. There was a growth spurt in the mid 1800s from the development of the railroad through town (Shelvey, 2005). Historic maps in city records show that many of the current roads and downtown buildings were constructed by 1900. The outskirts of the city, where there is significant strip development, was largely constructed sometime around the 1960s.

Because the Moon Brook watershed is so small, there are no records available regarding channel management history. While there are no records of channel management history, Center for Watershed Protection et al. (1999) found channel cross-sections from 1954 for the Granger Street crossing and Brightview Avenue. These crossings became sites M001 and M002 respectively and considerable data were collected at these locations in 1998. Many sections of Moon Brook show evidence of channel straightening through urbanized areas. The majority of evident channel straightening within the Moon Brook watershed seems to be associated with farm fields and development within the river corridor, including channelization to accommodate numerous stream crossings.

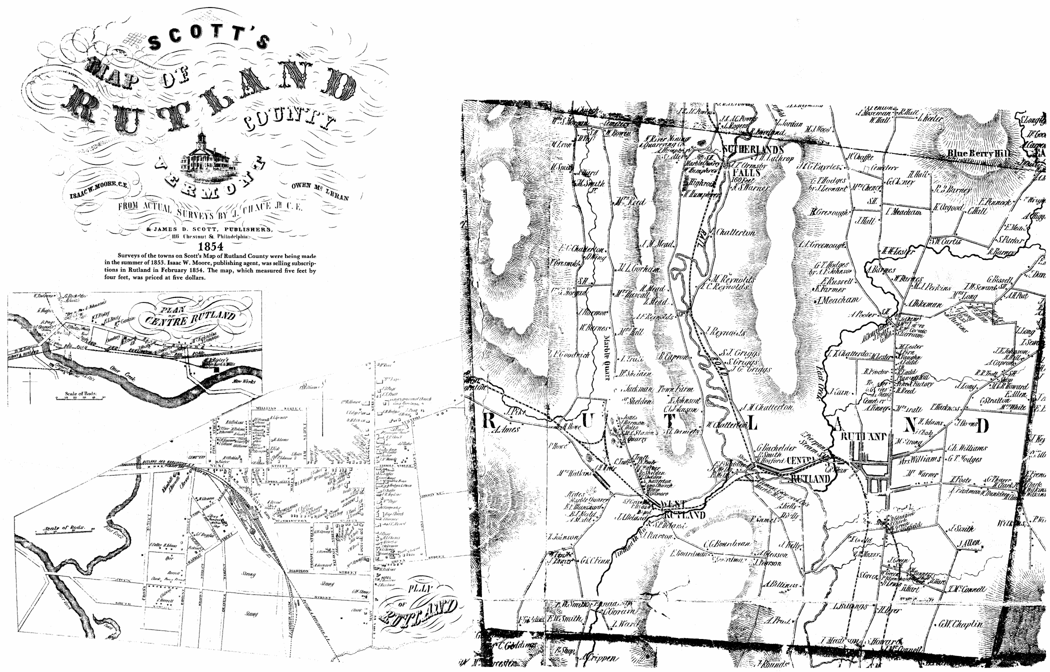


Figure 4. Scott's Map of Rutland (Scott, 1854)

3.2 Geologic Setting

3.2.1 Mountain Provinces and Glacial History

The Moon Brook watershed is located in the physiographic region of the Vermont Valley in between the Green Mountains and Taconic Mountains. The Vermont Valley has been notably influenced by the most recent glaciation at the end of the Pleistocene. The Laurentide ice sheet advanced from northeast to southwest, and retreated in the opposite direction, widely depositing glacial till throughout the region. The Mendon moraine, a glacial deposit containing glacial till and sand and gravel, extends to the north and east of Rutland. As the ice sheet retreated it blocked the flow of surface water and formed Glacial Lake Vermont which inundated the both the Vermont and Champlain Valleys approximately 13,500 years ago. Lacustrine sediments were deposited in the valleys at that time (Wright, 2003).

3.2.2 Bedrock Geology

The bedrock of the Vermont Valley is comprised of shallow marine sedimentary deposits from the Paleozoic Era that were metamorphosed during the Taconic Orogeny (Doolan, 1996). This valley also contains broad marble bands on the valley floor that are easily eroded and a more resistant band of quartzite east, west and north of Rutland City (Van Diver, 1987).

3.2.3 Surficial Geology and Soils

The dominant surficial geology of the Moon Brook watershed consists of alluvium, glacial till, and ice contact deposits. The reaches characterized as C channels within the watershed have glacial till, glacial lake and ice-contact deposits as the dominant geologic materials. These soils are rarely flooded and their erodibility is moderate to very severe. The E type channels have dominant geologic materials consisting of alluvium, ice-contact, glacial till, glacial lake and ice-contact deposits. These soils flood frequently to rarely and have a slight to very severe erodibility. For the A and B type channels, the geologic materials are dominated by till and ice contact deposits. These soils are rarely flooded and have a very severe erodibility.

3. 3Geomorphic Setting

3.3.1 Description and Mapped Location of the Assessed Reaches

A Phase 1 Stream Geomorphic Assessment was conducted on the main stem of Moon Brook, Mussey Brook, and one other major tributary. A Phase 2 assessment was conducted on the entire mainstem of Moon Brook and Mussey Brook (Figure 5).

The Moon Brook watershed was divided into 20 reaches for the Phase 1 and Phase 2 Stream Geomorphic Assessments. Each reach represents a similar section of the stream based on physical attributes such as valley confinement, slope, sinuosity, bed material, dominant bedform, land use, and other hydrologic characteristics. Figure 5 also shows the location of study reaches used in the Stream Geomorphic Assessment. Each point represents the downstream end of the reach. Reaches M22-S1.04 (Piedmont Pond), M22-S1.06 (Combination Pond), and M22-S1.01-S1.05 were excluded from both assessments because these reaches are not fluvial systems but are impounded on-stream ponds.

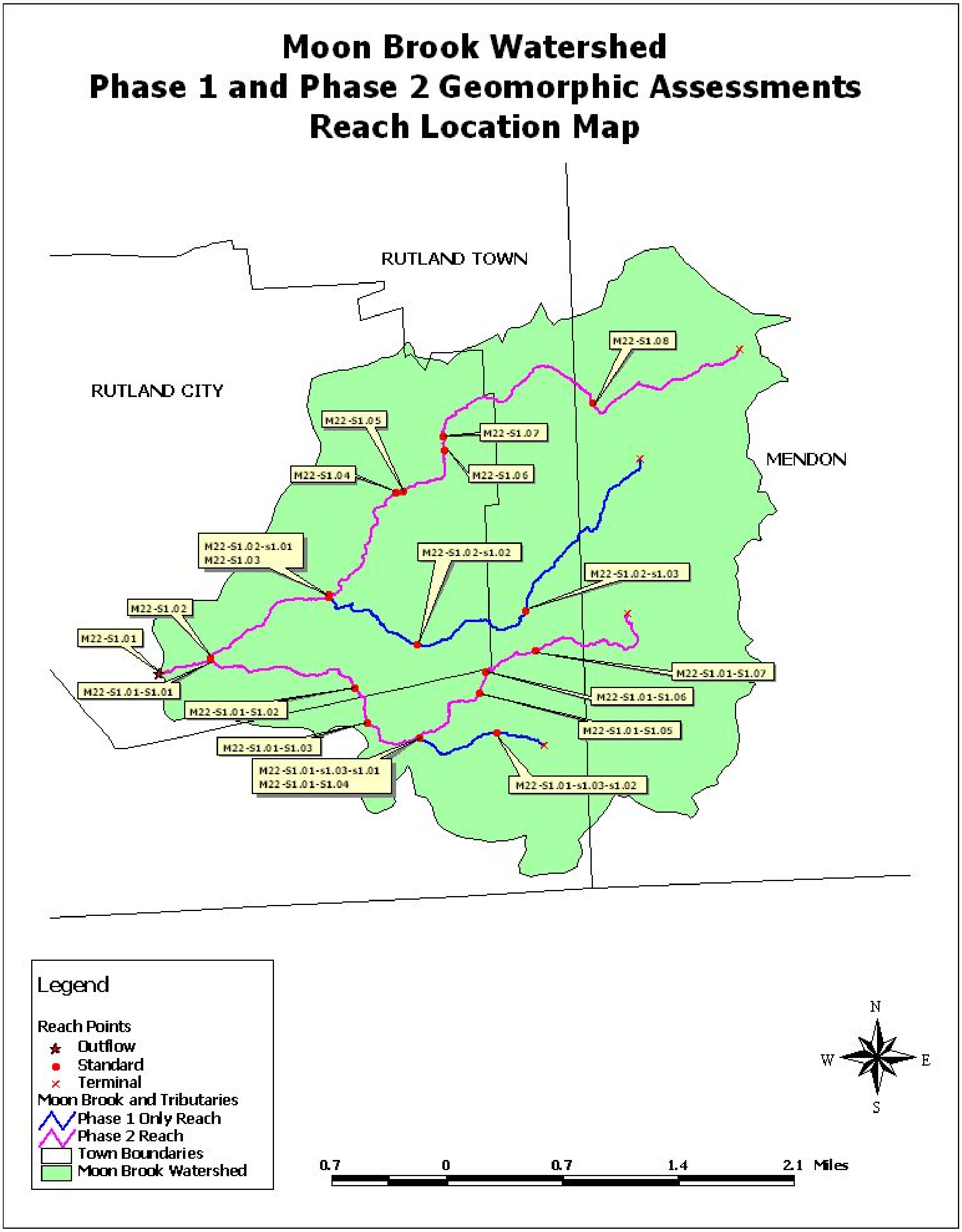


Figure 5. Reach location map for Phase 1 and Phase 2 Stream Geomorphic Assessments.

3.3.2 Longitudinal Profile, Alluvial Fans, and Natural Grade Controls

One possible alluvial fan was identified in reach M22-S1.02-S1.03 due to a sharp break in valley slope that was noted on the topographic map. The soil map indicated that the parent soils in this reach are glacial outwash or till and not alluvium, and there was no evidence of an alluvial fan in the field. The steepness of the valley side slopes was determined using a combination of a topographic map and the soils layer. The valley side slope steepness was variable, but overall flat to hilly slopes dominated the Moon Brook watershed. Natural bedrock grade controls were noted in six of the assessed reaches (M22-S1.03, M22-S1.08, M22-S1.01-S1.01, M22-S1.01-S1.03, M22-S1.01-S1.04 and M22-S1.01-S1.07).

3.3.3 Valley and Reference Stream Types

Reference stream types are defined as stream channel forms and processes that would exist in the absence of human-related changes to the channel, floodplain, and/or watershed. Stream and valley characteristics including valley confinement, and slope determined from digital USGS topographic maps were used to determine the stream type. The reference reach characteristics were later refined during the windshield survey and Phase 2 Assessment. Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems.

Reference stream types for each reach within the project area are summarized in Table 1 and are shown on the map in Figure 6. The majority of the stream reaches fall within the E or C stream types (see Table 2). E stream types comprised 46 percent of the assessed reaches by length. Approximately 32 percent of the study reaches by length were C type streams. Both C and E streams are unconfined, have moderate to gentle slopes, and gravel or finer bed material except for some of the plane bed systems, which were dominated by cobbles.

Table 1. Moon Brook Watershed Phase 1 reference reach data

Reach ID	Drainage Area (Sq mi)	Valley Type	Channel Width (ft^2)	Channel Slope (%)	Sinuosity	Reference Stream Type	Channel Bedform
M22-S1.01	8.74	Very Broad	34.0	1.11	1.01	E	Dune-Ripple
M22-S1.01-S1.01	3.03	Very Broad	21.3	0.93	1.07	E	Dune-Ripple
M22-S1.01-S1.02	2.68	Broad	20.2	0.73	1.72	E	Riffle-Pool
M22-S1.01-S1.03	2.57	Very Broad	19.8	0.94	1.07	C	Riffle-Pool

Table 1. Moon Brook Watershed Phase 1 reference reach data

Reach ID	Drainage Area (Sq mi)	Valley Type	Channel Width (ft^2)	Channel Slope (%)	Sinuosity	Reference Stream Type	Channel Bedform
M22-S1.01-s1.03-s1.01	0.64	Broad	10.7	2.40	1.06	C	Plane Bed
M22-S1.01-s1.03-s1.02	0.08	Narrowly Confined	4.3	15.28	1.04	A	Cascade
M22-S1.01-S1.04	1.62	Very Broad	16.2	1.33	1.36	C	Riffle-Pool
M22-S1.01-S1.06	1.00	Very Broad	13.1	2.33	1.21	E	Riffle-Pool
M22-S1.01-S1.07	0.82	Semi Confined	12.0	5.43	1.13	C	Riffle-Pool
M22-S1.02	5.43	Very Broad	27.6	0.42	1.11	E	Dune-Ripple
M22-S1.02-s1.01	1.81	Very Broad	17.0	2.38	1.21	C	Plane Bed
M22-S1.02-s1.02	1.65	Very Broad	16.3	0.92	1.15	C	Dune-Ripple
M22-S1.02-s1.03	0.67	Semi Confined	11.0	4.18	1.12	B	Step-Pool
M22-S1.03	3.10	Very Broad	21.6	1.04	1.25	E	Riffle-Pool
M22-S1.05	1.97	Very Broad	17.6	1.40	1.11	E	Riffle-Pool
M22-S1.07	1.64	Very Broad	16.3	3.03	1.07	E	Riffle-Pool
M22-S1.08	0.33	Semi Confined	8.1	19.53	1.11	A	Cascade

Two reaches, comprising approximately 12 percent of the study area by length, fall into the A stream type. Cascade systems are narrowly confined, very steep (valley slope greater than 6.5%), with boulder or cobble dominated bed material. One reach (approximately 10 percent of the study area by stream length) falls within the B stream type. This reach was categorized as a step-pool system. This step-pool B stream is semi-confined, has a steep slope, and cobble bed material. Reach M22-S1.01-S1.03-S1.02, located in the upper part of the watershed, was not easily accessible and was not visited during the windshield survey. Best professional judgment was used to assign a bed form for this reach.

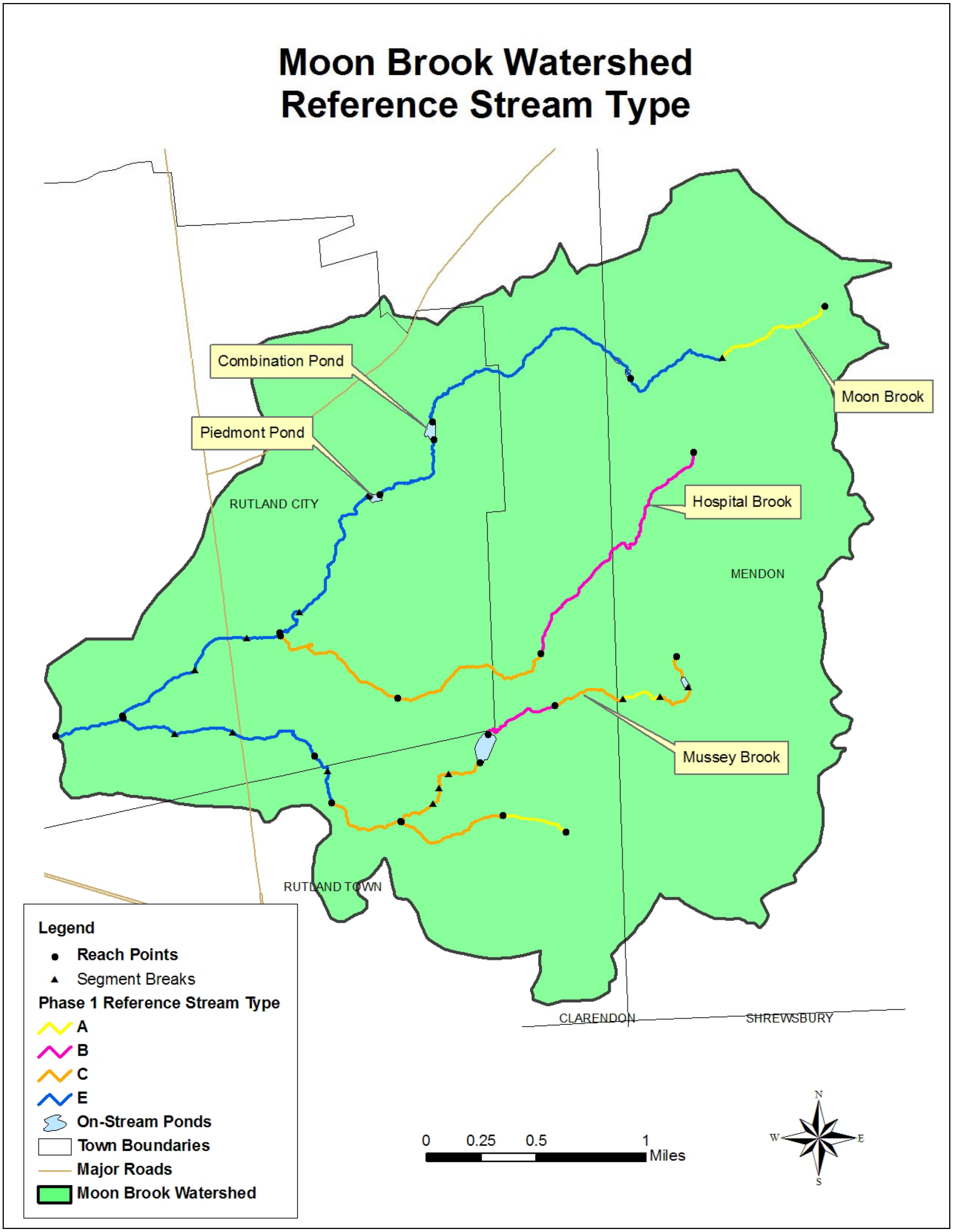


Figure 6. Stream Typing for Phase 1 Assessment Reaches

Table 2. Reference Stream Type by Percentage of Channel Length

Stream Type	Confinement	Channel Slope	Bed Material	Percentage by channel length of Assessed Reaches
A/ Cascade	Narrowly or semi confined	Very steep	Boulder	12
B/Step-pool	Narrow	Steep	Cobble	10
C/Plane Bed	Narrow, Broad or Very Broad	Moderate to gentle	Cobble or finer	17
C/Riffle-pool	Narrow, Broad or Very Broad	Moderate to gentle	Gravel	15
E/Riffle-pool	Narrow, Broad or Very Broad	Moderate to gentle	Gravel or finer	20
E/Dune-ripple	Narrow, Broad or Very Broad	Moderate to gentle	Sand	26

3.4 Hydrology

3.4.1 Streamflow Gages

The U.S. Department of Interior, U.S. Geological Survey (USGS) operated a stream gage on Moon Brook between 1964 and 1978. The gage is too short term to obtain an understanding of the flood history. In order to better understand the flood history of the Moon Brook watershed, long term data from the USGS gage on Otter Creek in Rutland, VT (gage #04282000) were obtained. The Otter Creek gage was selected because it is located near Moon Brook. Although the drainage area at the Otter Creek gage is much larger (307 sq. miles) than the Moon Brook watershed, it does provide some useful information about when large flood events occurred. Seventy-six years of record are available for the Otter Creek gage in Rutland. The gage provides a continuous record of flow from 1929 through the present. The long term record shows peak discharges between a ten year and 25 year recurrence interval occurred during water years[1] 1947, 1949, 1973, 1976, 1977, and 1987. A Flood less frequent than the 50 year discharge occurred during water year 1938. These USGS peak discharge flow values for each year do not account for the effects of flow regulations and diversions. A graph of the flood frequency analysis is provided in Figure 7 below.

[1] A water year is the twelve month period from October 1 through September 30.

There are five on-stream ponds in the watershed (three on Moon Brook and two on Mussey Brook). The Moon Brook watershed is very small and therefore there are no records at the Vermont Water Quality Division and the Facilities Engineering, Dam Safety Section regarding any water withdrawals. The dams within the watershed are not used for water withdrawal but have been rated high for changing the flow regime and disrupting natural sediment transport within the watershed.

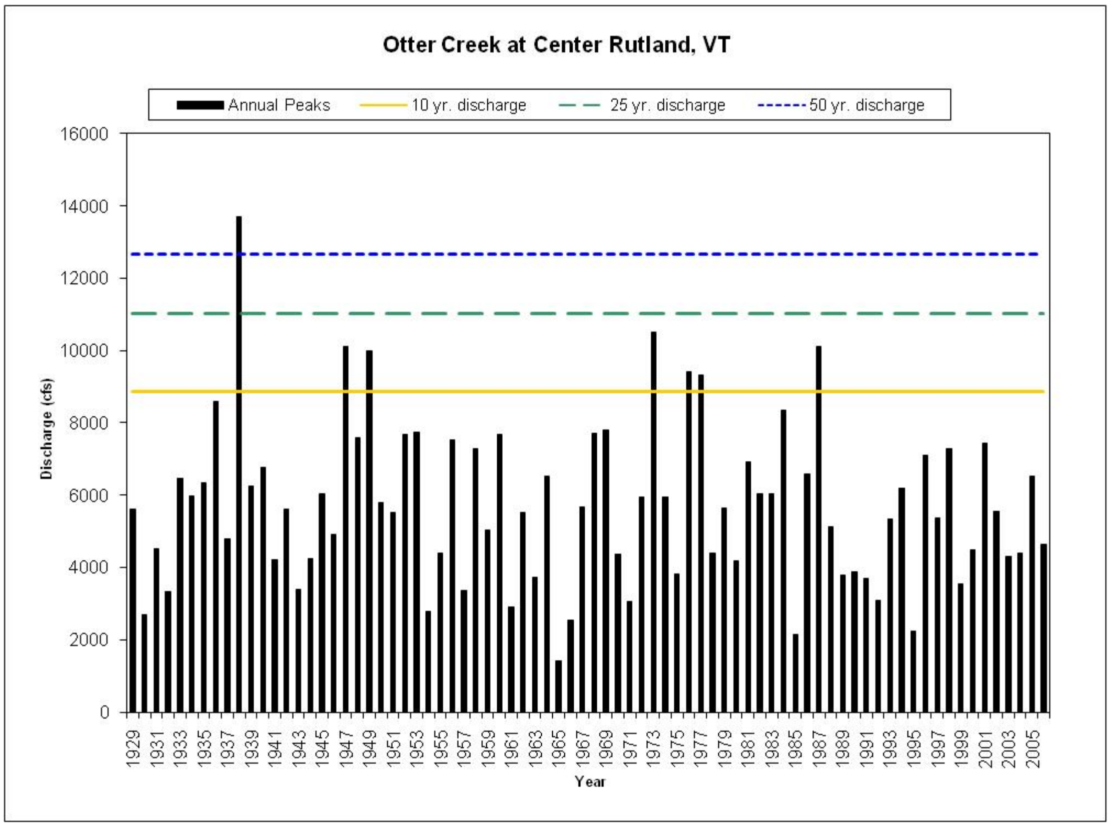


Figure 7. Flood frequency analysis for Otter Creek

3.4.2 Flood History

According to Alan Shelvey, City Engineer for the City of Rutland, Moon Brook has flooded between Strongs Avenue and South Main Street along the south side of Clover Street. The subwatershed for reach M22-S1.02 includes this area. The frequency of the flooding has been about two times in the last 30 years, approximately 1972 and 2001. This area is located within Zone A10 according to the city's flood maps, which means that it is within the 100 year floodplain. Another location in the watershed that floods about every spring is in the meadows by Forest Street (M22-S1.01). There is no development in this area that is impacted. This area is designated as Zone A8 according to the flood maps.

3.5 Ecological Setting

3.5.1 Distribution of Instream, Riparian and Wetland Habitats

Sediment contributions of sand and fine gravel from the watershed, as well as localized contributions from eroding banks due to river adjustment, have created an embedded river bottom along much of the study area. Increased sediment accumulations have been observed upstream of Combination Pond due to development in the upper part of the watershed. The on-stream ponds and abundant stormwater runoff within the watershed appear to be greatly impacting the temperature and organic matter of the stream network. The on-stream ponds also disrupt the natural migration of aquatic species through the watershed (Fiske, 2008).

Much of the Moon Brook watershed has significant intrusion into the river corridor and lacks adequate riparian buffers. The riparian habitat has been anthropogenically impacted due to intensive development along the Route 7 corridor. Commercial, industrial and residential developments now encroach upon what would likely be vegetated riparian habitats. Wetland habitats are limited in the urbanized setting of the Moon Brook watershed. The existence of hydric soils indicates that wetlands were historically more prevalent within the watershed, but have since been filled in.

3.5.2 Unique Plant and Animal Communities

The Vermont ANR Biomonitoring Section has collected biological samples of bugs and fish from Moon and Mussey Brooks in order to assess the biological integrity of the watershed. None of the species collected from the Moon Brook watershed are considered unique or rare in state.

4.0 METHODS

4.1 Fluvial Geomorphic and Habitat Assessment Protocols

4.1.1 Phase 1 Methodology

The Phase I assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Phase 1 Handbook (Vermont Agency of Natural Resources, 2005a), and used version 3.02 of the Stream Geomorphic Assessment Tool (SGAT) GIS extension. All assessment data were recorded on the Agency of Natural Resources (ANR) Phase I data sheets, and were entered into the ANR Data Management System (DMS).

During the Phase 1 Assessment, data was collected for the following parameters: Watershed Land Cover/Land Use, Corridor Land Cover/Land Use, Riparian Buffer Width, Flow Regulations and Water Withdrawals, Bridges and Culverts, Bank Armoring and Revetments, Channel Modifications, Dredging and Gravel Mining History, Berms and

Roads; River Corridor Development, Depositional Features, Meander Migration/Channel Avulsion, Meander Width Ratio, Wavelength Ratio, Bank Erosion (Relative Magnitude), and Debris and Ice Jam Potential. The parameters were then rated according to the following menu options (NS – not significant, low impact, high impact or No info –no information). A zero was scored for options NS and No info, a one for low impact and a two for high impact.

The reach indexing tool (RIT) was used to document steps 5.3, 5.4, and 6.1. This tool is an extension of ArcView and utilizes the Vermont Hydrography Dataset (VHD) (Vermont Center for Geographic Information, 2003) to automate measuring the length of stream segments. The impacts were entered into an attribute table, which was uploaded to the DMS.

4.1.2 Phase 2 Methodology

The Phase 2 assessment of the Moon Brook and Mussey Brook followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (Vermont Agency of Natural Resources, 2005b). All assessment data were recorded on the Agency of Natural Resources Phase 2 data sheets, and were entered in to the ANR Stream Geomorphic Assessment DMS. The Phase 1 database was updated using the field data from the Phase 2 assessment in October and November, 2005.

The parameters and protocols used for undertaking each of the above steps are outlined in the Phase 2 Handbook (Vermont Agency of Natural Resources, 2005b). The entire length of each Phase 2 reach was walked to determine segment breaks. Bank erosion, grade control structures, bank revetments, debris jams, depositional features, stormwater inputs, flood chutes and other important features were mapped within all segments.

4.1.3 Bridge and Culvert

The Bridge and Culvert Assessment and Survey Protocols specified in Appendix G of the Vermont Stream Geomorphic Assessment Handbook (Vermont Agency of Natural Resources, 2007a) were followed. All assessment data were recorded on the Agency of Natural Resources (ANR) Bridge and Culvert Assessment – Geomorphic and Habitat Parameters data sheet, and were entered into the ANR DMS. An ArcView shapefiles of stream crossings for the State of Vermont "TRANS_TRANSTRUC_POINT" was downloaded from the Vermont Center for Geographic Information. This shapefile includes stream crossings on state and town roads.

The bankfull channel width from the Phase 2 fieldwork was used to determine the expected bankfull width in the vicinity of a particular structure. Latitude and Longitude at each of the structures was determined using a Garmin Etrex Vista GPS unit. The assessment included photo documentation of the inlet, outlet, upstream, and downstream of each of the structures.

4.1.4 River Corridor Plan

The Vermont Agency of Natural Resources used SGAT version 4.56 and shapefiles prepared by Bear Creek Environmental to index features that were mapped during the Phase 2 assessment. The VTANR also indexed locations where riparian buffers are less than 25 feet on either side of the channel and locations where corridor encroachments exist based on National Agriculture Imagery Program (NAIP 2003) photos and e911 buildings data where applicable. Additional features, such as steep riffles, debris jams, stormwater inputs and flow regulations were indexed by Bear Creek Environmental from field maps during fall 2007.

The Vermont Agency of Natural Resources River Corridor Planning Guide (2007c) and Draft 9 of Chapter 5 of the plan dated October 2, 2007 were followed to generate a series of stressor maps. These maps were created using indexed data from the Phase 1 and Phase 2 Stream Geomorphic Assessments along with existing data available from VCGI, including railroads, e911 roads, e911 buildings and e911 driveways. In addition, NAIP 2003 photos and polygon shapefiles of buildings and parking areas available from the City of Rutland were used to identify additional corridor encroachments and lateral constraints that were not included in the e911 layers. The stressor maps were then used to identify potential project locations that have few constraints to channel adjustment.

4.2 Quality Control/Quality Assurance Procedures

To assure a high level of confidence in the Phase 1 and 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 as well as automated and manual QC checks with the DEC River Management Program. The three base shapefiles (valley walls, meander centerlines, and subwatershed) were submitted to Shannon Hill for QA review prior to running the SGAT extension. After Step 2 of the Phase 1 Assessment was completed, Bear Creek Environmental conducted its own manual QA review of the reference stream types. Then the SGAT project and resultant shapefiles were sent to the River Management Program for another QA review, which included a manual QA review of reference stream types. In early June 2005, Phase 1 ArcView shapefiles were submitted to Shannon Hill for a QA review following the completion of Step 7 of the Phase 1 assessment.

In October 2005, BCE completed its own in-house QA review after all the Phase 2 data were entered into the DMS and the Phase 1 data were updated. The Phase 1 DMS and ArcView shapefiles were updated by Michael Blazewicz and Pamela DeAndrea based on the Phase 2 field assessment work during the Phase 2 QA/QC process in early November 2005. The DMS and the ArcView shapefiles for the Moon Brook Phase 2 study were submitted to

Shannon Hill of the ANR for a Quality Assurance review in late November 2005. Some minor revisions were made by Bear Creek Environmental to the DMS following this review. These change included one stream type revision, a sub-class slope change, and filling in blank spaces in the DMS.

4.3 Special Studies

4.3.1 Alternatives Analysis of Mussey Brook in Vermont State Fairgrounds

The project team of Bear Creek Environmental (BCE) and DuBois & King, Inc. (D&K) were retained by the Rutland Natural Resources Conservation District to conduct an alternatives analysis for Mussey Brook (Bear Creek Environmental, 2006b) within the Vermont State Fairgrounds. The project was funded through the Vermont Clean and Clear Program.

BCE completed a field survey of the channel from the VT Route 7 crossing to the downstream end of the railroad track culvert. The survey included a longitudinal profile as well as the survey of 13 stream cross sections using a laser level. Each of the four road crossings within the Fairgrounds was also surveyed. The survey was tied into National Geodetic Survey Monuments located at each end of the study area. Vertical datum was referenced to the GIS plan (1929 VGVD) developed by the Rutland City from a December 2001 flyover.

D&K estimated peak discharge rates for several storms including the bankfull, annual, 2-year, 5-year, 10-year, 25-year, and 100-year events. The bankfull discharge was estimated using ANR's Vermont 2001 Regional Hydraulic Geometry Curves (Vermont Water Quality Division, 2001). Hydraulic modeling was performed by D&K to better understand flooding within the Vermont State Fairgrounds. Flood inundation maps were prepared by Bear Creek Environmental using the results of the hydraulic modeling. Conceptual level design alternatives for increasing ecological function of the Mussey Brook were prepared.

4.3.2 Moon Brook Temperature Monitoring
(Prepared by Evan Pilachowski, Associate City Engineer, City of Rutland)

The City of Rutland has conducted temperature monitoring in the Moon Brook Watershed within the City of Rutland each of the last three years (2005-2007). Temperatures have been recorded with the HOBO Water Temp Pro from Onset. Six of these underwater temperature loggers were deployed in 2005 and eleven were deployed in 2006 and 2007. This monitoring project was partially funded through the Local Community Implementation Fund (LCIF) administered by the State of Vermont. The loggers were deployed in the spring of each year and collected in fall. The City has maintained certain sampling locations while adding new locations from year to year. The sampling locations that have been maintained each year are shown below:

- Moon Brook Above Combination Pond

- Moon Brook Below Combination Pond Outfall
- Moon Brook Below Piedmont Pond Outfall
- Moon Brook at White's Playground
- Moon Brook at Forest St. Bridge
- Mussey Brook below Fairgrounds

5.0 RESULTS

5.1 Phase 2 Results

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, 2005b). The reference condition for each of the Phase 2 reaches was previously identified in Figure 6. Of the 10 segments where Phase 2 RGA's were conducted on Moon Brook, five segments rated in the good category and four segments rated in the fair category. One segment, on Moon Brook within the Route 7 corridor, rated in poor condition. (Bear Creek Environmental, 2006a) In an earlier study, the Center for Watershed Protection used a modified RGA to evaluate channel stability of lower Moon Brook within reach M22-S1.02 and M22-S1.03. The results of the modified RGA showed Moon Brook was in adjustment, and was found to be outside of the expected range of variance for channels of similar type (Center for Watershed Protection et al., 1999)

Approximately half the segments on Mussey Brook were in good condition, while the other half were in fair condition. One very short segment, located in a wetland, downstream of what was formerly know as Eddy Pond, was found to be in reference condition. Figure 8 illustrates the geomorphic condition of the streams in relation to the watershed.

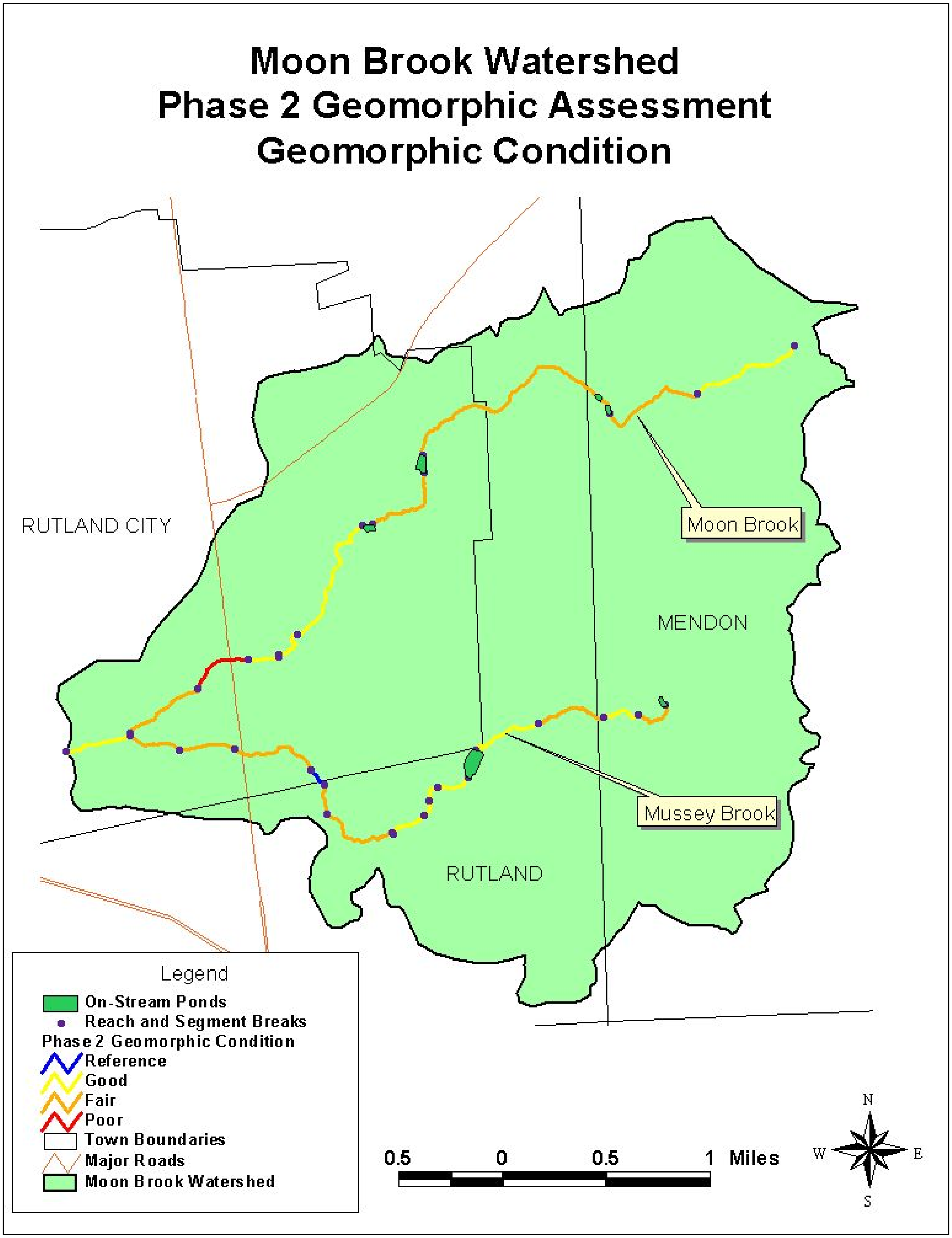


Figure 8: Phase 2 Geomorphic Condition of the Moon Brook Watershed

5.2 Bridge and Culvert Assessment

Thirteen bridges/arches and ten culverts were included in the assessment of public stream crossing conducted during 2007. The geomorphic and habitat data for this bridge and culvert assessment were collected following the ANR protocol. Bridge and culvert data were also available from the alternatives analysis of Mussey Brook that was conducted within the Vermont State Fairgrounds (Bear Creek Environmental, 2006b).

In order to assist local municipalities with priorities for replacement of the structures, priority lists were generated using the information and photographs taken during the assessment. The bridge span and the culvert diameters as a percentage of the channel width were used as a first cut in prioritizing the structures for replacement. The habitat data from the ANR bridge and culvert assessment was used to identify potential barriers to movement and migration. The following categories were used to determine project priorities for stream crossings.

High Priority: Bridges and culverts with spans of approximately 50 percent of the bankfull width or less, which are significantly impeding natural sediment transport or are blocking aquatic organism passage (AOP).

Moderate Priority: Bridges and culverts with spans less than 50 percent that are not causing significant geomorphic instability or blocking AOP and structures with spans greater than 50% that are causing instability and/ or impeding aquatic organism migration are also in this category.

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

Tables 2 (Moon Brook) and Table 3 (Mussey Brook) below provide a summary of the stream crossings assessed within the Moon Brook watershed. All of the culverts were identified as potentially blocking aquatic organism passage (AOP). There were two segments within the watershed that were identified as higher priority for replacement due to multiple stream crossing structures within a short distance and undersized structures. These two segments are M22-S1.02-B on Moon Brook within the Route 7 corridor and M22.S1.01-S1.01-B on Mussey Brook within the Vermont State Fairgrounds.

Table 2. Moon Brook Stream Crossing Structures

Reach/ Segment No.	Structure No.	Structure Type	Road Name/ Location	% Channel Width	Blocks AOP	Problems Noted		Priority for Replacement
						Sediment Transport	Alignment	
M22-S1.01	203018001411192	Bridge	Forest Street	75				Low
M22-S1.02-A	990000000411191	Bridge	Granger Street	83		√	√	Moderate
M22-S1.02-A	990000000211193	RR Bridge	Between Scale Ave and Park St.	**39**				Moderate
M22-S1.02-B	990000000001193	Culvert	Scale Ave	**46**	Potentially			Moderate
M22-S1.02-B	990000000111193	RR Bridge	Downstream of Strongs Ave	**49**		√		High
M22-S1.02-B	990003001411191	Bridge	Strongs Ave	**40**				Moderate
M22-S1.02-B	300019009811191	Bridge	S Main Street	100				Low
M22-S1.03-B	990011000311191	Culvert	Perry Lane	55	Potentially			Low
M22-S103-B	990000000211191	Bridge	Jackson Ave	**43**				Moderate
M22-S1.03-B	990000000211191	Bridge	Killington Ave	148				Low
M22-S1.03-B	990000001711191	Culvert	Ronaldo Court	**30**		√		High
M22-S1.05	990009000811191	Arch	Stratton Road	70				Low
M22-S1.07	700093053811203	Culvert	E Mountainview Drive	**29**	Potentially			Moderate
M22-S1.07	700008012511203	Culvert	Town Line Road	**29**	Potentially			Moderate

Bold indicates section of Moon Brook within the Route 7 corridor with multiple stream crossings within a short distance and undersized structures

Table 3. Mussey Brook Stream Crossing Structures

Reach/ Segment No.	Structure No.	Structure Type	Road Name/ Location	% Channel Width	Blocks AOP	Problems Noted		Priority for Replacement
						Sediment Transport	Alignment	
M22-S1.01-S1.01-A	990012000611191	Bridge	Park Street	83				Low
M22-S1.01-S1.01-B	990000000411193	RR Bridge	Below VT State Fairgrounds	**46**		√		High
M22-S1.01-S1.01-B	Private (S-C)	Culvert	VT State Fairgrounds	58	Potentially	√		Moderate
M22-S1.01-S1.01-B	Private (S-D)	Culvert	VT State Fairgrounds	**36**	Potentially	√		High
M22-S1.01-S1.01-B	Private (S-E)	Foot Bridge	VT State Fairgrounds	71			√	High (causing significant bank erosion)
M22-S1.01-S1.01-B	Private (S-F)	Culvert	VT State Fairgrounds	50	Potentially	√	√	High
M22-S1.01-S1.01-B	Private (S-G)	Culvert	VT State Fairgrounds	58	Potentially			Low
M22-S1.01-S1.01-C	300019009711191	Arch	S Main Street	83				Low
M22-S1.01-S1.01-C	990000000311193	RR Bridge	Between Allen and Curtis Ave	81				Low
M22-S1.01-S1.01-C	990000001311191	Culvert	Curtis RD next to Fitness Center	**39**	Potentially	√		High
M22-S1.01-S1.03	990005000111201	Culvert	Cold River Road	71	Potentially			Low
M22-S1.01-S1.03	700005009511203	Bridge	Cold River Road	77			√	Moderate
M22-S1.01-S1.04-D	990027000311201	Culvert	Stratton Road	55	Potentially			Low
M22-S1.01-S1.07	990006000011101	Culvert	S Mendon Road	50	Potentially			Low

Bold indicates section of Mussey Brook within the Vermont State Fairgrounds with multiple stream crossings within a short distance and undersized structures

5.3 Special Studies

5.3.1 Mussey Brook Alternatives Analysis in Vermont State Fairgrounds

The project team evaluated three different alternatives for implementation. The three design alternatives considered include: 1. Improve the riparian buffer with no channel or floodplain modifications; 2. Improve the riparian buffer and excavate a floodplain bench within the upper part of the study reach; 3. Realign the planform and plant native trees and shrubs.

Of the three alternatives, alternative #1 best accommodates land use expectations. Alternative #3 requires significant space along the channel to work and would likely require a much engineered solution to keep the channel back from buildings and in alignment with the stream crossings. Option #2 may result in accelerated channel migration, also requiring more space. Option #3 most strongly meets the objective of improving channel and floodplain functions. None of the three alternatives address the flooding concerns within the fairgrounds.

All three options are expected to make the fairgrounds aesthetically pleasing and will provide shade for visitors to the fairgrounds as well as aquatic life, such as fish. Option #1 perhaps, provides the quickest "bang for the buck". This option is least expensive and the benefits of a vegetated riparian corridor are quickly evident. Alternative #1 would help to filter pollutants and go a long way towards reducing stream temperatures.

The Mussey Brook Fairgrounds Alternative Analysis Committee made up of Ethan Swift (DEC), Nanci McGuire (Rutland NRCD), Mary Nealon (BCE) and Shayne Jaquith (ANR) met on November 8, 2006 to discuss the alternatives analysis and to make recommendations for a design option. Mike Adams of the Army Corps of Engineers (ACOE) also attended the meeting to provide information on the jurisdiction of the Army Corps of Engineers. The consensus of the Alternative Analysis Committee was to recommend Alternative #1. This option was selected due to land use constraints, limited benefits in excavating a floodplain over such a short distance, and a quick cost/benefit analysis. In addition, the committee was aware of a proposal underway to relocate the rail yard at the lower end of the project segment. It was felt that Alternative #1 offered many water quality benefits.

5.3.2 Moon Brook Temperature Study
(Prepared by Evan Pilachowski, Associate City Engineer, City of Rutland)

The monitoring results have shown a significant increase in temperature across Combination Pond and Piedmont Pond (Exhibit #1). Results have also shown an increase in temperature on Mussey Brook across the fairgrounds (Exhibit #2). Brook trout serve as an indicator organism for coldwater fisheries because they are intolerant of high temperatures. Biological indicator testing in Rutland City has consistently shown a lack of coldwater species including brook trout. According to a study conducted by the Surface Water Quality Bureau of the New Mexico Environment Department in July of 1999, a coldwater fishery is classified as having instantaneous temperatures below 75.2 °F (20 °C), no single day with temperatures above 68 °F (20 °C) for more than 8 hours, and no more than three days in a row with maximum temperatures above 68 °F (20 °C). This study was based on survival rates of trout species at different temperatures. The following table was prepared using the coldwater fishery standards and the collected data from the 160 day period from April 26, 2007 to October 3, 2007.

Location	Approximate Location Upstream of Confluence (mi)	Number of Days Outside Coldwater Fisheries Criteria
Paint Mine Brook[1]	0.1	3
Mussey Brook Above Fairgrounds[2]	0.1	18
Mussey Brook Below Fairgrounds	0.7	40
Moon Brook Above Combination Pond[3]	2.9	0
Moon Brook 3ft Below Combination Pond Outfall	2.7	95
Moon Brook 20 ft Below Combination Pond Outfall	2.7	94
Moon Brook Above Piedmont Pond[4]	2.3	64
Moon Brook Below Piedmont Pond Outfall	2.1	81
Moon Brook at White's Playground[5]	1.2	33
Moon Brook at Strongs Ave[5]	0.9	28
Moon Brook at Forest St[5]	0.3	32

[1] Paint Mine Brook is a small tributary of Moon Brook approximately 1.6 miles upstream of the confluence with Otter Creek. The stream is well vegetated and is monitored because of its relatively pristine condition.

[2] Mussey Brook is a tributary of Moon Brook approximately 0.3 miles upstream of the confluence with Otter Creek. The fairgrounds is straight, unshaded stretch of brook, and it is suspected that this area contributes greatly to the thermal load on the brook.

[3] The surface area of Combination Pond is approximately 2.15 acres and is mostly unshaded. The thermal impacts of the pond to Moon Brook are of concern.

[4] The surface area of Piedmont Pond is approximately 0.68 acres and is mostly unshaded. The thermal impacts of the pond to Moon Brook are of concern.

[5] The remainder of the sampling locations were selected to periodically test the temperature. There are no suspected areas where major thermal impacts are expected to significantly increase the temperature in Moon Brook.

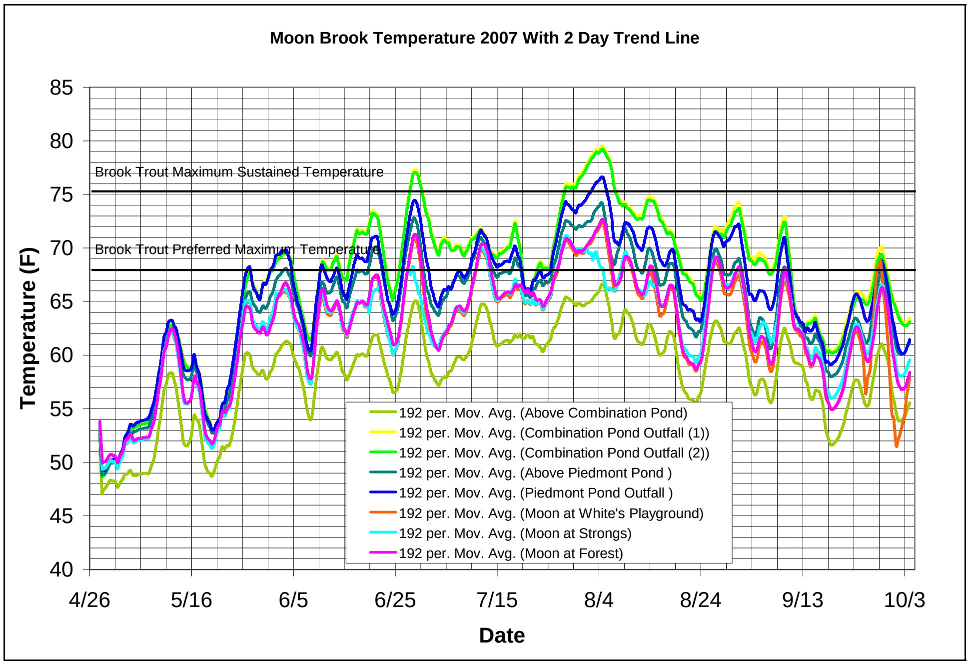


Exhibit #1

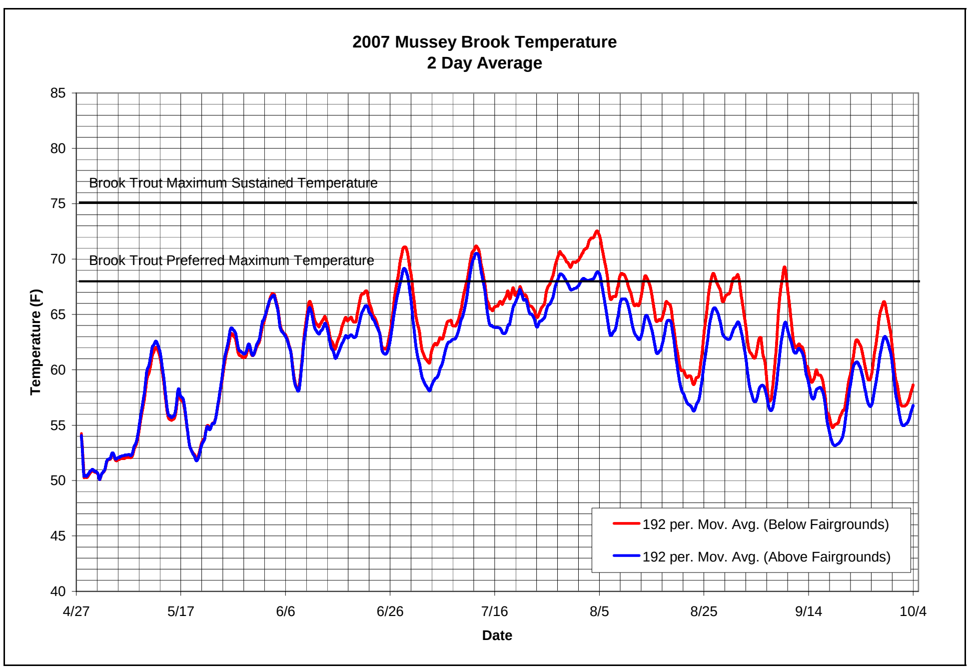


Exhibit #2

Because the influence of Combination Pond on downstream temperature was the greatest of any of the highlighted land features, further study of the pond was deemed necessary. In addition to temperature monitoring in the Moon Brook Watershed, a temperature profile of Combination Pond was completed in 2006 (Exhibit #3). A pond depth profile was prepared prior to monitoring temperatures. The depth of the pond was tested with a range pole to obtain an approximate contour map of the bottom of the pond. The pond is approximately 9 feet at its deepest, directly adjacent to the outfall. Four locations were tested using the underwater temperature monitors. The locations were upstream of Combination Pond, three feet below the surface of the pond at the outlet structure, six feet below the surface of the pond at the outlet structure, and in Moon Brook just downstream of the pond outfall. Since water flows over the top of a concrete outlet structure, the surface water temperature was assumed to be equal to the temperature measured just downstream of the pond. Though there was some data corruption downstream of Combination Pond due to some unknown source, the results showed that there is very little temperature difference between the different levels within Combination Pond.

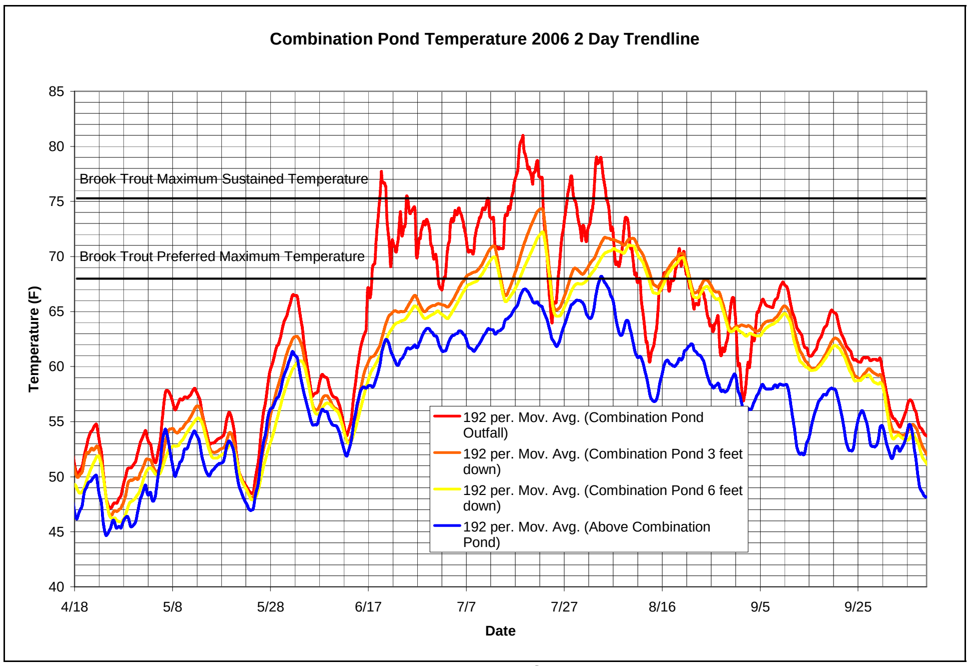


Exhibit #3

The City plans to continue monitoring temperatures within the Moon Brook Watershed, and to use this data to analyze the effectiveness of any future temperature mitigation projects.

6.0 STRESSOR, DEPARTURE AND SENSITIVITY ANALYSIS

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Moon Brook stream network that were observed during the Phase 1 and Phase 2 Stream Geomorphic Assessments. These maps also provide an indication of the degree to which the channel adjustment processes within the watershed have been altered, at both the watershed scale and the reach scale. The analysis of existing and historic departures from equilibrium conditions along a stream network allows for the prediction of future alterations within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

6.1 Departure Analysis and Stressor Identification

6.1.1 Hydrologic Regime Stressors

The hydrologic regime is the timing, volume, and duration of flow events throughout the year and over time and is characterized by the input and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. The land use within the watershed plays a role in the hydrology of the receiving waters. The percentage of urban and cropland development within the watershed are factors which change a watershed's response to precipitation. The most common effects of urban and cropland development is increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture 1986).

The dominant watershed land cover/land use within the Moon Brook watershed is urban and forest. Fourteen of the twenty reaches resulted in a watershed land cover/land use impact rating of high (10% or more is crop and/or urban). Analysis of hydric soils located where current land uses are agricultural or urban indicates some loss of wetland attenuation. Historical deforestation in the Moon Brook watershed may also have contributed to historic incision.

The Moon Brook watershed has an extensive network of roads as shown in Figure 9. The road density for the subwatersheds of Moon Brook from the Route 7 corridor up to Combination pond (M22-S1.02 through M22-S1.05) and Mussey Brook from the Route 7 Corridor through Curtis Avenue (M22-S1.01.S1.01) are greater than 7 miles per square mile. The road densities in these highly developed areas ranged from 7 mi/ sq. mile to 17 mi/sq mile. The extensive network of roads within the Moon Brook watershed has likely significantly contributed to increased flows within the brook resulting both from increased runoff and stormwater ditching. According to Foreman and Alexander (1998), increased peak flows in streams may be evident at road densities of 3.2 miles/ square mile. Subwatersheds with road densities of greater than 3.2 mile/ square mile account for approximately 72 percent of the Moon Brook watershed.

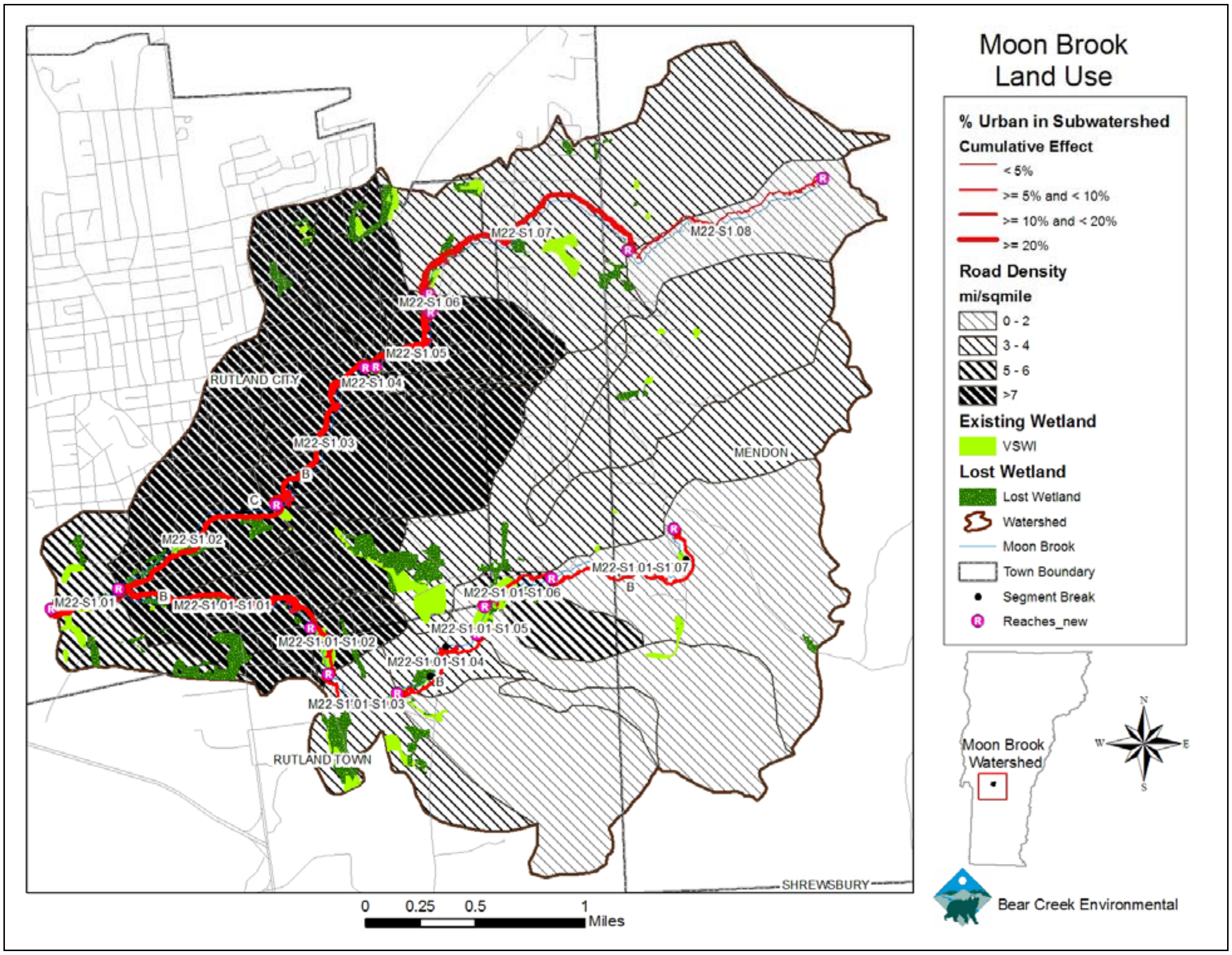


Figure 9. Land use map showing cumulative percent of urban land use, road density and lost wetlands.

6.1.2 Sediment Regime Stressors

The sediment regime is the quantity, size, transport, sorting and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and the specific morphology of the valley, floodplain, and stream. The Sediment Load Indicators Map (Page 1 of Appendix 1) shows the distribution of sediment load indicators in the Moon Brook watershed at the watershed scale. No mass wasting sites or gullies were identified during the Stream Geomorphic Assessments. Localized areas of bank erosion and depositional features (steep riffles, mid channel bars, delta bars, flood chutes, and/or avulsions) are prevalent.

6.1.3 Reach Scale Sediment Regime Stressors

The previously discussed alterations to flow and sediment load at the watershed scale serve as a pretext for understanding the timing and degree to which reach scale modifications are contributing to field observed channel adjustment. When the valley, floodplain, channel and channel boundary conditions are modified, a stream may change the way sediment is transported, sorted, stored and distributed. The stressors that alter these conditions either increase or decrease stream power and or increase or decrease the resistance of its boundary conditions. This is helpful for determining why a reach is under adjustment and what types of management activities will be beneficial in returning the stream to equilibrium conditions. The primary stressors in each segment of the Moon Brook watershed are identified in Table 4 (Moon Brook) and Table 5 (Mussey Brook).

Table 4. Moon Brook Hydrologic and Sediment Load Stressors				
	Watershed Input Stressors		Reach Modification Stressors	
River Segment	Hydrologic	Sediment load	Stream Power **Bold**=increase Plain=decrease	Boundary Resistance **Bold**=increase Plain=decrease
M22-S1.01	Wetland loss Road Density (H) % Urban (E)		**Straightening (E)** Constrictions	Reduced riparian vegetation (M)
M22-S1.02 A	Stormwater input (M), Road density (E), % Urban (E), Wetland Loss	Historic degradation	**Straightening (E) Encroachment (H)** Constrictions	**Armoring (M)**
M22-S1.02 B	Stormwater input (M), Wetland loss Road Density (E) % Urban (E)	Historic Degradation, Depositional Features (H)	**Straightening (E) Encroachment (H)** Constrictions	**Armoring (H)**
M22-S1.02 C	Stormwater input (H), Wetland loss Road Density (E) % Urban (E)		**Straightening (E) Encroachment (H)**	**Armoring (M)**
M22-S1.03 A	Wetland loss Road Density (E) % Urban (E)	Bank Erosion (M)	**Straightening (H) Encroachment (H)**	Reduced riparian vegetation (M)
M22-S1.03 B	Road Density (E) % Urban (E)	Bank Erosion (M)	**Straightening (H) Encroachment (H)** Constrictions Grade Controls	**Armoring (M)** Reduced riparian vegetation (M)
M22-S1.04 (Pond)				

Table 4. Moon Brook Hydrologic and Sediment Load Stressors

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	Hydrologic	Sediment load	Stream Power **Bold**=increase Plain=decrease	Boundary Resistance **Bold**=increase Plain=decrease
M22-S1.05	Stormwater Input (H), Wetland loss Road Density (E) % Urban (E)	Depositional Features (H) Bank Erosion (M)	**Straightening (E)** **Encroachment (H)** Constrictions	**Armoring (M)** Reduced riparian vegetation (M)
M22-S1.06 (Pond)				
M22-S1.07	Wetland loss Road Density (M) % Urban (E)	Historic Degradation, Depositional Features (M)	Constrictions	Reduced riparian vegetation (M)
M22-S1.08 A		Depositional Features (H) Bank Erosion (M)	**Head Cuts**	
M22-S1.08 B			Grade Controls	
Moderate High Extreme				

Table 5. Mussey Brook Hydrologic and Sediment Load Stressors

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	Hydrologic	Sediment load	Stream Power **Bold**=increase Plain=decrease	Boundary Resistance **Bold**=increase Plain=decrease
M22-S1.01-S1.01 A	Stormwater Input (H) Wetland loss Road Density (E) % Urban (E)	Depositional Features (H) Bank Erosion (M)	**Straightening (E)** **Encroachment (H)** Constrictions	**Armoring (M)** Reduced riparian vegetation (H)
M22-S1.01-S1.01 B	Stormwater Input (H) Wetland loss Road Density (E) % Urban (E)	Bank Erosion (H)	**Straightening (E)** **Encroachment (H)**	Reduced riparian vegetation (H)
M22-S1.01-S1.01 C	Stormwater Input (H) Wetland loss Road Density (E) % Urban (E)	Depositional Features (H) Bank Erosion (M)	**Straightening (E)** **Encroachment (H)** Constrictions Grade Controls	Reduced riparian vegetation (H)

Table 5. Mussey Brook Hydrologic and Sediment Load Stressors				
Watershed Input Stressors			Reach Modification Stressors	
River Segment	Hydrologic	Sediment load	Stream Power **Bold**=increase Plain=decrease	Boundary Resistance **Bold**=increase Plain=decrease
M22-S1.01-S1.02 A	Wetland loss Road Density (E) % Urban (H)	Bank Erosion (M)		
M22-S1.01-S1.02 B	Wetland loss Road Density (E) % Urban (H)	Historic Degradation, Depositional Features (H) Bank Erosion (H)		
M22-S1.01-S1.03	Stormwater Input (M) Wetland loss Road Density (M) % Urban (H)	Historic Degradation, Depositional Features (H)	**Straightening (E)** **Encroachment (H)** Constrictions Grade Controls	**Armoring (M)** Reduced riparian vegetation (H)
M22-S1.01-S1.04 A	Wetland loss Road Density (M) % Urban (H)			Reduced riparian vegetation (M)
M22-S1.01-S1.04 B	Wetland loss Road Density (M) % Urban (H)	Depositional Features (H) Bank Erosion (M)	**Straightening (E)** Constrictions	Reduced riparian vegetation (M)
M22-S1.01-S1.04 C	Road Density (M) % Urban (H)	Depositional Features (H)	Grade Controls	Reduced riparian vegetation (M)
M22-S1.01-S1.04 D	Road Density (M) % Urban (H)	Depositional Features (H)	Constrictions	Reduced riparian vegetation (M)
M22-S1.01-S1.05 (Pond)				
M22-S1.01-S1.06	Wetland loss Road Density (H) % Urban (H)	Depositional Features (M)	**Straightening (E)** **Encroachment (H)**	Reduced riparian vegetation (H)
M22-S1.01-S1.07 A	% Urban (H)	Depositional Features (H)	Head Cuts	**Armoring (M)** Reduced riparian vegetation (M)
M22-S1.01-S1.07 B	% Urban (H)	Depositional Features (H) Bank Erosion (M)	Grade Controls	Reduced riparian vegetation (M)
M22-S1.01-S1.07 C	Stormwater Input (M) % Urban (H)	Depositional Features (H) Bank Erosion (M)	Constrictions	Reduced riparian vegetation (M)

Table 5. Mussey Brook Hydrologic and Sediment Load Stressors				
Watershed Input Stressors			Reach Modification Stressors	
River Segment	Hydrologic	Sediment load	Stream Power **Bold**=increase Plain=decrease	Boundary Resistance **Bold**=increase Plain=decrease
M22-S1.01-S1.07 D	% Urban (H)	Bank Erosion (M)		Reduced riparian vegetation (M)
Moderate High Extreme				

6.1.4 Channel Slope Modifiers

Results from the Moon Brook watershed indicate that primary stressors include extensive straightening of the channel along with road and development encroachments (see Channel Slope Modifiers map on page 2 of Appendix I). Since the Moon Brook watershed is so small (<10 square miles), there are no records at the Vermont Agency of Natural Resources regarding dredging of the channel. Likewise, no existing data indicates that dredging has occurred within the stream network of concern in this study. However, where the channel showed that it had been straightened, it is likely that some dredging may have occurred during the straightening process.

6.1.5 Boundary Conditions and Riparian Modifiers

Riparian buffers provide many benefits. Some of these benefits are protecting and enhancing water quality, providing fish and wildlife habitat, providing streamside shading, and providing root structure to prevent bank erosion. Seven of the stream reaches had 75 percent or more of the reach with little or no buffer on at least one bank. The data for the locations indicated as having little to no buffer on the Boundary Conditions and Riparian Modifiers map (Page 3 of Appendix I) were indexed by the ANR based on NAIP photos. These stream reaches which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion. Due to the highly urbanized setting of much of the Moon Brook watershed and the consequent loss of natural riparian buffer, many stream banks are stabilized with rip rap or hard bank armoring where they are adjacent to human constructed infrastructure.

6.1.6 Constraints to Sediment Transport and Attenuation

Successful river corridor restoration and protection projects depend on a thorough understanding of the sources, volumes, and attenuation of flood flows and sediment loads within the stream network. If increased loads are transported through the network to a sensitive reach, where conflicts with human investments are creating a management expectation, little success can be expected unless the restoration design accommodates the increased load or finds a way to attenuate the loads upstream (Vermont Agency of Natural Resources, 2007c).

Within a reach, the principles of stream equilibrium dictate that stream power and sediment will tend to distribute evenly over time (Leopold, 1994). Changes or modifications to watershed inputs and hydraulic geometry create disequilibrium and lead to an uneven distribution of power and sediment. Large channel adjustments observed as dramatic erosion and deposition may be the result of this uneven distribution and may continue.

The sediment regime departure map (Figure 10) shows the Phase 1 reference stream sediment conditions for each reach within the stream network. These reference type streams use available floodplain access as a means to store sediment within the watershed. The majority of the stream network has a reference sediment regime of a *Coarse Equilibrium (in=out) & Fine Deposition*. The uppermost reaches of both Moon and Mussey Brooks are *Transport* reaches by reference.

Changes in hydrology (primarily development and urbanization of the riparian corridor) and sediment storage within the watershed have altered the reference sediment regime types for some reach segments. Some segments that were *Coarse Equilibrium (in=out) & Fine Deposition* type segments by reference have been converted to *Fine Source and Transport & Coarse Deposition* sediment regimes based on the Phase 2 Stream Geomorphic Assessment data. This means that most fine sediment entering the stream is either being transported through without being deposited as a result of channel incision and reduced floodplain access. Additionally coarse sediment storage is increased due to increased load along with lower transport capacity. One segment (M22-S1.01-S1.02-B) that was *Coarse Equilibrium (in=out) & Fine Deposition* by reference has been converted to a *Confined Source and Transport* sediment regime due to increased transport capacity derived from the gradient and/or entrenchment of the channel.

All departures were derived from the DMS according to the sediment regime criteria established by the Vermont Agency of Natural Resources (2007c). In cases where the DMS was not able to categorize a segment based upon its attributes (M22-S1.08-A, M22-S1.08-B, M22-S1.01-S1.07-A, M22-S1.01-S1.07-B, and M22-S1.01-C), Bear Creek Environmental used the protocols set forth in the VT ANR River Corridor Guide (2007c) to identify the proper existing sediment regime.

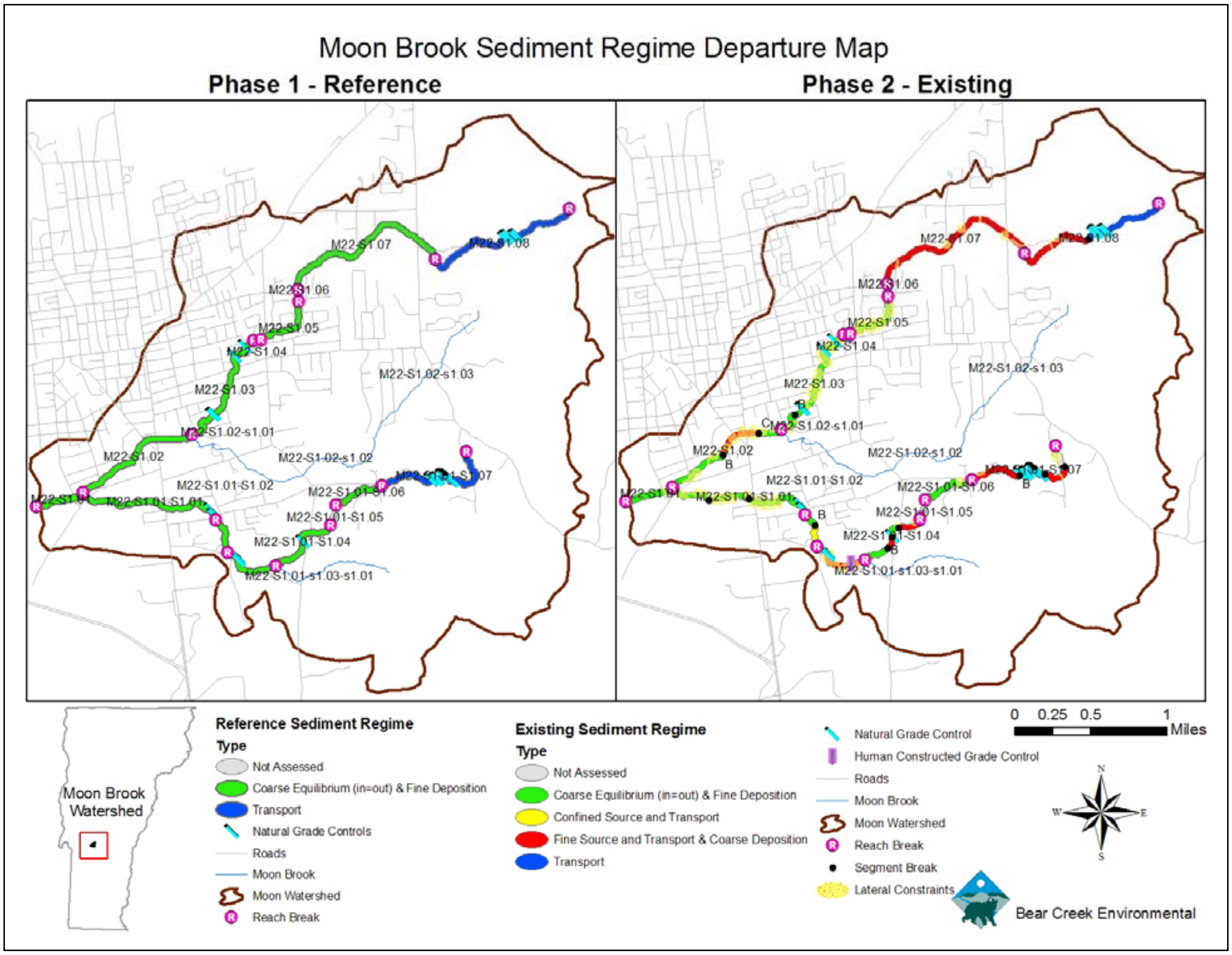


Figure 10. Sediment Regime Departure Map

The existing sediment regime for the Moon Brook watershed includes reduced floodplain access, increased stream power, reduced boundary resistance, and lateral constraints at various locations throughout the stream network. 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, 2007c). Segments and reaches of the Moon Brook watershed that can act as attenuation assets are identified below to help in designing stream corridor protection and restoration projects within the stream network. These segments include:

M22-S1.01
M22-S1.02-A
M22-S1.04 (Piedmont Pond)
M22-S1.06 (Combination Pond)
M22-S1.07
M22-S1.01-S1.02-A

M22-S1.01-S1.04
M22-S1.01-S1.05 (Onstream Pond)
M22-S1.01-S1.06

6.2 Sensitivity Analysis

Stream sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, such as; floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation (Vermont Agency of Natural Resources, 2007b).

Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the setting characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive (Vermont Agency of Natural Resources, 2007b).

There are many variables that are contributing to the sensitivity of the streams in the Moon Brook watershed. Cohesive bed and bank substrates in many of the "E" type channels of Moon Brook are more resistant to lateral and vertical adjustment and therefore seem to be in reality less sensitive streams. Additionally, bank vegetation and its soil holding roots, help to improve the boundary condition between water and land and have reduced the sensitivity of sections of Moon and Mussey Brook that are well buffered. Removal of this vegetation tends to make stream segments more sensitive to channel adjustment.

The location and slope of a stream also affects is morphology and sensitivity. Streams that are transporting sediment through the channel are less sensitive than streams that are storing and responding to sediment. Low gradient streams, like many in the Moon Brook watershed, with high sediment supplies are very sensitive and may undergo adjustment following minor changes in channel geometry or boundary conditions.

Additionally, flow regime and floodplain constrictions may be affecting the sensitivity of Moon Brook streams. Changes in land use and land cover that increase impervious cover, peak discharges, and/or the frequency of high flows will heighten a stream's sensitivity to change and adjustment. Confinement becomes a significant sensitivity concern when structures such as roads, railroads, and berms significantly change the confinement ratio, reduce or restrict a stream's access to floodplain, and result in higher stream power during flood stage. Figure 11 is a map presenting the stream sensitivity, generalized according to stream type and condition as per the ANR protocol, and current adjustments for each reach segment in the Moon Brook watershed. The stream sensitivity map also documents vertical channel adjustments currently going on within a reach segment. Major degradation or aggradation adjustment processes are displayed on the corridor where they were found to be actively occurring and not evaluated as historic. This information is helpful in prioritizing the implementation of the projects identified in section 7 of this report, as certain management actions may be influenced by these active adjustment processes. Current vertical channel adjustments exist in the following reaches:

Segment ID	Current Major Adjustment Process
M22-S1.01	Aggradation
M22-S1.08-A	Degradation
M22-S1.01-S1.01-A	Aggradation
M22-S1.01-S1.01-B	Aggradation
M22-S1.01-S1.01-C	Aggradation
M22-S1.01-S1.07	Degradation

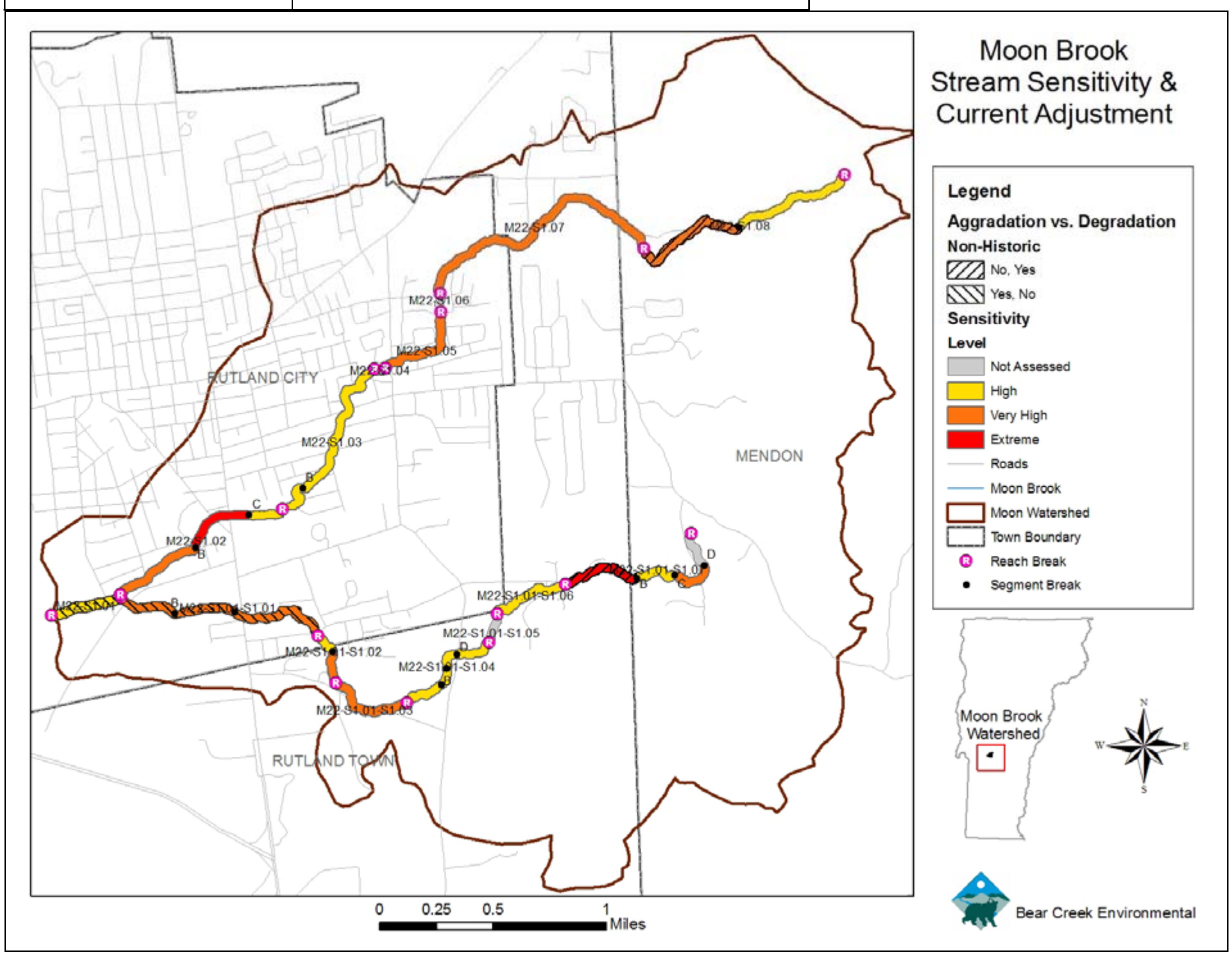


Figure 11. Moon Brook Watershed Stream Sensitivity and Current Adjustment

7.0 PRELIMINARY PROJECT IDENTIFICATION AND PRIORITIZATION

The departure and sensitivity analyses presented in Section 6.0 of this report provide beneficial background for selecting potential projects that will effectively help the channel return to equilibrium conditions by assessing limiting factors and by identifying underlying causes of channel instability. 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 when stream conditions are generally good and nearing a state of dynamic equilibrium. Typically, conservation is applied to minimally disturbed stream reaches where river structure and function and vegetation associations are relatively intact.

7.1 Watershed-Level Opportunities

Fluvial Erosion Hazard Zones

Of all types of natural hazards experienced in Vermont, flash flooding represents the most frequent disaster mode and has resulted in by far the greatest magnitude of damage suffered by private property and public infrastructure. While inundation-related flood loss is a significant component of flood disasters, the predominant mode of damage is associated with the dynamic, and oftentimes catastrophic, physical adjustment of stream channel dimensions and location during storm events due to bed and bank erosion, debris and ice jams, structural failures, flow diversion, or flow modification by man-made structures. These channel adjustments and their devastating consequences have frequently been documented wherein such adjustments are related to historic channel management activities, floodplain encroachments, adjacent land use practices and/or changes to watershed hydrology associated with land use and drainage.

The purpose of defining Fluvial Erosion Hazard Zones is to prevent increases in fluvial erosion resulting from uncontrolled development in identified fluvial erosion hazard areas;

minimize property loss and damage due to fluvial erosion; prohibit land uses and development in fluvial erosion hazard areas that pose a danger to health and safety; and discourage the development of property that is unsuited for the intended purposes due to fluvial erosion hazards.

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, defined through VTANR Stream Geomorphic Assessment (2007b), 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. Figure 12 displays the Draft Fluvial Erosion Hazards Zones for the Moon Brook watershed.

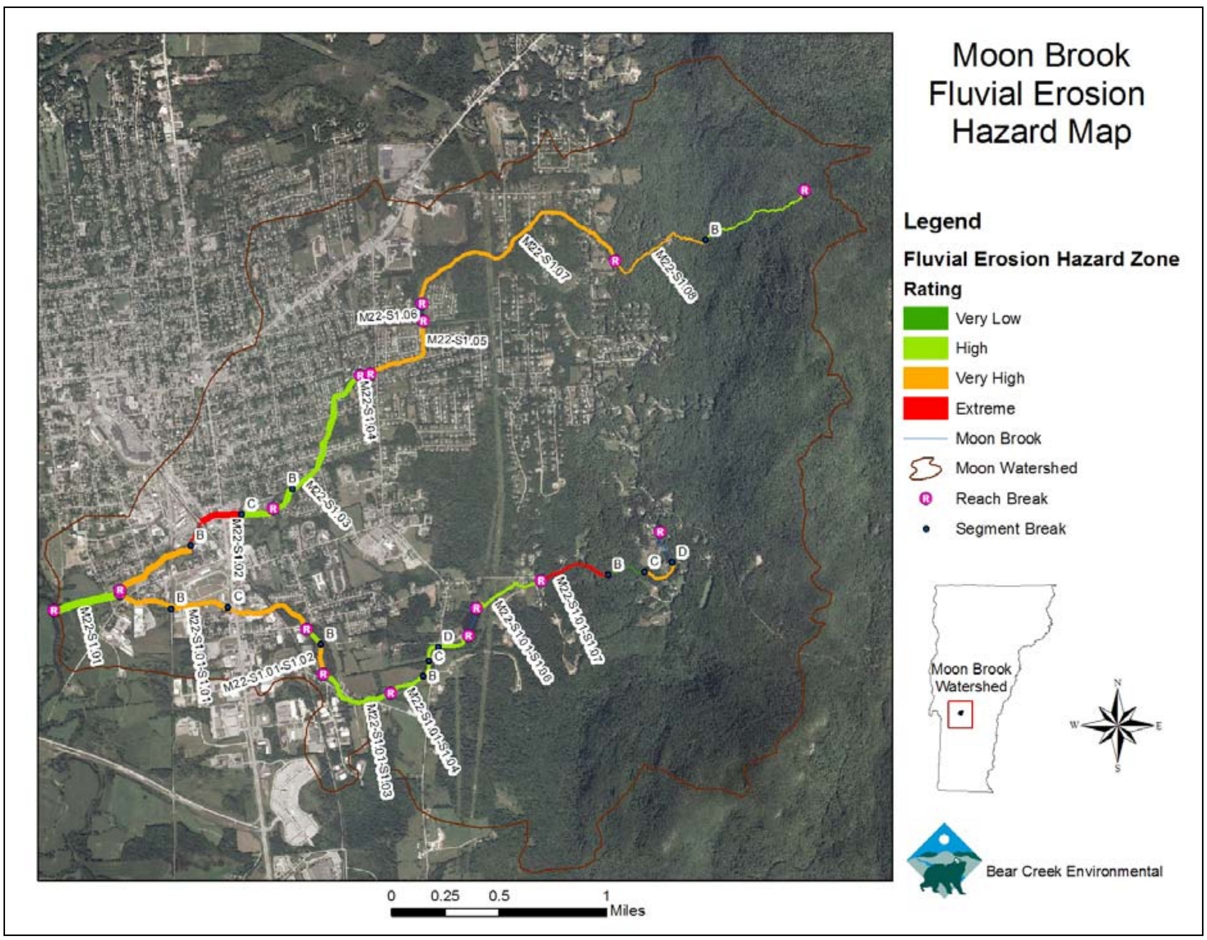


Figure 12. Draft Fluvial Erosion Hazard Zones for the Moon Brook Watershed

Stormwater

Stormwater runoff rates are of particular concern in highly urbanized 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. Moon Brook from its mouth to river mile 2.3 is currently listed as an impaired waterbody, wherein it does not meet the Vermont Water Quality Standards. Its status as "impaired" is primarily due to urban stormwater runoff, erosion, and land development (Vermont Department of Environmental Conservation, 2006).

7.2 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 are listed from downstream to upstream on Moon Brook and then downstream to upstream on Mussey Brook.

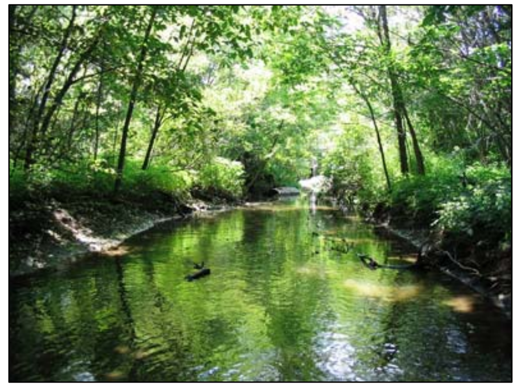
MOON BROOK

Reach M22-S1.01
1- Protect River Corridor
2- Improve Riparian Buffer

Reach M22-S1.01 is the most downstream reach on Moon Brook and drains a watershed area of 8.74 square miles. It begins at the confluence with the Otter Creek and continues upstream to the confluence with Mussey Brook. This reach is an "E" type channel with a ripple-dune bedform.

Riparian conditions on the banks of this reach have been influenced by agricultural practices which have removed much of the riparian buffer leaving only 5-25 feet on each side. Orthophotographs and a local landowner have confirmed that this reach had historically been extensively straightened. The reach, however, does not appear to have incised. This may be due to one or a combination factors including; cohesive substrates on the bed and banks, increased sedimentation from upstream that have continued to fill in the channel, and/or grade control provided by the concrete footing of the Forest Street Bridge. The reach is currently undergoing some minor planform adjustment, evident by minor bank erosion on the outside bends.

Segment M22-S1.02-A
1. Protect River Corridor



Segment M22-S1.02-A begins just above the confluence with Mussey Brook. This segment is an "E" channel that has undergone historic degradation, perhaps as a result of a head cut that began in the straightened reach M22-S1.01 below (prior to the concrete footing grade control of the Forest Street Bridge). The reach has rebuilt a small floodplain at a lower elevation and is approaching stage V of the channel evolution model. The segment has a relatively healthy riparian buffer (51-100 feet) through which to dissipate floodwaters and build meanders.

Segment M22-S1.02-B
1-Replace Undersized Culverts

Segment M22-S1.02-B runs through the Route 7 corridor of Rutland City. It is an "E" type channel by reference, however, due to floodplain encroachment (there is quite a bit of fill, development, and retaining walls on both sides of the streambank) and historic channelization, this segment is now an entrenched "G" type channel. In addition to floodplain encroachment, there are also several undersized structures that are constricting the channel and disrupting sediment transport within this reach.

<u>Segment M22-S1.02-C</u>
1-Protect River Corridor

Segment M22-S1.02-C is located between downtown Rutland and White's Pool. Although the stream corridor is still heavily developed, it is not incised like segment B and therefore has remained an "E" type channel with access to its floodplain. The reach has been impacted by riparian vegetation removal, however, overall is in good geomorphic condition.

Segment M22-S1.03-A
1. Protect River Corridor

This segment is a moderately sinuous "E" type channel with a healthy riparian buffer that has only slightly been influenced by development in the river corridor. The segment has no bank revetments and the dense vegetation has kept bank erosion to a minimal.

Segment M22-S1.03-B
1. Improve Riparian Buffer

Segment M22-S1.03-B is a slightly widened segment of Moon Brook that is an "E" channel with a riffle-pool bedform. Over half of this reach has development in the river corridor. In some instances, the naturally steep banks of the "E" channel have been sloped back and the riparian vegetation has been removed.

The re-establishment of buffer vegetation would be particularly valuable for reducing water temperatures downstream of Piedmont Pond. Some historic channel straightening was also noted in this segment. Additionally, a small tributary, Paint Mine Brook, enters half-way through this reach. According to field data collected by the ANR Stormwater Section, this tributary had been historically dredged during the development of the area and has become very incised (Pease, 2006). Inputs of sediment from this incision may have affected Moon Brook.

M22-S1.03-B is exhibiting minor adjustment. Planform adjustment, in particular, is indicated by the moderate amounts of bank erosion and bank revetments found in this segment. Even with the influence of development, M22-S1.03-B generally has good floodplain access throughout much of this segment.

Reach M22-S1.04 (Piedmont Pond)
1. **Modify Onstream Pond**
2. **Improve Riparian Buffers**

Piedmont Pond is a small onstream pond located in a residential section within the Moon Brook watershed. The onstream pond is contributing to elevated water temperatures in Moon Brook. An alternatives analysis could be completed to determine the best option for reducing water temperatures, allowing for sediment transport and aquatic organism movement. A complete sediment and hydraulic analysis of downstream impacts would be necessary to assess possible impacts to downstream landowners.

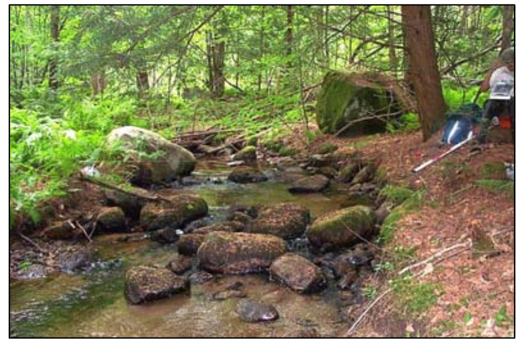
Reach M22-S1.05
1. **Improve Riparian Buffers**
2. **Improve Floodplain Access**

This reach starts at Piedmont Pond and continues upstream to Combination Pond, a large impoundment that is known to be affecting sediment transport and thermally impacting Moon Brook. Reach M22-S1.05 is a somewhat entrenched "E" type channel. In areas where floodplain development and/or straightening have occurred, the stream has undergone incision and widening and appears more as a "C" type channel, but rapidly becomes an "E" channel again where it has floodplain access, streamside vegetation, and sinuosity have been preserved. There are isolated areas within this reach where floodplain access is limited due to historic and recent floodplain encroachments. These areas with floodplain encroachment were noted to be more incised and were associated with higher rates of bank erosion. The riparian buffer of this reach has been largely disturbed and averages between 5 and 25 feet wide. There are both moderate amounts of erosion and riprap along the reach indicating active planform adjustment and widening. Overall the reach appears to be in fair to good geomorphic condition and would benefit from improved floodplain access and the reestablishment of a healthy riparian buffer.

Reach M22-S1.06 (Combination Pond)
1. **Modify Onstream Pond**
2. **Improve Riparian Buffers**

Combination Pond is a large onstream pond that has been documented to significantly elevate the water temperature of Moon Brook. An alternatives analysis could be completed to determine the best option for reducing water temperatures, allowing for sediment transport and aquatic organism movement. As with Piedmont Pond, a complete sediment and hydraulic analysis of downstream impacts would be necessary to assess possible impacts to downstream landowners.

Reach M22-S1.07
1. Preserve Riparian Buffer



Reach M22-S1.07 begins upstream of Combination Pond and continues until a small on-stream pond located off of Birch Road. It travels much of its length through a wetland system and a mature pine forest. The channel is dominated by gravels with a slope of 3.2%. There is some evidence of historic incision through this reach; however, the most active adjustment processes are channel widening and aggradation of sediment in the channel. Multiple mid-channel bars, islands, and channel avulsions indicate active planform adjustment as well within this reach.

Segment M22-S1.08-A
1. **Arrest Headcuts**
2. **Improve Riparian Buffer**

Segment M22-S1.08-A begins upstream of a private on-stream pond and continues for approximately 3000 feet until a major change in slope occurs in the watershed. This lower segment is an "E" type channel with a healthy riparian buffer; however, some floodplain development has occurred. The stream is actively incising through several large head cuts which have an unidentified origin. Continued headcutting and incision

through the reach will be followed by channel widening and planform adjustments as the stream works to redevelop a floodplain at a lower elevation. Property loss may be a concern for several landowners whose land borders this reach. Sediments from this active erosion will likely be retained by the pond at the end of this reach. The portions of this segment that have not degraded are in good geomorphic condition. These, however, may be affected in the future as the headcuts migrate upstream.

Segment M22-S1.08-B
1. Protect River Corridor

Segment M22-S1.08-B begins at approximately 1100 feet in elevation and continues into the high elevation headwaters of East Mountain. Stream segment M22-S1.08-B is a steep "A" type channel with a healthy riparian forest that appears to have good geomorphic stability.

MUSSEY BROOK

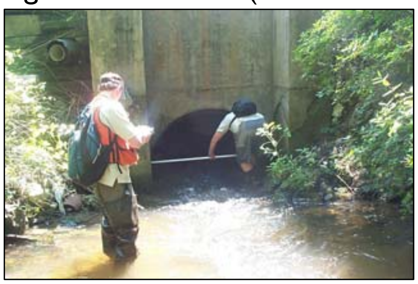
Segment M22-S1.01-S1.01-A
This segment begins at the confluence with Moon Brook and continues upstream to the Rutland railroad tracks. The reach is an "E" type channel with a ripple-dune bedform. Floodplain encroachment has been moderate through this reach.

Segment M22-S1.01-S1.01-B
1. **Replace Undersized Culverts**
2. **Improve Riparian Buffer**

The reach flows through the Rutland Fairgrounds. It begins at the culvert under the Rutland railroad tracks and continues upstream to the cement culvert underneath Route 7. This segment has been greatly altered by floodplain encroachment, floodplain fill, channel straightening, and the disturbance and removal of riparian vegetation. Bank erosion seems to have accelerated through the segment, and the in-stream habitat was the only segment in the entire study area that received a rating of poor.

Segment M22-S1.01-S1.01-C
1. Replace Undersized Culvert

This reach begins at the upstream end of the Fairgrounds and continues upstream to a culvert that lies just above a bedrock waterfall below the former Eddy Pond. The reach is an "E" type channel in "fair" geomorphic condition. It has a significant amount (50% on the right bank) of development within the stream corridor. The reach is actively undergoing planform adjustment and aggrading as it works to regain sinuosity and floodplain access that has been altered by this development. An undersized culvert at Curtis Avenue is contributing to sediment transport problems in this segment.



Segment M22-S1.01-S1.02-A
1. Protect River Corridor

Reach M22-S1.01-S1.02 flows through a wetland that used to be artificially flooded as an outdoor skating rink, formally known as Eddy Pond. This short (500 feet) segment of Mussey Brook flows through a natural wetland that is created by the bedrock constriction at the downstream end. Segment M22-S1.01-S1.02-A has a very low slope, high sinuosity, and very dense riparian vegetation. It is an "E" type channel. This is the only reach in the Moon Brook watershed that received a geomorphic condition rating of "reference".

Segment M22-S1.01-S1.02-B
1. Protect River Corridor

Segment B is also within the area once occupied by a human-made pond. The channel has incised and is in the process of building a new lower floodplain bench through widening and planform adjustment. This segment, with a high width to depth ratio is a currently a "C" type channel, a departure from its reference stream type of "E".

This segment is actively storing sediment though point and side bars and will narrow itself after it has recreated a floodplain. The reach has a healthy riparian forest that will lend to long term stability in this reach.

Reach M22-S1.01-S1.03

Reach M22-S1.01-S1.03 begins upstream of the former Eddy Pond and continues to the confluence with tributary M22-S1.01-S1.03.S1.01. The reach has been significantly altered by floodplain encroachment and historic channel straightening. It is a C-type channel by reference; however, a human caused change in valley width has created a more entrenched "B" type channel through most of this segment. This stream type departure has also occurred in the bedform of the reach, where it has lost its habitat supporting riffle-pool bedform and is instead a plane bed system. Bank erosion appeared low in this reach in part due to the large cobble materials that lined the banks, stone walls, and log revetments that were installed to prevent channel migration and erosion.

Segment M22-S1.01-S1.04-A

1. **Protect River Corridor**
2. **Improve Riparian Buffer**

M22-S1.01-S1.04-A begins at the confluence of a major tributary to Mussey Brook. It is in good geomorphic condition, has a healthy riparian canopy and stable stream channel. The larger riparian corridor, however, is impacted by hay fields. These hayfields have limited the buffer and are only between 5 and 25 feet wide on average.

Segment M22-S1.01-S1.04-B

1. Protect River Corridor

Segment B is a "C" type channel. It has a steeper slope, and has developed a mid-channel bar, a point bar, and several side bars. It too is in good geomorphic condition and does not look to be undergoing any major adjustment process. No photograph is available for this segment.

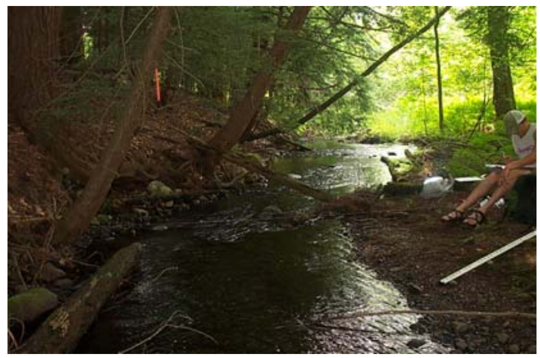
Segment M22-S1.01-S1.04-C

1. Protect River Corridor

In segment C, the reach returns to an "E" type channel through an area that has been historically dammed by beavers. The stream through this reach flows through a healthy riparian corridor with wetland plants along the near bank and conifer and deciduous trees outlying the wetland. This segment is in good geomorphic condition and is not undergoing any major channel adjustment process. No photograph is available for this segment.

Segment M22-S1.01-S1.04-D

1. Protect River Corridor



Segment M22-S1.01-S1.04-D begins at a crossing with Stratton Road and continues upstream to an on-stream pond. This segment is a "C" type channel with a riffle-pool bedform. Sediment storage is occurring in the form of multiple mid-channel, point and side bars. There is some evidence of planform change, including an avulsion and flood chute; however, the reach is only slightly entrenched and appears to have access to its floodplain and the ability to meander as needed. Overall the segment is in good geomorphic condition and with the exception of a few areas has a healthy riparian buffer.

Reach M22-S1.01-S1.05

This reach is an onstream pond on Mussey Brook, and was not assessed during the Phase 2 stream geomorphic assessment.

Reach M22-S1.01-S1.06

1. Improve Riparian Buffers

Mussey Brook reach M22-S1.01-S1.06 begins at the upstream end of an on-stream pond and continues just past a culvert on Dailey Road. Although much of the reach has been historically straightened, it appears to be in stable geomorphic condition and is not undergoing any major adjustments at this time. Future stability might be encouraged by increasing the riparian buffer of this reach, which averages between 5 and 10 feet wide, as well as by allowing it to regain access to its floodplain

by removing berms that line approximately one quarter of the reach. Removing the berms would be difficult due to the encroachments in the corridor. Residents have reported flooding of nearby buildings.

Segment M22-S1.01-S1.07-A
1. Protect River Corridor

The first segment of this reach begins just above the culvert on Dailey Road. It is a "C" channel by reference and is one of the more active reaches in the watershed in terms of adjustment. The largest factor relating to instability has been historic and active incision that has occurred within this segment. The degradation of the bed is coupled with channel widening and planform adjustment as the stream seeks to rebuild a new floodplain at a lower elevation. Segment M22-S1.01-S1.07-A is currently an "F" type channel and will continue to rework its banks and planform as it evolves back into a "C" channel.

Segment M22-S1.01-S1.07-B
1. Protect River Corridor

This reach begins at a ledge approximately 2000 feet from the beginning of the reach. The entire segment is dominated by a bedrock bottom stream that is mostly a cascade and step-pool bedform. It is an "A" type channel and is relatively stable. Bedrock control did not exist on the banks, however, and there exists the potential that the stream may widen or go through planform adjustment. There exists a healthy riparian buffer on both sides of this stream segment that is acting to slow and stabilize geomorphic adjustment processes as well as provide healthy habitat and shade to Mussey Brook.

Segment M22-S1.01-S1.07-C
1. Protect River Corridor

Segment M22-S1.01-S1.07-C is the highest reach surveyed by the Phase 2 team on Mussey Brook. It begins several hundred feet downstream of South Mendon Road where the bedrock control ends and continues to an on-stream pond that is upstream of South Mendon

Road. This reach is a "C" type channel with a riffle-pool bedform. The Phase 2 assessment of this reach noted some minor signs of degradation, aggradation, widening, and planform adjustment. The reach has a healthy riparian buffer and floodplain access.

7.3 Site Level Opportunities

Site specific projects were identified using the criteria outlined by the ANR in Chapter 6 Preliminary Project Identification and Prioritization (Vermont Agency of Natural Resources, 2007c). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium. The site level projects that were developed for Moon Brook and Mussey Brook are provided below in Tables 6 and 7. The project strategy, technical feasibility, and priority for each project are listed by project number and reach.

Maps of the ten high priority project sites are found in Appendix 2. These high priority projects include river corridor protection projects to provide attenuation of sediment and floodwaters. River corridor protection projects have been identified at the lower end of Moon Brook, on Moon Brook between the confluence of Mussey Brook and Scale Avenue, on Moon Brook between Brightview Avenue and Wesley Avenue, and on Mussey Brook near the intersection of Cold River Road and Stratton Road. Buffer restoration to provide bank stability, decrease water temperature and to allow for other important riparian functions is also a goal for all of the proposed river corridor protection projects. An effort to conserve and protect the river corridor and existing buffers is recommended for Moon Brook between Combination Pond and Birch Road. Active head cuts have been identified in the upper Moon Brook watershed upstream of a small onstream pond and downstream of Birch Road. Restoration measures to arrest these active head cuts are recommended. A number of projects have been identified for replacement of undersized or misaligned stream crossings that are disrupting sediment transport. The RNRCD and VANR are looking for riparian landowners who are interested in implementing these important projects.

7.4 Next Steps

The river corridor planning team, in cooperation with local landowners and community members, has identified twenty-two potential protection and restoration projects that could successfully restore portions of the Moon Brook watershed. These potential projects have been identified as high, moderate or low priority based on their effectiveness and feasibility.

The project partners, in collaboration with the local community members, will work together to evaluate further at least one of the identified reach-level restoration or protection efforts. The project selected for further evaluation will be chosen based on land use constraints, support, restoration and protection activities required, cost estimates, regulatory requirements and landowner cooperation. The results of this effort will be presented in a Project Development Status Report, to be submitted to the ANR.

Table 6. Moon Brook Site Level Opportunities for Restoration and Protection								
Project #, Reach	**Condition and Channel Evolution Stage**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#1 M22-S1.01	Good, DIIC	Riparian banks influenced by agricultural practices; historically straightened	Protect River Corridor to allow for planform adjustment or consider placing stream back in former channel	High priority	Flood and sediment attenuation asset; habitat improvement	Cost of river corridor easement acquisition and possibly alternatives analysis	Hay to forested	CREP, ANR, VRC, RNRCD
#2 M22-S1.01	Good, DIIC	Farmer does not want trees falling into channel and creating planform adjustment	Plant stream buffer	Low priority	Prevent erosion and reduce water temperature	Cost of trees and shrubs	Hay to forested	CREP, ANR, USFWS, RNRCD
#3 M22-S1.02-A	Fair, FIV	Undergone historic degradation and is rebuilding floodplain at lower elevation, has healthy riparian corridor (51-100 feet); some minor lateral constraints	Protect River Corridor to provide attenuation area	High priority (important location in watershed, but some minor lateral constraints and multiple landowners)	Flood and sediment attenuation asset	Cost of river corridor easement acquisition	Land use conversion may be minimal	ANR, VRC, RNRCD
#4 M22-S1.02-B	Poor, FII	Extreme urbanization and historic channel straightening (Route 7 Corridor)	Replace Undersized structures in Route 7 Corridor	Moderate priority	Possibly reduce flooding	Hydraulic and sediment study to determine feasibility; Cost of culvert replacement	None	Rutland City, ANR
#5 M22-S1.02- C	Good, DIIC	Between downtown Rutland and White's Pool; stream corridor is heavily developed on north side, but channel not incised	Protect River Corridor	Low priority (existing structures on north side of brook)		Cost of river corridor easements	No land conversion would be needed on south side (currently ball fields at White's Playground)	Landowners, RNRCD, Rutland City, ANR
#6 M22-S1.03-A to lower end of M22-S1.03-B	A: Good, F-I B: Good, D-IIc	Relatively undisturbed segment that starts at basketball courts at White's Recreation Center and ends at Wesley Ave; basketball courts and Brightview Ave. within corridor at lower end	Protect River Corridor	High priority	Flood and sediment attenuation asset	Cost of river corridor easements	No additional structures in corridor	Landowners, RNRCD, ANR, VRC

Table 6. Moon Brook Site Level Opportunities for Restoration and Protection								
Project #, Reach	**Condition and Channel Evolution Stage**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#7 M22-S1.03-B	Good, D-IIc	Upstream of Wesley Ave. Moon Brook flows through a residential area where the dominant buffer is less than five feet wide	Improve Riparian Buffer	Low priority (many landowners)	Decreasing water temperatures will improve suitability for trout	Cost of trees and shrubs and design of planting plan	Lawn to vegetated buffer	USFWS, landowners, RNCRC, ANR
#8 M22-S1.04	Not assessed – Piedmont Pond	Onstream pond that is resulting in elevated water temperature	Alternatives Analysis for modifying pond	Low priority (many landowners, not much area around pond)	Decreasing water temperatures will improve suitability for trout	Alternatives Analysis, sediment and hydraulic analysis, meetings with landowners	Dependent upon alternative selected	Landowners, RNRCD, ANR
#9 M22-S1.05	Fair, D-IIC	Between two onstream ponds; dense residential development	Improve Riparian Buffer	Low priority (many landowners)	Decreasing water temperatures will improve suitability for trout	Cost of trees and shrubs and design of planting plan	Lawn to vegetated buffer	USFWS, landowners, RNCRC, ANR
#10 M22-S1.06	Not assessed – Combination Pond	Large onstream pond that is affecting sediment transport and resulting in thermal impacts to Moon Brook	Alternatives Analysis for modifying pond	High priority (onstream pond having large impact on Moon Brook; some area for possible restoration project)	Decrease water temperatures to improve suitability for trout; allow natural migration of aquatic organisms; sediment transport	Alternatives Analysis, sediment and hydraulic analysis, meetings with landowners	Dependent upon alternative selected	Landowners, RNRCD, ANR
#11 M22-S1.07	Fair, F-IV	Between Combination Pond to Town Line Road) Few lateral constraints	Conserve and Protect River Corridor and existing buffer	High priority (few property owners)	Flood and sediment attenuation asset	Cost of river corridor easements	Currently wetland and mature pine forest	Landowners, RNRCD, ANR, VRC
#12 M22-S1.08-A	Fair, F-II	Downstream of Birch Road	Active degradation (headcuts)	High priority to arrest head cuts (few landowners)	Reduce sediment , prevent loss of land	Materials and labor to arrest head cuts	None	Landowners, RNRCD, ANR, YCC
#13 M22-S1.08-B	Good, F-I	High elevation stream with healthy riparian forest	Conserve and Protect River Corridor	Moderate priority	Conservation	Cost of river corridor easements	No additional structures in corridor	Landowners, RNRCD, ANR

Table 7. Mussey Brook Site Level Opportunities for Restoration and Protection

Project #, Reach	Condition and Channel Evolution Stage	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#1 **M22-S1.01-S1.01-B**	Fair, F-III	Channelized section with lack of riparian buffer through Vermont State Fairgrounds; lateral constraints include outbuildings, buildings and driveways	Replace undersized culverts, bridge with alignment problem and reduce number of stream crossings	High priority	Improve sediment transport	Cost of design and replacement of structures	Reduction in number of crossings	Property owner, ANR, RNRCD
#2 **M22-S1.01-S1.01-B**	Fair, F-III	Vermont State Fairgounds (see above)	Plant stream buffer	High priority	Reduce water temperature	Cost of trees and shrubs	Open space to buffer	Property owner, ANR, USFWS, RNRCD
#3 **M22-S1.01-S1.01-C**	Fair, F-III	RR crossing to Curtis Ave.; Mobile home park and a couple of buildings provide some lateral constraints	Protect River Corridor	Moderate priority (small section, but important location in watershed)	Potential flood and sediment attenuation asset	Cost of river corridor easements	No additional structures in corridor	Landowners, RNRCD, ANR, VRC
#4 **M22-S1.01-S1.01-C**	Fair, F-III	Undersized culvert at Curtis Ave. contributing to sediment transport problems	Replace undersized culvert at Curtis Ave.	High priority – causing sediment transport problems	Improved sediment transport and geomorphic stability	Cost of design and replacement of culvert	Not applicable	City of Rutland, ANR, Rutland NRCD
#5 M22-S1.01-S1.02-A &B	A: Reference, F-I B: Fair, F-III	Formally know as Eddy Pond, wetland with dense riparian vegetation, building floodplain in upper segment	Conserve and Protect River Corridor and existing buffer	Low priority (Class II wetland already provides protection)	Flood and sediment attenuation area (wetland); habitat	Cost of river corridor easements	No additional structures in corridor	Rutland City, landowners, ANR, Rutland NRCD, VRC
#6 **M22-S1.01-S1.04**	Good, F-IV	Few lateral constraints in reach; upstream of reach that has been significantly altered by floodplain encroachment	Protect River Corridor	High priority – above reach that is significantly altered by floodplain encroachment	Flood and sediment attenuation area upstream of reach with significant floodplain encroachment	Cost of river corridor easements	No additional structures in corridor	Landowners, RNRCD, ANR, VRC

Table 7. Mussey Brook Site Level Opportunities for Restoration and Protection

Project #, Reach	Condition and Channel Evolution Stage	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#7 M22-S1.01-S1.04-A	Good, F-IV	Narrow buffers due to hayfields	Improve Riparian Buffer	Low priority (channel appears stable and near bank vegetation is dense)	Decreasing water temperatures will improve suitability for trout	Cost of trees and shrubs and design of planting plan	Hay to vegetated buffer	CREP, USFWS, landowners, RNCRC, ANR
#8 M22-S1.01-S1.06	Good, F-III	Starts at upstream end of onstream pond. Much of reach historically straightened	Improve Riparian Buffer and project river corridor	Low priority (multiple landowners; Class II wetland affords some protection)	Decreasing water temperatures will improve suitability for trout and improve geomorphic stability; possible flood and sediment attenuation asses	Cost of trees and shrubs and design of planting plan and /or acquisition of river corridor easements	Lawn to riparian buffer; no additional structures in corridor	Landowners, CREP, RNRCD, ANR, USFWS
#9 M22-S1.01-S1.07	A: Fair, F-III (STD) B: Good, F-I C: Fair, F-III	Reach is in headwaters of Mussey Brook. The lower segment has encroachments in the corridor	River Corridor Protection	Moderate priority (protect headwaters)	Allow channel to adjust in lower segment	Cost of river corridor easements	No additional structures in corridor	Landowners, RNRCD, ANR, VRC

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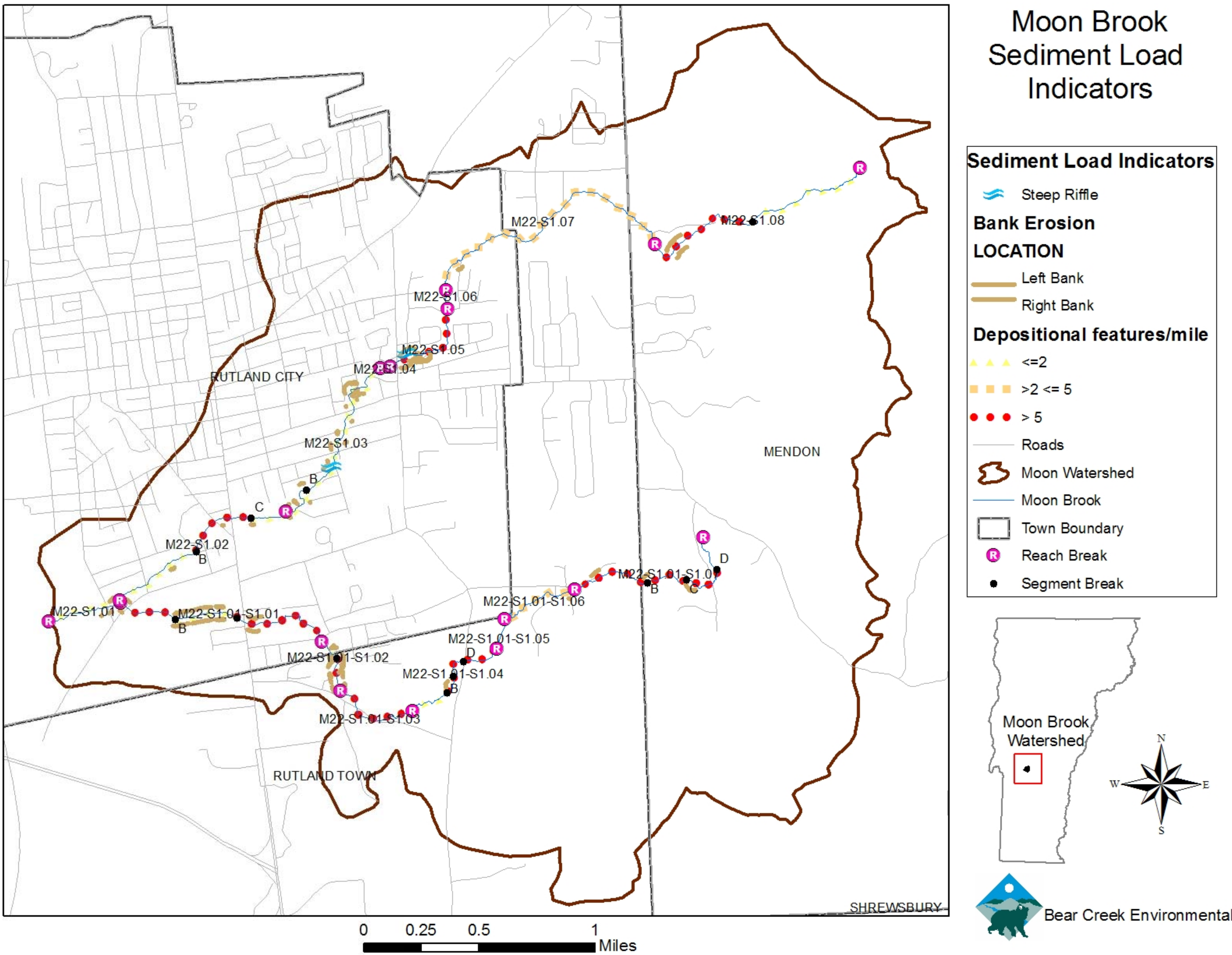
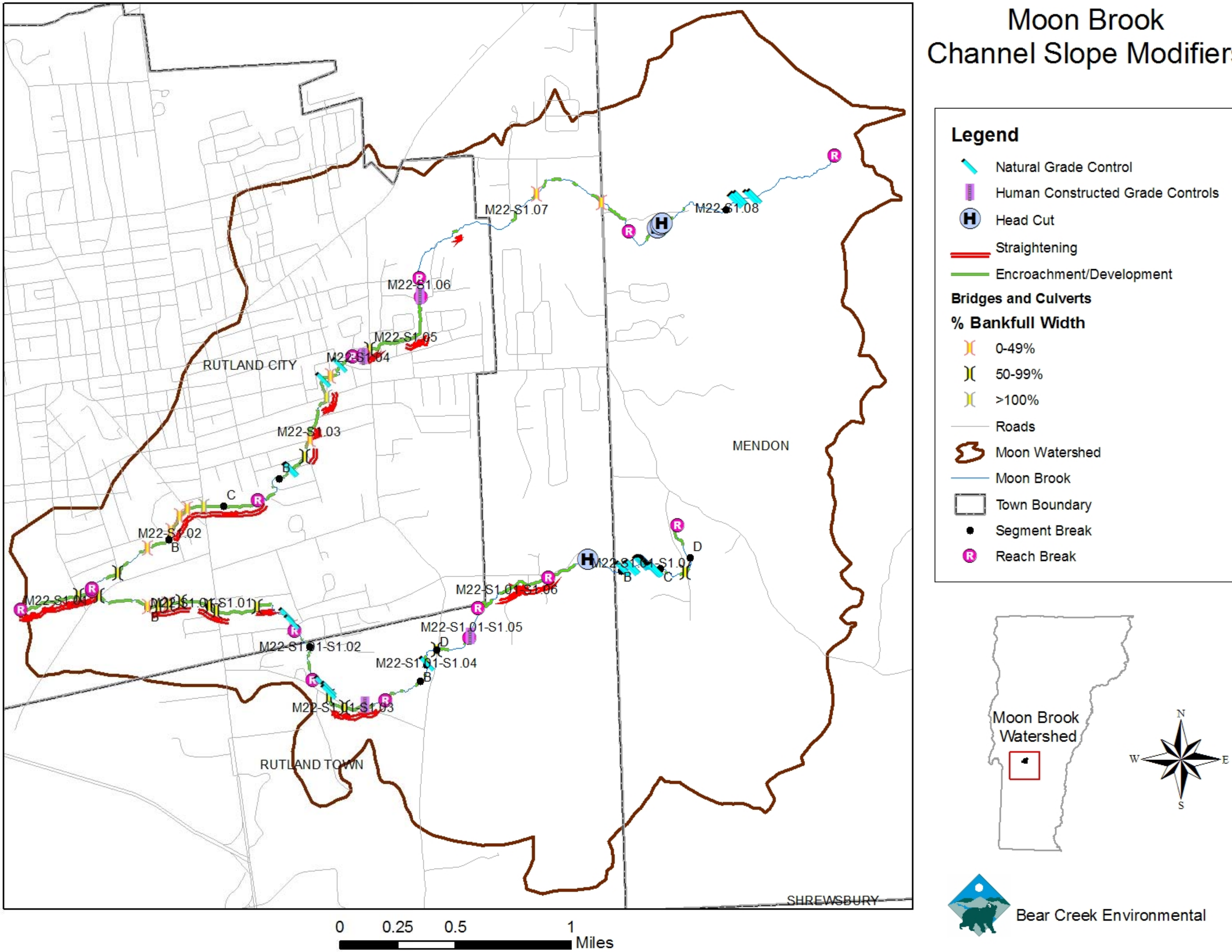
Appendix 1

Stressor Identification Maps

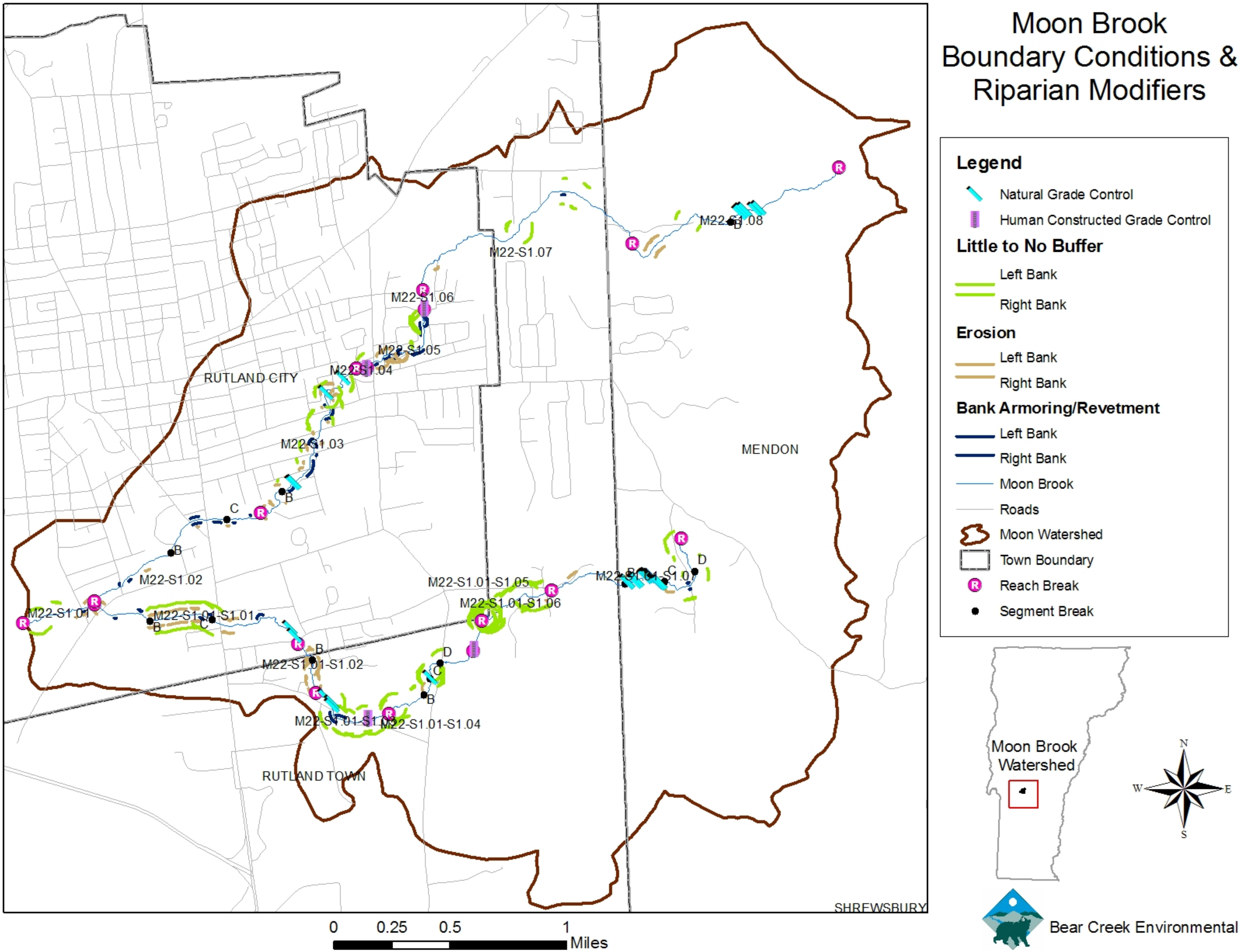


Moon Brook Sediment Load Indicators
Sediment Load Indicators
Steep Riffle
Bank Erosion
LOCATION
Left Bank
Right Bank
Depositional features/mile
<=2
>2 <= 5
> 5
Roads
Moon Watershed
Moon Brook
Town Boundary
Reach Break
Segment Break
RUTLAND CITY
RUTLAND TOWN
MENDON
SHREWSBURY
M22-S1.01
M22-S1.02
M22-S1.03
M22-S1.04
M22-S1.05
M22-S1.06
M22-S1.07
M22-S1.08
M22-S1.01-S1.01
M22-S1.01-S1.02
M22-S1.01-S1.03
M22-S1.01-S1.04
M22-S1.01-S1.05
M22-S1.01-S1.06
M22-S1.01-S1.07
Moon Brook Watershed
N
E
S
W
0
0.25
0.5
1
Miles
Bear Creek Environmental

Moon Brook Channel Slope Modifiers



Moon Brook Boundary Conditions & Riparian Modifiers



Appendix 2

Maps of High Priority Projects

M22-S1.01 Moon Brook Potential Project Location

Legend

- Moon Brook
- Former Channel
- Parcel
- Lateral Constraint
- Railroad
- Road or Driveway
- Building or Parking Area
- River Corridor

Little to No Buffer

- Left Bank
- Right Bank
- Potential Project Location

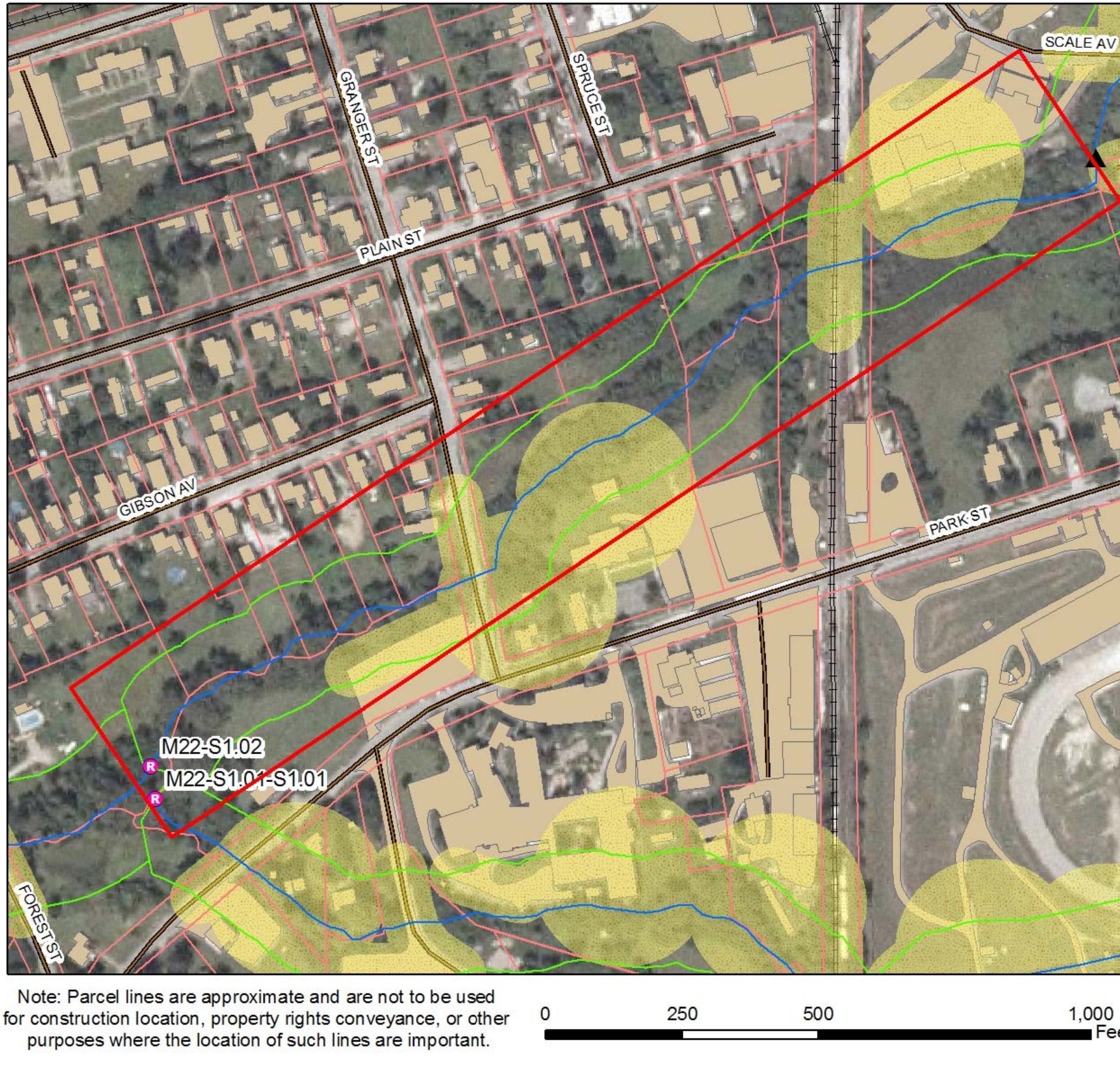
Project Descriptions

1) Protect river corridor to allow for planform adjustment or consider placing stream back in former channel

2) Plant stream buffer

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.02-A Moon Brook Potential Project Location



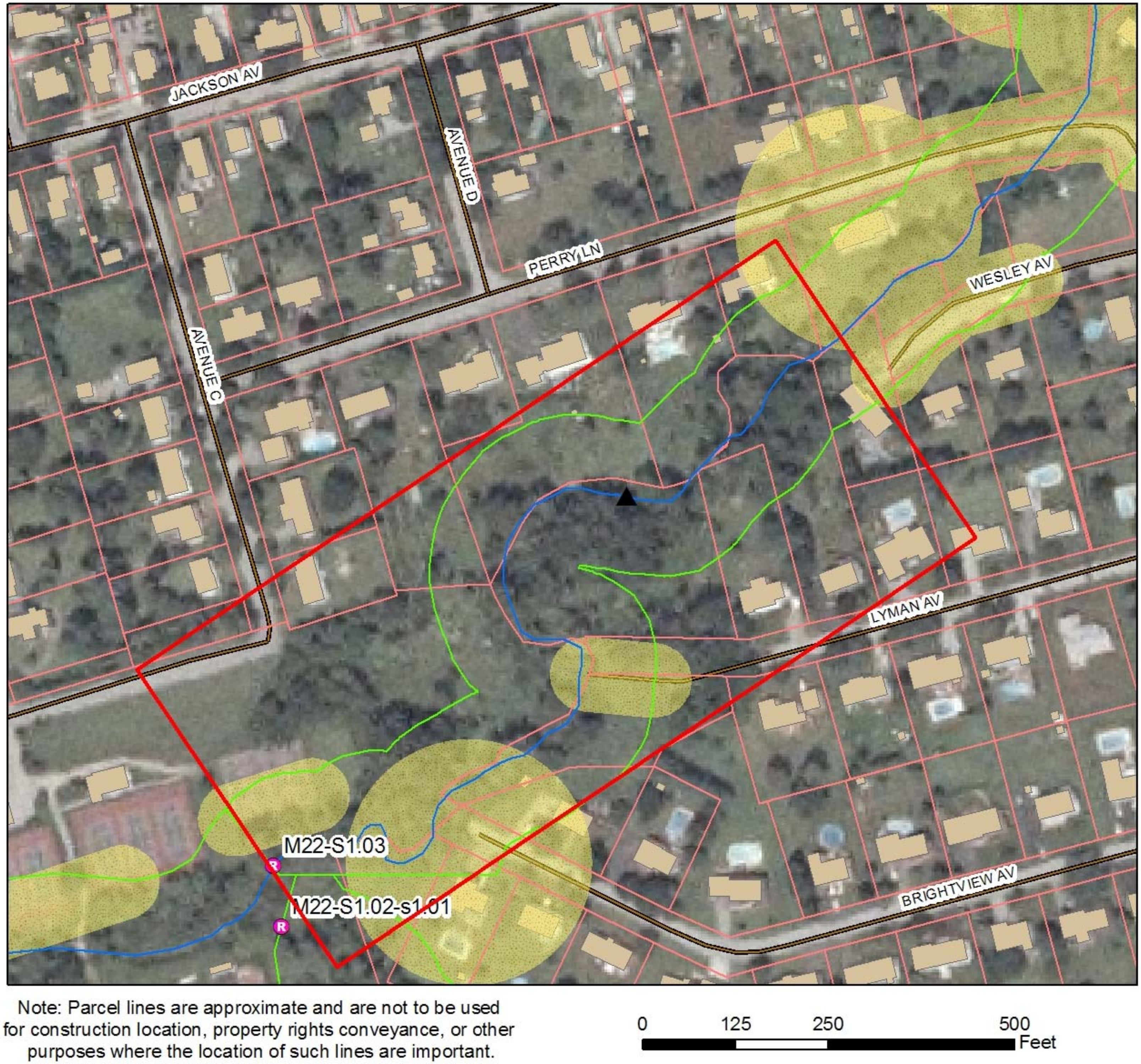
Legend

- Moon Brook
- Railroad
- Road or Driveway
- Building or Parking Area
- Parcels
- Lateral Constraint
- River Corridor
- Segment Break
- EMERGENCY_DW_LINE
- Potential Project Location

Project Description
Protect river corridor to provide attenuation area from start of reach upstream to end of segment M22-S1.02-A

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.03-A Moon Brook Potential Project Location



Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

Legend

- Moon Brook
- Railroad
- Road or Driveway
- Building or Parking Area
- Parcels
- Lateral Constraint
- River Corridor
- Segment Break
- Potential Project Location

Project Description

Protect river corridor to provide attenuation area from start of reach upstream to Wesley Avenue

M22-S1.06 Moon Brook Potential Project Location

Legend

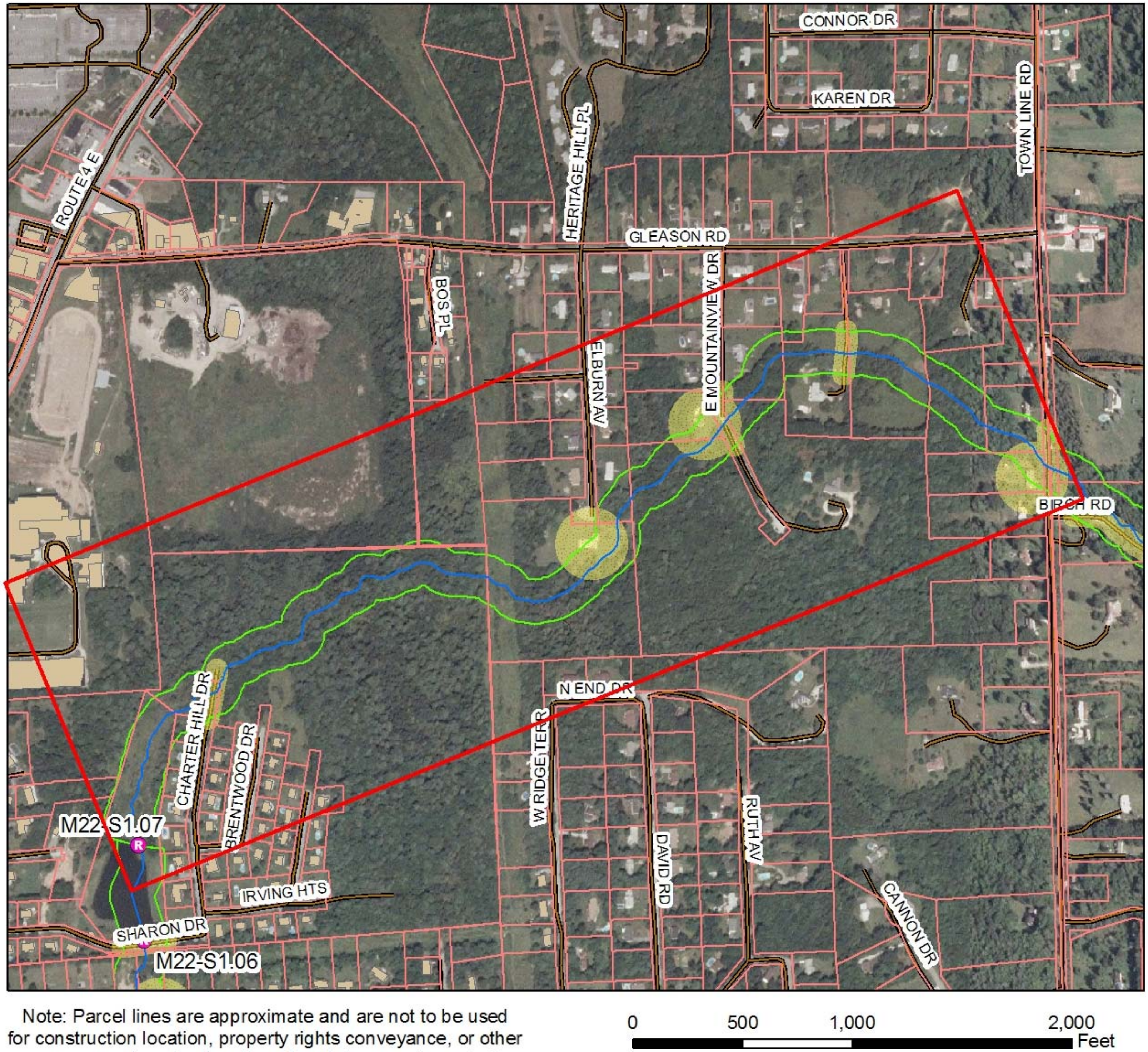
- Moon Brook
- Railroad
- Road or Driveway
- Building or Parking Area
- Lateral Constraint
- Parcels
- River Corridor
- Potential Project Location

Project Description

Alternatives Analysis for modifying Combination Pond (Not assessed)

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.07 Moon Brook Potential Project Location



Legend

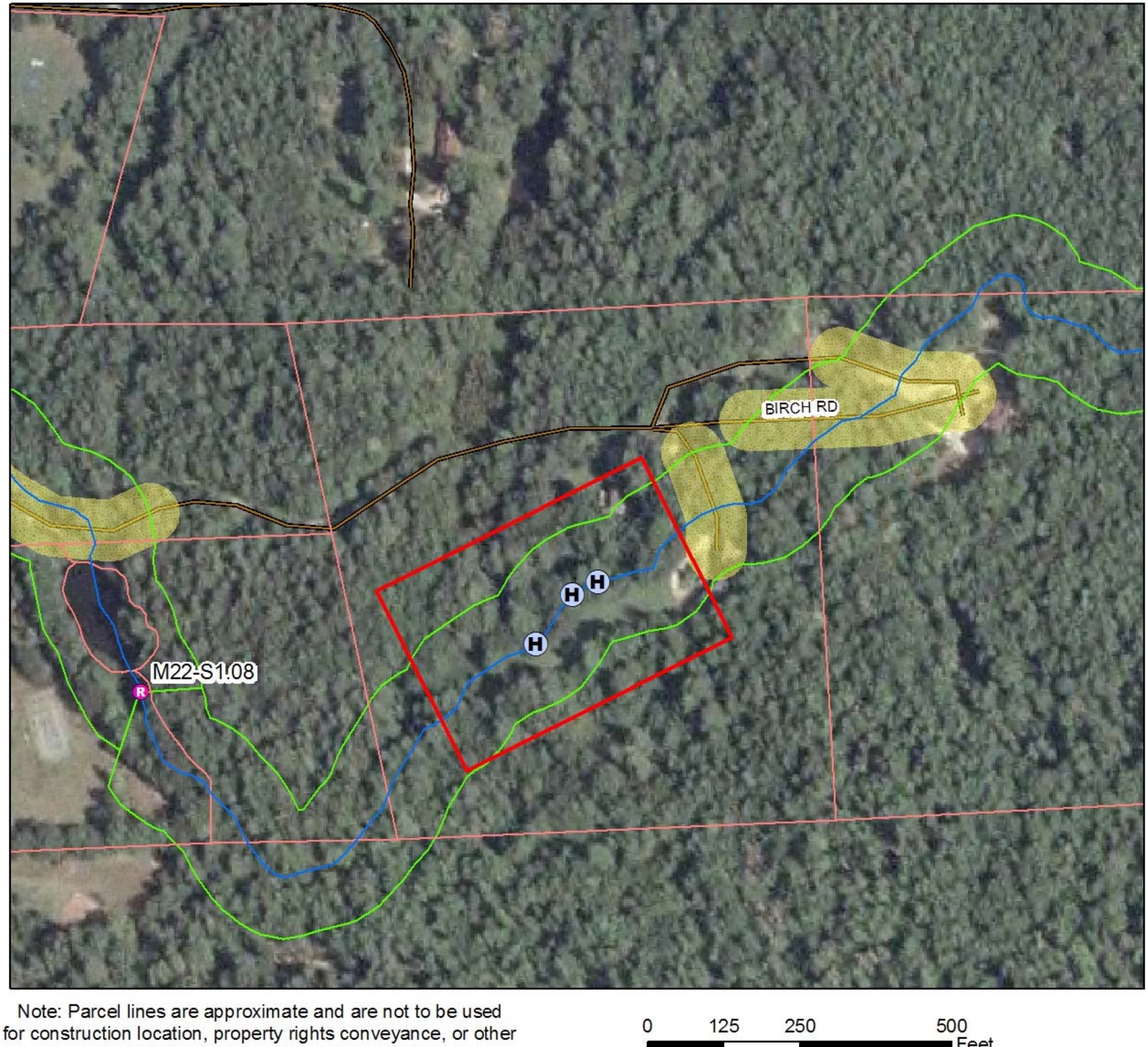
- Moon Brook
- Railroad
- Road or Driveway
- Building or Parking Area
- Lateral Constraint
- River Corridor
- Parcel
- Potential Project Location

Project Description

Conserve and Protect River Corridor and existing buffer from start of reach upstream to Town Line Road

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.08-A Moon Brook Potential Project Location



Legend

- Headcut
- Moon Brook
- Railroad
- Road or Driveway
- Building or Parking Area
- Lateral Constraint
- River Corridor
- Parcels
- Potential Project Location

Project Description

Arrest active headcuts

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.01-S1.01-B Mussey Brook Potential Project Location

Legend

- Moon Brook
- Segment Break
- Railroad
- Road or Driveway
- Building or Parking Area
- Lateral Constraint
- Parcels
- River Corridor

Little to No Buffer

- Left Bank
- Right Bank
- Potential Project Location

Project Descriptions

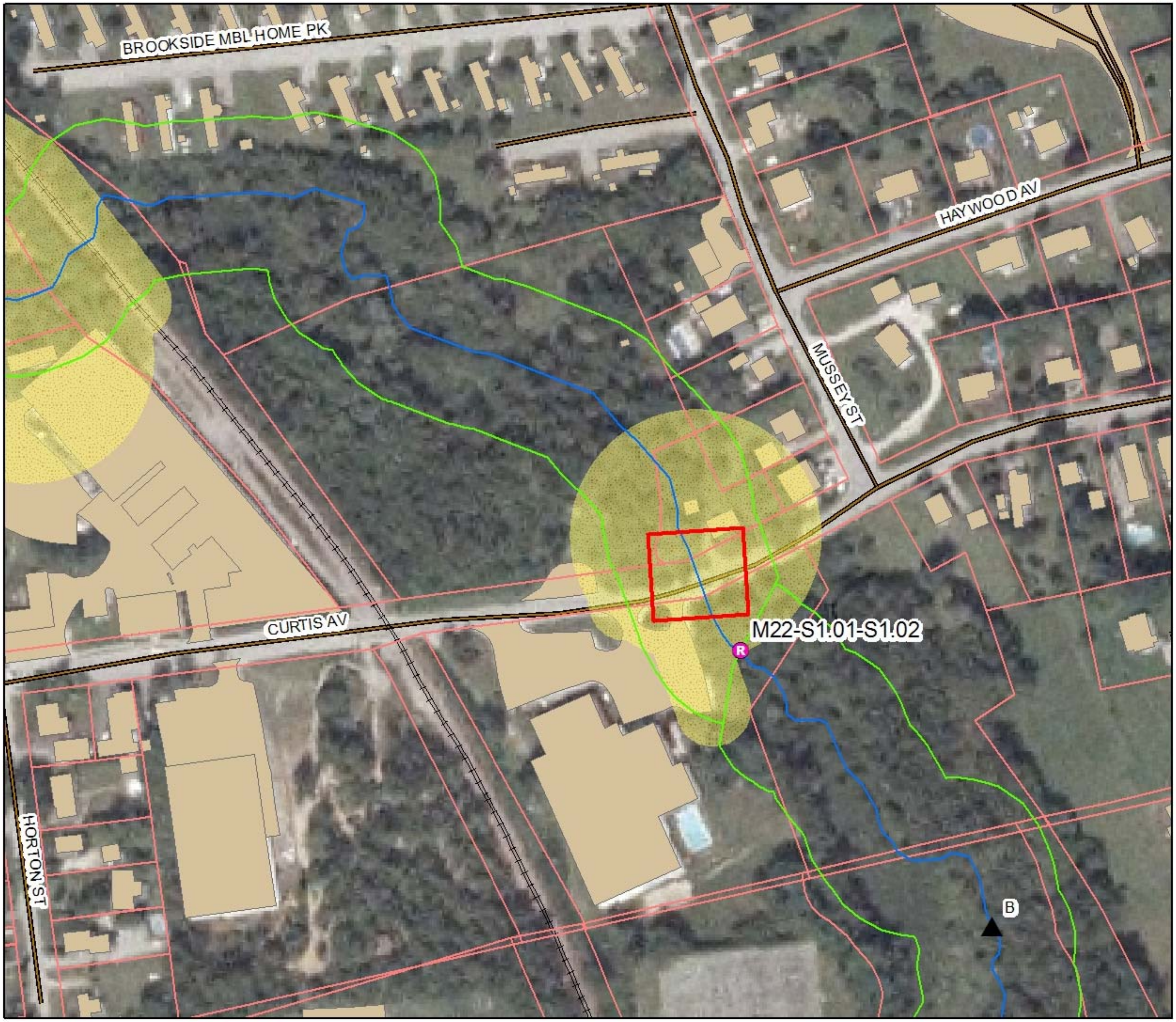
1) Replace undersized culverts, bridge with alignment problem, and reduce number of stream crossings

2) Plant stream buffer

0 250 500 1,000 Feet

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.01-S1.01-C Mussey Brook Potential Project Location



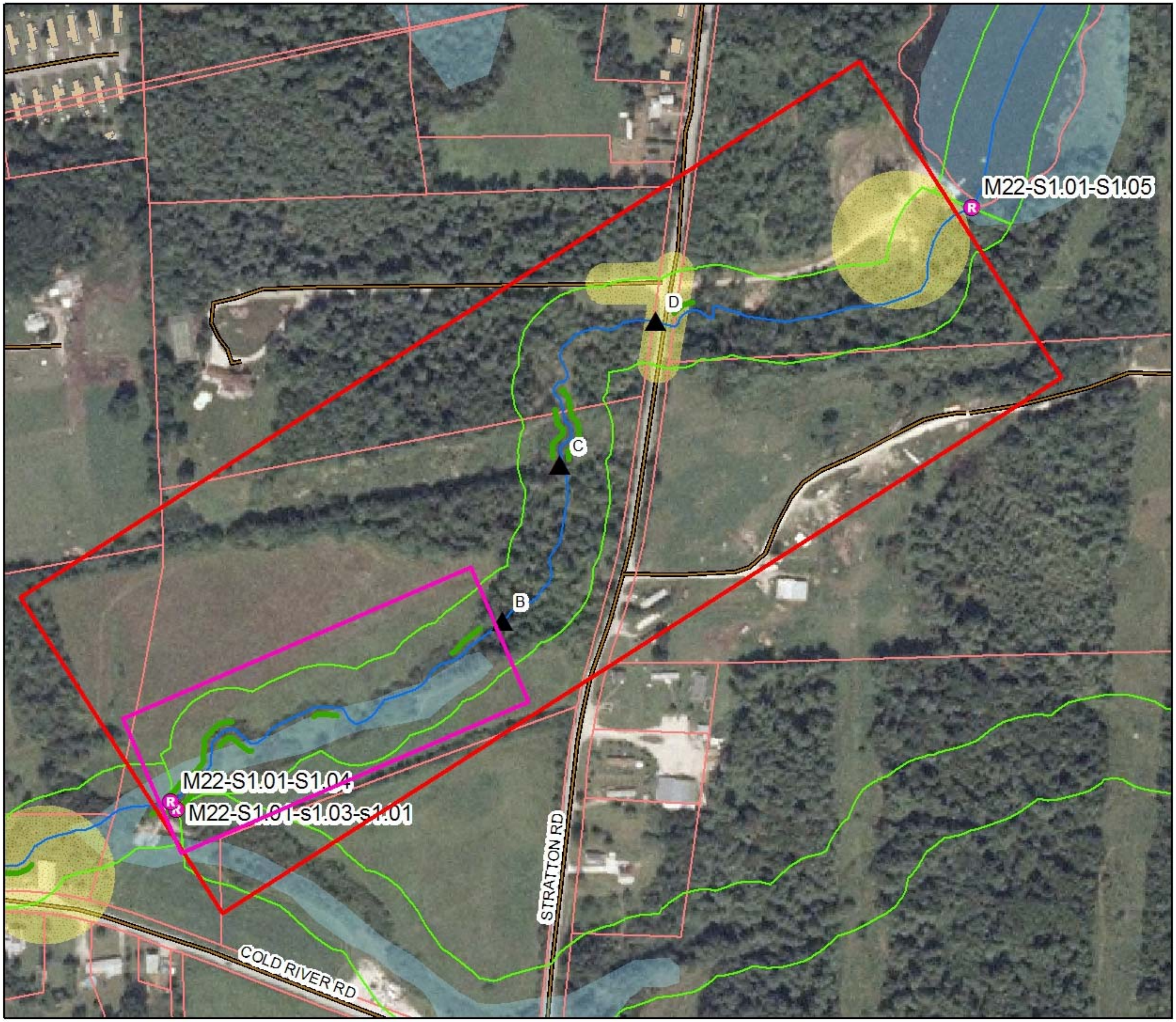
Legend

Project Description

1) Replace undersized culvert at Curtis Ave.

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.

M22-S1.01-S1.04 Mussey Brook Potential Project Location



Legend

- Moon Brook
- Segment Break
- Railroad
- Road or Driveway
- Building or Parking Area
- Wetland (VSWI)
- Lateral Constraint
- Little to No Buffer
- Left Bank
- Right Bank
- Parcels
- River Corridor
- Potential Project Location #1
- Potential Project Location #2

Project Descriptions

1) Protect River Corridor

2) Improve riparian buffer

Note: Parcel lines are approximate and are not to be used for construction location, property rights conveyance, or other purposes where the location of such lines are important.