Browns River Phase I & II Geomorphic Assessment Project

~Cilley Hill Dam in Jericho on Browns River main stem reach M 15~

Final Report Submitted by:

Winooski Natural Resources Conservation District

Project Partners:

Chittenden County Regional Planning Commission
VT Department of Environmental Conservation
VT Department of Fish and Wildlife

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Browns River Geomorphic Assessment

Phase 1 & 2 Project Summary

Watershed planning in Vermont is experiencing rapid and positive change. The most significant is the growing recognition of environmental concerns and the broad acceptance of public participation in decision-making processes. Currently the Agency of Natural Resources (ANR) is actively involved in watershed planning throughout the State through the development of Stream Geomorphic Assessment (SGA) protocols. The Winooski NRCD received two grants from the Lake Champlain Basin Program to undertake a collaborative geomorphic assessment of the entire Browns River watershed, focusing on the main stem of the Browns River and 10 significantly contributing tributaries during the Phase 1 assessment and eight highly sensitive reaches during the Phase 2. Based on these protocol guidelines, we considered the instability of stream channels and the resulting channel adjustment processes, as well as prioritized sections suitable for protection or restoration. Through remote sensing, mapping, and GIS work (Phase 1), confirmed by field documentation and evaluation (Phase 2), we have found that most in-stream channel adjustments can generally be traced to anthropogenic sources, such as developments within active floodplains (including dwellings, roads, and bridges), channel management activities (including gravel mining, bank armoring, dredging and channelization), removal or suppression of vegetation in the riparian zone, and changes in watershed hydrology, such as increased stormwater runoff or water diversions. Bridge and culvert assessments were also completed to inventory these stream crossings and to identify structures contributing to stream instability and sedimentation, and/or hindering fish passage.

The interactions of various land uses and their effects on a watershed or river system can be complex, and require thorough evaluation of the many factors through a watershed-wide assessment, in order to achieve effective solutions to water quality impairments. Our goal was to identify current stream conditions and types of instability within the Browns River watershed as well as to document and survey undersized or failing bridge and culvert structures. This information is necessary for landowners, volunteer organizations, and towns to develop, prioritize and implement restoration and corridor protection measures. Collaborative watershed restoration efforts that are developed using Phase 1 & Phase 2 SGA data will hopefully aim to reduce stream instability and in so doing reduce phosphorus loads in the Browns River and ultimately Lake Champlain. Partners participating on this project include ANR DEC, U.S. Fish & Wildlife Service, Williston and Berlin USDA Natural Resources Conservation Service (NRCS) offices, Winooski Natural Resources Conservation District (NRCD), Chittenden County Regional Planning Commission (CCRPC), and Vermont Agency of Agriculture.

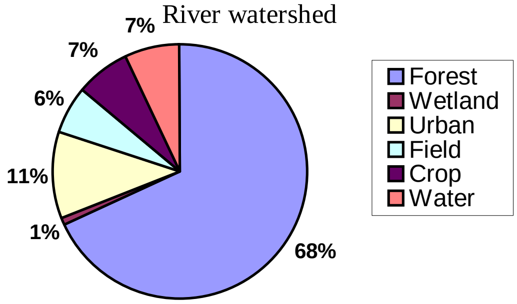
Watershed Background

The Browns River is a sub watershed of the lower Lamoille River watershed, comprising 92 square miles within the towns of Westford, Essex, Jericho and Underhill, Vermont. Figure 1A denotes the watershed location. The Browns River has been listed as impaired for 7.5 miles due to severe streambank erosion through the town of Essex and portions of Westford and Jericho. The pollutant is listed as sediment and the possible cause of the impairment is stated as streambank erosion due to agricultural encroachments and previous in-stream gravel mining operations (Department of Environmental Conservation (DEC), 2001). The impaired section runs through predominately agricultural land that is currently in corn, hay and pastureland. Due to increasing developments pressures in Chittenden County, upland areas and land along tributaries have transitioned from agricultural to residential and commercial land uses. The Browns River watershed still remains primarily forested.

Looking upstream at the Lee River (largest tributary to the Browns River)

The generalized land uses within the Browns River watershed are compared here in Figure 1.

Figure 1: Generalized Land Use/Land Cover in the Browns River watershed



Data taken from the most downstream reach (M1) on the Browns River. This data gives a general representation of the land uses throughout the watershed.

In general, the Browns River is described as a meandering riffle-pool sand bottom system with a wide valley and broad floodplain. These stream systems are extremely susceptible to instability when natural vegetation is removed. Given the fact that a portion of the river is sediment impaired, and that aerial photos indicate that woody riparian buffers are sparse in much of this area, stream geomorphic assessment is needed to determine more specifically the factors leading to impairment in the Browns River watershed.

Phase 1 Assessment Process

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Watershed Assessment Methodology and Results

Watershed Assessment Methodology:

Following the Phase 1 SGA protocol, stream reaches were defined by creating reach breaks using valley width and slope, geologic materials, and tributary influence. Twenty-one reaches were delineated on the Browns River main stem and 47 reaches on the tributaries. Reaches were numbered to efficiently organize, track, and communicate reach-related data (Table 1). After stream reaches were defined, watershed, sub-watershed, tributary, and reach watershed areas were delineated and calculated. A stream reach identification map can be found in the Appendix, Figure 2A.

Table 1: Reaches assessed on the Browns River and ten major tributaries

	Stream Designations	Number of reaches	Drainage Area at downstream most location (in square miles)
Browns River	M	21	92.32
Morgan Brook	T1	5	11.57
Rogers Brook	T2	5	6.27
Abbey Brook	T3	6	3.5
Lee River	T4	6	15.41
The Creek	T5	6	10.87
Roaring Brook	T5S1	5	3.81
Steinhour Brook	T6	3	1.81
Crane Brook	T7	3	2.58
Clay Brook	T8	4	2.52
Stevensville Brook	T9	4	3.06
TOTAL		**68**	

Stream Geomorphic Assessment Tool (SGAT)

Using the Stream Geomorphic Assessment Tool (SGAT), numerous parameters were calculated including: valley width, length, and slope; channel length and slope; stream confinement; sinuosity; and reference channel width. Based on this data, reference stream types were classified according to characteristics of the valley, geology, and climate of the stream (Table 2). The reference stream type describes the natural channel tendency of channel form and process in the absence of human-related changes to the channel (Table 2).

Table 2: Reference stream type classification

Stream Type	A	B	C	E	Unclassified	Total
Browns River reaches	2	3	9	7	0	21
Major Tributary reaches	9	14	7	6	11	47
Total						68

Classification of Rosgen (1996) Stream Type

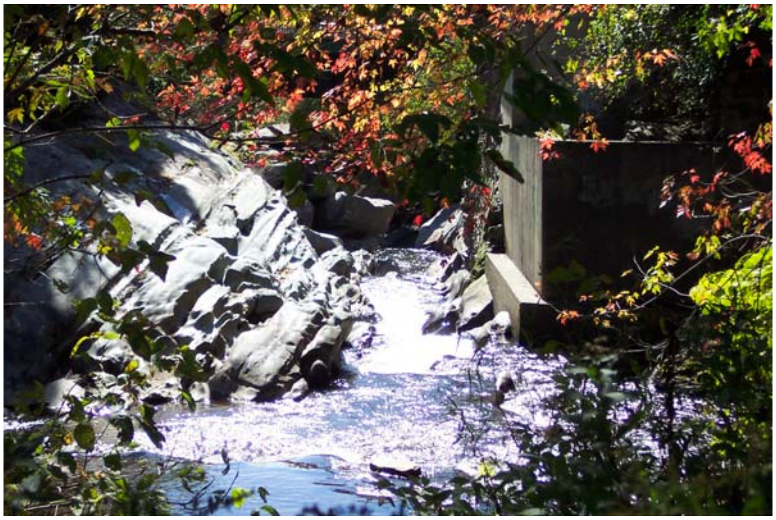
Table 3: Reference Stream Typing Chart

ream Type	Confinement (Valley Type)	Valley Slope*	Dominant Bed Material (Step 7)	Bed Form (Step 7)
A / Cascade	Narrowly confined (NC)	Very Steep > 6.5 %	Bedrock-Boulder	Tumbling jet and wake flow
A / Step-pool	Confined (NC)	Very Steep 4.0 - 6.5 %	Boulder-cobble	Steps and channel spanning pools
B / Step-pool	Confined or Semi-confined (NC, SC)	Steep 3.0 - 4.0 %	Boulder-cobble	Steps and channel spanning pools
B / Plane bed	Confined or Semi-confined or Narrow (NC, SC, NW)	Mod.- Steep 2.0 – 3.0 %	Cobble-boulder-gravel or finer	Run, riffle, and rapid
C or E / Riffle-Pool or Dune-ripple	Unconfined (NW, BD, VB)	Mod.- Gentle < 2.0 %	Gravel-cobble-sand or finer	Undulating
D / Braided Channel	Unconfined (NW, BD, VB)	Mod.- Gentle < 4.0 %	Gravel or finer-cobble-boulder	Braided

SGAT, Remote Sensing, Local Knowledge, and Field Verification

Using a combination of SGAT, remote sensing, local knowledge, and windshield surveys (field verification) the following parameters and their respective impacts were inventoried and/or calculated, and assessed:

- Valley side slopes
- River corridor delineation
- River corridor and reach land use and land cover
- Riparian buffer condition
- Hydrologic groups
- Soils and geology influences
- Alluvial fans
- Grade controls
- River corridor development
- Bank armoring
- Bridge and culverts



Old Mill in Jericho

- Flow regulation and water withdrawal
- Channel modifications
- Flood plain encroachments
- Dredging and channel mining history
- Depositional features
- Meander migration
- Meander width ratio
- Stream wavelength
- Debris jam potential
- Dominant bed form and materials

Depositional feature on the Browns River in Essex

Browns River Phase 1 Impact Rating Methodology and Reach Results Summary

Of the parameters assessed above, several were highlighted for data interpretation. These parameters are listed below and described individually in the following paragraphs.

Phase 1 Parameters highlighted for data interpretation:

- Watershed Land Cover/Land Use
- Corridor Land Cover/Land Use
- Riparian Buffer Width
- Channel Modification
- Depositional Features
- Meander Migration
- Bridge and Culvert Survey-using Appendix G datasheet

Watershed Land Cover/Land Use- Step 4.1

Lakes, wetlands, and perennial vegetation play an important role in a watershed by storing water and trapping sediment, which helps reduce flood peaks and maintain summer base flows in rivers and streams. Urban development and cropland typically increase the peak and change the duration of stormwater and sediment runoff events. Recent orthophotos were used to evaluate this parameter.

Results Summary

The following reaches recorded high impact ratings for watershed land use land cover:

High Impact Rating scores indicate 10% or more of the reach watershed is crop and/or urban.

M1-17	Browns River (mouth to Underhill Center)
T1.01-.05	Morgan Brook
T2.01-.04	Abbey Brook
T4.01-.02	Lee River
T5.01-.06	The Creek
T5.S1.01-.02	Roaring Brook
T6.01	Steinhour Brook
T7.01-.03	Crane Brook

Corridor Land Cover/Land Use- Step 4.2

Land use/land cover within the stream corridor is particularly important with respect to sediment deposition and erosion during annual flood events. Wetlands, ponds, and perennial vegetation moderate stormwater and sediment runoff, while impervious surfaces within urban areas and the exposed soils found in cropland have the potential to increase watershed inputs.

Results Summary

The following reaches recorded high impact ratings for corridor land use land cover:

High Impact Rating scores indicate 10% or more of the reach corridor is crop and/or developed.

M1-6; 8-20	Browns River (the entire main stem excluding one reach along Rte 128 and at the confluence with the Lamoille River)
T1.01 & .03-.05	Morgan Brook
T2.01; .03 & .05	Rogers Brook
T3.01-.06	Abbey Brook
T4.01-.04	Lee River
T5.01	The Creek
T5.S1.01-.02	Roaring Brook
T6.01-.02	Steinhour Brook
T7.01 & .03	Crane Brook
T8.01-.02	Clay Brook
T9.03	Stevensville

Riparian Buffer Width- Step 4.3

The riparian buffer is the area of land directly adjacent to the channel along the channel's banks and floodplain that is covered with native woody vegetation and largely unmanaged. Riparian buffers protect and enhance water quality, fish and wildlife habitats, aesthetics, and recreational values associated with streams. Streams without riparian vegetation often experience high rates of lateral erosion and may see such large increases in sediment that they undergo major adjustment of channel dimension, pattern, and profile. Orthophotos were used to estimate the percent of each buffer width category along the right and left banks.

Results Summary

The following reaches recorded high impact ratings for riparian buffer width. See Figure 3A for a map of these high impact areas, with those sections lacking riparian buffers denoted in red.

High Impact Rating scores indicate that 75% of the reach has little or no buffer (0-25 feet) on one or both banks.

M1-2; 7-9 & 14	Browns River
T1.01-.05	Morgan Brook
T2.01 & .03	Rogers Brook
T3.01-.04	Abbey Brook
T5.02-.04	The Creek
T5.S1.01	Roaring Brook
T8.01	Clay Brook

Channel Modifications- Step 5.4

Channelization is the process of changing the natural path of a river through activities such as windrowing and straightening. A channelized stream may degrade, or cut down vertically into its bed and cause the channel to lose access to its floodplain. The sediment resulting from the degradation process is re-deposited downstream of the channelized area. This results in aggradation, or building up, of the channel bed in this downstream area. Aggradation can result in channel widening, bank instability, and other channel responses, most of which are detrimental to both riverside land and aquatic habitat. Interviews with natural resource professionals, and review of orthophotos and topographic maps were used to examine this parameter. Figure 6A provides an historic comparison of a channel modification of the main stem under Route 15 in Essex.

Results Summary

The following reaches recorded high impact ratings for channel modifications:

High Impact Rating scores indicate that greater than 20% of the reach had been channelized.

M6-12; 14-16 & 18	Browns River
T3.01	Abbey Brook
T4.01 & .03	Lee River
T8.01-.02	Clay Brook

Dredging and Gravel Mining History- Step 5.5

Dredging and mining gravel bars from a channel may initiate a channel evolution process. Such activities straighten and steepen the channel and cause the river to cut down and erode its bed. The stream channel eventually aggrades with sediment supplied from upstream reaches as headcuts in the streambed move up-valley. Information and records from DEC's Stream Alteration Engineer was used to determine the relative frequency and volume of gravel extraction.

Results Summary

The following reaches recorded high impact ratings for dredging and gravel mining history:

High Impact Rating scores indicate that the reach was historically used for commercial gravel mining and/or dredged for flood remediation.

M11-12; 15-17	Browns River
T4.01-.03	Lee River

Depositional Features- Step 6.3

An unvegetated bar is sign that the bar was recently formed and is growing. Mid-channel bars, large unvegetated point bars, and delta bars may indicate an increased sediment load (from upstream) and the high likelihood that the streambed is actively aggrading and/or undergoing rapid lateral movement. The sediment source for these bars may be from bank failures or the degradation of the channel upstream. It may also be from upland watershed sources. Orthophoto interpretation and windshield surveys were used to evaluate this parameter.

Results Summary

The following reaches recorded high impact ratings for depositional features:

High Impact Rating scores indicate numerous, large unvegetated mid-channel, point and/or delta bars present.

M10-12; 15-19	Browns River
T3.03	Abbey Brook
T4.01-.03	Lee River
T6.02	Steinhour Brook
T8.01	Clay Brook

Meander Migration/ Channel Avulsions- Step 6.4

Some amount of lateral migration is natural in most alluvial stream systems, but the rate of migration may be increased in streams due to changes in the sediment supply and/or sediment transport capacity of the channel.

Comparisons channel paths from similarly scaled orthophotos of different years were used to identify channel migration, bifurcation, and/or avulsions. Channel migration occurs as the channel erodes its outer banks on meander bends. Bifurcation describes when the stream has split into two or more active channels. An avulsion describes a channel planform change due to a meander cutoff. See Table 4 for a complete list of possible parameters.

Table 4: Classifications of Meander Migrations

Migration	Channel has migrated by eroding its outer banks on meander bends
Bifurcation	Stream flow has split into two or more active channels
Avulsion	Channel planform has changed due to meander cut-offs
Multiple	More than one of the above in the reach—use only where none of the above planform change types are dominant
None	None of the above
No Info	Unknown if there are channel migrations or avulsions— unable to see the stream on orthophoto due to forest cover and/or inability to access entire reach during windshield survey

Results Summary

The following reaches recorded high impact ratings for meander migration:

High Impact Rating scores indicate frequent occurrences of channel migration, bifurcation, and/or channel avulsions along the reach.

M7-12; 14-16	Browns River
T4.01 & .03	Lee River

Meander Width Ratio-Step 6.5

The meander belt width is the horizontal distance between the opposite banks of fully developed meanders. Unconfined, gravel-based streams in shallow-sloped valleys that are in regime have belt widths generally in the range of 5 to 8 times the width of the channel. Higher values may indicate that the stream, possibly due to an increase in fine sediment, has started to aggrade and become more sinuous, decreasing its channel slope as it migrates laterally. Lower values may indicate that the stream has become straighter and steeper, possibly degrading its bed and losing access to its floodplain. Orthophotos and topographic maps were used to determine the reach's average belt width.

Results Summary

The following reaches recorded high impact ratings for meander width ratio.

High Impact Rating scores indicate the meander width ratio is less than 3 or greater than 10, well outside the 5-8 range of reaches within regime.

M1-11;14-16;18-19	Browns River
T1.02-.03;.05	Morgan Brook
T2.02-.04	Rogers Brook
T3.01-.04	Abbey Brook
T4.01-.02 & .04	Lee River*
T5.01-.06	The Creek
T5.S1.01-.02	Roaring Brook
T8.01	Clay Brook

**The Lee River is the only high impact stream due to high sinuosity (meander width ratio >10). The other high impact ranked streams are due to the stream being straightened, resulting in a meander width ratio <3.*

Bridge and Culvert- field verified data

A watershed-wide bridge and culvert inventory and assessment was conducted to determine if stream crossings were contributing to localized streambank erosion, sedimentation, and impaired fish passage. The Agency of Natural Resources Bridge and Culvert Phase 1 protocols were used (ANR, 2003). Bridge spans and culvert diameter measurements were compared to calculated bankful width measurements to determine whether structures were significantly undersized and potentially constricting water and sediment flows through the stream channel. The bankfull width, also known as the channel forming flow, is directly related to watershed drainage area. The bankfull flow is the discharge at which the majority of erosion and deposition takes place. Undersized bridges and culverts are not properly designed to accommodate both flow and sediment. During flood events large point bars can consequently deposit upstream of undersized bridges and culverts. During catastrophic flood events crossings can become outflanked, taking out large sections of roads and driveways. Significant sediment discharges to waterways can result. Sedimentation of the river poses water quality and aquatic habitat concerns.

Twenty-eight bridges and culverts were assessed on the Browns River main stem. Often span and diameter measurements were estaimated rather than accurately measured due to the flow stage of the water and water access at the crossing sites. Bridge and culvert inventories and assessments were also conducted on Morgan Brook, Rogers Brook, Abbey Brook, Steinhour Brook, Stevensville Brook, Clay Brook, Crane Brook, Lee River and Roaring Brook. Thirty-two bridges and culverts were assessed on these tributaries.

Impact ratings were developed from our detailed inventory of the following parameters: undersized structures, sharp approaching river bends to the structures, free fall culvert outlets impeding aquatic species passage, and large point bar development and significant streambank erosion both upstream and downstream of crossings. From these impact scores, red-flagged crossings were identified (Table 5).

Table 5: Red flagged crossings during Phase 1 in the Browns River watershed

	Browns River	**Tributaries**
Bridge or Culvert totals (B or C)	26B + 2C *28 total*	19B + 13C *32 total*
***Undersized structure**	**14**	**16**
Significant streambank erosion	9	4
Large point bars- sedimentation	5	7
Sharp approaching bend	5	3
Free fall culverts	0	5

Most important parameter observed

Results Summary

The following reaches recorded high impact ratings for bridge and culvert impairment.

M2; 4;7-10; 12-13; 15; 17-18; 20	Browns River
T1.01-.02	Morgan Brook
T2.02-.04	Rogers Brook
T3.01-.04	Abbey Brook
T4.01	Lee River
T5.S1.01	Roaring Brook
T7.01	Crane Brook
T8.01-.02	Clay Brook

Phase 1 Results Discussion

Browns River

The Browns River begins as a high gradient step-pool bed and plane bed morphology dominated by cobble substrate from its headwaters to Underhill Center. Underhill Center represents a transition of the main stem to a riffle-pool stream system dominated by gravel substrate except for a short high gradient section between the Cilley Hill Dam and the Red Mill. Crane, Stevensville, Clay, and Steinhour Brooks all converge their confluences in the Underhill Center area. The Browns River transitions to a dune-ripple morphology dominated by sand and silt substrate just upstream of the Route 15 crossing in Essex. The main stem transitions back to a riffle-pool dominated system just upstream of Westford Village to the confluence of the Lamoille River in Fairfax.

According to Phase 1 data, the majority of the Browns River main stem from the mouth to Underhill Center is affected by significant cropland and urban development within the watershed (high impact ratings-greater than

10% developed or cropped). River corridor impacts from cropland and urban development affect the entire main stem. Phase 1 results indicate that 52% of the stream channel has undergone significant channel straightening and windrowing. This stream channel modification changes the natural path and morphology of the river. The stream evolutional processes of degradation (cutting down of the stream bed due to increased velocity and slope) and consequent aggradation (the building up of sediment downstream in the channel bed) is often set in motion by this planform change (see Figure 2 for a diagram of the 5 stages of channel evolution). A state of aggradation can result in bed and bank instability, which can be detrimental to riparian land and aquatic habitat (VT ANR, 2003). There has been significant planform adjustment in the Browns River mainstem that may be an indicator of system-wide rather than local instability. Identifying the locations in the watershed where this instability is most prominent will help prioritize candidate reaches for restoration and protection projects. See Table 2A for a complete list of high impact reaches within significant parameters.

Significant channel modification has occurred between M6-M18 (the Essex-Westford line to Underhill Center). A large channel modification was discovered at the Route 15 crossing in the town of Essex, Reach M11. (See Figure 6A). Significant historic gravel mining has also been documented between reaches M11-M17 (the Route 15 crossing in Essex to Underhill Center) except for the high gradient reaches M13 and M14. Significant depositional features were recorded in the section M10-M19 downstream of the Essex Route 15 crossing to Underhill Center, again except for M13 and M14. Evidence of channel widening and planform adjustment was apparent as channel migrations in reaches M7-M16. A reconnaissance of M12 and M10 confirmed the presence of very large unvegetated point bars with steep slopes on the downstream sides, recent planform adjustment, and significant streambank erosion on outside bends on unarmored banks. Field visits confirmed M12 as being a riffle-pool morphology dominated by gravel substrate while M11 demonstrated a dune-ripple sand-silt dominated substrate. M10 demonstrated a significantly altered dune-ripple system possibly evolving into a riffle-pool system due to channelization. Recent rip rap bank armoring to a section of M10 attempted to prevent a channel avulsion and neck cutoff to protect a large cornfield.

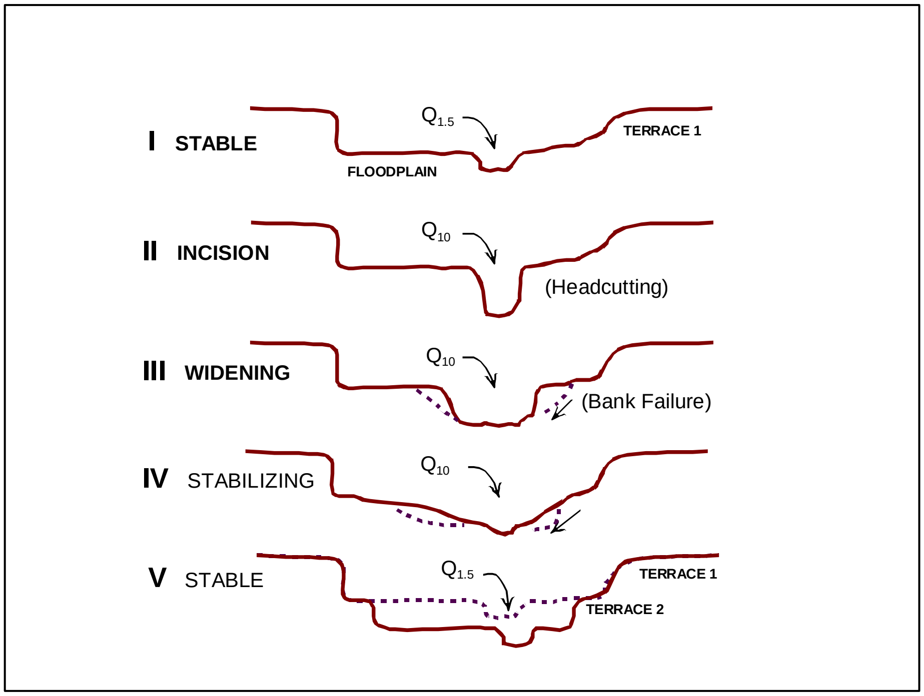
Much of the lower main stem was classified as a dune-ripple E stream type in Phase 1. E stream types are generally very sinuous and stable systems in natural conditions. However, these stream types are also extremely sensitive to disturbance. The Phase 1 Assessment results indicate that a significant portion of the main stem has been historically straightened or channelized as well as had riparian vegetation removed for agricultural purposes. Channelization was apparent in M12, M11, and M10 during recent field visits. Portions of the three reaches were incised, with bank heights greater than 10 feet on both sides. Aggradation within M10 is probably the result of historic upstream and within reach channelization efforts.

Table 6: Valley Typing

Valley Type	Confinement
1-NC	Narrowly Confined
1-SC	Semi-confined
2-NW	Narrow
3-BD	Broad
3-VB	Very Broad

A large section of the Browns River has also been extensively mined for gravel. Channelization and gravel mining generally set in motion a series of river responses, which include channel degradation, widening, and aggradation (see Channel Evolution Model- Figure 2) until a new flood plain is established at a lower elevation. Phase 1 assessment indicates that many of the impacted reaches are likely in Stage 3 of the Channel Evolution Model. The channel's aggradational response within and downstream of the channel modification reaches is more apparent in the riffle-pool gravel dominated reaches where depositional features such as large unvegetated bars are more common than in dune-ripple systems. The dune-ripple reaches of stream have demonstrated responses to the anthropogenic responses as far as plan form adjustment and low meander width ratios with less aggradational features present. Channel spanning bedrock at the Red Mill and upstream and the Cilley Hill Dam may have prevented significant negative channel responses from occurring within reaches M13 and M14. In our Phase 1 evaluation, M15 had high impact ratings in channel modifications, gravel mining, aggradation, and meander migration which may be influenced by the Cilley Hill Dam creating sediment transport discontinuity and a backwater effect.

Figure 2. Five Stages of Channel Evolution



Significantly undersized bridges and culverts represented approximately 50% of the main stem's total crossings. Undersized culverts can lead to structure outflanking and contribute significant sources of sediment and phosphorus during flash flood events. Inadequately sized bridges on the main stem were also responsible for localized streambank erosion and the creation of large depositional features. Most of the undersized structures were bridges. Only 2 of the 28 crossing structures were culverts. The majority of the undersized bridges were located between the M7 to M18 reaches which coincided with the most highly impacted reaches overall. The location of the majority of the undersized crossings at the most highly impacted reaches indicate the greater potential for catastrophic failure during flash flood events as streams in disequilibrium (Stage III of CEM above) generally require a greater span to accommodate the widening process. It is especially important to note that significantly undersized crossings were noted along 4 highly impacted depositional reaches (M12, M15, M17, and M18) indicating large sources of bedload material, which generally require additional spans.

Tributary Results Summary

The major Browns River tributaries generally fall into one of two categories: headwaters tributaries and lower watershed tributaries. The headwaters tributaries such as the upper Lee River, Stevensville, Clay, and Steinhour Brooks originate in the forested high elevation and narrow valley areas of the Underhill Firing Range as step-pool and plane bed systems dominated by boulder and cobble substrate. The lower reaches of these headwaters tributaries transition to riffle-pool gravel bottom dominated systems. Headwaters tributaries were not highly impacted by watershed and corridor land uses and lack of woody buffers because their watersheds are still primarily forested. Clay Brook, however, has been impacted significantly (50%) by previous channel modification, probably as the result of past flood mitigation work. In addition, Crane Brook, another upper watershed stream, has been highly impacted by watershed and corridor land use.

Lower watershed tributaries such as Abbey Brook, Morgan Brook, The Creek, the lower Roaring Brook, the lower Lee River, and Rogers Brook are dominated by current agricultural lands and former agricultural lands converted to residential development. Increased residential development has lead to increased installation of stream crossings in these tributaries, and the subsequent conflicts that arise between natural stream systems and improperly installed bridges and culverts. Watershed and corridor land use impacts and lack of woody riparian buffers were also substantially higher for these tributaries. Several anthropogenic disturbances were noted in the lower Lee River (T4.01-.03) including channel modification, gravel mining, depositional features, channel migration and avulsions, and meander width ratios outside regime. In general, the most downstream reaches of each stream were the most highly impacted. Lower portions of the tributaries were often in conflict with transportation infrastructure, residential development, and other anthropogenic flood plain encroachments. Many of these tributary reaches are located in natural alluvial fan areas, which are highly sensitive to disturbance.

The Phase 1 bridge and culvert survey results indicate that 67% of the stream crossings on Abbey Brook, 60% on Rogers Brook, 40% on Morgan Brook, and 50% on Clay Brook were significantly undersized. Abbey Brook, Clay Brook, and the lower Lee River contained both undersized crossing structures and highly impacted depositional features on the same reaches.

Public Participation

Public participation has been an integral part of the Phase 1 assessment process on the Browns River. In 2002, the Winooski Natural Resources Conservation District distributed letters to farmers discussing the river's impairments, notifying them of the watershed-wide assessment planned for the next few years, and sharing the voluntary cost share programs that are available in the state. Following the completion of Phase 1 assessment, two public forums were held in the towns of Underhill and Westford in winter of 2003 to present and discuss the assessment results with the local communities. The Winooski NRCD, DEC, and CCRPC presented information at the forums, and the Westford meeting was co-sponsored by the Westford Conservation Commission. An example public meeting announcement is found in Figure 4A.

Several questions and concerns were expressed at the Phase 1 public meetings. Numerous community members asked that closer attention be paid to fish habitat criteria in the second assessment. Also, the Town of Underhill identified a specific crossing in town that they are concerned with. Underhill recently invested in a town road and new bridge; we will be sure to include this bridge crossing (M18) in our assessment. Two areas in Underhill Center and Westford that were discussed at the public forums, along Route 128 and Route 15, respectively, have been preliminarily targeted as problem areas. As a consequence, considerable time during the Phase 2 in-stream assessment was dedicated to these areas. Volunteers were recruited at the public forums to assist in the data collection in the Phase 2 in-stream geomorphic and fisheries habitat assessment.

Finally, Copies of the Phase 1 geomorphic assessment results were distributed to all partners, municipalities within the watershed, and any requesting residents. The potential to incorporate the results from this watershed assessment into other formats, for example town plans, is possible since Jericho, Westford and Underhill town plans were up for renewal in spring of 2004. Westford and Underhill both agreed to include watershed planning concerns into the approval of their town plan. Figure 5A provides a suggestion to the Underhill Town Plan Revision submitted by Ian MacDougall, CCRPC as a result of the Phase 1 assessment process. Bridge and culvert surveys conducted during the assessment are to be provided to the respective towns and others interested in our list of top priority sites for potential projects. Local acceptance and participation is helpful in completing this process but essential in adopting the proposed changes. Successful restoration and protection projects are impossible without support and understanding of the issues concerning human influence on stream morphology

Phase 2 Assessment Process

The results of the Phase 1 Geomorphic Assessment were used to target reaches for additional detailed in-stream evaluation in the Phase 2 Rapid Geomorphic and Fisheries Habitat Assessments. Phase 1 identified what parameters could possibly lead to the current stream adjustment processes. Considering the windshield survey (Step 7) remains the only field verification step in the Phase 1 process, these Phase 1 adjustment processes can only be considered potential processes. This second phase of assessment is designed to field verify data collected at the remote sensing level of the Phase 1 assessment using in-stream quantitative criteria to determine fisheries habitat health and stream stability.

The results of this collective assessment process will be used to direct water quality improvement projects throughout the Browns River watershed. Current stream conditions and types of instability will provide the basis for the alternatives analysis and a prioritization of restoration reaches and restoration strategies within the basin.

The Winooski NRCD and its partners conducted the second phase of the stream geomorphic assessment on the priority reaches within the watershed in summer and fall of 2004. Some follow up assessment work continued into the spring and early summer of 2005. Upon review during the Phase 1 process of the Browns River watershed assessment, key areas, or reaches, of the watershed were identified as being highly impacted and highly sensitive. Due to an increased susceptibility to change on highly sensitive reaches, more detailed assessment was necessary on these reaches for effective planning of restoration projects. Originally our assessment group had planned to conduct further assessment on all 12 sensitive reaches on the main stem of the Browns as well as one reach on each of the 10 major tributaries. However, we found this number of reaches (22) to be cost prohibitive and beyond the time line and scope of this project. Instead we narrowed our focus to eight reaches of the main stem of the Browns that were moderately to highly sensitive and were of concern for other reasons . M9 & M10 were assessed because of heavy agricultural use within the river corridor, lack of forested riparian buffers and historic channelization. M11& M12 were chosen due to the extent of lateral stream migration and bank erosion here, as well as the fact that the Lee River, the watershed’s largest tributary, enters the Browns at the M12 reach break. M15& M16 were assessed because gravel mining historically occurred along Rte 15 and River Rd. M17 & M18 represent a very confined area of the watershed where 4 other high gradient tributaries enter the main stem in Underhill Center. These two reaches are under significant development pressure and constrictions, and were chosen for assessment for these reasons. Four of these reaches chosen for Phase 2 assessment were also found to contain undersized bridge or culvert crossings in Phase 1. Undersized bridges & culverts are especially important for further review as potential sources of sediment to the watershed.

Over the spanning 3 years dedicated to this project, numerous assessment protocols from VT DEC River Management Division have been revised and updated, often a result of recommendations from projects in the field. The bridge and culvert survey format and content currently differs dramatically from the original 2002 form were began collecting data with. Consequently, we have gone out in the field numerous times over the duration of the project to gather additional data to better capture what is happening in a particular section of stream. In 2002, an estimated bridge span or culvert diameter was acceptable data collection. During the Phase 2 assessment, it was determined that a more precise measurement was needed on these potentially undersized structures. Therefore, field time has been spent actually comparing the calculated crossing span with the reach or segment’s revealed bankfull width. This further analysis has resulted in some updates to the database for significantly undersized crossings as well as identified some potential sources of sediment entering the Browns River system. Tables 3A and 4A show the updated bridge and culvert assessment results.

The more detailed Phase 2 assessment results combined with the quality assurance/quality control review re-examined the data that was presumed to be true from the Phase 1 assessment and developed an actual picture of the current stream condition. This data is designed to help direct restoration projects necessity in the watershed.

Phase 2 Watershed Assessment Methodology and Results

Phase 2 Reach Assessment Methodology

The Phase 2 rapid assessment involves collection of data and field observations to verify Phase 1 stream geomorphic data on a reach specific basis. Stream geomorphic condition, physical habitat condition, adjustment processes, reach sensitivity and the stage of channel evolution are identified by data gathered from erosion and depositional characteristics, changes in channel and floodplain configuration, and fluctuating riparian land use/land cover. The Rapid Stream Assessment for each reach created field maps and photos demonstrating stream type, the geomorphic condition evaluation, and a stream habitat evaluation.

Standard map and field survey work was conducted to measure the parameters that define watershed and stream geomorphology for purposes of classification and assessment of channel condition, adjustment, and sensitivity. The work was conducted by the Winooski NRCD staff and trained intern under the supervision of VT DEC and Fish & Wildlife staff. Consultation within the field crew occurred for each reach assessed before data was entered into the database. A comprehensive list of the parameters and methods of assessment and survey are described in detail in the Stream Geomorphic Assessment Phase 2 Protocol Handbook.

The assessment will generate a watershed Access database that will include rapid geomorphic and rapid habitat assessment results. The database can be built upon and queried for various attributes that will prioritize future protection and restoration projects.

In July-August 2005, this Phase 2 data will be entered into a VT River Management stream geomorphic data management system (DMS) designed to facilitate organization, reduction and efficient analysis of remote sensing and field data. This new web-based system will provide river managers with the high quality data necessary for effective allocation of resources to address sediment loading and other erosion-related stream morphology problems. The DMS will also support the evaluation of Vermont rivers for listing or de-listing of waters pursuant to section 303d of the Federal Clean Water Act. Reach and site-specific electronic and paper files containing raw data and documentation of reduction and analyses procedures are retained at the Winooski NRCD office. Digital photographs were also taken and catalogued under the specific reach alphanumeric code.

Phase 2 Reach Results Summary

Maps and Graphs

The Appendix contains collected data that has been summarized and displayed in graphs and maps to better depict the current stream condition of the Browns River watershed. Particular parameters were continually evaluated on 8 reaches during the Phase 2 assessment process. Due to further detailed examination during Phase 2, the mainstem reach M16 was broken in 3 segments based upon floodplain encroachment, riparian buffer condition and degree of channel alteration. Though the segments were assessed separately as M16A, M16B, and M16C, all three were compared against the same Phase 1 data which was collected for M16 as a continuous reach.

Our assessment process intensively evaluated Phase 2 stream types and compared the data for each stream reach to the reference stream type identified during Phase 1. Any stream type departures were identified at this point. Compare the Phase 1 & Phase 2 stream types identified per reach in Figures 7A and 8A. The stream's current stage of the channel evolution process was also developed; determining what process(es) the stream had already undergone and the current evolution stage of the stream- Figure 9A. Since the data collected during Phase

1 identified what parameters could possibly lead to the current adjustment processes, they are sited at only potential processes. Windshield surveys were the only field verification in the Phase 1 process and Phase 2 is focused on the data collection in the field. These results are found in Figure 15A. Rapid habitat and geomorphic condition assessments represent this field data and were taken to assess the inherent health of the stream ecosystem and to document the current adjustment process occurring in the reach (or segment). These results are pictured in Figure 11A & 12A. Specific calculations, incision and entrenchment ratios -Figure 13A & 14A- were also mapped to confirm the channels either lateral or vertical adjustment. Based on the stream type and stream condition, the likelihood that the stream will respond to change due to natural causes and/or human activity, or the stream sensitivity was evaluated –Figure 10A. Riparian buffer widths (Fig. 16A), % erosion (Fig. 18A) and rip rap bank revetments (Fig. 17A) were also calculated capturing the potential for each reach to be contributing sediment to the river system.

Reach (Segment) Analysis
M9

Phase 2 assessment found M9 to be an E type stream with sand dominated bed substrate in a dune-ripple system (as expected based on Phase 1 information). The bankfull width identified in Phase 2 assessment (37.7 ft) was narrower than expected based upon the calculated Phase 1 channel width (81.6 ft). This is not an unexpected result, however, since Phase 1 channel widths are determined using VT Regional Hydraulic Geometry Curves, which are more accurate for C type streams. These curves often overestimate channel widths for E type streams.

The river corridor in M9 is primarily in agricultural land use (hay and corn), and riparian buffers are small (5 to 25' in most cases for both banks). Bank erosion was noted on small portions of this reach, but was not significant overall (6.5% of left bank and 3% of right bank). Likewise, hard bank armoring was noted along only 4.7% of the left bank and 3.4% of the right bank on reach M9. Phase 1 found the reach condition to be poor and highly sensitive and aggradation as the potential current adjustment process. Further Phase 2 assessment found major degradation happening and only minor aggradation and planform adjustment occurring in this river section. Because it is an E stream type, we found the system was able to effectively transport sediment (only point bars depositing) rather than retain sediment. Some significantly undersized bridges and recent avulsions were apparent, explaining the aggradation and planform adjustment processes. Historically, Reach M9 was straightened; currently it is migrating laterally but holding channel dimensions. The current stage of channel evolution was determined to be incision (stage II), as evidenced by the incision ratio of 1.62. Phase 2 assessment found the reach habitat condition to be fair and the geomorphic condition to be good.

If additional time and funds were available another cross section would be advised, considering only one cross section was done on this reach.

M10

Like M9, M10 was found to be an E type stream with sand dominated bed substrate in a dune-ripple system. River corridor land uses are primarily agricultural (hay and corn fields) with some small forested sections. Little to no vegetated buffer exists along the majority of this reach (dominant buffer width is <5'). The percentage of eroded banks in M10 was higher than that in M9, with 15% of the right bank and 12% of the left bank eroding. However, very little of this reach was armored: rip-rap was noted on only 3.7% of the left bank and none of the right bank. Channel constrictions identified during Phase 2 assessment include an active beaver dam at the downstream end of the reach, near the confluence with Abbey Brook (T3). Also, two bridges (one small farm bridge and a larger bridge where Rte 128 crosses M10) and a pair of old bridge abutments are present in this reach. The larger Rte 128 bridge is not undersized for this channel; however, the smaller farm bridge and abutments may be significantly undersized. Large sediment deposits were noted upstream of the old abutments during the windshield survey and Phase 2 assessment. Considerable amounts of large woody debris were observed (an average of 1 piece every 41 feet of stream), and three debris jams were identified in sinuous stretches of the reach. The debris jams were not immediately upstream of bridges, however, suggesting that they may not related to channel constriction by bridge infrastructure. A few side bars and a mid-channel bar (forming downstream of a debris jam), as well as one channel avulsion were identified in Phase 2. Point bars were generally larger in the upstream portion of this reach, suggesting that deposition may be greater here. The stream channel is wider (62.6 ft.) than the downstream reach M 9 (37.7). Typically as water is transported down through the watershed the watershed size and channel width both increase.

Phase 1 found the reach condition to be fair and highly sensitive and aggradation was identified as the possible current adjustment process. Phase 1 assessments are based on generalizations made primarily on C stream types, which are traditionally wider and shallower and don't transport sediment as efficiently as E type streams. Considering the fact that M10 has lost its boundary conditions, noted by the increased amounts of sediment, some incision, channel avulsion, flood chutes and significant bank erosion, even the stable E streams will begin to degrade (incises), adjust planform and lose some of its sediment transports capabilities. Phase 2 confirmed that minor aggradation and planform adjustment is occurring, with historic degradation in this river section. The current stage of channel evolution was determined to be incision (stage II), due to incision ratio >1. Phase 2 assessments found the reach habitat condition to be good and the geomorphic condition also to be good.

M11

M11 was also found to be an E type stream with sand dominated bed substrate in a dune-ripple system. River corridor land uses are primarily agricultural (hay and corn fields) with some small forested sections. Little to no vegetated buffer exists along the majority of this reach (dominant buffer width is <5'). Two roads, Rte 15 and Naylor Rd., were identified as river corridor encroachments along 27% of the reach length. This section of river was severely altered sometime after 1962 when the river was straightened under Rte 15. This channel alteration shortened the river's length, thereby increasing the flow velocity and the potential upstream and downstream hazard, resulting in significant bank erosion. Thirteen percent of the right bank and 10% of the left bank have been hard-armored (rip-rapped) in attempt to address this erosion problem. An additional 5% of the right and left bank combined show active erosion. This would explain the significant aggradation and channel avulsion found downstream in M10. Again, once the riparian vegetation is gone and the stream widens, it is likely to no longer function as a transport stream. Although M11 is not entrenched, the incision ratio of 1.27 demonstrates that the river likely underwent a downcutting, or degrading process. Phase 1 found the reach condition to be fair and highly sensitive and planform as the probable current adjustment process. Phase 2 confirmed that minor planform adjustment is occurring in this river section. The current stage of channel evolution was determined to be incision (stage II), as explained by the incision ratio of 1.27. Phase 2 assessment found the reach habitat condition to be fair and the geomorphic condition to be good.

M12

Phase 2 determined M12 to be a C type stream with sand dominated bed substrate in a riffle-pool system. This section of the Browns River represents a stream type transition from downstream E type streams to C streams upstream. E type streams are often considered stable, effectively functioning, highly sinuous, dune-ripple systems that are very sensitive to disturbances and will rapidly adjust if stream dimension, pattern or profile change. C type streams, on the other hand, have higher width to depth ratios and have well-developed floodplains, with more riffle-pool systems. They are also generally steeper, have coarser bed material, and store more sediment instead of transporting it. In keeping with this, significant sediment storage bars were identified in this highly sinuous reach. The incredible amounts of mobilized sediment within this reach can be explained by the bar scalping and dredging that historically occurred here. M12 appears to be retaining large amounts of sediment and acting as the upstream slow-release sediment source to the downstream M11 and M10 reaches. The high sensitivity ranking of the 3 previous downstream reaches (M11-M9) suggests that if the sediment stored in M12 were to move down through these reaches, there is a high likelihood that these sensitive stream sections would adjust dramatically.

Fairly large (>50') deciduous riparian buffers dominated this reach. Eight percent of the right bank and 5% of the left bank within this reach demonstrated active bank erosion, while 7% on the right bank and 5% on the left remained stabilized in rip-rap. A 670 foot berm is located near the downstream end of the reach, representing 9% of the right bank length. An undersized channel-constricting farm bridge is also located in the downstream section of the stream, just below the stream-side berm. Significant large woody debris was found in this reach (one piece for every 41 feet of the reach length).

Phase 1 found the reach condition to be fair and highly sensitive and degradation as the probable current adjustment process. In contrast, Phase 2 data found minor aggradation and planform adjustment to be occurring in this river section. Because the reach is aggrading, it is neither entrenched nor incised. The current stage of channel evolution was determined to be predominately widening (stage III). Phase 2 assessment found both the reach habitat and geomorphic conditions to be good.

Because upstream sections of M12 (above the confluence with the Lee River) are dominated by bedrock at the Old Red Mill site, and because the Cilley Hill dam acts as a sediment trap just above in Reach M15, sediment stored in M12 is coming either from within the reach (which indicates we have underestimated the amount of bank erosion present) or from the Lee River or a section of M13 that was not considered high impact during Phase 1. If additional funds become available, further attention should be dedicated to this area of the watershed in order to determine the sediment sources for M12.

M15

Phase 2 assessment found M15 to be a C type stream with gravel dominated bed substrate in a riffle-pool system. The river corridor land uses are predominately agricultural (hay and pasture), although a moderate riparian buffer of 5-25 feet has been maintained in this reach. Nine percent of the left bank and 10% of the right bank demonstrated active erosion. A very small section of stream (<1%) was protected with rip rap. The upstream section of this reach is dominated by huge amounts of sediment through which the river picks numerous paths depending upon the year and the stream's flow. One adjacent landowner noted that the stream had just established a new path (i.e. stream channel) the night before our assessment. Numerous transverse bars, indicative of aggradation, are apparent in this upper section of the reach. Historical bar scalping occurred in this area and one long section of river was straightened. Avulsions, old oxbows, braiding, chute cuts off, and signs of historic incision are also visible results of these past practices.

Further downstream, the river flows under the Raceway Rd. bridge which was replaced and realigned in 1993. The new bridge is appropriately sized and appears to allow for effective transport of water and sediment through the system. Below the straightened section of the reach, which does exhibit a healthy forested riparian buffer, the stream dimensions begin to deteriorate again. No buffer exists along the stream, cows have stream access, large sediment deposits and transverse bars are apparent, and the high clay banks are actively eroding. In addition, recent channel avulsions have occurred and another section is about to avulse, numerous deep pools exist, and some increase of fine sediment in the system can be found. The Cilley Hill Dam, functioning as a run-of-the-river impoundment, marks the downstream point of this reach.

Phase 1 assessment found the reach condition in M15 to be fair and highly sensitive and planform as the potential current adjustment process. Phase 2 assessment found very high stream sensitivity within this reach and the current channel evolution stage to be widening as well as planform. The incision ratio of 1.50 confirmed that the stretch has also undergone historic channel bed degradation. Phase 2 assessment found both the reach habitat and geomorphic conditions to be fair.

The complete cause of this reach's significant adjustment processes is still unknown. Additional analysis, possible segmentation of the reach, as well as more detailed survey work is needed to further explain this reach. The effects of historical channel modifications and the in stream dam are still presumed causes of the disrupted system.

M16A

Reach segment M16A begins at the confluence of The Creek and the Browns River mainstem, and continues upstream to Mill Brook Park. Phase 1 data for M16 as a whole found the reach to be in fair condition and highly sensitive with planform as the probable current adjustment process. Although the stream type for M16 was determined as C in Phase 1, Phase 2 assessment identified segment M16A as a gravel bottom F type stream. This stream type departure is likely attributable to an entrenchment ratio (1.3) and the extensive amount of hard bank armoring on both banks signifying lateral instability. This segment is also heavily incised (incision ratio = 2.26) without access to its floodplain. Significant historic gravel mining occurred on this segment, explaining the incision and entrenchment. Sediment from this channelized lower section of M16 is currently being supplied to the reach downstream (M15). Data collected on this segment remains incomplete; no rapid geomorphic or habitat assessments were done on this segment due to a lack of field time. Additional work on this reach should include completing the Phase 2 assessment.

M16B

Phase 1 data for M16 as a whole found the reach to be in fair condition and highly sensitive with planform as the probable current adjustment process. Although the stream type for M16 was determined as a C in a riffle-pool system in Phase 1, Phase 2 assessment identified segment M16A as a gravel bottom D type stream. This stream type departure is attributed to the braided channel, extreme width to depth ratio (37.9), pervasive lateral bank erosion, and extensive amount of transverse bar development. 13% of the right bank and 6% of the left bank are stabilized by rock rip rap. An additional 4-6% of the stream demonstrates active erosion. This amount of streambank erosion and stabilization activity addresses the lateral instability issues and explains the significant amount of sediment deposition within the segment.

Channel straightening, bar scalping and gravel mining are all apparent on this segment. This historic behavior, combined with the system’s extreme sensitivity, explains the lateral instability and channel braiding. Recent rip rap projects in this reach, new animal crossing forged across the segment, building point bars, old outflanked rip rap show the segment under serious current adjustment. The channel width calculated in Phase 1 was 58 feet, while the Phase 2 cross section determined a bankfull width 2 times greater (117 ft). This supports the Phase 2 determined channel adjustment processes of widening and planform. Phase 2 assessment determined the current channel evolution stage to be widening (stage III), again exposed by the width to depth ratio and lateral adjustments. The segment habitat condition was identified as fair while the geomorphic condition was determined poor, as a consequent of the extensive lateral bank erosion, recent channel avulsions and unvegetated midchannel and diagonal bars.

Stabilizing parameters within this segment are removed and the stream is undergoing current lateral migration, in an attempt to establish equilibrium. This section of river warrants exploration of the potential procurement of permanent conservation easements of the floodplain areas and hopefully discussion of fluvial erosion hazard mapping & zoning.

M16C

Again, the Phase 1 data for M16 as a whole found the reach to be in fair condition and highly sensitive with planform as the probable current adjustment process. The Phase 1 and Phase 2 assessments concurred that the stream type for M16C was a gravel bottom C. Phase 1 recognized the segment as a riffle-pool system where as the Phase 2 assessment found more of a step pool arrangement with a larger boulder composition. Phase 2 identified M16C as an efficiently functioning transfer stream without sediment storage bars or bank erosion, with significant forested riparian buffers (>50 ft.), limited amounts of bank armoring (<5%), and only slight incision. This short, 5202 segment length actually represents a section of the Browns River in reference condition, for both habitat and geomorphic assessments. This reference condition means the segment has not undergone significant departure from the reference or natural stream condition and remains primarily in equilibrium. Comparing sections of river in reference condition to areas in significant adjustment is helpful in determining what the system can and should look and function like.

M17

Phase 2 assessment found M17 to be B stream type in a riffle pool system dominated by gravel. This concurred with the Phase 1 assessment presumptions. B type streams are generally slightly sinuous, dominated by runs with infrequent riffles and pools, only slightly incised, with a moderate width to depth ratio. Based on the extreme width to depth ratio (41.8), the moderate sinuosity, and steep riffles and occasional pools found in M17, the stream could likely be an F type; F stream types have a higher width to depth ratio and are moderately sinuous. If a project were proposed for this reach, additional data and cross sections are necessary to confirm the stream type departure.

Phase 1 presumed the current adjustment processes to be degradation and aggradation but Phase 2 showed that the current aggradation may simply be a result of sediment entering the reach from 2 significant tributaries. Steinhour and Crane Brook both enter the mainstem of the Browns at this reach. Downstream of the confluence some large mid channel bars have developed. Further downstream resides the bridge that the Town of Underhill replaced in the 1990's and has made considerable monetary investments to preserve. 10% of the right bank and 3% of the left bank, all directly up stream of the River Rd. bridge, have been hard armored to prevent outflanking of the new bridge.

The high width/depth ratio of 41.76 validates the stream's current adjustment process is widening. Evidence of elevation change from a previous head cut and historic degradation of the stream, probably a result of historic gravel mining in this area, was observed, confirming historic degradation. The river has now established a new accessible floodplain and appears to be stabilizing (stage IV of the channel evolution process).

M18

Phase 1 and 2 assessment results show M18 to be a riffle pool C type stream with a gravel bottom. Phase 1 presumed the current adjustment processes to be degradation and aggradation but Phase 2 showed that aggradation and planform adjustments are currently occurring. Currently the reach exhibits significant lateral erosion, 40% of the left bank and 28% of the right bank and an additional 12% on the left and 10% on the right bank are protected by rock rip rap. Two bridges within the reach are undersized and causing channel constrictions, depositing sediment upstream of the structure, and causing bank erosion below the structure. Sections of the reach were historically straightened and gravel mined and the river is responding by slowly regaining some sinuosity. The reach is also slightly incised (incision ratio = 1.72) meaning the stream historically degraded, likely in response to these channel modifications. The current condition results in a fair habitat and geomorphic assessment.

The channel evolution stage is stabilizing (stage IV). The development pressures within the floodplain and Underhill Center and the tributary influences (Clay Brook enters at the upstream end of the reach) add to the complexity of this stretch of river. As a near headwater, higher gradient reach, we often expect near reference condition. Additional time and analysis is needed to explain and plan restoration projects for M18 and M17.

Bridge and Culvert Data Update

Bridge spans and culvert diameter measurements were compared to calculated bankfull width measurements to determine whether structures were significantly undersized (span <70% of channel width). This process was more intensive than the process during Phase 1. Numerous bridge and culvert crossings assessed in Phase 1 had estimated spans and diameters. Actual bridge span and culvert diameters were measured and GPS waypoints taken, denoting their location, during Phase 2. This more detailed information is critical for establishing priority projects in the watershed. Some presumably undersized structures from the Phase 1 assessment were confirmed during Phase 2 and others were determined not to be constricting flow and sediment transport through the watershed.

Table 7: Phase 1 Deliverables

Objective	Task	Product	Work Completed
Identify significant physical watershed features of the Browns River	Complete Phase I, Vermont Stream Geomorphic Assessment on the Browns River Watershed.	Watershed database GIS Watershed map with stream and valley type classifications. Stream impact ratings, stream stability ratings, and current and historic land use.	CCRPC, Winooski NRCD & DEC used aerial photos, orthophotos, USGS topographical maps and collected existing data from VT ANR to enter data into SGAT database GIS watershed map was completed
Secure landowner permission and cooperation	Mailings, phone calls and/or visits	Cooperator Database	Letters were sent to all adjacent landowners identified along the Browns River & its major tributaries; follow up visits with concerned/interested landowners were also done by Winooski NRCD employees Phase I Database was completed
Verify the accuracy of data collected by remote sensing	Groundtruthing	Accurate Data/Field verification	Windshield survey, bridge and culvert assessment were conducted on the Browns River main stem and 8 of 9 tributaries identified with major watershed influence
Community outreach	Hold public forums and send out press releases	Informational meeting presenting the Phase I geomorphic protocol to landowners.	An initial public meeting was held to explain and share the Phase I geomorphic assessment process with project partners and a local volunteer group Outreach to community and landowners was conducted through a watershed-wide mailing; press releases were also submitted to 3 area newspapers -Essex Reporter, The Burlington Free Press, & Mountain Gazette
Community outreach	Produce and distribute assessment summary, include this in a press release. Hold a public forum to present this to landowners.	A lay-person friendly summary of the geomorphic assessment	Winooski NRCD, CCRPR & DEC held 2 public meetings, in towns of Underhill and Westford, to share results with the community and town officials; press releases were printed in local newspapers (attached) Reference to the Phase I Assessment results was made in the Underhill Town Plan revision, April 2004 (attached) Copies of the final report will be mailed to interested community members, all town municipalities, and to each project partnering agency
Project coordination & administration	Communication among partners, project timing, technical assistance, administration, fund distribution, two press releases, quarterly reports and a final report.	Work plan submittal, invoice submittal, & overall project coordination	Project coordination achieved through weekly email correspondence & bimonthly team meetings for identifying priorities; DEC technical assistance was provided on a weekly basis with SGAT and field data collection; quarterly reports were also completed & submitted Combined Final report for Phases I & II will be completed and submitted to LCBP at the conclusion of the Phase II grant

Phase 2 Deliverables

Objective	Task	Product	Work Completed
Secure landowner permission and cooperation	Mailings, phone calls, and/or visits	Cooperator database	Letters were sent by Winooski NRCD to all adjacent landowners identified along the Browns River and its major tributaries explaining the Phase 2 assessment field work timeline A watershed-wide mailing asked for interested volunteers to assist with field work; received numerous phone call and email responses
Community outreach and education	Hold 3 public meetings and send out 3 press releases	Informational meeting presenting the Phase 2 Geomorphic and Fisheries Habitat Assessment results	VT DEC watershed coordinator & Winooski NRCD staff met with Underhill Select board to follow up on concerns exhibited during Phase 1 public meeting A public meeting is planned within the watershed to share the results of the SGA; 3 meetings will not be possible due to funding limitations
Community outreach and education	Produce and distribute assessment summary.	A summary of the geomorphic and fisheries habitat assessment	Not distributed by mail; SGA data collected will be available on the VT DEC Data Management System (DMS) in July-August 2005 and be accessible to all interested partners and landowners
Project coordination & administration	Communication among partners, project scheduling, administration, quarterly reports, and final report	Work plan and invoice submittal and overall project coordination	Project coordination achieved through extensive field work in the Summer 2004 season, attenuation of a VT Fish & Wildlife summer intern, weekly field site visits & technical assistance from VT F&W, DEC River Mang. and Watershed staff Invoices submitted quarterly as requested to LCBP and NEIWPCC Final report, from Phase 1 & 2 SGA results, completed and submitted to LCPB at the conclusion of grant period
On-site assessments	Collect & compile field data, prepare report & database	Rapid geomorphic & habitat assessment scores, site sketches & photo logs, inventory of flood plain	DEC & VT F&W provided technical support to Winooski NRCD and intern in the field and in the office associated with data collection Assessment sheets were filled out following field day with tech. support from professionals in the field DEC QA/QC project manager assisted with quality control review of the database DEC staff and Winooski NRCD staff collaborated on preparation of final report

References:

Rosgen, Dave, 1996. Applied River Morphology, Pagosa Springs, Colorado

"Town of Jericho Comprehensive Town Plan", adopted June 25 2001, Jericho, VT

"Underhill Town Plan", adopted February 25th, 1999, Underhill, VT

U.S. Geological Society, (USGS), 1983-1987, topographical maps

Vermont Agency of Natural Resources, 2003, 2004 & 2005. *Vermont Stream Geomorphic Assessment Phase 1 Watershed Assessment, Phase 2 Rapid Assessment, Phase 3 Survey Assessment, and Handbook Appendices*. Waterbury, VT.

Vermont Center for Geographic Information (VCGI), 1993-2003, GIS Data, Waterbury, VT

Vermont Department of Environmental Conservation, 2001. *Lamoille River Watershed Assessment Report.* Vermont Agency of Natural Resources, Waterbury, VT.

Vermont Mapping Program, 1999, Orthophotos, Waterbury, VT

"Westford Town Plan", adopted May 10, 1999, Westford, VT

APPENDIX

Phase 1 Figures & Tables

Phase 2 Figures & Tables

Phase 1 Figures & Tables

Figure 1A: The Browns River watershed

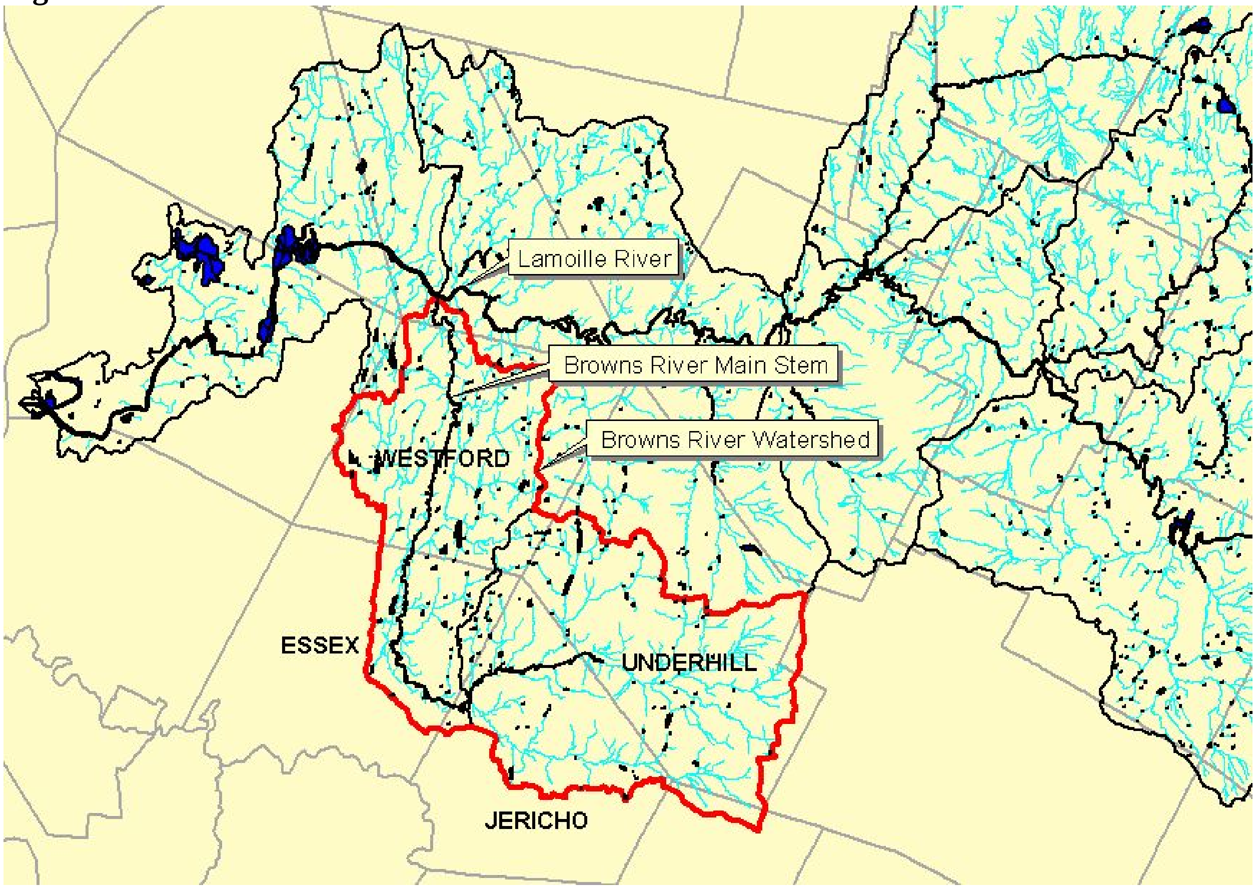


Figure 2A: Browns River watershed reach identification map

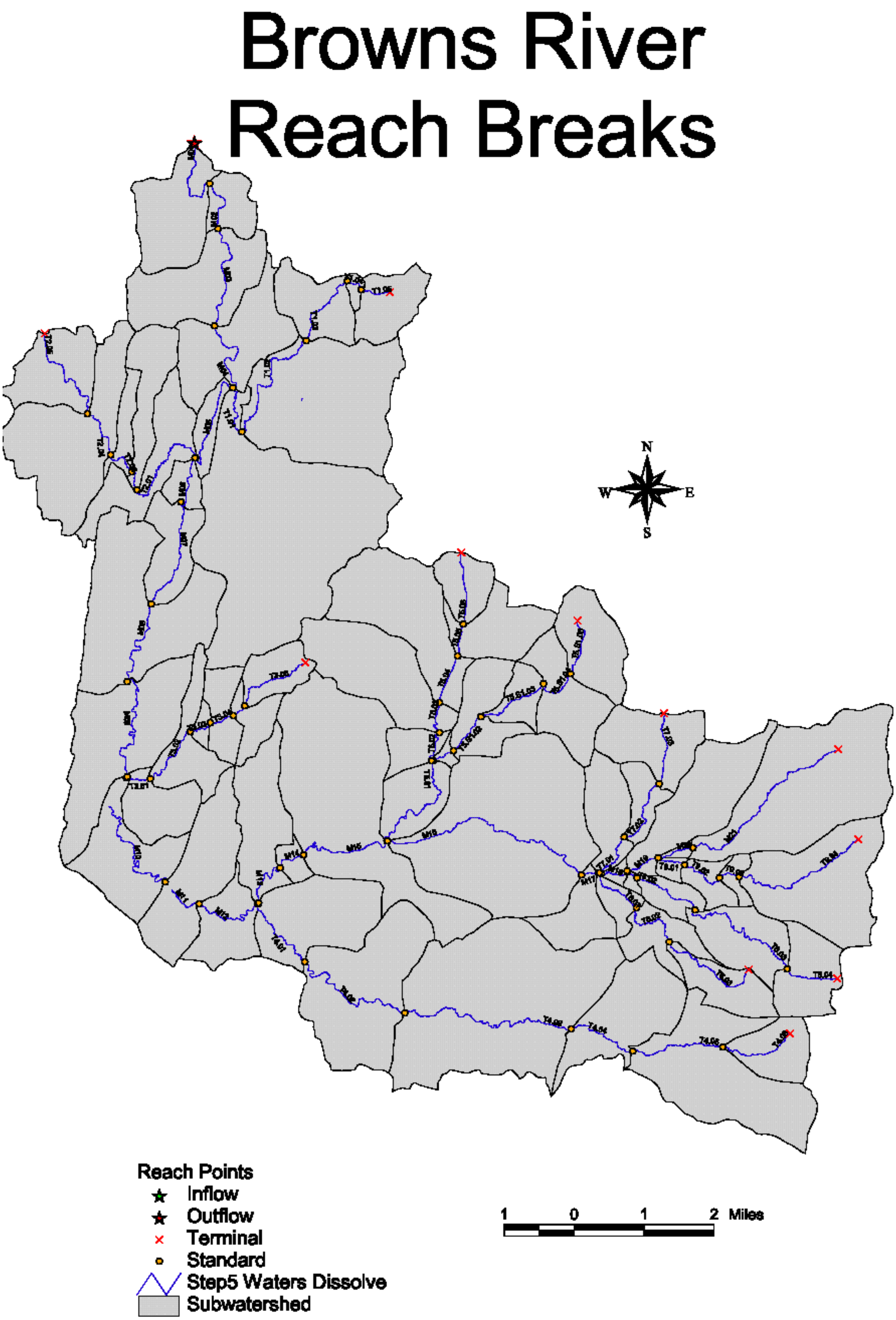
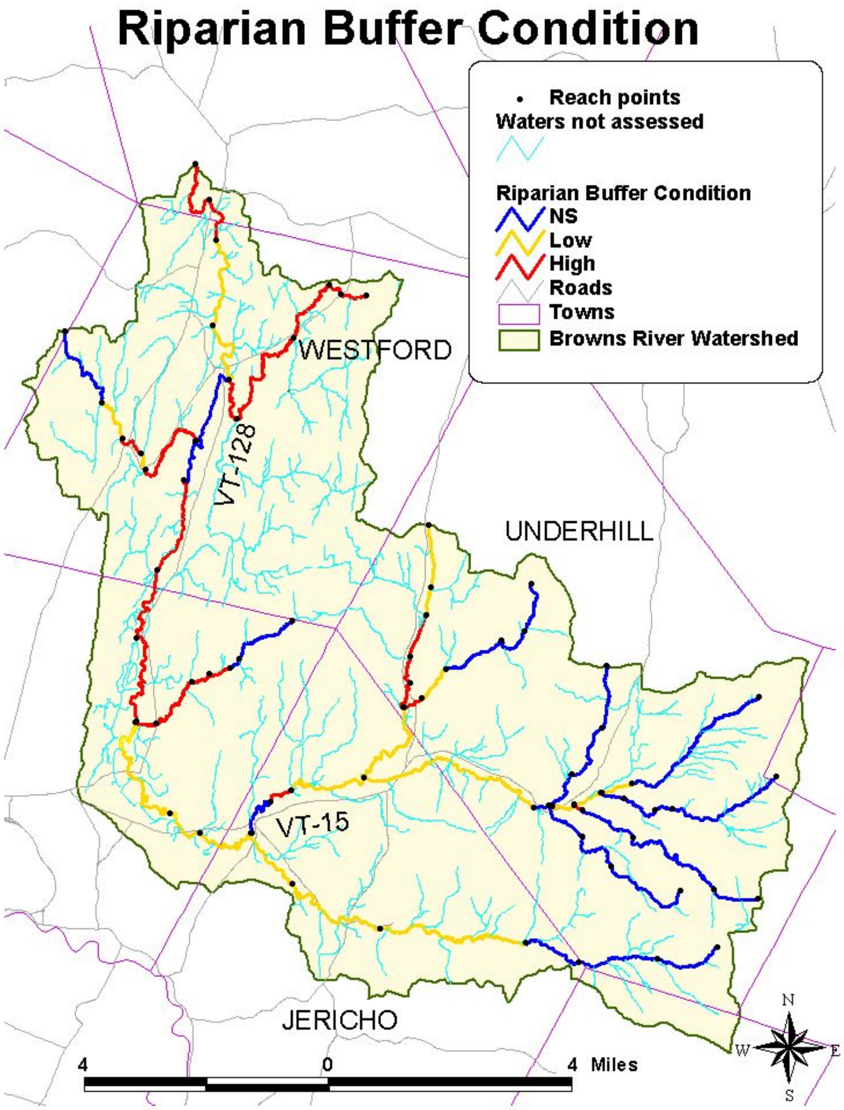


Figure 3A: Phase 1 assessed riparian buffers in the Browns River watershed



NS = "*Not Significant*" denoting areas where less than 25% of reach has little or no buffer (0-25') on one of both banks

Figure 4A: Example meeting notification press release

WHAT: Brown's River Watershed Assessment Public Meeting to gather local perspective and concerns before directing water quality improvements throughout the Brown's River watershed.

<u>WHERE</u>: Underhill Town Hall, upstairs conference room

<u>WHEN</u>: Tuesday December 16th, 2003

<u>TIME</u>: 6:30 – 8:00 pm (Beginning with refreshments)

The Winooski Conservation District, Chittenden County Regional Planning Commission and State of Vermont have partnered in a collaborative effort to assess the Brown's River watershed, focusing on the main stem and major tributaries. Our goal is to determine the sources of stream bank erosion that have caused the Brown's River to be listed on the state's Impaired Waters list for sedimentation.
We are currently in Phase I of the stream assessment, which has primarily been GIS map work and some field surveying. Next summer we will begin the second phase, which consists of more mapping and field analysis of severe erosion sites. We are looking to share the data collected thus far as well as discuss areas of concern in the watershed. Receiving public input is extremely important to the success of the assessment. We are also looking for volunteers who would be interested in helping us during Phase II to *"protect the best and restore the rest"*.

If you are interested in participating in the assessment or cannot attend this meeting but would like more information, please contact Abbey Willard at the Winooski Conservation District office at (802) 828-4493.

Figure 5A: Underhill Town Plan Revision suggestions

Underhill Town Plan Renewal Zoning Suggestions

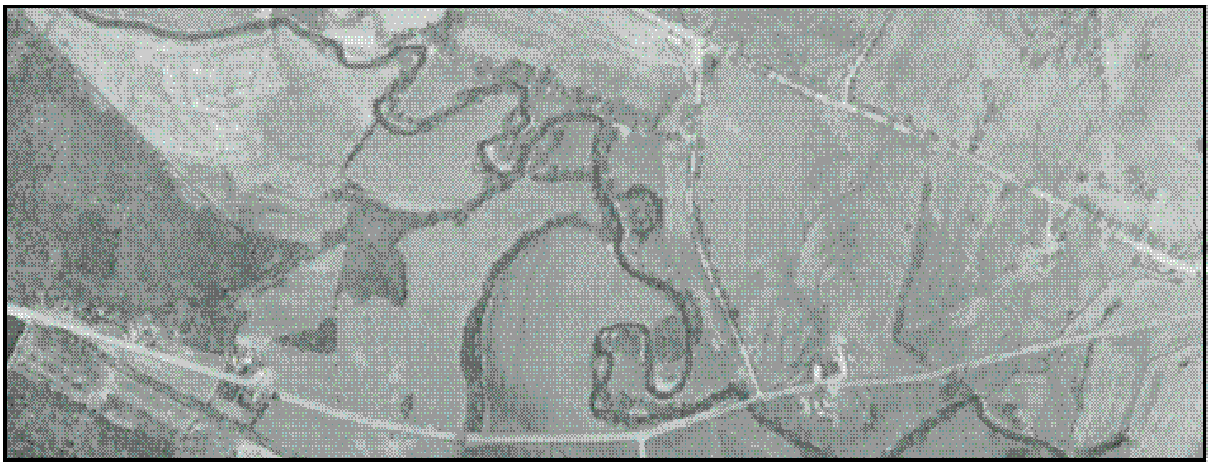
Watershed planning is an integrated ecosystem approach to land use planning that is governed by the limits of the watershed. Managing a watershed differ from many municipal responsibilities because it is governed by geographic and not political boundaries. Local government is a critical stakeholder with respect water resource management because it has the necessary understanding of the public perception and priorities. Management of water resources requires a combination of both regulatory and non-regulatory strategies. Regulatory strategies require government action. The traditional strategies include: zoning, subdivision control and wetland protection. Individuals outside but in concert with the local government usually perform the non-regulatory strategies.

In December 2003 the *Agency of Natural Resources* completed Phase I of the geomorphic assessment of the Brown's River Watershed. This assessment aims to determine why the watershed is impaired and equally important, to identify the most vulnerable areas. A Phase II assessment is scheduled for the watershed and will provide a detailed analysis of the ecosystem. Underhill has a special interest in the health of the watershed because the headwaters for Browns River commence in Underhill and flow north through the town and eventually drain into the Lamoille River. Therefore, any future amendments to Underhill's regulatory tools will aim to support the findings of these two studies intended to manage effectively water resources within the Browns River Watershed.

Suggestions provided by Ian MacDougall, CCRPC, to the Town of Underhill to consider for inclusion in their 2004 town plan renewal. Results were gathered from the Phase I assessment on the Brown's River watershed

Figure 6A: Historic comparison depicting channel modification on Reach M11

Browns River - Reach M11



1962 - Aerial Photo of Reach M11

1999 - Digital Orthophoto of Reach M11

Table 1A. Summary of Phase 1 stream types and total impact scores in the Browns River watershed

Reach Number	Stream Type	Bed Feature	Watershed Size	Confinement	Total Impact Score (out of 32)
T9.01			3.06		2.00
T5.S1.03			2.78	3-VB	5.00
T5.06			0.62	3-VB	7.00
T5.05			1.63	3-VB	7.00
T5.04			3.85	3-VB	8.00
T5.S1.02			3.74	3-VB	9.00
T5.02			6.21	3-VB	9.00
T5.03			5.79	3-VB	9.00
T2.02			5.00	3-VB	10.00
T5.01			10.87	3-VB	11.00
T4.03			10.86	3-VB	13.00
T8.04	A		0.99		0.00
T5.S1.05	A		1.14		0.00
T4.05	A		3.67		0.00
T4.06	A		0.79		0.00
T6.03	A		0.81		1.00
T5.S1.04	A		2.32		2.00
M21	A	Step-Pool	3.64	1-NC	2.00
T9.04	A		2.39		2.00
T9.02	A		2.94		3.00
T9.03	A	Plane Bed	2.58		3.00
M20	A	Step-Pool	6.76	1-NC	6.00
T8.03	B		2.08		0.00
T3.05	B		1.06		2.00
T3.06	B		0.62		2.00
T2.05	B		1.18		3.00
T7.03	B		1.23		4.00
T7.02	B	Riffle-Pool	1.70		4.00
T7.01	B	Riffle-Pool	2.58		7.00
M13	B	Step-Pool	53.89	2-NW	8.00
T4.04	B		5.38		9.00
T1.04	B		0.91	3-VB	9.00
T6.01	B	Riffle-Pool	1.81		10.00
T6.02	B	Riffle-Pool	1.51		10.00
T8.02	B	Step-Pool	2.47	3-VB	11.00
M04	B	Plane Bed	88.47	2-NW	15.00
T5.S1.01	B	Riffle-Pool	3.81	3-VB	17.00
M18	B	Plane Bed	11.09	1-SC	18.00
T8.01	B		2.52	3-VB	18.00
M03	C		90.29	3-BD	7.00
T2.01	C		6.27	3-VB	8.00
T1.05	C		0.82		10.00
M19	C		8.49	3-VB	10.00
M01	C	Riffle-Pool	92.32	3-BD	11.00

T3.02	C	Riffle-Pool	2.64	3-VB	12.00
M05	C	Riffle-Pool	75.18	3-BD	12.00
M06	C		68.54	3-BD	12.00
T2.03	C	Riffle-Pool	4.11	3-VB	13.00
T1.01	C	Riffle-Pool	11.57	3-VB	13.00
M14	C		37.11	3-VB	15.00
M17	C	Riffle-Pool	16.22	3-VB	15.00
M15	C	Riffle-Pool	36.90	3-VB	16.00
M16	C	Riffle-Pool	32.23	3-VB	16.00
T3.01	C	Riffle-Pool	3.50	3-VB	17.00
T3.03	C	Riffle-Pool	1.76	3-VB	20.00
T2.04	E	Dune-Ripple	3.74	3-VB	10.00
T1.03	E	Dune-Ripple	1.85	3-VB	11.00
M02	E	Dune-Ripple	90.83	3-BD	13.00
T3.04	E	Dune-Ripple	1.63	3-VB	14.00
T1.02	E	Dune-Ripple	5.31	3-VB	16.00
M07	E	Dune-Ripple	68.24	3-VB	17.00
T4.01	E	Dune-Ripple	15.41	3-VB	17.00
M11	E	Dune-Ripple	56.58	3-VB	18.00
T4.02	E	Dune-Ripple	13.64	3-VB	18.00
M09	E	Dune-Ripple	64.21	3-VB	20.00
M08	E	Dune-Ripple	67.36	3-VB	21.00
M10	E	Dune-Ripple	58.11	3-VB	21.00
M12	E	Riffle-Pool	54.79	3-VB	22.00

Table 2A: Significant Phase 1 Parameters and High Impact Scores in the watershed

Stream Reaches	4.1 Watershed lc/lu	4.2 Corridor lc/lu	4.3 Riparian buffer width	5.4 Channel Modifications	5.5 Dredging & Gravel Mining History	6.3 Depositional Features	6.4 Meander Migration/ Channel Avulsions	6.5 Meander Width Ratio	Bridge & Culvert Survey	Most Impacted Reaches
Abbey Brook										
T3.01	H	H	H	H				H	H	*
T3.02	H	H	H					H	H	*
T3.03	H	H	H			H		H	H	*
T3.04	H	H	H					H	H	*
T3.05		H								
T3.06		H								
% of High Impact Scores within the Stream	67%	100%	67%	17%	0%	17%	0%	67%	67%	
Browns River										
M01	H	H	H					H		
M02	H	H	H					H	H	*
M03	H	H						H		
M04	H	H						H	H	
M05	H	H						H		
M06	H	H		H				H		
M07	H		H	H			H	H	H	*
M08	H	H	H	H			H	H	H	*
M09	H	H	H	H			H		H	*
M10	H	H		H		H	H	H	H	*
M11	H	H		H	H	H	H	H		*
M12	H	H		H	H	H	H		H	*
M13	H	H							H	
M14	H	H	H	H			H	H		*
M15	H	H		H	H	H	H		H	*
M16	H	H		H	H	H	H			*
M17	H	H			H	H			H	*
M18		H		H		H		H	H	*
M19		H				H		H		
M20		H							H	
M21										
% of High Impact Scores within the Stream	81%	90%	29%	52%	24%	38%	43%	62%	57%	
Clay Brook										
T8.01		H	H	H		H		H	H	*
T8.02		H		H					H	
T8.03										
T8.04										
% of High Impact Scores within the Stream	0%	50%	25%	50%	0%	25%	0%	25%	50%	

Crane Brook										
T7.01	H	H							H	*
T7.02	H									
T7.03	H	H								
% of High Impact Scores within the Stream	**100%**	**67%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**33%**	
Lee River										
T4.01	H	H		H	H	H	H	H	H	*
T4.02	H	H			H	H		H		*
T4.03		H		H	H	H	H			*
T4.04		H						H		
T4.05										
T4.06										
% of High Impact Scores within the Stream	**33%**	**67%**	**0%**	**33%**	**50%**	**50%**	**33%**	**50%**	**17%**	
Morgan Brook										
T1.01	H	H	H						H	*
T1.02	H		H					H	H	*
T1.03	H	H	H					H		*
T1.04	H	H	H							
T1.05	H	H	H					H		*
% of High Impact Scores within the Stream	**100%**	**80%**	**100%**	**0%**	**0%**	**0%**	**0%**	**60%**	**40%**	
Roaring Brook										
T5.S1.01	H	H	H					H	H	*
T5.S1.02	H	H						H		
T5.S1.03										
T5.S1.04										
T5.S1.05										
% of High Impact Scores within the Stream	**40%**	**40%**	**20%**	**0%**	**0%**	**0%**	**0%**	**40%**	**20%**	
Rogers Brook										
T2.01	H	H	H							
T2.02	H							H	H	
T2.03	H	H	H					H	H	*
T2.04	H							H	H	
T2.05		H								
% of High Impact Scores within the Stream	**80%**	**60%**	**40%**	**0%**	**0%**	**0%**	**0%**	**60%**	**60%**	
Steinhour Brook										
T6.01	H	H								*
T6.02		H				H				*
T6.03										
% of High Impact Scores within the Stream	**33%**	**67%**	**0%**	**0%**	**0%**	**33%**	**0%**	**0%**	**0%**	

Stevensville Brook										
T9.01										
T9.02										
T9.03		H								*
T9.04										
% of High Impact Scores within the Stream	**0%**	**25%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	
The Creek										
T5.01	H	H						H		*
T5.02	H		H					H		*
T5.03	H		H					H		*
T5.04	H		H					H		*
T5.05	H							H		
T5.06	H							H		
% of High Impact Scores within the Stream	**100%**	**17%**	**50%**	**0%**	**0%**	**0%**	**0%**	**100%**	**0%**	

Phase 2 Figures & Tables

Figure 7A: Phase 1 Stream Types

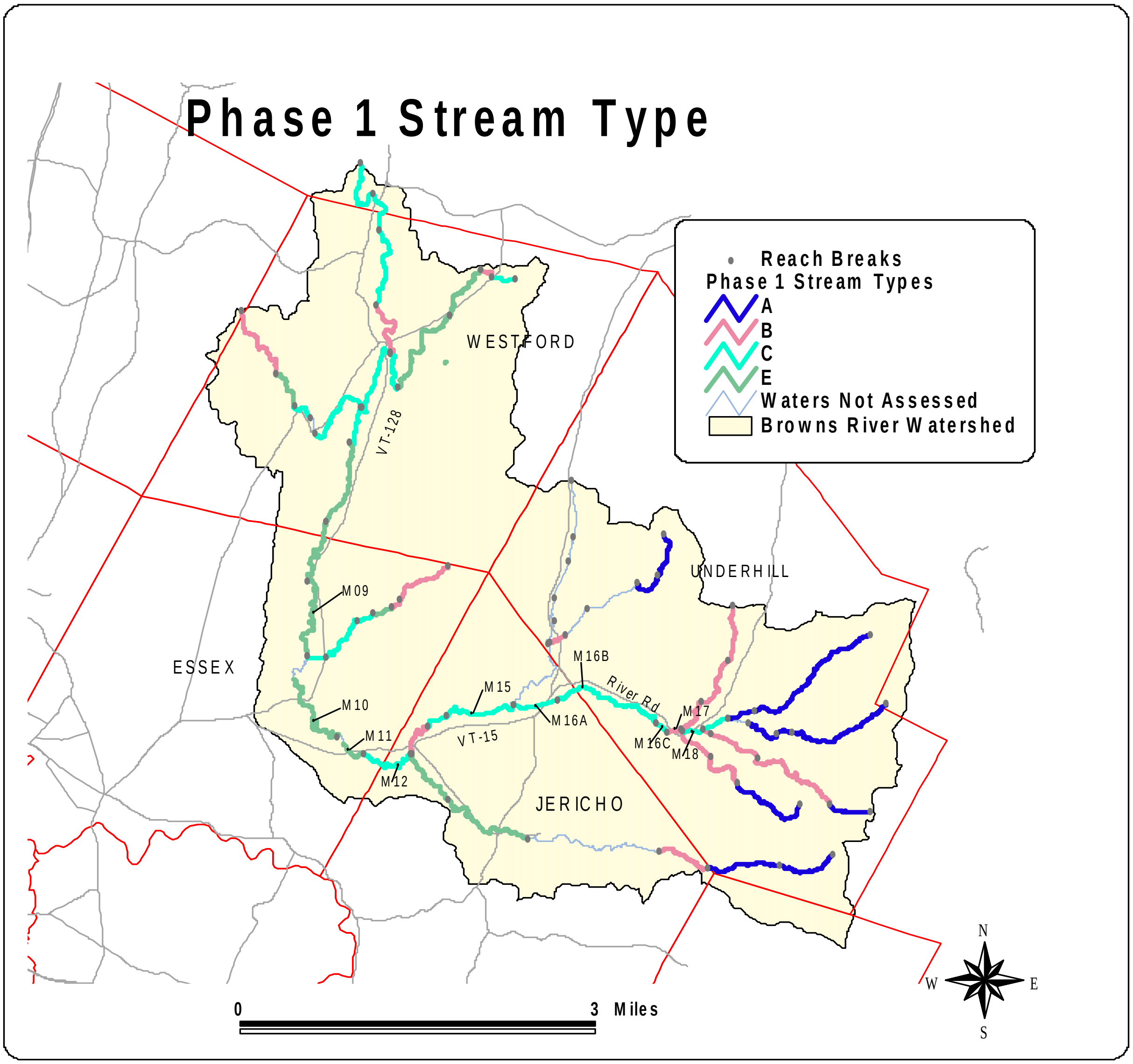


Figure 8A: Phase 2 Stream Types

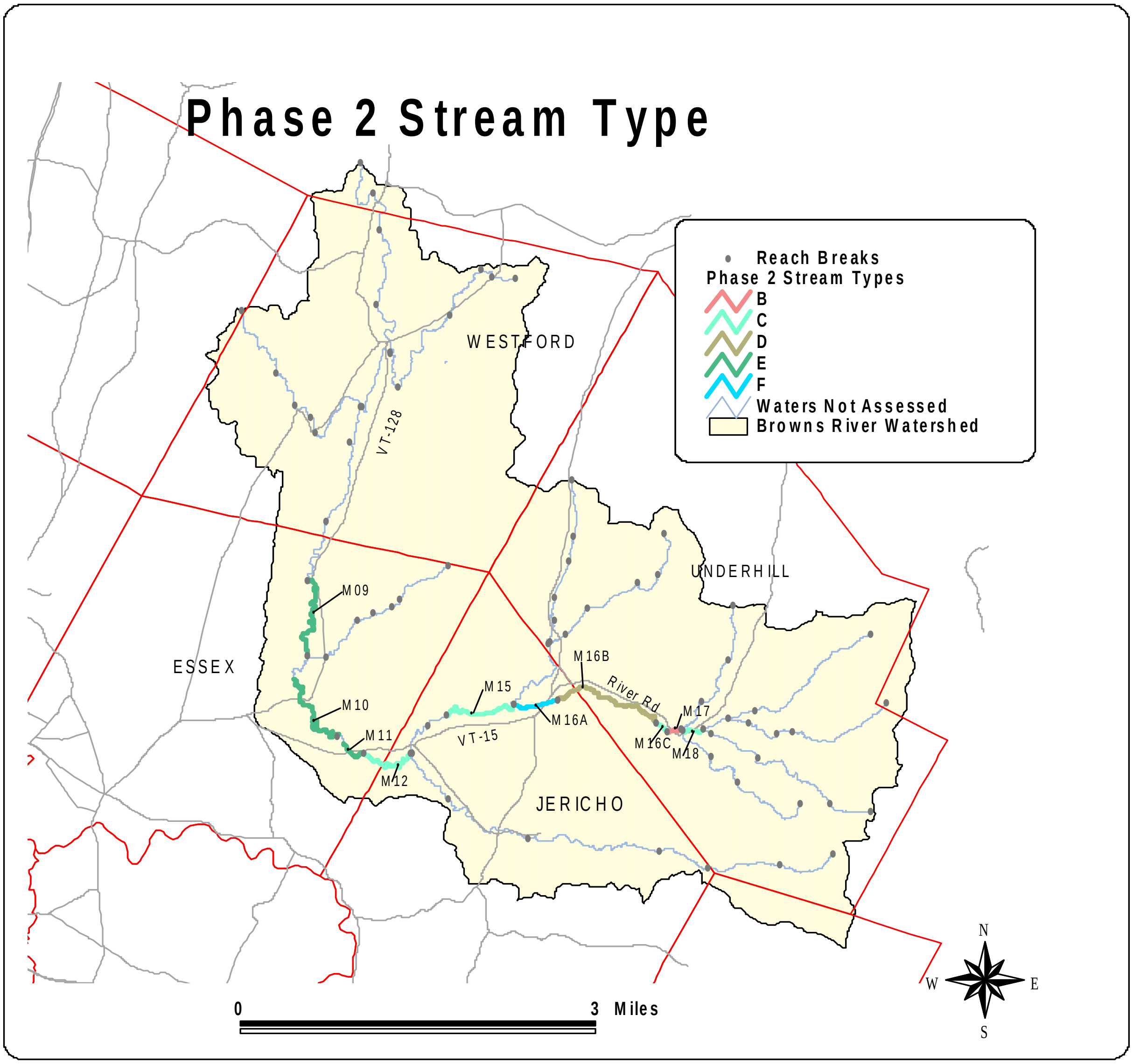
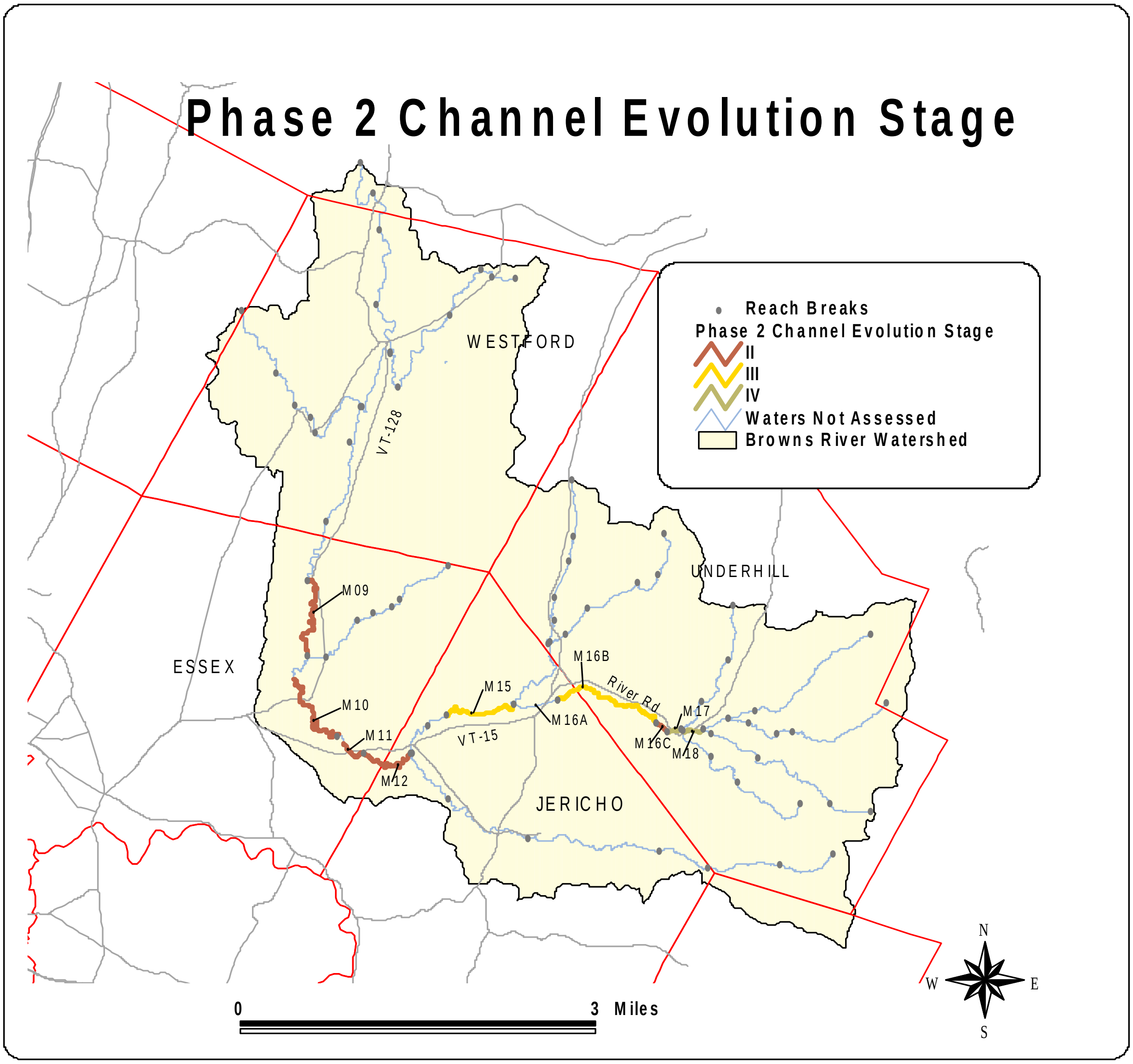


Figure 9A: Phase 2 Reach/Segment Channel Evolution Stage



Phase 10A: Phase 2 Reach/Segment Stream Sensitivity

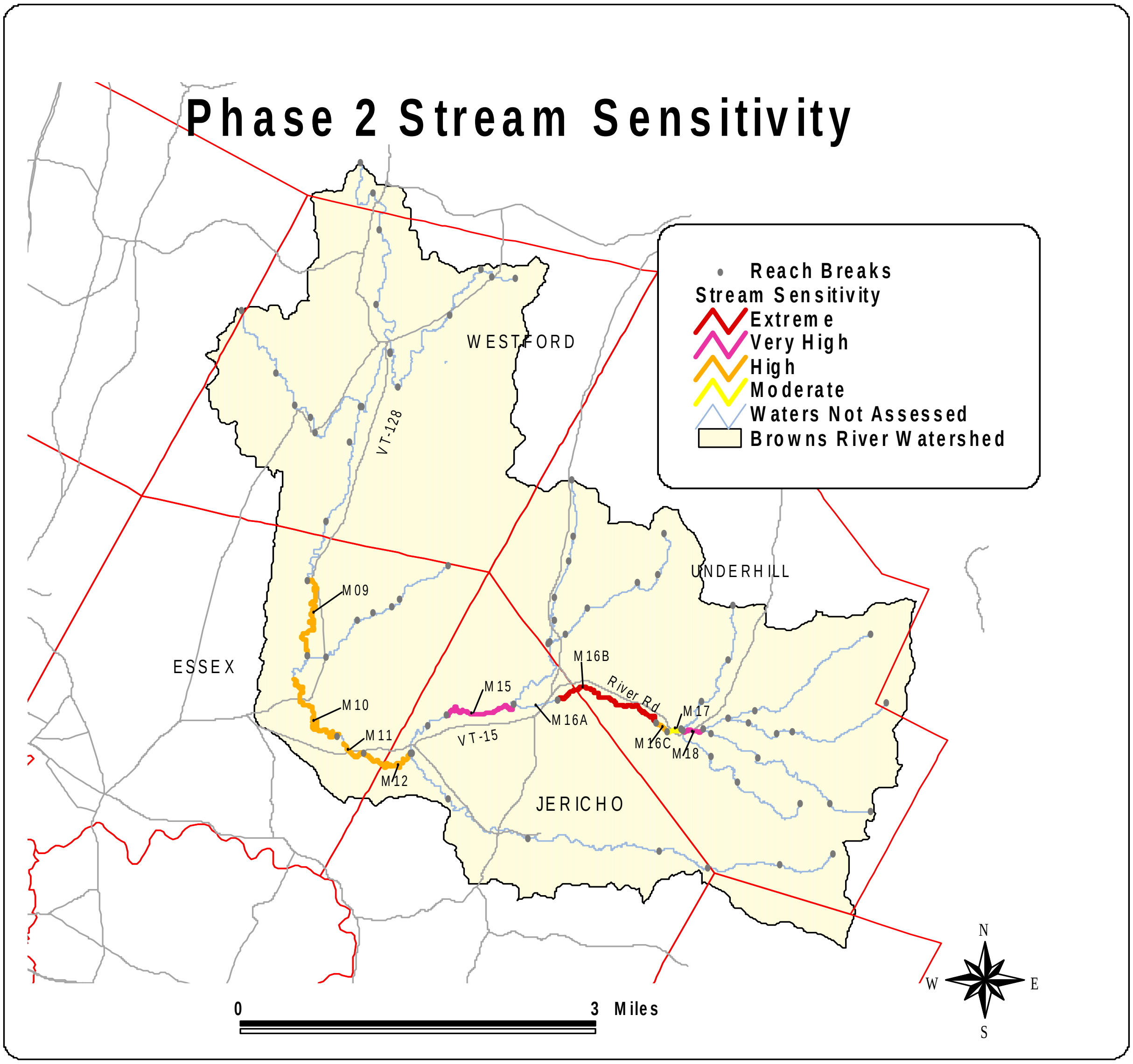


Figure 11A: Phase 2 Habitat Condition Ratings

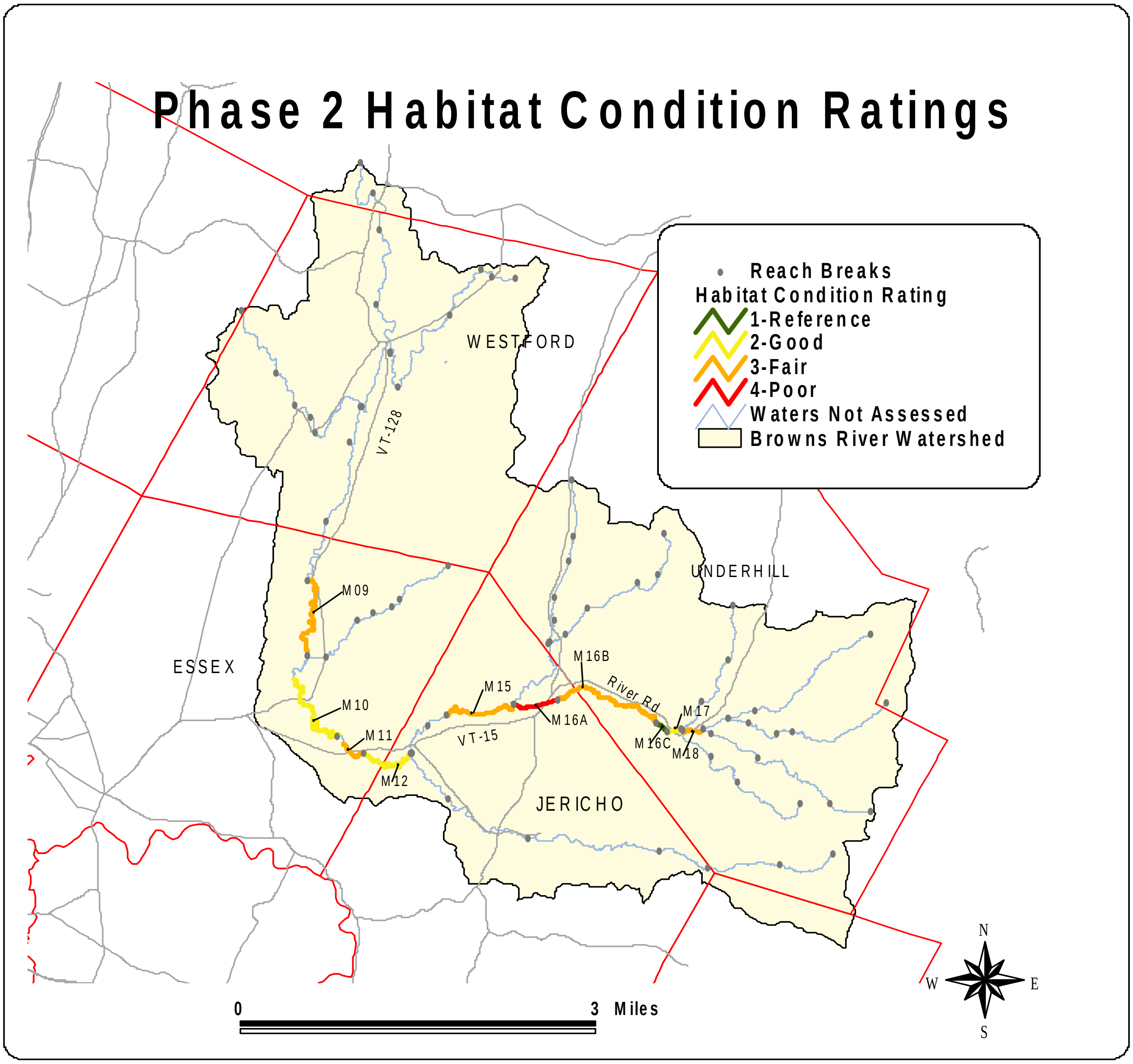


Figure 12A: Phase 2 Geomorphic Condition Ratings

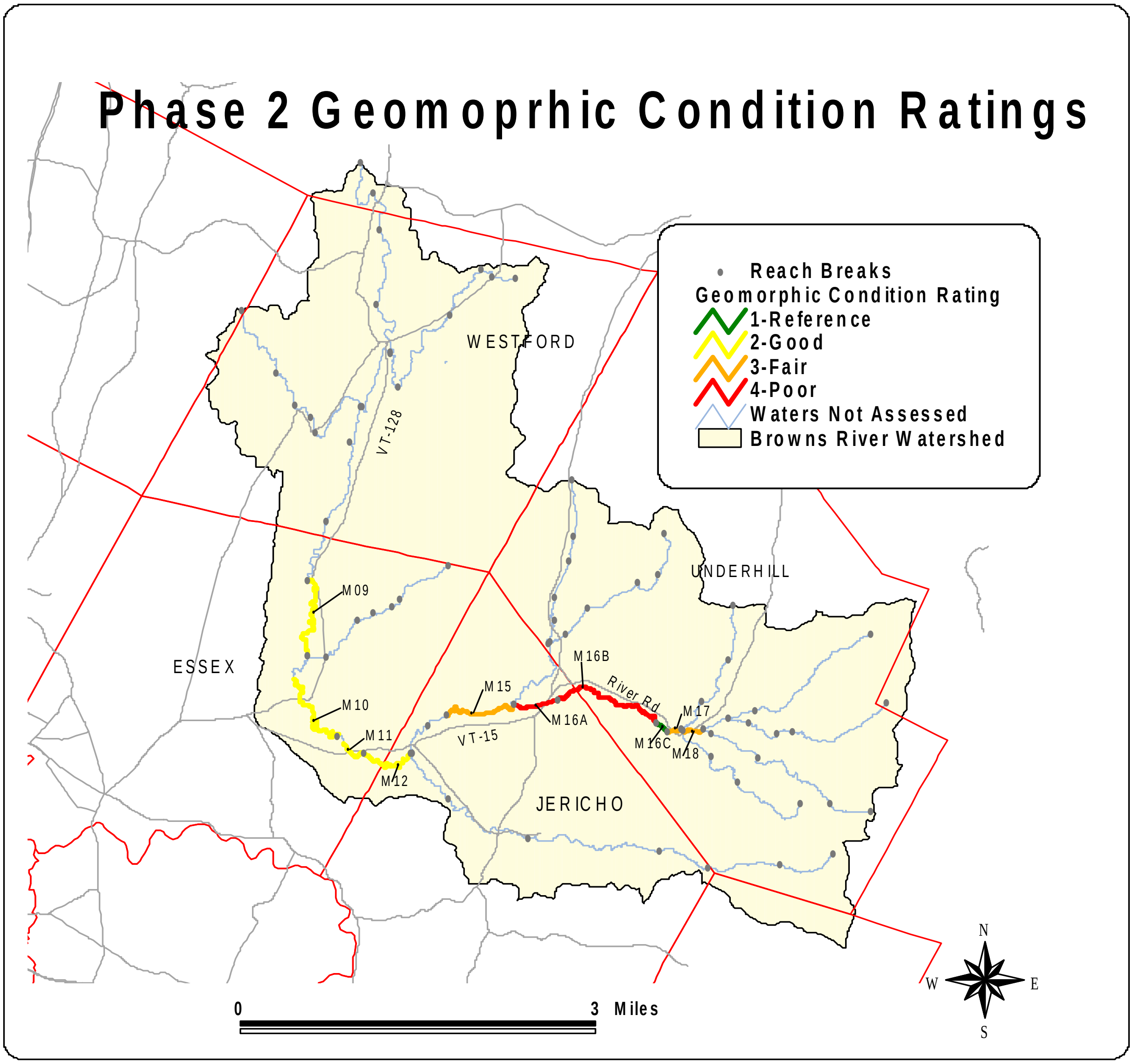


Figure 13A: Phase 2 Incision Ratios

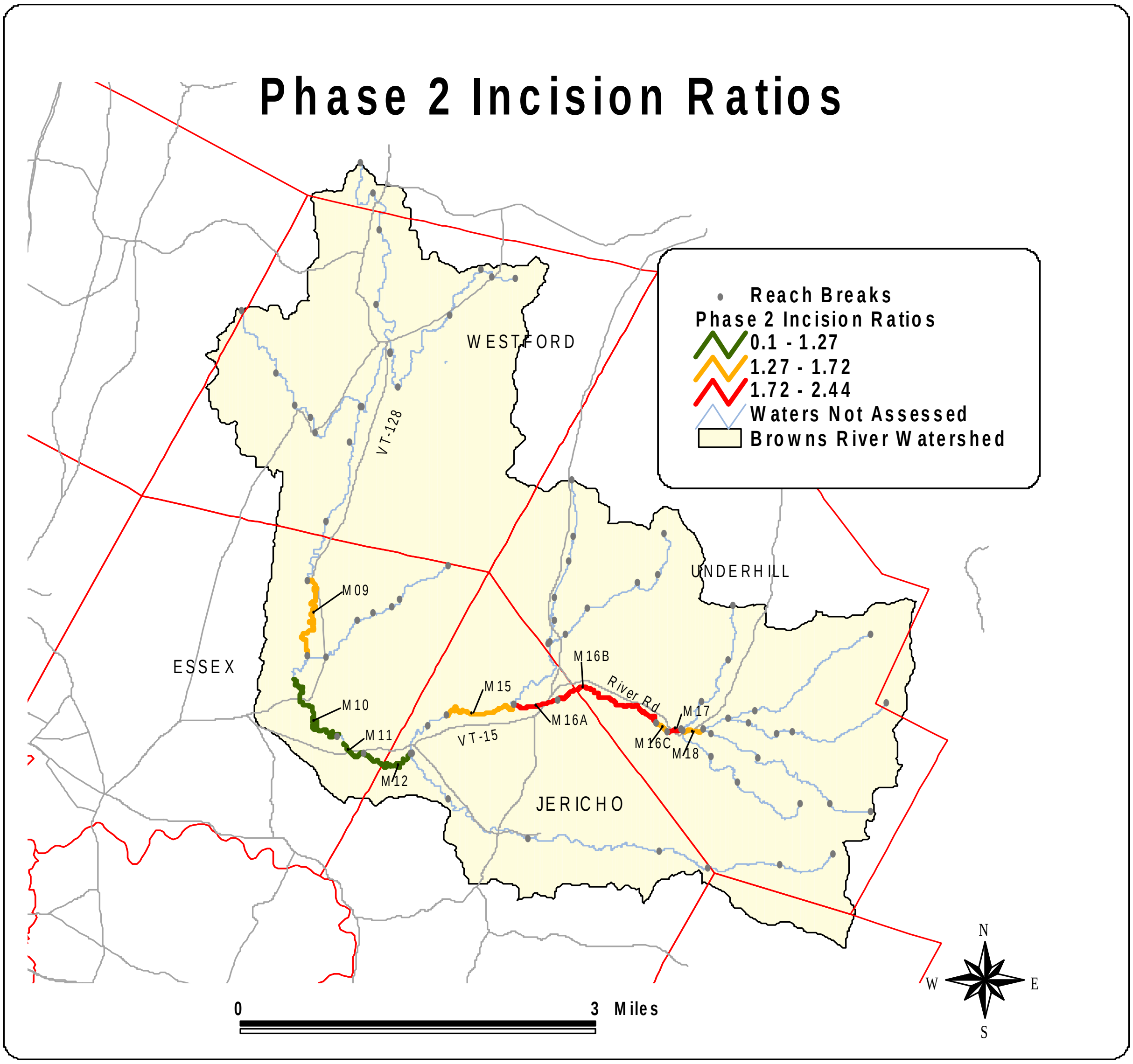


Figure 14A: Phase 2 Entrenchment Ratios

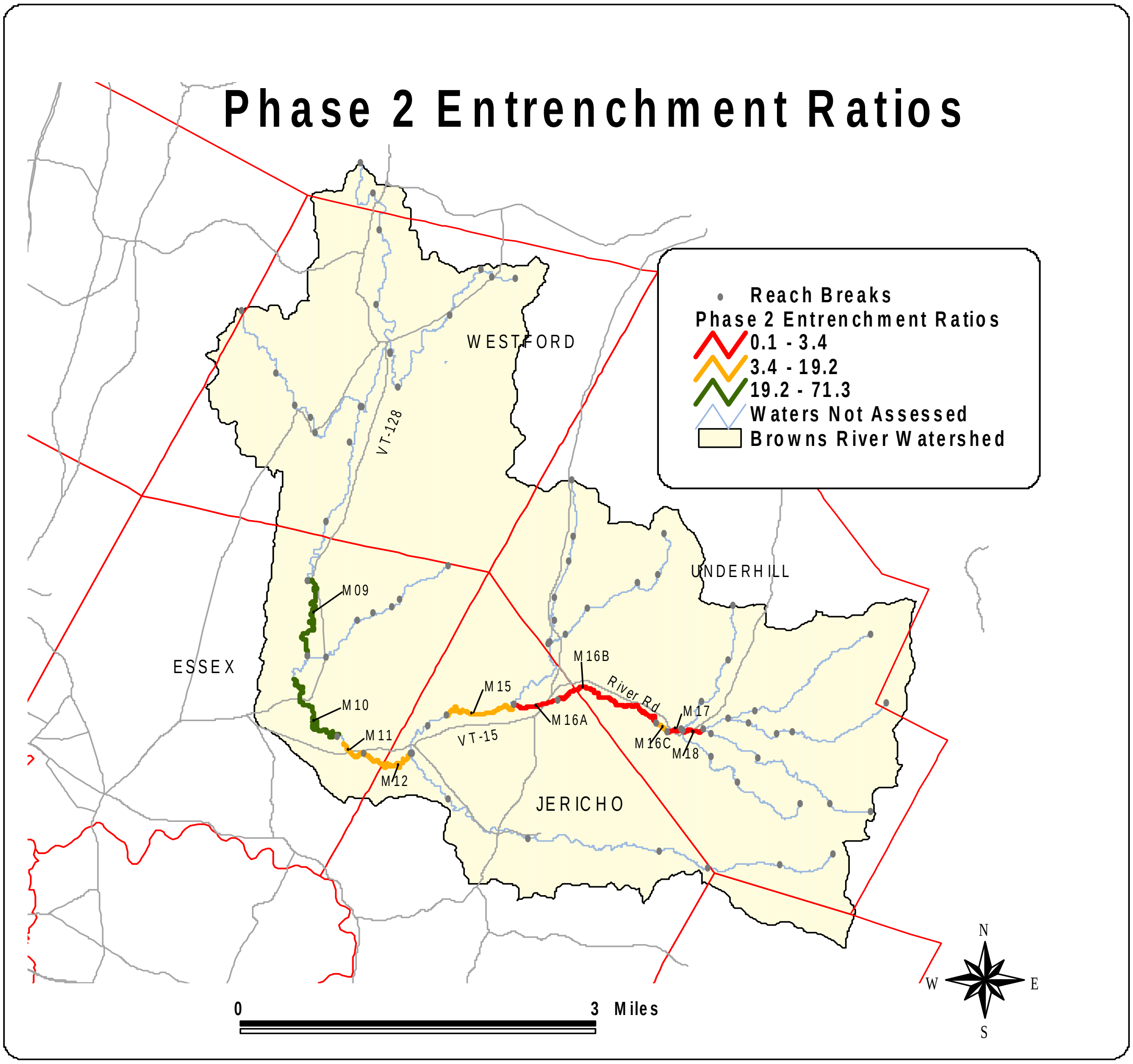


Figure 15A: Phase 2 Channel Adjustment Processes

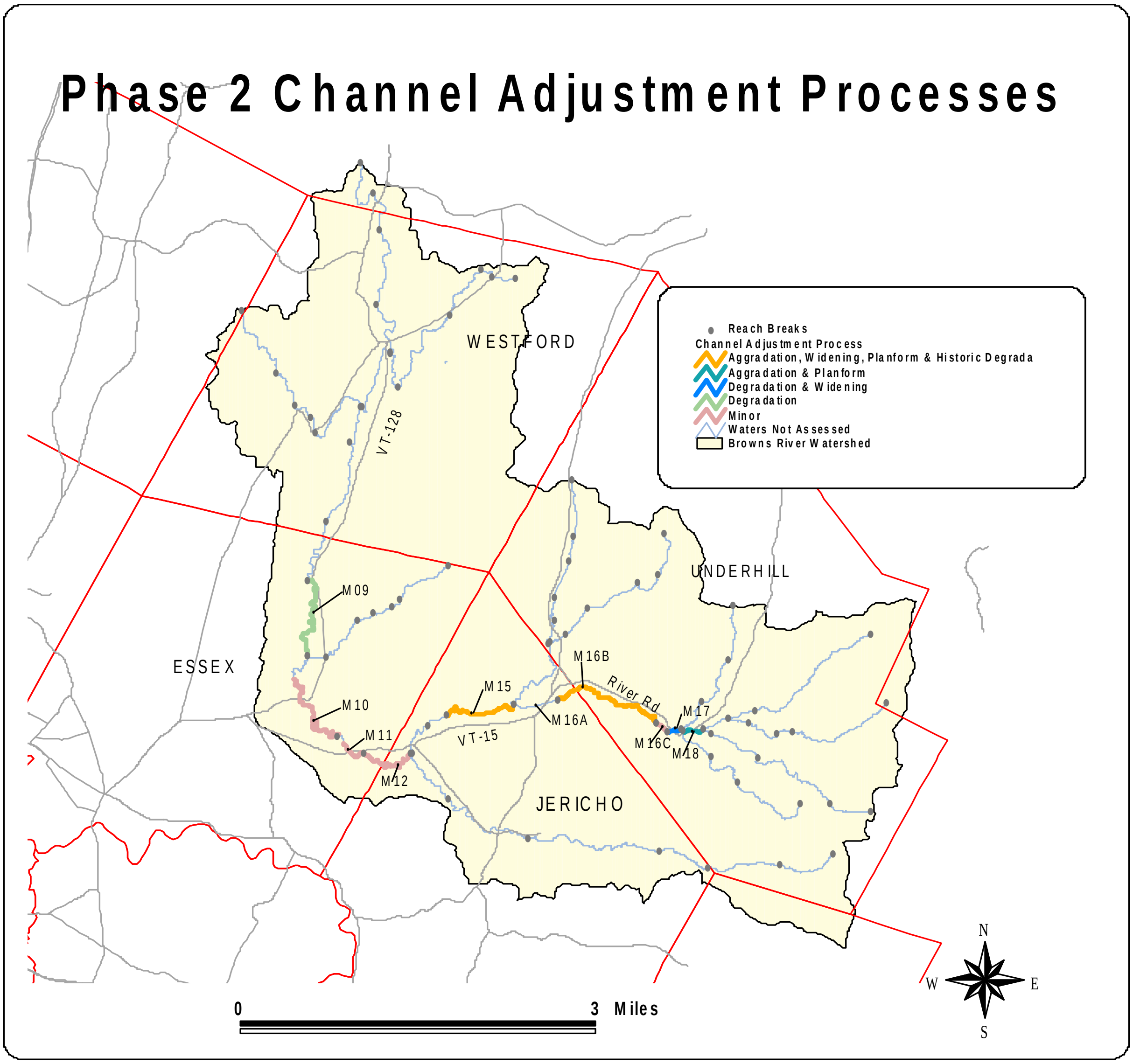


Figure 16A: Phase 2 dominant forested riparian buffer widths

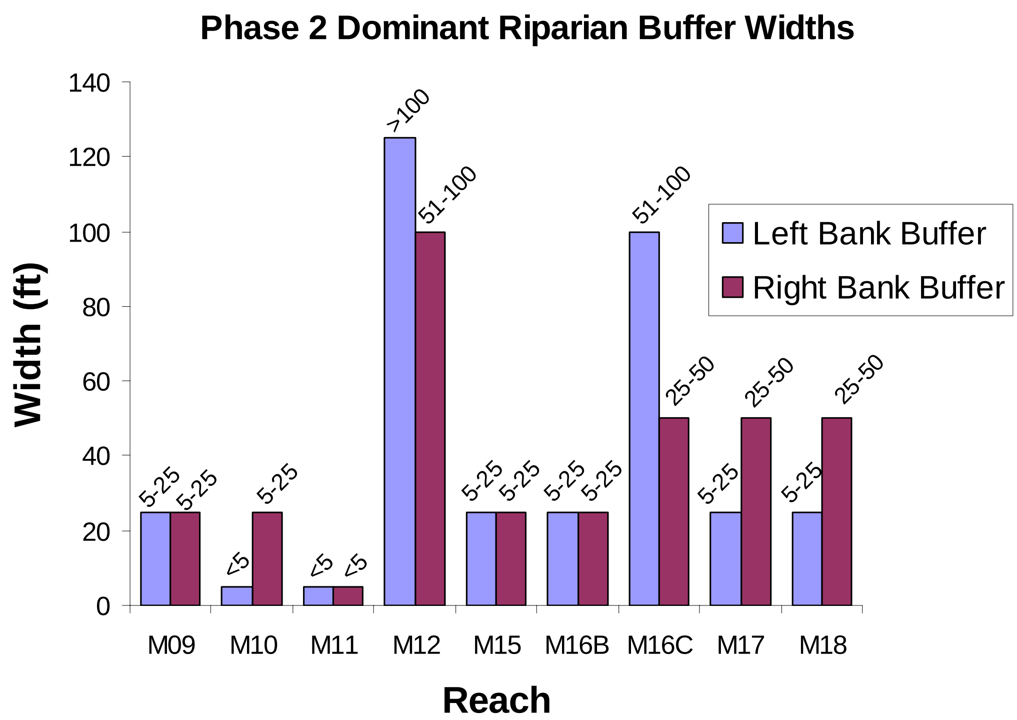


Figure 17A: Phase 2 Bank Revetments

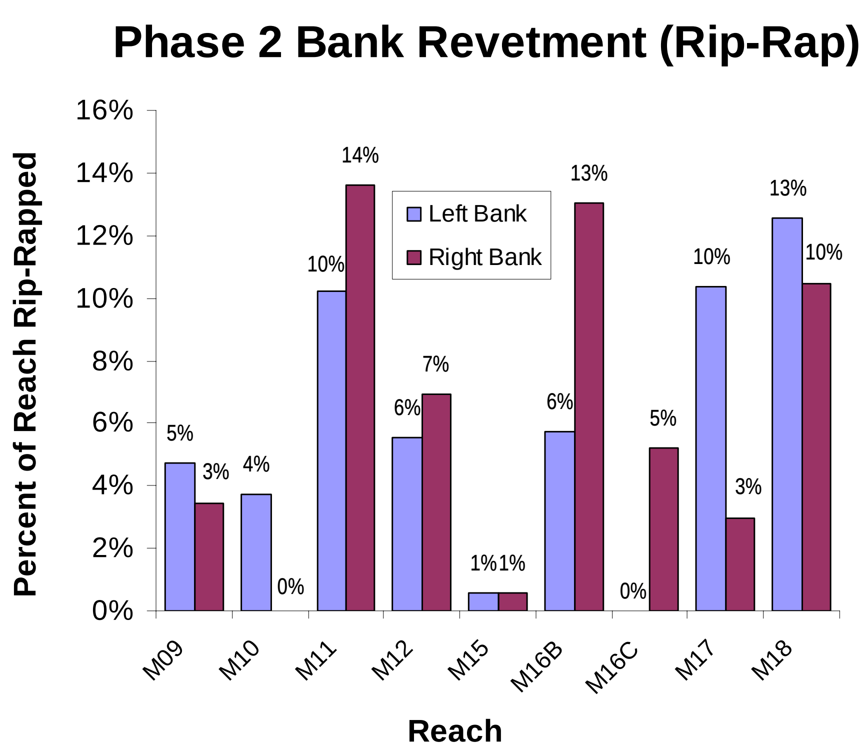


Figure 18A: Phase 2 % Erosion

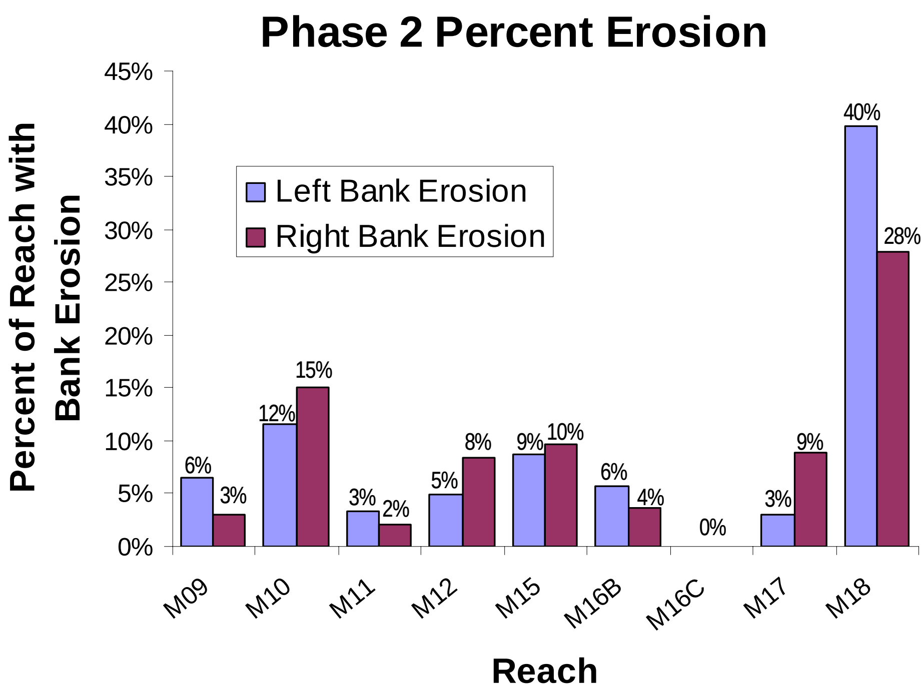


Table 3A: Phase 2 Bridge & Culvert Assessment Results

Structures Assessed in Phase 2[a]							
Structure #	***Type***	***Reach***	***Town***	***Span* (ft)***	***Bankful Width (ft)***	***Span/BW (%)***	***Undersized?***
011-F	Bridge	M9	Essex	36	37.7	95%	Yes
012-I	Bridge	M9	Essex	30	37.7	80%	Yes
013-H	Bridge	M9	Essex	20*	37.7	53%	Yes
014-G	Bridge	M9	Essex	30*	37.7	80%	Yes
015-E	Bridge	M10	Essex	80	62.6	128%	No
016-D	Bridge	M10	Essex	40*	62.6	64%	Yes
017-C	Bridge	M10	Essex	#	62.6		
018-B	Bridge	M11	Essex	75	55	136%	No
019-A	Bridge	M12	Essex	#	78		
022	Bridge	M15	Jericho	82	86.8	94%	Yes
023	Bridge	M16A	Underhill	82	54	152%	No
024	Bridge	M17	Underhill	55	71	77%	Yes
028	Culvert	M17	Underhill	10*	71	13%	Yes
025	Bridge	M18	Underhill	57	42	136%	No

[a] Structures shaded in orange are significantly undersized (span <70% bankfull width)

* estimated span

Spans have not yet been measured, or only abutments exist, but structure is presumed undersized.

Table 4A: Phase 1 Bridge Results

Bridges Assessed in Phase 1[a]							
Bridge #	***Reach***	***River Name***	***Town***	***Span* (ft)***	***Channel Width (ft)***	***Span/CW (%)***	***Undersized?***
001-R	M1	Browns	Fairfax	118	98	120%	No
002-Q	M2	Browns	Fairfax	70	97	72%	Yes
003-P	M4	Browns	Westford	75	96	78%	Yes
004-O	M5	Browns	Westford	70	88	80%	Yes
005	M7	Browns	Westford	40	84	50%	Yes
006-L	M7	Browns	Westford	18*	84	21%	Yes
007	M7	Browns	Westford	#	84		
008-J	M8	Browns	Essex	25*	84	30%	Yes
009-Jb	M8	Browns	Essex	67	84	80%	Yes
010-K	M8	Browns	Essex	30*	84	36%	Yes
011-F	M9	Browns	Essex	36	82	44%	Yes
012-I	M9	Browns	Essex	30	82	37%	Yes
013-H	M9	Browns	Essex	20*	82	24%	Yes
014-G	M9	Browns	Essex	30*	82	37%	Yes
015-E	M10	Browns	Essex	80	62	129%	No
016-D	M10	Browns	Essex	40*	62	65%	Yes
017-C	M10	Browns	Essex	#	62		
018-B	M11	Browns	Essex	75	55	136%	No
019-A	M12	Browns	Essex	#	75		
020	M13	Browns	Jericho	54	75	72%	Yes
021	M13	Browns	Jericho	52	75	69%	Yes
022	M15	Browns	Jericho	82	62	132%	No
023	M16	Browns	Underhill	82	58	141%	No
024	M17	Browns	Underhill	55	41	134%	No
025	M18	Browns	Underhill	57	34	133%	No
032	M19	Browns	Underhill	35	30	117%	No
026	M20	Browns	Underhill	17	26	65%	Yes
056	T1.1	Morgan	Westford	12*	35	34%	Yes
053	T2.3	Rogers	Westford	9.5	21	45%	Yes
042	T4.1	Lee	Jericho	65	40	163%	No
044	T4.2	Lee	Jericho	44.5	38	117%	No
045	T4.2	Lee	Jericho	80.6	38	212%	No
046	T4.2	Lee	Jericho	51	38	134%	No
AG MC 0005 (1)	T4.2	Lee	Jericho	80	38	211%	No
041	T5.1 S1.1	Roaring	Underhill	57	20	285%	No
039	T6.1	Browns	Underhill	17.5*	14	125%	No
037	T6.1	Steinhour	Underhill	60	14	429%	No
030	T8.1	Clay	Underhill	16	16	100%	No
033	T8.2	Clay	Underhill	25	16	156%	No
034	T8.2	Clay	Underhill	14	16	88%	Yes
031	T9.3	Stevensville	Underhill	23	16	144%	No

[a] Structures shaded in orange are significantly undersized (span <70% channel width)

* estimated span

Spans have not yet been measured, or only abutments exist, but structure is presumed undersized.