Browns River Corridor Plan
Browns River Watershed
Chittenden and Franklin Counties, Vermont

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Executive Summary

The Browns River Watershed has a watershed size of approximately 92 square miles. The Browns River is a tributary of the Lamoille River. Watershed origins include the towns of Bolton, Stowe, Jericho, Underhill, Essex, Westford and Fairfax, as such, reaching three counties in Vermont-Lamoille, Chittenden and Franklin. The towns of Underhill, Jericho, Westford and Essex through their Conservation Commissions and Planning Commissions are committed to protecting, enhancing and improving the health of the Browns River and its tributaries.

In the winter of 2007 the Winooski Natural Resources Conservation District, as part of a project funded by the Vermont Department of Environmental Conservation River Corridor Grant Program, initiated development of a community-based river corridor management plan for the main branch of the Browns River and select tributaries. Phase I and Phase 2 Stream Geomorphic Assessments were conducted for the Browns River Watershed. The Phase 1 assessments identified priority reaches for the Phase 2 assessments. The assessments were completed by the Winooski Conservation District and Arrowwood Environmental over the course of approximately 5 years. This Corridor Plan focuses on the twenty-two Phase 2 assessed stream reaches.

The Browns River watershed study area is characterized by a combination of agricultural, forest and residential landuses. There is a significant agricultural presence within the river valley of the Browns River with increasing residential development in the surrounding woodlands. The lower reaches of the Browns River are less developed and contain higher percentages of agriculture and forest land in comparison to the upper reaches and the assessed tributaries.

Many land uses are incompatible with the meandering and ever-changing nature of rivers and streams. Rivers and streams are often straightened, armored, dredged, bermed, or encroached upon to protect property investments or to make floodplain available for other land uses. Channel straightening and bank armoring remove or alter natural meanders, while undersized bridges and culverts act as channel constrictions, forcing the stream to flow faster through a narrow area. These channel alterations directly affect the stream by increasing its slope and power, resulting in areas of bed and bank erosion.

Streams naturally exhibit erosion and deposition processes. When systems are not in equilibrium, the degree and rate of erosion may overwhelm the streams natural ability to transport sediment and natural depositional processes. Sedimentation and associated degradation of aquatic habitat are concerns in the Browns River and its tributaries. At the watershed scale, erosive materials present in upper sideslopes of steep valley walls, alluvial soils on exposed streambanks, and bed materials contribute to a high sediment-load system. Geomorphic instability related to the downcutting (and loss of floodplain access) of many of the study reaches have resulted in adjustment processes that are manifested largely in redistribution of the sediment loads as the river tries to regain equilibrium and establish a new floodplain.

Watershed and reach scale stressors were evaluated for each study reach including hydrologic alterations, land use and land cover changes, sediment regime stressors, channel slope and depth modifiers, boundary conditions and riparian modifiers. Changes to sediment regime and reach sensitivity to future adjustments were also evaluated. Figures and Tables were created to allow for in-depth evaluation of how each of these stressors has contributed to the current condition of the study reaches, and how that differs from the expected reference (or equilibrium) condition. Restoration and conservation techniques were developed for each reach, and a comprehensive Project and Practices Summary Table was created to prioritize the identified restoration and conservation strategies.

The findings of the Browns River Corridor Plan are summarized as follows:

- Historically, the Browns River watershed acted as a sediment and nutrient attenuation zone, with incoming fine sediments from upstream stored on the floodplain, and inputs of coarse sediment essentially in balance and equal to outputs of coarse sediment.
- The watershed has largely been transformed into a sediment and nutrient source and transport zone where floodplain access is limited and sediment and nutrients are funneled through the system to downstream receiving waters, due to the historic and ongoing adjustment processes and stressors documented in the watershed.
- The highest priority projects developed for the watershed are those that attempt to restore the sediment and nutrient attenuation assets which once dominated the system.
- Other recommended project types include riparian buffer and corridor enhancement to filter out excess nutrients, help stabilize streambanks, restore wetlands, and provide shade and cover to improve aquatic habitat; and replacement of undersized bridges and culverts

to reduce channel constrictions, restore normal flow patterns, and improve aquatic habitat.

This Corridor Plan encourages coordination of landowner and municipal efforts to approach restoration with an eye to watershed scale dynamics. The Winooski Natural Resources Conservation District can play a critical role in coordinating restoration efforts, and this report aims to facilitate such coordination in a way that can help landowners understand the part their properties play within the context of the entire watershed.

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1.0 PROJECT OVERVIEW

Phase I and Phase 2 Stream Geomorphic Assessments were conducted by the Winooski Conservation District for the Browns River Watershed. The Phase 1 assessment team completed steps 1-7 of the Stream Geomorphic Assessment Phase 1 Protocols using the SGAT GIS extension. The Phase 1 assessments identified priority reaches for the Phase 2 assessments. Phase 2 assessments were completed on 8 reaches by the Winooski Conservation District in 2004. An additional 15 reaches were evaluated by Arrowwood Environmental in the summer/fall of 2007.

In the winter of 2007 the Winooski Natural Resources Conservation District, as part of a project funded by the Vermont Department of Environmental Conservation River Corridor Grant Program, initiated development of a community-based river corridor management plan for the main branch of the Browns River and select tributaries.

2.0 INTRODUCTION

The towns of Underhill, Jericho, Westford and Essex through their Conservation Commissions and Planning Commissions are committed to protecting, enhancing and improving the health of the Browns River and its tributaries. The following excerpts are from Town Plans within the Browns River Watershed, and serve to summarize the goals the towns have for the River and its watershed and also to identify strategies to accomplish those goals.

Underhill Town Plan:

"As the headwaters of the Browns River commence in Underhill, we have a special responsibility for maintaining the health of the watershed, including ground water aquifers and recharge areas."

"Managing a watershed goes beyond municipal responsibilities because it is governed by geographic realities. Results of the assessment of the Browns River watershed by the Agency for

Natural Resources might necessitate amendments in regulations, such as establishing appropriate setbacks from Brown's River or the creation of an environmentally sensitive district."

Jericho Comprehensive Plan:

"An understanding of the community's water resources is critical to planning for future land use and community facilities and services. Water resources provide domestic and commercial water supplies and recreation opportunities. They are also unique and fragile areas, which if not properly used, managed, and protected, will cause public harm."

Westford Town Plan:

"Promote conservation of open space for recreational and/or agricultural uses. Promote conservation, and protection where appropriate, of Westford's natural resources using the best information available. Examples of these resources include: forests, critical wildlife habitat, rare and endangered species habitat, biological diversity, wetlands, groundwater, surface waters, flood plains, air quality, and the best examples of ecological and geological features in Westford."

"Surface waters include any body of water that exists throughout the year on the land surface; these typically include rivers, streams, ponds and lakes. They are important as a source of drinking water for humans and wildlife, recreation, flood control, and for aesthetic value. The Browns River is the water feature that dominates Westford, traversing the Town from south to north. There are many smaller streams in Town, most of which empty into the Browns River or one of the many wetlands in Westford. There are several small ponds in Westford, but there is no official public access to any of these ponds. However there is public access to the Browns River near the Town Common for fire department use. Potential threats to surface waters include: pollution from failed septic systems; siltation and erosion from construction, logging, sand and gravel operations, agricultural lands, gravel/dirt roads; and pollution from agricultural and residential run-off."

Essex Town Plan:

"As a priority task for updating natural resources information, the Town shall conduct studies to improve understanding of the existing water quality conditions in the Town and propose recommendations for improving the Town's water quality management."

“The Community Development Office in conjunction with the Department of Public Works and Conservation Committee should initiate water quality improvement studies in the Town. The Town will coordinate with the appropriate State/Regional agencies and any University departments. This work shall be coordinated with implementation of the Town’s Storm Water Management Plan for improving the quality of impaired waterways.”

“Prepare a GIS-based watershed map of the Town and perform an analysis of the watersheds to better understand how existing and proposed land uses will affect water quality, including information on the percentage of impervious surfaces in each watershed.”

“Consider revising buffer widths for streams, rivers and other water bodies, by examining the watershed and taking into account topography, vegetation, soils, land use designation, and other pertinent considerations.” “Provide townspeople with information about environmentally sound management of land and ways individuals can assist in protecting natural resources.”

3.0 BACKGROUND INFORMATION

3.1 GEOGRAPHIC SETTING

The Browns River Watershed has a watershed size of approximately 92 square miles. The Browns River is a tributary of the Lamoille River. Watershed origins include the towns of Bolton, Stowe, Jericho, Underhill, Essex, Westford and Fairfax, as such, reaching three counties in Vermont-Lamoille, Chittenden and Franklin. The main branch of the Browns River is approximately 29 miles long, from its headwaters in Underhill to its mouth at the Lamoille River in the town of Fairfax. Approximately 1.4 miles of the river are located within the town of Fairfax, 8.6 miles in Westford, 6.8 miles in Essex, 5.5 miles in Jericho, and 6.6 miles in Underhill. The Lamoille River ultimately discharges to Lake Champlain in the town of Milton.

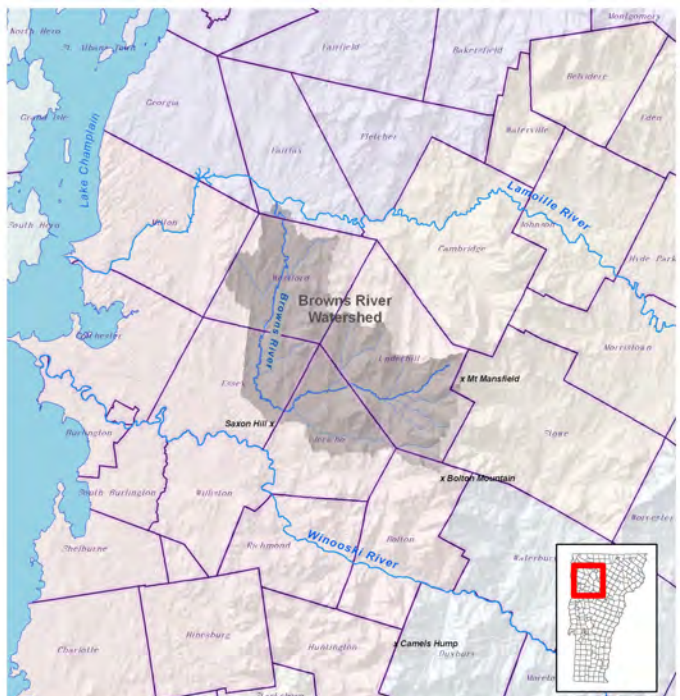

Figure 1. Browns River Watershed Map

For the purpose of geomorphic assessment and corridor planning, the Browns River has been divided into ‘reaches,’ twenty-two of which fall within the scope of this Corridor Plan. A reach is a section of stream with similar characteristics; this determination is primarily based on physical characteristics such as slope, sinuosity, dominant bed material, bed form, and valley confinement. The Corridor Plan focuses on stream reaches on the Browns River and seven of its major tributaries. The study reaches are located on the following waters within the following towns:

Browns River	**Jericho, Underhill, Westford, Fairfax**
Abbey Brook	**Essex**
Lee River	**Jericho**
The Creek	**Jericho, Underhill**
Roaring Brook	**Underhill**
Steinhour Brook	**Underhill**
Crane Brook	**Underhill**
Clay Brook	**Underhill**

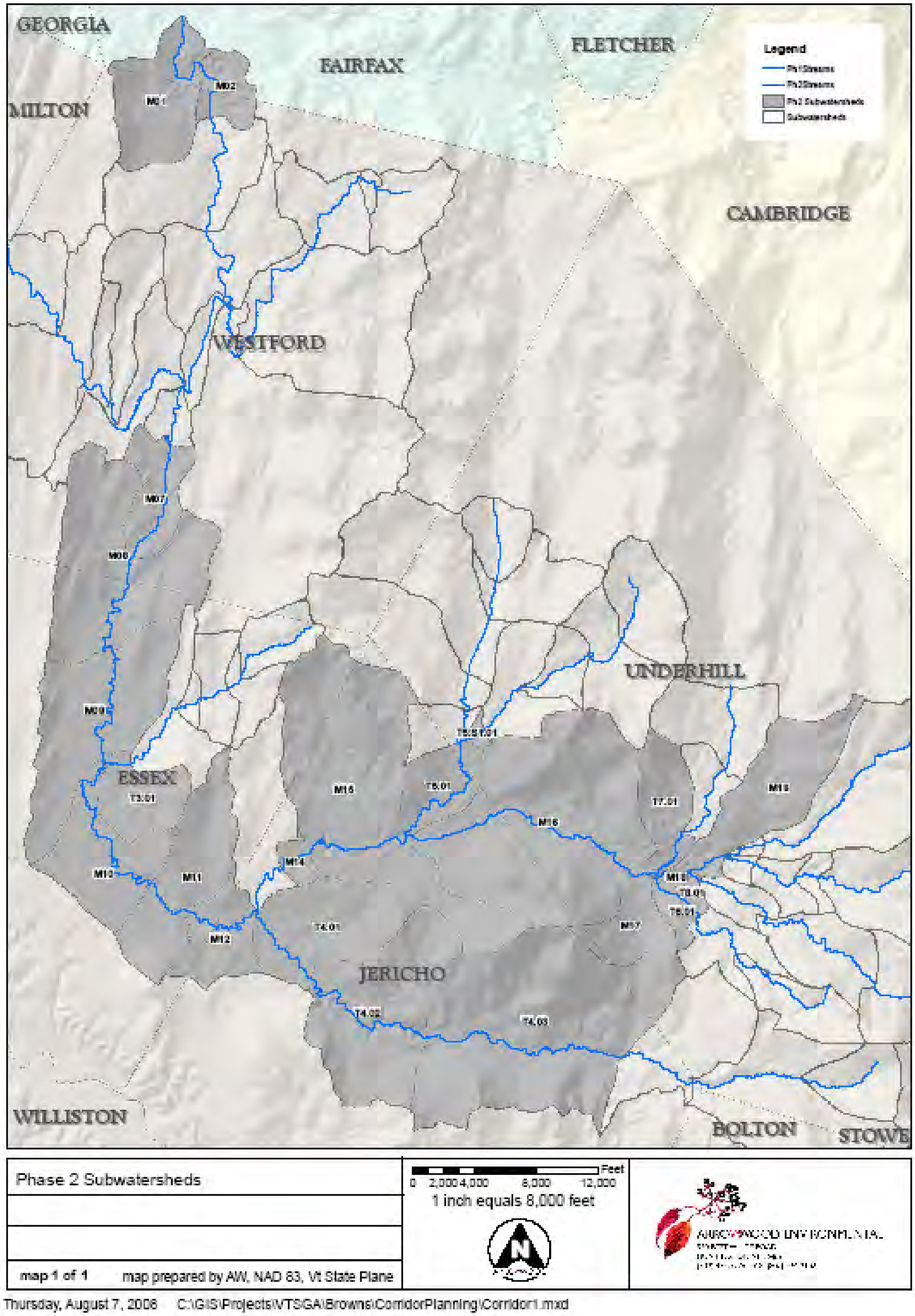

Figure 2. Browns River Subwatershed Map

3.1.2 Land Use History and Current General Characteristics

The Browns River watershed is predominately a rural area. While the dominant watershed land cover/land use within the watershed is forest, the majority of the Browns River corridor from the mouth to Underhill Center is dominated by cropland and residential development.

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. Headwaters tributaries are still primarily forested. 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.

3.2 GEOLOGIC SETTING

The Browns River is located within the Northern Green Mountains biophysical region. The Northern Green Mountains of today are primarily metamorphic rocks, mainly schist's, phyllites, gneisses, and quartzite's. Over the millions of years since their formation, the Green Mountains have eroded to only a fraction of their original height. In more recent geologic time, glaciers advanced from northwest to southeast over the Green Mountains. Much of the mid to higher elevations of the Browns River watershed, like the entire biophysical region, are covered with glacial till.

Upon retreat of the glaciers roughly 10,000 years ago, lowland portions of the watershed were flooded by the massive Lake Vermont, formed as glacial meltwater was dammed by the remaining glaciers to the north. This flooding resulted in areas of lake bottom (sands and silts) and glacial outwash (gravels and sands) sediments especially prevalent today in the lower elevations of the watershed.

Table 1. Browns River Geology and Soils Summary

Reach **ID**	Geologic materials			Valley side slopes		Soil Properties	
	Dominant	% Dom	Sub-Dominant	Left	Right	Highly Erodible Land (%)	Potentially Highly erodible (%)
M01	Till	61	Glacial Lake	Steep	Hilly	22	61
M02	Ice Contact	62	Glacial Lake	Hilly	Flat	47	9
M07	Till	40	Glacial Lake	Steep	Steep	21	53
M08	Till	64	Glacial Lake	Extremely Steep	Very Steep	17	65
M09	Till	37	Alluvium	Extremely Steep	Steep	7	49
M10	Ice-Contact	38	Alluvium	Hilly	Hilly	2	21
M12	Glacial Lake	26	Till	Hilly	Steep	11	43
M14	Ice Contact	47	Alluvium	Steep	Steep	2	19
M15	Till	66	Ice Contact	Flat	Flat	15	58
M16	Till	65	Ice Contact	Hilly	Flat	42	36
M17	Till	83	Ice Contact	Steep	Steep	33	59
M18	Ice Contact	51	Alluvium	Steep	Steep	10	6
M19	Till	74	Ice Contact	Hilly	Hilly	20	72
T3.01	Till	58	Glacial Lake	Flat	Flat	4	71
T4.01	Ice Contact	54	Till	Flat	Hilly	14	40
T4.02	Till	58	Ice Contact	Steep	Steep	22	62
T4.03	Till	66	Other	Very Steep	Very Steep	32	39
T5.01	Till	43	Ice Contact	Steep	Steep	5	47
T5.S1.01	Ice Contact	80	Alluvium	Hilly	Flat	30	0
T6.01	Ice Contact	71	Till	Steep	Steep	30	49
T7.01	Till	58	Ice Contact	Hilly	Steep	31	64
T8.01	Ice Contact	97	Alluvium	Hilly	Flat	60	22

3.3 GEOMORPHIC SETTING

The Browns River watershed was divided into 68 reaches during Phase 1 assessment; 22 reaches had Phase 2 assessments completed. Each reach was determined based upon physical characteristics such as slope, sinuosity, valley confinement, and hydrologic characteristics. The data collected in the Phase 1 assessments provide an overview of the general physical characteristics of a watershed. Maps, aerial pictures, and historic information are combined with field interpretations to produce reference stream typing, stream impact ratings, and provisional geomorphic condition evaluations. (VANR Phase 1 Handbook, April 2007). Phase 1 data describe what one would expect the river system to look like in a natural state with no human influences. Below is a summary of the Phase 1 assessment results for the study area.

The Phase 1 assessment conducted for the Browns River concluded that the ‘reference type’ for fifteen of the included reaches was a C type which are lower gradient streams that are slightly entrenched, and have moderate to high width-depth ratios. These streams are characterized by riffle-pool sequences (Rosgen 1994) dominated by gravel/cobble substrates. This channel type is typically found in unconfined alluvial valleys and is noted for its meandering nature. Channels have characteristic point bars and broad, well defined floodplains to reduce energy during flood events.

Five of the included reaches were an E type, dune-ripple system (Rosgen 1994) and well developed floodplains. The channels are dominated by sand substrates. This channel type is typically associated with low gradient and highly sinuous channels, in unconfined valleys. These stream types are slightly entrenched with low width-depth ratios.

Only two of the included reaches were a B channel type, step-pool system (Rosgen 1994) dominated by gravel/cobble/bedrock substrates. These stream types are moderately entrenched with moderate width-depth ratios and sinuosity. This channel type is typically associated with moderately steep channels in confined “V” type valleys, usually in forested systems.

Table 2 briefly summarizes the results of the Phase 1 assessment of the study reaches. Further detailed descriptions of the reaches, with associated Phase I and II observations, are found in

Section 6 of this report along with individual reach maps depicting Phase 2 segment delineations in the appendix.

Table 2. Phase 1 Summary Data

Reach ID	Drainage Area (sq mi)	Valley width (ft)	Valley Type	Channel width (ft)	Channel Slope (%)	Sinuosity	Reference Stream Type	Channel Bedform
M01	92.32	603	BD	95.94	0.3	1.27	C	Riffle/Pool
M02	90.83	766	BD	95.26	0.46	1.19	C	Dune/Ripple
M07	68.24	817	BD	83.99	NA	1.08	E	Dune/Ripple
M08	67.36	1927	VB	83.51	NA	1.22	E	Dune/Ripple
M09	64	3623	VB	82	0.00	1.25	E	Dune/Ripple
M10	58	2,515	VB	78	0.00	1.24	E	Dune/Ripple
M11	56.58	2069	VB	77.3	0.24	1.12	E	Dune/Ripple
M12	55	1,275	VB	76	0.28	1.48	C	Riffle/Pool
M14	37.11	1501	VB	64.24	0.84	1.23	C	Riffle/Pool
M15	37	1,260	VB	64	0.29	1.29	C	Riffle/Pool
M16	32	1,498	VB	60	0.70	1.11	C	Riffle/Pool
M17	16	487	BD	45	0.59	1.25	B	Riffle/Pool
M18	11	NA	VB	38	2.02	1.21	C	Riffle/Pool
M19	8.49	560	VB	33.56	1.47	1.03	C	Riffle/Pool
T3.01	3.5	751	VB	22.73	NA	1.10	C	Riffle/Pool
T4.01	15.41	989	VB	43.64	0.29	1.17	C	Riffle/Pool
T4.02	13.64	475	VB	41.36	0.81	1.28	C	Riffle/Pool
T4.03	10.86	730	VB	37.42	1.21	1.24	C	Riffle/Pool
T5.01	10.87	1231	VB	37.43	0.37	1.45	C	Riffle/Pool
T5.S1.01	3.81	653	VB	23.61	2.11	1.11	C	Riffle/Pool
T6.01	1.81	184	VB	17.02	3.11	1.02	E	Riffle/Pool
T7.01	2.58	250	VB	19.88	1.84	1.12	C	Riffle/Pool
T8.01	2.52	892	VB	19.67	2.28	1.0	B	Riffle/Pool

3.4 ECOLOGIC SETTING

The Browns River watershed occupies a diverse landscape position from an ecological standpoint. With headwaters rising from the summit of Vermont's highest mountain, Mt. Mansfield, traveling down rugged, heavily forested and seldom disturbed slopes, passing through growing population centers before descending into flatlands dominated by broad floodplains and wetlands, now often functioning as agricultural land, this is a watershed of contrasts.

The high elevation summit of Mt. Mansfield hosts some of the most rare plant and animal communities in the state. A drop of rainwater landing on this forbidding and harsh mountaintop will travel downhill through brief bands of sub-alpine krumholz and montane spruce and fir before entering the more common northern hardwood forest dominated by sugar maple, beech and birch, with occasional softwood species such as red spruce and hemlock. As the water flows into the open valleys of Underhill and Jericho, residential development becomes more common. With this increase in human influence and disturbance comes an increase in invasive and exotic plants and animals. The water moves through the suburban landscape, skirting the edge of the largest population density in Vermont it turns sharply to the north into broad valleys, expansive swamps and floodplains converted to crop and pasture years ago, more and more reverting to wetland and forest today. Finally, the water of the Browns River merges with the much larger Lamoille River, turns sharply west and flows to Lake Champlain.

The Browns River watershed is heavily dominated by 2 basic land cover classifications. Roughly 70% of the overall watershed is forested and 24% is in some kind of agricultural or open land state. While the Browns River comes close to the most heavily populated areas of Chittenden County, only 4% of the watershed is developed, primarily for rural residences and transportation infrastructure.

Some 2500 acres of wetland have been mapped in the Browns River watershed, and another 7100 acres of soil likely to support wetlands exist. Many of these wetlands are located within the river valleys and are critical to providing floodwater retention as well as wildlife habitat and a myriad of other functions.

White-tailed deer are found throughout the watershed and there are roughly 3400 acres of mapped deer winter habitat within the watershed, which is most certainly an underestimate of the actual total. Some mammals present in the upland portions of the watershed include black bear, red and grey fox, coyote, fisher, bobcat, moose and many smaller mammals. In the wetlands and riparian zones, mink, river otter, beaver, muskrat and others join the mix.

There are no major lakes or ponds within the watershed. Occasional small natural and man-made ponds are scattered throughout the watershed, but generally, the larger surface water features tend to be wetlands with varying levels of beaver influence.

3.5 WATER QUALITY

The Browns River is listed as altered for sedimentation and channel alterations in DEC's Lamoille Watershed Assessment (2001). The altered section starts at the upstream end of M03 and extends through M12 within the towns of Westford, Essex and Jericho. The alteration is the result of former channel alterations, including former gravel mining, loss of riparian vegetation, streambank erosion due to agricultural encroachments, and flood events. The altered section of river runs through predominately agricultural land.

The State of Vermont has been conducting benthos and fish surveys on the Browns River from its mouth to the confluence of Lords Brook and tributaries including Rogers and Abbey Brook, approximately 25 miles. Assessment comments describe extensive gravel mining that has altered the watercourse in some areas and destabilized riverbanks resulting in sedimentation of the channel. It was noted in the assessments that the channel has become wider and shallower leading to increased temperatures and fish community impairment. Fish sampling for the last ten years have produced the following results:

Year	Rm0.4	Rm0.5	Rm5.9	Rm10.4	Rm11.4	Rm18.5
1994	Exc	--	--	--	--	--
1995	Exc	--	--	--	--	--
1996	Exc	--	Poor	Poor	--	--
1997	--	--	Poor	Fair	--	--
1998	vgood	--	Poor	Poor	--	--
1999	vgood	--	Poor	Poor	--	--
2000	--	--	Fair	Fair	--	--
2001	--	--	--	--	--	Fair
2002	--	vgood	--	--	Poor	--
2003	--	--	--	--	Fair	Poor
2004	--	--	--	--	--	Poor

The State of Vermont monitors another 41.2 miles of the Browns River from the confluence of Lords Brook to headwaters and tributaries including Lee River, The Creek, Roaring Brook, Stevensville Brook, Clay Brook, and Crane Brook. Within this area, the Stevensville Brook (from rivermile 2.0 upstream to headwaters) is described as impaired aquatic habitat due to low pH from acid rain inputs. The Browns River from just west of the Jericho-Essex town line to 7.5 miles upstream in Underhill, is described as stressed with impacts on aesthetics and aquatic habitat due to sediments, temperature increases, and physical alteration of the riverbed due to former gravel mining on a large scale, bank destabilization, stream channel instability, and major flood events.

Macroinvertebrate and fish sampling on the upper Browns River has been conducted with varying frequency since 1991 with the following results:

Year	Rm20.1*	Rm20.8	Rm26.8*	Rm31.0
1991	--	Good	--	--
1992	--	Fair	--	--
1993	--	Good	--	--
1994	--	Excellent	--	--
1995	--	Good	--	--
1996	--	Fair	--	--
1997	--	Excellent	--	--
1998	--	Fair	--	--
1999	--		--	--
2000	--	--	--	--
2001	Good	--	Good	--
2002	Good	Excellent/VGood	Good	Excellent/Good

*Fish survey only

For milepoint 20.8 on the Browns, the fair assessments were attributed in part to flood effects (scouring) on top of low alkalinity. The condition of the macroinvertebrate community in this upper reach of the river was considered good overall.

Macroinvertebrate sampling has occurred on Stevensville Brook at rivermile 2.1 in Underhill from 1992 to 2002 with the following results:

Year	Macroinvertebrate Rating
1992	Excellent
1993	Excellent
1994	Excellent
1995	Fair
1996	Good
1997	Good
1998	Fair
1999	Fair
2000	Very Good
2001	--
2002	Excellent

The fair rating was attributed to low densities as a result of scouring from flood events in those years. Low alkalinity and low pH have been found when sampling there and so the brook was considered impaired due to acidity. The following levels of pH have been recorded:

Year	pH
1995	6.6
1996	6.7
1997	5.6
1998	5.6
1999	6.5
2000	6.1

On the Lee River, fish sample data from 1992 and 1993 at milepoint 2.7 and 2.8 showed the fish community to be good to excellent.

4.0 METHODS

4.1 STREAM GEOMORPHIC ASSESSMENT

In an effort to provide a sound basis for decision-making and project prioritization and implementation, the Vermont Agency of Natural Resources (VTANR) has developed protocols for conducting geomorphic assessments of rivers. The results of these assessments provide the scientific background to inform planning in a manner that incorporates an overall view of watershed dynamics as well as the reach-scale dynamics that have been a primary focal point of project planning in the past. Incorporating upstream and downstream dynamics in the planning process can help increase the effectiveness of implemented projects by addressing the sources of river instability that are largely responsible for erosion conflicts, increased sediment and nutrient loading, and reduced river habitat quality (VTANR, 2007). Trainings have been held to provide consultants, regional planning commissions, and watershed groups with the knowledge and tools necessary to make accurate and consistent assessments of Vermont's rivers.

The stream geomorphic assessments are divided into three phases. A Phase 1 assessment is a preliminary analysis of the condition of the stream through remote data sources such as aerial photographs, maps, and 'windshield survey' data collection. Phase 2 involves rapid assessment fieldwork to inform a more detailed analysis of what adjustment processes are taking place and predicting how the river will continue to evolve in the future. Phase 3 involves detailed fieldwork for the identification and implementation of management and restoration projects.

Phase I and Phase 2 Stream Geomorphic Assessments were conducted by the Winooski Natural Resources Conservation District for the Browns River Watershed. The Phase 1 assessment team completed steps 1-7 of the Stream Geomorphic Assessment Phase 1 Protocols using the SGAT GIS extension. The Phase 1 assessments identified priority reaches for the Phase 2 assessments. Phase 2 assessments were completed on 7 reaches by the District in 2004. An additional 15 reaches were evaluated by Arrowwood Environmental in the summer/fall of 2007.

4.2 QUALITY ASSURANCE AND QUALITY CONTROL

Arrowwood Environmental conducted the Phase 2 assessment in compliance with the Vermont DEC River Management Program. The Microsoft Access Phase 2 database was submitted to the ANR for a QA review in February/March 2008. A QA summary report was provided in the Appendix of the Phase 2 report. Photos were taken at each study cross-section and problem areas. Photos were digitally provided on an attached CD.

5.0 RESULTS

The following sections summarize the results of the Phase I and II SGA data collection for the Browns River. Stressor, departure, and sensitivity maps are presented as a means to organize the data that has been collected and show the interaction of watershed and reach-scale dynamics. In addition, these maps should assist in identifying practical restoration and protection actions that can move the river towards a healthy equilibrium. Alterations to watershed-scale hydrologic and sediment regimes can greatly influence reach-scale dynamics, and if not considered adequately can undermine protection and restoration efforts at the reach level.

The data, tables, and maps described in Section 5 will be used to identify restoration and conservation techniques on a reach scale basis that meet the goals and objectives of reducing fluvial erosion hazards, increasing sediment and nutrient attenuation sites, and improving aquatic and riparian habitat.

5.1 DEPARTURE ANALYSIS

Section 5.1 summarizes watershed-scale stressors on the physical stability and habitat conditions of the river. Section 5.1 also characterizes reach-scale stressors.

5.1.1 Hydrologic regime stressors

The hydrologic regime involves the timing, volume, and duration of flow events throughout the year and over time; as addressed in this section, the regime 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. Where hydrologic modifications are persistent, the impacted stream will adjust morphologically (e.g., enlarging when stormwater peaks are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches (VTANR, 2007).

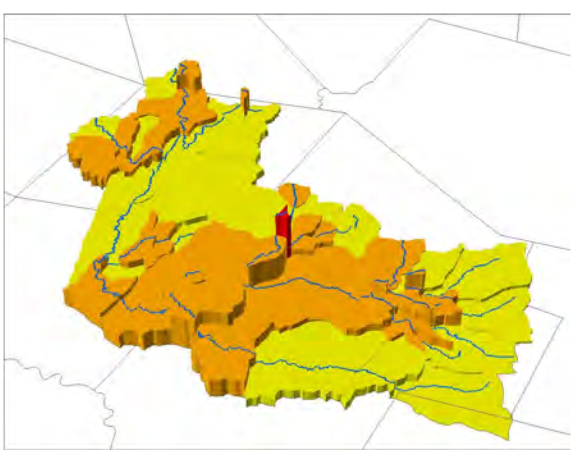

Figure 3. Developed Land within the Browns River Watershed

Natural land cover types (e.g. forests, wetlands) play important roles in watersheds by storing and filtering run-off, trapping sediment, reducing peak flood levels, and maintaining base flows during summer. Deforestation and urban and agricultural development increase rainwater runoff by decreasing the amount of natural vegetation to naturally filter water and sediment. Additionally, urban lands contain large amounts of impervious surfaces where stormwater will quickly run off into adjacent drainages rather than slowly percolate through the soil, resulting in higher peak flood levels in addition high nutrient and sediment inputs. These levels can trigger a channel to enlarge and incise due to consistently high stormwater runoff.

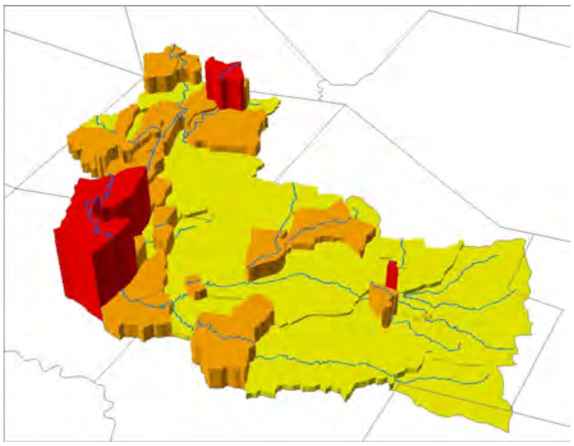

Figure 4. Cultivated Land within the Browns River Watershed

The Browns River watershed study area is characterized by a combination of agricultural, forest and residential landuses. There is a significant agricultural presence within the river valley of the Browns River with increasing residential development in the surrounding woodlands. The lower reaches of the Browns River are less developed and contain higher percentages of agriculture and forest land in comparison to the upper reaches and the assessed tributaries.

Land use and 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.

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.

Analysis of hydric soils and existing agricultural and developed land uses indicates significant loss of wetland attenuation of precipitation inputs. Wetlands have been filled, ditched, diverted and otherwise manipulated resulting in a loss of hydrologic function. See Figure 5 Wetland Losses within the Browns River Watershed map below.

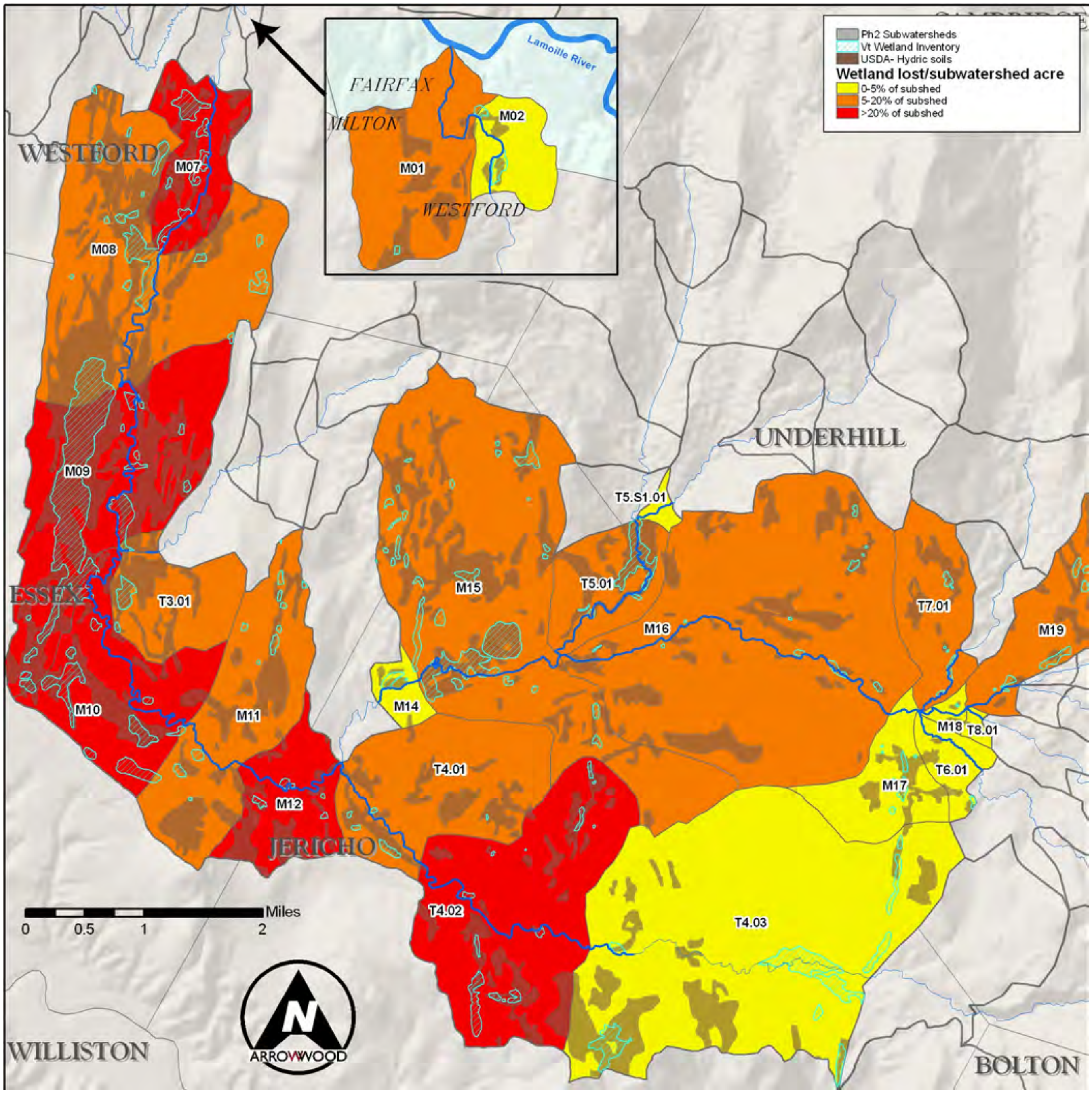

Figure 5. Wetland Losses within the Browns River Watershed

Many of the roads and crop lands throughout the watershed have been ditched over time, contributing to intensified inputs to the rivers and streams, but the primary historical nature of downcutting in the stream channel observed in the Browns River Watershed is likely related to historical deforestation in the watershed. Historical clearing (late 18th and 19th centuries) initially contributed to higher runoff of both water and sediment, which accumulated in the valleys. Additionally, removal of large woody debris from stream channels, likely related to use of the streams for log drives and agricultural uses, combined with road developments to change the rainfall-runoff regime in such a way that water inputs intensified through deposited sediments, and the watershed's hydrologic regime became more "flashy". See Figure 6 Road Density within the Browns River Watershed map below.

The downcutting observed throughout the watershed has been sufficient to limit access to the historical floodplain throughout much of the watershed, meaning that high volume flows are now contained within the channels and smaller precipitation events can generate levels of impact previously associated with more extreme precipitation events. Under these conditions, thunderstorms, mid-winter rains, and snow melt events can cause significant hydrologic impacts.

One of the most significant hydrologic stressors for the Browns River watershed, and the majority of Vermont, is the large scale deforestation that occurred in the 19th century. As the state was settled much of the forest was cut for timber and the land cleared for agriculture. Where today Vermont is approximately 80% forestland and 20% open, in the late 19th and early 20th century it was only 20% forested and 80% open. The effect of those land use changes are still being seen today. With much of the land cleared higher intensity flash floods were more common and carried with them a tremendous amount of sediment down into the valleys. This sediment built up in the river systems and raised the bed elevation of many streams. The Browns River is now eroding down through the built-up sediment and losing access to its floodplain. This process is increased through channel management techniques such as channelization, dredging, and ditching (VT ANR 2007).

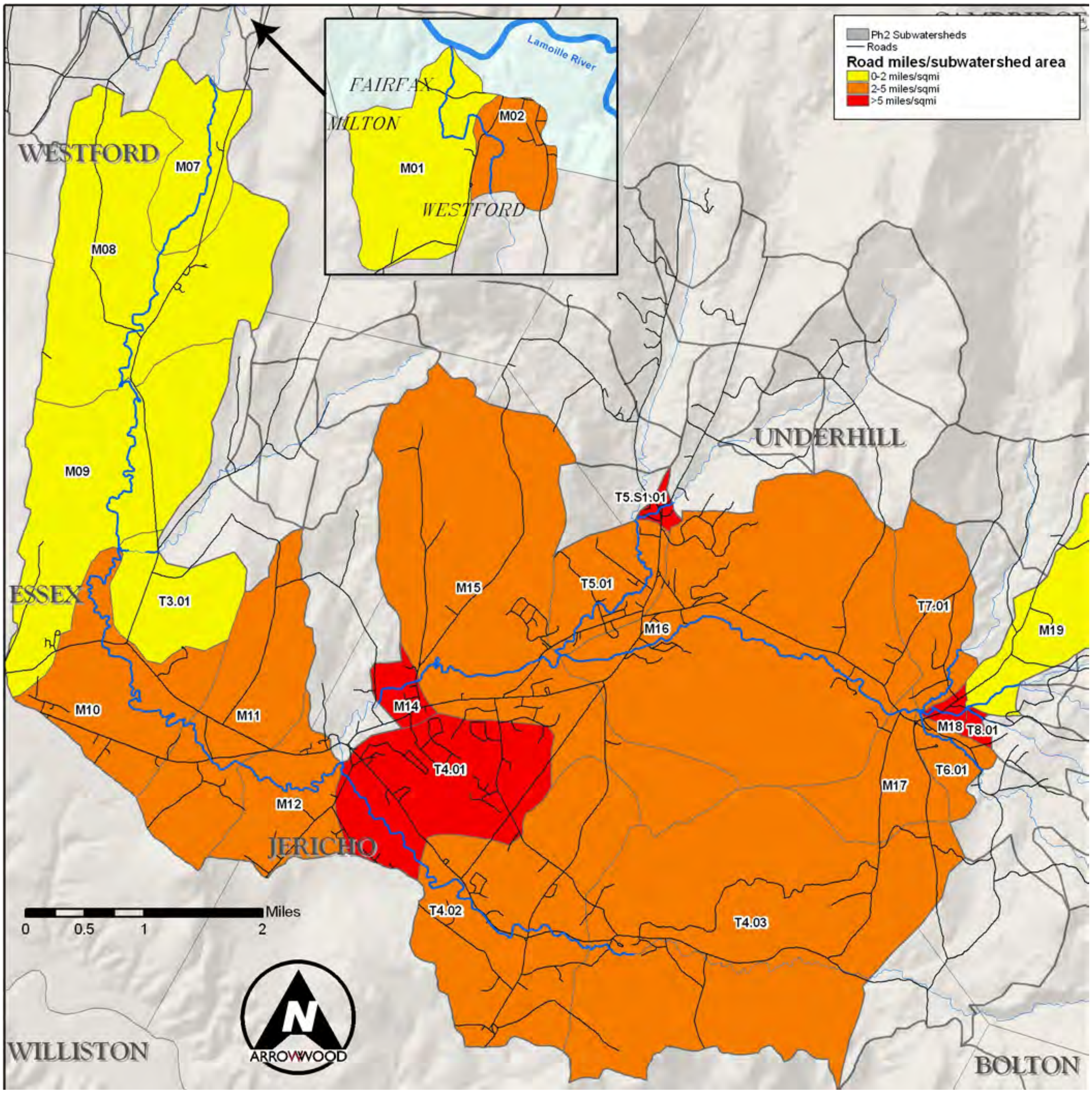

Figure 6. Road Density within the Browns River Watershed.

5.1.2 Sediment Regime Stressors

Streams naturally exhibit erosion and deposition processes. When systems are not in equilibrium, the degree and rate of erosion may overwhelm the streams natural ability to transport sediment and natural depositional processes. Sedimentation and associated degradation of aquatic habitat are concerns in the Browns River and its tributaries. At the watershed scale, erosive materials present in upper sideslopes of steep valley walls, alluvial soils on exposed streambanks, and bed materials contribute to a high sediment-load system. Geomorphic instability related to the downcutting (and loss of floodplain access) of many of the study reaches have resulted in adjustment processes that are manifested largely in redistribution of the sediment loads as the river tries to regain equilibrium and establish a new floodplain. Additional stressors in this system can include sheet and gully erosion on exposed soils of tilled croplands in the river corridor in particular, where the extensive ditching system can transport these materials easily in runoff events. On lower elevation sideslopes, multiple occurrences of mass failures increase sediment loads to the river.

Data collected in Phase 2 can be evaluated to determine whether the transport capacity of the channel has been exceeded, indicating a high sediment load. The stream deposition rating (indicating the number of steep riffles, mid-channel bars, delta bars, flood chutes, avulsions, and braiding present per mile) and the erosion rating (indicating the percentage of the reach/segment length eroding), number of mass wasting or gullies per reach/segment, and presence of rejuvenating tributaries is used to determine which reaches/segments are experiencing increased sediment loads.

5.1.3 Reach Scale Sediment Regime Stressors

Watershed scale stressors provide a backdrop for understanding the timing and degree to which reach-scale modifications are contributing to field observed channel adjustments (VTANR 2007). Modifications to the valley, floodplain, and channel, as well as boundary (bank and bed) conditions, at the reach scale can change the hydraulic geometry, and thus change the way sediment is transported, sorted and distributed. Phase 1 and Phase 2 assessments provide semi-quantitative data-sets for examining stressors and their effects on sediment regime when channel hydraulic geometry is modified.

Many land uses are incompatible with the meandering and ever-changing nature of rivers and streams. Rivers and streams are often straightened, armored, dredged, bermed, or encroached upon to protect property investments or to make floodplain available for other land uses. Channel straightening and bank armoring remove or alter natural meanders, while undersized bridges and culverts act as channel constrictions, forcing the stream to flow faster through a narrow area. These channel alterations directly affect the stream by increasing its slope and power, resulting in areas of bed and bank erosion. The following Sediment Load Stressors Map shows that the major tributaries have high deposition ratings as well as the same high erosion ratings as the lower reaches of the main branch of the Browns (M01 and M02; M07 and M08). These reaches together have increased sediment loads caused by one or more hydrologic stressors. Historic landuses and resulting stream alterations changed the hydraulic geometry of the channel, and thus changed the way sediment is transported, sorted and distributed.

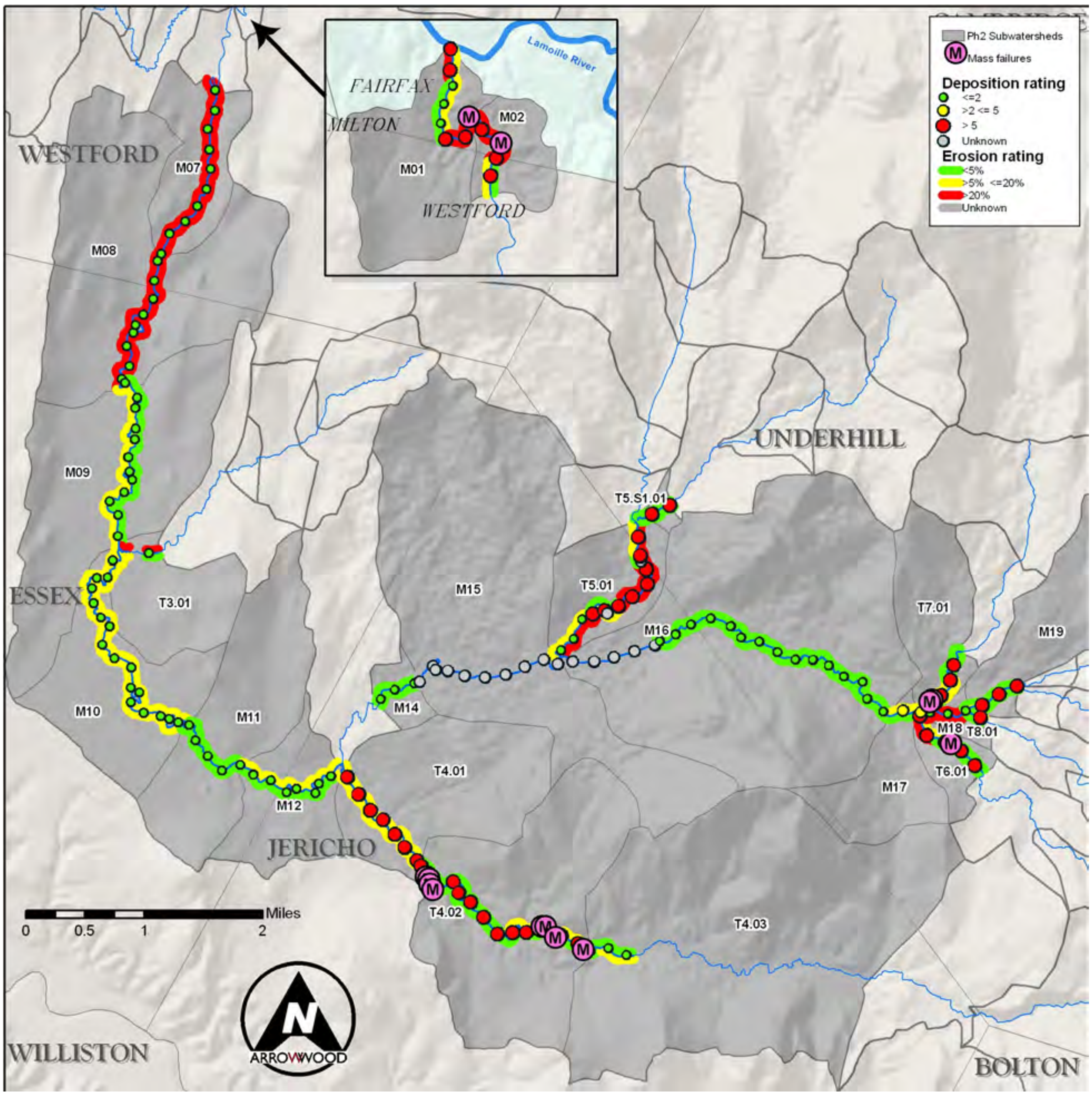

Figure 7. Sediment Load Stressors Map

5.1.4 Channel Slope Modifiers

Results for the Browns River indicate that primary stressors include areas of extensive straightening of the channel, and corridor encroachments (including roads and development). Channel straightening can result in bed and bank erosion stemming from a measurable loss in floodplain access (i.e., increased incision), and play a significant role in enhancing sediment transport capacity as a result of the increased slope and depth at flood stage. With a significant increase in sediment load from upstream, the enhanced transport capacity has also resulted in stress to reaches downstream: instead of storing some of the increased load, the straightened reaches are now conveying sediment. Roads and development within the river corridor indirectly lead to an increased channel slope when structural measures are used to protect those encroachments.

There are six natural/man made grade controls and forty bridges/culverts within the Project area serving to decrease channel slope and reduce stream power. Phase 2 data collection indicated that less than half of the bridges were adequately sized to permit transport of both water and sediment, with only minor deposition due to channel constrictions and few problems related to geomorphic incompatibility of theses structures with stream processes. The remaining structures are not adequately sized, resulting in upstream and downstream deposition and problems with scour about the structure. More than half of the bridges/culverts are also known to be acting as floodplain constrictions.

The following maps present summary data collected during the Phase 2 assessment related to potential slope modifiers (increasers and decreasers) within the study reaches. Collectively, these modifications indicate the potential for increased erosion, possible incision, and decreased channel stability in some study reaches.

The Slope Modifiers Map, presented below, shows that the lower reaches of the Browns (M01-M02 and M07 and M08) as well as the upper tributaries have been altered by historic straightening and encroachments. These same reaches have been identified as sediment load stressors with out of balance sediment regimes.

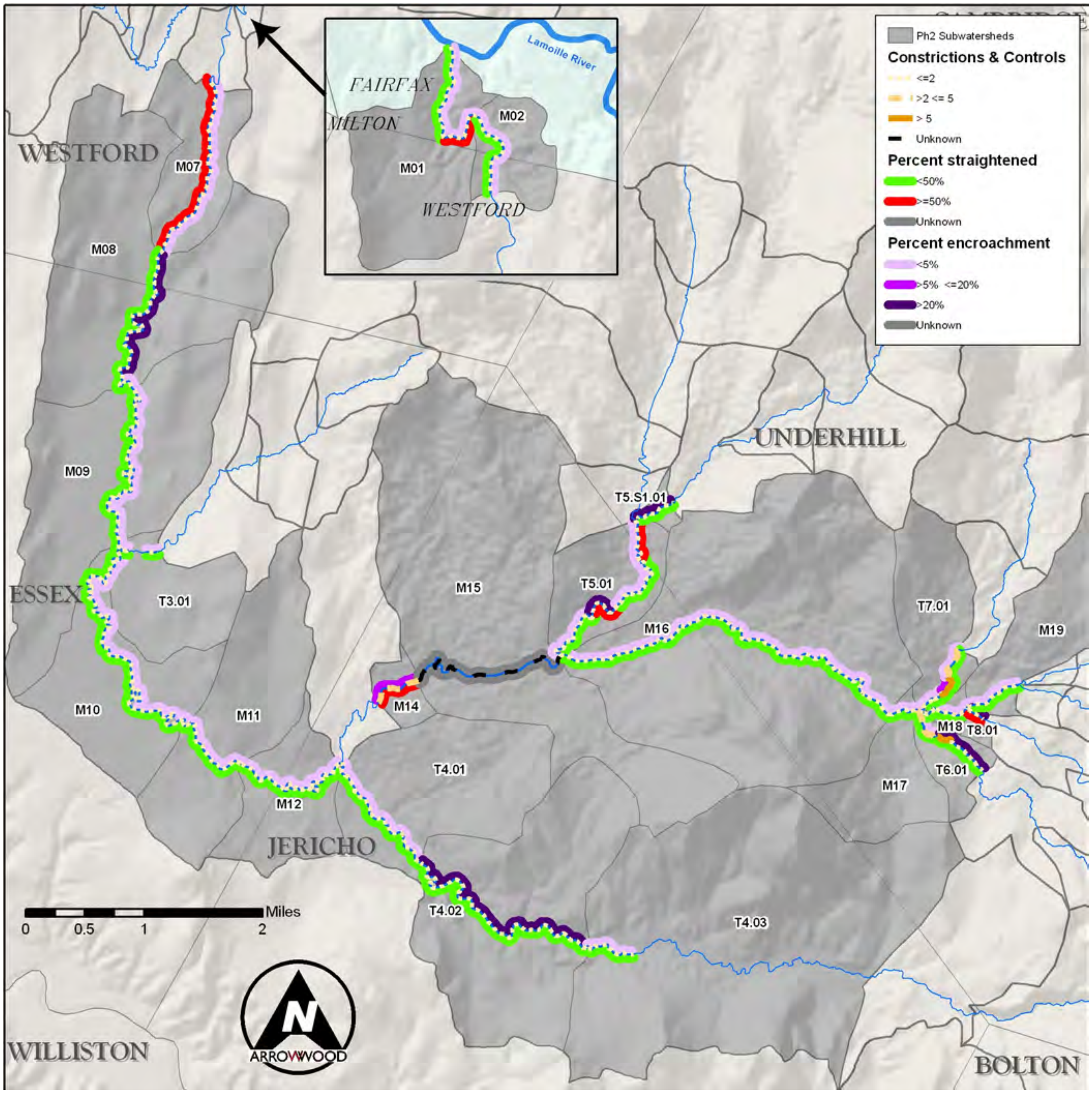

Figure 8. Slope Modifiers Map

5.1.5 Channel Depth Modifiers

Phase 2 data collection indicated a high impact of corridor encroachment in several reaches of the Browns River which serves to reduce the effective width of the valley and floodplain. Encroachments within the river corridor increase the depth of flood flows, and thus also increase stream power. Significant deposition creates the potential for more shallow depths during moderate flows due to the mid-channel deposits. Stream power is reduced leading to further deposition.

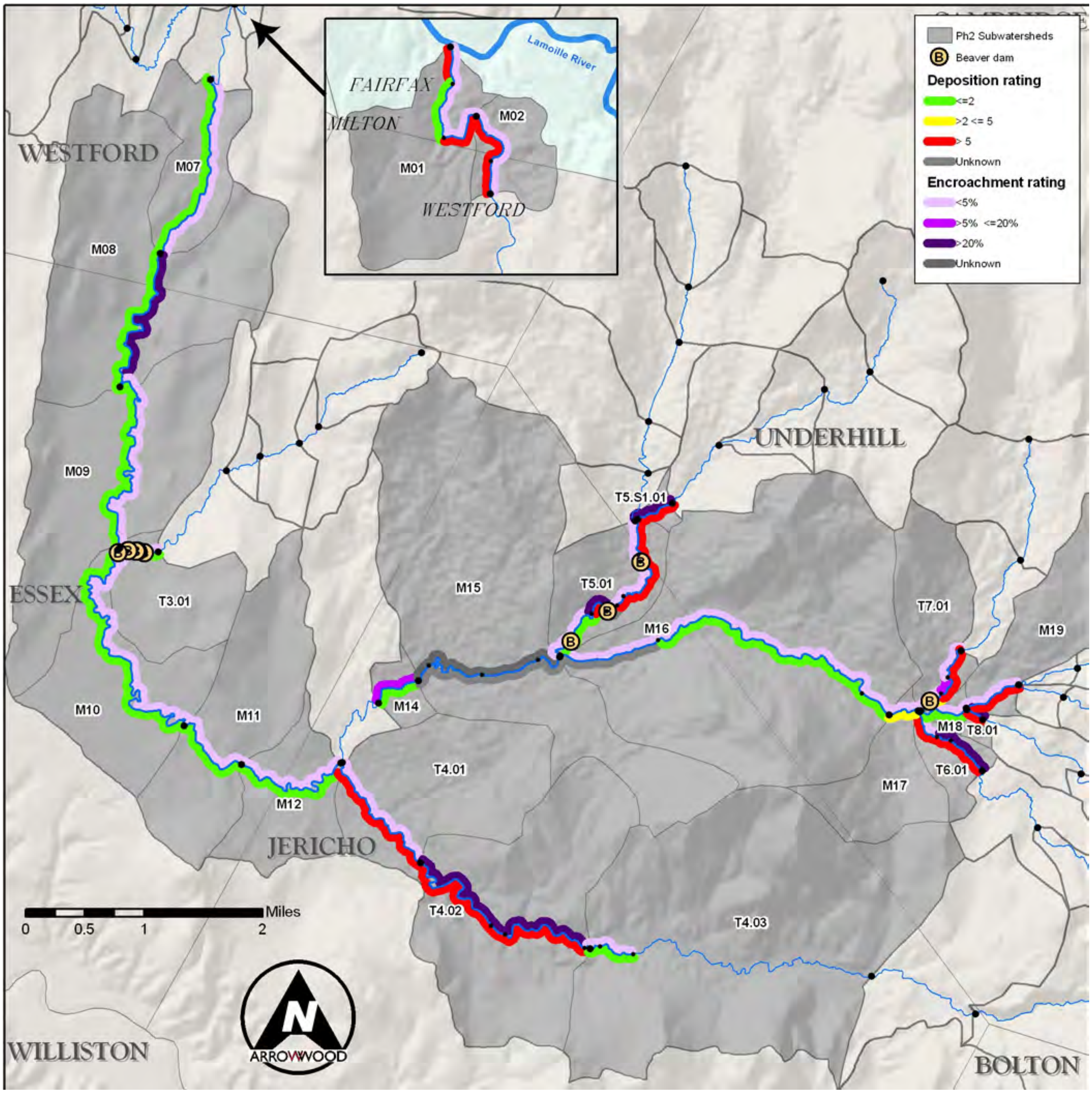

Figure 9. Depth Modifiers Map

Many of the reaches within the Browns River watershed contain multiple stressors which are affecting both the stream slope and depth. The cumulative effect of these stressors in most reaches has led to widespread incision, and ultimately decreased sediment and nutrient attenuation capacity as the stream has lost access to its historic floodplain.

5.1.6 Riparian Buffer Conditions

Stream boundaries include bed and banks, and are also affected by the condition of buffer vegetation in the riparian corridor. Root systems from woody vegetation help bind stream bank soils. The resistance of the channel boundary materials to the shear stress and stream power exerted, will, in large part, determine whether the channel will undergo adjustment. Riparian vegetation and human-placed bed and bank armoring are effective means of resisting erosion, although, armoring is considered a temporary condition. (VANR, River Corridor Planning Guide, 2007) The following map presents the condition of the riparian buffers within the study reaches.

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. Phase 2 data indicate that dominant buffer widths were generally less than 25ft within the reaches of the study area, likely contributing to the high amounts of erosion recorded in the majority of the study reaches. Segments M2B (C3), M12 (C5), T4.03B (D4), T5.01F (NA), T6.01B (F4), and T7.01 (C4) all have good buffer vegetation and low erosion levels. It is clear that the presence of wooded buffers could greatly aid the stability of the banks in the project area.

Of concern, is the absence of vegetated buffers on the C and E stream type reaches within the project area. In these stream types, vegetation has a great influence on channel stability. When it is lacking, these channel types are highly sensitive to disturbance which may result in increased levels of streambank erosion and downcutting. These streams are highly sensitive to changes in sediment and stream flow.

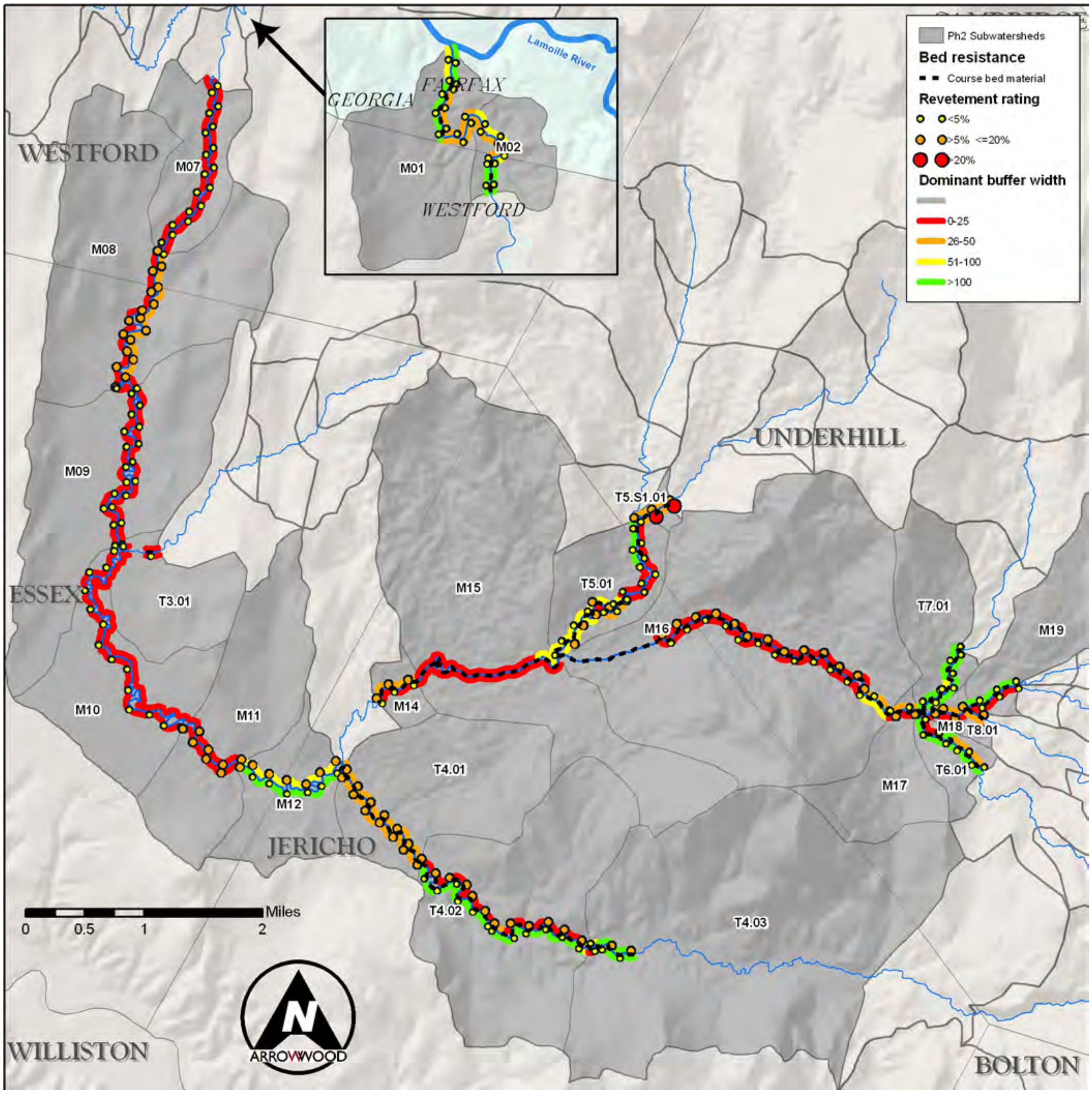

Figure 10. Boundary Resistance Map

The primary hydrologic and sediment stressors in each assessed segment of the Browns River watershed are identified in Table 3.

Table 3. Browns River Stressors Identification table

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
M01A	Development: Low Road Density: Low (0-2 miles/sq.mi) Wetland Loss: Mod (5-20%)	Deposition Rating: High Erosion Rating: Mod (RB) to High (LB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Deposition Rating: High **Increased stream power: slope** Encroachments: Low	**Decreased bank resistance** Erosion Rating: Mod (RB) to High (LB)
M01B	Road Density: Low Wetland loss: Mod Development: Low	Deposition Rating: Low Erosion Rating: Low (LB) to Mod (RB) Exposed Crop Soils: Mod	**Decreased stream power: depth** Bridges: 1 **Increased stream power: slope/depth** Encroachments: Low Straightening >50%	**Decreased bank resistance** Erosion Rating: Mod (RB)
M01C	Road Density: Low Wetland loss: Mod Development: Low	Deposition Rating: High Erosion Rating: High (both) Exposed Crop Soils: Mod Mass Failure	**Decreased stream power: depth** Deposition Rating: High **Increased stream power: slope/depth** Encroachments: Low Straightening	**Decreased bank resistance** Erosion Rating: High (both)
M02A	Road Density: Mod (2-5 mi/sqmi) Wetland loss: Low (0-5%) Development: Low	Deposition Rating: High Erosion Rating: High (both) Exposed Crop Soils: Mod Mass Failure	**Decreased stream power: depth** Deposition Rating: High Bridges: 1 **Increased stream power: slope/depth** Encroachments: Low	**Decreased bank resistance** Erosion Rating: High (both)
M02B	Road Density: Mod (2-5 mi/sqmi) Wetland loss: Low (0-5%) Development: Mod (13%) (lateral constraints)	Deposition Rating: High Erosion Rating: Low (RB) to Mod (LB) Exposed Crop Soils: Mod	**Decreased stream power: depth** Deposition Rating: High	**Decreased bank resistance** Erosion Rating: Mod (RB)

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
M02b			**Increased stream power: slope/depth** Encroachments: Low	
M07	Development: Low (lateral constraints) Road Density: Low Wetland Loss: High (>20%)	Deposition Rating: Low Erosion Rating: High (both) Exposed Crop Soils: Mod	**Decreased stream power: depth** Bridges: 3 undersized **Increased stream power: slope/depth** Encroachments: Low Straightening >50%	**Decreased bank resistance** Dom Buffer: RB/LB:0-25' Erosion Rating: High (both)
M08	Development: Low (lateral constraints) Road Density: Mod Wetland Loss: Mod	Deposition Rating: Low Erosion: High (both) Exposed Crop Soils: Mod	**Decreased stream power: depth** Bridges: 3 undersized **Increased stream power: slope/depth** Encroachments: High Straightening	**Decreased bank resistance** Dom Buffer: LF:0-25' Erosion: Mod **Increased bank resistance** Bank armoring: Mod (both)
M09	Road Density: Low Wetland Loss: High Development: Low	Deposition Rating: Low Erosion: Low (RB) to Mod (LB) Exposed Crop Soils: High	**Decreased stream power: depth** Bridges: 2 undersized Old abutments: 2 **Increased stream power: slope/depth** Straightening	**Decreased bank resistance** Dom Buffer: LF:0-25' Erosion: Mod (RB)
M10	Road Density: Mod Wetland Loss: High Development: Mod (9%)	Deposition Rating: Low Erosion: Mod (both) Mass Failure Exposed Crop Soils: High	**Decreased stream power: depth** Bridges: 3 Beaver Dam **Increased stream power: slope/depth** Encroachments: Low	**Decreased bank resistance** Dom Buffer: RB/LB:0-25ft Erosion Rating: Mod

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
M11	Road Density: Mod Wetland Loss: Mod Development: Mod (7%)	Deposition Rating: Low Erosion: Low (both) Exposed Crop Soils: Low Mass Failure	**Increased stream power: slope/depth** Straightening	**Decreased bank resistance** Dominant buffer: LB/RB:0-25ft **Increased bank resistance** Bank armoring: Mod
M12	Development: Mod (9%) (lateral constraints) Road Density: Mod Wetland Loss: High	Deposition Rating: Low Erosion Rating: Low (LB) to Mod (RB) Exposed Crop Soils: Mod Mass Failure	**Decreased stream power: depth** Bridges: 1 undersized	**Increased bank resistance** Bank armoring: Mod (RB) Erosion Rating: Mod (RB)
M14	Road Density: High Wetland Loss: Low Development: Mod 17%(lateral constraints)	Deposition Rating: Low Erosion Rating: Low Exposed Crop Soils: Mod	**Decreased stream power: depth** Bridge: 1 Grade controls: 2 **Increased stream power: slope** Encroachment: Mod Straightening: High	**Decreased bank resistance** Dom Buffer: LB:0-25' **Increased bank resistance** Bank armoring: Mod (RB)
M15A	Road Density: Mod Wetland Loss: Mod Development: Mod 7% (lateral constraints)	Deposition Rating: Low Erosion: Low (both) Exposed Crop Soils: Low	**Decreased stream power: depth** Grade Control: 1 dam **Increased stream power: slope/depth** Encroachment: Low	**Decreased bank resistance** Dom Buffer: RB/LB: 0-25ft

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
M15B	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: Low Erosion: Mod Exposed Crop Soils: Low	**Increased stream power: slope/depth** Dredging	**Decreased bank resistance** Erosion Rating: Mod Dom Buffer: RT/LB: 0-25'
M15C	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: Low Erosion: Low Exposed Crop Soils: Low	**Increased stream power: slope/Depth** Straightening Encroachment: High	**Decreased bank resistance** Dom Buffer: LB/RT: 0-25'
M15D	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: Mod Erosion: Low Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 1 undersized Deposition Rating: Mod **Increased stream power: slope/Depth** Encroachment: Mod	**Decreased bank resistance** Dom Buffer: LB: 0-25'
M16A	Road Density: Mod Wetland Loss: Mod Development: Mod 5% (lateral constraints)	Deposition Rating: unknown Erosion: Unknown Exposed Crop Soils: Low	**Unknown**	**Unknown**
M16B	Road Density: Mod Wetland Loss: Mod Development: Mod 5% (lateral constraints)	Deposition Rating: Low Erosion: Low Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 2 **Increased stream power: slope/Depth** Encroachment: Low Straightening	**Decreased bank resistance** Dom Buffer: LB/RB:0-25' **Increased bank resistance** Bank armoring: Mod (RB)
M16C	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: Low Erosion: Low Exposed Crop Soils: Low Mass Failure		

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
M17	Road Density: Mod Wetland Loss: Low Development: Mod 8%(lateral constraints)	Deposition Rating: Mod Erosion: Low (LB) to Mod (RB) Exposed Crop Soils: Low Mass Failure	**Decreased stream power: slope** Culvert: 1 undersized Deposition Rating: Mod **Increased stream power: slope/Depth** Encroachment: Low Gravel Mining	**Decreased bank resistance** Dom Buffer: LB:0-25' Erosion Rating: Mod (RB) **Increased bank resistance** Bank armoring: Mod (LB)
M18	Road Density: High Wetland Loss: Low **Development: Mod (lateral constraints)**	Deposition Rating: Low Erosion: High (Both) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bridge: 1 **Increased stream power: slope/Depth** Encroachment: Low Straightening	**Decreased bank resistance** Dom Buffer: LB:0-25' Erosion Rating: High (both) **Increased bank resistance** Bank armoring: Mod (both)
M19	Road Density: Low Wetland Loss: Mod Development: Low (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 1 Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: Low	**Decreased bank resistance** Dom Buffer: LB:0-25'
T3.01A	Road Density: Low Wetland Loss: Mod Development: Low (lateral constraints)	Deposition Rating: Low Erosion: Mod (LB) to High (RB) Exposed Crop Soils: Mod	**Increased stream power: slope/Depth** Encroachment: Low	**Decreased bank resistance** Dom Buffer: LB/RB:0-25' Erosion Rating: Mod-High
T3.01B	Road Density: Low Wetland Loss: Mod Development: Low (lateral constraints)	Deposition Rating: Unknown Erosion: Unknown Exposed Crop Soils: Mod	**Decreased stream power: slope** Beaver Dams (5)	**Decreased bank resistance** Dom Buffer: LB/RB:0-25'

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
T3.01C	Road Density: Low Wetland Loss: Mod Development: Low (lateral constraints)	Deposition Rating: Mod Erosion: Low (LB) to High (RB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Culvert: 1 undersized Deposition Rating: Mod **Increased stream power: slope/Depth** Encroachment: Low	**Decreased bank resistance** Dom Buffer: LB/RB:0-25' Erosion Rating: High (RB)
T4.01	Road Density: High Wetland Loss: Mod Development: Mod 16% (lateral constraints)	Deposition Rating: High Erosion: Mod (both banks) Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 2 (1 undersized) Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: Low	**Decreased bank resistance** Erosion Rating: Mod **Increased bank resistance** Bank armoring: Mod (both)
T4.02A	Road Density: High Wetland Loss: Mod Development: Mod 9% (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Mod Mass Failures	**Decreased stream power: slope** Bridge: 1 Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: High	**Decreased bank resistance** Dom Buffer: RB:0-25' **Increased bank resistance** Bank armoring: Mod (RB)
T4.02B	Road Density: High Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Mod	**Decreased stream power: slope** Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: High	**Increased bank resistance** Bank armoring: Mod (RB)
T4.02C	Road Density: High Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (LB) to Mod (RB) Exposed Crop Soils: Mod Mass Failures	**Decreased stream power: slope** Bridge: 3 Deposition Rating: High Grade Control: 1 ledge	**Decreased bank resistance** Dom Buffer: RB:0-25' Erosion Rating: Mod (RB) **Increased bank resistance** Bank armoring: Mod (RB)

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
T4.02C			**Increased stream power: slope/Depth** Encroachment: High	
T4.02D	Road Density: High Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (LB) to High (RB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: High	**Decreased bank resistance** Erosion Rating: High (RB)
T4.03A	Road Density: Mod Wetland Loss: Low Development: Low (lateral constraints)	Deposition Rating: Low Erosion: Low Exposed Crop Soils: Low		**Decreased bank resistance** Dom Buffer: LB:0-25’
T4.03B	Road Density: High Wetland Loss: Mod Development: Low (lateral constraints)	Deposition Rating: High Erosion: Low (RB) to Mod (LB) Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 1 Deposition Rating: High	**Decreased bank resistance** Erosion Rating: Mod (LB) **Increased bank resistance** Bank armoring: Mod (RB)
T4.03C	Road Density: High Wetland Loss: Mod Development: Low (lateral constraints)	NA	**NA**	**NA**
T5.01A	Road Density: Mod Wetland Loss: Mod Development: Mod 17% (lateral constraints)	Deposition Rating: Low Erosion: Mod (RB) to High (LB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bridge: 1 Culvert: 1 undersized Beaver Dam	**Decreased bank resistance** Erosion Rating: Mod to High **Increased bank resistance** Bank armoring: Mod (LB)
T5.01B	Road Density: Mod Wetland Loss: Mod Development: Mod 17% (lateral constraints)	Deposition Rating: High Erosion: Low (RB) to Mod (LB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bridge: 1 Deposition Rating: High	**Decreased bank resistance** Dom Buffer: LB:0-25’ Erosion Rating: Mod (LB)

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
T5.01B			**Increased stream power: slope/Depth** Encroachment: High Straightening >50%	
T5.01C	Road Density: Mod Wetland Loss: Mod Development: (lateral constraints)	Deposition Rating: Unknown Erosion: Mod (both) Exposed Crop Soils: Mod	**Decreased stream power: slope** Beaver Dam **Increased stream power: slope/Depth** Encroachment: Low	**Decreased bank resistance** Erosion Rating: Mod
T5.01D	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (RB) to High (LB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Beaver Dam Deposition Rating: High **Increased stream power: slope/Depth** Straightening >50%	**Decreased bank resistance** Erosion: High (LB) **Increased bank resistance** Bank armoring: Mod (LB)
T5.01E	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: High (both) Exposed Crop Soils: Mod	**Decreased stream power: slope** Culvert: 1 undersized Deposition Rating: High **Increased stream power: slope/Depth** Straightening	**Decreased bank resistance** Dom Buffer: LB/RB:0-25' Erosion Rating: High
T5.01F	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Mod	**Decreased stream power: slope** Beaver Dam Deposition Rating: High	
T5.01G	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Mod (RB) to High (LB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Deposition Rating: High **Increased stream power: slope/Depth** Straightening >50%	**Decreased bank resistance** Dom Buffer: LB:0-25' Erosion Rating: Mod to High

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
T5.S1.01	Road Density: High Wetland Loss: Low Development: High 28% (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bridge: 2 Old Abutment: 1 Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: High Straightening	**Increased bank resistance** Bank armoring: High (LB)
T6.01A	Road Density: Mod Wetland Loss: Low Development: Mod 10% (lateral constraints)	Deposition Rating: High Erosion: Mod (RB) to High (LB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bridge: 2 (1 undersized) Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: Low	**Decreased bank resistance** Dom Buffer: RB:0-25’ Erosion Rating: Mod to High
T6.01B	Road Density: Mod Wetland Loss: Low Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (LB) to Mod (RB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bedrock outcrop Grade control: waterfall Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: Mod	**Decreased bank resistance** Erosion Rating: Mod (RB)
T6.01C	Road Density: Mod Wetland Loss: Low Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Mod Mass Failure	**Decreased stream power: slope** Culvert: 1 undersized Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: Mod	

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic (Increased Flows)**	**Sediment Load (Increased)**	**Stream Power**	**Boundary Resistance**
T7.01A	Road Density: Mod Wetland Loss: Mod Development: Mod 7% (lateral constraints)	Deposition Rating: Mod Erosion: Low (LB) to Mod (RB) Exposed Crop Soils: Low Mass Failure	**Decreased stream power: slope** Beaver Dam Deposition Rating: Mod	**Decreased bank resistance** Erosion Rating: Mod (RB)
T7.01B	Road Density: Mod Wetland Loss: Mod Development:Mod (lateral constraints)	Deposition Rating: High Erosion: Mod (both) Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 2 Culvert: 1 undersized Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: Mod	**Decreased bank resistance** Erosion Rating: Mod
T7.01C	Road Density: Mod Wetland Loss: Mod Development: Mod (lateral constraints)	Deposition Rating: High Erosion: Low (both) Exposed Crop Soils: Low	**Decreased stream power: slope** Bridge: 1 Deposition Rating: High	
T8.01	Road Density: Mod Wetland Loss: Low Development: Mod 11% (lateral constraints)	Deposition Rating: High Erosion: Low (LB) to Mod (RB) Exposed Crop Soils: Mod	**Decreased stream power: slope** Bridge: 1 Deposition Rating: High **Increased stream power: slope/Depth** Encroachment: High Straightening >50%	**Decreased bank resistance** Erosion Rating: Mod (RB) Dom Buffer: RB:0-25' **Increased bank resistance** Bank armoring: High (RB)

5.1.7 Sediment Regime Departure, Constraints to Sediment Transport, and Attenuation

Within a reach, the principals 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. Whether a project works with or against the physical processes at play in a watershed is primarily determined by examining the source, volumes, and attenuation of flood flows and sediment loads from one reach to the next within the stream network. If increasing 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 (VTANR 2007).

Under reference conditions, the sediment regime of the Browns River would be one in which all reaches would provide for coarse particle equilibrium (in = out: stream power, which is produced as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance) and fine sediment deposition at annual flood flows.

The existing sediment regime has been converted to one in which several reaches of the Browns now function as transport reaches, with coarse deposition occurring when stream power is reduced or sediment load exceeds the carrying capacity of the stream. Thirty-two of the forty-one assessed segments have been converted to 'Fine Source and Transport & Coarse Deposition' reaches. The remaining nine reaches are characterized by the reference sediment regime of "Coarse Equilibrium & Fine Deposition". Little sediment and nutrient attenuation is occurring because the channel has lost much of its historic floodplain access. The result of this conversion is that sediment and nutrients are no longer retained in the watershed, but carried downstream to other reaches and receiving waters, namely the Lamoille River and eventually Lake Champlain.

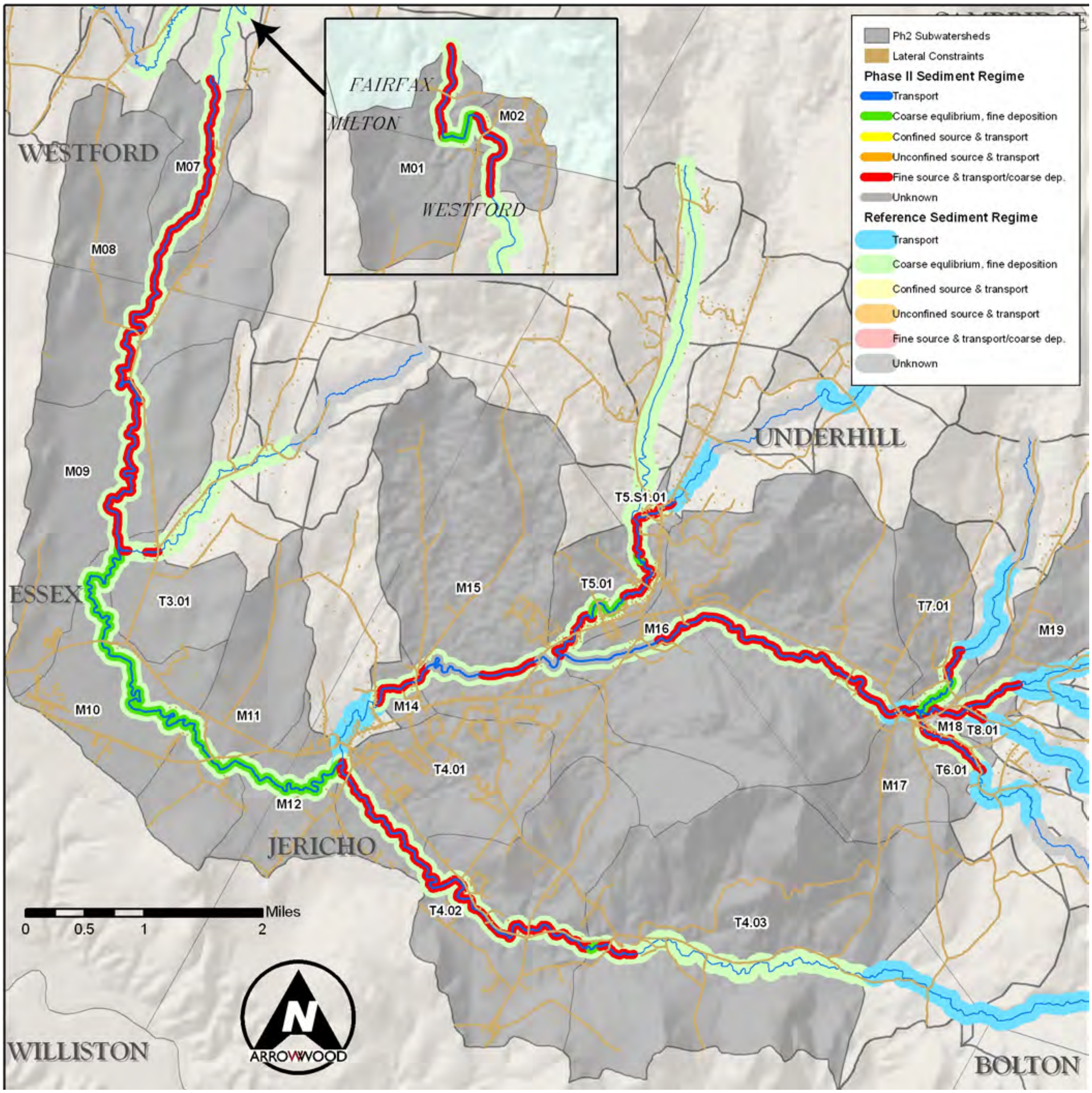

Figure 11. Sediment Regime Map

With much of the stream channel in the Browns incised sufficiently to prevent unfettered access to historical floodplains, efforts of the river to re-establish equilibrium are causing and will continue to cause widening of channels and lateral migration until it is able to rebalance the power of the water in the channel with the amount of sediment being moved. Hence, it is important to identify areas where sediment and nutrients can be stored within the Browns River Corridor.

Sediment Regime	Stage of Channel Evolution Geomorphic Condition	Common Existing Stream Type	Delimiting criteria related to Sediment supply, transport, and storage	Natural Valley Type
Fine Source and Transport & Coarse Deposition	Stage II-IV Fair-Poor	E3, E4, E5 C3, C4, C5, B3c, B4c, B5c, F3, F4, F5	Bank armor < 50% W/d > 30 Incision ratio ≥ 1.3	NW, BD, VB
	Stage II-IV Fair-Poor	D3, D4, D5	Bank armor < 50% Incision ratio ≥ 1.3	NW, BD, VB
Coarse Equilibrium (in = out) & Fine Deposition	Stage I or V Fair-Good-Ref	D3, D4, D5	Incision ratio < 1.3	NW, BD, VB
	Stage I or V Fair-Good-Ref	C2, C3, E3	W/d < 30 Incision ratio < 1.3	NW, BD, VB
	Stage I or V Fair-Good-Ref	C4, C5 E4, E5	W/d > 30 Incision ratio < 1.3	NW, BD, VB

Phase 2 work assessed all reaches of the Browns River as being at Stage I to IV of channel evolution (Table 4). Schumm (1977 and 1984) has described five stages of channel evolution (F-stage model) for reaches such as those found in the study area, where the stream has a bed and banks that are sufficiently erodible to be shaped by the stream over time, paraphrased from the SGA protocols (VTANR 2007, Appendix C) as follows:

I. **Stable** – in regime, reference to good condition. Insignificant to minimal adjustment; planform is moderate to highly sinuous.

II. **II. Incision** – Fair to poor condition, major to extreme channel degradation. High flow events are contained in the channel, and channel slope is typically increased.

III. **Widening/Migration** – Fair to poor condition, major to extreme widening and aggradation.

IV. **Stabilizing** – Fair to good condition, major reducing to minor aggradation, widening and planform adjustments

V. **Stable** – In regime, reference to good condition. Insignificant to minimal adjustment.

Table 4. Sediment Regime Reach Summary Table

Sediment Regime	Stage of Channel Evolution Geomorphic Condition	Common Existing Stream Type	Delimiting criteria related to Sediment supply, transport, and storage	Natural Valley Type
Reach M01	1A: Stage III: Fair 1B: Stage IV:Good	C5 C4	Incision ratio 1.58 W/d 16.23 Incision ratio 1.65 W/d 20.92	BD BD
	1C:Stage III: Poor	C5	Incision ration 1.25 W/d 16.57	BD
Reach M02	2A: Stage III: Fair 2B: Stage III: Fair	C5 C3	Incision ratio 1.51 W/d 15.94 Incision ratio 1.39 W/d 21.19	BD BD
Reach M07	Stage III: Poor	E5	Incision ratio 1.39 W/d 9.75	BD
Reach M08	Stage III: Fair	F5	Incision ratio 2.2 W/d 16.27	VB
Reach M09	Stage II: Good	E5	Incision ratio 1.62 W/d 6.98	VB
Reach M10	Stage I: Good	E5	Incision ratio 1.25 W/d 11.12	VB
Reach M11	Stage II: Fair	E5	Incision ratio 1.27 W/d 9.87	VB
Reach M12	Stage II: Fair	C5	Incision ratio 1.00 W/d 13.68	VB
Reach M14	Stage IV: Fair	C4	Incision ratio 1.65 W/d 17.53	VB
Reach M15	15A: III: Fair 15C: Stage III:Fair	C4 C4	Incision ratio 2.07 W/d 26.52 Incision ratio 1.51 W/d 9.74	VB VB
	15B: NA 15D: NA	E4 E4	Incision ratio 1.85 W/d 8.87 Incision ratio 1.50 W/d 41.33	VB NC
Reach 16	16A: NA	F4	Incision ratio 2.26 W/d 23.38	NA
	16B: Stage III:Fair 16C: Stage II: Ref	D4 C4	Incision ratio 2.44 W/d 37.86 Incision ratio 1.58 W/d 20.87	BD BD
Reach 17	Stage IV: Good	B4	Incision ratio 2.06 W/d 41.76	BD
Reach 18	Stage IV: Fair	C4	Incision ratio 1.72 W/d 20.0	VB
Reach 19	Stage III: Good	C3	Incision ratio 1.76 W/d 20.75	VB
Reach T3.01	T3.01A: III: Poor T3.01C: III: Fair	G6 E4	Incision ratio 3.42 W/d 10.00 Incision ratio 1.94 W/d 11.24	VB VB
	T3.01B: NA	NA	NA	VB
Reach T4.01	Stage III: Fair	C4	Incision ratio 1.52 W/d 18.9	VB

Reach T4.02	T4.02A: III:Good T4.02B: IV: Good T4.02C: III: Good T4.02D: III: Fair	C4 B4 C4 D4	Incision ratio 1.70 Incision ratio 1.41 Incision ratio 1.70 Incision ratio 1.41	W/d 13.89 W/d 28.03 W/d 13.89 W/d 96.15	BD NC BD BD
Reach T4.03	T4.03A: III: Fair	D4	Incision ratio 1.22	W/d 96.15	BD
	T4.03B:III: Good	F4	Incision ratio 2.02	W/d 16.9	VB
	T4.03C: NA	NA	NA		NA
Reach T5.01	T5.01A: II: Fair T5.01E: III: Fair T5.01G: III: Fair	C4 E5 E4	Incision ratio 1.77 Incision ratio 1.95 Incision ratio 1.58	W/d 16.44 W/d 11.9 W/d 10.25	VB VB VB
	T5.01B: IV: Good T5.01D: IV: Good	C3 C4	Incision ratio 1.17 Incision ratio 1.17	W/d 11.85 W/d 11.85	VB VB
	T5.01C: NA T5.01F: NA	NA NA	NA NA		NA NA
Reach T5.S1.01	Stage III: Fair	C3	Incision ratio 1.68	W/d 10.59	VB
Reach T6.01	T6.01A: III: Fair T6.01B: II: Good T6.01C: III: Good	E4 F4 C4	Incision ratio 1.87 Incision ratio 3.00 Incision ratio 1.88	W/d 9.30 W/d 18.18 W/d 15.65	VB SC BD
Reach T7.01	T7.01A: II: Good T7.01B: II: Good	C4 B4	Incision ratio 1.18 Incision ratio 1.00	W/d 13.28 W/d 22.94	VB BD
	T7.01C: IV: Good	E4	Incision ratio 1.48	W/d 11.18	VB
Reach T8.01	Stage III: Fair	B4	Incision ratio 1.68	W/d 13.95	VB

Under the existing sediment regime, which includes limited floodplain access and increased stream power, erosion, widening, and lateral migration are likely to increase and deposition is primarily occurring in the Browns River when sediment load exceeds carrying capacity, or when channel geometry changes sufficiently to decrease stream power.

The combination of increased stream power and sediment transport along with erosive materials on both bed and banks raise the following issues on the Browns River:

a) both bed and banks are susceptible to further erosion as part of a process of channel evolution as the stream attempts to regain equilibrium;
b) maintenance of banks through continued channelization increases the likelihood of further bed incision (including potential headcuts) that would further limit access to floodplain and initiate further channel adjustments

c) lack of access to floodplain and extensive channel straightening means that the bulk of sediment deposition impacts are being transferred to downstream reaches;

d) deposition is occurring whenever stream power is reduced, and will likely continue to accumulate quickly in these areas (building on the further decrease of stream power caused by that deposition), increasing the likelihood of channel avulsions in the highly erodible materials along the river corridor;

e) lack of access to floodplains and meanders for sediment storage means that nutrients are being transported downstream

The primary lateral constraints to stream processes identified in both Phase 1 and Phase 2 work on the Browns River are road and residential development encroachment in the river corridor, along with maintenance of highly-valued agricultural resources along the river corridor. Given the existing sediment transport regime and stage of channel evolution of reaches in the study area, likely entailing increased erosion and widening as the river attempts to reestablish equilibrium with the increased stream power, restoration of floodplain access would be a critical component in re-establishing a reference sediment regime. Identification of “attenuation assets” to accommodate high flows and sediment deposition would include areas where the river can be allowed to reestablish meanders (rather than being straightened) as well as access to the floodplain.

Table 5. Attenuation Asset Summary Table

	Constraints		**Sediment Transport-Type Stream**		**Attenuation (storage type stream)**		
River Segment	Vertical	Lateral	Natural Transport Type	Converted by Human Constraints	Natural Deposition Zone	Increased Sediment Supply	Asset to Future Deposition
M01		Agriculture			X		
A				X		X	X
B		Bridge		X			
C						X	X
M02		Agriculture/Roads			X		
A		Bridge		X		X	X
B				X		X	X
M07		Agriculture 3 Undersized Bridges		X	X	X	X

	Constraints		Sediment Transport-Type Stream		Attenuation (storage type stream)		
River Segment	Vertical	Lateral	Natural Transport Type	Converted by Human Constraints	Natural Deposition Zone	Increased Sediment Supply	Asset to Future Deposition
M08		Agriculture 2 Undersized Bridges Development		X	X	X	X
M09	Ledge	Agriculture 3 Undersized Bridges		X	X		X
M10		Agriculture/Roads 1 Undersized Bridge			X		X
M11		Agriculture/Roads Development Bridge			X		
M12		Agriculture/Roads 1 Undersized Bridge			X		X
M14	Dam Ledge	Agriculture 1 Bridge Development Roads		X	X		
M15 A B C D	 Dam	Roads Development 1 Undersized Bridge		 X X	X		 X X
M16 A B C		Roads Develop/Bridge 2 Bridges		 X X	X		 X
M17		Roads 1 Undersized Culvert		X	X	X	
M18		Agriculture Roads Development 1 Bridge		X	X	X	
M19		1 Bridge Development		X	X	X	Limited
T3.01 A B C		Agriculture 1 Undersized Culvert		 X X	X	 X X	
T4.01		2 Bridges (1 undersized) Roads			X	X	X

	Constraints		Sediment Transport-Type Stream		Attenuation (storage type stream)		
River Segment	Vertical	Lateral	Natural Transport Type	Converted by Human Constraints	Natural Deposition Zone	Increased Sediment Supply	Asset to Future Deposition
T4.02					X		
A		Agriculture/Roads Bridge/Dev.				X	
B	Ledge	Development				X	
C		3 Bridges				X	
D		Development				X	
T4.03		Roads			X		
A							Limited
B		Bridge		X		X	Limited
C							
T5.01		Agriculture/Roads			X		
A		Bridge/ Undersized Culvert		X			
B		Bridge/Dev.				X	
C							
D				X		X	X
E		Undersized Culvert				X	X
F				X		X	X
G						X	X
T5.S1.01		Agriculture/Roads 2 Bridges Development		X	X	X	
T6.01		Agriculture/Roads			X		
A		2 Bridges (1Undersized)		X		X	Limited
B	Ledge	Development		X		X	X
C		Undersized Culvert/Dev.		X		X	Limited
T7.01		Roads			X		
A						X	X
B		Undersized Culvert and Bridge/Dev.				X	Limited
C		1 Bridge/Dev.		X		X	Limited
T8.01		Agriculture/Roads 2 Bridges (1 undersized) Development		X	X	X	

5.2 SENSITIVITY ANALYSIS

The preceding departure analysis identifies the watershed and reach scale stressors that help explain the sediment regime departure currently existing in several reaches of the Browns. Designing stream corridor protection and restoration projects that are compatible with channel evolution processes, and prioritizing them at the watershed scale, also requires an understanding of stream sensitivity.

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, and an indication as to the potential rate of channel evolution (VTANR 2007, Phase 2 Step 7.7; VTANR 2007 Sec. 5.2). While every stream changes in time, a sensitivity rating indicates that some streams, due to their setting and location within the watershed, are more likely to be in a state of change or adjustment (VTANR 2007, Phase 3 Step 6.2).

Alteration of sediment and flow regimes that have converted 18 of the 22 Browns River reaches to transport reaches, combined with fine-grained and erosive boundary conditions have led to conditions in which all but one stream segment (M17) are highly to extremely sensitive. A stream type departure was indicated for M08 assessed in Phase 2, converting this stream segment to F (entrenched) from E (slightly entrenched). A second stream type departure was indicated for T3.01A, converting this stream segment to a G (entrenched) from C (slightly entrenched). A third stream type departure was indicated for T4.02B, converting this stream segment to a B (moderately entrenched) from C (slightly entrenched). A fourth stream type departure was indicated for T4.03B, converting this stream to an F (entrenched) from C (slightly entrenched). A fifth stream departure was indicated for T6.01B, converting this stream to an F (entrenched) from B (moderately entrenched). These departures are indicative of the loss of floodplain access that is contributing to elevated stream sensitivity.

Two additional stream type departures were identified in reaches T4.02D and T4.03A converting from C type channels to a D indicating destabilization of the channel within these segments. The channel aggradation/degradation and lateral extension processes, notably active in "C" stream types, are inherently dependent on the natural stability of streambanks, the existing upstream watershed conditions and flow and sediment regime. C-type channels can be significantly altered and rapidly de-stabilized when the effects of changes in bank stability, watershed condition, or flow regime are combined to cause an exceedance of a channel stability threshold. (Rosgen, D.L. and H.L. Silvey. 1996. Applied River Morphology. Wildland Hydrology Books, Fort Collins, CO)

Although the lack of floodplain access has currently converted a significant part of the Browns to a transport regime, the high sediment load and high sensitivity of the reaches, along with relatively limited constraints within parts of the corridor at present, indicates good possibilities for success of passive geomorphic projects, which would allow the river to utilize its own energy and watershed inputs to re-establish its meanders, floodplains, and self maintaining equilibrium conditions over time.

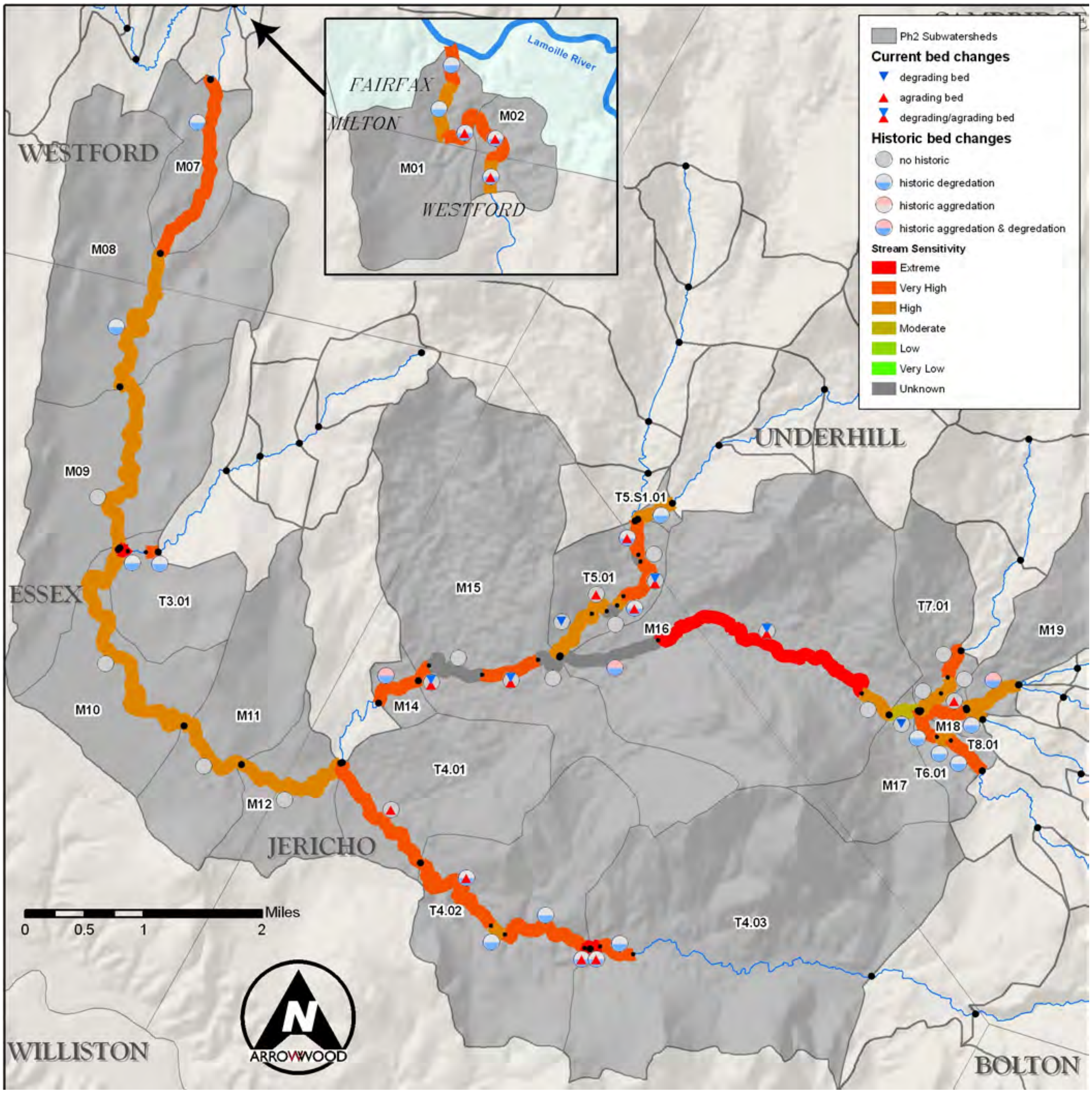

Figure 12. Stream Sensitivity Map

6.0 PRELIMINARY PROJECT IDENTIFICATION

The preceding departure and sensitivity analysis provides the watershed and reach scale background to guide prioritization and selection of projects in a manner that maximizes their effectiveness and reduces the likelihood of failure, specifically by assessing the underlying causes of channel instability. With the information from these maps and tables, a step-wise process has been conducted to identify the following actions, in order of priority, in a manner designed to facilitate restoration of the stream to equilibrium conditions (VTANR 2007):

Step 6.1. Protecting River Corridors
Step 6.2. Planting Stream Buffers
Step 6.3. Stabilizing Stream Banks
Step 6.4. Arresting head cuts and nick points
Step 6.5. Removing Berms and other constraints to flood and sediment load attenuation
Step 6.6. Removing/Replacing Structures (e.g. undersized culverts, constrictions, low dams)
Step 6.7. Restoring Incised Reaches
Step 6.8. Restoring Aggraded Reaches

As indicated in Section 5.2 of this report, the high to extreme sensitivity of the reaches in the Browns River study area indicates that passive geomorphic projects, particularly given the high sediment load and the rapidity of channel evolutions evidenced in the past, is generally an appropriate management alternative. This places a very high priority, throughout the study area, on the first two items identified in the stepwise procedure above. The third item, stabilization of stream banks, is generally not recommended due to vertical instability in all reaches and continuing widening in channel evolution processes, increasing the likelihood of failure of such efforts. This recommendation needs to be assessed in regards to site specific recommendations and critical infrastructure. It should be recognized, however, that the current conversion of the majority of the assessed study reaches sediment regimes to transport types will mean that further armoring of banks will aggravate downstream deposition impacts.

Bed materials are sensitive to erosion, and three headcuts were documented in Phase 2 in reaches T5.01E, T7.01A and T7.01B. The incised nature of the main branch of the Browns and its major tributaries makes Step 6.4 an item to be regularly assessed in all reaches.

Reach maps are included in the appendix and were created from available GPS data and field sketches. Of note, is the fact that nine reaches (M08, M09, M10, M11, M12, M15, M16, M17, and M18) were assessed prior to the indexing of areas with buffers less than 25 ft. For these reaches poor buffers may be indicated in the Reach Stressor tables below but not identified on the reach map.

In addition to the eight actions identified above, potential wetland restoration projects are included in the analysis of each reach segment. Vermont recently completed the Lake Champlain Basin Wetland Restoration Plan. This plan identifies impaired wetlands within the Vermont portion of the Lake Champlain Basin and prioritizes them for restoration. Using a geographic information system (GIS)-based model 4,883 potential wetland restoration opportunities were identified in the basin. A different model was then used to prioritize these opportunities. The resulting GIS database of potential restoration sites was included on the attached reach maps. For reaches containing potential restoration opportunities, wetland restoration was included in the projects and practices table.

6.1 REACH DESCRIPTIONS

Preliminary project identification for the Browns River is presented on a reach by reach basis in the following pages. Results of the Phase 2 study are summarized below by reach number, and individual reach summary reports from the Phase 2 database are included in the appendices. Field measurements and locations of other features are overlayed on 2008 aerial photos (NAIP).

6.1.1 Preliminary Project Identification: Reach M01

M01A Summary Data

Reach/Segment Length	**1720 ft**
Valley Confinement	**Broad**
Reference Stream Type	**C3**
Existing Stream Type	**C5**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**III**
Adjustment Process	**Widening/ some aggradation**
Habitat Condition	**Fair**
Stream Sensitivity	**Very High**

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

M01b Summary Data	
Reach/Segment Length	2713 ft
Valley Confinement	Broad
Reference Stream Type	C3
Existing Stream Type	C4
Geomorphic Condition	Good
Channel Evolution Stage	IV
Adjustment Process	Minor Adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

M01C Summary Data	
Reach/Segment Length	2261 ft
Valley Confinement	Broad
Reference Stream Type	C3
Existing Stream Type	C5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation
Habitat Condition	Poor
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M01a,b, c	Protect River Corridor	Landowner cooperation needed . Asset to future deposition.
M01b,c	Plant Stream Buffers	Contact landowners; investigate possible grant programs for plantings; Segment C is in still widening so plantings should be set back from the immediate streambank

6.1.2 Preliminary Project Identification: Reach M02

M02a Summary Data

Reach/Segment Length	2902 ft
Valley Confinement	Broad
Reference Stream Type	C5
Existing Stream Type	C5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

M02b Summary Data

Reach/Segment Length	1476 ft
Valley Confinement	Broad
Reference Stream Type	C5
Existing Stream Type	C3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	widening, some aggradation
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M02 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M02a,b	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
M02a,b	Plant Stream Buffers	Stream is still widening so plantings should be set back from immediate streambank. Contact landowners, investigate possible grant programs for plantings
M02a	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
M02a	Structure replacement	Undersized bridge at Rte 128 crossing. Upstream and downstream deposition observed.

6.1.3 Preliminary project identification: Reach M07

M07 Summary Data	
Reach/Segment Length	9218 ft
Valley Confinement	Broad
Reference Stream Type	E5
Existing Stream Type	E5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ planform changes
Habitat Condition	Poor
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors
Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M07 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M07	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
M07	Relocate Pasture Fencing	Contact landowners; organize volunteers to relocate fences from streambank and restrict cattle access to stream
M07	Bridge replacement (Upstream end of segment, 18’ wide)	Very narrow, undersized farm bridge creating a pinch point for stream. Sediment deposition observed downstream. Contact landowner and research grant possibilities
M07	Structure replacement	The remaining two bridges are also significantly undersized causing sediment deposition upstream and downstream.
M07	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
M07	Plant Stream Buffers	Stream is still widening so plantings should be set back from immediate stream bank. Contact landowners, investigate possible grant programs for plantings

6.1.4 Preliminary Project Identification: Reach M08

M08 Summary Data	
Reach/Segment Length	8456 ft
Valley Confinement	Very Broad
Reference Stream Type	E5
Existing Stream Type	F5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors
Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M08 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M08	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
M08	Dump Cleanup (one junk car frame)	Contact landowner, organize volunteers, and arrange for proper disposal.
M08	Structure repair/removal (upstream of Pettingill Road crossing)	Significantly undersized and undermined bridge. Upstream and downstream sediment deposits observed. Abutments are falling into the stream from undermining. Maybe an old railroad bridge? Contact landowner and research grant possibilities
M08	Structure repair/removal (downstream of Pettingill Road crossing)	Significantly undersized bridge. Undermined by scour. Downstream sediment deposits observed. Contact landowner and research grant possibilities
M08	Plant Stream Buffers	Stream is still widening so plantings should be set back from streambank. Contact landowners, investigate grant opportunities.
M08	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
M08	Wetland Restoration	12 acres within the corridor have been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.5 Preliminary Project Identification: Reach M09

M09 Summary Data	
Reach/Segment Length	11,550 ft
Valley Confinement	Very Broad
Reference Stream Type	E5
Existing Stream Type	E5
Geomorphic Condition	Good
Channel Evolution Stage	II
Adjustment Process	Degradation
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M09 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M09	Protect River Corridor	Landowner cooperation needed . Asset to future deposition.
M09	Plant Stream Buffers	Contact farmers to plant stream buffer with woody vegetation. Investigate possible grant programs for plantings
M09	Structure removal	Two old abutments. Conduct detailed field evaluation before removal, determine if grade control is needed to protect against headcuts. Contact landowners and research grant possibilities for removal and disposal.
M09	Structure removal	Discuss possibility of removing one of the two undersized bridge crossings with landowner. Research grant possibilities for replacement of one of the undersized bridges.
M09	Wetland Restoration	6 acres within the corridor have been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.6 Preliminary Project Identification: Reach M10

M10 Summary Data	
Reach/Segment Length	12,429 ft
Valley Confinement	Very Broad
Reference Stream Type	E5
Existing Stream Type	E5
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	Minor Adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Reach M10 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M10	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
M10	Plant Stream Buffers	Contact farmers to plant stream buffer with woody vegetation (right bank is in greatest need throughout this reach). Investigate possible grant programs for plantings
M10	Stabilize Streambanks	Reach is in Stage 1 with minor adjustments so planting buffers may be sufficient. Further field survey can be conducted to determine locations where more active streambank stabilization is warranted.
M10	Structure removal	Old abutment in between two bridges. Conduct detailed field evaluation before removal, determine if grade control is needed to protect against headcuts. Contact landowner and research grant possibilities for removal and disposal.
M10	Structure removal	Old abutment (undersized) downstream of Reach M11 break. Conduct detailed field evaluation before removal, determine if grade control is needed to protect against headcuts. Contact landowner and research grant possibilities for removal and disposal.
M10	Structure replacement	Discuss possibility of replacing undersized farm bridge (upstream of Rte 128 bridge) with landowner. Research grant possibilities for replacement of bridge.
M10	Wetland Restoration	1 acre within the corridor has been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.7 Preliminary Project Identification: Reach M11

M11 Summary Data	
Reach/Segment Length	2937 ft
Valley Confinement	Very Broad
Reference Stream Type	E5
Existing Stream Type	E5
Geomorphic Condition	Good
Channel Evolution Stage	II
Adjustment Process	Minor Adjustments
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Reach M11 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M11	Plant Stream Buffers	Contact farmers to plant stream buffer with woody vegetation. Investigate possible grant programs for plantings

6.1.8 Preliminary Project Identification: Reach M12

M12 Summary Data	
Reach/Segment Length	7196 ft
Valley Confinement	Very Broad
Reference Stream Type	C5
Existing Stream Type	C5
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	Aggradation
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts
Berms

Reach M12 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M12	Protect River Corridor	Landowner cooperation needed. Key attenuation asset.
M12	Structure replacement	Preliminary data indicate that the bridge in this reach is undersized. A complete bridge assessment is needed to determine if this is a priority replacement project.

6.1.9 Preliminary Project Identification: Reach M14

M14 Summary Data	
Reach/Segment Length	2388 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	IV
Adjustment Process	Minor Adjustments
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M14 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M14	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
M14	Plant Stream Buffers/Fence Relocation	Contact farmer at downstream end of reach to move fences back from edge of bank for horses with open access (not an actual crossing, just access) and to plant stream buffer with woody vegetation. Investigate possible grant programs for plantings

6.1.10 Preliminary Project Identification: Reach M15

M15a Summary Data	
Reach/Segment Length	855 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

M15b Summary Data

Reach/Segment Length	3896 ft
Valley Confinement	Very Broad
Reference Stream Type	E4
Existing Stream Type	E4
Geomorphic Condition	Poor
Channel Evolution Stage	III
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

M15c Summary Data

Reach/Segment Length	2676 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

M15d Summary Data

Reach/Segment Length	1563 ft
Valley Confinement	Narrow
Reference Stream Type	E4
Existing Stream Type	E4
Geomorphic Condition	Poor
Channel Evolution Stage	III
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach M15 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M15b,c	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
M15a,b, c, d	Plant Stream Buffers	Stream is still widening so plantings should be set back from the streambank. Contact landowners, investigate possible grant programs for plantings
M15b,c,d	Eliminate animal crossings	Contact farmer/landowner to discuss possibility of reducing the number of animal crossings within segments b,c and d.
M15a,b	Dam Backwater Impact	Downstream dam is creating a backwater impact. Discussion between landowner and Winooski Conservation District regarding potential projects
M15b	Wetland Restoration	2 acres within the corridor have been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.11 Preliminary Project Identification: Reach M16

M16a Summary Data

Reach/Segment Length	1115 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	F4
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	Extreme

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts
Berms

M16b Summary Data	
Reach/Segment Length	12261 ft
Valley Confinement	Broad
Reference Stream Type	D4
Existing Stream Type	D4
Geomorphic Condition	Poor
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation/ planform changes
Habitat Condition	Fair
Stream Sensitivity	Extreme

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts
Berms

M16c Summary Data	
Reach/Segment Length	5202 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Reference
Channel Evolution Stage	II
Adjustment Process	Minor adjustments
Habitat Condition	Reference
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts
Berms

Preliminary project recommendations are presented in the following table.

Reach M16 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M16b	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
M16b	Dump site removal	Contact landowner. Research grants for removal and disposal costs.
M16b	Wetland Restoration	2 acres within the corridor have been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.12 Preliminary Project Identification: Reach M17

M17 Summary Data

Reach/Segment Length	**1690 ft**
Valley Confinement	**Broad**
Reference Stream Type	**B4**
Existing Stream Type	**B4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**IV**
Adjustment Process	**Minor widening**
Habitat Condition	**Good**
Stream Sensitivity	**Moderate**

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

River Segment ID	Project	Next Steps and other Project Notes
M17	Structure Replacement	River Road bridge is undersized. A full bridge assessment has not been completed.

6.1.13 Preliminary Project Identification: Reach M18

M18 Summary Data

Reach/Segment Length	**2391 ft**
Valley Confinement	**Very Broad**
Reference Stream Type	**C4**
Existing Stream Type	**C4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**IV**
Adjustment Process	**Aggradation and planform adjustments**
Habitat Condition	**Fair**
Stream Sensitivity	**Very High**

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

River Segment ID	Project	Next Steps and other Project Notes
M18	Structure replacement	The Pleasant Valley Road bridge is undersized. A complete bridge assessment is needed.

6.1.14 Preliminary Project Identification: Reach M19

M19 Summary Data	
Reach/Segment Length	2724 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	C3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Table 9f. Reach M19 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M19	Plant Stream Buffers (left bank downstream)	Contact landowners, investigate possible grant programs for plantings

6.1.15 Preliminary Project Identification: Reach T3.01

T3.01a Summary Data Abbey Brook	
Reach/Segment Length	503 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	G6
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ planform changes
Habitat Condition	Poor
Stream Sensitivity	Extreme

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank
Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T3.01b Summary Data *Impounded by beavers	
Reach/Segment Length	888 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	NA
Geomorphic Condition	NA
Channel Evolution Stage	NA
Adjustment Process	NA
Habitat Condition	NA
Stream Sensitivity	NA

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T3.01c Summary Data	
Reach/Segment Length	554
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach T3.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T3.01a,b,c	Plant stream buffers	Stream is still widening so plantings should be set back from the streambanks. Contact landowners and research grant opportunities.
T3.01c	Structure Repair/Replacement	Severely undermined and undersized culvert at Rte 128 crossing. Check with AOT for replacement potential.

6.1.16 Preliminary Project Identification: Reach T4.01

T4.01 Summary Data
Lee River

Reach/Segment Length	6807 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ planform changes
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank
Vegetation

Reach Stressors
Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach T4.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T4.01	Protect River Corridor	Landowner cooperation necessary. Asset to future deposition.
T4.01	Planting Stream Buffers	Stream is still widening so plantings should be set back from streambanks. Contact interested landowners and research grant opportunities.
T4.01	Structure Removal (old bridge abutment downstream of Plains Road)	Conduct detailed field evaluation before removal, determine if grade control is needed to protect against headcuts. Contact landowner and research grant possibilities.
T4.01	Structure Removal (steel bridge upstream of Plains Road bridge)	There are two bridges side by side. The steel bridge is out of use and significantly undersized. Contact landowner, research grant possibilities for removal and disposal.
T4.01	Eliminate active dredging	Contact landowner. Educate about impacts of channel manipulation
T4.01	Wetland Restoration	2 acres within the corridor have been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.17 Preliminary Project Identification: Reach T4.02

T4.02A Summary Data
Lee River

Reach/Segment Length	6373 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ minor widening
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T4.02B Summary Data
Lee River

Reach/Segment Length	757 ft
Valley Confinement	Narrow
Reference Stream Type	C4
Existing Stream Type	B4
Geomorphic Condition	Fair
Channel Evolution Stage	IV
Adjustment Process	Minor adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T4.02C Summary Data
Lee River

Reach/Segment Length	4904 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ widening
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts
Berms

T4.02D Summary Data Lee River	
Reach/Segment Length	330 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	D4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation/ planform changes
Habitat Condition	Fair
Stream Sensitivity	Extreme

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts
Berms

Preliminary project recommendations are presented in the following table.

Reach T4.02 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T4.02c	Erosion controls	Contact sand/gravel pit to discuss installation of silt fences and create larger buffers to stream
T4.02 a,c	Planting Stream Buffers	Stream is still widening so plantings should be set back from streambanks. Contact interested landowners and research grant opportunities.
T4.02c	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

6.1.18 Preliminary Project Identification: Reach T4.03

T4.03a Summary Data Lee River	
Reach/Segment Length	570 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	D4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, aggradation, planform changes
Habitat Condition	Fair
Stream Sensitivity	Extreme

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T4.03b Summary Data Lee River	
Reach/Segment Length	1763 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	F4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ planform changes
Habitat Condition	Good
Stream Sensitivity	Extreme

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

T4.03C Summary Data Lee River	
Reach/Segment Length	14191 ft
Valley Confinement	NA
Reference Stream Type	NA
Existing Stream Type	NA
Geomorphic Condition	NA
Channel Evolution Stage	NA
Adjustment Process	
Habitat Condition	NA
Stream Sensitivity	NA

*No property access

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

Reach T4.03 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T4.03 a,b	Plant Stream Buffer	Stream is still widening so plantings should be set back from streambanks. Focus on downstream portion of Segment B. Contact interested landowners and research grant opportunities.
T4.03 b	Structure removal (old bridge abutment just upstream of A/B segment break)	Contact landowner, research grant possibilities for removal and disposal.

6.1.19 Preliminary Project Identification: Reach T5.01

T5.01a The Creek: Summary Data

Reach/Segment Length	3277 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	II
Adjustment Process	Degradation/ planform changes
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T5.01b Summary Data The Creek

Reach/Segment Length	1180 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C3
Geomorphic Condition	Good
Channel Evolution Stage	IV
Adjustment Process	Minor adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T5.01c The Creek: Summary Data
***Not Assessed due to Beaver Impoundment**

Reach/Segment Length	632ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	NA
Geomorphic Condition	NA
Channel Evolution Stage	NA
Adjustment Process	NA
Habitat Condition	NA
Stream Sensitivity	NA

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs

T5.01d Summary Data
The Creek

Reach/Segment Length	632 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	E4
Geomorphic Condition	Good
Channel Evolution Stage	IV
Adjustment Process	Minor Adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs

T5.01e Summary Data
The Creek

Reach/Segment Length	2973 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	E5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ widening/ planform
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs

T5.01f The Creek: Summary Data
***Not assessed due to beaver impoundment**

Reach/Segment Length	445 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	NA
Geomorphic Condition	NA
Channel Evolution Stage	NA
Adjustment Process	NA
Habitat Condition	NA
Stream Sensitivity	NA

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs

T5.01g Summary Data The Creek	
Reach/Segment Length	1724 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ planform changes
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs

Preliminary project recommendations are presented in the following table.

Reach T5.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T5.01 d,e,f,g	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
T5.01 a,b,d,f,g	Plant Stream Buffer	Segment G is still widening so plantings should be set back from streambanks. Contact landowner, investigate possible grant programs for plantings
T5.01e	Arrest Head Cut	Conduct additional field survey and investigation to determine if this is a priority project.
T5.01a	Structure removal/replacement (culvert under Raceway Road)	Steel corrugated pipe which is rotting, stream is flowing under the undersized pipe. Contact the Town, research grant possibilities for replacement
T5.01a, d	Dump site (Segment D has a debris jam with old bridge pieces at the segment break with E)	Contact landowners. Organize volunteers. Research grant possibilities for disposal costs.
T5.01e	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
T5.01d, e,g	Wetland Restoration	1 acre, 6 acres and 3 acres within the corridor of segment D,E, and G, respectively, have been identified as having the wetland restoration potential. Detailed site investigation is needed to determine priority of this project for the reach.

6.1.20 Preliminary Project Identification: Reach T5.S1.01

T5.S1.01 Summary Data
Roaring Brook

Reach/Segment Length	1892ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	C3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Reach T1.05S1.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.05S1.01	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
T1.05S1.01	Structure removal (old concrete abutment and grade control at Poker Hill Road)	Conduct detailed field evaluation before removal, determine if grade control is needed to protect against headcuts. Contact landowner; organize volunteers; investigate grants for disposal costs
T1.S5S1.01	Structure Replacement	Undersized bridge at Brook Bend Road. Downstream deposition observed.

6.1.21 Preliminary Project Identification: Reach T6.01

T6.01a Summary Data
Steinhour Brook

Reach/Segment Length	1748 ft
Valley Confinement	Very Broad
Reference Stream Type	E4
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation,
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T6.01b Summary Data
Steinhour Brook

Reach/Segment Length	707 ft
Valley Confinement	Semi-confined
Reference Stream Type	E4
Existing Stream Type	F4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Relatively Stable
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T6.01c Summary Data
Steinhour Brook

Reach/Segment Length	2050 ft
Valley Confinement	Broad
Reference Stream Type	E4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation,
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal
Crossings
Dredging
Poor Stream
Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Table 9m. Reach T6.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T6.01a,c	Plant Stream Buffers	Stream is still widening so plantings should be set back from streambanks. Contact landowners, investigate possible grant programs for plantings
T6.01a	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
T6.01c	Structure replacement	Significantly undersized culvert at Beartown Road. Sediment deposits observed downstream of structure.

6.1.22 Preliminary Project Identification: Reach T7.01

T7.01a Summary Data
Crane Brook

Reach/Segment Length	1535 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	C4
Geomorphic Condition	Good
Channel Evolution Stage	II
Adjustment Process	Incising in places
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T7.01b Summary Data
Crane Brook

Reach/Segment Length	1151 ft
Valley Confinement	Broad
Reference Stream Type	C3
Existing Stream Type	B4
Geomorphic Condition	Fair
Channel Evolution Stage	II
Adjustment Process	Minor adjustments/ local incision
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

T7.01c Summary Data Crane Brook	
Reach/Segment Length	1673 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	IV
Adjustment Process	Planform changes
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating
Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations for Reach T7.01 are presented in the following table.

Reach T7.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T7.01a	Protect River Corridor	Landowner cooperation needed. Asset to future deposition.
T7.01a,b	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
T7.01a,b	Arrest Head Cuts	Conduct additional field survey and investigation to determine if this is a priority project.
T7.01b	Structure removal	Wood shed on the banks/looks like it is going to fall into the stream. Contact landowner to discuss relocation of structure. Organize volunteers.
T7.01 b	Structure replacement	One undersized bridge and one undersized culvert (Irish Settlement Road). Upstream deposits observed.

6.1.23 Preliminary Project Identification: Reach T8.01

T8.01 Summary Data
Clay Brook

Reach/Segment Length	856 ft
Valley Confinement	Very Broad
Reference Stream Type	B3
Existing Stream Type	B4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ widening
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations for Reach T8.01 are presented in the following table.

Reach T8.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T8.01	Plant Stream Buffers	Stream still widening so plantings should be placed back from the streambanks. Contact landowners, investigate possible grant programs for plantings

6.2 PROJECT PRIORITIZATION

This Corridor Plan encourages coordination of landowner and municipal efforts to approach restoration with an eye to watershed scale dynamics. The Winooski Natural Resources Conservation District can play a critical role in coordinating restoration efforts, and this report aims to facilitate such coordination in a way that can help landowners understand the part their properties play within the context of the entire watershed.

With the bulk of the assessment area in Stage 3 of channel evolution, indications are that the Browns River and its tributaries are starting to migrate laterally in efforts to reestablish functional floodplains. This is likely to aggravate erosion problems in particular, and situations are likely to arise calling for bank stabilization and channelization as short-term remedies. Restoration plans/projects should be consistent with the objective of returning streams to dynamic equilibrium, while taking into account human and capital constraints. In some cases, land use conflicts along the river corridor (such as roads or residential development) may make reinforcing current stream banks a priority. However, the critical issues for long-term stability in the watershed will involve identifying and protecting key areas that allow for floodplain access and reestablishment of river meander patterns to facilitate diffusion of stream power under high flow conditions as well as sediment and nutrient storage within the watershed.

Preliminary project identification has resulted in the selection of eight primary restoration methods for the study reaches within the Browns River watershed. Those methods include the following:

Protecting River Corridors
Planting Stream Buffers
Stabilizing Stream Banks
Arresting Headcuts and Nick Points
Removing Berms
Removing/Replacing Structures
Corridor Enhancement Projects
Wetland Restoration Projects

Watershed and reach priority projects for each of the identified restoration methods are identified in this section.

6.2.1 Protecting River Corridors

High sensitivity reaches identified as potential attenuation assets are targeted as high priority reaches for establishing a protected river corridor. The targeted priority reaches have been evaluated for storing flood flows, capturing and storing sediments, and reducing fluvial erosion hazards.

M01: Reach M01 is a highly sensitive reach in Stages III and IV of channel evolution with an average incision ratio of 1.5. This reach has limited access to its floodplain, partially due to historic straightening. This reach has a high agricultural component in its riparian corridor (50-75%) with few development encroachments and fair to good buffer widths. Given the presence of a bridge in Segment B, Segments A and C are higher priority reaches for corridor protection.

This reach has been identified as a potential attenuation asset. Protection of this reach is both a reach and watershed priority.

M02A: Reach M02 is a highly sensitive reach in Stage III of channel evolution with an average incision ratio of 1.4. Segment A has a high agricultural component within the river corridor (50-75%) and Segment B a moderate agricultural component (25-50%). Neither segment has significant encroachments from development. This reach has been identified as a potential attenuation asset. Protection of this reach is both a reach and watershed priority.

M07: Reach M07 is a highly sensitive reach in Stage III of channel evolution with an incision ratio of 1.39. This reach was historically straightened. The corridor is dominated by agricultural activity (50-75%) with approximately 35% of the available agricultural land experiencing erosion. Given the space to migrate, this reach will likely reestablish its meanders and become an attenuation asset for the watershed as it regains access to its floodplain.

M08: Reach M08 is a highly sensitive reach in Stage III of channel evolution with an incision ratio of 2.2. This reach has lost access to its historic floodplain. It is in the process of widening as evidenced by high levels of erosion. The river corridor is dominated by agricultural land uses (50-75%) with few encroachments from development. This reach is a watershed priority for corridor protection. Regaining access to its floodplain through active restoration or through passive restoration will result in a key attenuation asset for the watershed.

M09: Reach M09 is a highly sensitive reach in Stage II of channel evolution with an incision ratio of 1.62. This reach has lost access to its floodplain. It has low rates of erosion and has not progressed into Stage III widening of the channel. The river corridor for this reach is dominated by agricultural land uses (50-75%) with few encroachments from development. Abbey Brook (T3) discharges into M09, the first reach of which is impacted by poor buffers, erosion, and constrictions. Reach M09 is a priority for corridor protection. Regaining access to its floodplain through active restoration or through passive restoration will result in a key attenuation asset for the watershed.

M10: Reach M10 is a highly sensitive reach in Stage I of channel evolution with an incision ratio of 1.25. The riparian buffer has a significant agricultural component (25-50%) with few development encroachments. This reach has been identified as an attenuation asset. Protection of the river corridor is a watershed priority.

M12: Reach M12 is a highly sensitive reach in Stage II of channel evolution with an incision ratio of 1.0. This reach has an agricultural component in its riparian buffer with few encroachments. This reach has access to its floodplain and generally good buffer conditions. M12 is the receiving reach for the Lee River (T4) which suffers from development encroachments, poor buffers, erosion, and constrictions. M12 is one of the few reaches in the study area to have access to its floodplain for dissipation of flood flows and protection of this reach is a watershed priority.

M16b: Reach M16b is an extremely sensitive reach in Stage III of channel evolution with an incision ratio of 2.44. This reach segment has lost access to its floodplain. The Creek (T5) discharges into M16, the lower segments of which are impacted by encroachments, poor buffers, erosion, straightening, and constrictions. Reach M16b is a priority for corridor protection in the watershed. Regaining access to its floodplain through active restoration or through passive restoration will result in a key attenuation asset for the watershed.

6.2.2 Planting Stream Buffers

Stream buffer planting is a high priority in sensitive reaches that are vertically stable. The majority of the study reaches for the Browns River are in Stages II, III and IV of channel evolution and actively adjusting. Due to the instability of the study reaches, planting of vegetation on the immediate stream banks is generally not a high project priority. Plantings within the corridor, set back from the streambanks, is a high priority in the majority of the study reaches. Figure (13) below shows the bank protection opportunity within the watershed as percentage of banks in agricultural production that are currently eroding. Areas with high percentage of erosion in agricultural production should be prioritized for stream buffer plantings, particularly Reach M07 and Reach M08. The following table presents a summary of agricultural presence on a reach segment basis and the degree of streambank erosion within the agricultural setting.

Table 6 . Summary Data Regarding Streambank Erosion within Agricultural Settings

Segment ID	Corridor Acres in Agriculture	Feet of Erosion in Agricultural Setting	% of Streambank in Agriculture and Eroding
M01A	**8.46**	**558.02**	**8.1%**
M01B	9.79	-	-
M01C	**16.38**	**754.10**	**8.3%**
M02A	**14.35**	**640.03**	**5.5%**
M02B	1.05	-	-
M07-	**61.78**	**12,734.20**	**34.5%**
M08-	**75.44**	**8,077.68**	**23.9%**
M09-	89.94	380.62	0.8%
M10-	67.60	460.80	0.7%
M11-	20.68	-	-
M12-	13.37	176.67	0.6%
M14-	3.62	-	-
M15A	1.90	-	-
M15B	**13.65**	**1,625.36**	**10.4%**
M15C	17.32	119.98	1.1%
M15D	1.11	-	-
M16A	2.78	-	-
M16B	14.87	147.06	0.3%
M16C	2.77	-	-
M17-	-	-	-
M18-	-	-	-
M19-	0.90	-	-
T3.01A	**0.52**	**208.93**	**10.3%**
T3.01C	1.39	86.70	3.9%
T4.01-	14.78	149.79	0.6%
T4.02A	4.79	-	-
T4.02B	-	-	-
T4.02C	-	-	-
T4.02D	-	-	-
T4.03A	-	-	-
T4.03B	-	-	-
T5.01A	0.08	-	-
T5.01B	-	-	-
T5.01D	0.01	-	-
T5.01E	1.19	505.05	4.2%
T5.01G	-	-	-
T5.S1.01-	0.00	-	-
T6.01A	-	-	-
T6.01B	-	-	-
T6.01C	-	-	-
T7.01A	-	-	-
T7.01B	-	-	-
T7.01C	-	-	-
T8.01-	-	-	-

In addition to prioritizing the planting of stream buffers in actively eroding agricultural settings, planting of stream buffers is recommended as a priority in reach M10. Reach M10 is an E5 stream type in Stage I channel evolution with poor stream buffers (dominant buffer on both banks is <25') and moderate erosion. Stabilizing stream banks and establishing buffer vegetation is a reach priority for M10.

Locations of invasive plant species were inventoried and mapped for all but nine (M08, M09, M10, M11, M12, M15, M16, M17, and M18) of the study reaches. The following reaches were found to contain populations of invasive species on the stream banks and/or within the immediate boundary of the river corridor: M2a, M7, M8, M14, T4.02C, T5.01e, and T6.01a. Locations of species populations identified during the field assessments are included on the reach field maps.

Invasive plant species removal and/or control are difficult tasks. There are various methods of control and possibly eradication including chemical treatments, biological and mechanical or manual removal. Any option likely involves multiple treatments over many years. This topic is included in the method of planting stream buffers because ideally the invasive species treatment would involve a step of planting native species in treatment areas. The Nature Conservancy and the Natural Resources Conservation Service are good resources for projects contemplating invasive species control and/or removal.

6.2.3 Stabilizing Streambanks

Stabilizing streambanks is a high priority on geomorphically stable reaches. There are few geomorphically stable reaches in the study area. The deposition of sediment from the active erosion processes will likely be beneficial to the process of redevelopment of floodplains in the watershed.

Stabilizing streambanks is recommended as a priority in reach M10. Reach M10 is an E5 stream type in Stage I channel evolution with poor stream buffers (dominant buffer on both banks is <25') and moderate erosion. Stabilizing stream banks and establishing buffer vegetation is a reach priority for M10.

6.2.4 Arresting Headcuts and Nick Points

Arresting headcuts is a priority in reaches where channel lowering will result in significant loss of floodplain or human place structures. Three headcuts were documented in Phase 2 in reaches T5.01E, T7.01A, and T7.01B.

Reach segment T5.01E is a very highly sensitive reach in Stage III of channel evolution with an incision ratio of 1.95. This reach has been impacted by historic straightening and has lost access to its floodplain. The headcut is located approximately 750ft downstream of a culvert under Palmer Road. Arresting this headcut is not currently a reach priority.

Reach segment T7.01a is a highly sensitive reach in Stage II of channel evolution with an incision ratio of 1.18. This first reach segment of Crane Brook is impacted by poor buffers and erosion. The headcut is located at the mouth of Crane Brook just upstream of the discharge to reach M17 on the main branch of the Browns River, and downstream of a beaver dam. This segment still has access to its floodplain and is not impacted by development encroachments. Arresting this headcut is a reach priority for preserving floodplain access in the watershed.

Reach segment T7.01b is a highly sensitive reach in Stage II of channel evolution with an incision ratio of 1.0. This reach is impacted by encroachments and constrictions. The headcut is located approximately 150ft downstream of an undersized culvert crossing Irish Settlement Road. This reach segment still access to its floodplain. Arresting this headcut is a reach priority for preserving floodplain access and potentially protecting a human placed structure.

6.2.5 Removing Berms

Removing berms is a priority project in reaches where a significant portion of the river corridor would become accessible to the stream if the berm were removed or if the berm is the predominant reason for why the channel is incised. Two sections of berms were identified during the Phase 2 investigation in reaches M12 and M16b.

Reach M12 has an incision ratio of 1.00 and the berm segment (right bank only) has not significantly impacted stream access to the river corridor. Berm removal is not a priority in this reach.

Reach M16b is an extremely sensitive D4 stream channel in Stage III of channel evolution with an incision ratio of 2.44. The section of berm is approximately 250’ in length and located on the right bank. It is unlikely that this short section of berm has had a significant impact on the channel incision in this reach. This reach has been historically straightened and armored along a significant portion of its length. Berm removal is not a priority in this reach segment.

Identification of berms during the Phase 2 assessment is a difficult process. The Phase 2 assessment is primarily conducted from the stream channel where visibility of the near bank is often obscured by vegetation. Further investigation for the presence of berms is likely warranted in a watershed with such a high agricultural component as the Browns River.

6.2.6 Removing/Replacing Structures

Removing or replacing structures is a high priority for structures no longer in use or structures that contribute to a significant increase in erosion hazard or structures likely to result a channel avulsion during a storm event.

Six relict bridge abutments have been identified as channel constrictions in the study reaches. These abutments are located in reaches M9 (2 structures present), M10, T4.01, T4.03C, and T5.S1.01. Before prioritizing these structures for removal, further field assessment is necessary. Field evaluations should focus on whether these structures are significantly constraining the vertical and lateral movement of the channel and/or resulting in a significant constriction of the floodplain within the reach. Evaluation of impacts of structure removal (including potential bank instability or channel bed elevation changes) upon corridor development and/or land use is recommended prior to project initiation.

There are twenty undersized bridges and culverts in the study area serving as constrictions of the stream channel. Table 7 provides summary data for all of the structures identified in the study area.

Table 7: Bridge and Culvert Summary Data Table

Segment ID	MapID	SGAID	TOWN	Stream	Type	Structure Width	Calc. Channel Width	Ph2 Bankfull Width	Problem	% less than Bankfull Width
M01B	40	100033000106041	Fairfax	Browns	Bridge	120.0	95.9	100.0		-20.0%
M02A	**39**	**200128000106042**	**Fairfax**	**Browns**	**Bridge**	**72.0**	**95.3**	**91.0**	**Width**	**20.9%**
M07-	**36**	**700000000304063**	**Westford**	**Browns**	**Bridge**	**18.0**	**84.0**	**52.4**	**Width**	**65.7%**
M07-	**37**	**700000000404063**	**Westford**	**Browns**	**Bridge**	**22.0**	**84.0**	**52.4**	**Width**	**58.0%**
M07-	**38**	**700000000504063**	**Westford**	**Browns**	**Bridge**	**25.0**	**84.0**	**52.4**	**Width**	**52.3%**
M08-	**33**	**700000000104063**	**Essex**	**Browns**	**Bridge**	**24.0**	**83.5**	**55.0**	**Width**	**56.4%**
M08-	34	100044001204061	Essex	Browns	Bridge	69.0	83.5	55.0		-25.5%
M08-	**35**	**700000000204063**	**Essex**	**Browns**	**Bridge**	**23.0**	**83.5**	**55.0**	**Width**	**58.2%**
M09-	28	7000000001104063	Essex	Browns	Bridge	45.0	81.8	37.7		-19.4%
M09-	31	990128000004063	Essex	Browns	Bridge	0.0	81.8	37.7		100.0%
M09-	**32**	**200128000904062**	**Essex**	**Browns**	**Bridge**	**30.0**	**81.8**	**37.7**	**Width**	**20.4%**
M10-	**20**	**100063000704061**	**Essex**	**Browns**	**Bridge**	**40.0**	**78.3**	**62.6**	**Width**	**36.1%**
M14-	18	100409003704091	Jericho	Browns	Bridge	92.0	64.2	71.0		-29.6%
M15D	**21**	**400013000204091**	**Jericho**	**Browns**	**Bridge**	**82.0**	**64.1**	**86.8**	**Width**	**5.5%**
M17-	**13**	**300001001504151**	**Underhill**	**Browns**	**Bridge**	**55.0**	**44.6**	**71.0**	**Width**	**22.5%**
M18-	12	100001001504151	Underhill	Browns	Bridge	57.0	37.8	42.0		-35.7%
M19-	15	100037001404151	Underhill	Browns	Bridge	40.0	33.6	33.0		-21.2%
T3.01C	**27**	**300128000104061**	**Essex**	**Abbey**	**Culvert**	**10.0**	**22.7**	**17.2**	**Width**	**41.9%**
T4.01-	**6**	**700000000504093**	**Jericho**	**Lee**	**Bridge**	**35.0**	**43.6**	**42.9**	**Width**	**18.4%**
T4.01-	7	100007000104091	Jericho	Lee	Bridge	87.0	43.6	42.9		-102.8%
T4.02A	5	700000000404093	Jericho	Lee	Bridge	45.0	41.4	40.0		-12.5%
T4.02C	2	100002000104091	Jericho	Lee	Bridge	84.0	41.4	40.0		-110.0%
T4.02C	3	100002000204091	Jericho	Lee	Bridge	81.0	41.4	40.0		-102.5%
T4.02C	4	100001000904091	Jericho	Lee	Bridge	54.0	41.4	40.0		-35.0%
T4.03B	1	700000000104093	Jericho	Lee	Bridge	80.0	37.4	36.0		-122.2%
T5.01A	**23**	**400013000104091**	**Underhill**	**Creek**	**Culvert**	**14.5**	**37.4**	**24.0**	**Width**	**39.6%**
T5.01A	24	700000000604153	Underhill	**Creek**	Bridge	33.0	37.4	24.0		-37.5%
T5.01B	25	700000000204093	Underhill	Creek	Bridge	30.0	37.4	25.0		-20.0%
T5.01E	**26**	**400012000104091**	**Underhill**	**Roaring**	**Culvert**	**16.0**	**37.4**	**17.5**	**Width**	**8.6%**
T5.S1.01-	**29**	**700000000104151**	**Underhill**	**Roaring**	**Bridge**	**25.0**	**23.6**	**25.3**	**Width**	**1.2%**
T5.S1.01-	30	200015000104152	Underhill	Roaring	Bridge	63.0	23.6	25.3		-149.0%

Segment ID	MapID	SGAID	TOWN	Stream	Type	Structure Width	Calc. Channel Width	Ph2 Bankfull Width	Problem	% less than Bankfull Width
T6.01A	9	100048000104151	Underhill	Mill	Bridge	40.0	17.0	16.0		-150.0%
T6.01A	**10**	**300001001604151**	**Underhill**	**Steinhour**	**Bridge**	**12.2**	**17.0**	**16.0**	**Width**	**23.8%**
T6.01C	**8**	**400040000904151**	**Underhill**	**Mill**	**Culvert**	**7.5**	**17.0**	**20.5**	**Width**	**63.4%**
T7.01B	**16**	**400415002404151**	**Underhill**	**Crane**	**Culvert**	**10.5**	**19.9**	**25.0**	**Width**	**58.0%**
T7.01B	**17**	**700000000104153**	**Underhill**	**Crane**	**Bridge**	**18.0**	**19.9**	**25.0**	**Width**	**28.0%**
T7.01B	19	700000000204153	Underhill	Crane	Bridge	30.0	19.9	25.0		-20.0%
T7.01C	22	700000000304153	Underhill	Crane	Bridge	23.0	19.9	18.0		-27.8%
T8.01-	11	700000000404153	Underhill	Clay	Bridge	25.0	19.7	24.0		-4.2%
T8.01-	**14**	**700000000504153**	**Underhill**	**Clay**	**Bridge**	**16.0**	**19.7**	**24.0**	**Width**	**33.3%**

Nine structures were identified during the Phase 2 field assessments as priority projects for repair or replacement. These priority structures are located in M10 (farm bridge), M9 (two undersized bridge crossings on same property), M7 (narrow, undersized farm bridge), M8 (undersized and undermined bridge upstream of Pettingill Road, undersized and undermined bridge downstream of Pettingill Road), T3.01C (severely undermined and undersized culvert at Rte 128), T4.01 (old steel bridge out of use upstream of Plains Road), and T5.01a (undersized and rotting steel culvert at Raceway Road). Figure (13) below presents the problem structures with the town based on percentage less than bankfull.

6.2.7 Corridor Enhancement Projects

Dump Sites: The Phase 2 field assessments resulted in the identification of four riverside dump sites. These sites are located in reaches: M8, M16d, T5.01b, and T5.01d. Dump cleanup projects provide an opportunity to engage landowners and volunteers in a river enhancement project with immediate visual results and improved water quality and overall stream habitat. The Vermont Youth Conservation Corps was involved in a recent dump cleanup along the Huntington River and may be a valuable source of volunteer labor for similar projects within the Browns River watershed.

Pasture Fencing: The Phase 2 assessment identified fence removal/relocation as a priority project in reaches M7 and M14. Fence relocation projects can provide opportunities for volunteers to assist farmers in river enhancement resulting in improved water quality and aquatic habitat.

Livestock Stream Crossings: The Phase 2 assessment identified reducing the number of livestock stream crossings as a priority in Reach M15 segments (B), (C), and (D).

Elimination of Active Dredging: The Phase 2 assessment identified active dredging in Reach T4.01. Contact with the landowner should consist of discussion of discontinuing dredging activity.

Erosion Control and Sediment Prevention: The Phase 2 assessment identified the presence of relict erosion control measures within the river corridor downslope of the gravel pit in Reach T4.02C. These erosion control measures are not longer functioning. Contact with the landowner should consist of discussions of long term maintenance of erosion control measures and increased setback distances from the river.

6.2.8 Wetland Restoration Projects

Wetlands have an important role in protecting the water quality of our rivers and lakes. Vermont has lost an estimated 35 percent of our wetlands since colonial times, with a corresponding decrease in water quality protection. However, in certain cases it is possible to restore impaired wetlands, bringing back their water quality protection function. With this in mind, Vermont recently completed the Lake Champlain Basin Wetland Restoration Plan. This plan identifies impaired wetlands within the Vermont portion of the Lake Champlain Basin and prioritizes them for restoration. Using a geographic information system (GIS)-based model 4,883 potential wetland restoration opportunities were identified in the basin. A different model was then used to prioritize these opportunities. (http://www.vtfishandwildlife.com/LakeChamplainBasin.cfm)

The following table summarizes the identified wetland restoration potential within the study area.

Table 8. Wetland Restoration Summary Table

Segment ID	Hydric Soil Acres in Segment Subwatershed	Mapped Wetland Acres in Segment Subwatershed	Restoration Site Acres in Segment Subwatershed	Restoration Site Acres in Segment Corridor
M01A	-	-	-	-
M01B	34	-	-	-
M01C	116	4	11	-
M02A	17	9	-	-
M02B	10	8	-	-
M07-	144	59	4	-
M08-	**645**	**137**	**126**	**12**
M09-	**796**	**366**	**198**	**6**
M10-	358	121	101	1
M11-	215	26	9	0
M12-	135	11	24	-
M14-	14	9	-	-
M15A	335	64	19	-
M15B	**190**	**96**	**22**	**2**
M15C	95	36	0	-
M15D	3	1	-	-
M16A	**144**	**1**	**10**	**2**
M16B	228	18	53	-
M16C	1	0	-	-
M17-	85	12	-	-
M18-	5	0	-	-
M19-	138	26	-	-
T3.01A	2	0	2	0
T3.01C	246	82	7	-
T4.01-	**195**	**11**	**31**	**2**
T4.02A	59	28	-	-
T4.02B	1	-	-	-
T4.02C	201	17	6	-
T4.02D	-	-	-	-
T4.03A	-	-	-	-
T4.03B	223	42	-	-
T5.01A	8	2	-	-
T5.01B	46	1	-	-
T5.01C	-	-	-	-
T5.01D	8	1	4	1
T5.01E	**86**	**30**	**38**	**6**
T5.01F	-	-	-	-
T5.01G	**40**	**18**	**15**	**3**
T5.S1.01-	-	0	0	-
T6.01A	1	-	-	-
T6.01B	1	-	-	-
T6.01C	6	2	-	-
T7.01A	-	1	-	-
T7.01B	-	1	-	-
T7.01C	71	8	-	-
T8.01-	-	-	-	-

As the Table 8 shows, Reaches M08 and M09 have the greatest potential acreage identified for potential wetland restoration. Given the importance of these reaches as sediment and nutrient attenuation assets for the entire watershed, wetland restoration is both a watershed and reach priority for these reaches. The following map displays the wetland restoration potential on a reach basis for the study area.

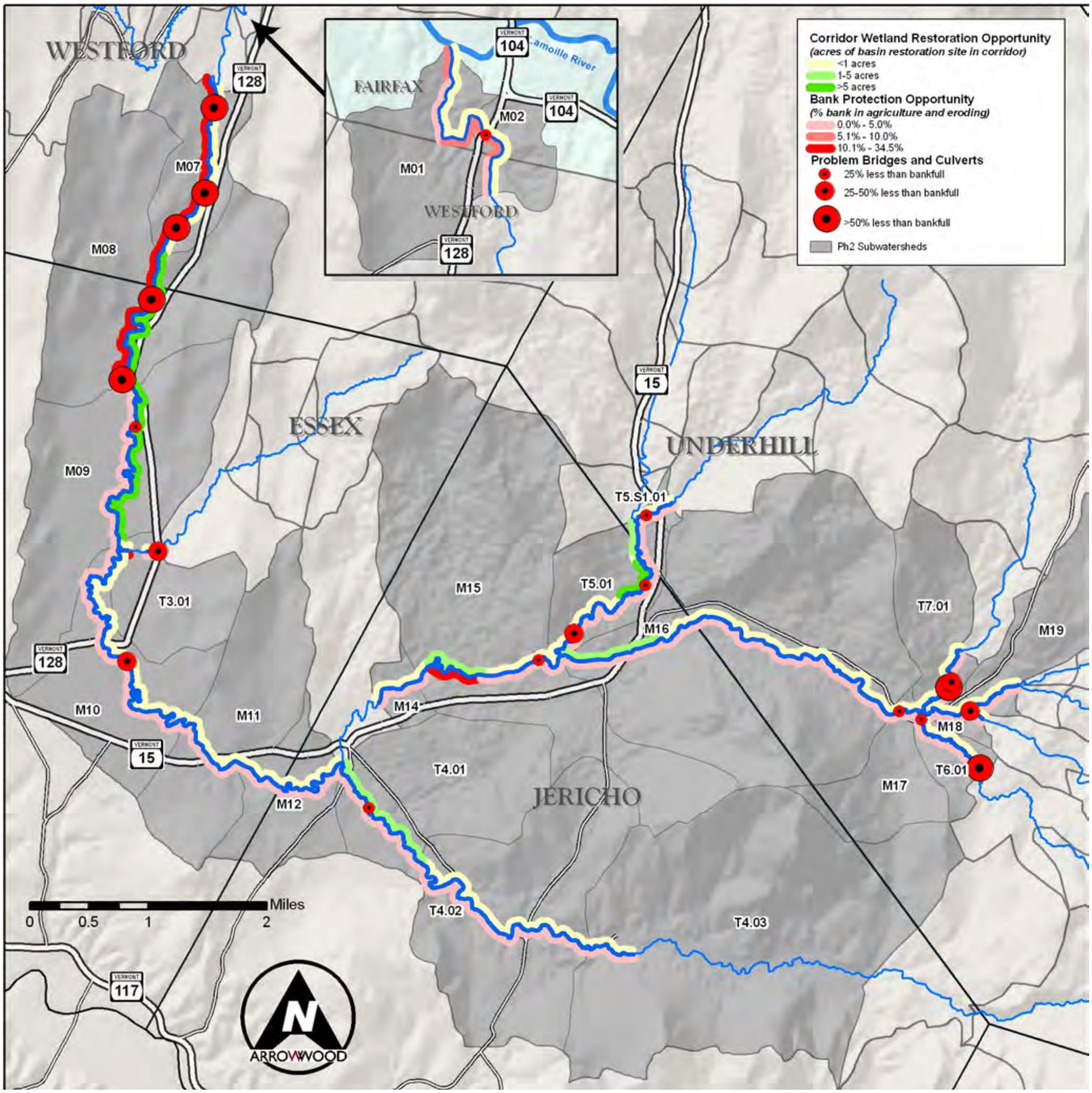

Figure 13. Wetland Restoration Potential, Band Protection Opportunities, and Problem Structures Map

7.0 STATE AND MUNICIPAL ACTIONS

Several strategies can be used by state agencies and municipalities to reduce human conflicts with the river. The first strategy, planning and zoning to minimize future encroachment, includes tools such as corridor-based zoning ordinances, participation in the National Flood Insurance Program, and fluvial erosion hazard protection areas.

The National Flood Insurance Program (NFIP) was created by Congress through the National Flood Insurance Act of 1968. It enables property owners in participating communities to purchase insurance protection against flood related losses. The insurance provides an alternative to disaster assistance by covering damage repairs to buildings and their contents. Participation in the NFIP is based on an agreement between the Federal Government and local communities that states the Federal Government will make flood insurance available if a community adopts and enforces a floodplain management ordinance to reduce flood risks to new construction in Special Flood Hazard Areas (SFHA). The SFHAs and other risk premium zones that affect participating communities are depicted on Flood Insurance Rate Maps. The Mitigation Division within the Federal Emergency Management Agency manages the NFIP, and oversees the floodplain management and mapping components of the Program (http://www.fema.gov/business/nfip/).

Mapping of Fluvial erosion hazard (FEH) protection areas uses the geomorphic data collected in Phases I and II to rate the erosion hazards in the zone along the river based on the predicted movement of the river (http://www.anr.state.vt.us/cleanandclear/rivstrm.htm).

Mapping of FEH protection areas was completed for the Browns River by Arrowwood Environmental in the winter of 2008. The RMP conducted a formal QA review of the data and approved the draft map. The Browns River FEH Protection Areas map can now be made available to the towns in the Project Area. In each town, corridor-based municipal zoning ordinances can be considered as a means to limit encroachment and landuse conflicts within the FEH zones identified.

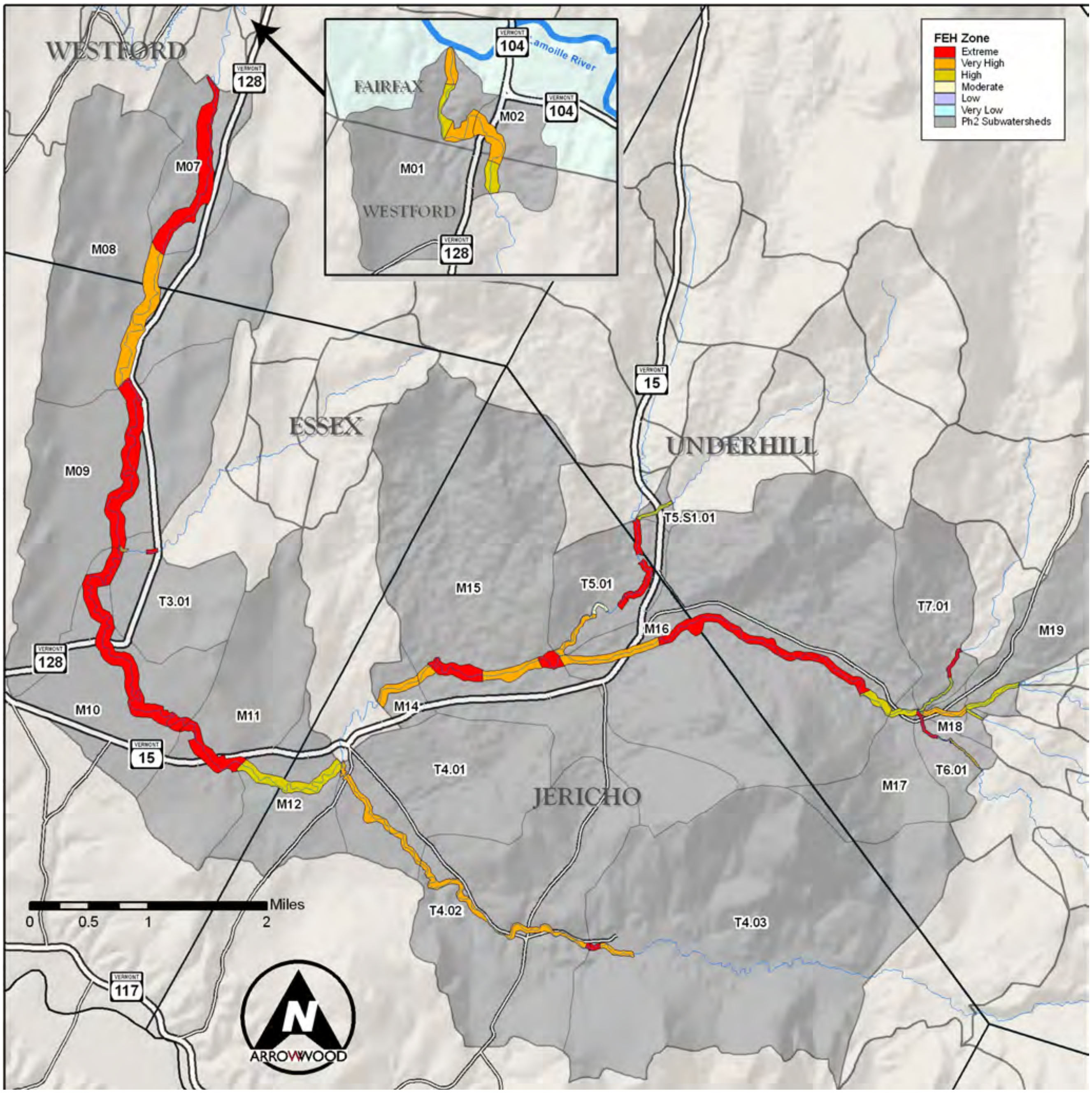

Figure 14. Browns River FEH Protection Areas Map

8.0 RECOMMENDATIONS FOR FUTURE STREAM ASSESSMENTS

The following assessments are recommended within the Browns River Watershed.

Phase 2 Assessments: Phase 2 assessments have not been completed on mainstem reaches M03-M06 and M13. It is recommended that a Phase 2 assessment be conducted on these reaches and the Corridor Plan updated with the new information. Reach locations are presented on in Figure 15 below.

Detailed Bridge and Culvert Assessments: Preliminary assessments for Reaches M16; M12, M11, M13, M10m M15 and M18 indicate the presence of undersized structures in these reaches. Detailed bridge and culvert assessments are necessary in these reaches to determine whether these structures should be prioritized for replacement or repair. Details regarding these structures is included in the following table. Figure 15 presents the locations of the structures.

MapID	Reach	Notes	Latitude	Longitude
1	M16	not assessed	44.51547	-72.95025
2	M16	not assessed	44.51701	-72.92704
3	M16	not assessed	44.51251	-72.91256
4	M16	not assessed	44.51641	-72.94663
5	M11	not assessed	44.50218	-73.02143
6	M12	not assessed	44.50057	-73.01403
7	M13	not assessed	44.50420	-72.99931
8	M13	not assessed	44.50864	-72.99377
9	M19	Recently replaced- needs assessment of current structure	44.50898	-72.89227
10	M15	In DMS- SGA ID-400013000204091, data incomplete	44.51455	-72.96540
11	M09	In DMS- SGAID-990128000004063 data incomplete	44.54044	-73.03467

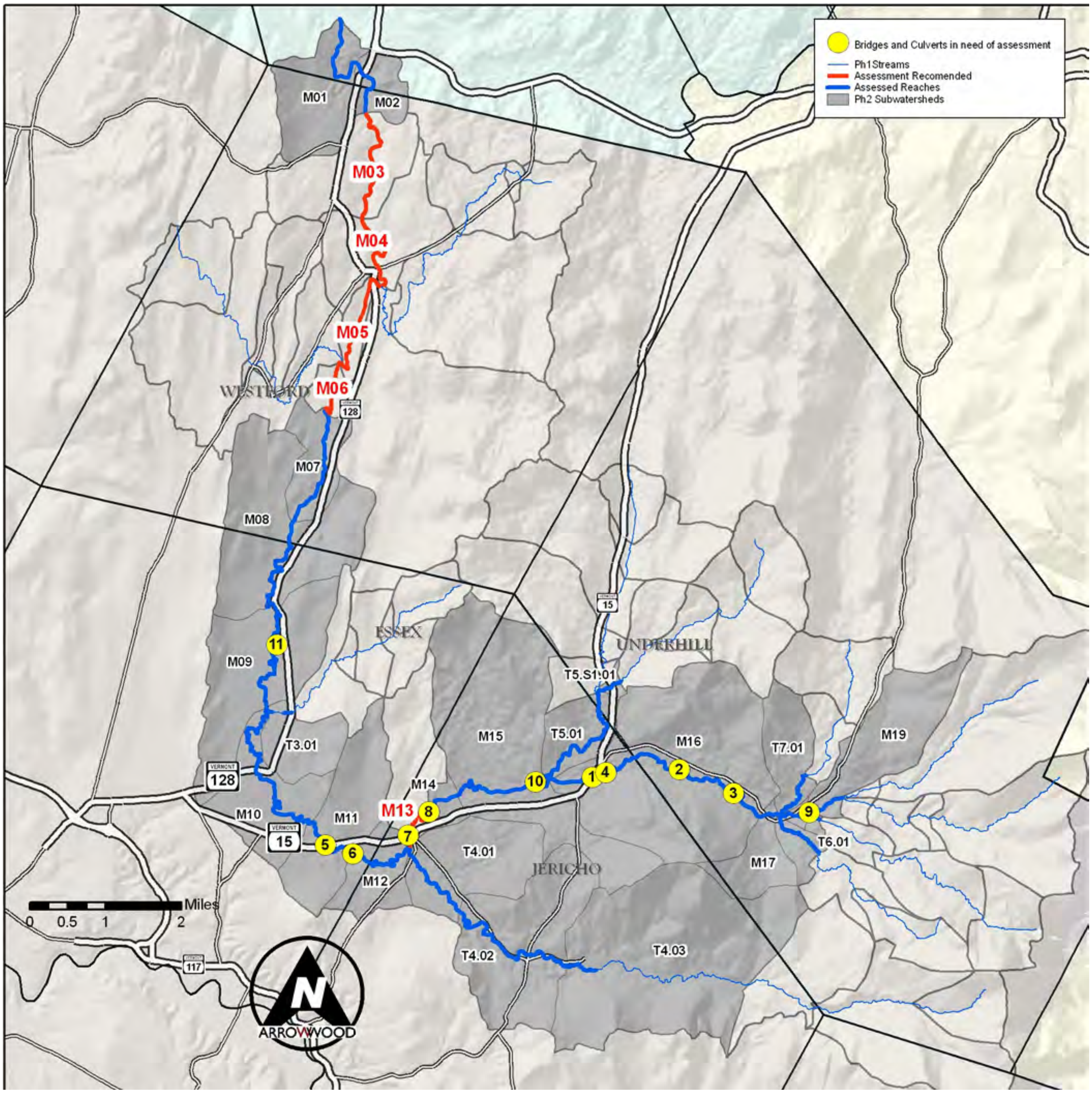

Figure 15. Structues and Reaches Recommended for Further Assessment

Investigation of abutments: Phase 2 assessments identified the presence of relict bridge abutments in reaches M9 (2); M10; T4.01, T4.03c, and T5.S1.01. Detailed field assessment of the impact of these structures is necessary to determine whether removal is a priority at a reach or watershed level.

Investigation of Headcuts: Phase 2 assessments identified three headcuts in the study area. Field investigation of the impacts of these headcuts is needed to determine whether arresting them is a priority at the reach or watershed level. At a minimum, these headcuts should be field reviewed on a periodic basis to track any migration upstream.

9.0 RECOMMENDATIONS FOR CORRIDOR PLAN UPDATES

It is recommended that periodic Browns River Corridor Plan updates be made, preferably at least every five years. The Winooski Natural Resources Conservation District appears well situated to continue coordinating such efforts provided funding is available. These updates could include:

- Assessment of management strategies in light of project implementation and further geomorphic assessments
- Identification of additional reach and watershed scale management options
- Updates on financial and technical resources available to riparian landowners
- Public outreach and education concerning these efforts

10.0 LITERATURE CITED

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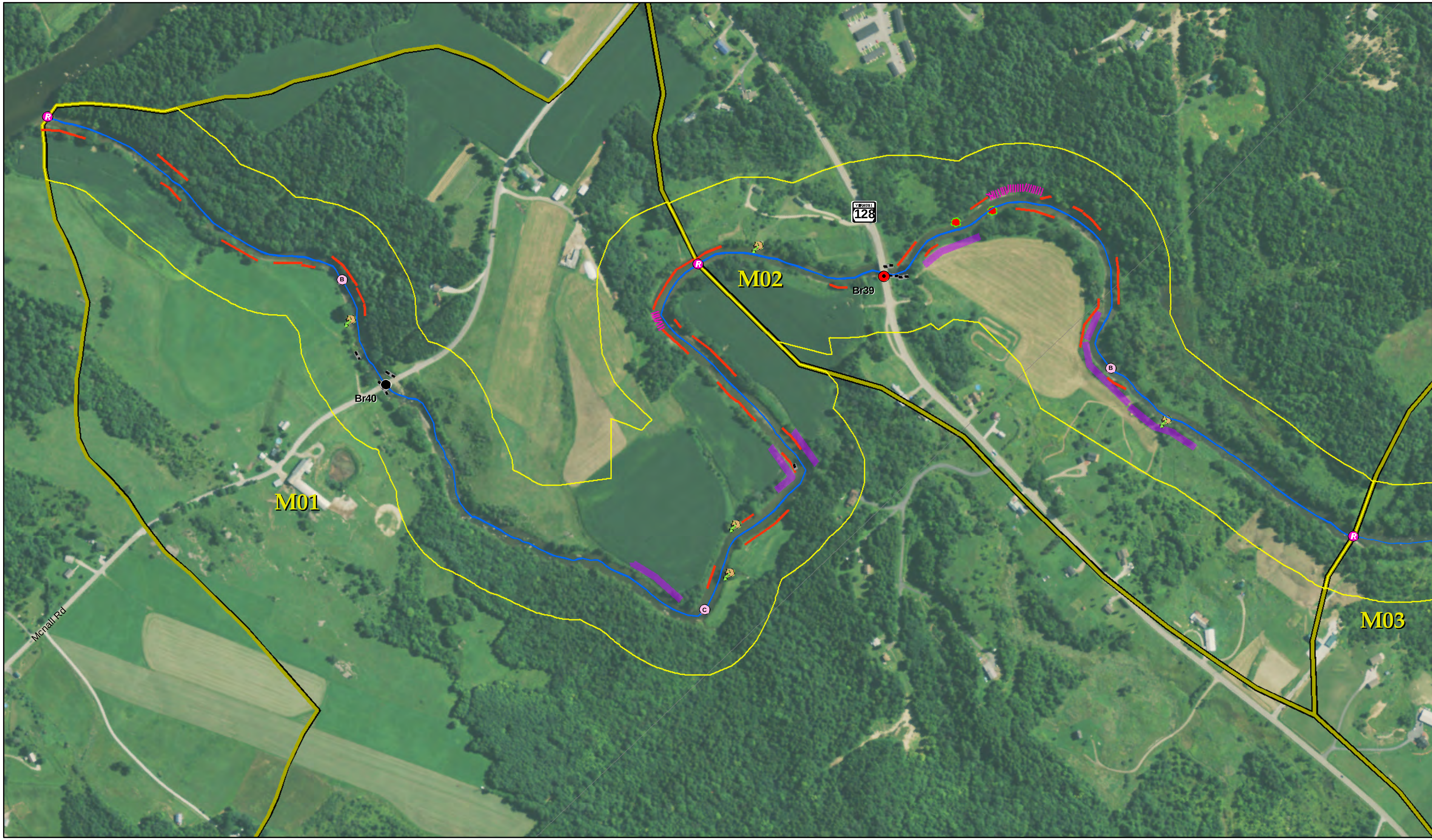

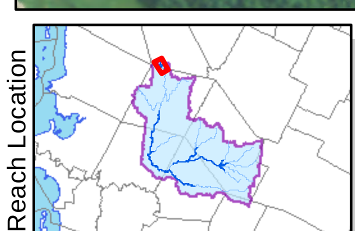

Ph1 streams
Ph2 streams
reach breaks
segment breaks
corridor (s09)
bridge or culvert assessment needed
bridge or culvert
problem bridge or culvert
beaver dam
head cut
abutment
animal crossing
ford
dump site
scalping/mining
grade control
stormwater input
regulation
bank armoring
tree revetement
bank erosion
mass failure
straightening
berm
buffer <25'
invasive-jkw
invasive-other
invasive
basin wetland restoration sites
ranked in top 500
other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwoood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- M01, M02

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 80 160 320 480 640
1 inch = 450 feet

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HUNTINGTON VT 05462
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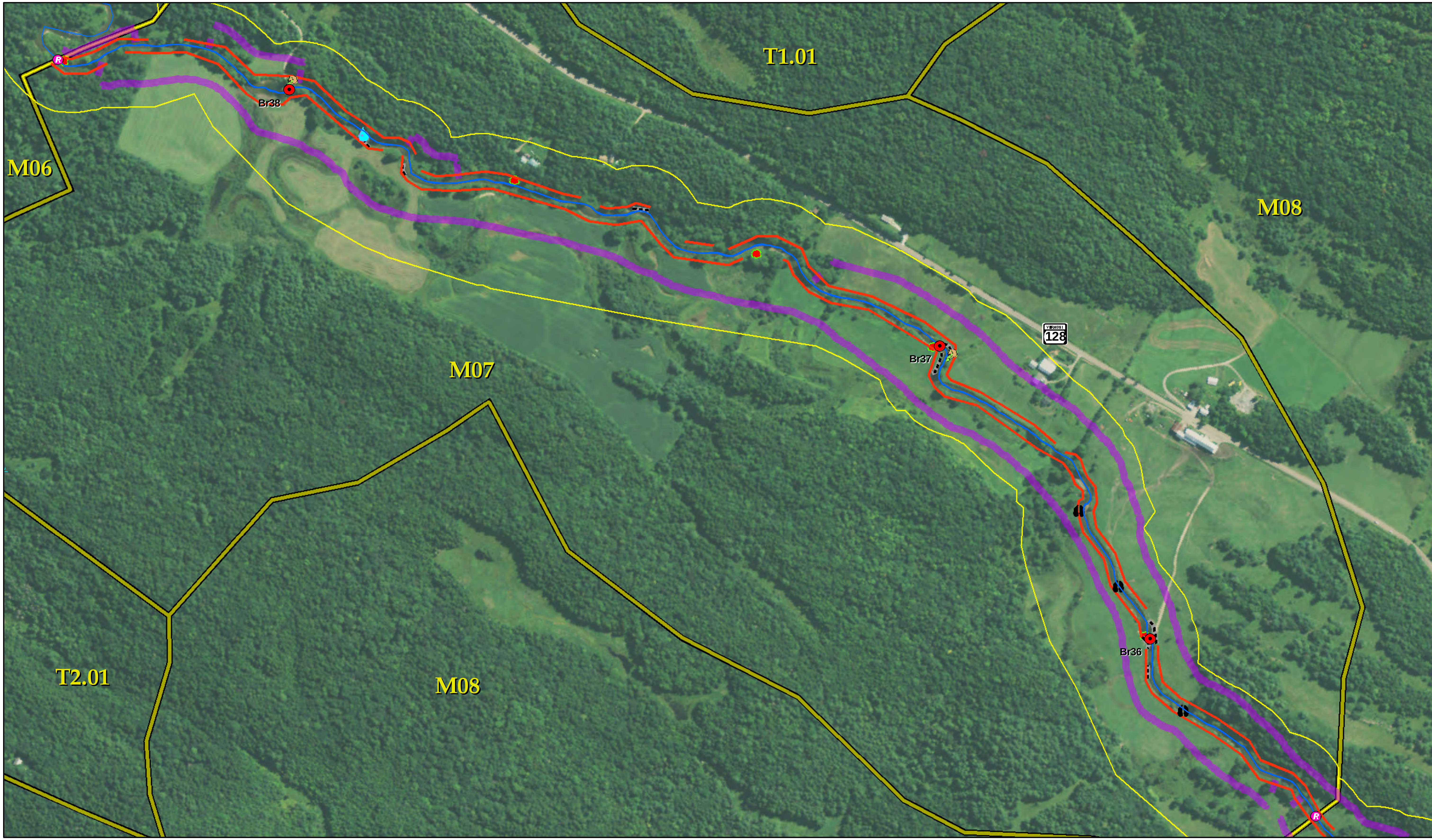

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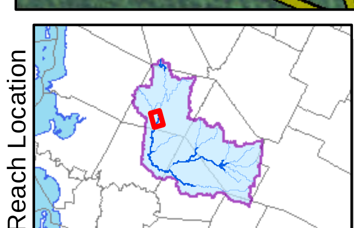
Reach Location



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- Ph2 streams
- reach breaks
- segment breaks
- corridor (s09)
- bridge or culvert assessment needed
- bridge or culvert
- problem bridge or culvert
- beaver dam
- head cut
- abutment
- animal crossing
- ford
- dump site
- scalping/mining
- grade control
- stormwater input
- regulation
- bank armoring
- tree revetement
- bank erosion
- mass failure
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- berm
- buffer <25'
- invasive-jkw
- invasive-other
- invasive
- *basin wetland restoration sites*
- ranked in top 500
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Browns River Corridor Plan, 2009

Reach Map- M07

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

0 87.5 175 350 525 700 Feet

1 inch = 500 feet

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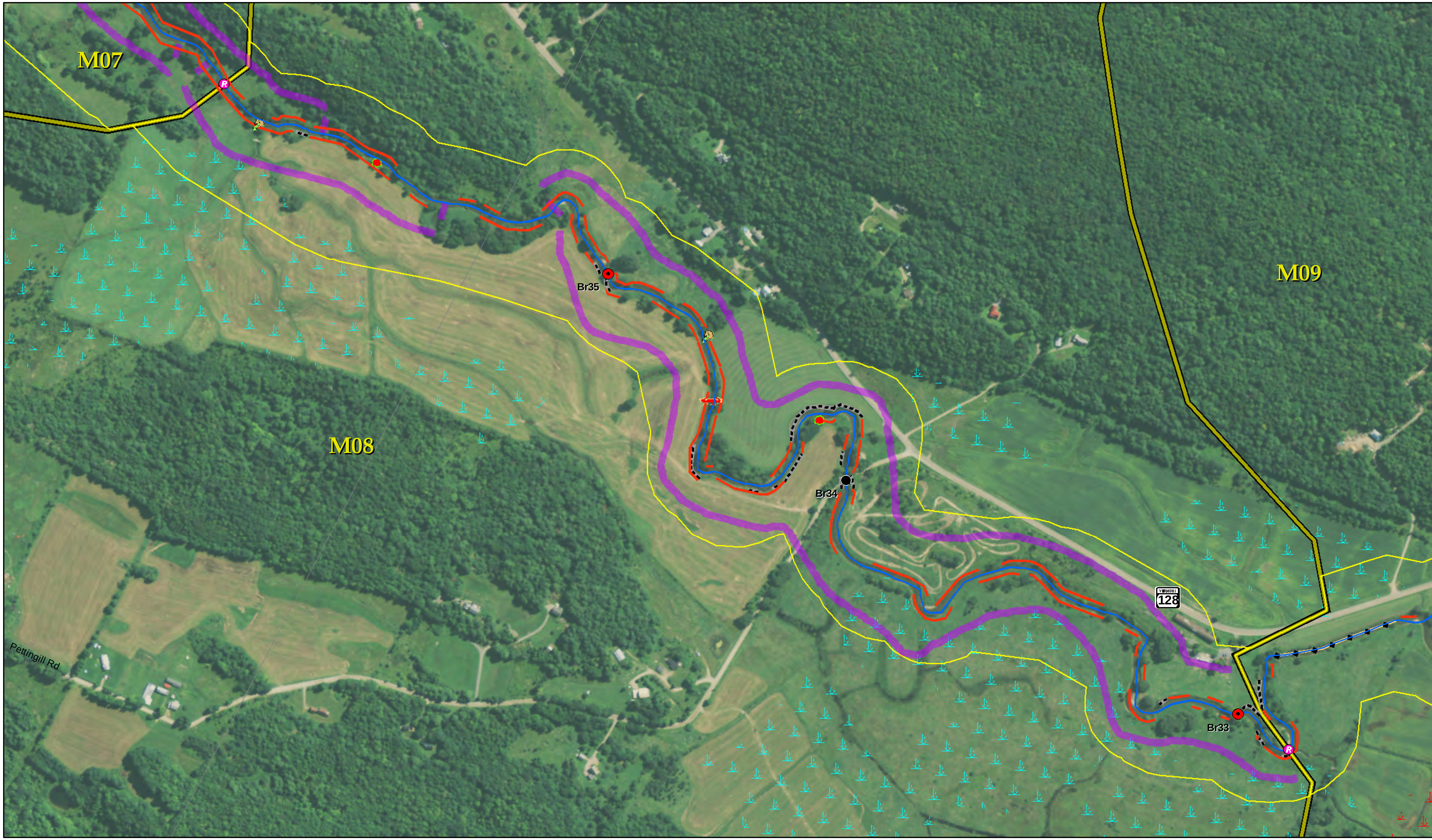

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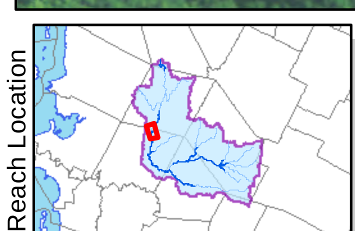

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Browns River Corridor Plan, 2009

Reach Map- M08

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Feet
0 80 160 320 480 640
1 inch = 450 feet

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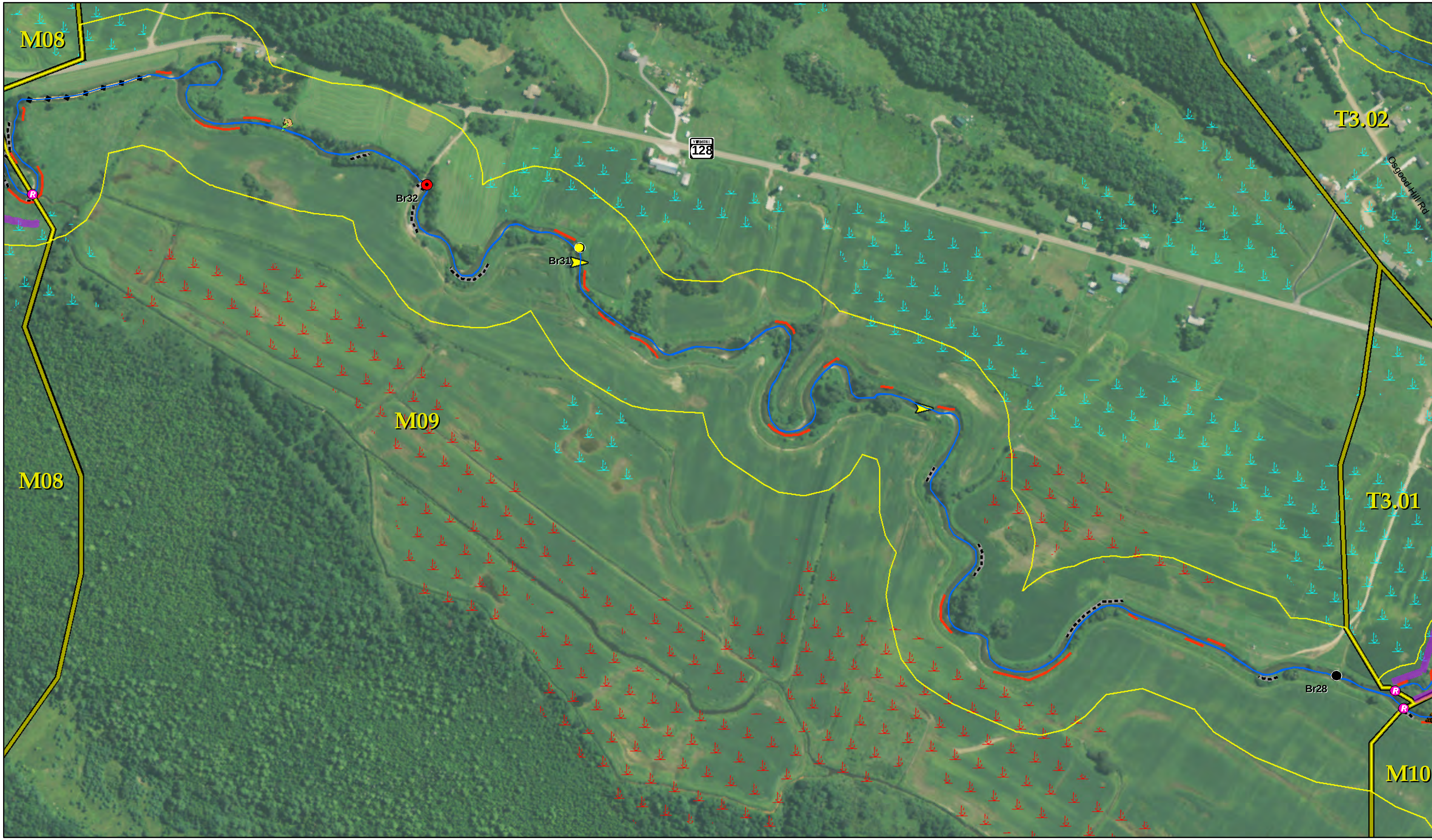

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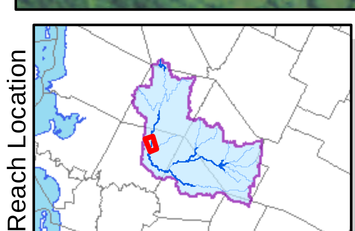

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Browns River Corridor Plan, 2009

Reach Map- M09

Jan 16, 2009

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0 80 160 320 480 640 Feet

1 inch = 450 feet

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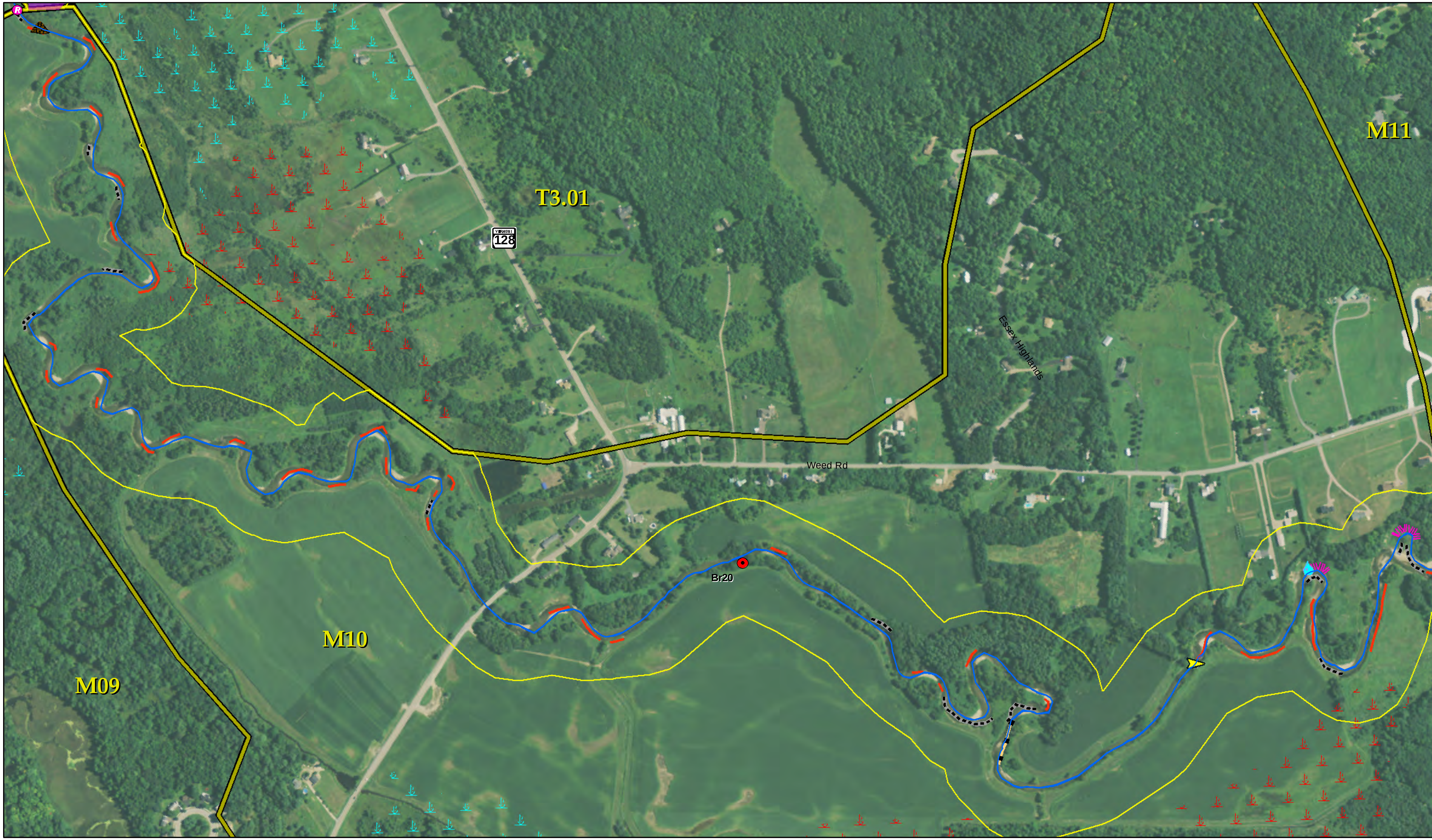

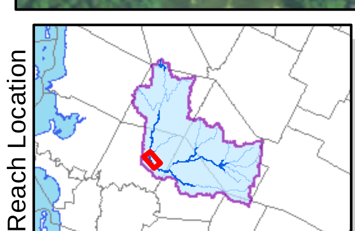

Ph1 streams
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Browns River Corridor Plan, 2009

Reach Map- M10

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 87.5175 350 525 700
1 inch = 500 feet

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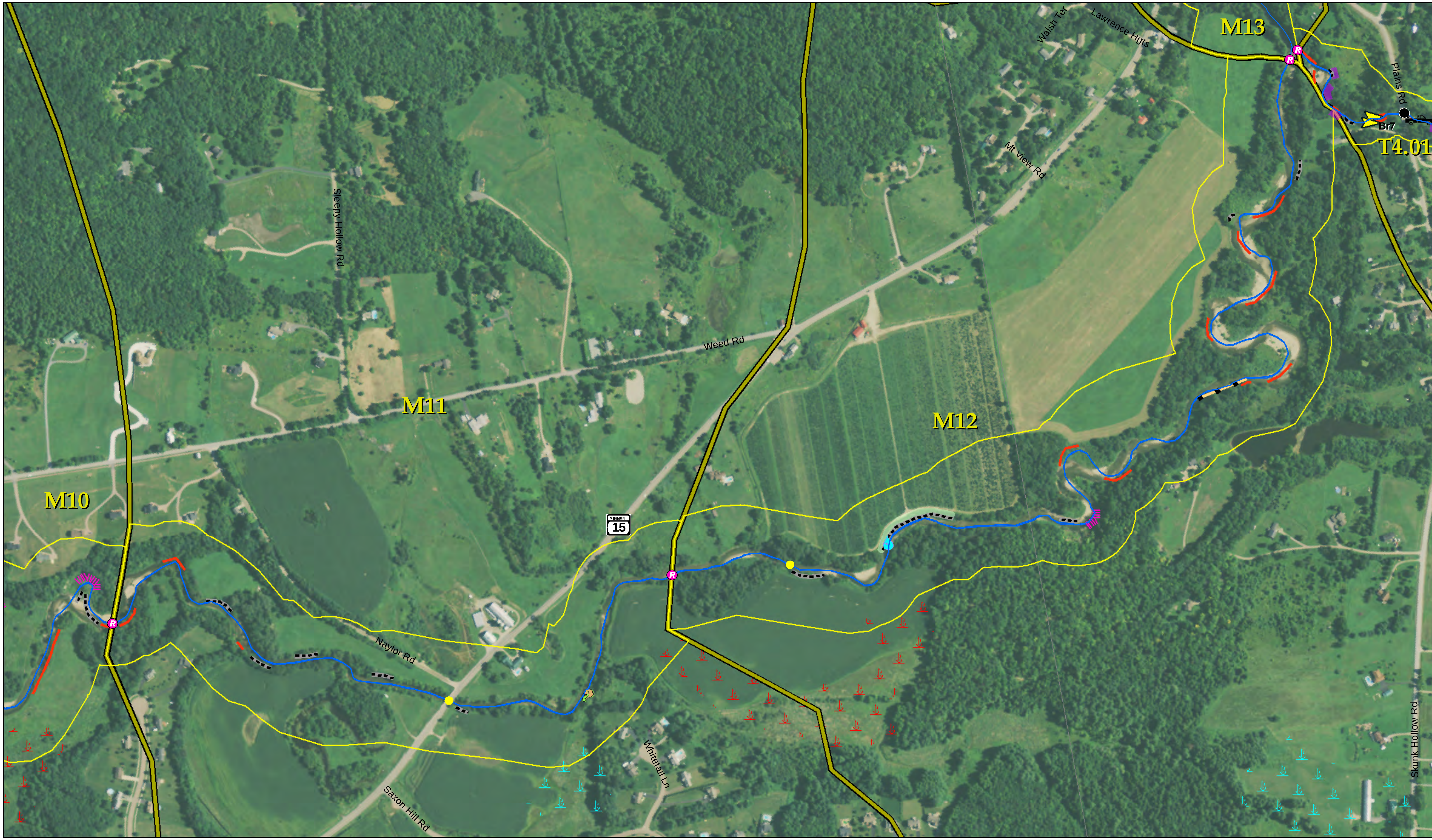

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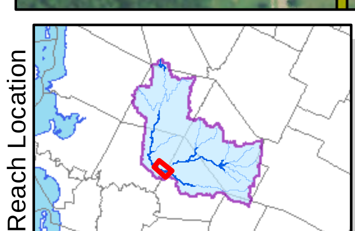

- Ph1 streams
- Ph2 streams
- reach breaks
- segment breaks
- corridor (s09)
- bridge or culvert assessment needed
- bridge or culvert
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- beaver dam
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Browns River Corridor Plan, 2009

Reach Map- M11,M12

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 87.5175 350 525 700
1 inch = 500 feet

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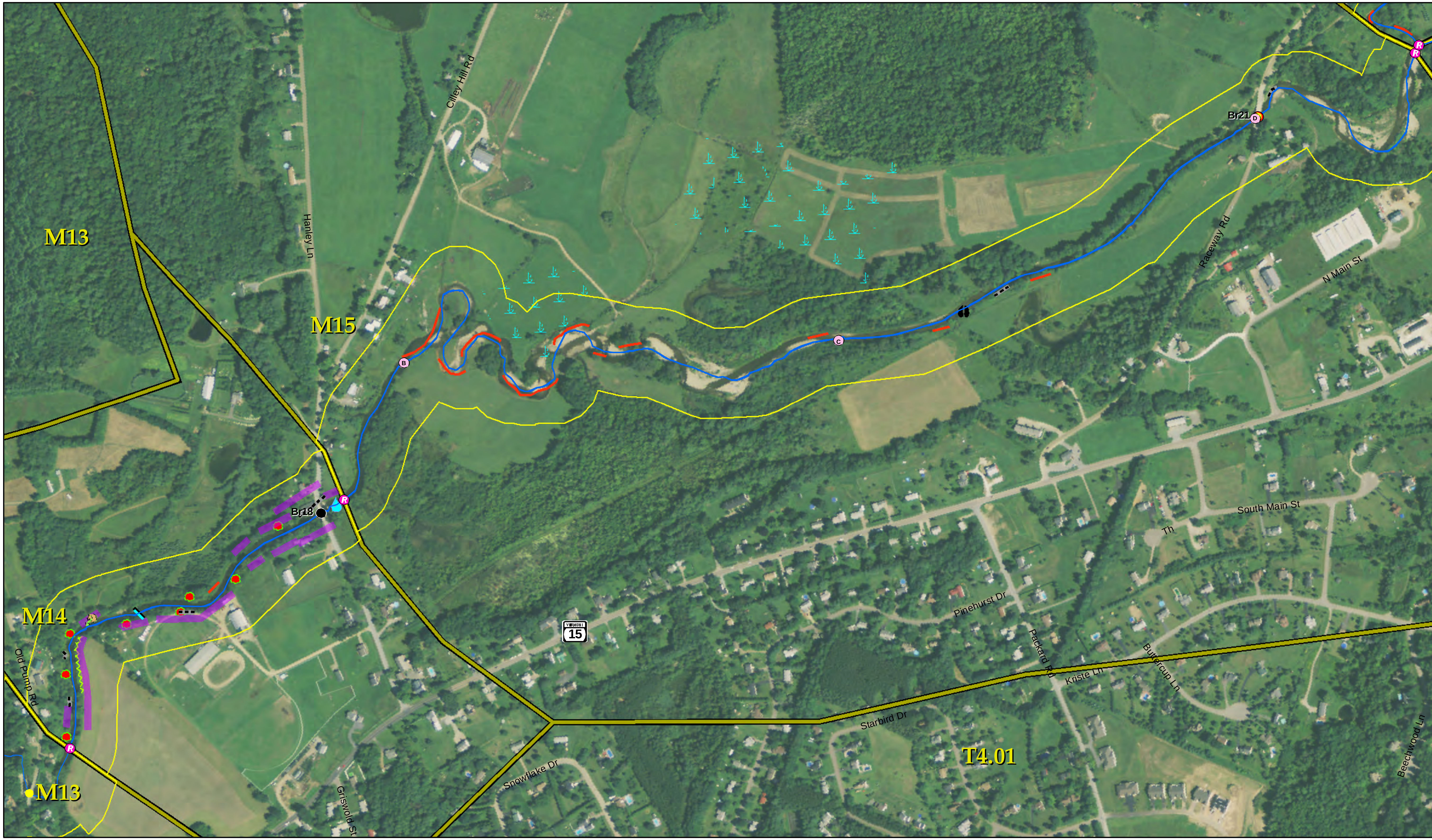

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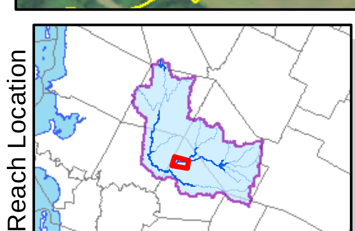
Reach Location



Ph1 streams
Ph2 streams
reach breaks
segment breaks
corridor (s09)

bridge or culvert assessment needed
bridge or culvert
problem bridge or culvert
beaver dam
head cut

abutment
animal crossing
ford
dump site
scalping/mining

grade control
stormwater input
regulation
bank armoring

tree revetement
bank erosion
mass failure
straightening
berm
buffer <25'

invasive-jkw
invasive-other
invasive
basin wetland restoration sites
ranked in top 500
other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- M14, M15

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 87.5 175 350 525 700
1 inch = 500 feet

N

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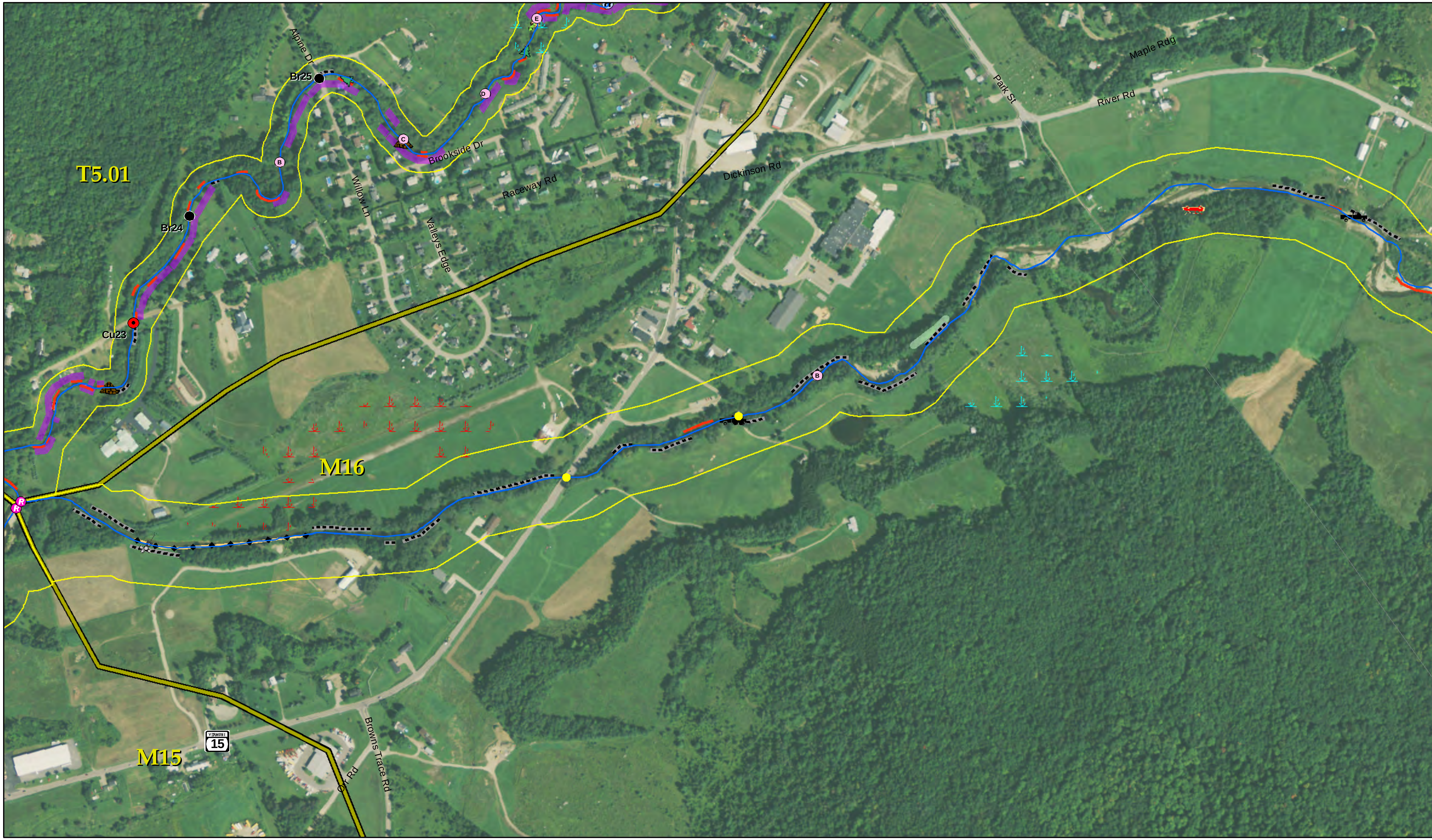
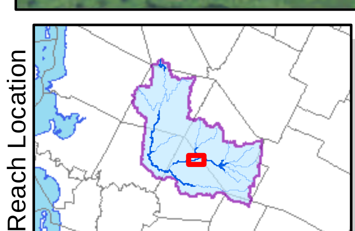


Reach Location



Ph1 streams
Ph2 streams
reach breaks
segment breaks
corridor (s09)
bridge or culvert assessment needed
bridge or culvert
problem bridge or culvert
beaver dam
head cut
abutment
animal crossing
ford
dump site
scalping/mining
grade control
stormwater input
regulation
bank armoring
tree revetement
bank erosion
mass failure
straightening
berm
buffer <25'
invasive-jkw
invasive-other
invasive
basin wetland restoration sites
ranked in top 500
other sites

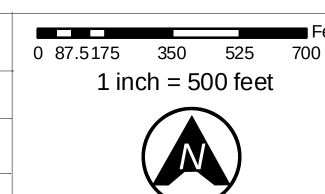
Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- **M16-1**

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane



1 inch = 500 feet

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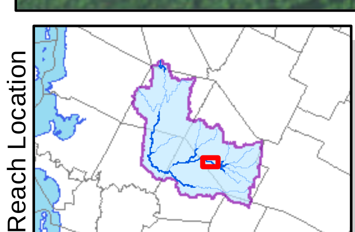
Reach Location



Ph1 streams	bridge or culvert assessment needed	abutment	grade control	tree revetement	invasive-jkw
Ph2 streams	bridge or culvert	animal crossing	stormwater input	bank erosion	invasive-other
reach breaks	problem bridge or culvert	ford	regulation	mass failure	invasive
segment breaks	beaver dam	dump site	bank armoring	straightening	*basin wetland restoration sites*
corridor (s09)	head cut	scalping/mining		berm	ranked in top 500
				buffer <25'	other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- M16-2

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 87.5 175 350 525 700

1 inch = 500 feet

N

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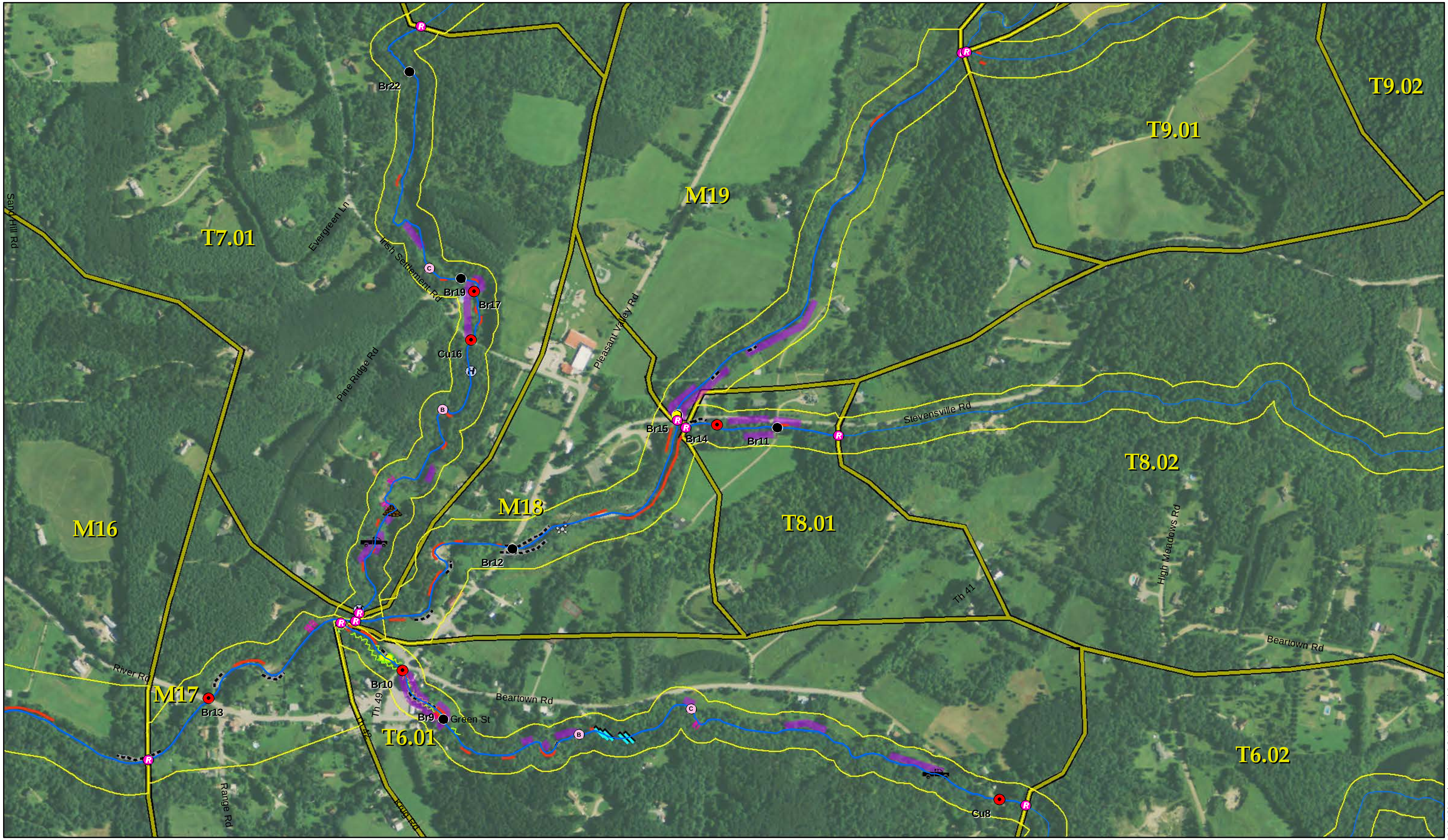
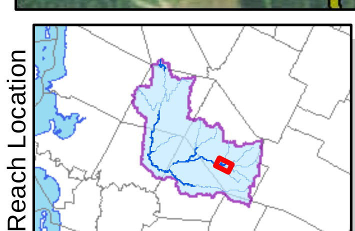


Reach Location



Ph1 streams	bridge or culvert assessment needed	abutment	grade control	tree revetement	invasive-jkw
Ph2 streams	bridge or culvert	animal crossing	stormwater input	bank erosion	invasive-other
reach breaks	problem bridge or culvert	ford	regulation	mass failure	invasive
segment breaks	beaver dam	dump site	bank armoring	straightening	*basin wetland restoration sites*
corridor (s09)	head cut	scalping/mining		berm	ranked in top 500
				buffer <25'	other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- M17-M19, T6,T7,T8

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

0 87.5 175 350 525 700 Feet

1 inch = 500 feet

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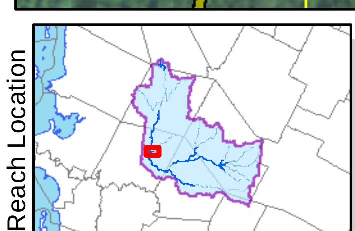

Ph1 streams
Ph2 streams
reach breaks
segment breaks
corridor (s09)

bridge or culvert assessment needed
bridge or culvert
problem bridge or culvert
beaver dam
head cut

abutment
animal crossing
ford
dump site
scalping/mining

grade control
stormwater input
regulation
bank armoring

tree revetement
bank erosion
mass failure
straightening
berm
buffer <25'

invasive-jkw
invasive-other
invasive
basin wetland restoration sites
ranked in top 500
other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwoood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- T3

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 70 140 280 420 560
1 inch = 400 feet

N

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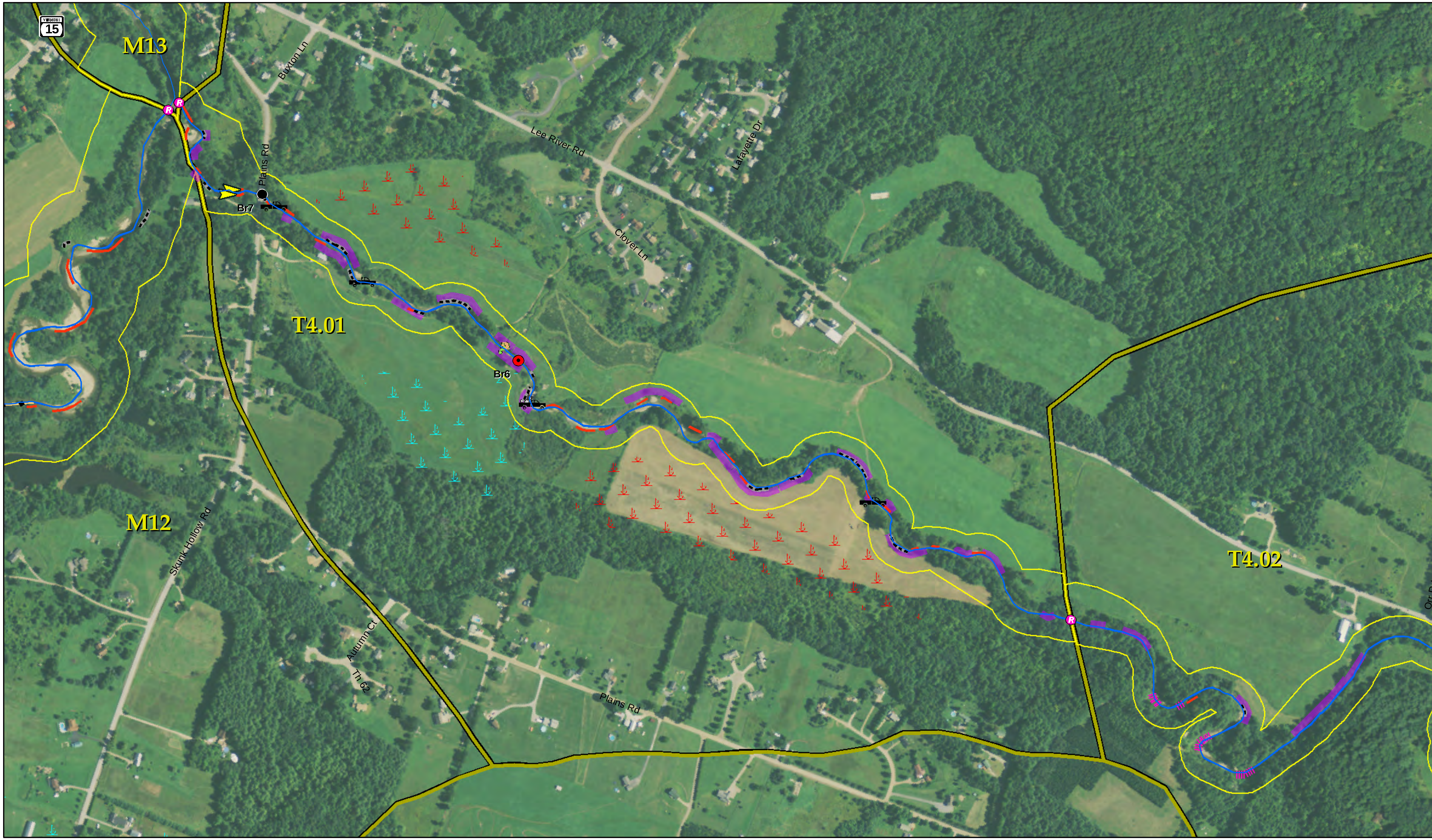

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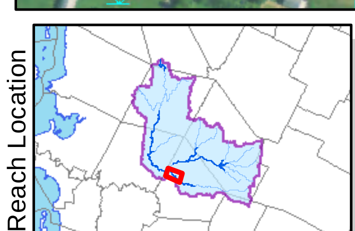
Reach Location



- Ph1 streams
- Ph2 streams
- reach breaks
- segment breaks
- corridor (s09)
- bridge or culvert assessment needed
- bridge or culvert
- problem bridge or culvert
- beaver dam
- head cut
- abutment
- animal crossing
- ford
- dump site
- scalping/mining
- grade control
- stormwater input
- regulation
- bank armoring
- tree revetement
- bank erosion
- mass failure
- straightening
- berm
- buffer <25'
- invasive-jkw
- invasive-other
- invasive

basin wetland restoration sites

- ranked in top 500
- other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- T4.01

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

0 87.5 175 350 525 700 Feet

1 inch = 500 feet

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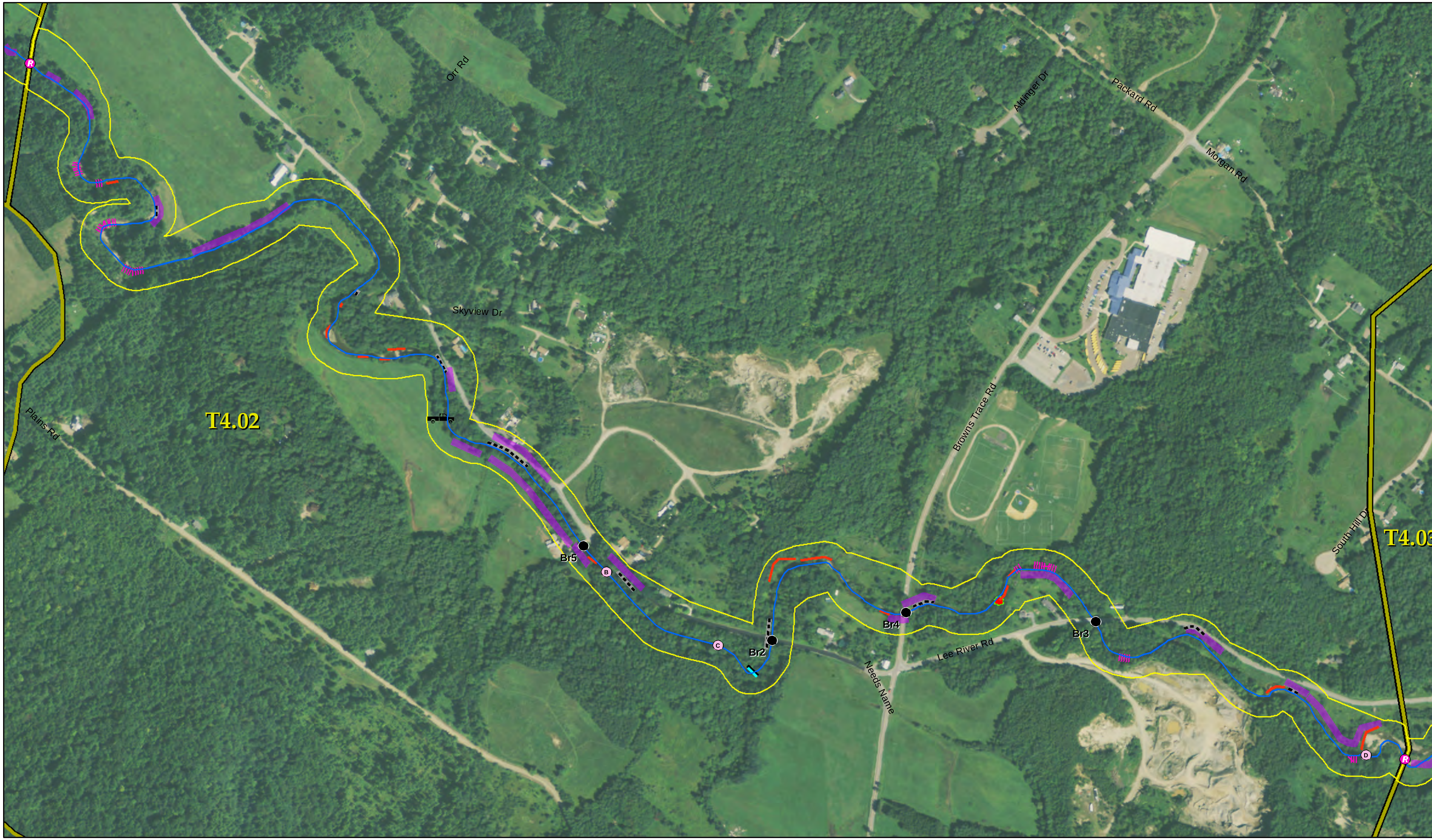
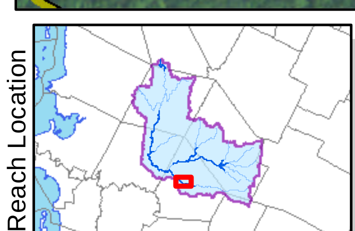


Reach Location



Ph1 streams
Ph2 streams
reach breaks
segment breaks
corridor (s09)
bridge or culvert assessment needed
bridge or culvert
problem bridge or culvert
beaver dam
head cut
abutment
animal crossing
ford
dump site
scalping/mining
grade control
stormwater input
regulation
bank armoring
tree revetement
bank erosion
mass failure
straightening
berm
buffer <25'
invasive-jkw
invasive-other
invasive
basin wetland restoration sites
ranked in top 500
other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- T4.02

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

0 87.5 175 350 525 700 Feet

1 inch = 500 feet

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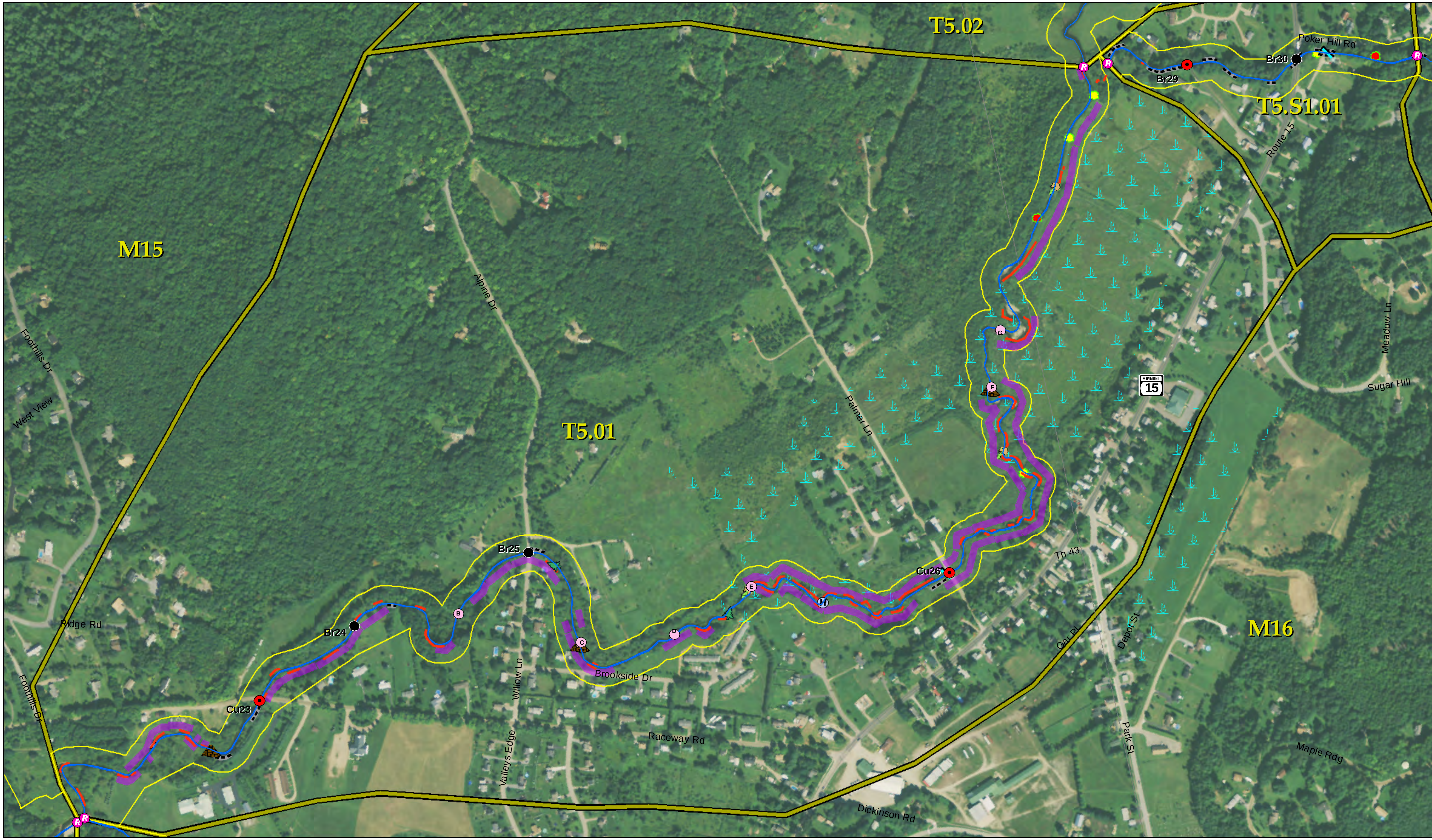
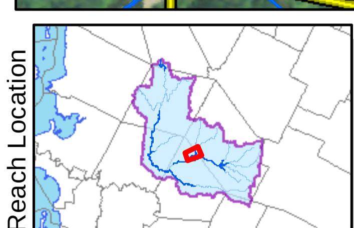


Reach Location



Ph1 streams
Ph2 streams
reach breaks
segment breaks
corridor (s09)
bridge or culvert assessment needed
bridge or culvert
problem bridge or culvert
beaver dam
head cut
abutment
animal crossing
ford
dump site
scalping/mining
grade control
stormwater input
regulation
bank armoring
tree revetement
bank erosion
mass failure
straightening
berm
buffer <25'
invasive-jkw
invasive-other
invasive
basin wetland restoration sites
ranked in top 500
other sites

Data notes: Stream channel features collected by GPS by or digitized from various field sketches by Arrowwood Environmental. Stream centerlines derived from VHD data from VCGI. Reach, segment, subwatershed and corridor data derived through geomorphic assessment protocols. Wetland restoration sites from Vt. Dept of Fish and Wildlife (Basin Restoration Plan, 2007). Other data from VCGI. Background imagery is 2008 NAIP.

Browns River Corridor Plan, 2009

Reach Map- T5.01, T5S1

Jan 16, 2009

Arrowwood Environmental, 2009 , NAD 83, Vt State Plane

Feet
0 87.5 175 350 525 700
1 inch = 500 feet

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