East Branch Passumpsic River Corridor Plan

Burke and Lyndon, Vermont
January 2009

Prepared By:
Kerry O'Brien, District Manager

Caledonia County Natural Resources Conservation District
481 Summer Street, Suite 202 St. Johnsbury, VT 05819
802.748.3885 x110
www.caledoniadistrict.org   kerry.obrien@vt.nacdnet.net   fax: 748.1621

Table of Contents

List of Figures

List of Tables

Acknowledgements

Support for geomorphic assessments on the East Branch Passumpsic River was provided by The Upper Connecticut Mitigation and Enhancement Fund, managed by the New Hampshire Charitable Foundation, and River Corridor Grants, managed by the Vermont Department of Environmental Conservation. Field work on the East Branch Passumpsic River has taken place over many years, initially in 2003 and 2004, with updates and completion in 2006 and 2008. Field assistance was provided by a number of individuals including Staci Pomeroy, Shayne Jaquith, Barry Cahoon, Kerry O'Brien, Andrea Machell, Ben Copans, and Elise Morgan. Thank you to streamside landowners for providing access to the river.

1.0 Executive Summary

This corridor plan is part of a larger effort to conduct stream geomorphic assessments and analysis in the Upper Passumpsic River Watershed, including the Miller' Run, and the East and West Branches of the Passumpsic River. Initial geomorphic assessments took place on the East Branch Passumpsic in 2003, following a major flood in 2002 that inundated the town of Lyndon and Saint Johnsbury, and caused extensive damage. As of 2008, we have completed and updated assessments on all three major tributaries. In addition, a Phase 2 assessment was conducted on one reach of Dishmill Brook, a tributary of the East Branch Passumpsic River that enters just upstream from the East Burke Dam, and is summarized in this report. Assessment results are presented in this report and include an analysis of stream stressors and departures, and stream sensitivity. This overview provides the context for a more detailed reach by reach analysis as well as preliminary identification of river restoration and protection needs and opportunities. Recommendations for restoration and protection projects are outlined and prioritized in Chapter 6. Particular attention is given to those projects that will enhance sediment and floodwater attenuation, restore the river to a condition of equilibrium, and reduce river corridor erosion and other flood related hazards throughout Lyndon and downstream communities. Otherwise, preliminary projects are generally intended to improve water quality, enhance habitat and restore the East Branch Passumpsic River to equilibrium conditions.

There are two major processes occurring on the East Branch that have caused a departure from equilibrium. One is channel incision, largely the result of historic channel dredging and bed degradation, in part from the 2002 flood, which is rendering open and undeveloped floodplains along the East Branch to be consistently inaccessible to the stream. The second is the impact from the East Burke dam, which has altered the sediment regime of the East Branch and Dishmill Brook by depriving sediment downstream and backing up sediment upstream. These two processes have resulted in reduced floodflow storage capacity along the river corridor as well as disrupted and inconsistent sediment transport.

Channel incision on the East Branch has occurred from both natural and human processes, and has resulted in a degraded channel bed, high banks and reduced access to floodplains. Floodflows within an incised river cannot overtop the channel banks and spill onto the floodplain, which causes a tremendous amount of high velocity flow and power to be contained in the channel and lead to additional channel degradation. The containment of this powerful flow results in increased shear stress on stream banks, as well as increased erosion and inundation hazards. Floodwater storage on the Upper Passumpsic tributaries is critical to attenuating floods on the Passumpsic River main stem. The East Branch channels the full force and volume of floodwater downstream instead of storing it while flows in the channel recede.

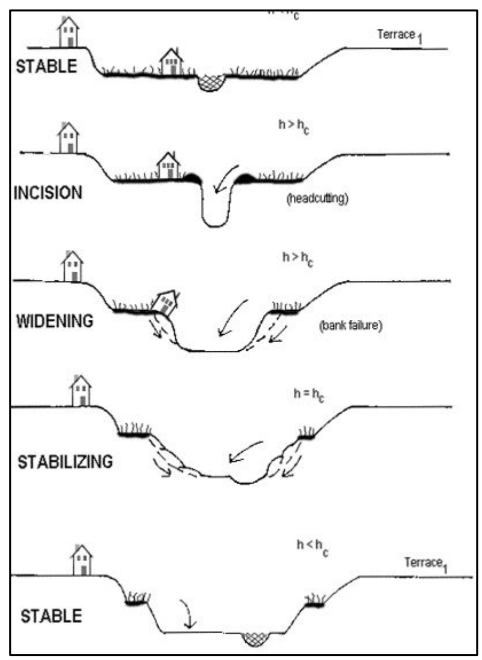


Figure 1: Schumm Channel Evolution Model (ANR, 2009)

Compounding channel incision on the East Branch is a disrupted sediment regime. The East Burke Dam deprives downstream stream reaches of sediment. This deprivation of sediment has led to increased bank erosion on these reaches to recapture this needed sediment. In addition, episodic flood deposits also observed on the East Branch have led to increased planform adjustments to accommodate the inconsistent supply of sediment. Upstream of the dam, the natural channel substrate is covered by fine sediments blocked from transport, which is increasing channel elevation, decreasing slope and significantly altering the natural channel geometry and habitat conditions of the stream.

There is evidence that the East Branch is recovering from the 2002 flood by building new floodplain, however this process is occurring very slowly and many stream reaches are still in stage II channel evolution (see Figure 1). Under the current conditions, the town of Lyndon is vulnerable to the full force and volume of floodwater that the East Branch would deliver. There is open and undeveloped land along the East Branch that could provide favorable conditions to accommodate the natural channel adjustments and floodplain development that could attenuate such floodflows. The East Branch is limited in part by Route 114 and residential development that makes the protection of this open land more critical. Restoring floodplain access to these areas would promote sediment attenuation and reduce flood hazards downstream.

2.0 Project Background and Overview

The East Branch Passumpsic River has been receiving an increasing amount of attention over the last seven years since a major flood occurred in June of 2002. Shortly after this flood event, the Caledonia County Natural Resources Conservation District (NRCD) with assistance from VT Department of Environmental Conservation's (DEC) Stream Alteration Engineer, Barry Cahoon, established the East Branch Corridor Protection Project with funding from the Upper Connecticut Mitigation and Enhancement Fund. This project targeted a two-mile stretch of the East Branch for restoration and protection efforts. This section of river underwent a significant amount of adjustment during the flood of 2002, including high levels of bed degradation and erosion. It was critical for equilibrium conditions to be restored to this section of river in order to reduce risks from subsequent flood events. The project included initial geomorphic assessments, targeted outreach to streamside landowners, installation of buffers along the river, relocation of a logging road that was previously along the edge of the river, as well as an effort to protect streamside land with conservation easements through the support and involvement of the Passumpsic Valley Land Trust (PVLT).

As the River Management Program continued to expand and refine their stream geomorphic assessment protocol, recent efforts have involved the assessment of a larger section of the East Branch Passumpsic River to meet the parameters of the current protocol. A number of related activities and projects also provided momentum for this full assessment. First, feasibility studies and public meetings have been taking place for the potential removal of the East Burke Dam, located on the East Branch in East Burke Village. PVLT acquired the dam from Northern Star Burke Mountain Ski Area in 2000 and have been working to secure the required permitting and evaluate the potential of its removal. As this project came to the table, there was more interest in acquiring geomorphic assessment data upstream and downstream of the dam, as well as the tributary just upstream of the dam, Dishmill Brook, which is also evaluated in this report.

Second, *The Passumpsic River Flood Mitigation Study* was prepared for the town of Lyndon by Gomez and Sullivan Engineers, P.C. in November of 2006. This study came about as a result of frequent flooding in the town of Lyndon, particularly the flood in June of 2002. The study was intended to assist the town of Lyndon in understanding the reasons for the flooding and outline recommendations for structural and nonstructural alternatives. The Flood Mitigation Study discussed the need for more information on the upper main tributaries into Lyndon; the Miller's Run River, as well as the East and West Branches of the Passumpsic River. At the time of the study, some Phase 2 information was available for the East Branch Passumpsic, and the study noted increased incision and decreased floodwater storage from the East Branch contributing to problem flooding in Lyndon. It was unknown what impact the West Branch and Miller's Run were having on the Passumpsic main stem, and more information was necessary to fully explore the tributary impacts and potential for flood attenuation. (G&S, 2006).

The following are excerpted recommendations from The Flood Mitigation Study (G&S 2006)

- *Using the East Branch Phase 2 geomorphic assessment, along with some follow-up field work, estimate the storage capacity on the East Branch. Quantify how much storage capacity could be gained in those areas where the East Branch currently can not access its floodplain. Quantify the overall floodplain storage capacity and the benefit relative to curtailing flooding in Lyndon.*

- *Work with the Vermont Rivers Management department to conduct geomorphic assessments on the other major tributaries- West Branch and Miller Run- to determine if these rivers can access their floodplains. Conduct the same evaluations described above for the East Branch, including quantifying the floodplain storage capacity that could be made available.*

- *It is recommended that first geomorphic studies be conducted on Miller Run and the West Branch to a) determine the river's stability, b) identify floodplains that provide key attenuation assets and c) compute he total belt width along each river that would define the river corridor. It is recognized that some floodplains are already occupied by houses or roads, thus emphasis should be placed on floodplains that remain relatively undeveloped.*

This study provides guidance for the Phase 2 stream geomorphic assessment of upper tributaries of the Passumpsic River, including the East Branch, and presents pertinent research questions. Flood storage capacity and floodplain evaluation of the East Branch are key foci in understanding the role the East Branch plays in problem flooding in the town of Lyndon.

The Federal Emergency Management Agency (FEMA) conducted a Flood Insurance Study (FIS) for the town of Lyndon in 1977, which was updated in 1988. As part of the study, FEMA delineated 100-year, 500 year and floodway boundaries, which assume varying degrees of flooding in any given year. A 100-year flood assumes a 1% chance of flood inundation within the delineated boundary in any given year. A floodway, more specifically, indicates the area of the floodplain within which any filling would result in an increase to the elevation of the 100 year floodplain and with that carries more development restrictions.

Phase 1 and 2 stream geomorphic assessments took place on Reaches T101 through T107 of the East Branch, from the mouth to just near the southern town line of East Haven, VT. The length of the stream included in the assessment spans for approximately 10 miles and flows through the towns of Burke and Lyndon. Segments in Reach T105 and T106 were excluded from the assessment due to impoundment of the stream from the East Burke Dam.

3.0 Background Watershed Information

3.1 Geographic Setting

The East Branch is one of the major tributaries of the Passumpsic River, a 507 square mile watershed and one of the largest tributaries of the Northern Connecticut River. The Passumpsic River passes through seven hydroelectric stations over 34 miles, meanders around Nine Mile Islands and empties into the Connecticut River. The main stem of the Passumpsic River begins at the confluence of the East and West Branches of the Passumpsic in the town of Lyndon. Approximately 1.5 miles downstream of this confluence is where the Miller's Run River empties into the main stem.

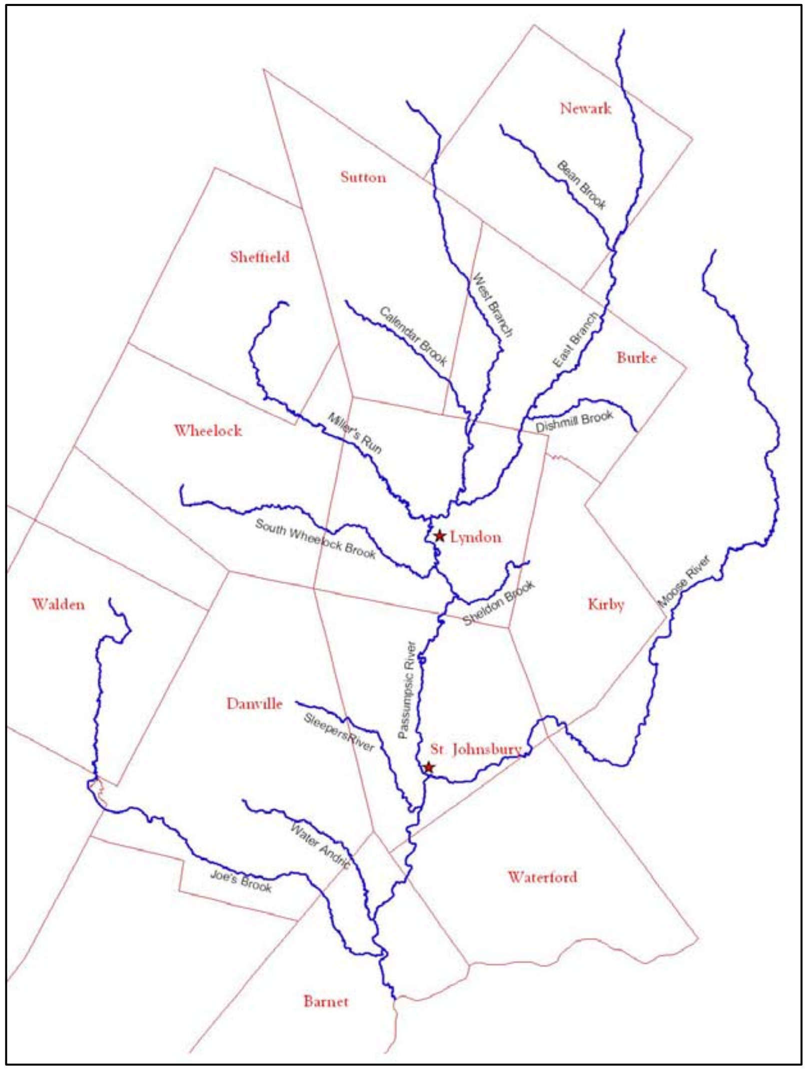
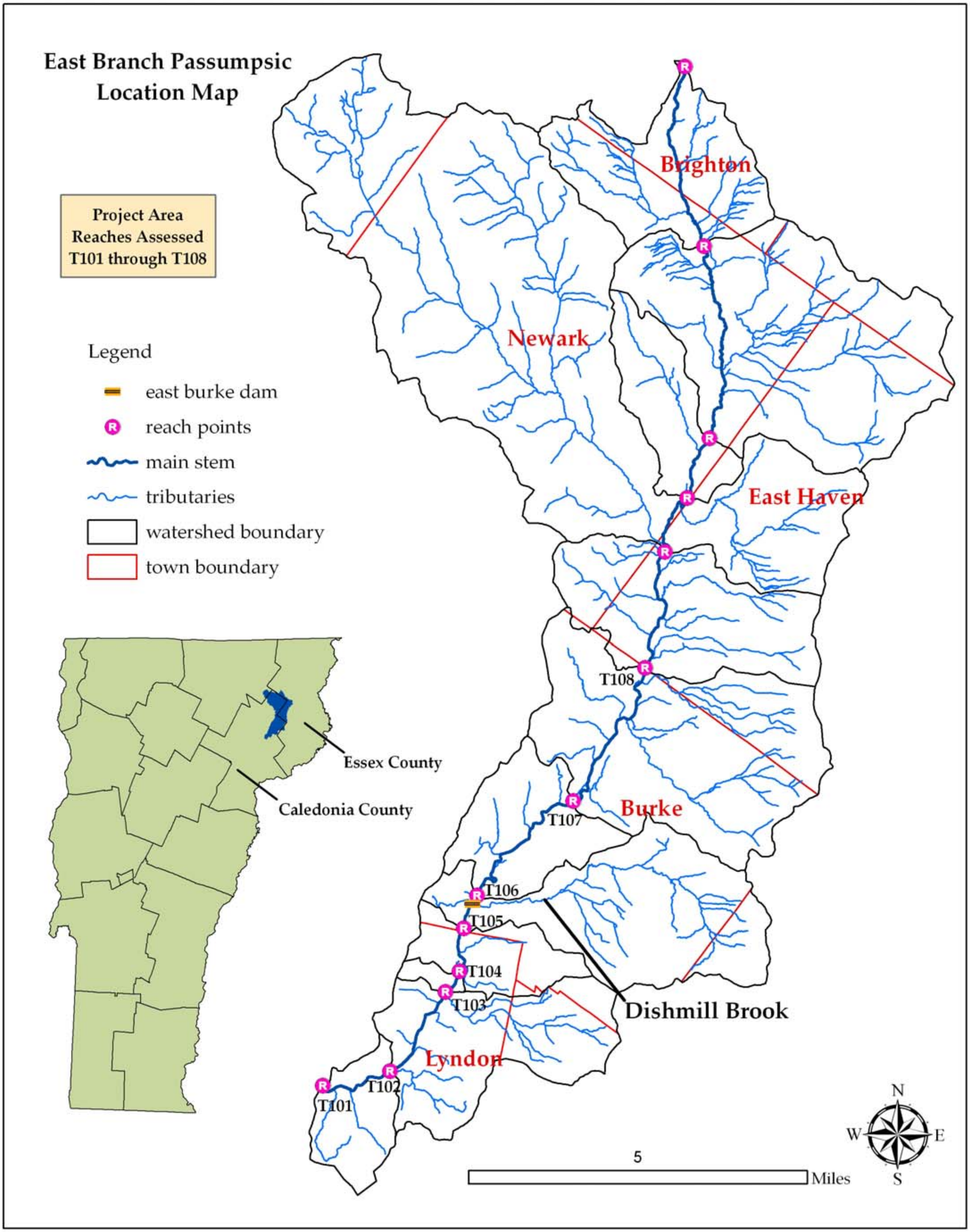


Figure 1a: Passumpsic River Watershed

The East Branch Passumpsic River drains approximately 80.8 square miles. Its tributary inputs generally drain from Burke Mountain and East Haven along the river's east side and along the ridge referred to as Darling Hill and north to Burke Green/Maple Ridge Road on the west side. The headwaters originate in the town of Brighton, and northern tributaries include a large portion of the town of Newark and a small portion of Westmore. One of its main tributaries, Dishmill Brook, drains Burke Mountain and the Burke Mountain ski area, flows into the East Branch in East Burke village just upstream from the East Burke Dam. The East Branch's river valley is occupied by Route 114, with the majority of development clustered mainly around East Burke village and in Lyndon along Deer Run Lane. Residences, businesses and agricultural land use are sprinkled throughout the valley and along the river, while the rest of the watershed is primarily mountainous and forested.

Figure 1b: East Branch Passumpsic River Location Map



3.1 Political Jurisdictions

Project reaches are located in the towns of Burke and Lyndon. The complete drainage area of the East Branch also includes the towns of Newark, East Haven, Victory, Kirby, Brighton, and Westmore, which are situated in both Caledonia and Essex Counties.

3.2 Geologic Setting

The East Branch Passumpsic River lies within the Burke quadrangle. The river valley generally follows parallel to the contact between the Waits River formation to the west and the Gile Mountain formation to the east. The Gile Mountain to Waits River contact is gradual and varying but is generally characterized by a change from the rigid and resistant quartzite and schist of Gile Mountain, to the more easily weathered limestone of the Waits River Formation. Granite rocks are evident in the Burke quadrangle, linking the area more closely to New Hampshire than to the rest of Vermont.

Pleistocene glaciation is evident throughout the entire Burke quadrangle, and is characterized by considerable glaciofluvial gravel and sand deposits seen along the river valley. Eskers along the northern end of the watershed and kame moraines further south create an uneven topography along the river valley. Many areas of stratified gravel and sand can be along the lower reaches of the East and West Branches, and have become the medium for gravel operations that we see today. In the context of the three upper Passumpsic Tributaries, the East and West branches have similar characteristics to each other (generally steeper with coarser substrate) while the Miller's Run is more transitional, running perpendicular to the Waits River and Gile Mountain contact, and showing a lower gradient and finer sediment.

Soils are consistent with the geologic setting. The wider open fields generally consist of alluvial soils that flood occasionally, with some coarser materials and glaciofluvial deposits in the rest of the valley. See Table 1 for more information.

Table 1: Dominant Soil Types by Reach

Reach ID	Dominant Soil Type	%Dom	Parent Material	Flooding	Hydro Group	Drainage Class	Hydric
T101	Podunk Fine Sandy Loam 31A	72	loamy alluvium over sandy alluvium	occasional	B	moderately well drained	no
T102	Podunk Fine Sandy Loam 31A	42	loamy alluvium over sandy alluvium	occasional	B	moderately well drained	no
	Ondawa Sunday Complex 30A	13	coarse loamy alluvium over sandy and gravelly alluvium	occasional	B	well drained	no
T103	Podunk Fine Sandy Loam 31A	24	loamy alluvium over sandy alluvium	occasional	B	moderately well drained	no
	Ondawa-Sunday Complex 30A	16	coarse loamy alluvium over sandy and gravelly alluvium	occasional	B	well drained	no
T104	Podunk Fine Sandy Loam 31A	25	loamy alluvium over sandy alluvium	occasional	B	moderately well drained	no
	Colton-Duxbury Complex 32D	19	sandy gravelly glaciofluvial deposits	none	A	excessively well drained	no
T105	Colton Duxbury Complex 32A	38	sandy gravelly glaciofluvial deposits	none	A	excessively well drained	no
T106	Podunk Fine Sandy Loam 32A	34	loamy alluvium over sandy alluvium	occasional	B	moderately well drained	no
	Rumney Fine Sandy Loam 42A	15	loamy alluvium over sandy alluvium	frequent	C	poorly drained	yes
T107	Monadnock Fine Sandy Loam 75E	32	sandy gravelly ablation till	none	B	well drained	no
	Podunk Fine Sandy Loam 31A	17	loamy alluvium over sandy alluvium	occasional	B	moderately well drained	no

3.3 Geomorphic Setting

The East Branch Passumpsic River was divided into 12 reaches for the Phase 1 assessment, with 10 reaches assessed. A total of seven reaches were selected for Phase 2. Reaches are homogeneous sections of stream, with breaks located where there are visible changes in physical aspects of the stream and valley such as channel confinement, sinuosity and/or hydrologic characteristics such as tributary inputs. During the Phase 1 assessment of the East Branch, the remote sensing phase, preliminary reference stream types are determined based on the confinement, slope and other characteristics that are outlined below. Table 2 outlines the reference characteristics of the stream reaches as recorded in Phase 1.

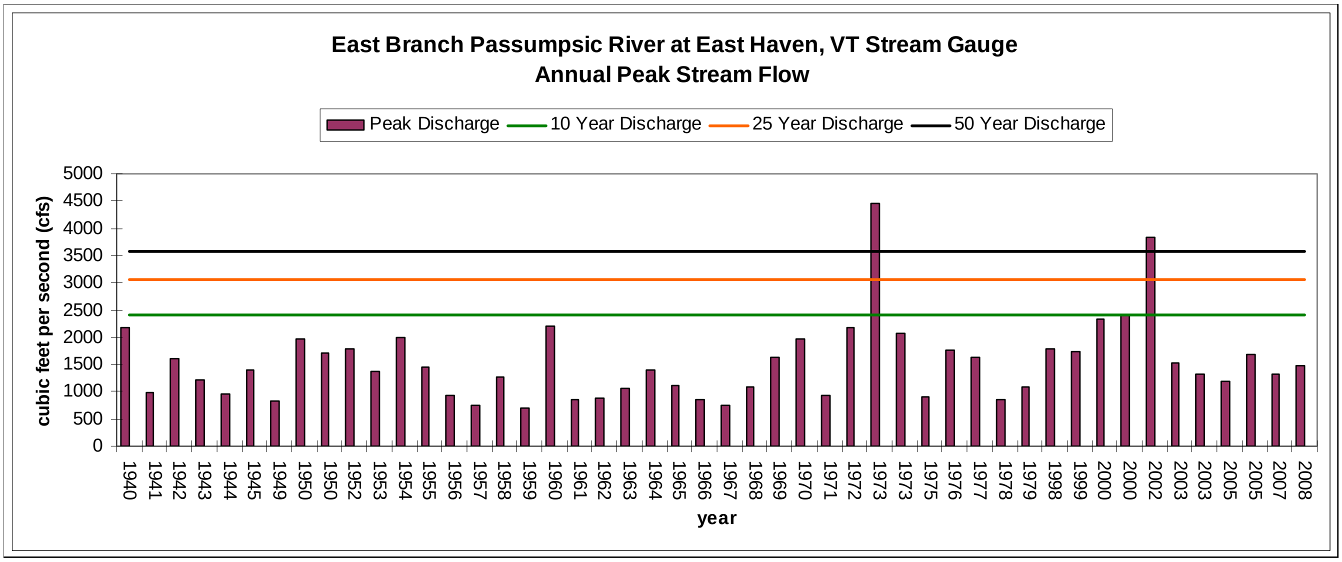
Table 2: Reference Stream Characteristics by Reach

Reach ID	Drainage Area (sq mi)	Valley Width (ft)	Valley Type	Channel Width (ft)	Channel Length (ft)	Channel Slope %	Sinuosity	Reference Stream Type	Channel Bed Form
T101	80.82	1100	Very broad	90.5	6498	.31	1.14	C	Riffle pool
T102	78.86	621	Broad	89.5	8084	.74	1.02	C	Plane Bed
T103	73.62	404	Narrow	86.8	2086	Gentle gradient	1.12	C	Riffle Pool
T104	73.33	731	Broad	105	3838	.52	.52	C	Riffle pool
T105	71.29	628	Broad	85.6	2921	.68	1.05	C	Riffle Pool
T106	64.38	832	Very Broad	81.9	13390	.3	1.24	C	Riffle Pool
T107	61.04	528	Broad	80	13939	.72	1.11	C	Riffle Pool
T108	51.19	853	Very Broad	74	10707	.37	1.05	C	Riffle Pool
T109	45.25	707	Very Broad	70.1	5935	.67	1.27	C	Riffle Pool
T110	19.72	568	Very Broad	48.6	5497	.36	1.07	C	Riffle Pool

5.4 Hydrology and Flood History

The United States Geological Survey (USGS) collects data from river gauging stations throughout Vermont. The USGS gage on the East Branch Passumpsic in East Haven provides a historical record of flows at a location where the stream is not impacted by any upstream impoundments, thus reflecting an unregulated stream flow. Insight can be drawn from the East Branch gage in determining annual peak flows and how they relate to the flooding history of the Upper Passumpsic watershed. The period of record for the East Branch gage is not continuous, with a prominent break in record from 1979 to 1997.

Figure 1c: Annual Peak Stream Flow at East Haven, VT Gauge



The largest flood measured on record from the East Branch gauging station was in 1973, with the second highest and most recent flood in 2002. According to interviews with Vermont DEC, the 2002 flood caused extensive damage throughout Lyndon and downstream to St. Johnsbury, including property damage, power outages, as well as road and business closures. The photo on the left shows the Passumpsic River main stem near the confluence of the East and West Branches and the Miller's Run River. This is an area of frequent flooding and sediment accumulation, which is additionally challenged by development and transportation routes. As we examine the Upper Passumpsic watershed, it is clear that these three tributaries are critical components in the discussion of flood attenuation.

Figure 2: Photo by Kenneth Mason: 2002 Passumpsic River main stem flooding near junction of Rte 114 and Rte 5 in Lyndon and Miller's Run confluence

3.5 Ecological Setting

The northern end of the Upper Passumpsic Watershed is generally part of the Northeastern Highlands biophysical region, an area more similar to New Hampshire and Quebec than the rest of Vermont. This area is characterized by colder climate, granite bedrock and rugged terrain. There are glacial till deposits through the region, particularly in the river valleys, and the area also features many glacial erratics or large scattered boulders. While this biophysical region accounts for the northern Passumpsic watershed and sections of East Haven and Brighton, the watershed also makes a transition to Northern Vermont Piedmont biophysical region as well. This region is more prominently featured in most of the lower Passumpsic watershed and lower East Branch, but it is characterized by a slightly warmer climate more easily weathered material as compared to the granitic mountains of the Northeastern Highlands.

Forest types in the East Branch watershed include Northern Hardwood stands, as well as Hemlock and Spruce/Fir forests. Northern Hardwoods are generally broad-leafed forests with some conifers, and feature a wide range of trees including sugar maples, beech, yellow birch and white ash. There are many softwood stands in the East Branch watershed as well, including hemlock, red spruce, balsam fir and white pine. These forest types are generally situated relative to exposure, with the Northern Hardwoods favoring southern and eastern facing slopes. Widespread deforestation during early settlement, however, has resulted in many of these forest stands showing a greater mix of these species as they work through forest succession processes.

Riparian habitat on the East Branch favors colder climate species, with large portions of the stream showing good to excellent habitat conditions. Forested buffers, shaded banks, substrate mixture and in-stream woody debris are providing good opportunities for fish and other aquatic habitat. Areas with low buffer widths and homogenous gravel substrate along the East branch have reduced habitat and in some cases the habitat has been classified as ‘poor.’

4.0 Research Methods

4.1 Stream Geomorphic Assessment Protocols

Fluvial geomorphology functions to explain the interrelationships between flowing water, sediment and various land forms. Understanding how streams interact with their environment is the central focus of the Vermont Agency of Natural Resources comprehensive stream geomorphic assessment protocols. With the ultimate goal of resolving or avoiding conflicts between river systems and human investments, the stream assessment protocols provide comprehensive physical and habitat data of a watershed and stream system that can be utilized for long term planning and restoration practices. Excerpted from the Vermont Agency of Natural Resources (VT ANR, 2007), the stream geomorphic assessment program objectives are:

1) To create a data collection protocol for the physical assessment of streams and rivers that is scientifically sound and produces repeatable results, so that data can be compared not only within a watershed but between watersheds and regions.

2) To create a state GIS and database system of fluvial geomorphic data that is accessible to users inside and outside the Agency of Natural Resources.

3) To create a method for predicting stream channel and flood plain evolution in Vermont that will technically support the resolution of river/land use conflicts and allow for sound land use practices and planning at the watershed scale.

4) To create a river assessment methodology that will help lay people understand how human activities over time within a watershed can be conducted in a manner that is both ecologically and economically sustainable.

Stream geomorphic assessments are divided into two phases. The phase 1 assessment, the remote sensing phase, is a preliminary analysis from existing studies, maps, aerial photos and "windshield surveys" of the watershed. Phase 2 involves in-stream data collection, cross section surveys and a more detailed and comprehensive analysis of the streams' adjustment patterns, as well as physical and habitat characteristics. Both phases function in tandem with a spatial database of the watershed and an online data management system (DMS) at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

4.2 Quality Assurance and Quality Control

Vermont's River Management Program conducted quality assurance/quality control (QA/QC) checks on the East Branch data in January of 2009. The QA/QC tools were developed by the VT ANR and are partially built into the online database management system. The spatial (GIS) database of the watershed and uploaded spatial data are also reviewed through the QA/QC process. Geomorphic assessment data was initially collected on the East Branch in 2003-2004, prior to some significant changes in the SGA protocol. Current parameters of the protocol would require inclusion of the all East Branch tributaries into the spatial database and as a component of the Phase 1 data collection. Because the Arcview project was created prior to this expansion, only the main stem of the East Branch is included in the spatial data and project.

5.0 Departure Analysis and Stressor Identification

5.1 Hydrologic Regime Stressors

The timing, volume and duration of flow events throughout the year and over time determine the hydrologic regime of a watershed (VT ANR 2007). The following description from VT Agency of Natural Resources River Corridor Planning Guide explains hydrologic regime and stressors.

> The hydrologic regime may be influenced by climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology. The hydrologic regime, as addressed in this section, is characterized by the input and manipulation of water at the watershed scale and should not be confused with channel and floodplain "hydraulics," which describes how the energy of flowing water affects reach-scale physical forms and is affected by reach-scale physical modifications (e.g., bridges modify channel and floodplain hydraulics). 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.

Analysis of land cover and land use is useful in understanding hydrologic stressors. Historic deforestation has had prominent impacts on hydrologic regimes statewide by altering the flow and ability of land to absorb the volume of water during a storm event. Precipitation on open land has a far greater tendency to create erosion and concentrated flows of runoff and associated sediment, as opposed to forested land that has a much greater capacity to store water and hold sediment in place (VT ANR, 2007). Land use and land cover for the East Branch is summarized below in Table 3. The watershed is largely forested (83%), but land use and cover within the corridor is more mixed. The dominant land cover/land use within the East Branch stream corridor is wetland and water, recorded at 39%. While approximately 21% of this land cover is the stream itself, about 18% is forested or non-forested wetland, which would make forested land dominant in the corridor and watershed.

Table 3: Corridor and Watershed Land Cover/Land Use Percentages

Corridor Land Cover/Use Type	% Cover
Forested	31%
Agriculture	18%
Wetland and Water*	39%
Residential/Commercial/Industrial	2%
Transportation	10%

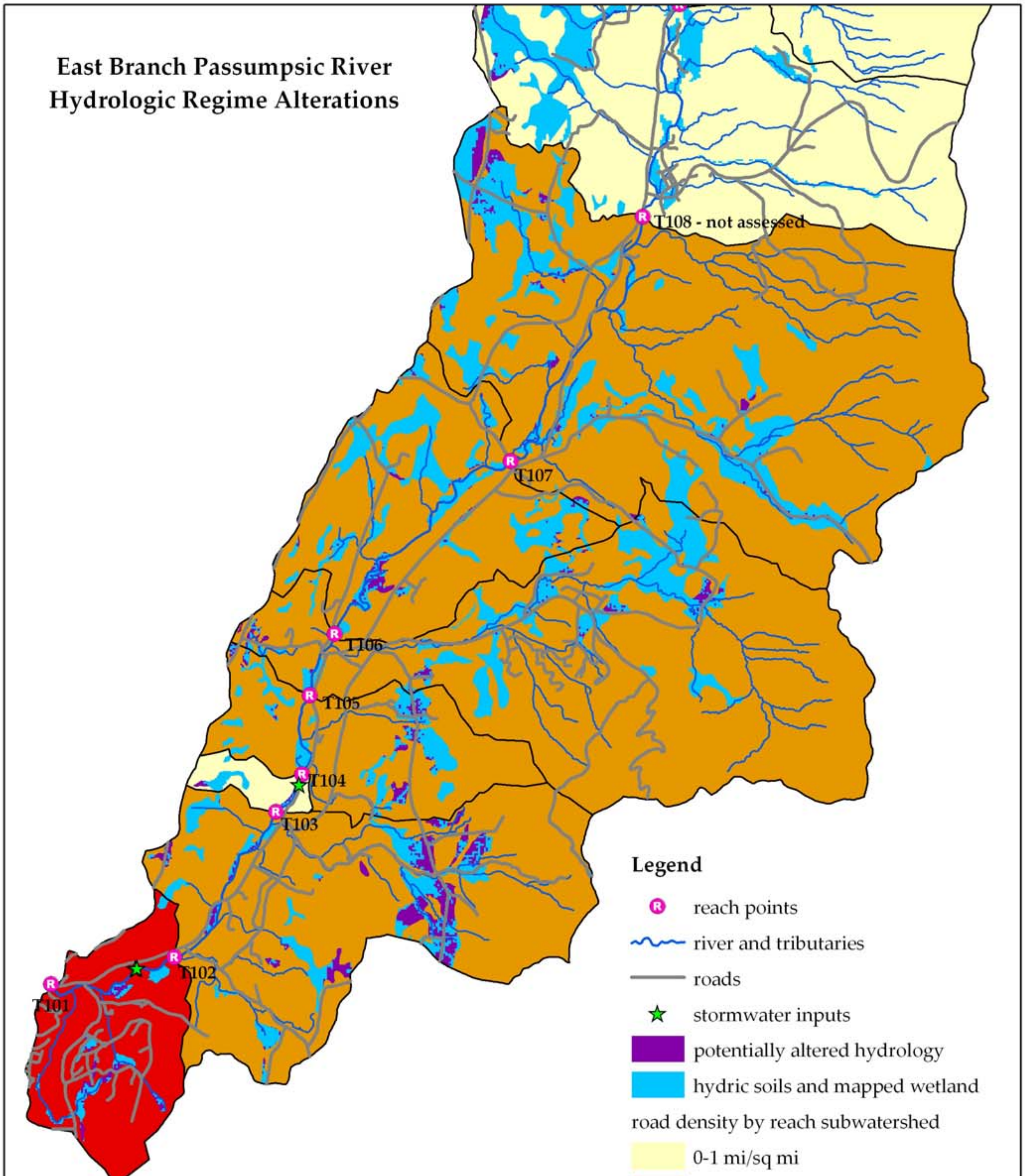
*18% wetland

Watershed Land Cover/Use Type	% Cover
Forested	83%
Agriculture	6%
Wetland and Water	7%
Residential/Commercial/Industrial	1%
Transportation	3%

The majority of wetland within the stream corridor is upstream of the assessed area, though its presence does provide some insight into the amount of watershed inputs near the stream. In Figure 2a, agricultural and urban land uses were correlated with hydric soils, and where they overlap is referred to as 'potentially altered hydrology.' Agricultural and urban land uses have the potential to decrease floodwater storage capacity in the stream corridor, and hydric soils are a good indicator of where watershed inputs were once stored. It can be argued that a floodplain forest would store and absorb more water than open land, partly due to root mass but also due to micro-topography which may include small depressions in the landscape that would store and absorb water. Clearing and tilling a streamside field may reduce these opportunities and thereby alter the hydrologic regime of the watershed. This is difficult to quantify, but Figure 5 provides a visual context for this discussion by showing where agriculture and urban land uses intersect with hydric soils, and the potential in these areas for decreased water storage and absorption capacity. Agriculture along the stream corridor on the East Branch is present but isolated to a few large cornfields, and is seemingly having a smaller impact on the hydrologic and sediment regime than the Miller's Run. Residential land is present along the entire corridor, and shows the potential for small isolated impacts on the hydrologic regime of the East Branch, but represents only a small amount of land use along the East Branch. The ski area on Burke Mountain feature large swaths of cleared ski trails, which likely influence the hydrology of this drainage area by channeling more runoff, which is further augmented by snowmaking.

To show the impacts of roads on the hydrologic regime of the East Branch, Figure 2a also shows an analysis of road densities by reach subwatershed. Road densities are generally low in the East Branch, with higher densities towards the mouth, likely due to the development around the Lyndon town school, which is still relatively low. Route 114 does follow the river valley and at times pinches the river against the valley wall. This has an impact on the hydrologic regime by restricting the river's access to floodplain and concentrating flows within the stream channel. The rest of the assessed area has low road densities. The last potential hydrologic regime stressor is the East Burke Dam, which is the only impoundment on the East Branch. The dam is "run of the river", meaning it does not have a managed flow but the river flows over the top of the dam. The dam is having a greater impact on the sediment regime rather than the hydrologic regime and is discussed further in the next section.

Figure 2a: Hydrologic Regime Alterations



5.2 Sediment Regime Alterations

The sediment regime is the quantity, size, transport, sorting and distribution of sediments (VT ANR 2007). Stressors to this regime result from alterations to stream power and sediment supply. The following description from VT Agency of Natural Resources River Corridor Planning Guide explains sediment regime and stressors.

> The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain and stream morphology. Understanding changes in sediment regime at the reach and watershed scales is critical to the evaluation of stream adjustments and sensitivity. The sediment erosion and deposition patterns, unique to the equilibrium conditions of the stream reach, and create and maintain habitat. In all but the most dynamic areas (e.g., alluvial fans), they provide for relatively stable bed forms and bank conditions.

Sediment load indicators are mapped on Figure 3 and include agricultural and urban land use, erosion, as well as depositional and migration features such as steep riffles and flood chutes. Upstream of the influence of the East Burke Dam in Reach T106, erosion and deposition features are moderate, and several flood chutes and two steep riffles are noted. Continuing downstream towards the dam in Reach T105, sediment transport is impounded and impacts are noted for approximately 2000' upstream of the dam. Immediately downstream of the dam, the stream is deprived of sediment and then it dramatically widens and erosion on both banks increases (erosion data shown on Figure 3 is from 2004 and 2006, and a walk of reach T105a and T104 in 2009 showed that bank erosion has increased to greater levels than the original data). A high degree of bank erosion downstream of an impoundment is not uncommon due to the fact that the water coming over the dam is unburdened by sediment and highly erosive. This is commonly referred to as the "hungry water" scenario. Removal of the dam would provide a greater level of sediment equilibrium and likely decrease the degree of erosion within this segment.

Continuing downstream of T104, we begin to see increased incision ratios and greater impacts from the flood in 2002 and the stream generally migrates between stage II and stage III of channel evolution (see figure 3). Along reach T103 as well as the downstream end of T104, the stream is straightened and confined by Route 114 on its left bank with the valley wall along its right bank. This section efficiently transports sediments that are delivered to it from upstream and no depositional features are present. Depositional features increase in the upstream end of reach T102, and then become more moderate from T102B to the mouth. Reach T102 to the mouth was deeply scoured by the 2002 flood, and has been historically dredged. Incision ratios are mapped on Figure 4, with the highest levels of incision seen at the downstream end where it reaches close to 2.0 in sections. A stream with high incision and poor floodplain access will have an impacted sediment regime, particularly in response to high flows. Without access to a floodplain upon which to deposit sediment and dissipate high energy during a flood event, the full force of the flow is contained within the channel, resulting in greater erosion and associated hazards. The sediment and floodwater that would otherwise be attenuated along the floodplains of Reach T102 will instead be transported to Lyndonville resulting in increased flood heights and lateral migration.

Agricultural and urban/industrial land uses are also displayed on Figure 3. Most of this land use is concentrated towards the downstream end of the East Branch. Several large cornfields are present along the river valley, and may be providing some hydrologic and sediment alteration, though the greatest impact from this land use is related to channel dredging rather than clearing and tillage.

Channel dredging is discussed further in the context of channel slope and depth modifications in the next chapter.

Figure 3: Sediment Load Indicators Map

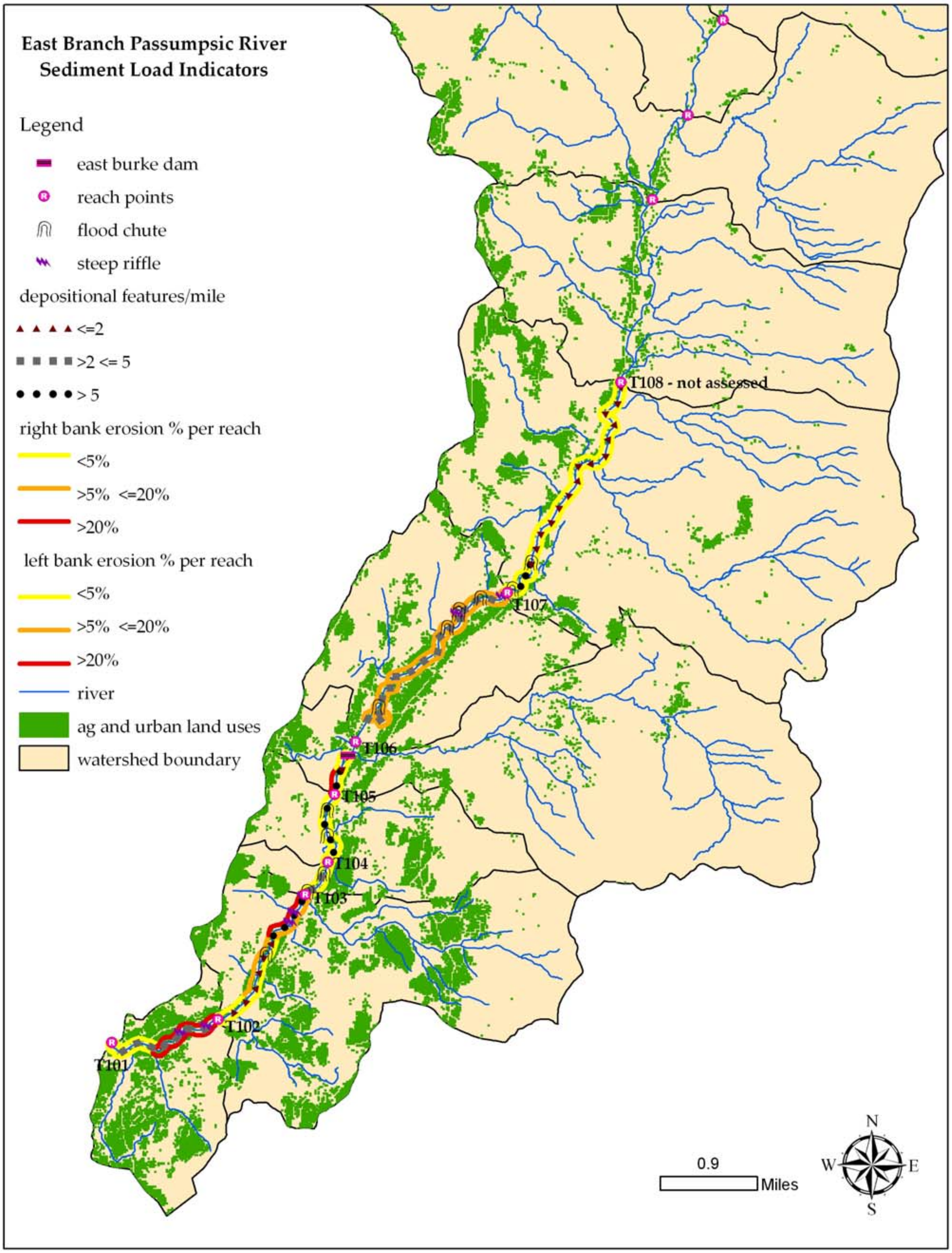
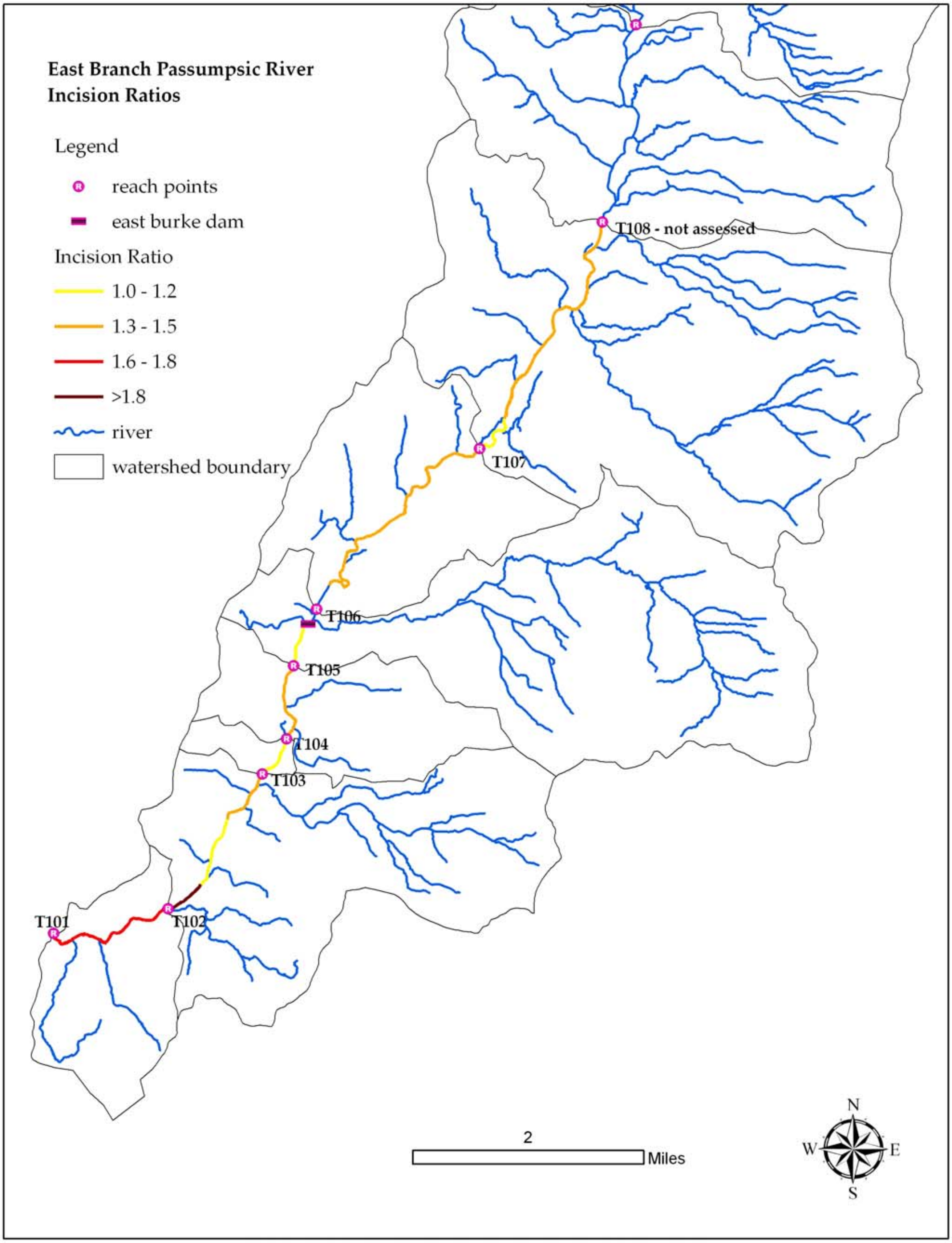


Figure 4: East Branch Passumpsic River Incision Ratios



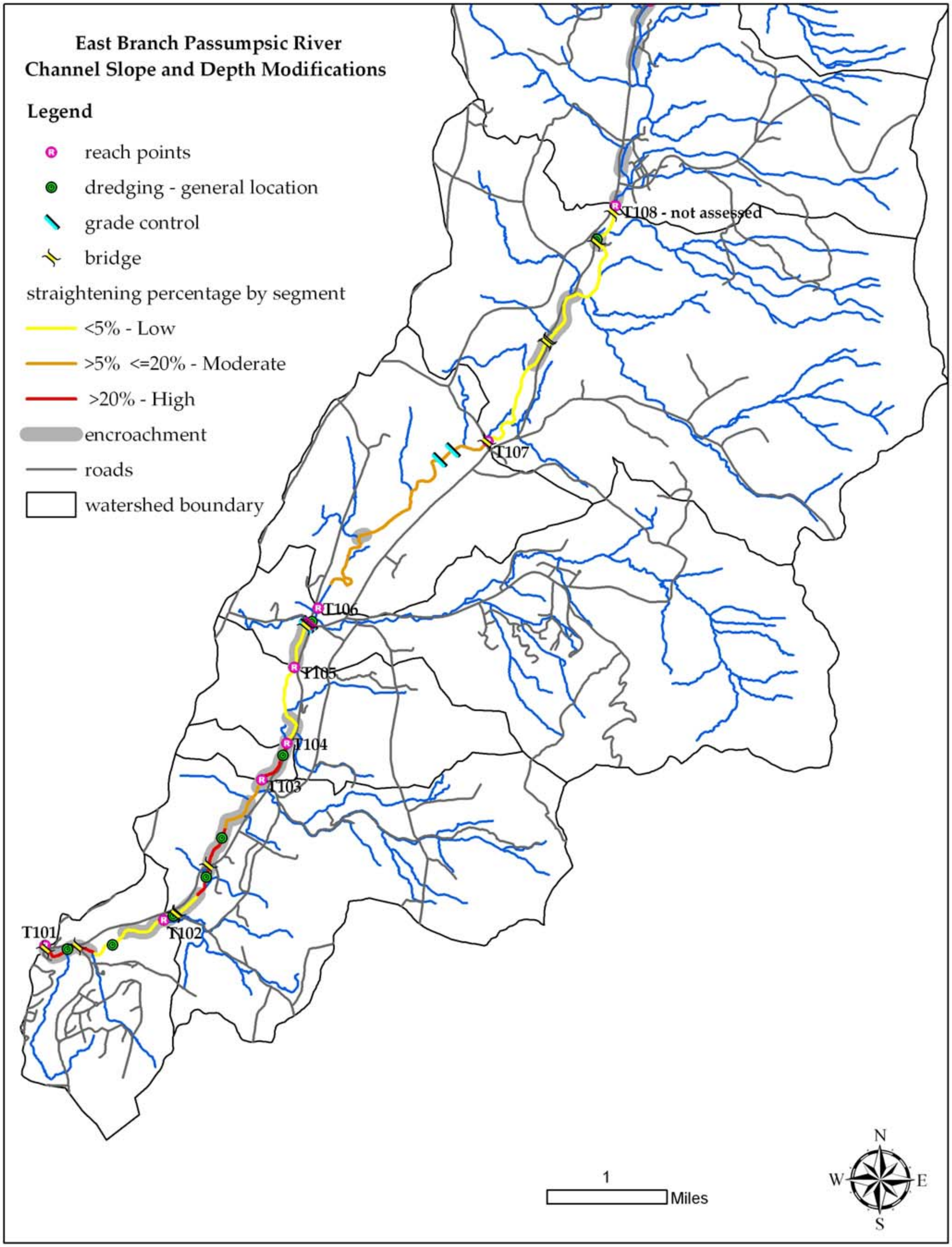
5.3 Channel Slope and Depth Modifiers

The two primary factors influencing the amount of shear stress (the extent of power within a channel and its corresponding ability to erode) generated by river flow are channel slope and flow depth. Changes to these factors and the resulting change in shear stress within the channel affect the rivers ability to transport sediment. Historic channel modifications and manipulations are significant in influencing channel geometry and floodplain access. Channel straightening increases channel slope and leads to increased sediment transport, bed erosion and incision ratios. Loss of floodplain access leads to heightened flow depths and subsequent shear stresses during times of high flows. Slope decreases occur from channel constrictions such as bridges and other structures, which often cause unnatural meander bends upstream due to an accumulation of sediment at the point of constriction.

Streamside encroachments such as roads, development or agriculture are often associated with dredging and berming of the stream channel, which increase the depth of a stream and raise the height of the floodplain. These practices will confine the stream to its channel and cut off access to the floodplain and the opportunity to store floodwaters in its natural location. While this may provide temporary protection from flood inundation at this point of the stream, floodwaters that would otherwise be stored on the floodplain are transported downstream creating increased fluvial erosion hazards and subsequent downstream inundation.

Channel slope and depth modifiers are mapped on Figure 5 and include dredging, straightening, bridges and grade controls. The East Burke Dam is contributing to a decrease in channel slope upstream. Existing land use is currently accommodating this adjustment, which is characterized by moderate sediment accumulation and planform adjustment. Bridges on the East Branch are channel constrictions and decreasing channel slope upstream, however the impact seems to only be at the points of constriction and do not seem to pose any broader reach level adjustments as no major planform changes are observed. The most significant modification is an increase in channel depth and slope due to historic dredging, resulting in an increase in stream power. The majority of the encroachment shown on Figure 5 is due to roads and residential development, which is also contributing to an increase in channel depth and stream power. Resulting conditions include an increase in fluvial erosion hazards, incision and lacking floodplain access. The flood in 2002 demonstrated the bed degradation and bank erosion that occurs when a channel is subjected to the full force of a flood, without ability to dissipate energy and store floodwater on the floodplain. While the channel is adjusting and beginning to build new floodplain at points since the flood, most of the channel is still in stage II channel evolution.

Figure 5: Channel Slope and Depth Modification

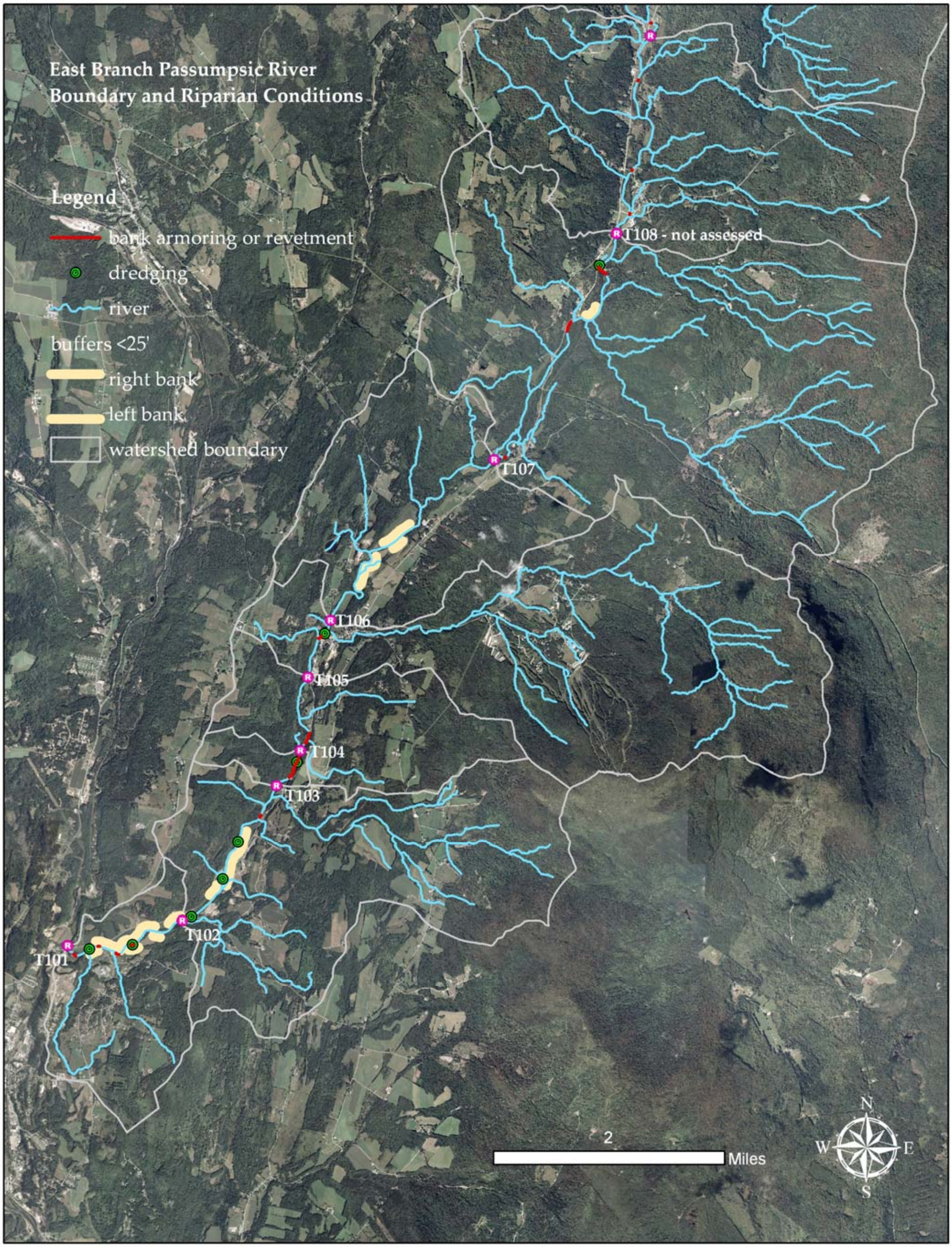


5.4 Boundary and Riparian Conditions

Examining the boundary and riparian conditions provides insight into the ability of the channel to adjust. Buffer composition and bank material determine the amount of resistance that is present and impacting planform change. Channel armoring, for example, is a common channel boundary modifier and is intended to increase the banks resistance to erosion, whether widening or developing planform change. Vegetated buffers also provide boundary resistance and removal of the riparian buffer would reduce the strength of the bank making it more susceptible to erosion. Bed substrate composition also impacts the resistance of the channel bed, and human made structures such as weirs and dams, or natural grade controls will increase the bed's boundary resistance.

Boundary and riparian conditions are mapped on Figure 6 and include bank armoring, dredging erosion and buffer information. Bank material was not mapped but is non-cohesive on the East Branch except for bedrock (cohesive) bank material noted on the right bank just downstream from the East Burke Dam. There are several recent buffer plantings which will eventually provide greater resistance to erosion, but the vegetation is still too young to provide increased boundary protection presently. Buffers that are less than 25' in width are mapped, however an additional 1300 linear feet, approximately, of new buffer should still be considered in the short term as having less resistance. Erosion is mapped according to feature indexing tool (FIT) data, but erosion percentages can be referred to on the Sediment Load Indicators map on Figure 3. Erosion is moderate to low upstream of the East Burke Dam, but is noted as high in locations downstream, particularly on Reach T101B. In general, boundary resistance on the East Branch is land use dependent. In select locations with residences and road encroachment, there is very little room for lateral channel adjustment. The majority of the stream shows decreased boundary resistance due to non-cohesive bank material and dredging. Downstream reaches show the highest level of decreased boundary resistance, due to the factors listed above, as well as low buffer widths.

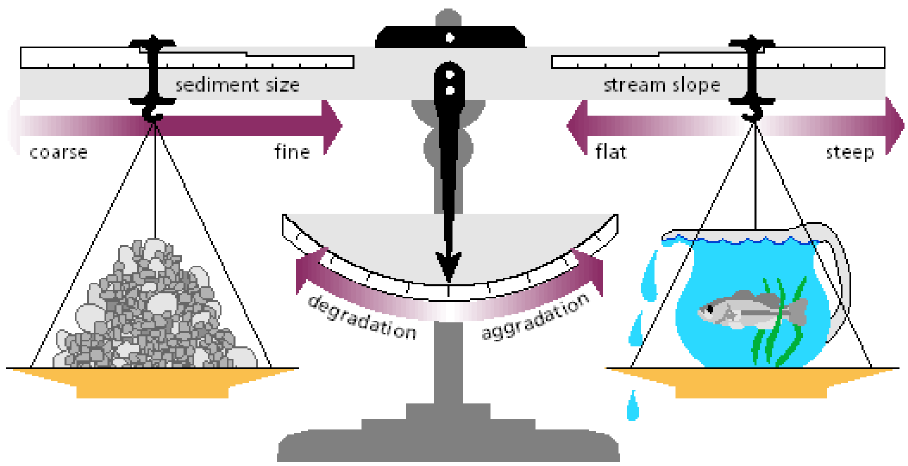
Figure 7: Boundary and Riparian Conditions



5.5 Sediment Regime Departure Analysis

The balance of stream power and sediment load is the defining element to stream equilibrium (Leopold 1994). Rivers are in constant adjustment as they work to deal with an uneven distribution of power or sediment (disequilibrium), typically caused by stressors or modifications to channel geometry or watershed inputs. This concept of balance has been widely documented by Lane (1955) and his depiction of a scale to show the elements of dynamic equilibrium at work. See Figure 8 below. Streams are naturally adaptive to minor changes in stream power or sediment, however, land use changes and other management practices can create major changes in these inputs making the state of dynamic equilibrium more difficult to achieve. A river management practice or land use decision that works against the physical processes of this balance will undoubtedly be a continuing source of conflict.

Figure 8: Lane's Balance (1955).



The analysis of sediment regime departure is a useful method for understanding the context of stream disequilibrium and channel evolution. The VT ANR River Corridor Planning Guide (2007) has developed a methodology for understanding reference and existing sediment regime types. Sediment regimes are summarized below in Table 4.

Table 4: A Summary of Sediment Regimes (VT ANR, 2007)

Sediment Regime	Narrative Description
Transport	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or natural entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.

Unconfined Source and Transport	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
Fine Source and Transport & Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) & Fine Deposition	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is un-confined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produced as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); storage of fine sediment as a result of flood-plain access for high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V of channel evolution.

Figure 9 displays the reference sediment regime type, which is largely determined by valley confinement and slope. All reaches assessed in Phase 2 were determined to be C-type streams in Phase 1. C-type streams are typically in a broader valley and have adequate access to their floodplains. The reference sediment regime for all the assessed reaches on the East Branch was Coarse Equilibrium and Fine Deposition (CEFD). The reference CEFD regime generally means the stream is transporting and depositing sediment in equilibrium. Figure 10 shows the existing sediment regime assessed in Phase 2. There were a number of sediment regime departures on the East Branch. Upstream of the East Burke Dam and at the downstream end of the East Branch at the mouth, the stream departed to Fine Source and Transport and Coarse Deposition. This is a common departure on incised streams with low boundary resistance and poor access to their floodplains. In reference condition, the stream was able to store fine sediment on the floodplains, but due to channel bed degradation, an excess of fine sediment is transported and large depositional bars form within the channel.

The segment immediately downstream of the East Burke dam has departed to a transport regime that features no depositional features and supplies little to no sediment downstream. This lends itself to the departure we see immediately downstream, Confined Source and Transport. This departure is consistent with streams impacted by upstream impoundments that are sediment starved and working to recapture sediment. It also related to varying levels of channel confinement as the stream follows the valley wall on its right and is at times flanked by Route 114 on its left. The stream alternates between CEFD and this departure before it reaches T102A, where it shifts to Fine Source and Transport. It is clear from this analysis that the East Burke Dam and dredging are the most significant stressors to the sediment regime on the East Branch.

Figure 10: Reference Sediment Regime

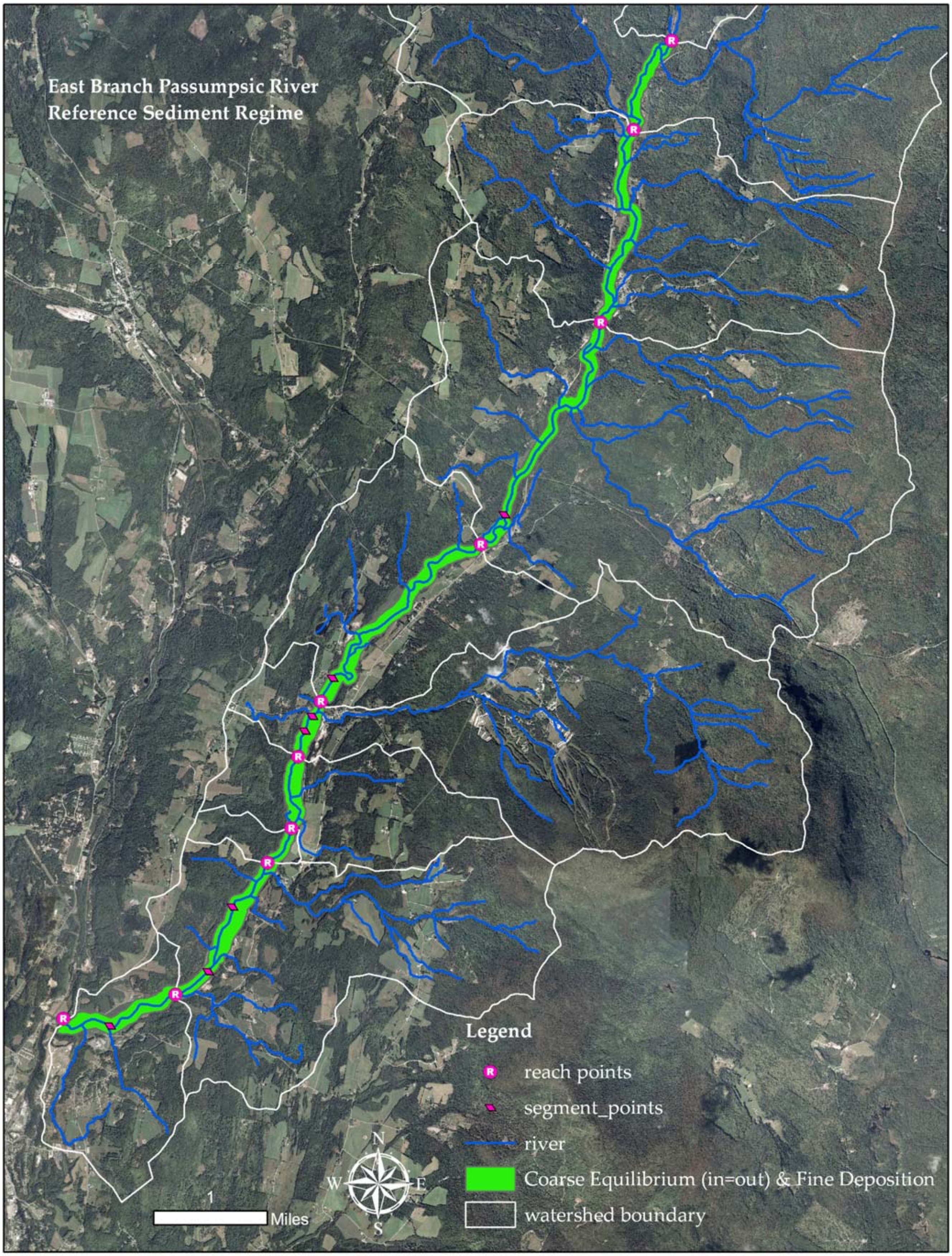
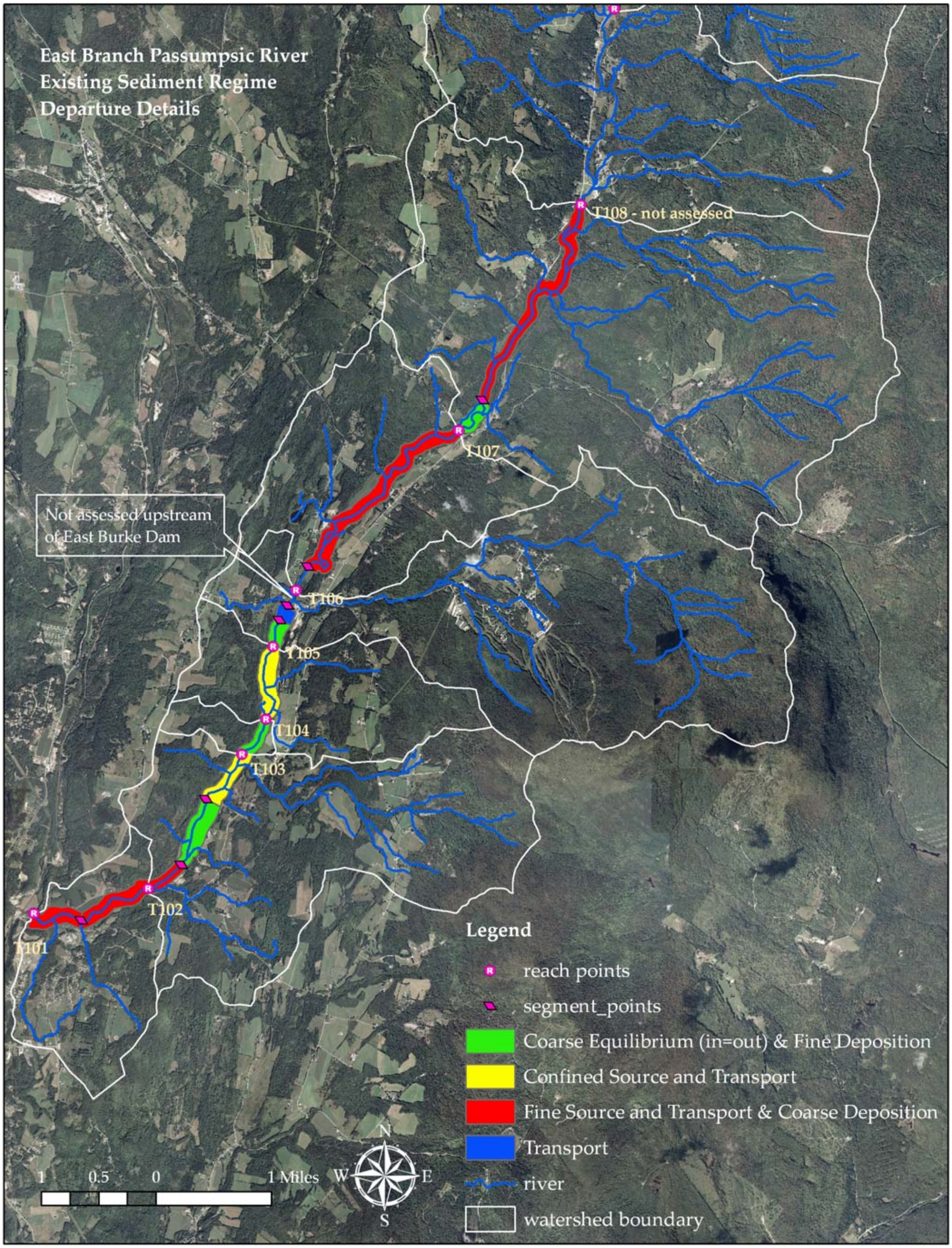


Figure 10: Existing Sediment Regime



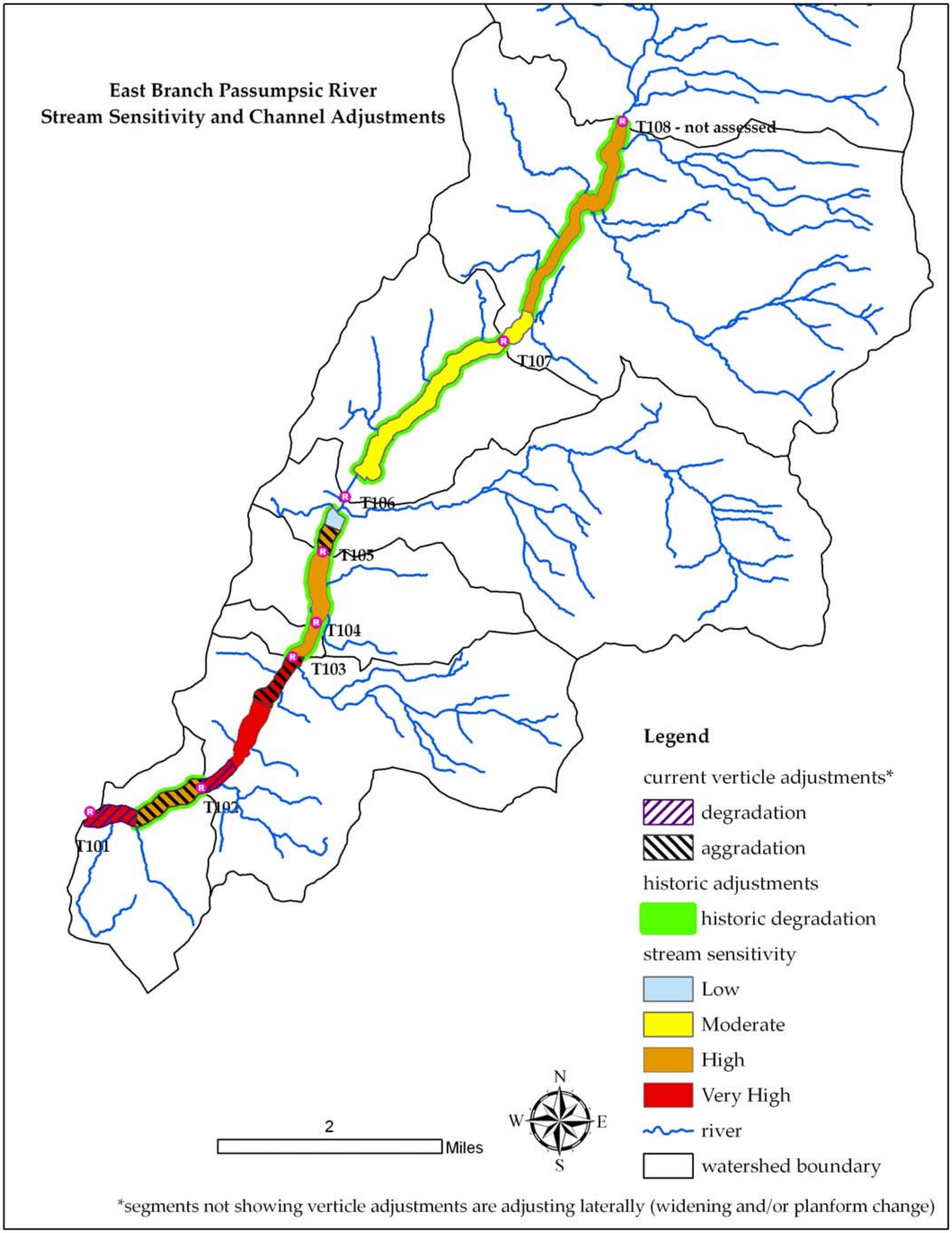
5.6 Stream Sensitivity Analysis

An examination of a stream's sensitivity provides a context to better understand a channel's adjustment processes and the ability of the channel to respond to changes. As explained by the VT Agency of Natural Resources Stream Geomorphic Assessment Protocols (VT ANR 2007):

> Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor. Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the setting characteristics that influence a stream's natural adjustment rate including boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive. (VT ANR Section 5.2)

Figure 11 maps the sensitivity ratings for each reach on the East Branch, and additionally shows current and historic channel adjustments. Downstream of the East Burke Dam, the East Branch varies from high to very highly sensitive, meaning that it is in a rapid state of change and is very responsive to stressors and changes in the stream channel**.** All various forms of channel adjustments are noted, largely due to shifts in confinement and land use along the East Branch, as well as its recovery from the flood of 2002. Upstream of the dam, T106 is noted as having moderate sensitivity and T107 with high sensitivity. Current adjustments on both of these reaches are lateral rather than vertical, and both are noted as having historic incision.

Figure 11: Stream Sensitivity



6.0 Preliminary Project Identification

A primary goal of stream geomorphic assessments is to inform management of streams towards equilibrium conditions. In the previous chapter, we examined the East Branch Passumpsic River, its departures from equilibrium and its sensitivity ratings to provide a context by which we can then select priority projects that will produce the greatest benefits to the stream channel. The following chapter indentifies preliminary projects on a reach by reach basis. Projects are prioritized and it should be noted that social constraints have not been considered as limiting factors for any project. "Left bank" and "right bank" descriptions are referenced looking downstream.

6.1 Reach T101: Mouth to downstream of Burrington Bridge Road

Reach T101 is 6498' in length and was classified in Phase 1 as a C-type stream with a riffle pool bed form. The reach was divided into two segments due to differing channel dimensions and entrenchment ratios. The downstream segment T101A extends 2662' from the mouth to upstream of the Lily Pond Bridge where a tributary enters the stream. The reference riffle pool bed form is now plane bed, and the stream is characterized by featureless gravel bed with low gradient. The segment was recorded as a C-type stream, however one cross section did key to a B-type and it is noted that parts of the segment were more entrenched. The incision ratio was recorded at 1.6 and an entrenchment ratio of 2.67. Banks are steep and high, and the stream has poor access to its floodplain throughout the segment even with the C-type stream classification. Vegetation is visible on banks, but upon closer examination there was quite a bit of bare soil evident beneath the plants. Straightening and dredging is evident throughout the segment. Land use along the segment ranges from new buffers that were planted along the left bank following the flood, a recreational ball field, corn field and other mixed vegetation. Two bridges are recorded and both are channel constrictions. Flooding and erosion was significant on this reach during the 2002 flood. It was noted that the channel is in stage II channel evolution, incised with only a few depositional features (considered late stage II).

Other characteristics of T101A include:

- Non-cohesive bank material
- Right bank dominant buffer is 0-25'
- Left bank dominant buffer is >100
- Geomorphic condition is Fair
- Stream sensitivity is Very High
- Habitat condition is Fair

Figure 12: Photo taken in 2003, one year after flood, looking downstream towards Lily Pond Bridge on Reach T101A.Bridge is a channel constriction, showing sediment accumulations upstream, and was an area of conflict during flood.

Reach T101B is 3836' long and extends from the tributary upstream of Lily Pond Bridge to just downstream of Burrington Bridge Road. The segment has a recorded stream-type departure from a C-type stream to a more entrenched F-type stream. This segment was significantly impacted by the 2002 flood and the channel bed was deeply scoured by flood flows. The segment was first assessed in 2003, then again in 2006 and 2008, and it was noted that there was an increase in depositional features, providing some evidence that aggradation is occurring and the channel is beginning to widen. The incision ratio for the segment was recorded at 1.7, and with high banks the stream has very poor access to the floodplain. Along the right bank is a large agricultural field with little vegetated buffer. There is a new residence and business built after the flood along the right bank that is an area of conflict and could be impacted by flood erosion hazards. The left bank corridor is occupied by a residential area along Deer Run Lane, and buffers were planted here in 2005. New development along the left bank has also occurred since the flood including mowing and other activities very close to the stream. New bank armoring was placed here. A hayfield along the left bank has an existing buffer, which was also enhanced during the 2005 buffer plantings.

Figure13: Right bank of Reach T101B showing streamside residence and business that could be impacted by fluvial erosion hazards. Tall eroding banks also observed showing poor access to floodplain.

Figure 14: Reach T101B looking upstream showing new bank armoring protecting residential activities along left bank. Some new bar development on opposite bank

Other characteristics of T101B include:

- Evidence of dredging
- Gravel dominated substrate
- Bankfull width 116'
- Non-cohesive bank materials
- Two stormwater inputs
- Two steep riffles and seven depositional bars
- Riffle pool bed form
- Geomorphic condition is Fair
- Stream sensitivity is High
- Habitat condition is Fair

When considering the entire reach for project identification and development, an important factor is the lack of floodplain access. This is particularly concerning considering the problem flooding downstream at the confluence with the Miller's Run. Floodwater storage along the East Branch is critical to attenuating flooding downstream. Reach T101 is a C-type stream by reference, featuring a wide open valley and several undeveloped agricultural fields. Restoring floodplain access and allowing the reach to return to equilibrium would provide critical benefits for the upper Passumpsic watershed.

Table 5: Preliminary Project Identification Reach T101

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T101A	Restore Floodplain	Moderate	Moderate	No	Exploration of floodplain restoration potential on recreational field along left bank and agricultural field along right bank.
T101B		Very High	Very High	No	Floodplain excavation along any of the three large agricultural fields would provide critical floodwater storage and flood attenuation assets. Land use would need to change temporarily but could be restored.
T101	Protect River Corridor	Very High	High		Allowing this reach to return to equilibrium conditions is important for both flood and sediment attenuation. Recommend a consideration of corridor protection through easements for all available undeveloped land in river corridor.
	Replace Bridge Structure	High	Moderate	Yes	Lily Pond bridge was problematic during 2002 flood and remains an area of conflict due to being undersized. Replacement with larger structure should be considered.
	Install/Enhance Buffers	High	Moderate	Yes	Buffers should continue to be installed and enhanced to help protect corridor and provide stability and habitat
	Examine conflict at residence/auto business	High	Low	Yes	Area should be monitored closely and landowner made aware of potential erosion hazards.

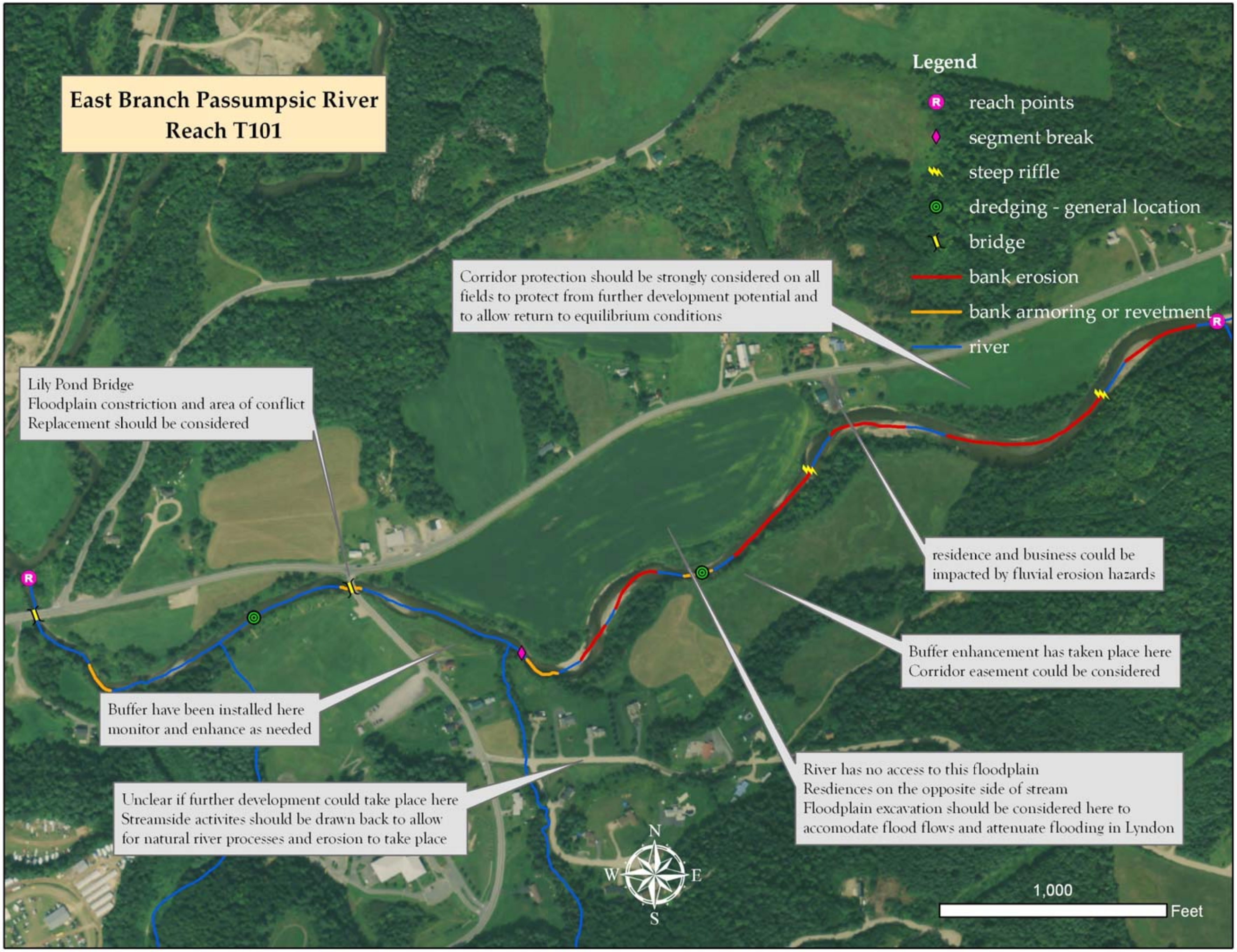


Figure 15: Preliminary Project Details Reach T101

6.2 Reach T102 – Downstream of Burrington Bridge Rd to near junction of Mount Hunger/Rte 114

This reach extends for 8084' and was divided into three segments. Each segment is reviewed separately in order to address specific issues. The downstream segment T102A is situated around Burrington Bridge Road and is 1898' long. There are two bridges on this segment, one on Burrington Bridge road, and the other is a retired covered bridge that sits just upstream. Both bridges are channel constrictions. There is a gravel pit that extends for most of the left bank corridor, upstream from the bridges. The right bank corridor, also on the upstream end, is a conserved piece of land owned by the Passumpsic Valley Land Trust (PVLT). The PVLT also holds a conservation easement along the downstream end of the segment along the left bank, where a logging road was retired in 2005, which also extends into the downstream segment as well. This segment was impacted by the 2002 flood which heavily scoured the stream bed. Dredging along this segment is evident as well.

Figure 16: View looking upstream beneath Burrington Bridge (in background) and the covered bridge on Reach T102A taken in 2003. Channel degradation evident with reinforcements necessary beneath original footings. Stream level was formerly at base of concrete footing.

Figure 17: View looking downstream beneath Burrington Bridge covered bridge in background on Reach T102A taken in 2009. New footing on covered bridge and additional rock placed under Burrington Bridge.

While the entire reach was classified as a C-type stream in Phase 1, this segment has departed to an F-type stream with an incision ratio of 1.96. In reference condition the river would have access to its broad valley in flood conditions, but this segment currently has an entrenchment ratio of 1.14. T101A is slightly more naturally confined that the rest of the reach, however. In Stage II channel evolution, channel degradation is the current adjustment pattern taking place. Under flood conditions, floodwaters would be confined to the channel creating continued intense stream power, erosion hazards, channel degradation and increased water volume delivered downstream and to Lyndon. There is a conserved parcel along the right bank upstream of the bridges, and a gravel pit operation along the left corridor. The gravel pit and the stream are separated by a 30' tall stream bank that drops down approximately 10' to the gravel pit.

Other characteristics of T102A include:

- Gravel dominated substrate, with cobble and boulder mixture
- Some existing buffer throughout the segment, though narrow in locations
- One point bar and two side bars recorded

- Geomorphic condition is Poor
- Habitat condition is Fair
- Stream Sensitivity is Very High

Table 6: Preliminary Project Identification Reach T102A

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T102A	Protect River Corridor	High	High	Yes	Recommend a consideration of corridor protection through easements for all available undeveloped land in river corridor.
T102A	Examine Bridge Structures	Moderate	Moderate	Yes	Some recent work was completed on the bridge footings however both structures are still channel constrictions and causing channel bed scour. Bridges impact should be examined and replacement considered.
T102A	Restore floodplain access	Low	Low		Explore excavation along right bank to lower elevation of floodplain and help restore floodwater storage. Natural confinement may be prohibitive.
T102A	Restore floodplain access	Low	Low	Yes	Explore potential of excavation between gravel pit and stream which may offer additional floodwater storage by terracing. Gravel operation could potentially benefit from additional material in exchange for corridor protection.

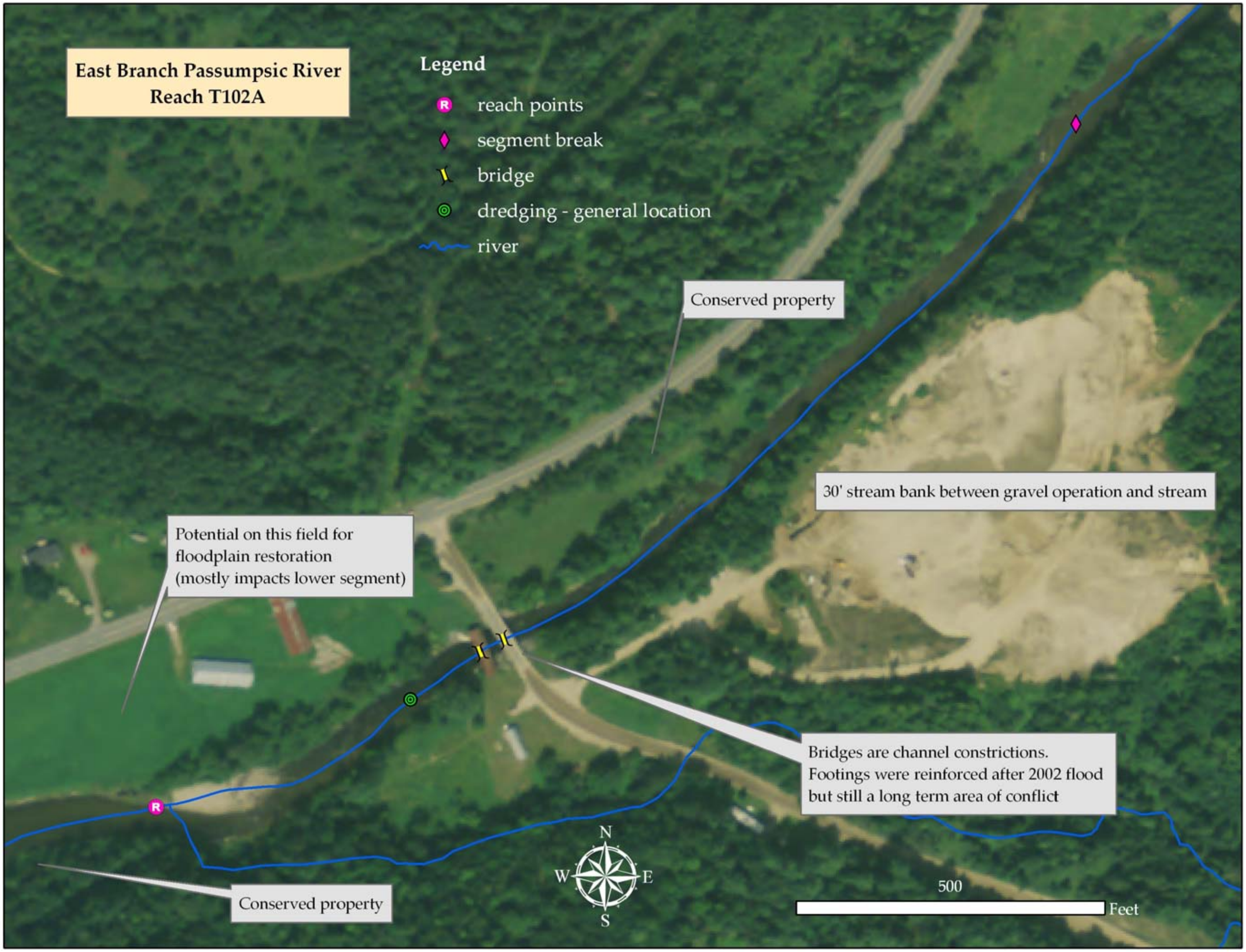


Figure 18: Preliminary Project Details Reach T102A

Reach T102B extends for 3343’ from the downstream end of Riverside Life Enrichment Center’s fields to the upstream end of a 12’ acre cornfield. This segment keyed out to a C-type stream with gravel dominated substrate. The entrenchment ratio is 2.4 and the incision ratio is 1.2 though there were sections noted with very high eroding banks and pockets of greater incision and B-type stream features. The segment shows evidence of widening, bar development and planform change. Dredging and straightening are noted on this segment as well. Land use features a large 12-acre cornfield on the upstream end of the segment along the left bank, with the valley wall on the right. The stream passes under Rte 114 and then between a sparsely populated residential area on the left bank and the Riverside Center (a facility for the elderly) on the right. There are no buffers along the cornfield or the residential area and facility. The valley wall is the only vegetated area. The Center facility is in an area of conflict, as there is little space for the river to adjust. Evidence of dredging and straightening is noted. This segment is in stage III of channel evolution, aggrading and widening to build new floodplain.

Figure 19: Mass failure on Reach T102B

Figure 20: Looking upstream towards Route 114 Bridge on Reach T102B, Riverside Center on left. Sediment deposits and channel widening evident.

Other characteristics of Reach T102B include:

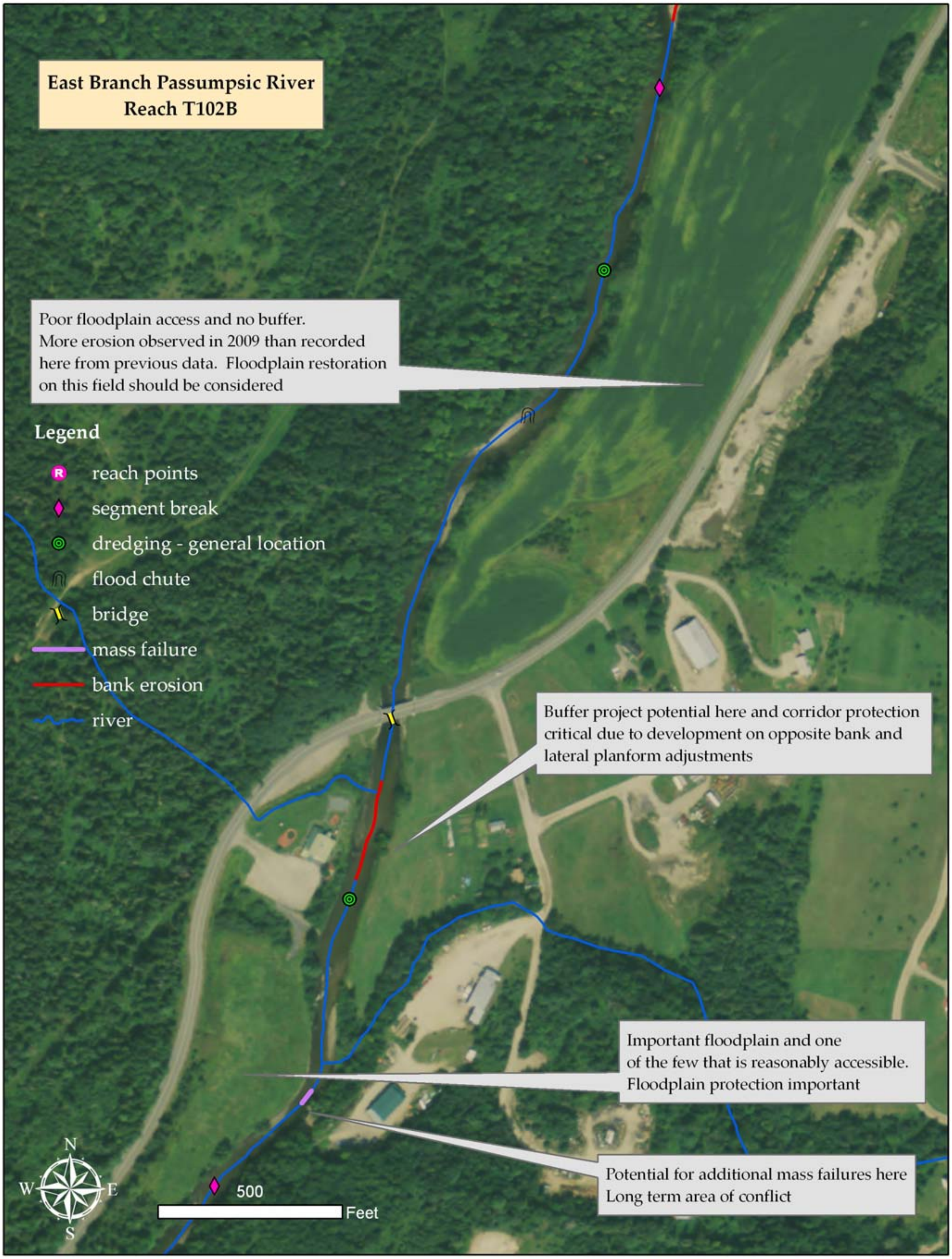
- Geomorphic condition is Fair
- There are 9 depositional features noted
- Habitat condition is Fair
- Stream Sensitivity is Very High
- Road encroachment in corridor throughout segment

Figure 21: Looking upstream towards Route 114 Bridge on Reach T102B, Riverside Center on left. Sediment deposits and channel widening evident.

Table 7: Preliminary Project Identification Reach T102B

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T102B	Protect River Corridor	High	High	Yes	Recommend a consideration of corridor protection through easements for all available undeveloped land in river corridor. River is adjusting and widening and it should be allowed to continue its natural processes. Riverside Life Center lower field very important floodplain.
T102B	Install buffers	High	Moderate	Yes	Eroding and unbuffered banks could be improved through installation of vegetated buffers.
T102B	Examine Bridge Structures	Moderate	Moderate	Yes	Some recent work was completed on the bridge footings however both structures are still channel constrictions and causing channel bed scour. Bridges impact should be examined and replacement considered.
T102B	Examine conflict at facility	Moderate	Low	Yes	Channel adjustments could impact land use at Riverside Enrichment Center. Bank erosion has subsided since 2003, but adjustments could occur at any time.

Figure 22: Preliminary Project Details Reach T102B



Reach T102C is 2843' long and begins at the upstream end of the 12-acre cornfield and extends to the reach break near the junction of Mount Hunger Road and Route 114. This reach was segmented due to having a greater level of depositional features and residential land use. The segment is flanked by the valley wall on the right bank, and the left corridor is occupied by 4-5 residences that sit between the river and Route 114. The river frontage is an integral part of the residential properties. A large amount of coarse sediment was deposited here during the 2002 flood and the river has been adjusting. Planform changes have been active historically in the segment as observed from historic photos where old channel and flood chutes are observed. Landowner interviews conducted on this segment also concur that the river has made planform changes since 2002 and some properties are experiencing enlargement of point bars, while others are experiencing more erosion. The segment keyed out to a C-type stream with gravel dominated substrate and a bed form of planed bed. The incision ratio on the segment is recorded at 1.3 and the entrenchment ratio is 2.2. The segment had some areas with entrenchment ratios similar to a B-type stream, however there are small but consistent pockets of floodplain along the valley wall. One of the landowners along the left bank built a berm after the 2002 flood with the available coarse materials deposited there. There is still potential for erosion hazards in the event of high water. The stream is in stage III channel evolution, with aggradation and widening noted as the current adjustments. The river will continue to make adjustments as it works through the excess sediment and tries to recapture floodplain. The cornfield at the downstream end of the segment has no buffer and is a high bank with erosion occurring.

Figure 23: Looking upstream at berm on Reach T102C in 2003, one year after flood.

Figure 24: Looking downstream on the same berm in 2008. Floodplain is building.

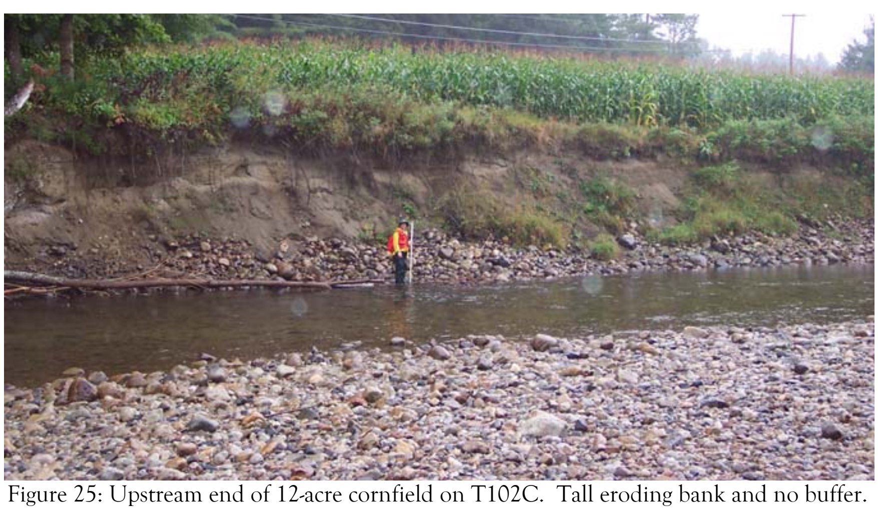


Figure 25: Upstream end of 12-acre cornfield on T102C. Tall eroding bank and no buffer. The majority of this large agricultural field is in Reach T102B

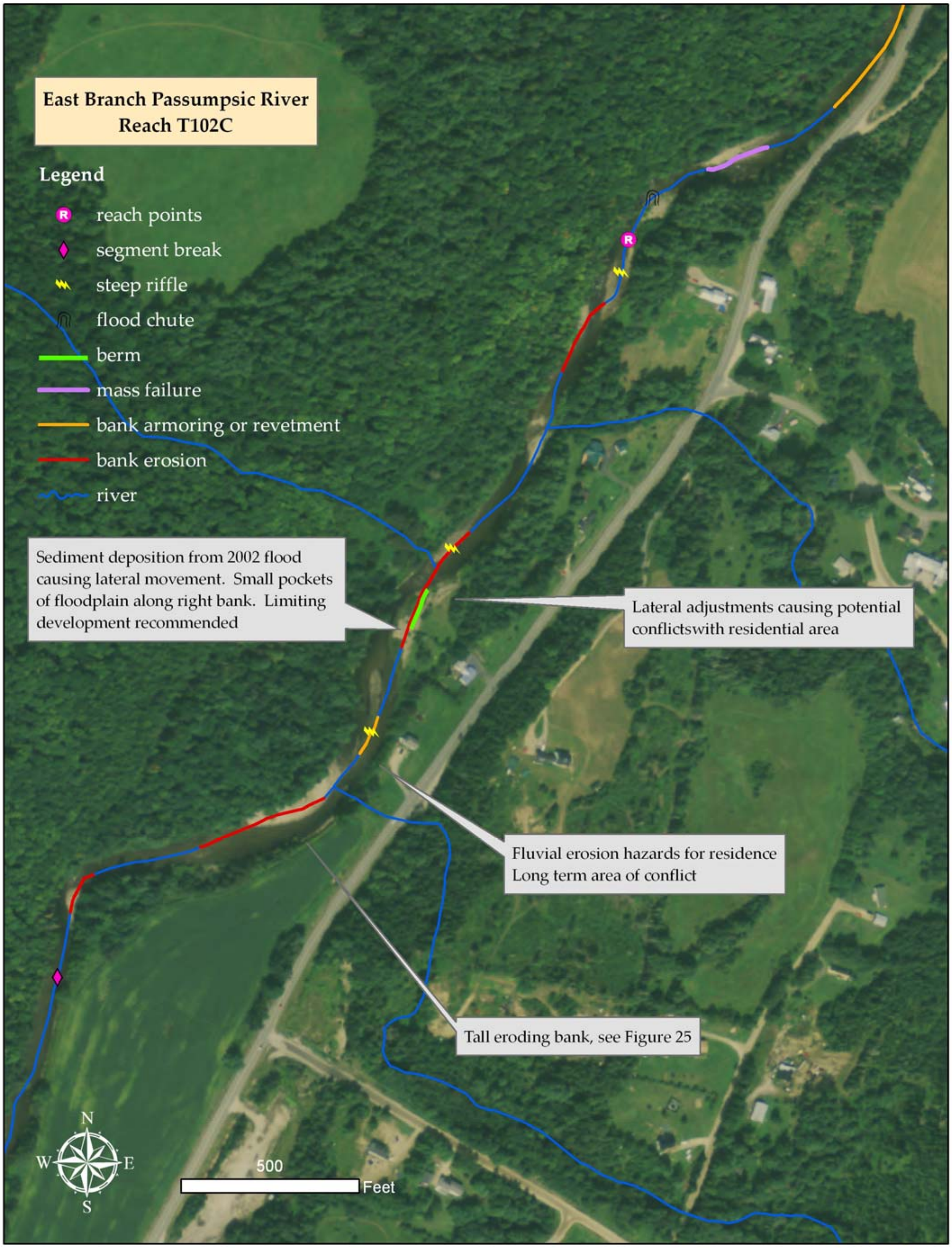
Other characteristics of T102C include:

- Geomorphic condition is Fair
- Stream sensitivity is Very High
- Habitat Condition is Fair
- Twelve depositional bars recorded
- Three steep riffles recorded
- Dominant buffer width right bank >100
- Dominant buffer width left bank 26-50', 0-25' subdominant
- Silt/clay present
- Wide channel width 132'
- Road encroachment in left bank corridor

Table 8: Preliminary Project Identification Reach T102C

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T102C	Protect River Corridor	High	Moderate	Yes	Residences along left bank corridor are dependent on small pockets of floodplain along right bank and valley wall. Segment is undergoing a great deal of adjustment. Erosion and trees/debris adding to adjustment. Further development should be prohibited.
T102C	Landowner Outreach	High	Moderate	Yes	Recommend continued outreach to landowners so they're made aware of potential conflicts.
T102C	Install buffers	Moderate	Moderate	Yes	Opportunity for buffer on 12-acre corn field.
T102C	Examine areas of conflict	Moderate	Moderate	Yes	Fluvial erosion hazards are evident at lower residence. House was built on same location where former house fell into stream. Area should be monitored very closely.

Figure 26: Preliminary Project Details Reach T102C



6.3 Reach T103: Reach along Rte 114 just north of Mount Hunger Road Junction

Reach T103 extends for 2086' and is flanked on its entire left bank corridor by Route 114. It pulls away from the road slightly towards the downstream end of the segment, where there is a mass failure and an old vehicle within the bank. The right bank is flanked by the valley wall with small pockets of floodplain at its base. There is evidence of straightening and dredging on this reach. The reach keys out to a C subclass b type stream with gravel dominated substrate and riffle pool bed form. While the reach seems confined and locked against the valley wall by the road, there is enough room largely due to the small floodplain pockets along the right bank for planform movement to occur. There are some recent deposits along the reach, likely from the 2002 flood, but it was determined that the reach is in an early stage II of channel evolution with an incision ratio of 1.1 and an entrenchment ratio of 2.7. Channel degradation that was observed was historic.

Other characteristics of Reach T103 include:

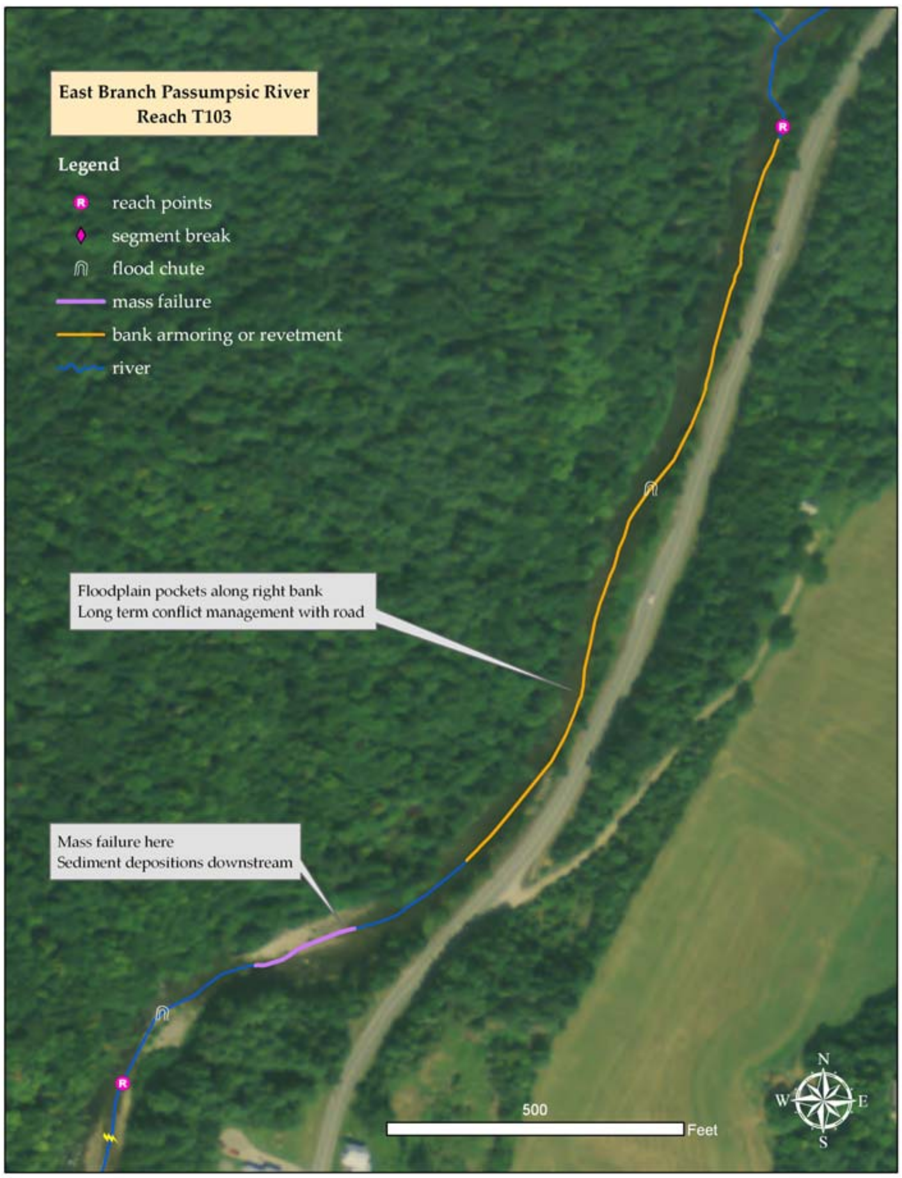
- Dominant buffer width on right bank is >100
- Dominant buffer width on left bank is 26-50'
- Geomorphic condition is Good
- Stream sensitivity is High
- Habitat condition is Fair
- Non-cohesive bank materials

Figure 27: Reach T103 with Route 114 on left, mass failure downstream and floodplain pockets along right bank, photo taken in 2003 one year after flood

Table 9: Preliminary Project Identification Reach T103

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T103	Protect River Corridor	Moderate	Moderate	Yes	Floodplains along right bank should be protected to provide flood and sediment attenuation assets, particularly since this reach is upstream from a residential area
T103	Long term road management	Moderate	Low	Yes	Long term road conflict management will be necessary

Figure 28: Preliminary Project Details Reach T103



6.4 Reach T104: Section of stream transitioning from Lyndon to Burke, pulls west away from Rte 114

This reach is 3838' long and is a C-type stream with gravel dominated substrate. There was an avulsion at the upstream end of the reach that created an island. The old channel is still accessed by the stream. There is a small amount of residential development in the left corridor along Route 114. This is the first significant area downstream of the dam where sediment attenuation occurs. The upstream segment is largely deprived of sediment due to the impoundment in East Burke. Aggradation and widening are the current adjustments on this reach, and the reach is noted as being in Stage III channel evolution. The field along the left bank on the upstream end of the reach is conserved by PVLT, and a recent buffer was planted there in 2008-2009. There are two flood chutes recorded on the reach and several depositional features. The incision ratio is recorded at 1.36 with an entrenchment ratio of 3.42, which allows for reasonable floodplain access throughout the reach. Buffer widths are adequate, recorded as 26-50' wide along the left bank and >100' along the right.

Figure 29: Reach T104 showing some bar formation

Other characteristics of T104 include:

- Channel width of 105'
- Road encroachment in left corridor for 1393'
- Non-cohesive bank materials
- Geomorphic condition is Good
- Stream sensitivity is High
- Habitat Condition is Good

Table 10: Preliminary Project Identification Reach T104

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T104	Protect River Corridor	High	Moderate	Yes	Long term potential of development pressures which could compromise the ability of the river to adjust along the left bank. Sediment attenuation assets on this reach.
T104	Long term road management	Moderate	Low	Yes	Long term road conflict management will be necessary

Figure 30: Preliminary Project Identification Reach T104

6.5 Reach T105: Near Burke town line to upstream of East Burke Dam

Reach T105 was divided into three segments. The upstream segment (T105C) was not assessed due to the East Burke Dam impoundment. Dishmill Brook enters the East Branch just upstream of the dam and assessment of the first reach of Dishmill Brook is included in the analysis of Reach T105. The two segments downstream of the dam were examined separately due primarily to a depositional features and substrate size change, as a bedrock dominated substrate was observed just downstream of the dam, which then changed to a more mixed substrate in T105A. Reach T105A is 1286' long and keyed out to a C-type stream with cobble dominated substrate and a riffle pool bed form. The segment is dramatically wider and showing more erosion and sediment accumulation than the upstream segment. This is largely due to the impoundment which is depriving the upstream segment of sediment and necessitating a reliance on bank erosion to recapture sediment. The valley is semi-confined and the stream classification bordered on a B-type stream, as the entrenchment ratio was 2.29. There was no incision recorded however the segment was determined to be in stage III, with recent sediment deposits observed that seem to have quickly created new floodplain. The upstream segment is deprived of sediment due to the impoundment. The right bank is the valley wall, with small forested floodplains that are providing both sediment and woody debris to this segment. Developments along the left bank corridor (businesses and homes) are reducing the ability of the river to adjust away from the valley wall.

Other characteristics of T105A include:

- Road encroachment for 1248'
- Bankfull width of 90'
- Sedimented riffles
- Geomorphic condition of Fair
- Stream Sensitivity is High
- Habitat Condition is Good

Figure 31: Reach T105A showing bank erosion supplying coarse sediment to segment and channel widening.
First depositional features downstream of East Burke Dam.

Figure 32: Reach T105A showing additional depositional features and bifurcated flow

Reach T105B is just downstream of the East Burke Dam and extends for a short 812'. Typically a reach would not be segmented to this small of a scale but there was a significant change in substrate and bed form. This segment represents the length of the stream downstream of the dam which is often described as "hungry water", or deprived of sediment. Fine and coarse sediments are at a minimum on this segment, with 89% of the channel substrate recorded as bedrock, and only 4% as coarse gravel or smaller (<2.5 inches). The entire reach including upstream and downstream of the dam was classified as a C-type stream in reference condition. This segment, however, was classified as a sub-reach, a b-type stream in reference form due to short natural confinement. In reference form (without the influence of the impoundment), we would likely see a greater mix of substrate and cobble or gravel dominated substrate. The segment's cascade bed form and fast moving water is also characteristic of hungry water, as the sediment that would otherwise be occupying the channel and dispersing the energy of the stream is absent. In addition, there is a great deal of exposed bedrock within the channel, as the sediment deprivation has confined flows to the lower elevations of bedrock within the channel. The right bank is made up of bedrock with the valley wall behind it, and the left bank is a mixture of non-cohesive gravel, sand and soil. The left bank floodplain is largely occupied by an auto business and there are disposed car parts along the bank and corridor. The incision ratio on this segment was recorded at 1.2, with an entrenchment of 2.09. There are no depositional features and it was determined that the stream is in stage II of channel evolution.

Other characteristics of T105B include:

- Geomorphic condition is Good
- Stream sensitivity is Low
- Habitat condition is Fair
- Two stormwater inputs at bridge
- Bridge is 42' wide and channel constriction
- Bankfull width is 75'

Figure 33: Looking downstream on Reach T105B. Segment is deprived of sediment due to upstream impoundment

Table 11: Preliminary Project Identification Reach T105A and T105B

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T105 A & B	Dam removal	High	Moderate	Yes	Dam removal would restore sediment continuity downstream and reduce reliance on bank erosion to capture material. Dam removal would also provide habitat connectivity.
T105 A & B	Protect River Corridor	High	Moderate	Yes	Development pressures along left bank could reduce river's ability to adjust away from valley wall and access floodplain. Corridor protection should be considered to allow stream to recapture equilibrium.
T105B	Replace Bridge	Moderate	Moderate	Yes	Bridge structure is undersized and a channel constriction. Replacement should be considered.
T105 A&B	Address Invasive Species	Moderate	Moderate	Yes	Three separate invasive plants are noted in this area with high concentrations of honeysuckle and knotweed. Invasive plant removal should be considered as the plants will continue to spread downstream.

Figure 34: Preliminary Project Details Reach T105A and T105B:

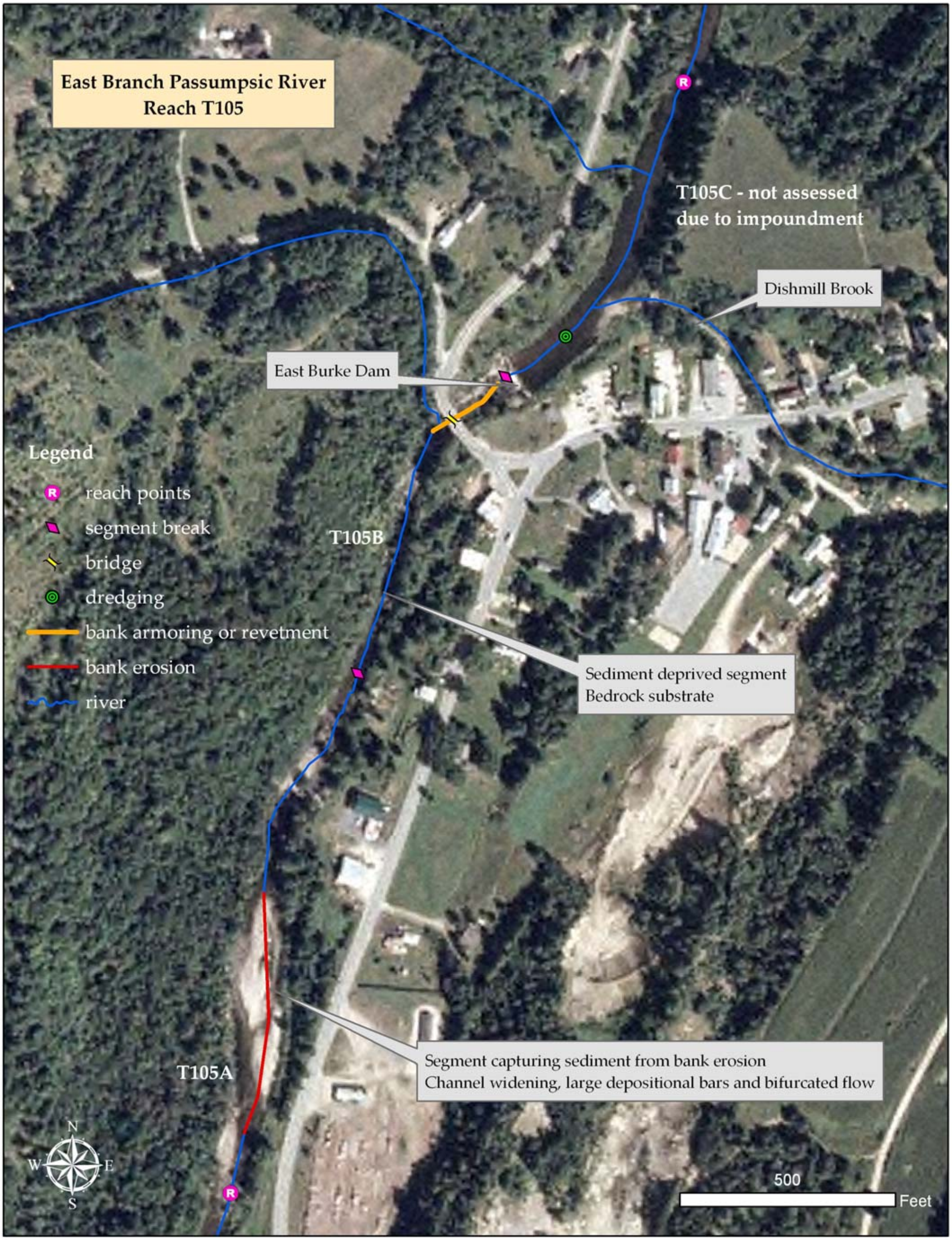


Figure 35: Reach T105 East Burke Dam and mouth of Dishmill Brook

6.6 Dishmill Brook Reach M101A and M101B

Dishmill Brook enters the East Branch Passumpsic River just upstream of the East Burke Dam. A geomorphic assessment was performed on Dishmill Brook in order to provide a broader context for the discussion of East Branch Reach T105. A Phase 2 assessment was conducted on the first reach of Dishmill Brook, which extends from the mouth for 1900'. The reach was divided into two segments that are examined separately below.

Reach M101A: Mouth to upstream of Route 114 bridge in East Burke

Reach M101A is 888' long and begins at a segment break upstream of the Route 114 bridge in East Burke village, and flows behind East Burke Market and into the East Branch Passumpsic River. The segment is flanked on both sides by development. There is a berm on both sides of the river for 326' downstream of the bridge, and another upstream of the bridge extending for 334' along the left bank. The stream was a C-type stream by reference but has departed to an F-type stream with gravel dominated substrate. The departure is largely due to East Burke village encroachments that have necessitated berming, straightening and dredging over time. The stream is entrenched with an entrenchment ratio of 1.23, and an incision ratio of 1.23 that is considered historic. Historic incision is paired with the current adjustment pattern of aggradation, in part due to the East Burke dam acting as a grade control and causing sediment to back up on the East Branch and Dishmill Brook.

This segment of Dishmill Brook has a dominant 0-25' foot buffer width, with some small pockets of vegetation along the right bank. The bank vegetation observed is made up primarily of invasive plants such as Japanese Knotweed and honeysuckle. Land use in the riparian corridor is primarily commercial or residential, though some small floodplain pockets were observed and one cross section did barely key out to a C-type stream, though was not the most representative of the segment. The segment is considered to be in stage II channel evolution. The stream sensitivity is noted as extreme, meaning it is extremely responsive to channel adjustments. Both the geomorphic and habitat conditions of this segment are recorded as Fair.

There are two bridges on this segment. The downstream bridge near the mouth of the river is 54' wide and has limited access, primarily for bikers, snowmobiles and foot traffic. With the bankfull width of the stream at 42', this bridge is not acting as a channel constriction. The upstream bridge on Route 114 in East Burke village is nearly half the width of bankfull, recorded at 22' wide. This bridge is a clear area of conflict with the stream and is showing all the common signs of being significantly undersized including deposition upstream of the bridge, channel scour below, and alignment problems. This bridge was jammed with ice and debris in 2008 that caused widespread flooding and ice flow in East Burke village.

Reach M101B: Upstream of East Burke village

This reach is 1012' long and runs behind the residential area along Route 114 north of East Burke village. The segment keyed out to a C-type stream with a step-pool bed form. Gravel was the dominant substrate though a significant amount of cobble-sized substrate was observed and makes up 37% of the bed material. This segment is steeper than the downstream segment and is afforded a larger buffer, with >100' along the left bank and 26-50' on the right. This segment is not entrenched, with an entrenchment ratio of 7.5, and no incision was recorded. This segment is in Stage I channel evolution and is considered stable.

Table: 12: Preliminary Project Identification Reach M101 Dishmill Brook

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
M101A	Assess floodplains	High	Moderate	Yes	Explore potential of securing floodplain access in small pockets to provide opportunity for sediment and flood attenuation.
M101A	Dam Removal on East Branch	Moderate	High	Yes	Removal would help restore sediment continuity and provide some protection from flooding. Since this segment is incising due to village encroachments, removing a grade control at the downstream end could lead to headcutting and tributary rejuvenation. These potential impacts will need to be weighed out and addressed in the removal scenario
M101A	Replace Bridge	Very High	Moderate	Yes	Bridge structure is significantly undersized and a channel constriction. Replacement is strongly considered considering the adjacent investments in East Burke

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
M101A	Address Invasive Species	Moderate	Moderate	Yes	Three invasive plants are noted in the area with high concentrations of honeysuckle and Japanese knotweed. Invasive plant removal should be considered as the plants will continue to spread downstream.

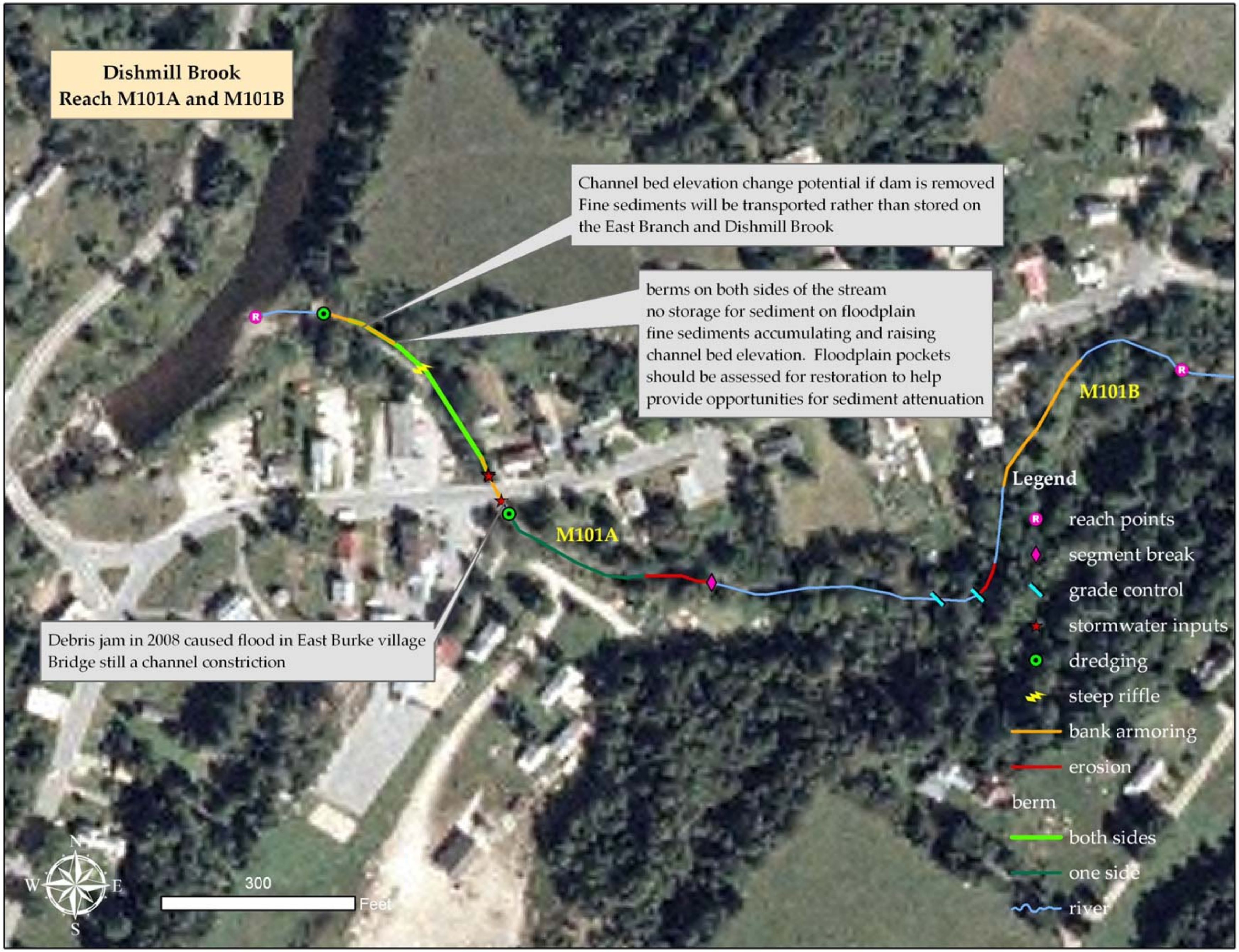
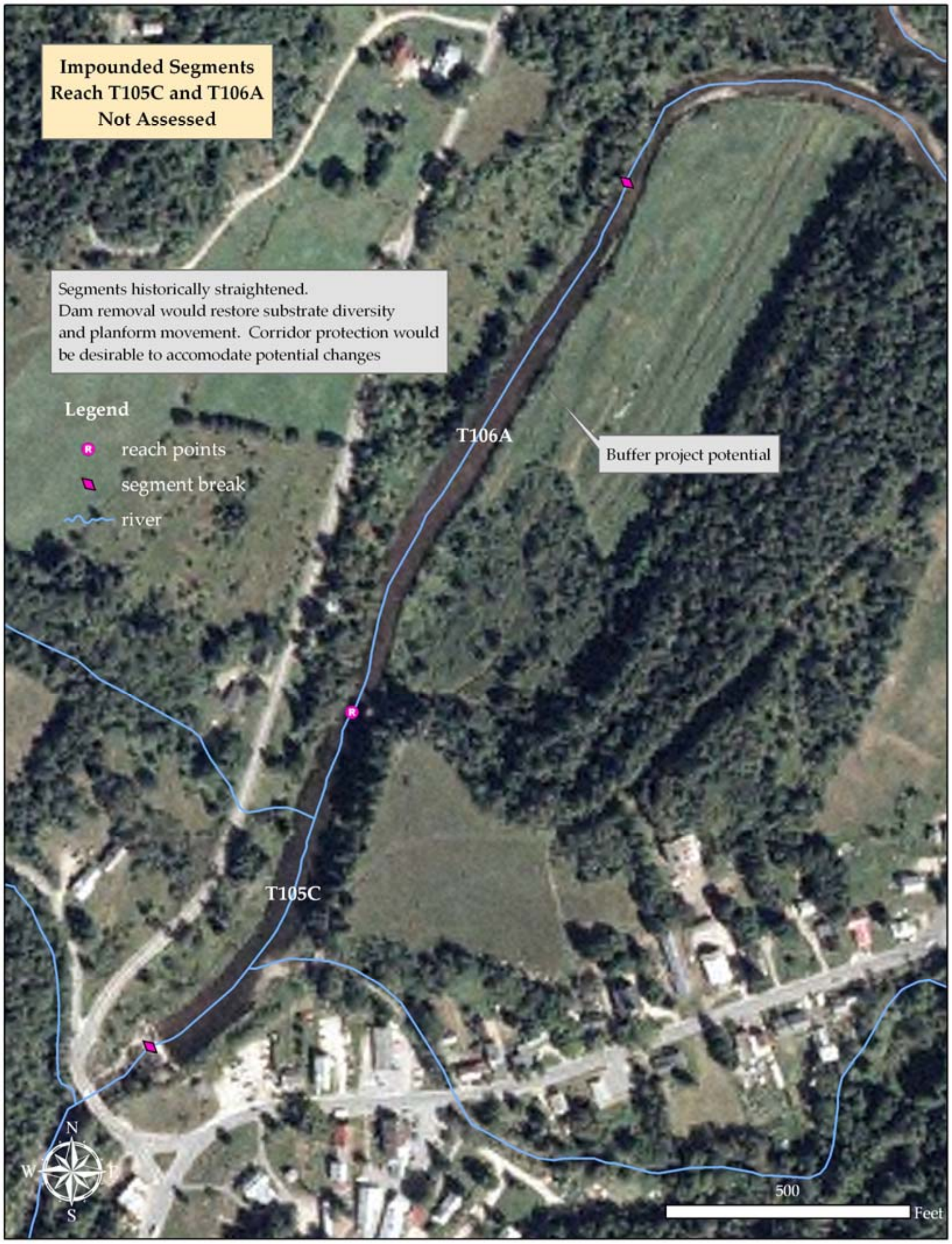


Figure 36: Preliminary Project Details Reach M101 Dishmill Brook

6.7 Reach T105C and T106A: Backwater from East Burke dam

Reach T105C extends for 823' and T106 for 1428'. Their combined length of 2051' represents the approximate length of stream that is impounded by the East Burke Dam, though the length will vary from year to year. Both of these segments were not assessed in Phase 2 due to the impacts of the impoundment. A map is provided of both segments to provide a context for geomorphic conditions upstream and downstream of the dam. Dam removal would help restore these two segments to equilibrium by allowing sediment transport to restore sediment continuity and diversity, as well as allow for planform movement. Corridor protection and buffer plantings are recommended.

Figure 37: Impounded segments upstream of East Burke Dam



6.8 Reach T106B: From end of East Burke dam backwater upstream to White School Road Bridge

T106B extends for 11,962' and flows through a wide valley north of East Burke village. Dominant land use surrounding this segment is forestland, with agriculture as sub-dominant. Route 114 follows along the left valley wall which leaves the majority of the valley open to the stream. The segment keyed out to a C-type stream with cobble dominated substrate and plane bed form. There were some riffles on the reach that were observed to be sedimented, with several depositional features including point bars and flood chutes. The Incision ratio was recorded as 1.4 at the selected cross section, although it was determined that the segment was still in Stage 1 channel evolution. A historic rock crib was observed on the segment that provided evidence of vertical stability. Planform changes are noted as the dominant current adjustment pattern, with some aggradation.

There are two large agricultural fields along the segment. The lower field along the left bank has a short tributary that was accessed by the stream at high flows at one point, and is now a deep gully through the field. Both fields would provide good opportunities for buffer plantings. A water withdrawal is located mid-segment used for snow-making on Burke Mountain.

At the upstream end of the segment, the White School bridge crosses the stream and is 72' wide, There is a 62' wide old abutment next to the bridge. Together these structures are acting as a constriction to the 67' wide channel and are showing associated deposition above and scour below.

Other characteristics of T106 include:

- Entrenchment ratio of 13
- Historic agricultural straightening evident, limited habitat on these sections
- Invasive plants present
- Geomorphic condition is Good
- Habitat condition is Good
- Natural grade controls present in two locations
- Two debris jams noted during 2006 assessment

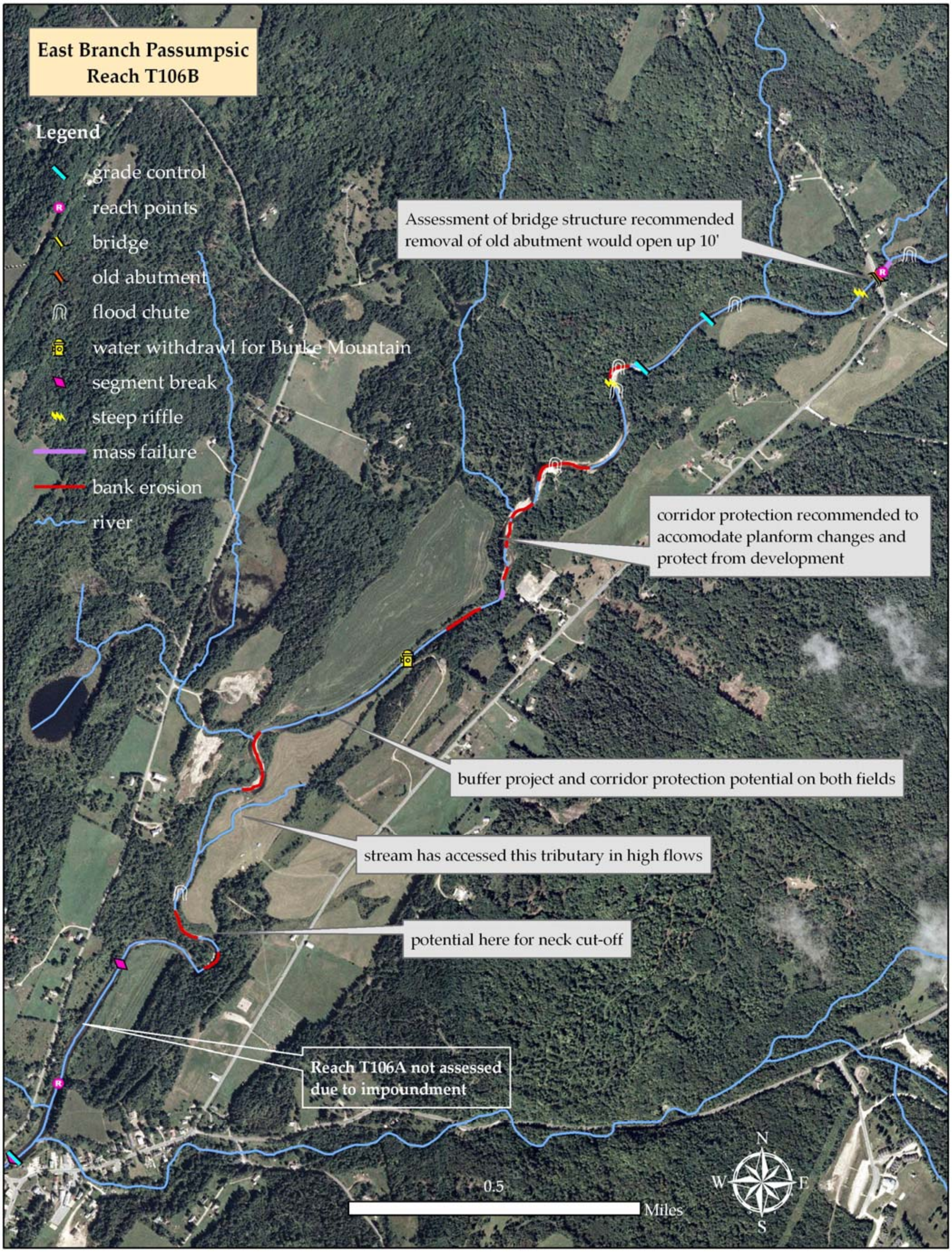
Figure 38: Reach T106B near agricultural fields

Figure 39: Reach T106B at water intake for Burke Mountain

Table 13: Preliminary Project Identification Reach T106B

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T106B	Protect River Corridor	Moderate	Moderate	Yes	Explore potential of protecting river corridor to help accommodate channel adjustments and protect from development pressure. Dam removal would increase priority for this
T106B	Install Buffers	Moderate	Moderate	Yes	Agricultural fields would benefits from the installation of a vegetative buffer. Reducing sediment into East Burke village would also provide a benefit
T106B	Remove old abutment, assess bridge structure	Moderate	Low	Yes	Old abutment is channel constriction and does not have a purpose. Removal would open up 10' to accommodate channel.
T106B	Address Invasive Species	Moderate	Low	Yes	Invasive plants should be addressed as they will continue to spread downstream

Figure 40: Preliminary Project Details Reach T106B



6.9 Reach T107: White School Road Bridge to near Burke/East Haven town line

Reach T107 was divided into two segments due to differences in sinuosity, bed form and substrate size. Reach T107A extends upstream of the White School Road Bridge for 2460'. The segment keyed out to a C-type stream with gravel dominated substrate and a riffle-pool bed form. The segment is in reference condition with a 1.1 incision ratio, adequate access to its floodplain and broad forested buffers. The stream banks are general stable throughout the segment except for a small amount of riprap protecting a house at the top of a bank, and one small mass failure. The stream is in stage I channel evolution and shows good habitat. A small amount aggradation is evident.

Reach T107B extends for 11,479' from the segment break to just near the Burke/East Haven town line. This segment features long forested sections and interaction with Route 114. The segment keyed out to a C-type stream with gravel dominated substrate and plane bed form. There is evidence of historic incision and historic widening with well established terraces on the one bank and new floodplain on the other. The segment is considered to be in Stage V channel evolution, and is generally stable with small pockets of disequilibrium associated with human investments.

There are two old abutments noted on the reach as well as two bridges. At the Route 114 crossing, the bridge is 90' and the old abutment immediately downstream is 35'. The bankfull width is 87'. The bridge has alignment problems and together with the abutment the structures are acting as a channel constriction. The upstream bridge on Worden Road is 40' wide. The bank armoring recorded near the Worden Road bridge was noted as riprap but it is likely the result of windrowing after a flood event, with dredging also evident. And additional old abutment upstream measures 33' wide. There is just over 2000' of bank armoring which is located primarily where the stream abuts Route 114 or surrounding bridge structures. A natural gas pipeline crosses under the East Branch and a small rise in bed elevation is evident there.

Figure 41: Reach T107B Worden Road Bridge

Other characteristics of T107B include:

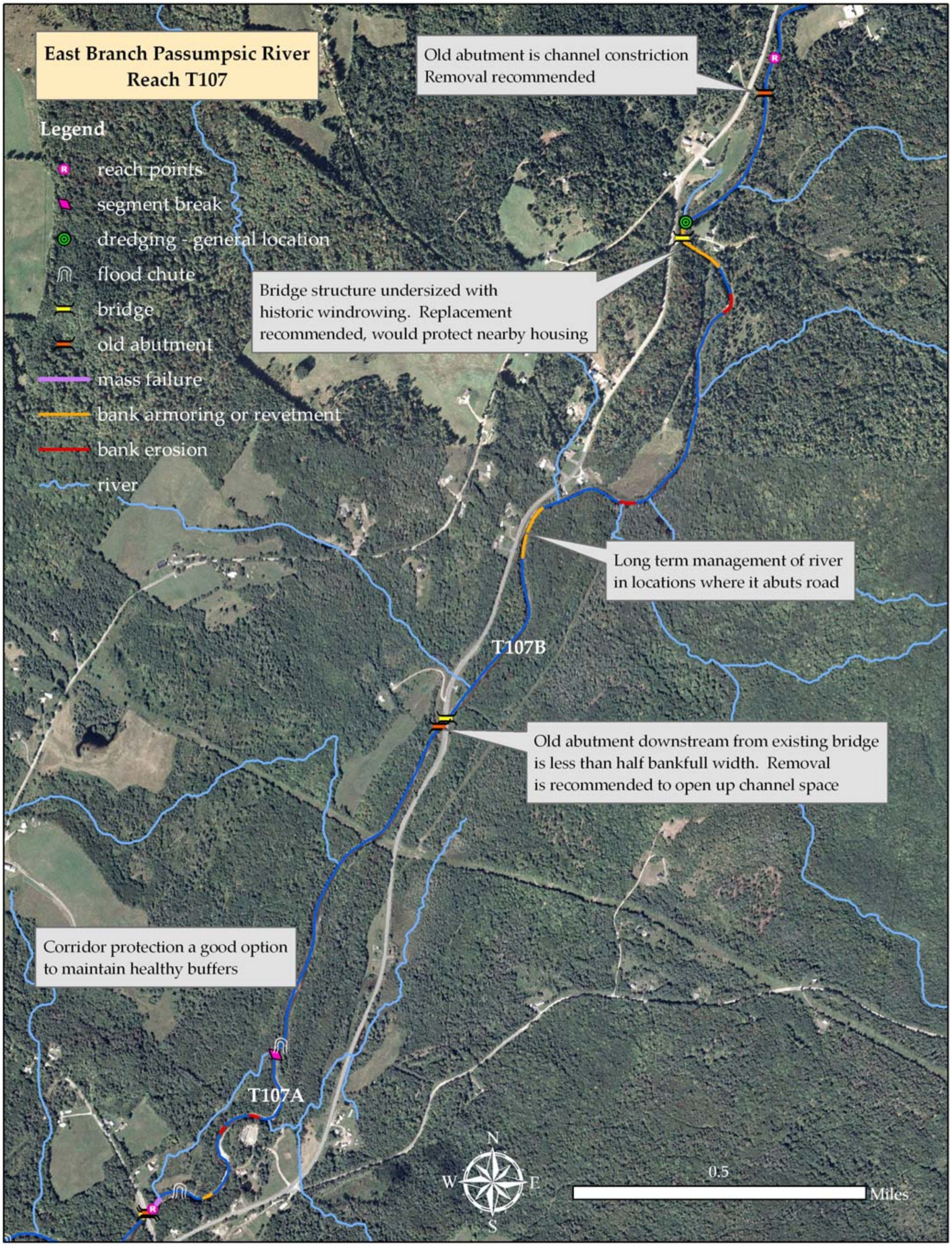
- Incision ratio of 1.37
- Entrenchment ratio of 4.66
- Geomorphic condition is Good
- Habitat condition is Good
- 9 Depositional features
- Road encroachment for 4123'

Figure 42: Reach T107B Route 114 90' wide bridge with 35' old abutment immediately downstream

Table 14: Preliminary Project Identification Reach T107

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T107B	Remove old abutments	High	Moderate	Yes	Removal of old abutments highly recommended as they are less than half bankfull width and constricting the channel.
T107B	Assess Bridge Structure	Moderate	Moderate	Yes	Worden Road bridge undersized and acting as a channel constriction
T107B	Monitor long term areas of conflict	Moderate	Low	Yes	Stream abuts road several times through reach and will need to be monitored/maintained in the long term
T107A T107B	Protect River Corridor	Moderate	Low	Yes	Good opportunity here to maintain healthy buffers through corridor protection

Figure 42: Preliminary Project Details Reach T107



References

Doll, Charles G. *The Geology of the Lyndonville Quadrangle, Vermont*. Montpelier, VT: Vermont Development Department, 1965.

Lane, S. 1995. The Dynamics of Dynamic River Channels. Physical Geography Now. Geography, Volume 80(2), Pages 147-162.

Rosgen, D.L. 1994 A Classification of Natural Rivers, *Catena* 22(3), 169-199.

Schumm S. A. *The Fluvial System.* John Wiley and Sons, New York, 1977.

Thompson, Elizabeth H. and Eric R. Sorenson. *Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont*. Hanover, NH: University Press of New England, 2000.

Vermont Agency of Natural Resources (VT ANR). *River Corridor Planning Guide*. River Management Program, 2007.

VTANR. 2007 http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_greoassesspro.htm