Phase 2 Stream Geomorphic Assessment
Browns River Watershed
Chittenden and Franklin Counties, Vermont

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EXECUTIVE SUMMARY

- Arrowwood Environmental was retained by the Vermont River Management Program (RMP) to conduct a Phase 2 Stream Geomorphic Assessment of select stream reaches within the Browns River watershed in Chittenden and Franklin Counties.
- The Phase 2 study focused on stream reaches on the Browns River, Abbey Brook, Lee River, The Creek, Roaring Brook, Steinhour Brook, Crane Brook, and Clay Brook primarily within the towns of Fairfax, Westford, Essex, Underhill, and Jericho.
- Protocols outlined in the Agency of Natural Resources, Stream Geomorphic Assessment, Phase 2 Handbook (Vermont Agency of Natural Resources 2007) were employed. The Phase 2 data were entered into the most current version of the Phase 2 database management system (DMS).
- ArcView shapefiles were constructed from the GPS mapped field data for major parameters such as:

Bank erosion	Beaver dams
Channel straightening	Debris jams
Bank armoring	Stormwater inputs
Floodplain development	Stream migration
Bridges and culverts	Grade controls
Floodplain encroachments	Channel cross-section
Riparian buffer width	

- The Phase 1 geomorphic condition is compared to the Phase 2 geomorphic condition in this report. The Phase 1 geomorphic condition ranged from good to poor for the 15 reaches assessed under the Phase 2 Assessment. Eleven of the 15 reaches rated fair in the Phase 1 geomorphic condition assessment. Of the 31 assessed stream segments under Phase 2, twenty-seven were rated fair.

- The Phase 2 Rapid Geomorphic Assessment (RGA) was used to evaluate the stage of channel evolution as part of the Schumm Evolution model. Of the 31 segments assessed on the Main Branch, four segments were found to be in stage 2, twenty-one segments were found to be in stage 3, and six segments were found to be in stage 4. During stage 2 of channel evolution, rivers exhibit loss of floodplain access and riffle erosion. Segments

undergoing stage 3 channel adjustment processes typically exhibit significant bank failure, erosion and sedimentation of riffles. The Phase 2 assessment confirmed that the majority of the study reaches are in stage 3 channel evolution. Stream segments at stage 4 evolution continue to exhibit some channel adjustment. Channel width begins to narrow through aggradation and the development of point bars.

- The Rapid Habitat Assessment (RHA) rating was generally the same or slightly higher as the RGA rating. Fourteen of the 31 total segments resulted in a rating of fair for both the RHA and the RGA. Four of 31 segments resulted in a rating of good for both the RHA and RGA. Nine of the 31 segments scored slightly higher on the RHA than the RGA and two of the 31 segments scored slightly lower on the RHA than the RGA.

- The Bridge and Culvert survey resulted in assessment of 33 structures. Of the 33 structures, eighteen were appropriately sized for the channel. The remaining 15 bridges and culverts functioned as channel constrictions, altering the channel slope and flow regimes, and presenting localized areas of erosion, scour pools and sediment deposition. In some cases, the stream was no longer aligned with the constriction due to migration in the vicinity of the undersized structure. These are areas where water could undermine the bridge or culvert during high flows; these are also areas where floodwaters could flow over and around the bridge, causing property damage and erosion.

- Preliminary project recommendations consisted of the following activities:

    - Protect River Corridors
    - Plant Stream Buffers
    - Arrest Head Cuts
    - Remove Berms
    - Remove or Replace Structures
    - Restrict Cattle Access
    - Remove Dump Sites
    - Remove Invasive Plants
    - Discontinue Active Dredging of Stream Channel

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1.0 INTRODUCTION

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

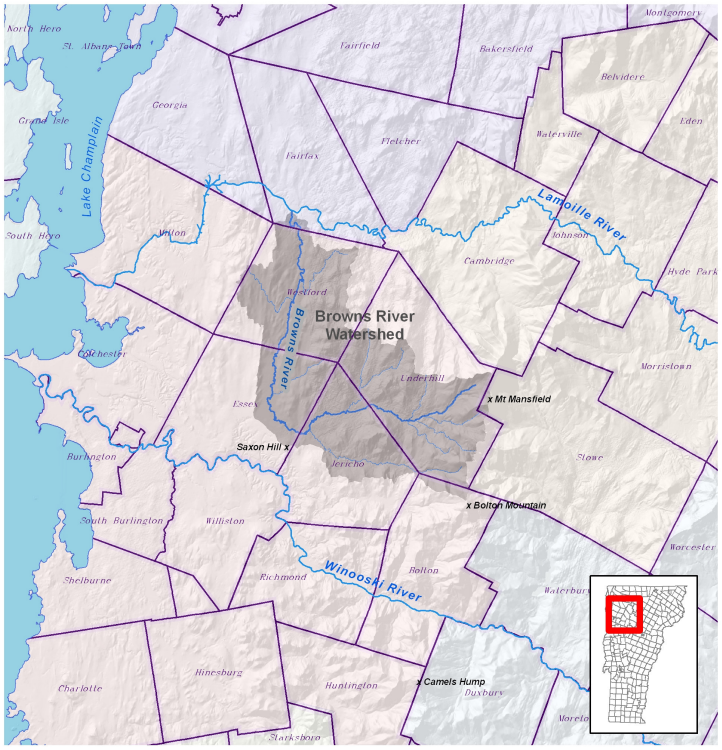


Figure a. Watershed Location Map

The Phase 2 assessment provides the citizens of the local towns, local watershed organizations, the Vermont Agency of Natural Resources, Winooski Conservation District and entities of the Federal Government with scientific information about the stream channel and river corridor that can be used in watershed planning. Specific products of the Phase 2 assessment for each assessed reach include: existing stream type determination; a geomorphic condition evaluation, including, reach condition, channel adjustment process and reach sensitivity; a stream habitat assessment; and field maps and photographs.

In addition to the specific work products outlined above, the Phase II assessment provides information needed to manage toward, protect, and restore the fluvial geomorphic equilibrium condition of the Browns River and its tributaries, a stated goal of the River Management Program. Information collected in this study can be used to help resolve conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner possible. (July 11, 2007 Draft River Corridor Planning Guide, Agency of Natural Resources)

2.0 METHODOLOGY

The Phase 2 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (Vermont Agency of Natural Resources 2007). All assessment data were recorded on the Agency of Natural Resources (ANR) Phase 2 data sheets, and were entered in to the most current version of the ANR Phase 1 _2 data management system (DMS). The Phase 1 database was updated using the field data from the Phase 2 assessment.

The Phase 2 assessments consisted of in-depth GPS mapping and evaluation of selected reaches and involved wading or canoeing entire sections of stream. Reaches were selected based on results of the Phase 1 assessment, with preference towards reaches that could potentially benefit from restoration or protection projects. The data collected included sketch maps, photographs, channel and floodplain measurements to document the condition of the stream itself and its adjacent floodplain. The following features were measured and GPS mapped in the field:

Bank erosion	Beaver dams
Channel straightening	Debris jams
Bank armoring	Stormwater inputs
Floodplain development	Stream migration
Bridges and culverts	Grade controls
Floodplain encroachments	Channel cross-section
Riparian buffer width	Pebble counts

Stream health was rated based on its geomorphic condition and its habitat condition. These ratings were based on the field measurements listed above and upon other characteristics, including sediment deposition and erosion patterns, channel evolution stage, and degree of floodplain access. All of these features were mapped with the SGAT extension and are presented in the following pages of this report. Like the Phase 1 data, the complete datasets are available to the public in the DMS database.

2.1 Field Protocols

The ANR's Phase 2 stream geomorphic assessment protocol includes seven steps.
These steps are as follows:

1. Valley and River Corridor
2. Stream Channel
3. Riparian Banks, Buffers and Corridor
4. Flow Modifiers
5. Channel, Bed and Planform Changes
6. Rapid Habitat Assessment (RHA)
7. Rapid Geomorphic Assessment (RGA)

The parameters and protocols used for undertaking each of the above steps are outlined in the Phase 2 Handbook (ANR 2007). The length of each Phase 2 reach was walked to determine segment breaks. Bank erosion, grade control structures, bank revetments, beaver dams, debris jams, depositional features, and other important features were mapped via GPS and/or field sketches within all segments. GIS coverages were developed from site sketches and GPS data. The Feature Indexing Tool (FIT) was used to index features in the following steps of the Phase 2 protocols: 1.2, 1.3, 1.6, 3.1, 5.5, 4.4, 4.6, 4.9, 5.2, 5.3, 5.4 and Step 2 (cross section and pebble

count locations). Phase 2 field sheets were not completed for some segments due to access issues related to lack of landowner permission, or difficult terrain.

A Bridge and Culvert Survey was also conducted as part of this study. Geomorphic and habitat parameters were evaluated for structures crossing study reaches. The most recent version of the Bridge and Culvert field data sheet was completed for each structure and entered data into the DMS. A GIS point coverage was created for assessed structures.

2.2 QA Review

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

3.0 FLUVIAL GEOMORPHIC SETTING

The Browns River Watershed has a watershed size of approximately 92 square miles. The study reaches are located on the following reaches within the following towns:

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

For the purpose of geomorphic assessment and corridor planning, the Browns River has been divided into 'reaches,' fifteen of which fall within the scope of this Phase 2 assessment. A reach is a section of stream with similar characteristics; this determination is primarily based on physical characteristics such as slope, sinuosity, dominant bed material, bed form, and valley confinement. The Phase 2 study focuses on stream reaches on the Browns River and seven of its major tributaries.

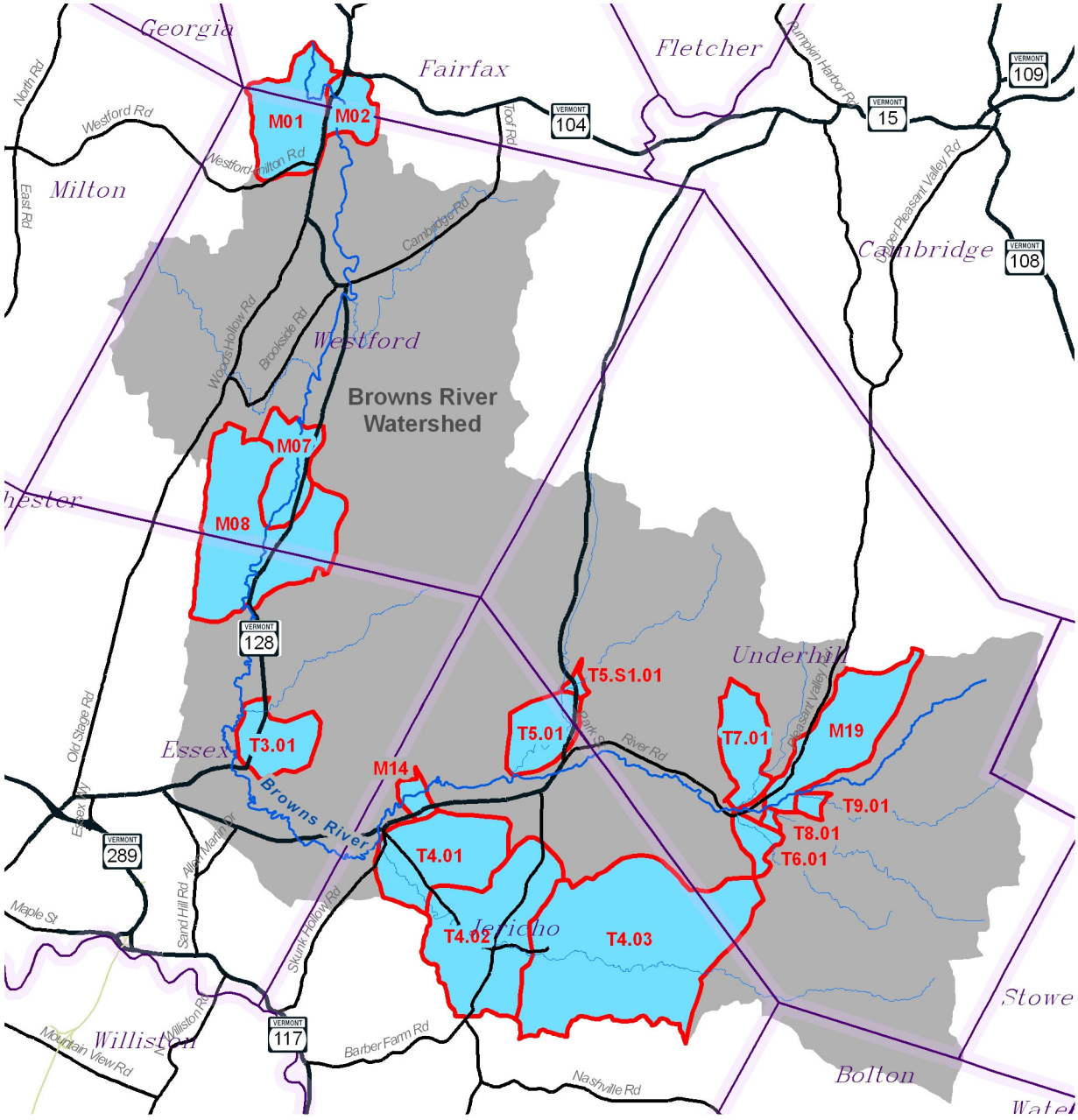


Figure b. Reach Location Map

3.1 Phase 1 Reference Reach Conditions

The data collected in the Phase 1 assessments provide an overview of the general physical characteristics of a watershed. Maps, aerial pictures, and historic information are combined with field interpretations to produce reference stream typing, stream impact ratings, and provisional geomorphic condition evaluations. (VANR Phase 1 Handbook, April 2007). Table 1 briefly summarizes the Phase 1 assessment of the study reaches. Further detailed descriptions of the

reaches, with associated Phase 1 and 2 observations, are found in Section 5 of this report along with maps depicting Phase 2 segment delineations.

Table 1. Browns River Phase 1 reference reach summary statistics

Reach ID	Drainage Area (sq mi)	Valley width (ft)	Valley Type	Channel width (ft)	Channel Slope (%)	Sinuosity	Reference Stream Type	Channel Bedform
M01	92.32	603	BD	95.94	0.3	1.27	C	Riffle/Pool
M02	90.83	766	BD	95.26	0.46	1.19	C	Dune/Ripple
M07	68.24	817	BD	83.99	NA	1.08	E	Dune/Ripple
M08	67.36	1927	VB	83.51	NA	1.22	E	Dune/Ripple
M14	37.11	1501	VB	64.24	0.84	1.23	C	Riffle/Pool
M19	8.49	560	VB	33.56	1.47	1.03	C	Riffle/Pool
T3.01	3.5	751	VB	22.73	NA	1.10	C	Riffle/Pool
T4.01	15.41	989	VB	43.64	0.29	1.17	C	Riffle/Pool
T4.02	13.64	475	VB	41.36	0.81	1.28	C	Riffle/Pool
T4.03	10.86	730	VB	37.42	1.21	1.24	C	Riffle/Pool
T5.01	10.87	1231	VB	37.43	0.37	1.45	C	Riffle/Pool
T5.S1.01	3.81	653	VB	23.61	2.11	1.11	E	Riffle/Pool
T6.01	1.81	184	VB	17.02	3.11	1.02	E	Riffle/Pool
T7.01	2.58	250	VB	19.88	1.84	1.12	C	Riffle/Pool
T8.01	2.52	892	VB	19.67	2.28	1.0	B	Riffle/Pool

The selection of Phase 2 study reaches was completed by the River Management Program and the Winooski Conservation District based upon results of the Phase 1 and the 2004 Phase 2 geomorphic assessments, local knowledge of existing problem areas, and potential project sites. The following tables provide Phase 1 reach condition and reach sensitivity ratings for the targeted Phase 2 study reaches.

Table 2. Browns River Phase I Reach Condition and Sensitivity Ratings

Reach ID	Reference Stream Type	Channel Bedform	Reach Condition	Reach Sensitivity
M01	C	Riffle/Pool	Fair	Moderate
M02	C	Dune/Ripple	Fair	High
M07	E	Dune/Ripple	Fair	High
M08	E	Dune/Ripple	Poor	High
M14	C	Riffle/Pool	Fair	High
M19	C	Riffle/Pool	Good	Moderate
T3.01	C	Riffle/Pool	Fair	Moderate
T4.01	C	Riffle/Pool	Fair	High
T4.02	C	Riffle/Pool	Fair	High
T4.03	C	Riffle/Pool	Good	High
T5.01	C	Riffle/Pool	Fair	High
T5.S1.01	E	Riffle/Pool	Poor	Moderate
T6.01	E	Riffle/Pool	Fair	High
T7.01	C	Riffle/Pool	Fair	Moderate
T8.01	B	Riffle/Pool	Fair	Moderate

3.2 Current Stream Channel Characteristics

The Phase 2 Rapid Stream Assessment is a detailed protocol for gathering data about the stream channel and riparian corridor. One of the products of the Phase 2 assessment is the determination of existing stream type. The stream type describes general physical characteristics of the channel and the fluvial processes going on in the assessed reach. Stream typing in the field provides and opportunity to verify the provisional reference stream type made during the Phase 1 assessment and to identify where the existing stream type has departed from the reference stream type. (VANR Phase 2 Handbook, May 2007).

Measurements of channel dimensions were made using a depth rod, a measuring tape, a hand-held tape ruler, and a hand level. Channel dimensions were measured at cross over (riffle) locations, and conducted at least one cross-section per stream segment. The cross section data was entered in the Vermont Agency of Natural Resources, Phase 2 Stream Geomorphic Assessment Database. The stream geometry data are included in the appendices.

Table 3 summarizes the existing channel conditions, including entrenchment ratio, width/depth ratio, incision ratio, sinuosity, sediment storage types, stream types, bed material and bed form for the Phase 2 study reaches.

Table 3. Browns River Phase 2 Channel Summary Data

Segment ID	Entrenchment Ratio	Width/ Depth Ratio	Incision Ratio	Sediment Storage Types	Phase 2 Stream Type	Bed Material	Bed Form
M01A	2.55	16.23	1.58	Mid, point, side, diagonal	C	Sand	Dune/Ripple
M01B	3.57	20.92	1.65	Island	C	Gravel	Riffle/Pool
M01C	10.49	16.57	1.25	Mid, point, side, delta	C	Sand	Dune/Ripple
M02A	8.13	15.94	1.51	Mid, point, side	C	Sand	Dune/Ripple
M02B	3.13	21.19	1.39	Diagonal	C	Cobble	Plane Bed
M07	9.32	9.75	1.39	Mid, point, side	E	Sand	Dune/Ripple
M08	1.10	16.27	2.2	Mid, point, side	F	Sand	Dune/Ripple
M14	13.37	17.53	1.65	Side, island	C	Gravel	Plane Bed
M19	2.3	20.75	1.76	Mid, point, side, diagonal	C	Cobble	Riffle/Pool
T3.01A	1.6	10.0	3.42	Point, side	G	Silt	Dune/Ripple
T3.01B	NA	NA	NA	NA	NA	NA	NA
T3.01C	10.17	11.24	1.92	Diagonal, island	E	Gravel	Riffle/Pool

Segment ID	Entrenchment Ratio	Width/ Depth Ratio	Incision Ratio	Sediment Storage Types	Phase 2 Stream Type	Bed Material	Bed Form
T4.01	27.97	18.9	1.52	Mid, point, side, diagonal	C	Gravel	Riffle/Pool
T4.02A	4.5	13.89	1.7	Mid, point, side, diagonal, island	C	Gravel	Riffle/Pool
T4.02B	1.83	28.03	1.65	Mid, side	B	Gravel	Riffle/Pool
T4.02C	4.5	13.89	1.7	Mid, side, point, diagonal	C	Gravel	Riffle/Pool
T4.02D	3.0	96.15	1.41	Point	D	Gravel	Plane Bed
T4.03A	2.96	96.15	1.22	Point, side, diagonal, island	D	Gravel	Plane Bed
T4.03B	1.33	16.9	2.05	Point, side, diagonal, island	F	Gravel	Riffle/Pool
T4.03C	NA	NA	NA	NA	NA	NA	NA
T5.01A	4.04	16.44	1.77	Point, side, diagonal, island	C	Gravel	Riffle/Pool
T5.01B	10.0	11.85	1.17	Side, island	E	Cobble	Plane Bed
T5.01C	NA	NA	NA	NA	NA	NA	NA
T5.01D	10.0	11.85	1.17	Mid, side	C	Gravel	Plane Bed
T5.01E	35.71	11.9	1.95	Mid, point, side, diagonal, delta	E	Sand	Dune/Ripple
T5.01F	NA	NA	NA	NA	NA	NA	NA
T5.01G	21.71	10.25	1.58	Mid, point, side, diagonal, delta	E	Gravel	Plane Bed
T5.S1.01	3.04	10.59	1.68	Point, side, diagonal	E	Cobble	Riffle/ Pool
T6.01A	29.63	9.3	1.87	Mid, point, side, diagonal	E	Gravel	Riffle/Pool
T6.01B	0.91	18.18	3.0	Mid, point	F	Gravel	Step/ Pool
T6.01C	2.2	15.65	1.88	Mid, side, island	C	Gravel	Riffle/Pool
T7.01A	16.18	13.28	1.18	Point, side, island	C	Gravel	Riffle/Pool
T7.01B	2.0	22.94	1.0	Mid, point, side	B	Gravel	Riffle/Pool
T7.01C	9.5	11.18	1.48	Mid, point, side, diagonal, island	E	Gravel	Riffle/Pool
T8.01	2.08	13.95	1.68	Mid, side	B	Gravel	Riffle/Pool

3.3 Channel Evolution Model

The Phase 2 Rapid Geomorphic Assessment (RGA) was used to evaluate the stage of channel evolution. Schumm (1977 and 1984) has described five stages of channel evolution. These stages are described in the ANR Phase 2 manual (ANR 2007) as follows:

I. Stable – in regime, reference to good condition. Insignificant to minimal adjustment; planform is moderate to highly sinuous.
II. Incision – Fair to poor condition, major to extreme channel degradation. High flow events are contained in the channel, and channel slope is typically increased.
III. Widening – Fair to poor condition, major to extreme widening and aggradation.
IV. Stabilizing – Fair to good condition, major reducing to minor aggradation, widening and planform adjustments
V. Stable – In regime, reference to good condition. Insignificant to minimal adjustment.

The results of the RGA and Rapid Habitat Assessment (RHA) are provided on the reach summary sheets for each study area included in the appendices. Table 4 below shows a comparison of the habitat condition based on the RHA and the geomorphic condition based on the RGA.

Table 4. RGA and RHA Summary Results for the Browns River

Segment ID	RGA Rating	Stream Sensitivity	Channel Adjustment Process	Channel Evolution Stage	RHA Rating
M01A	Fair	Very High	Widening/ some aggradation	III	Fair
M01B	Good	High	Minor adjustments	IV	Good
M01C	Fair	Very High	Widening/ aggradation	III	Poor
M02A	Fair	Very High	Widening/ aggradation	III	Fair
M02B	Fair	High	Aggradation	III	NA
M07	Fair	Very High	Widening/ planform changes	III	Poor
M08	Fair	High	Widening	III	Fair
M14	Fair	Very High	Minor adjustments	IV	Fair
M19	Fair	High	Widening	III	Good
T3.01A	Fair	Extreme	Widening/ planform changes	III	Poor
T3.01B	NA	NA	NA	NA	NA
T3.01C	Fair	Very High	Widening	III	Fair
T4.01	Fair	Very High	Widening/ planform changes	III	Fair
T4.02A	Fair	Very High	Aggradation/ minor widening	III	Good
T4.02B	Fair	High	Minor adjustments	IV	Good
T4.02C	Fair	Very High	Aggradation/ widening	III	Good
T4.02D	Fair	Extreme	Widening/ aggradation/ planform changes	III	Fair

Segment ID	RGA Rating	Stream Sensitivity	Channel Adjustment Process	Channel Evolution Stage	RHA Rating
T4.03A	Fair	Extreme	Widening/ aggradation/ planform changes	III	Fair
T4.03B	Fair	Very High	Widening/ planform changes	III	Good
T4.03C	NA	NA	NA	NA	NA
T5.01A	Fair	Very High	Degradation/ planform changes	II	Fair
T5.01B	Good	High	Minor adjustments	IV	Good
T5.01C	NA	NA	NA	NA	NA
T5.01D	Good	Very High	Minor adjustments	IV	Good
T5.01E	Fair	Extreme	Aggradation/ planform changes	III	Fair
T5.01F	NA	NA	NA	NA	NA
T5.01G	Fair	Very High	Aggradation/ planform changes	III	Fair
T5.S1.01	Fair	High	Aggradation	III	Fair
T6.01A	Fair	Very High	Widening/ aggradation	III	Fair
T6.01B	Fair	High	Relatively stable	II	Good
T6.01C	Fair	Very High	Widening/ aggradation	III	Good
T7.01A	Good	High	Incising in places	II	Good
T7.01B	Fair	High	Minor adjusting/ incising in specific locations	II	Good
T7.01C	Fair	Very High	Planform changes	IV	Good
T8.01	Fair	High	Aggradation/ widening	III	Fair

4.0 IDENTIFICATION OF HYDROLOGIC AND SEDIMENT REGIME STRESSORS IN THE WATERSHED

4.1 Hydrologic regime stressors

The hydrologic regime involves the timing, volume, and duration of flow events throughout the year and over time; as addressed in this section, the regime is characterized by the input and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. Where hydrologic modifications are persistent, the impacted stream will adjust morphologically (e.g., enlarging when stormwater peaks are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches (VTANR, 2007).

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

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

Preliminary analysis of hydric soils and existing agricultural and developed land uses indicates significant loss of wetland attenuation of precipitation inputs. Wetlands have been filled, ditched, diverted and otherwise manipulated resulting in a loss of hydrologic function.

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

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

4.2 Sediment Regime Stressors

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

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

Table 5. Browns River Watershed Scale Sediment Load Stressors

Segment ID	Deposition Rating	Erosion Rating (Left Bank)	Erosion Rating (Right Bank)	Mass Failures Gullies	Tributary Rejuvenation
M01A	> 5	>20%	>5% <=20%	No	No
M01B	>2 <= 5	<5%	>5% <=20%	No	No
M01C	> 5	>20%	>20%	Yes	No
M02A	> 5	>20%	>20%	Yes	
M02B	> 5	>5% <=20%	<5%	No	No
M07	<=2	>20%	>20%	No	No
M08	<=2	>20%	>20%	No	No
M14	>2 <= 5	<5%	<5%	No	No
M19	> 5	<5%	<5%	No	Yes
T3.01A	> 5	>5% <=20%	>20%	No	No
T3.01C	> 5	<5%	>20%	No	No
T4.01	> 5	>5% <=20%	>5% <=20%	No	No
T4.02A	> 5	<5%	<5%	Yes	No
T4.02B	> 5	<5%	<5%	No	No
T4.02C	> 5	<5%	>5% <=20%	Yes	No
T4.02D	> 5	<5%	>20%	No	No
T4.03A	> 5	<5%	<5%	No	No
T4.03B	> 5	>5% <=20%	<5%	No	No
T5.01A	> 5	>20%	>5% <=20%	No	No
T5.01B	> 5	>5% <=20%	<5%	No	No
T5.01C	Unknown	>5% <=20%	>5% <=20%	No	
T5.01D	> 5	>20%	<5%	No	No
T5.01E	> 5	>20%	>20%	No	No
T5.01F	Unknown	<5%	<5%	No	
T5.01G	> 5	>20%	>5% <=20%	No	No
T5.S1.01	> 5	<5%	<5%	No	No
T6.01A	> 5	>20%	>5% <=20%	No	No
T6.01B	> 5	<5%	>5% <=20%	No	No
T6.01C	> 5	<5%	<5%	Yes	No
T7.01A	> 5	<5%	>5% <=20%	Yes	No
T7.01B	> 5	>5% <=20%	>5% <=20%	No	No
T7.01C	> 5	<5%	<5%	No	No
T8.01	> 5	<5%	>5% <=20%	No	No

4.3 Reach Scale Sediment Regime Stressors

Channel Slope Modifiers

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

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

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

Table 6. Browns River Potential Slope Modifiers

	Slope Increasers		Slope Decreasers	
Segment ID	Straightening (% per reach)	Encroachments (% per reach)	# Constrictions & Controls per mile	# Beaver Dams/mile
M01A	<5%	<5%	<=2	<=2
M01B	>20%	<5%	<=2	<=2
M01C	>20%	<5%	<=2	<=2
M02A	<5%	<5%	<=2	<=2
M02B	<5%	<5%	<=2	<=2
M07	>20%	<5%	<=2	<=2
M08	>20%	>20%	<=2	<=2
M14	>20%	>5% <=20%	>2 <= 5	<=2
M19	<5%	<5%	<=2	<=2
T3.01A	<5%	<5%	<=2	<=2
T3.01C	<5%	<5%	<=2	<=2
T4.01	>5% <=20%	<5%	<=2	<=2
T4.02A	<5%	>20%	<=2	<=2
T4.02B	<5%	>20%	<=2	<=2
T4.02C	<5%	>20%	<=2	<=2
T4.02D	<5%	<5%	<=2	<=2
T4.03A	<5%	<5%	<=2	<=2
T4.03B	<5%	<5%	<=2	<=2
T5.01A	<5%	<5%	<=2	<=2
T5.01B	>20%	>20%	<=2	<=2
T5.01C	>20%	>20%	<=2	<=2
T5.01D	<5%	<5%	<=2	<=2
T5.01E	>5% <=20%	<5%	<=2	<=2
T5.01F	<5%	<5%	<=2	<=2
T5.01G	>20%	<5%	<=2	<=2
T5.S1.01	>20%	>20%	<=2	<=2
T6.01A	<5%	<5%	>2 <= 5	<=2
T6.01B	<5%	>20%	> 5	<=2
T6.01C	<5%	>20%	<=2	<=2
T7.01A	<5%	<5%	<=2	<=2
T7.01B	<5%	>5% <=20%	> 5	<=2
T7.01C	<5%	<5%	>2 <= 5	<=2
T8.01	>20%	>20%	<=2	<=2

Table 7 shows the widths of all bridges and culverts measured in the Phase 2 assessments. Note that of the 33 structures listed, eighteen were appropriately sized for the channel. The remaining 15 bridges and culverts functioned as channel constrictions, altering the channel slope and flow regimes, and presenting localized areas of erosion, scour pools and sediment deposition. In some cases, the stream was no longer aligned with the constriction due to migration in the vicinity of the undersized structure. These are areas where water could undermine the bridge or culvert during high flows; these are also areas where floodwaters could flow over and around the bridge, causing property damage and erosion.

Table 7. Browns River Channel and floodplain constrictions found during Phase 2 assessments

Reach	Type	Constriction Width (ft)	Channel Width (ft)	Channel Constriction?	Floodprone Constriction?	Problem
M01B	Bridge	120	100	No	Yes	Deposition Below
M02A	Bridge	72	68	No	Yes	Deposition Above, Deposition Below
M07	Bridge	18	42	Yes	No	Deposition Below
M07	Bridge	22	45	Yes	No	Deposition Above, Deposition Below
M07	Bridge	25	56	Yes	No	Deposition Below
M08	Bridge	24	48	Yes	Yes	Deposition Above, Deposition Below, Scour Above, Scour Below
M08	Bridge	23	38	Yes	No	Deposition Below, Scour Above, Scour Below
M08	Bridge	69	55	No	Yes	Deposition Above, Deposition Below
M14	Bridge	92	71	No	Yes	None
M19	Bridge	40	33	No	Yes	Deposition Above, Deposition Below
T3.01C	Culvert	10	15	Yes	Yes	Scour Above, Scour Below
T4.01	Bridge	87	43	No	Yes	Deposition Above, Deposition Below, Scour Above
T4.01	Bridge	35	43	Yes	No	Deposition Below, Scour Above, Scour Above
T4.01	Bridge	35	43	Yes	No	Deposition Above, Deposition Below (not in use)
T4.02A	Bridge	45	41	No	No	None
T4.02C	Bridge	84	40	No	No	Deposition Above
T4.02C	Bridge	54	40	No	Yes	Deposition Below, Scour Above
T4.02C	Bridge	81	40	No	Yes	None

Reach	Type	Constriction Width (ft)	Channel Width (ft)	Channel Constriction?	Floodprone Constriction?	Problem
T4.03B	Bridge	80	26	No	No	None
T5.01A	Bridge	33	20	No	No	None
T5.01A	Culvert	14.5	25	Yes	Yes	Alignment, Deposition Above, Scour Above, Scour Below
T5.01B	Bridge	30	32	Yes	Yes	None
T5.01E	Culvert	16	17.5	Yes	Yes	Deposition Above, Deposition Below, Scour Above, Scour Below
T6.01A	Bridge	12.2	17	Yes	Yes	Alignment, Deposition Above, Deposition Below, Scour Above
T6.01A	Bridge	40	16	No	Yes	Deposition Below
T6.01C	Culvert	7.5	20	Yes	Yes	Alignment, Deposition Below
T7.01B	Culvert	10	20	Yes	Yes	Deposition Above, Deposition Below, Scour Above
T7.01C	Bridge	18	25	Yes	No	Deposition Above
T7.01C	Bridge	30	17	No	No	Deposition Above
T7.01C	Bridge	23	17	No	No	Deposition Above
T8.01	Bridge	25	16	No	Yes	Deposition Below
T5.S1.01	Bridge	25	25	No	Yes	Deposition Above
T5.S1.01	Bridge	63	25	No	Yes	Deposition Below

Riparian Buffer Conditions

Stream boundaries include bed and banks, and are also affected by the condition of buffer vegetation in the riparian corridor. Root systems from woody vegetation (and to a lesser extent, herbaceous vegetation) help bind stream bank soils.

The resistance of the channel boundary materials to the shear stress and stream power exerted, will, in large part, determine whether the channel will undergo adjustment. Riparian vegetation and human-placed bed and bank armoring are effective means of resisting erosion, although, armoring is considered a temporary condition. (VANR, River Corridor Planning Guide, July 11, 2007) The following tables summarize the condition of the riparian buffers within the study reaches.

Table 8. Browns River Riparian Buffer Conditions

Segment ID	Left Buffer Dominant Width (ft)	Right Buffer Dominant Width (ft)	Left Bank Revetment (%)	Right Bank Revetment (%)
M01A	51-100	>100	<5%	<5%
M01B	>100	26-50	<5%	<5%
M01C	26-50	26-50	<5%	<5%
M02A	26-50	51-100	<5%	<5%
M02B	>100	>100	<5%	<5%
M07	0-25	0-25	<5%	<5%
M08	0-25	26-50	>5% <=20%	>5% <=20%
M14	0-25	26-50	<5%	>5% <=20%
M19	0-25	>100	<5%	<5%
T3.01A	0-25	0-25	<5%	<5%
T3.01B	0-25	0-25	NA	NA
T3.01C	0-25	0-25	<5%	<5%
T4.01	26-50	26-50	>5% <=20%	>5% <=20%
T4.02A	>100	0-25	<5%	>5% <=20%
T4.02B	>100	26-50	<5%	>5% <=20%
T4.02C	>100	0-25	<5%	>5% <=20%
T4.02D	51-100	51-100	<5%	<5%
T4.03A	0-25	51-100	<5%	<5%
T4.03B	>100	>100	<5%	>5% <=20%
T5.01A	51-100	51-100	>5% <=20%	<5%
T5.01B	0-25	51-100	<5%	>5% <=20%
T5.01C	26-50	>100	<5%	<5%
T5.01D	26-50	51-100	>5% <=20%	<5%
T5.01E	0-25	0-25	<5%	<5%
T5.01F	>100	>100	<5%	<5%
T5.01G	0-25	>100	<5%	<5%
T5.S1.01	26-50	26-50	>20%	>5% <=20%
T6.01A	>100	0-25	<5%	<5%
T6.01B	>100	>100	<5%	<5%
T6.01C	>100	26-50	<5%	<5%
T7.01A	>100	>100	<5%	<5%
T7.01B	>100	51-100	<5%	<5%
T7.01C	>100	>100	<5%	<5%
T8.01	26-50	0-25	<5%	>5% <=20%

5.0 Phase 2 Results by Reach

The results of the Phase 2 study are summarized below by reach number, and individual reach summary reports from the Phase 2 database are included in the appendices. Results from the Phase 2 field surveys are summarized in the following pages. Field measurements and locations of other features are overlayed on 2003 aerial photos (USDA 2003). Preliminary project recommendations are provided on a per reach/segment basis.

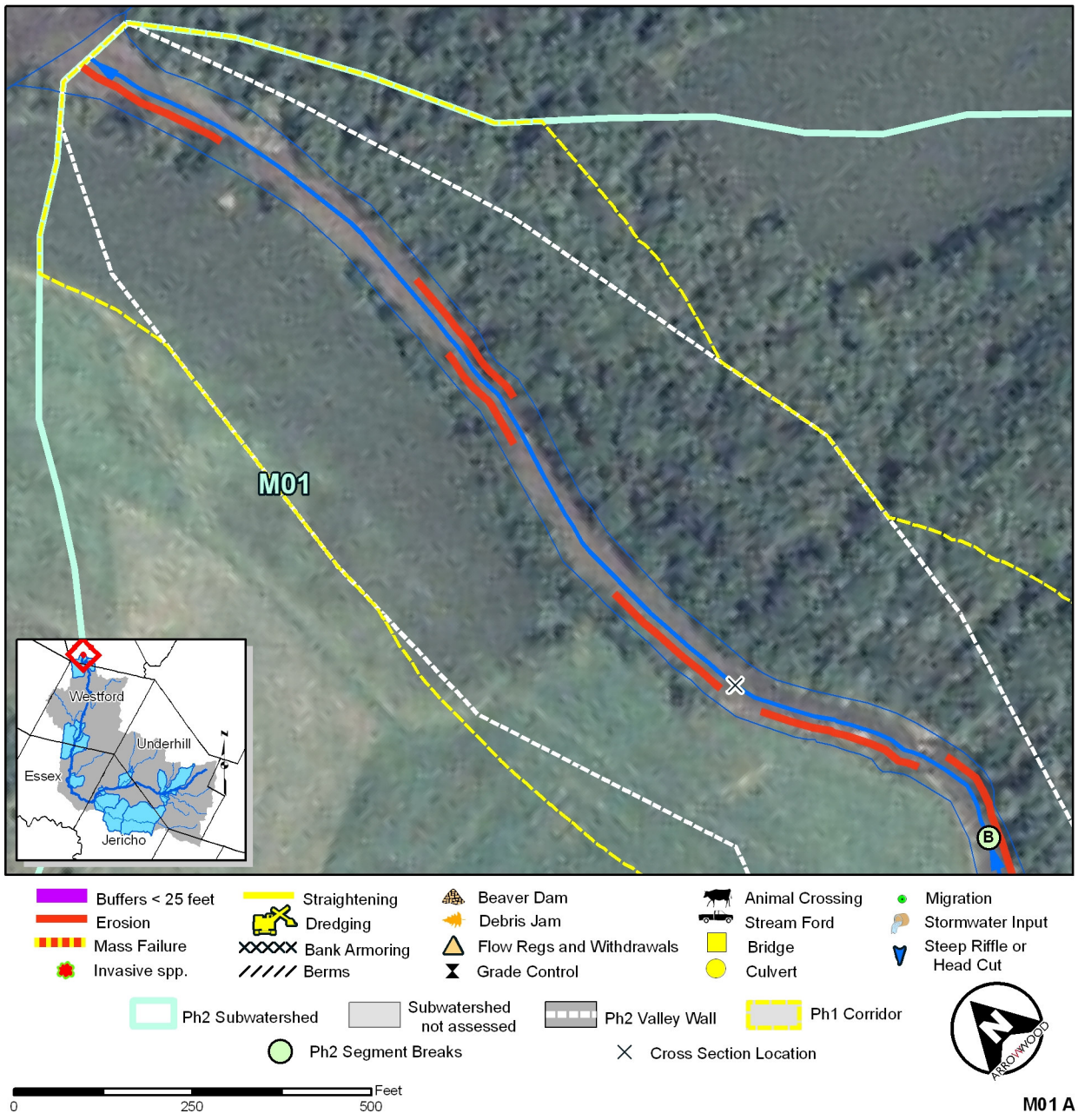


Figure c. Reach M01A Inventory Map

M01A Summary Data

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

M01b Summary Data

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

M01C Summary Data

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

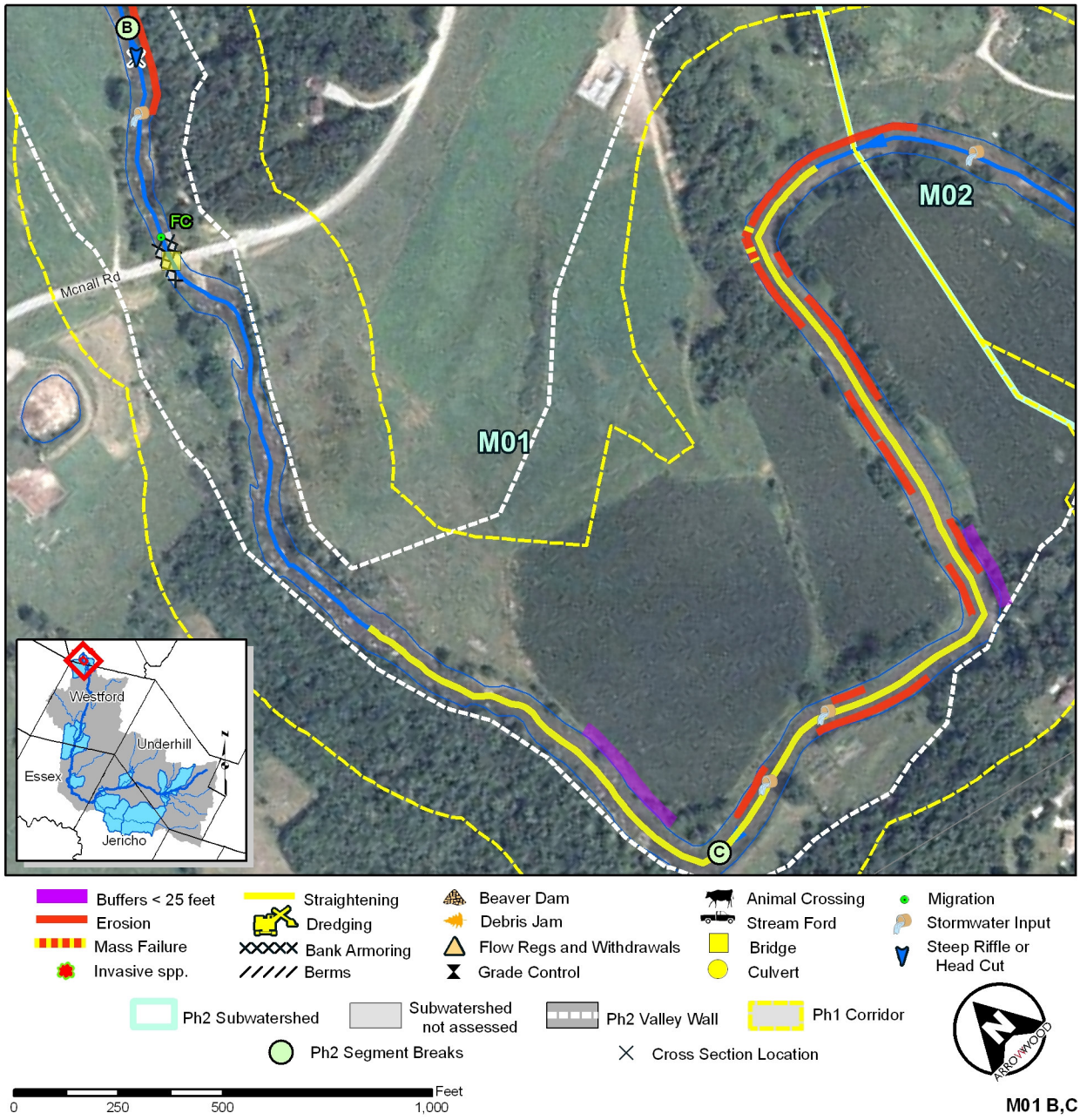


Figure d. Reach M01B,C Inventory Map

Preliminary project recommendations are presented in the following table.

Table 9a. Reach M01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M01b,c	**Plant Stream Buffers**	**Contact landowners on right bank; investigate possible grant programs for plantings**

Figure e. M01 Segment C cross section: left bank with erosion and no buffer

Figure f. M01 Segment B. Groundwater flowing over clay downstream of cross section

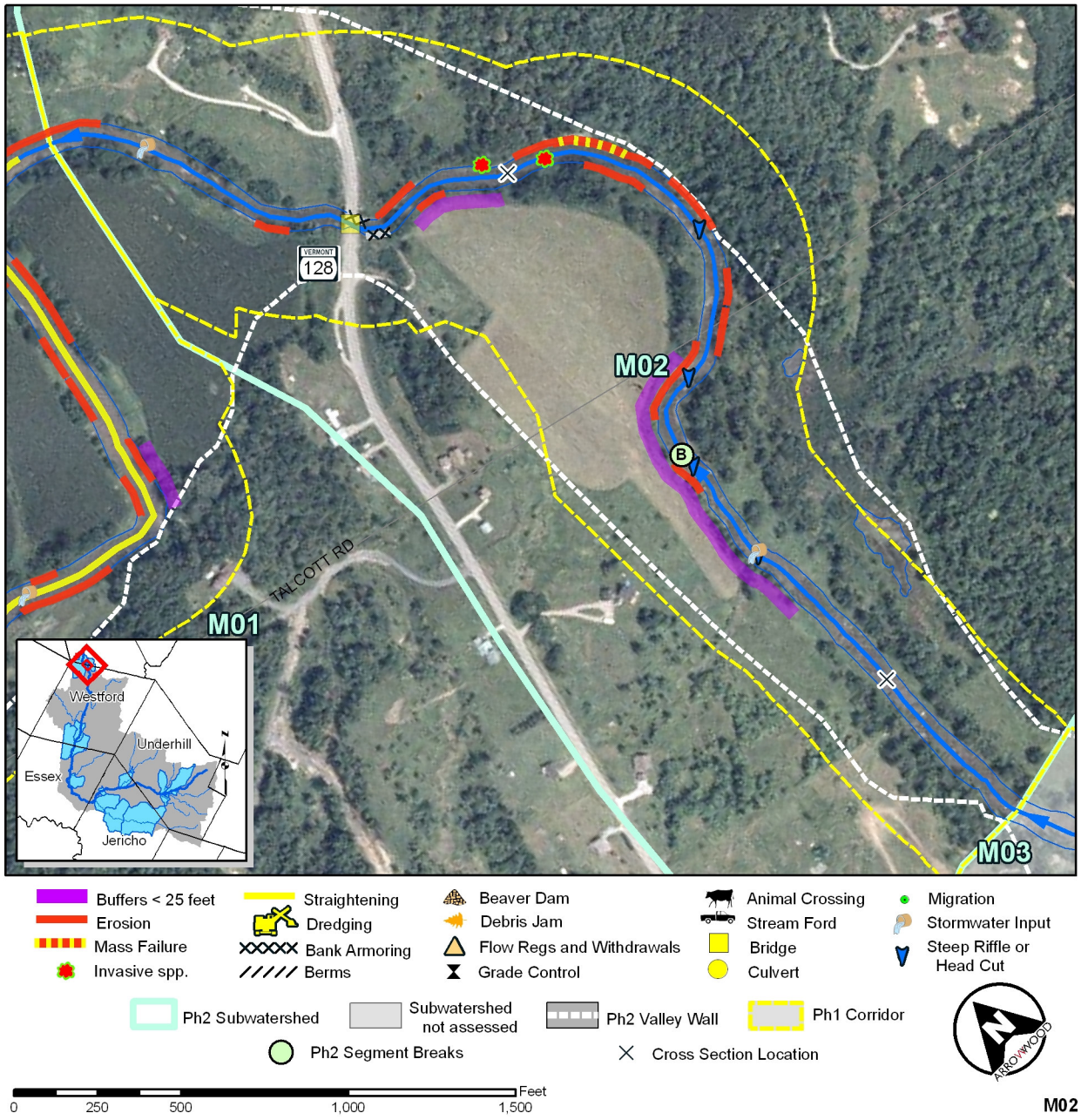


Figure g. Reach M02 Inventory Map

Figure h. M02 Segment A. Incised channel with poor buffers

M02a Summary Data	
Reach/Segment Length	2902 ft
Valley Confinement	Broad
Reference Stream Type	C5
Existing Stream Type	C5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

M02b Summary Data	
Reach/Segment Length	1476 ft
Valley Confinement	Broad
Reference Stream Type	C5
Existing Stream Type	C3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	widening, some aggradation
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Preliminary project recommendations are presented in the following table.

Table 9b. Reach M02 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M02a	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
M02a,b	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
M02a	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

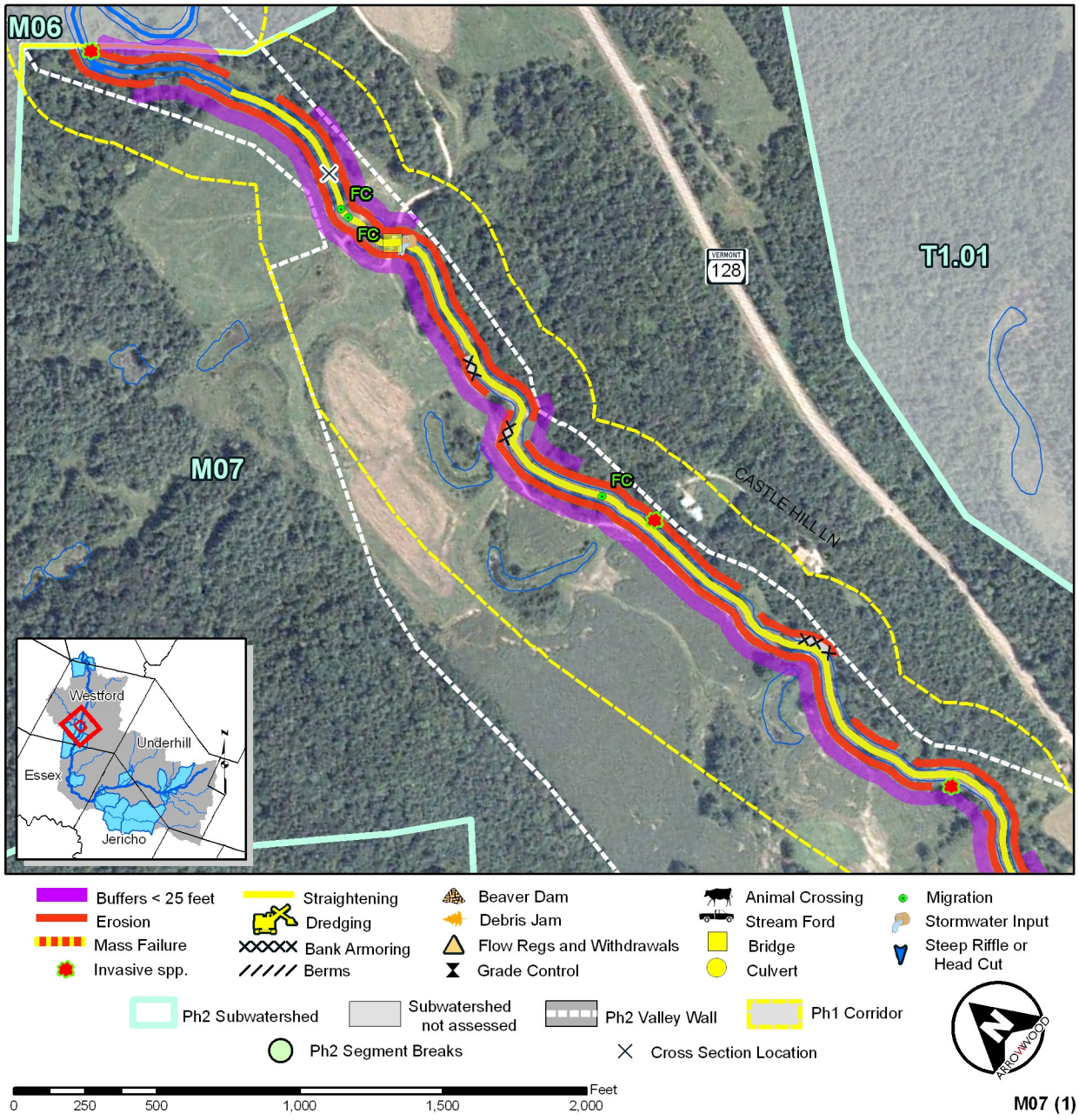


Figure i. Reach M07 Inventory Map

Figure j. Erosion on outside bend

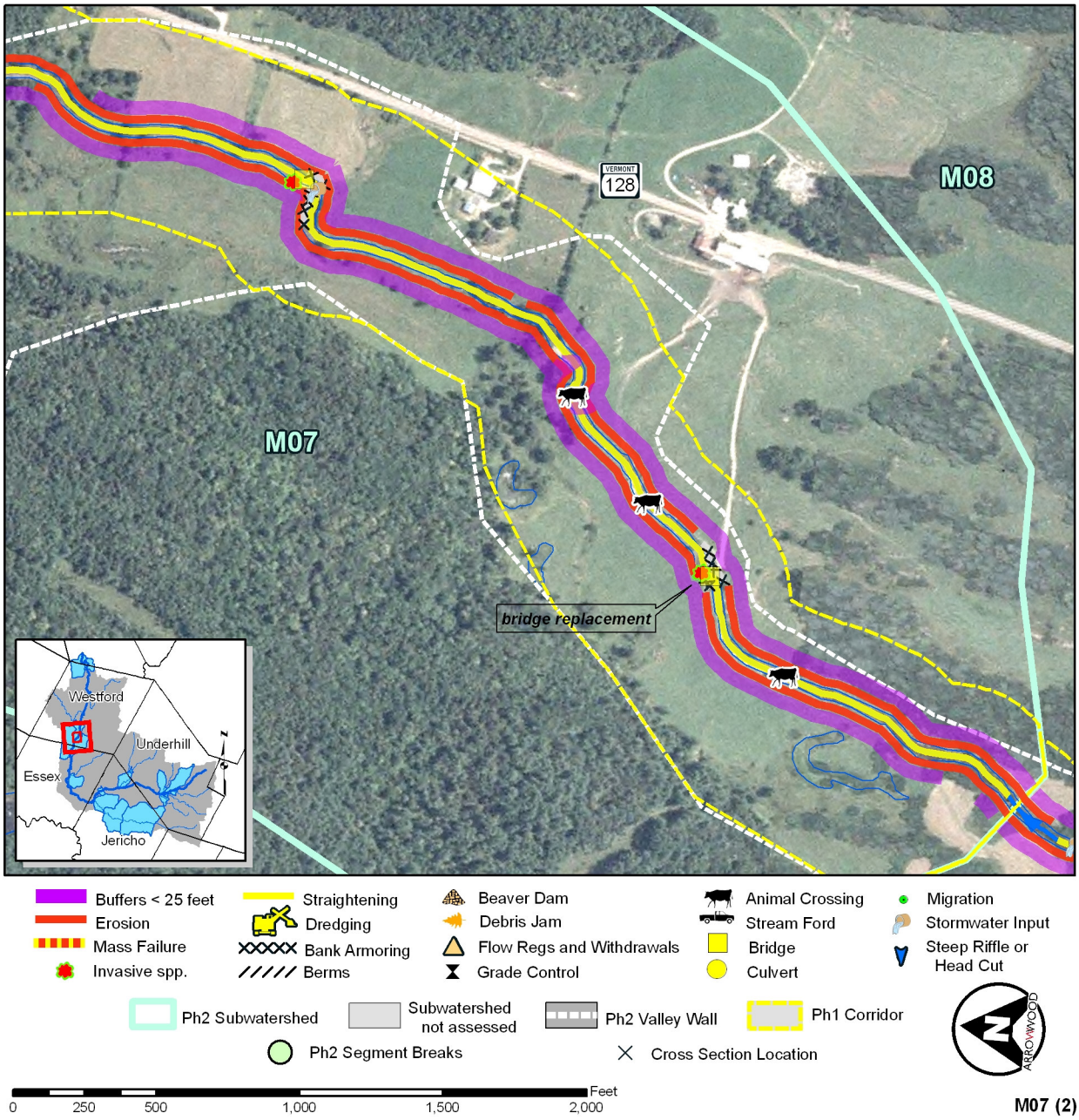


Figure k. Reach M07 Inventory Map

Figure l. Channel at cross section

Preliminary project recommendations are presented in the following table.

M07 Summary Data

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Table 9c. Reach M07 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M07	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
M07	Plant Stream Buffers/Relocate Pasture Fencing	Contact landowners, investigate possible grant programs for plantings; organize volunteers to relocate fences from streambank and restrict cattle access to stream
M07	Bridge replacement (Upstream end of segment, 18' wide)	Very narrow, undersized farm bridge creating a pinch point for stream. Contact landowner and research grant possibilities
M07	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

Figure m. Channel constriction, potential replacement project

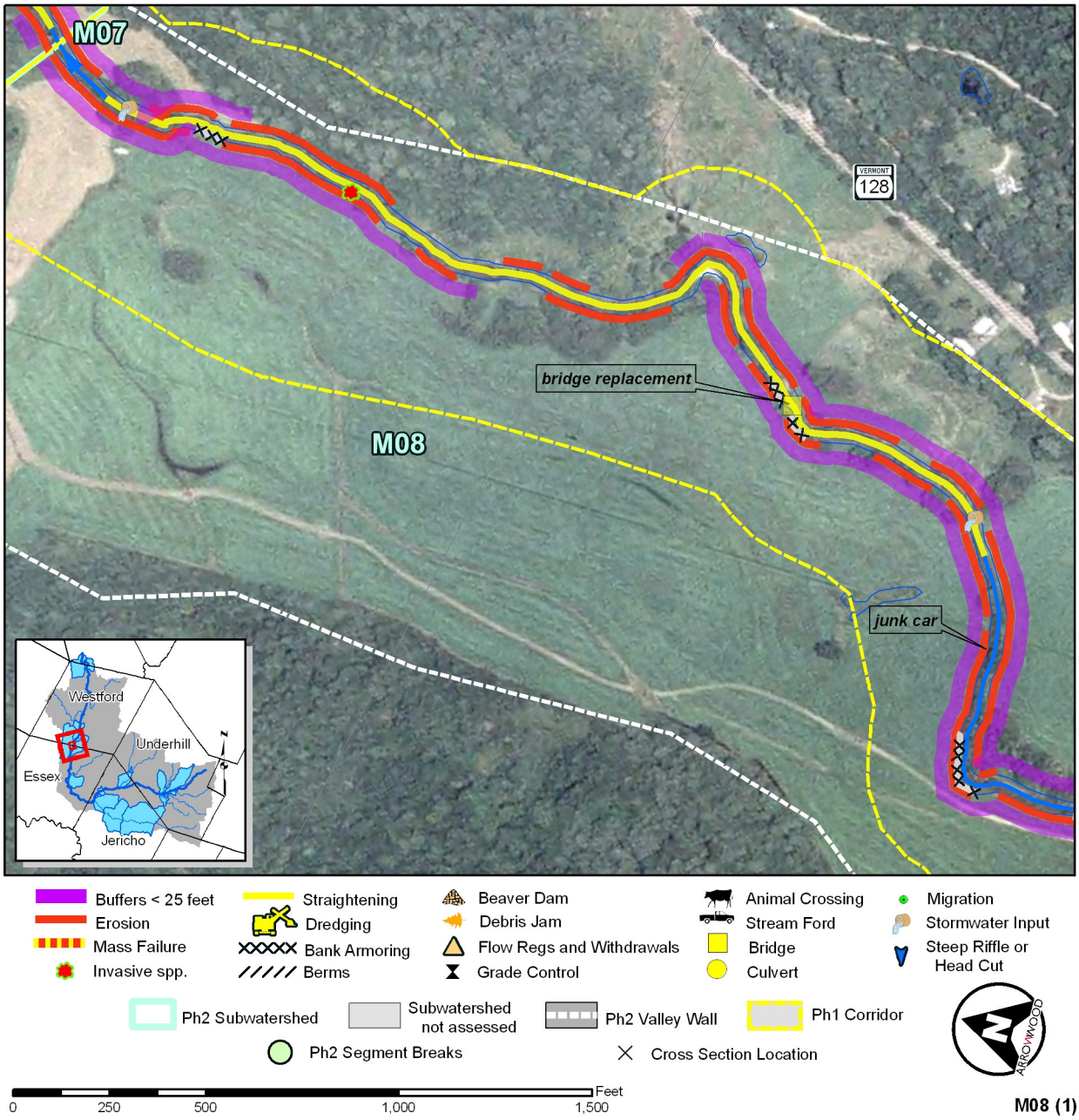


Figure n. Reach M08 Inventory Map

Figure o. Channel at cross section

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 9d. Reach M08 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M08	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
M08	Dump Cleanup (one junk car frame)	Contact landowner, organize volunteers, arrange for proper disposal.
M08	Structure repair/removal (upstream of Pettingill Road crossing)	Undersized and undermined bridge. Abutments are falling into the stream from undermining. Maybe an old railroad bridge? Contact landowner and research grant possibilities
M08	Structure repair/removal (downstream of Pettingill Road crossing)	Undersized bridge. Undermined by scour. Contact landowner and research grant possibilities
M08	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

Figure p. Undermining abutments at structure downstream of junk car and Pettingill Road.

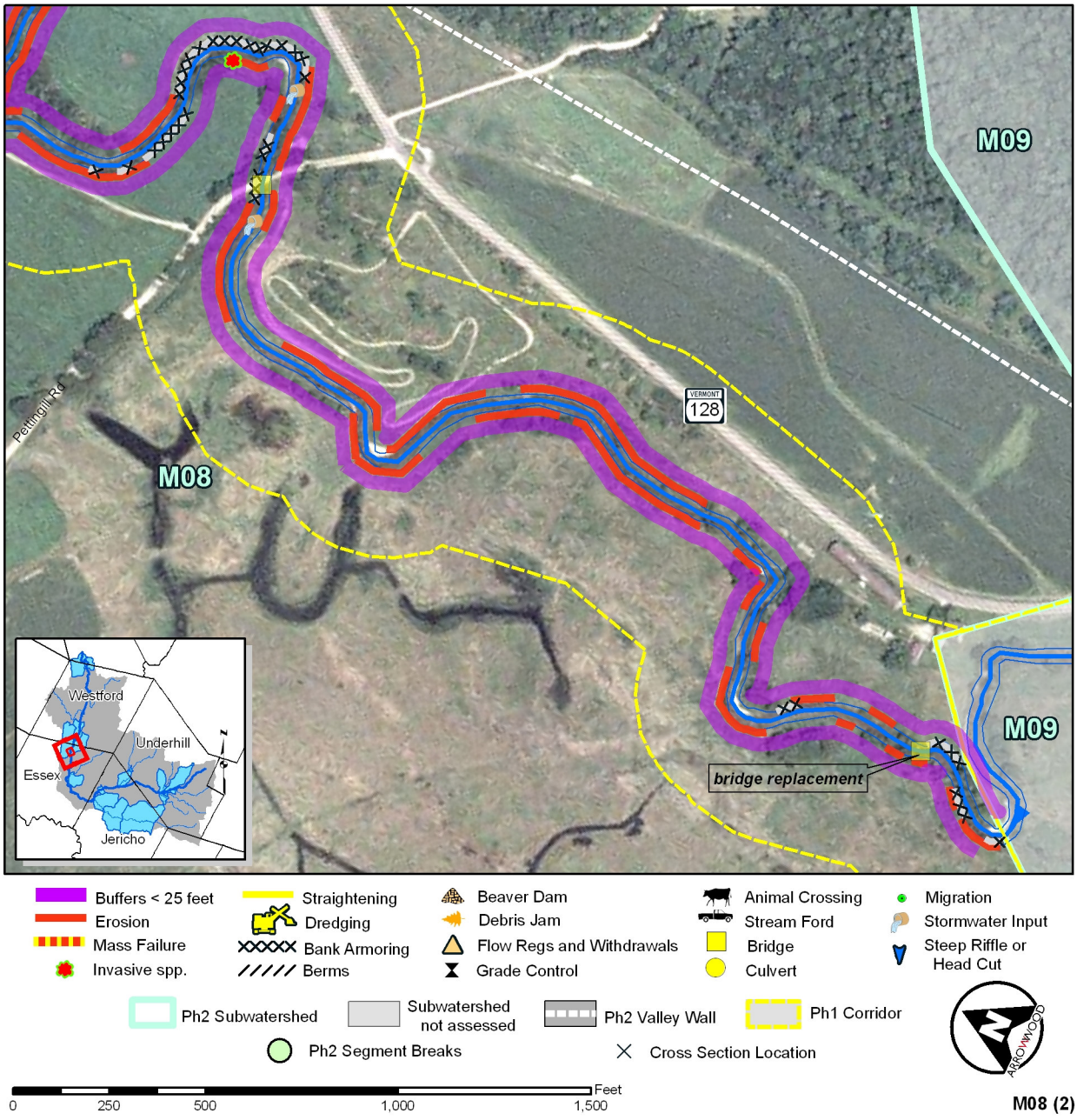


Figure q. Reach M08 Inventory Map

Figure r. Left abutment of recommended bridge replacement project just downstream of M09 reach boundary

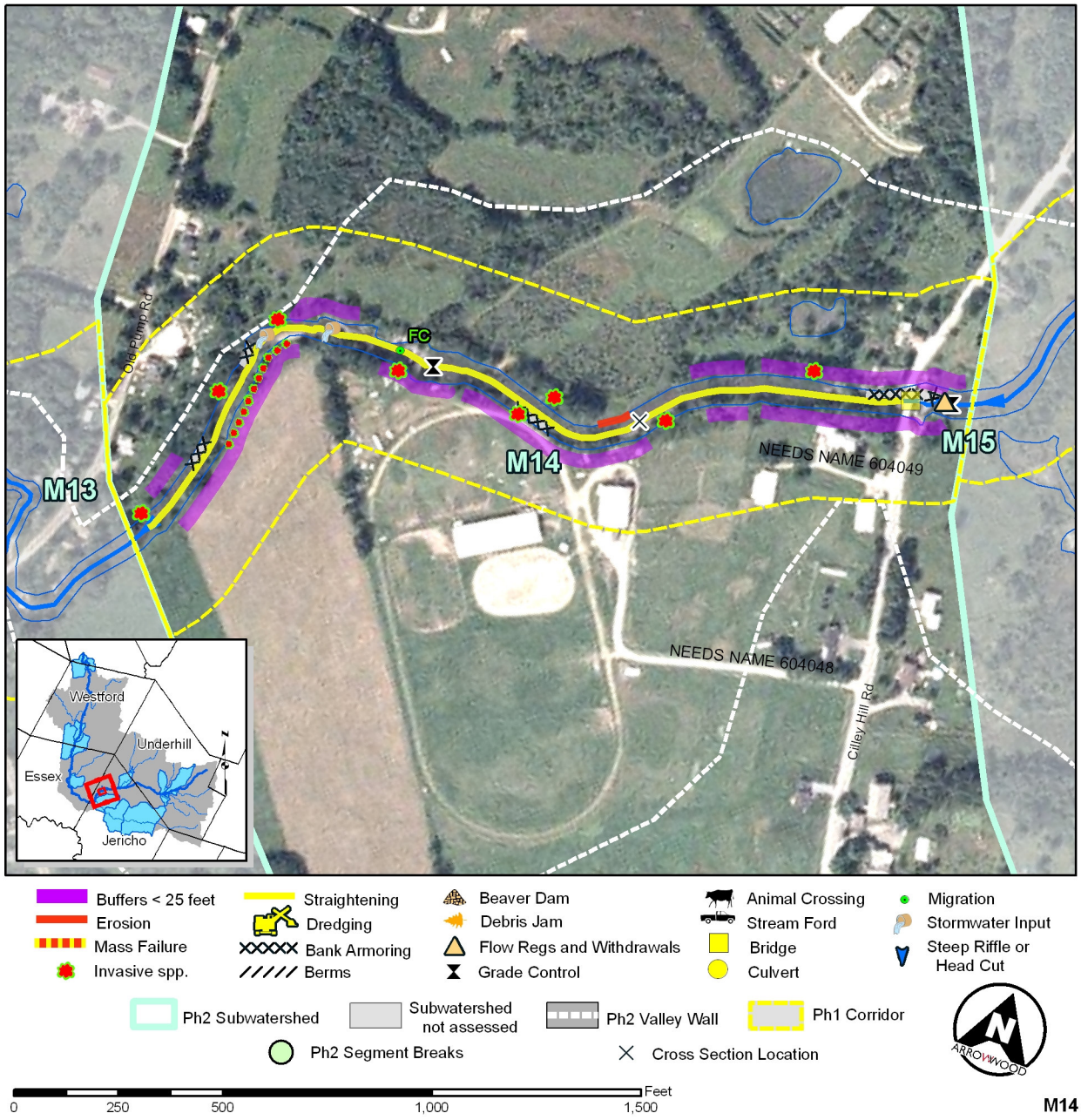


Figure s. Reach M14 Inventory Map

Figure t. Dam/Grade control upstream of Rte 15 crossing

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Preliminary project recommendations are presented in the following table.

Table 9e. Reach M14 Projects and Practices Table

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

Figure u. Encroachment/hardbank downstream of Rte 15 dam

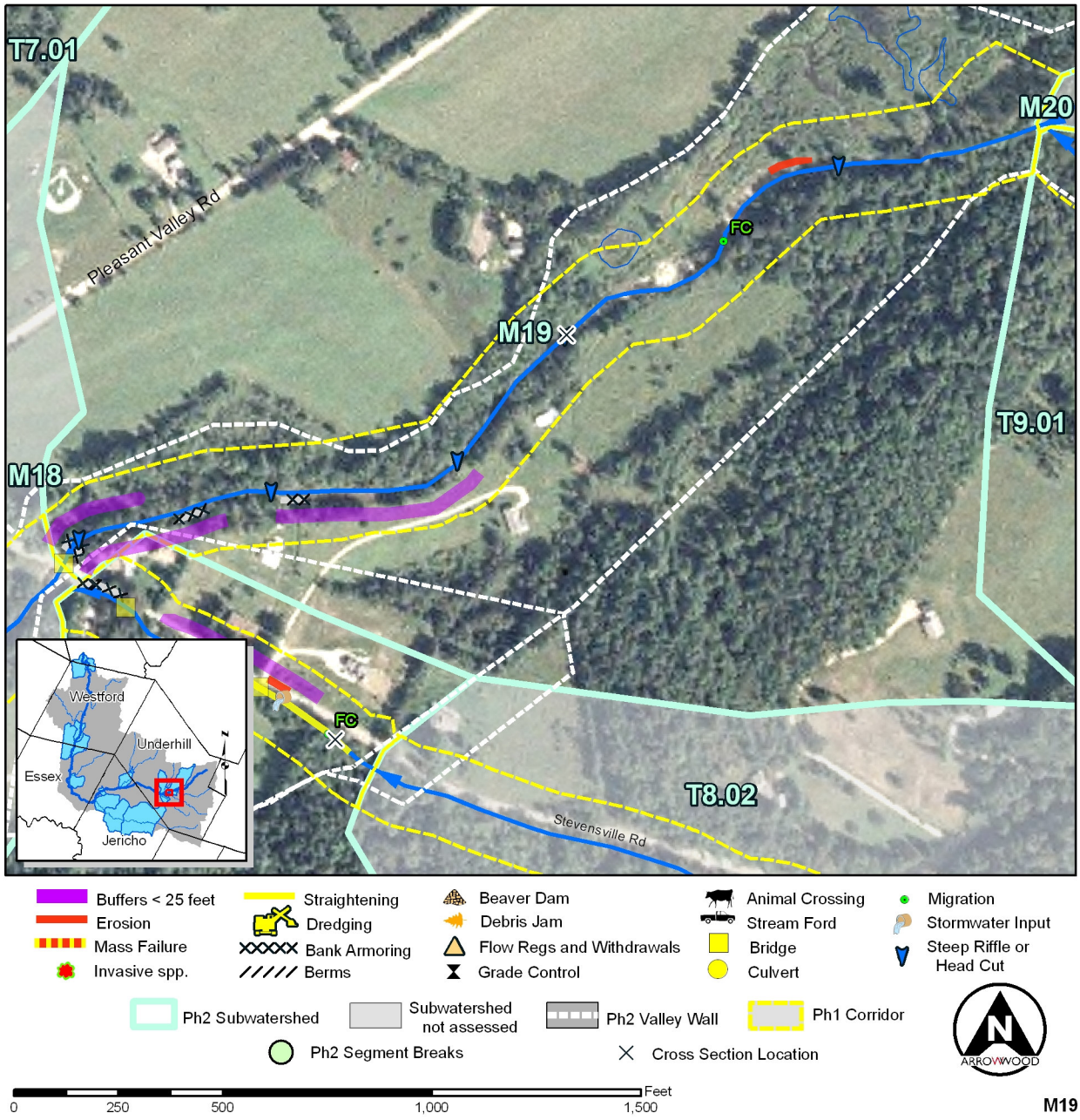


Figure v. Reach M19 Inventory Map

Figure w. Encroachment on banks of stream.

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

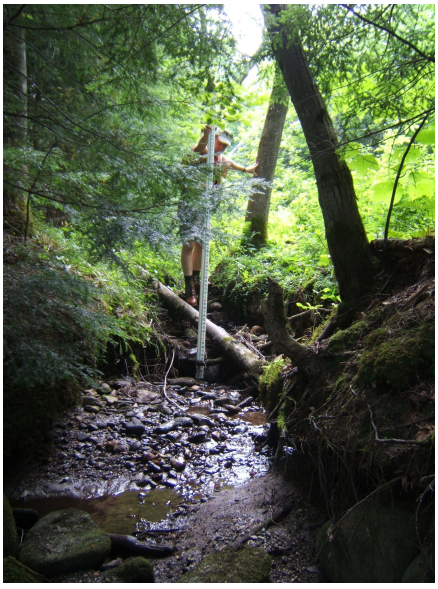
Poor Buffers
Erosion
Mass Failures
Encroachments
Straightening
Revetments
Constrictions
Rejuvenating Tributaries
Dredging
Stormwater inputs
Headcuts

Preliminary project recommendations are presented in the following table.

Table 9f. Reach M19 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M19	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
M19	Plant Stream Buffers (left bank downstream)	Contact landowners, investigate possible grant programs for plantings

Figure x. Rejuvenating tributary



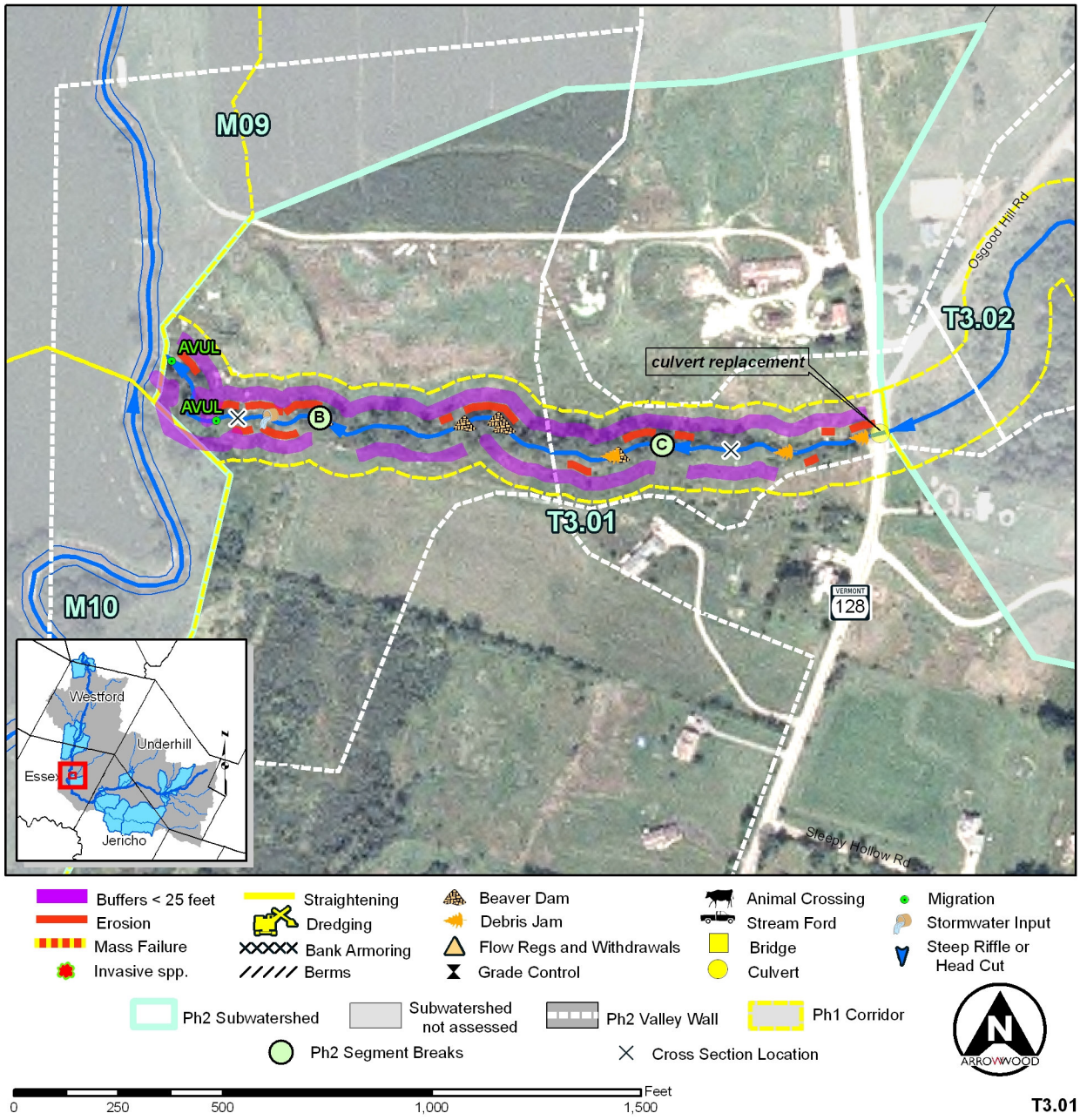


Figure y. Reach T3.01 Inventory Map

Figure z. T3.01C cross section, looking upstream at poor buffers

T3.01a Summary Data
Abbey Brook

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

T3.01b Summary Data
*Impounded by beavers

Reach/Segment Length	888 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	NA
Geomorphic Condition	NA
Channel Evolution Stage	NA
Adjustment Process	NA
Habitat Condition	NA
Stream Sensitivity	NA

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

T3.01c Summary Data

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Preliminary project recommendations are presented in the following table.

Table 9g. Reach T3.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T3.01a,b,c	Plant Stream Buffers	Contact landowner, investigate possible grant programs for plantings
T3.01c	Structure Repair/Replacement	Severely undermined and undersized culvert at Rte 128 crossing. Check with AOT for replacement potential.

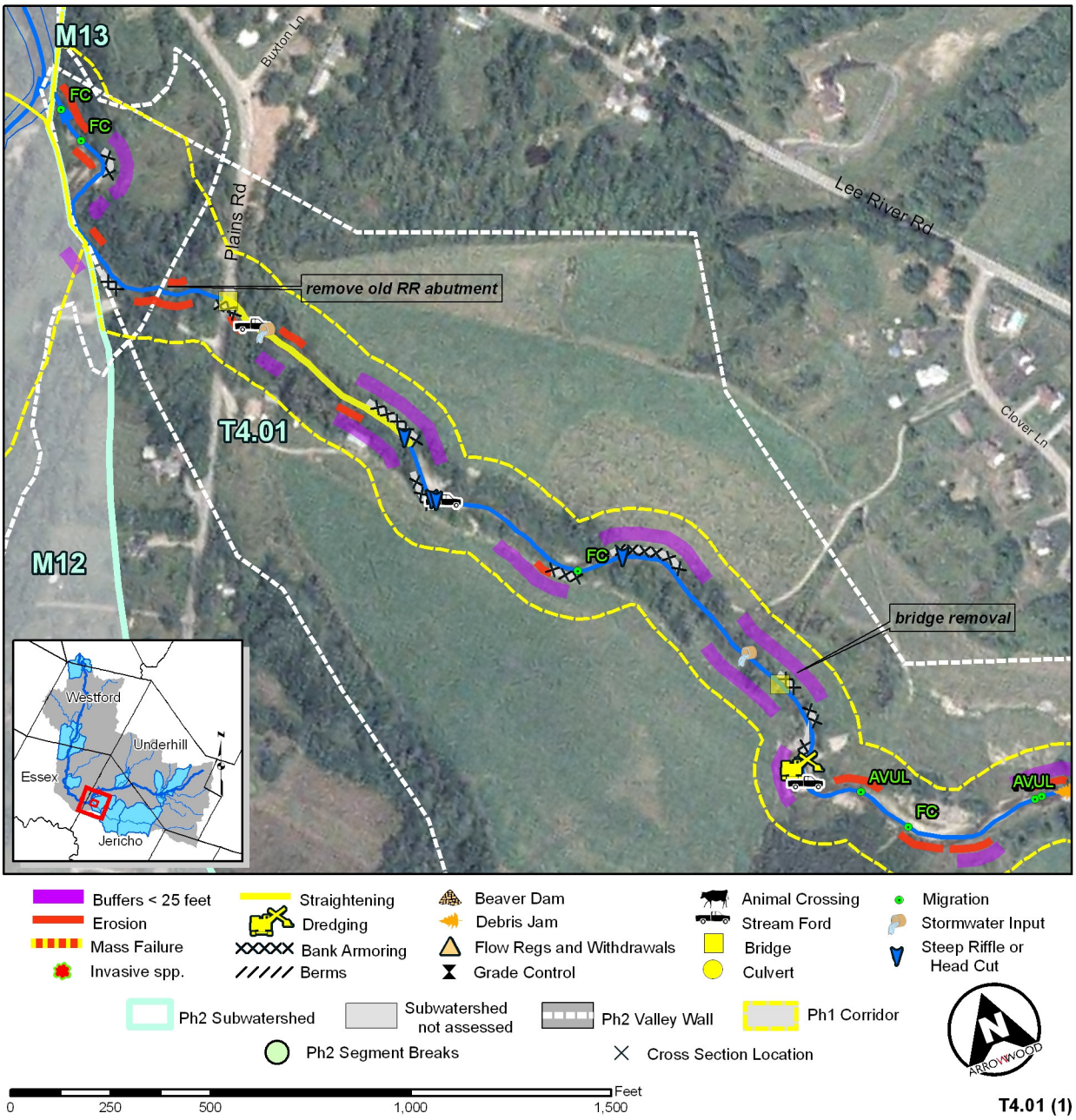


Figure aa. Reach T4.01 Inventory Map

T4.01 Summary Data Lee River	
Reach/Segment Length	6807 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ planform changes
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 9h. Reach T4.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T4.01	Plant Stream Buffers	Contact landowner, investigate possible grant programs for plantings
T4.01	Structure Removal (old bridge abutment downstream of Plains Road)	Contact landowner and research grant possibilities.
T4.01	Structure Removal (steel bridge upstream of Plains Road bridge)	There are two bridges side by side. The steel bridge is out of use and significantly undersized. Contact landowner, research grant possibilities for removal and disposal.
T4.01	Eliminate active dredging	Contact landowner. Educate about impacts of channel manipulation

Figure bb. Recommended structure removal, steel bridge out of use upstream of Plains Road bridge

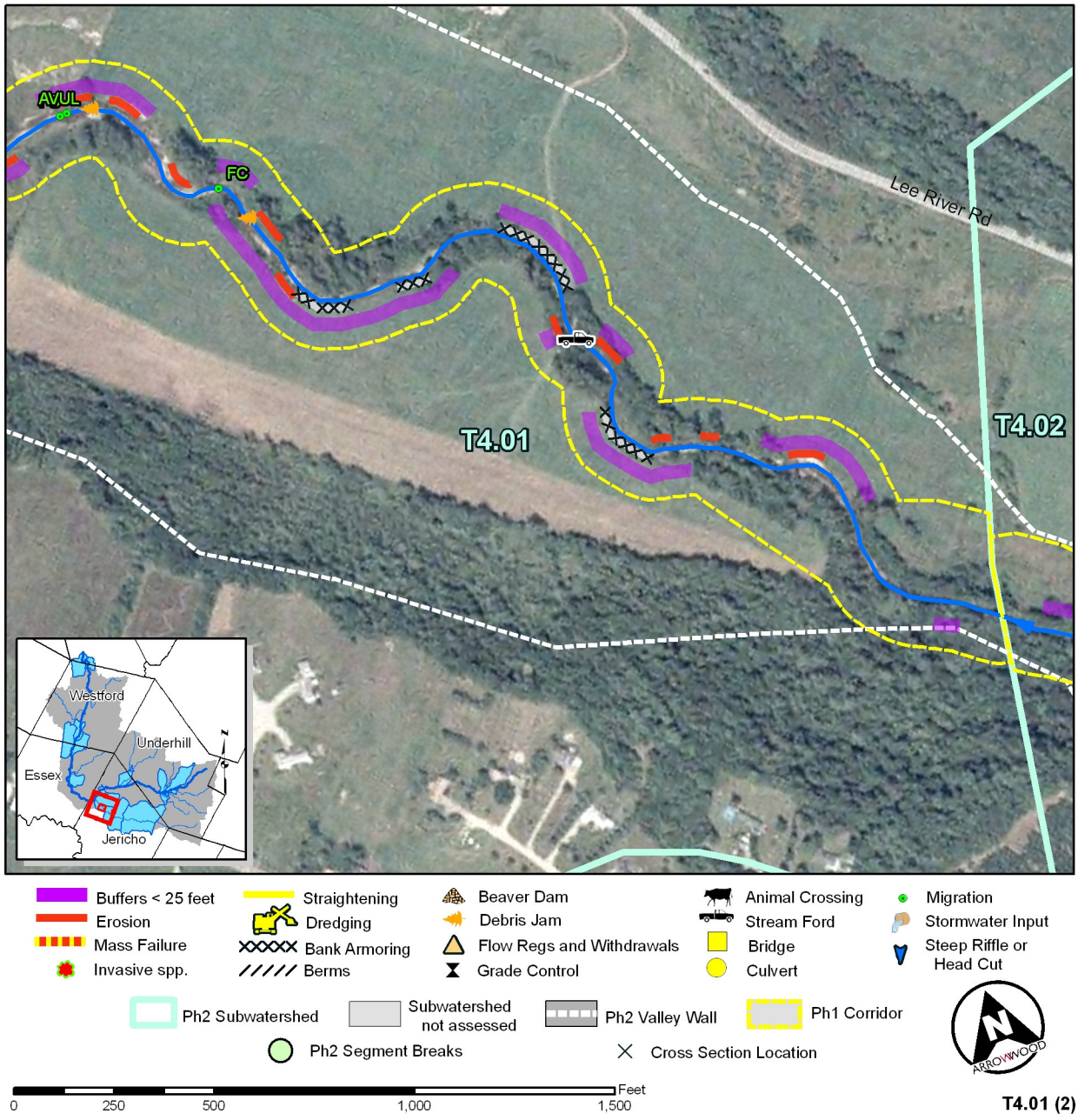


Figure cc. Reach T4.01 Inventory Map

Figure dd. Stream ford

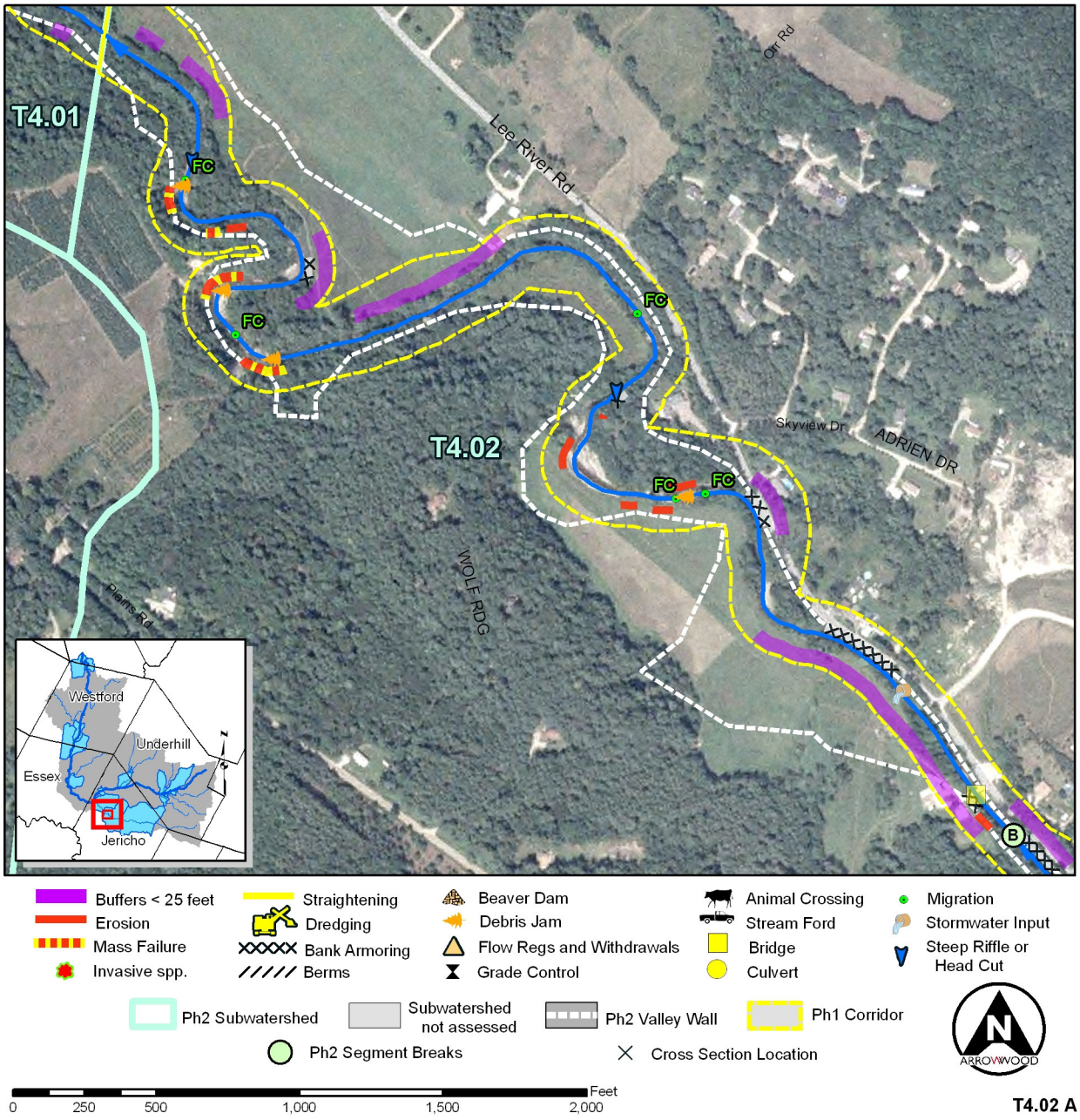


Figure ee. Reach T4.02 A Inventory Map

Figure ff. Mass failure in T4.02a

T4.02A Summary Data Lee River	
Reach/Segment Length	6373 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ minor widening
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

T4.02B Summary Data Lee River	
Reach/Segment Length	757 ft
Valley Confinement	Narrow
Reference Stream Type	C4
Existing Stream Type	B4
Geomorphic Condition	Fair
Channel Evolution Stage	IV
Adjustment Process	Minor adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Figure gg. T4.02 Segment B channel cross section, upstream to downstream

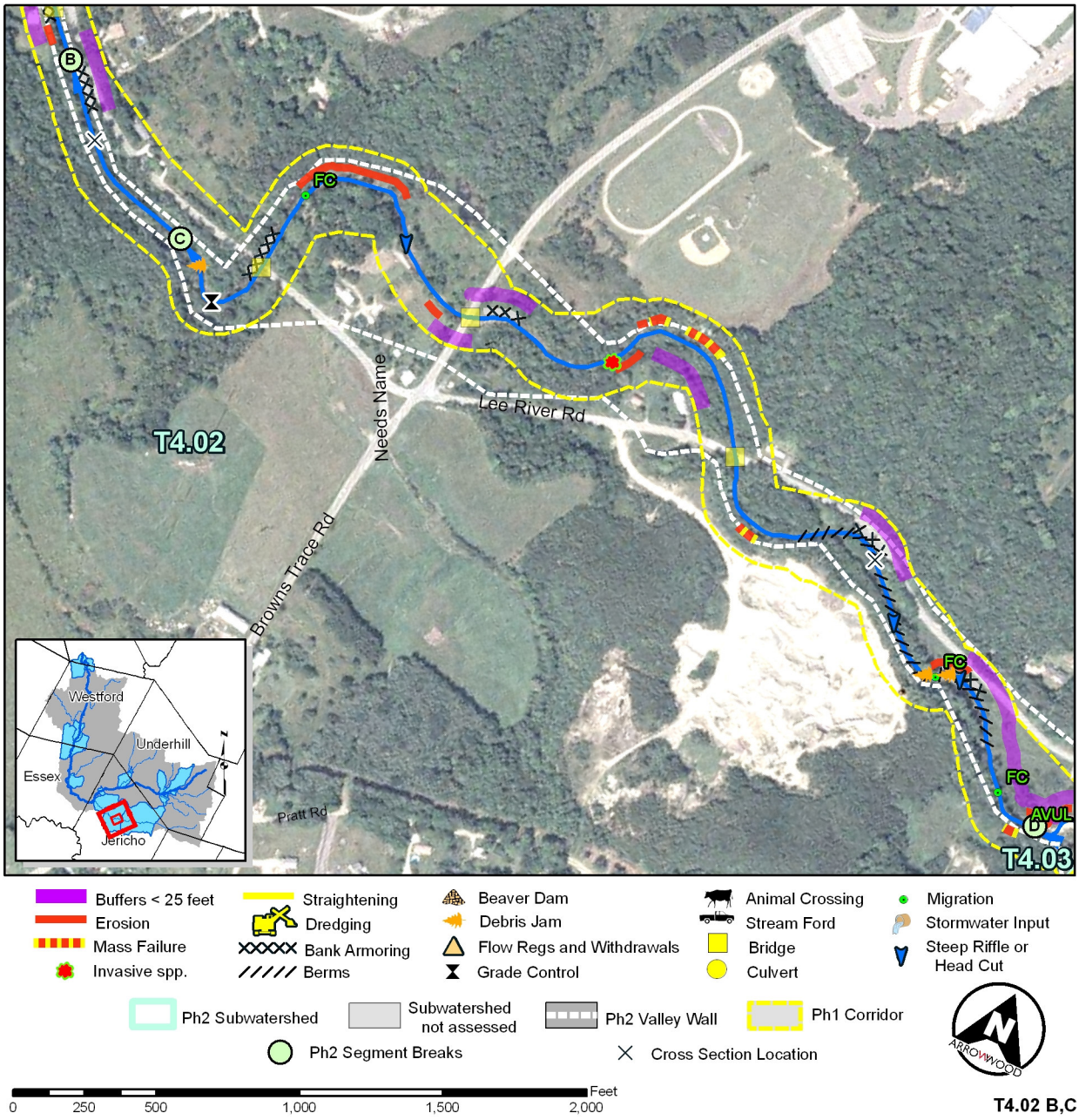


Figure hh. Reach T4.02 Inventory Map

Figure ii. Segment C debris jam and sediment deposition

T4.02C Summary Data Lee River	
Reach/Segment Length	4904 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ widening
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Preliminary project recommendations are presented in the following table.

Table 9i. Reach T4.02 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T4.02a,c,d	Plant Stream Buffers	Contact landowner, investigate possible grant programs for plantings
T4.02c	Berm Removal	Conduct additional field investigation; contact landowner
T4.02c	Erosion controls	Contact sand/gravel pit to discuss installation of silt fences and create larger buffers to stream
T4.02c	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

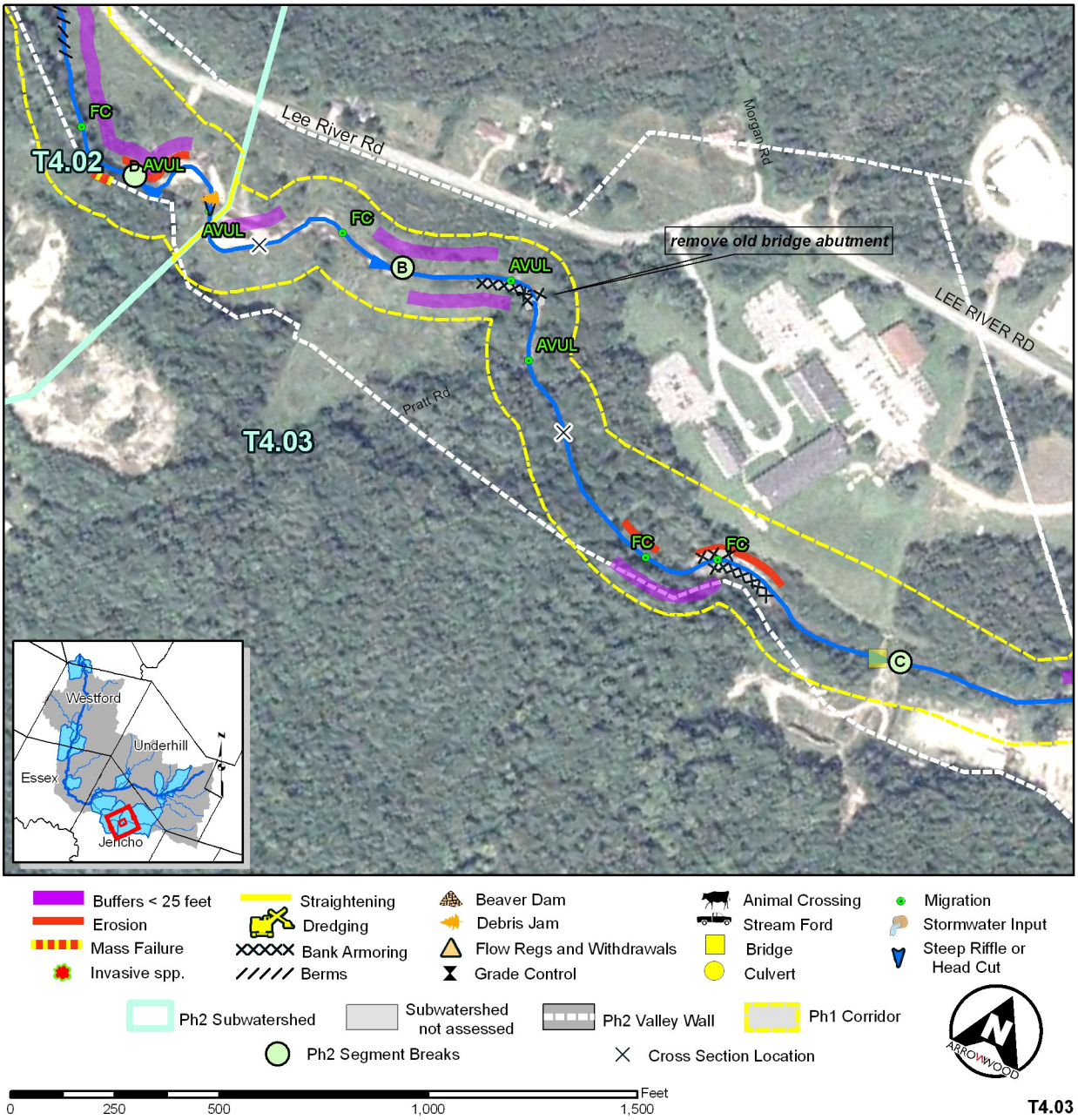


Figure jj. Reach T4.03 Inventory Map

Figure kk. Segment A at channel cross section, sediment deposition and debris

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

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

*No property access

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Table 9j. Reach T4.03 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T4.03 b	Structure removal (old bridge abutment just upstream of A/B segment break)	Contact landowner, research grant possibilities for removal and disposal.

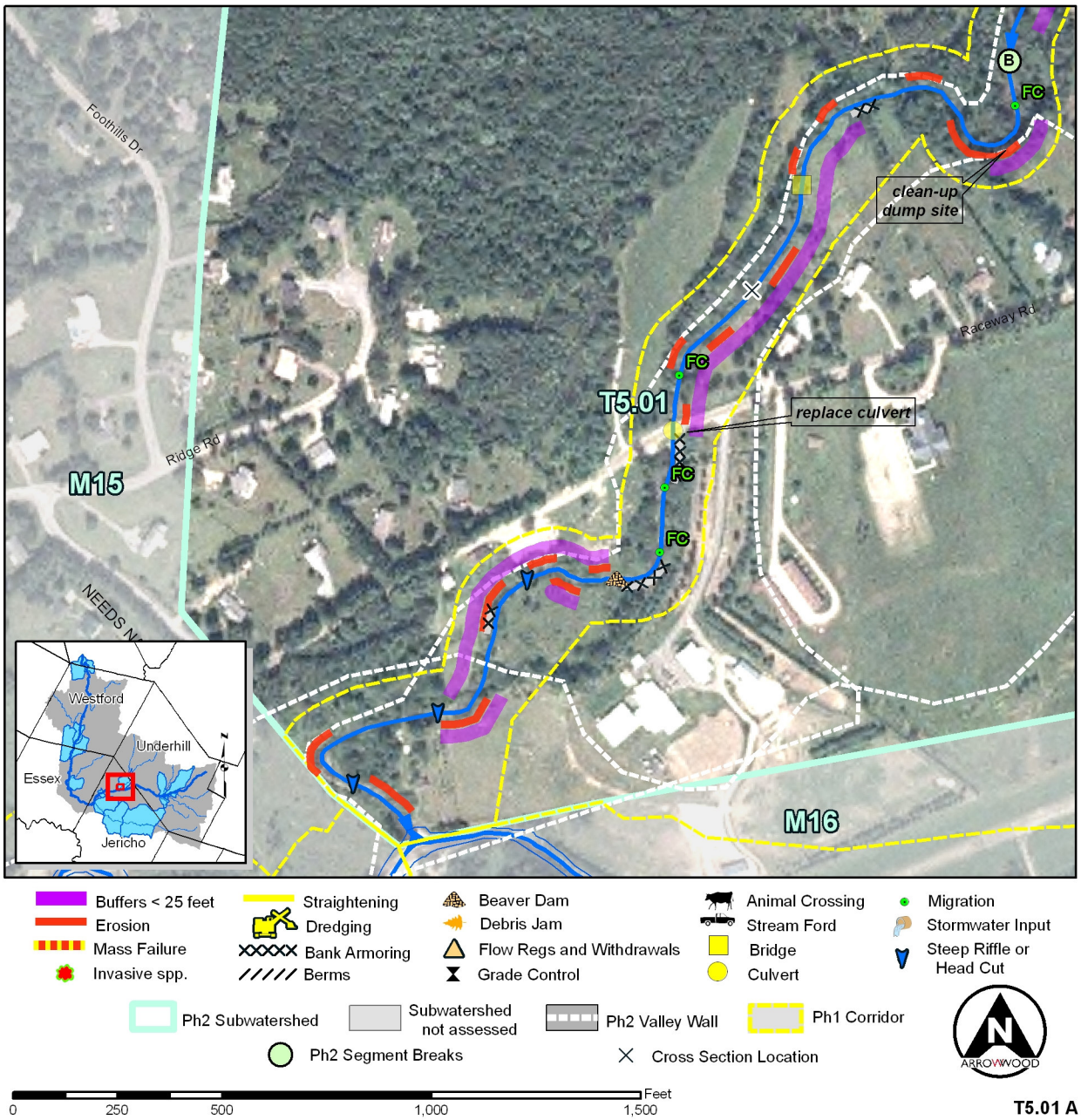


Figure ll. Reach T5.01a Inventory Map

T5.01a The Creek: Summary Data	
Reach/Segment Length	3277 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	II
Adjustment Process	Degradation/ planform changes
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

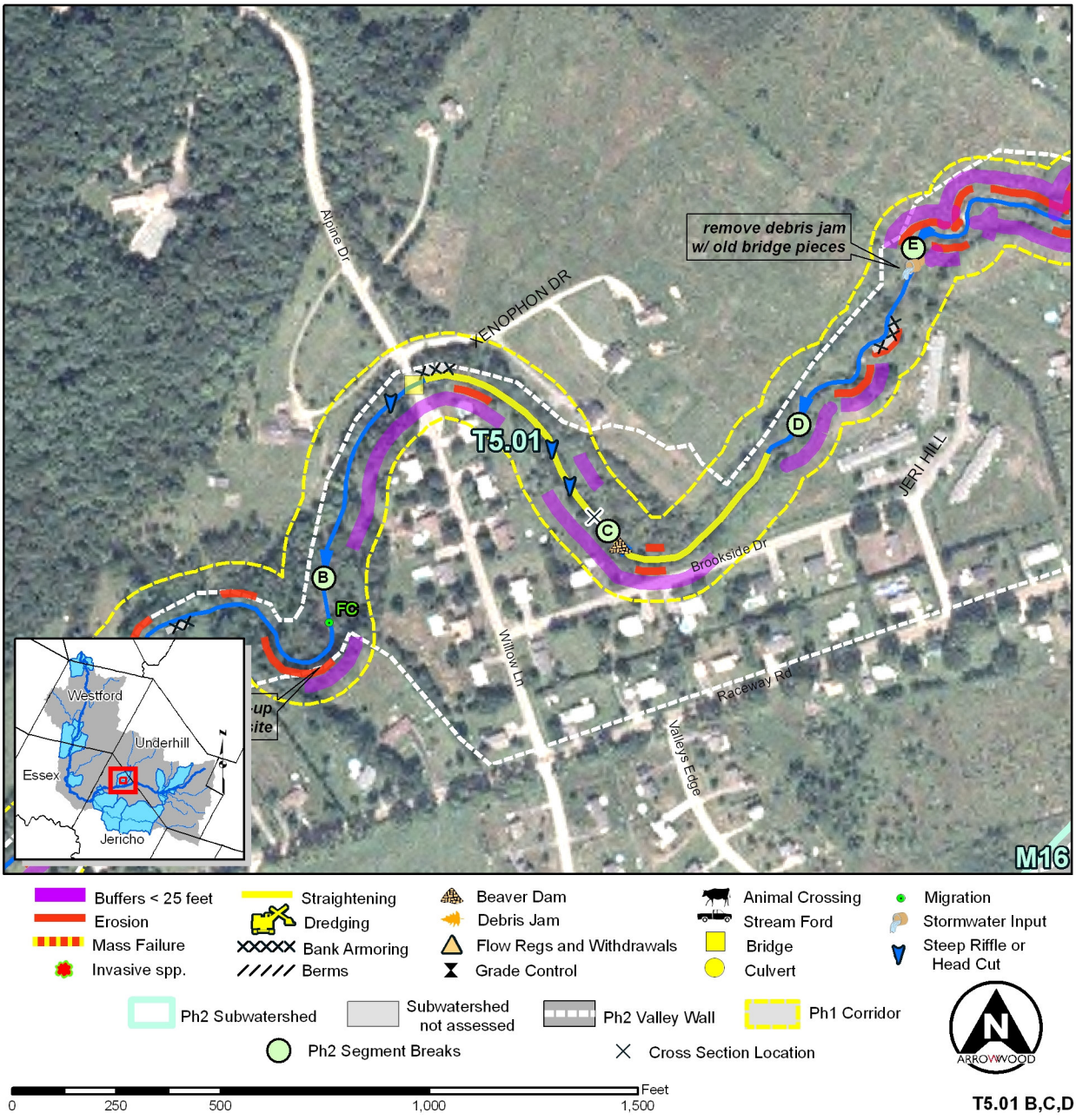


Figure mm. Reach T5.01 B,C,D Inventory Map

T5.01b Summary Data
The Creek

Reach/Segment Length	1180 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	E3
Geomorphic Condition	Good
Channel Evolution Stage	IV
Adjustment Process	Minor adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

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

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

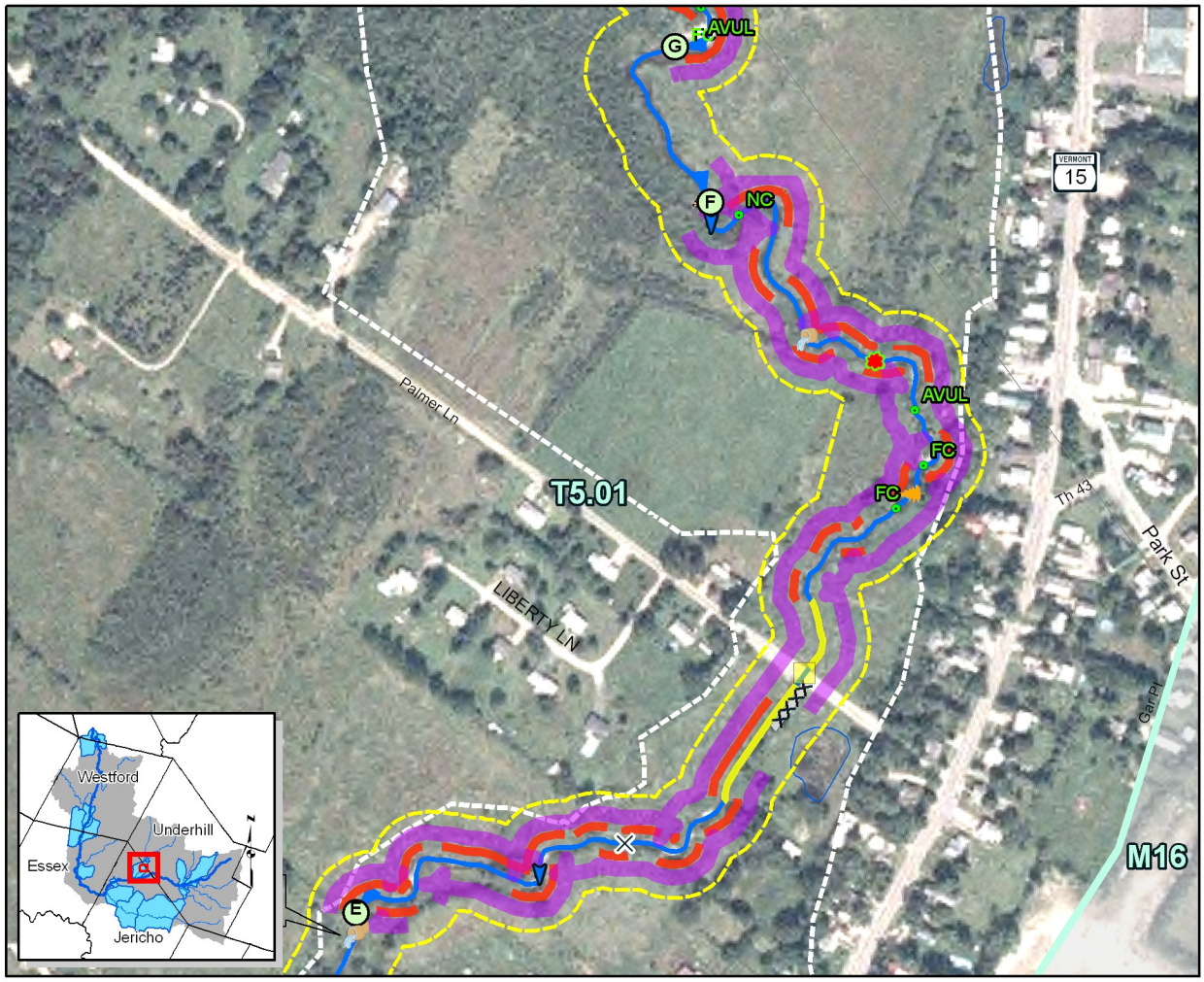
T5.01d Summary Data
The Creek

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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



T5.01 E,F

T5.01e Summary Data
The Creek

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

Habitat Stressors

- Invasive Plants
- Dump Sites
- Animal Crossings
- Dredging
- Poor Stream Bank Vegetation

Reach Stressors

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

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

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Figure nn. Segment A beaver dam

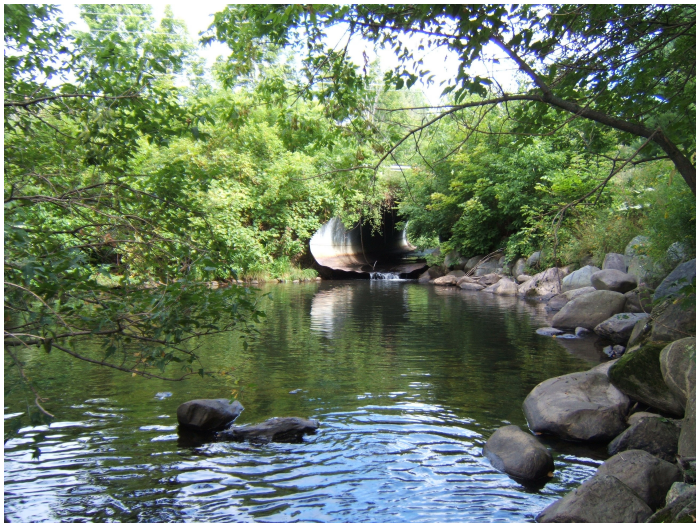
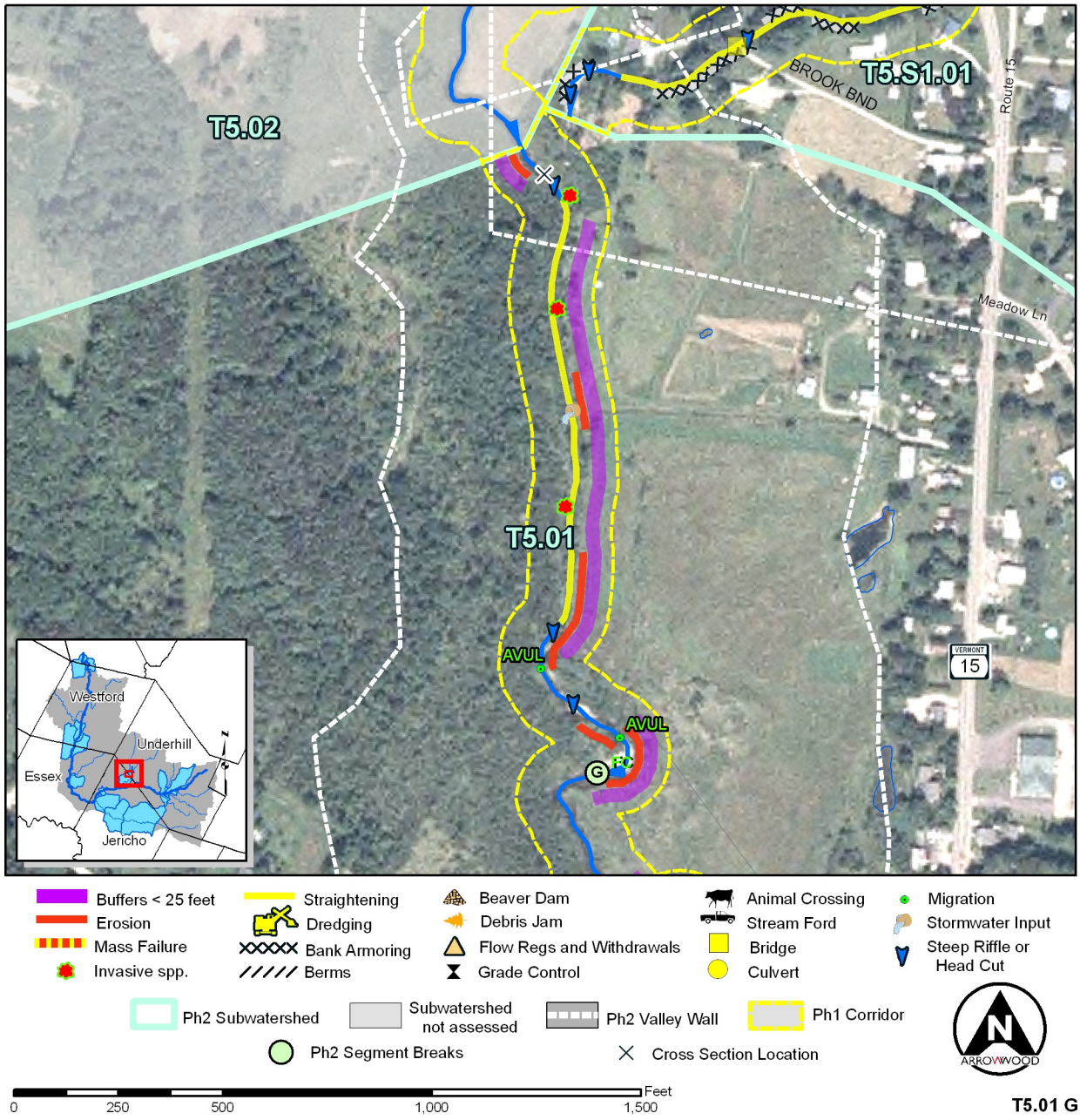


Figure oo. Segment A recommended culvert replacement project



T5.01 G

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 9k. Reach T5.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T5.01 a,b,c,d,e	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T5.01 a,b,c,d,e,g	Plant Stream Buffer	Contact landowner, investigate possible grant programs for plantings
T5.01a	Arrest Head Cut	Conduct additional field investigation
T5.01a	Structure removal/replacement (culvert under Raceway Road)	Steel corrugated pipe which is rotting, stream is flowing under the undersized pipe. Contact the Town, research grant possibilities for replacement
T5.01a, d	Dump site (Segment D has a debris jam with old bridge pieces at the segment break with E)	Contact landowners. Organize volunteers. Research grant possibilities for disposal costs.
T5.01e	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

Figure pp. Segment E. Erosion and poor buffers

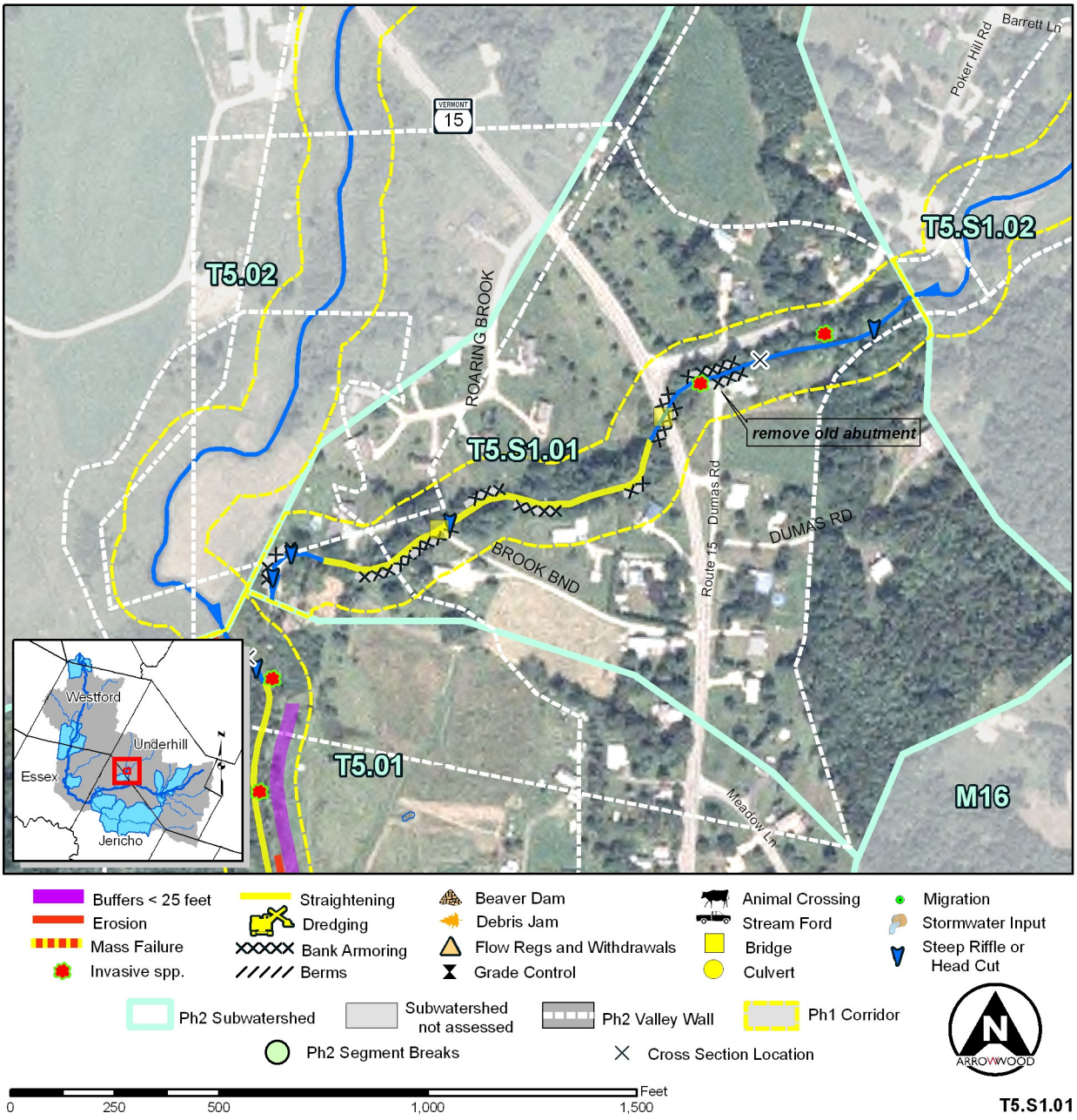


Figure qq. Reach T5.S1.01Inventory Map

Figure rr. Corridor encroachment and streambank revetments along the channel.

T5.S1.01 Summary Data Roaring Brook	
Reach/Segment Length	1892ft
Valley Confinement	Very Broad
Reference Stream Type	E3
Existing Stream Type	E3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Preliminary project recommendations are presented in the following table.

Table 9l. Reach T1.05S1.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.05S1.01	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T1.05S1.01	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
T1.05S1.01	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
T1.05S1.01	Structure removal (old concrete abutment and grade control at Dumas Road)	Contact landowner; further field assessment; organize volunteers; investigate grants for disposal costs

Figure ss. Old concrete abutment recommended for removal

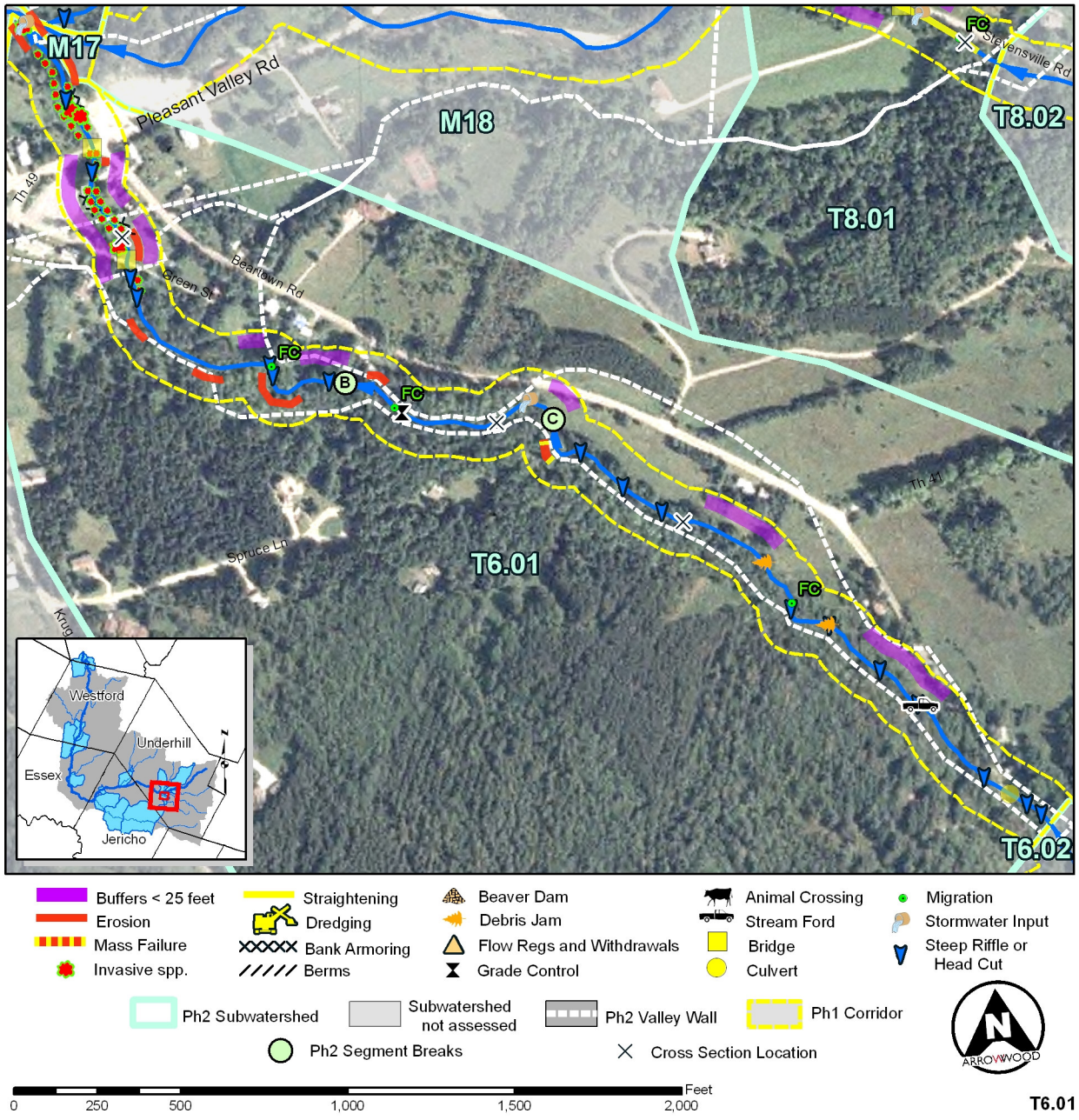


Figure tt. Reach T6.01 Inventory Map

Figure uu. Invasive plants at the T6.01 segment A channel cross section

T6.01a Summary Data Steinhour Brook	
Reach/Segment Length	1748 ft
Valley Confinement	Very Broad
Reference Stream Type	E4
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation,
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

T6.01b Summary Data Steinhour Brook	
Reach/Segment Length	707 ft
Valley Confinement	Semi-confined
Reference Stream Type	E4
Existing Stream Type	F4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Relatively Stable
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

T6.01c Summary Data Steinhour Brook	
Reach/Segment Length	2050 ft
Valley Confinement	Broad
Reference Stream Type	E4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening/ aggradation,
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

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

River Segment ID	Project	Next Steps and other Project Notes
T6.01a,b,c	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T6.01a	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
T6.01a	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

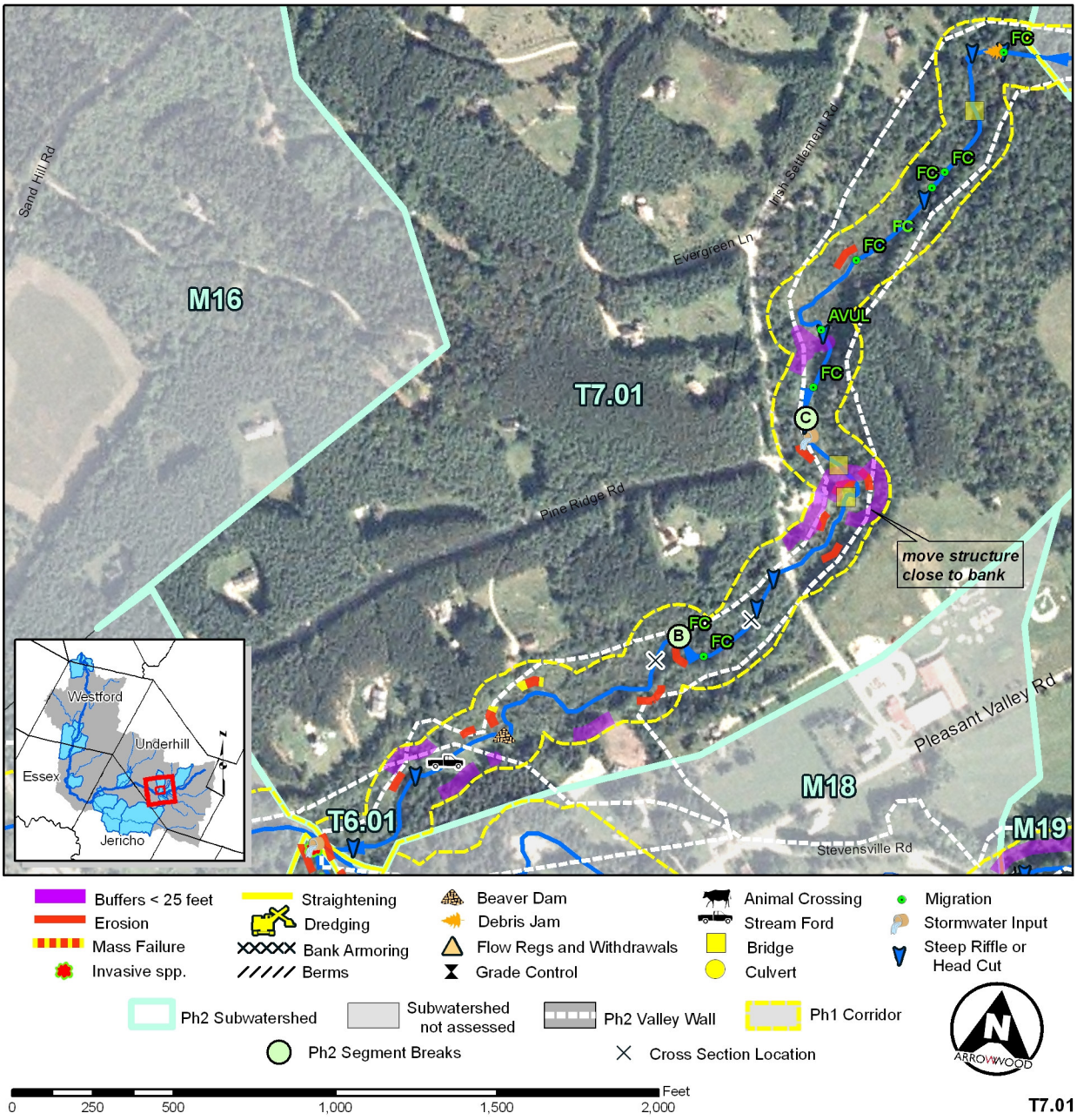


Figure vv. Reach T7.01 Inventory Map

T7.01a Summary Data
Crane Brook

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

T7.01b Summary Data
Crane Brook

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

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

T7.01c Summary Data
Crane Brook

Reach/Segment Length	1673 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	IV
Adjustment Process	Planform changes
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 9n. Reach T7.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T7.01a	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
T7.01a	Arrest Head Cuts	Conduct additional field investigation
T7.01b	Structure removal	Wood shed on the banks/looks like it is going to fall into the stream. Contact landowner to discuss relocation of structure. Organize volunteers.

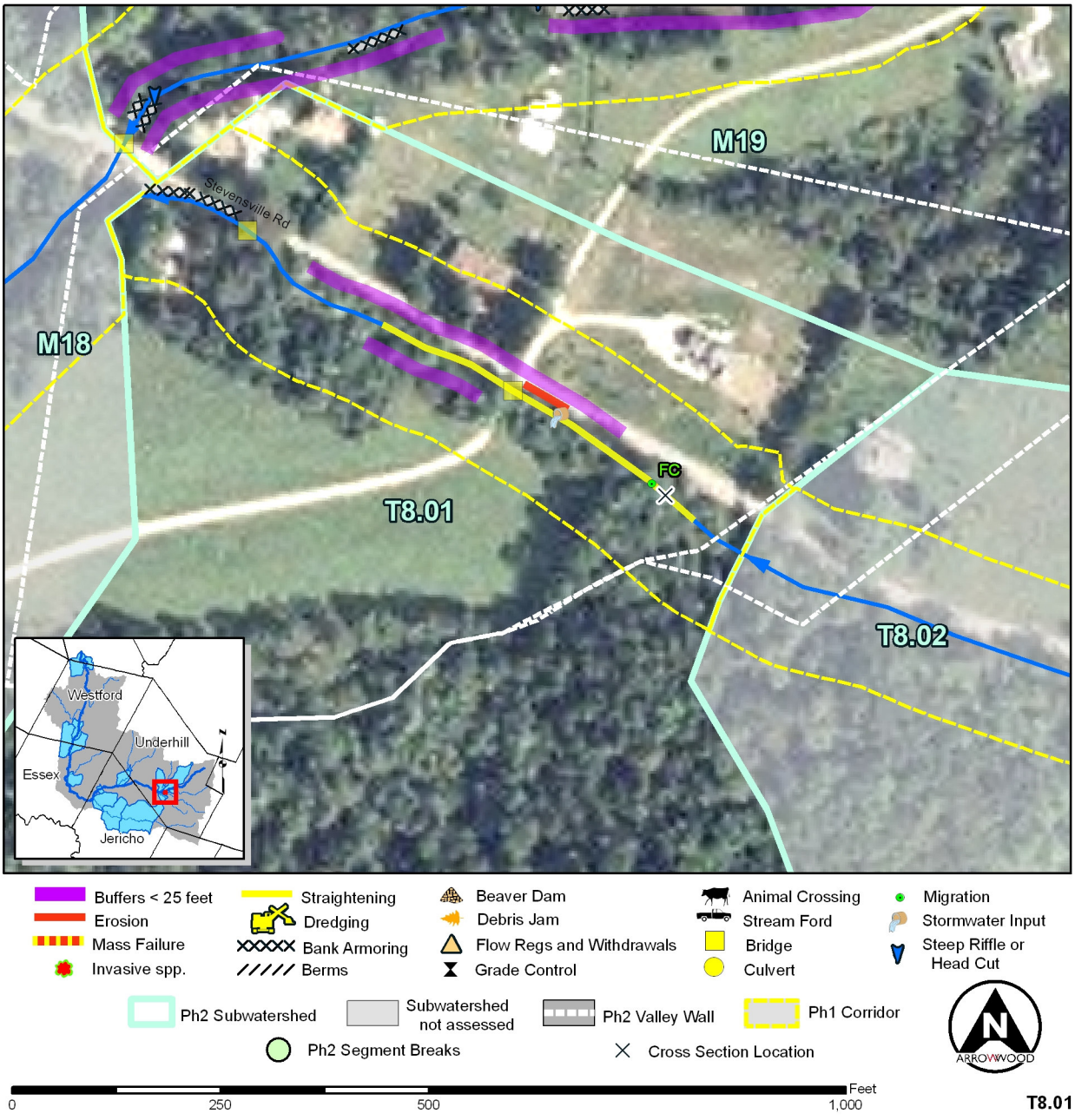


Figure ww. Reach T8.01 Inventory Map

T8.01 Summary Data Clay Brook	
Reach/Segment Length	856 ft
Valley Confinement	Very Broad
Reference Stream Type	B3
Existing Stream Type	B4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Aggradation/ widening
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations: None at this time.

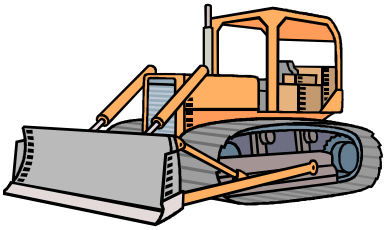
6.0 INDIVIDUAL OR MULTIPLE LANDOWNER INITIATIVES

This Phase 2 assessment has preliminarily identified many potential projects. We encourage coordination of landowner and municipal efforts to approach restoration with an eye to watershed scale dynamics. The Winooski Conservation District can play a critical role in coordinating restoration efforts, and this report aims to facilitate such coordination in a way that can help landowners understand the part their properties play within the context of the entire watershed.

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

An alternative analysis of three restoration and protection plans (as presented in The Vermont Agency of Natural Resources River Corridor Planning Guide, July 11, 2007) is listed below:

1. Active restoration attempts to restore rivers to a geomorphic state of dynamic equilibrium using human constructed meanders, flood plains, and stabilized banks. These types of projects are designed to work within human constraints and, when possible, restore rivers to reference conditions. Active restoration plans tend to have high upfront costs and achieve bank stability in a relatively short time period.



2. Passive restoration allows the stream to return to a natural equilibrium primarily by the removal of human restraints within the river corridor. Over an extended period of time, the stream will regain meanders and access to its floodplain by use of its own energy and watershed input. Active buffer re-vegetation is essential to this approach, along with long term protection of the river corridor. This alternative is less expensive than active restoration, but often requires a longer time period to achieve equilibrium conditions.

3. Active/Passive Combination involves a sequenced combination of active and passive approaches to accommodate the varying constraints that typically occur along a project reach.

A passive restoration approach is generally recommended for the majority of the Browns River watershed study area due to low cost, moderate land-use conflicts, and high to extreme stream sensitivity. The primary goal would be regaining access to floodplains and reestablishment of stream meander geometry, both intended as a means of diffusing stream power and permitting greater nutrient and sediment storage within the watershed. Active restoration may be appropriate in conjunction with passive restoration in limited circumstances, particularly when human constraints present strong limitations to floodplain or meander access on certain portions of properties that may provide these benefits elsewhere.

In an effort to improve habitat and improve water quality, active approaches are recommended for the replacement and removal of select structures (including berms), the removal of dump sites, the restriction of cattle access to streams, the stopping of in stream mechanical dredging, and the removal/control of invasive plant species. These projects provide an opportunity for

landowners and volunteers to get involved with watershed improvements that will have a direct impact on improving the quality of their treasured local water resources.

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