Phase 2 Stream Geomorphic Assessment Missisquoi River Watershed Mainstem, Jay Branch, and Mud Creek Orleans and Franklin Counties, Vermont

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EXECUTIVE SUMMARY

- Arrowwood Environmental was retained by the Missisquoi River Basin Association (MRBA) to conduct a Phase 2 Stream Geomorphic Assessment of select stream reaches within the Missisquoi River watershed in Orleans and Franklin Counties.

- The Phase 2 study focused on stream reaches on the main stem of the Missisquoi River, the Jay Branch and Mudd Creek primarily within the towns of Troy, Newport, Jay, Richford and Berkshire.

- 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 fair to poor for the 5 reaches assessed under the Phase 2 Assessment for the Main Branch. Of the 8 assessed stream segments under Phase 2, eight were rated fair. The Phase 1 condition ranged from poor to reference on the 10 reaches assessed for the Jay Branch. Of the 14 assessed stream segments under Phase 2, one was rated poor, six were rated fair, six were rated good, and one rated reference. The Phase 1 condition ranged from poor to good on the 9 reaches assessed for Mudd Creek. Of the 13 assessed stream segments under Phase 2, seven rated fair, 5 rated good, and one rated reference.

- 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 8 segments assessed on the Main Branch, one segment was found to be in stage 2, and seven segments were found to be in stage 3. Of the 14 segments assessed on the Jay Branch, five segments

were found in stage 1, eight segments were found in stage 3, and one segment was found in stage 4. Of the 13 segments assessed on Mudd Creek, three segments were found in stage 1, one segment was found in stage 2, and eight segments were found in stage 3. Segments in Stage 1 are relatively stable channels in good to reference geomorphic condition. During stage 2, 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. Thirteen of 35 total segments resulted in a rating of fair for both the RHA and the RGA. Eight of 35 segments resulted in a rating of good or reference for both the RHA and RGA. Nine of the 35 segments scored slightly higher on the RHA than the RGA and five of the 35 segments scored slightly lower on the RHA than the RGA.

- The Bridge and Culvert survey resulted in assessment of 47 structures. Of the 47 structures, only eight were appropriately sized for the channel. The remaining 39 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: 18 reaches
    - Plant Stream Buffers: 18 reaches
    - Arrest Head Cuts: 1 reach
    - Remove Berms: 1 reach
    - Remove or Replace Structures: 10 reaches
    - Restrict Cattle Access: 6 reaches
    - Restrict active stream dredging: 2 reaches
    - Remove Dump Sites: 5 reaches
    - Remove Invasive Plants: 11 reaches

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1.0 INTRODUCTION

Phase I Stream Geomorphic Assessments were conducted by the Northwest Regional Planning Commission (NRPC) for the Mud Creek and Jay Branch study reaches, and by the Northeastern Vermont Development Association and South Mountain Research and Consulting (SMRC) for the Main Branch study reaches. 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. The fieldwork for the Phase 2 assessment was conducted by Arrowwood Environmental. The assessment was completed in the fall of 2007.

In June 2006, the Missisquoi River Basin Association (MRBA), as part of its 2006 River Corridor Restoration and Protection Grant with Vermont Department of Environmental Conservation, extended a Request for Proposals for a Phase 2 Geomorphic Assessment of select stream reaches in Orleans and Franklin Counties. The Phase 2 assessment provides the citizens of the local towns, local watershed organizations, the Vermont Agency of Natural Resources, MRBA 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.

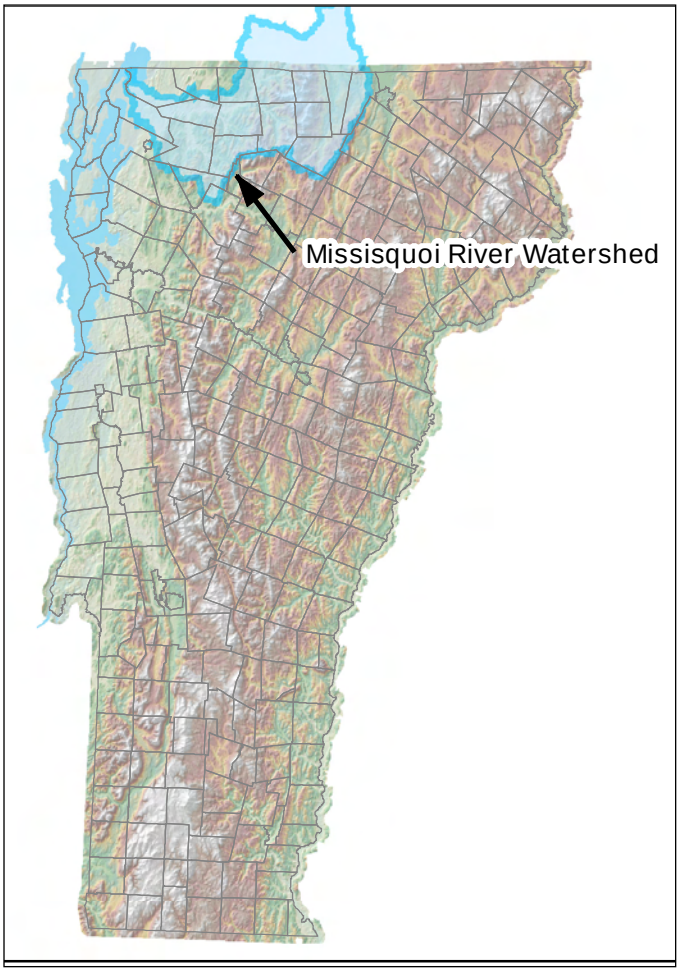


Figure a. Missisquoi River Watershed

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 Missisquoi 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. QA summary reports are provide for each study area in Appendices A,B and C. 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 Missisquoi River Watershed has a watershed size of 855 square miles, of which 619 square miles are in Vermont and 236 square miles are in Canada. The study reaches are located on Mud Creek (9 reaches); Jay Branch (10 reaches); and the main branch of the Missisquoi (5 reaches).

The proposed study areas drain lands primarily found in the following towns:

Mud Creek:	**Jay Branch:**
Troy	**Jay**
Newport	**Troy**
Main Branch:	
Richford	
Berkshire	

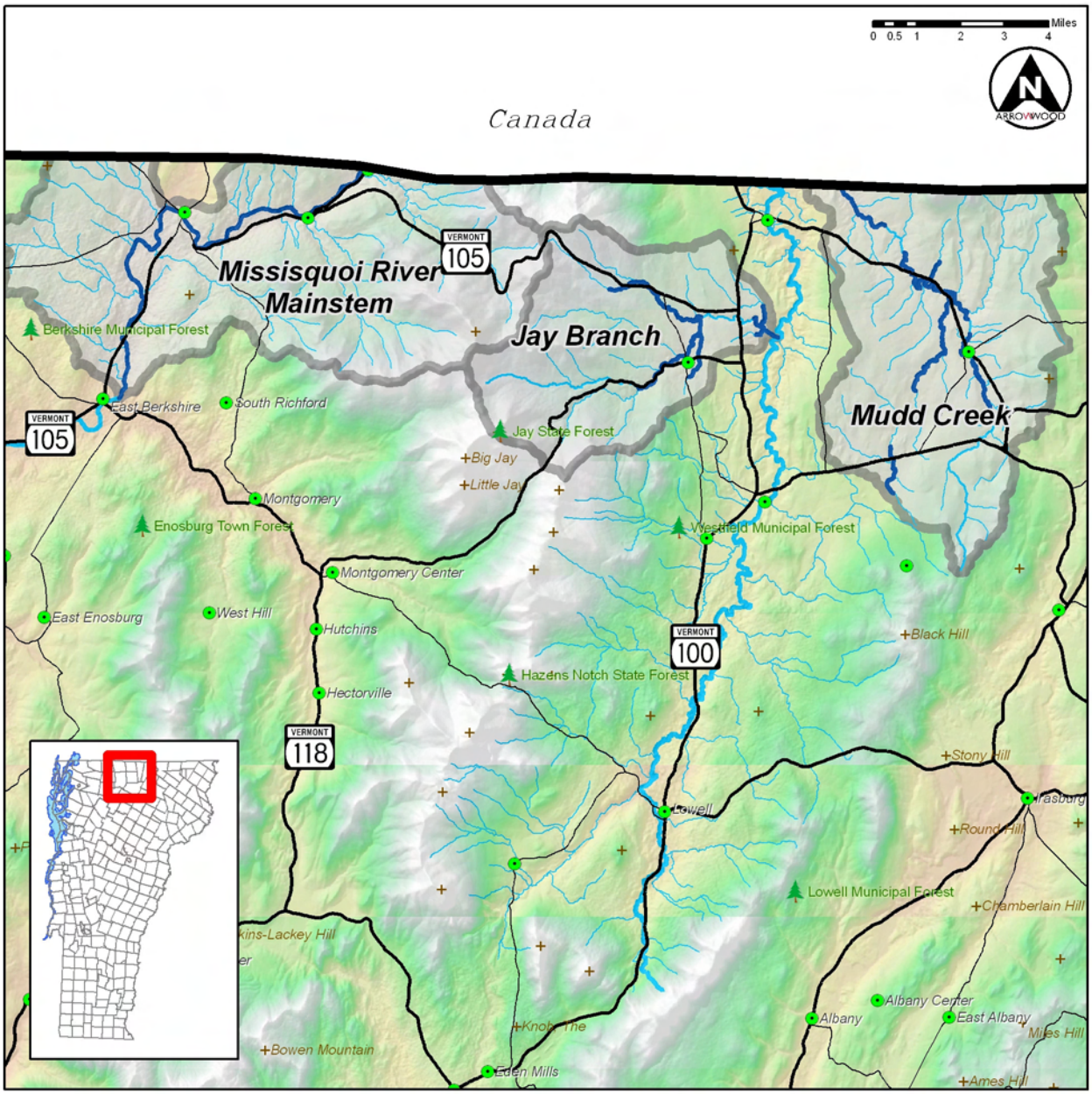


Figure b. Watershed Map of Three Study Areas

For the purpose of geomorphic assessment and corridor planning, the Missisquoi River has been divided into 'reaches,' twenty-four 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 main stem of the Missisquoi River (5 reaches), the Jay Branch (10 reaches) and Mudd Creek (9 reaches).

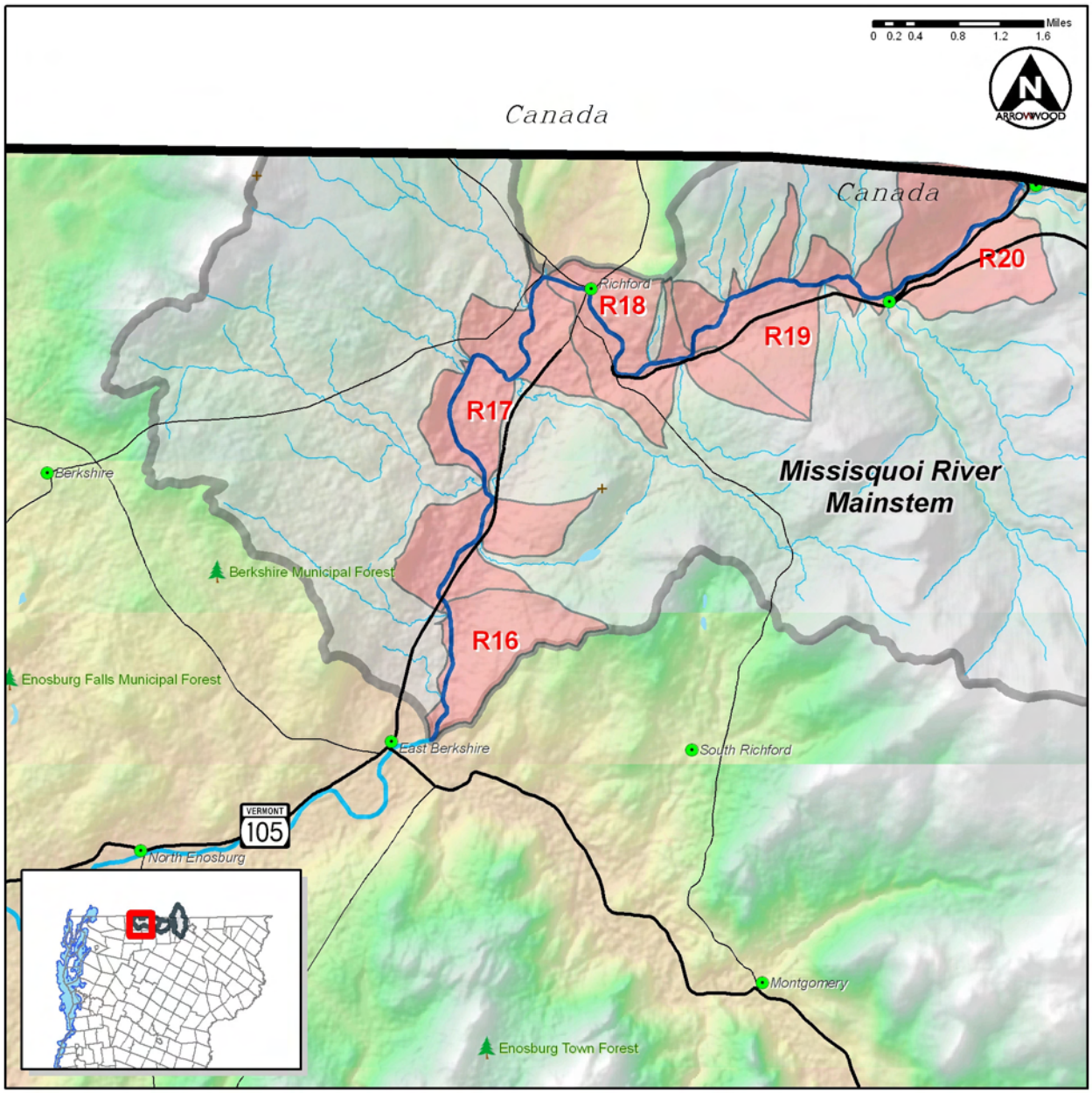


Figure c. Main Branch Reach Location Map

Reach Lengths	Channel Slope
R16: 7,170 ft	**0.18%**
R17: 23,054 ft	**0.08%**
R18: 9,934 ft	**0.40%**
R19: 12,650ft	**0.02%**
R20: 8,859 ft	**0.01%**

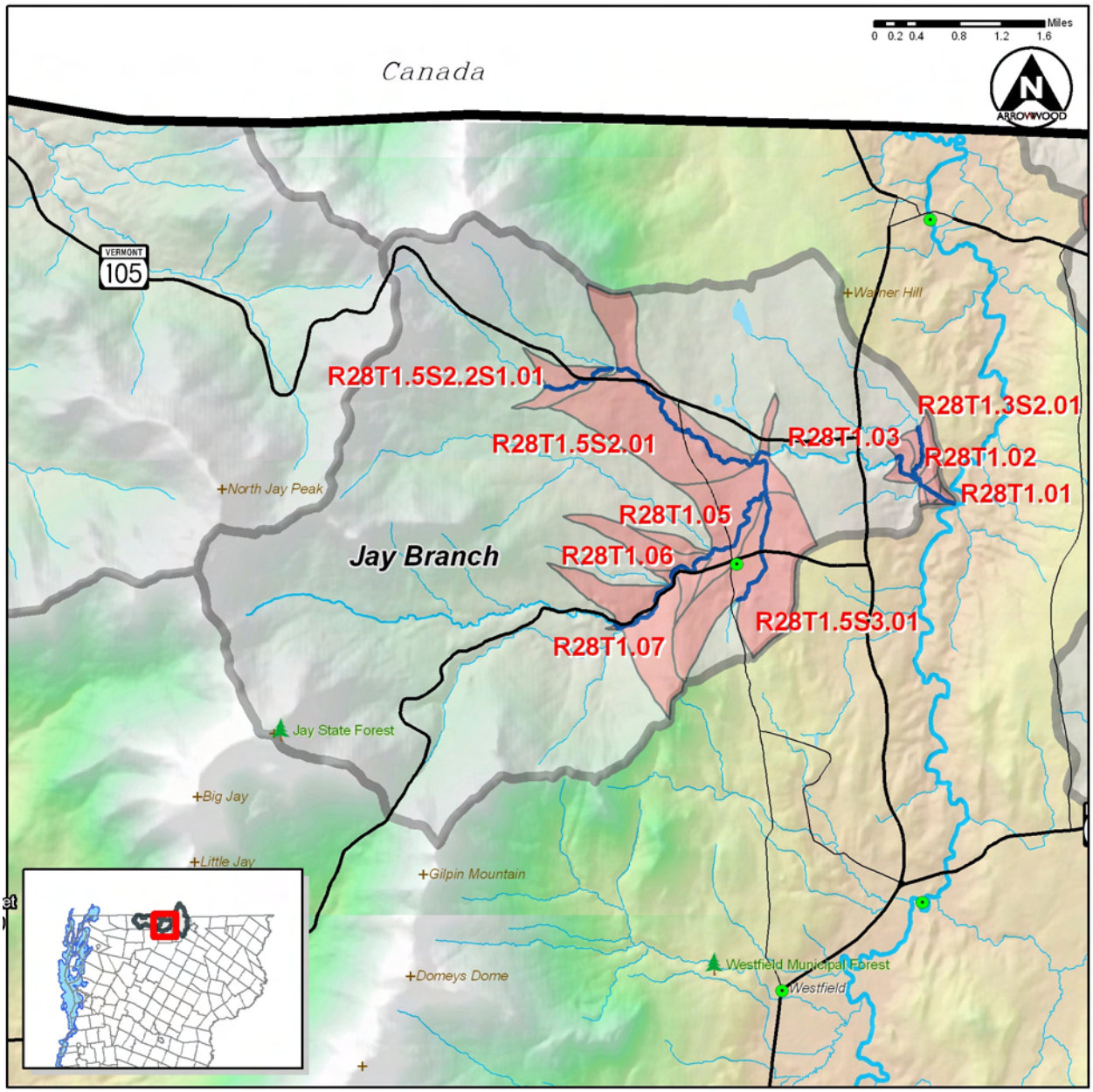


Figure d. Jay Branch Reach Location Map

	Length	Slope		Length	Slope
T1.01	**838 ft**	**1.31%**	**T1.07**	**4,789ft**	**2.80%**
T1.02	**885 ft**	**1.02%**	**T1.3S2.01**	**3,260 ft**	**2.20%**
T1.03	**2,604 ft**	**0.58%**	**T1.5S2.01**	**9,995 ft**	**2.85%**
T1.05	**8,501 ft**	**0.68%**	**T1.5S2.2.2S1.01**	**3,967ft**	**5.55%**
T1.06	**2,517 ft**	**2.42%**	**T1.5S3.01**	**6,297 ft**	**1.29%**

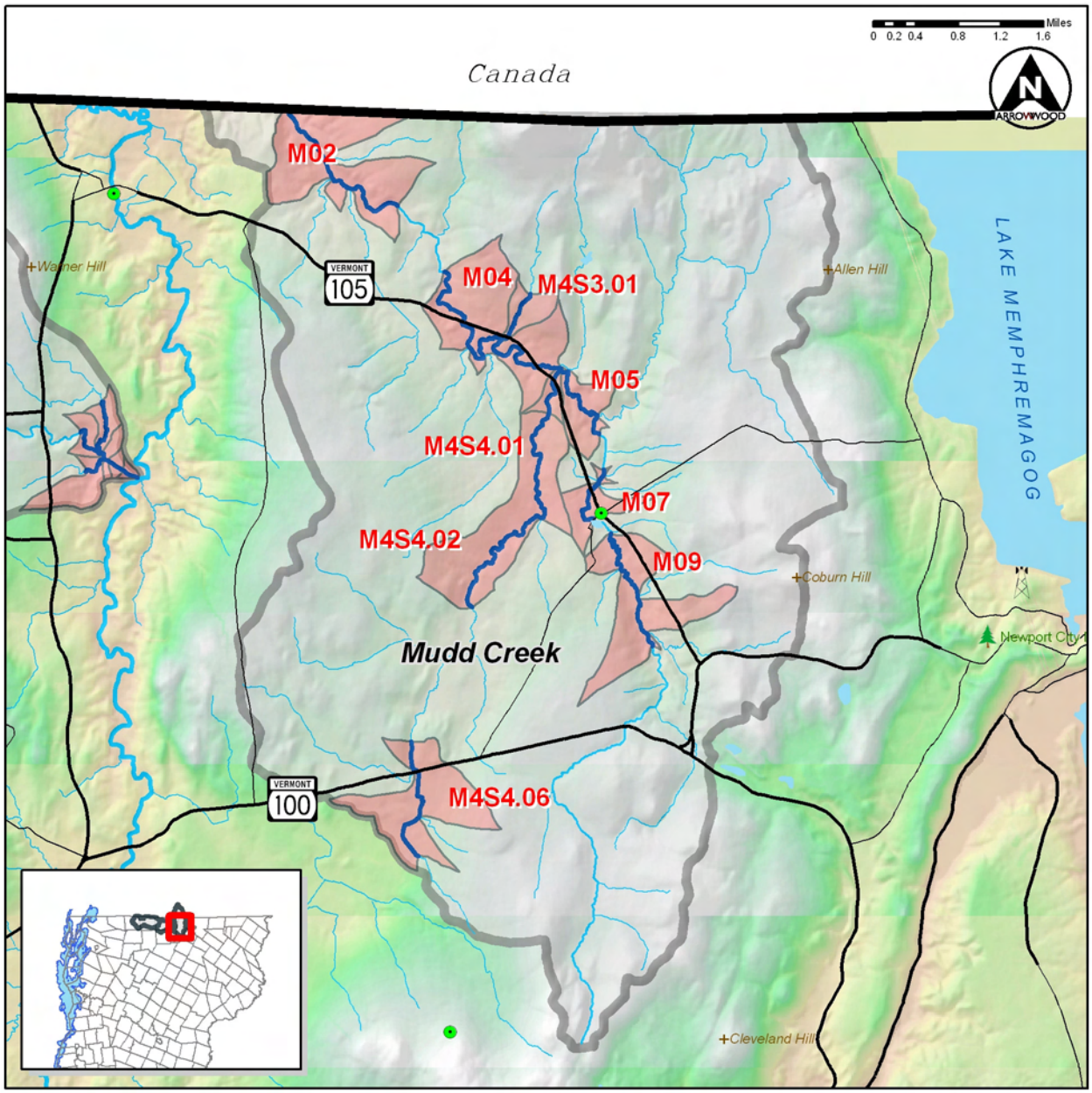


Figure e. Mudd Creek Reach Location Map

	Length	Slope		Length	Slope
M02	**9,171 ft**	**0.49%**	**M4S4.01**	**2,630 ft**	**1.56%**
M04	**14,836 ft**	**0.23%**	**M4S4.02**	**14,418 ft**	**0.65%**
M05	**5,111 ft**	**0.49%**	**M4S4.06**	**7,004 ft**	**0.59%**
M07	**3,691 ft**	**0.65%**	**M4S3.01**	**2,926 ft**	**5.37%**
M09	**7,913 ft**	**0.33%**			

3.1 Phase I Reference Reach Conditions

The data collected in the Phase I 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 I Handbook, April 2007). Table 1 briefly summarizes the Phase 1 assessment of the study reaches. Further detailed descriptions of the reaches, with associated Phase I and II observations, are found in Section 5 of this report along with maps depicting Phase 2 segment delineations.

Table 1a. Main Branch 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
R16	476.80	1,845	BD	198	0.18	1.01	C	Riffle-Pool
R17	473.88	1,402	VB	197	0.08	1.07	C	Riffle-Pool
R18	390.93	898	BD	181	0.40	1.14	C	Riffle-Pool
R19	388.46	1,956	VB	181	0.02	1.16	D	Braided
R20	374.08	644	N	178	0.01	1.03	C	Riffle-Pool

Table 1b. Jay Branch 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
R28T1.01	24		VB	53	1.31	1.02	C	Riffle-Pool
R28T1.02	23.98	120	SC	53	1.02	1.01	B	Riffle-Pool
R28T1.03	23.95	336	NW	53	0.58	1.18	C	Riffle-Pool
R28T1.05	20.65	1700	VB	50	0.68	1.19	C	Riffle-Pool
R28T1.06	9.99	375	BD	36	2.42	1.13	B	Step-Pool
R28T1.07	9.69	253	NW	44	2.8	1.03	B	Step-Pool
R28T1.03 S2.01	2.05	120	BD	18	2.02	1.23	E	Riffle-Pool
R28T1.05 S2.01	3.89	236	BD	24	2.85	1.10	B	Step-Pool
R28T1.05 S2.02S1.01	1.5	78	NW	16	5.55	1.08	B	Step-Pool
R28T1.05 S3.01	1.2	2066	VB	14	1.29	0.00	E	Riffle-Pool

Table 1c. Mud Creek 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
M02	35.92	449	BD	63	0.49	1.14	C	Riffle-Pool
M04	29.75	396	BD	58	0.17	1.37	C	Riffle-Pool
M05	15.25	466	VB	43	0.49	1.27	C	Riffle-Pool
M07	8.73	378	VB	34	0.65	1.13	C	Riffle-Pool
M09	7.47	682	VB	32	0.33	1.28	C	Riffle-Pool
M4S3.01	0.54	106	VB	10	5.37	1.04	B	Cascade
M4S4.01	9.13	248	BD	35	1.56	1.04	C	Riffle-Pool
M4S4.02	9.05	311	BD	42	0.65	1.14	C	Riffle-Pool
M4S4.06	2.94	837	VB	21	0.59	1.07	C	Plane Bed

The selection of Phase 2 study reaches was completed by the River Management Program and the Missisquoi River Basin Association based upon results of the Phase I geomorphic assessment, local knowledge of existing problem areas, and potential project sites. The following tables provide Phase I reach condition and reach sensitivity ratings for the targeted Phase 2 study reaches.

Table 2a. Main Branch Phase I Reach Condition and Sensitivity Ratings

Reach ID	Reference Stream Type	Channel Bedform	Reach Condition	Reach Sensitivity
R16	C	Riffle-Pool	Fair	High
R17	C	Riffle-Pool	Poor	High
R18	C	Riffle-Pool	Poor	High
R19	D	Braided	Fair	Extreme
R20	C	Riffle-Pool	Fair	High

Table 2b. Jay Branch Phase I Reach Condition and Sensitivity Ratings

Reach ID	Reference Stream Type	Channel Bedform	Reach Condition	Reach Sensitivity
R28T1.01	C	Riffle-Pool	Poor	High
R28T1.02	B	Riffle-Pool	Fair	Moderate
R28T1.03	C	Riffle-Pool	Fair	High
R28T1.05	C	Riffle-Pool	Fair	High
R28T1.06	B	Step-Pool	Reference	Moderate
R28T1.07	B	Step-Pool	Poor	Moderate
R28T1.03S2.01	E	Riffle-Pool	Good	High
R28T1.05S2.01	B	Step-Pool	Fair	Moderate
R28T1.05S2.02S1.01	B	Step-Pool	Fair	Moderate
R28T1.05S3.01	E	Riffle-Pool	Fair	High

Table 2c. Mudd Creek Phase I Reach Condition and Sensitivity Ratings

Reach ID	Reference Stream Type	Channel Bedform	Reach Condition	Reach Sensitivity
M02	C	Riffle-Pool	Fair	High
M04	C	Riffle-Pool	Fair	High
M05	C	Riffle-Pool	Poor	High
M07	C	Riffle-Pool	Poor	Fair
M09	C	Riffle-Pool	Fair	High
M4S3.01	B	Cascade	Fair	Moderate
M4S4.01	C	Riffle-Pool	Poor	Moderate
M4S4.02	C	Riffle-Pool	Good	Moderate
M4S4.06	C	Plane Bed	Fair	High

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.

Figure f. Field evaluation of Jay Branch.

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 3a. Main Branch Phase 2 Channel Summary Data

Segment ID	Entrenchment Ratio	Width/ Depth Ratio	Incision Ratio	Sinuosity	Sediment Storage Types	Phase 2 Stream Type	Bed Material	Bed Form
R16	1.3	32.9	1.5	Low	Mid, point, side, diagonal, delta, island	F	Gravel	Riffle-Pool
R17a	2.8	30.9	1.5	Low	Mid, point, side, diagonal, delta, island	C	Gravel	Riffle-Pool
R17b	1.2	28.4	2.0	Low	Mid, point, side, delta	F	Gravel	Riffle-Pool
R17c	2.4	18.9	1.7	Low	Mid, point, side, diagonal	C	Gravel	Plane Bed
R18a	3.6	28.6	1.7	Low	Mid	C	Gravel	Plane Bed
R18b				Low	Mid, side, island	B	Bedrock	Bed rock
R18c	2.1	38.2	1.3	Low	Mid, point, side, diagonal, delta	C	Gravel	Riffle-Pool
R19	1.4	148.0	1.00	Mod	Mid, point, side, diagonal, delta, island	D	Gravel	Braid
R20	3.3	36.8	1.8	Moderate	Mid, point, side, delta, island	C	Gravel	Riffle-Pool

Table 3b. Jay Branch Phase 2 Channel Summary Data

Segment ID	Entrenchment Ratio	Width/ Depth Ratio	Incision Ratio	Sinuosity	Sediment Storage Types	Phase 2 Stream Type	Bed Material	Bed Form
R28T1.01	11.2	17.3	1.2	Low	Mid, side, diagonal	C	Gravel	Riffle-Pool
R28T1.02	1.0	29.6	5.4	Low	Mid, side, diagonal	F	Gravel	Riffle-Pool
R28T1.03	1.3	21.8	1.8	Low	Mid, point, side, diagonal	F	Gravel	Riffle-Pool
R28T1.05A	1.7	34.3	3.4	Low	Mid, point, side, diagonal, delta, island	B	Gravel	Riffle-Pool
R28T1.05B	2.2	21.1	1.3	Low	Point, side, diagonal, island	C	Gravel	Riffle-Pool
R28T1.06	1.2	28.7	1.8	Low	Mid, point, side	F	Cobble	Step-Pool
R28T1.07	1.6	17.3	1.3	Low	Mid, point, side, diagonal, delta, island	B	Cobble	Step-Pool
R28T1.03 S2.01A	4.1	13.2	1.2	Low	Mid, point, side, diagonal	C	Gravel	Riffle-Pool
R28T1.03 S2.01 B	1.4	11.61	1.0	Low	Mid, point, delta	A	Bedrock	Cascade
R28T1.03 S2.01C	8.2	9.3	1.5	Low	Mid, point, side, diagonal, island	E	Gravel	Riffle-Pool
R28T1.05 S2.01A	1.5	15.4	1.6	Low	Mid, point, side, diagonal, island	B	Gravel	Step-Pool
R28T1.05 S2.01B	NA	NA	NA	NA	NA	NA	NA	NA
R28T1.05 S2.01C	1.7	16.2	1.2	Low	Mid, point, side	B	Gravel	Step-Pool
R28T1.05 S2.02 S1.01 A	NA	NA	NA	NA	NA	NA	NA	NA
R28T1.05 S2.02 S1.01 B	1.6	13.3	2.5	Low	Mid, point, side, diagonal	B	Cobble	Step-Pool
R28T1.05 S3.01A	51.8	5.2	1.4	Mod	Point, side, island	E	Sand	Riffle-Pool
R28T1.05 S3.01B	NA	NA	NA	NA	NA	NA	NA	NA
R28T1.05 S3.01C	NA	NA	NA	NA	NA	NA	NA	NA

Table 3c. Mudd Creek Phase 2 Channel Summary Data

Segment ID	Entrenchment Ratio	Width/Depth Ratio	Incision Ratio	Sinuosity	Sediment Storage Types	Phase 2 Stream Type	Bed Material	Bed Form
M02	3.0	24.8	1.8	Low	Mid, Point, side, diagonal, delta, island	C	Gravel	Plane Bed
M04A	NA	NA	NA	NA	Mid	NA	NA	NA
M04B	3.5	16.8	1.5	Moderate	Point, side, diagonal	C	Cobble	Riffle-Pool
M04C	NA	NA	NA	NA	NA	NA	NA	NA
M04D	12.1	25.4	1.5	Moderate	Mid, point, side, diagonal, delta, island	C	Sand	Riffle-Pool
M05A	10.2	20.5	1.8	Moderate	Mid, point, side, diagonal, delta	C	Sand	Riffle-Pool
M05B	1.4	16.4	1.00	Moderate	Mid, island	B	Bedrock	Cascade
M07A	6.1	23.1	1.3	Low	Mid, side, island	C	Gravel	Riffle-Pool
M07B	NA	NA	NA	NA	NA	NA	NA	NA
M09A	12.7	14.2	1.1	Moderate	Point	C	Sand	Dune-Ripple
M09B	29.4	10.0	1.4	Moderate	Side	E	Gravel	Plane Bed
M09C	2.4	36.7	2.0	Moderate	Mid, point, side, diagonal	C	Gravel	Riffle-Pool
M4S3.01A	5.5	9.4	1.4	Low	none	E	Gravel	Plane Bed
M4S3.01B	1.7	20.6	1.0	Low	none	B	Cobble	Cascade
M4S4.01	5.9	17.6	1.5	Low	Mid, point, side, diagonal	C	Cobble	Riffle-Pool
M4S4.02A	5.0	16.1	1.	Low	Mid, point, side, delta, island	C	Cobble	Riffle-Pool
M4S4.02B	NA	NA	NA	NA	NA	NA	NA	NA
M4S4.06A	3.6	14.21053	1.00000	Low	Island	C	Gravel	Plane Bed
M4S4.06B	27.5	9.90099	1.00000	Low	Island	E	Silt	Plane Bed

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 4a. RGA and RHA Summary Results for the Main Branch of the Missisquoi River

Segment ID	RGA Rating	Stream Sensitivity	Channel Adjustment Process	Channel Adjustment Stage	RHA Rating
R16	Fair	Very High	Aggradation, widening	III	Good
R17a	Fair	Very High	Planform, widening, aggradation	III	Fair
R17b	Fair	Very High	Widening, some aggradation	III	Fair
R17c	Fair	Very High	Planform, Aggradation, some widening	III	Fair
R18a	Fair	Very High	Planform change	III	Fair
R18b	NA	NA	NA	NA	Fair
R18c	Fair	Very High	Widening, some planform	III	Good
R19	Fair	Extreme	Aggradation, widening, planform (very unstable channel)	IId	Fair
R20	Fair	Very High	Aggradation, widening	III	Fair

Table 4b. RGA and RHA Summary Results for the Jay Branch

Segment ID	RGA Rating	Stream Sensitivity	Channel Adjustment Process	Channel Evolution Stage	RHA Rating
R28T1.01	Good	High	Minor Adjustments	IV	Fair
R28T1.02	Good	High	Aggradation	III	Good
R28T1.03	Fair	Very High	Widening, planform	III	Fair
R28T1.05A	Poor	High	Aggradation, widening, planform	III	Fair
R28T1.05B	Fair	Very High	Minor adjustments: planform, widening	III	Good
R28T1.06	Fair	High	Widening, planform	III	Good
R28T1.07	Fair	High	Widening, some planform	III	Good
R28T1.3S2.01A	Good	High	Minor adjustments	I	Good
R28T1.3S2.01B	Reference	Very Low	Minor adjustments	I	Good
R28T1.3S2.01C	Good	High	Some aggradation	I	Good
R28T1.5S2.01A	Fair	High	Major Widening, planform	III	Good
R28T1.5S2.01B	NA	NA	NA	NA	NA
R28T1.5S2.01C	Good	Moderate	Minor adjustments	I	Reference
R28T1.5S2.2S1.01A	NA	NA	NA	NA	NA
R28T1.5S2.2S1.01B	Good	Moderate	Minor adjustments	I	Reference
R28T1.5S3.01A	Fair	Very High	Some aggradation, widening	III	Fair
R28T1.5S3.01B	NA	NA	NA	NA	NA
R28T1.5S3.01C	NA	NA	NA	NA	NA

Figure g. Reach T1.05 Segment C: Channel Migration and Sediment Deposition

Table 4c. RGA and RHA Summary Results for Mudd Creek

Segment ID	RGA Rating	Stream Sensitivity	Channel Adjustment Process	Channel Evolution Stage	RHA Rating
M02	Fair	Very High	Aggradation, widening, planform	III	Good
M04A	NA	NA	NA	NA	NA
M04B	Good	Moderate	Minor adjustments	II	Fair
M04C	NA	NA	NA	NA	NA
M04D	Fair	Very High	Aggradation, widening, planform	III	Fair
M05A	Fair	Very High	Aggradation, widening, planform	III	Fair
M05B	Good	Moderate	Minor adjustments	I	Good
M07A	Fair	Very High	Widening, aggradation	III	Fair
M07B	NA	NA	NA	NA	NA
M09A	Good	High	beaver influenced	I	Fair
M09B	Fair	Very High	Minor adjustments (beaver influence)	III	Fair
M09C	Fair	Very High	Widening with some aggradation, planform	III	Good
M4S3.01A	NA	NA	NA	NA	Fair
M4S3.01B	NA	NA	NA	NA	Fair
M4S4.01	Good	Moderate	Widening	III	Fair
M4S4.02A	Fair	High	Widening, planform	III	Good
M4S4.02B	NA	NA	NA	NA	NA
M4S4.06A	Reference	High	No major adjustments	I	Good
M4S4.06B	Good	High	Minor adjustments, human manipulation of channel	I	Poor

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 Missisquoi watershed study area is primarily agricultural. There is a high percentage of agriculture within the Jay Branch and the Mudd Creek study reaches, and the lower study reaches of the Main Branch. The mid section reaches of the Main Branch, about Richford Center, are heavily developed with both commercial and residential uses. Only the upper reaches of the Main Branch maintain a high percentage of forest cover within the study area.

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 Missisquoi 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

Figure h. Mass Failure in Main Branch Reach R16

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 Missisquoi 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 5a. Main Branch Watershed Scale Sediment Load Stressors

Segment ID	Deposition Rating	Erosion Rating (Left Bank)	Erosion Rating (Right Bank)	Mass Failures Gullies	Tributary Rejuvenation
R16	> 5	>5% <=20%	>20%	<=2	No
R17A	> 5	>20%	>5% <=20%	None	No
R17B	>2 <= 5	>5% <=20%	<5%	None	No
R17C	Unknown	Unknown	Unknown	None	No
R18A	>2 <= 5	<5%	<5%	None	No
R18B	>2 <= 5	<5%	<5%	None	No
R18C	> 5	>5% <=20%	>5% <=20%	<=2	No
R19	> 5	>5% <=20%	>5% <=20%	None	No
R20	<=2	<5%	>5% <=20%	None	No

Table 5b. Jay Branch Watershed Scale Sediment Load Stressors

Segment ID	Deposition Rating	Erosion Rating (Left Bank)	Erosion Rating (Right Bank)	Mass Failures Gullies	Tributary Rejuvenation
R28T1.07	> 5	<5%	>20%	None	No
R28T1.3S2.01A	> 5	<5%	<5%	None	No
R28T1.3S2.01B	>2 <= 5	>20%	>5% <=20%	None	No
R28T1.3S2.01C	> 5	>5% <=20%	<5%	None	No
R28T1.5S2.01A	> 5	>5% <=20%	>5% <=20%	None	No
R28T1.5S2.01B	> 5	>5% <=20%	>5% <=20%	None	No
R28T1.5S2.01C	>2 <= 5	>5% <=20%	>5% <=20%	None	No
R28T1.5S2.2S1.01A	> 5	>5% <=20%	>5% <=20%	None	No
R28T1.5S2.2S1.01B	> 5	<5%	<5%	None	No
R28T1.5S3.01A	> 5	<5%	<5%	None	No
R28T1.5S3.01B	> 5	>5% <=20%	>5% <=20%	None	Yes
R28T1.5S3.01C	<=2	<5%	<5%	None	No
R28T1.07	> 5	<5%	<5%	None	No
R28T1.3S2.01A	Unknown	Unknown	Unknown	Unknown	Unknown
R28T1.3S2.01B	> 5	<5%	<5%	None	No
R28T1.3S2.01C	> 5	>5% <=20%	<5%	None	No
R28T1.5S2.01A	> 5	<5%	<5%	None	No
R28T1.5S2.01B	Unknown	Unknown	Unknown	Unknown	Unknown

Table 5C. Mudd Creek Watershed Scale Sediment Load Stressors

Segment ID	Deposition Rating	Erosion Rating (Left Bank)	Erosion Rating (Right Bank)	Mass Failures Gullies	Tributary Rejuvenation
M02	> 5	>5% <=20%	>5% <=20%	None	No
M04A	Unknown	>20%	>20%	None	
M04B	<=2	>5% <=20%	>5% <=20%	None	No
M04C	Unknown	<5%	<5%	None	
M04D	<=2	>20%	>20%	None	No
M05A	<=2	>20%	>20%	None	No
M05B	> 5	<5%	>5% <=20%	None	No
M07A	>2 <= 5	>20%	>20%	None	No
M07B	NA	NA	NA	NA	NA
M09A	<=2	>5% <=20%	>5% <=20%	None	No
M09B	<=2	>5% <=20%	<5%	None	No
M09C	> 5	>5% <=20%	>5% <=20%	None	No
M4S3.01A	<=2	>5% <=20%	<5%	None	No
M4S3.01B	<=2	<5%	<5%	None	No
M4S4.01	> 5	>5% <=20%	>20%	None	No
M4S4.02A	> 5	<5%	<5%	None	No
M4S4.06A	<=2	<5%	<5%	None	No
M4S4.06B	<=2	>5% <=20%	<5%	None	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, channel incision, and decreased channel stability.

Table 6a. Main Branch Potential Slope Modifiers

	Slope Increasers		Slope Decreasers	
Segment ID	**Straightening (% per reach)**	**Encroachments (% per reach)**	**# Constrictions & Controls per mile**	**# Beaver Dams/mile**
R16	<5%	<5%	<=2	<=2
R17A	<5%	>20%	<=2	<=2
R17B	<5%	>20%	<=2	<=2
R17C	<5%	<5%	<=2	Unknown
R18A	>20%	>20%	<=2	<=2
R18B	<5%	>20%	> 5	<=2
R18C	<5%	>20%	<=2	<=2
R19	<5%	>5% <=20%	<=2	<=2
R20	<5%	>20%	<=2	<=2

Figure i. Corridor Encroachment along Main Branch Reach R18

Table 6b. Jay Branch Potential Slope Modifiers

	Slope Increasers		Slope Decreasers	
Segment ID	**Straightening (% per reach)**	**Encroachments (% per reach)**	**# Constrictions & Controls per mile**	**# Beaver Dams/mile**
R28T1.01	>20	>20%	<=2	<=2
R28T1.02	<5%	>20%	<=2	<=2
R28T1.03	<5%	<5%	>2 <= 5	<=2
R28T1.05	<5%	>20%	<=2	<=2
R28T1.05	<5%	>20%	<=2	<=2
R28T1.06	<5%	>5% <=20%	<=2	<=2
R28T1.07	<5%	>20%	> 5	<=2
R28T1.3S2.01	<5%	<5%	>2 <= 5	<=2
R28T1.3S2.01	<5%	<5%	> 5	<=2
R28T1.3S2.01	<5%	<5%	>2 <= 5	<=2
R28T1.5S2.01	<5%	<5%	>2 <= 5	<=2
R28T1.5S2.01	<5%	<5%	> 5	<=2
R28T1.5S2.01	<5%	>5% <=20%	<=2	<=2
R28T1.5S2.2S1.01	<5%	<5%	<=2	Unknown
R28T1.5S2.2S1.01	<5%	<5%	> 5	<=2
R28T1.5S3.01	<5%	>20%	<=2	<=2
R28T1.5S3.01	<5%	<5%	<=2	>2 <= 5
R28T1.5S3.01	<5%	<5%	<=2	Unknown

Table 6c. Mudd Creek Potential Slope Modifiers

	Slope Increasers		Slope Decreasers	
Segment ID	**Straightening (% per reach)**	**Encroachments (% per reach)**	**# Constrictions & Controls per mile**	**# Beaver Dams/mile**
M02	>5% <=20%	<5%	<=2	<=2
M04A	<5%	<5%	<=2	<=2
M04B	<5%	<5%	<=2	<=2
M04C	<5%	<5%	>2 <= 5	<=2
M04D	<5%	>5% <=20%	<=2	>2 <= 5
M05A	<5%	<5%	<=2	<=2
M05B	<5%	>20%	> 5	<=2
M07A	<5%	<5%	<=2	>2 <= 5
M07B	NA	NA	NA	NA
M09A	<5%	<5%	<=2	> 5
M09B	>20%	>20%	<=2	> 5
M09C	<5%	<5%	<=2	<=2
M4S3.01A	<5%	>20%	<=2	<=2
M4S3.01B	<5%	<5%	<=2	<=2
M4S4.01	>20%	<5%	<=2	<=2
M4S4.02A	<5%	<5%	<=2	<=2
M4S4.06A	<5%	<5%	<=2	<=2
M4S4.06B	>20%	<5%	<=2	<=2

Table 7 shows the widths of all bridges and culverts measured in the Phase 2 assessments. Note that of the 47 structures listed, only eight were appropriately sized for the channel. The remaining 39 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 7a. Main Branch Channel and floodplain constrictions found during Phase 2 assessments

Reach	Type	Constriction Width (ft)	Channel Width (ft)	Channel Constriction?	Floodprone Constriction?	Problem
R17A	Bridge	135	163	Yes	Yes	Deposition Below
R17A	Bridge	144	163	Yes	Yes	None
R17B	Bridge	144	81	No	Yes	Deposition Above, Deposition Below
R18A	Bridge	120	146	Yes	Yes	None
R18B	Bridge	126	152	Yes	Yes	None
R18C	Bridge	198	167	No	Yes	Deposition Below
T4.01B	Bridge	15	27	Yes	Yes	Deposition Above, Scour Below, Alignment
T4.01B	Bridge	15	27	Yes	Yes	None
T5.03B	Bridge	6	24	Yes	Yes	Deposition Below, Scour Above
T5.03D	Culvert	4	24	Yes	Yes	Deposition Above, Scour Below
T5.03E	Culvert	4	24	Yes	Yes	Deposition Above, Scour Below, Alignment
T6.01A	Bridge	22	23	Yes	Yes	Scour Above, Scour Below
T6.01A	Bridge	22	23	Yes	Yes	Deposition Below, Scour Above
T6.02	Bridge	24	48	Yes	Yes	Deposition Above, Deposition Below, Scour Above
T6.02	Bridge	60	48	No	Yes	Alignment
T6.02	Bridge	115	48	No	No	None
T6.03	Bridge	27	47	Yes	Yes	Scour Above ,Scour Below

Table 7b. Jay Branch Channel and floodplain constrictions found during Phase 2 assessments

Reach	Type	Constriction Width (ft)	Channel Width (ft)	Channel Constriction?	Floodprone Constriction?	Problem
R28T1.05A	Bridge		40	Yes	Yes	Deposition Below
R28T1.05B	Bridge		40	Yes	Yes	None
R28T1.07	Bridge		23	Yes	Yes	Deposition Below, Scour Above, Scour Below
R28T1.07	Bridge		32	Yes	Yes	Deposition Above, Deposition Below, Scour Above, Scour Below
R28T1.03S2.01A	Culvert		9.5	Yes	Yes	Deposition Above
R28T1.05S2.01A	Bridge		29	No	No	Deposition Above, Scour Above, Scour Below
R28T1.05S2.01C	Bridge		24	Yes	No	None
R28T1.05S2.01C	Bridge		16	Yes	Yes	Deposition Above, Scour Above, Alignment
R28T1.05S2.02S1.01B	Culvert		15	Yes	Yes	None
R28T1.05S2.02S1.01B	Bridge		6.3	Yes	Yes	Deposition Below, Scour Above, Scour Below
R28T1.05S3.01A	Culvert		8	No	Yes	None
R28T1.05S3.01B	Culvert		3	Yes	No	Scour Above, Scour Below
R28T1.05S3.01B	Culvert		4.4	Yes	Yes	Scour Above

Figure j. Channel Constriction in Jay Branch Reach T1.07

Table 7c. Mudd Creek Channel and floodplain constrictions found during Phase 2 assessments

Reach	Type	Constriction Width (ft)	Channel Width (ft)	Channel Constriction?	Floodprone Constriction?	Problem
R17A	Bridge	135	163	Yes	Yes	Deposition Below
R17A	Bridge	144	163	Yes	Yes	None
R17B	Bridge	144	81	No	Yes	Deposition Above, Deposition Below
R18A	Bridge	120	146	Yes	Yes	None
R18B	Bridge	126	152	Yes	Yes	None
R18C	Bridge	198	167	No	Yes	Deposition Below
T4.01B	Bridge	15	27	Yes	Yes	Deposition Above, Scour Below, Alignment
T4.01B	Bridge	15	27	Yes	Yes	None
T5.03B	Bridge	6	24	Yes	Yes	Deposition Below, Scour Above
T5.03D	Culvert	4	24	Yes	Yes	Deposition Above, Scour Below
T5.03E	Culvert	4	24	Yes	Yes	Deposition Above, Scour Below, Alignment
T6.01A	Bridge	22	23	Yes	Yes	Scour Above, Scour Below
T6.01A	Bridge	22	23	Yes	Yes	Deposition Below, Scour Above
T6.02	Bridge	24	48	Yes	Yes	Deposition Above, Deposition Below, Scour Above
T6.02	Bridge	60	48	No	Yes	Alignment
T6.02	Bridge	115	48	No	No	None
T6.03	Bridge	27	47	Yes	Yes	Scour Above ,Scour 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 areas.

Table 8a. Main Branch Riparian Buffer Conditions

Segment ID	Left Buffer Dominant Width (ft)	Right Buffer Dominant Width (ft)	Left Bank Revetment (%)	Right Bank Revetment (%)
R16	>100	0-25	<5%	>5% <=20%
R17A	0-25	0-25	>5% <=20%	>5% <=20%
R17B	26-50	0-25	>5% <=20%	>5% <=20%
R17C	0-25	26-50	Unknown	Unknown
R18A	26-50	0-25	>5% <=20%	>20%
R18B	0-25	0-25	>20%	>20%
R18C	26-50	26-50	>20%	>5% <=20%
R19-	26-50	>100	>5% <=20%	<5%
R20-	26-50	51-100	>5% <=20%	<5%

Table 8b. Jay Branch Riparian Buffer Conditions

Segment ID	Left Buffer Dominant Width (ft)	Right Buffer Dominant Width (ft)	Left Bank Revetment (%)	Right Bank Revetment (%)
R28T1.01	26-50	>100	>5% <=20%	<5%
R28T1.02	51-100	>100	<5%	<5%
R28T1.03	26-50	>100	<5%	<5%
R28T1.05	51-100	51-100	<5%	>5% <=20%
R28T1.05	0-25	26-50	>5% <=20%	>5% <=20%
R28T1.06	>100	>100	<5%	>5% <=20%
R28T1.07	26-50	>100	>5% <=20%	>5% <=20%
R28T1.3S2.01A	>100	>100	>5% <=20%	>5% <=20%
R28T1.3S2.01B	>100	>100	<5%	<5%
R28T1.3S2.01A	>100	>100	<5%	<5%
R28T1.5S2.01B	>100	>100	<5%	<5%
R28T1.5S2.01C	>100	>100	<5%	<5%
R28T1.5S2.01D	>100	>100	<5%	<5%
R28T1.5S2.2S1.01A	>100	>100	Unknown	Unknown
R28T1.5S2.2S1.01B	>100	>100	>5% <=20%	<5%
R28T1.5S3.01A	>100	>100	<5%	<5%
R28T1.5S3.01B	>100	>100	<5%	<5%
R28T1.5S3.01C	>100	>100	Unknown	Unknown

Table 8c. Mudd Creek Riparian Buffer Conditions

Segment ID	Left Buffer Dominant Width (ft)	Right Buffer Dominant Width (ft)	Left Bank Revetment (%)	Right Bank Revetment (%)
M02	>100	>100	<5%	<5%
M04A	0-25	>100	<5%	<5%
M04B	0-25	0-25	<5%	<5%
M04C	51-100	>100	>5% <=20%	>5% <=20%
M04D	0-25	0-25	<5%	<5%
M05A	0-25	0-25	<5%	<5%
M05B	51-100	51-100	<5%	>5% <=20%
M07A	0-25	0-25	<5%	>5% <=20%
M07B	NA	NA	NA	NA
M09A	0-25	26-50	<5%	<5%
M09B	0-25	0-25	<5%	<5%
M09C	>100	>100	<5%	<5%
M4S3.01A	0-25	0-25	<5%	<5%
M4S3.01B	>100	>100	<5%	<5%
M4S4.01	0-25	0-25	<5%	>5% <=20%
M4S4.02A	51-100	>100	<5%	<5%
M4S4.06A	NA	NA	<5%	<5%
M4S4.06B	>100	>100	<5%	<5%

Figure k. No Buffers and High Erosion, Mudd Creek Reach M04

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.

5.1 Main Branch of Missisquoi River Study Reaches

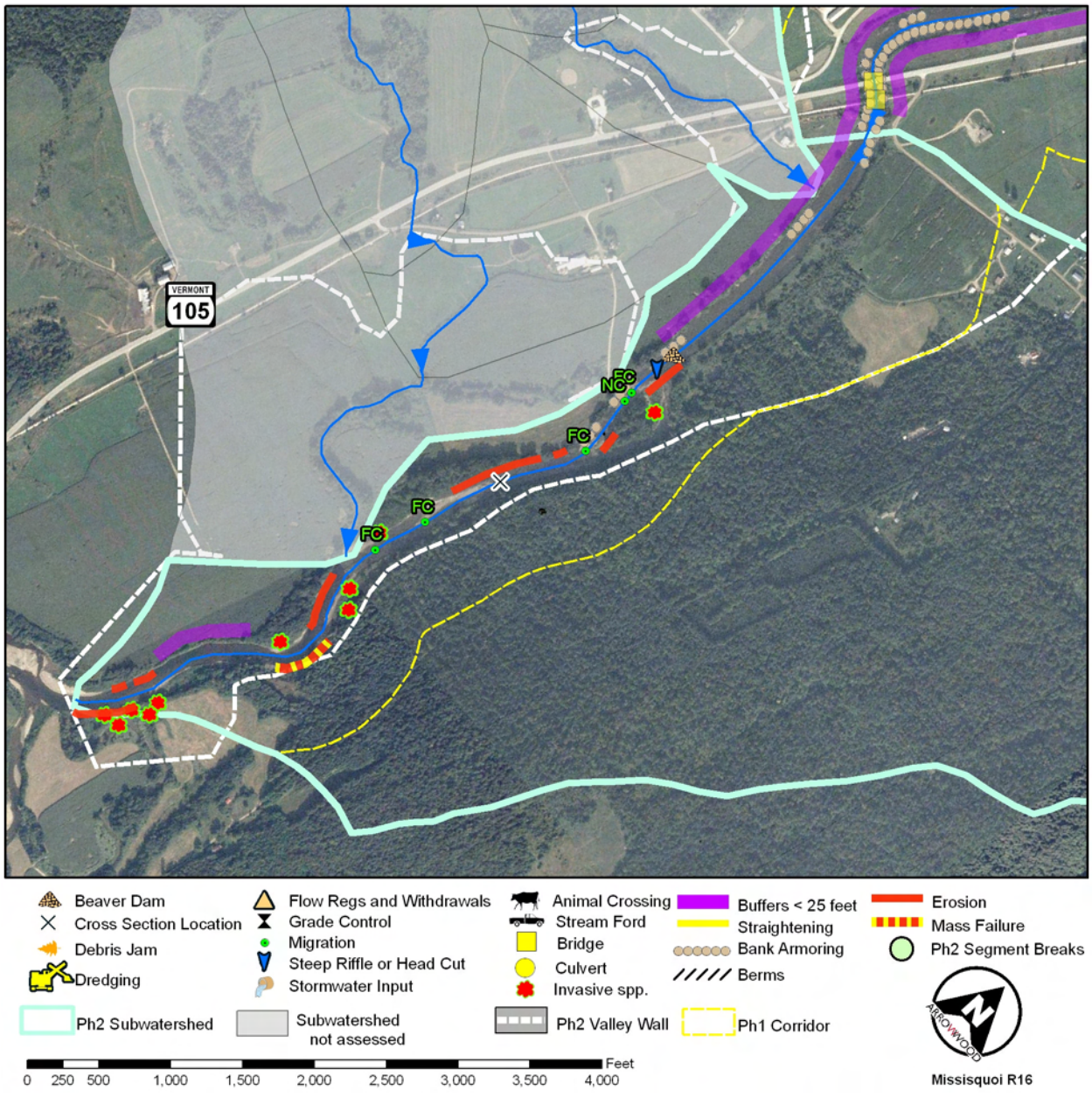


Figure l. Reach R16 Inventory Map

R16 Summary Data	
Reach/Segment Length	7170 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	F4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	aggradation widening planform change
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 9a. Reach R16 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
R16	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners (particularly on the right bank)
R16	Plant Stream Buffers	Contact landowners on right bank; investigate possible grant programs for plantings
R16	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

Figure m. Invasive Plants Along Reach R16

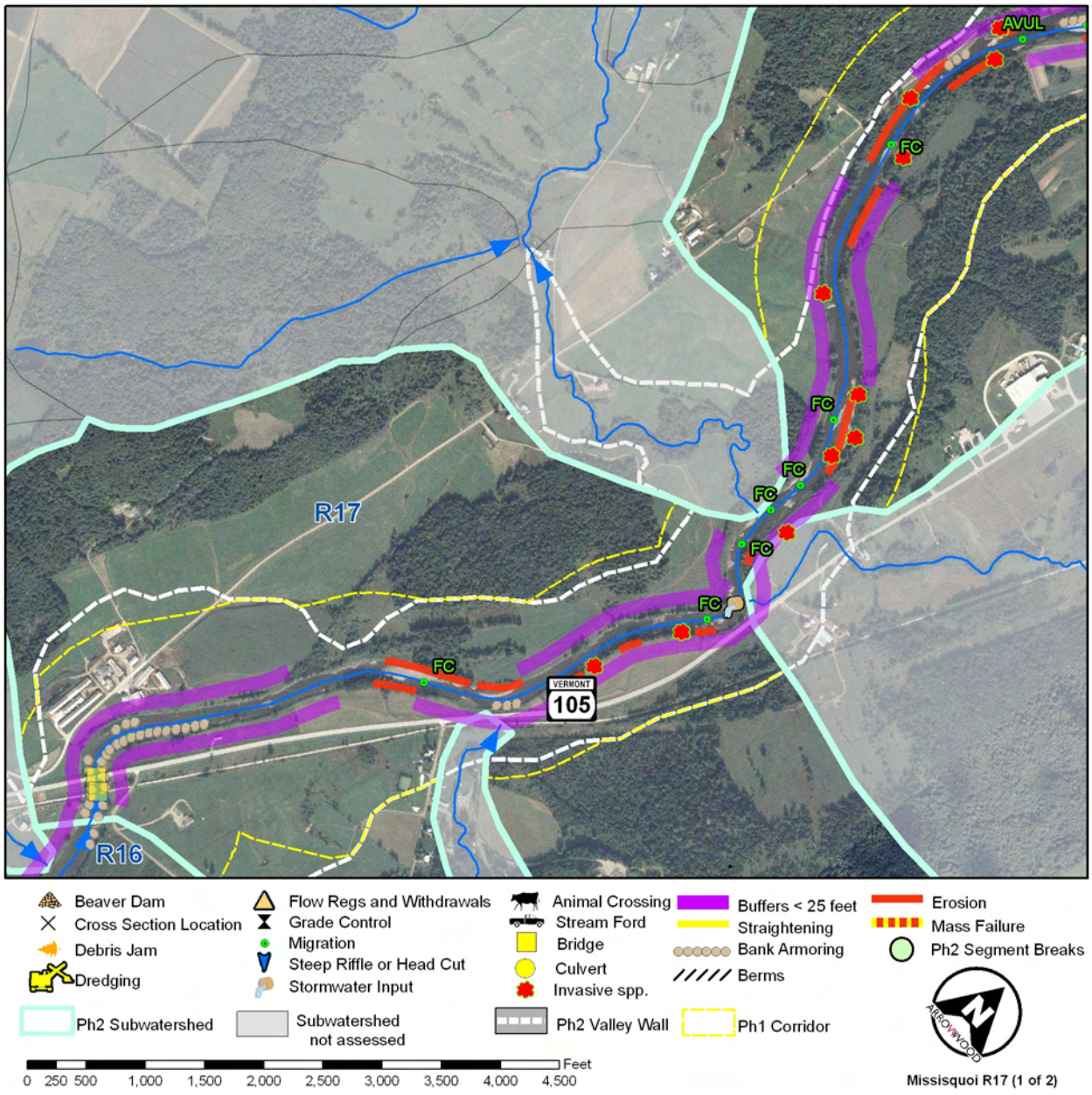


Figure n. Reach R17A Inventory Map

R17a Summary Data

Reach/Segment Length	**20,028 ft**
Valley Confinement	**Broad**
Reference Stream Type	**C4**
Existing Stream Type	**C4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**III**
Adjustment Process	**Planform, 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

R17b Summary Data

Reach/Segment Length	3,026 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	F4
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

R17c Summary Data

Reach/Segment Length	3351 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Planform, aggradation, some widening
Habitat Condition	Fair
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Figure o. Poor Buffers Along Reach M17C

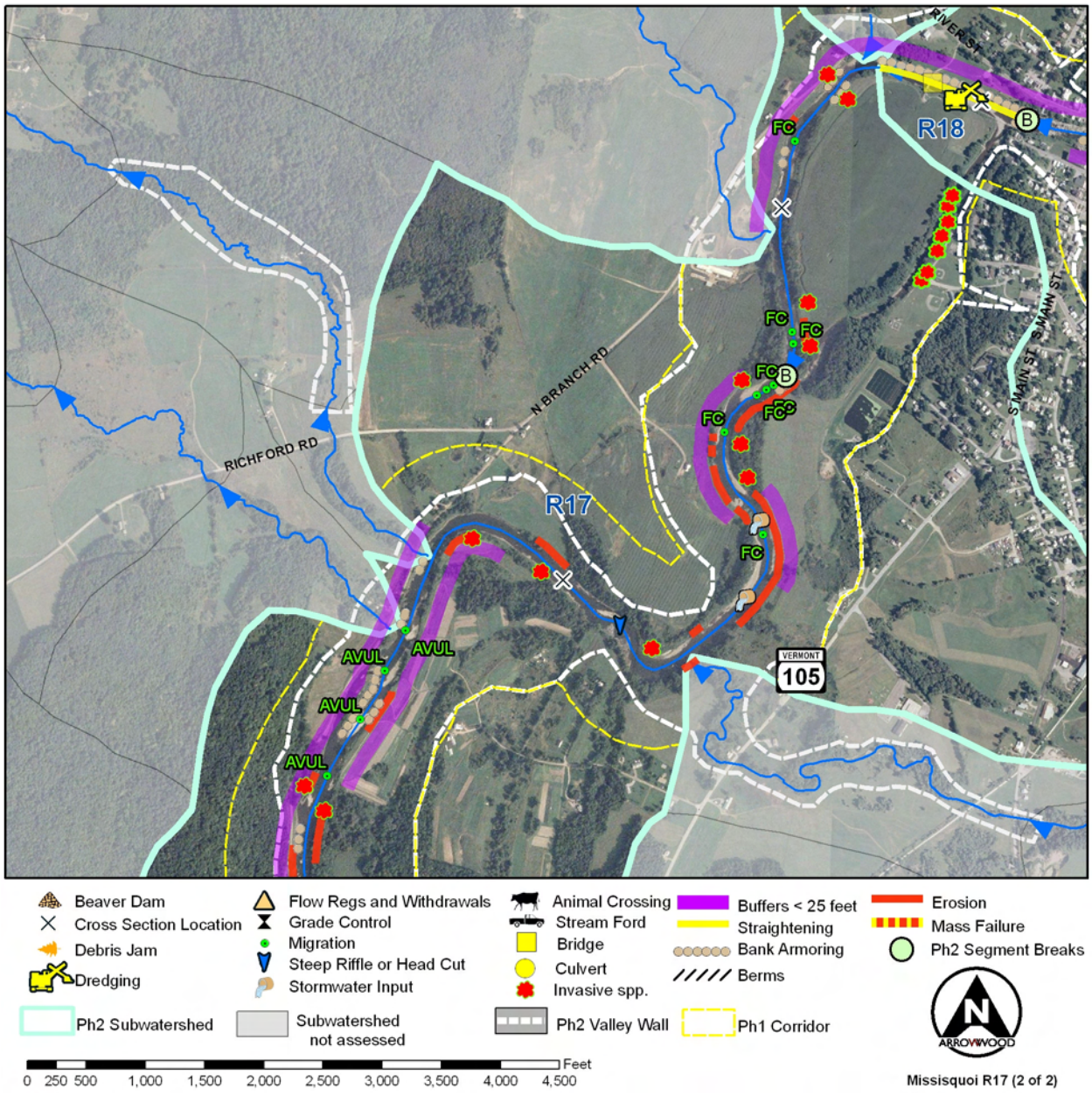


Figure p. Reach R17B Inventory Map

Preliminary project recommendations are presented in the following table.

Table 9b. Reach R17 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
R17a, R17b	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
R17a, R17b, R17c	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
R17a, R17b, R17c	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

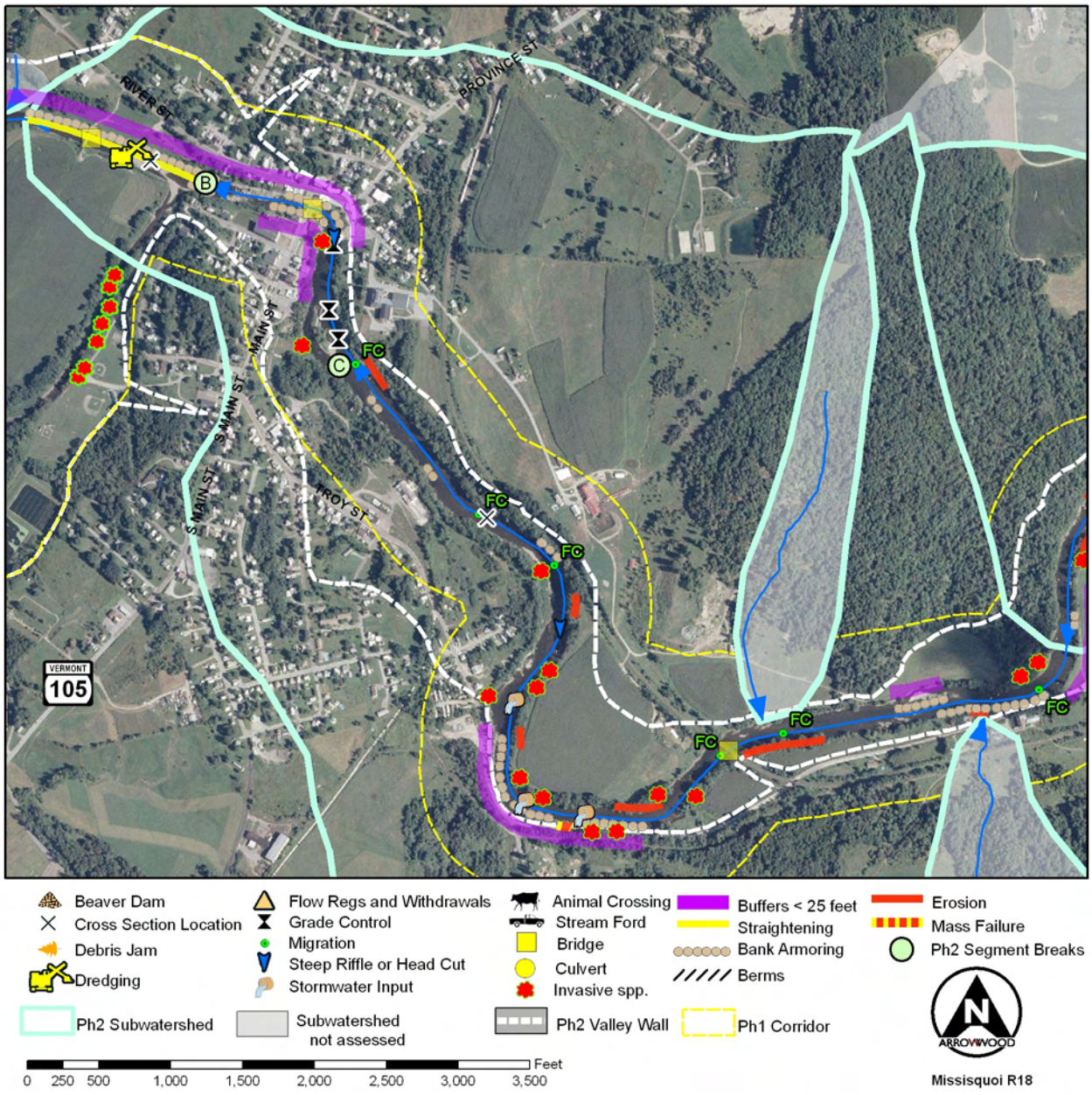


Figure q. Reach R18 Inventory Map

R18a Summary Data

Reach/Segment Length	**1322 ft**
Valley Confinement	**Narrow**
Reference Stream Type	**C4**
Existing Stream Type	**C4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**III**
Adjustment Process	**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
Headcuts

R18b Summary Data

Reach/Segment Length	1924 ft
Valley Confinement	Narrow
Reference Stream Type	C4
Existing Stream Type	B1
Geomorphic Condition	NA
Channel Evolution Stage	NA
Adjustment Process	NA
Habitat Condition	Fair
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

R18c Summary Data

Reach/Segment Length	8101 ft
Valley Confinement	Narrow
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening and some Planform
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 9c. Reach R18 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
R18c	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
R18a	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
R18a, b,c	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
R18c	Dump site removal	Contact landowner; organize volunteers; investigate grants for disposal costs

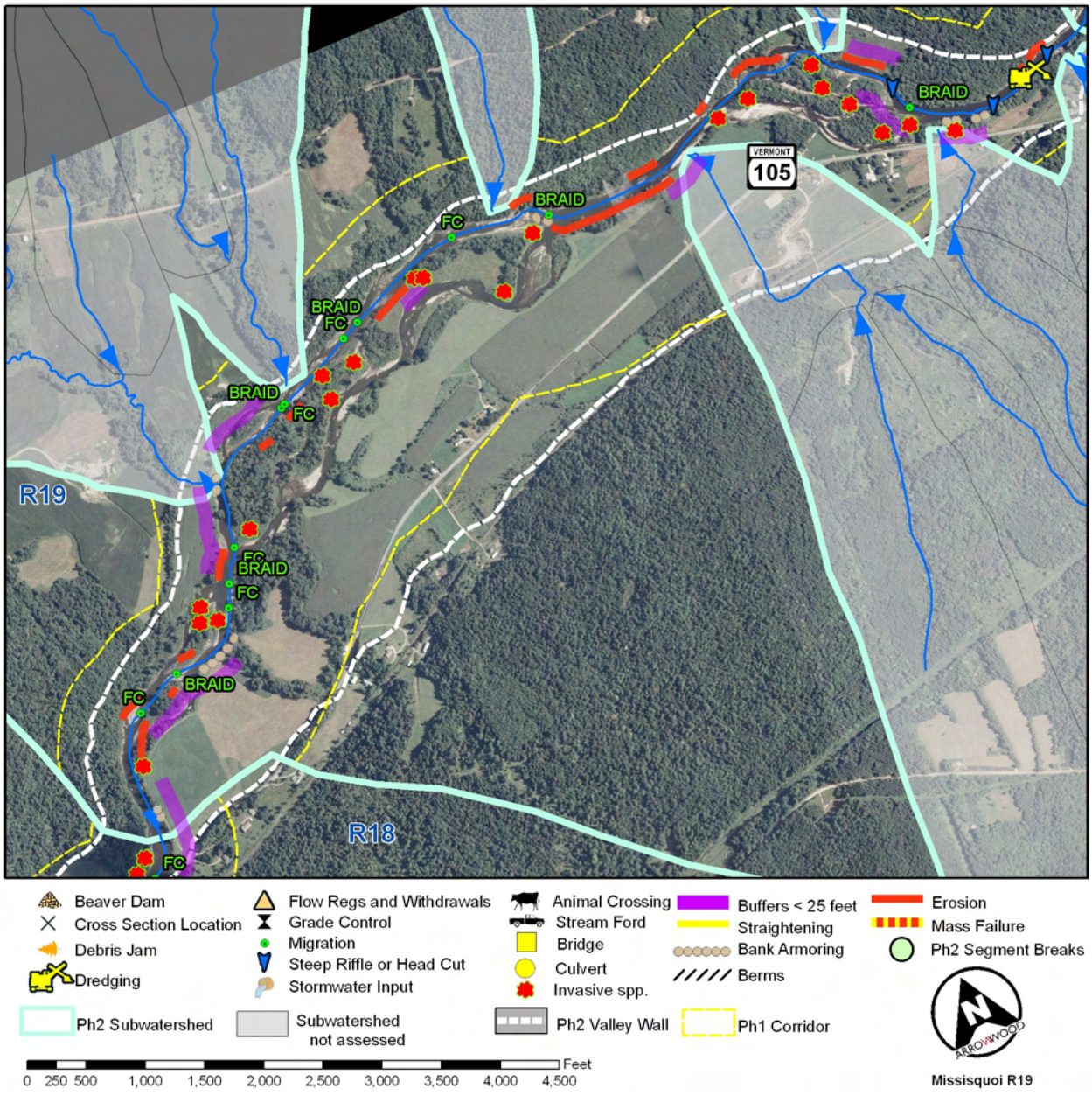


Figure r. Reach R19 Inventory Map

R19 Summary Data

Reach/Segment Length	**12,650 ft**
Valley Confinement	**Very Broad**
Reference Stream Type	**D4**
Existing Stream Type	**D4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**IId**
Adjustment Process	**Widening, aggradation, planform**
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

Preliminary project recommendations are presented in the following table.

Table 9d. Reach R19 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
R19	**Protect River Corridor**	**Develop FEH Protection Areas map; contact interested landowners**
R19	**Invasive Plant Removal**	**Landowner contacts; labor intensive; multi- year project; results may be limited**

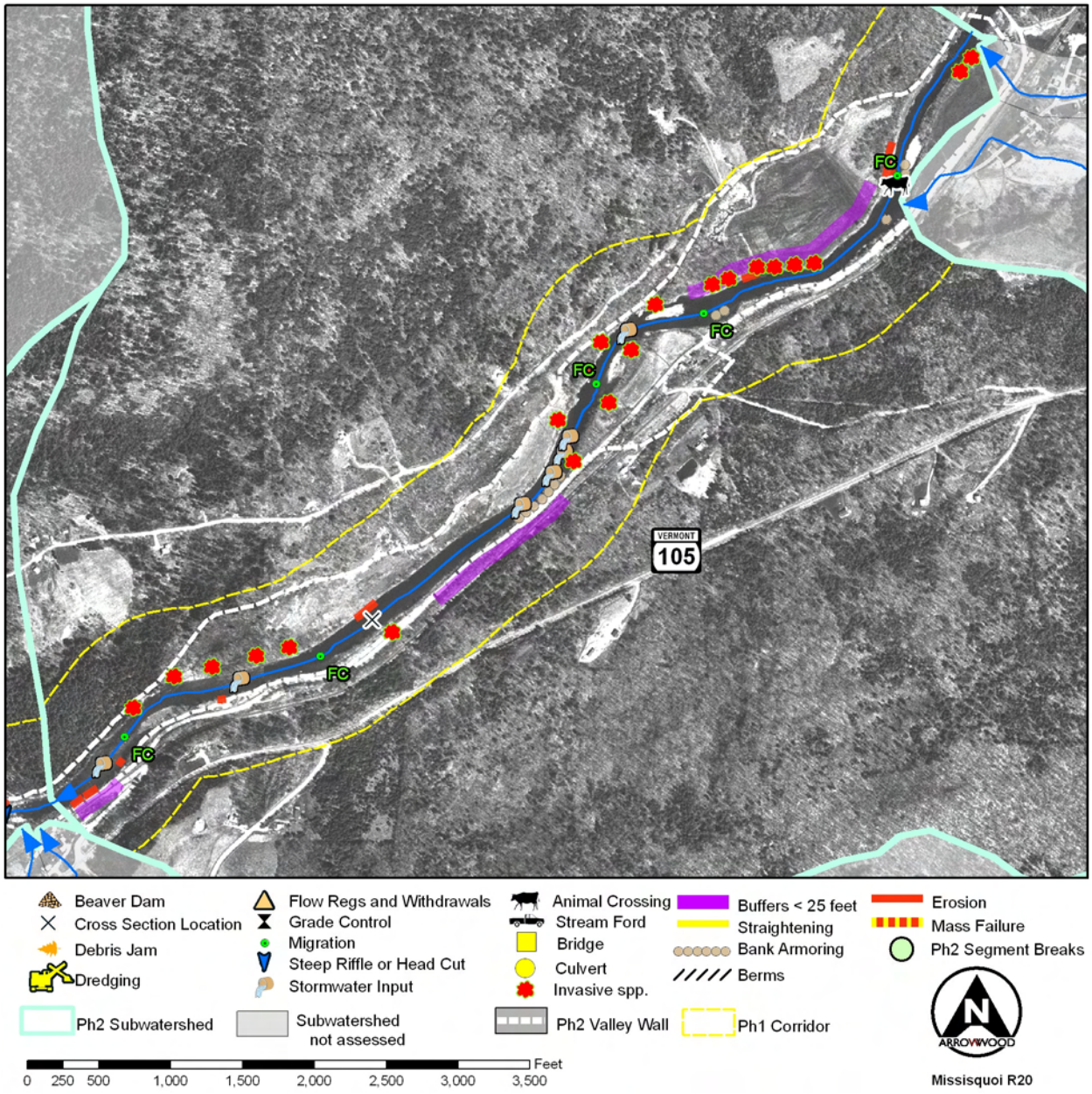


Figure s. Reach R20 Inventory Map

R20 Summary Data	
Reach/Segment Length	8,859 ft
Valley Confinement	Semi-confined
Reference Stream Type	C4
Existing Stream Type	C4
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

Preliminary project recommendations are presented in the following table.

Table 9e. Reach R20 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
R20	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
R20	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited

5.2 Jay Branch Study Reaches

Figure t. Jay Branch Reach T1.02

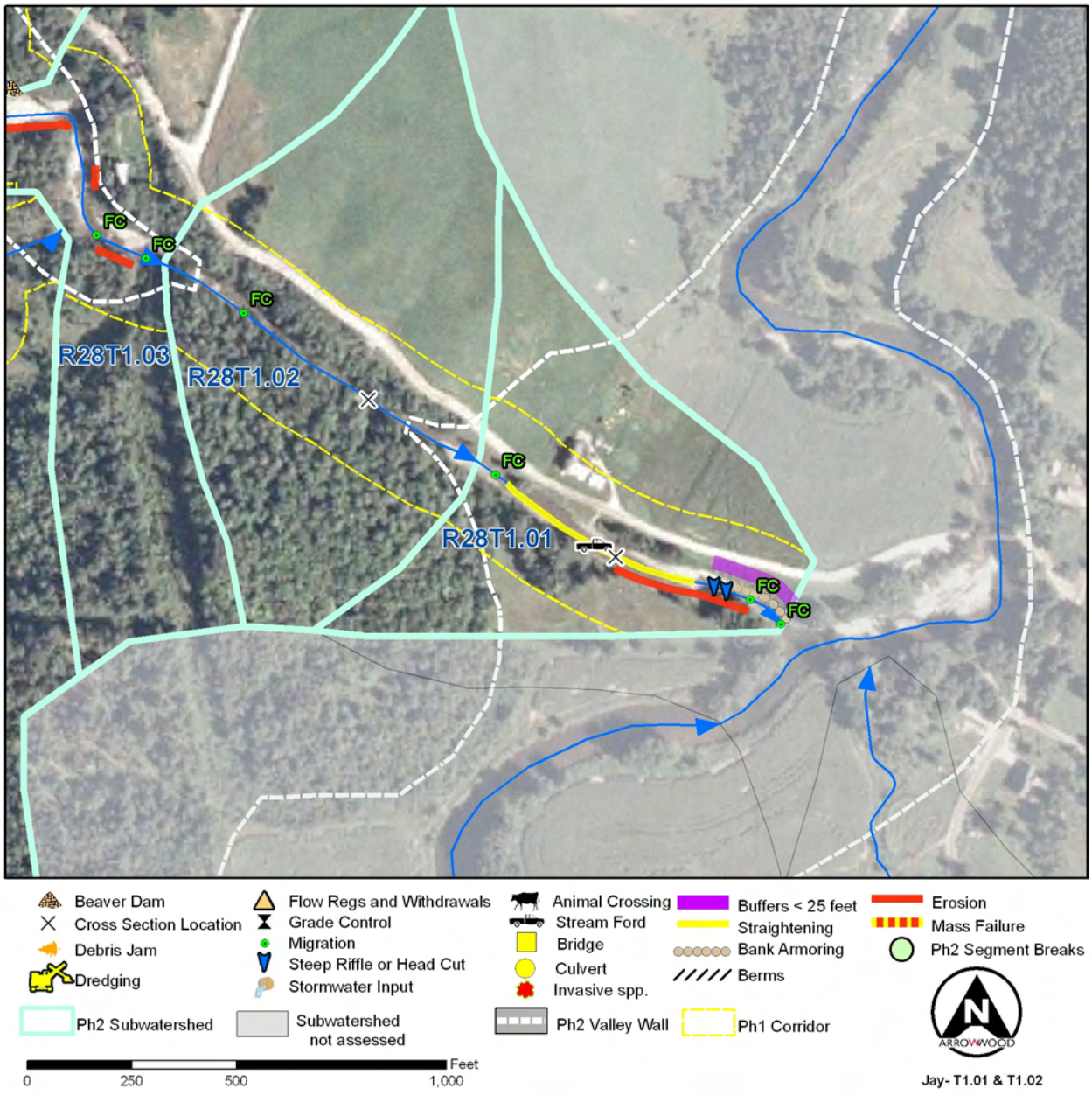


Figure u. Reach T1.01/T1.02 Inventory Map

Figure v. Corridor Encroachment Along T1.01

T1.01 Summary Data	
Reach/Segment Length	838 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	IV
Adjustment Process	Minor adjustments
Habitat Condition	Fair
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 10a. Reach T1.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.01	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T1.01	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings

T1.02 Summary Data	
Reach/Segment Length	885 ft
Valley Confinement	Semi-confined
Reference Stream Type	Bc
Existing Stream Type	F4
Geomorphic Condition	Good
Channel Evolution Stage	III
Adjustment Process	Aggradation
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations: none at this time.

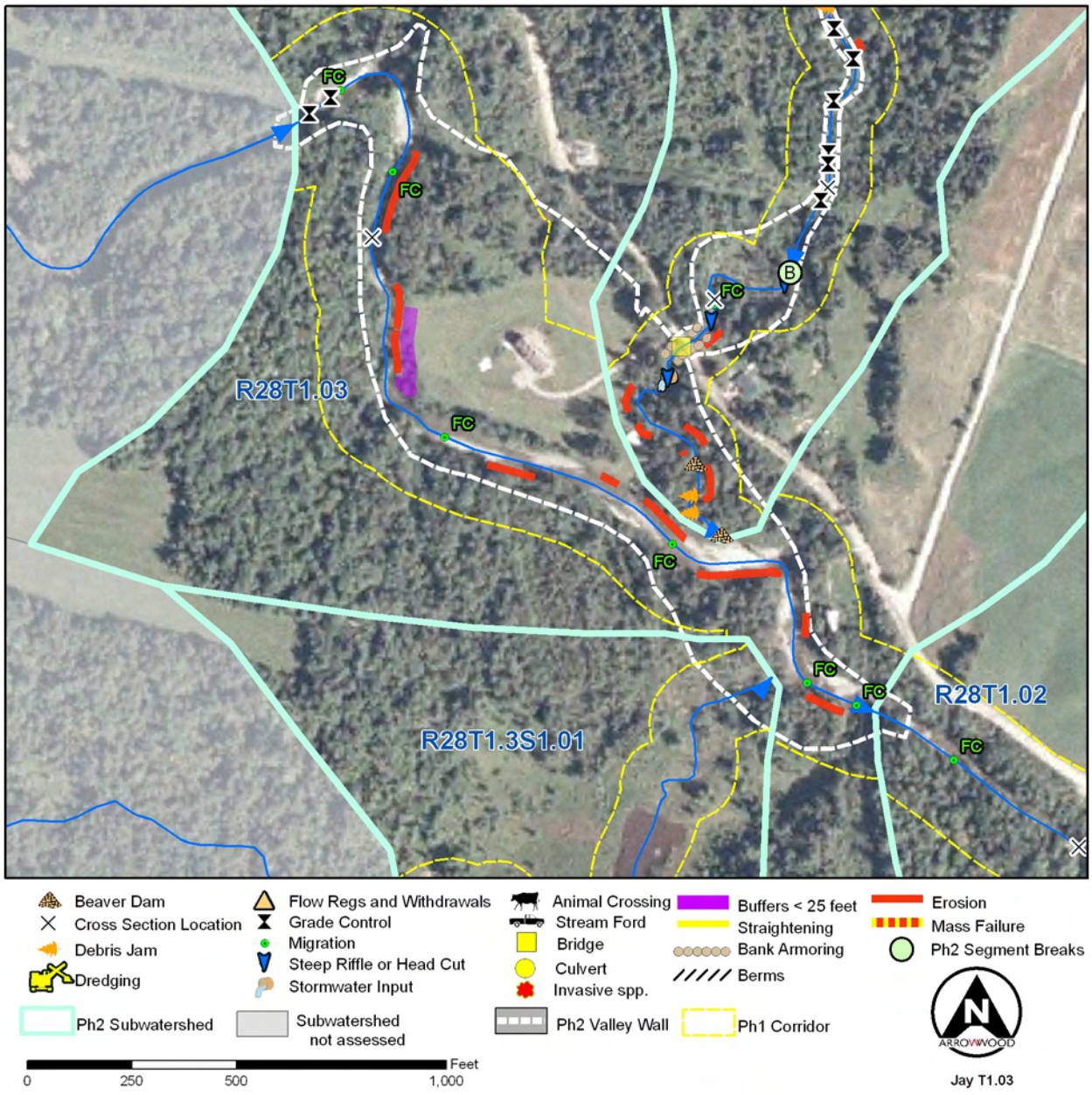


Figure w. Reach T1.03 Inventory Map

T1.03 Summary Data

Reach/Segment Length	**2,604 ft**
Valley Confinement	**Narrow**
Reference Stream Type	**C4**
Existing Stream Type	**F4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**III**
Adjustment Process	**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
Headcuts

Preliminary project recommendations are presented in the following table.

Table 10b. Reach T1.03 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.03	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T1.03	Plant Stream Buffers	Contact landowner (left bank), investigate possible grant programs for plantings

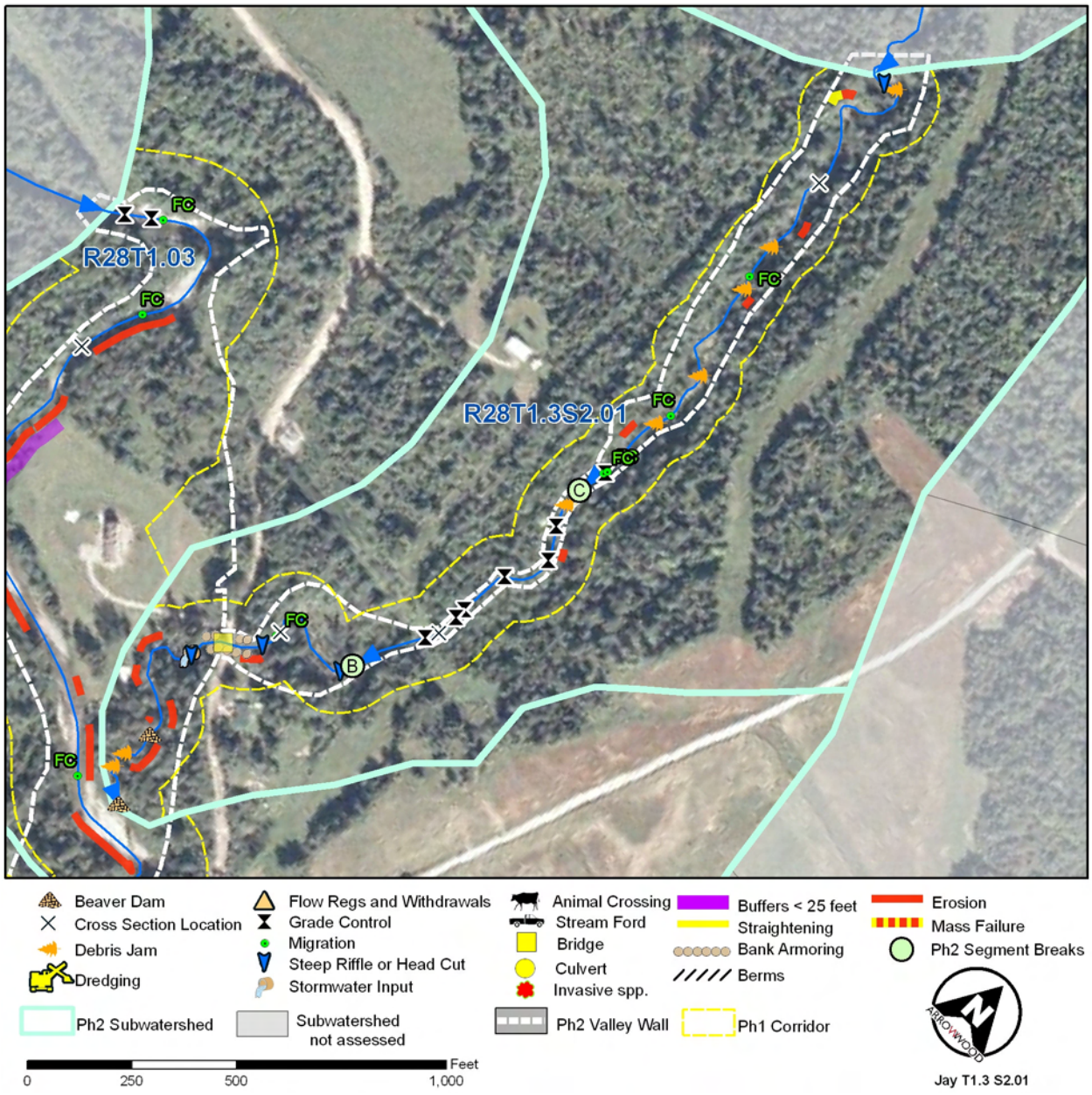


Figure x. Reach T1.03S2.01 Inventory Map

T1.03 S2.01a Summary Data

Reach/Segment Length	1097 ft
Valley Confinement	Very Broad
Reference Stream Type	E4
Existing Stream Type	C4
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	Minor adjustments
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

T1.03 S2.01b Summary Data

Reach/Segment Length	743 ft
Valley Confinement	Semi-confined
Reference Stream Type	Ab
Existing Stream Type	Ab
Geomorphic Condition	Reference
Channel Evolution Stage	I
Adjustment Process	
Habitat Condition	Good
Stream Sensitivity	Very Low

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

T1.03 S2.01c Summary Data

Reach/Segment Length	1420 ft
Valley Confinement	Very Broad
Reference Stream Type	E4
Existing Stream Type	E4
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	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 10c. Reach T1.03 S2.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.03S2.01a	**Protect River Corridor**	**Develop FEH Protection Areas map; contact interested landowners**

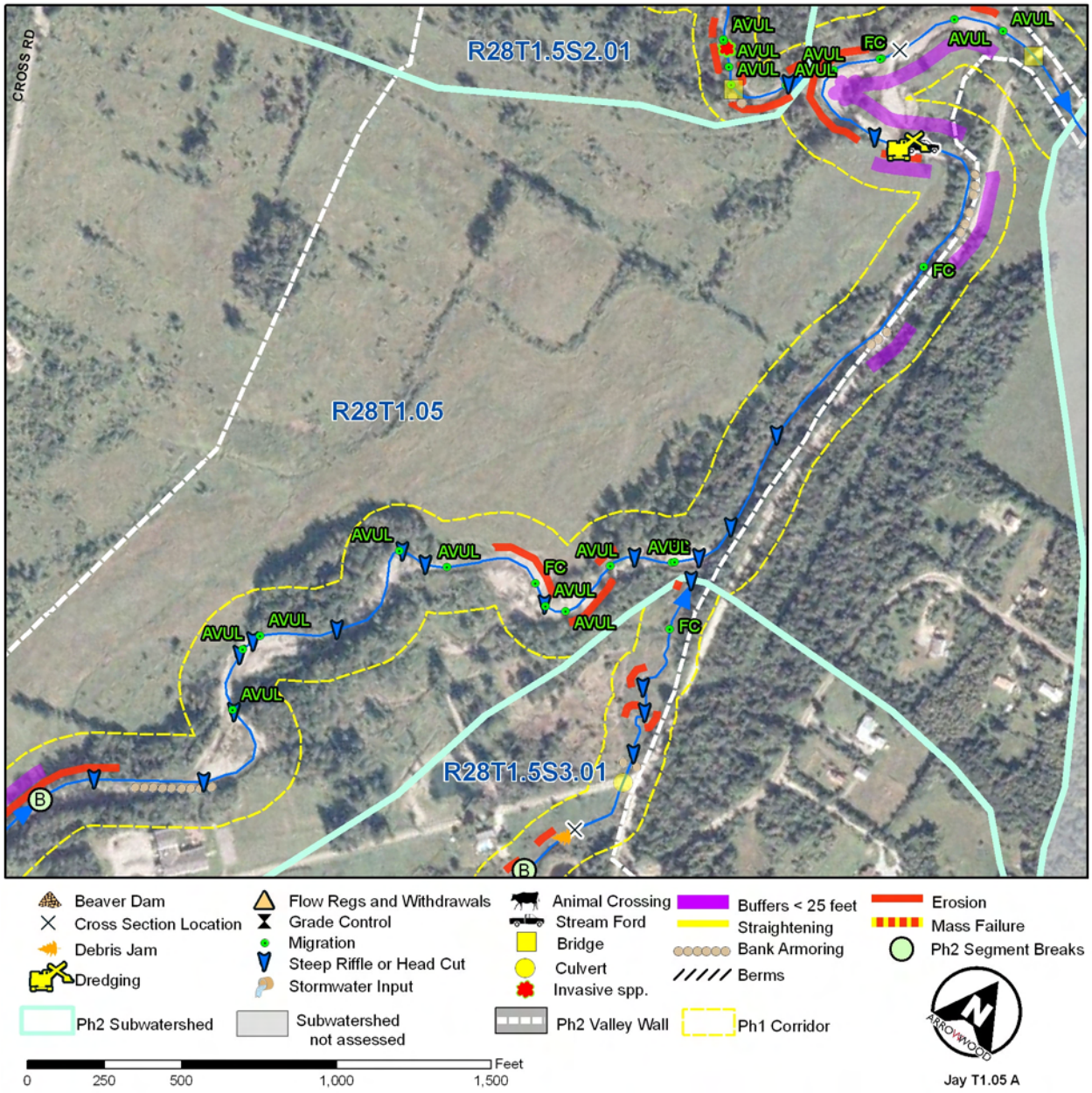


Figure y. Reach T1.05A Inventory Map

T1.05a Summary Data	
Reach/Segment Length	6,138 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	B4
Geomorphic Condition	Poor
Channel Evolution Stage	III
Adjustment Process	Widening, aggradation, and planform
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

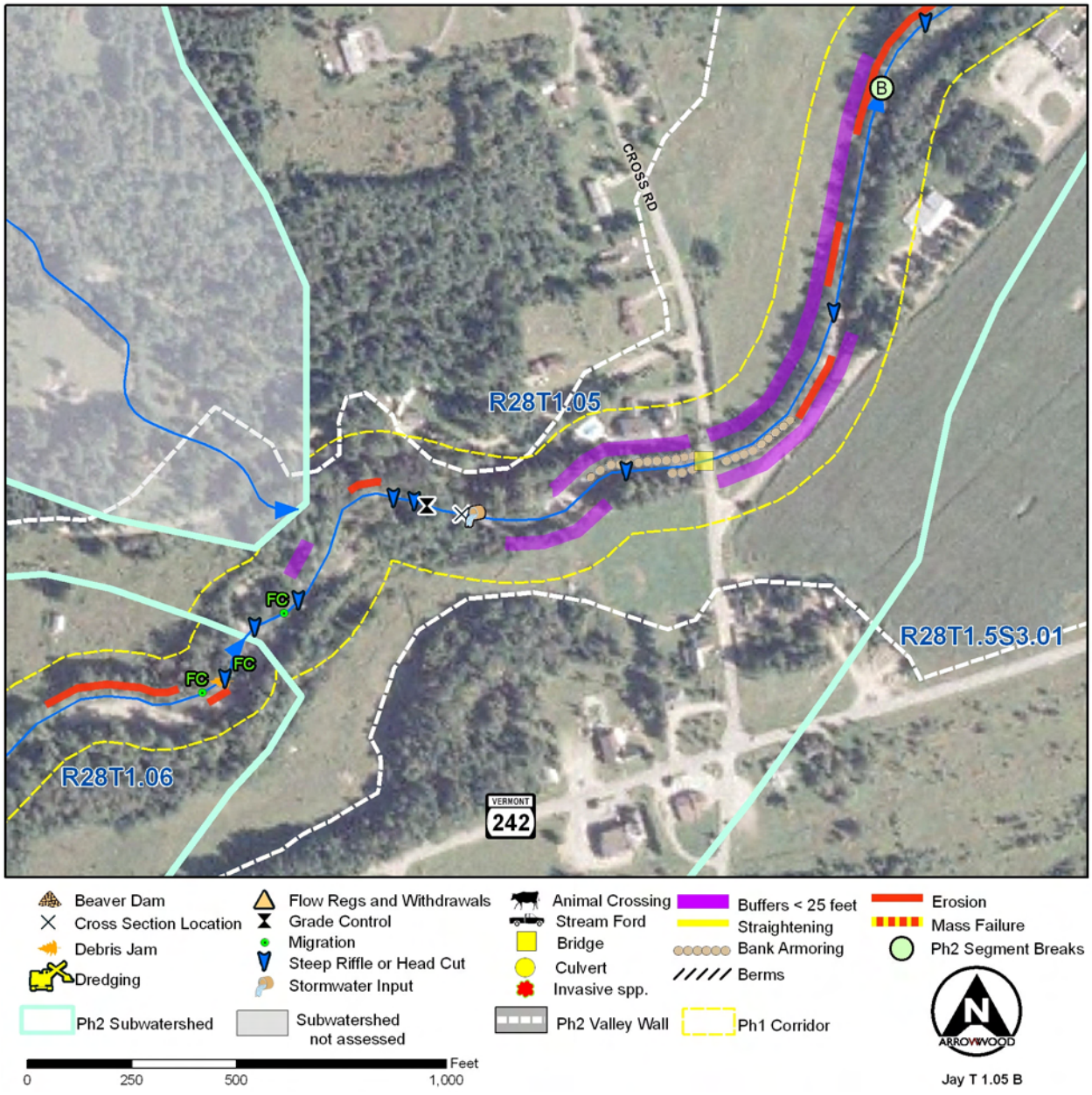


Figure z. Reach T1.05B Inventory Map

T1.05b Summary Data	
Reach/Segment Length	2,364 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Minor adjustments
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 10d. Reach T1.05 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.05a, b	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners

Figure aa. Reach T1.05 Segment B

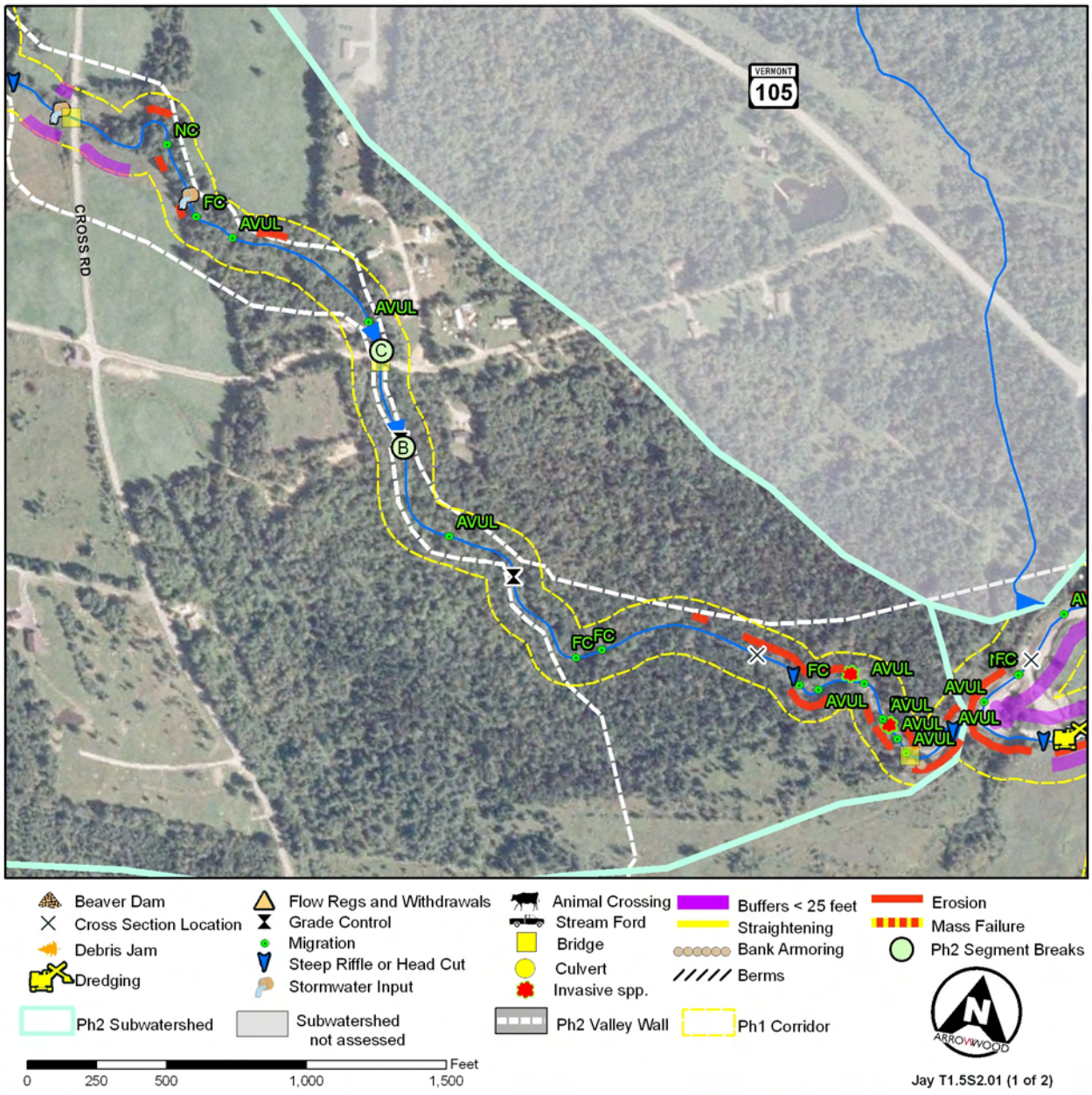


Figure bb. Reach T1.05S2.1A/B/C Inventory Map

T1.05 S2.01a Summary Data	
Reach/Segment Length	2851 ft
Valley Confinement	Very Broad
Reference Stream Type	B4
Existing Stream Type	B4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Major Widening, planform
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

T1.05 S2.01b Summary Data

Reach/Segment Length	363 ft
Valley Confinement	Narrow
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

*** Rock Gorge: Not assessed in field**

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

T1.05 S2.01c Summary Data

Reach/Segment Length	6,811 ft
Valley Confinement	Broad
Reference Stream Type	B4
Existing Stream Type	B4
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	
Habitat Condition	Reference
Stream Sensitivity	Moderate

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream
Bank Vegetation

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

Figure cc. Mass Failure in Segment C

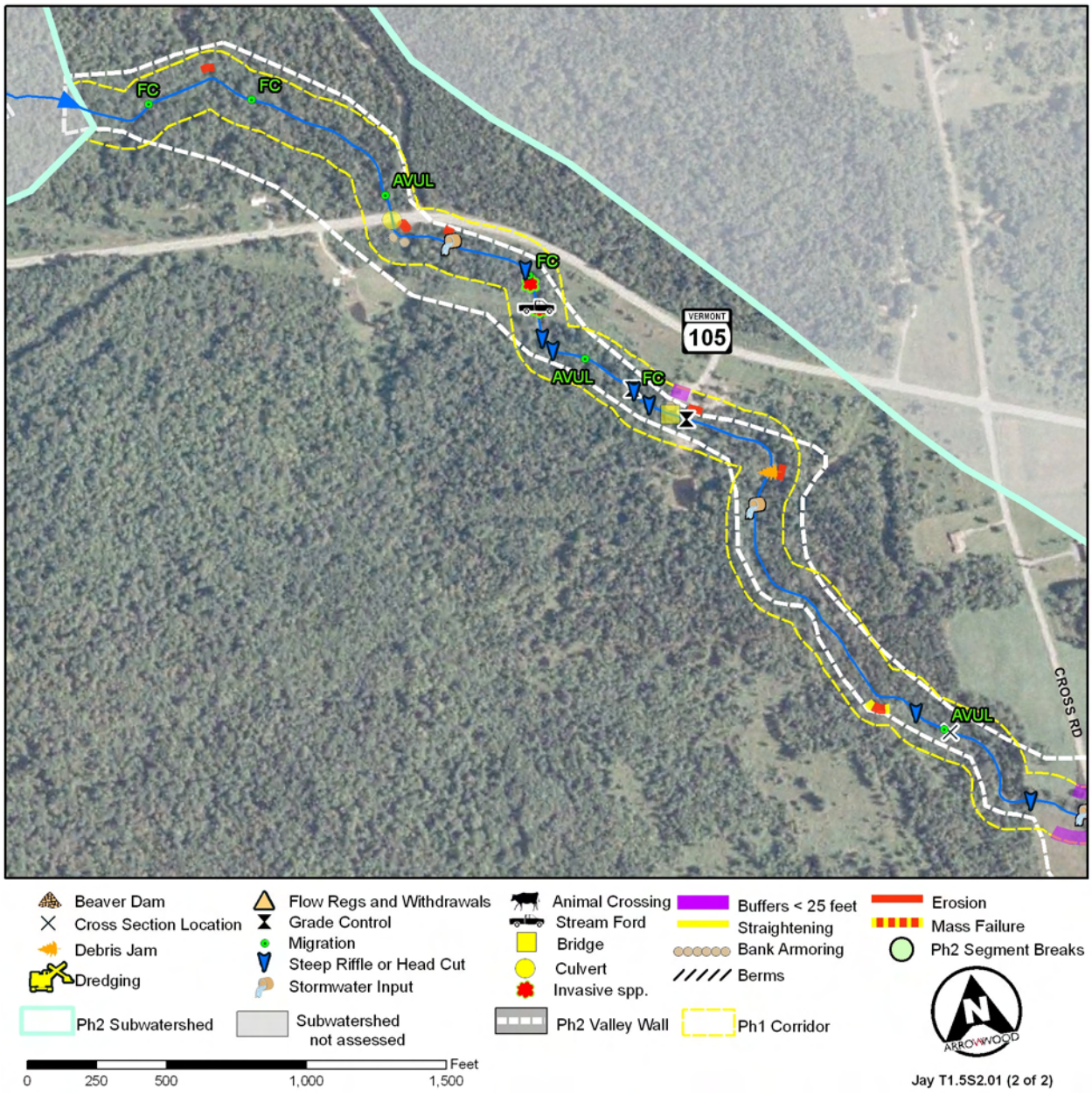


Figure dd. Reach T1.05S2.01C Inventory Map

. Preliminary project recommendations are presented in the following table.

Table 10e. Reach T1.05 S2.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.05S2.01a, c	**Invasive Plant Removal**	**Landowner contacts; labor intensive; multi- year project; results may be limited**
T1.05S2.01c	**Structure removal (washed out timber bridge)**	**Contact landowner; organize volunteers; investigate grants for disposal costs**

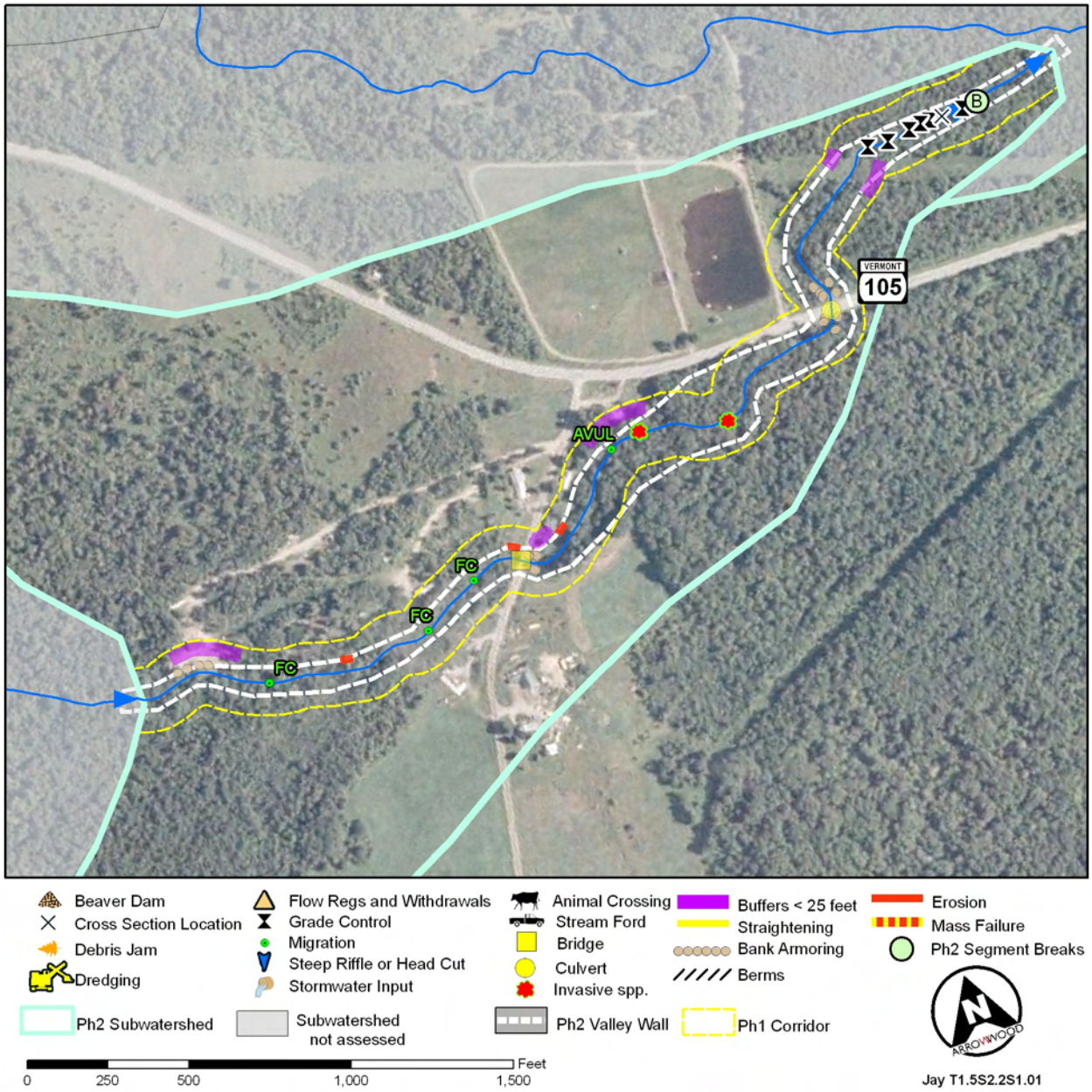


Figure ee. Reach T1.05S2.2S1.01 Inventory Map

T1.05 S2.02 S1.01a Summary Data *Rock Gorge: Not assessed in Field	
Reach/Segment Length	**280 ft**
Valley Confinement	**Narrow**
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

T1.05 S2.02 S1.01b Summary Data	
Reach/Segment Length	3688 ft
Valley Confinement	Narrow
Reference Stream Type	B3
Existing Stream Type	B3
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	Minor adjustments
Habitat Condition	Reference
Stream Sensitivity	Moderate

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

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

Preliminary project recommendations are presented in the following table.

Table 10f. Reach T1.5S2.2S1.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.5S2.2S1.01b	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T1.5S2.2S1.01b	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
T1.5S2.2S1.01b	Invasive Plant Removal	Landowner contacts; labor intensive; multi- year project; results may be limited
T1.5S2.2S1.01b	Dump site removal (~700' upstream of Rte 105 crossing)	Contact landowner; organize volunteers; investigate grants for disposal costs
T1.5S2.2S1.01b	Structure removal (Morse Road; 3 bridges stacked on each other #700012000010123)	Contact landowner; organize volunteers; investigate grants for disposal costs

Figure ff. Morse Road Bridge, Segment B

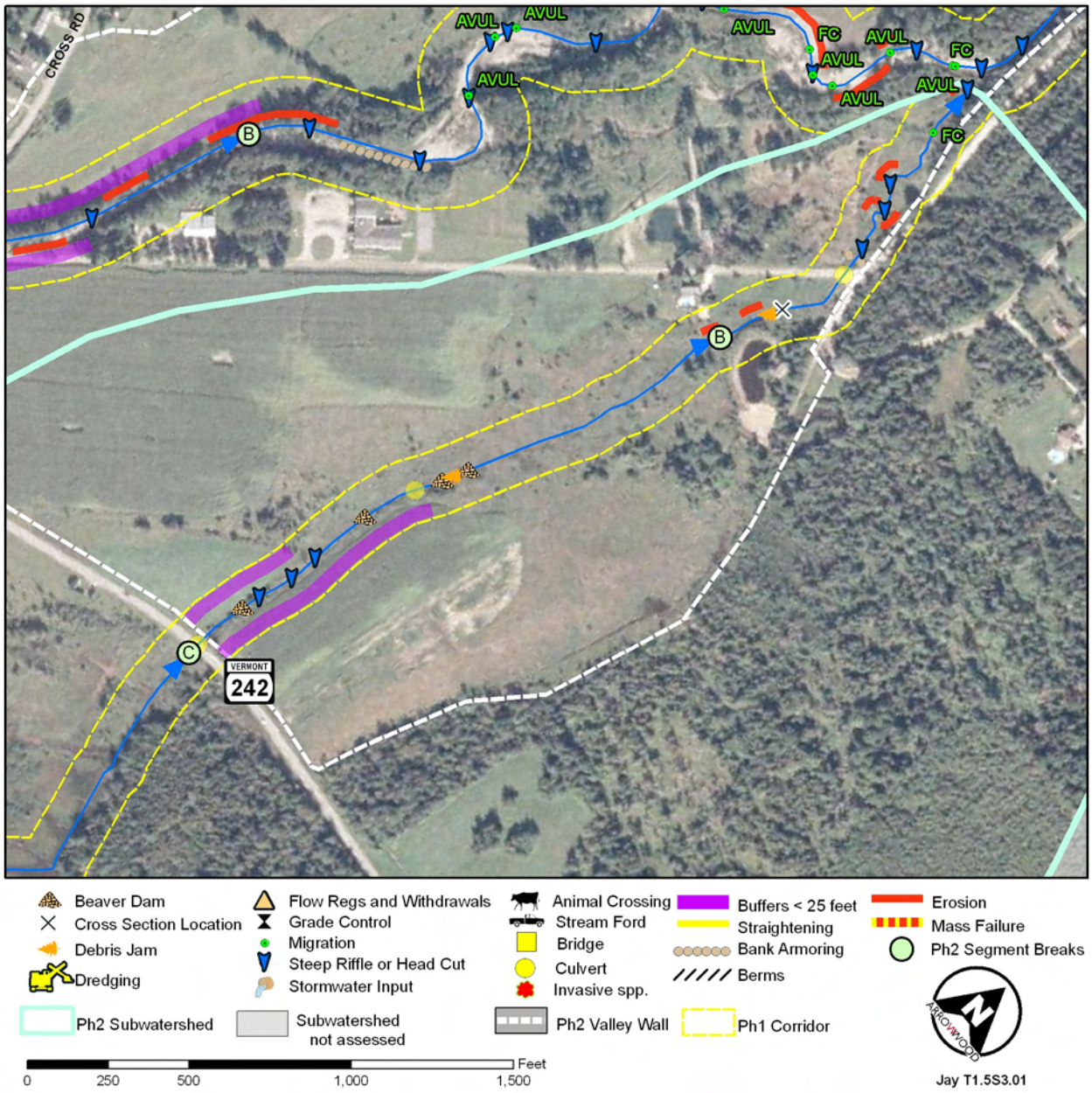


Figure gg. Reach T1.05S3.01 Inventory Map

T1.05 S3.01a Summary Data

Reach/Segment Length	**1207 ft**
Valley Confinement	**Very Broad**
Reference Stream Type	**E5**
Existing Stream Type	**E5**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**III**
Adjustment Process	**Some 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

T1.05 S3.01b Summary Data	
Reach/Segment Length	1924 ft
Valley Confinement	Very Broad
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

***Beaver Dam: Not assessed in the field.**

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

T1.05 S3.01c Summary Data	
Reach/Segment Length	3166 ft
Valley Confinement	Very Broad
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

***Beaver Dams: Not assessed in field**

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.

Figure hh. Segment B Stream Channel

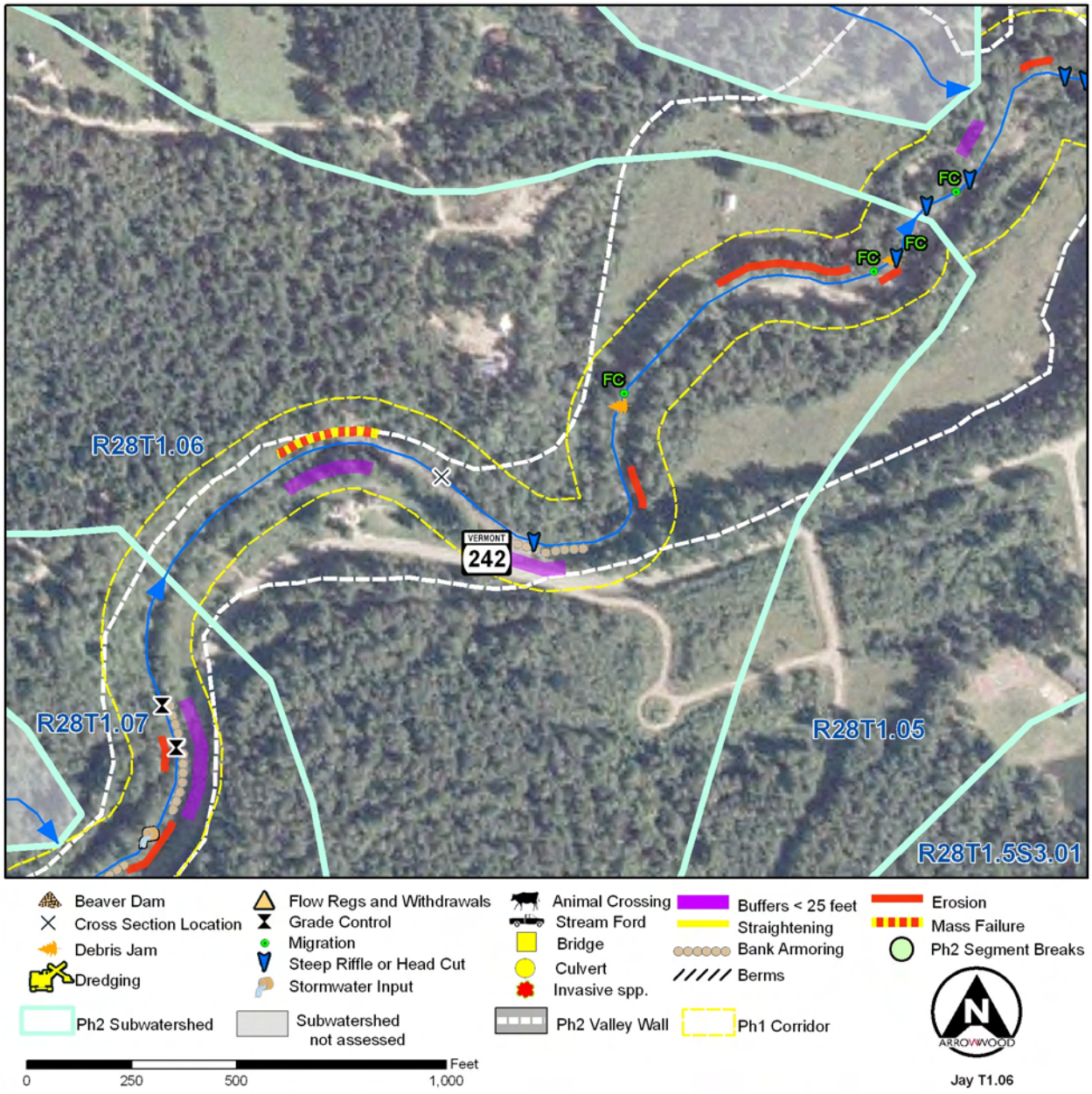


Figure ii. Reach T1.06 Inventory Map

T1.06 Summary Data	
Reach/Segment Length	2,517 ft
Valley Confinement	Broad
Reference Stream Type	B3
Existing Stream Type	F3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, planform
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 10g. Reach T1.06 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.06	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners

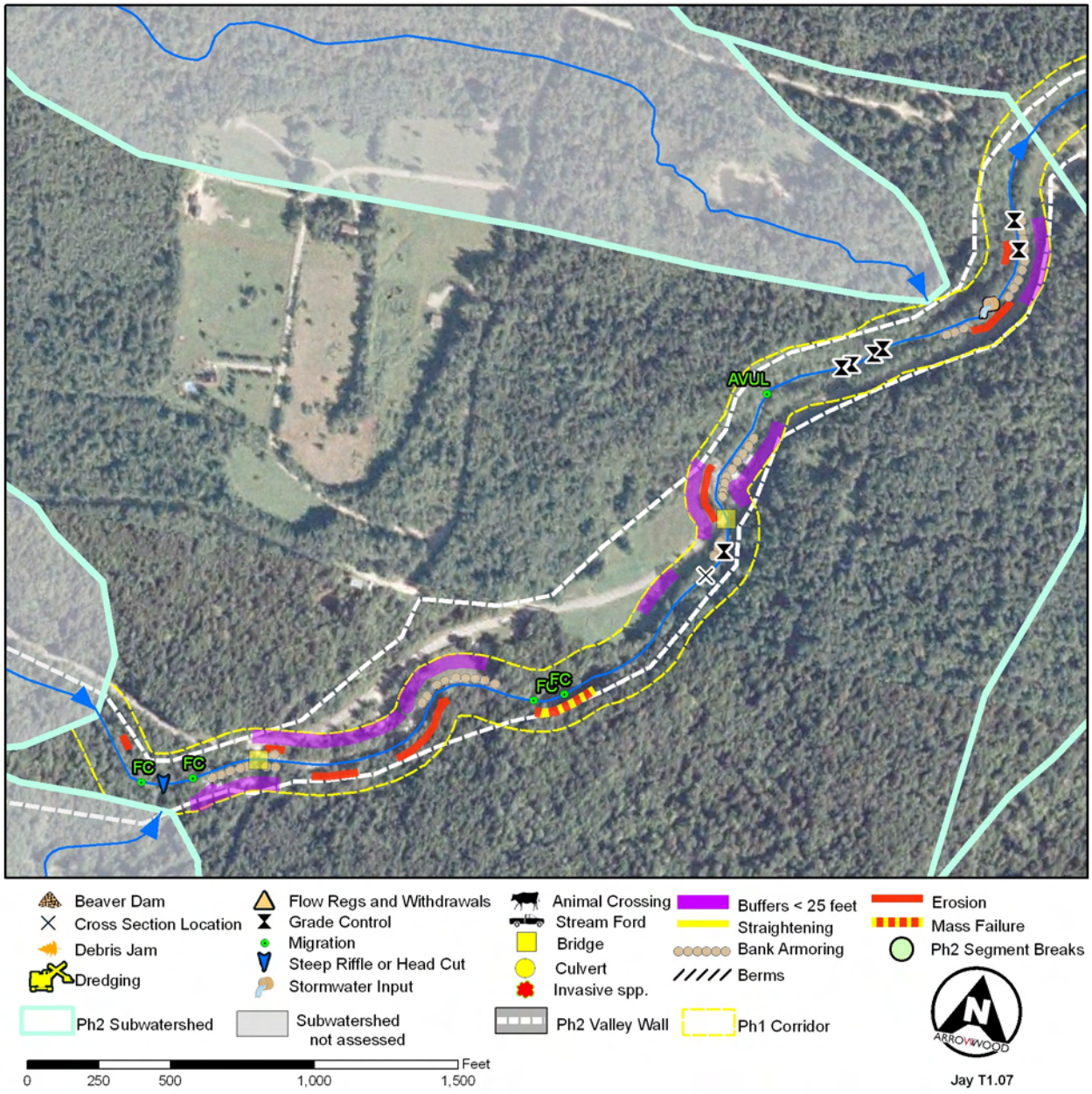


Figure jj. Reach T1.07 Inventory Map

T1.07 Summary Data	
Reach/Segment Length	4,789 ft
Valley Confinement	Semi-confined
Reference Stream Type	B3
Existing Stream Type	B3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, some planform
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 10h. Reach T1.07 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
T1.07	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
T1.07	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
T1.07	Structure replacement (#100242000010122)	Contact AOT regarding possible replacement of Rte 242 bridge

5.3 Mudd Creek Study Reaches

Figure kk. Reach M02 Stream Channel

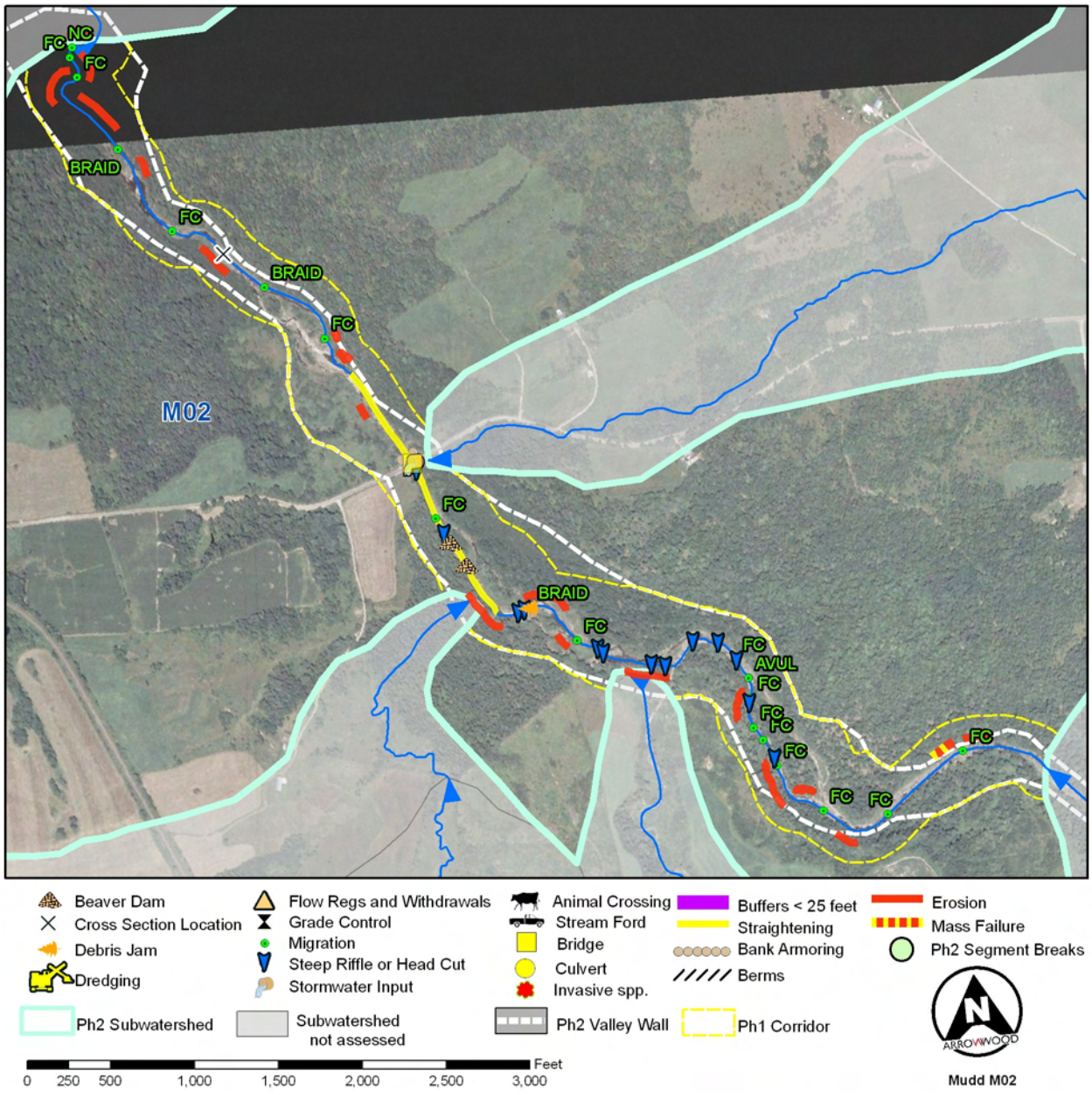


Figure ll. Reach M02 Inventory Map

M02a Summary Data	
Reach/Segment Length	9171 ft
Valley Confinement	Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, aggradation, 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
Headcuts

Preliminary Project Identification: No projects recommended at this time.

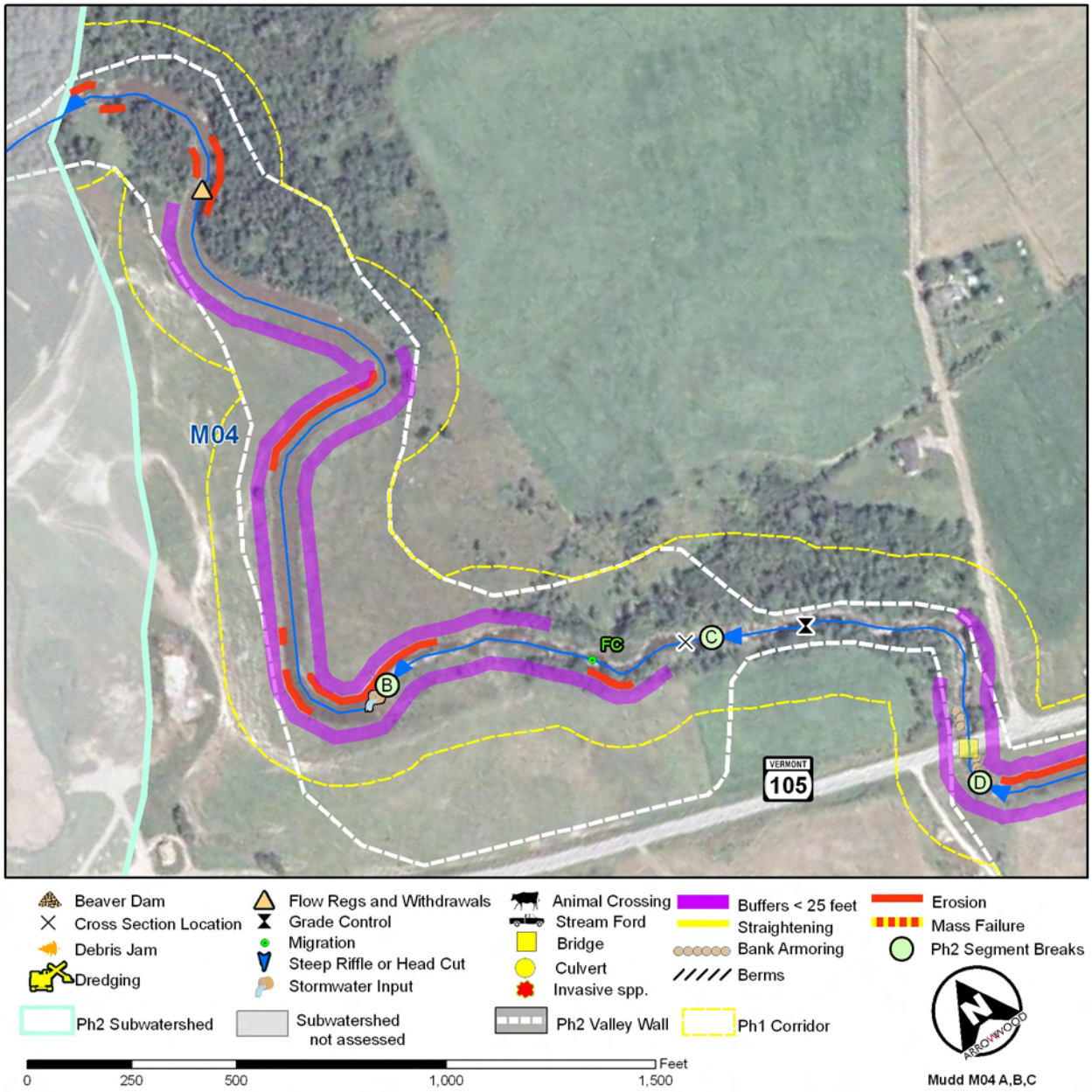


Figure mm. Reach M04 A,B,C Inventory Map

M04a Summary Data	
Reach/Segment Length	2361 ft
Valley Confinement	
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	Impounded, not assessed in field
Habitat Condition	
Stream Sensitivity	

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

M04b Summary Data

Reach/Segment Length	842 ft
Valley Confinement	Very Broad
Reference Stream Type	C3
Existing Stream Type	C3
Geomorphic Condition	Good
Channel Evolution Stage	II
Adjustment Process	Minor adjustments
Habitat Condition	Fair
Stream Sensitivity	Moderate

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

M04c Summary Data

Reach/Segment Length	955 ft
Valley Confinement	
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

***Rock gorge: Not assessed in field**

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

M04d Summary Data

Reach/Segment Length	10,679 ft
Valley Confinement	Semi-confined
Reference Stream Type	C3
Existing Stream Type	C5
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, aggradation, 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
Headcuts

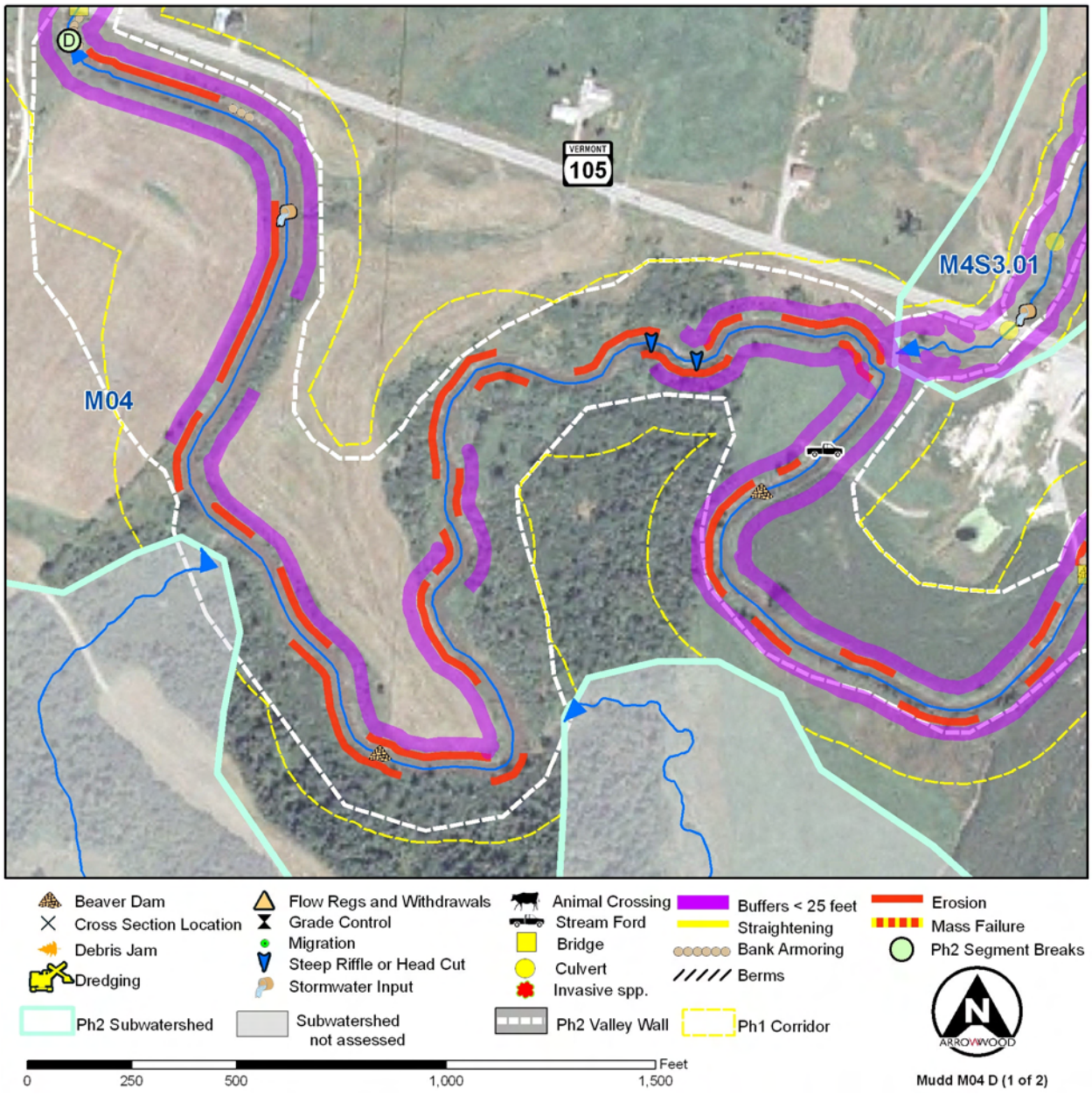


Figure nn. Reach M04D Inventory Map

Figure oo. No buffers and erosion is Segment D

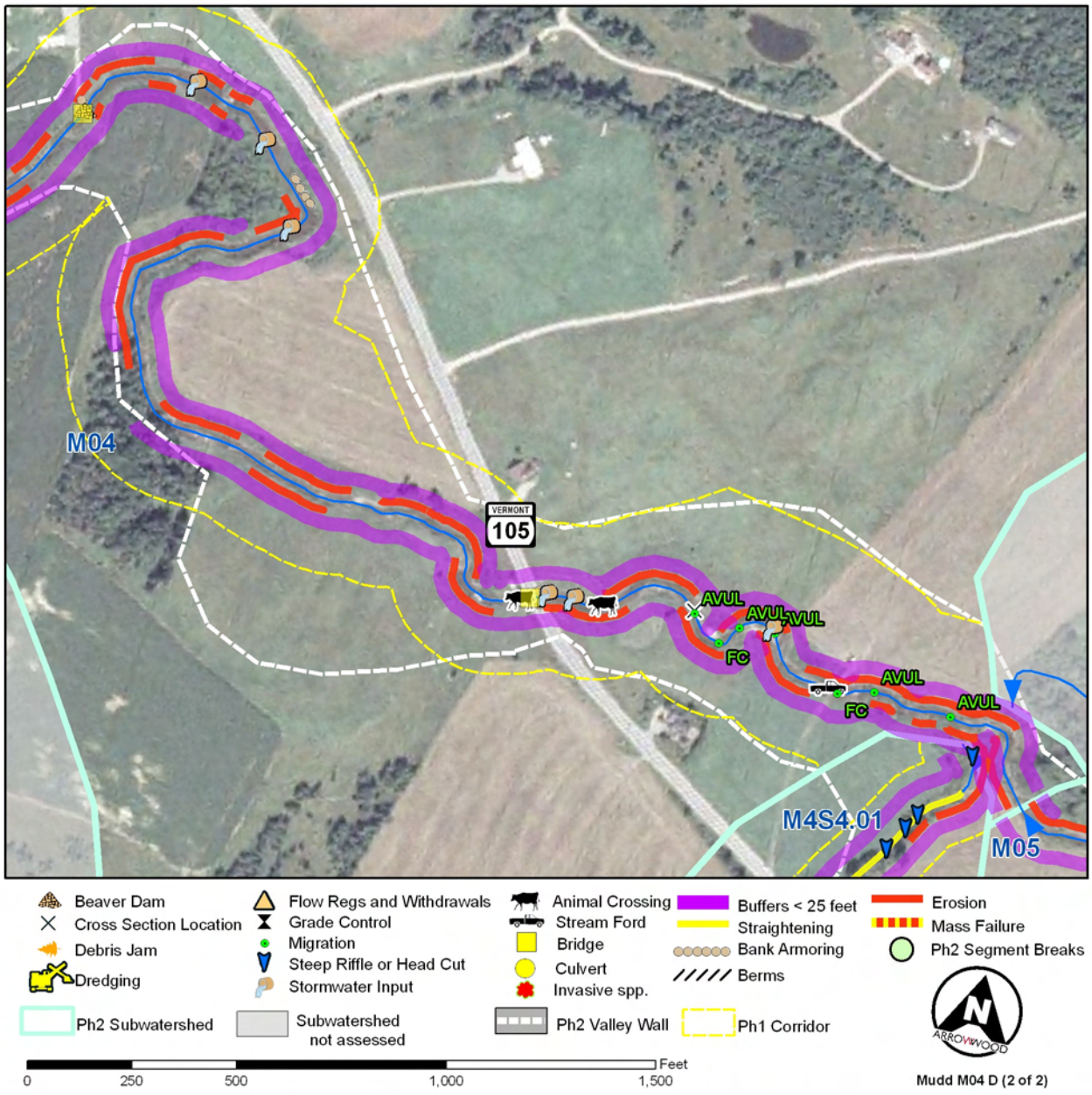


Figure pp. Reach M04D Inventory Map (page 2)

Preliminary project recommendations are presented in the following table.

Table 11a. Reach M04 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M04d	**Protect River Corridor**	**Develop FEH map; contact interested landowners**
M04b, c	**Plant Stream Buffers**	**Contact landowners, investigate possible grant programs for plantings**
M04d	**Restrict cattle access to creek**	**Contact landowners; research grant possibilities for fencing and water access points**
M04a	**Structure removal (small run-of-river dam made of rocks)**	**Contact landowner; organize volunteers; investigate removal options**
M04d	**Structure removal (Bridge #700008000010163) not in use**	**Contact landowner; organize volunteers; investigate grants for removal and disposal costs**

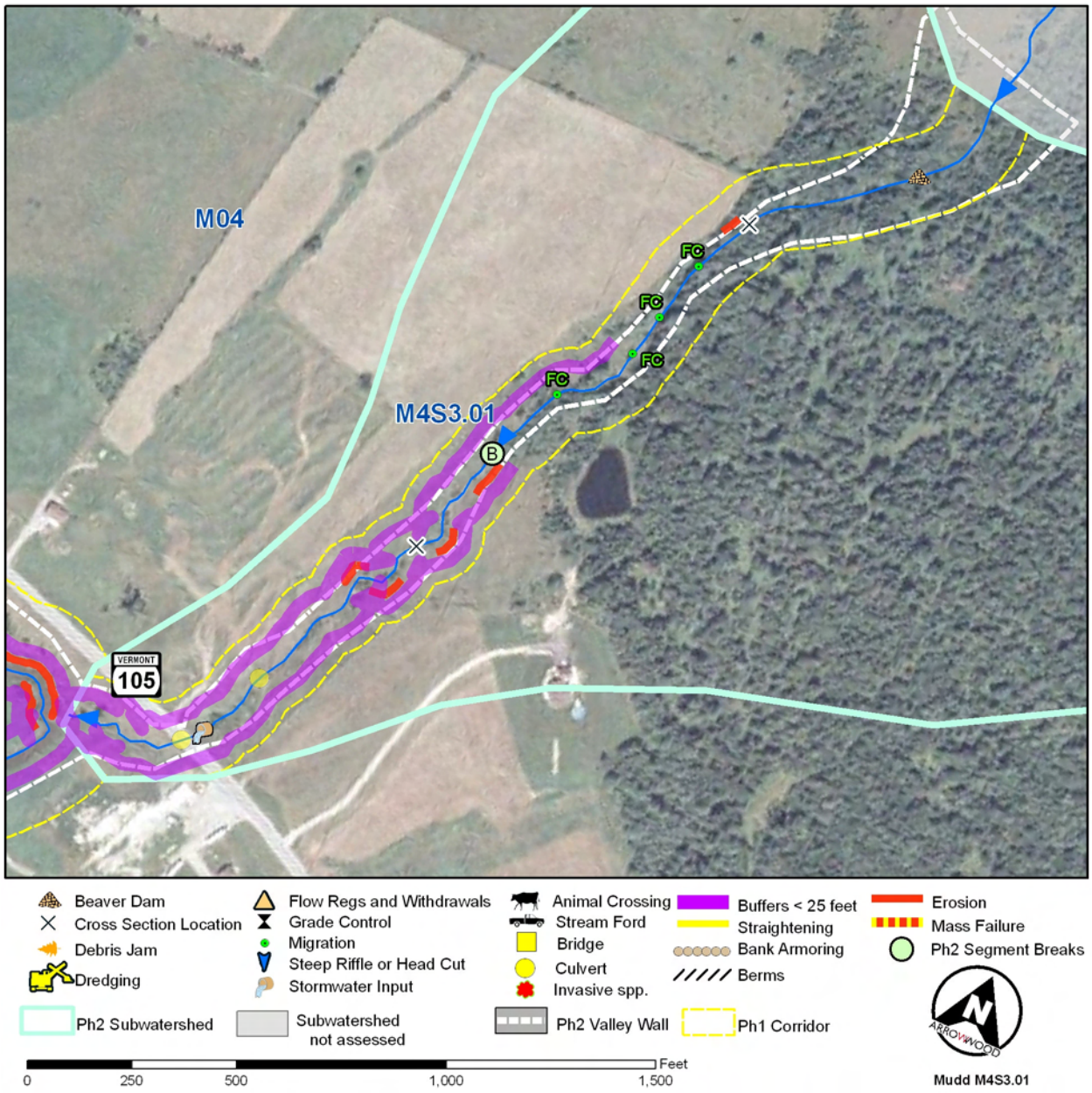


Figure qq. Reach M4S3.01 Inventory Map

M4S3.01a Summary Data

Reach/Segment Length	**1392 ft**
Valley Confinement	**Very Broad**
Reference Stream Type	**B3**
Existing Stream Type	**E4**
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	**No flow in channel**
Habitat Condition	**Fair**
Stream Sensitivity	

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

M4S3.01b Summary Data	
Reach/Segment Length	1534 ft
Valley Confinement	Very Broad
Reference Stream Type	B3
Existing Stream Type	B3
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	Fair
Stream Sensitivity	

*No flow in channel

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 11b. Reach M4S3.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M4S3.01a	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners; landowner suggested a major subdivision was being developed in near future
M4S3.01a	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
M4S3.01a	Structure replacement (Rte 105 culvert; #300105000110162)	Contact AOT; landowner suggested that this was already on a list for replacement

Figure rr. Rte 105 Culvert Constriction

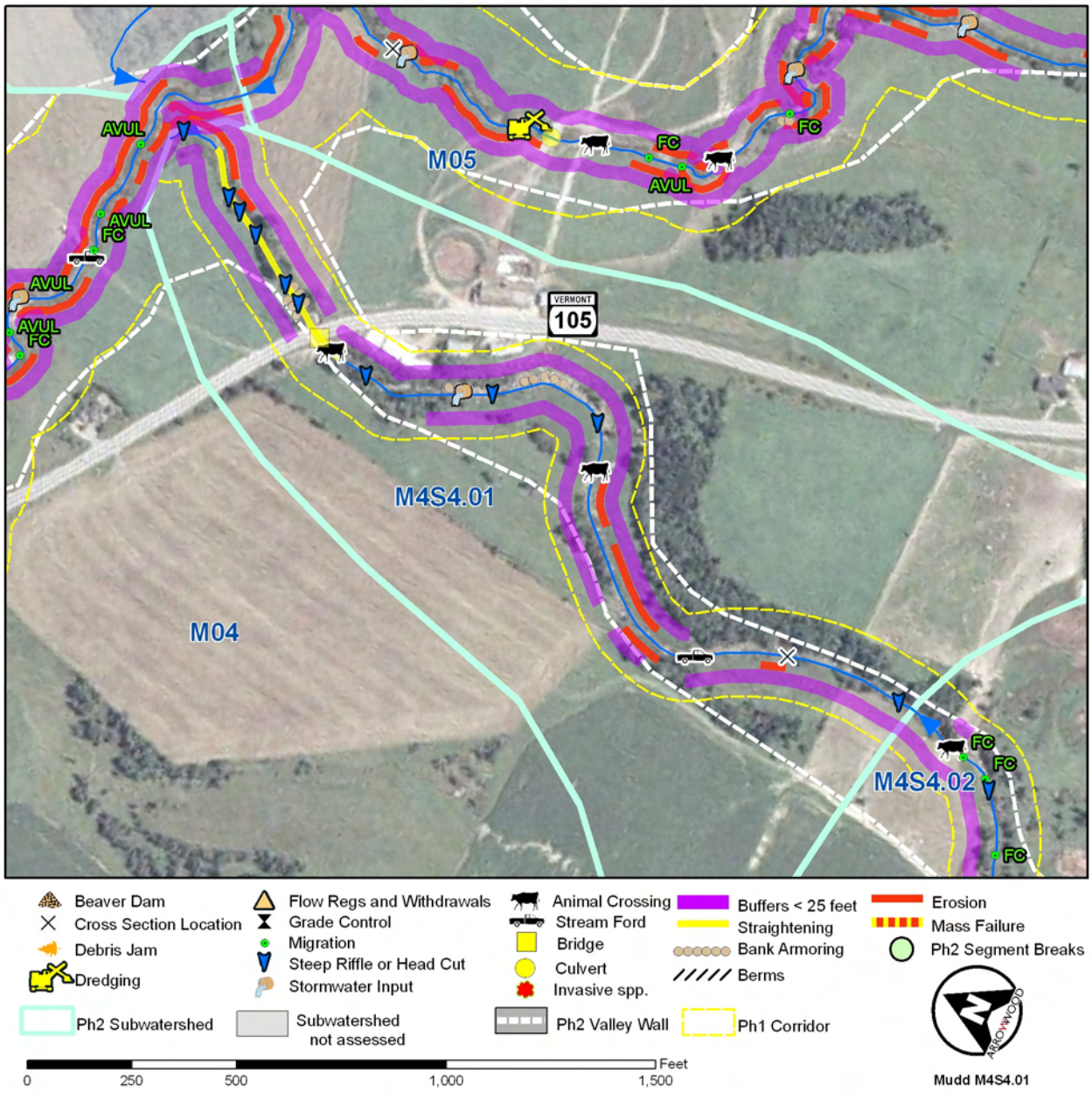


Figure ss. Reach M4.S4.01 Inventory Map

M4.S4.01 Summary Data	
Reach/Segment Length	2630 ft
Valley Confinement	Broad
Reference Stream Type	C3
Existing Stream Type	C3
Geomorphic Condition	Good
Channel Evolution Stage	III
Adjustment Process	Some widening
Habitat Condition	Fair
Stream Sensitivity	Moderate

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 11c. Reach M4S4.01 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M4S4.01	**Plant Stream Buffers**	**Contact landowners, investigate possible grant programs for plantings**
M4S4.01	**Restrict cattle access to creek**	**Contact landowners; research grant possibilities for fencing and water access points**
M4S4.01	**Structure removal (old abutment at Rte 105 crossing)**	**Contact landowner; organize volunteers; investigate grants for removal and disposal costs**

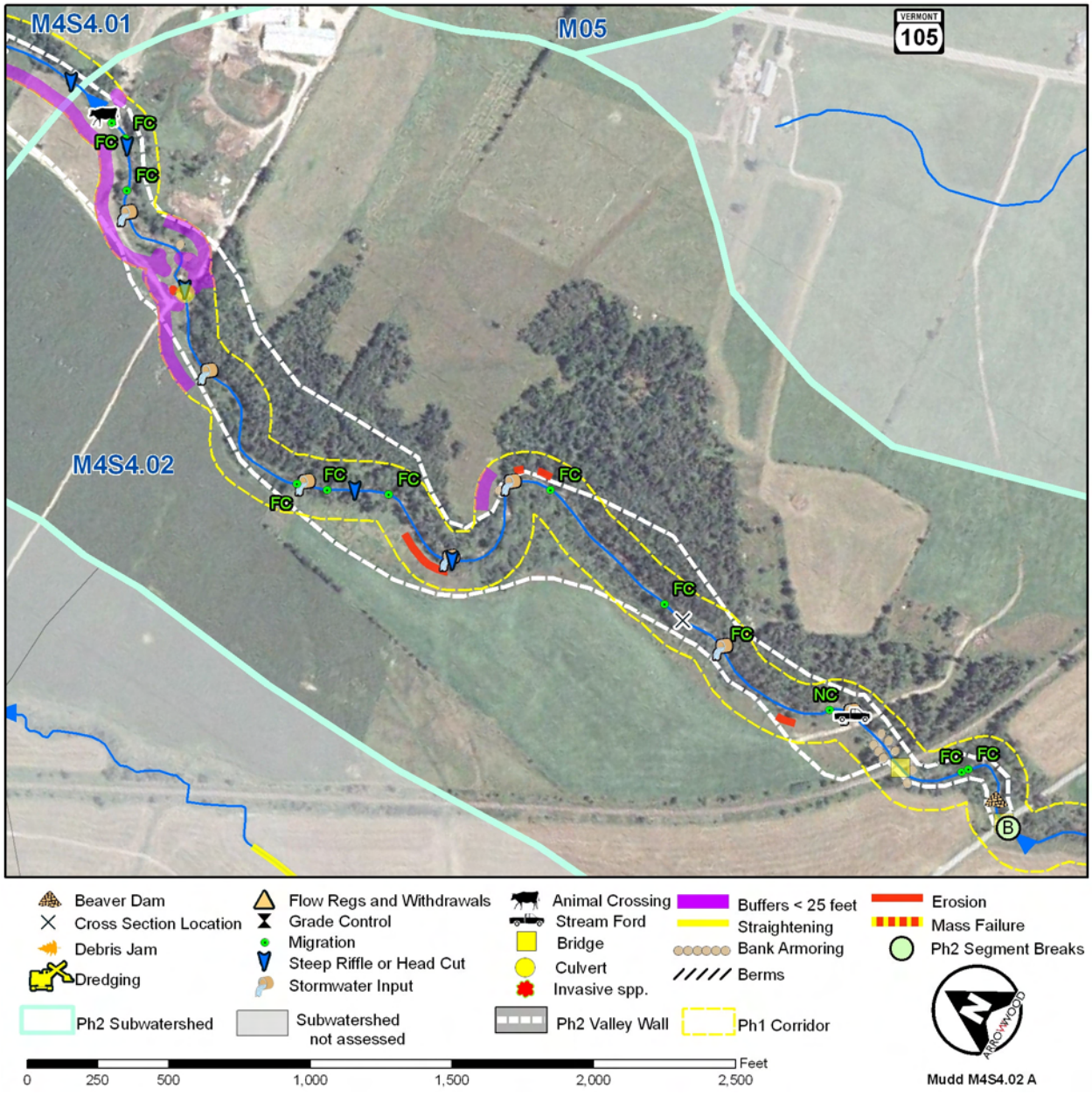


Figure tt. Reach M4S4.02A Inventory Map

M4S4.02a Summary Data

Reach/Segment Length	5225 ft
Valley Confinement	Broad
Reference Stream Type	C3
Existing Stream Type	C3
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, planform
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

M4S4.02b Summary Data

Reach/Segment Length	9193 ft
Valley Confinement	
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

***Beaver dams: not assessed in field**

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 11d. Reach M4S4.02 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M4S4.02A	Restrict cattle access to stream	Contact landowners; research grant possibilities for fencing and water access points
M4S4.02a	Possible head cut arrest	Landowner contacts; further field investigation needed
M4S4.02a	Structure replacement (undersized culvert; #700013000010163)	Contact landowner; organize volunteers; investigate grants for removal and replacement costs

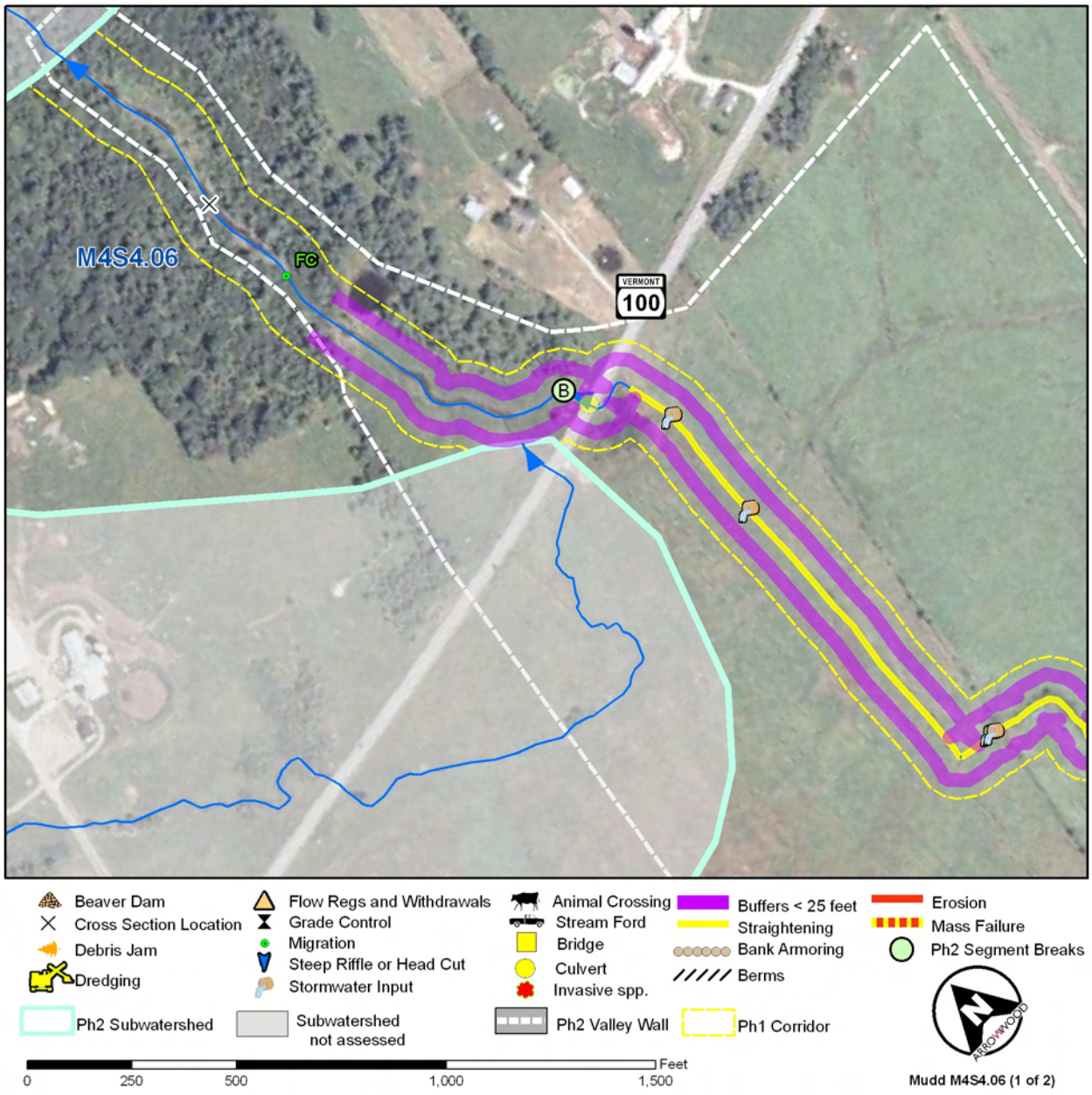


Figure uu. Reach M4S4.06 A/B Inventory Map

Reach M4S4.06a Summary Data	
Reach/Segment Length	1572 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Reference
Channel Evolution Stage	I
Adjustment Process	
Habitat Condition	Good
Stream Sensitivity	High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank
Vegetation

Reach Stressors

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

Reach M4S4.06b Summary Data	
Reach/Segment Length	5432 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	E5
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	Extensive human manipulation
Habitat Condition	Poor
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

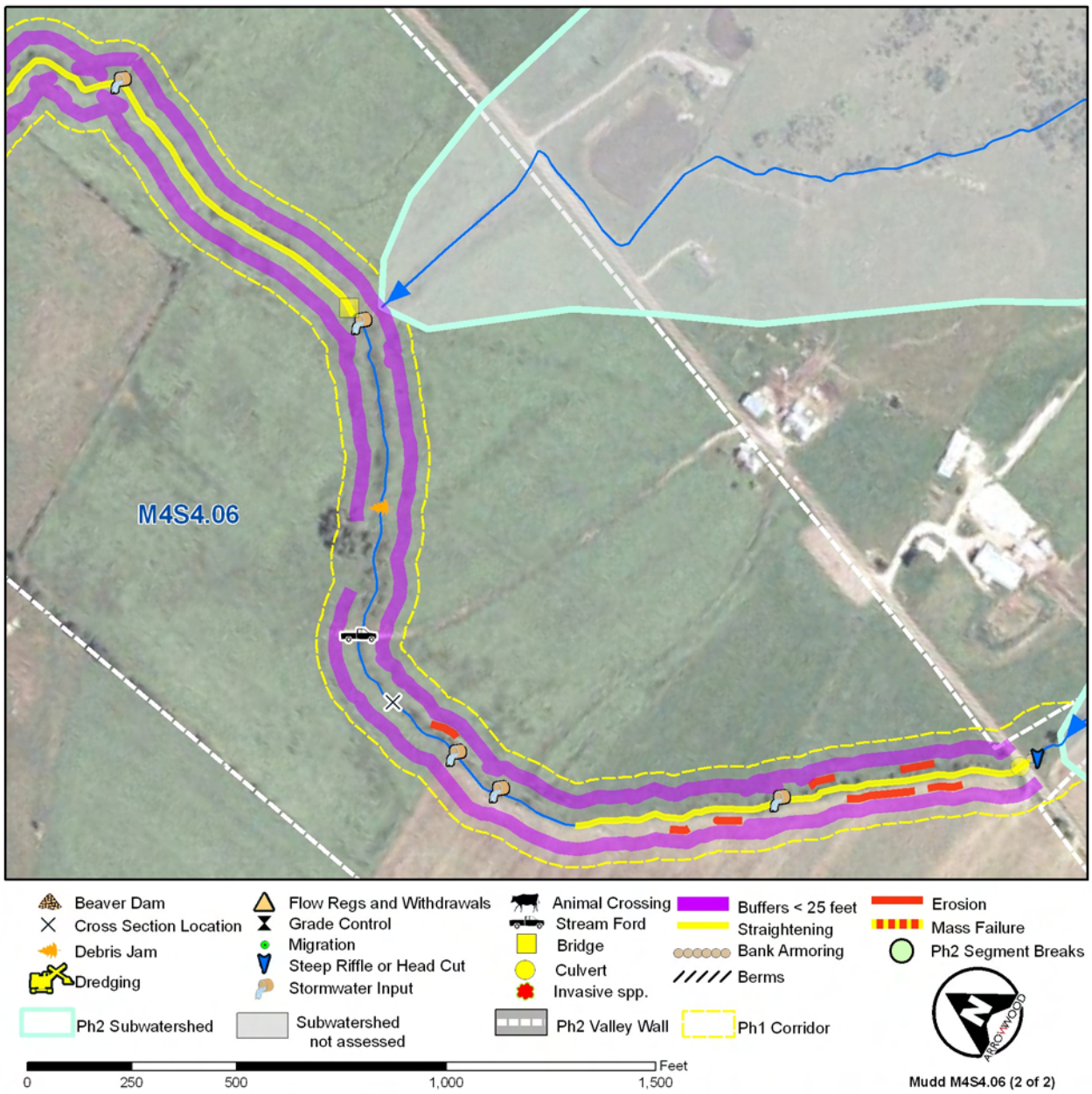


Figure vv. Reach M4S4.06 B Inventory Map

Preliminary project recommendations are presented in the following table.

Table 11e. Reach M4S4.06 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M4S4.06a,b	Plant Stream Buffers (right bank of segment A, both banks for segment b)	Contact landowners, investigate possible grant programs for plantings
M4S4.06b	Restrict cattle access to creek; eliminate stream dredging	Contact landowners; research grant possibilities for fencing and water access points; educate about stream channel manipulation impacts
M4S4.06b	Dump site removal (at stream ford downstream of Tetreault Road crossing)	Contact landowner; organize volunteers; investigate grants for disposal costs

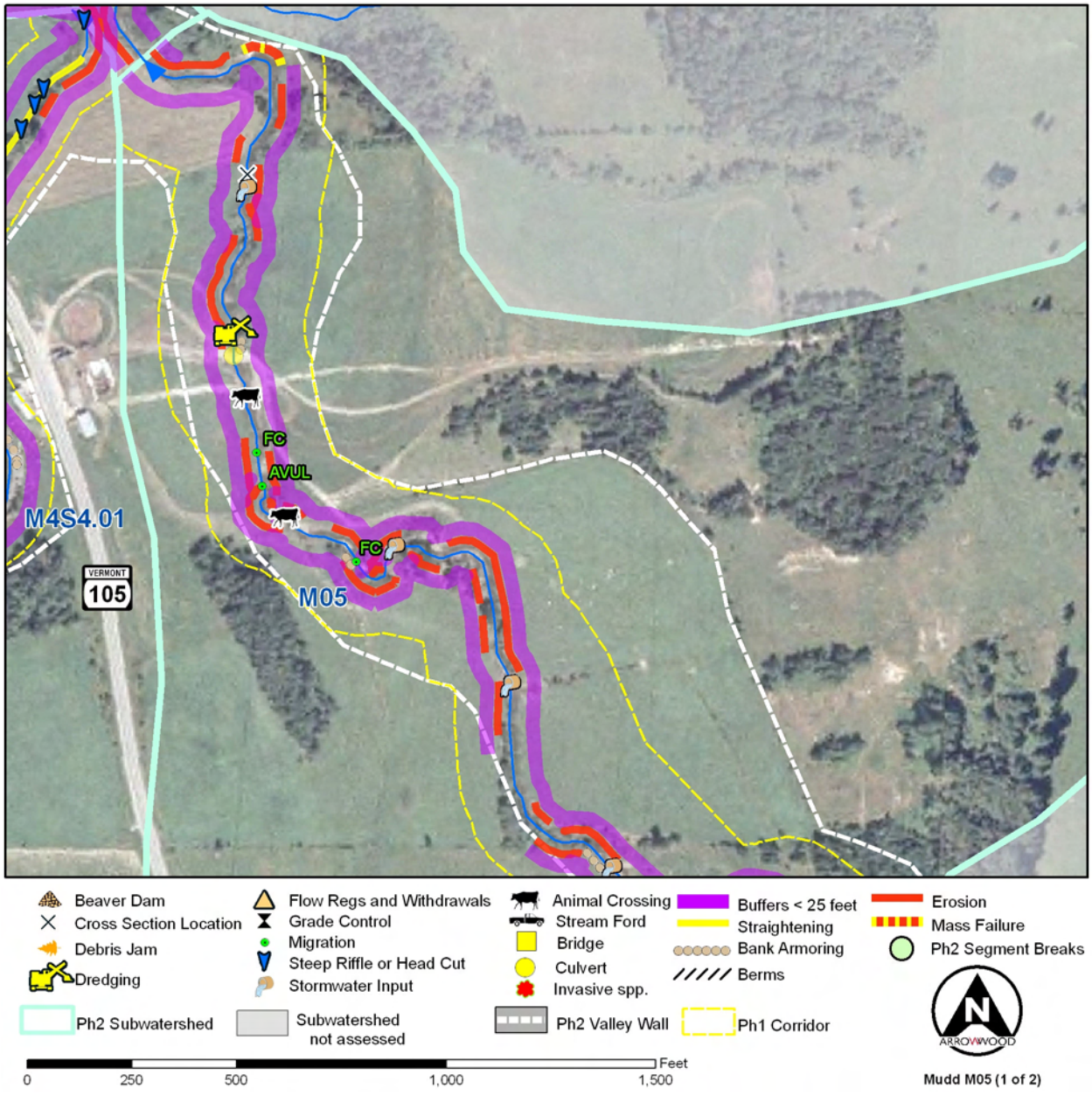


Figure ww. Reach M05 Inventory Map

M05a Summary Data

Reach/Segment Length	4288 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
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

M05b Summary Data

Reach/Segment Length	824 ft
Valley Confinement	Narrow
Reference Stream Type	B1
Existing Stream Type	B1
Geomorphic Condition	Good
Channel Evolution Stage	I
Adjustment Process	Minor adjustments
Habitat Condition	Good
Stream Sensitivity	Moderate

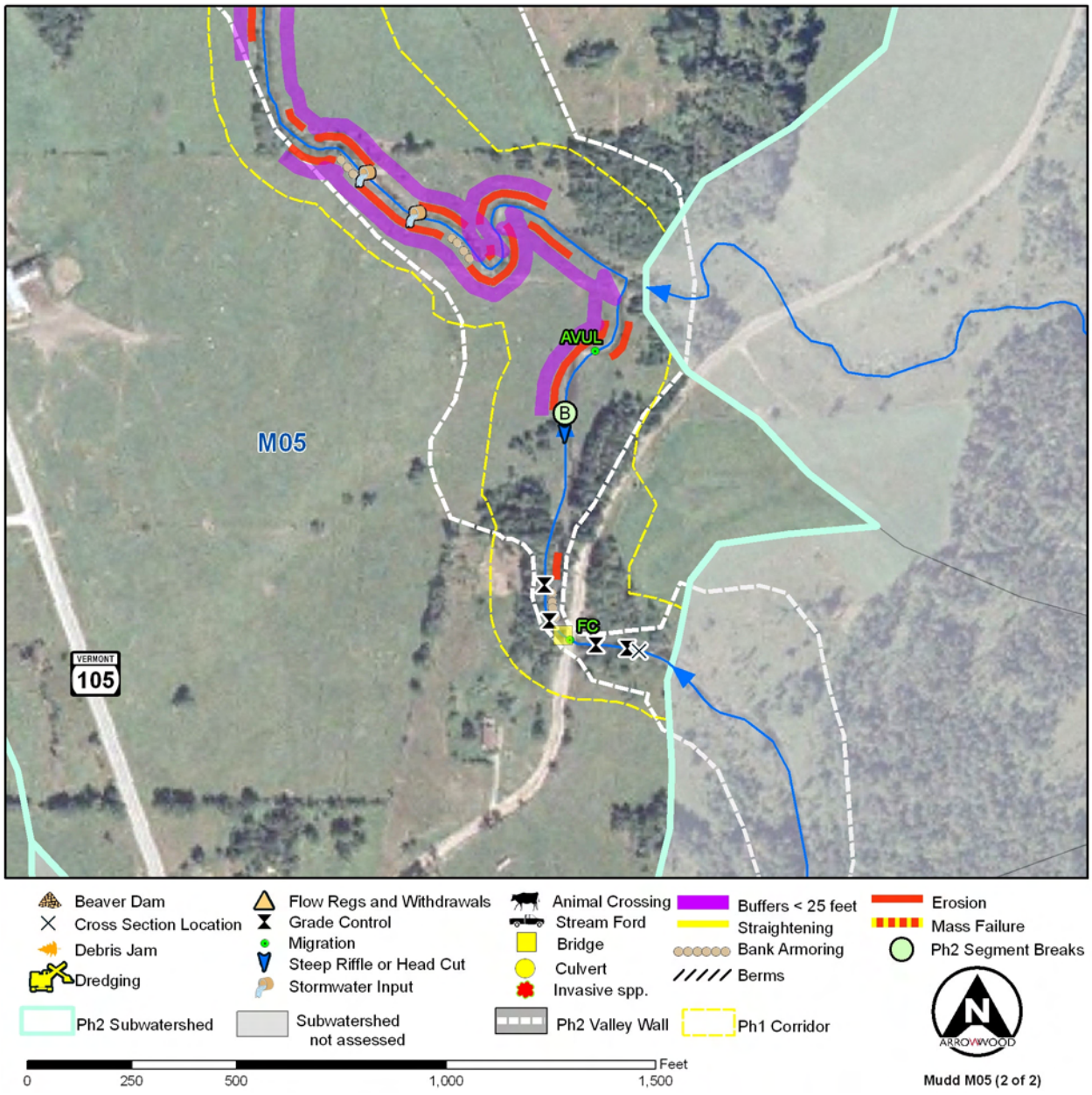
Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Figure xx. Segment M05A Undersized Culvert



Preliminary project recommendations are presented in the following table.

Table 11f. Reach M05 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M05a	**Plant Stream Buffers**	**Contact landowners, investigate possible grant programs for plantings**
M05a	**Restrict cattle access to creek; eliminate stream dredging**	**Contact landowners; research grant possibilities for fencing and water access points; educate about stream channel manipulation impacts**
M05a	**Structure replacement (undersized culvert #700009000010163)**	**Contact landowner; organize volunteers; research grant possibilities for removal and replacement costs**
M05b	**Dump site removal (just downstream of Buzzel Road crossing on right bank)**	**Contact landowner; organize volunteers; investigate grants for disposal costs**

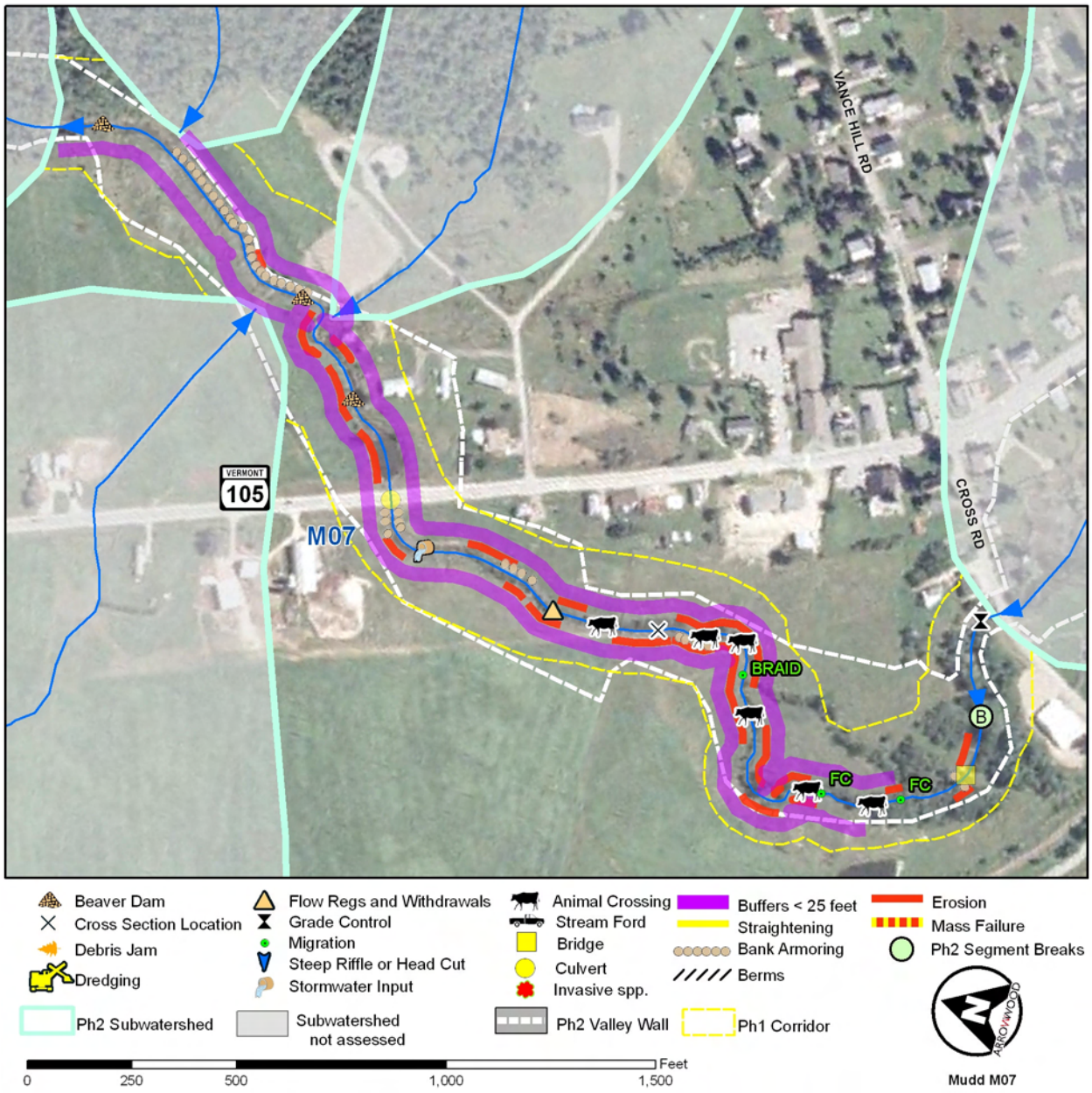


Figure yy. Reach M07 Inventory Map

M07a Summary Data

Reach/Segment Length	**3419 ft**
Valley Confinement	**Very Broad**
Reference Stream Type	**C4**
Existing Stream Type	**C4**
Geomorphic Condition	**Fair**
Channel Evolution Stage	**III**
Adjustment Process	**Widening, aggradation**
Habitat Condition	**Fair**
Stream Sensitivity	**High**

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

M07b Summary Data	
Reach/Segment Length	272 ft
Valley Confinement	
Reference Stream Type	
Existing Stream Type	
Geomorphic Condition	
Channel Evolution Stage	
Adjustment Process	
Habitat Condition	
Stream Sensitivity	

*Rock Gorge: not assessed in field

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 11g. Reach M07 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M07a	Protect River Corridor	Develop FEH Protection Areas map; contact interested landowners
M07a	Restrict cattle access to creek	Contact landowners; research grant possibilities for fencing and water access points
M07a	Structure removal (small run of river consisting of concrete chunks)	Contact landowner; organize volunteers; research removal options; research grants for removal and disposal costs;
M07b	Dump site removal (just downstream of the dam at the segment break on left bank)	Contact landowner; organize volunteers; investigate grants for disposal costs

Figure zz. M07 Segment B Encroachment

Figure aaa. M07B Dump Site on Banks

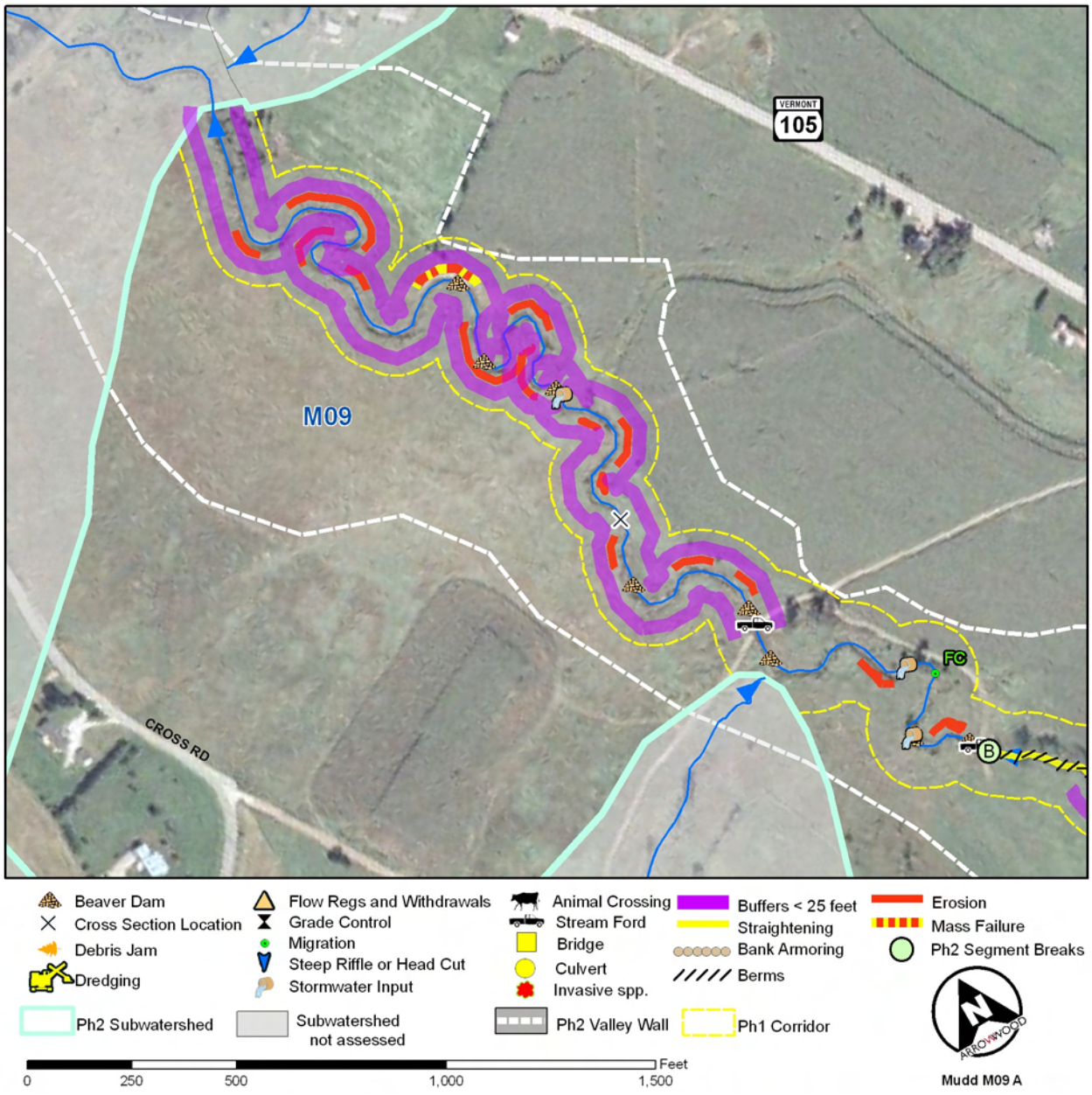


Figure bbb. Reach M09A Inventory Map

M09a Summary Data

Reach/Segment Length	**3,972 ft**
Valley Confinement	**Very Broad**
Reference Stream Type	**C4**
Existing Stream Type	**C5**
Geomorphic Condition	**Good**
Channel Evolution Stage	**I**
Adjustment Process	**Heavy beaver influence**
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

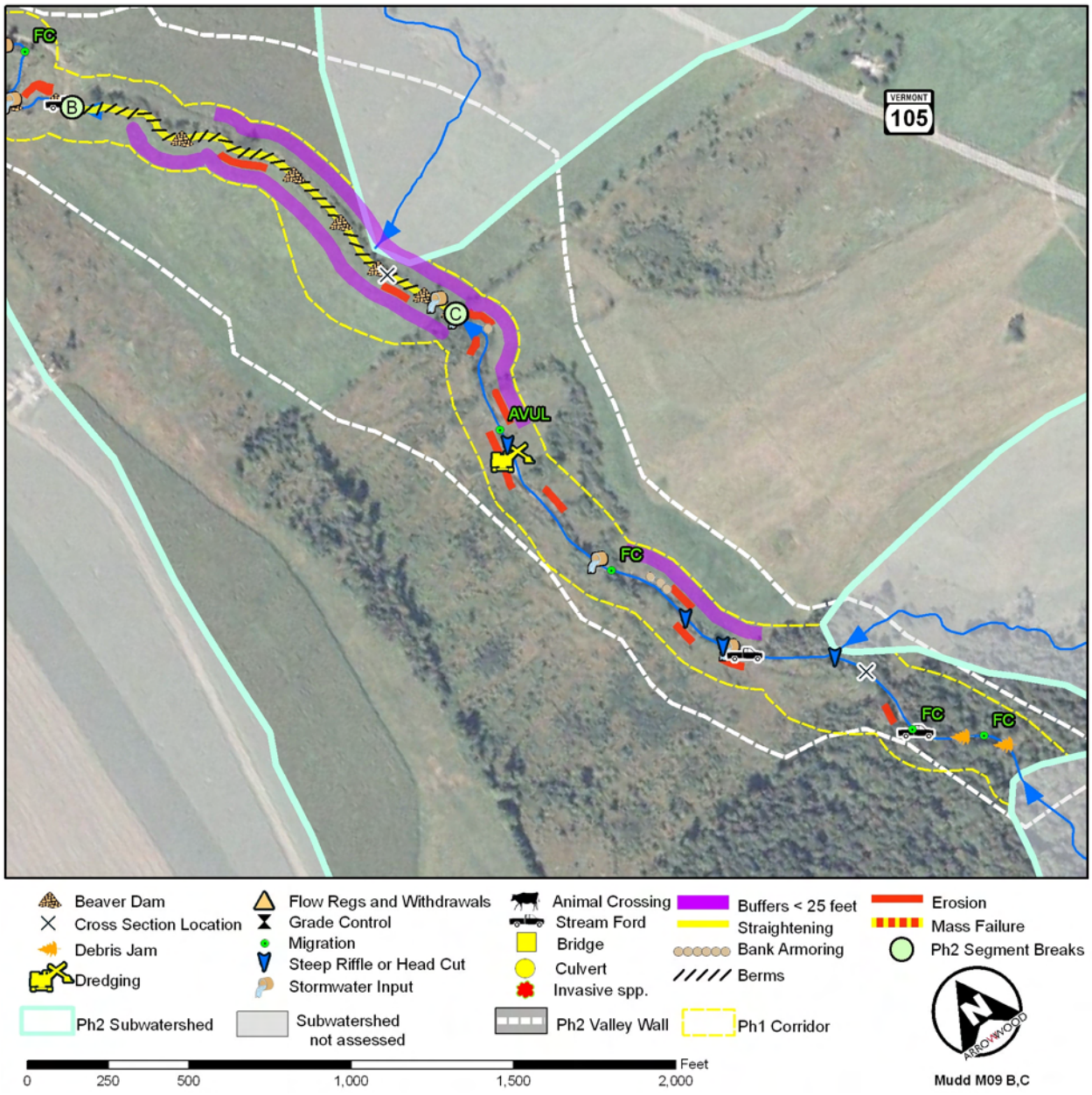


Figure ccc. Reach M09B/C Inventory Map

M09b Summary Data	
Reach/Segment Length	1427 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	E4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Minor adjustments; beaver influence
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

M09c Summary Data	
Reach/Segment Length	2514 ft
Valley Confinement	Very Broad
Reference Stream Type	C4
Existing Stream Type	C4
Geomorphic Condition	Fair
Channel Evolution Stage	III
Adjustment Process	Widening, some aggradation,
Habitat Condition	Good
Stream Sensitivity	Very High

Habitat Stressors

Invasive Plants
Dump Sites
Animal Crossings
Dredging
Poor Stream Bank Vegetation

Reach Stressors

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

Preliminary project recommendations are presented in the following table.

Table 11h. Reach M09 Projects and Practices Table

River Segment ID	Project	Next Steps and other Project Notes
M09a,b	Plant Stream Buffers	Contact landowners, investigate possible grant programs for plantings
M09b	Berm Removal	Contact landowner; organize volunteers; investigate grants removal costs

6.0 INDIVIDUAL OR MULTIPLE LANDOWNER INITIATIVES

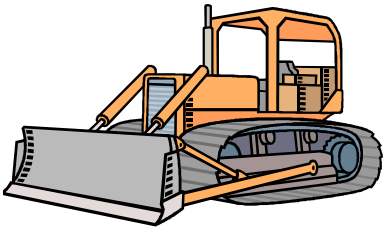
This Phase 2 assessment has preliminarily identified many potential projects. We encourage coordination of landowner and municipal efforts to approach restoration with an eye to watershed scale dynamics. The Missisquoi River Basin Association can play a critical role in coordinating restoration efforts, 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.

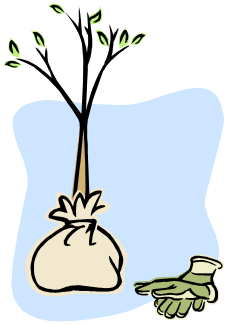
With the bulk of the assessment area in stage 3 of channel evolution, indications are that the Main Branch and its tributaries are starting to migrate laterally in efforts to reestablish functional floodplains. This is likely to aggravate erosion problems in particular, and situations are likely to arise 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 Missisquoi 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, 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.

7.0 REFERENCES

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