Beaver River Watershed Assessment

FINAL

April 30, 2021





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TABLE OF CONTENTS

Beaver River Watershed Assessment Report – FINAL

Town of Richmond, Rhode Island

Tables

Figures

Appendices

1. Introduction

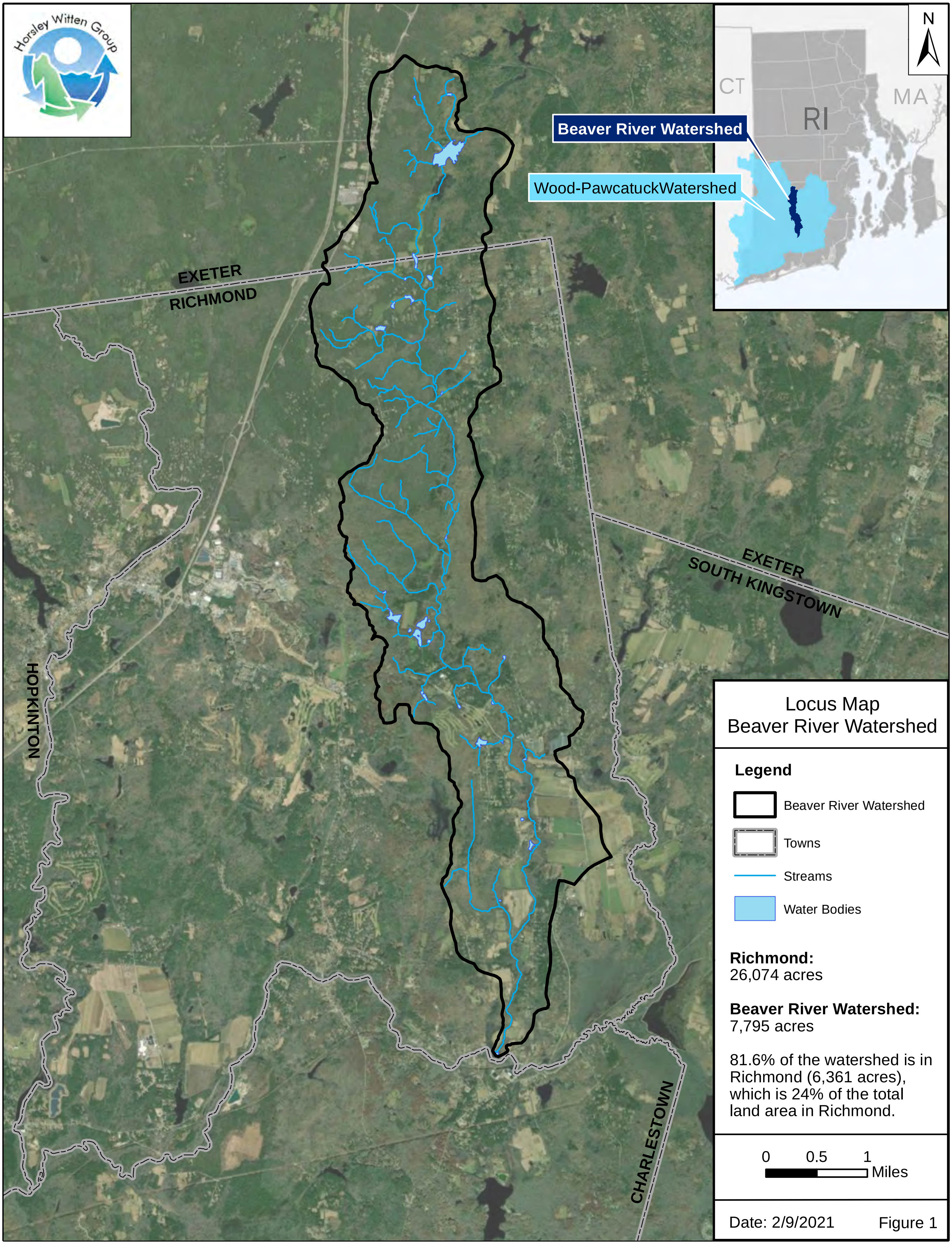
The Town of Richmond received grant funding from the New England Interstate Water Pollution Control Commission and the Southeast New England Watershed Program to perform an assessment focused on the Beaver River Watershed. This is a planning-level spatial analysis project that relies solely on previously collected data. The goal of this assessment is to identify important natural resources and habitats and prioritize sites and projects that will enhance, restore and/or protect the Beaver River.

1.1. Background

Beaver River is an incredible water resource for the Town of Richmond, and indeed, the state of Rhode Island. This small, second-order stream flows from James Pond in Exeter south to the Pawcatuck River. Most of its 11 miles flows through forested areas, of which, over half is protected land (WPWSSC, 2018). The watershed is just over 12 square miles, much of which is in Richmond. In fact, Beaver River Watershed comprises almost 25% of the Town of Richmond (**Figure 1**).

The watershed is mostly undeveloped, with the remaining land mostly used for agriculture (e.g., turf farms), a golf course, and some residential and commercial development. Not surprisingly, these exceptional characteristics help the Beaver River Watershed support a diverse range of aquatic and terrestrial species, including healthy populations of wild brook trout, a coldwater-dependent species. In 2019, the Wood-Pawcatuck Watershed, including the Beaver River, was nationally designated as Wild and Scenic. This designation potentially opens the door to additional funding and support. In addition to ecological values, Beaver River was also designated as Wild and Scenic due to cultural values - Hillsdale Historic and Archaeological District is the site of a former mill that used Beaver River for water power starting around 1800.

However, there are threats to this outstanding resource. Water quality, stream hydrology and temperature, and aquatic habitat are impacted by deteriorating inactive dams, undersized and perched culverts, and unmanaged stormwater runoff (Fuss & O'Neill, 2017). Development pressures can reduce forest canopy and groundwater recharge, disrupt wildlife corridors and nesting areas, and bring additional light pollution that disorients a wide range of species. The changing climate is bringing larger, more intense storms on a more frequent basis, putting additional stress on the dams and culverts, while rising temperatures jeopardize the coldwater-dependent species such as brook trout. All of these factors add strain to the intricate, interconnected web of life in the Beaver River Watershed.



Locus Map
Beaver River Watershed

Legend

▭	Beaver River Watershed
▭	Towns
―	Streams
▨	Water Bodies

Richmond:
26,074 acres

Beaver River Watershed:
7,795 acres

81.6% of the watershed is in Richmond (6,361 acres), which is 24% of the total land area in Richmond.

Date: 2/9/2021

Figure 1

Path: H:\Projects\2020\20022 Beaver River Watershed Assessment\GIS\Maps\210120_WtrshdLocusMap.mxd

1.2. Project Objectives

While more broad plans have been completed or are now being developed for the larger Wood-Pawcatuck River Watershed, this desktop, spatial data analysis focuses specifically on the Beaver River Watershed, and the resulting habitat restoration and protection recommendations will be used to inform decisions and strategies in the watershed. The objectives of this project include:

- Identify existing and potential future land uses in the watershed
- Identify potential restoration projects and actions and land protection measures to address watershed water quality and quantity
- Develop criteria for scoring, evaluating and prioritizing potential restoration and land protection projects
- Provide recommendations for implementing projects with future funding opportunities
- Instill and enhance community stewardship values and citizen scientist roles to increase support for watershed restoration, land protection, and sustainable, high quality water resources
- Serve as a model for implementing restoration and conservation actions and conserving lands in other portions of Richmond situated in the Wood-Pawcatuck River watershed in the future

The results of this assessment should be used to complement and build on the recommendations and actions from other efforts in the Town, such as the Comprehensive Community Plan update, as well as in the greater Wood-Pawcatuck River Watershed, such as the Wood-Pawcatuck Watershed Flood Resiliency Management Plan (Fuss & O'Neill, 2017) and the Town and State-endorsed Wood-Pawcatuck Wild and Scenic Rivers Stewardship Plan (WPWSSC, 2018) as a part of the federal designation of the Wood-Pawcatuck Wild and Scenic Watershed.

1.3. Advisory Stakeholder Group

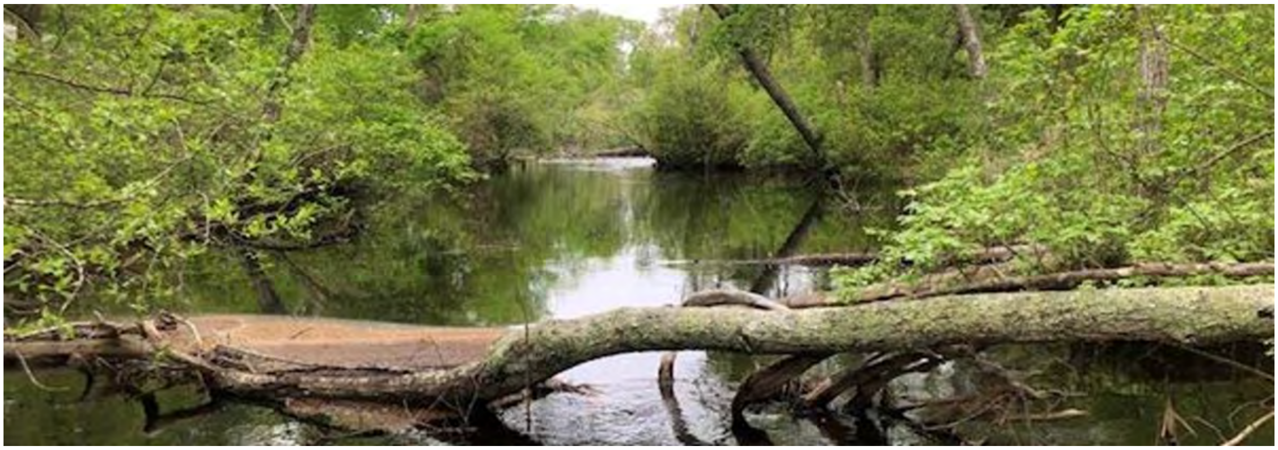
A key component to this project is the Advisory Stakeholder Group. This group has been involved throughout the various phases of the project, providing data, general guidance and advice, and review of draft materials. It is comprised of members from the following organizations:

- Rhode Island Department of Environmental Management (RIDEM)
- Trout Unlimited Rhode Island Chapter 225
- The Nature Conservancy (TNC)
- Wood-Pawcatuck Watershed Association (WPWA), Wood-Pawcatuck Wild and Scenic Rivers Stewardship Council (WPWSRSC)

- Protect Rhode Island Brook Trout
- Beaver River Valley Association
- Richmond Rural Preservation Land Trust (RRPLT)

At the beginning of the project, the Advisory Stakeholder Group determined the following list of interconnected watershed concerns and priorities that have guided this assessment.

- Forest and Stream Buffer Protection
- Wetlands Restoration
- Groundwater Recharge
- Habitat Protection/Enhancement
    - Rare Species Habitat
    - Cold Water Habitat
- Agricultural Impact Reduction
- Hydrologic/Hydraulic Connection Improvement



2. Methodology

This project is a planning-level spatial analysis project that relies solely on previously collected data (i.e., secondary data). The methodology for data collection, analysis, and groundtruthing is included below, with additional information on the parallel citizen science data collection efforts on stream temperature.

Because this project received grant funding through the New England Interstate Water Pollution Control Commission (NEIWPCC), Southeast New England Watershed Program (SNEP), and Narragansett Bay Estuary Program (NBEP), a Quality Assurance Project Plan (QAPP) was required for the use of secondary data. This QAPP was developed to comply with the NEIWPCC's Guide for Development and Approval of Quality Assurance Project Plans, Version 2.0 (March 2016) as a secondary data project (NEIWPCC guide, **Appendix B**) and approved prior to undertaking data analysis. The main text of the approved QAPP is attached to this report (**Appendix A**).

2.1. Secondary Data Collection and Analysis

Working with the Advisory Stakeholder Group, relevant existing data for the Beaver River Watershed was identified, collected, and assessed for quality suitability (as described in the QAPP in **Appendix A**) from sources such as RIGIS, Town of Richmond GIS, Town of Exeter GIS, USGS, USDA-NRCS, RIDEM, the Rhode Island Wildlife Action Plan (RI WAP), and the Wood-Pawcatuck Watershed Flood Resiliency Management Plan (Fuss & O'Neill, 2017), among others. Additional species-specific habitat requirements were confirmed using reliable website data from U.S. Fish and Wildlife Service (USFWS) and NatureServe, with additional data borrowed from Massachusetts Division of Fisheries & Wildlife. **Table 1** lists main data sources (white background) as well as potential supplementary data sources (grey background) for each key data category.

Once the QAPP was approved, existing and projected conditions and watershed characteristics were compiled and analyzed for the Beaver River Watershed. From this assessment, a set of potential restoration projects was developed and prioritized, as well as a separate set of land protection opportunities, that would benefit Beaver River water quality, habitat, and ecology.

2.2. Groundtruthing

Field reconnaissance visits were conducted in the watershed for “ground-truthing,” to confirm assumptions made in the desktop analysis. These site visits were conducted on September 23 and October 20, 2020. Observations from these visits were used to support and/or contradict the secondary data described above to better fine-tune project ranking and ultimate recommendations. Field observations are identified throughout this report where relevant to the assessment to differentiate from secondary data analysis.

2.3. Stream Temperature Analysis

Although not specifically part of this project, the Town engaged a group of volunteers and citizen scientists to help gather additional information on temperatures in the Beaver River during the typical warm season period so critical to coldwater-dependent species. These volunteers installed in-stream temperature loggers in multiple locations throughout the watershed, following the field protocol previously developed by RIDEM (**Appendix C**) and using the Quality Assurance Handbook and Guidance Documents for Citizen Science Projects to ensure the usability of the data to this project. Temperature loggers were installed by the end of May 2020 and pulled at the beginning of October 2020 to identify potential elevated temperatures adverse to coldwater-dependent aquatic resources (e.g., brook trout). The data were downloaded and analyzed by RIDEM Fish & Wildlife staff per their on-going methodology, focusing on the stream temperature averages for the summer months (June – August). Three key temperature classifications are used by RIDEM Fish & Wildlife for analyzing brook trout habitat: cold (<18.3 C); cool (between >18.3 C and <21.7C); and warm (>21.7C) (Beauchene et al., 2014). As brook trout are a coldwater obligate fish species, they thrive in high quality streams within the “cold” temperature designation. However, they may also reside in areas with a “cool” designation depending on local habitat characteristics and specific groundwater intrusion locations. In general, a brook trout population cannot be sustained within “warm” streams.

Table 1. List of Data Sources by Data Category for the Beaver River Watershed Assessment (from the approved QAPP in Appendix A).

Data Category	Secondary Data Source Title	Originating Organization	Year	Link (if applicable)
Base Map Information	Watershed Boundary Dataset: HUC 12	RIGIS	2019	http://www.rigis.org/datasets/watershed-boundary-dataset-huc-12
Topography	Contour Lines - 2 Foot	RIGIS	2011	http://www.rigis.org/datasets/contour-lines-2-foot-1
LU Class	Land Use and Land Cover	RIGIS	2011	http://www.rigis.org/datasets/land-use-and-land-cover-2011
Future Land Use	Land Use (2025)	RIGIS	1995	http://www.rigis.org/datasets/land-use-2025
	Richmond Buildout Analysis	Town of Richmond	2019	Received internally.
Zoning Data	Richmond Zoning Data	Town of Richmond	2018	Received internally.
	Exeter Zoning Data	Town of Exeter	2018	Received internally.
Parcels	Richmond Cadastral Data	Town of Richmond	2018	Received internally.
	Exeter Cadastral Data	Town of Exeter	2018	Received internally.
Forest/Shrub Cover	Forest Habitat	RIGIS	2010	http://www.rigis.org/datasets/forest-habitat-2010
	Ecological Communities Classification	RIGIS	2017	Received internally.
Streams	Freshwater Rivers and Streams (1:5,000)	RIGIS	2006	http://www.rigis.org/datasets/f06b84e8b5c74efb82e1c7bd5b075308_0
Waterbodies	Ponds and Lakes	RIGIS	2017	http://www.rigis.org/datasets/ponds-and-lakes
Wetlands	National Wetlands Inventory	USFWS	2014	https://www.fws.gov/wetlands/Data/Mapper.html
Species Habitat	Natural Heritage Areas & Species	RIGIS & RIDEM	2019	http://www.rigis.org/datasets/natural-heritage-areas
	Beaver River Species Data	RIDEM	1998-2019	Received internally.
	Margaritafera margaritafera Habitat	RIDEM	2019	Received internally.
	List of Species of Greatest Conservation Concern (SGCN) (Amphibians and reptiles)	RIDEM; RI WAP	2019; 2015	Received internally. http://www.dem.ri.gov/programs/fish-wildlife/wildlifehuntered/swap15.php
	Wood Turtle Habitat	RIDEM	2019	Received internally.
	Species-Specific Habitat Requirements	USFWS	2020	https://www.fws.gov/northeast/ecologicalservices/endangeredspecies.html

Data Category	**Secondary Data Source Title**	**Originating Organization**	**Year**	**Link (if applicable)**
Invasive Species	RI Forest Health Works Project: Points All Invasives	RIGIS	2019	http://www.rigis.org/datasets/ri-forest-health-works-project-points-all-invasives
Impervious Area	Impervious Surfaces	RIGIS	2011	http://www.rigis.org/datasets/8c40daec43ce4ea2a90396c42e739df0
Watershed Size	StreamStats	USGS	2020	https://streamstats.usgs.gov/ss/
Soil Type	Soils (HSG)	USDA NRCS	2018	https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
	Hydric soils	USDA NRCS	2018	https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Water Temperature Data	Beaver River Temperature Data	RIDEM	2016-2019	Received internally.
	An Assessment of Brook Trout (*Salvelinus fontinalis*) Distribution and Water Temperature Fluctuations in the Beaver River, Rhode Island, By Jon C. Vander Werff	URI	2018	Received internally.
	Citizen Science Data from Temperature Loggers	Town of Richmond	2020	Received internally
Flooding	Areas of Flooding	Fuss & O'Neill	2017	Received internally.
	FEMA Floodplain, to be in effect in April Town of Richmond	FEMA/Town of Richmond	2020	Received internally.
Culverts/ Bridges	Culverts and Bridges Ratings	Fuss & O'Neill	2017	Received internally.
	Road – Stream Crossings	Town of Richmond	2019	Received internally.
Dams	Dam Management Recommendations	Fuss & O'Neill	2017	Received internally.
	Dams	RIGIS	2018	http://www.rigis.org/datasets/dams
	Northeast Aquatic Connectivity Assessment Project	TNC	2017	Received internally.
Assessment Sites	Geomorphic Assessment Sites	Fuss & O'Neill	2017	Received internally.
Restoration Sites	River Corridor Restoration Sites	Fuss & O'Neill	2017	Received internally.

3. Existing Conditions

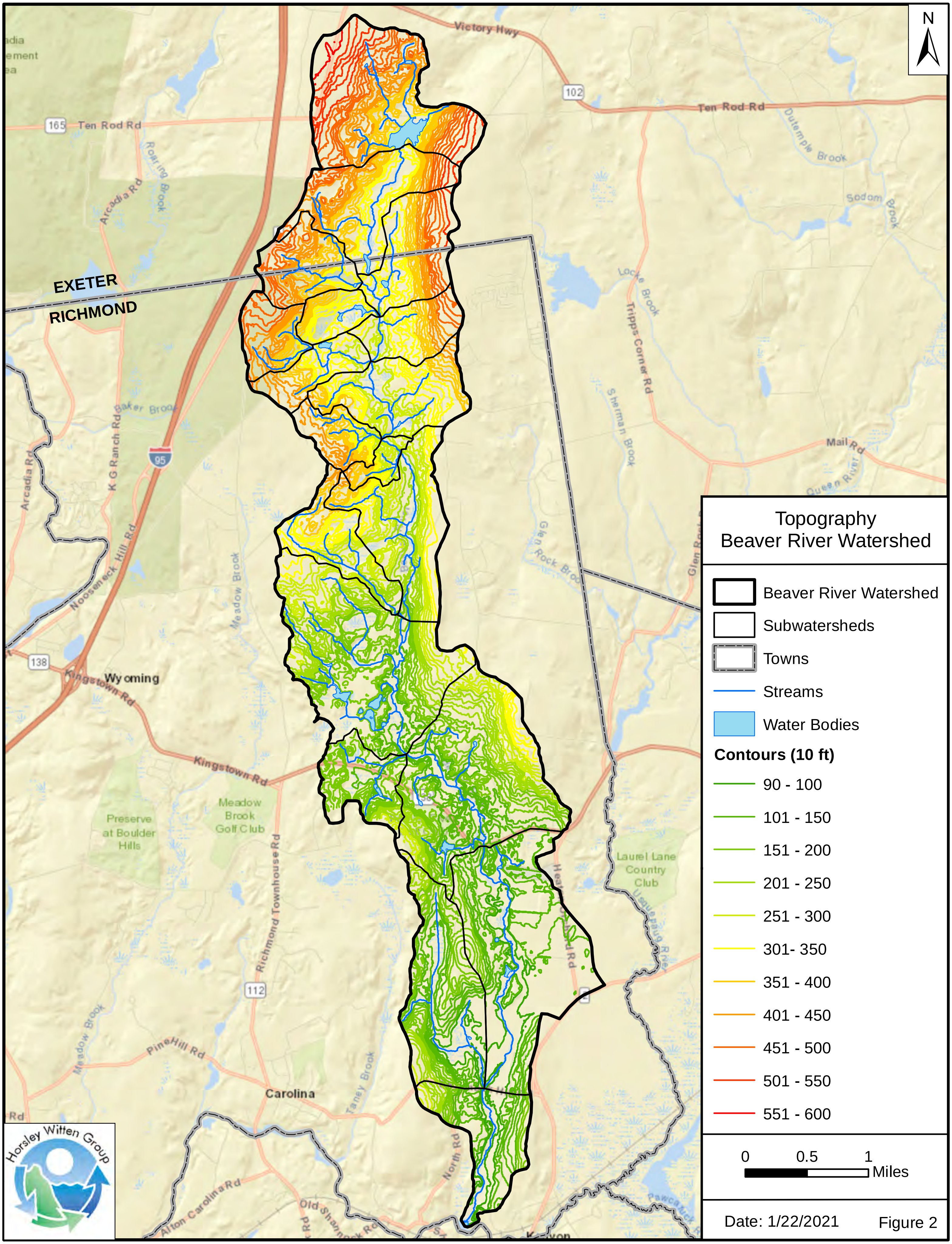
Using the data and methodologies described in Section 2, a range of information was compiled to characterize the existing conditions in the Beaver River Watershed. This information is broken down into three major categories and described further below: watershed characteristics, wildlife and plant species and habitats, and stream temperature analysis.

3.1. Watershed Characteristics

3.1.1. Topography and Drainage Divides

The topography around a stream corridor is key to identifying drainage divides for tributaries and the shape of the overall contributing watershed. The Beaver River Watershed is a long, skinny watershed with steep valley walls. Contour data (RIGIS, 2011) show that the highest elevation in the watershed is in the northwest corner in Exeter at ~570 feet above sea level, while the lowest is at the mouth where Beaver River joins the Pawcatuck River, at ~90 feet above sea level (**Figure 2**). The Beaver River Watershed is a delineated "subwatershed" (hydrologic unit code (HUC)-12) by USGS using their nationwide, standardized system based on mapped topographic and surface hydrologic features. However, closer inspection using the detailed 2-foot contours, recent aerial imagery, and mapped streams and wetlands against the HUC-12 boundary made it clear that the watershed delineation needed additional refinement in a few areas – as an example, a watershed boundary should not cut across a stream feature, but should encompass the entirety of the upper portion/headwaters of the stream. Using this information, as well as information about manmade drainage features such as road infrastructure and rooftops that can redirect runoff, the revised watershed boundary shown on **Figure 3** was created. While not drastically different than the HUC-12 boundary, it is important to have a more accurate delineation based on site-specific information when doing an assessment at this scale rather than for a larger river basin.

In addition, the Beaver River Watershed was divided into three main focus areas based on natural breaks or changes in the watershed: Upper (ends at Old Mountain Trail), Middle (ends at Route 138), and Lower (ends at the mouth of Beaver River). These focus areas are helpful for looking at general trends. The watershed was further divided into 18 subwatersheds based on key locations (e.g., large tributaries, change in land use, etc.) to help pinpoint potential priority resource areas and restoration opportunities. These focus areas and subwatersheds are used below to summarize existing conditions.



Topography
Beaver River Watershed

Date: 1/22/2021

Figure 2

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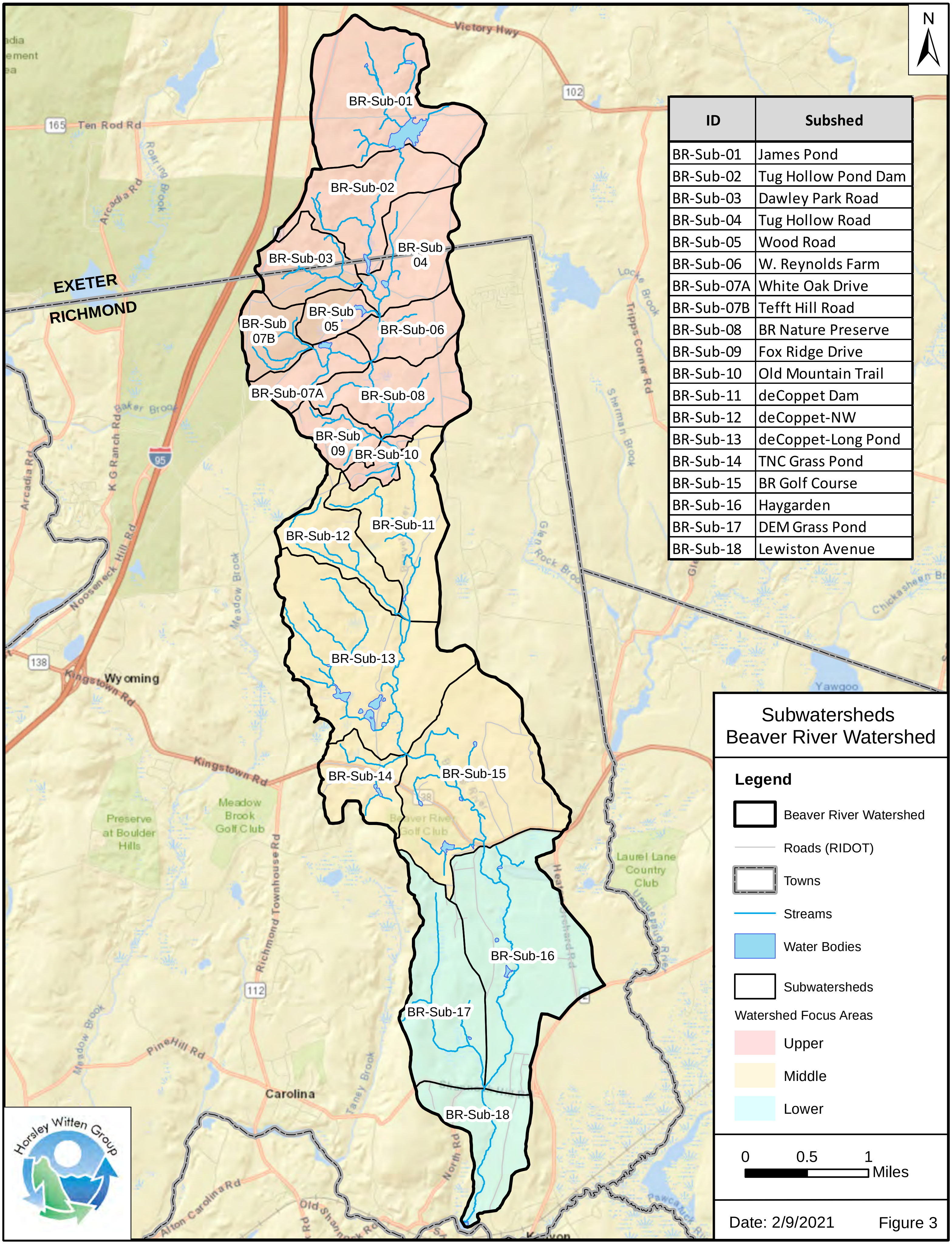

ID	Subshed
BR-Sub-01	James Pond
BR-Sub-02	Tug Hollow Pond Dam
BR-Sub-03	Dawley Park Road
BR-Sub-04	Tug Hollow Road
BR-Sub-05	Wood Road
BR-Sub-06	W. Reynolds Farm
BR-Sub-07A	White Oak Drive
BR-Sub-07B	Tefft Hill Road
BR-Sub-08	BR Nature Preserve
BR-Sub-09	Fox Ridge Drive
BR-Sub-10	Old Mountain Trail
BR-Sub-11	deCoppet Dam
BR-Sub-12	deCoppet-NW
BR-Sub-13	deCoppet-Long Pond
BR-Sub-14	TNC Grass Pond
BR-Sub-15	BR Golf Course
BR-Sub-16	Haygarden
BR-Sub-17	DEM Grass Pond
BR-Sub-18	Lewiston Avenue

Subwatersheds
Beaver River Watershed

Legend

- ▭ Beaver River Watershed
- — Roads (RIDOT)
- ▭ Towns
- — Streams
- ▨ Water Bodies
- ▭ Subwatersheds

Watershed Focus Areas

- ▨ Upper
- ▨ Middle
- ▨ Lower

0 0.5 1 Miles

Date: 2/9/2021

Figure 3

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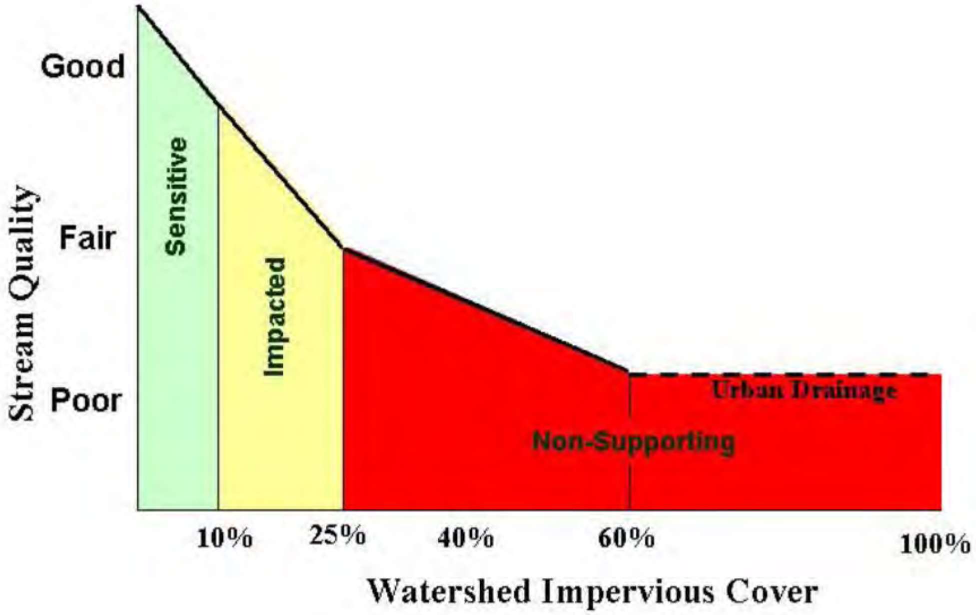
3.1.2. Impervious Cover

Impervious cover refers to any land surface that prevents water from soaking into the ground, and instead, creates "runoff" that flows downhill when it rains, warming up and collecting dirt and other pollutants as it goes. It includes many forms of developed surfaces such as parking lots, driveways, roads, and rooftops. Research has shown that the level of impervious cover in a watershed can be a good indicator of small (1st, 2nd, or 3rd-order) stream quality (Schueler, 1994). High impervious cover often indicates low forest cover, leading to impacts such as less habitat, warmer stream temperatures, and less groundwater recharge, to name a few. Impervious surfaces also create more turbid, polluted runoff with higher flows during storm events than forest soils and other pervious surfaces where rainfall can soak into the ground. Increased flows then lead to streambank erosion, channel incision, tree falls and loss or degradation of riparian habitat. This inverse relationship between impervious cover and stream quality, referred to as the Impervious Cover Model, predicts an important threshold at 10% impervious cover, above which the associated stream quality is impacted (**Figure 4**).

Figure 4. Impervious Cover Model predicting relationship between watershed impervious cover and stream quality (Schueler, 1994).



As shown in **Table 2**, the Beaver River Watershed is only 3.3% impervious, well within the "sensitive" classification and below the "impacted" threshold of 10%. In addition, each subwatershed has impervious cover less than 10%. **Figure 5** shows that for much of the watershed, particularly the Upper and Middle, the impervious cover is located away from the stream corridor. Stormwater impacts from impervious cover in the watershed are discussed further below.

Table 2. Summary of watershed characteristics related to impervious cover and natural resources.[1]

Subshed Group	Subshed	ID	Area	Impervious Cover		Stream Length	Wetlands		Forest Cover	
			ac	ac	% of subshed area	miles	ac	% of subshed area	ac	% of subshed area
Upper	James Pond	BR-Sub-01	718.0	24.1	3.4	2.9	11.1	1.5	616.4	85.8
Upper	Tug Hollow Pond Dam	BR-Sub-02	428.4	8.3	1.9	2.1	45.9	10.7	363.3	84.8
Upper	Dawley Park Road	BR-Sub-03	251.9	9.2	3.7	1.6	8.3	3.3	227.4	90.3
Upper	Tug Hollow Road	BR-Sub-04	338.2	10.0	3.0	1.5	24.7	7.3	302.5	89.5
Upper	Wood Road	BR-Sub-05	123.3	5.1	4.1	0.2	10.6	8.6	74.3	60.2
Upper	W. Reynolds Farm	BR-Sub-06	218.1	11.7	5.4	0.8	10.0	4.6	161.0	73.8
Upper	White Oak Drive	BR-Sub-07A	174.3	5.8	3.3	1.2	6.2	3.5	139.1	79.8
Upper	Tefft Hill Road	BR-Sub-07B	176.5	7.1	4.0	1.4	0.0	0.0	147.5	83.6
Upper	BR Nature Preserve	BR-Sub-08	384.6	9.3	2.4	2.5	22.3	5.8	341.4	88.8
Upper	Fox Ridge Drive	BR-Sub-09	153.3	4.9	3.2	1.6	0.5	0.4	136.5	89.1
Upper	Old Mountain Trail	BR-Sub-10	73.3	3.8	5.1	0.8	1.0	1.4	62.4	85.0
Upper Totals			*3039.9*	*99.1*	*3.3%*	*16.6*	*140.6*	*4.6%*	*2571.7*	*84.6%*
Middle	deCoppet Dam	BR-Sub-11	489.5	7.1	1.4	3.0	27.4	5.6	468.9	95.8
Middle	deCoppet-NW	BR-Sub-12	264.2	1.9	0.7	2.4	10.4	4.0	253.0	95.8
Middle	deCoppet-Long Pond	BR-Sub-13	971.6	6.8	0.7	5.8	44.6	4.6	897.3	92.3
Middle	TNC Grass Pond	BR-Sub-14	243.3	13.3	5.5	1.2	5.4	2.2	198.9	81.8
Middle	BR Golf Course	BR-Sub-15	936.1	57.6	6.2	3.4	23.7	2.5	739.2	79.0
Middle Totals			*2904.7*	*86.7*	*3.0%*	*15.8*	*111.6*	*3.8%*	*2557.3*	*88.0%*
Lower	Haygarden	BR-Sub-16	952.0	42.6	4.5	3.0	65.2	6.9	406.2	42.7
Lower	DEM Grass Pond	BR-Sub-17	558.1	10.1	1.8	2.7	47.7	8.5	437.6	78.4
Lower	Lewiston Avenue	BR-Sub-18	340.3	15.1	4.4	1.3	30.6	9.0	207.3	60.9
Lower Totals			*1850.4*	*67.8*	*3.7%*	*7.0*	*143.5*	*7.8%*	*1051.1*	*56.8%*
Watershed Totals			**7,794.97**	**253.6**	**3.3%**	**39.4**	**395.8**	**5.1%**	**6180.1**	**79.3%**

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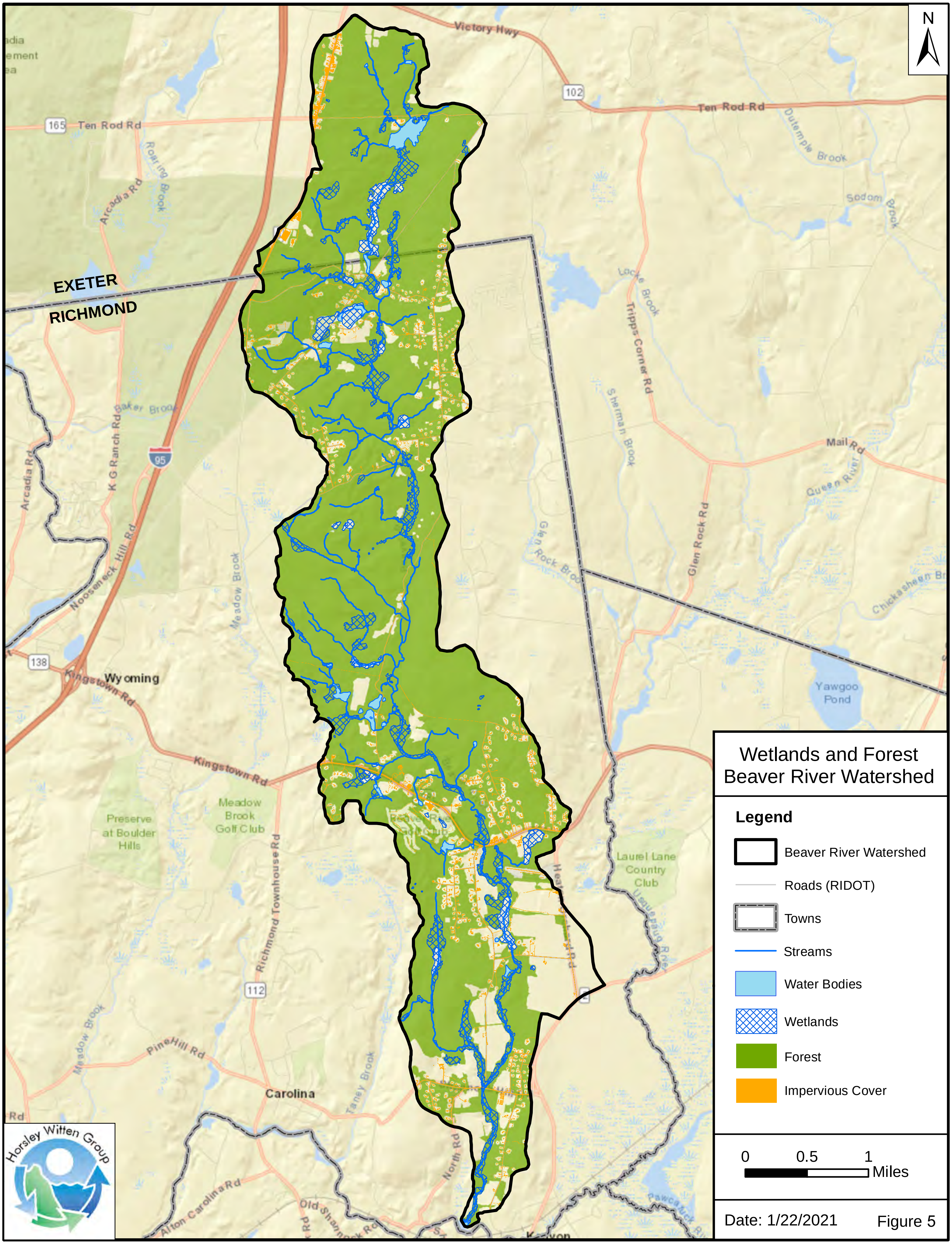
[1] This table is not intended to include all of the land cover types, but instead provide a quick summary of some of the most important watershed characteristics/metrics for determining watershed health (i.e., impervious + wetlands + forest does not equal 100%). A complete breakdown by land cover/land use is included in **Table 5**.



Wetlands and Forest
Beaver River Watershed

Date: 1/22/2021

Figure 5

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3.1.3. Wetlands and Forest Cover

Healthy intact wetlands and forests are key for ensuring high quality streams and habitat. National Wetlands Inventory (USFW, 2014) and Forest Habitat (RIGIS, 2010) data were used to depict wetlands and forest cover. In some areas, these data overlap; for example, forested wetlands, and in some cases shrub swamps, are included within the forested cover data layer. Beaver River Watershed has 396 acres of mapped wetlands, which is just over 5% of the watershed (**Table 2**), with the highest percent of wetlands in the Lower Watershed (7.8%). Mapped forest cover totals 6,180 acres, almost 80% of the watershed. The most forested land is in the Middle Watershed (88%), with the least in the Lower Watershed (57%).

3.1.4. Stream Buffers and Encroachments

While the main stem of the Beaver River is 11 miles, all mapped tributaries increase the total stream length in the watershed to almost 40 miles (**Table 2**). To adequately protect water quality and wildlife habitats in many headwater streams like Beaver River and its tributaries, a vegetated stream or riparian buffer of 200 feet and greater is necessary, particularly for coldwater-dependent species (see **Appendix D** for an excerpt from RIDEM & RICRMC, 2011 on riparian buffers). Accordingly, RIDEM in conjunction with the RI Coastal Resources Management Council (CRMC) is currently in the process of updating their regulations[2] to provide even greater protection for small-order streams like the Beaver River by increasing the buffer jurisdiction from 100 feet to 200 feet. Therefore, a stream buffer dataset was created 200 feet on either side of the mapped streams and waterbodies.

Buffer encroachment was defined for this project as any portion of the delineated 200-foot buffer that is not currently "forest" cover[3], using the forest cover dataset described above. Thus, encroachment here includes not only structures and paved areas, but cleared areas such as for gravel driveways, some agricultural fields, or lawn. See **Figure 6** for a map showing the delineated stream buffer and encroachments. **Table 3** provides a summary of the amount of encroachment by subwatershed. Just over 8% of the total stream buffer is encroached upon, with the highest percent in the Lower Watershed (>10% of stream buffer). These encroachment calculations are approximate only, particularly since the forest cover dataset represents 2010 conditions. The actual amount of encroachment may be more or less than shown here. These data help to identify potential buffer impact areas where conditions may adversely affect stream habitat and species.

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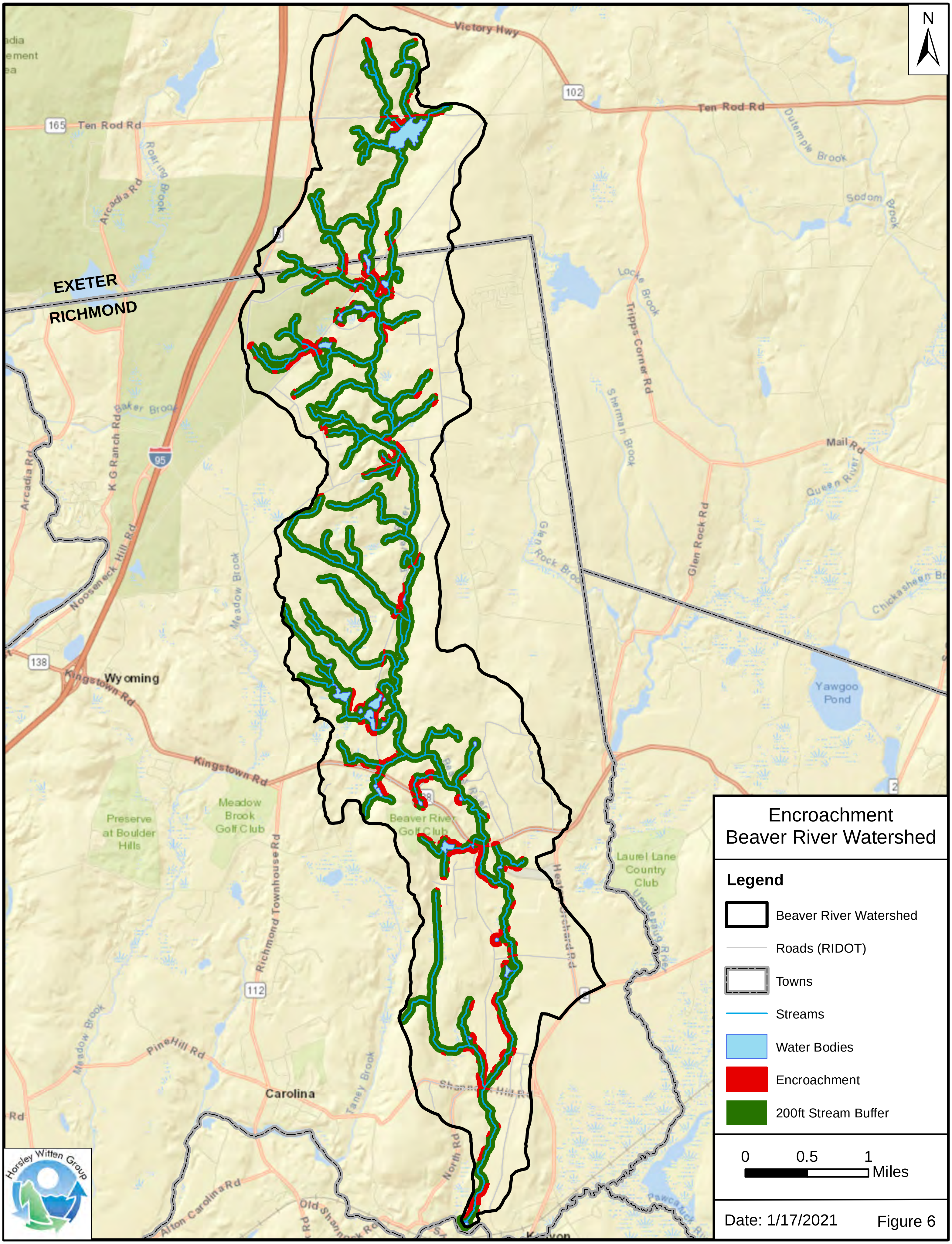
[2] RIDEM Rules and Regulations Governing the Administration and Enforcement of the Fresh Water Wetlands Act provide for protection and regulation of freshwater wetlands and establish in essence a regulatory buffer to rivers and streams, regulated as Riverbank Wetlands.

[3] It is important to note that the forest cover dataset may include some isolated areas with heavy brush/shrubs rather than only mature forest, but for simplification with this spatial assessment, it is just referred to as forest.



Encroachment
Beaver River Watershed

Legend

- ▭ Beaver River Watershed
- — Roads (RIDOT)
- ▭ Towns
- — Streams
- 🟦 Water Bodies
- 🟥 Encroachment
- 🟩 200ft Stream Buffer

0 0.5 1 Miles

Date: 1/17/2021

Figure 6

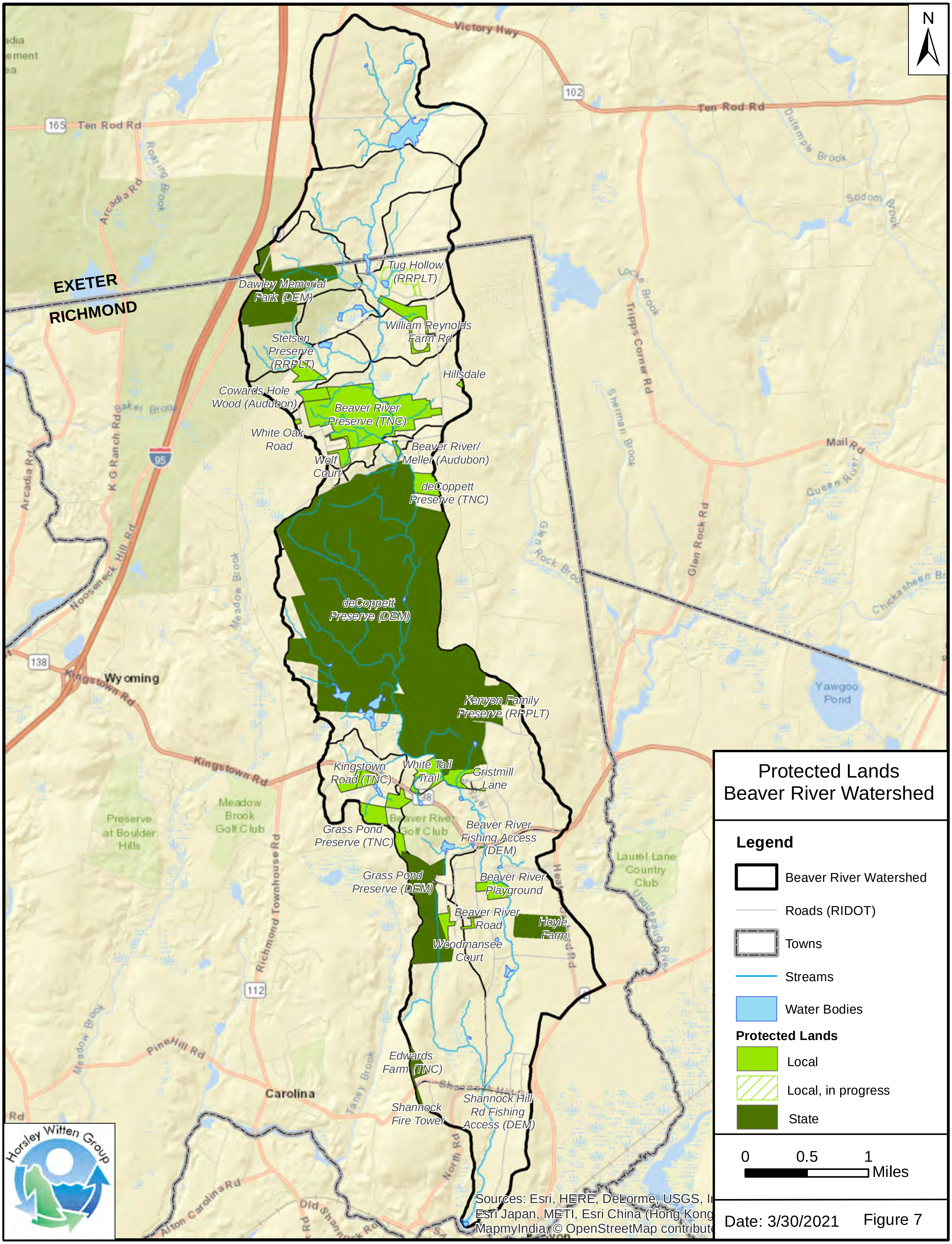
Path: H:\Projects\2020\20022 Beaver River Watershed Assessment\GIS\Maps\210117_EncroachmentMap.mxd

Table 3. Summary of Stream Buffer Encroachment and Protected Lands in the Beaver River Watershed.

Subshed Group	Subshed	ID	Area	Buffer Encroachment		Protected Lands	
			ac	ac	% of stream buffer area	ac	% of subshed area
Upper	James Pond	BR-Sub-01	718.0	6.3	3.4	0.0	0.0
Upper	Tug Hollow Pond Dam	BR-Sub-02	428.4	1.5	1.4	0.0	0.0
Upper	Dawley Park Road	BR-Sub-03	251.9	2.1	2.7	94.5	37.5
Upper	Tug Hollow Road	BR-Sub-04	338.2	5.8	8.3	6.7	2.0
Upper	Wood Road	BR-Sub-05	123.3	3.9	12.0	0.0	0.0
Upper	W. Reynolds Farm	BR-Sub-06	218.1	1.8	5.1	24.3	11.1
Upper	White Oak Drive	BR-Sub-07A	174.3	4.1	6.8	19.8	11.4
Upper	Tefft Hill Road	BR-Sub-07B	176.5	5.5	9.1	51.5	29.2
Upper	BR Nature Preserve	BR-Sub-08	384.6	1.7	1.5	155.6	40.4
Upper	Fox Ridge Drive	BR-Sub-09	153.3	0.8	1.2	83.4	54.4
Upper	Old Mountain Trail	BR-Sub-10	73.3	4.1	11.3	30.0	41.0
Upper Totals			*3039.9*	*37.7*	*6.9*	*465.8*	*15%*
Middle	deCoppet Dam	BR-Sub-11	489.5	1.7	1.2	414.4	84.7
Middle	deCoppet-NW	BR-Sub-12	264.2	1.7	1.5	245.6	93.0
Middle	deCoppet-Long Pond	BR-Sub-13	971.6	6.7	2.1	775.3	79.8
Middle	TNC Grass Pond	BR-Sub-14	243.3	5.6	8.7	51.5	21.2
Middle	BR Golf Course	BR-Sub-15	936.1	18.1	10.2	307.5	32.8
Middle Totals			*2904.7*	*33.8*	*7.5*	*1794.4*	*62%*
Lower	Haygarden	BR-Sub-16	952.0	19.7	12.7	74.4	7.8
Lower	DEM Grass Pond	BR-Sub-17	558.1	6.1	4.7	131.4	23.5
Lower	Lewiston Avenue	BR-Sub-18	340.3	6.4	10.3	2.5	0.7
Lower Totals			*1850.4*	*32.3*	*10.7*	*208.3*	*11%*
Watershed Totals			**7,794.97**	**103.7**	**8.3**	**2468.5**	**31.7%**

3.1.5. Protected Lands

Land protection is a key tool in watershed management, providing areas that can be preserved and or restored without fear of further development, as well as in many cases, providing the public access to and education about a watershed's natural resources. The Beaver River Watershed has an abundance of protected lands, as shown on **Figure 7**. More than 30% of the watershed is protected in some form, with the majority of protected lands in the Middle Watershed (62%) with one subwatershed as high as 93% protected (**Table 3)**. These protected areas include land owned/managed by the State, regional non-profits (e.g., The Nature Conservancy (TNC), Audubon Society of Rhode Island), local groups (Town of Richmond and Richmond Rural Preservation Land Trust (RRPLT)), and conservation restrictions on private land. The largest of these is the DeCoppet Estate; this 1,825-acre property is the largest donation ever made to the State, transferred in 2014. On the other end of the scale, there are two small RIDEM-owned areas set aside specifically for fishing access: one at Rte 138, and a second at Shannock Hill Rd. From large to small, all of these protected lands play an important role in the long-term preservation of water quality and habitat in the Beaver River Watershed.



Protected Lands Beaver River Watershed

Sources: Esri, HERE, DeLorme, USGS, I
Esri Japan, METI, Esri China (Hong Kong
MapmyIndia, © OpenStreetMap contribut

Date: 3/30/2021 Figure 7

Path: H:\Projects\2020\20022 Beaver River Watershed Assessment\GIS\Maps\210317_ProtectedLands.mxd

3.1.6. Soils

The soils in a watershed are good indicators of, among other things, the areas where you would expect the most annual rainfall to infiltrate and recharge the groundwater (based on hydrologic soil group (HSG)) as well as where you would expect wetland habitat (hydric soils). The HSG is a soil property reported by the USDA Natural Resources Conservation Service (NRCS) that indicates the estimated runoff potential, broken down into four major groups:

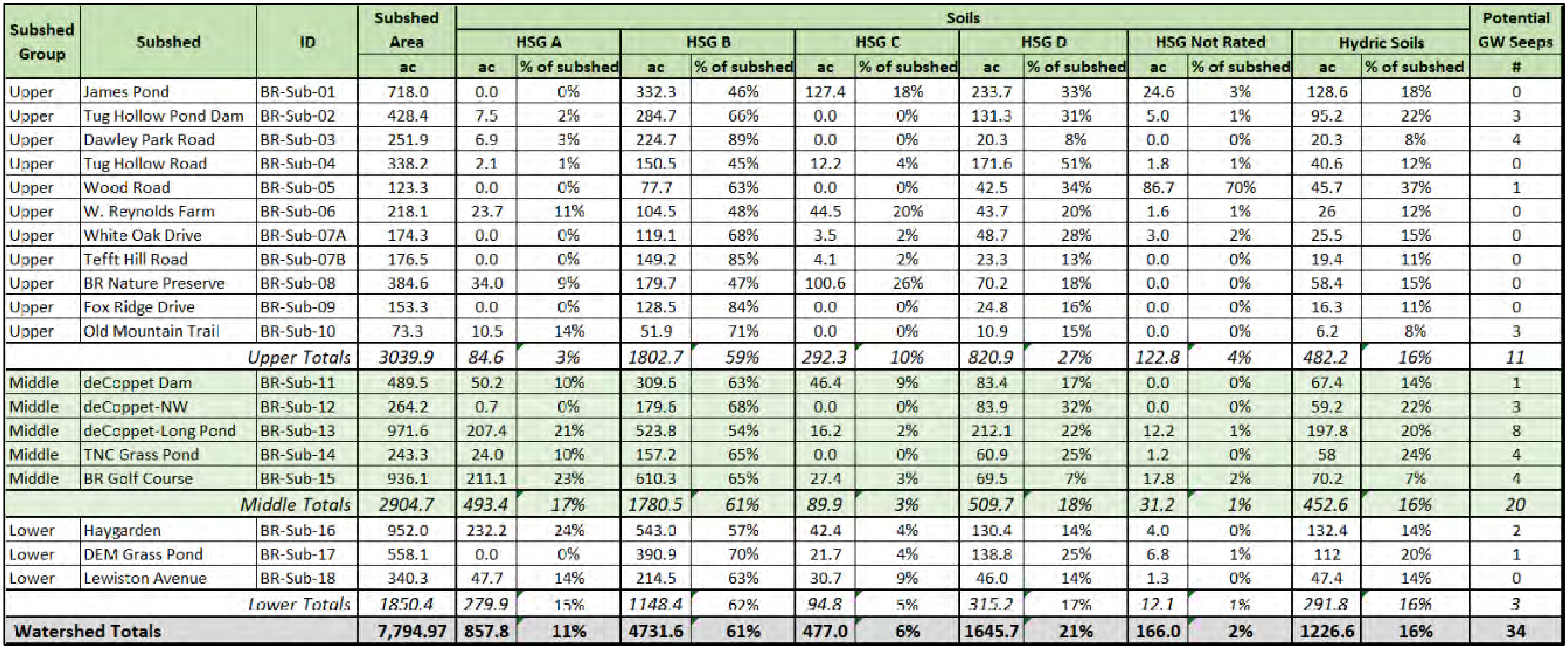
- HSG A. High infiltration rate (low runoff potential). These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission and are the best for recharging groundwater.
- HSG B. Moderate infiltration rate. These consist of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission and are also important for groundwater recharge along with HSG A.
- HSG C. Slow infiltration rate. These consist of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission and do not readily recharge groundwater.
- HSG D. Very slow infiltration rate (high runoff potential). These consist of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.
- In addition, some soils are listed as “Not Rated” when a specific runoff potential cannot be determined for a variety of reasons, including presence of highly disturbed urban land, rock outcrops, gravel pits, open water, etc.

In the Beaver River Watershed, the soils range from loamy fine sands to mucky peats, many that are very to extremely rocky. **Table 4** provides a summary of soils in each subwatershed, broken down by HSG per the NRCS “Soil Survey of Washington County (“South County”), Rhode Island,” and **Figure 8** shows the spatial distribution of each HSG and hydric soils. A majority of the soils are HSG B (61%), with HSG A soils mostly along the river corridor.

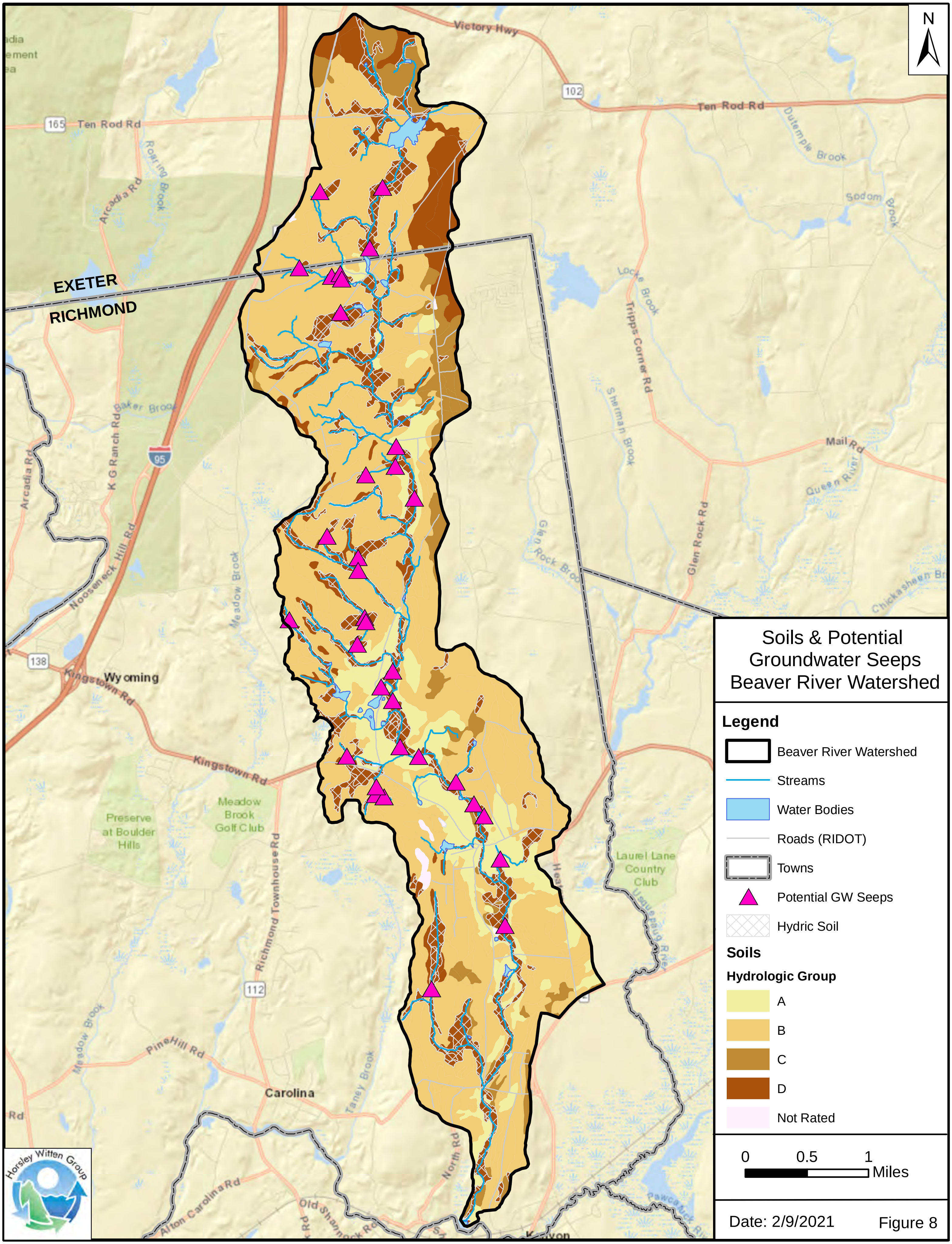
Potential Groundwater Seeps

The Beaver River is mostly base-flow driven (Chambers et al., 2017), fed by the cold water of groundwater aquifers. While preserving land with HSG A and B soils is important to maintain groundwater recharge, the locations where that groundwater feeds the streams, groundwater upwelling and seeps, are also important. These locations are not currently mapped; however, potential seep locations were identified using topography and hydric soil data. Areas with 15% slopes and greater along hydric soils were assumed to be potential groundwater seeps. These are summarized in **Table 4** and mapped on **Figure 8**.

Table 4. Summary of soil distribution by subwatershed ("subshed"), hydrologic soil group (HSG), and hydric soils.



Subshed Group	Subshed	ID	Subshed Area	Soils												Potential GW Seeps
				HSG A		HSG B		HSG C		HSG D		HSG Not Rated		Hydric Soils		
			ac	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	#
Upper	James Pond	BR-Sub-01	718.0	0.0	0%	332.3	46%	127.4	18%	233.7	33%	24.6	3%	128.6	18%	0
Upper	Tug Hollow Pond Dam	BR-Sub-02	428.4	7.5	2%	284.7	66%	0.0	0%	131.3	31%	5.0	1%	95.2	22%	3
Upper	Dawley Park Road	BR-Sub-03	251.9	6.9	3%	224.7	89%	0.0	0%	20.3	8%	0.0	0%	20.3	8%	4
Upper	Tug Hollow Road	BR-Sub-04	338.2	2.1	1%	150.5	45%	12.2	4%	171.6	51%	1.8	1%	40.6	12%	0
Upper	Wood Road	BR-Sub-05	123.3	0.0	0%	77.7	63%	0.0	0%	42.5	34%	86.7	70%	45.7	37%	1
Upper	W. Reynolds Farm	BR-Sub-06	218.1	23.7	11%	104.5	48%	44.5	20%	43.7	20%	1.6	1%	26	12%	0
Upper	White Oak Drive	BR-Sub-07A	174.3	0.0	0%	119.1	68%	3.5	2%	48.7	28%	3.0	2%	25.5	15%	0
Upper	Tefft Hill Road	BR-Sub-07B	176.5	0.0	0%	149.2	85%	4.1	2%	23.3	13%	0.0	0%	19.4	11%	0
Upper	BR Nature Preserve	BR-Sub-08	384.6	34.0	9%	179.7	47%	100.6	26%	70.2	18%	0.0	0%	58.4	15%	0
Upper	Fox Ridge Drive	BR-Sub-09	153.3	0.0	0%	128.5	84%	0.0	0%	24.8	16%	0.0	0%	16.3	11%	0
Upper	Old Mountain Trail	BR-Sub-10	73.3	10.5	14%	51.9	71%	0.0	0%	10.9	15%	0.0	0%	6.2	8%	3
Upper Totals			*3039.9*	*84.6*	*3%*	*1802.7*	*59%*	*292.3*	*10%*	*820.9*	*27%*	*122.8*	*4%*	*482.2*	*16%*	*11*
Middle	deCoppet Dam	BR-Sub-11	489.5	50.2	10%	309.6	63%	46.4	9%	83.4	17%	0.0	0%	67.4	14%	1
Middle	deCoppet-NW	BR-Sub-12	264.2	0.7	0%	179.6	68%	0.0	0%	83.9	32%	0.0	0%	59.2	22%	3
Middle	deCoppet-Long Pond	BR-Sub-13	971.6	207.4	21%	523.8	54%	16.2	2%	212.1	22%	12.2	1%	197.8	20%	8
Middle	TNC Grass Pond	BR-Sub-14	243.3	24.0	10%	157.2	65%	0.0	0%	60.9	25%	1.2	0%	58	24%	4
Middle	BR Golf Course	BR-Sub-15	936.1	211.1	23%	610.3	65%	27.4	3%	69.5	7%	17.8	2%	70.2	7%	4
Middle Totals			*2904.7*	*493.4*	*17%*	*1780.5*	*61%*	*89.9*	*3%*	*509.7*	*18%*	*31.2*	*1%*	*452.6*	*16%*	*20*
Lower	Haygarden	BR-Sub-16	952.0	232.2	24%	543.0	57%	42.4	4%	130.4	14%	4.0	0%	132.4	14%	2
Lower	DEM Grass Pond	BR-Sub-17	558.1	0.0	0%	390.9	70%	21.7	4%	138.8	25%	6.8	1%	112	20%	1
Lower	Lewiston Avenue	BR-Sub-18	340.3	47.7	14%	214.5	63%	30.7	9%	46.0	14%	1.3	0%	47.4	14%	0
Lower Totals			*1850.4*	*279.9*	15%	*1148.4*	62%	*94.8*	5%	*315.2*	17%	*12.1*	*1%*	*291.8*	*16%*	*3*
Watershed Totals			**7,794.97**	**857.8**	**11%**	**4731.6**	**61%**	**477.0**	**6%**	**1645.7**	**21%**	**166.0**	**2%**	**1226.6**	**16%**	**34**



Soils & Potential Groundwater Seeps Beaver River Watershed

Date: 2/9/2021

Figure 8

Path: H:\Projects\2020\20022 Beaver River Watershed Assessment\GIS\Maps\210122_SoilsMap.mxd

3.1.7. Land Use/Land Cover

Land use (how humans use the land) and land cover (physical land type) are important factors in determining the health of a watershed, as well as predicting where impacts may occur. In particular, certain land uses can change the way wildlife, water, and pollutants move through the watershed. For this project, land use and land cover (LULC) data were obtained from RIGIS (2011). **Table 5** includes a summary of this data by subwatershed, and **Figure 9** shows the spatial distribution throughout the watershed. For simplification purposes for this project, “Agricultural” includes the following land use categories: cropland; idle agriculture; orchards, groves, and nurseries; and pasture. Similarly, “Forest” includes deciduous, mixed, and softwood forests, and “Residential” includes low (>2 acre lots) to medium-high (1/4-acre to 1/8-acre lots) density residential lots.

As you can see in **Table 5** and discussed above in Section 3.1.3, the majority of the watershed is covered with forests. The LULC data track nicely with the Forest Habitat (RIGIS, 2010) used above, showing 80% of the watershed as forested. The second highest land use is agricultural at only 9% of the watershed. Agricultural lands, particularly the active croplands, are focused in the Lower Watershed, at just over 30%, with very little agricultural land in the Upper and Middle Watersheds (2.9% and 1.6%, respectively).

The rest of the watershed is mainly residential, at 6.5% of the area. Residential lots are spread fairly evenly across the Upper, Middle, and Lower Watersheds, with the Lower having the highest coverage at 8.4%. Commercial and industrial land uses, where high intensity development is more likely to occur, are very scarce in the watershed. The majority of commercial and industrial properties are focused along Route 3 (Nooseneck Hill Road) in Exeter and Route 138 (Kingstown Road) in Richmond.

Table 5. Summary of land use and land cover in Beaver River Watershed.

Subshed Group	Subshed	ID	Area	Land Use/Land Cover Categories																													
				Agricultural		Airports		Brushland		Cemeteries		Commercial		Recreation		Forest		Industrial		Institutional		Mixed Barren		Residential		Transitional Areas		Vacant Land		Waste Disposal		Water/Wetland	
			ac	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed	ac	% of subshed
Upper	James Pond	BR-Sub-01	718.0	28.0	3.9%	0.0	0.0%	0.0	0.0%	0.0	0.0%	14.5	2.0%	0.0	0.0%	611.7	85.2%	0.0	0.0%	1.1	0.2%	0.0	0.0%	28.8	4.0%	0.3	0.0%	0.0	0.0%	3.1	0.4%	30.4	4.2%
Upper	Tug Hollow Pond Dam	BR-Sub-02	428.4	9.7	2.3%	0.0	0.0%	1.0	0.2%	0.0	0.0%	5.2	1.2%	0.0	0.0%	383.6	89.5%	0.0	0.0%	0.0	0.0%	0.0	0.0%	2.1	0.5%	0.0	0.0%	0.0	0.0%	7.5	1.8%	19.4	4.5%
Upper	Dawley Park Road	BR-Sub-03	251.9	4.5	1.8%	0.0	0.0%	0.4	0.2%	0.0	0.0%	2.9	1.2%	0.0	0.0%	228.8	90.8%	2.6	1.0%	0.5	0.2%	0.0	0.0%	4.4	1.7%	0.0	0.0%	0.0	0.0%	2.0	0.8%	5.8	2.3%
Upper	Tug Hollow Road	BR-Sub-04	338.2	3.6	1.1%	0.0	0.0%	1.4	0.4%	0.0	0.0%	0.0	0.0%	0.0	0.0%	303.2	89.7%	0.0	0.0%	0.6	0.2%	0.0	0.0%	27.7	8.2%	0.1	0.0%	0.0	0.0%	0.0	0.0%	1.6	0.5%
Upper	Wood Road	BR-Sub-05	123.3	1.2	1.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	72.5	58.8%	0.0	0.0%	0.0	0.0%	0.0	0.0%	15.2	12.3%	0.0	0.0%	0.0	0.0%	0.0	0.0%	34.4	27.9%
Upper	W. Reynolds Farm	BR-Sub-06	218.1	19.1	8.8%	0.0	0.0%	0.3	0.1%	0.0	0.0%	0.0	0.0%	1.9	0.9%	159.3	73.1%	0.0	0.0%	0.3	0.2%	1.3	0.6%	32.2	14.8%	2.8	1.3%	0.0	0.0%	0.0	0.0%	0.8	0.4%
Upper	White Oak Drive	BR-Sub-07A	174.3	6.7	3.8%	0.0	0.0%	0.3	0.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	144.9	83.1%	0.0	0.0%	0.0	0.0%	0.0	0.0%	19.9	11.4%	0.0	0.0%	0.0	0.0%	0.0	0.0%	2.4	1.4%
Upper	Tefft Hill Road	BR-Sub-07B	176.5	1.3	0.8%	0.0	0.0%	7.5	4.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	152.1	86.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	14.6	8.3%	0.0	0.0%	0.0	0.0%	1.0	0.6%	0.0	0.0%
Upper	BR Nature Preserve	BR-Sub-08	384.6	13.1	3.4%	0.0	0.0%	0.0	0.0%	0.0	0.0%	1.8	0.5%	0.0	0.0%	333.3	86.7%	0.0	0.0%	0.0	0.0%	0.0	0.0%	27.3	7.1%	0.0	0.0%	0.0	0.0%	5.0	1.3%	4.1	1.1%
Upper	Fox Ridge Drive	BR-Sub-09	153.3	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	137.2	89.5%	0.0	0.0%	0.0	0.0%	0.0	0.0%	16.1	10.5%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Upper	Old Mountain Trail	BR-Sub-10	73.3	1.5	2.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	61.5	83.8%	0.0	0.0%	0.0	0.0%	0.0	0.0%	10.4	14.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Upper Totals			*3039.9*	*88.7*	*2.9%*	*0.0*	*0.0%*	*10.9*	*0.4%*	*0.0*	*0.0%*	*24.4*	*0.8%*	*1.9*	*0.1%*	*2588.2*	*85.1%*	*2.6*	*0.1%*	*2.5*	*0.1%*	*1.3*	*0.0%*	*198.6*	*6.5%*	*3.1*	*0.1%*	*0.0*	*0.0%*	*18.6*	*0.6%*	*98.9*	*3.3%*
Middle	deCoppet Dam	BR-Sub-11	489.5	1.1	0.2%	0.0	0.0%	0.7	0.1%	0.0	0.0%	0.0	0.0%	0.0	0.0%	474.1	96.8%	0.0	0.0%	0.0	0.0%	0.0	0.0%	13.1	2.7%	0.0	0.0%	0.2	0.0%	0	0.0%	0.4	0.1%
Middle	deCoppet-NW	BR-Sub-12	264.2	0.1	0.0%	0.0	0.0%	0.5	0.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	255.2	96.6%	0.0	0.0%	0.0	0.0%	0.0	0.0%	5.3	2.0%	0.0	0.0%	0.8	0.3%	0	0.0%	2.2	0.8%
Middle	deCoppet-Long Pond	BR-Sub-13	971.6	29.5	3.0%	0.0	0.0%	9.8	1.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	910.2	93.7%	0.0	0.0%	0.0	0.0%	0.0	0.0%	5.1	0.5%	0.0	0.0%	0.0	0.0%	0	0.0%	16.9	1.7%
Middle	TNC Grass Pond	BR-Sub-14	243.3	6.2	2.5%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	9.7	4.0%	200.4	82.4%	0.0	0.0%	6.1	2.5%	0.0	0.0%	18.6	7.6%	0.0	0.0%	0.0	0.0%	0	0.0%	2.4	1.0%
Middle	BR Golf Course	BR-Sub-15	936.1	10.9	1.2%	0.0	0.0%	0.3	0.0%	2.2	0.2%	5.6	0.6%	54.3	5.8%	736.5	78.7%	0.0	0.0%	0.3	0.0%	0.0	0.0%	113.9	12.2%	4.6	0.5%	0.0	0.0%	0	0.0%	7.4	0.8%
Middle Totals			*2904.7*	*47.8*	*1.6%*	*0.0*	*0.0%*	*11.3*	*0.4%*	*2.2*	*0.1%*	*5.6*	*0.2%*	*64.0*	*2.2%*	*2576.4*	*88.7%*	*0.0*	*0.0%*	*6.4*	*0.2%*	*0.0*	*0.0%*	*156.0*	*5.4%*	*4.6*	*0.2%*	*1.0*	*0.0%*	*0.0*	*0.0%*	*29.4*	*1.0%*
Lower	Haygarden	BR-Sub-16	952.0	397.0	41.7%	9.5	1.0%	4.9	0.5%	0.0	0.0%	0.6	0.1%	0.8	0.1%	432.9	45.5%	0.0	0.0%	0.0	0.0%	0.0	0.0%	93.2	9.8%	9.0	0.9%	0.0	0.0%	0	0.0%	4.1	0.4%
Lower	DEM Grass Pond	BR-Sub-17	558.1	91.4	16.4%	0.0	0.0%	3.9	0.7%	0.0	0.0%	0.0	0.0%	0.0	0.0%	440.2	78.9%	0.0	0.0%	0.0	0.0%	0.0	0.0%	22.3	4.0%	0.0	0.0%	0.0	0.0%	0	0.0%	0.3	0.0%
Lower	Lewiston Avenue	BR-Sub-18	340.3	74.3	21.8%	0.0	0.0%	0.6	0.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	223.9	65.8%	0.0	0.0%	0.1	0.0%	0.0	0.0%	40.1	11.8%	0.0	0.0%	0.0	0.0%	0	0.0%	1.2	0.4%
Lower Totals			*1850.4*	*562.8*	30.4%	*9.5*	0.5%	*9.4*	0.5%	*0.0*	0.0%	*0.6*	0.0%	*0.8*	0.0%	*1097.0*	59.3%	*0.0*	0.0%	*0.1*	0.0%	*0.0*	0.0%	*155.7*	8.4%	*9.0*	0.5%	*0.0*	0.0%	*0.0*	*0.0%*	*5.6*	*0.3%*
Watershed Totals			**7,794.97**	**699.3**	**9.0%**	**9.5**	**0.1%**	**31.6**	**0.4%**	**2.2**	**0.0%**	**30.6**	**0.4%**	**66.7**	**0.9%**	**6261.6**	**80.3%**	**2.6**	**0.0%**	**9.1**	**0.1%**	**1.3**	**0.0%**	**510.3**	**6.5%**	**16.8**	**0.2%**	**1.0**	**0.0%**	**18.6**	**0.2%**	**133.8**	**1.7%**

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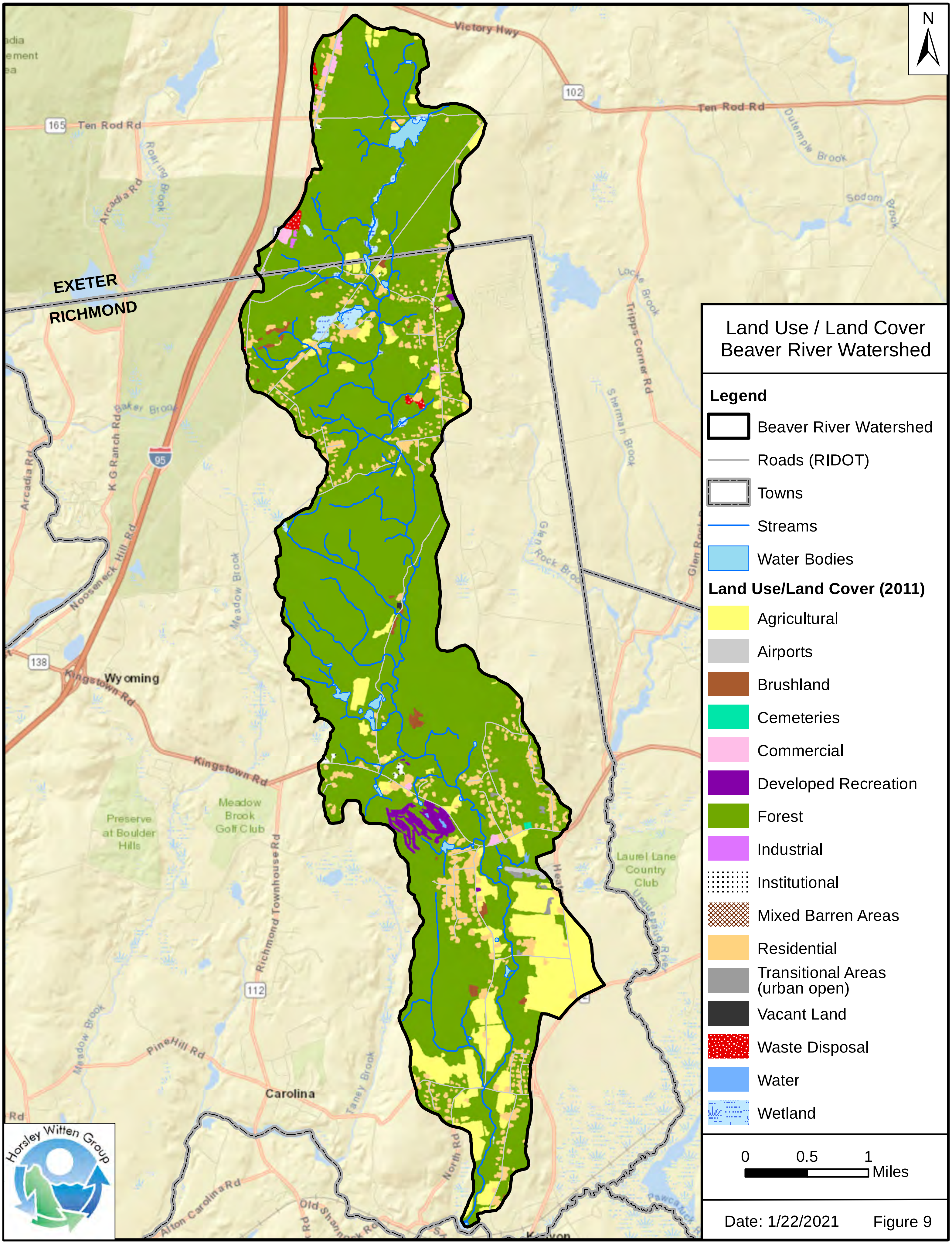

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3.1.8. Stormwater

Stormwater runoff from developed areas is a known contributor to water quality impairments and habitat degradation. Stormwater picks up excess nutrients, oils and chemicals, and sediment from our paved areas and many times, carries these pollutants to ponds, streams, and rivers. In addition, impervious cover increases the amount of runoff by preventing rainfall from soaking into the ground and interception from trees and shrubs, which can cause erosion and stream channel scour and incision. Lastly, stormwater runoff from developed areas is warmer than runoff from woods and meadows, which is particularly harmful in coldwater systems like Beaver River.

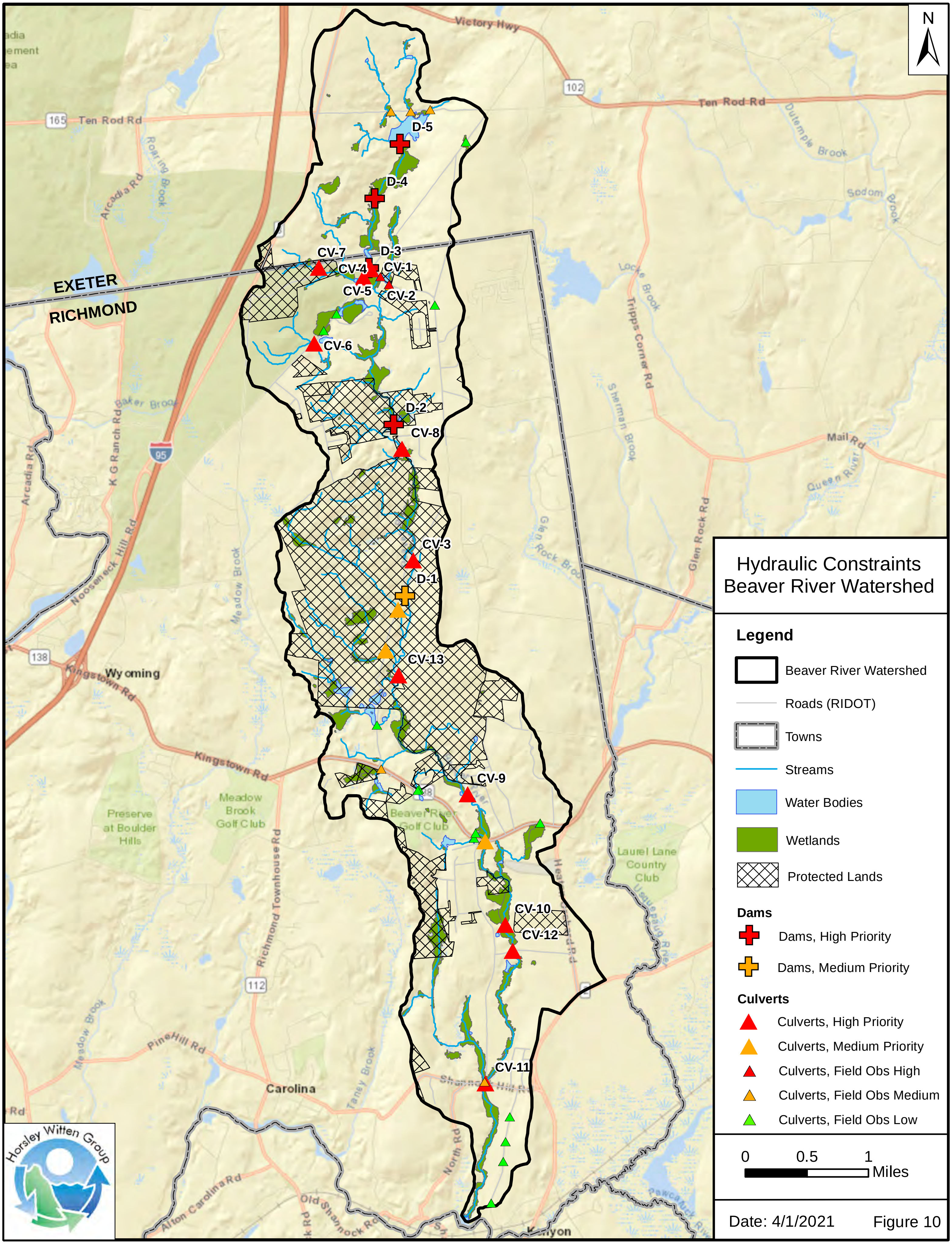
Luckily, in the Beaver River Watershed with only 3% impervious cover, stormwater runoff is not the main issue of concern. For most roads and residential areas in the watershed, stormwater flows overland into the shoulder area or off into the woods rather than into a closed drainage network of catch basins, pipes, and direct outfalls to receiving waters. However, some neighborhoods and commercial areas do have stormwater infrastructure, and many of the older systems do not have any treatment before discharging into streams or wetlands. While stormwater infrastructure mapping was not available for this project, and no green infrastructure retrofit sites were identified in the Flood Resiliency Management Plan (Fuss & O'Neill, 2017), these features/opportunities were observed sporadically throughout the watershed during the field reconnaissance.

However, stormwater is likely a contributor to a recent (new in 2016) recreation impairment documented in Rhode Island's Impaired Waters List (March 2018) for Enterococcus. RIDEM, as well as URI Watershed Watch, has done limited water quality monitoring in recent years (2011, 2015-2017) at the Rte 138 bridge where Enterococcus was present above thresholds for recreational uses. More sampling should be done to here to identify estimated stormwater contributions vs. potential wastewater sources. While there are no direct stormwater outfalls in this location, highway runoff concentrates along the shoulders and has created erosion gullies down to the river.

3.1.9. Hydraulic Constraints

Hydraulic constraints are obstructions to natural stream flow in the watershed. These constraints can impact both downstream and upstream stream conditions, creating scour pools and drop-offs, stream widening, impoundments, sedimentation, slow/stagnant water conditions, and warming to name a few. This impacts aquatic species' ability to travel along the stream corridor, degrades stream bed habitat and resting areas, impairs coldwater species' viability, can cause flooding and water quality issues, and affects long-term resilience of the stream system particularly in the face of a changing climate.

Beaver River Watershed currently has a number of hydraulic constraints, historical, modern, and even natural in the form of old mill dams, undersized culverts, and beaver dams. While a complete survey of the stream channel was not performed as a part of this work, many of these hydraulic constraints have been mapped and analyzed by previous work (Fuss & O'Neill, 2017) and most locations were observed/confirmed by our fieldwork. Additional dams and culverts observed in the field are indicated ("Field Obs") along with those from previous work on **Figure 10** below and dams in **Table 6**.



Hydraulic Constraints
Beaver River Watershed

Date: 4/1/2021

Figure 10

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In the Flood Resiliency Management Plan (Fuss & O'Neill, 2017), particularly Appendix G - Dams Bridges Culverts Assessment, detailed analysis was performed to prioritize culverts based on hydraulic capacity, flooding impact potential, geomorphic vulnerability, and aquatic organism passability. Each of these ratings was scored between 1-5, with 1 reflecting the lowest priority in that category and 5 the highest. Then, they applied a weighting factor for each, with hydraulic capacity weighted 43%, flooding impact potential weighted 29%, geomorphic vulnerability weighted 14%, and aquatic organism passage weighted 14%. The structures were then assigned a final priority of "low" (1-2), "medium" (2-3), or "high" (3-5) based on the total scores. These priority ratings should be used as a starting point for implementation, but an opportunity to address a low or medium rated culvert while doing adjacent roadwork should be taken. See **Appendix F** for the original culvert field sheets from the Fuss & O'Neill study.

This previous study did assess many of the culverts in the watershed; however, during our field reconnaissance, additional culverts were observed. For the most part, these were just recorded to identify hydrologic connections. However, in a few cases, critical culverts with obvious impacts were observed (eg., crushed ends, filled with sediment/debris, etc.); since these were not part of the previous study, additional fieldwork and analysis may be needed to confirm conditions and preliminary ranking. In particular, culverts on Tug Hollow Pond Road, in addition to beaver activity, have a large impoundment[4] on a tributary where high temperatures were recorded on an otherwise very cold stream. While not part of the secondary dataset, stream habitat, connectivity, and water quality would benefit from addressing these culverts as well.

Two dams were identified and ranked in the Flood Resiliency Management Plan (Fuss & O'Neill, 2017): D-1 and D-3. The dams were ranked based on a detailed analysis of a variety of factors such as conditions, capacity, hazard rating, impact on aquatic organisms, etc. Then, management recommendations were provided to either remove/breach the dam, repair, re-purpose, add an aquatic organism structure, or no action. Both dams assessed were recommended for dam removal - see **Appendix F** for the original dam field sheets from the Fuss & O'Neill study. Three additional dams were identified during this project during field observations. These dams were also near temperature loggers and all showed warming impacts from their impoundments.

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[4] RIDEM Dam Safety Program inspects this impoundment; it has an ID of 718 and a hazard classification of "Low."

Table 6. List of Known Dams in the Beaver River Watershed

Dam ID	Dam Name	Data Source	Ownership	Removal Priority	RIDEM ID	Hazard Class
D-1	DeCoppett Pond Dam	*F&O, 2017*	*RIDEM*	Medium	230	Low
D-2	Beaver River Preserve Dam	*Field Observation (HW)*	*TNC*	High	NA	NA
D-3	Tug Hollow Pond Dam	*F&O, 2017*	*Private*	High	232	Low
D-4	Exeter Wetlands Dam	*Field Observation (RIDEM)*	*Private*	High	NA	NA
D-5	James Pond Dam	*Field Observation (RIDEM)*	*Private*	High	231	Low

Three of the identified dams in the watershed are currently inspected by RIDEM's Dam Safety Program; their corresponding IDs and Hazard Class are included in **Table 6**. The hazard classifications are defined in the Dam Safety Regulations as described below; all inspected dams in the Beaver River Watershed are listed as Low Hazard.

- **High Hazard** – a dam where failure or misoperation will result in a probable loss of human life.
- **Significant Hazard** –a dam where failure or misoperation results in no probable loss of human life but can cause major economic loss, disruption of lifeline facilities or impact other concerns detrimental to the public's health, safety or welfare. Examples of major economic loss include washout of a state or federal highway, washout of two or more municipal roads, loss of vehicular access to residences, (e.g. a dead end road whereby emergency personnel could no longer access residences beyond the washout area) or damage to a few structures.
- **Low Hazard**–a dam where failure or misoperation results in no probable loss of human life and low economic losses.

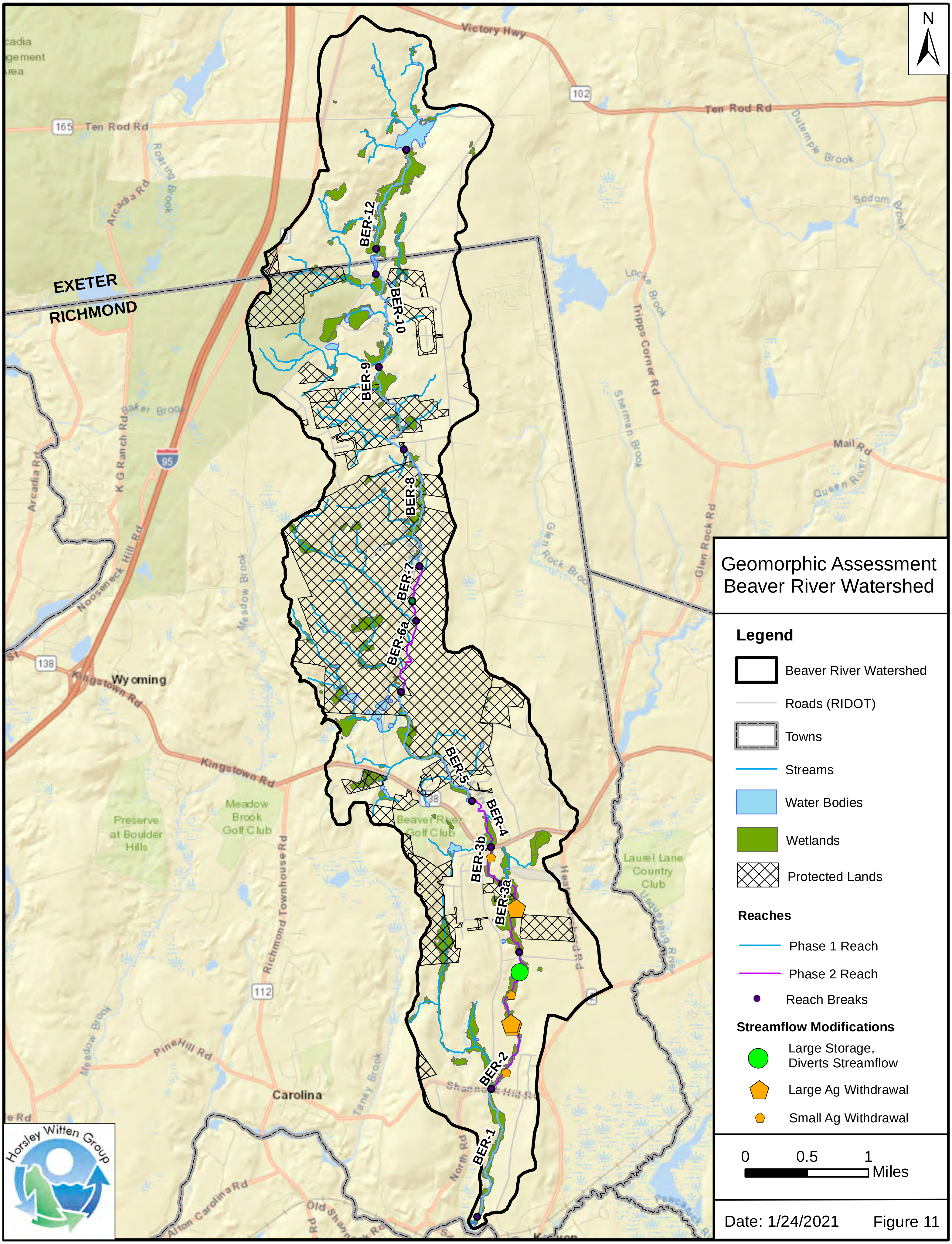
3.1.10. Geomorphic Conditions

Fluvial geomorphology is the study of how humans and natural processes affect river channels form and processes. Geomorphic assessments can help inform appropriate management activities to restore channel equilibrium, reduce flooding, and achieve sustainable habitat improvements (Field, 2016). Geomorphic assessments were performed on various reaches of the Beaver River as a part of the Flood Resiliency Management Plan (Fuss & O'Neill, 2017); in particular, Appendix H (Fluvial Geomorphic Assessment – Field, 2016) and Appendix I (River Corridor Plan – Field, 2016).

The reaches are shown on **Figure 11**; a Phase 1 or desktop assessment was performed on Reaches 1-12, while a Phase 2 or field assessment was performed only on Reaches 2-4 and 6-7. Phase 2 reaches were chosen as the highest priority focus areas based on results from the Phase 1 assessment. Data on a range of geomorphic features were collected, including meanders, scour pools, eroding stream banks, areas of channel straightening, stream flow withdrawals, encroachment, to name a few. Management recommendations for these reaches include: restore straightened or incised channel, replant encroached buffers, add large woody debris (LWD) to add habitat complexity, and remove water withdrawals. See **Table 7** for a summary of the major recommendations for the focus reaches and **Appendix F** for the original field sheets from the Fuss & O'Neill study. This geomorphic data should be cross-referenced as watershed restoration opportunities are pursued to address not only the main project (e.g., dam removal or culvert replacement) but also nearby issues such as streambank erosion.

Table 7. Summary of major recommendations for stream reach based on geomorphic assessment in the Beaver River Watershed (Field, 2016)

Reach	Restore Straightened/ Incised Channel	Replant Buffers	Add LWD	Remove Water Withdrawals
2		X		X
3	X			X
4				
6	X	X	X	
7	X		X	



Geomorphic Assessment Beaver River Watershed

Date: 1/24/2021

Figure 11

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3.2. Wildlife and Plant Species and Habitats

3.2.1. Wildlife and Plant Species

The project proponents in conjunction with conservation and state agencies have compiled a list of species of importance within the Beaver River Watershed. This list includes species identified in the 2015 Rhode Island State Wildlife Action Plan (RI WAP) as Species of Greatest Conservation Concern (SGCN) and species on the RI Natural Heritage Species List, Federal Threatened & Endangered species, as well as other species, including several fish species and additional species which have been identified as vulnerable in Rhode Island.

A total of 40 species that have been identified as important for preservation within the Beaver River Watershed. These include eleven fish species, and particularly, brook trout (*Salvelinus fontinalis*); seven reptiles (three turtle species, including the wood turtle (*Glyptemys insculpta*), and four snakes); six amphibians (frogs and salamanders); five Odonates (dragonflies and damselflies); five Lepidoptera (butterflies/moths); four plants; one bird; and one mammal. These species are listed by classification in **Appendix B**. Of these species, five are considered State- and/or Federally-listed Threatened and Endangered species, with an additional 13 species identified as either State species of Concern (SC) or else State Historic (SH) **(Table 8)**. A list of SGCN as identified in the 2105 RI WAP is provided in **Table 9**.

Table 8. List of Federal and State-listed Threatened and Endangered Species and RI Species of Concern

Common Name	Latin Name	Status*
Eastern Spadefoot	*Scaphiopus holbrookii*	SE
Ringed Boghaunter	*Williamsonia lintneri*	SE
Sandplain Gerardia, Agalinis	*Agalinis acuta*	FE
(Large-spiked) Beak-rush	*Rhynchospora macrostachya*	ST
Northern Long-eared Bat	*Myotis septentrionalis*	FE
Wood Turtle	*Glyptemys insculpta*	SC
Eastern Hognose Snake	*Heterodon platirhinos*	SC
Eastern Rat Snake	*Pantherophis alleghaniensis*	SC
Common Ribbon Snake	*Thamnophis sauritus*	SC
Spatterdock Darner	*Aeshna mutata*	SC
Pine Barrens Bluet	*Enallagma recurvatum*	SC
Dusted Skipper	*Atrytonopsis hianna*	SC
Hessel's Hairstreak	*Callophrys hesseli*	SC
Hoary Elfin	*Callophrys polios*	SC
Bog Copper	*Lycaena epixanthe*	SC
Colic-root, Stargrass	*Aletris farinosa*	SC
Whorled Milkwort	*Polygala verticillata*	SC
Vesper Sparrow	*Pooecetes gramineus*	SH

**Status Codes:*
ST = State Threatened
SE = State Endangered
FE = Federal Endangered
SC = State species of Concern
SH = State Historic

Brook Trout

One particular species is very important in the Beaver River for ecological, cultural, and social reasons: the brook trout (*Salvelinus fontinalis*). Brook trout is part of the salmon family and is an obligate coldwater species, meaning that they require lower temperatures than other fish to thrive or even survive. Healthy, wild populations have been documented in certain stretches of Beaver River and its tributaries. In addition, RIDEM stocks Beaver River, at least once in the spring, with hatchery-raised brook trout in three locations: Rt. 138, Beaver River Schoolhouse Rd, and Shannock Hill Rd (RIDEM pers comm).

In 2004, Saila et al. took a close look at the most important habitat requirements for the brook trout in small streams, including Beaver River (*Assessing Habitat Requirements for Brook Trout (Salvelinus fontinalis) in Low Order Streams*). Their findings suggest that the most important indicator for healthy brook trout populations is the distance from dams/impoundments. Their findings also indicate that adequate canopy cover and presence of pools are significant indicators of ideal brook trout habitat, offering cooler stream temperatures, adequate protection, and habitat diversity. In addition, it is important to note that brook trout are known as the weakest swimmers of the salmonid species (Saila et al., 2005) and do not attempt to leap over obstructions like many of the others, so even small dams and perched culverts can be insurmountable impediments.

Table 9. List of SGCN Species within the Beaver River Watershed per RI WAP

Common Name	**Latin Name**	**Status***
American Eel	*Anguilla rostrate*	NL
Brook Trout	*Salvelinus fontinalis*	NL
Spotted Turtle	*Clemmys gutatta*	NL
Northern Black Racer	*Coluber constrictor*	NL
Wood Turtle[5]	*Glyptemys insculpta*	SC
Eastern Hognose Snake	*Heterodon platirhinos*	SC
Eastern Rat Snake	*Pantherophis alleghaniensis*	SC
Eastern Box Turtle	*Terrapene carolina*	NL
Common Ribbon Snake	*Thamnophis sauritus*	SC
Spotted Salamander	*Ambystoma maculatum*	NL
Marbled Salamander	*Ambystoma opacum*	NL
Four-toed salamander	*Hemidactylium scutatum*	NL
Wood Frog	*Lithobates sylvaticus*	NL
Red-spotted Newt	*Notophthalmus viridescens*	NL
Eastern Spadefoot	*Scaphiopus holbrookii*	SE
Pine Barrens Bluet	*Enallagma recurvatum*	SC
Ringed Boghaunter	*Williamsonia lintneri*	SE
Dusted Skipper	*Atrytonopsis hianna*	SC
Hessel's Hairstreak	*Callophrys hesseli*	SC
Hoary Elfin	*Callophrys polios*	SC
Bog Copper	*Lycaena epixanthe*	SC
Northern Long-eared Bat	*Myotis septentrionalis*	FE

**Status Codes:*
ST = State Threatened
SE = State Endangered
FE = Federal Endangered
SC = State species of Concern
NL = Not Listed by RI Natural History Survey

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[5] Wood turtle is currently being considered for federal listing; the USFWS will make a decision if listing is warranted in 2023. Spotted turtle is also being considered for listing by the USFWS.

One species that was not identified as important, per se, but is worth including in this assessment is the species that lends to the river's name, the beaver (*Castor canadensis*). Beavers have played an active role in shaping the ecology of the landscape for many centuries, creating wetlands from uplands and along streams and providing habitat that can be dynamic over time. Thus, the habitat that is created by beaver ponds supports a wide variety of wildlife species, including species such as the red-spotted newt, and other species identified as SGCN species in Rhode Island. However, while beaver dams are considered important structures in providing ecological processes, sometimes they result in fish passage barriers, and may have undesirable thermal effects on in-stream conditions. Beaver dams can also exacerbate manmade impoundment and infrastructure connectivity issues, and in some cases, removal could be considered if dams are creating flood/safety hazards along private or public properties.

3.2.2. Wildlife Habitat and Ecological Community Descriptions

Protection of these species is predicated on protection and preservation of their supporting habitats. **Appendix B** provides a matrix of these species by critical supporting habitat, which ranges from open grasslands to forested habitats, wetlands habitats, rivers, and open water bodies depending upon the species. Habitats identified within **Appendix B** are derived from the Rhode Island Ecological Communities Classification (Enser, 2011; *Classification*) and the Natural Communities of Rhode Island (Enser and Lundgren, 2006). For simplicity, some of the habitats have been combined for the purposes of this assessment as they provide similar habitat features.

Note also that many of these same habitats identified for preservation or restoration to support species in the Beaver River Watershed also provide critical habitat for other SGCN animals, such as a variety of threatened or imperiled mammals within Rhode Island.

A brief description of these habitats is provided below. **Figure 12** depicts the range and distribution of these various habitats within the Beaver River Watershed.

UPLAND COMMUNITIES

Open Uplands (Grassland & Shrubland)

Open Uplands collectively includes grasslands and shrublands that are dominated by upland grass or herbaceous species and/or shrubs. For the purposes of this assessment, Open Uplands also includes ruderal grassland/shrubland that has resulted from succession following removal of woody vegetation, such as old fields, hedgerows lining fields, utility, rights-of-way. Open Uplands provides important supporting habitat for several of the reptile and moth species identified in **Appendix B** as well as three of the four plant species and the historic bird species. It should be noted that certain agricultural fields/pastures found within the watershed may also provide habitat for some of these species.

Mixed Deciduous/Coniferous Forests

Collectively forested habitat within the Beaver River is made up of several types of upland forests from mixed hardwoods to mixed deciduous/coniferous forests of oaks and pines, and mixed oak forests. The most widely distributed upland forest community in Rhode Island is deciduous forests dominated by mixed oaks (*Quercus* spp.). While the *Classification* distinguishes among the various types of upland forest types based upon the dominant canopy and understory species, for the purposes of this assessment all upland forests are considered as a collective unit. Forested habitat within the watershed is shown in **Figure 12**.

According to the RI WAP, the "the primary wildlife values associated with oak forests is in the size of these habitats, with largest tracts supporting forest interior specialists," including many species on the SGCN list. Forested upland communities provide essential habitat for several of the reptiles, non-breeding habitat for amphibians, and certain moth species. Three of the four plant species identified occupy open sandy areas, particularly along the coastal plain. They are included in the forested habitat type as each may be found along forest edges or in open sandy woodlands. The Federally Endangered Sandplain Gerardia (*Agalinus acuta*) was identified through an Information, Planning, and Consultation (IPaC)[6] resource list, which is an automatically generated list of species and other natural resources under U.S. Fish and Wildlife Service (USFWS) jurisdiction. The IPaC list includes species that are known to occur or would be expected to be located within the Beaver River Watershed. Finally, upland forest communities also provide important habitat for the Federally Endangered Northern Long-eared Bat (*Myotis septentrionalis*), which while not specifically identified for this assessment, has been included as it is a SGCN as identified in the RI WAP and is a species of conservation concern across the northeastern quadrant of the United States. The IPaC list also identifies this species.

Palustrine Communities

Palustrine communities include wetland areas that include both seasonally and permanently flooded areas supporting hydrophytic plant species and hydric soils. Several types of wetland communities are found through the watershed, including herbaceous or shrub dominated open wetlands, bogs, forested wetlands, and vernal pools.

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[6] Included within an IPaC report are federally-Threatened or Endangered species as regulated under the Endangered Species Act; Migratory Birds; Facilities; and Wetlands in the National Wetlands Inventory (NWI).

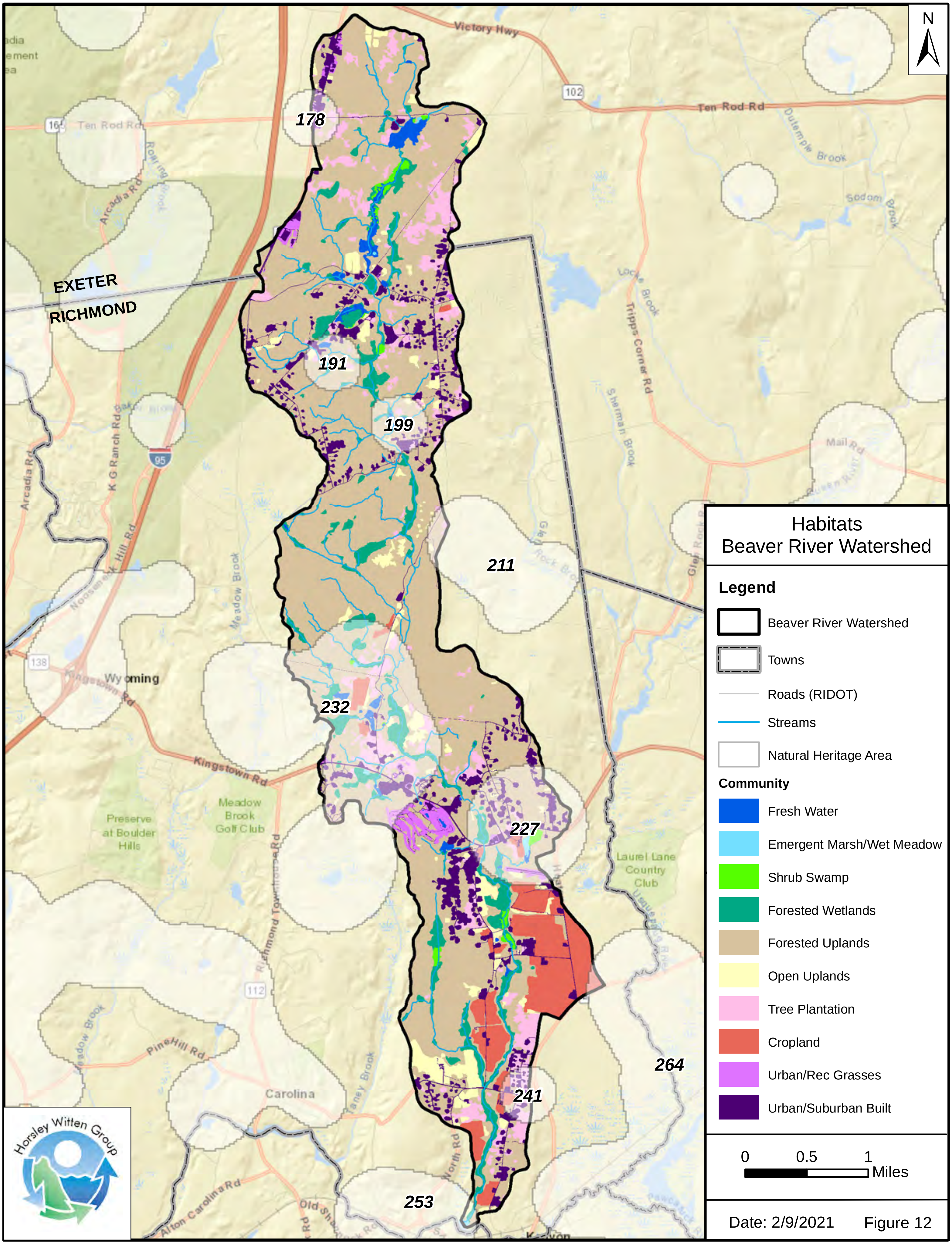

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Figure 12

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Freshwater Emergent Marsh/Wet Meadow

Open Palustrine wetlands such as freshwater emergent marshes or wet meadows are grouped together for this assessment as they provide similar wetland habitat. The *Classification* distinguishes between these two systems, defined by their largely herbaceous (grasses and forbs) plant communities and hydrologic regime. Emergent marshes generally support a slightly wetter condition and are often formed around the edges of lakes/ponds and slow-moving streams, while wet meadows are subject to seasonal flooding or saturation without standing water throughout the year. Open plant communities such as these provide habitat for several of the reptile and amphibian species, and notably the red-spotted newt (*Notophthalmus viridescens*), as well as Odonate species and the state-Threatened large-spiked beak-rush. Shallow marshes supporting scattered shrubs also support a number of other SGCN species. Often these types of habitat can be created through beaver activity.

Shrub Swamps

In contrast to wet meadow communities that support occasional shrubs, shrub-swamps appear more as shrub-dominated wetland habitats with scattered small openings of primarily herbaceous plants. Similar to wet meadows, shrub swamps are flooded for a portion of the growing season but generally do not have standing water throughout the year. Over time shrub swamps may mature into forested communities or by contrast may be artificially flooded by beaver activity and revert to an emergent marsh community. Several areas of open wetlands were observed throughout the Beaver River Watershed during this assessment’s field reconnaissance, contributing the habitat diversity of the wetland communities. In addition to providing habitat for reptiles and the large-spiked beak-rush, shrub swamps also support a variety of breeding birds, including those also identified as SGCN species.

Coastal Plain Peatlands

Coastal Plain Peatlands area a subset of the larger classification of open peatlands formed through an accumulation of organic deposits (peat) that are often referred to as bogs. These plant communities are typically acidic and nutrient poor and develop in kettlehole depressions or along open water or along abandoned stream channels. Sphagnum moss (*Sphagnum* spp.) typically occurs in scattered mats or clumps rather than as a floating bog. Coastal Plain Peatlands support at least two of the reptiles (ribbon snake and spotted turtle), several Odonates, and Lepidoptera species; areas where sphagnum moss overhang pockets of standing water also may provide suitable habitat for the four-toed salamander (*Hemidactylium scutatum*).

A subset of this broader community is _Acidic Graminoid Fen_, which is sedge-dominated peatland fed by groundwater. Typical species include several sedge species and mats of sphagnum moss. This habitat may also support shrubs along its periphery. This habitat was specifically identified as an important wetland community of concern as it provides habitat for the State-Endangered Ringed Boghaunter (*Williamsonia lintneri*). A well-known example of this habitat is Diamond Bog in Richmond, which occurs just southwest of the Beaver River Watershed. Smaller unidentified pockets of this habitat may also occur within the Beaver River Watershed.

Forested Wetlands (Deciduous and Coniferous)

Forested wetlands are broadly considered in this assessment and include Floodplain Forests and Forested Swamps (both deciduous swamps and coniferous-dominated communities) with the most common community being a Red Maple Swamp. These forested communities typically support a dense understory and shrub community that supports a wide variety of wildlife species including reptiles and amphibians and at least one of the Lepidoptera species, many of which are also identified as SGCN species. Similar to forested uplands, wildlife values tend to increase with overall size of the forest tract. Floodplain forests and forested swamps where vegetation overhangs the river contributes to the overall health of the riverine system by providing shade that helps to maintain cooler water temperatures that are critical to cold water fisheries.

One subset of Forested Wetlands includes the Atlantic White Cedar Swamp which is dominated by Atlantic white cedar (*Chamaecyparis thyoides*), which serves as the sole larval food plant for Hessel's hairstreak (*Callophrys hesseli*).

Seeps/Springs/Vernal Pools

Collectively assessed as Seeps/Springs/Vernal Pools, this Palustrine habitat includes small freshwater wetland communities that are typically found among upland forested communities. Seeps and springs arise from groundwater sources, and area typically associated with headwater streams that feed larger streams and waterbodies. According to the RI WAP, seeps and springs "maintain a constant cold temperature and high levels of dissolved oxygen," which are critical features contributing to a healthy riverine system.

Vernal pools are small, shallow seasonally flooded basins area characterized by a lack of fish species, and by periods of dryness. Vernal pool habitat is extremely important to a variety of wildlife species including some amphibians that breed exclusively in vernal pools as well as to other wildlife species that utilize vernal pools for breeding, feeding, and other important functions. In addition to providing habitat for the several amphibian species identified for this assessment, vernal pools also provide habitation for the spotted turtle (*Clemmys gutatta*) and for the state Threatened large-spike beak-rush (*Rhynchospora* *macrostachya*). While not specifically identified through the RIGIS mapping of the Beaver River Watershed, HW observed several areas that may serve as potential vernal pools among the landscape.

RIVERINE COMMUNITIES

Rivers and Streams

Riverine systems are not included within the *Classification* but are covered in the Natural Communities of Rhode Island (Enser, 2006) and described as important key habitats within the RI WAP (2015). These include flowing water ecosystems ranging from headwater streams to intermittently flowing first order streams to larger, perennially flowing streams and rivers. Streams are defined by both their energy input and channel gradient. According to the RI WAP, the majority of the rivers and streams in Rhode Island are classified as headwaters and creeks, and “only about 10% of Rhode Island’s headwaters and creeks are high gradient (fast-moving), cold temperature streams.” These coldwater streams tend to be well oxygenated and are critical to supporting coldwater fisheries such as brook trout (*Salvelinus fontinalis*) previously discussed.

As described above, Beaver River is a small second-order stream that flows through the Towns of Exeter and Richmond to its confluence with the Pawcatuck River. Partly due to the fact that much of the stream itself is surrounded by protected lands held by RIDEM and TNC to name a few, its ecosystem supports healthy populations of coldwater fisheries and freshwater mussels, while its surrounding riparian corridor contains numerous vernal pools that support resident amphibian species. Slower flowing reaches of Beaver River and its tributaries with sandy bottoms and densely vegetated banks provide excellent wood turtle habitat.

It is worth noting that tremendous efforts have been made by a federal and state agency-NGO-private industry consortium to remove dams on the mainstem of the Pawcatuck River since 2010. As a result, the Pawcatuck River now has full connectivity from its mouth in Little Narragansett Bay to Worden Pond in nearby South Kingstown, RI. Thus, river herring, and particularly alewife (*Alosa pseudoharengus*), are now returning to the Pawcatuck River including access upstream of the Horseshoe Falls dam and Denil fishway, and this successful passage has been documented for several years. River herring have access into the mouth of the Beaver River up to the first impediment, and it is anticipated that the Beaver River would serve as quality spawning habitat for both anadromous river herring, including alewife and blueback herring (*A. aestivalis*), and catadromous species such as American eel (*Anguilla rostrata*).

LACUSTRINE COMMUNITIES

Lakes and Ponds

The Beaver River Watershed supports many lakes and ponds that vary in size and depth; most are artificially created along the river by artificial dams built by human development to provide drinking water supplies or to support industrial and agricultural uses. Other lakes and ponds have been artificially created by beavers or even undersized or damaged culverts. These lakes and ponds, many with shallow emergent plant communities, support nearly all of the fish species identified for this assessment, as well as two of the Odonate species and one of the state-Threatened plant species. However, artificial impoundments often also impede aquatic organism passage, increase competition for riverine species, and raise water temperatures, which can be lethal for coldwater species.

3.2.3. Rare Species Habitat

The Beaver River Watershed supports several areas that have been mapped habitat by the Rhode Island Natural History Survey (NHS) where known occurrences of State and/or Federal listed Threatened and Endangered species or state Species of Concern. **Appendix B** identifies the protected status of each of the species identified for this assessment.

These are nine NHS areas mapped within the Beaver River Watershed, numbered from north to south: 178, 191, 199, 211, 232, 227, 264, 241, and 253 (see **Figure 12**). Several of these NHS areas support one or more species identified for this watershed assessment as well as other State-listed Species of concern (SC); four of these areas support habitat and known occurrences of State- and Federally-listed Threatened and Endangered Species. Due to the sensitive nature of these NHS habitat areas, the species found within each area are not disclosed within this report.

3.2.4. Invasive Plant Species

Invasive plants are non-native species that have been introduced to areas outside of their native range, where they often thrive and out-compete and overtake endemic plant communities. Non-native plants are characteristically aggressive in their growth, have few natural predators and/or limiting biological factors within their introduced range, and tend to have very effective reproductive abilities. The spread of such plants is a major concern in the United States, as they reduce the functions and values of habitat for native flora and fauna within both wetlands and uplands and are a nuisance to manage once they have become established within an area. Adverse economic and environmental impacts are also often incurred by the establishment of invasive species.

The Rhode Island Invasive Species Council (RIISC) first developed and maintains a list of non-native, invasive plant species in 2001 that identifies those plants that have been assessed to date, using the established criteria. The list categorizes invasive plant species by extent (widespread, restricted, or need more information), association (species known to be invasive in neighboring states but not yet assessed in RI), and, potentially invasive in other states, but not yet invasive in RI. RIISC updated the list of widespread and localized invasive plant species in 2013, broken out by growth form (trees, shrubs, herbaceous/grasses, vines, and aquatic).

In addition to the lists of non-native species, in 2020, RIISC also developed a list of "plant species that impair the untended function of constructed, vegetated features such as stormwater swales, retention ponds, rain gardens, and constructed wetlands and thereby can negatively affect water quality." This list extends beyond those species identified as invasive by the state and includes weedy species (both native and non-native).

During the field reconnaissance, a fair number of these species were observed in varying amounts throughout the watershed. The most prevalent species observed include Japanese knotweed (*Fallopia japonica*), multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), honeysuckle (*Lonicera* sp.), Oriental bittersweet (*Celastrus orbiculatus*), purple loosestrife (*Lythrum salicaria*), and common reed (*Phragmites australis*). The presence of non-native invasive plant species threatens not only species diversity but habitat for those species of importance that have been identified for this assessment.

3.3. Stream Temperature Analysis

The water temperature in a stream or river is extremely important to aquatic species, particularly those dependent on coldwater conditions, such as brook trout. The RIDEM Department of Fish and Wildlife has been studying the water temperature and species composition in the Beaver River for many years. In particular, they have been documenting stream temperatures at 2-4 sites from 2016-2019 (RIDEM correspondence, 2020). This data is summarized in the figure included in **Appendix C**, showing the average warm season temperatures (June – August) for segments of stream based on the nearest logger station. This information is helpful to broadly understand temperature variation, but does not include enough data points (i.e., logger locations) to pinpoint specific problem areas. More logger locations are needed to provide a better picture of where warmer waters are coming from and thus provide insight on restoration activities that could be implemented to reduce those temperatures.

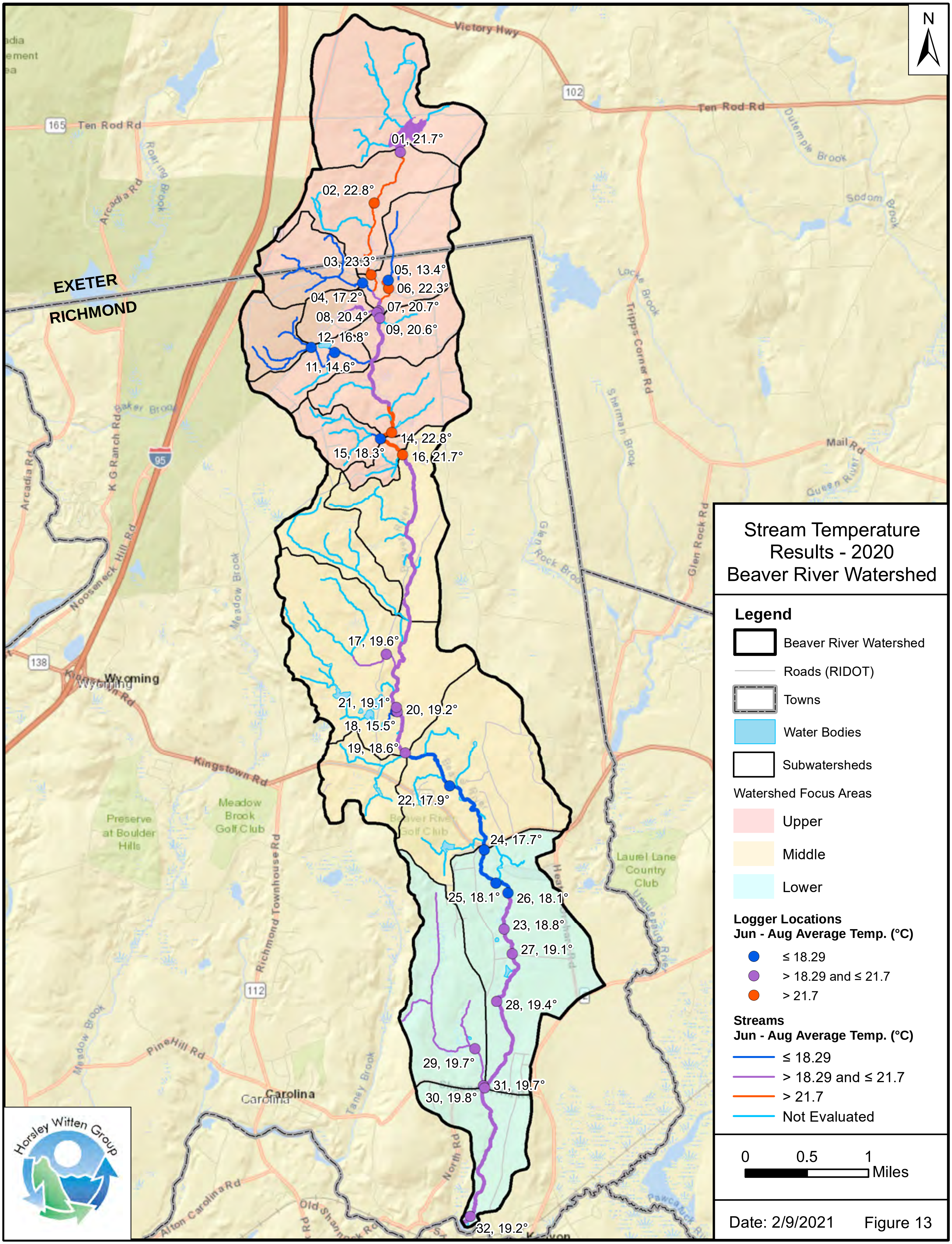
As such, a group of volunteers and citizen scientists installed in-stream temperature loggers in multiple locations throughout the watershed in the summer of 2020. While the temperature logger effort was not part of this project, the Project Team did provide an analysis to inform logger placement for most effective data based on the data described above. See the table in **Appendix C** for a list of loggers and additional information on each location, including the reason it was chosen.

Volunteer during temperature logger installation (*photo provided by Jim Turek*).

The data and analysis provided by RIDEM Fish & Wildlife staff focused on the stream temperature averages for the typical warm season period (June – August) (**Table 10**). This data was used to create **Figure 13**, showing the logger results color-coded for the three key temperature thresholds for brook trout (cold - <18.3 C, cool – between 18.3 C up to and including 21.7C, and warm - >21.7C). These results were applied to the surrounding stream segments and/or impoundments using best professional judgment based on direction of flow. Stream segments where a temperature class could not be applied with great confidence are indicated separately.

Table 10. Water temperature results from loggers deployed in the Beaver River system between late May and early October (RIDEM F&W, 2020). The records highlighted with gray indicate compromised data due to loggers exposed to air for some portion of the period of record.

		Stream	Location	Jun-Aug Average Temp	Jun-Aug StDev	Maximum 7-day Avg Temp	Maximum 24-hour Avg Temp
TL	1	Main Stem of Beaver River	Downstream of James Pond	21.66	1.88	23.65	24.99
TL	2	Main Stem of Beaver River	Downstream of Dam	22.81	1.79	25.05	25.72
TL	3	Main Stem of Beaver River	Tug Hollow Pond Dam	23.31	2.16	25.27	26.29
TL	4	Tributary to the west	New London Turnpike Trib	17.17	1.32	20.31	22.13
TL	5	Tributary to the east	Tug Hollow Road Trib - upstream	13.36	0.72	14.82	15.10
TL	6	Tributary to the east	Tug Hollow Road Trib - downstream	22.33	3.30	25.45	27.09
TL	7	Main Stem of Beaver River	Upstream of Wood Rd Trib	20.70	2.24	23.25	23.88
TL	8	Tributary to the west	Wood Rd Trib	20.45	3.20	23.51	25.35
TL	9	Main Stem of Beaver River	Downstream of Wood Rd Trib	20.58	2.18	23.07	23.70
TL	11	Tributary to the west	Trib below pond on New London	14.64	1.55	16.64	17.69
TL	12	Tributary to the west	Trib Upstream of New London Tpk	16.84	2.30	19.69	20.83
TL	14	Main Stem of Beaver River	Downstream of Lake - TNC Land	22.85	2.94	26.51	27.42
TL	15	Tributary to the west	Tributary Near Old Mtn Road	18.29	3.27	23.05	24.88
TL	16	Main Stem of Beaver River	Downstream of Old Mtn Road	21.70	2.37	24.30	24.94
TL	17	Tributary to the west	South Trib at Hillsdale Rd	19.56	3.09	22.87	24.64
TL	18	Tributary to the west	Long Pond Trib	15.54	1.18	16.54	16.96
TL	19	Main Stem of Beaver River	Downstream of Large Wetland	18.57	2.03	20.45	21.29
TL	20	Tributary to the west	Downstream from Long Pond Trib	19.16	2.02	21.04	21.82
TL	21	Main Stem of Beaver River	Upstream from Long Pond Trib	19.09	1.98	20.95	21.70
TL	22	Tributary to the west	Below Whitetail Trib	17.89	1.75	19.45	20.18
TL	23	Main Stem of Beaver River	Beaver River Rd Covered Bridge	18.76	2.04	20.94	22.46
TL	24	Main Stem of Beaver River	Downstream RTE 138 Culvert	17.68	1.78	19.42	20.56
TL	25	Main Stem of Beaver River	Beaver River Park Upstream	18.10	1.92	20.51	24.09
TL	26	Main Stem of Beaver River	Beaver River Park Downstream	18.14	1.94	20.02	21.86
TL	27	Main Stem of Beaver River	Beaver River Schoolhouse Rd	19.05	2.18	21.34	22.91
TL	28	Main Stem of Beaver River	Upstream of Western Ag Land	19.44	2.14	21.63	22.79
TL	29	Tributary to the west	Trib Upstream of Western Ag Land	19.75	2.77	23.30	24.70
TL	30	Tributary to the west	Tributary at Shannock Hill Rd	19.83	3.06	23.39	25.50
TL	31	Main Stem of Beaver River	Shannock Hill Rd	19.74	2.27	22.23	23.75
TL	32	Main Stem of Beaver River	Mouth of Beaver River	19.18	2.11	21.58	22.81



Stream Temperature Results - 2020
Beaver River Watershed

Date: 2/9/2021 Figure 13

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This temperature dataset creates a much more detailed picture of conditions in the Beaver River system than earlier efforts. In a mostly wooded, undeveloped watershed, there are surprisingly several locations where "warm" measurements were recorded. However, while this analysis is effective for comparing relative stream temperatures from many logger locations measured in the same season, these data are just a snapshot of one particular year. Summer 2020 was hotter and drier than usual. In fact, at the end of September 2020, 99% of Rhode Island was in extreme drought and the U.S. Drought Monitor called the week of Sept. 29 "the most intense period of drought" for Rhode Island since 2000, when the Drought Monitor was started. Even so, the relative temperatures do provide an indication of where the warmest waters are and additional insight into their potential causes. A detailed discussion of the results is included below by watershed focus area.

Upper Watershed

From **Figure 13**, you can see that right from the first logger location at James Pond, an impoundment from a manmade dam, water temperatures were right at the threshold between "cool" and "warm." Between the pond and the next dam (TL 2), temperatures warmed to 22.8 C, and warmed again at the next dam (TL 3, Tug Hollow Dam) to the highest average measured, 23.3 C. On a nearby tributary, an impoundment created by damaged and undersized culverts as well as beaver activity also shows high water temperatures (TL 6, average 22.3 C), particularly when compared to the coldest water measured in the watershed (TL 5, average 13.4 C) just upgradient of the impoundment. A small tributary to the northwest of New London Turnpike brings coldwater into the system (TL 4, average 17.2 C), which helps to bring the Beaver River water temperature down to "cool" at TL 7 (average 20.7 C). A small tributary brings in warm water at TL 8 (average 20.4 C) from a large wetland, keeping the main stem cool at TL 9 (average 20.6 C). The next logger locations were placed on a tributary to the west of the main stem, both upstream and downstream of the crossing at New London Turnpike. "Cold" water was measured at both locations (TL 11 – average 14.6 C and TL 12 – average 16.8). TL 10 was eliminated as not needed, and TL 13 was missing in the fall, most likely due to beaver activity. The next logger was just downstream of a large impoundment created by an old stone dam with additional beaver activity, TL 14. The stream temperature at this location is "warm," at an average 22.8 C. TL 15 collected water temperature data from a tributary flowing through the TNC's Beaver River Preserve, which showed an average temperature right at the "cold" threshold, 18.3 C.

Middle Watershed

The middle portion of the watershed starts where Beaver River flows under Old Mountain Road through an undersized culvert. Water temperature was collected here at TL 16, which showed an average at the threshold between "cool" and "warm" conditions (average 21.7 C). From here, the stream flows through the large DeCoppett Estate, which is now managed by the State. TL 17 measures stream temperatures from a "cool" tributary (average 19.6 C) while TL 18 measures stream temperature from a “cold” tributary (average 15.5 C). The temperatures in the main stem continue to drop as the stream flows through the Estate; averages of 19.1 C and 19.2 C at TL 21 and 20, down to 18.6 C at TL 19 (loggers out of order in this stretch; TL 19 is the furthest downstream) and becomes “cold” for the first time (average 17.9 C) at TL 22.

Lower Watershed

The lowest portion of the watershed continues in the “cold” range at an average of 17.7 C at TL 24 (TL 23 was moved out of order further downstream), which is located just downstream from the Route 138 crossing, at the Beaver River Fishing Access managed by RIDEM. The next two loggers on the main stem, TL 25 and 26, continued to show “cold” conditions at an average of 18.1 C. However, the remaining stretch of Beaver River down to the mouth measured in the “cool” range. Temperatures increased as the river flows through an area dominated by agriculture lands and the highest amount of stream buffer encroachment (TL 23 – 18.8 C, TL 27 – 19.1 C, TL 28 – 19.4 C, and TL 31 – 19.7 C). A tributary to the west that flows through the Grass Pond Preserve as well as agricultural lands also was measured as “cool” (TL 29 – 19.7 C and TL 30 – 19.8 C). The logger at the mouth of the Beaver River (TL 32) measured cooler temperatures, but still in the “cool” range at 19.2 C.

Temperature Logger Discussion

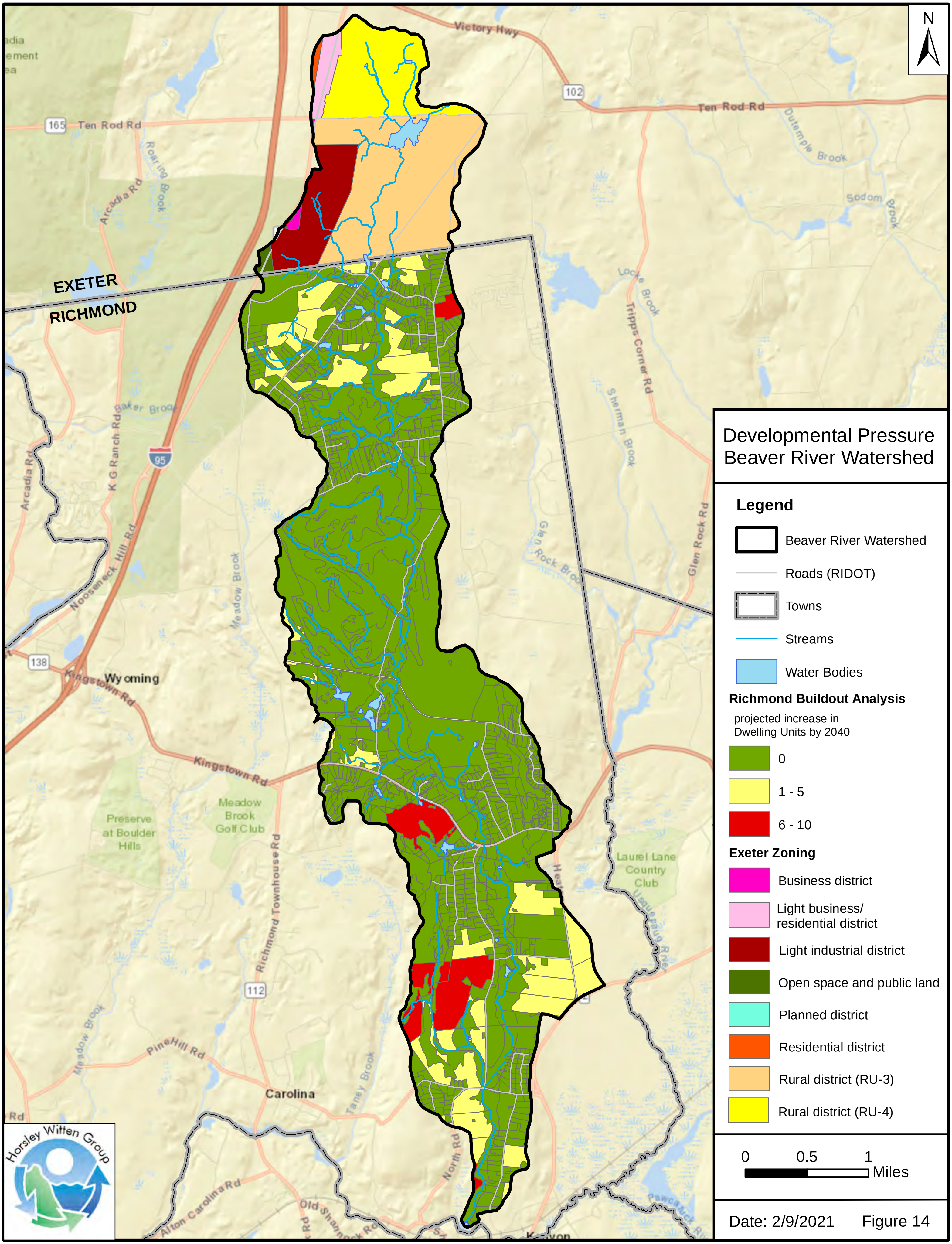
While the impact of open water impoundments on water temperature is well known and studied, this dataset clearly shows a warming effect at every dam/impoundment where a temperature logger was placed. The most drastic of these is between TL 5 and TL 6, where the coldest water in the watershed was raised to almost the highest in a very short distance. Additional takeaways from this temperature analysis include the cooling role of forested stream buffers and forested tributary drainage areas, observed particularly through the DeCoppett Estate, as well as the positive correlation with groundwater inputs (particularly at the DeCoppett-Long Pond Subwatershed with high potential groundwater intrusion points and large percent of HSG A soils). An inverse correlation was observed on stream temperatures in areas with an increase in agricultural lands. This could be due to the associated encroachments on the stream buffer as well as potentially from groundwater withdrawals for irrigation.

4. Projected Conditions

The projected conditions for this assessment were predominately developed from the Town of Richmond Buildout Analysis 2018 (MPS), which was conducted in support of the *Town of Richmond's Comprehensive Community Plan Update*. This buildout analysis estimated both the amount and location of future single-family residential development on a lot-by-lot basis allowed under the current Town's Zoning Ordinance, Zoning Map and Land Development and Subdivision Regulations at that time (MPS, 2018). The buildout analysis was based on 20-year projections, roughly for the year 2040.

In the Beaver River Watershed, 40 parcels in Richmond were identified to gain 1 to 10 additional dwelling units by the year 2040. These locations where development pressure is expected are shown on **Figure 14** below, separated by those parcels with lighter pressure (1-5 additional units) and those with greater pressure (6-10 additional units). The only change to the buildout analysis data for this project was to remove the recently RRPLT-acquired land from the lighter pressure category, as it is no longer facing further development. Not surprisingly, the majority of parcels with development pressure are located in the Upper and Lower Watersheds, given that much of the Middle Watershed is protected. In particular, the parcels with greater pressure are concentrated in the Lower Watershed.

For the portion of the watershed located in the Town of Exeter, no buildout data were available for this project. However, Exeter's zoning data are shown on **Figure 14** to indicate the type of possible future development.



Developmental Pressure Beaver River Watershed

Date: 2/9/2021 Figure 14

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5. Restoration and Land Protection Opportunities

5.1. Restoration Opportunities

Based on the above data and analysis, several restoration opportunities were identified to improve water quality and habitat in the watershed. Restoration actions include dam removal, culvert replacement, stream buffer restoration, reforestation, wetland restoration, streambank/stream corridor restoration, and additional projects.

5.1.1. Dam Removal/Restoration

As discussed in Section 3.3, temperature monitoring data indicated that impoundments have the greatest impact on stream temperature in the watershed. These results are supported by earlier studies along the Beaver River (Salia et al., 2005), which showed that it took up to 5 miles for the stream to recover from temperature impacts due to a small dam. In addition, dams that cause impoundments also greatly reduce aquatic passage along the stream corridor, particularly for the brook trout, a weak swimmer. While certain wildlife species require open water, the majority of the species of importance in the Beaver River Watershed require forested stream corridors. Given these significant impacts, the removal of one or more of these barriers should be considered to allowing the stream channel, corridor, and floodplain to re-establish. Additional analysis will be needed to determine the extent of stream corridor restoration that will be needed along with the dam removal. Smaller dam removals can typically be allowed to re-form and re-vegetate naturally. Surprisingly, recent dam removal/stream restoration projects throughout New England have shown that natural, viable seedbanks lie dormant in the saturated soil below impounded water. When the dams are removed, the seedbank becomes exposed to air and sunlight and can quickly germinate, which can facilitate rapid riparian revegetation with little effort. The removal of larger dams may require restoration features such as bank forming/stabilization, woody structures, and revegetation to prevent large amounts of erosion/sedimentation from occurring and smothering downstream habitats and infrastructure.

Table 11 includes the identified dams along with their removal priority. If a dam cannot be removed, bypass structures could be considered at a minimum to enhance aquatic connectivity.

Table 11. Removal Priority of Identified Dams in the Beaver River Watershed

Dam ID	Dam Name	Ownership	Priority
D-1	DeCoppett Pond Dam	RIDEM	Medium
D-2	Beaver River Preserve Dam	TNC	High
D-3	Tug Hollow Pond Dam	Private	High
D-4	Exeter Wetlands Dam	Private	High
D-5	James Pond Dam	Private	High

We note that there may be one or more smaller dams on the lower Beaver River that may be important considerations to identify and analyze in future phases of this assessment. With recent restoration efforts that reopened access from Little Narragansett Bay along the Pawcatuck River to the mouth of the Beaver River, it is anticipated that the Beaver River would serve as quality spawning habitat for river herring once these first obstructions are removed or bypassed with aquatic passage structure. Consideration for removal or retrofitting of these obstructions would have an important ecological value for both anadromous and catadromous fisheries.

5.1.2. Culvert Replacement

As discussed in Section 3.1.9, culverts in the watershed were ranked as a part of the Flood Resiliency Management Plan (Fuss & O'Neill, 2017). The high priority culverts should be replaced to allow aquatic passage, remove impoundments that warm stream temperature, as well as provide hydraulic capacity to pass large storms (100-year events) considering climate change and associated predictions in increased rainfall. Additional analysis will be needed to determine the best size and type of culvert. The results are included in **Table 12** below, along with the ranking criteria. This list also includes two culverts identified during the field reconnaissance for this project on Tug Hollow Pond Road that are damaged and need to be addressed. They are currently creating an impoundment along a tributary where high temperatures were recorded on an otherwise very cold stream, and thus, are included here as the highest priority structures.

Table 12. High priority culvert replacements in the Beaver River Watershed with a summary of key ranking criteria.

Project Code	Previous Study Code	Road Crossing	Identified By	Ranking Criteria Aquatic Organism Passability	Geomorphic	Existing Capacity
CV-1	NA	Tug Hollow Rd	HW	NA	NA	NA
CV-2	NA	Tug Hollow Rd	HW	NA	NA	NA
CV-3	BVR-BEA-0-4	Hillsdale Road	F&O	No AOP	High	< 10-Year
CV-4	BVR-BEA-0-6	New London Turnpike	F&O	No AOP	High	< 10-Year
CV-5	BVR-BEA-6-1	New London Turnpike	F&O	No AOP	High	< 10-Year
CV-6	BVR-BEA-5-1	New London Turnpike	F&O	Reduced AOP	High	< 10-Year
CV-7	BVR-BEA-6-2	Dawley Park Road	F&O	No AOP	High	< 10-Year
CV-8	BVR-BEA-0-5	Old Mountain Road	F&O	Reduced AOP	Medium	< 10-Year
CV-9	BVR-FOUND-20150817	Trail	F&O	No AOP	Medium	< 10-Year
CV-10	BVR-FOUND-20151015	Driveway	F&O	Reduced AOP	High	< 10-Year
CV-11	BVR-BEA-0-1	Shannock Hill Road	F&O	Reduced AOP	High	< 10-Year
CV-12	BVR-BEA-0-2	Schoolhouse Road	F&O	Reduced AOP	High	< 10-Year
CV-13	BVR-FOUND-20150630	Punchbowl Road	F&O	Full AOP	High	< 10-Year

5.1.3. Stream Buffer Restoration

Encroachment in the stream buffer impacts habitat and can warm stream temperatures. Encroachment areas should be restored with native vegetation, including a variety of large and small tree species, as well as shrubs and seeding. We used the following criteria to identify parcels where buffer restoration is a high priority:

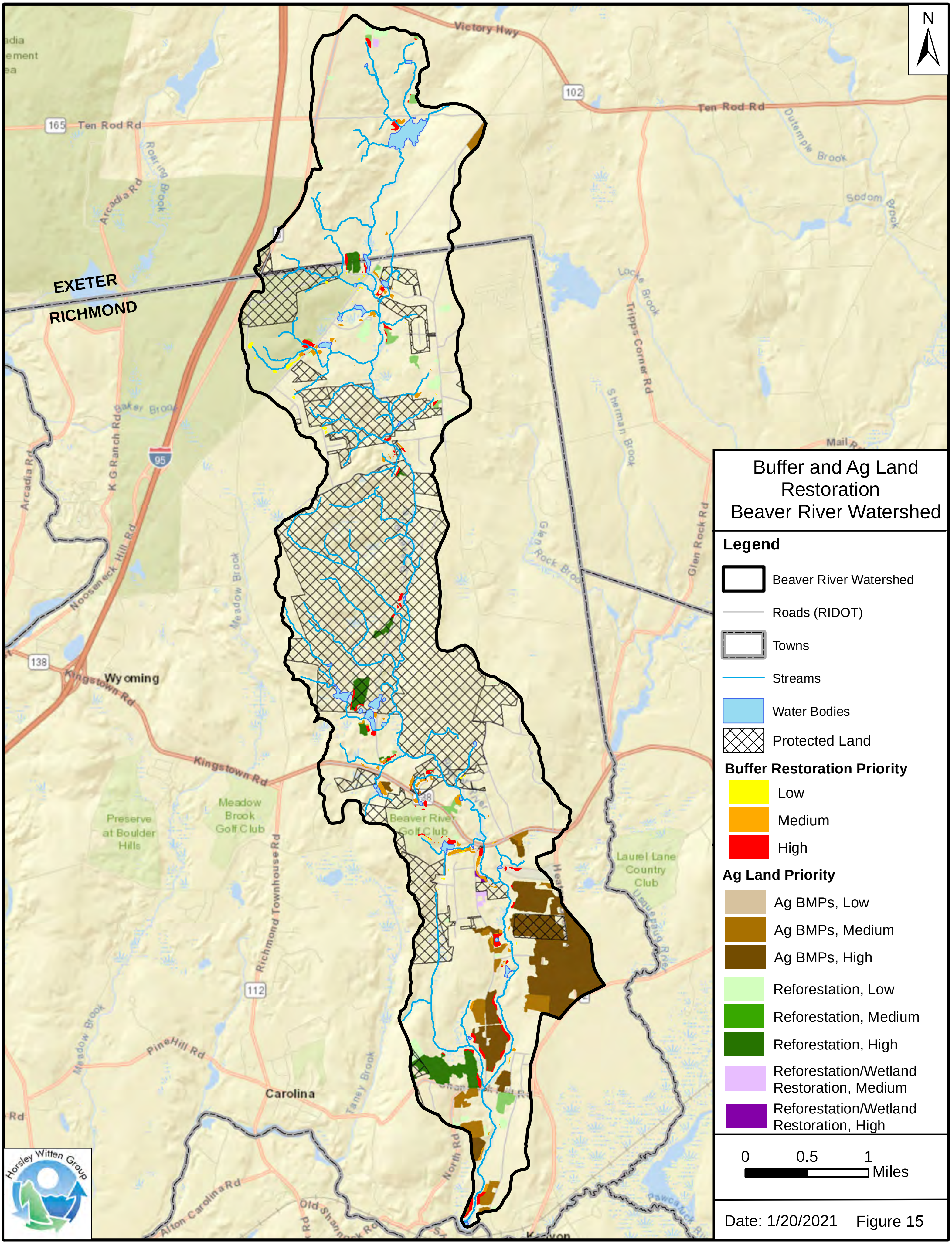
- Parcels with some encroachment of the stream buffer were used as the starting point
- Removed parcels with < 250 sf of encroachment
- Stream temperature: cool waters = 1, warm waters = 2
- Ag lands: Agricultural land use = 1, others = 0
- Hydric soils: mapped hydric soils = 1, others = 0
- Rare habitat: mapped rare habitat = 1, others = 0
- Larger encroachments received more points
    - Size: 0-0.1 acres = 0, 0.1-1 acres = 1, >1 acre = 2 points
- Parcels with 2 points or less were considered low priority, 3-4 points were medium, and 5 points or more were considered high priority for buffer restoration.

Using these criteria, a total of 5 parcels in Exeter were identified as high priority for buffer restoration with a total of 6.45 acres of encroachment, while there are 152 parcels in Richmond with a total of 83.7 acres of encroachment (watershed total of 90.2 acres). The results are included in **Table 13**, and as indicated, there are many overlaps between areas identified for buffer restoration, reforestation, agricultural best management practices, and protection with conservation restrictions. For that reason, **Figure 15** shows all of these related restoration and land protection opportunities.

Table 13. High priority stream buffer restoration sites.

Project Code	Town	Map Block Lot	Site Address	Buffer Encroachment (acres)	Ranking Criteria					
					Stream Temp	Ag Land	Hydric Soils	Rare Species Habitat	Size	Total Rank
BR-1	Richmond	04D/001-000	156 HILLSDALE RD	2.50	2	1	1	0	2	6
BR-2	Richmond	10E/001-000	SHANNOCK VILLAGE RD	2.27	1	1	1	1	2	6
BR-3	Richmond	01D/007-000	108 DAWLEY PARK RD	1.35	2	1	1	0	2	6
BR-4	Richmond	07E/026-000	23 HEATON ORCHARD RD	1.32	1	1	1	1	2	6
BR-5	Richmond	06D/007-000	WHITETAIL TRAIL	1.05	1	1	1	1	2	6
BR-6	Richmond	08E/012-000	172 BEAVER RIVER RD	3.19	1	1	1	0	2	5
BR-7	Richmond	02D/002-000	162 NEW LONDON TRNPK	3.04	0	1	1	1	2	5
BR-8	Richmond	08E/002-000	159 BEAVER RIVER RD	2.68	1	1	1	0	2	5
BR-9	Richmond	08E/001-000	180 SHANNOCK HILL RD	2.28	1	1	1	0	2	5
BR-10	Richmond	08E/006-000	BEAVER RIVER RD	2.18	1	1	1	0	2	5
BR-11	Exeter	33-2-7	NA	2.11	1	1	1	0	2	5
BR-12	Richmond	10E/003-000	LEWISTON AVE	1.98	1	1	1	0	2	5
BR-13	Richmond	05D/006-000	HILLSDALE RD	1.91	0	1	1	1	2	5
BR-14	Exeter	20-5-1	Victory Highway	1.68	1	1	1	0	2	5
BR-15	Richmond	06E/038-001	343 KINGSTOWN RD	1.62	1	0	1	1	2	5
BR-16	Richmond	07E/018-000	84 BEAVER RIVER RD	1.62	1	1	1	0	2	5
BR-17	Richmond	05D/013-000	32 HILLSDALE RD	1.55	0	1	1	1	2	5
BR-18	Richmond	06E/037-000	379 KINGSTOWN RD	1.55	1	1	1	0	2	5
BR-19	Richmond	02D/018-017	16 WILLIAM REYNOLDS FARM RD	1.46	1	1	1	0	2	5
BR-20	Richmond	06E/041-001	6 BEAVER RIVER RD	1.31	0	1	1	1	2	5
BR-21	Richmond	01D/015-009	15 TUG HOLLOW RD	1.19	2	0	1	0	2	5
BR-22	Richmond	07E/019-005	80 BEAVER RIVER RD	1.15	1	1	1	0	2	5
BR-23	Richmond	05D/010-003	7 HILLSDALE RD	1.01	0	1	1	1	2	5
BR-24	Exeter	46-2-7	New London Trnpk	0.94	2	1	1	0	1	5
BR-25	Richmond	07E/021-002	HEATON ORCHARD RD	0.79	1	1	1	1	1	5
BR-26	Richmond	02D/008-000	182 OLD MOUNTAIN TRAIL	0.68	2	1	0	1	1	5
BR-27	Richmond	02E/039-000	334 HILLSDALE RD	0.55	2	1	1	0	1	5
BR-28	Richmond	03D/006-000	171 OLD MOUNTAIN TRAIL	0.34	2	0	1	1	1	5
BR-29	Richmond	03D/003-008	160 OLD MOUNTAIN TRAIL	0.21	2	0	1	1	1	5

Light green shaded parcels are also high priority for reforestation; light brown are also high priority for Ag BMPs; light blue are also high priority for CR or other protections; dark green indicates high priority for reforestation AND Ag BMPs; and dark blue is high priority reforestation AND CR or other protections.



Buffer and Ag Land Restoration
Beaver River Watershed

Date: 1/20/2021 Figure 15

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5.1.4. Reforestation

Reforestation of cleared lands is an effective way to improve habitat, reduce runoff/increase groundwater recharge, and cool streams. This is similar to buffer restoration described above but is based on larger upland areas not limited to the stream corridor. To identify the highest priority locations for reforestation in the watershed, lands classified as "Agricultural" were used as the starting point. These include the following land use categories based on conditions in 2011: cropland; idle agriculture; orchards, groves, and nurseries; and pasture. Since conditions have changed since 2011, visual inspection using aerial imagery was used to remove areas that have revegetated since the mapping was performed. In addition, agricultural areas that were on the watershed border with the majority of land outside were removed. Beaver River Park was also removed, as well as areas in parcels ranked for purchase (see Land Protection section below) and parcels identified as cemeteries. The following criteria were used to prioritize agricultural land for reforestation:

- Ag lands categorized as idle and pasture were considered for reforestation, as well as some cropland that appeared idle based on visual inspection. Active Ag lands were ranked separately for improved land management in the next section.
- Lands with important groundwater recharge capacity (HSG A soils) (1 point)
- Ag lands that encroach on a portion of the stream buffer (1 point)
- Lands in subwatersheds with stream temperatures: cool waters = 1, warm waters = 2
- Lands with high probability groundwater seeps (hydric soils with steep slopes) (1 point)
- Hydric soils: mapped hydric soils = 1, others = 0
- Rare habitat: mapped rare habitat = 1, others = 0
- Size of contiguous agricultural area: 0-1.5 acres = 0, 1.5-10 acres = 1, >10 acre = 2
- Lands with 2 points or less were considered low priority, 3-5 points were medium, and 6 points or more were considered high priority for reforestation.

The high priority Ag land was cross-referenced with parcel data for easier referencing. There are 17 parcels containing agricultural lands that ranked as high priority for reforestation, for a total of almost 108 acres in the watershed. The high priority results are included in **Table 14,** and all ranked agricultural lands for reforestation are shown on **Figure 15**.

It is important to note that while this restoration opportunity is referred to as simply "reforestation" for this spatial analysis, consideration may be warranted to managing certain agricultural fields outside of riverine corridors as open, maintained fields. This type of management could provide important and declining grassland and meadow habitat for potentially expanding range of the federally endangered Sandplain Gerardia, as well as ground-nesting birds (such as the Vesper Sparrow), and for providing important pollinator habitat. Many species of grassland nesting birds have experienced widespread declines, including several species identified as SGCN. According to the RI WAP, “grassland-nesting birds have been a priority for survey and conservation work since the origination of the Natural Heritage Program in 1979” due to dramatic population declines. Open pollinator habitats benefit a variety of Lepidoptera species as well as bees and other insects. Pollinator habitats provide these insects with a critical food source and habitat, while addressing the larger issue of decline of many insect pollinators, some of which are identified in the RI WAP.

5.1.5. Wetland Restoration

Wetlands provide important habitat in the watershed, as well as other ecosystem functions such as flood control, filtering nutrients, and for forested wetlands, cooling surface waters. Thus, wetland restoration of degraded wetlands (usually from development impacts) can be an important tool in watershed management.

The wetlands in the Beaver River Watershed are for the most part high quality systems. Field reconnaissance did not identify large areas of degraded wetland for restoration. Some isolated locations of invasive species, particularly along roadsides and/or culverts were observed, but at small amounts. Thus, this analysis focused on agricultural lands that may have been previously cleared wetlands using a similar methodology as described above for reforestation, but focusing on areas with the most hydric soils. These areas should be restored for wetland conditions, ideally, forested wetlands. The following criteria were used to identify areas where the agricultural land is a high priority for reforestation/wetland restoration:

- Ag lands categorized as idle and pasture were considered for reforestation/wetland restoration, as well as some cropland that appeared idle based on visual inspection. Active Ag lands were ranked separately for improved land management in the next section.
- Lands with important groundwater recharge capacity (HSG A soils) (1 point)
- Ag lands that encroach on a portion of the stream buffer (1 point)
- Lands in subwatersheds with stream temperatures: cool waters = 1, warm waters = 2
- Lands with high probability groundwater seeps (hydric soils with steep slopes) (1 point)
- Hydric soils: mapped hydric soils = 1, others = 0
- Rare habitat: mapped rare habitat = 1, others = 0
- Size of contiguous agricultural area: 0-1.5 acres = 0, 1.5-10 acres = 1, >10 acre = 2
- Lands with 2 points or less were considered low priority, 3-5 points were medium, and 6 points or more were considered high priority.

The high priority Ag land was cross-referenced with parcel data for easier referencing. There are 3 parcels containing agricultural lands that ranked as high priority for reforestation/wetland restoration, for a total of almost 2.5 acres in the watershed. The high priority results are included in **Table 15,** and all ranked agricultural lands for reforestation/wetland restoration are shown on **Figure 15**.

Table 14. High priority areas recommended for reforestation.

						Ranking Criteria							
Project Code	Town	Map Block Lot	Restoration Recommendation	Agricultural Classification	Size (acres)	200ft Buffer	HSG A Soils	Stream Temp	GW Seeps	Hydric Soils	Rare Species Habitat	Size	Total Rank
RF-1	Richmond	05D/006-000	Reforestation	Cropland (tillable)	17.86	1	1	1	1	0	1	2	7
RF-2	Exeter	46-2-7	Reforestation	Cropland (tillable)	11.11	1	1	2	1	0	0	2	7
RF-3	Richmond	01D/007-000	Reforestation	Cropland (tillable)	6.32	1	1	2	1	0	0	2	7
RF-4	Richmond	08E/001-000	Reforestation	Pasture (agricultural not suitable for tillage)	49.92	1	0	1	1	1	0	2	6
RF-5	Richmond	04D/001-000*	Reforestation	Cropland (tillable)	6.04	1	1	1	1	0	1	1	6
RF-6	Richmond	09D/016-000	Reforestation	Pasture (agricultural not suitable for tillage)	5.55	1	0	1	1	1	0	2	6
RF-7	Richmond	05D/013-000	Reforestation	Cropland (tillable)	3.39	1	1	1	1	0	1	1	6
RF-8	Richmond	04D/001-000*	Reforestation	Pasture (agricultural not suitable for tillage)	1.92	1	1	2	1	0	0	1	6
RF-9	Richmond	08D/013-000	Reforestation	Pasture (agricultural not suitable for tillage)	1.47	1	0	1	1	1	0	2	6
RF-10	Richmond	05D/014-001	Reforestation	Cropland (tillable)	1.29	1	1	1	1	0	1	1	6
RF-11	Richmond	05D/010-003	Reforestation	Pasture (agricultural not suitable for tillage)	0.87	1	1	1	1	0	1	1	6
RF-12	Richmond	02D/008-000	Reforestation	Pasture (agricultural not suitable for tillage)	0.68	1	1	2	1	0	1	0	6
RF-13	Richmond	05D/010-000	Reforestation	Pasture (agricultural not suitable for tillage)	0.46	1	1	1	1	0	1	1	6
RF-14	Richmond	05D/010-001	Reforestation	Pasture (agricultural not suitable for tillage)	0.23	1	1	1	1	0	1	1	6
RF-15	Richmond	08E/002-000	Reforestation	Pasture (agricultural not suitable for tillage)	0.22	1	0	1	1	1	0	2	6
RF-16	Richmond	08D/012-000	Reforestation	Pasture (agricultural not suitable for tillage)	0.21	1	0	1	1	1	0	2	6
				TOTAL	**107.66**								

* indicates duplicate parcels due to more than one type of Ag Land. Each type was ranked separately.

Light gray shading indicates parcels that were also ranked high priority for buffer restoration. Dark gray shading indicates parcels that are also high priority for buffer restoration and a CR or other protection.

Table 15. High priority areas recommended for reforestation/wetland restoration.

						Ranking Criteria							
Project Code	Town	Map Block Lot	Restoration Recommendation	Agricultural Classification	Size (acres)	200ft Buffer	HSG A Soils	Stream Temp	GW Seeps	Hydric Soils	Rare Species	Size	Total Rank
RFWR-1	Richmond	07E/020-009	Refor/WetRest	Idle Agriculture	2.12	1	1	1	1	1	0	1	6
RFWR-2	Richmond	07E/020-010	Refor/WetRest	Idle Agriculture	0.23	1	1	1	1	1	0	1	6
RFWR-3	Richmond	07E/020-000	Refor/WetRest	Idle Agriculture	0.13	1	1	1	1	1	0	1	6
				TOTAL	**2.48**								

5.1.6. Streambank/Stream Corridor Restoration

As discussed in Section 3.1.10, there are areas of the main stem of the Beaver River that have been straightened in the past and lack key habitat structures beneficial for fish and other aquatic species. These areas would benefit from in-stream feature installation to recreate and/or mimic meandering conditions as well as adding stream structure, such as riffles/pools, and protected areas along the streambank. Examples of this type of restoration include features such as J-hooks, cross vanes, rock weirs, lunkers, addition of large woody debris (LWD), etc. As identified above in Section 3, Reaches 3, 6 and 7 would benefit from stream restoration. Of these, efforts should be focused on Reaches 6 and 7 that flow through the protected RIDEM DeCoppett Estate. Prioritizing this area complements the recommended dam and culvert restoration actions described above. Reach 3 should also be addressed as part of the stream buffer and agricultural best management actions described above and below.

5.1.7. Additional Projects

During the field reconnaissance, two additional restoration projects were identified. While not specifically part of the spatial analysis described throughout this assessment, these areas represent good opportunities for restoration in line with those described above.

Beaver River Fishing Access (RIDEM)

Opportunities for stormwater management, erosion control, bank restoration and buffer enhancement were observed along this section of Beaver River where fishing activities and access to the river have resulted in complete removal of shrubs and trees. Sedimentation from the unpaved parking lot has migrated along the banks and into the river. This location is a great opportunity to work with RIDEM to address these issues as well as provide public education about the importance of Beaver River and its watershed.

Beaver River Park & Playground

Located east of Beaver River Road between the intersections of Anthony Drive and Rocky Way, the Beaver River Park & Playground has wide open trails with points of interest overlooking the Beaver River and its associated wetland communities. Unfortunately, the trail edges have become overgrown with non-native invasive species such as autumn olive (*Elaeagnus umbellata*) and multiflora rose (*Rosa multiflora*) with dense entanglements of Asiatic bittersweet (*Celastrus orbiculatus*), as well as lesser amounts of shrub honeysuckle (*Lonicera* sp.) and European buckthorn (*Frangula alnus*) which have begun to colonize along interior trails traversing wetland areas. The proximity of non-native fruit-bearing shrubs to the river creates the potential for downstream spread of invasives to otherwise pristine freshwater wetland communities. The centrally located fields have become overgrown with invasive shrubs and weedy herbaceous vegetation. In addition, direct access to the river is open and nearly devoid of woody vegetation and subject to erosion and further spread of invasive species downstream.

Opportunities to restore wetland buffers, improve habitat for local wildlife, and public education regarding invasive species are numerous at this location. The wide trails allow for easy access to problem areas. These efforts would be intensive and on-going for many years. It may be productive to first manage a test plot, removing non-native species and revegetating with native species to help refine the long-term management plan.

5.2. Land Protection Opportunities

Land protection actions can be as important or even more important that restoration projects, particularly in a high quality watershed such as the Beaver River. While there are already many protected lands in the watershed as discussed above, development pressures are predicted in the coming years. In addition, even within some of the currently protected lands, forested areas are nearly 50% denuded, most likely evidence of significant gypsy moth caterpillar damage stemming from an outbreak in 2017. These issues lend even greater importance to preservation of forested habitat within the watershed, particularly along stream corridors.

Using the data collected on the watershed, the following land protection opportunities are recommended and described further below: land purchase of undeveloped land, conservation restrictions or similar protections, promotion of agricultural best management practices, and updates to Town ordinances and regulations.

5.2.1. Land Purchase

To identify the most important parcels for land purchase and protection from development, the following criteria and point system were used:

- Undeveloped, privately-owned parcels (starting point)
- Forested land (1 point)
- Wetlands (1 point)
- Parcels that encompass a portion of the stream/stream buffer (1 point)
- Parcels with important groundwater recharge capacity (HSG A soils) (1 point)
- Parcels with rare species and/or important habitat (1 point)

- Parcels in subwatersheds with coldwater temperatures (<18.3 degrees) (1 point)
- Parcels with high development pressure (1 or 2 points) or industrial zoning (Exeter; 1 pt)
- Large parcels receive more points:
    - <20 acres=0 points, 20-55 acres=1 point, 55-90 acres=2 points, >90 acres=3 points
- Parcels with high probability groundwater seeps (hydric soils with steep slopes) (1 point)
- Parcels with 4 points or less were considered low priority, 5-7 points were medium, and 8 points or more were considered high priority for land acquisition.

Using these criteria and point system, a total of 10 undeveloped parcels were identified in Exeter with 2 that are high priority, at a total of 500 acres. In Richmond, there are 51 undeveloped parcels identified, with 4 that are high priority, at a total of 233 acres. The results are included in **Table 16** and **Figure 16.**

5.2.2. Conservation Restrictions

There are some developed parcels in the watershed that were identified with developmental pressure over the next twenty years. To determine which of these parcels are the most important to protect with a Conservation Restriction (CR) or other similar type of protection to prevent additional development, the following criteria and point system were used:

- Privately-owned parcels with high development pressure that already have some form of development, i.e., residential home or agricultural use (starting point)
- Forested land (1 point)
- Wetlands (1 point)
- Parcels that encompass a portion of the stream/stream buffer (1 point)
- Parcels with important groundwater recharge capacity (HSG A soils) (1 point)
- Parcels with rare species and/or important habitat (1 point)
- Parcels in subwatersheds with coldwater temperatures (<18.3 degrees) (1 point)
- Parcels with high development pressure (1 or 2 points) or industrial zoning (Exeter; 1 pt)
- Large parcels receive more points:
    - <20 acres=0 points, 20-55 acres=1 point, 55-90 acres=2 points, >90 acres=3 points
- Parcels with high probability groundwater seeps (hydric soils with steep slopes) (1 point)
- Parcels with 4 points or less were considered low priority, 5-7 points were medium, and 8 points or more were considered high priority for CRs or other protections.

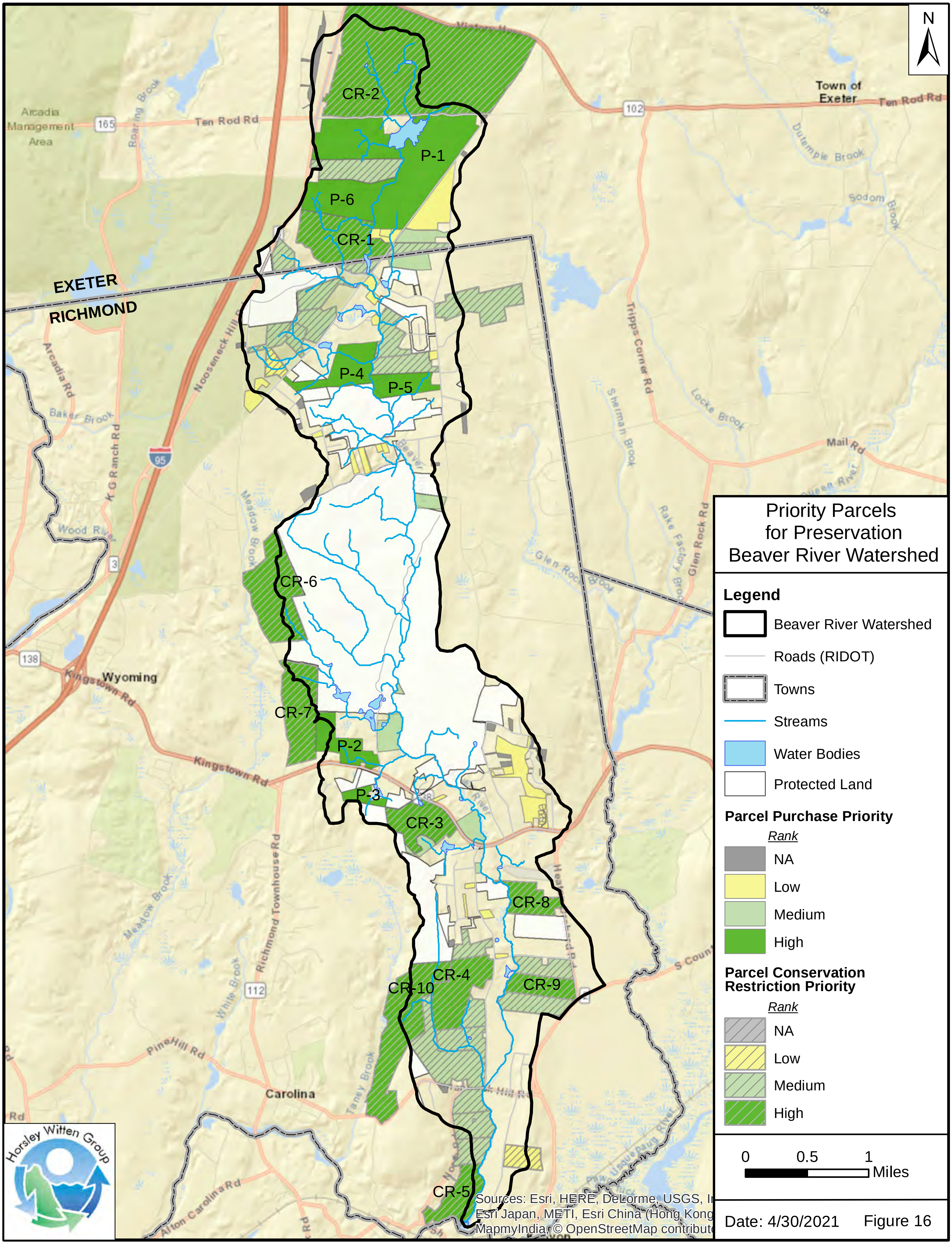
Using these criteria and point system, a total of 5 key parcels with development pressure were identified in Exeter with 2 that are high priority, at a total of 895 acres, although not all of the parcel area is located completely within the watershed (see **Figure 16**). Likewise, there are 27 in Richmond with 8 that are high priority, at a total of 908 acres, although not all of the parcel area is located completely within the watershed. **Table 17** summarizes these high priority parcels.

Table 16. High priority parcels for land acquisition.

Project Code	Town	Map Block Lot	Street	Zoning	Size (acres)	Ranking Criteria									
						Forest	Wetland	HSG A Soils	200ft Buffer	GW Seeps	Developmental Pressure (Richmond)/ Zoning (Exeter)	Size	Coldwater	Rare Species Habitat	Total Rank
P-1	Exeter	33-2-2	Ten Rod Road	LI/RU-3	389.4	1	1	0	1	1	1	3	1	1	10
P-2	Richmond	05D/014-000	Hillsdale Road	R-3	70.4	1	1	1	1	1	1	2	1	1	10
P-3	Richmond	06D/012-001	Kingstown Road	R-2	21.0	1	1	1	1	1	2	1	1	1	10
P-4	Richmond	02D/004-000	123 New London Trnpk	R-2	86.1	1	1	1	1	0	1	2	1	1	9
P-5	Richmond	02E/042-000	Hillsdale Road	R-2	55.6	1	1	0	1	0	1	2	1	1	8
P-6	Exeter	46-2-10	Nooseneck Hill Rd	LI/RU-3	110.8	1	1	0	1	1	1	3	0	0	8
				TOTAL	**733.30**										

Table 17. High priority parcels for conservation restriction or similar protection.

Project Code	Town	Map Block Lot	Street	Zoning	Size (acres)	Ranking Criteria									
						Forest	Wetland	HSG A Soils	200ft Buffer	GW Seeps	Developmental Pressure (Richmond)/ Zoning (Exeter)	Size	Coldwater	Rare Species Habitat	Total Rank
CR-1	Exeter	46-2-7	New London Trnpk	LI/RU-3	147.5	1	1	1	1	1	1	3	1	0	10
CR-2	Exeter	20-5-1	Victory Highway	RU-4	746.4	1	1	0	1	0	0	3	1	1	8
CR-3	Richmond	06E/038-001	343 Kingstown RD	R-2	91.5	1	1	1	1	0	2	3	1	1	11
CR-4	Richmond	08E/004-001	121 Beaver River Rd	R-2	114.3	1	1	0	1	1	2	3	1	0	10
CR-5	Richmond	10E/001-000	Shannock Village Rd	SV	76.7	1	1	1	1	0	2	2	0	1	9
CR-6	Richmond	04C/010-000	163 Carolina Nooseneck Rd	R-3	171.2	1	1	0	1	1	1	3	1	0	9
CR-7	Richmond	05D/015-000	25 Carolina Nooseneck Rd	R-3	132.3	1	1	0	1	0	1	3	1	1	9
CR-8	Richmond	07E/021-002	Heaton Orchard Rd	R-3	58.1	1	1	1	1	0	1	2	1	1	9
CR-9	Richmond	08E/007-000	139 Heaton Orchard Rd	R-3	55.8	1	1	1	1	0	1	2	1	0	8
CR-10	Richmond	09D/015-000	96 Shannock Hill Rd	R-2	207.9	1	1	0	1	0	2	3	0	0	8
				TOTAL	**1,801.80**										



Priority Parcels for Preservation Beaver River Watershed

Sources: Esri, HERE, DeLorme, USGS, I
Esri Japan, METI, Esri China (Hong Kong
MapmyIndia, © OpenStreetMap contribut

Date: 4/30/2021 Figure 16

Path: H:\Projects\2020\20022 Beaver River Watershed Assessment\GIS\Maps\210416_LandPreservationMap.mxd

5.2.3. Agricultural Lands

Active agricultural lands can impact watershed quality by reducing forest habitat, encroaching on streams, raising stream temperature sensitivity with water withdrawals and/or diversions, and by adding nutrients from fertilizers in runoff and groundwater. This does not mean that there should be no actively farmed areas in a watershed. However, there are recommended best management practices (BMPs) for improving watershed health such as minimizing or eliminating water withdrawals from the stream and groundwater, ensuring a vegetated stream buffer to protect stream temperatures and filter nutrients, removing steep slopes from actively farmed areas, and restoring any areas with hydric soils back to wetlands, to name a few. See RI NRCS for more detailed information on these BMPs and the Conservation Planning process (https://www.nrcs.usda.gov/wps/portal/nrcs/main/ri/technical/cp/). To identify the high priority lands for improved agricultural BMPs, a similar process was used as described above for reforestation and wetland restoration, but focusing on the actively farmed areas:

- Ag lands categorized as cropland, orchards/groves/nurseries, and some pasture that appeared active based on visual inspection and field reconnaissance.
- Lands with important groundwater recharge capacity (HSG A soils) (1 point)
- Ag lands that encroach on a portion of the stream buffer (1 point)
- Lands in subwatersheds with stream temperatures: cool waters = 1, warm waters = 2
- Lands with high probability groundwater seeps (hydric soils with steep slopes) (1 point)
- Hydric soils: mapped hydric soils = 1, others = 0
- Rare habitat: mapped rare habitat = 1, others = 0
- Size of contiguous agricultural area: 0-1.5 acres = 0, 1.5-10 acres = 1, >10 acre = 2
- Lands with 2 points or less were considered low priority, 3-5 points were medium, and 6 points or more were considered high priority.

The high priority Ag land was cross-referenced with parcel data for easier referencing. There are 34 parcels containing agricultural lands that ranked as high priority for improved management practices, for a total of almost 360 acres in the watershed. The high priority results are included in **Table 18,** and all agricultural lands ranked for improved BMPs are shown on **Figure 15** in the section above.

5.2.4. Ordinance/Regulation Recommendations

Ordinance and regulation updates can help protect the watershed from future development and climate change impacts. **Appendix E** includes recommendations from RIDEM on a variety of ways that communities can protect habitat and rare species with their codes. These include the following ordinances/regulations that are most important for the Beaver River Watershed:

- No-touch 200-ft stream buffer (see **Appendix D** for an excerpt from RIDEM & RICRMC, 2011 with more information on how other communities have addressed this)
- Land use/development restrictions within identified vulnerable or high priority areas or perhaps watershed-wide. Certain hotspot land uses, water withdrawals (particularly during summer months), and clearcutting should be avoided to name a few, particularly near or within the stream buffer.
- Green stormwater infrastructure and low impact development requirements
- Dark Sky ordinance to reduce light pollution impacts on rare and/or important species
- Revisions to the tree ordinance to include protection for large trees.

These ordinance/regulation revisions could be applied town-wide or could perhaps be focused on the Beaver River Watershed with an overlay.

Table 18. High priority agricultural lands for improved best management practices.

						Ranking Criteria							
Project Code	Town	Map Block Lot	Restoration Recommendation	Agricultural Classification	Size (acres)	200ft Buffer	HSG A Soils	Stream Temp	GW Seeps	Hydric Soils	Rare Species Habitat	Size	Total Rank
AG-1	Richmond	07E/019-000	Ag_BMPs	Cropland (tillable)	45.13	1	1	1	1	1	1	2	8
AG-2	Richmond	07E/021-002	Ag_BMPs	Cropland (tillable)	42.25	1	1	1	1	1	1	2	8
AG-3	Richmond	07F/005-000	Ag_BMPs	Cropland (tillable)	36.41	1	1	1	1	1	1	2	8
AG-4	Richmond	08E/007-000	Ag_BMPs	Cropland (tillable)	36.38	1	1	1	1	1	1	2	8
AG-5	Richmond	08F/001-000	Ag_BMPs	Cropland (tillable)	30.13	1	1	1	1	1	1	2	8
AG-6	Richmond	07E/005-000	Ag_BMPs	Cropland (tillable)	29.34	1	1	1	1	1	1	2	8
AG-7	Richmond	07E/007-000	Ag_BMPs	Cropland (tillable)	24.49	1	1	1	1	1	1	2	8
AG-8	Richmond	08E/008-000	Ag_BMPs	Cropland (tillable)	13.66	1	1	1	1	1	1	2	8
AG-9	Richmond	07E/021-000	Ag_BMPs	Cropland (tillable)	3.25	1	1	1	1	1	1	2	8
AG-10	Richmond	07E/019-001	Ag_BMPs	Cropland (tillable)	1.54	1	1	1	1	1	1	2	8
AG-11	Richmond	07E/021-001	Ag_BMPs	Cropland (tillable)	1.32	1	1	1	1	1	1	2	8
AG-12	Richmond	08E/009-000	Ag_BMPs	Cropland (tillable)	0.47	1	1	1	1	1	1	2	8
AG-13	Richmond	07E/019-003*	Ag_BMPs	Cropland (tillable)	0.46	1	1	1	1	1	1	2	8
AG-14	Richmond	07E/006-000	Ag_BMPs	Cropland (tillable)	0.38	1	1	1	1	1	1	2	8
AG-15	Richmond	07E/010-000	Ag_BMPs	Cropland (tillable)	0.23	1	1	1	1	1	1	2	8
AG-16	Richmond	07E/022-000	Ag_BMPs	Cropland (tillable)	0.20	1	1	1	1	1	1	2	8
AG-17	Richmond	08E/012-000	Ag_BMPs	Cropland (tillable)	31.01	1	1	1	1	1	0	2	7
AG-18	Richmond	08E/006-000	Ag_BMPs	Cropland (tillable)	14.74	1	1	1	1	1	0	2	7
AG-19	Richmond	06E/035-000	Ag_BMPs	Pasture (agricultural not suitable for tillage)	5.12	1	1	1	1	1	1	1	7
AG-20	Richmond	09E/011-000	Ag_BMPs	Orchards, Groves, Nurseries	10.75	1	1	1	0	1	0	2	6
AG-21	Richmond	08E/002-000	Ag_BMPs	Cropland (tillable)	10.50	1	0	1	1	1	0	2	6
AG-22	Richmond	09E/025-000	Ag_BMPs	Orchards, Groves, Nurseries	2.65	1	1	1	1	0	1	1	6
AG-23	Richmond	09E/025-002	Ag_BMPs	Orchards, Groves, Nurseries	2.59	1	1	1	1	0	1	1	6
AG-24	Richmond	08E/019-000	Ag_BMPs	Orchards, Groves, Nurseries	2.37	1	1	1	1	0	1	1	6
AG-25	Richmond	07E/002-002	Ag_BMPs	Pasture (agricultural not suitable for tillage)	2.15	1	1	1	1	1	0	1	6
AG-26	Richmond	07E/019-003*	Ag_BMPs	Pasture (agricultural not suitable for tillage)	1.69	1	1	1	1	1	0	1	6
AG-27	Richmond	06D/012-005	Ag_BMPs	Cropland (tillable)	1.53	1	0	2	1	0	1	1	6
AG-28	Richmond	06D/012-004	Ag_BMPs	Cropland (tillable)	1.19	1	0	2	1	0	1	1	6
AG-29	Richmond	07E/019-005	Ag_BMPs	Pasture (agricultural not suitable for tillage)	1.16	1	1	1	1	1	0	1	6
AG-30	Richmond	06D/012-006	Ag_BMPs	Cropland (tillable)	1.12	1	0	2	1	0	1	1	6
AG-31	Richmond	09E/025-001	Ag_BMPs	Orchards, Groves, Nurseries	1.07	1	1	1	1	0	1	1	6
AG-32	Richmond	07E/018-000	Ag_BMPs	Pasture (agricultural not suitable for tillage)	0.78	1	1	1	1	1	0	1	6
AG-33	Richmond	07E/019-001	Ag_BMPs	Pasture (agricultural not suitable for tillage)	0.65	1	1	1	1	1	0	1	6
AG-34	Richmond	06D/012-000	Ag_BMPs	Cropland (tillable)	0.55	1	0	2	1	0	1	1	6
				TOTAL	**357.24**								

* indicates duplicate parcels due to more than one type of Ag Land. Each type was ranked separately.

Light gray shading indicates parcels that were also ranked high priority for buffer restoration. Dark gray shading indicates parcels that are also high priority for buffer restoration and reforestation.

6. Recommendations and Next Steps

The Beaver River watershed currently remains a high quality natural resource area with habitat for a variety of important species. However, this assessment shows that there are opportunities to address existing impacts as well as vulnerable areas that would benefit from protection. The following discussion summarizes the recommendations and next steps for both restoration and land protection opportunities.

Restoration Opportunities - Recommendations and Next Steps

- The top priority projects for this watershed are the dam removal sites. To advance these projects, they could be grouped as follows: 1) D-1 and D-2; and 2) D-3, D-4, and D-5. In this way, focus can be placed on the downstream structures first, that also happen to be located on protected land with interested partners (RIDEM and TNC). The upstream dams are located on private land and will need more time to coordinate/collaborate with owners. Funding should be sought to first proceed with a detailed analysis of each dam to determine the best methodology for removal and restoration with the least impact to public safety and downstream properties as well as to identify required permitting.
- The next priority for restoration opportunities is to address the high priority culverts, pursuing funding for culvert analysis and design, grouping culverts together by location and ownership. Local public roads can be easier logistically to replace; all high and medium priority culverts could be cross-referenced with Richmond DPW's road improvement projects (Capital Improvement Plan) to opportunistically upgrade them when roadwork is done in that area. RIDOT is another potential partner for coordination on upgrading culverts and stormwater runoff improvement opportunities on Route 138 – Kingstown Road, particularly given the Enterococcus levels documented in this area.
- Stream buffer, reforestation, wetland restoration, and stream corridor restoration projects on public lands could be addressed in coordination with nearby dam and culvert projects (e.g., DeCoppett Dam and Hillsdale Culvert) as possible for the best leverage of funding and partnership coordination. Implementation of the two specific project locations identified at the Rte 138 Fishing Access and Beaver River Park and Playground would not only improve habitat and water quality, but are very visible locations to improve public education and recruit local champions and volunteers. In addition, work at the Rte 138 Fishing Access could be combined with efforts to address the recently listed Enterococcus impairment for recreational uses. Given the popularity of this location for recreational fishing, determining and reducing bacteria sources is a high priority.

- For <u>private land restoration opportunities</u>, the most effective way to approach funding and implementation is to group them together based on priority and location. Owners could be contacted, and their interest gauged; if several adjacent property owners are interested in the identified restoration opportunities or similar, they can work together with the Town or other watershed partner to apply for a larger grant or similar funding assistance. An informational workshop could be scheduled to education residents on these issues and opportunities and build interest and perhaps even volunteers for implementation projects.
- <u>Wild brook trout populations</u> should be further protected to preserve genetic variability and improve population dynamics. As these populations hopefully grow and expand into more stream reaches with implementation of the recommended restoration opportunities, additional partner coordination may be useful to reduce competition with hatchery trout, improve available in-stream habitat, and monitor the success of projects. Particularly as stream connectivity improves, continued stocking at the three locations on Beaver River could be reconsidered to reduce conflict with wild populations in those areas.
- Coordination with key staff in Exeter would be helpful to not only make them aware of this assessment but also to pursue partnership and collaboration opportunities for priority projects in the Exeter portion of the watershed.
- Given the historical nature of the area, any restoration project should work with the Rhode Island Historical Preservation and Heritage Commission (RIHPHC) and local groups to ensure important historical features are protected during implementation.

Land Protection - Recommendations and Next Steps

- <u>Land acquisition</u> is the top priority land protection opportunity. Project partners should be approached to determine which organization would be best equipped for these purchases (e.g., the Town, RRPLT, a non-profit such as TNC, or RIDEM). As stated above, this is another excellent opportunity to work with Exeter to pursue partnership and funding options for purchasing priority lands in the Exeter portion of the watershed. Grant funding and/or fundraising could be pursued, and current landowners should be approached. A similar method would be appropriate for the properties identified for conservation restrictions.
- <u>Agricultural practices</u> can greatly impact the watershed, particularly along the lower Beaver River. Small changes can have a big impact on habitat and overall water quality. Property owners of high priority agricultural properties should be contacted, and a working group formed to identify the best ways to address the concerns from this assessment while also meeting farming needs with best practices. Funding and technical assistance may be more readily available for a group of farmers/land owners working together to implement changes.

- The Town has an opportunity to incorporate land protection recommendations into the Comprehensive Community Plan update where relevant. Ordinance and regulation recommendations can be taken to relevant boards for consideration, applying recommended changes to the whole Town, a Beaver River Watershed overlay, or specific vulnerable/priority areas within the watershed.

6.1. Potential Funding Sources and Partnerships

While implementation of the recommended restoration and land management opportunities can be daunting, there are many potential funding sources and partnerships to assist with watershed restoration projects like these. The stakeholder group for this project is a great starting point for partners, as well as a number of other federal, state, and local like-minded groups. Working together can increase likelihood of successful grants and help leverage limited funds, particularly in terms of match from in-kind services. A few specific funding sources seem like particularly good fits for this type of work, described below. In addition, a funding matrix based on organization and project type is included in **Table 19.** This should not be viewed as an all-inclusive list but a starting point.

SNEP Watershed Grants awards grants to organizations and partnerships working to restore clean water, healthy coastal ecosystems, and sustainable communities in Rhode Island and Southeastern Massachusetts.
https://estuaries.org/snepgrantprogram/

The **State Wildlife Grant Program**, funded through the USFWS and administered by the Wildlife & Sport Fish Restoration Program, can provide funds of planning and implementation of restoration efforts identified in the RI WAP to proactively protect species identified as species of greatest conservation concern (SGCN) and their habitats.
https://www.fws.gov/wsfrprograms/Subpages/GrantPrograms/SWG/SWG.htm

The **Clean Water State Revolving Fund** (CWSRF) program is a federal-state partnership that provides communities low-cost financing for a wide range of water quality infrastructure projects.
https://www.epa.gov/cwsrf

The **Rhode Island Climate Resilience Fund**, funded through RIDEM, seeks to fund projects to improve climate resilience, community resilience, and public safety in vulnerable coastal and riparian areas. The grants stemming from the project are divided into two categories: Nature-

Based Solutions and Removal, Relocation, or Redesign of Infrastructure, and appear to vary by grant funding year.
http://www.dem.ri.gov/programs/water/finance/wwtf-resilience-fund.php

New England Forests and Rivers Fund provides annual grant funds for restoring and sustaining healthy forests and rivers that provide habitat for diverse native bird and freshwater fish populations in New England.
https://www.nfwf.org/programs/new-england-forests-and-rivers-fund

R.I. Coastal and Estuarine Habitat Restoration Program and Trust Fund provides grant funds for projects that restore or enhance ecological conditions that have been degraded by human impacts in coastal or estuarine habitats including anadromous fish runs. Priority will be placed on those projects that seek to enhance coastal habitats' resiliency to climate change and sea level rise.
http://www.crmc.ri.gov/habitatrestoration.html

Table 19. Matrix of Potential Funding Sources by Project Type

	Dam Removal	Stream/floodplain Restoration	Culvert Retrofit	Water Quality Infrastructure/ Stormwater Retrofits / Green Infrastructure	Habitat Restoration (Forests & Rivers) (Supporting Birds and Fisheries Habitat)	Planning & Restoration specifically related to RI WAP	Wildlife & Habitat Protection	Land Acquisition / Land Management	Community Engagement & Education	
POTENTIAL FUNDING SOURCE	**TYPE OF PROJECT FUNDED**									**LINK**
State Wildlife Grant Program (SWG) - Rhode Island				●		●				https://www.fws.gov/wsfrprograms/Subpages/GrantPrograms/SWG/SWG.htm
Clean Water State Revolving Fund (CWSRF) - Rhode Island				●			●			https://www.epa.gov/cwsrf/learn-about-clean-water-state-revolving-fund-cwsrf#eligibilities
Rhode Island Climate Resilience Fund - Rhode Island	●	●	●	●						http://www.dem.ri.gov/programs/water/finance/wwtf-resilience-fund.php
RICRMC Coastal and Estuary Habitat Restoration Program and Trust Fund - Rhode Island	●	●	●	●	●					http://www.crmc.ri.gov/habitatrestoration.html
SNEP Watershed Grants - Federal Funds, Requires 33% Match	●	●	●	●	●		●		●	https://estuaries.org/snepgrantprogram/
SNEP Watershed Technical Assistance - No Match				●		●				https://snepnetwork.org/technical-services/
Rhode Island Forest Legacy Program - Rhode Island								●		www.dem.ri.gov/programs/forestry/forestlegacy/
New England Forests and Rivers Fund	●	●	●	●	●		●			https://www.nfwf.org/programs/new-england-forests-and-rivers-fund
Wild & Scenic Rivers Stewardship Partnership Funding (funding source clearinghouse)	●	●	●	●	●		●		●	https://www.rivernetwork.org/wild-scenic-rivers-stewardship-partnership-funding/
Trout Unlimited (funding source clearinghouse)	●	●	●	●	●		●		●	https://www.tu.org/get-involved/volunteer-tacklebox/fundraising-resources/grants-corporate-fundraising/applying-for-grants/
American Rivers (funding source clearinghouse)	●	●	●	●	●		●		●	https://www.americanrivers.org/river-restoration-funding-sources/
Business for Water Stewardship Project Bank (Nationwide)	●	●	●	●	●		●		●	https://businessforwater.org/
FEMA Flood Mitigation Assistance Grant Program (Nationwide)	●	●	●							https://www.fema.gov/grants/mitigation/floods
FEMA Hazard Mitigation Grant Program (Nationwide)	●	●								https://www.fema.gov/grants/mitigation
Federal Highway Administration Surface Transportation Block Grant Program (Nationwide)			●							https://www.fhwa.dot.gov/specialfunding/stp/
National Fish and Wildlife Foundation (Nationwide)							●			https://www.nfwf.org/apply-grant
National Oceanic and Atmospheric Administration Restoration Center (needs coastal connection)	●	●	●		●		●		●	https://www.fisheries.noaa.gov/funding-opportunities
Society for Non-Profits: Environmental Project Funders (clearinghouse for grant opportunites)	●	●	●	●	●		●		●	https://www.snpo.org/publications/fundingalert_bycategory.php?cs=ENVI
U.S. Army Corps of Engineers Public Law 84-99 Rehabilitation Assistance for Non-Federal Flood Control Projects		●								https://www.spa.usace.army.mil/Portals/16/docs/emergencymgmt/PL84-99-Rehab_Assist_NFFC_Projects.pdf
U.S. Army Corps of Engineers Section 206 Aquatic Ecosystem Restoration Projects	●	●	●	●	●		●		●	https://www.hsdl.org/?view&did=823207
U.S. Army Corps of Engineers Section 1135 Environmental Restoration Program	●	●	●	●	●		●		●	https://www.hsdl.org/?view&did=823207
U.S. Fish and Wildlife Service National Fish Passage Program	●		●							https://www.fws.gov/fisheries/fish-passage.html
USDA Natural Resources Conservation Service Agricultural Conservation Easement Program		●						●		https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/easements/acep/?cid=stelprdb1242695
USDA Natural Resources Conservation Service Environmental Quality Incentives Program	●	●						●		https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/
USDA Natural Resources Conservation Service Regional Conservation Partnership Program		●						●		https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/rcpp/
USDA Natural Resources Conservation Service Watershed and Flood Prevention Operations Program	●	●	●	●	●		●		●	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/
Wildlife Conservation Society Climate Adaptation Fund	●	●	●	●	●		●		●	https://www.wcsclimateadaptationfund.org/
RI Department of Transportation - Planning & Program Development			●	●						http://www.dot.ri.gov/about/who/planning.php

In some cases, pursuing mitigation funds will make sense for projects. State compensatory mitigation programs, such as in-lieu fee or mitigation banking programs, might be worth exploring and vary by state.

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APPENDICES

Appendix A

Quality Assurance Project Plan (QAPP)

1. Project Management

1.1. Title and Approval

BEAVER RIVER WATERSHED ASSESSMENT

Prepared by:
Town of Richmond, RI
Horsley Witten Group, Inc.

4/13/2020
Version 1.0
NEIWPCC QAPP ID: Q20-017
EPA Grant Number: CE00A00004
RFA Number: RFA 20046
NEIWPCC Job Code: 0338-002; Project Code: S-2019-017

Approved by: NORA CONLON Digitally signed by NORA CONLON Date: 2020.04.16 10:17:19 -04'00' ______
Nora Conlon, EPA Quality Assurance Officer, EPA Region 1 date

Approved by: Cait Whittle 4/16/2020
Caitlyn Whittle, EPA Project Officer, EPA Region 1 date

Approved by: ______ 4/15/2020
Peter Zaykoski, QA Program Manager, NEIWPCC date

Approved by: ______ 04.15.2020
Dr. Richard Friesner, Director of Water Quality Programs, NEIWPCC date

Approved by: Courtney E Schmidt 4/14/2020
Dr. Courtney Schmidt, Staff Scientist, Narragansett Bay Estuary Program date

Approved by: ______ 4/13/2020
Shaun Lacey, Town Planner, Richmond, RI date

Approved by: Michelle J West 4/13/2020
Michelle West, P.E., Project Manager, Horsley Witten Group, Inc. date

Approved by: Geraldine L. Camilli 4/13/2020
Geraldine Camilli, P.E., QA Manager, Horsley Witten Group, Inc. date

1.2. Table of Contents

Table of Contents

List of Appendices:

List of Figures:

List of Tables:

1.3. QAPP Distribution List

QAPP distribution list

Signed copies of this Quality Assurance Project Plan (QAPP) and all subsequent revisions will be sent to the following individuals by electronic mail:

Courtney Schmidt, Staff Scientist, NBEP, courtney.schmidt@nbep.org
Richard Friesner, Director of Water Quality Programs, NEIWPCC, rfriesner@neiwpcc.org
Peter Zaykoski, Quality Assurance Program Manager, NEIWPCC, pzaykoski@neiwpcc.org
Alexandra Morneau, Quality Assurance Receiver, NEIWPCC, qapps@neiwpcc.org
Nora Conlon, Quality Assurance Reviewer, USEPA, conlon.nora@epa.gov
Caitlin Whittle, EPA Project Officer, USEPA Region 1, whittle.caitlyn@epa.gov
Chris Fox, Executive Director, Wood Pawcatuck Watershed Association, chris@wpwa.org
Kassi Archambault, Outreach Coordinator, Wood Pawcatuck Watershed Association, kassi@wpwa.org
Glenn Place, President, Trout Unlimited, Rhode Island Chapter, tu225president@gmail.com
Corey Pellitier, Fishery Biologist, RIDEM, Corey.Pelletier@dem.ri.gov
John Torgan, Executive Director, The Nature Conservancy, Rhode Island, jtorgan@tnc.org
Shaun Lacey, Town Planner, Town of Richmond, Rhode Island, townplanner@richmondri.com
Neal Price, Associate Principal, Horsley Witten Group, Inc., nprice@horsleywitten.com
Michelle West, Project Manager, Horsley Witten Group, Inc., mwest@horsleywitten.com
Maria Pozimski, GIS Analyst, Horsley Witten Group, Inc., mpozimski@horsleywitten.com
Amy Ball, Senior Ecologist, Horsley Witten Group, Inc., aball@horsleywitten.com

1.4. Project Organization and Responsibilities

The Town of Richmond's consultant for this project is the Horsley Witten Group, Inc. (HW). HW's Project Manager, Principal in Charge, GIS Analyst, and Senior Ecologist are responsible for carrying out nearly every aspect of this project, including data gathering and analyses, quality assurance, identifying restoration and land management activities, writing most of the report, reviewing and editing sections that may be provided by contributors, and soliciting guidance on prioritization and to ensure the accuracy of the final report. More details are provided in the following list of project participants and their responsibilities:

EPA Project Officer: Caitlyn Whittle

- Responsible for reviewing the draft report and approving final report

EPA Quality Assurance Reviewer: Nora Conlon

- Provides technical assistance for QAPP development and supports the Quality Assurance managers to ensure that all elements of the project are completed in accordance with QA procedures in the QAPP.

NEIWPCC Project Manager: Richard Friesner

- Responsible for overseeing implementation of the project work plan, reviewing the draft report, approving final report, managing the project budget with the Town

NEIWPCC QA Program Manager: Peter Zaykoski

- Responsible for maintaining NEIWPCC Quality Management Plan; reviews the project QAPP and subsequent revisions in terms of quality assurance and project goals or designates authorized staff to do the same

NBEP Program Director: Mike Gerel

- Responsible for managing NBEP staff, reviewing the draft report, approving final report

NBEP Staff Scientist: Courtney Schmidt

- Responsible for being the contact person between NEIWPCC, EPA, the Science Advisory Committee, the Town and the contractor, providing guidance on the QAPP, reviewing the draft report, approving final report

Town Planner: Shaun Lacey

- Responsible for providing general guidance and advice on all issues regarding the Town, coordinating communication and contract between the Town and the contractor, processing invoices, coordinating with NEIWPCC, submitting quarterly project progress reports, reviewing the draft report, approving final report

Conservation Commission Chairperson: James Turek

- Responsible to serve as the liaison between the Advisory Committee and the consultant, provide general and technical guidance and advice on all issues involving the project and the Conservation Commission, review the draft report, and approve final report

Advisory Committee comprised of the Rhode Island Department of Environmental Management, Trout Unlimited, The Nature Conservancy, Wood Pawcatuck Watershed Association, Protect Rhode Island Brook Trout, and Beaver River Valley Association, along with the Town.

- Responsible for providing data, general guidance and advice on all scientific and technical aspects of the report, input on metrics and ranking methodology for proposed actions, and reviewing the draft report

HW Project Manager: Michelle West, P.E.

- Responsible to serve as the contact person between the client and the HW Team, for overseeing implementation of the project work plan, including developing and prioritizing restoration and land management activities, writing the draft report with support from the HW Team, the Town, and Advisory Committee. Manages the project budget and submits invoices and progress reports to the Town on a monthly basis.

HW QA Manager: Geraldine Camilli

- Responsible to review the project QAPP and subsequent revisions in terms of quality assurance and project goals or designates authorized staff to do the same. Maintains and distributes the approved QAPP and any subsequent revisions.

Principle In Charge, Senior Hydrogeologist: Neal Price

- Responsible to review the draft report, approving final report. Responsible in helping to identify the priority sites for habitat restoration and protection, and decisions and strategies on implementing projects benefiting water resources in the watershed.

GIS Analyst: Maria Pozimski

- Responsible to take the lead on the existing data collection and existing/projected conditions analyses, including collecting and compiling data in Excel spread sheets and file geodatabases, assuring secondary data quality according to the approved QAPP, performing data analyses where necessary and appropriate, creating charts, and providing data as well as all coordination with the Town's GIS consultant and other data sources as necessary.

Senior Ecologist: Amy Ball

- Responsible for providing guidance on vegetation communities and ecological benefits of habitat restoration and protection based on the priorities previously identified and on the habitat requirements of the most vulnerable species that have been identified in the watershed.

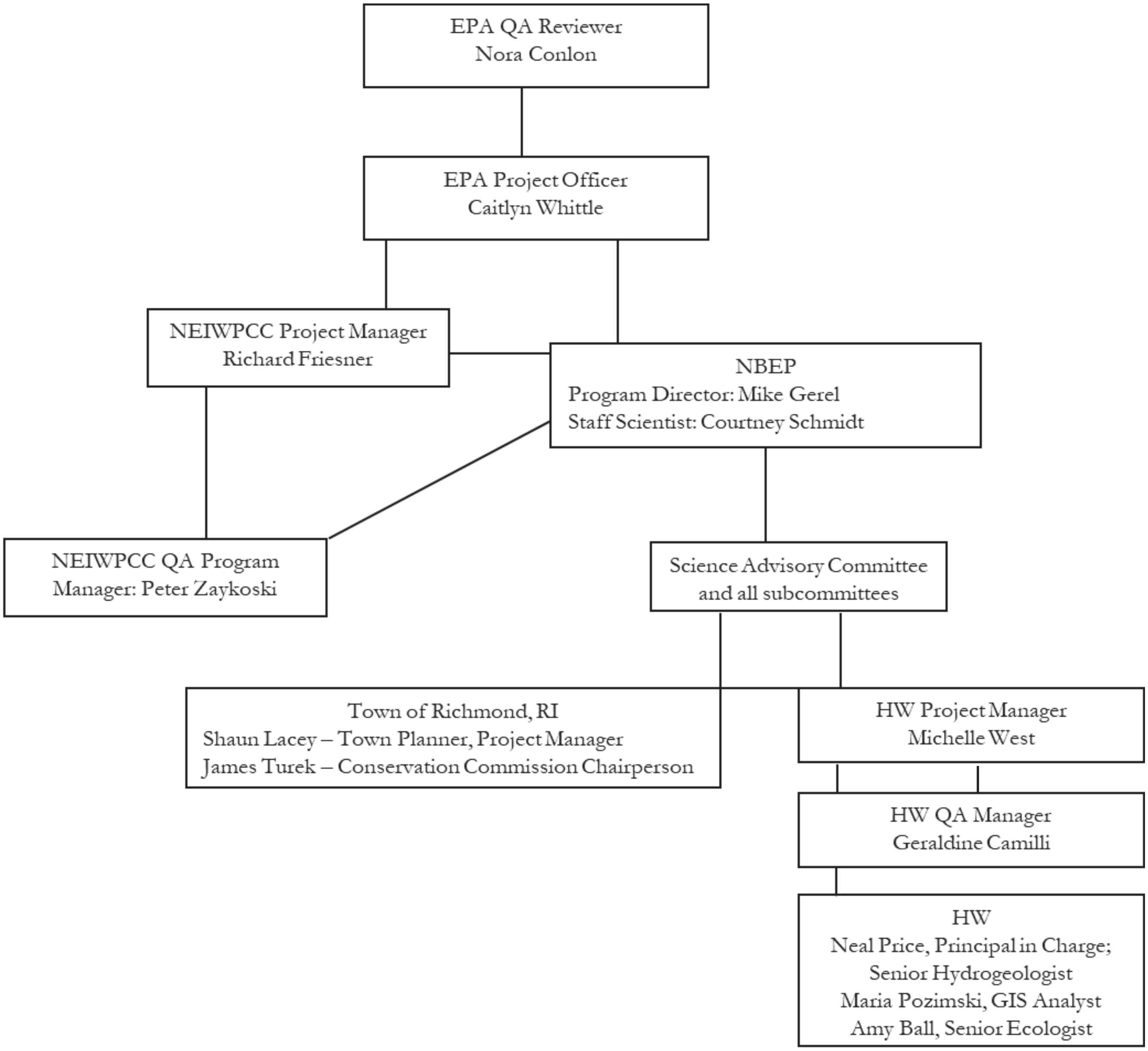


Figure 1. Organizational Chart.

1.5. Problem Definition/Background

The Town seeks to undertake a planning assessment focused on the Beaver River watershed to identify important natural resources and prioritize sites and projects that will enhance, restore and/or protect both the quality and quantity of the Beaver River. This planning-level project will rely solely on previously collected, secondary data. No original field data will be collected as part of this project. While more broad plans have been completed or are now being developed for the federally-designated Wild and Scenic Wood-Pawcatuck River watershed, this desktop, spatial data analysis focuses specifically on a portion of Richmond, and the outcome will be to use the habitat restoration and protection prioritizations for decisions and strategies on implementing projects benefiting water resources in the watershed. Ultimately, an outcome of this assessment will be a deliverable to serve as a model for implementing restoration and conservation actions and conserving lands in other portions of Richmond situated in the Wood-Pawcatuck River watershed in the future. The objectives of the analysis using secondary data include:

- Identify existing and potential future land uses in the watershed
- Identify potential restoration projects and actions and land protection measures to address watershed water quality and quantity
- Develop criteria for scoring, evaluating and prioritizing potential restoration and land protection projects
- Provide recommendations for implementing projects with future funding opportunities
- Instill and enhance community stewardship values and citizen scientist roles to increase support for watershed restoration, land protection, and sustainable, high quality water resources

The Town expects this watershed study will address the Narragansett Bay Program's Comprehensive Conservation and Management Plan (CCMP) priority actions including:

(1) Section 1, protect and restore clean water – Action 4.2: utilize watershed-based plans to coordinate prioritized actions to protect, restore and manage land and water resources in watersheds; and
(2) Section 3, protect and restore fish, wildlife and habitats – Action 1.1: focus resources and enhance land protection efforts on less-developed areas, particularly areas threatened by development.

Secondary data in the form of existing, spatial datasets will be collected and analyzed to complete an assessment of land use conditions and changes, as well as a prioritization of potential projects that could be conducted to benefit water resource management and restoration. This analysis will be focused on the following restoration and management activities:

Restoration Activities

- Dam Removals
- Culvert Replacements
- Stream Restoration
- Buffer Restoration
- Stormwater Retrofits
- Wetland Restoration
- Invasive Species Management

Watershed Non-structural Management Activities

- Enhanced Regulations (e.g., Enhanced Buffer Protection, Land Use Restrictions, Water Withdrawal Restrictions, Dark Sky Ordinance, Tree protections)
- Preservation of Land (e.g., Land Purchases, Conservation Restrictions)

- Improved Agricultural Practices

The following table lists concerns for the health of the watershed as well as the potential restoration or land management activities that might be able to address each watershed concern. The last column lists all data layers that will be used in the analysis to find/prioritize the potential restoration or land management activities. The dataset categories correspond to the Table 3, which lists the data sources for each category.

Table 1. Watershed Concerns and Potential Activities to Address Them

Watershed Concerns		**Potential Restoration or Land Management Activity**	**Necessary Datasets**
Forest and Buffer Protection		Preservation of Land (Land Purchases, Conservation Restrictions)	Forest/Shrub Cover
			Streams
			Wetlands
			Parcels
		Buffer Restoration	Parcels
			Streams
			LU class
Wetlands Restoration		Wetland Restoration	Wetlands
			Soil type
			LU class
Groundwater Recharge		Preservation of Land (Land Purchases, Conservation Restrictions)	Soil type
			Topography
			Parcels
		Enhanced Regulations (e.g., Enhanced Buffer Protection, Land Use Restrictions, Water Withdrawal Restrictions, Dark Sky Ordinance, Tree protections)	Soil type
			Streams
			Wetlands
		Preservation of Land (Land Purchases, Conservation Restrictions)	Parcels
Habitat Assessment	Rare Species Habitat	Dam Removals	Species Habitat
			Dams
		Culvert Replacements	Species Habitat
			Culverts and Bridges
		Stream Restoration	Species Habitat
			Streams
			Assessment Sites
		Buffer Restoration	Species Habitat
			Streams
			Restoration Sites
		Wetland Restoration	Species Habitat
			Wetlands
		Invasive Species Management	Species Habitat
			Invasive Species

Watershed Concerns		Potential Restoration or Land Management Activity	Necessary Datasets
		Enhanced Regulations (e.g., Enhanced Buffer Protection, Land Use Restrictions, Water Withdrawal Restrictions, Dark Sky Ordinance, Tree protections)	Species Habitat
		Preservation of Land (Land Purchases, Conservation Restrictions)	Species Habitat
			Parcels
		Improved Agricultural Practices	Species Habitat
			LU class
			Groundwater Quality
			Nutrient Loading
	Cold Water Habitat	Dam Removals	Water Temperature Data
			Waterbodies
			Dams
		Culvert Replacements	Water Temperature Data
			Culverts and Bridges
		Buffer Restoration	Water Temperature Data
			Streams
		Stormwater Retrofits	Water Temperature Data
			Impervious Surface
			Groundwater Quality
			Nutrient Loading
		Wetland Restoration	Water Temperature Data
			Wetlands
		Enhanced Regulations (e.g., Enhanced Buffer Protection, Land Use Restrictions, Water Withdrawal Restrictions, Dark Sky Ordinance, Tree protections)	Water Temperature Data
		Preservation of Land (Land Purchases, Conservation Restrictions)	Water Temperature Data
			Parcels
		Improved Agricultural Practices	LU class
			Groundwater Quality
			Nutrient Loading
Agricultural Impacts		Buffer Restoration	LU class
			Streams
			Soil type
			Topography
		Wetland Restoration	LU class
			Wetlands
			Soil type
			Topography
		Improved Agricultural Practices	LU class
			Soil type
			Topography

Watershed Concerns	Potential Restoration or Land Management Activity	Necessary Datasets
		Groundwater Quality
		Nutrient Loading
Hydrologic/ Hydraulic Connections	Culvert Replacements	Streams
		Culverts and Bridges
		Watershed Size
	Dam Removals	Dams
		Topography
		Watershed Size
		Assessment Sites

1.6. Project Description

Deliverable

The primary deliverable of this project is a final report with prioritizations for potential restoration and land management activities in the Beaver River watershed, with scaled maps and tables supplementing the report document. The report will include a description of the study, project objectives, summary of project activities, maps and photographs, action plan for next steps and expected outcomes, and GIS data that can be incorporated into the NBEP's watershed restoration database.

Description

Project work is organized into a series of tasks culminating in the final report with ranked and prioritized restoration and protection projects.

Task 3 – Existing and Projected Conditions
Task 3.1 – Data Collection
Existing secondary data will be collected and assessed for quality suitability (as described in this QAPP) from sources such as RIGIS, Town of Richmond GIS, Town of Exeter GIS, USGS, RIDEM, StreamStats, Ecosheds.org and the Wood-Pawcatuck Watershed Flood Resiliency Management Plan (Fuss & O'Neill 2017). Additional species-specific habitat requirements will be confirmed using reliable website data from U.S. Fish and Wildlife Service (USFWS) or NatureServe, with additional data borrowed from Massachusetts Division of Fisheries & Wildlife.

Task 3.2 – Existing and Projected Conditions Assessment and Mapping
The secondary data, which has been assessed for quality, will be used to perform the change analyses to determine existing conditions (baseline) of land uses and build-out status and projected developmental pressures, which will likely impact the Beaver River watershed. To this end, HW will consider RIGIS Land Use/Land Cover projections for 2025, the Town of Richmond's Buildout Analysis as well as Zoning Data from the Town of Exeter. Existing and projected conditions will be mapped and areas which will likely experience higher development pressure will be highlighted.

Task 4 - Prioritization of Recommended Actions
Based on the secondary data reviewed in Task 3, HW will identify a set of potential restoration projects, as well as land conservation, regulatory reform, or other non-structural watershed planning opportunities that would benefit Beaver River habitat and ecology, especially considering the previously identified

developmental pressures. Those potential projects will be evaluated and ranked against a set of performance metrics to be developed by HW in consultation with the Town and Advisory Committee. Field visits to the potential priority sites will be conducted for "ground-truthing," to ensure that all assumptions made in the desktop analysis were correct. The culmination of this task will be a final list of prioritized projects.

Schedule

The tentative schedule for the project is provided in the following table.

Table 2. Tentative Schedule for the Project

	Task	**Anticipated Start Date**	**Anticipated End Date**
QAPP	Preparation	1-Feb-20	19-Mar-20
	Acceptance	19-Mar-20	15-May-20
Task 3	Data Collection	1-Feb-20	15-Mar-20
	Data Analysis and Mapping	16-May-20	31-Jun-20
Task 4	Restoration/Protection Actions	1-Jul-20	31-Jul-20
	Metrics Development/Ranking Methods	1-Aug-20	30-Sep-20
	Prioritization	1-Oct-20	31-Oct-20
Task 5	Produce Draft Report	1-Nov-20	31-Dec-20
Task 6	Public Meeting	1-Jan-20	31-Jan-20
	Final report	1-Feb-21	30-Feb-21
QAPP End Date/End of Contract	End of all activities	30-May-21	30-May-21

Geographical Locations

The Beaver River watershed, an approximately 12-square mile area situated almost entirely within the limits of Richmond, a suburban-rural community in Washington County ("South County"), Rhode Island. Approximately 15 % of the watershed area is located in the Town of Exeter, RI and 85% is located in the Town of Richmond, RI (Figure 2). The 11-mile long Beaver River is one of 8 tributaries of the Wood-Pawcatuck River watershed that was recently designated as part of the Wild and Scenic River system.

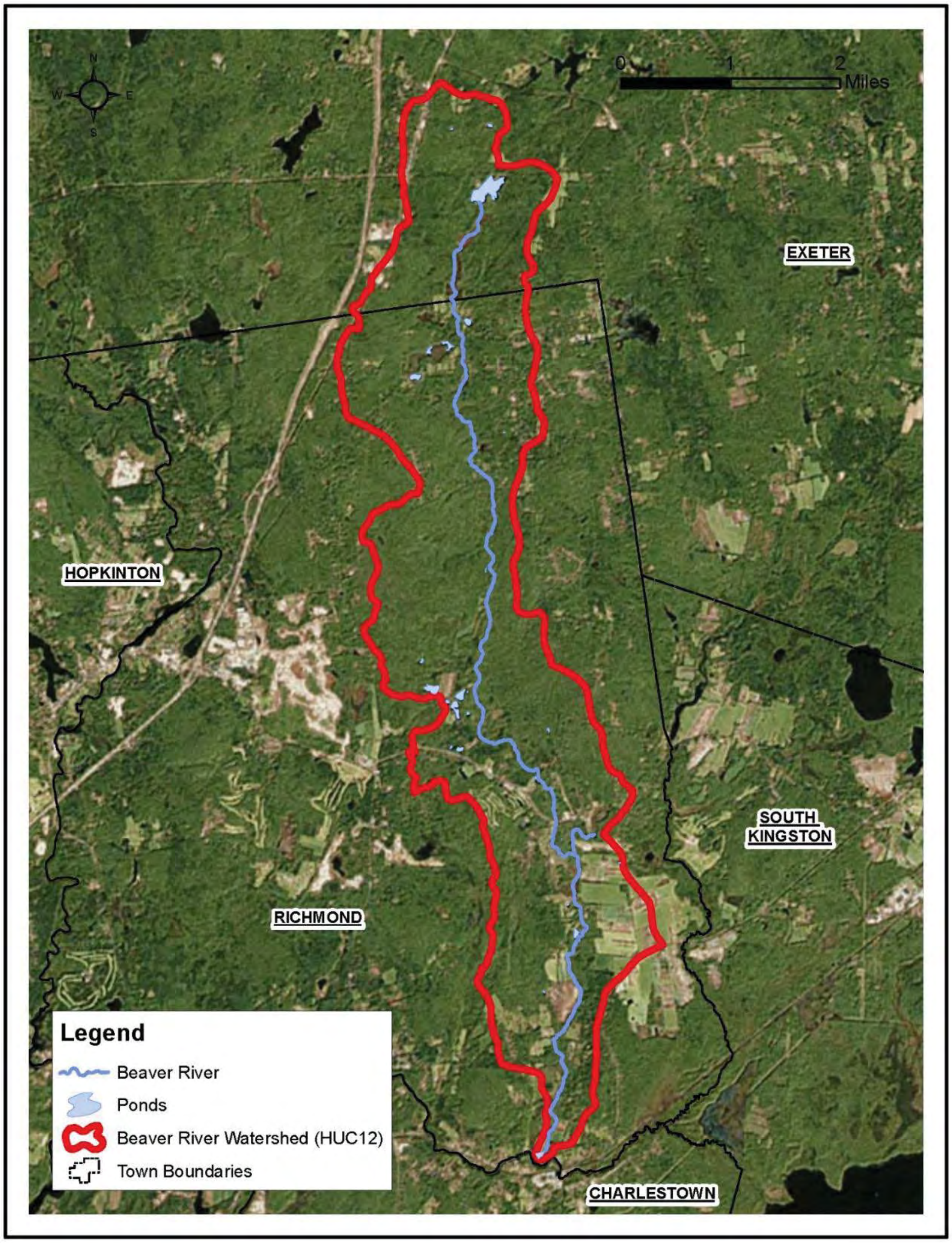


Figure 2. Map of the Beaver River Watershed Assessment Study Area.

Resources and Time Constraints

The Town and its consultant Horsley Witten Group, Inc. (HW) anticipate the completion of the desk-top analysis project within an approximate 12-month time period, using the project grant's finite funds and in-kind services.

As part of the Town's own efforts of continuous assessment of the natural resource that the Beaver River represents, the Town seeks to utilize volunteer engagement and citizen science to install in-stream temperature loggers in multiple locations throughout the watershed, following a field protocol previously developed by the Rhode Island Department of Environmental Management (RIDEM) and using the Quality Assurance Handbook and Guidance Documents for Citizen Science Projects to ensure the usability of the data to this project. Temperature loggers will ideally be installed no later than mid-May to identify potential elevated temperature thresholds adverse to aquatic resources (e.g., brook trout). This data collection project including volunteer engagement, training and logger installation is separate from the Beaver River Watershed Assessment and is not funded by NEIWPCC or EPA. However, it would be vastly helpful to determine the most appropriate logger installation sites before the loggers are employed. To this end, it will be beneficial for the Town if an initial analysis of spatial cover data could be performed by the consultant before the data loggers will be employed. Thus, it will be important for the initial analysis of secondary data to be completed by late April 2020, to the extent possible.

1.7. Quality Objectives and Criteria

In general, the quality of the data set will be assessed on the basis of:

- Source (federal, state and regional agencies preferred);
- Age (the most recent data revision of a given dataset will be used);
- Type (geospatial data will be preferred over data sources that will need to be digitized);
- Extent (only data which covers the Beaver River Watershed will be selected); and
- Metadata (data with sufficient metadata and/or background information will be preferred)

The following decision tree will be used to assess the quality of secondary data:

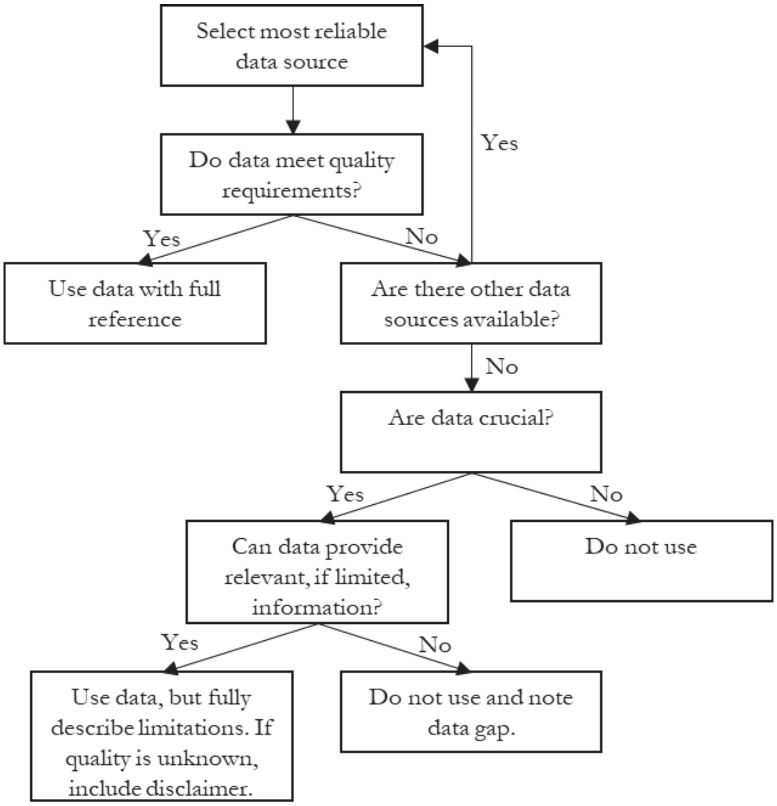


Figure 3. Data Decision Tree

1.8. Special Training/Certification

HW staff participating in this project have the background and experience to evaluate the acceptability of the data and perform the work. The key technical individuals who work on this assignment have an expert working knowledge of the procedures discussed in this QAPP.

Michelle West, P.E., is the project manager. She has eighteen years of professional experience in civil and environmental engineering. Her specific expertise is in stormwater management, watershed planning, hydraulic/hydrologic modeling, ecological restoration, and low impact development (LID)/green infrastructure planning, assessment, design, and implementation. She also has extensive experience with geographic information system (GIS) mapping, analysis, and modeling.

Geraldine Camilli, P.E., is the HW QA Manager for this project. She is a project manager and professional environmental engineer with almost 20 years of professional experience, including over a decade working on EPA projects. Her areas of expertise and experience include water and wastewater management, Geographic Information System (GIS) mapping, modeling, training, and data development; mathematical and numerical modeling; and sediment transport and coastal processes. Geraldine has managed a broad range of water and wastewater management studies and developed a number of models to evaluate water quality and quantity issues.

Maria Pozimski is the GIS Modeler for this project. During her seven years of experience in various GIS applications and hydrological modeling she has worked with private, public and governmental agencies as well as academic institutions on the creation and maintenance of databases and online data platforms, information gathering, data modeling, analysis and visualization. Maria's skills include: Coding in HTML, Java, Python and SQL, database management, analytical and hydrological modeling. Maria is proficient in the use of ArcGIS and the ArcGIS Online Platform, ENVI, Google Earth Engine, and ERDAS Imagine.

Neal Price is the Principal in Charge and Senior Hydrogeologist for this project. He has over 27 years of professional experience in the fields of hydrology and hydrogeology. Neal is a Senior Hydrologist and Associate Principal at HW and has conducted fieldwork, data analysis and interpretation, report preparation, and client contact for HW's varied hydrologic and hydrogeologic investigations over the past 23 years. The nature and extent of the work he has conducted includes wetlands, stream, and pond restorations; dam removals; culvert replacements; estuarine hydrology studies; nutrient management; wastewater disposal feasibility studies, design, and permitting; groundwater and surface water modeling; watershed and drinking water protection studies; and water supply investigations, design, and permitting.

Amy Ball, PWS, is the Senior Ecologist for this project. She has more than 24 years of professional experience as a wetland scientist and ecologist. Her specific expertise is in wetland botany and ecology, wetland restoration and mitigation, rare species and wildlife habitat assessments, wetland assessment and monitoring, and invasive species management.

1.9. Documentation and Records

As discussed in the customized Quality Management Plan (QMP) (HW, 2016), attached as Appendix A, HW has established procedures for the process of developing, reviewing, approving, and disseminating final work products.

Report Format:
HW will prepare and submit a draft report in WORD format that will include a description of the study,

project objectives, summary of project activities, maps and photographs, restoration and protection prioritizations, recommendations for next steps and expected outcomes, and EXCEL file attachment with GIS data that can be incorporated into the NBEP's watershed restoration database. The final report will be submitted in PDF format.

Data Report Package Information:
Maps will be provided in .JPG and .PDF formats, and GIS data produced through this project will be delivered in the ESRI File Geodatabase format in the UTM Zone 19N and Horizontal Datum NAD83, units feet. Feature classes within Feature Datasets will be in this projection. GIS data produced on this project will adhere to the requirements of EPA's National Geospatial Data Policy.

Metadata or documentation for all produced data, shall include source information (scale and accuracy, date, coordinate system), specific information about digital data layers (i.e., method used, geographic extent of data layer, file format, date of creation, staff contact, description and definition of data fields and their contents, related files, if any) and description of data quality and quality assurance methods use).

Data Storage and Public Access:
Data will be downloaded and stored electronically when possible. Data meeting an identified need will be organized in a folder with the topic name. Documents that meet the review standards as described in this QAPP will be shared among HW staff on the HW server, or some other means of file sharing, when requested. When data are available electronically, HW will keep all project materials as digital files on a company server. Each resource will be named with a meaningful title and saved in the project folder. The resources will be stored in HW's office in Sandwich, Massachusetts for at least five years after project completion unless the NEIWPCC and EPA project managers request otherwise. HW will conduct daily backup of files stored electronically.

The Town intends to post a PDF copy of the report to the Town website for availability to the public. Information will also be provided on the Town website indicating the availability of land cover data sets to the public and indication that entities and organizations interested in securing land cover data sets can contact the Town Planner to request information.

QAPP Dissemination:
The HW QA Manager will disseminate a copy of the QAPP to everyone on the distribution list (see Section 1.3) and will provide HW staff with a copy of this QAPP, and an overview of the quality assurance process associated with this project.

2. Data Acquisition

2.1. Sources of Secondary Data

In January of 2020, the Town of Richmond invited stakeholders to discuss potential sources for previously identified secondary data categories (see section 1.5). For each category, data sources of known and documented quality available were preferred. However, stakeholders also provided a number of potential data sources with either documentation deficiencies or gaps. These data will not necessarily be excluded but, instead, will be evaluated for use in specific, appropriate circumstances. For example, incompletely documented data could still be valuable to augment or refine the main, documented data sources, illustrate the current state of knowledge and uncertainties about watershed conditions, and illustrate the need for either improved, or additional monitoring programs.

The following table lists main data sources (white background) as well as potential supplementary data sources (grey background) for each data category that was introduced in Table 1.

Table 3. List of Data Sources by Data Category

Data Category	Secondary Data Source Title	Originating Organization	Year	Link (if applicable)
Base Map Information	Watershed Boundary Dataset: HUC 12	RIGIS	2019	http://www.rigis.org/datasets/watershed-boundary-dataset-huc-12
Topography	Contour Lines - 2 Foot	RIGIS	2011	http://www.rigis.org/datasets/contour-lines-2-foot-1
LU Class	Land Use and Land Cover	RIGIS	2011	http://www.rigis.org/datasets/land-use-and-land-cover-2011
Future Land Use	Land Use (2025)	RIGIS	1995	http://www.rigis.org/datasets/land-use-2025
	Richmond Buildout Analysis	Town of Richmond	2019	Received internally.
	Scenario 360 Buildout Wizard*	Community Viz	2018	https://communityviz.city-explained.com/communityviz/scenario360.html
Zoning Data	Richmond Zoning Data	Town of Richmond	2018	Received internally.
	Exeter Zoning Data	Town of Exeter	2018	Received internally.
Parcels	Richmond Cadastral Data	Town of Richmond	2018	Received internally.
	Exeter Cadastral Data	Town of Exeter	2018	Received internally.
Forest/Shrub Cover	Forest Habitat	RIGIS	2010	http://www.rigis.org/datasets/forest-habitat-2010
	Ecological Communities Classification	RIGIS	2017	Received internally.
Streams	Freshwater Rivers and Streams (1:5,000)	RIGIS	2006	http://www.rigis.org/datasets/f06b84e8b5c74efb82e1c7bd5b075308_0
Waterbodies	Ponds and Lakes	RIGIS	2017	http://www.rigis.org/datasets/ponds-and-lakes
Wetlands	National Wetlands Inventory	USFW	2014	https://www.fws.gov/wetlands/Data/Mapper.html
Nutrient Loading	Pawcatuck River and Little Narragansett Bay Water Quality Data	RIDEM	2019	Received internally.
	Watershed Treatment Model**	Center for Watershed Protection	2013	https://owl.cwp.org/mdocs-posts/watershed-treatment-model-documentation-final/
Rainfall Data	Average Annual Rainfall Data	NOAA	2019	https://www.ncdc.noaa.gov/cdo-web/
Species Habitat	Natural Heritage Areas and Species	RIGIS & RIDEM	2019	http://www.rigis.org/datasets/natural-heritage-areas
	Beaver River Species Data	RIDEM	1998-	Received internally.

Data Category	**Secondary Data Source Title**	**Originating Organization**	**Year**	**Link (if applicable)**
			2019	
	Margaritafera Margaritafera Habitat	RIDEM	2019	Received internally.
	List of Species of Greatest Conservation Concern (SGCN) (Amphibians and reptiles)	RIDEM	2019	Received internally.
	Wood Turtle Habitat	RIDEM	2019	Received internally.
	Species-Specific Habitat Requirements	USFWS	2020	https://www.fws.gov/southeast/endangered-species-act/critical-habitat/
Invasive Species	RI Forest Health Works Project: Points All Invasives	RIGIS	2019	http://www.rigis.org/datasets/ri-forest-health-works-project-points-all-invasives
Impervious Area	Impervious Surfaces	RIGIS	2011	http://www.rigis.org/datasets/8c40daec43ce4ea2a90396c42e739df0
Watershed Size	StreamStats	USGS	2020	https://streamstats.usgs.gov/ss/
Ground Water Quality	Groundwater Quality Standard	RIGIS	2018	http://www.rigis.org/datasets/groundwater-quality-standard
Soil Type	Soils (HSG)	USGS	2018	https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
	Hydric soils	USGS	2018	https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Water Temperature Data	Beaver River Temperature Data	RIGIS	2016-2019	Received internally.
	An Assessment of Brook Trout (Salvelinus fontinalis) Distribution and Water Temperature Fluctuations in the Beaver River, Rhode Island By Jon C. Vander Werff	URI	2018	Received internally.
	Citizen Science Data from Temperature Loggers employed by the Town (if	Town of Richmond	2020	To be collected.

Data Category	Secondary Data Source Title	Originating Organization	Year	Link (if applicable)
	available)			
	Landsat Oli-8 (TIR)	USGS	2019	https://earthexplorer.usgs.gov/
Flooding	Areas of Flooding	Fuss&O'Neill	2017	Received internally.
	FEMA Floodplain, to be in effect in April Town of Richmond	FEMA/Town of Richmond	2020	Received internally.
Culverts/Bridges	Culverts and Bridges Ratings	Fuss&O'Neill	2017	Received internally.
	Road – Stream Crossings	Town of Richmond	2019	Received internally.
Dams	Dam Management Recommendations	Fuss&O'Neill	2017	Received internally.
	Dams	RIGIS	2018	http://www.rigis.org/datasets/dams
	Northeast Aquatic Connectivity Assessment Project	TNC	2017	Received internally.
Assessment Sites	Geomorphic Assessment Sites	Fuss&O'Neill	2017	Received internally.
Restoration Sites	River Corridor Restoration Sites	Fuss&O'Neill	2017	Received internally.

* If needed, a watershed wide build-out analysis will be performed using the Scenario 360 Build-Out Wizard. This will allow an estimation of the amount and location of development for the entire watershed. Performing a build-out analysis identifies the holding capacity of the land. A build-out is a supply-side calculation applied to a clearly delineated area that is based on assumptions for density, and secondary data inputs for physical constraints to development (such as waterbodies, wetlands and flood zones), and land-use regulations. Traditionally, planners have performed build-out analyses by using spreadsheet tables to associate build-out assumptions with a hard copy map. The Scenario 360 Build-Out Wizard automates the entire build-out process. Data sources for the necessary data inputs are listed in this table.

**If needed, the Watershed Treatment Model (WTM) will be used to estimate annual pollutant loads for sediment, nutrients (total nitrogen and total phosphorus), and bacteria, as well as annual stormwater runoff volumes. The WTM is a public-domain, spreadsheet model which relies principally on the following secondary data inputs: annual rainfall; watershed size; land use and corresponding standard pollutant loading and runoff coefficients; and soil data, including type and depth to groundwater. Data sources for the necessary data inputs are listed in this table.

2.2. Quality of Secondary Data

Any problems with the quality of data published by RIGIS or federal agencies are considered unlikely. Other, supplementary datasets will only be incorporated if they meet the quality standards described in this section.

HW has a Secondary Data Assessment Checklist (Appendix B) that analysts use to verify that data will be matched for the work. A visual inspection of data will be done to check for anomalous values before inclusion in the final report (Section 4.2). If following a visual inspection, an analyst is satisfied that the main and supplementary data sources correspond with each other, then the data quality verification threshold is considered satisfied.

If while verifying data accuracy, or performing the work, an analyst detects data quality issues that will affect the results, HW will consult with the NEIWPCC and EPA project managers and document the resolution in the final reports. Flawed sources will be handled on a case-by-case basis. A data quality objective of this work is to have confidence in the results—so all decisions about data need to be sound.

Any limitations in data quality will be fully disclosed. If a decision is made to use data of unknown quality, then this limitation will be indicated in a disclaimer that will be added to any project deliverable. The disclaimer will read: "These data are of unknown quality and presented here for illustrative purposes only. No inferences regarding the environmental condition of the Beaver River Watershed should be made based on these data until their quality can be determined."

2.3. Data Management

Management & Storage
See Section 1.9

Data handling equipment:
All spatial data will be processed, compiled and analyzed using the ArcMap 10.7.1 software including the spatial analyst extension. Relevant metadata will be recorded using EPA Metadata Editor (EME) 5.0 in the EPA Geospatial Metadata Style (see Appendix C).

Spatial data will be stored in a file geodatabase format on the HW server, through which it can also be shared within HW. To transfer geospatial data, files will be sent in geodatabase format to retain relevant metadata. Other data types, such as spreadsheets, reports, etc. will be handled with the programs of the Microsoft Office 365 Business Suite.

Individual(s) responsible for data management
Each individual receiving/creating content within this project has the following responsibilities:

- Save a read-only, unedited, copy of the original file in a designated "Originals" folder immediately upon receipt/creation of the data.
- Record appropriate metadata.
- If a file becomes outdated, do not delete it, but move it to a designated "Archive" folder.
- In case of errors contact the person responsible for overall data management.

The GIS Analyst will be responsible for the overall oversight of the data management in this project. Their responsibilities include:

- Checking files regularly for correct naming, metadata and location of the file in the folder structure.
- Checking each file that will be part of the final product for correct naming, metadata.
- Respond to data management questions from the team.

3. Assessment and Oversight

3.1. Assessments and Response Actions

The technical staff will conduct assessments of the secondary data sources before incorporating them into the analysis and will fully describe metadata, limitations and potentially disclaimers.

The QA Manager will review data limitations and potential disclaimers of the secondary data sources. Furthermore, the QA manager will review the analysis outcomes and project deliverables before submittal (for schedule see Section 1.6). Any issues and potential solutions will be discussed with the EPA and NEIWPCC project managers.

NEIWPCC may implement, at their discretion, various audits or reviews of this project to assess conformance and compliance to the quality assurance project plan in accordance with the NEIWPCC Quality Management Plan.

NEIWPCC may issue a stop work order and require corrective action(s) if nonconformance or noncompliance to the Quality Assurance Project Plan is found.

3.2. Reports to Management

The Town of Richmond will file quarterly reports as a mechanism to keep NEIWPCC and EPA project managers apprised of progress and communicate any QA-related findings associated with the project's secondary data. The Town anticipates that Quarterly Reports will be submitted in April 2020, July 2020, October 2020, and January 2021.

4. Data Reduction, Reporting, and Validation

4.1. Data Reduction

In general, data reduction will be kept to a minimum. The data reduction types anticipated for this project include:

- Datasets with multiple categories may need to be combined (summed). (e.g., data on land cover types within the watershed may be reduced by grouping certain land covers (e.g., types of forest, types of residential) into a single category)
- Data units may need to be changed for report consistency and/or to allow comparisons across data sources.
- Certain datasets may be reduced and presented as percentages (e.g., percentage of fish species caught).

- Some data reduction may also be needed to display data in map form (maps will normally be intended to summarize some of the available information). Possible data reductions include:
    - Average values at a site (e.g., stream temperature)
    - Data may be reduced for comparison with a given benchmark. (e.g., concentrations of fecal coliform may be compared to the recommended standards and data displayed as above or below this benchmark)
    - GIS data may be reduced using geoprocessing techniques to combine, analyze, and/or select relevant data for the indicators. These data may be organized into one or several layers.

4.2. Verification and Validation Methods

The accuracy of project data is validated by careful and clearly defined data reduction and performing visual inspection of data before including it in the deliverables. The following procedures will be observed for secondary data validation:

- A copy of every original dataset obtained from each data source will be saved as a read-only, protected file in the event the integrity of the working datasets is compromised.
- Working data will be stored in spreadsheet format and will include all relevant raw data, which will be locked for editing.
- Data manipulation will be minimized to decrease the chances of inadvertently introducing errors. If necessary, then it will be starting from the raw, protected dataset. All formulas, along with units and conversion factors, will be shown in the spreadsheet.
- Prior to inclusion in the project deliverables, raw and/or reduced data will be displayed in graphic form and inspected to detect any anomalous value. Most environmental indicators to be displayed have been measured in the past and values are expected to fluctuate between "generally accepted values." If apparently anomalous values are detected, then any data reduction will be verified. If the seeming anomaly is present in the original dataset, the data generator will be contacted for clarification and/or the issue will be discussed with appropriate parties. Any decision to eliminate "anomalous values" will be documented in the working data spreadsheets that will be kept as part of the project files and will be noted in the list of sources of secondary data (Section 2.1).
- In rare occasions, a dataset may only be available in hard copy format. In these cases, data will be manually entered into a spreadsheet. To ensure an error-free copy, summary statistics will be checked if possible. In addition, a few individual values will be cross-checked as well.
- Data downloaded, submitted by a secondary party, or created by HW through GIS geoprocessing methods, will be stored with original files for repository data management and also be re-projected to a common horizontal datum and coordinate system (NAD 1983 – UTM Zone 19N). This coordinate system is suitable for the region of the Beaver River Watershed. The re-projected data will be converted and stored into a Feature Dataset which will maintain this coordinate system within each Geodatabase.
- All data displayed and used in ArcGIS will have the projected coordinate system (NAD 1983 - UTM Zone 19N). This will be verified by checking the Data Frame properties within each ArcGIS map.
- When necessary, GIS data will be clipped for the Beaver River Watershed. The manipulation of datasets will be noted and new metadata will be created reflecting the purpose, sources, and geoprocessing of the outputs shown in the report.
- Any limitations on data usability or remaining data uncertainty will be communicated in the final report.

4.3. Reconciliation with User Requirements

As described in Section 1.9, the final report, which includes all data limitations, will be made available on the Town website. All data limitations are therefore available to the public and all potential users of the analysis results.

5. References

Caraco, D. 2013. Watershed Treatment Model (WTM) 2013 Documentation. Center for Watershed Protection, Ellicott City, MD. https://owl.cwp.org/mdocs-posts/watershed-treatment-model-documentation-final/

Community viz: Community Viz Scenario 360, 2018, Working with the Build-Out Wizard Scenario 360 v.5.2. https://communityviz.city-explained.com/PDFs/latest/WorkingWithTheBuild-OutWizard.pdf

Fuss & O'Neill. 2016. Quality Assurance Project Plan (QAPP) – Developing a Resiliency Management Plan for Pawcatuck River Watershed (CT, RI). 41 pp and 7 Appendices.

Fuss & O'Neill. 2017. Wood-Pawcatuck Watershed Flood Resiliency Management Plan. 109 pp and 13 Appendices.

Narragansett Bay Estuary Program (NBEP). 2012. Comprehensive Conservation and Management Plan. Update 2012. Envisioning an Ecological Future for the Narragansett Bay Region. 73 pp.

Rhode Island Department of Environmental Management (RIDEM). 2015. Wildlife Action Plan. Seven chapters + appendices.

Wood-Pawcatuck Wild and Scenic Study Committee (WPWSSC). 2018. Wood-Pawcatuck Wild and Scenic River Stewardship Plan for the Beaver, Chipuxet, Green Fall-Ashaway, Pawcatuck, Queen-Usquepaug, Shunnock, and Wood Rivers.

Appendix B

Matrix of Species Identified for Preservation and Habitat Type (by System)

Matrix of Species Identified for Preservation and Habitat Type (by System)

SPECIES				SUPPORTING HABITAT (BY SYSTEM)											
				Open Uplands (Grassland & Shrubland)	Mixed Deciduous/Coniferous Forests	Emergent Marsh / Wet Meadow	Shrub Swamp	Coastal Plain Peatlands (Bogs)	Acidic Graminoid Fen	Forested Wetlands (Incl. Floodplains)	Seeps / Springs /Vernal Pools	Small to Medium Rivers	Large Rivers	Lakes	Ponds
Classification	Common Name	Latin Name	RI Status	Upland		Palustrine						Riverine		Lacustrine	
FISH	Brown Bullhead	*Ameiurus nebulosus*	NL									x	x	x	x
	American Eel	*Anguilla rostrate*	NL*									x	x		x
	White Sucker	*Catostomus commersonii*	NL									x	x	x	
	Chain Pickerel	*Esox niger*	NL											x	x
	Redfin Pickerel	*Esox Pickerel*	NL												x
	Tesselated Darter	*Etheostoma olmstedi*	NL												x
	Pumpkin Seed	*Lepomis gibbosus*	NL											x	x
	Largemouth Bass	*Micropterus salmoides*	NL											x	x
	Yellow Perch	*Perca flavescens*	NL												x
	Brook Trout	***Salvelinus fontinalis***	**NL***									**x**		**x**	**x**
	Fall Fish	*Semotilus corporalis*	NL									x	x	x	
REPTILES	***Spotted Turtle***	***Clemmys gutatta***	**NL***			**x**	**x**	**x**	**x**	**x**	**x**				**x**
	Northern Black Racer	*Coluber constrictor*	NL*	x	x										
	Wood Turtle	***Glyptemys insculpta***	**SC***	**x**	**x**	**x**				**x**		**x**			
	Eastern Hognose Snake	***Heterodon platirhinos***	**SC***	**x**	**x**		**x**								
	Eastern Rat Snake	***Pantherophis alleghaniensis***	**SC***	**x**	**x**										
	Eastern Box Turtle	***Terrapene carolina***	**NL***	**x**	**x**										
	Common Ribbon Snake	*Thamnophis sauritus*	SC*			x		x	x	x					
AMPHIBIANS	***Spotted Salamander***	***Ambystoma maculatum***	***NL****		**x**						**x**				
	Marbled Salamander	***Ambystoma opacum***	***NL****		**x**					**x**	**x**				
	Four-toed salamander	*Hemidactylium scutatum*	NL*			x		x		x	x				
	Wood Frog	*Lithobates sylvaticus*	NL*		x					x	x				
	Red-spotted Newt	*Notophthalmus viridescens*	NL*		x	x									
	Eastern Spadefoot	***Scaphiopus holbrookii***	**SE***		**x**					**x**	**x**				
ODONATES	***Spatterdock Darner***	***Aeshna mutata***	***SC***					**x**	**x**						**x**
	Pine Barrens Bluet	***Enallagma recurvatum***	***SC****		**x**	**x**			**x**						**x**
	Bluebell, Elfin Skimmer	*Nannothemis bella*	NL			x		x							
	Sedge Sprite	*Nehalennia irene*	NL						x						
	Ringed Boghaunter	***Williamsonia lintneri***	***SE****					**x**	**x**						
BUTTERFLIES/ MOTHS	Burgess's Apamea	*Apamea burgessi*	NL	x											
	Dusted Skipper	***Atrytonopsis hianna***	***SC****	**x**	**x**										
	Hessel's Hairstreak	***Callophrys hesseli***	***SC****					**x**		**x**					
	Hoary Elfin	***Callophrys polios***	***SC****	**x**	**x**			**x**							
	Bog Copper	***Lycaena epixanthe***	***SC****					**x**	**x**						
PLANTS	***Sandplain Gerardia, Agalinis***	***Agalinis acuta***	***FE***	**x**	**x**										
	Colic-root, Stargrass	***Aletris farinosa***	**SC**	**x**	**x**										
	Whorled Milkwort	***Polygala verticillata***	**SC**	**x**	**x**										
	(Large-spiked) Beak-rush	***Rhynchospora macrostachya***	***ST***			**x**	**x**	**x**	**x**		**x**			**x**	
BIRDS	***Vesper Sparrow***	***Pooecetes gramineus***	***SH***	**x**											

SC	State Concerned
ST	State Threatened
SE	State Endangered
SH	State Historical
FE	Federal Endangered
NL	Not Listed

Acid Graminoid Fen was specifically identified

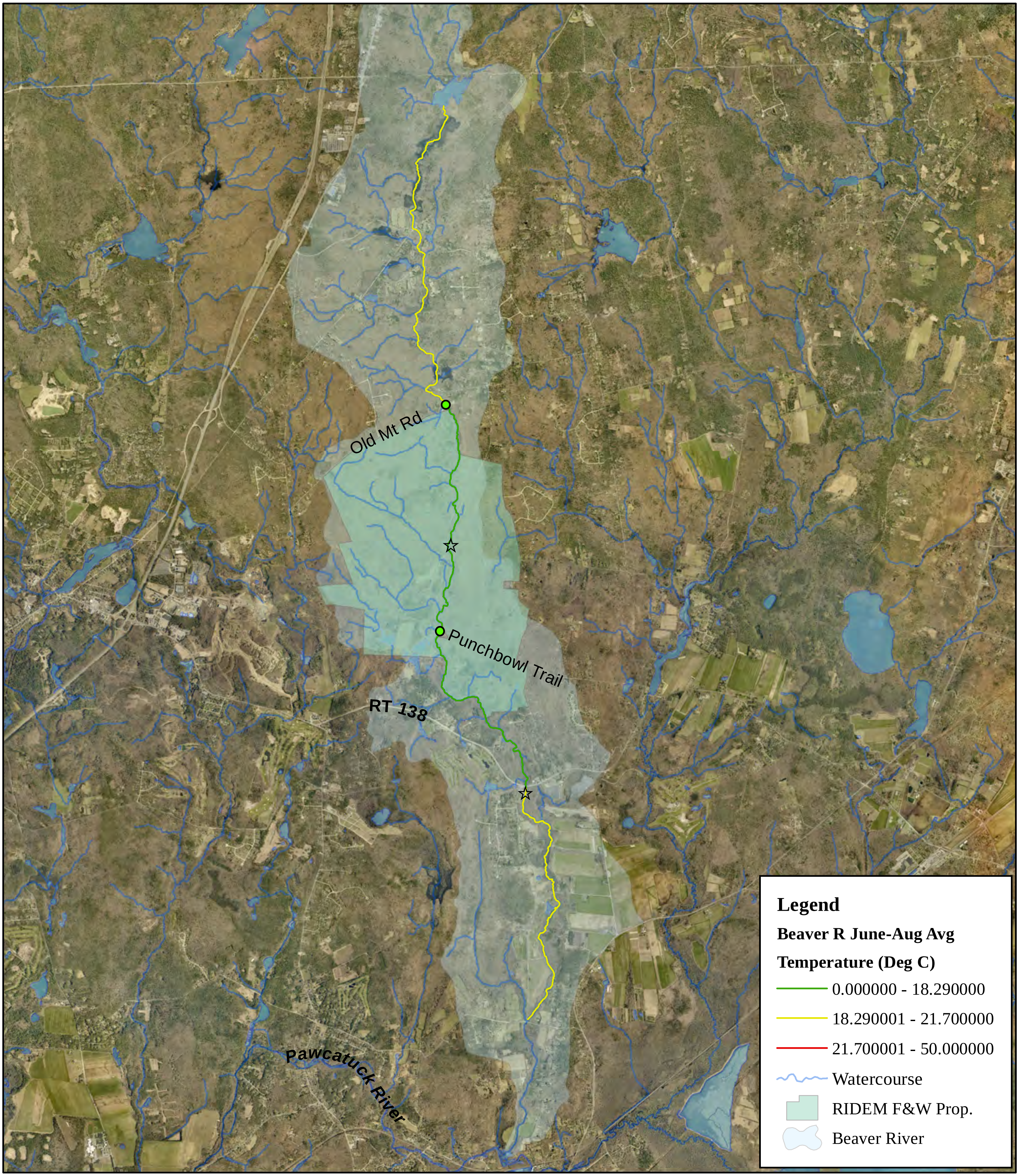
* Species of Greatest Conservation Concern (2015 SWPA)

bolded species include species specifically identified as higher priority for this project and includes State- and Federally-listed species

Appendix C

Stream Temperature Monitoring

-Map showing 2019 Results
-Data Logger Installation Standard Operating Procedure (SOP)
-Summary of 2020 Logger Locations



Legend

Beaver R June-Aug Avg Temperature (Deg C)

- 0.000000 - 18.290000
- 18.290001 - 21.700000
- 21.700001 - 50.000000
- Watercourse
- RIDEM F&W Prop.
- Beaver River

Rhode Island Department of Environmental Management

Beaver River

EBTJV January 2019 Meeting

1 inch = 5,500 feet

0 0.5 1 2 Miles

Data Logger Installation Standard Operating Procedure (SOP)

***This SOP is used by the Rhode Island Division of Fish and Wildlife and The Rhode Island Chapter of Trout Unlimited for annual temperature monitoring**

***For Onset HOBO V2 loggers and Thermocron I-Button 4K**

Logger Setup

Logging of I-Buttons and HOBO loggers will be initiated prior to deploying in the field

- Add a site name to each logger in the software and mark the logger with a piece of tape or flagging to identify its proposed location
- Loggers should be set to log at one-hour intervals, taking measurements on the hour
- Loggers will be set to record in degrees Celsius
- Time zone should be set to GMT -4 (Eastern Daylight Time)

Install logger into housing- this can be done in the office or field, after the logger has been turned on and begun logging

- HOBO loggers will be zip tied into PVC housings which are bolted to a metal anchor (fence post or metal plate)
- I-Buttons will be waterproofed either with a purchased logger housing through Thermocron or adequately sealed with waterproof tape

Logger Deployment

Determine the best location in proximity to the mapped point for data logger placement. Each logger location will be identified according to review of spatial coverage datasets and other relevant watershed information.

- Loggers should be placed in a location least accessible or visible to local foot traffic
- At road crossings, loggers can be placed beneath or a short distance up or downstream as to not be seen from the roadway
- Most importantly, loggers should be placed in pools or into deeper runs so that during periods of low flow, the logger remains submerged

Secure the logger to the streambed

HOBO loggers using weighted housings:

- an adequate length of rope should be tied from the anchor, running to the shoreline and tied off to a root or base of a tree
- The rope attaching the logger to the bank should be “mudded up” to reduce its visibility and in cases where visibility and potential vandalism remains a concern, rocks can be used to cover the rope

I-Buttons:

- attach to a piece of rebar approximately 24” long using waterproof tape, allowing enough distance for the rebar to be driven into the streambed so it cannot be washed away during high flows

- the logger should sit just above the streambed once the rebar is driven into the substrate

Documenting logger locations

- Rough locations will be identified on a map but exact locations need to be determined in the field and documented with GPS coordinates
- On a blank piece of paper, draw a quick sketch of the stream layout and logger placement
  - Details to include:
    - Person(s) installing logger
    - Large trees or identifiable features instream and along the banks
    - Stream flow direction
    - Distance estimates between logger and nearby feature(s)
    - Adjacent roadways, bridges, culverts, and trails
- One or two photos should be taken of each logger location including someone in the photo pointing at the logger for reference
- The photos should be taken from a vantage point that encompasses most of the stream and gives a good viewscape of the surroundings
- Photos numbers for each logger should be noted on the respective sketch sheet
- GPS coordinates should be taken at each logger site

Summary of Temperature Loggers Installed in the Beaver River System (2020)

Logger_ID	DEM ID	Install Date	Installed Time	Location	Closest Road	Stream	Existing Logger Location	Purpose	Notes
TL-001	TU10	5/26/2020	11:35	Downstream of James Pond	NA	Main Stem of Beaver River	no	Effects of Impoundment	Private property, difficult access
TL-002	TU12	5/26/2020	10:30	Downstream of Dam	NA	Main Stem of Beaver River	no	Effects of Impoundment/ groundwater seeps	Shrubby wetland
TL-003	TU14	5/26/2020	1:00	Tug Hollow Pond Dam	New London Turnpike	Main Stem of Beaver River	yes	Effects of Impoundment	Near high priority culvert
TL-004	TU13	5/26/2020	1:09	New London Turnpike Trib	New London Turnpike	Tributary to the west	no	Effects of Impoundment	Near high priority culvert
TL-005	TU05	5/26/2020	12:53	Tug Hollow Rd Trib-upstream	Tug Hollow Road	Tributary to the east	no	Effects of Impoundment	Area of known flooding
TL-006	TU02	5/26/2020	12:45	Tug Hollow Rd Trib-downstream	Tug Hollow Road	Tributary to the east	no	Effects of Impoundment	Near high priority culvert
TL-007	TU18	5/28/2020	1:45	Upstream of Wood Rd Trib	Wood Road	Main Stem of Beaver River	no	Effects of Wetlands	Corey has permission to access property
TL-008	TU03	5/28/2020	1:50	Wood Rd Trib	Wood Road	Tributary to the west	no	Effects of Wetlands	Corey has permission to access property
TL-009	TU15	5/28/2020	1:55	Downstream of Wood Rd Trib	Wood Road	Main Stem of Beaver River	yes	Effects of Wetlands	Corey has permission to access property
TL-011	TU07	5/26/2020	2:00	Trib below pond on New London	New London Turnpike	Tributary to the west	no	Effects of Impoundment	Downstream of TL-012 trib confluence with pond outflow
TL-012	TU11	5/26/2020	1:25	Trib Upstream of New London	New London Turnpike	Tributary to the west	no	Effects of Undeveloped Land	Near high priority culvert
TL-013	TU16	5/26/2020	2:50	Upstream of Lake - TNC Land	Old Mountain Road	Main Stem of Beaver River	no	Effects of Impoundment	TNC Land
TL-014	TU01	5/26/2020	2:40	Downstream of Lake-TNC Land	Old Mountain Road	Main Stem of Beaver River	no	Effects of Impoundment	TNC Land
TL-015	TU09	5/28/2020	1:20	Tributary Near Old Mtn Road	Old Mountain Road	Tributary to the west	no	Effects of Tributary	
TL-016	TU19	5/28/2020	1:05	Downstream of Old Mtn Road	Old Mountain Road	Main Stem of Beaver River	yes	Existing data record	Near high priority culvert; Beginning of middle, cold section of river
TL-017	TU04	5/28/2020	12:43	South Trib at Hillsdale Rd	Hillsdale Road	Tributary to the west	no	Effects of Tributary-Undeveloped, Protected Land	State Land; Near medium priority culvert
TL-018	TU17	5/28/2020	12:05	Long Pond Trib	Hillsdale Road	Tributary to the west	no	Effects of Tributary-Undeveloped, Protected Land	Mostly on State Land
TL-019	TU20	5/28/2020	11:30	Downstream of Large Wetland	Hillsdale Road	Main Stem of Beaver River	no	Effects of Wetlands	
TL-020	TU06	5/28/2020	12:15	Downstream from Long Pond	Hillsdale Road	Main Stem of Beaver River	no	Effects of Tributary	
TL-021	TU08	5/28/2020	12:10	Upstream from Long Pond Trib	Hillsdale Road	Main Stem of Beaver River	no	Effects of Tributary	
TL-022	FW02	5/28/2020	10:58	Below Whitetail Trib	Whitetail Trail	Tributary to the west	no	Effects of Residential Development	
TL-023	FW01	5/28/2020	2:40	Middle of Eastern Ag Land	Beaver River Road	Tributary to the west	no	Effects of Golf Course	Beaver River Golf Club
TL-024	TU21	5/28/2020	4:23	Downstream RTE 138 Culvert	RTE 138/Beaver River Rd	Main Stem of Beaver River	yes	Effects of Golf Course	Near medium priority culvert
TL-025	FW04	5/28/2020	10:23	Upstream of Solar Farm Trib	Beaver River Road	Tributary to the east	no	Effects of Solar Farm/Airport	Near Richmond Airport
TL-026	FW11	5/28/2020	4:34	Downstream of Solar Farm Trib	Beaver River Road	Main Stem of Beaver River	no	Effects of Solar Farm/Ag Land	Beaver River Park
TL-027	FW14	5/28/2020	2:06	Middle of Eastern Ag Land	Beaver River School House Rd	Main Stem of Beaver River	no	Effects of Ag Buffers	
TL-028	FW12	5/28/2020	1:43	Upstream of Western Ag Land	Beaver River Road	Main Stem of Beaver River	no	Effects of Ag Buffers	
TL-029	FW13	5/28/2020	1:16	Trib Upstream of Western Ag Land	Shannock Hill Road	Tributary to the west	no	Effects of Ag Buffers	
TL-030	FW03	5/28/2020	12:44	Trib Downstream of Western Ag Land	Shannock Hill Road	Tributary to the west	no	Effects of Ag Buffers	
TL-031	FW06	5/28/2020	12:52	Upstream of Western Ag Trib	Shannock Hill Road	Main Stem of Beaver River	yes	Effects of Ag Buffers	Upstream of Confluence with Western Ag Trib; to compare with TL-028
TL-032	TU22	5/28/2020	11:43	Mouth of Beaver River	Lewiston Avenue	Main Stem of Beaver River	no	Conditions at Mouth	

Appendix D

Riparian Buffer Standards – Excerpt from the Rhode Island Low Impact Development Site Planning and Design Guidance Manual (RIDEM & RICRMC, 2011)

3.0 RIPARIAN BUFFER STANDARDS

Current Practice

A riparian buffer is the area of land along streams and rivers and other open water bodies. Riparian buffers are essential to the ecology of aquatic systems. Riparian buffer zones, due to their location between surface waters and adjacent land areas, provide a range of important functions such as:

- Trapping/removing sediment and phosphorus, nitrogen, and other nutrients from runoff, as these pollutants lead to eutrophication of aquatic ecosystems;
- Trapping/removing other contaminants, such as pesticides;
- Providing habitat and contiguous travel corridors for wildlife;
- Stabilizing stream banks and reducing channel erosion;
- Storing flood waters, thereby decreasing damage to property;
- Maintaining habitat for fish and other aquatic organisms by moderating water temperatures and providing woody debris;
- Improving the aesthetics of stream corridors (which can increase property values); and
- Offering recreational and educational opportunities.

Because they maintain all of these services, riparian buffers can be thought of as a "**conservation bargain**." Preserving a relatively narrow strip of land along streams and rivers, which is frequently unsuitable for other uses, can help maintain good water quality, provide habitat for wildlife, protect people and buildings from flood waters, and extend the life of reservoirs. The preservation and restoration of natural riparian buffers is considered to be the single most important management practice to protect water resources.

Figure 3-1 Healthy Riparian Buffers.

The Clean Water Act goal that all waters should be fishable and swimmable is not achievable in Rhode Island's waters without the careful protection of riparian buffers (RI Rivers Council 2005 Establishment of Riparian and Shoreline Buffers: A Report to the Governor). ((c) 2008 Paul Somers, http://bioimages.vanderbilt.edu/)

In Rhode Island, most freshwater wetlands, and the buffer areas protecting them, are regulated by the Freshwater Wetlands Act[1], administered by the RI DEM. In addition, the RI CRMC regulates both fresh and tidal water resources and their buffers within the coastal zone of Rhode Island. The RI DEM Wetlands Program framework does not protect riparian buffers around all wetlands.[2] Both programs protect the minimum buffers as defined by the Act. Some weaknesses in the current regulatory program are as follows:

- RI DEM is not able to protect riparian buffers around all wetland systems. Special aquatic sites (vernal pools), small ponds less than one-quarter acre in size, and small forested/shrub wetlands less than three acres in size do not have regulated buffer zones;
- Authors of the Wetland Act had the foresight to protect adjacent buffer areas for other wetlands; however, the science regarding the importance of buffers has grown in the last 30 years, and we now know that current buffer zones regulated by law are often not large enough (e.g., the buffer zone width should consider sensitivity of wetland type and the land use that is proposed in both urban and suburban settings, as well as other factors); and
- State regulatory programs can be limited where substandard lots of record have been created and property use is grandfathered.

Most communities rely on RI DEM or RI CRMC to regulate buffers instead of exercising their zoning authority to help guide new development away from these sensitive areas. Eighteen RI municipalities have their own setbacks from wetland edges. Of these, seven communities regulate all disturbances within the setback; three communities regulate all buildings, structures and on-site wastewater treatment systems (OWTS), and the remaining eight regulate only OWTS location. In most cases the setbacks apply community-wide. A few communities either apply the setback only within a critical resource area or establish more stringent setbacks and/or performance standards for the critical area. R.I. General Law 45-24-30, the RI Zoning Enabling Act, enables communities to regulate development through a municipal zoning ordinance, giving them the ability to protect environmental resources while providing for orderly growth and development which recognizes:

3(ii) The natural characteristics of the land, including its suitability for use based on soil characteristics, topography, and susceptibility to surface or groundwater pollution.

3(iii) The values and dynamic nature of coastal and freshwater ponds, the shoreline and freshwater and coastal wetlands.

Objective

Communities should use their land use regulatory power to require the preservation or restoration of a naturally vegetated buffer along all jurisdictional wetland resources to the maximum extent practicable[3] in both new development and redevelopment. The

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[1] Rhode Island General Law 2-1-18 et seq.

[2] Refer to Perimeter Riverbank and Floodplain Wetlands Fact Sheet No.9 (RI DEM, 2007)

[3] For all references to "maximum extent practicable" in this guide, an applicant must demonstrate the following: (1) all reasonable efforts have been made to meet the standard in accordance with current local, State, and Federal regulations, (2) a complete evaluation of all possible management measures has been performed, and (3) if full compliance cannot be achieved, the highest practicable level of management is being implemented.

determination of buffer widths may require extra consideration in different locations depending on site specific characteristics, such as the presence of hydric soils and steep slopes.

Figure 3-2 Example of Vegetated Riparian Buffers.

The green area in the figure represents the vegetated riparian buffer and the shaded blue area indicates a buffer zone of 100 feet on either side of the stream. (HW graphic)

Recommended Practice

A community buffer program should be created to establish a naturally vegetated buffer system along all streams and wetlands to supplement and expand upon the minimum requirements of the RI DEM and RI CRMC programs where applicable. Other important environmental features important to water quality preservation and enhancement should be included within the buffer, such as the 100-year floodplain and steep slopes. Communities implementing buffer programs should consider issues such as minimum width, target vegetation, allowable uses, and performance standards to avoid and minimize impact, as discussed below.

Minimum Buffer Width

The effectiveness of various buffer widths has received much attention from the scientific and regulatory community, particularly in relation to water quality and local land use policy. A summary of over 150 scientific studies of effective buffer widths for a variety of biological, hydrologic, and physical functions is summarized by the Environmental Law Institute (2003). The Army Corps of Engineers (Corps) released national recommendations for riparian buffer design in 2000 (Fischer and Fischneich, 2000). Desbonnet, et al. (1994) published material specific to Rhode Island that can also be used to shed light on site specific buffer issues. Table 3-1 summarizes a wide range of buffer widths reported by these studies and provides a recommended minimum width to support a variety of buffer functions. A minimum buffer of 100 feet seems to be the most widely recommended width for protection of most buffer functions. Critical resources, such as public drinking water supplies may have larger buffer requirements for enhanced protection and should be clearly identified in the buffer regulations. The values recommended represent the distance from the edge of a resource (e.g., stream bank, not the centerline).

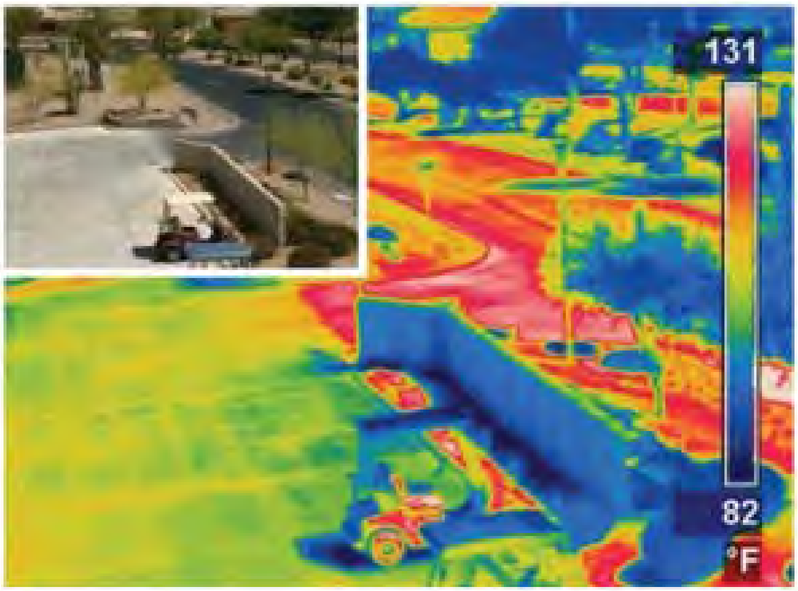
Table 3-1 Recommended Minimum Buffer Widths. (Adapted from Environmental Law Institute, 2003)

Function	**Range of Riparian Buffer Widths**		**Minimum Recommended Buffer Width**
	Environmental Law Institute (2003)	*Fischer and Fischneich (2000)*	
Stream Stabilization	30-170 ft	30-65 ft	50 ft[1]
Water Quality Protection	15-300 ft (remove nutrients)[2] 10-400 ft (remove sediment)	15-100 ft	100 ft[3]
Flood Attenuation	65-500 ft	65-500 ft	FEMA 100-year floodplain plus an additional 25 ft[4]
Riparian/Wildlife Habitat	10 ft-1 mile	100 ft-0.3 mile	300 ft[5]
Protection of Cold Water Fisheries	>100 ft (5 studies) 50-200 ft (1 study)	--	150 ft[6]

1. Larger buffers may be necessary based on steep slopes and highly erodible soils.
2. Different buffer designs should be considered for protection of different resources (coastal vs. inland).
3. Larger buffers may be necessary based on land use, resource goals, slope, and soils.
4. Additional buffer recommended to compensate for variability in flood model results at a site level and due to a changing climate.
5. Larger buffers may be necessary based on species and vegetation.
6. Larger buffers are necessary as the impervious cover in the watershed exceeds 8%.

In developed areas, as stormwater runoff flows over impervious surfaces such as asphalt and concrete, it increases in temperature before reaching a stream or other water body. Water temperatures are also increased due to shallow ponds and impoundments along a watercourse as well as fewer trees along streams to shade the water. Since warm water can hold less dissolved oxygen than cold water, this "thermal pollution" further reduces oxygen levels in suburban and urban streams. As described in the RI Stormwater Manual, temperature changes can severely disrupt certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.

Figure 3-3 Thermal Imaging of Pavement.



This infrared imagery shows how hot the surface of impervious cover can get, creating a situation where any subsequent stormwater runoff will have dramatic temperature impacts on adjacent streams. (Kaloush, Kamil; Pavements and the Urban Heat Island Effect)

For the specific protection of trout habitat, a number of researchers have demonstrated that a larger protective buffer is needed. A 150-foot minimum "no touch" buffer zone seems to be the most widely recognized width for protection of cold water streams. Effective riparian buffer widths reported for protecting trout stream habitat range from 50 to 200 feet. Meyer et al. (2005) studied the correlation between forested buffers, in-stream temperature, and benthic substrate conditions in over 8,000 trout streams to evaluate the impact of a State policy to reduce required buffer widths from 100 to 50 feet. They found that the reduction of forested riparian buffers widths from 100 to 50 feet resulted in a 3-4 degree increase in stream temperatures and 11% increase in sediment in riffle habitats. While this change seems insignificant, this shift is expected to reduce the young trout populations by 81-88%.

Vegetative Target

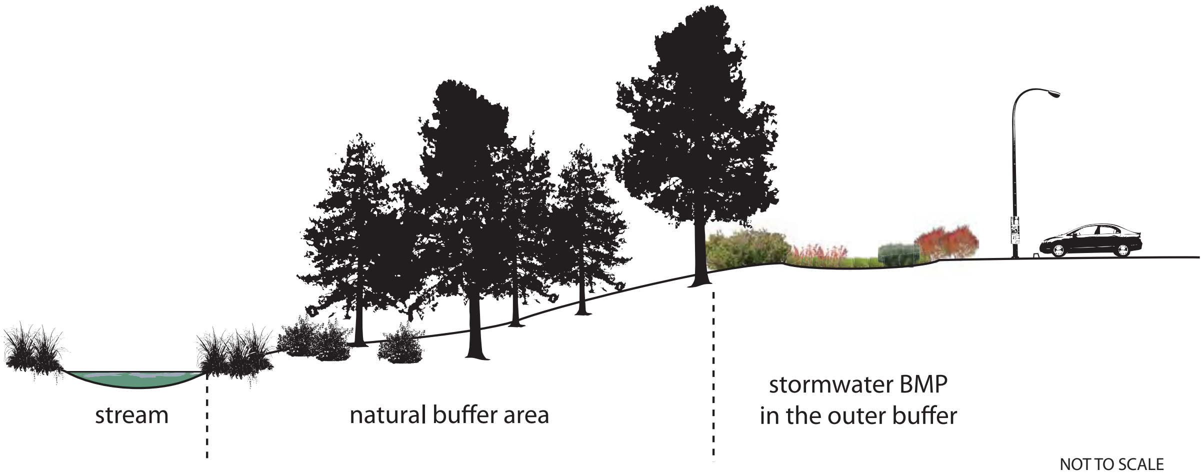
The ultimate target for the vegetation in the buffer should be specified. In general, this target should reflect the predevelopment, natural vegetative community present in the area. The target can be met by either preserving the existing vegetation or managing a disturbed buffer. To preserve existing buffers, these areas should be well marked on site plans, as well as in the field during construction. Disturbed areas should be either planted with native species or allowed to revert to the natural vegetation over time, with an aggressive invasive species management plan. Some selective clearing may be allowed in the outer portion of a buffer; in particular, to allow owners to remove dead or diseased trees that endanger personal property.

Buffer Uses

While the ultimate goal of a community buffer program is to create a continuous vegetated area adjacent to resources, certain uses can be allowed. Buffer crossings (by utilities, roadways or pedestrian bridges) will be necessary in certain areas, and a buffer program should specify performance criteria that address items such as crossing width, angle, frequency, and elevation. The allowable crossing width should be the minimum required for maintenance. Direct right angles are preferred since they require the least amount of clearing in the buffer. Only one road crossing per project should be allowed, and all utility crossings should be at least three feet below the streambed to prevent exposure by future channel erosion. The road crossing should be designed to pass the flow from the 100-year flood event. Bridges should be used for the crossing to the maximum extent practicable and if culverts are unavoidable, arch or box culverts should be used to minimize impact on wildlife. Communities must understand that all crossings are subject to RI DEM/CRMC review. For more information regarding techniques to avoid and minimize impacts to riparian buffers and wetlands refer to the *Wetland BMP Manual: Techniques for Avoidance and Minimization* (RI DEM, 2010).

Another potentially acceptable use within the buffer is for stormwater treatment; however, it is important to note that small scale LID practices located upgradient of buffer areas are preferable. Stormwater Best Management Practices (BMPs) should not be used in buffers where they significantly compromise the buffer's existing functions, and should only be used when no practical alternative exists. The outer portion of buffers can be utilized for stormwater management facilities, as long as sites are chosen carefully, located outside of State jurisdictional areas, and clearing of vegetation is minimized. One potentially effective way to use the edge of the buffer areas is to disperse channelized stormwater flow, which can be accomplished with small amounts of grading. Stormwater facilities should be designed with LID techniques and use the natural topography and undulating features that incorporate existing trees. See the RI Stormwater Manual for more information on how to properly design stormwater treatment practices.

Figure 3-4 Example of Stormwater BMP in the Outer Buffer Zone.



(HW graphic)

The red triangles in the graphic below represent the location of stormwater BMPs. Some of these have been effectively implemented in the very outer edge of the vegetated buffer (green area) along the riparian corridor in Montgomery County, MD. The shaded blue area indicates a buffer zone of 100 feet on either side of the stream as a reference.

Figure 3-5 Locations of Stormwater BMPs Relative to Stream Buffers.

The red triangles represent stormwater BMPs; the green area represents the vegetated riparian buffer; and the shaded blue area indicates a buffer zone of 100 feet on either side of the stream as a reference. (HW graphic)

Development Standards

When discussing development criteria for buffer zones in the context of the urban environment, it is important to understand many of the site limitations that could exist by virtue of an existing development. Industrial structures that were developed many decades ago were constructed as close as possible to adjacent waters in order to take advantage of hydraulic power opportunities and the ability to dispose of waste into rivers and streams. In these cases, existing structures may severely inhibit the ability to restore any vegetated buffer adjacent to surface waters.

Due to these potential constraints, it is important for local review agencies to approach redevelopment situations with a flexible mindset. Re-establishing buffers where there are severe site restrictions should be considered under the 'maximum extent practicable' approach. Where minimum buffer widths are in place, these values should be seen as guidance principles within the context of urban redevelopment and should not preclude the possibility of redevelopment if specific buffer standards cannot be attained. Moreover, communities should be very flexible with other local regulations that may force development into buffer areas. These local regulations include, but are not necessarily limited to, parking requirements and front yard setbacks.

Figure 3-6 Typical Subdivision Design Impacting Wetlands.

Uniform requirements for lot size and setbacks cause subdivisions like the one in this aerial photo to consume far more land than necessary. This subdivision has encroached into wetland and pond buffer areas causing visible signs of eutrophication as indicated by the light green algal bloom. (Google Maps)

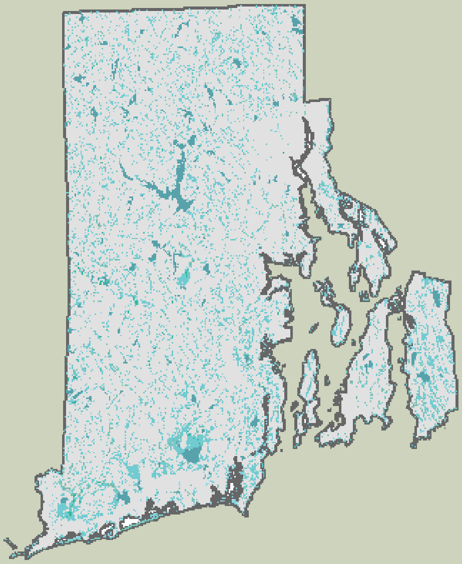
General Guidelines

1. *Minimum Width:* See Table 3-1 for recommended minimum widths to achieve various buffer functions.

   As mentioned above, this width represents an "ideal" condition that may not be achievable on all urban sites. However, the greatest buffer width that is practical should be maintained and restored and should not be reduced to less than 25 feet from wetland edge or below State regulatory requirements. **It should also be noted that both RI DEM and RI CRMC have regulatory jurisdiction for fresh water and coastal wetlands and surface waters including buffer requirements that may be greater than 100 feet. Local buffer programs should augment existing requirements.**

2. *Buffer Delineation and Mapping:* Preliminary mapping of surface water buffers can be performed through the use of readily available data from Rhode Island Geographic Information Systems (RIGIS, www.edc.uri.edu/rigis/). Although the accuracy of these features from RIGIS is not adequate for site-specific design, it can be used as an indicator of the presence of hydrologic features and can be useful during a pre-application conference or other preliminary discussions with municipal officials. These delineations are appropriate for conceptual site designs. Site designs for master plan review or beyond should include mapping of buffer delineations performed by a qualified wetland scientist in conjunction with a registered surveyor and be field verified by RI DEM or RI CRMC. Communities may want to consider requiring a RI DEM verified wetland edge at the pre-application phase, depending on the extent of potential impacts and scale of the project. A verified wetland edge should be required for any variance or special use permit application.

Figure 3-7 State of Rhode Island Wetland Coverage.



(Rhode Island Geographic Information System)

3. *Protecting Buffers During Construction:* Although buffer areas can be set aside as "undisturbed" on site plans and development applications, it is important for local officials and developers to understand the construction process and what risks could be posed to on-site vegetated buffer zones. **See Chapter 4 for more information on site clearing and grading guidance.** To minimize risks during the construction phase, the following precautionary measures can be required as part of a construction plan:

    - Buffer zones and limits of disturbance should be required on every drawing within every set of construction plans including, but not limited to, clearing and grading plans and sediment control plans;

    - Buffer limits should be staked out in the field prior to any construction activity;

    - Limits of disturbance can be marked with orange construction fence barriers with accompanying signs to prevent storage of construction materials and intrusion of vehicles, or any work beyond the limit;

    - A pre-construction walk-through should be performed with the municipal official or representative responsible for construction inspections and the person who was responsible for delineating the resource areas; and

    - Third-party inspectors can be hired by the community, at the applicant's expense as authorized within the Subdivision and Land Development Regulations, to conduct site visits during and after construction to insure construction activity does not impair surface waters, wetlands, or buffers. **Refer to third-party review fees guidance in Chapter 9.**

4. *Landscaping:* Landscaping on a site already containing an existing vegetated

buffer should use only plant and tree varieties specifically cited as native species in Sustainable Trees and Shrubs for Southern New England, prepared by the University of Rhode Island, University of Massachusetts, and the United States Department of Agriculture (1993), or in another credible scientific document that specifically lists any proposed planting (genus and species) as being indigenous to the region. Appendix B in the RI Stormwater Manual also provides guidance on native landscaping. **In addition, refer to Chapter 8 for guidance on how to implement landscaping requirements on the local level.**

5. *Prohibited Activities:* Activities which can be typically prohibited by a local ordinance in the buffer include: land disturbing activities that may result in erosion or sedimentation, structures, impervious surfaces, application of fertilizers, herbicides and pesticides (except as needed to restore a buffer), storage tanks for petroleum products, septic system tanks/ leach fields (where applicable) and, clear cutting of vegetation other than maintenance mowing. Different levels of restriction can be placed in different regions of a buffer depending on how wide and densely vegetated the buffer zone is. In general, the shoreline region should serve as a "no-touch" zone, though uses such as passive recreation, including limited access paths for walking and canoe launches, can be allowed. The second zone should be limited to passive management and consist of shrub land and trees. The third and final zone, farthest from the surface water resource, would consist primarily of wooded canopy and can be managed for heavier foot and bicycle traffic and may be acceptable for stormwater BMPs with a LID design.

6. *Public Access or Recreation:* In both urban and rural settings, river corridors provide good opportunities for trails, or where appropriate, canoe/kayak launch sites. No proposed development adjacent to a vegetated buffer should prevent existing and, where appropriate, new public access to the resource. Any proposed public access or recreation should be consistent with the Community Comprehensive Plan, the State Comprehensive Outdoor Recreation Plan (SCORP) State Guide Plan 152 (RI DEM, 2009), and applicable State regulations.

7. *Redevelopment Criteria:* Any proposed redevelopment of a site containing a buffer zone to an existing surface water or wetland resource should demonstrate that post-development conditions will improve the capacity of the buffer to: provide continued public access to the resource (assuming access exists); protect the resource area from stormwater runoff; and/or provide wildlife habitat. Improvement strategies can include, but would not be limited to:

    - Re-establish vegetation in areas of the buffer that were previously developed or impervious to the maximum extent practicable. A minimum of 25 feet beyond jurisdictional wetlands is recommended. This can be accomplished by requiring a mitigation planting ratio based on new impervious area proposed within an existing degraded buffer (e.g., 3:1).

    - Provide pre-treatment of stormwater runoff directed to the buffer zone, and design site runoff to enter the buffer as sheet flow. Where necessary, incorporate water quality BMPs into the buffer zone to treat concentrated inflow.

- Maintain historic public access points to surface water resources.

- Consolidate access points and restore the buffer zones in old access areas.

- Enhance the existing buffer vegetation with native vegetation and remove exotic and invasive species. Special care should be taken when removing invasive species to compensate for any loss of pollutant attenuation or habitat. Invasive species removal should be performed by a qualified professional[4] and only if a sustainable future condition with native species is assured.

Figure 3-8 Buffer Zone Planting.

Careful placement and installation of native vegetation is required for restoring buffer areas that were cleared. (HW photo)

8. *Buffer Flexibility:* Building flexibility into buffer zone guidelines allows developers to creatively address existing site constraints and, by providing developers with different options, avoids any claims that buffering criteria are too restrictive. Provisions for flexibility relative to buffer zone criteria can include one or more of the following:

   - *Preserving or Restoring Buffer Zones as Open Space:* The applicant may enter into negotiations with the municipality to dedicate a buffer area to the City or Town along with access rights across the property as a potential improvement to the buffer. This situation may be particularly attractive in areas where the resource already provides a significant level of recreational opportunity to the general public. Conservation easements are also an option that a landowner could use as a tax benefit by either donating the land to a land trust or to the community.

   - *Buffer Averaging:* Local criteria for buffer zones can use an averaging approach

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[4] A qualified professional has the educational background and/or experience to properly identify and remove invasive species.

where the average width of the buffer across the site is either optimized or reaches the specific target.

- *Density Compensation:* If buffer restrictions render a significant amount of land as "undevelopable," provisions in local zoning could allow for increased density on the remainder of the site to add value to the development provided that there is adequate infrastructure (water, sewer, and stormwater) to support the increase. An example of density credit calculations can be found in Article 39 of The Practice of Watershed Protection "The Architecture of Urban Stream Buffers" (Schueler et al., 2000).

- *Waivers or Deviations:* As a rule of thumb with any ordinance or land development regulations, language should provide the permitting authority the power to waive a portion of, or reduce a particular criterion where legally permitted by an enabling local ordinance.

- *Off-Site Buffer Restoration:* If the establishment of a buffer on an existing site is not possible, communities can consider requiring a developer to restore a buffer area off-site or place money for restoration in a restricted receipt account, referred to as "fee-in-lieu." In any case the restoration should be in the same watershed. This requirement should be based on clearly stated public needs and policy goals outlined for the community buffer program within the Comprehensive Plan and clear standards would need to be specified in the subdivision and land development regulations.

- *Net-Improvement to the Site:* Examine the quality of existing stormwater discharge or other conditions such as hardened shorelines to find other areas that might be improved in lieu of enforcing stringent buffer width restrictions.

Perceptions and Realities

Perception	Reality
Buffer standards will result in a loss of developable land.	A 100-foot wide stream buffer typically consumes only 5% of land in a watershed. In addition, flexibility can be incorporated into local regulations to protect property owners.
Landowners with buffers are required to provide public access.	Public access is not necessary for an effective buffer program; instead, they can be maintained in private ownership through deed restrictions and conservation easements.
Buffer programs will be a hardship on a community's staff and resources.	In a survey by Heraty (1993), most government participants stated that their staff spent only 1 – 10% more time to administer a buffer program.

RI DEM and RI CRMC already protect all buffers.	RI DEM regulations are limited in some cases, and enforcement of buffers over time is challenging when lots are created adjacent to sensitive buffers.

Successful Buffer Programs

The key to a successful buffer program is education and flexibility. Buffers should be well demarcated by permanent boundaries and/or signage and also clearly noted on all deeds and recorded site plans and subdivision / land development plans. Buffer owners should be educated about their responsibilities and the benefits of buffers. Most encroachment issues are due to ignorance about the buffer program rather than complete disregard. In addition, flexible measures can be incorporated in a buffer program with many of the techniques described above (e.g., buffer averaging, conservation easements, and variances) and can go a long way toward gaining the support of the public.

Figure 3-9 Wetland Buffer Signage.

(A. Kitchell)

Benefits

Buffer zones to fresh and saltwater resources—whether they are rivers, streams, bays, ponds, or wetlands—play an integral role in both protecting these resources and providing habitat for wildlife. The use of local land use authority to preserve or restore vegetated buffers is critical to the overall health of watershed systems and to public health and safety. The following table is taken from the Center for Watershed Protection's The Practice of Watershed Protection (Schueler et al., 2000) and clearly illustrates the myriad of benefits derived from proper buffer management and restoration. Specific benefits as related to stormwater and economics are listed below Table 3-2.

Table 3-2: Twenty Benefits of Urban Stream Buffers

(ƒ) = Benefit Amplified by or Requires Forest Cover

1. Reduces watershed imperviousness by 5%. An average buffer width of 100 feet protects up to 5% of watershed area from future development.

2. Distances areas of impervious cover from the stream. More room is made available for placement of stormwater practices, and septic system performance is improved. (ƒ)

3. Reduces small drainage problems and complaints. When properties are located too close to a stream, residents are likely to experience and complain about backyard flooding, standing water, and bank erosion. A buffer greatly reduces complaints.

4. Stream "right of way" allows for lateral movement. Most stream channels shift or widen over time; a buffer protects both the stream and nearby properties.

5. Effective flood control. Other, expensive flood controls not necessary if buffer includes the 100-yr floodplain.

6. Protection from streambank erosion. Tree roots consolidate the soils of floodplain and stream banks, reducing the potential for severe bank erosion. (ƒ)

7. Increases property values. Homebuyers perceive buffers as attractive amenities to the community. 90% of buffer administrators feel buffers have a neutral or positive impact on property values. (ƒ)

8. Increased pollutant removal. Buffers can provide effective pollutant removal for development located within 150 feet of the buffer boundary, when designed properly.

9. Foundation for present or future greenways. Linear nature of the buffer provides for connected open space, allowing pedestrians and bikes to move more efficiently through a community. (ƒ)

10. Provides food and habitat for wildlife. Leaf litter is the base food source for many stream ecosystems; forests also provide woody debris that creates cover and habitat structure for aquatic insects and fish. (ƒ)

11. Mitigates stream warming. Shading by the forest canopy prevents further stream warming in urban watersheds. (ƒ)

12. Protection of associated wetlands. A wide stream buffer can include riverine and palustrine wetlands that are frequently found along the stream corridor.

13. Prevent disturbance to steep slopes. Removing construction activity from these sensitive areas is the best way to prevent severe rates of soil erosion. (ƒ)

14. Preserves important terrestrial habitat. Riparian corridors are important transition zones, rich in species. A mile of stream buffer can provide 25-40 acres of habitat area. (ƒ)

15. Corridors for conservation. Unbroken stream buffers provide "highways" for migration of plant and animal populations. (ƒ)

16. Essential habitat for amphibians. Amphibians require both aquatic and terrestrial habitats and are dependent on riparian environments to complete their life cycle. (ƒ)

17. Fewer barriers to fish migration. Chances for migrating fish are improved when stream crossings are prevented or carefully planned.

18. Discourages excessive storm drain enclosures/channel hardening. Can protect headwater streams from extensive modification.

19. Provides space for stormwater BMPs. When properly placed, the outer zone of the buffer can be an acceptable location for stormwater practices that remove pollutants and control flows from urban areas.

20. Allowance for future restoration. Even a modest buffer provides space and access for future stream restoration, bank stabilization, or reforestation.

Stormwater Benefits

Effective resource buffers minimize the need for flood control by helping to attenuate stormwater flows before they reach a water body and allowing the lateral movement of streams. By preventing development in the buffer area, the overall quantity of stormwater in the watershed is reduced, which will also help to reduce streambank erosion and flooding. Finally, vegetated buffers function as natural filtering mechanisms for removing sediment, nutrients, bacteria and other pollutants typically found in stormwater runoff.

Buffers can be very important for coldwater trout streams in particular, not only providing shade for the stream itself but also by helping to cool and infiltrate stormwater before it reaches the stream. They are also sources of large woody debris, which is very important for trout habitat. By infiltrating stormwater runoff, buffers increase groundwater recharge, which in turn helps to maintain the baseflow of the stream.

Economic Benefits

Stream and wetland buffers can actually have economic benefits to communities in the long run. The presence of buffers improves the market value of adjacent properties. As listed in the Better Site Design Handbook (1998), examples of the positive market influence of buffers include:

- When managed as a "greenway," stream buffers can increase the value of adjacent parcels as illustrated by several studies. Pennypack Park in Philadelphia is credited with a 33% increase to the value of nearby property. A net increase of more than $3.3 million in real estate is attributed to the park (Chesapeake Bay Foundation, 1996).
- Nationally, buffers were thought to have a positive or neutral impact on adjacent property in 32 out of 39 communities surveyed (Schueler, 1995).
- Effective shoreline buffers can increase the value of urban lake property. A recent study in Maine found that increased water clarity (visibility depth increased by three feet) resulted in $11 to $200 more per foot of shoreline property, potentially generating millions of dollars in increased value per lake (Michael et al., 1996).

In addition, buffers help save municipalities money by reducing the need for floodwater storage and stormwater treatment. Drainage problems and thus complaints from the public are reduced by buffers, which saves municipal staff time and money. Examples of cost saving which may be realized due to buffer presence include:

- The Minnesota Department of Natural Resources (MN DNR) estimated cost savings of $300 per acre-foot associated with a minimized need for floodwater storage due to the preservation of riparian wetlands;
- Forested stream and shoreline buffers situated on the flat soils of the coastal plain have been found to be effective in removing sediment, nutrients, and bacteria from stormwater runoff and septic system effluent in a wide variety of rural and agricultural settings along the East Coast (Desbonnet et al., 1994);
- Buffers can sharply reduce the number of drainage complaints received by municipal public works departments; and
- Buffers are often an effective means to mitigate or even prevent stream or shoreline erosion.

Case Studies

Within Rhode Island, most communities rely on RI DEM or RI CRMC to regulate buffers to wetlands and surface waters instead of exercising local regulatory authority to help guide new development away from these resources. However, there are some communities that are applying unique strategies within the regulation of wetland, riparian or coastal areas to increase protective measures. There are a variety of approaches for regulating buffers such as: enforcement through zoning overlay districts, applying additional standards on certain uses through special use permits, or addressing the various impacts of wastewater within the buffer area. The standards from two Rhode Island communities, Barrington and South Kingstown, are reviewed here as two different approaches to wetlands protection in local ordinances.

Barrington, Wetlands Overlay District

The Town of Barrington has adopted an overlay district within its zoning ordinance to provide additional protection to its wetland areas. The overlay is described as follows:

> *The Wetlands Overlay District shall consist of coastal wetlands, defined as salt marshes bordering on tidal waters, and freshwater wetlands, defined as those areas of 1/2 acre or greater, that are inundated or saturated with surface and/or ground water at a frequency or duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. (Zoning Ordinance Section 185-171)*

The regulations within the overlay are triggered by new construction, reconstruction, or expansion of existing buildings, or new, expanded, or modified uses of property within 100 feet of the overlay district. One of the primary mechanisms used to protect wetland resources is the list of prohibited activities including:

A. The discharge or introducing of any organic or inorganic chemical or biological pollutants.
B. The storage of any hazardous, toxic or infectious materials or wastes.
C. The placing or depositing of any solid waste or debris.
D. The discharging of any effluent creating a thermal gradient deleterious to indigenous plants, fish or wildlife.

In addition to the prohibited activities, any activity that falls within 100 feet of the overlay district must meet several development standards to be eligible for a special use permit under the overlay regulations. These development standards are provided to minimize, to the degree possible, any negative impacts to the wetlands through the following provisions:

A. All new structures and expansions, paved areas, and land disturbances will be set back at least 100 feet from the wetland edge.
B. The proposed project will not obstruct floodways in any detrimental way, or reduce the net capacity of the site and adjoining properties to retain floodwaters.
C. The proposed project will not cause any sedimentation of wetlands, and will include all necessary and appropriate erosion and sediment control measures.
D. The proposed project will not reduce the capacity of any wetland to absorb pollutants.
E. The proposed project will not directly or indirectly degrade the water quality in any wetland or water body.
F. The proposed project will not reduce the capacity of any wetland to recharge groundwater.
G. The proposed project will not degrade the value of any wetland as a spawning ground or nursery for fish and shellfish or habitat for wildlife or wildfowl.

These regulations provide an additional layer of protection above and beyond the jurisdiction of RI DEM and RI CRMC. The overlay district method is a very straightforward approach for local communities that have the capacity for a comprehensive wetlands mapping process to determine appropriate boundaries for the district.

Readers interested in looking more closely at this suite of strategies can review the ordinance through the Town's website: http://www.ci.barrington.ri.us/. The applicable text of the zoning ordinance begins in ARTICLE XXV, § 185-169 — § 185-179.

South Kingstown, Special Use Permits

The Town of South Kingstown provides additional protection to wetlands through identifying uses that trigger a special use permit within the Town's zoning ordinance.[5] Several items have been identified for this additional permitting requirement, such as: individual sewage disposal systems (ISDS)[6] , hazardous waste management facilities, and accessory apartments. The regulations for such uses are as follows:

No ISDS shall be allowed within:

- 150 feet from a freshwater wetland
- 150 feet from a river
- 200 feet from a flowing body of water having a width of 10 feet or more
- 150 feet from a floodplain
- 150 feet from a coastal wetland

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[5] It should be noted that the Town of South Kingstown was considering amendments to this ordinance at the time this manual was being drafted. No changes had been made before the manual was published, but readers may find that certain provisions have changed when compared to the case study presented here.

[6] Since the adoption of this ordinance, RI DEM has changed their official name for septic systems from Individual Sewage Disposal Systems (ISDS) to On-site Wastewater Treatment Systems (OWTS).

No hazardous waste management facility shall be allowed within 500 feet of areas identified as freshwater wetlands or areas in a special flood hazard district.

An accessory apartment which is not serviced by a public sewer system may be established by special use permit only, and the accessory apartment along with the associated ISDS must meet heightened standards relative to its location near wetland resources.

Readers interested in looking more closely at this suite of strategies can review the ordinance through the Town's website: http://www.southkingstownri.com/town-government/municipal-departments/building-inspection-and-zoning. The applicable text of the zoning ordinance begins in Section 504.

Suggested Resources

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Appendix F

Datasheets from Dam, Culvert, and Geomorphic Assessments in the Beaver River Watershed (F&O, 2017)

RI WAP AND COMPREHENSIVE PLANS

Municipalities are strongly encouraged to incorporate specific goals for wildlife conservation and the ***RI Wildlife Action Plan (RI WAP)*** Conservation Opportunity Areas (COA) mapping into their Comprehensive Plans. Statewide Planning recognized the importance of COAs and Ecological Community Classifications by including them in their revised GUIDANCE HANDBOOK #2: PLANNING FOR NATURAL RESOURCES and GUIDANCE HANDBOOK #15: MAPPING FOR COMPREHENSIVE PLANS that supplement the Comprehensive Planning Standards Manual. Safeguarding COAs is an effective way to try to conserve all the species and habitats in a municipality (i.e. keep species from becoming rare as well as protect those that are already rare) rather than focusing only on the Natural Heritage polygons (i.e. known populations of rare species only). As such, I'm trying to get municipalities away from the strong tendency to include the Natural Heritage layer and then call it a day for addressing wildlife conservation. Below is some background on incorporating RI WAP into comprehensive plans and using the COA map.

For some of the more rural towns, the COAs can seem too numerous to be useful for planning purposes and/or to be politically palatable as conservation targets. If the Cores are too numerous to be useful for the Town's purposes, a more focused approach would be to prioritize the largest ones for conservation and to focus on expanding already conserved lands within forest Cores.

The following information on COAs and incorporating habitat into Comprehensive Plans is summarized from the ***RI WAP Companion Guide***.

Conservation Opportunity Areas (COAs)
COAs provide an inclusive, landscape-scale approach to wildlife conservation that is particularly relevant to the long-range planning efforts represented by municipal Comprehensive Plans. COAs help identify areas critical to preserving Rhode Island's rich fish and wildlife heritage. They are composed of three elements (**Core Natural Areas, Corridors**, and **Sites**). Collectively, these three elements provide wildlife with sufficient room to move within and among suitable habitats and are critical to safeguarding RI's full suite of key species and habitats. As such, they are an important addition to a suite of mapping tools that continues to evolve with new and more specific information.

Core Natural Areas are large undeveloped habitat patches that do not contain roads and are targeted for land preservation and creative land use techniques to minimize fragmentation. Decision makers are urged to conserve the largest blocks of undeveloped land within their communities and to consult with neighboring communities when identifying COAs and seeking assistance to conserve pieces they couldn't on their own.

Corridors are pieces of land that connect Core Natural Areas. They often follow rivers, particularly in more urban areas, but may also be wetlands or other undeveloped lands. Wildlife must be able to move freely between undeveloped lands and across political boundaries. This "room to move" is particularly important given the uncertainties of climate change on future habitat conditions. Fish and wildlife rely on habitat connectivity to find scarce resources, preserve gene flow, and locate alternatives to lost habitat. Connectivity is vital to maintaining plant and animal diversity, so identifying corridors is critical.

Sites are smaller areas that have one or more unique values (other than size) deserving protection. Sites contain specialized habitats, rare species, wetlands, sensitive surface waters, or other features that communities should protect. Sites also contain high variety Ecological Land Units (ELUs). ELUs assess the physical diversity of the landscape as a surrogate for biological diversity. This is important because sufficient biological information is often lacking. ELUs also consider climate change because diverse areas are typically more resilient than the surrounding landscape. We can't know what species will occupy these areas in the future, but we can assume they'll continue to support a diversity of species even as the climate changes.

Municipalities and Local Comprehensive Plans

Comprehensive Plans are one of the most powerful tools municipalities have to protect land and ensure its appropriate management. If a municipality wishes to protect wildlife habitat effectively, including the enactment of ordinances or regulations, it must address this topic sufficiently in its comprehensive plan.

- Section 6 of the Rhode Island General Laws' *Rhode Island Comprehensive Planning and Land Use Act* (§45-22.2-6) lists the required content of a comprehensive plan. The **most important sections for addressing wildlife conservation are within the goals and policies, maps, natural resources, and implementation sections.** The goals and policies section should include a long-term vision for natural resource conservation, including fish and wildlife Species of Greatest Conservation Need (SGCN) and habitat protection. The maps and natural resource sections should include *all* natural resources and be guided by the COAs and other mapping in RI WAP. **The natural resources section should not only provide an inventory of wildlife habitats and other resources, but should also address the local value of these wildlife habitats, as well as "goals, policies, and implementation techniques for the protection and management of these areas." The implementation program should refer back to the wildlife conservation objectives and describe a plan to meet them, including any municipal actions required to adopt or amend any codes or ordinances to conform to the comprehensive plan. The zoning ordinance and map may need to be amended and the land use section should also address the process and schedule by which these amendments will be made to accommodate wildlife.** For example, plans can be written or amended to include policies on protecting undeveloped habitat blocks**.**

GETTING STARTED

Municipal planners should start by reviewing their existing comprehensive plan. What is said regarding goals for the community? Is habitat included? If not, goals and policies for protecting habitat should be added. Municipalities can use the COA mapping to identify areas where development or redevelopment may be directed to avoid sensitive habitat and preserve community character. A simple start could be to add language indicating that development should be directed away from COAs and that COAs should be protected to the extent possible. Town planners can also note if there are any future road or utility plans for undeveloped blocks of land, as town infrastructure policies can contribute significantly to habitat fragmentation, and it is more economically and environmentally sound to avoid areas that do not have existing infrastructure.

Incorporating Habitat into Comprehensive and Open Space Plans

RI municipalities are required to prepare an open space inventory for their comprehensive plans. Using the mapping resources above, municipalities can work with local land trusts and other conservation organizations to identify parcels adjacent to already-conserved properties or public lands that, taken together, would protect new core natural areas or expand existing ones. The goal is to protect a range of resources, including habitat, unique or rare geologic or landscape features, water quality, historical sites, scenic views, important landscapes, farms, and trail systems, and these resources often overlap. Include the RI WAP COAs or go a step further and prioritize your town's individual needs based on specific habitat and other natural resource information.

For further detail, please see *Appendix: Wildlife Habitat Protection Checklist* in the RI WAP Companion Guide.

MAPPING TOOLS

The Conservation Opportunity Areas (COA) mapping

- Paul Jordan has included both a downloadable map package and an online version of this map in the RIDEM Map Room Gallery. For those who want to use desktop GIS to incorporate the layers, the statewide COA map is (currently) the second map in from the right on the bottom row. Clicking on it will download a map package you can bring into new or existing maps. Feel free to contact me if you are having any trouble getting around these layers.

RI Ecological Community Classification (ECC) mapping

- This is another statewide GIS layer that shows land use/land cover from an ecological perspective (i.e. by plant communities/habitats). This map is a great resource for a number of uses. It's based on the Natural Communities of Rhode Island (NCRI). Enser, R.W. and J.A. Lundgren. 2006, which were used to identify the terrestrial key habitats in the RI WAP. The Natural Communities classes and RI WAP habitats are not 100% interchangeable with the ECC mapping because the mapping thus far has not been at a level of detail sufficient to break out everything (i.e. understory information is not presently included). That said, it's a great start!

The ECC mapping is included in the online map of COAs; you just need to turn it on in the online viewer. You can also download a zip file for desktop GIS use on the RIGIS website: http://www.rigis.org/datasets/ecological-communities-classification.

ENERGY

- Focus on efficiency first.
- Leading by example on energy conservation efforts might be supplemented with an incentives/recognition program for exemplary businesses and residents. Such a model might be applied to many other conservation efforts as well.

LIGHTING AND WILDLIFE

While light pollution has long been an issue, it has become urgent to consider new aspects of the problem because of the rapid conversion of outdoor lighting to LEDs and the building evidence that not all LEDs are created equal when it comes to the wellbeing of people and wildlife. Ideally the take-away messages from this information would make it into the town comprehensive plan (and outreach to citizens) and then be addressed accordingly whenever the town selects bulbs, fixtures, etc. Beyond capital improvement projects, the town could institute a town-wide ordinance and/or private incentive program. There are several towns in RI that have ordinances that could serve as guidance along with the information below. This information is not intended to villainize LEDs, which are a valuable tool to save energy and money, and which have useful features, such as the ability to be dimmed considerably. It is intended to facilitate careful consideration of which types to use and which fixtures and other techniques (dimmers, timers, etc.) to use with whatever bulbs are selected.

ISSUES, LINKS, and RECOMMENDATIONS

Please consider using International Dark Sky Association (IDA) standards for any outdoor lighting. One concerning issue that's arisen from the extensive conversion of street and other outdoor lighting to LEDs is that many of the more common and "cost-effective" LEDs are within the blue or "cool white" color spectrum. There is a body of evidence indicating that these types of lights are unhealthy for us as well as for wildlife in most outdoor/night time conditions. The International Dark-Sky Association, Florida Fish & Wildlife Conservation Commission, Harvard Health Publications, and Earth Island Journal have all put out interesting and somewhat alarming materials related to this issue as it affects humans, animals, and even plants.

Perhaps most compelling, the American Medical Association issued a press release and report of its findings on the topic in June of 2016. The recommendations at the end of the latter are consistent with guidance adopted by the International Dark Sky Association in 2014 (IDSA LED Practical Guide), namely to **use only as much light as necessary, keep it low and shielded, make use of dimmers, and minimize the amount of blue light emitted by keeping the Correlated Color Temperature (CCT) below 3000 Kelvin**. This last recommendation addresses the blue light issue directly. In addition to the obvious benefits, the other recommendations indirectly benefit everybody by avoiding unnecessary light exposure, including to species that are most impacted by portions of the light spectrum other than blue (like birds, for example).

The IDA website is full of great information/links, but some of the most useful for municipal staff and their advisors are:

- Outdoor lighting basics and the
- LED Practical guide. It's important to select the right LEDs rather than vilify them. This is an especially important point as so many towns are converting over to LEDs for cost and energy-savings reasons. For that reason, the title of the IDA press release (*AMA Report Affirms Human Health Impacts from LEDs*), is a bit regrettable, since the AMA report itself is far more measured and offers solutions to allow for safer use of LEDs in communities.

The "lighting" tab of the IDA main page also has a lot of information geared toward policy makers, planners, and advocates (ordinances and such).

There are a lot of public outreach materials as well. These brochures are a succinct way to catch people's attention and share some of the more powerful reasons to care about this issue. A few of the most compelling are the:

- IDA general brochure,
- IDA health brochure,
- IDA safety brochure,
- And of course, the IDA wildlife brochure ties this issue directly to my project.

There are also visuals throughout that depict what the recommended actions would look like so people don't think they are being asked to do away with nighttime lights altogether.

To actually "see" local light pollution, a compelling map can be found at https://www.lightpollutionmap.info/. While it's always best to stick with the original source of the data, which can be found here, the former website is a bit more user-friendly for a quick peak at a given neighborhood or town.
Finally, if such lights are already in, they are unlikely to be changed over absent some serious public outcry (which has happened in some places across the country). In that case, it still makes a lot of sense to ease the harm by relying on the other facets of protecting dark skies (dimming, shielding, etc.) to minimize human and wildlife exposure most efficiently. One of the big benefits of LEDs is the ability to dim them quite a bit where and when appropriate. It should be reiterated that these "other facets" are really the top priority regardless of the color of a bulb, since species react differently to different portions of the light spectrum, and they minimize unwanted exposure to all light. A blue bulb shining in neighborhood windows at night is far more damaging than one that's only shining down at the road and sidewalk it's intended to illuminate.

The above information about the health benefits of doing so may assist the town in encouraging residents to adopt Dark Sky-compliant lighting voluntarily on private land and/or to be more supportive of a Dark Sky Ordinance that applies to businesses and/or residents.

RENEWABLE ENERGY

Renewable energy is preferable to fossil fuels for numerous reasons. It is perhaps even a good thing that the consequences of localized power are felt close to home, as they are easier to see and harder to ignore. Regardless, it's very important to try to minimize these costs by making siting and design decisions that make use of the best available science to minimize impacts to wildlife (e.g. birds, bats, marine mammals etc.) and humans. Nearly all industrial-scale energy development has the potential to consume large amounts of undeveloped land if improperly sited. Converting woodlands and limited active farmland acreage isn't desirable, and the decommissioning of infrastructure to return to farmable soils, woodland, or other viable open space is not a simple matter.

Woodlands and open fields provide important wildlife habitat. Woodlands themselves combat the effects of climate change by cleaning and cooling the air and reducing carbon emissions, and food grown on local farms doesn't need to be transported into the state. As such, all three of these land uses (renewable energy, woodlands, and local food) are important to increasing resiliency and reducing emissions in Rhode Island and beyond. Planning and siting decision makers should take great care to see that these become complementary rather than competing uses and that one does not suffer for the other(s). This document is specific to wildlife and habitat conservation. Please also see the Office of Energy Resources Solar Guidance and Model Ordinance Development page for additional resources and points to consider.

- Renewable energy should be encouraged and incentivized on sites that are already developed and zoned for commercial or industrial use, including landfills and brownfields.
- For solar, commercial, industrial, and residential rooftop installation should be prioritized first and foremost. Many roofs are likely to have good sun exposure with little or no site alteration, and such installations require no additional space and have no impacts to wildlife (win-win).
- Expanding ground solar or wind installations to residential zones is not recommended without some well-considered restrictions to prevent fragmentation and loss of forest and farmland.
- It may be appropriate to add a geographic component to a renewable energy ordinance that calls for avoiding sensitive natural areas and other important resources.
- If the municipality is going to entertain proposals to construct wind energy facilities, a proactive assessment of land use/availability and efficacy of wind is recommended.
- As with any form of development, careful consideration should be given to where renewable energy installations may or may not be appropriate so that the municipality can guide these elements rather than permit requests driving them.

With respect to wildlife, not only siting, but also design, installation, and operation are all important considerations.

- Ordinances should consider BMPs for projects (for instance, blade speeds on wind turbines influence bat mortality, so cut-in speeds have become one common BMP in the northeast).
- Amend or refine zoning regulations and design standards for renewable energy systems at regular intervals. This is really important as the science (and thus Best Management Practices) of renewables continues to advance (e.g. scientists are still learning what influences bat activity around turbines and working on how to reduce mortality).
- Regulations should also confer responsibility for decommissioning energy facilities and their attendant infrastructure at the end of their serviceable life. This includes a decommissioning /restoration plan and financial security. See OER's Model Ordinance Templates Zoning and Taxation (Appendix B) for recent RI and MA decommissioning payment types and amounts.

NATURAL RESOURCES AND LAND USE

Please see the RI WAP section above for information on identifying, prioritizing and mapping Natural Resources.

RETAINING HABITAT: FORESTS AND FARMS

While wetlands have a degree of protection, wildlife (unless it is a rare species that uses regulated wetlands) and other important natural resources (forests, etc.) do not. If these other resources aren't identified, if actions aren't set forth to protect them, and if programs such as Farm, Forest and Open Space, Transfer of Development Rights, Low Impact Development, and other Smart Growth techniques aren't employed where appropriate, they won't be preserved.

- Encourage and assist farm and woodland owners in acquiring funding to conserve their land, including the acquisition of conservation easements and promoting use of the Farm, Forest and Open Space Program to eligible landowners. With substantial landowner participation, this program could complement land acquisition, conservation easements, and other programs to protect working land, water quality, wildlife habitat, etc.

- With respect to preserving forest and farm land, the Town may also wish to revisit its zoning and other regulations to make sure that appropriate accessory businesses, which can help wood lot and farm landowners stay on their land, are supported. Grow Smart Rhode Island is a great resource on this issue, as they have staff on-hand willing to work with towns to meet their unique needs. Grow Smart RI is also a great resource for information on other smart growth techniques.
- As technology affords increasing opportunities for people to work from home and roads become increasingly congested, the Town may want to revisit its zoning and other regulations to make sure they support home businesses in general.

The RI Woodland Partnership (RIWP) recently issued a position statement on *Preventing the Loss of Rhode Island's Forests*. It includes the action "Take a leadership role: No state or local policy should result in and/or encourage the loss of forest land."

- Adoption of this or similar language, as well as comparable commitments to conserve other valued natural resources (e.g. farmland), would help to reinforce the importance of these resources and provide a metric by which decisions should be evaluated.

The following additional resources are good ones to cite for the importance of forests in general and for mitigating climate change specifically. Together, they paint a strong picture for why retaining forests and increasing renewable energy cannot be an either-or approach if we are to meet our emissions reduction goals.

Currently, there are no strong State policies in RI to prevent renewable energy siting in green fields, but you can reference the ***Rhode Island Wildlife Action Plan*** and ***Rhode Island Forest Resources Assessment And Strategies: "A Path To Tomorrow's Forests"*** (aka the Forest Action Plan) as having policies that discourage the fragmentation of forest.

- In addition to its 2017 position statement on *Preventing the Loss of Rhode Island's Forests*, the Rhode Island Woodland Partnership (RIWP) also issued a 2015 position statement on *The Importance of Rhode Island's Forests in Mitigating and Adapting to Climate Change*. If you site either, RIWP asks that you include a link to their page as well.

- ***Rhode Island Forest Resources Assessment and Strategies: "A Path to Tomorrow's Forests"***
  This plan lays out the value of forests to RI. Although this Plan is due to be updated, the June 2010 version is the most recent official version. It incorporates climate change mostly by reference to another publication, *FORESTRY, AGRICULTURE, AND LAND USE CHANGE STRATEGIES FOR REDUCING GREENHOUSE GAS EMISSIONS IN RHODE ISLAND: A Report to the Forestry Working Group of the Rhode Island Greenhouse Gas Process* (included in the Plan as Appendix D). Table ES-1 of this report sums up some of the implementation pathways for mitigating climate change, and as one can imagine it advocates for forest land conservation, management, and restoration as well as (to a lesser degree) forward thinking agricultural practices.

- The much more current 2016 Rhode Island Greenhouse Gas Emissions Reduction Plan also provides mitigation pathways. In addition to a host of energy conservation and technology adoption approaches, the plan discusses Non-energy GHG reduction measures, including *Land Use, Land-Use Change, and Forestry (LULUCF)* (p. 79), a "mitigation strategy that assumes no net loss of forest, wetlands, and pasture lands in RI from 2017 to 2035. The strategy represents a scenario where Rhode Island households shift to more dense residential developments, and where demand for new housing and commercial development is met by filling in already developed lands before developing natural lands."

The climate change piece of forest conservation, with its attendant plans already out there in support of the need to maintain forests at current levels, may help strengthen a case that already includes water quality, wildlife, etc. The reverse is also true. The more places these reports are cited and the larger the audience that's aware of them, the more it might bolster the will to execute something like a "no net forest loss" approach with its obvious ecological dividends.

LAND USE TECHNIQUES

Communities should make development and zoning decisions at a statewide scale before such decisions are forced by an individual application for zoning changes. Transfer of Development Rights (TDR), Rural Residential Compounds, Village development, Mixed Use development, Conservation Development, and strong policies for siting commercial development, energy, etc. are tools to consider sooner rather than later. It is even more true that municipalities' hands are tied when said developer *doesn't* require a zoning change to do something harmful because it's an allowed use. As such, ordinances should be well considered and clear.

In accordance with *LandUse 2025,* encouraging additional public services outside of the Urban Service Boundary is not advised.

- Consider a comprehensive build-out analysis to estimate future residential development potential in town. If full build out occurs, minimum Rural Residential/Agriculture designations are not enough to prevent sprawl. In fact, medium to large minimum lot size can contribute to it without other measures in place. As such, showing full build-out (i.e. what can happen without additional proactive planning) can be a powerful motivator to help citizens embrace additional land conservation and smart growth techniques.

- Consider zoning changes that would expand options for mixed used, two-family and multi-family units as appropriate.

- A Transfer of Development Rights (TDR) Program is one of the most effective tools for towns with both heavily developed sections and a strong rural component to retain their character. It allows towns the flexibility to encourage and incentivize redevelopment and infill development wherever appropriate and is perhaps the best way to amend the FLUM to guide development (i.e. by identifying sending and receiving areas). Aware that TDR is not a one-size fits all approach, DEM and partners developed a Rhode Island Transfer of Development Rights Manual in 2015 that is an excellent reference.

- Recommend establishing an action and associated implementation schedule for TDR. TDR target sending areas could include large forested Cores from the COA map and areas adjacent to already preserved lands to ultimately expand them into larger cores for people and wildlife.

- Conservation Development is a preferable alternative to cluster development, the latter of which often results in much less meaningful open space conserved than the former. Consider replacing a Cluster Subdivision Ordinance with a Conservation Development ordinance.

- Transit-Oriented Development is another technique the town may wish to consider.

- Commercial Uses should be place-sensitive, relatively compact and well defined.

- Incorporate Low Impact Development (LID) techniques to reduce impervious surface cover and curb polluted runoff. It is better to make these techniques a requirement rather than a recommendation; not only does this provide more force behind them, but it also insulates Planning Boards from losing this important priority/measure to turnover.

- While it is advisable to incorporate as much of the Rhode Island Low Impact Development Site Planning and Design Guidance Manual as applies, one really important measure the town can take from a wildlife perspective is to require site footprinting so that land is not cleared as a matter of course on development projects. Site footprinting (LID Manual, p. 39) is "a technique that reduces clearing to the minimum area required for building and roadway footprints, construction access, and safety setbacks."

- Consider developing and implementing a Town-Wide Soil Erosion and Sedimentation Control Ordinance, and Earth Excavation Ordinance. Rhode Island's comprehensive Soil Erosion and Sediment Control Handbook, revised in 2014, includes a model ESC ordinance, and the RI LID Manual addresses the value of such municipal ordinances and additional recommended practices.

- Review setbacks. Consider that large front-yard setbacks can tend to promote more clearing than is needed for house lots and thus contribute to fragmentation. They also necessitate longer driveways and thus more impervious or compacted/erodible surface. When building size and form fit the rural landscape, it is less of a concern to "hide" them off the road. Additionally, when ample open space is protected, the appearance of residential homes in villages and more sparingly on rural roads should not detract from rural character. Maintaining more natural vegetation in front yards as screening can also help to maintain this aesthetic even with houses closer to the road.

- In addition to RIDEM's LID Manual, RIDEM's Wetland BMP Manual: Techniques for Avoidance and Minimization (April 2010) might prove helpful. Although the target audience for the latter publication is primarily developers and their consultants, the publication contains BMPs that the Town might wish to promote either as guidance or something more forceful.

LAND MANAGEMENT

- Consider a mix of regulatory, incentive-based, and education/outreach solutions to address landscaping; drainage; impervious surface cover; the use of native species; minimizing fertilizers, pesticides, household chemicals, and other pollutants; etc.
- Adopt a native species policy that specifies the use of native plants for all street trees and other landscape plantings, and clearly define "native species" as RI-native. Many non-natives used for their aesthetics or other attributes have proved themselves invasive only after decades (sometimes over a century) of "behaving" on the landscape. Planting natives employs the precautionary principle and serves to benefit wildlife and promote sense of place at the same time.
- If a RI-natives only policy is not acceptable to the town, there should at least be a provision to exclude non-native species even suspected to be aggressive (i.e. potentially invasive), and this language should be incorporated into all sections of town ordinances that address plantings.
- Avoid cultivars and so-called "nativars." Monikers like 'October glory' after the Latin name of a plant indicate selective breeding for certain traits that are considered desirable (to people), sometimes to the point where a nursery species has little in common with the original wild-type in terms of what makes it useful to a critter. A classic example is that the double blooms that gardeners prize so much can shut out bees from accessing their pollen.
- Where possible, institute a 'no mow' policy on town-owned land (roadsides, open fields, etc.) to provide habitat for beneficial pollinators and other wildlife. This would involve mowing only as necessary to maintain the desired conditions, generally once per year or less and in the dormant season (ideally at the beginning of March) to avoid impacts to breeding and nesting wildlife, such as turtles and songbirds, as well as to flowering plants.
- If the town does outreach, include education about why more natural, native-based landscaping is important for wildlife as well as a sense/pride of place. Include education on minimizing the use of chemicals in and out of the home for humans and wildlife.
- Capitalize on excitement about native plants and pollinators and encourage/incentivize residents and businesses to convert unused portions of lawn to more low-maintenance, drought-tolerant habitat for birds, butterflies, and other wildlife. These can include pollinator gardens as well as rain gardens that also help reduce stormwater runoff.
- Demonstration gardens/landscapes are an opportunity to showcase functional and aesthetic benefits as well as promote now uncommon native plants.
- Reach out to businesses and provide some kind of PR incentive for businesses to landscape in a way that reduces stormwater and pollutants and increases habitat.
- For coastal communities, Save The Bay's *Bay-Friendly Backyards* *webpage* *and* *brochure* *provide some nice information and examples.*

MANAGING ACCESS ON SENSTIVE LANDS

From a wildlife perspective, it makes sense to make a distinction between lands that are primarily for public access and recreation (passive or active) and those that are primarily for natural resource conservation and to strike a balance between wildlife/natural resource protection and access/recreation needs on mixed properties. These goals need not always be at odds, but just as excessive use can reduce an area's ability to safeguard drinking water resources, excessive foot traffic, trails, etc. reduces an area's value for safeguarding sensitive plants and animals, particularly when such access cuts through the sensitive inner portions of forest tracts and other important habitats.

- As such, it makes sense to identify the most important properties (or portions of properties) where access/trails should be minimal and to develop and encourage access on other parcels. This approach also makes sense as the Town considers how to promote tourism, as it can be deliberate about which properties it advertises and influence access that way as well.
- On conserved lands with a wildlife conservation component, evaluate the need to extend trail networks before doing so. If trails are warranted, evaluate the best path prior to taking action. If the Town would like more guidance on siting trails, please feel free to contact the RI WAP Community Liaison, at amanda.freitas@dem.ri.gov.
- Localized vehicle parking, seasonal access, and mowing schedules and are additional ways to protect resources while still allowing the public access when and where it is least harmful.

HOUSING

In many towns, the 20-year population and corresponding housing need projections speak of a need for significant additional LMI housing much more so than a need for more total units.

- Therefore, it very much behooves towns to develop an affordable housing plan so they are not forced to accept all development proposals that involve at least 20% LMI units. Such developments have the potential to grossly over-develop the Town while dragging out the progression to 10% LMI overall.
- The efficacy of density bonuses and all other options to both increase LMI housing and reduce sprawl can be strengthened with the designation of sending and receiving areas under a TDR program.

COMMUNITY SERVICES AND FACILITIES

WASTE REDUCTION

- Research ways to educate and incentivize commercial establishments to recycle, particularly large producers of recyclable materials.
- Make waste reduction and composting prominent initiatives alongside recycling programs. Recycling is important, but people are often unaware or easily forget that plastic recyclables only have one or two more "lives" before they cannot be downcycled any further and become trash. Since there is so much packaging and so many single use products out there, a lot of waste reduction involves purchasing decisions long before it is time to compost, throw away, or recycle.
- As such, waste reduction campaigns can also target businesses to be greener and help their customers feel more welcome to do "green" acts like bring in their own bags, coffee mug, etc. Many businesses even have financial incentives programs for such things that for whatever reason they don't promote. And many people tend to feel awkward doing such things if they perceive they'll stick out or they don't know about a sanctioned program.
- With businesses and institutions, recommend increasing durables and compostables over plastic recyclables. Perhaps a program to reward businesses that do this or are transitioning (it could be PR rather than financial)?

ECOMIC DEVELOPMENT

- Explore areas with potential for redevelopment and economic revitalization with the smallest impact to community character, natural areas, and wildlife. This includes developed areas that are currently underutilized by business but have substantial residential populations. These areas often have great potential for both functional and aesthetic improvements.

- Promote agricultural activities through the Small Business Association and the RI Conservation Districts.

- Other potential information sources to help farmers keep farming, (e.g. on-farm businesses; assistance with legacy planning; farm to plate, table, or institution; etc.) include the Natural Resource Conservation Service (NRCS), RI Food Policy Council, Land For Good, the Northeast Organic Farming Association of RI (NOFA/RI), and the Southeastern Massachusetts Agricultural Partnership (SEMAP).

TRANSPORTATION

- Consider multimodal transportation options, including complete streets, increased linkages, and a comprehensive parking plan. All of these can reduce incentives for congestion and sprawl.
- Sidewalks/design of new developments: When the Town is planning roadways, curbing, etc. in areas of known vernal pools especially, please consider that one way to help vernal pool amphibians where they cross roads during migration and mating season is to design curbs and other measures that don't impede their movement or trap them. One of the best sources on this is Calhoun and Klemens 2002. If the Town is interested in identifying places this may be appropriate, or where seasonal street signs might alert passersby of the migration happening on these nights, please contact the RI WAP Community Liaison.

Appendix C

Quality Assurance Project Plan (QAPP)

Datasheets from Dam Assessments in the Beaver River Watershed (F&O, 2017)

DAM SAFETY INSPECTION

NAME OF DAM: Decappett Pond Dam
STATE ID #: 230
AKA NAME:
WATER COURSE NAME: Beaver River

DAM LOCATION INFORMATION

CITY/TOWN: Richmond
LAT. / LONG.: 41.521328 -71.640602
STATE: RI
HAZARD CLASS: Low

GENERAL DAM INFORMATION

TYPE OF DAM: Earthan embankment with upstream and downstream stone masonry walls
PURPOSE OF DAM: Old Mill
YEAR BUILT: Unknown
OVERALL LENGTH (FT): ~150'
STRUCTURAL HEIGHT (FT): 10'
EL. NORMAL POOL (FT):
HYDRAULIC HEIGHT (FT): 7'
EL. MAXIMUM POOL (FT):

INSPECTION SUMMARY

DATE OF INSPECTION: 8/4/2015
NAME OF INSPECTOR: MKF
TIME OF INSPECTION: 11:30
OTHER ATTENDEES: NJL
WEATHER CONDITIONS: 80s Sunny

GENERAL DAM DATA

PRIMARY SPILLWAY TYPE: Stone Masonry Overflow
AUXILIARY SPILLWAY TYPE: Conduits
PRIMARY SPILLWAY LENGTH: 12'
AUXILIARY SPILLWAY LENGTH: 1' and 4" diameters
NUMBER OF OUTLETS: 1
TYPE OF OUTLETS: Unknown (partially collapsed, seeping)
HAS THE DAM BEEN BREACHED OR OVERTOPPED? Appears to have been overtopped
IS THERE A FISH LADDER (LIST TYPE IF PRESENT)? No
DOES THE CREST SUPPORT A PUBLIC ROAD? No
ACCESS CONDITIONS TO THE SITE: Fair-- wooded but accessible down a steep slope

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

EMBANKMENT (D/S SLOPE)

AREA INSPECTE	CONDITION	OBSERVATIONS
D/S SLOPE	1. WET AREAS (NO FLOW)	None (wall)
	2. SEEPAGE	
	3. SLIDE, SLOUGH, SCARP	
	4. EMB.-ABUTMENT CONTACT	
	5. SINKHOLE/ANIMAL BURROWS	
	6. EROSION	
	7. UNUSUAL MOVEMENT	
	8. VEGETATION (PRESENCE/CONDITION)	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

EMBANKMENT (U/S SLOPE)

AREA INSPECTEI	CONDITION	OBSERVATIONS
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	None (wall)
	2. SLOPE PROTECTION TYPE AND COND.	
	3. SINKHOLE/ANIMAL BURROWS	
	4. EMB.-ABUTMENT CONTACT	
	5. EROSION	
	6. UNUSUAL MOVEMENT	
	7. VEGETATION (PRESENCE/CONDITION)	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

INSTRUMENTATION

AREA INSPECTE	CONDITION	OBSERVATIONS
INSTR.	1. PIEZOMETERS	None Observed
	2. OBSERVATION WELLS	
	3. STAFF GAGE AND RECORDER	
	4. WEIRS	
	5. INCLINOMETERS	
	6. SURVEY MONUMENTS	
	7. DRAINS	
	8. FREQUENCY OF READINGS	
	9. LOCATION OF READINGS	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

DOWNSTREAM WALLS

AREA INSPECTE	CONDITION	OBSERVATIONS		
D/S WALLS	1. WALL TYPE	Unmortared/ partially collapsed stone masonry		
	2. WALL ALIGNMENT	Collapsed in sections		
	3. WALL CONDITION	Poor-- partially collapsed		
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: 9'	max: 12'	avg: 11'
	5. SEEPAGE OR LEAKAGE	None observed (water seems low) there is a defined flow path downstream; but observed efflorescence in the downstream area (not on walls)		
	6. ABUTMENT CONTACT	Left- fair; Right- poor (partial collapse)		
	7. EROSION/SINKHOLES BEHIND WALL	yes--one major area of loss of embankment material		
	8. ANIMAL BURROWS	None observed		
	9. UNUSUAL MOVEMENT	Falling stones		
	10. WET AREAS AT TOE OF WALL	None observed		
	11. VEGETATION	Big trees and some shrubs		
	12. SCOUR/EROSION AT BASE OF WALL	Yes		

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

UPSTREAM WALLS

AREA INSPECTE	CONDITION	OBSERVATIONS		
U/S WALLS	1. WALL TYPE	Concrete		
	2. WALL ALIGNMENT	Fair		
	3. WALL CONDITION	Poor-major spalling and some sections of wall are missing		
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: 0	max: 5'	avg: 4'
	5. ABUTMENT CONTACT	Poor-- little to no contact on each site		
	6. EROSION/SINKHOLES BEHIND WALL	Yes-- erosion behind walls		
	7. ANIMAL BURROWS	None observed		
	8. UNUSUAL MOVEMENT	None observed		
	9. VEGETATION	Vines/grass		
	10. SCOUR/EROSION AT BASE OF WALL	Unknown (underwater)		

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

EMBANKMENT (CREST)

AREA INSPECTE	CONDITION	OBSERVATIONS
CREST	1. SURFACE TYPE	Tall grasses
	2. SURFACE CRACKING	None observed
	3. SINKHOLES, ANIMAL BURROWS	Yes-- sinkholes
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	Deep depressions ~1' deep
	5. HORIZONTAL ALIGNMENT	Loss of material in some areas
	6. RUTS AND/OR PUDDLES	None observed
	7. VEGETATION (PRESENCE/CONDITION)	Tall grasses
	8. ABUTMENT CONTACT	Uneven contact at crest

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

DOWNSTREAM AREA

AREA INSPECTEI	CONDITION	OBSERVATIONS
	1. ABUTMENT LEAKAGE	Wet areas in downstream channel from secondary spillway (overflow pipes)
	2. FOUNDATION SEEPAGE	Yes-- efflorescence in downstream channel (see sketch)
	3. SLIDE, SLOUGH, SCARP	Yes, collapsed downstream structures (walls, mill structures)
D/S AREA	4. WEIRS	None observed
	5. DRAINAGE SYSTEM	None observed
	6. INSTRUMENTATION	None observed
	7. VEGETATION	Woody vegetation
	8. ACCESSIBILITY	Fair
	9. DOWNSTREAM HAZARD DESCRIPTION	

ADDITIONAL COMMENTS:

Collapsed mill structures (stone masonry walls and iron shaft) in downstream channel
from secondary spillway

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

PRIMARY SPILLWAY

AREA INSPECTE	CONDITION	OBSERVATIONS
SPILLWAY	SPILLWAY TYPE	Stone overflow
	WEIR TYPE	Broad crested
	SPILLWAY CONDITION	Fair
	TRAINING WALLS	Collapsed stone masonry
	SPILLWAY CONTROLS AND CONDITION	Uneven crest
	UNUSUAL MOVEMENT	None observed
	APPROACH AREA	Clear
	DISCHARGE AREA	Clear
	DEBRIS	None observed
	WATER LEVEL AT TIME OF INSPECTION	~+4" to -3"

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

AUXILIARY SPILLWAY

AREA INSPECTEI	CONDITION	OBSERVATIONS
SPILLWAY	SPILLWAY TYPE	Overflow conduits
	WEIR TYPE	1'x7" box into DIP (no flow); 4" dia PVC about 2' above water surface
	SPILLWAY CONDITION	Poor (PVC pipe loose-laying on ground)
	TRAINING WALLS	Upstream walls (completely eroded in section of embankment)
	SPILLWAY CONTROLS AND CONDITION	PVC may not be effective
	UNUSUAL MOVEMENT	Loose pipe
	APPROACH AREA	Clear
	DISCHARGE AREA	Clear
	DEBRIS	None observed
	WATER LEVEL AT TIME OF INSPECTION	Approx.. two feet below PVC

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Decappett Pond Dam
INSPECTION DATE 8/4/2015

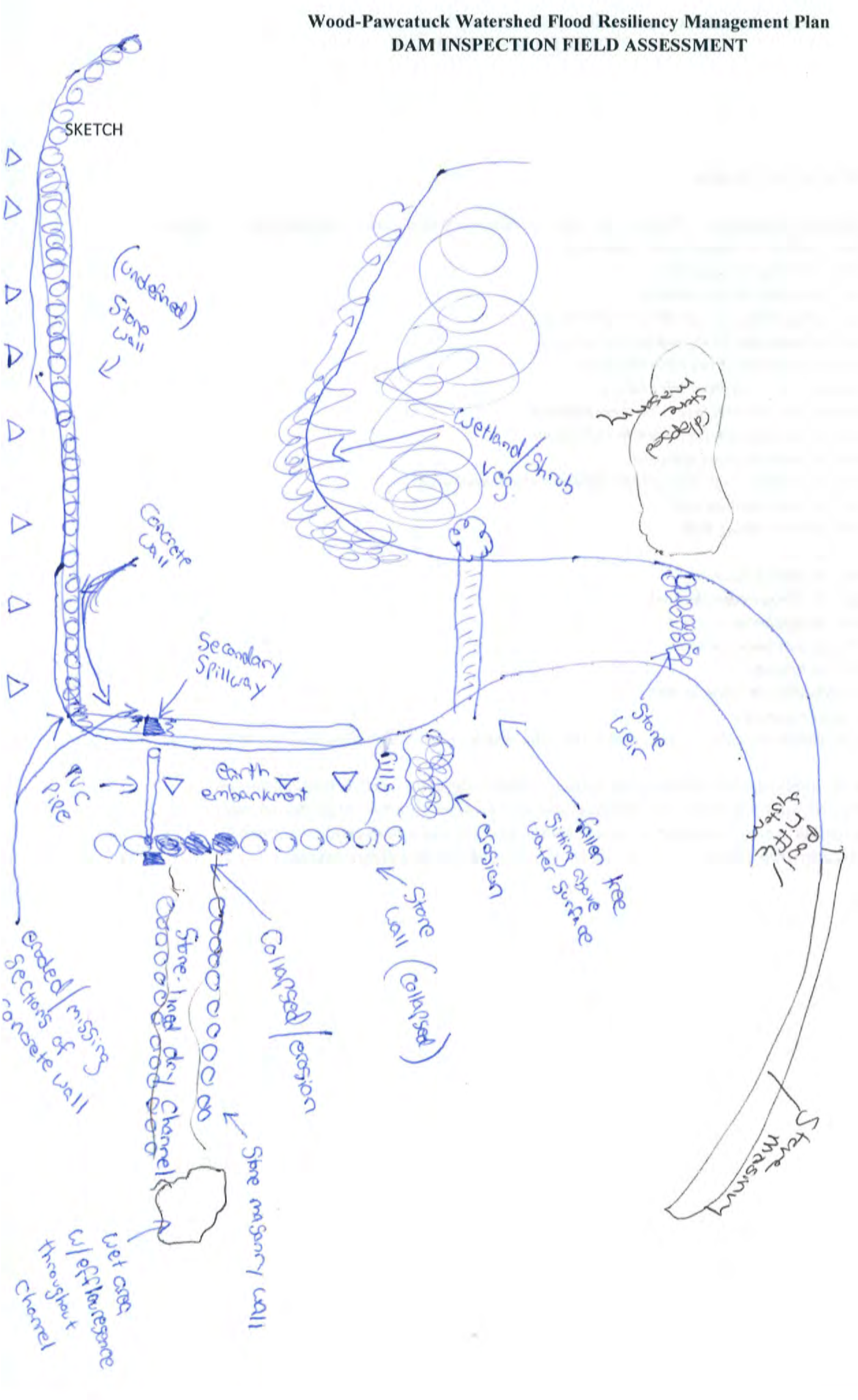
OUTLET WORKS

AREA INSPECTEI	CONDITION	OBSERVATIONS
OUTLET WORKS	TYPE	See additional comments
	INTAKE STRUCTURE	
	TRASHRACK	
	PRIMARY CLOSURE	
	SECONDARY CLOSURE	
	CONDUIT	
	OUTLET STRUCTURE/HEADWALL	
	EROSION ALONG TOE OF DAM	
	SEEPAGE/LEAKAGE	
	DEBRIS/BLOCKAGE	
	UNUSUAL MOVEMENT	
	DOWNSTREAM AREA	
	MISCELLANEOUS	

ADDITIONAL COMMENTS: Outlet pipe located on downstream but intake not located, suspect that pipe discharged to mill structure (no water movement through pipe, but seepage downstream)

SKETCH

De Cappett Pond Dam



DAM SAFETY INSPECTION

NAME OF DAM: Tug Hollow Pond Dam

STATE ID #: 232

AKA NAME:

WATER COURSE NAME: Beaver River

DAM LOCATION INFORMATION

CITY/TOWN: Richmond

LAT. / LONG.: 41.559933 -71.646370

STATE:

HAZARD CLASS: Low

GENERAL DAM INFORMATION

**** Majority of embankment area is densely vegetated---visual inspection partially obstructed****

TYPE OF DAM: Earthen embankment/stone masonry walls

PURPOSE OF DAM: Former Mill?

YEAR BUILT: Unknown

OVERALL LENGTH (FT): ~70'

STRUCTURAL HEIGHT (FT): ~8.5'

EL. NORMAL POOL (FT):

HYDRAULIC HEIGHT (FT): ~7'

EL. MAXIMUM POOL (FT):

INSPECTION SUMMARY

DATE OF INSPECTION: 7/17/2015

NAME OF INSPECTOR: MKF

TIME OF INSPECTION: 8:30

OTHER ATTENDEES: ZV

WEATHER CONDITIONS: 70s, Sunny

GENERAL DAM DATA

PRIMARY SPILLWAY TYPE: Overflow

AUXILIARY SPILLWAY TYPE Drop inlet @ primary spillway

PRIMARY SPILLWAY LENGTH: ~8'

AUXILIARY SPILLWAY LENGTH: 10" diameter pipe @ 1.5'x1.5' drop

NUMBER OF OUTLETS: None observed

TYPE OF OUTLETS:

HAS THE DAM BEEN BREACHED OR OVERTOPPED? Unknown

IS THERE A FISH LADDER (LIST TYPE IF PRESENT)? No

DOES THE CREST SUPPORT A PUBLIC ROAD? No

ACCESS CONDITIONS TO THE SITE: Poor- Private property and dense vegetation

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

EMBANKMENT (D/S SLOPE)

AREA INSPECTE	CONDITION	OBSERVATIONS
D/S SLOPE	1. WET AREAS (NO FLOW)	None observed (walls)
	2. SEEPAGE	
	3. SLIDE, SLOUGH, SCARP	
	4. EMB.-ABUTMENT CONTACT	
	5. SINKHOLE/ANIMAL BURROWS	
	6. EROSION	
	7. UNUSUAL MOVEMENT	
	8. VEGETATION (PRESENCE/CONDITION)	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

EMBANKMENT (U/S SLOPE)

AREA INSPECTE	CONDITION	OBSERVATIONS
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	None observed (walls)
	2. SLOPE PROTECTION TYPE AND COND.	
	3. SINKHOLE/ANIMAL BURROWS	
	4. EMB.-ABUTMENT CONTACT	
	5. EROSION	
	6. UNUSUAL MOVEMENT	
	7. VEGETATION (PRESENCE/CONDITION)	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

INSTRUMENTATION

AREA INSPECTE	CONDITION	OBSERVATIONS
INSTR.	1. PIEZOMETERS	None observed
	2. OBSERVATION WELLS	
	3. STAFF GAGE AND RECORDER	
	4. WEIRS	
	5. INCLINOMETERS	
	6. SURVEY MONUMENTS	
	7. DRAINS	
	8. FREQUENCY OF READINGS	
	9. LOCATION OF READINGS	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

DOWNSTREAM WALLS

AREA INSPECTE	CONDITION	OBSERVATIONS		
D/S WALLS	1. WALL TYPE	Stone masonry (unmortared)		
	2. WALL ALIGNMENT	Good		
	3. WALL CONDITION	Minimal bulging		
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: 8'	max: 9'	
	5. SEEPAGE OR LEAKAGE	None observed (partially obstructed by vegetation)		
	6. ABUTMENT CONTACT	Fair-- embankment bends at roadway with perpendicular stone masonry wall		
	7. EROSION/SINKHOLES BEHIND WALL	None observed (partially obstructed by vegetation)		
	8. ANIMAL BURROWS	None observed (partially obstructed by vegetation)		
	9. UNUSUAL MOVEMENT	None observed (partially obstructed by vegetation)		
	10. WET AREAS AT TOE OF WALL	None observed (partially obstructed by vegetation)		
	11. VEGETATION	Dense at base of wall and some vines on wall		
	12. SCOUR/EROSION AT BASE OF WALL	Not visible due to vegetation		

ADDITIONAL COMMENTS: Dense vegetation at base of wall obstructed visual inspection

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

UPSTREAM WALLS

AREA INSPECTE	CONDITION	OBSERVATIONS		
U/S WALLS	1. WALL TYPE	Stone masonry-- may just be placed riprap above waterline forming short wall		
	2. WALL ALIGNMENT	Fair		
	3. WALL CONDITION	Fair		
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: 1	max: 2	avg: 2
	5. ABUTMENT CONTACT	Good		
	6. EROSION/SINKHOLES BEHIND WALL	None observed (partially obstructed by vegetation)		
	7. ANIMAL BURROWS	None observed, some depressions/undulations observed		
	8. UNUSUAL MOVEMENT	None observed		
	9. VEGETATION	Dense shrubs/tall grasses		
	10. SCOUR/EROSION AT BASE OF WALL	Underwater (no visual inspection completed)		

ADDITIONAL COMMENTS: Heights of wall reported above waterline (visible portion)

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

EMBANKMENT (CREST)

AREA INSPECTE	CONDITION	OBSERVATIONS
CREST	1. SURFACE TYPE	Earthen with shrubs and tall grasses
	2. SURFACE CRACKING	None observed (partially obstructed by vegetation)
	3. SINKHOLES, ANIMAL BURROWS	None observed (partially obstructed by vegetation)
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	None observed (partially obstructed by vegetation)
	5. HORIZONTAL ALIGNMENT	Fair (minor variation)
	6. RUTS AND/OR PUDDLES	None observed (partially obstructed by vegetation)
	7. VEGETATION (PRESENCE/CONDITION)	Dense tall grasses and shrubs
	8. ABUTMENT CONTACT	Good

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

DOWNSTREAM AREA

AREA INSPECTE	CONDITION	OBSERVATIONS
D/S AREA	1. ABUTMENT LEAKAGE	Seepage noted across roadway from embankment to the left of the discharge culvert
	2. FOUNDATION SEEPAGE	None observed (partially obstructed by vegetation)
	3. SLIDE, SLOUGH, SCARP	None observed (partially obstructed by vegetation)
	4. WEIRS	None observed (partially obstructed by vegetation)
	5. DRAINAGE SYSTEM	None observed (partially obstructed by vegetation)
	6. INSTRUMENTATION	None observed (partially obstructed by vegetation)
	7. VEGETATION	Dense shrubs
	8. ACCESSIBILITY	Visual accessibility ok (improved from recent Google roadway images of site),
		poor physical access
	9. DOWNSTREAM HAZARD DESCRIPTION	

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

PRIMARY SPILLWAY

AREA INSPECTE	CONDITION	OBSERVATIONS
SPILLWAY	SPILLWAY TYPE	Concrete overflow weir
	WEIR TYPE	Broad crested
	SPILLWAY CONDITION	Good
	TRAINING WALLS	Good
	SPILLWAY CONTROLS AND CONDITION	Good
	UNUSUAL MOVEMENT	None observed
	APPROACH AREA	Some vegetative debris (minimal)
	DISCHARGE AREA	Clear
	DEBRIS	Minimal vegetative debris
	WATER LEVEL AT TIME OF INSPECTION	Approx. 1" over the crest

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

AUXILIARY SPILLWAY

AREA INSPECTE	CONDITION	OBSERVATIONS
	SPILLWAY TYPE	Drop inlet at elevation of primary spillway
	WEIR TYPE	Broad crested
	SPILLWAY CONDITION	Good
SPILLWAY	TRAINING WALLS	None
	SPILLWAY CONTROLS AND CONDITION	Not visible
	UNUSUAL MOVEMENT	None observed
	APPROACH AREA	Minimal vegetative debris
	DISCHARGE AREA	Clear
	DEBRIS	Vegetative
	WATER LEVEL AT TIME OF INSPECTION	Approx. +1" over primary spillway elevation

ADDITIONAL COMMENTS:

Wood-Pawcatuck Watershed Flood Resiliency Management Plan
DAM INSPECTION FIELD ASSESSMENT

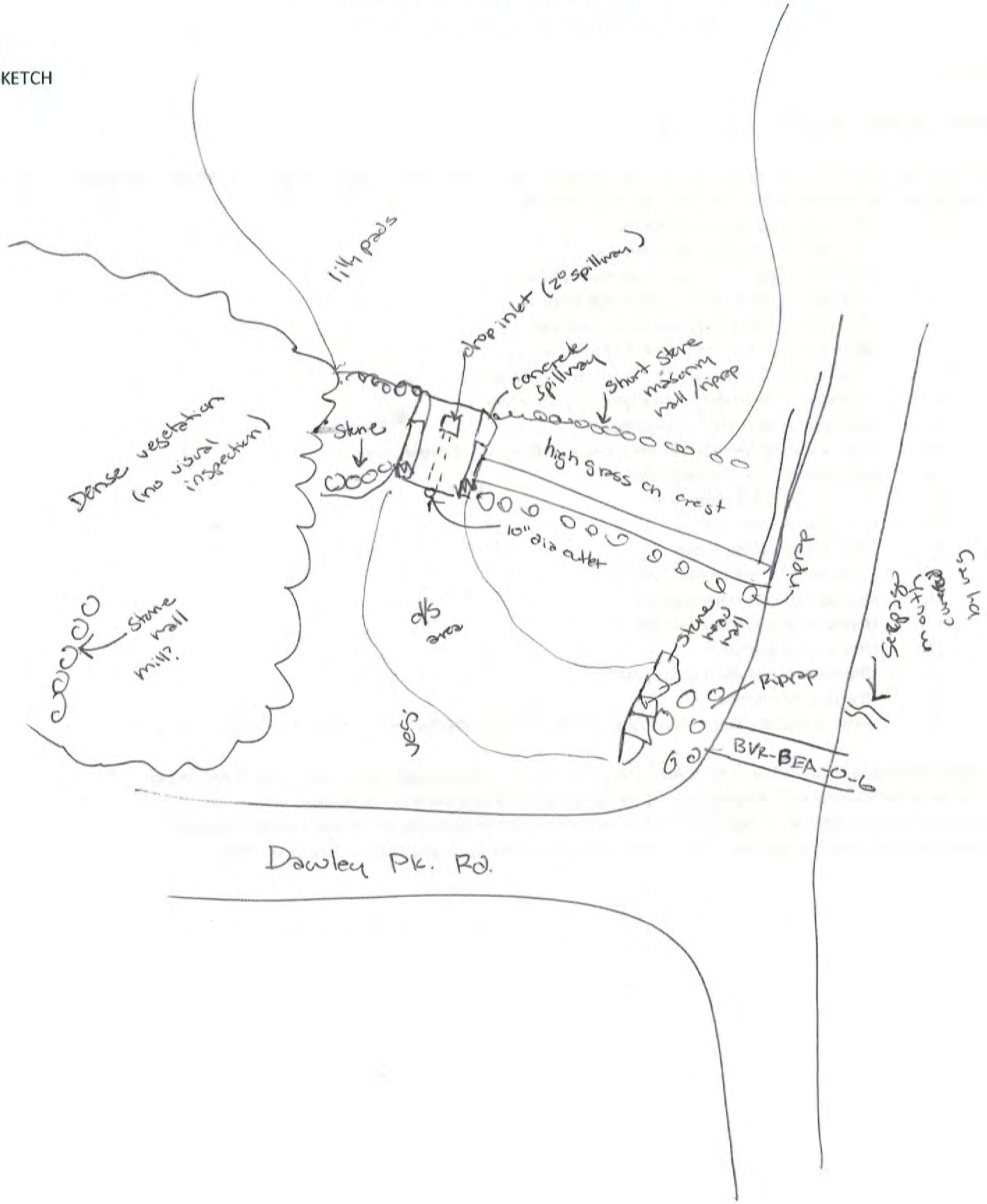
DAM NAME Tug Hollow Pond Dam
INSPECTION DATE 7/17/2015

OUTLET WORKS

AREA INSPECTE	CONDITION	OBSERVATIONS
OUTLET WORKS	TYPE	None observed
	INTAKE STRUCTURE	
	TRASHRACK	
	PRIMARY CLOSURE	
	SECONDARY CLOSURE	
	CONDUIT	
	OUTLET STRUCTURE/HEADWALL	
	EROSION ALONG TOE OF DAM	
	SEEPAGE/LEAKAGE	
	DEBRIS/BLOCKAGE	
	UNUSUAL MOVEMENT	
	DOWNSTREAM AREA	
	MISCELLANEOUS	

ADDITIONAL COMMENTS:

SKETCH


lilly pads
drop inlet (2° spillway)
concrete spillway
short stone masonry wall / riprap
Dense vegetation (no visual inspection)
stone
high grass on crest
10" dia outlet
riprap
Stone wall mill?
d/s area
stone head wall
Riprap
veg.
Seepage mouth covered by veg
BVR-BEA-O-6
Dawley Pk. Rd.

Datasheets from Culvert Assessments in the Beaver River Watershed (F&O, 2017)

Bridge & Arch Assessment - Geomorphic & Habitat Parameters

Structure Type: bridge / [✓ arch]

SGAStructure ID	BVR-BEA-01		
Observer(s) / Organization(s)	RLW, NJL	Date	7/6/15
Town	Richmond	Phase 1 Project	
Reach VTID	Beaver River Rd.		
Road Name	Shamrock Hill Rd - Intersection of ~~Beaver Hill Rd~~	Road Type	[✓ paved] gravel trail railroad
Stream Name	Beaver River	High Flow Stage	yes [✓ no]

Structure Length	26 (ft.)	Structure Material	aluminum, wrought iron, cast iron [✓ concrete] masonry (arches) & slabs prestressed concrete/post-tensioned steel timber other	Channel Width curve measured	32 (ft.)
Constricting Opening Height	3.9 (ft.)			# of bridge piers or # arches at crossing	1
Structure Width	12 (ft.)			Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Bridge at intersection (three-way)

Floodplain filled by roadway approaches: [✓ entirely] partially not significant

Structure located at a significant break in valley slope: [✓ yes] → minor break no unsure

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~50 (feet)

Angle of stream flow approaching structure: sharp bend mild bend [✓ naturally straight] channelized straight

Downstream

Pool present immediately downstream of structure: [✓ yes] no

Maximum pool depth: ________ (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Stepped footers: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes no	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes no	1 2 [✓ 3] [✓ 4] 5 UK bedrock present: yes no
Sediment deposit types	[✓ none] delta side point mid-channel	none delta side point [✓ mid-channel]	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none].	at edge of pool; behind both wingwalls high [✓ low] none	
Hard bank armoring	[✓ intact] failing none unknown	[✓ intact] failing none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] abutments footers wing walls	[✓ none] abutments footers wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: _________ ft.	yes [✓ no] distance: _________ ft.	

Bed Material Codes
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

* noted multiple areas used as vehicle pull-offs (likely for fishing, etc.)

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	yes [✓ no]	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)

species:
[✓ none] None

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
Birds	audible		
fish	rises, fishing activity		
velvet-winged damselflies	visual		

Spatial data collected w/GPS: yes no

Photos taken: yes no
Please fill out photo log below

Comments:

****See PHOTO LIST for photos that need to be taken***

Roll and Frame #	Photo View	Description of Features in Photo

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BAA-0-2		
Observer(s) / Organization(s)	NJL, RWW	Date	7/6/15
Town	Richmond		
Road Name	Beaver River Schoolhouse Rd	Road Type	[✓ paved] gravel trail railroad
Stream Name	Beaver River	High Flow Stage	yes [✓ no]
Culvert Length	28.5 (ft.)	Channel Width curve measured	38 (ft.)
Culvert Height	4 (ft.)	# of culverts at crossing	1
Culvert Width	8 (ft.)	Overflow pipe(s)	yes [✓ no]
		Structure skewed to roadway	yes [✓ no]

Structure Material: [✓ concrete] plastic corrugated plastic smooth tank steel corrugated stone aluminum corrugated other mixed

8.5' to road

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant]

Structure located at a significant break in valley slope: [✓ yes] no

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): [✓ wood debris] sediment deformation [✓ none]

→ very minor upstream, some DS at pool exit

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~50 (feet) - more to left

Angle of stream flow approaching structure: sharp bend mild bend [✓ naturally straight] channelized straight

Downstream

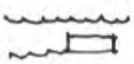
Water depth in culvert (at outlet): .5-.8 (0.0 feet)

Culvert outlet invert: [✓ partially backwatered] or at grade cascade free fall

Backwater Length (measured from outlet): 0 (0.0 feet)

Outlet drop (invert to water surface): 0 (0.0 feet)

→ water level is above outlet invert → water is at grade due to level "high enough"



Pool present immediately downstream of structure: [✓ yes] no

Pool depth at point of streamflow entry: .8 (0.0 feet)

Maximum pool depth: >4 ft (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

U/S: 9.59'
Center: 3.92'
D/S: 9.62'

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 [✓ 3] 4 [✓ 5] UK bedrock present: yes no	1 2 [✓ 3] 4 [✓ 5] UK bedrock present: yes no	0 1 2 3 4 [✓ 5] UK material throughout: yes no
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	minor left exit of Pool high [✓ low] none	
Hard bank armoring	[✓ intact] failing none unknown	[✓ intact] failing none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

Bed Material Codes
- 0-none
- 1-bedrock
- 2-boulder
- 3-cobble
- 4-gravel
- 5-sand
- UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500'or more up/downstream?	[✓ yes] no	yes [✓ no]	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
- C-coniferous forest
- D-deciduous forest
- M-mixed forest
- S-shrub/sapling
- H-herbaceous/grass
- B-bare
- R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)

species:
[✓ none]

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
Birds			

Spatial data collected w/GPS: yes no

Photos taken: yes no
Please fill out photo log below

Comments:
****See PHOTO LIST for photos that need to be taken***

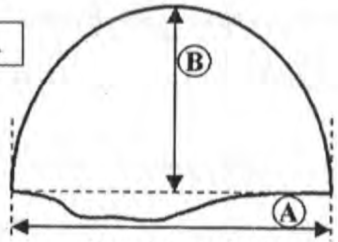
Roll and Frame #	Photo View	Description of Features in Photo

BVR-BEA-0-2
07/6/15

Appendix 2 Field data collection form, p. 3 of 5

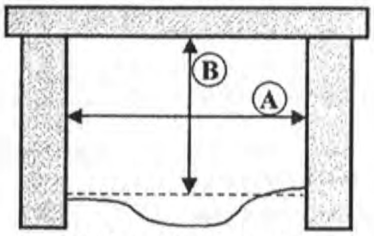
Crossing Dimensions

1.

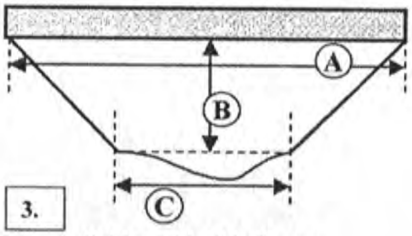


Open Bottom Arch

2.

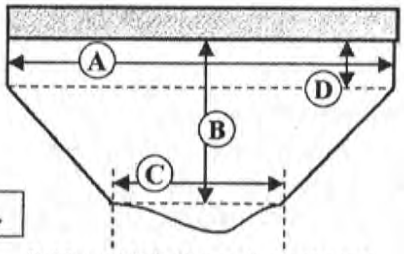


Bridge with Abutments



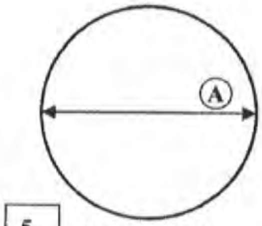
3.

Bridge with Side Slopes

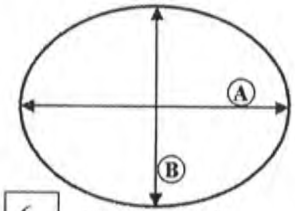


4.

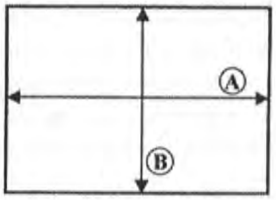
Bridge w/ Side Slopes & Abutments



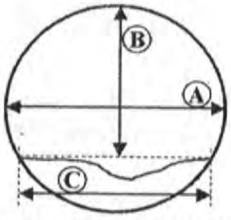
5. Round Culvert



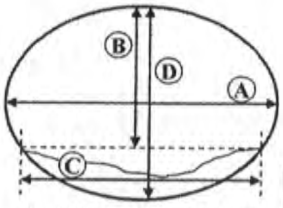
6. Elliptical Culvert



Box Culvert 7.



8. Embedded Round Culvert



Embedded Elliptical Culvert 9.

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☒ 7. ☐ 8. ☐ 9. ☐ Ford

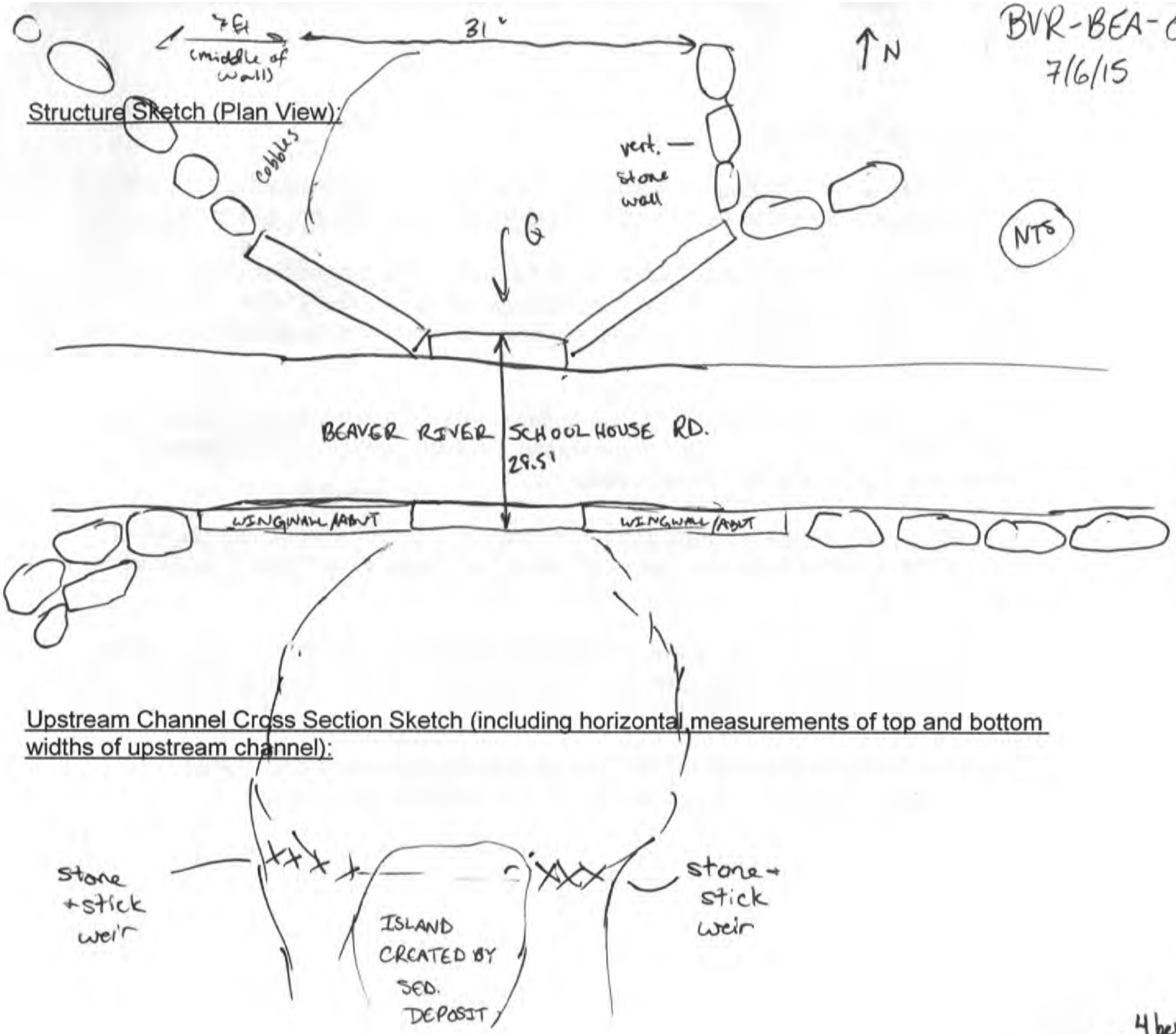
Upstream Dimensions (ft.): A) 8' B) 4' C) ____ D) ____

Downstream Dimensions (ft.): A) 8 B) 4' C) ____ D) ____

Length of stream through crossing (ft.): 28.5 Crossing slope (%) ____

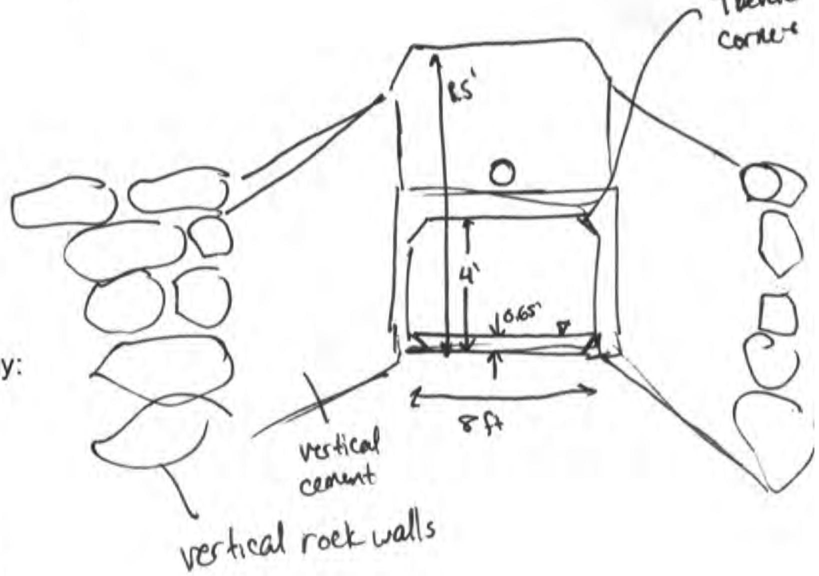
BVR-BEA-0-2
7/6/15

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):

Height from Structure Upstream Invert to Roadway:



U/S and D/S Structure Inverts (using survey rod):

U/S	9.59 ft
D/S	9.62 ft
Road	3.92 ft

Culvert Assessment - Geomorphic & Habitat Parameters

Field Map # ______

SGA Structure ID	BVR-BEA-0-3	Local ID	
Observer(s) / Organization(s)	A. Berlin	Date	10/26/15
Town	Richmond	Phase 1 Project	
Location		Longitude (E/W)	
Reach VTID	R 3B	Latitude (N/S)	
Road Name	Kingstown Rd	Road Type	[✓ paved] gravel trail railroad
Stream Name	Beaver River	High Flow Stage	yes [✓ no]

Culvert Length	51 (ft.)	Structure Material	[✓ concrete] plastic corrugated plastic smooth tank steel corrugated stone aluminum corrugated other mixed	Channel Width curve measured	22 (ft.)
Culvert Height	11 (ft.)			# of culverts at crossing	1
Culvert Width	15 (ft.)			Overflow pipe(s)	[✓ yes] no
				Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: [✓ entirely] partially not significant

Structure located at a significant break in valley slope: yes [✓ no] unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: cross road [✓ follow road] unsure

Estimated distance avulsion would follow road: 114 (feet)

Angle of stream flow approaching structure: sharp bend [✓ mild bend] naturally straight channelized straight

Downstream

Water depth in culvert (at outlet): 2.2 (0.0 feet)

Culvert outlet invert: [✓ partially backwatered or at grade] cascade free fall

Backwater Length (measured from outlet): 65 (0.0 feet)

Outlet drop (invert to water surface): ______ [✓ (0.0 feet)]

Pool present immediately downstream of structure: yes [✓ no]

Pool depth at point of streamflow entry: 1.7 (0.0 feet)

Maximum pool depth: 1.7 (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	**UPSTREAM**	**DOWNSTREAM**	**IN STRUCTURE**
Dominant bed material at structure	1 2 3 [✓ 4] 5 UK bedrock present: yes [✓ no]	1 2 3 [✓ 4] 5 UK bedrock present: yes [✓ no]	0 1 2 3 4 [✓ 5] UK material throughout: yes [✓ no]
Sediment deposit types	none delta [✓ side] point [✓ mid-channel]	none delta [✓ side] point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	[✓ yes] no	[✓ yes] no	yes [✓ no]
Bank erosion	high [✓ low] none	high low [✓ none]	
Hard bank armoring	intact [✓ failing] none unknown	intact [✓ failing] none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	none culvert footer [✓ wing walls] RB	none culvert footer [✓ wing walls] Both	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	**LEFT**	**RIGHT**	**LEFT**	**RIGHT**
Dominant vegetation type	D	D	D	H
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	yes [✓ no]	yes [✓ no]	[✓ yes] no	yes [✓ no]

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)
species:
[✓ **none**]

Wildlife sign and species observed near (up/downstream) and inside structure (circle none or list species and sign types)	**Outside Structure**		**Inside Structure**	
	species (none)	**sign**	**species (none)**	**sign**
			Bird	Nest

Spatial data collected w/GPS: [✓ **yes**] **no**

Photos taken: [✓ **yes**] **no**
Please fill out photo log below

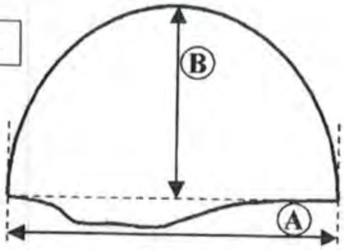
Comments:

Roll and Frame #	**Photo View**	**Description of Features in Photo**

Appendix 2 Field data collection form, p. 3 of 5

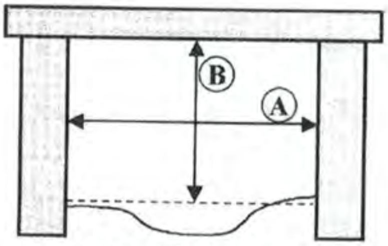
Crossing Dimensions

1.



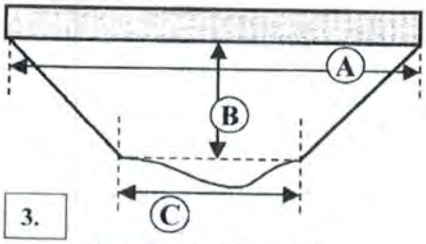
Open Bottom Arch

2.



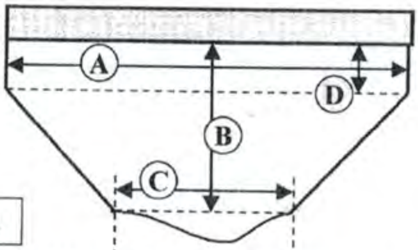
Bridge with Abutments

3.



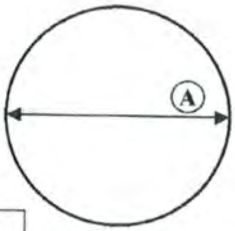
Bridge with Side Slopes

4.



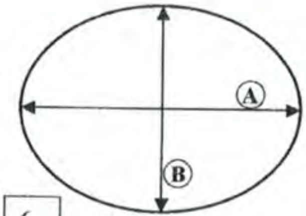
Bridge w/ Side Slopes & Abutments

5.

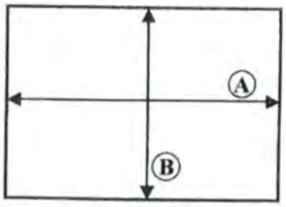


Round Culvert

6.

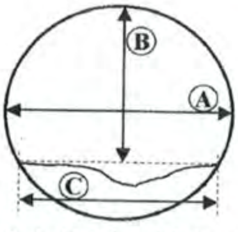


Elliptical Culvert



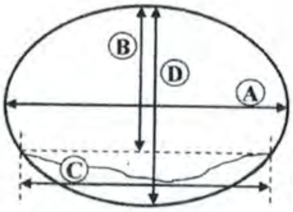
Box Culvert

7.



8.

Embedded Round Culvert



Embedded Elliptical Culvert

9.

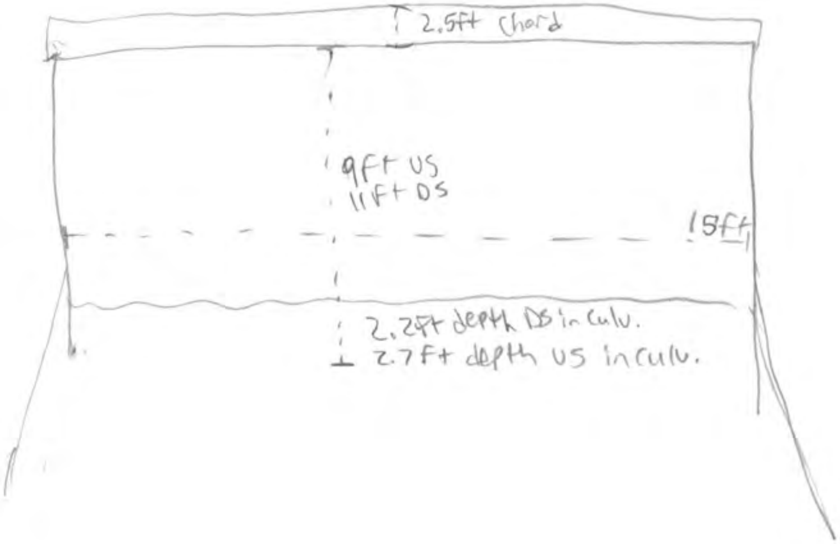
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☑ 7. ☐ 8. ☐ 9. ☐ Ford

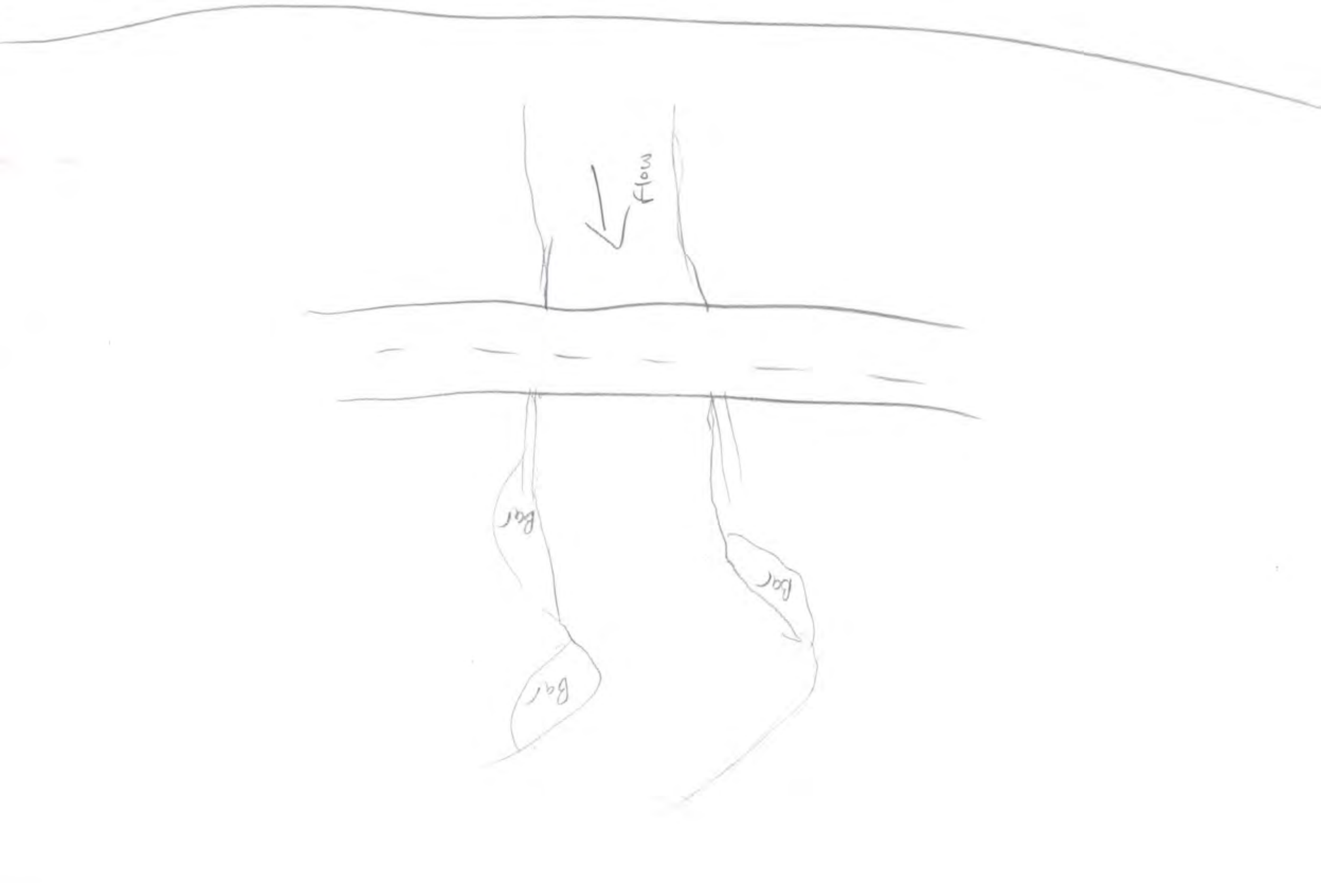
Upstream Dimensions (ft.): A) 14 B) 11 C) ______ D) ______

Downstream Dimensions (ft.): A) 14 B) 11 C) ______ D) ______

Length of stream through crossing (ft.): 51 **Crossing slope (%)** ______

Channel slope → 0.0043 Ft


2.5ft chord
9ft US
11ft DS
15ft
2.2ft depth DS in culv.
2.7ft depth US in culv.


Flow
Bar
Bar
Bar

Appendix 2 Field data collection form, p. 4 of 5

DIMENSIONS WORKSHEET FOR MULTIPLE CULVERT CROSSINGS

Crossing ID# ______

Note: *When inventorying multiple culverts, label left culvert 1 and go in increasing order from left to right from downstream end (outlet) looking upstream.*

Number of Culverts or Bridge Cells ______

Culvert or Bridge Cell 2 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Downstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Length of stream through crossing (ft.): ______ **Crossing slope (%)** ______

Culvert or Bridge Cell 3 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Downstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Length of stream through crossing (ft.): ______ **Crossing slope (%)** ______

Culvert or Bridge Cell 4 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Downstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Length of stream through crossing (ft.): ______ **Crossing slope (%)** ______

Culvert or Bridge Cell 5 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Downstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Length of stream through crossing (ft.): ______ **Crossing slope (%)** ______

Culvert or Bridge Cell 6 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Downstream Dimensions (ft.): A) ______ B) ______ C) ______ D) ______

Length of stream through crossing (ft.): ______ **Crossing slope (%)** ______

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-0-4				
Observer(s) / Organization(s)	RLW, NJL			Date	7/6/15
Town	Richmond				
Road Name	Hillsdale Rd.			Road Type	[✓ paved] gravel trail railroad
Stream Name	Beaver River			High Flow Stage	yes [✓ no] → no water in overflow Pipe
Culvert Length	29 (ft.)		Structure Material: [✓ concrete] plastic corrugated plastic smooth tank steel corrugated stone aluminum corrugated other mixed	Channel Width curve measured	8', 20' total (ft.)
deformed/ poorly poured Culvert Height	right 2.95' Ø <3	left 3' Ø (ft.)		# of culverts at crossing	2+ large overflow
overflow 2' Culvert Width	2.95'	3' (ft.)		Overflow pipe(s)	1 [✓ yes] no
				Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant]

Structure located at a significant break in valley slope: [✓ yes] no unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~35 (feet)

Angle of stream flow approaching structure: sharp bend mild bend [✓ naturally straight] channelized straight

Downstream

Water depth in culvert (at outlet): right 6" | left 5" (both 6") (0.0 feet)

Culvert outlet invert: partially backwatered or at grade cascade [✓ free fall]

Backwater Length (measured from outlet): ~1' (0.0 feet)

Outlet drop (invert to water surface): right: 6", +18" (0.0 feet) (first drop, second drop) | left: 6", + 2'

Pool present immediately downstream of structure: yes [✓ no]

Pool depth at point of streamflow entry: — (0.0 feet)

Maximum pool depth: — (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

① right US: 10.39' D/S: 10.45'

② left U/S: 10.44' D/S: 10.43'

③ left overflow US: 9.9' DS: 9.09'

Center: 4.25'
low: 4.65'

Geomorphic and Fish Passage Data	**UPSTREAM**	**DOWNSTREAM**	**IN STRUCTURE**
Dominant bed material at structure	1 2 [✓ 3] [✓ 4] [✓ 5] UK bedrock present: yes no	1 [✓ 2] [✓ 3] [✓ 4] 5 UK bedrock present: yes no	[✓ 0] 1 2 3 4 5 UK material throughout: yes no
Sediment deposit types	delta side point [✓ mid-channel]	none delta [✓ side] left of exit point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	rt DS Side [✓ high] low none	
Hard bank armoring	intact [✓ failing] none unknown	intact [✓ failing] none [✓ unknown]	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: _________ ft.	yes [✓ no] distance: _________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	**LEFT**	**RIGHT**	**LEFT**	**RIGHT**
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	[✓ yes] no	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)	species: [✓ none]

Wildlife sign and species observed near (up/downstream) and inside structure (circle none or list species and sign types)	**Outside Structure**		**Inside Structure**	
	species (none)	**sign**	**species (none)**	**sign**
	birds	aud.		
	velvet-winged damselfly	vis.		

Spatial data collected w/GPS: **yes no** Photos taken: **yes no** Please fill out photo log below	**Comments:** ****See PHOTO LIST for photos that need to be taken***

Roll and Frame #	**Photo View**	**Description of Features in Photo**
①	overflow culvert	D/S looking upstream
②	left culvert	↓
③	right culvert	

Appendix 2 Field data collection form, p. 4 of 5

DIMENSIONS WORKSHEET FOR MULTIPLE CULVERT CROSSINGS

Crossing ID#

Note: *When inventorying multiple culverts, label left culvert 1 and go in increasing order from left to right from downstream end (outlet) looking upstream.*

Number of Culverts or Bridge Cells 3

Middle (left culvert)

Culvert or Bridge Cell 2 of 3
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☒ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) 3 B) ___ C) ___ D) ___
Downstream Dimensions (ft.): A) 3 B) ___ C) ___ D) ___
Length of stream through crossing (ft.): 29 **Crossing slope (%)** ___

Left (S

Culvert or Bridge Cell 3 of 3 Overflow pipe
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☒ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) 2 B) ___ C) ___ D) ___
Downstream Dimensions (ft.): A) 2 B) ___ C) ___ D) ___
Length of stream through crossing (ft.): 29 **Crossing slope (%)** ___

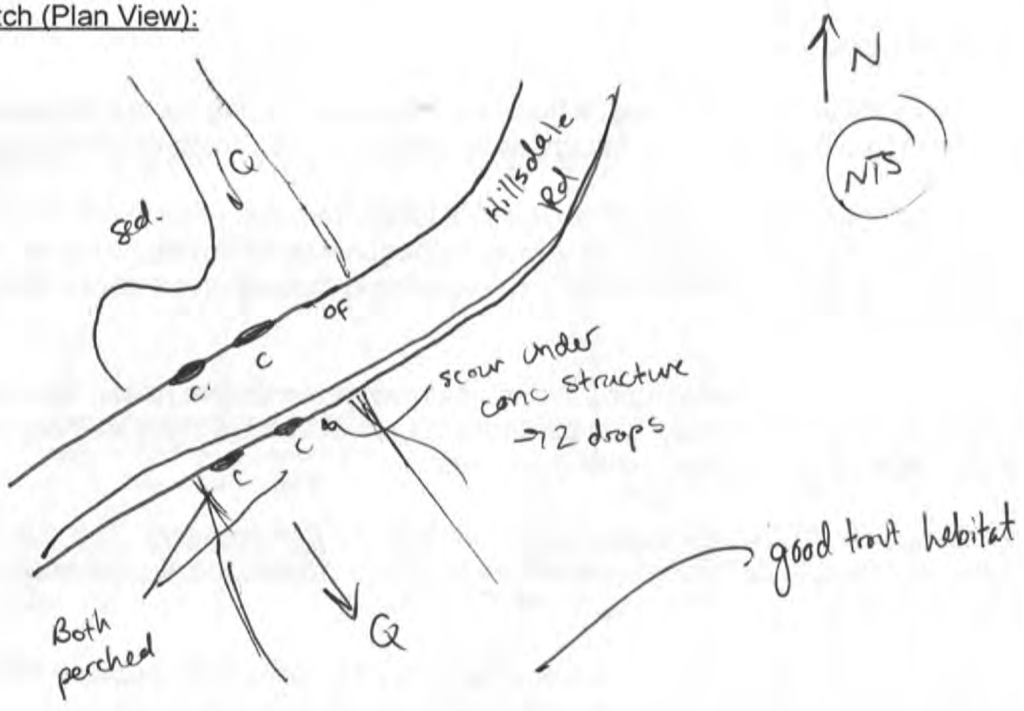
Culvert or Bridge Cell 4 of ___
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___ B) ___ C) ___ D) ___
Downstream Dimensions (ft.): A) ___ B) ___ C) ___ D) ___
Length of stream through crossing (ft.): ___ **Crossing slope (%)** ___

Culvert or Bridge Cell 5 of ___
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___ B) ___ C) ___ D) ___
Downstream Dimensions (ft.): A) ___ B) ___ C) ___ D) ___
Length of stream through crossing (ft.): ___ **Crossing slope (%)** ___

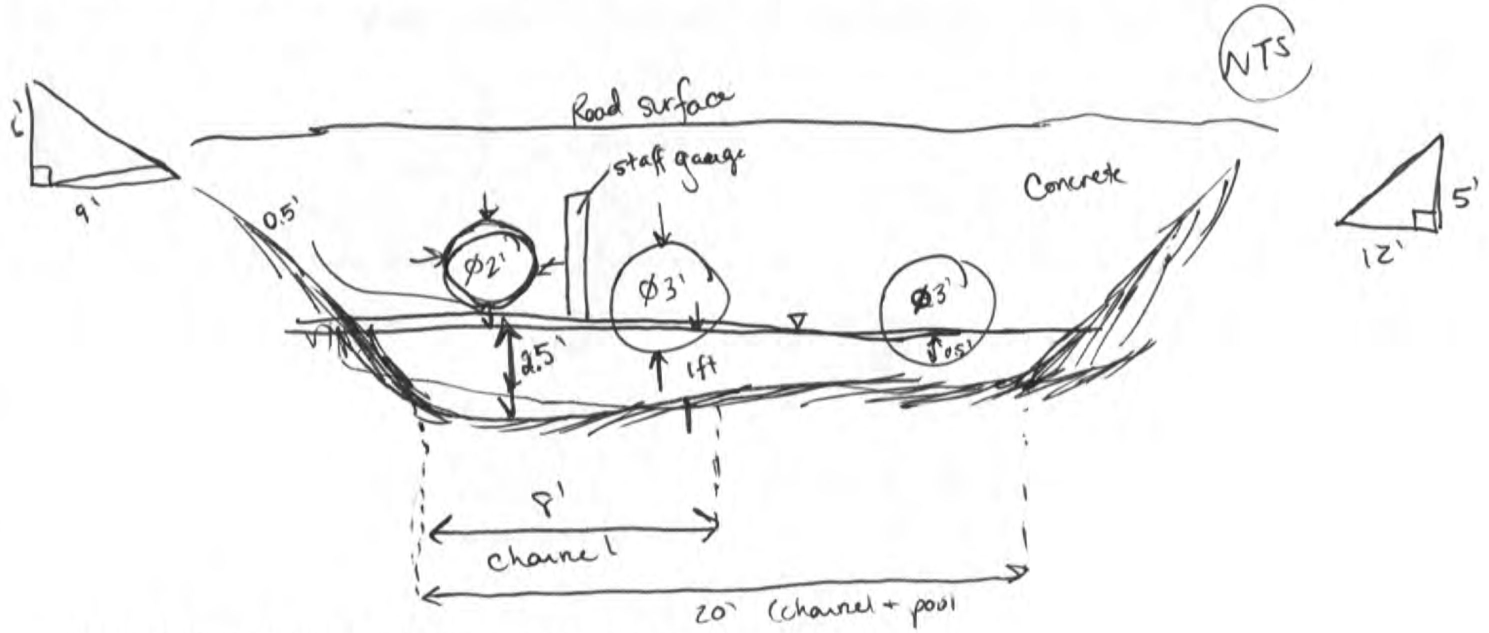
Culvert or Bridge Cell 6 of ___
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___ B) ___ C) ___ D) ___
Downstream Dimensions (ft.): A) ___ B) ___ C) ___ D) ___
Length of stream through crossing (ft.): ___ **Crossing slope (%)** ___

BYR - BEA - 0-4

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

U/S and D/S Structure Inverts (using survey rod):

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-0-5		
Observer(s) / Organization(s)	RLW, NJL	Date	7/6/15
Town	Richmond		
Road Name	Old Mountain Rd	Road Type	[✓ paved] gravel trail railroad
Stream Name	Beaver River	High Flow Stage	yes [✓ no]
Culvert Length	29 (ft.)	Channel Width curve measured	15 (ft.) → bend: 20'
Culvert Height	3 (ft.)	# of culverts at crossing	2
Culvert Width	3 (ft.)	Overflow pipe(s)	yes [✓ no]
Structure Material	[✓ concrete] plastic corrugated plastic smooth tank steel corrugated stone aluminum corrugated other mixed	Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant]

Structure located at a significant break in valley slope: yes ← mild break [✓ no] unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): [✓ wood debris] → most in left culvert sediment deformation none

Steep riffle present immediately upstream of structure: [✓ yes] no

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~25 (feet) - more on right side

Angle of stream flow approaching structure: [✓ sharp bend] mild bend naturally straight channelized straight

Downstream

Water depth in culvert (at outlet): left 1.2' | right 1.4' (0.0 feet)

Culvert outlet invert: partially backwatered or [✓ at grade] cascade free fall

Backwater Length (measured from outlet): — (0.0 feet)

Outlet drop (invert to water surface): — (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] no

Pool depth at point of streamflow entry: L 2', R 4' (0.0 feet)

Maximum pool depth: 4' (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 [✓ 3] [✓ 4] 5 UK bedrock present: yes no	1 [✓ 2] [✓ 3] [✓ 4] 5 UK bedrock present: yes [✓ no]	[✓ 0] 1 2 3 4 5 UK material throughout: yes no
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	intact failing [✓ none] unknown	[✓ intact] failing none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	[✓ yes] no	~~yes~~ [✓ no]	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)
species: none
river runs aside road

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
Bird	vis. toad.		
butterfly	vis		
vw damselflies	vis		

Spatial data collected w/GPS: yes no

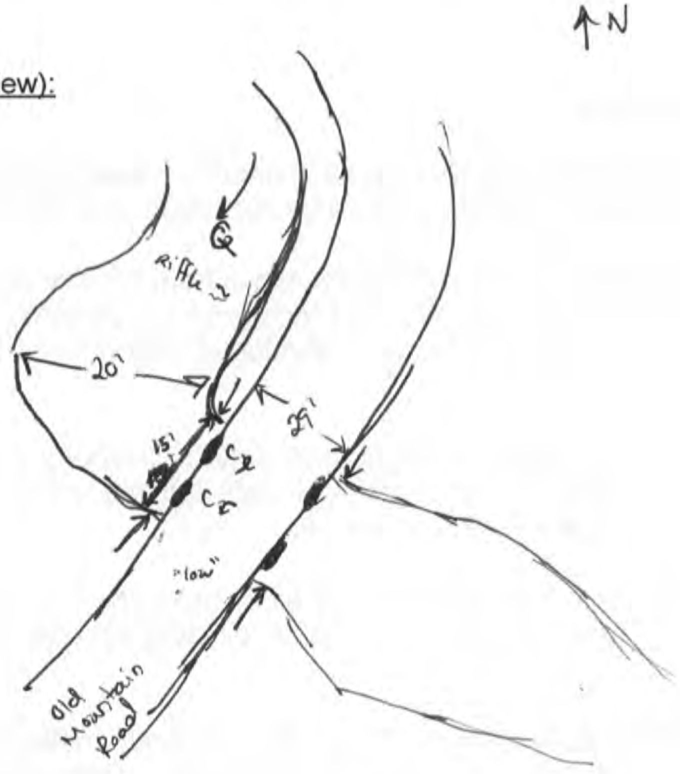
Photos taken: yes no
Please fill out photo log below

Comments:
****See PHOTO LIST for photos that need to be taken***

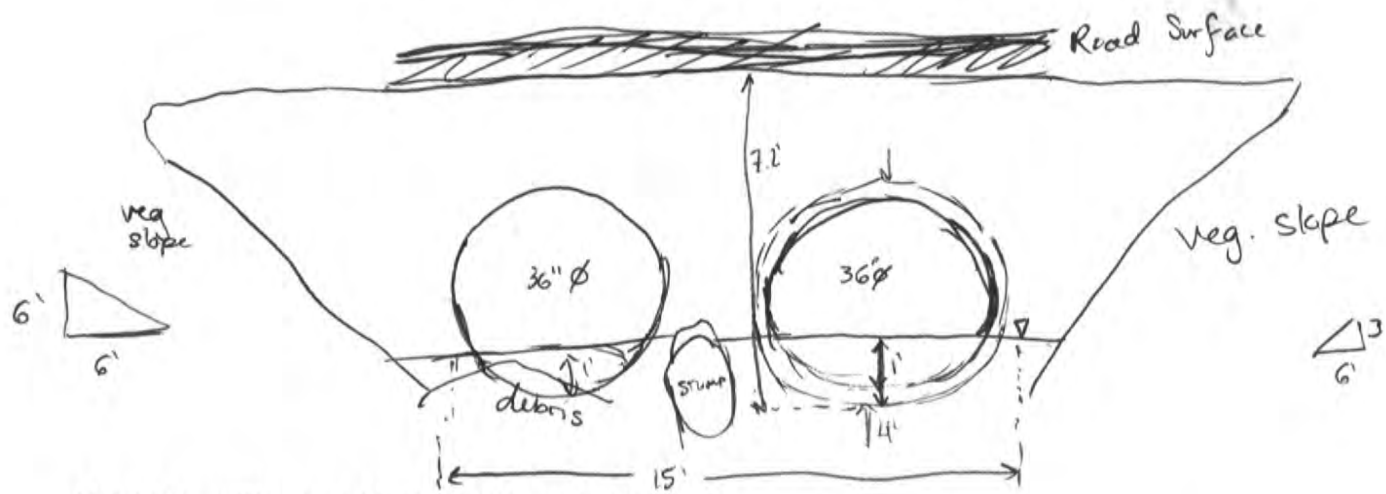
Roll and Frame #	Photo View	Description of Features in Photo

BVR-BEA-0-5
7/6/15

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

Left
U/S: 7.46'
D/S: 8.71'

Right
U/S: 7.58'
D/S: 8.75'

Center: 4.16'

low: 4.75'

U/S and D/S Structure Inverts (using survey rod):

Culvert Assessment - Geomorphic & Habitat Parameters

Structure ID	BVR-BEA-6-6		
Observer(s) / Organization(s)	MKF + ZV	Date	7/17/15
Town			

Crossing Substrate: **Sediment** [✓ **Vegetation**] **Concrete** **HDPE** **Metal** Other: ________ Aquatic Grass

Other Physical Barriers: ________

Flow Condition Through Crossing: **Turbulent** [✓ **Smooth**] Other: ________

Road Name	New London Turnpike			Road Type	[✓ **paved**] **gravel** **trail** **railroad**
Stream Name	Beaver River			High Flow Stage	**yes** [✓ **no**]
Culvert Length	40' (ft.)	Structure Material	**concrete** **plastic corrugated** **plastic smooth** **tank** [✓ **steel corrugated**] **stone** **aluminum corrugated** **other** **mixed**	Channel Width **curve measured**	15' (ft.)
Culvert Height	4' Ø (ft.)			# of culverts at crossing	1
Culvert Width	— (ft.)			Overflow pipe(s)	**yes** [✓ **no**]
				Structure skewed to roadway	[✓ **yes**] **no** Slightly

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: **entirely** [✓ **partially**] **not significant**

Structure located at a significant break in valley slope: [✓ **yes**] **no** **unsure**

Culvert slope as compared with the channel slope is: **higher** **lower** [✓ **same**]

Upstream

Is structure opening partially obstructed by (circle all that apply): **wood debris** **sediment** **deformation** **none**
Plant material

Depth of sediment/obstruction in structure upstream: <6"

Steep riffle present immediately upstream of structure: [✓ **yes**] **no** riffle present, over some cobble/bedrock

If channel avulses, stream will: [✓ **cross road**] **follow road** **unsure**

Estimated distance avulsion would follow road: <75 ft (feet)

Angle of stream flow approaching structure: **sharp bend** [✓ **mild bend**] **naturally straight** **channelized straight**

Water depth in culvert (upstream): <6" (0.0 feet)

Downstream

NO ACCESS
HARD TO SEE

Water depth in culvert (at outlet): ________ (0.0 feet)

Culvert outlet invert: **partially backwatered or at grade** **cascade** [✓ **free fall**]

Backwater Length (measured from outlet): ________ (0.0 feet)

Outlet drop (invert to water surface): ________ (0.0 feet)

Pool present immediately downstream of structure: **yes** [✓ **no**]

Pool depth at point of streamflow entry: — (0.0 feet)

Maximum pool depth: — (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: [✓ **yes**] **no**

Is structure opening partially obstructed by (circle all that apply): **wood debris** **sediment** **deformation** **none**

Depth of sediment/obstruction in structure upstream:

Geomorphic and Fish Passage Data	**UPSTREAM**	**DOWNSTREAM**	**IN STRUCTURE**
Dominant bed material at structure further u/s →	1 2 3 [✓ 4] [✓ 5] UK bedrock present: [✓ yes] no	1 [✓ 2] 3 4 [✓ 5] UK bedrock present: yes no	0 1 2 3 [✓ 4] [✓ 5] UK material throughout: [✓ yes] no
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	[✓ intact] failing none unknown	intact failing [✓ none] unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	NO ACCESS none culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: — ft.	yes [✓ no] distance: — ft.	

Bed Material Codes
- **0**-none
- **1**-bedrock
- **2**-boulder
- **3**-cobble
- **4**-gravel
- **5**-sand
- **UK**-unknown

Wildlife Data (left/right bank determined facing downstream)	**LEFT**	**RIGHT**	**LEFT**	**RIGHT**
Dominant vegetation type	H	H	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	[✓ yes] no Potentially	yes [✓ no]	yes [✓ no]	[✓ yes] no

Vegetation Type Codes
- **C**-coniferous forest
- **D**-deciduous forest
- **M**-mixed forest
- **S**-shrub/sapling
- **H**-herbaceous/grass
- **B**-bare
- **R**-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)

species:
[✓ **none**]

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		**Inside Structure**	
species (none)	**sign**	**species (none)**	**sign**
Snake	Visual	—	—
Mouse	Visual		
Damselfly	Visual		

Spatial data collected w/GPS: **yes** [✓ **no**]

Photos taken: [✓ **yes**] **no**
Please fill out photo log below

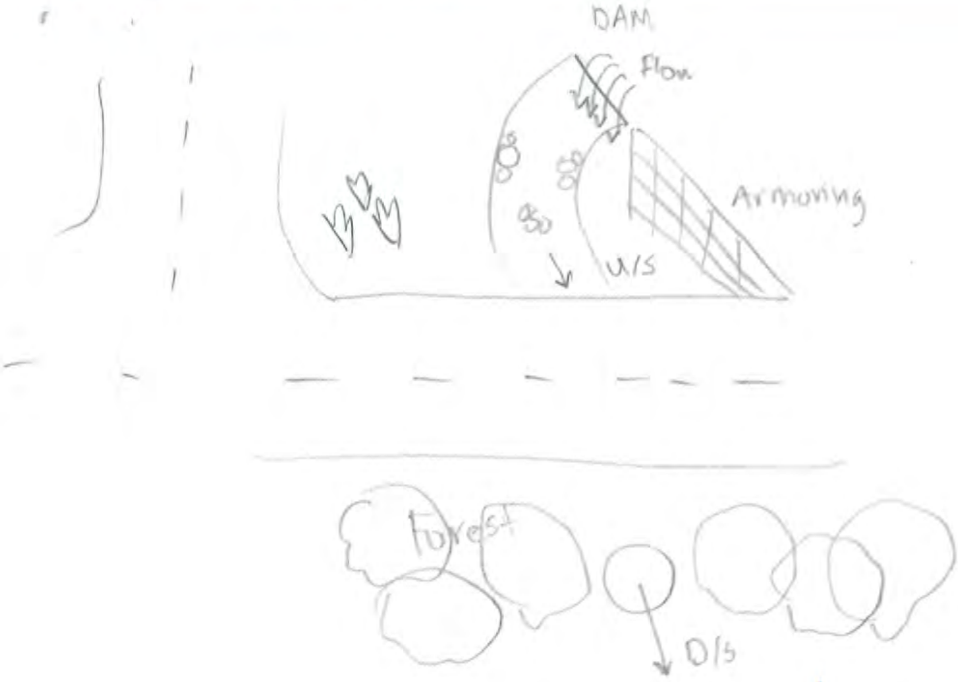
Comments:

****See PHOTO LIST for photos that need to be taken***

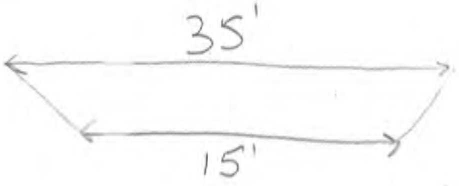
- Seepage on L of D/S
- Muddy Sediment

Roll and Frame #	**Photo View**	**Description of Features in Photo**

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

Rdwy: 5.46

U/S and D/S Structure Inverts (using survey rod):

U/S: 11.84

D/S: 13.85

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-2-1		
Observer(s) / Organization(s)	RLW, NJL	Date	7/6/15
Town	Richmond		
Road Name	Hillsdale Rd	Road Type	[✓ **paved**] **gravel** **trail** **railroad**
Stream Name	Unnamed	High Flow Stage	**yes** [✓ **no**]
Culvert Length	23 (ft.)	Channel Width **curve measured**	5 (ft.)
Culvert Height	36" (ft.)	# of culverts at crossing	1
Culvert Width	36" (ft.)	Overflow pipe(s)	**yes** [✓ **no**]
		Structure skewed to roadway	**yes** [✓ **no**]

Structure Material:
[✓ **concrete**] →different Sections, Slightly out of alignment
plastic corrugated
plastic smooth
tank
steel corrugated
stone
aluminum corrugated
other
mixed

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: **entirely** **partially** [✓ **not significant**]

Structure located at a significant break in valley slope: [✓ **yes**] →mild break, prominent on Rt. **no** **unsure**

Culvert slope as compared with the channel slope is: **higher** **lower** [✓ **same**]

Upstream

Is structure opening partially obstructed by (circle all that apply): [✓ **wood debris**] →minor fallen brush **sediment** **deformation** **none**

Steep riffle present immediately upstream of structure: **yes** [✓ **no**]

If channel avulses, stream will: [✓ **cross road**] **follow road** **unsure**

Estimated distance avulsion would follow road: ~25 (feet)

Angle of stream flow approaching structure: [✓ **sharp bend**] [✓ **mild bend**] **naturally straight** **channelized straight**

Downstream

Water depth in culvert (at outlet): 9.5" (0.0 feet)

Culvert outlet invert: **partially backwatered or** [✓ **at grade**] **cascade** **free fall**

Backwater Length (measured from outlet): — (0.0 feet)

Outlet drop (invert to water surface): — (0.0 feet)

Pool present immediately downstream of structure: **yes** [✓ **no**]

Pool depth at point of streamflow entry: — (0.0 feet)

Maximum pool depth: — (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: [✓ **yes**] **no**

U/S: 6.7' center (side): 4.1' D/S: 6.31'

Geomorphic and Fish Passage Data	**UPSTREAM**	**DOWNSTREAM**	**IN STRUCTURE**
Dominant bed material at structure	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes [✓ no]	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes [✓ no]	0 1 2 3 4 [✓ 5] UK material throughout: yes [✓ no]
Sediment deposit types	none delta [✓ side]* point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high [✓ low] none → roadway above culvert	high low [✓ none]	
Hard bank armoring	intact failing [✓ none] unknown	intact failing [✓ none] unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

Bed Material Codes
- 0-none
- 1-bedrock
- 2-boulder
- 3-cobble
- 4-gravel
- 5-sand
- UK-unknown

*at band of river, almost mid-channel

Wildlife Data (left/right bank determined facing downstream)	**LEFT**	**RIGHT**	**LEFT**	**RIGHT**
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	[✓ yes] no	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
- C-coniferous forest
- D-deciduous forest
- M-mixed forest
- S-shrub/sapling
- H-herbaceous/grass
- B-bare
- R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)

species:
none Squirrel

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		**Inside Structure**	
species (none)	**sign**	**species (none)**	**sign**
birds			
Squirrels			

Spatial data collected w/GPS: yes no

Photos taken: yes no

Please fill out photo log below

Comments:

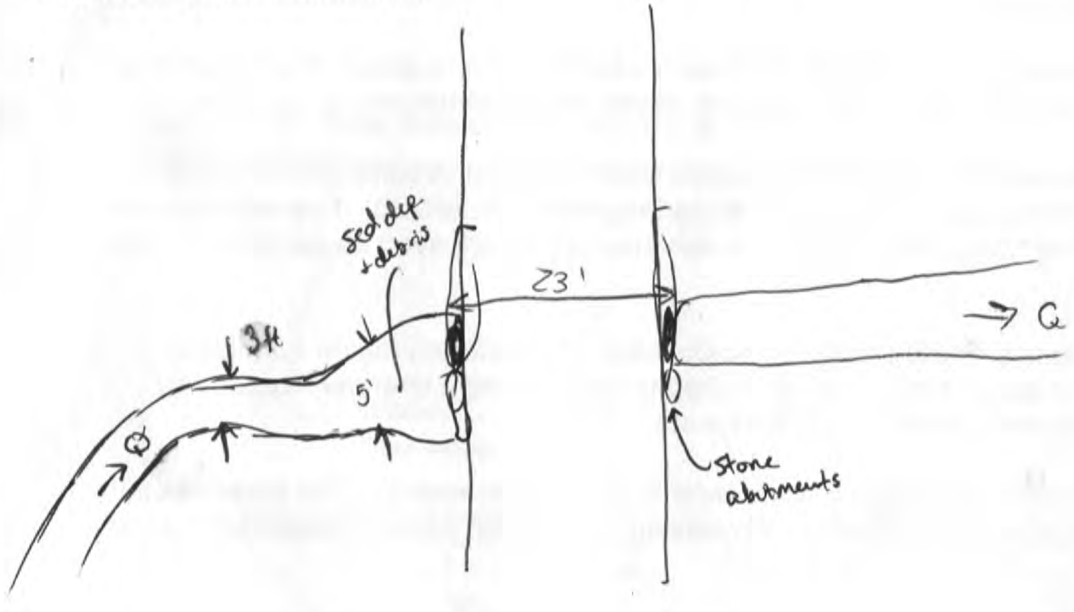
****See PHOTO LIST for photos that need to be taken***

Roll and Frame #	**Photo View**	**Description of Features in Photo**
*	Culvert Interior	Taken DS due to debris blockage

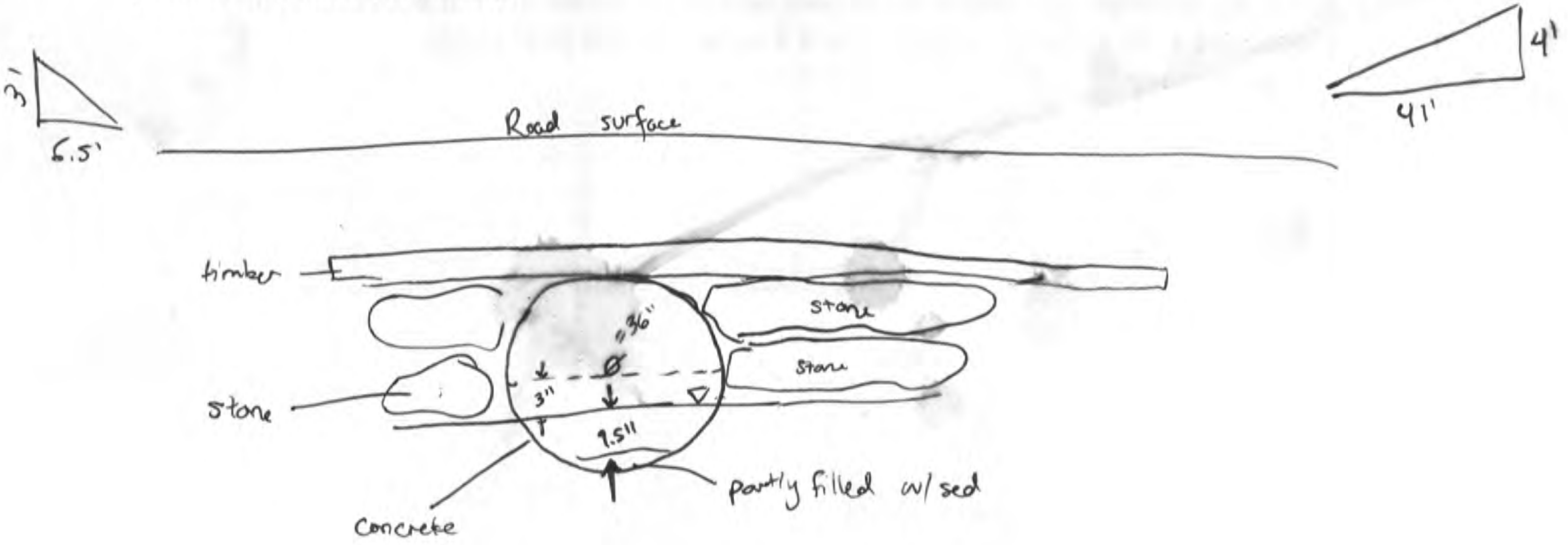
BVR-BEA-2-1

↑N

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

U/S 6.7'   Road (shoulder): 4.1'

D/S 6.31'

U/S and D/S Structure Inverts (using survey rod):

Dry culvert

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-3-1			
Observer(s) / Organization(s)	RLW, NSL		Date	7/6/15
Town	Richmond			
Road Name	Hillsdale Rd		Road Type	[✓ paved] gravel trail railroad
Stream Name	Unnamed		High Flow Stage	yes [✓ no] → river was dry upon inspection
Culvert Length	43' (ft.)	Structure Material [✓ concrete] plastic corrugated plastic smooth tank steel corrugated stone aluminum corrugated other mixed	Channel Width curve measured	5 (ft.)
Culvert Height	Ø 36" 3 (ft.)		# of culverts at crossing	1
Culvert Width	Ø 36" (3 (ft.))		Overflow pipe(s)	yes [✓ no]
			Structure skewed to roadway	[✓ yes] no

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant] bends at Culvert US

Structure located at a significant break in valley slope: [✓ yes] → mild break no unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] → due to skew of structure follow road unsure

Estimated distance avulsion would follow road: ~25 (feet)

Angle of stream flow approaching structure: [✓ sharp bend] naturally straight channelized straight

Sharp bend

Downstream

Water depth in culvert (at outlet): 0 (0.0 feet)

Culvert outlet invert: partially backwatered cascade [✓ free fall]

Backwater Length (measured from outlet): – (0.0 feet)

Outlet drop (invert to water surface): – (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] ~~no~~ Not wide but scoured downward

Pool depth at point of streamflow entry: – (0.0 feet)

Maximum pool depth: – (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 [✓ 3] [✓ 4] 5 UK bedrock present: yes [✓ no]	1 2 [✓ 3] [✓ 4] 5 UK bedrock present: yes [✓ no]	[✓ 0] 1 2 3 [✓ 4] 5 UK material throughout: yes [✓ no]
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	intact failing [✓ none] unknown	intact failing [✓ none] unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: _________ ft.	yes [✓ no] distance: _________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D, C	D, C	D	D, C
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500'or more up/downstream?	[✓ yes] no	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)
species:
none Squirrel

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
birds			
Squirrels			

Spatial data collected w/GPS: yes no

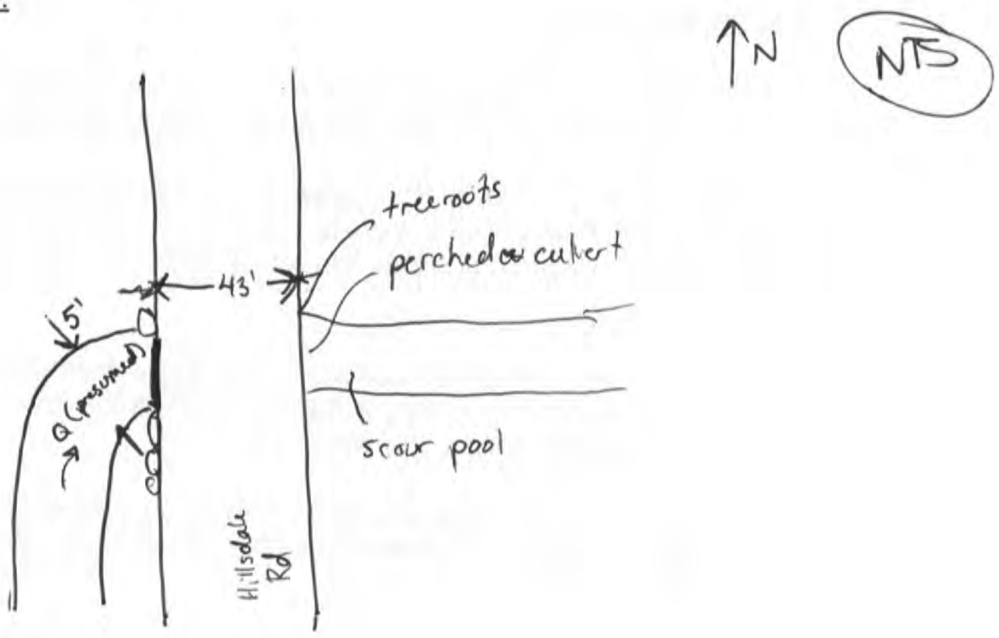
Photos taken: yes no
Please fill out photo log below

Comments:
****See PHOTO LIST for photos that need to be taken***

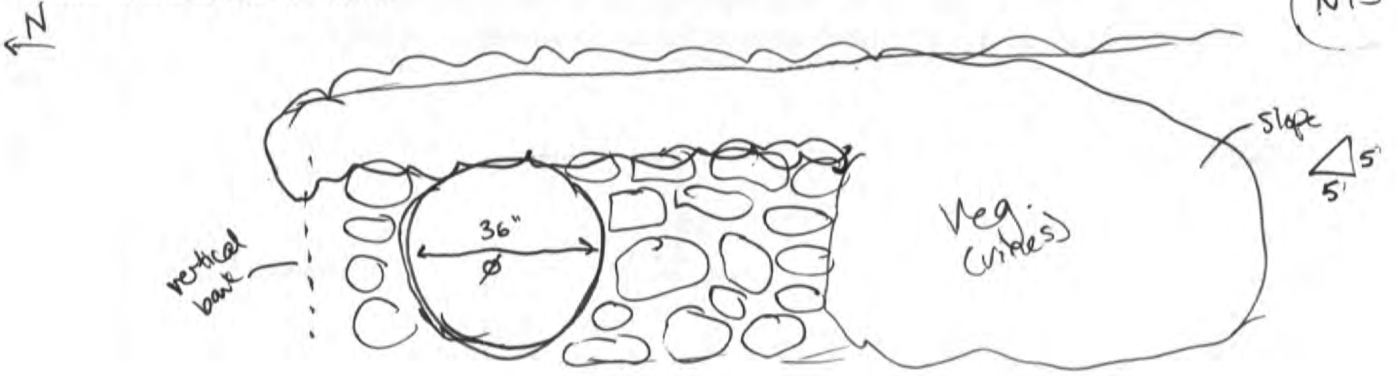
Roll and Frame #	Photo View	Description of Features in Photo

BVR-BEA-3-1
7/6/15

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

U/S 9.47'
D/S 10.48'
Road center 5'

U/S and D/S Structure Inverts (using survey rod):

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-3-2					
Observer(s) / Organization(s)	RLW, NSL				Date	7/6/15
Town	Richmond					
Road Name	Old Mountain Rd				Road Type	[✓ paved] gravel trail railroad
Stream Name	Unnamed				High Flow Stage	yes [✓ no]
Culvert Length	28.5'	(ft.)	Structure Material	[✓ concrete] plastic corrugated plastic smooth tank steel corrugated stone aluminum corrugated other mixed	Channel Width curve measured	2 (ft.)
Culvert Height	15"	(ft.)			# of culverts at crossing	1
Culvert Width	15"	(ft.)			Overflow pipe(s)	yes [✓ no]
					Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant]

Structure located at a significant break in valley slope: [✓ yes] → mild break no unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none] some plant material present

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~25 (feet)

Angle of stream flow approaching structure: sharp bend mild bend [✓ naturally straight] channelized straight

Downstream

Water depth in culvert (at outlet): >1" (0.0 feet)

Culvert outlet invert: partially backwatered or at [✓ grade] cascade free fall → flow reversed

Backwater Length (measured from outlet): - (0.0 feet)

Outlet drop (invert to water surface): - (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] no → Small / Wetland

Pool depth at point of streamflow entry: 5" (0.0 feet)

Maximum pool depth: 5" (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes [✓ no]	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes [✓ no]	[✓ 0] 1 2 3 4 [✓ 5] UK material throughout: yes [✓ no]
Sediment deposit types	[✓ none] delta side point mid-channel	none delta [✓ side] point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	road runoff high [✓ low] [✓ none] left	road runoff left high [✓ low] none side	
Hard bank armoring	intact failing [✓ none] unknown	intact failing [✓ none] unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

build up @ right side of exit

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	SD	SD
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	yes no	yes no	[✓ yes] no	[✓ yes] no

wetland

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)	species: [✓ none]

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
bird	aud.		
Frog	aud.		

Spatial data collected w/GPS: yes no

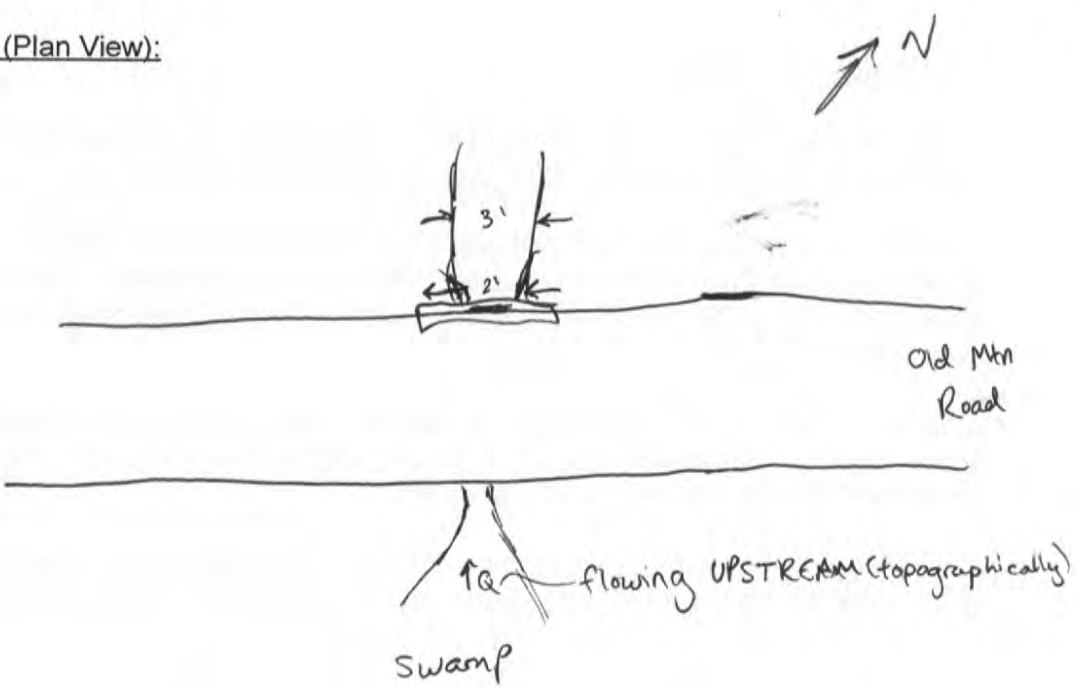
Photos taken: yes no
Please fill out photo log below

Comments:
****See PHOTO LIST for photos that need to be taken***

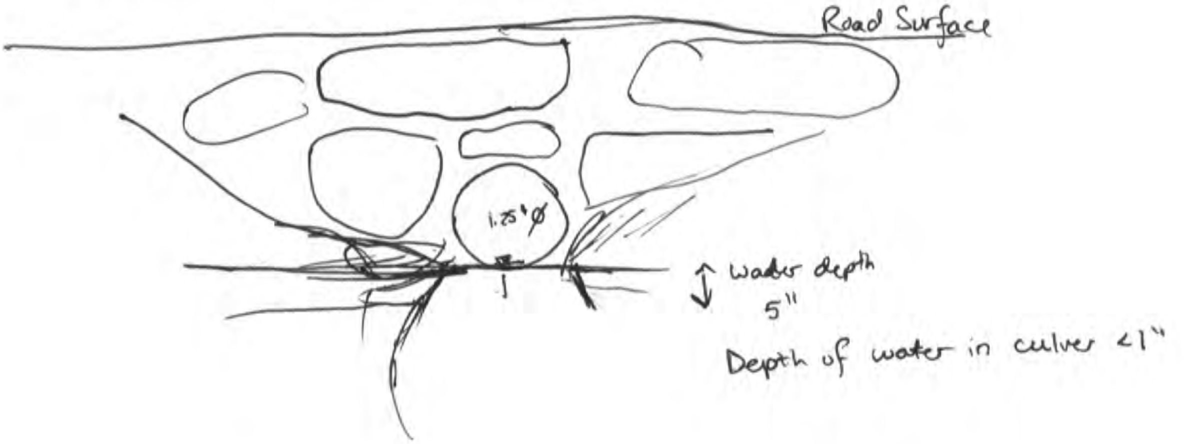
Roll and Frame #	Photo View	Description of Features in Photo

BVR-BEA-3-2

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

U/S and D/S Structure Inverts (using survey rod):

U/S: 7.62'

center: 4.12'

D/S: 7.12'

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-5-1		
Observer(s) / Organization(s)	RLW, NJL	Date	7/6/15
Town	Richmond		
Road Name	New London Tnpke.	Road Type	[✓ paved] gravel trail railroad
Stream Name	Unnamed	High Flow Stage	yes [✓ no]

Culvert Length	32'	(ft.)	Structure Material	Channel Width curve measured	6 (ft.)
Culvert Height	L+R: 2 ft	(ft.)	concrete plastic corrugated plastic smooth tank steel corrugated stone [✓ aluminum corrugated] other mixed	# of culverts at crossing	2
Culvert Width	L+R: 2 ft	(ft.)		Overflow pipe(s)	yes [✓ no]
				Structure skewed to roadway	[✓ yes] no Partially

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant]

Structure located at a significant break in valley slope: yes [✓ no] unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~20 (feet)

Angle of stream flow approaching structure: sharp bend [✓ mild bend] naturally straight channelized straight

Downstream

R	L
3"	3"

Water depth in culvert (at outlet): R 3" | L 3" (0.0 feet)

Culvert outlet invert: partially backwatered or [✓ at grade] cascade free fall

Backwater Length (measured from outlet): - (0.0 feet)

Outlet drop (invert to water surface): - (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] no

Pool depth at point of streamflow entry: .5' (0.0 feet)

Maximum pool depth: .5' (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 3 [✓ 4] [✓ 5] UK bedrock present: yes [✓ no]	1 2 3 [✓ 4] 5 UK bedrock present: yes [✓ no]	0 1 2 3 4 [✓ 5] UK material throughout: yes [✓ no]
Sediment deposit types	none delta [✓ side] left point mid-channel	none delta [✓ side] very minor → Left point mid-channel	none delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes no
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	intact failing [✓ none] unknown	intact failing [✓ none] unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	none [✓ culvert] small gap footer [✓ wing walls]	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	S	D	D	DC
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500'or more up/downstream?	yes [✓ no]	[✓ yes] no	yes [✓ no]	yes [✓ no]

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)

species:
none

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
Bird	aud.		
Fish → trout	local land owner		

Spatial data collected w/GPS: **yes** **no**

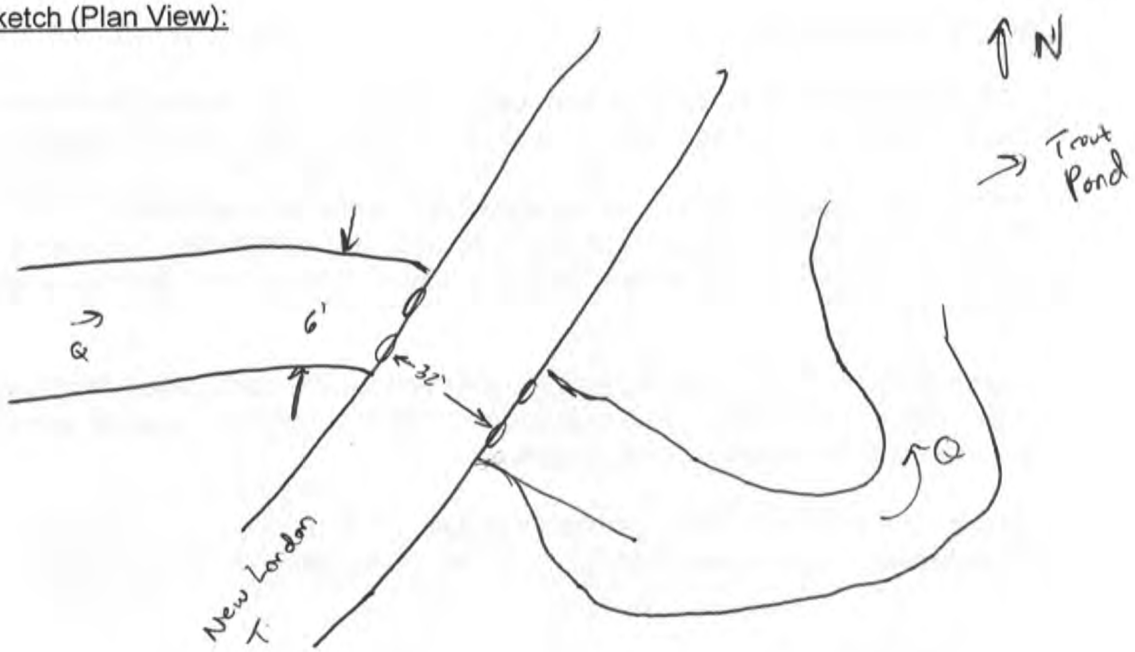
Photos taken: **yes** **no**
Please fill out photo log below

Comments:
****See PHOTO LIST for photos that need to be taken***

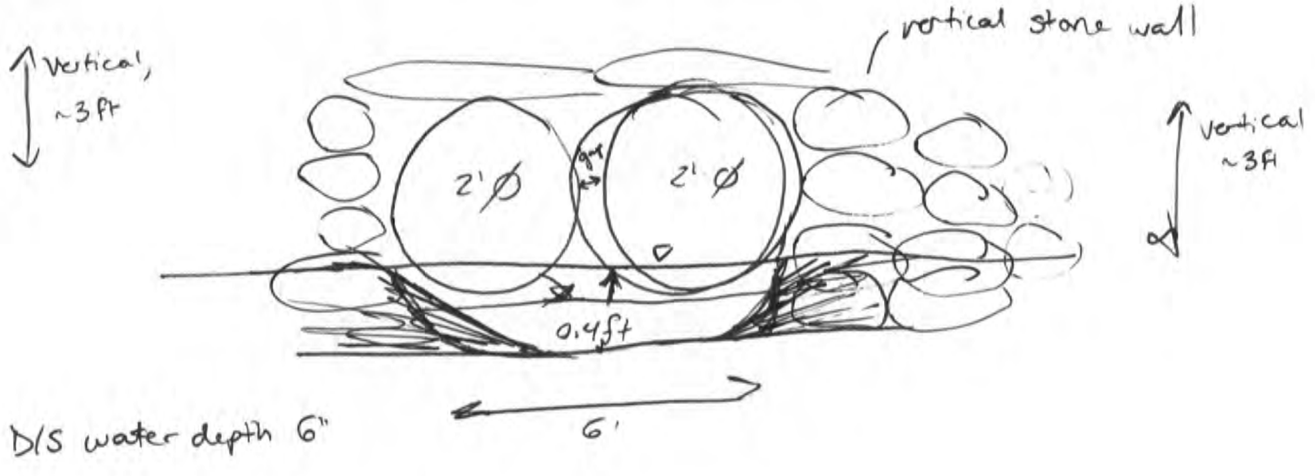
Roll and Frame #	Photo View	Description of Features in Photo

BVR-BGA-51
7/6/15

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



D/S water depth 6"

Height from Structure Upstream Invert to Roadway:

Left
U/S : 7.94'
D/S: 8.14'

Right
U/S: 7.95'
D/S: 8.1'

Center : 4.72'

U/S and D/S Structure Inverts (using survey rod):

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-6-1				
Observer(s) / Organization(s)	RLW, NBL			Date	7/6/15
Town	Richmond				
Road Name	New London T., intersection of Dawley Park			Road Type	[✓ paved] gravel trail railroad
Stream Name	Unnamed			High Flow Stage	yes [✓ no]
Culvert Length	40' (ft.)	Structure Material	concrete plastic corrugated plastic smooth tank steel corrugated stone [✓ aluminum corrugated] other mixed	Channel Width curve measured	5-6' (ft.)
Culvert Height	3'.5 (ft.)			# of culverts at crossing	1
Culvert Width	3.5' (ft.)			Overflow pipe(s)	yes [✓ no]
				Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

→U/S Pond + Waterfall

Floodplain filled by roadway approaches: [✓ entirely] partially not significant

Structure located at a significant break in valley slope: [✓ yes] no unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Wetland Plants U/S

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: [✓ yes] no → Steep flow from waterfall

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~30 (feet)

Angle of stream flow approaching structure: [✓ sharp bend] mild bend naturally straight channelized straight

Downstream

Water depth in culvert (at outlet): .5 (0.0 feet)

Culvert outlet invert: partially backwatered or at grade [✓ cascade]

Backwater Length (measured from outlet): 1.5' (0.0 feet)

Outlet drop (invert to water surface): 1 (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] no

Pool depth at point of streamflow entry: 2' (0.0 feet)

Maximum pool depth: 3' (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: [✓ yes] no

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	[✓ 1] 2 [✓ 3] [✓ 4] 5 UK bedrock present: [✓ yes] no	1 [✓ 2] [✓ 3] 4 5 UK bedrock present: yes [✓ no]	0 1 2 3 4 [✓ 5] UK → some wood material throughout: [✓ yes] no
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	none delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	[✓ intact] → left side failing none unknown	intact failing [✓ none] [✓ unknown] → likely none, but view was obstructed	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	[✓ none] culvert footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: _________ ft.	yes [✓ no] distance: _________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	H	S	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	yes [✓ no]	yes [✓ no]	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)
species:
none

Wildlife sign and species observed near (up/downstream) and inside structure (circle none or list species and sign types)	Outside Structure		Inside Structure	
	species (none)	sign	species (none)	sign
	Bird	aud		
	frog	aud		
	Snake	vis (farther u/s)		

Spatial data collected w/GPS: yes no

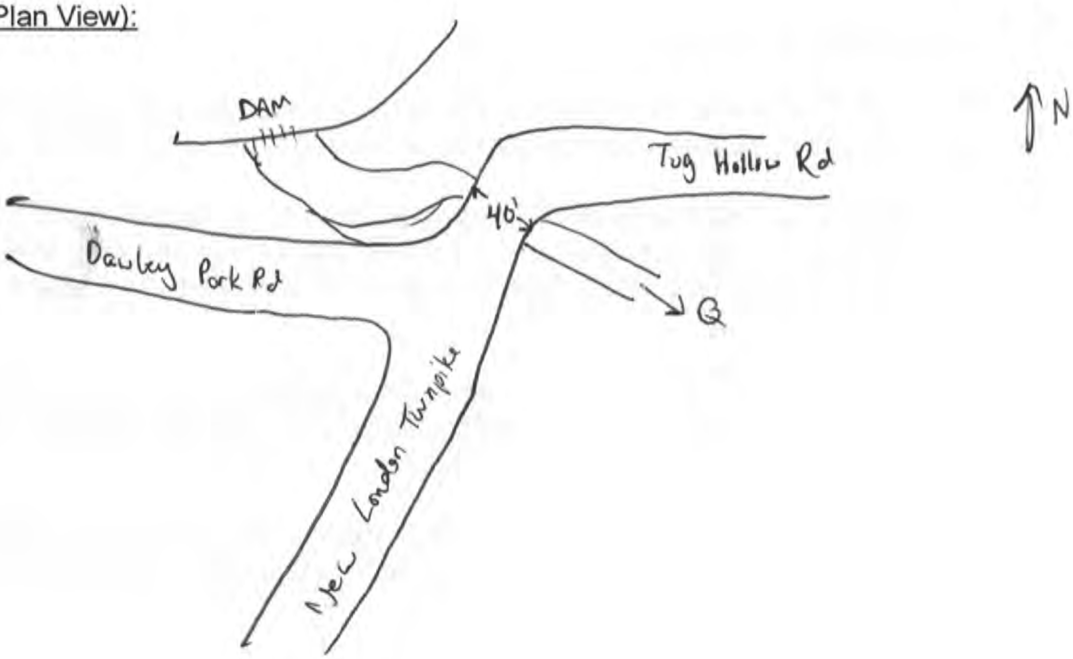
Photos taken: yes no
Please fill out photo log below

Comments:
****See PHOTO LIST for photos that need to be taken***

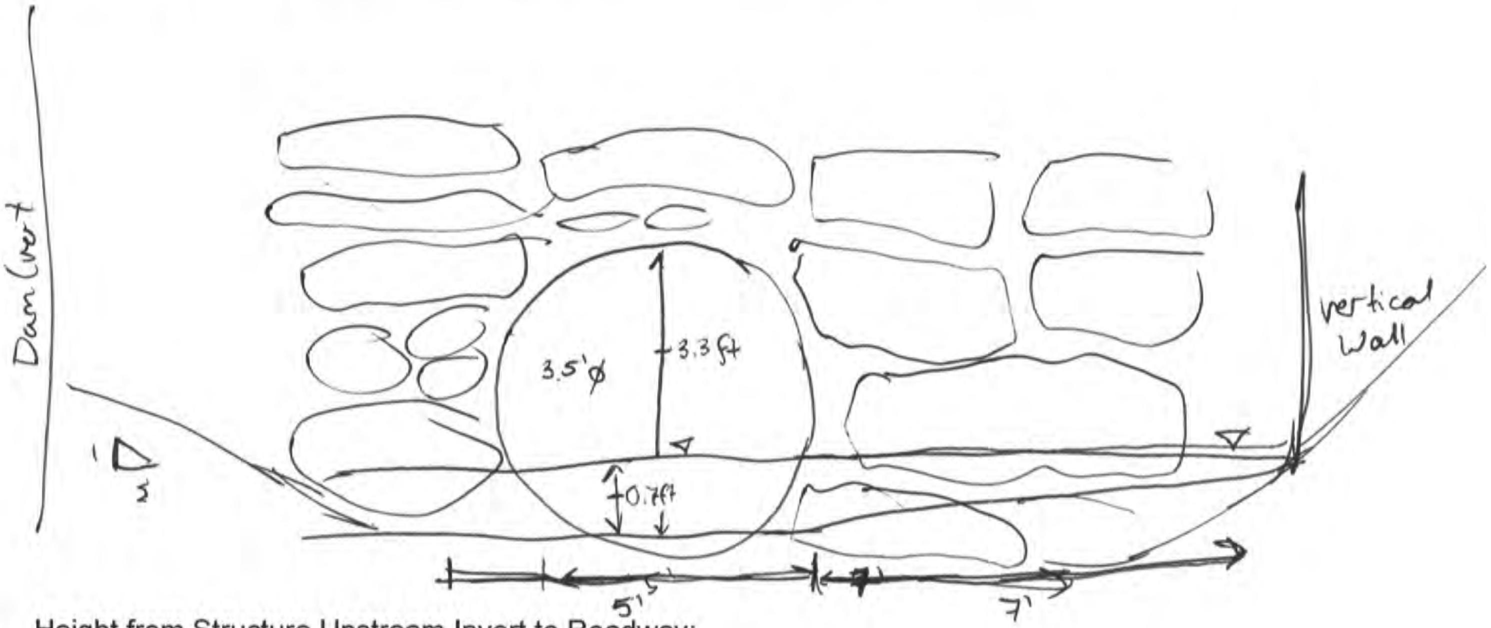
Roll and Frame #	Photo View	Description of Features in Photo

BVR-BEA-6-1
7/6/15

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

Roadway 3.35'

U/S and D/S Structure Inverts (using survey rod):

U/S 6.49'
D/S 6.16'

Center 3.35'

→ would flood @ intersection

Culvert Assessment - Geomorphic & Habitat Parameters

SGA Structure ID	BVR-BEA-T6-2		
Observer(s) / Organization(s)	RLW, NSL	Date	7/6/15
Town	Richmond		
	U/S - box culvert, D/S - retro-fitted culvert pipe		
Road Name	Dawley Park Rd	Road Type	[✓ paved] gravel trail railroad
Stream Name	Unnamed	High Flow Stage	yes [✓ no]
Culvert Length	35.5' (ft.)	Channel Width curve measured	3' (ft.)
Culvert Height	U/S 3' | D/S 2.5' (ft.)	# of culverts at crossing	1 → U/S + D/S different types
Culvert Width	3' | 2.5' (ft.)	Overflow pipe(s)	yes [✓ no]
Structure Material	[✓ concrete] – D/S plastic corrugated plastic smooth tank steel corrugated [✓ stone] — U/S aluminum corrugated other mixed	Structure skewed to roadway	[✓ yes] no

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely partially [✓ not significant]

Structure located at a significant break in valley slope: [✓ yes] no unsure

Culvert slope as compared with the channel slope is: higher lower [✓ same]

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: [✓ cross road] follow road unsure

Estimated distance avulsion would follow road: ~25 (feet)

Angle of stream flow approaching structure: sharp bend [✓ mild bend] naturally straight [✓ channelized straight] right at opening

Downstream

Water depth in culvert (at outlet): 71'' (0.0 feet)

Culvert outlet invert: partially backwatered or at grade [✓ cascade] free fall

Backwater Length (measured from outlet): 1'' (0.0 feet)

Outlet drop (invert to water surface): 2.5'' (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] no

Pool depth at point of streamflow entry: .5' (0.0 feet)

Maximum pool depth: .5' (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	[✓ 1] [✓ 2] 3 [✓ 4] 5 UK bedrock present: [✓ yes] no	1 [✓ 3] [✓ 4] 5 UK bedrock present: yes [✓ no]	0 1 2 3 [✓ 4] 5 UK material throughout: [✓ yes] no
Sediment deposit types	[✓ none] delta side point	none delta [✓ side] left side point mid-channel	none delta [✓ side] point [✓ mid-channel]
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	[✓ intact] failing none unknown	intact [✓ failing] none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] culvert footer wing walls	none [✓ culvert] footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ______ ft.	yes [✓ no] distance: ______ ft.	

→ failing
Round Cobble/stone

) minor, right of culvert

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	[✓ yes] no	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)
species:
none

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
Frog	vis.		
bird	aud.		

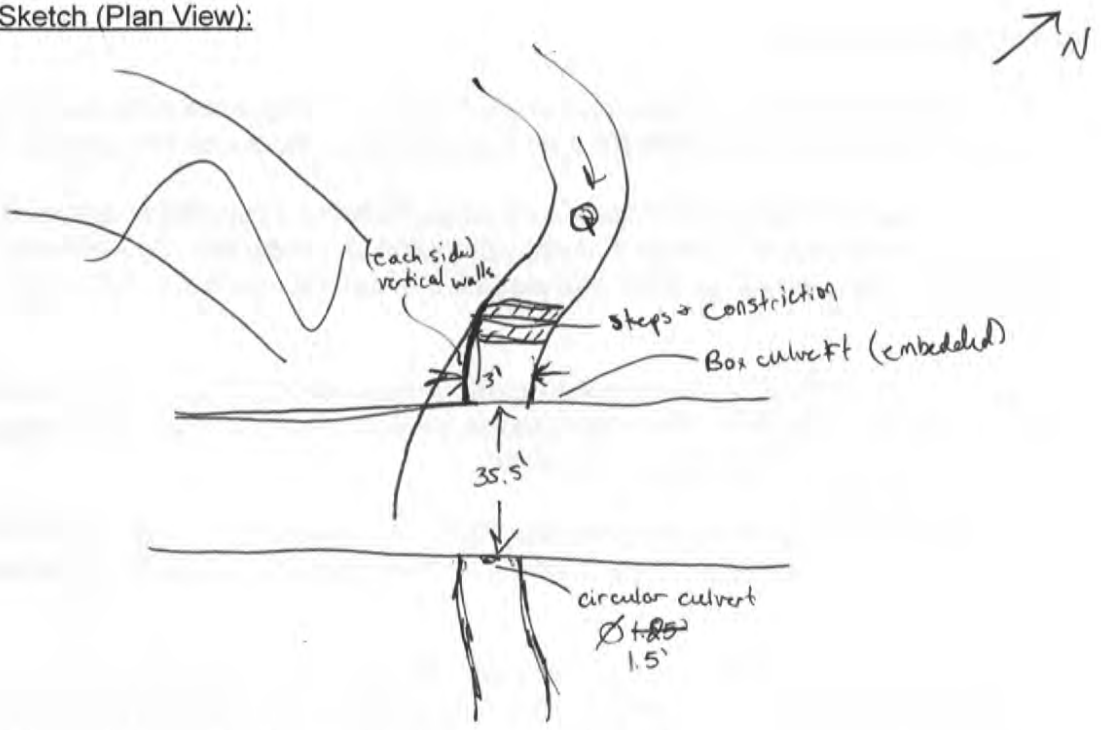
Spatial data collected w/GPS: yes no

Photos taken: yes no
Please fill out photo log below

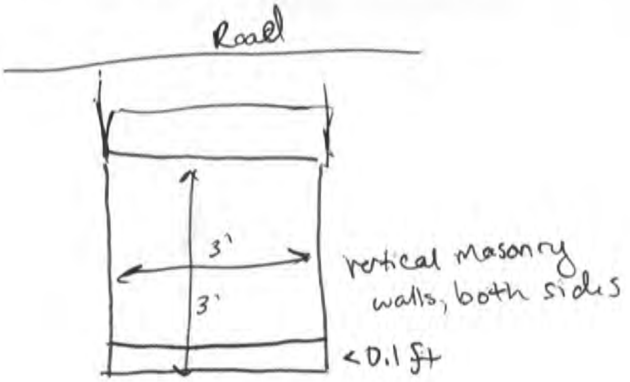
Comments:
****See PHOTO LIST for photos that need to be taken***

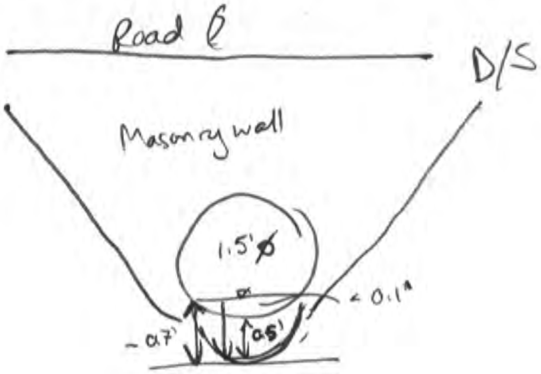
Roll and Frame #	Photo View	Description of Features in Photo

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):





Height from Structure Upstream Invert to Roadway:

U/S 9.12
D/S 11.2
Center 3.37

U/S and D/S Structure Inverts (using survey rod):

Bridge & Arch Assessment - Geomorphic & Habitat Parameters

Structure Type: [✓ bridge] / arch

SGAStructure ID					
Observer(s) / Organization(s)	A. Bolin & J. Graber			Date	6/30/15
Town	Richmond			Phase 1 Project	
Reach VTID	BER6A				
Road Name	Punch Bowl Trail			Road Type	paved gravel [✓ trail] railroad
Stream Name	Beaver River			High Flow Stage	yes [✓ no]
Structure Length	4.9ft (ft.)	Structure Material	aluminum, wrought iron, cast iron concrete masonry (arches) & slabs - Abut prestressed concrete/post-tensioned steel timber → Deck other	Channel Width curve measured	27 (ft.)
Constricting Opening Height	4.3 (ft.)			# of bridge piers or # arches at crossing	1 col, 0 piers
Structure Width	15.5 (ft.)			Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely [✓ partially] not significant

Structure located at a significant break in valley slope: yes [✓ no] unsure

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: [✓ yes] no

If channel avulses, stream will: cross road [✓ follow road] unsure

Estimated distance avulsion would follow road: 28ft (feet)

Angle of stream flow approaching structure: sharp bend mild bend naturally straight [✓ channelized straight]

Downstream

Pool present immediately downstream of structure: yes [✓ no]

Maximum pool depth: 2.1 (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Stepped footers: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 [✓ 3] 4 5 UK bedrock present: yes no	1 2 [✓ 3] 4 5 UK bedrock present: yes no	1 2 [✓ 3] 4 5 UK bedrock present: yes no
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	[✓ intact] failing none unknown	[✓ intact] failing none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	none [✓ abutments] footers wing walls	none [✓ abutments] footers wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: _________ ft.	yes [✓ no] distance: _________ ft.	

Bed Material Codes
- 1-bedrock
- 2-boulder
- 3-cobble
- 4-gravel
- 5-sand
- UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500'or more up/downstream?	[✓ yes] no	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
- C-coniferous forest
- D-deciduous forest
- M-mixed forest
- S-shrub/sapling
- H-herbaceous/grass
- B-bare
- R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)

species:
none

Wildlife sign and species observed near (up/downstream) and inside structure

(circle none or list species and sign types)

Outside Structure		Inside Structure	
species (none)	sign	species (none)	sign
		Spiders	Sight

Spatial data collected w/GPS: [✓ yes] no

Photos taken: [✓ yes] no
Please fill out photo log below

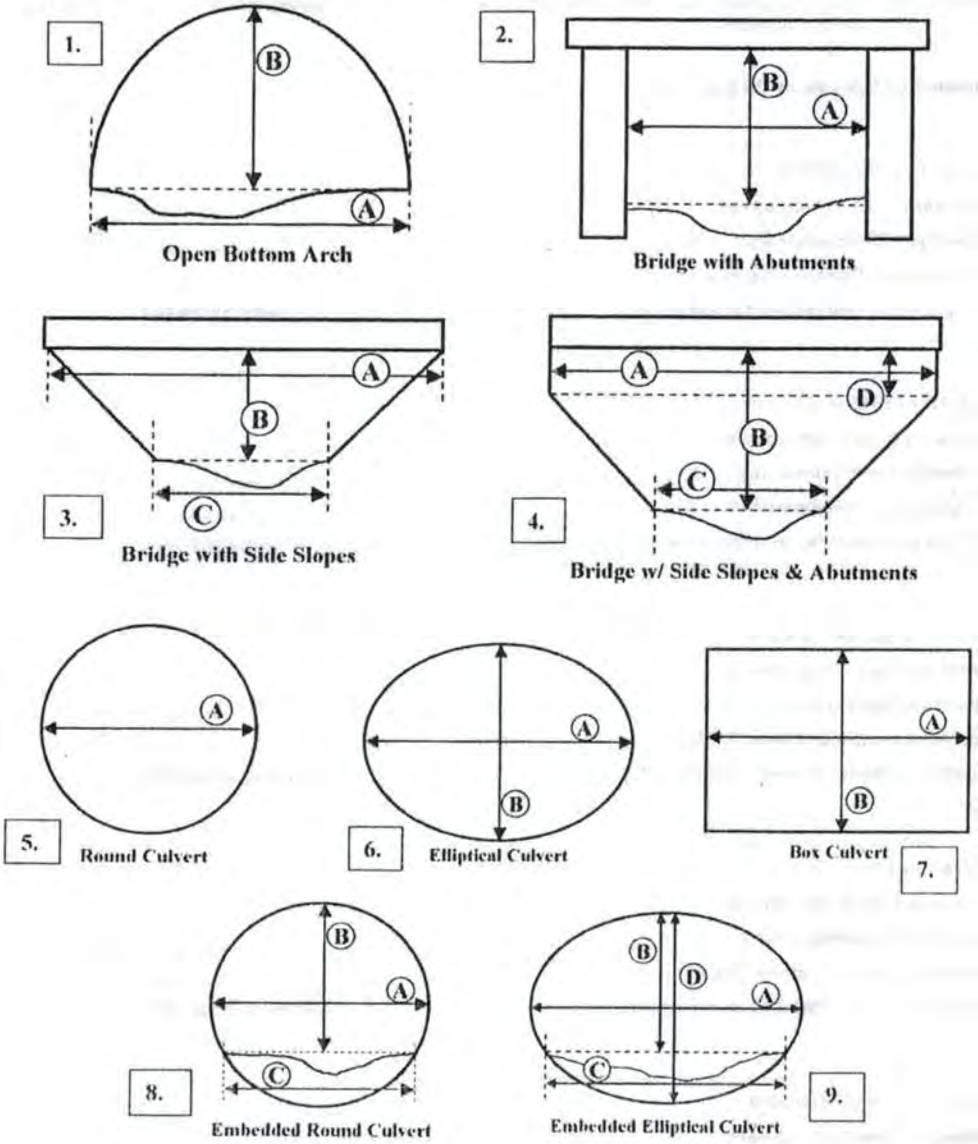
Comments:

****See PHOTO LIST for photos that need to be taken***

Roll and Frame #	Photo View	Description of Features in Photo

Appendix 2 Field data collection form, p. 3 of 5

Crossing Dimensions



Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☑ Ford

Upstream Dimensions (ft.): A) 15.5 B) 2.9 C) ______ D) ______

Downstream Dimensions (ft.): A) 15.5 B) 2.6 C) ______ D) ______

Length of stream through crossing (ft.): 4.9 **Crossing slope (%)** ______

Appendix 2 Field data collection form, p. 4 of 5

DIMENSIONS WORKSHEET FOR MULTIPLE CULVERT CROSSINGS

Crossing ID# __________

Note: *When inventorying multiple culverts, label left culvert 1 and go in increasing order from left to right from downstream end (outlet) looking upstream.*

Number of Culverts or Bridge Cells ________

Culvert or Bridge Cell 2 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Downstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

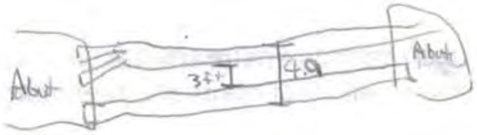
Culvert or Bridge Cell 3 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Downstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Culvert or Bridge Cell 4 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Downstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

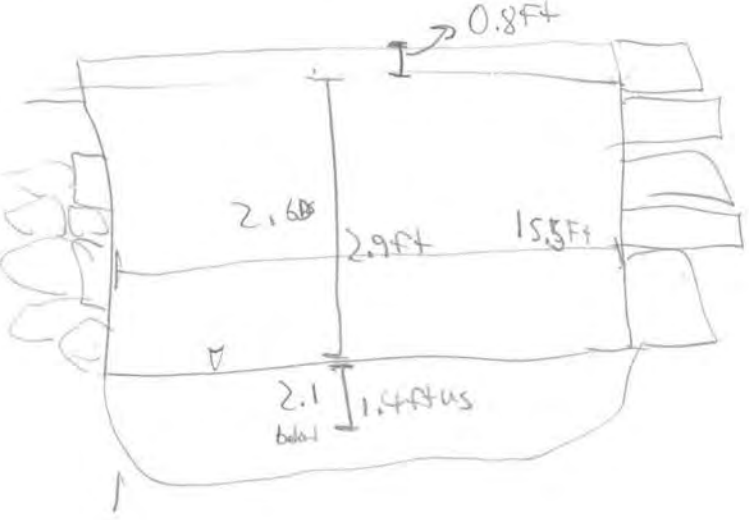
Culvert or Bridge Cell 5 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Downstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Culvert or Bridge Cell 6 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Downstream Dimensions (ft.): A) ___________ B) ___________ C) ___________ D) ___________
Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Structure Sketch (Plan View):



Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

0.8ft

U/S and D/S Structure Inverts (using survey rod):

$.12245ft = \frac{0.6ft}{4.9ft}$ = Local Bedslope

= Ws Slope same as Segment

Culvert Assessment - Geomorphic & Habitat Parameters

Field Map # ______

SGA Structure ID	BVR-FOUND-20150817	Local ID	
Observer(s) / Organization(s)	A. B. & J. G.	Date	8/17/15
Town	Richmond RI	Phase 1 Project	
Location	Top of BER4	Longitude (E/W)	
Reach VTID		Latitude (N/S)	
Road Name	—	Road Type	paved gravel [✓ trail] railroad Concrete
Stream Name	Beaver River	High Flow Stage	yes [✓ no]
Culvert Length	3F4 (ft.)	Channel Width curve measured	19 (ft.)
Culvert Height	3.7 (ft.)	# of culverts at crossing	1 box
Culvert Width	13.2 (ft.)	Overflow pipe(s)	yes [✓ no]
		Structure skewed to roadway	yes [✓ no]

Structure Material: [✓ concrete] plastic corrugated; plastic smooth; tank; steel corrugated; stone; aluminum corrugated; other; mixed

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: entirely [✓ partially] not significant

Structure located at a significant break in valley slope: yes no [✓ unsure]

Culvert slope as compared with the channel slope is: [✓ higher] lower same

Upstream

Is structure opening partially obstructed by (circle all that apply): wood debris sediment deformation [✓ none]

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: cross road [✓ follow road] unsure

Estimated distance avulsion would follow road: 10 (feet)

Angle of stream flow approaching structure: sharp bend mild bend naturally straight [✓ channelized straight]

Downstream

Water depth in culvert (at outlet): 0.2 (0.0 feet)

Culvert outlet invert: partially backwatered or at grade [✓ cascade] free fall

Backwater Length (measured from outlet): 50 (0.0 feet)

Outlet drop (invert to water surface): 1.0 (0.0 feet)

Pool present immediately downstream of structure: [✓ yes] no

Pool depth at point of streamflow entry: .2 (0.0 feet)

Maximum pool depth: 3 (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 3 [✓ 4] 5 UK bedrock present: yes [✓ no]	1 2 [✓ 3] 4 5 UK bedrock present: yes [✓ no]	[✓ 0] 1 2 3 4 5 UK material throughout: yes [✓ no]
Sediment deposit types	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	yes [✓ no]	yes [✓ no]	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	intact [✓ failing] RB none unknown	intact [✓ failing] Both none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	none [✓ culvert] footer wing walls	none [✓ culvert] footer wing walls	
Beaver dam near structure Distance from structure to dam	yes [✓ no] distance: ________ ft.	yes [✓ no] distance: ________ ft.	

Bed Material Codes
0-none
1-bedrock
2-boulder
3-cobble
4-gravel
5-sand
UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	M	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	[✓ yes] no	[✓ yes] no	[✓ yes] no	[✓ yes] no

Vegetation Type Codes
C-coniferous forest
D-deciduous forest
M-mixed forest
S-shrub/sapling
H-herbaceous/grass
B-bare
R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)	species: [✓ none]

Wildlife sign and species observed near (up/downstream) and inside structure (circle none or list species and sign types)	Outside Structure		Inside Structure	
	species (none)	sign	species (none)	sign
	Frogs	sight		

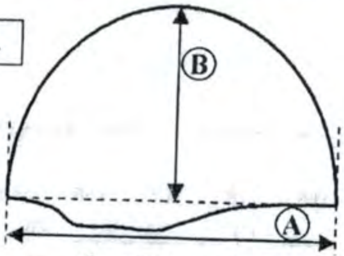
Spatial data collected w/GPS: [✓ yes] no Photos taken: [✓ yes] no Please fill out photo log below	**Comments:**

Roll and Frame #	Photo View	Description of Features in Photo

Appendix 2 Field data collection form, p. 3 of 5

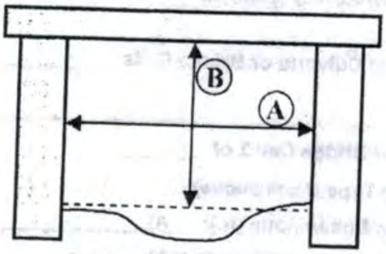
Crossing Dimensions

1.

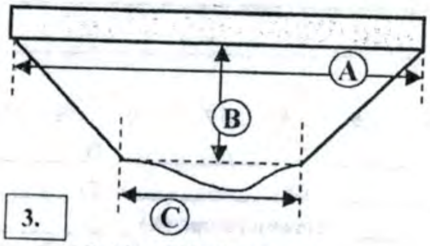


Open Bottom Arch

2.

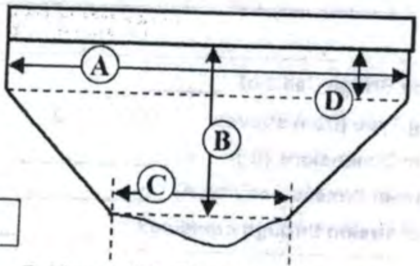


Bridge with Abutments



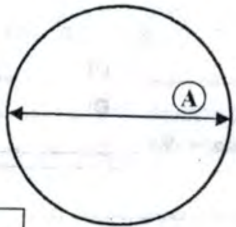
3.

Bridge with Side Slopes

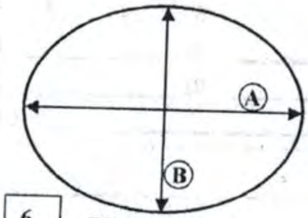


4.

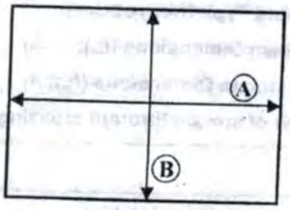
Bridge w/ Side Slopes & Abutments



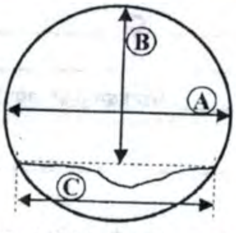
5. Round Culvert



6. Elliptical Culvert

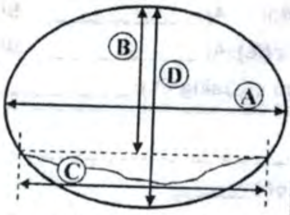


Box Culvert 7.



8.

Embedded Round Culvert



9.

Embedded Elliptical Culvert

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☑ 7. ☐ 8. ☐ 9. Ford

Upstream Dimensions (ft.): A) 13.2 B) 3.9 C) ____ D) ____

Downstream Dimensions (ft.): A) 13.2 B) 3.9 C) ____ D) ____

Length of stream through crossing (ft.): 3 **Crossing slope (%)** ____

Appendix 2 Field data collection form, p. 4 of 5

Crossing ID#

DIMENSIONS WORKSHEET FOR MULTIPLE CULVERT CROSSINGS

Note: When inventorying multiple culverts, label left culvert 1 and go in increasing order from left to right from downstream end (outlet) looking upstream.

Number of Culverts or Bridge Cells ________

Culvert or Bridge Cell 2 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3 ☐ 4. ☐ 5. ☐ 6. ☐ 7 ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Downstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Culvert or Bridge Cell 3 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Downstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Culvert or Bridge Cell 4 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Downstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Culvert or Bridge Cell 5 of ______

Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Downstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Culvert or Bridge Cell 6 of ______

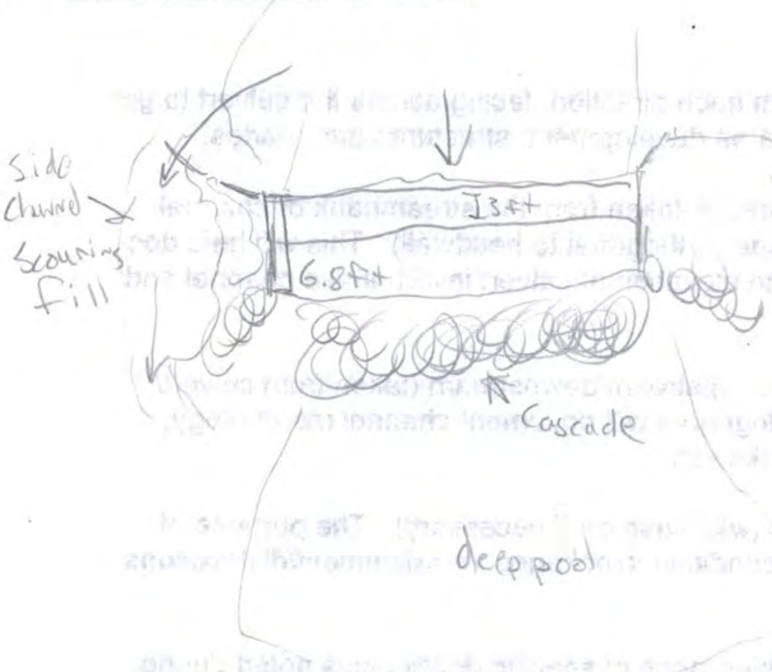
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

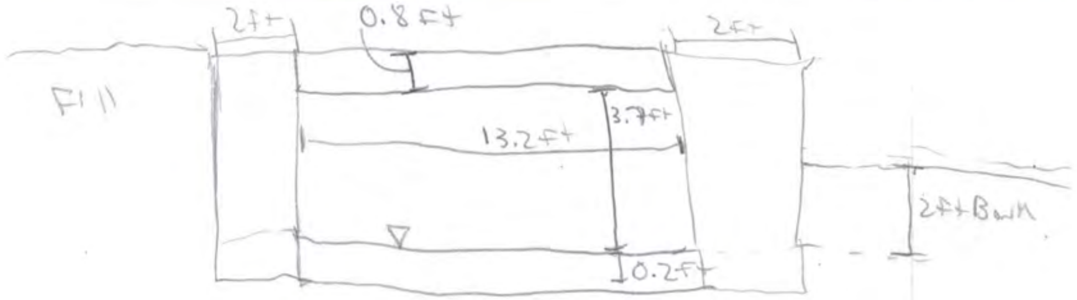
Downstream Dimensions (ft.): A) __________ B) __________ C) __________ D) __________

Length of stream through crossing (ft.): ____________________ **Crossing slope (%)** ________________

Structure Sketch (Plan View):



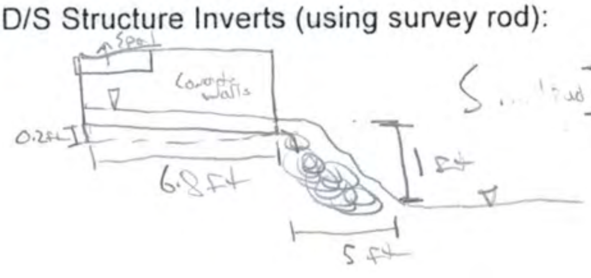
Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

0.8 ft

U/S and D/S Structure Inverts (using survey rod):



S [illegible] = 0.2 ft / 6.8 ft → in structure

List of Photo Locations:

1. Overall Roadway Photographs from each direction, facing across the culvert to get an idea of approaches and adjacent area development, structures and grades.

2. Culvert Headwall/Wingwall Photographs taken from the streambank or channel facing the culvert/bridge invert and road (orthogonal to headwall). This will help document structure type/configuration and elevation of culvert invert above channel and below road.

3. Culvert Channel Photographs facing upstream/downstream (taken from culvert/ bridge ends or headwalls). This photographs will document channel morphology, grade, bed characteristics, scour, banks etc.

4. Inside Culvert/Bridge Photographs (with flash on if necessary). The purpose of these photos is to document interior condition, blockages, misalignment/dislocations etc.

5. Deficiency Photographs. Take photographs of specific deficiencies noted during the inspection such as scour, damage, hazards, debris dams, blockages, sedimentation deposits, etc.

Above all, need to stay safe - If and perspectives/locations are not accessible, or questionable, do not take photographs if it compromises your safety.

Bridge & Arch Assessment - Geomorphic & Habitat Parameters

Structure Type: [✓ bridge] / arch

SGAStructure ID	BVR-FOUND-20151015		
Observer(s) / Organization(s)	A B + I G	Date	10/15/15
Town	Richmond	Phase 1 Project	
Reach VTID	BER 3A		
Road Name	Driveway	Road Type	[✓ paved] gravel trail railroad
Stream Name	Beaver River	High Flow Stage	yes [✓ no]

Structure Length	16 (ft.)	Structure Material	aluminum, wrought iron, cast iron concrete masonry (arches) & slabs prestressed concrete/post-tensioned steel [✓ timber] - Span other	Channel Width curve measured	30 (ft.)
Constricting Opening Height	6.4 (ft.)			# of bridge piers or # arches at crossing	1 cell
Structure Width	21 (ft.)			Structure skewed to roadway	yes [✓ no]

Geomorphic and Fish Passage Data

General

Floodplain filled by roadway approaches: [✓ entirely] partially not significant

Structure located at a significant break in valley slope: yes [✓ no] unsure

Upstream

Is structure opening partially obstructed by (circle all that apply): [✓ wood debris] sediment deformation none

Steep riffle present immediately upstream of structure: yes [✓ no]

If channel avulses, stream will: cross road [✓ follow road] unsure

Estimated distance avulsion would follow road: ____________ (feet)

Angle of stream flow approaching structure: sharp bend [✓ mild bend] naturally straight channelized straight

Downstream

Pool present immediately downstream of structure: [✓ yes] no

Maximum pool depth: 5 (0.0 feet or >4feet)

Downstream bank heights are substantially higher than upstream bank heights: [✓ yes] no

Stepped footers: yes [✓ no]

Geomorphic and Fish Passage Data	UPSTREAM	DOWNSTREAM	IN STRUCTURE
Dominant bed material at structure	1 2 3 4 [✓ 5] UK bedrock present: yes [✓ no]	1 2 [✓ 3] 4 5 UK bedrock present: yes [✓ no]	1 2 3 4 [✓ 5] UK bedrock present: yes [✓ no]
Sediment deposit types	none delta side point [✓ mid-channel]	none delta side [✓ point] mid-channel	[✓ none] delta side point mid-channel
Elevation of sediment deposits is greater than or equal to ½ bankfull elevation:	[✓ yes] no	[✓ yes] no	yes [✓ no]
Bank erosion	high low [✓ none]	high low [✓ none]	
Hard bank armoring	[✓ intact] failing none unknown	[✓ intact] failing none unknown	
Streambed scour causing undermining around/under structure (circle all that apply)	[✓ none] abutments footers wing walls	[✓ none] abutments footers wing walls	
Beaver dam near structure Distance from structure to dam	[✓ yes] no distance: 3ft ft.	yes [✓ no] distance: ______ ft.	

Bed Material Codes
- 1-bedrock
- 2-boulder
- 3-cobble
- 4-gravel
- 5-sand
- UK-unknown

Wildlife Data (left/right bank determined facing downstream)	LEFT	RIGHT	LEFT	RIGHT
Dominant vegetation type	D	D	D	D
Does a band of shrub/forest vegetation that is at least 50' wide start within 25' of structure and extend 500' or more up/downstream?	yes [✓ no]	yes [✓ no]	yes [✓ no]	yes [✓ no]

Vegetation Type Codes
- C-coniferous forest
- D-deciduous forest
- M-mixed forest
- S-shrub/sapling
- H-herbaceous/grass
- B-bare
- R-road embankment

Road-killed wildlife within ¼ mile of structure? (circle none or list species)	species: [✓ none]

Wildlife sign and species observed near (up/downstream) and inside structure (circle none or list species and sign types)	Outside Structure		Inside Structure	
	species [✓ (none)]	sign	species (none)	sign

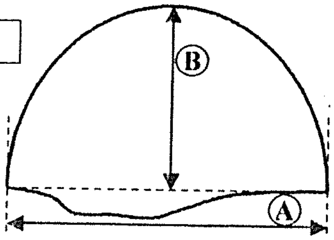
Spatial data collected w/GPS: [✓ yes] no Photos taken: [✓ yes] no Please fill out photo log below	**Comments:** ****See PHOTO LIST for photos that need to be taken***

Roll and Frame #	Photo View	Description of Features in Photo

Appendix 2 Field data collection form, p. 3 of 5

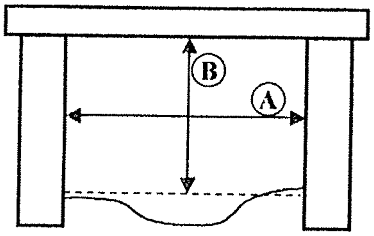
Crossing Dimensions

1.

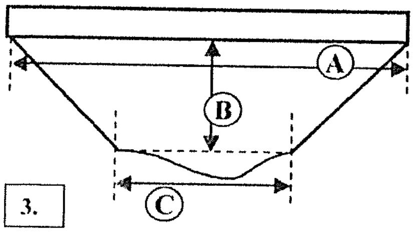


Open Bottom Arch

2.

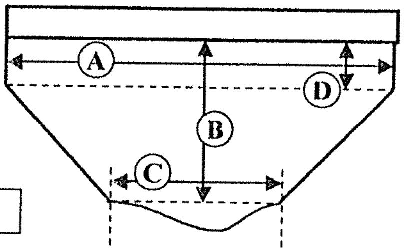


Bridge with Abutments



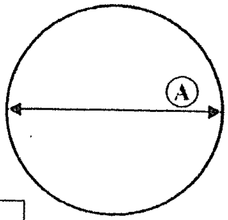
3.

Bridge with Side Slopes

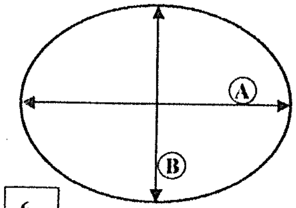


4.

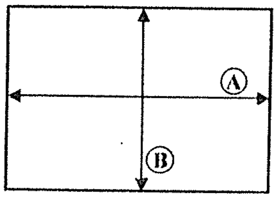
Bridge w/ Side Slopes & Abutments



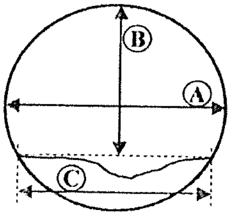
5. Round Culvert



6. Elliptical Culvert

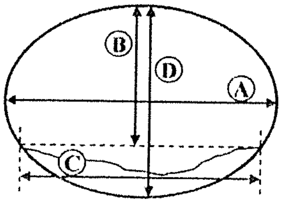


Box Culvert 7.



8.

Embedded Round Culvert



9.

Embedded Elliptical Culvert

Crossing Type (from above): ☐ 1. ☐ 2. ✓ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft.): A) 21 B) 4.4 C) 9 D) ____

Downstream Dimensions (ft.): A) 21 B) 4.8 C) 9 D) ____

Length of stream through crossing (ft.): 16 Crossing slope (%) ____

Appendix 2 Field data collection form, p. 4 of 5

DIMENSIONS WORKSHEET FOR MULTIPLE CULVERT CROSSINGS

Crossing ID# __________

Note: When inventorying multiple culverts, label left culvert 1 and go in increasing order from left to right from downstream end (outlet) looking upstream.

Number of Culverts or Bridge Cells ________

Culvert or Bridge Cell 2 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Downstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Length of stream through crossing (ft.): ______________________ **Crossing slope (%)** __________________

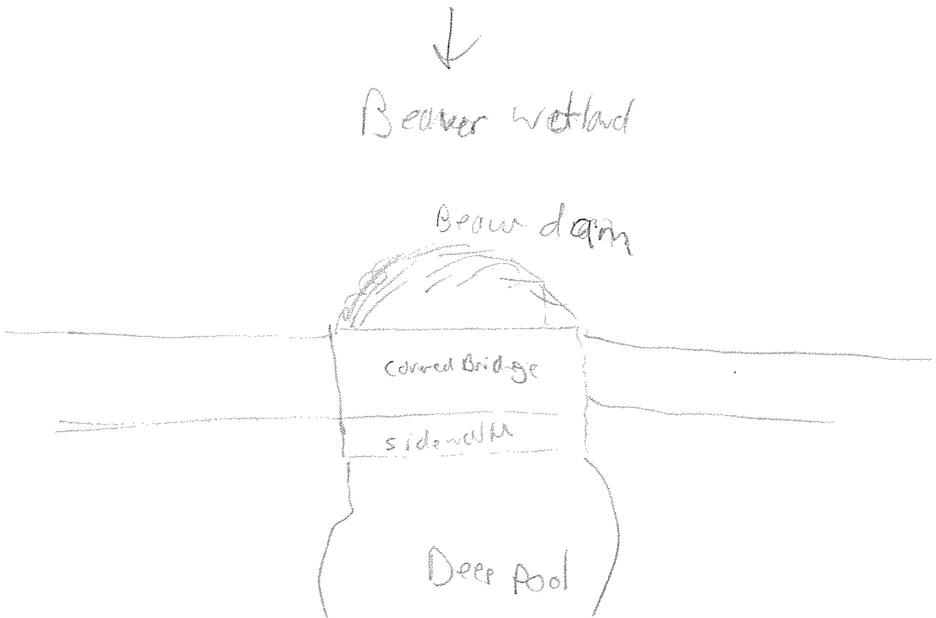
Culvert or Bridge Cell 3 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Downstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Length of stream through crossing (ft.): ______________________ **Crossing slope (%)** __________________

Culvert or Bridge Cell 4 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Downstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Length of stream through crossing (ft.): ______________________ **Crossing slope (%)** __________________

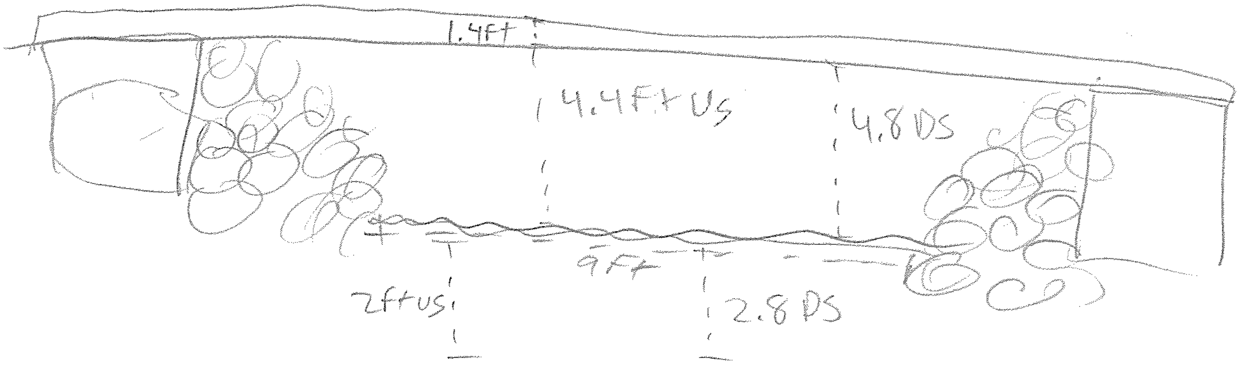
Culvert or Bridge Cell 5 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Downstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Length of stream through crossing (ft.): ______________________ **Crossing slope (%)** __________________

Culvert or Bridge Cell 6 of _______
Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford
Upstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Downstream Dimensions (ft.): A) ____________ B) ____________ C) ____________ D) ____________
Length of stream through crossing (ft.): ______________________ **Crossing slope (%)** __________________

Structure Sketch (Plan View):



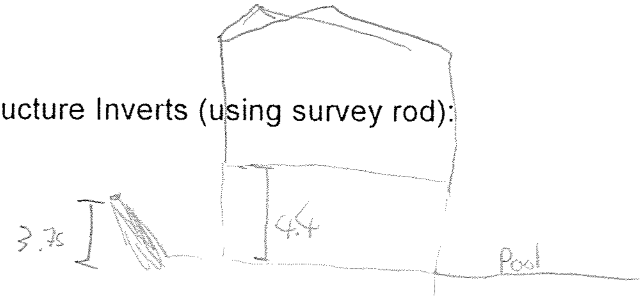
Upstream Channel Cross Section Sketch (including horizontal measurements of top and bottom widths of upstream channel):



Height from Structure Upstream Invert to Roadway:

1,4ft

U/S and D/S Structure Inverts (using survey rod):



List of Photo Locations:

1. Overall Roadway Photographs from each direction, facing across the culvert to get an idea of approaches and adjacent area development, structures and grades.

2. Culvert Headwall/Wingwall Photographs taken from the streambank or channel facing the culvert/bridge invert and road (orthogonal to headwall). This will help document structure type/configuration and elevation of culvert invert above channel and below road.

3. Culvert Channel Photographs facing upstream/downstream (taken from culvert/ bridge ends or headwalls). This photographs will document channel morphology, grade, bed characteristics, scour, banks etc.

4. Inside Culvert/Bridge Photographs (with flash on if necessary). The purpose of these photos is to document interior condition, blockages, misalignment/dislocations etc.

5. Deficiency Photographs. Take photographs of specific deficiencies noted during the inspection such as scour, damage, hazards, debris dams, blockages, sedimentation deposits, etc.

Above all, need to stay safe - If and perspectives/locations are not accessible, or questionable, do not take photographs if it compromises your safety.

Culvert Calculator Report
BVR-BEA-0-1

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	91.45	ft	Headwater Depth/Height	1.45	
Computed Headwater Elevation	91.45	ft	Discharge	284.23	cfs
Inlet Control HW Elev.	91.05	ft	Tailwater Elevation	89.87	ft
Outlet Control HW Elev.	91.45	ft	Control Type	Outlet Control	

Grades

Upstream Invert	86.00	ft	Downstream Invert	86.00	ft
Length	26.00	ft	Constructed Slope	0.000000	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	3.87	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	2.69	ft
Velocity Downstream	7.99	ft/s	Critical Slope	0.004229	ft/ft

Section

Section Shape	Arch		Mannings Coefficient	0.012	
Section Material	Concrete		Span	6.08	ft
Section Size	73.0 x 45.0 inch		Rise	3.75	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	91.45	ft	Upstream Velocity Head	0.99	ft
Ke	0.50		Entrance Loss	0.50	ft

Inlet Control Properties

Inlet Control HW Elev.	91.05	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall (arch)		Area Full	35.6	ft²
K	0.00980		HDS 5 Chart	0	
M	2.00000		HDS 5 Scale	0	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
BVR-BEA-0-2

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	100.02	ft	Headwater Depth/Height	1.40	
Computed Headwater Elevation	100.02	ft	Discharge	258.38	cfs
Inlet Control HW Elev.	100.02	ft	Tailwater Elevation	98.35	ft
Outlet Control HW Elev.	99.85	ft	Control Type	Inlet Control	

Grades

Upstream Invert	94.42	ft	Downstream Invert	94.35	ft
Length	29.40	ft	Constructed Slope	0.002381	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	4.00	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	3.19	ft
Velocity Downstream	8.07	ft/s	Critical Slope	0.003115	ft/ft

Section

Section Shape	Box		Mannings Coefficient	0.012	
Section Material	Concrete		Span	8.00	ft
Section Size	8 x 4 ft		Rise	4.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	99.85	ft	Upstream Velocity Head	1.01	ft
Ke	0.40		Entrance Loss	0.41	ft

Inlet Control Properties

Inlet Control HW Elev.	100.02	ft	Flow Control	N/A	
Inlet Type	90° headwall w 3/4 inch chamfers		Area Full	32.0	ft²
K	0.51500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	1	
C	0.03750		Equation Form	2	
Y	0.79000				

Culvert Calculator Report
BVR-BEA-0-3

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	118.54	ft	Headwater Depth/Height	1.86	
Computed Headwater Elevation	118.54	ft	Discharge	1,432.02	cfs
Inlet Control HW Elev.	115.33	ft	Tailwater Elevation	115.33	ft
Outlet Control HW Elev.	118.54	ft	Control Type	Outlet Control	

Grades

Upstream Invert	103.70	ft	Downstream Invert	104.49	ft
Length	53.00	ft	Constructed Slope	-0.014906	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	10.84	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	5.42	ft
Velocity Downstream	8.95	ft/s	Critical Slope	0.044721	ft/ft

Section

Section Shape	Box		Mannings Coefficient	0.045	
Section Material	Concrete		Span	10.00	ft
Section Size	10 x 8 ft		Rise	8.00	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	118.54	ft	Upstream Velocity Head	1.24	ft
Ke	0.50		Entrance Loss	0.62	ft

Inlet Control Properties

Inlet Control HW Elev.	115.33	ft	Flow Control	N/A	
Inlet Type	90° headwall w 3/4 inch chamfers		Area Full	160.0	ft²
K	0.51500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	1	
C	0.03750		Equation Form	2	
Y	0.79000				

Culvert Calculator Report
BVR-BEA-0-4 (MAIN)

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	6.18	ft	Headwater Depth/Height	2.06	
Computed Headwater Elevation	6.18	ft	Discharge	144.54	cfs
Inlet Control HW Elev.	6.18	ft	Tailwater Elevation	3.00	ft
Outlet Control HW Elev.	5.78	ft	Control Type	Inlet Control	

Grades

Upstream Invert	0.01	ft	Downstream Invert	0.00	ft
Length	29.00	ft	Constructed Slope	0.000345	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	3.00	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	2.69	ft
Velocity Downstream	10.22	ft/s	Critical Slope	0.010379	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	5.78	ft	Upstream Velocity Head	1.62	ft
Ke	0.50		Entrance Loss	0.81	ft

Inlet Control Properties

Inlet Control HW Elev.	6.18	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	14.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
BVR-BEA-0-4 (OVERFLOW)

Solve For: Discharge

Culvert Summary					
Allowable HW Elevation	4.44	ft	Headwater Depth/Height	1.82	
Computed Headwater Elevation	4.44	ft	Discharge	23.98	cfs
Inlet Control HW Elev.	4.44	ft	Tailwater Elevation	2.00	ft
Outlet Control HW Elev.	4.14	ft	Control Type	Inlet Control	

Grades					
Upstream Invert	0.81	ft	Downstream Invert	0.00	ft
Length	29.00	ft	Constructed Slope	0.027931	ft/ft

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	1.32	ft
Slope Type	Steep		Normal Depth	1.16	ft
Flow Regime	N/A		Critical Depth	1.73	ft
Velocity Downstream	10.89	ft/s	Critical Slope	0.010287	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	4.14	ft	Upstream Velocity Head	1.07	ft
Ke	0.50		Entrance Loss	0.53	ft

Inlet Control Properties					
Inlet Control HW Elev.	4.44	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	3.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
BVR-BEA-0-5 (LEFT)

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	7.72	ft	Headwater Depth/Height	2.16	
Computed Headwater Elevation	7.72	ft	Discharge	85.92	cfs
Inlet Control HW Elev.	7.72	ft	Tailwater Elevation	3.00	ft
Outlet Control HW Elev.	6.97	ft	Control Type	Inlet Control	

Grades

Upstream Invert	1.25	ft	Downstream Invert	0.00	ft
Length	29.00	ft	Constructed Slope	0.043103	ft/ft

Hydraulic Profile

Profile	CompositeS1S2		Depth, Downstream	2.18	ft
Slope Type	Steep		Normal Depth	1.71	ft
Flow Regime	N/A		Critical Depth	2.82	ft
Velocity Downstream	15.58	ft/s	Critical Slope	0.014344	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	6.97	ft	Upstream Velocity Head	2.41	ft
Ke	0.20		Entrance Loss	0.48	ft

Inlet Control Properties

Inlet Control HW Elev.	7.72	ft	Flow Control	N/A	
Inlet Type	Groove end w/headwall		Area Full	7.1	ft²
K	0.00180		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	2	
C	0.02920		Equation Form	1	
Y	0.74000				

Culvert Calculator Report
BVR-BEA-0-5 (RIGHT)

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	7.76	ft	Headwater Depth/Height	2.20	
Computed Headwater Elevation	7.76	ft	Discharge	87.07	cfs
Inlet Control HW Elev.	7.76	ft	Tailwater Elevation	3.00	ft
Outlet Control HW Elev.	6.96	ft	Control Type	Inlet Control	

Grades

Upstream Invert	1.17	ft	Downstream Invert	0.00	ft
Length	29.00	ft	Constructed Slope	0.040345	ft/ft

Hydraulic Profile

Profile	CompositeS1S2		Depth, Downstream	2.23	ft
Slope Type	Steep		Normal Depth	1.76	ft
Flow Regime	N/A		Critical Depth	2.83	ft
Velocity Downstream	15.46	ft/s	Critical Slope	0.014733	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	6.96	ft	Upstream Velocity Head	2.47	ft
Ke	0.20		Entrance Loss	0.49	ft

Inlet Control Properties

Inlet Control HW Elev.	7.76	ft	Flow Control	N/A	
Inlet Type	Groove end w/headwall		Area Full	7.1	ft²
K	0.00180		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	2	
C	0.02920		Equation Form	1	
Y	0.74000				

Culvert Calculator Report
BVR-BEA-0-6

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	8.39	ft	Headwater Depth/Height	1.60	
Computed Headwater Elevation	8.39	ft	Discharge	124.51	cfs
Inlet Control HW Elev.	8.39	ft	Tailwater Elevation	4.00	ft
Outlet Control HW Elev.	8.22	ft	Control Type	Inlet Control	

Grades

Upstream Invert	2.01	ft	Downstream Invert	0.00	ft
Length	40.00	ft	Constructed Slope	0.050250	ft/ft

Hydraulic Profile

Profile	CompositeS1S2		Depth, Downstream	2.62	ft
Slope Type	Steep		Normal Depth	2.50	ft
Flow Regime	N/A		Critical Depth	3.35	ft
Velocity Downstream	14.24	ft/s	Critical Slope	0.024667	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	4.00	ft
Section Size	48 inch		Rise	4.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	8.22	ft	Upstream Velocity Head	1.91	ft
Ke	0.50		Entrance Loss	0.95	ft

Inlet Control Properties

Inlet Control HW Elev.	8.39	ft	Flow Control	N/A	
Inlet Type	Headwall		Area Full	12.6	ft²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
BVR-BEA-2-1

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	5.38	ft	Headwater Depth/Height	1.92	
Computed Headwater Elevation	5.38	ft	Discharge	71.95	cfs
Inlet Control HW Elev.	5.38	ft	Tailwater Elevation	3.00	ft
Outlet Control HW Elev.	5.20	ft	Control Type	Inlet Control	

Grades

Upstream Invert	-0.39	ft	Downstream Invert	0.00	ft
Length	23.00	ft	Constructed Slope	-0.016957	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	3.00	ft
Slope Type	N/A		Normal Depth	0.00	ft
Flow Regime	N/A		Critical Depth	2.68	ft
Velocity Downstream	10.18	ft/s	Critical Slope	0.010301	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	5.20	ft	Upstream Velocity Head	1.61	ft
Ke	0.20		Entrance Loss	0.32	ft

Inlet Control Properties

Inlet Control HW Elev.	5.38	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	7.1	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
BVR-BEA-3-1

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	5.48	ft	Headwater Depth/Height	1.49	
Computed Headwater Elevation	5.48	ft	Discharge	61.95	cfs
Inlet Control HW Elev.	5.48	ft	Tailwater Elevation	3.00	ft
Outlet Control HW Elev.	5.31	ft	Control Type	Inlet Control	

Grades

Upstream Invert	1.01	ft	Downstream Invert	0.00	ft
Length	43.00	ft	Constructed Slope	0.023488	ft/ft

Hydraulic Profile

Profile	CompositeS1S2		Depth, Downstream	1.95	ft
Slope Type	Steep		Normal Depth	1.69	ft
Flow Regime	N/A		Critical Depth	2.54	ft
Velocity Downstream	12.76	ft/s	Critical Slope	0.008195	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	5.31	ft	Upstream Velocity Head	1.47	ft
Ke	0.20		Entrance Loss	0.29	ft

Inlet Control Properties

Inlet Control HW Elev.	5.48	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	7.1	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
BVR-BEA-3-2

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	3.00	ft	Headwater Depth/Height	2.80	
Computed Headwater Elevation	3.00	ft	Discharge	9.54	cfs
Inlet Control HW Elev.	2.79	ft	Tailwater Elevation	1.25	ft
Outlet Control HW Elev.	3.00	ft	Control Type	Outlet Control	

Grades

Upstream Invert	-0.50	ft	Downstream Invert	0.00	ft
Length	28.50	ft	Constructed Slope	-0.017544	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	1.25	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	1.17	ft
Velocity Downstream	7.78	ft/s	Critical Slope	0.018865	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.25	ft
Section Size	15 inch		Rise	1.25	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	3.00	ft	Upstream Velocity Head	0.94	ft
Ke	0.20		Entrance Loss	0.19	ft

Inlet Control Properties

Inlet Control HW Elev.	2.79	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	1.2	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
BVR-BEA-5-1

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	3.40	ft	Headwater Depth/Height	1.62	
Computed Headwater Elevation	3.40	ft	Discharge	35.30	cfs
Inlet Control HW Elev.	2.74	ft	Tailwater Elevation	2.00	ft
Outlet Control HW Elev.	3.40	ft	Control Type	Outlet Control	

Grades

Upstream Invert	0.17	ft	Downstream Invert	0.00	ft
Length	32.00	ft	Constructed Slope	0.005313	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	2.00	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	1.51	ft
Velocity Downstream	5.62	ft/s	Critical Slope	0.024422	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	3.40	ft	Upstream Velocity Head	0.49	ft
Ke	0.50		Entrance Loss	0.25	ft

Inlet Control Properties

Inlet Control HW Elev.	2.74	ft	Flow Control	N/A	
Inlet Type	Headwall		Area Full	6.3	ft²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
BVR-BEA-6-1

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	6.31	ft	Headwater Depth/Height	1.90	
Computed Headwater Elevation	6.31	ft	Discharge	78.70	cfs
Inlet Control HW Elev.	5.60	ft	Tailwater Elevation	3.50	ft
Outlet Control HW Elev.	6.31	ft	Control Type	Outlet Control	

Grades

Upstream Invert	-0.33	ft	Downstream Invert	0.00	ft
Length	40.00	ft	Constructed Slope	-0.008250	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	3.50	ft
Slope Type	N/A		Normal Depth	N/A	ft
Flow Regime	N/A		Critical Depth	2.77	ft
Velocity Downstream	8.18	ft/s	Critical Slope	0.022249	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	3.50	ft
Section Size	42 inch		Rise	3.50	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	6.31	ft	Upstream Velocity Head	1.04	ft
Ke	0.90		Entrance Loss	0.94	ft

Inlet Control Properties

Inlet Control HW Elev.	5.60	ft	Flow Control	N/A	
Inlet Type	Projecting		Area Full	9.6	ft²
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Calculator Report
BVR-BEA-6-2

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	7.83	ft	Headwater Depth/Height	3.83	
Computed Headwater Elevation	7.83	ft	Discharge	19.38	cfs
Inlet Control HW Elev.	7.83	ft	Tailwater Elevation	1.50	ft
Outlet Control HW Elev.	6.38	ft	Control Type	Inlet Control	

Grades

Upstream Invert	2.08	ft	Downstream Invert	0.00	ft
Length	35.50	ft	Constructed Slope	0.058592	ft/ft

Hydraulic Profile

Profile	CompositeS1S2		Depth, Downstream	1.10	ft
Slope Type	Steep		Normal Depth	0.98	ft
Flow Regime	N/A		Critical Depth	1.46	ft
Velocity Downstream	13.99	ft/s	Critical Slope	0.030230	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	6.38	ft	Upstream Velocity Head	1.89	ft
Ke	0.50		Entrance Loss	0.95	ft

Inlet Control Properties

Inlet Control HW Elev.	7.83	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	1.8	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
BVR-FOUND-20150630

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	5.10	ft	Headwater Depth/Height	1.20	
Computed Headwater Elevation	5.10	ft	Discharge	410.47	cfs
Inlet Control HW Elev.	4.53	ft	Tailwater Elevation	4.30	ft
Outlet Control HW Elev.	5.10	ft	Control Type	Outlet Control	

Grades

Upstream Invert	0.30	ft	Downstream Invert	0.00	ft
Length	4.90	ft	Constructed Slope	0.061224	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	4.30	ft
Slope Type	N/A		Normal Depth	1.51	ft
Flow Regime	N/A		Critical Depth	2.73	ft
Velocity Downstream	6.41	ft/s	Critical Slope	0.011041	ft/ft

Section

Section Shape	Box		Mannings Coefficient	0.023	
Section Material	Concrete		Span	8.00	ft
Section Size	8 x 4 ft		Rise	4.00	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	5.10	ft	Upstream Velocity Head	0.64	ft
Ke	0.20		Entrance Loss	0.13	ft

Inlet Control Properties

Inlet Control HW Elev.	4.53	ft	Flow Control	N/A	
Inlet Type	90° headwall w 33.7° bevels		Area Full	64.0	ft²
K	0.48600		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	3	
C	0.02520		Equation Form	2	
Y	0.86500				

Culvert Calculator Report
BVR-FOUND-20150817

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	4.70	ft	Headwater Depth/Height	1.15	
Computed Headwater Elevation	4.70	ft	Discharge	314.89	cfs
Inlet Control HW Elev.	4.64	ft	Tailwater Elevation	3.70	ft
Outlet Control HW Elev.	4.70	ft	Control Type	Outlet Control	

Grades

Upstream Invert	0.09	ft	Downstream Invert	0.00	ft
Length	3.00	ft	Constructed Slope	0.030000	ft/ft

Hydraulic Profile

Profile	M1		Depth, Downstream	3.70	ft
Slope Type	Mild		Normal Depth	3.08	ft
Flow Regime	Subcritical		Critical Depth	2.78	ft
Velocity Downstream	7.09	ft/s	Critical Slope	0.039737	ft/ft

Section

Section Shape	Box		Mannings Coefficient	0.040	
Section Material	Concrete		Span	6.00	ft
Section Size	6 x 4 ft		Rise	4.00	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	4.70	ft	Upstream Velocity Head	0.81	ft
Ke	0.20		Entrance Loss	0.16	ft

Inlet Control Properties

Inlet Control HW Elev.	4.64	ft	Flow Control	N/A	
Inlet Type	90° headwall w 3/4 inch chamfers		Area Full	48.0	ft²
K	0.51500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	1	
C	0.03750		Equation Form	2	
Y	0.79000				

Culvert Calculator Report
BVR-FOUND-20151015

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	7.80	ft	Headwater Depth/Height	1.65	
Computed Headwater Elevation	7.80	ft	Discharge	516.53	cfs
Inlet Control HW Elev.	6.40	ft	Tailwater Elevation	6.40	ft
Outlet Control HW Elev.	7.80	ft	Control Type	Outlet Control	

Grades

Upstream Invert	1.20	ft	Downstream Invert	0.00	ft
Length	16.00	ft	Constructed Slope	0.075000	ft/ft

Hydraulic Profile

Profile	PressureProfile		Depth, Downstream	6.40	ft
Slope Type	N/A		Normal Depth	1.70	ft
Flow Regime	N/A		Critical Depth	3.19	ft
Velocity Downstream	8.07	ft/s	Critical Slope	0.012459	ft/ft

Section

Section Shape	Box		Mannings Coefficient	0.024	
Section Material	Concrete		Span	8.00	ft
Section Size	8 x 4 ft		Rise	4.00	ft
Number Sections	2				

Outlet Control Properties

Outlet Control HW Elev.	7.80	ft	Upstream Velocity Head	1.01	ft
Ke	0.20		Entrance Loss	0.20	ft

Inlet Control Properties

Inlet Control HW Elev.	6.40	ft	Flow Control	N/A	
Inlet Type	90° headwall w 33.7° bevels		Area Full	64.0	ft²
K	0.48600		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	3	
C	0.02520		Equation Form	2	
Y	0.86500				

Excerpts and Datasheets from Geomorphic Assessments in the Beaver River Watershed (F&O, 2017)

at the upstream end that have been arrested by the presence of large wood in the channel. However, the reach soon becomes significantly aggraded with fine sediment downstream. This aggradation causes significant erosion and frequent avulsions as flow is diverted around bars. These channel adjustments in turn recruit high amounts of large wood into the channel and create great habitat complexity when flow is in the channel (but was dry in October 2015). The aggradation results from a partially breached dam just upstream of Kenyon Hill Trail that backs up high flows for most of the reach, although the old impoundment is now only a wetland at low flow. An old pair of bridge abutments constrict the channel at the upstream end of the wetland, so, as is typical of undersized structures, deposition is occurring upstream and erosion downstream. Downstream of the partially breached dam, the reach is not incised but rather multi-threaded due to the effects of an undersized culvert downstream.

In-stream wood additions would speed the process of recovery of MEB-8a by arresting incision, aggrading the bed, and reconnecting the brook with its floodplain. In MEB-7, removing the old abutments and old dam will decrease the backwater in the old impoundment and potentially lower the water table so some of the wetlands can be converted into a floodplain forest over time.

5.4.5 Beaver River in Hillsdale (BER-7-6)

BER-7 is one of the highest gradient reaches assessed in the Wood-Pawcatuck Watershed. The reach begins at an extremely undersized culvert that has created a vertical drop at its outlet. The historically straightened reach has a step-pool morphology with a cobble bed. Most of the corridor is free of modern development, although several old mill foundations are in the right corridor; a breached dam is also present that acts as a channel constriction. Further downstream is another breached dam and old bridge abutments. Upstream of this second dam, an old side channel carries water during high flows. A short portion of the reach has an insufficient buffer on the right bank from Hillsdale Road to the downstream end of the reach. The reach is in Fair geomorphic condition due to incision from the breached dams, historic straightening, and a recent channel avulsion. The incision is limited by the coarseness of the bed. The RHA score is also Fair from lack of large wood and pools as well as obstructions to AOP at the culverts. The culvert at the upstream end of the reach needs to be replaced and the old dams could be removed to provide the river with better access to its floodplain and create a more natural anastomosing planform that would reduce downstream flooding and sediment loading.

BER-6 begins at the dam downstream of BER-7 and was split into two segments, because the upper section is a steep cobble-bed channel with a step-pool morphology. The lower section is less steep with a gravel bed and a riffle-pool bedform. BER-6b starts at a partial breach in the dam at the downstream end of BER-7. The upper segment is confined whereas the downstream segment is adjacent to a wide floodplain. Despite the floodplain, the channel is confined in BER-6a as a berm is present on the right bank and the channel flows against the left bank valley wall due to historic channel straightening. The reach is in Good geomorphic condition despite the historic channel changes, because the coarse substrate has prevented significant incision.

BER-6a begins where the valley widens significantly and flows down past the Punchbowl Trail ATV crossing. This reach is experiencing incision due to the dam upstream and the more easily eroded finer bed material. Further downstream, the channel has completed an incision phase and has begun widening and reforming meanders. Portions of this stream have been historically straightened with some evidence of berming (Figure 22). The only development in the river corridor are private camp sites and ATV trails. This reach has a Fair RGA score because it is actively responding to the upstream impoundment, but has a Good RHA score given its ability to migrate and create high quality habitat. As long as development does not encroach in the corridor, the reach will continue a natural evolution towards equilibrium. Removing the dam upstream will provide the segment with more sediment to create bars, develop a meandering planform, and achieve equilibrium more quickly.

Management actions could include removing the dam at the upstream end of BER-6b as the dam is no longer functioning. Replacing the Hillsdale Road culvert with a properly sized crossing, as well as removing old berms and dam remnants in both reaches, will give the reach greater floodplain access and allow for the maintenance of existing habitat. Wood additions could create pools and further promote floodplain connectivity. The valley bottom in both of these reaches should be protected from further development and the Punchbowl Trail crossing could be removed.

5.4.6 Lower Beaver River (BER-4-2)

BER-4 starts at an old low dam with a concrete farm bridge upstream of Route 138 in Richmond, RI. The bridge and dam at the top of the reach have been breached on the right bank through the elevated bridge approach. Further downstream, the reach has old armor on the left bank that is scouring due to an unnatural hard bend along an artificially straightened channel. This straight section is the steepest part of the reach and the old remnant meandering channel is now a side channel on the left bank. Downstream of this straightened section, the river has reformed meanders and flood chutes cross the inside of the bends. A small orchard and an old stone wall are found in the right bank river corridor. Some residential property is at the upstream end of the reach and some commercial property off of Route 138 is in the right bank river corridor. Otherwise, development in the reach is limited. The lower part of the reach has a finer substrate with greater deposition and evidence of planform change. The RGA score is Fair mostly due to historic incision, active aggradation, bank erosion, and planform changes.

BER-3 goes from the Route 138 culvert down to Beaver River School House Road and was split into two segments. BER-3b is steeper and flows through a narrower valley. The culvert at the upstream end constricts both the channel and valley. Development in the corridor is also limited to the upper reach and consists mainly of residential properties, river access areas, and one water withdrawal for a farm. The river avulsed around an old dam and mill race, creating an over-steepened riffle (Figure 23). The abundant flood chutes and islands in this segment reflect the ongoing aggradation and planform changes that result in a Fair RGA score and Very High sensitivity rating (Table 5). However, little development is at risk and the changes could be reducing downstream flooding and sediment loading.

Downstream of BER-3b, the valley widens and BER-3a is a lower gradient channel with a sand/silt bed, low banks, and abundant side channels and wetlands. Most of the reach is backwatered by a 4-foot high beaver dam built around an undersized culvert for a private driveway. This beaver dam creates abundant flood chutes upstream and blocks the culvert to create a risk to the private driveway and stream crossing. Downstream of the large beaver dam, depositional features abound as the river winds through a wetlands area that appears backwatered by an old bridge abutment downstream. The only other infrastructure in the corridor is a road crossing and a house beside the river at the downstream end of the reach that is at risk of flooding. The channel has Extreme sensitivity to planform change. The stream crossing with the beaver dam could be widened to discourage future beaver activity.

BER-2 begins downstream of the old abutments and immediately flows through a significantly undersized culvert at Beaver River Schoolhouse Road that is causing scour and widening upstream. Several human alterations of the channel are found in this reach including a failed weir perhaps intended to prevent the creation of a side channel. Several sites of water withdrawals that feed the adjacent turf farms are found along the reach with a large berm and pond created adjacent to the reach to store and release the majority of the in-channel flow. Not far downstream of this pond another low gradient section begins that is backwatered by a series of beaver dams much like BER-3 (Figure 24). The upper part of the beaver wetland is still a channel with abundant flood chutes and low banks. Downstream of the beaver dam the reach becomes a mostly anastomosing and aggrading channel with a pool-riffle morphology with some residential development on the left bank. Another significantly undersized culvert at Shannock Hill Road is at the downstream end of the reach. This reach nets a poor RGA score due to abundant aggradation and migration features, including some recent channel avulsions. The aggradation and migration are related to each other and enhanced by the undersized road crossings and beaver dams.

The culvert at the downstream end of BER-4 is a channel and floodplain constriction that causes backwater effects upstream. The reach has good habitat and should be allowed to adjust naturally by excluding further development in the corridor, a process that could be accelerated through large wood additions. The private driveway stream crossing in BER-3a could be replaced with a wider span and flood relief culverts also added to help prevent overtopping of the driveway. Both culverts in BER-2 should be replaced with wider spans. The corridors in all three reaches should be protected from further development to maintain the existing flood storage capacity.

5.4.7 Queens River at Liberty Road (QUS-11)

QUS-11 lies upstream of the Mail Road crossing in Exeter, RI. The reach begins where the valley expands downstream. This reach is very dynamic with primarily a multi-threaded channel, abundant side channels, and considerable in-stream wood. These features give the Queens River a Good RHA score. But the abundant bar deposition and migration features result in a Fair RGA rating and falls within the Very High sensitivity category. The only infrastructure in the reach is Mail Road and a USGS Gage. The Mail Road stream crossing is significantly undersized, creates multiple mid-channel bars and flood chutes upstream of the crossing, and a large over-widened scour pool downstream of the culvert. The culvert is slightly damaged as a result of these channel adjustments around, and because of, the structure. The only management suggestion for this reach is to replace the culvert with a wider span to eliminate the localized scour and deposition.

Table 2. (continued) Phase 1 geomorphic data.

Reach name	Im--pounded	Phase 2 reach	Watershed area (mi^2)	Sub watershed area (mi^2)	Stream length (ft)	Valley width (ft)	Reference channel width (ft)	Valley width/ channel with (ft)	Stream slope	Valley slope	Sinuosity	Predicted stream type
MEB-8b		yes	2.4	0.72	3229	1242	21.4	58.1	0.57%	0.61%	1.06	C or E
MEB-9			1.7	0.48	2884	2153	18.5	116.5	0.10%	0.11%	1.07	C or E
MEB-10			1.2	0.29	5489	417	16.1	25.9	0.76%	0.93%	1.22	C or E
MEB-11			0.9	0.22	3659	206	14.4	14.4	2.98%	3.05%	1.02	D
MEB-12			0.7	0.67	1519	361	12.8	28.2	1.04%	1.03%	1.00	C or E
BER-1			11.7	0.55	6382	868	40.7	21.3	0.14%	0.15%	1.10	C or E
BER-2		yes	11.2	1.52	7403	1039	39.9	26.0	0.07%	0.08%	1.20	C or E
BER-3a		yes	9.7	0.67	3852	1437	37.6	38.2	0.09%	0.11%	1.18	C or E
BER-3b		yes	9.0	0.08	1991	679	36.5	18.6	0.87%	0.87%	1.00	C or E
BER-4		yes	8.9	0.61	2896	973	36.4	26.7	0.01%	0.01%	1.26	C or E
BER-5			8.3	1.47	7426	780	35.4	22.1	0.21%	0.25%	1.20	C or E
BER-6a		yes	6.8	1.20	3976	558	32.7	17.1	0.56%	0.71%	1.27	C or E
BER-6b		yes	5.6	0.05	897	313	30.2	10.4	3.33%	3.57%	1.07	D
BER-7		yes	5.6	0.12	1715	353	30.1	11.7	2.26%	2.45%	1.09	C or E
BER-8			5.5	0.75	6360	685	29.9	22.9	0.39%	0.48%	1.22	C or E
BER-9			4.7	0.94	5185	786	28.1	27.9	0.67%	0.83%	1.24	C or E
BER-10			3.8	1.89	5135	821	25.7	31.9	0.77%	0.92%	1.20	C or E
BER-11	yes		1.9	0.14	1391	877	19.4	45.2	0.09%	0.11%	1.21	C or E
BER-12			1.7	0.62	5306	844	18.8	44.8	0.40%	0.45%	1.12	C or E
QUS-1			43.8	6.39	6386	2200	69.2	31.8	0.04%	0.06%	1.38	C or E
QUS-2			37.4	0.83	7174	4773	64.9	73.5	0.09%	0.11%	1.24	C or E
QUS-3			36.6	1.06	6348	1401	64.4	21.8	0.01%	0.02%	1.52	C or E
QUS-4			35.5	0.42	4336	1530	63.6	24.1	0.04%	0.06%	1.38	C or E
QUS-5			35.1	1.50	6401	1023	63.3	16.2	0.11%	0.19%	1.72	C or E
QUS-6	yes		33.6	5.15	7754	651	62.2	10.5	0.06%	0.07%	1.13	C or E
QUS-7			28.5	7.19	6404	1104	58.2	19.0	0.05%	0.07%	1.37	C or E

Table 3. (continued) Phase 1 watershed land use statistics.

Reach Name	Sub watershed area (mi^2)	% Developed land 2011	% Agricultural land 2011	Development+ Agriculture 2011	Development+ Agriculture 1992	% Increase in Development +Agriculture from 1992 to 2011	Road density (mi/mi^2)
GAS-2	0.46	29.86%	12.99%	42.86%	31.59%	11.27%	5.3
GAS-3	0.66	18.97%	21.41%	40.38%	31.25%	9.14%	4.2
GAS-4	3.76	14.22%	13.05%	27.27%	17.45%	9.82%	5.0
GAS-5	2.94	3.47%	19.76%	23.23%	16.88%	6.35%	2.3
GAS-6	11.98	4.62%	8.78%	13.40%	9.55%	3.86%	3.5
GAS-7	0.71	3.09%	17.36%	20.45%	15.83%	4.62%	3.4
GAS-8	0.13	10.63%	0.00%	10.63%	1.64%	8.98%	9.6
GAS-9	1.23	4.68%	4.97%	9.65%	6.53%	3.12%	3.1
GAS-10	0.86	3.50%	2.17%	5.67%	2.46%	3.21%	3.5
GAS-11	0.05	0.00%	0.00%	0.00%	0.68%	-0.68%	0.0
GAS-12	1.18	3.50%	3.91%	7.42%	4.32%	3.09%	1.9
GAS-13	2.13	2.29%	0.33%	2.61%	1.14%	1.47%	2.1
GAS-14	0.30	1.62%	0.00%	1.62%	0.46%	1.16%	3.6
GAS-15	0.02	0.00%	0.00%	0.00%	0.00%	0.00%	4.7
GAS-16	1.21	2.96%	0.00%	2.96%	0.32%	2.65%	5.0
GAS-17	0.29	2.73%	0.00%	2.73%	0.00%	2.73%	4.6
GAS-18	0.40	3.18%	0.00%	3.18%	0.43%	2.75%	1.1
GAS-0	0.06	1.14%	0.00%	1.14%	8.62%	-7.48%	12.8
MEB-1	0.15	23.06%	36.00%	59.06%	24.34%	34.72%	7.3
MEB-2	0.21	11.39%	34.16%	45.54%	46.56%	-1.01%	0.7
MEB-3	0.73	6.90%	26.57%	33.48%	30.61%	2.87%	1.7
MEB-4	0.44	8.35%	1.64%	9.98%	3.29%	6.70%	2.2
MEB-5	0.81	6.90%	0.00%	6.90%	0.04%	6.86%	3.1
MEB-6	0.78	19.99%	4.61%	24.60%	13.58%	11.02%	3.6
MEB-7	1.49	18.66%	1.89%	20.56%	7.69%	12.87%	2.1
MEB-8a	0.04	0.00%	0.00%	0.00%	0.00%	0.00%	0.0
MEB-8b	0.72	12.27%	10.49%	22.76%	14.22%	8.55%	1.0
MEB-9	0.48	4.79%	6.53%	11.32%	6.19%	5.13%	1.3
MEB-10	0.29	7.83%	1.30%	9.13%	3.21%	5.93%	2.1
MEB-11	0.22	16.19%	2.67%	18.87%	5.32%	13.55%	6.1
MEB-12	0.67	9.30%	0.00%	9.30%	2.13%	7.17%	2.9
BER-1	0.55	7.79%	20.85%	28.64%	18.23%	10.41%	4.6
BER-2	1.52	6.15%	21.18%	27.32%	30.31%	-2.99%	2.4
BER-3a	0.67	7.03%	26.63%	33.66%	26.04%	7.62%	2.0
BER-3b	0.08	27.85%	34.25%	62.10%	48.86%	13.24%	8.4
BER-4	0.61	24.83%	12.75%	37.58%	9.53%	28.05%	4.6
BER-5	1.47	11.98%	3.49%	15.47%	6.49%	8.98%	2.4

Table 3. (continued) Phase 1 watershed land use statistics.

Reach Name	Sub watershed area (mi^2)	% Developed land 2011	% Agricultural land 2011	Development+ Agriculture 2011	Development+ Agriculture 1992	% Increase in Development +Agriculture from 1992 to 2011	Road density (mi/mi^2)
BER-6a	1.20	3.46%	0.00%	3.46%	1.72%	1.74%	0.8
BER-6b	0.05	3.21%	0.00%	3.21%	0.00%	3.21%	0.4
BER-7	0.12	11.21%	0.00%	11.21%	1.78%	9.43%	2.8
BER-8	0.75	4.94%	0.00%	4.94%	1.30%	3.64%	2.5
BER-9	0.94	6.51%	0.37%	6.88%	5.10%	1.78%	2.5
BER-10	1.89	13.56%	2.53%	16.09%	5.44%	10.65%	3.8
BER-11	0.14	3.95%	11.60%	15.56%	15.85%	-0.30%	0.7
BER-12	0.62	8.91%	0.00%	8.91%	2.41%	6.50%	1.8
BER-0	1.12	10.84%	3.57%	14.41%	8.00%	6.41%	3.4
QUS-1	6.39	13.50%	8.92%	22.42%	13.09%	9.33%	2.7
QUS-2	0.83	10.35%	42.55%	52.90%	38.43%	14.47%	2.1
QUS-3	1.06	9.59%	18.29%	27.88%	22.62%	5.26%	0.4
QUS-4	0.42	15.41%	9.51%	24.92%	20.76%	4.16%	2.5
QUS-5	1.50	14.48%	25.53%	40.02%	34.44%	5.58%	2.8
QUS-6	5.15	5.28%	6.99%	12.28%	10.84%	1.44%	2.5
QUS-7	7.19	6.64%	7.48%	14.12%	8.28%	5.84%	2.0
QUS-8	0.24	0.00%	21.05%	21.05%	13.49%	7.56%	0.1
QUS-9	1.23	5.01%	6.00%	11.01%	5.29%	5.72%	1.5
QUS-10	0.44	8.89%	2.81%	11.70%	2.98%	8.72%	3.5
QUS-11	0.91	4.46%	3.66%	8.12%	5.37%	2.75%	1.8
QUS-12	0.35	0.00%	21.66%	21.66%	24.80%	-3.14%	0.0
QUS-13	13.31	9.41%	6.16%	15.57%	13.58%	1.99%	2.7
QUS-14	0.42	18.96%	5.76%	24.73%	23.75%	0.97%	5.6
QUS-15	0.56	18.01%	2.05%	20.06%	17.30%	2.76%	3.5
QUS-16	0.02	0.00%	25.76%	25.76%	27.14%	-1.39%	0.0
QUS-17	0.52	31.83%	1.66%	33.49%	24.21%	9.28%	2.6
QUS-18	0.10	75.87%	0.00%	75.87%	68.33%	7.55%	0.0
QUS-19	0.23	37.52%	0.15%	37.67%	19.42%	18.25%	3.3
QUS-20	0.96	9.04%	3.18%	12.22%	4.95%	7.27%	1.8
QUS-21	0.10	14.70%	24.01%	38.71%	14.86%	23.85%	6.9
QUS-22	0.21	0.00%	1.01%	1.01%	0.50%	0.50%	0.0
QUS-23	0.65	1.93%	0.00%	1.93%	0.43%	1.50%	0.9
QUS-24	0.87	0.40%	0.00%	0.40%	0.04%	0.36%	0.0
QUS-0	0.16	11.71%	0.00%	11.71%	6.37%	5.34%	3.4
CHIP-1	5.13	25.31%	10.07%	35.37%	29.13%	6.24%	4.9
CHIP-2	0.58	10.94%	10.70%	21.64%	22.36%	-0.72%	2.7
CHIP-3	0.14	40.93%	12.01%	52.94%	31.34%	21.60%	9.1
CHIP-4	0.45	35.24%	35.08%	70.32%	52.42%	17.90%	5.1

Table 4. (Continued) Summary of reach characteristics calculated using the Feature Indexing Tool.

Reach / Segment	Stream length (ft)	Channel straight-ening (%)	Bank erosion (%)	Bank armor (%)	Deposition length (ft/mile)	Buffer width <25 ft (%)	Corridor develop-ment (%)
MEB-8a	1501	39.1%	17.5%	4.5%	483	0.0%	1.4%
MEB-8b	3229	93.9%	25.6%	7.3%	578	47.0%	53.8%
BER-2	7403	64.3%	2.7%	1.5%	2511	6.9%	22.2%
BER-3A	3852	0.0%	1.6%	1.4%	1222	3.2%	25.7%
BER-3B	1991	42.7%	2.4%	10.2%	1131	3.8%	41.5%
BER-4	2896	28.2%	27.9%	0.5%	858	0.0%	12.6%
BER-6a	3976	30.1%	5.5%	0.0%	711	0.5%	9.3%
BER-6b	897	100.0%	9.8%	3.8%	210	0.0%	39.6%
BER-7	1715	33.7%	0.7%	4.8%	658	6.0%	21.7%
QUS-11	2370	29.5%	14.3%	0.0%	1163	1.4%	1.5%
CHIP-8	7076	30.0%	9.7%	9.8%	1394	5.5%	14.7%
CHIP-10	4743	63.1%	3.4%	12.5%	956	12.0%	19.5%
Total	**204700**	**54.1%**	**15.5%**	**8.6%**	**1083**	**27.0%**	**28.2%**

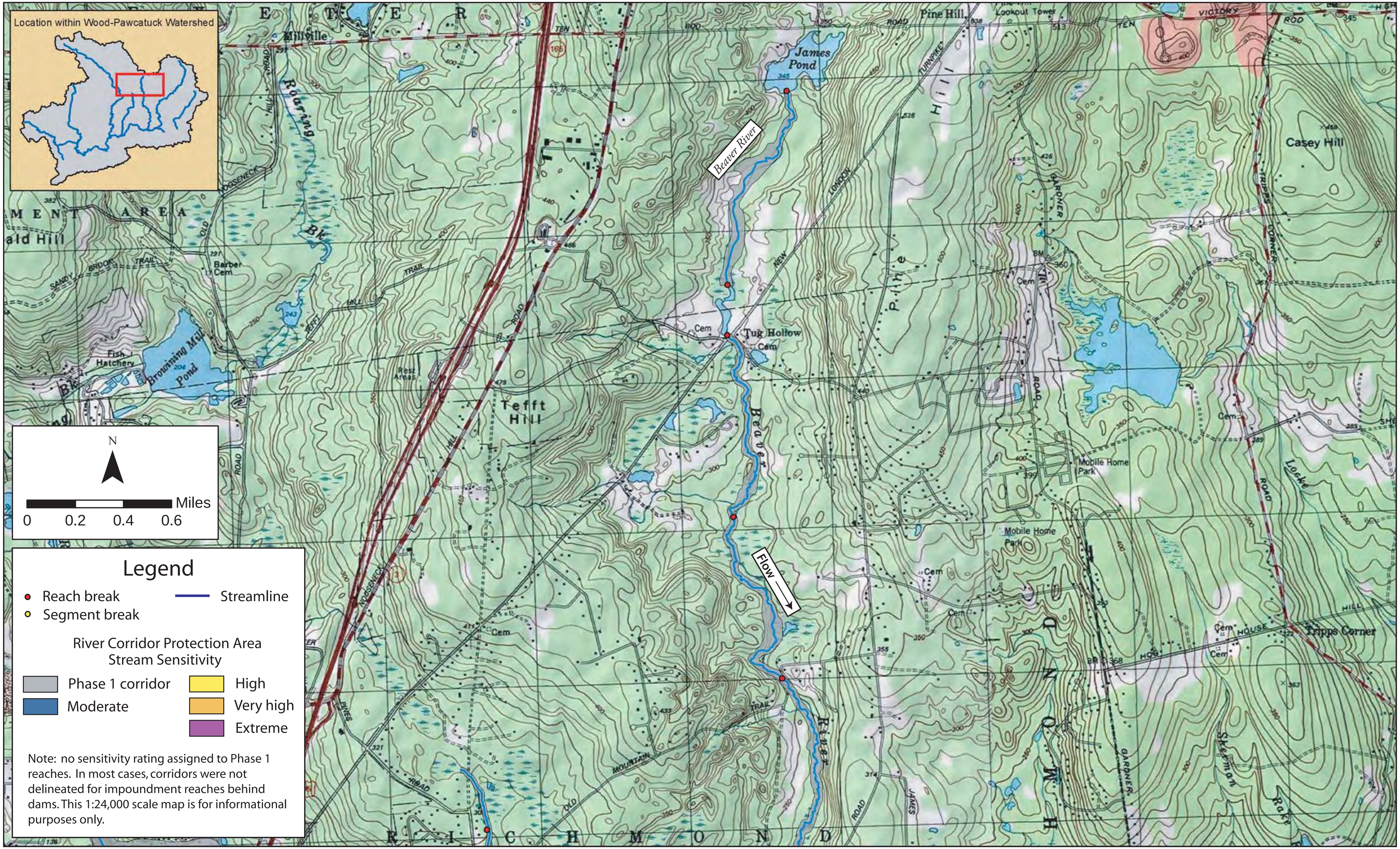
Table 5. (continued) Summary of Phase 2 RGA scores and stream sensitivity rankings.

Reach / Segment	Channel degradation	Channel aggradation	Channel widening	Change in planform	Total score	Condition rating (%)	Stream condition	Stream sensitivity	Channel evolution stage
SHUN-10b	7	13	12	12	44	55	Fair	High	II
GAS-1	14	14	11	5	44	55	Fair	Very High	III
GAS-2	10	11	12	9	42	53	Fair	Moderate	IV
GAS-4	13	12	10	5	40	50	Fair	Very High	IV
GAS-8	10	9	12	9	40	50	Fair	High	IV
MEB-7	11	5	9	9	34	43	Fair	Very High	III
MEB-8a	10	12	13	11	46	58	Fair	Very High	II
MEB-8b	11	9	13	12	45	56	Fair	Very High	IV
BER-2	11	5	12	5	33	41	Poor	Very High	III
BER-3a	14	8	13	5	40	50	Fair	Extreme	IV
BER-3b	11	10	13	12	46	58	Fair	Extreme	IV
BER-4	11	11	14	10	46	58	Fair	Very High	IV
BER-6a	10	13	14	5	42	53	Fair	Very High	III
BER-6b	10	14	15	13	52	65	Good	Moderate	II
BER-7	12	13	13	5	43	54	Fair	Very High	IV
QUS-11	15	10	10	5	40	50	Fair	Very High	III
CHIP-8	12	5	11	4	32	40	Fair	Very High	IV
CHIP-10	11	13	12	10	46	58	Fair	Very High	IV

Table 6. (continued) Summary of Phase 2 RHA scores and habitat ratings.

Reach / Segment	Woody debris cover	Bed substrate cover	Scour and deposition features	Channel morphology	Hydrologic characteristics	Connectivity	River banks		Riparian area		Total score	Percentage	Habitat condition
							LB	RB	LB	RB			
WOR-11	14	10	13	14	16	16	8	10	5	9	115	72.0%	Good
WOR-12	20	8	11	9	16	6	8	8	6	6	98	61.0%	Fair
WOR-14	17	11	6	12	13	14	7	7	10	9	108	67.5%	Good
WOR-15	16	14	17	13	18	16	9	9	10	10	132	82.5%	Good
WOR-16	18	15	18	12	16	16	9	9	10	10	132	82.5%	Good
SHUN-10a	10	14	11	8	11	7	8	6	7	3	85	53.0%	Fair
SHUN-10b	7	11	9	8	11	6	8	8	5	2	75	47.0%	Fair
GAS-1	20	14	17	14	15	11	8	8	6	8	121	76.0%	Good
GAS-2	16	5	9	11	10	10	7	6	6	5	85	53.0%	Fair
GAS-4	15	10	12	6	14	14	6	8	8	8	100	63.0%	Fair
GAS-8	17	14	9	10	11	12	8	8	8	8	105	65.0%	Good
MEB-7	17	3	8	13	7	8	7	7	8	8	86	53.0%	Fair
MEB-8a	18	10	5	13	2	4	7	7	8	7	81	50.0%	Fair
MEB-8b	8	8	5	10	1	5	3	3	1	1	45	28.0%	poor
BER-2	15	8	10	10	15	12	6	6	4	4	90	52.0%	Fair
BER-3A	7	4	8	19	15	13	6	6	7	7	92	57.5%	Fair
BER-3B	14	9	14	12	14	9	8	8	5	7	100	62.0%	Fair
BER-4	15	14	11	10	14	10	9	9	8	8	108	67.5%	Good
BER-6a	18	9	14	12	13	9	8	8	9	9	109	68.0%	Good
BER-6b	10	15	15	10	9	10	9	9	9	9	105	65.0%	Good
BER-7	9	13	11	10	12	7	9	9	8	7	95	59.0%	Fair
QUS-11	17	12	14	14	16	15	8	8	7	7	108	67.5%	Good
CHIP-8	15	10	7	13	13	9	6	8	5	8	94	59.0%	Fair
CHIP-10	17	9	10	7	12	10	5	7	5	7	89	56.0%	Fair

Wood-Pawcatuck Watershed River Corridor Protection Area Map - Beaver River (Map 1 of 3)

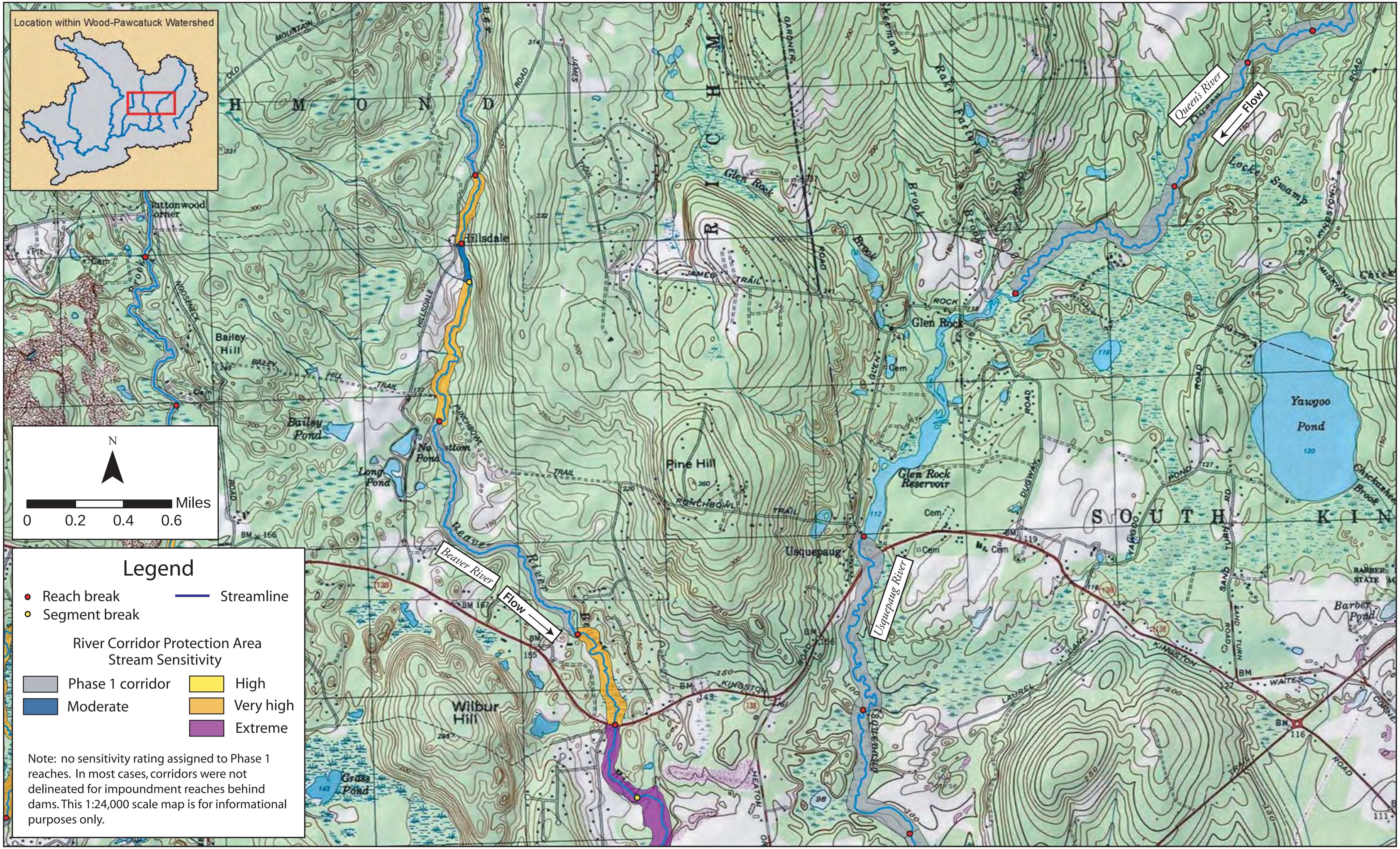


Basemap imagery: USA Topo Maps (http://services.arcgisonline.com/ArcGIS/rest/services/USA_Topo_Maps/MapServer)
GIS data: Field Geology Services 2015-2016
Map prepared February 2016

Map prepared by:
Field Geology Services
Fluvial Geomorphology

With support from:
FUSS & O'NEILL

Wood-Pawcatuck Watershed River Corridor Protection Area Map - Beaver River (Map 2 of 3)



Note: no sensitivity rating assigned to Phase 1 reaches. In most cases, corridors were not delineated for impoundment reaches behind dams. This 1:24,000 scale map is for informational purposes only.

Basemap imagery: USA Topo Maps (http://services.arcgisonline.com/ArcGIS/rest/services/USA_Topo_Maps/MapServer)
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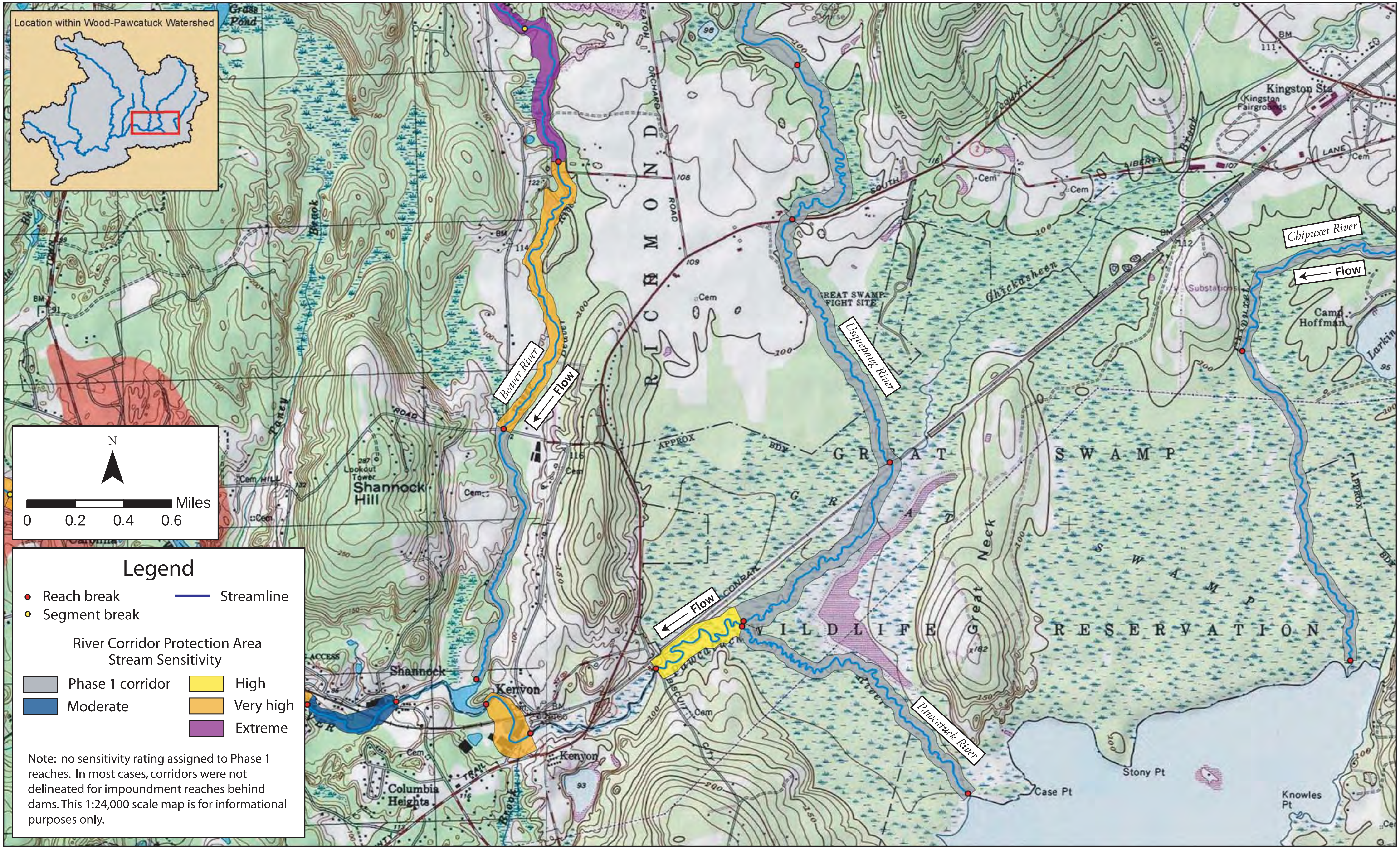
Map prepared February 2016

Map prepared by:
Field Geology Services
Fluvial Geomorphology

With support from:
FUSS & O'NEILL

Wood-Pawcatuck Watershed River Corridor Protection Area Map - Beaver River (Map 3 of 3)



Note: no sensitivity rating assigned to Phase 1 reaches. In most cases, corridors were not delineated for impoundment reaches behind dams. This 1:24,000 scale map is for informational purposes only.

Basemap imagery: USA Topo Maps (http://services.arcgisonline.com/ArcGIS/rest/services/USA_Topo_Maps/MapServer)
GIS data: Field Geology Services 2015-2016
Map prepared February 2016

Map prepared by: Field Geology Services Fluvial Geomorphology

With support from: FUSS & O'NEILL

Table 2 (continued). Potential for various types of restoration activities in each Phase 2 assessment reach.

Reach / Segment	Protect Corridor	Plant Buffer	Stabilize Stream Banks	Arrest Head Cut	Encroachment Removal	Encroachment Type	Replace Structure	Reoccupy Old Channel	Protect Downst. corridor	Protect Corridor (meander creation)	Remove/ Retrofit Structures	Restore Aggraded Reach	Protect Corridor (channel widening)
WOD-11	-	-	High	-	-	-	-	-	-	-	Low	-	-
WOD-12	High	High	-	-	-	-	-	-	-	-	-	Low	-
WOD-14	High	-	-	-	-	-	-	-	-	-	-	-	High
WOD-15	High	-	-	-	-	-	-	-	-	Low	-	-	High
WOD-16	High	High	-	-	-	-	Low	-	-	-	-	High	-
BER-2	-	High	-	-	Low	Berm	-	-	-	-	High	-	-
BER-3a	High	High	-	-	-	-	High	-	-	-	High	-	-
BER-3b	High	-	-	-	-	-	High	-	-	-	High	-	-
BER-4	High	-	-	-	-	-	Low	Low	-	-	Low	-	-
BER-6a	High	High	-	Low	Low	Berm	Low	Low	-	-	-	-	High
BER-6b	High	High	-	Low	Low	Berm	High	-	-	High	-	-	High
BER-7	High	-	-	-	Low	Berm	Low	-	-	-	-	-	High
SHUN-10a	High	-	-	-	-	-	-	-	-	-	-	-	High
SHUN-10b	-	High	-	-	Low	Berm/Road	-	-	-	-	-	-	High
CHIP-8	High	-	-	-	-	-	High	-	-	-	High	-	-
CHIP-10	High	-	-	-	-	-	High	-	-	-	High	-	-
GAS-1	High	-	High	-	-	-	High	-	-	-	-	-	High
GAS-2	-	Low	-	-	-	-	-	-	-	-	High	-	-
GAS-4	High	High	-	-	-	-	High	High	-	-	High	-	-
GAS-8	High	High	-	-	-	-	-	-	-	-	-	-	-
MEB-7	High	High	-	Low	-	-	Low	-	-	High	Low	-	-
MEB-8a	High	High	-	Low	-	-	Low	-	-	High	-	-	High
MEB-8b	-	High	-	-	-	-	High	Low	-	-	Low	-	-
QUS-11	High	-	-	-	-	-	High	-	-	-	High	-	-

Table 3 (continued). Priority restoration sites by project type.

Reach	Town	Bridge/ Culvert Code	Location Lat.	RCPA Long.	Priority	Description	Photograph
CHIP-8	Exeter, RI	4455	41.518	-71.526	High	Significantly undersized, beaver occupied	
BER-7	Richmond, RI	2967	41.526	-71.639	High	Undersized, perched at outlet, culvert was overtopped in 2010	
GAS-8	North Stonington, CT	347	41.472	-71.816	Low	Undersized, side channels and aggradation upstream, large scour pool downstream	

Table 3 (continued). Priority restoration sites by project type.

Reach	Town	Bridge/ Culvert Code	Location Lat.	RCPA Long.	Priority	Description	Photograph
GAS 2	Hopkinton, RI		41.425	-71.790	High	Causing vibration damage to adjacent house, raises water level around bridge potentially	
GAS-2	Hopkinton, RI		41.431	-71.790	High	Dam not in use, partially broken down, blocking fish passage to high quality habitat	
BER-6b	Richmond, RI		41.521	-71.640	High	Pond not in use but backs water up to road, potentially high quality habitat with connectivity	

Table 3 (continued). Priority restoration sites by project type.

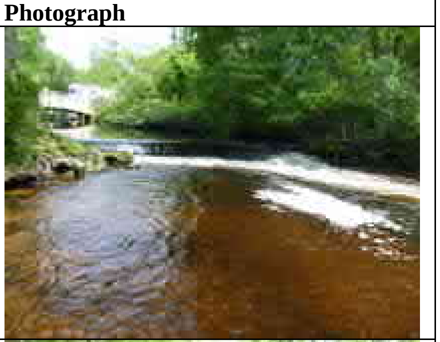
Reach	Town	Bridge/ Culvert Code	Location Lat.	RCPA Long.	Priority	Description	Photograph
PAR-18	Charlestown, RI		41.443	-71.681	Low	Only dam/weir without some sort of fish ladder on mainstem, gage could function without weir	
BER-4	Richmond, RI		41.498	-71.631	Low	Splits up good habitat, not in use, contributed to trail washout	
MEB-7	Richmond, RI		41.488	-71.676	Low	Will turn wetlands back into a floodplain forest	

Table 3 (continued). Priority restoration sites by project type.

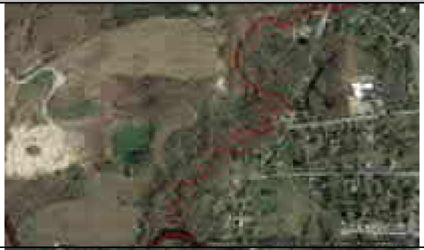
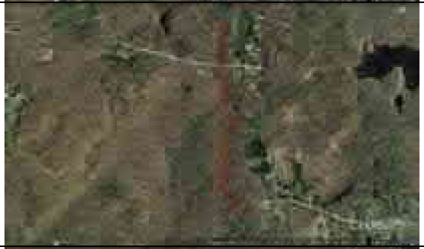
Reach	Town	Bridge/ Culvert Code	Location Lat.	RCPA Long.	Priority	Description	Photograph
				Corridor protection			
GAS-1	Hopkinton, RI		41.418	-71.797	High	Entire reach should be protected, very dynamic, great habitat, poor location for development, luckily development has not encroached significantly	
GAS-4	Hopkinton, RI		41.441	-71.797	High	Dynamic channel, recent avulsion, good habitat	
GAS-8	North Stonington, CT		41.471	-71.817	High	Archaeological sites, good habitat potential, little modern encroachment	
BER-6-7	Richmond, RI		41.520	-71.640	Low	Archaeological sites, good cold water habitat potential, could use wood additions	

Table 3 (continued). Priority restoration sites by project type.

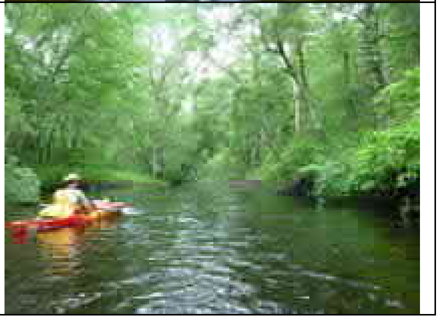
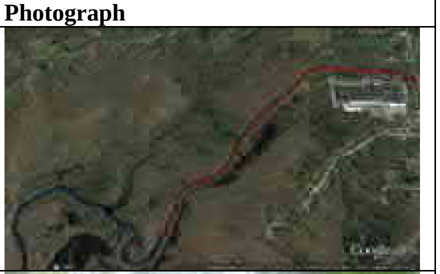
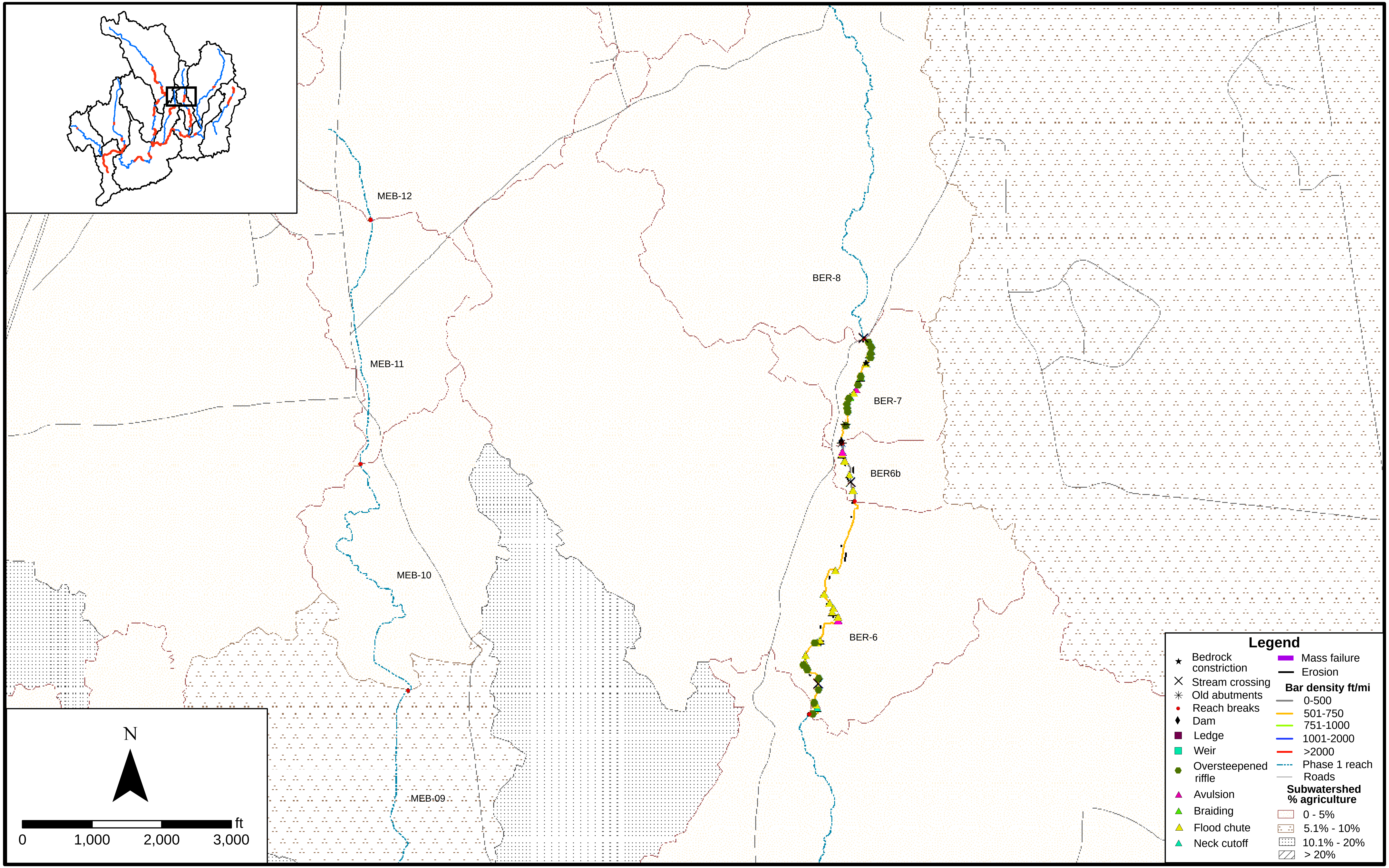
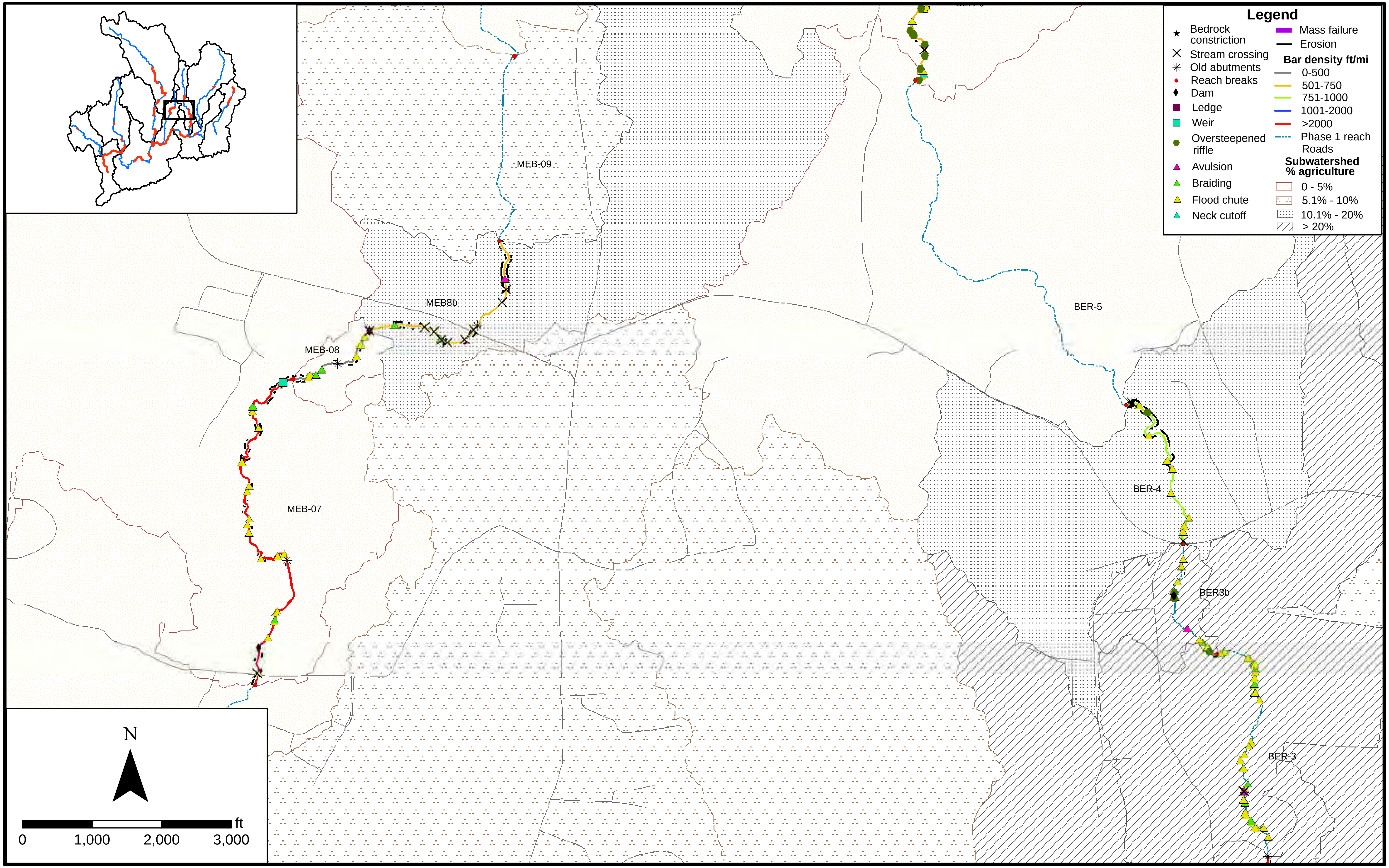
Reach	Town	Bridge/ Culvert Code	Location Lat.	RCPA Long.	Priority	Description	Photograph
BER-6-7	Richmond, RI		41.521	-71.640	High	Wood additions to create habitat complexity and increase use of side channels	
PAR-18	Charlestown, RI		41.443	-71.681	High	Log jams could be used to help reform meanders	
WOD-14-16	Exeter, RI		41.560	-71.714	Low	Improve already good habitat with additional wood to create log jams	

Table 3 (continued). Priority restoration sites by project type.

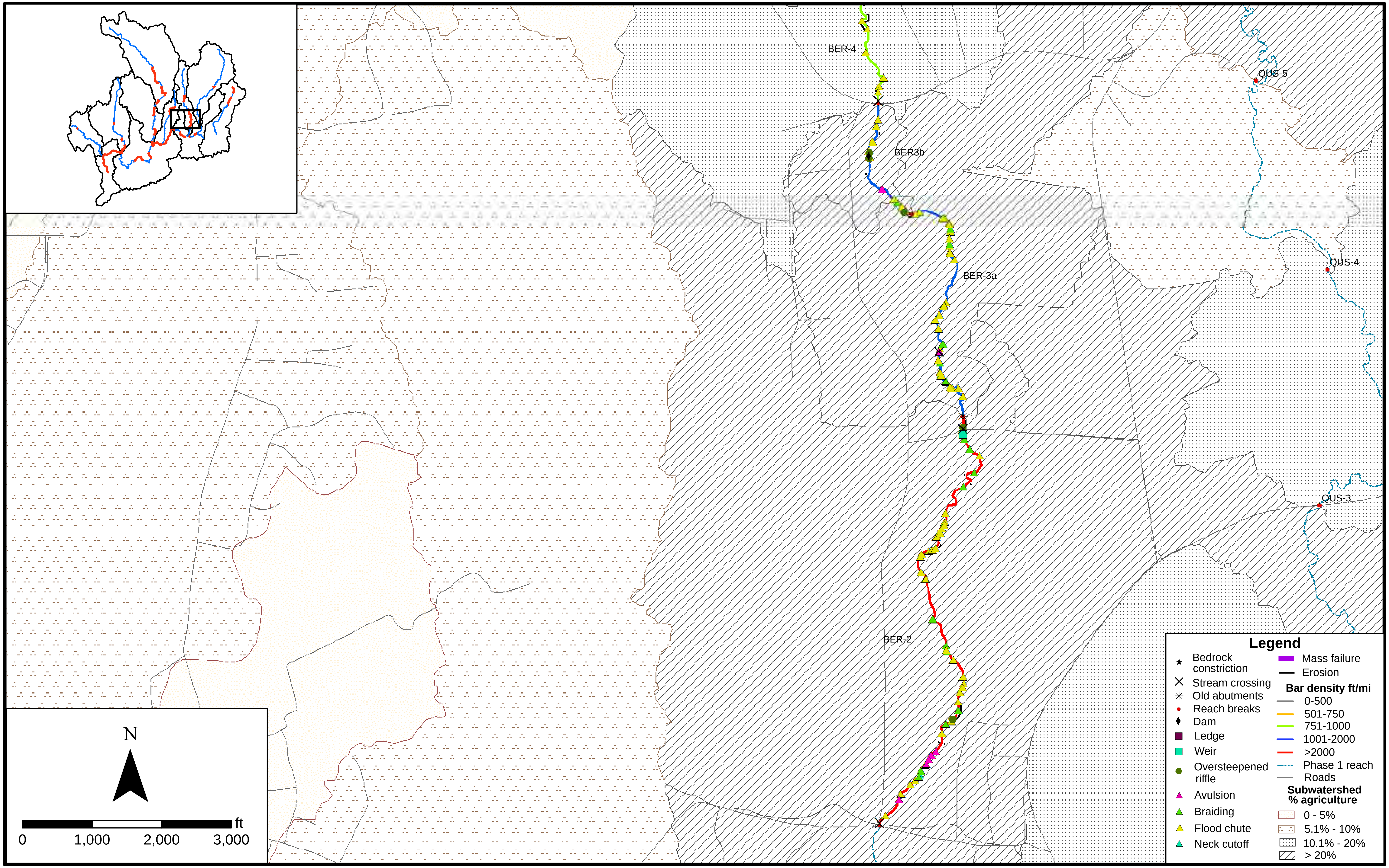
Reach	Town	Bridge/ Culvert Code	Location Lat.	RCPA Long.	Priority	Description	Photograph
PAR-12	Westerly, RI		41.403	-71.760	Low	Ponds downstream of Bradford mill complex should be moved further away from stream to remove avulsion hazard and increase floodplain width	
BER-2	Richmond, RI		41.478	-71.624	Low	Pond takes lots of water out of stream, potential avulsion risk	
CHIP-8	Exeter, RI		41.517	-71.526	Low	Pond/berm that could be breached to increase floodplain access	
PAR-15	Charlestown, RI		41.411	-71.726	Low	Artificial floodplain constriction that could be alleviated with flood relief culverts, development present upstream	



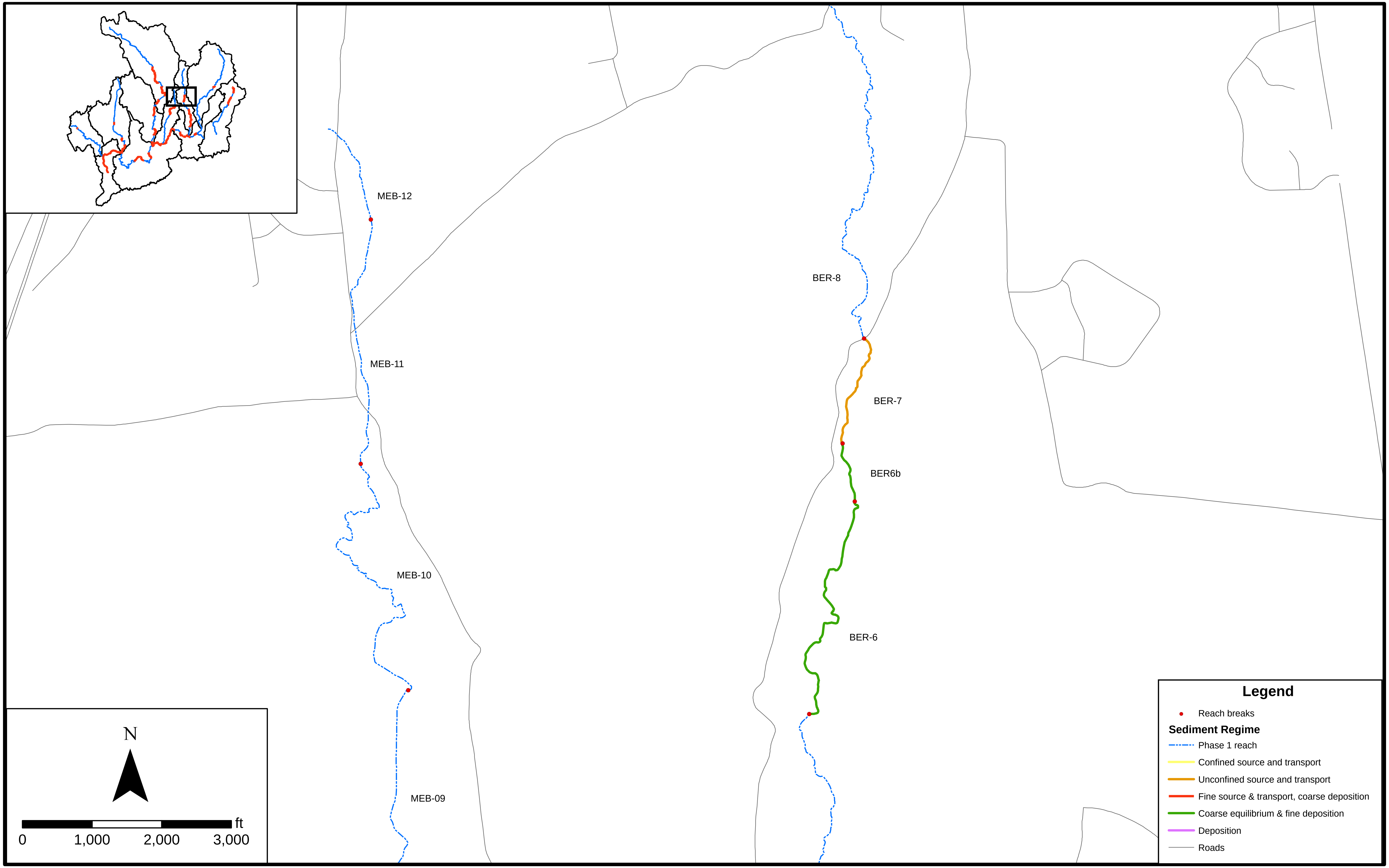
Appendix 1. Sediment stressor map.



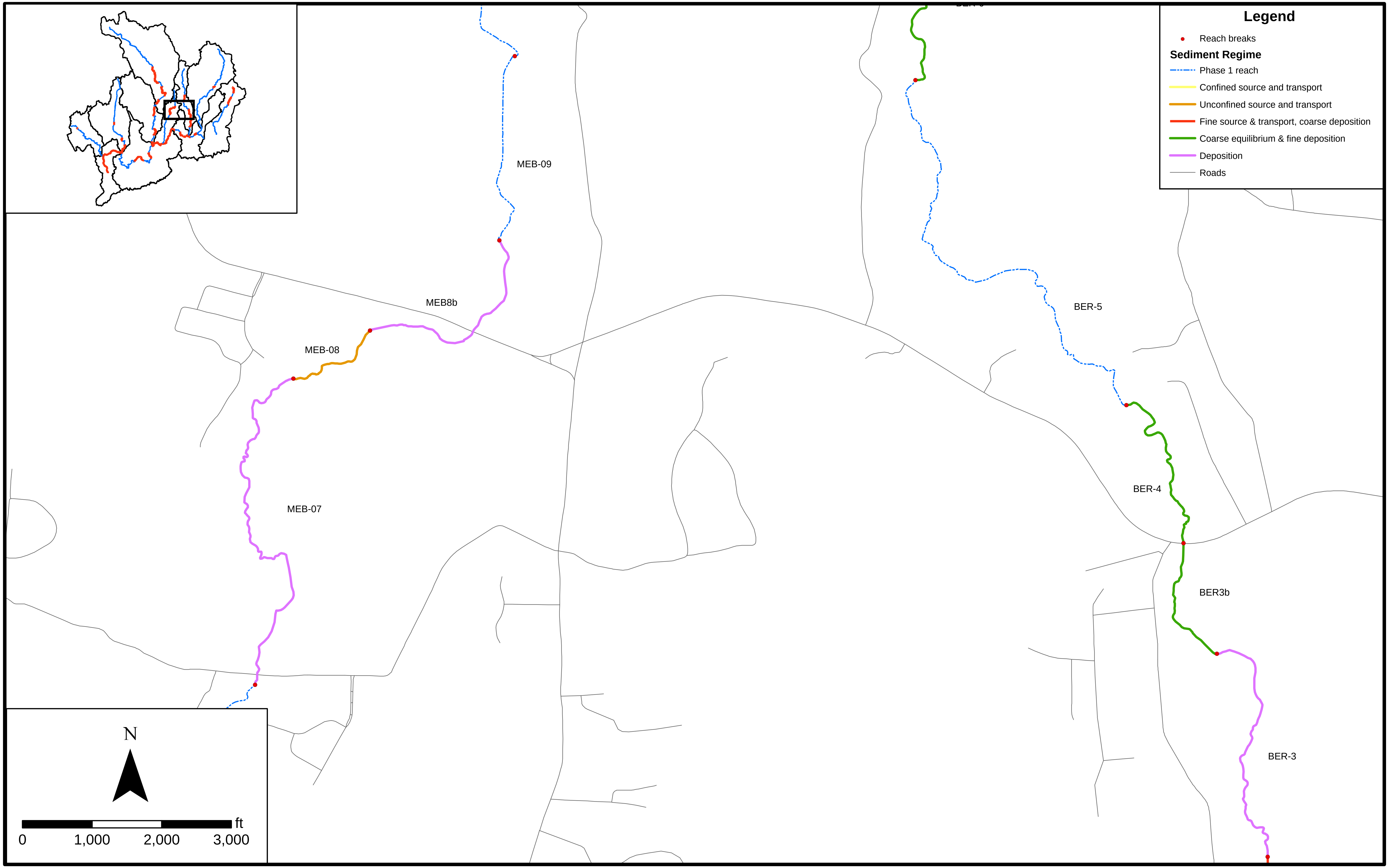
Appendix 1. Sediment stressor map.



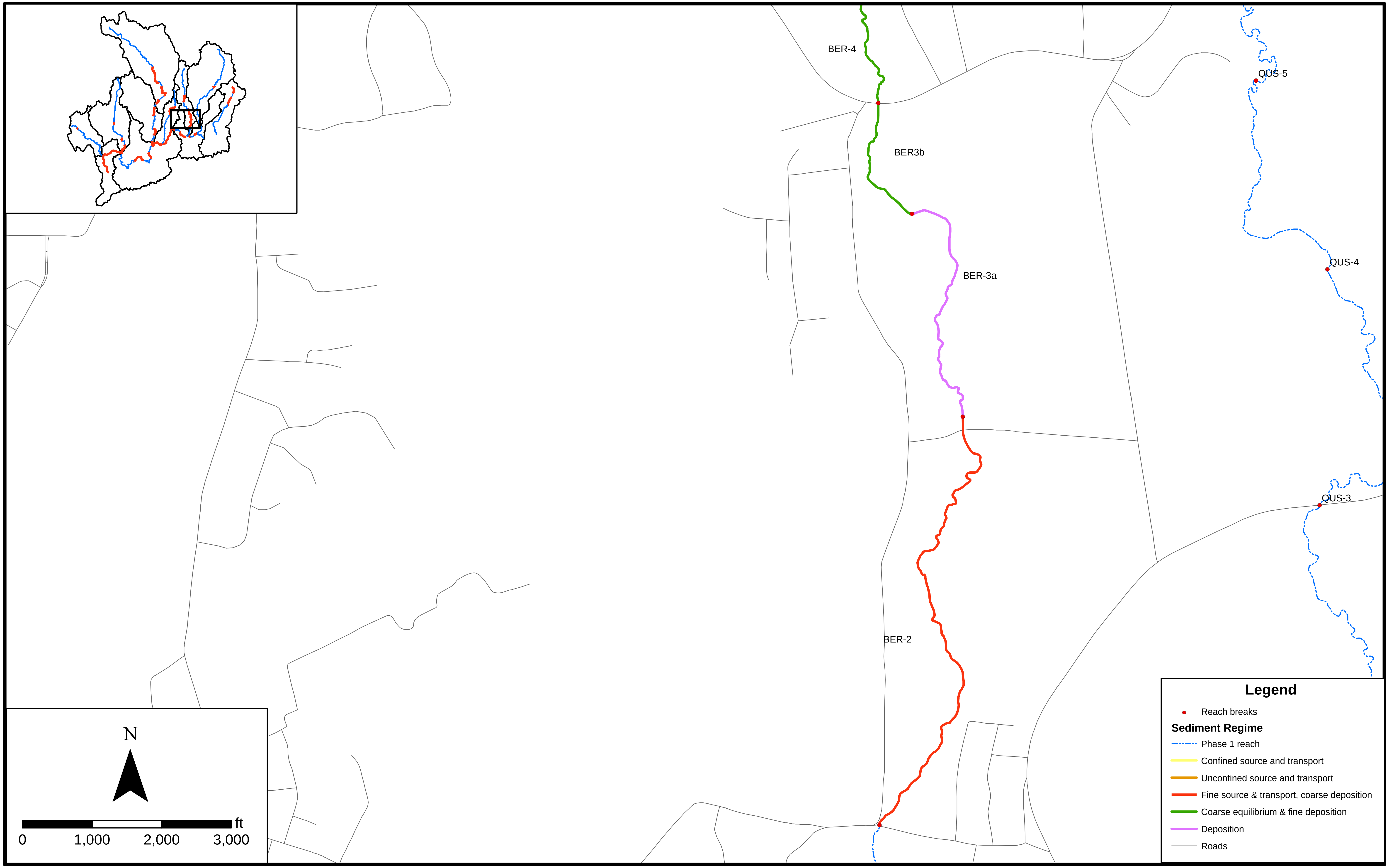
Appendix 1. Sediment stressor map.



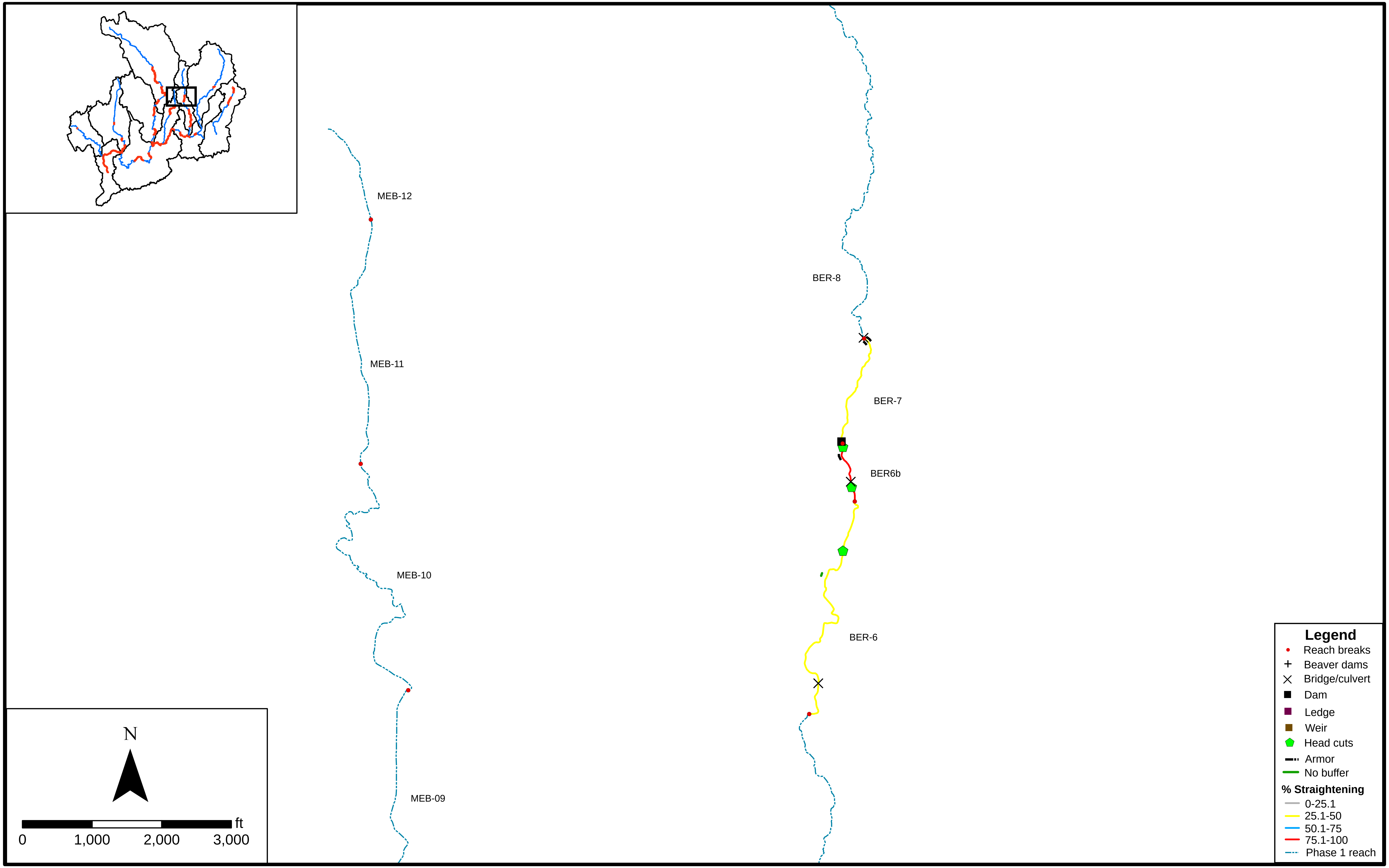
Appendix 1. Sediment regime map.



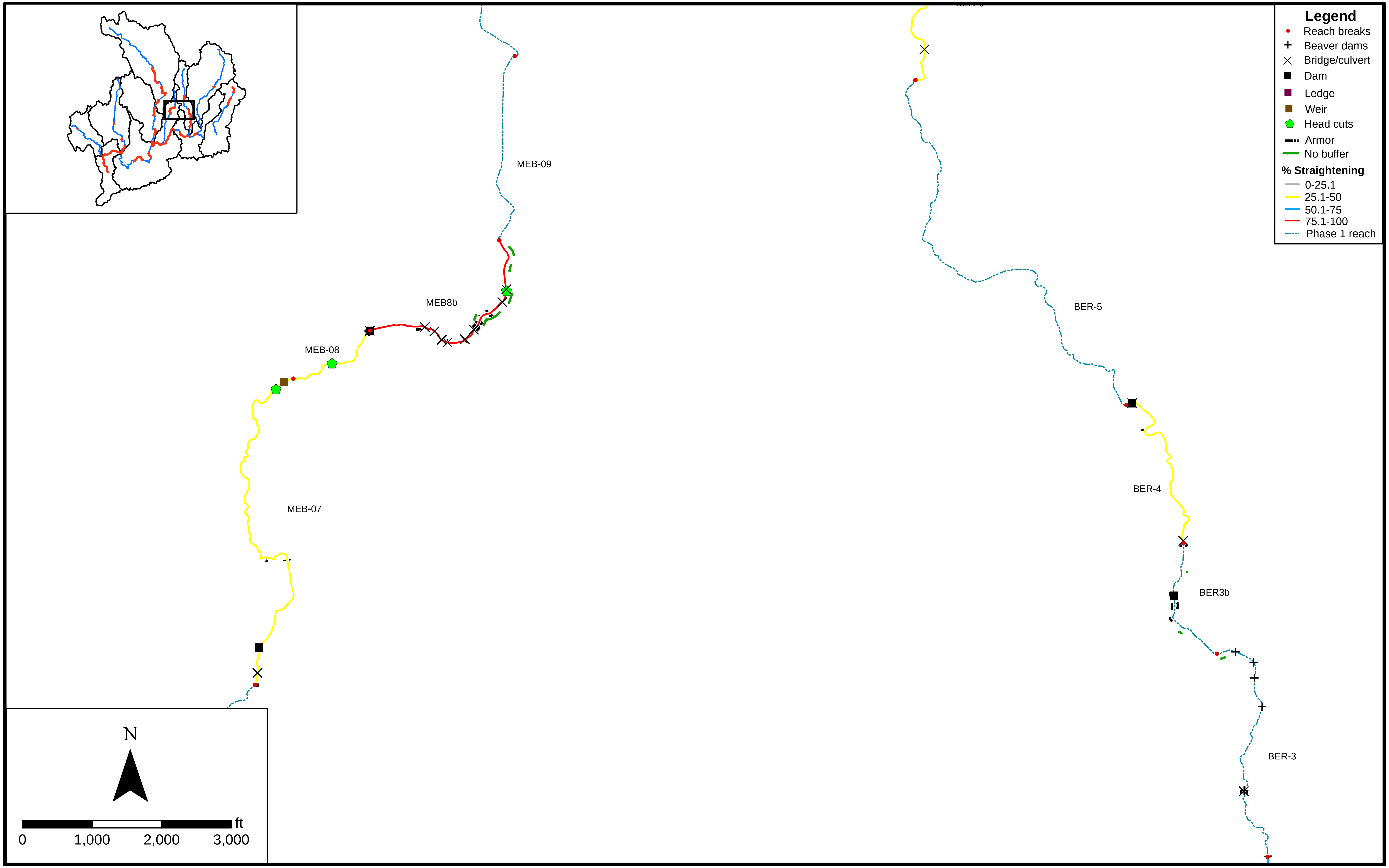
Appendix 1. Sediment regime map.



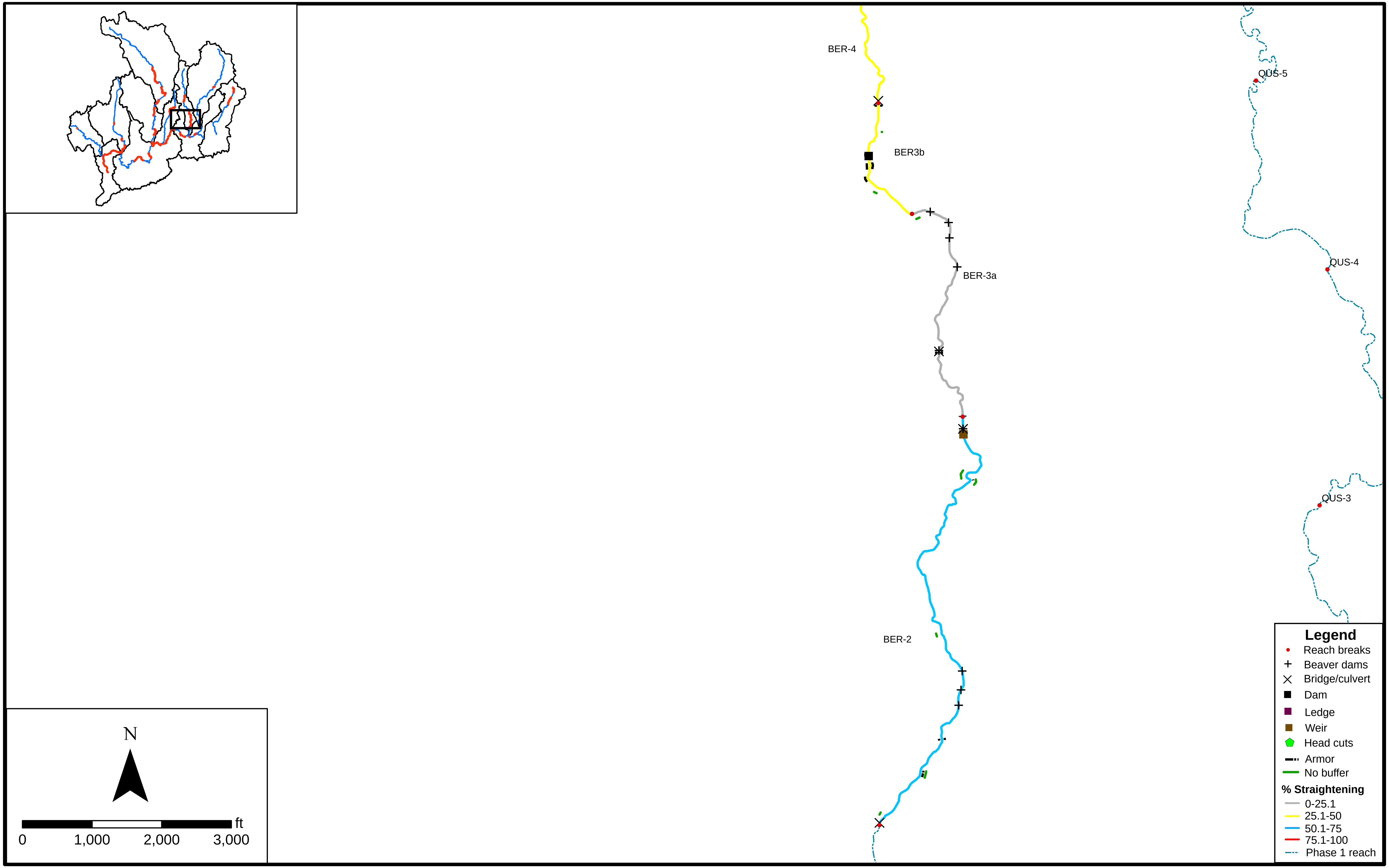
Appendix 1. Sediment regime map.



Appendix 1. Channel boundary modifiers.



Appendix 1. Channel boundary modifiers.



Appendix 1. Channel boundary modifiers.