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MEMORANDUM

TO: MVP Core Team, Uxbridge, MA

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RE: Road-Stream Crossing Assessment
Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan MVP Action Grant – Town of Uxbridge

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1 Introduction

Inadequate or undersized road-stream crossings can be flooding and washout hazards and can serve as barriers to the passage of fish and other aquatic organisms. As precipitation events become more intense and less predictable as a result of climate change, inadequate or undersized road-stream crossings throughout the Town of Uxbridge are expected to pose a greater threat of failure; flooding damage to homes and businesses, transportation infrastructure, and utilities; and stream channel erosion.

Fuss & O'Neill assessed road-stream crossings throughout the towns in support of Uxbridge's Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan, a project which was funded through the FY19 round of the Commonwealth's Municipal Vulnerability Preparedness (MVP) Action Grant funding. The primary goal of the overall project is to increase resilience to flooding and flood-related impacts throughout the Town. To that end, the project systematically assessed road-stream crossings Town-wide to identify vulnerabilities and rank high priority culvert/bridge replacement projects that would address flood vulnerability, reduce flooding impacts, and increase stream continuity for aquatic organism passage.

The assessments consisted of field surveys of individual stream crossings using established road-stream crossing assessment protocols, followed by analysis of the field data to assign vulnerability ratings to each crossing based on multiple factors including hydraulic capacity, structural condition, geomorphic risk, aquatic organism passage, transportation and emergency services, other flooding impacts, and climate change considerations. The vulnerability ratings are used to prioritize structures for upgrade or replacement. The results of the stream crossing assessments will inform the selection of infrastructure and natural system solutions to increase flood resilience in the community.

This memorandum summarizes the methods and results of the road-stream crossing field surveys and vulnerability assessment. Recommendations are presented based on field observations and the vulnerability assessment and prioritization process.

2 Stream Crossing Field Surveys

2.1 Selection of Crossings

Road-stream crossings to be included in the assessment were initially identified based on review of aerial imagery, flood mapping, and other local, county, or state-wide data layers. The MVP Core Team reviewed these maps and provided additional information on locations of known culvert/bridge infrastructure where flooding was already a concern. The project sought to assess all crossings Town-wide which could reasonably and safely be assessed. Crossings of Route 146 were excluded from the assessment due to access and safety issues.

Ninety-one (91) road-stream crossings throughout the Town were ultimately assessed via field surveys and desktop vulnerability assessments. The locations of the selected crossings are shown on the watershed map in Figure 1. Summary information on each crossing is provided in Appendix B—Table 1.

2.2 Field Data Collection

Field surveys of the selected crossings were conducted between September 17th and November 22nd, 2019 using road-stream crossing assessment procedures and field data collection forms documented in the RIDOT Road-Stream Crossing Assessment Handbook (available at http://www.dot.ri.gov/about/stormwater.php), which was developed by Fuss & O'Neill. This is the same methodology that has been used for road-stream crossings throughout Massachusetts through several other MVP grants, which allows comparison of results across communities. Methods for assessing aquatic connectivity and structural condition were adapted from the North Atlantic Aquatic Connectivity Collaborative (NAACC) Methods for collection and assessment of other field data for evaluating geomorphic vulnerability, hydraulic capacity, and potential flooding impacts to infrastructure and public services were developed by Fuss & O'Neill and/or adapted from other standardized assessment protocols used in the northeastern U.S. Digital photographs were taken at each crossing. A blank copy of the field data collection form is provided in Appendix A.

The crossing surveys were performed by a two-person field crew consisting of water resources and wetland scientists. The field crew was led by a NAACC-Certified Lead Observer; additional training was also provided for all field personnel prior to the field work. Digital field data collection methods were used to complete the crossing surveys, using a GPS-enabled tablet with a pre-loaded digital version of the field form, aerial imagery, and the crossing locations. Field data for the project were saved and managed using an ArcGIS database and web application. Following the stream crossing surveys, field data were checked for quality control purposes.

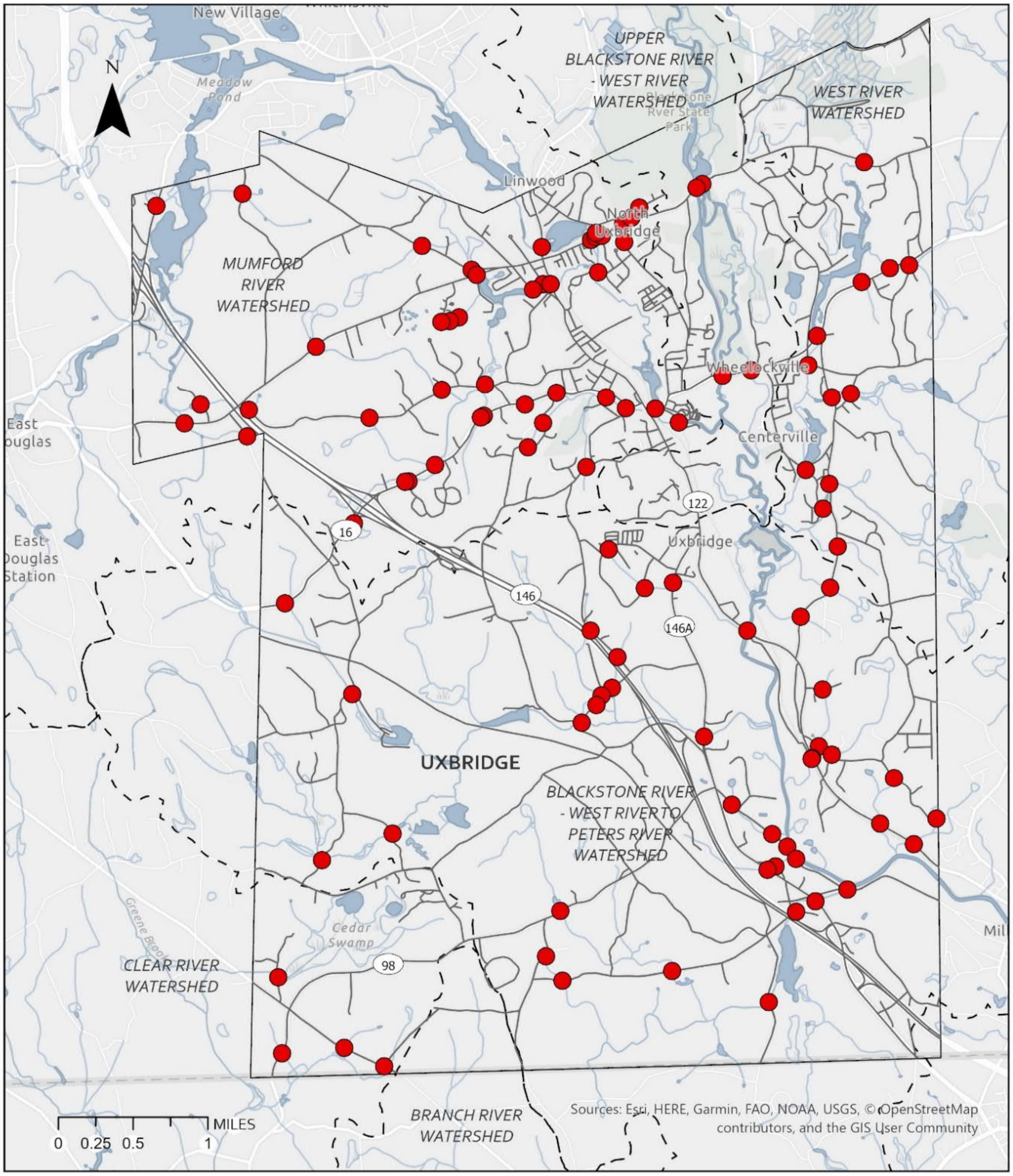

Figure 1. Road-stream crossings selected for assessment in the Town of Uxbridge. Watershed boundaries are indicated by dotted lines.

2.3 Crossing Survey Findings Summary

Appendix B summarizes key field data and findings of the road-stream crossing surveys for the Town of Uxbridge.

The following issues were observed at the surveyed stream crossings:

- Poor Structural Condition: The majority (80%) of the crossings assessed were observed to be in poor condition and in need of significant repairs or replacement. Deterioration of headwalls, and/or wingwalls, armoring, and joints and seams was common at many of these crossings, as was evidence of embankment piping. Invert deterioration and footing deterioration were also relatively common among crossings in the Town. Photos showing examples of structural deficiencies observed at Uxbridge crossings are provided in Figure 2.


Figure 2. Examples of crossing structures in poor structural condition observed at various locations during field assessments. Left: Structure exhibiting a sinkhole, critical structural integrity, and critical joints and seams. Right: Severely blocked culvert inlets.

- Flow Constriction: All but thirteen (13) of the assessed crossings are significantly narrower than the bankfull width of the stream channel and therefore appear to constrict flood flows. Twenty-eight (28) of the crossings were rated as severely constricted, indicating that the bankfull width of the stream channel was at least twice as wide as the structure opening(s). The hydraulic capacities of many of the crossings in the watershed are limited due to undersized crossing structures and/or significant accumulation of sediment at some locations. Constriction also negatively impacts aquatic organism passage.
- Aquatic Organism Passage Barriers: Only fourteen (14) of the assessed crossings (16%) are considered significant or severe barriers to aquatic organism passage. An additional 56% were determined to be moderate or minor barriers, while 28% were assessed as providing full aquatic organism passage.
- Channel Erosion: Varying degrees of stream channel erosion were observed in the reaches immediately upstream and/or downstream of the assessed crossings. Efforts to repair recent channel erosion through channel grading and bank stabilization were evident at some of the surveyed locations.

- Sediment Deposition: Sediment deposition was observed at the majority of the crossings throughout the Town.
- Utilities: All but nine (9) of the assessed crossings carry one or more utilities attached to, above, or buried within the crossing structure. Failure of crossings at locations with buried utilities could also result in some level of failure of the associated utilities. Overhead lines are less likely to be affected by failure, but poles may be affected by severe erosion or embankment failure associated with a culvert washout.
- Adjacent Crossings: All but twenty-six (26) crossings had one or more additional crossings located within one half mile upstream or downstream. Where crossings are located in close proximity along the same stream, failure of one crossing can cause the failure of adjacent crossings, especially downstream of the failed crossing and during flood conditions.

3 Vulnerability Assessment and Prioritization

Using data from the stream crossing surveys and available GIS data, each of the assessed crossings was assessed for vulnerability to flooding and associated impacts relative to hydraulic capacity, structural condition, geomorphic conditions, aquatic organism passage, transportation services, land use, and climate change considerations The vulnerability and impact ratings were then combined to generate an overall rating, which was used to assign a priority to each crossing for potential upgrade or replacement. Methods and equations are provided in Appendix C.

3.1 Assessment Method

The following individual assessments were performed for each stream crossing:

- Existing and Projected Future Streamflow: Estimation of existing and future (climate change scenario) peak discharge for common recurrence intervals using regional regression equations developed by USGS for estimating peak flows at ungaged locations (i.e., StreamStats) or drainage area ratios for crossing locations where regional regression equations are unreliable. Flood flows under future climate change were estimated using a design flow multiplier of 1.2, representing a 20% increase in rainfall intensity above current conditions to account for anticipated increases in design rainfall intensities associated with future climate change projections. The recommended 20% increase in design rainfall intensity is consistent with climate change projections for extreme precipitation under a medium to high emissions scenario and a 50- to 100-year planning horizon, based on the typical design life (50 years) of most storm drainage infrastructure, and the useful life, which is typically 50-100 years for stormwater infrastructure. It should be noted that design life is different from useful life, which is typically longer than the design life and more accurately represents the extended service life of infrastructure, assuming regular maintenance.
- Hydraulic Capacity: Estimation of the hydraulic capacity of each road-stream crossing using standard Federal Highway Administration culvert/bridge hydraulic calculation methods following FHWA Hydraulic Design Series Number 5 (HDS-5). Bentley CulvertMaster, which employs HDS-5 methods, was used for the analysis. Hydraulic capacity was determined for a selected headwater depth, which represents that depth at which the crossing is at risk of structural failure or the roadway is at risk of overtopping, depending on crossing type and material. Manning's Equation for uniform open channel flow was used to estimate the crossing hydraulic capacity for lager structures (bridges) or where the cross-sectional area could not be approximated with CulvertMaster. A capacity ratio

(defined as the ratio of estimated hydraulic capacity to the estimated peak discharge for a specified return interval) was calculated for each crossing for both existing and projected future peak streamflow.

- Structural Condition: Assignment of condition ratings and scores based on visual observation of the structural condition of the crossing inlet, outlet, and barrel adapted from the latest version of the NAACC Culvert Condition Assessment Manual, which was developed with input from state transportation departments throughout the Northeast and other stakeholders. The NAACC condition assessment methodology is designed as a rapid assessment tool for use by trained observers for purposes of flagging crossings that should be examined more closely for potential structural deficiencies.
- Geomorphic Impacts: Assessment of the potential for crossing structures to impact geomorphic processes that might, in turn, threaten the structure itself and other adjacent infrastructure. The assessment procedure distinguishes between crossings that are: 1) not prone to and have not experienced geomorphic adjustments; 2) prone to but have not experienced geomorphic adjustments; and 3) prone to and have experienced geomorphic adjustments. The approach rates the relative likelihood that impacts could occur and the type and severity of impacts that have already occurred. Factors that were considered include stream alignment, bankfull width, degree of constriction, significant breaks in valley slope, bank erosion, sediment deposition, structure and channel slope, stream bed material, and other geomorphic parameters.
- Aquatic Organism Passage (AOP): Assessment of aquatic passability using the latest NAACC protocols and rating system for assessing stream continuity. The method was adapted from the NAACC Numeric Scoring System for AOP, which was developed with input from multiple experts in aquatic passability. The NAACC Numeric Scoring System methodology is designed as a quantitative but rapid assessment tool for use by trained observers. The assessment is not species-specific, but rather seeks to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.
- Ecological Integrity: The habitat quality of the river reaches made accessible by removing an existing barrier to aquatic passage is also an important consideration in the crossing prioritization process. Ecological integrity scores were assigned to each crossing based on the concept of Index of Ecological Integrity (IEI). IEI scores were obtained from the Critical Linkages dataset for Massachusetts developed by the Landscape Ecology Lab at UMass Amherst as part of the Conservation Assessment and Prioritization System (CAPS) program.
- Impacts to Transportation Services: Evaluation of the potential disruption of transportation services resulting from single crossing failures by considering the federal functional classification of the roadway (i.e., level of travel mobility and access to property that it provides). Disruption of transportation services is assumed to occur if the crossing is either overtopped or washed away by flooding, as either failure mode would prohibit the use of the road-stream crossing by traffic.
- Other Potential Flooding Impacts: Assessment of the potential impact to existing development, infrastructure, and land use upstream and downstream of each stream crossing in the event of failure of the crossing. A potential impact area was approximated for each crossing, having a width defined by buffering the stream centerline by a distance equal to two times the bankfull width, and a length defined as 0.5 miles upstream and downstream of the crossing. Flooding vulnerability was quantified based on the percentage of developed land cover, using 0.5 meter resolution land cover data from

the Massachusetts statewide 2016 Land Cover/Land Use dataset (https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use), and the presence of upstream or downstream crossings within the impact area, as well as any infrastructure (gas, sewer, water, etc.) observed to be attached to or located within the crossing structure.

3.2 Prioritization Method

The crossing structures were assigned a relative priority for replacement, repair, or removal based on the results of the individual assessments and consideration of failure risk as well as the assessment of the ecological benefit of crossing removal.

Failure risk is defined as the product of the probability of failure of a crossing (determined through assessment of the crossing's hydraulic, geomorphic, and structural condition) and the potential consequences of failure (i.e., impacts). A crossing may be at risk if the probability of failure is high, if the consequences of failure are high, or both. Risk scores were calculated for hydraulic risk, geomorphic risk, and structural risk according to equations provided in Appendix C. The overall failure risk for a crossing (represented by the Crossing Risk Score), which is dictated by the highest (i.e., worst-case) level of risk, was then calculated as the maximum of the hydraulic risk and future hydraulic risk scores, geomorphic risk score, and structural risk score.

The ecological value of removing or replacing a crossing depends on both the quality and the extent of aquatic habitat that is reconnected as a result of removing the existing crossing or replacing it with a structure that provides for improved aquatic passage. The Aquatic Passage Benefit Score was calculated by combining the aquatic passability score with the ecological integrity score.

A Crossing Priority Score was calculated for each crossing by combining the Crossing Risk Score with the Aquatic Passage Benefit Score. The two scores are combined by summing the maximum of the two scores with the average of the two scores. This approach prioritizes those crossings that rate highly for both factors, while simultaneously ensuring that a very high score for either one factor will be preserved. The Crossing Priority Score was then re-scaled to a range from 0 to 1 for ease of interpretation. It is important to note that the Crossing Priority Score should only be used for relative comparisons between crossings, and not as an absolute measure of any physical or other aspect of the crossings.

3.3 Assessment and Prioritization Results

Table 1 summarizes the hydraulic risk (existing and future), geomorphic risk, structural risk, and aquatic organism passability scores, as well as the Scaled Crossing Priority Score (normalized on a scale of 0 to 1) for each of the highest priority crossings located in the Town of Uxbridge. The detailed road-stream crossing assessment and prioritization worksheets and scores are provided in Appendix B.

Hydraulic Risk

22% of the crossings assessed are hydraulically undersized under existing precipitation conditions, having insufficient capacity to convey the 10-year peak flow (Figure 3). Another 7% of crossings are

Table 1. Top-Ranked High Priority Crossings: Road-Stream Crossing Vulnerability Assessment and Prioritization Results Summary

Road Name	HUC 12 Watershed Name	Impact Score	Existing Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Value	Scaled Crossing Priority	Relative Priority Rating
Crown and Eagle Road	Mumford River	5	25	25	20	25	15	25	45	0.9	High
Route 16/Douglas Street	Mumford River	5	5	5	20	25	9	25	42	0.84	High
Route 16/Mendon Street	West River	4	4	4	16	20	20	20	40	0.8	High
Hartford Avenue East	Mumford River	5	5	5	15	25	4	25	39.5	0.79	High
Taft Hill Lane	Mumford River	5	10	15	10	25	3	25	39	0.78	High
Hunter Road	Mumford River	4	4	4	16	20	12	20	36	0.72	High
Crownshield Avenue	Blackstone River-West River to Peters River	4	4	8	16	20	12	20	36	0.72	High
Crownshield Avenue	Blackstone River-West River to Peters River	4	4	4	20	20	10	20	35	0.7	High
High Street	Mumford River	4	20	20	12	20	9	20	34.5	0.69	High
Route 16/Douglas Street	Blackstone River-West River to Peters River	4	20	20	12	20	9	20	34.5	0.69	High
Route 16/Douglas Street	Mumford River	4	20	20	16	20	9	20	34.5	0.69	High
Route 16/Douglas Street	Mumford River	4	4	4	16	20	9	20	34.5	0.69	High
146a/Quaker Highway	Blackstone River-West River to Peters River	4	4	4	12	20	8	20	34	0.68	High
Route 122/North Main Street	Mumford River	4	20	20	12	20	8	20	34	0.68	High

hydraulically undersized relative to the 25-year return interval flow (Figure 3). 56% of crossings were found to be sized such that they could pass the 100-year return interval flow under existing conditions; these generally include larger bridges, as well as some smaller structures on headwater streams with small drainage areas.

Under future expected flows (assuming an increase in peak flows of 20%) some structures are expected to be at greater risk. In this scenario 23% of crossings are expected to be undersized for the 10-year peak flow, and an additional 10% are expected to be undersized for the 25-year return interval flow. 48% of the structures are expected to still be able to pass the 100-year return interval flow (Figure 3).

Geomorphic Risk

Geomorphic risk is a common problem at road-stream crossing sites in Uxbridge. Approximately 43% of all assessed crossings were rated as having severe or significant geomorphic risk, taking into account both observed geomorphic impacts and potential geomorphic impacts (Figure 6). An additional 49% were rated as having moderate geomorphic risk. The remaining 8% of crossings were found to have low geomorphic risk. The three crossings with the highest geomorphic risk are located on Crown and Eagle Road, Crownshield Avenue, and Route

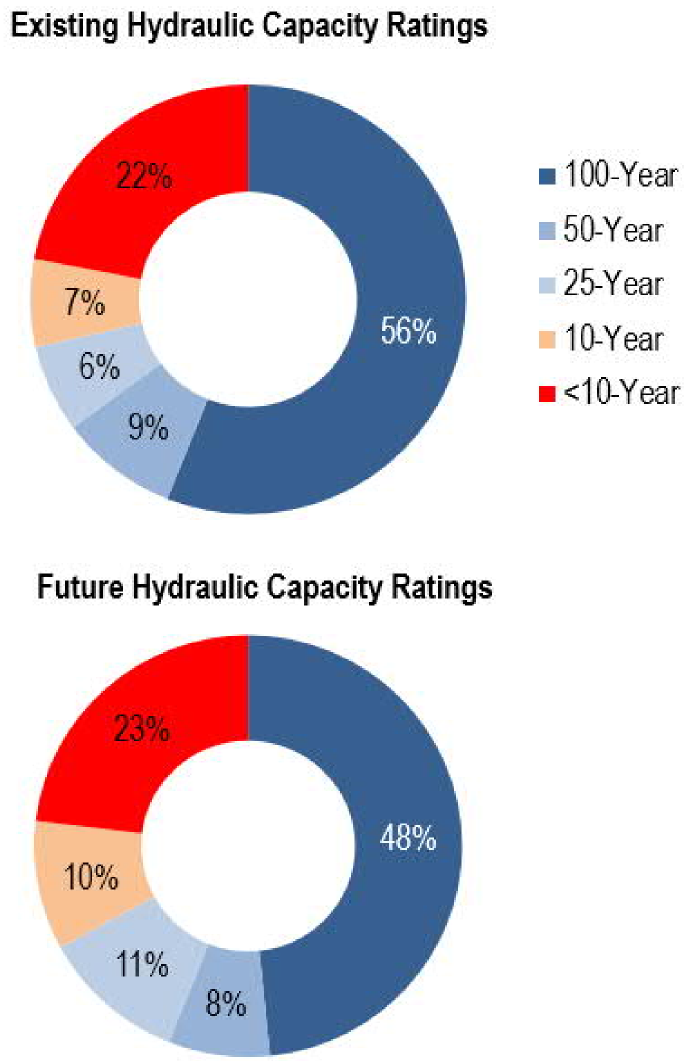

Figure 3. Distribution of hydraulic capacity ratings across all assessed crossings, for both existing conditions (top) and expected future precipitation conditions under climate change (bottom).

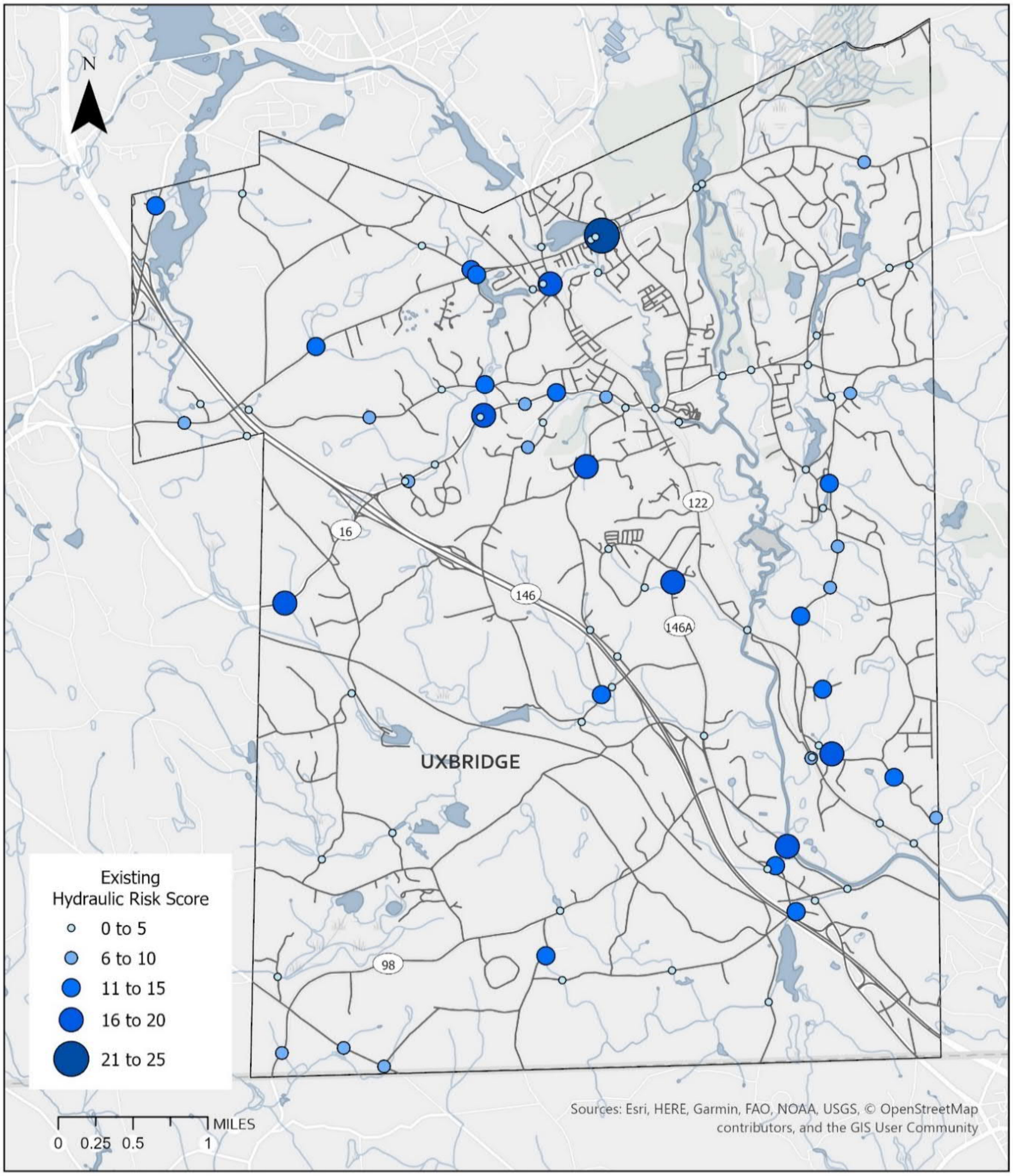

Figure 4. Spatial distribution of hydraulic risk scores for all assessed crossings under existing precipitation conditions.

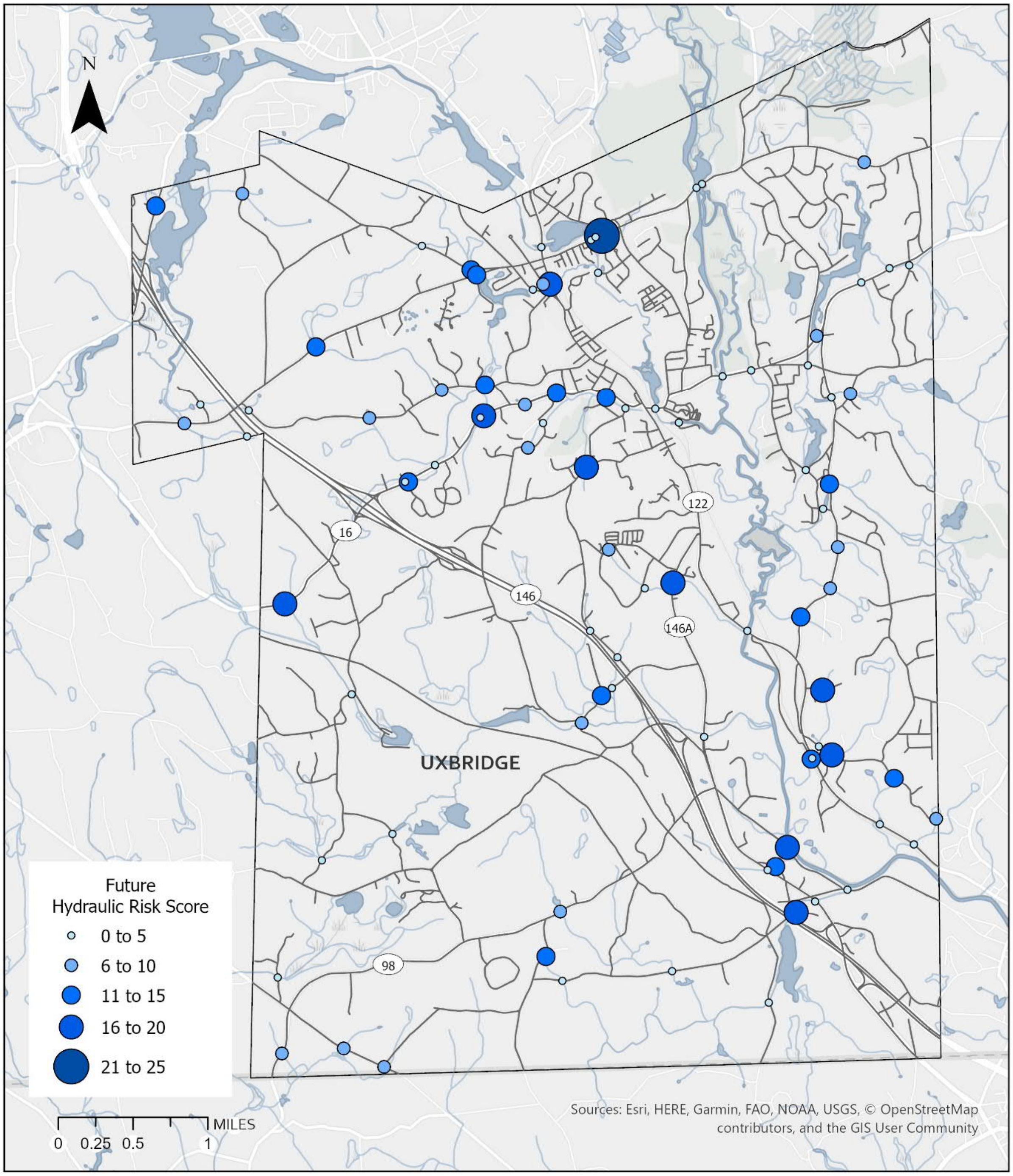

Figure 5. Spatial distribution of hydraulic risk scores for all assessed crossings under future precipitation conditions.

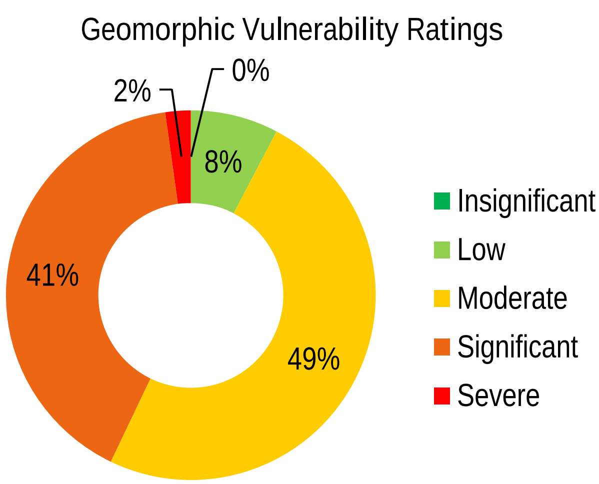

Figure 6. Distribution of geomorphic vulnerability ratings across all assessed crossings.

16/Douglas Street. Many of the remaining structures of high concern are located on State Routes 16 and 146A and on Hartford Avenue, which are some of the more major transportation routes within the Town. (Figure 8).

Structural Risk

Structural risk is an even more common problem at road-stream crossing sites in Uxbridge, with 49% of assessed crossings rated as "Critical" for structural condition and a further 31% rated as "Very Poor" or "Poor" (Figure 7). Only 19% of crossings received ratings of "Good" or "Satisfactory." Of the nineteen crossings that rated highest for structural risk based on structural condition and potential for flooding impacts (with scores of 20 to 25 out of 25), all are also among the top priority crossings overall (Table 1). Several crossings rated as having severe structural risk are located along State Route 16 and other high-traffic roads in the Town of Uxbridge (Figure 9).

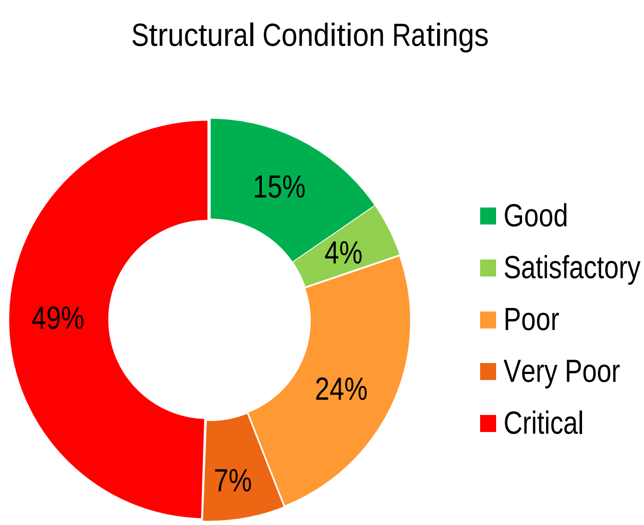

Figure 7. Distribution of structural condition ratings across all assessed crossings.

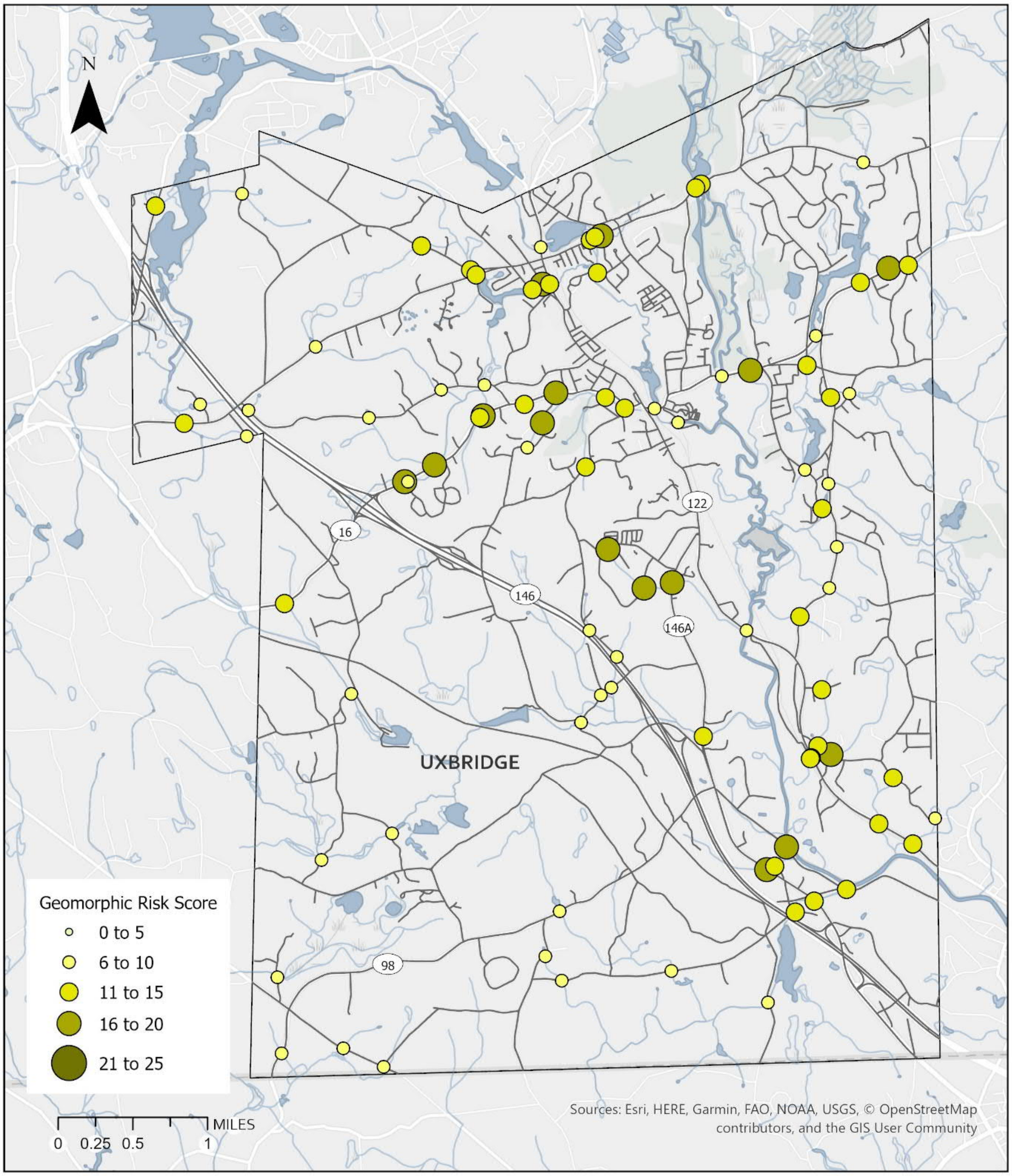

Figure 8. Spatial distribution of geomorphic risk scores for all assessed crossings.

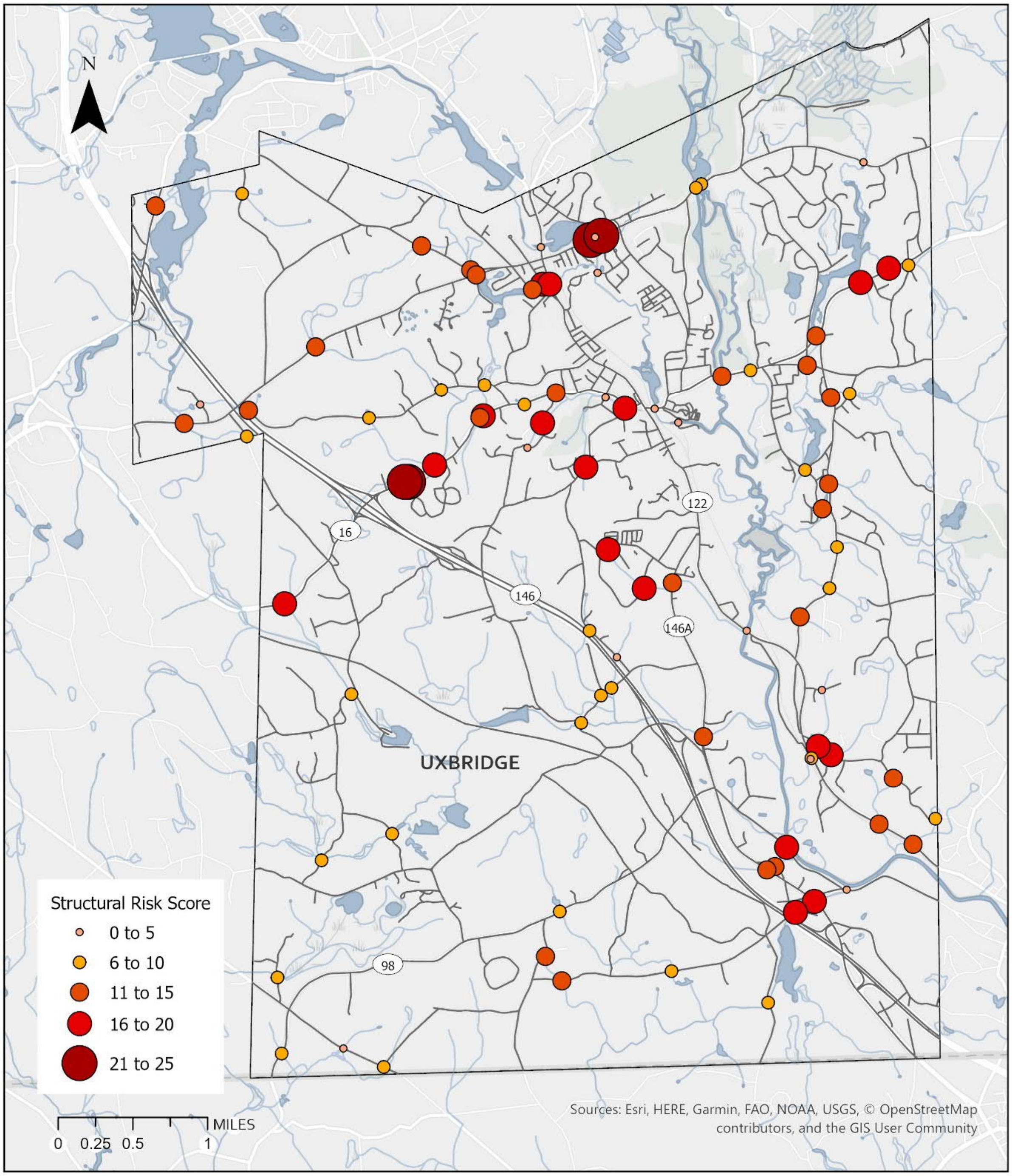

Figure 9. Spatial distribution of structural risk scores for all assessed crossings.

Aquatic Organism Passage

The majority of crossings assessed were rated as providing full passage (28%) or as only minor barriers (25%) to aquatic passage (Figure 10). Only 16% of barriers were considered significant or severe barriers to aquatic organism passage. However, of the 16 crossings receiving the highest AOP Benefit Scores (scores of 10-25), over half received High Relative Priority Ratings overall. Figure 12 depicts the spatial distribution of the AOP Benefit Scores.

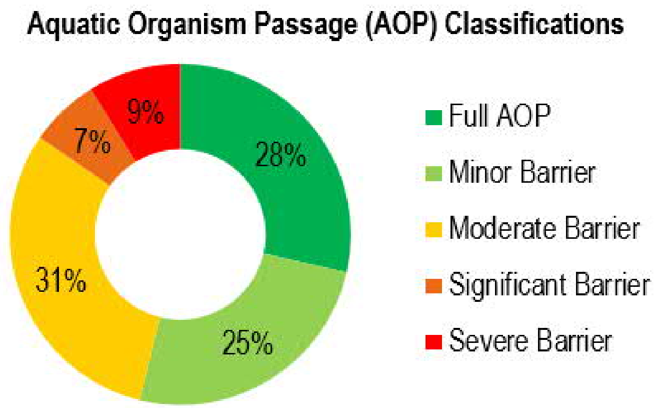

Figure 10. Distribution of aquatic organism passage classifications across all assessed crossings.

Impact Ratings

Because impacts to transportation services were calculated solely as a function of road classification, the crossings with the highest potential for transportation disruption were found to occur on state roadways. The crossings receiving the highest binned transportation disruption ratings were located on State Route 16 (crossings on Route 146 were not assessed due to safety concerns regarding site access). The sites with the highest potential for flooding impacts were located in densely developed areas, particularly within the Uxbridge town center area (Figure 11, Figure 13).

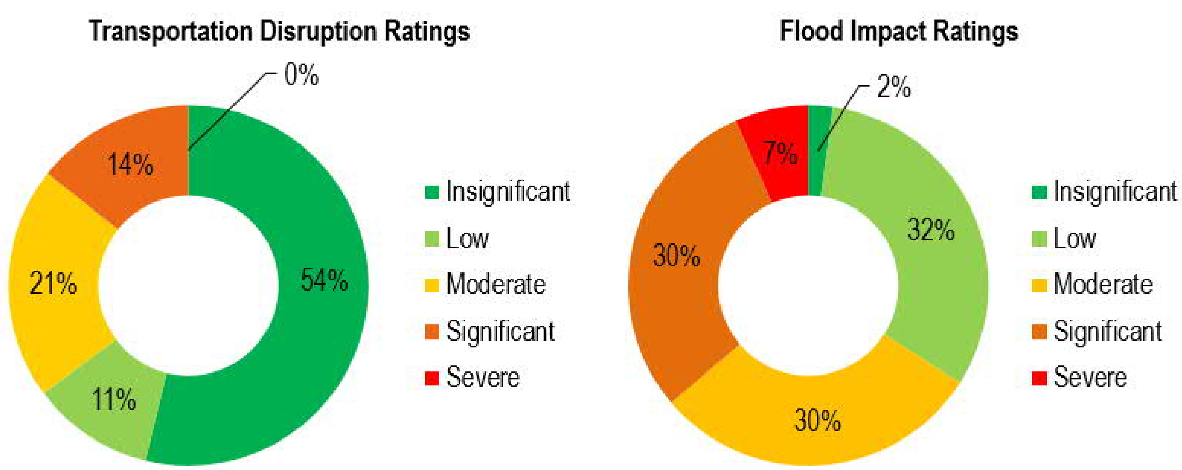

Figure 11. Distribution of transportation disruption ratings (left) and flood impact ratings (right) across all assessed crossings.

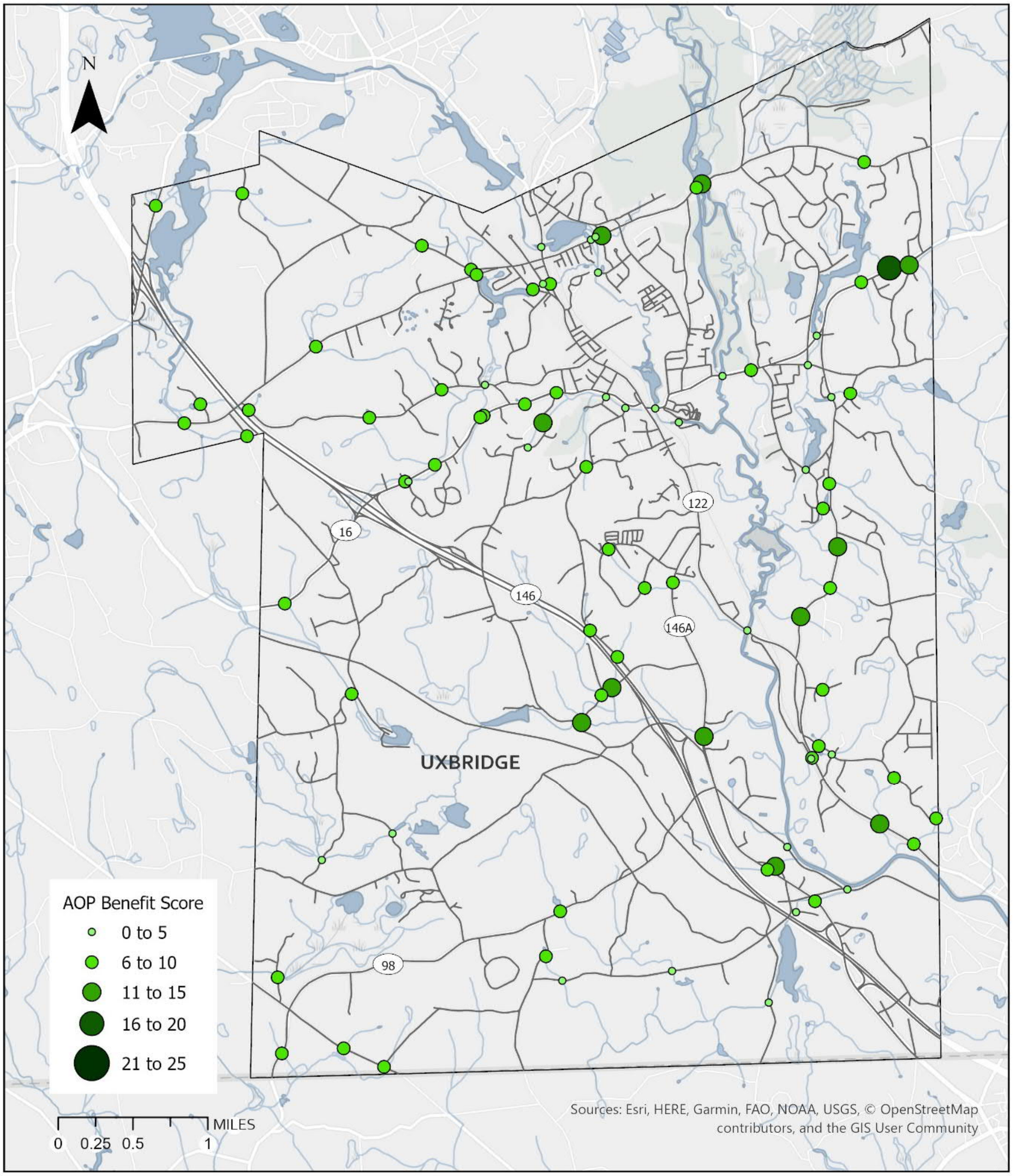

Figure 12. Spatial distribution of AOP benefit scores for all assessed crossings.

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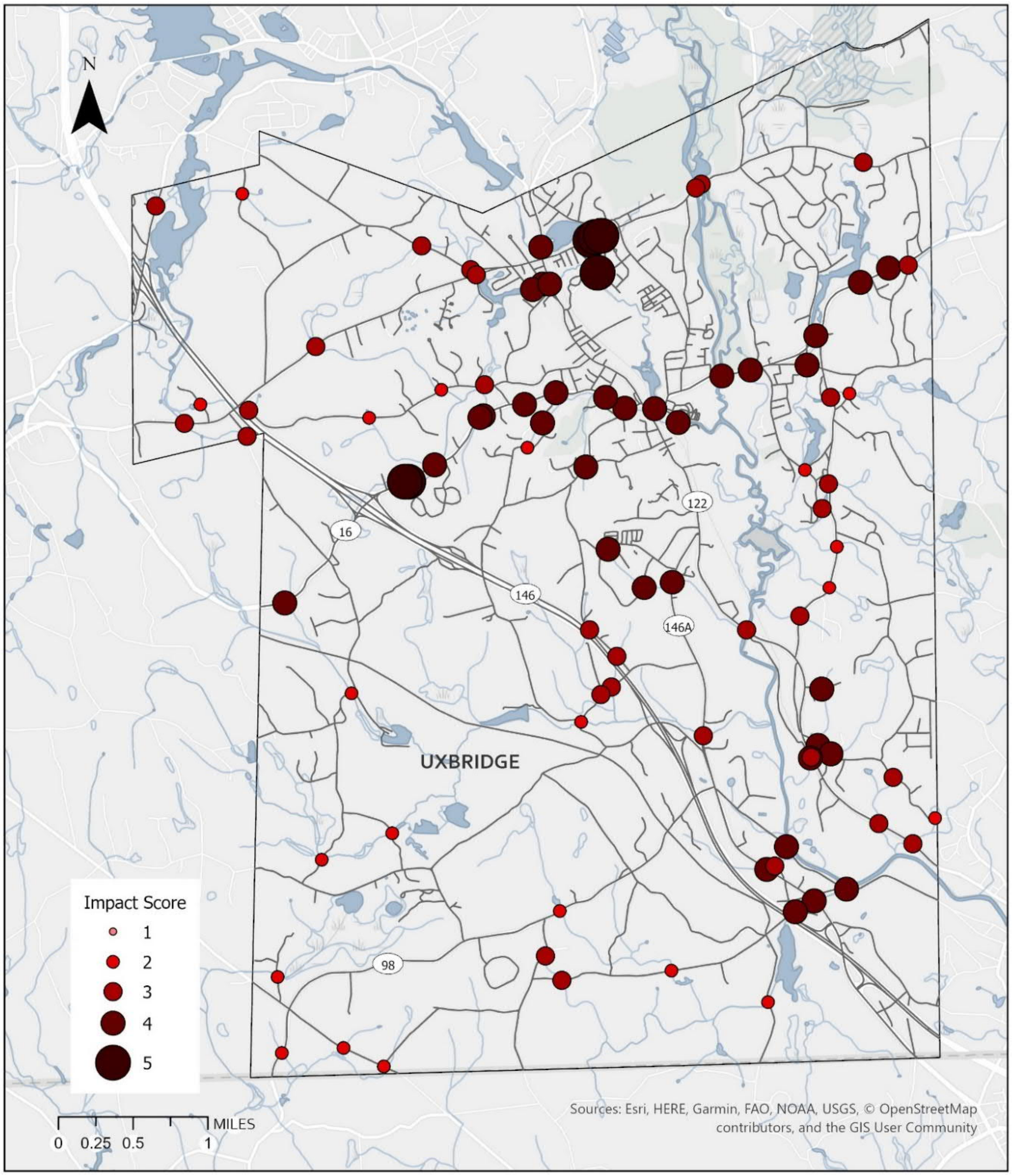

Figure 13. Spatial distribution of impact scores for all assessed crossings.

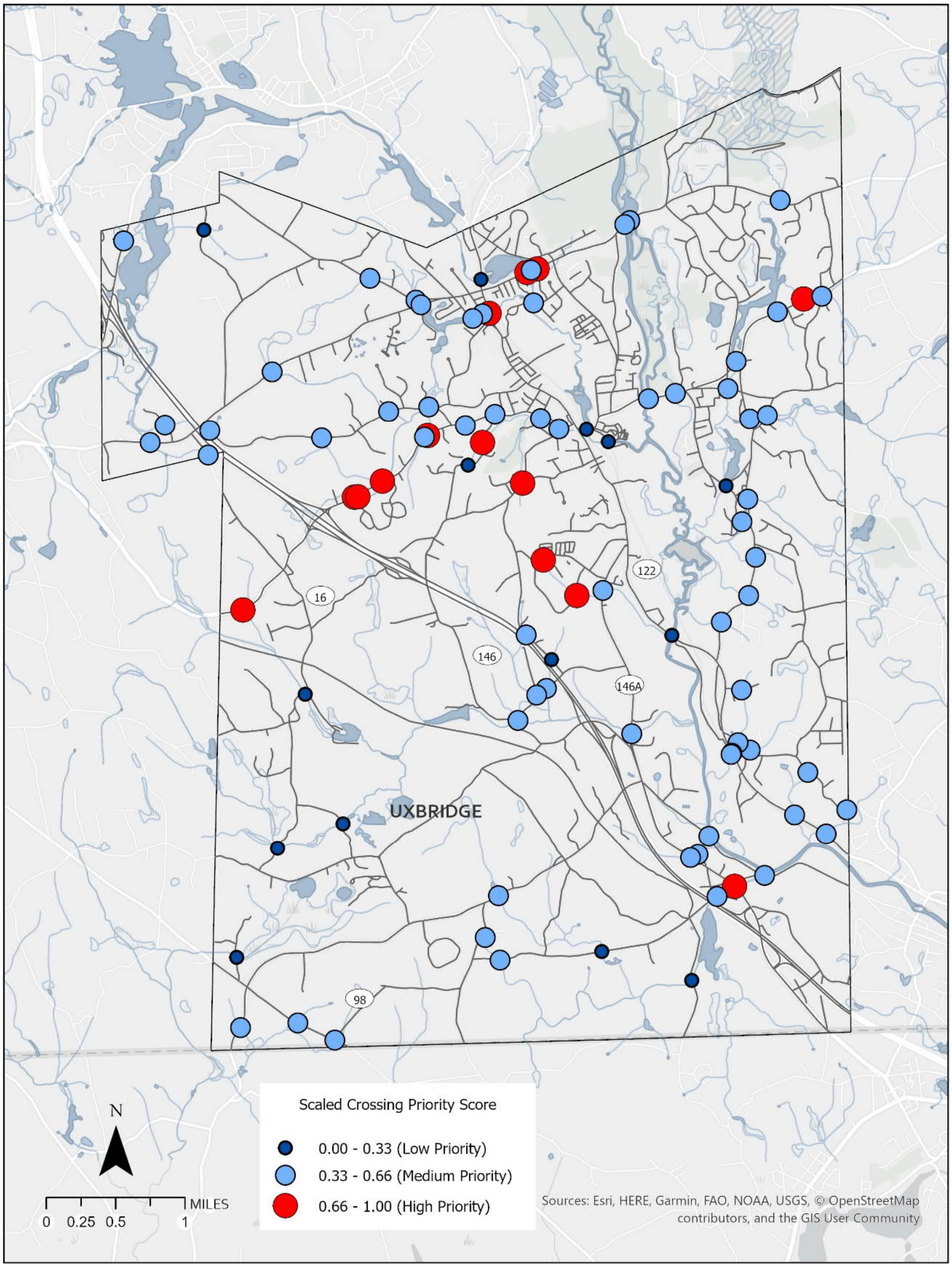

Figure 14. Spatial distribution of Scaled Crossing Priority Scores for all assessed crossings. Red dots indicate high priority crossings, light blue dots indicate medium priority crossings, and dark blue dots indicates low priority crossings.

Prioritization

Fourteen (14) crossings received the highest overall Scaled Crossing Priority Scores of 0.66 or higher and were therefore assigned a High Relative Priority Rating (Table 1, Figure 14). In general, road-stream crossings with higher Scaled Crossing Priority Scores and High Relative Priority Ratings should be examined first to determine if and how it should be replaced. However, this does not necessarily indicate that these crossings should be replaced in this order. The methods described in this report comprise a screening-level analysis and cannot account for every factor that should determine whether a crossing should be replaced and when. Factors such as historical flooding, upstream and downstream impacts of replacement, jurisdiction, and availability of funding for projects of different scales could not be accounted for completely within this prioritization analysis but should be considered in final project selection.

Route 16/Douglas Street crossing of an unnamed tributary to the Mumford River was scored as the second highest priority crossing overall, with the highest potential for impacts due to flooding or service disruptions and high risks associated with both current and future hydraulic capacity. Seven of the High priority crossings are located on state highways (five of which are located on Route 16) and most of the High priority crossings are located in or around the most developed portion of the town. All of the High priority crossings received severe structural risk scores, as did many crossings receiving Medium Relative Priority Ratings.

The Crown and Eagle Road crossing of an unnamed tributary to the Mumford River (located downstream of Whitin Dam and just off Hartford Avenue East) received the highest Scaled Crossing Priority Score, and an additional canal crossing on Hartford Avenue East downstream of Whitin Pond Dam also scored very high. However, these crossings have been built over canals built in association with the Whitin Pond Dam and should not simply be removed or rebuilt without consideration of the actual flow through these structures, the historical and aesthetic value of the existing structures, and the relationship of these structures to Whitin Pond Dam.

On the other hand, two crossings that received Medium Relative Priority Ratings should be considered for replacement due to their history of flooding and/or integration with existing dam structures. These crossings, on Route 98/Aldrich Street and on Albee Road, are discussed below in Sections 4.1.4 and 4.1.5, respectively.

Fourteen (14) crossings received Scaled Crossing Priority Scores of 0.33 or lower, resulting in a Low Relative Priority Rating. The Town may choose not to replace these crossings or crossings that received a Medium Relative Priority Rating due to relatively low Scaled Crossing Priority Scores, or the Town may wait to replace these crossings until higher priority crossings have been addressed and/or funding becomes available that can bundle these crossings into larger infrastructure projects.

3.4 General Recommendations

The following recommendations apply generally to crossings throughout the town:

- In general, where crossings are replaced and upsized to increase hydraulic capacity, crossings on the same stream should be replaced starting with the downstream-most crossing and progressing upstream. This limits the chance that increasing the size of a crossing will negatively impact downstream crossings during flood flows.
- Crossings impacted by or structurally integrated with adjacent infrastructure, particularly dams or nearby crossings, should be replaced in a manner that maintains the necessary function of the infrastructure in question and/or in a manner that does not compromise the safety of that infrastructure. In the case of dams in particular, the crossing should generally be replaced in conjunction with the removal or repair of the dam (depending on site-specific conditions and

recommendations) in order to achieve the greatest public safety and environmental benefits while making the most effective use of available funding.

- Multiple crossings on State Route 16 are rated as High and Medium priority, often for similar reasons. Depending on the availability of funding, the most financially effective method to replace these crossings would be to replace multiple crossings as part of a single project, particularly in conjunction with state or federally funded roadway projects. Replacing multiple crossings at once allows for economies of scale when designing the replacement crossing (standard designs may be applied), in mobilizing and demobilizing construction, and in purchasing construction materials.
- Coordinating crossing replacement projects with paving or utility installation/replacement projects may also allow more effective use of funding by reducing the cost of excavating and repaving the roadway multiple times.

4 High Priority Crossings

The following site descriptions are provided for five of the road-stream crossings that received High or Medium Relative Priority Ratings based on measures such as hydraulic, structural, and geomorphic risk and ecological benefit, and therefore should be considered when deciding on initial projects. However, these crossings are not listed in order of absolute priority. The Town may decide based on additional factors that some crossings should be replaced immediately while others should be replaced later, or may decide that other crossings in Town should be replaced first even if they received lower Scaled Crossing Priority Scores.

Site descriptions are also provided for crossings affected by additional factors not accounted for in the scoring methodology that may nevertheless increase the relative priority of these crossings. Except where specially noted below, the recommendations for these crossings generally consist of replacement of the crossing with a crossing constructed according to the Massachusetts Stream Crossing Standards.

4.1.1 Route 16/Douglas Street (xy42069387166088)

One of many road-stream crossings located along Route 16, this crossing is located approximately 0.2 miles northeast of the intersection of Route 16 and Route 146 and consists of three round concrete pipes each approximately 3 feet in diameter (Figure 16). The inlet area is blocked by over 50%, reducing the structure's aquatic passability and contributing to the crossing's structural condition rating of severe. The overall crossing condition is also negatively impacted by deficiencies in the structure's integrity, joints and seams, armoring, and headwalls and wingwalls as well as evidence of embankment piping. The structure is adequately sized hydraulically for both existing and future predicted 100-year flood flows, if the debris blocking the structure inlets is removed and the crossings are maintained in a condition free of debris. Although the crossing is not severely constricted, the combined widths of the three structures is sufficient to span only the channel and not the streambanks.

Figure 16. The inlet at crossing xy42069387166088 on Route 16/Douglas Street.

4.1.2 Route 16/Mendon Street (xy42090197159787)

The crossing of Rock Meadow Brook on Route 16/Mendon Street is located approximately 0.15 miles southwest of the Uxbridge-Mendon town boundary. The crossing consists of twin 77-foot-long corrugated metal pipe arches (Figure 17). The cascade condition at the outlet and the blockage of one of the structure inlets with sediment and debris results in a "severe barrier" rating for the crossing. The structure is adequately sized hydraulically for both existing and future predicted 100-year flood flows, if the debris blocking the structure inlets is removed and the crossings are maintained in a condition free of debris. Structurally the crossing is considered critical due to blockage of the inlet as well as the poor condition of the armoring and the headwall/endwall and wingwalls and the presence of signs of embankment piping. Geomorphic risk is rated significant due to a number of factors, including the presence of an outlet drop, a significant amount of bank erosion, and the poor alignment of the crossing with the channel.

Figure 17. The inlet at crossing xy42090197159787 on Route 16/Mendon Street.

4.1.3 Taft Hill Lane (xy42069427166042)

Taft Hill Lane crosses Cold Spring Brook within 200 feet of the Route 16/Douglas Street crossing described in Section 4.1.1. The crossing consists of a 17-foot wide concrete arch (Figure 19) and appears to have been recently reconstructed according to the Massachusetts Stream Crossing Standards. However, the crossing is rated high priority mainly due to the severe structural risk score which it received due to a single factor: the level of blockage within the structure, which obstructs more than 50% of the structure's cross-sectional area.

Because the structure has been recently reconstructed and appears to be adequately constructed to encompass the full bed and banks, full replacement is not recommended for this structure. Instead, the blockage of this structure can be addressed by removing the materials blocking the structure and reconstructing the banks through the structure according to best design practices.

Figure 19. The outlet at the crossing on Taft Hill Lane (xy42069427166042). Note the accumulation of debris on banks that appear to have been incorrectly constructed within the crossing.

4.1.4 Route 98/Aldrich Street (xy42027767164059)

Route 98/Aldrich Street crosses an unnamed tributary to the Blackstone River approximately 1.7 miles west of Route 146. The crossing consists of a 6-foot by 10-foot concrete box culvert. The structure is partially submerged because of its location within the impoundment and immediately upstream of a dam (Figure 20).

The structure received only a Medium Relative Priority Rating, but is structurally integrated with the dam located immediately downstream, which has been recommended for removal. Replacement of the crossing according to the Massachusetts Stream Crossing Standards is recommended in coordination with removal of the dam.

Figure 20. The outlet at the crossing on Route 98/Aldrich Street (xy42027767164059).

4.1.5 Albee Road (xy42040747159721)

Albee Road crosses an unnamed tributary to the Blackstone River 0.2 miles southeast of the intersection of Albee Road with East Street. The crossing's outlet consists of a 1-foot diameter round corrugated metal pipe with a small free fall above the downstream water surface. The structure is integrated with a dam formed by the road embankment and was possibly built as the outlet structure of the dam. The crossing received moderately high hydraulic, structural, and geomorphic risk ratings.

The structure received only a Medium Relative Priority Rating, but is a known flooding location. Replacement of the structure is recommended according to the Massachusetts Stream Crossing Standards such that the embankment no longer forms a dam.

Figure 21. The outlet at the crossing on Albee Road (xy42040747159721). Note the misalignment of the stone blocks forming the culvert endwall.

Appendix A

Stream Crossing Survey Field Data Form (blank)

FUSS & O'NEILL

Road-Stream Crossing Assessment Field Data Form

QA/QC INITIALS:________ DATE:________

Status ____FINAL ____FOLLOW-UP

CROSSING DATA

pp. 4-5

Crossing Code ________ State or Local ID/Name ________ Date ________ Start Time ________ AM / PM

Lead Field Data Collector ________ Asst. Field Data Collectors ________ End Time ________ AM / PM

Municipality ________ County ________ Stream ________

Road ________ Type ☐ MULTI-LANE ☐ PAVED ☐ UNPAVED ☐ DRIVEWAY ☐ TRAIL ☐ RAILROAD

GPS Coordinates (Decimal degrees) ☐☐.☐☐☐☐☐ °N Latitude — ☐☐.☐☐☐☐☐ °W Longitude

Location Description ________

pp. 5-7

Crossing Type ☐ BRIDGE ☐ CULVERT ☐ MULTIPLE CULVERT ☐ FORD ☐ NO CROSSING ☐ REMOVED CROSSING ☐ BURIED STREAM ☐ INACCESSIBLE ☐ PARTIALLY INACCESSIBLE ☐ NO UPSTREAM CHANNEL ☐ BRIDGE ADEQUATE

Number of Culverts / Cells ________

Photo #____ INLET Photo #____ OUTLET Photo #____ ________ Photo #____ ________

Photo #____ UPSTREAM Photo #____ DOWNSTREAM Photo #____ ________ Photo #____ ________

Photo #____ ROADWAY Photo #____ ________ Photo #____ ________ Photo #____ ________

Flow Condition ☐ NO FLOW ☐ TYPICAL-LOW ☐ MODERATE ☐ HIGH

Road-Killed Wildlife ________ or None

Visible Utilities ☐ OVERHEAD WIRES ☐ WATER/SEWER PIPES ☐ GAS LINE ☐ NONE ☐ OTHER ________

pp. 9-12

Alignment ☐ SHARP BEND ☐ MILD BEND ☐ NATURALLY STRAIGHT ☐ CHANNELIZED STRAIGHT

Road Fill Height ________ Road Crest Height ________

Bankfull Width ________ Confidence ☐ HIGH ☐ LOW/ESTIMATED

Constriction ☐ SEVERE ☐ MODERATE ☐ SPANS ONLY BANKFULL/ACTIVE CHANNEL ☐ SPANS FULL CHANNEL & BANKS

Tailwater Scour Pool ☐ NONE ☐ SMALL ☐ LARGE

HY-8

pp. 8, 13-15

Using HY-8? ☐ YES ☐ NO

Estimated Overtopping Length ________ Crest Width ________

Road Surface Type ☐ PAVED ☐ GRAVEL ☐ GRASS

Channel Slope ________

Side Slope ☐ 5:1 ☐ 4:1 ☐ 3:1 ☐ 2:1 ☐ 1:1 ☐ 0.5:1 ☐ steeper than 0.5:1

Stream Substrate ☐ MUCK/SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

GEO.

pp. 13

Bank Erosion ☐ HIGH ☐ LOW ☐ ESTIMATED ☐ NONE

Significant Break in Valley Slope ☐ YES ☐ NO ☐ UNKNOWN

Sediment Deposition ☐ UPSTREAM ☐ DOWNSTREAM ☐ WITHIN STRUCTURE ☐ NONE

Elevation of Sediment Deposits >= 1/2 Bankfull Height ☐ YES ☐ NO

TIDAL

pp. 16-18

Tidal? ☐ YES ☐ NO ☐ UNKNOWN

Tide Chart Location ________

Tide Prediction ____:____ AM / PM

Tide Stage ☐ LOW SLACK TIDE ☐ LOW EBB TIDE ☐ LOW FLOOD TIDE ☐ UNKNOWN ☐ OTHER ________

Vegetation Above/Below ☐ COMPARABLE ☐ SLIGHTLY DIFFERENT ☐ MODERATELY DIFFERENT ☐ VERY DIFFERENT ☐ UNKNOWN

Tide Gate Type ☐ NONE ☐ STOP LOGS ☐ FLAP GATE ☐ SLUICE GATE ☐ SELF-REGULATING ☐ OTHER ________

Tide Gate Severity ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE ☐ NO AQUATIC PASSAGE

CROSSING COMMENTS

pp. 5

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STRUCTURE 1

OUTLET

Structure Material ■ SMOOTH PLASTIC ■ CORRUGATED PLASTIC ■ SMOOTH METAL ■ CORRUGATED METAL ■ CONCRETE ■ WOOD ■ ROCK/STONE ■ FIBERGLASS ■ COMBINATION

pp. 19-35

Outlet Shape ■ 1 ■ 2 ■ 3 ■ 4 ■ 5 ■ 6 ■ 7 ■ FORD ■ UNKNOWN ■ REMOVED   Outlet Armoring ■ NONE ■ NOT EXTENSIVE ■ EXTENSIVE

Outlet Grade (Pick one) ■ AT STREAM GRADE ■ FREE FALL ■ CASCADE ■ FREE FALL ONTO CASCADE ■ UNKNOWN

Outlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

Outlet Drop to Water Surface_________.____ Outlet Drop to Stream Bottom_________.____ E. Abutment Height (Type 7 bridges only)_____________.____

L. Structure Length (Overall length from inlet to outlet)_____________.____

INLET

pp. 35-43

Inlet Shape ■ 1 ■ 2 ■ 3 ■ 4 ■ 5 ■ 6 ■ 7 ■ FORD ■ UNKNOWN ■ REMOVED

Inlet Type ■ PROJECTING ■ HEADWALL WITH SQUARE EDGE ■ HEADWALL WITH GROOVED EDGE ■ HEADWALL WITH SQUARE EDGE AND WINGWALLS ■ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ■ MITERED TO SLOPE ■ OTHER ■ NONE

Inlet Grade (Pick one) ■ AT STREAM GRADE ■ INLET DROP ■ PERCHED ■ CLOGGED/COLLAPSED/SUBMERGED ■ UNKNOWN

Inlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ____________ Slope Confidence ■ HIGH ■ LOW   Internal Structures ■ NONE ■ BAFFLES/WEIRS ■ SUPPORTS ■ OTHER________

Structure Substrate Matches Stream ■ NONE ■ COMPARABLE ■ CONTRASTING ■ NOT APPROPRIATE ■ UNKNOWN

Structure Substrate Type (Pick one) ■ NONE ■ SILT ■ SAND ■ GRAVEL ■ COBBLE ■ BOULDER ■ BEDROCK ■ UNKNOWN

Structure Substrate Coverage ■ NONE ■ 25% ■ 50% ■ 75% ■ 100% ■ UNKNOWN

Physical Barriers (Pick all that apply) ■ NONE ■ DEBRIS/SEDIMENT/ROCK ■ DEFORMATION ■ FREE FALL ■ FENCING ■ DRY ■ OTHER

Severity (Choose carefully based on barrier type(s) above) ■ NONE ■ MINOR ■ MODERATE ■ SEVERE

Water Depth Matches Stream ■ YES ■ NO-SHALLOWER ■ NO-DEEPER ■ UNKNOWN ■ DRY

Water Velocity Matches Stream ■ YES ■ NO-FASTER ■ NO-SLOWER ■ UNKNOWN ■ DRY

Dry Passage through Structure? ■ YES ■ NO ■ UNKNOWN   Height above Dry Passage____________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 2

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

Outlet Drop to Water Surface_________.____ Outlet Drop to Stream Bottom_________.____ E. Abutment Height (Type 7 bridges only)_________.____

L. Structure Length (Overall length from inlet to outlet)_________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ___________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage___________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 3

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

Outlet Drop to Water Surface__________.____ Outlet Drop to Stream Bottom__________.____ E. Abutment Height (Type 7 bridges only)__________.____

L. Structure Length (Overall length from inlet to outlet)__________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % __________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN Height above Dry Passage__________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 4

OUTLET pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width________.____ B. Height________.____ C. Substrate/Water Width________.____ D. Water Depth________.____

Outlet Drop to Water Surface________.____ Outlet Drop to Stream Bottom________.____ E. Abutment Height (Type 7 bridges only)________.____

L. Structure Length (Overall length from inlet to outlet)________.____

INLET pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width________.____ B. Height________.____ C. Substrate/Water Width________.____ D. Water Depth________.____

ADDITIONAL CONDITIONS pp. 43-56

Slope % ________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage________

STRUCTURAL CONDITION ASSESSMENT pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS pp. 44

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STRUCTURE 5

OUTLET

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

pp. 19-35

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED   Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width_________._____ B. Height_________._____ C. Substrate/Water Width_________._____ D. Water Depth_________._____

Outlet Drop to Water Surface_________._____ Outlet Drop to Stream Bottom_________._____ E. Abutment Height (Type 7 bridges only)_________._____

L. Structure Length (Overall length from inlet to outlet)_________._____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

pp. 35-43

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width_________._____ B. Height_________._____ C. Substrate/Water Width_________._____ D. Water Depth_________._____

ADDITIONAL CONDITIONS

Slope % ____________ Slope Confidence ☐ HIGH ☐ LOW   Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

pp. 43-56

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN   Height above Dry Passage____________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

pp. 44

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STRUCTURE 6

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED   Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width_______.____ B. Height_______.____ C. Substrate/Water Width_______.____ D. Water Depth_______.____

Outlet Drop to Water Surface_______.____ Outlet Drop to Stream Bottom_______.____ E. Abutment Height (Type 7 bridges only)_______.____

L. Structure Length (Overall length from inlet to outlet)_______.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width_______.____ B. Height_______.____ C. Substrate/Water Width_______.____ D. Water Depth_______.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ________ Slope Confidence ☐ HIGH ☐ LOW   Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN   Height above Dry Passage________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 7

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

pp. 19-35

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

Outlet Drop to Water Surface_________.____ Outlet Drop to Stream Bottom_________.____ E. Abutment Height (Type 7 bridges only)_________.____

L. Structure Length (Overall length from inlet to outlet)_________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % __________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage__________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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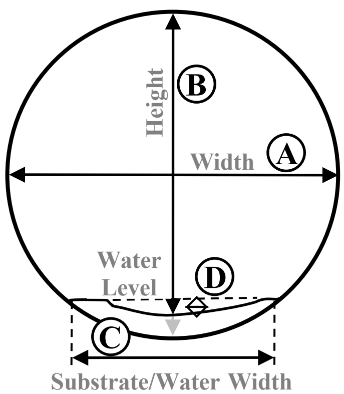
Structure Shape & Dimensions

1) Select the Structure Shape number from the diagrams below and record it on the form for Inlet and Outlet Shape.
2) Record on the form in the appropriate blanks dimensions **A, B, C** and **D** as shown in the diagrams;
   C captures the width of water or substrate, whichever is wider; for dry culverts without substrate, C = 0.
   D is the depth of water -- be sure to measure inside the structure; for dry culverts, D = 0.
3) Record Structure Length (**L**) . (Record abutment height (**E**) only for Type 7 Structures.)
4) For multiple culverts, also record the Inlet and Outlet shape and dimensions for each additional culvert.

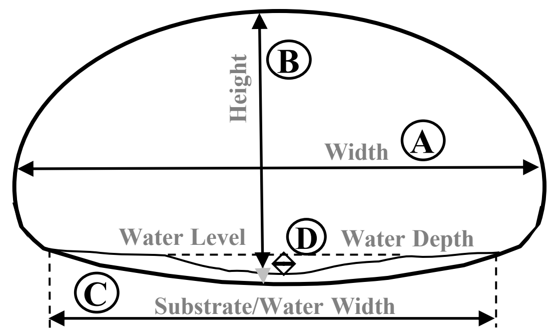
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to substrate).

1



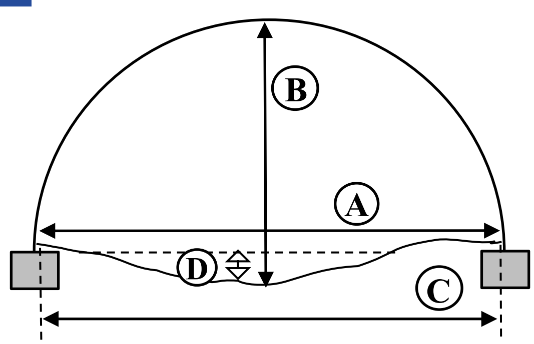
Round Culvert

2



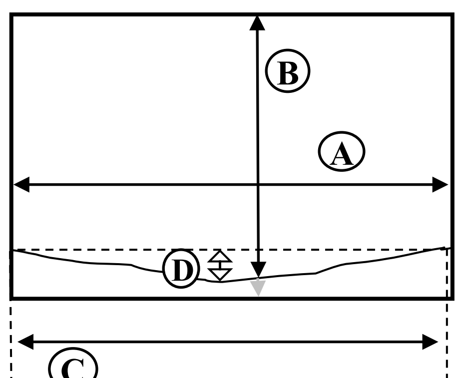
Pipe Arch/Elliptical Culvert

3



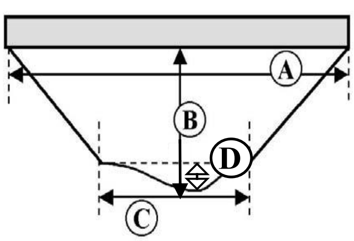
Open Bottom Arch Bridge/Culvert

4



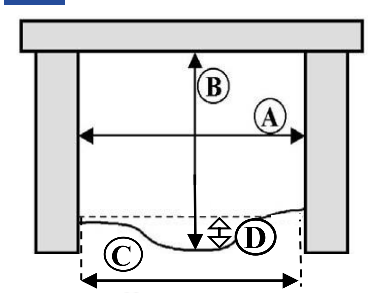
Box Culvert

5



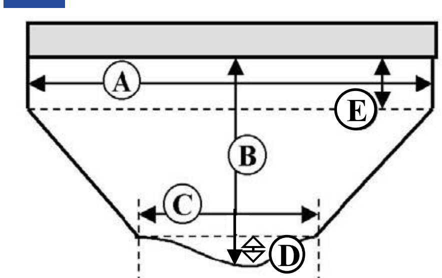
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

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Appendix B

Road-Stream Crossing Scoring and Prioritization Results

Appendix B--Table 1: Road-Stream Crossing Scoring and Priorization Results by Scaled Crossing Priority

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Existing Hydraulic Risk Score-Binned	Future Hydraulic Risk Score-Binned	Geomorphic Vulnerability Score	Structural Condition Score	Transportation Disruption Score	Flood Impact Potential Score	AOP Score	Ecological Benefit Score	Impact Score	Existing Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Value	Scaled Crossing Priority	Relative Priority Rating
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	5	4	5	1	5	5	3	5	25	25	20	25	15	25	45	0.9	High
xy42069387166088	Route 16/Douglas Street	Unnamed	Mumford River	1	1	4	5	4	5	3	3	5	5	5	20	25	9	25	42	0.84	High
xy42090197159787	Route 16/Mendon Street	Rock meadow Brook	West River	1	1	4	5	4	3	5	4	4	4	4	16	20	20	20	40	0.8	High
xy42092907163674	Hartford Avenue East	Canal off Mumford	Mumford River	1	1	3	5	3	5	1	4	5	5	5	15	25	4	25	39.5	0.79	High
xy42069427166042	Taft Hill Lane	Cold Spring Brook	Mumford River	2	3	2	5	1	5	1	3	5	10	15	10	25	3	25	39	0.78	High
xy42075127164293	Hunter Road	Unknown	Mumford River	1	1	4	5	1	4	4	3	4	4	4	16	20	12	20	36	0.72	High
xy42062867163535	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	1	2	4	5	1	4	4	3	4	4	8	16	20	12	20	36	0.72	High
xy42059137162965	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	1	1	5	5	1	4	5	2	4	4	4	20	20	10	20	35	0.7	High
xy42070867163730	High Street	Unnamed	Mumford River	5	5	3	5	1	4	3	3	4	20	20	12	20	9	20	34.5	0.69	High
xy42057587167649	Route 16/Douglas Street	Unnamed	Blackstone River-West River to Peters River	5	5	3	5	4	2	3	3	4	20	20	12	20	9	20	34.5	0.69	High
xy42075827165065	Route 16/Douglas Street	Unnamed/Unmapped	Mumford River	5	5	4	5	4	4	3	3	4	20	20	16	20	9	20	34.5	0.69	High
xy42071047165697	Route 16/Douglas Street	Cold Spring Brook	Mumford River	1	1	4	5	4	4	3	3	4	4	4	16	20	9	20	34.5	0.69	High
xy42028787160746	146a/Quaker Highway	Bacon Brook	Blackstone River-West River to Peters River	1	1	3	5	3	4	2	4	4	4	4	12	20	8	20	34	0.68	High
xy42088617164201	Route 122/North Main Street	Cold Spring Brook	Mumford River	5	5	3	5	3	4	2	4	4	20	20	12	20	8	20	34	0.68	High
xy42027727160994	Ironstone Road	Bacon Brook	Blackstone River-West River to Peters River	3	4	3	5	1	4	1	4	4	12	16	12	20	4	20	32	0.64	Medium
xy42043037160531	Albee Road	Unnamed	Blackstone River-West River to Peters River	5	5	4	5	1	4	2	2	4	20	20	16	20	4	20	32	0.64	Medium
xy42088607164297	Elm Street	Cold Spring Brook	Mumford River	1	2	4	5	1	4	1	4	4	4	8	16	20	4	20	32	0.64	Medium
xy42076567163220	Carney Street	Unknown	Mumford River	1	1	3	5	1	4	1	3	4	4	4	12	20	3	20	31.5	0.63	Medium
xy42034047161108	River Road	Unnamed	Blackstone River-West River to Peters River	5	5	4	5	1	4	1	3	4	20	20	16	20	3	20	31.5	0.63	Medium
xy42056397160940	Blackstone Street	Unnamed	Blackstone River-West River to Peters River	4	4	4	5	2	3	5	3	3	12	12	12	15	15	15	30	0.6	Medium
xy42059677162601	Route 146A/Quaker Highway	Unknown	Blackstone River-West River to Peters River	4	4	4	3	3	4	3	3	4	16	16	16	12	9	16	28.5	0.57	Medium
xy42078077164119	Route 16/Douglas Street	Unnamed	Mumford River	3	3	4	3	4	4	3	3	4	12	12	16	12	9	16	28.5	0.57	Medium
xy42043837160702	Albee Road	Unnamed	Blackstone River-West River to Peters River	1	1	3	4	1	4	3	3	4	4	4	12	16	9	16	28.5	0.57	Medium
xy42032137161262	Ironstone Road	Unnamed	Blackstone River-West River to Peters River	5	5	4	5	1	3	4	3	3	15	15	12	15	12	15	28.5	0.57	Medium
xy42031807161366	Route 146A/Quaker Highway	Unnamed	Blackstone River-West River to Peters River	1	1	4	3	3	4	3	3	4	4	4	16	12	9	16	28.5	0.57	Medium
xy42044747162195	Route 146A/Quaker Highway	Emerson Brook	Blackstone River-West River to Peters River	1	1	4	5	3	2	3	4	3	3	3	12	15	12	15	28.5	0.57	Medium
xy42036297159905	Route 122/Millville Road	Unnamed	Blackstone River-West River to Peters River	1	1	4	5	3	3	4	3	3	3	3	12	15	12	15	28.5	0.57	Medium
xy42098337162229	Hartford Avenue East	Blackstone River	Upper Blackstone River-West River	1	1	4	3	3	2	5	3	3	3	3	12	9	15	12	28.5	0.57	Medium
xy42063177160459	Blackstone Street	Unnamed	West River	5	5	4	5	2	2	5	3	2	10	10	8	10	15	10	27.5	0.55	Medium
xy42023397164243	Glendale Street	Unnamed	Blackstone River-West River to Peters River	5	5	3	5	1	3	3	3	3	15	15	9	15	9	15	27	0.54	Medium
xy42049347163384	Mill Street	Unnamed	Blackstone River-West River to Peters River	1	1	3	3	1	3	5	3	3	3	3	9	9	15	9	27	0.54	Medium
xy42048747163527	Mill Street	Happy Hollow Brook	Blackstone River-West River to Peters River	5	5	3	3	1	3	3	3	3	15	15	9	9	9	15	27	0.54	Medium
xy42049317160651	Glen Street	Unnamed	Blackstone River-West River to Peters River	3	4	3	1	1	4	2	3	4	12	16	12	4	6	16	27	0.54	Medium
xy42066867160650	Bacon Street	Still Corner Brook	West River	1	1	5	5	1	3	3	3	3	3	3	15	15	9	15	27	0.54	Medium
xy42088837160154	Route 16/Mendon Street	Unnamed	West River	1	1	3	4	4	3	2	3	4	4	4	12	16	6	16	27	0.54	Medium
xy42080307161589	Route 16/Mendon Street	Unnamed (Old Hecla Canal?)	Upper Blackstone River-West River	1	1	4	2	4	2	2	3	4	4	4	16	8	6	16	27	0.54	Medium
xy42034307159464	Route 122/Millville Road	Unnamed	Blackstone River-West River to Peters River	1	1	4	5	3	3	3	3	3	3	3	12	15	9	15	27	0.54	Medium
xy42075037168957	Hartford Avenue West	Dunleavey Brook	Mumford River	3	3	4	5	3	2	3	3	3	9	9	12	15	9	15	27	0.54	Medium
xy42096127169335	Lackey Dam Road	Unnamed	Mumford River	4	4	4	5	3	2	3	3	3	12	12	12	15	9	15	27	0.54	Medium
xy42040747159721	Albee Road	Unnamed	Blackstone River-West River to Peters River	5	5	4	5	1	3	4	2	3	15	15	12	15	8	15	26.5	0.53	Medium
xy42069257160569	Blackstone Street	Still Corner Brook	West River	5	5	3	5	2	3	2	3	3	15	15	9	15	6	15	25.5	0.51	Medium
xy42089987165230	Sutton Street	Cold Spring Brook	Mumford River	5	5	4	5	1	3	2	3	3	15	15	12	15	6	15	25.5	0.51	Medium
xy42089507165161	Hartford Avenue West	Cold spring Brook	Mumford River	4	4	4	5	3	3	2	3	3	12	12	12	15	6	15	25.5	0.51	Medium
xy42082497167248	Hartford Avenue West	Unnamed	Mumford River	5	5	3	5	3	2	2	3	3	15	15	9	15	6	15	25.5	0.51	Medium
xy42092297165875	Sutton Street	Unnamed	Mumford River	1	1	4	5	1	3	3	2	3	3	3	12	15	6	15	25.5	0.51	Medium
xy42078847165049	Hazel Street	Cold Spring Brook	Mumford River	5	5	3	3	1	3	1	4	3	15	15	9	9	4	15	24.5	0.49	Medium
xy42077657160540	Blackstone Street	Meadow Brook	West River	1	1	4	5	2	3	1	4	3	3	3	12	15	4	15	24.5	0.49	Medium
xy42090497159532	Rockmeadow Road Extension	Rock Meadow Brook	West River	1	1	4	3	1	3	3	4	3	3	3	12	9	12	12	24	0.48	Medium
xy42093187163615	Hartford Avenue East	Mumford River	Mumford River	1	1	3	1	3	5	1	3	5	5	5	15	5	3	15	24	0.48	Medium
xy42089747163582	Rogerson Crossing	Mumford Canal	Mumford River	1	1	3	1	1	5	1	3	5	5	5	15	5	3	15	24	0.48	Medium
xy42046107163782	Mill Street	Emerson Brook	Blackstone River-West River to Peters River	1	3	3	5	1	2	3	4	2	2	6	6	10	12	10	23	0.46	Medium
xy42097967162302	Hartford Avenue East	Blackstone River	Upper Blackstone River-West River	1	1	4	3	3	2	2	5	3	3	3	12	9	10	12	23	0.46	Medium
xy42075647165106	Route 16/Douglas Street	Unnamed	Mumford River	1	1	3	3	4	3	3	3	4	4	4	12	12	9	12	22.5	0.45	Medium
xy42076317168120	Hazel Street	Unnamed	Mumford River	1	1	3	4	1	3	3	3	3	3	3	9	12	9	12	22.5	0.45	Medium
xy42088087164429	Rivulet Street	Cold Spring Brook	Mumford River	1	1	3	3	2	4	2	4	4	4	4	12	12	8	12	22	0.44	Medium
xy42076917164531	Route 16/Douglas Street	Unknown	Mumford River	2	2	3	2	4	4	2	3	4	8	8	12	8	6	12	21	0.42	Medium
xy42042707160790	Route 122/Millville Road	Unnamed	Blackstone River-West River to Peters River	1	1	4	3	3	3	2	3	3	3	3	12	9	6	12	21	0.42	Medium
xy42083647160733	Route 16/Mendon Street	West River	West River	1	2	2	3	4	4	1	5	4	4	8	8	12	5	12	20.5	0.41	Medium
xy42079747161962	Route 16/Mendon Street	Blackstone River	Upper Blackstone River-West River	1	1	2	3	4	2	1	5	4	4	4	8	12	5	12	20.5	0.41	Medium
xy42080807160848	Henry Street	West River	West River	1	1	3	3	1	4	1	5	4	4	4	12	12	5	12	20.5	0.41	Medium
xy42021047164032	Elmwood Avenue	Unnamed	Blackstone River-West River to Peters River	1	1	3	4	1	3	2	2	3	3	3	9	12	4	12	20	0.4	Medium
xy42029917160327	River Road	Bacon Brook	Blackstone River-West River to Peters River	1	1	3	1	1	4	1	4	4	4	4	12	4	4	12	20	0.4	Medium
xy42013937167673	Route 98/Aldrich street	Unnamed	Clear River	4	5	4	3	2	2	3	3	2	8	10	8	6	9	10	19.5	0.39	Medium
xy42075577166554	Hazel Street	Unnamed	Mumford River	5	5	4	3	1	2	3	3	2	10	10	8	6	9	10	19.5	0.39	Medium
xy42077637163476	Marywood Street	Unnamed	Mumford River	2	3	3	1	1	4	1	3	4	8	12	12	4	3	12	19.5	0.39	Medium
xy42059177160555	Blackstone Street	Unnamed	Blackstone River-West River to Peters River	5	5	4	5	2	2	3	3	2	10	10	8	10	9	10	19.5	0.39	Medium
xy42100477160119	Hartford Avenue East	West River	West River	2	3	3	1	3	2	2	5	3	6	9	9	3	10	9	19.5	0.39	Medium

Appendix B--Table 1 continued: Road-Stream Crossing Scoring and Priorization Results by Scaled Crossing Priority

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Existing Hydraulic Risk Score-Binned	Future Hydraulic Risk Score-Binned	Geomorphic Vulnerability Score	Structural Condition Score	Transportation Disruption Score	Flood Impact Potential Score	AOP Score	Ecological Benefit Score	Impact Score	Existing Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Value	Scaled Crossing Priority	Relative Priority Rating
xy42036807159173	Albee Road	Unnamed	Blackstone River-West River to Peters River	5	5	3	5	1	2	3	3	2	10	10	6	10	9	10	19.5	0.39	Medium
xy42042607160797	Old Millville Road	Unnamed	Blackstone River-West River to Peters River	2	3	3	1	1	4	1	3	4	8	12	12	4	3	12	19.5	0.39	Medium
xy42076867168750	Dunleavey Brook Drive	Dunleavey Brook	Mumford River	1	1	4	1	1	2	5	2	2	2	2	8	2	10	8	19	0.38	Medium
xy42027767164059	Route 98/Aldrich street	Unnamed	Blackstone River-West River to Peters River	2	3	3	5	2	2	2	3	2	4	6	6	10	6	10	18	0.36	Medium
xy42012667166347	Douglas Pike	Unnamed	Clear River	5	5	4	5	2	1	2	3	2	10	10	8	10	6	10	18	0.36	Medium
xy42055027163675	Richardson Street	Unknown	Blackstone River-West River to Peters River	1	1	3	3	1	3	3	3	3	3	3	9	9	9	9	18	0.36	Medium
xy42078337165614	Hazel Street	Farrel Brook	Mumford River	2	3	3	5	1	2	2	3	2	4	6	6	10	6	10	18	0.36	Medium
xy42078027160294	Hollis Street	Meadow Brook	West River	4	4	3	5	1	2	2	3	2	8	8	6	10	6	10	18	0.36	Medium
xy42014457166867	Douglas Pike	Unnamed	Clear River	3	4	3	2	2	1	3	3	2	6	8	6	4	9	8	17.5	0.35	Medium
xy42073757168144	West Street	Unnamed	Mumford River	1	1	3	2	1	3	4	2	3	3	3	9	6	8	9	17.5	0.35	Medium
xy42052457163320	Richardson Street	Unnamed	Blackstone River-West River to Peters River	1	1	3	1	1	3	2	3	3	3	3	9	3	6	9	16.5	0.33	Low
xy42035267166242	Laurel street	Laurel Brook	Blackstone River-West River to Peters River	1	1	3	5	1	2	1	3	2	2	2	6	10	3	10	16.5	0.33	Low
xy42032667167153	West St	Laurel Brook	Blackstone River-West River to Peters River	1	2	3	5	1	2	1	3	2	2	4	6	10	3	10	16.5	0.33	Low
xy42021297167727	Hathaway Lane	Cedar Swamp Brook	Clear River	1	2	3	4	1	2	2	3	2	2	4	6	8	6	8	15	0.3	Low
xy42097317168211	Rawson Street	Unnamed	Mumford River	2	3	4	3	1	2	3	2	2	4	6	8	6	6	8	15	0.3	Low
xy42070617160877	Hecla Street	West River	West River	1	1	3	4	1	2	1	5	2	2	2	6	8	5	8	14.5	0.29	Low
xy42075197162529	Depot Street	Mumford River	Mumford River	1	1	2	1	1	4	1	5	4	4	4	8	4	5	8	14.5	0.29	Low
xy42076517162833	Route 16/Mendon Street	Mumford River	Mumford River	1	1	2	1	4	3	1	5	4	4	4	8	4	5	8	14.5	0.29	Low
xy42092197164318	Route 122/North Main Street	Mumford river	Mumford River	1	1	2	1	3	4	1	4	4	4	4	8	4	4	8	14	0.28	Low
xy42072747164492	Hunter Road	Unnamed	Mumford River	3	4	3	1	1	2	1	3	2	6	8	6	2	3	8	13.5	0.27	Low
xy42048397166773	West St	Scadden Brook	Blackstone River-West River to Peters River	1	1	3	3	1	2	2	3	2	2	2	6	6	6	6	12	0.24	Low
xy42055037161631	Route 122/Millville Road	Blackstone River and Canal	Blackstone River-West River to Peters River	1	1	2	1	3	3	1	5	3	3	3	6	3	5	6	11.5	0.23	Low
xy42018967161348	South Street	Bacon Brook	Blackstone River-West River to Peters River	1	2	3	3	1	2	1	4	2	2	4	6	6	4	6	11	0.22	Low
xy42021977162606	Elmwood Avenue	Unnamed	Blackstone River-West River to Peters River	1	1	3	3	1	2	1	3	2	2	2	6	6	3	6	10.5	0.21	Low

Appendix B-- Table 2: Top Ranked Crossings Based on Existing Hydraulic Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	25	25	20	25	15	25	45	0.9	High
xy42070867163730	High Street	Unnamed	Mumford River	4	20	20	12	20	9	20	34.5	0.69	High
xy42057587167649	Route 16/Douglas Street	Unnamed	Blackstone River-West River to Peters River	4	20	20	12	20	9	20	34.5	0.69	High
xy42075827165065	Route 16/Douglas Street	Unnamed/Unmapped	Mumford River	4	20	20	16	20	9	20	34.5	0.69	High
xy42034047161108	River Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	3	20	31.5	0.63	High
xy42043037160531	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	4	20	32	0.64	High
xy42088617164201	Route 122/North Main Street	Cold Spring Brook	Mumford River	4	20	20	12	20	8	20	34	0.68	High
xy42059677162601	Route 146A/Quaker Highway	Unknown	Blackstone River-West River to Peters River	4	16	16	16	12	9	16	28.5	0.57	High
xy42023397164243	Glendale Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	9	15	9	15	27	0.54	Medium
xy42048747163527	Mill Street	Happy Hollow Brook	Blackstone River-West River to Peters River	3	15	15	9	9	9	15	27	0.54	Medium
xy42078847165049	Hazel Street	Cold Spring Brook	Mumford River	3	15	15	9	9	4	15	24.5	0.49	Medium
xy42069257160569	Blackstone Street	Still Corner Brook	West River	3	15	15	9	15	6	15	25.5	0.51	Medium
xy42032137161262	Ironstone Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	12	15	12	15	28.5	0.57	High
xy42089987165230	Cold Spring Brook Road	Cold Spring Brook	Mumford River	3	15	15	12	15	6	15	25.5	0.51	Medium
xy42040747159721	Albee Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	12	15	8	15	26.5	0.53	Medium
xy42082497167248	Hartford Avenue West	Unnamed	Mumford River	3	15	15	9	15	6	15	25.5	0.51	Medium

Appendix B--Table 3: Top Ranked Crossings Based on Future Hydraulic Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	25	25	20	25	15	25	45	0.9	High
xy42070867163730	High Street	Unnamed	Mumford River	4	20	20	12	20	9	20	34.5	0.69	High
xy42057587167649	Route 16/Douglas Street	Unnamed	Blackstone River-West River to Peters River	4	20	20	12	20	9	20	34.5	0.69	High
xy42075827165065	Route 16/Douglas Street	Unnamed/Unmapped	Mumford River	4	20	20	16	20	9	20	34.5	0.69	High
xy42034047161108	River Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	3	20	31.5	0.63	High
xy42043037160531	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	4	20	32	0.64	High
xy42088617164201	Route 122/North Main Street	Cold Spring Brook	Mumford River	4	20	20	12	20	8	20	34	0.68	High
xy42059677162601	Route 146A/Quaker Highway	Unknown	Blackstone River-West River to Peters River	4	16	16	16	12	9	16	28.5	0.57	High
xy42049317160651	Glen Street	Unnamed	Blackstone River-West River to Peters River	4	12	16	12	4	6	16	27	0.54	Medium
xy42027727160994	Ironstone Road	Bacon Brook	Blackstone River-West River to Peters River	4	12	16	12	20	4	20	32	0.64	High
xy42023397164243	Glendale Street	Unnamed	Blackstone River-West River to Peters River	3	15	15	9	15	9	15	27	0.54	Medium
xy42048747163527	Mill Street	Happy Hollow Brook	Blackstone River-West River to Peters River	3	15	15	9	9	9	15	27	0.54	Medium
xy42078847165049	Hazel Street	Cold Spring Brook	Mumford River	3	15	15	9	9	4	15	24.5	0.49	Medium
xy42069257160569	Blackstone Street	Still Corner Brook	West River	3	15	15	9	15	6	15	25.5	0.51	Medium
xy42032137161262	Ironstone Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	12	15	12	15	28.5	0.57	High
xy42089987165230	Cold Spring Brook Road	Cold Spring Brook	Mumford River	3	15	15	12	15	6	15	25.5	0.51	Medium
xy42040747159721	Albee Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	12	15	8	15	26.5	0.53	Medium
xy42082497167248	Hartford Avenue West	Unnamed	Mumford River	3	15	15	9	15	6	15	25.5	0.51	Medium
xy42069427166042	Taft Hill Lane	Cold Spring Brook	Mumford River	5	10	15	10	25	3	25	39	0.78	High

Appendix B--Table 4: Top Ranked Crossings Based on Geomorphic Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	25	25	20	25	15	25	45	0.9	High
xy42069387166088	Route 16/Douglas Street	Unnamed	Mumford River	5	5	5	20	25	9	25	42	0.84	High
xy42059137162965	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	4	4	4	20	20	10	20	35	0.7	High
xy42075827165065	Route 16/Douglas Street	Unnamed/Unmapped	Mumford River	4	20	20	16	20	9	20	34.5	0.69	High
xy42034047161108	River Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	3	20	31.5	0.63	High
xy42043037160531	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	4	20	32	0.64	High
xy42059677162601	Route 146A/Quaker Highway	Unknown	Blackstone River-West River to Peters River	4	16	16	16	12	9	16	28.5	0.57	High
xy42078077164119	Route 16/Douglas Street	Unnamed	Mumford River	4	12	12	16	12	9	16	28.5	0.57	High
xy42062867163535	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	4	4	8	16	20	8	20	34	0.68	High
xy42088607164297	Elm Street	Cold Spring Brook	Mumford River	4	4	8	16	20	4	20	32	0.64	High
xy42075127164293	Hunter Road	Unknown	Mumford River	4	4	4	16	20	12	20	36	0.72	High
xy42031807161366	Route 146A/Quaker Highway	Unnamed	Blackstone River-West River to Peters River	4	4	4	16	12	9	16	28.5	0.57	High
xy42080307161589	Route 16/Mendon Street	Unnamed (old Hecla Canal?)	Upper Blackstone River-West River	4	4	4	16	8	6	16	27	0.54	Medium
xy42090197159787	Route 16/Mendon Street	Rock Meadow Brook	West River	4	4	4	16	20	20	20	40	0.8	High
xy42071047165697	Route 16/Douglas Street	Cold Spring Brook	Mumford River	4	4	4	16	20	9	20	34.5	0.69	High
xy42092907163674	Hartford Avenue East	Canal off Mumford	Mumford River	5	5	5	15	25	4	25	39.5	0.79	High
xy42093187163615	Hartford Avenue East	Mumford River	Mumford River	5	5	5	15	5	3	15	24	0.48	Medium
xy42089747163582	Rogerson Crossing	Mumford Canal	Mumford River	5	5	5	15	5	3	15	24	0.48	Medium
xy42066867160650	Bacon Street	Still Corner Brook	West River	3	3	3	15	15	9	15	27	0.54	Medium

Appendix B--Table 5: Top Ranked Crossings Based on Structural Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	25	25	20	25	15	25	45	0.9	High
xy42069387166088	Route 16/Douglas Street	Unnamed	Mumford River	5	5	5	20	25	9	25	42	0.84	High
xy42092907163674	Hartford Avenue East	Canal off Mumford	Mumford River	5	5	5	15	25	4	25	39.5	0.79	High
xy42069427166042	Taft Hill Lane	Cold Spring Brook	Mumford River	5	10	15	10	25	3	25	39	0.78	High
xy42059137162965	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	4	4	4	20	20	10	20	35	0.7	High
xy42075827165065	Route 16/Douglas Street	Unnamed/Unmapped	Mumford River	4	20	20	16	20	9	20	34.5	0.69	High
xy42034047161108	River Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	3	20	31.5	0.63	High
xy42043037160531	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	4	20	32	0.64	High
xy42062867163535	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	4	4	8	16	20	8	20	34	0.68	High
xy42088607164297	Elm Street	Cold Spring Brook	Mumford River	4	4	8	16	20	4	20	32	0.64	High
xy42075127164293	Hunter Road	Unknown	Mumford River	4	4	4	16	20	12	20	36	0.72	High
xy42090197159787	Route 16/Mendon Street	Rock Meadow Brook	West River	4	4	4	16	20	20	20	40	0.8	High
xy42071047165697	Route 16/Douglas Street	Cold Spring Brook	Mumford River	4	4	4	16	20	9	20	34.5	0.69	High
xy42070867163730	High Street	Unnamed	Mumford River	4	20	20	12	20	9	20	34.5	0.69	High
xy42057587167649	Route 16/Douglas Street	Unnamed	Blackstone River-West River to Peters River	4	20	20	12	20	9	20	34.5	0.69	High
xy42088617164201	Route 122/North Main Street	Cold Spring Brook	Mumford River	4	20	20	12	20	8	20	34	0.68	High
xy42027727160994	Ironstone Road	Bacon brook	Blackstone River-West River to Peters River	4	12	16	12	20	4	20	32	0.64	High
xy42076567163220	Carney Street	Unknown	Mumford River	4	4	4	12	20	3	20	31.5	0.63	High
xy42028787160746	146A/Quaker Highway	Bacon Brook	Blackstone River-West River to Peters River	4	4	4	12	20	8	20	34	0.68	High
xy42043837160702	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	4	4	12	16	9	16	28.5	0.57	High
xy42088837160154	Route 16/Mendon Street	Unnamed	West River	4	4	4	12	16	6	16	27	0.54	Medium
xy42066867160650	Bacon Street	Still Corner Brook	West River	3	3	3	15	15	9	15	27	0.54	Medium
xy42032137161262	Ironstone Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	12	15	12	15	28.5	0.57	High
xy42089987165230	Cold Spring Brook Road	Cold Spring Brook	Mumford River	3	15	15	12	15	6	15	25.5	0.51	Medium
xy42040747159721	Albee Road	Unnamed	Blackstone River-West River to Peters River	3	15	15	12	15	8	15	26.5	0.53	Medium
xy42056397160940	Blackstone Street	Unnamed	Blackstone River-West River to Peters River	3	12	12	12	15	15	15	30	0.6	High
xy42089507165161	Hartford Avenue West	Cold Spring Brook	Mumford River	3	12	12	12	15	6	15	25.5	0.51	Medium
xy42096127169335	Lackey Dam Road	Unnamed	Mumford River	3	12	12	12	15	9	15	27	0.54	Medium
xy42075037168957	Hartford Avenue West	Dunleavey Brook	Mumford River	3	9	9	12	15	9	15	27	0.54	Medium
xy42077657160540	Blackstone Street	Meadow Brook	West River	3	3	3	12	15	4	15	24.5	0.49	Medium
xy42044747162195	Route 146A/Quaker Highway	Emerson Brook	Blackstone River-West River to Peters River	3	3	3	12	15	12	15	28.5	0.57	High
xy42036297159905	Route 122/Millville Road	Unnamed	Blackstone River-West River to Peters River	3	3	3	12	15	12	15	28.5	0.57	High
xy42034307159464	Route 122/Millville Road	Unnamed	Blackstone River-West River to Peters River	3	3	3	12	15	9	15	27	0.54	Medium
xy42092297165875	Sutton street	Unnamed	Mumford River	3	3	3	12	15	6	15	25.5	0.51	Medium
xy42023397164243	Glendale Street	Unnamed	Blackstone River-West River to Peters River	3	15	15	9	15	9	15	27	0.54	Medium
xy42069257160569	Blackstone Street	Still Corner Brook	West River	3	15	15	9	15	6	15	25.5	0.51	Medium
xy42082497167248	Hartford Avenue West	Unnamed	Mumford River	3	15	15	9	15	6	15	25.5	0.51	Medium

Appendix B--Table 6: Top Ranked Crossings Based on Aquatic Organism Passage (AOP) Benefit Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42090197159787	Route 16/Mendon Street	Rock Meadow Brook	West River	4	4	4	16	20	20	20	40	0.8	High
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	25	25	20	25	15	25	45	0.9	High
xy42056397160940	Blackstone Street	Unnamed	Blackstone River-West River to Peters River	3	12	12	12	15	15	15	30	0.6	High
xy42063177160459	Blackstone Street	Unnamed	West River	2	10	10	8	10	15	10	27.5	0.55	High
xy42098337162229	Hartford Avenue East	Blackstone River	Upper Blackstone River-West River	3	3	3	12	9	15	12	28.5	0.57	High
xy42049347163384	Mill Street	Unnamed	Blackstone River-West River to Peters River	3	3	3	9	9	15	9	27	0.54	Medium

Appendix B--Table 7: Top Ranked Crossings Based on Impact Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42093307163533	Crown and Eagle Road	Unnamed	Mumford River	5	25	25	20	25	15	25	45	0.9	High
xy42069387166088	Route 16/Douglas Street	Unnamed	Mumford River	5	5	5	20	25	9	25	42	0.84	High
xy42092907163674	Hartford Avenue East	Canal off Mumford	Mumford River	5	5	5	15	25	4	25	39.5	0.79	High
xy42069427166042	Taft Hill Lane	Cold Spring Brook	Mumford River	5	10	15	10	25	3	25	39	0.78	High
xy42093187163615	Hartford Avenue East	Mumford River	Mumford River	5	5	5	15	5	3	15	24	0.48	Medium
xy42089747163582	Rogerson Crossing	Mumford Canal	Mumford River	5	5	5	15	5	3	15	24	0.48	Medium
xy42090197159787	Route 16/Mendon Street	Rock Meadow Brook	West River	4	4	4	16	20	20	20	40	0.8	High
xy42075127164293	Hunter Road	Unknown	Mumford River	4	4	4	16	20	12	20	36	0.72	High
xy42059137162965	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	4	4	4	20	20	10	20	35	0.7	High
xy42075827165065	Route 16/Douglas Street	Unnamed/Unmapped	Mumford River	4	20	20	16	20	9	20	34.5	0.69	High
xy42071047165697	Route 16/Douglas Street	Cold Spring Brook	Mumford River	4	4	4	16	20	9	20	34.5	0.69	High
xy42070867163730	High Street	Unnamed	Mumford River	4	20	20	12	20	9	20	34.5	0.69	High
xy42057587167649	Route 16/Douglas Street	Unnamed	Blackstone River-West River to Peters River	4	20	20	12	20	9	20	34.5	0.69	High
xy42043837160702	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	4	4	12	16	9	16	28.5	0.57	High
xy42059677162601	Route 146A/Quaker Highway	Unknown	Blackstone River-West River to Peters River	4	16	16	16	12	9	16	28.5	0.57	High
xy42078077164119	Route 16/Douglas Street	Unnamed	Mumford River	4	12	12	16	12	9	16	28.5	0.57	High
xy42031807161366	Route 146A/Quaker Highway	Unnamed	Blackstone River-West River to Peters River	4	4	4	16	12	9	16	28.5	0.57	High
xy42075647165106	Route 16/Douglas Street	Unnamed	Mumford River	4	4	4	12	12	9	12	22.5	0.45	Medium
xy42062867163535	Crownshield Avenue	Unnamed	Blackstone River-West River to Peters River	4	4	8	16	20	8	20	34	0.68	High
xy42088617164201	Route 122/North Main Street	Cold Spring Brook	Mumford River	4	20	20	12	20	8	20	34	0.68	High
xy42028787160746	146A/Quaker Highway	Bacon Brook	Blackstone River-West River to Peters River	4	4	4	12	20	8	20	34	0.68	High
xy42088087164429	Rivulet Street	Cold Spring Brook	Mumford River	4	4	4	12	12	8	12	22	0.44	Medium
xy42088837160154	Route 16/Mendon Street	Unnamed	West River	4	4	4	12	16	6	16	27	0.54	Medium
xy42080307161589	Route 16/Mendon Street	Unnamed (Old Hecla Canal?)	Upper Blackstone River-West River	4	4	4	16	8	6	16	27	0.54	Medium
xy42076917164531	Route 16/Douglas Street	Unknown	Mumford River	4	8	8	12	8	6	12	21	0.42	Medium
xy42049317160651	Glen Street	Unnamed	Blackstone River-West River to Peters River	4	12	16	12	4	6	16	27	0.54	Medium
xy42080807160848	Henry Street	West River	West River	4	4	4	12	12	5	12	20.5	0.41	Medium
xy42083647160733	Route 16/Mendon Street	West River	West River	4	4	8	8	12	5	12	20.5	0.41	Medium
xy42079747161962	Route 16/Mendon Street	Blackstone River	Upper Blackstone River-West River	4	4	4	8	12	5	12	20.5	0.41	Medium
xy42075197162529	Depot Road	Mumford River	Mumford River	4	4	4	8	4	5	8	14.5	0.29	Low
xy42076517162833	Route 16/Mendon Street	Mumford River	Mumford River	4	4	4	8	4	5	8	14.5	0.29	Low
xy42043037160531	Albee Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	4	20	32	0.64	High
xy42088607164297	Elm Street	Cold Spring Brook	Mumford River	4	4	8	16	20	4	20	32	0.64	High
xy42027727160994	Ironstone Road	Bacon Brook	Blackstone River-West River to Peters River	4	12	16	12	20	4	20	32	0.64	High
xy42029917160327	River Road	Bacon Brook	Blackstone River-West River to Peters River	4	4	4	12	4	4	12	20	0.4	Medium
xy42092197164318	Route 122/North Main Street	Mumford River	Mumford River	4	4	4	8	4	4	8	14	0.28	Low
xy42034047161108	River Road	Unnamed	Blackstone River-West River to Peters River	4	20	20	16	20	3	20	31.5	0.63	High
xy42076567163220	Carney Street	Unknown	Mumford River	4	4	4	12	20	3	20	31.5	0.63	High
xy42077637163476	Marywood Street	Unnamed	Mumford River	4	8	12	12	4	3	12	19.5	0.39	Medium
xy42042607160797	Old Millville Road	Unnamed	Blackstone River-West River to Peters River	4	8	12	12	4	3	12	19.5	0.39	Medium

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Appendix C

Road-Stream Crossing Scoring and Prioritization Methods

Hydraulic Capacity Worksheet
Massachusetts Road-Stream Crossing Assessment
Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan – Town of Uxbridge
June 2020

Table 1: Headwater Depth at $Q_{failure}$

Road-Stream Crossing Structure Type and Material	Allowable Headwater Depth[1]
Stone Masonry or Wood Culvert	HW = 1.0 x D
Smooth or Corrugated Metal or Plastic Culvert[2]	HW = 1.2 x D
Concrete Culvert	HW = 1 foot below lowest point in roadway surface
Bridge	HW = 1 foot below lowest point of bottom of bridge deck

Table 2: Tailwater Depth used in Calculating Hydraulic Capacity ($Q_{failure}$)

Crossing Type	Crossing Structure Slope	Tailwater Depth
Non-Tidal Crossings	> 2%	TW = 0.75 x D
	< 2%	TW = 0.75 x D when HW/D < 1.3 TW = 1.0 x D when HW/D ≥ 1.3
Tidal Crossings	Not Applicable	TW = 1.0 x D
Crossings discharging directly into a lake, pond, or wetland[1]	Not Applicable	Based on elevation of receiving water body or wetland
Crossings with cascade or free fall at the outlet with a significant drop to the normal elevation of the downstream channel	Not Applicable	Based on elevation drop at outlet

[1] Situations where the tailwater depth is dictated by the water elevation in the downstream receiving water body or wetland and does not vary with flow, where available.

Table 3: Hydraulic Capacity Score

Hydraulic Capacity Rating (Capacity Ratio > 1.0 for listed Return Interval)	Hydraulic Capacity Score
100-Year	1
50 Year	2
25-Year	3
10 Year	4
< 10-Year	5

Equation 1: Hydraulic Capacity Ratio

$$Capacity\ Ratio_{R.I.} = \frac{HW_{failure}}{HW_{R.I.}}$$

$$Capacity\ Ratio_{R.I.} > 1.0$$

Crossing has sufficient capacity to convey the return interval peak discharge

$$Capacity\ Ratio_{R.I.} \leq 1.0$$

Crossing is undersized for the return interval peak discharge

Geomorphic Vulnerability Worksheet
Massachusetts Road-Stream Crossing Assessment
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Table 1: Crossing Alignment Impact Potential Ratings

Impact Rating	Alignment
1	Naturally straight
2	Mild bend
3	--
4	Channelized straight
5	Sharp bend

Table 2: Bankfull Width Impact Potential Ratings When Confident Width Measurements are Available

Impact Rating	Inlet Width/Bankfull Width Ratio (ft/ft)
1	≥1.0
2	1.0-0.85
3	0.85-0.7
4	0.7-0.5
5	≤0.5

Table 3: Bankfull Width Impact Potential Ratings When No Confident Width Measurements are Available

Impact Rating	Constriction
1	None – Spans full channel and banks
2	Slight – Spans only bankfull/active channel
3	--
4	Moderate
5	Severe

Table 4: Channel and Crossing Structure Slope Impact Potential Ratings

Impact Rating	Slope Conditions at Crossing
1	No natural break in slope AND crossing structure slope = channel slope
2	No natural break in slope but crossing structure slope greater than channel slope
3	Natural break in slope present but crossing structure = channel slope
4	No natural break in slope but crossing structure slope less than channel slope
5	Natural slope break present AND crossing structure slope different from channel slope (less than or greater than)

Table 5: Sediment Continuity Impact Ratings

Impact Rating	Sediment Deposition, Elevation of Sediment Deposits, and Tailwater Scour Pool
1	No deposition upstream AND no tailwater scour pool
2	Deposition upstream <½ bankfull height OR small tailwater pool
3	No deposition upstream AND large tailwater scour pool downstream
	Deposition upstream <½ bankfull height AND small tailwater pool
	Deposition upstream ≥½ bankfull height AND no tailwater scour pool
4	Both deposition AND tailwater pool present with either deposition ≥½ bankfull height OR a large tailwater scour large pool
5	Deposition upstream ≥½ bankfull height AND large tailwater pool

Table 6: Bank Erosion and Outlet Armoring Impact Ratings

Impact Rating	Bank Erosion and Outlet Armoring
1	No bank erosion or outlet armoring
2	--
3	Low levels of bank erosion and/or Outlet armoring not extensive
4	--
5	High levels of bank erosion and/or extensive outlet armoring

Table 7: Inlet and Outlet Grade Impact Ratings

Impact Rating	Character of Inlet and Outlet Grade
1	Both inlet and outlet at stream grade
2	Inlet drop OR cascade at outlet
3	Inlet drop AND cascade at outlet
4	Perched or clogged/collapsed/submerged inlet
	Free fall or free fall onto cascade at outlet
5	Inlet drop AND either free fall or free fall onto cascade at outlet

Table 8: Combined Geomorphic Potential Impact Ratings

Combined Potential Impact Rating	Likelihood for Geomorphic Impacts
3	Very unlikely
4-6	Unlikely
7-9	Possible
10-12	Likely
13-15	Very likely

Table 9: Combined Observed Geomorphic Impact Ratings

Combined Impact Rating	Degree of Observed Geomorphic Impacts
3	None
4-6	Minor
7-9	Moderate
10-12	Significant
13-15	Severe

Table 10: Overall Geomorphic Impact Score

Sum of Geomorphic Potential Impact Ratings and Observed Geomorphic Impact Ratings	Geomorphic Impact score
6	1
7-12	2
13-18	3
19-24	4
25-30	5

Structural Condition Worksheet
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Table 1: Level 1 Variables

Number of Variables Marked "Critical" (Inlet, Outlet, or Both)	Condition Score
Any one of the following variables: • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.0
None of the above variables are marked "Critical"	1.0

Table 2A: Level 2 Variables – Part I

Number of Variables Marked "Critical"	Condition Score
Any three of the following variables (inlet, outlet, or both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Longitudinal Alignment • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.0
Any two of the following variables (inlet, outlet, or both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Longitudinal Alignment • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.1
Any one of the following variables (inlet/outlet/both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Longitudinal Alignment • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.2
None of the above variables are marked "Critical"	1.0

Table 2B: Level 2 Variables – Part II

Number of Variables Marked "Poor"	Condition Score
Any three of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.0
Any two of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.1
Any one of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.2
None of the above variables are marked "Poor"	1.0

Table 3: Level 3 Variables

Variables marked as "Poor" (inlet, outlet, or both)
Buoyancy or Crushing
Invert Deterioration
Joints and Seams Condition
Longitudinal Alignment
Headwall/Wingwall Condition
Flared End Section Condition
Apron/Scour Protection Condition (outlet only)
Armoring Condition
Embankment Piping

Table 4: Structural Condition Binned Score

Lowest Score Resulting from Level 1, Level 2, and Level 3 Variable Assessment	Structural Condition Binned Score
0.81 - 1.00	1
0.61 - 0.80	2
0.11 - 0.60	3
0.01-0.10	4
0.0	5

Equation 1: Level 3 Condition Score

$$Score = 1.0 - (0.1 \times N)$$
$$N = number\ of\ variables\ from\ Table\ 3\ marked\ "Poor"$$

Aquatic Organism Passage Worksheet
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Table 1: Component Scores for AOP Field Variables

Field Variable	Level	Component Score
Constriction	Severe Moderate Spans Only Bankfull/Active Channel Spans Full Channel and Banks	0 0.5 0.9 1
Inlet Grade	Inlet Drop Perched Clogged/Collapsed/Submerged Unknown At Stream Grade	0 0 1 1 1
Internal Structures	Baffles/Weirs Supports Other None	0 0.8 1 1
Outlet Apron	Extensive Not Extensive None	0 0.5 1
Physical Barriers	Severe Moderate Minor None	0 0.5 0.8 1
Scour Pool	Large Small None	0 0.8 1
Substrate Coverage	None 25% 50% 75% 100%	0 0.5 0.5 0.7 1
Substrate Matches Stream	None Not Appropriate Contrasting Comparable	0 0.25 0.75 1
Water Depth	No (Significantly Deeper) No (Significantly Shallower) Yes (Comparable) Dry (Stream Also Dry)	0.5 0 1 1
Water Velocity	No (Significantly Faster) No (Significantly Slower) Yes (Comparable) Dry (Stream Also Dry)	0 0.5 1 1

Equation 1: Openness Measurement (feet)

$$Openness\ Measurement = \frac{Structure\ Cross\ Sectional\ Area}{Structure\ Length}$$

Equation 2: Openness Score (S_o), for openness measurement (x) in feet

$$S_o = (1 - e^{-5.7x})^{2.6316}$$

Equation 3: Height Score (S_h) for height measurement (x) in feet

$$S_h = min\left(\frac{1.1x^2}{4.84 + x^2}, 1\right)$$

Table 2: Weights associated with each variable in the component scoring algorithm

Parameter	Weight
Outlet Drop	0.161
Physical Barriers	0.135
Constriction	0.090
Inlet Grade	0.088
Water Depth	0.082
Water Velocity	0.080
Scour Pool	0.071
Substrate Matches Stream	0.070
Substrate Coverage	0.057
Openness	0.052
Height	0.045
Outlet Apron	0.037
Internal Structures	0.032

Table 3: Binned Aquatic Passability Score

Aquatic Passability Score	Descriptor	Binned Aquatic Passability Score
1.00	No Barrier	1
0.80 - 0.99	Insignificant Barrier	1
0.60 - 0.79	Minor Barrier	2
0.40 - 0.59	Moderate Barrier	3
0.20 - 0.39	Significant Barrier	4
0.0 - 0.19	Severe Barrier	5

Table 4: Binned Ecological Integrity Score

Aquatic Index of Ecological Integrity (IEI) Value	Binned Ecological Integrity Score
0.0-0.3	1
0.31-0.5	2
0.51-0.7	3
0.71-0.9	4
0.91-1.0	5

Equation 4: Outlet Drop Score (S_{od}) for outlet drop measurement (x) in feet

$$S_{od} = 1 - \frac{1.029412x^2}{0.26470588 + x^2}$$

Equation 5: Aquatic Passability Score

$$Aquatic\ Passability\ Score = Minimum\ [Composite\ Score,\ Outlet\ Drop\ score]$$

Table 1: Transportation Disruption Component Scores

Disruption Rating	Road Classification (Highway Functional Classification)
1	Local Roads, Trails, Driveways
2	Major and Minor Collectors
3	Minor Arterials
4	Other Principal Arterials
5	Interstates, Freeways, and Expressways

Flood Impact Potential Worksheet
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Equation 1: Stream Buffer Distance as a Function of Bankfull Width (for use where bankfull width available)

$$Stream\ Buffer\ Distance = 2 \times Bankfull\ Width$$

Table 1: Stream Buffer Distance as a Function of Crossing Structure Width and Degree of Constriction

(for use where bankfull width not available)

Crossing Structure Constriction Rating	Stream Buffer Distance (Substitute for Equation 8-1)
Severe	4 x Structure Width
Moderate	3 x Structure Width
Spans Only Bankfull Active Channel	2 x Structure Width
Spans Full Channel and Banks	2 x Structure Width

Table 2: Flood Impact Rating – Developed Area

Flood Impact Rating	Percent Developed Area within Potential Flood Impact Area Buffer Polygon
1	<5% developed area
2	<10% developed area
3	<25% developed area
4	<50% developed area
5	>50% developed area

Table 3: Flood Impact Rating – Upstream and Downstream Crossings

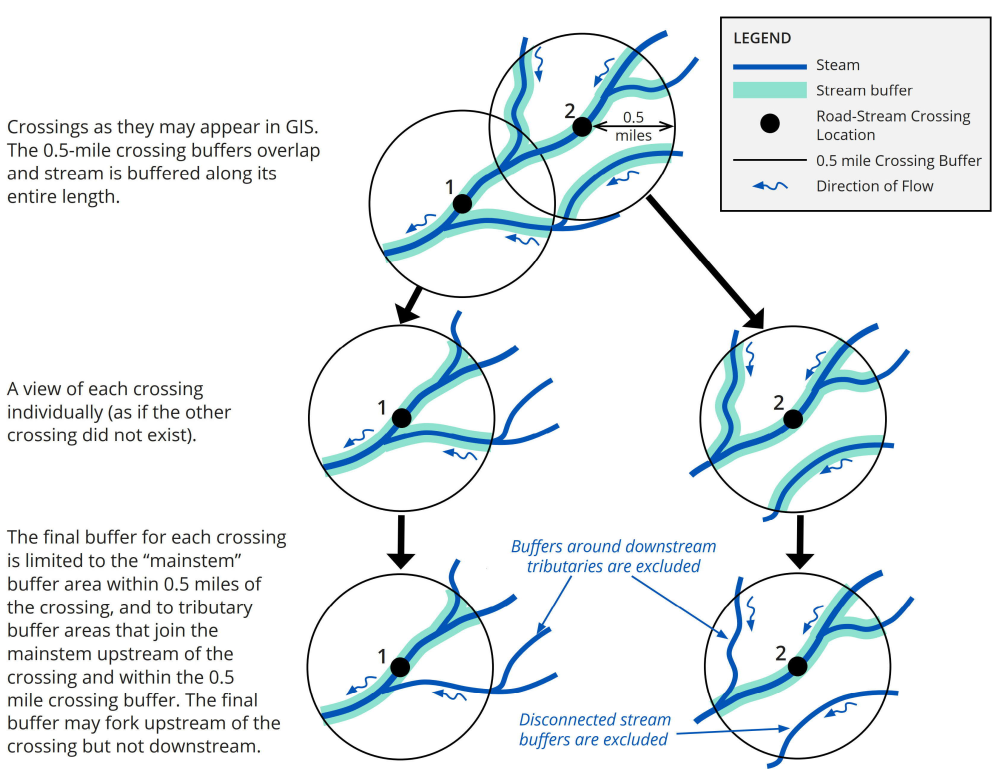
Flood Impact Rating	Number of Upstream and Downstream Crossings within Potential Flood Impact Area Buffer Polygon
1	0
2	--
3	1
4	--
5	>1

Note: -- indicates category not used

Table 4: Binned Flood Impact Potential Scores

Binned Flood Impact Potential Score	Sum of Component Flood Impact Ratings
1	1 – 2
2	3 – 4
3	5 – 6
4	7 – 8
5	9 – 10

Figure 1: Stream Crossing Buffer Diagram



Prioritization Worksheet
Massachusetts Road-Stream Crossing Assessment
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Equation 1: Crossing Failure Risk

$$Failure\ Risk = Probability\ of\ Failure \times Magnitude\ of\ the\ Impact\ of\ Failure$$

Equation 2: Impact Score

$$Impact\ Score = Maximum\begin{bmatrix} Binned\ Transportation\ Disruption\ Score, \\ Binned\ Flood\ Impact\ Potential\ Score \end{bmatrix}$$

Equation 3: Existing Hydraulic Risk Score

$$Existing\ Hydraulic\ Risk\ Score = Binned\ Existing\ Hydraulic\ Capacity\ Score \times Impact\ Score$$

Equation 4: Future Hydraulic Risk Score

$$Future\ Hydraulic\ Risk\ Score = Binned\ Future\ Hydraulic\ Capacity\ Score \times Impact\ Score$$

Equation 5: Geomorphic Risk Score

$$Geomorphic\ Risk\ Score = Binned\ Geomorphic\ Vulnerability\ Score \times Impact\ Score$$

Equation 6: Structural Risk Score

$$Structural\ Risk\ Score = Binned\ Structural\ Condition\ Score \times Impact\ Score$$

Equation 7: Crossing Risk Score

$$Crossing\ Risk\ Score = Maximum\begin{bmatrix} Existing\ Hydraulic\ Risk\ Score, \\ Climate\ Change\ Risk\ Score, \\ Geomorphic\ Risk\ Score, \\ Structural\ Risk\ Score \end{bmatrix}$$

Equation 8: Aquatic Passage Benefit Score

$$Aquatic\ Passage\ Benefit\ Score = Binned\ Aquatic\ Passability\ Score \times Binned\ Ecological\ Integrity\ Score$$

Equation 9: Crossing Priority Score

$$Crossing\ Priority\ Score = Maximum[Aquatic\ Passage\ Benefit\ Score, Crossing\ Risk\ Score] + Average[Aquatic\ Passage\ Benefit\ Score, Crossing\ Risk\ Score]$$

Table 1: Relative Priority Ratings

Crossing Priority Score (normalized)	Priority Rating
0.66 – 1.00	High
0.33 - 0.65	Medium
0.00 - 0.32	Low