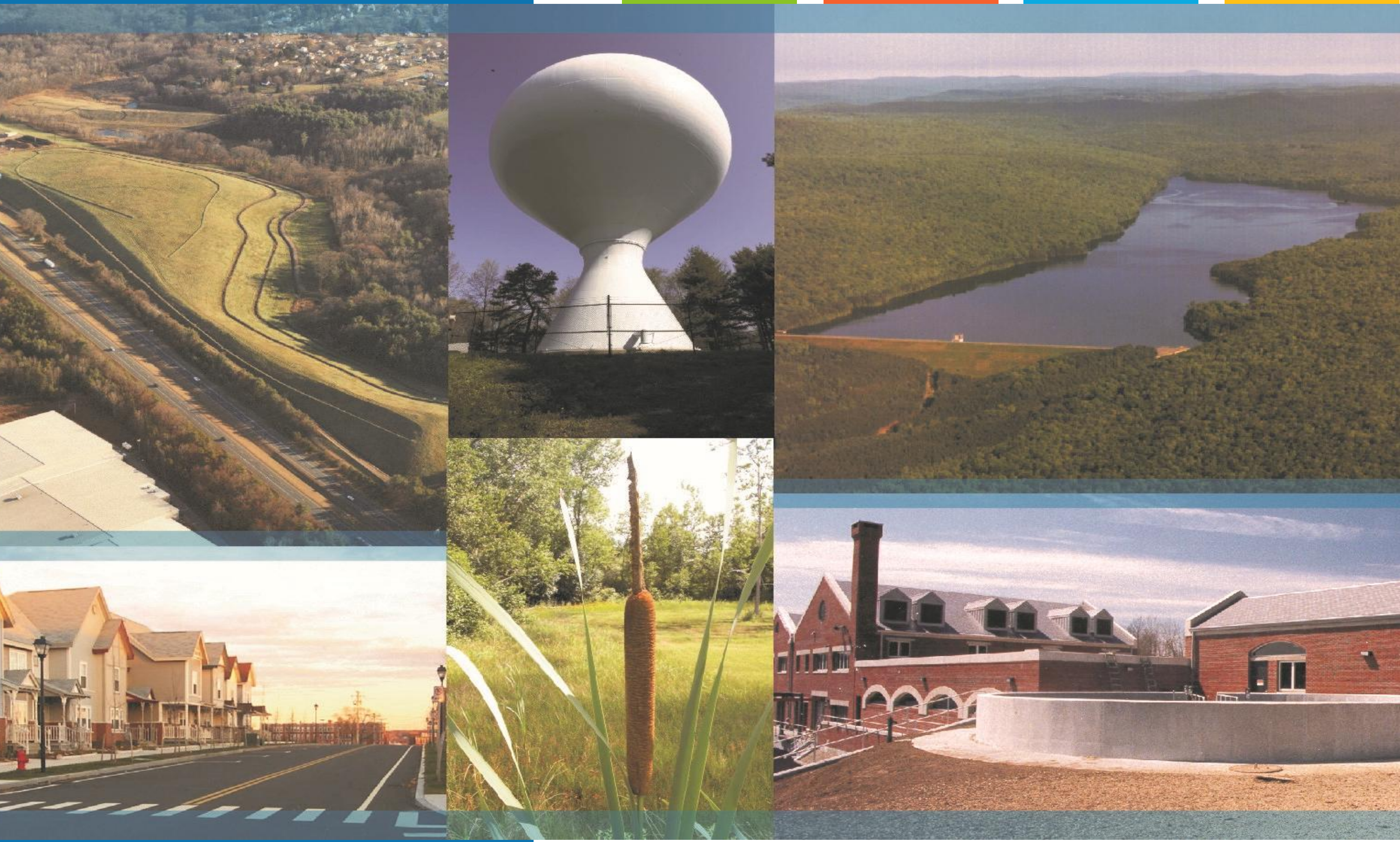

Dover Stormwater Asset Management Plan

Town of Dover MA

October 2025

Funded in part by the 2023 Asset Management Grant Program by the Massachusetts Department of Environmental Protection, and its State Revolving Fund partner the Clean Water Trust (CWSRF-11391)

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Section 1 Introduction

The Town of Dover is responsible for operating and maintaining the stream crossings and municipal separate storm sewer system (MS4) to manage rainfall that travels off land surfaces during storms and from snowmelt (known as stormwater runoff), as well as protecting public health and safety and preserving environmental resources. Historically, the primary goals of managing stormwater runoff were to prevent immediate threats to life and property due to flooding and to maintain safe and passable streets. In the last two decades, federal and state regulations (e.g., the Environmental Protection Agency's [EPA's] Phase II Small MS4 Program and permits and Massachusetts Stormwater Management Standards and Handbook) have imposed increasingly stringent requirements on communities to locally manage stormwater runoff in order to address the adverse impacts that increased runoff quantity, temperature, and pollutants (such as nutrients, bacteria, and sediment) carried by this runoff have on local waterbodies. Likewise, land development and increased storm intensity have increased the rate and volume of runoff that drainage systems must convey.

The Town recognizes that the stormwater system, much like the Town's water distribution and wastewater collection systems, is a necessary public utility that should be managed to benefit residents and local businesses. The Town sought to expand its stormwater and culvert inventory to gain a thorough understanding of the condition of and vulnerabilities in the drainage system. Therefore, Dover staff identified development of a Stormwater Asset Management Plan (AMP) as a priority to help prioritize the municipal drainage system, improve upon overall stormwater management, and establish a proactive stormwater system maintenance, repair, and replacement program.

A Massachusetts Department of Environmental Protection (MassDEP) AMP Grant application was submitted by Tighe & Bond and the Town in August 2022 to establish an asset management program for the Town's stormwater system. In April 2023, MassDEP notified that the Town qualified for the AMP Grant on the Massachusetts Clean Water State Revolving Fund's (CWSRF) Final Intended Use Plan (IUP) and on November 6, 2023, the Town was issued a Notice to Proceed. This grant reimburses 60% of the cost associated with development of an AMP.

The Town's objectives for the AMP project were as follows:

- Develop an inventory and a better understanding of the existing stream crossings
- Develop an inventory and a better understanding of the existing drainage system and outlets
- Create a risk-based AMP and capital improvement planning methodology that will support decision makers and be available for public presentation.
- Develop a program that emphasizes proactive measures to improve existing maintenance practices to avoid systems reaching failure.
- Coordinate with the Town's established water quality programs (MS4, lakes and ponds, etc.) and resilience planning.
- Define a desired level of service, develop a stormwater map in GIS. Determine the condition of all stream crossings and a representative selection of existing drainage, and develop a prioritized list of culverts.

- Obtain conceptual Opinions of Probable Construction Costs (OPCC) for repair or replacement of the most severely ranked infrastructure as needed to program capital requirements.

1.1. Overview of Asset Management Principles

Utilities that incorporate asset management planning often result in improved delivery of services and maximization of economic value of those assets. Asset management includes the planning, design, construction, operation, maintenance, rehabilitation, and replacement of infrastructure that performs a function for the Town in a cost-effective manner. There are numerous benefits of asset management that include, but are not limited to:

> The EPA defines asset management as *"maintaining a desired level of service for what you want your assets to provide at the lowest life cycle cost. Lowest life cycle cost refers to the best appropriate cost for rehabilitating, repairing or replacing an asset."* [1]

- Understanding the Town's stormwater system assets, desired level of services, and costs associated with operation and maintenance;
- Communicating with transparency, justifying investments to the community, and demonstrating a responsible investment in infrastructure;
- Budgeting based on improved understanding about the timing and expense of rehabilitation, repair, and/or replacement needs;
- Prolonging asset life;
- Meeting level of service expectations;
- Addressing regulatory requirements;
- Improving responses to emergencies;
- Providing methodologies for determining replacement of existing infrastructure prior to failure;
- Providing Town staff with the necessary tools by acquiring equipment for recording and transfer to new or existing software systems;
- Outlining predetermined schedules for asset replacement prior to failure; and
- Identifying annual budget line-item costs for implementation of Asset Management Plans.

[1] EPA, "Asset Management: A Best Practices Guide," April 2008.
URL: https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P1000LP0.txt

The general process of asset management is shown in **Figure 1-1** and involves defining the following items:

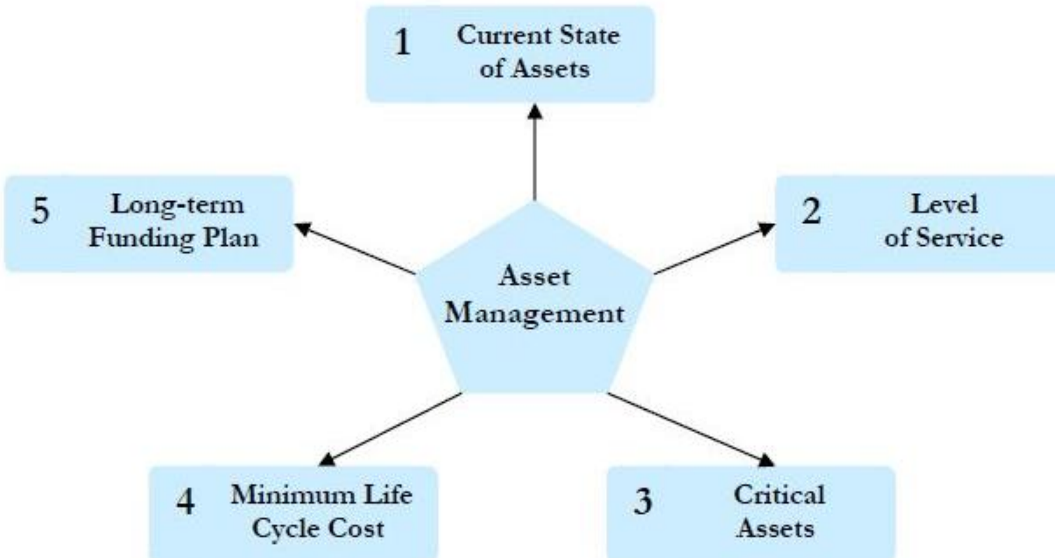


Figure 1-1 The Five Core Questions for Implementing Asset Management[2]

1. **Current State of Assets**: Inventory the available assets throughout the stormwater system. The inventory list consists of asset location, condition, maintenance history, service life, and value, if possible.

2. **Level of Service**: Determine a system operation that is sustainable by considering water quality, water quantity, system reliability, regulatory requirements, and environmental standards.

3. **Critical Assets**: Assign criticality scores to the assets required for continued sustainable system operation. An asset's risk of failing due to their condition, consequences in the event of failure, and cost of repair or replacement in the event of failure may dictate the criticality score.

4. **Minimum Life Cycle Cost**: Analyze existing Operation and Maintenance (O&M) procedures and activities to determine how they may be optimized based on cost, criticality, and level of service.

5. **Long-Term Funding Plan**: Establish the financial capital necessary to maintain a desired level of service by proactively evaluating rate structure and available funding opportunities.

[2] EPA, "Asset Management: A Best Practices Guide," April 2008.
URL: https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P1000LP0.txt

Often communities conduct O&M activities on a reactive basis, with resources allocated to emergency response and rehabilitation or replacement of failed assets. This is classified as a Run-to-Failure Management Model, as shown in **Figure 1-2**. Under this model, assets that have not yet failed are aging, defects are worsening, and future problems are developing. Ultimately, this can lead to higher and unanticipated costs for maintenance and replacement or repair.

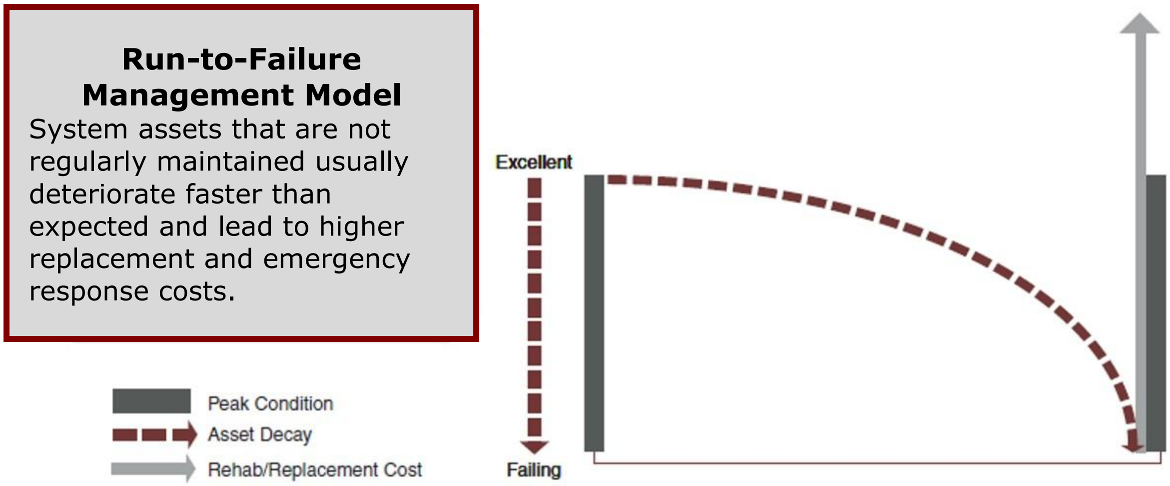


Figure 1-2 Run-to-Failure Management Model [3]

Alternatively, utilizing an asset management approach, as shown in **Figure 1-3**, allows aging infrastructure to be maintained and replaced prior to failure. This prevents adverse consequences of failure and distributes costs over the service life of the asset.

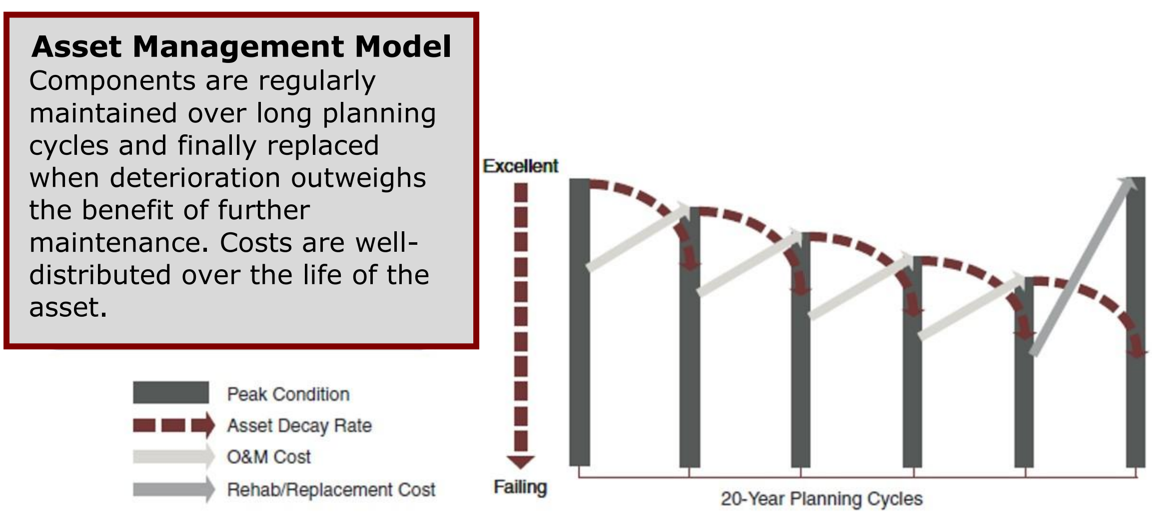


Figure 1-3 Asset Management Model [3]

[3] EPA, "Fact Sheet: Asset Management for Sewer Collection Systems," April 2002. URL: https://www.epa.gov/sites/default/files/2015-10/documents/assetmanagement.pdf

1.2. Development of the Asset Management Program

Tighe & Bond worked closely with the Town of Dover staff to develop this stormwater AMP to provide the Town with its desired programmatic and level of service goals. The plan was developed through the following major steps, which are described in subsequent sections of this report.

1. Develop Level of Service goals for the AMP (Section 1.2.1);
2. Develop an initial inventory of culverts, stormwater structures (i.e. catch basins and manholes, and targeted areas of drainage connectivity in Dover (Section 2);
3. Identify areas in Town with drainage improvement or flood mitigation needs (Section 2);
4. Create a drainage structure assessment field form and a culvert assessment procedure and field form (Section 2 and 3);
5. Develop an inventory and complete condition assessments for drainage system culverts and targeted drainage structures (Sections 2 and 3);
6. Determine a risk-based prioritization for culvert repairs and replacement (Section 4); and
7. Develop a written AMP that includes:
    - A description of the drainage structures and culvert inventories and condition assessment results (Sections 2 and 3);
    - The risk-based prioritization process (Section 4);
    - Recommendations for capital improvements, further investigation, maintenance, programmatic improvements, and a Five-Year Action Plan (Section 5);
    - Funding considerations (Section 6); and
    - Potential permitting pathway for proposed culvert replacements and repairs (Section 7).

1.2.1. Level of Service Workshop

Tighe & Bond and Town staff held a Level of Service Workshop on November 30, 2023 to review and discuss the goals and objectives of the AMP. Representatives from multiple Town departments, including Public Works, Highway, and Conservation, provided input on the AMP program goals and potential challenges, level of service goals, consequence of failure considerations, and critical or at-risk areas in Dover where failure of the drainage system would lead to significant negative impact. This input was solicited through a customized Level of Service “questionnaire” and at the Level of Service workshop.

Through the questionnaire and LOS Workshop, the goals of the AMP were further refined as follows:

Asset Preservation and Condition Goals:

- No catch basin sumps will be greater than 50% full
- Update Town’s GIS stormwater mapping after system improvements and maintenance are completed or annually at a minimum

- Implement long-term CIP to replace, repair, and maintain assets on a proactive schedule
- Sweep all streets twice per year

Conservation, Compliance and Enforcement Goals:

- Complete Annual Reports documenting compliance with most program elements
- Protect wetlands, ACECs, vernal pools, and aquifers

Health, Safety and Security Goals:

- Minimize flooded roadways
- Design stormwater improvements to mitigate expected flooding from future storms

Service Quality and Cost Goals:

- Board of Public Works and Board of Selectmen support for proposed program budget
- Use the long-term CIP to identify grants
- Update Town's Stormwater Asset Criticality Ranking and CIP project list yearly
- Revisit the stormwater rate structure and fees for updated revenue requirements and consider equity

See **Appendix A** for a copy of the initial questionnaire and a summary of questionnaire responses, including the final program goals and objectives.

1.2.2. Public Education and Outreach

The Town of Dover posted a press release to the Town website on April 25, 2023 announcing this project and the grant monies received from the Clean Water Trust as means of informing the community about the upcoming project.

Summary slides have been created as **Appendix B** and uploaded to the Town's website to provide an overview of the AMP and its findings.

1.2.3. Asset Inventory Development, Software, and Training

The Town uses the Environmental Systems Research Institute, Inc. (ESRI) ArcGIS platform within the Massachusetts Department of Transportation (MassDOT) GeoDOT GIS organization to map the stormwater system. Previously, the Town had GIS shapefiles of outfall locations but did not have drainage structures, Best Management Practices (BMPs), culverts, or closed drainage system connectivity mapped. Information on stormwater infrastructure was generally kept in hard copy format through construction drawings or record plans. Through the stormwater AMP, the GIS mapping and data management processes were significantly improved and refined. The current GIS map includes the existing outfall data, and newly mapped drainage manholes, catch basins, culverts, and representative areas of drainage connectivity.

The initial stormwater asset inventory was created through a desktop analysis and fieldwork. Existing outfall mapping was added to the GIS stormwater map, potential culvert locations were identified through a desktop analysis, and drainage structures (i.e., manholes and catch basins) were identified through four (4) days of fieldwork to locate them using ESRI ArcGIS tablet applications, as shown below in **Figure 1-4**. Town staff accompanied Tighe & Bond during the fieldwork which resulted in more comprehensive mapping by capturing institutional knowledge of problematic, buried, or submerged structures. The GIS supports tracking of drainage system maintenance activities as well as asset inventory mapping and recording asset condition. This software was used throughout the AMP, as described in Section 2, and the Town should continue to use it moving forward for implementation of the AMP.

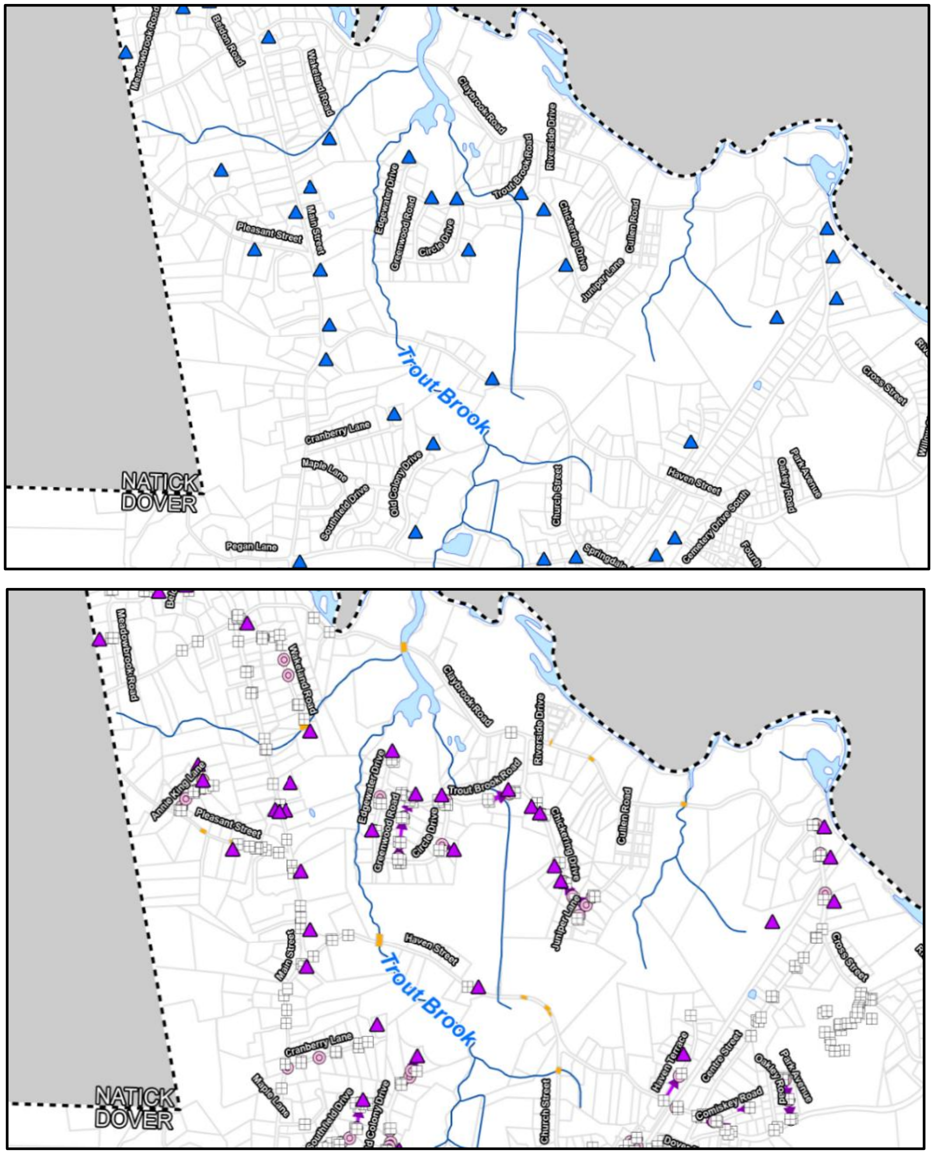


Figure 1-4 Example of GIS Improvements
Initial Inventory (top) to Updated Inventory (bottom)

Prior to the start of the field investigation, Tighe & Bond developed digital field forms to collect data on asset characteristics, condition, illicit discharge concerns, maintenance needs, and more during field assessments of stormwater assets. The forms were created in ESRI Survey123 and therefore, condition assessment data is linked to each stormwater asset as applicable.

1.2.4. Age of Assets

Implementing an asset management program requires knowledge about the age of infrastructure. Currently, the GIS inventory contains limited information on the year of installation for different drainage assets. This information should be populated as available for existing drainage structures, pipes, and culverts to better understand the age and remaining service life of the drainage system.

For comprehensive asset management, it is also important to understand the typical service life of an asset. The expected service life for different asset types typical to Dover's stormwater system (e.g., gravity drain pipes, culverts, catch basin laterals, drain manholes, catch basins, outfalls, and infiltration and detention basins) ranges from 50 to 100 years depending on the material type and asset use. For example, corrugated metal pipes (CMP) typically have a shorter service life than reinforced concrete pipes.

It must be noted that Dover's infrastructure will have longer or shorter service lives depending on the original quality of the infrastructure and installation, the specific environment and conditions, and operation and maintenance throughout the asset's service life. Since there is limited data related to date installed or asset age within the Town's GIS inventory, more meaningful age information needs to be obtained to assess the remaining service life of individual assets within Dover's drainage system.

Section 2 Closed Drainage System Condition Assessment

This section discusses condition assessments completed for multiple stormwater asset types as part of field work completed for the Town's AMP, including drainage structures (i.e., catch basins and manholes) and drain pipes.

2.1. Structure and Pipe Condition Assessment

Tighe & Bond worked with the Town to perform assessments of drainage structures and pipes to collect inventory and condition information. An example of a drainage structure assessment photo is presented in **Figure 2-1** below. The following section describes the process, procedures, and results completed as part of these assessments.

2.1.1. Methodology and Procedures

As noted in Section 1.1, after the Level of Service workshop in November 2023, Tighe & Bond obtained further input from Town staff to help prioritize areas for the stormwater system assessments, which focused on areas with known concerns. Priority areas identified for the field work in 2024 included:

- Centre St/Center of Town (as noted in the Level of Service workshop)
- Walpole Street (as noted in the Level of Service workshop)
- Subdivisions
- Additional locations identified by Town staff during fieldwork

These areas are identified in the map in **Appendix C**.

Figure 2-1 Drainage Manhole DMH-177

Tighe & Bond with Town staff completed drainage system assessments during ten (10) days between May and October 2024. This effort included collecting attribute information such as size and material, as well as assessing the condition of a variety of drain manholes, catch basins, and drainage pipes.

A rapid condition assessment was completed using an Envirosight Quickview zoom inspection camera, as shown in **Figure 2-2**. This camera allows high-resolution video logs of pipes and structures to be obtained without confined space entry. The Quickview camera also allows for rapid inspection of pipelines and does not require any cleaning prior to inspecting the line.

The inspections were completed following simplified National Association of Sewer Service Companies (NASSCO) Pipeline/Manhole Assessment Certification Program (PACP/MACP) protocols. Following the PACP/MACP guidelines and using the zoom inspection camera allowed for a quick, in-field determination of size, condition, material, and general connectivity of the drainage system, as well as the identification of any visible pipe defects or instances of obstructed flow. Note that the Quickview camera does not allow the user to inspect beyond bends in a drainage pipe or past any blockages or obstructions, so occasionally connectivity cannot be verified.

Figure 2-2 Envirosight Quickview Zoom Camera

During the field inspections, Tighe & Bond and Town staff collected data in GIS using ESRI's Field Maps and Survey123 tablet applications. The inspectors inserted the Quickview zoom camera into a structure and aimed the camera down the first pipe to be inspected. The camera was controlled by staff using an iPad and Envirosight application to visually zoom down the pipe as far as possible while the camera recorded a video. Once the inspection footage was captured, the camera was zoomed out and rotated to the next pipe to be inspected, where the process was repeated. In this way, each pipe within a structure was inspected. A photograph was also taken of each structure during the inspection and the condition of the structure was documented, as well as any apparent structural issues or sediment buildup issues.

Condition of inspected drain structures and pipes were recorded using Survey123 and included the following information:

- Date and time of inspection;
- Weather conditions;
- Inspector;
- Location and identification number of inspected asset;
- General structure observations (condition, maintenance needs, etc.);
- Internal structure observations (material and condition of cover/grate, frame, chimney, cone, wall, steps, etc.);
- Pipe observations (material, diameter, depth to invert, condition, etc.);
- Observations of any evidence of an illicit discharge or odor;
- Photos and videos; and
- Any additional notes about the inspected structures and/or pipes.

As shown in **Table 2-1**, 132 drainage structures were assessed during this field effort, as well as 176 of the associated drainage pipes. Note that the quantity of pipe segments, instead of length of pipe, was used in discussions about pipe assessments, because the zoom camera used for inspections is unable to precisely measure the total linear footage of assessed pipe.

Table 2-1 Quantity of Drainage System Assets Inspected During Rapid Condition Assessment

Date	Number of Drain Manholes Assessed	Number of Catch Basins Assessed	Number of Pipe Segments Assessed	Total Number of Assets Assessed
5/21/2024	8	1	18	**27**
6/12/2024	5	6	13	**24**
6/18/2024	5	7	13	**25**
9/19/2024	13	1	18	**32**
9/23/2024	7	4	17	**27**
9/24/2024	13	5	23	**42**
9/30/2024	9	6	19	**34**
10/1/2024	15	4	21	**40**
10/8/2024	5	4	13	**22**
10/9/2024	11	3	21	**35**
Total Number of Assets Assessed	**91**	**41**	**176**	**308**

Due to the limited time spent in the field, only a small portion of the Town's mapped drainage system was assessed as part of the rapid condition assessment: approximately 26% of the drain manholes and 4% of the catch basins. **Appendix C** includes a map showing the locations of the assets visited during field work. An export of the data collected is included in **Appendix D**.

While the condition information collected during this field effort provides a snapshot of the drainage system condition status, it should be noted that results may not be representative of other areas of Town. Additional assessments could be completed to obtain a more comprehensive understanding of the total system.

2.1.2. Condition of Inspected Drainage Structures

Of the drainage structures inspected, 69% were drain manholes and 31% were catch basins. During the condition assessment, Tighe & Bond evaluated structure components and noted attribute information (i.e., size and material) and condition observations in the Town's GIS. Most structures were concrete/precast or block.

Of the assessed drainage structures, the distribution of structural defects (i.e., the chimney, frame, cover, cone, or wall was noted as "defective" in the survey) is as follows:

- 14% had no structural defects noted;
- 13% had one structural defect noted;
- 21% had two structural defects noted; and
- 52% had three or more structural defects noted.

The three (3) structures with more than 4 structural defects are included in **Table 2-2**. A complete list and map of the structures with defects is included in **Appendix E**.

Table 2-2 Structures with Multiple Structural Defects

Structure ID	Street	Notes
DMH-103	Park Avenue	Frame has surface damage; mortar missing in chimney, cone, and wall
279A	Greenwood Road	Cover and chimney have surface damage; wall is missing mortar; cone has mortar missing, surface damage, and sinkhole forming
DMH-309	Crest Drive	Frame has surface damage; chimney has a fracture, is missing mortar, and has surface damage; cone and wall are missing mortar

Figure 2-3 includes an example of a drain structure that is in sound condition (the block drain manhole on the left) and an example of a drain structure that had defects observed (the block manhole on the right). The structure on the right was found to have missing/displaced blocks in the chimney. Structures with observed defects should be repaired or monitored, especially as it relates to undermining the roadway.

Figure 2-3 Example Manhole Condition
Left Image is of drainage manhole in sound condition (DMH-7). Right image is of drainage manhole with defective conditions (DMH-103)

2.1.3. Condition of Inspected Drainage Pipes

Of the drainage pipes inspected, 59% were 12” in diameter, and almost 95% were reinforced concrete pipe (RCP). More than 63% of the pipes assessed were noted to be in sound condition. A simplified scoring system was used to score pipes based on their condition. A list and map of these results are included in **Appendix C**. Observed structural defects (such as offset joints, root intrusion, and broken pipes) and operation and maintenance concerns (such as sediment buildup, obstructions like rocks and debris, and vermin) were noted during condition assessments and logged in the Town's GIS. An export of this data is included in **Appendix D**.

Most of the pipes inspected had very little sediment, but about 9% of the pipes inspected were more than 40% full. This is demonstrated in **Figure 2-4**.

Figure 2-4 Example of Sedimentation in Pipes
Left Image is of a drainage pipe less than 40% full of sediment (Pipe-296A). Right image is of a drainage pipe more than 40% full of sediment (Pipe 299A)

When debris or sediment buildup was noted during the rapid condition assessment, it was noted and logged in the Town's GIS. This will allow Town staff to identify priority areas for cleaning by locating the pipelines with the most debris (i.e., pipes with a higher percentage of the pipe full). The locations of the pipes with severe sediment buildup (greater than 40% full) are listed in **Table 2-3** and should be prioritized for cleaning.

Table 2-3 Drainage Pipes with Severe Sediment Buildup

Pipe ID	Street	Notes
145A	Knollwood Drive	
696A	Abbe Road	
390A	Comisky Road	
782B	Pond Street	
782A	Pond Street	
90B	Greenwood Road	
274A	Circle Drive	
299A	Ruel Drive	
299B	Ruel Drive	
299C	Ruel Drive	Pipe buried under sediment, too deep for proper video
279AB	Oak Circle	Drainage pipe could not be inspected due to 100% full sediment buildup
279AA	Oak Circle	Drainage pipe could not be inspected due to 100% full sediment buildup
13A	Raleigh Road	Drainage pipe could not be inspected due to 100% full sediment buildup
12A	Raleigh Road	
TPC24B	Raleigh Road	

As shown in **Table 2-3**, three (3) pipes were noted to be completely full of sediment during the assessment. Therefore, an inspection of the full pipe length could not be completed. These pipes are considered to be in a state of failure because they are not operational and should be considered a high priority for maintenance. A recommendation for expedited cleaning of these pipes is included in Section 5. As pipes are cleaned, they can be reassessed to determine the condition.

Section 3 Culvert Inventory and Condition Assessment

A goal of this AMP was to evaluate the condition of the culverts in Town. To complete the evaluation, Tighe & Bond used a protocol adapted from the North Atlantic Aquatic Connectivity Collaborative (NAACC), which is a "*network of individuals from agencies and organizations focused on improving aquatic connectivity across a thirteen-state region. The NAACC provides protocols for road-stream crossings (culverts and bridges) to assess and score crossings for fish and wildlife passability, as well as culvert condition and other data useful for evaluating risk of failure*."[4]

3.1. Culvert Asset Inventory

As discussed in Section 1.2.3, Tighe & Bond developed an inventory of culverts in the GIS prior to culvert assessments. The initial asset inventory identified 61 potential culvert locations based on road and stream intersections. However, when analyzing the Town for hydrologic connections and receiving feedback from the Town, several additional potential culvert locations were identified. The ID's of these additional culvert locations were given the prefix "TPC" to identify them as a "Town Potential Culvert". As a result, Tighe & Bond prioritized visiting all potential culvert locations on Town-owned roads over visiting municipally owned bridges included in the MassDOT bridge database due to Town receipt of biannual bridge inspections reports from MassDOT. This Section presents an overview of the stream crossing inventory. Complete inventory data is included in the GIS online database. A geodatabase of the GIS will be provided to the Town electronically.

Table 3-1 summarizes the number and types of crossings in the Town's GIS database at the conclusion of this project, including both bridges and culverts, as well as the associated ownership status. **Appendix F** includes a Town-wide map showing culvert locations by type and ownership. The notes associated with **Table 3-1** explain which structures were assessed in the field.

Table 3-1 Stream Crossing Inventory Summary

Category	Owner	Number of Locations
Culvert	Town	115
	Private	18
	Did Not Exist	25
Bridge	Town	4
	MassDOT (State)	3
	Total	**165**

Notes:
1. Culverts include single barrel and multiple barrels.
2. All of the Town's culverts were visited under this AMP. See Section 3.2 for additional information on work completed. Two of the culverts identified during the initial desktop inventory were determined to meet the definition of a short span bridge during field work (bridges categorized as a "short span" have a span between 10 and 20 feet). See Section 4.1.1 for additional information. These locations were assessed as part of the culvert program and associated results and recommendations are included herein.
3. Private culverts include culverts under driveways, on private property, or under roadways that are not accepted by the Town, as identified in the Town's GIS. Private culverts were not field assessed.
4. 25 additional potential culvert locations were visited and no structure was identified. These locations should be deleted from the Town's culvert inventory.

[4]NAACC Data Center. URL: https://naacc.org/naacc_data_center_home.cfm

The Massachusetts Department of Transportation (MassDOT) maintains a bridge inventory that is available online[5], which includes eight (8) in Dover, listed in **Table 3-2.** MassDOT performs biannual inspections of bridges at no cost to the Town; therefore, the Town is in possession of updated condition data for these structures. Four (4) crossings included in MassDOT's Bridge Inventory are Town-owned and also mapped in the Town's GIS:

- Culvert 5 is included in MassDOT's database as BIN AFX, categorized as an NBI Bridge. They note the structure type as a prestressed concrete girder bridge. DOT last inspected the structure on 09/21/2023. The inspection report notes the bridge is in good condition with hairline to light cracking with efflorescence throughout.
- Culvert 70 is included in MassDOT's database as BIN AFA, categorized as an NBI Bridge. They note the structure type as a prestressed concrete slab. DOT last inspected the structure on 08/29/2024. The inspection report notes the bridge is in good condition with hairline cracking with minor spalling at the deck joints and hairline cracking with efflorescence throughout.
- Culvert 52 is included in MassDOT's database as BIN 33N, categorized as an NBI Bridge. They note the structure type as masonry deck arch. DOT last inspected the structure on 03/18/2024. The inspection report notes the bridge is in fair condition with shifting walls and parapets, voids along the masonry joints, missing stones, and a spall with exposed rebar in the south parapet.
- Culvert 43 is included in MassDOT's database as BIN B26, categorized as an NBI Bridge. They note the structure type as concrete deck arch. DOT last inspected the structure on 10/26/2023. The inspection report notes the bridge is in good condition with minor spalling by drain holes, moderate efflorescence along the walls and arch ring at both faces.

Table 3-2 Summary of Crossings in MassDOT Bridge Inventory

Culvert ID	MassDOT Bridge ID	BIN	Structure Type	Inspection Date	Owner
5	D10001	AFX	Bridge (NBI)	2023/09/21	MUN
19	D10007	4D8	Bridge (NBI)	2023/09/20	DOT
24	D10008	4D9	Bridge (NBI)	2024/03/08	DOT
43	D10004	B26	Bridge (NBI)	2023/10/26	MUN
52	D10003	33N	Bridge (NBI)	2024/03/18	MUN
-*	D10006	375	Bridge (NBI)	2024/01/19	DOT
55	D10005`	367	Bridge (NBI)	2023/11/21	DOT
70	D10002	AFA	Bridge (NBI)	2024/08/29	MUN

*Included in the MassDOT bridge database but not a stream crossing; therefore, no culvert ID was identified at this location during asset inventory development discussed in Section 1.2.3. This bridge crossing intersects a railroad.

Because bridges, structures with a span of greater than 10 feet, are differentiated from culverts by MassDOT, the costs associated with additional design requirements can be substantial. As a result, the Town may wish to further refine their GIS mapping by creating a layer of structures that meet the definition of a bridge as defined by MassDOT. Attributes of this layer may be added to include information from the MassDOT inspection reports or assessments performed by the Town. As such, Tighe & Bond recommends adding the

[5] MassDOT bridge database, last updated March 25, 2024.
URL: https://gis.data.mass.gov/datasets/MassDOT::bridges/explore

structures listed in **Table 3-2** to this layer in addition to culverts 42 and 47 as identified through the culvert assessments of this asset management project (discussed in **Section 3.1.1.**).

3.1.1. Culverts that Meet the Definition of Short Span Bridge

Tighe & Bond identified culverts that should be considered short span bridges following the methods defined by the Commonwealth of Massachusetts.[6]

- A short span bridge is a highway bridge structure that meets the Massachusetts General Laws (MGL), which recognize structures having a span greater than 10 feet as bridges, but not the federal definition of a bridge, which defines a bridge as a structure having a span greater than 20 feet. Thus, a short span bridge has a span greater than 10 feet but not greater than 20 feet.
- The "span" is the distance between adjacent centerlines of bearings.
- The bridge must be on and carry a public way.

Based on the definition, two (2) of the 108 prioritized Town-owned culvert locations assessed during field work are considered short span bridges (culverts 42 and 47). Culvert 42 is located on Willow Street and includes a 10-foot stone and concrete span (field measured), although this is part of a dam owned by Massachusetts Department of Conservation and Recreation (MassDCR). Culvert 47 is located on Draper Road and includes two concrete boxes, spanning 17 feet (field measured). The Town should provide these locations and any relevant data to MassDOT District 6 so they can be added to the State's routine inspection program.

3.1.2. Culverts Determined to Not Exist

During the assessment work, it was determined that 25 crossings in the initial culvert list do not exist. These are listed in **Table 3-3**.

Table 3-3 Summary of Culverts Determined not to Exist

Culvert ID	Address	Notes
10B	Claybrook Rd	Duplicate point
13	Haven St	Pipe sticking out of ground
18	Brookfield Rd	Duplicate point
25	Reservation Rd	Duplicate point
40	Donnelly Dr	Wetlands on both sides of road without culvert connecting them
71	Powisset St	Likely seepage under road
74	Rocky Brook Rd	Outfall connected to catch basin
76	Rocky Brook Rd	Duplicate point
84	Snow Hill	Outfall connected to catch basin
87	Hamlins Ct	Outfall connected to catch basin
90	Wilsondale St	No crossing located in field
92	Wilsondale St	Likely seepage under road
97	Bridle Path Circ	No location for crossing
TPC-1	Meadowbrook Rd	Duplicate point
TPC-8	Dedham St	No crossing located in field

[6] Determining if a structure is a "BRI", MassDOT. URL: https://www.mass.gov/service-details/determining-if-a-structure-is-a-bri

Culvert ID	Address	Notes
TPC-11	Picardy Ln	Duplicate point
TPC-16C	Haven St	Duplicate point
TPC-17	Haven St	Shallow Stream without pipe. Likely seepage under road
TPC-30	Grand Hill Dr	Duplicate point
TPC-37	Donnelly Dr	Duplicate point
TPC-39	Centre St	Duplicate point
TPC-49	Ledgewood Dr	Duplicate point
TPC-51	Hartford St	Duplicate point
TPC-52	County St	Duplicate point
TPC-54	Powisset St	Duplicate point

3.1.3. Culverts Determined to be Privately-Owned

During the assessment work, it was determined that eighteen (18) culverts in the initial list were privately-owned, and seven culverts were located on unaccepted roads. A full list of these culverts is located in **Table 3-4.** These culverts were not assessed during the effort. We recommend the GIS inventory be updated accordingly.

Table 3-4 Summary of Culverts Determined to be Privately-Owned or Unaccepted

Culvert ID	Address	Ownership
6	Near Hunt Dr	Private
28	Near Farm St	Private
29	Near Farm St	Private
30	Near Farm St	Private
32	Miller Hill Rd	Private
33	Miller Hill Rd	Private
36	Near Brookfield Rd	Private
46	Near Centre St	Private
48	Turtle Ln	Private
54	Near Old Meadow Rd	Private
96	Miller Hill Rd	Private
8	On school property	Unaccepted Road
34	Hill St	Unaccepted Road
39	Stonegate Ln	Unaccepted Road
79	Hill St	Unaccepted Road
80	Hill St	Unaccepted Road
89	Riverside Dr	Unaccepted Road
TPC-55	Centre St	Unaccepted Road

3.1.4. Culverted Pipes

As culvert assessment field work was completed, Tighe & Bond came across thirteen (13) instances where culvert inverts were suspected to join and convey streamflow through the closed drainage system. A full list of these culverts is included in **Table 3-5**. For the purposes of data analysis completed under this AMP, the inlets were assessed using the field protocol described in Section 3.2.1. Further information about some of these structures was gathered through rapid condition assessment of adjacent stormwater structures using an Envirosight Quickview zoom inspection camera as noted in **Table 3-5**. Culverted streams that are longer than a road crossing should be prioritized in the Town's Illicit Discharge Detection and Elimination (IDDE) Plan.

Table 3-5 Summary of Suspected Connections to Closed Drainage System

Culvert ID	Address	Zoom Camera Used?	Closed Drainage System Connection Confirmed?
9	Picardy Ln	No	No
31	Main St	Yes	Yes; Pipe run 31A downstream of CB 480 has a blind interconnection with pipe run Outfall 31
95B	Trail	No	Confirmed outfall 95B flows into DMH22
95C	Trail	Yes	Confirmed that outfall 95C flows downstream into DMH21
98	Old Farm Rd	No; water level too high	Verified 98 is downstream of CB 659
99	Ledgewood Dr	No	No
TPC-24	Raleigh Rd	Yes	Yes
TPC-29	Farm St	No	Structures and pipe runs TPC-29 could not be identified
TPC-35	Partridge Hill Rd	No	Could not verify outfall connectionTPC-35 due to damaged DMH 51
TPC-50	Hartford St	Yes; see 1060A	Pipe bends right; assuming connection
Field 1	Ledgewood Dr	Yes; see DMH 283	Yes
Field 4	Raleigh Rd	Yes	No
TPC-22	Raleigh Rd	Yes	TPC-22 is downstream of DMH 11 and drains into a ditch that leads to Field 4

3.2. Culvert Assessment Field Work

Over the course of ten (10) days between March 21, 2024 and November 19, 2024, Tighe & Bond staff completed assessments of Town culverts to collect inventory and condition information to be used in a risk-based prioritization. This Section describes the process, procedures, and results of these assessments.

3.2.1. Assessment Protocol

Tighe & Bond developed a culvert assessment protocol and field form to be used during field assessments. The assessment information was developed using Tighe & Bond's experience with culvert assessments and the following resources:

- *Culvert Condition Assessment Manual* and *Culvert Assessment Form,* developed by UMass Transportation Center, NAACC, and the Center for Agriculture, Food, and the Environment, 2019
- *NAACC Stream Crossing Instruction Manual for Aquatic Passability Assessments in Non-tidal Stream and Rivers* and *Aquatic Connectivity Stream Crossing Survey Data Form,* developed by NAACC and UMass Amherst, November 2019

Appendix G includes the protocol with a paper version of the field form. Many of the terms used in this discussion of culvert condition are described in this protocol. ESRI's mobile applications Field Maps and Survey123 were used to collect data during field assessments for culverts. In the Survey123 field form, photos could be taken and stored. These applications also allow photos of the culvert's condition to be stored in the form and linked to its location in GIS. Data collected during assessment includes, but is not limited to the following fields:

- Date and time of assessment;
- Weather conditions;
- Observer;
- Identification number of culvert;
- General roadway, guardrail, sidewalk, curbing observations;
- General upstream and downstream conditions and bankfull widths;
- Dimensions at the inlet and outlet;
- Structural conditions at the inlet and outlet (buoyancy/crushing, alignment, invert deterioration, etc.);
- Aquatic passability conditions (constriction, outlet drop, water velocity, etc.);
- Operation and maintenance concerns (sediment in culvert, presence of trees or beaver dams, etc.);
- Photos; and
- Additional notes.

3.2.2. Culvert Assessment Prioritization

Through desktop GIS analysis of potential stream crossings, 165 potential culvert locations were identified for field verification and assessment.

Note that upon further inventory review and fieldwork, seven (7) stream crossings were identified as short-span or NBI bridges in the MassDOT bridge database and were not assessed (see Section 3.1), 25 culverts were determined to not exist (see Section 3.1.2) and 18 culverts were determined to be privately-owned (see Section 3.1.3). This reduced the culvert inventory to 115 culverts for condition assessment and prioritization. Of these 115 culverts confirmed to exist, 82 assessments were complete, 26 assessments were partially completed, and 7 culverts were not assessed due to site constraints (see Section 3.2.5). Tighe & Bond and Town staff performed visual assessments of the 108 prioritized Town-owned culverts to collect inventory data and to evaluate existing conditions.

3.2.3. Condition of Assessed Culverts

The inlet and outlet of each structure was assessed with respect to structural deficiencies (such as invert deterioration, deformation of structure, and condition of joints and seams) and hydraulic deficiencies (such as inlet and outlet elevation and scour) in accordance with the NAACC protocol, as well as operation and maintenance needs.

Of the assessed culverts, 56% were determined to be concrete material, 2% plastic, 12% corrugated metal pipe (CMP), 5% rock/stone, 9% were comprised of a combination of materials, and 17% were of unknown material. More than half of the assessed culvert barrels were 2 feet in diameter/span or less, with the remainder ranging up to 17 feet.

For the structural condition criteria evaluated at the inlet, 89% of the fully assessed culverts were found to be in adequate condition in terms of cross-section deformation, with 1% assessed to have deformation rated as “poor”, and 9% were unknown due to inaccessible inlets. Of the assessed culverts, 72% were found to have adequate joints and seams, 18% had poor joints and seams, and 1% had critical joints and seams. Furthermore, 83% of the assessed culverts had adequate structural integrity, with 7% poor or critical. This information was considered as part of the risk-based prioritization of culvert repairs and replacement, as discussed in Section 5.

Of the 13 CMP culverts assessed, eight (8) were small diameter (up to 2 feet) and five (5) were larger diameter (greater than 2 feet). 54% of the assessed CMP culverts had some level of invert deterioration (see an example shown in **Figure 3-1**), which will require more aggressive monitoring of the culvert condition in terms of deterioration and blockages.

Figure 3-1 Example of invert deterioration in a CMP culvert (Culvert 66)

3.2.4. Material Changes

Ten (10) of the 108 culverts assessed change material between the inlets and outlets of the culverts, as follows:

- Culverts 4, 42, and 68 change from concrete to stone/rock;
- Culverts 17 and 91 changes from metal to concrete;
- Culvert 37 changes from concrete to high-density polyethylene (HDPE);
- Culvert 78 changes from concrete to metal;
- Culverts 85 and Field 5 change from stone/rock to metal; and
- TPC-4 begins as RCP, transitions to clay, and outlets as RCP.

Culverts that change material throughout their length pose additional challenges to their structural integrity. In particular, joints where the material changes should be monitored more aggressively for separation, gaps, and root and sediment intrusion. This may require Closed-Circuit Television (CCTV) or other means to access the middle of the culvert span, since the condition of the inlet and outlet may not be representative of the mid-section condition.

3.2.5. Operation and Maintenance Observations

During assessments, O&M concerns were noted, such as tree growth, obstructions, excess trash, bulk dumping/yard waste, and nearby beaver dams. Obstructions may include items such as debris, stones, logs, trees, leaves, vegetation that partially or fully block flow through the culvert and reduce the structure’s hydraulic capacity. Some culverts were noted as having material or substrate present in the culvert (e.g., rock, gravel, sand) that can reduce the culvert capacity. This section summarizes these issues.

A beaver dam was observed near the inlet of two culverts (51, 59). The beaver dam was located within the culvert barrel of culvert 59 and directly outside the barrel of culvert 51.

Of the assessed culverts, 57 had a tree present near the upstream and/or downstream headwall/wingwall. Trees and their roots, if too close to culverts, can cause damage to the headwall/wingwalls and culverts and these culverts should be further assessed, monitored, and trees removed when needed to prevent future damage. A summary of culverts with nearby trees is provided in **Table 3-6**. These culverts should be further assessed, and trees removed as applicable to prevent future damage.

Table 3-6 Summary of Culverts with Trees near Headwalls/Wingwalls

Culvert ID	Address	Tree Location	Culvert ID	Address	Tree Location
1	Dedham St	Both	91	Old Farm Rd	Downstream
11	Haven St	Downstream	93	Francis St	Upstream
14	Hartford St	Both	94	Centre St	Downstream
17	Main St	Upstream	95C	Trail	Upstream
21	Centre St	Downstream	Field 3	Francis St	Downstream
22	Strawberry Hill St	Both	TPC-10	Strawberry Hill St	Upstream
26	Old Meadow Rd	Upstream	TPC-12	Bretton Rd	Downstream
35	Dedham St	Upstream	TPC-13	Normandie Rd	Downstream
38	Wakeland Rd	Upstream	TPC-14	Centre St	Downstream
4	Chestnut St	Both	TPC-15	Pegan Ln	Both
41	Donnely Dr	Upstream	TPC-18	Haven Ter	Upstream
42	Willow St	Both	TPC-2	Meadowbrook Rd	Both
44	Centre St	Both	TPC-20	Sherbrooke Dr	Downstream
47	Draper Rd	Both	TPC-21	Windsor Rd	Both
49	Hunt Dr	Downstream	TPC-24	Raleigh Rd	Upstream
50	Hunt Dr	Downstream	TPC-29	Farm St	Upstream
51	Dedham St	Both	TPC-3	Brook Rd	Both
53	Farm St	Both	TPC-31	Grand Hill Dr	Downstream
58	Hales Hollow	Upstream	TPC-33	Grand Hill Dr	Both
60	Springdale Ave	Upstream	TPC-34	Grand Hill Dr	Both
62	Wilsondale St	Upstream	TPC-36	Partridge Hill Rd	Upstream
63	Wilsondale St	Both	TPC-42	Snows Hill Ln	Downstream
65	Woodridge Rd	Both	TPC-43	Snows Hill Ln	Downstream
67	Cedar Hill Rd	Upstream	TPC-45	Pine St	Downstream
7	Grand Hill Rd	Both	TPC-47	Riga Rd	Downstream
73	Brookfield Rd	Upstream	TPC-57	Hartford St	Upstream
81	Greystone Rd	Downstream	TPC-6	Pleasant St	Upstream
83	Cedar Hill Rd	Both	TPC-9	Dedham St	Both
86	Old Farm Rd	Upstream	TPC-26	Farm St	Upstream
88	Mill St	Both			

Poor or critical roadway embankment conditions were noted at sixteen (16) upstream locations and fourteen (14) downstream locations. Poor roadway embankment conditions show severely undermined embankment protection (significant erosion of the embankment) and should be repaired as soon as possible. Critical roadway embankments noted have severe scour of the embankment and threaten the stability of the roadway, as shown in **Figure 3-2**. These should be addressed immediately. Of the 16 upstream locations, one (1) is noted as critical. Of the 14 downstream locations, three (3) are critical. The culverts identified as having critical embankment(s) are included in **Table 3-7**. **Appendix H** includes a summary of roadway embankment concerns.

Figure 3-2 Example of a culvert with a tree at the headwall and critical roadway embankment (Culvert 4)

Table 3-7 Summary of Culverts with Critical Roadway Embankments

Culvert ID	Address	Location
4	Chestnut St	Outlet
78	Farm St	Outlet
TPC-13	Normandie Rd	Outlet
TPC-7	Claybrook Rd	Inlet

Upstream scour damage was noted at 20 culverts. Scour could continue to erode the stream embankment, exposing the culvert structure. One location (Culvert 11) showed significant/extensive undermining and exposure of the culvert. Note that downstream scour damage was also evaluated and included as part of the criticality assessment described in Section 5. **Appendix H** includes a summary of upstream scour damage concerns.

Bends mid-crossing of the culvert were noted if present and the severity of the skew if applicable. These bends indicate the alignment of the crossing structure relative to the direction of the crossing inlet. Culverts found to have a bend indicate the culvert changes structural alignment under the roadway, and the greater the angle the more severe the rating. Culverts that have bends pose additional challenges to their structural integrity and should be monitored more aggressively for separation, gaps, and root and sediment intrusion. Culverts with bends greater than 45 degrees are shown in **Table 3-8**. **Appendix H** includes a summary of culverts with bends.

Table 3-8 Summary of Culverts with Bends Mid-Crossing (>45º)

Culvert ID	Address
20	Meadowbrook Rd
37	Centre St
TPC-25	Bridge St
TPC-32	Grand Hill Dr
TPC-33	Grand Hill Dr
TPC-38	Fox Run Rd

The condition of roadway features (road, guardrail, sidewalk, curbing) was also collected in the field at each culvert location. Each of these parameters can be used to help inform decisions in situations of rehabilitation or replacement of a culvert. Often, culvert defects and structural deficiencies will result in road settlement, pavement cracking, and ultimately roadway collapse. Guardrail condition, while not indicative of culvert condition, can be a useful metric to the Town's planning of roadway projects. **Table 3-9** includes a summary of culverts with at least one roadway feature rated in critical condition. Sidewalks and curbing were not present at the culverts included in the table.

Table 3-9 Culverts with Critical Roadway Features

Culvert ID	Address	Road	Guardrail
2	Willow St	Critical	Critical
3	Old Farm Rd	Adequate	Critical
59	Claybrook Rd	Adequate	Critical

Obstructions were observed at the culverts, including items such as screens or grates, wood, sediment, trash, piled vegetation or rocks, and debris. Some of the culverts had severe obstructions that limited the assessment of the barrels condition. **Figure 3-3** demonstrates the critical obstruction of TPC-29 because sediment and debris was built up, blocking the entire culvert inlet. The obstructions identified in the field are summarized in **Table 3-10**. These culverts should be further investigated and/or addressed as needed, and the condition of the culvert reevaluated once addressed.

Figure 3-3 Example of Critical Obstruction at Culvert Inlet

Table 3-10 also summarizes culverts that could not be assessed at the inlet and/or outlet. For example, TPC-23 was located was located but the inlet and outlet of the culvert barrel(s) were completely buried by sediment, water, and vegetation. Some culvert ends when visited were submerged in water so an assessment of the interior of the pipe could not be successfully completed.

Culverts that were found to be submerged for at least one end of the culvert are included in **Table 3-10**. If water levels do not regularly recede enough to expose the submerged culverts, there may be a hydraulic restriction within the stream branch. The Town could consider completing an additional assessment of hydraulic capacity to confirm whether the culverts are properly sized or if tailwater conditions exist.

Four culverts had an inlet or outlet that could not be located. These culverts should be added to the Town's culvert assessment and maintenance program for additional investigation.

Table 3-10 Summary of Culverts that Could Not Be Assessed or Have Obstructions

Culvert ID	Address	Inlet/Outlet	Reason
Culverts That Could Not Be Assessed			
3	Old Farm Rd	Both	Submerged
9	Picardy Ln	Both	Inlet covered by board; outlet is culverted pipe
12	Bryant Ln	Outlet	Submerged
15	Springdale Ave	Both	Submerged

Culvert ID	Address	Inlet/Outlet	Reason
16	Powisset St	Outlet	Debris blocking pipe
21	Centre St	Outlet	Submerged
42	Willow St	Inlet	Could not access inlet due to a high wall
45	Walpole St	Outlet	Submerged
51	Dedham St	Inlet	Blocked by beaver dam
59	Claybrook Rd	Inlet	Submerged
65	Woodridge Rd	Outlet	Buried underneath debris
75	County St	Both	Pipe full of debris
88	Mill St	Inlet	Submerged
98	Old Farm Rd	Both	Submerged inlet, outlet is culverted pipe
TPC-2	Meadowbrook Rd	Inlet	Inlet full of wood planks
TPC-5	Pleasant St	Both	Pipe full of debris
TPC-10	Strawberry Hill St	Inlet	Submerged or buried under debris
TPC-16	Haven St	Outlet	Buried under debris
TPC-23	Sterling Dr	Inlet	12” concrete pipe blocked by debris
TPC-44	Pine St	Inlet	Buried under debris
TPC-48	Abbott Rd	Both	Submerged
TPC-53	Powisset St	Inlet	Buried underneath debris
Obstructed Culverts			
10	Claybrook Rd	Inlet	Debris blockage
11	Haven St	Inlet	Debris blockage
38	Wakeland Rd	Inlet	Debris blockage
59	Claybrook Rd	Outlet	Critical blockage due to dam
67	Cedar Hill Rd	Inlet	Debris blockage
77	Trout Brook Rd	Both	Debris blockage
82	Smith St	Outlet	Debris blockage
TPC-7	Claybrook Rd	Both	Debris blockage
TPC-20B	Sherbrooke Dr	Inlet	Debris blockage
TPC-29	Farm St	Inlet	Debris blockage
TPC-40	Hamlins Crossing	Outlet	Blockage by bucket
1	Dedham St	Inlet	Fencing
63	Wilsondale St	Outlet	Fallen stone
91	Old Farm Rd	Inlet	Fencing
95A	Trail	Inlet	Fencing
TPC-28	Smith St	Inlet	Stone wall

Section 4 Risk-Based Prioritization

4.1. The Case for Asset Management

Stormwater systems have historically been managed by prioritizing the more immediate problems as they arise. This approach may underestimate the urgency of other stormwater system upgrades. Thus, the Town sought to take more of a proactive, data-driven decision making process to target stormwater assets that should be prioritized before they run to failure and become an emergency.

The current funding prioritization process for maintenance and capital projects does not consider "criticality" of drainage system components. **The relationship between the probability and consequence of failure determines the criticality of an asset**, as demonstrated in **Figure 4-1**. An asset in new condition (low probability of failure) with a low consequence of failure is considered a low risk asset. Conversely, an asset that is in poor condition (high probability of failure) and has a high consequence of failure is considered a critical asset with a high risk for the Town and should be at the top of the priority list. In this section, we describe how assessed culverts were prioritized using this approach. Criticality was not comprehensively scored for pipes and drainage structures. However, recommendations for this infrastructure based on simplified ranking is included in Section 5.

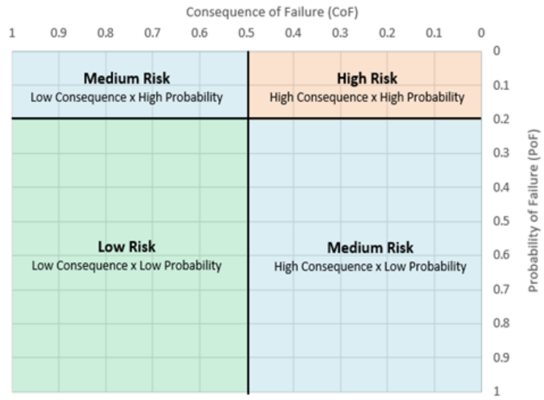


Figure 4-1 Criticality Matrix

Adopting an asset management approach for strategic maintenance and risk-based capital improvements will save Dover time and money in the long-term.

4.2. Priority Ranking of Assessed Culverts

Tighe & Bond utilized the culvert assessment results as components in assessing criticality. A full criticality assessment was not completed for other stormwater system assets. The Action Plan (see Section 6.6) includes recommendations to address observed maintenance needs and repair/replacement of other stormwater system infrastructure in poor condition.

In determining a culvert's criticality, there are two important questions:

1. How likely is the culvert to fail?
2. If the culvert does fail, what will be the consequence?

In the context of asset management, criticality is defined as an asset's probability of failure (PoF) multiplied by the severity and extent of the consequences of that failure (CoF). **Criticality allows the Town to manage its overall risk and provides a logical framework for allocation of operation and maintenance dollars and capital expenditures.**

The likelihood that an infrastructure component will fail is a function of the component's condition, performance, reliability, and maintenance history. Failure refers to the state of not meeting a desirable or intended objective. There are several modes of failure[7] that may occur, including:

- Mortality – The asset stops functioning due to a physical condition or break;
- Capacity – The asset is functioning but will not provide the quantity of service required;
- Level of service – Changes in needs or in regulations demand a higher level of service than the asset can deliver; and
- Financial inefficiency – The asset is costing more to repair than it would to replace.

Tighe & Bond's methodology for determining PoF and CoF and subsequently criticality for Dover's culverts is described in the following sections. The criticality analysis for culverts was completed and ranked using NAACC's probability of failure criteria and Tighe & Bond's customized consequence of failure criteria, as described in the following sections. It should be noted that additional factors, such as age, could be used in the Town's CoF and PoF analysis. However, since Dover is in the early stages of their asset management program and age data is limited, we used only the data available supplemented with visual assessments completed in the field.

4.3. Probability of Failure (PoF)

Failure of a culvert can be structural or hydraulic in nature. Structural failure could result in a partial or complete roadway collapse, as well as flooding and habitat impacts. Hydraulic failure, when there is partial or complete blockage of the structure, can lead to localized flooding and impacts to abutters or the roadway, or detrimental effects to sensitive habitat and aquatic species. A culvert may also be undersized for rainfall duration and intensity in combination with hydrological changes due to development and impervious surfaces in the watershed.

Probability of Failure was evaluated for each culvert assessed based on the data collected during condition assessments described in Section 3, as summarized in the following sections. The NAACC culvert condition scoring system discussed was used as the primary PoF rank to determine overall criticality. Additional data collected related to roadway condition and environmental concerns is presented in Section 4, which can also be used to help prioritize culvert maintenance, assessment, and rehabilitation needs.

[7] Modes of failure adapted from University of Southern Maine. Issue Brief, "Asset Management for Stormwater," April 2014. Available at: http://digitalcommons.usm.maine.edu/cgi/viewcontent.cgi?article=1000&context=sustainable_communities.

4.3.1. NAACC Culvert Condition PoF

In addition to the *Culvert Condition Assessment Manual* and *Culvert Assessment Form*, NAACC also has a *Culvert Condition Scoring System* that was used to assign a criticality score based on structural data collected in the field. The structural data used in the analysis included:

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

Per the NAACC methodology, if cross-section deformation, structural integrity of barrel, footings, or level of blockage at the inlet and/or outlet were marked as "critical" during the field assessment, the entire culvert was given a score of 0 for a highly critical PoF. The NAACC methodology has additional PoF rankings based on how many other parameters are noted as critical and/or poor, as summarized in **Appendix I**.[8] As described in the methodology, each culvert was assigned a score for each structural deficiency variable and the minimum score resulting from those is the overall score given for each culvert. For example, if a culvert appears to be in adequate structural condition at the inlet but the outlet has an obstruction blocking more than 75% of the opening, the outlet obstruction parameter would be categorized as critical during the field evaluation, and the overall culvert PoF would be categorized as critical as part of the NAACC ranking methodology. The scores ranged from 0 (most critical) to 1 (adequate condition). See Section 4.5 for a visual representation of the range of PoF scores.

Following the NAACC *Culvert Condition Assessment* methodology, 32 culverts were scored as critical for PoF. **However, not all culverts with a high PoF need replacement; some may simply need a minor repair or maintenance to extend the service life.** To further prioritize the culvert needs, Tighe & Bond completed an additional review of the critical PoF culverts (PoF score of 0 or 0.1) and used best professional judgement to sort them into different categories for various levels of recommended action: Monitoring, Maintenance, Rehabilitation, and Replacement. Additionally, using the Consequence of

[8] It should be noted that NAACC's scoring system also adds the term "not fully assessed" to the score if any field parameter was marked as "Unknown." Due to many Footings being of unknown condition (e.g., not visible, so unknown if they exist without referring to design plans), Tighe & Bond did not include this term in the culvert scoring.

Failure assessment discussed in Section 5.4, an overall criticality rank was determined to use risk to prioritize the Town's culverts. **Table 4-1** includes a summary of the 32 culverts that scored as critical for PoF. The recommendations for each category are further described in Section 5 and associated budgets are included in the Action Plan. CMP culverts tended to be identified as a higher priority in the criticality assessment when compared to other culvert materials. Three (3) of these culverts may require replacement, as discussed in Section 5. A budget for a regular monitoring program and culvert replacement and repair, as applicable, is presented in the Action Plan in Section 5.6.

Table 4-1 Summary of High PoF Culverts Based on NAACC Culvert Scoring

Culvert ID	Location	Criticality Rank	Notes and Recommendations
Maintenance/Further Investigation			
TPC-29	Farm Street	Medium	Stone masonry; clear inlet blockage, monitor structural integrity of walls
59	Claybrook Road	Medium	RCP; remove blockage
38	Wakeland Road	Medium	RCP; clear debris from inlet
60	Springdale Avenue	Medium	RCP; clear debris from inlet; monitor concrete deterioration and joint seperation
67	Cedar Hill Road	Medium	RCP; clear inlet blockage; monitor joint seperation
77	Trout Brook Road	Medium	RCP; clear debris blockage
TPC-2	Meadowbrook Road	Medium	RCP; clear wood blockage from inlet; monitor joint seperation
TPC-40	Hamlins Crossing	Medium	RCP; remove bucket
TPC-44	Pine Street	Medium	CMP; clear debris, monitor invert deterioration
Monitoring			
23	Old Meadow Road	Medium	Monitor invert deterioration
50	Hunt Drive	Medium	RCP; monitor structural alignment
TPC-7	Claybrook Road	Medium	RCP and concrete box; clear internal blockage
TPC-9	Dedham Street	Medium	RCP; clear blockage
Rehabilitation			
78	Farm Street	Medium	Metal pipe; replace damaged pipe section, repair headwall
14	Hartford Street	Medium	Repair headwall; monitor separation of joints
4	Chestnut Street	Medium	Repair headwall
TPC-20B	Sherbrooke Drive	Medium	RCP; repair headwall, clear blockage
TPC-27	Smith Street	Medium	RCP; repair headwalls
TPC-57	Hartford Street	Medium	CMP; repair damaged apron
TPC-6	Pleasant Street	Medium	RCP; repair headwall, monitor joint seperation
Replacement			
2	Willow Street	Medium	Replaced Summer 2024 after assessment
10	Claybrook Road	Medium	RCP; failing headwall, undersized, often blocked by beavers; Town applied for DER grant
11	Haven Street	High	CMP; deteriorating metal; heavy blockage; Town applied for DER grant
60	Springdale Avenue	Medium	RCP; undersized with invert deterioration, dammed; Town applied for DER grant for replacement study phase

66	Hartford Street	Medium	CMP; 100% section loss; Town applied for OneStop Grant
82	Smith Street	Medium	Stone; critical structural integrity; Put in catch basin and new pipe in-house
TPC-26	Farm Street	Medium	Stone; falling stones, blockage and poor alignment
TPC-28	Smith Street	Medium	CMP; invert deterioration and failing headwall; Replace in-house
TPC-50	Hartford Street	Medium	RCP; 100% section loss; culvert is programmed for replacement by DPW
Field 5	Farm Street	Medium	Metal pipe and stone; undersized and floods; failing headwall
51	Dedham Street	High	CMP; deteriorating invert, beaver dam upstream
62	Wilsondale Street	Medium	Stone; walls falling; under design
86	Old Farm Road	Medium	RCP; undersized with blockage; floods upstream; culvert is programmed for replacement by DPW

4.3.2. NAACC Aquatic Passage

In addition to NAACC's culvert condition assessment, NAACC also provides guidance for aquatic passability assessments in non-tidal streams and rivers. PoF was also evaluated for each culvert assessed based on the aquatic data collected during assessments described in Section 3. NAACC's *Aquatic Passability Scoring System* was used to assign a criticality score based on aquatic data collected in the field. The data used in the analysis included:

- Constriction
- Inlet grade
- Internal structures
- Outlet armoring
- Physical barriers
- Scour pool
- Substrate coverage
- Substrate matches stream
- Water depth
- Water velocity
- Outlet drop
- Openness
- Height

Appendix I includes the methodology for determining each culvert's aquatic passability PoF. To numerically evaluate each assessed culvert's aquatic passability, we used NAACC's scoring system that uses an algorithm to compute a score, ranging from 0 (most critical) to 1 (adequate). **Table 4-2** presents the NAACC aquatic passability scoring ranges. The scoring system is not particular to any taxonomic or functional group but instead seeks to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.

Table 4-2 NAACC Aquatic Passability Scoring Ranges

Descriptor	Aquatic Passability Score(s)
No Barrier	1.0
Insignificant Barrier	0.80-0.99
Minor Barrier	0.6-0.79
Moderate Barrier	0.40-0.59
Significant Barrier	0.20-0.39
Severe Barrier	0.00-0.19

Table 4-3 highlights the culverts with the lowest score for aquatic passability deficiencies. The highest weighted parameter is outlet drop, as NAACC's scoring guide states "although many factors can affect aquatic organism passage, when an outlet drop is above a certain size it becomes the predominant factor that determines passability." The following culverts were ranked the worst due to the size of their outlet drop or other factors as noted.

Table 4-3 Summary of Severe & Significant Barriers NAACC Aquatic Passability Scoring

Culvert ID	Aquatic Passability Score	Notes
50	-0.01[1]	Large Scour Pool Damage, Outlet Drop (4')
27	0.02	Outlet Drop (2'-3")

Culvert ID	Aquatic Passability Score	Notes
58	0.05	Outlet Drop (1’-10”)
49	0.07	Severe Constriction, Outlet Drop (1’-7”)
4	0.09	Outlet Drop (1’-4”)
60	0.09	Severe Constriction, Large Scour Pool Damage, Outlet Drop (1’-5”), Faster Water
11	0.22	Severe Constriction, Large Scour Pool Damage, Outlet Drop (11”), Shallower Water
47	0.22	Large Scour Pool Damage, Outlet Drop (11”)
81	0.22	Outlet Drop (11”)
TPC-19	0.25	Severe Constriction, Outlet Drop (10”), Faster Water,
53	0.30	Large Scour Pool Damage, Outlet Drop (9”)
TPC-13	0.30	Outlet Drop (9”), Shallower Water
61	0.31	Inlet Drop, Outlet Drop (5”), Shallower Water, Faster Water

[1] As shown in **Appendix I**, an equation is used to calculate outlet drop. For large, field measured values of outlet drops, the equation can produce a negative score.

4.4. Consequence of Failure (CoF)

If a component of Dover’s stormwater system fails, the consequences widely differ in severity and impact to the Town and its residents. A Consequence of Failure assessment considers hypothetical failure scenarios and the cost or impact of failure on the community, local government, or regulatory compliance. In particular, the CoF for culverts considers extent and severity of flooding and associated impact on the community (e.g., disruption of emergency services due to decreased access or reroute required, impaired ability for residents to egress from their homes/roadway to a main road, or impact to sensitive populations such as schools or nursing homes), the extent and severity of water quality degradation (e.g., impact on drinking water supply, sensitive species, or public bathing or recreational uses), and the difficulty of construction for replacement (e.g., existing site conditions or constraints). In many ways the CoF rating is subjective since it is often difficult to foresee all the direct and indirect consequences of a failure of an individual piece of equipment or infrastructure.

A summary of the items evaluated to determine the CoF ranking for each culvert location is listed below. These items were considered in terms of a complete culvert failure.

- Roadway class or type
- Number of houses impacted on a dead-end road OR length of a detour if a culvert failed and closed the road
- Culvert size and length
- If the culvert is in close proximity to buildings
- If a larger diameter town utility (water > 18”, sewer > 24”) crosses the culvert
- Road fill height
- Whether the culvert meets stream crossing standards
- If the culvert is located within a 100 or 500-year Federal Emergency Management Agency (FEMA) Flood Zone or a National Heritage & Endangered Species Program (NHESP) Priority/Estimated Habitat

Appendix J includes the methodology, criteria, ranking, weight, and maximum possible points for determining each asset's CoF. CoF factors were weighted based on the severity of the impact. Assets were evaluated for each criterion and assigned rankings based on the determined weighting factor. The value of each CoF category was summed and divided by the maximum possible CoF value to determine a normalized CoF for each drainage asset on a 0 to 1 scale, with a minimum score of 0 (most critical CoF) and a maximum score of 1 (least critical CoF). See Section 5.5 for a visual representation of the range of normalized CoF scores.

4.4.1. Environmental and Societal Assessment

As stated by MA Division of Fisheries and Wildlife, "A Coldwater Fish Resource (CFR) is a waterbody (stream, river, or tributary thereto) used by reproducing coldwater fish to meet one or more of their life history requirements. CFRs are particularly sensitive habitats."[9] Four (4) **coldwater fisheries** are located within Dover, as shown by the blue lines in **Figure 4-2**[10]. These include Trout Brook, Noanet Brook, Tubwreck Brook, and Mill Brook. Seven Town culverts (Culverts 10, 11, 15, 45, 47, 51, and 66) assessed as part of this effort are located along a coldwater fishery and are shown as red dots in the figure.

[9] MA Division of Fisheries and Wildlife. URL: https://www.mass.gov/info-details/coldwater-fish-resources
[10] MA Division of Fisheries and Wildlife, Sept 2022. URL: https://www.mass.gov/info-details/coldwater-fish-resources

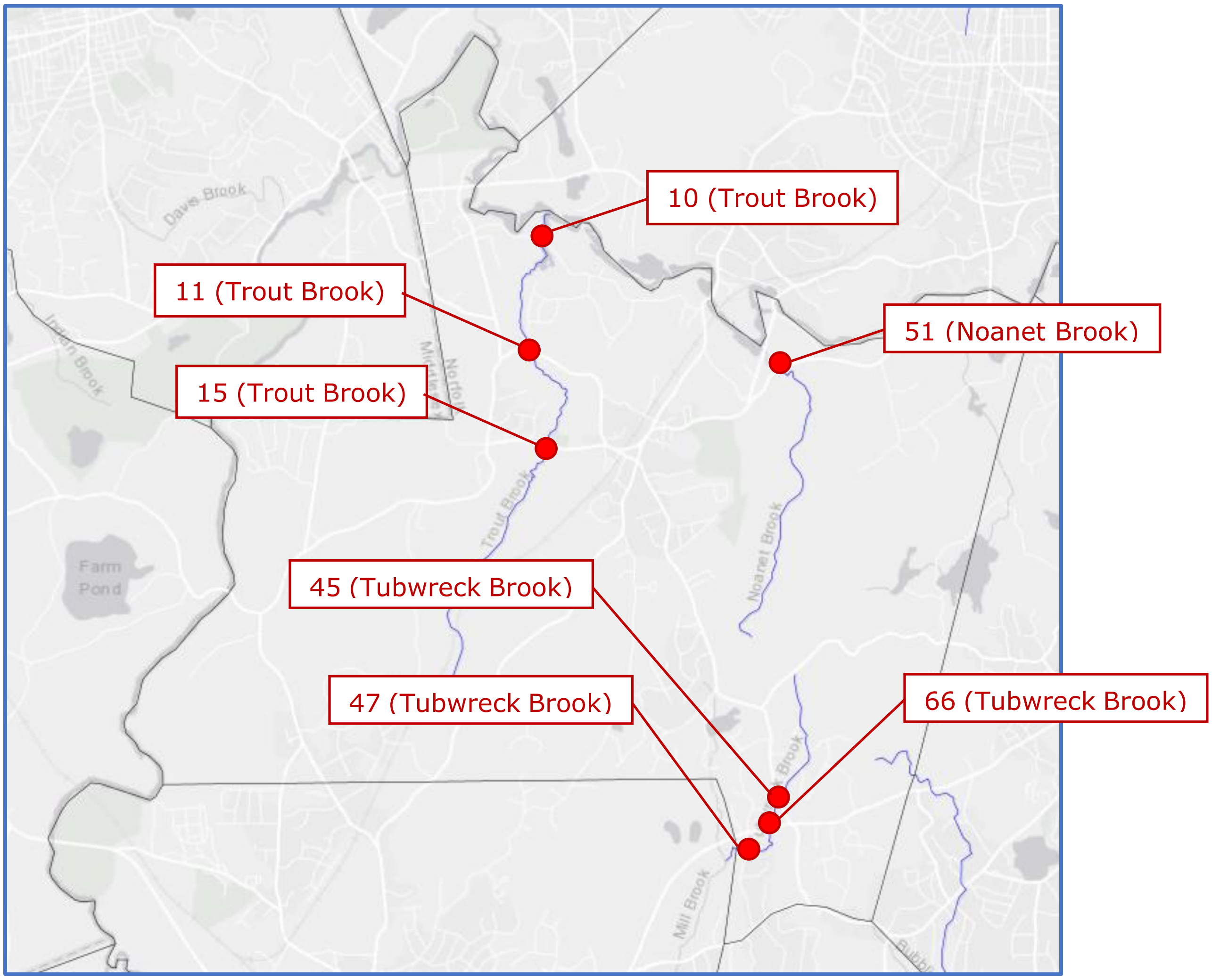


Figure 4-2 Coldwater Fisheries in Dover
(Source: MassGIS)

BioMap[11] is the result of an ongoing collaboration between MassWildlife and the Massachusetts Chapter of The Nature Conservancy (TNC). It is a framework for the strategic protection and stewardship of lands and waters that are most important for conserving biological diversity in Massachusetts. BioMap conservation targets are organized into two main elements: **Core Habitat and Critical Natural Landscape**. Core Habitat identifies areas that are critical for the long-term persistence of rare species, exemplary natural communities, and resilient ecosystems. Critical Natural Landscape identifies large landscape blocks that are minimally impacted by development, as well as buffers to core habitats and coastal areas, both of which enhance connectivity and resilience.

[11] BioMap, MassWildlife and the Massachusetts Chapter of The Nature Conservancy. Online mapping tool is available at the following URL: https://gis.eea.mass.gov/portal/apps/webappviewer/index.html?id=e2b6c291e0294c3281488621aaa095bf

There are areas of both Core Habitat and Critical Natural Landscape in Dover, as shown in **Figure 4-3**[12]. Replacement of culverts located within these areas may be more competitive for grant funding because they are located within areas of high ecological value. For example, the Massachusetts Division of Ecological Restoration's Culvert Replacement Municipal Assistance Grant Program prioritizes funding for an "undersized, perched, and/or degraded culvert located in an area of high ecological value" (see Section 6.3 for additional information on grant opportunities).

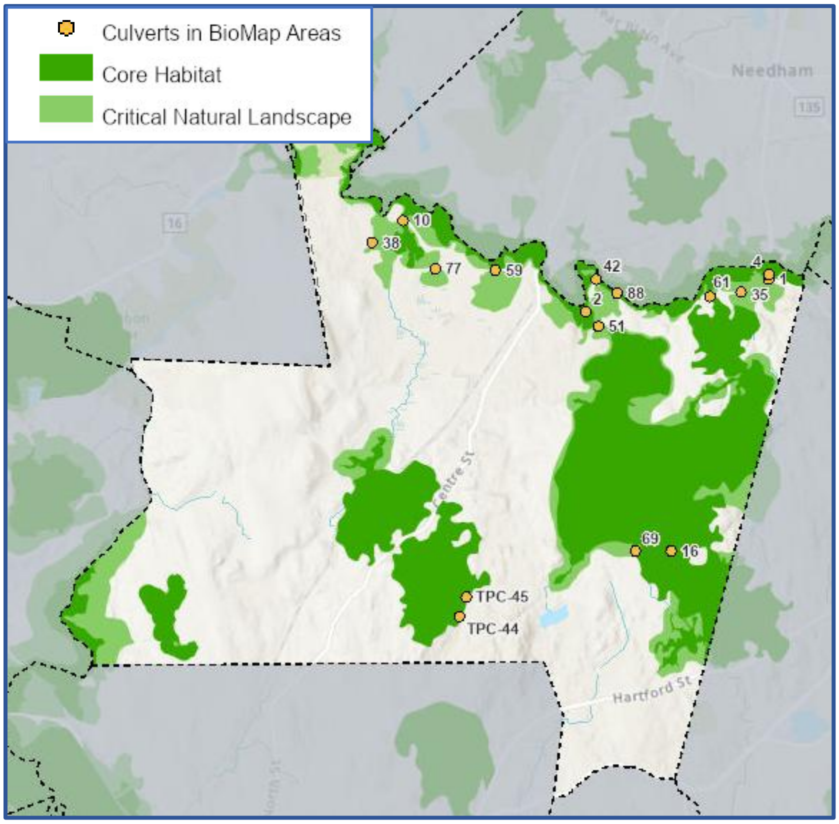


Figure 4-3 Culverts in BioMap Core Habitat and Critical Natural Landscapes in Dover

Table 4-4 includes a list of Dover's assessed culverts that are located within a BioMap area.

Table 4-4 Assessed Culverts Located within a BioMap Area

Culvert ID	Address	BioMap Category
1	Dedham Street	Core Habitat
10	Claybrook Road	Core Habitat and Critical Landscape
16	Powisset Street	Core Habitat and Critical Landscape
2	Willow Street	Core Habitat and Critical Landscape
35	Dedham Street	Core Habitat
38	Strawberry Hill Street	Core Habitat
4	Old Farm Road	Core Habitat and Critical Landscape
42	Willow Street	Core Habitat and Critical Landscape
51	Dedham Street	Core Habitat

[12] Source: MassMapper, January 2025. URL: https://maps.massgis.digital.mass.gov/MassMapper/MassMapper.html

59	Claybrook Road	Core Habitat and Critical Landscape
61	Dedham Street	Core Habitat
69	Powisset Street	Core Habitat
77	Trout Brook Road	Core Habitat
88	Mill Street	Core Habitat and Critical Landscape
TPC-44	Pine Street	Critical Landscape
TPC-45	Pine Street	Critical Landscape

Areas of Critical Environmental Concern (ACEC) are "places in Massachusetts that receive special recognition because of the quality, uniqueness, and significance of its natural and cultural resources."[13] The goal of identifying ACECs is to support and increase their level of protection. There are no ACECs in Dover.

The Town has no **environmental justice (EJ) area** within its boundaries[14]. These areas represent disadvantaged communities. As described by the MassGIS database, the areas are based on 2020 Census block groups that would meet one or more of the criteria listed below:

i. *"The annual median household income is not more than 65 percent of the statewide annual median household income;*

ii. *Minorities comprise 40 percent or more of the population;*

iii. *25 percent or more of households lack English language proficiency; or*

iv. *Minorities comprise 25 percent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 percent of the statewide annual median household income."*

4.5. Overall Criticality

Overall criticality for each culvert assessed during field work was determined by evaluating the PoF and CoF. The Criticality values fall into a "high," "medium," or "low" category with a recommended action for each.

Table 4-5 Criticality Categories and Associated Recommended Actions

Criticality Category	Value	Recommended Action
High criticality	If CoF ≤ 0.5 and PoF ≤ 0.2	Immediate Attention
Medium criticality	If CoF > 0.5 and PoF ≤ 0.2	Aggressive Maintenance
	or If CoF ≤ 0.5 and PoF > 0.2	Aggressive Monitoring
Low criticality	If CoF > 0.5 and PoF > 0.2	Routine Maintenance and Monitoring

[13] Information available at: https://www.mass.gov/info-details/acec-program-overview

[14] Source: MassMapper, January 2025. URL: https://maps.massgis.digital.mass.gov/MassMapper/MassMapper.html

A criticality matrix was created within Excel and the results are shown in **Figure 4-4**. Note that each dot in the figure may represent multiple culverts with the same score. This figure gives a snapshot of the overall condition of Dover's culverts and indicates that they are largely in good condition (bottom left quadrant), with some in need of regular maintenance and possibly replacement (top left quadrant, high PoF) and monitoring (bottom right quadrant, high CoF).

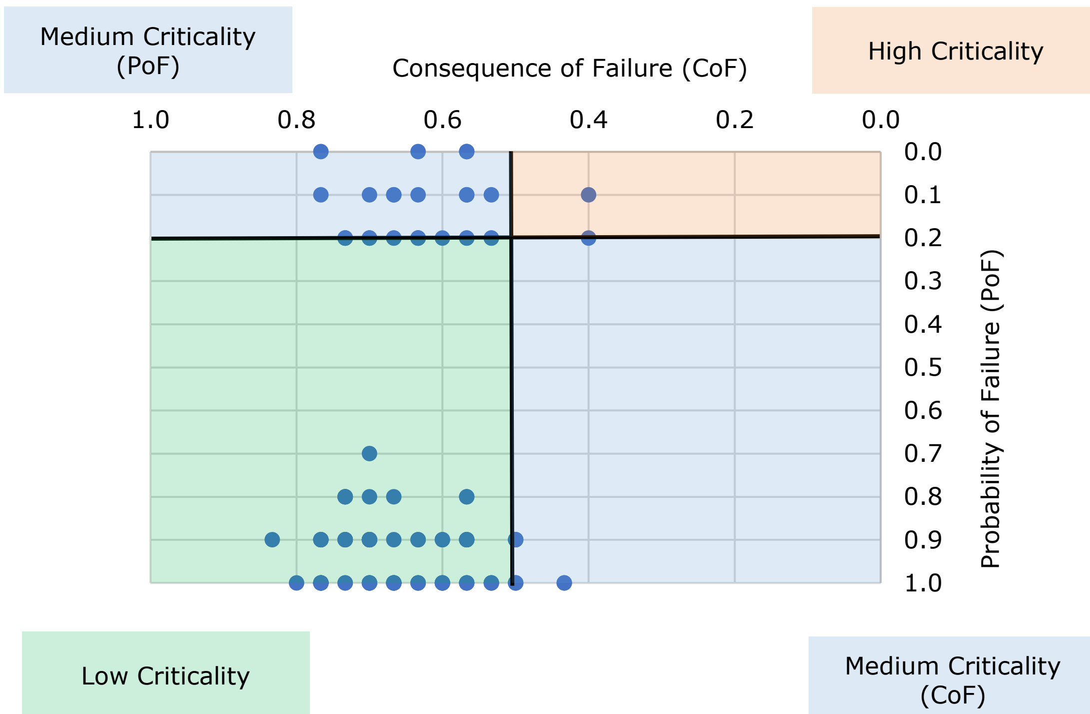


Figure 4-4 Assessed Culvert Criticality Matrix

A summary of the two (2) culverts with the highest criticality ranking is included in the following table. These culverts are located in the top right quadrant of the overall criticality figure.

Table 4-6 Culverts with High Criticality Scoring

Culvert ID	Location	Recommendation
11	Haven Street	Replacement
51	Dedham Street	Replacement

As described in Section 4.3, not all culverts with a low PoF (high criticality) are in need of replacement; some may simply need a minor repair or maintenance to extend the service life. Recommendations for these High Criticality culverts are further described in Section 5. The CoF and PoF ranks, criticality score, and priority ranking of each culvert assessed during field work is included in **Appendix K**.

Section 5 Recommendations

This Section presents recommendations to further refine and implement the Town's Stormwater Asset Management Program based on work completed to date, including capital improvements, further investigation or study, maintenance needs, and overall programmatic improvements.

5.1. Capital Improvements

Based on the finding of this asset management study, the following culverts are recommended to be prioritized for repair or replacement. A proposed schedule to complete these projects is included in the Action Plan in Section 5.6. Project Summaries and opinions of probable construction cost (OPCC) are included in **Appendix L** for the recommended culverts for replacement. Recommendations for high priority maintenance and additional repairs are discussed in Section 5.2.

Table 5-1 Recommended Repair or Replacement Capital Improvements

Culvert ID	Location	Summary of Recommendations
Years 1-5		
10	Claybrook Road	Replace
11	Haven Street	Replace
60	Springdale Avenue	Replace
66	Hartford Street	Replace
82	Smith Street	Replace
TPC-26	Farm Street	Replace
TPC-28	Smith Street	Replace
TPC-50	Hartford Street	Replace
51	Dedham Street	Replace
62	Wilsondale Street	Replace
78	Farm Street	Partial demo and repair
86	Old Farm Road	Replace in-house
After Year 5		
Field 5	Farm Street	Replace
14	Hartford Street	Repair Headwall
4	Chestnut Street	Repair Headwall
TPC-20B	Sherbrooke Drive	Repair Headwall
TPC-27	Smith Street	Repair Headwalls
TPC-57	Hartford Street	Repair Apron
TPC-6	Pleasant Street	Repair Headwall

5.1.1. Estimated Replacement Cost Methodology

OPCCs were developed for three (3) of the highest priority culvert repair or replacement capital projects and included in **Appendix L**. Descriptions of our assumptions are summarized in this Section. It should be noted that these OPCCs were developed using the limited information available based on the field assessment, with no detailed survey or design having been performed. Two (2) of the OPCCs propose repair or replacement of the existing culvert with a concrete pipe. One OPCC proposes replacement of the existing culvert with a box culvert structure. Other costs included in the CIP were obtained from the Town for in-progress replacements.

At the request of the town, OPCCs were done assuming replacement structures would remain a culvert. Costs could increase significantly if future studies indicate a larger structure size, requiring MADOT CH85 review and approval.

The suitability of the box and pipe culvert structure assumes competent subsurface conditions at each site to support the proposed replacement structure. All culverts were assumed to bear directly on grade, and it was assumed no spread footings or deep foundations will be required.

The presence of water and sewer utilities at each structure was considered based on available GIS data during the development of these OPCCs. The presence of buried gas, electric, and telecommunications utilities is unknown and will need to be confirmed during preliminary design.

Full road closure was assumed for the purpose of developing the OPCC for culvert 78. Phased construction was assumed for TPC-26 and TPC-50. No considerations for Accelerated Bridge Construction (ABC) techniques were included in the costs presented.

Due to the limitations highlighted above in addition to a highly volatile economic climate, a 30 to 40% Project Contingency and an allowance for minor items has been included in these OPCCs. Upon further assessment and design of each culvert, these contingencies may be lowered to better reflect the advanced design and bidding climate at the time.

The OPCCs for Culvert 78 and TPC-50 assume Town staff will complete the design, permitting, and construction versus hiring an engineer and contractor to reduce costs. Additionally, if culverts were replaced in-kind instead of improving existing conditions (e.g., installing/replacing guardrails, meeting stream crossing standards), the Town could realize some cost savings. Justification would need to be provided to the State regarding MARSCS if site conditions exist such that MARSCS cannot be met. Tighe & Bond does not advise this approach unless emergency replacement is needed and precludes improvements.

5.2. Targeted Maintenance and Repairs

Many of the more significant O&M concerns noted during assessments are summarized in Sections 2 and 3. Additional information is included in the asset inventories and the GIS inventory. Completing targeted maintenance and repairs may extend a culvert's service life and allow the Town to reassess the Probability of Failure and overall Criticality.

To supplement the Town's existing routine stormwater maintenance plan, Tighe & Bond developed a standard operating procedure (SOP) related to culvert repair and maintenance. The SOP is included in **Appendix M** and can be referenced for culvert maintenance and repairs.

A suggested schedule of targeted maintenance with identified maintenance or repair needs is provided below, which can be modified and adapted to best fit the Town's needs. Once maintenance or repairs are completed, the Town can update the GIS inventory with a record of the work complete and log updated photos. Additionally, the condition of the asset can be reassessed and the PoF and criticality rankings updated.

Table 5-2 Recommended Targeted Maintenance or Repair Schedule

Maintenance Item	Schedule
Targeted replacement recommendations (Table 4-1 "Replacement" category)	Address needed replacements in FY2025 through FY2034. A budget is carried in the Five-Year Action Plan in Section 6.6.
Targeted maintenance/ rehabilitation recommendations (Table 4-1 "Maintenance/ Further Investigation" and "Rehabilitation" categories)	Address recommended rehabilitation, maintenance and re-assess the culverts as necessary to determine culvert condition.
Targeted monitoring recommendation (Table 4-1 "Monitoring" category)	Conduct frequent monitoring of the culvert's condition. See Section 5.5.3.1 for more information. An annual budget is included in the Action Plan.
Remove culvert obstructions (Section 3.2.5)	Clean culverts with obstructions and beaver dams in FY2026 through FY2034 and reassess culvert condition. An annual budget is included in the Action Plan.
Remove trees after additional assessment (Table 3-6)	Assess the culverts noted with tree growth annually starting in FY2026, and remove trees damaging the culvert with concurrence from Conservation Commission. Assess annually after removal.
Further investigation (Table 3-10)	Clean and conduct further investigations of the culverts that were submerged, buried, and/or not located. An annual budget is included in the Action Plan.
Targeted maintenance/repairs recommendations (Section 2.1.2, Table 2-3)	In FY2024, the Town should drainage pipes with maintenance needs. An annual budget is included in the Action Plan. Re-assessments should be completed as necessary to determine asset condition.
Targeted repair/rehabilitation recommendations	Address needed repairs of drainage pipes in FY2025 through FY2034. An annual budget is carried in the Action Plan.

5.3. Further Assessment or Study

Culverts that could not be assessed because of sediment, debris, or water levels should be cleaned in order to update the inventory and determine whether there are any deficiencies. For some culverts, Tighe & Bond was able to obtain enough condition information to determine a high PoF; however, additional investigation is recommended prior to design to provide additional information about the condition and identify possible construction constraints. **Table 3-10** includes a summary of culverts that could not be assessed and require additional investigation.

Once maintenance is complete, we recommend completing assessments at the higher priority culverts that had substantial sediment buildup. An annual budget for follow-up camera investigations is included in the Five-Year Action Plan in Section 5.6. The Town should use additional information from future assessments to revise the PoF score and overall criticality rank. For example, additional evidence of risk of failure for a high CoF culvert would increase the criticality rank to High and require expedited improvements at the culvert.

5.4. Opportunistic Asset Repair or Replacement

Roadway, water, and/or sewer system improvement projects may offer a cost-effective opportunity to replace or repair stormwater infrastructure within the proposed project extents. Specific roadway, water, and/or sewer system improvement projects did not influence the prioritization analysis completed herein. The Town should evaluate whether a culvert or other drainage structure replacement or repair is necessary while planning a construction project to assess feasibility of including additional stormwater system upgrades as part of the project. In some cases, a lower priority asset could be proactively addressed during a planned capital project.

5.5. Programmatic Recommendations

Based on the work completed as part of developing this program, Tighe & Bond is providing the following programmatic recommendations to help the Town plan and schedule key asset management activities for AMP implementation in the near-term.

5.5.1. Ongoing Stormwater Management Program Implementation

The Town recognizes that the stormwater system is a necessary public utility and in an ongoing effort to minimize stormwater impacts within Dover, has worked to develop stormwater management within Town. In order to continue to support its goals, Sections 2 and 3 highlighted aspects of the stormwater system that require continued upkeep. The Town should complete dry weather screening of newly mapped outfalls and investigate catchment areas of outfalls or interconnections for possible illicit discharges or connections. Follow-up investigations and mapping modifications are recommended. The Town should continue to improve drainage system mapping during subsequent field investigations. Connectivity between structures and outfalls should be refined and the GIS mapping updated accordingly.

5.5.2. Coordinate with MassDOT on Small Bridges Identified

The Town of Dover may coordinate with MassDOT by providing location information for the culvert with 10-foot or larger span (potentially a small span bridge) identified during this project (see Section 3.1.1). Dover staff can coordinate directly with the District 6 Engineer. The benefit of doing this is that MassDOT will ultimately provide an inventory and complete inspections of the small span bridges consistent with the State's system, and those locations are eligible for funding under the Municipal Small Bridge Program. See Section 6.3 for more information about the Program.

5.5.3. Develop a Routine Assessment Program

The Town of Dover may develop a routine culvert assessment program. The culvert assessment protocol and electronic field form developed as part of this project can be used to evaluate culverts that have not been assessed under this AMP or the NAACC program to determine a baseline condition of all existing culverts. Once that baseline is established, the Town should continue to complete re-assessments of the culverts. Re-assessments do not need to consist of a full inventory, but instead should be completed to collect comparative information and to continue to monitor drainage asset condition over time. Photographs and limited notes are critical to follow-up. An annual budget has been included in the Action Plan in Section 5.6 for development and implementation of a routine assessment program for the drainage system, with a goal of each culvert being assessed every five (5) years at a minimum. **Assessment frequencies should be more frequent for culverts with critical CoF and for CMP culverts.**

5.5.4. Additional Staff Training

Train additional Town staff upon hiring and regularly thereafter on how to properly complete the various components in the asset management program, including asset inventory data collection, assessments, workflow, and record management. Incorporate GIS applications into staff training wherever possible.

5.5.5. Data Collection and Tracking

Continue to implement GIS data management practices to manage the Town's stormwater assets across Town departments. A consistent workflow and record management process is recommended for culvert and drainage system management. The current data collection forms can be used for new assets located or installed and adapted for future re-assessments as needed. The Town should evaluate the current workflow and records management process to identify any needed changes or updates. The culvert inventory should be updated with a new assessment as culverts are improved or replaced, including culvert 2 on Willow Street which was recently replaced.

5.5.6. Continued Risk Assessment

Broaden the Asset Management Program risk assessment evaluation to rank all stormwater assets into a high, medium, and low priority list to help inform future stormwater capital improvement projects. The ranking should be updated continuously as infrastructure is newly assessed, replaced, and/or rehabilitated.

5.5.7. Additional Public Education and Outreach

As drainage system improvements are completed, the Town could consider a public education campaign outlining the work and the benefits to the community (both water quality and drainage performance).

5.5.8. Staff and Equipment

The Town will need to evaluate the necessity of hiring additional Highway Department staff and purchasing additional vehicles and equipment to implement and oversee the recommendations described. In the future, building upon the Town's existing Highway staff may improve workflow and tracking drainage-related expenditures. See Section 6 for additional analysis of the Town's stormwater funding needs.

5.6. Five-Year Action Plan

Table 5-3 presents the Five-Year Action Plan to support capital improvements, further investigations, targeted maintenance and repairs, and programmatic recommendations for Dover's drainage system. The Plan presents recommended projects, follow-up actions, and associated budgets as previously described in this report. Recommendations may be for one-time costs or annual costs. Capital and programmatic recommendations were evaluated against the goals of this Program and a five-year plan was developed with consideration for desired level of service, local priorities, and available funding. Note that not all of the culverts listed in **Table 5-1** are scheduled within the Five-Year Action Plan; medium priority culverts will be targeted after Year 5.

The Action Plan provides the Town with the ability to prioritize spending, plan for and normalize expenditures over the planning period, and minimize operating and maintenance costs.

Note the Action Plan includes a nominal budget for stormwater program compliance, including MS4 consulting services. The budget generally does not include routine good housekeeping or Town staff field work under the IDDE Program. Annual budgets for compliance should be evaluated in more detail for each MS4 Permit Year; this may be completed once the 2024 draft Small MS4 General Permit is issued as final.

TABLE 5-2
5-Year ACTION PLAN

Culvert ID	Road Name	Criticality Score	Recommendation	Notes	Opinion of Probable Cost FY27	FY28	FY29	FY30	FY31
Priority Capital Planning									
10*	Claybrook Road	Medium-High PoF	Replace - DER grant	RCP; failing headwall, undersized, often blocked by beavers	$ 100,000.00	$ 500,000.00			
11*	Haven Street	High	Replace - DER grant	CMP; deteriorating metal; heavy blockage		$ 100,000.00	$ 500,000.00		
60 *	Springdale Avenue	Medium-High PoF	Replace - DER study phase grant	RCP; undersized with invert deterioration, dammed			$ 100,000.00	$ 500,000.00	
66*	Hartford Street	Medium-High PoF	Place - OneStop grant	CMP; 100% section loss		$ 100,000.00	$ 500,000.00		
82*	Smith Street	Medium-High PoF	Replace -Put in catch basin and new pipe	Stone; critical structural integrity; Town would like to complete replacement in-house		$ 100,000.00	$ 500,000.00		
TPC-26	Farm Street	Medium-High PoF	Replace - 6' Box Culvert	Stone; falling stones, blockage and poor alignment			$ 283,000.00	$ 1,157,000.00	
TPC-28*	Smith Street	Medium-High PoF	Replace	CMP; invert deterioration and failing headwall; Town would like to complete replacement in-house				$ 100,000.00	$ 500,000.00
TPC-50	Hartford Street	Medium-High PoF	Replace with 3' RCP pipe	RCP; 100% section loss			$ 140,000.00	$ 415,000.00	
51*	Dedham Street	High	Replace	CMP; deteriorating invert, beaver dam upstream; shovel ready	$ 500,000.00				
62*	Wilsondale Street	Medium-High PoF	Replace	Stone; walls falling; under design	$ 100,000.00	$ 500,000.00			
78	Farm Street	Medium-High PoF	Partial demo and repair	Metal pipe; replace damaged pipe section, repair headwall				$ 140,000.00	$ 190,000.00
86*	Old Farm Road	Medium-High PoF	Replace	RCP; undersized with blockage; floods upstream; Town would like to complete replacement in-house				$ 100,000.00	$ 500,000.00
				SUBTOTAL	**$ 600,000.00**	**$ 800,000.00**	**$ 2,023,000.00**	**$ 2,412,000.00**	**$ 1,190,000.00**
				SUBTOTAL plus 3% annual inflation	**$ 636,540.00**	**$ 874,181.60**	**$ 2,276,904.32**	**$ 2,796,169.07**	**$ 1,420,922.23**
Targeted Maintenance and Repairs									
Refer to Section 5.2†					$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
				SUBTOTAL	**$ 10,000.00**	**$ 10,000.00**	**$ 10,000.00**	**$ 10,000.00**	**$ 10,000.00**
				SUBTOTAL plus 3% annual inflation	**$ 10,609.00**	**$ 10,927.27**	**$ 11,255.09**	**$ 11,592.74**	**$ 11,940.52**
Programmatic Improvements									
Culvert Assessment Program (annual budget)					$ 15,000.00	$ 15,000.00	$ 15,000.00	$ 15,000.00	$ 15,000.00
Ongoing Maintenance†					$ 25,000.00	$ 25,000.00	$ 25,000.00	$ 25,000.00	$ 25,000.00
GIS Data Maintenance (in-house)					$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
Annual Updated PoF, Criticality, and Recommendations					$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
				SUBTOTAL	**$ 55,000.00**	**$ 55,000.00**	**$ 55,000.00**	**$ 55,000.00**	**$ 55,000.00**
				SUBTOTAL plus 3% annual inflation	**$ 58,349.50**	**$ 60,099.99**	**$ 61,902.98**	**$ 63,760.07**	**$ 65,672.88**
				TOTAL	**$ 705,498.50**	**$ 945,208.86**	**$ 2,350,062.40**	**$ 2,871,521.88**	**$ 1,498,535.63**

Notes:
* Denotes culverts where the Town would like to carry $100,000 for design and permitting and $500,000 for construction.
† Tighe & Bond has assumed that the majority of this maintenance work can be performed by the Town. This cost is an annual allowance for materials and limited outside contractor support.
1. See Appendix L for culvert replacement OPCC.
2. Costs included herein are FY26 dollars. Annual culvert capital improvement project subtotals carry 3% inflation annually after FY26. Note estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the probable cost.

Color Key:	
$	Design & Permitting Costs
$	Construction Cost

Section 6 Funding Considerations for Implementation

The previous sections demonstrated the Town's initiative and desire to proactively manage their stormwater system assets. However, the greatest challenge associated with implementation of any asset management program is a municipality's ability to consistently allocate funds to pay for the improvements identified in Section 6. The following section presents a summary of potential funding opportunities.

6.1. Anticipated Future Program Costs

As shown in the Action Plan budgets (**Table 5-2**), the average annual program expenditure for FY26 through FY35 is approximately **$1.7 Million** for both capital and AMP operating budgets. With the projected increased level of service required to complete the Town's currently unfunded needs, as well as plan for future capital projects, the Town may consider implementing a stormwater utility fee in the future and/or investigating additional stormwater funding alternatives outlined in the following section. Due to the limitations of Massachusetts Proposition 2 ½ (G.L c59 §21C), the Town may not fully fund these report recommendations with only the General Fund. It may be necessary to borrow for the more significant culvert projects and incorporate debt service into the annual budget.

6.2. Stormwater Enterprise Fund

Similar in structure to the enterprise funds many public water and wastewater utilities use for funding their associated operation and maintenance costs, funding for stormwater management programs can be generated through a separate public enterprise fund, which is in turn funded by revenue from fees for that service. This fund, and the associated task of implementing a fee schedule, has been authorized by the Commonwealth (G.L. c.83 §16) as an acceptable way to raise money for stormwater management. Specifically, a fee can be charged to generate funds "to plan, construct, operate and maintain stormwater facilities and to conduct stormwater programs." With an enterprise fund, the Town charges a user fee to each property (a user of the Town's stormwater services) based on the characteristics of the property that drives stormwater management costs.

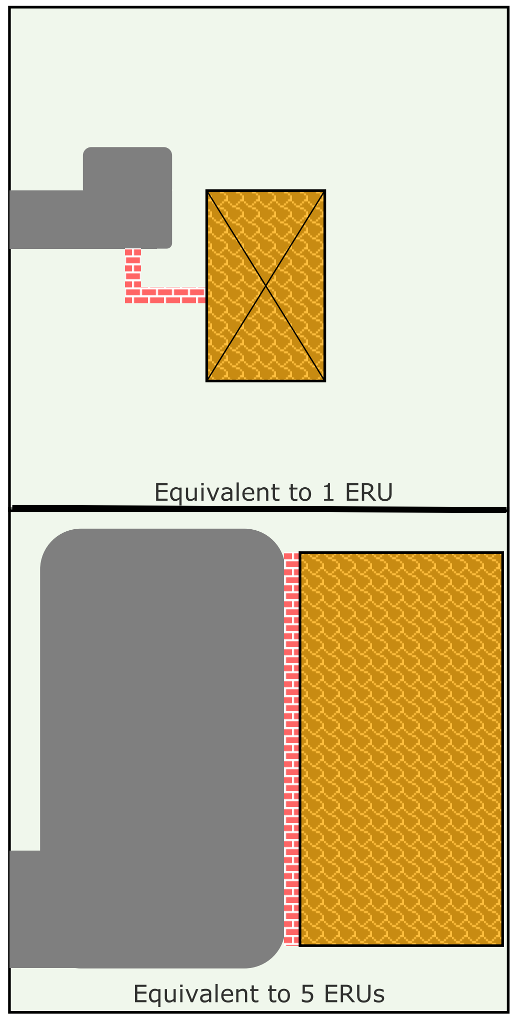


Figure 6-1 Demonstration of the ERU Concept

Impervious area is the most used method to assess stormwater fees in the United States. It is a well-established method to measure a property's stormwater impact. "The relationship (or nexus) between impervious area and stormwater impact is relatively easy to explain to the public—you pave, you pay."[15] The key data required to establish a stormwater fee is impervious cover per parcel. An Equivalent Residential Unit (ERU) is commonly used to simplify system accounting and represents the median amount of impervious cover in a typical residential parcel. Using this value as a common denominator, an ERU equivalent is calculated for non-residential parcels by dividing the impervious area of each parcel by the residential value. For example, if a property has five times more impervious cover than the typical residential property, they will have five times the ERU and would pay five times the fee charged a typical residential property. **Figure 6-1** demonstrates this concept.

Dover does not have a stormwater fee but may consider establishing one to provide funds for the operation, maintenance, repair, and capital improvement of the Town's stormwater system. This will be explored under the Phase 2 Asset Management Plan awarded through the 2025 IUP.

6.3. Additional Stormwater Funding

The following State or Federal grant and loan programs were investigated for eligibility and reliability of obtaining funds for implementation of the AMP:

- Massachusetts Chapter 90 Program;
- Clean Water State Revolving Fund (SRF) Loan Program;
- Water Infrastructure Assessment Management and Planning Grants;
- Section 319 Nonpoint Source Competitive Grants Program;
- Section 604b Grant Program: Water Quality Management Planning;
- Stormwater MS4 Municipal Assistance Grant Program;
- Federal Emergency Management Agency (FEMA) Hazard Mitigation Assistance Grant;
- Municipal Vulnerability Preparedness (MVP) Action Grant Program;
- MassDOT Municipal Small Bridge Program; and
- DER Culvert Replacement Municipal Assistance Grant Program.

Table 6-1 summarizes key information on these potential funding sources to determine the feasibility of procuring funds for Dover's Stormwater AMP. Though several other communities have used these funding sources, the Town should investigate these further to determine if any are appropriate. Additional information on these funding sources and other potential funding options is provided by the Massachusetts Office of Coastal Zone Management "Available Funding for Stormwater Projects in Massachusetts" webpage.[16]

[15] U.S. Environmental Protection Agency New England. *Funding Stormwater Programs* (EPA 901-F-09-004). April 2009. URL: https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/FundingStormwater.pdf
[16] Available funding for stormwater projects in Massachusetts: https://www.mass.gov/service-details/available-funding-for-stormwater-projects-in-massachusetts

Advantages

- Additional funding sources could lessen the burden on the Town's taxpayers or ratepayers.
- Dover has had a lot of success applying for and being awarded grants for the Town's culvert replacement program. Dover staff is familiar with many grant processes.

Disadvantages

- Grants and loans are not a reliable funding source.
- There are increased administration costs associated with grant or loan application and management.
- While some grant projects may help meet some AMP goals, projects will need to significantly advance other State or Federal initiatives such as improving water quality, resiliency, or climate mitigation to be considered for funding.

Table 6-1 Summary of Potential Grant and Loan Funding Sources

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
Chapter 90 Funds Grant Program	Capital improvement projects such as highway construction, preservation and improvement projects that create or extend the life of capital facilities. Includes roadside drainage projects incidental to roadway projects.	100% reimbursable loan program.	For additional information see: https://www.mass.gov/chapter-90-program#:~:text=Chapter%2090%20entitles%20cities%20and,the%20life%20of%20capital%20facilities
Clean Water State Revolving Fund (SRF) Loan Program	Projects that help to meet water quality standards and create clean water systems. The program emphasizes watershed management priorities, stormwater management, and green infrastructure. Eligible projects include, but are not limited to: • Nonpoint source pollution abatement projects, such as pollution prevention and stormwater remediation. • Non-structural projects, such as green infrastructure planning projects for nonpoint source problems which are consistent with the MassDEP's Nonpoint Source Management Plan and that identify pollution sources and suggest potential remediation strategies.	Low-interest loan program. The current subsidy is provided via a 2% interest loan or a 0% interest loan for certain wastewater nutrient management projects. In recent years the program has operated with $400 to $450 million per year, representing the financing of 50 to 70 projects annually.	Competitive projects: • Will have demonstrable water quality benefits. • Will eliminate or mitigate a risk to public health. • Is needed to achieve or maintain compliance with applicable discharge permits or other water pollution control requirements. • Will implement or be consistent with watershed management plans (or addresses a watershed priority) and is consistent with local and regional growth plan. For additional information see: https://www.mass.gov/service-details/srf-clean-water-program

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
Section 319 Nonpoint Source Competitive Grants Program	Projects that address the prevention, control, and abatement of nonpoint source pollution. NPDES and MS4 permit required items are not eligible under this grant program unless projects are outside of the Regulated Area or completed in advance of permit deadlines. In general, eligible projects must: • Implement measures that address the prevention, control, and abatement of NPS pollution. • Target the major source(s) of nonpoint source pollution within a watershed/sub-watershed. • Contain an appropriate method for evaluating the project results. • Address activities that are identified in the Massachusetts NPS Management Plan. Draft and Final NPDES MS4 and RDA stormwater permit requirements will dictate project eligibility. Projects within MS4 regulated areas that meet the grant program requirements are eligible provided the work is not required under a current or pending NPDES stormwater permit. In areas regulated by these permits, s.319 funds cannot be used for work that is required in the permits. The regulated discharges become point sources that are no longer eligible for nonpoint source funding. A municipality that contains both regulated and unregulated areas is eligible for s.319 funds for work in the unregulated area.	Funds are paid on a reimbursement basis, and MassDEP retains 10% of the award amount until the project is finalized. From FY1990-2021, individual grant awards have ranged from $10,000-$500,000. For FY2022 the total anticipated grant expenditure was $1,600,000, with MassDEP having the discretion to award various funding amounts per project.	For additional information see: https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality https://www.mass.gov/guides/determining-ms4-status-of-the-project-area

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
Section 604b Grant Program: Water Quality Management Planning	Projects that address water quality assessment and management planning. For FY2022, MassDEP focused funds on watershed or sub-watershed based nonpoint source assessment and planning projects that result in one of the following: • Development of Watershed-based Plans (WBP) for local watershed planning and to support future 319 grant implementation projects. • Development of a WBP for the Section 319 Grant's Healthy Watersheds Project, to be used to guide watershed protection and management activities. • Determination of the nature, extent, and causes of water quality problems and determination of pollutant load reductions necessary to meet water quality standards. • Development of preliminary designs and implementation plans that will address water quality impairments in impaired watersheds. • Development of green infrastructure projects that manage wet weather events to maintain or restore natural hydrology. (See: https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality#604(b)-grant-program:-water-quality-management-planning)	In general, individual grant awards range from $25,000-$50,000 and approximately 4 to 6 projects are selected annually. A monetary match is not required but is preferred. Funds are paid on a reimbursement basis, and MassDEP retains 10% of the award amount until the project is finalized.	Competitive projects: • Support basin-wide water quality management activities. • Identify sources of water quality impairment due to nonpoint source pollution in high priority waterbodies • Use watershed-based plans to build partnerships and build capacity as well as identify water quality remediation or protection strategies in high priority waterbodies. • Link the proposed Best Management Practice (BMP) to the pollutant of concern and impact to targeted water resources. • Provide clearly defined, practical, and cost-effective objectives. • Propose strategies with a high likelihood of success. • Consider long-term resiliency to climate change impacts in site prioritization, design, siting, and selection of BMPs. • For additional information see: https://www.mass.gov/info-details/grants-financial-

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
			assistance-watersheds-water-quality
Stormwater MS4 Municipal Assistance Grant Program	Applicants must be groups of two or more Massachusetts municipalities or Regional Planning Agencies, stormwater coalitions, or non-profit organizations representing two or more municipalities that are subject to the 2016 Small MS4 General Permit. Projects must result in tools or approaches that will help multiple municipalities meet one or more requirement(s) of the 2016 Small MS4 General Permit. Eligible projects must also: • Provide a shared benefit to multiple communities, including environmental justice communities. • Not duplicate work already done by any Massachusetts stormwater coalition or where a previously funded project delivery is applied to another region. Examples of potentially eligible, MS4-focused projects include, but are not limited to: (see list here: https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality#stormwater-ms4-municipal-assistance-grant-program-).	Total funding currently available under this grant is $300,000 and individual awards typically range from $50,000 to $300,000. Applicants are not required to provide matching funds but are encouraged to identify other known sources of funding.	For additional information see: https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality#stormwater-ms4-municipal-assistance-grant-program-

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
FEMA Hazard Mitigation Grant Program	A variety of mitigation projects including, but not limited to: • Drainage improvement projects to reduce flooding (flood risk reduction projects). Retrofits to utilities and other infrastructure to enhance resistance to natural hazards (utility retrofits).	Funding is based on the estimated total or aggregate cost of disaster assistance: • Up to 15% of the first $2 billion. • Up to 10% for amounts between $2 billion and $10 billion. • Up to 7.5% for amounts between $10 billion and $35.333 billion. States with enhanced mitigation plans: Up to 20%, not to exceed $35.333 billion.	Communities must submit a sub-applicant application to the state who submits it to FEMA. A non-federal cost share is required for all sub-applications and may consist of cash, donated or third-party in-kind services, materials, or any combination thereof. Generally, the cost share is 75% federal/25% non-federal. For additional information see: https://www.fema.gov/grants/mitigation/hazard-mitigation
Municipal Vulnerability Preparedness (MVP) Action Grant Program	Open to municipalities who have completed the Community Resilience Building (CRB) process and received MVP Community designation from EEA. The MVP program's 10 Core Principles should be incorporated into the application: (see full list here: https://www.mass.gov/doc/mvp-core-principles/download)	Projects are required to provide monthly updates, project deliverables, and a brief project case study of lessons learned. Eligible applicants can request up to $3,000,000 in funding. The municipality is required to match 25% of total project cost using cash or in-kind contributions.	For additional information see: https://www.mass.gov/info-details/mvp-action-grant

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
MassDOT Municipal Small Bridge Program	Bridges must be on a local public way and must be on the State Bridge Inventory with a span between 10 and 20 feet.	Each municipality may receive up to $100,000 for design services and $500,000 for construction per year to aid in the replacement and preservation of municipally-owned bridges. Costs over $500,000 will be borne by the municipality. This program provides for state reimbursement to municipalities of up to 100% of the total design and construction cost of eligible projects. MassDOT and selected municipalities enter into an agreement to reimburse funds for approved projects.	For additional information see: https://www.mass.gov/municipal-small-bridge-program
NOAA Restoring Fish Passage through Barrier Removal Grants	Funds to implement locally-led removals of dams and other in-stream barriers. Selected projects will assist in sustaining fisheries and contributing to the recovery of threatened and endangered species	NOAA will accept proposals between $750,000 and $8 million for the entire award, with typical funding anticipated to range from $3 million to $5 million.	For additional information see: https://www.fisheries.noaa.gov/grant/restoring-fish-passage-through-barrier-removal-grants
NFWF Northeast Forests and Rivers Fund	The Northeast Forests and Rivers Fund is dedicated to restoring and sustaining healthy forests and rivers that provide habitat for diverse native bird and freshwater fish populations in the New England states. Funds apply to projects that restore early successional and mature forest habitat, modify and replace barriers to fish movement, restore riparian and instream habitat, and restore stream connectivity.	This program annually awards competitive grants ranging from $75,000 to $300,000 each.	For additional information see: https://www.nfwf.org/programs/northeast-forests-and-rivers-fund

Grant/Loan Program	Eligible Project Types – Relevant to Stormwater	Funding	Additional Notes
MassWorks	Improvements to publicly-owned infrastructure including streets, roads and by extension, culverts and small bridges—particularly when they support economic development, safety, housing, or transit	Planning $5K Construction $5M	https://www.mass.gov/info-details/community-one-stop-for-growth
MassDER Culvert Replacement Municipal Assistance Grant Program	Replacement or removal of undersized, perched, and/or degraded culverts in areas of high ecological value.	Historically, individual awards have ranged from $25,000 to $400,000. Awards over $200,000 are anticipated for construction projects only.	https://www.mass.gov/how-to/culvert-replacement-municipal-assistance-grant-program
Massachusetts Federal Grant Matching Funds (FFIO)	Matching Funds for federal awards	N/A	https://www.mass.gov/orgs/federal-funds-infrastructure-office
Congressionally Directed Funding	Projects Vary	N/A	https://www.warren.senate.gov/congressionally-directed-spending-federal-funding-requests-fy2025

Section 7 Permitting for Culvert Replacements

Drainage system replacement or repair projects, specifically for culverts, may require permits under the following federal, state, and local regulatory programs. Permit pathways for any repair or replacement projects depend largely on site-specific conditions, the selected design alternative, and cumulative resource area impacts. Potentially applicable regulatory approvals are summarized herein.

- **Wetlands Protection Act Notice of Intent/Order of Conditions –** Culvert improvements are assumed to involve work within jurisdictional resource areas regulated by the Massachusetts Wetlands Protection Act (WPA; *M.G.L. c. 131*, § *40*) and implementing regulations (310 CMR 10.00). It is assumed that a Notice of Intent (NOI) filing would be required with the Dover Conservation Commission and MassDEP.
- **Massachusetts Environmental Policy Act (MEPA) –** Depending on the project, review thresholds set forth by MEPA (defined under 301 CMR 11.03) may be exceeded and the preparation and submittal of an Environmental Notification Form (ENF) could be required. MEPA review involves submission of an ENF to the Office of Energy and Environmental Affairs (EEA), public notice requirements, a site visit, and response to comments resulting from the public comment period.
- **Massachusetts Endangered Species Act (MESA) Review –** Depending on the culvert location, *Priority Habitats of Rare Species* or *Estimated Habitats of Rare Wildlife* may be present. If present, the project may be subject to a MESA Project Review. Rare Species Information Request would likely also need to be submitted the Massachusetts Natural Heritage and Endangered Species Program (NHESP) to verify the species identified within the project area to guide project design and best management practice development.
- **Chapter 91 Waterways License –** Projects involving activities other than in-kind replacement or basic maintenance that result in the installation of a different size structure may require Chapter 91 licensing, if the stream is considered a jurisdictional waterway under Chapter 91 of the Massachusetts Public Waterfront Act and implementing regulations at 310 CMR 9.00. Jurisdictional waterways include submerged lands lying below the high water mark of any non-tidal river or stream on which public funds have been expended for stream clearance, channel improvement, or any form of flood control or prevention work, either upstream or downstream within the river basin, except for any portion of any such river or stream which is not normally navigable during any season, by any vessel including canoe, kayak, raft, or rowboat are jurisdictional.
- **Section 401 Water Quality Certification –** A Section 401 Water Quality Certification (WQC) may be required for culvert replacements if any project results in either in a loss of 5,000 square feet cumulatively of Bordering or Isolated Vegetated Wetlands and Land Under Water, the amount of any proposed dredging is greater than 100 cubic yards, or if any of the other thresholds listed in 314 CMR 9.04 are met. If impact areas do not exceed these thresholds, the WPA Order of Conditions will serve as the 401 WQC.
- **Section 404 Army Corps Pre-Construction Notification –** Culvert replacement projects will involve work within Wetlands and Waters of the United States

regulated under Section 404 of the Clean Water Act. The Corps' General Permits (GP) for Massachusetts cover specific activities within the limits of Corps' jurisdiction as stated in each of the activity General Permits. The total temporary and permanent impact area is used to determine if a project is eligible for Self-Verification, Pre-Construction Notification, or Individual Permit coverage. It is assumed that most, if not all, of the projects would require a permit application to submitted to the Corps.

In addition to environmental factors, the MA General Permit requires notification of the State Historic Preservation Officer (SHPO), Tribal Historic Preservation Officers (THPOs), and the Massachusetts Board of Underwater Archaeological Resources (MABUAR) per Section 106 of the National Historic Preservation Act, which could take place as part of the Massachusetts Historical Commission (MHC) PNF submittal discussed below.

- **Massachusetts Historic Commission –** Any new construction projects or renovations to existing structures that require funding, licenses, or permits from any state or federal governmental agencies must be reviewed by the State Historic Preservation Officers, including MHC, MABUAR, and pertinent THPOs for impacts to historic and archaeological properties in accordance with Section 106 of the National Historic Preservation Act of 1966 and 950 CMR 71. The purpose of this review is to ensure that projects minimize or mitigate adverse effects to properties listed in the National and/or State Register of Historic Places. It is assumed that a Project Notification Form (PNF) will need to be completed and submitted to relevant parties for all replacement projects. Should review under the MEPA be required, a copy of the MEPA ENF can be provided to these agencies to initiate historical review and may preclude the need to file a PNF.
- **MassDOT State Highway Access Permit –** Any work that is to take place within State Highways, including detours and traffic signage, require a State Highway Access Permit. The State Highway Access Permit will determine the level of traffic management and control required, changes needed on the alignment, the level of pavement restoration required, the types of bonds and insurances required, and revisions to the design for work in the State Highway.
- **MassDOT Chapter 85 –** If a culvert replacement increases the structure's span to 10 feet or greater (to meet MARSCS, for example), it would be considered a bridge by MGL definition. Designs for proposed vehicular bridges in the Commonwealth of Massachusetts are subject to MassDOT review and approval per MGL Chapter 85. The review covers hydraulic, geotechnical, and structural design components. It should be noted that design requirements under MGL Chapter 85 are far more extensive than those of culverts and therefore are more costly to design and construct.

APPENDIX A

Tighe&Bond

November 10, 2023
Dover Stormwater Asset Management Plan Questionnaire

Project Overview:

The Dover Stormwater Asset Management Plan provides the Town with support to develop an improved stormwater asset inventory to help inform capital improvement planning and build a more robust stormwater asset management and operations and maintenance program.

An important step in the development of an Asset Management Program (AMP) is to determine the Level of Service goals. We would like to gain your input on goals, priorities, problems, and future plans for the stormwater system and overall AMP. Please read through this questionnaire for background on the project and the AMP, and think about items that are important to the Town. This will be discussed further at the Level of Service workshop.

Project Goals and Vision:

Project Goals Identified in the Asset Management Grant Application:

- Develop an inventory and a better understanding of existing stream crossings, including bridges and culverts.
- Develop an inventory and a better understanding of the existing drainage system and outlets.
- Create a risk-based AMP and capital improvement planning methodology that will support decision makers and be available for public presentation.
- Develop a program that emphasizes proactive measures to improve existing maintenance practices to avoid systems reaching failure.
- Coordinate with the Town's established water quality programs (MS4, lakes and ponds, etc.) and resiliency planning.
- Define a desired Level of Service, develop a stormwater map in GIS, determine the condition of all stream crossings, and a representative selection of existing drainage, and develop a prioritized primary and secondary list of assets.
- Obtain conceptual Opinions of Probable Construction Cost (OPCC) for repair or replacement of the most severely ranked structures as needed to program capital requirements.

Identify your top 2 goals and any challenges to meet goals in the questionnaire on pg. 3.

Level of Service (LOS):

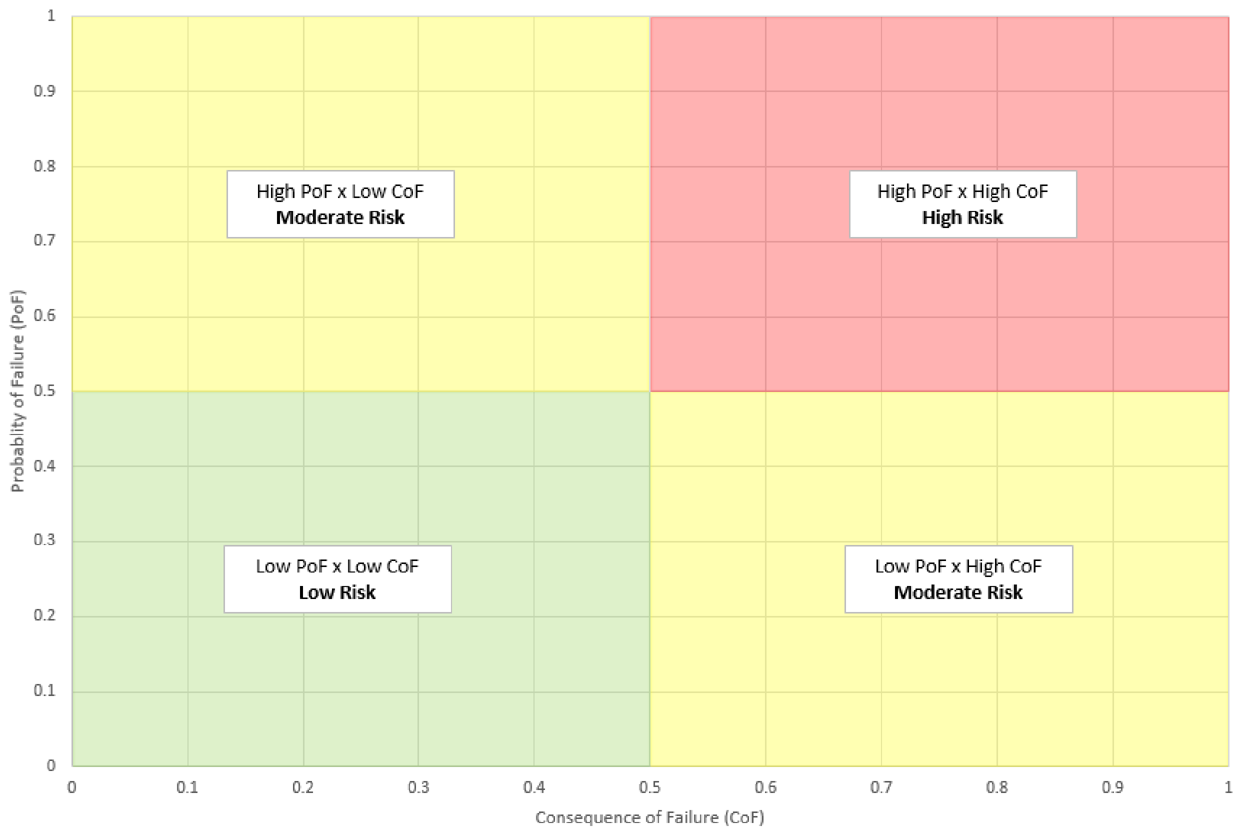
- How a system operates and manages its assets to meet customer expectations
- LOS sets the framework for stormwater spending decisions.
- Set **SMART(ER)** Goals: **S**pecific, **M**easurable, **A**ttainable, **R**elevant, **T**ime-bound, **E**valuate, **R**e-do. Examples:
    - Clean and inspect a minimum of 50% of catch basins and drain manholes to ensure proper functioning of the drainage system and prevent flooding.
        - Is it measurable? Yes. Inspect biannually and clean if needed.

Review questionnaire on pg. 3 and attached example LOS goals spreadsheet and start thinking about LOS goals for the Town's stormwater program. These will be discussed during the LOS workshop.

Assessing Infrastructure Criticality for Risk-Based Prioritization

Infrastructure Criticality is evaluated and ranked using Probability of Failure (PoF) and Consequence of Failure (CoF). For example, an asset in excellent condition (low PoF) with a low CoF is considered a low risk asset. The asset criticality rankings feed into a prioritized list of recommended projects for a Capital Improvement Plan (CIP).

$$\textit{Criticality Risk} = \textit{PoF x CoF}$$



Probability of Failure (PoF), or likelihood of failure, metrics are based on the asset itself, and can include:

- <u>Material</u> – clay and corrugated metal pipes will have higher PoF scores.
- <u>Condition</u> – assets in poor condition with known issues or recurring failures will have a higher PoF score. Useful metrics include failure history, maintenance history, inspection reports, known performance issues, field condition assessments.
- <u>Capacity</u> – culverts, catch basins, or drainage pipes full of sediment and not functioning properly will have higher PoF scores.

Consequence of Failure (CoF) metrics are more subjective and specific to each user/ community related to the cost or impact of failure on the community, local government, or regulatory compliance. They can include:

- Severity of impact of a failed infrastructure component (environmental, social, economic, safety impacts, etc.)
- Size of drainage infrastructure may play a role, as failure of a 48" culvert would have a larger impact than failure of a 12" culvert.

Fill out questionnaire on pg. 3 and 4 to help determine CoF scoring for a variety of factors.

Tighe&Bond

Level of Service Questionnaire

Fill out the questionnaire and return it to Eric Ohanian at EOhanian@TigheBond.com by November 17, 2023. Tighe & Bond will compile responses to aide in the discussion at the Level of Service Workshop.

Name and Title: ____

Project Goals and Vision:

What are your top two goals for your stormwater infrastructure/Asset Management Program or desired outcomes for this project?

1. ____

____

____

2. ____

____

____

What will be the biggest challenges to achieve the project goals?____________________

____

____

____

____

Level of Service Goals: Identify your top five LOS Goals *(review attached spreadsheet for examples LOS Goals)*:

1. ____
2. ____
3. ____
4. ____
5. ____

Level of Service Questionnaire, cont.

Consequence of Failure factors:

Score each CoF factor from 1 (low importance) to 5 (high importance):
Ranking numbers may be used more than once.

________ **General Impacts to Users**: assets with greater potential user impact or disruption to the public will have a higher CoF score (e.g., distance of detour for road closure to repair culvert)

________ **Critical Customers or Locations**: assets serving critical customers (schools, hospitals, etc.) or locations of the system (main roads, downtown, railroad, etc.) will have a higher CoF score. *Identify these areas or properties below.*

________ **Asset Size**: Larger pipe or capacity is usually indicative of higher CoF

________ Potential Impact to **Sensitive Environmental Resources** (e.g., Natural Heritage and Endangered Species Priority (NHESP) or Estimated Habitat)

________ Potential Impact to **Disadvantaged Communities (Environmental Justice)** (e.g., regular flooding in a low-income neighborhood)

Other CoF considerations?____

____

____

____

____

Identify the critical customers or locations in Town:__________________________

____

____

____

____

Identify any critical areas in Dover.
Add notes, why is it critical?
Examples: areas prone to flooding, critical locations or customers, etc.

____

____

____

Tighe&Bond

November 10, 2023
Dover Stormwater Asset Management Plan Questionnaire

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Project Goals and Vision:

Project Goals Identified in the Asset Management Grant Application:

- Develop an inventory and a better understanding of existing stream crossings, including bridges and culverts.
- Develop an inventory and a better understanding of the existing drainage system and outlets.
- Create a risk-based AMP and capital improvement planning methodology that will support decision makers and be available for public presentation.
- Develop a program that emphasizes proactive measures to improve existing maintenance practices to avoid systems reaching failure.
- Coordinate with the Town's established water quality programs (MS4, lakes and ponds, etc.) and resiliency planning.
- Define a desired Level of Service, develop a stormwater map in GIS, determine the condition of all stream crossings, and a representative selection of existing drainage, and develop a prioritized primary and secondary list of assets.
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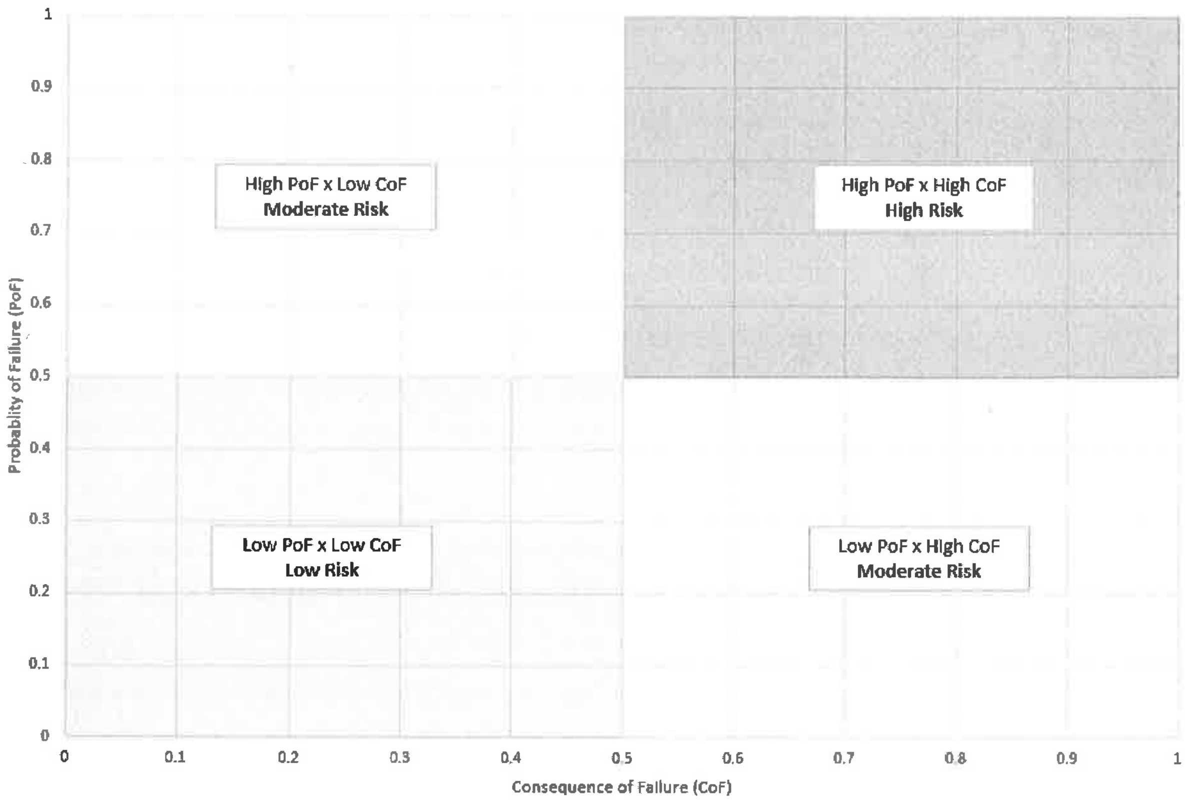
$$Criticality\ Risk = PoF \times CoF$$



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- Size of drainage infrastructure may play a role, as failure of a 48" culvert would have a larger impact than failure of a 12" culvert.

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Level of Service Questionnaire

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Name and Title: Todd Wilcox Acting Chief

Project Goals and Vision:

What are your top two goals for your stormwater infrastructure/Asset Management Program or desired outcomes for this project?

1. Improve existing maintenance to avoid Culvert / drainage failure.
2. Get a better understanding of the existing Culverts and drainage systems.

What will be the biggest challenges to achieve the project goals? Funding to rebuild systems.

Level of Service Goals: Identify your top five LOS Goals *(review attached spreadsheet for examples LOS Goals)*:

1. Identify and Correct problem areas
2. Minimize future flooding
3. Clean basins / culverts routinely
4. ~~Minimize the~~ Water Quality
5. Schedule long term repair / maintenance.

Tighe&Bond

November 10, 2023
Dover Stormwater Asset Management Plan Questionnaire

Project Overview:

The Dover Stormwater Asset Management Plan provides the Town with support to develop an improved stormwater asset inventory to help inform capital improvement planning and build a more robust stormwater asset management and operations and maintenance program.

An important step in the development of an Asset Management Program (AMP) is to determine the Level of Service goals. We would like to gain your input on goals, priorities, problems, and future plans for the stormwater system and overall AMP. Please read through this questionnaire for background on the project and the AMP, and think about items that are important to the Town. This will be discussed further at the Level of Service workshop.

Project Goals and Vision:

Project Goals Identified in the Asset Management Grant Application:

- Develop an inventory and a better understanding of existing stream crossings, including bridges and culverts.
- Develop an inventory and a better understanding of the existing drainage system and outlets.
- Create a risk-based AMP and capital improvement planning methodology that will support decision makers and be available for public presentation.
- Develop a program that emphasizes proactive measures to improve existing maintenance practices to avoid systems reaching failure.
- Coordinate with the Town's established water quality programs (MS4, lakes and ponds, etc.) and resiliency planning.
- Define a desired Level of Service, develop a stormwater map in GIS, determine the condition of all stream crossings, and a representative selection of existing drainage, and develop a prioritized primary and secondary list of assets.
- Obtain conceptual Opinions of Probable Construction Cost (OPCC) for repair or replacement of the most severely ranked structures as needed to program capital requirements.

Identify your top 2 goals and any challenges to meet goals in the questionnaire on pg. 3.

Level of Service (LOS):

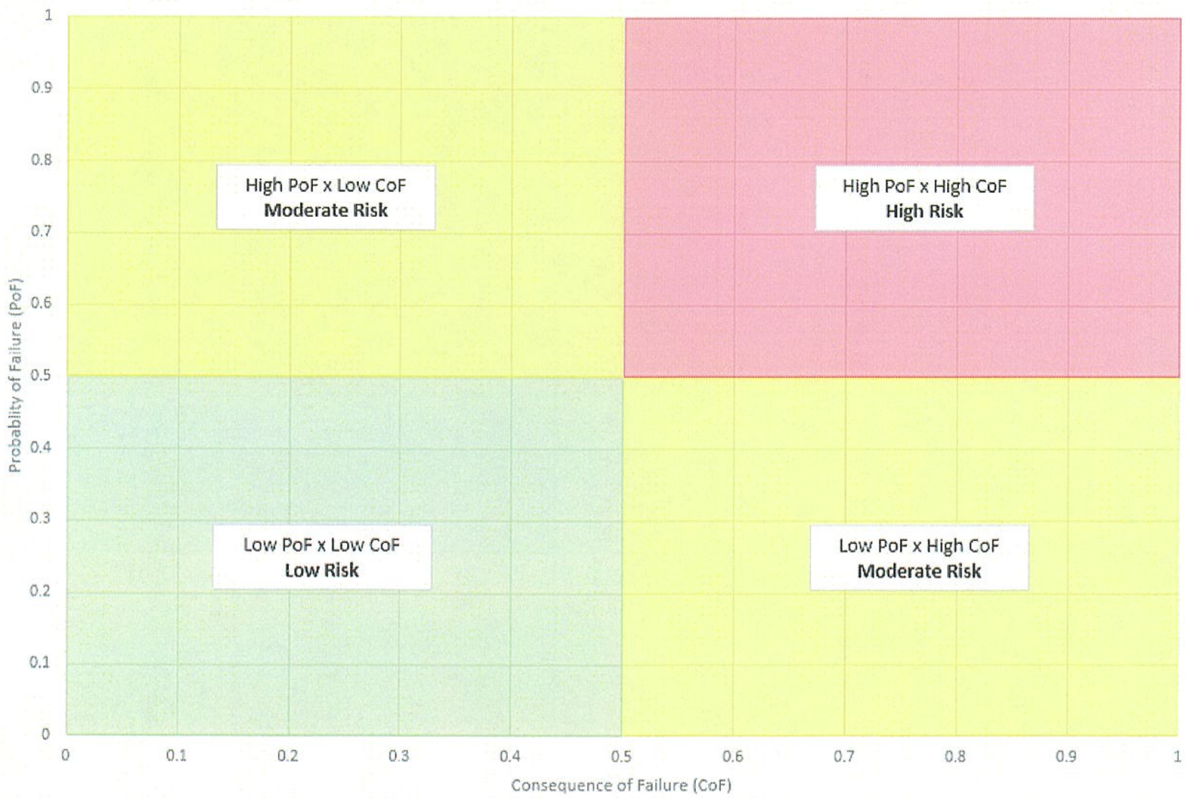
- How a system operates and manages its assets to meet customer expectations
- LOS sets the framework for stormwater spending decisions.
- Set **SMART(ER)** Goals: **S**pecific, **M**easurable, **A**ttainable, **R**elevant, **T**ime-bound, **E**valuate, **R**e-do. Examples:
  - Clean and inspect a minimum of 50% of catch basins and drain manholes to ensure proper functioning of the drainage system and prevent flooding.
    - Is it measurable? Yes. Inspect biannually and clean if needed.

Review questionnaire on pg. 3 and attached example LOS goals spreadsheet and start thinking about LOS goals for the Town's stormwater program. These will be discussed during the LOS workshop.

Assessing Infrastructure Criticality for Risk-Based Prioritization

Infrastructure Criticality is evaluated and ranked using Probability of Failure (PoF) and Consequence of Failure (CoF). For example, an asset in excellent condition (low PoF) with a low CoF is considered a low risk asset. The asset criticality rankings feed into a prioritized list of recommended projects for a Capital Improvement Plan (CIP).

$$\textit{Criticality Risk} = \textit{PoF} \times \textit{CoF}$$



Probability of Failure (PoF), or likelihood of failure, metrics are based on the asset itself, and can include:

- Material – clay and corrugated metal pipes will have higher PoF scores.
- Condition – assets in poor condition with known issues or recurring failures will have a higher PoF score. Useful metrics include failure history, maintenance history, inspection reports, known performance issues, field condition assessments.
- Capacity – culverts, catch basins, or drainage pipes full of sediment and not functioning properly will have higher PoF scores.

Consequence of Failure (CoF) metrics are more subjective and specific to each user/ community related to the cost or impact of failure on the community, local government, or regulatory compliance. They can include:

- Severity of impact of a failed infrastructure component (environmental, social, economic, safety impacts, etc.)
- Size of drainage infrastructure may play a role, as failure of a 48" culvert would have a larger impact than failure of a 12" culvert.

Fill out questionnaire on pg. 3 and 4 to help determine CoF scoring for a variety of factors.

Tighe&Bond

Level of Service Questionnaire

Fill out the questionnaire and return it to Eric Ohanian at EOhanian@TigheBond.com by November 17, 2023. Tighe & Bond will compile responses to aide in the discussion at the Level of Service Workshop.

Name and Title: Kevin McCabe DPW Director

Project Goals and Vision:

What are your top two goals for your stormwater infrastructure/Asset Management Program or desired outcomes for this project?

1. Identify biggest risk to town, to plan replacement to be proactive.

2. Compile robust capital to plan for grants & local funding.

What will be the biggest challenges to achieve the project goals? Funding to reconstruct many culverts / drain lines.

Level of Service Goals: Identify your top five LOS Goals *(review attached spreadsheet for examples LOS Goals)*:

1. Implement long-term CIP to replace, repair, & maintain asset on proactive schedule
2. minimize flooded roadways
3. use CIP to identify grants
4. Water quality
5. Sustainable funding (storm water utility)

Level of Service Questionnaire, cont.

Consequence of Failure factors:

Score each CoF factor from 1 (low importance) to 5 (high importance):
Ranking numbers may be used more than once.

5 **General Impacts to Users**: assets with greater potential user impact or disruption to the public will have a higher CoF score (e.g., distance of detour for road closure to repair culvert)

5 **Critical Customers or Locations**: assets serving critical customers (schools, hospitals, etc.) or locations of the system (main roads, downtown, railroad, etc.) will have a higher CoF score. *Identify these areas or properties below.*

5 **Asset Size**: Larger pipe or capacity is usually indicative of higher CoF

5 Potential Impact to **Sensitive Environmental Resources** (e.g., Natural Heritage and Endangered Species Priority (NHESP) or Estimated Habitat)

1 Potential Impact to **Disadvantaged Communities (Environmental Justice)** (e.g., regular flooding in a low-income neighborhood)

Other CoF considerations? ADT Count / Roadway Classification.

Identify the critical customers or locations in Town: See MVP / haz mitigation Docs

Identify any critical areas in Dover.
Add notes, why is it critical?
Examples: areas prone to flooding, critical locations or customers, etc.

See MVP / haz mitigation Docs

Level of Service Questionnaire, cont.

Consequence of Failure factors:

Score each CoF factor from 1 (low importance) to 5 (high importance):
Ranking numbers may be used more than once.

5 **General Impacts to Users**: assets with greater potential user impact or disruption to the public will have a higher CoF score (e.g., distance of detour for road closure to repair culvert)

5 **Critical Customers or Locations**: assets serving critical customers (schools, hospitals, etc.) or locations of the system (main roads, downtown, railroad, etc.) will have a higher CoF score. *Identify these areas or properties below.*

5 **Asset Size**: Larger pipe or capacity is usually indicative of higher CoF

5 Potential Impact to **Sensitive Environmental Resources** (e.g., Natural Heritage and Endangered Species Priority (NHESP) or Estimated Habitat)

1 Potential Impact to **Disadvantaged Communities (Environmental Justice)** (e.g., regular flooding in a low-income neighborhood)

Other CoF considerations? Would be impacts on traffic and safety of motorists.

Identify the critical customers or locations in Town: Centre St/Center of town. Walpole St several areas

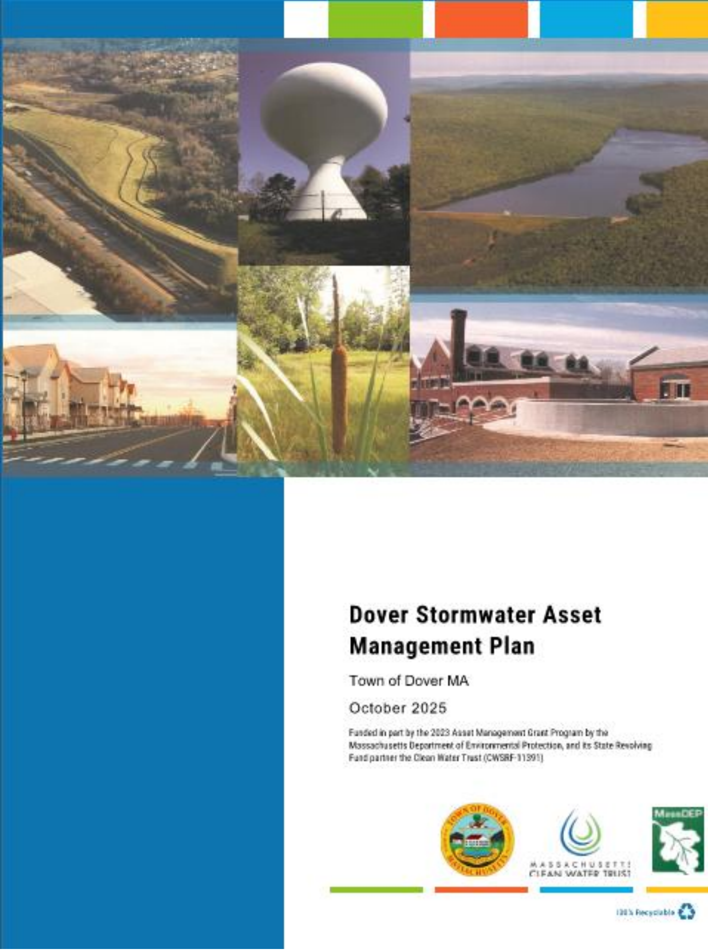
Identify any critical areas in Dover.
Add notes, why is it critical?
Examples: areas prone to flooding, critical locations or customers, etc.

Same as above - The Center of town effects local businesses - Bank / Deli / Mobil / Town Hall

Dover
Stormwater Asset Management - Level of Service Goals

Service Area	Objective	Measure	Units	Frequency	Driver	Data Location
Asset Preservation and Condition	No catch basin sumps will be greater than 50% full			Annually	MS4 Compliance	GIS
	Sweep all streets twice per year	quantity	swept streets	Annually	Flooding	GIS
	Remove sediment/debris from pipes routinely. Measure in feet of drainage pipes cleared per year	Linear feet of drainage pipes	Linear feet	Annually	Preventing Asset Failure	GIS
	Update Town's GIS stormwater mapping after system improvements and maintenance are completed or annually at a minimum	N/A	N/A	Annually	Maintain Updated Records	GIS
	Implement long-term CIP to replace, repair, and maintain assets on a proactive schedule	N/A	N/A	Annually	Preventing Asset Failure	GIS
Conservation, Compliance and Enforcement	Complete Annual Reports documenting compliance with most program elements	N/A	N/A	Annually	MS4 Compliance	GIS
	Protect wetlands, ACECs, vernal pools, and aquifers	N/A	N/A	Annually	Many private drinking water wells	GIS
Health, Safety and Security	Minimize flooded roadways	Flooding	Number of Roadways	Annually	Flooding	GIS
	Design stormwater improvements to mitigate expected flooding from future storms	Capacity	CF	Annually	Flooding	GIS
Service Quality and Cost	Board of Public Works and Board of Selectmen support for proposed program budget	N/A	N/A	Annually	Funding	GIS
	Use the long-term CIP to identify grants	N/A	N/A	Annually	Funding	GIS
	Update Town's Stormwater Asset Criticality Ranking and CIP project list every five years	N/A	N/A	Every 5 years	Funding	GIS
	Identify sustainable funding method	N/A	N/A	Annually	Funding	GIS

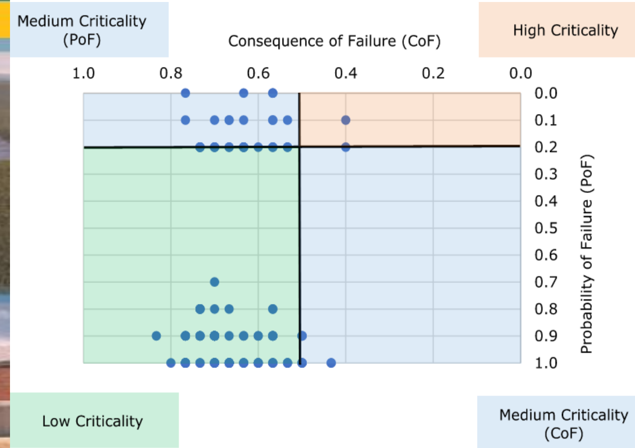
APPENDIX B


Dover Stormwater Asset Management Plan

Town of Dover MA

October 2025

Funded in part by the 2023 Asset Management Grant Program by the Massachusetts Department of Environmental Protection, and its State Revolving Fund partner the Clean Water Trust (CWSRF-11391)



DOVER STORMWATER ASSET MANAGEMENT PLAN

Executive Summary
October 2025

Funded in part by the 2023 Asset Management Grant Program by the Massachusetts Department of Environmental Protection, and its State Revolving Fund partner the Massachusetts Clean Water Trust (CWSRF-12515)

Tighe&Bond

EXECUTIVE SUMMARY OBJECTIVES

- Summarize stormwater and asset management principles
- Provide an overview of the work completed under the Stormwater Asset Management Plan (AMP)
- Present the risk-based prioritization of Dover's stormwater infrastructure
- Review recommendations for implementation of the AMP

Tighe&Bond

ACRONYMS

- **AMP** Asset Management Plan/Program
- **BMP** Best Management Practice
- **CB** Catch Basin
- **COF** Consequence of Failure
- **CWSRF** Clean Water State Revolving Fund
- **EPA** U.S. Environmental Protection Agency
- **GIS** Geographic Information Systems
- **MassDEP** Massachusetts Department of Environmental Protection
- **POF** Probability of Failure

WHAT IS STORMWATER?

- When it rains or when snow melts, **stormwater** runs off impervious surfaces like roads, driveways, and roofs, and enters the Town's drainage system
- Stormwater picks up pollutants
  - Such as trash, oil, fertilizers, sediment, sand, and bacteria (often from pet waste)
- Stormwater travels through drainage pipes to our local waterbodies, typically with NO treatment
- Stormwater pollution can impact the environment, public health, and recreation

Stormwater Runoff Discharges to Nearby Waters

40% of known pollution to the nation's waters is caused by stormwater runoff

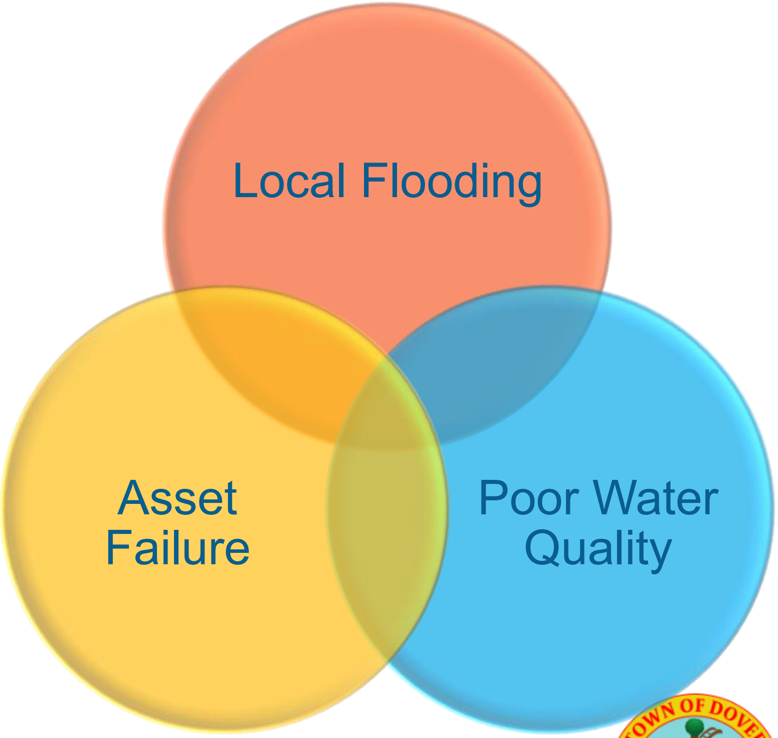
OVERVIEW OF ASSET MANAGEMENT PRINCIPLES

- Change from reactive to proactive approach for drainage system maintenance, repair, and replacement
- Prevents adverse consequences of failure such as flooding, road closures, or water quality issues
- Distributes costs over the service life of the infrastructure
- Learn more about asset management: https://www.epa.gov/dwcapacity/about-asset-management

ASSET MANAGEMENT FOR DOVER

- **Dover's Goals:**
  - Aim to maintain the stormwater system through annual sweeping, catch basin upgrades, updated mapping, and a capital improvement plan with yearly compliance reports.
  - Support asset management by securing funding, pursuing grants, and updating priorities

What could happen if we don't maintain drainage systems?



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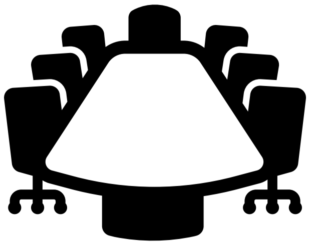
PROJECT TIMELINE

September 2023

- Notice to Proceed from MassDEP



Fall 2023

Planning Components
- Level of service
- Prioritization of field work areas
- Data collection methods

2024/2025

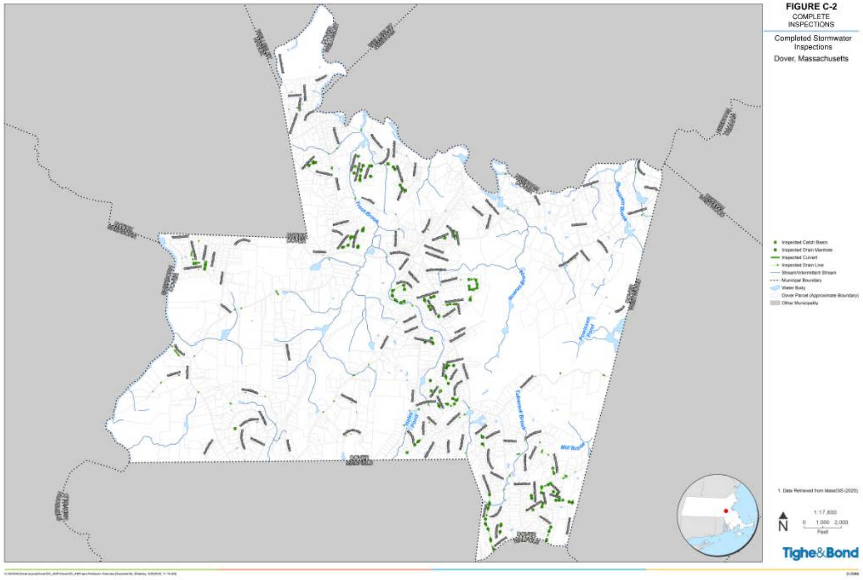
Condition Assessments
- Pipes, drain manholes, and catch basins
- Culverts

2025

- Priority ranking of assets
- Development of report
- Final Report to MassDEP

GIS & DATA MANAGEMENT IMPROVEMENTS

- **AMP provided an opportunity to make an investment in the Town's stormwater Geographic Information Systems (GIS) mapping**
  - Tighe & Bond trained town staff on data collection and workflow
  - Mapping improvements made based on field observations
  - Inspection forms were developed in Survey123 and within the GIS inventory for electronic data collection



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ASSET INVENTORY

- ## Crossing Inventory

Category	Owner	Number of Locations
Culvert	Town	115
	Private	18
	Did Not Exist	25
Bridge	Town	4
	MassDOT (State)	3
	Total	**165**

Quantities based on the Town's current inventory in GIS (August 2025)

Stream crossings are structures where roads cross streams, such as culverts and bridges. These crossings should promote natural stream conditions and allow fish and wildlife to move unrestricted while balancing transportation demands.

- ## Closed Drainage Inventory

Date	Number of Drain Manholes Assessed	Number of Catch Basins Assessed	Number of Pipe Segments Assessed	Total Number of Assets Assessed
5/21/2024	8	1	18	**27**
6/12/2024	5	6	13	**24**
6/18/2024	5	7	13	**25**
9/19/2024	13	1	18	**32**
9/23/2024	7	4	17	**27**
9/24/2024	13	5	23	**42**
9/30/2024	9	6	19	**34**
10/1/2024	15	4	21	**40**
10/8/2024	5	4	13	**22**
10/9/2024	11	3	21	**35**
Total Number of Assets Assessed	**91**	**41**	**176**	**308**

The **closed drainage system** collects and conveys stormwater away from roadways and other developed areas. These structures should remain free of debris to maximize conveyance.

CONDITION ASSESSMENTS – CULVERTS

- ***Culvert***: structure that channels water under roads, railroads, etc.
- **Assessments of culverts**
  - Noted culvert size and material
  - Structural condition
  - Maintenance concerns
- **Takeaways**
  - Conduct routine maintenance and repairs
  - Continue to inspect newly mapped Town-owned outfalls and culverts

RISK-BASED PRIORITIZATION

Historically:

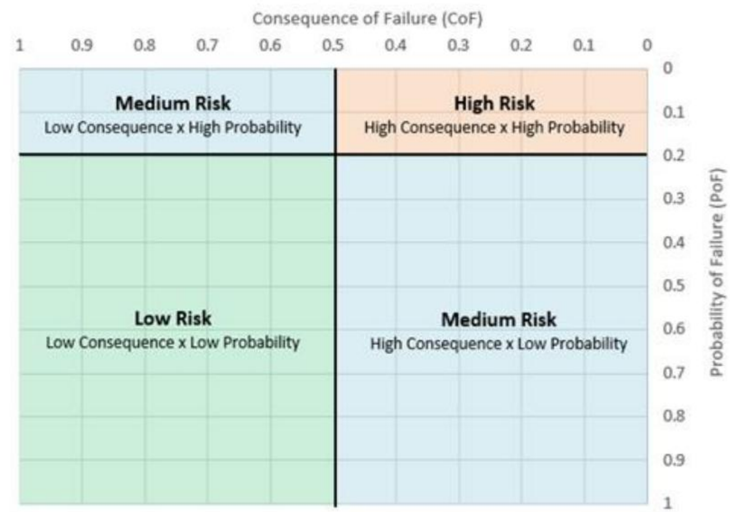
- Priority given to immediate problems as they arise.
- This approach may underestimate the urgency of other system upgrades.

Asset management helps target assets that should be prioritized for repair or replacement BEFORE they fail and become an emergency.

RISK-BASED PRIORITIZATION

Every town has more infrastructure needs than they can afford to address.
This method of prioritization is a way to identify the most cost-effective projects.

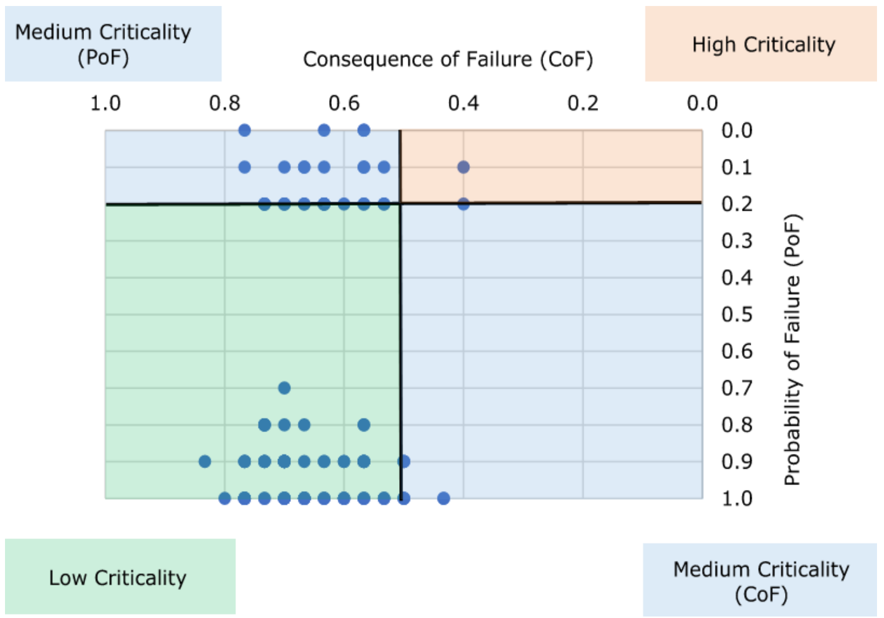
- **Probability of Failure (POF)**
  - Based on data collected during condition assessments
- **Consequence of Failure (COF)**
  - Considers hypothetical failure scenarios and the cost or impact to the community
- **Overall Asset Prioritization**
  - **High** = immediate attention
  - **Medium** = aggressive maintenance or monitoring
  - **Low** = routine maintenance and monitoring



Risk-based prioritization allows the Town to manage its overall risk and provides a logical framework for allocation of operation and maintenance dollars and capital expenditures.

RISK-BASED PRIORITIZATION – CULVERTS

- **Key Takeaways:**
  - Some culverts in good condition (bottom left quadrant)
  - Some in need of regular maintenance and possibly replacement (top left quadrant, high PoF)
  - Culverts to be monitored (bottom right quadrant, high CoF).
  - Prioritized culverts (top right quadrant, high PoF and high CoF



Culvert Criticality Matrix

PRIORITY CULVERT: 51, DEDHAM ST

- Corrugated metal
- Poor structural integrity
- Undersized leading to blockages
- Located in cold water fishery
- Located in FEMA flood zone

<u>Recommendation:</u>
Replacement

PRIORITY CULVERT: 11, HAVEN ST

- Change in culvert materials
- Poor structural integrity
- Poor blockage/ root intrusion
- Fallen headwall stones

Recommendation:
Replacement

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PRIORITY CULVERT: 10, CLAYBROOK ROAD

- Poor blockage
- Critical headwall/wingwalls
- Poor embankment
- Appears undersized

Recommendation:
Replacement

Tighe&Bond

PRIORITY CULVERT: 60, SPRINGDALE AVE

- Poor blockage
- Poor headwall/wingwalls
- Poor joints and seams

<u>Recommendation:</u>
Rehab until replacement

PRIORITY CULVERT: 66, HARTFORD ST

- Poor structural integrity
- Critical invert deterioration
- Poor headwall/wingwalls

<u>Recommendation:</u>
Replacement

PRIORITY CULVERT: 82, SMITH ST

- Critical structural integrity
- Critical joints and seams
- Poor longitudinal alignment

<u>Recommendation:</u>
Replacement

PRIORITY CULVERT: TPC-26, FARM ST

- Poor structural integrity
- Poor longitudinal alignment

Recommendation:
Replacement

PRIORITY CULVERT: TPC-28, SMITH ST

- Critical invert deterioration
- Poor joints and seams
- Poor headwall/wingwalls

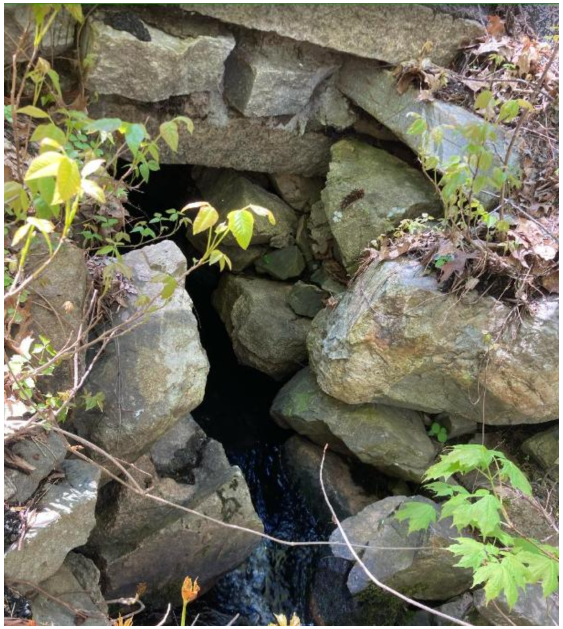
Recommendation:
Replacement

PRIORITY CULVERT: TPC-50, HARTFORD ST

- Critical invert deterioration
- Poor structural integrity

Recommendation:
Replacement

PRIORITY CULVERT: 62 WILSONDALE ST



- Poor headwall/wingwalls
- Poor structural integrity

<u>**Recommendation:**</u>
Replacement

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PRIORITY CULVERT: 78, FARM ST

- Critical invert deterioration
- Poor joints and seams
- Poor longitudinal alignment
- Poor headwall/wingwalls

Recommendation:
Partial demo & repair

Tighe&Bond

PRIORITY CULVERT: 86, OLD FARM RD

- Poor joints and seams
- Poor longitudinal alignment
- Poor blockage

Recommendation:
Replacement

SUMMARY OF RECOMMENDATIONS

- Implement targeted maintenance and repairs
- Prioritize work on capital improvements
- Investigate and study uninspected culverts
- Consider programmatic recommendations

FIVE-YEAR ACTION PLAN*

TABLE 5-2
5-Year ACTION PLAN

Culvert ID	Road Name	Criticality Score	Recommendation	Notes	FY27	FY28	FY29	FY30	FY31
							Opinion of Probable Cost		
Priority Capital Planning									
10*	Claybrook Road	Medium-High PoF	Replace - DER grant	RCP; failing headwall, undersized, often blocked by beavers	$ 100,000.00	$ 500,000.00			
11*	Haven Street	High	Replace - DER grant	CMP; deteriorating metal; heavy blockage		$ 100,000.00	$ 500,000.00		
60 *	Springdale Avenue	Medium-High PoF	Replace - DER study phase grant	RCP; undersized with invert deterioration, dammed			$ 100,000.00	$ 500,000.00	
66*	Hartford Street	Medium-High PoF	Place - OneStop grant	CMP; 100% section loss		$ 100,000.00	$ 500,000.00		
82*	Smith Street	Medium-High PoF	Replace -Put in catch basin and new pipe	Stone; critical structural integrity; Town would like to complete replacement in-house		$ 100,000.00	$ 500,000.00		
TPC-26	Farm Street	Medium-High PoF	Replace - 6' Box Culvert	Stone; failing stones, blockage and poor alignment			$ 283,000.00	$ 1,157,000.00	
TPC-28*	Smith Street	Medium-High PoF	Replace	CMP; invert deterioration and failing headwall; Town would like to complete replacement in-house				$ 100,000.00	$ 500,000.00
TPC-50	Hartford Street	Medium-High PoF	Replace with 3' RCP pipe	RCP; 100% section loss			$ 140,000.00	$ 415,000.00	
51*	Dedham Street	High	Replace	CMP; deteriorating invert, beaver dam upstream; shovel ready	$ 500,000.00				
62*	Wilsondale Street	Medium-High PoF	Replace	Stone; walls failing; under design	$ 100,000.00	$ 500,000.00			
78	Farm Street	Medium-High PoF	Partial demo and repair	Metal pipe; replace damaged pipe section, repair headwall				$ 140,000.00	$ 190,000.00
86*	Old Farm Road	Medium-High PoF	Replace	RCP; undersized with blockage; floods upstream; Town would like to complete replacement in-house				$ 100,000.00	$ 500,000.00
				SUBTOTAL	**$ 600,000.00**	**$ 800,000.00**	**$ 2,023,000.00**	**$ 2,412,000.00**	**$ 1,190,000.00**
				SUBTOTAL plus 3% annual inflation	**$ 636,540.00**	**$ 874,181.60**	**$ 2,276,904.32**	**$ 2,796,169.07**	**$ 1,420,922.23**
Targeted Maintenance and Repairs									
Refer to Section 5.2†					$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
				SUBTOTAL	**$ 10,000.00**	**$ 10,000.00**	**$ 10,000.00**	**$ 10,000.00**	**$ 10,000.00**
				SUBTOTAL plus 3% annual inflation	**$ 10,609.00**	**$ 10,927.27**	**$ 11,255.09**	**$ 11,592.74**	**$ 11,940.52**
Programmatic Improvements									
Culvert Assessment Program (annual budget)					$ 15,000.00	$ 15,000.00	$ 15,000.00	$ 15,000.00	$ 15,000.00
Ongoing Maintenance†					$ 25,000.00	$ 25,000.00	$ 25,000.00	$ 25,000.00	$ 25,000.00
GIS Data Maintenance (in-house)					$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
Annual Updated PoF, Criticality, and Recommendations					$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
				SUBTOTAL	**$ 55,000.00**	**$ 55,000.00**	**$ 55,000.00**	**$ 55,000.00**	**$ 55,000.00**
				SUBTOTAL plus 3% annual inflation	**$ 58,349.50**	**$ 60,099.99**	**$ 61,902.98**	**$ 63,760.07**	**$ 65,672.88**
				TOTAL	**$ 705,498.50**	**$ 945,208.86**	**$ 2,350,062.40**	**$ 2,871,521.88**	**$ 1,498,535.63**

Notes:
* Denotes culverts where the Town would like to carry $100,000 for design and permitting and $500,000 for construction.
† Tighe & Bond has assumed that the majority of this maintenance work can be performed by the Town. This cost is an annual allowance for materials and limited outside contractor support.
1. See Appendix L for culvert replacement OPCC.
2. Costs included herein are FY26 dollars. Annual culvert capital improvement project subtotals carry 3% inflation annually after FY26. Note estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the probable cost.

Color Key:	
$	Design & Permitting Costs
$	Construction Cost

** Suggested timeline, not mandatory – pending availability of funds*

Tighe&Bond

FUNDING THE AMP

- **Leverage state and federal grants and loans**
  - MA Chapter 90 Program, MassDOT Small Bridge Program, Municipal Vulnerability Preparedness (MVP) Action Grant Program
- **Long-term funding mechanisms**
  - Stormwater Enterprise Fund: Would provide dedicated revenue by establishing a user fee for all properties based on impervious cover
  - MassDER Culvert Replacement Municipal Assistance Program: Potential for selection as long-term Culvert Replacement Training Site which could provide additional grant funding
- **Capital projects should be phased on a schedule that makes sense for Dover**
  - The AMP and Action Plan are living documents that should be updated regularly

NEXT STEPS

Consider a public education campaign outlining improvement work

Continue assessment of the stormwater system and risks

Develop a Routine Culvert Inspection Program

Train new and existing staff on asset management program tasks

Maintain consistent workflow and recordkeeping of assets

Assess need for more staff, equipment, and vehicles to implement recommendations

FOR MORE INFORMATION ON DOVER'S STORMWATER PROGRAM, VISIT:

https://www.doverma.gov/185/Stormwater

APPENDIX C

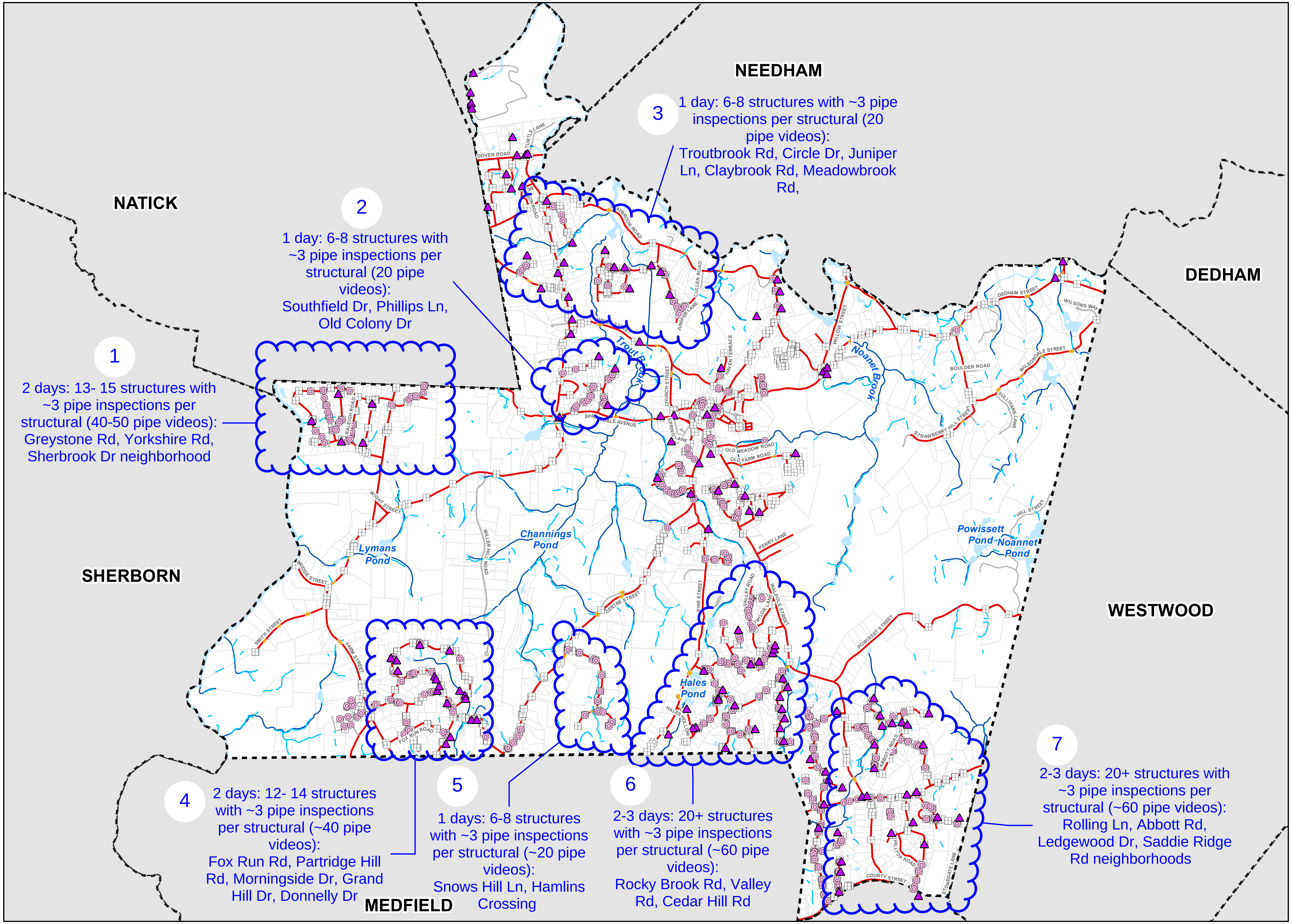


FIGURE C-1
Proposed Structure and Pipe Inspections

LEGEND

- Outfall
- Drain Manhole
- Catch Basin
- Culvert
- State Road
- Town-Owned Road
- DCR Road
- Private Road / Other/Unknown
- Hydrologic Connections
- Stream/Intermittent Stream
- Water Body
- Dover Parcels (Approximate Boundary)
- Town Boundary
- Other Municipal Boundary

LOCUS MAP

N

0 1,500 3,000
Feet
1:35,000

NOTES

1. Data retrieved from MassGIS.
2. Stormwater data collected during fieldwork.

Dover Stormwater
Dover, Massachusetts

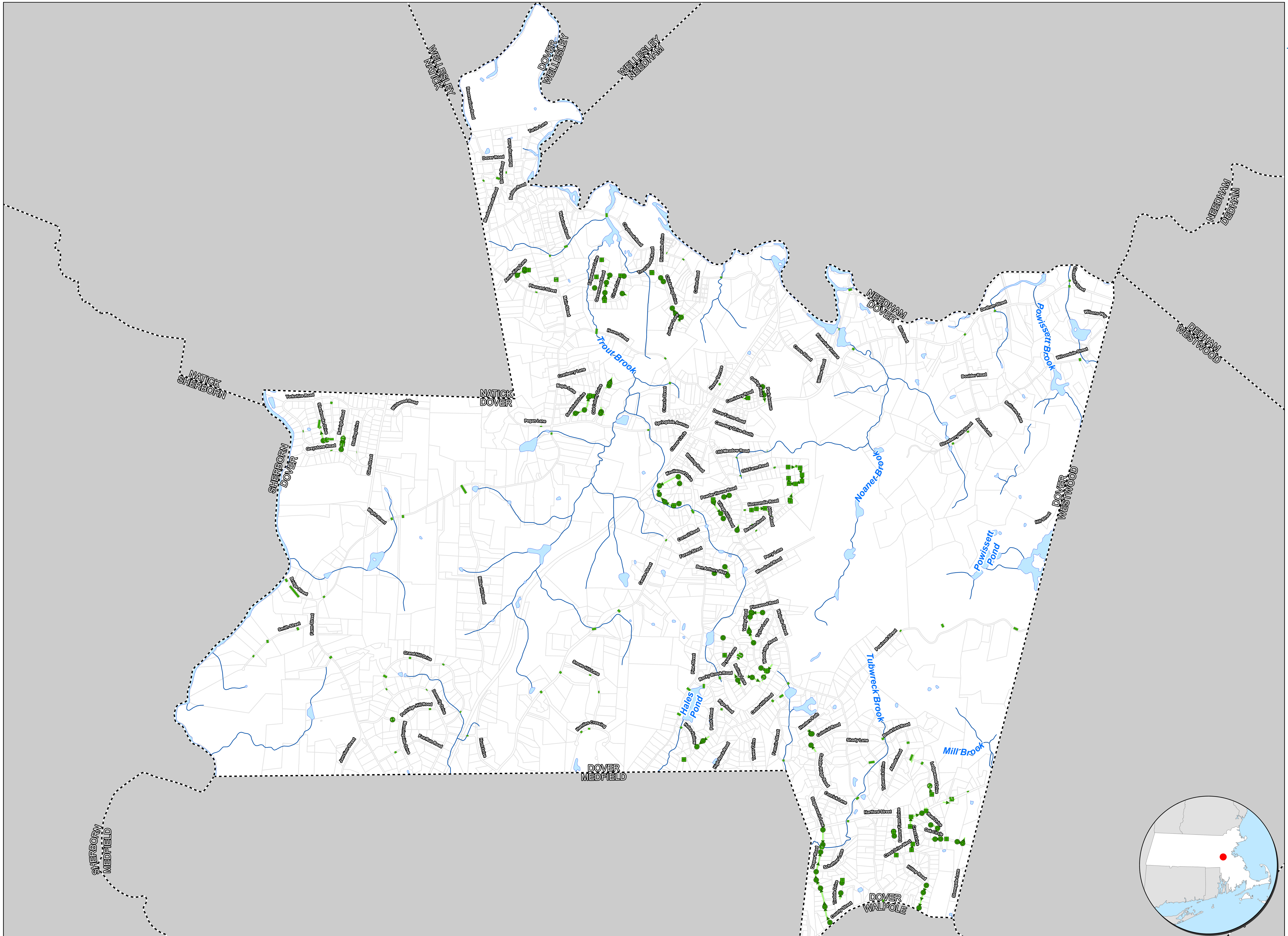
April 2024

Tighe&Bond

FIGURE C-2
COMPLETE INSPECTIONS

Completed Stormwater Inspections

Dover, Massachusetts



- Inspected Catch Basin
- Inspected Drain Manhole
- Inspected Culvert
- Inspected Drain Line
- Stream/Intermittent Stream
- Municipal Boundary
- Water Body
- Dover Parcel (Approximate Boundary)
- Other Municipality

1. Data Retrieved from MassGIS (2025).

N

1:17,600

0 1,000 2,000

Feet

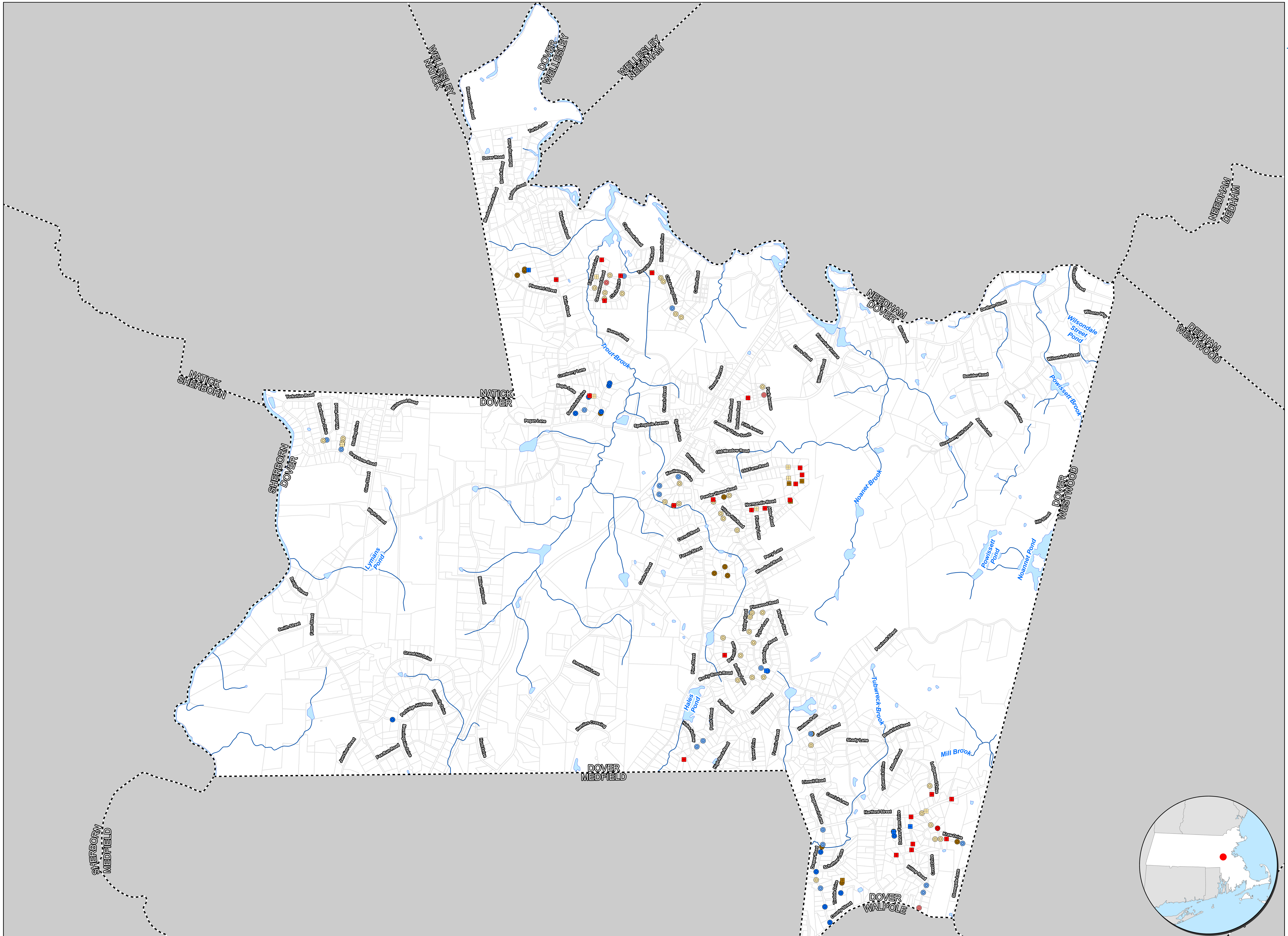
Tighe&Bond

G:\GIS\MA\Dover\avproj\DoverSW_AMP\DoverSW_AMP.aprx\Fieldwork Overview [Exported By: EManley, 5/28/2025, 11:18 AM]

D-5066

FIGURE 2
OVERVIEW
October 2025

Drainage Structure
Fieldwork
Dover, Massachusetts



Number of Defects
- 1
- 2
- 3
- Non-Defective Catch Basin

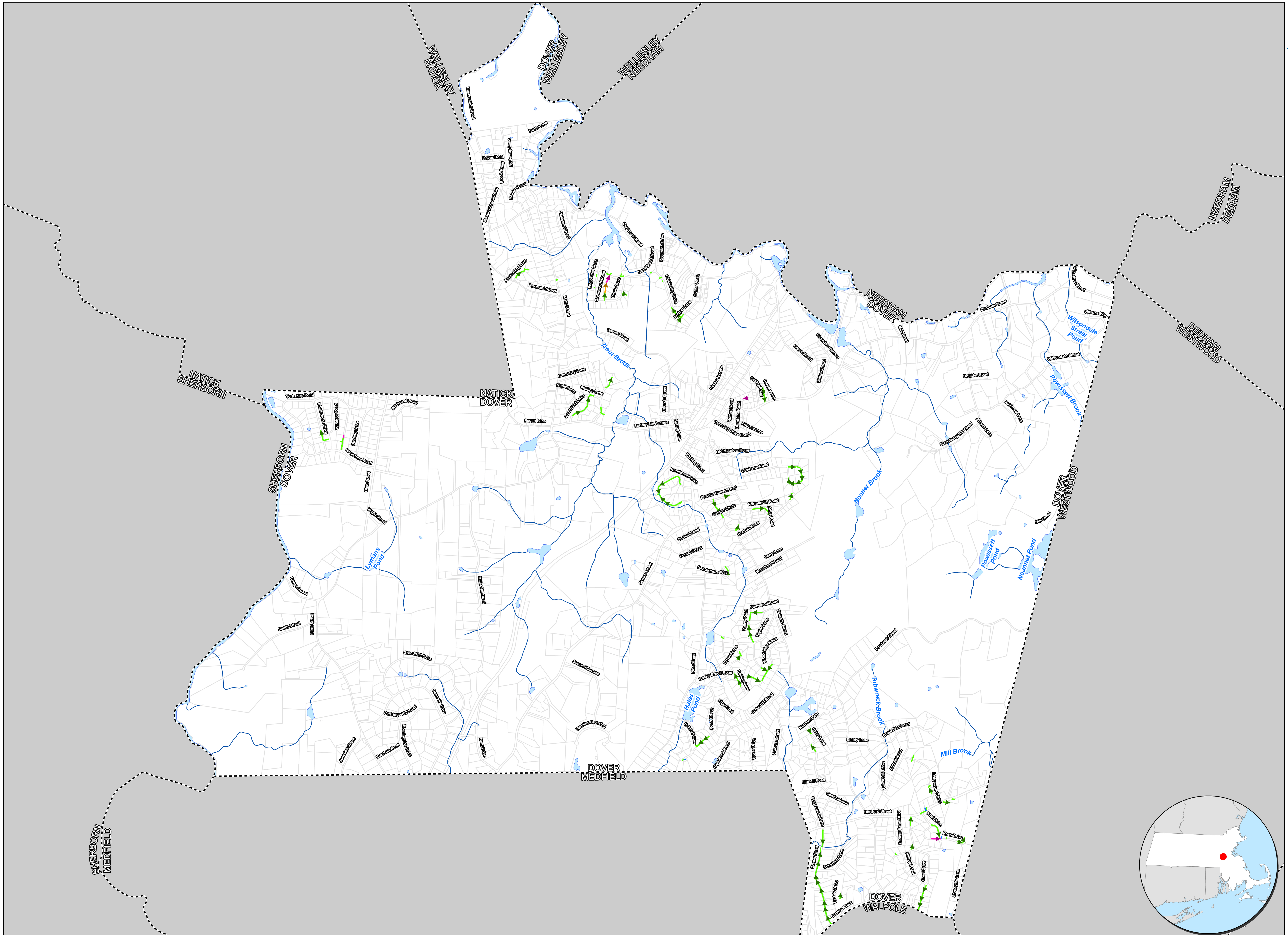
Number of Defects
- 1
- 2
- 3
- 4
- 5
- Non-Defective Drain Manhole
- Stream/Intermittent Stream
- Municipal Boundary
- Water Body
- Dover Parcel (Approximate Boundary)
- Other Municipality

1. Data Retrieved from MassGIS (2025).

Tighe&Bond

FIGURE 3
OVERVIEW
October 2025

Drain Pipe Criticality
Dover, Massachusetts



Probability of Failure

- Low
- Medium
- High
- Collapsed
- Stream/Intermittent Stream
- Municipal Boundary
- Water Body
- Dover Parcel (Approximate Boundary)
- Other Municipality

1. Data Retrieved from MassGIS (2025).

N

1:17,600

0 1,400 2,800
Feet

Tighe&Bond

APPENDIX D

Drainage structure and pipe data delivered electronically.

Tighe&Bond

APPENDIX E

Appendix E
Structures with Defects

Structure ID	Number of Defects	Cover Condition	Cover Structural Defects	Frame Condition	Frame Structural Defects	Chimney Condition	Chimney Structural Defects	Cone Condition	Cone Structural Defects	Wall Condition	Wall Structural Defects	Bench Condition	Bench Structural Defects	Channel Condition	Channel Structural Defects
DMH-142	3	Sound		Sound		Defective	Surface Damage, Fracture, Crack, Hole	Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing				
DMH-144	2	Sound		Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing				
DMH-146	2	Sound		Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing	Defective	Mortar Missing				
DMH-148	2	Sound		Sound		Sound		Defective	Mortar Missing, Surface Damage, Fracture	Defective	Mortar Missing				
DMH-151	3	Sound		Sound		Defective	Surface Damage	Defective	Mortar Missing, Surface Damage, Fracture	Defective	Mortar Missing				
CB-621	3	Sound		Sound		Defective	Surface Damage, Brickwork Brick Displaced Missing	Defective	Brickwork Brick Displaced Missing, Mortar Missing, Surface Damage, Fracture	Defective	Mortar Missing, Brickwork Brick Displaced Missing				
DMH-153	3	Sound		Sound		Defective	Surface Damage, Hole, Mortar Missing	Defective	Mortar Missing, Surface Damage, Brickwork Brick Displaced Missing	Defective	Surface Damage, Mortar Missing				
DMH-155	3	Sound		Sound		Defective	Surface Damage, Mortar Missing, Hole, Fracture	Defective	Surface Damage, Mortar Missing, Fracture	Defective	Brickwork Brick Displaced Missing, Mortar Missing, Surface Damage, Fracture				
DMH-164	3	Sound		Sound		Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing, Surface Damage, Fracture	Defective	Surface Damage	Sound		Sound	
DMH-166	3	Sound		Sound		Defective	Mortar Missing, Crack, Surface Damage, Brickwork Brick Displaced Missing	Defective	Mortar Missing, Broken, Surface Damage	Defective	Mortar Missing				
CB-668	3	Sound		Sound		Defective	Fracture, Broken, Mortar Missing, Brickwork Brick Displaced Missing	Defective	Surface Damage, Fracture	Defective	Surface Damage				
DMH-168	3	Sound		Sound		Defective	Surface Damage, Crack, Mortar Missing	Defective	Crack, Mortar Missing, Broken	Defective	Mortar Missing				
DMH-170	3	Sound		Sound		Defective	Surface Damage	Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing, Surface Damage, Fracture				
DMH-172	3	Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing, Broken, Surface Damage	Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing, Crack				
CB-700	3	Sound		Sound		Defective	Mortar Missing, Surface Damage	Defective	Surface Damage, Fracture, Brickwork Brick Displaced Missing, Broken	Defective	Collapse, Brickwork Brick Displaced Missing, Mortar Missing, Broken				
CB-697	2	Sound		Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Surface Damage, Hole, Fracture				
CB-696	3	Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Surface Damage, Hole, Fracture	Defective	Mortar Missing				
CB-694	3	Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing, Surface Damage, Hole				
CB-659	2	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Sound					
CB-657	3	Sound		Sound		Defective	Surface Damage, Fracture	Defective	Surface Damage, Mortar Missing, Brickwork Brick Displaced Missing	Defective	Surface Damage				
CB-654	3	Sound		Sound		Defective	Brickwork Brick Displaced Missing, Surface Damage	Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing, Surface Damage				
CB-653	3	Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing, Surface Damage, Hole	Defective	Surface Damage, Mortar Missing, Fracture	Defective	Surface Damage, Mortar Missing				
DMH-104	3	Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing, Broken	Defective	Mortar Missing, Fracture, Crack	Defective	Surface Damage, Mortar Missing, Fracture				
DMH-103	4	Sound		Defective	Surface Damage	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Broken	Defective	Mortar Missing, Surface Damage, Broken, Fracture	Defective	Mortar Missing				
CB-390	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Surface Damage, Fracture	Defective	Surface Damage				
DMH-234	2	Sound		Defective	Surface Damage	Defective	Crack, Surface Damage	Sound		Sound		Sound		Sound	
DMH-238	3	Sound		Sound		Defective	Brickwork Brick Displaced Missing, Mortar Missing, Hole, Fracture	Defective	Fracture, Mortar Missing	Defective	Mortar Missing, Fracture, Crack	Sound			
DMH-175	3	Sound				Defective	Surface Damage, Brickwork Brick Displaced Missing	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-177	2	Sound		Sound		Defective	Surface Damage, Mortar Missing, Fracture	Defective	Fracture, Mortar Missing, Broken	Sound					
DMH-176	3	Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing, Fracture, Surface Damage	Defective	Surface Damage, Fracture, Mortar Missing				
DMH-179	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-182	3	Sound		Sound		Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-184	3	Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing, Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing				
CB-723	1	Sound		Sound		Sound		Sound		Defective	Fracture				
722A	2	Sound		Sound		Defective	Mortar Missing, Fracture	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Broken	Sound					
188A	3	Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing			Sound	
DMH-185	1	Sound		Sound		Defective	Broken, Surface Damage	Sound		Sound					
DMH-190	3	Sound		Sound		Defective	Surface Damage	Defective	Broken, Surface Damage, Mortar Missing	Defective	Mortar Missing				
DMH-195	3	Sound		Sound		Defective	Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing				
CB-747	3	Sound		Sound		Defective	Surface Damage	Defective	Surface Damage, Mortar Missing	Defective	Surface Damage, Mortar Missing				
DMH-196	3	Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing, Fracture			Sound	
CB-782	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing, Surface Damage				
780A	2	Sound		Sound		Sound		Defective	Mortar Missing	Defective	Surface Damage				
DMH-211	2	Sound		Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Fracture				
CB-269	3	Sound		Sound		Defective	Mortar Missing	Defective	Hole, Mortar Missing, Surface Damage	Defective	Mortar Missing, Hole, Surface Damage				
CB-270	2	Sound		Sound		Defective	Hole, Surface Damage, Mortar Missing	Defective	Mortar Missing	Sound					
DMH-88	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing, Fracture				
DMH-90	3	Sound		Sound		Defective	Mortar Missing, Broken, Fracture	Defective	Mortar Missing, Surface Damage, Fracture	Defective	Mortar Missing, Surface Damage				
279A	4	Defective	Surface Damage	Sound		Defective	Surface Damage, Mortar Missing, Brickwork Brick Displaced Missing	Defective	Mortar Missing, Surface Damage, Hole	Defective	Mortar Missing				
DMH-86	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-85	2	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Hole, Broken	Sound					
CB-262	3	Sound		Sound		Defective	Mortar Missing	Defective	Broken, Mortar Missing, Surface Damage	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Collapse				
DMH-89	3	Sound		Sound		Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing				
CB-274	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Brickwork Brick Displaced Missing	Defective	Mortar Missing, Fracture, Hole				
283A	3	Sound		Sound		Defective	Mortar Missing, Surface Damage, Brickwork Brick Displaced Missing	Defective	Mortar Missing, Fracture	Defective	Mortar Missing, Fracture				
CB-255	2	Sound		Sound		Defective	Mortar Missing	Sound		Defective	Surface Damage, Mortar Missing				
CB-256	3	Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing, Broken, Hole	Defective	Mortar Missing, Surface Damage	Defective	Fracture, Surface Damage				
DMH-91	3	Sound				Defective	Surface Damage, Mortar Missing, Broken	Defective	Mortar Missing, Fracture, Surface Damage	Defective	Surface Damage, Mortar Missing				
DMH-92	3			Sound		Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing, Fracture				
DMH-94	3	Sound		Sound		Defective	Mortar Missing, Surface Damage, Broken	Defective	Fracture, Mortar Missing	Defective	Mortar Missing				
DMH-95	3	Sound		Sound		Defective	Surface Damage	Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing, Surface Damage, Fracture				
DMH-93	2	Sound		Sound		Defective	Surface Damage	Defective	Mortar Missing, Surface Damage	Sound					
CB-215	1	Sound		Sound		Defective	Broken, Fracture, Mortar Missing	Sound		Sound					
DMH-192	3	Sound		Sound		Defective	Surface Damage, Hole, Fracture	Defective	Mortar Missing	Defective	Mortar Missing, Fracture	Sound		Sound	
DMH-309	4	Sound		Defective	Surface Damage	Defective	Fracture, Mortar Missing, Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-307	2	Sound		Sound		Defective	Surface Damage, Fracture, Mortar Missing, Brickwork Brick Displaced Missing	Defective	Mortar Missing	Sound					
DMH-306	2	Sound		Sound		Defective	Surface Damage, Mortar Missing, Crack	Defective	Mortar Missing	Sound					
CB-1021	3	Sound		Sound		Defective	Mortar Missing, Brickwork Brick Displaced Missing, Fracture	Defective	Mortar Missing	Defective	Mortar Missing, Fracture				
CB-1024	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing, Surface Damage, Fracture				
CB-1020	3	Sound		Sound		Defective	Brickwork Brick Displaced Missing, Mortar Missing, Hole, Broken	Defective	Mortar Missing, Fracture, Broken	Defective	Mortar Missing, Surface Damage, Brickwork Brick Displaced Missing				
CB-1017	1	Sound		Sound		Defective	Mortar Missing	Sound		Sound					

Appendix E
Structures with Defects

Structure ID	Number of Defects	Cover Condition	Cover Structural Defects	Frame Condition	Frame Structural Defects	Chimney Condition	Chimney Structural Defects	Cone Condition	Cone Structural Defects	Wall Condition	Wall Structural Defects	Bench Condition	Bench Structural Defects	Channel Condition	Channel Structural Defects
CB-1016	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Fracture, Surface Damage	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Fracture, Hole				
DMH-296	3	Sound		Sound		Defective	Brickwork Brick Displaced Missing, Surface Damage, Broken, Hole	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Surface Damage	Defective	Mortar Missing, Fracture, Surface Damage	Sound		Sound	
DMH-302	5	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing	Defective	Fracture, Broken	Defective	Broken, Fracture, Crack
DMH-299	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Surface Damage				
DMH-301	2	Sound		Defective	Broken, Fracture	Sound		Sound		Defective	Crack				
CB-1002	3			Sound		Defective	Mortar Missing, Fracture	Defective	Mortar Missing	Defective	Mortar Missing, Surface Damage, Brickwork Brick Displaced Missing, Hole				
297A	3	Sound		Sound		Defective	Mortar Missing, Crack, Surface Damage	Defective	Mortar Missing, Brickwork Brick Displaced Missing, Surface Damage, Hole, Broken	Defective	Mortar Missing, Fracture, Crack				
DMH-295	3	Sound				Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing	Sound		Sound	
CB-1059	2	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Fracture, Surface Damage	Sound					
CB-965	3	Sound		Sound		Defective	Hole, Surface Damage	Defective	Fracture, Hole, Mortar Missing	Defective	Fracture, Surface Damage, Mortar Missing				
DMH-285	3	Sound		Sound		Defective	Mortar Missing, Fracture	Defective	Fracture, Mortar Missing, Hole	Defective	Fracture, Mortar Missing				
CB-1012	1	Sound		Sound		Defective	Mortar Missing, Surface Damage	Sound		Sound					
DMH-305	1	Sound		Sound		Defective	Surface Damage	Sound		Sound					
DMH-253	2	Sound		Sound		Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing	Sound					
DMH-254	2	Sound		Sound		Defective	Mortar Missing, Surface Damage	Defective	Surface Damage, Mortar Missing, Fracture	Sound					
DMH-256	1	Sound		Sound		Sound		Defective	Surface Damage	Sound					
DMH-257	1	Sound		Sound		Sound		Defective	Mortar Missing	Sound					
DMH-264	3	Sound		Sound		Defective	Surface Damage	Defective	Surface Damage, Mortar Missing	Defective	Crack				
DMH-265	2	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Sound					
DMH-267	1	Sound		Sound		Defective	Crack, Mortar Missing	Sound		Sound					
DMH-269	1	Sound		Sound		Sound		Defective	Surface Damage	Sound					
DMH-314	1	Sound		Sound		Defective	Fracture, Crack			Sound					
CB-651	2	Sound		Sound		Sound		Defective	Mortar Missing	Defective	Surface Damage, Mortar Missing				
CB-659	3	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-11	2	Sound		Sound		Defective	Hole, Mortar Missing, Surface Damage, Broken	Defective	Mortar Missing	Sound					
CB-43	2	Sound		Sound		Defective	Collapse, Surface Damage, Mortar Missing, Fracture	Defective	Surface Damage, Broken, Mortar Missing	Sound					
DMH-10	2	Sound		Sound		Defective	Surface Damage	Defective	Mortar Missing, Fracture	Sound					
DMH TPC24	3	Sound		Sound		Defective	Mortar Missing, Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing, Surface Damage				
DMH-12	3	Sound				Defective	Surface Damage	Defective	Mortar Missing	Defective	Mortar Missing, Fracture				
DMH-51	1	Defective	Crack												
CB-1062	3	Sound		Sound		Defective	Mortar Missing	Defective	Surface Damage, Mortar Missing	Defective	Mortar Missing				
60A	1	Sound		Sound		Sound		Defective	Mortar Missing	Sound					
DMH-62	2	Sound		Sound		Defective	Surface Damage	Defective	Fracture, Crack, Mortar Missing	Sound					
DMH-64	1	Sound		Sound		Sound		Defective	Mortar Missing	Sound					
DMH-65	3	Sound		Sound		Defective	Mortar Missing, Broken, Fracture	Defective	Fracture, Mortar Missing	Defective	Mortar Missing, Fracture				
CB-189	3	Sound		Sound		Defective	Mortar Missing	Defective	Fracture, Mortar Missing	Defective	Surface Damage, Mortar Missing				
CB-193	2	Sound		Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing, Fracture				
DMH-67	1	Sound		Sound		Defective	Mortar Missing	Sound		Sound		Sound		Sound	
DMH-68	1	Sound				Sound		Defective	Mortar Missing, Fracture	Sound					
DMH-70	1	Sound		Sound		Sound		Defective	Mortar Missing	Sound					
CB-480	3	Sound		Sound		Defective	Mortar Missing, Broken, Fracture, Brickwork Brick Displaced Missing	Defective	Mortar Missing	Defective	Mortar Missing				
DMH-21	3	Sound				Defective	Mortar Missing, Brickwork Brick Displaced Missing, Broken, Surface Damage	Defective	Surface Damage, Fracture, Mortar Missing	Defective	Mortar Missing, Fracture, Crack				
DMH-22	2	Sound		Sound		Defective	Mortar Missing	Defective	Mortar Missing	Sound					

APPENDIX F

Appendix F
List of Culverts in Dover

CulvertID	Location:	Owner:	Investigation Status	If not Assessed, Reason
1	Dedham Street	Town	Assessment Complete	
10	Claybrook Road	Town	Assessment Complete	
10B	Claybrook Road	Unassigned	Not Assessed	Duplicate point
11	Haven Street	Town	Assessment Complete	
12	Bryant Lane	Town	Incomplete Assessment	Submerged outlet
13	Haven Street	Unassigned	Not Assessed	Pipe sticking out of ground
14	Hartford Street	Town	Assessment Complete	
15	Springdale Ave	Town	Not Assessed	Submerged
16	Powisset Street	Town	Incomplete Assessment	Outlet blocked by debris
17	Main Street	Town	Assessment Complete	
18	Brookfield Road	Unassigned	Not Assessed	Duplicate point
19	Cheney Drive	MassDOT	Not Assessed	Bridge (NBI)
2	Willow Street	Town	Assessment Complete	
20	Meadowbrook Road	Town	Assessment Complete	
21	Centre Street	Town	Incomplete Assessment	Submerged outlet
22	Strawberry Hill Street	Town	Assessment Complete	
23	Old Meadow Road	Town	Assessment Complete	
24	Reservation Road	MassDOT	Not Assessed	Bridge (NBI)
25	Reservation Road	MassDOT	Not Assessed	Bridge (NBI)
26	Old Meadow Road	Town	Assessment Complete	
27	Rocky Brook Road	Town	Assessment Complete	
28	Near Farm Street	Private/Unaccepted	Not Assessed	Private
29	Near Farm Street	Private/Unaccepted	Not Assessed	Private
3	Old Farm Road	Town	Not Assessed	Submerged
30	Near Farm Street	Private/Unaccepted	Not Assessed	Private
31	Main Street	Town	Incomplete Assessment	Culverted Pipe
32	Miller Hill Road	Private/Unaccepted	Not Assessed	Private
33	Miller Hill Road	Private/Unaccepted	Not Assessed	Private
34	Hill Street	Private/Unaccepted	Not Assessed	Unaccepted
35	Dedham Street	Town	Assessment Complete	
36	Near Brookfield Road	Private/Unaccepted	Not Assessed	Private
37	Centre Street	Town	Assessment Complete	
38	Wakeland Road	Town	Assessment Complete	
39	Stonegate Lane	Private/Unaccepted	Not Assessed	Unaccepted
4	Chestnut Street	Town	Assessment Complete	
40	Donnelly Drive	Unassigned	Not Assessed	Wetlands on both sides of road with culvert connecting them.
41	Donnelly Drive	Town	Assessment Complete	
42	Willow Street	Town	Incomplete Assessment	Could not access inlet due to a high wall
43	Willow Street	Town	Not Assessed	Bridge (NBI)
44	Centre Street	Town	Assessment Complete	
45	Walpole Street	Town	Incomplete Assessment	Submerged outlet
46	Near Centre Street	Private/Unaccepted	Not Assessed	Private
47	Draper Road	Town	Assessment Complete	
48	Turtle Lane	Private/Unaccepted	Not Assessed	Private
49	Hunt Drive	Town	Assessment Complete	

Key	
	Not Assessed
	Incomplete Assessment
	Not Town-Owned

Appendix F
List of Culverts in Dover

CulvertID	Location:	Owner:	Investigation Status	If not Assessed, Reason
5	Bridge Street	Town	Not Assessed	Bridge (NBI)
50	Hunt Drive	Town	Assessment Complete	
51	Dedham Street	Town	Incomplete Assessment	Inlet blocked by beaver dam
52	Centre Street	Town	Not Assessed	Bridge (NBI)
53	Farm Street	Town	Assessment Complete	
54	Near Old Meadow Road	Private/Unaccepted	Not Assessed	Private
55	Chestnut Street	MassDOT	Not Assessed	Bridge (NBI)
56	Centre Street	Town	Assessment Complete	
57	Centre Street	Town	Assessment Complete	
58	Hales Hollow	Town	Assessment Complete	
59	Claybrook Road	Town	Incomplete Assessment	Submerged inlet
6	Near Hunt Drive	Private/Unaccepted	Not Assessed	Private
60	Springdale Avenue	Town	Assessment Complete	
61	Dedham Street	Town	Assessment Complete	
62	Wilsondale Street	Town	Assessment Complete	
63	Wilsondale Street	Town	Assessment Complete	
64	Tubwreck Drive	Town	Assessment Complete	
65	Woodridge Road	Town	Incomplete Assessment	Could not locate outlet; buried underneath debris
66	Hartford Street	Town	Assessment Complete	
67	Cedar Hill Road	Town	Assessment Complete	
68	Farm Street	Town	Assessment Complete	
69	Powisset Street	Town	Assessment Complete	
7	Grand Hill Drive	Town	Assessment Complete	
70	Dover Road	Town	Not Assessed	Bridge (NBI)
71	Powisset Street	Unassigned	Not Assessed	Likely seepage under road
72	Ledgewood Drive	Town	Assessment Complete	
73	Brookfield Road	Town	Assessment Complete	
74	Rocky Brook Road	Unassigned	Not Assessed	Outfall connected to catch basin
75	County Street	Town	Not Assessed	Pipe full of debris
76	Rocky Brook Road	Unassigned	Not Assessed	Duplicate point
77	Trout Brook Road	Town	Assessment Complete	
78	Farm Street	Town	Assessment Complete	
79	Hill Street	Private/Unaccepted	Not Assessed	Unaccepted
8	On school property	Private/Unaccepted	Not Assessed	Unaccepted
80	Hill Street	Private/Unaccepted	Not Assessed	Unaccepted
81	Greystone Road	Town	Assessment Complete	
82	Smith Street	Town	Assessment Complete	
83	Cedar Hill Road	Town	Assessment Complete	
84	Snow Hill Lane	Unassigned	Not Assessed	Outfall connected to catch basin
85	Farm Street	Town	Assessment Complete	
86	Old Farm Road	Town	Assessment Complete	
87	Hamlins Court	Unassigned	Not Assessed	Outfall connected to catch basin
88	Mill Road	Town	Incomplete Assessment	Submerged inlet
89	Riverside Drive	Private/Unaccepted	Not Assessed	Unaccepted
9	Picardy Lane	Town	Not Assessed	Inlet covered by board; outlet is culverted pipe
90	Wilsondale Street	Unassigned	Not Assessed	No crossing located in field

Appendix F
List of Culverts in Dover

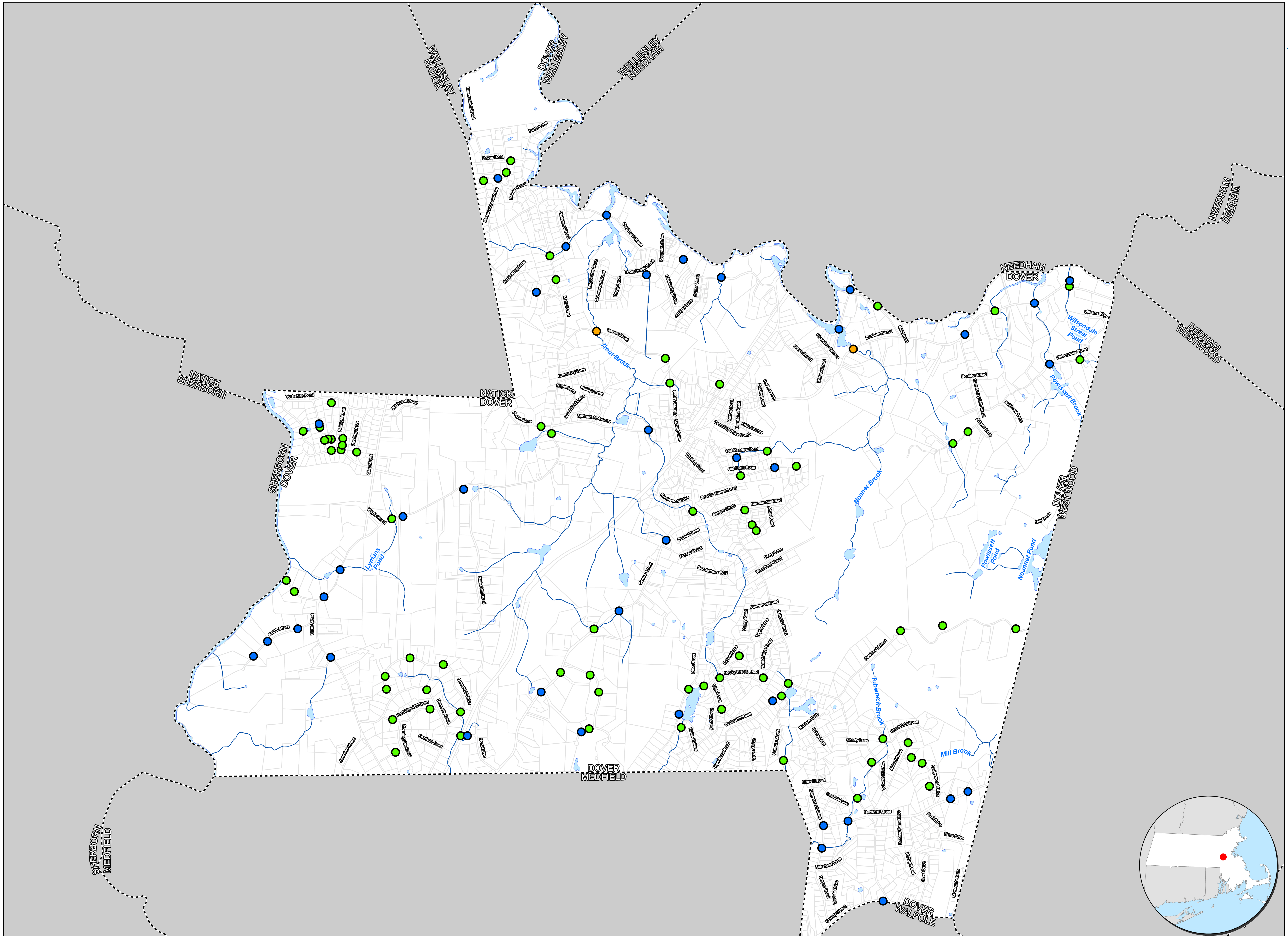
CulvertID	Location:	Owner:	Investigation Status	If not Assessed, Reason
91	Old Farm Road	Town	Assessment Complete	
92	Wilsondale Street	Unassigned	Not Assessed	Likely seepage under road
93	Francis Street	Town	Assessment Complete	
94	Centre Street	Town	Assessment Complete	
95A	Trail	Town	Assessment Complete	
95B	Trail	Town	Incomplete Assessment	Culverted Pipe
95C	Trail	Town	Incomplete Assessment	Culverted Pipe
96	Miller Hill Road	Private/Unaccepted	Not Assessed	Private
97	Bridle Path Circuit	Unassigned	Not Assessed	No location for crossing
98	Old Farm Road	Town	Not Assessed	Submerged inlet, outlet is culverted pipe
99	Ledgewood Drive	Town	Incomplete Assessment	Culverted Pipe
Field 1	Ledgewood Drive	Town	Incomplete Assessment	Culverted Pipe
Field 3	Francis Street	Town	Assessment Complete	
Field 4	Raleigh Road	Town	Incomplete Assessment	Culverted Pipe
Field 5	Farm Street	Town	Assessment Complete	
TPC-1	Meadowbrook Road	Unassigned	Not Assessed	Duplicate point
TCP-10	Strawberry Hill Street	Town	Incomplete Assessment	Could not locate inlet; submerged or buried under debris
TPC-11	Picardy Lane	Unassigned	Not Assessed	Duplicate point
TPC-12	Bretton Road	Town	Assessment Complete	
TPC-13	Normandie Road	Town	Assessment Complete	
TPC-14	Centre Street	Town	Assessment Complete	
TPC-15	Pegan Lane	Town	Assessment Complete	
TPC-16	Haven Street	Town	Incomplete Assessment	Could not locate culvert; buried underneath debris
TPC-16C	Haven Street	Unassigned	Not Assessed	Duplicate point
TPC-17	Haven Street	Unassigned	Not Assessed	Shallow stream without pipe; likely seepage under road
TPC-18	Haven Terrace	Town	Assessment Complete	
TPC-19	Yorkshire Road	Town	Assessment Complete	
TPC-2	Meadowbrook Road	Town	Incomplete Assessment	Inlet blocked by wood planks
TPC-20	Sherbrooke Drive	Town	Assessment Complete	
TPC-20B	Sherbrooke Drive	Town	Assessment Complete	
TPC-21	Windsor Road	Town	Assessment Complete	
TPC-22	Raleigh Road	Town	Incomplete Assessment	Culverted Pipe
TPC-23	Sterling Drive	Town	Incomplete Assessment	12” concrete pipe blocked by debris at inlet
TPC-24	Raleigh Road	Town	Incomplete Assessment	Culverted Pipe
TPC-25	Bridge Street	Town	Assessment Complete	
TPC-25B	Bridge Street	Town	Assessment Complete	
TPC-26	Farm Street	Town	Assessment Complete	
TPC-27	Smith Street	Town	Assessment Complete	
TPC-28	Smith Street	Town	Assessment Complete	
TPC-29	Farm Street	Town	Incomplete Assessment	Culverted Pipe
TPC-3	Brook Road	Town	Assessment Complete	
TPC-30	Grand Hill Drive	Unassigned	Not Assessed	Duplicate point
TPC-31	Grand Hill Drive	Town	Assessment Complete	
TPC-32	Grand Hill Drive	Town	Assessment Complete	
TPC-33	Grand Hill Drive	Town	Assessment Complete	
TPC-34	Grand Hill Drive	Town	Assessment Complete	

Appendix F
List of Culverts in Dover

CulvertID	Location:	Owner:	Investigation Status	If not Assessed, Reason
TPC-35	Partridge Hill Road	Town	Incomplete Assessment	Culverted Pipe
TPC-36	Partridge Hill Road	Town	Assessment Complete	
TPC-37	Donnelly Drive	Unassigned	Not Assessed	Duplicate point
TPC-38	Fox Run Road	Town	Assessment Complete	
TPC-39	Centre Street	Unassigned	Not Assessed	Duplicate point
TPC-4	Dover Road	Town	Assessment Complete	
TPC-40	Hamlins Crossing	Town	Assessment Complete	
TPC-41	Hamlins Crossing	Town	Assessment Complete	
TPC-42	Snow Hill Lane	Town	Assessment Complete	
TPC-43	Snow Hill Lane	Town	Assessment Complete	
TPC-44	Pine Street	Town	Incomplete Assessment	Could not locate inlet; buried underneath debris
TPC-45	Pine Street	Town	Assessment Complete	
TPC-46	Rocky Brook Road	Town	Assessment Complete	
TPC-47	Riga Road	Town	Assessment Complete	
TPC-48	Abbott Road	Town	Not Assessed	Submerged
TPC-49	Ledgewood Drive	Unassigned	Not Assessed	Duplicate point
TPC-5	Pleasant Street	Town	Not Assessed	Pipe full of debris
TPC-50	Hartford Street	Town	Incomplete Assessment	Culverted Pipe
TPC-51	Hartford Street	Unassigned	Not Assessed	Duplicate point
TPC-52	County Street	Unassigned	Not Assessed	Duplicate point
TPC-53	Powisset Street	Town	Incomplete Assessment	Could not locate inlet; buried underneath debris
TPC-54	Powisset Street	Unassigned	Not Assessed	Duplicate point
TPC-55	Centre Street	Private/Unaccepted	Not Assessed	Unaccepted
TPC-57	Hartford Street	Town	Assessment Complete	
TPC-6	Pleasant Street	Town	Assessment Complete	
TPC-7	Claybrook Road	Town	Assessment Complete	
TPC-8	Dedham Street	Unassigned	Not Assessed	Determined to not exist
TPC-9	Dedham Street	Town	Assessment Complete	

FIGURE 1
OVERVIEW
October 2025

Culvert Criticality
Dover, Massachusetts



Culvert Criticality Rank

- Low
- Medium
- High
- Stream/Intermittent Stream
- Municipal Boundary
- Water Body
- Dover Parcel (Approximate Boundary)
- Other Municipality

1. Data Retrieved from MassGIS (2025).

N

1:17,600

0 1,400 2,800
Feet

Tighe&Bond

G:\GIS\MA\Dover\avproj\DoverSW_AMP\DoverSW_AMP.aprx\Culvert Criticality [Exported By: EManley, 10/1/2025, 2:12 PM]

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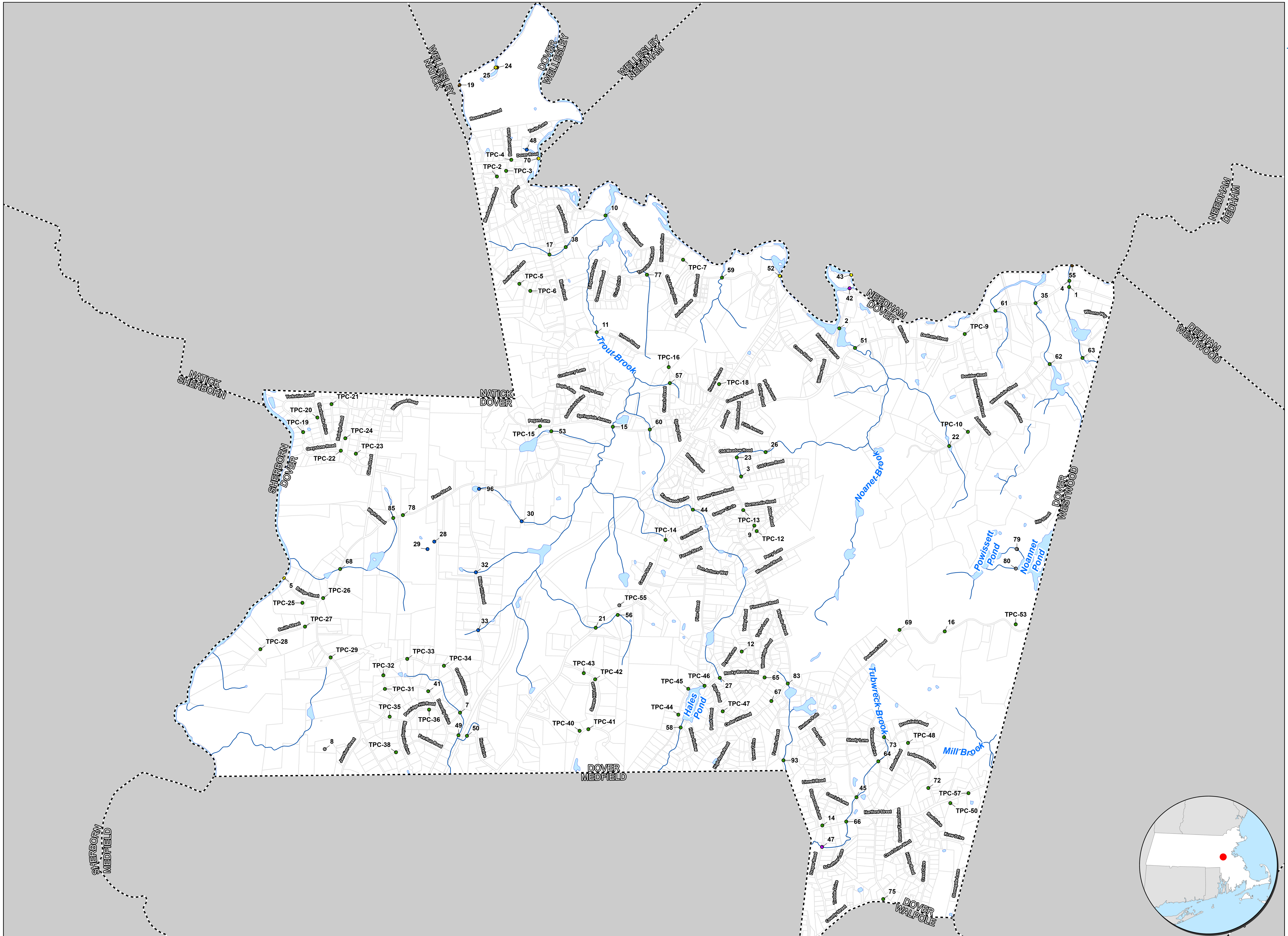
FIGURE 3
OVERVIEW
October 2025

Culvert Locations
Dover, Massachusetts



Culvert Status
- Town-Owned Culvert
- Bridge- Municipality
- Bridge- DOT
- Field Identified Bridge
- Private
- Unaccepted
- Stream/Intermittent Stream
- Municipal Boundary
- Water Body
- Dover Parcel (Approximate Boundary)
- Other Municipality

1. Data Retrieved from MassGIS (2025).

1:17,600

0 1,400 2,800
Feet

N

Tighe&Bond

Tighe&Bond

APPENDIX G

Dover
Culvert Assessment Protocol

Town of Dover, MA

November 2023

Tighe&Bond

Table of Contents

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Section 1
Background

The Town of Dover is located within the Neponset River Watershed and the Charles River Watershed. The Town of Dover makes up approximately 2.3 square miles and 13.1 square miles of Neponset River and Charles River watersheds respectively, and includes many streams, brooks, and tributaries to the Charles River. These streams are conveyed under roads via culverts throughout town.

Culvert Inventory

Prior to beginning field work, the Town of Dover did not have an inventory of the culverts in Town. Hard copies of construction drawings and record drawings for some culverts were kept in a record room. As a result, Tighe & Bond intersected streams and roads to identify potential culvert locations. This exercise resulted in 136 potential culvert locations. The presence of these culverts will be field-verified and those that exist will be assessed and ranked as part of this asset management project.

Assessment Guidance

Tighe & Bond developed this culvert assessment protocol and field form to be used during field assessment. The assessment information was developed using Tighe & Bond's experience with culvert assessments and the following resources:

- *Culvert Condition Assessment Manual* and *Culvert Assessment Form,* developed by UMass Transportation Center, the Nature Conservancy, North Atlantic Aquatic Connectivity Collaborative (NAACC), and the Center for Agriculture, Food, and the Environment, 2019
- *NAACC Stream Crossing Instruction Manual for Aquatic Passability Assessments in Non-tidal Stream and Rivers* and *Aquatic Connectivity Stream Crossing Survey Data Form,* developed by the North Atlantic Aquatic Connectivity Collaborative, UMass Amherst, November 2019

These NAACC resources were developed to:

> "*provide guidance for completing the North Atlantic Aquatic Connectivity (NAACC) Stream Crossing Survey Data Form.*
> *The North Atlantic Aquatic Connectivity Collaborative (NAACC) is a network of individuals from universities, conservation organizations, and state and federal natural resource and transportation departments focused on improving aquatic connectivity across a thirteen-state region, from Maine to Virginia. The NAACC has developed common protocols for assessing road-stream crossings (culverts and bridges) and developed a regional database for these field data. The information collected will identify high priority bridges and culverts for upgrade and replacement. The NAACC will support planning and decision-making by providing information about where restoration projects are likely to bring the greatest improvements in aquatic connectivity. The survey data form is to be used for an entire road-stream crossing, which may include single or multiple culverts or multiple cell bridges.*"

NAACC has become the industry standard for data collection of this type. Although it is focused on Aquatic Organism Passage (AOP), it also covers standardized data collection for the roadway and culvert. Engineering judgement will be used when evaluating the data for roadway infrastructure improvement purposes.

The following Sections provide guidance from these various resources on conducting the culvert assessments. Please note:

- NAACC defines a bridge as "a deck supported by abutments (or stream banks). It may have more than one cell or section separated by one or more piers". It defines a culvert as "a structure buried under some amount of fill".
    - Crossings with a span greater than 20 feet are bridges that the Federal Highway Administration mandates be inspected in accordance with National Bridge Inspection Standards. These bridges were excluded from this specific town assessment.
    - Crossings with a span greater than 10 feet are recognized as bridges by Massachusetts General Laws, and repair and replacement of these structures are subject to Chapter 85 approval. This includes multiple barrel culverts. MassDOT keeps an inventory of these structures and documentation of these structure inspections is the same as that for the National Bridge Inspection Standards. Thus, crossings of a span greater than 10 feet that are included in the online MassDOT bridge inventory are excluded from this specific town assessment. This includes multiple barrel culverts with a span greater than 10 feet.
- The words *crossing* and *culvert* may be used interchangeably throughout this assessment protocol document since both the NAACC Culvert Condition Assessment Manual and the NAACC Stream Crossing Instruction Manuals were used in the development of the guide.

Section 2
Tighe & Bond Data Collection

While primarily using the NAACC protocol for the assessments, Tighe & Bond developed additional assessment criteria for the roadway, culvert, and operation and maintenance concerns that could be indicative of potential modes of failure. **Section 2** outlines these supplemental assessment criteria and provides extra photos and descriptions of each for reference during field work.

Roadway Condition

Adequate: Pavement has no visible defects, small cracks, or maintenance patches. Unpaved roads (gravel, dirt) have minor erosion or ruts.

Poor: Significant cracking, spalling, potholes, or maintenance patches affecting up to 20% of any single travel lane or shoulder. Unpaved roads (gravel, dirt) have erosion, ruts affecting up to 20% of the travel lanes.

Critical: Extensive cracking, spalling, potholes, or maintenance patches affecting at least 20% of any single travel lane or shoulder. Unpaved roads (gravel, dirt) have erosion and ruts affecting at least 20% of the travel lanes.

Survey also includes options of:

- Unknown
- N/A

Other notes within the survey:

- Roadway Observations: Use this text box to explain the condition of the road in more detail (i.e., alligator cracking, missing curbing, etc.)
- Road Sketch: Use this to draw any other roadway observations you'd like to note.

Sidewalk

Sidewalk Location
Note the presence or absence of a sidewalk on one or both sides of the crossing.

Sidewalk Material

- Asphalt
- Granite
- Concrete
- Other – use this option to describe if more than one material is present.

Sidewalk Condition*

Adequate: Some slight wear and a few areas with larger shallow cracks.

Poor: Sidewalk has patching and cracks.

Critical: Sidewalk has cracks and patches covering more than half the surface.

Survey also includes option of:

- **Other** to describe differing conditions if 2 sidewalks are present.

**Note: The assessment does not consider ADA requirements.*

Curbing

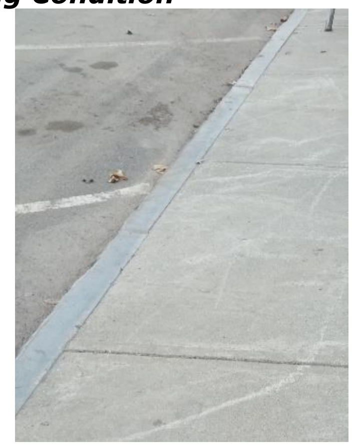
Curbing Location

Note the presence or absence of curbing on one or both sides of the crossing.

Curbing Material

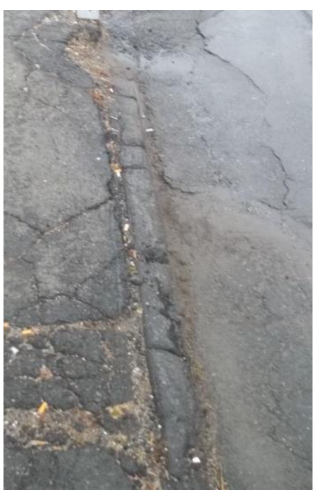
- Asphalt Berm
- Granite Curb
- Concrete Curb
- Other - use this option to describe if more than one material is present.

Curbing Condition*



Adequate: Majority (over 70%) is in good condition; minimal damage or chipping.

Poor: Some areas of worn and damaged curbing with chips and other damage visible, and some areas of curbing in good condition.



Critical: Significant areas of worn and damaged curbing.

Survey also includes option of:

- **Other** to describe differing conditions if 2 curbs are present.

**Note: The assessment does not consider ADA requirements.*

Pavement Width

Measured from edge of pavement to edge of pavement perpendicular to the roadway.

Guardrail

Guardrail Location

Note the presence or absence of a rail system on one or both sides of the crossing.

Guardrail Condition

Adequate: Guardrail has no visible defects.

Poor: Guardrail may be leaning appearing unstable, have significant section loss or deformation.

Critical: Guardrail has severe section loss, severe deformation, missing connections.

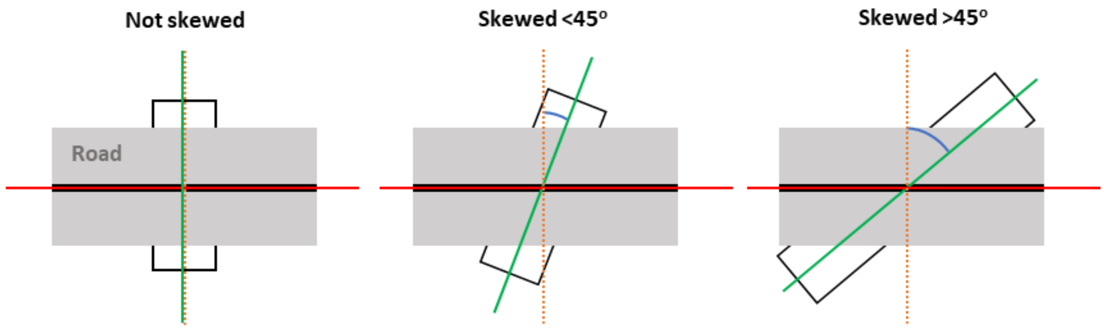
Survey also includes options of:

- **Other** to describe differing conditions if 2 guardrails are present.

Crossing Alignment to Roadway

Indicates the alignment of the crossing structure relative to the roadway. The skew is defined as the angle between the centerline of the crossing (green, solid line) and a line perpendicular (orange, dotted line) to the roadway centerline (red line).

- **No Skew**: Road-aligned, the crossing structure is situated at roughly a 90-degree angle (perpendicular) to the road.
- **Skewed** (<45-degrees or >45-degrees): The crossing is not situated at roughly a 90-degree angle to the road. Note whether it is less or more than 45-degrees.

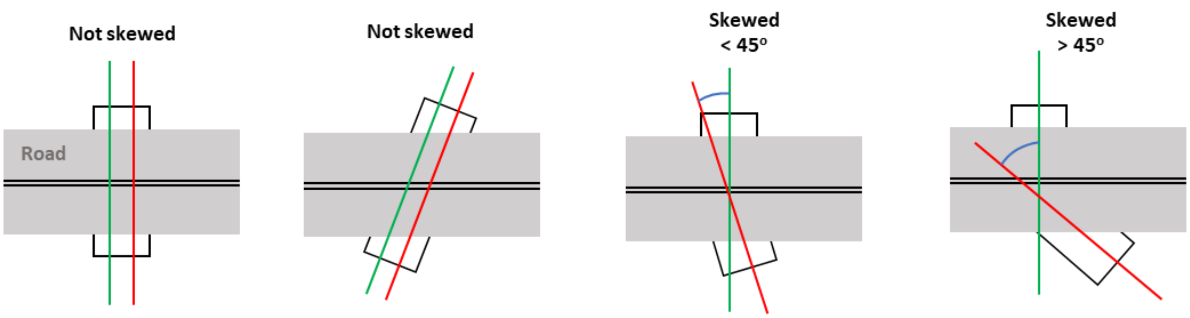


Note: Sketch developed by Tighe & Bond based on NAACC Stream Crossing Instruction Manual (2019) "Alignment" description.

Bend Mid-Crossing

Indicates the alignment of the crossing structure relative to the direction of the crossing inlet. Compare the centerline of the crossing inlet to the centerline of the crossing outlet.

- **None**: The centerline of the crossing is straight throughout the entire crossing.
- **Skewed** (<45-degrees or >45-degrees): The crossing structure alignment changes under the roadway. Note whether it is less or more than 45-degrees.



Note: Sketch developed by Tighe & Bond based on NAACC Stream Crossing Instruction Manual (2019) "Alignment" description.

Distance Between Culvert Barrels

When multiple barrels are present, measure the distance between each barrel (upstream and downstream). The measurement is taken from inside of the first pipe horizontal to the inside of the second pipe.

Tree Present by Headwall/Wingwall

Note the presence of trees within close enough proximity to the structure that the roots could undermine the structural integrity.

Condition of Upstream & Downstream Roadway Embankment

Adequate: No noteworthy deficiencies which affect the condition of the embankment protection.

Critical: Embankment protection has failed causing severe scour of embankment and threatening the stability of the roadway embankment.

Poor: Embankment protection is severely undermined causing significant erosion of embankment and in need of immediate repairs.

Headwall & Wingwall Materials

If present, select or describe the material:

Concrete

Stone

Upstream Scour

Note if Present:

- Yes
- No
- Unknown

Note the Location:

- Culvert
- Wingwalls
- Footings

Note the Damage:

Small: Minor undermining of the culvert barrel or wingwalls, and/or the footing is exposed.

Large: Significant/extensive undermining and exposure of the culvert barrel, wingwall, and/or footing.

Operation & Maintenance: Potential Illicit Discharges

Note the Location:

- Nearby Outfall Upstream/Downstream
- Observed at Inlet/Outlet
- Unknown

Note the Evidence:

- Odor
- Discoloration of Flow
- Floatables (does not include trash)
- Deposits or Staining
- Excessive Vegetation or Benthic Growth
- Suds
- Yard Waste
- Trash
- Oil
- Other

Beaver Dam Near Crossing

If a beaver dam is observed upstream or downstream of the crossing, note its location and measure/approximate the distance from the crossing inlet or outlet.

Field Recommendations

Is further action required? This includes None, Maintenance, Rehabilitation, or Replacement of the culvert. This data is used for daily quality control and as a screening tool for immediate town follow-up needs.

Section 3
NAACC Data Collection

See attached NAACC Stream Crossing Instruction Manual (2019) and Culvert Condition Assessment Manual and Form (2019) for explanations of criteria used in the Dover culvert condition assessments. Comments in red text were added by Tighe & Bond if there were modifications made for the Tighe & Bond assessment form.

NAACC Stream Crossing Instruction Manual Table of Contents

NAACC Stream Crossing Instruction Manual for Aquatic Passability Assessments in Non-tidal Stream and Rivers

North Atlantic Aquatic Connectivity Collaborative

Version 1.3 – June 2, 2019
(for Data Form dated May 26, 2016)

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For more information, go to: **www.streamcontinuity.org/naacc**

ACKNOWLEDGEMENTS

The development of this instruction guide and the survey protocol it explains would not have been possible without the effort of many people involved with the NAACC. First and foremost, we would like to thank our colleagues from the NAACC Core Group who worked so diligently to develop and refine the concepts reflected here, and the documents resulting from their many days and hours of effort. The core group includes Rich Kirn of the Vermont Department of Fish and Wildlife, Jessie Levine, Erik Martin, and Michelle Brown of The Nature Conservancy, Jed Wright of the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Melissa Ocana and Bob English of the University of Massachusetts Amherst, and Keith Nislow of the U.S. Forest Service. We are particularly thankful to Jessie Levine for her many hours of thorough editing.

In addition, the NAACC relies on a Working Group composed of dozens of professionals working across the region in state and federal agencies and nongovernmental organizations dedicated to improving stream connectivity for the health and resilience of our aquatic and terrestrial ecosystems, as well as safeguarding our infrastructure in the face of a changing climate and increasingly intense, and sometimes devastating storms. Thanks to all those who have lent their time and expertise to making our collaborative successful.

And, finally, thanks to the U.S. Fish and Wildlife Service North Atlantic Landscape Conservation Cooperative for funding this important work.

Alex Abbott & Scott Jackson

Suggested Citation

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TABLE OF CONTENTS

OVERVIEW

This document provides guidance for completing the North Atlantic Aquatic Connectivity (NAACC) Stream Crossing Survey Data Form.

The North Atlantic Aquatic Connectivity Collaborative (NAACC) is a network of individuals from universities, conservation organizations, and state and federal natural resource and transportation departments focused on improving aquatic connectivity across a thirteen-state region, from Maine to Virginia. The NAACC has developed common protocols for assessing road-stream crossings (culverts and bridges) and developed a regional database for these field data. The information collected will identify high priority bridges and culverts for upgrade and replacement. The NAACC will support planning and decision-making by providing information about where restoration projects are likely to bring the greatest improvements in aquatic connectivity.

The survey data form is to be used for an entire road-stream crossing, which may include single or multiple culverts or multiple cell bridges. On the first page, the top of the form contains general information about the crossing, and the bottom half of that page is for data on the first (or only) structure at the crossing. Subsequent pages are used to add data where there are additional culverts or bridge cells. It can be difficult to determine how best to evaluate multiple culvert/cell crossings. Please remember that it is essential to gather all of the data required for each structure (pipe or bridge cell) for accurate assessment of the entire crossing.

Stream crossing survey data can be collected digitally on a variety of devices, including tablet computers and smart phones. While data collected digitally must be reviewed before upload to the NAACC database, data upload can be done in “batches” without the need for manual entry. Paper forms can also be used, with subsequent manual data entry to the NAACC online database. Further instructions for data entry by each of these methods is provided in survey training sessions, and at www.streamcontinuity.org.

Please be sure to complete every possible element of the field data form.

SURVEY PLANNING

GENERAL PLANNING

Any effort to survey stream crossings should be based on a plan that includes answers to the following key questions:

1. ***Who is primarily responsible for managing the surveys?***
   Each NAACC state or region has a coordinator who helps decide on priority areas for survey and how to manage the data once surveys are completed. This coordinator will also plan for, oversee, and collect data from the surveys. Contact the project at contact@streamcontinuity.org for more information, or refer to the NAACC website to locate a coordinator in your region: https://www.streamcontinuity.org/participating_states.htm.

2. ***How will surveyors be trained?***
   Training should be arranged through your regional or state coordinator, and includes both classroom and field survey practice. Trainings are posted on https://www.streamcontinuity.org/about_naacc/training_prog.htm. The most important elements of training are becoming familiar with this instruction manual and gaining practice through survey of a variety of crossings with an experienced surveyor.

3. ***When should surveys be done?***
   Ideally, surveys should be conducted during low-flow periods, particularly summer and early fall.

4. ***How should we decide where to survey?***
   Consult with your regional coordinator to decide whether surveys will be conducted in one or more watersheds, towns, or counties. Plan to have maps to help you navigate to sites you plan to survey, either copies of existing maps such as the DeLorme Atlas and Gazeteer, or more sophisticated maps from a geographic information system (GIS). When collecting data digitally on a tablet computer or smart phone, survey coordinators must identify and map planned survey sites for your chosen survey area.

   For each state in the NAACC region, United States Geological Survey (USGS) HUC-12 subwatersheds have been prioritized for field surveys by the NAACC project team. These subwatersheds were prioritized based on several objectives including brook trout, diadromous fish, and the potential vulnerability of culverts to failure. These prioritized results can be a useful starting place for identifying areas to survey. In addition, there may be locally important watersheds or habitats in your state or region that may help guide location of surveys. To see the NAACC priority subwatersheds in your area, visit the web map at http://arcg.is/1F2rPJu. This web map also depicts road-stream crossings symbolized by their estimated restoration potential which can help focus survey efforts within a subwatershed.

5. ***Which sites will be surveyed?***
   Work with your state or regional coordinator to decide whether all crossings, or only certain types or sizes of streams will be considered. Some crossing surveys focus primarily on designated *perennial* streams containing most aquatic habitats, while other survey projects include all *ephemeral* and *intermittent* streams. In other cases, certain places in the watershed or town may be identified as highest priority for surveys, based on ecological or other criteria.

6. ***How will we keep track of the sites visited?***
   You should maintain records, possibly as notations on paper maps, or in a table listing each planned survey site, showing which sites have been surveyed and when. Organize your survey forms by date, and be sure each survey form is complete. Once data has been entered to the NAACC database (https://streamcontinuity.org/cdb2), you will be able to see all surveyed sites through online maps to verify that you have completed all planned crossings.

7. ***How can we access crossings on major highways, railroads and private land?***
Depending on the scope of your surveys, you should have easy access to stream crossings on most public roads, though it is important to be aware of the right-of-way to avoid inadvertently trespassing on private land. Access to interstate highways and railroads is generally much more limited. For cases with limited access to crossings, you are responsible for contacting the appropriate owner or manager of those crossings to request access to conduct surveys. Similarly, for crossings on private roads, you should make concerted efforts to notify private landowners to request permission to conduct surveys on their lands. It may help to work with a local land trust, town or county governments, or state resource agencies to gain access from these landowners, as they often have similar needs for conducting habitat surveys or other resource assessments. In some survey efforts, when allowed by specific laws in effect in those jurisdictions, it has been considered permissible to survey crossings on private roads, particularly if good faith efforts to notify landowners have been undertaken first, or so long as crossings are not on posted or gated roads.

8. ***How can we be sure our data will lead to crossing improvements?***
For your data to be useful in setting stream restoration priorities, we encourage you to collect data as completely and accurately as possible and ensure that the data are entered properly into the database. Finally, be sure that all data, including survey forms and site photographs, whether collected digitally or on paper, are transmitted to your state or regional coordinator for archiving.

Safety

Streams can be hazardous places, so take care to sensibly evaluate risks before you begin a survey at each stream crossing. While these efforts to record data about crossings are important, they are not nearly as important as your safety and well-being. Working around roads can be dangerous, so be sure to wear highly visible clothing, preferably safety vests in bright colors with reflective material; some vests have the additional bonus of containing many pockets to hold gear. Take care when parking and exiting your vehicle, and when crossing busy roads.

These surveys are best undertaken by teams of two people. This will facilitate taking measurements, making decisions in challenging situations, and recording data.

Take measurements seriously and carefully, but make estimates if necessary for your safety. Avoid wading into streams – even small ones – at high flows and entering pools of unknown depths, and take care scaling steep and rocky embankments. There are usually ways to effectively estimate some dimensions without risk. For example, an accurate laser rangefinder is a safe way to measure longer distances when conditions are unsafe, such as measuring culvert lengths through them instead of across busy roads.

Stream crossing inventory work may place NAACC observers in situations where they inadvertently contribute to the spread of aquatic invasive species (AIS), particularly when they cross watershed boundaries. AIS are harmful non-native plants, animals, and microorganisms living in some aquatic habitats that damage ecosystems or threaten commercial, agricultural, and recreational activities. The following best management practices are recommended for NAACC observers to prevent the spread of AIS between drainage basins.

Avoiding the Spread of Invasive Species

Stream crossing inventory work may place NAACC observers in situations where they inadvertently contribute to the spread of aquatic invasive species (AIS), particularly when they cross watershed boundaries. AIS are harmful non-native plants, animals, and microorganisms living in some aquatic habitats that damage ecosystems or threaten commercial, agricultural, and recreational activities. The following best management practices are recommended for NAACC observers to prevent the spread of AIS between drainage basins.

Survey planning:

- Complete surveys of HUC12 watersheds one at a time. Staying within a HUC12 rather than changing sub-basins can help stop the spread of invasive species.
- Whenever possible, start surveying stream crossing sites at the upstream end of a HUC12 watershed and progress downstream over the course of the day. Invasive species are naturally moved downstream by streamflow but do not easily move upstream on their own. By progressing from upstream to downstream in surveys, observers can avoid helping move invasive species to upstream locations.
- Do not use waders with felt soles.
- In waters known to contain invasive species, try to avoid entering the stream to take measurements. This may not be possible at many sites but could be at some.

Between site surveys:

- Before leaving a survey site, clean, drain, and dry (or treat) equipment. Clean equipment by inspecting it for attached mud, plants, and debris. Remove and dispose of anything found. Scrub equipment with a stiff brush and rinse with water. Drain any standing water in waders and other equipment.
- Keep a plastic drum filled with bleach or quaternary ammonia solution (which is less harmful on gear than bleach) in the back of the vehicle and put the wading boots in the drum while driving to the next site.
- When survey schedules or logistics prevent cleaning and drying/treating of equipment, a set of duplicate wading boots are recommended when observers change watershed boundaries during a single day. Observers should change into dry boots before surveying crossings in new watersheds and cycle the previous pair to be clean and dry for the following day.

At the end of the day, or when moving between HUC12 watersheds, use one of these options:

- Dry equipment completely for at least 48 hours. Preferable ways to dry equipment include direct sunlight, a heated garage, or a boot drying device such as a PEET Dryer device.
- Soak or spray equipment with a mild bleach solution (1 Tbsp bleach per gallon of water) for 10 minutes. The bleach solution must be mixed daily to maintain its effectiveness after 24 hours.
- Visit a "wader wash" station, if available.
- Freeze equipment for 6-8 hours.

EQUIPMENT

To collect data on stream crossing structures, you will need several essential pieces of equipment for measuring and recording, and some other items to keep you healthy and safe:

- ✓ **Instruction Guide for the NAACC Stream Crossing Survey Data Form** (this document)
- ✓ **Measuring Implements** in feet and tenths (decimal feet rather than inches)
    - o **Reel Tape:** For measuring structure lengths and channel widths; 100 feet.
    - o **Pocket Tape:** Best in 6 foot "Pocket Rod" version with no spring to rust.
    - o **Stadia Rod:** Telescoping, 13 feet long to measure structure dimensions such as water depth.
- ✓ **Safety Vests:** Brightly colored, reflective vests, preferably with lots of pockets to hold equipment, but most importantly to be seen on the road.
- ✓ **Waders or Hip Boots:** To stay dry, insulate from cold water, minimize abrasions, and allow access to tailwater pools and deeper streams.
- ✓ **Flashlight:** To be able to see features inside long dark structures.
- ✓ **Rangefinder** (optional): To safely take measurements without crossing structures, busy roadways or streams; should be accurate to within one foot for adequate data accuracy.
- ✓ **Sun Protection:** Hat, sunglasses, and sunscreen as needed.

- ✓ **Insect Repellent:** To protect from annoying or dangerous bites.
- ✓ **First Aid Kit:** To deal with any minor injuries, cuts, scrapes, etc.
- ✓ **Cell Phone:** In case of emergency, to coordinate surveys, or to ask questions of coordinators.

For Paper Surveys

- ✓ **Stream Crossing Survey Forms**: Best printed on waterproof paper. Bring along more than you expect to use. Even digital surveys should include these in case a digital device becomes inoperable.
- ✓ **Clipboard**, **Pencils & Erasers**
- ✓ **Stream Crossing Maps**: For planning sites to survey, and for recording sites assessed, a *DeLorme Atlas and Gazeteer* or similarly accurate and updated set of maps with topography is helpful for navigation.
- ✓ **GPS Receiver**: Set GPS to collect data in WGS84 datum, with Latitude and Longitude in decimal degrees.
- ✓ **Digital Camera**: Best if waterproof and shockproof, with sufficient battery power for a full day of surveying, and capable of storing approximately 100 low to moderate resolution images (approximately 100 - 500 kilobyte stored size, generally less than 1 million pixels–1 megapixel). Include batteries or battery charger, and download cable. A backup memory chip can be very useful to have on hand.

For Digital Surveys:

- ✓ **Tablet Computer:** Should be waterproof, and preferably shockproof, to be able to survive wet and rugged field conditions. Various mapping applications can be run to allow navigation to planned survey sites, replacing paper maps. For more information on this method of survey, refer to the NAACC Digital Data Collection User's Guide available at https://www.streamcontinuity.org/resources/naacc_documents.htm
- ✓ **GPS Receiver:** If not integral to the tablet computer, an external GPS device will be needed either to connect to the tablet via Bluetooth or wire, or at the least, to be able to provide correct coordinates for entering to the tablet manually.
- ✓ **Stream Crossing Survey Forms**: As a backup in case digital devices fail.

Unmapped Sites and Nonexistent Crossings

Survey teams may encounter unmapped crossings, or it may be unclear whether a crossing they have found in the field is on their map because its location does not match the map. In most cases, the surveyed crossing should be within 100-200 feet of the planned crossing. Survey teams also may encounter unmapped crossings because either the road was not mapped, as in the case of a road built to serve a new housing development, or because of an error in the road or stream data.

If there is no planned crossing near the site you are assessing, you need to assign a temporary *Crossing Code* to that crossing. A *Crossing Code* is composed of the prefix "xy" followed by the latitude and longitude of the site, with decimal degree latitude and longitude values as seven-digit numbers. For instance, a crossing located at 42.32914 degrees north and -72.67522 degrees west, will have the resulting *xy code* = "xy42329147267522," followed by the notation: "NEW XY" to indicate that this crossing site must be added to the map.

Conversely, a crossing may exist on the map but not in the field. If you try to navigate to a site and are certain that there is no crossing in the vicinity, you should select the "No Crossing" option for *Crossing Type* on the field data form. Some crossings may not actually exist due to errors in generating the crossing points. Another possibility is that there may have been a road crossing there at one time, but the crossing has been removed, but may still need to be surveyed to note passage problems. For these sites, you will select the "Removed Crossing" option. Similarly, sometimes an entire stream reach has been moved, particularly underground, in which case you will select the "Buried Stream" *Crossing Type*.

In all cases where a survey crew either cannot locate a mapped crossing or intends to add a new unmapped crossing, it is essential to check the location carefully to minimize navigation and data collection errors.

COMPLETING THE SURVEY DATA FORM

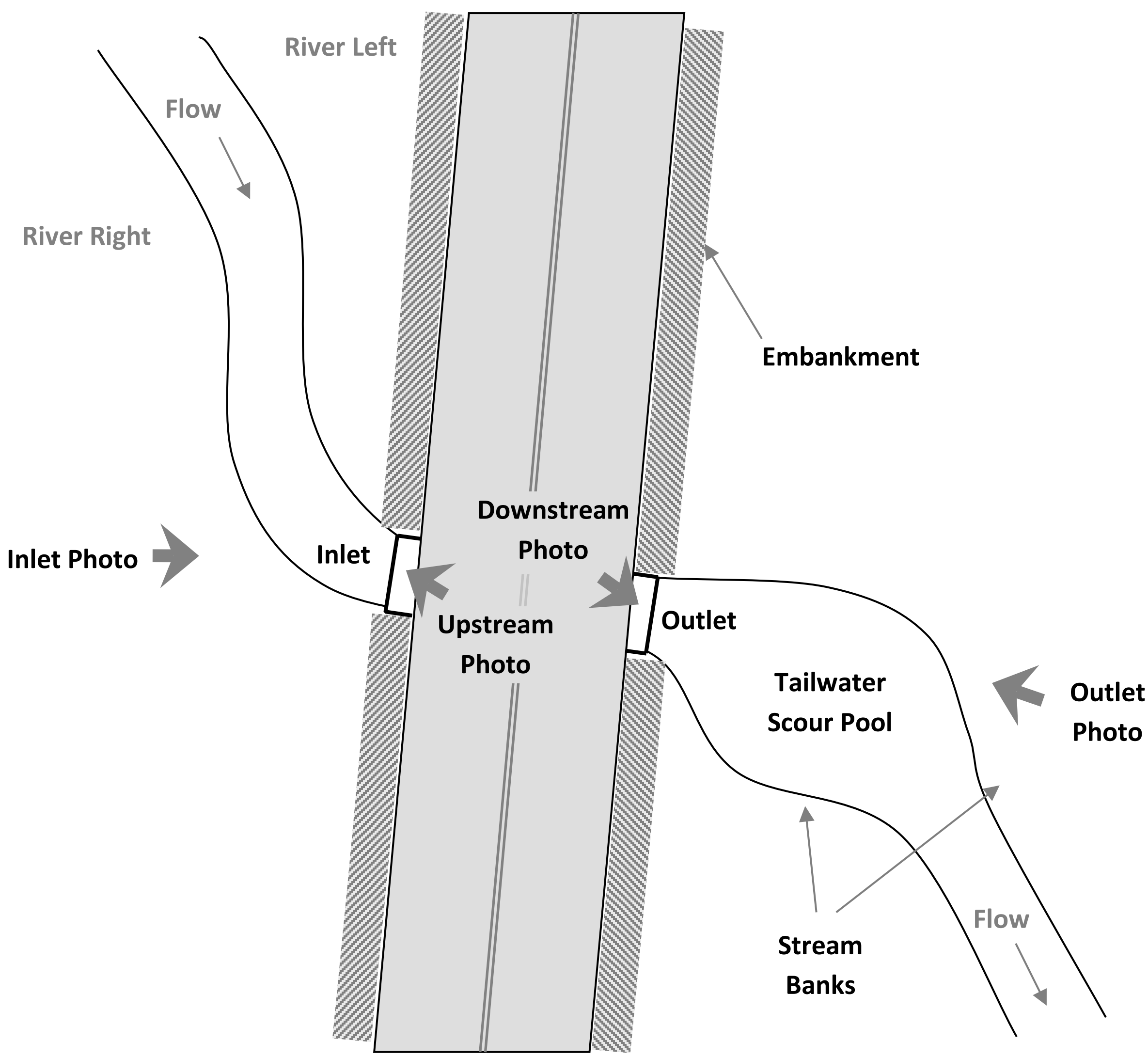
N/A

SHADED BOXES

The shading on the data form is intended to make the form easier to follow and complete. The different shading sets off elements related to certain groups of information from others.

SITE IDENTIFICATION

While each crossing will be different from others in its details, many common features will be assessed, measured, or otherwise observed during all surveys. The diagram below contains the basic terminology for key stream crossing features in a simplified overhead view.



Undisturbed Stream Reference Reaches

When conducting crossing surveys, elements of this data form require you to understand key characteristics of an undisturbed, "natural" section of the stream (called a *reference reach*) near where the crossing is located. These characteristics include the stream's approximate width, depth, and velocity, and the type of substrate that predominates there. In general, you will need to go a distance upstream or downstream from the crossing that is between 10 and 20 times the width of the stream to get away from the influence of the crossing. This means for a 10-foot wide stream, you will need to go between 100 and 200 feet upstream or downstream from the crossing to find an undisturbed reach. The distance will be much larger for larger streams. Note that sometimes you will be unable to locate such a reference reach, either because upstream and downstream reaches are too disturbed or modified, or because access is limited, such as by *No Trespassing* signs.

Crossing Data

Complete this section for the entire crossing. Choose only one option for the fields with checkboxes in the crossing data section.

N/A **Crossing Code**: This is the 18-character "xy code" assigned to each planned survey crossing on survey maps. Be very careful to record the correct numbers, as they represent the precise latitude and longitude of the planned crossing, which can be compared with the actual location you record as GPS Coordinates below.

Local ID: Optional field for a program's own coding systems. Does NOT replace the Crossing Code.

Date Observed: Date that the crossing was evaluated, following the form *M/D/Y*.

Lead Observer: The name of the survey team leader responsible for the quality of the data collected.

Town/County: The town or county in which the assessed crossing is located according to the map.

Stream: The name of the stream taken from the map, or if not named on the map, the name as known locally, or otherwise list as *Unnamed*.

Road: The name of the road taken from the map or from a road sign. Numbered roads should be listed as "Route #", where # is the route number, with multiple numbers separated by "/" when routes overlap at the crossing (e.g., "Route 1/95"). For driveways, trails, or railroads lacking known names, enter *Unnamed*.

Road Type: Choose only one option:

Multilane: > 2 lanes, including divided highways (assumed paved)
Paved: public or private roads
Unpaved: public or private roads
Driveway: serving only one or two houses or businesses (paved or unpaved)
Trail: primarily unpaved, or for all-terrain vehicles only, but includes paved recreational paths
Railroad: with tracks, whether or not currently used

GPS Coordinates: Latitude and Longitude in decimal degrees to 5 decimal places. Use of a GPS (Global Positioning System) receiver is required, but your smart phone or tablet computer may include this capability.

Map Datum: It is best to use *WGS84* datum.

Location Format: Use Latitude-Longitude decimal-degrees (often in GPS menu as "hddd.ddddd").

You should stand above the stream centerline, and ideally on the road centerline, when taking the GPS point, but use your judgment and beware of traffic.

Location Description: If there is any doubt about whether someone could find this crossing again, provide enough information about the exact location of the crossing so that others with your data sheet would be confident that they are at the same crossing that you evaluated. For example, the description might include "between houses at 162 and 164 Smith Road," "across from the Depot Restaurant," or "driveway north of Smith Road off Route 193." This information could also include additional location information, such as a site identification number used by road owners or managers.

Crossing Type: If a crossing is found at the planned location, choose the one most appropriate option.

Bridge: A bridge has a deck supported by abutments (or stream banks). It may have more than one cell or section separated by one or more piers, in which case enter the number of cells to *Number of Culverts/Bridge* Cells. Enter data for any additional cells in *Structure 2 Data*, *Structure 3 Data*, etc.

Culvert: A culvert consists of a structure buried under some amount of fill. If it is a single culvert, you need only complete the first page of the data form.

Multiple Culvert: If there is more than one culvert, you must indicate that in *Number of Culverts/Bridge Cells* to the right. Data must be entered in sections for additional structures starting on the second page (*Structure 2 Data*, *Structure 3 Data*, etc.). Count ALL structures, regardless of their size.

Ford: A ford is a shallow, open stream crossing, in which vehicles pass through the water. Fords may be armored to decrease erosion, and may include pipes to allow flow through the ford (*vented ford*).

If a planned crossing cannot be found or surveyed, the site will fit one of the following types:

No Crossing: There is no crossing where anticipated, usually because of incorrect road or stream location on maps. No further data is required. (Be sure you are in the correct location.)

Removed Crossing: A crossing apparently existed previously at the site but has been removed, so the stream now flows through the site with no provision for vehicles to cross over it. Continue to complete the survey form to the extent possible. Include information in Crossing Comments to explain your observations. For instance, indicate if an old culvert pipe is seen at the site, or if removal of the previous crossing structure left the stream with problems for aquatic organism passage.

Buried Stream: The planned crossing site does not include an inlet and/or outlet, likely because a stream previously in this location has been rerouted, probably underground. In this case, survey is not possible, and no further data is required.

Inaccessible: Survey is not possible because roads or trails to the crossing are not accessible. This may be due to private property posting, gates, poor condition, or other factors. Record in Crossing Comments why the site is inaccessible. No further data is required.

Partially Inaccessible: Use this option when you can access a crossing well enough to collect some but not all required data. This is most likely to occur when you cannot access either the inlet or outlet side of a crossing and cannot reasonably estimate the dimensions or assess things like inlet grade, outlet grade, scour pool or tailwater armoring.

No Upstream Channel: This option is for places where water crosses a road through a culvert but no road-stream crossing occurs because there is no channel up-gradient of the road. This can occur at the very headwaters of a stream or where a road crosses a wetland that lacks a stream channel (at least on the up-gradient side).

Bridge Adequate: Coordinators have the option of using this classification for large bridges for which it is obvious that they present no barrier to aquatic organism passage. Observers may collect and enter data for these crossings but these data are not required.

AKA "Number of Barrels"

Number of Culverts/Bridge Cells: For all Bridges with multiple sections or cells, and for all multiple culverts, you must enter the number of those cells or culvert structures here.

Photo IDs: All surveys should include a minimum of four digital photos of the following: crossing inlet, crossing outlet, stream channel upstream of crossing, and stream channel downstream of crossing. These photos are immensely useful in setting priorities for restoration. Note that photos of buried streams are optional but recommended.

It is essential that all photos be associated with the correct crossing. If you take photos with a digital camera (and sometimes when using a smart phone or tablet computer), you should record the photo numbers assigned by the camera on the survey form in the space for each photo perspective. To record the correct photo numbers from any camera, each person taking photos must be familiar with the numbering system of the camera used. Record the ID number of each photo in the blanks on the data form.

While you may take multiple photos at a site in order to choose the best ones later, you must record on the data form the ID numbers of all photos taken at the site. It can be very helpful to have one or more additional photos, especially when important characteristics are not captured on the four required photos. For instance, if there is extreme erosion at the site, or if other aspects of the crossing make it a likely barrier to connectivity, it is useful to capture these with one or two additional photos.

A simple way to know which photos were taken at a particular site is to use a black marker on a white dry-erase board to record the date and Crossing Code, and to have the first photo at the crossing show this white board displaying the date and Crossing Code. The white board should be strategically placed in the photo so that it is legible and does not block key features of the crossings. This will make the photo readily identifiable with the appropriate crossing. Some people have noted that white dry-erase boards and white paper reflect so much light that they are often "washed out" in the photos, making the codes written on the board impossible to read; use of a small blackboard and chalk may be preferable depending on light conditions.

Another option for keeping track of photos is to make the first photo at each site an image of the field data sheet with the xycode and location information. All other photos of that crossing should immediately follow the photo of data form (with the xycode). It is important to remember to photograph the data form first, before you take any other photos for each crossing. Otherwise, you risk mixing up photos from different crossings.

Here are several additional tips for taking useful photos:

- Always include more than just the structure or stream area you are photographing; it is better to capture more context. Remember that with digital photos, we can zoom in to see detail.
- Including a stadia rod in photos of the inlet and outlet can be valuable to verify some measurements, and as a general reference for scale.
- When available, use a date/time stamp to code each photo.
- Set your camera to record in low to medium resolution so that the photos do not take up too much space on the memory card and when downloaded for storage. To minimize storage space but still allow a reasonable quality image, each photo should be between 100 and 500 kilobytes in size when downloaded. This often equates to a camera resolution setting of "1 Megapixel."
- Review photos at the site to discard bad photos and to be sure all perspectives are well represented.
- If you haven't used the camera before, practice to be sure you know how to take photos in dark or mixed light situations, as these often exist when surveying stream crossings.

The following are some examples of useful photos:

Site 1 **Site2** **Site 3**

Inlet

Outlet

Upstream

Downstream

Flow Condition: Check the appropriate box to indicate how much water is flowing in the stream. Normally, the value selected for the first perennial crossing of the day will hold for all perennial sites in the area during that day, unless a rainfall event changes the situation. Choose only one option.

No Flow: No water is flowing in the natural stream channel; this option is typical of extreme droughts for perennial streams, or frequent conditions for intermittent or ephemeral streams.

Typical-Low: This is the most commonly used and expected value for surveys conducted during summer low flows, particularly on perennial streams. Water level in the stream will typically be below the level of non-aquatic vegetation, exposing portions of stream banks and bottom.

Moderate: This value is selected when recent rains have raised water levels at or above the level of herbaceous (non-woody) stream bank vegetation.

High: This value is selected only rarely, when flows are very high relative to stream banks, making crossing surveys very difficult or impossible, normally due to very recent, or ongoing major rain events. Avoid surveying crossings under high flows as data will not reflect more frequent flow conditions.

Crossing Condition: Check one box that best summarizes the condition of the crossing, based on your observations of the overall state or quality of the crossing, including all structures, particularly the largest or those carrying most of the flow. We are primarily trying to identify crossings in immediate danger of failing or in imminent need of replacement, as well as those that have been very recently installed. Focus primarily on the condition of structure materials.

OK: This is the value given to the vast majority of crossings. Many crossings have deficiencies such as surface rust, dents, dings, or cracks which do not indicate risk of failure.

Poor: This value is intended for structures where the material appears to be failing, such as metal culverts with rot (not just surface rust), or concrete, stone or wooden structures that are already collapsing, or in danger of immediate failure (see images below as examples).

New: This value is assigned only to a crossing that has been installed very recently. Look for unblemished structures with new riprap and/or vegetative bank stabilization.

Unknown: This value applies to all sites where the condition of the crossing cannot be assessed, such as when submerged.

N/A

Tidal Site: Sites in tidal areas will often require additional survey to fully assess aquatic organism passage. This element is primarily meant to identify sites in a tidal zone. Choose only one option. Survey of tidal crossings is best done within one hour of low tide to improve access and provide the most useful data. Freshwater streams influenced by tides, often at great distances from the ocean, are more difficult to identify. Coordinators working in such areas should provide Lead Observers with guidance on survey of such sites.

Yes: Evidence shows that tidal waters regularly reach the crossing site. Evidence includes a clear wrack line (line of debris) marking the limit of recent tides. Other indications include observation of salt marsh plants (*spartina spp.*, not upland vegetation or freshwater wetland plants like cattails and common reed (*phragmites*), though both of these wetland plants *can* exist on the fringes of salt marshes) in the vicinity.

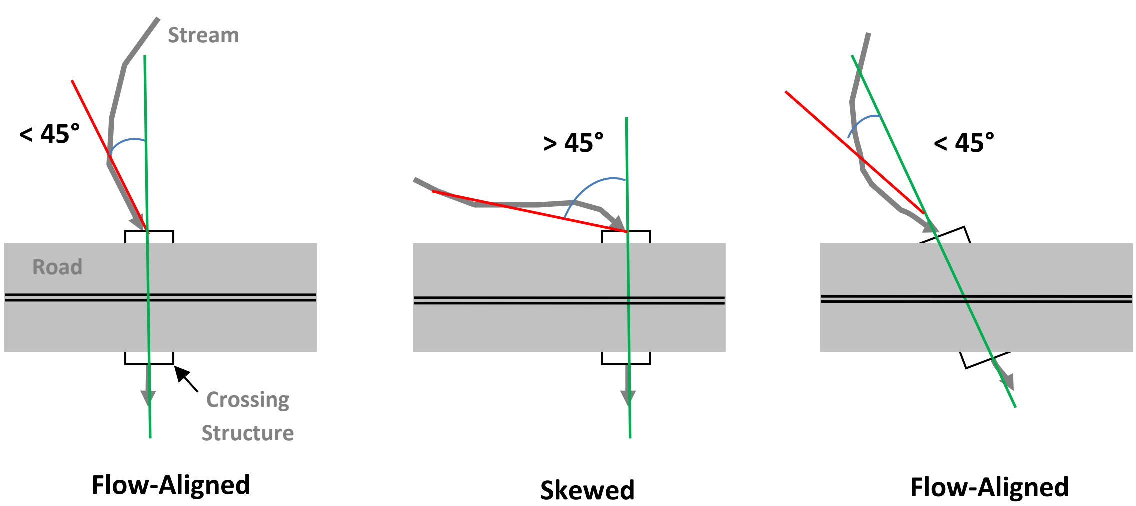
No: Sites are not tidal if downstream banks obviously contain plants that could not survive salt water inundation, such as alders, maples, ferns, etc., normally seen on stream banks in upland areas.

Unknown: Select when unsure of whether a crossing is in a tidal zone.

Alignment: Indicates the alignment of the crossing structure(s) relative to the stream at the inlet(s). Compare the crossing centerline (green lines below) to a centerline of the stream where it enters the crossing (red lines below).

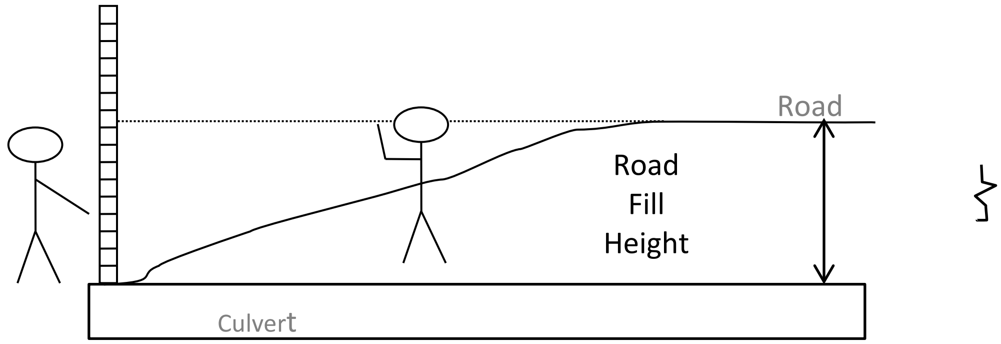
Flow-Aligned: The stream approaches the crossing at less than a 45 degree angle from the centerline.

Skewed: The stream approaches the crossing structure(s) at an angle greater than 45 degrees from the centerline. Note that for some crossings the centerline is not perpendicular to the road.



AKA "Crossing Alignment to Stream"

Road Fill Height: Within 1 foot, measure the height of fill material between the top of the crossing structure(s) and the road surface. This is best measured with two people when the road surface or fill height is above a surveyor's height, with one person holding a stadia rod, and the other sighting the elevation of the road surface from the side (see diagram below). For multiple culverts with differing amounts of fill over them, provide an average fill height.

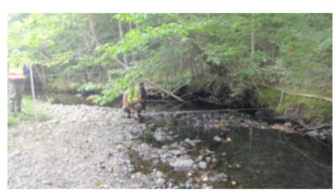


Added post-processing from Stream Stats

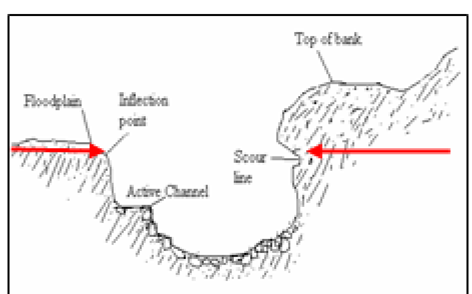
Bankfull Width (optional measurement)**:** This is a measure of the active stream channel width at bankfull flow, the point at which water completely fills the stream channel and where additional water would overflow into the floodplain. Estimates of the frequency of bankfull flows vary, but they may happen as often as twice a year, or only once every one or two years. Each state or regional coordinator will define whether or not you should measure bankfull width in your surveys. When done with high confidence (see next metric), bankfull width can be an extremely useful measurement, but it can be difficult and time consuming, and it will not be possible for all surveyors and sites (even with experienced surveyors). The first step is to identify bankfull flow indicators in an undisturbed reach, and the second step is to measure the width from bank to bank at those locations. Indicators of bankfull flow (shown in the photographs below as the red line) include[1]:

Abrupt transition from bank to floodplain: The point of change from a vertical bank to a more horizontal surface is the best identifier of bankfull stage, especially in low-gradient meandering streams.

Top of point bars: The point bar consists of channel material deposited on the inside of meander bends. Set the top elevation of point bars as the lowest possible bankfull.



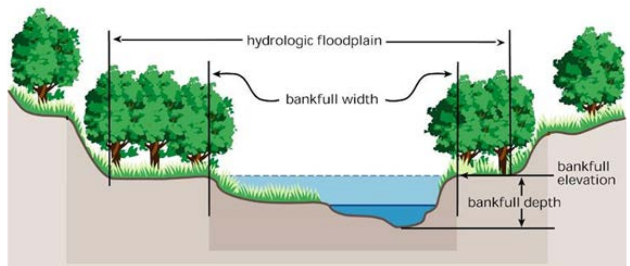
Bank undercuts: Maximum heights of bank undercuts are useful indicators of bankfull flow in steep channels lacking floodplains.



[1] Adapted from Georgia Adopt-A-Stream "Visual Stream Survey" manual. Georgia Department of Natural Resources, 2002.

Changes in bank material: Changes in the particle size of sediment (rocks, soil, etc.) may indicate the upper limits of bankfull flows, with larger sediments exposed to more frequent channel-forming flows.

Change in vegetation: Look for the low limit of woody vegetation, especially trees, on the bank, or a sharp break in the density or type of vegetation.



Added post-processing from Stream Stats

Bankfull Width Confidence: This qualifies your assessment of Bankfull Width based on your experience with its measurement and whether sufficient criteria were met in your measurements. Choose only one option.

High: Select this option only when you are highly confident that your assessment of Bankfull Width meets the following criteria:

- Clear indicators are present to define the limits of Bankfull Width.
- The recorded value is an average of at least three measurements in different locations.
- All measurements of Bankfull Width were taken in undisturbed locations well upstream or downstream of the crossing.
- No tributaries enter between the crossing and your area(s) of measurements.
- No measures taken at stream bends, pools, braided channels, or close to stream obstructions.

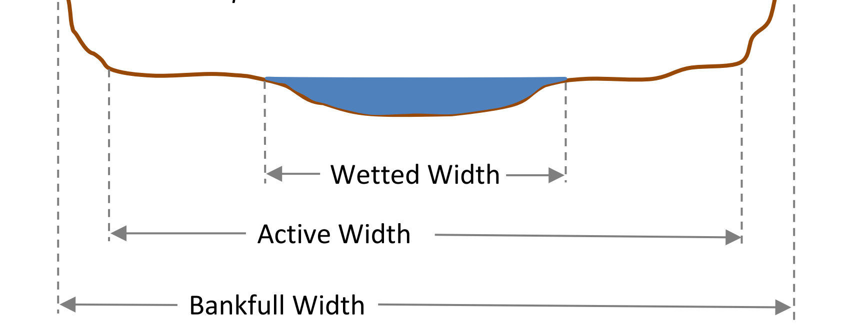
Low/Estimated: Select this when **any** of the above criteria cannot be met.

Constriction: Regardless of whether you measured Bankfull Width above, this element assesses how the width of the crossing (including all of its structures) compares to the width of the natural stream channel. Refer to the above section on determining Bankfull Width for reference. Two other ways of assessing the width of the natural stream channel consider the *active channel* and the *wetted channel*.

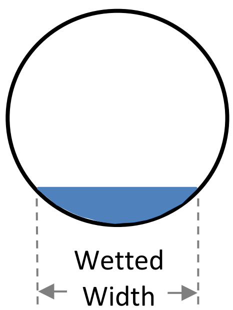
The *active channel* is the area of the stream that is very frequently affected by flowing water. The width of the *active channel* can often be very close to the Bankfull Width when stream banks are very steep. The *wetted channel* is simply the area of the stream that contains water at the time of survey, which may be significantly less than the *active channel*, depending on flow.

Refer to the general illustrations below, and check the appropriate description from the list below to assess how constricted the flow of the stream is by the crossing compared to either the *bankfull*, *active*, or *wetted* channel. Choose only one option.

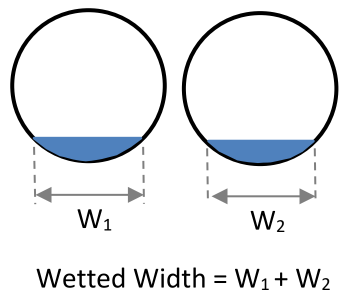
Example Natural Stream Cross Section



Example Culvert Cross Section



Example Multiple Culvert Cross Section



Severe: The total width of the crossing (sum of widths of all crossing structures) is less than 50% of the bankfull or active width of the natural stream, or the total *wetted width* of the crossing is less than 50% of the wetted width of the stream.

Moderate: The crossing is *greater than* 50% of the bankfull or active width of the natural stream, but less than the full bankfull or active channel width.

Spans Only Bankfull/Active Channel: The crossing encompasses the approximate width of the bankfull or active channel.

Spans Full Channel & Banks: The crossing completely spans beyond the *Bankfull Width* of the natural stream, as often evidenced by banks within the crossing structure.

Tailwater Scour Pool: This is a pool created downstream of a crossing as a result of high flows exiting the crossing. Use as a reference natural pools in a portion of the stream that is outside the influence of the crossing structure. A scour pool is considered to exist when its size (a combination of length, width, and depth) is larger than pools found in the natural stream. Check *Large* if the length, width **or** depth of the pool is two or more times larger than of pools in the natural stream channel. Otherwise, check *Small* if the pool is between one and two times the length, width, **or** depth of pools in the natural channel.

None: There is no difference between the length, width, or depth of the tailwater pool compared with reference pools, or no tailwater pool exists at the site.

Small: The tailwater pool is between one and two times the length, width, or depth of reference pools.

Large: The tailwater pool is more than twice the length, width or depth of reference pools.

Crossing Comments: Use this area for brief comments about any aspect of the overall crossing survey that warrants additional information. Do <u>not</u> use this box for comments about particular structures; comment boxes for each structure are provided elsewhere on the form.

STRUCTURE DATA

Choose only one option for structure data fields **except** when identifying Internal Structures and Physical Barriers.

When there are multiple culverts and/or bridge cells, number them from left to right, while looking downstream toward the culvert inlet. The left-most structure is Structure 1, and structure numbers increase to the right. See examples below. When entering data via the ODM or data entry screen make sure that you enter the structures in the same order in which they are numbered.

For each structure, you will complete the following information.

Structure Material: Record here the primary material of which the structure is made, i.e., the material that makes up the majority of the structure. When in doubt, focus on the material that is most in contact with the stream. If a structure is made of two materials, such as a bridge with concrete abutments and a steel deck structure, a metal culvert that has been lined along its entire bottom with concrete, or a crossing with different types of structures at inlet and outlet, select *Combination*. Choose only one option.

Outlet Shape: Refer to the diagrams on the last page of the field data form, and record here the structure number that best matches the shape of the structure opening observed at the inlet of the culvert. This is usually simple, but when a shape seems unusual, you should carefully choose the most reasonable option from among the eight available. We collect this information to be able to find the "open area" inside the structure above any water or substrate, so the shape is vital to accurately calculate area. Choose only one option.

1 - Round Culvert: This is a circular pipe. It may or may not have substrate inside, even though the diagram on the field form shows a layer of substrate. It may be compressed slightly in one dimension, and should be considered round unless it is truly squashed so that it reflects a type 2 shape below.




2 - Pipe Arch/Elliptical Culvert: This is essentially a squashed round culvert, where the lower portion is flatter, and the upper portion is a semicircular arch, or as on the right below, more of a pure ellipse. It may or may not have substrate inside (the diagram on the field form shows a layer of substrate).

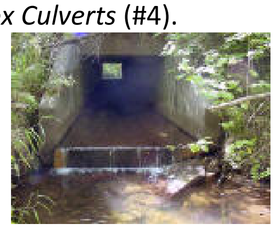
   

3 - Open Bottom Arch Bridge/Culvert: This structure will often look like a round culvert on the top half, but it will not have a bottom. There will be some sort of footings to stabilize it, either buried metal or concrete footings, or concrete footings that rise some height above the channel bottom. There will be natural substrate throughout the structure. To distinguish between an embedded Pipe Arch Culvert and an Open Bottom Arch, note that the sides of the Pipe Arch curve inward in their lower section, while the sides of the Open Bottom Arch will run straight downward into the streambed substrate or to a vertical footing. Beware of confusion between an Open Bottom Arch and an embedded Round Culvert; Open Bottom Arches tend to be larger than most Round Culverts. This shape could also be selected for certain bridges that have a similar arched shape and are not well represented by other bridge types (Types 5, 6, 7, below).

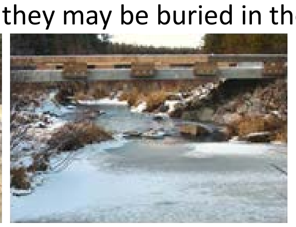
   

4 - Box Culvert: These structures are usually made of concrete or stone, but sometimes of corrugated metal with a slightly arched top. Typically, they have a top, two sides, and a bottom.

A box culvert <u>without</u> a bottom, called a bottomless box culvert, should be classified as a *Box/Bridge with Abutments* (#6, below). If you cannot tell if the structure has a bottom, classify it as a *Box/Bridge with Abutments* (#6). The images below show *Box Culverts* (#4).

5 - Bridge with Side Slopes: This is a bridge with angled banks up to the bottom of the road deck. This type will have no obvious abutments, though they may be buried in the road fill.

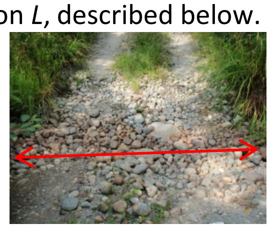
6 - Box/Bridge with Abutments: This is a bridge or bottomless box culvert with vertical sides.




7 - Bridge with Side Slopes and Abutments: This is a bridge with sloping banks and vertical abutments (typically short) that support the bridge deck. (Arrows below show the abutments.)




Ford: A ford is a shallow, open stream crossing that may have aminimal structure to stabilize where vehicles drive across the stream bottom. The arrows below indicate the length of a ford, to be measured as Dimension *L*, described below.

Unknown: Select when a structure's shape is unidentifiable for any reason. Typically, the inlet shape may be unidentifiable because it is submerged or completely blocked with debris.

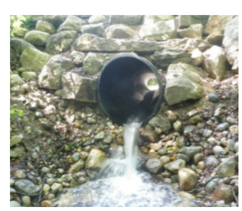
Removed: Select when the structure is no longer present.

Outlet Armoring: Select from the options to indicate the presence and extent of material placed below the outlet for the purpose of diffusing flow and minimizing scour. The most common form of outlet armoring is riprap (angular rock) placed below the outlet. A few pieces of rock that may have fallen into the stream near the structure's outlet **do not** constitute outlet armoring. Armoring of the road embankment and stream banks should not be confused with armoring of the stream bottom at the outlet. Choose only one option.

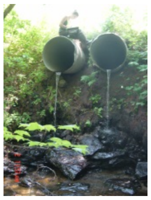
Refer to the photos below for examples of each option.

None: This situation represents the majority of crossing structures. You may observe rocks that have fallen from the embankment or that are natural to the stream. Most cascades do not constitute armoring unless specifically put in place to minimize outlet scour.




Not Extensive: There is of a layer of material covering an area *less than 50% of the stream width* placed purposefully below the outlet specifically to minimize the effects of scour.



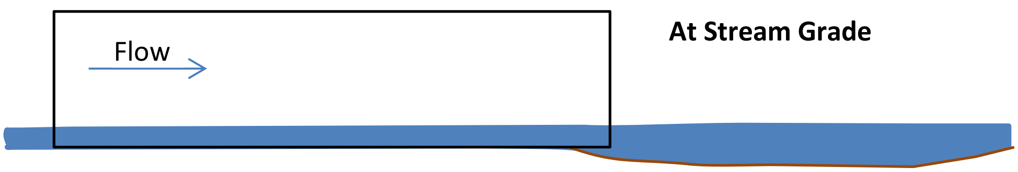


Extensive: Select this option only if you observe an extensive layer of material covering an area more than 50% of the stream width, which was put in place specifically to minimize scour at the outlet.



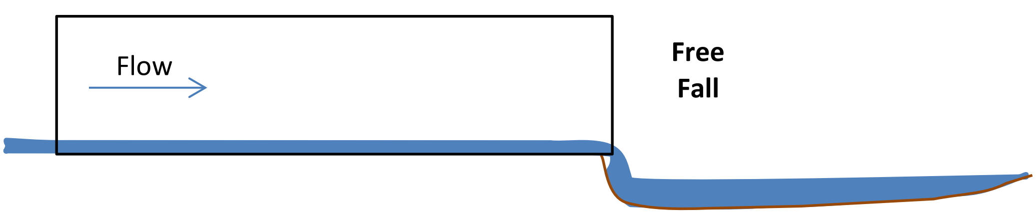

Outlet Grade: Outlet grade is an observation of the relative elevation of the structure to the streambed and how water flows as it exits the structure. This is not an assessment of stream slope (gradient).
<u>Choose only one option</u>.

At Stream Grade: The bottom of the outlet of the structure is at approximately the same elevation as the stream bottom (there may be a small drop from the inside surface of the structure down to the stream bottom), such that <u>**water does not drop downward at all**</u> when flowing out of the structure. Such outlets can normally be considered to be "backwatered" by the downstream stream bed.



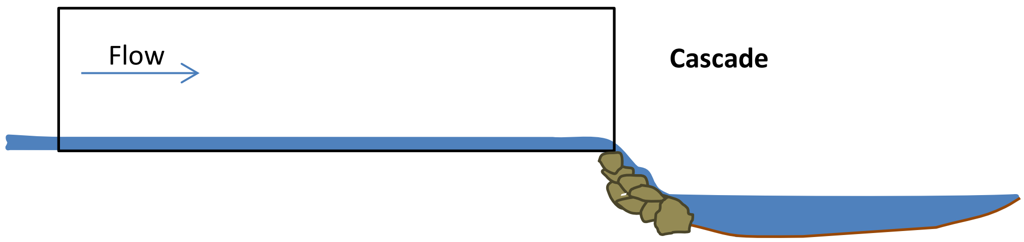



Free Fall: The outlet of the structure is above the stream bottom such that <u>**water drops vertically**</u> when flowing out of the structure.



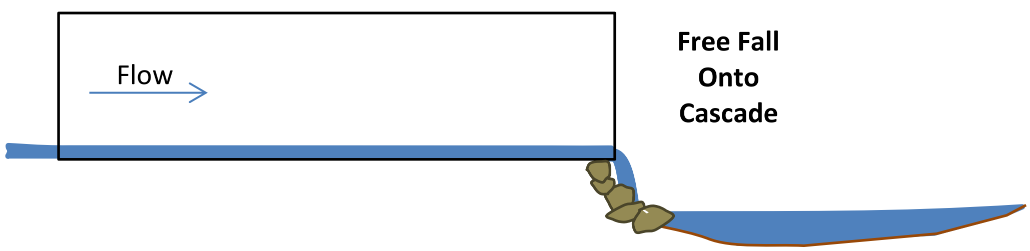
   

Cascade: The outlet of the structure is raised above the stream bottom at the outlet such that **<u>water flows very steeply downward across rock or other hard material</u>** when flowing from the structure. Think of this as series of small waterfalls at the outlet.



Free Fall Onto Cascade: The outlet of the structure is raised above the stream bottom at the outlet such that **<u>water drops vertically onto a steep area of rock or other hard material, then flows very steeply downward</u>** until it reaches the stream.



Clogged/Collapsed/Submerged: The structure outlet is either full of debris, collapsed, or completely underwater (not usually all three), making outlet measurements impossible. This may be found in places where beavers or sediment have plugged or inundated a structure so completely that water has backed up and covered the outlet, or where a crossing has collapsed to the point that it cannot be measured at its outlet. **Chose this option only if you are unable to collect data on outlet dimensions.**

Outlet Dimensions: <u>Four</u> measurements should be taken at the outlet and <u>inside</u> all structures, and an additional **<u>two</u>** should be taken for all structures with an Outlet Grade marked as *Free Fall, Cascade* or Free *Fall Onto Cascade*. The four measurements are shown on the diagrams on the last page of the field data form, and the others are illustrated below.

Dimension A, ***Structure Width***: To the nearest tenth of a foot, measure the full width of the structure outlet according to the location of the horizontal arrows labeled ***A*** in the diagrams. Take this measurement **<u>inside</u>** the structure.

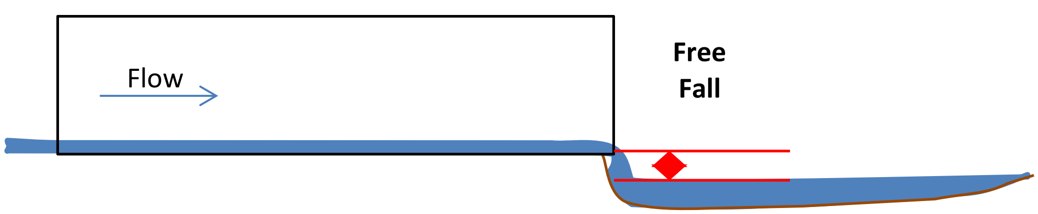
Dimension B, ***Structure Height***: To the nearest tenth of a foot, measure the height of the structure outlet according to the location of the vertical arrows labeled ***B*** in the diagrams. Take this measurement **<u>inside</u>** the structure. If there is no substrate inside, this will be the full height of a structure from bottom to top. If there is substrate inside, this will be the height from the top of the stream bottom substrate up to the inside top of the structure.

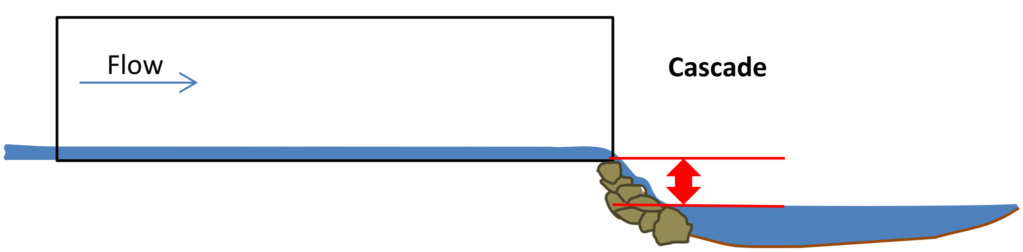
Dimension C, ***Substrate/Water Width***: To the nearest tenth of a foot, measure the width of **either** the substrate layer in the bottom of the structure, or of the water surface, whichever is **<u>wider</u>** according to the general location indicated by the arrows labeled ***C*** in the diagrams. This measurement must be taken **<u>inside</u>** the structure near the outlet. Some rules of thumb for Dimension C are below:

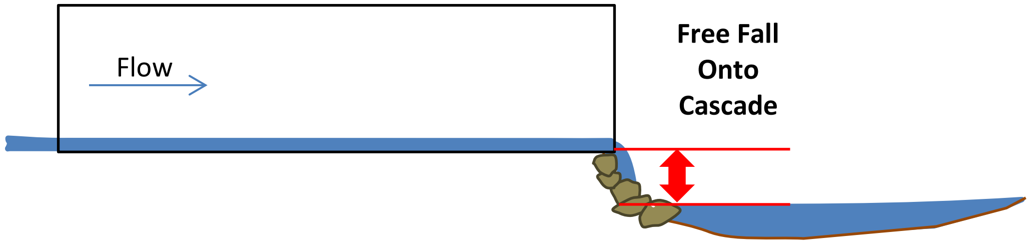
- When there is no substrate in a structure, measure only the width of the water surface.
- When there is no water in a structure, but there is substrate, measure the width of substrate.
- When there is no substrate or water in a structure, C = 0.

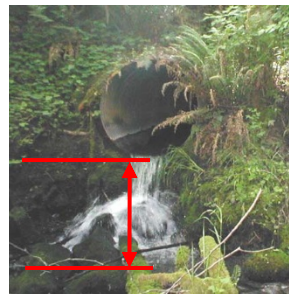
Dimension D, ***Water Depth***: To the nearest tenth of a foot (except when < 0.1 foot, to the nearest hundredth of a foot), measure the average depth of water in the structure at the outlet according to the location of the vertical arrows labeled ***D*** in the diagrams. This measurement must be taken **<u>inside</u>** the structure. When there are lots of different depths due to a very uneven bottom, take several measurements and record the average. For fords, measure the water depth at the downstream limit of the ford.

Outlet Drop to Water Surface: This measurement is only applicable to *Free Fall, Cascade* and Free *Fall Onto Cascade* outlets. To the nearest tenth of a foot, measure from the inside bottom surface of the structure (**not** the top of the water) down to the water surface outside the structure. For *Cascade* and *Free Fall Onto Cascade* structures, measure to the surface of the water at the bottom of the cascade. Refer to the diagrams and photos below for guidance; the red arrows indicate where to make this measurement. When assessing *At Stream* Grade structures or dry structures in streams without flow or water in an outlet pool, this measurement must be *zero*.



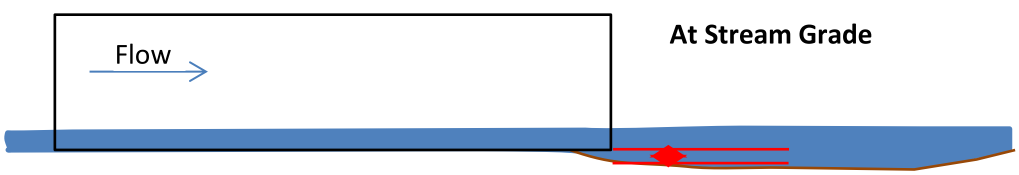


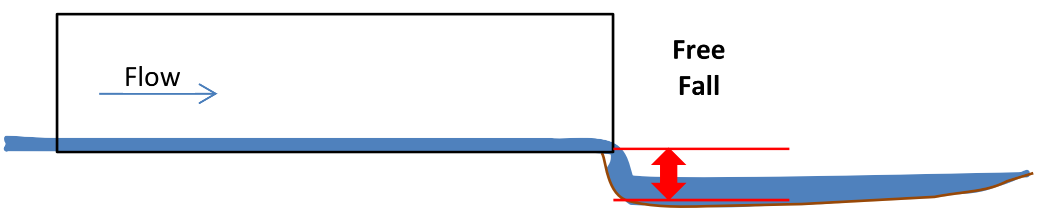


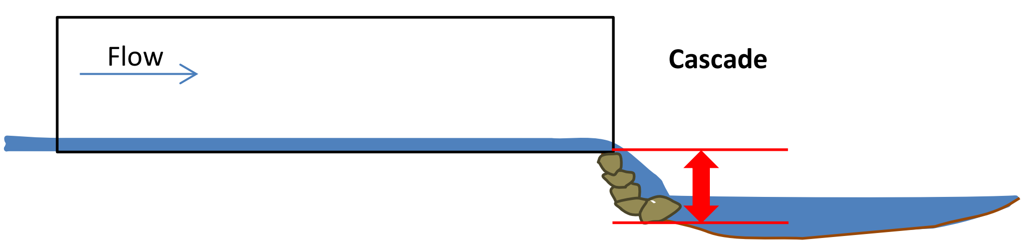


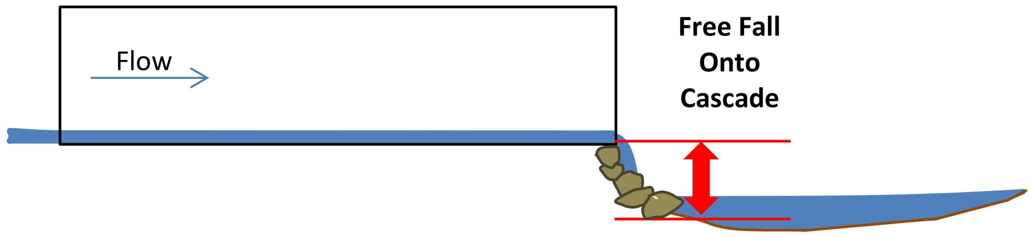
Free Fall   Free Fall   Free Fall onto Cascade

Outlet Drop to Stream Bottom: To the nearest tenth of a foot, measure from the inside bottom surface of the structure (**not** the top of the water) down to the stream bottom at the place where the water falls from the outlet. For At Stream Grade structures, this may be hard to measure, and may be a very small drop. For Cascade and Free Fall Onto Cascade structures, measure the full vertical drop to the stream bottom at the end of the cascade. Refer to the diagrams below for guidance.





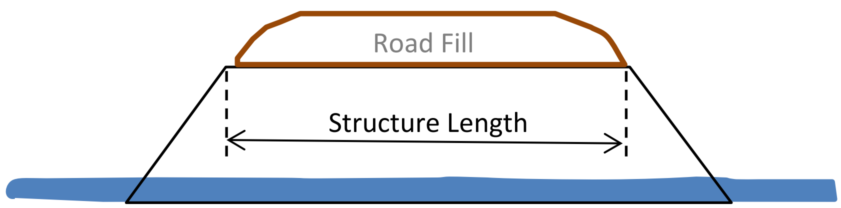




Abutment Height, *Dimension E*: This measurement is taken <u>only</u> when surveying a *Bridge with Side Slopes and Abutments* (#7 structure**)**. To the nearest foot, measure the height of the vertical abutments from the top of the side slopes up to the bottom of the bridge deck structure.

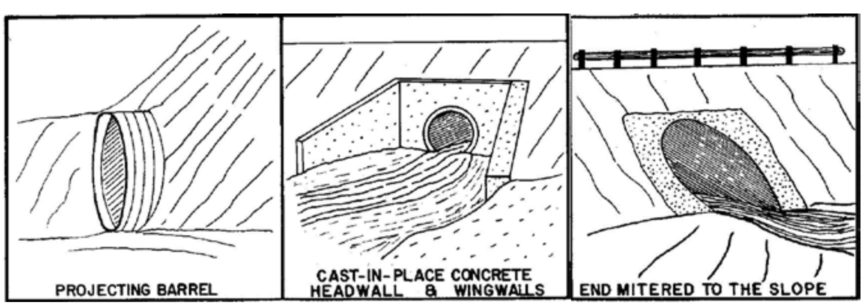


Structure Length, *Dimension L*: To the nearest foot, measure the length of the structure at its top.



Inlet Shape: Refer to the diagrams on the last page of the field data form, and record here the number that best matches the shape of the structure at its outlet. Refer to the instructions for **Outlet Shape** for examples and photos.

Inlet Type: <u>Choose only one option</u> for the style of a culvert inlet, which affects how water flows into the crossing, particularly at higher flows. The drawings here are meant as general guides, but refer to the photos below for more specific images of each type.



Projecting: The inlet of the culvert projects out from (is not flush with) the road embankment.

Headwall: The inlet is set flush in a vertical wall, often composed of concrete or stone.

Wingwalls: The inlet is set within angled walls meant to funnel water flow. These walls can be composed of the same material as the culvert, or different material. It is relatively rare to see wingwalls without a headwall.

Headwall & Wingwalls: The inlet is set flush in a vertical wall, and has angled walls to funnel flow.

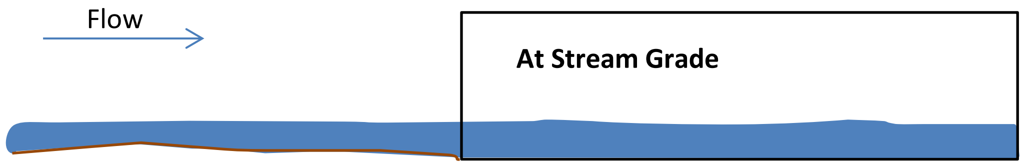
Mitered to Slope: The inlet is angled to fit **flush with the slope of the road embankment**. Note that many mitered culverts project out from the embankment, and should be recorded as *Projecting*.

Other: There may be some other inlet characteristics that do not match any of the above types and which may limit flow into the culvert (but are not *Physical Barriers*), in which case select *Other*, and explain in *Structure Comments*.

None: The inlet does not have any of the above features or characteristics.

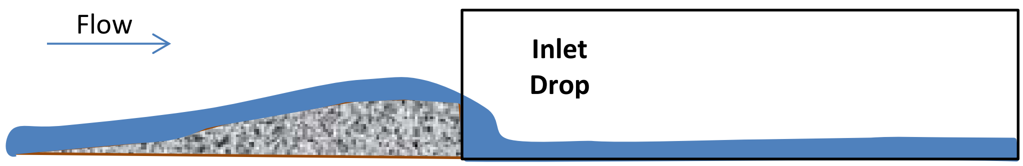
Inlet Grade: An observation of the relative elevation of the stream bottom as it enters the structure. This is not an assessment of stream slope (gradient). Choose only one option.

At Stream Grade: The inlet of the structure is at approximately the same elevation as the stream bottom upstream of the structure.



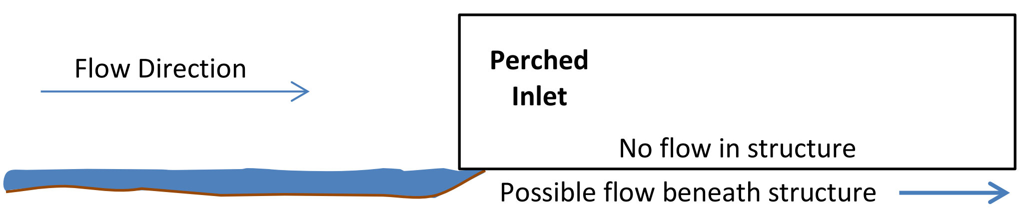



Inlet Drop: Water in the stream has a near-vertical drop from the stream channel down into the inlet of the structure. This usually occurs because sediment has accumulated above the inlet. The drop should be very obvious and not typical of natural drops in that stream. If there is a debris blockage or dam at the inlet, use **Physical** Barriers to record those features, and mark *At Stream Grade* here.



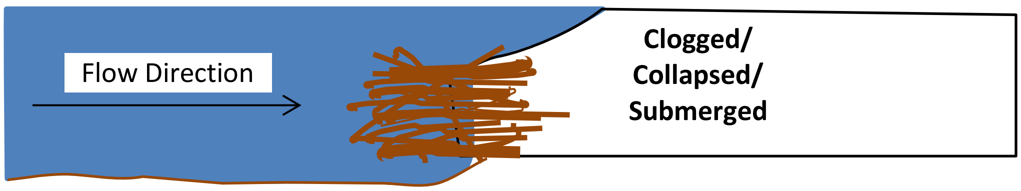



Perched: The inlet of the structure is set too high for the stream, and little water passes through the structure during normal low summer flows, though the stream has water upstream and downstream of the crossing. The structure inlet is above the surface of water in the stream. Water can enter the structure only at higher flows. This is a relatively rare condition, found mostly on very small streams. At such sites, there is generally water backed up above the inlet. In some cases water may be "piping" underneath the structure.






Clogged/Collapsed/Submerged: The structure inlet is either full of debris, collapsed, or completely underwater (not usually all three), making inlet measurements impossible. This may be found in places where beavers or debris have plugged a structure inlet so completely that water has backed up and covered the inlet, or where a crossing has collapsed to the point that it cannot be measured at its inlet. **Chose this option only if you are unable to collect data on inlet dimensions.**






Unknown: The inlet cannot be located or observed, or for some other reason you cannot determine the *Inlet Grade*, or take any inlet measurements.

Inlet Dimensions: There are four basic measurements to take at the inlet and outlet of each structure; these four measurements are to be made inside the structure. These are shown on the diagrams on the last page of the field data form.

Dimension A, ***Structure Width:*** To the nearest tenth of a foot, measure the full width of the structure inlet according to the location of the horizontal arrows labeled ***A*** in the diagrams. Take this measurement **inside** the structure.

Dimension B, ***Structure Height***: To the nearest tenth of a foot, measure the height of the structure inlet according to the location of the vertical arrows labeled ***B*** in the diagrams. Take this measurement **inside** the structure. This may be the full height of a culvert pipe if there is no substrate inside, or if there is substrate, it will be the height from the top surface of the substrate up to the inside top of the structure.

Dimension C, ***Substrate/Water Width***: To the nearest tenth of a foot, measure the width of **either** the substrate layer in the bottom of the structure, or the water surface, whichever is wider, according to the general location indicated by the arrows labeled ***C*** in the diagrams. Take this measurement **inside** the structure at the inlet. Some rules of thumb for Dimension C are below:

- When there is no substrate in a structure, measure the width of the water surface.
- When there is no water in a structure, but there is substrate, measure the width of substrate.
- When there is no substrate or water in a structure, C = 0.

Dimension D, ***Water Depth***: To the nearest tenth of a foot (except when < 0.1 foot, to the nearest *hundredth* of a foot), measure the average depth of water in the structure at the inlet according to the location of the vertical arrows labeled ***D*** in the diagrams. This measurement must be taken **inside** the structure. When there are many different water depths due to a very uneven structure bottom, take several measurements and record the average. For fords, measure the water depth at the upstream limit of the ford.

N/A

Slope %*:* (Optional) Calculate or estimate the percent slope of the crossing from inlet to outlet by using one of several optional methods described below. Note that this measurement or estimate can be important to calculating the hydraulic capacity of the crossing, and is difficult to measure accurately without the proper tools. In general, the ease and accuracy of these different methods relates directly to the cost of the tools needed, with the most easy-to-use and accurate measurement tools costing more.

1) The simplest accurate method for measuring slope is to use an accurate laser rangefinder/hypsometer with a slope function, and to measure from inlet to outlet at the same height in relation to each invert. For instance, a person with a known eye height of 5.0 feet sights from one end of a culvert by standing on top of the inlet to the 5.0 foot mark on a stadia rod on top of the outlet. You must take at least three measurements and average them, and be sure the instrument is set to read in percent, not degrees.
2) Another method for measuring slope is to use an auto level or other accurate survey instrument to measure the vertical difference between inlet and outlet invert elevations, then dividing this number by the length of the structure, and multiplying by 100.
3) The next best approach is to use a clinometer that measures slope to the nearest half percent, measuring from a fixed point above one invert (inlet or outlet) to the same height above the opposite invert such as described above under method 1. Many clinometers include both percent and degree scales; be sure to use the percent scale.
4) Another less accurate approach is to sight from a fixed elevation above the inlet invert with a hand level to a stadia rod at the outlet invert, to take the difference in height between the two points, divide by the structure length, and multiply by 100.

Slope Confidence: Rate the confidence you have in your slope measurement or estimate according to the criteria below:

High: Used method 1 above, taking multiple measurements and averaging them, or used method 2 above.

Low: Used methods 3 or 4 above, taking multiple measurements and averaging them.

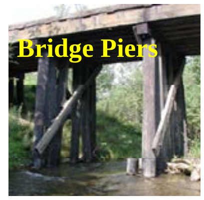
Internal Structures: Indicate the presence of structures inside the crossing structure. These may include baffles or weirs used to slow flow velocities and help to pass fish, as well as trusses, rods, piers or other structures intended to support a crossing structure, but which may interfere with flow and aquatic organism passage. See photos below for examples of internal structures. Choose any option(s) that apply.

None: There are no apparent structures inside the crossing structure.

Baffles/Weirs: Baffles (partial width) or weirs (full width, notched or not) are incorporated into the structure, either inside or at its outlet, to help aquatic organisms move through the structure.

Supports: Some type of structural supports, such as bridge piers, vertical or horizontal beams, or rods apparently meant to support the structure, are observed inside the crossing structure.

Other: Structure(s) other than the categories above are present inside the crossing structure. Provide a very brief description of those structures here, or more fully describe them under **Structure Comments**. <u>**Do not**</u> include here items such as bedrock, material blockages, structural deformation, or inlet fencing to exclude beavers, which will be recorded below as **Physical Barriers**.







Structure Substrate Matches Stream*:* Choose only one option based on a comparison of the substrate (e.g., rock, gravel, sand) inside the structure and the substrate in the natural, undisturbed stream channel.

None: Select this option when there is very little (e.g., a thin layer of silt or a few pieces of rock) or no substrate inside the structure.

Comparable: The substrate inside the structure is similar in size to the substrate in the natural stream channel.

Contrasting: The substrate inside the structure is different in size from the substrate in the natural channel.

Not Appropriate: The substrate inside the structure is very different in size (usually much larger) than the substrate in the natural stream channel. Imagine turtles that typically move along a sandy stream trying to traverse an area of large cobbles, angular riprap or boulders (rarely observed).

Unknown: There is no way to observe if there is substrate inside the structure or what type it is. Select this option when deep, fast, or dark water or other factors do not allow direct observation.

Structure Substrate Type: Choose only one option from the table below to indicate the most common or dominant substrate type inside the structure. If you are certain that the structure contains substrate, but cannot assess the type, select *Unknown*. If there is no substrate in the structure, select *None*.

Substrate Type	Feet	Approximate Relative Size
Silt	< 0.002	Finer than salt
Sand	0.002 – 0.01	Salt to peppercorn
Gravel	0.01 – 0.2	Peppercorn to tennis ball
Cobble	0.2 – 0.8	Tennis ball to basketball
Boulder	> 0.8	Bigger than a basketball
Bedrock	Unmeasurable	Unknown - buried

Structure Substrate Coverage: Choose one option, based on the extent of the substrate inside the crossing structure as a ***continuous*** layer across the entire bottom of the structure from bank to bank (side to side).

None: Substrate covers less than 25% of the length of the structure, or there is no substrate inside the structure at all.

25%: Substrate covers *at least* 25% of the length of the structure.

50%: Substrate covers *at least* 50% of the length of the structure.

75%: Substrate covers *at least* 75% of the length of the structure.

100%: Substrate forms a ***continuous*** layer throughout the ***entire*** structure.

Unknown: It is not possible to directly observe whether substrate forms a continuous layer on the structure bottom.

Physical Barriers: Select any of these barrier types in or associated with the structure you are surveying, but do not include here information already captured in **Outlet Grade**. Note here additional barriers, including those associated with Inlet Grade or blockages, or Internal Structures. If a barrier feature affects more than one structure at a crossing (e.g., a beaver dam), include it for all affected structures. Refer to the photos below for examples of physical barriers.

Note that some structures have a combination of physical barriers. Check all that apply.

None: There are no physical barriers associated with this structure aside from any already noted in **Outlet Grade**.

Debris/Sediment/Rock: Woody debris or synthetic material, rock, or sediment blocks the flow of water into or through the structure. This can consist of wood or other vegetation, trash, sand, gravel, or rock. Do not check this option if you observe only very small amounts of debris that are likely to be washed away during the next rain event. Also, do not confuse sediment inside a structure that constitutes an appropriate stream bed with an accumulation that limits flow or passage of organisms.

Deformation: The structure is deformed in such a way that it significantly limits flow or inhibits the passage of aquatic organisms. This does not include minor dents and slightly misshapen structures.

Free Fall: In addition to its **Outlet Grade**, which may include a *Free Fall*, the structure has one or more **additional** vertical drops associated with it. These may include a dam at the inlet, a vertical drop over bedrock inside the structure, or some other feature likely to inhibit passage of aquatic organisms. Note that a *Free Fall* inside a structure is often more limiting than similar size drops found in an undisturbed natural reach of the same stream which occur where there may be multiple paths for organisms to follow. A *Free Fall* can exist because of a debris blockage, so both physical barriers would be recorded.

N/A: *See NAACC Culvert Assessment Manual for Level of Blockage assessment criteria.*

Fencing: The structure has some sort of fencing, often at the inlet to deter beavers. Depending on the mesh size of that fencing, it may directly block the movement of aquatic and terrestrial organisms, and it may become clogged with debris. If also blocked with debris, be sure to check *Debris/Sediment/Rock* as a **Physical Barrier** type as well.




Dry: There is no water in this structure, though water is flowing in the stream. Note that if you recorded *No Flow* for crossing Flow Condition, you should not select *Dry* here, as we expect a dry structure at a dry crossing; it is not in itself a physical barrier. This barrier type helps to identify passage problems associated with overflow or secondary crossing structures.

Other: There may be different situations that do not fit clearly into one of the above categories, but may still represent significant physical barriers to aquatic organism passage. Use this option to capture such situations, and add information in Structure Comments. Below are examples of some unusual physical barriers which may not fit under Physical Barrier categories listed above.

These are examples of structures with a combination of physical barriers. Multiple relevant barrier types should be selected.





N/A: *See NAACC Culvert Assessment Manual for Level of Blockage assessment criteria.*

Severity: Choose only one option for each surveyed structure, and rank the severity based on an assessment of *the cumulative effect of all physical barriers affecting that structure* according to the table that follows. Do not consider information already captured in **Outlet Grade**. Decide on an overall severity for each structure by considering all the different Physical Barriers present. If any barrier affects more than one structure at a crossing, it should be included in the severity rating for each structure affected. Refer to the table below for guidance in choosing the **Severity** rating.

Physical Barrier	Severity	Severity Definition
None	*None*	No physical barriers exist - **apart from** Outlet Grade
Debris/Sediment/Rock *Logs, branches, leaves, silt, sand, gravel, rock*	*None*	None beyond few leaves or twigs as may occur in stream
	Minor	< 10% of the open area of the structure is blocked
	Moderate	10% - 50% of open area blocked
	Severe	> 50% of open area of structure blocked
Deformation *Significant dents, crushed metal, collapsing structures*	*None*	Small dents and cracks – insignificant effect on flow
	Minor	Flow is limited < 10%
	Moderate	Flow is limited between 10% - 50%
	Severe	Flow is limited > 50%
Free Fall *Vertical or near-vertical drop*	*None*	No vertical drop exists - **apart from** Outlet Grade
	Minor	0.1 - 0.3 foot vertical drop - **apart from** Outlet Grade
	Moderate	0.3 - 0.5 foot vertical drop - **apart from** Outlet Grade
	Severe	> 0.5 foot vertical drop - **apart from** Outlet Grade
Fencing *Wire, metal grating, wood*	*None*	No fencing exists in any part of the structure
	Minor	Widely spaced wires or grating with > 0.5 foot (6 inch) gaps
	Moderate	Wires or grating with 0.2 - 0.5 foot (~ 2-6 inches)spacing
	Severe	Wires or grating with < 0.2 foot (~ 2 inch) spacing
Dry	*Minor*	May be passable at somewhat higher flows
	Moderate	Not likely passable at higher flows
	Severe	Impassable at higher flows
Other	*Minor*	Use best judgment based on above standards
	Moderate	Use best judgment based on above standards
	Severe	Use best judgment based on above standards

Water Depth Matches Stream: Compare the water depth inside the structure with the water depth in the natural stream channel away from the influence of the crossing. Choose only one option.

N/A: *See NAACC Culvert Assessment Manual for Level of Blockage assessment criteria.*

Yes: The depth in the crossing falls within the range of depths naturally occurring in that reach of the stream and **for comparable distances** along the length of the stream. For example, if a structure has a water depth of 0.2 feet through the entire structure's length of 60 feet, and there comparable sections of the stream with a 0.2 foot water depth for approximately 60 feet of the channel, select *Yes*.

No-Shallower: This means that the water depth in the crossing is less than depths that occur naturally in a similar length of the undisturbed stream, or the shallower depth through the structure covers a greater length than occurs in the natural stream.

No-Deeper: This means that the water depth in the crossing is greater than depths that occur naturally in a similar length of the undisturbed stream. This is rarely observed.

Unknown: A comparison of structure depth to natural stream depth is not possible.

Water Velocity Matches Stream*:* Compare the water velocity inside the structure with the velocity in the natural stream channel away from the influence of the crossing. Choose only one option.

Yes: The water velocity in the crossing falls within the range of velocities naturally occurring in that reach of the stream **for comparable distances**. If velocities in the crossing are observed in the natural stream channel, and those velocities persist over the same distance as the structure length, select *Yes.*

No-Faster: This means that the water velocity in the structure is greater than velocities that occur naturally in a similar length of the undisturbed stream, or the velocity through the structure persists over a longer distance than occurs in the natural stream.

No-Slower: This means that the velocity in the crossing is less than velocities that occur naturally in a similar length of the undisturbed stream. This is rarely observed.

Unknown: A comparison of structure velocity to natural stream velocity is not possible.

Dry Passage Through Structure? Consider this question two different ways, depending on whether water is flowing through the structure. Choose only one option.

If there is water flowing in the structure: Is there a continuous dry stream bank through at least one side of the structure that allows the safe movement of terrestrial or semi-aquatic animals, and does this dry pathway connect to the stream banks upstream and downstream of the structure?

If there is no water flowing in the structure: then there is continuous dry passage through the structure.

Yes: A continuous bank connects upstream, through the structure, and downstream, or there is otherwise continuous dry passage through the structure.

No: There is no dry passage, the dry passage is not continuous, or the dry passage through the structure does not connect with stream banks upstream or downstream.

Unknown: It is not possible to determine if continuous dry passage exists through this structure.

N/A **Height Above Dry Passage:** If there is dry passage through the structure, measure the average height from the dry stream bank to the top of the structure directly above (i.e., the clearance) to the nearest tenth of a foot. If both stream banks are dry and connected, record the higher measurement. If the structure has no water flow, measure the average height above the bottom of the structure or dry stream bed to the top of the structure.

Comments: Use this area to briefly comment on any aspects of the structure needing more information. Enter comments about the overall crossing in the **Crossing Comments** box.

AQUATIC CONNECTIVITY
Stream Crossing Survey
DATA FORM

DATABASE ENTRY BY ______ ENTRY DATE ______

DATA ENTRY REVIEWED BY ______ REVIEW DATE ______

CROSSING DATA

~~Crossing Code~~ N/A ______ Local ID (Optional) ______

Date Observed (00/00/0000) ______ Lead Observer ______

Town/County ______ Stream ______

Road ______ Type ☐ MULTILANE ☐ PAVED ☐ UNPAVED ☐ DRIVEWAY ☐ TRAIL ☐ RAILROAD

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

Location Description

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

Number of Culverts/ Bridge Cells AKA "Number of Barrels" ______

Photo IDs INLET______ OUTLET______ UPSTREAM______ DOWNSTREAM______ OTHER______

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

Crossing Condition ☐ OK ☐ POOR ☐ NEW ☐ UNKNOWN

N/A ~~Tidal Site ☐ YES ☐ NO ☐ UNKNOWN~~

AKA "Crossing Alignment to Stream" Alignment ☐ FLOW-ALIGNED ☐ SKEWED (>45°)

Road Fill Height (Top of culvert to road surface; bridge = 0) ______

Bankfull Width (Optional) ______ Confidence ☐ HIGH ☐ LOW/ESTIMATED

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

Tailwater Scour Pool ☐ NONE ☐ SMALL ☐ LARGE

Crossing Comments

STRUCTURE 1

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

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 ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ 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

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & 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

N/A ~~Slope % (Optional)______ 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

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

N/A ~~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~~ N/A ______

Comments

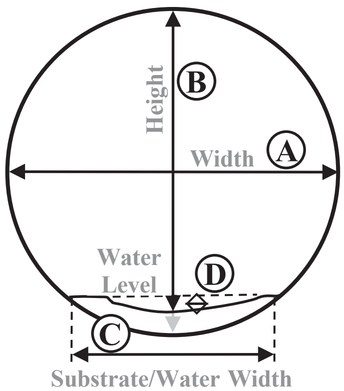
5/26/16

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 approriate 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.

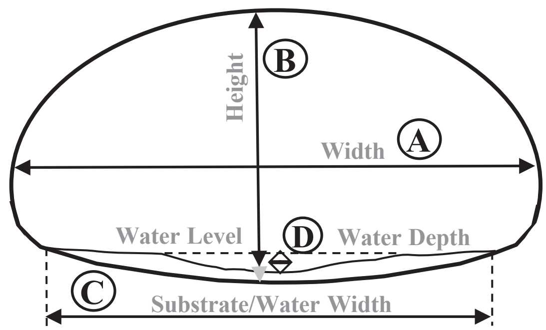
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to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

1



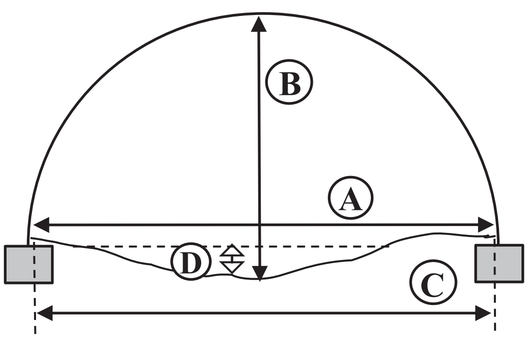
Round Culvert

2



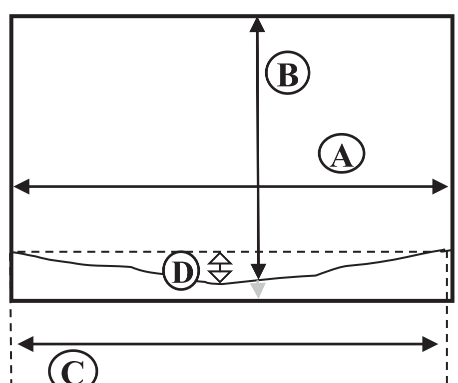
Pipe Arch/Elliptical Culvert

3



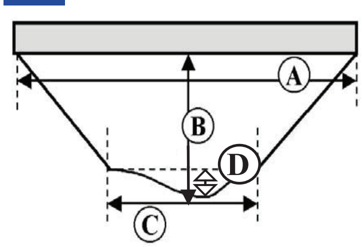
Open Bottom Arch Bridge/Culvert

4



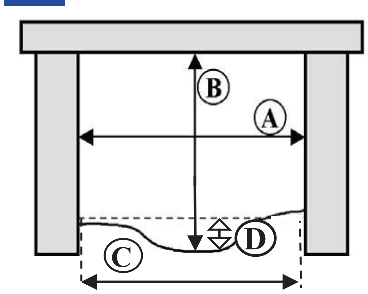
Box Culvert

5



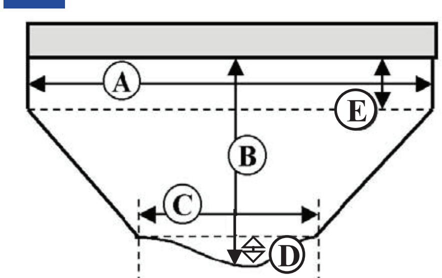
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

NAACC Culvert Condition Assessment Manual & Form Table of Contents

2019 Edition

Culvert Condition Assessment Manual

The Center *for* Agriculture, Food and the Environment

North Atlantic Aquatic Connectivity Collaborative NAACC

The Nature Conservancy

UMassAmherst
College of Engineering
UMass Transportation Center

Purpose

This document provides guidance for completing the Culvert Condition Assessment Form. The information collected will assist in the identification of culverts for repair or replacement. The assessment data form is to be used for an entire road-stream crossing, which may include single or multiple culverts or multiple cell bridges. The top of the form (see page 22) contains general information about the crossing and the bottom half of that page is for specific data on the condition of the crossing. The form is designed for a rapid assessment by trained lay observers (not necessarily engineers) for purposes of flagging crossings that should be examined more closely for potential structural deficiencies. It is essential to gather all of the data required for each structure for accurate assessment of the entire crossing. This assessment module is one of several develop and maintained by the North Atlantic Aquatic Connectivity Collaborative (NAACC). Data collected through use of this Culvert Assessment Form will be stored in the NAACC online database on the NAACC website: https://www.streamcontinuity.org/

Index

Safety

Safely conducting the Culvert Assessment is of the utmost importance. The conditions under which assessments can be done should require the following items for a team of two assessors. Assessments requiring advanced safety equipment (i.e. climbing rope, air monitoring devices) should not be done unless conducted by people with the proper safety training and equipment.

List of Culvert Sites and Map
Assessment Guide
Blank Assessment Forms
Clipboards and Writing Implements
2 Waterproof Flashlights and/or Headlights
4 28" Orange Collapsible Safety Cones with Reflective Bands
2 Class II Safety Vests
2 Safety Glasses
2 Work Gloves and/or Heavy Rubber Gloves
Camera
Hand Held GPS
2 Chest Waders
2 Cell Phones and/or Portable Radios
Bug Spray
First Aid Kit with Blood Stop
Snake Bite and Poisonous Vegetation Kits
Pruning Shears or Machete
A Pocket Rod
Chipping Hammer
Duct Tape
Gallon Size Ziploc Bags
5 Gallon Bucket (to carry items)
100' Reel Tape (measurements should be in feet and tenths of feet)
Telescoping Stadia Rod
Measuring Wheel
Small Round Point Shovel
Small Iron Rake (7" wide)
Wasp and Hornet Spray
Probing Rod or Walking Stick

Completing the Culvert Condition Assessment Form

Before heading to the field, plan a route and discuss a strategy to most efficiently assess the maximum number of culverts within the time allowed. Make sure you have everything in your vehicle that you will need for the entire time you plan to stay in the field. When you arrive at the site, identify a safe location to park the vehicle. If it is on the shoulder of the road, place the orange safety cones in a manner to alert traffic as to its presence. Ideally the vehicle is parked off the roadway as not to interfere with traffic. Don your personnel protective equipment, scan the site for potential hazards and collect your forms and tools.

Start by completing all general information on the Culvert Assessment Form such as Date, Lead Observer, Location, Time, Weather, etc... If any information is unknown, leave the space blank.

Position yourself on the road as close to the midpoint of the culvert as is safely possible to determine and record the GPS coordinates in decimal degrees. A GPS device is required for this step. GPS devices should be set to WGS84 datum.

Starting with the outlet side of the culvert and record the pertinent data in the boxed sections of the form. If there is a circumstance or area of concern that is not covered on the form, record the information in the "Notes" section. Take as many photographs as is necessary to properly record the condition of the culvert and appurtenances. Identify the photographs by number and description in the shaded area at the bottom of the form.

Safely move to the inlet side of the culvert, record the pertinent data in the boxed sections of the form. If there is a circumstance or area of concern that is not covered on the form, record the information in the "Notes" section. Take as many photographs as is necessary to properly record the condition of the culvert and appurtenances. Identify the photographs by number and description in the shaded area at the bottom of the form.

Observe the condition of the pavement or soil above the culvert and note any holes or cracks which could indicate a void underneath.

In the field assess each aspect of the culvert (including appurtenances) as "Adequate," "Poor," or "Critical." Aspects that are new, excellent, very good or good are all classified as "Adequate" for purposes of this assessment. The manual describes, in text and photographs, characteristics of culverts that would lead to assessments of adequate, poor and critical. If you are unsure of any terminology on the form, please refer to the glossary on page 24.

It is necessary to complete a Culvert Assessment Form for each culvert. For example, if two culverts are side by side and have identical characteristics, two culvert forms must still be completed. Standing at the inlet of a crossing with multiple culverts looking downstream, the culvert on the left will be #1. Continue numbering the culverts sequentially going from left to right.

For maintenance purposes, the Performance Problems Requiring Action section should be completed and the appropriate agencies notified of any areas of concern.

Complete and store the Culvert Assessment Form(s) and then head safely to the next crossing location.

Culvert Reference Material

A glossary of terms used in the Culvert Condition Assessment Form may be found on page 25 of this manual. The Culvert Assessment Reference Chart which contains detailed descriptions of Culvert Shapes and Dimensions can be found on page 23

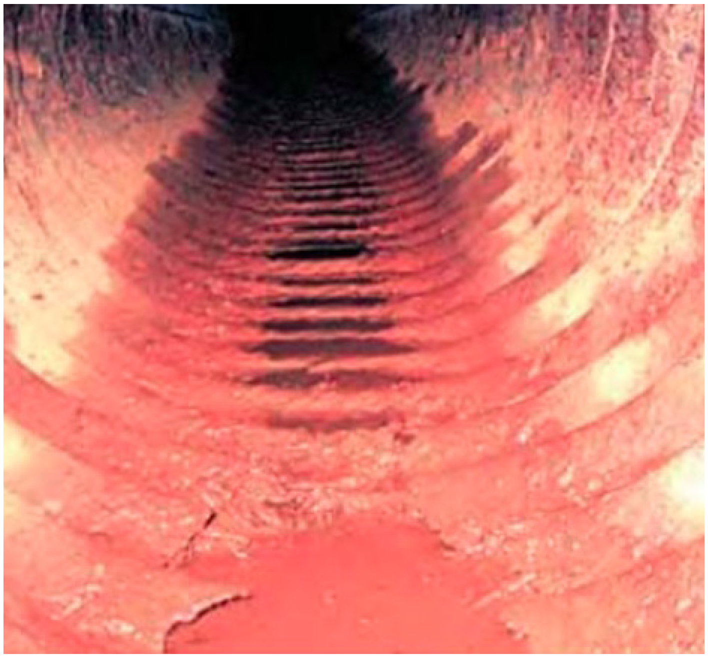
Invert Deterioration

Adequate

Minor corrosion and pitting, no holes or distortion. Cannot penetrate metal with sharp point of chipping hammer. Minor isolated spalls in concrete.

Poor

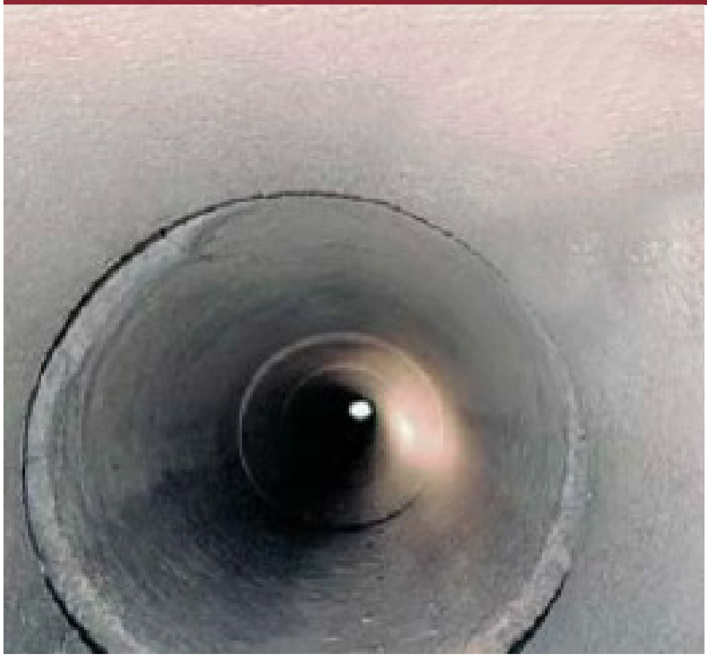
Perforations visible and/or connection hardware failing (metal). Heavy abrasion and scaling with exposed steel reinforcement (concrete). Heavy abrasion or scour damage (plastic). Displaced mortar and/or blocks, holes in invert area (masonry).



Critical

Holes or section loss with extensive voids beneath invert and/or embankment/roadway damage. Holes and gaps with extensive infiltration of soil, bedding, or backfill material (masonry).

Joints & Seams



Adequate

Minor separation of joints and seams up to 1″, minor backfill infiltration.

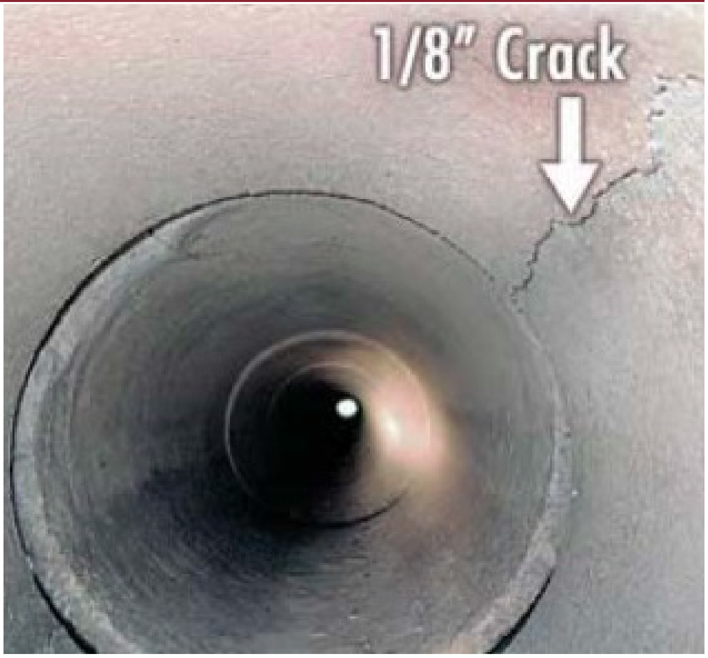
Poor

Significant separation of joints and seams between 1″ to 3″; infiltration of backfill into culvert; voids visible in fill through offset of joints.

Critical

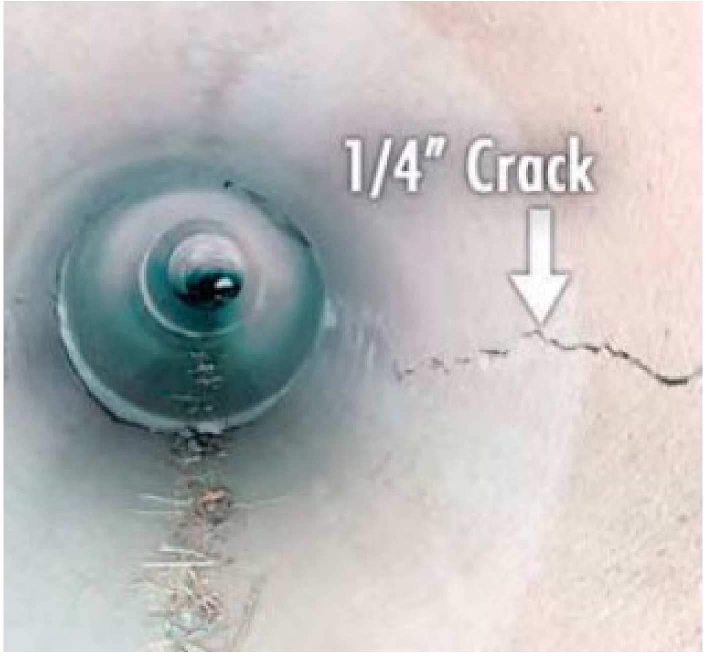
Severe separation of joints and seams greater than 3″; infiltration of backfill into culvert; large voids visible in fill through offset of joints.

Structural Integrity of Barrel (Concrete)



Adequate

Longitudinal cracks less than 1/8″ in width, spalls up to 1/4″ deep.



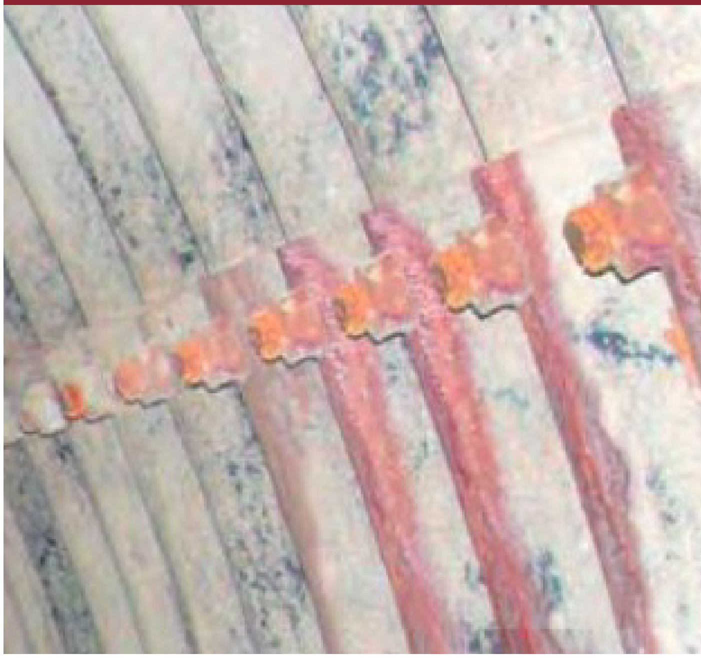
Poor

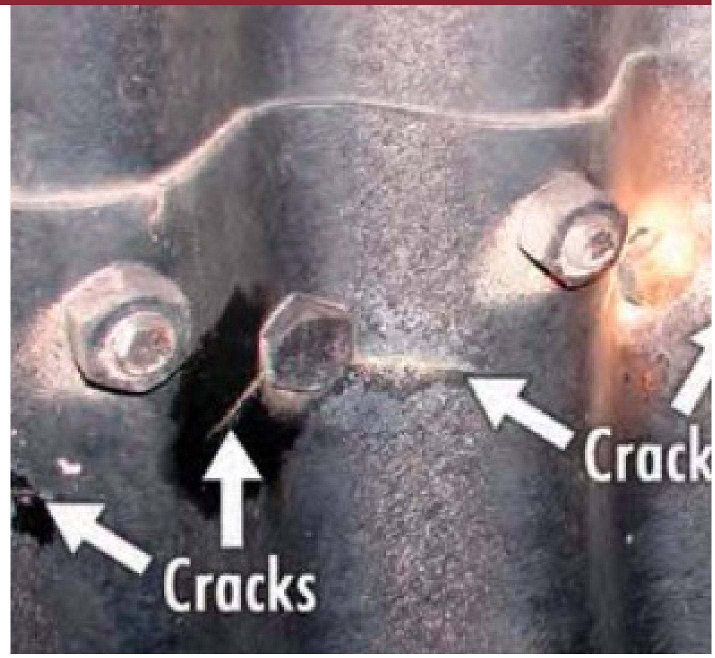
Longitudinal cracks between 1/8″-1/4″ in width, spalls larger than 1/2″ deep, and spalls have exposed rebar.

Critical

Severe cracking and spalls greater than 1/2″ on culvert walls, sections of culvert are partially collapsed, major corrosion of rebar.

Structural Integrity of Barrel (Metal)



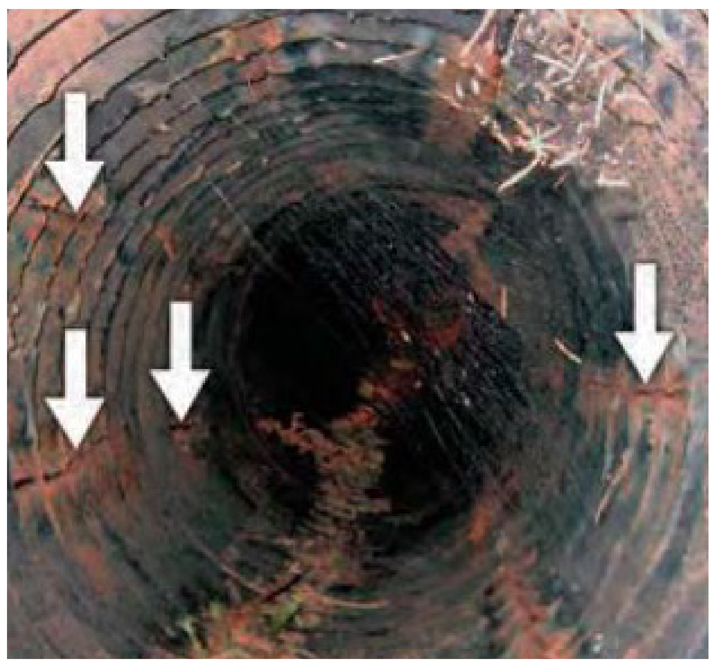


Adequate

Minor cracking around bolt holes or seams at isolated sections.

Poor

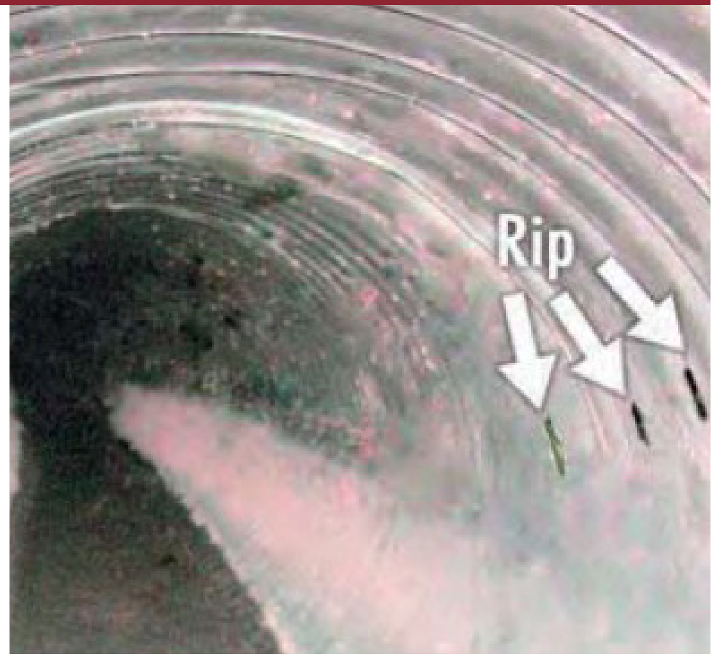
Significant cracking and/or deterioration along bolt holes and isolated seams of plates.



Critical

Severe cracking and or deterioration along bolt holes and along seams of plates.

Structural Integrity of Barrel (Plastic)



Adequate

Minor isolated rip or tear caused by debris less than 6″ in length and 1/2″ in width. Minor cuts or gouges to end sections from maintenance or construction activities.

Poor

Cracking, splits or tears over 6″ in length and up to 3/4″ in width. Openings in pipe causing loss of backfill material.

Critical

Cracking, splits, punctures, or tears over 6″ in length and over 1″ in width. Openings in pipe causing loss of backfill material.

Headwall/Wingwall

Adequate

Minor spalls and cracks less than 1/8″ in width. No exposed rebar or surface evidence of rebar corrosion. Minor settlement of the wall.

Poor

Significant spalls and cracks between 1/8″ to 1/4″ in width. Exposed rebar with corrosion. Significant settlement of the wall.

Critical

Extensive deterioration with loss of concrete. Corrosion of rebar and extensive section loss. Extensive settlement of the wall.

Apron

Adequate

Some minor undermining of culvert and small scour hole. Some deterioration of joint between apron and headwall.

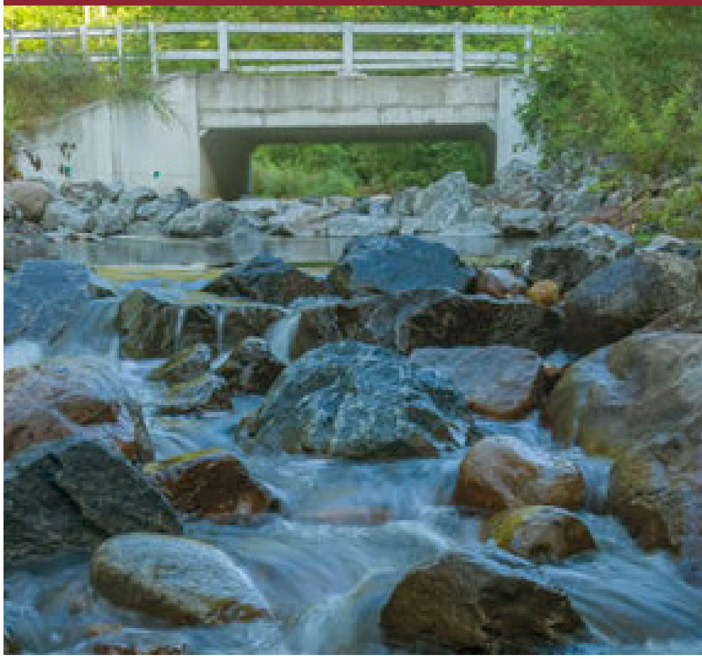
Poor

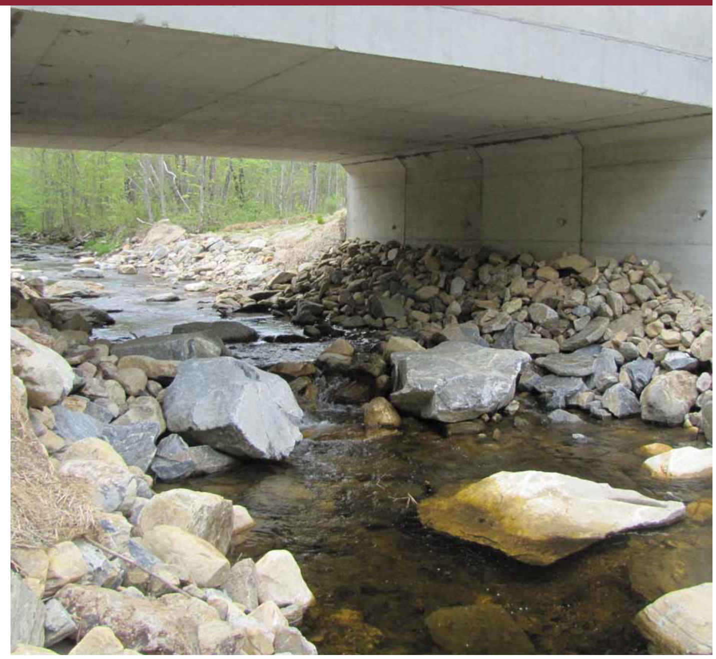
Significant undermining of culvert and evidence of scour hole. Significant deterioration of joint between apron and headwall.

Critical

Extensive undermining of culvert and development of a large hole under a structural element of the culvert. Substantial deterioration of joint between apron and headwall.

Armoring





Adequate

Streambed and streambanks are reinforced with a protective covering of rocks or engineering materials.

Poor

Significant displacements, undermining or deterioration affecting the performance of the culvert structure.

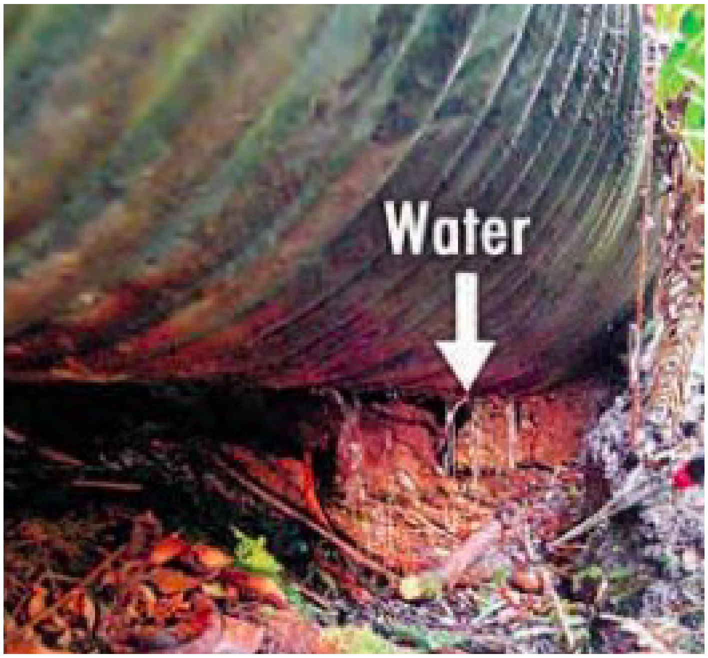
Critical

Partially or totally failed, significantly affecting performance and/or causing embankment/roadway damage or undermining of the culvert barrel or footings.

Embankment Piping

Fair

Embankment moist only in areas surrounding culvert barrel. No evidence of flow or sediment transport observed.



Poor

Evidence of seepage through the embankment along the outside of the culvert barrel, sediment transport not observed.

Critical

Evidence of flow through embankment along the outside of culvert barrel. Evidence of sediment transport, "voids" or sink holes observed.

Cross-Section Deformation (Metal)

METAL	CULVERT SIZES (Round Pipes)						
	Original pipe diameter						
	12″	24″	36″	48″	60″	72″	84″
GOOD	< 12 1/2	< 25 3/16	< 37 3/4	< 50 1/4	< 63	< 75 1/2	< 88 1/4
FAIR (5% - 15%)	12 1/2 - 13 3/4	25 3/16 - 27 1/2	37 3/4 - 41 1/2	50 1/4 - 55 1/4	63 - 69	75 1/2 - 82 3/4	88 1/4 - 96 1/2
POOR (15% -20%)	13 3/4 - 14 1/2	27 1/2 - 28 3/4	41 1/2 - 43 1/4	55 1/4 - 57 1/2	69 - 72	82 3/4 - 86 1/2	96 1/2 - 101
CRITICAL (>20%)	> 14 1/2	> 28 3/4	> 43 1/4	> 57 1/2	> 72	> 86 1/2	> 100

Observed culvert width or span

Adequate

Minor distortions isolated within the pipe resulting in flattening of invert and/or crown. Isolated sections are slightly non-symmetrical. Span dimension is within 5-15% of design.

Poor

Significant distortions within the pipe resulting in flattening of invert and/or crown of pipe. Span dimension is within 15-20% of design.

Critical

Severe distortions and deflection within the pipe; flattening of the crown or invert; structure is partially collapsed. Span dimension is greater than 20% of design.

Cross-Section Deformation (Plastic)

PLASTIC	CULVERT SIZES (Round Pipes)						
	Original pipe diameter 12"	24"	36"	48"	60"	72"	84"
GOOD	< 12 1/2	< 25 3/16	< 37 3/4	< 50 1/4	< 63	< 75 1/2	< 88 1/4
FAIR (5% - 10%)	12 1/2 - 13 1/4	25 3/16- 26 3/8	37 3/4 - 39 1/2	50 1/4 - 52 3/4	63 - 66	75 1/2 - 79 1/4	88 1/4 - 92 1/2
POOR (10% -15%)	13 1/4- 13 3/4	26 3/8- 27 1/2	39 1/2 - 41 1/2	52 3/4 - 55 1/4	66 - 69	79 1/4 - 82 3/4	92 1/2 - 96 1/2
CRITICAL (>15%)	> 13 3/4	> 27 1/2	> 41 1/2	> 55 1/4	> 69	> 82 3/4	> 96 1/2

Observed culvert width or span

Adequate

Minor isolated distortions and dimpling within the pipe. Pipe deflection 5-10% from original shape.

Poor

Significant distortions; wall buckling; flattening of invert/crown throughout the pipe. Pipe deflection 10-15% from original shape.

Critical

Severe distortions; wall buckling; flattening of invert/crown throughout the pipe; cracking/tearing present. Pipe deflection greater than 20% of original shape.

Structural (Longitudinal) Alignment

Adequate

Minimal horizontal or vertical misalignment of the pipe.

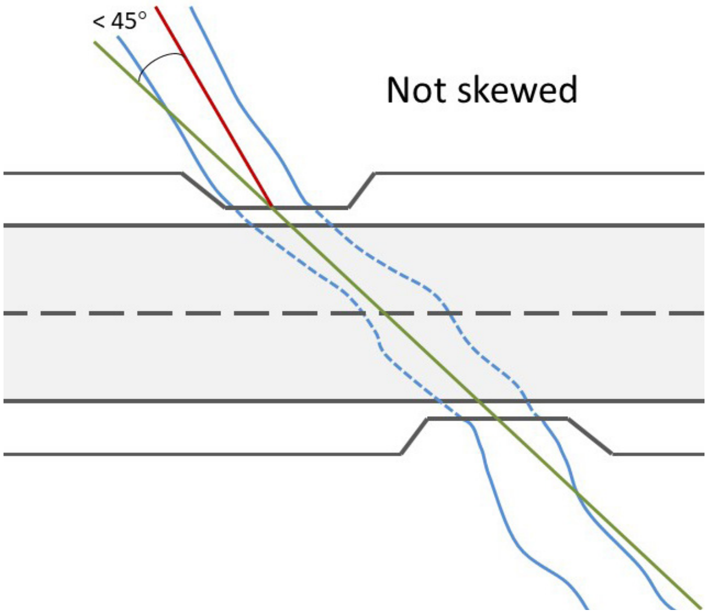
Poor

Significant horizontal or vertical misalignment of the pipe (Note: do not confuse this with constructed pipe bends).

Critical

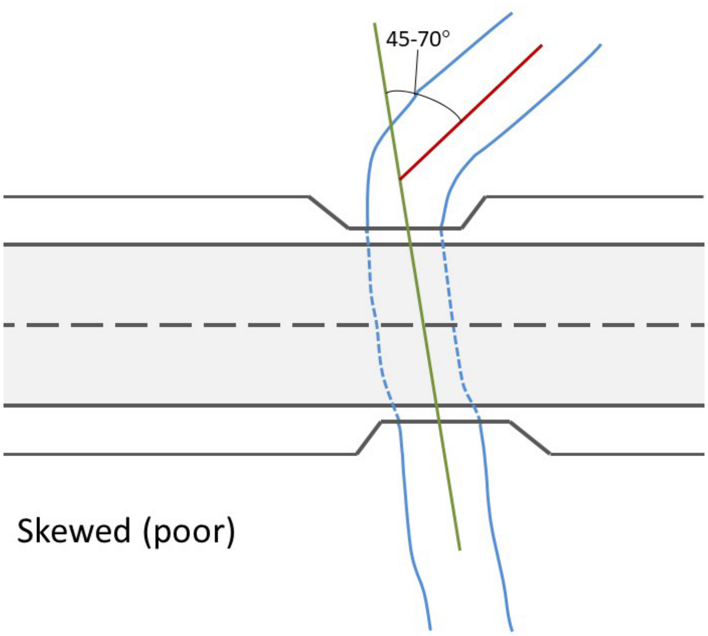
Significant misalignment resulting in deformation of pipe or embankment/roadway damage.

Channel Alignment



Adequate

Angle measured from upstream channel to centerline of culvert barrel is from 0-45 degrees.



Poor

The stream channel approaches the crossing at an angle of 45-70 degrees from the centerline of the structure.

Critical

The stream channel approaches the crossing at an angle of 70-90 degrees from the centerline of the structure.

Footing

Adequate

Minor to moderate deterioration. Concrete -moderate cracking, scaling or leaching (minor delamination or spalling). Masonry - moderate weathering (minor joint deterioration). Slight settlement or undermining. Minor footing exposure.

Poor

Extensive deterioration. Concrete - extensive cracking, scaling or leaching (delamination or spalling may be prevalent). Masonry - extensive weathering (significant joint deterioration). Significant settlement or undermining. Footing exposed and undermined.

Critical

Severe or critical deterioration. Function or structural capacity of the culvert has been severely impacted - immediate repairs or structural analysis may be required. Concrete - severe cracking, scaling, delamination, or spalling. Masonry - severe weathering (failed joints or displaced masonry blocks) Severe settlement or undermining.

Level of Blockage

Adequate
Blockage is 10-30% of opening.

Poor
Blockage is 30-75% of opening.

Critical
Blockage is >75% of opening.

Flared End Section

Adequate

Minor cracking, deterioration, or deformation. Minor undermining.

Poor

Significant cracks, piping or undermining affects >50% of appurtenance. End crushed or separated from barrel.

Critical

Deterioration is significantly effecting performance and/or causing embankment and/or roadway damage.

Buoyancy or Crushing

Adequate

Hydraulic uplift is overcome by a combination of the weight of the pipe, weight of the fill material over the pipe and weight of the water in the pipe.

Poor

Light to moderate denting or deformation of inlet and/or outlet end of flexible pipe culvert. The invert of the inlet is at the streambed elevation (no uplift).

Critical

Invert of inlet bent upward above stream bed or mitered edges crumpled inward.

Culvert Assessment Form

CROSSING DATA

For multiple culvert crossings use one sheet per culvert. Go from left to right, standing at inlet looking downstream.

Crossing Code:________________**Local ID**: (Optional)_________________**Date Observed:** (00/00/0000) ____/____/________Lead **Observer:**_________________________

Number of Culverts: _____ **Culvert** ____ **of** _____ **Stream:**______________________________________**Road:**____

Location: (St.#, Pole#, Etc.)____**Town:**___________________________**County:**______________________State:______

GPS Coordinates: __ __ . __ __ __ __ __°N Latitude __ __ . __ __ __ __ __ °W Longitude Time:_________________Weather:____

Crossing Type: ☐Bridge ☐Culvert ☐Multiple Culvert ☐Ford ☐No Crossing ☐Removed Crossing ☐Buried Stream ☐Inaccessible ☐Partially Inaccessible ☐No Upstream Channel

Culvert Material: ☐Metal ☐Concrete ☐Plastic ☐Wood ☐Rock/Stone ☐Fiberglass ☐Combination **Length of Culvert**: ____

INLET

Appurtenance: ☐Headwall ☐Wingwalls ☐Headwall & Wingwalls ☐Mitered To Slope ☐Projecting ☐Flush ☐Recessed ☐Other ☐None

Inlet Shape: ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 **Inlet Dimensions: A. Width:**____**B. Height:**____**C. Substrate/Water Width:**____**D. Water Depth:**____**E. Abutment Height:**____

Inlet Grade: ☐At Stream Grade ☐Inlet Drop ☐Perched ☐Clogged/Collapsed/Submerged ☐Unknown

OUTLET

Appurtenance: ☐Headwall ☐Wingwalls ☐Headwall & Wingwalls ☐Mitered To Slope ☐Projecting ☐Flush ☐Recessed ☐Other ☐None

Outlet Shape: ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 **Outlet Dimensions: A. Width:**____**B. Height:**____**C. Substrate/Water Width:**____**D. Water Depth:**____**E. Abutment Height:**____

Outlet Grade: ☐At Stream Grade ☐Free Fall ☐Cascade ☐Free Fall Onto Cascade ☐Clogged/Collapsed/Submerged ☐Unknown

	INLET *Please check only one level for each item*					OUTLET *Please check only one level for each item*				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Structural (Longitudinal) Alignment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Channel 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	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Embankment Piping	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

To provide additional feedback on performance problems use the optional second sheet

Performance Problems Requiring Action

Debris/Veg Blockage >1/3 of rise	☐	Local Outlet Scour	☐	Embankment Slope Instability	☐
Sediment Blockage >1/2 the opening	☐	Previous and/or Frequent Overtopping	☐	No Access/Ends Totally Buried/Submerged	☐
Buoyancy or Crushing-Related Inlet Failure	☐	Embankment Piping	☐	Aggressive Abrasion/Corrosion/Chemical	☐
Poor Channel Alignment	☐	Channel Degradation/Headcut	☐	Exposed Footing (Open-Bottom Culvert Only)	☐

Notes:____

____

____

Photo #:____ Description:______________________________________Photo #:____ Description:______________________________________

Photo #:____ Description:______________________________________Photo #:____ Description:______________________________________

Photo #:____ Description:______________________________________Photo #:____ Description:______________________________________

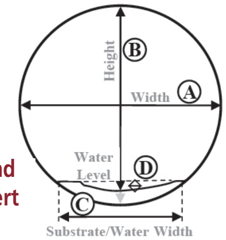
Photo #:____ Description:______________________________________Photo #:____ Description:______________________________________

2019

Culvert Assessment Reference Chart

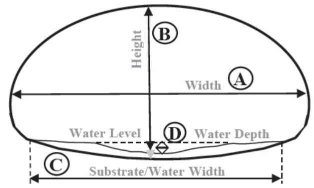
CULVERT SHAPE & DIMENSIONS

1.



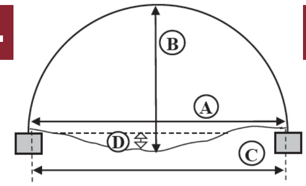
Round Culvert

2.



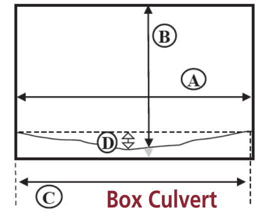
Pipe Arch/Elliptical Culvert

3.



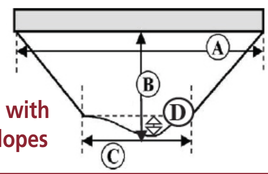
Open Bottom Arch Bridge/Culvert

4.



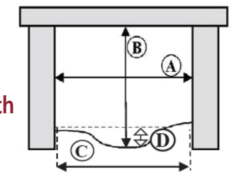
Box Culvert

5.



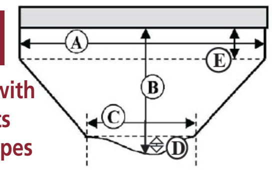
Bridge with Side Slopes

6.



Box/Bridge with Abutments

7.



Box/Bridge with Abutments and Side Slopes

CULVERT CONDITION REFERENCE

Structural (Longitudinal) Alignment

Poor: Significant horizontal or vertical misalignment of the pipe (Note: do not confuse this with constructed pipe bends).

Critical: Significant misalignment resulting in deformation of pipe or embankment/ roadway damage.

Channel Alignment

Poor: The stream channel approaches the crossing at an angle of 45-70 degrees from the centerline of the structure.

Critical: The stream channel approaches the crossing at an angle of 70-90 degrees from the centerline of the structure.

Level of Blockage

Poor: Debris/sediment/vegetation blocks 1/3 of more of the inlet/outlet opening.

Critical: Sediment blocks more than ½ the inlet/outlet opening (and not designed that way for aquatic organism passage).

Flared End Section

Poor: Significant cracks, piping or undermining affects >50% of section. End crushed or separated from barrel.

Critical: Deterioration is significantly affecting performance and/or causing embankment/ roadway damage.

Invert Deterioration

Poor: Perforations visible and/or connection hardware failing (metal). Heavy abrasion and scaling with exposed steel reinforcement (concrete). Heavy abrasion or scour damage (plastic). Displaced mortar and/or blocks, holes in invert area (masonry)

Critical: Holes or section loss with extensive voids beneath invert and/or embankment/ roadway damage. Holes and gaps with extensive infiltration of soil, bedding or backfill material (masonry).

Bouyancy or Crushing

Poor: Light to moderate denting or deformation of inlet and/or outlet end of fl exible pipe culvert. The invert of the inlet is at the streambed elevation (no uplift).

Critical: Invert of inlet bent upward above streambed or mitered edges crumpled inward.

Cross-Section Deformation

Poor: Significant perceptible deformation. Deformation with accompanying longitudinal cracking (concrete).

Critical: Excessive deformation resulting in significant reduction of available flow area, and/or extensive infiltration of soil, voids, structural failure or embankment/roadway damage.

Structural Integrity of Barrel

Poor: *Concrete:* Open cracks >1/8" wide with voids and significant infiltration of soil and/or leakage of water. Heavy rust staining and/or exposed steel reinforcement in sides and top of barrel.
Masonry: Missing and/or displaced blocks
Plastic: Several splits, tears and cracks >6" long. Significant deformation of liner or wall buckling.

Critical: Cracks, tears, splits, bulges, holes or section loss have led to extensive infiltration of soil, structural failure, voids and embankment/ roadway damage.

Joints and Seams

Poor: Open or displaced with significant infiltration of soil and/or leakage of water and voids visible. Missing mortar or displaced blocks (masonry).

Critical: Open or displaced with significant infiltration of soil and accompanying embankment/roadway damage.

Footings

Poor: Top portion of footing exposed, but no cracking or breaking off of flakes or chips.

Critical: Footing exposed with signs of cracking or breaking off of flakes or chips. Bottom of footing exposed and/or undercut.

Headwall/Wingwalls

Poor: Cracking or breaking off of flakes or chips affecting >50% of area and/or exposed steel reinforcement. Gap >4" between barrel and wall. Footing exposed and undermined.

Critical: Partially or totally collapsed with damage to embankment/roadway.

Armoring

Poor: Significant displacements, undermining or deterioration affecting the performance of the culvert structure.

Critical: Partially or totally failed, significantly affecting performance and/ or causing embankment/roadway damage or undermining of the culvert barrel or footings.

Apron

Poor: Significant cracking affects >50% of apron. Significant piping or undermining.

Critical: Partially or totally collapsed, significantly affecting performance and/or causing embankment/roadway damage.

Embankment Piping

Poor: Slight pavement cracking above the culvert, perhaps with a noticeable bump/ depression when driving, but no evidence of holes in the embankment or soil infiltration in the culvert barrel.

Critical: Partially or totally failed, significantly affecting performance and/or causing embankment/roadway damage or undermining of the culvert barrel or footings.

GLOSSARY

Appurtenance	Structures, such as aprons, flared end structures, headwalls and wingwalls, that give support to the culvert end or header.
Apron	Erosion protection at the inlet or outlet consisting of rip rap or concrete.
Armoring	Artificial surfacing of a channel bed, bank, or embankment slope to resist scour or erosion.
Bridge	Deck supported by abutments (or stream banks). It may have more than one cell or section separated by one or more piers.
Buoyancy	Water exerting upward pressure on the culvert.
Buried Stream	Segment of stream that flows within a pipe extending well beyond the road crossing. The planned crossing site does not include an inlet and/or outlet, likely because a stream previously in this location has been rerouted, probably underground.
Cascade	The outlet of the structure is raised above the stream bottom at the outlet such that water flows very steeply downward across rock or other hard material when flowing from the structure.
Channel Alignment	Indicates the alignment of the crossing structure relative to the stream at the inlet. Compare the crossing centerline to a centerline of the stream where it enters the crossing.
Corrosion	Deterioration and rusting of metal through oxidation.
Crossing Code	A unique ID for each crossing in the database provided by the assigning authority (NAACC xycode).
Culvert	A culvert consists of a structure buried under some amount of fill. Culverts can be made of stone, brick or masonry.
Delamination	Splitting or separating of concrete or asphalt in the culvert.
Flush	The end of the culvert is not recessed nor does it extend beyond the headwall.
Ford	A ford is a shallow, open stream crossing, in which vehicles pass through the water. Fords may be armored to decrease erosion, and may include pipes to allow flow through the ford (vented ford).
Free Fall	The outlet of the structure is above the stream bottom such that water drops vertically when flowing out of the structure.
Free Fall onto Cascade	The outlet of the structure is raised above the stream bottom at the outlet such that water drops vertically onto a steep area of rock or other hard material, then flows very steeply downward until it reaches the stream.
Headwall	A structure at either end of the culvert whose purpose is to hold back the embankment, retain the culvert and prevent erosion.
Inlet	The in-flow end of the culvert.
Inlet Drop	Water in the stream has a near-vertical drop from the stream channel down into the inlet of the structure. This usually occurs because sediment has accumulated above the inlet.
Lead Observer	Person responsible for data collection and data quality.
Leaching	Water that is penetrating through the culvert and traveling along the outside of the barrel.
Local ID	Identification code assigned by local agency or organization.
Location	Description that will allow another person to locate the culvert using only the supplied information.
Mitered to Slope	The end of the culvert is cut at an angle to match that of the topography.
Multiple Culvert	Two or more adjacent culverts at a single crossing.
No Crossing	A crossing that exists on a map that does not exist in the field.
No Upstream Channel	Areas where water crosses a road through a culvert but no road-stream crossing occurs because there is no channel up-gradient of the road. This can occur at the very headwaters of a stream or where a road crosses a wetland that lacks a stream channel (at least on the up-gradient side).
Outlet	The out-flow end of the culvert.
Overtopping	When the amount of flowing water exceeds the capacity of the culvert and flows over the road surface.
Perched	When the outlet is above the level of the stream bottom causing water leaving the culvert to form a waterfall or cascade.
Recessed	The end of the culvert does not protrude through the headwall, nor is it flush with the headwall.
Removed Crossing	A crossing apparently existed previously at the site but has been removed, so the stream now flows through the site with no provision for vehicles to cross over it.
Scaling	Loss of concrete in thin, plate-like pieces, lamina, or flakes that peel off from a surface due to freeze/thaw.
Scour	Removal of sediment such as sand and gravel from a channel bed or bank caused by swiftly moving water.
Soil Infiltration	Soil entering a culvert through a joint or hole.
Spalling	Breaking or splitting off of surface concrete in chips or bits.
Stream Grade	Elevation at which the water flows.
Substrate/Water Width	The widest width of the water or substrate within a culvert, whichever is wider.
Structural (Longitudinal) Alignment	Pertaining to the horizontal or vertical alignment of the pipe. (Note: do not confuse this with constructed pipe bends).
Wingwall	A short section of wall connected to the side of a headwall used as a retaining wall and to stabilize abutment and guide stream into culvert.

APPENDIX H

Appendix H

Poor and Critical Roadway Embankments

Culvert ID	Location	Condition of Upstream Embankment	Condition of Downstream Embankment
1	Dedham Street	Poor	Adequate
10	Claybrook Road	Poor	Adequate
14	Hartford Street	Adequate	Poor
17	Main Street	Poor	Adequate
21	Centre Street	Poor	Unknown
4	Chestnut Street	Adequate	Critical
44	Centre Street	Adequate	Poor
45	Walpole Street	Poor	Unknown
49	Hunt Drive	Adequate	Poor
53	Farm Street	Adequate	Poor
56	Centre Street	Poor	Adequate
58	Hales Hollow	Adequate	Poor
62	Wilsondale Street	Poor	Poor
66	Wilsondale Street	Poor	Poor
78	Farm Street	Adequate	Critical
82	Smith Street	Poor	Poor
TPC-13	Normandie Road	Adequate	Critical
TPC-15	Pegan Lane	Poor	Adequate
TPC-20B	Sherbrooke Drive	Poor	Unknown
TPC-27	Smith Street	Poor	Adequate
TPC-28	Smith Street	Adequate	Poor
TPC-45	Pine Street	Poor	Adequate
TPC-53	Powisset Street	Unknown	Poor
TPC-6	Pleasant Street	Poor	Poor
TPC-7	Claybrook Road	Critical	Adequate
TPC-9	Dedham Street	Poor	Adequate

Bends Mid-Crossing

Culvert ID		Bend Mid Crossing-Barrel 1	Bend Mid Crossing-Barrel 2
12	Bryant Lane	Skewed Less than 45 Degrees	
20	Meadowbrook Road	Skewed Greater than 45 Degrees	
26	Old Meadow Road	Skewed Less than 45 Degrees	
37	Centre Street	Skewed Greater than 45 Degrees	
4	Chestnut Street	Skewed Less than 45 Degrees	
44	Centre Street	Skewed Less than 45 Degrees	
56	Centre Street	Skewed Less than 45 Degrees	
61	Dedham Street	Skewed Less than 45 Degrees	
62	Wilsondale Street	Skewed Less than 45 Degrees	
72	Ledgewood Drive	Skewed Less than 45 Degrees	
78	Farm Street	Skewed Less than 45 Degrees	
91	Old Farm Road	Skewed Less than 45 Degrees	
TPC-12	Bretton Road	Skewed Less than 45 Degrees	
TPC-14	Centre Street	Skewed Less than 45 Degrees	
TPC-25	Bridge Street	Skewed Greater than 45 Degrees	
TPC-26	Farm Street	Skewed Less than 45 Degrees	
TPC-32	Grand Hill Drive	Skewed Greater than 45 Degrees	
TPC-33	Grand Hill Drive	Skewed Greater than 45 Degrees	
TPC-34	Grand Hill Drive	None	Skewed Less than 45 Degrees
TPC-35	Partridge Hill Road	Skewed Less than 45 Degrees	
TPC-38	Fox Run Road	Skewed Greater than 45 Degrees	
TPC-4	Dover Road	Skewed Less than 45 Degrees	
TPC-47	Riga Road	Skewed Less than 45 Degrees	

Upstream Scour Damage

Culvert ID		Scour Location:	Scour Damage:
10	Claybrook Road	Culvert	Small
11	Haven Street	Wingwalls	Large
2	Willow Street	Culvert	Small
31	Main Street	Culvert	Small
35	Dedham Street	Culvert	Small
4	Chestnut Street	Culvert	Small
42	Willow Street	Culvert	Small
45	Walpole Street	Culvert	Small
49	Hunt Drive	Culvert	Small
62	Wilsondale Street	Culvert	Small
66	Hartford Street	Culvert	Small
72	Ledgewood Drive	Culvert	Small
73	Brookfield Road	Culvert	Small
81	Greystone Road	Culvert	Small
83	Cedar Hill Road	Culvert	Small
85	Farm Street	Culvert	Small
93	Francis Street	Culvert	Small
TCP-10	Strawberry Hill Street	Culvert	Small
TPC-3	Brook Road	Culvert	Small
TPC-33	Grand Hill Drive	Wingwalls	Small

APPENDIX I

Culvert Condition Scoring System – August 27, 2019

<u>Two "scores" will be assigned to each crossing:</u>

1. Culverts with performance problems will be flagged.
2. A condition score (0.0-1.0) is calculated for each crossing, as follows:
   a) For each culvert, assign a score for each of the three variables below (V1, V2, V3) using data from the Condition Assessment Form.
   b) The minimum score resulting from V1, V2, or V3 is the overall condition score for each culvert. The score will range from 0 (most critical condition) to 1 (good condition).

      PLUS

      If any Section is marked "Unknown" then add "not fully assessed" to the score unless the score is 0.0. For example: "0.7-not fully assessed" or "0.3-not fully assessed" but not "0-not fully assessed"
   c) For multiple culvert crossings, the overall condition score for the crossing is the lowest condition score among the culverts that make up the crossing.

V1 Structural Deficiency – Highly Critical

Variables marked "Critical"	**Score**
Any one of the following	0.0
Cross-Section Deformation	Inlet or outlet
Structural Integrity of Barrel	Inlet or outlet
Footings	Inlet or outlet
Level of Blockage	Inlet or outlet

V2 Structural Deficiency – Critical

Any three or more of the following Any two of the following Any one of the following	0.0 0.1 0.2
Variables marked "Critical"	**Score**
Buoyancy or Crushing	Inlet or outlet or both counts as 1
Invert Deterioration	Inlet or outlet or both counts as 1
Joints and Seams	Inlet or outlet or both counts as 1
Longitudinal Alignment	Inlet or outlet or both counts as 1
Headwall/Wingwalls	Inlet or outlet or both counts as 1
Flared End Section	Inlet or outlet or both counts as 1
Apron/Scour Protection	Outlet
Armoring	Inlet or outlet or both counts as 1
Embankment Piping	Inlet or outlet or both counts as 1
Variables marked "Poor"	
Cross-Section Deformation	Inlet or outlet or both counts as 1
Structural Integrity of Barrel	Inlet or outlet or both counts as 1
Footings	Inlet or outlet or both counts as 1
Level of Blockage	Inlet or outlet or both counts as 1

V3 Structural Deficiency – Poor

Variables marked "Poor"	Score
For each of the following identified as "Poor"	0.1 pt. deduction from 1.0 down to a minimum score of 0.3
Buoyancy or Crushing	Inlet or outlet or both counts as 1
Invert Deterioration	Inlet or outlet or both counts as 1
Joints and Seams	Inlet or outlet or both counts as 1
Longitudinal Alignment	Inlet or outlet or both counts as 1
Headwall/Wingwalls	Inlet or outlet or both counts as 1
Flared End Section	Inlet or outlet or both counts as 1
Apron/Scour Protection	Outlet
Armoring	Inlet or outlet or both counts as 1
Embankment Piping	Inlet or outlet or both counts as 1

Scoring Road-Stream Crossings as Part of the North Atlantic Aquatic Connectivity Collaborative (NAACC)

Adopted by the NAACC Steering Committee
November 10, 2015

INTRODUCTION

The North Atlantic Aquatic Connectivity Collaborative (NAACC) was launched in 2015 with a rapid assessment protocol for evaluating aquatic passability at road-stream crossings and an online database (https://www.streamcontinuity.org/cdb2) for storing and scoring data collected using this protocol. Two scoring systems are proposed to evaluate aquatic passability at road-stream crossings. The first is a coarse screen for use in classifying crossings into one of three categories: "Full AOP" (Aquatic Organism Passage), "Partial AOP," and "No AOP." The second system is an algorithm for computing an aquatic passability score, ranging from 0 (low) to 1 (high), for each road-stream crossing. These two scoring systems are not particular to any taxonomic or functional group but instead seek to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.

NAACC COARSE SCREEN

Table 1 below identifies characteristics and conditions that allow crossings to be classified as providing "Full AOP," "Reduced AOP," or "No AOP."

Table 1. NAACC Coarse Screen

Metric	Flow Condition	Crossing Classification		
		Full AOP	**Reduced AOP**	**No AOP**
		If all are true	*If any are true*	*If any are true*
Inlet Grade		At Stream Grade	Inlet Drop or Perched	
Outlet Grade		At Stream Grade		Cascade, Free Fall onto Cascade
Outlet Drop to Water Surface		= 0		≥ 1 ft
Outlet Drop to Water Surface/ Outlet Drop to Stream Bottom				> 0.5
Inlet or Outlet Water Depth	Typical-Low	> 0.3 ft		< 0.3 ft w/Outlet Drop to Water Surface > 0
	Moderate	> 0.4 ft		< 0.4 ft w/Outlet Drop to Water Surface > 0
Structure Substrate Matches Stream		Comparable or Contrasting		
Structure Substrate Coverage		100%	< 100%	
Physical Barrier Severity		None	Minor or Moderate	Severe

The primary objective of the coarse screen is to identify those crossings that are likely to be a barrier to most or all species and those that are likely to provide something close to full aquatic organism passage. If it is necessary to get a better feel for how bad those crossing are that are labeled as "reduced AOP" one can use the numeric scoring system.

N/A: We did not use the Coarse Screen and instead used the numeric scoring system to be able to more fully assess each culvert's aquatic passability.

NAACC NUMERIC SCORING SYSTEM

The numeric scoring algorithm is based on the opinions of experts who decided both the relative importance of all the available predictors of passability as well as a way to score each predictor. Scoring involves three steps: (1) generating a component score for each predictor variable, (2) combining these predictions with a weighted average to generate a composite score for the crossing, and (3) assigning a final score based on the minimum of the composite score or the component score for the *outlet drop* variable.

Variables Used

Crossing assessments are generally done during "typical low-flow conditions." Some variables are important for assessing conditions at the time of the survey; others provide indirect evidence of likely conditions at higher flows.

<u>Inlet Grade</u>: The position of the structure invert relative to the stream bottom at the inlet.

<u>Outlet Drop</u>: Outlet drop is based on the variable *Outlet Drop to Water Surface* unless the value for *Water Depth Matches Stream* = "Dry" in which case outlet drop is based on the variable *Outlet Drop to Stream Bottom*.

<u>Physical Barriers</u>: This variable covers a wide variety of circumstances ranging from obstructions to dewatered culverts or bridge cells that represent physical barriers to aquatic organism passage.

<u>Constriction</u>: The relative width of the crossing compared to the width of the stream. "Severe" = <50%, "Moderate" = 50-100%; other options include "Spans Only Bankfull/Active Channel" and "Spans Full Channel & Banks." *Constriction* is an indirect indicator of potential velocity issues at higher flows.

<u>Water Depth</u>: Water depth in the structure relative to water depths found in the natural channel at the time of survey.

<u>Water Velocity</u>: Water velocity in the structure relative to water velocities found in the natural channel at the time of survey.

<u>Scour Pool</u>: Presence/absence of a scour pool at the crossing outlet and size relative to the natural stream channel. *Scour Pool* is an indirect indicator of potential velocity issues at higher flows. *Scour pool* is included solely as an indicator of velocities at higher flows. It is not based on the effects of the pool itself which can actually be positive for fish passage.

<u>Substrate Matches Stream</u>: An assessment of whether the substrate in the structure matches the substrate in the natural stream channel. *Substrate Matches Stream* is used to evaluate how a discontinuity in substrate might inhibit passage for species that either use substrate as the medium for travel (e.g., mussels) or require certain types of substrate for cover during movements (e.g., crayfish, salamanders, juvenile fish).

Substrate Coverage: Degree to which a crossing structure is covered by substrate. *Substrate Coverage* is directly related to passability for some aquatic species that require substrate or that tend to avoid areas that lack cover. It is also an important element of roughness that can create areas of low-velocity water (boundary layers) utilized by weak-swimming organisms. *Substrate Coverage* is also an indirect indicator of potential velocity issues at higher flows.

Openness: Cross-sectional area of the structure opening divided by the structure length (distance between inlet and outlet) measured in feet. *Openness* is calculated for both the inlet and outlet and the lower value is assigned to the structure. If there are multiple structures at a crossing the value for the structure with the highest *Openness* is assigned to the crossing as a whole. Turtles are believed to be affected by the *Openness* of a crossing structure; other species may be affected as well.

Height: Maximum height of the crossing structure. This variable is parameterized so that it only comes into play for very small structures.

Outlet Armoring: Presence/absence of streambed armoring (e.g., riprap, asphalt, concrete) at the outlet and the relative amount of armoring. Armoring is considered “extensive” if the length (upstream to downstream) of the streambed that is armored is greater or equal to half the bankfull width of the natural stream channel. *Outlet Armoring* is an indirect indicator of potential velocity issues at higher flows.

Internal Structures: Presence/absence of structures inside a culvert or bridge (e.g. weirs, baffles, supports). The *Internal Structures* variable is used in the scoring algorithm as it relates to the potential for creating turbulence within a crossing structure. To the extent that *Internal Structures* physically block the movement of aquatic organisms it is covered by the *Physical Barriers* variable.

Step 1: Component Scores

The component scores are not meant to equate to passability. In each case the component score is intended the cover the full range of problems (assessable by our protocol) associated with that variable: from 0 (worst case) to 1 (best case). For *inlet grade*, having an inlet drop or perched inlet is the worst case among the options, thus they score "0." This is not meant to say that all structures with inlet drops are impassible. The effect of *inlet grade* on passability scores is controlled by the weight it is given in computing the composite score (see Step 2 below).

Scoring categorical predictors is simply a matter of assigning a score for each possible category. Table 2 lists all of the categorical predictors and the scores associated with each category.

Scoring continuous predictors requires a function to convert the predictor to a score. There are three continuous predictors and three associated functions. The functional forms used were chosen because they have shapes desired by the expert team or because they fit the series of points specified by the expert team. Appendix A includes the r code defining each of these functions (“x” is the measured value for each variable).

The scoring equation for *Openness* is:

(1) $s_o = a(1 - e^{-kx(1-d)})^{1/(1-d)}$

Where S_o is the score for openness, a=1, k=15, and d = 0.62
when openness is recorded in feet.

The equation for Height is:

(2) $s_h = \min(\frac{ax^2}{b^2 + x^2}, 1)$

Where S_h is the component score for height, a = 1.1, and b=2.2
when height is recorded in feet.

The equation for Outlet Drop is:

(3) $s_{od} = 1 - \frac{ax^2}{b^2 + x^2}$

Where S_{od} is the Outlet Drop component score, a=1.029412, and b=0.51449575
when outlet drop is recorded in feet.

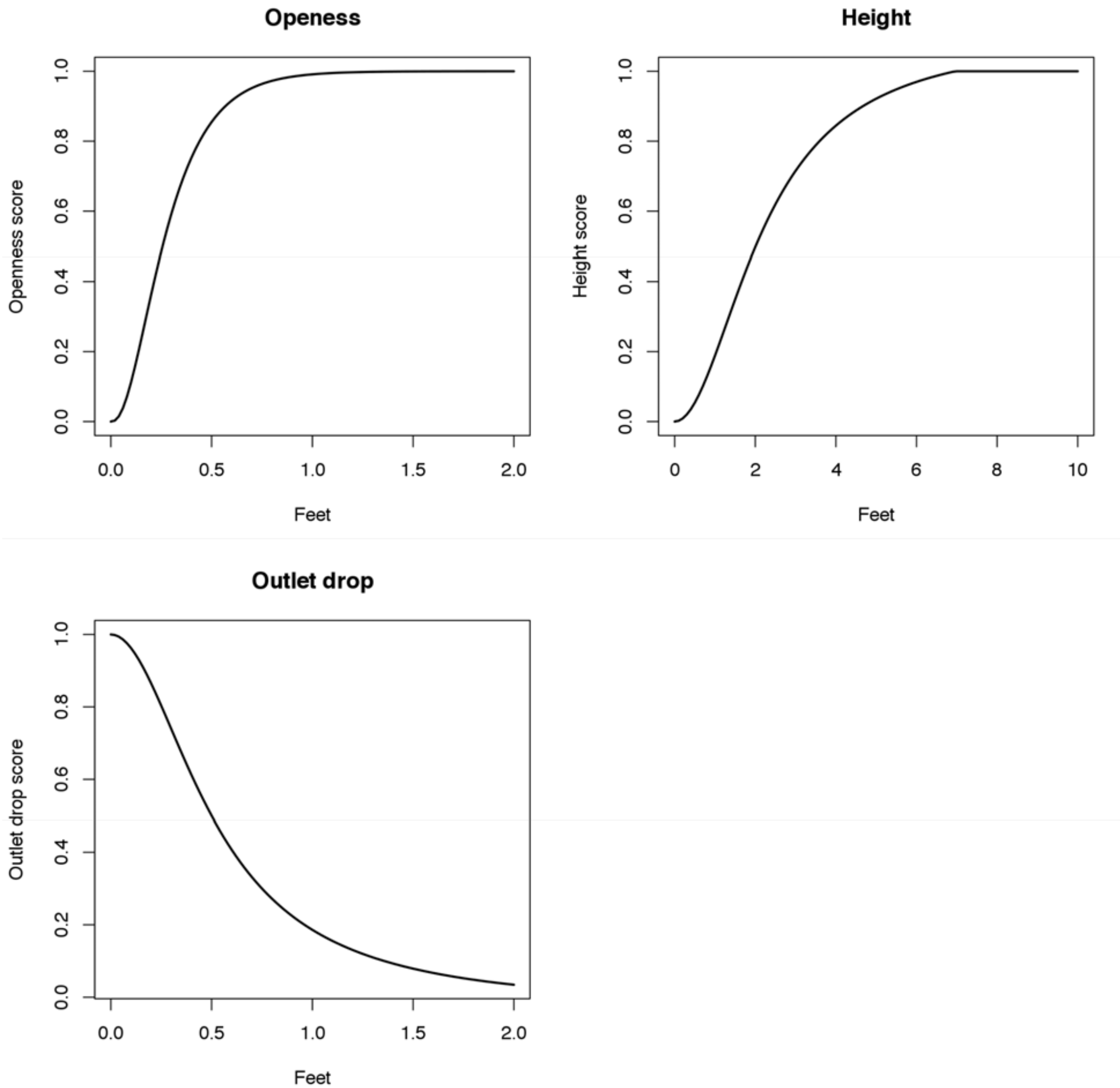


Figure 1. Continuous predictor variables

Table 2. Component scores for categorical variables used in calculating the crossing score

parameter	level	score
Constriction	severe	0
Constriction	moderate	0.5
Constriction	spans only bankfull/active channel	0.9
Constriction	spans full channel and banks	1
Inlet grade	at stream grade	1
Inlet grade	inlet drop	0
Inlet grade	perched	0
Inlet grade	clogged/collapsed/submerged	1
Inlet grade	unknown	1
Internal structures	none	1
Internal structures	baffles/weirs	0
Internal structures	supports	0.8
Internal structures	other	1
Outlet armoring	extensive	0
Outlet armoring	not extensive	0.5
Outlet armoring	none	1
Physical barriers	none	1
Physical barriers	minor	0.8
Physical barriers	moderate	0.5
Physical barriers	severe	0
Scour pool	large	0
Scour pool	small	0.8
Scour pool	none	1
Substrate coverage	none	0
Substrate coverage	25%	0.3
Substrate coverage	50%	0.5
Substrate coverage	75%	0.7
Substrate coverage	100%	1
Substrate matches stream	none	0
Substrate matches stream	not appropriate	0.25
Substrate matches stream	contrasting	0.75
Substrate matches stream	comparable	1
Water depth	no (significantly deeper)	0.5
Water depth	no (significantly shallower)	0
Water depth	yes (comparable)	1
Water depth	dry (stream also dry)	1
Water velocity	no (significantly faster)	0
Water velocity	no (significantly slower)	0.5
Water velocity	yes (comparable)	1
Water velocity	dry (stream also dry)	1

Some notes about the component scores

1. The option "clogged/collapsed/submerged" for *inlet grade* is an option surveyors use to indicate that it was not possible to measure the structure's dimensions. If the inlet is clogged or collapsed enough to affect passability it will be covered under *physical barriers*. This is why it receives a "1" instead of a "0", because problems associated with this option are covered by the *physical barriers* variable.

2. The rationale for giving a component score of "1" to "unknown" for *inlet grade* is similar to that for "clogged/collapsed/submerged." It is hard to know how to interpret "unknown." However, if conditions at the inlet are creating a physical barrier to passage it will be covered under *physical barriers*.

3. We included *inlet grade* as a variable in addition to *physical barriers* because inlet drops create both velocity and physical barrier (jump barrier) issues. The physical barrier issues are covered by the *physical barriers* variable. The *inlet grade* variable captures the velocity issues at the inlet. Perched inlets can create depth issues at low flows (if water can't get into the structure inlet). These may not be apparent at the time of the survey. Thus, the presence of a perched inlet is a concern even if it doesn't represent a physical barrier ("dry") at the time when the survey is conducted.

4. The variable *internal structures* is included to account for turbulence issues. There is likely to be turbulence associated with weirs and baffles when these are included inside crossing structures. If they also create physical barriers they will be covered by the *physical barriers* variable. They are often included in structures to help aquatic organism passage but they sometimes do more harm than good and may be good for some species while creating problems for others. The inclusion of well-designed weirs or baffles is likely to improve the component scores for water depth and water velocity. They get docked a little in our scoring system for introducing turbulence.

5. It is difficult to know how to score the "other" option under *internal structures* because it is difficult to know what, if any, impact these other structures will have on turbulence. If, however, they represent a physical barrier they will be covered under the *physical barriers* variable.

Step 2: Weighted Composite Scores

An expert team of nine people provided input on how the variables should be weighted based on best professional judgement. The weights used with the component scores are listed in table 3. The weights are simply the means of the nine weights for each variable provided by the experts. We display the weights out to three decimal places not to suggest that we know the weights to this level of precision but to reduce overall error in the model by not introducing an additional source of error (rounding error). The composite score is the sum of the products of each component score and its weight.

Table 3. Weights associated with each parameter in the scoring algorithm.

parameter	weight	Adjusted Weight*
Outlet drop	0.161	0.186
Physical barriers	0.135	--
Constriction	0.090	0.104
Inlet grade	0.088	0.102
Water depth	0.082	0.095
Water velocity	0.080	0.092
Scour pool	0.071	0.082
Substrate matches stream	0.070	0.081
Substrate coverage	0.057	0.066
Openness	0.052	0.060
Height	0.045	0.052
Outlet armoring	0.037	0.043
Internal structures	0.032	0.037

Step 3: Final Aquatic Passability Score

The final Aquatic Passability Score is the lower of either the composite score or the *Outlet Drop* component score. The rationale for this is that although many factors can affect aquatic organism passage, when an outlet drop is above a certain size it becomes the predominant factor that determines passability.

Aquatic Passability Score = Min[Composite Score, *Outlet Drop* score]

* Data related to the "physical barriers" parameter was only collected in the field as part of the Culvert Condition assessment. Weights were adjusted to remove this parameter from Aquatic Passage so the total weight remains equal to 1.

Mapping Aquatic Passability Scores

For mapping purposes, we assigned narrative descriptors for different ranges of aquatic passability as follows.

Descriptor	Aquatic Passability Score(s)
No barrier	1.0
Insignificant barrier	0.80 – 0.99
Minor barrier	0.60 – 0.79
Moderate barrier	0.40 – 0.59
Significant barrier	0.20 – 0.39
Severe barrier	0.00 – 0.19

People often ask about the relationship between these categories and actual passability for fish and other aquatic organisms. At this point the relationship is unknown and we regard it as a fruitful area for future research. The concept of aquatic passability is complicated and includes: variation in the swimming and leaping abilities of individuals within a species (what proportion of the population can pass), variability in passage requirements for a broad diversity of species that inhabit rivers and streams (what proportion of species can pass), and the timing of passability (for what proportion of the year is the structure passable).

For now, the best way to consider the aquatic passability scores is that they represent the degree to which crossings deviate from an ideal. We assume that those crossings that are very close to the ideal (scores > 0.6) will present only a minor or insignificant barrier to aquatic organisms. Those structures that are farthest from the ideal (scores < 0.4) are likely to be either significant or severe barriers. These are, however, arbitrary distinctions imposed on a continuous scoring system and should be used with that in mind.

APPENDIX A - R code for continuous scoring functions.

```
#---------------------------------------------------------------------------#
# define function for Openness score calculation
#---------------------------------------------------------------------------#
calc.openness.score <- function(x){
	# Using von Bertalanffy functional form (Bolker pg 97)
	a = 1
	k = 15
	d=0.62
	return(a * (1-exp(-k*(1-d)*x))^(1/(1-d)))
	# note exp is based on e not 10.
}

#---------------------------------------------------------------------------#
# Define Function for Calculating Height Scores
#---------------------------------------------------------------------------#
calc.height.score <- function(x){
	a <- 1.1
	b <- 2.2
	# Use Holling Type II function (Bolker pg 92):
	result <- a*x^2/(b^2 + x^2)
	result[result > 1] <- 1 # Truncate results to 1
	return(result)
}


#---------------------------------------------------------------------------#
# Define Function for Calculating Outlet Drop Scores
#---------------------------------------------------------------------------#
calc.outlet.drop.score <- function(x){
	a <- 1.029412
	b <- 0.51449575
	score <- 1 - a*x^2/(b^2 + x^2)
	score[x > 36] <- 0
	return(score)
}
```

APPENDIX J

Consequence of Failure (CoF) Evaluation Criteria

The following descriptions provide an overview of the CoF evaluation criteria for culverts that were assessed during field work.

Roadway Class or Type: Failure of culverts on major roadways will have a greater impact on public safety, residents, and commuters, and require greater construction and traffic control coordination depending on the criticality of the road. We utilized MassGIS's field class[1] for MassDOT roadways:

- **1** - Limited Access Highway
- **2** - Multi-lane Highway, not limited access
- **3** - Other numbered route (e.g., Route 113, Route 3A, etc.)
- **4** - Major road - arterials and collectors
- **5** - Minor street or road *(with Road Inventory information, not class 1-4)*
- **6** - Minor street or road *(with minimal Road Inventory information and no street name)*
- **Railroad Crossing**
- **Off-road**

Dead End Houses or Detour Length: If a culvert were to fail and close a road, this item considered the number of houses that would be impacted on a dead-end road or the length of a detour for through-streets.

Culvert Size: Larger culverts typically convey a more substantial flow than smaller ones and present a higher consequence if they are to fail.

Utility Crossing (Sewer/Water): A culvert that has a water or sewer main crossing and fails has a higher potential to negatively impact the public drinking water distribution and sanitary sewer collection systems. The Town's water and sewer system GIS mapping was used to determine locations where a water main and/or a sewer main crosses the culvert. Note that failure of culverts with other utility crossings (e.g., gas mains or telecommunications) would also have a negative effect on those utilities; however, data was not collected on other utilities as part of this Asset Management Plan.

Culvert Length: Failure of culverts with larger lengths may be more challenging to replace or restore.

Road Fill Height: Failure of culverts with larger road fill heights (i.e., deeper under the roadway) may be more challenging to replace or restore.

Stream Crossing Standards: An evaluation of the assessed culverts' bankfull width ratio was evaluated to determine whether the culverts met the Massachusetts Stream Crossing Standards. In accordance with the Standards, culvert spans should be a minimum of 1.2 times

[1] https://www.mass.gov/info-details/massgis-data-massachusetts-department-of-transportation-massdot-roads#attributes-

the bankfull width of the stream. Culverts that do not meet these Standards are considered undersized and may not be sufficient to meet hydraulic and/or wildlife passage requirements.

Proximity to Floodplains: A failure within a floodplain will have a greater impact during a flooding event, leading to exacerbated flooding. The 100-year and 500-year Federal Emergency Management Agency (FEMA) flood zones were used for this analysis.

Natural Heritage and Endangered Species (NHESP) Priority or Estimated Habitat: A failure in a mapped habitat area could have a detrimental impact to an endangered, threatened, or special concern species or the natural communities that make up their habitats.

Coldwater Fishery: A failure in a coldwater fishery could have a detrimental impact to reproducing coldwater fish that require it for their life history requirements.

TABLE J-1
Culvert CoF Evaluation Criteria

Category/Item	Rating Factor	Score	Weight	Max Score
Roadway Class or Type	1 - Limited Access Highway	0	2	10
	2 - Multi-lane Highway	0		
	Railroad	0		
	3 - Other numbered route	5		
	Off-road	0		
	4 - Major road	3		
	5 - Minor street or road (with Road Inventory information)	1		
	6 - Minor street or road (with minimal Road Inventory information and no street name)	1		
Dead End Houses	≥ 20	5	2	10
	15-19	4		
	10-14	3		
	5-9	2		
	< 5	1		
Detour Length (mi)	> 4	5	2	10
	3 to 4	4		
	2 to 3	3		
	Off-road	3		
	1 to 2	2		
	< 1	1		
Culvert Size (ft)	> 5	5	2	10
	4	3		
	3	1		
Utility Crossing (sewer/water)	Water Main Diameter ≥ 12	5	1	5
	Sewer Main Diameter ≥ 8	5		
	Crosses 2 water main pipes **or** 2 sewer pipes	5		
	No	1		
	Water Main Less than 12"	3		
	Sewer Less than 8"	3		
Culvert Length (ft)	≤ 50	1	1	5
	50 < culvert length ≤ 100	3		
	> 100	5		
Road Fill Height (ft)	>2	1	1	5
	Unknown	3		
	2 < height ≤ 8	3		
	> 8	5		
Stream Crossing Standards	Does Not Meet Standards	5	1	5
	Meets Standards	1		
Within 100 or 500-year FEMA Flood Zones	No	1	1	5
	Yes	5		
Within NHESP Priority/Estimated Habitat	No	1	1	5
	Yes	5		
In Coldwater Fishery	No	1	1	5
	Yes	5		

TOTAL: 75

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APPENDIX K

Appendix K

Criticality Assessment Summary

Culvert ID	Location:	Road Type:	Material	PoF Score	COF Score	Criticality Rank
1	Dedham Street	Paved	Concrete	1.00	0.53	Low
10	Claybrook Road	Paved	Concrete	0.10	0.53	Medium-High PoF
11	Haven Street	Paved	Metal	0.10	0.40	High
12	Bryant Lane	Paved	0	1.00	0.73	Low
14	Hartford Street	Paved	Concrete	0.10	0.70	Medium-High PoF
16	Powisset Street	Paved	0	1.00	0.77	Low
17	Main Street	Paved	Combination	0.90	0.73	Low
2	Willow Street	Paved	Rock/Stone	0.00	0.57	Medium-High PoF
20	Meadowbrook Road	Paved	Rock/Stone	0.90	0.73	Low
21	Centre Street	Paved	0	1.00	0.53	Low
22	Strawberry Hill Street	Paved	Concrete	0.90	0.77	Low
23	Old Meadow Road	Paved	Metal	0.20	0.70	Medium-High PoF
26	Old Meadow Road	Trail	Concrete	0.80	0.73	Low
27	Rocky Brook Road	Paved	Concrete	1.00	0.67	Low
3	Old Farm Road	Paved	0	1.00	0.60	Low
31	Main Street	Paved	0	0.90	0.70	Low
35	Dedham Street	Paved	Concrete	1.00	0.50	Medium-High CoF
37	Centre Street	Paved	Combination	0.90	0.50	Medium-High CoF
38	Wakeland Road	Paved	Concrete	0.20	0.73	Medium-High PoF
4	Chestnut Street	Paved	Combination	0.20	0.53	Medium-High PoF
41	Donnelly Drive	Paved	Concrete	1.00	0.67	Low
42	Willow Street	Paved	Combination	1.00	0.43	Medium-High CoF
44	Centre Street	Paved	Concrete	1.00	0.53	Low
45	Walpole Street	Paved	0	0.90	0.57	Low
47	Draper Road	Paved	Concrete	1.00	0.43	Medium-High CoF
49	Hunt Drive	Paved	Metal	0.90	0.57	Low
50	Hunt Drive	Paved	Concrete	0.20	0.67	Medium-High PoF
51	Dedham Street	Paved	Metal	0.20	0.40	High
53	Farm Street	Paved	Plastic	0.90	0.60	Low
56	Centre Street	Paved	Concrete	0.90	0.50	Medium-High CoF
57	Church Street	Paved	Concrete	1.00	0.67	Low
58	Hales Hollow	Paved	Metal	1.00	0.63	Low
59	Claybrook Road	Paved	Concrete	0.00	0.57	Medium-High PoF
60	Springdale Avenue	Paved	Concrete	0.20	0.60	Medium-High PoF
61	Dedham Street	Paved	Concrete	1.00	0.57	Low
62	Wilsondale Street	Paved	Rock/Stone	0.20	0.57	Medium-High PoF
63	Wilsondale Street	Paved	Concrete	0.70	0.70	Low
64	Tubwreck Drive	Paved	Concrete	0.90	0.77	Low
65	Woodridge Road	Paved	0	1.00	0.70	Low
66	Hartford Street	Paved	Metal	0.10	0.67	Medium-High PoF
67	Cedar Hill Road	Paved	Concrete	0.20	0.63	Medium-High PoF
68	Farm Street	Paved	Combination	1.00	0.50	Medium-High CoF
69	Powisset Street	Paved	Concrete	0.90	0.60	Low
7	Grand Hill Drive	Paved	Metal	1.00	0.57	Low
72	Ledgewood Drive	Paved	Concrete	0.80	0.70	Low

Key

(orange)	High Risk
(blue)	Medium Risk
(green)	Low Risk

Appendix K
Criticality Assessment Summary

Culvert ID	Location:	Road Type:	Material	PoF Score	COF Score	Criticality Rank
73	Brookfield Road	Paved	Concrete	1.00	0.60	Low
75	County Street	Paved	0	1.00	0.50	Medium-High CoF
77	Trout Brook Road	Paved	Concrete	0.20	0.53	Medium-High PoF
78	Farm Street	Paved	Combination	0.10	0.57	Medium-High PoF
81	Greystone Road	Paved	Concrete	1.00	0.77	Low
82	Smith Street	Paved	Rock/Stone	0.00	0.77	Medium-High PoF
83	Cedar Hill Road	Paved	Concrete	0.90	0.73	Low
85	Farm Street	Paved	Combination	0.90	0.57	Low
86	Old Farm Road	Paved	Concrete	0.20	0.63	Medium-High PoF
88	Mill Street	Paved	Concrete	1.00	0.60	Low
9	Picardy Lane	Paved	0	1.00	0.70	Low
91	Old Farm Road	Paved	Combination	0.90	0.77	Low
93	Francis Street	Paved	Concrete	0.90	0.67	Low
94	Centre Street	Paved	Concrete	0.90	0.57	Low
95A	Trail	Trail	Metal	0.90	0.70	Low
95B	Trail	Trail	0	1.00	0.77	Low
95C	Trail	Trail	0	0.90	0.83	Low
99	Ledgewood Drive	Paved	0	0.90	0.73	Low
Field 1	Ledgewood Drive	Paved	0	1.00	0.73	Low
Field 3	Francis Street	Paved	Concrete	0.90	0.63	Low
Field 4	Raleigh Road	Paved	0	1.00	0.77	Low
Field 5	Farm Street	Paved	Combination	0.10	0.57	Medium-High PoF
TCP-10	Strawberry Hill Street	Paved	Concrete	1.00	0.77	Low
TPC-12	Bretton Road	Paved	Concrete	1.00	0.77	Low
TPC-13	Normandie Road	Paved	Concrete	0.80	0.73	Low
TPC-14	Centre Street	Paved	Concrete	0.90	0.50	Medium-High CoF
TPC-15	Pegan Lane	Paved	Metal	0.90	0.70	Low
TPC-16	Haven Street	Paved	0	1.00	0.67	Low
TPC-18	Haven Terrace	Paved	Concrete	0.90	0.70	Low
TPC-19	Yorkshire Road	Paved	Concrete	0.90	0.63	Low
TPC-2	Meadowbrook Road	Paved	Concrete	0.20	0.73	Medium-High PoF
TPC-20	Sherbrooke Drive	Paved	Concrete	0.90	0.70	Low
TPC-20B	Sherbrooke Drive	Paved	0	0.20	0.70	Medium-High PoF
TPC-21	Windsor Road	Paved	Concrete	0.80	0.73	Low
TPC-22	Raleigh Road	Paved	0	0.90	0.77	Low
TPC-23	Sterling Drive	Paved	Concrete	1.00	0.70	Low
TPC-24	Raleigh Road	Paved	0	1.00	0.80	Low
TPC-25	Bridge Street	Paved	Concrete	0.80	0.57	Low
TPC-25B	Bridge Street	Paved	Plastic	1.00	0.57	Low
TPC-26	Farm Street	Paved	Rock/Stone	0.10	0.63	Medium-High PoF
TPC-27	Smith Street	Paved	Concrete	0.20	0.73	Medium-High PoF
TPC-28	Smith Street	Paved	Metal	0.10	0.77	Medium-High PoF
TPC-29	Farm Street	Paved	0	0.00	0.63	Medium-High PoF
TPC-3	Brook Road	Paved	Concrete	1.00	0.70	Low
TPC-31	Grand Hill Drive	Paved	Concrete	0.90	0.70	Low
TPC-32	Grand Hill Drive	Paved	Concrete	1.00	0.67	Low

Appendix K
Criticality Assessment Summary

Culvert ID	Location:	Road Type:	Material	PoF Score	COF Score	Criticality Rank
TPC-33	Grand Hill Drive	Paved	Concrete	0.80	0.67	Low
TPC-34	Grand Hill Drive	Paved	Concrete	1.00	0.70	Low
TPC-35	Partridge Hill Road	Paved	0	1.00	0.77	Low
TPC-36	Partridge Hill Road	Paved	Concrete	1.00	0.67	Low
TPC-38	Fox Run Road	Paved	Concrete	0.90	0.70	Low
TPC-4	Dover Road	Paved	Combination	1.00	0.63	Low
TPC-40	Hamlins Crossing	Paved	Concrete	0.20	0.63	Medium-High PoF
TPC-41	Hamlins Crossing	Paved	Concrete	0.90	0.57	Low
TPC-42	Snows Hill Lane	Paved	Concrete	1.00	0.60	Low
TPC-43	Snows Hill Lane	Paved	Concrete	1.00	0.63	Low
TPC-44	Pine Street	Paved	Metal	0.20	0.73	Medium-High PoF
TPC-45	Pine Street	Paved	Metal	0.80	0.73	Low
TPC-46	Rocky Brook Road	Paved	Concrete	0.90	0.70	Low
TPC-47	Riga Road	Paved	Concrete	0.90	0.70	Low
TPC-48	Abbott Road	Paved	0	1.00	0.67	Low
TPC-50	Hartford Street	Paved	0	0.10	0.67	Medium-High PoF
TPC-53	Powisset Street	Paved	Concrete	0.80	0.57	Low
TPC-57	Hartford Street	Paved	Metal	0.20	0.70	Medium-High PoF
TPC-6	Pleasant Street	Paved	Concrete	0.20	0.67	Medium-High PoF
TPC-7	Claybrook Road	Paved	Concrete	0.20	0.57	Medium-High PoF
TPC-9	Dedham Street	Paved	Concrete	0.20	0.63	Medium-High PoF

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APPENDIX L

Planning Level Engineer's Opinion of Probable Cost
Culvert 78 Repair (18" RCP, 20' Long)
Hartford Street
Town of Dover

ITEM	DESCRIPTION	Notes	QTY	UNITS	UNIT PRICE	AMOUNT
101.	Clearing and Grubbing		0.10	ACRE	$ 65,000	$ 6,500
116.1	Demolition of Existing Culvert		1	LS	$ 10,000	$ 10,000
140.1	Culvert Excavation		30	CY	$ 65	$ 1,950
151.	Gravel Borrow		30	CY	$ 75	$ 2,250
151.2	Gravel Borrow for Backfilling Structures and Pipes		20	CY	$ 70	$ 1,400
156.1	Crushed Stone for Bridge Foundations		6	TON	$ 80	$ 480
170.	Fine Grading and Compacting		60	SY	$ 10	$ 600
415.1	Pavement Milling		60	SY	$ 10	$ 600
460.	Hot Mix Asphalt		18	TON	$ 300	$ 5,400
748.	Mobilization		1	LS	$ 4,000	$ 4,000
850.	Maintenance of Traffic		1	LS	$ 30,000	$ 30,000
986.2	Modified Rockfill		10	CY	$ 100	$ 1,000
991.1	Control of Water - Structure No. 1		1	LS	$ 20,000	$ 20,000
995.011	Culvert Structure, Culvert No. 1		1	LS	$ 20,000	$ 20,000
	Utility Allowance		1	LS	$ 10,000	$ 10,000
	Minor Item Allowance		1	LS	$ 20,000	$ 20,000
					Subtotal	$ 134,180
			Contingency	40%		$ 54,000
					Total	**$ 188,180**
					SAY	**$ 190,000**

This is an engineer's Opinion of Probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

Unit Prices are based upon Massachusetts Department of Transportation Weighted Bid Prices, as of May 2025 and recent bids conducted by Tighe & Bond.

Planning Level Engineer's Opinion of Probable Cost
TPC-26 (6' Box Culvert, 44' Long) Culvert Replacement
Farm Street
Town of Dover

ITEM	DESCRIPTION	Notes	QTY	UNITS	UNIT PRICE	AMOUNT
101.	Clearing and Grubbing		0.20	ACRE	$ 65,000	$ 13,000
116.1	Demolition of Existing Culvert		1	LS	$ 40,000	$ 40,000
140.1	Culvert Excavation		260	CY	$ 65	$ 16,900
151.	Gravel Borrow		50	CY	$ 75	$ 3,750
151.2	Gravel Borrow for Backfilling Structures and Pipes		220	CY	$ 70	$ 15,400
156.1	Crushed Stone for Bridge Foundations		50	TON	$ 80	$ 4,000
170.	Fine Grading and Compacting		140	SY	$ 10	$ 1,400
415.1	Pavement Milling		130	SY	$ 10	$ 1,300
460.	Hot Mix Asphalt		43	TON	$ 300	$ 12,900
620.12	Guardrail, TL2 (Single-Faced)		40	FT	$ 35	$ 1,400
748.	Mobilization		1	LS	$ 20,000	$ 20,000
850.	Maintenance of Traffic		1	LS	$ 30,000	$ 30,000
986.2	Modified Rockfill		40	CY	$ 100	$ 4,000
991.1	Control of Water - Structure No. 1		1	LS	$ 30,000	$ 30,000
995.011	Culvert Structure, Culvert No. 1		1	LS	$ 365,000	$ 365,000
	Utility Allowance		1	LS	$ 30,000	$ 30,000
	Minor Item Allowance		1	LS	$ 95,000	$ 95,000
					Subtotal	$ 684,050
	Construction Phasing Factor			30%		$ 205,215
			Contingency	30%		$ 267,000
	Engineering Costs:					
			Data Collection, Design, and Permitting			$ 140,000
			Construction Phase Services	15%		$ 143,000
					Total	**$ 1,439,265**
					SAY	**$ 1,440,000**

This is an engineer's Opinion of Probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

Unit Prices are based upon Massachusetts Department of Transportation Weighted Bid Prices, as of May 2025 and recent bids conducted by Tighe & Bond.

Planning Level Engineer's Opinion of Probable Cost

TPC-50 (3' RCP, 50' Long) Culvert Replacement

Hartford Street

Town of Dover

ITEM	DESCRIPTION	Notes	QTY	UNITS	UNIT PRICE	AMOUNT
101.	Clearing and Grubbing		0.20	ACRE	$ 65,000	$ 13,000
116.1	Demolition of Existing Culvert		1	LS	$ 30,000	$ 30,000
140.1	Culvert Excavation		60	CY	$ 65	$ 3,900
151.	Gravel Borrow		70	CY	$ 75	$ 5,250
151.2	Gravel Borrow for Backfilling Structures and Pipes		60	CY	$ 70	$ 4,200
156.1	Crushed Stone for Bridge Foundations		12	TON	$ 80	$ 960
170.	Fine Grading and Compacting		190	SY	$ 10	$ 1,900
415.1	Pavement Milling		180	SY	$ 10	$ 1,800
460.	Hot Mix Asphalt		60	TON	$ 300	$ 18,000
620.12	Guardrail, TL2 (Single-Faced)		40	FT	$ 35	$ 1,400
748.	Mobilization		1	LS	$ 8,000	$ 8,000
850.	Maintenance of Traffic		1	LS	$ 30,000	$ 30,000
986.2	Modified Rockfill		10	CY	$ 100	$ 1,000
991.1	Control of Water - Structure No. 1		1	LS	$ 20,000	$ 20,000
995.011	Culvert Structure, Culvert No. 1		1	LS	$ 55,000	$ 55,000
	Utility Allowance		1	LS	$ 20,000	$ 20,000
	Minor Item Allowance		1	LS	$ 30,000	$ 30,000
					Subtotal	$ 244,410
	Construction Phasing Factor			30%		$ 73,323
			Contingency	30%		$ 96,000
					Total	**$ 413,733**
					SAY	**$ 415,000**

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Unit Prices are based upon Massachusetts Department of Transportation Weighted Bid Prices, as of May 2025 and recent bids conducted by Tighe & Bond.

APPENDIX M

STANDARD OPERATING PROCEDURE — *Culvert Assessment and Maintenance*

Culverts carry rivers, brooks, and streams under roadways throughout town. A culvert assessment protocol was developed to be used during field assessments. The protocol uses Tighe & Bond's experience with culvert assessments and the following resources:

- *Culvert Condition Assessment Manual* and *Culvert Assessment Form*, developed by UMass Transportation Center, the Nature Conservancy, North Atlantic Aquatic Connectivity Collaborative (NAACC), and the Center for Agriculture, Food, and the Environment, 2019
- *NAACC Stream Crossing Instruction Manual for Aquatic Passability Assessments in Non-tidal Stream and Rivers* and *Aquatic Connectivity Stream Crossing Survey Data Form*, developed by the North Atlantic Aquatic Connectivity Collaborative, UMass Amherst, November 2019

Suggested Standard Operating Procedures

Implement the following practices to reduce potential modes of failure to the maximum extent practicable.

- Complete culvert maintenance and repairs as needed based on the field assessment results.
- The Highway Department should maintain an inventory of maintenance activities.
- Inform employees that culverts are a part of the stormwater drainage system.
- Report any illicit (illegal) discharges to the Highway Department. Report oil spills immediately to the Fire Department and Highway Department.

Routine Assessment and Maintenance

Routinely assess Town culverts and address issues as needed to maintain culvert functionality and proper streamflow. When present, check and maintain beaver deceivers and inlet grates. As stated by the US DOT *Culvert Repair Practices* Manual, regular maintenance of culverts is important to assessing the condition of the culvert "as the life of the culvert progresses and land use in the vicinity of the culvert changes". NAACC's *Culvert Condition Assessment Manual* and *Culvert Assessment Form* includes the following problems that require action. US DOT's *Culvert Repair Practices* Manual provides details on routine maintenance for a variety of items, as described below.

Debris/Vegetation Removal:

- NAACC Action:
  - Debris/Vegetation Blockage at least 1/3 of the rise
- US DOT Maintenance:
  - Remove debris collecting at the inlet or within the culvert by tying a rope to a long stick or pole. Push the stick and rope through the culvert to the other end, tie it to a piece of wood or metal bucket. Have crew on other end pull the rope and bucket through.
  - Vegetation impeding stream flow should be pruned, trimmed or removed.
  - Consider the need for debris-control structures in cases of frequent, large amounts of blockage.

Flushing/Sediment Removal:

- NAACC Action:
    - Sediment Blockage of at least 1/2 of the opening
- US DOT Maintenance:
    - Sediment deposits reduce size and capacity of the culvert, and should be removed via hand cleaning, mechanized cleaning, or high pressure water stream.

Streambed Maintenance:

- NAACC Action:
    - Buoyancy or Crushing-Related Inlet Failure
    - Local Outlet Scour
    - Channel Degradation/Headcut
    - Embankment Piping
    - Embankment Slope Instability
    - No Access/Ends Totally Buried/Submerged
    - Poor Channel Alignment
- US DOT Maintenance:
    - Use vegetation or geotextiles to stabilize and protect streambanks from erosion.
    - Scour hole repair – May be filled, at least temporarily, with crushed stone, rubble, or riprap. The installation should be inspected to assess its performance after a number of storm events.
    - Channel – Inspect for scour undermining of the culvert or eroding of the embankment. If a lining system (riprap) appears insufficient, other methods of channel lining should be considered.
    - Alignment horizontal – Indications of erosion and changes in the horizontal direction of the stream channel should be noted, as changes cause increased erosion along the outside and inside of the curve as well as damage to the culvert.
    - Alignment vertical – Vertical alignment issues (culvert barrel is higher or lower than the streambed) can cause scour and sediment problems.

Depending on the severity, these items may need to be flagged for more in-depth repair or replacement. Other Items that should be flagged include:

- Previous and/or Frequent Overtopping
- Aggressive Abrasion/Corrosion/Chemical
- Exposed Footing (Open-Bottom Culvert Only)

Reporting

- Report any repair or maintenance problems to the Highway Department. Repair problems may include culvert replacement.
- Keep a log of culverts assessed or maintained.

References

NAACC. *Culvert Condition Assessment Manual* and *Culvert Assessment Form*. URL: https://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/CulvertManual_2019_082919.pdf

NAACC. *Stream Crossing Instruction Manual for Aquatic Passability Assessments in Non-tidal Stream and Rivers*. URL: https://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/NAACC_Non-tidal%20Aquatic%20Assessment%20Instructions%206-2-19.pdf

US DOT, Federal Highway Administration. *Culvert Repair Practices Manual Volume 1*. URL: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=36&id=94

US DOT, Federal Highway Administration. *Culvert Repair Practices Manual Volume 2*. URL: https://rosap.ntl.bts.gov/view/dot/58544

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