Appendix A

NAACC Instructions, Fact Sheet, and Sample Data Form

NAACC Stream Crossing Survey Data Form
Instruction Guide

Developed by the

North Atlantic Aquatic Connectivity Collaborative

Including: University of Massachusetts Amherst
The Nature Conservancy
U.S. Fish and Wildlife Service

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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

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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.

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.

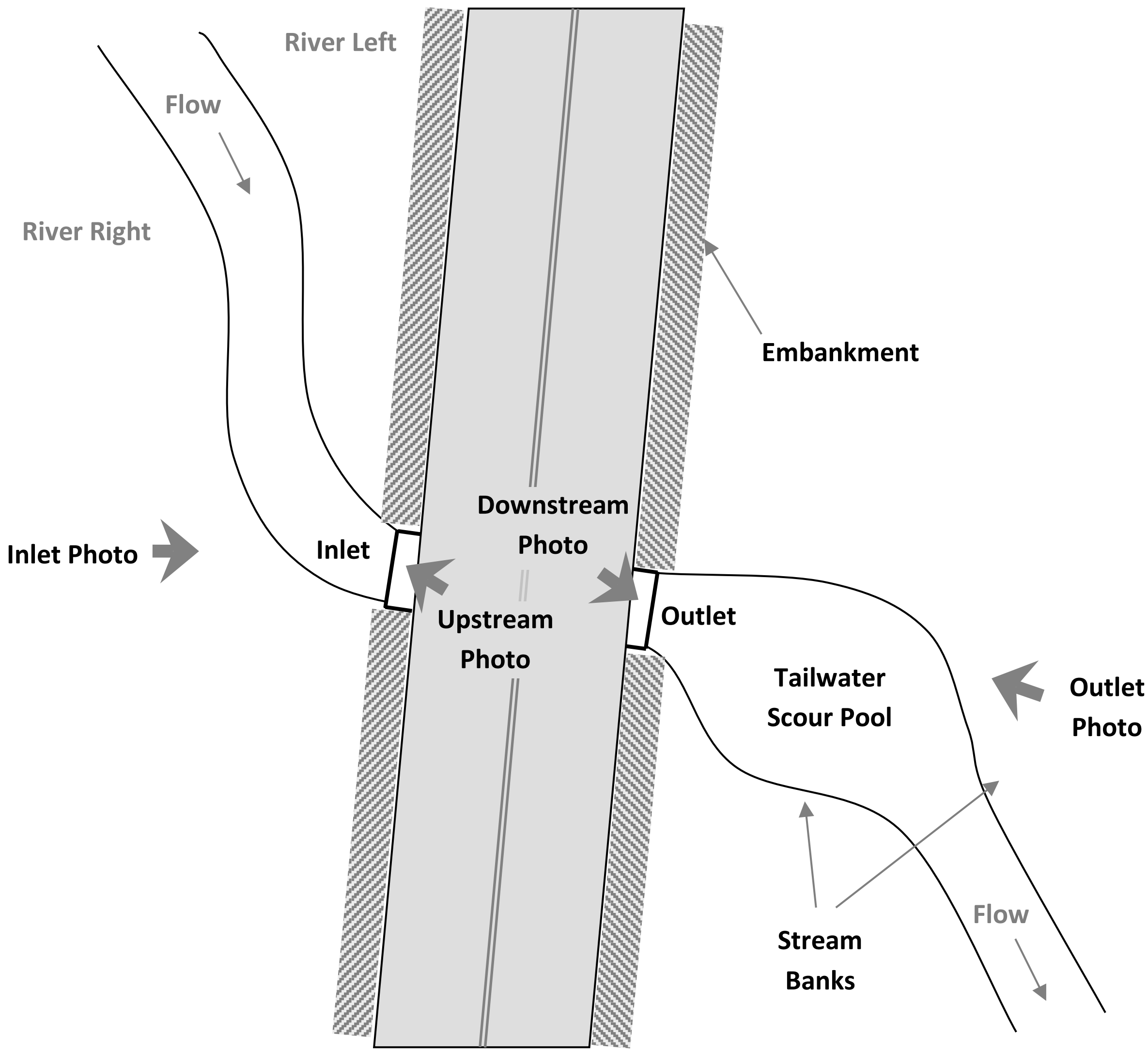
COMPLETING THE SURVEY DATA FORM

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.

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 <u>one</u> 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. <u>(Be sure you are in the correct location.)</u>
>
> *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.

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.

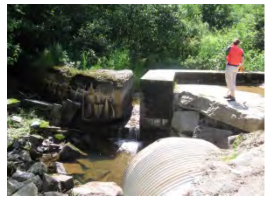
A simple way to know which photos were taken at a particular site is to use a black marker on a white dry-erase board to record the date and Crossing Code, and to have the first photo at the crossing show this white board displaying the date and Crossing Code. The white board should be strategically 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.

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.

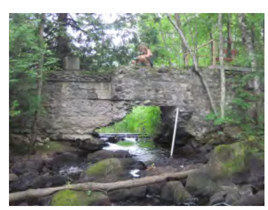
Moderate: This value is selected when recent rains have raised water levels at or above the level of herbaceous (non-woody) stream bank vegetation.

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.

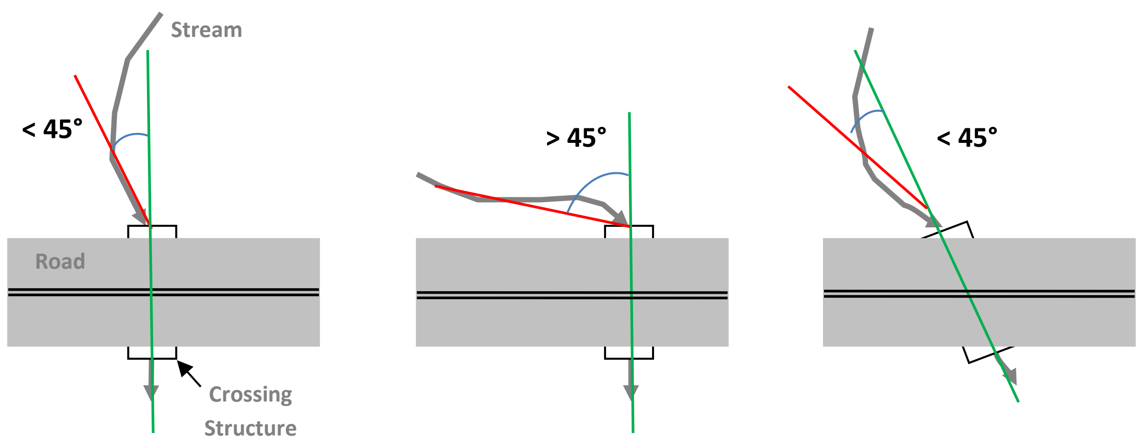
Unknown: This value applies to all sites where the condition of the crossing cannot be assessed, such as when submerged.

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. <u>Choose only one option</u>. 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 <u>wrack line</u> (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.

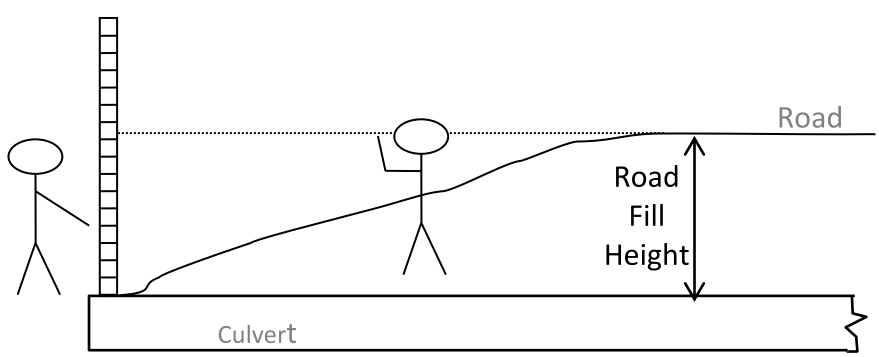
Alignment: Indicates the alignment of the crossing structure(s) relative to the stream at the inlet(s). Compare the crossing centerline (green lines below) to a centerline of the stream where it enters the crossing (red lines below).

> *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.



Flow-Aligned **Skewed** **Flow-Aligned**

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.

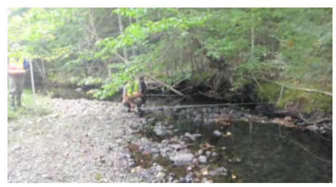


Bankfull Width (optional measurement)**:** This is a measure of the active stream channel width at bankfull flow, the point at which water completely fills the stream channel and where additional water would overflow into the floodplain. Estimates of the frequency of bankfull flows vary, but they may 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]:

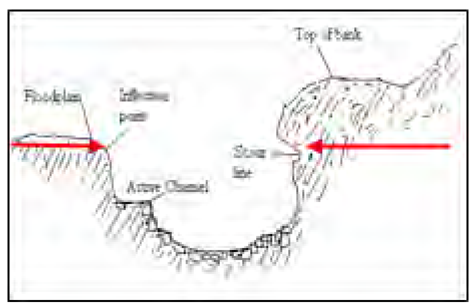
Abrupt transition from bank to floodplain: The point of change from a vertical bank to a more horizontal surface is the best identifier of bankfull stage, especially in low-gradient meandering streams.



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.

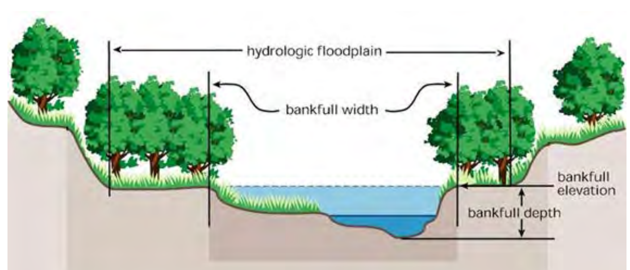


Bank undercuts: Maximum heights of bank undercuts are useful indicators of bankfull flow in steep channels lacking floodplains.



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.



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

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:

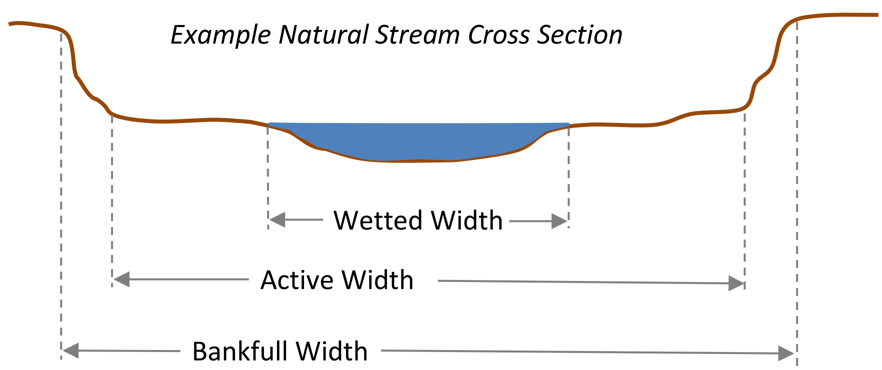
- Clear indicators are present to define the limits of Bankfull Width.
- The recorded value is an average of at least three measurements in different locations.
- All measurements of Bankfull Width were taken in undisturbed locations well upstream or downstream of the crossing.
- No tributaries enter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

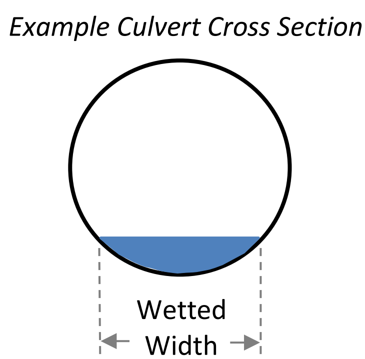
Low/Estimated: Select this when **any** of the above criteria cannot be met.

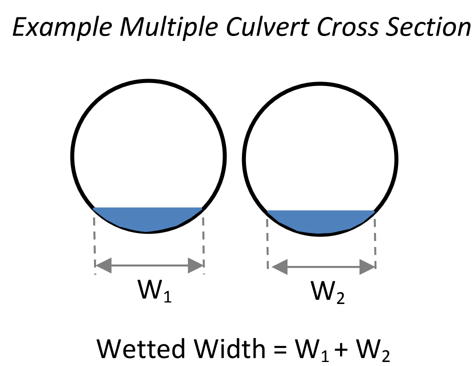
Constriction: Regardless of whether you measured Bankfull Width above, this element assesses how the width of the crossing (including all of its structures) compares to the width of the natural stream channel. Refer to the above section on determining Bankfull Width for reference. Two other ways of assessing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







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

<u>Choose only one option</u> 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.

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*. <u>Choose only one option</u>.

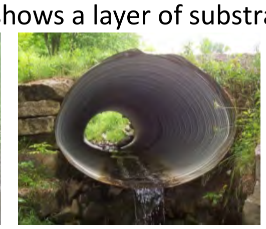
Outlet Shape: Refer to the diagrams on the last page of the field data form, and record here the structure number that best matches the shape of the structure opening observed at the inlet of the culvert. This is usually simple, but when a shape seems unusual, you should carefully choose the most reasonable 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. <u>Choose only one option</u>.

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).



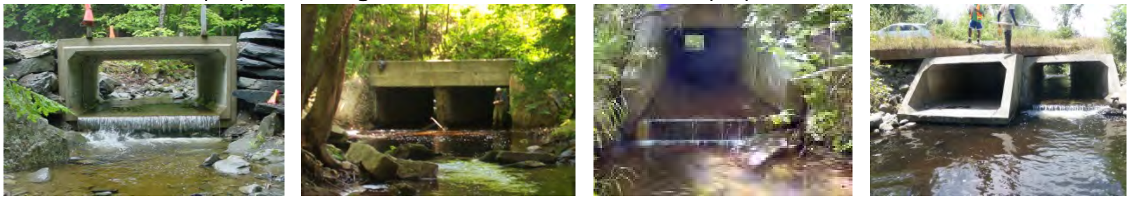



3 - Open Bottom Arch Bridge/Culvert: This structure will often look like a round culvert on the top half, but it will not have a bottom. There will be some sort of footings to stabilize it, either buried metal or concrete footings, or concrete footings that rise some height above the channel bottom. 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).



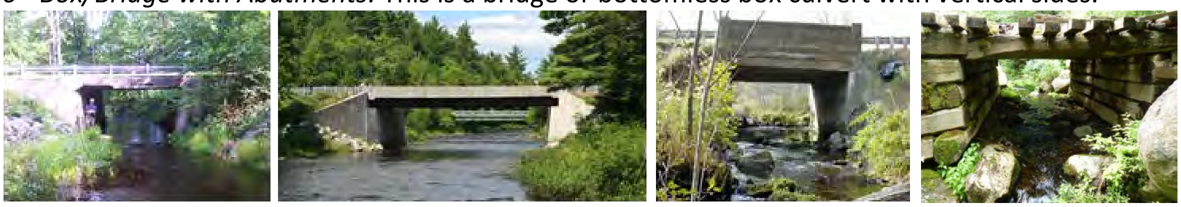

4 - Box Culvert: These structures are usually made of concrete or stone, but sometimes of corrugated metal with a slightly arched top. Typically, they have a top, two sides, and a bottom.

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 a layer of 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. <u>Choose only one option</u>.

Refer to the photos below for examples of each option.

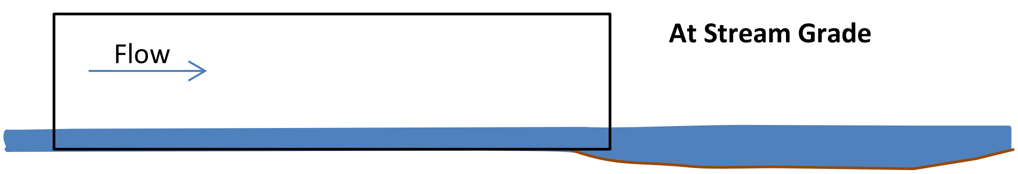
None: This situation represents the majority of crossing structures. You may observe rocks that have fallen from the embankment or that are natural to the stream. Most cascades do not constitute armoring unless specifically put in place to minimize outlet scour.

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.

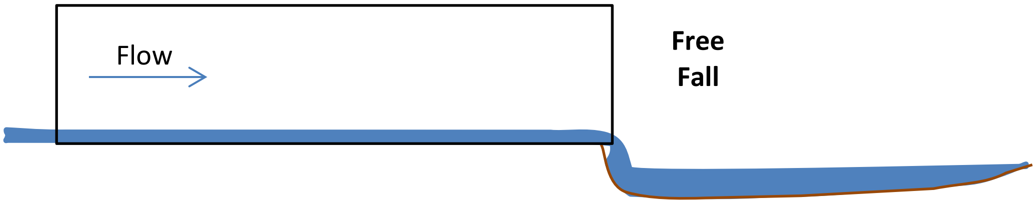
Extensive: Select this option only if you observe an extensive layer of material covering an area more than 50% of the stream width, which was put in place specifically to minimize scour at the outlet.

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>.

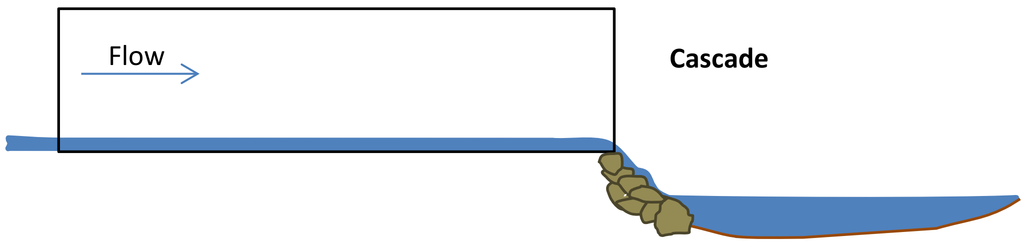
At Stream Grade: The bottom of the outlet of the structure is at approximately the same elevation as the stream bottom (there may be a small drop from the inside surface of the structure down to the stream bottom), such that **<u>water does not drop downward at all</u>** when flowing out of the structure.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



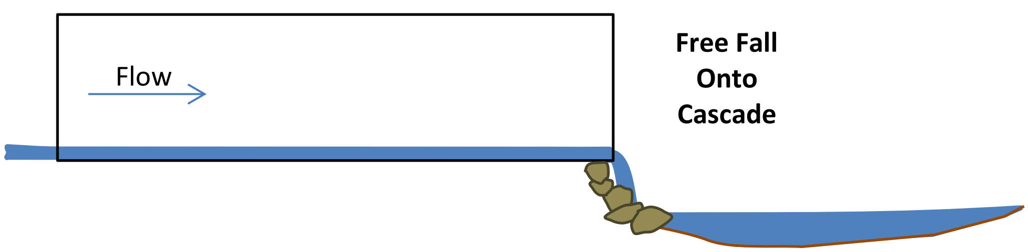
Free Fall: The outlet of the structure is above the stream bottom such that **<u>water drops vertically</u>** when flowing out of the structure.



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.



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 **inside** the structure.

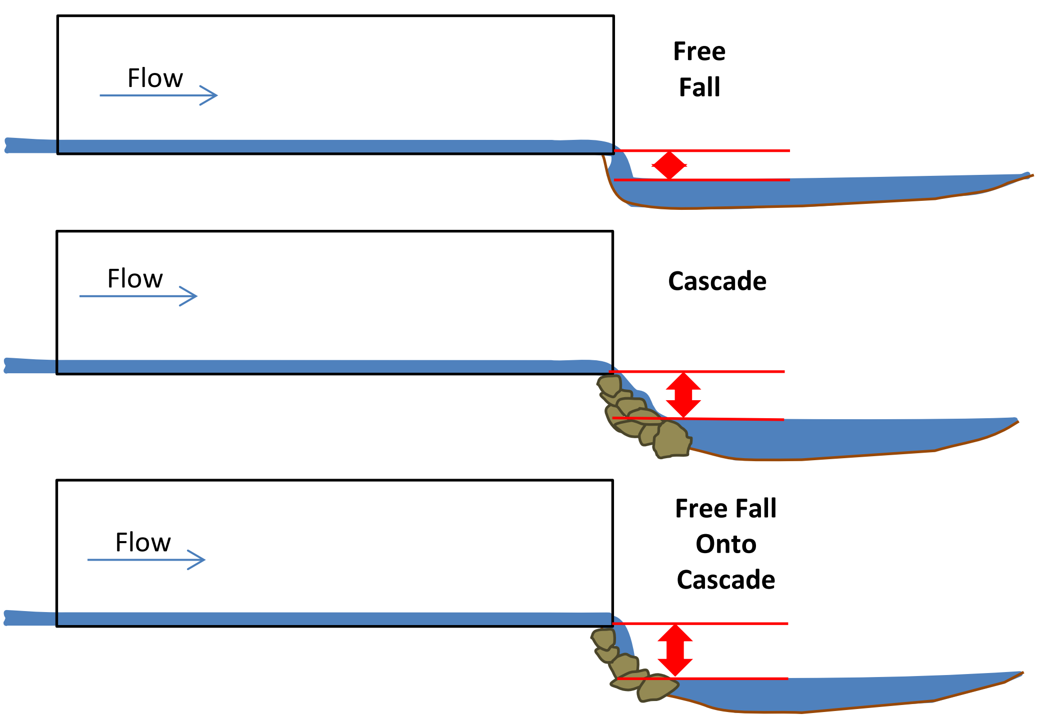
Dimension B, ***Structure Height***: To the nearest tenth of a foot, measure the height of the structure outlet according to the location of the vertical arrows labeled ***B*** in the diagrams. Take this measurement **inside** the structure. If there is no substrate inside, this will be the full height 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 **wider** according to the general location indicated by the arrows labeled ***C*** in the diagrams. This measurement must be taken **inside** 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.

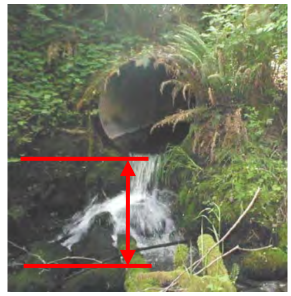
Dimension D, ***Water Depth***: To the nearest tenth of a foot (except when < 0.1 foot, to the nearest hundredth of a foot), measure the average depth of water in the structure at the outlet according to the location of the vertical arrows labeled ***D*** in the diagrams. This measurement must be taken **inside** 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*.



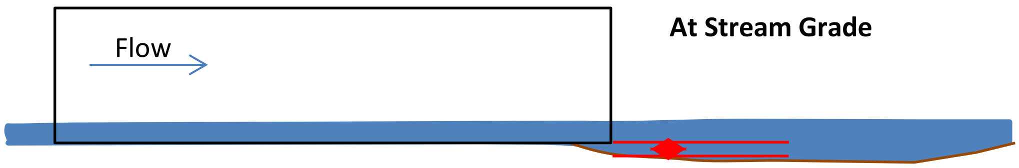
Free Fall

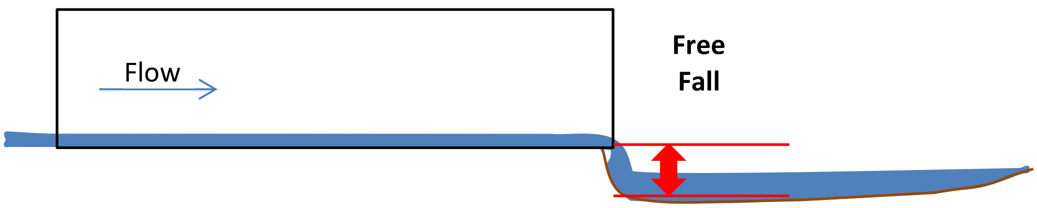
Free Fall

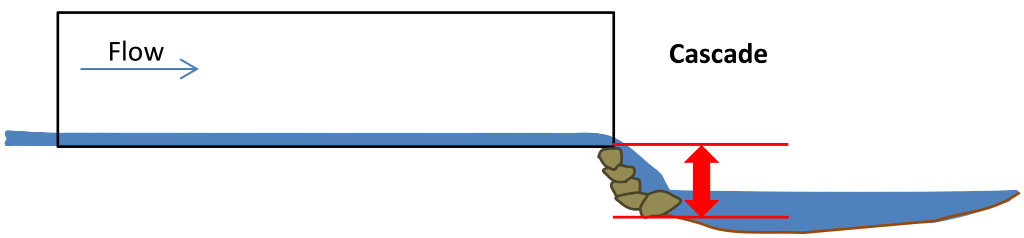


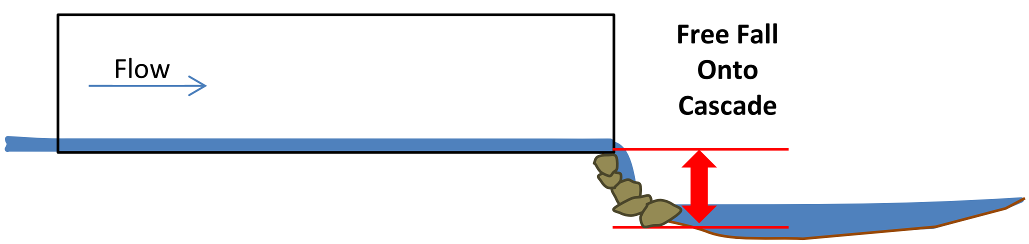
Free Fall Onto Cascade

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.





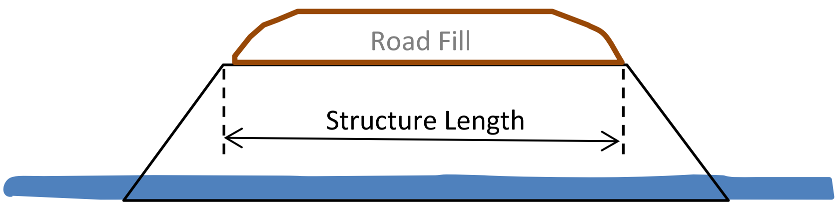




Abutment Height, *Dimension E*: This measurement is taken <u>only</u> when surveying a *Bridge with Side Slopes and Abutments* (#7 structure**)**. To the nearest foot, measure the height of the vertical abutments from the top of the side slopes up to the bottom of the bridge deck structure.

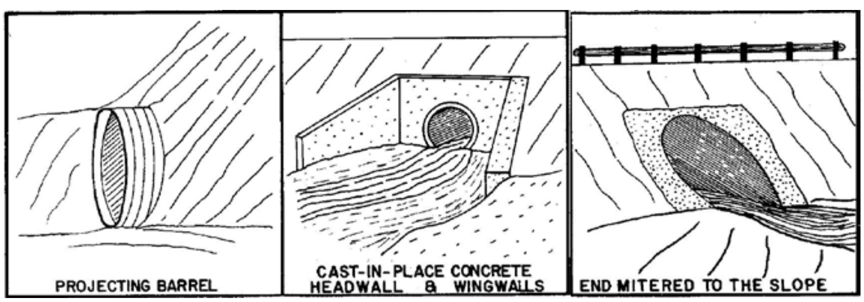



Structure Length, *Dimension L*: To the nearest foot, measure the length of the structure at its top.



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.

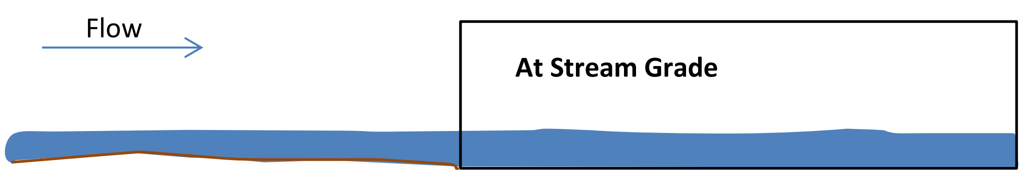
Mitered to Slope: The inlet is angled to fit **flush with the slope of the road embankment**. Note that many mitered culverts project out from the embankment, and should be recorded as *Projecting*.

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*.

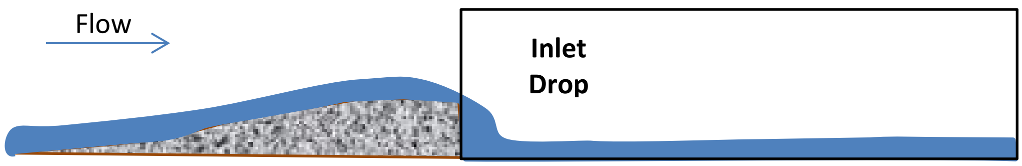
None: The inlet does not have any of the above features or characteristics.

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). <u>Choose only one option</u>.

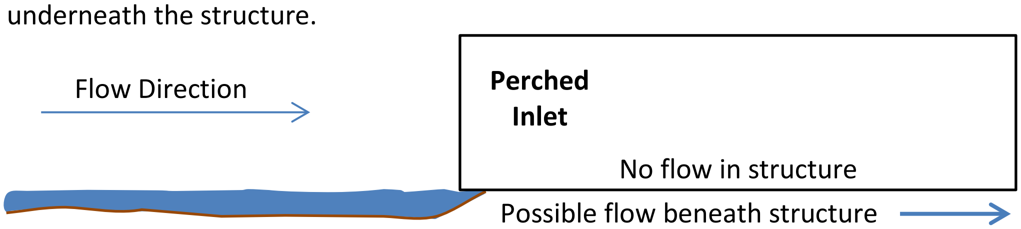
At Stream Grade: The inlet of the structure is at approximately the same elevation as the stream bottom upstream of the structure.



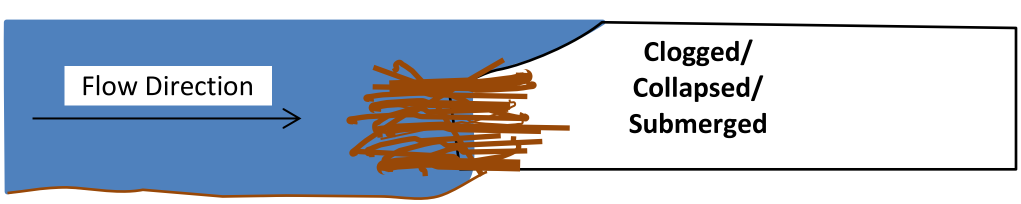
Inlet Drop: Water in the stream has a near-vertical drop from the stream channel down into the inlet of the structure. This usually occurs because sediment has accumulated above the inlet. The drop should be very obvious and not typical of natural drops in that stream. If there is a debris blockage or 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.



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 **<u>inside</u>** 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 **<u>inside</u>** 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 **<u>either</u>** 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 **<u>inside</u>** 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 **<u>inside</u>** 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.

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.

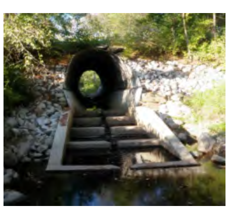
Internal Structures: Indicate the presence of structures inside the crossing structure. These may include baffles or weirs used to slow flow velocities and help to pass fish, as well as trusses, rods, piers or other structures intended to support a crossing structure, but which may interfere with flow 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.

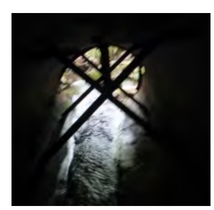
Baffles/Weirs: Baffles (partial width) or weirs (full width, notched or not) are incorporated into the structure, either inside or at its outlet, to help aquatic organisms move through the structure.

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: <u>Choose only one option</u> 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 <u>significantly</u> limits flow or inhibits the passage of aquatic organisms. This does not include minor dents and slightly misshapen structures.

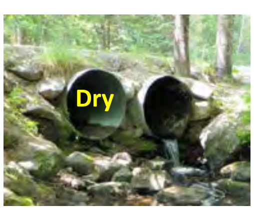
*Free Fall***:** In addition to its **Outlet Grade**, which may include a *Free Fall*, the structure has one or more **<u>additional</u>** vertical drops associated with it. These may include a dam at the inlet, a vertical drop over bedrock inside the structure, or some other feature likely to inhibit 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.

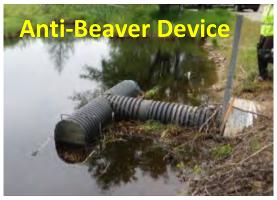
Fencing: The structure has some sort of fencing, often at the inlet to deter beavers. Depending on the mesh size of that fencing, it may directly block the movement of aquatic and terrestrial organisms, and it may become clogged with debris. If also blocked with debris, be sure to check *Debris/Sediment/Rock*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

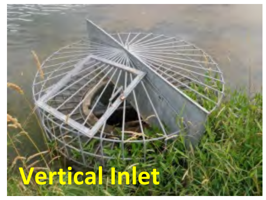
   

Dry: There is no water in this structure, though water is flowing in the stream. Note that if you recorded *No Flow* for crossing Flow Condition, you should not select *Dry* here, as we expect a dry structure at a dry crossing; it is not in itself a physical barrier. This barrier type helps to identify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





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.

> *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.

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.

North Atlantic Aquatic Connectivity Collaborative

Assessing road-stream crossings to improve river and stream continuity across the North Atlantic U.S.

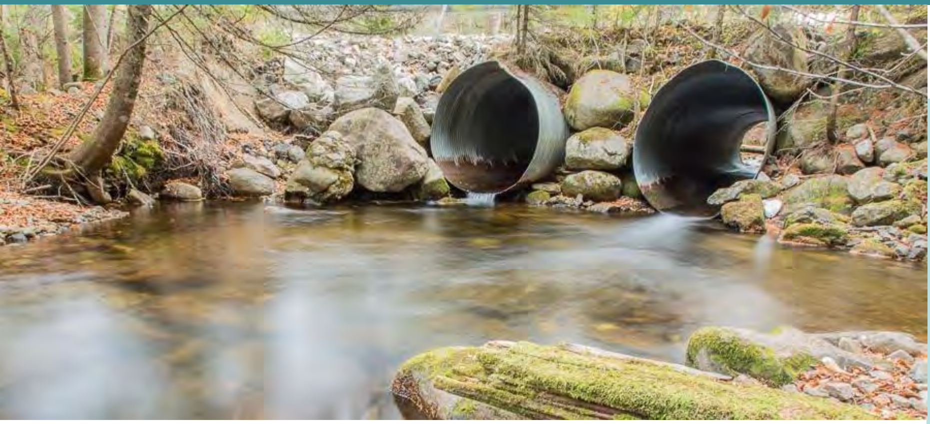


Photo: Erika Edgley, The Nature Conservancy

Improving Aquatic Connectivity and Increasing Flood Resilience

Road-stream crossings, which include culverts and bridges, are an essential element of our transportation networks, allowing roads to pass over rivers and streams. Undersized or poorly designed crossings fragment streams, contribute to erosion, exacerbate flooding, and prevent fish and other organisms from accessing the habitat they need to survive and reproduce. The good news is that thoughtfully-designed and well-placed culvert and bridge replacements can increase habitat connectivity for fish and wildlife while also enhancing resiliency of roads to flooding.

Maximizing limited restoration resources requires careful assessment and prioritization. To address this need, the University of Massachusetts Amherst (UMass), The Nature Conservancy, the U.S. Fish and Wildlife Service, and other experts from 13 states, with support from the North Atlantic Landscape Conservation Cooperative, have formed the North Atlantic Aquatic Connectivity Collaborative (NAACC). The NAACC is developing common protocols for assessing stream crossings, in order to identify high priority bridge and culverts for upgrade and replacement. The work of 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. By bringing together a range of partners – conservation organizations, local citizens, and state and federal natural resource and transportation agencies – the network will facilitate the exchange of information as well as collaboration on efforts to improve aquatic connectivity.

The Challenges

For aquatic organisms:

- There are millions of stream crossings across this 13-state region. In New York alone, there are an estimated 1.2 million crossings.
- The majority of stream crossings limit the movement of fish and wildlife. In Maine, nearly 60% of surveyed crossings are complete or partial barriers,
- Fragmentation of streams due to crossings has a range of negative consequences for river and stream ecosystem. As the climate changes, many organisms depend upon access to cooler upstream habitat to survive and reproduce.

For people:

- This region is experiencing more frequent extreme rain events, and the trend is expected to continue. Much of our transportation infrastructure is not designed to withstand these storms, which results in costly flood damage and potentially dangerous conditions. For example, an estimated 1,000 culverts in the state of Vermont sustained damage from Tropical Storm Irene.
- A recent UMass study found that stream crossings that are more severe barriers to fish and wildlife are also the most vulnerable to failure during large storms.

This undersized culvert is "perched" above the stream, making it a complete barrier to the movement of aquatic organisms.

Photo: The Nature Conservancy

The depth and speed of the water within this culvert match natural conditions upstream and downstream, and the natural bottom creates suitable conditions for stream dwelling organisms to move. The crossing is also large enough to handle flood flows,

The NAACC project will:

- Assemble a network of practitioners working to enhance aquatic connectivity.
- Develop a standard road-stream crossing field survey protocol for use across the 13-state region that reconciles different approaches for crossing assessments and scoring systems.
- Launch an online stream crossing assessment training program.
- Create an online database and map interface that provide a system for storing, scoring, and making available data from stream crossing assessments throughout the region.
- Support state coordinators, volunteers, and technicians in conducting crossing assessments in targeted areas throughout the region, as part of the U.S. Fish & Wildlife Service Hurricane Sandy recovery and mitigation effort.
- Identify opportunities to improve aquatic connectivity by prioritizing crossings for assessment and upgrade based on their potential ecological benefit.
- Build on existing work, such as The Nature Conservancy's Northeast Aquatic Connectivity Project: http://rcngrants.org/content/northeast-aquatic-connectivity.

Photo: Erika Edgley, The Nature Conservancy

Working Together

Funding for the North Atlantic Aquatic Connectivity Collaborative project is provided by the North Atlantic Landscape Conservation Cooperative and the U.S. Department of Interior Hurricane Sandy Mitigation funds. Numerous partners from conservation organizations, federal and state agencies, and academia are contributing data and providing advice and expertise.

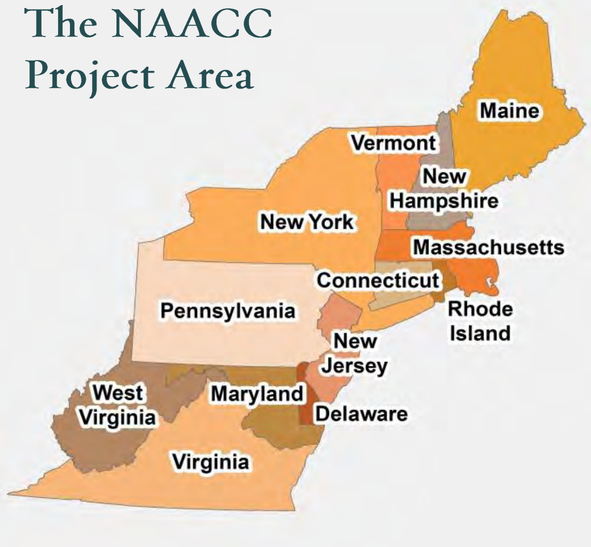
Brook Trout, a cold-water species, require access to cool headwater tributaries. Stream crossings are critical to providing navigable pathways for trout and other aquatic organisms.

Photo: Ben Letcher, USGS

The Wood Turtle is a semi-aquatic animal that travels along rivers and streams and is vulnerable to road mortality. Well-designed crossings allow these and other semi-aquatic wildlife to move safely along stream corridors.

Photo: Michael Jones, UMass

The NAACC Project Area



What we can accomplish:

- Reconnect streams and rivers to **support healthier populations of fish and wildlife** in a changing climate.
- Proactively identify and help prioritize sites for stream crossing upgrades and replacements to **bolster the flood resilience** of transportation infrastructure.
- Facilitate **communication and information sharing** among partners working to improve stream crossings across the region.

For more information:

To learn more about the NAACC and how you can get involved in the work group, contact Jessica Levine at jlevine@tnc.org.

November 2014

North Atlantic Aquatic Connectivity Collaborative

Search Crossings | Add New Record | Add-Edit-View Observers | Edit-View Coordinators | LogIn | LogOut

Offline Data Manager v1.4

Status: offline

Enable GpsGate (in some browsers you may need to allow "unsafe" scripts)

Check Storage Space

Service Worker Registration: **successful**

Service Worker State: **activated**

Saved offline crossing records:

Name	On device	Survey ID	Delete Crossing
xy4138186573095886	View/Correct	Not submitted	Delete
xy4138198573094637	View/Correct	Not submitted	Delete
xy4138528473092652	View/Correct	Not submitted	Delete
xy4139600073095181	View/Correct	Not submitted	Delete
xy4139603373095296	View/Correct	Not submitted	Delete
xy4139849373093714	View/Correct	Not submitted	Delete
xy4139856673093672	View/Correct	Not submitted	Delete
xy4142165073109041	View/Correct	Not submitted	Delete

Add offline crossing record:

Please enter a "Crossing Record Title" before proceeding.

(This is the name you will use when offline to view or edit this crossing record.)

xy4138528473092652

Photos:

Select a radio button to describe the photo before taking picture or choosing file.

○ Inlet Photo ○ Outlet Photo ○ Upstream Photo ○ Downstream Photo ◉ Other 1 Photo ○ Other 2 Photo ○ Other 3 Photo

Show/Hide Camera or Choose File WIN_201804…44_Pro.jpg

\

Inlet (Delete)

Outlet (Delete)

Upstream (Delete)

Downstream (Delete)

Other 1 (Delete)

Other 2 (Delete)

Your photo will appear in this box.

Other 3 (Delete)

Your photo will appear in this box.

Save to Device Validate form(s) online/offline

or Save to Server

Crossing Data

Coordinator: Jastremski, Michael [L2]

Crossing Code:

Local ID: (Optional)

Date Observed: (m/d/yyyy) 03 / 11 / 2018

Lead Observer: Morehouse, Courteny [Obs]

Town/County: Seymour, CT

Stream/River: Unnamed trib of Nickel Mine Bro

Road: Bungay Road

Type: ○ Multilane road (>2 lanes) ◉ Paved ○ Unpaved ○ Driveway ○ Trail ○ Railroad

GPS Decimal Coordinates: (WGS 84 EPSG:4326)

(Decimal degrees) 41.385103 °N Latitude -73.092733 °W Longitude

Capture GPS coordinates

GPS to crossing distance (meters):

Location Description: Seymour Land Conservation Trust; 42 Bungay Road

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: 2

Flow Condition: ○ No Flow ◉ Typical low-flow ○ Moderate ○ High

Crossing Condition: ◉ OK ○ Poor ○ New ○ Unknown **Tidal Site:** ○ Yes ◉ No ○ Unknown

Road Fill Height: *(Top of culvert to road surface; Bridge = 0)* 4.15 (ft.)

Alignment: ◉ Flow-Aligned ○ Skewed (>45°)

Bankfull Width: *(optional)* 10 (ft.) **Bankfull Width Confidence:** ○ High ◉ Low/Estimated

Constriction: ◉ Severe ○ Moderate ○ Spans Only Bankfull/Active Channel ○ Spans Full Channel & Banks ○ Unknown

Tailwater Scour Pool: ◉ None ○ Small ○ Large ○ Unknown

Crossing Comments: Comments...

Save To Device

Show All to Save PDF

Structure1

Structure Data

Structure Material: ○ Metal ◉ Concrete ○ Plastic ○ Wood ○ Rock/Stone ○ Fiberglass ○ Combination

Outlet Shape: 1 - Round Culvert

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 2.5 (ft.) **B. Height** 2.5 (ft.) **C. Substrate/Water Width** 2.3 (ft.) **D. Water Depth** 0.24 (ft.) **E.Abutment Height** *(Type 7 bridges only)* (ft.)

Outlet Drop to Water Surface: 0 (ft.)

Outlet Drop to Stream Bottom: 0 (ft.)

L.Structure Length: 87.5 (ft.)

Inlet Shape: 1 - Round Culvert

Inlet Type: ○ Projecting ○ Headwall ○ Wingwalls ○ Headwall and Wingwalls ◉ Mitered to Slope ○ Other ○ None

Inlet Grade: *(pick one)* ◉ At Stream Grade ○ Inlet Drop ○ Perched ○ Clogged/Collapsed/Submerged ○ Unknown

Inlet Dimensions: A. Width 2.5 (ft.) **B. Height** 2.5 (ft.) **C. Substrate/Water Width** 0.8 (ft.) **D. Water Depth** 0.06 (ft.)

Slope Percent: *(optional)*

Slope Confidence: *(optional)* ○ High ○ Low

Internal Structures: ◉ None ○ Baffles/Weirs ○ Supports ○ Other Ot

Structure Substrate Matches Stream: ◉ None ○ Comparable ○ Contrasting ○ Not Appropriate ○ Unknown

Structure Substrate Type: ◉ None ○ Silt ○ Sand ○ Gravel ○ Cobble ○ Boulder ○ Bedrock ○ Unknown

Structure Substrate Coverage: ◉ None ○ 25% ○ 50% ○ 75% ○ 100% ○ Unknown

Physical Barriers: *(pick all that apply)* ☑ None ☐ Debris/Sediment/Rock ☐ Deformation ☐ Free Fall ☐ Fencing ☐ Dry ☐ Other

Severity: *(Choose carefully based on barrier type(s) above)* ◉ None ○ Minor ○ Moderate ○ Severe

Water Depth Matches Stream: ○ Yes ◉ No-Shallower ○ No-Deeper ○ Unknown ○ Dry

Water Velocity Matches Stream: ◉ Yes ○ No-Faster ○ No-Slower ○ Unknown ○ Dry

Dry passage through structure? ○ Yes ◉ No ○ Unknown

Height above dry passage: (ft.)

Structure Comments: Comments...

Save To Device | Validate form(s) offline

Structure2

Structure Data

Structure Material: ○ Metal ● Concrete ○ Plastic ○ Wood ○ Rock/Stone ○ Fiberglass ○ Combination

Outlet Shape: 1 - Round Culvert

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 2.4 (ft.) **B. Height** 2.3 (ft.) **C. Substrate/Water Width** 1.7 (ft.) **D. Water Depth** 0.1 (ft.) **E.Abutment Height** *(Type 7 bridges only)* (ft.)

Outlet Drop to Water Surface: 0 (ft.)

Outlet Drop to Stream Bottom: 0 (ft.)

L.Structure Length: 87.5 (ft.)

Inlet Shape: 1 - Round Culvert

Inlet Type: ○ Projecting ○ Headwall ○ Wingwalls ○ Headwall and Wingwalls ● Mitered to Slope ○ Other ○ None

Inlet Grade: *(pick one)* ● At Stream Grade ○ Inlet Drop ○ Perched ○ Clogged/Collapsed/Submerged ○ Unknown

Inlet Dimensions: A. Width 2.5 (ft.) **B. Height** 2.5 (ft.) **C. Substrate/Water Width** 0.7 (ft.) **D. Water Depth** 0.04 (ft.)

Slope Percent: *(optional)*

Slope Confidence: *(optional)* ○ High ○ Low

Internal Structures: ● None ○ Baffles/Weirs ○ Supports ○ Other Ot

Structure Substrate Matches Stream: ● None ○ Comparable ○ Contrasting ○ Not Appropriate ○ Unknown

Structure Substrate Type: ● None ○ Silt ○ Sand ○ Gravel ○ Cobble ○ Boulder ○ Bedrock ○ Unknown

Structure Substrate Coverage: (•) None ( ) 25% ( ) 50% ( ) 75% ( ) 100% ( ) Unknown

Physical Barriers: *(pick all that apply)* [x] None [ ] Debris/Sediment/Rock [ ] Deformation [ ] Free Fall [ ] Fencing [ ] Dry [ ] Other

Severity: *(Choose carefully based on barrier type(s) above)* (•) None ( ) Minor ( ) Moderate ( ) Severe

Water Depth Matches Stream: ( ) Yes (•) No-Shallower ( ) No-Deeper ( ) Unknown ( ) Dry

Water Velocity Matches Stream: (•) Yes ( ) No-Faster ( ) No-Slower ( ) Unknown ( ) Dry

Dry passage through structure? ( ) Yes (•) No ( ) Unknown **Height above dry passage:** (ft.)

Structure Comments: Comments...

Save To Device   Validate form(s) offline

Appendix B

UCONN Data Collection Protocol, Scope of Work

UCONN HYDRO MODEL SUPPLEMENTAL DATA FORM
DATA COLLECTION GUIDANCE DOCUMENT
1/22/18

*****NOTE: Bold text represents the field label in the electronic data form. Text in parenthesis represents the spreadsheet output heading for that corresponding field. Leave fields blank on data form if they are not required/applicable.**

CROSSING CODE (CROSSING_CODE): The 16 digit crossing code assigned by the North Atlantic Aquatic Connectivity Collaborative (NAACC). These 16 digits preceded by "xy" correspond with the predicted latitude and longitude of the road-stream crossing, ex. "xy4123456773123456" represents a crossing at 41.234567 latitude and -73.123456 longitude.

SURVEYOR (SURVEYOR): The first and last initial of the surveyor entering data.

SUBSHED (SUBSHED): The name of the priority subwatershed in which the crossing falls within, sometimes not applicable.

STREAM (STREAM): The name of the stream that flows through the crossing. If the stream is unnamed please enter "Unnamed".

TOWN (TOWN): The town in which the crossing falls within.

STATE (STATE): The state in which the crossing falls within.

DATE (DATE): The date in which the survey was completed.

 # OF BARRELS (#_BARRELS): The number of culverts at a crossing.

*****NOTE: All of the below fields that contain multiple values, (example: "SHAPE_1, SHAPE_2, etc.") refer to the fact that there may be more than one culvert at a crossing, and therefore we are reporting values for each culvert. These multiple culverts are numbered left to right looking at the inlet from upstream (Figure 1). Fields will only be populated for the corresponding number of culverts.**

Figure 1: Numbering convention for multiple culverts.

CULVERT SHAPE (SHAPE_1, SHAPE_2, etc.): A culvert falls into one of 4 categories, as defined in the UCONN Algorithm Theory Based Document (ATBD) (Figure 2). HVA is excluding all open bottom structures (bridges and open bottom arches) from risk of failure modeling.

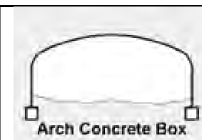
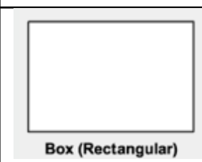
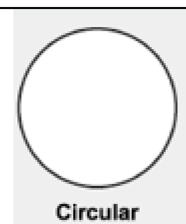
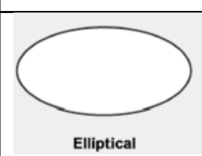
Culvert Shape	arc	
	box	
	circle	
	ellipse	

Figure 2: Culvert shapes.

PIPE MATERIAL (MATERIAL_1, MATERIAL_2, etc.): The ATBD lists five options for pipe material (Figure 3). *In the field, HVA also encountered smooth metal pipes which are recorded as RCP due to their similarity in roughness. Concrete box culverts are also classified as RCP.*

Pipe Material	CMP	corrugated metal pipe
	RCP	reinforced concrete pipe
	PVC	polyvinyl chloride pipe
	HDPE	smooth-lined high density poly ethylene pipe
	Corr PE	corrugated high density poly ethylene pipe

Figure 3: Pipe materials.

INLET EDGE TYPE (EDGE_1, EDGE_2, etc.): The ATBD lists four options for inlet edge type (Figure 4). *The ATBD did not have descriptions of each type; the following descriptions are from HVA.* Below are photographic examples of each type.

Inlet Edge Type	thin	The thin edge of the culvert is projecting outwards.
	square	The culvert edge is flush with the headwall or slope.
	grooved	An inlet indentation with right angles.
	beveled	An angled bevel from the headwall or slope.

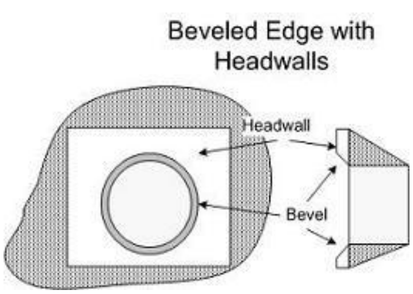
Figure 4: Inlet edge types.

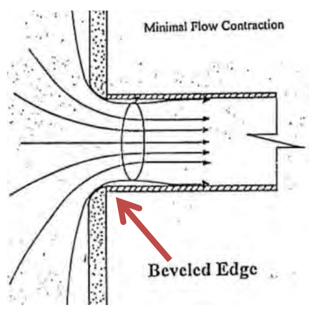
Thin:

Square:

Grooved:

Beveled:





INLET END TYPE (END): The ATBD lists five options for inlet end type (Figure 5). HVA has added a sixth category, "headwall & wingwalls" to capture scenarios where both end types are present (fairly common). *If there are multiple culverts with more than one inlet end type flag crossing and describe in notes.*

Inlet End Type	projecting	Projecting out from a slope or a wall.
	headwall	Likely a concrete face, flush with the inlet to the pipe.

	mitered	The pipe is cut to comform to the slope.
	end section	A piece of pipe attached as an apron.
	wingwalls	Walls angling from the inlet. The angle is measured from the parallel with the pipe.
	headwall & wingwalls	**ADDED BY HVA** to represent when a structure has both a headwall and wingwalls.

Figure 5: Inlet end types.

STRUCTURE/STREAM SKEW (SKEW): *HVA decided to collect this additional piece of information.* It is the angle between the structure centerline and the streamline, measured with a handheld compass (Figure 6).

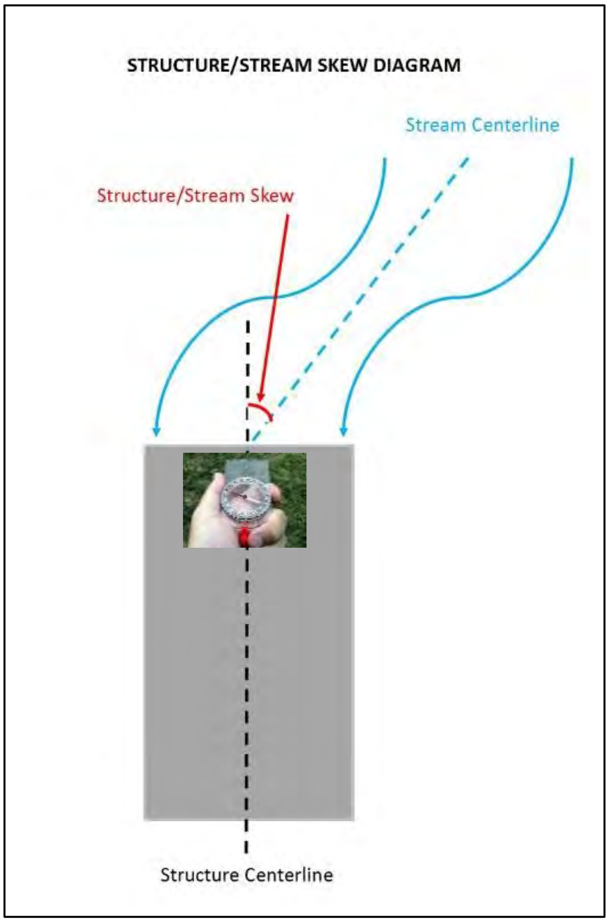


Figure 6: Structure/stream skew.

HEADWALL ANGLE (HEADWALL_ANGLE): If inlet end type is a headwall, this is the angle of the headwall in relation to the culvert parallel (usually 90 degrees). If Inlet End Type is an end section or mitered, then the headwall angle is the angle between the culvert parallel and the slope of the end section or structure edge (Figure 7).

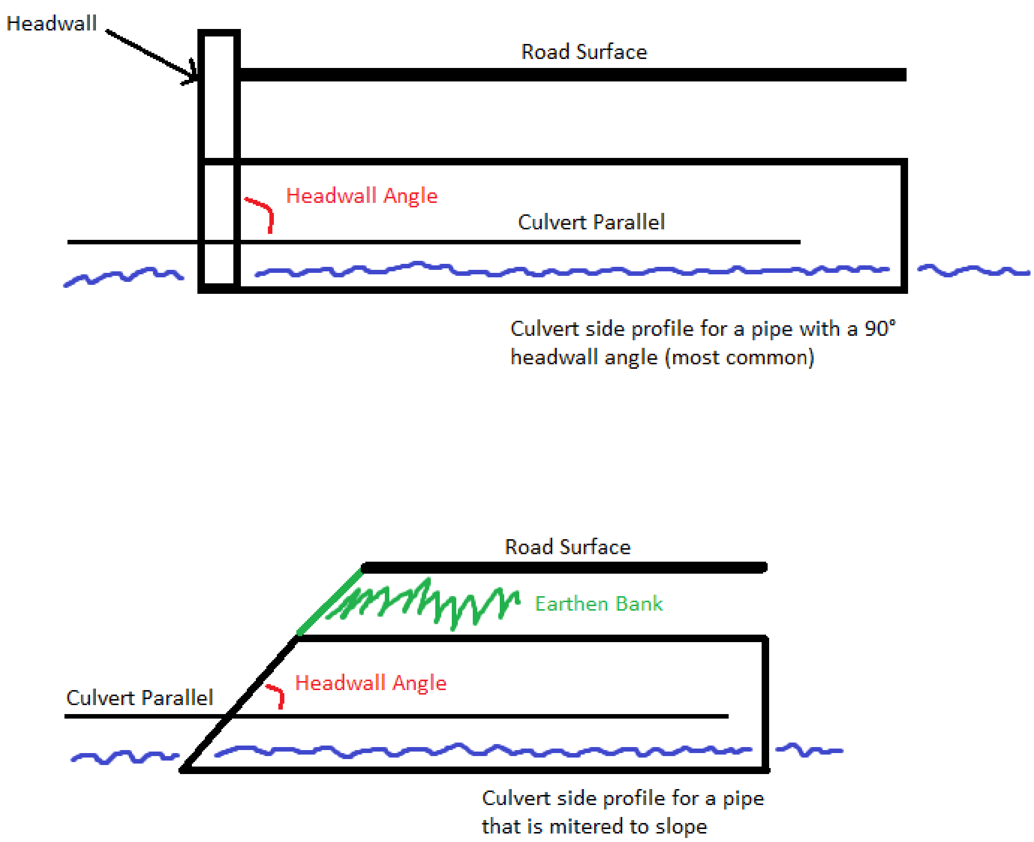
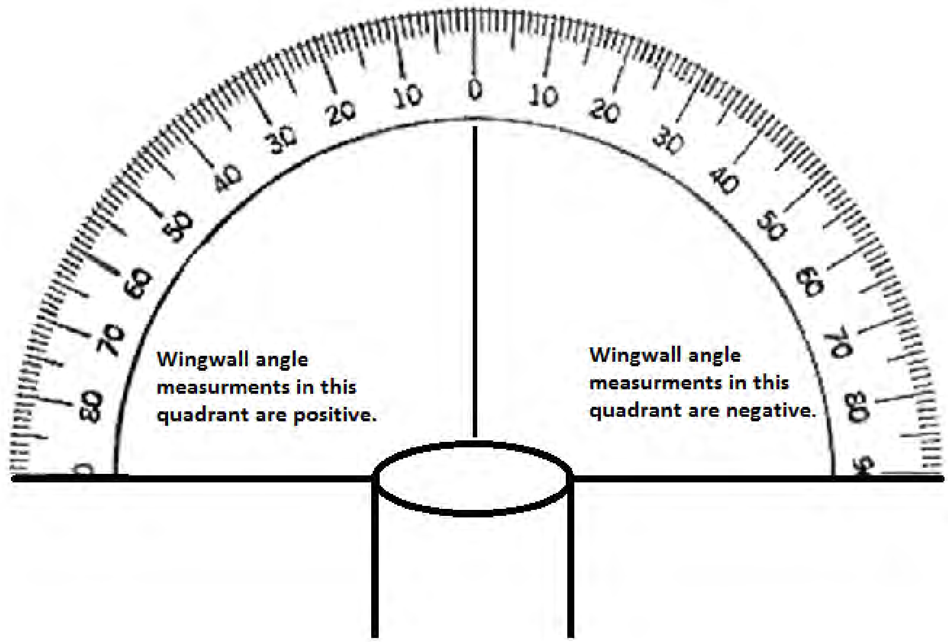
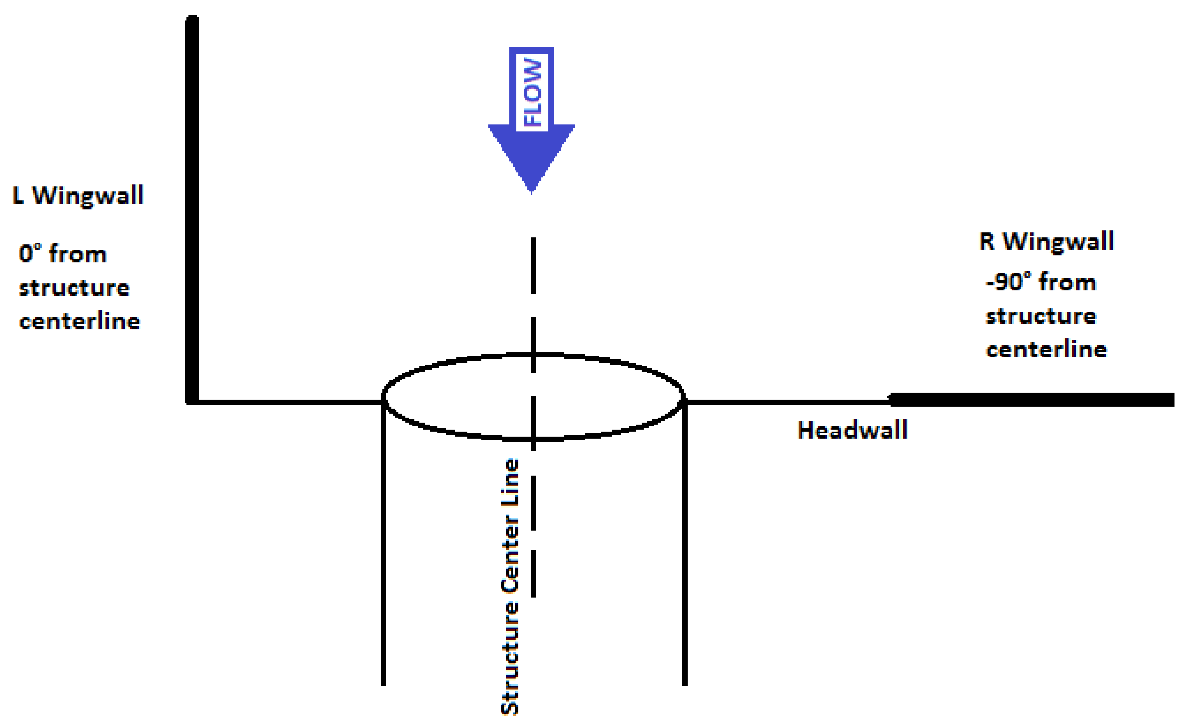


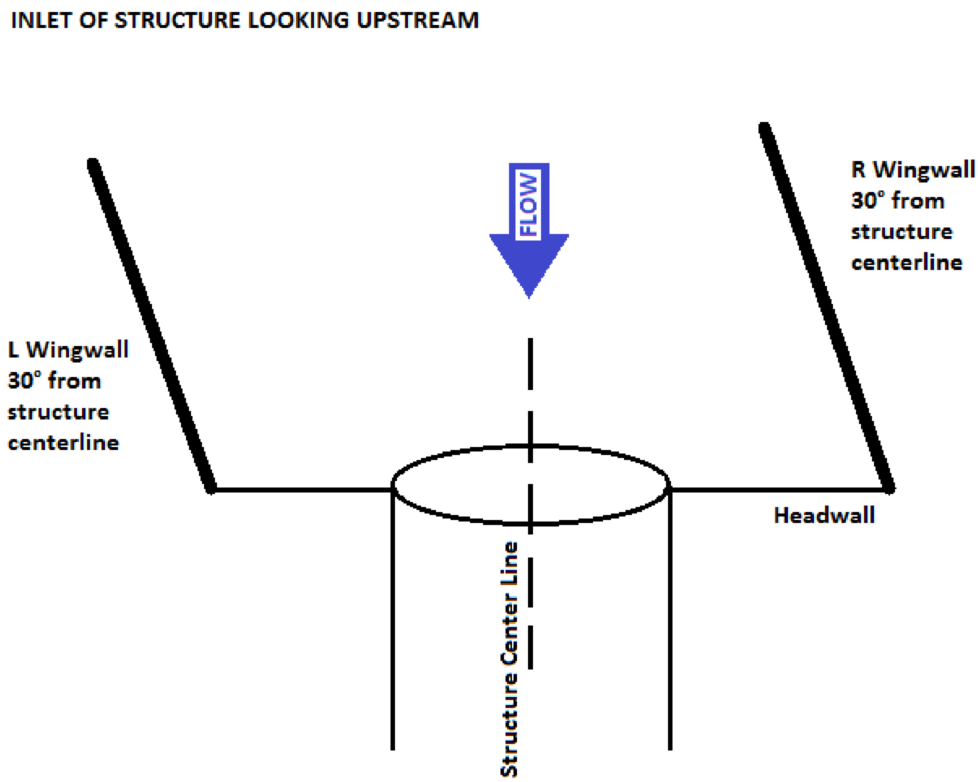
Figure 7: Headwall angles.

LEFT/RIGHT WINGWALL ANGLE (L_WINGWALL_ANGLE/R_WINGWALL_ANGLE): The angle between the structure centerline and the wingwall. The wingwalls are identified while looking from the inlet upstream. Angles are measured with a compass while standing on top of the culvert. Wingwalls that angle left are shown as positive, while wingwalls that angle right are shown as negative. (Figure 8). *Mitered and Projecting inlet end types do not require wingwall angle.* ***If inlet end type is headwall it still needs wingwall angle even though there are no real "wingwalls", measure these from pipe centerline to edge of headwall on each side, typically this results in a left wingwall angle of 90, and right angle of -90.***



INLET OF STRUCTURE LOOKING UPSTREAM





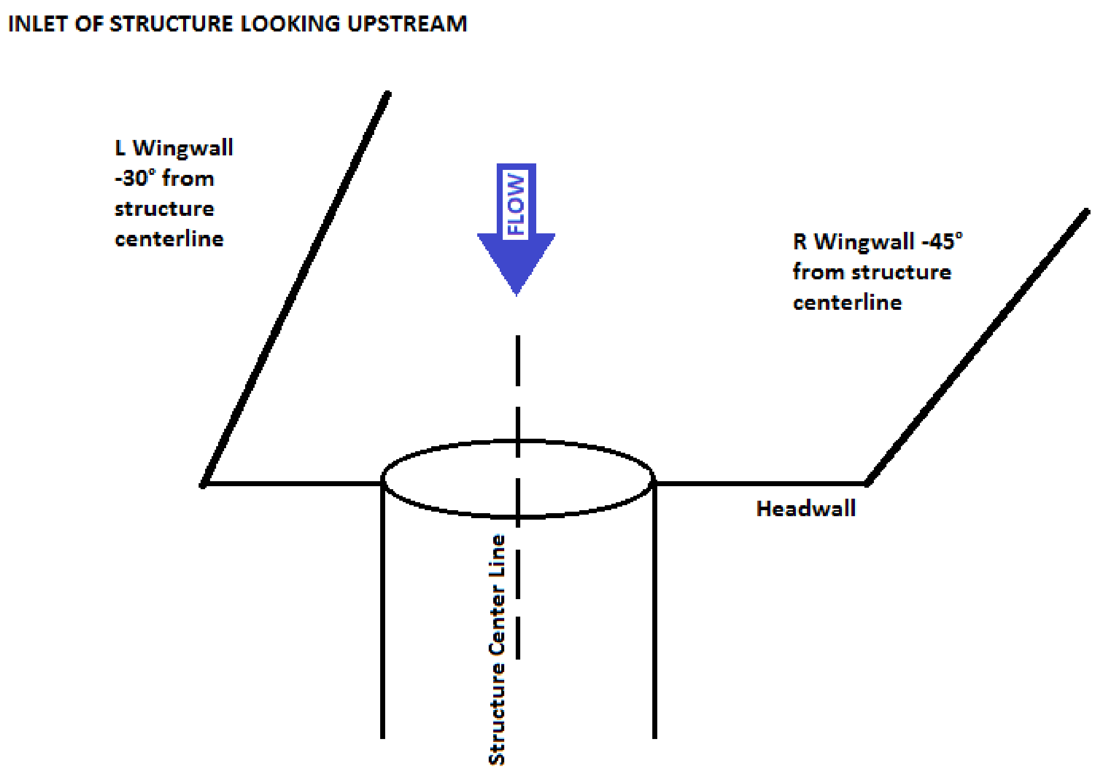


Figure 8: Wingwall angle measurements.

LEFT/RIGHT WINGWALL LENGTH (L_WINGWALL_LENGTH/R_WINGWALL_LENGTH): For "wingwalls" or "headwall & wingwalls" inlet end types, the length is measured from the tip of the wingwall to where it meets the headwall or structure (Figure 9). For "headwall" inlet end type, wingwall length is measured from the end of the headwall to the edge of the structure (Figure 10). *Mitered and Projecting inlet end types do not require wingwall length.* ***If inlet end type is headwall it still needs wingwall length even though there are no real "wingwalls", measure these from edge of pipe to edge of headwall on each side (see Figure 10).***

Figure 9: Wingwall length on a culvert with headwall and wingwalls inlet end type.

Figure 10: Wingwall length on a culvert with headwall inlet end type.

TOP BEVEL ANGLE (BEVEL_ANGLE_1, BEVEL_ANGLE_2, etc.): The angle between the structure centerline and the slope of the bevel (Figure 11).

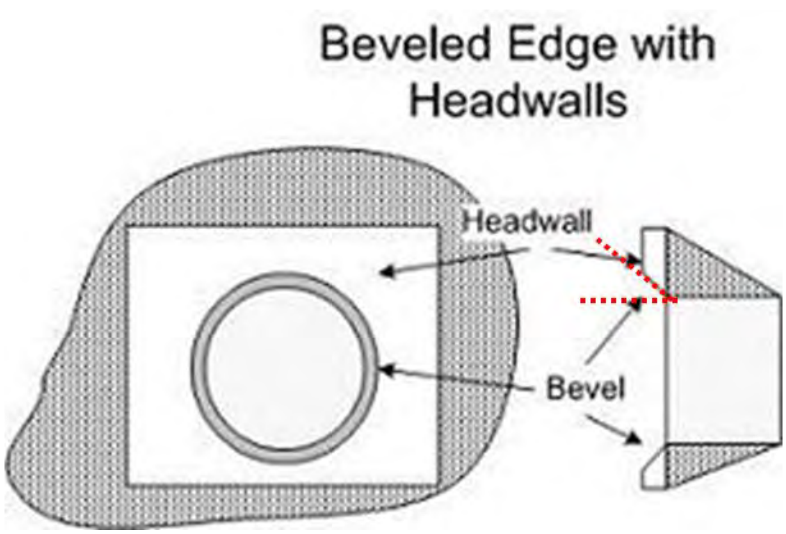


Figure 11: Top bevel angle on a culvert with a beveled inlet edge type.

SPAN (Width) (SPAN_1, SPAN_2, etc.): The width of the culvert at the inlet. In the case of grooved structures, the width is taken at the narrowest part.

RISE (Height) (RISE_1, RISE_2, etc.): The height of the structure at the inlet. In the case of grooved structures, the height is taken at the narrowest part.

LENGTH (LENGTH_1, LENGTH_2, etc.): The length of the structure from inlet to outlet.

WEIR CREST LENGTH (WEIRCREST_1, WEIRCREST_2, etc.): The distance between the tips of the wingwalls, measured parallel to the plane of the inlet. If the wingwalls are different lengths, measure across the face of the inlet from the tip of the shortest wingwall (Figure 12). For headwalls, the weir crest is the distance across the length of the headwall (Figure 13). For thin, projecting pipes with no headwall or wingwalls, the weir crest is the span (width) of the pipe. **If there are multiple projecting pipes (Figure 14) the weir crest is the sum of each projecting culvert's width and the distance between pipes, ex. (sum of SPAN_1 + 2 + 3 + sum of DISTANCE_BETWEEN_PIPES_1 + 2).** *If there is only one culvert, or multiple projecting culverts, record the single weir crest under "WEIRCREST_1". Having more than one weir crest is rare but occurs when there are two or more culverts with individual wing walls.*

Figure 12: Weir crest length on culvert with headwall and wingwalls inlet end type.

Figure 13: Weir crest length on double barrel culvert with headwall inlet end type.

Figure 14: Weir crest length and distance between pipes on multiple projecting culverts.

DISTANCE BETWEEN PIPES (DISTANCE_BETWEEN_PIPES_1, DISTANCE_BETWEEN_PIPES_2, etc.): The distance between two or more projecting culverts. *This field is only required when there are multiple projecting culverts (Figure 14).*

OUTLET DROP TO WATER SURFACE (OUTLET_TO_WATER_1, OUTLET_TO_WATER_2, etc.): The height of the drop from the outlet invert to the surface of the stream or waterbody.

OUTLET DROP TO STREAMBED (OUTLET_TO_BED_1, OUTLET_TO_BED_2, etc.): The height of the drop from the outlet invert to the streambed.

ELEVATIONS: Measured using a laser level on a tripod and receiver with stadia rod (Figure 15).

- **INLET ELEVATION** (INLET_ELEV_1, INLET_ELEV_2, etc.): Measured at the inlet invert.
- **TOP OF PIPE ELEVATION** (TOP_ELEV_1, TOP_ELEV_2, etc.): Measured from the top of the pipe itself.
- **ROADWAY ELEVATION** (ROADWAY_ELEV_1, ROADWAY_ELEV_2, etc.): Measured on the side of the road on the inlet side.
- **OUTLET ELEVATION** (OUTLET_ELEV_1, OUTLET_ELEV_2, etc.): Measured at the outlet invert.

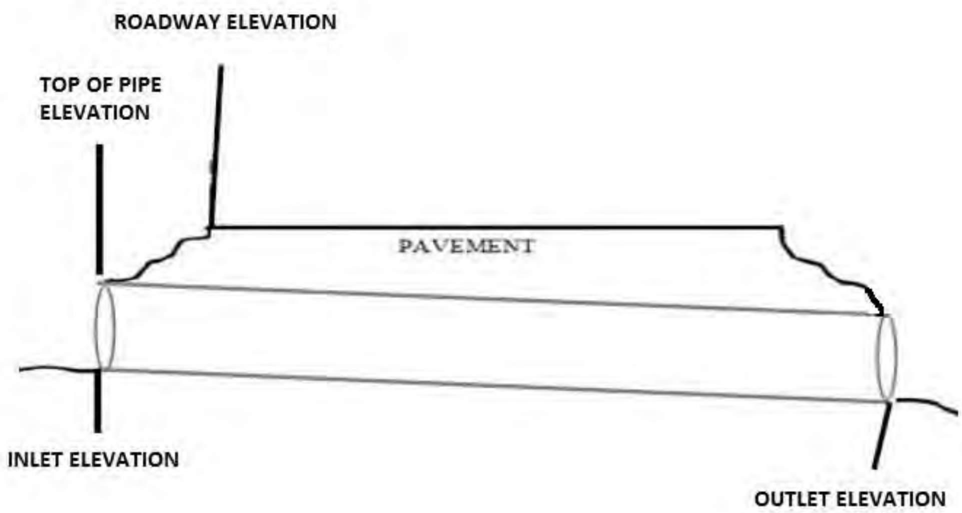


Figure 15: Elevation points.

SLOPE (SLOPE_1, SLOPE_2, etc.): Slope is calculated for each culvert by subtracting the inlet elevation from the outlet elevation and dividing that difference by the length of the culvert. *If the slope is greater than 0.10, double check to see if this is correct.*

LENGTH OF ARC (ARC_LENGTH_1, ARC_LENGTH_2, etc.): For a culvert with an arc top, this would be measured at the widest point of the arc.

HEIGHT OF RECTANGLE SECTION OF ARCH CONCRETE BOX (HEIGHT_OF_REC_1, HEIGHT_OF_REC_2, etc.): The height from the bottom of the culvert to the bottom of the arched section (Figure 16).

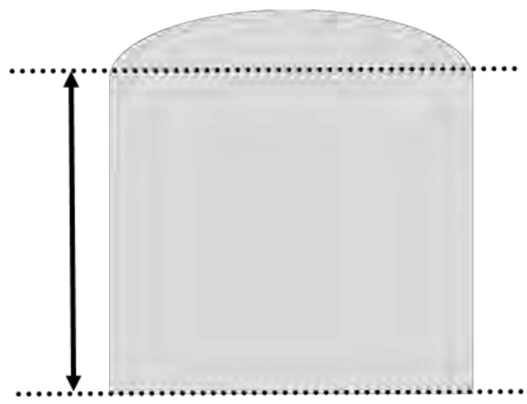


Figure 16: Height of rectangle section of an arch concrete box.

NOTES (NOTES): Anything that is not captured in the other fields.

FLAGGED (FLAGGED): A check box if something is out of the ordinary and must be reevaluated. Please use notes section to describe.

Statement of Work

Support Housatonic Valley Association's project entitled:
"Planning for Climate Resilient and Fish-Friendly Road/Stream Crossings in Connecticut's Northwest Hills"

PI: Emmanouil N. Anagnostou
Department of Civil & Environmental Engineering
School of Engineering
University of Connecticut

1. Introduction

The Housatonic Valley Association (HVA) and its partners will assess road/stream crossings in Northwest CT to identify barriers to fish and wildlife movement and potential flood risks in target watersheds known to support Eastern Brook Trout. In order to ensure integration of stream habitat restoration priorities into local operations, HVA and partners will use the results of their assessments to develop comprehensive road-stream crossing inventory documents- the first of their kind- for seven Northwest Connecticut towns containing significant portions of target watersheds. The Inventory documents will serve as the basis for collaboration with town highway managers and decision makers to prioritize crossings in target watersheds for replacement based on habitat restoration value and flood hazard mitigation potential. Conceptual designs and implementation strategies will be developed using the USFS Stream Simulation Design method for 1-2 top-ranked crossings in each town. Conceptual designs and supporting information will be bundled with the Inventory document and formally adopted by each town as a Road/Stream Crossing Management Plan. The Management Plans will build local capacity to take advantage of opportunities to address stream habitat and flood risk issues at road/stream crossings in the future, particularly in the wake of the next flood, and formally integrate stream habitat restoration priorities into local highway management and flood hazard mitigation.

2. Project Objective and Tasks

The objective of the proposed work is to support HVA providing evaluation of flood risk at road-stream crossings in the project area. Specific project tasks proposed to address the project objectives include:

- Run CREST distributed hydrologic model for Housatonic watershed based on the North America Land Data Assimilation System 35-year atmospheric reanalysis dataset;

- Verify model simulations based on records of historic floods in the project area and through comparisons against independent observations (e.g. satellite data on evapotranspiration; comparison against available streamflow data);
- Determine daily peak flows at approximately 550 crossings in the project area for the 2-, 10-, 25-, 50-, and 100- year recurrence interval flood events;
- Based on data collected by HVA in the field, determine rating curves for selected road-stream crossings;
- Generate risk-of-failure information for each crossing at each assessed recurrence interval;
- Provide documentation of methods suitable for inclusion in road-stream crossing management plan documents, grant reporting, etc.
- Conduct joint presentations of the project/results with HVA staff as appropriate.

3. Project Methodology

Figure 1 shows the computational steps for evaluating the potential of flood overtopping of road-stream crossings for the targeted project sites.

1) Over the study area, the 35-year North America Land Data Assimilation System (NLDAS) and possibly (if time permits) the 50-year Global Land Data Assimilation System (GLDAS) data will be adjusted by the best available observations (i.e. corrected Stage IV radar precipitation product) using the quantile approach.
2) Stage IV and the adjusted NLDAS or GLDAS precipitation and atmospheric time series will be used to force the CREST distributed hydrologic model independently to generate 35 or 50 years of flow simulations, which will facilitate flood frequency analyses that will derive the 2, 5, 10, 25, 50, and 100-year return period flood flows for each road-stream crossing.
3) Input the flow peaks for the various return periods from step 1) to the UCONN-HVA jointly developed culvert evaluation model (described in the subsequent section) and through this process determine the risk-of-failure information for each crossing at each scenario.

4. Project timeline

The proposed project deliverables timeline is as following:

By March 2016	Derive the culvert model and run the CREST based on the reanalysis datasets.
By May 2016	Complete the flood frequency analysis for the selected road-stream crossings.
Beginning May 2016; Complete by July 2016	Report risk-of-failure results for the road-stream crossings based on the culvert model and the 2, 5, 10, 25, 50, and 100-year return period flood flows derived from flood frequency analysis
August 2016	Final project report and proposal for future studies

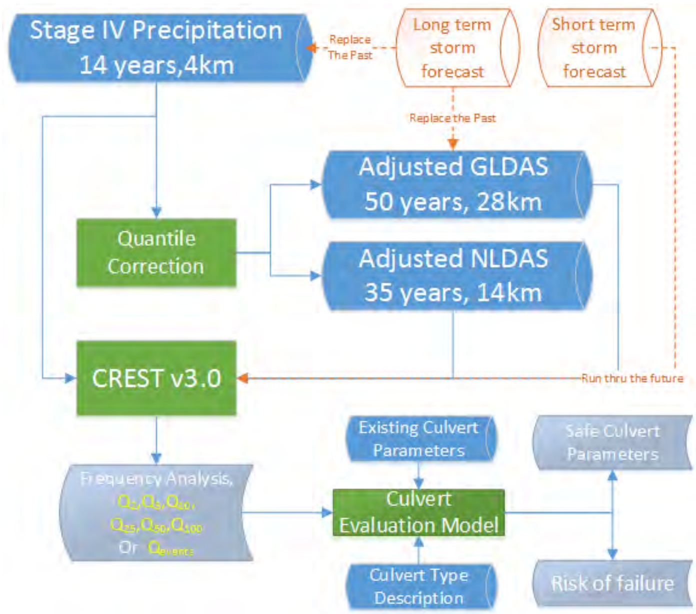
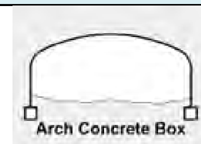
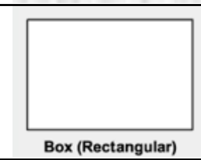
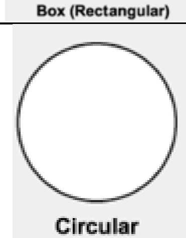
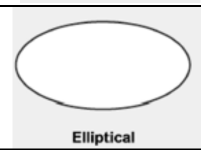


Figure 1 Diagram of the culvert evaluation system

5. Parameter list for the Culvert model

Table 1 Type and Material of culverts

Culvert Property	Symbol	Description
Culvert Shape	Arc	
	box	
	circle	
	ellipse	
Pipe Material	CMP	corrugated metal pipe
	RCP	reinforced concrete pipe
	PVC	polyvinyl chloride pipe
	HDPE	smooth-lined high density poly ethylene pipe
	Corr PE	corrugated high density poly ethylene pipe
Inlet Edge Type	thin	
	square	
	grooved	
	beveled	
Inlet End Type	projecting	out from a slope or wall
	headwall	likely a concrete face, flush with the inlet to the pipe
	mitered	the pipe is cut to comform to the slope
	End section	a piece of pipe attached as an apron
	wingwalls	the angle is

		measured from the parallel with the pipe

The four consideration factors are used to determine the **Gauckler-Manning coefficient *n*.** The computational steps for designing culvert under a certain flow Q requires input of culvert parameters listed in Table 2.

Table 2 parameters of culverts that requires survey

Culvert Property	Symbol	Type	Unit
Culvert Slope	S_0	All	-
Culvert Length	L_c	All	ft
Culvert Inlet Elevation	h_{inlet}	All	ft
Culvert Outlet Elevation	h_{outlet}	All	ft
Roadway Elevation	$H_{roadway}$	All	ft
Number of Barrels	N_b	All	-
The length of arch	L_{arc}	Arc	ft
The length of weir crest	L	All	ft
Culvert Rise	B	All	ft
Culvert Span	D	All	ft
The height of rectangle part for arch concrete box	H_{arc}	Arc	ft
Submerged area	A_w		ft^2
Submerged perimeter	P_w		ft

Table 3 lists the area formulae of cross section for all culvert types.

Table 3. Area equations for all types

arc	$A = \frac{L_{arc}r}{2} - \frac{1}{2}r^2 \sin\left(\frac{180L_{arc}}{\pi r}\right) + D \cdot H_{\mathrm{arc}}$	(1)
	$L_{arch} = n\pi r/180$	(2)
	$\frac{D}{2} = sin(\frac{n}{2}) \cdot r$	(3)
box	$A = BD$	(4)
circular	$A = \pi(D/2)^2$	(5)
elliptical	$A = \pi\frac{BD}{4}$	(6)

Table 4 Manning's "n" values (source: USDOT,1985)

Type of Conduit	Wall & Joint Description	Manning's "n"
Concrete Pipe	Good joints, smooth walls	0.012
	Good joints, rough walls	0.016
	Poor joints, rough walls	0.017
Concrete Box	Good joints, smooth finished walls	0.012
	Poor joints, rough, unfinished walls	0.018
Corrugated Metal Pipes and Boxes Annular Corregations	2-2/3- by ½-inch corrugations	0.024
	6- by 1-inch corrugations	0.025
	5- by 1-inch corrugations	0.026
	3- by 1-inch corrugations	0.028
	6-by 2-inch structural plate	0.035
	9-by 2-1/2 inch structural plate	0.035
Corrugated Metal Pipes, Helical Corrugations, Full Circular Flow	2-2/3-by ½-inch corrugated 24-inch plate width	0.012
Spiral Rib Metal Pipe	3/4 by 3/4 in recesses at 12 inch spacing, good joints	0.013
High Density Polyethylene (HDPE)	Corrugated Smooth Liner	0.015
	Corrugated	0.020
Polyvinyl Chloride (PVC)		0.011

Note: For further information concerning Manning "n" values for selected conduits consult Hydraulic Design of Highway Culverts, Federal Highway Administration, HDS No. 5, page 163

6. Computational steps of culvert hydraulics

1. Establish design data, including the parameters in
Parameter list for the **Culvert model**

Table *1* and Table 2
2. Determine the first trial size of the culvert
3. Assuming INLET CONTROL. Solve for HW using equations (7), (8) and Q_{100} computed by CREST v3.0.

1) unsubmerged weir flow equation

$$Q = C_w L (HW)^{3/2} \tag{7}$$

where C_w is weir coefficient, 3.0.

2) submerged orifice flow equation

$$Q = C_d A \sqrt{2g(HW) - B/2} \tag{8}$$

where C_d is orifice discharge coefficient;0.6.

For inlet control, enter D and Q and fine HW/D for entrance type.

- For drainage facilities with crosssectin area equal to or less than 30 ft^2, HW/D sho uld be equal to or less than 1.5.
- For drainage facilities with cross-sectional area greater than 30 ft^2, HW/D should be equal to or less than 1.2.

If the HW is large enough to be overtopping, increase the trial size and re-compute this step.
4. Assuming OUTLET CONTROL
Before computing HW, there are two conditions to be considered:

1) both inlet and outlet submerged
2) inlet is submerged while outlet is unsubmerged

For case 1)

$$HW + S_0 L = TW + h_e + h_f + h_v \tag{9}$$

The entrance Losses

$$h_e = K_e \frac{v^2}{2g} \tag{10}$$

K_e is the culvert entrance loss coefficient.

Table 5 culvert entrance loss $\boldsymbol{K_e}$

Type of Structure & Design of Entrance	Coefficient K_e
Pipe Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2

Square-edge	0.5
Rounded [radius = 1/12(D)]	0.2
Mitered to conform to fill slope	0.7
End-Section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal[1]	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to fill slope, paved or unpaved slope	0.7
End-Section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of [1/12(D)] or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of [1/12(D)] or beveled top edge	0.2
Wingwalls at 10° or 25° to barrel	
Square-edged at crown	0.5
Side- or slope-tapered inlet	0.2

[1] Although laboratory tests have not been completed on K_e values for High-Density Polyethylene (HDPE) pipes, the K_e values for corrugated metal pipes are recommended for HDPE pipes.
* Note: End Section conforming to fill slope, made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control.

The friction losses

$$h_f = 29\frac{n^2 L}{R^{4/3}}\left(\frac{v^2}{2g}\right) \tag{11}$$

$$v = \frac{1.49}{n} R_h^{2/3} S^{1/2} \tag{12}$$

where R_h is the hydraulic radius defined as

$$R_h = \frac{A_w}{P_w} \tag{13}$$

where A_w and P_w are wetted (submerged) crosssectional area and wetted perimeter respectively. For full culvert, A_w is A computed in Table 2 and P_w is the circumference of the crosssection given by Table 6.

Table 6 equations of P_w for all culvert types

arc	$\left(\frac{180L_{arch} \cdot \pi \cdot D}{\pi r} + 2W + D\right)$	(14)
box	2(B+D)	(15)
circular	πD	(16)
elliptical	$\tau(B + D)/2$	(17)

For case 2), which is rare than case 1)

$$HW = E + H - S_0 \Delta L \tag{18}$$

where

$$H = \left(K_e + 29 \frac{n^2 L}{R^{\frac{4}{3}}} + 1 \right) \frac{v^2}{2g} \tag{19}$$

$$E = B + \frac{Q^2}{2gA^2} \tag{20}$$

and ΔL is the length of full-flowing culvert.

5. Comparing HW from step 3 and 4, the higher HW governs and indicate the flow control existing under the specified conditions for the trail calculation.

If inlet control governs, then the design is complete and no further analysis is required. If outlet control governs and the HW is unacceptable, select a larger trial size and find another HW with the outlet control nomographs. Since the small size of culvert had been selected for allowable HW by the inlet control nomographs, the inlet control for the larger pipe need not be checked.

6.As well, the culvert should be sized to maintain floodfree conditions on classified road ways.

Appendix C

Municipal prioritization workshop proceedings

Planning for Flood Resilient and Fish-Friendly Road-Stream Crossings In the Ten Mile River Watershed

Northeast Prioritization Workshop – May 1, 2020, 1 p.m.

Attendees

- Amanda Cabanillas, Housatonic Valley Association (HVA)
- Mike Jastremski, HVA
- Lindsay Larson, HVA
- Chris Kennan, Town Supervisor, Town of Northeast
- Robert Stevens, Highway Supervisor, Town of Northeast
- Cole Lawrence, Highway Supervisor, Village of Millerton
- George Kaye, Town Board, Town of North East
- Kathy Chow, Climate Smart Communities (CSC)
- Andrew Stayman, CSC
- Jennifer Dawley, CSC

Village of Millerton Priorities

- xy4195340273517144, Survey ID 70406
  - Cole Lawrence has observed increased frequency of flooding, about six times per summer. NAACC barrier evaluation = moderate barrier to aquatic organism passage
- xy4194997673508970, Survey ID 71296
  - The stream takes a 90 degree turn to enter the structure; no water over the road in the past 3 years (since Cole has been around), but the situation seems to be getting worse [with the water hitting the structure as it turns]; Cole Lawrence said he hasn't had to go in and clear out debris

- xy4195511973514594, Survey ID 70416
  - Cole Lawrence densely vegetated and possibly slowing flows on the upstream end, but did not indicate that there are any issues with the actual structure
- General note about the Village: there is a lot of sedimentation and build-up of road sand, it is an issue throughout the whole village

Town of Northeast Priorities

- xy4189638073550359, Survey ID 69103, Perrys Corners Road
  - The last section toward the outlet is pulling apart and causing the road to cave in; they have never seen it flood the road; note that this structure is a conservation priority (significant barrier)

- xy4189754173547786, Survey ID 69105, Perrys Corners Road
  - The only issue is when the inlet gets blocked with the debris, then the water has gone over the road ~once every 5 years
  - Would make sense to do this structure when they do the one above, ideally within the next 5 years
  - These first two could be winners in terms of town priority/condition priority/conservation value priority
- xy4190063373576388, Survey ID 70793
  - Headwall is failing; they don't have issues with flooding or debris
  - This one is also a conservation priority (significant barrier)
- xy4196367273519163, Survey ID 70907
  - Concrete is failing; they don't have issues with flooding or debris
- xy4197602673525807, Survey ID 70916
  - Poor condition, nothing left for the guiderail to attach to
- xy4190072073616305, Survey ID 69554
  - There have been on-going discussions of closing the road, it is currently a town road, but there are landowners who are avid fishermen and they want to replace/remove the culvert
  - Probably not worth focusing on this one because of those on-going conversations
- **Figure out way to assess the area where the stream goes under the HVRT, alongside Mill Road, adjacent to crossing xy4191837473518146, Survey ID 73701
  - Town would like to address this situation somewhere, but would be a significant engineering challenge
  - May be helpful to schedule a site visit

Other Notes

- County is replacing xy4191538073551387, Survey ID 69304
  - This does not appear to be a conservation or flooding priority

Appendix D

Rubric for Culvert Prioritization Ranking

Aquatic Passage and Habitat Quality Prioritization Ranking Rubric (developed by Trout Unlimited and adapted by HVA)

Priority Metric		Dataset	Methodology	Ranking
Habitat Connectivity Ranking (5 pts)	**Barrier Significance class**	NAACC dataset	The barrier significance classes used are Severe, Significant, Moderate, Minor, and Insignificant. The barrier severity scores for field-surveyed road-stream crossings are calculated in the NAACC database using the scoring algorithm described in the NAACC Numeric Scoring System.	Barrier Severity Ranking (Severe barrier = 5, Significant barrier = 3, Otherwise = 0)
Condition and Flood Risk Ranking (10 pts)	**Hydraulic Capacity**	University of Connecticut modeling results from NAACC survey data	University of Connecticut modeling results from NAACC survey data	Capacity Ranking (≤ 2 yr=5, ≤ 10 yr=4,≤ 25 yr=3, ≤ 50 yr =2, ≤ 100 yr =0)
	Geomorphic Compatibility	NAACC dataset	Suvey data results in either flow aligned or flow skewed	Alignnment Ranking (Flow Aligned = 0, Skewed = 1)
	Crossing Condition	NAACC dataset		Crossing Condition Ranking (Poor = 4, Fair = 2, Okay and Excellent = 0)
Habitat Quality Ranking (4 pts)	**Critical Linkages (when available)**	The University of Massachusetts and The Nature Conservancy worked with state agencies to complete a comprehensive analysis of connections that must be protected and restored to support wildlife and biodiversity resources. The Critical Linkages project uses spatially explicit tools to understand the impact of mitigating road stream crossing barriers across a regional landscape. It is a"coarse-filter" approach in our assessment of connectivity; one that does not involve any particular focal species but instead holistically considers ecological systems.	This value represents the importance of this crossing to the overall connectivity of the landscape for aquatic organisms. It is derived from the potential improvement in aquatic connectedness if this crossing were removed or upgraded, weighted by the index of ecological integrity. A greater value indicates a greater improvement to overall connectivity if the structure were replaced or upgraded.	Linkage Ranking: High (CL effect (ln) ≥ 7.5) = 2, Average (CL effect (ln) between 5 and 7.5) = 1, Low (CL effect (ln) < 5)=0)
Town Ranking (5 pts)	**Town Priority**	Input from Town	Priority crossings were specificed by town officials and employees during a Town Workshop	Town Priority (Ranked by town= 5, not ranked by town= 0)

Appendix E

Vulnerable Population Assessments

Notes on Vulnerable Populations
June 4, 2021

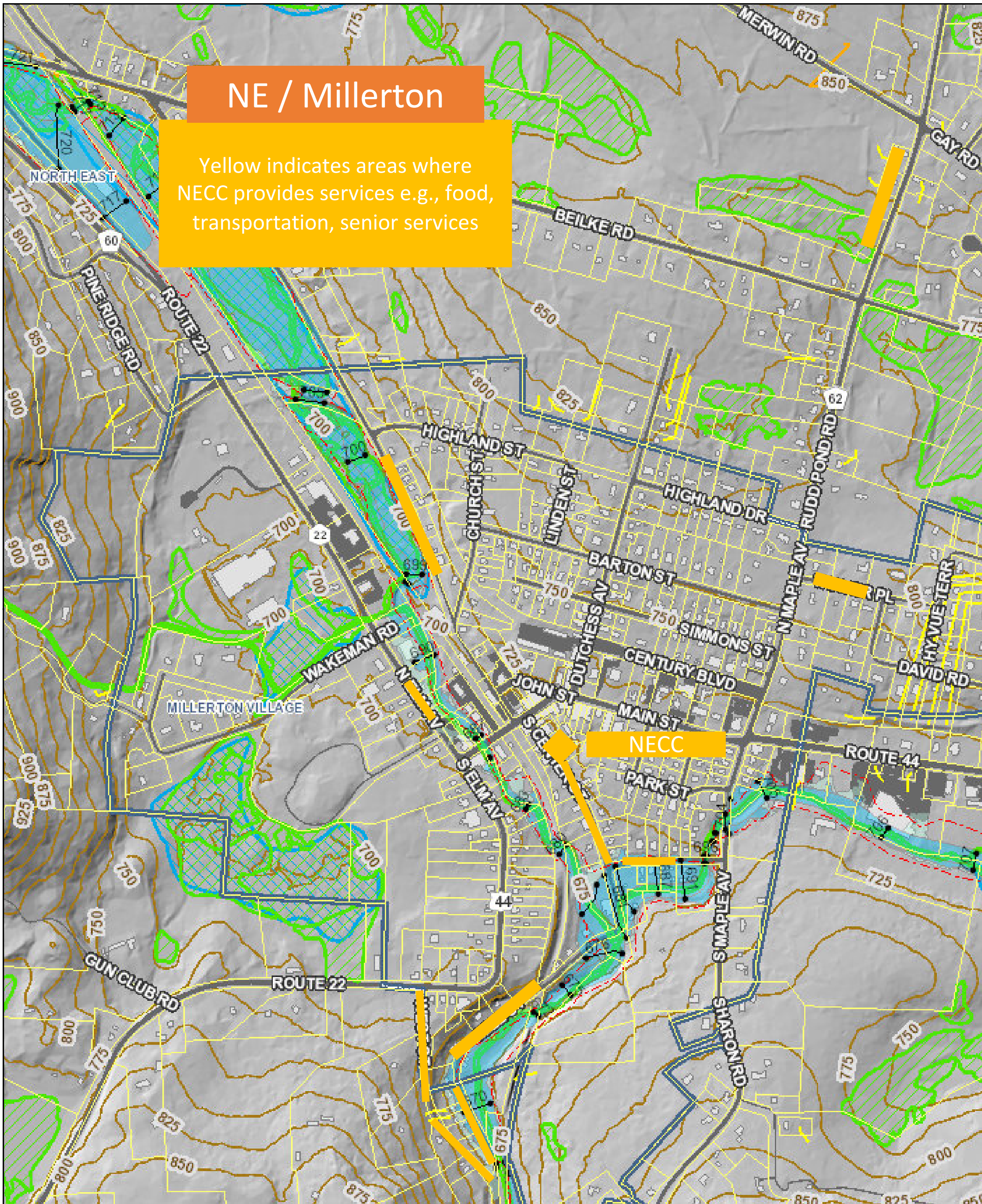
Christine Sergent, ED North East Community Center
christine@neccmillerton.org

Josh Schultz, Millerton Trustee, Emergency Services, Highway Department
joshl.schultz@gmail.com

Chris Kennan, Supervisor, North East
supervisor@townofnortheastny.gov

Kathy Chow, CSC Coordinator
katchow@mac.com

The North East Community Center provides food, transportation, emergency assistance. The locations of their clients are the best indication of where the most vulnerable residents live. In both the town and village, the corridor along the Webatuck Creek is home to the largest numbers of NECC's clients – AND areas at risk of flooding
The NECC building is located on South Center Street, in a 100 year flood plain. Flooding there would impact their ability to serve their clients.



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New York

Parcel Lines

Dutchess County, NY

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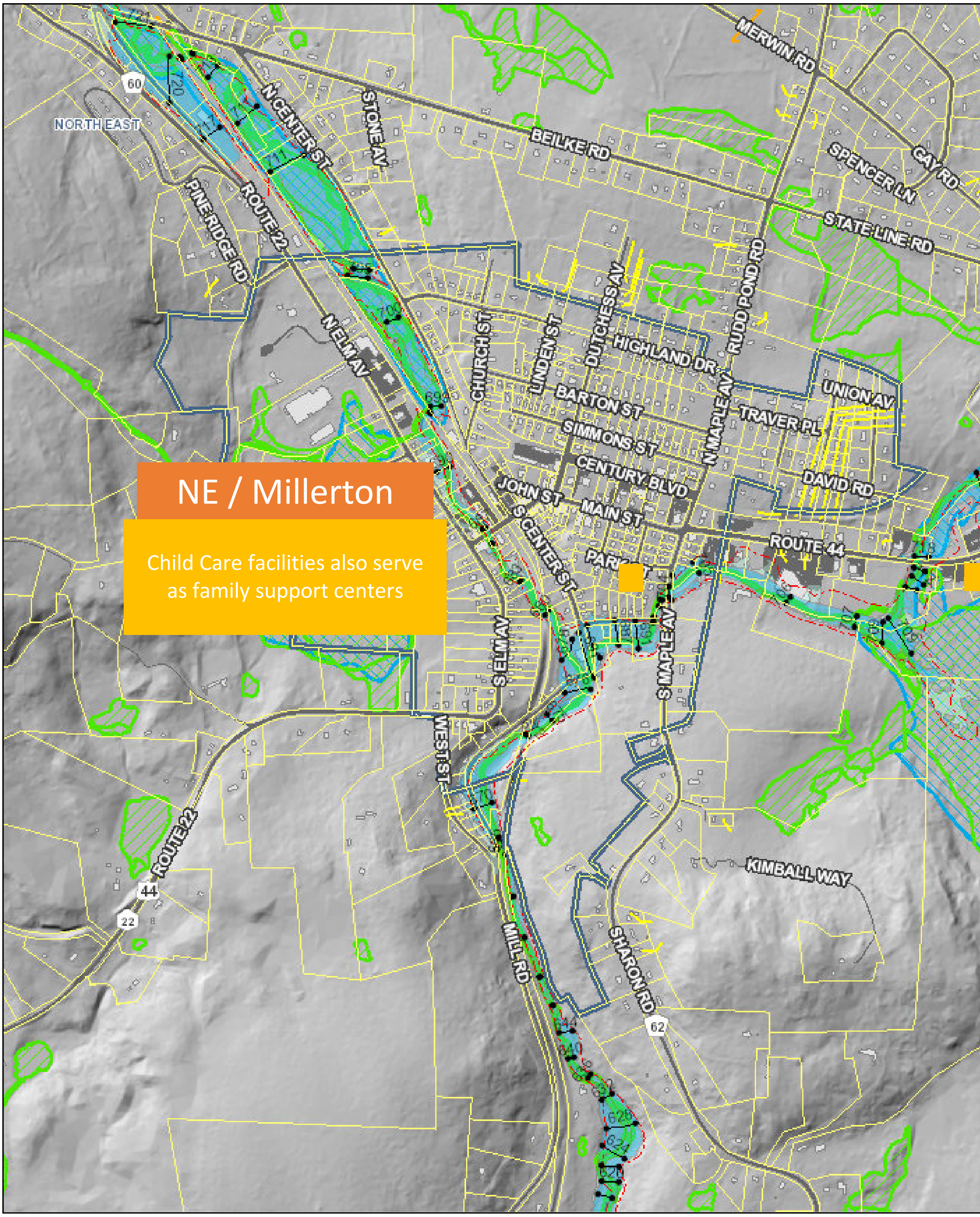

NE / Millerton

Child Care facilities also serve as family support centers

Dutchess County New York

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Dutchess County, NY

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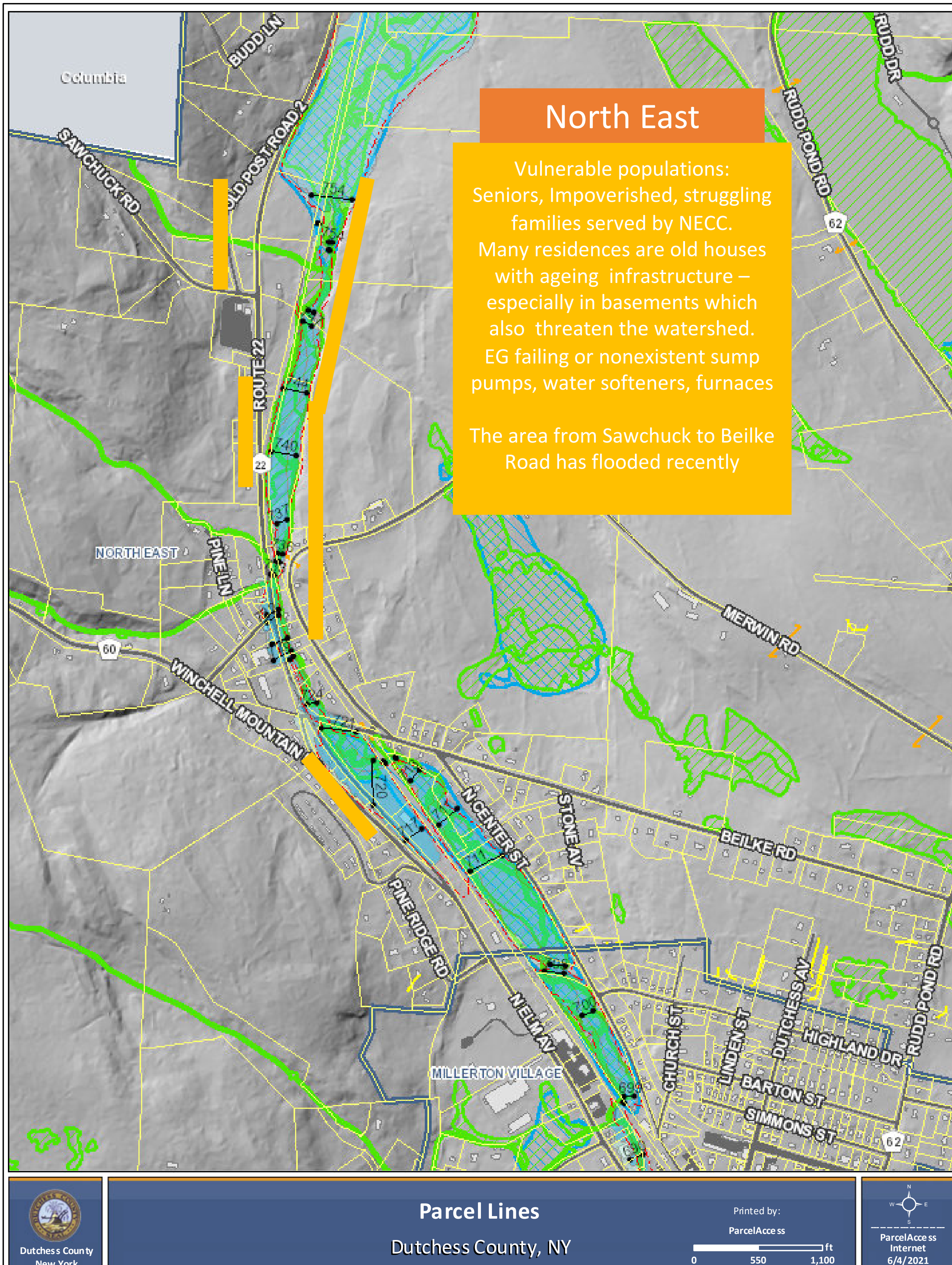
North East
Vulnerable populations:
Seniors, Impoverished, struggling families served by NECC.
Many residences are old houses with ageing infrastructure – especially in basements which also threaten the watershed.
EG failing or nonexistent sump pumps, water softeners, furnaces
The area from Sawchuck to Beilke Road has flooded recently
Columbia
BUDD LN
SAWCHUCK RD
OLD POST ROAD 2
ROUTE 22
22
NORTH EAST
PINE LN
60
WINCHELL MOUNTAIN
RUDD DR
RUDD POND RD
62
MERWIN RD
N CENTER ST
STONE AV
BEILKE RD
PINE RIDGE RD
N ELM AV
MILLERTON VILLAGE
CHURCH ST
LINDEN ST
DUTCHESS AV
HIGHLAND DR
BARTON ST
SIMMONS ST
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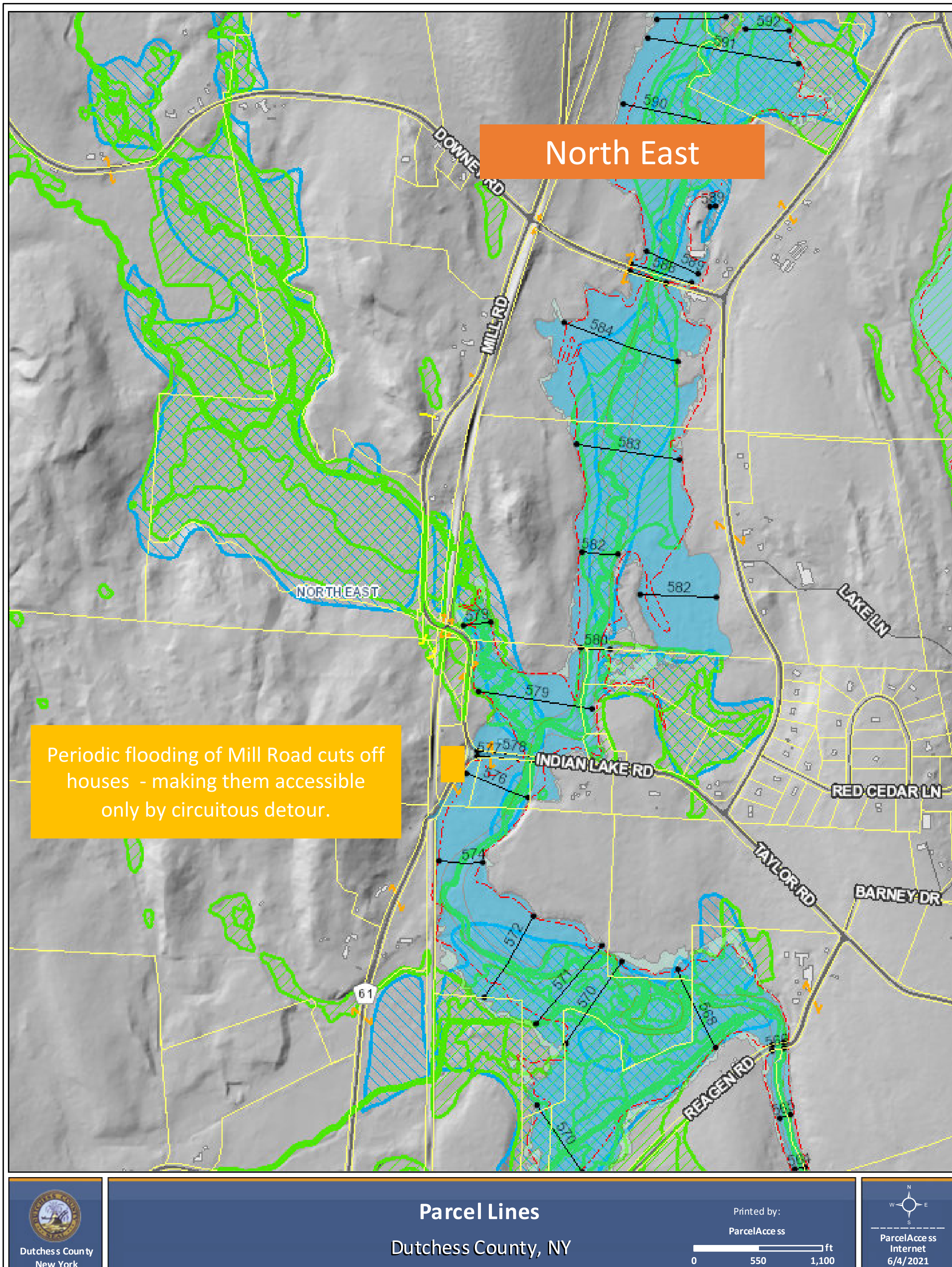
North East
Periodic flooding of Mill Road cuts off houses - making them accessible only by circuitous detour.
DOWNEY RD
MILL RD
NORTH EAST
INDIAN LAKE RD
LAKE LN
RED CEDAR LN
TAYLOR RD
BARNEY DR
REAGEN RD
61
592
591
590
584
583
582
580
579
578
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Dutchess County
New York
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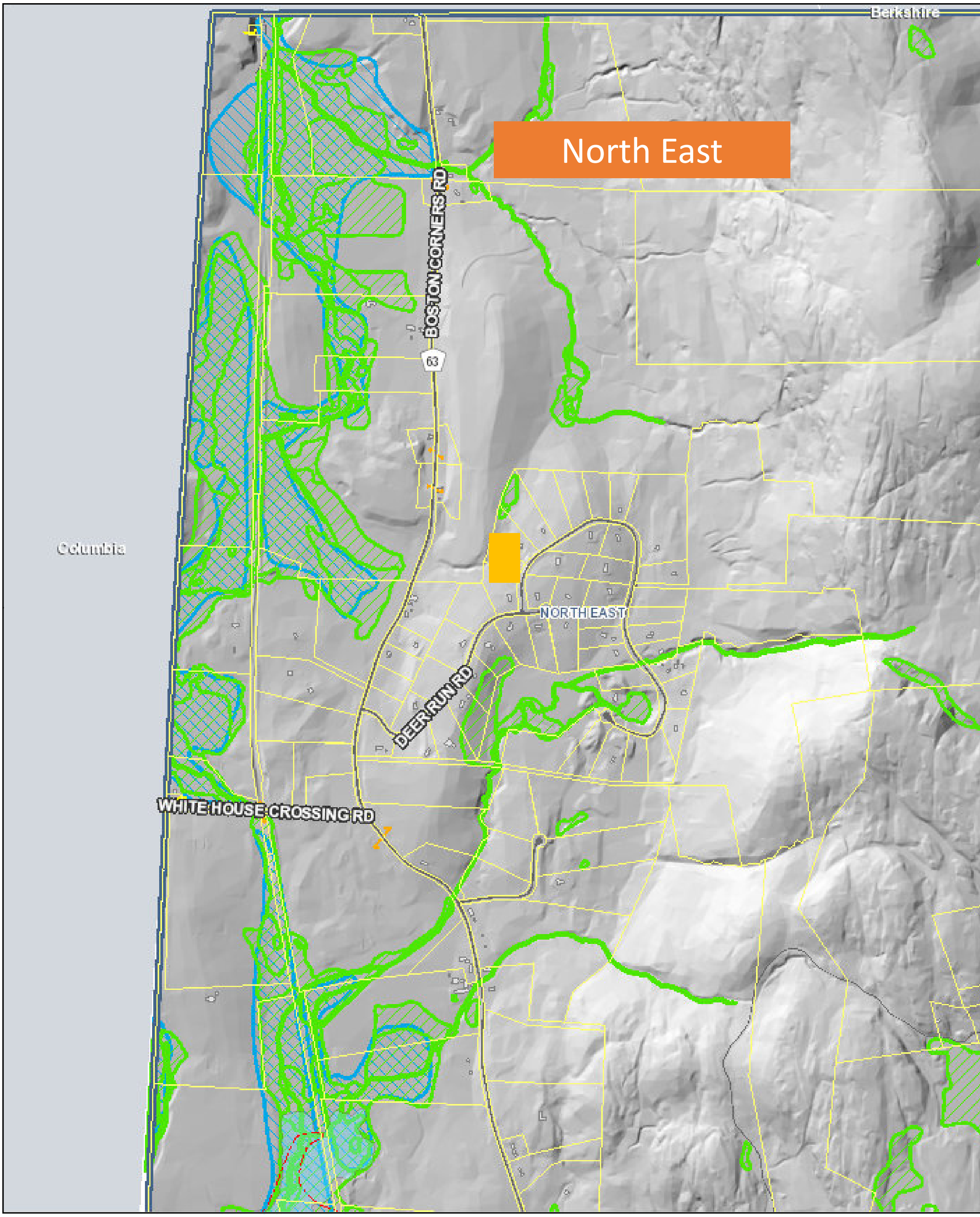

Dutchess County
New York

Parcel Lines

Dutchess County, NY

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Appendix F

Ten Mile River Watershed Management Plan's Road-Stream Crossing Projects for the Village of Millerton & Town of North East

Collaborative watershed-scale planning is a widely accepted and proven method for addressing issues like pollution, flooding and biodiversity conservation that transcend municipal boundaries and organizational missions. Watershed planning builds partnerships and frameworks for collaboration, gathers and interprets existing research and planning, identifies information gaps that must be filled to make management decisions and collects that information, brings diverse stakeholders together to articulate goals for watershed management, and identifies the actions that partners need to take to achieve those shared goals.

In 2014, an active and engaged group of watershed municipalities, federal, state and regional agencies and conservation non-profits came together to form the Ten Mile River Collaborative (TMRC). This group has met regularly since then to discuss watershed management issues and look for opportunities to work together to achieve shared management goals. Municipal members of the TMRC formally resolved to support collaborative management of the Ten Mile River, including the development of a Watershed Management Plan. The TMRC is the driving force behind this Watershed Plan. TMRC members have collectively committed thousands of hours to assessing the state of the Ten Mile River watershed, articulating a shared vision for its future, and identifying the steps we need to take to get there. The TMRC identified the following five key Focus Areas for management of the Ten Mile River watershed that form the framework of the Watershed Plan:

- Water Quality
- Recreation Enhancement and Promotion
- Climate Change Resilience and Stream Corridor Management
- Natural Heritage
- Agriculture and Producer Support

Once the TMRC reached consensus on the Vision and Goals, the next step in the Watershed Planning process was to identify specific Actions that must be taken to achieve a healthy, resilient Ten Mile River watershed. Actions were generally organized as non-construction programs (Actions like water quality monitoring and educating youth about the Ten Mile River) and construction projects (Actions like planting trees along a stream or capturing polluted runoff from a parking lot to filter out pollution). The TMRC identified over 30 Actions across the five focus areas, aimed at everything from involving local youth in Plan implementation, to enhancing river access for paddlers and anglers, to encouraging streamside homeowners to use sustainable lawn management practices. The TMRC then worked collaboratively to prioritize Actions for implementation based on pollution reduction potential, existing and potential partnerships to support implementation, cost-effectiveness/feasibility and potential to address multiple Goals across the five Watershed Plan Focus Areas.

The following two pages were featured in the TMRC's *Project and Program Packet* that was used in the Action prioritization process. They contain brief write-ups of road-stream crossing projects that were identified in the Village of Millerton through the data collection and prioritization that went into the completion of this Road-Stream Crossing Management Plan. More in-depth descriptions of these Actions can now be found in the Implementation Strategy chapter of the *Ten Mile River Watershed Management Plan*.

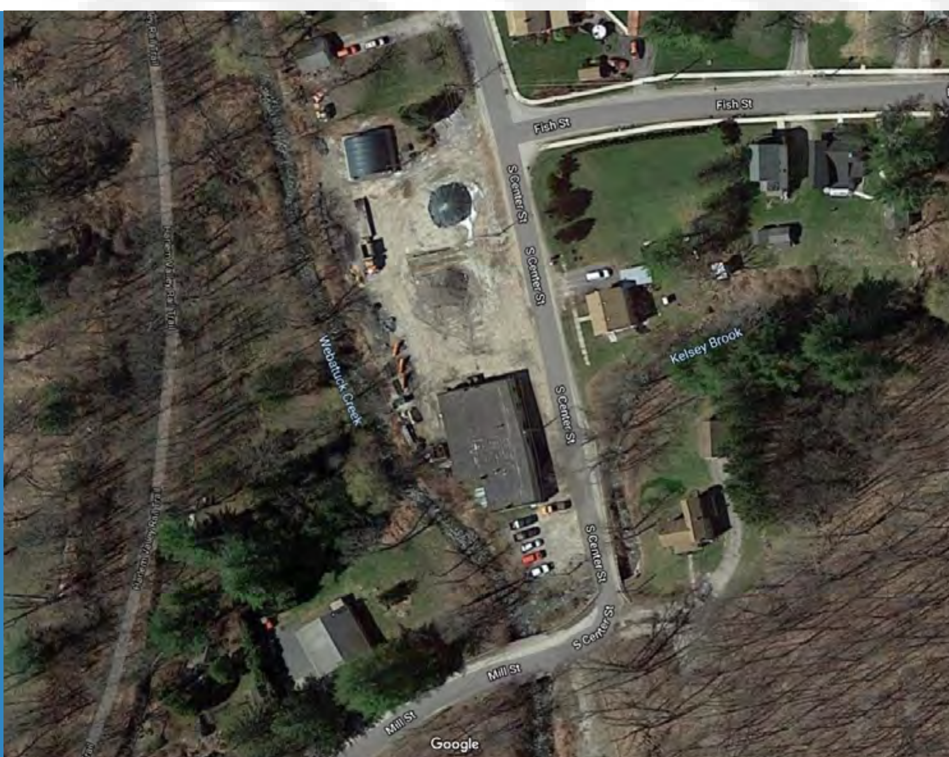
NORTH EAST HIGHWAY GARAGE & SOUTH CENTER RD BRIDGE

Relevant Watershed Plan Focus Areas: Water Quality, Climate/Flood Damage Prevention, Recreation Enhancement, Natural Heritage

Site Description: The Town of North East has worked to remove salt and sand storage to a new location and out of the Webatuck Creek floodplain. The site presents a unique opportunity for recreation enhancement in proximity to the Harlem Valley Rail Trail.
Just downstream of the garage, the Webatuck Creek meets Kelsey Brook. The two road-stream crossing structures at this confluence regularly becomes blocked with debris and is a "backwatering hotspot".

Goals:

- Assist Town of North East Highway Department in removing the existing garage and sediment piles from the floodplain. Secure funding for new garage.
- Prepare the site for transition to recreational open space.
- Floodplain to stream channel reconnection.
- Design geomorphically compatible structure for the confluence of Webatuck Creek and Kelsey Brook. Replace existing structures.



ABOVE (TOP TO BOTTOM)

- Existing salt shed and gravel piles adjacent to stream channel.
- Structures and sediment piles in the Webatuck Creek floodplain.
- Gravel piles within floodplain.

LEFT

- Aerial view including Webatuck Creek/Kelsey Brook confluence.

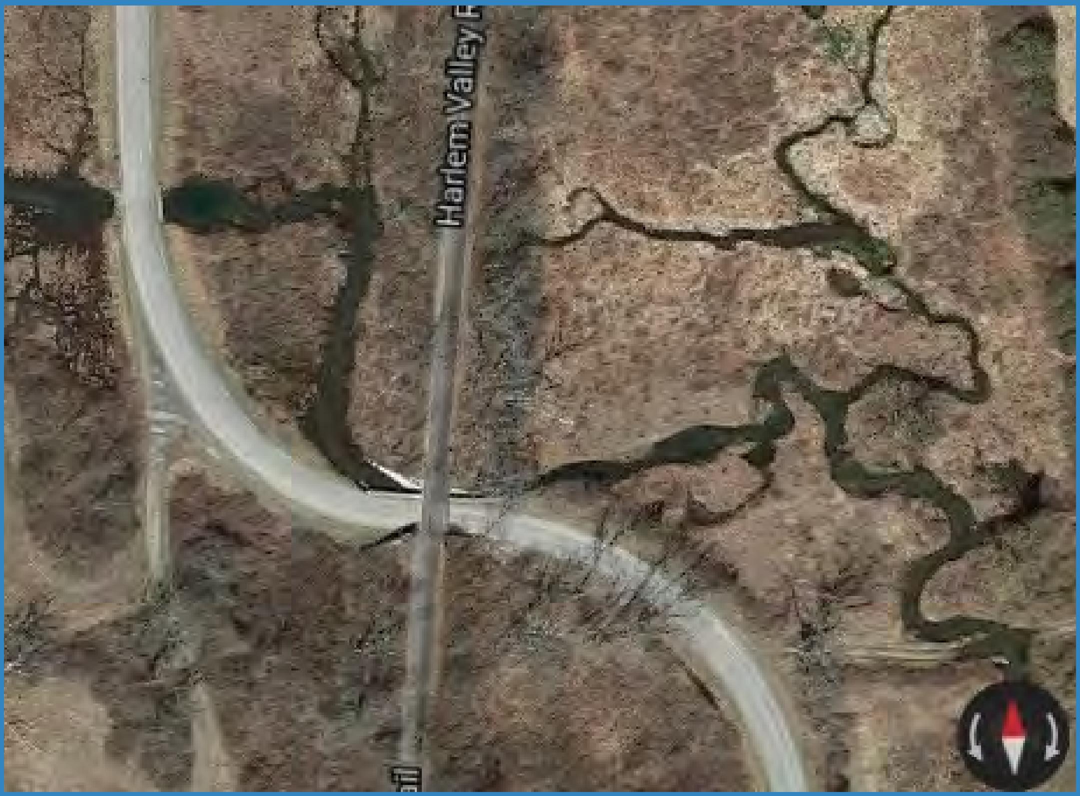
MILL RD. CHANNEL CORRECTION & ROAD STABILIZATION

Relevant Watershed Plan Focus Areas: Climate/Flood Damage Prevention, Water Quality, Natural Heritage

Site Description: A tributary to Webatuck Creek flows through a wetland complex and under Mill Rd. before pinching up between the road and Harlem Valley Rail Trail (HVRT) bridge abutment (HVRT bridge does not otherwise interact with stream channel). There is significant scour along the road embankment and the concrete blocks that are leaning over the channel could fail in the future. There is some scour along the base of the HVRT bridge abutment. The site is reported to flood during large precipitation events - shutting down road and leaving at least one landowner stranded.

Goals:

- Engineer a solution that would allow the water to pass under the road.
- Maintain channel connectivity and integrity of the wetland area.



ABOVE (TOP TO BOTTOM)

- HVRT bridge over Mill Rd.
- Concrete blocks leaning into channel.

LEFT

- Aerial view of project site.

Appendix G

UConn Methodology Statement

Housatonic Valley Association

150 Kent Road
PO Box 28
Cornwall Bridge, CT 06754
T: (860) 672-6678

Merwin House
14 Main Street
PO Box 496
Stockbridge, MA 01262
T: (413) 298-7024

37 Furnace Bank Road
PO Box 315
Wassaic, NY 12592
T: (845) 442-1039

HVA
hvatoday.org

Statement on UConn Hydraulic Capacity Modeling

The following statement has been prepared to describe the methodology used by the University of Connecticut's (UConn) Department of Civil and Environmental Engineering in modeling the hydraulic capacity of road-stream crossing structures in the Town of North East.

In 2019, the Housatonic Valley Association (HVA) was contracted by the Town of North East to assess each of the Town's 138 road-stream crossings. In addition to documenting impacts on habitat connectivity, a major goal of the project was – and continues to be – to reduce flood risk and mitigate flood-related hazards in the changing climate. To that end, and through collaboration with the UConn Department of Civil and Environmental Engineering, data collected were used to determine the hydraulic capacity and estimate the risk of failure of all closed-bottom structures.

UConn measures the risk of road-stream crossing failure (water reaching the road elevation) at multiple flood frequencies (2-, 10-, 25-, 50-, 100-, 200-year recurrence intervals) which is defined as the exceeding probability of the flow peak. The hydrological simulations employ the Coupled Routing and Excess Storage Soil Vegetation Atmosphere Snow (CREST-SVAS) model which uses more than 40 years of meteorological forcing data at 1/8 degree and hourly time steps (fine spatiotemporal resolution).

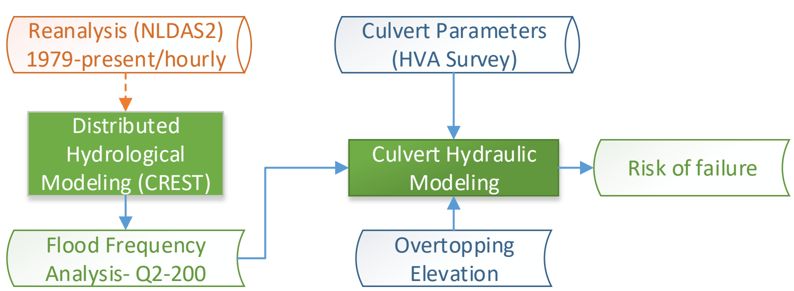


Figure 1. The CREST-SVAS workflow.

The CREST_SVAS model includes basin characteristics, precipitation, solar radiation, long wave radiation, humidity, pressure, air temperature, and wind speed in a suite of calculations to solve for the water and thermal balances at every time step. A long-term CREST simulation (1979-present) run at hourly time steps is used to determine flood frequency estimations, which are then adjusted using a Quantile-Quantile method. UConn then uses a hydraulic model to compute the water stage of a structure at the estimated peak flows.

Currently, peak flows for each of the modeled recurrence intervals are derived from hydrological simulations in the present climate; however, this robust modeling provides an invaluable analysis for use in the Town's assessment of vulnerabilities associated with the failure of these structures. Additionally, HVA's prioritization of structures with the greatest flood risk has been validated through communications with community members, on-the-ground emergency services personnel and municipal officials. In the future (and with access to funding), data collected through this project can be used for hydrological simulation in future climate scenarios.