Town of Hillsdale Road Stream Crossing Management Plan

Project Partners:

Town of Hillsdale

Trout Unlimited

New England Interstate Water Pollution Control Commission

NYS Hudson River Estuary Program

NYS DEC Region 4 Fisheries Department

Cornell Cooperative Extension of Columbia and Greene County

NYS Water Resources Institute at Cornell University

Housatonic Valley Association

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Glossary of Terms

Aquatic organism – An aquatic organism living in water for at least a portion of their life.

Bankfull– Bankfull is an established height at a given location along a river or stream, above which a rise in water surface will cause the river or stream to overflow the lowest natural stream bank somewhere in the corresponding reach.

Bankfull discharge – Bankfull discharge is the dominant channel forming flow with a recurrence interval seldom outside the 1 to 2-year range.

Bankfull width- The wetted width of the stream occurring at Bankfull.

Clear Span-The maximum inside width of a non-circular pipe or bridge. Cover height - The amount of fill material above a road stream crossing structure.

Design Load- The sum of all vertical forces (i.e. soil weight, passing vehicles, etc.) applied to a buried culverts or bridge.

Flood resiliency – Flood resiliency is the ability for the Town to withstand and recover from flood crisis.

Freeboard - The distance between normal water level and the bottom of the road stream crossing structure.

Geomorphic –Response of river and stream channels to various types of natural and human-caused disturbances including floods.

Head cut - A head cut in stream geomorphology, is an area of instream instability and erosional feature of streams with an abrupt vertical drop that can be perpetuated through the river system until equilibrium of channel dimensions and slope is attained.

Hydraulic capacity - The amount of water that can pass through a structure or watercourse.

Intermittent stream – An intermittent stream is a stream which normally ceases to flow for weeks or months each year.

Perennial stream – A perennial stream is a stream or river (channel) that has continuous flow in parts of its stream bed all year-round during years of normal rainfall.

Recurrence Interval - Statistical techniques, through a process called frequency analysis, are used to estimate the probability of the occurrence of a given precipitation event. The recurrence interval is based on the probability that the given event will be equaled to or exceeded in any given year. Ten or more years of data are required to perform a frequency analysis for the determination of recurrence intervals. Of course, the more years of historical data the better—a hydrologist will have more confidence on an analysis of a river with 30 years of record than one based on 10 years of record.[1]

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[1] https://water.usgs.gov/edu/100yearflood.html

Recurrence Intervals and Probabilities of Occurrences

Recurrence interval, in years	Probability of occurrence in any given year	Percent chance of occurrence in any given year
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

Regional regression – Regional regression equations are based on statistical relations between (1) streamflow statistics of interest computed from applicable records of the stations and (2) basin and climatic characteristics, for which data are typically readily available.

Road Stream Crossing – Road stream crossings are location where a road, paved or unpaved, crosses over a body of water within the physical extents of all supporting infrastructure (i.e. the proposed crossing infrastructure, wingwalls, etc.)

StreamStats - StreamStats is a USGS Web application that queries an assortment of Geographic Information Systems (GIS) analytical tools to calculate peak discharges for certain recurrence intervals. The calculations were established from publicly available US Geological Service research (USGS SIR 2006-5112 “Magnitude and Frequency of Floods in New York”) which established a relationship between watershed characteristics and peak discharges. StreamStats also is a USGS web application hat calculates bankfull dimensions from publicly available US Geological Service research (USGS SIR 2009-5144 “Bankfull Discharge and Channel Characteristics of Streams in New York State”) which established a relationship between watershed characteristics and bankfull dimensions.

Stormwater - Stormwater is water that originates during precipitation events and snow/ice melt that either soak into the soil (infiltrate), evaporates, or runs off and ends up in nearby streams, rivers, or other water bodies.

Wetland - A wetland is a distinct ecosystem that is inundated by water, either permanently or seasonally, where oxygen-free processes prevail.

1.0 Project Overview

Eastern brook trout is New York's state fish and a native species of the Eastern U.S. Brook trout need access to cold, clean water to survive (Photo TU).

The Town of Hillsdale Road Stream Crossing Management Plan is designed to improve community and ecosystem resiliency by identifying high priority road stream crossing replacement projects that reconnect high quality aquatic habitat and improve community flood resiliency and road infrastructure condition within the Town of Hillsdale. The scope of the Project included:

- i) an inventory of all state, county, town and private road stream crossing,
- ii) hydraulic modeling,
- iii) evaluation of aquatic organism passage,
- iv) prioritization of results using multiple objectives, and
- v) the development of conceptual and shovel ready designs and cost estimates for highest priority projects.

Inadequately sized or incorrectly installed culverts can be a seasonal or year-round barrier to aquatic species, fragmenting habitat and disconnecting the natural flow of organisms, material, nutrients and energy along river systems. This loss of stream connectivity is a critical threat to valuable and already vulnerable species such as the native Eastern brook trout (*Salvelinus fontinalis*), the American eel (*Anguilla rostrata*) and river herring (*Alosa spp*). The Hillsdale Road Stream Crossing Project has identified opportunities to reduce habitat fragmentation by prioritizing replacement barrier removal projects that provide the greatest improvement for these vulnerable species as well as other aquatic organisms.

In addition to habitat fragmentation caused by inappropriately sized culverts, flood risks and infrastructure damage are also a concern. Damage caused by flooding can be reduced if local decision-makers are aware of current infrastructure conditions to proactively plan and implement restoration strategies at high priority locations. The Hillsdale Road Stream Crossing Project has identified at-risk infrastructure, so the Town can prioritize their upgrades with hydraulically appropriate and geomorphologically ally compatible designs.

2.0 Project Steps

Step 1: Road Stream Crossing Inventory

At the request of the Town, a North Atlantic Aquatic Continuity Collaborative (NAACC) survey was completed by NYS Department of Environmental Conservation (NYS DEC) in the summers of 2016, 2017and 2018 and private crossings were surveyed by Housatonic Valley Association in 2018.

The NAACC is a participatory network of practitioners united in their efforts to enhance aquatic connectivity. The collaborative efforts of NAACC have so far:

1. developed unified protocols for road-stream crossing assessments that can help identify bridges and culverts that are problematic from an aquatic connectivity perspective,

2. launched an online assessment training program,
3. created an online database that serves as a common repository for crossing assessment data,
4. developed a tool to identify high priority watersheds and crossings for assessment, and
5. are supporting efforts to conduct assessments throughout the region.

The survey includes a variety of measurements that include structure type and condition, flow condition in and out of the structure, structure alignment and many other measurements that will provide the needed data to generate an aquatic passage score for each surveyed crossing. The standardized protocol can be found on the NAACC website.[2]

In the Town of Hillsdale 143 road stream crossings were surveyed. Of those crossings surveyed 96 were located on town roads. Only Town crossings were included in the prioritization process; however, county, state and private crossings were surveyed, and the data are publicly available.

The data from the survey can be accessed by the public through the NAACC online database.[3] In addition, a project specific map with survey, modeling and prioritization data can be accessed by the Town and the community.

Step 2: Aquatic Organism Passage Modeling

The survey data was entered in to the Aquatic Organism Passage (AOP) model developed by University of Massachusetts at Amherst and other NAACC partners. The model is not species specific but instead uses criteria on a variety of different life forms and life histories to assess the passage potential of each structure. The results from the model classify each structure based on "No AOP", "Reduced AOP" and "Full AOP". No AOP means that most species will not be able to pass through the structure. Reduced AOP means that some species may be able to pass under certain flows, but others may or may not be able to pass through the structure. Full AOP means that all species can pass through the structure. Within the No AOP and Reduced AOP category, a severity of the barrier is determined and classified as, "Severe", "Significant", "Moderate", "Insignificant" and "Minor". The results of the AOP modeling for the Town of Hillsdale are summarized below in Table 1 and highlighted in Appendix A: Map 1.

Table 1: Town of Hillsdale Aquatic Organism Passage Survey Results

AOP Severity Evaluation	Percent of Total Crossings Surveyed
Severe	19%
Significant	6%
Moderate	9%
Insignificant	35%
Minor	20%
No Barrier	7%

*Remaining 3% are missing data or inaccessible.

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[2] https://www.streamcontinuity.org/pdf_files/NAACC_Instructions%20for%20Field%20Data%20Form%205-22-16.pdf

[3] https://www.streamcontinuity.org/cdb2/naacc_search_crossing.cfm

Step 3: Hydraulic Capacity Modeling

The survey data is also used to determine the resiliency and flow capacity of each crossing structure. Cornell University Water Resource Institute, in partnership with the Northeast Regional Climate Center and Hudson River Estuary Program, developed the Cornell Resiliency Model to identify undersized culverts vulnerable to flooding under current and future climate conditions. [3] Using a combination of culvert inventory field data and peak discharge predictions for current and future climate scenarios, the model determines culvert flow capacity and highlights the flow event at which the structure will fail. A diagram of the model can be found in Appendix A: Figure 1.

This model consists of four main components: 1. watershed delineation, 2. peak discharge calculation, 3. capacity calculation, and 4. return period assignment. The watershed component of the model is conducted using ArcGIS, while the peak discharge calculation, capacity calculation and return period assignment are executed using Python scripts.

A detailed description of the steps in the Cornell Resiliency model are as follows:

1. The watershed delineation component of the model is conducted on ArcGIS using custom tools created by Rebecca Marjerison for her PhD dissertation. The tools first delineate the watershed of each culvert. Next, all culvert watersheds being evaluated are aggregated into a single shapefile. Finally, the area, weighted Curve Number (CN) and Time of Concentration (Tc) are computed for each watershed.

2. The second component of the model is the peak discharge calculation. The watershed data compiled in the initial phase of the model is used as the input for this component. The procedure set in the USDA Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) graphical method is used to determine peak discharge for various return period storms for each delineated watershed.

3. The third component of the model is the calculation of culvert capacity. Using field data, the capacity of each culvert is modeled using the inlet control equation set forth by the Federal Highway Administration Hydraulic Design Series 5. In this model, the headwater ponding height was assumed to be the height of the road surface above the culvert invert.

4. In the final component of the model, the assigned capacity of each culvert is compared against the peak discharges calculated for the culvert in order to determine the maximum return period storm that the culvert can safely pass.[4]

The model looks at flow conditions for the 2, 5, 10, 25, 50 and 100-year storm events. A detailed projection of future climate conditions for Columbia County can be found at the NYS DEC website. [5] Hydraulic capacity data from the Resiliency Model was generated for the Town of Hillsdale road stream crossings. The results are summarized below in Table 2 and highlighted in Appendix A: Map 2.

The results show that of those road stream crossings modeled 100% will be a flood issue under both extreme flows for current and future climatic conditions and 92% of the structures are anticipated to fail with the increase in the smaller flood return intervals such as the 2, 5, and 10-year flow event.

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[4] https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/CornellCulvertsModelInstructions_RevisedAug2018.pdf

[5] http://www.dec.ny.gov/docs/remediation_hudson_pdf/cphv.pdf

Table 2: Town of Hillsdale Hydraulic Capacity Results[6]

Flow Event	% of Structures that fail this event under current climatic conditions	% of Structures that fail this event under future climatic conditions
< = 2-year flow	92%	92%
< = 5-year flow	100%	100%
< = 10-year flow	100%	100%
< = 25-year flow	100%	100%
< = 50-year flow	100%	100%
< = 100-year flow	100%	100%

Step 4: Prioritization Process

Following the review of survey and model results, the data was separated into ownership to complete the prioritization process. Only the Town-owned or -maintained structures were included in the prioritization process. The prioritization process was a collaboration between the TU team and the Town. Prioritization metrics considered both infrastructure and ecosystem vulnerability. Infrastructure vulnerability metrics include hydraulic capacity, geomorphic compatibility, crossing condition, age of structure, maintenance issues and other concerns identified by the Town highway supervisor. Ecosystem vulnerability metrics considered stream type, aquatic passage ranking and severity, location of structure in the watershed to include the number of stream miles upstream and the number of barriers identified downstream. Additional metrics included presence of aquatic species of concern (e.g., threatened, endangered, or of conservation concern), stream classification and species composition upstream and downstream of the structure. A summary of the prioritization metrics and the data sources used in the analysis can be found in Appendix A: Table 1.

Each crossing was ranked according to the prioritization metrics. The goal of the ranking efforts was to identify three priority replacement structures that could then undergo further study and design development. It was determined that the top priority projects would focus on those structures that were located on perennial streams, [7] that represent severe or significant barriers to aquatic organisms and are a priority for the Town. The first step in the prioritization process was to determine which Town crossings were a severe or significant barrier to aquatic organism. The next step was to determine if the crossing was located on perennial, intermittent stream or whether the crossing was over a wetland or used for stormwater conveyance. There are 24 (25% of the crossings) severe or significant barriers in the Town. A summary of these results can be found in Table 1.

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[6] Data is based on modeling results from Cornell Water Resource Institute and include only 97 road stream crossings. Of those data, 41 crossings were unable to be modeled due to lack of data or the crossing is a bridge and 6 were classified as stormwater and results not included.

[7] A perennial stream is one that flows year-round under normal rainfall conditions. Perennial streams are ecologically important for the life histories of many species.

Table 3: Town of Hillsdale Road Stream Crossing Freshwater Type

Freshwater Type	Total # Road Stream Crossing
Perennial Stream	80
Intermittent Stream	9
Wetland	1
Stormwater	6

There are 13 road stream crossings that are located on perennial streams in the Town of Hillsdale with severe or significant barriers to aquatic organisms. Site visits were completed at all 13 sites structures. Results from the prioritization process and the site visits are summarized below in Table 4. Entire prioritization results for town structures on perennial streams can be found in Appendix A: Table 2-6.

Table 4: Top 4 Priorities for the Town of Hillsdale

Ranking	NAACC Survey Identification Number/Survey ID	Address	Latitude, Longitude
1	xy4217905173481934/45954	Breezy Hill Road	42.179051, -73.481934
2	xy4220636173479298/44602	Mitchell Road	42.206361, -73.479298
3	xy4220488973497030/66448	Collins Street	42.204889, -73.49703
4	xy4218709773501859 /44557	Tribrook Road	42.187081,-73.501866

Step 5: Conceptual and Final Design Development

Following the prioritization process and site visits, the TU team and the Town determined the four highest priorities. Of those, the top priority was identified. A summary of these results can be found in Table 4 above. Final design review and development was completed for the highest priority and conceptual level effort was completed for the second, third and fourth priority. Final design review and development includes construction documents that will be used to assist in project implementation. To support construction document development detailed calculations were completed to determine the necessary dimensions of the stream crossing (clear span, rise, etc.), severity level of destructive forces (scour, water velocity, etc.) and to size materials (stones, logs, etc.) to be stable during design conditions. Construction documents include a plan sheet that depicts how the desired stream crossing will be constructed a narrative which outlines design criteria and results and a bid item schedule which presents in tabular form the amount of materials or labor needed to construct the desired stream crossing.

The conceptual level design effort presents a plan view of the project sites showing the location of the desired stream crossing, its orientation, and proposed dimensions (clear span, rise) and supportive features to be built in the stream to protect the crossing. An estimated cost estimate was also developed. Due to the generalities in development the conceptual level alternatives, there is a higher level of uncertainty of the amount of work needed to construct that may be determined during final design development. The goal of the conceptual level design process is to prepare the Town for future planning and budgeting.

3.0 Planning for the Future: Best Management Practices for Road Stream Crossing Designs

Understanding how best to design and install a flood resilient and wildlife friendly culvert is the ultimate outcome of the road stream crossing management planning exercise. The examples identified and designed during the project highlight the types of structures and design criteria needed to ensure that the structure is meeting these goals.

A well-designed culvert should avoid constricting the stream channel, consider the width and skew of the river as well as be appropriately sized to pass the largest storm feasible - ideally, the 100-year storm. The structure should, maintain the continuity of the natural stream substrate, slope and water velocity through the structure. Non-constricting culverts installed with a similar natural slope will normally provide water depths, velocities, bottom substrates, and channel characteristics that are comparable to the natural stream.[8]

NYS DEC has compiled stream crossing standards that can be used to guide all road stream crossing construction projects. Project permits are required for projects that are located on perennial streams with a water quality classification of A, B, C(T) or C(TS). Information on water quality classification on perennial streams can be found in Appendix B: Map 1.

NYS Stream Crossing Standards

The following recommended standards and permit requirements are provided on the NYS DEC website[9] and are effective for reducing stream barriers and impediments to fish and wildlife.

Structure Type:

A. Bridges and bottomless arches are preferred and should be used whenever possible.

B. Box and Pipe culverts, if used, must be:

- Embedded into the streambed to at least 20 percent of the culvert height at the downstream invert
- Used only on "flat" streambeds (slopes no steeper than 3 percent)
- Installed level

Structure Width:

- The crossing opening (whether open arch, bridge, or culvert) should be at least 1.25 times the width of the stream channel bed. This width is measured bank to bank at the ordinary high-water level (OHW) or edges of terrestrial, rooted vegetation.
- An average of three measurements, (project location and straight sections of the stream upstream and downstream) should be used to determine the channel bed width.

Depth and Velocity:

- At low flows, water depths and velocities should be the same as they are in natural areas upstream and downstream of the crossing.

Substrate:

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[8] https://www.streamcontinuity.org/aquatic_connectivity/crossing_design/stream_simulation.htm

[9] http://www.dec.ny.gov/permits/49060.html

- Natural substrate should be used within the crossing, and it should match the upstream and downstream substrates. It should resist displacement during floods and should be designed so that appropriate material is maintained during normal flows.

Additional Design Criteria:

- Size of the structure is large enough to pass a 100-year flow event or the largest storm event feasible considering future climatic conditions.
- Placement of the structure is in line with the stream to reduce skew.
- Instream passable, grade control structures are installed to prevent channel head cuts[10] from causing additional erosion and instability within the stream.

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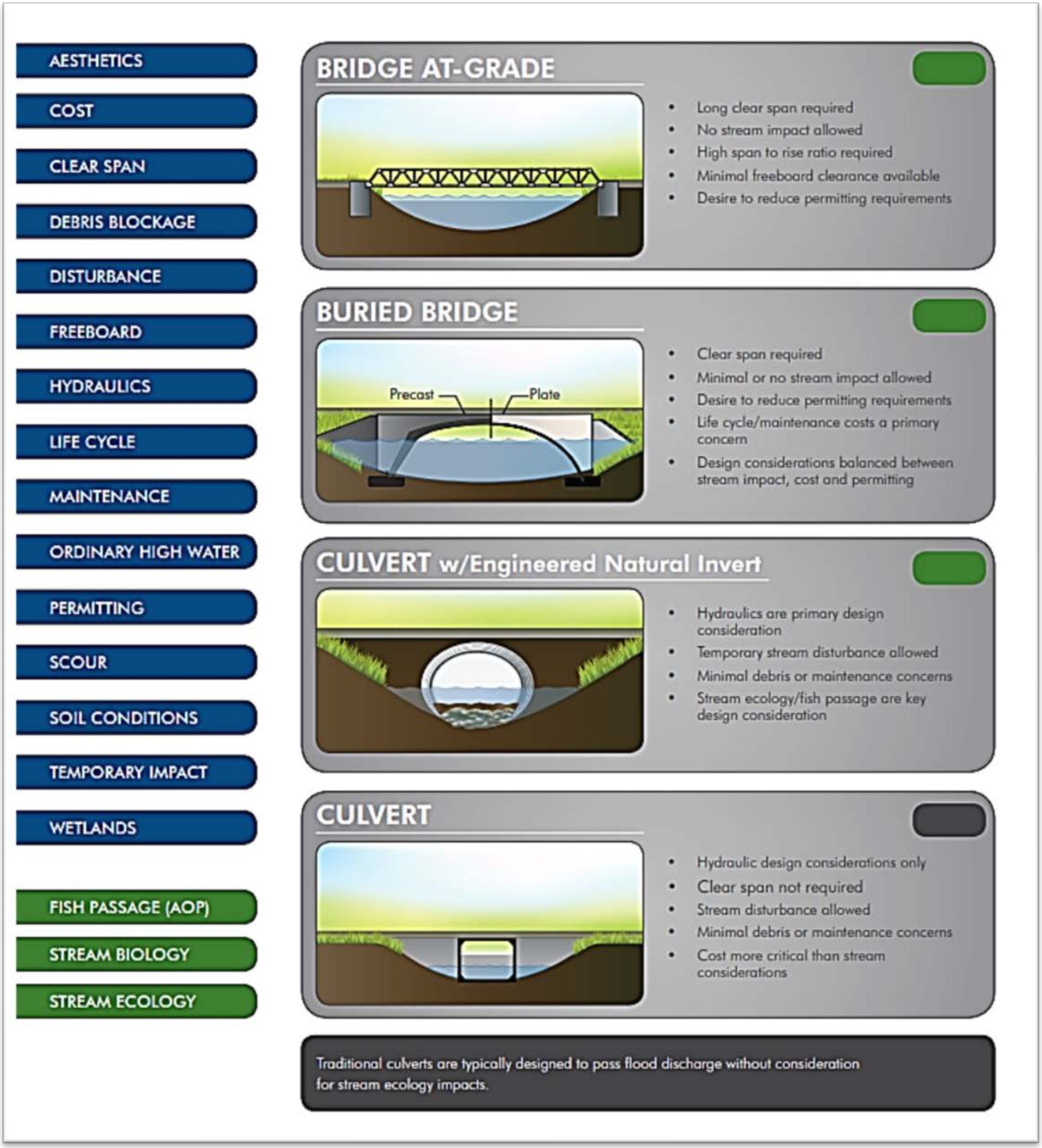
10 Head cut in stream geomorphology, is an area of instream instability and erosional feature of streams with an abrupt vertical drop that can be perpetuated through the river system until equilibrium of channel dimensions and slope is attained.

Design Considerations



- AESTHETICS
- COST
- CLEAR SPAN
- DEBRIS BLOCKAGE
- DISTURBANCE
- FREEBOARD
- HYDRAULICS
- LIFE CYCLE
- MAINTENANCE
- ORDINARY HIGH WATER
- PERMITTING
- SCOUR
- SOIL CONDITIONS
- TEMPORARY IMPACT
- WETLANDS

- FISH PASSAGE (AOP)
- STREAM BIOLOGY
- STREAM ECOLOGY

BRIDGE AT-GRADE 🟩

- Long clear span required
- No stream impact allowed
- High span to rise ratio required
- Minimal freeboard clearance available
- Desire to reduce permitting requirements

BURIED BRIDGE 🟩

- Clear span required
- Minimal or no stream impact allowed
- Desire to reduce permitting requirements
- Life cycle/maintenance costs a primary concern
- Design considerations balanced between stream impact, cost and permitting

CULVERT w/Engineered Natural Invert 🟩

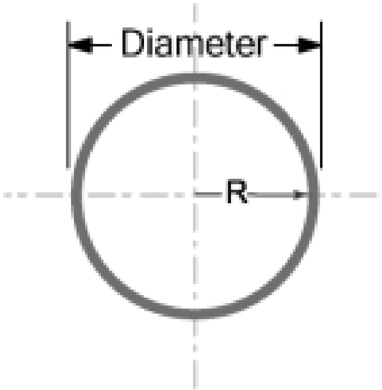
- Hydraulics are primary design consideration
- Temporary stream disturbance allowed
- Minimal debris or maintenance concerns
- Stream ecology/fish passage are key design consideration

CULVERT ⬛

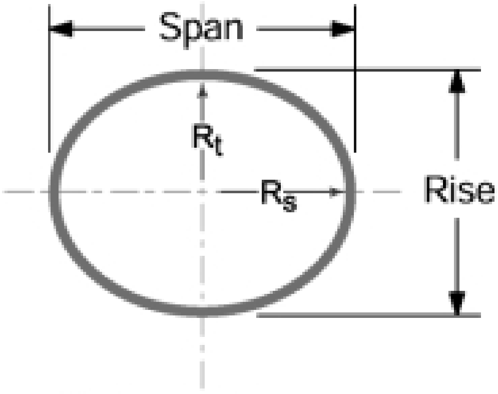
- Hydraulic design considerations only
- Clear span not required
- Stream disturbance allowed
- Minimal debris or maintenance concerns
- Cost more critical than stream considerations

Traditional culverts are typically designed to pass flood discharge without consideration for stream ecology impacts.

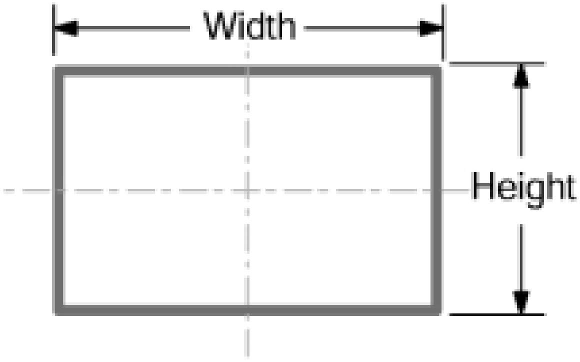
Culvert Shapes



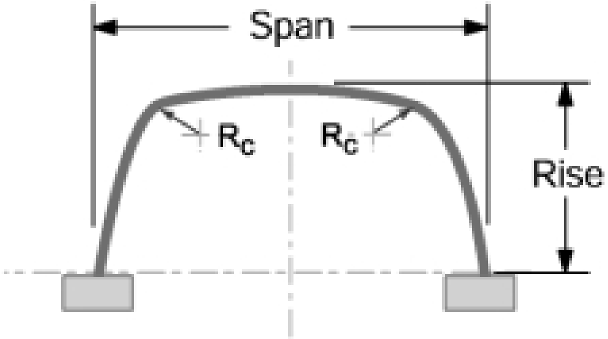
Circular Culvert



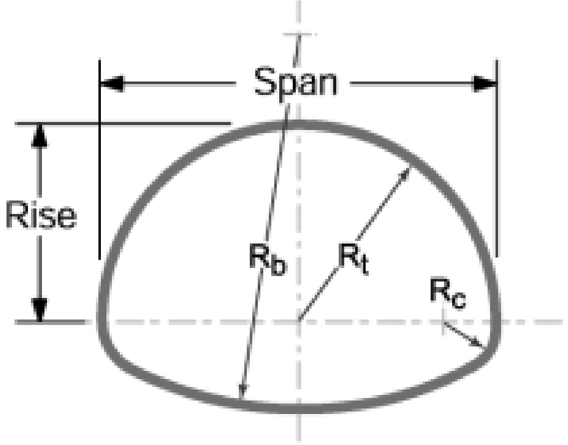
Horizontal Ellipse



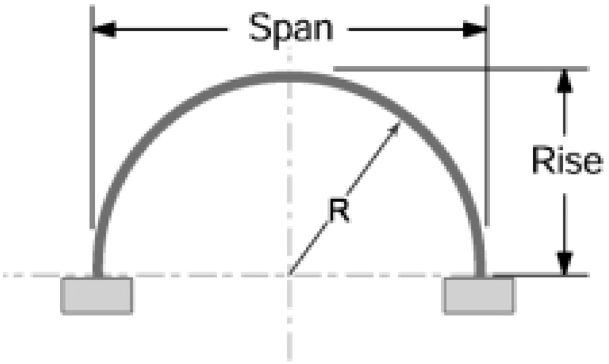
Box Culvert



Metal Box



Pipe-Arch
(Multiple Radius)



Open Bottom Arch
(Single Radius)

https://www.fs.fed.us/biology/nsaec/fishxing/index.html

Table 5: Recommended Non-Bridge Culvert Structure

Option 1: Three-Sided Concrete Box

 **Material –** Steel-reinforced concrete	
Usage Summary – Good structure to use if looking for a natural bottom, simple solution; should be considered on perennial streams	**Life Span –** 50-75 years
Benefits – Open bottom; may require some instream work to ensure stream stability, however this is a good solution for aquatic passage projects; can accommodate minimal road fill over top.	
Disadvantages – Can be higher profile; weight of concrete structures may limit installation options and require some towns to contract out work increasing cost; required installation of footers.	
Cost Comparison – Higher cost depending on the size and weight of the structure.	

Option 2: Aluminum Box Culvert with or without Invert

Considerations –

- Strict cover requirements.
- Can be installed with pre fab or poured in place concrete footers or with full invert on prepared bed.
- Potential extended road closure for footer installation.
- If using full invert contractor must ensure that natural material is added to the structure to mimic natural stream bed and depending on the size of the structure this can be challenging.
- Open bottom structure may require instream work to ensure channel stability.

Material - Aluminum

Life Span – 50-75 years

Usage Summary - Good structure to use if looking for a natural bottom, low profile solution

Specifications –

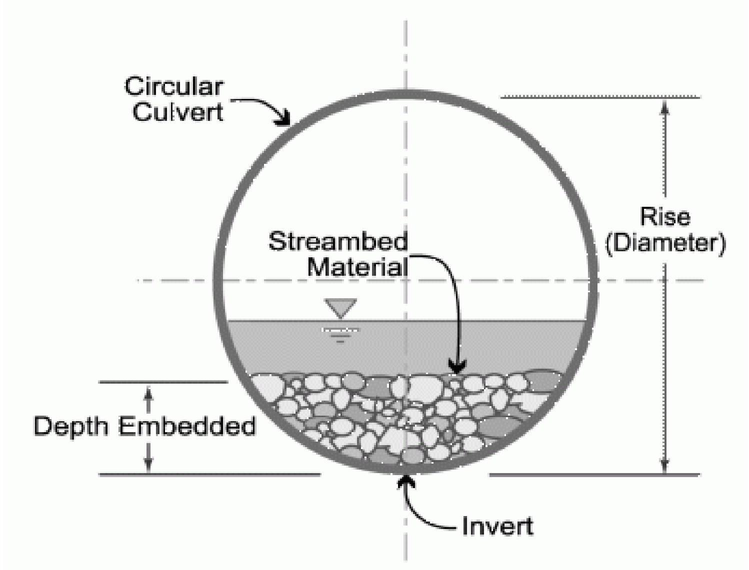
- Open bottom or full invert
- Spans to 35 ft
- Wide-span, low-rise structures
- Ideal for small bridge replacements
- **Light weight; variety of shapes and sizes**

Cost Comparison – Low cost solution as town may have the equipment to install these structures in house and may be a less expensive option because of transport and installation savings. Should balance cost savings with the reduced life span of the structure and the potential for extended road closure depending on footer design. Site specific needs and funding limitations should be considered.

Option 3 - Structural Plate (ALSP) Single Radius Arch

Material - Galvanized steel or aluminum	Life Span – **50-75 years**
Usage Summary – Wide span, low rise structures typically at lower material cost compared to concrete arches or aluminum box culverts.	
Benefits – Lower structure cost compared with concrete or aluminum box culvert alternatives. Offers a wide range of sizing options.	
Disadvantages – Requires concrete footers which can increase the duration of road closure. Requires a crew of laborers to fabricate plates. Typically requires at least 2.5’ of cover for HS25 loading.	
Cost Comparison – While material costs are comparatively low, labor costs tend to be higher.	

Option 4 - Embedded or at Stream Grade Round or Elliptical Culvert



**Structure can be buried to accommodate natural channel bottom. [11]

Material - Galvanized steel, plastic, steel reinforced concrete.

Life Span – 20-75 years

Usage Summary – Low cost solution for small intermittent streams, wetland crossings and stormwater infrastructure.

Benefits – Embedded pipe provided natural bottom; good for bankfull widths of less than 12’. Can be quickly installed; doesn’t require footers.

Disadvantages – Depending on size of the pipe it may be difficult to embed pipe and provide natural bottom; in both scenarios the culvert must span creek width, stream grade structure rarely adequate for fish passage at less than stream width. Requires 30” of cover.

Cost Comparison – Lower cost solution

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[11] https://www.fs.fed.us/biology/nsaec/fishxing/index.html

Information from Contech - https://www.conteches.com/bridges-and-structures/plate/aluminum-box-culvert

Other Design Considerations

The prioritization exercise highlighted in this report is just one way the road stream crossing data can be used to benefit the Town. Our example prioritization effort outlined in the report focuses on improving Town's natural resources. However, the results from the prioritization effort also demonstrate the benefit of consolidating the large dataset into smaller components to highlight opportunities for other priorities beyond aquatic organism passage.

To better facilitate the use of the data to achieve multiple prioritization efforts an online map resource was developed to be used by town and highway personnel. The map is accessible to the public with sign in credentials for those that are qualified to update and modify the data. The map resource supports the development of the inventory document that was provided to the town as part of this project. The inventory document is a printed version of the dataset by crossing that can be referenced to as needed. The online map can be found at https://trout.maps.arcgis.com/apps/webappviewer/index.html?id=4e9b2e8b23c64ce99e3f4df147285c83. The dataset can be used in a variety of other ways to benefit the town. Here are a few ways the data can be used:

- Provide specific data for each structure surveyed
- Provide data to help with planning and budgeting
- Prioritize structures based on flood potential (Appendix A: Table 3)
- Identify structures that will require permitting for replacement
- Identify stormwater infrastructure
- Prioritize structures based on structure condition

By using the strategies and design examples outlined in the report, the Town can ensure that all replacements are adequately sized and designed to pass the 100-year flow, preparing for future extreme weather. Adequately sized and appropriately designed culverts will result in a flood resilient community with connected and healthy aquatic habitat.

4.0 Project Results

The results from the design process are four replacement opportunities reviewed and vetted by the town that will pass the 100-year flow event as well as ensure aquatic passage. During the design process, alternative structures were compared to consider both the site-specific requirements and town concerns and budget. The structures considered were only those determined to be ecological and hydraulically appropriate. Since in most cases the existing structures are greatly undersized, comparing the costs to replace a structure with an in-kind inadequately sized structure in order to save money is not recommended. It may be detrimental to the process to consider short-term budgets only. Instead the goal of the planning process was to identify high priority sites where it makes the most sense for the town to invest resources. The cost comparison and vetting process weighed the up-front, one-time costs against the future and ongoing maintenance and replacement costs of replacing with smaller, inadequately sized structures.

In New York storm frequency and magnitude are predicted to increase. With the potential for more intense storms, the town's strategy for road stream crossing infrastructure replacements should consider the economic and public safety benefits achieved through properly sized road stream crossing structures. In addition, inadequately sized and inappropriately designed structure fragment stream systems impacting the organisms that need healthy and connected streams to survive. Although this cost is difficult to calculate and easy to ignore, considering these impacts with support the goals of the project and result in real ecological benefits. If the goal of the town is to improve their road infrastructure to withstand future flood and eliminate aquatic barriers, there are grant opportunities that may help reduce the higher upfront costs (Table 6) for replacement projects. The results of the prioritization efforts and selection of the top priority projects are summarized in Table 7. Section 6.0 contain the design and cost estimate summaries for each project.

Table 6: Grants Available for Culvert Replacement Projects

Granting Agency	Grant	Project Type
NYS DEC (Department of Environmental Conservation)	Hudson River Estuary Program, Local Stewardship Planning Grants	Grant funds planning and design work for water infrastructure to improve resiliency for flooding.
NYS DEC Hudson River Estuary Program in partnership with NEWIPCC	Restoration of Watershed Connectivity	Funding for restoration of aquatic connectivity for herring and eels.
NYS DEC	Climate Smart Communities Grant	Funding provided for culvert replacement and nature- based shoreline restoration projects.
NYS DEC	Water Quality Improvement Project: Non-Agricultural Nonpoint Source Abatement and Control	Funding for streambank stabilization and riparian buffers as well as culvert repair and replacement projects.
NYS DEC	Water Quality Improvement Project: Aquatic Connectivity Restoration	Restoration of aquatic connectivity with a maximum grant of $250,000.
NYS DEC	Non-Agricultural Nonpoint Source Planning Grant	Planning funds for streambank stabilization and culvert repair or replacement.
NYS DEC	Trees for Tribs	Trees from the Saratoga Tree Nursery to re-establish/restore riparian buffers using native vegetation. First come-first served, tree stock is quickly exhausted.
NYS DOS (Department of State)	Local Waterfront Revitalization Program	Funding to prepare a Local Waterfront Revitalization Plan (LWRP) or implement a component of an approved LWRP.
NYS EFC (Environmental Facility Corporation)	Clean Water State Revolving Fund	CWSRF can provide various forms of project finance for certain habitat restoration and protection

Granting Agency	Grant	Project Type
		projects in national estuary program areas. Short and long-term loans are available at no interest and low interest rates.
FEMA (Federal Emergency Management Agency)	Hazard Mitigation Assistance	Triggered by a disaster, funding can be made available for projects to mitigate future damages and can include culvert right sizing and stream stabilization; pre-disaster funding may also be available
HUD (US Department of Housing and Urban Development)	Community Development Block Grant Program	Program can potentially fund improvements in public infrastructure.
NYS Hudson River Valley Greenway	Greenways Communities Grant Program	Small projects that can fund natural resource protection initiatives.
NYS Department of Transportation (DOT)	BRIDGE program	The BRIDGE NY program provides enhanced assistance for local governments to rehabilitate and replace bridges and culverts.
NYS DOT	CHIPs: Consolidated Highway Improvement Program	CHIPS provide State funds to municipalities to support the construction and repair of highways, bridges, highway-railroad crossings, and other facilities that are not on the State highway system. Note that PAVE NY is closely related to CHIPs and may help finance resurfacing efforts.

Table 7: Proposed Priority Crossing Replacements for the Town of Hillsdale

Ranking	NAACC Survey Identification Number/Survey ID	Aquatic Passage/Habitat Quality Evaluation/Miles Connected	Flood Risk	Town Priority	Design Limitations	Permit Required	Proposed Replacement Structure	Structure Size	Estimated Cost
1	**Breezy Hill Road** **Final Design Development** xy4217905173481934 Survey ID #45954	Severe barrier Perennial High quality habitat 0.57 miles connected	High	High	Channel skew will require upstream channel modification to ensure best flow approach	C(T) Stream; Permit required	Single Radius Arch bottomless	17’x5’3”x32’	$77,780
2	**Mitchell Street** **Conceptual Design Development** xy4220636173479298 Survey ID # 44602	Severe barrier Perennial High quality habitat 0.67 miles connected	High	High	Length of pipe and steepness of slope will require multiple instream grade controls which should be included in the project scope	C(T) Stream; Permit required	Aluminum Box Culvert with full invert	12’3”x 4’5” X 80’	$98,621
3	**Collins Street** **Conceptual Design Development** xy4220488973497030 Survey ID# 66448	Significant barrier Perennial High habitat quality 1.02 miles connected	High	High	Steep creek slope will require multiple instream grade control structures; work upstream should also include landowner weir structure modifications to ensure aquatic passage	C(T) Stream; Permit required	Steel single radius arch bottomless	14’ x 4’ 8” x 40’	$91,759

Ranking	NAACC Survey Identification Number/Survey ID	Aquatic Passage/Habitat Quality Evaluation/Miles Connected	Flood Risk	Town Priority	Design Limitations	Permit Required	Proposed Replacement Structure	Structure Size	Estimated Cost
4	**Tribrook Road** **Conceptual Design Development** xy4218709773501859 Survey ID# 44557	Moderate barrier Perennial High habitat quality 1.33 miles reconnected	High	Low	County bridge just west on Tribrook Road is planned for removal; once the road is closed the culvert at Tribrook can be removed and restored according to the developed plans	C (T) Stream; Permit required	Remove pipe; restore creek	NA	$23,000

5.0 QA/QC Summary and Data Limitation

Data analysis was completed by TU. To ensure data quality control on the analysis and prioritization methods, Jo-Anne Humphreys, acting as the QA/QC manager, reviewed 20% of the data for accuracy and ranking effectiveness. Any discrepancies in the review were reexamined. Managing TU engineer, Jeff Tenley, reviewed all designs and specification for the priority crossings for accuracy.

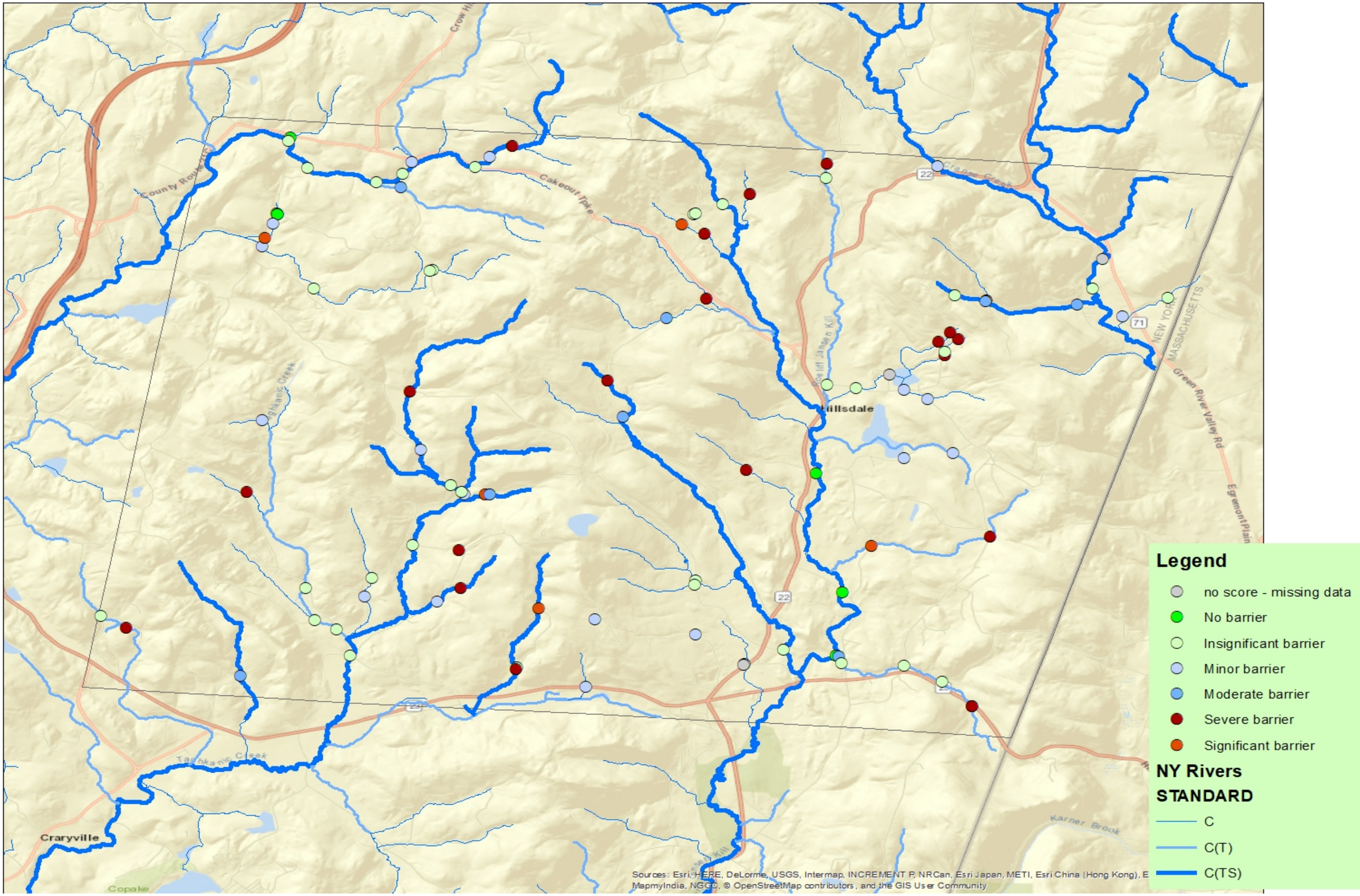
The results of prioritization activity are based on the several datasets that were generated by different entities. The metadata for each dataset is available and described in Appendix A: Table 1. The results are therefore dependent on the accuracy and the ability for these datasets to characterize the landscape in its current conditions. The use of these datasets was useful as a starting point but on the ground site visits and fish surveys were conducted in order to verify habitat conditions.

Also, the hydraulic model results consider each structure in isolation and do not consider flow impacts caused by upstream structures. As a result, it is recommended that further flood analysis should be completed in replacement scenarios where the replacement of an upstream structures may cause increased flows to downstream structures.

Special thanks to the Town of Hillsdale Board of Directors, Supervisor and Highway Supervisor for supporting this project. Both Peter Cipkowski and Richard Briggs spent countless hours working with the TU team to complete our work. Additional thanks to our project partners who participated and supported TU throughout the process. Our partners include: Vince Dubois from Columbia Greene Chapter of TU, Megan Lung, Peter Zaykoski and Stephanie Facchine from NEWIPCC and HREP, Steve Swenson and his crew from NYS DEC Region 4 Fisheries, Tracey Testo, Audrey Kropp and Kelsey Jean West from Cornell Cooperative Extension of Columbia and Greene County, Allison Truhlar and Josephine Anne Archibald from Cornell Water Resource Institute and Mike Jastremski and Lindsay Larson from Housatonic Valley Association.

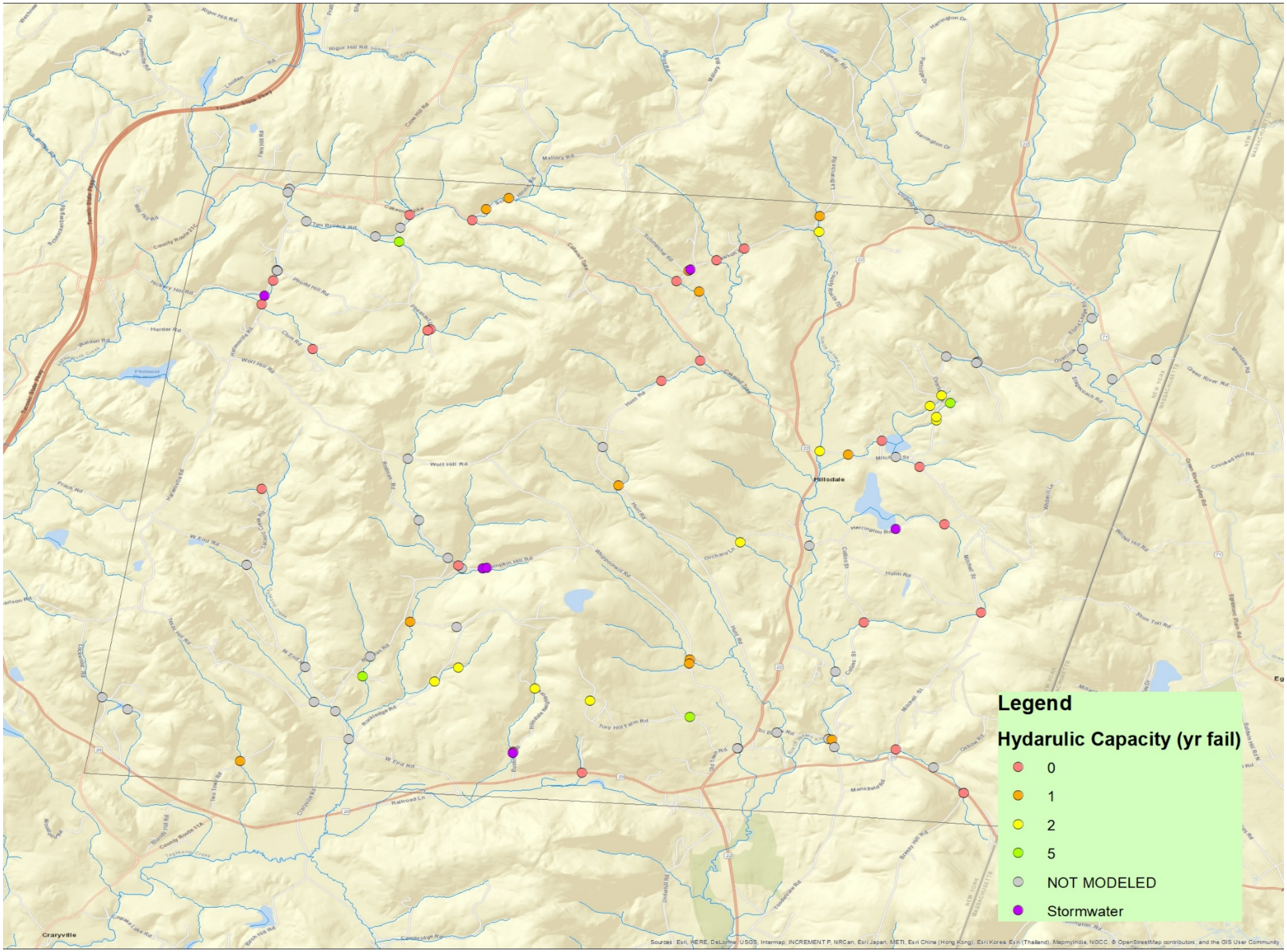
Appendix A - Project Maps and Data

Map 1: Road Stream Crossing Aquatic Organism Barrier Evaluation Result



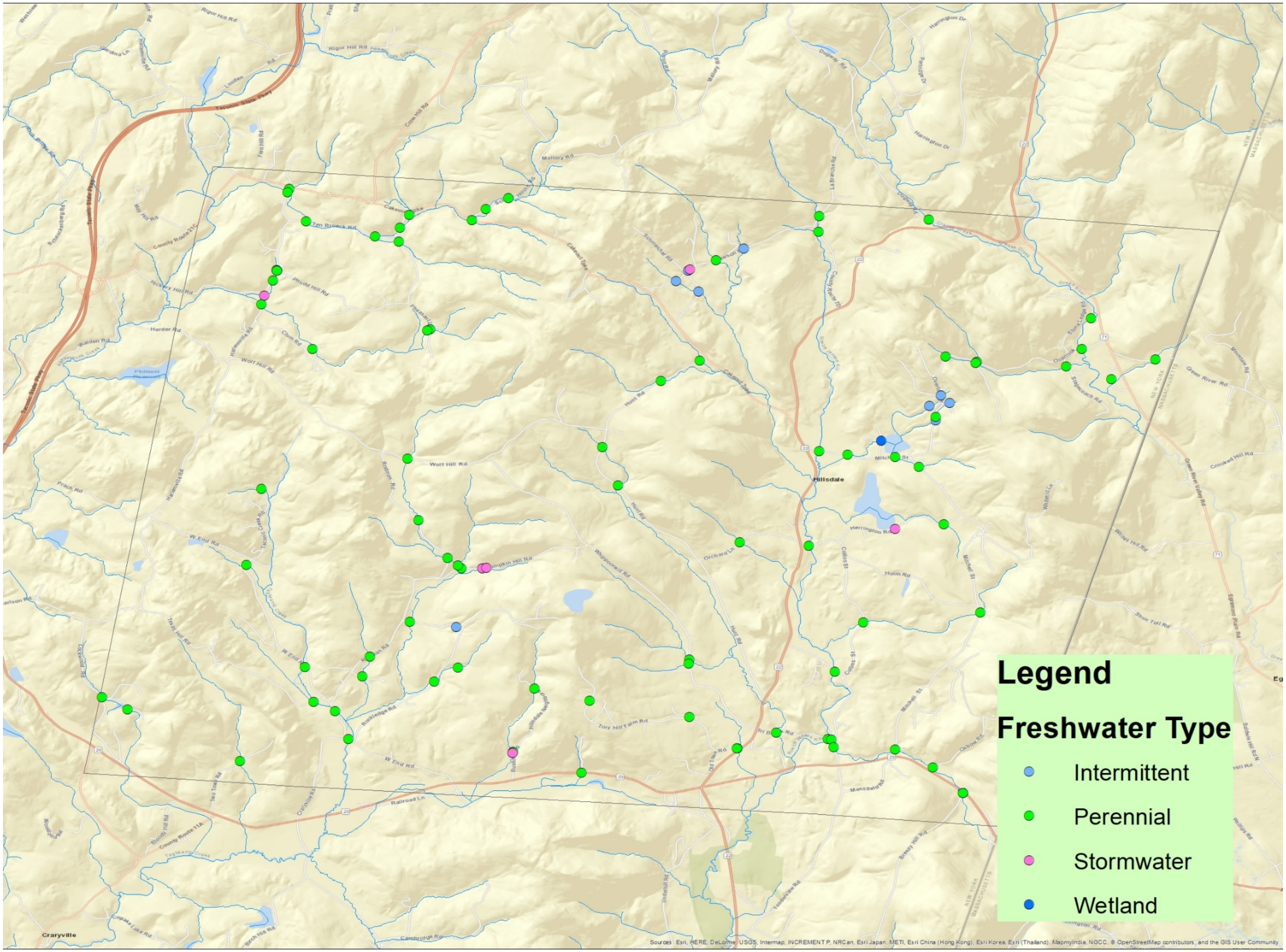
Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), E
MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Map 2: Road Stream Crossing Hydraulic Model Results

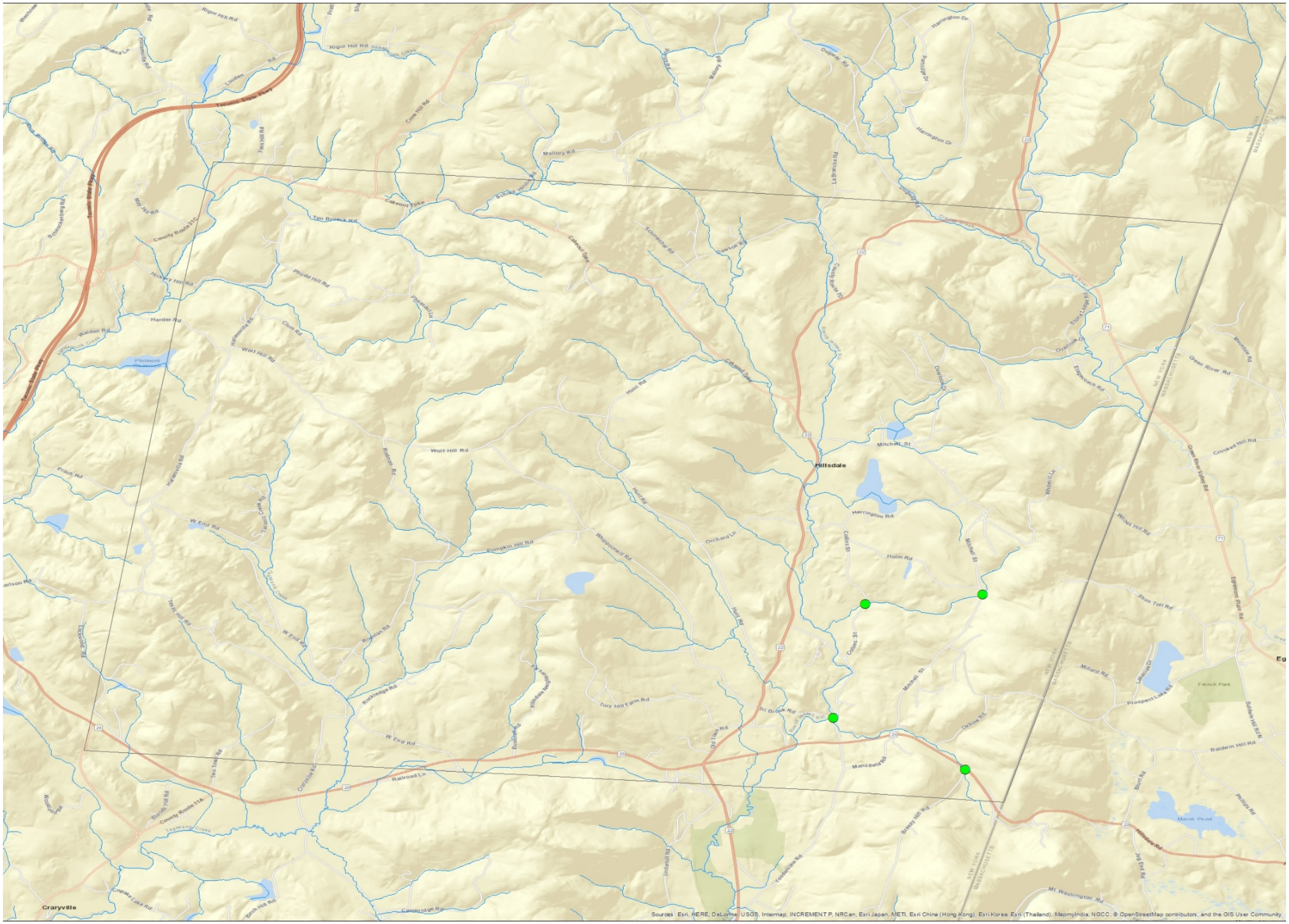


Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Map 3: Road Stream Crossing by Freshwater Type



Map 4: Prioritized Road Stream Crossings



Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Table 1: Prioritization Metrics

Priority Metric	Choices	Dataset	Methodology	Ranking
Freshwater Type	*Perennial, Intermittent, Wetland, Stormwater*	*Topo Maps; National Hydrography Dataset (NHD) Dataset; National Wetland Inventory Dataset*	*Perennial - Mapped; topographical info and obvious drainage: Wetland - based on dataset and survey info; Intermittent based on topographic and survey info - obvious drainage connected to perennial stream; Stormwater- based on topographical info with no obvious drainage and no wetland survey info confirms.*	*Stream Type Ranking (Perennial = 5, Otherwise = 0)*
AOP Ranking	*No AOP, Reduced AOP, Full AOP*	*AOP ranking classes are Full AOP, Reduced AOP and No AOP.*	*NAACC dataset*	*AOP (No AOP = 5, Otherwise = 0*
Barrier Significance class		*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.*	*NAACC dataset*	*AOP Ranking (Severe barrier = 5, Significant barrier = 3, Otherwise = 0)*
Hydraulic Capacity		*Cornell Water Resources 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		*Survey data results in either flow aligned, or flow skewed*	*NAACC dataset*	*Alignment Ranking (Flow Aligned = 0, Skewed = 1)*

# barriers downstream	*# barriers*	*NAACC dataset and AOP ranking*	*Manually count number of barriers from barrier of concern to confluence with next downstream mainstem using ARCMAP; include all barriers except minor or insignificant, dam or known natural barrier; NC= if intermittent or stormwater*	*Barrier Ranking (1 Downstream Barrier = 1, Otherwise = 0)*
Habitat Connectivity	*# barrier free upstream miles*	*NAACC dataset and AOP ranking*	*Manually use measure tool in ARCMAP to calculate distance from barrier of concern upstream to the next barrier; upstream barrier to include all road stream crossing barriers except minor or insignificant, dam or known natural barrier.*	*Connectivity Ranking (>=2 miles = 4, >=1 mile = 3, > .5 miles = 1, Otherwise = 0)*
Critical Linkages (where available)	*Perennial, Intermittent, Wetland, Stormwater*	*Topo Maps; National Hydrography Dataset (NHD) Dataset; National Wetland Inventory Dataset*	*Perennial - Mapped; topographical info and obvious drainage: Wetland - based on dataset and survey info; Intermittent based on topographic and survey info - obvious drainage connected to perennial stream; Stormwater-based on topographical info with no obvious drainage and no wetland survey info confirms.*	*Stream Type Ranking (Perennial = 5, Otherwise = 0)*
Crossing Condition	*No AOP, Reduced AOP, Full AOP*	*AOP ranking classes are Full AOP, Reduced AOP and No AOP.*	*NAACC dataset*	*AOP (No AOP = 5, Otherwise = 0*
Town Priority		*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.*	*NAACC dataset*	*AOP Ranking (Severe barrier = 5, Significant barrier = 3, Otherwise = 0)*

Priority Metric	*Choices*	*Dataset*	*Methodology*	*Ranking*
Fisheries Priority		*Cornell Water Resources modeling results from NAACC survey data*		*Capacity Ranking (<=2 yr=5, <=10 yr=4,<=25 yr=3, <=50 yr =2, <=100 yr =0)*
Stream Condition Index	*High, Average, Low*	*Using the Identifying and Protecting Healthy Watersheds framework, the NYSDEC Hudson River Estuary Program created a Stream Condition Index (SCI) with help from NYSDEC Division of Water, New York State Water Resources Institute and New York Natural Heritage Program. The SCI tallies eight individual metrics for each stream reach in the Hudson River Estuary watershed; and combines them into a condition between low and highest quality.*	*Location of crossing will determine scoring for habitat condition.*	*Habitat Condition Ranking (High = 2, Average = 1, Low=0)*

Table 2: Summary of Prioritization Results for Aquatic Passage Perennial Streams

SURVEY ID	CROSSING CODE	FRESHWATER TYPE	ECOLOGICAL VALUE	AQUATIC BARRIER EVALUATION	LATITUDE	LONGITUDE
62677	xy4219484873546795	Perennial	HIGH	Significant barrier	42.195	-73.5468
66448	xy4220488973497030	Perennial	HIGH	Significant barrier	42.205	-73.497
61982	xy4224425573479828	Perennial	HIGH	Significant barrier	42.244	-73.4798
41133	xy4226630273503673	Perennial	HIGH	Severe barrier	42.266	-73.5037
41138	xy4224450073521753	Perennial	HIGH	Severe barrier	42.245	-73.5218
41141	xy4221700773515720	Perennial	HIGH	Severe barrier	42.217	-73.5157
61787	xy4226907673550741	Perennial	HIGH	Severe barrier	42.269	-73.5507
44602	xy4220636173479298	Perennial	HIGH	Severe barrier	42.206	-73.4793
62646	xy4219802573558427	Perennial	HIGH	Severe barrier	42.198	-73.5584
44704	xy4223136573536517	Perennial	HIGH	Severe barrier	42.231	-73.5365
54405	xy4222958873566064	Perennial	HIGH	Severe barrier	42.23	-73.5661
54431	xy4221353973590454	Perennial	HIGH	Severe barrier	42.214	-73.5905
62566	xy4219172473608462	Perennial	HIGH	Severe barrier	42.192	-73.6085

Table 3: Summary of Flooding Prioritization Results for Town Structures

SURVEY ID	CROSSING CODE	CURRENT FLOOD RISK	FUTURE FLOOD RISK	CROSSING CONDITION	LATITUDE	LONGITUDE
62677	xy4219484873546795	HIGH	HIGH	OK	42.195	-73.5468
41134	xy4226396473503793	HIGH	HIGH	OK	42.264	-73.5038
66448	xy4220488973497030	HIGH	HIGH	OK	42.205	-73.497
41139	xy4224138873527713	HIGH	HIGH	OK	42.241	-73.5277
41140	xy4222555473534164	HIGH	HIGH	OK	42.226	-73.5342
44557	xy4218709773501859	HIGH	HIGH	Poor	42.187	-73.5019
41148	xy4225494373521931	HIGH	HIGH	OK	42.255	-73.5219
41150	xy4225651473525407	HIGH	HIGH	Poor	42.257	-73.5254
41152	xy4225969173519297	HIGH	HIGH	OK	42.26	-73.5193
41133	xy4226630273503673	HIGH	HIGH	OK	42.266	-73.5037
44639	xy4223072673503747	HIGH	HIGH	OK	42.231	-73.5037
44640	xy4222837573488577	HIGH	HIGH	Poor	42.228	-73.4886
44641	xy4223231373494286	HIGH	HIGH	OK	42.232	-73.4943
44642	xy4223020373499382	HIGH	HIGH	OK	42.23	-73.4994
44696	xy4223917473485299	HIGH	HIGH	New	42.239	-73.4853
44698	xy4223541773486073	HIGH	HIGH	New	42.235	-73.4861
41138	xy4224450073521753	HIGH	HIGH	OK	42.245	-73.5218
44706	xy4223803673483970	HIGH	HIGH	OK	42.238	-73.484
46209	xy4218558173492218	HIGH	HIGH	OK	42.186	-73.4922
41141	xy4221700773515720	HIGH	HIGH	OK	42.217	-73.5157
61787	xy4226907673550741	HIGH	HIGH	OK	42.269	-73.5507
61274	xy4225293473588164	HIGH	HIGH	OK	42.253	-73.5882
61614	xy4226242073567352	HIGH	HIGH	OK	42.262	-73.5674
61778	xy4226573673556266	HIGH	HIGH	OK	42.266	-73.5563
61780	xy4226649073565753	HIGH	HIGH	OK	42.266	-73.5658

SURVEY ID	CROSSING CODE	CURRENT FLOOD RISK	FUTURE FLOOD RISK	CROSSING CONDITION	LATITUDE	LONGITUDE
62563	xy4222508273588194	HIGH	HIGH	OK	42.225	-73.5882
62585	xy4218387873591407	HIGH	HIGH	OK	42.184	-73.5914
62587	xy4219670573572889	HIGH	HIGH	OK	42.197	-73.5729
62588	xy4219586273561994	HIGH	HIGH	OK	42.196	-73.562
62644	xy4220498673565670	HIGH	HIGH	OK	42.205	-73.5657
62678	xy4219298073538435	HIGH	HIGH	Poor	42.193	-73.5384
62679	xy4219055873523342	HIGH	HIGH	OK	42.191	-73.5233
62683	xy4219858573523484	HIGH	HIGH	OK	42.199	-73.5235
62686	xy4223597573486071	HIGH	HIGH	OK	42.236	-73.4861
62688	xy4223757173486976	HIGH	HIGH	OK	42.238	-73.487
62884	xy4218214573539691	HIGH	HIGH	OK	42.182	-73.5397
62888	xy4218527973550086	HIGH	HIGH	OK	42.185	-73.5501
66451	xy4221345473558371	HIGH	HIGH	OK	42.213	-73.5584

Table 4: Summary of Aquatic Habitat Prioritization Results for Perennial Streams

SURVEY ID	CROSSING CODE	ECOLOGICAL VALUE	AQUATIC BARRIER RISK	MILES CONNECTED	CONNECTIVITY VALUE	HABITAT VALUE	LATITUDE	LONGITUDE
66448	xy4220488973497030	HIGH	HIGH	1.07	HIGH	HIGH	42.205	-73.497
41138	xy4224450073521753	HIGH	HIGH	1.31	HIGH	AVERAGE	42.245	-73.5218
61787	xy4226907673550741	HIGH	HIGH	2.72	HIGH	AVERAGE	42.269	-73.5507

Table 5: Summary of Priority Crossings by Multiple Objectives

SURVEY ID	CROSSING CODE	AQUATIC BARRIER EVALUATION	TOWN PRIORITY	CONNECTIVITY VALUE	HABITAT VALUE	CURRENT FLOOD RISK	FUTURE FLOOD RISK	LAT	LONG
44557	xy4218709773501859	Moderate barrier	YES	HIGH	HIGH	HIGH	HIGH	42.187	-73.5019
44602	xy4220636173479298	Severe barrier	YES	MEDIUM	HIGH	NO DATA	NO DATA	42.206	-73.4793
45954	xy4217905173481934	Severe barrier	YES	MEDIUM	HIGH	HIGH	HIGH	42.179	-73.4819
66448	xy4220488973497030	Significant barrier	YES	HIGH	HIGH	HIGH	HIGH	42.205	-73.497

Table 6: Summary of Crossings by Freshwater Type

Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
41137	xy4225805773523571	Intermittent	Poor	Paved	42.258	-73.5236
41148	xy4225494373521931	Intermittent	OK	Paved	42.255	-73.5219
41150	xy4225651473525407	Intermittent	Poor	Unpaved	42.257	-73.5254
41153	xy4226138473515144	Intermittent	OK	Paved	42.261	-73.5151
44696	xy4223917473485299	Intermittent	New	Paved	42.239	-73.4853
44698	xy4223541773486073	Intermittent	New	Paved	42.235	-73.4861
44706	xy4223803673483970	Intermittent	OK	Unpaved	42.238	-73.484
53606	xy4220416373558671	Intermittent	OK	Unpaved	42.204	-73.5587
62688	xy4223757173486976	Intermittent	OK	Unpaved	42.238	-73.487
41133	xy4226630273503673	Perennial	OK	Unpaved	42.266	-73.5037
41134	xy4226396473503793	Perennial	OK	Paved	42.264	-73.5038

Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
41139	xy4224138873527713	Perennial	OK	Paved	42.241	-73.5277
41140	xy4222555473534164	Perennial	OK	Paved	42.226	-73.5342
41141	xy4221700773515720	Perennial	OK	Paved	42.217	-73.5157
41152	xy4225969173519297	Perennial	OK	Paved	42.26	-73.5193
44556	xy4218722473502362	Perennial	No data	Paved	42.187	-73.5024
44557	xy4218709773501859	Perennial	Poor	Paved	42.187	-73.5019
44558	xy4218601473501466	Perennial	OK	Paved	42.186	-73.5015
44600	xy4222986673492186	Perennial	Poor	Paved	42.23	-73.4922
44601	xy4221970873484817	Perennial	OK	Unpaved	42.22	-73.4848
44602	xy4220636173479298	Perennial	OK	Paved	42.206	-73.4793
44639	xy4223072673503747	Perennial	OK	Paved	42.231	-73.5037
44640	xy4222837573488577	Perennial	Poor	Paved	42.228	-73.4886
44642	xy4223020373499382	Perennial	OK	Paved	42.23	-73.4994

Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
44704	xy4223136573536517	Perennial	OK	Paved	42.231	-73.5365
44705	xy4219922573523355	Perennial	OK	Paved	42.199	-73.5234
45846	xy4218819573510216	Perennial	Poor	Paved	42.188	-73.5102
45848	xy4218583973516042	Perennial	OK	Paved	42.186	-73.516
45949	xy4221641873505287	Perennial	No data	Paved	42.216	-73.5053
45953	xy4217905173481934	Perennial	OK	Paved	42.179	-73.4819
45954	xy4217905173481934	Perennial	Poor	Paved	42.179	-73.4819
46209	xy4218558173492218	Perennial	OK	Paved	42.186	-73.4922
52806	xy4218292773486455	Perennial	OK	Paved	42.183	-73.4865
54380	xy4218717573574994	Perennial	OK	Paved	42.187	-73.575
54399	xy4219964973571741	Perennial	Poor	Paved	42.2	-73.5717
54405	xy4222958873566064	Perennial	OK	Unpaved	42.23	-73.5661
54409	xy4222027073564378	Perennial	OK	Paved	42.22	-73.5644
54410	xy4221460973559952	Perennial	OK	Unpaved	42.215	-73.56
54417	xy4221304773557859	Perennial	OK	Unpaved	42.213	-73.5579

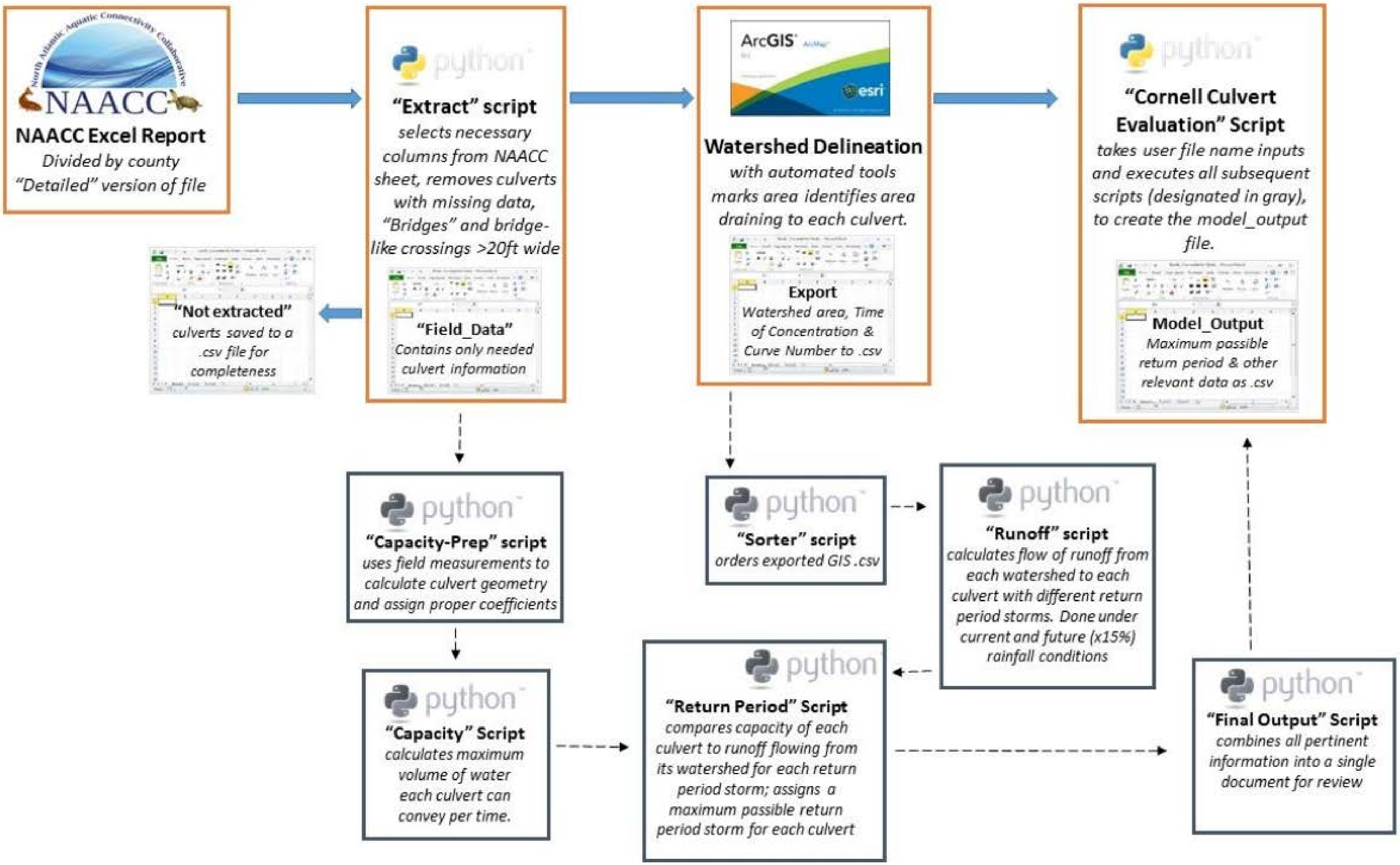
Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
54422	xy4219356273612307	Perennial	OK	Unpaved	42.194	-73.6123
54431	xy4221353973590454	Perennial	OK	Paved	42.214	-73.5905
54432	xy4219138473577040	Perennial	OK	Paved	42.191	-73.577
54433	xy4219285273580303	Perennial	OK	Unpaved	42.193	-73.5803
54434	xy4219806073581599	Perennial	OK	Paved	42.198	-73.5816
61239	xy4227042173583984	Perennial	No data	Paved	42.27	-73.584
61243	xy4226557273581416	Perennial	OK	Paved	42.266	-73.5814
61244	xy4226322373571001	Perennial	OK	Paved	42.263	-73.571
61245	xy4226456973567193	Perennial	OK	Paved	42.265	-73.5672
61249	xy4224921173562602	Perennial	OK	Unpaved	42.249	-73.5626
61250	xy4224463373452731	Perennial	OK	Paved	42.245	-73.4527
61251	xy4226578473487115	Perennial	OK	Unpaved	42.266	-73.4871
61257	xy4224356273466290	Perennial	OK	Unpaved	42.244	-73.4663
61258	xy4225088673462528	Perennial	No data	Driveway	42.251	-73.4625
61259	xy4224619473463947	Perennial	OK	Paved	42.246	-73.4639
61268	xy4224906773563086	Perennial	OK	Trail	42.249	-73.5631

Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
61269	xy4225809773585803	Perennial	No data	Paved	42.258	-73.5858
61270	xy4225818273585926	Perennial	No data	Unpaved	42.258	-73.5859
61271	xy4225811173585834	Perennial	No data	Unpaved	42.258	-73.5858
61272	xy4225661973586464	Perennial	Poor	Trail	42.257	-73.5865
61274	xy4225293473588164	Perennial	OK	Unpaved	42.253	-73.5882
61613	xy4226992673584205	Perennial	OK	Paved	42.27	-73.5842
61614	xy4226242073567352	Perennial	OK	Unpaved	42.262	-73.5674
61778	xy4226573673556266	Perennial	OK	Paved	42.266	-73.5563
61780	xy4226649073565753	Perennial	OK	Driveway	42.266	-73.5658
61783	xy4226737073554179	Perennial	OK	Unpaved	42.267	-73.5542
61787	xy4226907673550741	Perennial	OK	Unpaved	42.269	-73.5507
61980	xy4224511473484563	Perennial	Poor	Paved	42.245	-73.4846
61982	xy4224425573479828	Perennial	Poor	Paved	42.244	-73.4798
61985	xy4224411673479965	Perennial	Poor	Unpaved	42.244	-73.48
61988	xy4224164873459473	Perennial	OK	Trail	42.242	-73.4595
62562	xy4224619873580419	Perennial	Poor	Unpaved	42.246	-73.5804

Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
62563	xy4222508273588194	Perennial	OK	Unpaved	42.225	-73.5882
62566	xy4219172473608462	Perennial	OK	Unpaved	42.192	-73.6085
62585	xy4218387873591407	Perennial	OK	Paved	42.184	-73.5914
62587	xy4219670573572889	Perennial	OK	Unpaved	42.197	-73.5729
62588	xy4219586273561994	Perennial	OK	Paved	42.196	-73.562
62644	xy4220498673565670	Perennial	OK	Unpaved	42.205	-73.5657
62646	xy4219802573558427	Perennial	OK	Driveway	42.198	-73.5584
62677	xy4219484873546795	Perennial	OK	Paved	42.195	-73.5468
62678	xy4219298073538435	Perennial	Poor	Paved	42.193	-73.5384
62679	xy4219055873523342	Perennial	OK	Unpaved	42.191	-73.5233
62683	xy4219858573523484	Perennial	OK	Paved	42.199	-73.5235
62686	xy4223597573486071	Perennial	OK	Trail	42.236	-73.4861
62884	xy4218214573539691	Perennial	OK	Paved	42.182	-73.5397
62888	xy4218527973550086	Perennial	OK	Unpaved	42.185	-73.5501
62890	xy4218576973516132	Perennial	OK	Paved	42.186	-73.5161
66447	xy4219743273501335	Perennial	OK	Paved	42.197	-73.5013

Survey ID	Crossing Code	Freshwater Type	Crossing Condition	Road Type	Latitude	Longitude
66448	xy4220488973497030	Perennial	OK	Paved	42.205	-73.497
66451	xy4221345473558371	Perennial	OK	Unpaved	42.213	-73.5584
41136	xy4225827673523277	Stormwater	Poor	Unpaved	42.258	-73.5233
41144	xy4221895673492225	Stormwater	OK	Unpaved	42.219	-73.4922
54414	xy4221304573554738	Stormwater	OK	Unpaved	42.213	-73.5547
54415	xy4221315273554136	Stormwater	OK	Unpaved	42.213	-73.5541
61273	xy4225425473587699	Stormwater	OK	Unpaved	42.254	-73.5877
62887	xy4218508873550130	Stormwater	OK	Unpaved	42.185	-73.5501
44641	xy4223231373494286	Wetland	OK	Unpaved	42.232	-73.4943

Figure 1: Summary of Cornell University Resiliency Model Strategy



NAACC Excel Report
Divided by county
"Detailed" version of file

"Extract" script
selects necessary columns from NAACC sheet, removes culverts with missing data, "Bridges" and bridge-like crossings >20ft wide

"Field_Data"
Contains only needed culvert information

"Not extracted"
culverts saved to a .csv file for completeness

Watershed Delineation
with automated tools marks area identifies area draining to each culvert.

Export
Watershed area, Time of Concentration & Curve Number to .csv

"Cornell Culvert Evaluation" Script
takes user file name inputs and executes all subsequent scripts (designated in gray), to create the model_output file.

Model_Output
Maximum possible return period & other relevant data as .csv

"Capacity-Prep" script
uses field measurements to calculate culvert geometry and assign proper coefficients

"Capacity" Script
calculates maximum volume of water each culvert can convey per time.

"Sorter" script
orders exported GIS .csv

"Runoff" script
calculates flow of runoff from each watershed to each culvert with different return period storms. Done under current and future (x15%) rainfall conditions

"Return Period" Script
compares capacity of each culvert to runoff flowing from its watershed for each return period storm; assigns a maximum possible return period storm for each culvert

"Final Output" Script
combines all pertinent information into a single document for review