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U.S. Department of Transportation
Federal Highway Administration

## FHWA Climate Resilience Pilot Program:

# New York State Department of Transportation

The Federal Highway Administration's (FHWA)'s Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) in enhancing resilience of transportation systems to extreme weather events and climate change. In 2013–2015, nineteen pilot teams from across the country partnered with FHWA to assess transportation vulnerability to extreme weather events and climate change and evaluated options for improving resilience. For more information about the pilot programs, visit: **http://www.fhwa.dot.gov/environment/climate_change/adaptation/**.

In New York State, more frequent and intense future storms are predicted to increasingly threaten the life span and ability of culverts to function properly. Upgrading culverts across the board could increase the overall cost of the culvert program by as much as 80%, which renders the full set of upgrades infeasible in these resource-constrained times. However, cost increases may be justifiable at particular locations based on climate vulnerability and compelling environmental benefits. To inform investment decisions, New York State Department of Transportation (NYSDOT) developed a new decision support tool that helps determine when a culvert replacement is warranted based on risk (vulnerability and criticality), environmental importance, and economic benefits and costs.

NEW YORK STATE OF OPPORTUNITY. Department of Transportation

## Scope

NYSDOT collaborated with The Nature Conservancy's Adirondack Chapter (TNC; together referred to as the NYS Team) to assess culvert risk and develop a benefits valuation approach that considers social, economic, and environmental factors. The geographic focus of the project is the New York portion of the Lake Champlain Basin. The study area contains roughly 5,400 miles of mapped rivers and streams and approximately 4,500 stream-road crossings in New York. In 2011, a single subwatershed within the Basin (Ausable River) experienced an estimated $6.4 million dollars of damages to roads and bridges on town and county roads alone.

## Objectives

- Prioritize road-stream crossings and road segments that are: the most vulnerable to expected climate change impacts; of greatest safety importance; and the most ecologically important.
- Evaluate engineering-based design adaptation options for vulnerable road-stream crossings.
- Create an economic tool that evaluates the full benefits and costs of adaptation options, primarily culvert repairs and replacements, to help DOTs prioritize adaptation investments and evaluate alternative design options.
- Incorporate climate vulnerability results into existing NYSDOT standards, guidelines, and tools.

Culvert washout on New York State Route 9N during Tropical Storm Irene. Photo credit: Larry Master


Culvert washout in the Lake Champlain Basin during Tropical Storm Irene. Photo credit: Naj Wikoff


Roadway washout in the Lake Champlain Basin during Tropical Storm Irene. Photo credit: Tom Woodman

## Approach

**Estimate future peak flows.** NYSDOT worked with the United States Geological Survey (USGS) to develop an enhanced version of StreamStats to describe the potential impacts of climate change on streamflow. This new tool estimates the magnitude of future peak flows for streams and rivers in New York State using precipitation projections from five climate models and two greenhouse gas emissions scenarios. The outputs allow NYSDOT engineers to determine the range of future design discharges for bridge and culvert designs.

**Determine ecological culvert ranking.** NYSDOT developed a culvert prioritization methodology to identify culverts that have high ecological value. The prioritization methodology consisted of three steps:

1. As part of the *data preparation*, the NYS Team predicted the locations of culverts by intersecting existing hydrology data with roads data to obtain a point dataset of potential road-stream crossings.
2. For the *fragmentation analysis*, the NYS Team used a Barrier Analysis Tool (BAT) to analyze the fragmenting effects of dams and culverts on streams and identify the most intact stream networks in the watershed.
3. The *ecological ranking model* sums 15 ecological inputs (see Table 1) developed by an expert team comprised of NYSDOT, New York State Department of Environmental Conservation (NYSDEC), United States Fish and Wildlife Service (USFWS), State University of New York (SUNY) Plattsburgh, and TNC to obtain four ecological ranking tiers of road-stream crossings.

**Assess risk.** NYSDOT looked at two key components of flood risk: flood vulnerability and road criticality. First, to understand **vulnerability**, TNC held in-person meetings with staff from county and town public works departments (DPW) and collected data on culverts with flooding, safety, and maintenance issues. Road-stream crossings that the DPW staff identified as vulnerable to flooding were assigned a score of 10 (vulnerable) while all other crossings were scored with a 1 (not vulnerable).

Second, for **criticality**, the NYS Team assigned values to critical facilities and important roadways (i.e., functional classification score). Road segments received a critical facility score of five if a hospital, fire station, police station, or ambulance service is located on the segment, otherwise, road segments received a score of zero. The functional classification score assigned the FHWA functional class codes (a proxy for roadway importance and use) to a five point scale with five being assigned to principal arterials and one to local roads. The summed critical facility score and the functional classification score resulted in a total criticality score.

| Criteria | Data Source |
|---|---|
| Upstream culvert density | TNC |
| Downstream culvert density | TNC |
| Total length of upstream and downstream functional network from each culvert (miles) | TNC |
| Absolute gain in stream miles upstream of each culvert | TNC |
| Percent impervious surface in watershed upstream of culvert | USGS |
| Percent natural land cover in riparian area of upstream functional network | USGS |
| Percent natural land cover in riparian area of downstream functional network | USGS |
| Percent conserved land within riparian area of upstream functional network | TNC |
| Percent conserved land within riparian area of downstream functional network | TNC |
| Number of rare fish in upstream functional network | NY Natural Heritage Program |
| Number of rare fish in downstream functional network | NY Natural Heritage Program |
| Number of rare mussel in upstream functional network | NY Natural Heritage Program |
| Brook trout locations in downstream functional network | NYSDEC |
| Brook trout locations in upstream functional network | NYSDEC |
| "Healthy" Eastern Brook Trout watersheds (HIC12) at each culvert | Eastern Brook Trout Joint Venture |

Table 1: Criteria used by NYSDOT to identify priority ecological culverts.

Finally, the NYS Team obtained a **risk** score for each road segment and road-stream crossing by calculating the product of the vulnerability score and the criticality score. The NYS Team binned the risk score outcomes into high, medium, and low risk scores.

**Develop cost estimates.** At ten locations, NYSDOT tested a method for estimating and comparing the cost of various culvert replacements based on span, rise, culvert type, depth of cover, culvert embedment, and length. The design options evaluated include:

1. In-kind replacement of the existing crossing.
2. Replacement crossing based on StreamStats projections of future streamflow.
3. Replacement crossing that meets the U.S. Army Corps of Engineers General Conditions and General Regional Conditions in New York for aquatic passage.

**Calculate the benefits valuation score.** NYSDOT developed an approach to quantitatively value selected social and economic benefits, and qualitatively value the environmental benefits. The social and economic benefits are described in Table 2.

| Type of Benefit | Sub-Benefits | Metrics |
|---|---|---|
| Social | Safety | Not estimated at this time but would include:<br>• Fatalities<br>• Injuries |
| | Mobility | • Travel costs<br>• Travel time |
| | Access to critical facilities | • Fire station<br>• Emergency medical services<br>• Hospital |
| Economic | Avoided flood damages | • Federal Emergency Management Agency (FEMA) Damage Frequency Assessment |
| | Avoided freight disruption | • Detour cost<br>• Delay cost<br>• Inventory cost |

Table 2: Quantitative Benefits of Improved Road-Stream Crossings.

In the absence of quantitative environmental values, NYSDOT elected to use the ecological value scores to develop a benefits multiplier. The purpose of the multiplier was to account for high environmental value culverts, without monetarily valuing ecological features. The NYS Team binned the ecological scores into four tiers and assigned multipliers from 1.2 (highest tier) to 1.0 (lowest tier). NYSDOT calculated the final benefits valuation score for each road-stream crossing by multiplying the summed social and economic values by the environmental multiplier.

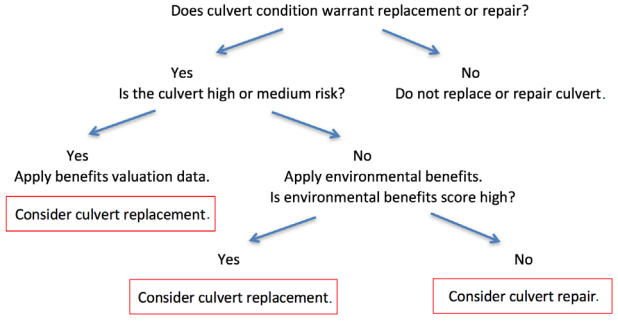


Figure 1: Decision tree to determine if culvert repair or replacement is warranted.

"NYSDOT is taking steps to incorporate climate vulnerability considerations into decisions through the institutionalization of an asset management framework that incorporates the Sustainability 'Triple Bottom Line' of economic competitiveness, social equity, and environmental stewardship in its investment decisions."

– NYSDOT Pilot Project Team

**Determine appropriate course of action.** Using the risk assessment and benefits valuation findings, NYSDOT created the following decision tree (Figure 1) to help engineers determine when to consider culvert replacement or repair and when to apply the benefits valuation approach considering culvert condition as a factor.

## Key Results & Findings

**Ecological ranking model:** NYS Team assessed more than 4,500 road-stream crossings using the ecological prioritization method. A general trend emerged showing headwaters and upstream subwatersheds in the Basin as higher ranked ecological priorities (see Figure 2). In the Lake Champlain Basin, these areas tend to be higher gradient, proximate to protected lands, and less fragmented by roads.

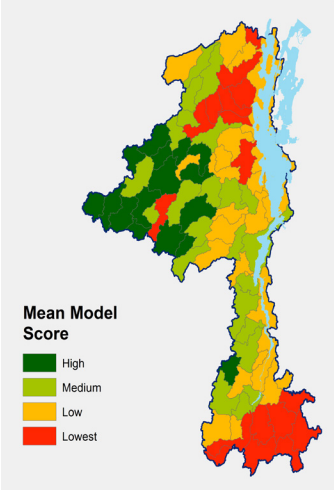


Figure 2: Mean stream-road crossing ranks based on ecological criteria.

**Risk assessment:** The assessment found that 98% of culverts in this region are low risk, less than 2% of culverts are medium risk, and less than 1% of culverts are high risk (seven crossings). Similarly, less than 1% of all road miles are ranked as high risk. Due to the scoring framework, a road segment or culvert must be identified as vulnerable to be ranked high risk.

**Cost of climate resilient culverts:** Based on an analysis of ten recent culvert replacements, NYSDOT found that the average projected increase in the 50 year flows is around 25 percent. With this increase in flow, there is little difference in the size or the cost of culverts needed to be resilient to projected changes in climate and those needed to meet the US Army Corps of Engineers regional conditions for

nationwide permits that address aquatic passage. Also, the cost of the concrete box itself is not a major component of the total project costs relative to other construction costs such as maintenance and protection of traffic, which is not affected by culvert size.

## Lessons Learned

**The flexible ecological prioritization scoring framework is applicable in other locations and at multiple scales.** This scalable framework is applicable in towns and across New York State and beyond, allowing others to take advantage of the data that has been identified and in some cases collected and processed. Also, using a consistent framework allows for better communication and may afford towns better access to state resources for project implementation.

**Take advantage of institutional knowledge but recognize its shortcomings.** To assess vulnerability, NYSDOT utilized a low-tech but fairly time-intensive outreach approach to capture institutional knowledge. The approach, which has been used in other places, such as Washington State, has the advantage of being repeatable but the disadvantage of being subjective.

**Requirements for aquatic passage may be sufficient to address future increases in streamflow.** However, further study is warranted to explore this hypothesis. Also, looking at climate change and aquatic passage together may help asset managers to justify replacement of high risk culverts in appropriate situations.

**Benefits data are severely lacking.** While data from other geographies can often be found, NYSDOT determined that it was rarely appropriate to transfer benefits data to other regions. Additionally, because the environmental benefits score and risk score are relative scores, they are useful for prioritization, but they do not work for direct monetary valuation.

**Strong asset management is key to properly adapting the transportation system.** A strong asset management strategy focuses funds on the right treatment at the right time in the right place, considering the condition of the assets, the location and context of the project in the transportation system and local geography, and the function of the roadway. The benefits valuation approach captures many of these values.

## Next Steps

**Improve ongoing data collection.** The primary challenge in this pilot was data availability and as such, NYSDOT is looking to improve information on social benefits (e.g., safety and accidents at road-stream crossing sites), economic benefits (e.g., flood damage data, including damage data by site rather than event), and environmental benefits (e.g., public willingness to pay for stream crossing replacements projects).

**Incorporate pilot findings in the decision making process.** NYSDOT's capital programming efforts are working to consider economic, social, and environmental benefits in decision making on projects and overall program selections. Specifically, the findings from this research project will provide valuable insights in how NYSDOT can approach asset prioritization in their upcoming Transportation Improvement Program/Statewide Transportation Improvement Program (TIP/STIP) in light of climate vulnerability and resiliency.

**Incorporate watershed-level environmental priority culverts in the NYSDOT environmental viewer.** NYSDOT has an environmental viewer that includes a multitude of environmental layers as well as capital program data, bridges, and culverts. In the culverts layer, information on environmental priority culverts has been added on a statewide scale, but this could be enhanced with watershed level environmental priority culvert information.

**Test the overall scoring framework in other areas.** The NYSDOT pilot area is in a rural part of New York, so additional studies from around the state will help to ensure the approach applies equally in all regions.

## For More Information

**Final report available at:**
**www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/**

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