Assessing Impediments to Free Passage of Eastern Brook Trout in Rivers Flowing from Shenandoah National Park into the Rappahannock River Watershed

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Introduction

Summary

This report describes the methods, findings, and related outreach activities associated with an aquatic organism passage (AOP) assessment undertaken by the Piedmont Environmental Council (PEC) and Trout Unlimited (TU) between September 2013 and December 2014. With financial assistance from the U.S. Fish and Wildlife Service's National Fish Passage Program, PEC and TU applied a proven AOP assessment protocol to all road-stream crossings on brook trout-bearing streams in Virginia's Rappahannock River watershed. A total of 133 road-stream crossings were assessed for AOP. Of these, 64 were determined to provide no or reduced AOP.

Field-collected data were transferred to a Geographic Information System (GIS) for analysis and sharing. PEC and TU are now planning the removal of two "demonstration" crossings and began discussing longer-term strategies to facilitate AOP in the region with the Virginia Department Transportation (VDOT), Virginia Department of Game and Inland Fisheries (VDGIF), and U.S. Department of Interior.

Background

In 2012, PEC and TU began a conservation outreach campaign directed at private landowners along brook trout-bearing streams in four counties in PEC's 9-county service area (Rappahannock, Madison, Greene, and Albemarle counties). Over two hundred letters were sent to landowners adjacent to brook trout-bearing streams offering assistance with land protection and stream and riparian habitat restoration. In-person meetings and field reconnaissance conducted after the mailing revealed that undersized road-stream crossings were a major—if not the major—cause of habitat degradation for brook trout in the area, with many crossings impeding brook trout movement and several causing significant near-crossing streambank erosion.

While PEC and TU documented the condition of notably problematic crossings with photographs and simple measurements, the decision to act on the removal or retrofit of particular crossings was hampered by a lack of understanding of each crossing's watershed context and likely impassability by brook trout. A comprehensive picture of road-stream crossings was needed to determine which made sense to remove. PEC relayed this need to the U.S. Fish and Wildlife Service, which invited a proposal to the National Fish Passage Program for a comprehensive AOP assessment. PEC received the grant and began working on the project in earnest in September 2013.

Protocol

PEC and TU used the road-stream crossing data collection protocol created by the River and Stream Continuity Project at the University of Massachusetts at Amherst ("UMass") for this project.[1] Thoroughly vetted by specialists and developed for use by volunteers,

[1] UMass Amherst River and Stream Continuity Project -- www.streamcontinuity.org.

the UMass field data collection form served as the basis for this project.[2] The detailed instructions proved extremely helpful.[3]

In terms of data collection, each crossing consisted of two datasets: one of the crossing itself, and one of its associated structures. A crossing was described as a bridge, ford, vented ford, culvert (either single or multiple) or open bottom arch. Each crossing had at least one structure, which for the purposes of this project was defined as the part of the crossing that the water flowed through. For example, a crossing that consisted of seven round culverts had seven associated structures with corresponding data.

Every structure had an inlet and an outlet structure that were defined and measured. All inlet and outlet structures were defined as: a bridge with abutments, a bridge with side slopes, a bridge with side slopes and abutments, an open bottom arch, a round culvert, an elliptical culvert, a box culvert, a round culvert embedded, or an elliptical culvert embedded. Inlets and outlets could be of the same type or different, depending on the situation. For example, it was possible to define the inlet as a round culvert and the outlet as an elliptical culvert on the same structure.

Different measurements (A, B, C and D) were taken depending on the type of inlet and outlet structure. The description of the measurements and a diagram detailing the type of inlet/outlet and its corresponding measurements can be found in the UMass Instructions Guide for the Field Data form.

To streamline data collection and storage, the UMass Field Data Form was converted to the ArcGIS Collector application for iPad. All data was recorded on an iPad using this Geographic Information Systems (GIS) app for this survey. The GIS app enabled the surveyor to record a GPS point for each crossing and associated structure(s) that was directly linked to all corresponding data, including the numerous photographs that were taken of each crossing and structure.

Crossing characteristics such as ownership, condition of crossing, alignment, presence of a tailwater scour pool, and surrounding land use were recorded. Structure characteristics, such as whether or not the structure was embedded, what kind of substrate it was made from, if it had any internal features, physical barriers, or dry passage for wildlife; a clear line of sight, and if water depth and velocity matched the stream, were also recorded. Drop type and measurements for the structure outlet and inlet were taken.

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[2] Field Data Collection Form -- http://streamcontinuity.org/pdf_files/Continuity%20Project%20Road-Stream%20Crossing%20Data%20Form%207-2-14.pdf

[3] Instruction Guide for Field Data Collection Form -- http://streamcontinuity.org/pdf_files/Instructions%20for%20Field%20Data%20Form%203-15-13.pdf

Field Data Collection
Data collection began in October 2013 and finished in May 2014. The heaviest survey period occurred between October 2013 and December 2013. During this time period, a PEC field technician and intern were able to make an initial pass at the entire project area. No data was collected between January and April 2014, but the PEC team was able to return the following May to a few of the private crossings that were missed during the fall survey period.

The PEC team began the survey in lower Greene County and then worked north into Madison, and then Rappahannock, counties. A few locations in Albemarle County were surveyed once data collection in the core project area was completed.

For each trout stream, the PEC GIS department created a map of the stream and its associated tributaries based on data from VDGIF, Shenandoah National Park, and county governments. Each stream was sectioned off into corresponding "mapbook" pages. A mapbook page consisted of an aerial photograph, road names, parcel boundaries and parcel landowners and acreage (if known).

An estimated 27 crossings in the project area were not surveyed. These crossings were all privately owned. For these crossings, either permission to access the property was not granted, the property owner was unable to be reached or located, or the property owner ignored attempts to gain permission. In some cases, ownership was unclear. If the property owner was not at the property at the time of surveying, a letter was left and the address was recorded. Two subsequent letters were mailed as a follow-up if no response was received. Many properties in the project area were second homes and the primary addresses of these property owners could only be obtained via tax records.

Post-Processing
Field-collected data were downloaded and exported to a geodatabase. Crossing and structure locations were overlaid on aerial photography in GIS to confirm that field-collected data accurately captured the true locations of crossings. In some instances, the GPS unit did not accurately record the location of crossings. In those cases, aerial photography was used to manually correct crossing locations in the geodatabase.

Application of Coarse Screen Filter
PEC and TU chose to use the Vermont Culvert AOP Screening Tool to classify each crossing's AOP status.[4] Minor modifications to this tool, noted in Appendix A, were made to fit the tool to the project dataset and allow for classification based on inlet

[4] Milone and MacBroom, Inc. *The Vermont Culvert Aquatic Organism Passage Screening Tool*. Prepared for Vermont Agency of Natural Resources (2009).
http://www.vtfishandwildlife.com/library/Reports_and_Documents/Aquatic%20Organism%20Passage%20at%20Stream%20Crossings/_The%20Vermont%20Culvert%20Aquatic%20Organism%20Passage%20Screening%20Tool.pdf

characteristics. Crossings were grouped into one of four categories: rull AOP, reduced AOP, no AOP for all aquatic organisms except adult salmonids, and no AOP for all aquatic organisms including adult salmonids.

Web Map Creation

Once edited, the geodatabase was made available in an ArcGIS Web Map.[5] This map presents the locations of crossings and allows for queries of crossings and structures based on ownership, type, and drop height. The geodatabase is available for download for for further analysis.[6]

Findings

A total of 133 road-stream crossings containing 244 individual structures were assessed. Highlights from the full dataset are provided below. Details on each crossing and structure are available at the abovementioned websites.

Crossing Type

Of all road-stream crossings, 51 (38%) were bridges, 54 (41%) were culverts, and 28 (21%) were fords. Among the 75 VDOT crossings, roughly half were bridges. Bridges made up 22 percent of non-VDOT crossings.

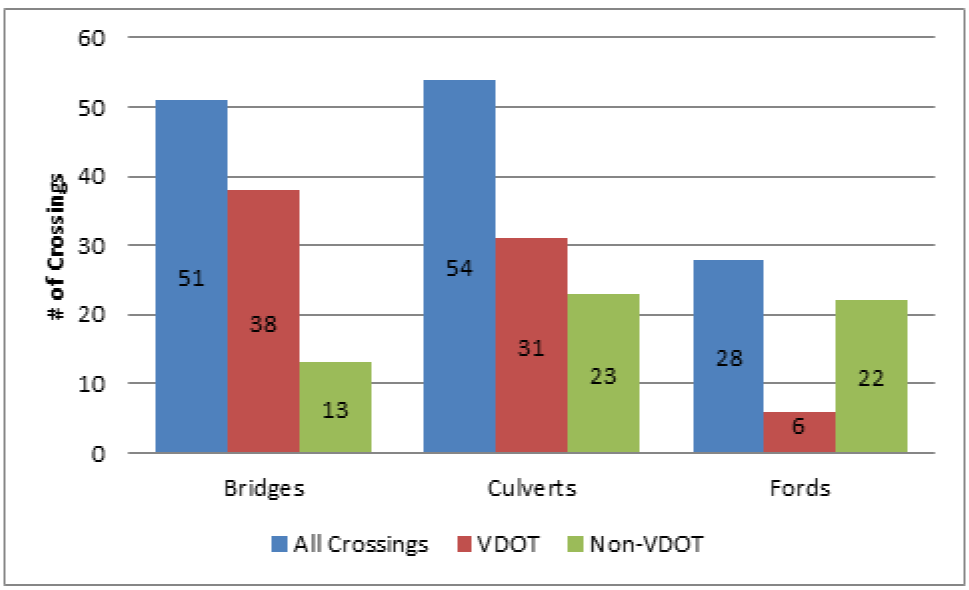

Figure 1. Crossings by Type and Owner

Crossing Span and Alignment

Over half of crossings exhibited some degree of channel constriction. Thirty (22%) severely constricted the stream channel, meaning that the crossing was half as wide, or narrower, than the bankfull width of the stream. Forty-two (31%) mildly constricted

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[5] www.pecva.org/troutmap

[6] www.pecva.org/troutdata (password-protected)

their stream channels (narrower than bankfull width but not severe). Channel constriction may lead to upstream accumulation of sediment and below-crossing scouring, which may result in the creation and/or deepening of outlet drops (and AOP barriers).[7]

Thirty-nine (29%) crossings were not aligned (i.e. skewed) with the stream. Poorly aligned crossings are more likely to be clogged with woody debris and cause severe bank erosion outside the culvert.[8]

Structure Characteristics
Thirty-seven percent of structures were not embedded in the stream channel, meaning they (all culverts) were not buried in the stream and lacked natural substrate. Structures that lack natural substrate create discontinuities in stream habitat.[9]

Excluding bridges, the most common type of outlet drop was "freefall" or "freefall into cascade" (46%), followed by "no drop" (34%), "cascade" (11%), and "none selected" (9%). Fifty-nine structures (24%) had an inlet or outlet drop greater than or equal to one foot. Ninety-four structures (39%) had an inlet or outlet drop of less than one foot but greater than zero. Inlet and outlet drops can represent physical barriers to many animal species.[10]

AOP Status
Applying the AOP coarse screen from Vermont, with minor modifications to fit our dataset, indicates that: 8 crossings (6%) provide no AOP for all aquatic organisms; 22 crossings (17%) provide no AOP for all aquatic organisms except adult salmonids; 34 crossings (26%) provide reduced AOP; and 54 crossings (41%) provide full AOP. AOP at 15 crossings (11%) was not rated because they were fords or lacked key structural data. Only one of these indeterminate crossings was a VDOT crossing. Generally, VDOT crossings were more likely to provide AOP than non-VDOT crossings, though this is largely explained by the number of VDOT crossings that are bridges.

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[7] Scott D. Jackson, "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garrett, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2003. http://streamcontinuity.org/pdf_files/ecological_considerations_stream_crossings.pdf
[8] "Steps and Considerations in the Stream-simulation Design." http://www.stream.fs.fed.us/fishxing/publications/PDFs/AOP_PDFs/Chapter6.pdf
[9] Jackson, *op. cit.*
[10] *Ibid.*

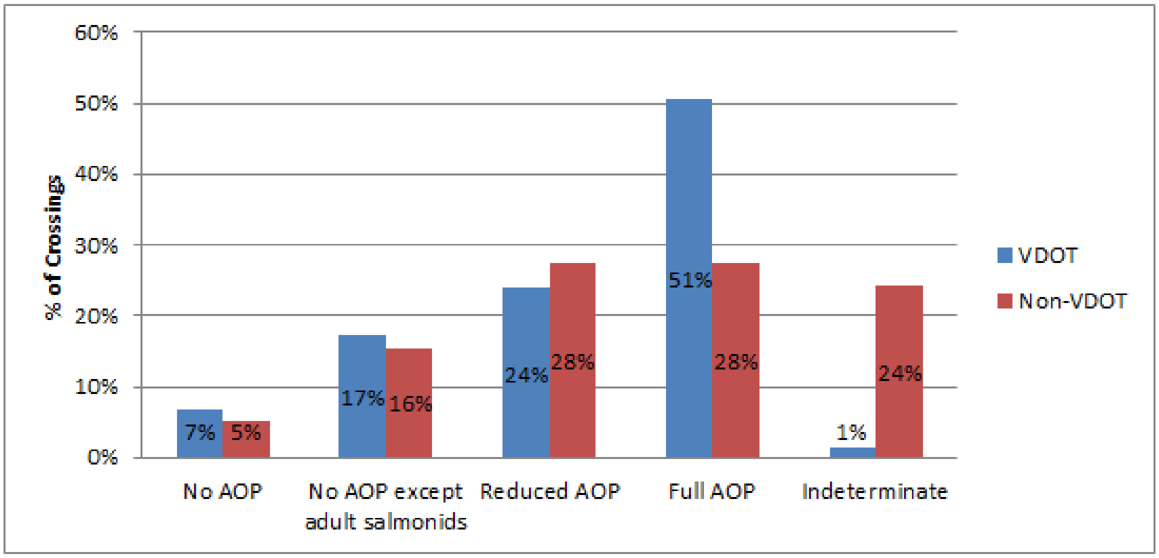
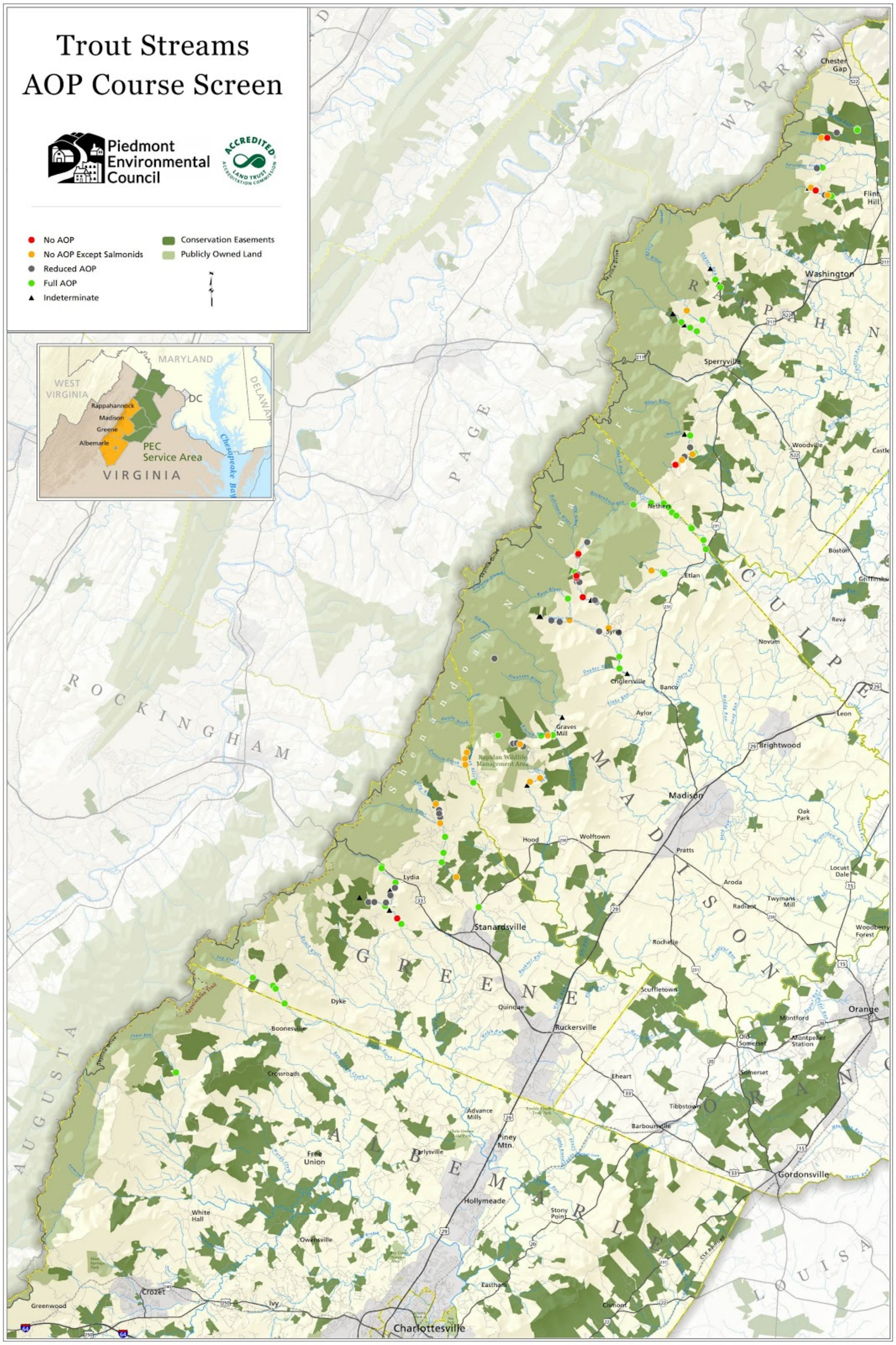


Figure 2. Crossings by AOP Category and Owner


Trout Streams
AOP Course Screen
Piedmont Environmental Council
No AOP
No AOP Except Salmonids
Reduced AOP
Full AOP
Indeterminate
Conservation Easements
Publicly Owned Land
MARYLAND
WEST VIRGINIA
DC
Rappahannock
Madison
Greene
Albemarle
PEC Service Area
VIRGINIA
Chesapeake Bay
WARREN
RAPPAHANNOCK
PAGE
ROCKINGHAM
CULPEPER
MADISON
GREENE
ALBEMARLE
AUGUSTA
ORANGE
LOUISA
Shenandoah National Park
Chester Gap
Flint Hill
Washington
Sperryville
Woodville
Castleton
Nethers
Etlan
Boston
Syria
Criglersville
Banco
Aylor
Graves Mill
Rapidan Wildlife Management Area
Brightwood
Madison
Oak Park
Pratts
Hood
Wolftown
Lydia
Stanardsville
Aroda
Radiant
Twymans Mill
Locust Dale
Rochelle
Scuffletown
Dyke
Quinque
Ruckersville
Boonesville
Montford
Orange
Old Somerset
Montpelier Station
Somerset
Crossroads
Eheart
Tibbstown
Advance Mills
Barboursville
Free Union
Earlysville
Piney Mtn.
Gordonsville
Hollymeade
White Hall
Stony Point
Owensville
Earlysville
Crozet
Ivy
Greenwood
Eastham
Charlottesville

Discussion

AOP barriers were identified on every stream surveyed but two (the Rush and Thornton rivers). While bridges more often occurred at lower elevations, AOP barriers were found at all elevations. Watersheds with more road development generally had more road-stream crossings—and hence greater risk of fragmentation—but the likelihood that those crossings were AOP barriers was no greater than it was for crossings in less developed watersheds. In short, a general pattern of the location of AOP barriers across the entire dataset is not apparent, which points to the need for additional analysis and prioritization among potential barrier removal projects.

At a stakeholder meeting on December 10, 2014, PEC and TU suggested four ways to further prioritize the removal of crossings that provide reduced or no AOP: (1) pursue projects only in watersheds with allopatric populations of brook trout; (2) assign a value of potential stream miles reconnected to each AOP barrier; (3) assign a value to each AOP barrier that describes the stream's VDGIF-designated trout class; and (4) add a field describing the distance of each barrier to Shenandoah National Park or the Rapidan Wildlife Management Area. Of these options, one and two drew the most interest from attendees. A suggestion was also made to consider applying emerging research on the thermal sensitivity of streams to changes in air temperature so as to favor reconnection projects in climate change-resilient watersheds.

PEC and TU intend to more closely evaluate and apply these additional criteria. For the time being, a short list of priorities was developed to support near-term removal opportunities. Crossings 66, 204, 342, 344, and 422 were selected as near term priorities given their structural characteristics, location on streams supporting allopatric brook trout populations, proximity to Shenandoah National Park, and landowner willingness to cooperate. Two of these crossings—204 and 422—are the subject of grant proposals submitted to the National Fish Passage Program in November 2014. Concept-level plans for the removal and retrofit of these crossings were assembled by staff from the USFWS Chesapeake Bay Field Office (CBFO). Significant matching funds have been committed by PEC, CBFO, and landowners for these projects, both of which occur on private land.

A VDOT representative at the December meeting asked for the data associated with all VDOT crossings. PEC and TU will convey this data and a more focused analysis of VDOT AOP priorities under separate cover. Attendees began discussing the potential for rectifying problematic VDOT crossings through its Six Year Improvement Program. PEC's land use staff already participates in this process and is well-positioned to advocate for the removal/retrofit of key AOP barriers. A suggestion was also made that partners could help VDOT with project design and possibly help fund construction (the portion costing more than the less-preferred alternative). This concept merits additional discussion with VDOT and VDGIF.

Significant potential exists to replicate this study elsewhere in Virginia. To PEC's and TU's knowledge, this is the only application of the River and Stream Continuity Project to streams on private land in Virginia. Given its ease of use by interns and volunteers (with some training), and the web mapping and digital data collection applications already developed by PEC, the cost of repeating this work elsewhere could be kept relatively low. Shenandoah National Park staff have already welcomed a similar study on the western (Shenandoah watershed) side of the park. A broader multi-state effort is currently underway to identify and prioritize culverts for removal, which this and future efforts could be rolled into.[11]

Conclusion

Nearly half of surveyed road-stream crossings on brook trout-bearing streams in the Rappahannock River watershed provide no or reduced AOP. The data collected through this project provides the baseline needed to identify which of those would be most strategic to remove for AOP purposes. Plans are underway for the removal of a small subset of privately-owned crossings for demonstration purposes. A companion strategy is under development for the removal of high priority public crossings. The applications (iPad app, web map) developed through this project may be transferable to other road-stream crossings inventories.

Deviations from Original Proposal

In July 2014, PEC's Sustainable Habitat Manager and director of this project resigned from PEC. As a result, the project needed a three-month extension. PEC's Sustainable Habitat Associate served as project director until completion on December 31, 2014.

[11] North Atlantic Landscape Conservation Cooperative, Restoring Aquatic Connectivity and Increasing Flood Resilience -- Hurricane Sandy Mitigation. http://northatlanticlcc.org/projects/aquatic-connectivity/restoring-aquatic-connectivity-and-increasing-flood-resilience-hurricane-sandy-mitigation

Appendix: Aquatic Organism Passage Classification Criteria
Adapted from the Vermont Culvert Aquatic Organism Passage Screening Tool

A. Begin by classifying AOP for **outlets**:

1. A crossing provides no AOP for all aquatic organisms including adult salmonids IF:
   a. The outlet is a free fall AND has an outlet drop greater than or equal to 1'; OR
   b. The outlet is a free fall AND no downstream pool is present; OR
   c. The outlet is a free fall AND pool entrance depth/outlet drop is less than 1; OR
   d. The outlet is a free fall AND water depth in culvert at outlet is less than 0.3'

2. A crossing provides no AOP for all aquatic organisms except adult salmonids IF:
   a. The outlet is a free fall AND has an outlet drop between 0' and 1'; OR
   b. The outlet is a free fall AND a downstream pool is present; OR
   c. The outlet is a free fall AND a downstream pool is present AND pool entrance depth/outlet drop is greater than or equal to 1

3. A crossing provides reduced AOP IF:
   a. The outlet invert is a cascade; OR
   b. The number of culverts at crossing is greater than 1; OR
   c. The structure is partially obstructed; OR
   d. There is no sediment throughout structure

4. A crossing provides full AOP IF:
   a. The culvert outlet invert is at grade or backwatered; AND
   b. The outlet drop is 0'; AND
   c. The number of culverts at crossing is 1; AND
   d. The structure if not partially obstructed; AND
   e. There is sediment throughout the structure

5. For crossings with multiple structures, use least threatening AOP class among its structures to classify the crossing for AOP, i.e. if one culvert is reduced AOP and one is no AOP for all aquatic organisms, categorize the crossing as reduced AOP.

B. For all crossings classified above as providing no AOP for all aquatic organisms except adult salmonids, reduced AOP, or full AOP, apply following criteria to classify AOP based on **inlets**:

6. A crossing provides no AOP for all aquatic organisms including adult salmonids IF the inlet has a drop greater than or equal to 1'

7. A crossing provides no AOP for all aquatic organisms except adult salmonids IF the inlet has a drop between 0' and 1'

8. If a crossing has multiple structures, use least threatening AOP class among its structures to classify the crossing's inlets for AOP, i.e. if one culvert is no AOP for all aquatic organisms except adult salmonids and one is no AOP for all aquatic organisms, classify the crossing's inlets as no AOP for all aquatic organisms except adult salmonids.

C. Adjust AOP classification using inlet criteria:

9. If a crossing's AOP classification for inlets is more threatening than its classification for outlets, apply the inlet classification to the crossing , i.e. if inlet classification is no AOP for all aquatic organisms and the outlet classification is reduced AOP, classify the crossing as no AOP for all aquatic organisms.

10. If a crossing's AOP classification for inlets is less threatening than its classification for outlets, leave the AOP classification based on outlet characteristics in place.

D. Designate all crossings lacking sufficient measurements to classify AOP as indeterminate.