Report to the Chesapeake Bay Trust

GIT Contract 13671

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Culvert Assessment in the Lower James River Basin of Virginia

Road-Stream Crossing Assessments in the Chesapeake Bay Watershed of Pennsylvania

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Table of Contents

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Background

Efforts to mitigate threats to Federal trust species and FWS Region 5 priority species include removal of impediments to fish passage and surrounding habitat restoration. Dams have long been recognized as a contributor to habitat fragmentation, negatively impacting river and stream continuity. Dedicated partnerships within the Chesapeake Bay watershed have worked for decades to reconnect fish populations with their historical migration routes and ensure corridors to beneficial spawning and nursery grounds. Currently, the role of road-stream crossings, in particular culverts, in aquatic ecosystem impairment is causing concern. Our transportation, economic, and societal infrastructures are highly dependent upon road-stream crossings. As urban sprawl and industrialization continues, additional roads and buildings result in further disruption and habitat alteration. Drastic reduction in pervious surface burdens road stream crossings, increasing the risk of failure and jeopardizing the integrity of rivers they cross. Yet, the future existence of interjurisdictional fisheries and other aquatic organisms may be contingent upon strategic retrofit of current barriers and placement and design of new culverts and bridges that are resilient and maintain passage.

The Virginia Fish and Wildlife Conservation Office (VFWCO) administers fisheries management and habitat restoration activities within major tributaries of the Chesapeake Bay including the James River. Nearly 350 miles long and a drainage area of over 10,200 square miles, the river is home to over a third of all Virginians and comprises nearly 25% of the Commonwealth. VFWCO is just one of the Fish and Wildlife Service (FWS) programs participating in the North Atlantic Aquatic Connectivity Collaborative (NAACC) to assess culverts. In addition to the FWS, the University of Massachusetts Amherst, the Nature Conservancy (TNC), and other organizations across 13 states network in

NAACC to utilize online tools and field protocol to standardize data, empowering decision makers to achieve maximum outcomes.

Project Purpose and Prioritization

VFWCO was awarded Chesapeake Bay Trust funding to conduct culvert assessments in the lower James River and evaluate potential barriers to river herring and shad (Figure 1). This drainage was selected in part because no NAACC road-stream crossing data was available, but mainly because the watershed supports historical diadromous fish runs.

A multi-pronged approach was taken to prioritize road-stream crossings in the lower James River. NAACC tiering of HUC12 sub watersheds and individual culverts is derived from specific suites of metrics. Factors considered when determining the severity of barriers to aquatic organisms include:

- potential risk of structure failure,
- impact of failure,
- uncertainty of passability,
- drainage area and,
- slope at crossing.

TNC Atlantic Coast HUC12 Alosine Prioritization involves weighted diadromous fish scenarios for prioritization of HUC12 units. It was incorporated into the NAACC ArcGIS Custom Prioritization Tool. The results produce individual log normalized culvert scores for river herring and American shad. Metrics assessed are:

- water quality,
- population/run counts,
- water quality,
- water quantity,
- habitat quantity and access.

Our focal region encompassed NAACC Tier 1 through Tier 3 prioritized HUC12 sub watersheds, yet further into project planning it was recognized important sites for alosines were also located in NAACC lower priority regions (Figure 2). The diadromous fish model log adjusted (ln) scores assigned to regional culverts were used to prioritize them for assessment in the lower James River drainage. Our prioritization process is discussed here as it was integral to the project scope and will guide the next phase of environmental monitoring at select sites:

1) Download and conversion of state spatial data to WGS1984 UTM17 N projection.
2) Based on fish run data present within historical reports we created layer file with the following counties known to support anadromous fish spawning tributaries in the lower James River Watershed. Some cities, such as Hopewell, were included due to geographic proximity to counties. This narrowed the culverts to search down to just over 3,000.
3) An estimated 100 tributaries and feeder creeks and streams were identified as known, or suspected to have at one time supported anadromous fish spawning from literature and subject matter expert input (Appendix A). We located these streams only within the counties where they have historically been found. This excludes upper reaches of streams unlikely to support spawning and out of our county level search area.
4) Identified unnamed tributaries or other streams that connect these identified streams to James, Chickahominy or Appomattox Rivers and include these as important streams also. For example, Mapsico Creek is listed in the available literature as a historic stream for anadromous fish runs. However, it does not connect directly to the James River, but empties into Kittewan Creek and then into the James. Kittewan Creek is considered a significant tributary even though it is not mentioned in the

literature because fish must pass through Kittewan Creek to reach Mapsico Creek.

5) Identified culverts that intersect important streams. These culverts were considered a priority for assessment. A culvert was considered to be "on" a stream if it was within 50 meters of the NHD flow line spatial data (national data set). This was considered appropriate because streams move over time and major ditches or storm water conveyances leading up to these streams would still have an impact on water quality. At this point 616 culverts for assessment remained.

6) Identified culverts with an Ln Impact Scores of 2.0-9.3. This range of values is assigned by NAACC as increasing in priority rank for potential barriers to alosines. Culverts with a score $\geq$7.0 are considered highest priority as potential barriers to diadromous fish passage. Culverts scoring $\leq$ 2.0 were mostly road ditch crossings or other structures which deemed unlikely to ever offer fish habitat. After this exercise, 381 sites remained spanning federal, state, county, and private jurisdictions in 14 counties and independent cities. Assessments occurred west of Boshers Dam and to the north and northwest of the City of Richmond then along course of the James River into Scotland, Surry County for approximately 75 miles (Figure 1). The scope of this project was 300 culverts, but some culverts were inaccessible due to location on private land or for safety reasons. Priority was placed on impediments closest to the mouth of a stream and on public land. Lower scoring culverts were assessed if they were the first structure on a feeder tributary of James, Chickahominy, or Appomattox Rivers, pending accessibility.

7) Utilized the TNC Chesapeake Bay Fish Passage Prioritization Tool to locate 25 dams on priority tributaries for river herring and shad.

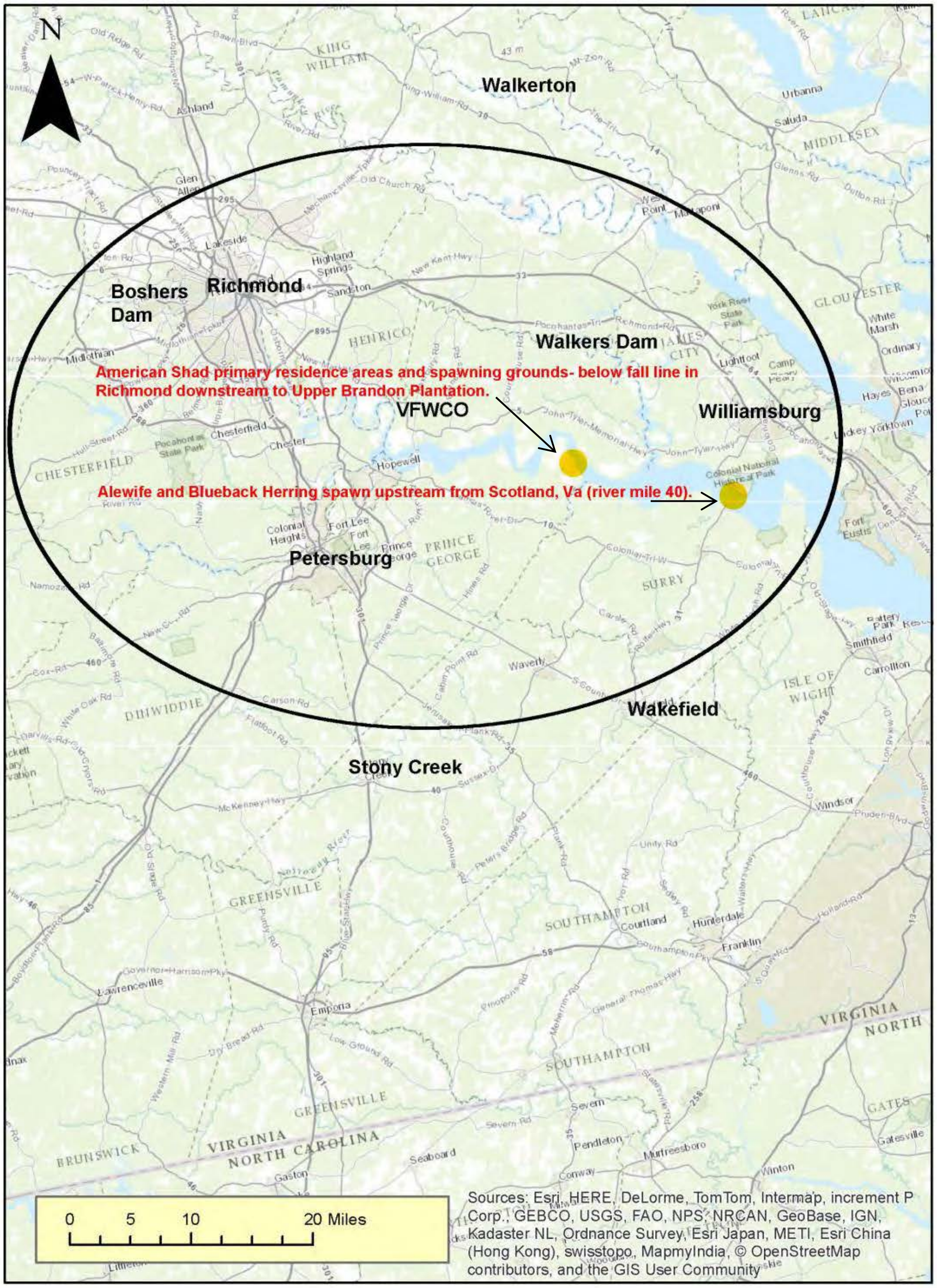


Figure 1. Focal region within 50 miles of VFWCO for culvert assessments in the lower James River watershed.

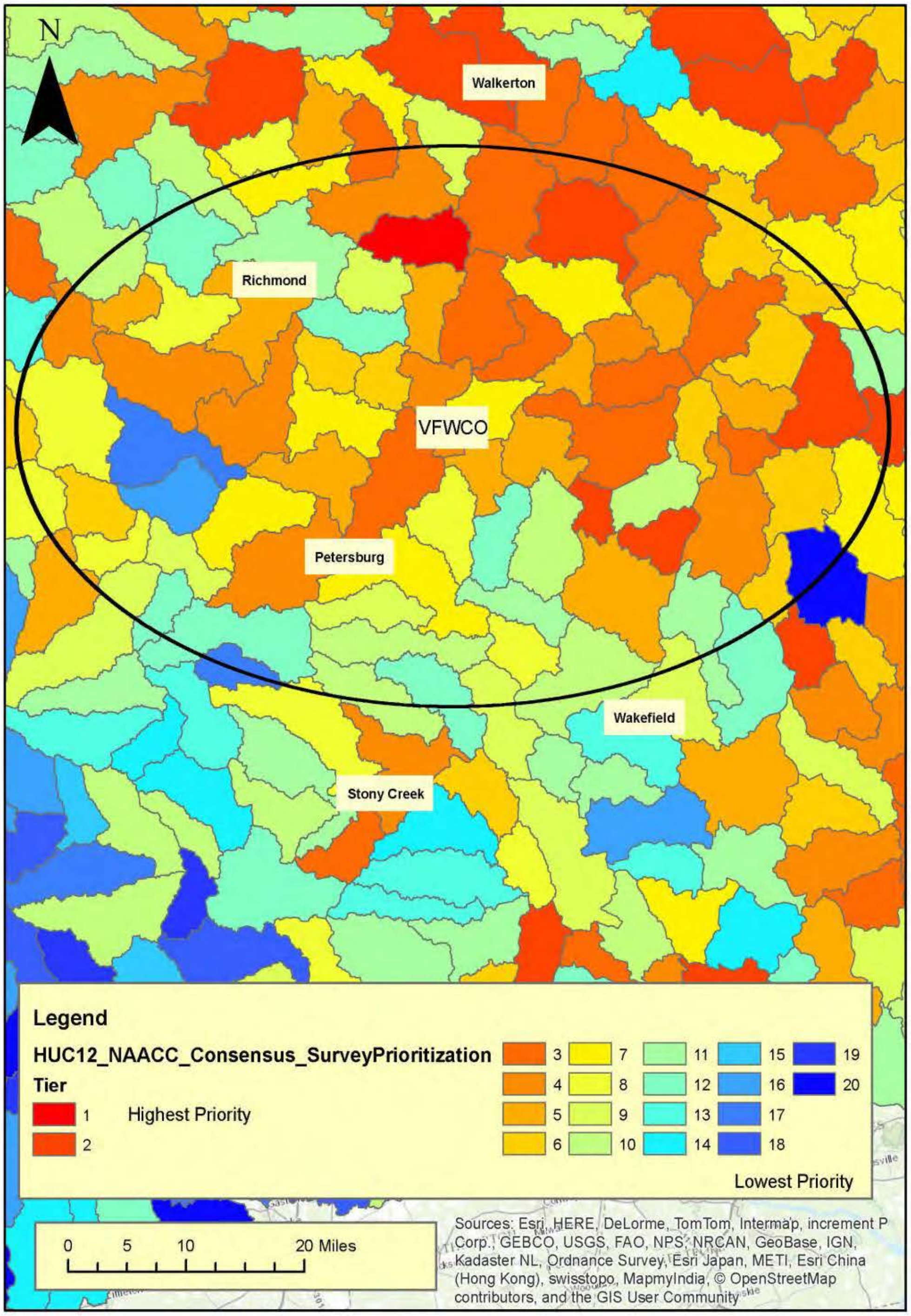


Figure 2. NAACC HUC12 prioritized sub watersheds in focal region for culvert assessments in the lower James River watershed.

Field Data Collection

September 21st through December 9th, 2016

Road-stream crossings were located on the main stem, creeks, streams, and impounded reservoirs of the James River and its major tributaries, the Appomattox and Chickahominy Rivers. A large map of priority tributaries and crossings overlaid with a grid was produced as a banner and displayed for daily planning of field work. Grid squares served as individual georeferenced maps and were printed and uploaded to an iPad Pro to facilitate navigation (Appendix B). Approximately 2,000 miles were logged in travel to and from sites. Sites were assessed on public, private, and Federal lands, including the National Park Service and Ft. Lee, and state agency areas, i.e. Chickahominy Wildlife Management Area. Information was collected employing the NAACC protocol. Staff trained online and in the field to become NAACC certified as lead observers and/or L1 or L2 coordinators. A minimum of two individuals were present at each survey site to meet data and safety requirements. Lisa Moss, Alicia Garcia, and Grace Whitehurst, with the much appreciated assistance of Albert Spells,Thomas Hoffman, Mandi Caldwell, and Virginia Department of Game and Inland Fisheries staff Alan Weaver, Kirk Dunn, and Robert Willis completed 319 assessments. Alicia and Grace also provided invaluable assistance with GIS mapping and data processing.

Most crossings were assessed in low-flow conditions, though record rainfall preceding September fieldwork caused limited to no accessibility in some instances. Unsafe conditions such as fast and steady traffic areas, deep water, and steep ravines observed at highways and railroads, as well as structures too large for physical measurement using equipment available, prevented complete data collection for some road-stream crossings. In most cases, large structures were classified by NAACC as bridge adequate. Sites requiring walking with equipment over a ¼- ½ mile and through very dense forest or thick brush were not completed either.

On occasion, on-the-spot permission was granted to assess culverts on private property. Trimble Terrain Navigator Pro® GIS application assisted in obtaining land parcel information. A spreadsheet was created listing the landowner contact information, and culvert location coordinates. At least 50% of the owners are timber companies or affiliates thereof. Public outreach conducted was on- site communication and mailed correspondence. The NAACC fact sheet and a request for site access were sent out to contacts. To date we have not received any responses. All field data collected was organized in Microsoft® Excel and uploaded into the NAACC database contributing to a total of 2,244 entries statewide.

Findings

Alosine Prioritization of Road-Stream Crossings and Crossing Type

A total of 319 crossings were assessed in the lower James River drainage during the fall of 2016. All, except five discovered in the field and assessed, had individual culvert scores assigned to them from the Alosine Prioritization model independent of NAACC Aquatic Passability Scores (Figure 3). Average Ln Impact Score for 314 crossings is 4.60. Twenty-two planned priority sites, nine being of highest priority (Ln Impact Score 7.0- 9.3) were not assessed due to posted signage clearly prohibiting trespassing.

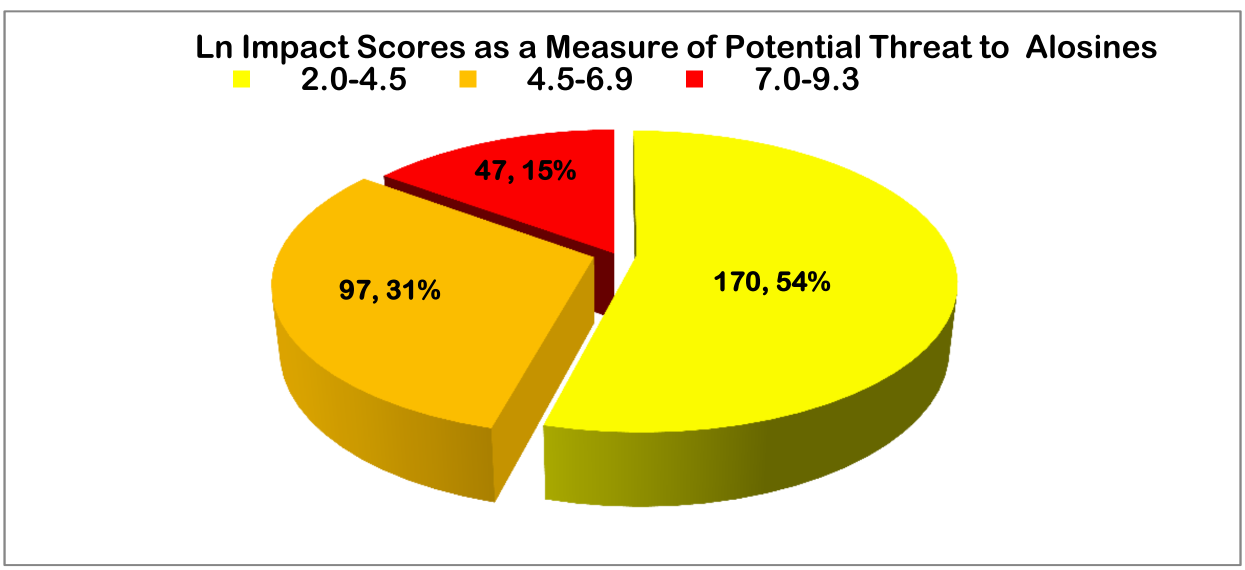


Figure 3. Priority crossings assessed in the lower James River drainage.

About four percent of NAACC crossings were evaluated as inaccessible while at their physical location or en-route by viewing satellite imagery in Google Maps™ and Terrain Navigator Pro®. These included attempted crossings on private property and those located several miles from a main or paved road. Railroad crossings with no reasonable access route and clogged, collapsed, and submerged culverts were also categorized by NAACC and entered into the database as inaccessible or partially inaccessible. At times no crossings (12 entries) could be found at or within proximity to the GPS coordinates associated with a structure. Removed crossings (two entries) existed previously, but now the stream flows through site. Inaccessible sites included two planned NAACC culverts observed in the field as a dam on Little Creek, a Chickahominy River tributary and the other a water control structure for an impoundment on Chappell Creek, a priority tributary of the James River. Ninety-nine (31%) bridges and one ford were assessed. Four types of culverts–round, pipe arch/elliptical, open bottom arch bridge/culvert and box -comprised 55% of all crossings evaluated (Figure 4).

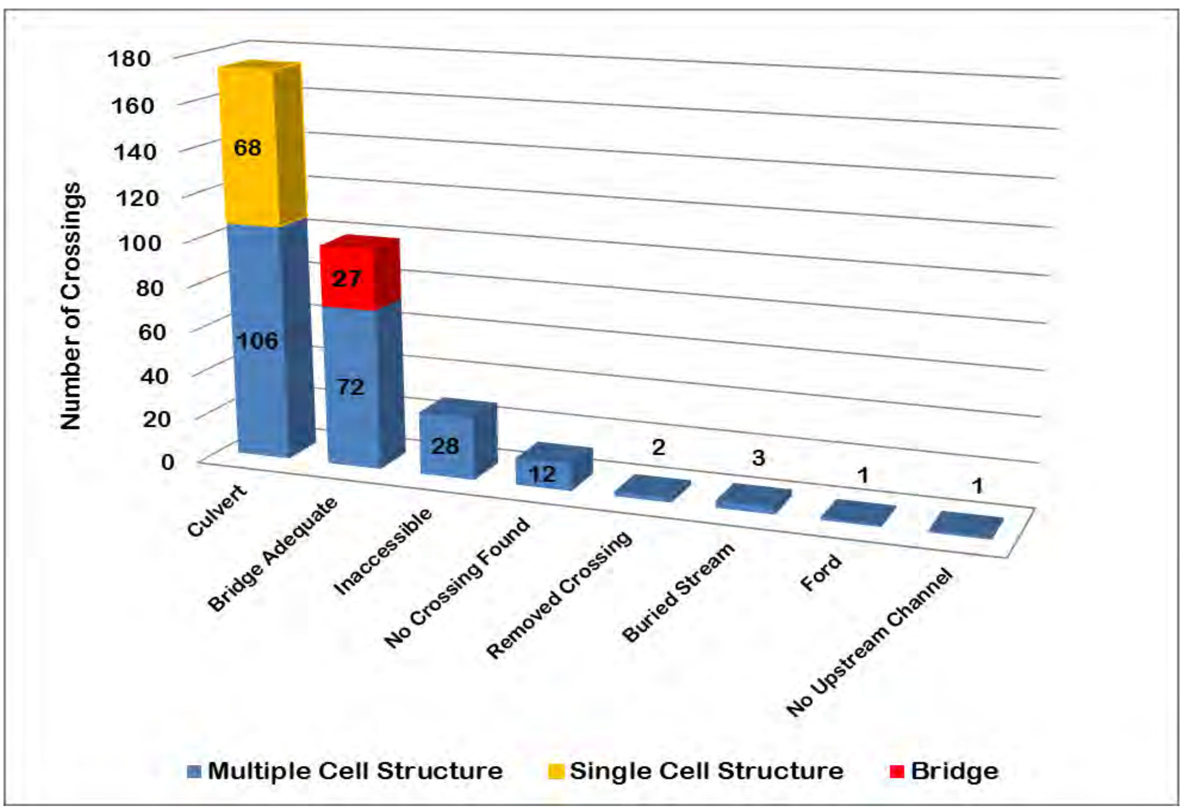


Figure 4. NAACC road-stream crossings assessed in the lower James River drainage.

NAACC Scoring Systems

NAACC Coarse Screen

The coarse screening tool utilized in NAACC classifies structures into one of three categories: Full AOP (Aquatic Organism Passage), Partial AOP, and No AOP. The main purpose of the coarse screen is to identify road-stream crossings likely to pose a barrier to most or all species and those likely to provide full aquatic organism passage (Appendix E). Thirty-six percent (116) of priority culverts assessed were evaluated by NAACC as providing Full AOP, 34% (108), Reduced AOP, and 16% classified as No AOP (Figure 5). There were a number of crossings for which no AOP score was produced due to database entry of no upstream channel, a removed or non-existent crossing, inaccessibility, and key missing data (marked as unknown) from field form.

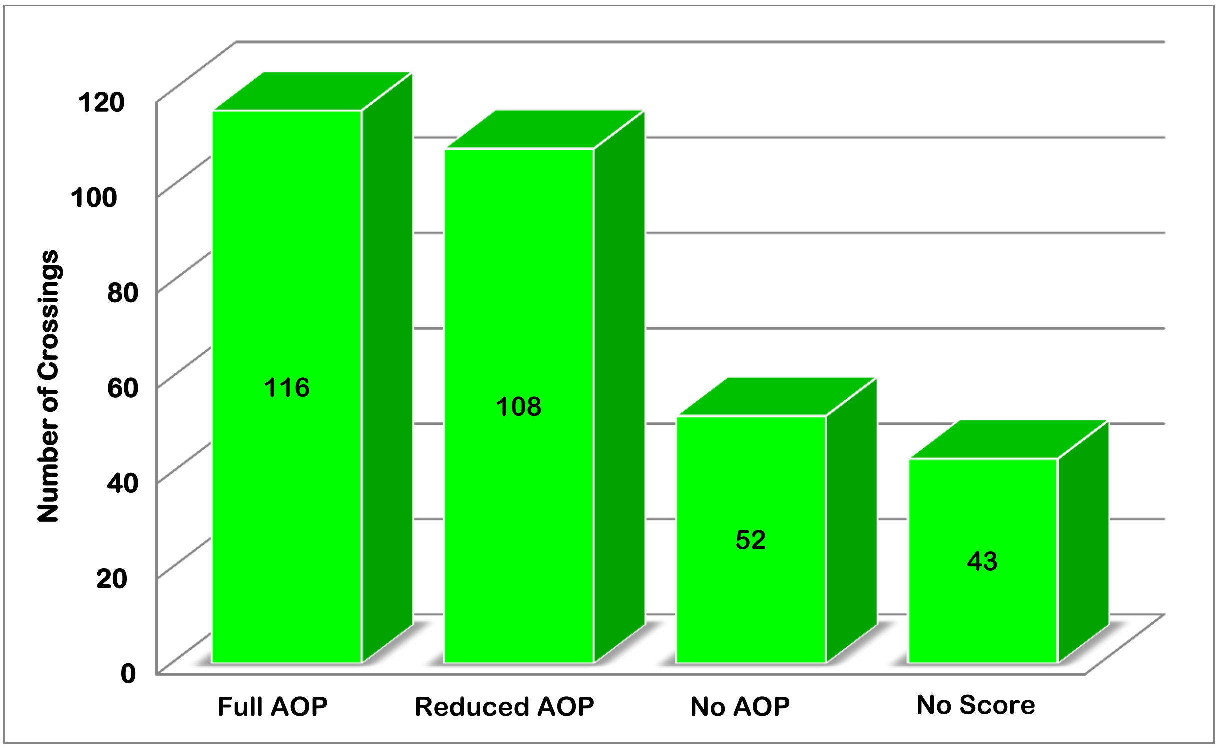


Figure 5. AOP status of priority road-stream crossings assessed.

NAACC Numeric Scoring System

The NAACC Numeric Scoring System is a more precise measure of aquatic passage and uses an algorithmic method to generate the Aquatic Passability Score - the degree to which a crossing deviates from an ideal. There are 13 variables, addressed on the field data form, used to assign a final score to a culvert including those important for assessment at time of survey and those providing indirect evidence of likely conditions at higher flows (NAACC 2016):

- **Outlet Drop: Outlet drop is based on the variable Outlet Drop to Water Surface unless the value for Water Depth Matches Stream = “Dry” in which case outlet drop is based on the variable Outlet Drop to Stream Bottom. When an outlet drop is above a certain size, it becomes the predominant predictor of passability.**

- **Physical Barriers: This variable covers a wide variety of circumstances ranging from obstructions to dewatered culverts or bridge cells that represent physical barriers to aquatic organism passage.**

- **Constriction: The relative width of the crossing compared to the width of the stream. “Severe” = <50%, “Moderate” = 50-100%; other options include “Spans Only Bankfull/Active Channel” and “Spans Full Channel & Banks.” Constriction is an indirect indicator of potential velocity issues at higher flows.**

- **Water Depth: Water depth in the structure relative to water depths found in the natural channel at the time of survey.**

- **Water Velocity: Water velocity in the structure relative to water velocities found in the natural channel at the time of survey.**

- **Scour Pool: Presence/absence of a scour pool at the crossing outlet and size relative to the natural stream channel. Scour Pool is an indirect indicator of potential velocity issues at higher flows. Scour pool is** included solely as an indicator of velocities at higher flows. It is not based on the effects of the pool itself which can actually be positive for fish passage.

- Substrate Matches Stream: An assessment of whether the substrate in the structure matches the substrate in the natural stream channel. Substrate Matches Stream is used to evaluate how a discontinuity in substrate might inhibit passage for species that either use substrate as the medium for travel (e.g., mussels) or require certain types of substrate for cover during movements (e.g., crayfish, salamanders, juvenile fish).

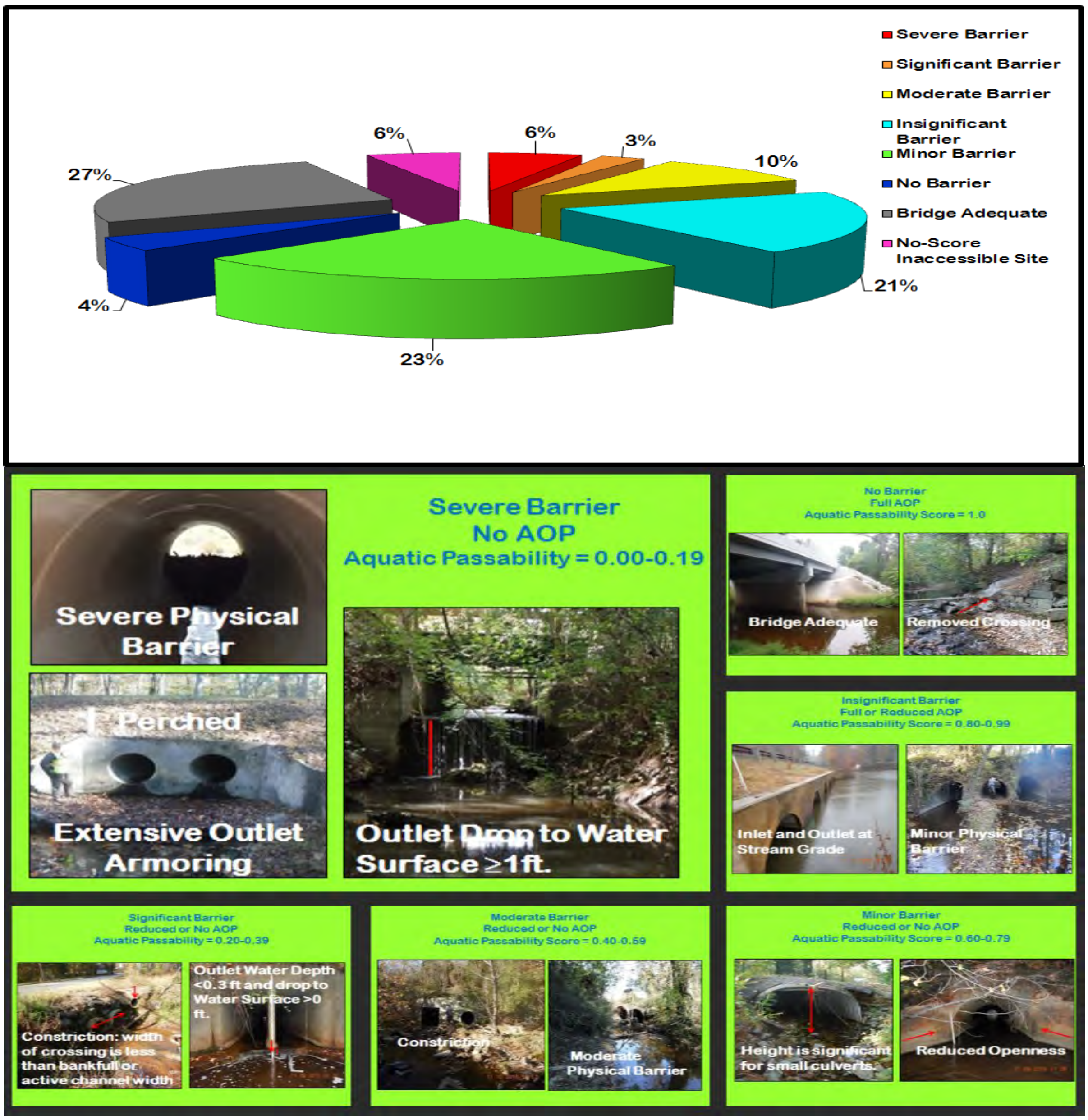


Figure 6. NAACC prioity road-stream crossing evaluation in lower James River drainage.

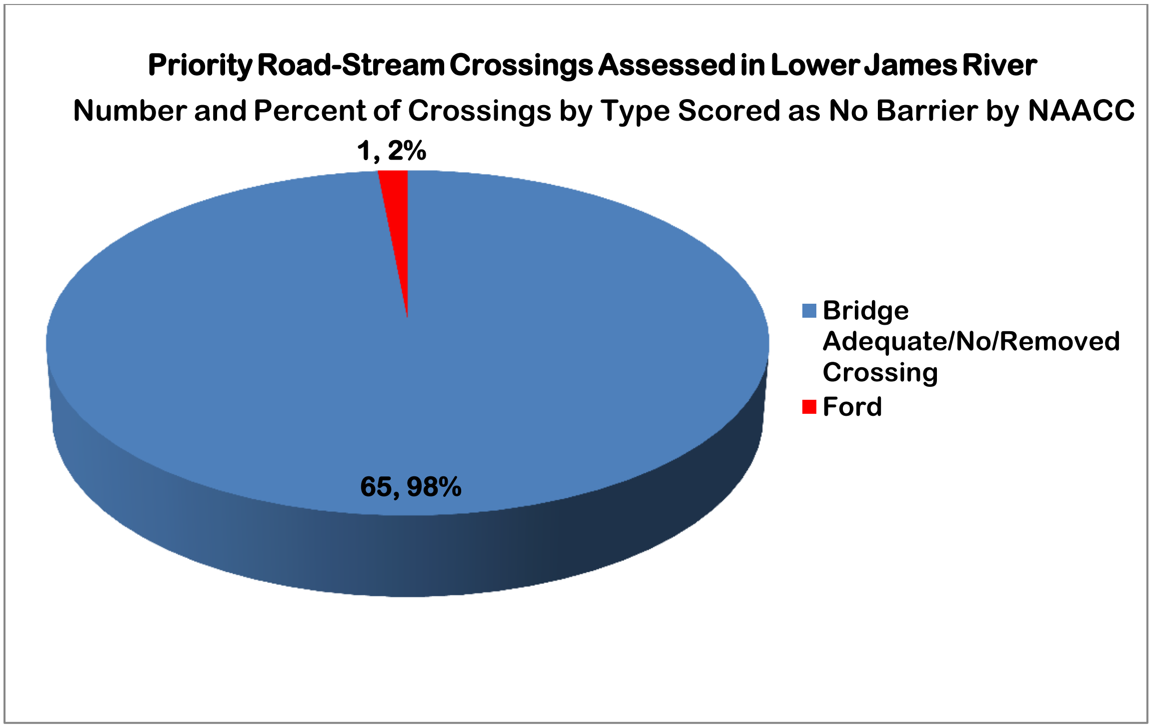


Figure 7. Road-stream crossing types scored in NAACC as No Barrier.

The No Barrier (AP Score=1.0) ranking includes bridge adequate structures, fords, and no crossing found at a planned site. The assumption is they allow for Full Aquatic Passage (AOP). One unarmored ford was assessed in a powerline area as a shallow open crossing in which vehicles could cross over to continue on access trail. Sixty-five bridges made up 98% of No Barrier entries (Figure 7). Remaining bridges were either not scored or scored as Insignificant Barrier.

Figure 8. At and downstream of ford in Proctors Creek, tributary of the James River.

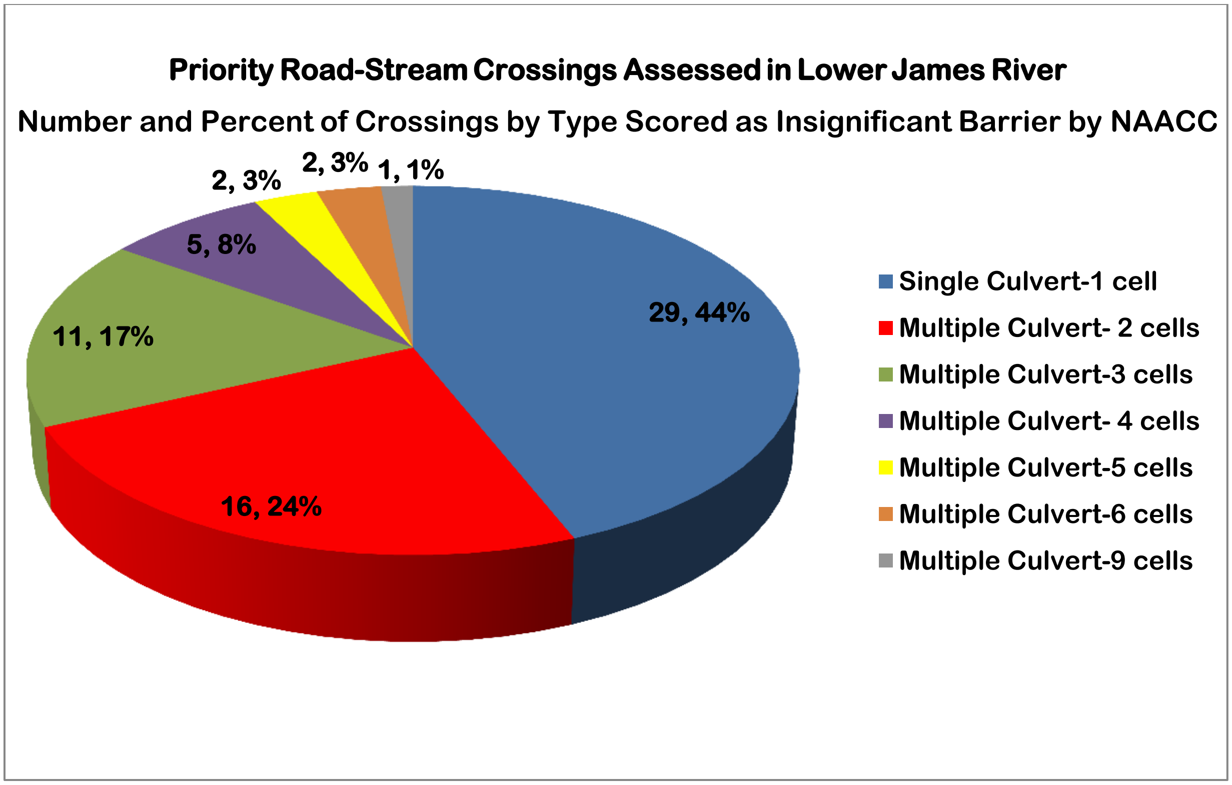


Figure 9. Road-stream crossing types scored in NAACC as Insignificant Barrier.

Multiple culvert refers to a structure having multiple cells or multiple structures at a crossing situated close to each other. Insignificant Barriers (AP Score=0.80-0.99) have Full or Reduced AOP. Fifteen percent of crossings scored as Insignificant Barriers and included bridges and medium to large culverts with multiple cells (openings). Multiple culverts include round culverts, box and bottomless culverts as overpass structures for railroads, interstate/main, and secondary roads. Culverts with one (44%) and two cells (24%) comprise the majority of Insignificant Barriers. Three cell culverts represented 17% (Figure 9).

Figure 10. Insignificant barrier and Full AOP.

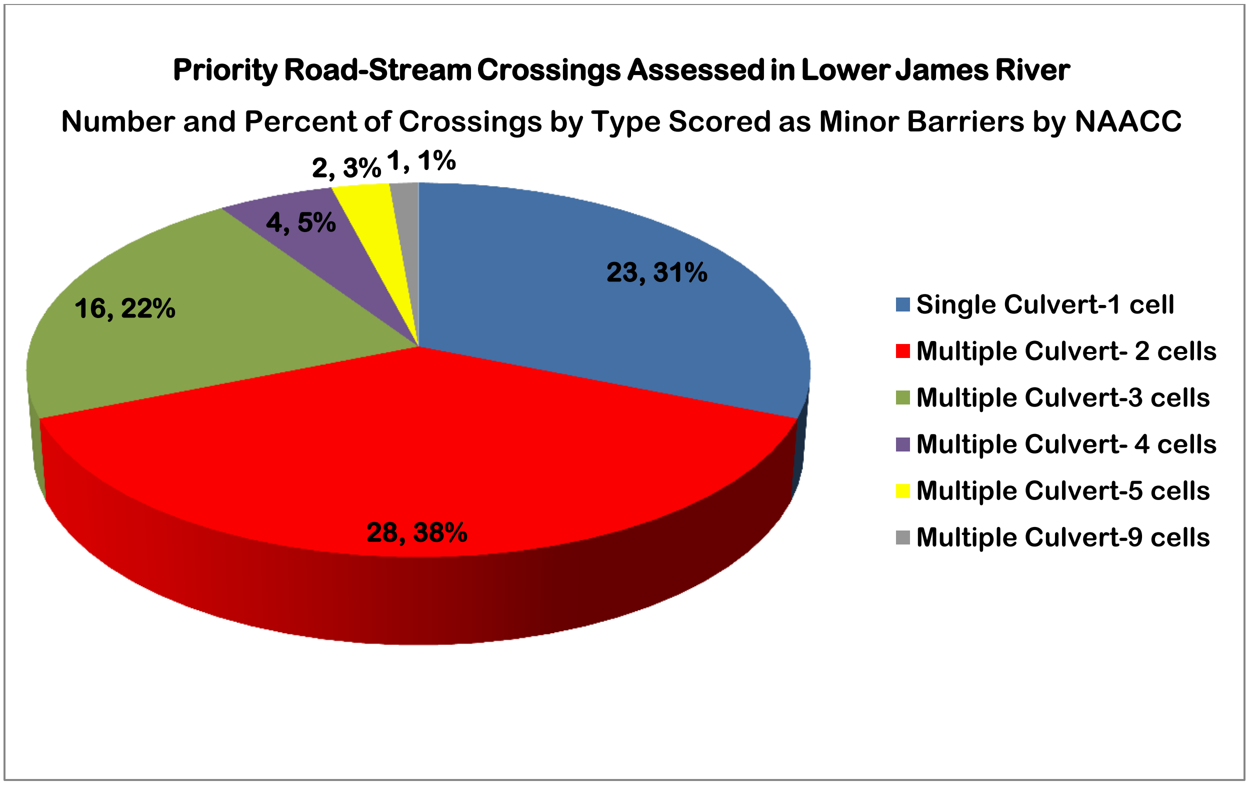


Figure 11. Road-stream crossing types scored in NAACC as Minor Barriers.

Crossings scored as Minor Barriers (AP Score=0.60-0.79) have Reduced or No AOP. Medium to large culverts with multiple cells represented nine percent of Minor Barriers. Both five and nine cell structures were distributed similarly as Insignificant and Minor Barriers at three and one percent, respectively. Large culverts included overpass structures for railroads, interstate/main, and secondary roads. Single cell culverts with one (31%) and two cells (38%) comprise the majority of minor barriers. Three cell culverts represented 22% of minor barriers.

Figure 12. Moderate Barrier and Reduced AOP.

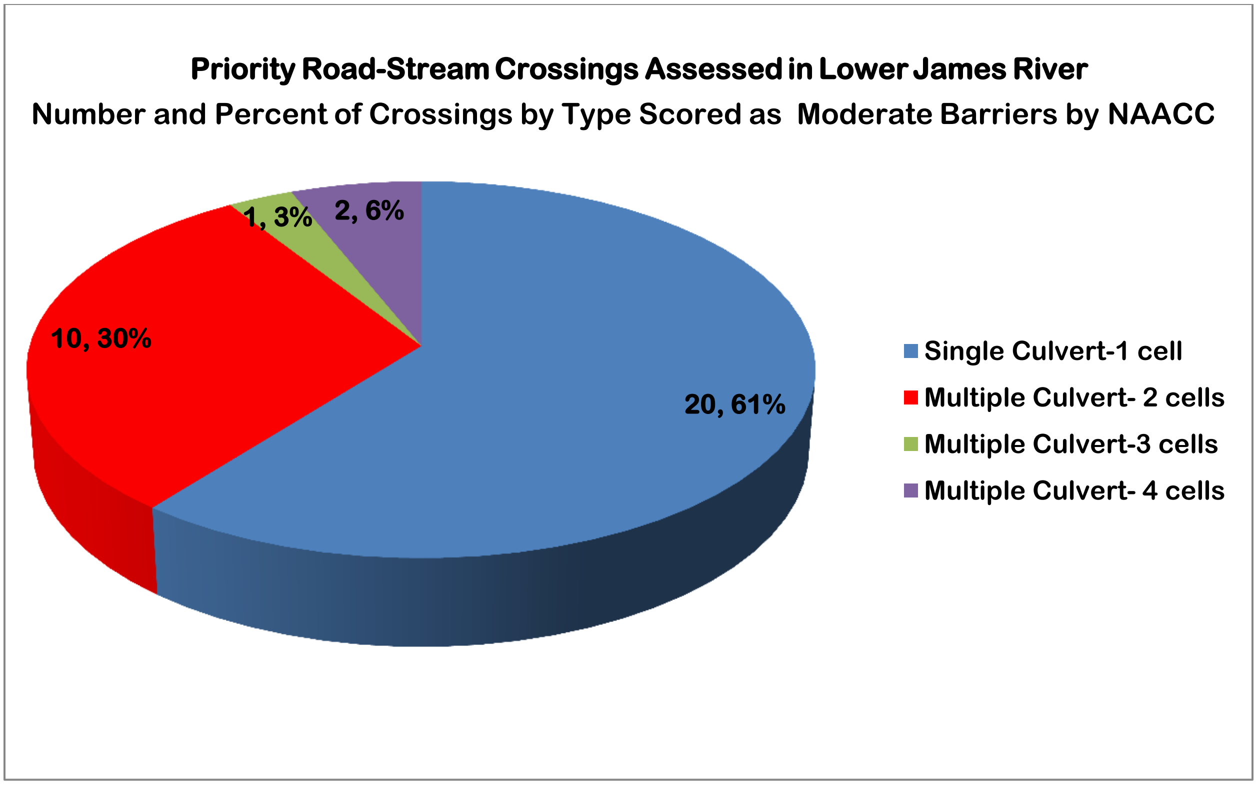


Figure 13. Road-stream crossing types scored in NAACC as Moderate Barriers.

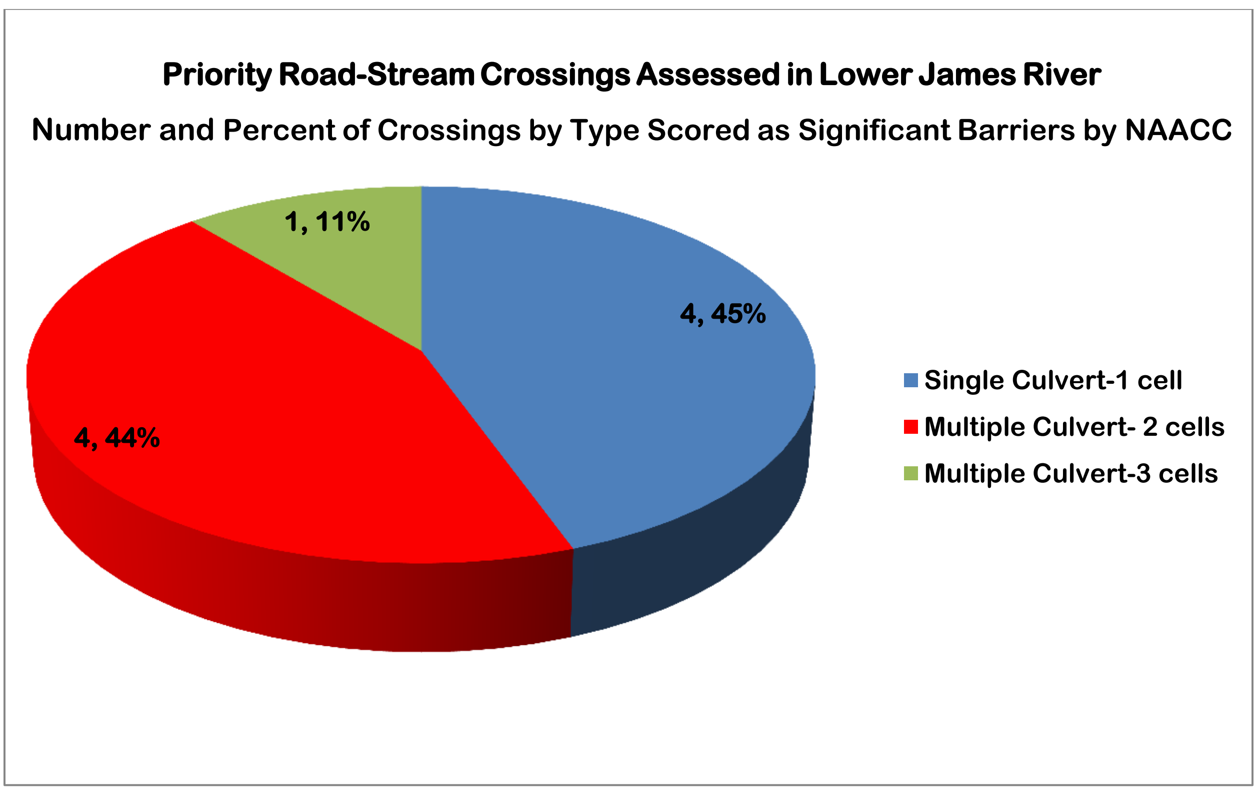


Figure 14. Road-stream crossing types scored in NAACC as Significant Barriers.

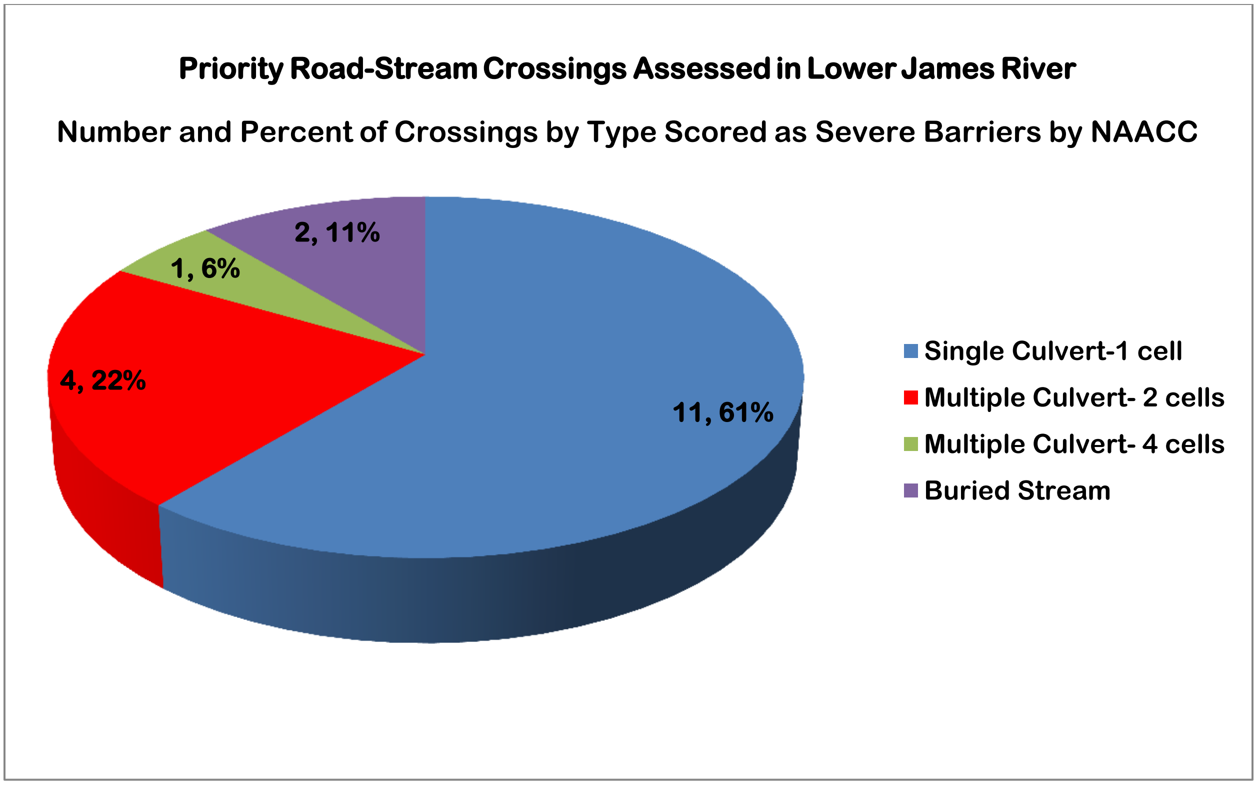


Figure 15. Crossing types scored in NAACC as Severe Barriers (AP Score=≤0.19).

Thirty-three crossings ranked as Moderate Barrier (AP Score0.40-0.59) and nine crossings ranked as a Significant Barrier (AP Score=0.20-0.39) resulting in Reduced or No AOP. Severe barriers represent < 6% (18) of all crossings assessed, two of which are buried streams. Single cell culverts represented the majority of all Moderate Barriers (61%), Significant (45%), and Severe Barriers (61%). No Aquatic Passability Scores were generated for 34 crossings due to reasons stated earlier.

Figure 16. Severe Barrier and No AOP.

Tidal Sites

The James River drainage is considered tidal east of the fall line in Richmond, Virginia to the mouth, where it connects to the Chesapeake Bay. Tributaries feeding directly into the James, Appomattox, and Chickahominy Rivers can experience significant tidal influence and it is in these regions where culverts could be hindering passage. There were 22 tidal sites assessed throughout the tide cycle and 10 (45%) were bridges categorized as No Score/Missing Data. The recent NAACC database update now scores bridge adequate structures as No Barrier. Four culverts scored as potential barriers at both low and high tides on priority spawning tributaries- Yarmouth Creek, Barnes Swamp, Manchester Run, and Mill Creek (Figure 17). River herring ascend small creeks and streams to spawn and may be hindered by the presence of box culverts. In the next phase of this project, there will be visits to culverts scored as moderate and significant barrier crossings to gain insight concerning current habitat utilization and determine if a long-term monitoring plan would be of benefit (Appendix J).

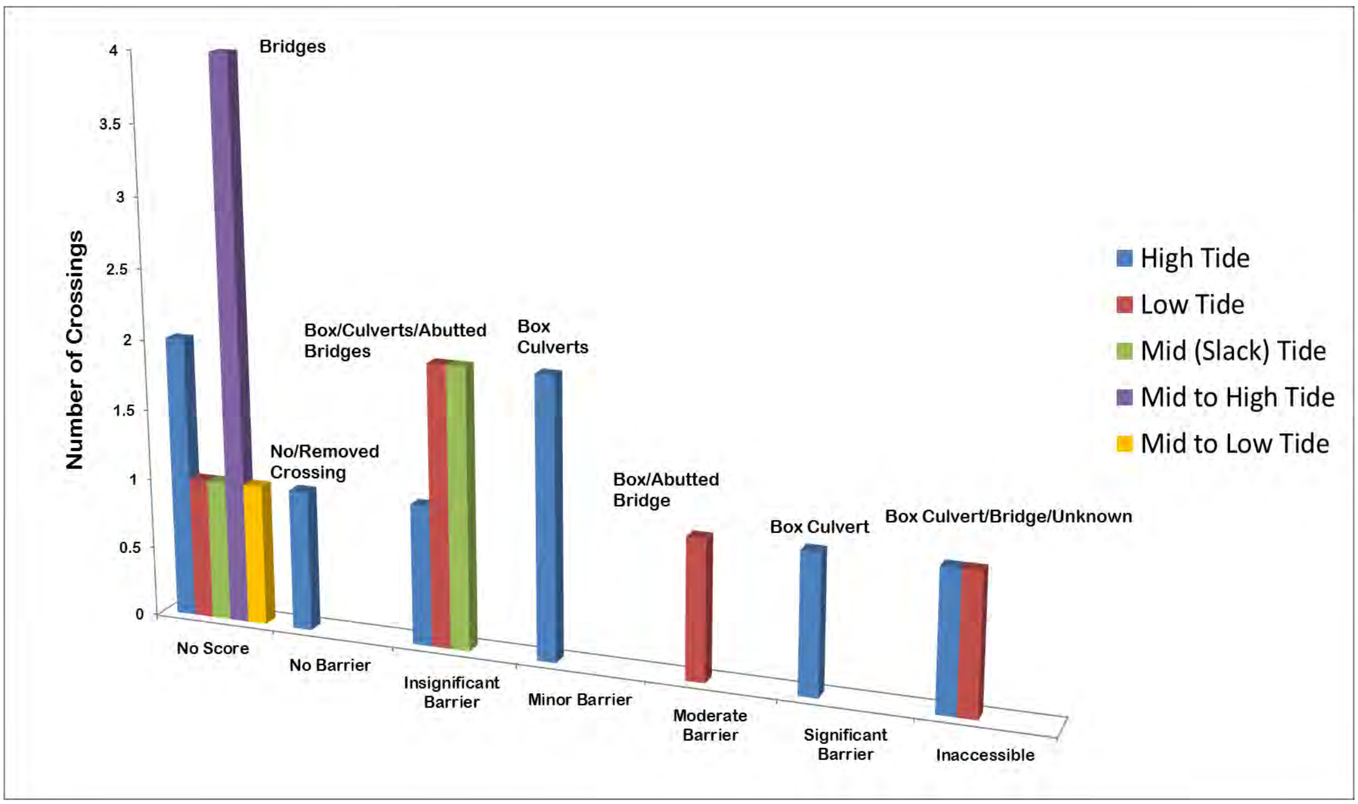


Figure 17. NAACC Ranking of Tidal Sites Assessed in the Lower James River drainage.

Discussion

The NAACC Coarse Screen and the Numeric Scoring System are broad in scope evaluating passability for a range of aquatic organisms, and not one group, i.e., migratory fish. This fact is behind the rationale for incorporating the Alosine Prioritization Model into prioritization of road-stream crossings in the lower James River. The question then becomes what is the relationship between Aquatic Passability Scores and actual fish passage. The answer is unknown at this time, but is relevant to our efforts to address culverts as potential impediments to fish movement. Moderate, significant, and severe barriers combined constitute 21% of all crossings given an Aquatic Passability Score, yet 58% demonstrate Reduced or No AOP. Interestingly, 55% of crossings assessed were culverts with 64% being of one cell (single opening). These results within 10 percentage points of each other lead us to consider more closely the influence culvert shape-round and elliptical versus square or slightly rectangular-may be having on fish passage. What is good for a turtle is not necessarily good for a fish. Results suggest round culverts are responsible for the majority of moderate, significant, and severe barriers according to NAACC. Two celled structures such as a box culvert unit and two round/elliptical culverts placed varying distances from one another are examples of second most prevalent barriers. Culverts assessed were constructed of concrete, stone aggregate, corrugated metal and plastic, and combinations thereof. Investigation of the interior surface texture and material as affecting water velocity and fish movement through a culvert may be worthwhile. Outlet drop, placement of a culvert in relation to the water surface and bottom of a stream, is an important metric in the NAACC Coarse Screen and the most heavily weighted metric for determining a culvert’s aquatic passability. Inappropriate culvert shape and placement in addition to culvert size would increase risk of crossing failure from both human and hydrological stress. Attention should be given to culverts on ephemeral streams that are prone to flash flooding and erosive stormwater events. Since there is overlap between crossing classifications

Reduced AOP and No AOP, and score based ranking as minor, moderate, and significant barriers, we will begin to look closer at individual culverts to determine how passability at a crossing correlates with the alosine ln impact score. Multiple culverts disrupting continuity in a lower order stream are also of interest.

It is our intention to continue the road-stream crossing assessment project in the lower James River by expanding the field data collected to develop a better understanding of how culverts may be interrupting upstream passage of anadromous fish populations and affecting proximate aquatic communities. Next steps include investigation of assessed culverts ranked as severe and significant barriers, and in some cases moderate and minor barriers depending on their location. Some crossings scored as lower priority for alosine (Ln Impact Score 2.0-4.5), yet ranked as Reduced or No AOP (Appendices G-L). NAACC variables such as outlet drop, water depth, water velocity, and substrate coverage within a structure, particularly during spawning season, may be of critical importance to anadromous fishes. We plan to further prioritize culverts to identify potential fish barriers and will compare our NAACC data with documented impediments to spawning migrations.

Since May of 2017, VFWCO in coordination with the Izaak Walton League of America's Virginia Save Our Streams program and the James River Association, has been conducting benthic macroinvertebrate sampling downstream of NAACC crossings scored as potential barriers (Appendix F). Biological stream health assessment at 35 select sites is planned to help evaluate the impact culverts (e.g. channelization) may be having on aquatic habitat in a stream reach. Culverts assessed thus far were assigned a VA SOS multimetric index score to determine ecological condition. We hope to work with a partnering institution to develop a molecular marker for river herring in the James River drainage to conduct environmental DNA sampling as an additional tool for addressing barriers to passage.

References

Davis, J., J.P. Miller, and W.L. Wilson. 1970. Biology and Utilization of Anadromous Alosids. Virginia Institute of Marine Science, Anadromous Fish Act (P.L. 89-304), Project VA AFC-1, Completion Report, Gloucester, Va.

NAACC. 2016. Scoring Road-Stream Crossings as Part of the North Atlantic Aquatic Connectivity Collaborative (NAACC), November 2015. Available: https://www.streamcontinuity.org/pdf_files/Aquatic_Passability_Scoring.pdf.

NAACC. 2016. NAACC Aquatic Connectivity Stream Crossing Survey Data Form. Available: https://streamcontinuity.org/pdf_files/NAACC%20Stream%20Crossing%20Survey%20%20Field%20Form%20052616.pdf.

NAACC. 2016. NAACC Stream Crossing Survey Data Form Instruction Guide, Version 1.2- May 2016. Available: https://streamcontinuity.org/pdf_files/NAACC_Instructions%20for%20Field%20Data%20Form%205-22-16.pdf.

Odom, M.C., R.J.Neves , J.J. Ney, and J.M. Mudre. 1986. Use of Tributaries of the Lower James River by Anadromous Fishes. Virginia Polytechnic Institute and State University, Final Report to the Virginia Highway Research Council, Blacksburg, Va.

The Nature Conservancy. 2013. Chesapeake Bay Fish Passage Prioritization Tool. Available: http://maps.tnc.org/EROF_ChesapeakeFPP/.

The Nature Conservancy. (n.d.). NAACC ArcGIS Custom Prioritization Tool. Available: https://tnc.app.box.com/s/vob8eep7s4k4xif4j2aoe3bb1k8lfp86.

Virginia Department of Game and Inland Fisheries. 2016. Hampton Roads (Sewells Pt.) Tide Table and Tide Correction Table in Virginia Wildlife 2016 Calendar.

Appendix A. Important Spawning Tributaries for Fish Passage.

Historical and Current Spawning Tributaries of Anadromous Fish along Lower James River		
Stream Identified in Literature Reviewed	**Stream Identified in Model**	**Comments / Why Included**
Almond Creek (JR)	Almond Creek	identified in literature
Appomattox River	Appomattox River	identified in literature
Ashton Creek (AR)	Ashton Creek	identified in literature
Baily Branch (JR)	included in James River data	identified in literature
	Back River	connects significant stream to James River
Barnes Swamp (CR)	Barnes Swamp	identified in literature
Barrows Creek (CR)	Barrows Creek	identified in literature
Beaverdam Creek (CR)	Beaverdam Creek	identified in literature
Billy Creek (JR)	Billy Creek	identified in literature
Blackstump Creek (CR)	Blackstump Creek	identified in literature
Brandon Gut (JR)	Brandon Gut	identified in literature
Bullhill Creek (AR)	Bullhill Run	identified in literature
	Cabin Creek	connects significant stream to James River
Chappell Creek (JR)	Chappell Creek	identified in literature
Chickahominy River	Chickahominy River	identified in literature
Coles Run (JR)	Coles Run	identified in literature
Cornelius Creek (JR)	Cornelius Creek	identified in literature
Courthouse Creek (JR)	Courthouse Creek	identified in literature
Crooked Branch (JR)	Crooked Branch	identified in literature
Cross Creek (JR)	Cross Creek	identified in literature
Curles Neck Creek (JR)	Curles Creek	identified in literature
Dark Swamp (JR)	Dark Swamp	identified in literature
Deerlick Branch (JR)	Deerlick Branch	identified in literature
Diascund Creek	Diascund Creek	identified in literature
Edwards Swamp (CR)	Edwards Swamp	identified in literature
Eppes Creek (JR)	Eppes Creek	identified in literature
Eppes Island Creek (JR)	included in Eppes Creek data	identified in literature
Falling Creek (JR)	Falling Creek	identified in literature
Farrar Island Oxbow (JR)	included in James River data	identified in literature
Flowerdew Hundred Creek (JR)	Flowerdew Hundred Creek	identified in literature
Fourmile Creek (JR)	Fourmile Creek	identified in literature
Gillies Creek (JR)	Gillies Creek	identified in literature
Gordon Creek (CR)	Gordon Creek	identified in literature
Gravelly Run (JR)	Gravelly Run	identified in literature
Grays Creek (JR)	Grays Creek	identified in literature
Great Branch (JR)	Great Branch	identified in literature
Grindall Creek (JR)	Grindall Creek	identified in literature
Gunns Run (JR)	Gunns Run	identified in literature
Harrison Branch (AR)	Harrison Branch	identified in literature
	Hatcher Run	connects significant stream to James River
Hatcher Island Oxbow (JR)	included in James River data	identified in literature

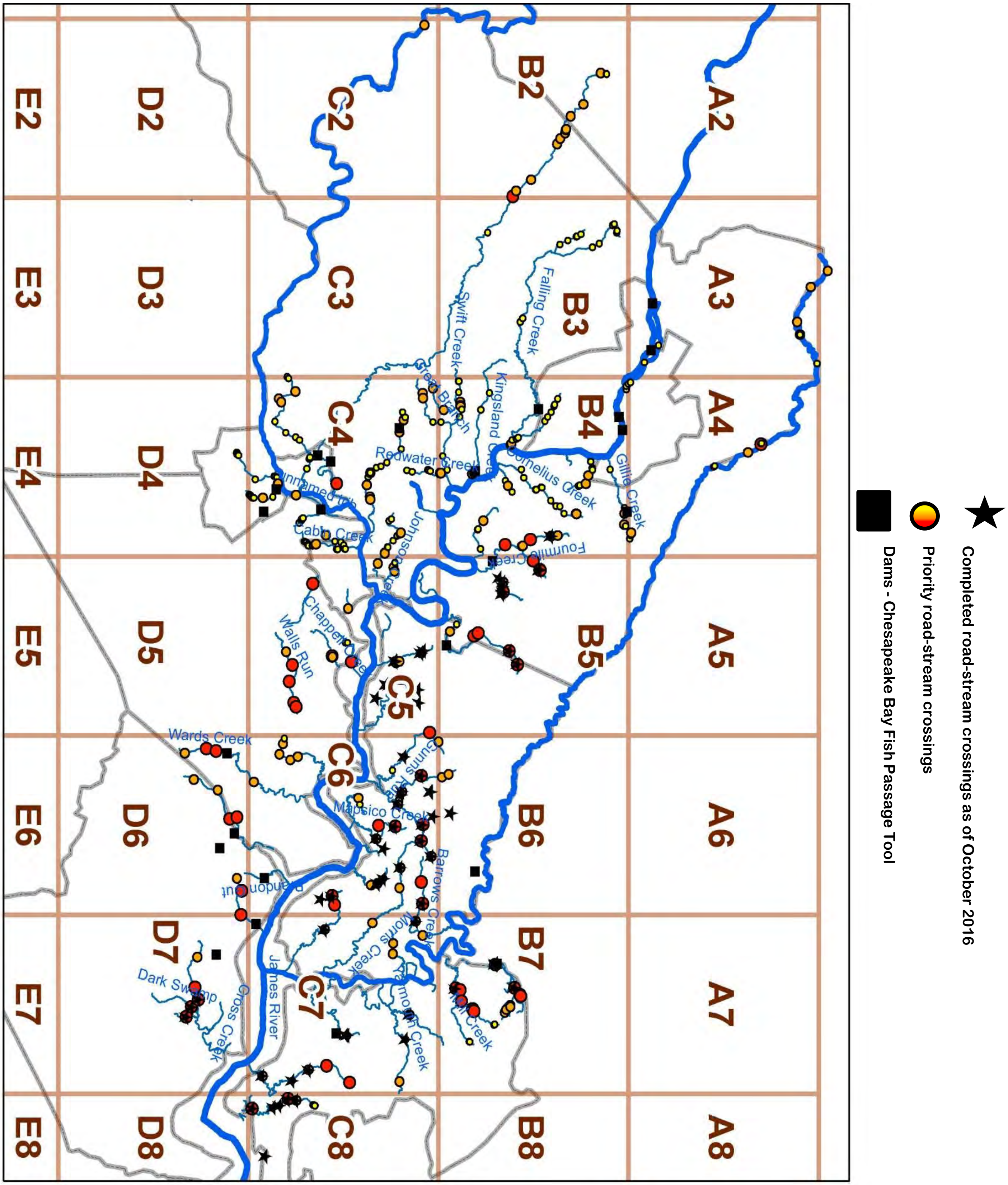
Appendix A. Important Spawning Tributaries for Fish Passage (cont'd).

Haystack Gut (JR)	Haystack Gut	identified in literature
Herring Creek (JR)	Herring Creek	identified in literature
Hog Neck Creek (CR)	Hog Neck Creek	identified in literature
Hulls Slash Gut (JR)	Hulls Slash Gut	identified in literature
James River	James River	identified in literature
	James River and Kanawha Canal	part of James River dataset
	James River Old Channel	part of James River dataset
Jenny Creek (JR)	Jenny Creek	identified in literature
Johnson Creek (AR)	Johnson Creek	identified in literature
Jones Neck Oxbow (JNO) (JR)	included in James River data	identified in literature
Kennon Creek (JR)	Kennon Creek	identified in literature
Kennon Marsh Creek (JR)	included in James River data	identified in literature
Kimages Creek (JR)	Kimages Creek	identified in literature
Kingsland Creek (JR)	Kingsland Creek	identified in literature
Lake Pasbehegh Creek (JR)	no longer runs normal length- dam placed to create a lake in residential area - no culverts on remainder	
	Kittewan Creek	connects significant stream to James River
Lieutenant Run (AR)	Lieutenant Run	identified in literature
Little Creek (CR)	Little Creek	identified in literature
Manchester Creek	unnamed trib to Powhatan Creek	
Mapsico Creek (JR)	Mapsico Creek	identified in literature
Mill Creek (JR)	Mill Creek	identified in literature
Morris Creek	Morris Creek	identified in literature
Mother Gut (JR)	included as an unnamed tributary of Grays Creek	
Nettles Creek (CR)	Nettles Creek	identified in literature
Old Neck Creek (CR)	Old Neck Creek	identified in literature
Oldtown Creek (AR)	Oldtown Creek	identified in literature
Parrish Hill Creek (JR)	Parrish Hill Creek	identified in literature
Parsons Creek (CR)	Parson Creek	identified in literature
Parsons Island Creek (CR)	included in Chickahominy River data	
Pasque Isle Creek (JR)	included in James River data	
Patapsco Creek	could not reconcile with any known tributary within geographic region	
Peach Orchard Gut (JR)	unnamed tributary of Grays Creek	
Poor Creek (AR)	Poor Creek	identified in literature
	Port Walthall Channel	connects significant stream to James River
Powhatan Creek (JR)	Powhatan Creek	identified in literature
Proctors Creek (JR)	Proctors Creek	identified in literature

Appendix A. Important Spawning Tributaries for Fish Passage (cont'd).

Pye Alley (AR)	included in Appomattox River data	
Queen Creek (JR)	Queens Creek	identified in literature
Railroad Creek (AR)	could not reconcile with any known tributary within geographic region	
Redwater Creek (JR)	Redwater Creek	probable ID in literature-illegible
Rosemary Lane (AR)	37.296460, -77.365939	no crossings
Roundabout Creek (JR)	Roundabout Creek	identified in literature
Shand Creek (AR)	Shand Creek	identified in literature
Shipyard Creek (CR)	Shipyard Creek	identified in literature
South Branch (JR)	included in James River data	identified in literature
Spring Creek (JR)	historical data indicates this probably destroyed by construction of Swift Creek Reservoir	
Sunken Meadow Creek (JR)	Sunken Meadow Creek	identified in literature
Sweeney Creek (JR)	Sweeney Creek	identified in literature
Swift Creek (AR)	Swift Creek	identified in literature
	The Thorofare	connects significant stream to James River
Tomahund Creek (CR)	Tomahund Creek	identified in literature
Turkey Island Creek (JR)	Turkey Island Creek	identified in literature
Tyler Creek (JR)	Tyler Creek	identified in literature
Upper Chippokes Creek (JR)	Upper Chippokes Creek	identified in literature
Wahrani Swamp (CR)	Wahrani Swamp	identified in literature
Walls Run (JR)	Walls Run	identified in literature
Wards Creek (JR)	Wards Creek	identified in literature
Weyanoke Point Creek (JR)	no culverts are located on this creek	
Yarmouth Creek (CR)	Yarmouth Creek	identified in literature
*(AR) = Tributary to Appomattox River		
*(CR) = Tributary to Chickahominy River		
* (JR) = Tributary to James River		

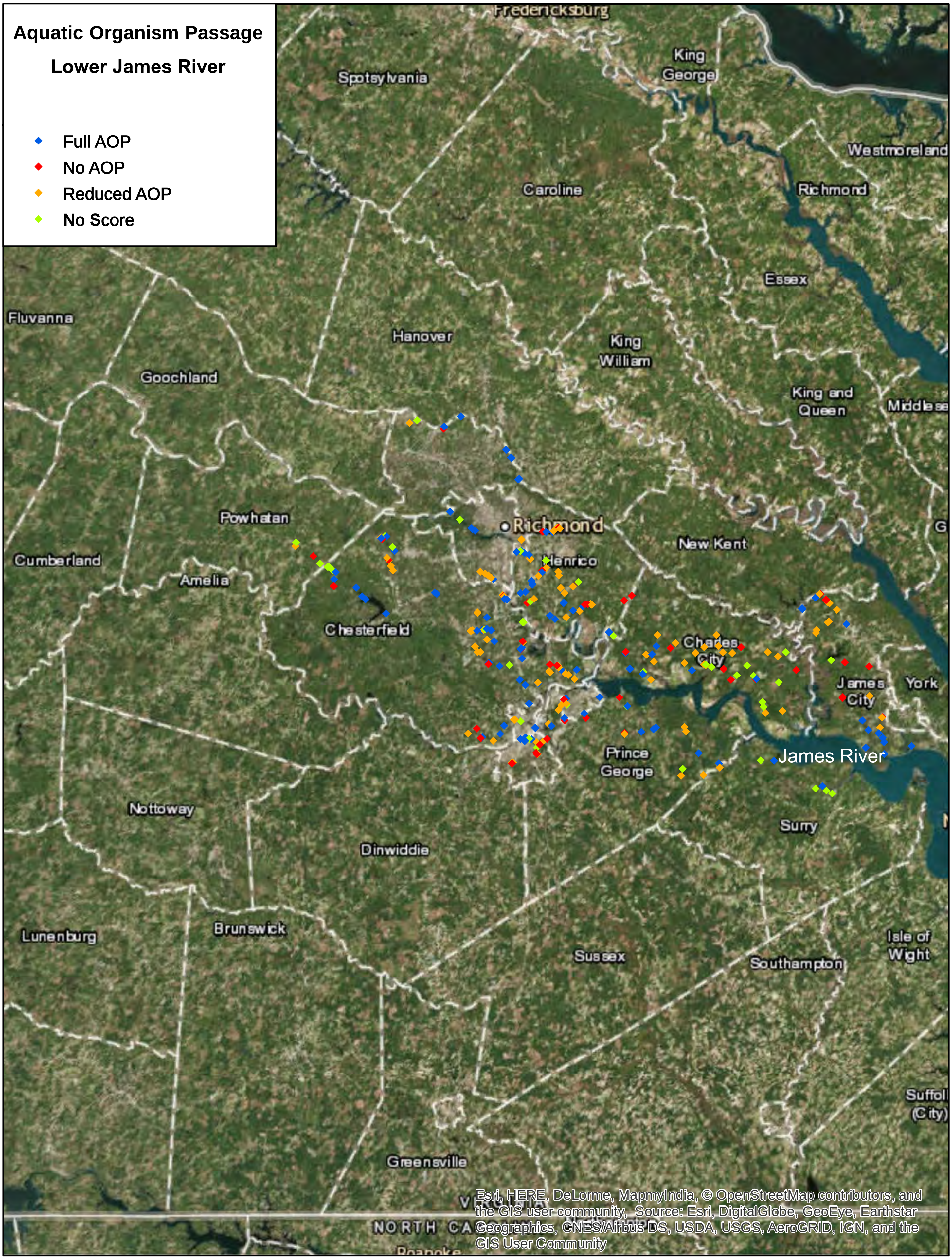
Appendix B. Lower James River- Priority Tributaries and Road-Stream Crossings.



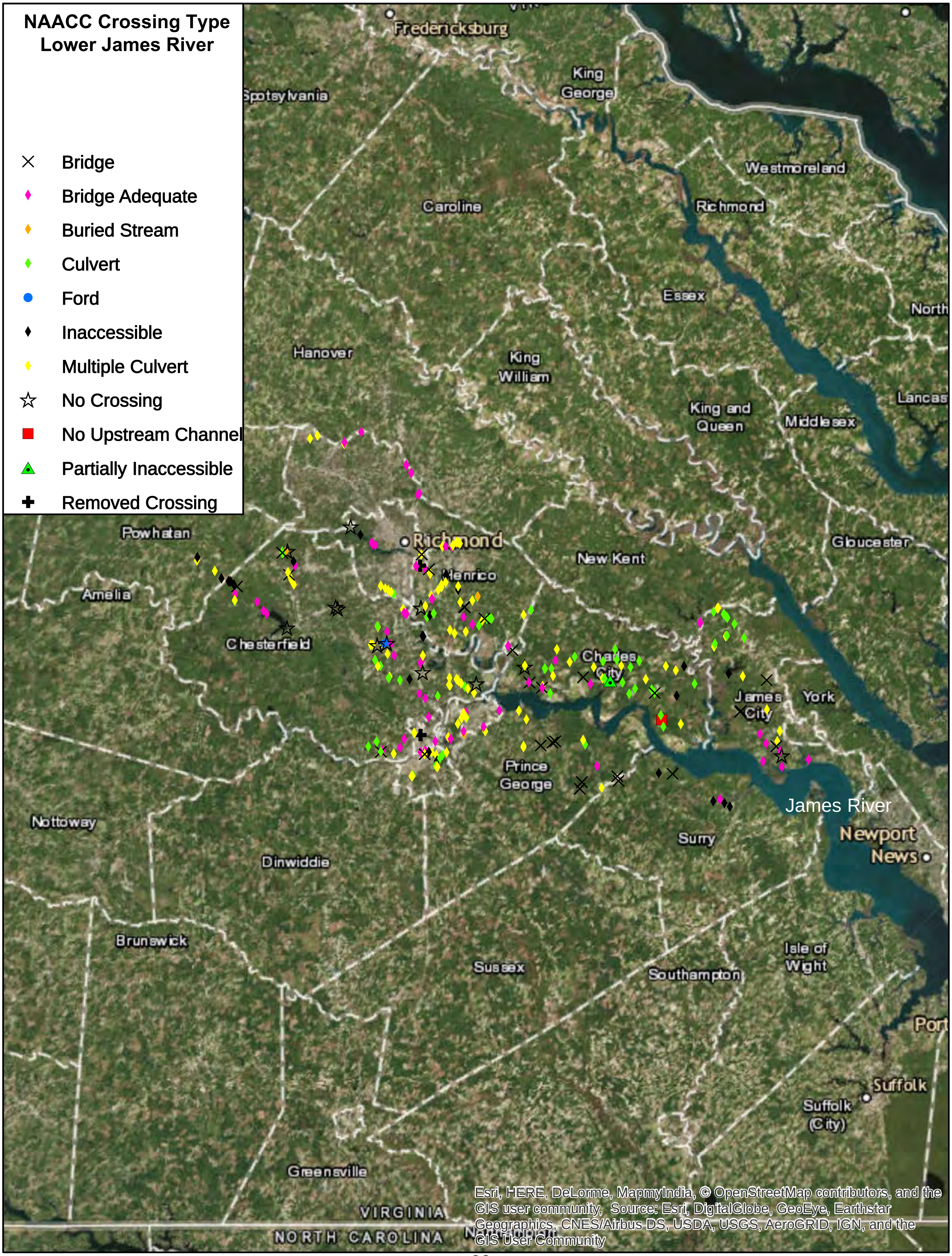
Appendix C.NAACC Coarse Screen (Source: NAACC 2016.)

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

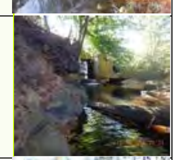
Appendix D. AOP of Road-Stream Crossing Types Assessed in the Lower James River basin.



Appendix E. Road-Stream Crossing Types Assessed in the Lower James River Basin.



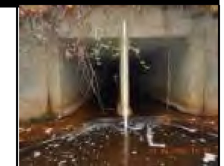
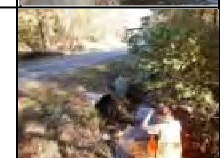
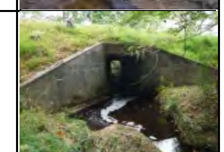
Appendix F. Barriers For Further Prioritization as Potential Barriers to Fish Passage.

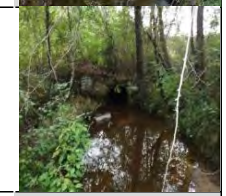
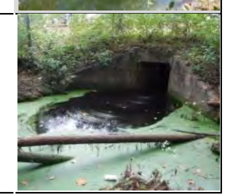
LAT/LONG	COUNTY/CITY	CREEK/STREAM	LOCATION	NAACC RANKING	NUMBER OF CULVERTS/CELLS	SITE
37.295698, -76.820107	Williamsburg VA	Gordon Creek	Jolly Pond Road	Severe barrier	1	
37.297076, -76.819251	Williamsburg VA	Gordon Creek	Jolly Pond Road	Severe barrier	1	
37.263329, -77.324717	Hopewell VA	Cabin Creek	Cousins Avenve	Severe barrier	1	
37.296738, -77.224555	Prince George VA	Billy Creek	Jordan Point Road	Severe barrier	2	
37.430514, -77.282597	Henrico VA	Tributary to Bailey Creek	Longbridge Road	Severe barrier	1	
37.443285, -77.202464	Charles City VA	Turkey Island Creek	Haupts Lane	Severe barrier	1	
37.436373, -77.216310	Henrico VA	Turkey Island Creek	Warriner Road	Severe barrier EMI:21 AEC	2	
37.431003, -77.287536	Henrico VA	Sweeney Creek	Yahley Mill Road	Severe barrier EMI:24 AEC	1	
37.437199, -76.850465	James City VA	Tributary to Barnes Swamp	I-64 East	Severe barrier	1	
37.437208, -76.849118	James City VA	Tributary to Barnes Swamp	I-64 West	Severe barrier	1	
37.442492, -77.435054	Chesterfield VA	Grindell Creek	Railroad	Severe barrier	2	
37.535115, -77.364128	Henrico VA	Gillies Creek	S. Laburnum Ave	Severe barrier	4	
37.236383, -77.356322	National Park Service Petersburg VA	Tributary to Harrison Creek	Siege Road	Severe barrier EMI:15 AEC	2	
37.216353, -77.376429	National Park Service Petersburg VA	Tributary to Poor Creek	Siege Road	Severe barrier EMI:9 PEC	1	

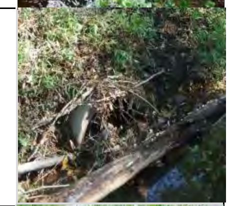
<u>Eastern Biomonitoring Method:</u>
Eastern Multimetric Index (EMI) Acceptable/Partially/ Unacceptable Ecological Condition (A/P/UEC)

Results represent initial and proximate stream health assessment for select culverts completed thus far.

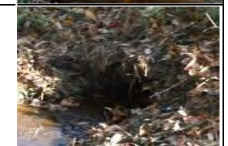
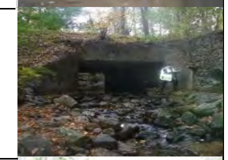
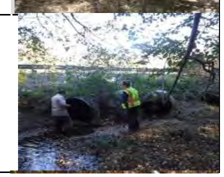
Culverts will be further prioritized for recurrent biomonitoring.

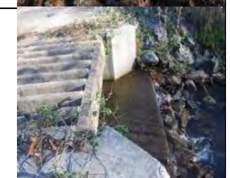
Crossing Code	County/City	Creek/Stream	Location	NAACC	# OF Culverts/ Cells	Site
xy3744607776860144	James City VA	Barnes Swamp	I-64 West	Significant barrier	2	
xy3743304577392182	Henrico VA	Coles Run	Osborne Tpke	Significant barrier EMI:21 AEC	1	
xy3736673777403024	Chesterfield VA	Redwater Creek	Osborne Road	Significant barrier EMI:21 AEC	3	
xy3747982377365585	Henrico VA	Cornelius Creek	Wilson Road	Significant barrier EMI:18 AEC	2	
xy3737732077400172	Chesterfield VA	Redwater Creek	Coxendale Road	Significant barrier EMI:6 UEC	2	
xy3732282276976548	Charles City VA	Kennon Creek	John Tyler Memorial Hwy	Rocky Bottom Method Significant barrier EMI:12 PEC	1	
xy3753645877345115	Henrico VA	Gillies Creek	Oakleys Lane	Rocky Bottom Method Significant barrier EMI:1 UEC	2	
xy3733581976903753	Charles City VA	Parson Creek	Chickahominy Wildlife Mgmt Area Eagles Nest Road	Significant barrier EMI:12 PEC	1	
xy3752508277655712	Chesterfield VA	Falling Creek	Castle Bridge Road	Significant barrier	1	

CROSSING CODE LAT/LONG	COUNTY/CITY	CREEK/STREAM	LOCATION	NAACC	# OF CULVERTS /CELLS	SITE
xy3732185577022546	Charles City VA	Mapisco Creek	Unnamed Road off Tylers Mill Rd.	Moderate barrier	1	
xy3735865877176908	Charles City VA	Unnamed trib to West Run Creek	West Run Dr.	Moderate barrier	1	
xy3725284376752103	Williamsburg VA	Mill Creek	John Tyler Highway	Moderate barrier	2	
xy3724584977215924	Prince George VA	Walls Run	Hall Farm Road	Moderate barrier EMI:18 AEC	2	
xy3715770176838675	Surry VA	Hulls Slash Gut	Rocky Bottom Road	Moderate barrier	2	
xy3733789277035309	Charles City VA	Mapisco Creek	John Tyler Highway	Moderate barrier	1	

CROSSING CODE LAT/LONG	COUNTY/CITY	CREEK/STREAM	LOCATION	NAACC	# OF CULVERTS/ CELLS	SITE
xy3743123577277014	Henrico VA	Sweeney Creek	Bradbury Road	Moderate barrier	1	
xy3746259777300330	Henrico VA	Deerlick Branch	Turner Road	Moderate barrier	1	
xy3743015777274880	Henrico VA	Sweeney Creek	Longbridge Road	Moderate barrier	1	
xy3736925577004332	Charles City VA	Parrish Hill Creek	Sturgeon Point Road	Moderate barrier	2	
xy3724752577103665	Prince George VA	Flowerdew Hundred Creek	Wards Creek Road	Moderate barrier	1	
xy3768345577543885	Henrico VA	Meredith Branch	Tidewater Quarries access road	Moderate barrier	2	

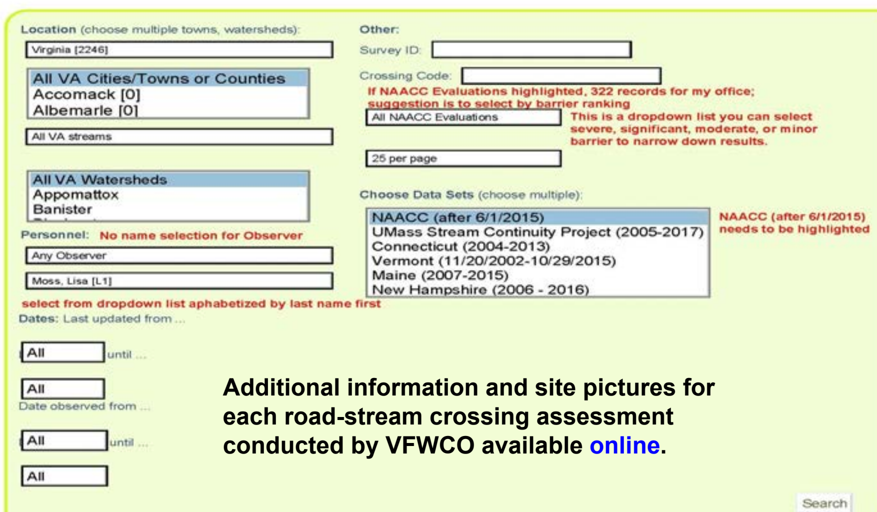
CROSSING CODE LAT/LONG	COUNTY/CITY	CREEK/STREAM	LOCATION	NAACC	# OF CULVERTS/ CELLS	SITE
xy3741175077321611	Henrico VA	Roundabout Creek	WRVA Road	Moderate barrier	2	
xy3752647177657175	Chesterfield VA	Falling Creek	W. Salisbury Road	Moderate barrier Rocky Bottom Method MI:6 UEC	1	
xy3743241276843390	James City VA	Unnamed Trib to Barnes Swamp	I-64 West	Moderate barrier	1	
xy3744409777436832	Chesterfield VA	Grindell Creek	Chippenham Parkway	Moderate barrier	3	
xy3737053077487476	Chesterfield VA	Crooked Branch	Holly Berry Drive	Moderate barrier EMI:6 UEC	1	
xy3736205777477540	Chesterfield VA	Great Branch	Chalkley Road	Moderate barrier EMI:12 PEC	1	
xy3741922177482726	Chesterfield VA	Kingsland Creek	Irongate Drive	Moderate barrier EMI:12 PEC	1	
xy3726426077415289	Colonial Heights VA	Old Town Creek	Railroad	Moderate barrier	1	

CROSSING CODE LAT/LONG	COUNTY/CITY	CREEK/STREAM	LOCATION	NAACC	# OF CULVERTS/ CELLS	SITE
xy3723766677476626	Petersburg VA	Old Town Creek	Wells Street	Moderate barrier	2	
xy3724470377499433	Chesterfield VA	Old Town Creek	Little Road	Moderate barrier EMI:15 AEC	1	
xy3720152377420925	Petersburg VA	Lieutenant Run	Halifax Road	Moderate barrier	2	
xy3721610777374432	Petersburg National Battlefield Petersburg VA	Poor Creek	Siege Road	Moderate barrier EMI: 9 PEC	1	
xy3721505577374261	Petersburg VA	Poor Creek	Winfield Road	Moderate barrier	2	
xy3731773177372709	Chesterfield VA	Feeder creek into Ashton Creek	Ruffin Mill Road Estates Driveway	Moderate barrier EMI:21 AEC	1	
xy3734273177338365	Chesterfield VA	Johnson Creek	RT 10 Exit ramp to I-295	Moderate barrier	4	
xy3734445377350999	Chesterfield VA	Johnson Creek	Bermuda Orchard Lane	Moderate barrier	4	

CROSSING CODE LAT/LONG	COUNTY/CITY	CREEK/STREAM	LOCATION	NAACC	# OF CULVERTS/ CELLS	SITE
xy3737542977122683	Charles City VA	Gunn Run	New Quarter Road	Moderate barrier	1	
xy3726778276747390	Williamsburg VA	Mill Creek	Trail	Moderate barrier	1	
xy3734157176771832	Williamsburg VA	Yarmouth Creek	Driveway	Moderate barrier	1	
xy3745744377743482	Chesterfield VA	Feeder creek into Swift Creek	Mount Hermon Road	Moderate barrier	2	

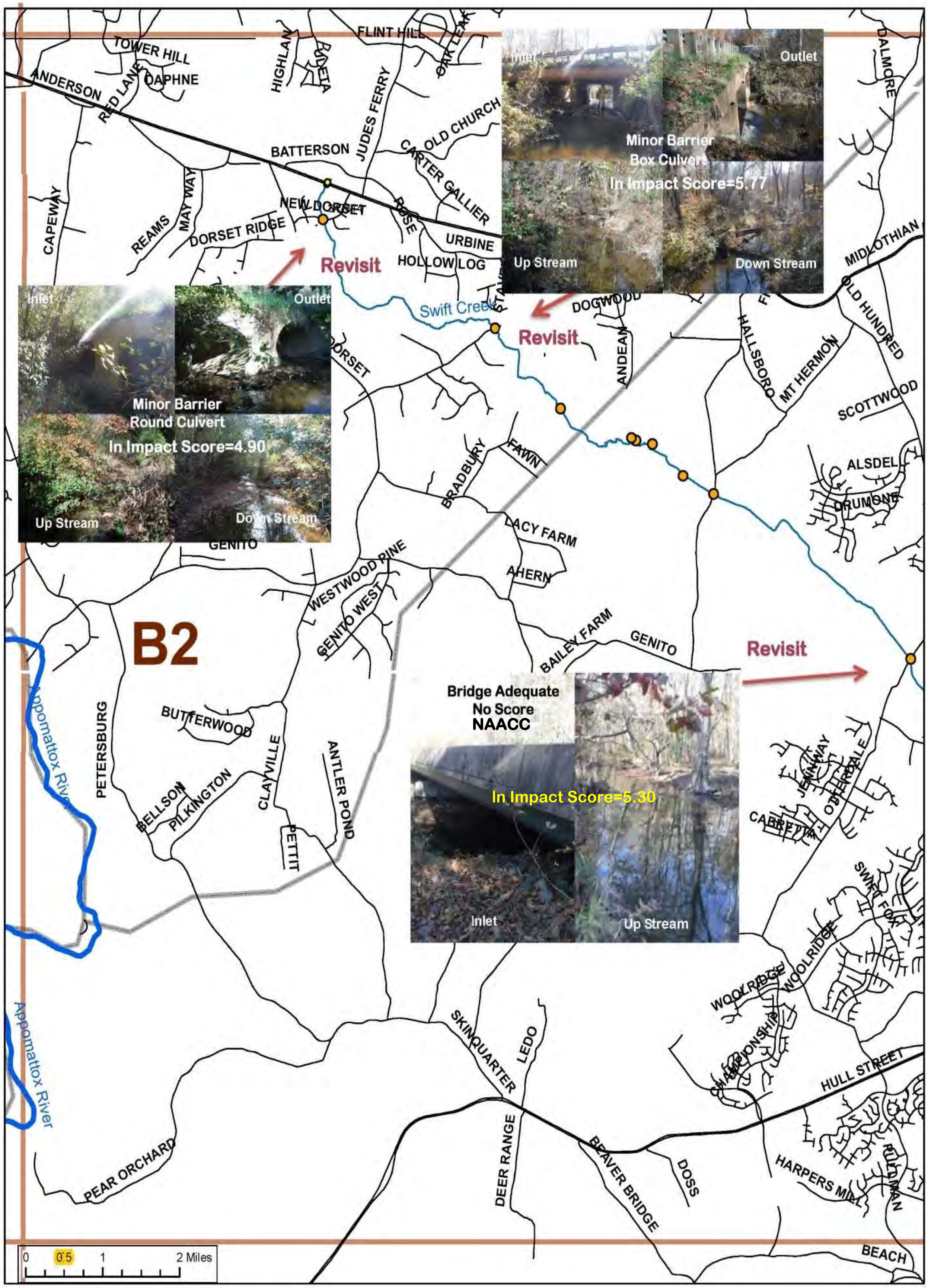
NAACC Data Center

Search Crossings Login

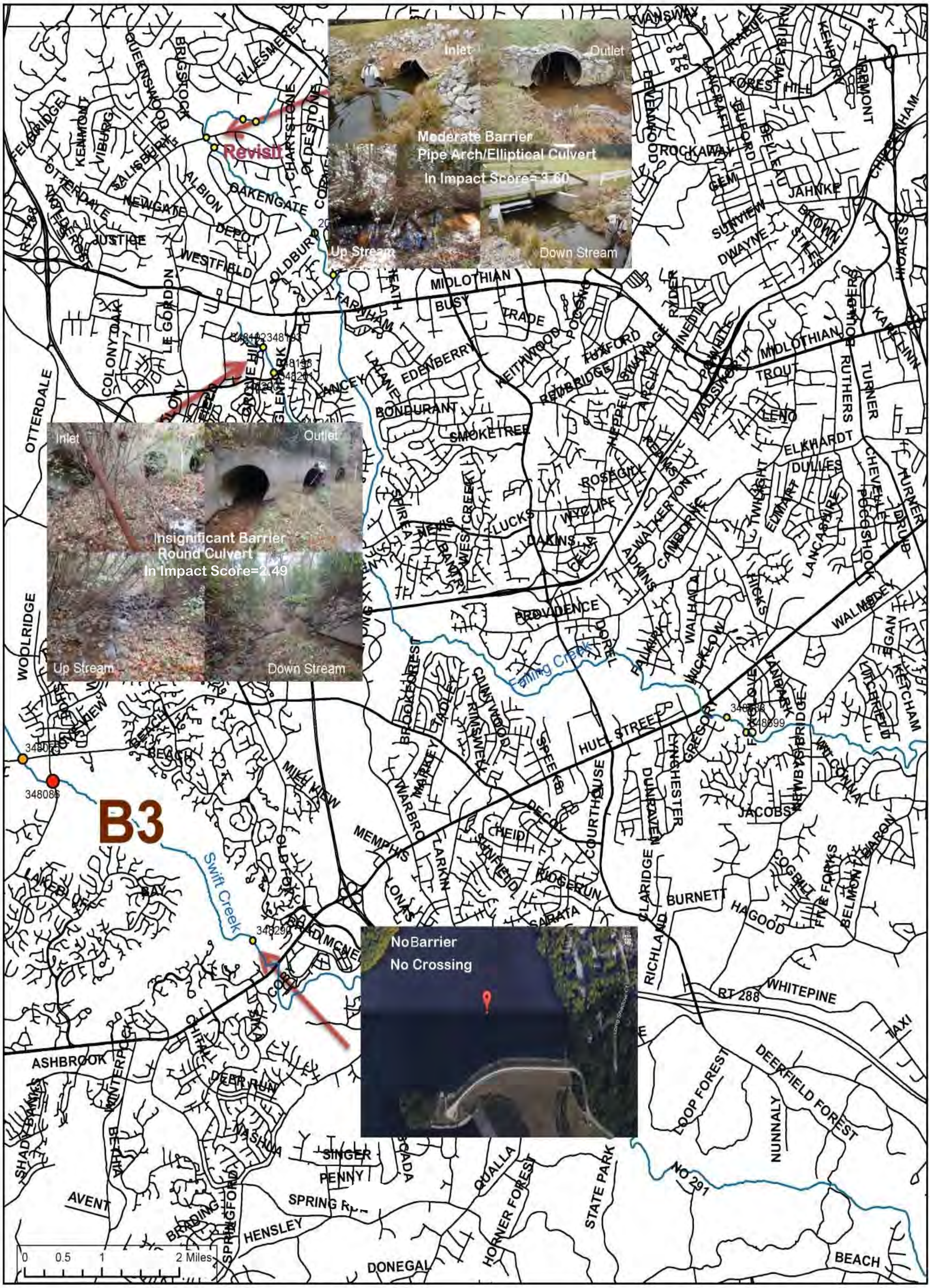


Additional information and site pictures for each road-stream crossing assessment conducted by VFWCO available online.

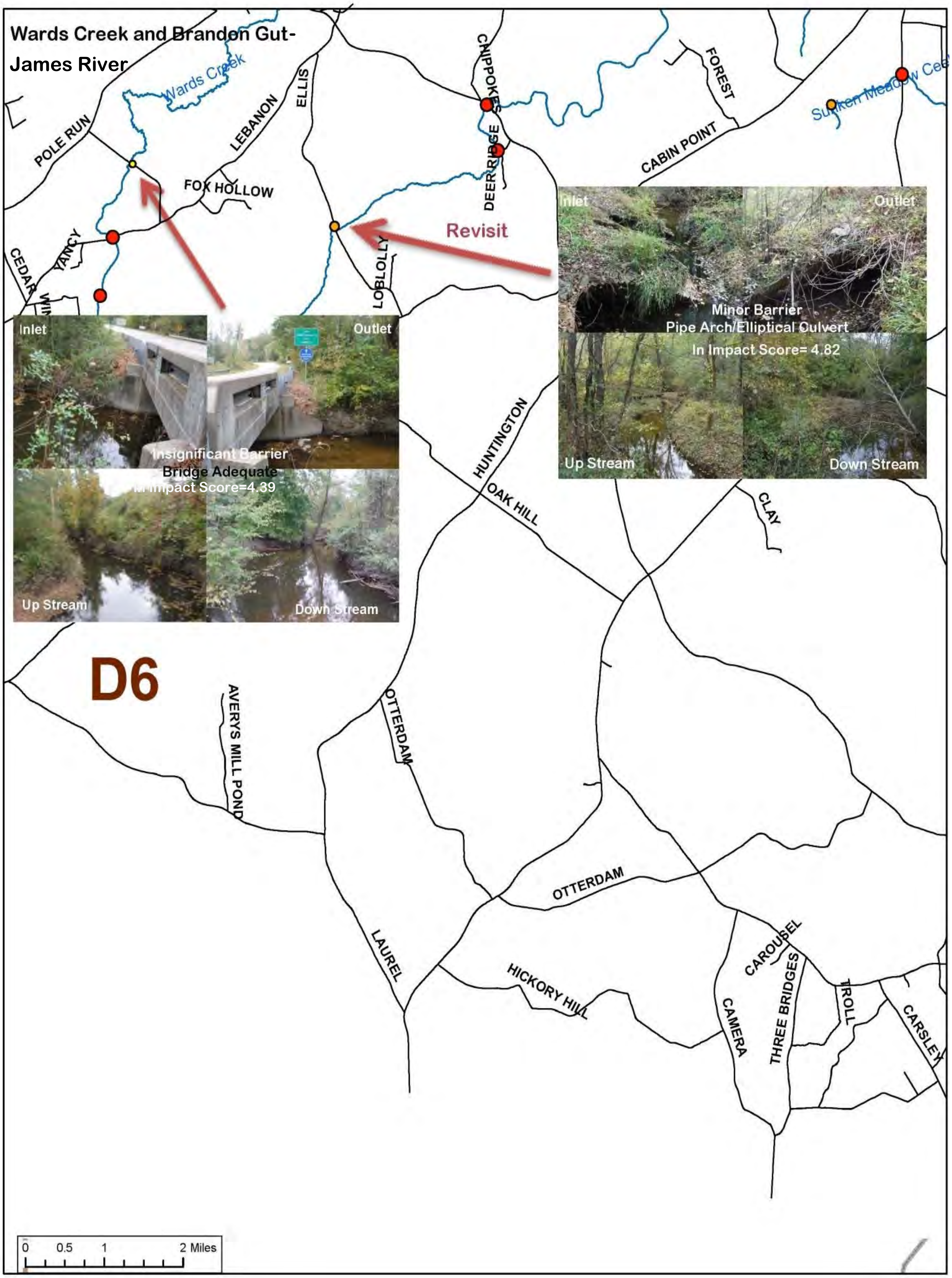
Appendix G. Minor Barriers as Priority Culverts for Alosine Passage in Appomattox River Watershed.



Appendix H. Moderate Barrier as Lower Priority Culvert for Alosine Passage in James River Watershed.

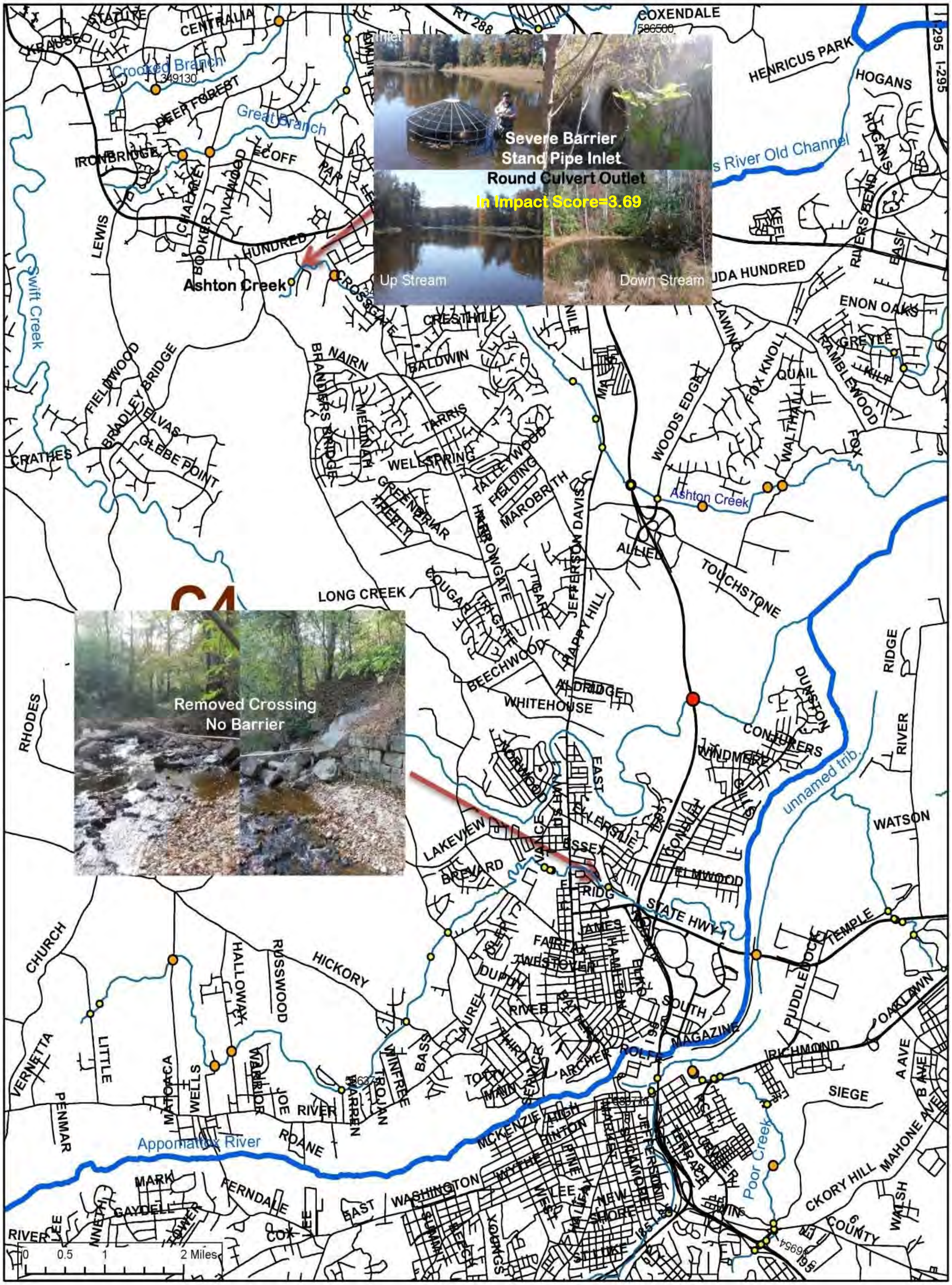


Appendix I. Minor Barrier as Priority Culvert for Alosine Passage in James River Watershed.

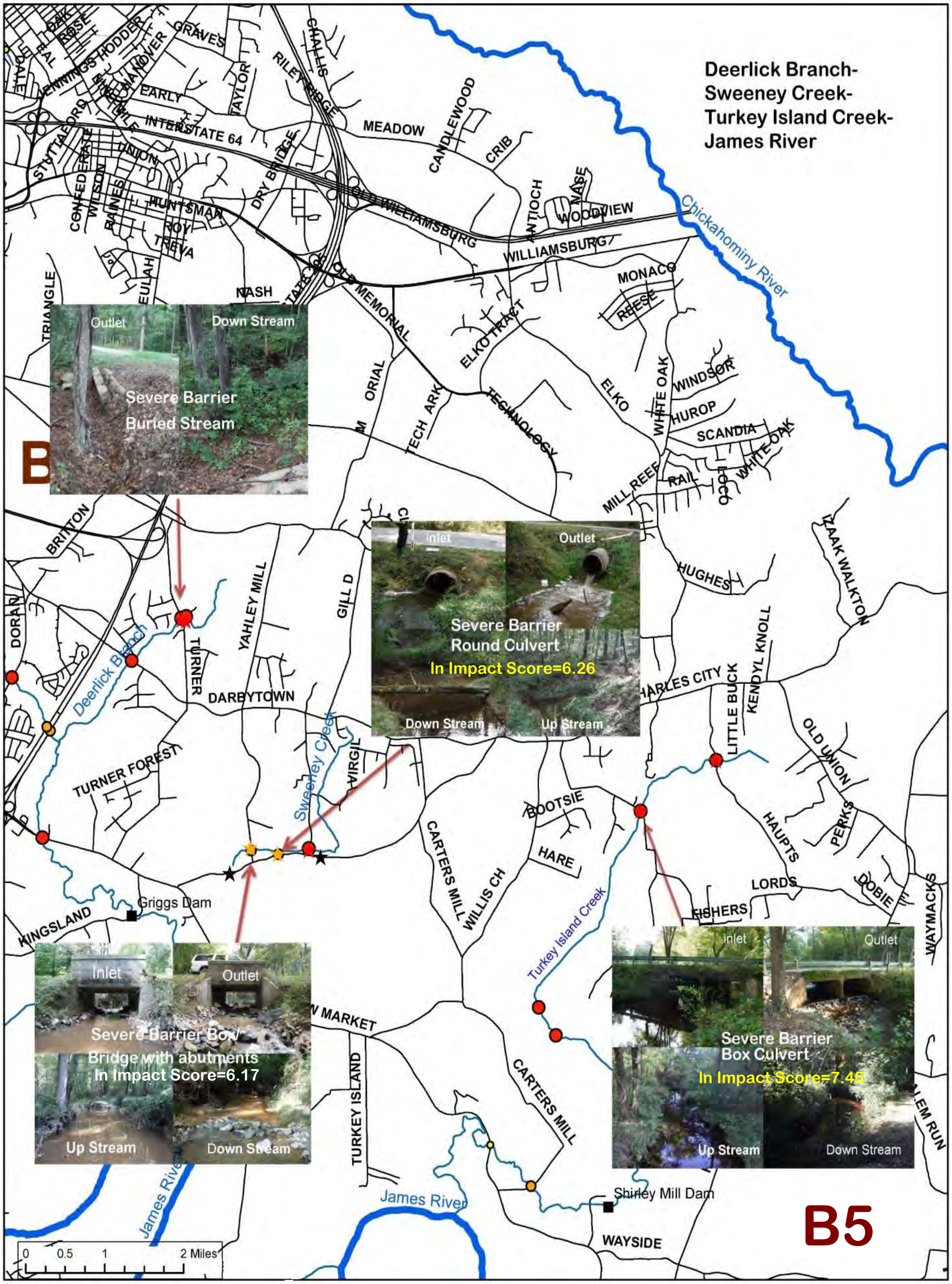


Appendix J. Significant Barrier as High Priority Culvert for Alosine Passage in Chickahominy River Watershed.

Appendix K. Severe Barrier as Lower Priority Culvert for Alosine Passage in Appomattox River Watershed.



Appendix L. Severe Barriers as High Priority Culverts for Alosine Passage in James River Watershed.



Road-Stream Crossing Assessments in the Chesapeake Bay Watershed of Pennsylvania

Final report to Chesapeake Bay Trust for agreement #13671 concerning EPA/GIT scope no. 2: Culvert Assessments for Fish Passage in Priority Watersheds.

Submitted by:

Tom Kehler, Project Manager
John Reynolds and Emily Underwood, Surveyors

US Fish and Wildlife Service
Northeast Fishery Center
308 Washington Avenue
Lamar, PA 16846

Objective

This report reflects the activities financially supported by grant no. 13671 from the Chesapeake Bay Trust (CBT) to the USFWS Northeast Fishery Center (NEFC) for EPA/GIT scope no. 2: Culvert Assessments for Fish Passage in Priority Watersheds. Moreover, the NEFC agrees to only assess road-stream crossings within priority HUC12 areas of the Chesapeake Bay watershed in Pennsylvania.

Methods and Results

At the end of June 2016, the NEFC hired two individuals to conduct road-stream crossing assessments. Both individuals completed necessary requirements mandated by the North Atlantic Aquatic Connectivity Collaborative (NAACC) to serve as lead observers for this project, which enabled the collection of survey data and entry into the NAACC database. This training included 3 hours of online protocol training, 6 hours of infield training, and survey shadowing with an experienced observer at 20 sites. Road-Stream crossings were evaluated by using the NAACC Instruction Guide Version 1.2 and Stream Crossing Survey Data Form (NAACC[1] 2016). Survey sites were selected utilizing NAACC's Tier 1 and Tier 2 prioritized HUC12 areas within a 90-minute driving radius of the NEFC and with the coordination with other organizations to eliminate repeated site surveys. Funding provided by the CBT supported the NEFC's road-stream crossing assessment project within the Chesapeake Bay Watershed of Pennsylvania from July 1, 2016 to September 30, 2016 (Appendix 1). The survey team completed site evaluations within eight Tier-1 and three Tier-2 priority HUC12 areas traveling over 4,400 miles in the project's three month period. These eleven HUC12 areas were in Centre, Clearfield, Clinton, Colombia, Lycoming, and Sullivan Counties of Pennsylvania (Appendix 2).

Sites visited

A total of 524 sites were visited or attempted to be visited from 11 priority HUC12 areas. Of these 524 sites, 335 (64%) have been entered into the NAACC database, 90 sites (17%) were found to be inaccessible because of private property or locked entrance gates, 54 sites (10%) were determined not to be a stream, but rather passage or drainage for high water events, and 45 sites (9%) were determined to be "bridge adequate" and not entered into the NAACC database. The "bridge adequate" classification refers to large bridges that contribute no obvious barriers to aquatic passage. As of January 2017, recorded sites designated as bridge adequate cannot be entered into the NAACC database until software provisions are altered.

Crossing Types

A variety of road-stream crossing types were evaluated and entered into the NAACC database (Figure 1). The survey team reported 227 sites containing a single culvert structure, 14 sites containing multiple culvert structures (27 entries), 82 sites containing bridges (80 one-cell and 2 two-cell bridges= 84 entries), 10 sites containing fords, four sites recorded as inaccessible, two sites removed of stream crossing, and one site recorded as unknown. In all, the survey crew entered 355 entries into the NAACC database.

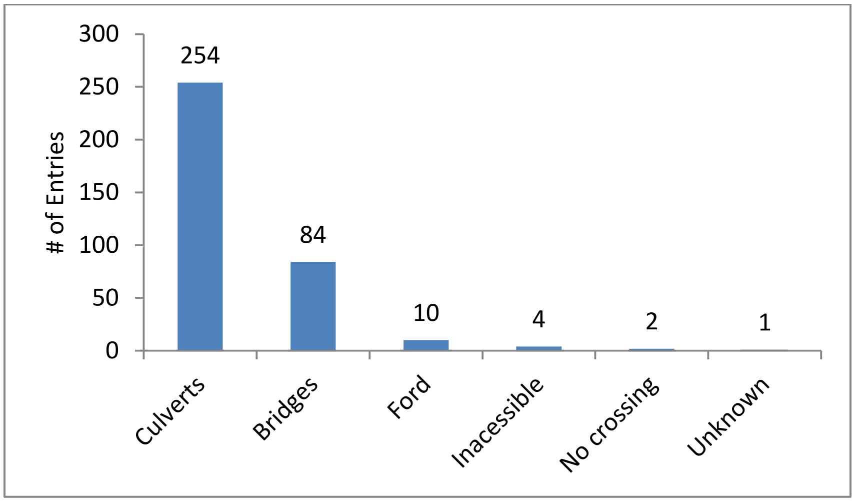


Figure 1. Crossing types entered in NAACC database by the NEFC.

Constriction classifications for bridges, culverts, and fords.

Crossing constriction defined by NAACC instructional guide is a comparison between the total width of the crossing, which may be multiple structures (i.e. sum of culvert pipes or bridge cells), to that of the natural stream channel and classified under four categories (NAACC[1] 2016).

1) *Severe*- when the total width of the crossing (summation width of multiple structures) is less than half of bankfull or active width of the natural stream or when the total wetted width of the crossing is less than half of the wetted width of the stream.
2) *Moderate*- when the crossing is greater than half of bankfull or the active width of the natural stream, but less than full bankfull or the active width.
3) *Spans Only Bankfull/Active Channel*- when the crossing is the approximately the same width of bankfull or the active channel.
4) *Spans Full Channel and Banks*- when the crossing spans beyond bankfull width.

The survey team reported 84 bridge entries consisting of all four classifications including seven entries missing data and referred to as “unknown”(Figure 2). These entries consisted of 24 (29%) bridges spanning full channel and bank, 37 (44%) spanning only Bankfull or the active channel, 10 (12%) with moderate constriction, six (7%) with severe constriction, and seven (8%) entries with unknown constrictions.

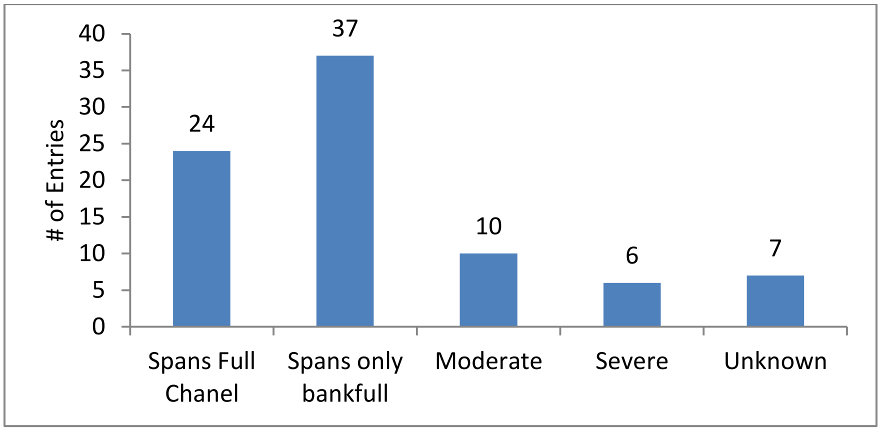


Figure 2. Constriction classifications of bridge entries.

The survey team reported 254 culvert entries from all four constriction classifications including 17 entries of missing data and referred to as “unknown” (Figure 3). Conversely to bridge entries, severe and moderate crossing constrictions made up 137 (54%) and 51 (20%) entries, respectively, followed by 44 (17%) spanning only fullbank or the active channel, 17 (7%) with unknown constriction, and five (2%) spanning full channel and bank.

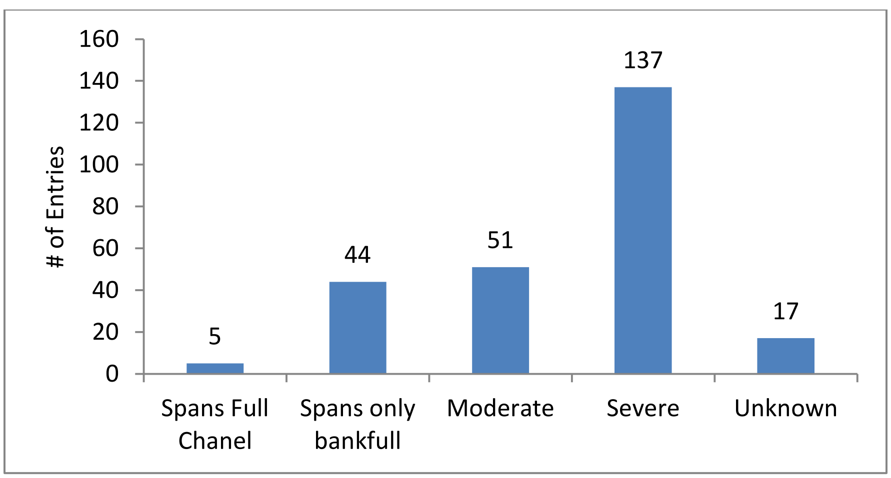


Figure 3. Constriction classifications of culvert entries.

A total of 10 ford crossings were evaluated for crossing constriction, which consisted of six crossings spanning full channel and banks, three only spanning bankfull or active channel, and one was unknown.

Structure and composition type of constricted culvert crossings

Round culverts made up the greatest number of structures within severe (n=112 or 82%), moderate (n=30 or 59%), and spans only bankfull/active channel (n=16 or 36%) constriction classifications (Figure 4). While pipe arch/ elliptical culverts comprised the second largest number of structures severely and moderately constricted, box culverts ranked second greatest for culverts spanning only bankfull or their active channel.

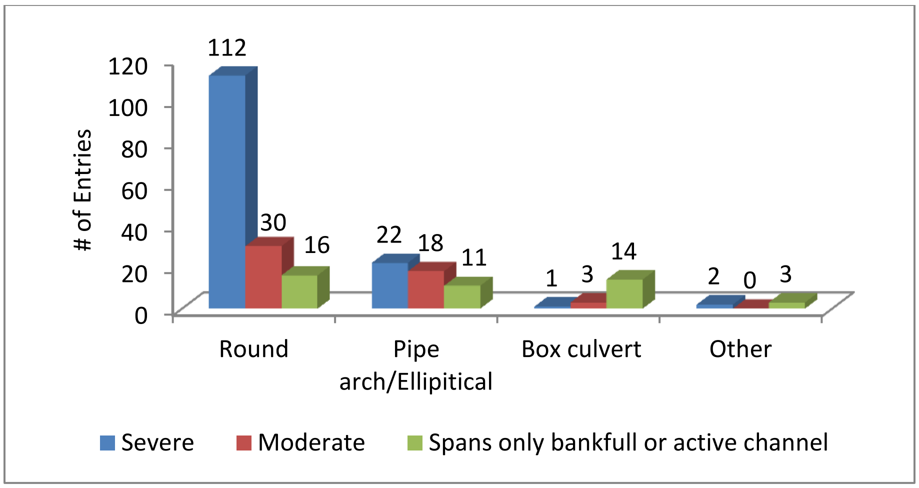


Figure 4. Structure types of constricted culverts.

Four main material groups were represented from severe, moderate, and spans only bankfull or active channel constriction categories for culverts (Figure 5). Metal culverts made up the largest number of severely and moderately constricted culverts with 71 (52%) and 25 (49%), respectively. Plastic culverts ranked second for the largest number of severely and moderately constricted culverts. Similarly, only three (7%) plastic culverts allowed only bankfull or active channel with 17 (39%) concrete and 16 (36%) metal culverts ranking first and second for the same constriction classification.

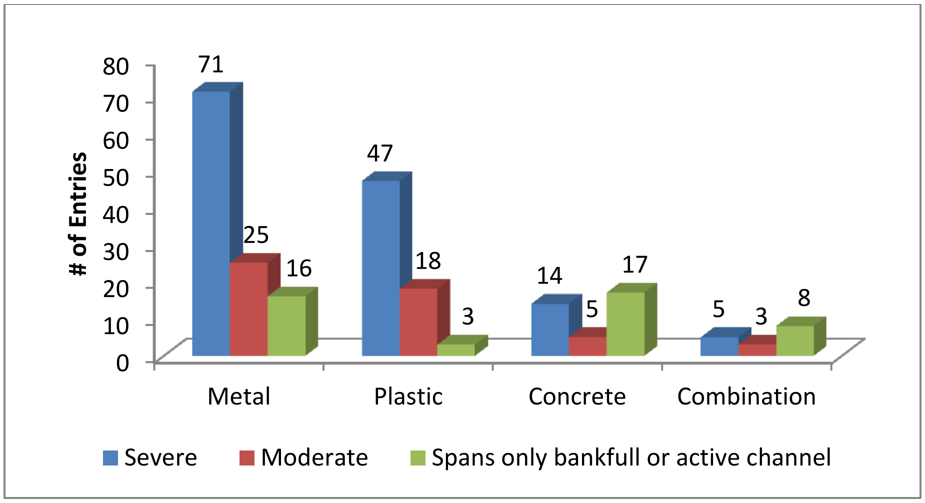


Figure 5. Material composition of constricted culvert crossings.

Aquatic passability for bridges, culverts, and fords.

The NAACC devised two scoring methods to evaluate aquatic passability for each road-stream crossing entry. The first method is a generalized screening tool designated to group entries into full, reduced, or no aquatic organism passage. The second is finer method using an algorithm to score aquatic passability from 13 measured or calculated crossing parameters representing how far the crossing departs from ideal conditions (NAACC[2] 2016). Moreover, this method served as an impetus for the creation of individual surveyed HUC12 areas depicting barrier classifications for aquatic passability (Appendix 3).

Bridges

Our survey crew reported bridges belonging to all barrier classifications except "no barrier" from the algorithm method and all three classifications using the generalized method (Figure 6). Results from the generalized method revealed 20 (24%) entries as having full aquatic passability, 54 (64%) as reduced , and 10 (12%) as no aquatic passability. Results from the algorithm method determined 75 (89%) bridges as insignificant barriers, five (6%) as minor barriers, and four entries belonging to other three classifications.

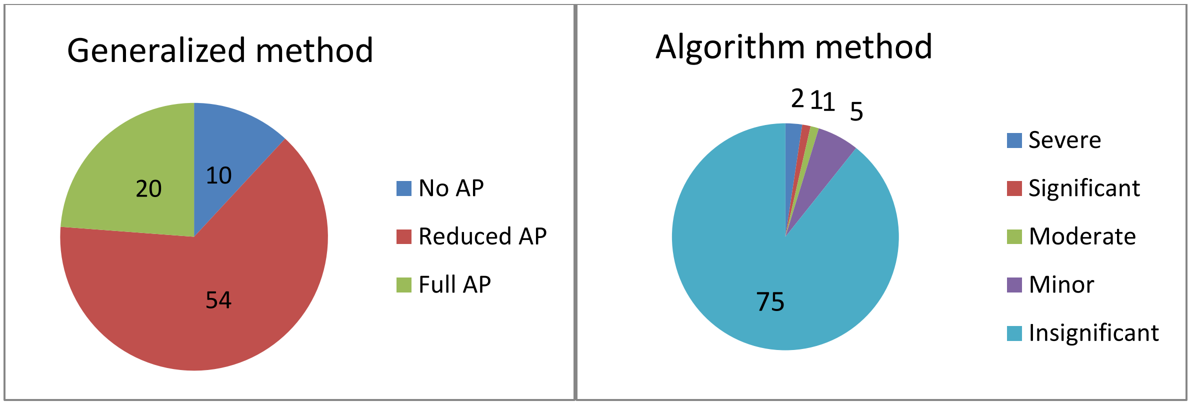


Figure 6. Categories of aquatic passability for bridges using a generalized (left) and an algorithm based (right) method.

Culverts

The survey crew reported culverts belonging to all barrier classifications except “no barrier” from the algorithm method and all three classifications using the generalized method including six entries having missing data (Figure 7). Results from the generalized method indicted only seven (3%) culverts support full aquatic passability, followed by 114 (45%) and 119 (47%) culverts having reduced or no aquatic passability, respectively, and 14 entries disqualified because of missing data. Over half (n= 160 or 63%) of the surveyed culverts from the algorithm method were insignificant or minor barriers. In addition, 45 (18%) culverts were classified as severe, 25 (10%) were reported as moderate, 18 (7%) were considered as significant, and six (2%) entries contained missing data and could not be scored.

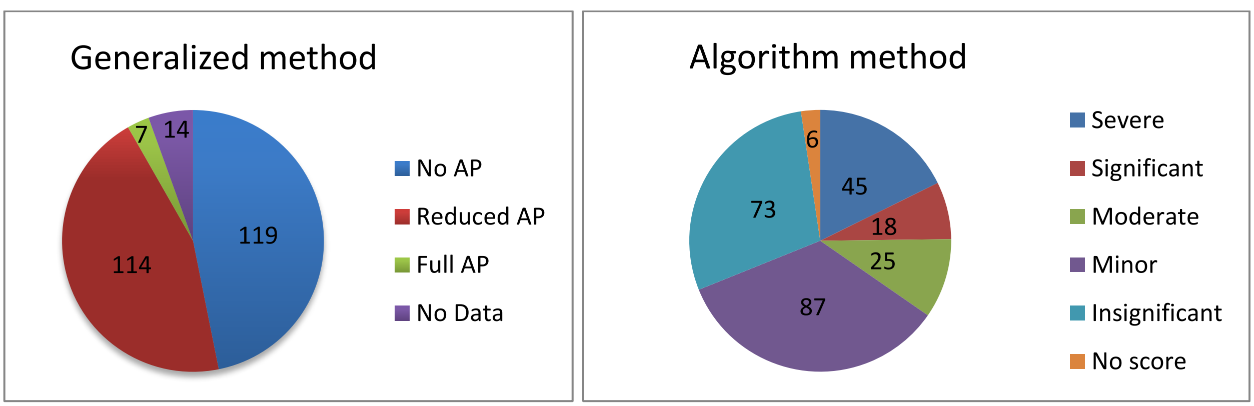


Figure 7. Categories of aquatic passability for culverts using a generalized (left) and an algorithm based method.

Fords- The generalized method determined two fords supported full aquatic passability, five as reduced, and three were disqualified for missing data. The algorithm method reported six crossing fords as no barriers and other four as insignificant barriers.

Other entries- the generalized method indicated two inaccessible entries support full aquatic passability and two had no data for evaluation. Also the same method had two no crossing entries supporting full aquatic passability, and an unknown entry having no score because of missing data. The algorithm method reported two inaccessible entries as insignificant barriers, two having no data for evaluation, two no crossing entries as no barriers for aquatic passability, and an unknown entry was missing data.

Discussion

Reported data from this project are intended to provide a snapshot of the general condition, constriction, and aquatic passability of the surveyed road-stream crossings. With bridges making up 24% of the data reported, we found less than 20% were severely or moderately constricted and 73 % maintaining crossing width equal or greater than bankfull. Since bridge development is uniquely different to other crossings because of the structure's foundation construction and placement, most bridges are designed to withstand excessive flooding (Johnson et al 2002). Our data support this premise since the large percentage of our bridges equal or exceeds their bankfull widths. In these scenarios, intensified flows during storm events are allowed to pass through the structures with no impediment, thus maintaining connectivity between up and downstream aquatic communities.

Conversely, over half of our surveyed culverts were severely constricted, meaning the structure's width was less than half of bankfull or active channel. In these culverts almost half had scour pools at the outflow side of the structure. These scour pools were evidence of accelerated flows being pushed through these structures during high water conditions. We found this scenario was less frequent within moderately constricted culverts (less than 25%). Still, scouring occurring at the outflow of the structure destabilizes the natural stream channel and overtime can permanently fragment aquatic communities (Gubernick et al 2004).

With a variety of materials making up the culverts assessed in this project, metal and plastic made up 48 and 29%, respectively. Interestingly, round metal culverts made up 45 % of the severely restricted culverts while plastic culverts made up 42%. It is unclear whether site remoteness determined culvert type and composition. Further investigation is prudent to determine why these round culverts are undersized at these locations.

We found overlap between the results from the two methods reporting aquatic passability for culverts. Culverts considered having full aquatic passability were considered also as insignificant or minor barriers. Culverts reported as having reduced aquatic passability had representation from all five barrier classifications and one no score, while culverts having no aquatic passability were considered severe, moderate, or minor barriers.

Observing the overlap of classifications between the two models, we believe the culvert algorithm method for aquatic passability may best benefit resource managers because of the greater defined barrier classifications. These detailed categories can assist with prioritized culverts for modification or replacement to maximize aquatic connectivity efforts.

References

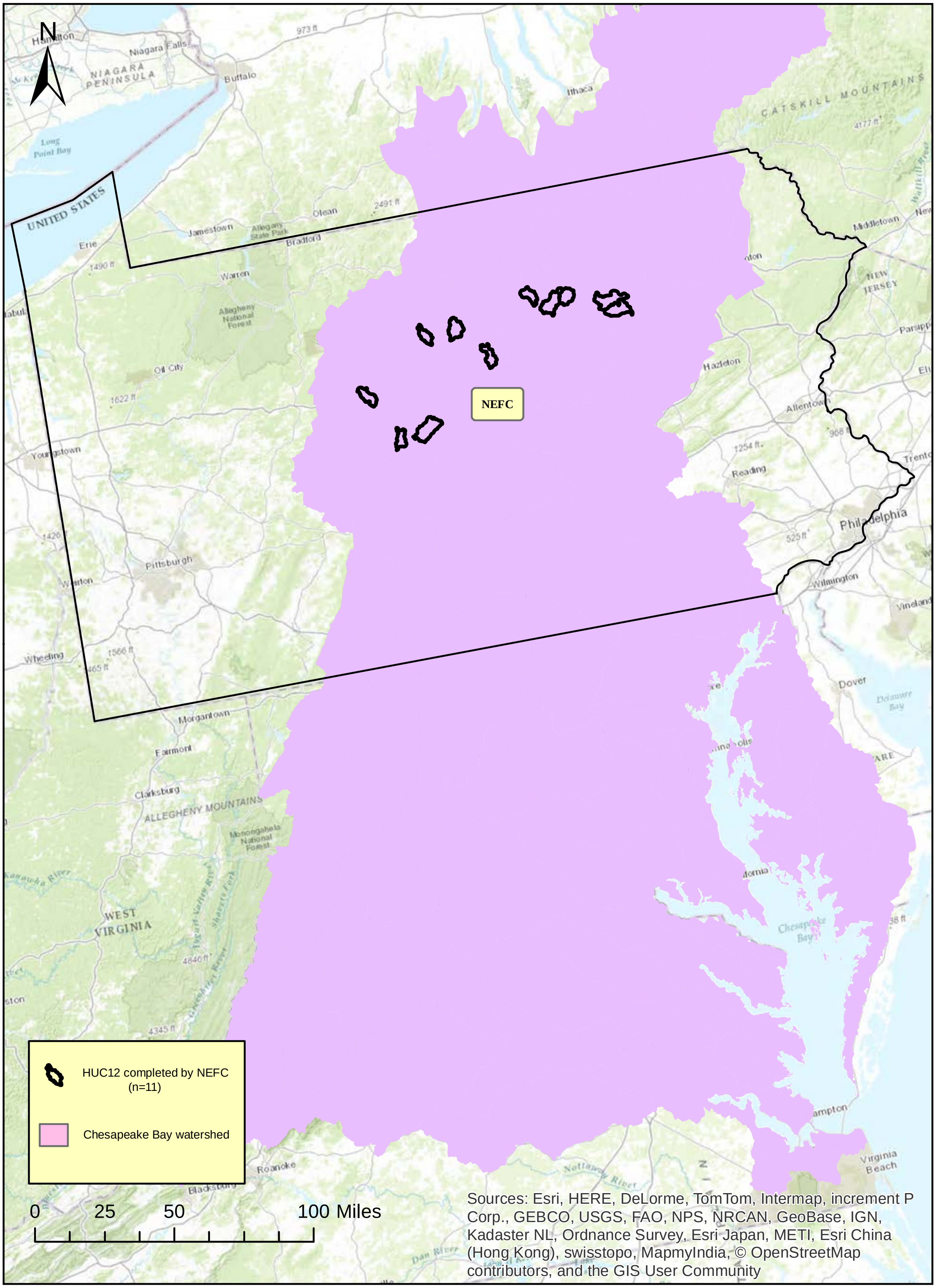
Gubernick, B., Clarkin, K., and Michael J. Furniss. 2004. Design and construction of aquatic organism passage at road-stream crossings: site assessment and geomorphic considerations in stream simulation culvert design. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin, CL Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp 30-41.

Johnson, P. A., Hey, D. H., Brown, E. R., and David L. Rosgen. 2002. Stream restoration in the vicinity of bridges. Journal of the American Water Resources Association V8 (1):55- 67

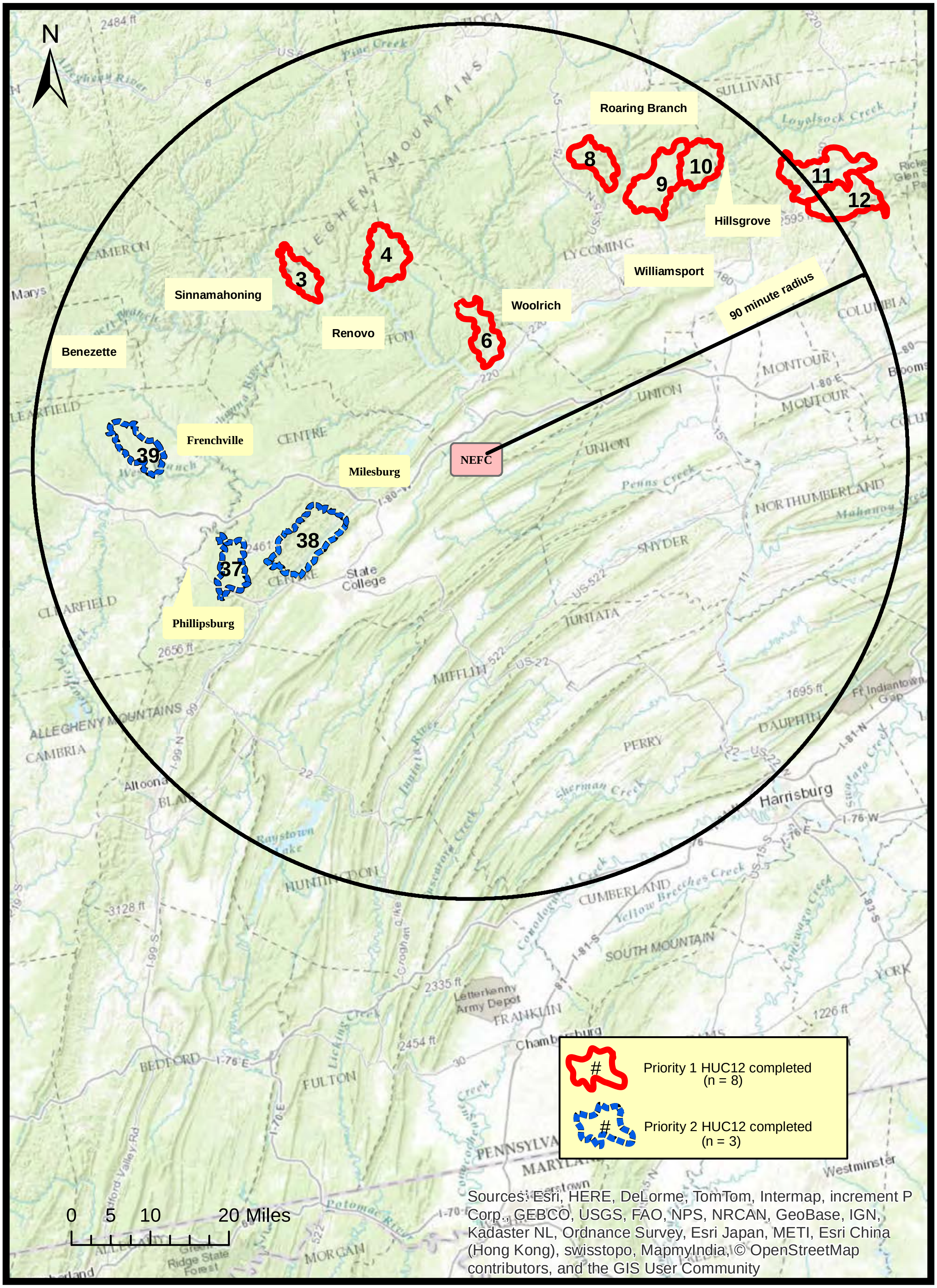
NAACC[1] 2016. NAACC Stream Crossing Survey Data Form and Instruction Guide, Version1.2- May 2016. https://www.streamcontinuity.org/pdf_files/NAACC_Instructions%20for%20Field%20Data%20Form%205-22-16.pdf

NAACC[2] 2016, NAACC Website. Scoring road-stream crossings as part of the North Atlantic Aquatic Connectivity Collaborative (NAACC). https://www.streamcontinuity.org/pdf_files/Aquatic_Passability_Scoring.pdf

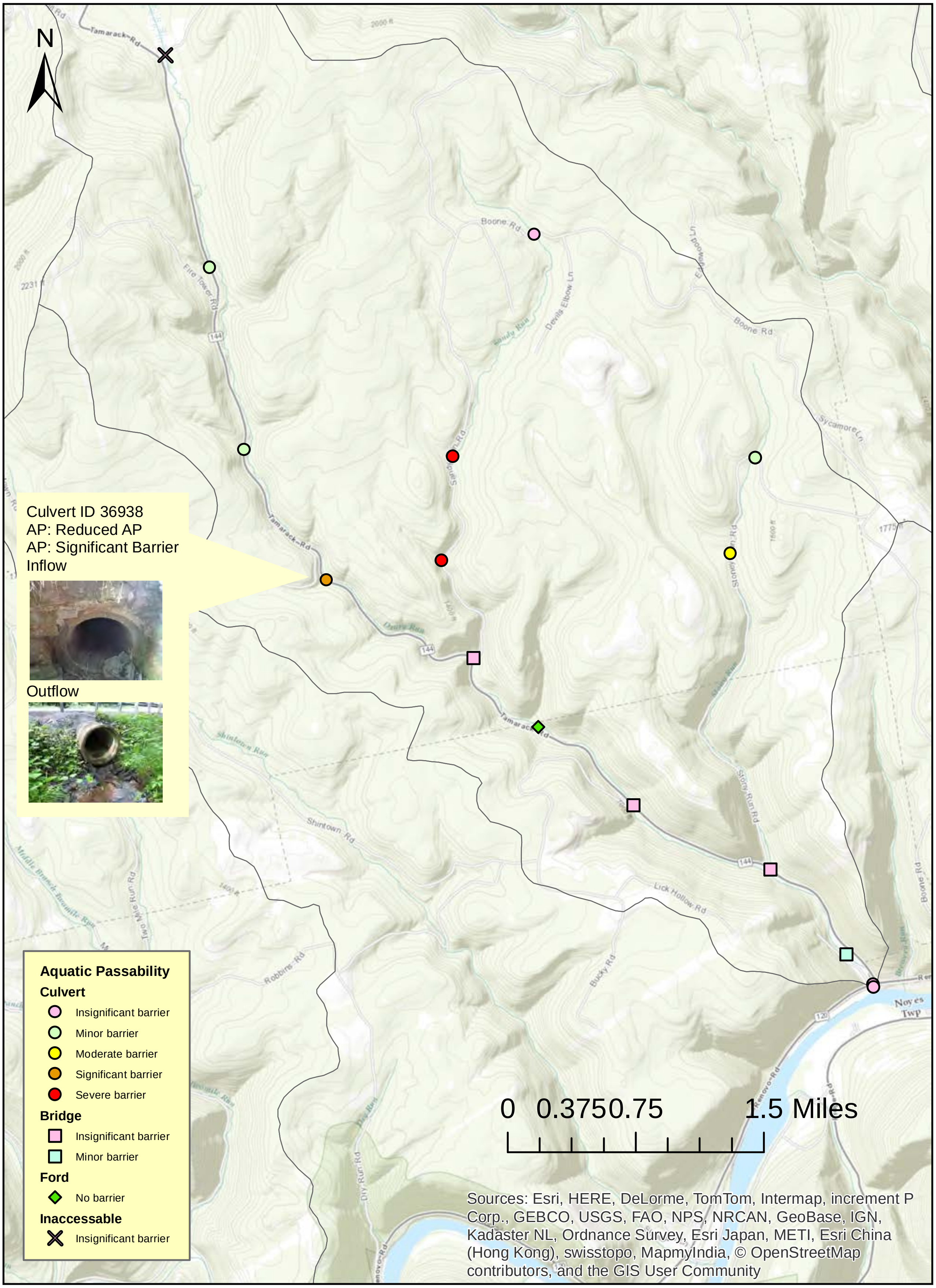
Appendix 1. Chesapeake Bay watershed within Pennsylvania



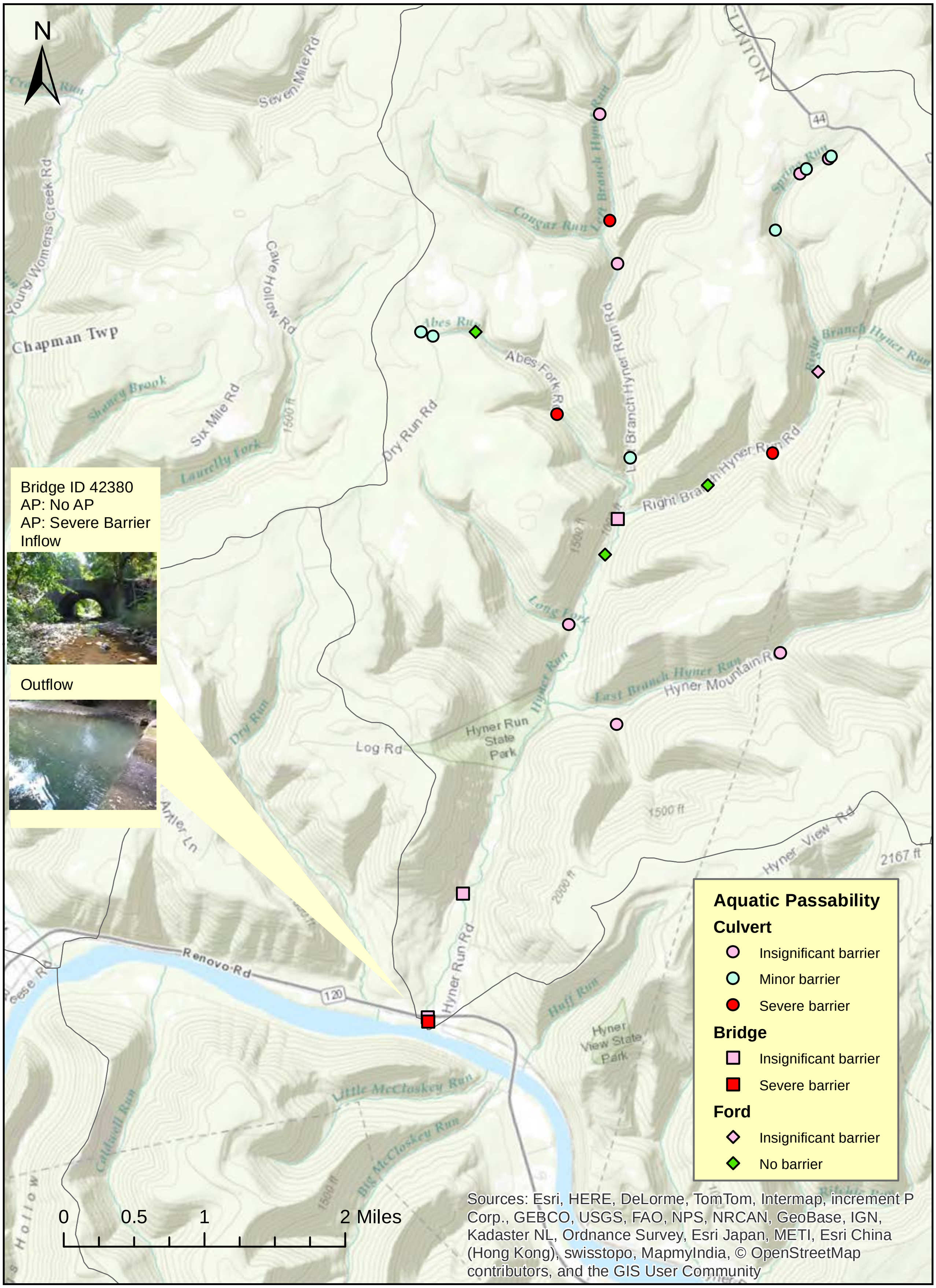
Appendix 2. Completed Tier 1 and 2 HUC12 subwatersheds



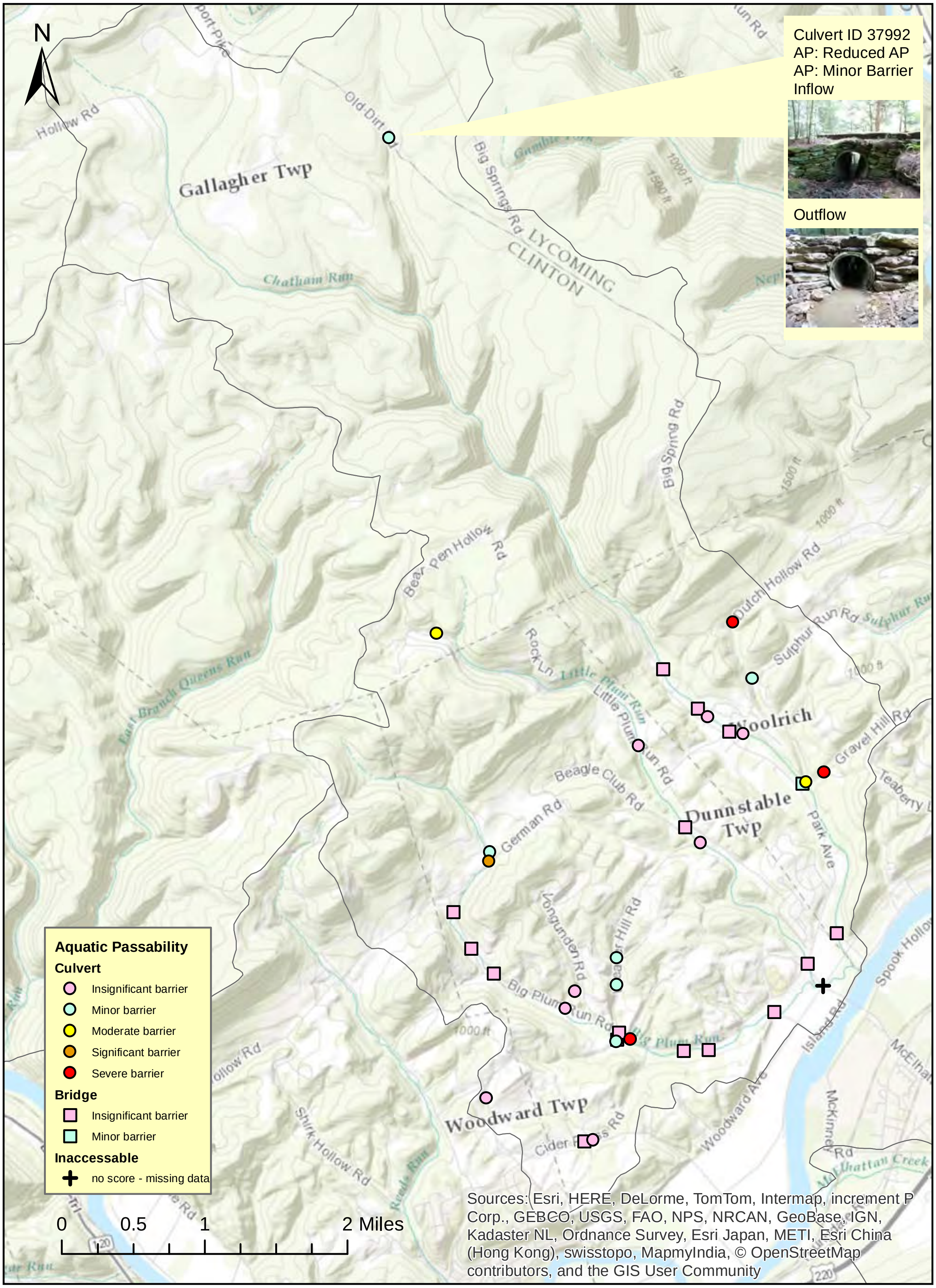
Appendix 3. Site 3 Aquatic Passability



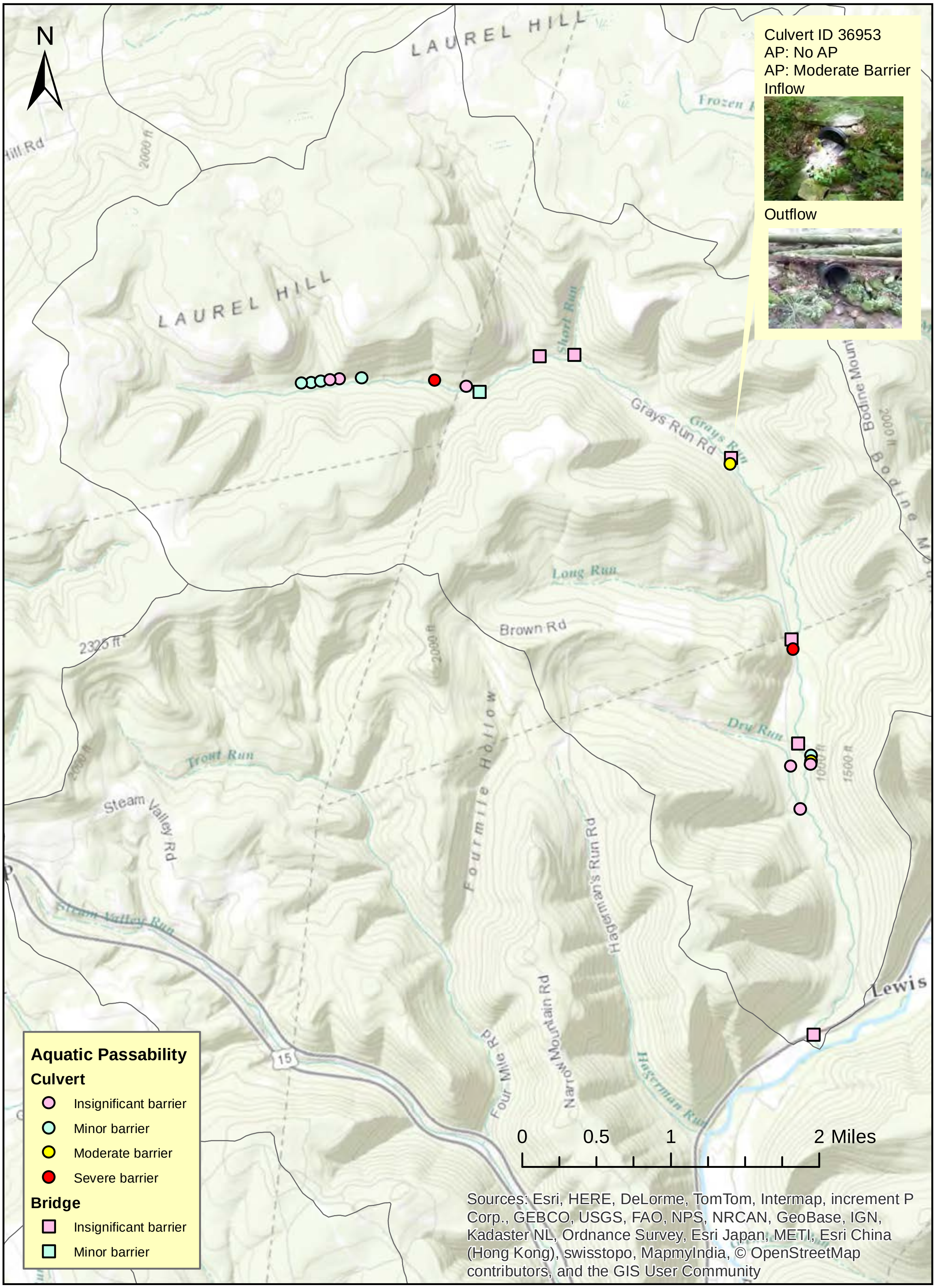
Appendix 3. Site 4 Aquatic Passability



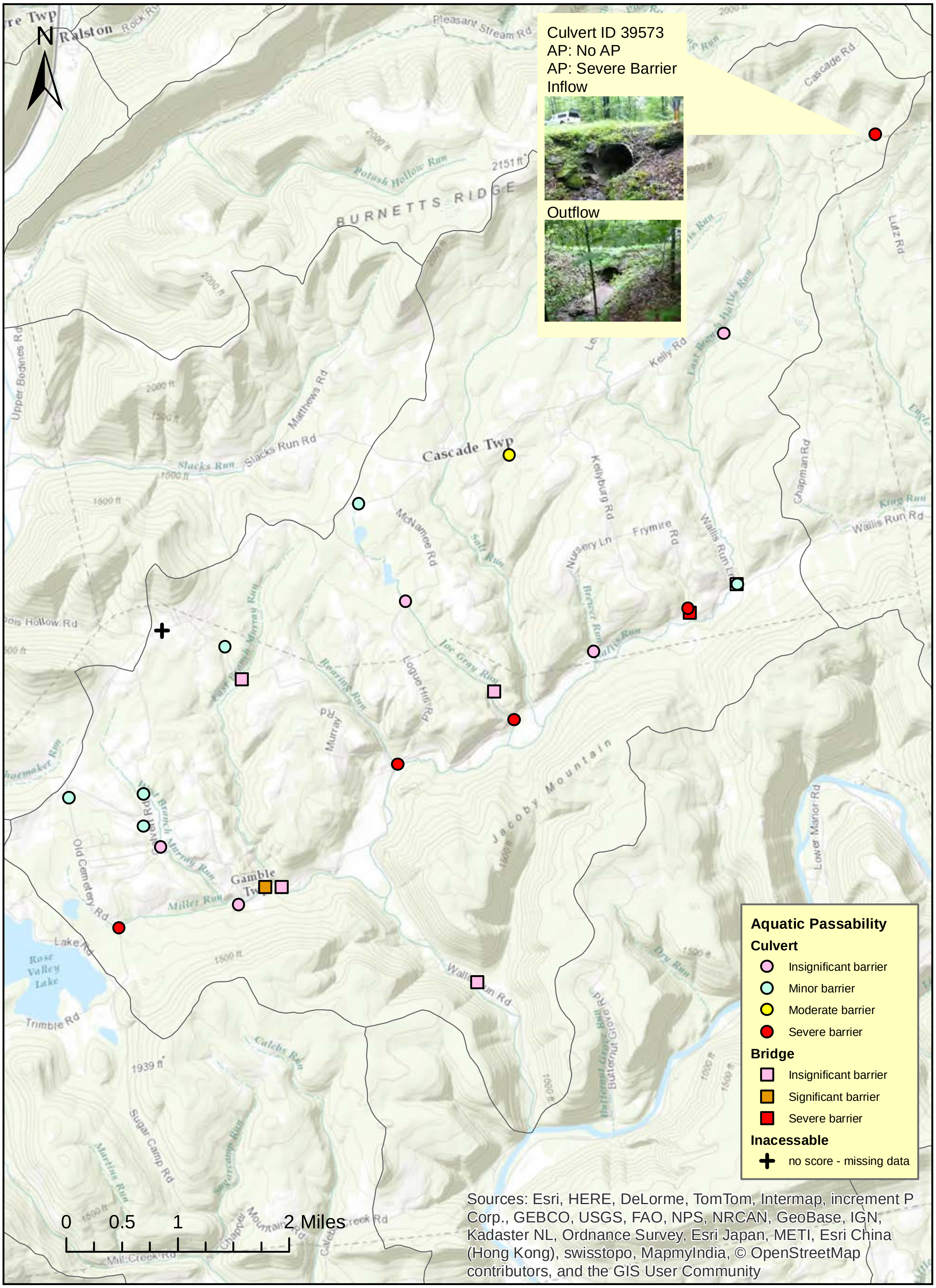
Appendix 3. Site 6 Aquatic Passability



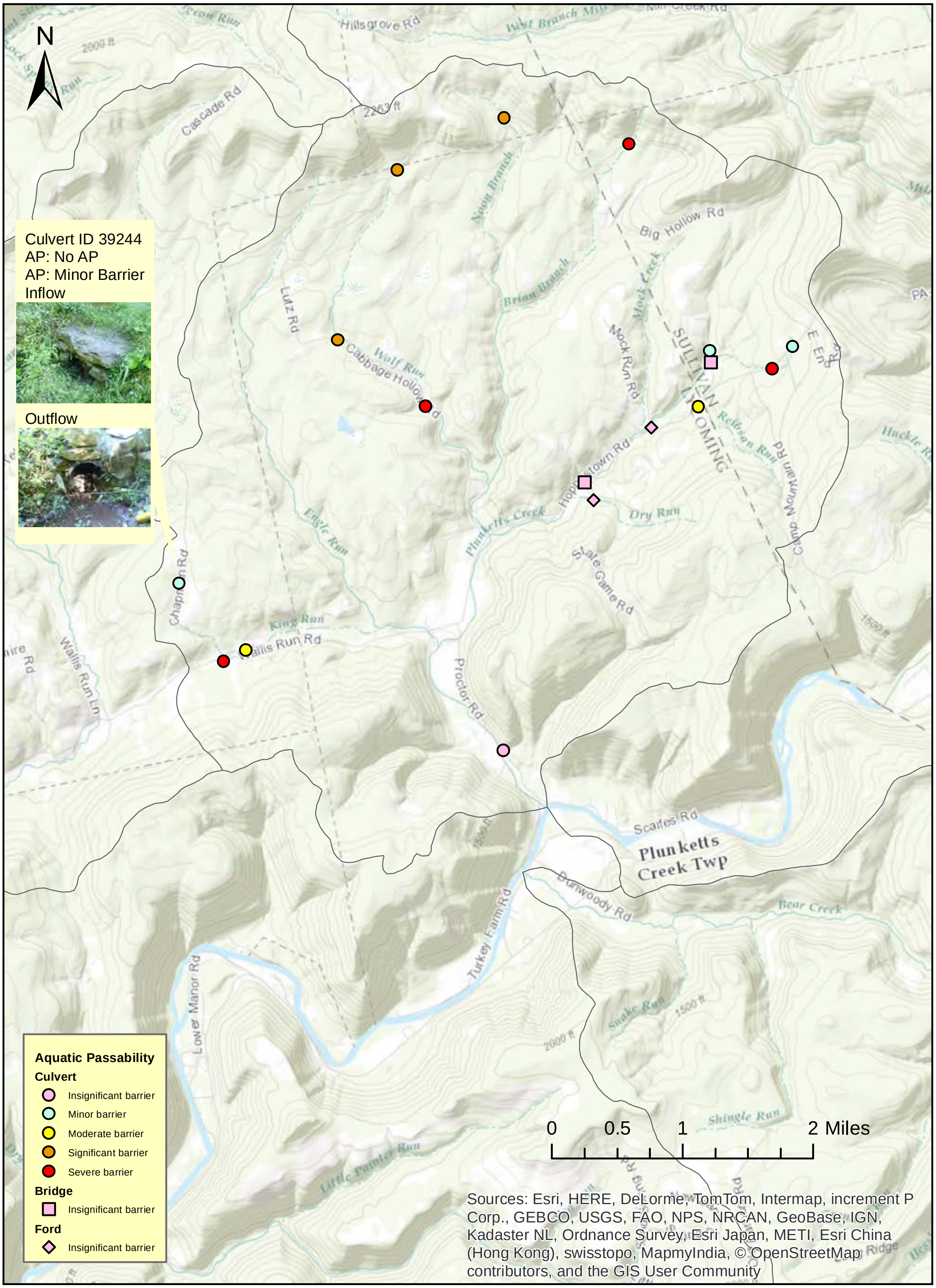
Appendix 3. Site 8 Aquatic Passability



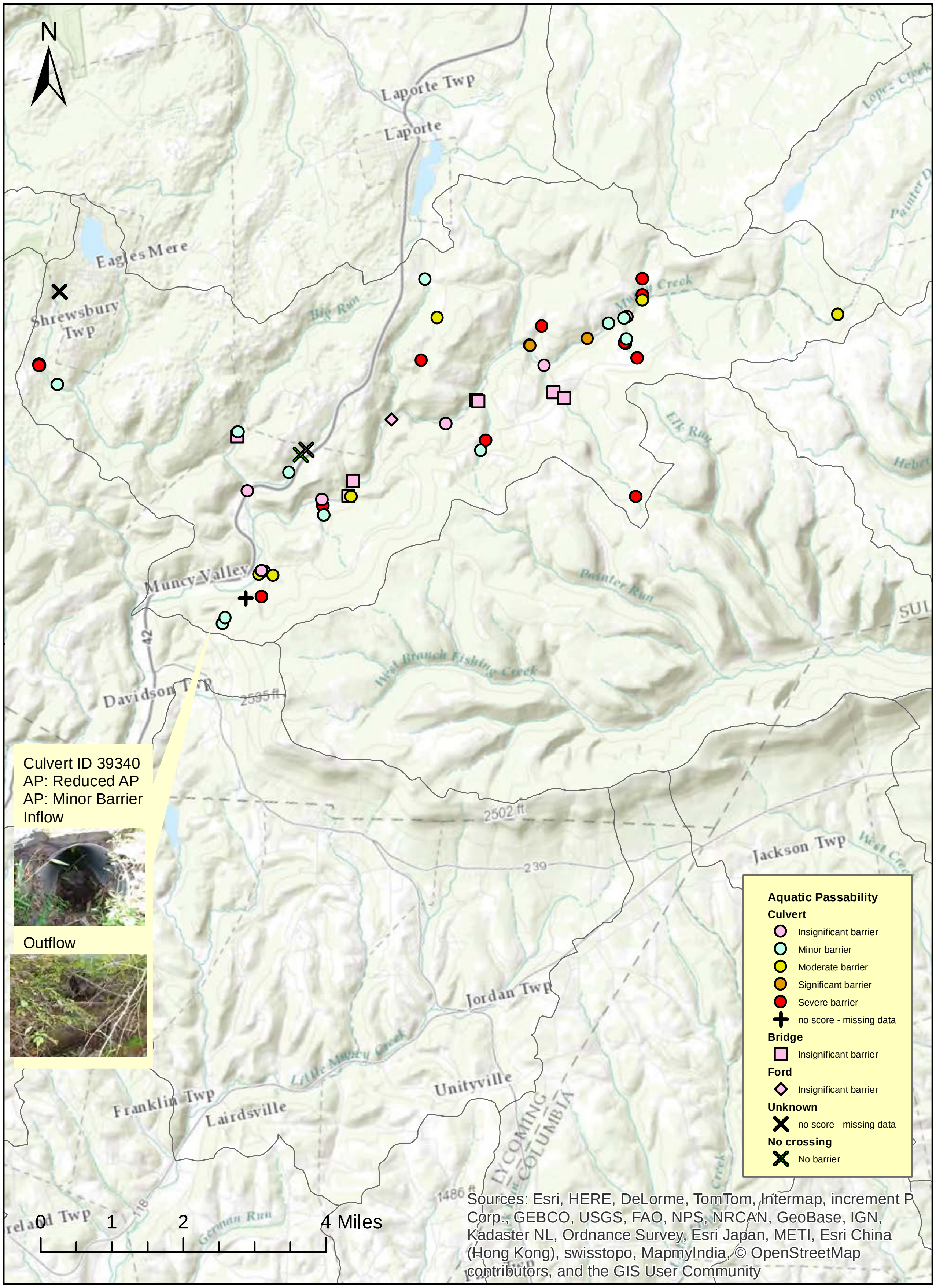
Appendix 3. Site 9 Aquatic Passability



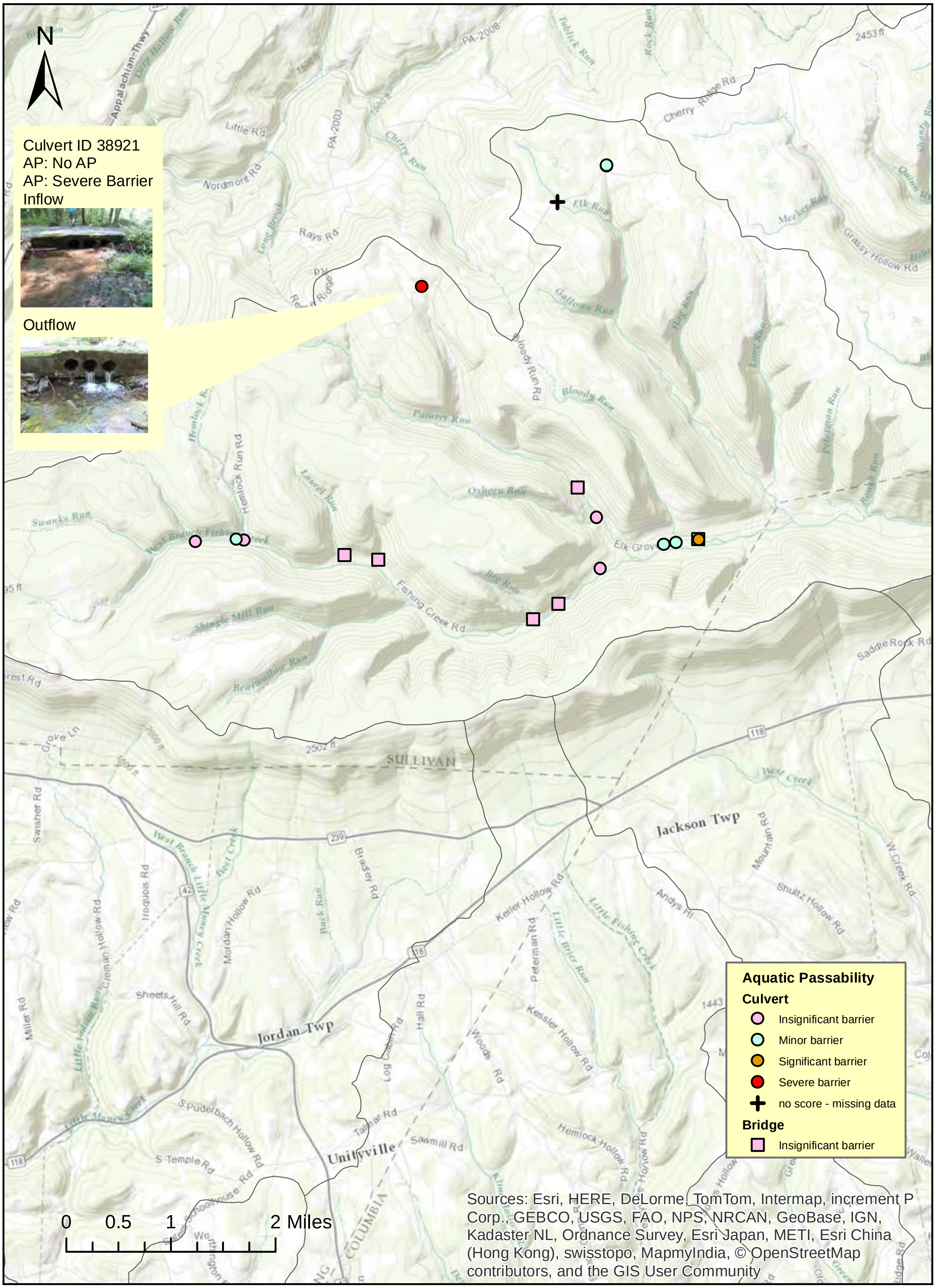
Appendix 3. Site 10 Aquatic Passability



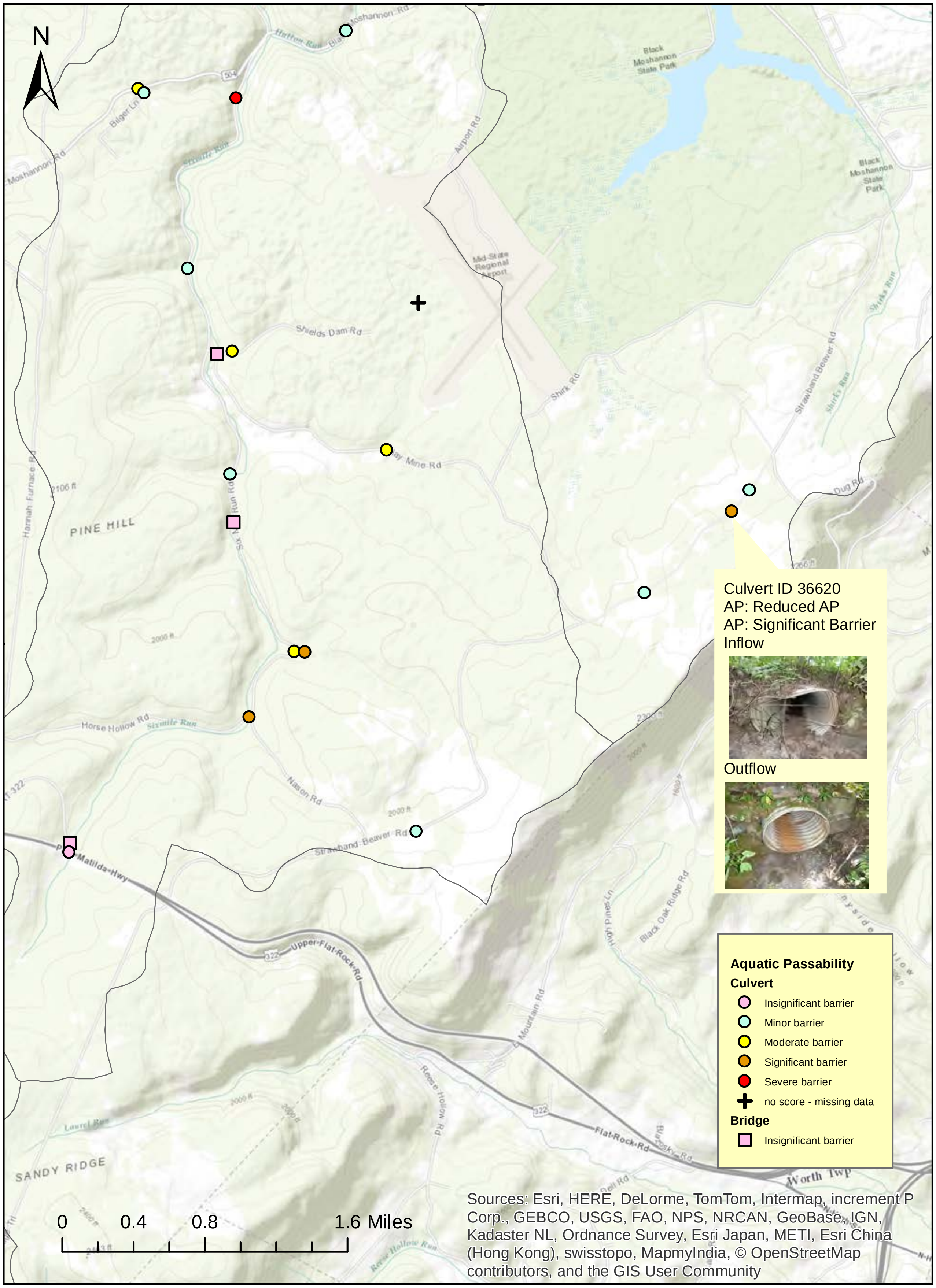
Appendix 3. Site 11 Aquatic Passability



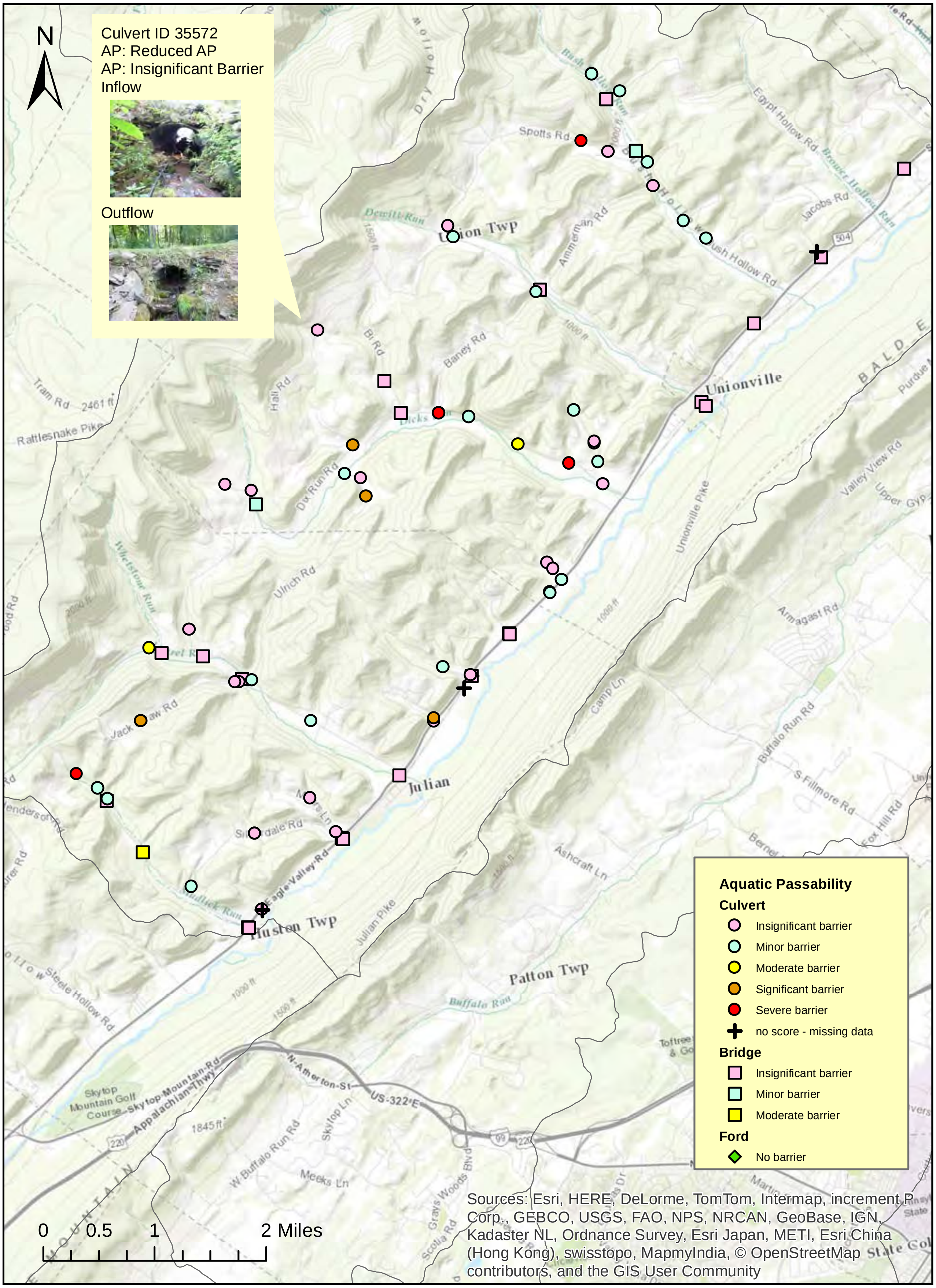
Appendix 3. Site 12 Aquatic Passability



Appendix 3. Site 37 Aquatic Passability



Appendix 3. Site 38 Aquatic Passability



Appendix 3. Site 39 Aquatic Passability