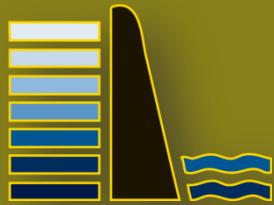




Photo: Robust Redhorse Sucker *Moxostoma robustum*  
© Brian Gratwicke Flickr Creative Commons



# SEACAP: Southeast Aquatic Connectivity Assessment Project

*Assessing the ecological impacts of dams on Southeastern rivers*



Photo: Little\_River\_Dam © Jim Liestman Flickr Creative Commons

*Corresponding author:*  
*Erik Martin*  
*The Nature Conservancy*  
*Eastern Conservation Team*  
*14 Maine Street, Suite 401*  
*Brunswick, ME 04011*  
*[emartin@tnc.org](mailto:emartin@tnc.org)*

*December 31, 2014*

*Please cite as:*

*Martin, E. H., Hoenke, K., Granstaff, E., Barnett, A., Kauffman, J., Robinson, S. and Apse, C.D. 2014. SEACAP: Southeast Aquatic Connectivity Assessment Project: Assessing the ecological impact of dams on Southeastern rivers. The Nature Conservancy, Eastern Division Conservation Science, Southeast Aquatic Resources Partnership. <http://www.maps.tnc.org/seacap>*



# Acknowledgements

Funding for this project was generously provided by the South Atlantic Landscape Conservation Cooperative (SALCC).

This project would not have been possible without substantial contributions from the SEACAP Workgroup. Over the two year course of the project, Workgroup members met on a regular basis, provided data, reviewed intermediate datasets and draft results, and provided valuable insight and opinions at key decision points. In particular, we would like to thank (in alphabetical order) Mark Cantrell, Will Duncan, Duncan Elkins, Kathleen Freeman, Paul Freeman, Sara Gottlieb, Chris Goudreau, Will Graf, Chad Holbrook, Ted Hoehn, Jeff Kipp, Wilson Laney, Erin McCombs, Rua Mordecai, Lisa Moss, Robert Newton, Bill Post, Fritz Rhode, Kristina Serbesoff-King, Tyler Stubbs, Alan Weaver, Mike Wicker, Daniel Wieferich and Bennett Wynne....for their involvement on and off Workgroup calls to field in-between-call questions, editing data, and promoting this project to their agencies and other scientists. A complete list of Workgroup participants is included as Appendix I.

Likewise, this project would not have been possible without the previous projects it built upon and the people who spearheaded them. This includes Arlene Olivero Sheldon and Mark Anderson's work on the [Northeast Aquatic Habitat Classification System](#), the [Chesapeake Fish Passage Prioritization Project](#) and the [Northeast Aquatic Connectivity](#) project and their respective Workgroups.

Finally, we would like to thank Jeff Zurakowski and Ty Gutherie on The Nature Conservancy's Spatial Data Infrastructure team for their behind-the-scenes support of the SEACAP web map and custom analysis tool and Susan Hertenstine for her guidance and leadership on project administration.

# Contents

Acknowledgements .....	2
List of Figures.....	5
List of Tables .....	6
1 Background, Approach, and Outcomes.....	7
1.1 Background .....	7
1.2 Approach .....	8
1.2.1 Workgroup.....	8
1.2.2 Project Extent.....	9
2 Data Collection and Preprocessing.....	9
2.1 Definitions.....	9
2.1.1 Functional River Networks.....	9
2.1.2 Watersheds.....	10
2.1.3 Stream size class.....	10
2.2 Hydrography .....	11
2.3 Database of Dams.....	13
2.3.1 Compilation of Existing Dam Databases.....	13
2.3.2 Estimated Dams .....	14
2.3.3 Final Database.....	16
2.4 Diadromous Fish Habitat .....	16
2.5 Resident Fish Data .....	17
2.5.1 Species Richness and Rare Species .....	17
2.5.2 Species Specific Ranges.....	18
2.6 Waterfalls.....	19
3 Analysis Methods.....	19
3.1 Metric Calculation.....	19
3.1.1 Derived Metrics.....	21
3.2 Metric Weighting.....	22
3.3 Prioritization.....	23
4 Results, Uses, & Caveats.....	25
4.1 Results .....	25

4.1.1	Diadromous Fish Scenario.....	25
4.1.2	Resident Fish Scenario.....	26
4.2	Result Uses.....	26
4.3	Data Limitations & Caveats .....	28
5	Web Map & Custom Analysis Tool.....	30
5.1	Web Map .....	31
5.1.1	Project Data .....	32
5.1.2	Widgets.....	32
5.2	Custom Dam Prioritization Tool.....	37
5.2.1	Applying Custom Weights & Order .....	38
5.2.2	Filtering Input Dams.....	39
5.2.3	Generating Summary Statistics .....	41
5.2.4	Dam Removal Scenarios.....	42
5.2.5	Viewing and Exporting Results.....	45
6	References.....	51
7	Appendix I: SEACAP Workgroup.....	53
8	Appendix II: Input Datasets .....	55
9	Appendix III: Resident Fish Species List .....	58
10	Appendix IV: Methodology for Identifying Duplicate Dams .....	67
11	Appendix V: Glossary and Metric Definitions.....	70

# List of Figures

Figure 1-1: Lassiter Mill Dam on the Uwharrie River in North Carolina was removed in 2013.....	7
Figure 1-2: SEACAP Study Area.....	8
Figure 2-1: Conceptual illustration of functional river networks .....	9
Figure 2-2: Watershed definitions.....	10
Figure 2-3: Size class definitions and map of rivers by size class in the SEACAP study area.....	11
Figure 2-4: Braided segments highlighted in blue were removed to generate a dendritic network....	12
Figure 2-5: Illustration of snapping a dam to the river network.....	13
Figure 2-6: Cleaning estimated dam data.....	16
Figure 2-7: Final project data for American shad.....	17
Figure 3-1: A hypothetical example ranking four dams based on two metrics.....	24
Figure 4-1: Workgroup-consensus Diadromous Fish Scenario results .....	25
Figure 4-2: Workgroup-consensus Resident Fish Scenario results, stratified by subregion .....	26
Figure 4-3: Steeles Mill Dam on Hitchcock Creek in North Carolina during and after removal.....	27
Figure 5-1: Conceptual architecture of web map & custom prioritization tool .....	30
Figure 5-2: Web map welcome screen. ....	31
Figure 5-3: Basic features of the web map.....	32
Figure 5-4: Widgets in the Widget Tray .....	33
Figure 5-5: Search widget- find a dam by name.....	34
Figure 5-6: The Draw widget.....	34
Figure 5-7: The Layers widget.....	35
Figure 5-8: Extract & Download Data widget.....	36
Figure 5-9: The additional Map Layers widget.....	36
Figure 5-10: Custom Dam Prioritization Tool layout .....	38
Figure 5-11: Changing the sort order for a metric .....	39
Figure 5-12: The Tool with the option to filter input dams highlighted .....	40
Figure 5-13: Building a filter.....	40
Figure 5-14: Adding a second filter using the Filter Builder.....	41
Figure 5-15: Final filter applied from the Filter Builder .....	41
Figure 5-16: Selecting the option to run summary statistics on custom prioritization results .....	42
Figure 5-17: Selecting the option to model dams for removal .....	43
Figure 5-18: Dams ready to be selected for modeled removal .....	44
Figure 5-19: A set of dams to be modeled as removed .....	45
Figure 5-20: The "Status" state of the Tool displaying updates on a current analysis.....	46
Figure 5-21: The “Results” state.....	47
Figure 5-22: Select a record in the Results to zoom to a corresponding feature.....	48
Figure 5-23: Sorting on a column in the results and buttons to work with the results.....	49
Figure 5-24: Summary statistics of custom scenario results .....	50

## List of Tables

Table 3-1: Natural waterbodies that were removed from the NHDPlus v2 waterbodies dataset if they were represented as polygons .....	15
Table 3-2: Invasive fish species attributed to dams based on occurrences within HUC8 watersheds .....	18
Table 4-1: Metrics calculated for each dam in the study .....	20
Table 4-2: Workgroup-Consensus metric weights for the Diadromous Fish Scenario.....	22
Table 4-3: Workgroup-Consensus metric weights for the Resident Fish Scenario.....	23

# 1 Background, Approach, and Outcomes

## 1.1 Background

The rivers and streams of the Southeastern United States are extremely diverse, containing numerous threatened and endangered species. In fact, southeastern rivers contain more at-risk freshwater fish and invertebrates than any other region of the country (Master et al. 1998).

The anthropogenic fragmentation of river habitats through dams and poorly designed culverts is one of the primary threats to aquatic species in the United States (Collier et al. 1997, Graf 1999). The impact of fragmentation on aquatic species generally involves loss of access to quality habitat for one or more life stages of a species. For example, dams and impassable culverts limit the ability of anadromous fish species to reach preferred spawning habitats and prevent brook trout populations from reaching thermal refuges.

Some dams provide valuable services to society including low or zero-emission hydro power, flood control, and irrigation. Many more dams, however, no longer provide the services for which they were

Figure 1-1: Lassiter Mill Dam on the Uwharrie River in North Carolina was removed in 2013.



designed (e.g. old mill dams) or are inefficient due to age or design. However, these dams still create barriers to aquatic organism passage. In addition, fish ladders have long been used to provide fish passage in situations where dam removal is not a feasible option. In many cases, these connectivity restoration projects have yielded ecological benefits such as increased anadromous fish runs, improved habitat quality for resident fish species, and expanded mussel

populations. These projects have been spearheaded by state agencies, federal agencies, municipalities, NGOs, and private corporations – often working in partnership. Notably, essentially all projects have had state resource agency involvement. The majority of the funding for these projects has come from the federal government (e.g. NOAA, USFWS), but funding has also come from state and private sources. All funding sources have been impacted by recent fiscal instability and federal funding for connectivity

restoration is subject to significant budget tightening and increased accountability for ecological outcomes.

To many working in the field of aquatic resource management it is apparent that given likely future constraints on availability of funds and staffing, it will be critical to be more strategic about investments in connectivity restoration projects. One approach to strategic investment is to assess the likely ecological “return on investment” associated with connectivity restoration.

The Chesapeake Fish Passage Prioritization Project (Martin and Apse 2013) assessed dams in the Chesapeake Bay Watershed based on their potential to provide ecological benefits for one or more targets (e.g. anadromous fish species or resident fish species) if removed or bypassed. Funded by the South Atlantic Landscape Conservation Cooperative (SALCC), the Southeast Aquatic Connectivity Assessment Project (SEACAP) grew out of and builds on the conceptual framework of the Chesapeake Fish Passage Prioritization Project and the Northeast Aquatic Connectivity Project (Martin and Apse 2011). The sections that follow detail the data, methods, results, and tools developed for SEACAP.

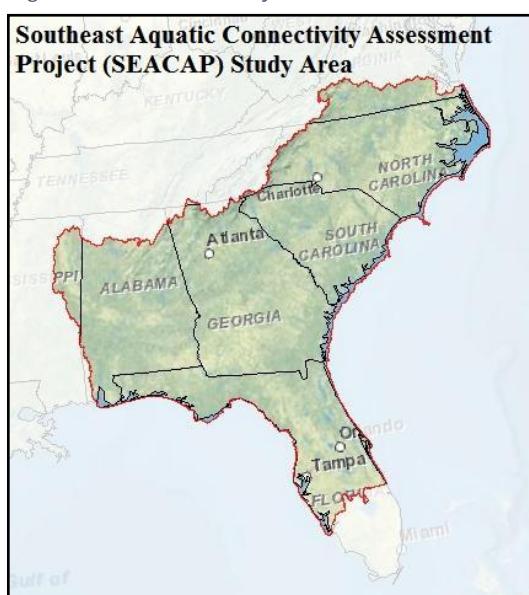
## 1.2 Approach

### 1.2.1 Workgroup

SEACAP was structured around a project workgroup, the SEACAP Workgroup, composed of members from federal and state agencies, NGOs, and academia. A full list of Workgroup participants can be found in Appendix I. Convening via both regular online meetings as well as in-person meetings, the Workgroup was involved in several key aspects of the project including data acquisition and review, key decision making, and review of draft results. This collaborative workgroup approach built upon TNC’s successful experience working with a state agency team to complete the Chesapeake Fish Passage Prioritization and the Northeast Aquatic Connectivity projects. In addition to providing input throughout the project,

the Workgroup members form a core user base, active in aquatic connectivity restoration and with a direct and vested interest in the results.

Central among the key decisions made by the Workgroup was to define the objectives of the prioritization. That is, 1) for what benefit are we prioritizing? and 2) what aspects of a dam or its location would make its removal or mitigation more likely to achieve the objective? This process of selecting targets and the metrics that would be used to evaluate the dams was both a collaborative and subjective process. The Workgroup selected two targets: diadromous fish and resident fish. Different metrics were used to create two separate prioritization scenarios for these two targets resulting in two prioritized lists of dams.



## 1.2.2 Project Extent

The study area, which consists of HUC 4 watersheds draining the SALCC region, covers 250,000 square miles, has over 350,000 miles of mapped rivers and streams, tens of thousands of dams, and hundreds of thousands of culverts.

# 2 Data Collection and Preprocessing

Spatial data for the project were gathered from multiple data sources and processed in a Geographic Information System (GIS) to generate descriptive metrics for each dam. The core datasets included river hydrography, dams, diadromous fish habitat, resident fish species occurrences, and natural waterfalls. Additional datasets were used as needed to generate metrics of interest to the Workgroup. These datasets include land cover and impervious surface data, roads, rare fish, mussel, and crayfish watersheds, fish species richness, and invasive species occurrences. A complete list of data used in the project can be found in Appendix II. A further description of the core datasets follows.

## 2.1 Definitions

Several terms are used throughout the discussion of data and metrics. The sections below detail some important terms for understanding the data and how metrics were calculated.

### 2.1.1 Functional River Networks

A dam's functional river network, also referred to as its connected river network or simply its network, is defined by those stream reaches that are accessible to a hypothetical fish within that network. A given target dam's functional river network is bounded by other dams, headwaters, or the river mouth, as is illustrated in Figure 2-1. A dam's total functional river network is simply the combination of its upstream and downstream functional river networks. The total functional network represents the total distance a fish could theoretically swim within the network if that particular dam was removed.

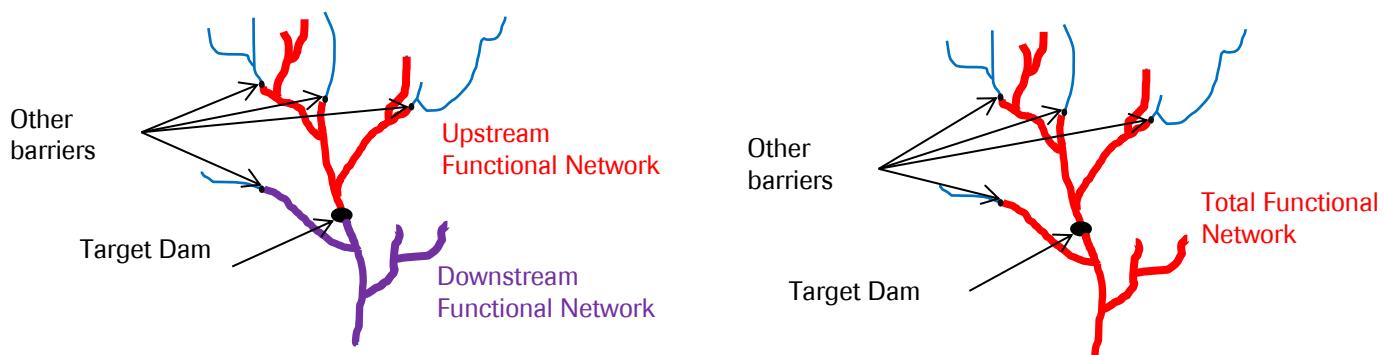


Figure 2-1: Conceptual illustration of functional river networks

## 2.1.2 Watersheds

For any given dam, metrics involving three different watershed scales are used in the analysis. The contributing watershed, or total upstream watershed, is defined by the total upstream drainage area above the target dam. Several metrics are also calculated within the watershed of a target dam's upstream and downstream functional river networks. These local watersheds are bounded by the watersheds for the next upstream and downstream functional river networks, as illustrated in Figure 2-2.

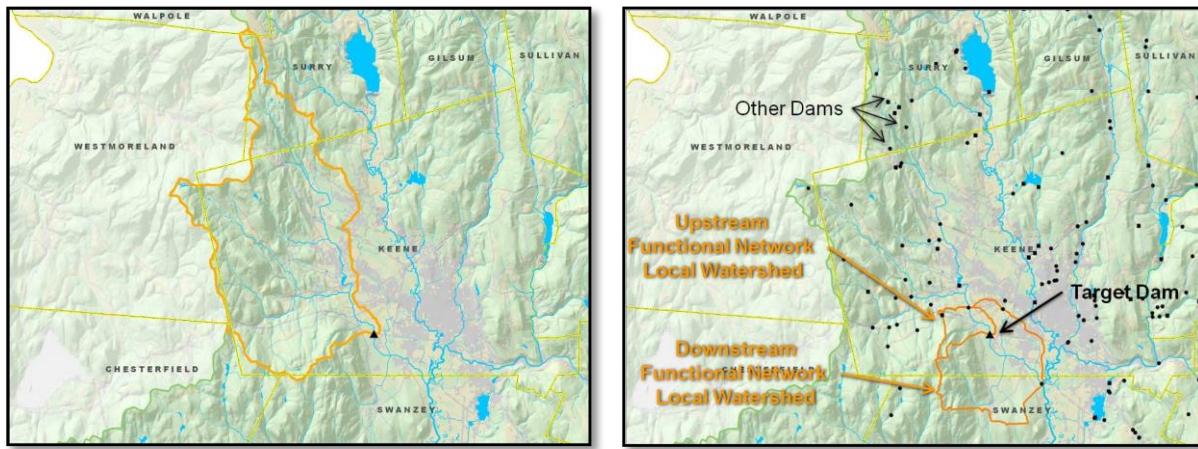


Figure 2-2: The contributing watershed is defined by the total drainage upstream of a target dam. The upstream and downstream functional river network local watersheds are bounded by the watershed for the next dams up and down stream.

## 2.1.3 Stream size class

Stream size is a critical factor for determining aquatic biological assemblages (Olivero and Anderson 2008; Vannote et al. 1980; Mathews 1998). In this analysis, river size classes, based on the catchment drainage size thresholds developed for the Northeast Aquatic Habitat Classification System (Olivero and Anderson 2008), were calculated for each segment of the project hydrography and in turn assigned to each dam (Figure 2-3). Size classes were used in several ways throughout the analysis including as a proxy for habitat diversity and to define fish habitat (e.g. American shad use size classes  $\geq$ Size 2).

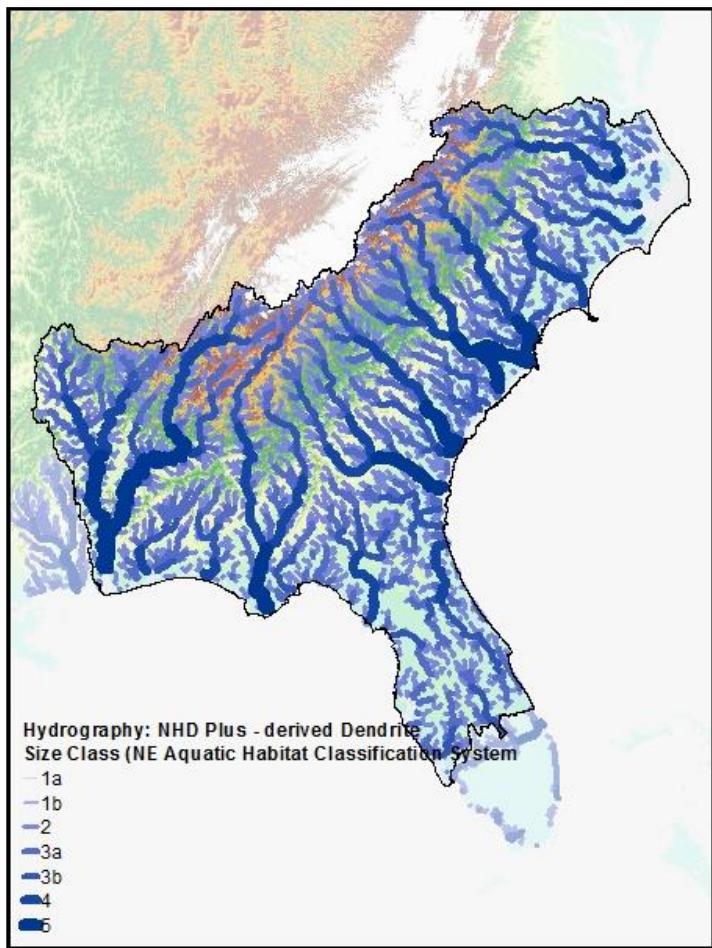


Figure 2-3: Size class definitions and map of rivers by size class in the SEACAP study area

- 1a) Headwaters ( $<3.861 \text{ mi}^2$ )
  - 1b) Creeks ( $\geq 3.861 < 38.61 \text{ mi}^2$ )
  - 2) Small River ( $\geq 38.61 < 200 \text{ mi}^2$ )
  - 3a) Medium Tributary Rivers ( $\geq 200 < 1000 \text{ mi}^2$ )
  - 3b) Medium Mainstem Rivers ( $\geq 1000 < 3861 \text{ mi}^2$ )
  - 4) Large Rivers ( $\geq 3861 < 9653 \text{ mi}^2$ )
  - 5) Great Rivers ( $\geq 9653 \text{ mi}^2$ )
- (Defining measure = upstream drainage area)

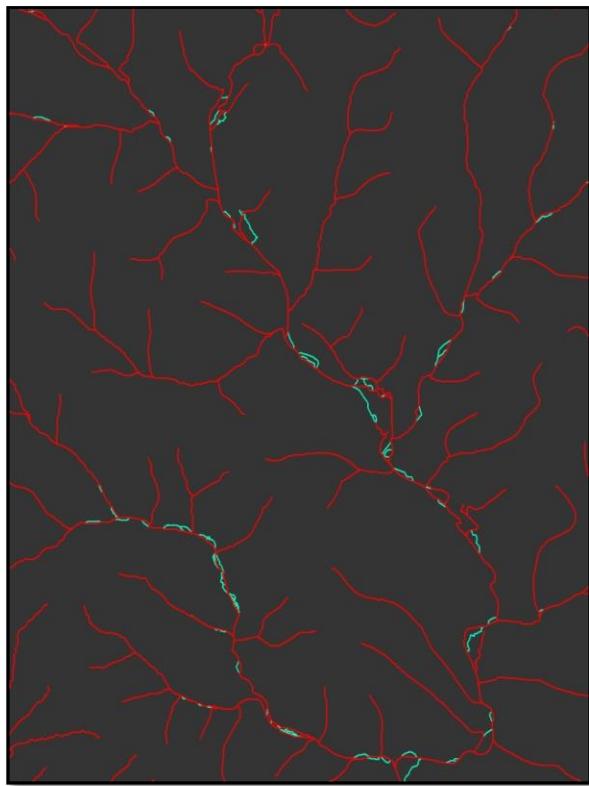
## 2.2 Hydrography

In order for dams to be included in the analysis, they had to fall on the mapped river network, or hydrography, that was used in the project: a modified version of the Medium Resolution National Hydrography Dataset Plus, Version 2 (NHDPlus v2) (Horizon Systems 2012). This hydrography was originally digitized by the United States Geological Survey primarily from 1:100,000 scale topographic

maps. Substantial additions and improvements were applied to the USGS NHD data by Horizon Systems Corporation to create the NHDPlus v2.

To be used in this analysis, the hydrography was processed to create a dendritic network, or dendrite, defined as a single-flowline network with no braids or other downstream bifurcation (Figure 2-4). Attributes in the medium-resolution NHDPlusV2 were queried to identify the mainstem of a river from a braided section. (NHDFlowline.FLOWDIR = 'With Digitized' AND NHDPlusFlowlineVAA.Divergence in (0,1) AND NHDPlusFlowlineVAA.StreamCalc <>0). Additional information on the NHDPlus v2 and these attributes can be found in the NHDPlus v2 User Guide (Horizon Systems 2012).

Figure 2-4: Braided segments highlighted in blue were removed to generate a dendritic network.



The result of this process was a single-flowline dendrite, based on the current Medium Resolution NHD, for the project area. This dendrite (hereafter referred to as the “project hydrography”) was then further processed using the ArcGIS Geometric Network toolset in ArcGIS 10.1 to establish flow direction for each segment. Additional processing using ArcGIS Spatial Analyst and custom Python scripts in ArcGIS was performed to accumulate upstream attributes for each line segment in the project hydrography. These processes produced values including the total upstream drainage area, percent impervious surface, and percent forested land cover for each river segment.

## 2.3 Database of Dams

### 2.3.1 Compilation of Existing Dam Databases

Dam data was obtained from several sources. Federal data sources constitute the backbone of the SEACAP dataset providing the locations of larger dams on the project hydrography. These sources include the US Army Corps of Engineer's National Inventory of Dams (NID), the USGS Geographic Names Information System (GNIS) database, the High Resolution NHD Dam Events dataset, and the National Anthropogenic Barrier Dataset (NABD), which includes dams from the 2009 NID dataset that were manually aligned to the medium resolution NHD flowlines. To locate dams not represented in these datasets, the SEACAP project team contacted representative Workgroup members from each state in the project area, as well as representatives from various state agencies, local watershed groups and non-profit organizations. Additional datasets were provided from a previous barrier assessment conducted by the University of Georgia (Elkins and Nibbelink 2012), as well as a manually edited database composed of multiple sources for the State of North Carolina used in the North Carolina Barrier Prioritization Tool (Hoenke 2014), a smaller barrier assessment that helped inform this project. Duplicate dams were removed using a series of steps outlined in Appendix IV: Methodology for Identifying Duplicate Dams. In short, duplicates were identified using federal and State IDs; if neither were present, search distances of 100 meters were used to identify potential duplicates. If a duplicate was present, the dam with the best geographic location and most complete attributes was retained.

Data preprocessing and review began after all available data were obtained for each state from the sources listed above. In order to perform network analyses in a GIS, the points representing dams must be topologically coincident with lines that represent rivers. This was rarely the case in the dam datasets as they were received from various data sources. To address this problem, dams were “snapped” in a GIS to spatially align them with the project hydrography (Figure 2-5).

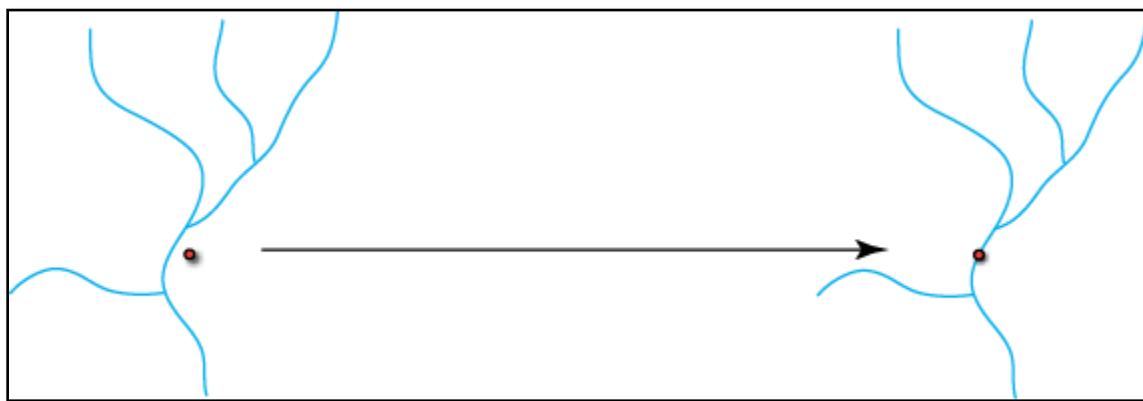


Figure 2-5: Illustration of snapping a dam to the river network

Dams that were obtained from the NABD had previously been snapped to the medium resolution (1:100,000) NHD and error checked as part of that project's review process. Thus, it was assumed that dams obtained from that project were in the correct location. However, dams from this database had outdated attribute information, as they were from the NID 2009. To remedy this, the spatial location

from dams in NABD was used for duplicates that shared the same NID identifier (NIDID) as dams from the 2013 NID database, but 2013 attribute information was retained. This method was also used for any dams from state databases sharing the NIDID with NABD dams, however state attribute information was retained. Similarly, any dams from local sources having few attributes were given attributes from a statewide dataset when available, or the NID 2013 dataset.

Snapping for non-NABD dams was performed using the Nature Conservancy's Barrier Analysis Tool (BAT). Although snapping is a necessary step which must be run prior to performing the subsequent network analyses, it also can introduce error into the data. For example, if the point in Figure 2-5 is, in fact, a dam on the main stem of the pictured river, the snapping will correctly position it on the hydrography. If, however, the point represents an off-stream farm pond next to the main stem, then snapping will incorrectly move it onto the hydrography. A snapping tolerance, or "search distance" can be set to help control which points are snapped. The project team selected a 100 meter snapping tolerance and developed a review process to error check the results.

The review process for snapped dams involved comparing the snapping distance as well as the "REACHCODE" attribute, which persists between different versions of the NHD. Dams which snapped to the project hydrography within the 100m snap tolerance and that had matching REACHCODEs were considered to be in the correct location. Other dam locations were manually reviewed based on a series of error 'flag' priorities and edited if necessary. Dams were further edited by the workgroup using ArcGIS Online.

### 2.3.2 Estimated Dams

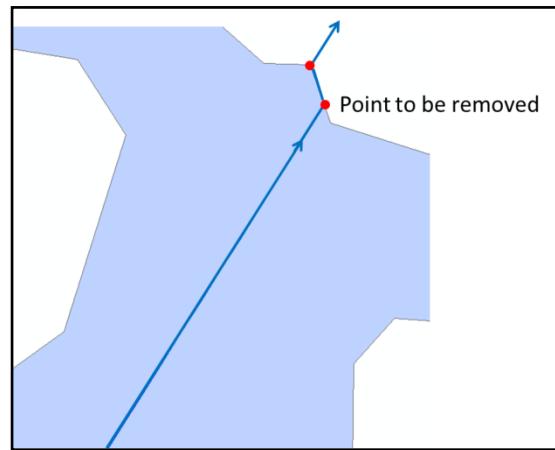
The dam databases described above are known to underrepresent the actual number of barriers on the ground in the Southeastern US, particularly smaller reservoirs and impoundments (Ignatius and Jones 2014; Ignatius and Stallins 2011). We developed an approach to estimate these missing impoundments using the NHDPlus v2 waterbody polygons and stream polylines. Our approach relied on the assumption that the presence of a lake or pond likely represented an impoundment as there are few naturally occurring waterbodies in the Southeastern US. We first removed known natural waterbodies represented in the NHDPlus v2 data (Table 2-1). For the state of Florida, we obtained the Florida Natural Areas Inventory (FNAI) Cooperative Land Cover, Version 2.1 (Dec. 2013) and removed all NHDPlus v2 waterbody polygons whose centroid occurred in a natural waterbody land cover (e.g., basin swamp, bottomland forest, floodplain swamp, hydric hammock, etc.). In addition to removing known natural waterbodies, we delineated a tidal-influence zone within which natural and estuarine waterbodies were likely to occur. To create this zone, we applied two elevation thresholds to a 30-m Digital Elevation Model (DEM) derived from a seamless mosaic of the National Elevation Dataset (NED; Gesch 2007; Gesch et al. 2002). We used a 2 m threshold for the Atlantic Coast and a 1 m limit for the Gulf of Mexico based on expert opinion and tidal information. Any NHDPlus v2 waterbodies that occurred within this zone were not used in the estimated dam analysis. After removing known and likely natural waterbodies, we dissolved the NHDPlus waterbodies by ReachCode to address cases where continuous lakes were represented as separate but adjacent polygons. All NHDPlus flowlines coded as Artificial Path, Connector, or CanalDitch were selected and then intersected with the dissolved NHDPlus

waterbodies. We used the NHDPlus VAA attributes to summarize and query the resultant polyline output to select the flowline with the largest cumulative drainage area for each unique waterbody to identify the outflow point for each waterbody. The selected flowlines (Artificial, Connector, or CanalDitch) were then converted to points using the end vertices as the waterbody outflow. A Python query was run to remove duplicate points that had the same waterbody ReachCode. Duplicate points occurred when the selected artificial flowline segment intersected a waterbody polygon more than once (Figure 2-6). Additional queries were run to remove estimated dams erroneously created when a single waterbody was spatially represented by multiple connected polygons with different ReachCodes.

Table 2-1: Natural waterbodies that were removed from the NHDPlus v2 waterbodies dataset if they were represented as polygons.

<b>State</b>	<b>Waterbody</b>
NC	Lake Waccamaw
NC	Lake Phelps
NC	Pungo Lake
NC	New Lake
NC	Lake Mattamuskeet
NC	Catfish Lake
NC	Great Lake
NC	Long Lake
NC	Little Lake
NC	Lake Ellis Simon
NC	Bay Tree Lake
NC	White Lake
NC	Little Singletary Lake
NC	Salters Lake
NC	Jones Lake
NC	Horseshoe Lake/Suggs Millpond
NC	Bakers Lake
SC	Ditch Pond Carolina bay
VA	Lake Drummond

Figure 2-6: This figure illustrates how two estimated dam locations were erroneously generated for a single waterbody polygon when an artificial flowline segment with the largest cumulative drainage area intersected a waterbody polygon twice. Direction of flow is indicated by a blue arrow on the NHDPlus flowline, the waterbody polygon is in light blue and the estimated dam locations are shown as red points.



Our approach has several caveats that should be considered. First, despite our efforts to remove known and likely natural waterbodies, not all of the remaining NHDPlus waterbody polygons may have been actual impoundments. Second and in contrast to the first issue, we found that the NHDPlus does not capture all waterbodies on the ground and underrepresents these features across the landscape. Third, there were instances where a continuous waterbody was represented as two or more separate polygons with different unique IDs in the NHDPlus dataset. In these cases, estimated dams would be generated for each distinct polygon, overestimating the presence of barriers. Finally, all pertinent NHDPlus waterbody and flowline attribute information was joined to the estimated dam locations, but we had no information on the estimated barrier itself such as type, size, age, etc. Given these caveats, our team manually reviewed the resulting estimated dams using aerial imagery and removed those that appeared erroneous. While this manual review greatly improved the accuracy of the estimated dam database, the review was subject to interpretation error and could not address errors inherent in the NHDPlus databases. After the manual review process was complete 3,590 estimated dams were left in the database. Review from individuals with on-the-ground knowledge of a particular area could further improve the accuracy of the estimated dam locations.

### 2.3.3 Final Database

There were 50,326 dams (46,736 known dams and 3,590 estimated dams) in the entire SEACAP database when all sources were combined. This number included pre-reviewed estimated dams, duplicates, dams outside the study area which are needed to bound the network analysis but which were not evaluated, dams on small streams which are not mapped in the NHDPlus hydrography, as well as other dams or structures which are not barriers such as breaches, levees, and removed dams. In the end 16,933 of these dams were evaluated in the analysis. This represents 51% of the 33,156 dams that are current barriers, with the remaining dams falling on small streams that are not mapped in the project hydrography, or which lie outside of the study area.

## 2.4 Diadromous Fish Habitat

Identifying opportunities to improve aquatic connectivity for the benefit of diadromous fish populations was one of the key goals of the project. Diadromous fish habitat downstream of a dam was one of the

Figure 2-7: Final project data for American shad.



most important factors chosen by the Workgroup for the Diadromous Fish Scenario to determine which dams have the greatest potential for ecological benefit if removed or mitigated.

Baseline habitat data were collected for American shad, hickory shad, Alabaman shad, blueback herring, alewife, striped bass, Atlantic sturgeon, and gulf sturgeon. These data were collected from the Atlantic States Marine Fisheries Commission (ASMFC 2004), as well as from the National Fish Habitat Partnership (NFHAP) database (Esselman et al 2013), the Multistate Aquatic Resources Information System (MARIS- <http://www.marisdata.org/>), and the North Carolina Museum Collection data (<http://collections.naturalsciences.org/>). These data were extensively reviewed and edited by fisheries biologists in the spring of 2014 at the Southern Division American Fisheries Society meeting in Charleston, South Carolina, as well as through a series of follow-up online meetings. This review process incorporated additional fish observance data as well as expert knowledge from biologists.

## 2.5 Resident Fish Data

Resident fish species data were attributed to dams using a suite of species occurrence data available at the 8-digit HUC watershed (HUC8s). Resident fish species data were assigned to HUC8 watersheds, as opposed to stream reaches, to help account for sampling inconsistencies and bias. These resident fish species data were used to calculate a fish species richness metric for use as a weighted metric in custom analysis scenarios. Additionally, the range of individual fish species can be used to filter dams in a custom analysis (e.g. only analyze dams that are in a watershed which supports rainbow darter.)

### 2.5.1 Species Richness and Rare Species

For users wishing to prioritize dams based on the variety of species present in a dam's watershed, a suite of optional ecological metrics are available. Two separate fish species richness values were calculated. The first was based directly on a NatureServe-calculated fish species richness metric which measures total resident fish species richness for all species in the NatureServe database. A second fish richness metric was calculated for species of interest identified by the Workgroup using data compiled from multiple sources (see Section 2.5.2). Freshwater mussel richness was calculated from NatureServe data in a similar manner, using individual species layers from NatureServe at the HUC8 scale. Finally, the numbers of rare fish, rare mussel and rare crayfish (G1-G3) in a HUC8 were obtained directly from NatureServe's HUC8 data.

## 2.5.2 Species Specific Ranges

In addition to providing the option to use species richness data as weighted metrics in a custom prioritization, the option is also presented to use a specific species' HUC8 range to limit the analysis inputs. Doing so would limit the analysis to only those dams that are in a watershed where that species is found. For example, an analysis could be performed to prioritize dams based on a user-defined suite of habitat metrics, but limited geographically to dams in watersheds with documented occurrences of robust redhorse. This could be useful if there was interest or funding to target passage projects to benefit a specific species or suite of species.

The species-specific HUC8 range maps were created by compiling three data sources: NatureServe HUC8-scale data, Multistate Aquatic Resources Information System (MARIS) point occurrence data, and USGS Biodiversity Information Serving Our Nation (BISON) database point occurrence data. Erring on the side of inclusion, any HUC8 where a given species was present in any of the three input data sources was assigned a value of "present" for that species. If none of the three data sources had records for a given species in a given HUC8, that HUC8 was assigned a value of "Absent." Each dam inherited the presence/absence value for each species from the HUC8 it was within. A complete list of the resident fish species used can be found in Appendix III: Resident Fish Species List.

Similarly to resident species, invasive species data were also made available at the HUC8 scale so that a user can filter prioritized dams and eliminate dams from the prioritization that may contain invasive species in the watershed. These data were compiled from the USGS Nonindigenous Aquatic Species (NAS) database and MARIS. Invasive species included in this dataset were selected by the SEACAP Workgroup and are presented in Table 2-2.

Table 2-2: Invasive fish species attributed to dams based on occurrences within HUC8 watersheds

Scientific Name	Common Name
<i>Channa argus</i>	Northern Snakehead
<i>Channa maculata</i>	Blotched Snakehead
<i>Channa marulius</i>	Bullseye Snakehead
<i>Clarias batrachus</i>	Walking Catfish
<i>Cyprinella lutrensis</i>	Red Shiner
<i>Dreissena polymorpha</i>	Zebra Mussel
<i>Hypophthalmichthys molitrix</i>	Silver Carp
<i>Hypophthalmichthys nobilis</i>	Bighead Carp
<i>Ictalurus furcatus</i>	Blue Catfish
<i>Ictiobus bubalus</i>	Smallmouth Buffalo
<i>Ictiobus cyprinellus</i>	Bigmouth Buffalo
<i>Micropterus coosae</i>	Redeye Bass
<i>Micropterus dolomieu</i>	Smallmouth Bass
<i>Micropterus henshalli</i>	Alabama Bass
<i>Misgurnus anguillicaudatus</i>	Oriental Weatherfish

Oncorhynchus mykiss	Rainbow Trout
Pylodictis olivaris	Flathead Catfish
Salmo trutta	Brown Trout

## 2.6 Waterfalls

Waterfalls, like dams, can act as barriers to fish passage. Including them in the analysis was important due to the impact natural barriers have across a network. For example, a waterfall just upstream of a dam would drastically affect the length of that dam's upstream functional network, or the number of river miles that would be opened by providing passage at that dam. Thus, although waterfalls are excluded from the project results, they were included in the generation of functional networks.

The primary data source for waterfalls was the USGS Geographic Names Information System (GNIS) database, which includes named features from 1:100,000 scale topographic maps. Additional waterfalls that were part of an initial effort of the USGS Aquatic GAP Program to compile a national waterfall database (Daniel Wieferich, personal communication) were also included. All waterfall data were merged together and snapped to the project hydrography using the same method previously described for dams.

## 3 Analysis Methods

The conceptual framework of the Southeast Aquatic Connectivity Assessment Project rests on a suite of ecologically relevant metrics calculated for every dam in the study area. These metrics are then used to evaluate the benefit of removing or providing passage at any given dam relative to any other dam. At its simplest, a single metric could be used to evaluate dams. For example, if one is interested in passage projects to benefit diadromous fish, the dam's upstream functional network length, or the number of river miles that would be opened by that dam's removal, could be used to prioritize dams. In this case, the dam with the longest upstream functional network—the dam whose removal would open up the most river miles—would rank at the top of the list. As multiple metrics are evaluated, weights can be applied to indicate the relative importance of each metric in a given scenario, as described in further detail in Section 3.2.

### 3.1 Metric Calculation

A total of 43 metrics were calculated for each dam in the study area using ArcGIS 10.1. Metrics were organized into five categories for convenience: Connectivity Status, Connectivity Improvement, Watershed/Local Condition, Ecological, and Size/System Type. Additionally, each metric is sorted in either ascending order or descending order to indicate whether large values or small values are desirable in a given scenario. For example, upstream functional network length is sorted descending because large values are desirable – a passage project on a dam that opens up more river miles is desired over a passage project which opens up few miles. Conversely, percent impervious surface is sorted ascending because small values are desirable – a passage project that opens up a watershed that

has little or no impervious surface is desired over a dam that opens up a watershed with a high percentage of impervious surface. Each of the metrics is presented in Table 3-1, and a more complete description of each metric can be found in Appendix V: Glossary and Metric Definitions.

Table 3-1: Metrics calculated for each dam in the study

Metric Category	Metric	Unit	Default Sort Order
Connectivity Status	# Dams Downstream	#	A
	# Dams Upstream	#	A
	Total Upstream River Length	m	D
	Downstream Waterfall Count on Flowpath	#	A
	Downstream Hydropower Dam Count on Flowpath	#	A
	Number of Dams on High Resolution NHD in upstream Drainage Area	#	A
	Upstream Barrier Density	#/m	A
	Downstream Barrier Density	#/m	A
	Density of Small (Unsnapped) Dams in Upstream Functional Network Local Watershed	#/m <sup>2</sup>	A
	Density of Small (Unsnapped) Dams in Downstream Functional Network Local Watershed	#/m <sup>2</sup>	A
	Density of Road & RR / Small Stream Crossings in Upstream Functional Network Local Watershed	#/m <sup>2</sup>	A
	Density of Road & RR / Small Stream Crossings in Downstream Functional Network Local Watershed	#/m <sup>2</sup>	A
Connectivity Improvement	Upstream Functional Network Length	m	D
	The total length of upstream and downstream functional network	m	D
	Downstream Functional Network Size	m	D
	Relative Gain	m	D
	Absolute Gain	m	D
Watershed / Local Condition	% impervious surface in Upstream Drainage Area	%	A
	% natural landcover in Upstream Drainage Area	%	D
	% forest cover in Upstream Drainage Area	%	D
	% agriculture in Upstream Drainage Area	%	A
	% Impervious Surface in ARA of Upstream Functional Network	%	A
	% Impervious Surface in ARA of Downstream Functional Network	%	A
	% Agriculture in ARA of Upstream Functional Network	%	A
	% Agriculture in ARA of Downstream Functional Network	%	A
	% Natural LC in ARA of Upstream Functional Network	%	D
	% Natural LC in ARA of Downstream Functional Network	%	D
	% Forested LC in ARA of Upstream Functional Network	%	D
	% Forested LC in ARA of Downstream Functional Network	%	D

Metric Category	Metric	Unit	Default Sort Order
	Dam is Located on Conservation Land	Boolean	D
	NFHAP Risk of Degradation Score	#	A
	Total storage / mean annual flow	cfs	D
Ecological	# Diadromous Species in DS Network	#	D
	Presence of Diadromous Species in DS Network	Boolean	D
	Resident fish species richness (NatureServe - all resident fish)	#	D
	Resident Fish Species Richness (HUC 8) Calculated Based on Workgroup List	#	D
	Resident Mussel Species Richness (HUC 8) Calculated Based on Workgroup List	#	D
	# of rare (G1-G3) fish HUC8	#	D
	# of rare (G1-G3) mussel HUC8	#	D
	# of rare (G1-G3) crayfish HUC8	#	D
Size / System Type	Number of new upstream size classes >0.5 miles gained by removal / bypass	#	D
	Total Reconnected # stream sizes (upstream + downstream) >0.5 Mile	#	D
	River Size Class	#	D

### 3.1.1 Derived Metrics

#### 3.1.1.1 Active River Area

The Active River Area (ARA) is a spatially explicit framework for modeling rivers and their dynamic interaction with the land through which they flow (Smith et al. 2008). Key features of the ARA include the meander belt, riparian wetlands, floodplains, terraces, material contribution areas. The ARA is different from, but was calibrated to and compared against the FEMA 100-year floodplain. The SEACAP project used the ARA as a unit within which various landcover metrics, such as forest cover and impervious surface, were summarized.

For the SEACAP project area, we delineated the ARA for each of the seven size classes described in Section 2.1.3, using a seamless mosaic of 10m DEM data from the National Elevation Dataset (Gesch 2007; Gesch et al. 2002) as well as stream polylines, waterbody polygons, and stream area polygons from the NHDPlus v2 dataset. We selected and resampled wetflat landforms from a 30m landform model developed for the Southeastern US (Anderson et al. 2014) to identify ARA components that occurred on wetflats and where longer-term storage of water is expected to occur. In addition, we obtained 100-yr floodplain polygons from the FEMA National Flood Hazard Layer (NFHL) in spring 2013 and used this data to inform cost distance threshold selection in the ARA delineation. Any FEMA 100-yr floodplain areas that were not captured by the ARA delineation were gridded at 10m resolution and merged underneath the ARA components in the final product. The final 10m ARA was resampled to 30m for use in the SEACAP metric calculations due to the resolution of other key input datasets (i.e., landcover).

The methods used to calculate all metrics was automated and documented via ArcGIS Model Builder models and custom Python scripts. Contact the authors for more information on the methods used to calculate metrics.

## 3.2 Metric Weighting

Depending on the objectives of a prioritization scenario some metrics will be of greater importance than other metrics. Thus, metrics are selected and weighted to develop a scenario for a given objective. For example, if the objective of a prioritization scenario is to identify dams which would benefit diadromous fish if passed, upstream functional network length may be of particular interest, while the percent impervious surface in a dam's watershed may be of less importance, and the presence of rare crayfish species may be of no interest. Relative weights, which must sum to 100, can be assigned to each metric to indicate its importance in a given scenario. Table 3-2 and Table 3-3 list the weights chosen by the SEACAP Workgroup, through an iterative, consensus-based process for the Diadromous Fish Scenario and the Resident Fish Scenario respectively.

Metric weights are subjective in nature; there are no hard and fast rules regarding how to properly select and weight metrics for a given target like diadromous fish. To arrive at the weights presented in the tables below, the Workgroup went through an iterative process of selecting draft weights based on their knowledge of the species of interest, then adjusting the weights in response to draft results and based on participants' current removal priorities. This process allowed the Workgroup to both understand the impact of making an adjustment to a given metric weight, and also served to better calibrate the results to known priorities.

Table 3-2: Workgroup-Consensus metric weights for the Diadromous Fish Scenario

Metric Category	Metric	Diadromous Weight
Connectivity Status	Downstream Dam Count on Flowpath	10
	Downstream Hydropower Dam Count on Flowpath	5
	Total Upstream River Length	10
	Density of Road & Railroad / Small Stream Crossings in Upstream Functional Network Local Watershed	10
Connectivity Improvement	Upstream Functional Network Size	15
	The total length of upstream and downstream functional network	5
Watershed / Local Condition	% impervious surface in Upstream Drainage Area	5
	% natural landcover in Upstream Drainage Area	5
	% Impervious Surface in ARA of Upstream Functional Network	5
	Total storage / mean annual flow	5
Ecological	# Diadromous Species in DS Network (incl Eel)	5
	Presence of Anadromous Species in DS Network	15
Size / System Type	# Upstream Size Classes >0.5mi gained	5

Table 3-3: Workgroup-Consensus metric weights for the Resident Fish Scenario.

Metric Category	Metric	Resident Weight
Connectivity Status	Density of All Small Dams (Snapped to High Res NHD or not) in Downstream Functional Network Local Watershed	5
	Density of Road & Railroad / Small Stream Crossings in Downstream Functional Network Local Watershed	10
	Density of All Small Dams (Snapped to High Res NHD or not) in Upstream Functional Network Local Watershed	5
	Density of Road & Railroad / Small Stream Crossings in Upstream Functional Network Local Watershed	10
Connectivity Improvement	Absolute Gain	20
Watershed / Local Condition	% impervious surface in Upstream Drainage Area	10
	% forest cover in Upstream Drainage Area	10
	% Impervious Surface in ARA of Upstream Functional Network	5
	% Impervious Surface in ARA of Downstream Functional Network	5
	% Forested LC in ARA of Upstream Functional Network	5
	% Forested LC in ARA of Downstream Functional Network	5
Size / System Type	Total Reconnected # stream sizes (upstream + downstream) >0.5 Mile	10

In addition to assigning relative weights for metrics, the universe of dams that are included in an analysis can be filtered. For example, only dams on small streams can be included in the prioritization if desired. Filters such as this can be based on geography (e.g. state, watershed) or any attribute (e.g. dam purpose, presence of a specific diadromous species). Additional details on using filters can be found in Section 5: Web Map and Custom Analysis Tool.

Of note, the SEACAP Workgroup chose to focus weighted metrics on habitat factors for the resident fish scenario, reserving biological data for use in the custom analysis tool as weighted metrics (e.g. fish species richness) or filters (e.g. only prioritizes dams in watersheds where robust redhorse are present).

### 3.3 Prioritization

Once metric values were calculated and relative weights assigned to the metrics of interest, metrics were combined through a weighted ranking process to develop a prioritized list for each scenario. The ranking process involves four steps and simple mathematical operations, as illustrated in .

1	Raw Values	HUC12	Upstream Functional Network Length (m)	Downstream Functional Network Length (m)
		Dam A	239,541	2,572
		Dam B	342,654	62,525
		Dam C	572,594	6,233
		Dam D	125,213	87,425
2	Ranked Values	HUC12	Upstream Functional Network Length (rank)	Downstream Functional Network Length (rank)
		Dam A	3	4
		Dam B	2	2
		Dam C	1	3
		Dam D	4	1
3	% Ranked Values	HUC12	Upstream Functional Network Length (% rank)	Downstream Functional Network Length (% rank)
		Dam A	33	0
		Dam B	66	66
		Dam C	100	33
		Dam D	0	100
4	Multiply by Weight	HUC12	Upstream Functional Network Length	Downstream Functional Network Length
		Dam A	33 * 0.75	0 * 0.25
		Dam B	66 * 0.75	66 * 0.25
		Dam C	100 * 0.75	33 * 0.25
		Dam D	0 * 0.75	100 * 0.25
5	Weighted Rank Values	HUC12	Upstream Functional Network Length (weighted rank)	Downstream Functional Network Length (weighted rank)
		Dam A	25	0
		Dam B	50	16.6
		Dam C	75	8.3
		Dam D	0	25
6	Combined Score	HUC12	Combined Score	
		Dam A	25	
		Dam B	66.6	
		Dam C	83.3	
		Dam D	25	
7	Final Rank	HUC12	Final Rank	
		Dam A	3	
		Dam B	2	
		Dam C	1	
		Dam D	3	

Figure 3-1:A hypothetical example ranking four dams based on two metrics.

- Step 1: Raw values are calculated for each metric in GIS
- Step 2: Raw values are ranked. For each metric, ranks are determined based on whether large values are desirable in a scenario (e.g. upstream functional network length) or small values are desirable (e.g. % impervious surface)
- Step 3: Ranked values are converted to a percent scale where the top ranked value is assigned a score of 100 and the lowest ranked value is assigned a score of 0.
- Step 4-5: Multiply the percent rank by the chosen metric weight
  - In this hypothetical example, assume upstream functional network length weight = 75 and downstream functional network length weight = 25.
- Step 6: Sum the weighted ranks for each metric for each dam
  - All metrics which are included in the analysis (weight >0) are summed to give a summed rank.
- Step 7: Rank the summed ranks
  - The summed ranks are, in turn, ranked

The final ranks are then binned into 5% tiers for presentation. This is an important step in acknowledging that the precision with which metrics can be calculated in a GIS is not necessarily indicative of on-the-ground differences. For example, a dam which opens up 3.234 miles of river habitat may not provide greater ecological benefit than a dam which opens up 3.25 miles of habitat.

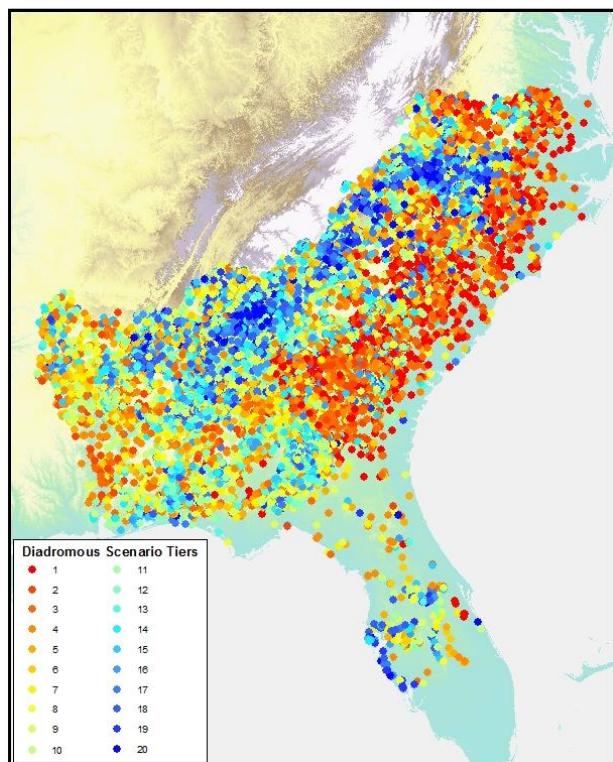
## 4 Results, Uses, & Caveats

### 4.1 Results

Results from the project include lists of dams prioritized based on two scenarios agreed upon by the Workgroup: diadromous fish scenario and resident fish scenario. These consensus-based scenarios were developed by selecting metrics and applying relative weights (see Section 3.2) for the dams and data compiled for the project (see Section 2). These results can be viewed and downloaded from <http://maps.tnc.org/seacap>.

Of note, dams with existing fish passage facilities are included in the results. Given the variability of fish passage functionality and the species passed during various flow conditions, as well as the relative lack of data to describe passage success rates, it was determined that these dams should remain in the analysis. Even dams with passage facilities are barriers to one degree or another and, if circumstances

Figure 4-1: Workgroup-consensus Diadromous Fish Scenario results



are conducive, their removal will benefit aquatic connectivity.

Although the prioritization produces a sequential list of dams, the precision with which metrics can be calculated in a GIS is not necessarily indicative of ecological differences. Therefore, throughout this report and on the project web map, results are binned in Tiers for presentation where each Tier includes 5% of the dams in the study area. Thus, 5% of the total dams are in the top Tier, Tier 1. These dams would provide the greatest ecological benefit to the given target if removed or otherwise remediated.

#### 4.1.1 Diadromous Fish Scenario

The first scenario which was defined by the Workgroup was a scenario to prioritize dams based on their potential to benefit diadromous fish species if removed or bypassed. This

scenario was developed using the metric weights presented in Table 3-2, and produced the results

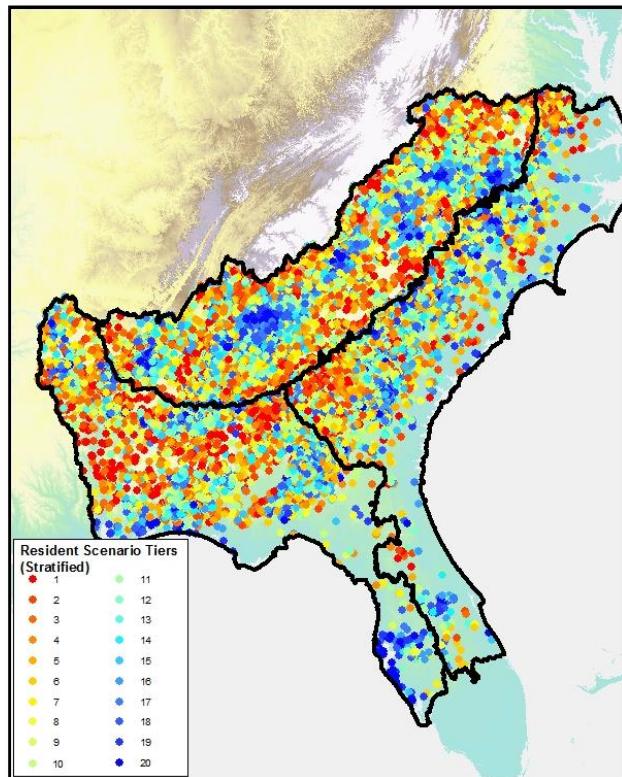
depicted in Figure 4-1. As one would expect in a scenario designed to benefit diadromous fish, the dams in the higher tiers, those whose removal would provide the greatest benefit to diadromous fish, tend to be found closer to the ocean and on the larger mainstem rivers. These include the major rivers in Southeastern states and many smaller coastal streams. These results directly reflect the metrics chosen and weights applied to them including anadromous fish presence (weight=15), number of dams downstream (weight = 10), and upstream functional network size (weight = 15).

#### 4.1.2 Resident Fish Scenario

Using the metrics and metrics weights selected by the SEACAP Workgroup (in Table 3-3), a Resident Fish Scenario was developed. This scenario was intended to reflect priorities for a set of non-migratory fish species like suckers, black basses, brook trout, shiners, or darters. As illustrated in Figure 4-2, these results differ substantially from the Diadromous Fish Scenario result. They are driven by absolute gain (weight=20), total reconnected number of stream sizes greater than 0.5 miles (weight=10), and a suite of land cover condition and stream crossing density metrics.

Unlike the diadromous fish scenario, the Workgroup chose to stratify the analysis based on three subregions. The regions, including the South Atlantic Coastal Region, South Atlantic Piedmont, and Gulf drainages, were defined by the SEACAP Core team and the Workgroup to reflect regional patterns of resident fish distribution and diverse assemblages of fish found in the subregions. The prioritization analysis was run separately in each of the three subregions, and then the results were stitched back together for the entire project area. Figure 4-2 depicts the results of the resident fish scenario, including the three stratification regions.

Figure 4-2: Workgroup-consensus Resident Fish Scenario results, stratified by subregion

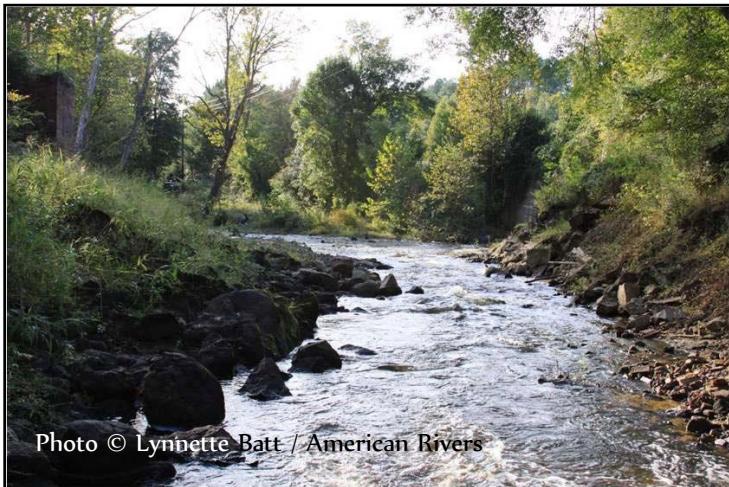


## 4.2 Result Uses

The Southeast Aquatic Connectivity Assessment Project can be used in several different ways to inform and support on-the-ground efforts to restore aquatic connectivity.

- **Project Selection:** A primary use is to help managers direct their limited resources to projects that can have the greatest benefit; to help them move away from a purely opportunistic approach to more of an ecological benefits approach (recognizing that opportunity among other non-ecological factors does and will continue to play an important role in project selection). Directing resources where they can have the greatest impact is increasingly important as federal and state budgets shrink in our current fiscal environment.

Figure 4-3: Steeles Mill Dam on Hitchcock Creek in North Carolina during and after removal in 2009



- **Improve Understanding of Current Conditions:**

**Current Conditions:** Project results from the previous studies (Chesapeake Fish Passage Prioritization) have been used to help direct managers to investigate previously unvisited dams to assess them for potential passage projects (Jim Thompson, MD DNR, personal communication March 13, 2013). In some cases this may reveal errors in the source data while in other cases it may direct attention to potential projects that had previously not been considered.

- **Database of Ecologically Relevant Metrics:**

**Relevant Metrics:** Prioritization aside, the results form a database of dams with 43 ecologically relevant metrics. These metrics can be used to investigate many aspects of aquatic connectivity on a dam-by-dam basis or other off-shoot analyses. For instance, a project manager with an opportunistic passage project can benefit from easy access to metric data, quickly identifying the dam's restoration potential if removed or bypassed. Metric data including length of connected network, species present downstream, and land cover

characteristics are some examples. In addition, as described further in Section 5, custom analyses can be performed as if one or more dams have been removed. Metric values and the prioritization are recalculated as if that dam had been removed, thus allowing managers to assess the potential impacts of proposed projects.

- **Funding:** The prioritized results can be used both by managers seeking funding for a potential project and by funders looking for information to inform or support a funding allocation decision.
- **Watershed Analysis:** Subwatersheds can be assessed based on the project results. Summary statistics can be generated via the custom analysis tool to provide an understanding of potential opportunities for passage projects in watersheds across the region.
- **Communication:** Results can be used to communicate the value of a given project to the local community, elected officials, or others with an interest in aquatic connectivity issues.

## 4.3 Data Limitations & Caveats

As with any modeled analysis, there are several caveats and limitations that are important to bear in mind when considering the results and data produced by this project and the custom analysis tool. First and foremost among them, the results are *not intended to be a “hit list”* of dams for removal. There are many cases where the benefits provided by a given dam outweigh the ecological benefits of removing it, although other passage projects can be considered when removal is not the best option.

Next, this project is based on data from many different sources (see Section 2). Each of these sources brings its own inherent error to the analysis. For example, the river hydrography, as represented in the NHD, does not perfectly represent flowing rivers on the ground. Any inaccuracies in the source data will be reflected in the metrics calculated using that data. For example, if a river segment is missing from NHD, the upstream functional river length for the dam below the missing segment will be too short.

Similarly, the prioritization is sensitive to inaccuracies in the dam database. If a dam is erroneously included in the database, the error ripples beyond the dam itself since its presence will impact the metrics for surrounding dams. For example, the calculated upstream functional network of the next dam downstream will be too short, the downstream functional network of upstream dams will be too short, the count of downstream dams for all dams upstream of the error will be too high, and so on. Although the SEACAP project team and Workgroup put substantial effort into compiling and revising the dam data using desktop GIS techniques, it should be expected that some errors remain. Thus, it is particularly important that results be examined on an individual basis using the best available local-scale data and on-the-ground knowledge before any actions are taken.



Additionally, this project, by design, only considers ecological factors. It does *not include any social, economic, or feasibility factors*, largely due to the fact that this information is difficult or impossible to capture through regionally-available GIS data. These factors could be layered onto the project results through a subsequent site-scale analysis, as has been done in Connecticut using results from the Northeast Aquatic Connectivity project (Steve Gephard, CT Department of Energy & Environmental Protection, personal communication).

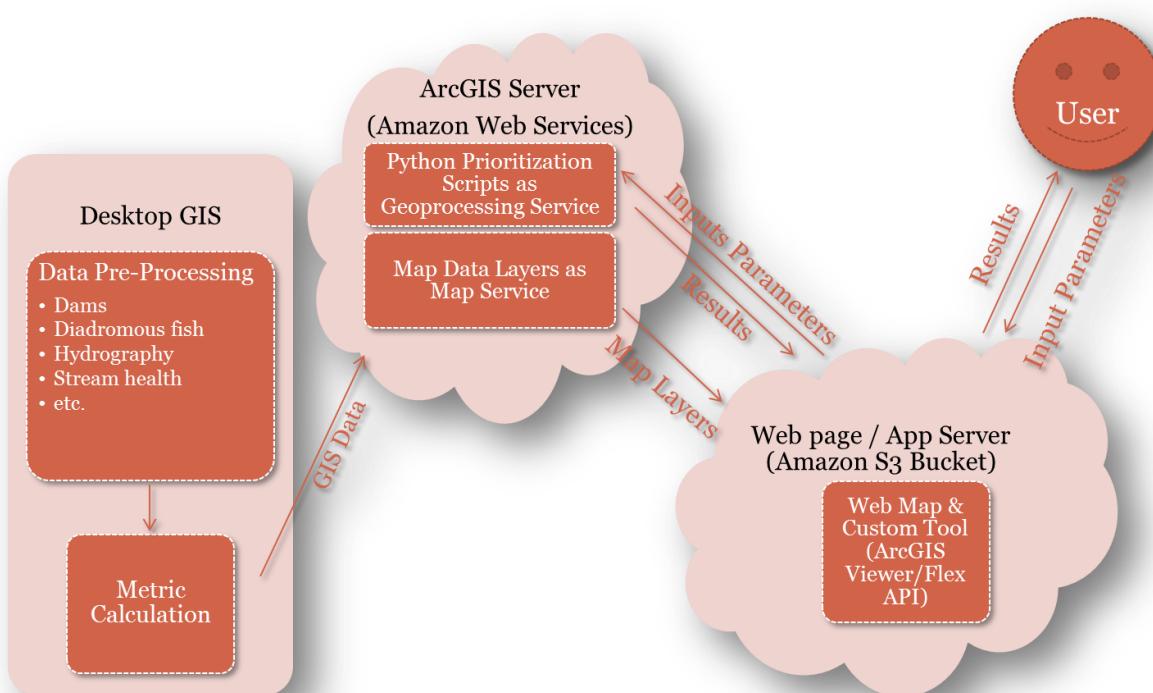
Results produced for this project are intended to be *screening-level* information that can *help* inform on-the-ground decision making, using the best available regional data. They are not a replacement for site-specific knowledge and field work.

Finally, it is important to note that any aquatic connectivity project will have ecological benefits. If an opportunity arises it should not be rejected solely on the grounds that it does not rank in one of the upper tiers of this project. Ultimately, whether the benefits provided by a given passage project justify the costs is a decision that rests with managers using all of the best information at their disposal. We hope that this project will be a useful and important tool in the aquatic connectivity toolkit, not the only one.

## 5 Web Map & Custom Analysis Tool

Project results and a tool to run custom user-defined scenarios can be found at <http://maps.tnc.org/seacap>. This web mapping platform allows users to view results in the context of other relevant data including project data and various base maps, query results, download data, search for a dam interactively or by name, annotate a map, and print or save a map. Map data is served to the internet using a cloud-based (Amazon Web Services) instance of ArcGIS Server (<http://www.esri.com/software/arcgis/arcgisserver>). This data is consumed via the ArcGIS Viewer for Flex (<http://resources.arcgis.com/en/communities/flex-viewer>) modified using the ArcGIS Flex API (<http://resources.arcgis.com/en/communities/flex-api>). Likewise, the custom analysis tool is developed using Python geoprocessing scripts and the ArcGIS arcpy module ([http://resources.arcgis.com/en/help/main/10.2/index.html#/What\\_is\\_ArcPy/000v000000v7000000/](http://resources.arcgis.com/en/help/main/10.2/index.html#/What_is_ArcPy/000v000000v7000000/)). These geoprocessing scripts are served to the internet via ArcGIS Server and consumed in the web map via the ArcGIS Viewer platform. Figure 5-1 illustrates the conceptual architecture of the web map and custom analysis tool.

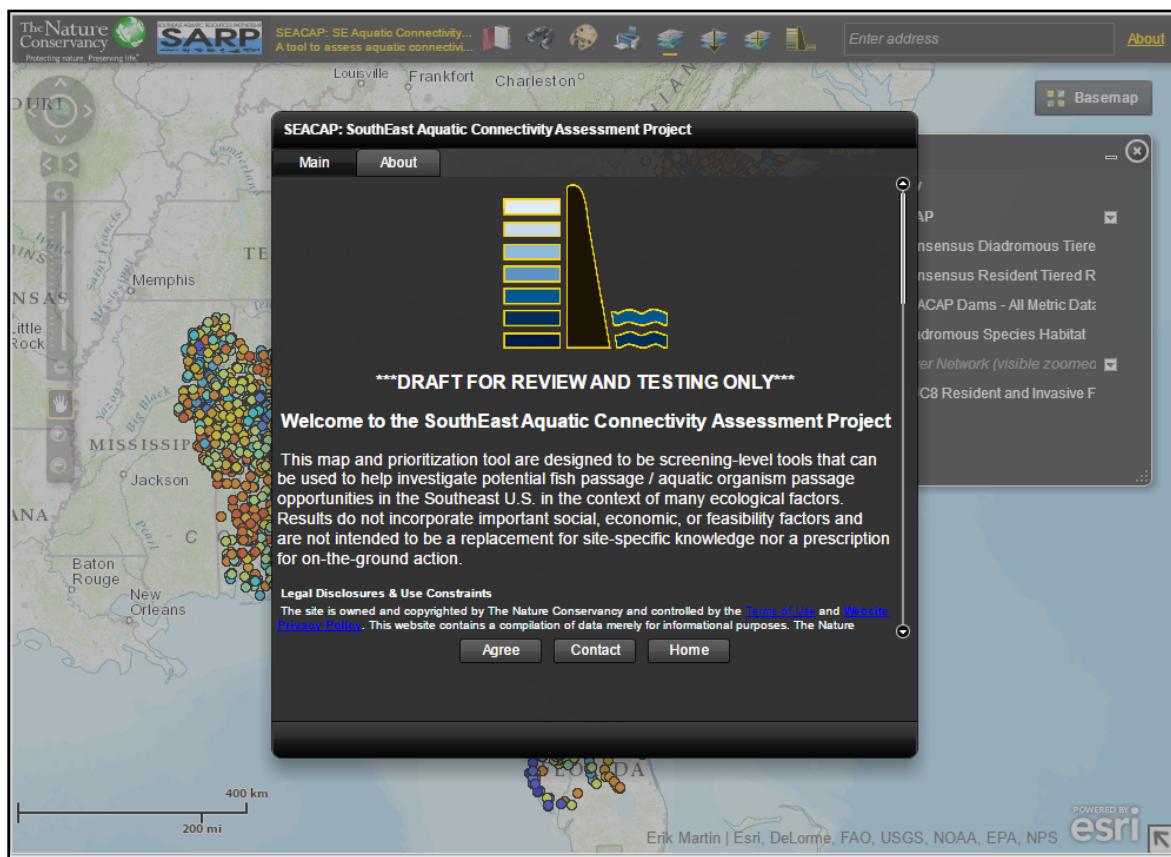
Figure 5-1: Conceptual architecture of web map & custom prioritization tool



## 5.1 Web Map

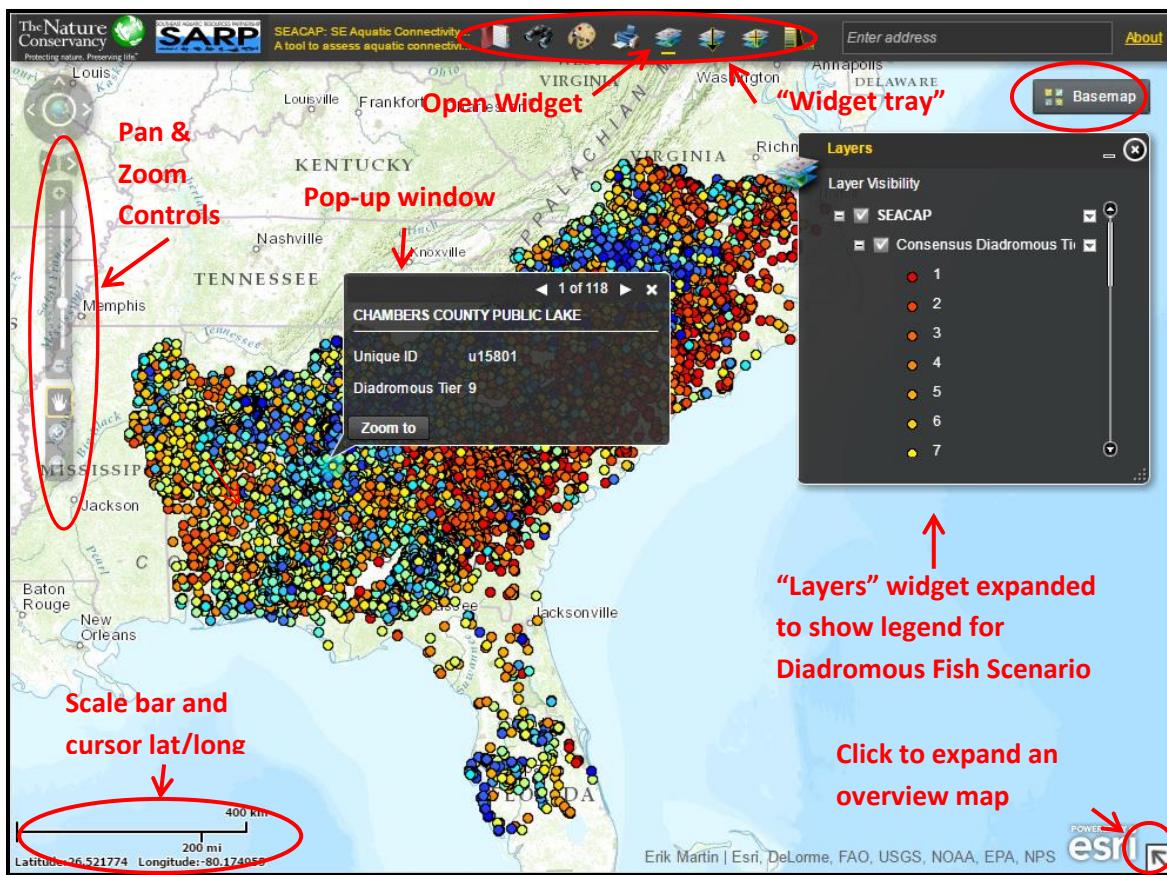
Upon first entering the map, a welcome screen pops up with important information about the project, links to additional information, and use limitations. Three buttons at the bottom of the welcome screen allows users to enter the map by accepting the use constraints (“Accept”), “Contact” the authors via email, and link to The Nature Conservancy’s website (“TNC”).

Figure 5-2: Web map welcome screen. Click on "Accept" to agree to the use constraints and enter the map.



By default, the map is loaded with the Workgroup-consensus Diadromous Fish Scenario results displayed. Clicking on a dam point brings up attribute information including values for all of the metrics that were used in the diadromous fish scenario. The basic features of the web map are noted in Figure 5-3. At the top of the map window is a tray of “Widgets.” Each widget opens a new window that contains some discrete functionality for use within the map. Widgets can be minimized, closed, expanded and dragged. Details about the different map widgets can be found in Section 5.1.2.

Figure 5-3: Basic features of the web map



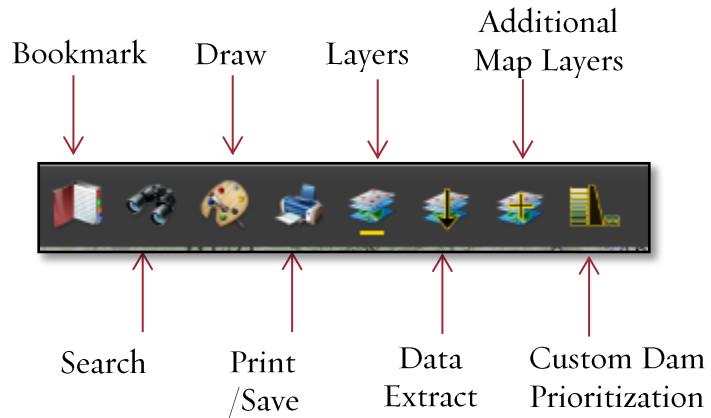
## 5.1.1 Project Data

Several project data layers are available in the map. These can be toggled on and off via the Layers “widget”, which is open by default. Expanding the “+” signs in the Layers widget reveals the Legend for each of the layers in the map. The dropdown arrow on the right side of each layer in the Layers widget can be used to zoom to the extent of that layer and to view a description of the layer. In addition to the two Workgroup-consensus scenarios, several supporting datasets are provided. These include diadromous fish habitat compiled for the project (described in Section 2.4), river hydrography, and resident fish data by HUC8 watershed.

## 5.1.2 Widgets

Several “widgets” are available to help users interact with the map. Like their generic mechanical counterparts, each widget performs a specific function; in this case that function is within the map. The widgets are located along the top of the map frame in the widget tray, as illustrated in Figure 5-4. Widgets that are open are indicated by a gold line under the widget icon in the widget tray.

Figure 5-4: Widgets in the Widget Tray



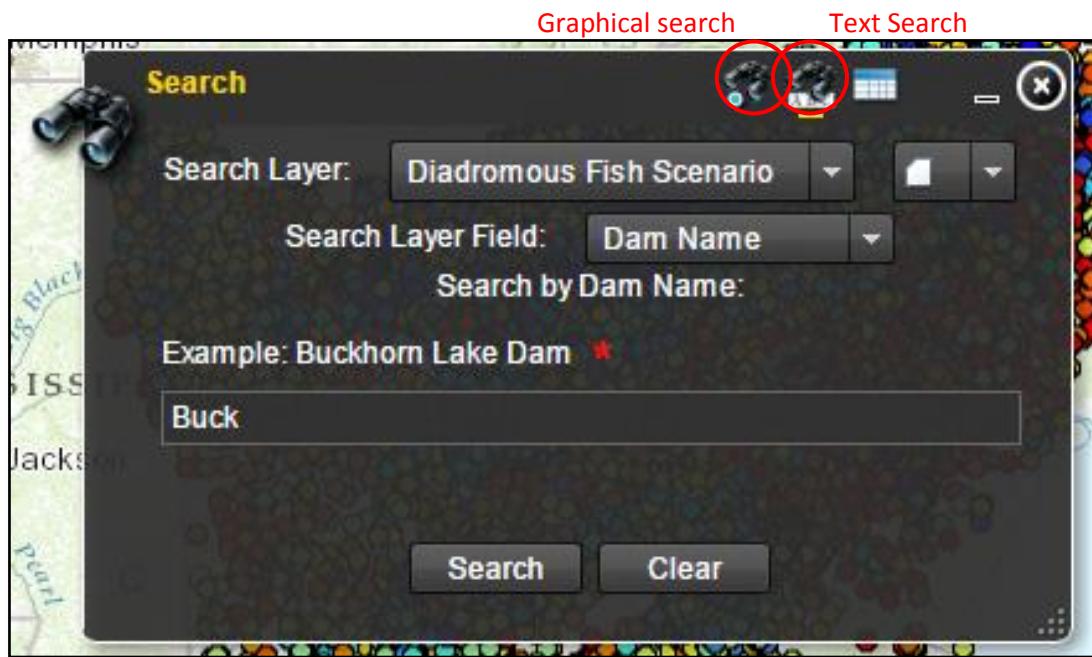
### 5.1.2.1 Bookmark

The Bookmark widget allows users to zoom to predefined map extents such as a state boundary. Users can also define and save the current map extent as a bookmark to easily return to later. However, these user-defined bookmarks do not persist between sessions.

### 5.1.2.2 Search

The Search widget can be used to locate dams by name, by SEACAP Unique ID, or graphically. To search for a dam by name, simply open the widget and enter all or part of a dam name, as depicted in Figure 5-5. The “text search” option to search by name is enabled by default when the widget is opened.

Figure 5-5: Search widget- find a dam by name.

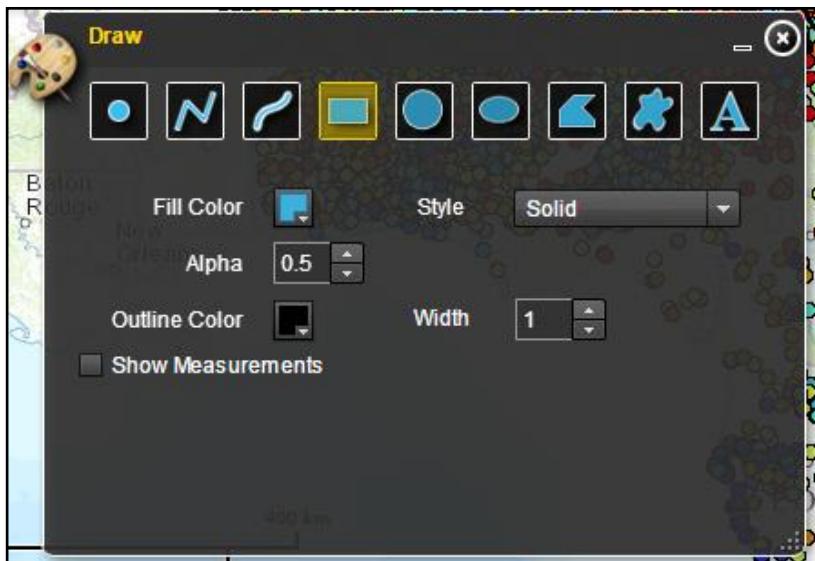


To search for dams graphically, select the “Graphical Search” icon at the top of the widget. Drawing tools can then be used with your mouse pointer to draw a box around a set of dams, for example, and retrieve a table of attributes for these dams. Additional information about the Search widget can be found at <http://www.arcgis.com/home/item.html?id=5d4995ccdb99429185dfd8d8fb2a513e>.

### 5.1.2.3 Draw

The Draw widget can be used to annotate a map with text or drawings. Several options are available to

Figure 5-6: The Draw widget



customize the look of drawings including fill color, outline color, and transparency (alpha). An option is also available to display measurements for drawings. Preferred units and fonts can be set if measurements are included. Drawings can be saved and shared or re-loaded into another map session. They will also be included if the map is saved (PDF) or printed via the Print widget.

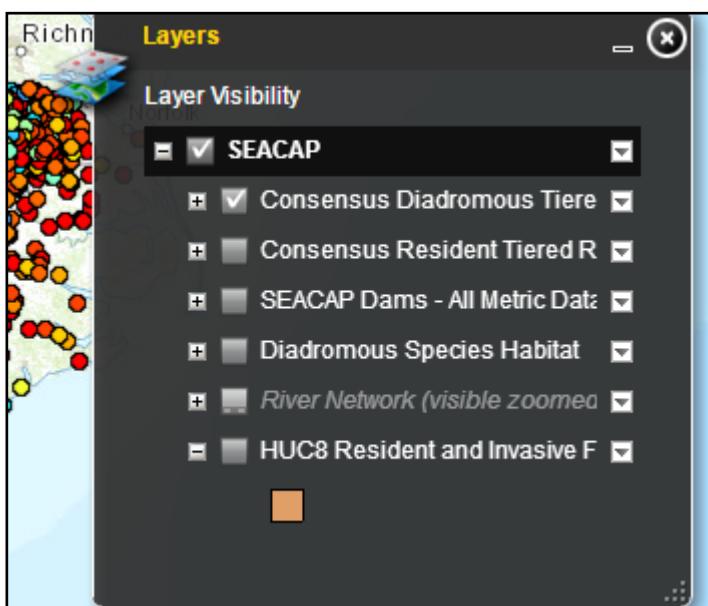
#### 5.1.2.4 Print

The Print widget allows the user to print the current map view, formatted as the map window only or to the selected size with border information (legend, scale bar, etc.) included. It can be saved as a PDF or image file (JPG, PNG). The result is opened as a new tab or window in the user's browser, whence it can be saved to the desired location.

#### 5.1.2.5 Layers

The Layers widget is open by default when the map loads. Individual layers can be turned on and off by

Figure 5-7: The Layers widget

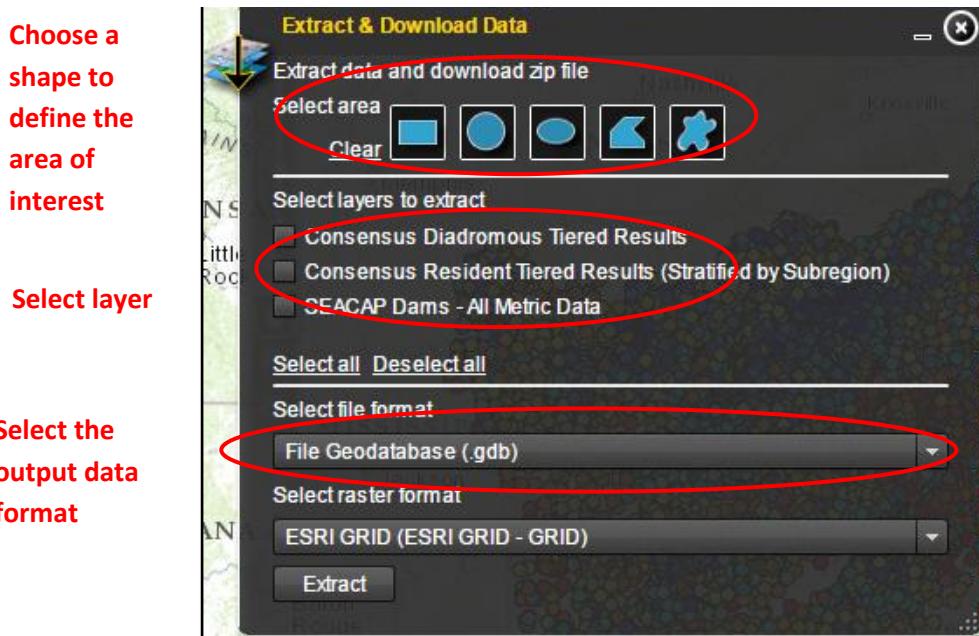


checking or unchecking the box for each layer. If a layer is part of a grouped layer, the box for the group must be checked in order for the layer to be visible in the map. Expanding the check boxes for each layer reveals any nested layers and displays the symbology if there are no nested layers. The drop-down arrow on the right side of each layer name allows users to zoom to the extent of the layer and view a brief description of the layer. These features are illustrated in Figure 5-7.

### 5.1.2.6 Extract & Download Data

The Extract & Download Data widget allows users to download all or a portion of the project results and dam data. First, a tool is selected to define an area of interest. If all of the dam data is desired, simply

Figure 5-8: Extract & Download Data widget

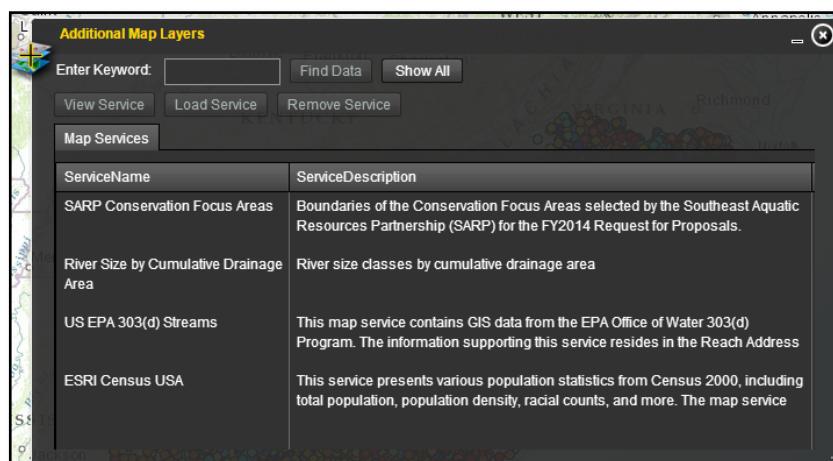


draw a box around the entire project area. Next, the data layers of interest are selected. Choices include the two consensus prioritization scenarios as well as the dam data with all of the metric attributes included. Finally the data format is selected. Choices include shapefiles or ESRI File Geodatabase.

### 5.1.2.7 Additional Map Layers

Users have the option to add map services, or a data layer that can be consumed by web mapping

Figure 5-9: The additional Map Layers widget



applications, from other sources. These map services are publicly available services which have thematic relevance to SEACAP, but are not directly associated with SEACAP. Selecting the “Additional Map Layers” widget will open a dialog with a list of possible map services. A map service may contain one or more

individual layers within it. Simply select a map service and click the “Load” button to add the new layers to the map. The “Layers” widget will reflect the addition of the new map layers.

#### 5.1.2.8 Custom Dam Prioritization

The Custom Dam Prioritization tool (widget) was developed for SEACAP to allow on-the-fly prioritizations based on user-specified metric weights. Further explanation of the Custom Dam Prioritization tool is in Section 5.2.

## 5.2 Custom Dam Prioritization Tool

The Custom Dam Prioritization tool (or the “Tool”) allows users to modify and build off of the two scenarios developed by the SEACAP Workgroup (see Section 4.1) by altering metric weights, filtering the input dams (e.g. by state or watershed), and running “removal scenarios” as if one or more dams had been removed from the network.

The Tool exists in four different states: Inputs, Status, Results, and Summary Statistics. The Inputs state is open by default and is the interface through which the user inputs all desired parameters. When all inputs are entered and processing has begun, the Tool will automatically switch to the Status state to report information on the status of the processing. When it is finished, it will automatically switch to the Results state, which displays a table of Attribute information for the custom prioritization results. Additional information on interacting with the Results is in Section 5.2.5.1. Finally, the Summary Statistics state displays a table of optional summary statistics, if they were calculated (See Section 5.2.3). Although the Tool will automatically switch between states at key times, the user can select a given state at any time by using the radio buttons along the top of the Tool.

Hovering the mouse over most items in the Tool summons tool tips – short descriptions of that button, input, or other feature. The tool tips contain instructions and other useful information. Descriptions of each metric can be found by clicking on the metric name. This will open a link to a PDF file which contains a full glossary of all metrics.

The basic features of the Custom Dam Prioritization tool are illustrated in Figure 5-10.

Figure 5-10: Custom Dam Prioritization Tool layout



## 5.2.1 Applying Custom Weights & Order

As has been described in Section 3.2, relative weights can be applied to metrics to indicate the relative importance of each metric in a given prioritization scenario. The Workgroup developed two weighting scenarios for diadromous fish and resident fish respectively, but any number of alternate scenarios could be developed based on the needs and objectives of the user. For example, if the primary objective of a user was to open up the most possible upstream river miles, then 100% of the weight could be applied to "Upstream Functional Network Length." The results of this prioritization would be analogous to sorting the dams so that the one with the longest upstream functional network was on top. Weights can be distributed as desired by the user so long as they sum to 100. A running tally of

metric weights is provided and a warning message will appear if an analysis is attempted with weights that do not sum to 100.

As shown in Figure 5-10, there are buttons to apply the Workgroup-consensus weights. Applying these weights and running a prioritization with no other alterations will produce the same results as what are pre-loaded into the map. After a set of Workgroup-consensus weights are applied they can be altered or removed as desired.

Implicit in the prioritization is the idea that for each metric, either large values are desirable or small values are desirable. Generally speaking, “Upstream Functional Network Length” is a metric where large values are desirable in a potential passage project – the intent is to open up the most miles of river habitat. In this case, the metrics are sorted in descending order where large values rank at the top. Conversely, the percent impervious surface in a dam’s watershed is a metric where small values are generally desirable – the intent is to open habitat that is in a more natural state to support healthy fish populations. In this case, the metric is sorted in ascending order where small values rank at the top. By default the sort order for each metric in the tool is set based on the implicit assumptions of the Workgroup. However, if a user has an interest in prioritizing dams in a watershed with a high percent impervious surface, they could simply switch the sort order for that metric from “A” to “D”, as depicted in Figure 5-11

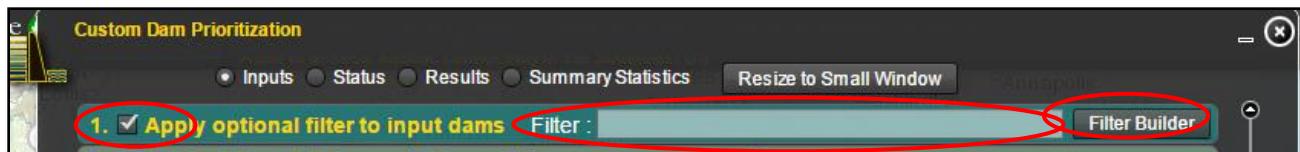


Figure 5-11: Changing the sort order for a metric

## 5.2.2 Filtering Input Dams

The universe of dams that is input into a given custom scenario can be subset from the entire dataset. This can be done by geography (e.g. to limit an analysis to a given state or watershed) or other attribute (e.g. to exclude hydropower dams from an analysis, or only include dams that have American shad in their downstream networks). To apply a filter, first check the “Filter” checkbox in the top left corner of the Tool, as shown in Figure 5-12. This will reveal a text input where an ArcGIS-compliant SQL-based definition query can be applied (e.g. “STATE” = ‘Georgia’).

Figure 5-12: The Tool with the option to filter input dams highlighted



To simplify the application of filters, users can select the “Filter Builder” button. This interactive dialog helps users build filter statements. Plain-English is displayed to the user and the appropriate GIS field names and syntax are automatically applied. The filter builder steps users through building a filter with a maximum of three filtering statements. First, the attribute used to filter is selected (e.g. “State”). Next the operator is selected (e.g. “=” ) and finally the desired parameter value is selected (e.g. “Virginia”). Help on using the proper operator (e.g. use “IN” if there are multiple values: “STATE” IN (‘VA’, ‘NC’) ) can be accessed via the Help link at the bottom of the Filter Builder.

As the statement is built, the “Working Filter” text box will update using the proper field names and GIS syntax. When the statement is complete, it must then be applied using the “Apply to Filter 1” button in order for it to be used. As illustrated in Figure 5-13, the statement then appears in the “Final Filter” text box at the bottom of the Filter Builder.

Figure 5-13: Building a filter

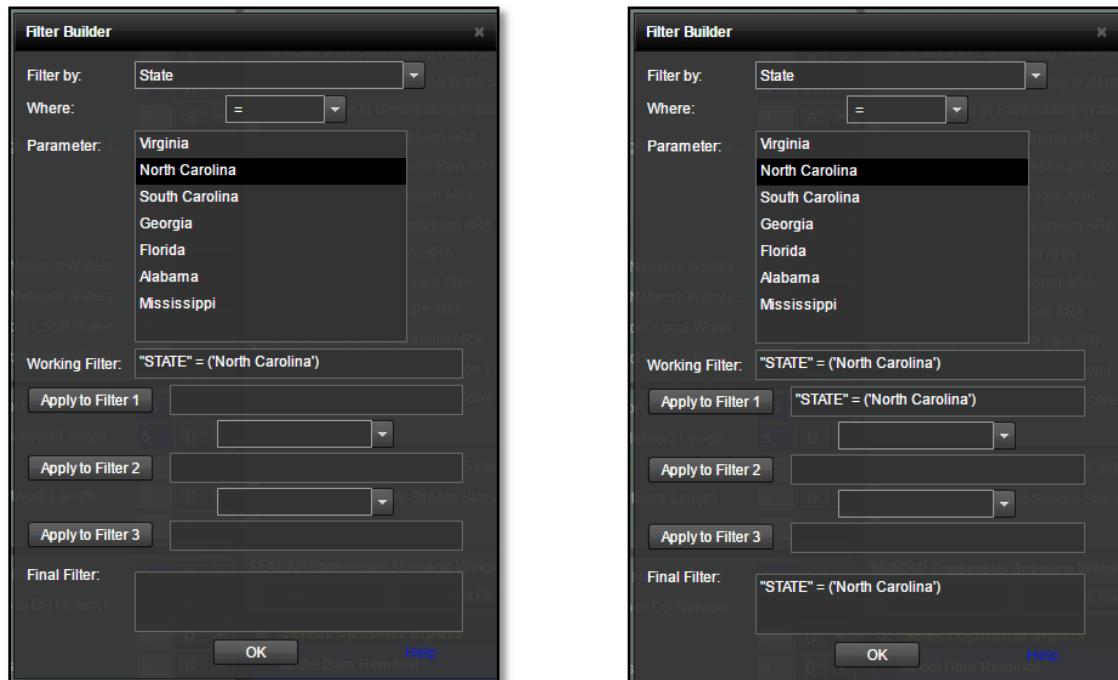




Figure 5-14: Adding a second filter using the Filter Builder

definition queries see:

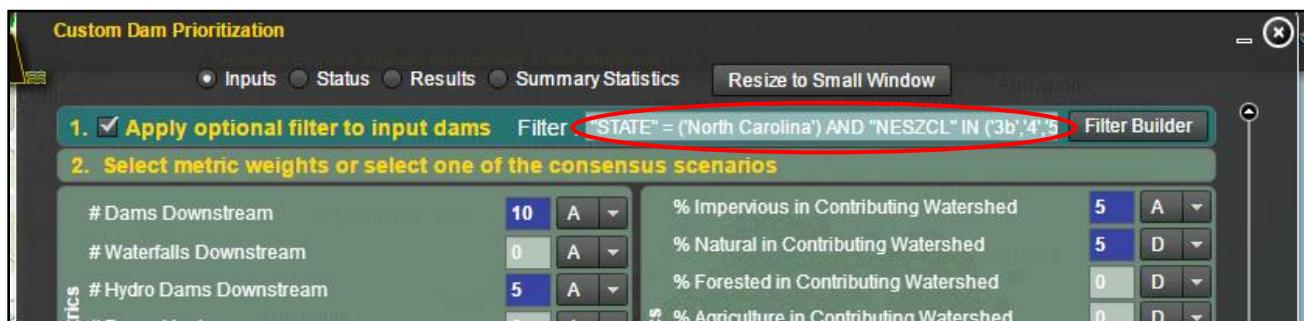
<http://resources.arcgis.com/en/help/main/10.2/index.html#/00s50000002t000000>.

If additional filters are desired, they can be developed by repeating the process. Figure 5-14 illustrates adding a second filter so that only dams on larger rivers are included in the analysis. Multiple values can be selected by holding down the Ctrl key and clicking. Another operator is placed between the two filter statements. The example depicted in Figure 5-14 results in the following filter statement : "STATE" = ('North Carolina') AND "NESZCL" IN ('3b','4','5','3a') , which restricts the dams in the analysis to dams in North Carolina on rivers that drain 200 or more square miles.

Finally, clicking on "OK" in the Filter Builder applies the Final Filter statement to the input filter dialog on the Tool, as depicted in Figure 5-15. Note that it is critical to keep the check box checked if using a filter. Unchecking it will remove the filter. Likewise, if the box is checked a filter must be applied.

For more information on ArcGIS-compliant SQL-based

Figure 5-15: Final filter applied from the Filter Builder



### 5.2.3 Generating Summary Statistics

Optionally, summary statistics can be produced for the custom prioritization scenario results. These summary statistics can be used to evaluate and make relative comparisons between watersheds or states. If summary statistics are desired, simply check the "Calculate Summary Statistics" box towards the bottom right corner of the Tool. This will reveal options to generate summary statistics for either Tier or the Final Rank (the un-binned sequential results) by either State or Watershed. The output table will enable users to make statements such as "Watershed X has a mean Tier value of 8 while

Watershed Y has a mean Tier value of 5." From this statement we can deduce that Watershed Y has more dams with greater potential to benefit the target of interest, based on the metric weights chosen by the user, than Watershed X.

Figure 5-16: Selecting the option to run summary statistics on custom prioritization results

The screenshot shows the 'Custom Dam Prioritization' software interface. At the top, there are tabs for 'Inputs', 'Status', 'Results', and 'Summary Statistics'. The 'Summary Statistics' tab is active. The main area is divided into several sections:

- Connectivity Status Metrics:** Includes fields like '# Dams Downstream' (value 10, status A), '# Waterfalls Downstream' (value 0, status A), etc.
- Connectivity Metrics:** Includes fields like 'Upstream Functional Network Length' (value 15, status D), 'Total (US+DS) Functional Network Length' (value 5, status D), etc.
- Ecological Metrics:** Includes fields like '# Anadromous Species in DS Network' (value 5, status D), 'Presence of Anadromous Spp in DS Network' (value 15, status A), etc.
- Watershed & Local Condition Metrics:** Includes fields like '% Impervious in Contributing Watershed' (value 5, status A), '% Natural in Contributing Watershed' (value 5, status D), etc.
- Size Metrics:** Includes fields like '# Upstream Size Classes >0.5 mile Gained' (value 5, status D), 'Total # Reconnected Stream Sizes >0.5 Mile (...)' (value 0, status D), etc.
- SEACAP Consensus Scenario Weights:** Shows 'Must = 100' with buttons for 'Diadromous Fish', 'Resident Fish', and 'Clear Inputs'.
- 3. Select optional inputs:** Contains a checked checkbox for 'Model Dam Removal' and another checked checkbox for 'Calculate Summary Statistics'. This section is circled in red.
- Summary Statistic Value:** A dropdown menu set to 'Tier'.
- Summarize Within Each:** A dropdown menu set to 'STATE'.
- 4. Begin Analysis:** A yellow button at the bottom.

## 5.2.4 Dam Removal Scenarios

One or more dams can be selected for “removal” when a prioritization is run. This functionality can allow users to assess the impact of a proposed project on the remaining dams in the network. When dams are modeled for removal, all of the metric values are recalculated as if that dam does not exist.

To run a prioritization scenario that includes modeled removals, first check the “Model Dam Removal” check box towards the bottom right corner of the Tool. This reveals a button to “Select Dams” as well as a text input box (Figure 5-17). If you know the UNIQUE\_ID for your dams of interest, you can simply enter these in the text box enclosed in single quotes and separated by commas. (e.g ‘u5253’, ‘u1546’). The UNIQUE\_ID is the SEACAP project-specific identifier for each dam. It is based on the ID from the

source dam database, but is specific to this project. The UNIQUE\_ID can be obtained by clicking on an individual dam. Entering UNIQUE\_IDS directly can be useful when running the same or similar scenarios multiple times.

Figure 5-17: Selecting the option to model dams for removal

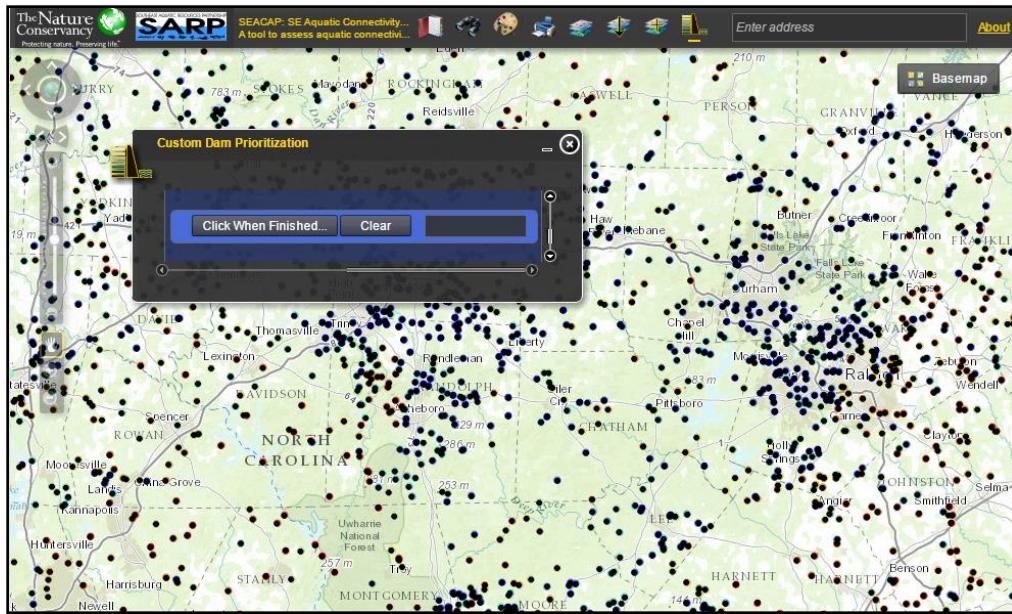
The screenshot shows the 'Custom Dam Prioritization' application window with the 'Inputs' tab selected. The interface is divided into several sections:

- Section 1: Apply optional filter to input dams**
- Section 2: Select metric weights or select one of the consensus scenarios**
- Connectivity Metrics** (left column):
  - # Dams Downstream: 10 (A)
  - # Waterfalls Downstream: 0 (A)
  - # Hydro Dams Downstream: 5 (A)
  - # Dams Upstream: 0 (A)
  - # Dams on Small Stream (High Res NHD) U...
  - Total Upstream River Length: 10 (D)
  - Upstream Barrier Density: 0 (A)
  - Downstream Barrier Density: 0 (A)
  - Density of Small Dams in US Network Waters...
  - Density of Small Dams in DS Network Waters...
  - Crossing Density in US Network Local Water...
  - Crossing Density in DS Network Local Water...
- Watershed & Local Condition Metrics** (right column):
  - % Impervious in Contributing Watershed: 5 (A)
  - % Natural in Contributing Watershed: 5 (D)
  - % Forested in Contributing Watershed: 0 (D)
  - % Agriculture in Contributing Watershed: 0 (D)
  - % Impervious in Upstream ARA: 5 (A)
  - % Impervious in Downstream ARA: 0 (A)
  - % Agriculture in Upstream ARA: 0 (A)
  - % Agriculture in Downstream ARA: 0 (A)
  - % Natural in Upstream ARA: 0 (D)
  - % Natural in Downstream ARA: 0 (D)
  - % Forested in Upstream ARA: 0 (D)
  - % Forested in Downstream ARA: 0 (D)
  - Dam is located on Conservation Land: 0 (D)
  - NFHAP Risk of Degradation Score: 0 (D)
  - Flow Alteration: 5 (A)
- Connectivity Metrics** (left column):
  - Upstream Functional Network Length: 15 (D)
  - Total (US+DS) Functional Network Length: 5 (D)
  - Absolute Gain: 0 (D)
  - Downstream Functional Network Length: 0 (D)
  - Relative Gain: 0 (D)
- Size Metrics** (right column):
  - # Upstream Size Classes >0.5 mile Gained: 5 (D)
  - Total # Reconnected Stream Sizes >0.5 Mile (...: 0 (D)
  - River Size Class: 0 (D)
- Ecological Metrics** (left column):
  - # Anadromous Species in DS Network: 5 (D)
  - Presence of Anadromous Spp in DS Network: 15 (A)
  - SEACAP Fish Spp Richness: 0 (D)
  - SEACAP FW Mussel Richness: 0 (D)
  - # of Rare (G1-G3) Fish Spp in HUC8: 0 (D)
  - # of Rare (G1-G3) Mussel Spp in HUC8: 0 (D)
  - # of Rare (G1-G3) Crayfish Spp in HUC8: 0 (D)
  - Native Fish Spp Richness (HUC8): 0 (D)
- SEACAP Consensus Scenario Weights** (bottom right):
 

Must = 100	100
Diadromous Fish	Resident Fish
Clear Inputs	
- 3. Select optional inputs** (bottom right):
  - Model Dam Removal
  - 
  - Calculate Summary Statistics
- 4. Begin Analysis** (yellow button at bottom right)
- Help** (button at bottom right)

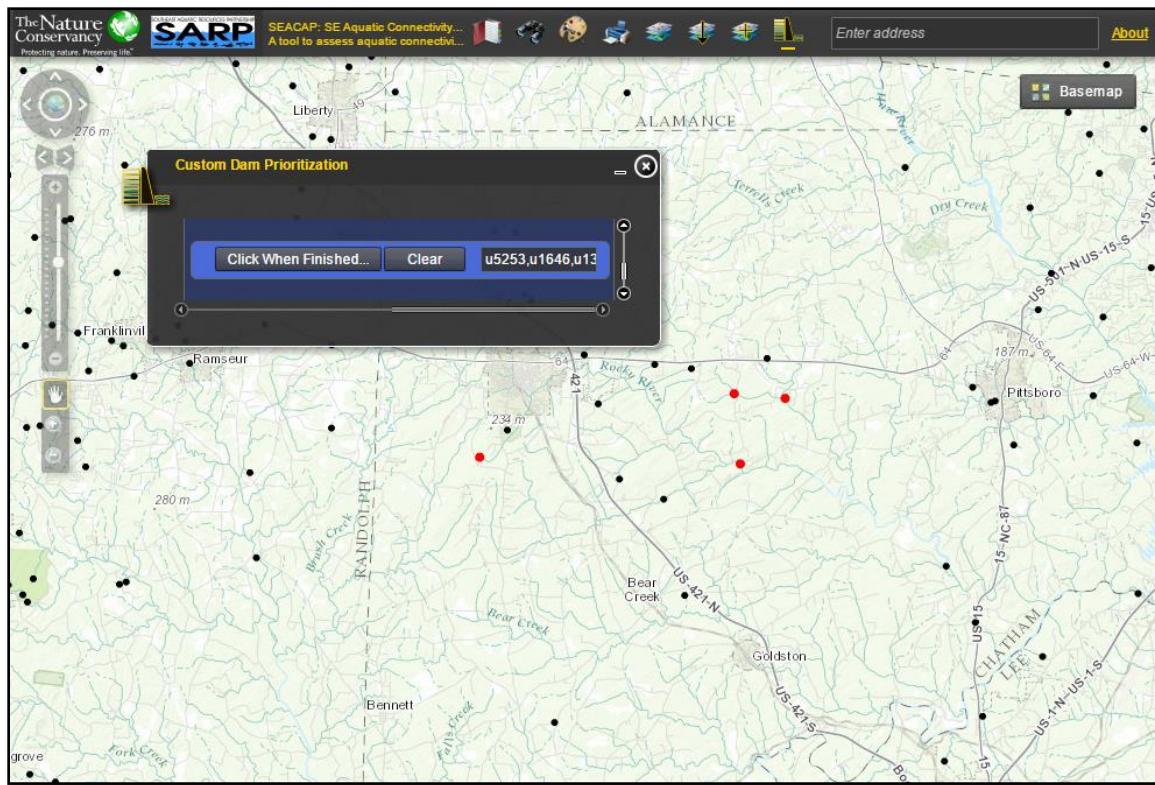
More convenient in many cases will be the option to select dams interactively through the web map. This can be done by clicking on the “Select Dams” button next to the Model Dam Removal check box. Clicking on this button prepares the Tool to interactively select dams for removal. This includes automatically resizing the Tool and moving it to a corner of the map, turning off all map layers, and adding a layer of all dams (symbolized as black points) that is used for selection. This process can take a few moments, and a warning message appears to inform the user as much. This process can be sped up by first zooming into the area of interest, thus eliminating the need for the browser to load and render all of the dams in the region.

Figure 5-18: Dams ready to be selected for modeled removal



When the warning message is dismissed, users can proceed to select dams for “removal.” This is simply done by clicking on a dam point, at which point it will turn red and its UNIQUE\_ID will be populated in the text input box. Currently, users are limited to selecting ten or fewer dams for removal to keep processing times reasonable. If a mistake is made, clicking on a red dam will return it to black and remove its UNIQUE\_ID from the text input box.

Figure 5-19: A set of dams (haphazardly selected for demonstration purposes) to be modeled as removed

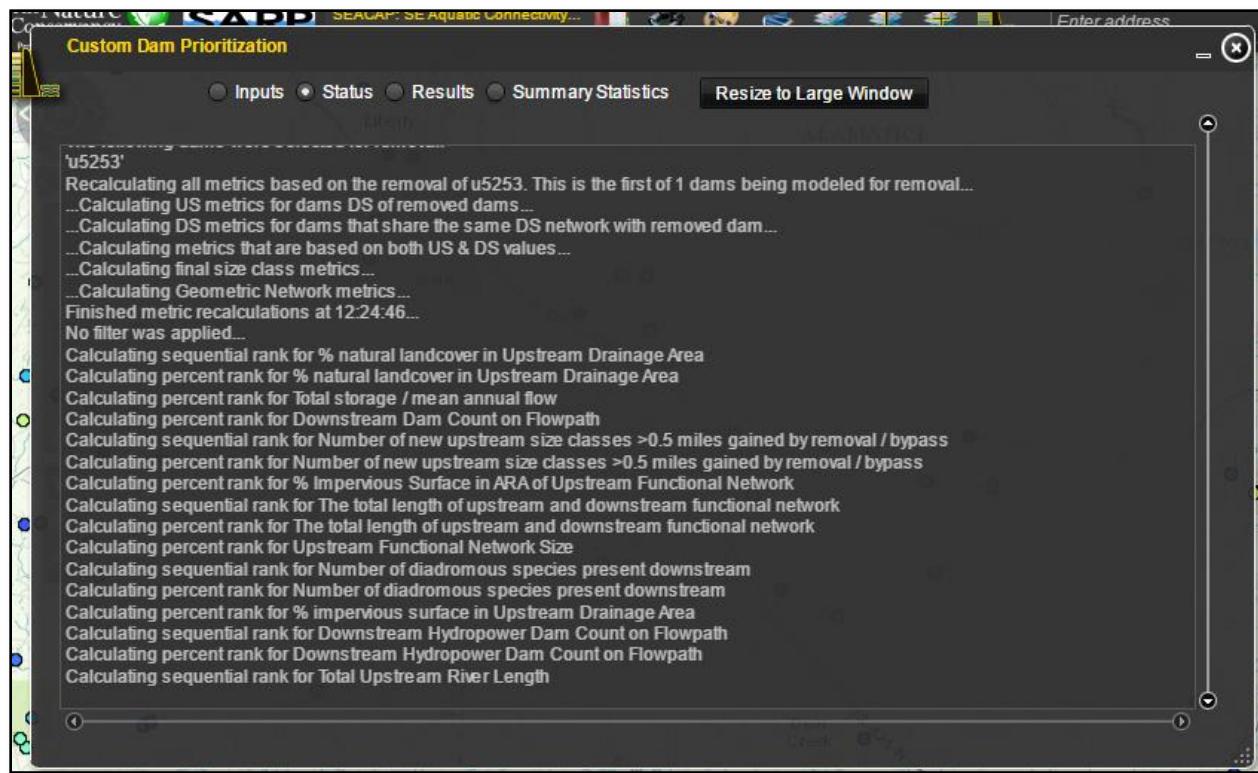


When finished, clicking on the “Click When Finished” button will reformat the UNIQUE\_IDs into the proper syntax, remove the selection layer from the map, and turn the other map layers back on. After metric weights are applied, the analysis can be started by clicking the “Submit” button. When the prioritization is complete, the values that are displayed in the Results are calculated as if the chosen dams had been removed – this is true of the prioritization outputs (Final Rank and Tier) as well as all of the metric values that were included in the analysis (those whose weight >0).

## 5.2.5 Viewing and Exporting Results

When an analysis is started, the Tool will automatically switch to the “Status” state. This state is used to report on the progress of the prioritization. The time required to run a prioritization varies based on the number of dams included in the analysis, the number of metrics included in the analysis, the number of dams being modeled for removal, whether summary statistics are being calculated, as well as server load. Generally, a custom analysis can be expected to run between 30 seconds and 2 minutes.

Figure 5-20: The "Status" state of the Tool displaying updates on a current analysis.



### 5.2.5.1 Results

Results are presented in the Results state of the Tool. When an analysis is complete the Tool will automatically switch to this state. If any dams were selected for “removal,” a warning message will appear to remind the user that the values presented in the Results are based on the selected dams being removed (Figure 5-21).

Figure 5-21: The “Results” state with a warning message indicating which dam(s) were selected for removal.

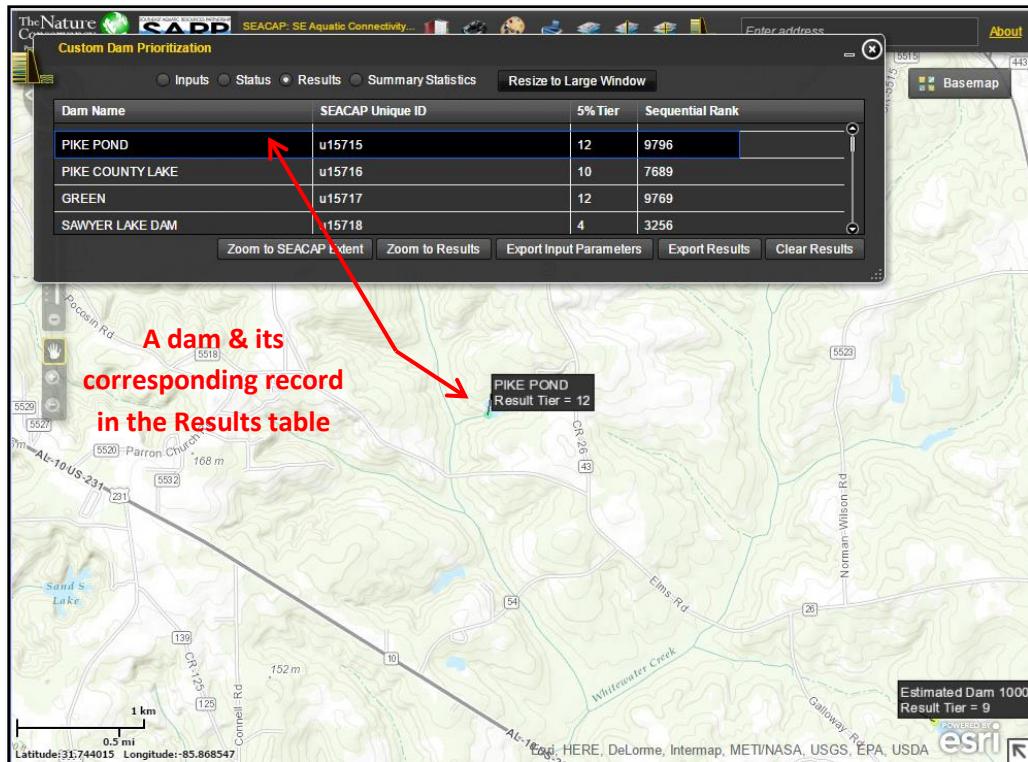
The screenshot shows a web-based application titled "SEACAP: SE Aquatic Connectivity...". The main interface includes a toolbar with various icons, a map view on the right, and a central table area. The table has four columns: "Dam Name", "SEACAP Unique ID", "5% Tier", and "Sequential Rank". The rows list various dams, such as "Estimated Dam 1182" (e1182, Tier 3, Rank 1948), "DONALDSON LAKE DAM" (u15650, Tier 10, Rank 7721), and "JERRY ADAMS" (u15652, Tier 17, Rank 13854). A modal dialog box is overlaid on the table, containing a warning message: "The prioritized results and individual metric values in the result table are derived from the original values based on the modeled removal of the following dams: 'u5253'". There is an "OK" button at the bottom of the dialog. Below the table, there are buttons for "Zoom to SEACAP Extent", "Zoom to Results", "Export Input Parameters", "Export Results", and "Clear Results".

Dam Name	SEACAP Unique ID	5% Tier	Sequential Rank
Estimated Dam 1182	e1182	3	1948
Estimated Dam 1183	e1183	10	8352
DONALDSON LAKE DAM	u15650	10	7721
CHARLES WOODHAM LAKE	u15651	10	7684
JERRY ADAMS	u15652	17	13854
CLIFTON MADDOX	u15653	17	14233
JAMES CRAVEY	u15654	6	1022
DANLEY ESTATES LAKE	u15655		
CLIFTON MADDOX	u15656		
CAROLINE WILSON	u15657		
ADAMS LAKE AND DAM	u15658		
DAVID WEST	u15659		
GERALD CROWLEY	u15660		
GI FN I AWRFNCE DAM	u15661	16	12947

After dismissing this warning, users enter the Results table. Similar to a desktop GIS, records in the Results table are linked to features in the map. The Results table includes the dam name, SEACAP Unique ID, Tiered Result (5% bins, which should be considered the “result” value), sequentially ranked result that the 5% bins are based on, as well as the raw metric values for only those metrics that were selected by the user. Clicking on a record in the table will highlight the dam in the map with a pulsing red halo. Double clicking on a record will zoom to the dam in the map. Likewise, clicking on a dam in the map will highlight the associated record in the table. Labels will appear in the map showing the dam’s name and its result tier for the custom scenario.

Note that the map latency (response time) may increase noticeably after custom results have been added to the map. In order to provide more functionality (specifically, the link between a dam in the map and a corresponding result in the table) results are dynamically drawn by the client browser. Thus, the speed which the map responds to user input (i.e. panning, zooming) will vary based on the user’s hardware and software configuration. Because the latency is a result of the browser drawing the dam graphics in the map, it will be more pronounced in a custom analysis that includes all the inputs dams as opposed to an analysis that only dams includes one state, for example. If the latency is severe, it can be managed by turning off the results layer before panning or zooming, then turning the layer back on when the desired extent is reached.

Figure 5-22: Select a record in the Results to zoom to a corresponding feature highlighted in the map.



The symbols of the resulting features in the map use the same color ramp as the pre-loaded Workgroup-consensus results to indicate Tier (Tier 1 = red, Tier 20 = blue). To help avoid confusion the default results are automatically turned off when a custom scenario result is added to the map. The default results can be turned back on at any time.

Any given column in the Results table can be used to sort the table. The custom result table only includes the raw metric values for those fields that were selected by the user as weighted metrics. Data for the other raw metrics can be obtained from the “SEACAP Dams – All Metric Data” layer in the map.

Figure 5-23: Sorting on a column in the results and buttons to work with the results.

The screenshot shows the 'Custom Dam Prioritization' interface. At the top, there are radio buttons for 'Inputs', 'Status', 'Results' (which is selected), and 'Summary Statistics'. To the right of these are 'Resize to Large Window' and a close button. Below this is a table with four columns: 'Dam Name', 'SEACAP Unique ID', '5% Tier', and 'Sequential Rank'. A red arrow points to the top of the 'Sequential Rank' column header, labeled 'sort order'. The table contains 12 rows of dam information. At the bottom of the table, a red circle highlights a row of buttons: 'Zoom to SEACAP Extent', 'Zoom to Results', 'Export Input Parameters', 'Export Results', and 'Clear Results'.

Dam Name	SEACAP Unique ID	5% Tier	Sequential Rank
YOUNGBLOOD	u15759	3	1785
HARRISON LAKE DAM	u9245	3	1786
Estimated Dam 1738	e1738	3	1787
WHETSTONE FISHING LAKE	u40590	3	1788
TATE DAM	u38570	3	1789
Estimated Dam 3098	e3098	3	1790
Godwin Lake Dam	u564	3	1791
COVINGTON FISH PONDS NUMBER 3 DAM	u17284	3	1792
Estimated Dam 2644	e2644	3	1793
KENNEDY POND DAM	u30052	3	1794
Denrock Dam	u6371	3	1795
LUCY GILES DAM	u8825	3	1796
Estimated Dam 142	e142	3	1797

A series of buttons along the bottom of the Results table allow users to interact with the results. From left to right these buttons zoom to the full extent of the Study area, zoom to the extent of the custom results, export input parameters (metric weights, filter, dams selected for removal) to a text file, export the results table as a Microsoft Excel file, and clear the results (both the table and the features on the map). *It is strongly recommended that input parameters always be saved with results, and that the file names be made to correspond to each other.*

### 5.2.5.2 Summary Statistics

Optionally, summary statistics can be performed on either Tier or Final Result (the un-binned, sequential rank) and by states or watersheds. To access the summary statistics table, select the Summary Statistics radio button at the top of the Tool (Figure 5-24). In the example below, summary statistics are shown by state for Tiers in an example custom analysis. Thus, all of the states in the analysis have at least one Tier 1 dam. Similarly to the Results table, the Summary Statistics can be exported as a Microsoft Excel (.xls) file and saved for future reference. Also, as with the results and input parameter exports, it is strongly recommended that summary statistics are exported as an Excel file that is named to clearly indicate from which scenario it is derived.

Figure 5-24: Summary statistics of custom scenario results

The screenshot shows a software window titled "Custom Dam Prioritization". At the top, there are four radio buttons: "Inputs", "Status", "Results", and "Summary Statistics", with "Summary Statistics" being the selected option (indicated by a red circle). To the right of these buttons is a "Resize to Large Window" button. Below the buttons is a table with the following data:

Summarized By	Number of Dams	Mean Value	Minimum Value	Maximum Value	Standard Deviation
Alabama	3907	11.56616	1	20	4.977308
Florida	1038	11.27746	1	20	5.033934
Georgia	5637	10.42363	1	20	5.670769
Mississippi	303	9.297029	2	20	4.646892
North Carolina	2954	11.29316	1	20	6.441961
South Carolina	2544	8.748034	1	20	5.92566
Virginia	550	6.692727	1	20	5.518816

At the bottom right of the table area is a button labeled "Export Summary Statistics" (also circled in red).

## 6 References

- Anderson, M.G., A. Barnett, M. Clark, C. Ferree, A. Olivero Sheldon, and J. Prince. 2014. Resilient Sites for Terrestrial Conservation in the Southeast Region. The Nature Conservancy, Eastern Conservation Science. 127 pp.
- Atlantic States Marine Fisheries Commission (ASMFC). 2004. Alexa McKerrow, Project Manager, Biodiversity and Spatial Information Center (BaSIC) at North Carolina State University (NCSU).
- Beyer, Hawthorne. 2009. Geospatial Modeling Environment (GME), version 0.3.4 Beta [software]. <http://www.spatialecology.com/gme/index.htm>
- Collier, M., R. Webb, and J. Schmidt, Dams and rivers: Primer on the downstream effects of dams, U.S. Geol. Surv. Circ., 1126, 1997.
- Elkins, D. and N. Nibbelink. 2012. Compilation of field and GIS-based barrier assessment studies in the Southeast Aquatic Resources Partnership (SARP) region. Warnell School of Forestry and Natural Resources. Athens, GA
- Esselman, P., D.M. Infante, D. Wieferich, A. Cooper, L. Wang, W. Taylor, R. Tingley, D. Thornbrugh, J. Ross, and J. Fenner. (May 2013) National Fish Habitat Action Plan (NFHAP) 2010 Community Fish Data. National Fish Habitat Partnership Data System 3.0. <http://dx.doi.org/doi:10.5066/F7QN64RG>
- Gesch, D.B., 2007, The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p. 99-118.
- Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steck, M., and Tyler, D., 2002, The National Elevation Dataset: Photogrammetric Engineering and Remote Sensing, v. 68, no. 1, p. 5-11.
- Graf, W.L., 1999. Dam nation: a geographic census of American dams and their largescale hydrologic impacts. Water Resources Research 35(4), 1305-1311.
- Hoenke, K., Kumar, M., Batt, L. A GIS based approach for prioritizing dams for potential removal, Ecological Engineering, Volume 64, March 2014, Pages 27-36, ISSN 0925-8574, <http://dx.doi.org/10.1016/j.ecoleng.2013.12.009>.
- Horizon Systems Corporation. 2012. NHDPlus Version 2. [http://www.horizon-systems.com/nhdplus/NHDPlusV2\\_documentation.php](http://www.horizon-systems.com/nhdplus/NHDPlusV2_documentation.php)
- Ignatius, A.R. and J. W. Jones, 2014. Small Reservoir Distribution, Rate of Construction, and Uses in the Upper and Middle Chattahoochee Basins of the Georgia Piedmont, USA, 1950–2010. *International Journal of Geo-Information*, 3(2): 460-480.
- Ignatius, A.R. and T.A. Stallins, 2011. Assessing Spatial Hydrological Data Integration to Characterize Geographic Trends in Small Reservoirs in the Apalachicola-Chattahoochee-Flint River Basin. *Southeastern Geographer*, 51(3): 371-393.

Martin, E. H. and Apse, C.D. 2013. Chesapeake Fish Passage Prioritization: An Assessment of Dams in the Chesapeake Bay Watershed. The Nature Conservancy, Eastern Division Conservation Science.  
[http://maps.tnc.org/erof\\_ChesapeakeFPP](http://maps.tnc.org/erof_ChesapeakeFPP)

Martin, E. H. and C. D. Apse. 2011. Northeast Aquatic Connectivity: An Assessment of Dams on Northeastern Rivers. The Nature Conservancy, Eastern Freshwater Program.  
<http://rcngrants.org/content/northeast-aquatic-connectivity>

Master, Lawrence L., Stephanie R. Flack and Bruce A. Stein, eds. 1998. Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity. The Nature Conservancy, Arlington, Virginia

Matthews, W.J. and H.W. Robison. 1988. The distribution of fishes of Arkansas: a multivariate analysis. Copeia :358-374.

National Elevation Dataset. United States Geological Survey. <http://ned.usgs.gov/about.html>

Olivero, Arlene and Anderson, Mark. 2008. Northeast Aquatic Habitat Classification System. Boston.  
<http://rcngrants.org/node/38>

Smith, Mark; Schiff, Roy; Olivero, Arlene; and MacBroom, James. 2008. The Active River Area: A River Conservation Framework for Protecting Rivers and Streams.

<https://www.conervationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/freshwater/floodplains/Pages/default.aspx>

Vannote, RL,G. W. Minshall, K. W. Cummins, J.R. Sedell, and E. Gushing 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

## 7 Appendix I: SEACAP Workgroup

Name	Affiliation
Mark Anderson	The Nature Conservancy - Eastern US Division
Colin Apse	The Nature Conservancy - Eastern US Division
Analie Barnett	The Nature Conservancy - Eastern US Division
Jose Barrios	USFWS
Lynette Batt	Unique Places, LLC (formerly American Rivers - North Carolina)
Braven Beaty	The Nature Conservancy - Virginia
Rebecca Benner	The Nature Conservancy - North Carolina
Walter (Tripp) Bolton	USFWS - Region 4
Mary Kate Brown	The Nature Conservancy - Alabama
Janet Cakir	South Atlantic Landscape Conservation Cooperative
Mark Cantrell	USFWS Region 4
Dan Catchings	Alabama Dept. of Natural Resources
Mary Conley	The Nature Conservancy - Alabama
John Damer	Georgia Dept. of Natural Resources
Will Duncan	USFWS Region 4
Duncan Elkins	University of Georgia
Kathleen Freeman	The Nature Conservancy - Florida
Mary Freeman	US Geological Survey - Georgia
Paul Freeman	The Nature Conservancy - Alabama
Nate Gillespie	US Forest Service - Fisheries Program
Lisa Gordon	Environmental Protection Agency Region 4
Sara Gottlieb	The Nature Conservancy - Georgia
Chris Goudreau	North Carolina Wildlife Resources Commission
Will Graf	The Nature Conservancy - SC / University of South Carolina
Emily Granstaff	Southeast Aquatic Resources Partnership
Emily Greene	NOAA Marine Habitat Program
Kale Gullett	Natural Resources Conservation Service
Kevin Hart	North Carolina Division of Marine Fisheries
Lisa Havel	Atlantic States Marine Fisheries Commission
Brent Hess	Georgia Dept. of Natural Resources
Ted Hoehn	Florida Fish & Wildlife Commission
Kat Hoenke	Southeast Aquatic Resources Partnership
Chad Holbrook	South Carolina Dept. of Natural Resources
Carol Johnston	Auburn University (Alabama)
John Kauffman	Southeast Aquatic Resources Partnership
Jeff Kipp	Atlantic States Marine Fisheries Commission
Eric Krueger	The Nature Conservancy - South Carolina

Name	Affiliation
Christi Lambert	The Nature Conservancy - Georgia
Wilson Laney	USFWS Region 4
Erik Martin	The Nature Conservancy - Eastern US Division
Brad Maurer	The Nature Conservancy - Mississippi
Erin McCombs	American Rivers
Keith McFadden	US Geological Survey - NHD
Kevin Moody	Federal Highway Administration
Rua Mordecai	USFWS - South Atlantic Landscape Conservation Cooperative
Lisa Moss	USFWS - Virginia Fisheries
January Murray	Georgia Dept. of Natural Resources
Robert Newton	The Nature Conservancy - South Carolina
Arlene Olivero Sheldon	The Nature Conservancy - Eastern US Division
Pat O'Neil	Geological Survey of Alabama
Bill Post	South Carolina Dept. of Natural Resources
Jeff Powell	USFWS - Daphne, Alabama
Peter Raabe	American Rivers
Kathy Rawls	North Carolina Division of Marine Fisheries
Fritz Rhode	NOAA Atlantic Branch (NC)
Scott Robinson	Southeast Aquatic Resources Partnership
Mark Scott	South Carolina Dept. of Natural Resources
Kristina Serbesoff-King	The Nature Conservancy - Florida
Tyler Stubbs	Mississippi Division of Wildlife, Fisheries, and Parks
Alan Weaver	Virginia Dept. of Game and Inland Fisheries
Mike Wicker	USFWS - North Carolina Coastal Program
Daniel Wieferich	US Geological Survey
Bennett Wynne	North Carolina Wildlife Resources Commission
Jerry Ziewitz	USFWS Region 4

## 8 Appendix II: Input Datasets

Dataset	Source	Description
Dams	Multiple sources including: state agencies, UGA SSBGIS, NC BPT, the National Inventory of Dams, National Anthropogenic Barrier Dataset, NHD Dam Events, and edited dams. Review and edits made by the SEACAP Workgroup	This dataset represents dams in the SALCC region that are spatially linked to the stream flowline in the NHDPlus v2 dataset. Dams that do not fall on mapped streams in the NHDPlus v2 are not included in the results. Complete metadata is available via <a href="http://maps.tnc.org/seacap/assets/metadata/SEACA_P_damsMetrics.xml">http://maps.tnc.org/seacap/assets/metadata/SEACA_P_damsMetrics.xml</a>
Waterfalls	<a href="#">USGS GNIS database</a> , SEACAP Workgroup. USGS draft data (Daniel Wieferich, personal communication)	Point dataset representing potential natural barriers to fish passage. Waterfalls were used in the development of functional river networks, but are not included in the prioritization results as potential candidates for fish passage projects.
Hydrography	NHDPlus version 2	In order for dams to be included in the analysis, they had to fall on the mapped river network, or hydrography, that was used in the project: a modified version of the Medium Resolution National Hydrography Dataset Plus, Version 2 (NHDPlus v2) (Horizon Systems 2012). This hydrography was originally digitized by the United States Geological Survey primarily from 1:100,000 scale topographic maps. Substantial additions and improvements were applied to the USGS NHD data by Horizon Systems Corporation to create the NHDPlus v2.  In order to be used in this analysis the hydrography had to be processed to create a dendritic network, or dendrite: a single-flowline network with no braids or other downstream bifurcation (Figure 2-4). The medium-resolution NHDPlus used in this project includes attributes which were used to select the mainstem of a river from a braided section using a simple definition query to extract a dendrite. (NHDFlowline.FLOWDIR = 'With Digitized' AND NHDPlusFlowlineVAA.Divergence in (0,1) AND NHDPlusFlowlineVAA.StreamCalc <>0). Additional information on the NHDPlus v2 and these attributes can be found in the NHDPlus v2 User Guide (Horizon Systems 2012).
Diadromous fish habitat	Data was from ASMFC, NFHAP, MARIS, and expert knowledge	Critical habitats (spawning, nursery or other critical habitats) assigned to segments of the project hydrography. Segments needed to reach the uppermost documented location for alewife, blueback herring, American shad, hickory shad, Alabama Shad, Atlantic sturgeon, Gulf sturgeon,

		striped bass, and American eel.
Active River Area	Smith et al. 2008	The Active River Area (ARA) is a spatially explicit framework for modeling rivers and their dynamic interaction with the land through which they flow (Smith et al. 2008). Key features of the ARA include the meander belt, riparian wetlands, floodplains, terraces, material contribution areas. The ARA is different from, but was calibrated to and compared against the FEMA 100-year floodplain. The SEACAP project used the ARA as a unit within which various landcover metrics, such as forest cover and impervious surface, were summarized.
Land Cover	<a href="#">2011 National Land Cover Database (NLCD2011)</a>	Land use / land cover data from the NLCD2011. This 30m gridded data was grouped into natural and agricultural. (Developed was addressed via the impervious surface data). Natural landcover includes the following classes: open water, barren land, deciduous forest, evergreen forest, mixed forest, scrub/shrub, grassland/herbaceous, woody wetlands, emergent wetlands. Agricultural includes the following classes: pasture/hay, cultivated crops. The percentages of both agricultural and natural land cover are assessed for the contributing watershed of each dam, as well as within the <a href="#">active river area</a> of the dam's upstream and downstream networks.
Impervious Surface	<a href="#">2011 National Land Cover Database (NLCD2011)</a>	% Impervious surface data from the NLCD2011. This 30m gridded data describes the % of impervious surface within each 30m cell. The percentages of impervious surface is assessed for the contributing watershed of each dam, as well as within the <a href="#">active river area</a> of the dam's upstream and downstream networks.
Resident fish, rare fish, mussels & rare crayfish	<a href="#">NatureServe</a> HUC8-scale data <a href="#">USGS BISON</a> point observations <a href="#">MARIS</a> point observations	Data for each species of interest (see Appendix 9) was assigned to HUC8s on a presence/absence basis. See Section 2.5 for more details. These metrics are available for custom prioritizations
Invasive Species	<a href="#">NatureServe</a> HUC8-scale data <a href="#">USGS BISON</a> point observations <a href="#">MARIS</a> point observations	Data for each species of interest (see Appendix 9) was assigned to HUC8s on a presence/absence basis. See Section 2.5.2 for more details. These metrics are available for custom prioritizations
Roads and Railroads	<a href="#">Esri</a> version 10.1 data	Roads and railroads obtained from Esri's ArcGIS version 10.1 data were intersected with small streams (drainage area <38.61sq mi) as a proxy for culvert locations.

Conservation Land	<a href="#">The Nature Conservancy</a>	Dams that lie on conservation lands are identified. Additionally, the percentage of conservation land is assessed within a 100m buffer of each dam's upstream and downstream functional river networks.
-------------------	--	---

## 9 Appendix III: Resident Fish Species List

Scientific Name	Common Name
<i>Acipenser fulvescens</i>	Shortnose Sturgeon
<i>Ambloplites cavifrons</i>	Roanoke Bass
<i>Ammocrypta beanii</i>	Naked Sand Darter
<i>Ammocrypta bifascia</i>	Florida Sand Darter
<i>Ammocrypta meridiana</i>	Southern Sand Darter
<i>Ammocrypta vivax</i>	Scaly Sand Darter
<i>Campostoma anomalum</i>	Central Stoneroller
<i>Campostoma oligolepis</i>	Largescale Stoneroller
<i>Campostoma pauciradii</i>	Bluefin Stoneroller
<i>Campostoma pullum</i>	Central Stone Roller Subspecies
<i>Carassius auratus</i>	Goldfish
<i>Chrosomus oreas</i>	Mountain Redbelly Dace
<i>Clinostomus funduloides</i>	Rosyside Dace
<i>Crystallaria asprella</i>	Crystal Darter
<i>Ctenopharyngodon idella</i>	Grass Carp
<i>Ctenopharyngodon idella trip</i>	Grass Carp
<i>Cyprinella analostana</i>	Satinfin Shiner
<i>Cyprinella caerulea</i>	Blue Shiner
<i>Cyprinella callisema</i>	Ocmulgee Shiner
<i>Cyprinella callistia</i>	Alabama Shiner
<i>Cyprinella callitaenia</i>	Bluestripe Shiner
<i>Cyprinella camura</i>	Bluntnose Shiner
<i>Cyprinella cercostigma</i>	Eastern Blacktail Shiner
<i>Cyprinella chloristia</i>	Greenfin Shiner
<i>Cyprinella galactura</i>	Whitetail Shiner
<i>Cyprinella gibbsi</i>	Tallapoosa Shiner
<i>Cyprinella hybrid</i>	
<i>Cyprinella labrosa</i>	Thicklip Chub
<i>Cyprinella leedsi</i>	Bannerfin Shiner
<i>Cyprinella lutrensis</i>	Red Shiner
<i>Cyprinella nivea</i>	Whitefin Shiner
<i>Cyprinella pyrrhomelas</i>	Fieryblack Shiner
<i>Cyprinella sp 1</i>	
<i>Cyprinella spiloptera</i>	Spotfin Shiner
<i>Cyprinella spp</i>	
<i>Cyprinella stigmatura</i>	Regal Shiner
<i>Cyprinella trichroistia</i>	Tricolor Shiner
<i>Cyprinella venusta</i>	Blacktail Shiner

Scientific Name	Common Name
<i>Cyprinella whipplei</i>	Steelcolor Shiner
<i>Cyprinella xaenura</i>	Altamaha Shiner
<i>Cyprinella zanema</i>	Santee Chub
<i>Cyprinus carpio</i>	Common Carp
<i>Ericymba amplamala</i>	Silverjaw Minnow
<i>Erimystax cahni</i>	Slender Chub
<i>Erimystax dissimilis</i>	Streamline Chub
<i>Erimystax insignis</i>	Blotched Chub
<i>Erimyzon oblongus</i>	Creek Chubsucker
<i>Erimyzon tenuis</i>	Sharpfin Chubsucker
<i>Etheostoma artesiae</i>	Redspot Darter
<i>Etheostoma bellator</i>	Warrior Darter
<i>Etheostoma blennioides</i>	Greenside Darter
<i>Etheostoma brevirostrum</i>	Holiday Darter
<i>Etheostoma brevispinum</i>	Carolina Fantail Darter
<i>Etheostoma caeruleum</i>	Rainbow Darter
<i>Etheostoma chermocki</i>	Vermillion Darter
<i>Etheostoma chlorobranchium</i>	Greenfin Darter
<i>Etheostoma chlorosoma</i>	Bluntnose Darter
<i>Etheostoma chlorosomum</i>	Bluntnose Darter
<i>Etheostoma chuckwachatte</i>	Lipstick Darter
<i>Etheostoma collis</i>	Carolina Darter
<i>Etheostoma colorosum</i>	Coastal Darter
<i>Etheostoma coosae</i>	Coosa Darter
<i>Etheostoma dawsoni</i>	Choctawhatchee Darter
<i>Etheostoma ditrema</i>	Coldwater Darter
<i>Etheostoma douglasi</i>	Tuscaloosa Darter
<i>Etheostoma edwini</i>	Brown Darter
<i>Etheostoma etowahae</i>	Etowah Darter
<i>Etheostoma flabellare</i>	Fantail Darter
<i>Etheostoma fricksium</i>	Savannah Darter
<i>Etheostoma fusiforme</i>	Swamp Darter
<i>Etheostoma gracile</i>	Slough Darter
<i>Etheostoma histrio</i>	Harlequin Darter
<i>Etheostoma hopkinsi</i>	Christmas Darter
<i>Etheostoma inscriptum</i>	Turquoise Darter
<i>Etheostoma jessiae</i>	Blueside Darter
<i>Etheostoma jordani</i>	Greenbreast Darter
<i>Etheostoma lachneri</i>	Tombigbee Darter
<i>Etheostoma lynceum</i>	Brighteye Darter

Scientific Name	Common Name
<i>Etheostoma mariae</i>	Pinewoods Darter
<i>Etheostoma meridianum</i>	Southern Sand Darter
<i>Etheostoma nigripinne</i>	Blackfin Darter
<i>Etheostoma nigrum</i>	Johnny Darter
<i>Etheostoma nuchale</i>	Watercress Darter
<i>Etheostoma okaloosae</i>	Okaloosa Darter
<i>Etheostoma olmstedi</i>	Tessellated Darter
<i>Etheostoma parvipinne</i>	Goldstripe Darter
<i>Etheostoma perlóngum</i>	Waccamaw Darter
<i>Etheostoma phytophilum</i>	Rush Darter
<i>Etheostoma podostemone</i>	Riverweed Darter
<i>Etheostoma proeliare</i>	Cypress Darter
<i>Etheostoma ramseyi</i>	Alabama Darter
<i>Etheostoma rufilineatum</i>	Redline Darter
<i>Etheostoma rupestre</i>	Rock Darter
<i>Etheostoma scotti</i>	Cherokee Darter
<i>Etheostoma serrifer</i>	Sawcheek Darter
<i>Etheostoma stigmaeum</i>	Speckled Darter
<i>Etheostoma swaini</i>	Gulf Darter
<i>Etheostoma tallapoosae</i>	Tallapoosa Darter
<i>Etheostoma thalassinum</i>	Seagreen Darter
<i>Etheostoma trisella</i>	Trispot Darter
<i>Etheostoma vitreum</i>	Glassy Darter
<i>Etheostoma whipplei</i>	Redfin Darter
<i>Etheostoma whipplei artesiae</i>	
<i>Etheostoma zonale</i>	Banded Darter
<i>Etheostoma zonifer</i>	Backwater Darter
<i>Exoglossum laurae</i>	Tonguetied Chub
<i>Exoglossum maxillingua</i>	Cutlip Minnow
<i>Gobiomorus dormitor</i>	Bigmouth Sleeper
<i>Gobionellus hastatus</i>	Highfin Goby
<i>Gobionellus oceanicus</i>	Highfin Goby
<i>Gobionellus spp</i>	Goby
<i>Gobiosoma bosc</i>	Naked Goby
<i>Gobiosoma robustum</i>	Code Goby
<i>Hemitremia flammea</i>	Flame Chub
<i>Hybognathus hayi</i>	Cypress Minnow
<i>Hybognathus nuchalis</i>	Mississippi Silvery Minnow
<i>Hybognathus placitus</i>	Plains Minnow
<i>Hybognathus regius</i>	Eastern Silvery Minnow

Scientific Name	Common Name
<i>Hybognathus spp</i>	
<i>Hybopsis amblops</i>	Bigeye Chub
<i>Hybopsis amnis</i>	Pallid Shiner
<i>Hybopsis hypsinotus</i>	Highback Chub
<i>Hybopsis labrosa</i>	Thicklip Chub
<i>Hybopsis lineapunctata</i>	Lined Chub
<i>Hybopsis rubrifrons</i>	Rosyface Chub
<i>Hybopsis sp 9</i>	
<i>Hybopsis sp cf winchelli</i>	
<i>Hybopsis spp</i>	
<i>Hybopsis winchelli</i>	Clear Chub
<i>Hybopsis zanema</i>	Santee Chub
<i>Hypentelium etowanum</i>	Alabama Hogsucker
<i>Hypentelium nigricans</i>	Northern Hog Sucker
<i>Hypentelium roanokense</i>	Roanoke Hogsucker
<i>Hypophthalmichthys molitrix</i>	Silver Carp
<i>Hypophthalmichthys nobilis</i>	Bighead Carp
<i>Lepomis auritus</i>	Redbreast Sunfish
<i>Lepomis cyanellus</i>	Green Sunfish
<i>Lepomis gibbosus</i>	Pumpkinseed
<i>Lepomis gulosus</i>	Warmouth
<i>Lepomis humilis</i>	Orangespotted Sunfish
<i>Lepomis macrochirus</i>	Bluegill
<i>Lepomis marginatus</i>	Dollar Sunfish
<i>Lepomis megalotis</i>	Longear Sunfish
<i>Lepomis microlophus</i>	Redear Sunfish
<i>Lepomis miniatus</i>	Redspotted Sunfish
<i>Lepomis punctatus</i>	Spotted Sunfish
<i>Lepomis symmetricus</i>	Bantam Sunfish
<i>Luxilus albeolus</i>	White Shiner
<i>Luxilus cerasinus</i>	Crescent Shiner
<i>Luxilus chrysocephalus</i>	Striped Shiner
<i>Luxilus chrysocephalus chryso</i>	
<i>Luxilus chrysocephalus isolep</i>	
<i>Luxilus coccogenis</i>	Warpaint Shiner
<i>Luxilus cornutus</i>	Common Shiner
<i>Luxilus zonistius</i>	Bandfin Shiner
<i>Lythrurus alegnotus</i>	Warrior Shiner
<i>Lythrurus ardens</i>	Rosefin Shiner
<i>Lythrurus atrapiculus</i>	Blacktip Shiner

Scientific Name	Common Name
<i>Lythrurus bellus</i>	Pretty Shiner
<i>Lythrurus fasciolaris</i>	Scarlet Shiner
<i>Lythrurus fumeus</i>	Ribbon Shiner
<i>Lythrurus lirus</i>	Mountain Shiner
<i>Lythrurus matutinus</i>	Pinewoods Shiner
<i>Lythrurus roseipinnis</i>	Cherryfin Shiner
<i>Lythrurus spp</i>	
<i>Lythrurus umbratilis</i>	Redfin Shiner
<i>Macrhybopsis aestivalis</i>	Speckled Chub
<i>Macrhybopsis hyostoma</i>	Shoal Chub
<i>Macrhybopsis meeki</i>	Sicklefin Chub
<i>Macrhybopsis sp 1</i>	
<i>Macrhybopsis sp 2</i>	
<i>Macrhybopsis spp</i>	
<i>Macrhybopsis storriana</i>	Silver Chub
<i>Margariscus margarita</i>	Pearl Dace
<i>Micropterus cataractae</i>	
<i>Micropterus coosae</i>	Redeye Bass
<i>Micropterus henshalli</i>	Alabama Bass
<i>Micropterus notius</i>	Suwannee Bass
<i>Micropterus punctulatus</i>	Spotted Bass
<i>Micropterus salmoides</i>	Largemouth Bass
<i>Moxostoma anisurum</i>	Silver Redhorse
<i>Moxostoma ariommum</i>	Bigeye Jumprock
<i>Moxostoma breviceps</i>	Smallmouth Redhorse
<i>Moxostoma carinatum</i>	River Redhorse
<i>Moxostoma cervinum</i>	Blacktip Jumprock
<i>Moxostoma collapsum</i>	Notchlip Redhorse
<i>Moxostoma duquesnei</i>	Black Redhorse
<i>Moxostoma duquesnii</i>	Black Redhorse
<i>Moxostoma erythrurum</i>	Golden Redhorse
<i>Moxostoma lachneri</i>	Greater Jumprock
<i>Moxostoma macrolepidotum</i>	Shorthead Redhorse
<i>Moxostoma n sp cpoeciluru</i>	
<i>Moxostoma pappillosum</i>	V-Lip Redhorse
<i>Moxostoma poecilurum</i>	Blacktail Redhorse
<i>Moxostoma robustum</i>	Robust Redhorse
<i>Moxostoma rupiscartes</i>	Striped Jumprock
<i>Moxostoma sp 1</i>	
<i>Moxostoma sp 3</i>	

Scientific Name	Common Name
<i>Moxostoma sp 4</i>	
<i>Moxostoma sp apalachicola re</i>	Sicklefin Redhorse
<i>Moxostoma sp c erythrurum</i>	Golden Redhorse
<i>Moxostoma sp c lachneri</i>	Greater Jumprock
<i>Moxostoma spp</i>	
<i>Nocomis effusus</i>	Redtail Chub
<i>Nocomis leptocephalus</i>	Bluehead Chub
<i>Nocomis leptocephalus bellicu</i>	Bluehead Chub
<i>Nocomis micropogon</i>	River Chub
<i>Nocomis platyrhynchus</i>	Bigmouth Chub
<i>Nocomis raneyi</i>	Bull Chub
<i>Nocomis spp</i>	
<i>Notemigonus crysoleucas</i>	Golden Shiner
<i>Notropis alborus</i>	Whitemouth Shiner
<i>Notropis altipinnis</i>	Highfin Shiner
<i>Notropis ammophilus</i>	Orangefin Shiner
<i>Notropis amoenus</i>	Comely Shiner
<i>Notropis amplamala</i>	Longjaw Minnow
<i>Notropis ariommus</i>	Popeye Shiner
<i>Notropis asperifrons</i>	Burrhead Shiner
<i>Notropis atherinoides</i>	Emerald Shiner
<i>Notropis baileyi</i>	Rough Shiner
<i>Notropis bifrenatus</i>	Bridle Shiner
<i>Notropis blennius</i>	River Shiner
<i>Notropis boops</i>	Bigeye Shiner
<i>Notropis buccatus</i>	Silverjaw Minnow
<i>Notropis buchanani</i>	Ghost Shiner
<i>Notropis cahabae</i>	Cahaba Shiner
<i>Notropis candidus</i>	Silverside Shiner
<i>Notropis chalybaeus</i>	Ironcolor Shiner
<i>Notropis chiliticus</i>	Redlip Shiner
<i>Notropis chlorocephalus</i>	Greenhead Shiner
<i>Notropis chrosomus</i>	Rainbow Shiner
<i>Notropis cummingsae</i>	Dusky Shiner
<i>Notropis edwardraneyi</i>	Fluvial Shiner
<i>Notropis harperi</i>	Redeye Chub
<i>Notropis hudsonius</i>	Spottail Shiner
<i>Notropis hybrid</i>	
<i>Notropis hypsilepis</i>	Hightscale Shiner
<i>Notropis leuciodus</i>	Tennessee Shiner

Scientific Name	Common Name
<i>Notropis longirostris</i>	Longnose Shiner
<i>Notropis lutipinnis</i>	Yellowfin Shiner
<i>Notropis maculatus</i>	Taillight Shiner
<i>Notropis mekistocholas</i>	Cape Fear Shiner
<i>Notropis melanostomus</i>	Blackmouth Shiner
<i>Notropis micropteryx</i>	Highland Shiner
<i>Notropis petersoni</i>	Coastal Shiner
<i>Notropis photogenis</i>	Silver Shiner
<i>Notropis procne</i>	Swallowtail Shiner
<i>Notropis rafinesquei</i>	Yazoo Shiner
<i>Notropis rubellus</i>	Rosyface Shiner
<i>Notropis rubricroceus</i>	Saffron Shiner
<i>Notropis rupestris</i>	Bedrock Shiner
<i>Notropis sabinae</i>	Sabine Shiner
<i>Notropis scabriceps</i>	New River Shiner
<i>Notropis scepticus</i>	Sandbar Shiner
<i>Notropis semperasper</i>	Roughhead Shiner
<i>Notropis shumardi</i>	Silverband Shiner
<i>Notropis sp c N sabinae</i>	Sabine Shiner
<i>Notropis sp c chlorocephal</i>	Greenhead Shiner
<i>Notropis sp c rubellus</i>	Rosyface Shiner
<i>Notropis spectrunculus</i>	Mirror Shiner
<i>Notropis spp</i>	
<i>Notropis stilbius</i>	Silverstripe Shiner
<i>Notropis stramineus</i>	Sand Shiner
<i>Notropis telescopus</i>	Telescope Shiner
<i>Notropis texanus</i>	Weed Shiner
<i>Notropis uranoscopuss</i>	Skygazer Shiner
<i>Notropis volucellus</i>	Mimic Shiner
<i>Notropis wickliffi</i>	Channel Shiner
<i>Notropis xaeonocephalus</i>	Coosa Shiner
<i>Noturus sp 2</i>	
<i>Opsopoeodus emiliae</i>	Pugnose Minnow
<i>Percina antesella</i>	Amber Darter
<i>Percina aurantiaca</i>	Tangerine Darter
<i>Percina aurolineata</i>	Goldline Darter
<i>Percina aurora</i>	Pearl Darter
<i>Percina austroperca</i>	Southern Logperch
<i>Percina brevicauda</i>	Coal Darter
<i>Percina burtoni</i>	Blotchside Logperch

Scientific Name	Common Name
<i>Percina caprodes</i>	Logperch
<i>Percina caprodes caprodes</i>	Logperch
<i>Percina copelandi</i>	Channel Darter
<i>Percina crassa</i>	Piedmont Darter
<i>Percina evides</i>	Gilt Darter
<i>Percina gymnocephala</i>	Appalachia Darter
<i>Percina jenkinsi</i>	Conasauga Logperch
<i>Percina kathae</i>	Mobile Logperch
<i>Percina kusha</i>	Brindled Darter
<i>Percina lenticula</i>	Freckled Darter
<i>Percina macrocephala</i>	Longhead Darter
<i>Percina maculata</i>	Blackside Darter
<i>Percina nevisense</i>	Chainback Darter
<i>Percina nigrofasciata</i>	Blackbanded Darter
<i>Percina notogramma</i>	Stripeback Darter
<i>Percina oxyrhynchus</i>	Sharpnose Darter
<i>Percina palmaris</i>	Bronze Darter
<i>Percina peltata</i>	Shield Darter
<i>Percina rex</i>	Roanoke Logperch
<i>Percina roanoka</i>	Roanoke Darter
<i>Percina sciera</i>	Dusky Darter
<i>Percina shumardi</i>	River Darter
<i>Percina sipsi</i>	Bankhead Darter
<i>Percina smithvanizi</i>	Muscadine Darter
<i>Percina sp muscadine darter</i>	Muscadine Darter
<i>Percina squamata</i>	Olive Darter
<i>Percina suttkusi</i>	Gulf Logperch
<i>Percina vigil</i>	Saddleback Darter
<i>Phenacobius catostomus</i>	Riffle Minnow
<i>Phenacobius crassilabrum</i>	Fatlips Minnow
<i>Phenacobius mirabilis</i>	Suckermouth Minnow
<i>Phenacobius teretulus</i>	Kanawha Minnow
<i>Phenacobius uranops</i>	Stargazing Minnow
<i>Phoxinus cumberlandensis</i>	Blackside Dace
<i>Phoxinus erythrogaster</i>	Southern Redbelly Dace
<i>Phoxinus oreas</i>	Mountain Redbelly Dace
<i>Phoxinus tennesseensis</i>	Tennessee Dace
<i>Pimephales notatus</i>	Bluntnose Minnow
<i>Pimephales promelas</i>	Fathead Minnow

Scientific Name	Common Name
<i>Pimephales spp</i>	
<i>Pimephales vigilax</i>	Bullhead Minnow
<i>Pimephales vigilax perspicuus</i>	
<i>Polyodon spathula</i>	Paddlefish
<i>Pteronotropis euryzonus</i>	Broadstripe Shiner
<i>Pteronotropis grandipinnis</i>	Apalachee Shiner
<i>Pteronotropis hypselopterus</i>	Sailfin Shiner
<i>Pteronotropis merlini</i>	Orangetail Shiner
<i>Pteronotropis metallicus</i>	Metallic Shiner
<i>Pteronotropis signipinnis</i>	Flagfin Shiner
<i>Pteronotropis stonei</i>	Lowland Shiner
<i>Pteronotropis welaka</i>	Bluenose Shiner
<i>Rhinichthys atratulus</i>	Eastern Blacknose Dace
<i>Rhinichthys cataractae</i>	Longnose Dace
<i>Rhinichthys obtusus</i>	Western Blacknose Dace
<i>Salvelinus fontinalis</i>	Brook Trout
<i>Semotilus atromaculatus</i>	Creek Chub
<i>Semotilus corporalis</i>	Fallfish
<i>Semotilus lumbee</i>	Sandhills Chub
<i>Semotilus thoreauianus</i>	Dixie Chub
<i>Thoburnia hamiltoni</i>	Rustyside Sucker
<i>Thoburnia rhothoeca</i>	Torrent Sucker

# 10 Appendix IV: Methodology for Identifying Duplicate Dams

## SEACAP Dam Merging Methods

Kat Hoenke

**GOAL:** To create a comprehensive and spatially accurate database of dams for the SEACAP study area using national and state datasets, while eliminating duplicates and retaining the most accurate information.

### Data Sources

#### National Datasets:

*National Anthropogenic Barrier Dataset (NABD):* This dataset is a spatially accurate dataset where NID 2009 dams were snapped to the medium resolution of NHD plus version 1.

*NHD dam events:* These dams are point events found on the NHD plus high resolution river 1:24000

*NID 2013:* This is the latest version of the National Inventory of Dams, downloaded on May 5, 2013.

#### State Datasets:

*Georgia EPA-* From SSBGIS, a dataset compiled by Duncan Elkins.

*Georgia Dam Safety-* From the Georgia dam safety office

*Tallapoosa impoundments-* These dams are from Georgia and Alabama. From SSBGIS, a dataset compiled by Duncan Elkins.

*Florida EPA-* From SSBGIS, a dataset compiled by Duncan Elkins.

*Florida Water Management*

*FL Impoundments added 12-3-13*

*Alabama Shelby County*

*Alabama Tuscaloosa County*

*Alabama Jefferson County*

*Alabama St. Clair County*

*Alabama Blount County*

*Alabama Marshall County*

*Alabama Etowah County*

*AL Impoundments added 12-3-13*

*NC VA Coastal –* These dams are coast wide, from multiple state sources. *From NC division of Marine Fisheries*

*NC Dam Safety- From the North Carolina dam safety office 2012 and 2013*

SC Dam Safety – From Upstate Forever, John Tynan  
VA Dam Safety- From the Virginia dam safety office

### **Duplicate Removal Methods**

#### **National dataset Methods:**

**Goal: Keep all snapped dams, retain any new dams, code all duplicates.**

- 1) Keep all dams from the NABD dataset to maintain snapping. Join in more current attributes using NID 2013.
- 2) If no NABD dam is available, keep all dams from NHD dam events. Join in current attributes using NID 2013.
- 3) Retained any NHD dam events or NID 2013 dams that did not overlap with NABD as new individual dams.
- 4) Possible duplicates coded as NABD or NHD dam event dikes removed
- 5) Coded national sources of dams within 100m of one another.
- 6) Coded dams within 500m of one another with similar names.

#### **State dataset methods:**

**Goal: Keep all state dams that are not duplicates with national datasets.**

- 1) State dams with a common NID or state ID in a national dataset were coded as duplicates
- 2) State dams that were within 100m (or a greater distance, if visual inspection showed more duplicates) of national dams were also coded as duplicates.

#### **Additional actions taken:**

1. Pre- Snap all dams on NABD and NHD dam events with matching reachcodes (Y in snapto100k field). Snap all dams within 100m to flowline, assuming they are in the correct location.

USE field:

- 1 = snapped dam
- 2 = unsnapped dam
- 0 = duplicate dam or other excluded dam

DUPLICATE\_CODES field:

- 0 - Non duplicate – Given 1 or 2 in USE field, depending on snapping.
- 1 - State duplicate common national NIDID, also within 100m of national dam -Given 0 in USE field
- 2 - State duplicate common national NIDID, further than 100m from a national dam-Given 0 in USE field
- 3 - State duplicate, within 100m of national dam. NIDID is not common. Given 0 in USE field
- 4 - State duplicate, within 100m of national dam. No NIDID present. Given 0 in USE field
- 6 - State duplicate, within 100m of another state dam with better location/attributes. Given 0 in USE field
- 7 - National duplicate within 100m of a snapped NABD dam. Given 0 in USE field
- 8 - Unsnapped dams within 100m of another dam. Contains duplicates and originals. Given 2 in USE field.
- 9 - Snapped dams within 100m of another dam. Contains duplicates and originals. Given 1 in use field, needs workgroup review.
- 10- Duplicate dam within 500m of another dam, similar dam name. Given 0 in USE field

SNAP field:

- 1 – Is snapped by BAT and part of a snapped dataset, should be snapped
- 2 – is snapped by BAT
- 3 – Should not be snapped.
- 0 – is not snapped

## 11 Appendix V: Glossary and Metric Definitions

The following is a glossary of metrics that were calculated for each dam in the SEACAP study area. It is available as a PDF file with working hyperlinks at

[http://maps.tnc.org/seacap/assets/Metric\\_Glossary.pdf](http://maps.tnc.org/seacap/assets/Metric_Glossary.pdf). Each metric within the Custom Dam

Prioritization tool is also linked to its associated glossary slide (See Section 5.2).



# Southeast Aquatic Connectivity Assessment Project

1

## GLOSSARY & METRIC DESCRIPTIONS

This glossary was developed to support the interpretation of  
SEACAP web map & tool  
<http://maps.tnc.org/seacap>

## Tiered Results (5% bins)

2

- Analysis results grouped into 20 bins where each bin has 5% of the dams in the analysis area.
- These are the results that should be used for dam assessments

## Sequential Rank

3

- The sequential list of dams produced by the analysis.
- This list should be used with extreme caution: the precision with which GIS can calculate metrics and rank dams is not necessarily indicative of ecological differences
- The Tiered Results (5% bins) should be used to assess dams for their potential ecological benefit

## Downstream Barrier Count

4

- Category: Connectivity Status
- The number of barriers downstream of a given barrier
- Includes natural waterfalls, which are included in network generation
- Does not include barriers excluded from network generation
- Unit: #

## Number of Waterfalls on Downstream Flowpath

5

- Category: Connectivity Status
- Count of waterfalls on downstream flowpath of a barrier
- Unit: #

## Number of Hydro Dams on Downstream Flowpath

6

- Category: Connectivity Status
- Count of hydropower dams on downstream flowpath of a barrier
- Unit: #

## Upstream Barrier Count

7

- Category: Connectivity Status
- The number of barriers upstream of a given barrier
- Includes natural waterfalls, which are included in network generation
- Does not include barriers excluded from network generation
- Unit: #

## Number of Dams on Small Streams in Upstream Watershed

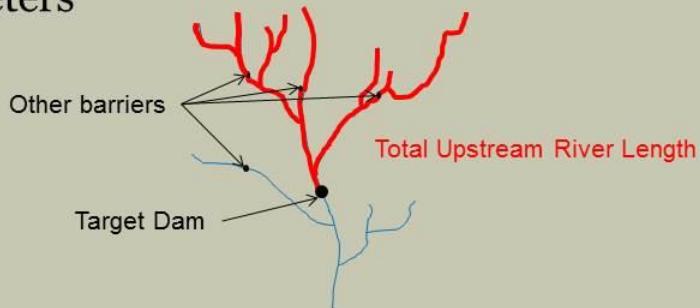
8

- Category: Connectivity Status
- Count of dams that are located on streams which are mapped in the High Resolution (1:24,000) [NHD](#) but are not mapped on the Medium Resolution (1:100,000) [NHD](#). Because these dams are not on the medium resolution NHD (the hydrography used in the project) they are not included in the results. This metric, however, gives an indication of fragmentation due to these dams in the upstream contributing watershed of each dam included in the analysis.
- Unit: #

## Total Upstream River Length

9

- Category: Connectivity Status
- Total length of river network upstream of a given barrier, regardless of any upstream barriers.
- Unit: meters



## Upstream Barrier Density

10

- Category: Connectivity Status
- Upstream Barrier Count divided by the total length of river upstream in meters
- Includes natural waterfalls, which are included in network generation
- Does not include barriers excluded from network generation
- Unit: # / meters

## Downstream Barrier Density

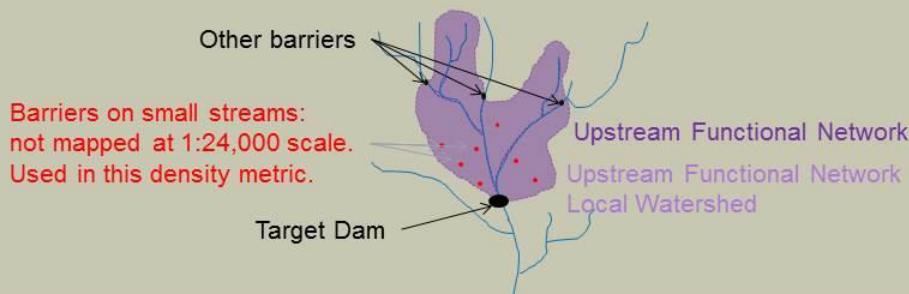
11

- Category: Connectivity Status
- Downstream Barrier Count divided by the Distance to River Mouth in meters
- Includes natural waterfalls, which are included in network generation
- Does not include barriers excluded from network generation
- Unit: # / meters

## Density of Dams on Small Streams in Upstream Functional Network Local Watershed

12

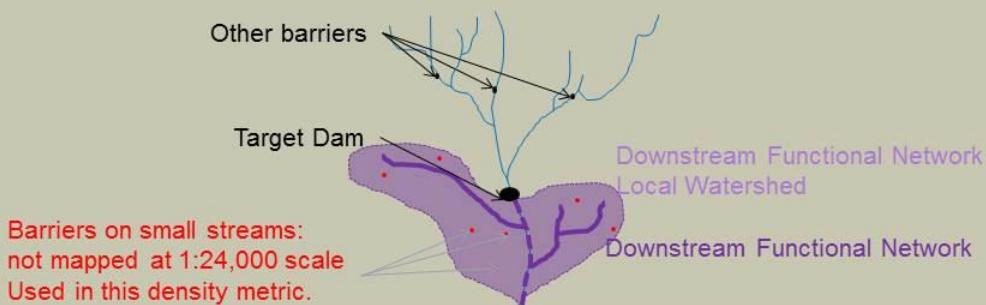
- Category: Connectivity Status
- Number of dams on small streams (dams did not snap to analysis hydrography) within the local watershed of the [upstream functional network](#) divided by that watershed area
- Unit: # / m<sup>2</sup>



## Density of Dams on Small Streams in Downstream Functional Network Local Watershed

13

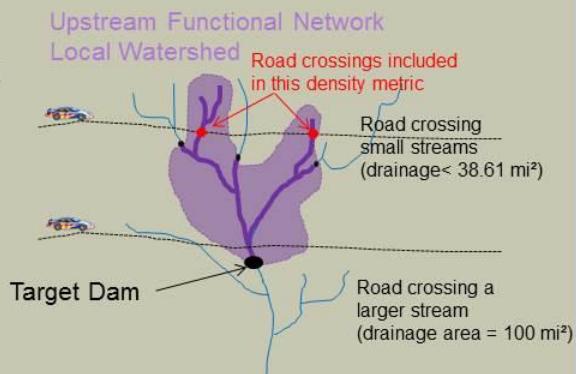
- Category: Connectivity Status
- Number of dams on small streams (dams did not snap to analysis hydrography) within local watershed of the [downstream functional network](#) divided by that watershed area
- Unit: # / m<sup>2</sup>



## Density of Road & Railroad / Small Stream Crossings in Upstream Functional Network Local Watershed

14

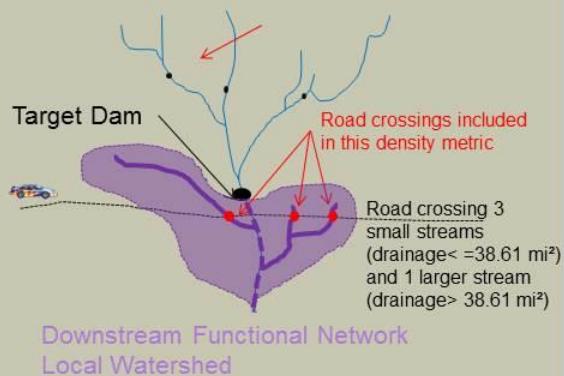
- Category: Connectivity Status
- Number of Road/Railroad and hydrography intersections within [upstream functional network](#) local watershed divided by that watershed area. A proxy for culverts.
- Road and RR data from ESRI Streetmap USA
- Only small streams (drainage <= 38.61 mi<sup>2</sup>) are included. Larger streams more likely to have bridges.
- Unit: # / m<sup>2</sup>



## Density of Road & Railroad / Small Stream Crossings in Downstream Functional Network Local Watershed

15

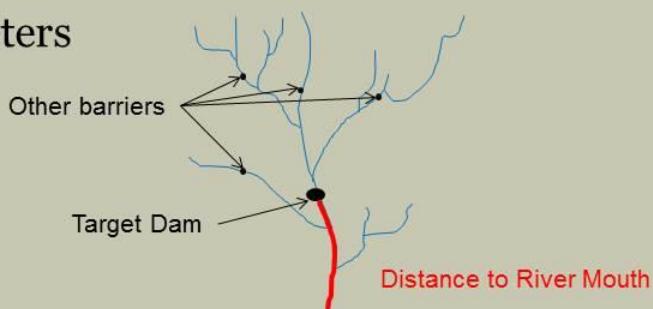
- Category: Connectivity Status
- Number of Road/Railroad and hydrography intersections within **downstream functional network** local watershed divided by that watershed area. A proxy for culverts.
- Road and RR data from ESRI Streetmap USA
- Only small streams (drainage  $\leq 38.61 \text{ mi}^2$ ) are included. Larger streams more likely to have bridges.
- Unit: # /  $\text{m}^2$



## Distance to River Mouth

16

- Category: Connectivity Status
- Distance from each barrier to the network mouth in meters
- Unit: meters

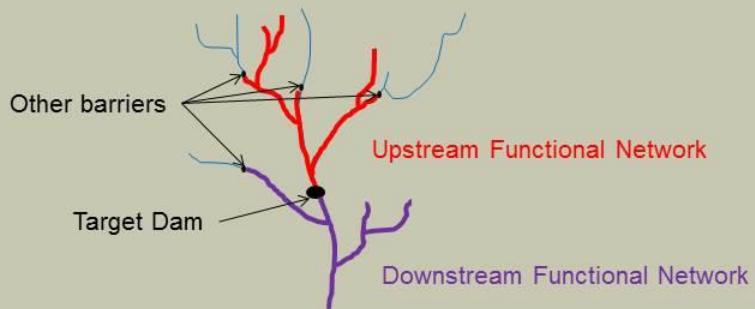


## Upstream Functional Network Length

17

- Category: Connectivity Improvement
- Length of the functional network upstream of a barrier. The functional network is defined by those sections of river that a fish could theoretically access from any other point within that functional network. Its terminal ends are barriers, headwaters, and/or the river mouth.

- Unit: meters

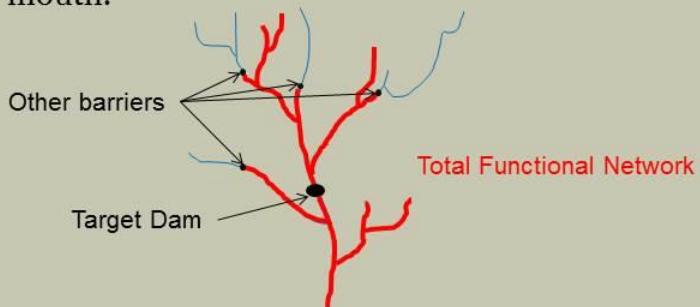


## The total length of upstream and downstream functional network

18

- Category: Connectivity Improvement
- Summed length of the upstream and downstream functional networks of a barrier. The functional network is defined by those sections of river that a fish could theoretically access from any other point within that functional network. Its terminal ends are barriers, headwaters, and/or the river mouth.

- Unit: meters



## Absolute Gain

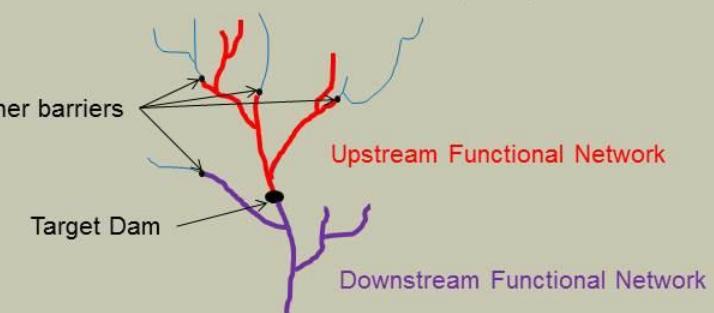
19

- Category: Connectivity Improvement
- This metric is the minimum of the two functional networks of a barrier. For example if the upstream functional network was 10 kilometers and downstream functional network was 5 kilometers, then the Absolute Gain will be 5 kilometers.
- Unit: meters

## Downstream Functional Network Length

20

- Category: Connectivity Improvement
- Length of the functional network downstream of a barrier. The functional network is defined by those sections of river that a fish could theoretically access from any other point within that functional network. Its terminal ends are barriers, headwaters, and/or the river mouth.



## Relative Gain

21

- Category: Connectivity Improvement
- This metric is Absolute gain divided by the total length of upstream and downstream functional networks.
- Unit: meters

## Number of Diadromous Species

22

- Category: Ecological
- The number of diadromous species with documented habitat in the downstream functional network of each dam based on the data and methods described for each species:
  - alewife, blueback herring, American shad, hickory shad, striped bass, shortnose sturgeon, Atlantic sturgeon, Gulf sturgeon, Alabama shad
- Unit: #

## Presence of Anadromous Species in Downstream Network

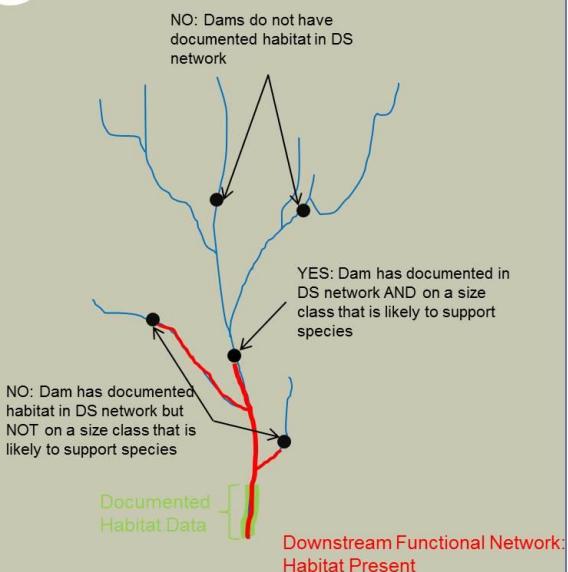
23

- Category: Ecological
- Presence of habitat for 1 or more of the 8 anadromous species included in this analysis based on the data and methods described for each species:
  - alewife, blueback herring, American shad, hickory shad, striped bass, Atlantic sturgeon, Gulf sturgeon, Alabama shad
- Habitat for each species is coded as “Current” or “None Documented”
- Unit: presence / absence

## Alewife habitat in Downstream Functional Network

24

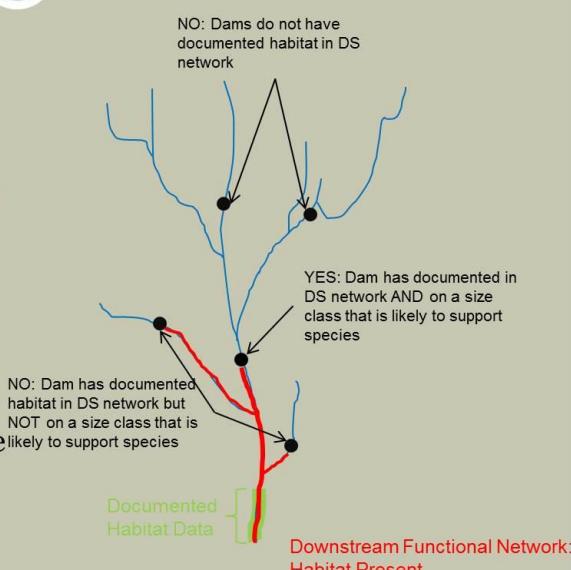
- Category: Ecological
- Presence of alewife downstream of dam. Based on:
  - Documented habitat in some portion of the dam's downstream functional network
  - AND Dam is on a stream that is likely to support that species based on stream size
    - Size 1a+
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: “Current”, “None Documented”



## Blueback Herring habitat in Downstream Functional Network

25

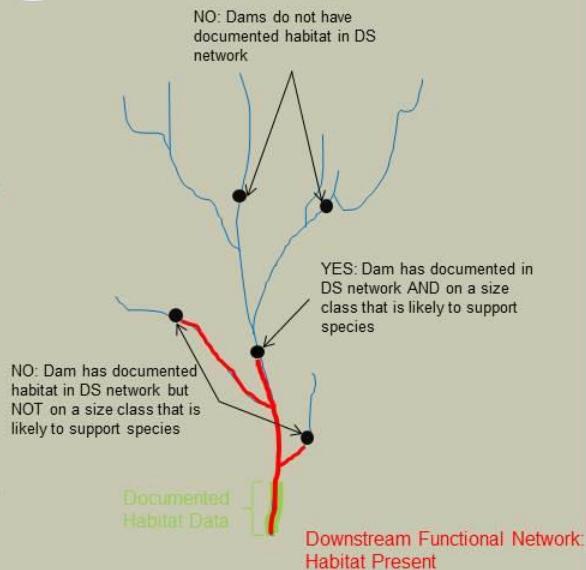
- Category: Ecological
- Presence of blueback herring downstream of dam. Based on:
  - Documented habitat in some portion of the dam's downstream functional network
  - AND Dam is on a stream that is likely to support that species based on stream size
    - 1. Size 1a +
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"



## American Shad habitat in Downstream Functional Network

26

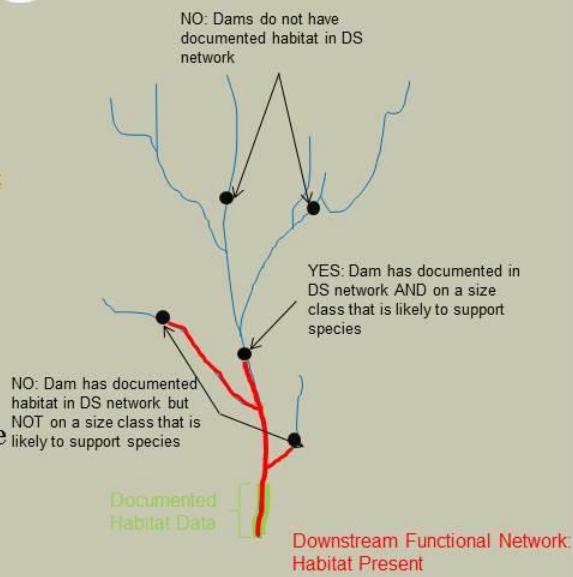
- Category: Ecological
- Presence of American shad downstream of dam. Based on:
  - Documented habitat in some portion of the dam's downstream functional network
  - AND Dam is on a stream that is likely to support that species based on stream size
    - 1. Size 2+ Rivers
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"
- 



## Hickory Shad habitat in Downstream Functional Network

27

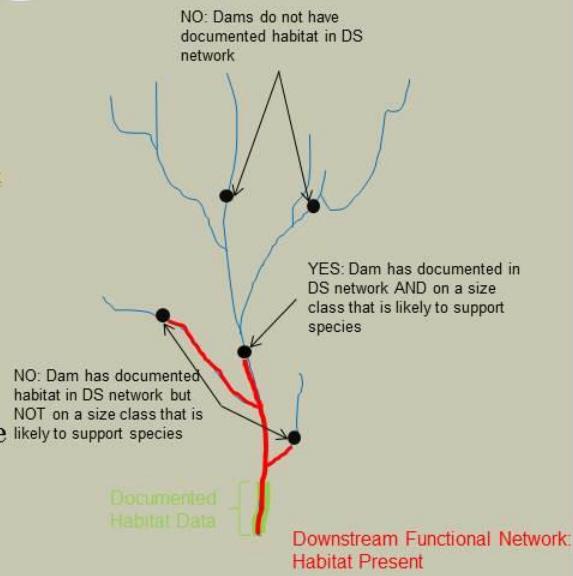
- Category: Ecological
- Presence of Hickory shad downstream of dam. Based on:
  - Documented habitat in some portion of the dam's [downstream functional network](#)
  - **AND** Dam is on a stream that is likely to support that species based on stream size
    1. [Size 2+ Rivers](#)
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"



## Alabama Shad habitat in Downstream Functional Network

28

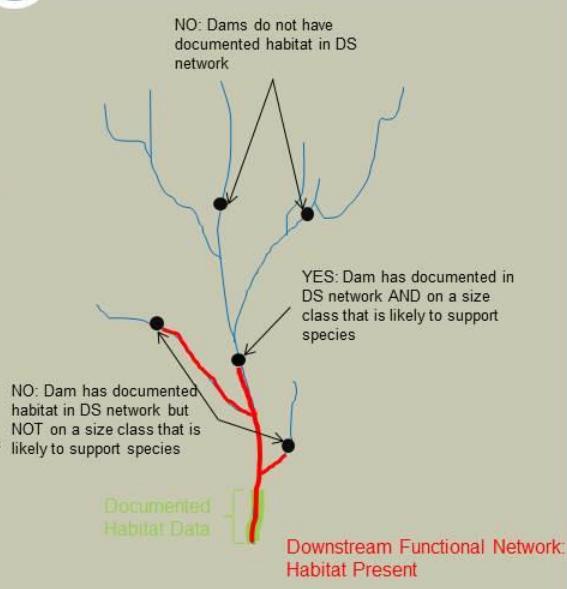
- Category: Ecological
- Presence of Alabama shad downstream of dam. Based on:
  - Documented habitat in some portion of the dam's [downstream functional network](#)
  - **AND** Dam is on a stream that is likely to support that species based on stream size
    1. [Size 2+ Rivers](#)
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"



## Striped Bass habitat in Downstream Functional Network

29

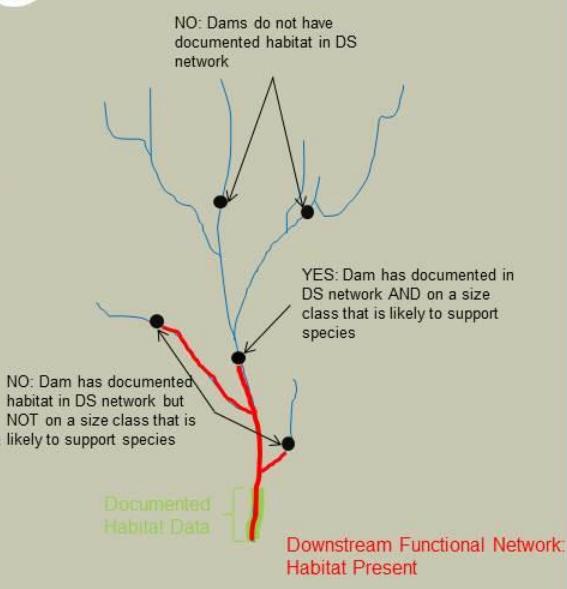
- Category: Ecological
- Presence of striped bass downstream of dam. Based on:
  - Documented habitat in some portion of the dam's [downstream functional network](#)
  - AND Dam is on a stream that is likely to support that species based on stream size
    1. [Size 3b+ Rivers](#)
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"



## Atlantic Sturgeon habitat in Downstream Functional Network

30

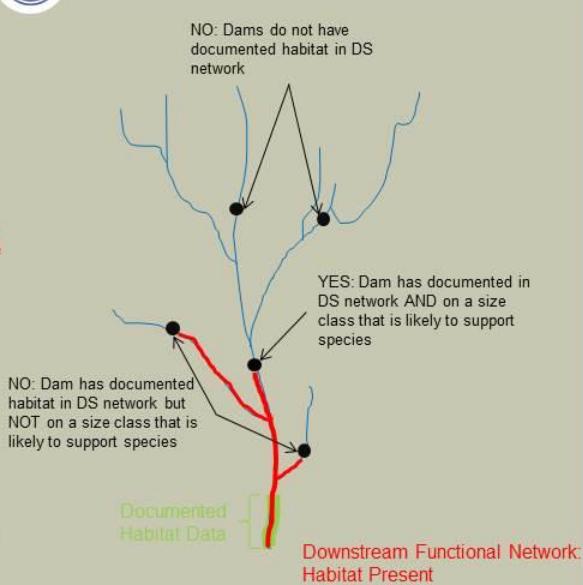
- Category: Ecological
- Presence of Atlantic sturgeon downstream of dam. Based on:
  - Documented habitat in some portion of the dam's [downstream functional network](#)
  - AND Dam is on a stream that is likely to support that species based on stream size
    1. [Size 4+ Rivers](#)
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"



## Gulf Sturgeon habitat in Downstream Functional Network

31

- Category: Ecological
- Presence of Gulf sturgeon downstream of dam. Based on:
  - Documented habitat in some portion of the dam's [downstream functional network](#)
  - AND Dam is on a stream that is likely to support that species based on stream size
    - 1. [Size 4+ Rivers](#)
- Fish habitat data from multiple sources, reviewed and edited by state fisheries biologists. Each line segment includes its data source.
- Unit: Unitless Classes: "Current", "None Documented"



## SEACAP Fish Species Richness

32

- Number of resident fish species within the [HUC8](#) watershed that the dam is located within
- Based on a [list of resident fish species](#) developed by the SEACAP workgroup
- For each [HUC8](#) each species is identified as present/absent using data from [MARIS](#), [BISON](#), and [NatureServe](#). Records for a species from any of these three data sources would flag that species as present in that [HUC8](#).
- Richness is the sum of the species within each [HUC8](#)

## SEACAP Freshwater Mussel Richness

33

- Number of freshwater mussel species within the [HUC8](#) watershed that the dam is located within
- Based on [NatureServe](#) data

## Rare Fish in HUC8

34

- Category: Ecological
- Count of rare (G1-G3) fish species in the watershed within which the dam is located
- Based on [NatureServe](#) watershed ([HUC8](#)) data
- Unit: #

## Rare Mussels in HUC8

35

- Category: Ecological
- Count of rare (G1-G3) mussel species in the watershed within which the dam is located
- Based on [NatureServe](#) watershed ([HUC8](#)) data
- Unit: #

## Rare Crayfish in HUC8

36

- Category: Ecological
- Count of rare (G1-G3) crayfish species in the watershed within which the dam is located
- Based on [NatureServe](#) watershed ([HUC8](#)) data
- Unit: #

## Native Fish Species Richness - HUC 8

37

- Category: Ecological
- Current native fish species richness in the watershed within which the dam is located
- Based on [NatureServe](#) watershed (8-digit HUC) data
- Unit: #

## % Impervious Surface in Contributing Watershed

38

- Category: Watershed & Local Condition
- % Impervious surface in entire upstream (contributing) watershed. Calculated [2011 National Landcover Database](#) percent developed imperviousness.
- Unit: %

## % Natural LC in Contributing Watershed

39

- Category: Watershed & Local Condition
- % natural landcover in entire upstream watershed. Calculated [2011 National Land Cover Database](#).
- Natural landcover aggregated from the following classes: open water, barren land, deciduous forest, evergreen forest, mixed forest, scrub/shrub, grassland/herbaceous, woody wetlands, emergent wetlands
- Unit: %

## % Forested LC in Contributing Watershed

40

- Category: Watershed & Local Condition
- % forested landcover in entire upstream watershed. Calculated [2011 National Land Cover Database](#).
- Forested landcover aggregated from the following classes: deciduous forest, evergreen forest, mixed forest
- Unit: %

## % Agricultural LC in Contributing Watershed

41

- Category: Watershed & Local Condition
- % agricultural landcover in entire upstream watershed. Calculated [2011 National Land Cover Database](#).
- Forested landcover aggregated from the following classes: cultivate crops, pasture/hay
- Unit: %

## % Impervious Surface in ARA of Upstream Functional Network

42

- Category: Watershed & Local Condition
- % impervious landcover within [Active River Area](#) of the [upstream functional river network](#).
- [National Landcover Database 2011](#) data
- Unit: %

## % Impervious Surface in ARA of Downstream Functional Network

43

- Category: Watershed & Local Condition
- % impervious landcover within [Active River Area](#) of the [downstream functional river network](#).
- [National Landcover Database 2011](#) data
- Unit: %

## % Agricultural LC in ARA of Upstream Functional Network

44

- Category: Watershed & Local Condition
- % agricultural landcover within [Active River Area](#) of the [upstream functional river network](#).
- [National Landcover Database 2011](#) data. Includes the following classes: cultivated crops, pasture/hay
- Unit: %

## % Agricultural LC in ARA of Downstream Functional Network

45

- Category: Watershed & Local Condition
- % agricultural landcover within [Active River Area](#) of the [downstream functional river network](#).
- [National Landcover Database 2011](#) data. Includes the following classes: cultivated crops, pasture/hay
- Unit: %

## % Natural LC in ARA of Upstream Functional Network

46

- Category: Watershed & Local Condition
- % natural landcover within [Active River Area](#) of the [upstream functional river network](#).
- [National Landcover Database 2011](#) data. Includes the following classes: open water, barren land, deciduous forest, evergreen forest, mixed forest, scrub/shrub, grassland/herbaceous, woody wetlands, emergent wetlands
- Unit: %

## % Natural LC in ARA of Downstream Functional Network

47

- Category: Watershed & Local Condition
- % natural landcover within [Active River Area](#) of the [downstream functional river network](#).
- [National Landcover Database 2011](#) data. Includes the following classes: open water, barren land, deciduous forest, evergreen forest, mixed forest, scrub/shrub, grassland/herbaceous, woody wetlands, emergent wetlands
- Unit: %

## % Forested in ARA of Upstream Functional Network

48

- Category: Watershed & Local Condition
- % forested landcover within [Active River Area](#) of the [upstream functional river network](#).
- [National Landcover Database 2011](#) data. Includes the following classes: deciduous, evergreen & mixed forest
- Unit: %

## % Forested in ARA of Downstream Functional Network

49

- Category: Watershed & Local Condition
- % forested landcover within [Active River Area](#) of the [downstream functional river network](#).
- [National Landcover Database 2011](#) data. Includes the following classes: deciduous, evergreen & mixed forest
- Unit: %

## Dam is located on Conservation Land

50

- Category: Watershed & Local Condition
- Dam is located on conservation land
- Based on [TNC's 2012 Eastern Division secured areas database](#)
- Includes conserved lands in [GAP Status](#) 1, 2, & 3 that do not have parcel-level restrictions on data distribution
- Unit: Boolean

## NFHP Risk of Degradation Score

51

- Relative risk of habitat degradation based on the mapped level of disturbance to fish habitats
- Based on [National Fish Habitat Partnership data](#)
- Scores are passed to each dam from the [NHD Plus](#) catchment it is located within, where:
  - 1.0 – 1.5 = Very High Relative Risk of Habitat Degradation
  - 1.6 – 2.5 = High Relative Risk of Habitat Degradation
  - 2.6 – 3.4 = Moderate Relative Risk of Habitat Degradation
  - 3.5 – 4.2 = Low Relative Risk of Habitat Degradation
  - 4.3 – 5.0 = Very Low Relative Risk of Habitat Degradation
- Dams located in catchments that were not scored (No Data) are given a Moderate value to minimize the impact of the lack of data on the relative dam prioritization

## Flow Alteration

52

- The ratio of total upstream storage to mean annual flow. Specifically:
  - The total accumulated upstream area (sq km) of waterbodies in the NHDPlus catchment polygon divided by the Mean Annual Flow in cubic feet per second (cfs) at bottom of flowline as computed by Unit Runoff Method
  - $[WBACC\_TOT]/[MAFLOWU]$
- Calculated from data produced through the [SARP Flow Alteration Assessment](#)

## # Upstream Size Classes Gained by Removal / Bypass

53

- Category: Size or System Type
- Number of upstream stream size classes gained if dam were to be removed. Stream segments must be >0.5 miles to be considered a gain and the size class must not be present in the downstream functional network.
- e.g. If a downstream functional network had small rivers (size 2) and medium tributary rivers (size 3a), while an upstream functional network had these as well as 2 miles of creek (size 1b), the gain would be 1.
- Based on stream size classes from the NE Aquatic Habitat Classification defined as:
  - 1a: Headwaters (<3.861 sq.mi.)
  - 1b: Creeks (>= 3.861<38.61 sq.mi.)
  - 2: Small River (>=38.61<200 sq. mi.)
  - 3a: Medium Tributary Rivers (>=200<1000 sq.mi.)
  - 3b: Medium Mainstem Rivers (>=1000<3861 sq.mi.)
  - 4: Large Rivers (>=3861 < 9653 sq.mi.)
  - 5: Great Rivers (>=9653 sq.mi.)(measure = upstream drainage area)
- Unit: #

## Total # Reconnected Stream Size Classes >0.5 Miles(upstream + downstream)

54

- Category: Size or System Type
- Number of unique stream size classes >0.5 miles in total upstream and downstream functional networks
- Based on stream size classes from the NE Aquatic Habitat Classification defined as:
  - 1a: Headwaters (<3.861 sq.mi.)
  - 1b: Creeks (>= 3.861<38.61 sq.mi.)
  - 2: Small River (>=38.61<200 sq. mi.)
  - 3a: Medium Tributary Rivers (>=200<1000 sq.mi.)
  - 3b: Medium Mainstem Rivers (>=1000<3861 sq.mi.)
  - 4: Large Rivers (>=3861 < 9653 sq.mi.)
  - 5: Great Rivers (>=9653 sq.mi.)(measure = upstream drainage area)

## River Size Class

55

- Category: Size or System Type
- River size class based on [NE Aquatic Habitat Classification](#).

1a: Headwaters (<3.861 sq.mi.)

1b: Creeks (>= 3.861<38.61 sq.mi.)

2: Small River (>=38.61<200 sq. mi.)

3a: Medium Tributary Rivers (>=200<1000 sq.mi.)

3b: Medium Mainstem Rivers (>=1000<3861 sq.

4: Large Rivers (>=3861 < 9653 sq.mi.)

5: Great Rivers (>=9653 sq.mi.)

*(measure = upstream drainage area)*

