



**HIGH DEFINITION STREAM SURVEY OF THE
CHATTAHOOCHEE RIVER NATIONAL RECREATION
AREA, GEORGIA, USA**

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HIGH DEFINITION STREAM SURVEY OF THE CHATTAHOOCHEE RIVER NATIONAL RECREATION AREA, GEORGIA, USA

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Introduction

Chattahoochee River National Recreation Area (CHAT), established in 1978, consists of the 77 km (48-mile) stretch of the Chattahoochee River flowing just north of Atlanta, GA along with adjacent land units. This segment of the Chattahoochee River begins at the US Army Corps of Engineers (USACE) Buford Dam which impounds Lake Sidney Lanier. Given its proximity to Atlanta, CHAT is heavily used for recreation with the Chattahoochee River seeing high levels of fishing, wading, and boating.

CHAT has challenges protecting the health of the river as a result of runoff from land development and wastewater overflow (<https://www.nps.gov/chat/learn/nature/environmentalfactors.htm>) as well as the impacts of the regulated water discharges from Buford Dam. To help better manage the river, the National Park Service is interested in documenting the streambank and channel conditions on all 74 km of the river associated with CHAT.

To accomplish this, Trutta Environmental Solutions, LLC. (TRUTTA) was contracted to assess the habitat type (riffle, shoal, run, pool), condition of the left and right streambank, and water depth on 72.7 kilometers of the Chattahoochee River. Additionally, a recreational use suitability model that included wading and boating types was developed, requiring the additional parameter of channel roughness to be classified. To accomplish this, a longitudinal High Definition Stream Survey (HDSS) was conducted during October 3 to 5, 2018 to collect a broad suite of video, sonar and global position system (GPS) data. A standard set of classification criteria was applied to the field data to determine streambank and channel conditions. The same standard set of classification criteria was used to develop the suitability model for recreational use. This project covered 72.7 km of the Chattahoochee River downstream of USACE Buford Dam to the Paces Mill land unit of CHAT. A StreamView video spanning the 72.7 river kilometers covered by this project, GIS layers for the three parameters (depth, habitat type, and streambank condition), a recreational use suitability model, and a list of the 20 worst stream segments and 5 worst tributary confluences are provided.

Objectives

This project focused on the following objectives:

1. collect dual track high-resolution, geo-referenced longitudinal surveys on 48 miles of the main channel of Chattahoochee River.
2. produce StreamView video showing the front, right and left video views along with sonar and a map of the current survey location,
3. analyze data by creating data layers for habitat type (riffle, shoal, run, pool), left and right bank condition scores, and water depth,
4. provide a ranking of the 20 worst 200 meter stretches of right and left streambank condition and 5 worst tributary confluences,
5. and classify additional HDSS data (bottom roughness) and develop Recreational Use suitability model for wading and boating.

Methods

The High Definition Stream Survey (HDSS) method was used to collect, classify, and analyze the data required for this project. In general, the HDSS approach followed a standardized series of steps that promotes rapid, systematic collection and processing of large amounts river conditions information (Figure 1). The specifics of the data collected may vary with the project's requirements but following the general HDSS process ensures a successful project.

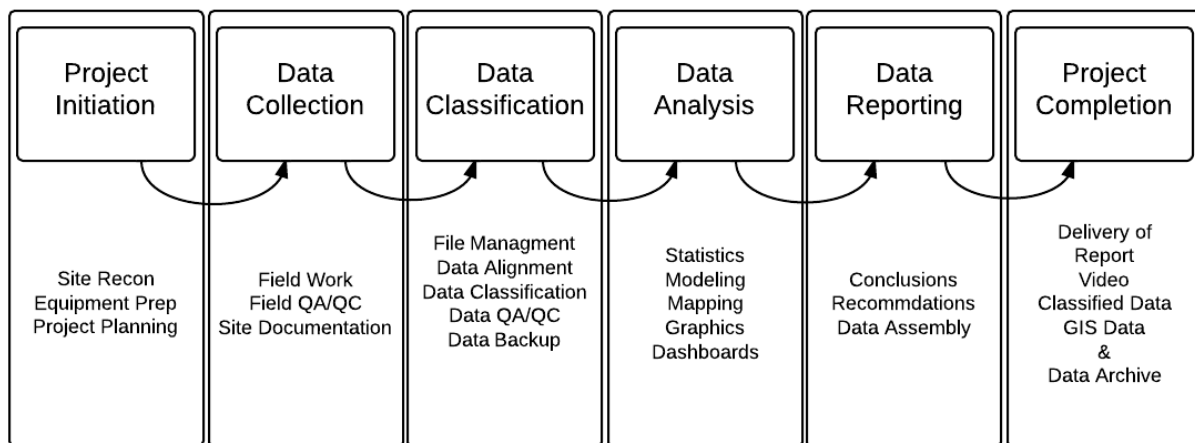


Figure 1: The standardized HDSS project flow chart.

Field Methods

Two 3.9 m long inflatable boats, powered by 2.5 horse power outboard motors, traveled in a downstream direction with each boat attempting to maintain its position at 1/3 the width of the river on each

respective bankline (a left and right track). Maintaining an exact position across the river was not possible in some locations as rapids, islands or other obstructions required the boat driver to adjust the path of the boat to safely continue down the river. Each boat was outfitted with a HDSS system consisting of three mounted GPS- enabled Garmin Virb XE video cameras (Garmin, Kansas City, MO) facing forward, left, and right (90°); and Hummingbird Helix 9 side-scan sonar (Johnson Outdoors Inc., Racine, WI), with a recreational grade Garmin GPSMap 64 GPS receiver (Garmin International, Inc., Olathe, KS) to record depth and location measurements respectively (Figure 2).

Coordinate position was simultaneously obtained for each sonar depth measurement using the recreational grade GPS receiver. The Garmin GPSMap 64 is a high- sensitivity GPS and GLONASS receiver with quad helix antenna to improve the precision and accuracy of locational data and provides approximately one-meter horizontal accuracy. The Garmin GPS Map64 was also Wide-Angle Augmentation System (WAAS) enabled to improve accuracy and integrity of the coordinates provided. Utilizing this ground connection network, a WAAS-enabled GPS is accurate to sub 7.6 meters in both horizontal and vertical measures 95% of the time, although in practice within the contiguous United States the WAAS correction typically provides better than 1m horizontal accuracy (Wide-Area Augmentation System Performance Analysis Report, 2006).



Figure 2: Sonar, Video Camera Array and GPS units used during the Chattahoochee River Survey.

Data Alignment

Following field data collection, geo-referenced video was combined with the GPS and sonar data such that each data point is associated with a Coordinated Universal Time (UTC) and coordinates (WGS84 datum). The individual files were assembled to form a single, georeferenced, continuous video tracklog (i.e., StreamView), referenced to a common location and time, covering CHAT (Figure 3). The StreamView video and its tracklog were linked using HDSS video coder software which allowed an appropriate score to be applied to each second of the video and associated GPS location for each variable.

Data from each survey track were used to document conditions along the river channel. Left and right streambank video were used from the boat closest to that respective bank for visual classification. In addition to having the locational data associated to the survey points along the left and right track, to allow the results from the dual track surveys to be compared at a single location, the data were mapped onto a centerline. This process created an additional track that allowed the data collected from the separate boats along the same area of the river to be compared (Figure 4). Creating a centerline dataset allowing every meter of the river to have data referencing the nearest survey information from the left and right track even where the boats were not exactly parallel during the field survey.

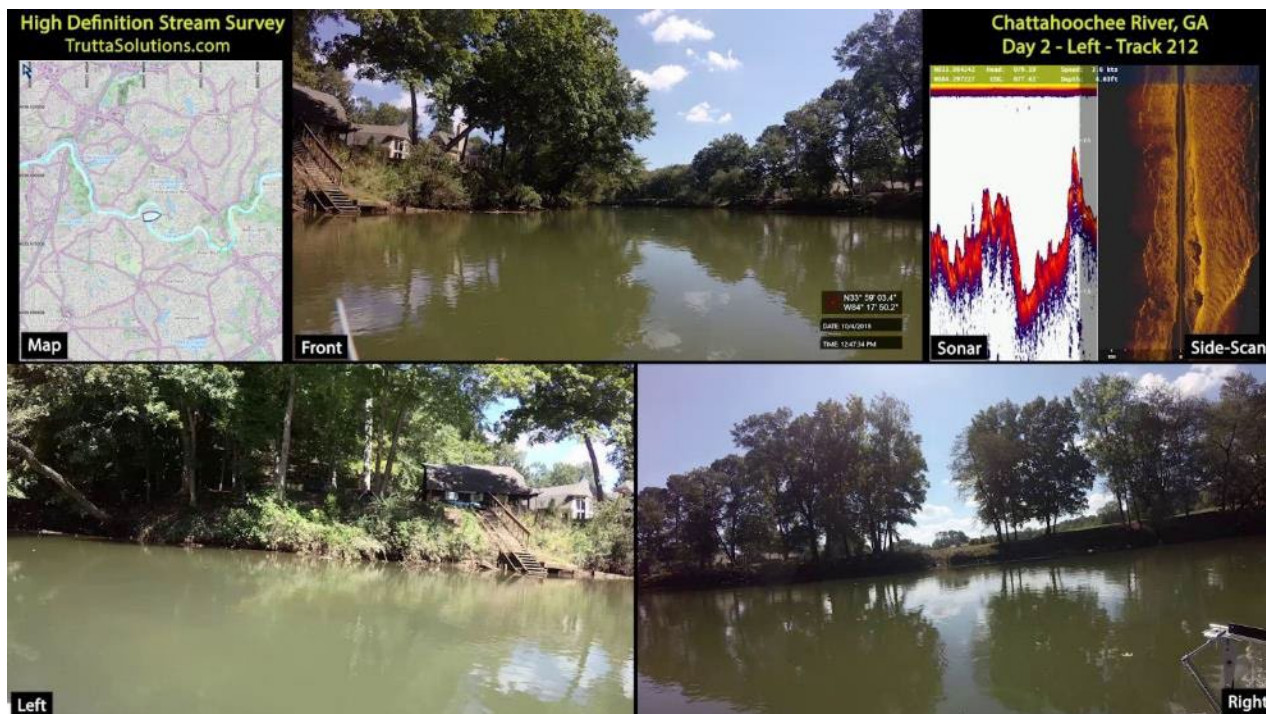


Figure 3: Example of the StreamView Video created for the Chattahoochee survey downstream of Buford Dam to the end of the Chattahoochee River National Recreation Area. Boat location can be seen in the map window in the upper left corner. Video Track number is in the upper right corner of the video. As noted in the upper right label, this is the StreamView video from the left boat and thus is used for classification of the left bank. The two-boat survey was necessary so that imagery was of sufficient detail along the riverbank to accurate classification. The right riverbank is clearly too far from the cameras for accurate classification.

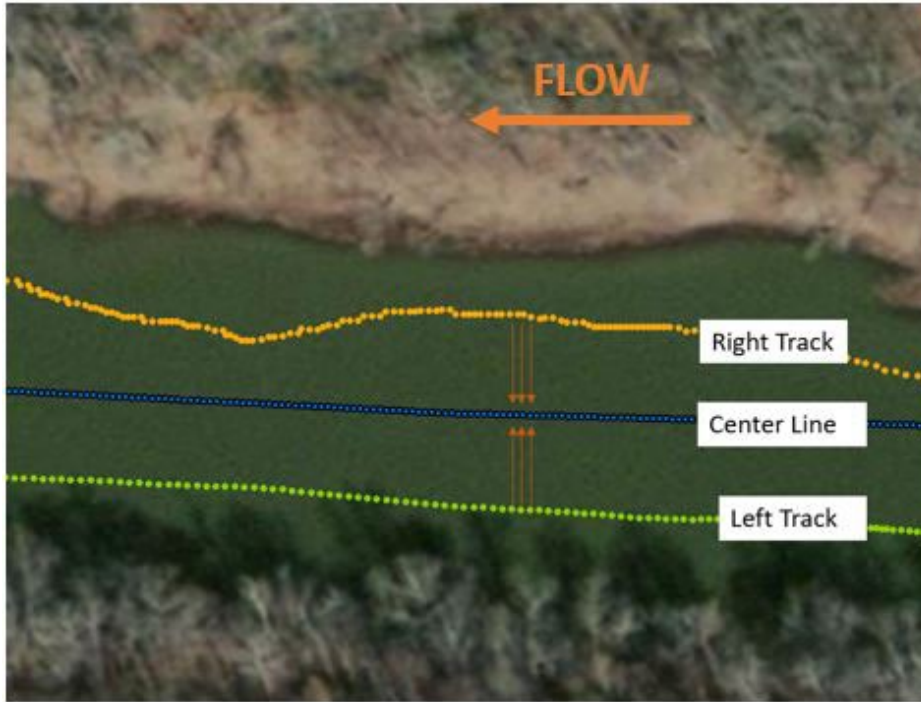


Figure 4: Example of mapping the data from the left and right boat survey tracks to a common centerline to allow the comparison of data at a single location. After the creation of the centerline data, there were three tracks (right, center, and left) available for analysis.

Data Quality

Following the assembly of the high definition video into a continuous StreamView tracklog, the quality of the video was assessed to determine the appropriateness of the video for visual classification and use prior to analysis. This is hereafter referred to as Data Quality. To ensure consistency, data quality classification identified the applicability of data and its use during analysis and defined how the data can be used to deliver specific parameters during analysis. For example, in shallow areas where the sonar transducer was lifted out of the water to avoid striking the bottom (dragging), corresponding depth readings were deemed inaccurate and removed. Additionally, the data quality review identified locations where the geo-referenced video was obscured, preventing classification. The continuous video file was classified into one of 12 categories listed in Table 1 below. For the Chattahoochee River survey, 83,475 of 85,374 observations were considered good (97.8) with 0.6% having an obscured bank. 0.4% of time we were out of the boat dragging them and 1.2% of the time the sonar transducers raised to get through shallow water.

Table 1: Data location and type with respective definitions used during Data Quality classification.

Data Location or Type	Definition
Good data	Video allows for analysis
Restricted data	All video data obstructed, limiting analysis

Data Location or Type	Definition
Right bank obscured	View of right bank obstructed, limiting analysis
Left bank obscured	View of left bank obstructed, limiting analysis
Left bank and streambed obscured	View of left bank and streambed obstructed, limiting analysis
Right bank and streambed obscured	View of right bank and streambed obstructed, limiting analysis
Dragging	Kayak is dragging on in-channel obstacle requiring the navigator to exit the kayak to continue, often over shallow riffles or debris jams
Transect	Video where cross-sectional transects were performed
Underground	Channel goes underground, inaccessible by foot or kayak
Off-channel	Video identifies a water management related structure (e.g., detention pond, terracing)
Revisit	Video needs additional review by field staff or others for clarification
Photo Survey	Video will be used for photographic description due to safety and difficulty of survey

Data Classification

Data were identified and classified using a standard set of criteria provided in the methods below. Software algorithms were used to classify habitat type and bottom roughness from digital sonar data while streambank condition were visually classified from the StreamView video. To avoid observer error based on different observers, all scoring of streambank condition were performed by a single experienced classifier. After classification, every GPS point had an associated collection time, latitude, longitude, depth, habitat type (i.e., riffle, shoal, run, pool), bottom roughness, left and right bank condition score.

The river condition variables that were assessed for the Chattahoochee River National Recreation Area included:

- water depth,
- habitat type (riffle, shoal, run and pool),
- bottom roughness,
- left and right bank condition.

To provide a measure of validation on the classification process. An independent reviewer visually scored 20 randomly selected samples without seeing the classified results. The reviewer provided both the classification score and comments on the score when needed. After the review classification was complete, the scores were compared to assess the overall accuracy of the classification and where and why inconsistencies in the classifications existed.

Water Depth

The data from both the side-scan-sonar and the GPS receivers were integrated using common time stamp associated with each unit's data recording. Depth data (m) were processed and corrected using

ReefMaster software (ReefMaster Software Ltd., West Sussex, UK). Anomalous readings were corrected after visual inspection to ensure accuracy (Figure 5). Most removed anomalous depth readings were likely the result of backscatter from debris floating in the water column or difficulty tracking the correct bottom return. These anomalies are often observed as a shallow depth reading (such as 0.3 m deep) with deep water (3 m) immediately on all sides. Most corrected depth readings were associated with steep drop-offs near the river bluffs. In these situations, shallow and deep depths were correctly found in close proximity.

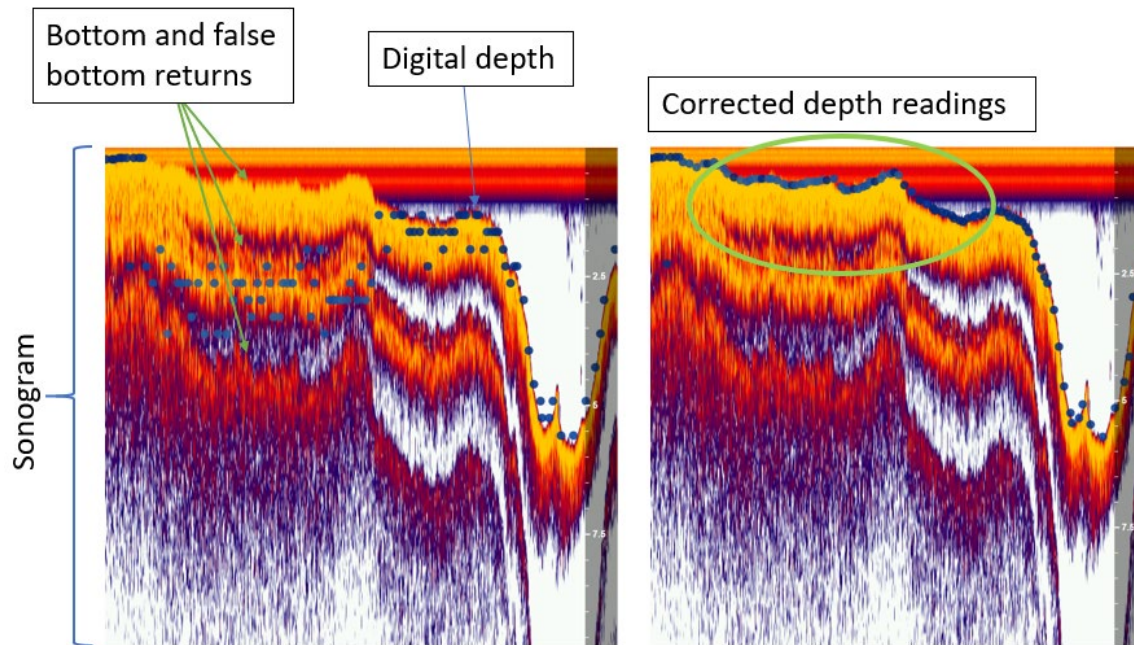


Figure 5: An example of an anomalous depth reading, highlighted in green, collected by the Humminbird Helix 9 G2N sonar.

Habitat Type

Rivers and streams are made up of a series of hydraulic units or habitat types (e.g., riffle, shoals, runs, and pools) which are often used to stratify sampling, identify habitat use of aquatic organisms and assess the effects of anthropogenic activities. In order for classified habitat to be advantageous, each habitat was consistently and objectively delineated by type. Habitat types were classified utilizing depth data derived from sonar data and recorded at approximately one point per second for the entire length of the river surveyed in order to obtain objective, comparable, and repeatable mesohabitat classifications.

A habitat was considered discrete only if its length was greater than or equal to the wetted width (Roper & Scarnecchia, 1995). To avoid misrepresenting exceptionally small habitat units (e.g., non-discrete habitats), such as a large boulder in a run which spans the thalweg and lies just a few inches below the water surface (and could be typed as riffle) the neighborhood mode is used to identify and correct for such instances. The length of the neighborhood mode was set to approximately the wetted width of the channel or 60 meters for CHAT.

The depth data was smoothed using a LOWESS method with a 60m moving window. The depth smoothing eliminates much of the natural roughness of the streambed and highlights the major changes in streambed structure. After smoothing, the depth data is classified into one of four groups. Riffles were defined by segments less than the 85% quantile of the depth data. Shoals were defined by points within the 70% to 85% quantile range and pools were defined as areas deeper than the 30% quantile. Runs were all areas between the 70% and 30% quantiles for smoothed depth. (Table 2). Figure 6 shows an example of a smoothed depth plot for a 400m segment of the river.

Table 2: Primary habitat type criteria and descriptions.

Habitat Type	Depth	Description
Riffle	Shallow ($\leq 85\%$ quantile)	Area of channel characterized by high current velocities and shallow depth; broken water surface often with partially exposed substrate.
Shoal	Shallow (between 85% and 70% quantiles)	Area of channel characterized by moderate current velocities and shallow depth, water surface turbulent and little or no exposed substrate.
Run	Moderate (between 70% and 30% quantiles)	Area of channel characterized by moderate current velocities and moderate depth; turbulent water surface.
Pool	Deep ($\geq 30\%$ quantile)	Area of channel characterized by slow current velocities and deep depth; smooth water surface.

To validate the habitat type classification, 20 habitat units were randomly selected, and the habitat type was visually classified. The observer completing the visual classification used both the video and sonar images to determine appropriate habitat type category. We compared the automated classification with our visual classification to document consistency among methods.

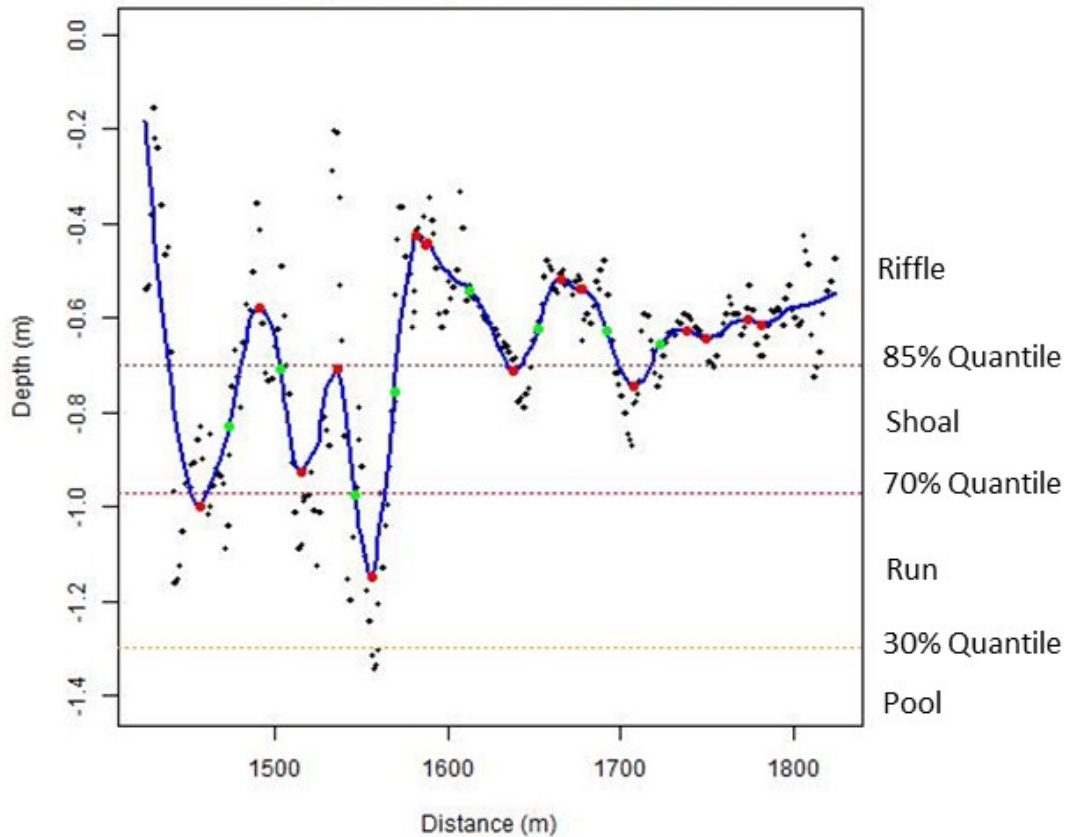


Figure 6: Example of smoothed depth plots for a 400m river segment of CHAT with riffle ($\leq 85\%$ quantile), shoals (between 70% and 85% quantiles), run (between 30% and 70% quantiles) and pool ($\leq 30\%$ quantile) break lines. Red dots are local maxima or minima, and the green dots are inflection points between subsequent habitat units.

Bottom Roughness

Bottom roughness is a measure of the localized microtopography of the streambed. The extent of bottom roughness can support or limit the area's suitability for particular recreational uses such as wading, boating, and fishing. Due to turbid water (reduced water clarity) an automated texture analysis of the streambed using echo return data from the sonar was utilized to classify bottom roughness. Bottom roughness was developed from the water depth readings along the longitudinal tracks.

The automated texture analysis does not provide a direct measure of grain size but rather a relative measure of variance between observed and predicted depth, which accounts for differences in major substrate types. In simplistic terms, bottom roughness compares the deviation between the actual depth (data) and the smooth depth (prediction) and is measured as the model's residual values. If the difference between the reported water depth and the predicted water depth is large, then it is assumed that the bottom is rough. In this case, the bottom would vary both deeper and shallower than the general depth trend. An example of this, would be passing over a boulder field (very rough) where it may average 1m deep, but the tops of the boulders would be 0.5 m and in between the boulders it may be 1.5m deep. In contrast to this situation, if the difference between the reported water depth and the predicted water depth is small, then it is assumed that the bottom is smooth. Here, almost no difference is observed and

an area with 1m average predicted deep would have consistent 1m readings at the individual measurement points.

Within the habitat type classification, a smoothed depth model was created that predicts the generalized water depth using a smoothing window approximately equal to the river width (e.g. 60m for the Chattahoochee River in this section). The model used a LOWESS smoothing process for the roughness analysis. Bottom roughness was classified into three categories based upon residual values of the nearest neighbor for the sonar return echoes. These include values less than the 30% quantile defined as smooth, and values greater than the 70% quantile defined as rough (Table 3). The moderate-rough classification was between these two quantiles. Bottom roughness categories and the depth deviation were recorded at the point unit.

Table 3: Category and description of bottom roughness classifications.

Category	Quantile break	Description
Smooth	<30 th quantile	Small amount of velocity breaks or holding spots observed.
Moderate Rough	≥30 th quantile but <70 th quantile	Generally small boulders, drops, or woody debris providing instream cover.
Rough	≥70 th quantile	Instream cover is present in large amounts and with extensive breaks in water velocity which should be present in all flow conditions. Typically, these include large trees in the water near the shoreline, large boulders, or sharp drop-offs into deep holes.

To validate the bottom roughness measure, 20 segments of a single continuous roughness category were randomly selected, and the bottom roughness was visually classified. The observer completing the visual classification used both the sonograph and sidescan sonar images to determine appropriate roughness category (Kaeser, Litts, & Tracy, 2012). We compared the automated classification with our visual classification to document consistency among methods. To understand the interaction between bottom roughness and habitat type, the roughness values were summarized within habitat types. Additionally, average roughness was plotted against habitat ID which provided a picture of how bottom roughness changed over the whole survey area.

Streambank Condition

Streambanks were defined as sloping lands that contain the stream under normal flows. Naturally occurring streambank erosion provides a direct supply of sediment to fluvial systems creating the habitats necessary to support a wide array of species. However, excessive erosion is often damaging the aquatic systems by reducing habitat heterogeneity, increasing water temperatures, lowering dissolved oxygen, and smothering and suffocating aquatic life (Ryan, 1991, Wilber & Clarke, 2001). This excess erosion contributes to the total load in sediment impaired streams.

Multiple methods focusing on the streambank condition and erosion potential have been used to determine the source and magnitude of streambank erosion. One commonly used method to assess streambank erosion is the Bank Erosion Hazard Index (BEHI) developed by (Rosgen, 1996). This method requires a trained individual to collect data in the field on bank and bank full height, root depth, root density, surface protection, and bank angle to determine its potential for erosion. The Bank Erosion Susceptibility Index (BESI) developed by (Connell B. A., 2012) collects parameters similar to BEHI but utilized a Streambank Video Mapping System to visually score the habitat, allowing for a rapid assessment of erosion susceptibility at the landscape scale. The HDSS method expands on the Streambank Video Mapping System (Connell, Ayers, Ludwig, Neff, & Parham, 2019) and uses a visual classification to integrate bank conditions to rapidly identify areas susceptible to erosion.

The method used to score condition was a visual classification developed specifically for HDSS surveys to determine for landscape scale assessments of streambank erosion susceptibility. Bank Condition scores reflect the potential for streambank erosion or streambank failure. Bank Condition is a visual integration of streambank angle, height, surface protection, and riparian condition. Compared to the BEHI method developed by Rosgen (1996), our method utilized a riparian condition parameter as a surrogate for root depth and root density and data were viewed on high definition video captured from the HDSS system. (Sass & Keane, 2012) created and validated a similar surrogate for the BEHI root parameters while assessing streambank erosion in Kansas. Additionally, video has been used with success to determine streambank erosion rates (Hensley & Ayers, 2018) and areas susceptible to erosion (Connell B. A., 2012). The major advantages of this method over traditional erosion assessments are the reduction of field time, cost, and uncertainty when extrapolating data to represent the entire river.

Left and right streambank condition was visually assessed utilizing and integration of bank angle, bank height, surface protection, and vegetated diversity (Figure 7) from the high definition video for both sides of the river. Each streambank was viewed independently during the classification process. Condition of each streambank was continuously rated fully functional (1) to non-functional (5) by a single experienced classifier; based on conditions during the survey for the entire sampling area. This classification system is analogous to past HDSS streambank scoring system that ranged from optimal (1) to very poor (5). The change mostly reflects a move away from subjective categories to function-based categories to allow the scoring system to be more easily integrated with other stream corridor assessments.

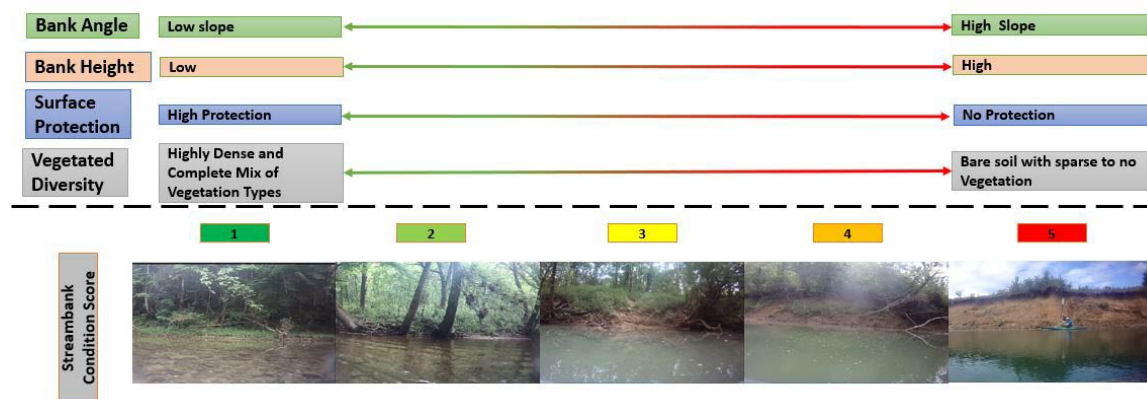


Figure 7: Streambank scoring criteria that is visually integrated to provide an overall streambank condition score (above) and examples of each of the five categories (below) ranging from 1-5, with 1 being the best and 5 being the worst.

Recreational Use Suitability Model

The suitability of recreational use for wading and boating along the CHAT varies with discharge and by location (Nestler, Fritschen, Milhous, & Troxel, 1986). Nestler used depth and velocity measurements along fixed location transects with data collected at different flow rates to develop suitability models for canoeing, rafting, and fishing. We attempted to create a model with a similar concept to Nestler's, only focused on the continuous longitudinal data (this report) vs cross-sectional data (Nestler et al. 1986).

Differences in the sampling design between the Nestler et al. 1986 report and our project made direct replication of their model impossible. The Nestler data collection and subsequent model focused on the change in suitable conditions with respect to river discharge. For this comparison, they collected water depth and velocity data at various river discharges. Our survey gathered water depth, habitat type, bank condition, and bottom roughness at relatively similar discharge rates over a much broader area of the river. We did not collect water velocity in this effort. This model incorporated habitat type and bottom roughness to assess suitability. Thus, we created a relationship that focused on the spatial distribution of conditions likely to be suitable for various boating and wading activities (our sampling strengths) vs the distribution of these conditions with respect to river discharge (Nestler et al. 1986 sampling strengths).

While a direct replication of the Nestler et al. 1986 approach was not possible, we reviewed their activity categories which included canoeing, rafting, and fishing with subcategories reflecting skill-levels (novice to mid-level) or techniques (wading, tubing or boating) (**Table 4**). We created two general classifications categories boating and wading and then created levels within these categories to reflect the extent or difficulty of the general categories (**Table 5**).

We used our habitat type variable to represent the general water depth in four classes and the roughness variable to represent the potential obstructions and difficulty to boating and wading. Habitat type was reclassified into categories of 10 to 40 and roughness in categories of 1 to 3 (**Table 6**). This resulted in 12 possible combined groups and those groups were rated with their most appropriate recreational use category and sub-category (**Table 7**). These groups were applied to results of the longitudinal survey to describe areas most suitable for a specific recreational use and then were further described by reaches from major access point to major access point along the river.

Table 4: Recreational activity table from Nestler et al 1986. (Table 9 Recreation Activities for Which Suitability Were Obtained. Modified, or Generated).

Activity	Type	Definition
Canoeing	Novice (river) and Novice (shoal)	Depths and velocities preferred by inexperienced canoeists. Depth must be less than 4 ft to allow canoeist to right a turned-over canoe.
	Midlevel	Depths and velocities preferred by inexperienced canoeists.
Rafting	Novice	Depths and velocities preferred by inexperienced slow-water rafters.
	Novice (preferred)	Same criteria as for novice rafters except that depths and velocities are reduced for safety.
	Midlevel	Depths and velocities preferred by experienced rafters.
	Landing	Depths and velocities preferred to successfully land a raft.
Fishing	Wading	Depths and velocities required for wade-fishing.
	Tubing	Depths and velocities required for tube-fishing.
	Boating (nonpower) and Boating low-power)	Depths and velocities preferred for boat fishing with and with small outboard engines.

Table 5: Recreational use categories and levels used within the recreational use model.

Recreational Use Category	Sub - category Level	Description
Boating	Novice	River surface is smooth with no obstructions and deep enough to not hit the bottom with paddles or motor
	Mid-level	Moderate depth water with some obstructions possible
	Advanced	Shallow water with frequency obstructions
	Limited	Very shallow water with numerous obstructions
Wading	Novice	Very shallow with smooth bottom
	Mid-level	Shallow with rough bottom. Greater bottom variability makes wading more difficult
	Limited	Smooth bottom and moderate depth water
	None	Water too deep and/or rough for safe wading

Table 6: Habitat suitability model parameters and numeric scores for suitability models of recreational use.

Habitat Type	Habitat Type Score	Bottom Roughness	Roughness Score
Riffle	10	Rough	1
Shoal	20	Moderately rough	2
Run	30	Smooth	3
Pool	40	-	-

Table 7: Habitat suitability model groups and designation for wading and boating recreational use.

Score	Description	Wading Class	Boating Class
11	Shallow and rough	Mid-level	Limited
12	Shallow and moderately rough	Mid-level	Limited
13	Shallow and smooth	Novice	Advanced
21	Moderately shallow and rough	Limited	Advanced
22	Moderately shallow and moderately rough	Limited	Advanced
23	Moderately shallow and smooth	Mid-level	Advanced
31	Moderately deep and rough	None	Mid-level
32	Moderately deep and moderately rough	None	Mid-level
33	Moderately deep and smooth	None	Novice
41	Deep and rough	None	Novice
42	Deep and moderately rough	None	Novice
43	Deep and smooth	None	Novice

Results

It is approximately 73.8 km (45.8 miles) from Buford Dam downstream to the boat ramp at Paces Mill. Of this area, a total of approximately 72.7 km (45.2 miles) of the main channel of the Chattahoochee River were sampled with dual track HDSS methodology during 3-5 October 2018. The survey started about 600m downstream of USACE Buford Dam and ended at the downstream boat ramp at Paces Mill. A small segment was missed as we had to portage around Morgan Falls Dam. We were not able to continue the survey past Paces Mill as there were no publicly available boat ramps downstream of that point for a number of miles. Two boat-mounted platforms were used due to the wide width of the river and provided high-quality imagery of instream and streambank conditions. The boats traveled downstream in roughly parallel tracks, with one boat closer to the left bank and one closer to the right bank. When an island was encountered, we passed on both sides of the island if there was enough water in the smaller channel to allow passage. The choice of going on both sides of an island was determined in the field by looking at the relative size of the smaller channel. Left and right bank labeling follows traditional methods of identifying left and right bank while looking downstream.

Local Flow Conditions

The HDSS for CHAT was completed during the period from 3 October 2018 to 5 October 2018. To understand local flow conditions during, pre, and post the survey period, we viewed the USGS gage data for three gages. For this project, 10 USGS gaging stations were located within the survey area (Table 8).

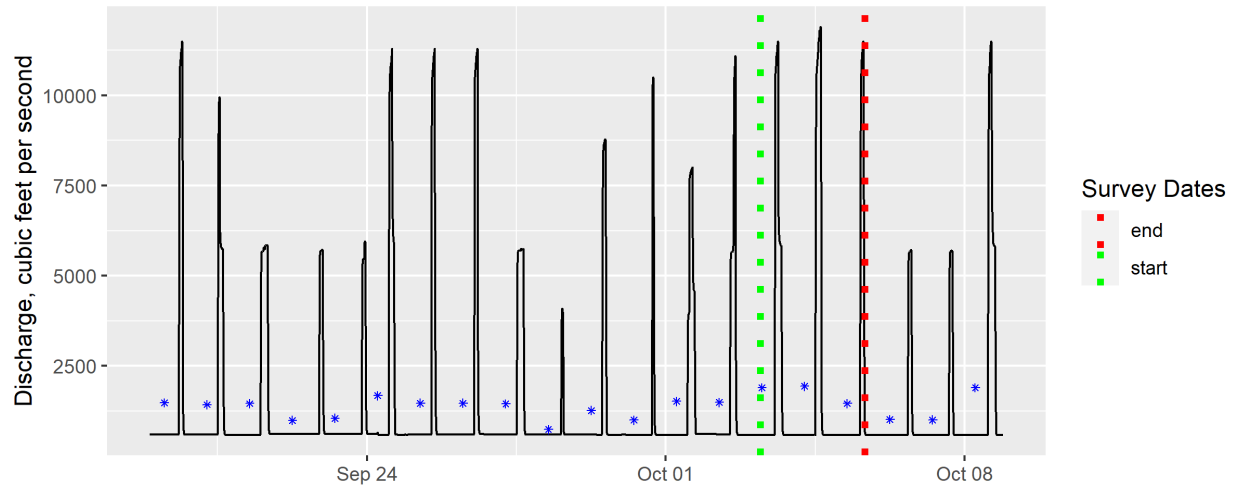
In general, stream discharge was seasonally low and fell slightly during the survey period, which was observed in both the short-term and long-term discharge plots (Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, Figure 13). During 3-5 October 2018, the local weather conditions were sunny with high temperatures in the upper 80s to lower 90s and low temperatures ranging from low to mid 60s. No precipitation was recorded during the survey, while a total of 0.39" was recorded in Atlanta the week before the survey, on 26-27 September 2018 combined.

Mean daily discharge was calculated by summing the instantaneous data observations, recorded and reported by the USGS every 15 minutes, from 00:00 to 23:45 each day and then dividing it by the total number of recorded observations during that period. The data for the following discharge plots were retrieved from the USGS website. Mean daily discharge ranged between 2000 cfs and 2500 cfs during our survey dates. There were scheduled pulse releases each day from Buford Dam and we started our surveys prior to these releases each day. This allowed us to avoid the high discharge pulse associated with the releases. On the second survey day, we did appear to pass over the previous day pulse release although there was not a large change in water elevation as we were already 30 km downstream of the dam. On the final day, Morgan Falls dam was just beginning to release an increased amount of water. We stayed mostly ahead of the release pulse during the third day, but it was probably the highest discharge of the three days ($\approx$ 2500 cfs).

Table 8: List of gage number and description for the 10 USGS stream gage stations within the survey area listed from upstream to downstream. * indicate gage locations where 190-day and 20-day hydrographs are provided for reference in this report.

Gauge Number	Gauge Description
USGS 02334401*	CHATTAHOOCHEE RIVER (BUFORD DAM) NR BUFORD, GA
USGS 02334430	CHATTAHOOCHEE RIVER AT BUFORD DAM, NEAR BUFORD, GA
USGS 02334653	CHATTAHOOCHEE R 0.76 MI US MCGINNIS FY SUWANEE GA
USGS 02335000	CHATTAHOOCHEE RIVER NEAR NORCROSS, GA
USGS 02335450*	USGS 02335450 CHATTAHOOCHEE RIVER ABOVE ROSWELL, GA
USGS 02335810	CHATTAHOOCHEE RIVER AT MORGAN FALLS DAM, GA
USGS 02335815	USGS 02335815 CHATTAHOOCHEE RIVER BELOW MORGAN FALLS DAM, GA
USGS 02335880	USGS 02335880 CHATT R AT POWERS FY & I-285 NR ATLANTA, GA
USGS 02335990	USGS 02335990 CHATTAHOOCHEE RIVER AT US 41, AT ATLANTA, GA
USGS 02336000*	CHATTAHOOCHEE RIVER AT ATLANTA, GA

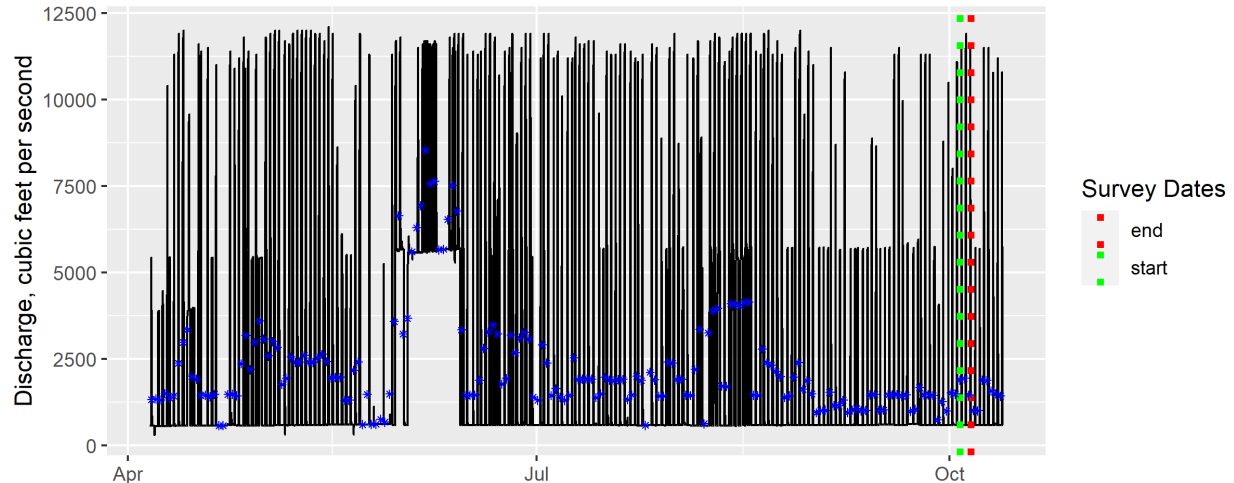
USGS Stream Discharge for CHATTAHOOCHEE RIVER AT BUFORD DAM, NEAR BUFORD, GA
Site number: 02334430



Data Source: <https://nwis.waterservices.usgs.gov/nwis/iv/?site=02334430&format=waterml,1.1&ParameterCd=00060&startDT=2018-09-19&endDT=2018-10-08>

Figure 8: 20-day stream discharge, 14 days prior and 3 days post sampling event, for USGS Site Number: 02334430, the most upstream USGS site in survey area. Blue stars represent mean daily discharge, the green vertical dashed line is survey beginning and red vertical dashed line is survey end.

USGS Stream Discharge for CHATTAHOOCHEE RIVER AT BUFORD DAM, NEAR BUFORD, GA
Site number: 02334430



Data Source: <https://nwis.waterservices.usgs.gov/nwis/iv/?site=02334430&format=waterml,1.1&ParameterCd=00060&startDT=2018-04-06&endDT=2018-10-12>

Figure 9: 190-day stream discharge, 180 days prior and 7 days post sampling event, for USGS Site Number: 02334430, the most upstream USGS site in survey area. Blue stars represent mean daily discharge, the green vertical dashed line is survey beginning and red vertical dashed line is survey end.

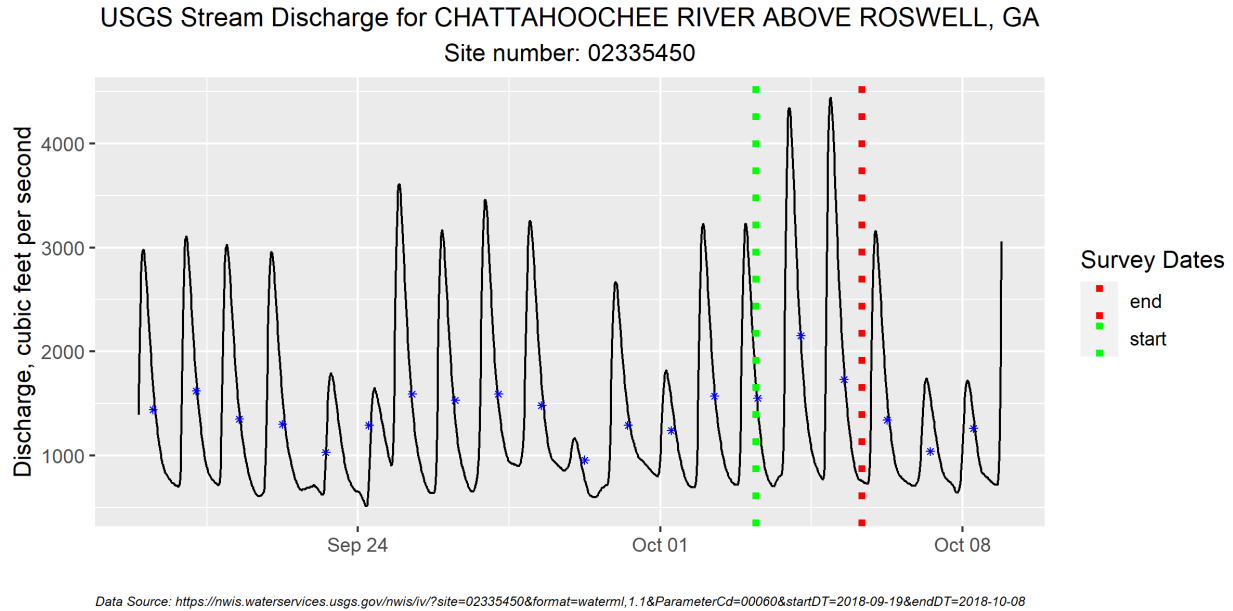


Figure 10: 20-day stream discharge, 14 days prior and 3 days post sampling event, for USGS Site Number: 02335450, near the middle of the survey area. Blue stars represent mean daily discharge, the green vertical dashed line is survey beginning and red vertical dashed line is survey end.

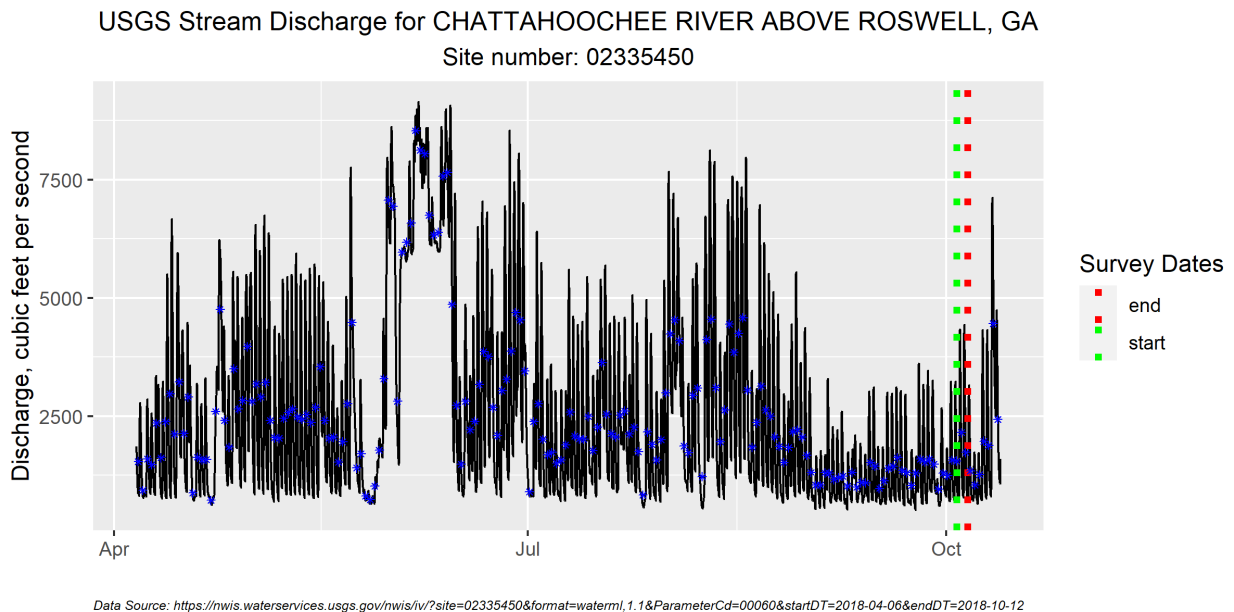


Figure 11: 190-day stream discharge, 180 days prior and 7 days post sampling event, for USGS Site Number: 02335450, near the middle of the survey area. Blue stars represent mean daily discharge, the green vertical dashed line is survey beginning and red vertical dashed line is survey end.

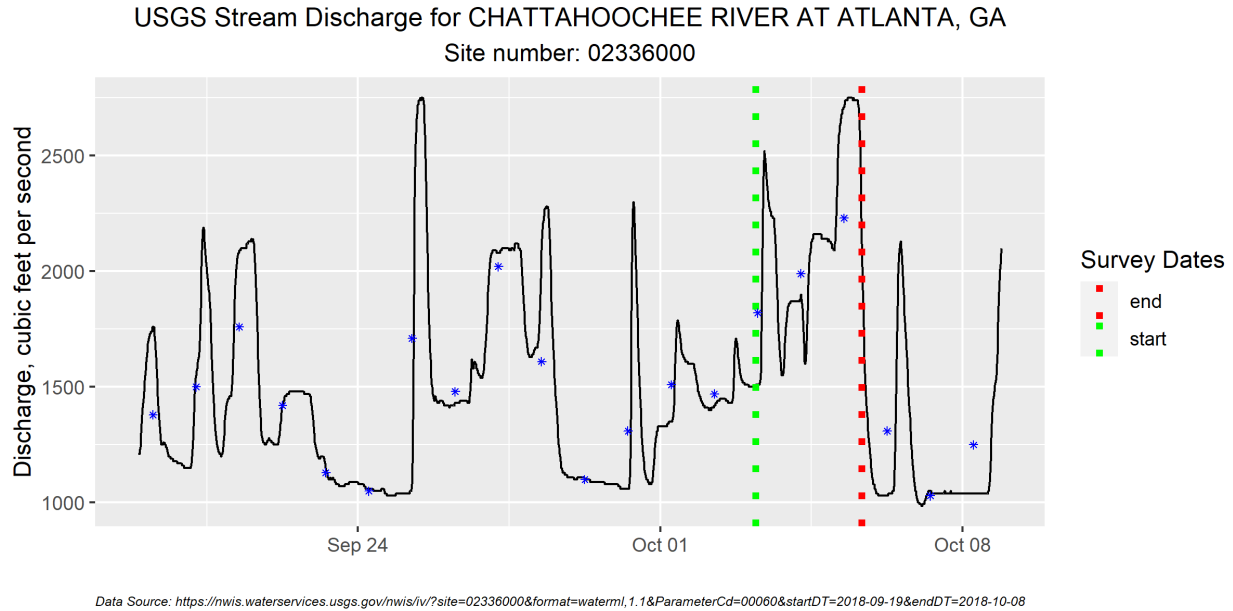


Figure 12: 20-day stream discharge, 14 days prior and 3 days post sampling event, for USGS Site Number: 02336000, the most downstream USGS site in survey area. Blue stars represent mean daily discharge, the green vertical dashed line is survey beginning and red vertical dashed line is survey end.

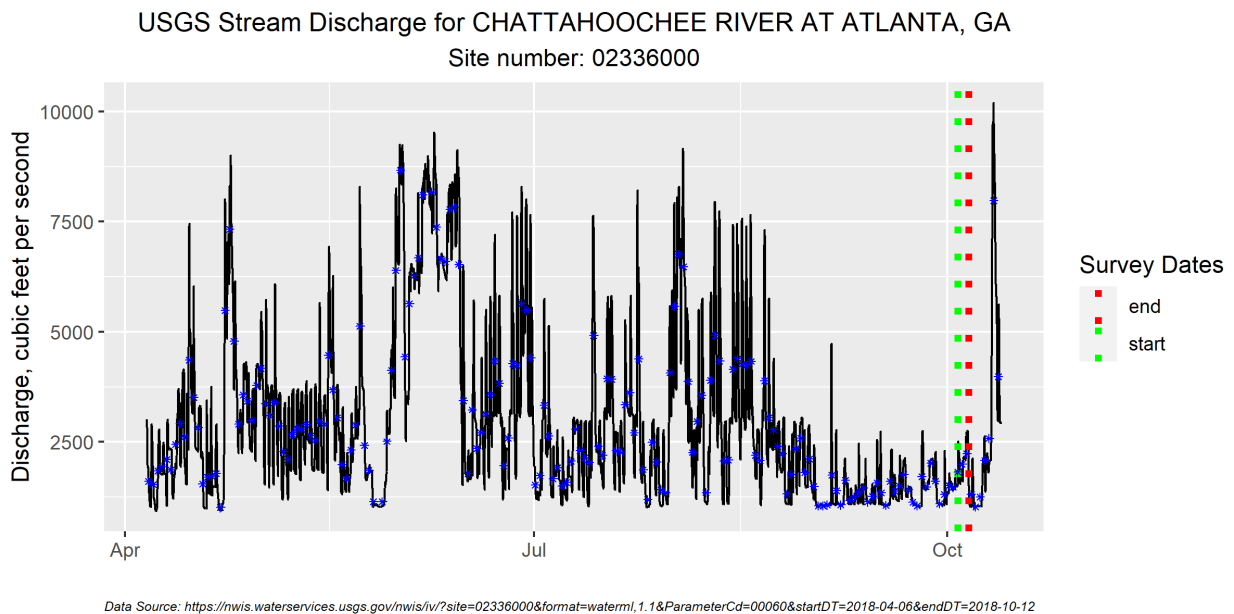


Figure 13: 190-day stream discharge, 180 days prior and 7 days post sampling event, for USGS Site Number: 02336000, the most downstream USGS site in survey area. Blue stars represent mean daily discharge, the green vertical dashed line is survey beginning and red vertical dashed line is survey end.

Survey Results

An objective of this survey was to collect and classify high resolution, geo-referenced data along 46 river miles at CHAT. A total of three days was required to complete the survey (Figure 14). The first two survey days consisted of a total of six tracks with each boat having three separate tracks. While on the third day, each boat had one track each (Table 9, Figure 15 and Figure 16). The length of the tracks was cut during production to approximately 2 hours to help prevent the file size from getting too large. The StreamView videos all have a Track number associated with them and these track numbers are included in the primary source data sheets so that it is easy to find the appropriate video that goes with the data.

Table 9: Survey Track collection information. The Track Number is a combination of the survey day, boat, and video segment.

Day	Boat	Track	Start	Date	Start Date and Time Stamp
1	1	111	10:54:07	3-Oct-2018	2018-10-03T10:54:07
1	1	112	12:44:46	3-Oct-2018	2018-10-03T12:44:46
1	1	113	14:44:53	3-Oct-2018	2018-10-03T14:44:53
1	2	121	10:54:46	3-Oct-2018	2018-10-03T10:54:46
1	2	122	12:54:54	3-Oct-2018	2018-10-03T12:54:54
1	2	123	14:45:02	3-Oct-2018	2018-10-03T14:45:02
2	1	212	12:25:36	4-Oct-2018	2018-10-04T12:25:36
2	1	213	14:22:00	4-Oct-2018	2018-10-04T14:22:00
2	2	221	10:30:06	4-Oct-2018	2018-10-04T10:30:06
2	2	222	12:03:12	4-Oct-2018	2018-10-04T12:03:12
2	2	223	13:43:19	4-Oct-2018	2018-10-04T13:43:19
2	1	211	10:30:04	4-Oct-2018	2018-10-04T10:30:04
3	1	311	10:38:08	5-Oct-2018	2018-10-05T10:38:08
3	2	321	10:37:45	5-Oct-2018	2018-10-05T10:37:45

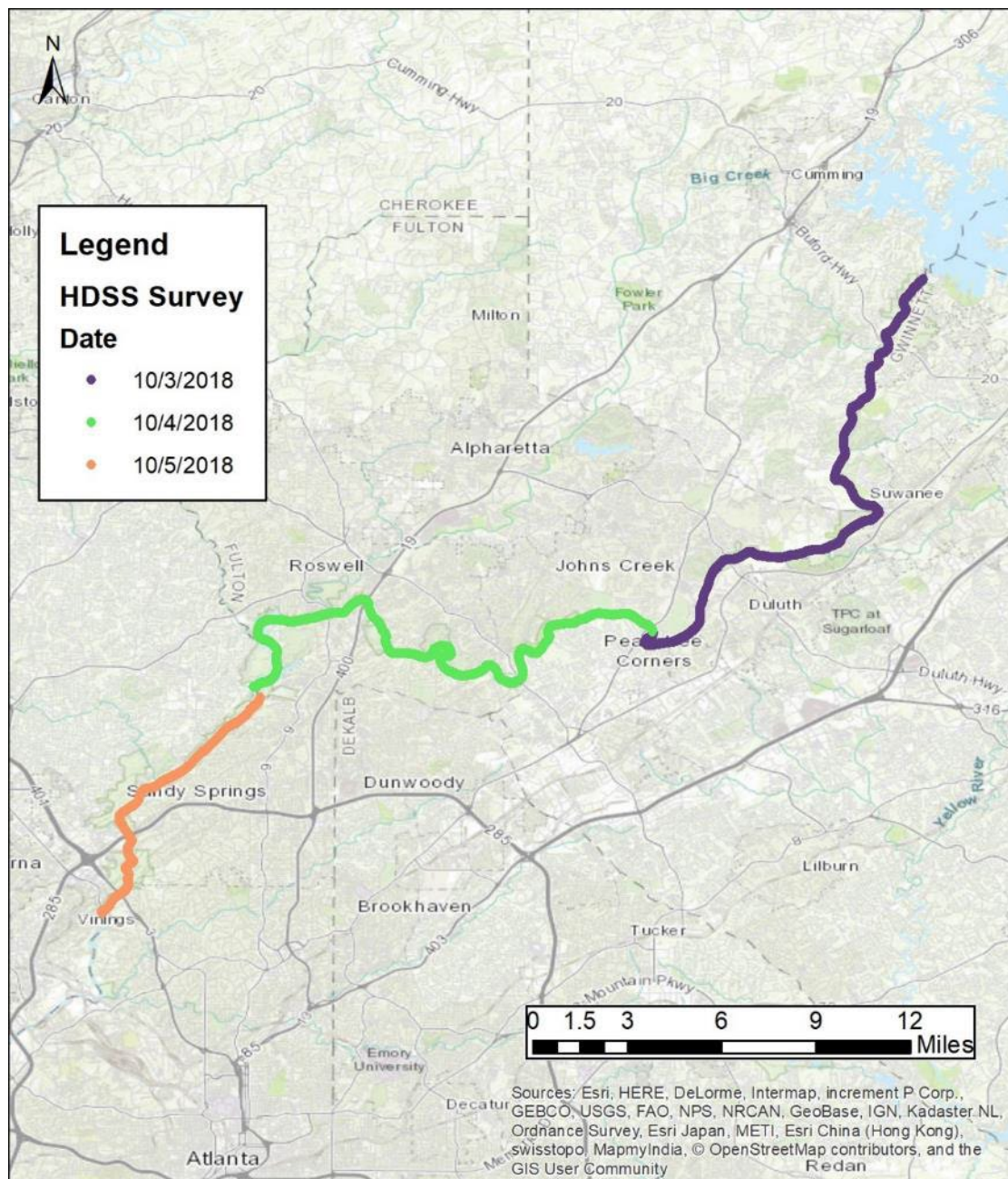


Figure 14: HDSS Survey dates for the Chattahoochee River.

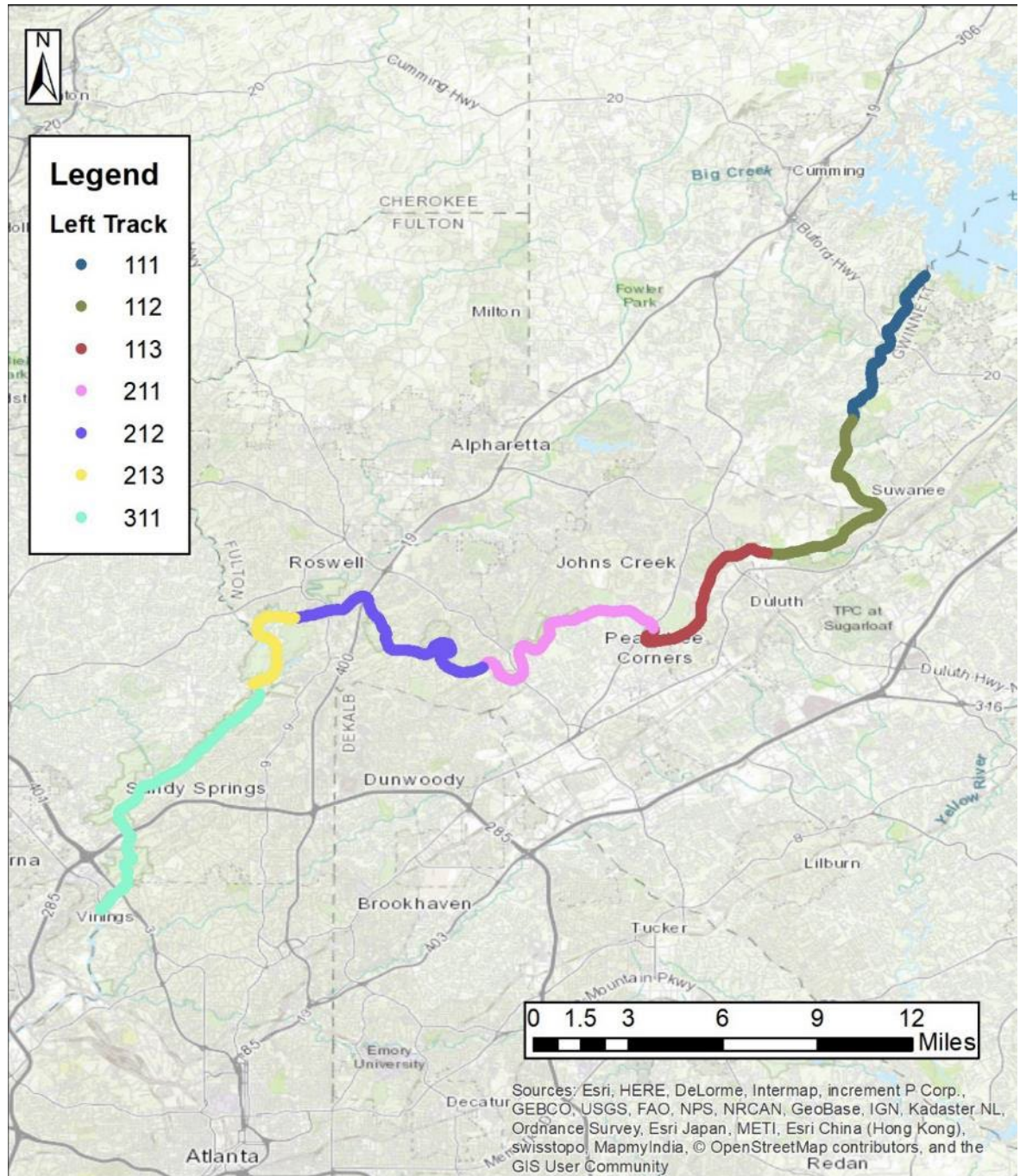


Figure 15: HDSS Video track numbers of the left bank for the Chattahoochee River survey.

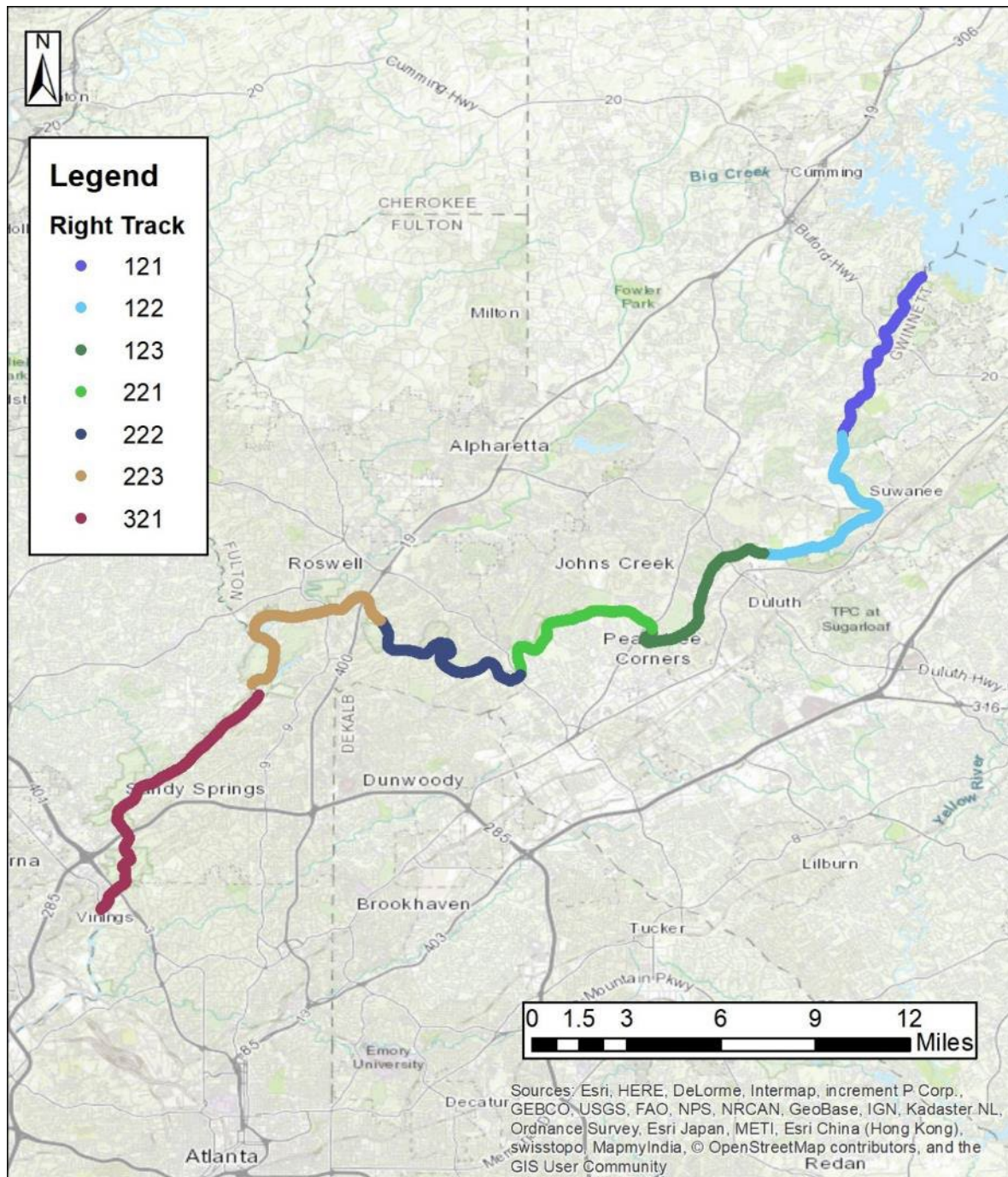


Figure 16: HDSS Video track numbers of the right bank for the Chattahoochee River survey.

Classification Results

Another objective was to create classified data layers for water depth, habitat type and left and right streambank condition. The results for each parameter were plotted on a map to see the spatial distribution and range.

Water Depth

The average water depth of the riverine sections showed no specific longitudinal pattern (Figure 17); however, the deeper sections of CHAT were often associated with sharp or tight bends of the river. The mean water depth was 1.28m with a minimum depth of 0.085m and a maximum depth of 11.43m. Water depth was recorded as less than 1.72m in 75% of the readings. Shallow areas were present throughout the survey segment (Figure 22 and Figure 26). Point data for water depth was affected by discharge fluctuations associated with power generation which influences both between-day and during-day water depths and while we did not survey during any large discharge pulse, some variation in discharge was observed (see local flow condition section). There was an instream reservoir created by Morgan Falls Dam that was deeper than most of the riverine segments and was located from approximately 50 to 59 km downstream from Buford Dam. Maps of left and right track water depth are shown in figures:

Left Bank:

- Full survey area - Figure 22
- Upstream survey area - Figure 23
- Middle survey area - Figure 24
- Downstream survey area - Figure 25

Right Bank:

- Full survey area - Figure 26
- Upstream survey area - Figure 27
- Middle survey area - Figure 28
- Downstream survey area - Figure 29

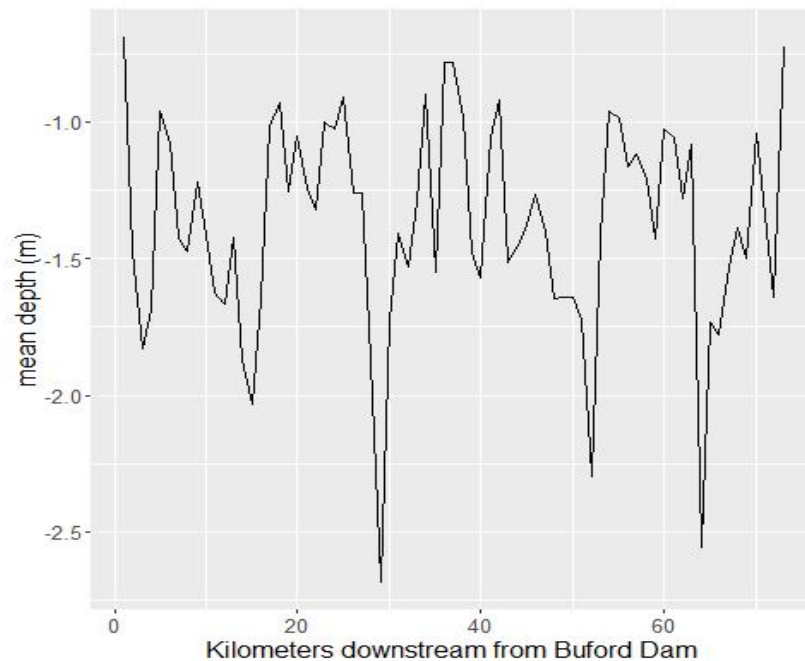


Figure 17: Mean water depth for 1 km segments of the Chattahoochee River National Recreation Area surveyed 3-5 October 2018.

Two measures of water depth were collected by the sonar. One is the sonograph of the sonar signal and one is the digital depth reading recorded by Humminbird's proprietary sonar software based on the sonograph. The digital depth readings were generally a good representation of water depth but were not always correct. To ensure the digital water depth recorded matched the sonograph, the results of each were compared using ReefMaster 2.0 software. Where the digital depth did not accurately represent the sonograph, the depth was corrected manually to fit the depth observed on the sonograph (Figure 18). To compare the results of the corrected digital depth values with the uncorrected digital depths, we randomly selected one depth track to compare the paired results. For this comparison, the water depth track for the boat on the left side of the river on day 1 (Track 111) was randomly selected.

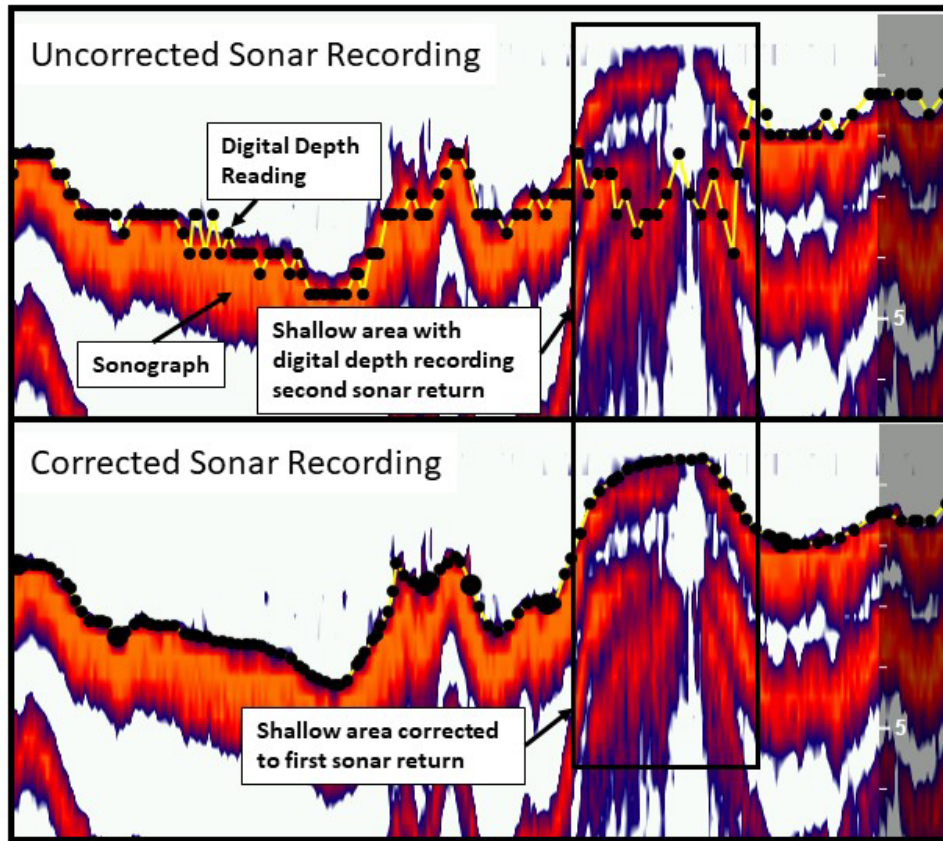


Figure 18: Example of uncorrected sonar recordings and corrected sonar recordings showing digital depth values and overall sonograph.

There were 43,818 sonar recordings in the comparison dataset with only 0.004m mean difference between the uncorrected and corrected water depth readings (Table 10). Most of the differences between the uncorrected and corrected were associated with shallow depth readings (Figure 19). At water depths under about 0.3m (1 ft) the Humminbird sonar appeared to find the next deepest sonar return (second echo) and substituted that depth reading for the echo instead of the depth for the first sonar return. This is likely a shallow depth limit by the sonar software so that it does not inadvertently determine surface clutter (e.g., wave or prop turbulence) in the return as water depth. This is an appropriate choice as most recreational boaters do not run their boats in water less than 1 ft deep. In our case, we routinely traverse shallow water and the sonograph shows the shallow depths but the digital depth return does not track it under 0.3m (1 ft). Figure 20 and Table 11 show the corrected water depth approximately 0.02m less than the uncorrected digital water depth recorded, for all points less than 1 m deep, by the sonar. In terms of the extent of the correction, a total of 3,923 or 9% of the water depth readings from the original 43,818 data points were modified in the correction process. The corrections averaged 0.047m and the largest corrections occurred in the shallow water (Figure 21 and Table 12). Overall, the digital water depth recorded was accepted 91% of the time and corrections generally averaged less than 0.05m.

Table 10: Comparison of uncorrected to corrected digital water depth readings from the full dataset. All depth measurements are in meters.

Variable	N	Mean	SD	p0	p25	p50	p75	p100	Histogram
Uncorrected Depth	43,818	1.620	0.654	0.417	1.139	1.578	1.998	5.278	
Corrected Depth	43,818	1.616	0.657	0.231	1.127	1.578	1.998	5.187	
Depth Difference	43,818	0.004	0.058	-0.67	0.000	0.000	0.000	2.118	

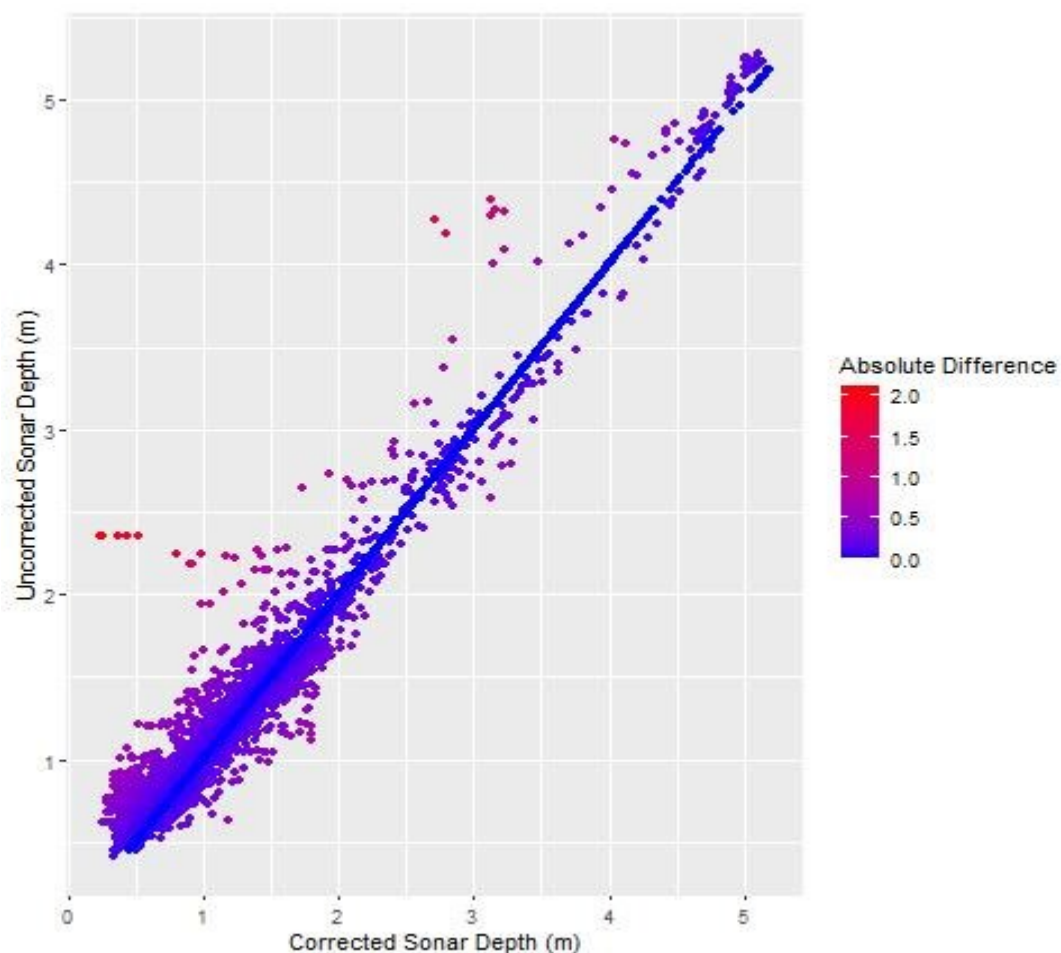


Figure 19: Plot of corrected vs. uncorrected digital water depth readings from the full dataset (N=43,818).

Table 11: Comparison of uncorrected to corrected digital water depth readings where corrected digital water depth readings were less than 1 m. All depth measurements are in meters.

Variable	N	Mean	SD	p0	p25	p50	p75	p100	Histogram
Uncorrected Depth	8,436	0.799	0.140	0.417	0.697	0.798	0.898	2.349	
Corrected Depth	8,436	0.779	0.144	0.231	0.688	0.788	0.898	0.999	

Variable	N	Mean	SD	p0	p25	p50	p75	p100	Histogram
Depth Difference	8,436	0.020	0.097	- 0.280	0.000	0.000	0.000	2.118	

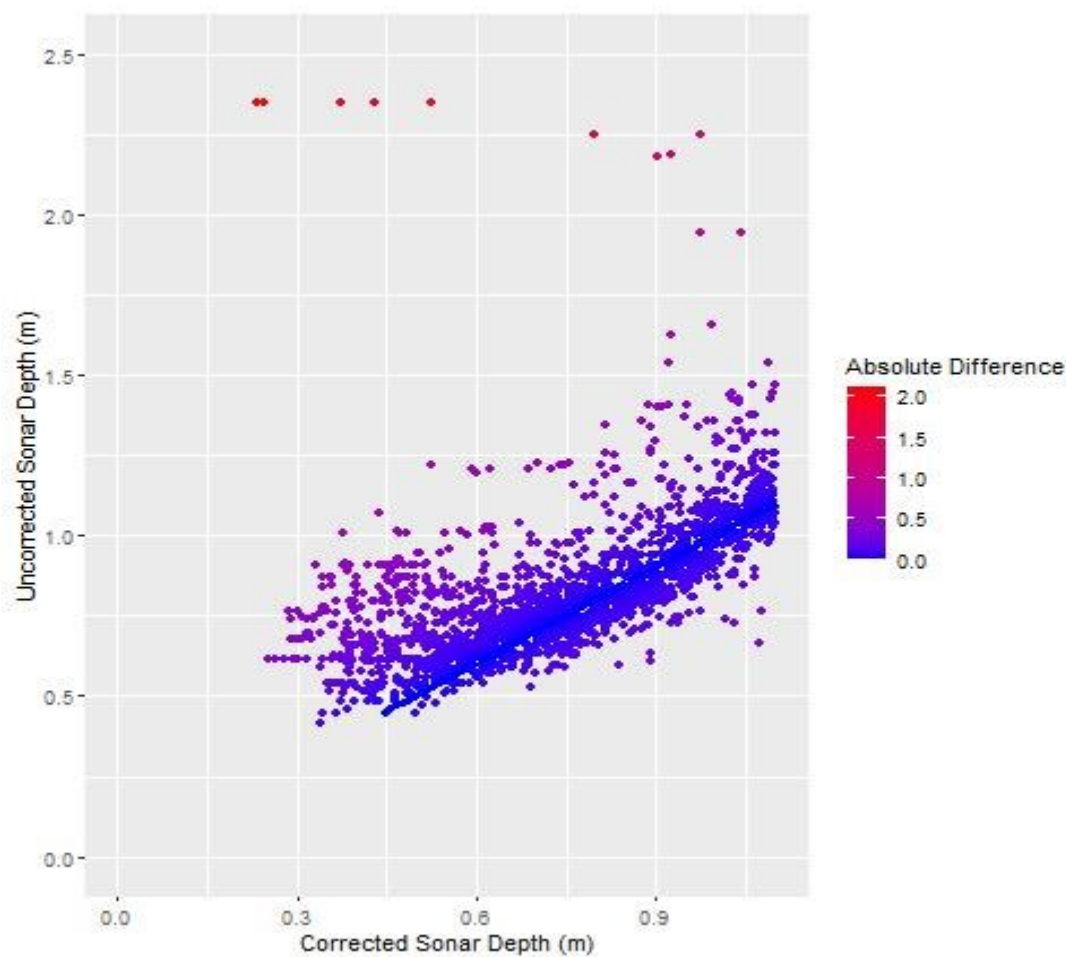


Figure 20: Plot of corrected vs. uncorrected digital water depth readings where corrected digital water depth readings were less than 1 meter (N=8,436).

Table 12: Comparison of uncorrected to corrected digital water depth readings where the difference in depth were not equal to 0. All depth measurements are in meters.

Variable	N	Mean	SD	p0	p25	p50	p75	p100	Histogram
Uncorrected Depth	3,923	1.266	0.720	0.417	0.793	1.139	1.499	5.278	
Corrected Depth	3,923	1.218	0.728	0.231	0.746	1.093	1.483	5.141	
Depth Difference	3,923	0.047	0.191	- 0.670	- 0.050	0.018	0.105	2.118	

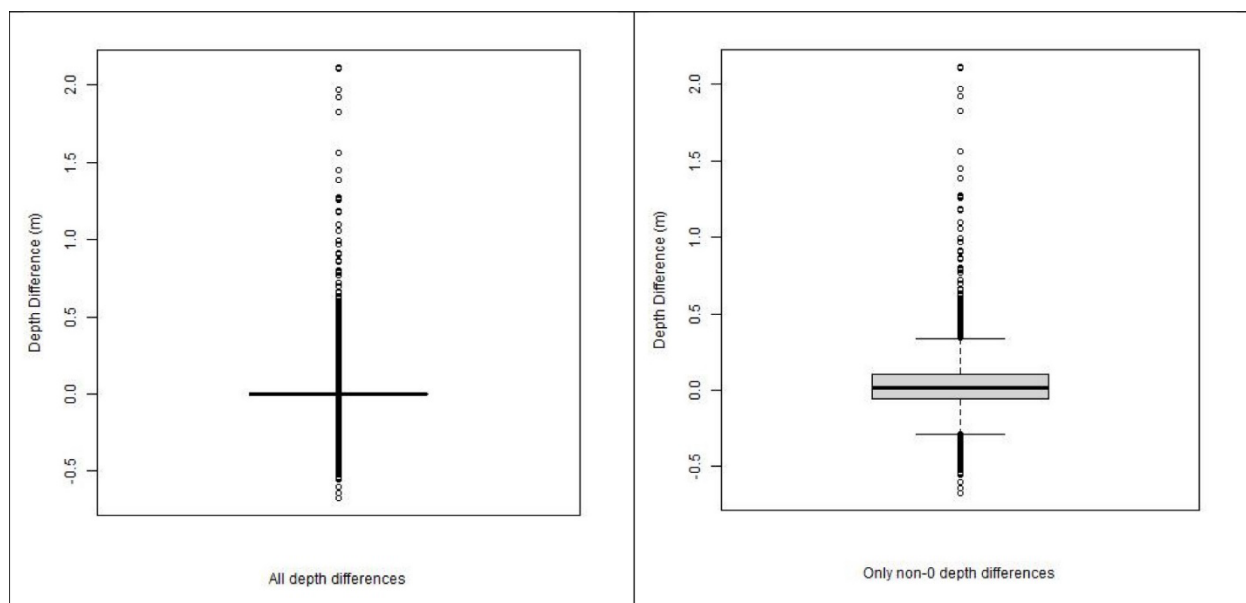


Figure 21: Box plot of water depth differences between the corrected and uncorrected comparison data (N=43,818) and where the depth difference is non-zero (N=3,923).

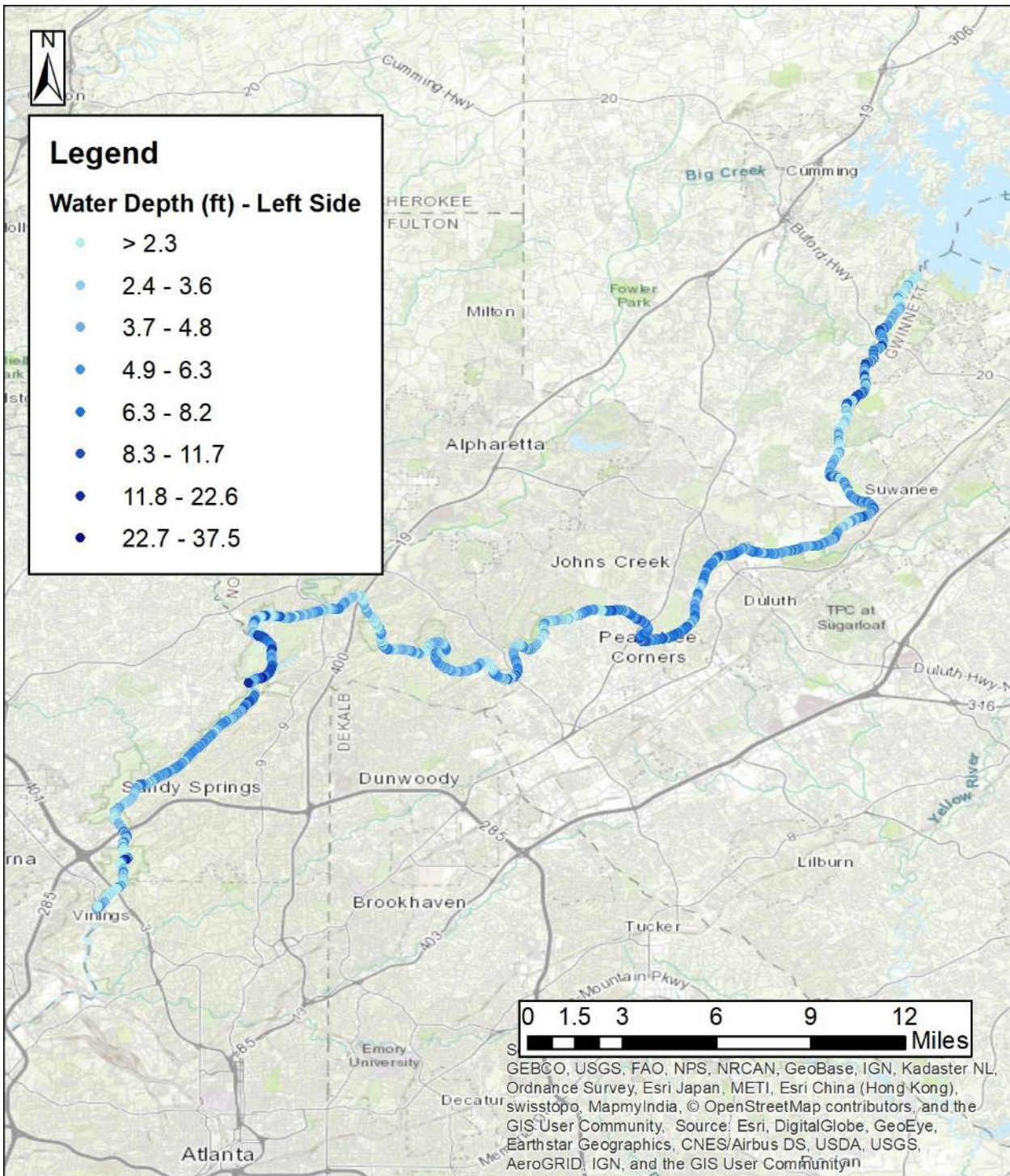


Figure 22: Left track Water Depth for the Chattahoochee River National Recreational Area.

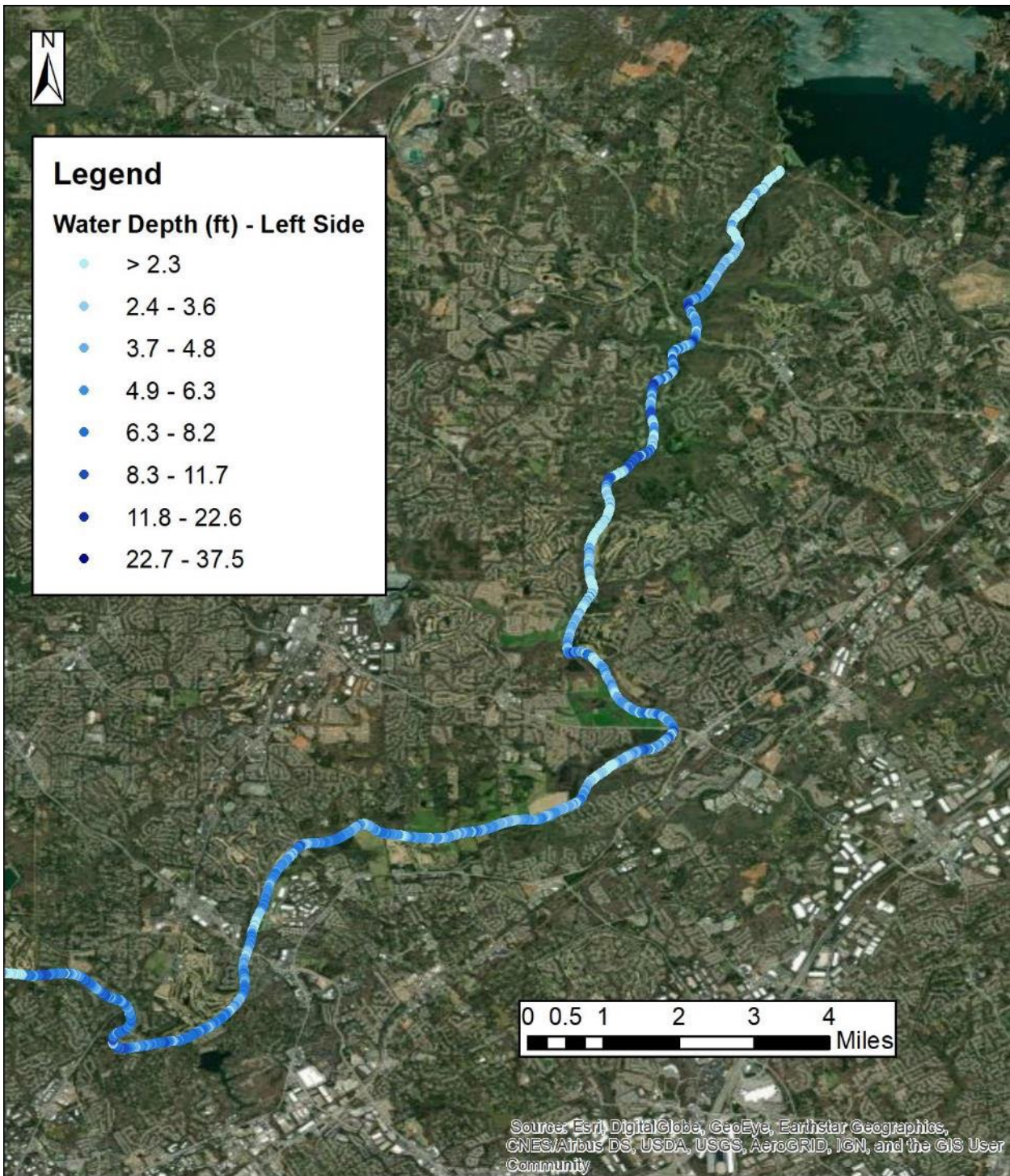


Figure 23: Left track Water Depth score for the upstream section of the Chattahoochee River National Recreational Area.

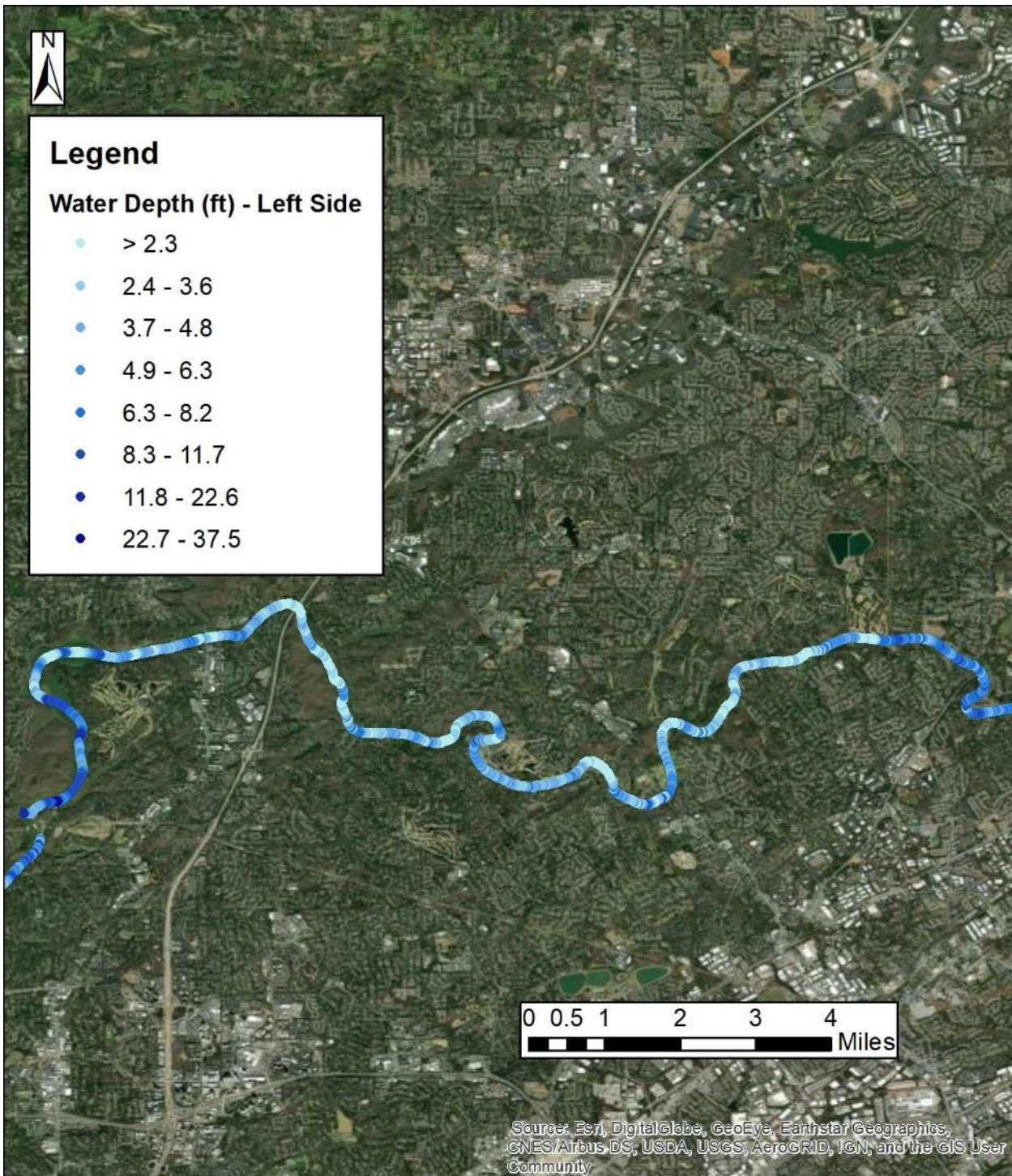


Figure 24: Left track Water Depth score for the middle section of the Chattahoochee River National Recreational Area.

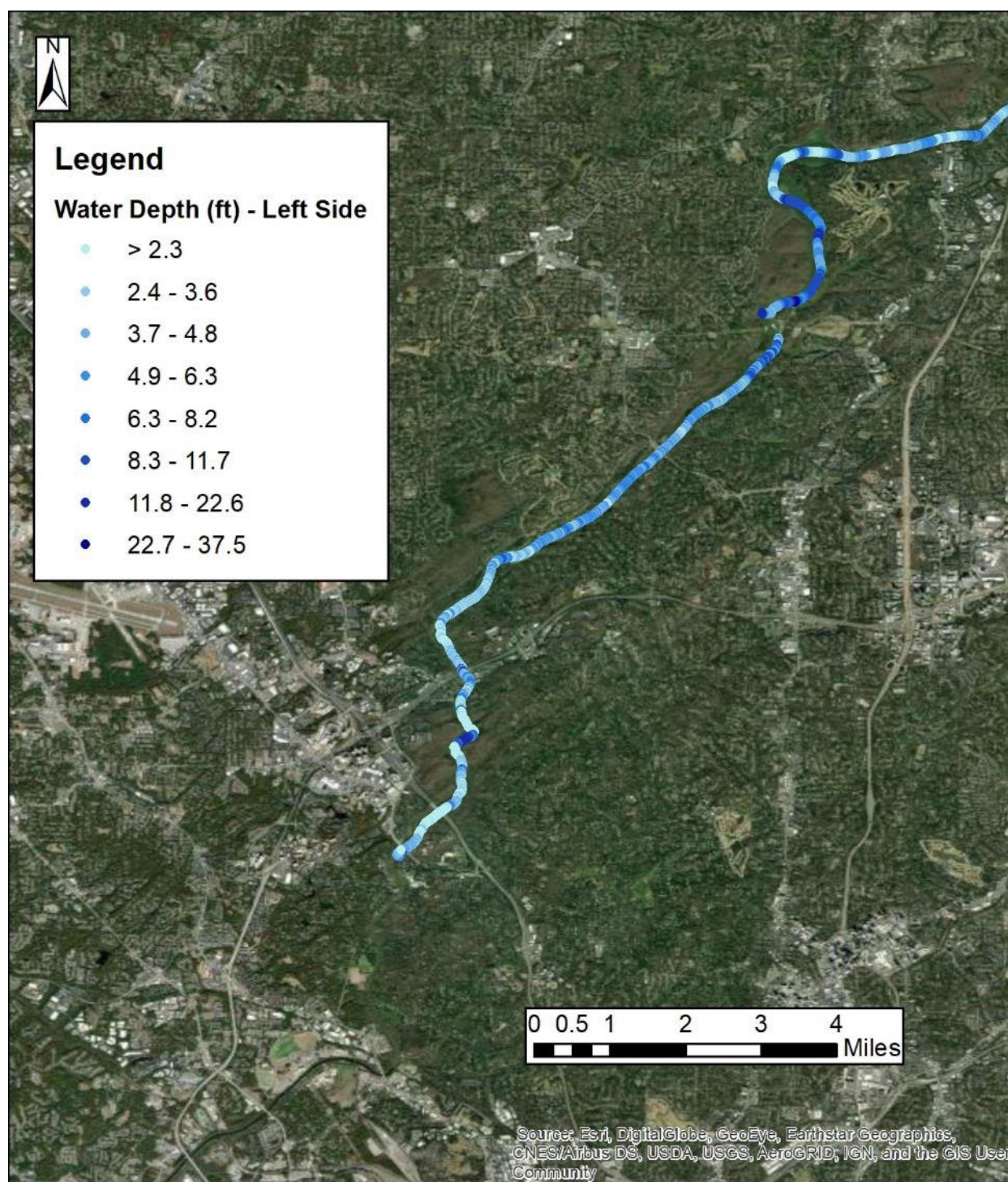


Figure 25: Left track Water Depth score for the downstream section of the Chattahoochee River National Recreational Area.

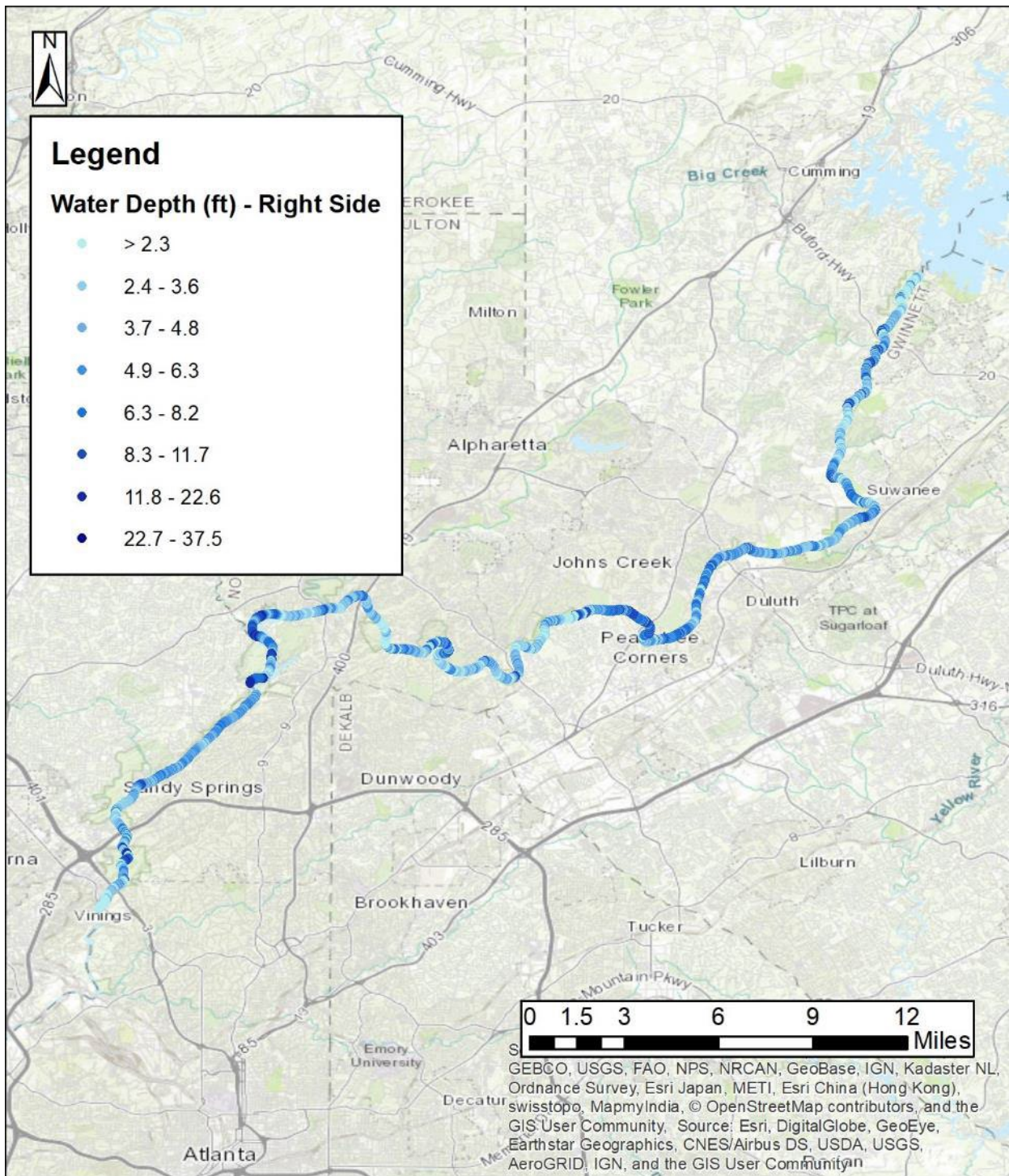


Figure 26: Right track Water Depth for the Chattahoochee River National Recreational Area.

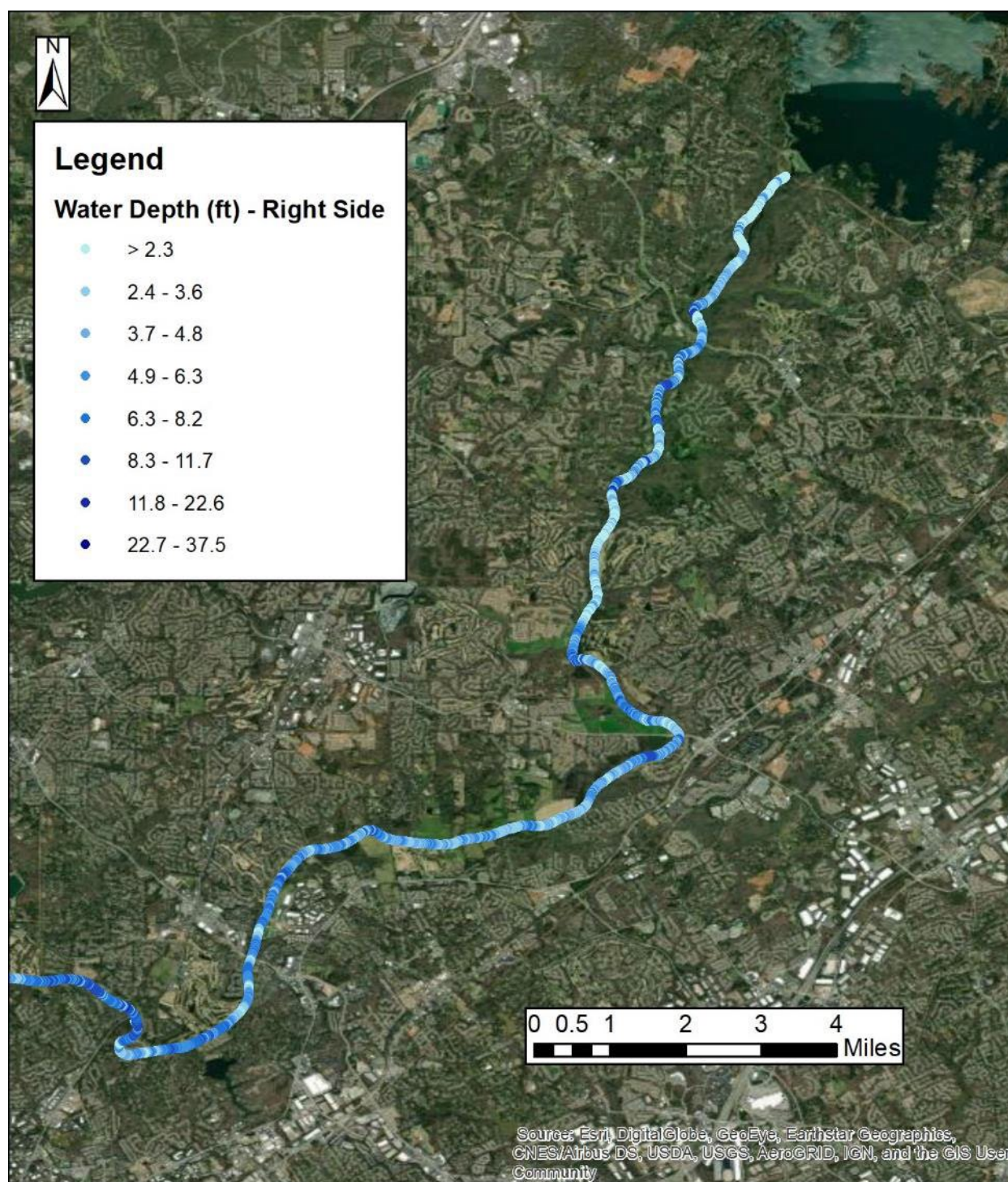


Figure 27: Right track Water Depth score for the upstream section of the Chattahoochee River National Recreational Area.

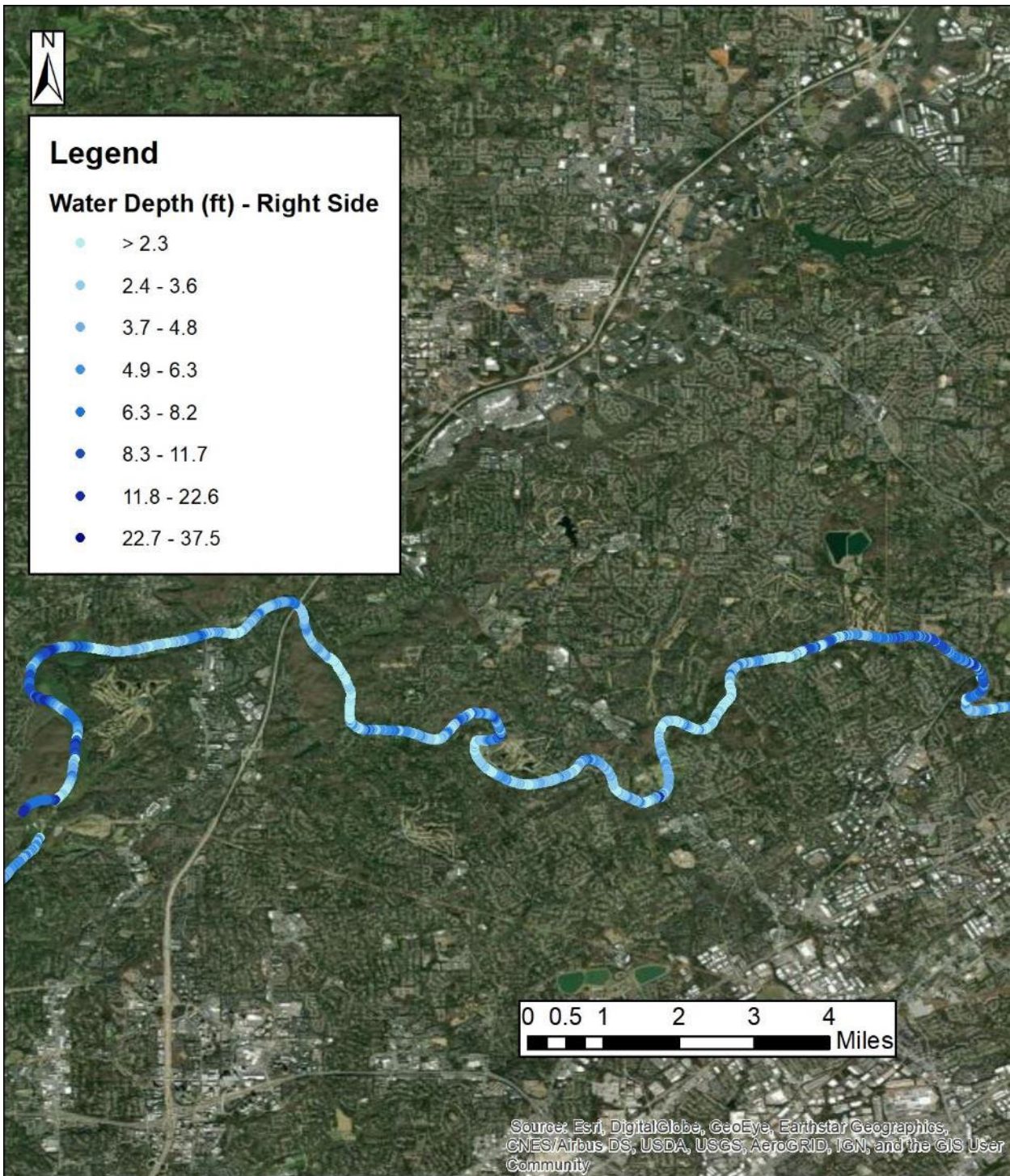


Figure 28: Right track Water Depth score for the middle section of the Chattahoochee River National Recreational Area.

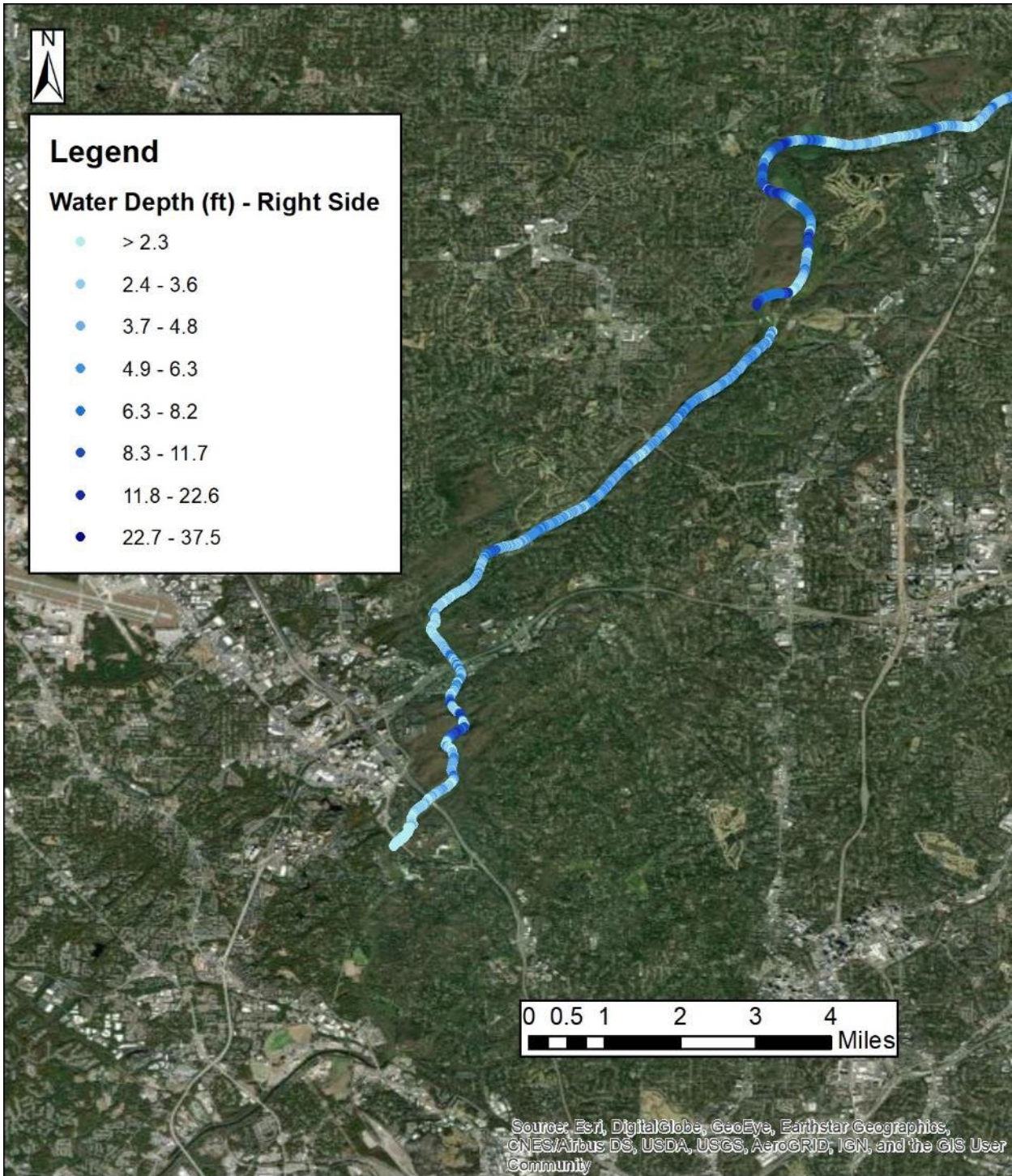


Figure 29: Right track Water Depth score for the downstream section of the Chattahoochee River National Recreational Area.

Habitat Type

Habitat Type was quantitatively classified with respect to the general water depth trend. Overall, 146,660 average water depth recordings were collected, 73,330 per left and right survey tracks. Each survey track provided a water depth for each meter of the longitudinal survey were available to determine the statistical breaks between habitat types. From the available water depth values, a subset of values was used in the analysis. Two issues were considered when including or excluding water depths from a particular section of the survey used to determine the statistical habitat type break points. The first criterion was:

Did the segment appear to be a riverine section or was it artificially impounded behind a dam?

To avoid the non-riverine section of impounded water above the Morgan Falls dam, the river segment from 40 to 59km had water depths excluded from both the right and left survey tracks. This resulted in 108,576 water depth recordings from both survey tracks combined, providing one-meter resolution for the longitudinal survey. Excluding the segment clearly impounded by Morgan Falls dam avoids the inclusion of any water depth reading that may have been artificially deeper than naturally expected due to the dam. The second criterion was:

Did other changes to river discharge (dam releases, inflow from tributaries, rain between survey days) substantially change the conditions observed during the survey, thus requiring additional subsetting of the data?

For the CHAT survey, neither inflow from tributaries nor rain between survey days appeared to be an issue. Inflow from tributary streams was small in comparison to the main Chattahoochee River and no high, muddy water was observed flowing into the main channel from the tributaries; therefore, it was unlikely that any segment was being flooded from tributary inflow. No local rainfall was recorded between the survey days; thus, river discharge was unlikely influenced by rainfall runoff. River discharge in this segment of the Chattahoochee River can be affected by water releases from Buford Dam. The effects of the water releases would change with respect to distance from the dam and overall volume of water released. Higher discharges result in higher downstream water surface elevations, but the height would diminish as distance increases from the dam due to the widening of the discharge pulse and the concordant lowering of the discharge peak.

Two possibilities exist to deal with the changes in river discharge due to dam releases. One is to separate the areas of obviously different discharge into distinct units and statistically determine habitat type break points for each unit. This approach would mitigate for the change in discharge by applying breaks to different depths among units based on the relative position within the water depth distribution. The difficulty would be in determining exactly where the peak starts and ends to appropriately segregate the river into like segments. The second approach would be to leave the data in one analysis. This would be most appropriate where the magnitude of the change in discharge was relatively small. The advantage would be a single consistent classification of habitat type. The difficulty with this approach would be determining what the standard was for a “relatively small change in discharge.” Both are viable approaches resulting in slightly different outcomes. For this project, we included all the riverine sections in the analysis as the influence of the change in discharge appeared relatively small.

While the habitat type cutoff values were determined from the non-impounded river segments, all of the 73.3 km survey area of the CHAT was classified for habitat type. The median depth riverine segment of streambed classified was 1.3 m. Depths less than the 85% percentile defined the riffle habitat, depths $\geq 85\%$ but $< 70\%$ percentile defined shoal, depths $\geq 70\%$ but $< 30\%$ percentile defined run, and depths $\geq 30\%$ percentile defined pool depth (Table 13).

Table 13: Attribute values used to determine the habitat unit types.

Attribute	Value
Window size (m)	60
Total number of Units (m)	147,702
Number of Units in Analysis (m)	107,591
Median value, p50 (m)	-1.30
Riffle/Shoal cutoff, p85 (m)	-0.70
Shoal/Run cutoff, p70 (m)	-0.97
Run/Pool cutoff, p30 (m)	-1.63

A total of 1,986 habitat units were classified into one of the four major habitat types of riffle, shoal, run, or pool. Run habitat was the most frequently classified type representing 36.5% of the total area classified, while riffle habitat was classified the least (16.1%; Table 14). Shoal and pool habitats accounted for 23.3% and 24.1% of the habitat units classified, respectively.

Mean longitudinal length among the four habitat types varied (Table 14). The mean longitudinal length of pools was the longest of habitat types at 91.2 m while riffles (mean=77.2 m) and runs (mean=76.9 m) were similar. The shortest mean habitat type was shoals at 48.8 m. The distributions around the median longitudinal length of each habitat type also varied and demonstrates that pools and runs had the greatest variance while shoals had the least (Figure 30 & Figure 31). Additionally, outliers had the greatest range within the pool habitats followed by riffle, run, and shoal, respectively.

Table 14: Number and percent of habitat types classified in the Chattahoochee River survey segment.

Habitat Type	Count	Percent	Mean Length (m)	Mean Depth (m)
1.Riffle	326	16.3%	77.0	-0.63
2.Shoal	455	22.7%	48.4	-0.89
3.Run	733	36.6%	74.9	-1.30
4.Pool	491	24.5%	88.3	-1.93
Total	2005	100.0%	–	–

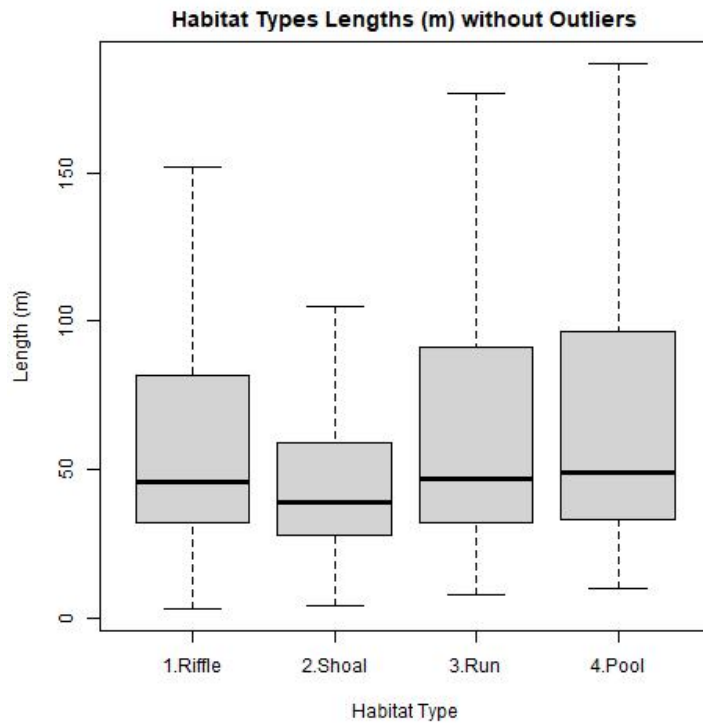


Figure 30. Boxplot of distribution of the longitudinal length (m) of habitat types without outliers.

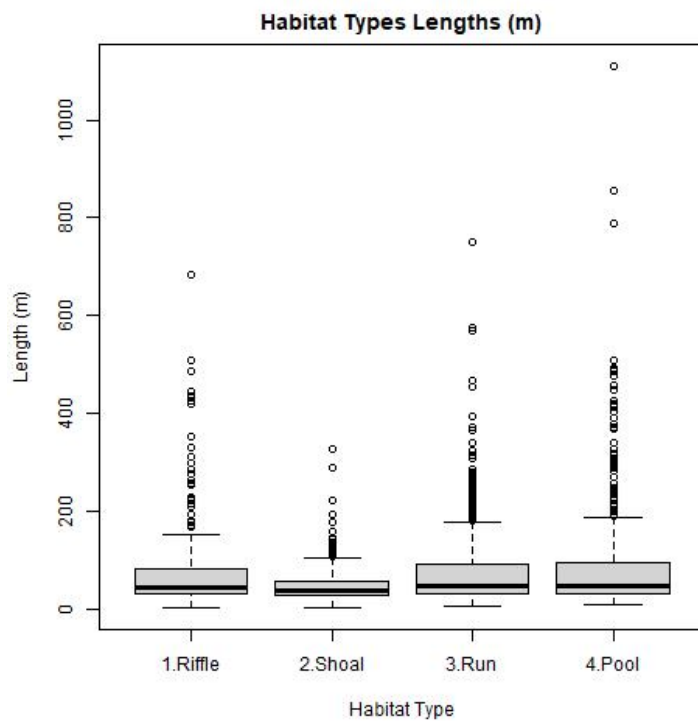


Figure 31: Boxplot of distribution of the longitudinal length (m) of habitat types with outliers.

Mean water depth also varied by habitat type with riffles being the shallowest (mean=0.69 m) and pools being the deepest (mean=1.94 m; Table 2). Similar to longitudinal length, the variance in depth was lowest for shoal habitat; however, pools also had the highest followed by riffle and then runs. Additionally, the distributional range for outliers increased with mean depth.

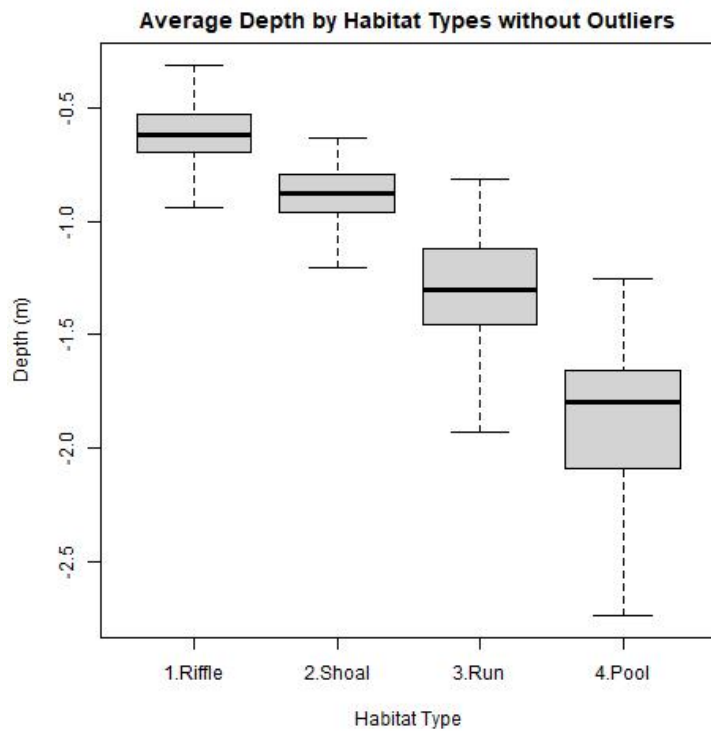


Figure 32: Boxplot of distribution of water depth within habitat types without outliers.

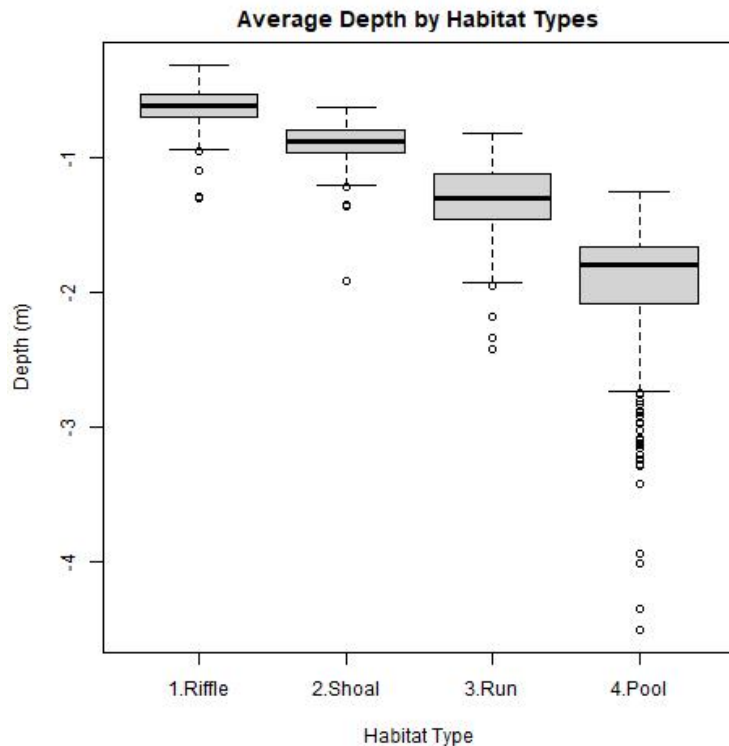


Figure 33: Boxplot of distribution of water depth within habitat types with outliers.

In general, the Chattahoochee River was a mix of riffle, shoal, run and pool habitat types (Figure 34). Riffle, run, and shoal habitats were widely dispersed through the classified section of the CHAT; however, some trends were observed. A minimum of two major riffle complexes were observed downstream of Buford Dam to Chattahoochee Point Park (Figure 35), downstream of River Pines Golf Club to Highway 400 bridge (Figure 36), and in lower six miles of the CHAT (Figure 37). Two areas had a predominance of pool habitats which occurred upstream and downstream of Medlock Bridge Area possibly caused by pooling above the Jones Bridge Shoals and Bull Sluice Lake Area. The area immediately downstream of Morgan Fall, for approximately the first five miles, had the greatest concentration of run habitat, while no obvious trends were observed for shoal habitat.

Maps of left and right habitat types are shown in figures:

- Full survey area - Figure 34
- Upstream survey area - Figure 35
- Middle survey area - Figure 36
- Downstream survey area - Figure 37

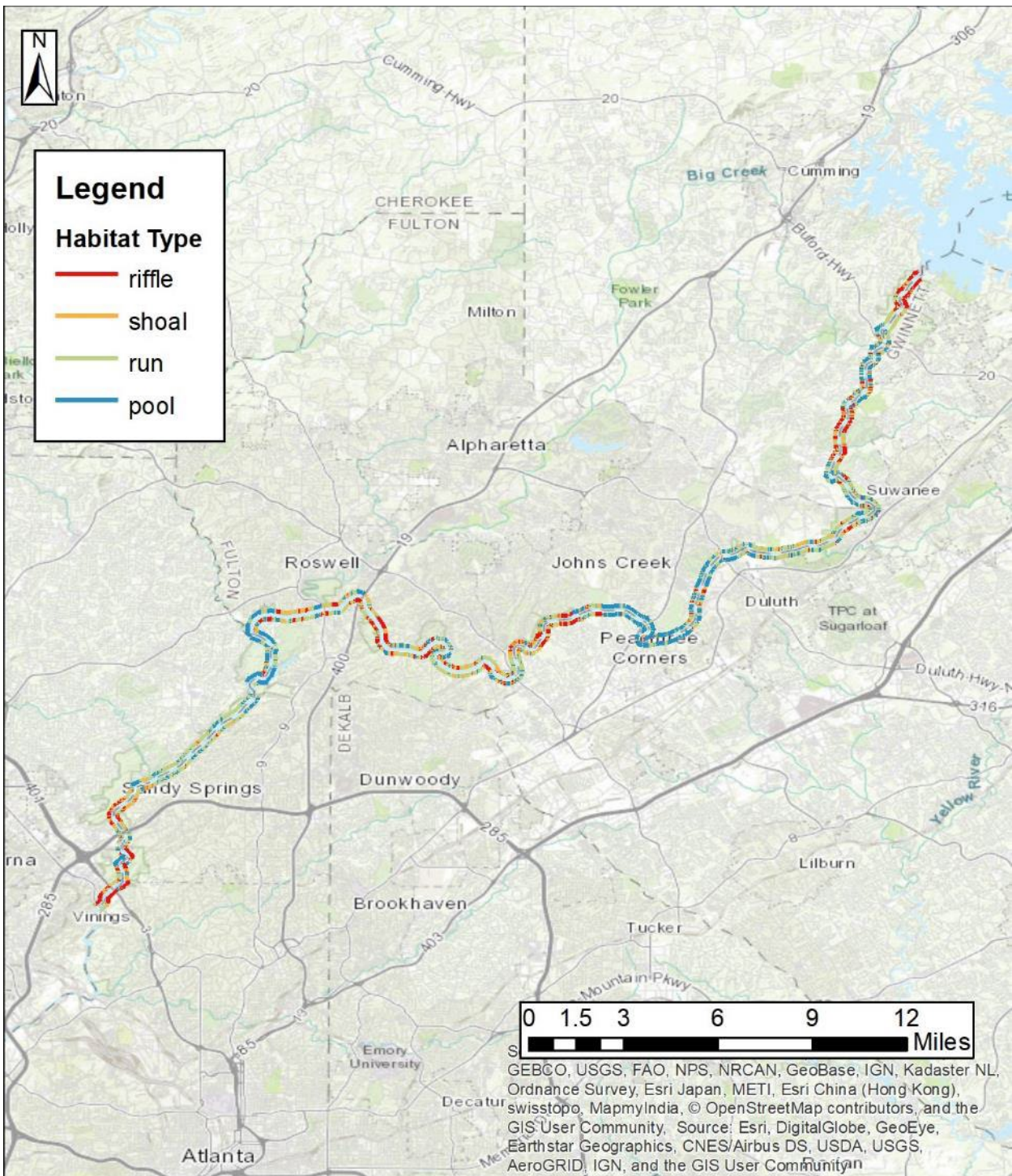


Figure 34: The location and distribution of the four habitat types of riffle, shoal, run, and pool for both the left and right boat tracks along the CHAT.

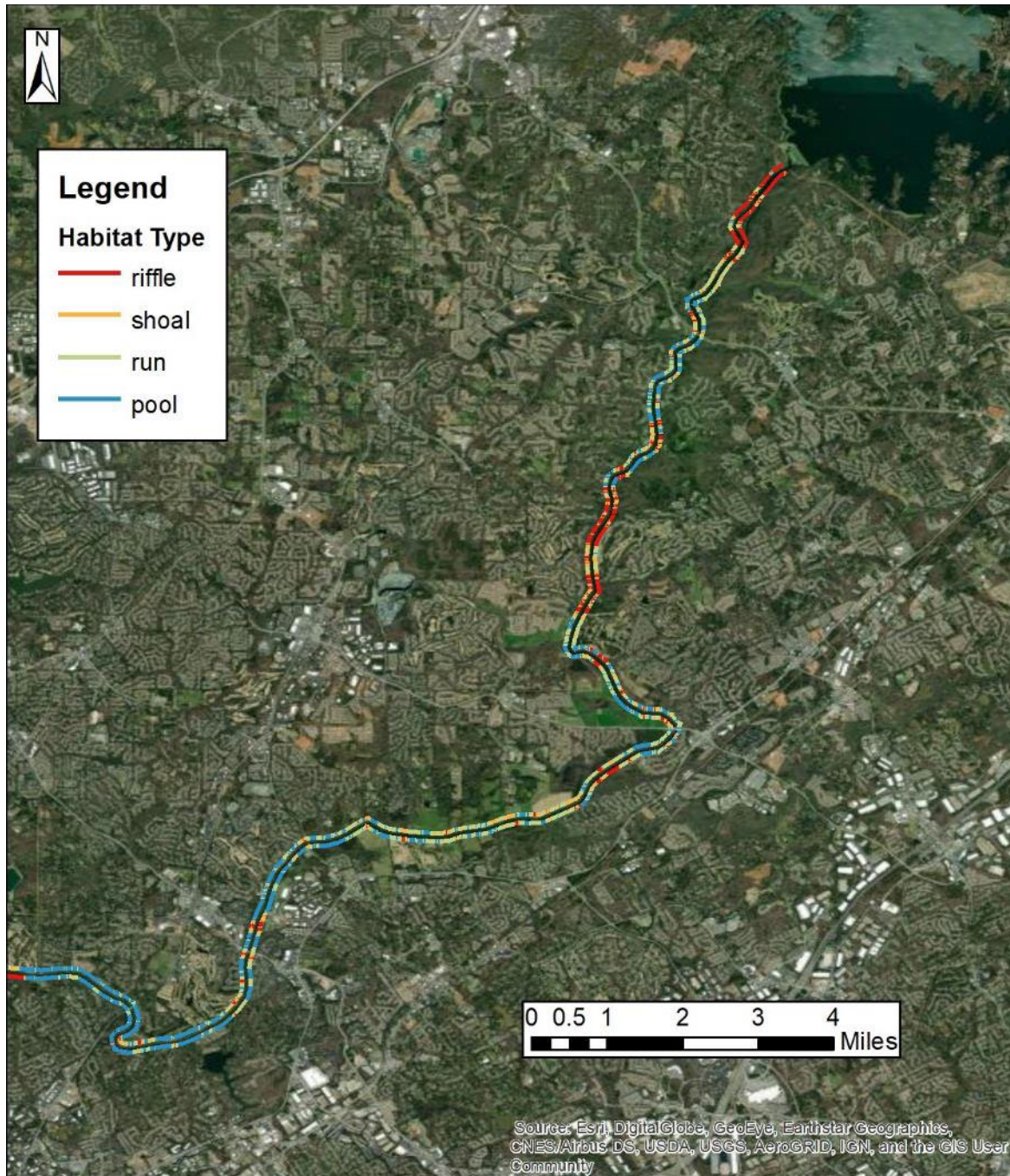


Figure 35: The location and distribution of the four habitat types of riffle, shoal, run, and pool for both the left and right boat tracks along the upper third of the CHAT.

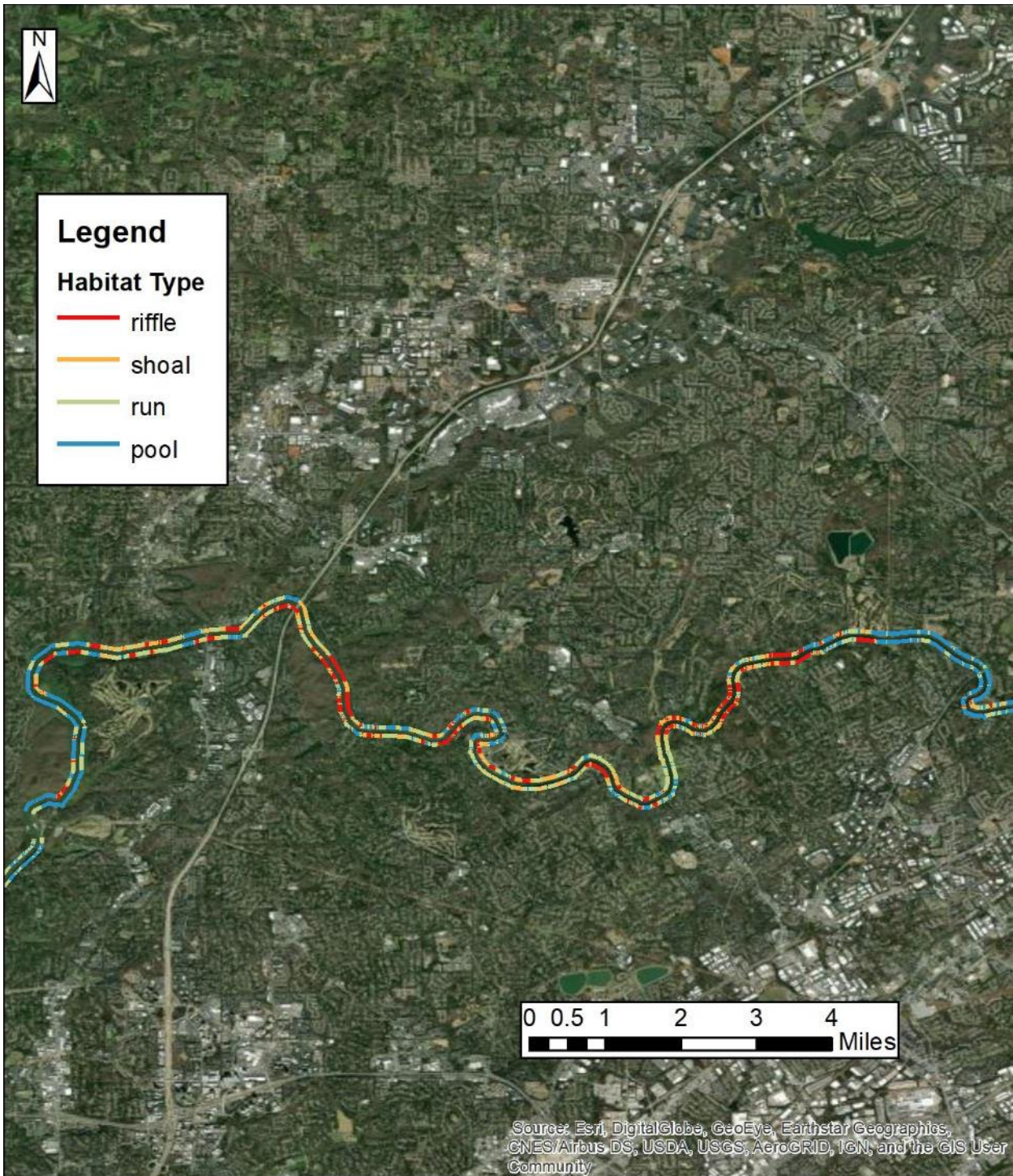


Figure 36: The location and distribution of the four habitat types of riffle, shoal, run, and pool for both the left and right boat tracks along the middle third of the CHAT.

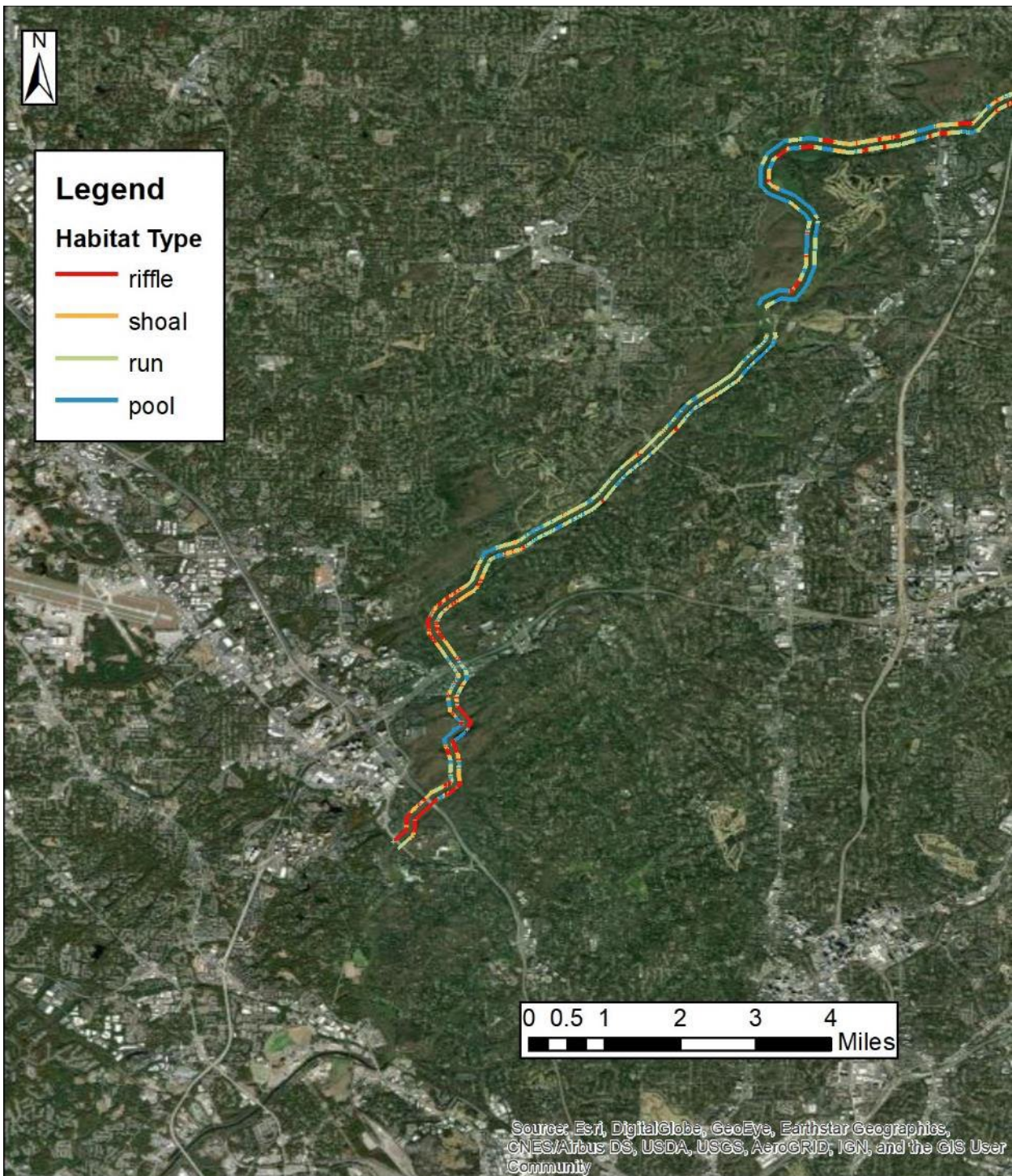


Figure 37: The location and distribution of the four habitat types of riffle, shoal, run, and pool for both the left and right boat tracks along lower third of the CHAT.

To verify and ensure consistency and accuracy of the Habitat Type model, a random set of habitat types were selected and visually assessed by a blind viewer; meaning the viewer was unaware of the score provided by the model. Of the total 1,986 habitats identified as riffle, shoal, run, and pool, 20 random

habitats were selected without replacement using a random seed number of 312 (Table 15). The results from the blind viewer were then compared to that of the model for the same habitat unit.

Table 15. Attribute and respective values used to during verification process.

Attribute	Value
Random Number Seed	312
Number of Review Sites	20
Random Review Sites	10071, 10110, 10281, 10318, 10484, 10570, 10612, 10682, 10785, 10877, 10879, 10936, 20066, 20128, 20384, 20394, 20567, 20666, 20871, 20884
Number Wrong	2
Accuracy Percent	90%

Model accuracy was 90% when compared to a visual assessment with both the model and viewer agreeing on 18 of the 20 predictions (Table 16 & Table 17). Eight of the randomly selected samples for verification were originally collected on 3 October, while on 4 October and 5 October each both had six samples verified (Table 16). The two habitat units where the model and reviewer did not agree were Habitat Id 10612 and 10682 (Table 17). Habitat Id 10612 was classified as shoal by the model while the reviewer identified it as run. Habitat Id 10682 was classified as riffle by the model while the reviewer identified it as shoal; however, the reviewer did provide a second classification of deep riffle. The data validation results suggest that both the model and visual classification provide similar results and thus are likely to delineate habitat types similarly. The classification errors tended to be in transition areas between adjacent habitat types. In this case, the model classification is likely more consistent than visual classification in the transition zones between habitat types as it is more difficult to be consistent when visually assessing the differences between similar habitat types. Additionally, it is also important to note that no major discrepancies between the model and visual reviewer were observed between the habitat types such as pool vs riffle, or shoal vs pool, or riffle vs run were observed.

These results support the continued use of this habitat typing model and demonstrate that the objective measure utilizing smoothed depth to define habitat is more consistent and less subjective at habitat typing when compared to the commonly used method for the visual identification (Bisson, Nielsen, Palmason, & Grove, 1981) (Hawkins, et al., 1993) (Kaufmann, 1998) of habitat types used in this verification.

Table 16: List of 20 random habitat units verified for habitat type. Habitat ID is the individual habitat unit visually classified for verification. Start and End Track are the StreamView video tracks where the habitat can be viewed, while Start Time, and End Time define the time periods in the StreamView video when these habitat units occurred. Boat indicates which boat the habitat was assessed for (left or right in the downstream direction), while Start Date is the day when the survey occurred.

Habitat ID	Start Track	End Track	Start Time	End Time	Boat	Start Date
10071	111	111	11:57:39	11:58:30	Left	2018-10-03
10110	111	111	12:33:50	12:35:43	Left	2018-10-03
10281	112	112	14:30:07	14:30:57	Left	2018-10-03
10318	113	113	14:55:23	14:55:41	Left	2018-10-03
10484	211	211	11:41:27	11:41:57	Left	2018-10-04
10570	212	212	12:40:46	12:41:55	Left	2018-10-04
10612	212	212	13:02:32	13:04:22	Left	2018-10-04
10682	212	212	13:51:34	13:54:47	Left	2018-10-04
10785	311	311	11:06:58	11:08:09	Left	2018-10-05
10877	311	311	11:52:31	11:53:36	Left	2018-10-05
10879	311	311	11:53:55	11:54:29	Left	2018-10-05
10936	311	311	12:32:38	12:32:58	Left	2018-10-05
20066	121	121	11:57:38	11:58:00	Right	2018-10-03
20128	121	121	12:34:52	12:35:02	Right	2018-10-03
20384	123	123	15:23:36	15:24:27	Right	2018-10-03
20394	123	123	15:32:03	15:32:50	Right	2018-10-03
20567	221	221	11:52:28	11:52:50	Right	2018-10-04
20666	222	222	12:52:06	12:52:58	Right	2018-10-04
20871	321	321	11:12:27	11:13:52	Right	2018-10-05
20884	321	321	11:22:39	11:23:01	Right	2018-10-05

Table 17: List of 20 random habitat units visually classified for habitat type by a blind reviewer. Habitat ID is the individual random habitat unit selected for verification. Model output of habitat type and respective habitat code for each verification are provided as well as the visual classification. Visual Classification 1 is the first choice for the habitat type, while Visual Classification 2 indicates that visual characteristics of a similar habitat type could also be observed. If agreement between the model classification and visual classification occurred, then Correct equals 0.

Habitat ID	Model Habitat Type	Model Habitat Code	Reviewer Habitat Code	Reviewer Visual Classification 1	Reviewer Visual Classification 2	Reviewer Correct =0
10071	1. Riffle	1	1	riffle	shallow shoal	0
10110	4. Pool	4	4	pool	–	0
10281	4. Pool	4	4	pool	deep run	0
10318	4. Pool	4	4	pool	deep run	0
10484	1. Riffle	1	1	riffle	shallow shoal	0
10570	3. Run	3	3	run	pool	0
10612	2. Shoal	2	3	run	–	1
10682	1. Riffle	1	2	shoal	deep riffle	1
10785	3. Run	3	3	run	shallow pool	0
10877	3. Run	3	3	run	shallow pool	0
10879	4. Pool	4	4	pool	–	0
10936	2. Shoal	2	2	shoal	riffle	0
20066	4. Pool	4	4	pool	–	0
20128	2. Shoal	2	2	shoal	–	0
20384	4. Pool	4	4	pool	–	0
20394	4. Pool	4	4	pool	–	0
20567	2. Shoal	2	2	shoal	–	0
20666	3. Run	3	3	run	shallow pool	0
20871	3. Run	3	3	run	Shallow pool	0
20884	2. Shoal	2	2	shoal	–	0

Bottom Roughness

A total of 146,660 roughness values were classified from the combined left and right survey tracks. By definition, 30% of the observations (43,998) were in each of the smooth ($< 0.025\text{m}$) and rough classes ($\geq 0.071\text{m}$) while 40% (58,664 observations) were in the moderately rough category (Table 18). When viewing the roughness data in comparison to the habitat type categories, no major difference appeared among habitat type categories, although riffles appear to have more smooth areas than pools (Figure 38). From a broad perspective looking at the distribution of the average roughness value by habitat unit ordered in a downstream direction, a trend line suggests that bottom roughness varies in a large spatial scale (Figure 39). There appears to be waves in the roughness values trending rougher and then back smoother as you move downstream. Admittedly, this is a visualization of the results and not a statistical test, but the trend line clearly shows the smoother area associated with the Morgan Falls Reservoir, which had the largest proportion of smooth likely due to sedimentation with the reservoir. The visualization also shows that the major shoal areas were rougher than average and this fits with our observations on the water. The use of GIS mapping of both the left and right boat tracks (Figure 40, Figure 41, Figure 42) highlight the effect of sedimentation in the reservoir and other areas along the CHAT. The upstream influence of the reservoir on sedimentation is less defined (Figure 41) when compared to the downstream terminus of the reservoir pool (Figure 42).

Table 18: Attribute values used to determine Roughness Categories

Attribute	Value
Total number of Units (m)	146,660
Number of Units in Analysis (m)	146,660
Median value, Q50 (m)	0.044
Very Rough cutoff $\geq$ Q70 (m)	0.071
Smooth cutoff $<$ Q30 (m)	0.025

The comparison of the automated roughness categorization vs. visual classification supports the categorization process as 80% of sites were consistently classified (Table 19). Many sites were easily classified and in the incorrect cases, the reviewer comments show that it was close between the automated classification and the visual classification with the reviewer always noting that it may be the other value (Table 20). In all cases of disagreement between the reviewer and the model the discrepancies were between consecutive categories, such as smooth and moderately rough or moderately rough and rough, and not non-consecutive categories, such as smooth and rough.

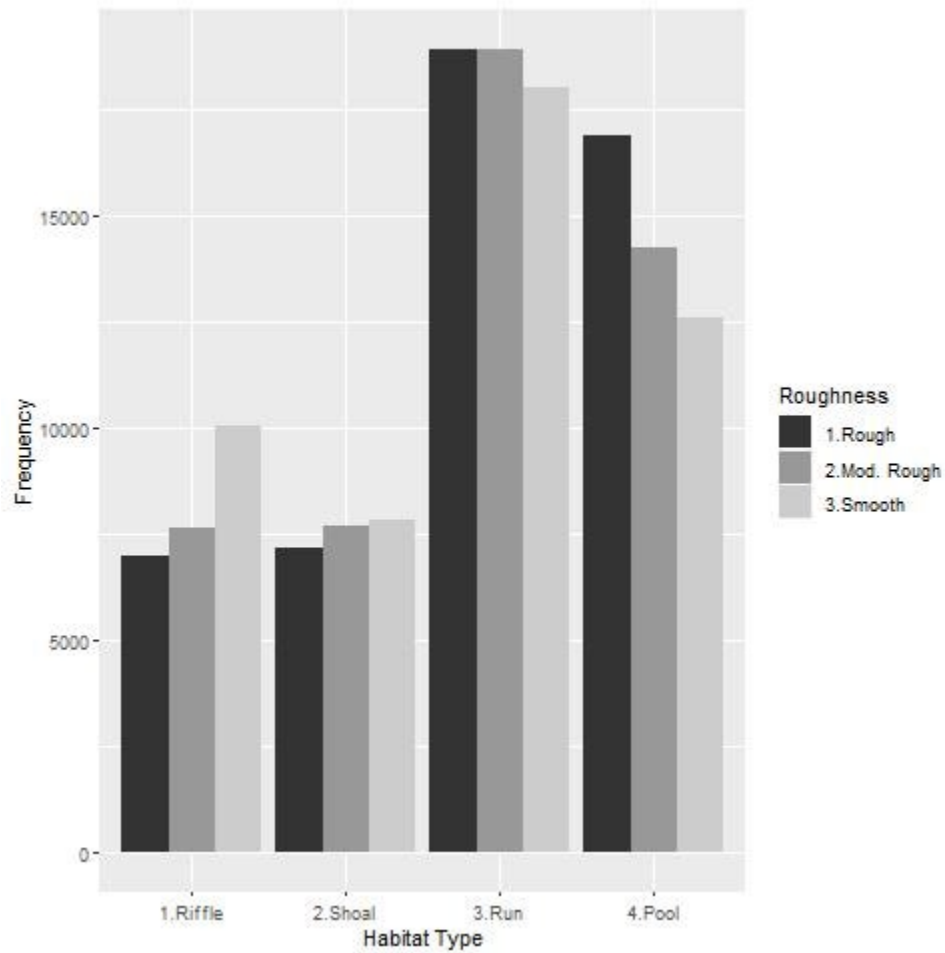


Figure 38: Frequency distribution of roughness values within habitat type categories. Frequency is based on data from both the left and right boat tracks.

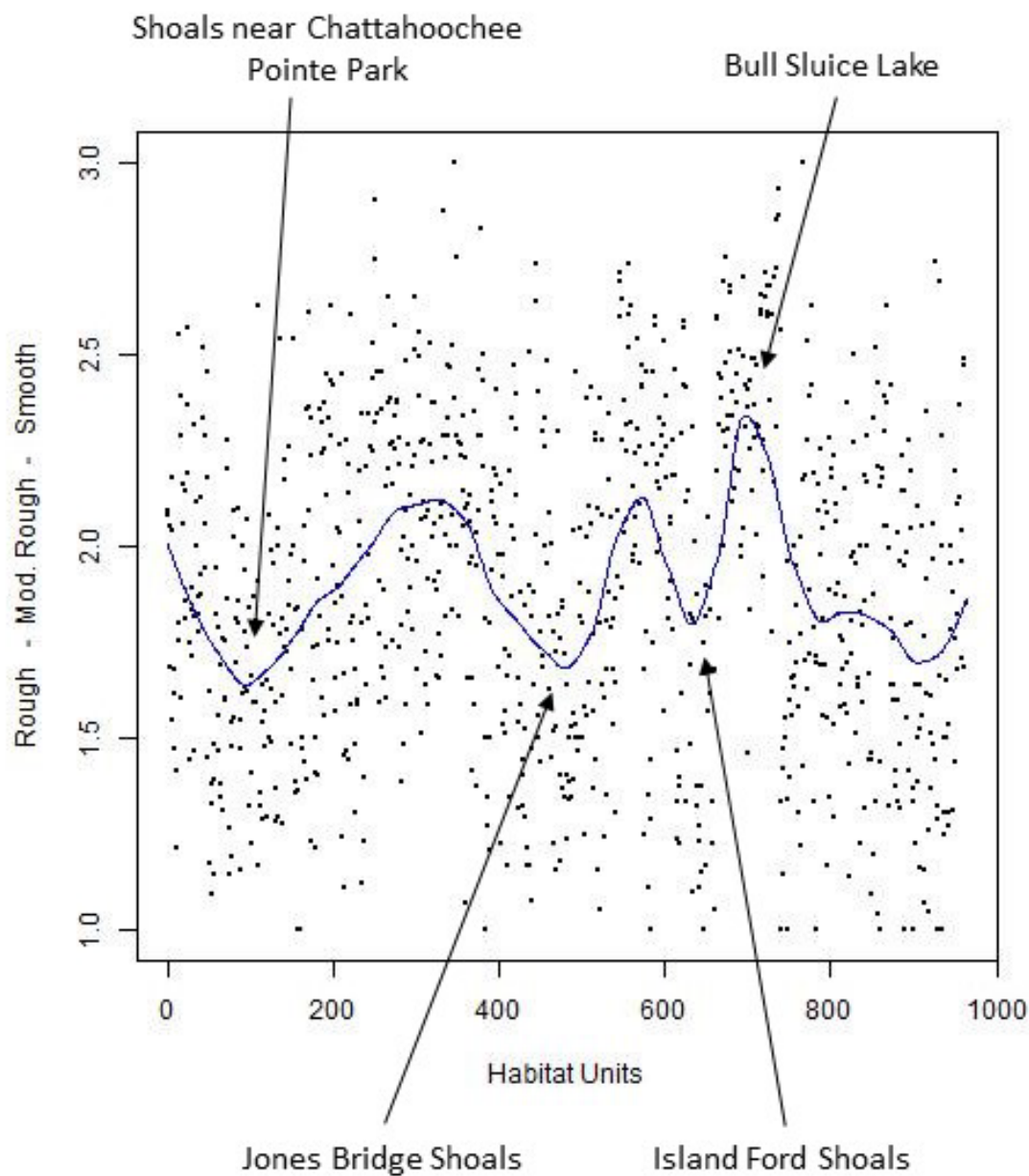


Figure 39: Average roughness by habitat units arranged in a downstream order. 1 is nearly Buford Dam and 963 would be the downstream end of the survey near Paces Mill Park. Additional location references are noted on plot.

Table 19. Attribute and respective values used to during verification process.

Attribute	Value
Random Number Seed	823
Number of Review Sites	20
Number Wrong	4
Accuracy Percent	80%

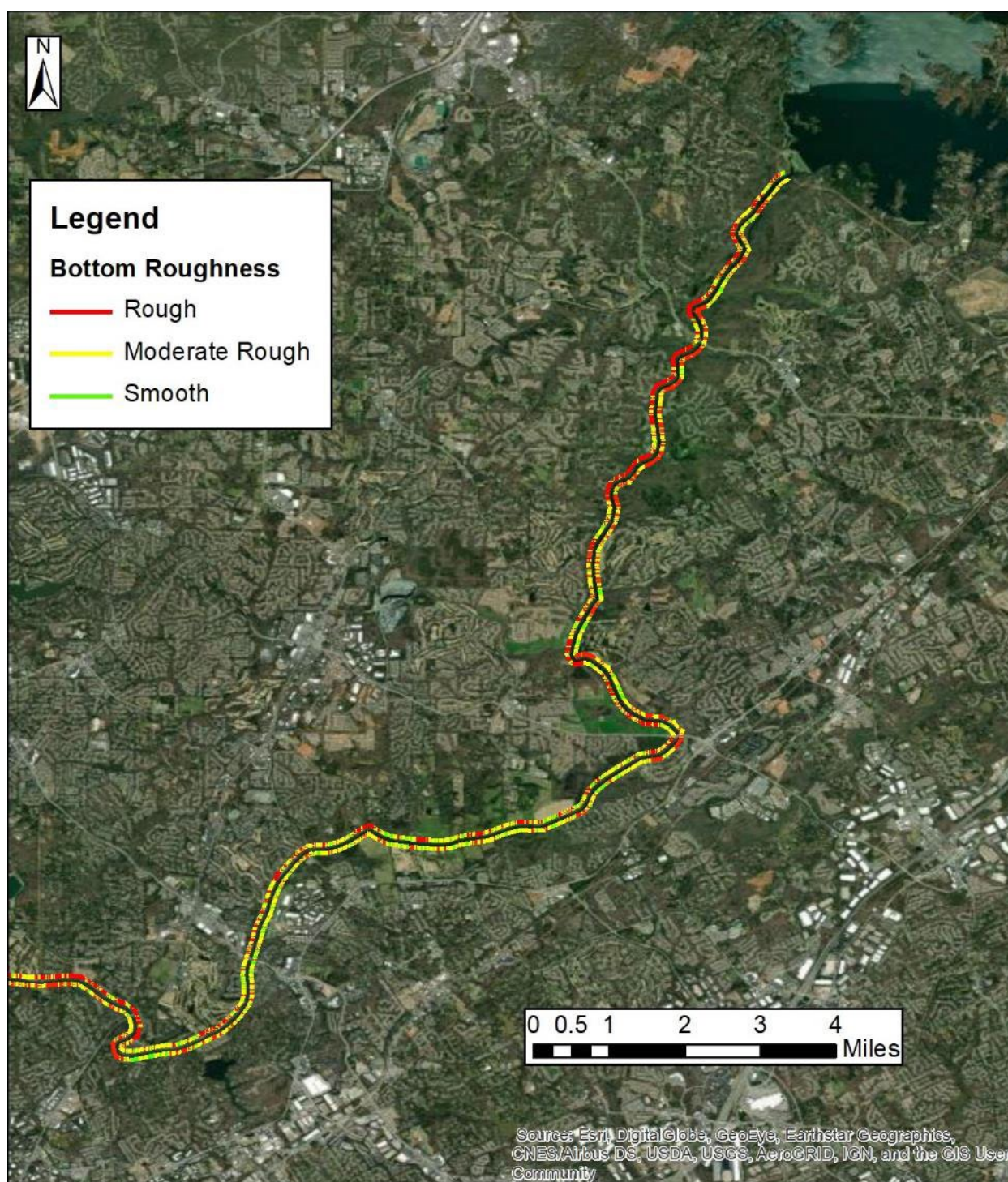


Figure 40: Bottom roughness for both the left and right tracks of the upper section of the Chattahoochee River National Recreation Area.

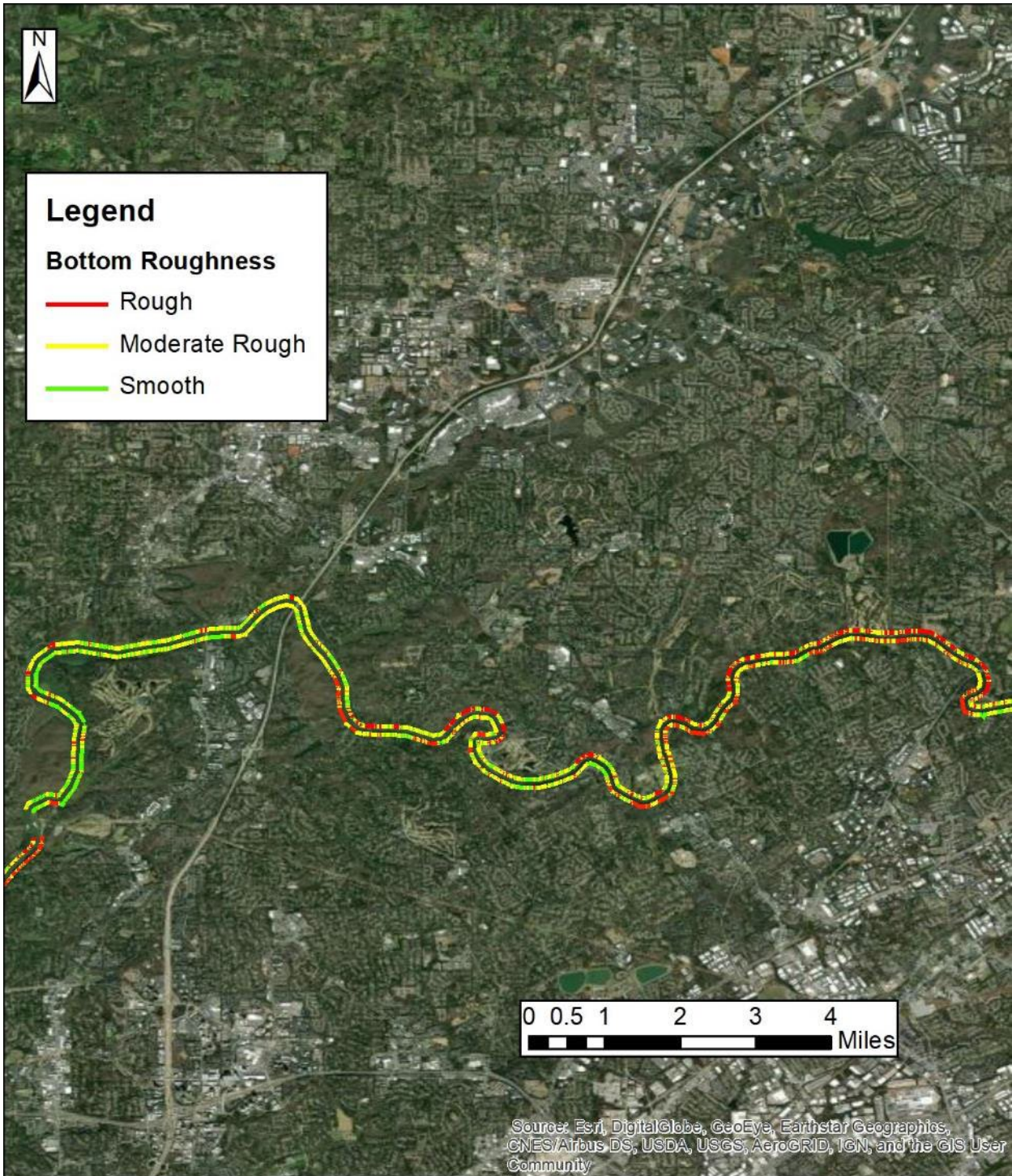


Figure 41: Bottom roughness for both the left and right tracks of the middle section of the Chattahoochee River National Recreation Area.

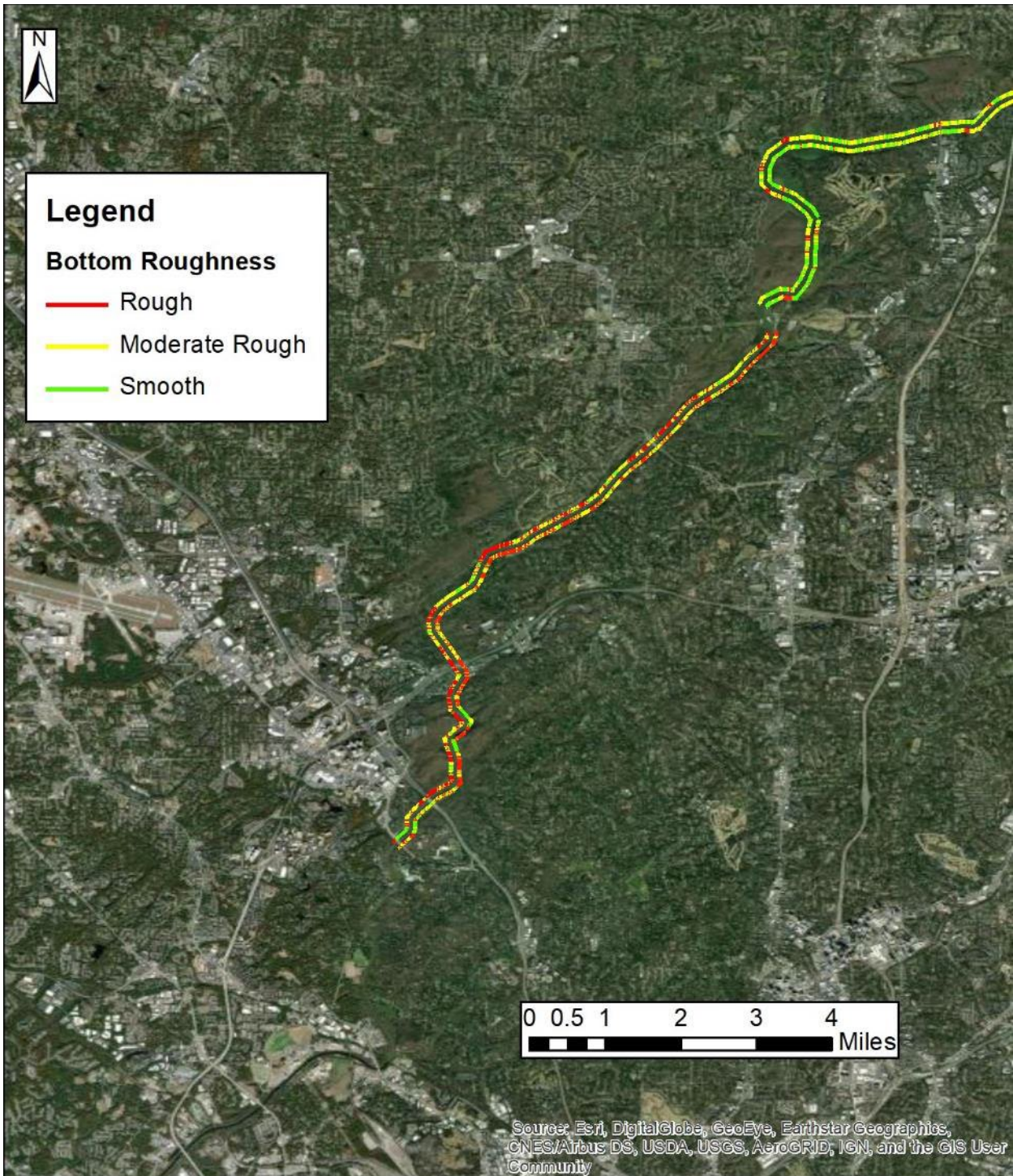


Figure 42: Bottom roughness for both the left and right tracks of the lower section of the Chattahoochee River National Recreation Area.

Table 20: Results of the roughness validation process.

Blind Segment ID	Track	Side	Date	Start Time	End Time	Model prediction Type	Model prediction Code	Visual (reviewer) Code	Visual (reviewer) Comment	Correct = 0
11442	112	Left	2018-10-03	13:18:05	13:18:21	2. Mod. Rough	2	3	maybe mod rough	1
14245	211	Left	2018-10-04	11:15:50	11:16:39	1. Rough	1	1	–	0
14449	211	Left	2018-10-04	11:32:16	11:32:30	1. Rough	1	1	–	0
15668	212	Left	2018-10-04	13:04:41	13:04:52	3.Smooth	3	3	–	0
16263	212	Left	2018-10-04	13:59:42	13:59:52	3.Smooth	3	3	–	0
17015	213	Left	2018-10-04	14:54:46	14:56:09	3.Smooth	3	3	–	0
17639	311	Left	2018-10-05	11:12:55	11:13:06	2. Mod. Rough	2	2	–	0
21530	122	Right	2018-10-03	13:27:45	13:28:01	1 Rough	1	2	maybe rough	1
21560	122	Right	2018-10-03	13:30:06	13:30:27	1 Rough	1	1	second choice Mod. rough	0
21795	122	Right	2018-10-03	13:49:04	13:49:19	2. Mod. Rough	2	2	trending toward smooth	0
21948	122	Right	2018-10-03	13:59:35	13:59:55	3.Smooth	3	3	–	0
22595	123	Right	2018-10-03	14:49:26	14:49:37	2. Mod. Rough	2	2	almost smooth, big sand waves	0
23044	123	Right	2018-10-03	15:18:40	15:19:01	1. Rough	1	1	–	0
23802	221	Right	2018-10-04	10:36:02	10:36:21	1. Rough	1	1	–	0
24654	221	Right	2018-10-04	11:46:58	11:47:14	1. Rough	1	1	–	0
25473	222	Right	2018-10-04	12:47:48	12:47:56	2. Mod. Rough	2	3	has 1 boulder in smooth area	1
25552	222	Right	2018-10-04	12:53:22	12:53:35	1. Rough	1	1	hard, smooth drop into very rough snag	0
26889	223	Right	2018-10-04	14:41:14	14:41:23	1. Rough	1	2	could be 1 - big snag	1
27780	321	Right	2018-10-05	11:15:16	11:15:28	2. Mod. Rough	2	2	Mod rough area, could be smooth area	0
28901	321	Right	2018-10-05	12:41:16	12:41:29	1. Rough	1	1	–	0

Streambank Condition

Streambanks were classified into one of five condition categories. Bank Condition categories represented the extent of impairment (fully functional to non-functional) on the streambank. The majority of the streambanks were functional or fully functional (Figure 43).

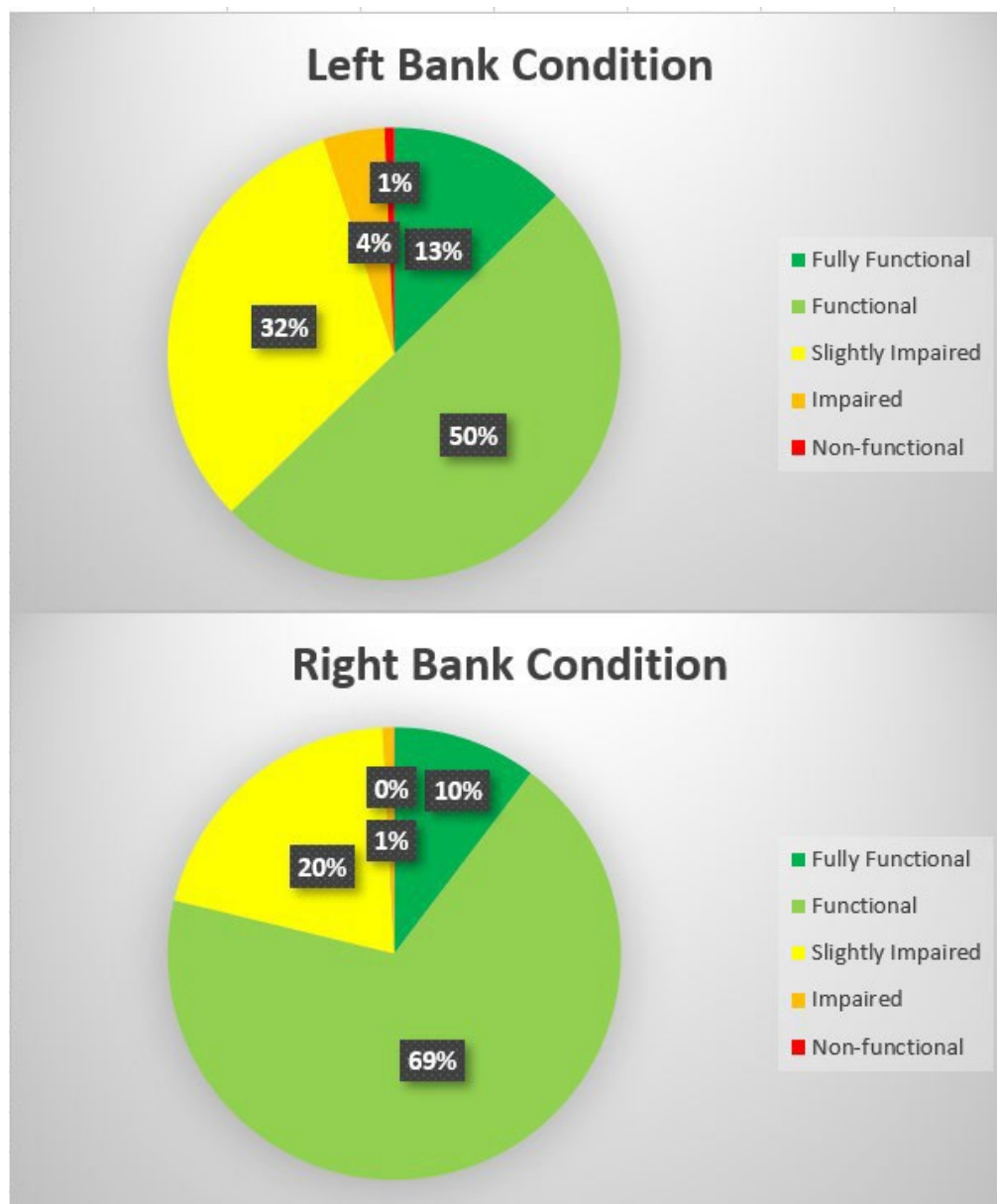


Figure 43: Streambank condition categories and percentages classified on the left (top) and right (bottom) streambank along the Chattahoochee River National Recreation Area.

In general, streambank conditions improved in the downstream direction. The majority of streambanks classified as impaired and non-functional occur in the section immediately downstream of Buford Dam (Figure 45 & Figure 49), followed by the middle section (Figure 46, Figure 50). Bowman's Island is located approximately 1.3 to 2.5km downstream of Buford Dam and had noticeable failing banks. We were not able to pass to both sides of the island, so the downstream left bank represents conditions observed on the island. Overall, we were able to pass around 3 small islands and 4 large islands during the survey. The greatest concentration of fully functional streambanks was along the Morgan Falls Reservoir portion of the CHAT.

Maps of left and right track streambank condition are shown in figures:

Left Bank:

- Full survey area - Figure 44
- Upstream survey area - Figure 45
- Middle survey area - Figure 46
- Downstream survey area - Figure 47

Right Bank:

- Full survey area - Figure 48
- Upstream survey area - Figure 49
- Middle survey area - Figure 50
- Downstream survey area - Figure 51

The comparison of the bank condition classification vs. second reviewer's visual classification supports the categorization process as 90% of sites were consistently classified (Table 21). Many sites were easily classified and in the incorrect cases, the reviewer comments show that it was close between the both classification with the reviewer commenting that it may be the other value (Table 22). In all cases of disagreement between the reviewer and the model the discrepancies were between consecutive categories, such as functional (2) to slightly impaired (3) and not between non-consecutive categories, such as functional (2) to impaired (4). Overall, we saw good agreement between the independent visual classifications.

Table 21. Attribute and respective values used to during verification process.

Attribute	Value
Random Number Seed	22
Number of Review Sites	20
Number Wrong	2
Accuracy Percent	90%

Table 22: Results of the bank condition validation process.

Unit ID	Track	Side	Start Time	End Time	Classification Code	Review Code	Review Comment
8	111	Left	2018-10-03T11:12:50	2018-10-03T11:16:00	3	3	can see a moderate peak discharge scar, but much of the bank is stable
31	111	Left	2018-10-03T12:01:44	2018-10-03T12:07:01	2	2	maybe 3 as it is stable but can see a high vertical bank in back.
39	111	Left	2018-10-03T12:17:56	2018-10-03T12:22:47	3	3	clear signs of impairment, but mostly vegetated, would go 4 next
47	111	Left	2018-10-03T12:41:44	2018-10-03T12:42:26	4	4	bad condition, but has some protection from fallen trees and vegetation
49	111	Left	2018-10-03T12:43:03	2018-10-03T12:47:02	2	2	banks vegetated, mostly intact trees, cut bank in back.
50	112	Left	2018-10-03T12:47:54	2018-10-03T12:48:48	4	4	tall cut bank, some trees, but lots of fallen trees
56	112	Left	2018-10-03T12:57:07	2018-10-03T12:58:08	4	4	tall cut bank, some trees, but lots of fallen trees
57	112	Left	2018-10-03T12:58:26	2018-10-03T12:59:26	2	3	maybe 2, but still pretty tall bank, vegetated with some issues
67	112	Left	2018-10-03T13:11:13	2018-10-03T13:13:01	2	2	similar to last site but better condition, maybe 3
157	211	Left	2018-10-04T11:29:35	2018-10-04T11:30:16	2	2	good area in between worse areas
166	211	Left	2018-10-04T11:56:58	2018-10-04T11:58:53	2	2	pretty good but some issues, maybe 3
180	211	Left	2018-10-04T12:15:33	2018-10-04T12:19:08	2	2	solid 2, few issues
199	212	Left	2018-10-04T12:56:03	2018-10-04T13:01:04	2	3	maybe 2, but human impact leans me to 3
211	212	Left	2018-10-04T13:53:11	2018-10-04T13:59:20	2	2	would trend toward 1 but for few issues
237	311	Left	2018-10-05T12:31:00	2018-10-05T12:45:39	2	2	good with slight erosion issues
239	311	Left	2018-10-05T12:46:20	2018-10-05T12:47:04	2	2	good condition after riprap bridge
260	121	Right	2018-10-03T11:49:27	2018-10-03T11:50:30	1	1	riprap area in perfect condition. Not likely to erode.
308	122	Right	2018-10-03T13:27:39	2018-10-03T13:28:33	4	4	bad area with lots of fallen trees
434	223	Right	2018-10-04T14:37:41	2018-10-04T14:38:18	3	3	active development area with erosion control in place, hard to score.
443	321	Right	2018-10-05T11:26:26	2018-10-05T11:27:31	2	2	pretty good with a few human and other impacts

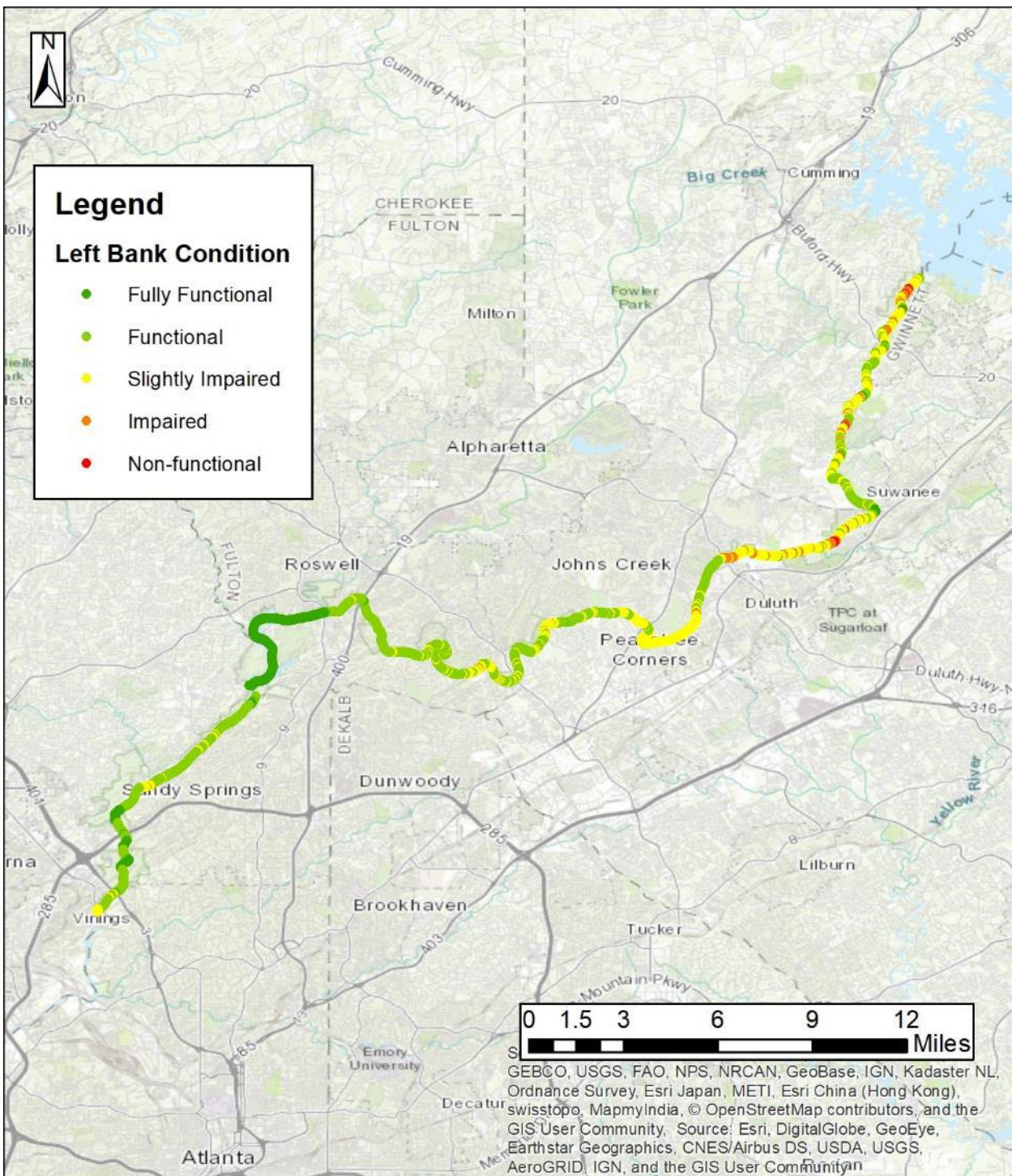


Figure 44: Left Bank Condition score for the entire Chattahoochee River National Recreational Area.

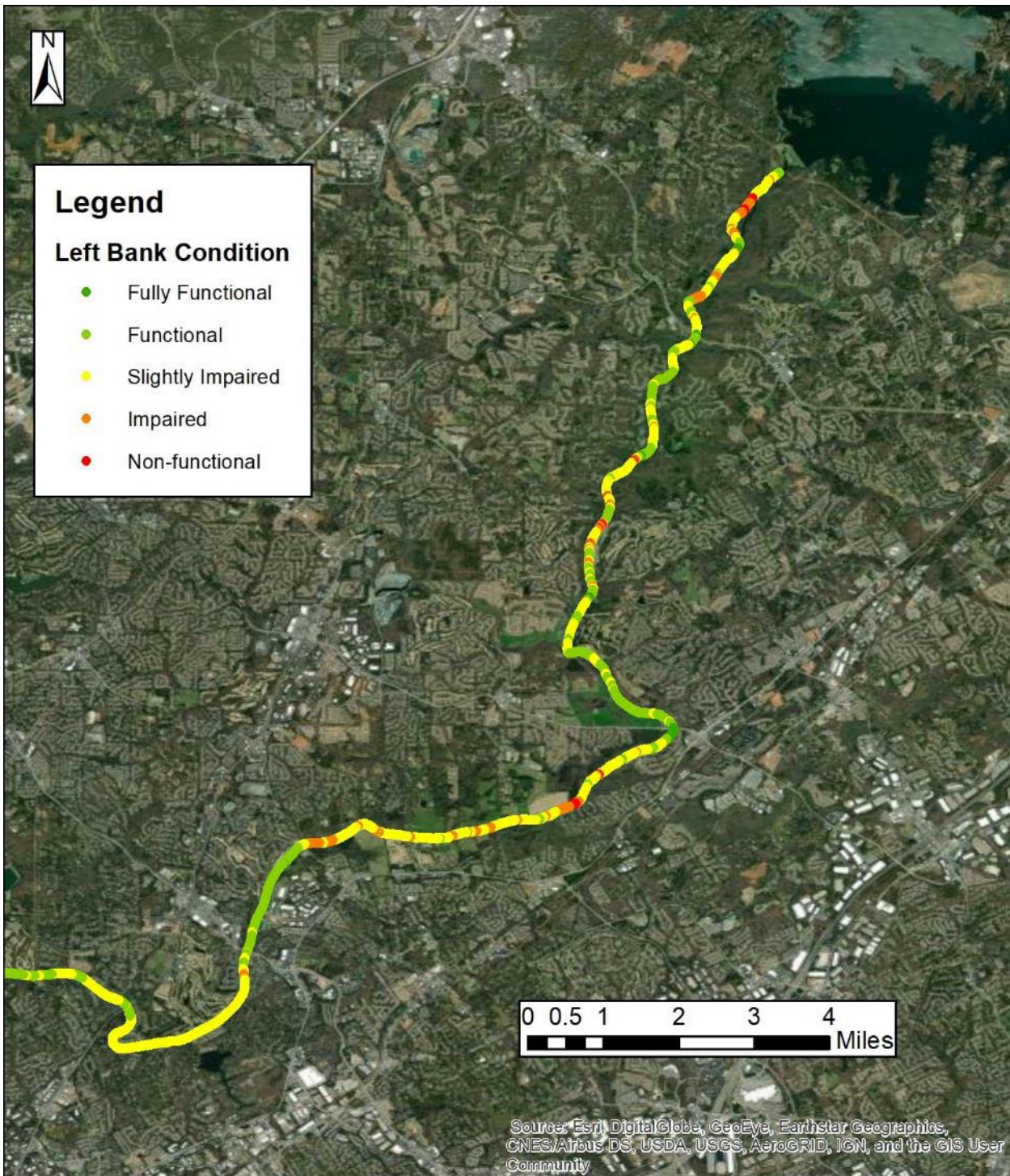


Figure 45: Left Bank Condition score for the upstream section of the Chattahoochee River National Recreational Area.

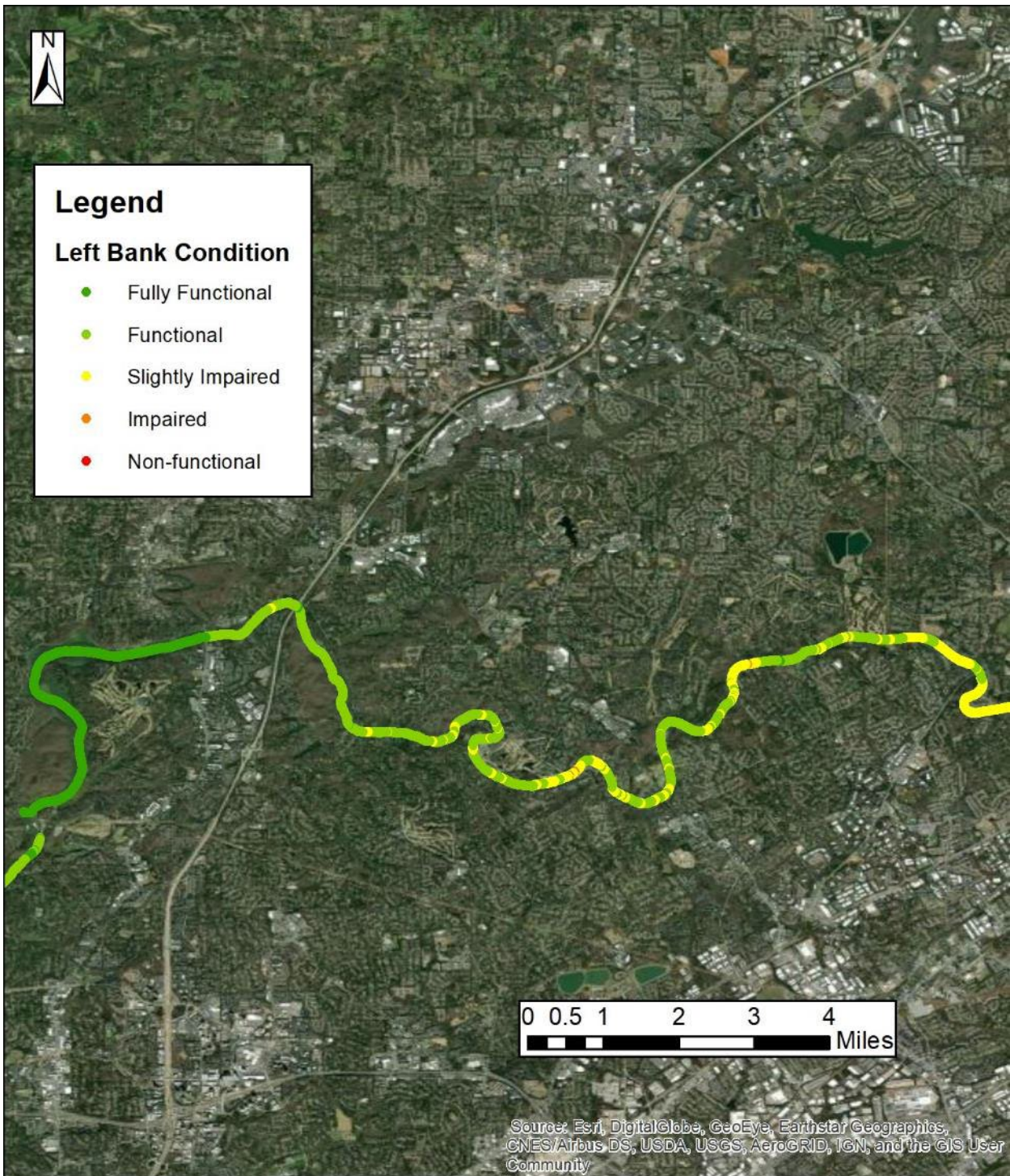


Figure 46: Left Bank Condition score for the middle section of the Chattahoochee River National Recreational Area.

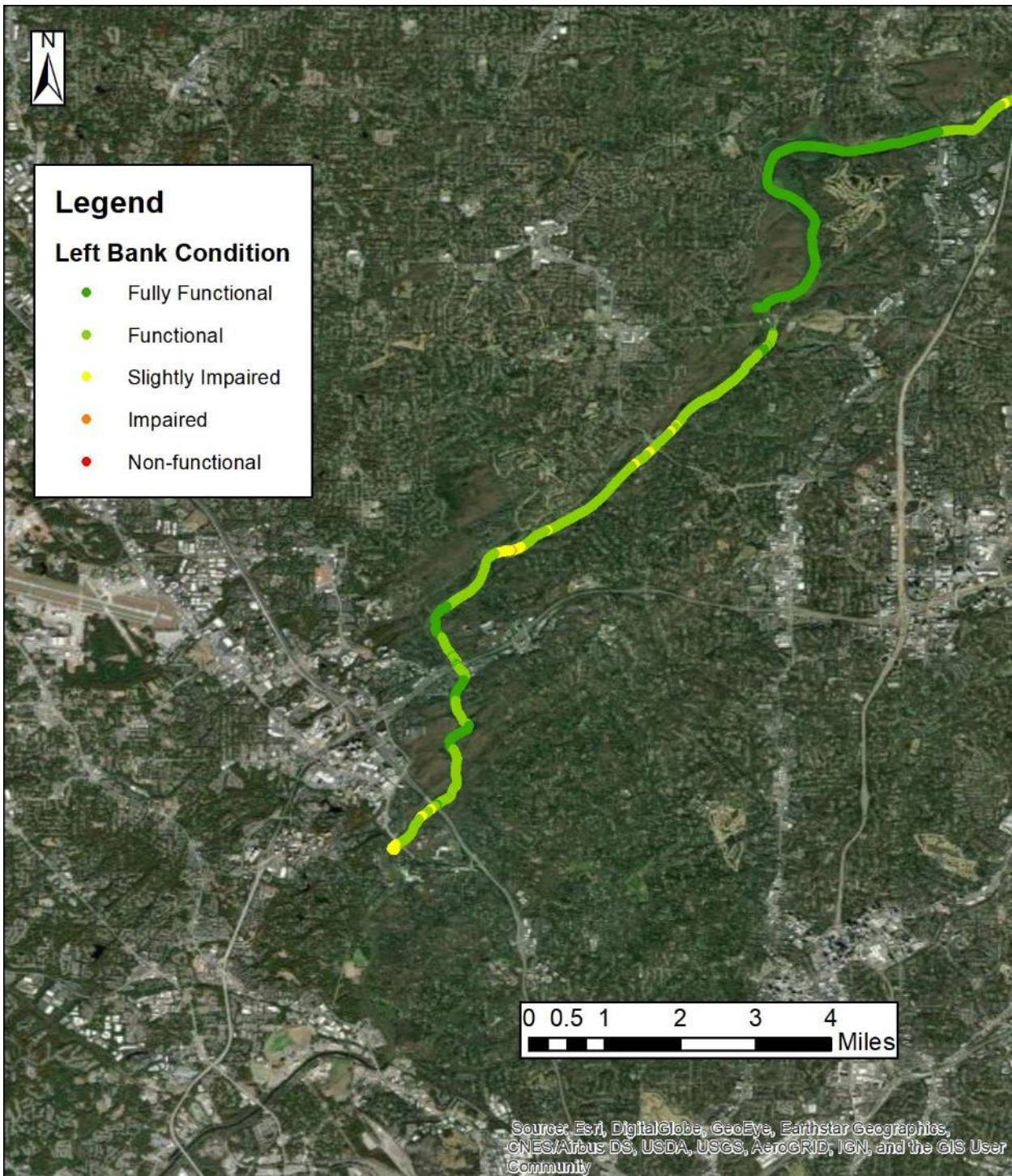


Figure 47: Left Bank Condition score for the downstream section of the Chattahoochee River National Recreational Area.

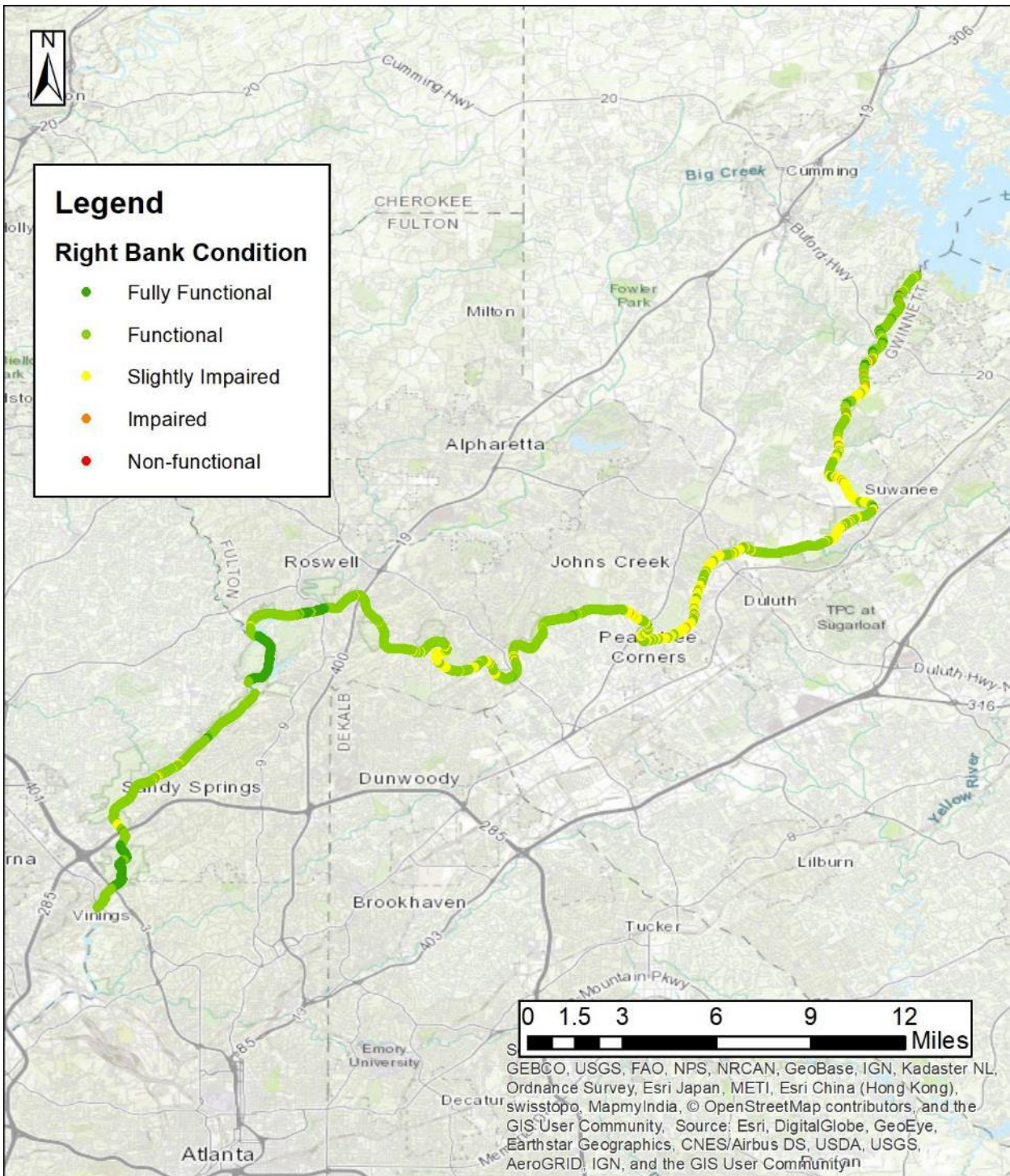


Figure 48: Right Bank Condition score for the entire Chattahoochee River National Recreational Area.

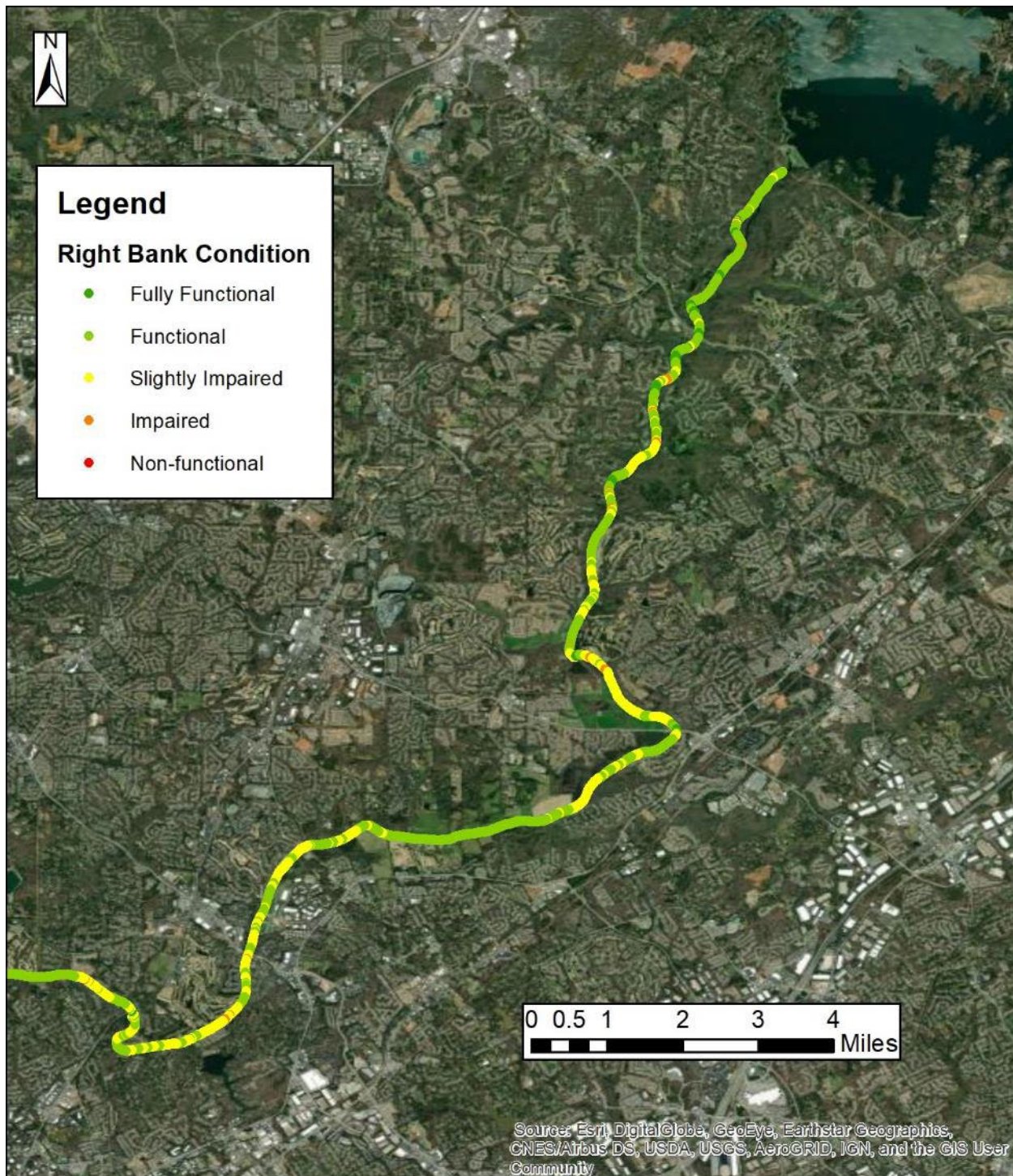


Figure 49: Right Bank Condition score for the upstream section of the Chattahoochee River National Recreational Area.

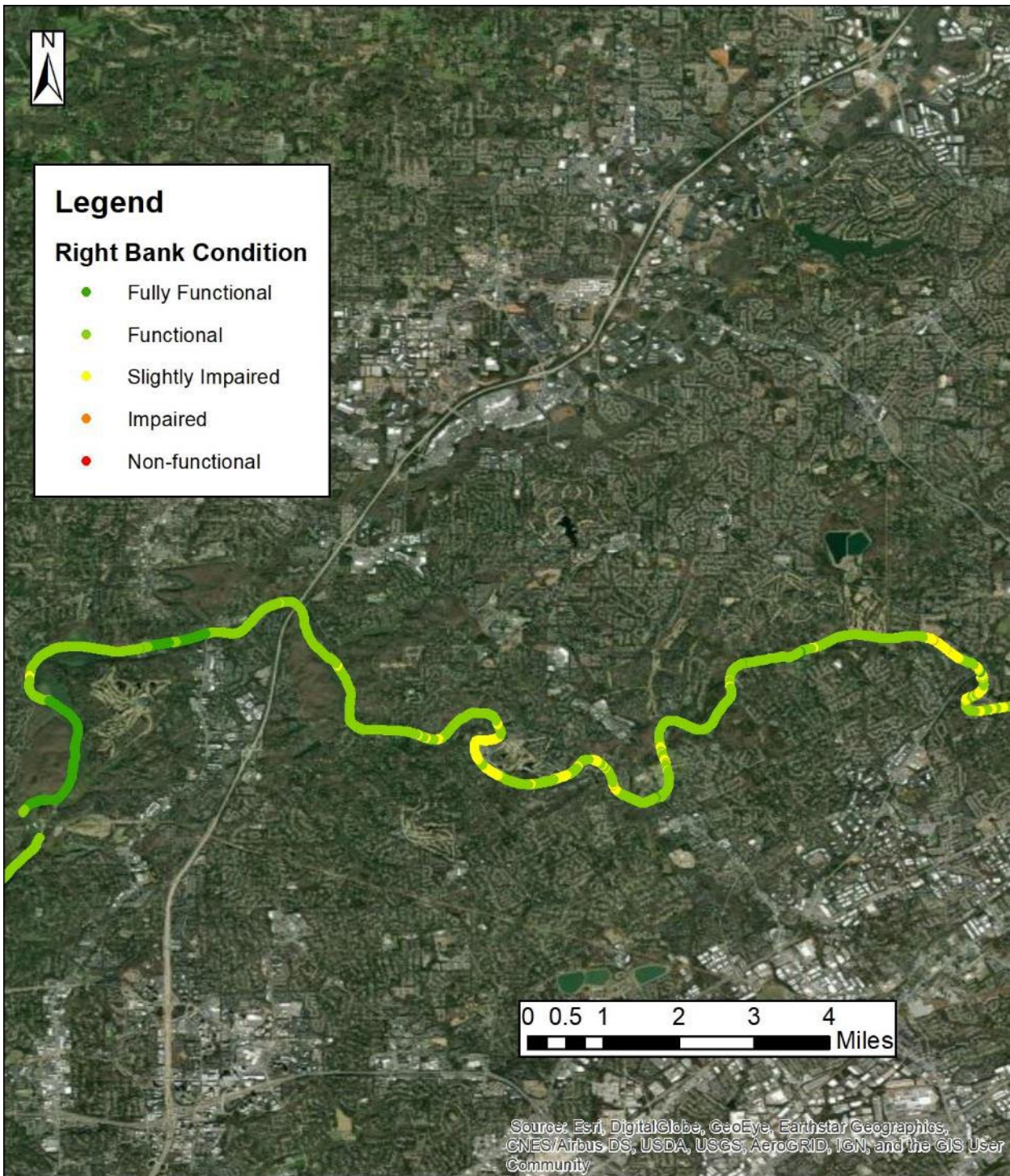


Figure 50: Right Bank Condition score for the middle section of the Chattahoochee River National Recreational Area.

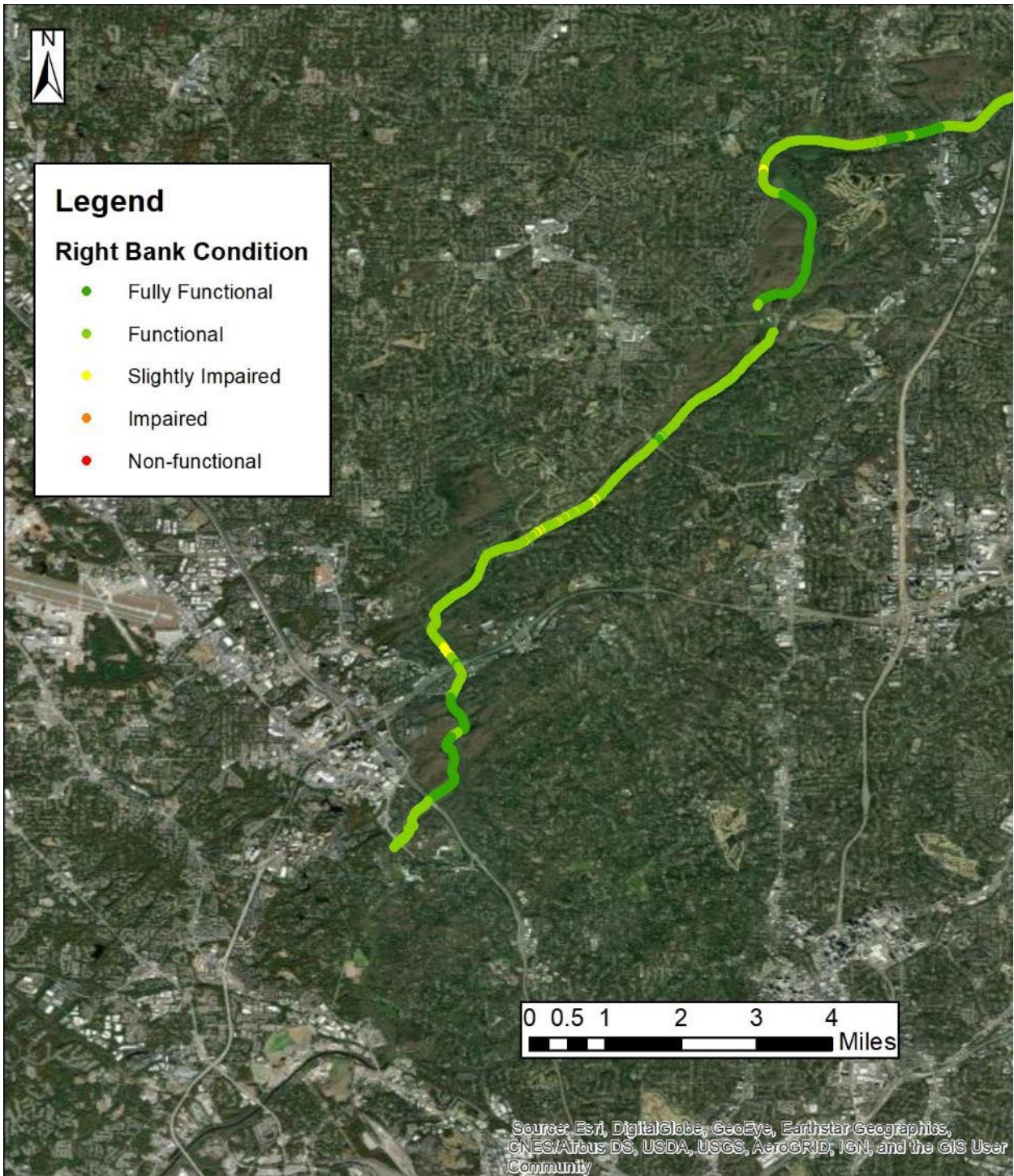


Figure 51: Right Bank Condition score for the downstream section of the Chattahoochee River National Recreational Area.

20 Most Degraded 200-m Segments of Streambank Condition

Another objective of the project was to rank the top twenty most degraded 200-meter segments on left and right streambank and identify the five worst tributary confluences. Determining locations with the most degraded conditions may allow managers to better plan for improvement of the failing riverbanks and decrease riverbank sedimentation along CHAT.

Streambank condition data was averaged into 200 m segments with the intent to view larger areas with degraded conditions to help facilitate identification of problem areas. Table 23 provides the 200m ranking, location of segment downstream from Buford Dam and the average bank condition for both the left and right streambanks. Images of the top 4 worst sites are provided in Figure 52, Figure 53 and Figure 54 as examples of the results of this ranking. A total of 20 sites were provided for the left bank segments and 32 segments for the right bank, as many segments were tied with a score of 3 (slightly impaired). Interestingly, only one area scored as impaired to non-functional. This area was located on the right bank near river km 17.2 (Table 23). This is a positive finding as many rivers we have surveyed in the Southeastern US have much more extensive bank erosion issues. None of the most degraded 200m segments were found downstream of Morgan Falls Dam.

The use of the 200m average may have obscured some of the smaller segments of highly degraded riverbanks. While this was intentionally done to located larger areas that may be more appropriately sized for restoration actions, it is likely that some smaller areas were not represented as a result. As an example of how the continuous HDSS data may be resorted to answer different questions, we selected all continuous segments greater than 30m in length with scores in the impaired (4) and non-functional (5) categories. A total of 29 riverbank segments resulted from this unique data query covering over 2 km of riverbank with an average length of 69m (Table 24). This suggests that the 200m criteria may be too large along CHAT.

Table 23: Ranking for the river segments in most need of management concern. Twenty segments are provided for the left bank due to ties in Average Left Bank Condition Scores among segments.

Left Streambank 200m Segment Rank	Left Streambank River km from Buford Dam	Left Streambank Average Bank Condition	Right Streambank 200m Segment Rank	Right Streambank River km from Buford Dam	Right Streambank Average Bank Condition
1	17.2	4.63	1	26.4	3.36
2	1	4.39	2	12.8	3.34
3	1.2	4.32	3	7.0	3.29
4	9.2	4.28	4	12.4	3.24
5 (Tie)	3.4	4.00	5	30.6	3.09
5 (Tie)	17.4	4.00	6	30.4	3.07
5 (Tie)	22.2	4.00	7	39.2	3.02
8	22	3.71	8 (Tie)	7.6	3.00
9	16.4	3.61	8 (Tie)	10.2	3.00
10	9.6	3.59	8 (Tie)	13.0	3.00

Left Streambank 200m Segment Rank	Left Streambank River km from Buford Dam	Left Streambank Average Bank Condition	Right Streambank 200m Segment Rank	Right Streambank River km from Buford Dam	Right Streambank Average Bank Condition
11	1.8	3.53	8 (Tie)	13.2	3.00
12	18.8	3.52	8 (Tie)	13.4	3.00
13	20.8	3.51	8 (Tie)	13.6	3.00
14	21.8	3.49	8 (Tie)	13.8	3.00
15	8.6	3.46	8 (Tie)	14.4	3.00
16	1.4	3.44	8 (Tie)	16.6	3.00
17	7.6	3.42	8 (Tie)	16.8	3.00
18	19	3.41	8 (Tie)	17.0	3.00
19	2.8	3.39	8 (Tie)	17.2	3.00
20	40.4	3.33	8 (Tie)	22.6	3.00
–	–	–	8 (Tie)	23.0	3.00
–	–	–	8 (Tie)	23.2	3.00
–	–	–	8 (Tie)	25.2	3.00
–	–	–	8 (Tie)	26.2	3.00
–	–	–	8 (Tie)	26.6	3.00
–	–	–	8 (Tie)	26.8	3.00
–	–	–	8 (Tie)	27.6	3.00
–	–	–	8 (Tie)	40.6	3.00
–	–	–	8 (Tie)	42.0	3.00
–	–	–	8 (Tie)	42.6	3.00
–	–	–	8 (Tie)	42.8	3.00
–	–	–	8 (Tie)	43.0	3.00

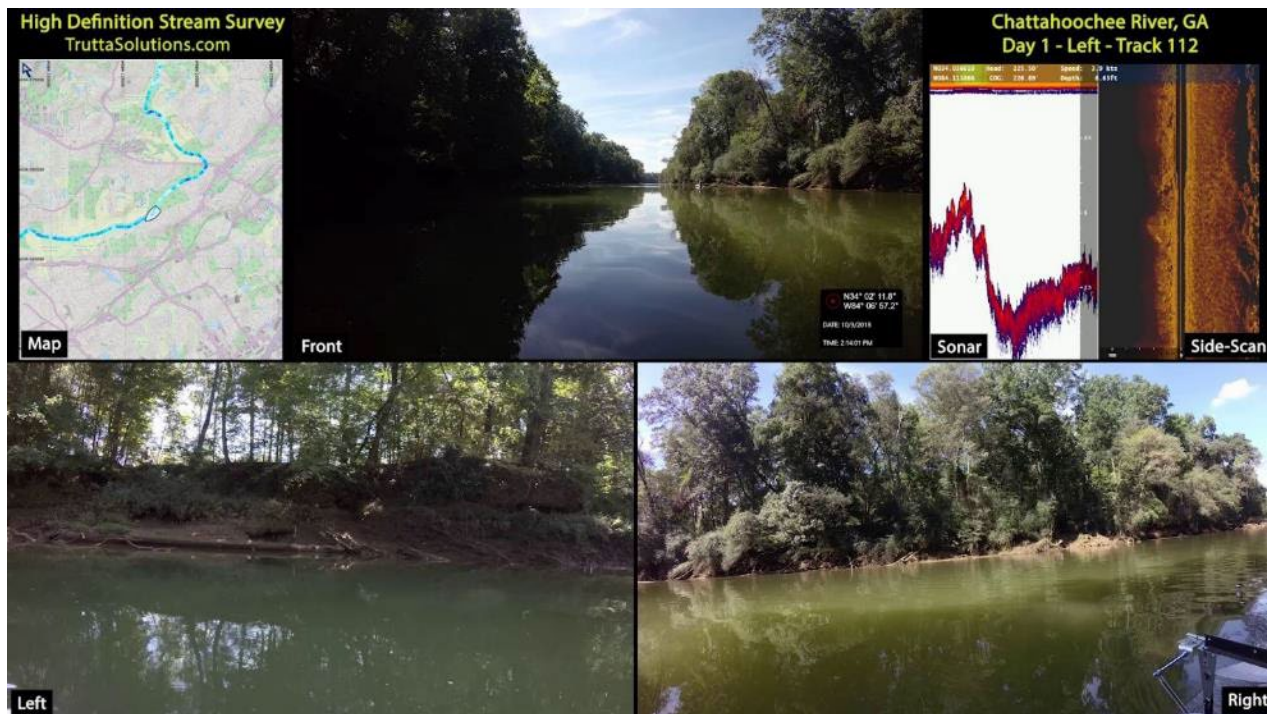


Figure 52: Image of number 1 worst area on left bank of the Chattahoochee River near river kilometer 17.2.



Figure 53: Example of image of second and third worst areas (a continuous segment of 400m) on left bank of the Chattahoochee River near river kilometer 1.0 and 1.2.

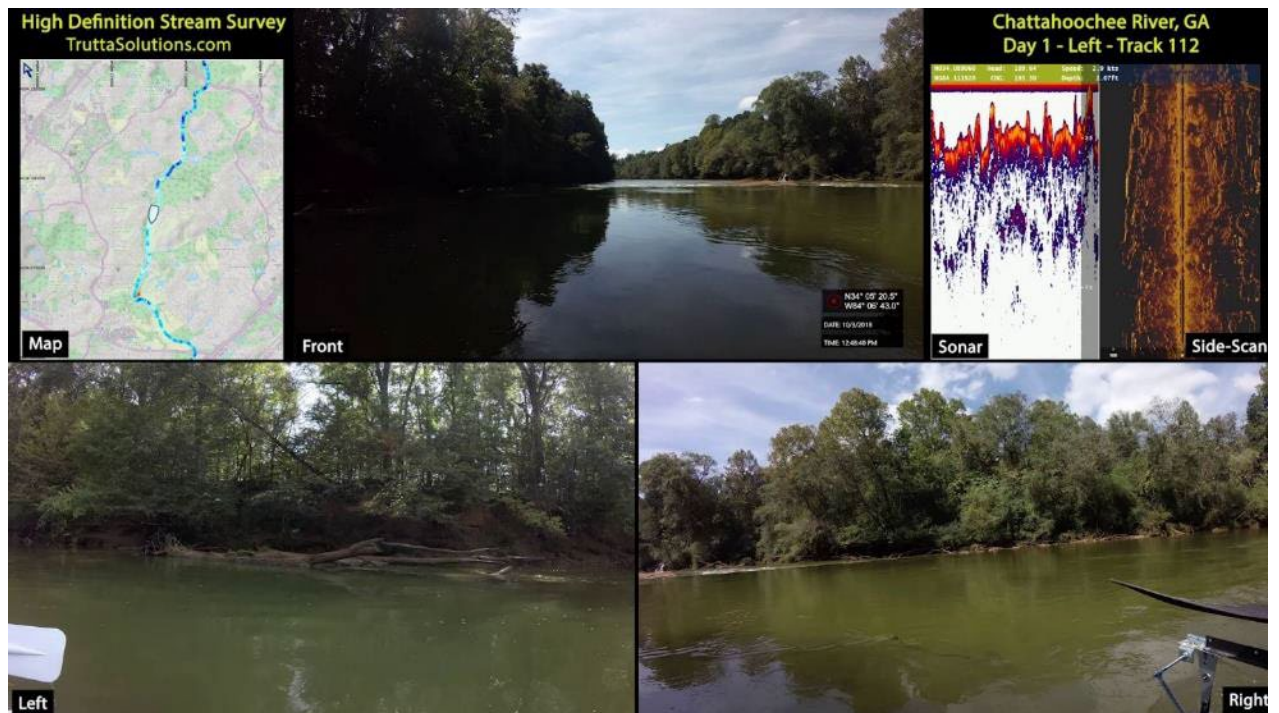


Figure 54 : Image of forth worst area on left bank of the Chattahoochee River near river kilometer 9.2.

Table 24: Results for segments greater than 30m in length scoring 4 or 5 for degraded bank condition.

Track	Side	Start Date and Time	End Date and Time	Bank Condition Score	Length (m)
111	Left	2018-10-03T11:08:27	2018-10-03T11:10:36	4	130
111	Left	2018-10-03T11:11:16	2018-10-03T11:12:49	4	94
111	Left	2018-10-03T11:16:01	2018-10-03T11:16:33	4	33
111	Left	2018-10-03T11:17:09	2018-10-03T11:19:00	4	98
111	Left	2018-10-03T11:32:47	2018-10-03T11:34:00	4	74
111	Left	2018-10-03T11:37:47	2018-10-03T11:40:04	4	138
111	Left	2018-10-03T12:41:44	2018-10-03T12:42:26	4	43
112	Left	2018-10-03T12:47:54	2018-10-03T12:48:48	4	54
112	Left	2018-10-03T12:48:57	2018-10-03T12:49:33	4	36
112	Left	2018-10-03T12:52:54	2018-10-03T12:53:29	4	36
112	Left	2018-10-03T12:57:07	2018-10-03T12:58:08	4	62
112	Left	2018-10-03T13:07:14	2018-10-03T13:08:14	4	61
112	Left	2018-10-03T14:13:50	2018-10-03T14:14:26	4	37
112	Left	2018-10-03T14:15:53	2018-10-03T14:18:12	4	140
112	Left	2018-10-03T14:29:29	2018-10-03T14:30:31	4	63
112	Left	2018-10-03T14:31:56	2018-10-03T14:32:52	4	57
112	Left	2018-10-03T14:36:20	2018-10-03T14:37:03	4	44
113	Left	2018-10-03T14:57:34	2018-10-03T14:59:01	4	89
113	Left	2018-10-03T14:59:34	2018-10-03T15:01:46	4	133
113	Left	2018-10-03T15:29:44	2018-10-03T15:30:37	4	54
121	Right	2018-10-03T12:20:39	2018-10-03T12:21:11	4	32
122	Right	2018-10-03T13:19:29	2018-10-03T13:19:59	4	31
122	Right	2018-10-03T13:27:39	2018-10-03T13:28:33	4	55
122	Right	2018-10-03T13:38:53	2018-10-03T13:39:38	4	46
123	Right	2018-10-03T15:25:59	2018-10-03T15:26:34	4	35
123	Right	2018-10-03T15:35:27	2018-10-03T15:37:38	4	132
111	Left	2018-10-03T11:07:15	2018-10-03T11:08:26	5	72
111	Left	2018-10-03T11:10:37	2018-10-03T11:11:15	5	39
112	Left	2018-10-03T14:14:27	2018-10-03T14:15:52	5	84

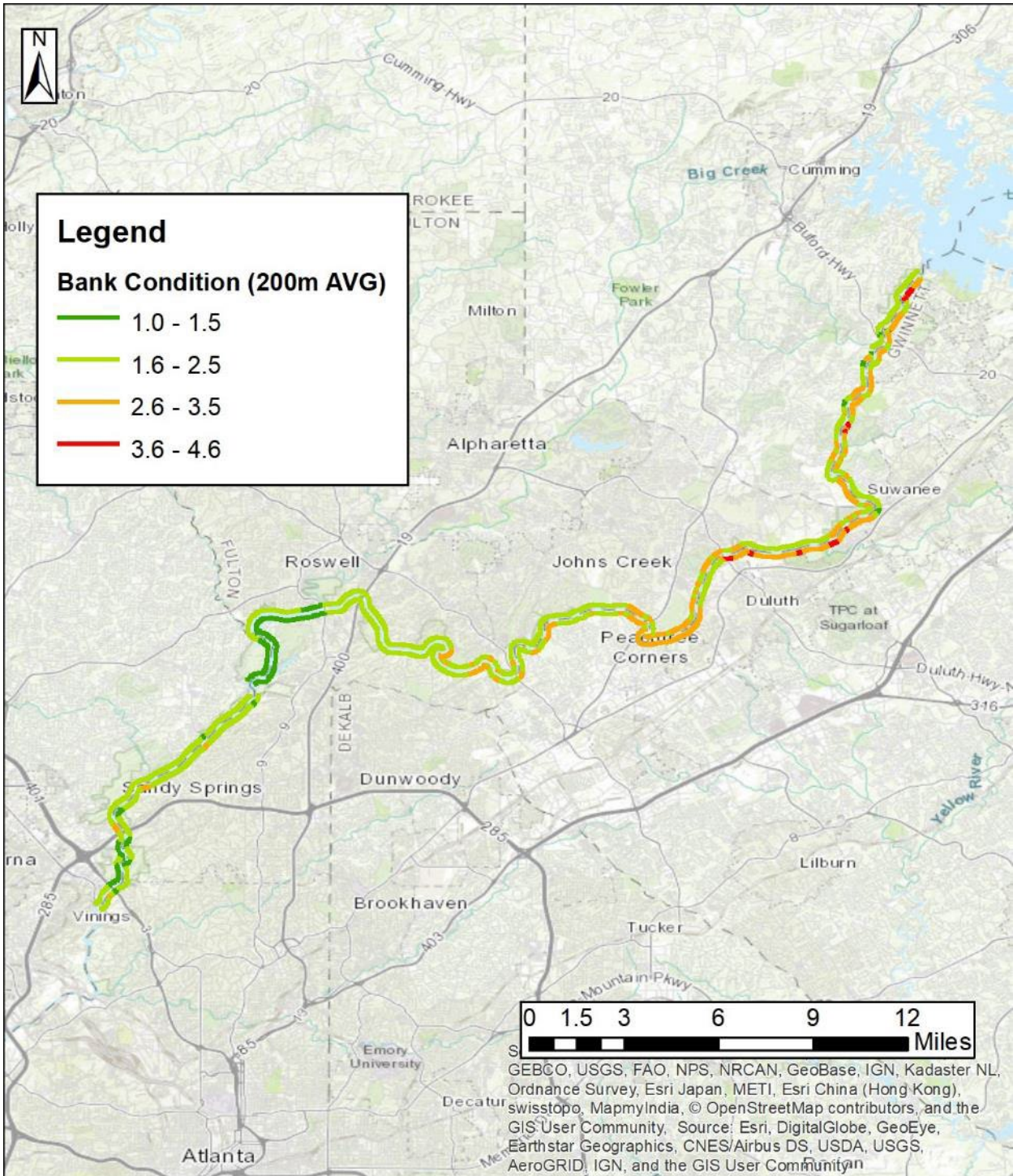


Figure 55: Average 200-m Bank Condition Areas from the HDSS results for the Chattahoochee River.

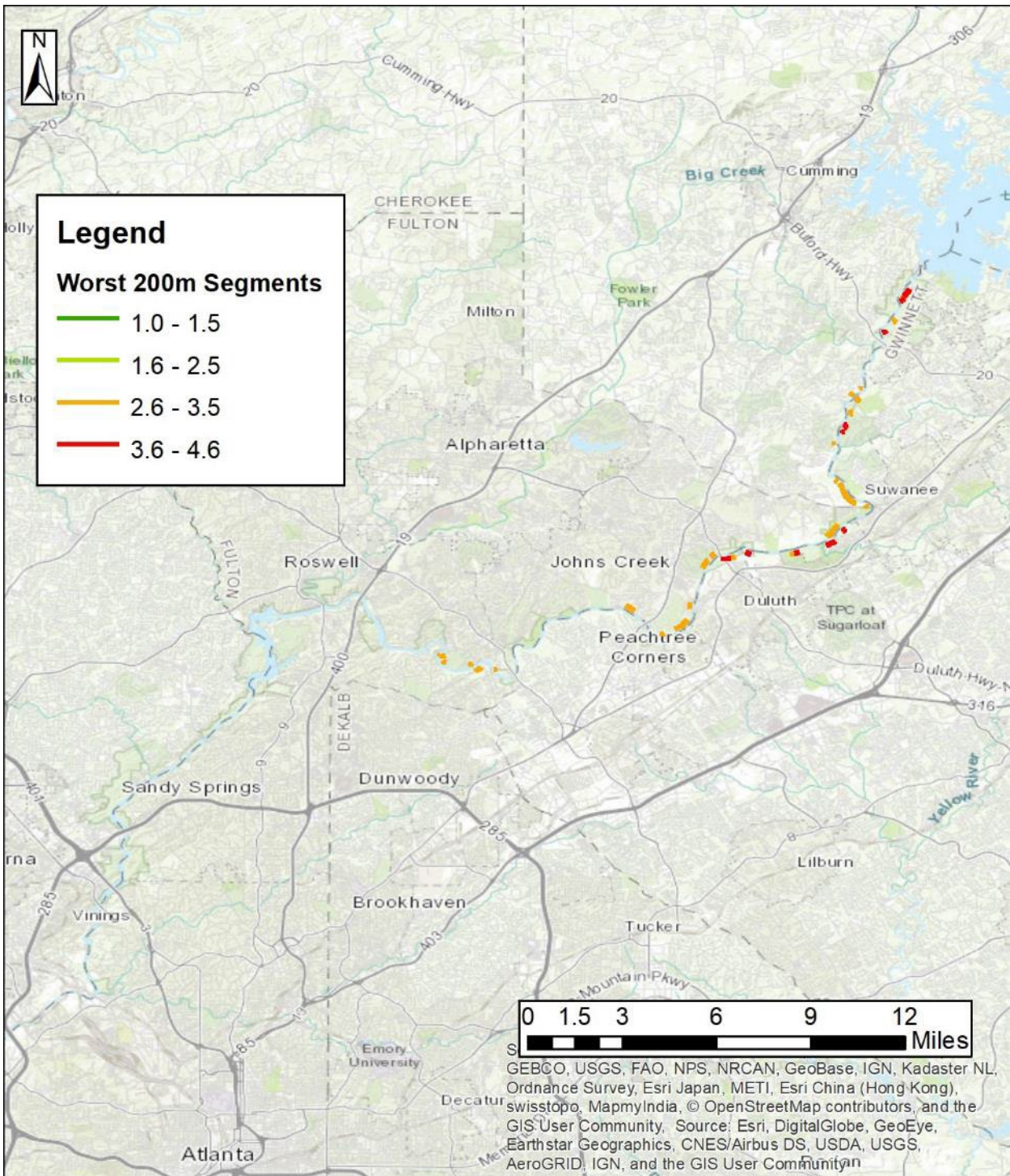


Figure 56: Worst Bank Condition Areas from the HDSS results for the Chattahoochee River National Recreation Area.

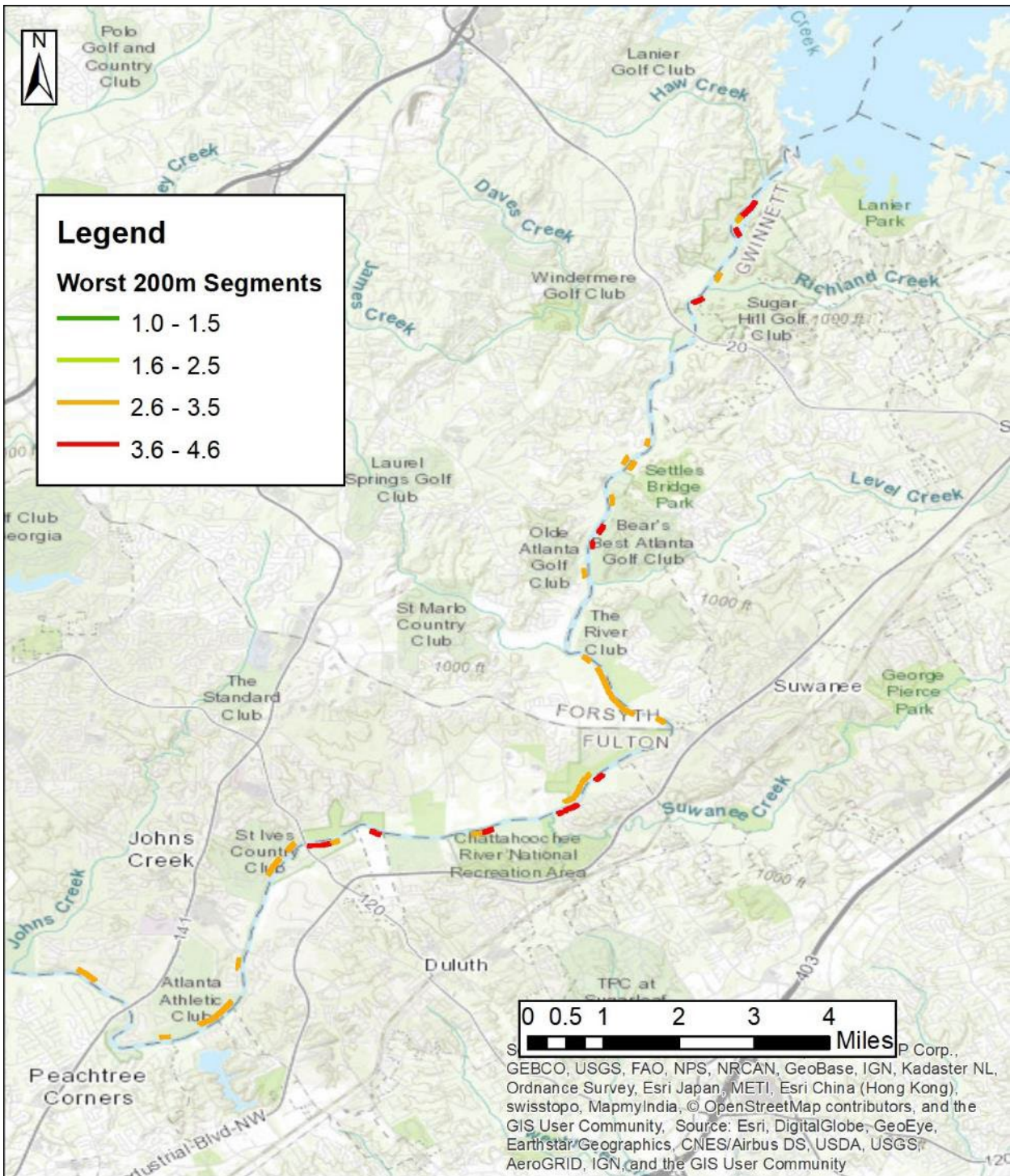


Figure 57: Worst Bank Condition Areas from the HDSS results for the upper survey section of the Chattahoochee River National Recreation Area.

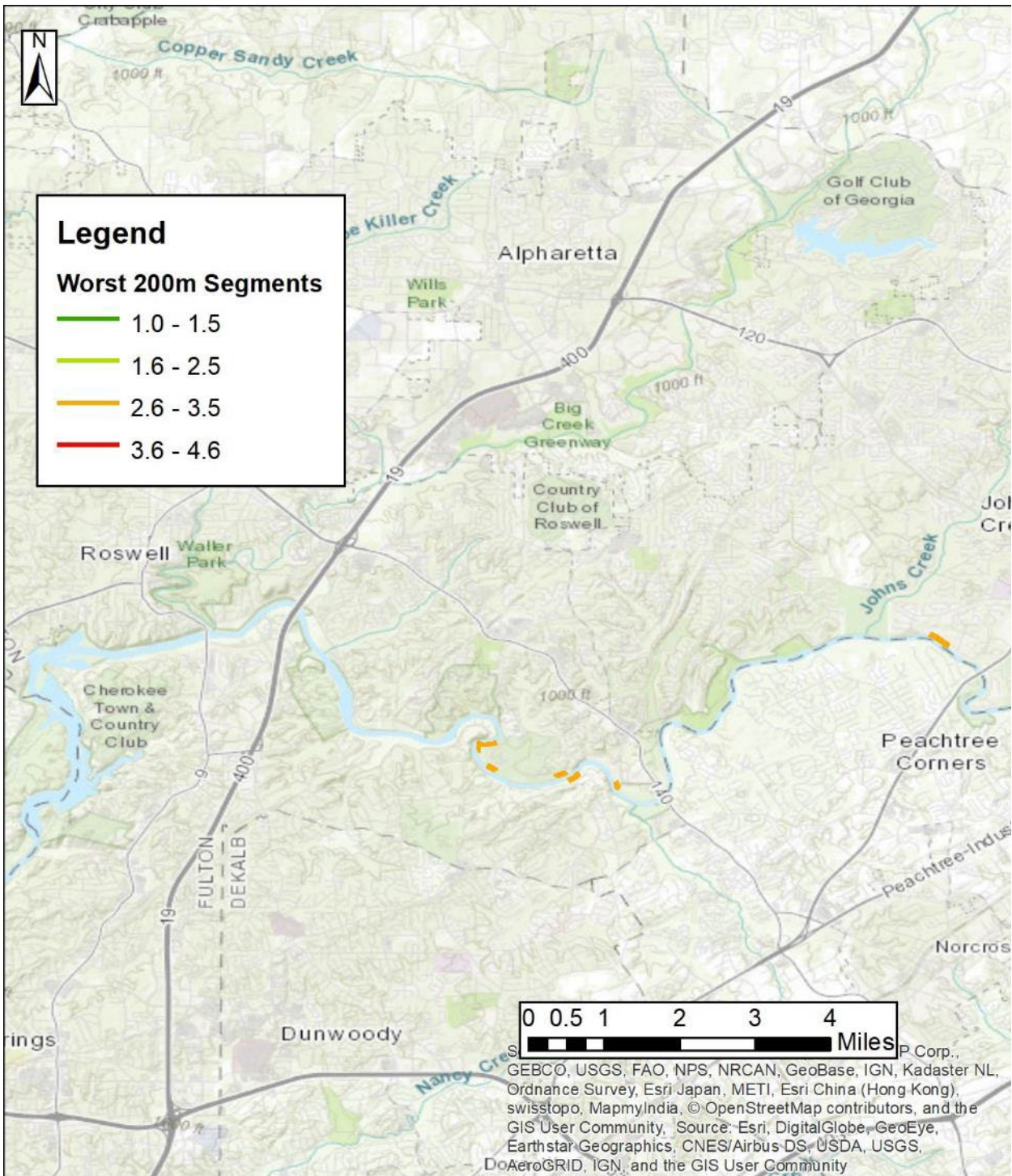


Figure 58: Worst Bank Condition Areas from the HDSS results for the middle survey section of the Chattahoochee River National Recreation Area.

5 Most Degraded Tributary Confluences

To rank and prioritize the confluences of perennial tributaries with the Chattahoochee River along CHAT, the StreamView video was used to visually assess each confluence. Perennial streams, as defined in the National Hydrography Dataset (NHD) as FCode 46006, were the focus of this classification. A number of intermittent streams and artificial flowpaths were included as some seemingly large streams were not included in the perennial stream designation (Figure 59). The visual assessment required the scoring of three individual stream metrics that included: 1) streambank condition of the tributary visible from the mainstem of the Chattahoochee River; 2) estimated abundance of LWD at the tributary confluence; and 3) size and scope of sediment bars deposited into the mainstem from the tributary. Bank Condition was scored using the methods described previously in this report. The abundance of LWD was scored as an estimate of the number of fallen trees with a diameter greater than 6 inches. The LWD score was (1) minor (0 to 2 LWD), (2) moderate (3-7 LWD) and severe (≥ 8 LWD). Sediment bars were assessed based on the combination of length and width of the bar relative to the wetted width of tributary mouth (Figure 60). Sediment bars were scored on a scale of minor (1) to severe (3). Not applicable (i.e., NA) was also used where our professional judgement could not be used due to limited/poor visibility of a confluence area. It is important to note that the confluence condition assessment was based on information seen from the HDSS StreamView of the mainstem Chattahoochee River.

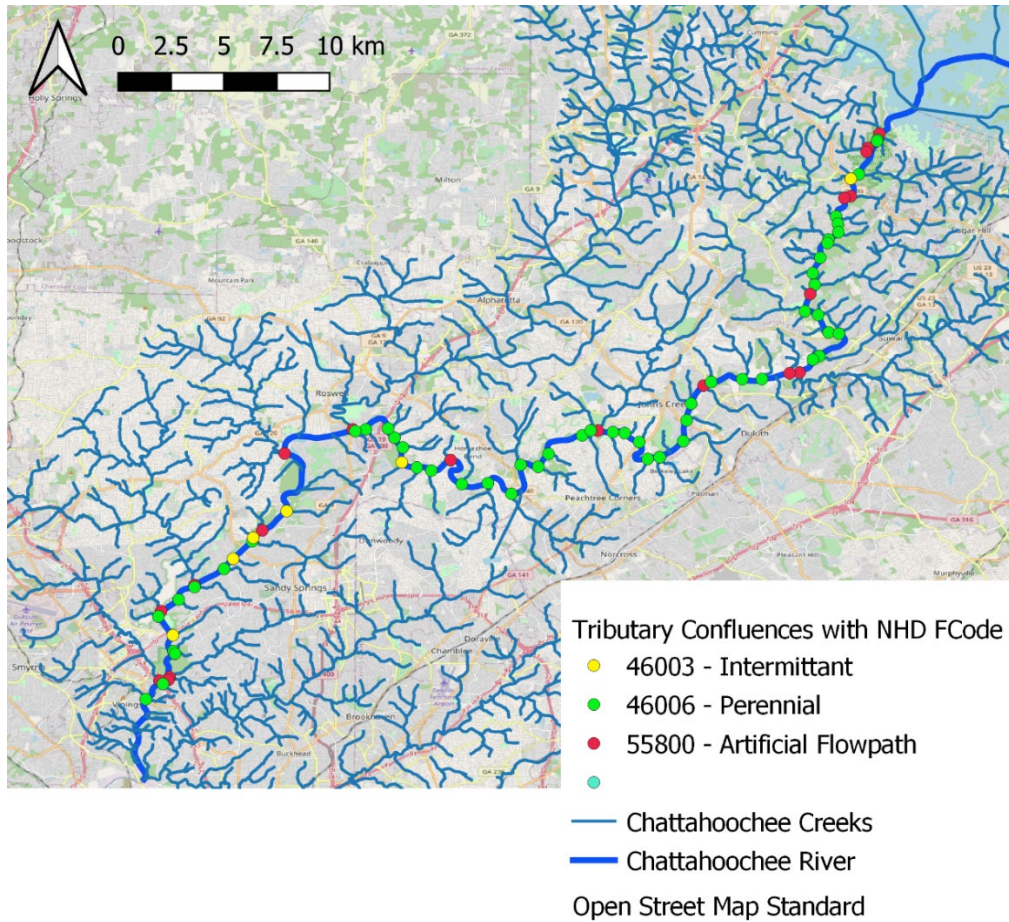


Figure 59: Location of the tributary confluences with their NHD flow status code.

Sedimentation	Parameter	Severity		
		Minor	Moderate	Severe
In-channel bars	Width	< 25% of channel width affected	> 25% but < 75% of channel affected	≥ 75% of channel width affected
	Length	< 2 x wetted width	3–9 x wetted width	> 10 x wetted width

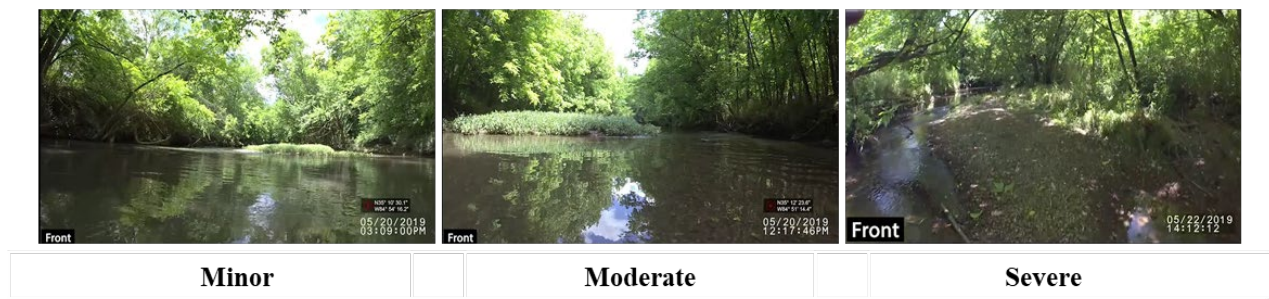


Figure 60: Criteria for classification of sediment bar severity with examples. Note images are not from the Chattahoochee River survey but are standard examples of the rating process.

A total of 77 tributaries were reviewed, and scores were provided for 63 tributaries based on the visible streambank condition of the incoming tributary and the severity of sediment bars and LWD. Fourteen tributaries were not scored due to poor/limited visibility of the confluence area from the mainstem of the Chattahoochee River. Of the 63 streams assessed, 42 were classified as perennial streams, 17 as artificial flowpaths, and 4 were intermittent streams. The total score, which is the sum of the three individual scores of tributary streambank condition, and severity of sediment bars and LWD, for all 63 ranked tributaries ranged for 4-10. The top-5 most degraded tributary confluences had combined values ranging between 8-10 (**Table 25**) and include Crayfish Creek, Dick Creek, Haw Creek, Richland Creek, and Brushy Creek (**Figure 61**, **Figure 62**, **Figure 63**, and **Figure 64**). It is evident that highly variable flows from hydropower-peaking discharges out of Buford Dam is having a negative effect on the tributary's confluences along the Chattahoochee River. When viewing the results by date, as a surrogate of distance from Buford Dam, scores showed a decreasing trend each day supporting the idea that the hydropower-peaking discharges were having greater impact in closer proximity to the dam (**Figure 66**). This is also supported by the distribution of scores when mapped on the river (**Figure 67**). When viewing the data by flow status (i.e., intermittent, perennial, or artificial flow path) as reported in the NHD dataset for FCode, no real trend was apparent (**Figure 68**). The lower scores for intermittent tributaries may be the result of their smaller overall impact on the main river channel. Individual tributary assessments are necessary to determine the upstream extent of these impacts on each tributary.

Table 25: Top 5 worst tributary confluences based on the total combined scored of streambank condition of the tributary and severity of LWD and sediment bars in the immediate area of the confluence. Additionally, tributary name, date, time, video track number, and individual scores for tributary bank condition, sediment bar, and LWD are provided.

Tributary	Date	Time	Video Track	Tributary Streambank Condition	Sediment Bar Severity	LWD Severity	Total Score
Crayfish Creek	10/3/2018	11:52:59	111	5	3	2	10
Dick Creek	10/3/2018	13:19:43	122	5	2	2	9
Haw Creek	10/3/2018	11:00:50	121	5	1	3	9
Richland Creek	10/3/2018	11:35:43	111	5	2	1	8
Brushy Creek	10/3/2018	14:06:04	112	5	2	1	8



Figure 61: Confluence of Crayfish Creek and Chattahoochee River along the CHAT. Left streambank image enlarged from Track 111 at 11:52:59 recorded on October 3, 2018.



Figure 62: Confluence of Dick Creek and Chattahoochee River along the CHAT. Right streambank image enlarged from Track 121 at 11:00:50 recorded on October 3, 2018.



Figure 63: Confluence of Haw Creek and Chattahoochee River along the CHAT. Right streambank image enlarged from Track 122 at 13:19:43 recorded on October 3, 2018.



Figure 64: Confluence of Richland Creek and Chattahoochee River along the CHAT. Right streambank image enlarged from Track 111 at 11:35:43 recorded on October 3, 2018.



Figure 65: Confluence of Brushy Creek and Chattahoochee River along the CHAT. Right streambank image enlarged from Track 112 at 14:06:04 recorded on October 3, 2018.

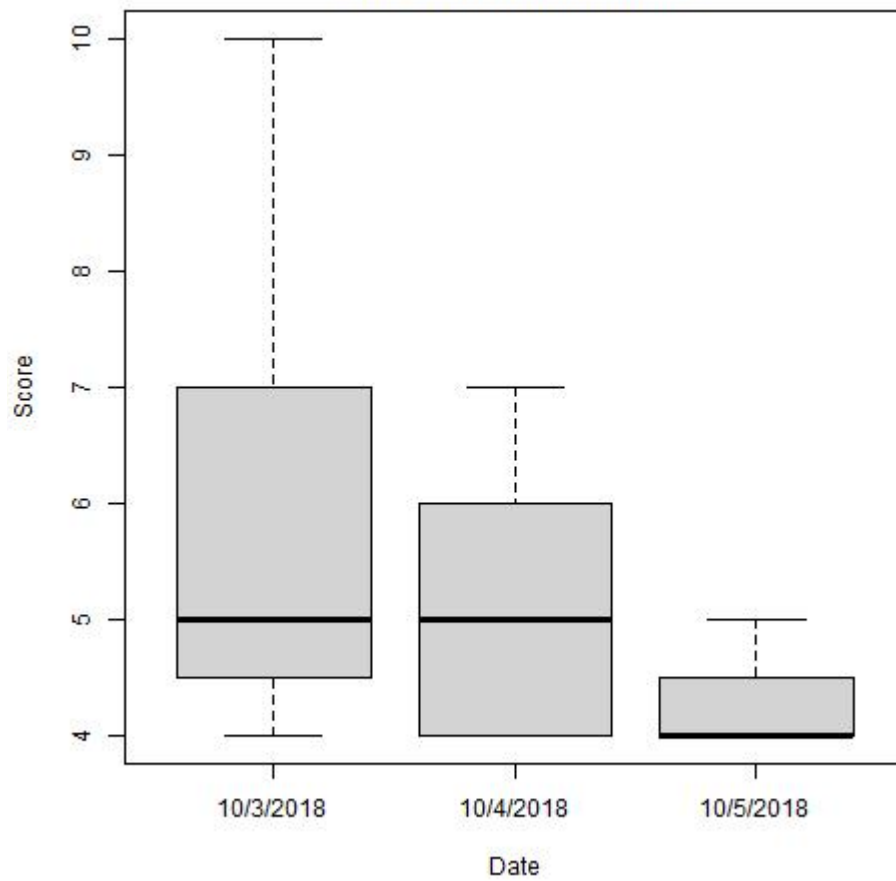


Figure 66: Boxplot of survey date vs. Tributary Score. A higher score indicates a poorer overall condition.

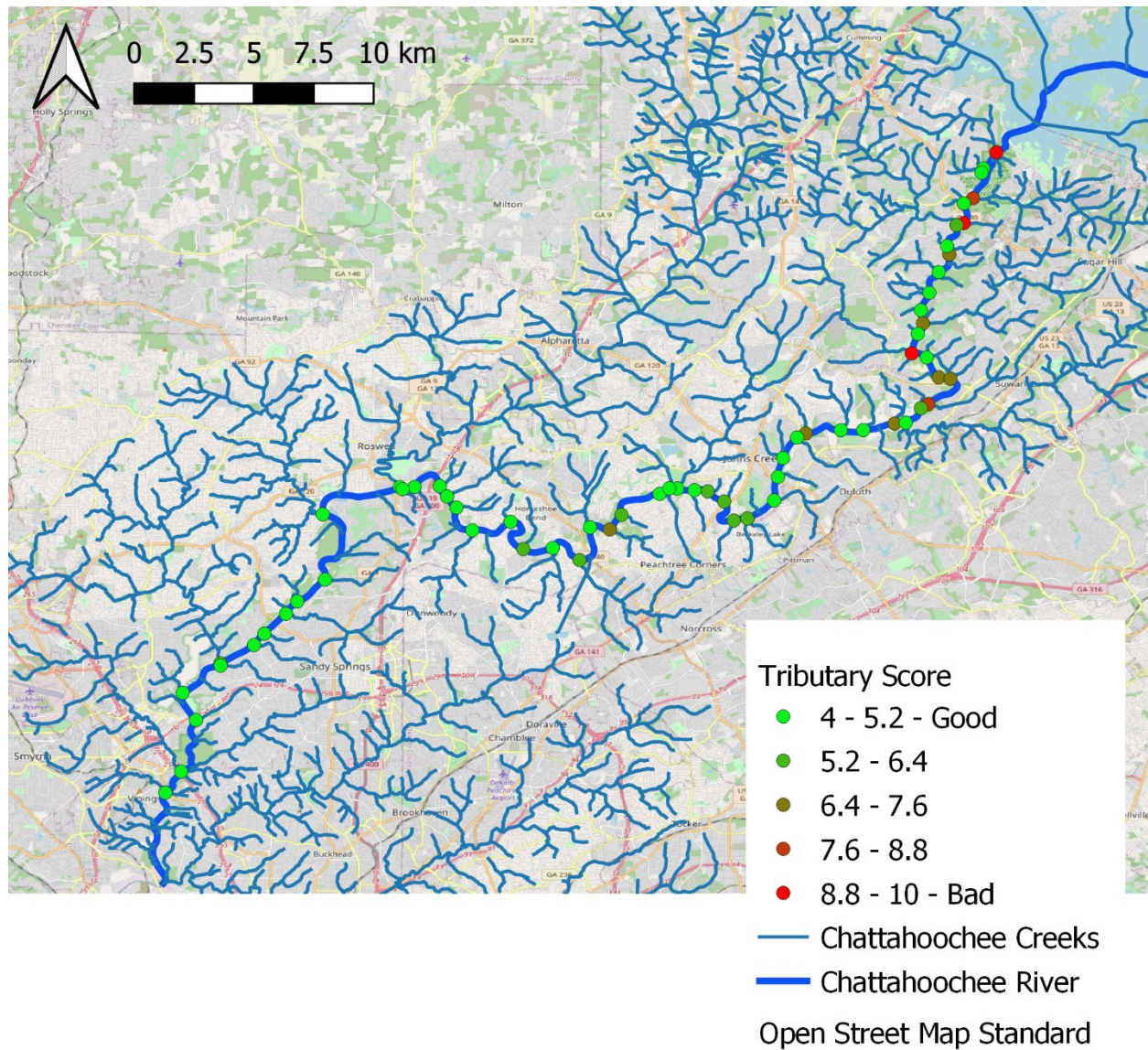


Figure 67: Distribution of tributary scores on the Chattahoochee River. The tributary network was from the National Hydrography Dataset

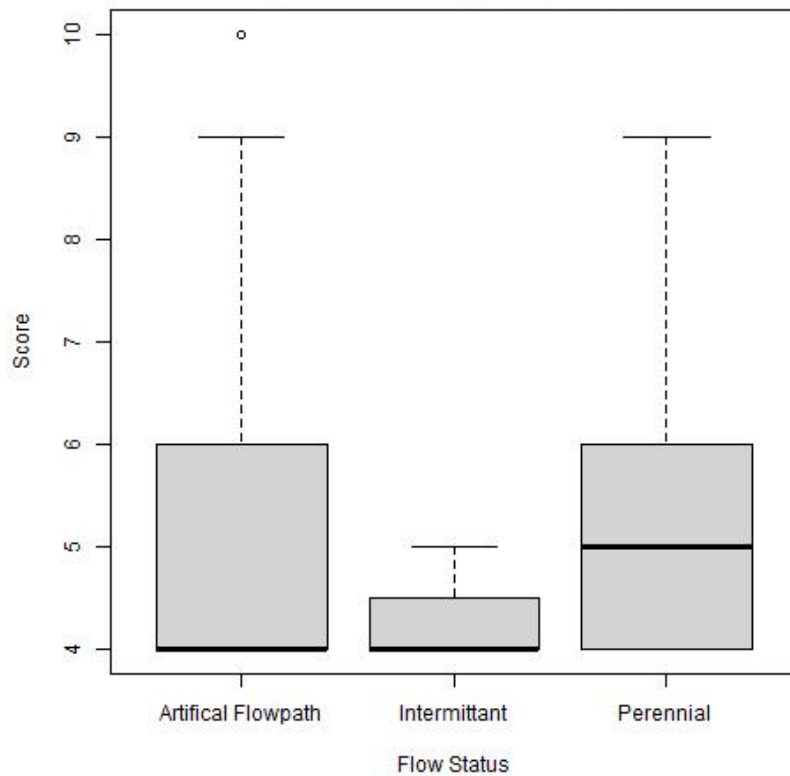


Figure 68: Boxplot of Flow Status vs. Tributary Score. A higher score indicates a poorer overall condition.

Recreational Use Suitability Model

The recreational use assessment of the CHAT identified areas suitable to different levels of wading and/or boating. The recreation use sub-categories were determined for both the right and left survey tracks and then were summarized as the least restrictive sub-category for that meter of the river. This means that at least a portion of the river at that location is suitable for the recreational use sub-category. For example, if a segment of the river was classed as suitable for novice waders, then a portion of the river at that location would be shallow and smooth bottomed even if a deeper channel existed near the opposite bank. Similarly, for boating, if a deep channel existed to allow boat passage, then the segment would be considered suitable for novice boating even if the opposite side of the river was shallow and rocky. Additionally, the sub-category levels can be considered cumulative such that lower sub-categories would be available to higher sub-category users, although the data tables are not calculated in a cumulative approach. For example, a mid-level wader could use areas for novice and mid-level waders.

In general, wading was available at some level in just under 49% of the river, although only 11 % of the river had areas that would be generally suitable for all waders at the discharge rates we surveyed (Table 26). Boating is possible in 100% of the river surveyed (we boat surveyed it all, although in a very shallow draft boat), although 16.3% does require careful navigating (the combined Advanced and Limited categories) (Table 27). Wading by definition was primarily focused around riffle and shoal areas while water for different boating activities was more widely available in pool and run areas.

While this general pattern was observed for the CHAT, it may be more informative to look more closely at specific areas or reaches within the river. To show how the distribution of recreational use categories varied among reaches, CHAT was separated into reaches based on the location of major access points (Table 28). Two percentages were calculated from the resulting data. The first was the within category percentage. This compares the overall total length of the category type with the length within a category. Here the percent within a category for the different reaches will sum to 100%. The second percentage was the within reach percentage. This is the percent within a category for the different reaches compared to the total length within the reach. This percentage will sum to 100% for each percent associated with a single reach.

The results of the reach based analysis showed that most wading (novice and mid-level combined) would be found in the Garrard Landing to Island Ford Access reach, Settles Bridge to Abbotts Bridge Ramp reach, and the Island Ford Access to Azalea Drive Ramp reach while Island Ford Access to Azalea Drive Ramp reach, Garrard Landing to Island Ford Access reach and Jones Bridge Ramp to Garrard Landing had the greatest percent of the reach length suitable for wading (Table 29). This fits well with the survey observations as these areas contain some large and spread out riffle and shoal areas. The amount of wading predicted in the Azalea Drive Ramp to Morgan Falls Dam reach is likely not correct as while we observed shallow smooth bottom areas, they were highly sedimented and not near the shoreline. These shallows were part of the original river floodplain now submerged by the reservoir impoundment. Although they technically fit the definition of suitable wading conditions, it is unlikely that they would be used by most people.

The results of the reach-based analysis showed that most boating (novice and mid-level combined) would be found in the Settles Bridge to Abbotts Bridge Ramp reach, the Garrard Landing to Island Ford Access reach and the Johnson Ferry Ramp to Powers Island Ramp reach. The results are influenced by the overall length of the segment as these are 3 or the 4 longest reaches (Table 30). When considering the percent of the reach available to boating, Azalea Drive Ramp to Morgan Falls Dam reach, Abbotts Bridge Ramp to Medlock Bridge Ramp reach and Garrard Landing to Island Ford Access reach had the greatest percent of the reach length suitable for boating (Table 30). This fits well with the survey observations as these areas contain extensive pools and runs.

Table 26: River wide length and percent for the wading recreational use categories.

Wade Category	Cat Name	length (m)	percent
1	Novice	8003	11.0
2	Mid-level	17838	24.5
3	Limited	9478	13.0
4	None	37387	51.4

Table 27: River wide length and percent for the boating recreational use categories.

Boat Category	Cat Name	length (m)	percent
1	Novice	43842	60.3
2	Mid-level	17038	23.4
3	Advanced	9425	13.0
4	Limited	2401	3.3

Table 28: Reach information based on major access points

Reach ID	Reach Name	Starting meter	Length (m)
1	Buford Dam to Settles Bridge	626	7,981
2	Settles Bridge to Abbotts Bridge Ramp	8,607	14,764
3	Abbotts Bridge Ramp to Medlock Bridge Ramp	23,371	6,466
4	Medlock Bridge Ramp to Jones Bridge Ramp	29,837	3,937
5	Jones Bridge Ramp to Garrard Landing	33,774	4,952
6	Garrard Landing to Island Ford Access	38,726	8,308
7	Island Ford Access to Azalea Drive Ramp	47,034	5,753
8	Azalea Drive Ramp to Morgan Falls Dam	52,787	6,306
9	Morgan Falls Dam to Johnson Ferry Ramp	59,093	3,361
10	Johnson Ferry Ramp to Powers Island Ramp	62,454	6,634
11	Powers Island Ramp to Paces Mill Ramp	69,088	4,293

Table 29: Category by reach information for the wading recreational use.

Wade Category ID	Cat Name	Reach ID	Reach Name	Cat length(m)	Cat %	Reach length(m)	Reach %
1	Novice	1	Buford Dam to Settles Bridge	940	11.8	7,981	11.8
1	Novice	2	Settles Bridge to Abbotts Bridge Ramp	1,222	15.3	14,764	8.3
1	Novice	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	326	4.1	6,466	5
1	Novice	4	Medlock Bridge Ramp to Jones Bridge Ramp	298	3.7	3,937	7.6
1	Novice	5	Jones Bridge Ramp to Garrard Landing	588	7.4	4,952	11.9
1	Novice	6	Garrard Landing to Island Ford Access	1,398	17.5	8,308	16.8
1	Novice	7	Island Ford Access to Azalea Drive Ramp	1,104	13.8	5,753	19.2
1	Novice	8	Azalea Drive Ramp to Morgan Falls Dam	781	9.8	6,306	12.4
1	Novice	9	Morgan Falls Dam to Johnson Ferry Ramp	55	0.7	3,361	1.6
1	Novice	10	Johnson Ferry Ramp to Powers Island Ramp	252	3.2	6,634	3.8
1	Novice	11	Powers Island Ramp to Paces Mill Ramp	1,017	12.7	4,293	23.7
2	Mid-level	1	Buford Dam to Settles Bridge	2,281	13.1	7,981	28.6
2	Mid-level	2	Settles Bridge to Abbotts Bridge Ramp	2,960	17	14,764	20
2	Mid-level	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	688	4	6,466	10.6
2	Mid-level	4	Medlock Bridge Ramp to Jones Bridge Ramp	719	4.1	3,937	18.3
2	Mid-level	5	Jones Bridge Ramp to Garrard Landing	1,861	10.7	4,952	37.6
2	Mid-level	6	Garrard Landing to Island Ford Access	2,614	15	8,308	31.5
2	Mid-level	7	Island Ford Access to Azalea Drive Ramp	2,370	13.6	5,753	41.2
2	Mid-level	8	Azalea Drive Ramp to Morgan Falls Dam	1,286	7.4	6,306	20.4
2	Mid-level	9	Morgan Falls Dam to Johnson Ferry Ramp	117	0.7	3,361	3.5
2	Mid-level	10	Johnson Ferry Ramp to Powers Island Ramp	1,180	6.8	6,634	17.8
2	Mid-level	11	Powers Island Ramp to Paces Mill Ramp	1,332	7.7	4,293	31
3	Limited	1	Buford Dam to Settles Bridge	1,225	13	7,981	15.3
3	Limited	2	Settles Bridge to Abbotts Bridge Ramp	2,137	22.6	14,764	14.5

Wade Category ID	Cat Name	Reach ID	Reach Name	Cat length(m)	Cat %	Reach length(m)	Reach %
3	Limited	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	392	4.1	6,466	6.1
3	Limited	4	Medlock Bridge Ramp to Jones Bridge Ramp	195	2.1	3,937	5
3	Limited	5	Jones Bridge Ramp to Garrard Landing	785	8.3	4,952	15.9
3	Limited	6	Garrard Landing to Island Ford Access	1,310	13.8	8,308	15.8
3	Limited	7	Island Ford Access to Azalea Drive Ramp	898	9.5	5,753	15.6
3	Limited	8	Azalea Drive Ramp to Morgan Falls Dam	381	4	6,306	6
3	Limited	9	Morgan Falls Dam to Johnson Ferry Ramp	202	2.1	3,361	6
3	Limited	10	Johnson Ferry Ramp to Powers Island Ramp	1,183	12.5	6,634	17.8
3	Limited	11	Powers Island Ramp to Paces Mill Ramp	751	7.9	4,293	17.5
4	None	1	Buford Dam to Settles Bridge	3,535	9.5	7,981	44.3
4	None	2	Settles Bridge to Abbotts Bridge Ramp	8,445	22.6	14,764	57.2
4	None	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	5,060	13.5	6,466	78.3
4	None	4	Medlock Bridge Ramp to Jones Bridge Ramp	2,725	7.3	3,937	69.2
4	None	5	Jones Bridge Ramp to Garrard Landing	1,718	4.6	4,952	34.7
4	None	6	Garrard Landing to Island Ford Access	2,986	8	8,308	35.9
4	None	7	Island Ford Access to Azalea Drive Ramp	1,381	3.7	5,753	24
4	None	8	Azalea Drive Ramp to Morgan Falls Dam	3,658	9.8	6,306	58
4	None	9	Morgan Falls Dam to Johnson Ferry Ramp	2,667	7.1	3,361	79.4
4	None	10	Johnson Ferry Ramp to Powers Island Ramp	4,019	10.7	6,634	60.6
4	None	11	Powers Island Ramp to Paces Mill Ramp	1,193	3.2	4,293	27.8

Table 30: Category by reach information for the boating recreational use.

Boat Category ID	Cat Name	Reach ID	Reach Name	Cat length(m)	Cat %	Reach length(m)	Reach %
1	Novice	1	Buford Dam to Settles Bridge	3,946	9	7,981	49.4
1	Novice	2	Settles Bridge to Abbotts Bridge Ramp	8,740	20	14,764	59.2
1	Novice	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	5,457	12.5	6,466	84.4
1	Novice	4	Medlock Bridge Ramp to Jones Bridge Ramp	3,026	6.9	3,937	76.9
1	Novice	5	Jones Bridge Ramp to Garrard Landing	1,741	4	4,952	35.2
1	Novice	6	Garrard Landing to Island Ford Access	4,946	11.3	8,308	59.5
1	Novice	7	Island Ford Access to Azalea Drive Ramp	2,765	6.3	5,753	48.1
1	Novice	8	Azalea Drive Ramp to Morgan Falls Dam	5,686	13	6,306	90.2
1	Novice	9	Morgan Falls Dam to Johnson Ferry Ramp	2,188	5	3,361	65.1
1	Novice	10	Johnson Ferry Ramp to Powers Island Ramp	3,388	7.7	6,634	51.1
1	Novice	11	Powers Island Ramp to Paces Mill Ramp	1,876	4.3	4,293	43.7
2	Mid-level	1	Buford Dam to Settles Bridge	1,906	11.4	7,981	23.9
2	Mid-level	2	Settles Bridge to Abbotts Bridge Ramp	3,571	21.4	14,764	24.2
2	Mid-level	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	697	4.2	6,466	10.8

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Boat Category ID	Cat Name	Reach ID	Reach Name	Cat length(m)	Cat %	Reach length(m)	Reach %
2	Mid-level	4	Medlock Bridge Ramp to Jones Bridge Ramp	473	2.8	3,937	12
2	Mid-level	5	Jones Bridge Ramp to Garrard Landing	1,470	8.8	4,952	29.7
2	Mid-level	6	Garrard Landing to Island Ford Access	2,755	16.5	8,308	33.2
2	Mid-level	7	Island Ford Access to Azalea Drive Ramp	1,567	9.4	5,753	27.2
2	Mid-level	8	Azalea Drive Ramp to Morgan Falls Dam	341	2	6,306	5.4
2	Mid-level	9	Morgan Falls Dam to Johnson Ferry Ramp	798	4.8	3,361	23.7
2	Mid-level	10	Johnson Ferry Ramp to Powers Island Ramp	2,176	13	6,634	32.8
2	Mid-level	11	Powers Island Ramp to Paces Mill Ramp	965	5.8	4,293	22.5
3	Advanced	1	Buford Dam to Settles Bridge	1,343	14.3	7,981	16.8
3	Advanced	2	Settles Bridge to Abbotts Bridge Ramp	1,969	21	14,764	13.3
3	Advanced	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	285	3	6,466	4.4
3	Advanced	4	Medlock Bridge Ramp to Jones Bridge Ramp	362	3.9	3,937	9.2
3	Advanced	5	Jones Bridge Ramp to Garrard Landing	1,381	14.7	4,952	27.9
3	Advanced	6	Garrard Landing to Island Ford Access	575	6.1	8,308	6.9
3	Advanced	7	Island Ford Access to Azalea Drive Ramp	1,117	11.9	5,753	19.4
3	Advanced	8	Azalea Drive Ramp to Morgan Falls Dam	79	0.8	6,306	1.3
3	Advanced	9	Morgan Falls Dam to Johnson Ferry Ramp	55	0.6	3,361	1.6
3	Advanced	10	Johnson Ferry Ramp to Powers Island Ramp	981	10.5	6,634	14.8
3	Advanced	11	Powers Island Ramp to Paces Mill Ramp	1,226	13.1	4,293	28.6
4	Limited	1	Buford Dam to Settles Bridge	786	33	7,981	9.8
4	Limited	2	Settles Bridge to Abbotts Bridge Ramp	484	20.3	14,764	3.3
4	Limited	3	Abbotts Bridge Ramp to Medlock Bridge Ramp	27	1.1	6,466	0.4
4	Limited	4	Medlock Bridge Ramp to Jones Bridge Ramp	76	3.2	3,937	1.9
4	Limited	5	Jones Bridge Ramp to Garrard Landing	360	15.1	4,952	7.3
4	Limited	6	Garrard Landing to Island Ford Access	32	1.3	8,308	0.4
4	Limited	7	Island Ford Access to Azalea Drive Ramp	304	12.8	5,753	5.3
4	Limited	8	Azalea Drive Ramp to Morgan Falls Dam	0	0.0	6,306	0.0
4	Limited	9	Morgan Falls Dam to Johnson Ferry Ramp	0	0.0	3,361	0.0
4	Limited	10	Johnson Ferry Ramp to Powers Island Ramp	89	3.7	6,634	1.3
4	Limited	11	Powers Island Ramp to Paces Mill Ramp	226	9.5	4,293	5.3

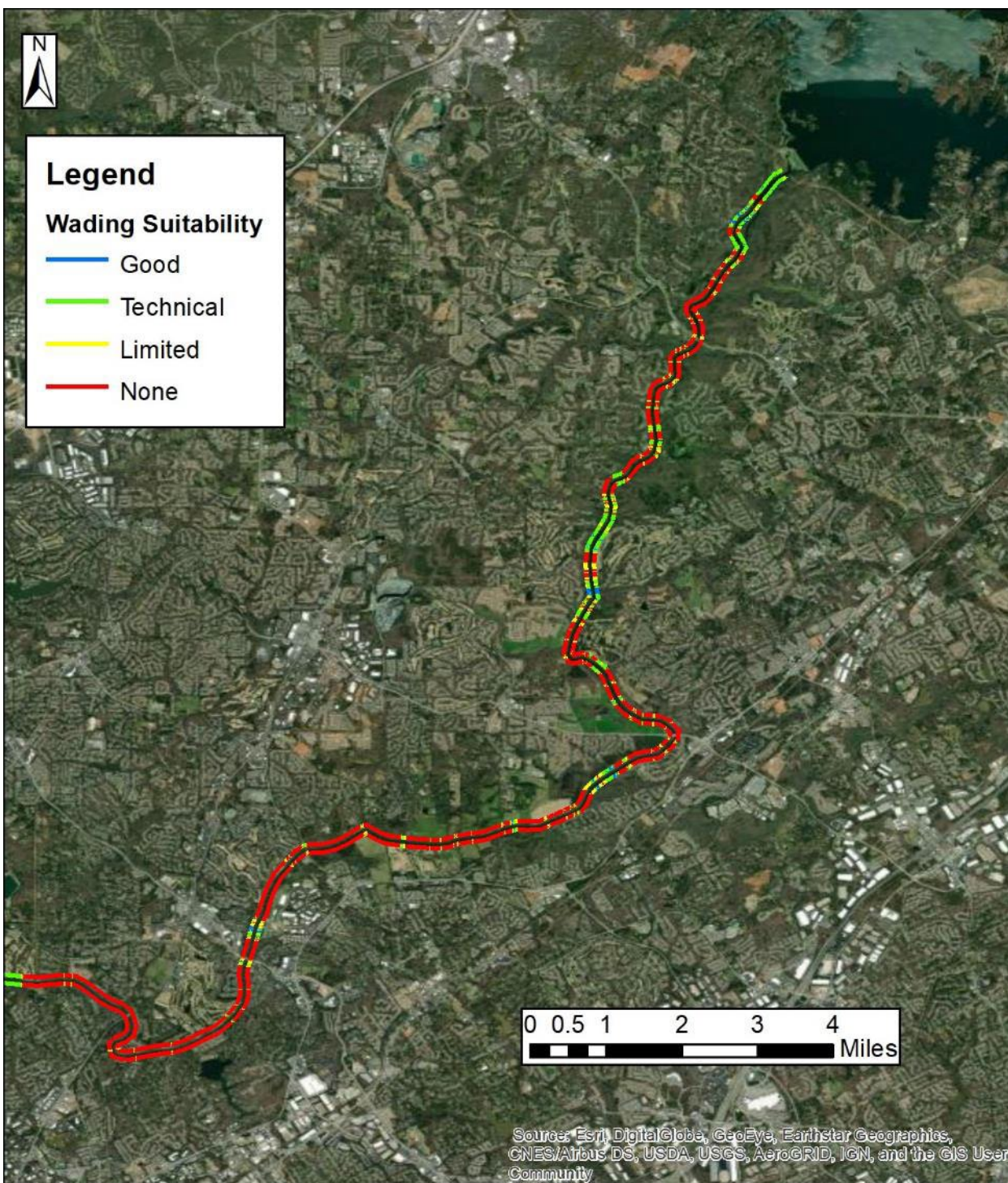


Figure 69: Image of wading suitability for the upper section of the Chattahoochee River National Recreation Area. Suitability was assessed at the four levels of Good=Novice, Technical=Mid-level, Limited and None.

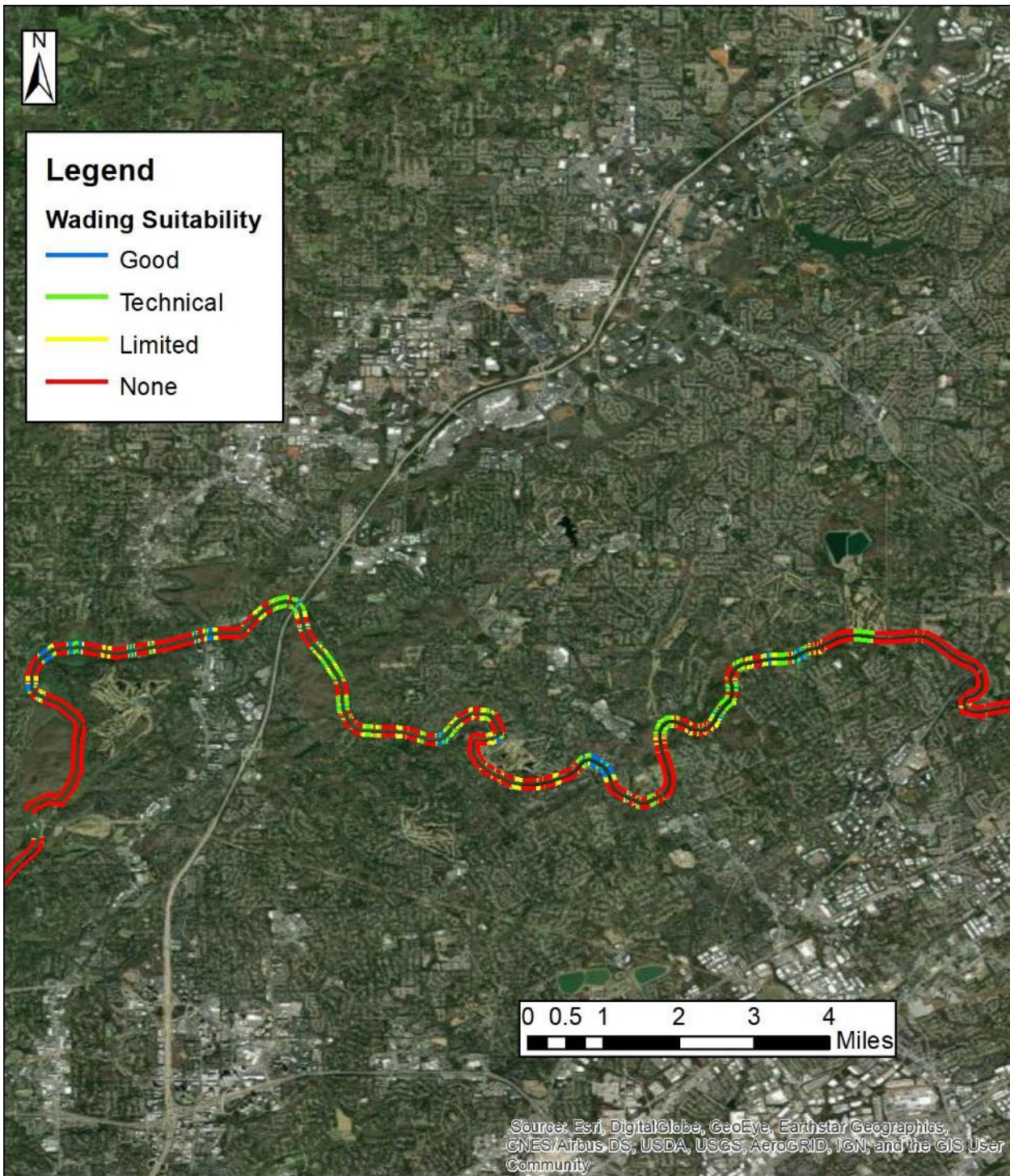


Figure 70: Image of wading suitability for the middle section of the Chattahoochee River National Recreation Area. Suitability was assessed at the four levels of Good=Novice, Technical=Mid-level, Limited and None.

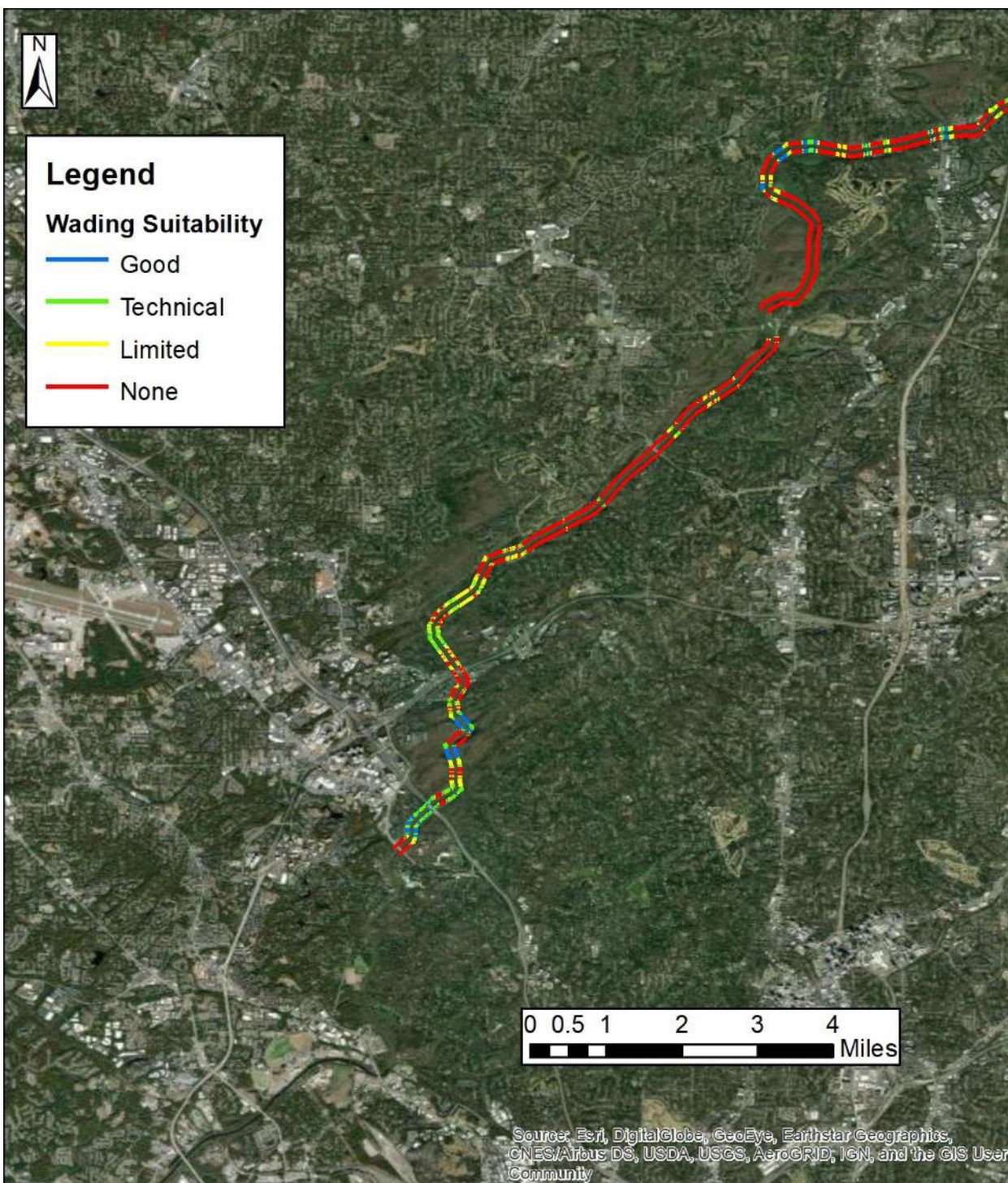


Figure 71: Image of wading suitability for the lower section of the Chattahoochee River National Recreation Area. Suitability was assessed at the four levels of Good=Novice, Technical=Mid-level, Limited and None.

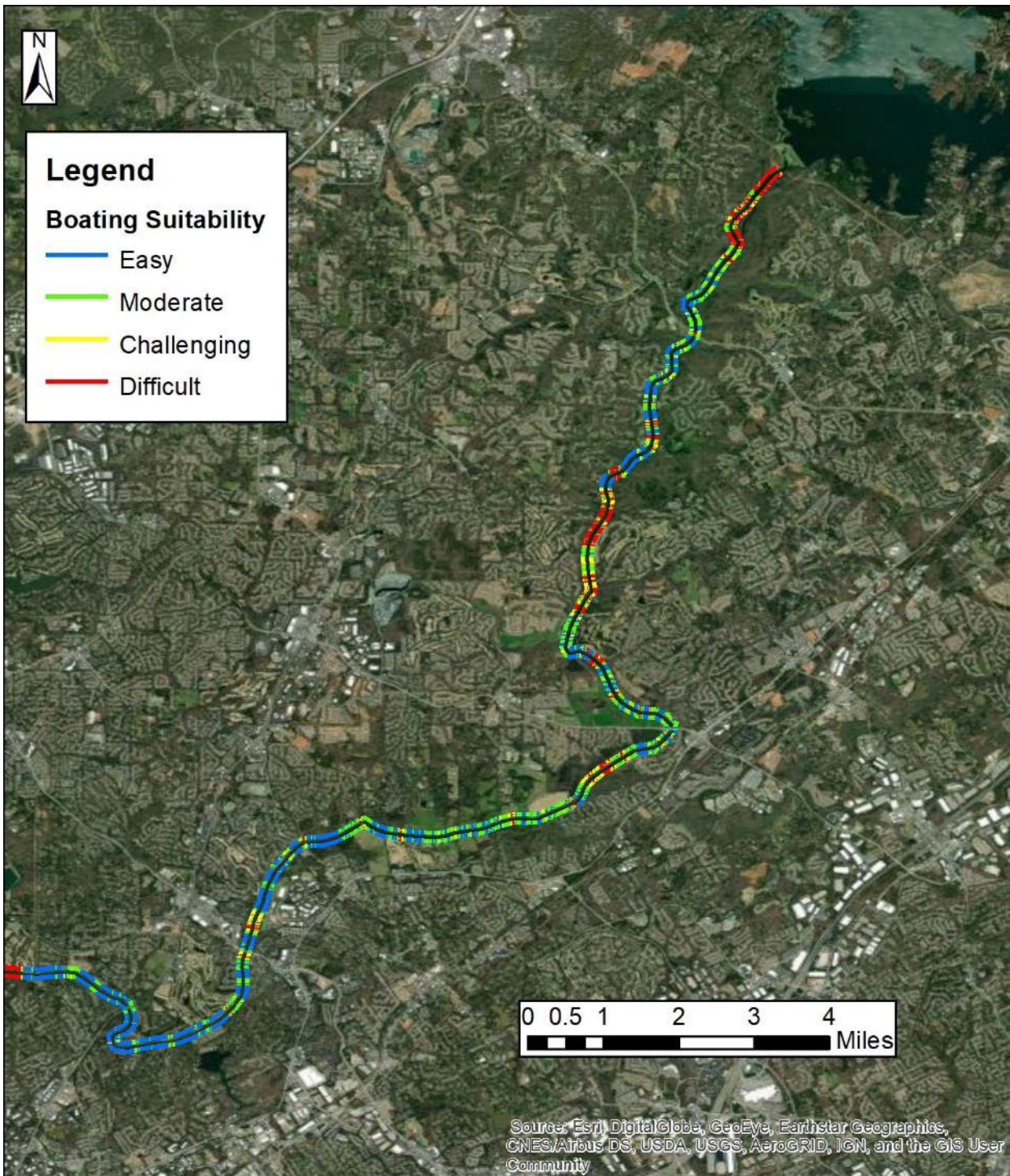


Figure 72: Image of boating suitability for the upper section of the Chattahoochee River National Recreation Area. Suitability was assessed at the four levels of easy=Novice, moderate=Mid-level, challenging=Advanced, and difficult=Limited.

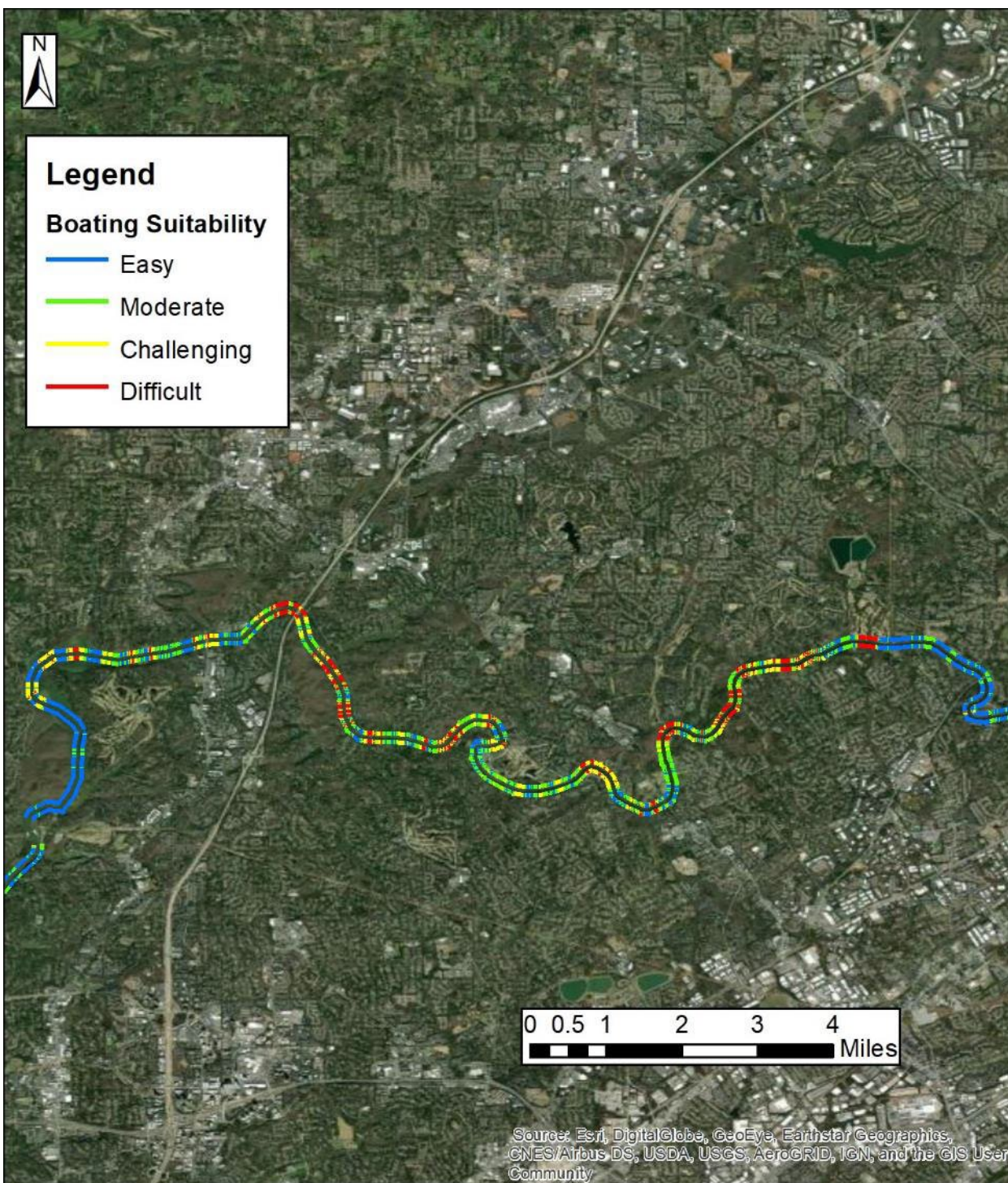


Figure 73: Image of boating suitability for the middle section of the Chattahoochee River National Recreation Area. Suitability was assessed at the four levels of easy=Novice, moderate=Mid-level, challenging=Advanced, and difficult=Limited.

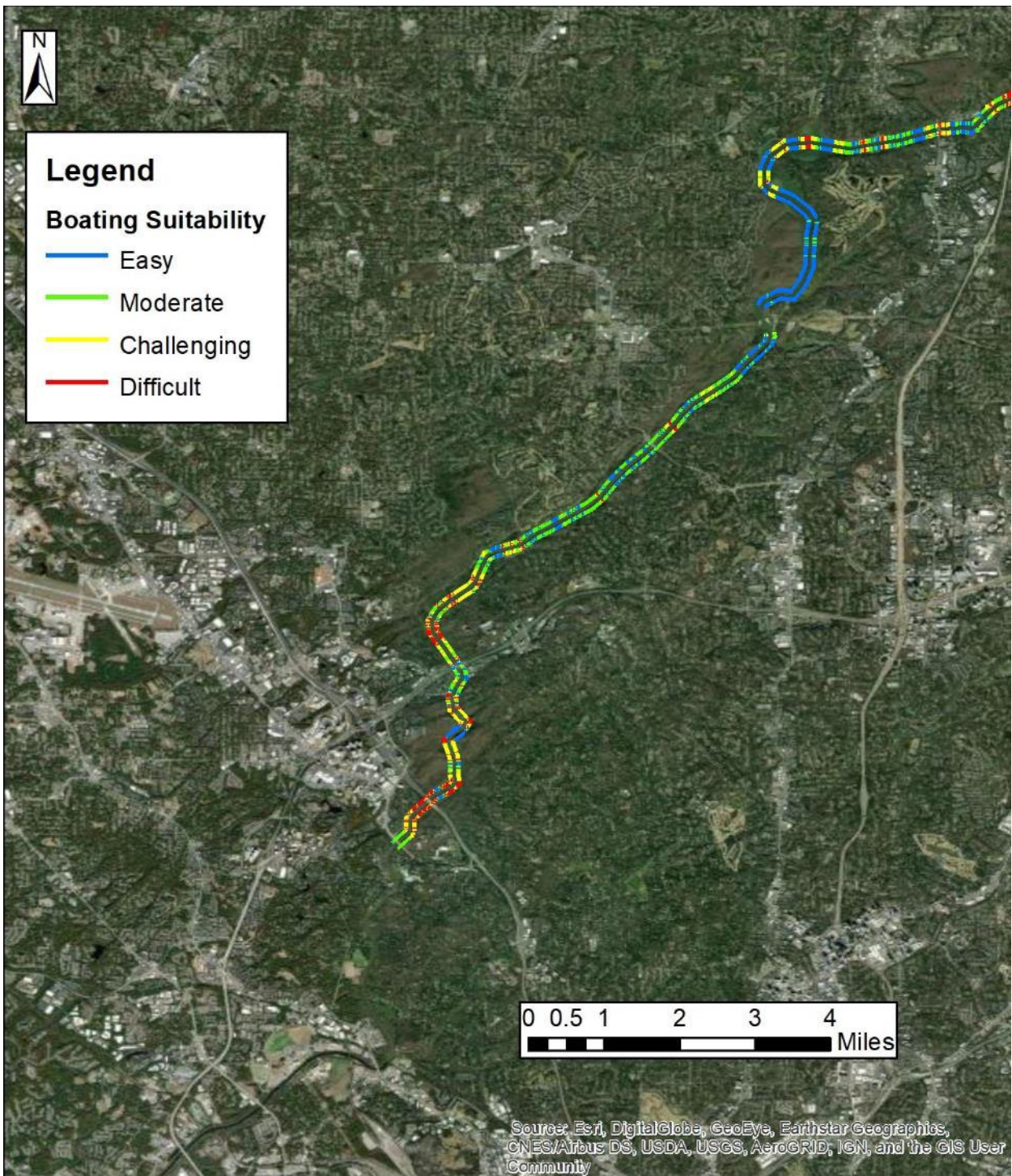


Figure 74: Image of boating suitability for the lower section of the Chattahoochee River National Recreation Area. Suitability was assessed at the four levels of easy=Novice, moderate=Mid-level, challenging=Advanced, and difficult=Limited.

Conclusions

The High Definition Stream Survey (HDSS) approach proved to be a rapid method to collect a wide range of data pertaining to river conditions within Chattahoochee River National Recreation Area. We surveyed 72.7 km and collected data about the stream bottom, water depth, and assessed the condition of both streambanks. This data and StreamView video should be useful to natural resource managers at CHAT for a range of river management issues.

The Chattahoochee River downstream of Buford Dam is a wide river with numerous rocky shoals. The general condition of the streambanks along CHAT was relatively good. The majority of the streambank condition scored as slightly impaired or better. The most upstream segment of CHAT, the area immediately downstream of Buford Dam, contained most of the impaired and non- functional streambanks. Impairment in this area is likely due to the fluctuating and sediment-starved flows eroding the streambank. Sediment starved discharges immediately downstream of dams seek to recapture its sediment load by eroding the bed and banks of the river (Kondolf, 1997). These areas in the upper section would be an excellent area to focus streambank rehabilitation efforts.

Like the bank condition problems being observed more commonly in close downstream proximity to Buford Dam, tributary confluence conditions were more degraded in this area as well. Highly erodible streambanks, fallen trees and sediment deltas were observed at a number of tributary confluences. The pulse discharges likely cause erosion issues in the immediate tributary confluence area, but the sediment deltas are likely the result of sediment flowing downstream from tributary watershed sources. Local protection of the streambanks from erosion and upstream sediment management practices could be implemented to improve the tributary confluence conditions.

The HDSS video is exceptionally useful in providing a baseline documentation of conditions throughout this long stretch of the Chattahoochee River during October of 2018. If future surveys are completed, comparison with this survey completed in 2018 would allow for the direct comparison of the changes in river conditions between surveys. This repeated approach would allow changes in the river corridor conditions to be accurately documented. As a result of the StreamView video, direct site by site comparisons could be made with the new survey. Even if the classifications presented here were not carried out in a similar way by the new survey observer, the StreamView video can easily be rescored to meet new or different classification systems. Part of the difficulty of using past traditional survey data to compare with new survey results is it is difficult to collect and analyze data with the same process. The HDSS approach attempts to minimize this problem by allowing future surveyors to view the conditions and compare the scoring results with any new survey. The StreamView video can also be completely reanalyzed by different observers or with different scoring systems to produce novel results. The ability to review the video of the survey conditions allows the results to be further validated, updated, or changed as future observers require.

Finally, use of the HDSS video allows for a wide range of interested viewers to see the conditions throughout the river. It is unlikely that most river managers, public officials, decision-makers or other interested parties will have time to spend boating down CHAT to look for problem areas. With the HDSS video, it is easy to review the instream conditions and view specific problem areas. The availability of this

video should help inform decision making throughout the river as issues can be identified and addressed using a comparative prioritization scheme.

The HDSS method provides resource managers with an integrated suite of stream corridor information to support effective decision- making. We collected continuous geo-referenced imagery of instream, streambank, and bathymetric data over a long reach. Using the HDSS approach, we delivered to managers and stakeholders more data at lower cost as compared to traditional methods. The HDSS platform allowed us to provide data-rich, 1- meter resolution GIS layers representing numerous instream and streambank parameters. These parameters can be combined in informative ways to create powerful decision-support tools allowing for a new holistic approach to river and stream management.

The value of this project is not this report, but the videos and spatial data provided with the report. The images in the report are general in nature and cover a long river segment and may not be directly suitable to answering specific management questions. However, the continuous 1m resolution data linked to high resolution video of the river corridor allows detailed inspection of instream conditions to support numerous different management decisions. For example, on other HDSS river survey projects the data has been used to estimate fish habitat, site drinking water intakes, determine stormwater management plans or quantify different project impact assessments. All of these issues and more are supported with the provided data from this survey.

Deliverables

The StreamView videos for CHAT were provided on an external hard drive with the first draft of the report.

All GIS and Tabular Data that supported the maps and graphics in this report were submitted via electronic file transfer with the report. These files included:

- CHAT_DepthValidation.xlsx – Spreadsheet data for the water depth comparison of uncorrected vs. corrected water depth.
- CHAT_HabTypeInfo.xlsx – Spreadsheet data associated with the results of the habitat type classification process.
- CHAT_HabTypeValidation.xlsx – Spreadsheet data associated with the independent review of the habitat type classification results.
- CHAT_BankCondition_Validation.xlsx – Spreadsheet data associated with the independent review of the bank condition classification results.
- CHAT_RoughnessTypeInfo.xlsx – Spreadsheet data associated with the results of the roughness classification process.
- CHAT_Roughness_Validation.xlsx – Spreadsheet data associated with the independent review of the roughness classification results.

- CHAT_TributaryConfluenceInfo.xlsx – Spreadsheet data associated with the results of the tributary confluence assessment process.
- CHAT_RecUseTypeInfo.xlsx – Spreadsheet data associated with the results of the recreational use model process.
- CHAT_Left_HDSS_GIS.gpkg – QGIS file with Left Track survey data and classifications in WGS84 datum
- CHAT_Right_HDSS_GIS.gpkg – QGIS file with Right Track survey data and classifications in WGS84 datum.
- CHAT_Centerline_HDSS_GIS.gpkg – QGIS file with centerline classification of Habitat Type, Roughness and Recreational Use. Centerline is a divided 1m line file based on the National Hydrography Dataset file for the main Chattahoochee River in NAD83(2011)/UTM zone 18N.

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