INSTREAM FLOW STUDY REPORT

PARR HYDROELECTRIC PROJECT

(FERC NO. 1894)

Prepared for:

South Carolina Electric & Gas Co.
Cayce, South Carolina

Prepared by:

Kleinschmidt

Lexington, South Carolina
www.KleinschmidtGroup.com

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

The Parr Hydroelectric Project (FERC No. 1894) (Project) is a 526.08 megawatt (MW) licensed hydroelectric facility and is owned and operated by South Carolina Electric & Gas (SCE&G). The Project consists of the Parr Shoals Development and the Fairfield Pumped Storage Development. Both developments are located along the Broad River in Fairfield and Newberry Counties, South Carolina (Figure 1-1).

The Parr Shoals Development forms Parr Reservoir along the Broad River. The Development consists of a 37-foot-high, 200-foot-long concrete gravity spillway dam with a powerhouse housing generating units with a combined licensed capacity of 14.88 MW. Parr Shoals operates in a modified run-of-river mode and normally operates to continuously pass Broad River flow. The 13-mile-long Parr Reservoir has a surface area of 4,400 acres at full pool and serves as the lower reservoir for pumped-storage operations. The Fairfield Pumped Storage Development is located directly off of the Broad River and forms the 6,800-acre upper reservoir, Monticello Reservoir, with four earthen dams. As noted, Parr Reservoir serves as the lower reservoir for pumped storage operations. The Fairfield Development has a licensed capacity of 511.2 MW and is primarily used for peaking operations, reserve generation, and non-peak energy storage.

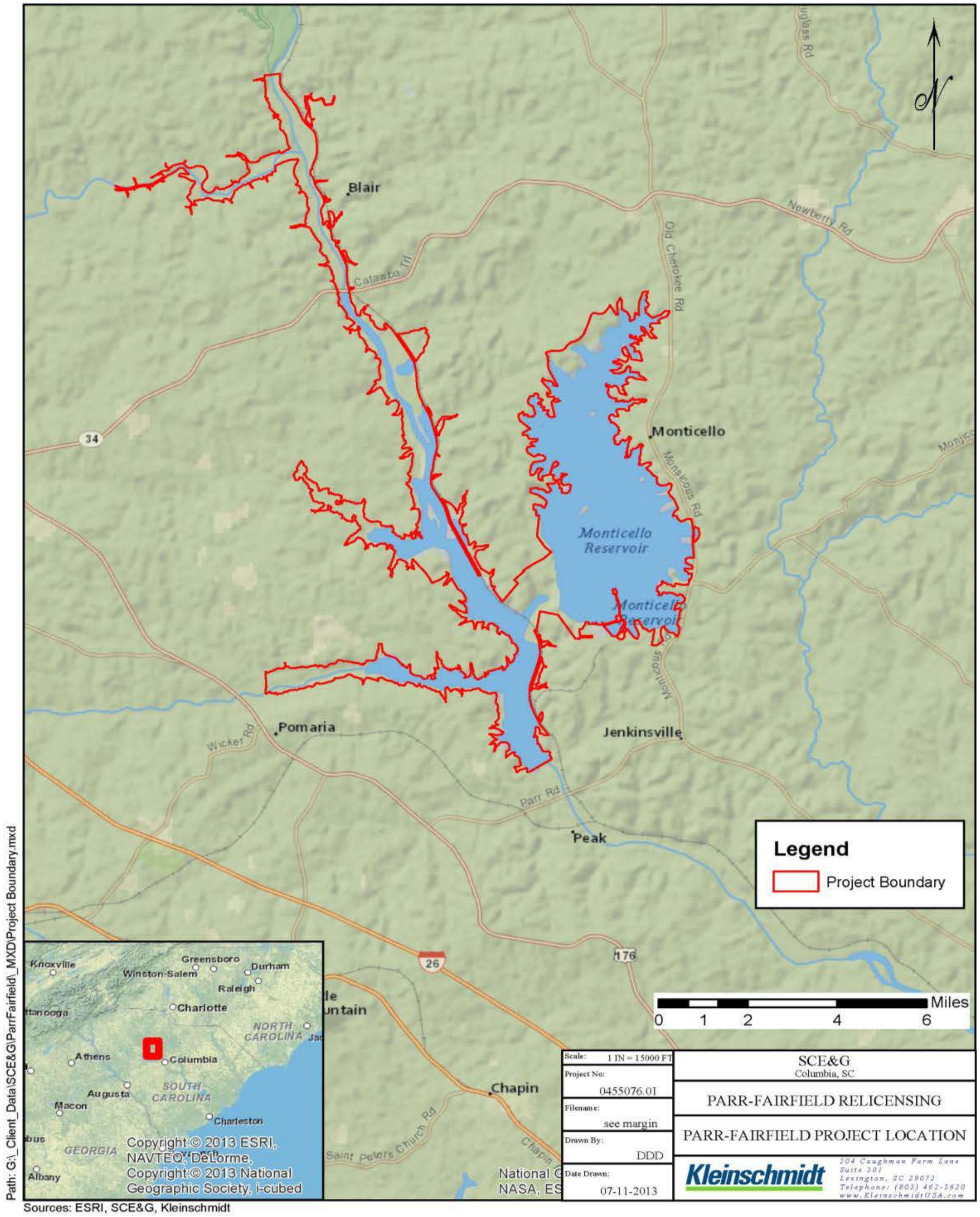
In anticipation of the Project relicensing process, SCE&G met with a number of state and federal resource agencies and interested stakeholders to begin scoping environmental issues as they pertain to project operations. As a result, the United States Fish and Wildlife Service (USFWS), South Carolina Department of Natural Resources (SCDNR), and several Non-governmental Organizations (NGO's) requested studies to determine the potential impact of Project operation on fishery resources and aquatic habitat, including an Instream Flow Incremental Methodology Study (IFIM) for the Broad River downstream of the Project. SCE&G formed a Technical

Working Committee (TWC) composed of representatives from each interested party that consult to provide input and guidance for the study design and execution.

The IFIM is a nationally recognized method used to solve competing instream water uses involving aquatic habitat. It was developed by the Instream Flow and Aquatic Systems Group of the U.S. Fish and Wildlife Service (now a branch of the USGS). The IFIM is a tool that provides decision-makers with information showing the degree of habitat available in a defined river reach, across a range of flows (Bovee 1982). It does this by developing a quantitative estimate of habitat area at selected discharges, from site-specific measurements of stream morphology, cover, substrate, depth, velocity and discharge gathered in reaches along the river. These physical measurements are then rated for habitat suitability, based on objective habitat use data developed for the aquatic species and life stages of concern.

The IFIM does not compute a single "answer", but instead estimates degrees of suitability under existing and alternative flow scenarios. In this application, it may be used to estimate the extent that various project water management proposals may affect aquatic habitat in particular stream reaches. IFIM results must be evaluated in the context of watershed hydrology and the strategic needs of other competing uses, which in this case include, but are not necessarily limited to Parr Reservoir lake levels, water quality, fisheries, boating, and hydroelectric power generation.

The scope of this study is to provide data quantifying the effects of flows on aquatic habitat suitability in the Broad River for the aquatic community and its managed fish resources, including diadromous and resident fish species, and to assist the TWC in identifying flow targets that support habitat requirements for a balanced aquatic community. These data are used in conjunction with hydrologic, operational and other models to evaluate the costs and benefits of providing alternate flows to the Broad River. This IFIM study was scoped and directed by a study team that included representatives from the TWC. The study was conducted by SCE&G under the supervision of the TWC.



Sources: ESRI, SCE&G, Kleinschmidt

FIGURE 1-1 PROJECT LOCATION MAP

2.0 DESCRIPTION OF THE STUDY AREA

The Broad River rises on the east slope of the Appalachian Mountains, and flows southeasterly across the Piedmont geomorphic province to its confluence at the fall line with the lower Saluda River in Columbia, South Carolina, where the combined flows form the Congaree River. Below the Parr Shoals Dam, the river is free flowing for approximately 26 miles through generally low gradient riverine geomorphology until just below Boatright Island. Below Boatright Island, the Broad River is influenced by backwatering from the Columbia Hydroelectric Project, which is located approximately two miles above the confluence with the lower Saluda River. The drainage area at the Parr Project is 4,750 square miles. A real time stream flow gage exists at USGS 02161000 (*Broad River at Alston, SC*), which is located approximately 1.5 miles below the Parr Shoals Dam.

2.1 UPSTREAM AND DOWNSTREAM BOUNDARIES

The TWC identified the segment of the Broad River between the Parr Shoals Dam and the downstream end of the Bookman Island complex as the study area (Figure 2-1). Flow in this reach is primarily influenced by releases from the Parr Shoals dam and powerhouse. There are no significant flow contributions from tributaries within the study reach.

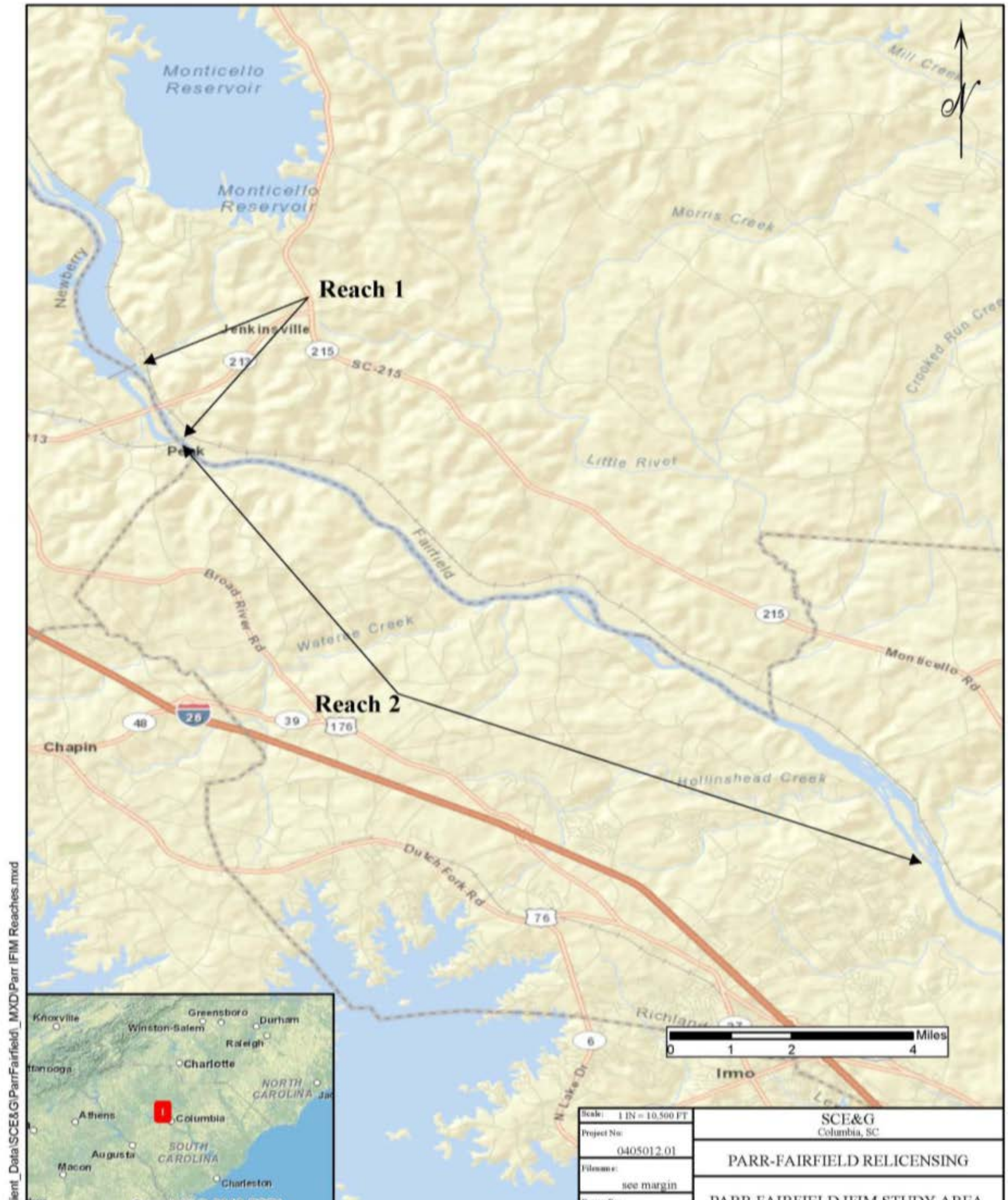


FIGURE 2-1 PARR FAIRFIELD INSTREAM FLOW STUDY AREA

2.2 HABITAT AND GEOMORPHOLOGY

The Broad River flows southeasterly through a river corridor that is predominantly rural, and in general the river banks and riparian zones are forested. Overall the river is relatively straight for much of the reach, with moderate levels of sinuosity. The upper segment of the study area (Reach One) is dominated by well-defined banks (i.e. with discernible and consistent crests and toes) and relatively low-gradient pools, runs and glides, periodically segmented by short riffles. The lower segment (Reach Two) also contains pools, glides and runs, but exhibits higher gradient bedrock drops and more pronounced riffles, and features ledge and boulder substrates which reflect down cutting through the piedmont terrace. There are several islands with pronounced side channels and/or braids such as Haltiwanger, Bookman and Huffman islands.

2.3 FISHERY MANAGEMENT

The varied instream features within the study area support a diverse community of warm water fish species and provide seasonal spawning and nursery habitat for anadromous American shad and striped bass. In addition, smallmouth bass, other centrarchids and catfish provide a sport fishery. Robust redhorse is a rare migratory sucker species present in the study area. Collaborative restoration efforts are underway to protect this fish, and the USFWS describes it as an At-Risk-Species (ARS). Features within the study reach may also provide suitable conditions for robust redhorse spawning and rearing (See Robust Redhorse Spawning Memo in Appendix A).

2.4 HYDROLOGY

The total contributing drainage area for the Parr Shoals development is 4,750 square miles, and the drainage area for the Fairfield Development is 15 square miles. Flows are recorded downstream of Parr Shoals dam at the USGS gage at Alston (USGS gage 02161000). This gage has a continuous period of record dating back to 1981. The monthly mean, minimum and maximum flows for the Project are presented below in Table 2-1. Annual flow-duration curves for the Project are contained in Appendix A of the Pre-Application Document (PAD).

TABLE 2-1 MONTHLY MEAN, MAXIMUM AND MINIMUM DATA FOR THE USGS GAGE AT ALSTON (02161000), FOR WATER YEARS 1981-2013, BY WATER YEAR (WY) (IN CUBIC FEET PER SECOND)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MEAN	3,565	4,016	5,650	7,252	7,877	9,023	6,606	5,033	3,791	3,198	3,475	2,760
MAX	17,360	14,500	14,190	17,790	16,960	21,560	18,040	14,830	8,909	12,440	10,210	14,740
(WY)	(1991)	(1993)	(2010)	(1993)	(1990)	(1993)	(2003)	(2003)	(2003)	(2013)	(1995)	(2004)
MIN	638	725	1,251	2,106	1,985	3,170	2,821	1,783	763	600	546	624
(WY)	(2008)	(2008)	(2008)	(2011)	(2009)	(2006)	(2012)	(2001)	(2008)	(2008)	(2002)	(2007)

3.0 METHODS

Aquatic habitat suitability at most sites was evaluated using standard field procedures and Physical Habitat Simulation (PHABSIM) modeling techniques of the Instream Flow Incremental Methodology (IFIM), developed by the National Ecology Research Center of the National Biological Survey (Bovee, 1982; Bovee, et al. 1998; Milhouse et al. 1989). The IFIM quantifies habitat values of alternative stream flows using pre-determined habitat suitability index (HSI) criteria for selected species based on stream hydraulics models of study reaches. HSI criteria are based on flow-related depth, velocity, substrate, and cover preferences of targeted lifestages of the evaluation species.

General procedures involve collecting hydraulic data (e.g. bed profile, depth, velocity, and water surface elevation at a series of known calibration flows) and habitat data (i.e. substrate and relevant cover characteristics) at a series of loci (“verticals”) along representative cross-sectional transects. Paired verticals along a transect define the lateral boundaries of a series of "cells". Each cell area is assumed to be homogeneous with respect to depth, velocity, substrate, and cover. The length of stream represented by each transect is determined by field mapping. Hydraulic modeling predicts changes in depth and velocity in each cell as discharge varies. The area of each cell is then weighted relative to HSI criteria for each evaluation species life stage to compute habitat suitability. Total habitat suitability at each flow is calculated by summing weighted habitat area at all transect cells. Weighted Usable Area (WUA) is the standard unit of habitat calculated in standard IFIM computations: one unit of WUA is equal to one square foot of “optimum” habitat suitability as defined by the habitat suitability criteria.

Locations where PHABSIM methodologies were not used include a braided reach where two-dimensional (2-D) modeling was employed (Sites 9 and 10), a backwater area affected by Project operations (Site 4) where wetted perimeter modeling was employed, and a site consisting of perched bedrock pools (Site 1) where calculation of pool volume turnover was conducted for purposes of addressing water quality concerns. These methodologies are discussed in greater detail below.

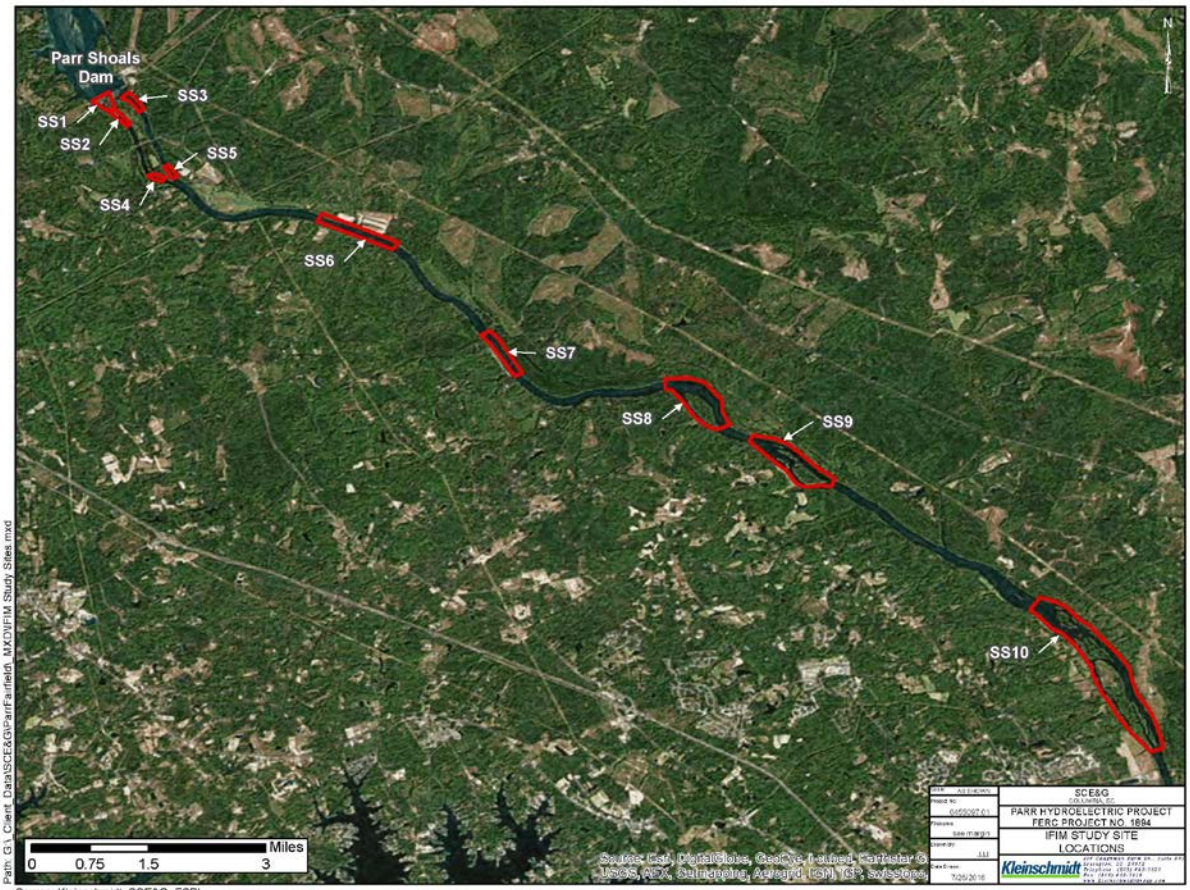
3.1 SCOPING

The study was collaboratively designed by members of the TWC, including biologists from USFWS, SCDNR and American Rivers. The TWC provided technical input to the consultant, and determined study area boundaries, evaluation lifestages, HSI criteria, modeling approach, and study site locations within each reach. These parameters were based on site reconnaissance and first-hand knowledge of habitat in the Broad River (Appendix B – TWC Scoping).

The TWC conducted a float trip in June 2013 to select study reaches study sites and in some cases transects, and data collection and modeling approaches. Based on this site visit, the study area was segmented into two independent reaches (Figure 2-1). Reach One extends from Parr Shoals Dam to the downstream end of Hampton Island, near the Palmetto Trail crossing, and includes five study sites selected by the TWC (Figure 3-1). The TWC determined that PHABSIM would be the primary tool to assess aquatic habitat suitability in Reach One, with the exception of Study Sites 1 and 4. Study Site 1 consisted primarily of perched bedrock pools located at the base of the dam. The TWC requested bathymetric mapping for purposes of determining pool volumes to support determination of flows necessary to maintain acceptable water quality. Study Site 4 was located in the west channel near the downstream terminus of Hampton Island and was deemed not suitable for PHABSIM modeling due to backwatering from the project tailrace. Study Site 4 was subsequently assessed through a wetted perimeter analysis.

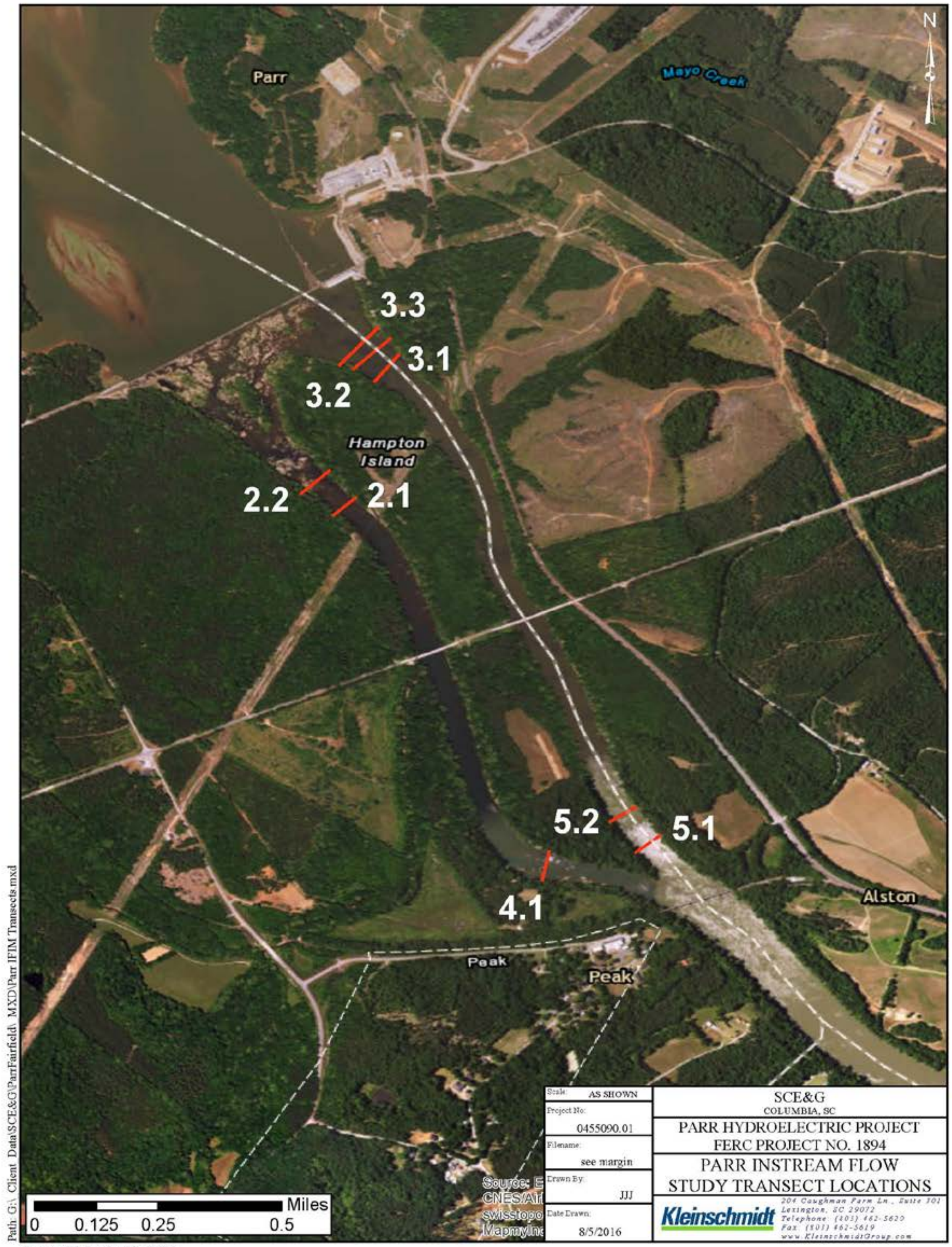
Reach Two extended from the Palmetto Trail trestle crossing at the base of Hampton Island to Boatright Island and included five additional study sites (Figure 3-1). PHABSIM was again the primary mean of assessing habitat suitability, with two exceptions. A 2-D modeling approach was deemed appropriate at Study Site 10 due to the braided and complex nature of the Bookman Island complex. Finally, the TWC determined that habitat at Study Site 9 (Huffman Island) was similar to habitat occurring at Study Site 10; therefore the former could be addressed through a simple flow demonstration to confirm transferability of 2-D modeling results from Study Site 10.

Each study site was chosen by the TWC to represent a specific type of representative and/or biologically strategic habitat within the subject reach. PHABSIM transects were placed within each study site (Figures 3-2 and 3-3) as necessary to portray channel configuration, slope, hydraulics and/or substrate and cover of specific mesohabitat types of interest (Table 3-1). The total length of stream represented by each study site within each reach was determined by mesohabitat mapping. Mesohabitat boundaries were delineated in the field by demarking the upstream boundary of each contiguous mesohabitat type with a handheld GPS unit. Boundaries were identified by visual inspection and soundings obtained from a small boat traversing the study area at a low flow (approximately 800 cfs). Additional detail regarding the mesohabitat assessment result are included in Appendix C.



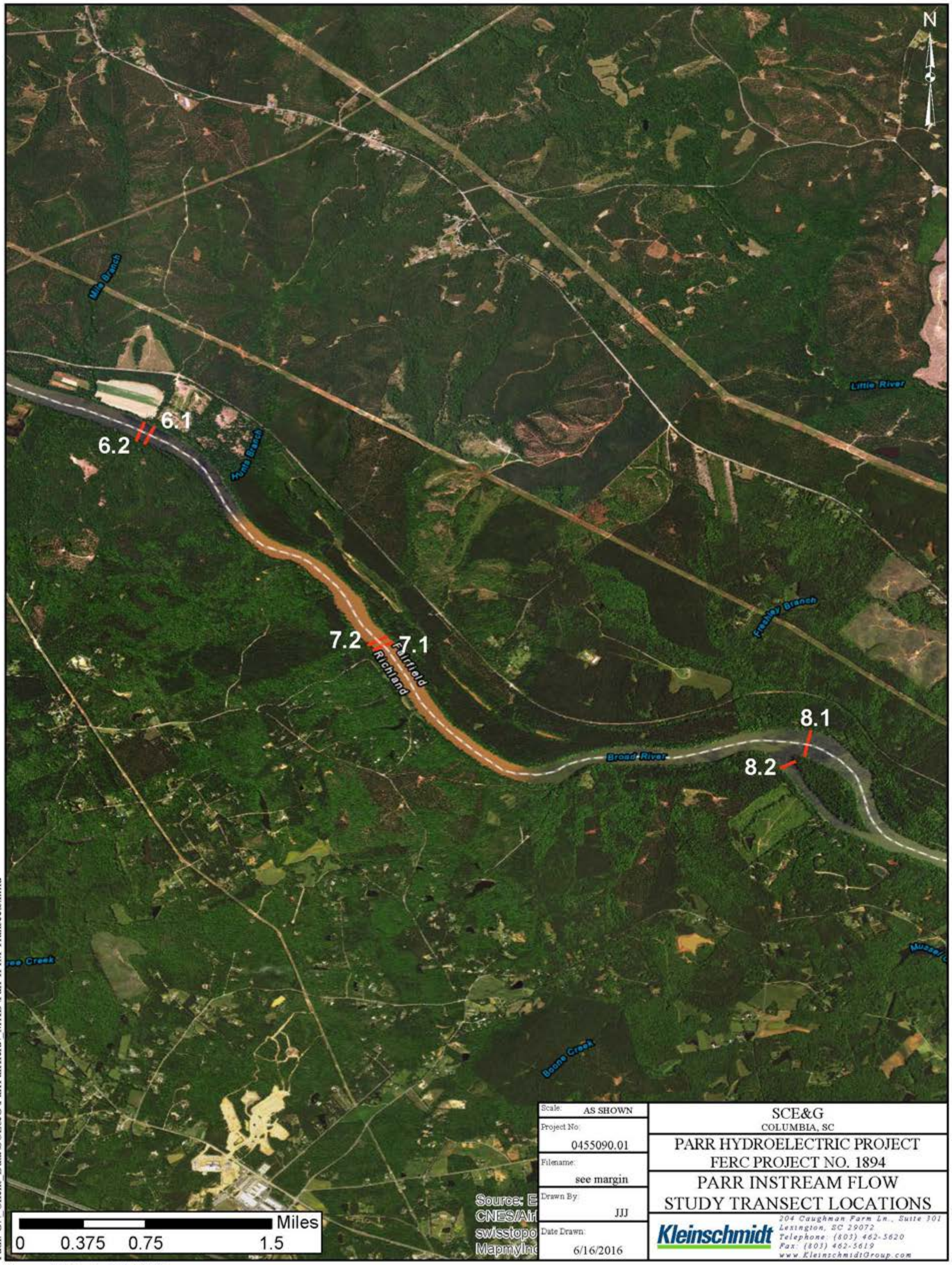
Source: Kleinschmidt. SCE&G. ESRI

FIGURE 3-1 PARR HYDRO PROJECT – IFIM STUDY SITES



Source: Kleinschmidt, ESRI

FIGURE 3-2 PARR HYDRO PROJECT - REACH ONE HABITAT TRANSECTS



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Source: Kleinschmidt, ESRI

FIGURE 3-3 PARR HYDRO PROJECT - REACH TWO HABITAT TRANSECTS

TABLE 3-1 PARR HYDRO IFIM STUDY - SUMMARY OF STUDY SITES AND TRANSECTS

STUDY SITE	TRANSECT ID	MESOHABITAT
2	2.2	Glide
	2.1	Run
3	3.3	Run
	3.2	Glide
	3.1	Riffle
4	4.1	backwater
5	5.2	Run
	5.1	Riffle
6	6.2	Glide
	6.1	Riffle
7	7.2	Glide
	7.1	Riffle
8	8.2	Riffle
	8.1	Riffle

In addition to habitat study sites, the TWC also identified two areas during scoping that were potentially restrictive to the upstream passage of fish. These areas were identified in the Study Plan as "Ledge 1" and "Ledge 2" (Figure 3-4). Ledge 1 consists of a bedrock ledge located at a lat/long of 34°12’49.999”N, 81°15’46.507”W, approximately 2.4 miles upstream of Haltiwanger Island. Ledge 1 is located directly downstream and serves as the hydraulic control for IFIM Study Site 7. The study plan originally identified a primary passage point for Ledge 1 on river left (looking upstream); however, a secondary passage point, located near mid-channel, was also noted during execution of the field effort. Ledge 2 consists of a bedrock ledge located at a lat/long of 34°10’18.154”N, 81°10’15.941”W, 1.3 miles upstream of Hickory Island and approximately 0.5 miles downstream of the mouth of Little River. Field investigations identified the primary navigational passage point on river left (looking upstream).

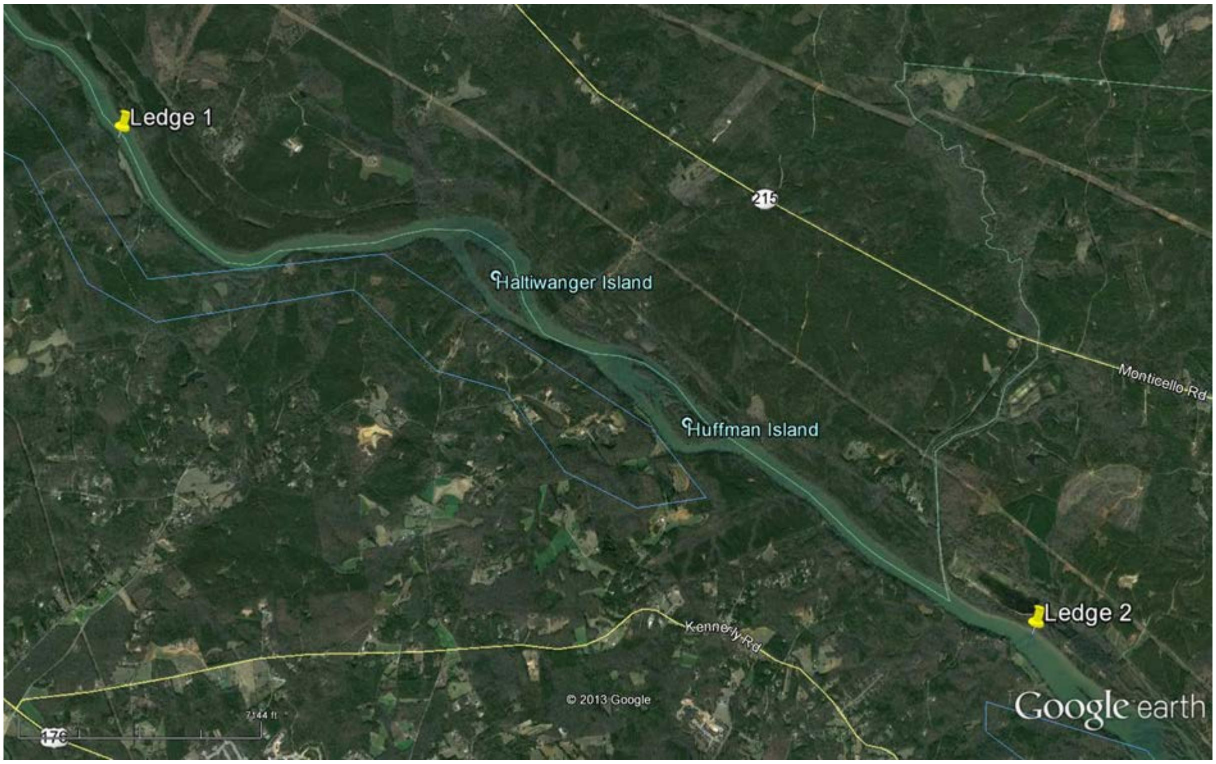

FIGURE 3-4 ZONE-OF-PASSAGE SITES IDENTIFIED BY THE TWC

3.1.1 EVALUATION LIFESTAGES

Each species and lifestage was quantitatively rated using HSI criteria, in which parameters of depth, velocity, and substrate were independently assigned rating values based on research, literature, observations, and/or professional judgment (Bovee, 1982; Bovee et al., 1998). The TWC originally identified 11 target species for evaluation during the IFIM study (Table 3-2). Consultation with the TWC resulted in many of these species being combined into guilds based on similar habitat requirements, with smallmouth bass (spawning, fry, juveniles and adults), redbreast sunfish (spawning and adults), and American shad (spawning) remaining as stand-alone species (Table 3-2).

HSI curves used in this study are included in Appendix D and were adopted primarily from the Lower Saluda River IFIM Study (Kleinschmidt 2008). One exception was smallmouth bass spawning depth, for which the TWC identified a HSI curve developed for the Deerfield River, MA as being more appropriate. Similarly, the TWC elected to utilize curves recently developed by Hightower et al. (2012) to quantify spawning habitat for American shad.

TABLE 3-2 TARGET SPECIES HABITAT USE GUILDS AND HSI CRITERIA SOURCE

	LIFESTAGE	SOURCE	GUILD
smallmouth bass	spawning (depth)	Deerfield River, MA	N/A
smallmouth bass	spawning (velocity and substrate)	Saluda	N/A
smallmouth bass	fry	Saluda	N/A
smallmouth bass	juvenile	Saluda	N/A
smallmouth bass	adult	Saluda	N/A
American shad	spawning	Hightower et al. 2012	N/A
brassy jumprock	adult	Saluda	deep fast/shallow fast
brassy jumprock	juvenile	Saluda	shallow fast
brassy jumprock	spawning	Saluda	shallow fast
whitefin shiner	adult	Saluda	shallow slow; deep slow
whitefin shiner	juvenile	Saluda	shallow slow
whitefin shiner	spawning	Saluda	shallow fast
robust redhorse	adult	Saluda	deep fast/shallow fast
robust redhorse	juvenile	Saluda	shallow fast
robust redhorse	spawning	Saluda	shallow fast
Santee chub	adult	Saluda	shallow fast
striped bass	adult	Saluda	deep fast
piedmont darter	adult	Saluda	shallow fast
piedmont darter	spawning	Saluda	shallow fast
snail bullhead	adult	Saluda	deep slow
redbreast sunfish	adult	Saluda	N/A
redbreast sunfish	spawning	Saluda	N/A
channel catfish	adult	Saluda	deep slow
channel catfish	juvenile	Saluda	deep slow; deep fast

3.2 PHABSIM 1-D MODELING SITES

Field Methods

The location of each transect was field blazed with flagging and paint and documented using Global Position System (GPS) technology. The transect headpin and tailpin ends were located at or above the top-of-bank elevation, and were secured by steel rebar. Each headpin was positioned on river right (looking downstream) and tailpins were located on river left. A measuring tape or kevlar line was secured at each transect to enable repeat field measurements to occur at specific stream loci. Stream bed and water elevations tied to a local datum were surveyed to the nearest 0.1 ft using standard optical surveying instrumentation and methods.

Depth, velocity, cover and substrate data were gathered at intervals (verticals) along each transect. Each vertical was located to the nearest 0.1 ft wherever an observed shift in depth or substrate/cover occurred. Verticals were arranged so that no more than 10% of the river discharge passed between any pair, enhancing hydraulic model calibration. A staff gage was set and monitored at the beginning and end of each set of hydraulic measurements to confirm stable flow during measurements.

Mean column velocity was measured to the nearest 0.1 ft/second with either a calibrated electronic velocity meter mounted on a top-setting wading rod or an Acoustic-Doppler Current Profiler (ADCP) transducer. In water less than 2.5 ft depth, measurements were made at 0.6 of total depth (measured from the water surface); at greater depths, paired measurements were made at 0.2 and 0.8 of total depth, and averaged.

Discharge through the study area is regulated by Parr Shoals Dam and therefore field work was coordinated with pre-arranged releases from the Project. Hydraulic data were collected at three calibration discharges according to study objectives (approximately 400; 2,000 and 6,000 cfs), to facilitate modeling in a range from approximately 200 cfs up to 15,000 cfs. One exception to this was Study Site Two, which is located in the West Channel below the dam and is not subject to powerhouse flows. At this site, calibration flows of approximately 46, 395 and 1,880 cfs were released into the West Channel via the spillway crest gates to allow modeling from 20 cfs up to 2,000 cfs.

Because the stage-discharge relationship is rarely linear, a minimum of three calibration flows is required to define the shape of stage-discharge curve for the flow range of interest. PHABSIM hydraulic models, as a rule of thumb, may extrapolate to as low as 40% of the lowest flow and up to 250% of the highest flow under ideal conditions. Therefore a low calibration flow of 400 cfs was selected to adequately provide data to model down to approximately 200 cfs and a high calibration flow of 6,000 cfs was selected to enable model extrapolation up to 15,000 cfs. The choice of middle calibration flow was made to be at least twice as high as the low flow in order to capture a set of hydraulic conditions significantly different than the low flow, and also approximately an order of magnitude lower than the high calibration flow.

Hydraulic Modeling

Hydraulic modeling and quality assurance/quality control techniques were conducted in accordance with standard practices for PHABSIM. Hydraulic modeling was accomplished by correlating each surveyed WSEL with discharge to develop a stage-discharge relationship for each transect. The model then adjusted velocities obtained at calibration flows to each flow increment of interest for which a defined water stage had been calculated. The model was then calibrated by comparing simulated hydraulics to empirical measurements taken at the calibration flows. Detailed steps are summarized below.

Field data collected at transects (e.g. cross section surveys, WSELs, velocities, discharge and slope measurements) were entered into a computer database compatible with PHABSIM software. All field calculations of discharge and data entry were proofed and cross-checked for accuracy. The field data included measurements at all three calibration flows, and were used to simulate depth, velocity, substrate, and cover conditions at discharges other than the calibration flows. Discharges and WSELs were determined for all calibration flows. Bed profiles, substrate, and cover used in the model were derived from surveys made during low flows. Velocity calibration in the PHABSIM model typically relies on velocities measured during mid-range flows, although velocity measurements are sometimes made in the field for low flows at features such as riffles where velocities are irregular across the cross section.

Transects within a common study site and mesohabitat type were linked hydraulically (*i.e.* within the same datum) with adjacent contiguous transects and/or with downstream hydraulic controls that create backwater conditions. Stand-alone transects were independently modeled. Simulation of water surface elevations at each transect was accomplished using one of three models within the PHABSIM analysis: IFG4, MANSQ or WSP. Often, all three models are run with the best stage-discharge relationship determined for each cross-section. The specific model used at a given transect depends on site characteristics, including gradient and backwatering from downstream hydraulic controls. IFG4 uses a log-log fit to determine a stage-discharge curve for the three calibration flows. MANSQ determines the stage-discharge relationship using the Manning's equation for stream flow, while WSP uses hydraulically-linked cross-sections in a backwater model to determine the relationship. WSP is similar to backwater models such as the U.S. Army Corps of Engineers' HEC-RAS program.

Velocity calibrations for each transect were performed using routines within the IFG4 model. The range of simulated flows represented by each calibration set is determined by the hydraulic engineer based on the model's performance at the calibration flows and trends in hydraulic parameters such as water surface elevation and velocity. PHABSIM output for each simulated flow, such as Velocity Adjustment Factors (VAFs), were plotted as smooth curves, with aberrations in these curves indicative of range boundaries for a given calibration flow. Typically, these fall toward extreme low or high flows in high gradient channels, at which point one of the other three calibration sets is used to continue the model out to the extremes. The hydraulic engineer reviewed all hydraulic output and determined and documented the acceptable range of simulated flows. This range usually extended from slightly below the low calibration flow to slightly higher than the high calibration flow.

3.3 DATA COLLECTION (2-D MODEL)

The TWC recommended that a 2-D hydraulic model as most appropriate for capturing the hydraulics and habitat suitability of the Bookman Island complex (Study Site 10) due to the complex channel characteristics. This process included the following steps:

- Raw data (terrain, velocity, depth and substrate) gathering and processing
- 2-D model development and calibration

- WUA computations

The preliminary data processing included the acquisition of remote-sensed terrain data, and merging this data with other bathymetric and topographic data. Aerial surveying was conducted at a flow of approximately 500 cfs, which provided comprehensive coverage of the study site. The end-product was a georeferenced bedfile, which is, in general terms, an xyz datafile with points that comprise the topology of the model domain (Figure 3-5).

FIGURE 3-5 SUBSECTION OF MODEL DOMAIN BEDFILE - (EACH PIXEL IS A DATAPOINT WITHIN THE 2D MODEL)

Depth, velocity, WSEL, and substrate information were collected throughout the reach during two different periods of controlled flows of 1,000 and 2,000 cfs. There were three water level loggers deployed within the study reach to provide additional model calibration data. These level loggers were deployed in the upper, middle, and lower sections of the study reach.

A two dimensional substrate map (Figure 3-6) was developed based on data collected during the field effort. Substrate and cover were categorized based on codes specified within the HSI curves.

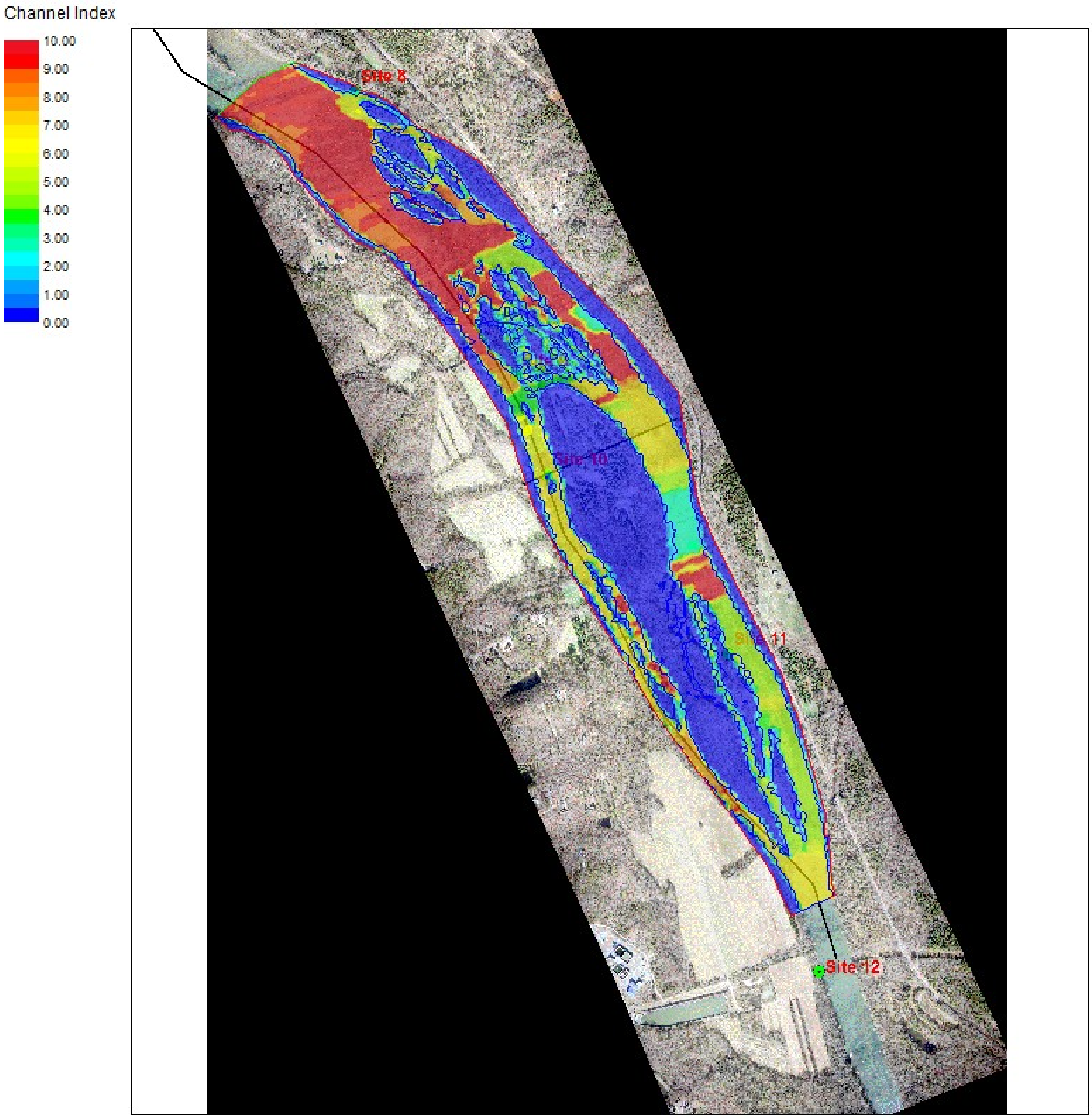

FIGURE 3-6 CHANNEL INDEX (SUBSTRATE) MAP - STUDY SITE 10

The 2-D modeling was performed with River2D (Steffler and Blackburn 2002), which is a public domain software package developed as a cooperative effort between the University of Alberta, Fisheries and Oceans – Canada, and the USGS. The River2D suite includes subroutines for bed editing, mesh development and editing, depth-averaged hydrodynamic modeling, and computation of WUA. Subsequent to the bedfile development, the model mesh was developed and edited in conjunction with the model calibration. The mesh editing and calibration, in brief, involved inspecting the flow pathways within the model domain. The majority of this effort was directed at refining the mesh in locations where the base data did not accurately shape the flow pathways (Figure 3-7).

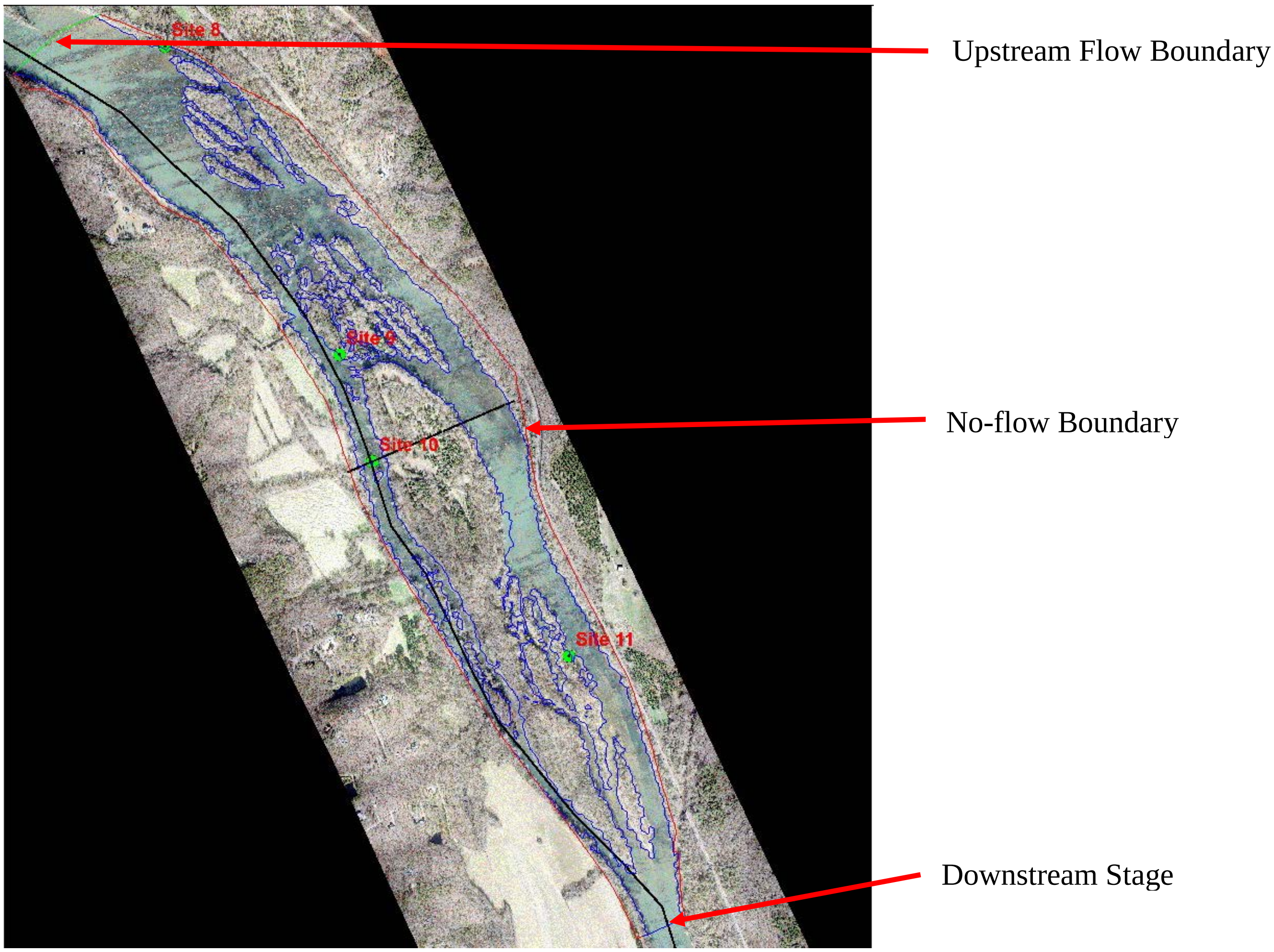

FIGURE 3-7 FLOW PATHWAY MAP - STUDY SITE 10

The WUA calculations were performed within the River2D model suite, using the same data that were used to simulate the flow. The HSI curves for depth, velocity and substrate were incorporated into the modeling data. The WUA calculations were performed using the simulated velocity and depth, and a lookup of the substrate. The WUA value was computed as the summation of the product of the HSI values times the area for all mesh cells.

3.4 DATA COLLECTION (LEDGE POOLS BELOW DAM IN STUDY SITE 1)

Bedrock pools occurring in the upper West Channel directly downstream of Parr Shoals Dam were surveyed using a Sontek M-9 ADCP unit to provide bathymetric data for the area.

Supplemental depth data was collected manually in each of the primary pools at full pool leakage flow (approximately 50 cfs) during a site visit conducted in May 2016. These representative depths were then used in combination with Geographic Information System (GIS)-based surface area calculation to determine pool volumes at low flow conditions when water quality issues are likely to occur.

3.5 DATA COLLECTION (WETTED PERIMETER AT STUDY SITE 4; BACKWATER AT LOWER WEST CHANNEL)

The transect end points at Study Site 4 were field blazed with flagging and paint and documented with sub-meter GPS. The transect headpin and tailpin ends were located above the top-of-bank elevation, and secured by steel rebar. A Kevlar line was secured at the transect to enable repeat field measurements at specific stream locations. Streambed and water elevations tied to a local datum were surveyed to the nearest 0.1 ft using standard optical surveying instrumentation and methods. Approximately 30 verticals were established along the transect to accurately depict cross-sectional channel geometry. Water elevation at three flows spanning the range of releases associated with the PHABSIM data collection was recorded through both survey and staff gaging, so that a stage-discharge relationship could be established. These data were then used to establish a wetted perimeter rating curve.

4.0 RESULTS

Calibration flow data were primarily collected in April, June and July of 2015, with additional low flow data in support of the 2-D modeling at Study Site 10 collected in April of 2016. Results are presented below for each study site, beginning upstream.

4.1 STUDY SITE 1 (BEDROCK POOLS IN UPPER WEST CHANNEL)

Bathymetric mapping in Study Site 1 indicated five primary pools in the upstream portion of the West Channel (Figure 4-1). The estimates of pool volume range in size from 0.2 to 4.9 acre-ft (Table 4-1). Additional testing is scheduled at this site for August 2016, during which pulses of varying magnitudes will be released to the West Channel via the spillway crest gates. The releases will be monitored to determine the extent which adequate turnover is achieved to reach the desired water quality conditions.

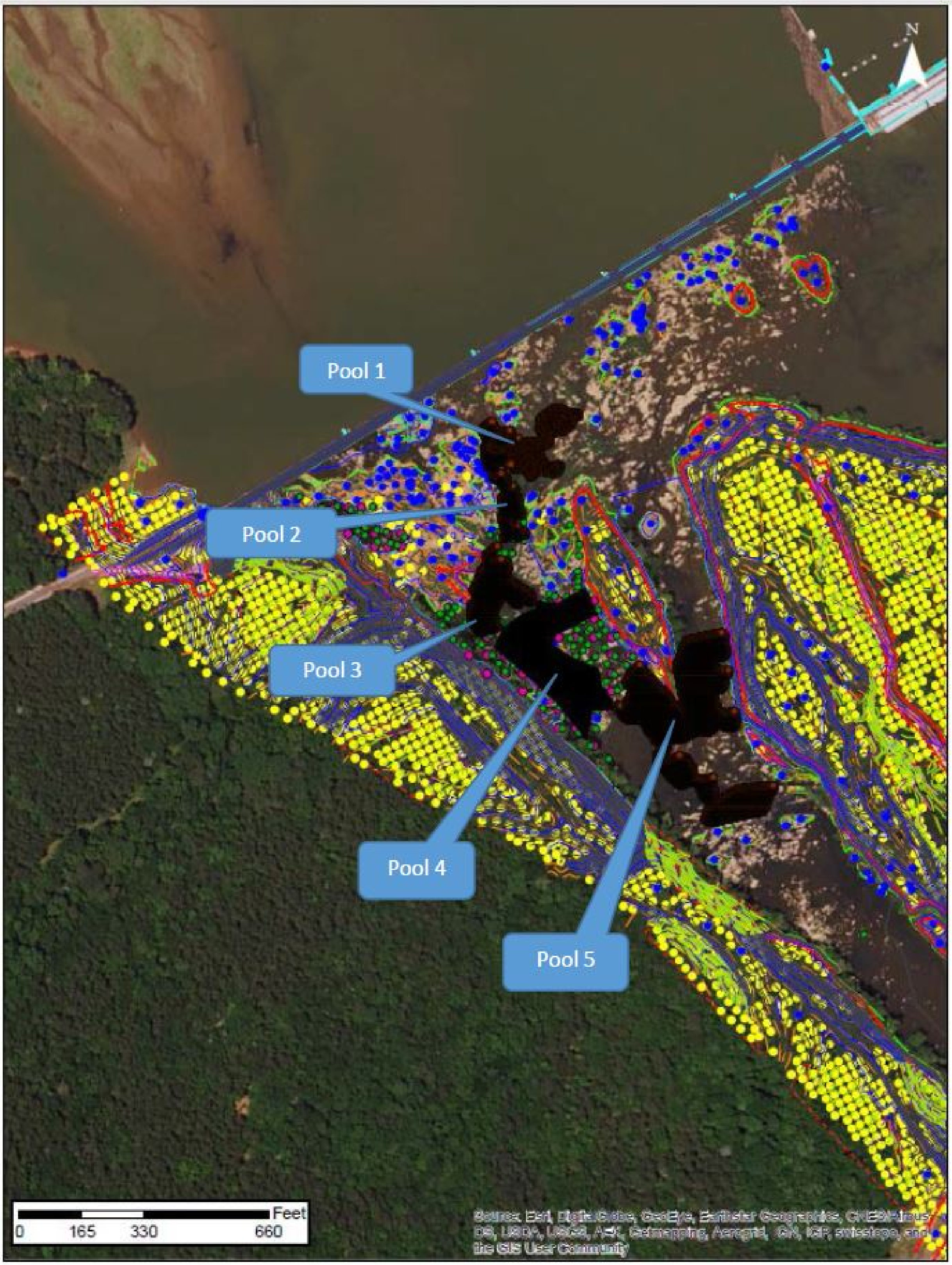

FIGURE 4-1 PRIMARY POOLS IN UPPER WEST CHANNEL BELOW PARR SHOALS DAM (IFIM STUDY SITE 1)

TABLE 4-1 ESTIMATED VOLUME OF FIVE MAJOR POOLS IN THE UPSTREAM PORTION OF THE WEST CHANNEL

POOL #	AREA (SQ FT)	DEPTH AT 50 CFS (FT)	POOL VOLUME (CUBIC FT)	POOL VOLUME (ACRE FT)
1	29,394	3.1	91,121	2.1
2	3,760	2.3	8,648	0.2
3	39,255	1.5	58,882	1.4
4	35,952	3.1	75,499	1.7
5	119,771	1.8	215,588	4.9
TOTAL				**10.3**

4.2 STUDY SITE 2 (RIFFLE AND RUN COMPLEX LOCATED IN WEST CHANNEL)

This site is comprised of two linked transects spanning a boulder-dominated riffle and run complex located in the West Channel below the project dam. Data from this site suggest that WUA for several key lifestages, namely adult redbreast sunfish, smallmouth bass juveniles and the deep-slow and shallow-fast guilds, peaks in the range of 250 to approximately 500 cfs (Figure 4-2) (Table 4-2). American shad spawning and smallmouth bass adults experience maximum WUA at approximately 1,000 cfs, but this is at the detriment of many other lifestages. Finally, several lifestages, including smallmouth bass fry, redbreast sunfish spawning and the shallow-slow guild, appear velocity limited at this site, with WUA values falling as flow increases from the base flow.

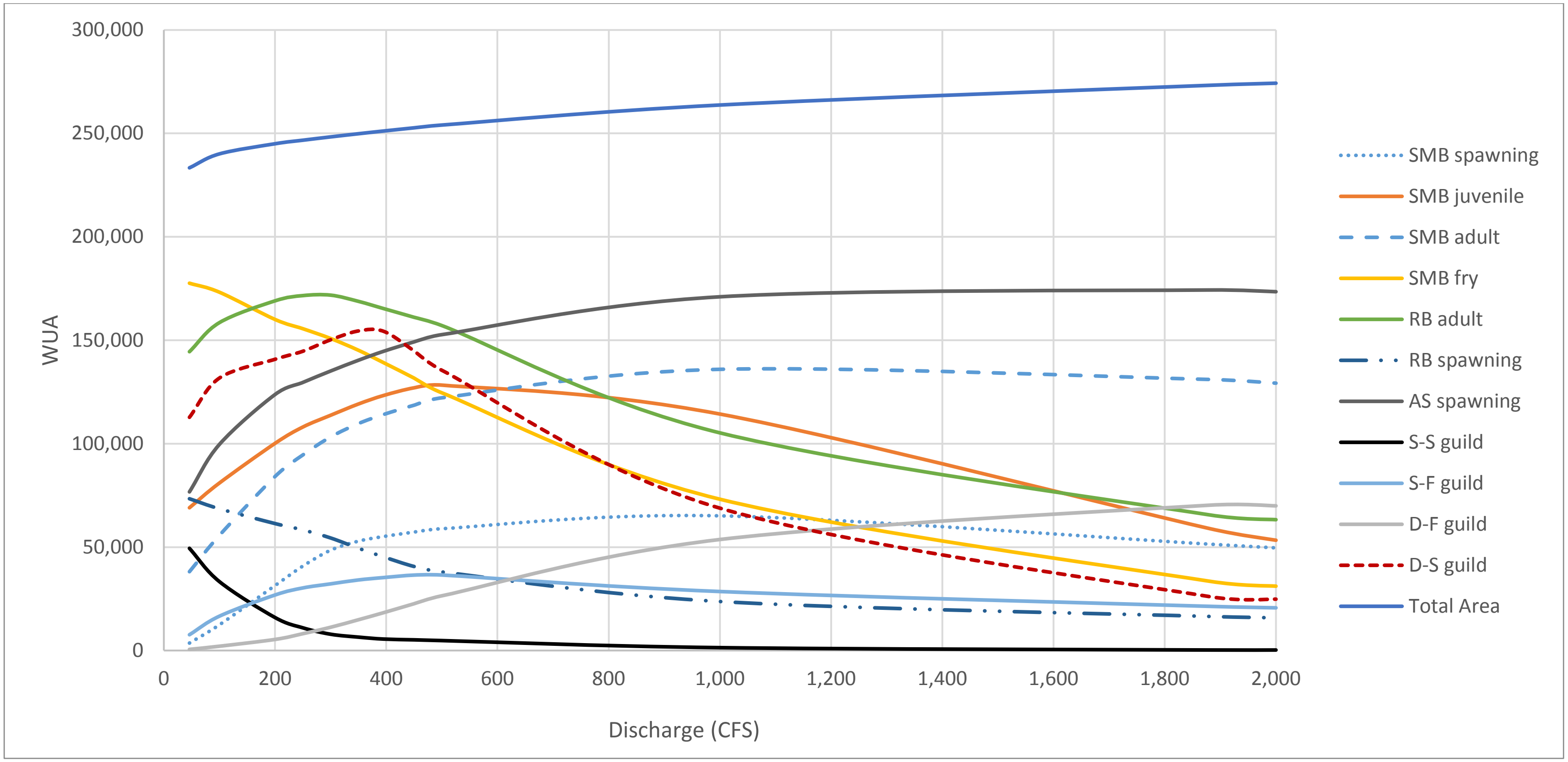

FIGURE 4-2 STUDY SITE 2 HABITAT SUITABILITY

TABLE 4-2 STUDY SITE 2 HABITAT SUITABILITY[1]

Discharge	SMB spawning		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
46	3,593	6%	69,023	54%	38,107	28%	177,587	100%	144,465	84%	73,381	100%	76,695	44%	49,409	100%	7,628	21%	552	1%	112,750	73%
100	12,447	19%	81,000	63%	55,695	41%	173,223	98%	158,542	92%	68,520	93%	99,675	57%	33,296	67%	16,616	46%	2,083	3%	131,748	85%
200	31,419	48%	100,168	78%	84,144	62%	160,052	90%	169,059	98%	61,376	84%	123,780	71%	15,941	32%	26,854	74%	5,358	8%	140,813	91%
250	40,828	63%	108,057	84%	94,555	70%	155,581	88%	171,592	100%	58,300	79%	129,619	75%	10,971	22%	30,255	83%	8,136	12%	144,693	94%
300	48,503	74%	113,747	89%	103,268	76%	150,849	85%	171,812	100%	54,404	74%	135,135	78%	7,869	16%	32,231	88%	11,255	16%	150,234	97%
350	52,879	81%	119,193	93%	109,727	81%	145,157	82%	168,805	98%	49,425	67%	140,343	81%	6,473	13%	34,118	93%	14,886	21%	154,505	100%
395	55,112	85%	123,293	96%	114,102	84%	139,183	78%	165,331	96%	45,290	62%	144,651	83%	5,539	11%	35,270	97%	18,281	26%	154,341	100%
450	57,259	88%	127,005	99%	118,596	87%	131,707	74%	161,105	94%	40,626	55%	149,215	86%	5,166	10%	36,469	100%	22,624	32%	144,867	94%
500	58,896	90%	128,312	100%	122,177	90%	124,582	70%	157,107	91%	37,982	52%	152,723	88%	4,803	10%	36,497	100%	26,461	38%	135,481	88%
600	60,139	92%	125,515	98%	124,932	92%	114,295	64%	146,731	85%	35,123	48%	156,382	90%	4,120	8%	34,903	96%	31,904	45%	122,150	79%
700	61,382	94%	122,718	96%	127,688	94%	104,008	59%	136,356	79%	32,265	44%	160,040	92%	3,437	7%	33,308	91%	37,347	53%	108,818	70%
800	62,626	96%	119,921	93%	130,443	96%	93,721	53%	125,980	73%	29,406	40%	163,699	94%	2,754	6%	31,713	87%	42,790	61%	95,487	62%
900	63,869	98%	117,124	91%	133,199	98%	83,434	47%	115,604	67%	26,547	36%	167,357	96%	2,071	4%	30,119	83%	48,233	69%	82,155	53%
1,000	65,112	100%	114,327	89%	135,955	100%	73,148	41%	105,229	61%	23,689	32%	171,016	99%	1,388	3%	28,524	78%	53,676	76%	68,823	45%
1,100	63,563	98%	108,227	84%	135,285	100%	68,944	39%	101,032	59%	22,900	31%	171,261	99%	1,274	3%	27,736	76%	55,303	79%	64,424	42%
1,200	62,014	95%	102,126	80%	134,615	99%	64,741	36%	96,834	56%	22,111	30%	171,507	99%	1,160	2%	26,948	74%	56,930	81%	60,025	39%
1,300	60,465	93%	96,025	75%	133,944	99%	60,537	34%	92,637	54%	21,322	29%	171,752	99%	1,045	2%	26,160	72%	58,556	83%	55,626	36%
1,400	58,916	90%	89,925	70%	133,274	98%	56,333	32%	88,440	51%	20,533	28%	171,998	99%	931	2%	25,371	70%	60,183	86%	51,227	33%
1,600	57,367	88%	83,824	65%	132,604	98%	52,130	29%	84,243	49%	19,745	27%	172,243	99%	817	2%	24,583	67%	61,810	88%	46,828	30%
1,880	51,434	79%	58,992	46%	131,051	96%	33,514	19%	65,590	38%	16,478	22%	174,298	100%	252	1%	21,364	59%	70,253	100%	26,080	17%
2,000	49,621	76%	53,321	42%	129,254	95%	31,112	18%	63,256	37%	15,800	22%	173,471	100%	245	0%	20,643	57%	69,943	100%	24,833	16%
100%	65,112		128,312		135,955		177,587		171,812		73,381		174,298		49,409		36,497		70,253		154,505	
75%	48,834		96,234		101,966		133,190		128,859		55,036		130,724		37,057		27,373		52,690		115,879	

[1] Shading indicates WUA value that are equal or exceed 75% of maximum WUA for that species/lifestage at that study site.

4.3 STUDY SITE 3 (RUN-GLIDE-RIFFLE COMPLEX DIRECTLY DOWNSTREAM OF PARR POWERHOUSE)

This site consists of three linked transects spanning a cobble and gravel dominated run-glide-riffle complex located directly downstream of the Parr Shoals powerhouse. This site has been noted as an important site for freshwater mussels and as a potential robust redhorse spawning site. WUA results show that several lifestages, including redbreast sunfish adult and smallmouth bass juveniles, have peak habitat suitability at flows ranging from 400 to approximately 900 cfs (Figure 4-3) (Table 4-3). The shallow-fast guild, which includes robust redhorse spawning, also peaks in this range. Finally, habitat suitability for smallmouth bass adults, smallmouth bass spawning and American shad spawning follow similar patterns to one another, peaking at approximately 1,500 to 2,000 cfs. Smallmouth bass fry and the shallow-slow guild appear to be velocity limited at this site, with WUA values falling as flow increases from the base flow. Both deep-slow and shallow-slow guilds have limited habitat suitability at this under all flow increments.

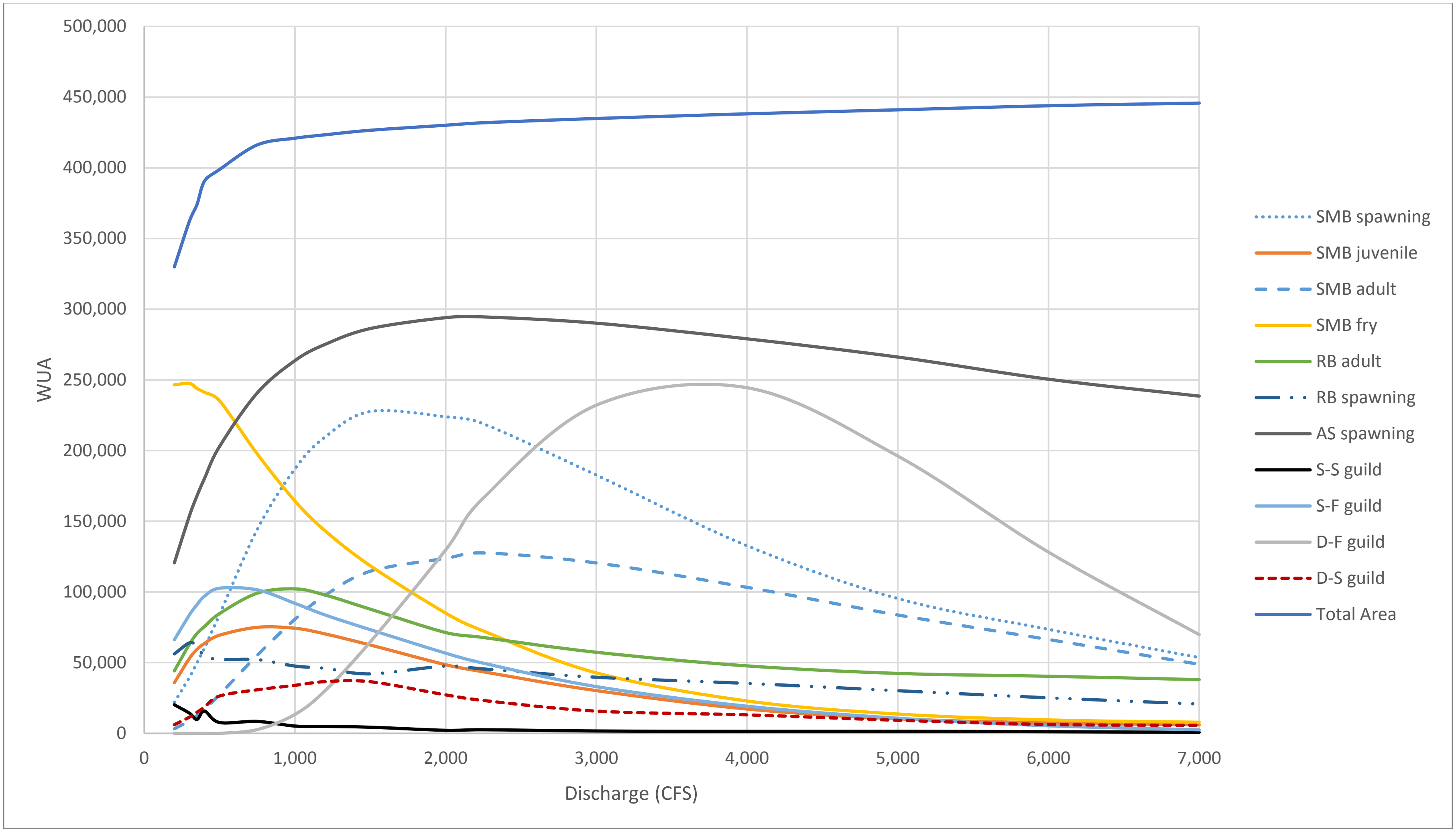

FIGURE 4-3 STUDY SITE 3 HABITAT SUITABILITY

TABLE 4-3 STUDY SITE 3 HABITAT SUITABILITY

Discharge	SMB spawning		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
200	22,010	10%	35,895	48%	3,245	3%	246,534	100%	44,190	43%	56,194	88%	120,632	41%	20,227	100%	66,201	64%	0	0%	6,155	17%
300	39,568	17%	53,023	71%	8,842	7%	247,519	100%	63,111	62%	64,009	100%	153,920	52%	14,301	71%	83,824	82%	0	0%	11,464	31%
350	49,956	22%	59,398	79%	12,657	10%	243,919	99%	70,590	69%	61,535	96%	167,976	57%	9,857	49%	91,012	89%	0	0%	14,970	41%
400	60,444	27%	63,598	85%	17,079	13%	241,241	97%	75,583	74%	54,781	86%	180,321	61%	15,779	78%	97,020	94%	0	0%	18,557	51%
500	84,153	37%	69,445	93%	27,450	22%	235,249	95%	84,730	83%	52,279	82%	202,960	69%	7,678	38%	102,671	100%	18	0%	26,424	72%
600	108,176	48%	71,675	96%	38,563	30%	220,223	89%	90,492	89%	52,231	82%	218,096	74%	7,989	39%	102,207	100%	1,084	0%	28,182	77%
750	144,211	63%	75,020	100%	55,233	43%	197,685	80%	99,135	97%	52,159	81%	240,800	82%	8,456	42%	101,510	99%	2,683	1%	30,820	84%
900	169,961	75%	74,625	99%	70,526	55%	177,690	72%	100,972	99%	49,417	77%	254,511	86%	6,481	32%	95,779	93%	9,107	4%	32,714	89%
1,000	187,128	82%	74,361	99%	80,722	63%	164,360	66%	102,196	100%	47,588	74%	263,652	90%	5,165	26%	91,959	90%	13,389	5%	33,976	93%
1,100	198,374	87%	72,351	96%	89,180	70%	153,828	62%	100,034	98%	46,805	73%	269,389	91%	5,037	25%	87,850	86%	21,793	9%	35,273	96%
1,200	209,621	92%	70,340	94%	97,638	77%	143,295	58%	97,872	96%	46,021	72%	275,126	93%	4,908	24%	83,741	82%	30,196	12%	36,570	100%
1,300	215,631	95%	67,729	90%	103,323	81%	135,051	55%	94,529	92%	44,706	70%	278,857	95%	4,721	23%	80,277	78%	41,700	17%	36,553	100%
1,400	221,641	97%	65,117	87%	109,007	85%	126,806	51%	91,187	89%	43,392	68%	282,587	96%	4,534	22%	76,813	75%	53,205	22%	36,537	100%
1,500	227,651	100%	62,505	83%	114,691	90%	118,562	48%	87,845	86%	42,077	66%	286,317	97%	4,346	21%	73,349	71%	64,709	26%	36,520	100%
1,600	226,903	100%	59,717	80%	116,507	91%	111,868	45%	84,541	83%	43,188	67%	287,860	98%	3,909	19%	70,025	68%	77,711	32%	34,663	95%
2,000	223,911	98%	48,562	65%	123,771	97%	85,089	34%	71,328	70%	47,632	74%	294,034	100%	2,162	11%	56,730	55%	129,719	53%	27,237	74%
2,250	218,971	96%	43,563	58%	127,623	100%	72,426	29%	67,802	66%	45,587	71%	294,550	100%	2,559	13%	49,660	48%	166,430	68%	23,277	64%
2,400	211,716	93%	40,901	55%	126,207	99%	66,497	27%	65,714	64%	44,409	69%	293,666	100%	2,384	12%	46,342	45%	179,569	73%	21,766	60%
2,600	206,879	91%	39,126	52%	125,263	98%	62,544	25%	64,322	63%	43,624	68%	293,076	99%	2,268	11%	44,130	43%	188,329	77%	20,759	57%
3,000	182,696	80%	30,254	40%	120,543	94%	42,781	17%	57,363	56%	39,697	62%	290,129	98%	1,686	8%	33,070	32%	232,128	95%	15,725	43%
3,500	157,697	69%	23,741	32%	111,904	88%	32,844	13%	52,545	51%	37,521	59%	284,590	97%	1,563	8%	26,136	25%	238,302	97%	14,404	39%
4,000	132,698	58%	17,228	23%	103,264	81%	22,907	9%	47,726	47%	35,346	55%	279,051	95%	1,440	7%	19,202	19%	244,475	100%	13,084	36%
4,500	114,045	50%	13,765	18%	93,499	73%	18,286	7%	45,068	44%	32,764	51%	272,609	93%	1,462	7%	14,954	15%	220,313	90%	11,167	31%
5,000	95,391	42%	10,302	14%	83,733	66%	13,665	6%	42,410	41%	30,183	47%	266,167	90%	1,483	7%	10,706	10%	196,150	80%	9,249	25%
6,000	73,583	32%	7,408	10%	66,396	52%	9,506	4%	40,400	40%	25,129	39%	250,501	85%	1,184	6%	5,364	5%	128,195	52%	6,275	17%
7,000	53,598	24%	6,030	8%	48,860	38%	7,856	3%	38,010	37%	20,758	32%	238,542	81%	721	4%	2,515	2%	69,829	29%	5,693	16%
100%	227,651		75,020		127,623		247,519		102,196		64,009		294,550		20,227		102,671		244,475		36,570	
75%	170,738		56,265		95,717		185,639		76,647		48,007		220,913		15,171		77,004		183,356		27,428	

4.4 STUDY SITE 4 (WEST CHANNEL WETTED PERIMETER TRANSECT)

A bed profile depicting the wetted perimeter transect at Study Site 4 is provided in Figure 4-4. A rating curve depicting the wetted width – flow relationship for Study Site 4 is provided is Figure 4-5.

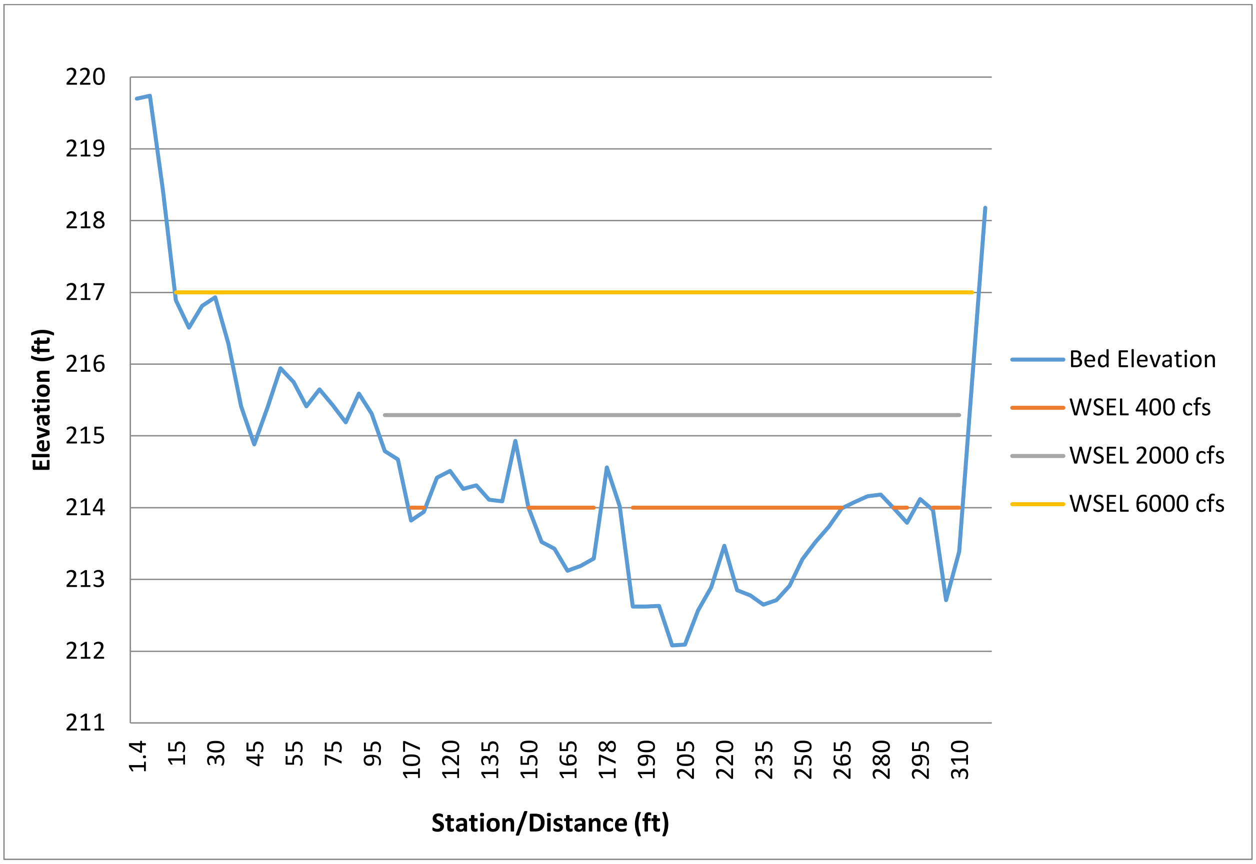

FIGURE 4-4 BED PROFILE AT STUDY SITE 4 SHOWING WATER SURFACE ELEVATION AT IFIM CALIBRATION FLOWS

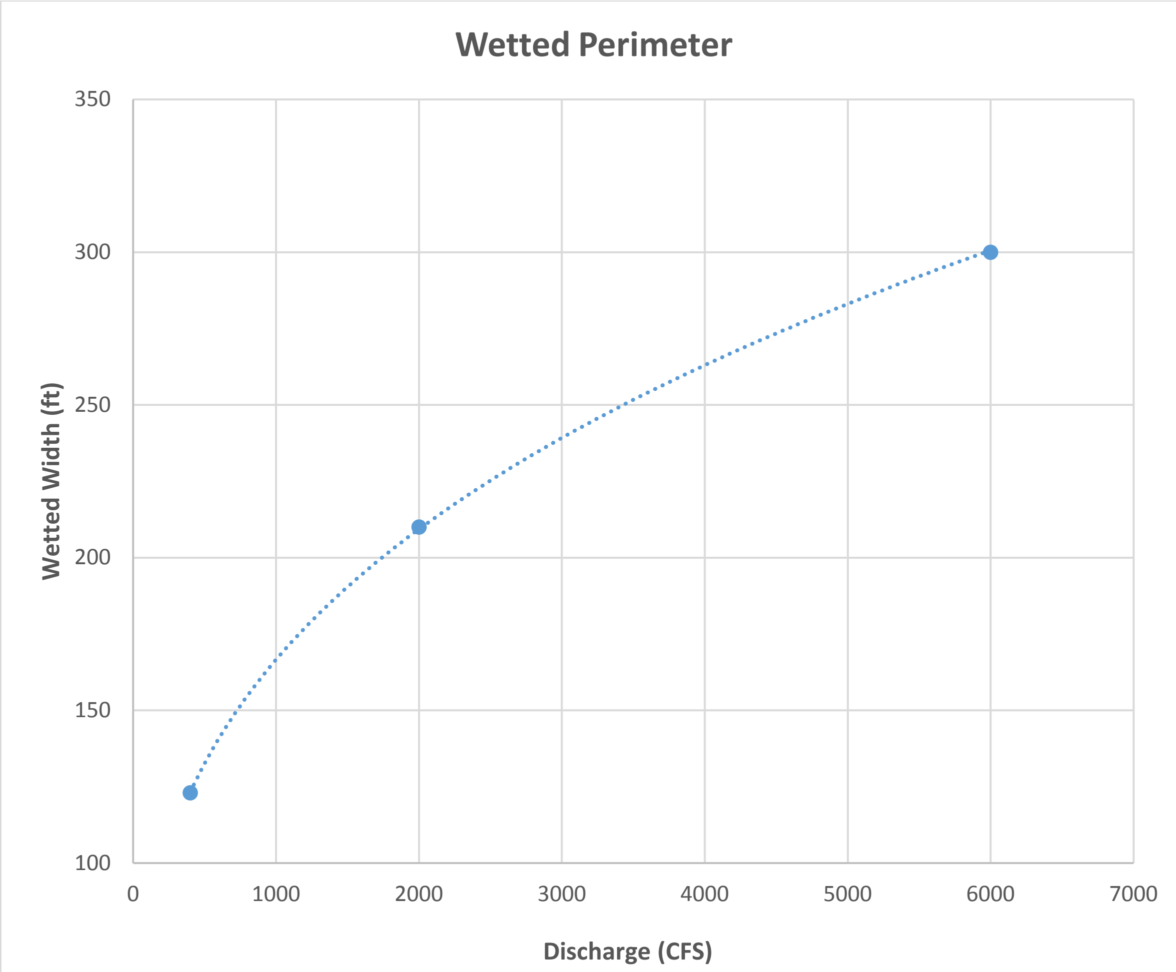

FIGURE 4-5 WETTED WIDTH RATING CURVE FOR STUDY SITE 4

4.5 STUDY SITE 5 (LEDGE-CONTROLLED RIFFLE IN LOWER EAST CHANNEL)

This site consists of two linked transects located at a ledge-controlled glide-riffle located downstream of the Parr Shoals powerhouse just upstream of the downstream terminus of Hampton Island. All of the lifestages and guilds modeled at this site experienced peak WUA in the range of 500 to approximately 1000 cfs (Figure 4-6) (Table 4-4). This site provides relatively limited suitability for a number of lifestages, including shallow-fast guild, deep-fast guild, smallmouth bass fry, and redbreast sunfish spawning.

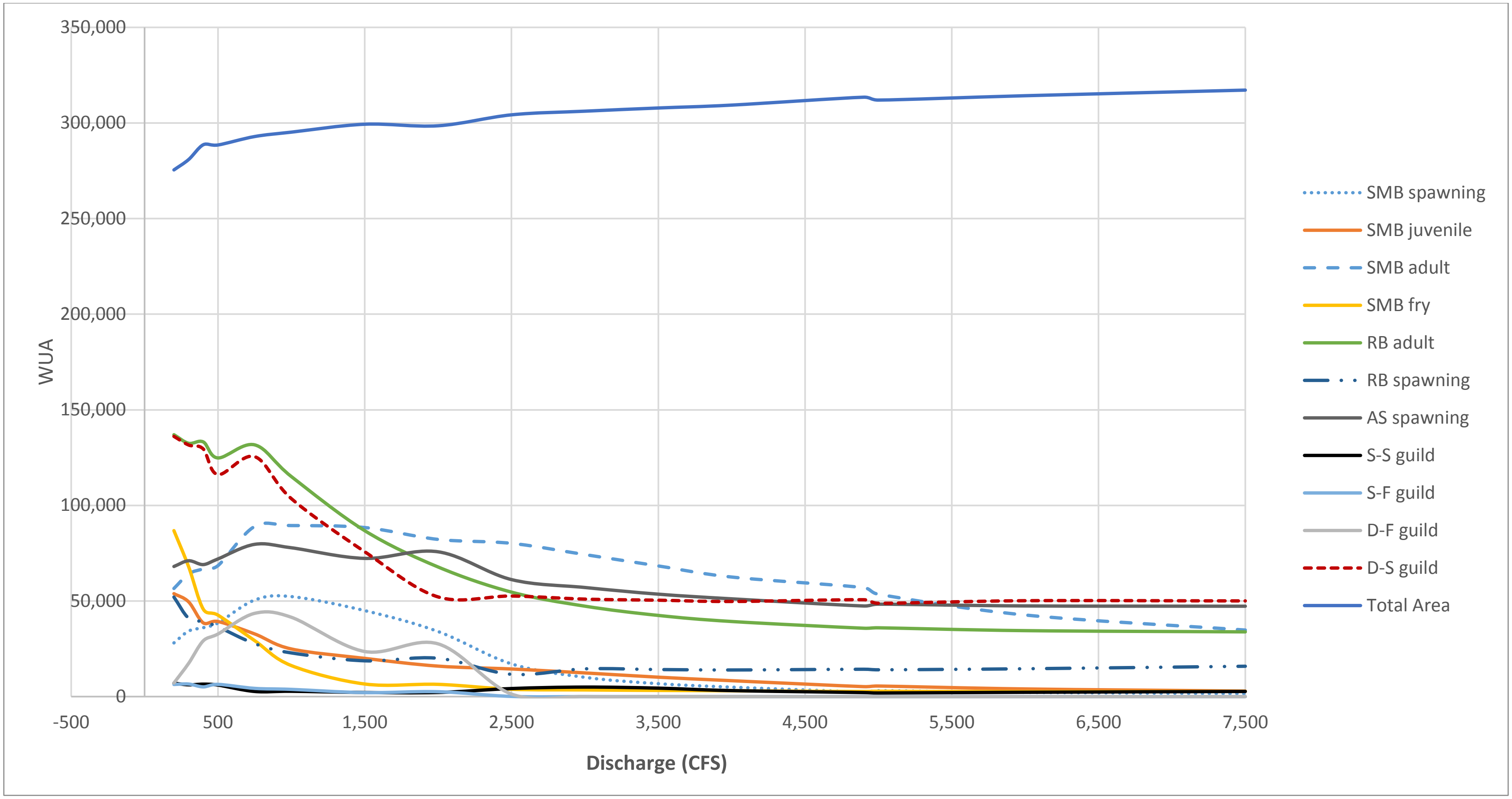

FIGURE 4-6 STUDY SITE 5 HABITAT SUITABILITY

TABLE 4-4 STUDY SITE 5 HABITAT SUITABILITY

Discharge	SMB spawn		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
200	28,083	54%	53,848	100%	56,543	63%	86,800	100%	136,977	100%	52,055	100%	68,051	85%	7,018	100%	6,342	96%	7,119	16%	136,092	100%
300	34,276	66%	49,561	92%	64,142	72%	67,987	78%	132,491	97%	40,997	79%	71,047	89%	6,160	88%	6,572	100%	17,363	40%	131,583	97%
400	36,049	69%	38,556	72%	66,756	75%	45,721	53%	133,190	97%	39,197	75%	69,047	87%	6,514	93%	5,081	77%	29,183	67%	129,485	95%
500	38,478	74%	39,271	73%	68,494	77%	42,613	49%	124,819	91%	36,520	70%	72,001	90%	6,032	86%	6,393	97%	32,730	75%	116,099	85%
600	43,284	83%	36,677	68%	76,693	86%	37,280	43%	127,556	93%	32,985	63%	75,054	94%	4,695	67%	5,556	85%	37,055	85%	119,861	88%
750	50,493	97%	32,787	61%	88,993	99%	29,282	34%	131,661	96%	27,682	53%	79,632	100%	2,689	38%	4,302	65%	43,541	100%	125,505	92%
900	51,580	99%	28,062	52%	89,268	100%	21,450	25%	121,716	89%	24,781	48%	78,559	99%	2,743	39%	3,989	61%	42,314	97%	112,328	83%
1,000	52,305	100%	24,913	46%	89,452	100%	16,229	19%	115,085	84%	22,847	44%	77,843	98%	2,779	40%	3,780	58%	41,495	95%	103,544	76%
1,150	50,107	96%	23,438	44%	89,140	100%	13,336	15%	106,593	78%	21,608	42%	76,174	96%	2,590	37%	3,268	50%	36,121	83%	95,210	70%
1,350	47,177	90%	21,472	40%	88,725	99%	9,478	11%	95,271	70%	19,956	38%	73,949	93%	2,338	33%	2,586	39%	28,956	67%	84,098	62%
1,500	44,979	86%	19,998	37%	88,413	99%	6,584	8%	86,780	63%	18,717	36%	72,279	91%	2,149	31%	2,075	32%	23,583	54%	75,763	56%
1,650	41,695	80%	18,779	35%	86,552	97%	6,532	8%	81,081	59%	19,116	37%	73,316	92%	2,150	31%	2,219	34%	24,783	57%	68,674	50%
1,850	37,318	71%	17,155	32%	84,070	94%	6,462	7%	73,483	54%	19,647	38%	74,697	94%	2,152	31%	2,411	37%	26,384	61%	59,221	44%
2,000	34,035	65%	15,936	30%	82,209	92%	6,410	7%	67,785	49%	20,045	39%	75,734	95%	2,153	31%	2,555	39%	27,585	63%	52,131	38%
2,500	17,113	33%	14,441	27%	80,148	90%	3,840	4%	54,643	40%	11,662	22%	61,197	77%	4,216	60%	91	1%	1,333	3%	52,594	39%
3,000	10,080	19%	12,385	23%	74,277	83%	3,483	4%	47,300	35%	14,517	28%	57,062	72%	4,976	71%	0	0%	0	0%	50,984	37%
3,500	6,759	13%	10,156	19%	68,334	76%	3,235	4%	42,455	31%	14,154	27%	53,573	67%	4,421	63%	0	0%	0	0%	50,415	37%
4,000	4,938	9%	8,315	15%	62,530	70%	3,046	4%	39,279	29%	13,929	27%	51,134	64%	3,144	45%	0	0%	0	0%	49,753	37%
4,900	2,439	5%	5,211	10%	56,984	64%	2,667	3%	35,760	26%	14,309	27%	47,393	60%	2,098	30%	0	0%	0	0%	50,663	37%
5,000	3,049	6%	5,526	10%	53,526	60%	2,802	3%	35,985	26%	14,020	27%	48,334	61%	1,890	27%	0	0%	0	0%	48,825	36%
6,000	2,213	4%	4,004	7%	42,668	48%	2,604	3%	34,497	25%	14,561	28%	47,419	60%	2,263	32%	0	0%	0	0%	50,155	37%
7,500	1,615	3%	2,883	5%	34,807	39%	2,755	3%	33,855	25%	15,873	30%	47,275	59%	2,690	38%	0	0%	0	0%	50,047	37%
100%	52,305		53,848		89,452		86,800		136,977		52,055		79,632		7,018		6,572		43,541		136,092	
75%	39,229		40,386		67,089		65,100		102,733		39,041		59,724		5,264		4,929		32,656		102,069	

4.6 STUDY SITE 6 (LARGE MAIN CHANNEL RIFFLE)

This site is comprised of two linked transects located in gravel and cobble-dominated riffle complex located approximately 3.5 miles downstream of Parr Shoals Dam. Habitat suitability for the majority of target lifestages and guilds peaks at approximately 1,500 to 1,900 cfs at this site. Smallmouth bass spawning and adult lifestages, as well as the deep fast guild, peaked at approximately 3500 cfs (Figure 4-7) (Table 4-5).

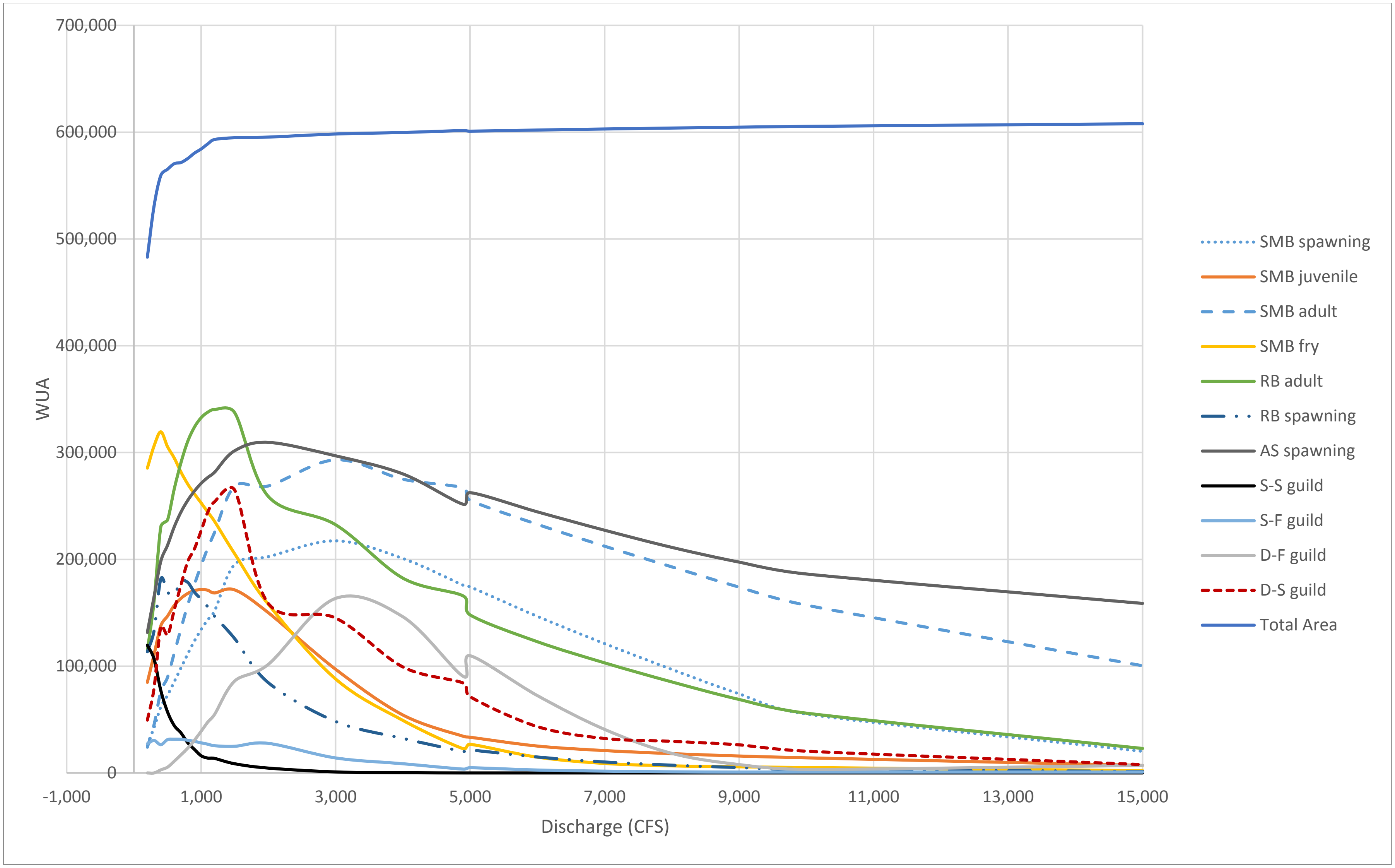

FIGURE 4-7 STUDY SITE 6 HABITAT SUITABILITY

TABLE 4-5 STUDY SITE 6 HABITAT SUITABILITY

Discharge	SMB spawning		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
200	26,585	12%	84,857	49%	24,118	8%	285,437	89%	114,115	34%	113,475	62%	131,577	43%	119,617	100%	27,340	86%	0	0%	49,474	19%
300	42,637	20%	110,798	65%	45,260	15%	306,222	96%	160,968	47%	133,234	73%	165,137	53%	106,635	89%	30,427	96%	0	0%	79,497	30%
400	61,906	28%	137,727	80%	76,247	26%	319,394	100%	230,410	68%	181,637	100%	198,199	64%	77,266	65%	26,471	84%	2,864	2%	136,779	52%
500	72,730	33%	146,876	86%	89,526	31%	305,488	96%	236,882	70%	169,259	93%	213,162	69%	57,169	48%	31,181	99%	5,417	3%	128,920	49%
600	85,471	39%	156,886	91%	112,313	38%	294,903	92%	265,947	78%	167,381	92%	230,434	74%	44,331	37%	31,617	100%	10,954	7%	152,720	58%
700	98,310	45%	163,508	95%	135,068	46%	281,734	88%	290,581	85%	179,292	99%	244,294	79%	37,514	31%	31,491	100%	16,941	10%	176,107	67%
800	111,494	51%	168,086	98%	157,142	54%	270,554	85%	310,409	91%	178,462	98%	255,182	82%	28,297	24%	30,600	97%	23,183	14%	197,806	75%
900	123,595	57%	170,807	100%	176,480	60%	261,320	82%	323,790	95%	169,242	93%	263,953	85%	22,044	18%	29,573	94%	30,634	19%	209,830	79%
1,000	134,345	62%	171,663	100%	194,370	66%	252,831	79%	332,639	98%	162,699	90%	271,192	88%	16,105	13%	28,176	89%	39,037	24%	226,852	86%
1,100	143,613	66%	171,112	100%	210,820	72%	244,155	76%	337,882	99%	155,421	86%	276,775	89%	13,912	12%	26,919	85%	47,747	29%	244,469	92%
1,200	151,615	70%	168,556	98%	225,268	77%	235,503	74%	340,255	100%	146,664	81%	281,595	91%	13,618	11%	25,488	81%	54,830	34%	253,984	96%
1,500	195,308	90%	171,373	100%	268,572	92%	205,111	64%	337,243	99%	125,677	69%	301,792	97%	8,596	7%	24,979	79%	86,147	53%	264,661	100%
2,000	202,531	93%	150,005	87%	268,770	92%	157,825	49%	258,831	76%	84,461	47%	309,582	100%	4,538	4%	27,685	88%	101,722	62%	158,617	60%
3,000	217,358	100%	97,067	57%	293,225	100%	87,967	28%	232,410	68%	48,187	27%	296,949	96%	942	1%	14,045	44%	163,477	100%	145,056	55%
4,000	200,810	92%	54,266	32%	275,050	94%	49,201	15%	182,416	54%	32,379	18%	280,009	90%	204	0%	8,629	27%	146,235	89%	99,247	37%
4,900	175,703	81%	34,291	20%	266,943	91%	22,600	7%	165,653	49%	20,187	11%	251,537	81%	0	0%	3,575	11%	90,326	55%	84,097	32%
5,000	174,226	80%	33,445	19%	255,326	87%	26,829	8%	147,997	43%	21,491	12%	262,462	85%	0	0%	4,891	15%	109,750	67%	71,327	27%
6,000	146,633	67%	25,185	15%	232,790	79%	14,774	5%	122,888	36%	14,915	8%	244,481	79%	0	0%	2,732	9%	72,430	44%	43,378	16%
7,000	121,113	56%	20,946	12%	212,332	72%	8,898	3%	103,098	30%	10,256	6%	227,281	73%	0	0%	1,687	5%	40,786	25%	32,282	12%
8,000	96,921	45%	18,087	11%	192,959	66%	6,637	2%	85,223	25%	7,271	4%	211,218	68%	0	0%	1,055	3%	18,319	11%	29,607	11%
9,000	74,082	34%	15,851	9%	174,016	59%	5,770	2%	68,824	20%	5,035	3%	197,430	64%	0	0%	836	3%	7,838	5%	26,329	10%
10,000	55,106	25%	14,153	8%	157,095	54%	5,083	2%	55,986	16%	3,257	2%	186,297	60%	0	0%	883	3%	3,321	2%	20,375	8%
15,000	20,244	9%	7,050	4%	100,384	34%	2,152	1%	22,933	7%	1,460	1%	158,756	51%	0	0%	863	3%	7,059	4%	7,834	3%
100%	217,358		171,663		293,225		319,394		340,255		181,637		309,582		119,617		31,617		163,477		264,661	
75%	163,019		128,747		219,919		239,546		255,191		136,228		232,186		89,713		23,713		130,782		198,495	

4.7 STUDY SITE 7 (PIZZA OVEN SITE)

This site is comprised of two linked transects located in a ledge-controlled riffle-glide complex located approximately 5.4 miles downstream of Parr Shoals Dam. Habitat suitability for the majority of target lifestages and guilds peaked at approximately 700 to 1,000 cfs at this site (Figure 4-8) (Table 4-6). American shad spawning reached an inflexion point at around 1,500 cfs and remained steady through the remainder of the flow range modeled. A much broader range of suitability was indicated for smallmouth bass adult, with a relatively broad peak occurring between approximately 500 and 4000 cfs. Habitat for the shallow-fast guild rose moderately as the flow departed from base flow, peaking at around 2000 cfs.

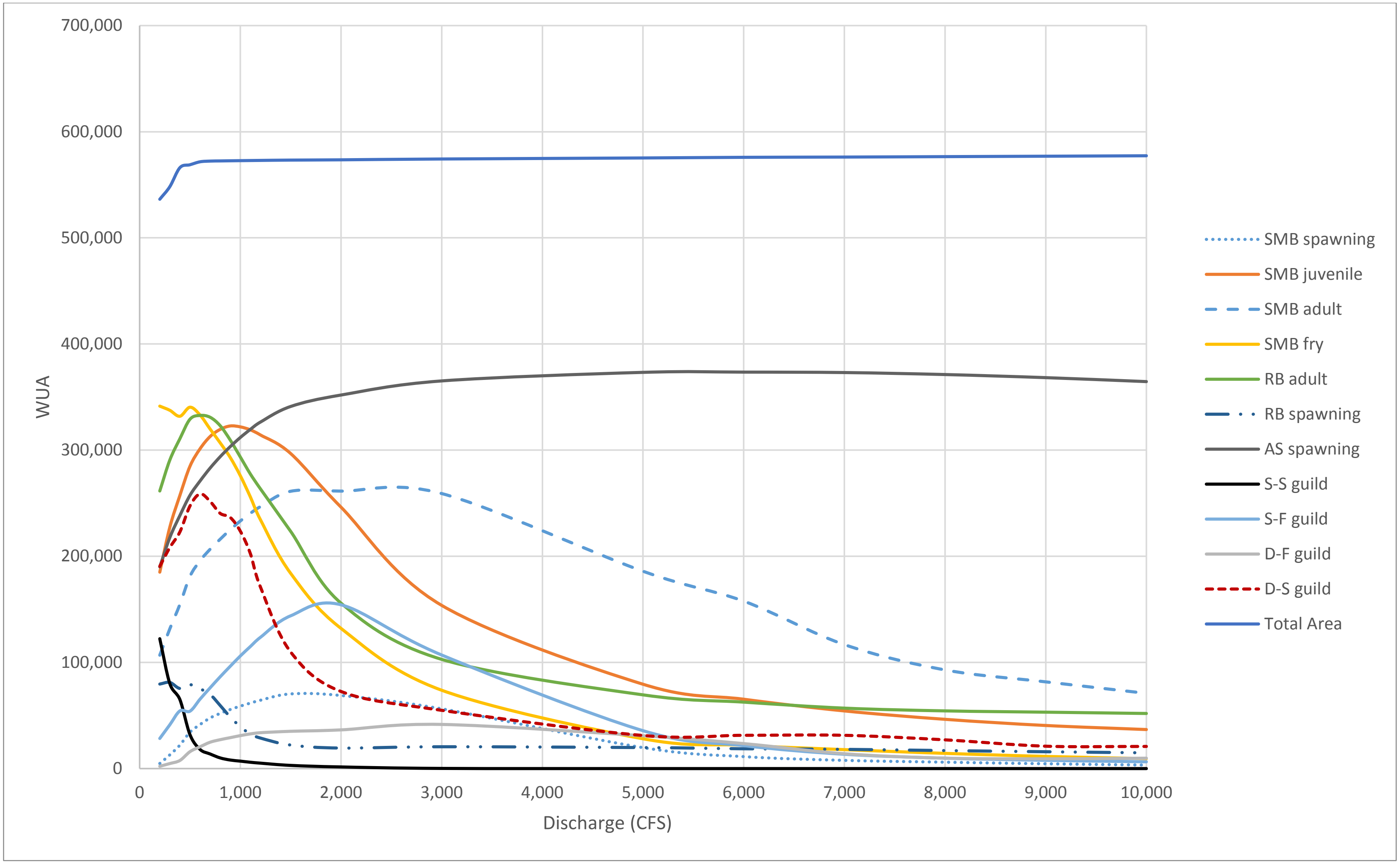

FIGURE 4-8 STUDY SITE 7 HABITAT SUITABILITY

Table 4-6 Study Site 7 Habitat Suitability

Discharge	SMB spawning		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
200	4,778	7%	185,059	57%	106,819	41%	341,484	100%	261,525	79%	79,634	98%	190,039	51%	122,349	100%	28,370	18%	2,170	5%	190,546	74%
300	12,942	18%	227,495	70%	131,731	50%	337,537	99%	290,739	87%	81,168	100%	217,716	58%	79,969	65%	41,312	27%	4,747	11%	208,321	81%
400	22,121	31%	257,381	80%	154,708	59%	331,938	97%	310,815	93%	75,471	93%	238,470	64%	64,989	53%	54,353	35%	7,648	18%	222,996	86%
500	34,302	49%	284,854	88%	181,096	69%	340,459	100%	329,123	99%	79,053	97%	257,465	69%	31,947	26%	54,073	35%	15,931	38%	247,404	96%
600	41,500	59%	301,292	93%	195,795	75%	333,109	98%	332,707	100%	75,154	93%	270,953	73%	18,056	15%	65,422	42%	20,536	49%	258,756	100%
700	47,678	68%	312,857	97%	206,639	79%	319,872	94%	330,990	99%	69,883	86%	283,123	76%	13,759	11%	76,079	49%	24,832	60%	251,728	97%
800	51,975	74%	319,568	99%	216,098	83%	306,876	90%	323,038	97%	59,448	73%	293,809	79%	10,047	8%	86,486	56%	27,215	65%	240,446	93%
900	55,638	79%	322,798	100%	225,065	86%	293,088	86%	309,500	93%	48,517	60%	303,336	81%	8,054	7%	96,392	62%	29,135	70%	236,609	91%
1,000	58,836	84%	321,939	100%	233,257	89%	275,941	81%	293,562	88%	39,499	49%	311,927	84%	7,023	6%	106,071	69%	31,049	75%	223,683	86%
1,100	61,701	88%	319,118	99%	240,484	92%	255,893	75%	277,494	83%	32,494	40%	319,565	86%	5,963	5%	115,004	75%	32,678	79%	202,451	78%
1,200	64,396	92%	314,315	97%	246,780	94%	234,437	69%	263,507	79%	28,756	35%	326,457	87%	5,119	4%	123,672	80%	33,791	81%	171,054	66%
1,500	70,354	100%	296,828	92%	261,265	100%	183,945	54%	223,513	67%	22,186	27%	341,146	91%	3,001	2%	143,933	93%	35,123	84%	109,837	42%
2,000	68,846	98%	246,315	76%	261,421	100%	132,089	39%	155,888	47%	19,335	24%	351,931	94%	1,539	1%	154,310	100%	36,462	88%	72,651	28%
3,000	56,303	80%	153,774	48%	259,133	99%	73,814	22%	102,887	31%	20,563	25%	365,229	98%	154	0%	106,998	69%	41,599	100%	54,884	21%
5,000	19,731	28%	79,456	25%	185,911	71%	28,076	8%	69,454	21%	19,786	24%	373,297	100%	0	0%	35,689	23%	30,924	74%	31,185	12%
6,000	11,261	16%	65,346	20%	157,747	60%	21,965	6%	62,599	19%	18,668	23%	373,525	100%	0	0%	21,625	14%	23,526	57%	31,344	12%
7,000	7,733	11%	54,310	17%	116,788	45%	17,849	5%	56,946	17%	18,123	22%	373,111	100%	0	0%	13,469	9%	13,985	34%	31,344	12%
8,000	6,028	9%	46,404	14%	92,940	36%	14,344	4%	54,355	16%	16,964	21%	371,234	99%	0	0%	9,784	6%	9,834	24%	27,074	10%
9,000	4,534	6%	40,600	13%	81,702	31%	11,438	3%	53,145	16%	15,861	20%	368,321	99%	0	0%	7,763	5%	9,207	22%	21,086	8%
10,000	3,312	5%	36,778	11%	70,898	27%	9,418	3%	51,921	16%	14,828	18%	364,584	98%	0	0%	6,388	4%	9,782	24%	20,862	8%
100%	70,354		322,798		261,421		341,484		332,707		81,168		373,525		122,349		154,310		41,599		258,756	
75%	52,765		242,098		196,066		256,113		249,530		60,876		280,144		91,762		115,733		31,199		194,067	

4.8 STUDY SITE 8 (HALTIWANGER ISLAND)

Study Site 8 consists of a pair of adjacent transects located near the upstream end of Haltiwanger Island, with one transect (8.1) located on the east side of the island and the second (8.2) on the west. Transect 8.1 is predominantly a riffle with a deeper run/thalweg along the east shore. Transect 8.2 is located in a steep riffle habitat and represents the smaller of the two channels. Hydraulic analyses indicate a 68:32 flow split between the east channel (Transect 8.2) and west channel (Transect 8.1), respectively, at the 400 cfs calibration flow; a 73:27 split at 2000 cfs; and 78:22 split at 6000 cfs. Habitat suitability at Transects 8.1 and 8.2 are combined below on Figures 4-9. Habitat suitability for the majority of target lifestages and guilds peaks at approximately 1,000 to 1,500 cfs at this site (Figure 4-9) (Table 4-7). American shad spawning reached an inflexion point at around 4,000 cfs and remained optimal throughout the remainder of the flow range. Adult smallmouth bass display a broad suitability, peaking at approximately 3,000 cfs and gradually decreasing with increased flow.

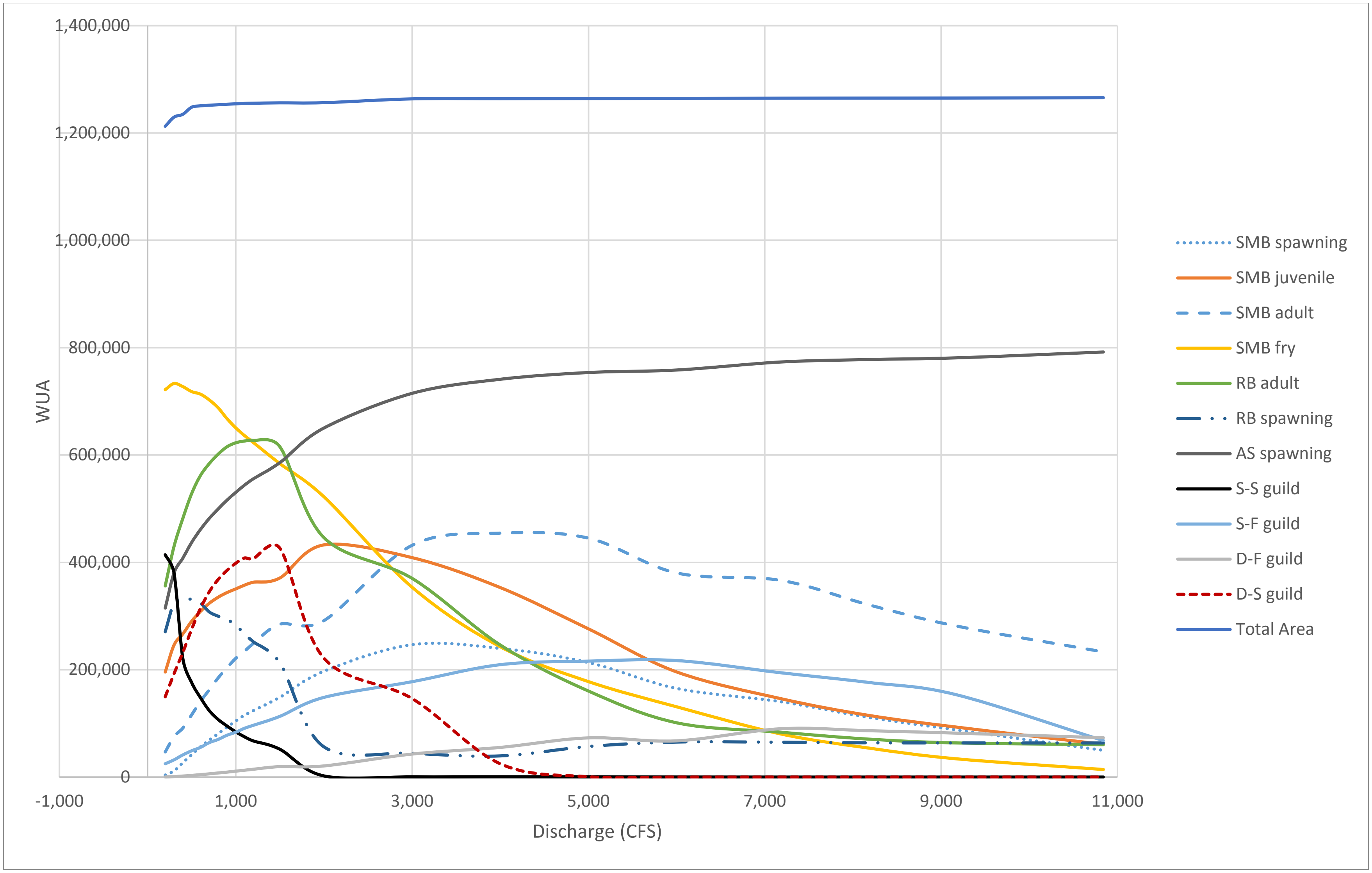

FIGURE 4-9 STUDY SITE 8 HABITAT SUITABILITY

TABLE 4-7 STUDY SITE 8 HABITAT SUITABILITY

Discharge	SMB spawning		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
200	3,720	2%	195,659	45%	46,839	10%	721,773	98%	356,086	57%	270,665	82%	314,815	40%	414,242	100%	24,760	11%	166	0%	149,560	35%
300	11,454	5%	245,974	57%	75,439	17%	733,279	100%	429,842	69%	324,069	98%	380,288	48%	379,840	92%	32,086	15%	840	1%	192,595	45%
400	26,831	11%	266,697	62%	91,273	20%	727,425	99%	482,042	77%	329,175	99%	407,905	52%	220,601	53%	41,293	19%	1,875	2%	232,315	54%
500	41,634	17%	290,381	67%	115,972	26%	718,183	98%	528,262	84%	331,371	100%	437,285	55%	175,901	42%	48,963	23%	3,065	3%	275,507	65%
600	56,489	23%	308,680	71%	141,045	31%	713,354	97%	561,905	90%	324,021	98%	461,329	58%	147,922	36%	55,300	25%	4,562	5%	314,469	74%
700	68,856	28%	323,788	75%	162,671	36%	702,619	96%	584,088	93%	307,575	93%	481,975	61%	123,687	30%	64,177	30%	5,953	7%	345,334	81%
800	80,862	33%	335,029	77%	184,653	41%	688,045	94%	601,579	96%	299,726	90%	499,479	63%	107,299	26%	70,081	32%	7,639	8%	367,988	86%
900	92,719	38%	343,683	79%	203,627	45%	667,906	91%	615,229	98%	293,642	89%	515,893	65%	95,238	23%	77,859	36%	9,176	10%	384,954	90%
1,000	104,570	42%	350,523	81%	221,233	49%	650,628	89%	622,795	99%	283,118	85%	530,301	67%	84,249	20%	83,585	39%	11,013	12%	398,347	93%
1,100	115,183	47%	357,569	83%	234,509	52%	636,083	87%	626,048	100%	266,684	80%	543,988	69%	74,911	18%	90,937	42%	12,743	14%	408,175	96%
1,200	123,807	50%	362,965	84%	248,852	55%	623,217	85%	627,310	100%	251,980	76%	555,727	70%	67,242	16%	96,478	44%	14,539	16%	407,006	95%
1,500	148,669	60%	370,903	86%	284,722	63%	584,023	80%	615,528	98%	212,865	64%	585,840	74%	51,834	13%	113,087	52%	19,458	22%	426,396	100%
1,750	172,905	70%	401,724	93%	288,049	63%	553,105	75%	530,790	85%	134,574	41%	618,084	78%	26,971	7%	130,762	60%	20,089	22%	323,960	76%
2,000	197,141	80%	432,546	100%	291,377	64%	522,187	71%	446,052	71%	56,283	17%	650,328	82%	2,109	1%	148,437	68%	20,719	23%	221,524	52%
2,500	221,910	90%	420,686	97%	361,574	80%	437,908	60%	408,119	65%	50,305	15%	682,629	86%	1,205	0%	163,054	75%	31,787	35%	183,913	43%
3,000	246,679	100%	408,827	95%	431,772	95%	353,629	48%	370,186	59%	44,326	13%	714,931	90%	301	0%	177,672	82%	42,856	48%	146,301	34%
3,500	243,189	99%	380,938	88%	443,135	97%	298,212	41%	308,111	49%	41,869	13%	728,038	92%	371	0%	193,536	89%	49,060	55%	85,503	20%
4,000	239,700	97%	353,049	82%	454,498	100%	242,795	33%	246,036	39%	39,412	12%	741,146	94%	441	0%	209,400	96%	55,265	61%	24,704	6%
4,500	226,543	92%	314,586	73%	449,830	99%	210,318	29%	203,154	32%	48,211	15%	747,432	94%	354	0%	212,696	98%	64,126	71%	12,632	3%
5,000	213,386	87%	276,123	64%	445,163	98%	177,842	24%	160,272	26%	57,011	17%	753,718	95%	267	0%	215,992	100%	72,986	81%	561	0%
6,000	165,147	67%	195,876	45%	380,246	84%	130,922	18%	101,113	16%	65,215	20%	758,374	96%	105	0%	217,047	100%	67,462	75%	0	0%
7,180	140,433	57%	146,134	34%	366,469	81%	80,343	11%	83,555	13%	64,896	20%	773,326	98%	0	0%	194,347	90%	89,994	100%	0	0%
8,180	111,113	45%	114,875	27%	320,858	71%	53,984	7%	70,642	11%	63,805	19%	777,900	98%	0	0%	176,258	81%	86,345	96%	0	0%
9,170	87,961	36%	93,164	22%	281,520	62%	34,044	5%	63,590	10%	63,553	19%	781,042	99%	0	0%	153,515	71%	81,857	91%	0	0%
10,840	49,805	20%	60,943	14%	233,230	51%	14,076	2%	60,365	10%	63,484	19%	791,919	100%	0	0%	68,001	31%	73,303	81%	0	0%
100%	246,679		432,546		454,498		733,279		627,310		331,371		791,919		414,242		217,047		89,994		426,396	
75%	185,009		324,409		340,873		549,960		470,482		248,528		593,939		310,681		162,785		67,496		319,797	

4.9 STUDY SITE 9 (HUFFMAN ISLAND)

This site is to be evaluated through the proposed flow demonstration only and will be described after the TWC field observations.

4.10 STUDY SITE 10 (BOOKMAN ISLAND COMPLEX)

Habitat suitability for velocity-intolerant lifestages such as shallow slow, and smallmouth bass fry peaked at 200 cfs and declined rapidly at higher flows due to increases in velocity (Figure 4-10). Redbreast sunfish spawning also declined at rising flows but at a gradual rate, inflecting downward at approximately 2,000 cfs. Smallmouth bass spawning and juvenile lifestages, adult redbreast sunfish, shallow-fast, and the deep fast guild, generally achieve the greatest suitability in a range between approximately 700 – 3,000 cfs before slowly declining in suitability at higher flows. Smallmouth bass adult exhibit a sharp peak of suitability at 3,000 cfs, but are generally in a plateau of relatively high suitability between 2,000-10,000 cfs. American shad spawning habitat suitability reaches an inflection point at approximately 1,200 cfs, gradually rises to an absolute peak at 4,000 cfs then gently declines at higher flows (Figure 4-10) (Table 4-8).

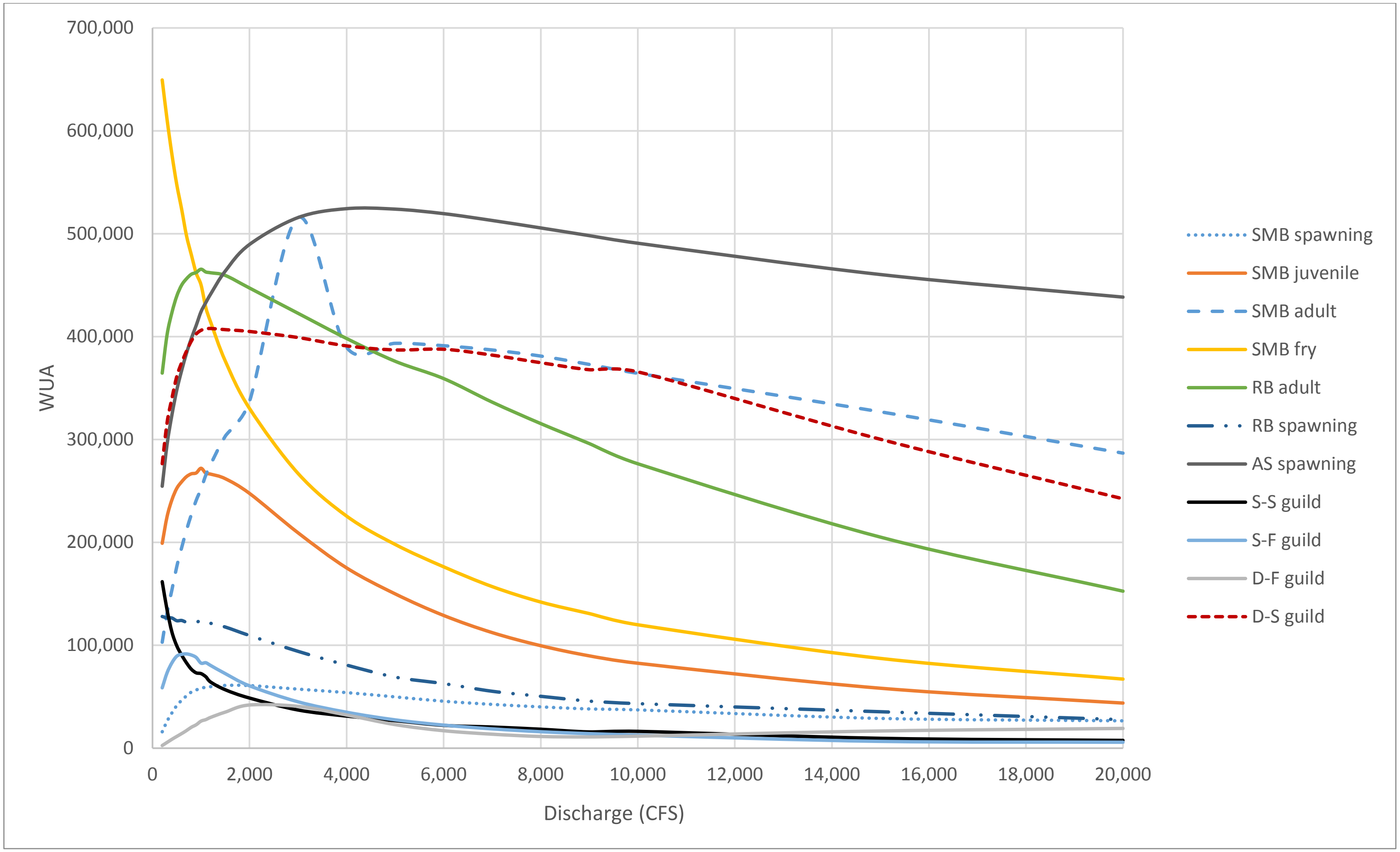

FIGURE 4-10 STUDY SITE 10 HABITAT SUITABILITY

TABLE 4-8 STUDY SITE 10 HABITAT SUITABILITY

Discharge	SMB spawning		SMB juvenile		SMB adult		SMB fry		RB adult		RB spawning		AS spawning		S-S guild		S-F guild		D-F guild		D-S guild	
200	15,928	26%	199,145	73%	102,985	20%	649,442	100%	364,539	78%	128,007	100%	254,591	49%	161,819	100%	58,679	64%	2,612	6%	276,504	68%
300	26,186	43%	225,022	83%	131,339	25%	611,007	94%	401,820	86%	126,720	99%	295,234	56%	134,449	83%	73,244	80%	5,633	13%	316,376	78%
400	34,282	56%	241,384	89%	153,838	30%	577,108	89%	423,349	91%	126,515	99%	323,861	62%	112,886	70%	82,985	91%	8,648	21%	340,069	83%
500	41,427	68%	252,537	93%	176,506	34%	547,736	84%	439,415	94%	123,901	97%	348,047	66%	99,508	61%	89,424	98%	11,441	27%	361,310	89%
600	46,541	76%	258,908	95%	194,749	38%	523,940	81%	450,035	97%	124,147	97%	366,965	70%	90,537	56%	91,205	100%	14,193	34%	374,690	92%
700	50,821	83%	263,908	97%	211,866	41%	498,166	77%	456,214	98%	122,416	96%	383,823	73%	82,987	51%	91,627	100%	17,128	41%	385,859	95%
800	54,551	89%	266,671	98%	226,999	44%	479,577	74%	460,611	99%	122,401	96%	398,192	76%	76,764	47%	90,558	99%	20,359	48%	395,625	97%
900	56,569	93%	267,506	98%	240,853	47%	461,675	71%	462,315	99%	122,196	95%	410,855	78%	73,243	45%	88,219	96%	22,786	54%	402,553	99%
1,000	58,310	96%	272,046	100%	252,029	49%	450,274	69%	465,506	100%	124,383	97%	424,207	81%	72,492	45%	82,685	90%	26,305	63%	406,112	100%
1,100	59,200	97%	267,211	98%	265,624	52%	427,936	66%	462,794	99%	122,957	96%	433,210	83%	69,395	43%	83,046	91%	27,813	66%	407,510	100%
1,200	59,811	98%	266,324	98%	275,994	54%	413,859	64%	462,037	99%	121,360	95%	441,486	84%	64,222	40%	80,362	88%	29,999	71%	407,904	100%
1,500	61,016	100%	261,923	96%	303,244	59%	376,252	58%	459,447	99%	117,753	92%	463,727	88%	56,794	35%	72,480	79%	35,081	84%	406,762	100%
1,750	60,939	100%	254,760	94%	320,287	62%	353,185	54%	453,329	97%	113,632	89%	476,669	91%	52,762	33%	66,538	73%	38,541	92%	405,882	100%
2,000	60,862	100%	247,598	91%	337,330	65%	330,119	51%	447,210	96%	109,511	86%	489,611	93%	48,730	30%	60,597	66%	42,000	100%	405,001	99%
2,500	59,135	97%	228,452	84%	426,528	83%	298,556	46%	434,926	93%	101,818	80%	502,668	96%	42,923	27%	52,835	58%	41,335	98%	402,054	99%
3,000	57,409	94%	209,306	77%	515,726	100%	266,992	41%	422,641	91%	94,124	74%	515,726	98%	37,115	23%	45,073	49%	40,670	97%	399,108	98%
3,500	55,722	91%	192,263	71%	452,623	88%	246,280	38%	410,404	88%	87,456	68%	520,046	99%	34,156	21%	40,010	44%	36,471	87%	395,051	97%
4,000	54,035	89%	175,220	64%	389,520	76%	225,568	35%	398,166	86%	80,787	63%	524,367	100%	31,196	19%	34,947	38%	32,272	77%	390,995	96%
4,500	51,951	85%	162,609	60%	391,503	76%	211,806	33%	387,110	83%	74,935	59%	524,136	100%	28,958	18%	31,245	34%	27,596	66%	389,029	95%
5,000	49,866	82%	149,997	55%	393,487	76%	198,045	30%	376,055	81%	69,083	54%	523,905	100%	26,720	17%	27,544	30%	22,921	55%	387,064	95%
6,000	45,643	75%	129,004	47%	391,164	76%	176,282	27%	359,215	77%	62,778	49%	519,506	99%	22,182	14%	22,432	24%	16,984	40%	387,711	95%
7,000	42,583	70%	112,357	41%	387,016	75%	157,062	24%	336,321	72%	55,331	43%	512,876	98%	20,562	13%	18,775	20%	13,608	32%	382,017	94%
8,000	40,152	66%	99,624	37%	381,099	74%	142,052	22%	315,493	68%	50,430	39%	505,625	96%	18,433	11%	16,008	17%	11,391	27%	374,653	92%
9,000	38,147	63%	89,761	33%	372,981	72%	130,865	20%	296,073	64%	45,753	36%	498,147	95%	15,818	10%	14,138	15%	10,965	26%	367,839	90%
10,000	37,224	61%	82,577	30%	364,316	71%	119,961	18%	276,451	59%	43,285	34%	490,768	94%	16,374	10%	12,723	14%	11,698	28%	365,756	90%
15,000	28,938	47%	58,283	21%	326,924	63%	87,254	13%	205,152	44%	35,439	28%	460,335	88%	9,615	6%	6,631	7%	16,741	40%	300,232	74%
20,000	26,610	44%	43,863	16%	286,761	56%	67,153	10%	152,602	33%	27,737	22%	438,390	84%	7,585	5%	5,804	6%	19,210	46%	242,391	59%
100%	61,016	100%	272,046	100%	515,726	100%	649,442	100%	465,506	100%	128,007	100%	524,367	100%	161,819	100%	91,627	100%	42,000	100%	407,904	100%
75%	45,762		204,035		386,795		487,082		349,129		96,006		393,275		121,364		68,720		31,500		305,928	

4.11 FISH PASSAGE LEDGES

SCDNR zone-of-passage criteria state that instream flow should be sufficient to provide a minimum 10 ft-wide passage point with a minimum depth of 1.5 ft. At Ledge 1 (IFIM Study Site 7). This criterion is met by a flow of 500 cfs, with the minimum 1.5 ft depth provided over a cross-sectional distance of approximately 85 ft at the primary passage point identified in the study plan (Figure 4-11). The secondary passage point at Ledge 1, which was identified during the field efforts, provides an additional passage point approximately 44 ft in width that also meets the minimum 1.5 ft depth criteria at 500 cfs (Figure 4-12). These results suggest that fish passage is not a limiting factor at this location for flows as low as 500 cfs.

At Ledge 2, field data demonstrate that the fish passage criterion is met at flows as lows as 700 cfs, with the minimum 1.5 ft depth provided over a cross-sectional distance of approximately 27 ft (Figure 4-13). These results indicate that Ledge 2, located just upstream of the Bookman Shoals complex, is the more limiting of the two study sites from both the navigational and fish passage perspectives.

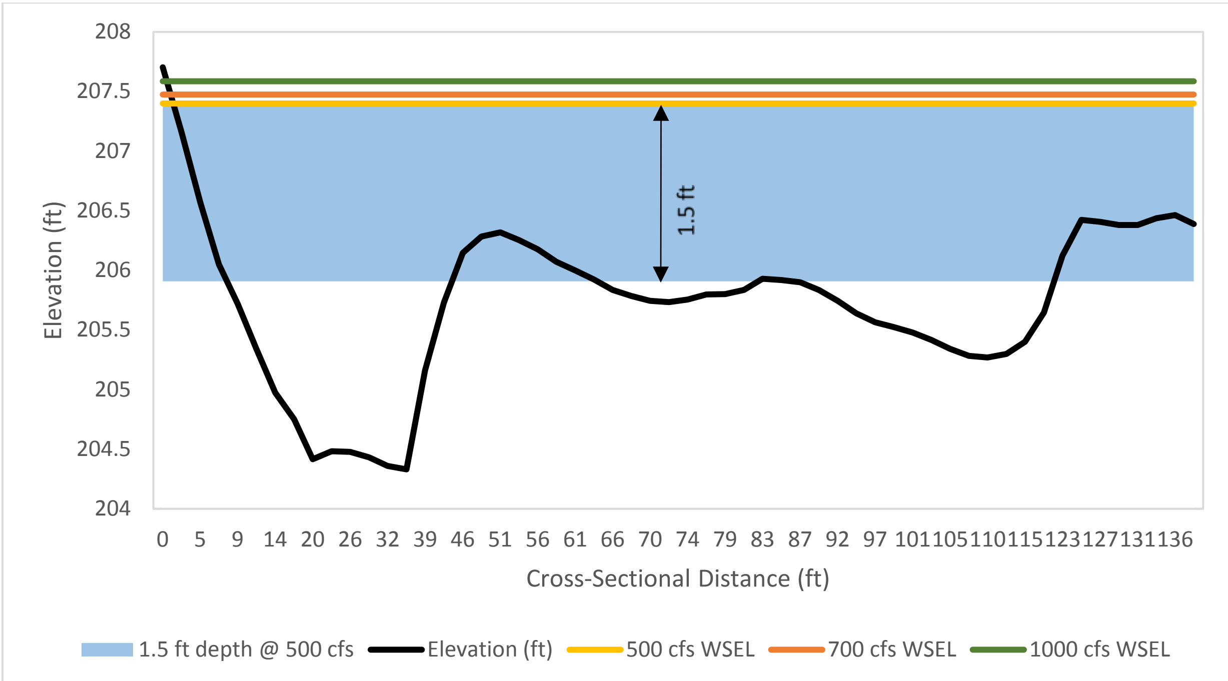

FIGURE 4-11 BED PROFILE AND WATER SURFACE ELEVATIONS AT THE RIVER LEFT PASSAGE POINT AT LEDGE 1 (UPSTREAM VIEW)

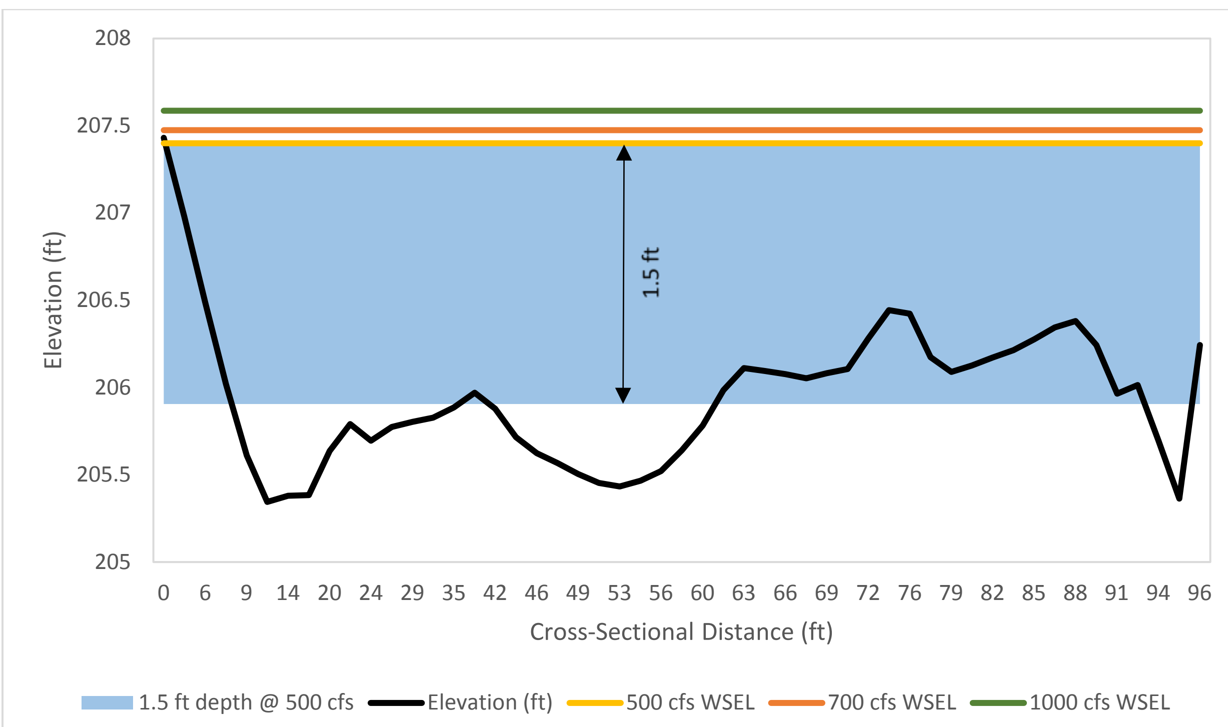

FIGURE 4-12 BED PROFILE AND WATER SURFACE ELEVATIONS AT THE MID-CHANNEL PASSAGE POINT AT LEDGE 1 (UPSTREAM VIEW)

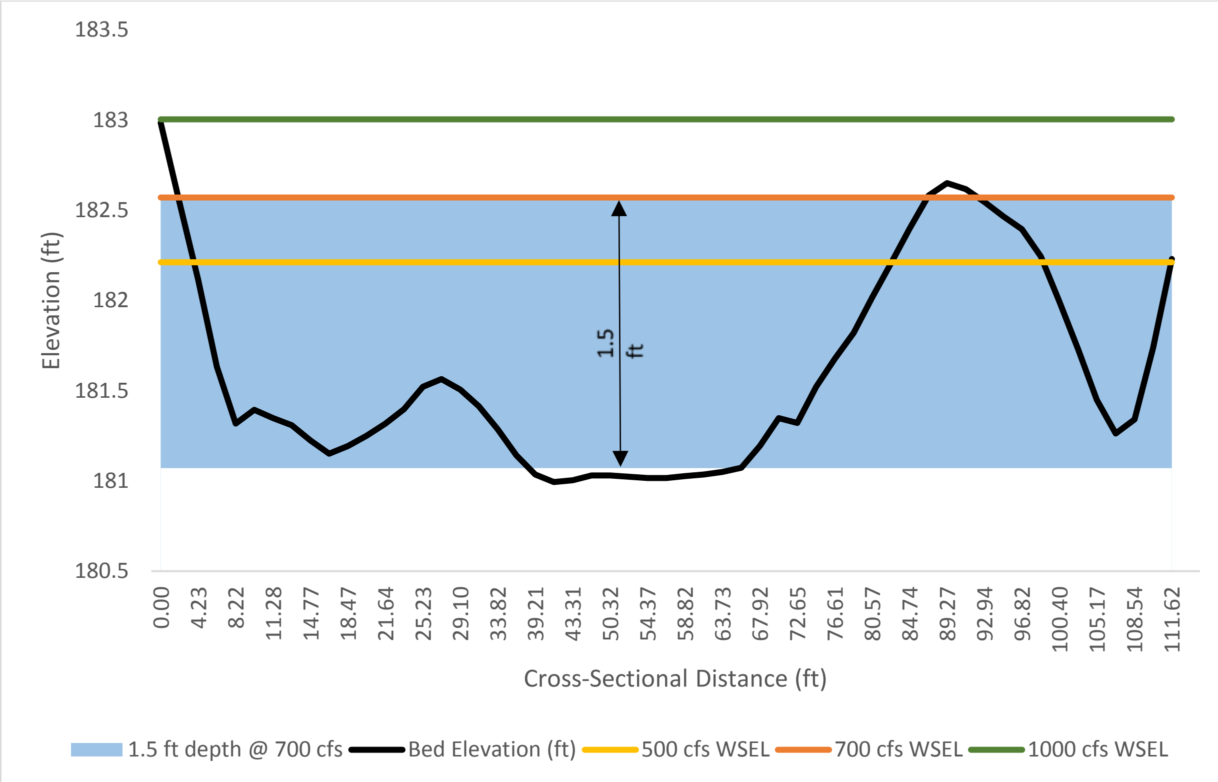

FIGURE 4-13 LEDGE 2 BED PROFILE SHOWING NAVIGATION PASSAGE AREA AT 700 CFS (UPSTREAM VIEW)

5.0 DISCUSSION

According to MESC (2001) "the basic WUA versus discharge relationships obtained in PHABSIM represent only instantaneous variation of physical habitat with flow and should not be interpreted in the absence of one or more alternative flow regimes for a particular study site". The purpose of this discussion is to recommend how these data may help determine suitable instream flow ranges for accommodating both aquatic habitat objectives and other instream uses. These data can then be integrated into additional analyses such as time series, and/or further dissection of results.

5.1 PRIORITIZATION OF SPECIES AND LIFESTAGES

In multiple species/lifestage assessments, WUA curves among target species and lifestages frequently peak and decline inharmoniously. Examples of such conflicting curves can be observed in this study. This makes it difficult to form recommendations that satisfy all biological goals (MESC 2001). A number of balancing techniques are commonly employed to resolve this type of issue; there is no single "right" or "wrong" approach. Most involve prioritizing particular species and lifestages either through time or space, or under different management priorities. Some possibilities include:

- delete species/lifestages that are not sensitive to habitat/flow changes;
- delete species/lifestages with redundant flow-WUA relationships;
- combine species in a post-modeling guilding such as cumulative multispecies curve;
- parse species and lifestages into monthly or seasonal time units that correspond to applicable seasonal habitat functions (e.g. spawning criteria are applied during March-May, etc., YOY criteria are applied June- October, etc.); and
- limiting lifestage. For species for which multiple lifestages are modeled, such as smallmouth bass, a particular lifestage may be determined to be the population bottleneck for recruitment to catchable sized fish. Giving habitat priority to the limiting or critical lifestage may relieve some conflicts and support the management for the species.

5.2 PRIORITIZATION AND BALANCING OF RIVER REACHES AND MESOHABITATS

The PHABSIM data contained in this report quantify the raw relationship between flow and aquatic habitat suitability in specific reaches of the Broad River, and are indices that can be applied to estimate the extent to which the existing project operation and alternatives may affect aquatic habitat suitability. Analysis of these data should be made in the context of watershed hydrology and the strategic needs of management of upstream reservoir fluctuations, water quality, recreation, and hydroelectric power generation. These data should be used in conjunction with specific hydrologic, operational and other models to evaluate the costs and benefits of providing alternate flows to the lower Broad River.

The study area is comprised of two independent study reaches, each with distinct geomorphic characteristics. Different mesohabitat types were modeled within each reach. WUA – flow relationships vary within each reach due to differences in hydraulics, stream slope and geometry, and in some cases because different guild criteria are applicable. The TWC will need to consider techniques for balancing and/or prioritizing these reaches.

Representative Habitat − WUA is an index calculated in units per 1,000 ft of similar stream reach. For reaches and mesohabitats shared by all species/lifestages, WUA results within each study site are commonly weighted and summed according to relative contributing reach length of each modeled mesohabitat type throughout the study area. The weighting information can be quantified directly from existing mesohabitat mapping measurements.

Critical Habitat − A particular reach, mesohabitat type or study site that may be a minority of the study area, but which is strategic because it is where a critical lifestage function (such as spawning) occurs is prioritized during the time of year it is required. Conversely, a reach, mesohabitat type or study site can be deleted from the analysis if no applicable species/lifestage-specific habitat function occurs there during a given time frame.

6.0 CONCLUSIONS

This IFIM study report will serve as the basis for TWC discussions regarding selection of a minimum flow for the Parr Project. The data contained in this report covers the life stages and transect areas that were identified as important by the TWC. After discussion and selection of a minimum flow(s), the TWC will schedule a field observation to observe the flow(s) at selected transect sites. These observations and recommendations from the TWC will be recorded and included in the creation of a protection, mitigation, or enhancement (PME) that will be evaluated as part of the Parr Project Operations Model. That Model will determine if the recommended flow(s) can be maintained in the new license without significant impact to the future project operations of the Parr and Fairfield Developments.

7.0 REFERENCES

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APPENDIX A

ROBUST REDHORSE SPAWNING MEMORANDUM

MEMORANDUM

TO: Parr/Fairfield Hydro Relicensing Fisheries and Instream Flow TWC

FROM: Shane Boring and Milton Quattlebaum

DATE: April 29, 2014

RE: Robust Redhorse Spawning Areas

An assessment of spawning habitat for robust redhorse (*Moxostoma robustum*) was requested by stakeholders during the study scoping phase of relicensing. Stakeholders agreed that a qualitative assessment of the Instream Flow Incremental Methodology (IFIM) study reach downstream of Parr Shoals Dam would be conducted concurrently with the mesohabitat assessment and other field efforts during the fall of 2013 and winter of 2014. This memorandum summarizes the assessment results.

Methods

The reach of the Broad River extending from Parr Shoals through the Bookman Island complex was observed by biologists (Milton Quattlebaum (SCANA), Ron Ahle (South Carolina Department of Natural Resources), and Shane Boring (Kleinschmidt Associates)) in October and November 2013 during the mesohabitat assessment conducted in support of the proposed IFIM Study. A follow up visit was made by Quattlebaum and Scott Lamprecht (South Carolina Department of Natural Resources) in February 2014. During the assessment, the group utilized published habitat suitability criteria to identify areas along the river reach they believed were potential robust redhorse (RRH) spawning sites. According to Freeman and Freeman (2001), RRH spawning habitat is characterized as being mid-channel gravel bars dominated by medium to coarse gravel with less that 30% sand and minimal fine particles. Spawning sites are also characterized as containing gravel small enough to be moved for egg deposition, but large enough to offer interstitial space for the eggs. Water depths are typically between 1 and 3.6 feet, with an average water column velocity of 0.85 to 2.20 ft/s. Sites encountered during the assessment that appeared to display these characteristics were noted on the field datasheets, their locations were documented with Global Positioning System (GPS), and in some instances, the sites were photographed.

Results

Four potential RRH spawning sites were examined during the assessment. The upstream-most site is located in the tailrace of the Parr development powerhouse within IFIM Study Site 3 (Figure 1). Fisheries Technical Working Committee (TWC) members have noted that RRH activity is well documented at that site, including observed potential spawning behavior. Three new sites were located during the assessment: one just upstream of Haltiwanger Island and two in the Bookman Shoals complex (IFIM Study Site 10) in the vicinity of Hickory Island (Figure 2). Results of PHABSIM and 2-D modeling conducted as part of the IFIM study will develop weighted usable area (WUA) estimates of spawning habitat under various flow scenarios, which will be taken into consideration by the TWC in developing a downstream flow recommendation that is best for multiple species, including RRH spawning.

FIGURES

FIGURE 1 POTENTIAL ROBUST REDHORSE SPAWNING AREA DOWNSTREAM OF PARR DAM

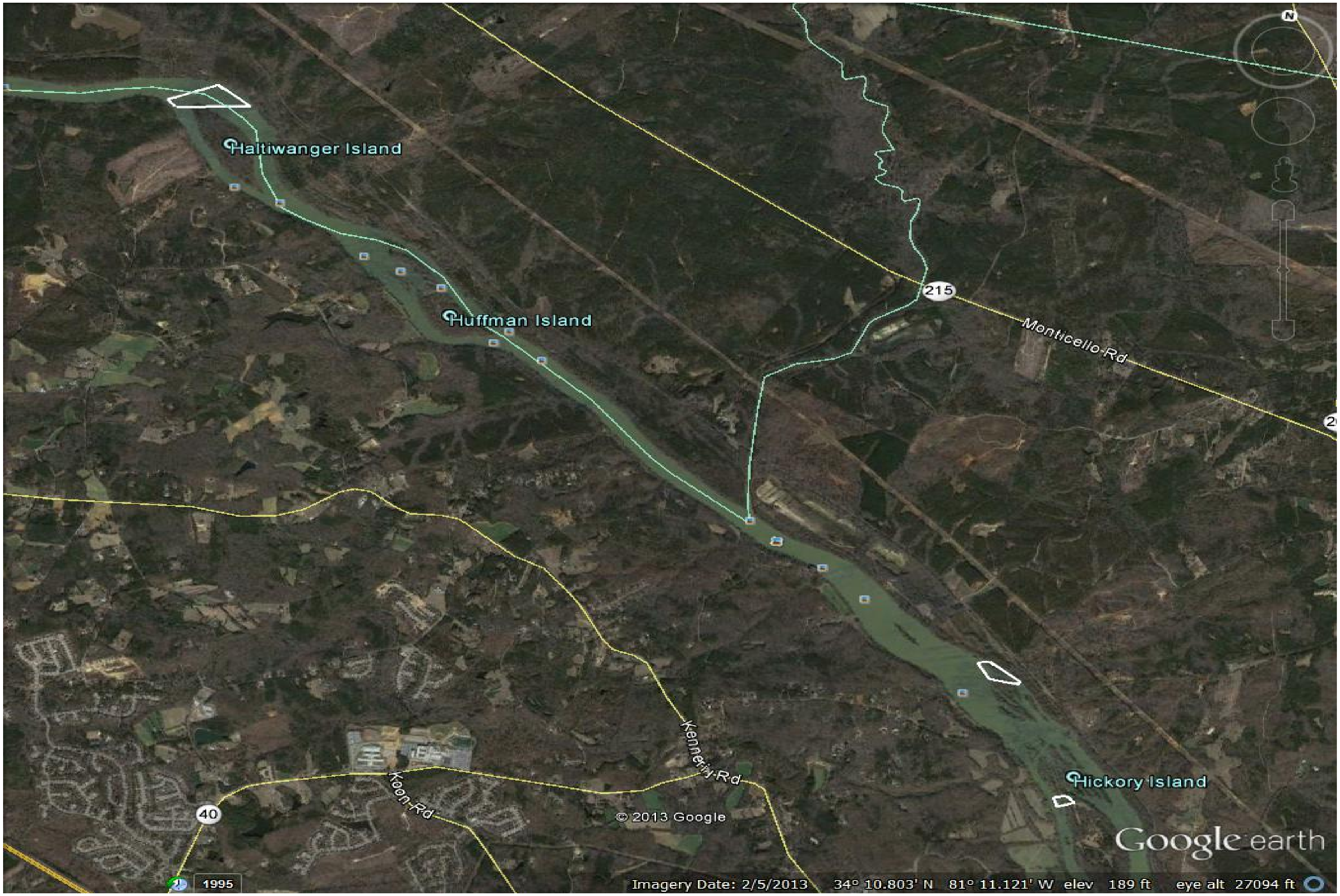


FIGURE 2 POTENTIAL ROBUST REDHORSE SPAWNING SITE AT HALTIWANGER ISLAND AND IN BOOKMAN SHOALS COMPLEX

APPENDIX B

TWC SCOPING

MEETING NOTES

SOUTH CAROLINA ELECTRIC & GAS COMPANY
Instream Flows TWC Meeting

May 7, 2013

Final KDM 05-31-13

ATTENDEES:

Bill Marshall (SCDNR)
Ron Ahle (SCDNR)
Gerrit Jobsis (American Rivers)
Shane Boring (Kleinschmidt)
Alan Stuart (Kleinschmidt)
Kelly Miller (Kleinschmidt)
Bill Stangler (Congaree Riverkeeper)
Ray Ammarell (SCE&G)
Vivianne Vejdani (SCDNR)
Bill Argentieri (SCE&G)
Milton Quattlebaum (SCANA)
Steve Summer (SCANA)
Randy Mahan (SCANA)
Dick Christie (SCDNR)
Tom McCoy (USFWS) via conference call
Prescott Brownell (NOAA)
Kerry Castle (SCDNR)

These notes serve to be a summary of the major points presented during the meeting and are not intended to be a transcript or analysis of the meeting.

Alan opens the meeting by briefly going over the agenda, then gives the group an overview of the float trip taken on March 19^{th} and 20^{th}. During this review, the group looks at the Project Area on a map, which sparks a discussion on the habitat just below the Parr Dam.

Ron explains how he is concerned about the separation in the habitat along the first mile of the Broad River, just below the Parr Dam. He says this is a highly utilized area of the river by fish species, and the side of the river along the west bank can grow stagnate during periods of low flow. Shane asks if a critical habitat study should be performed in this area. Ron says there are several critical habitats that need to be studied before the rest of the river is characterized. Prescott and Ron both mention they would like to have a habitat map made for as far down river as possible. Ron says that a habitat map should at least be made for the area immediately below the Parr Dam.

Gerrit tells the group he would also like to look at access along the river, since there are several areas that aren't accessible. Prescott mentions that he is interested in studying the tributaries along the river. Ron mentions that there is a good amount of data already available on the tributaries, collected by the DNR Stream Team.

Alan refers the group to a study on the Broad River, completed by Jason Bettinger (referred to throughout these notes as the Bettinger Study), as a possible starting point for the Parr Project's Mesohabitat Assessment and Instream Flow Study. The group notes that the Parr Project area was not included in this study, as the area in the Bettinger Study begins at Neal Shoals and extends upstream. However, the methodology used in the paper might still be utilized by the group.

After discussion on various needs for the Mesohabitat Assessment and Instream Flow Study, Gerrit focuses the group back on the agenda by beginning to list the goals and objectives for the study. Through much discussion the group agrees on four goals with corresponding objectives, as well as additional studies that need to be completed. These goals, objectives, and studies and included as an attachment at the end of these notes.

Steve and Ron then discuss the habitat issues at the west bank area. Ron says he believes that the decrease in DO and increase in temperature along the west bank area is related to the operating of the Fairfield Pumped Storage Project. Steve asks Bill if he has a copy of some aerial photos that were taken prior to Project construction since the west bank features are the result of natural topography, of which Bill answers he is not sure. Steve says he will try to find the photos, since they might show how river flow was distributed between the east and west bank area before the Project was built. Steve says that the issue will be getting water into that west channel during low flow situations. Gerrit says that Duke Energy is building a separate dam to help control flows at one of its projects. He believes the group needs to focus first on deciding what the flow needs for the area are, by seeing the area during higher flow situations. This will allow the group to evaluate how flows might be manipulated to create an even distribution over the area during low flow situations. Steve adds that LIDAR information will also be helpful, and that baseline data on temperature and DO in the west bank area will be needed to feed into the module. Ron mentions that spring through fall data needs to be collected, since he hasn't studied the area except during the summer. Kerry asks if turbidity will need to be examined along with the temperature and DO. The group considers this but decides that turbidity data is not necessary.

While looking at a photo of the dam, the group notes that there is a bit of leakage, which could be beneficial to the seemingly flow deprived west bank area. Ron agrees, but points out that during the summer, any benefits of the slight leakage at the dam may be diminished by the time they reach the central rocky location in the west channel.

The group then focuses their attention towards defining the geographic scope of the Mesohabitat Assessment and Instream Flow Study. The next hydro on the Broad River, downstream of the Parr Fairfield Project, is the Columbia Hydro Project. The upper reach of the PBL for the Columbia Hydro is noted as being at a Rocky Shoals Spider Lily population located just above the upper tip of Boatright Island. The group discusses whether or not this should mark the end of the scope for the Mesohabitat Assessment. It is decided that the scope for the Mesohabitat Assessment will stretch from Parr Dam downstream to the lower end of Bookman Island. Bill S. points out that there is a tributary on the lower end of Bookman Island, named Big Cedar Creek, and the scope should include this as well.

After deciding the scope, the group begins discussion on which definitions to use for the various mesohabitats. Two slightly varying sets of definitions are considered, including one used during the Saluda Hydro Relicensing Project, and one used in the Bettinger Study. Alan points out that using the definitions from the Bettinger study will be good for consistency, however, the group seems to prefer the definitions used during the Saluda Relicensing. Shane points out that there are several other commonly accepted definitions for the various mesohabitats and so the group decides to consider these options also. This issue is left undecided for now.

The group agrees to stay with the methodology that was used in the Bettinger Study. The group then discusses what the ideal flow would be when conducting the study. Ron says that lower flows make it easier to delineate the habitats, while Shane says the flow should be near the mean annual flow when mapping. Ron suggests a flow that is below 2,000 cfs would be best for conducting the study, and everyone agrees.

The focus then turns to identifying target and driver species for the various Habitat Use Guilds. Ron offers his personal list of fish species he has observed in the Broad River to be used as a starting point. The group decides on a list of driver species including:

- Smallmouth Bass
- American Shad
- Brassy Jumprock
- Whitefin Shiner
- Robust Redhorse
- Santee Chub
- Striped Bass
- Piedmont Darter
- Snail Bullhead
- Redbreast Sunfish
- Channel Catfish

Although the list is longer than is customary, Alan says that it can be included in the study plan with a caveat that says some of these species will later be grouped into guilds. Alan makes the point that the species which have HSI curves need to be identified, and suggests that Shane and Brandon Kulik work together on this task. Shane and Brandon will also recommend surrogates for the group to consider that can be used for the species that do not have HSI curves and work on guild classifications.

The group then focuses on establishing general transect locations for the study. Dick mentions that in the Bettinger Study a majority of the river was categorized as being glides, pools and shoals, and that these will be areas to look for when deciding on transect locations. Ron specifies that he would like at least one transect to be established right below the Parr Dam, in the area he has identified as a critical habitat. The group launches into a heavy discussion on where the transects should go and how many are needed. Eventually everyone agrees to four general areas for the study to implement the IFIM technique. These include an area immediately below Parr Dam, upstream of Haltiwanger Island, along the Coleman property, and at Haltiwanger Island. Additionally, two other sites were identified for studying wetted perimeter/staged discharge relationships, at Huffman Island and Bookman Island. These locations are included in Figure 1. With these sites agreed upon, the group decides to schedule a field trip to identify the specific locations for transects. Group members interested in participating in this trip are Ron Ahle, Shane Boring, Gerrit Jobsis, Bill Stangler, Bill Marshall, Alan Stuart, Vivianne Vejdani, Milton Quattlebaum, Tom McCoy, Prescott Brownell, Steve Summer, Ray Ammarell and/or Bill Argentieri.

To close the meeting, the group discusses scheduling, keeping in mind that the final study plan needs to be developed by early 2014 to be included in the PAD, which is due late 2014/early 2015. The actual IFIM study will be started during the summer of 2015. The group plans to meet again during the July-August timeframe to discuss the draft study plan and HSI curves. With this, the meeting adjourns. Action items stemming from this meeting are listed below, along with an attachment that includes all decisions made during the meeting.

ACTION ITEMS:

- Shane Boring will contact Brandon Kulik to work together on identifying relevant HSI curves and surrogates for the study. Shane will also ask Brandon to make guild recommendations.
- Shane Boring will research other options for mesohabitat definitions to be used in the study.
- Kelly will schedule the "Transect Identification Recon Trip" with the interested parties for June 18th and 19th.
- Kelly will schedule a follow-up meeting/conference call during the July-August timeframe for the discussion of HSI curves and study plan development.

Goals and Objectives of Mesohabitat Assessment and Instream Flow Study

Goal 1: Characterize the flow/habitat relationships for aquatic species present in the lower Broad River below Parr Dam

- Objective A: Classify and quantify/map (characterize/define) Mesohabitats occurring within study area
- Objective B: Establish target species/guilds
- Objective C: Identify study methodology (recommended IFIM)
- Objective D: Identify tributaries and study areas (reaches) on the lower Broad River of interest for the study

Goal 2: Determine effects of Parr and FFPS operations on flows of the lower Broad River below Parr Dam

- Objective A: Identify operational ranges/constraints of two facilities
- Objective B: Evaluate effects of Project operations on Parr Dam releases at various inflow ranges into Project

Goal 3: Develop recommendations for Parr Hydro Project operations to enhance flows for aquatic resources in the Congaree River (this does not include a transect study)

- Objective A: Influence on diadromous fish (includes striped bass, sturgeon)
- Objective B: Influence on other resident aquatic species (including RT&E)
- Objective C: Influence on Congaree National Park
- Objective D: Consideration of Saluda operations consistent with goals of the Santee Basin Accord

Goal 4: Develop flow recommendations for lower Broad River below Parr Dam

- Objective A: Evaluate baseline habitat
- Objective B: Evaluate high and low flows
- Objective C: Seasonal and inter-annual variations of flow recommendations
- Objective D: Evaluate low flow protocol recommendations

Additional studies:
Temperature and DO in the west channel below Parr Dam (three monitoring locations)
Recreation flows – operation of Parr
Navigation flows – operation of Parr
Water Quality – operation of Parr

Define Geographic scopes of Mesohabitat Assessment and Instream Flow Study / Discuss Mesohabitat Assessment (including methodologies)

Geographic Boundary - Parr Dam to downstream end (lower extent) of Bookman Island, just below the confluence of Big Cedar Creek

Methodologies –
Mesohabitat unit definitions for visual assessment. (NOTE: May be modified by use of Saluda descriptions)

Habitat	Type Description
Riffle	Relatively shallow (<0.5m), swift flowing section of river where water surface is broken.
Glide	Relatively shallow (<1m); with visible flow but mostly laminar in nature; minimal observable turbulence; relatively featureless bottom.
Run	Deep (>1m), swift flowing sections with turbulent flow; surface generally not broken.
Pool	Deep (>1m) slow moving sections.
Shoals	Shoal area; which may contain a variety of habitat complexes.

Use same methods Jason Bettinger used for his study in the upper Broad River, such as GPS for start and end of each classification.

Mesohabitat study should be conducted below 2,000 CFS

Define Species of Interest for Instream Flow Study

Summary of Habitat Use Guilds

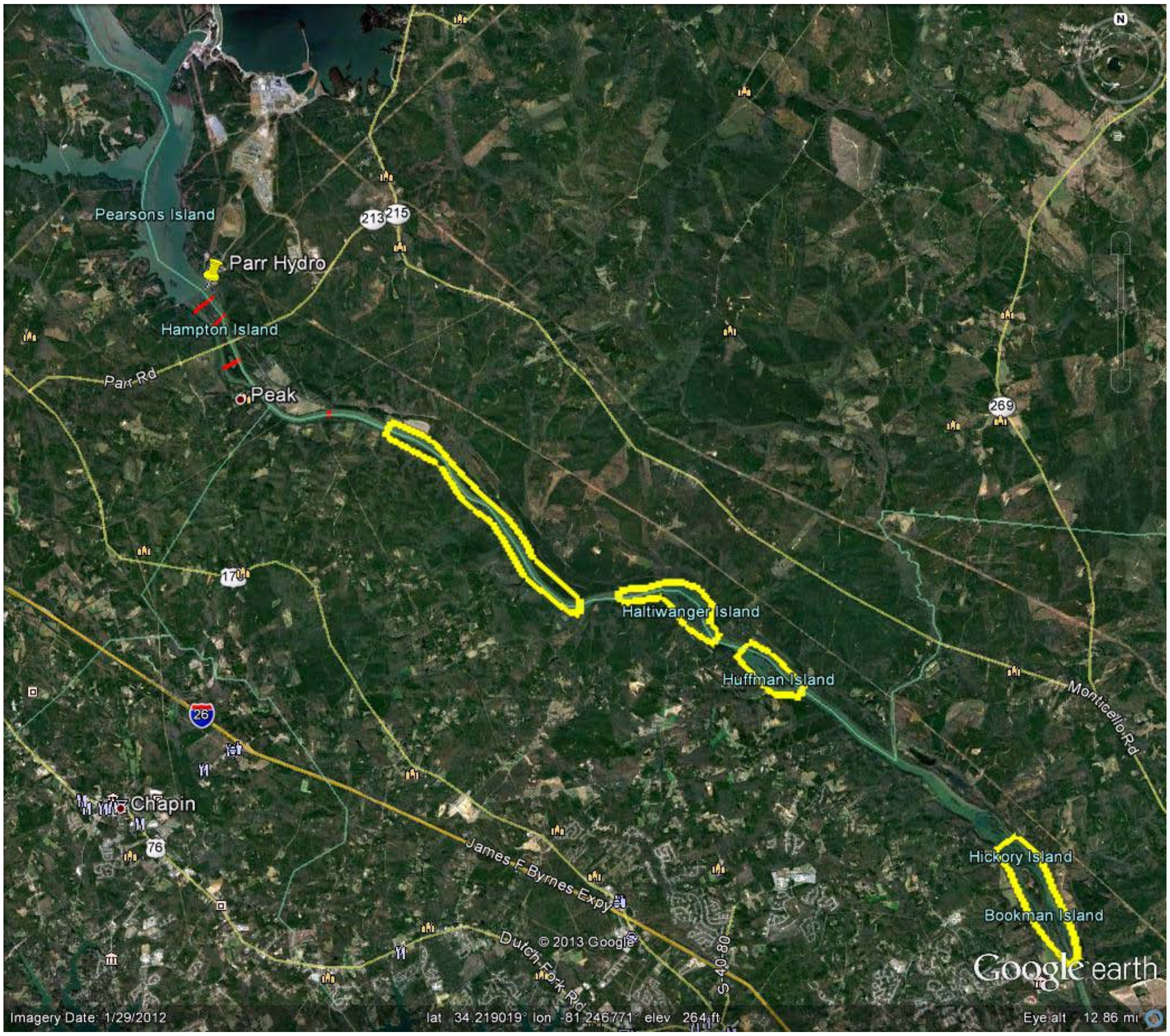
Driver Species:
American shad
Brassy jumprock
Channel catfish
Piedmont darter
Redbreast sunfish
Robust Redhorse
Santee chub
Small mouth bass
Snail bullhead
Striped bass
Whitefin shiner

Discuss Methodology (including HSI curves, number and location of transects, areas of specific interests)

Look for HSI curves that exist for driver species and make recommendations for surrogates and guilds

Methodology (number and location of transects, areas of specific interests): IFIM above Huffman Island, wetted perimeter for Huffman and Bookman islands.

Figure 1 General Transect Locations



Kleinschmidt

MEETING NOTES

SOUTH CAROLINA ELECTRIC & GAS COMPANY
Instream Flows TWC Meeting

March 5, 2014

Final KDM 04-8-14

ATTENDEES:

Bill Marshall (SCDNR)
Ron Ahle (SCDNR)
Gerrit Jobsis (American Rivers)
Shane Boring (Kleinschmidt)
Henry Mealing (Kleinschmidt)
Kelly Miller (Kleinschmidt)
Bill Stangler (Congaree Riverkeeper)
Vivianne Vejdani (SCDNR)
Bill Argentieri (SCE&G)
Milton Quattlebaum (SCANA)
Steve Summer (SCANA)
Brandon Kulik (Kleinschmidt) via conf. call
Dick Christie (SCDNR)
Randy Mahan (SCANA)
Byron Hamstead (USFWS)
Fritz Rhode (NOAA) via conf. call

These notes serve to be a summary of the major points presented during the meeting and are not intended to be a transcript or analysis of the meeting.

Henry opened the meeting with introductions and then Shane lead the group in a review of the Mesohabitat Assessment Report. Shane explained the intent of the study and reviewed the results, including an overview of the maps. Ron asked to see an individual breakdown of maps 2a, 2b and 2c and Shane said he will provide these maps to the group.

Bill M. asked if we learned anything new from the study. Shane said that the most restricted point on the river for fish passage and boat navigation was identified. This area is right above the Bookman Shoals complex. This area is identified in the IFIM Study Plan as an area that needs further study. Shane said they also did a survey for Robust Redhorse spawning areas during the mesohabitat study. Two areas were identified including a location right downstream of Parr Shoals Dam and another location upstream of Bookman Shoals. Shane said that Scott Lamprecht agreed that these spots seemed ideal for Robust Redhorse spawning. Milton said he also went out on the river with Scott and they identified another area near the Bookman Shoals complex and Hickory Island. A spot near Haltiwanger Island was also identified. Shane will develop a memo summarizing all of this information on Robust Redhorse spawning sites and will distribute this memo to the group. He will also append the memo to the final IFIM report. Shane will edit the IFIM Study Plan so it mentions that the Robust Redhorse memo will be appended to the final IFIM report.

Shane also said that during the mesohabitat assessment they learned that Bookman Island is very complex with lot of cross channels, braiding and varying elevations. He said that at least seven channels had been identified in the area. Fritz added that seams of bedrock add complexity because they act as weirs, moving the water in different directions depending on flow. He said it is good that 2D modeling will be performed in this area during the IFIM study. Byron asked if the 2D modeling will include the two Robust Redhorse sites identified in the Bookman Island complex and Shane said yes. Shane added that the upstream site at Haltiwanger Island will be studied using PHABSIM along with the site right below Parr Shoals Dam at Hampton Island. Ron said that the area just downstream of the Parr Shoals Dam is good for Robust Redhorse because there seems to be a dike formed by the rock with a gravel bed, covered by deep water. Ron said suckers are often found in this area.

Ron said that the Broad River downstream of Parr Shoals Dam is very complex, and that the maps included in the Mesohabitat Assessment Report are generalized. But he believes they are fairly accurate and that the proportions of the various mesohabitat types found in the river are accurate. Shane agreed and said that sometimes while looking at a cross section of the river, one side of the river may have a run and the other side may have a backwater pool. Shane said this was hard to convey in the maps, but that overall the map delineations and the report are very accurate.

Byron asked if areas of constriction throughout the river have been mapped out. Shane said GPS points have been taken and can be provided to the group, but cross sections detailing depth and other information has not been mapped out yet and will be completed as part of the IFIM study. Shane showed the group, using Bing maps, two areas in the river where fish passage and navigation may be possible. These areas will be studied in more detail during the IFIM study.

The group began reviewing the IFIM Study Plan and Shane mentioned that the Mesohabitat Assessment Report will be added as an appendix to the final IFIM Report. Byron wanted to know how the information collected in the IFIM study would be used for determining suitable crayfish habitat. Will the amount and type of cover available at various depths be examined? Henry said this will not be done using PHABSIM, but this information can be collected as part of the general description of the study area. Gerrit asked if when determining cover types, isn't it typical to not only look at the transect, but upstream as well? Brandon said yes because at the upstream/ downstream cell boundary level, the area is reasonably homogenous but within the cross section localized substrate variations can be like a mosaic, so it is typical to look upstream and downstream a reasonable distance to characterize the substrates assigned to a particular vertical. Brandon said that in regards to crayfish, the group can establish what the important cover types are for a particular species beforehand so that the field crews know what to look for during data collection. Byron said he will do some additional research to identify the preferred covers for the spiny crayfish. He is interested in determining how much cover is available and how much is exposed at varying water levels. Henry said that this may be possible with rocky substrates since they are fairly permanent, but that the abundance and distribution of woody debris can change from year to year so only general qualitative observations can be made. Henry said that if large woody debris is located at a PHABSIM transect, it will be surveyed in depth, otherwise just general descriptions of what is located upstream and downstream will be recorded to characterize conditions and where it is located relative to water levels. Brandon said that photos and possibly videos will also be taken to document the substrate and cover types in the area. If Byron develops a specific list of the type of substrate and cover that is important for crayfish, including a description of the types of woody debris preferred (approximate size and position in the water column), it will make it easier to document these during the study. Brandon said they can look at what is exposed during low flows and also record how high flows mobilize these substrates. Ron said that in his experience the large woody debris found in the central portion of the river is usually located in areas of accumulating sand and is typically transient and moving. All other woody debris tends to be found along the shorelines. Byron said that the wetted perimeter study will provide a lot of information on the woody debris found throughout the river. He will determine what the specific habitat requirements are for the spiny crayfish, an at risk species which is currently under candidate review, and provide these to the group prior to the IFIM study.

In section 3.2.2 of the IFIM Study Plan, Shane added in a description of the downstream ledge which may be a possible navigation site.

Bill S. asked why the river directionality is positioned looking upstream. Shane said that it just depends on how the biologist is trained. The group agrees to change all direction references to looking downstream.

Prior to the meeting, Gerrit submitted a comment regarding the inclusion of a Dual Flow analysis (DFA) into the IFIM Study Plan. Brandon explained to the group what a DFA is and his description is attached to the end of these notes. He said the goal of a DFA is to assess Project generating flows and how various operating scenarios affect habitat suitability. Base flow and generating flow couplets of interest are identified, along with selection of key species and lifestages. Effectively available habitat for a particular study site is calculated at pair of stream flows. A comparison of the amount of units of WUA available at the base flow versus the units of WUA at the generating flow is completed. DFA only records WUA corresponding to the lower of the two paired values regardless of whether the lower WUA occurs at the low or high flow. The assumption is that the lower WUA value represents the level of suitability persisting under both conditions For example, if the habitat value is zero at the low or high flow, then the value for that pairing is zero. Shane said this can be done as a desktop exercise and doesn’t require any extra field effort however a basic PHABSIM analysis must be completed and reviewed first since this step establishes the quantification basis.

Gerrit said DFA can also be done to mitigate the effects of peak flows by changing the base flow. He said you can iteratively move the base flow up or peak flow down to mitigate and lessen the affect on habitat to assess different operating scenarios. The idea is that if the higher the habitat suitability is a majority of the time, then the episodes of lower habitat suitability are less stressful to the aquatic species . Bill A. asked if base flows would be changed during certain times of the day or seasonally. Gerrit said this is a seasonal change. Brandon said spatially peaking effects attenuate going downstream so that the effect is most pronounced nearest the tailrace. The group would have to decide if the analysis should focus on the upstream reaches of the river or the downstream reaches.

The group decided that the study plan needs to include information on process steps regarding the DFA. The TWC will review initial WUA output and then meet to determine the DFA scope. No additional field work will be needed. Shane will add a few paragraphs to the IFIM Study Plan describing the DFA process. Kelly will send these paragraphs out to the TWC for review and comment.

Other additions to the IFIM Study Plan include mentioning the Robust Redhorse memo, adding in crayfish habitat suitability information (provided by Byron) and adding wording on the identification of substrates for crayfish during the IFIM study. Ron mentioned he would like to see a more specific schedule for when the IFIM study will take place because he would like to help. He would like to see the schedule already included in the IFIM Study Plan expanded to include more specifics. He would also like to see qualifiers added in to account for bad weather or flows that might inhibit data collection. All of these changes will be made to the study plan in track changes and sent out to the TWC for review and approval.

Dick asked the group if they want to specify the goals of the analyses in the study plan. For example, SCDNR's recommendation is to identify a minimum flow that would provide 80 percent of maximum WUA. The group decided to add a list or table outlining the process of the study, which will include an expanded section on TWC consultation.

Gerrit asked if there will be demonstration flows scheduled following the results of the IFIM study regarding navigation and fish passage. Bill A. said that there can be demonstration flows and Shane will add this into the process schedule.

Dick mentioned the navigation component of the IFIM Study Plan and said that it was not consistent with the Navigational Flows Study Plan, which is discussed in the Recreation TWC. The Navigational Flows Study Plan needs to be changed to include a description of the two-way navigation requirement. This study will still only focus on one way navigation, but a description of two-way navigation needs to be included. This study plan will be re-circulated to the Recreation TWC for approval and then finalized.

Shane then gave the group an overview of the 2014 field season efforts for the IFIM study. Level loggers will be deployed in late March or early April in 12 different locations from the Parr Shoals Dam to the Columbia Dam pool, near the rowing facility. Level logger data is being collected to examine travel time for flows and to develop stage discharge relationships. Additionally, 2-D data collection will be completed in the Bookman Shoals area (Study Site 10), which includes latitude, longitude and elevation data for the entire two mile study area. At Study Site 1, a terrain model for quantifying pools and fish passage will be created. Cross sectional profiles including bed elevations and water surface elevations will also be collected at Study Site 4. Bill S. asked how many points will be examined at Study Site 10. Shane said he isn't sure yet, but it will be a good idea to look at existing LiDAR data and DEM data to make sure they establish an adequate number of points. This should give clarity to the density of points needed for the model. Densities could be as tight at every three meters. Shane said that the TWC is welcome to help with these efforts this year as well. Emails will be sent to the group to notify them as soon as possible when the work will be done.

The IFIM Study Plan will be updated to reflect the items discussed at the meeting and sent back out to the TWC for approval. Action items stemming from this meeting are listed below.

ACTION ITEMS:

- Byron will identify the preferred habitat substrates for the spiny crayfish and provide this information to the group for use during the IFIM study.

- Shane will change the language in the IFIM Study Plan to reflect a "looking downstream" perspective.

- Shane will add in a section describing the process steps of the IFIM study with an expanded section on TWC consultation. He will also expand the schedule to include more specific dates and times which will include demonstration flows if possible. He will also add qualifiers to account for bad weather or flows that might inhibit data collection.

- Shane will add in a section to the IFIM Study Plan discussing Dual Flow Analysis. He will also add in a few sentences discussing the information collection on Robust Redhorse spawning areas. Additionally, once Byron provides the information regarding preferred spiny crayfish habitat substrates, Shane will include this in the IFIM Study Plan.

- Kleinschmidt will update the Navigational Flows Study Plan with information on two-way navigation and redistribute to the Recreation TWC.

DUAL FLOW ANALYSIS

- The basic WUA/flow relationship is the foundation
- Base flow/generating flow couplets of interest are identified
- Key species/lifestages (or guilds) are strategically selected
- Effectively available habitat for a study site[1] is calculated at pairs of stream flows: (base) non-peaking and a (generation) peaking flow.
- Dual Flow analysis only records WUA corresponding to the lower (*"effectively available"*) of the two paired values. If the habitat value is zero at either the low or high flow, then the value for that pairing is zero.
-

Example:

basic WUA/flow relationship (*example from Chippewa River, WI*):

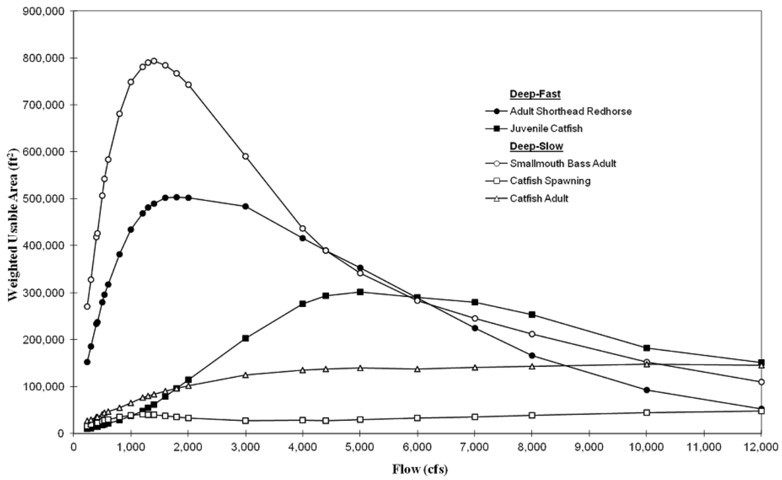
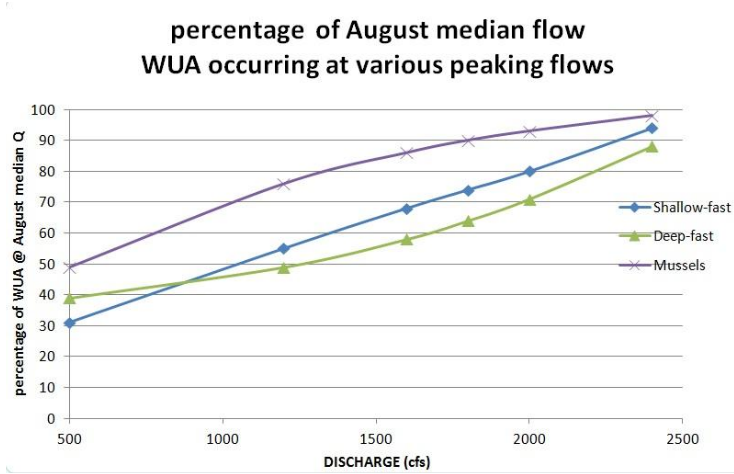


Figure 4. Habitat-discharge relations for fishes in Deep-Fast and Deep-Slow habitat guilds within the Cornell Project instream flow study area.

Effective Habitat WUA of generation vs. base flow condition plotted



[1] For non-mobile life stages such as macroinvertebrates or nest spawning, calculations can optionally be performed at the cell level using the "HABEF" routine in PHABSIM

MEETING NOTES

SOUTH CAROLINA ELECTRIC & GAS COMPANY
Instream Flows TWC Meeting

September 27, 2016

Final KMK 10-26-16

ATTENDEES:

Bill Argentieri (SCE&G)	Bill Marshall (SCDNR)
Ray Ammarell (SCE&G)	Dick Christie (SCDNR)
Caleb Gaston (SCANA)	Ron Ahle (SCDNR)
Mike Mosley (SCANA)	Tom McCoy (USFWS)
Brandon Stutts (SCANA)	Gerrit Jobsis (American Rivers)
Randy Mahan (SCANA)	Bill Stangler (Congaree Riverkeeper)
Shane Boring (Kleinschmidt)	Alex Pellet (SCDNR) via conf. call
Henry Mealing (Kleinschmidt)	Fritz Rhode (NOAA) via conf. call
Jordan Johnson (Kleinschmidt)	Brandon Kulik (Kleinschmidt) via conf. call

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These notes are a summary of the major points presented during the meeting and are not intended to be a transcript or analysis of the meeting.

Henry opened the meeting with introductions and a brief overview of the agenda and meeting goals. The goal of the meeting was to review the Parr Downstream Flow IFIM Study results, seek agreement on the results, and begin discussions of the potential minimum flow range that should be considered. The group was given handouts of the Wetted Usable Area (WUA) results from PHABSIM and 2D model runs to review.

Shane noted that, with the exception of Study Site 2 (west channel), the WUA tables had been revised to include the additional flow increments requested by SCDNR. Shane reminded all attendees that the goal of the IFIM study is to balance hydropower operations and aquatic habitat. He recommended that the group initially focus on putting boundaries around a flow range for minimum flow discussions. Ron commented that the group should carefully consider the study results before considering what is practical in relation to project operations. Caleb commented that the group should always keep project limitations in consideration when discussing the results as to not discuss flows/scenarios that aren't possible. Gerrit stated that he was expecting a habitat duration and/or dual flow analyses but did not see these items in the report. Shane said that the group should discuss and approve the raw WUA vs flow relationships contained in the PHABSIM model runs prior to discussions about next steps, which then could include the habitat duration and/or dual flow analyses. Gerrit noted that habitat duration is a very important aspect in making a minimum flow recommendation. Gerrit also provided the group with a brief explanation, noting that habitat duration allows the WUA data to be analyzed based on how often different flows occur at the Project. Brandon K. commented that the group should discuss and specify timeframes addressed in any duration analysis; annual/monthly vs. seasonal vs. periods of low flow. Shane added that due to the large of WUA output for the various species and lifestages, the group also needs to discuss “driver” species or study sites as to narrow down the dataset for any additional analysis.

Shane opened a PowerPoint presentation outlining the IFIM study. Reach 1 of the study is located from Parr Dam to the downstream end of Hampton Island. Reach 2 of the study is located from the downstream end of Hampton Island to the downstream end of the Bookman Island complex. These study reaches are primarily influenced by the Project with little inflow from tributaries. The only tributary of note is Little River, located just upstream of Bookman Island. Shane gave a brief overview of each study site, including their locations and characteristics. Shane made a special note of study site 9, located at Huffman Island, as it was originally slated for 2-D modeling. He explained that the TWC decided 2-D modelling of study site 10 (Bookman Island) would be sufficient and any flow recommendations would be verified by a site visit to study site 9.

Shane moved on to explain how the east and west channels below the dam, separated by Hampton Island, were analyzed. The west channel had its own calibration flows and was analyzed separately from the rest of the reach. The east channel, which encompasses all flow passed through the powerhouse, followed the 400, 2000, 6000 cfs calibration flows conveyed throughout the rest of the study area. Shane also gave a brief overview of the fish passage analysis completed as part of the IFIM study. Shane wrapped up his overview of the study by providing a table illustrating the target species, lifestage, Habitat Suitability Curve (HSC) sources, and guilds assigned during study scoping. He noted that recent comments from SCDNR were incorporated into the table. Brassy jumprock and robust redhorse were changed to the “deep fast; shallow fast” guild. Shane also explained one change made to HSC source data for smallmouth bass included data from a study in Deerfield River in MA.

Shane moved discussions over to the study results for each study site.

West Channel (*study sites 1,2 and 4*). The group started with discussions of site 1 in the upper West Channel. Shane explained the elevation data used to analyze pool volumes in study site 1; including DEM data collected by Glenn Associates, ADCP data collected by Watercube, and point elevations collected by Kleinschmidt and Glenn Associates. Henry also provided a brief discussion of methods and data collected during the 2016 West Channel Water Quality. He explained how those data will be used in ongoing discussions of conditions at Study Site 1. Shane wrapped up the West Channel IFIM results with a review of study site 4. He explained that the site was a “wetted perimeter” transect that is backwatered somewhat buy flow from the east channel, and showed the group the results of the analysis.

Shane then moved the group into discussions of the east channel and Reach 2 study sites.

East Channel
Study Site 3 is located immediately downstream of the Parr powerhouse. Shane noted the site has higher velocities and therefore the “slow” guilds and species returned poor results. Ron noted that the WUA table for study site 3 contained multiple flows that had 100% of available habitat. Shane explained that this was simply rounding by Microsoft Excel and that edits would be made to the tables. The group briefly discussed why the site was given the moniker “sucker city”. Ron explained that this is a result of observations made during electrofishing efforts in the area for robust redhorse spawning grounds.

Study Site 5. Shane gave a brief overview of the results, explaining that this site was deeper. Gerrit asked if it is known how water partitions into the east and west channels. Henry said that most of the flows from the powerhouse move down the east channel and that water released through the spillway gates moves to both channels (especially dependent upon which gates are releasing). The 2016 West Channel Water Quality Study should provide additional understanding of this relationship. Study site 6 results showed that optimal WUA ranges between 1,000-1,500 cfs for most of the species/guilds. Shane explained that the small "bumps" seen in the WUA curves at 5,000 cfs are artifacts of the hydraulic model. The group noted a few errors in the WUA tables that will be corrected. Dick noted that he would like to review the report again with any edits resulting from the meeting. Henry replied that the report and WUA tables would be redistributed to the group for review.

Downstream study sites

Shane returned discussions to **study site 6** by asking Ron to give a brief review of why the site was chosen for analysis. Ron commented that the site is a slate belt run with deeper pockets that is very important to the smallmouth bass fishery as it offers some of the best smallmouth bass fishing habitat in the river. He noted that the site also provides cover and habitat for juveniles in the shallower areas. Shane added that this site represents a situation where smallmouth bass could be a "driver" species when evaluating a minimum flow.

Study site 7 WUA peaks around 600-1,200 cfs. Shane also briefly mentioned that this site contained two passage points that were analyzed for fish and navigational passage.

Study site 8 (Haltiwanger Island) peak WUA values occur between 500-1,500 cfs. Shane explained that there was one transect located in each channel around the island; each one was independently modeled. Shane pointed out "fluctuations" in the WUA curves, explaining that this resulted from combining the PHABSIM results for each transect into one graph for analysis. He mentioned that higher flows were likely needed to provide the most habitat at this site. This is a result of the very wide and shallow nature of the western channel. **Study site 8** was the final site analyzed using PHABSIM. Gerrit commented that this site could be good for assessing seasonal and interannual flows, explaining that the project lends itself to providing more water during high flow years. Henry commented that while this is true, SCE&G will need an "or inflow" component with any minimum flow recommendation. Ray A. added that this should already be happening as Parr does not store any water. High flow years should be reflected in the flow record. Ron commented that if seasonal flows might be considered for a minimum flow recommendation, the group needs to be sure and consider all the different species if spawning seasons will be used.

Study site 10 (the Bookman Island complex). Shane explained that it was modeled with the program River2D due to the complexity of the reach including multiple channel bifurcations and patches of habitat. He explained that elevations throughout the reach were collected using a combination of methods. Elevation data were first collected during a flyover of the area using georeferenced aerial photogrammetry methods during low flows (400-600 cfs) in December 2014. These data were supplemented with additional field data collections with survey grade GPS. These elevation data were the basis for the River2D analysis. Shane broke down the WUA results, noting that the peaks tend to be around 1,000 cfs, with smallmouth bass peaking around 3,000 cfs.

Gerrit asked the group how the study sites should be weighted based on the varying analysis methods (1D/PHABSIM vs. River2D). Shane and Brandon K. explained that results could be weighted according to river linear length or they could not be weighted at all (these are the representative reach vs. critical habitat approaches). Shane added that results presented for each study site are standardized at WUA per 1,000 linear feet of stream, so study sites can be compared regardless of their length differences. The group noted that the WUA results could be also be weighted utilizing the results of the Mesohabitat mapping assessment, if the representative reach approach is chosen.

Zone of Passage

Shane reminded the group of the fish passage portion of the IFIM analysis. He gave the group an overview of the results noting the flows required to meet the passage criteria. The ledge at study site 7 meets fish passage criteria at 500 cfs. The ledge upstream of Bookman Island meets the criteria at 700 cfs. Shane summarized that most sites experience optimum WUA between 800 and 1,200 cfs.

Discussion of further analysis

Shane explained to the group that he would like to take the results presented to the group and discuss driver species and sites individually. Gerrit asked if the sites could be prioritized by suitability for species. He explained that he would like to see WUA comparisons by species across multiple sites, in addition to WUA comparisons by site across multiple species. Ray displayed flow duration curves (FDC) to the group that were developed utilizing a prorated inflow dataset used by the Project Operations Model. The group reviewed monthly flow duration curves, noting the 90% and 50% exceedance flows. Henry explained that he wanted the group to see these in response to Gerrit's comment about analyzing the WUA data in light of what flows are available in the river. The group broke for lunch, planning to have a workshop session in the afternoon to narrow down driver species and flow ranges to be addressed in any further analysis.

Workshop session

The group opened up the "workshop" session after lunch by constructing a calendar with the flows from the FDC review (Appendix A). They added bio-periods to the calendar based on species/guilds of importance. During the "workshop" session, Gerrit offered up a suggestion for how to analyze the WUA data by species rather than study site. He created an example table using the American Shad WUA from each study site (Appendix A). The group approved of Gerrit's suggestions, and created similar tables for adult smallmouth bass and robust redhorse/deep-fast guild. The tables allowed the group to rank/prioritize the study sites based on the available WUA.

After the workshop session, the group returned to the tables for discussion. Henry and Shane asked the group if there were priority species or study sites that the group is considering. Ron and Gerrit identified American shad, robust redhorse, and adult smallmouth bass as priority species. Ron added that smallmouth bass continues to be an important fishery for the SCDNR. Ron also pointed out that while study site 3 offers unique habitat for suckers not found in other parts of the river, it shouldn't take precedence over downstream study sites when evaluating for minimum flow. Since it is close to the powerhouse, conditions there remain relatively stable no matter the flow.

Henry provided a recap of what the TWC discussed in the meeting. He noted that the WUA tables will be presented by species rather than by study site. He noted that the group will need to continue to narrow the flow ranges discussed in order to start establishing minimum flow recommendations. He also noted that SCE&G would like to have 3 or less seasonal minimum flows in a year.

Seasonal Flow Targets
Caleb G. asked the group if they could identify periods of time where they would like to see certain minimum flows (i.e. bio-periods). He noted that this doesn't require a particular flow recommendation, just a general description such as low, medium, and high. The group referred back to the calendar produced during the "workshop" session. The group considered the exceedance flows provided by the inflow flow duration curves and the time periods identified that are of importance to the various species and guilds. They identified a period of "high" minimum flows starting February 15th and extending until May 15th or 30th depending on river conditions. The minimum flow would then drop back to a "medium" flow through June 30th. The "low" minimum flow period would extend until November 30th and then returning to "medium" flows until the following February 15th. The flow periods are illustrated in the attached tables. Henry asked the group if they could identify potential flows they would like to apply to the "low, medium, and high" flow periods. After clearly explaining that additional information (i.e. habitat duration) and analysis (i.e. dual flow) were needed before final recommendations could be made, Gerrit recommended for discussion purposes 2,500 cfs for the "high" period, 1,800 for the "medium" period, and 1,200 for the "low" period. SCE&G identified 2,000 cfs for the "high" flow, 1,300 cfs for the "medium" flow, and 700 cfs for the "low" flow period. Henry encouraged the other stakeholders and agencies to provide specific flows as this issue is resolved.

Habitat Duration
The group turned discussions back to the habitat duration analysis. Gerrit reiterated that applying the flow duration data to the WUA data would allow the group to make a flow recommendation that best benefits aquatic habitat. He noted that the analysis will also provide the group with more information to identify time periods that should be grouped into the low, medium, and high minimum flow periods. Brandon commented that completing the flow duration analysis can be accomplished utilizing existing data presented during the meeting.

Ray and Bill A. reiterated to the group that it's important to consider plant operations when recommending minimum flows. Ray explained that SCE&G currently calculates minimum flow as inflow minus evaporative loss. He added that current maximum evaporative loss is 118 cfs; however, this will increase to 180 cfs when the new nuclear units begin operating. SCE&G needs enough room between inflows and minimum flow requirement to account for these variables. SCE&G will review how inflows are currently calculated to ensure they are not overestimating. They will also review their compliance records to identify times where they struggled with maintaining minimum flows and see if the suggested flow ranges fit with their capabilities.

Brandon K. asked the group if there were species or guilds currently being analyzed that can be removed from future analyses. Ron recommended that the shallow-slow guild be removed. Gerrit added that the group most discussed robust redhorse, American shad, smallmouth bass, and the deep-fast guild during the "workshop" discussions.

Dual Flow analysis
Bill A. asked the group if the dual flow analysis still needed to be considered. Shane asked if, with the emphasis put on the habitat duration analysis, the dual flow analysis was still the best tool. Henry noted that the findings from the Downstream Flow Fluctuation Group could replace the dual flow analysis. He added that the TWC could incorporate the IFIM data into recommendations to SCE&G on an operational band for them to try and stay between while operating the project. He

noted that this could be included in an adaptive management plan and would provide a way for SCE&G to evaluate how they are managing downstream fluctuation flows while benefitting aquatic habitat. Gerrit replied that he is willing to suspend a dual flow analysis until after the results of the habitat duration analysis is presented. He explained that the dual flow analysis may provide a means of quantifying the effects of large spill events and offers a way to mitigate later.

The group discussed an operational band for Parr. Gerrit and Henry explained that there would be a target release for the project with an upper and lower band. There wouldn't be any penalty for operating below or above the target flow, as long as the project operated within the band. This could provide a means to mitigate instances where there are peaks and valleys created within the hydrograph by Project operations. Henry reiterated that this would be a means for the group to evaluate the success of SCE&G's operational changes to address project influenced flow fluctuations. Henry also reminded the group that they should consider low inflow protocols as part of their recommendations. Gerrit added that an operational band is about providing a buffer for project operations. He provided an example to the group. The minimum flow could be 1,200 cfs, if inflow were at or above 1,500 cfs. If inflows drop below 1,500 cfs, the minimum flow could, for example, drop to 1,000 cfs to allow for operational needs. Gerrit added that an operational band would allow for flexibility during low inflow periods, while also providing an opportunity for flows to be higher than a prescribed minimum flow requirement when there were higher inflows.

Gerrit asked if the group was still considering stabilization flows during spawning periods. Bill replied that it is still being considered, and will be addressed in the next Downstream Flow Fluctuations TWC meeting in October.

The meeting adjourned. Action items from this meeting are listed below.

ACTION ITEMS:

- Kleinschmidt - prepare meeting notes
- Kleinschmidt - increase detail of higher range of flows for Study Site 2
- Kleinschmidt - edit errors identified in the WUA table percentages
- Kleinschmidt - edit WUA tables and curves. Data by species/guild rather than study site.
- SCE&G - review how inflow is calculated by the operators, ensure not overestimating
- SCE&G - review compliance records to establish times where maintaining minimum flows were an issue. See if the TWC's suggested flow ranges match up with capabilities.
- Kleinschmidt - remove Shallow-Slow guild from list for further analyses
- All TWC Members - provide recommendations for upper and lower operational limits based on WUA tables
- Kleinschmidt - prioritize transects based on mesohabitat data
- Kleinschmidt - develop habitat duration curves

Workshop Attachments

American Shad			
Transect	**75% WUA Flows (cfs)**	**WUA Units**	**Rank**
SS3	750-7,000	238k-294k	5
SS5	200-2,500	61k-79k	6
SS6	700-6,000	244k-309k	4
SS7	700-10,000	283k-373k	3
SS8	1,750-10,840	618k-791k	1
SS10	800-20,000	398k-524k	2

Deep Fast/Robust Redhorse			
Transect	**75% WUA Flows (cfs)**	**WUA Units**	**Rank**
SS3	2,600-5,000	188k-244k	1
SS5	500-1,150	32-43k	4.5
SS6	3,000-4,000	146-163	2
SS7	1,200-3,000	34-42	5
SS8	5,000-10,800	67-90	3
SS10	1,500-4,000	32-42	5

Smallmouth Bass Adult			
Transect	**75% WUA Flows (cfs)**	**WUA Units**	**Rank**
SS3	1,200-4,500	96-128	5
SS5	400-3,500	67-89	6
SS6	1,200-6,000	220-293	3
SS7	600-3,000	196-261	4
SS8	2,500-7,180	341-455	2
SS10	2,500-7,000	387-516	1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
90% Exceedance	2,435	2,571	3,365	2,978	2,036	1,368	1,045	771	865	1,083	1,235	1,979
50% Exceedance	5,000		6,000	5,000	3,750	3,000	2,500	2,250	2,160	2,300	3,000	4,400
		D/F	AMS	AMS	AMS juv (shallow, fast)							
				RRH	RRH							
				SMB (spawn)	SMB (spawn fry)	SMB (juv/fry)						
					RBS (spawning)	RBS (spawn/fry)	RBS (fry/juv)					
				Striped Bass	Striped Bass							
FLOW		2/15			5/15 or 31		6/30					11/30
	Medium			High Flow Stakeholder -2,500 SCEG-2,000		Medium Flow Stakeholder -1,800 SCEG-1,300			Low Flow Agency-1,200 SCEG-700			

Kleinschmidt

MEETING NOTES

SOUTH CAROLINA ELECTRIC & GAS COMPANY
Instream Flows TWC Meeting

January 24, 2017

Final KMK 2-16-17

ATTENDEES:

Bill Argentieri (SCE&G)
Ray Ammarell (SCE&G)
Caleb Gaston (SCANA)
Brandon Stutts (SCANA)
Tom McCoy (USFWS)
Melanie Olds (USFWS)
Dick Christie (SCDNR)
Bill Marshall (SCDNR)
Ron Ahle (SCDNR)
Alex Pellett (SCDNR)
Gerrit Jobsis (American Rivers)
Bill Stangler (Congaree Riverkeeper)
Henry Mealing (Kleinschmidt)
Brandon Kulik (Kleinschmidt) via conf. call
Bret Hoffman (Kleinschmidt)
Jason Moak (Kleinschmidt)
Jordan Johnson (Kleinschmidt)
Kelly Kirven (Kleinschmidt)

These notes serve as a summary of the major points presented during the meeting and are not intended to be a transcript or analysis of the meeting.

Henry opened the meeting with introductions and distributed a memo entitled “Parr IFIM Study – Habitat Duration Analysis and Misc. Action Items” dated January 23, 2017. This memo was an update of the “Habitat Duration” memo distributed in December 2016. Henry then began a PowerPoint presentation, which is attached to the end of these notes along with the January 23rd memo. The goals of the meeting included selecting values for minimum flows, selecting seasonal date ranges for low, mid, and high minimum flows, discussing potential observation dates and discussing methods and transects for observation. Regarding the timing for the observation flows, Henry suggested that there will likely be three separate outings to view the flows; one in early spring, one in May, and one in August. Henry then reviewed the action items from the previous meeting. The corrected WUA tables from the IFIM report are included in Attachment A of the memo, the new figures and tables of WUA by target species and life-stage are in Attachment B of the memo, and the Habitat Duration Analysis is in Attachment C of the memo. The WUA data weighted by mesohabitat is presented in the body of the memo.

Henry then turned the presentation over to Bret, who discussed the Habitat Duration Analysis. He explained that seasonal hydrologic availability was compared to WUA and to the seasonal minimum flow ranges that were proposed at the previous TWC meeting (held on September 27, 2016). Bret explained that there was an inflection point in the prorated data around 3,900 cfs, which resulted in overestimation of inflows below this point and underestimation of inflows above it. Because of this, he used non-prorated data to complete the habitat duration analysis. Also, in order to tailor the effort during this analysis, he focused on select months, species/life stages and study sites that were noted as having the greatest interest or importance. Bret said the exceedance percentages, which are in Table 2 of the memo, display how often the low, transitional, and high flows are exceeded. For example, a flow of 1,800 cfs in June is available 74 percent of the time and not available 26 percent of the time. Henry added that this Project is not a storage reservoir, so outflows are totally dependent on inflow. SCE&G is not able to hold back excess water in the spring for release in the summer. Ray said that since SCE&G will try to avoid dropping gates as part of a parallel effort to dampen downstream flow fluctuations, this will drive water through the powerhouse more consistently.

Gerrit began discussing a potential Low Inflow Protocol (LIP). He said that, for example, if Flow A is the minimum flow and inflow decreases to a certain point, then Flow B will become the minimum flow. If inflow decreases to within 200 cfs of the minimum flow, then the minimum flow can be reduced and act as a buffer. Gerrit asked how SCE&G currently operates when they are at inflow now. Ray said when they are at inflow, they release inflow minus evaporation. He said he finds that losses are greater in the system as a whole than what is calculated for inflow, so they can still operate Fairfield, just a little less each day. Monticello Reservoir starts dropping each day during a drought or period of low flows, so the maximum amount you can release is constantly decreasing. He said in extreme periods of low flows, which may have more impact on Parr Hydro in the future due to the two new nuclear units at V.C. Summer, Fairfield operations are limited. When a storm comes and flows increase, SCE&G attempts to make up losses in the reservoir that occurred over the low flow period until Monticello is restored to full pool. The group agreed that this recovery mechanism for Monticello Reservoir should be incorporated into the LIP.

Henry said that he wants to ensure SCE&G has some flexibility in their operations so that they can meet their minimum flows and consistently stay within compliance. He also noted that a change in philosophy on how the Project is run, including removing downstream pulses and no longer operating with a daily average minimum flow, will affect the new minimum flows in a positive way.

The group refocused on the presentation and Jordan began explaining the representative reach analysis and methods for weighting WUA. He explained that this analysis focuses on Reach 2 of the IFIM study because this reach is hydraulically linked unlike Reach 1, which is split into east and west channels by Hampton Island and because Reach 2 includes critical study sites that were identified by the TWC. He then explained that the total linear feet for each mesohabitat type within Reach 2 was measured using ArcGIS. Study sites 6, 7, and 8 were assessed separately from Bookman Island because they contained different types of habitat and were modeled using different methods. The two areas were weighted based on their individual linear lengths and then the weighted values were summed to provide WUA for the entire Reach 2. Graphs were reviewed that compare WUA availability by species for low flows, high flows and transitional flows.

One conclusion from the analysis that Henry noted is that a low flow of 700 cfs provides 79-120 percent of the suitability of a flow of 1,200 cfs. Ron noted that the 700 cfs flow only reach 120 percent suitability when small mouth bass fry are included. He said that the fry stage lasts for a very short period of time and shouldn't be taken into account for low flows.

The stakeholders held a breakout session to review and discuss the data presented in the memo.

After lunch, the group reconvened. Gerrit acted as the spokesperson for the stakeholder group and explained what they had discussed and the recommendation they were proposing. He said that there were two important things they looked at regarding their flow recommendations. First, they identified certain species that were most affected by flows. Second, they identified Study Site 3 as being important since whatever flows are released in that area, a portion will be diverted to the west channel. They also identified Bookman Shoals and Haltiwanger Island as important areas. Gerrit said they also looked at the exceedance flows and took into account how often certain flows would be available in the river. They identified a flow duration exceedance (not a WUA score) of 75-80 percent as acceptable.

Gerrit said the minimum flows that the stakeholders are recommending are as follows:

- Low Flows – June 1-November 30 – base flow of 1,200 cfs – drivers are adult smallmouth bass habitat, Study Site 3 (West Channel)
- Transitional Flows – January, May, December – base flow of 2,250 cfs – drivers are adult smallmouth bass habitat, robust redhorse spawning (deep fast guild), Study Site 3
- High Flows – February, March, April – base flow of 3,000 cfs – drivers are robust redhorse spawning, American shad spawning, Study Site 3

Gerrit added that they also discussed having a step down mechanism built into the LIP. They identified 200 cfs as a reasonable buffer flow. For example, during the minimum flow period when inflow reaches 1,400 cfs, the minimum flow released from the Project will drop from 1,200 cfs to 1,000 cfs. Then, when inflow drops below 1,000 cfs, outflow will equal inflow. The same consideration will apply to transitional and high flows. When inflow is 3,200 cfs, the minimum flow will drop to 2,800 cfs (for high flow periods) and when inflow is 2,450 cfs, the minimum flow will drop to 2,050 cfs (for transitional flow periods). Stakeholders also agree to include a recovery period to allow Monticello Reservoir to recover to full pool after periods of low flows.

Ray said that these proposed minimum flows are higher than what the stakeholders proposed at the previous meeting. He said that including June in the low flow period and removing it from the transitional period seems reasonable. He said that a base flow of 1,200 cfs will be difficult to accomplish in August. SCE&G already struggles to meet the current minimum flow in August, which is a daily average of 800 cfs. Ron asked what years of data were included in the monthly exceedance percentages shown in Table 2 of the memo. Henry said that those numbers were developed using 35 years of data. Ron said that if the exceedance percentages were calculated using only the last 10 years or so, they may drop down. Kleinschmidt will redo the table using only data from the last 15 years, to possibly give a clearer image of recent flows.

Ray said that the suggested low flows are concerning and will be difficult to comply with since the Project doesn't have a storage reservoir. Ray asked if the stakeholders are okay with subtracting evaporation from inflow. Gerrit said yes. Ray said that an instantaneous minimum flow of 1,200 cfs versus a daily average of 800 cfs will be difficult and inflow may be what's passed very often, since summer flows are often below 1,200 cfs. Bill A. asked if they are open to having these numbers be daily averages. Gerrit said no, these numbers are instantaneous minimums.

Bill A. asked how long flows should be low before they step down to a lower minimum flow per the LIP. Gerrit said one 15 minute reading shouldn't cause an issue, but when the whole river drops down to a new level, then the LIP should be initiated.

Bill S. said that they had to consider moving flows to the west channel and how this would affect the east channel in Study Site 3. Caleb asked how much flow do stakeholders envision being diverted to the west channel. Bill S. said around 200 cfs. Henry said he was surprised by the proposed minimum flows and he thought they would move closer to the 20/30/40 % numbers identified in the state recommendations for minimum flows.

Ron said they didn't separate spawning and adult habitats for robust redhorse. Henry asked if the deep/fast guild was a driver in the proposed flows. Gerrit said that adults were a driver and they are in the deep/fast guild. He said that American shad and robust redhorse were drivers during high flows and the west channel was a driver for all flows. Henry reminded the group that the robust redhorse spawn in shallow fast habitats. After the meeting KA reviewed the record and robust redhorse juvenile and fry stages were originally placed in the deep slow guild based on studies on the Pee Dee River, which had been omitted in previous meetings. The deep fast habitat is likely linked only with adult habitat and not linked to spawning and recruitment.

Gerrit said he doesn't envision many long periods where only the minimum flow is passed. He thinks the outcome will be better if SCE&G doesn't focus on what the minimum flow is as much as they focus on better flow management. He said he doesn't want to close the book on coming up with something creative that addresses American Rivers' interest, which is having flows mimic natural river flows.

Henry asked if all transects and all species were considered. Ron said that with all of the transects put together, they will get 66 percent of the smallmouth bass habitat at 1,200 cfs. By ensuring water is there for smallmouth bass, they won't be taking anything away from other species. The stakeholders agree that smallmouth bass is an especially important species for recreation.

Henry noted that the higher the minimum flows, the more chances SCE&G could have deviations because the Project will be in the "or inflow" mode of operation. Henry said SCE&G has agreed to do several operational changes during the new license including diverting water to the west channel, stop or minimize downstream fluctuation flows, and implement new minimum flows. Henry asked if the stakeholders would consider allowing for a minimum flow adaptive management plan to test the new minimum flows over several years and see how easy or difficult it is to comply with the other operational changes being proposed. They can show progress each year on how they are meeting this goal and even submit reports to FERC. Gerrit said this is a reasonable request and might be possible.

Melanie asked if a gliding minimum flow could be set up, using a percentage of inflow from the previous day minus evaporation. The group agrees this is a good idea and Henry said we will explore this idea further. Henry said that something similar to this was agreed to at an Entergy Project on the Ouachita River and one of the Coosa Developments in Alabama. They use percentages of inflow to adjust outflows on a frequent basis.

Bill A. noted that based on this new set of flows proposed by the stakeholders, observation flow dates would not be scheduled at this time since the stakeholder flows had increased from their previous proposal.

Following this discussion, the meeting adjourned. Action items from the meeting are listed below.

ACTION ITEMS:

- Kleinschmidt will put together meeting notes and distribute to the group.
- Kleinschmidt will recalculate the exceedance percentages on Table 2 of the memo, using only data from the last 15 years.
- SCE&G will discuss the new proposed minimum flows with management and they will work with Kleinschmidt to come up with other possible options.
- Kleinschmidt and SCE&G will review the TWC recommendation and perform additional hydrologic and biological analysis for minimum flows more in line with the proposal from the last meeting.

APPENDIX C

MESOHABITAT ASSESSMENT MEMORANDUM

MEMORANDUM

TO: Parr/Fairfield Hydro Relicensing Instream Flow TWC

FROM: Shane Boring

DATE: January 8, 2014

RE: Mesohabitat Assessment

A mesohabitat assessment of the Broad River downstream of Parr Shoals Dam was completed by biologists from Kleinschmidt (Shane Boring), SCANA (Milton Quattlebaum) and the South Carolina Department of Natural Resources (Ron Ahle) during October and November of 2013. The assessment was conducted in support of the ongoing Parr/Fairfield Hydroelectric Project relicensing effort, and more specifically, in preparation for the upcoming Instream Flow Incremental Methodology (IFIM) and other studies. The purpose of the assessment was to classify and determine the quantity and spatial distribution of different mesohabitat types within the study area previously outlined by the Instream Flow Technical Working Committee (TWC) (Figure 1). These data will be used to weight the Weighted Usable Area (WUA) output from individual representative transects and study sites according to the relative abundance and distribution of the mesohabitat types throughout the study area.

"Mesohabitats" are generalized habitat types that are commonly used to describe stream habitat (i.e. riffle, run, pool). Acceptable mesohabitat definitions were determined in consultation with the Instream Flow TWC (See July 30, 2013 meeting notes), and include the following:

RIFFLE	Shallow, with moderate velocity, turbulent, high gradient, moderate to large substrates (cobble/gravel). Typically > 1% gradient.
GLIDE	Moderately shallow, well-defined non-turbulent laminar flow, transition from low to moderate velocity, lacking a definite thalweg, typically flat stream geometry, typically finer substrates, transitional from pool.
RUN	Moderately deep, well-defined non-turbulent laminar flow, range from low to moderate velocity, well-defined thalweg, typically concave stream geometry, varying substrates, gently downstream slope (<1%).
POOL	Deep, low to no velocity, well-defined hydraulic control at outlet.
RAPID/SHOAL	Shallow, with moderate to high velocity, turbulent, with chutes and eddies, high gradient, large substrates or bedrock. Typically >2% gradient.
BACKWATER	Varying depth, no or minimal velocity, off the primary channel flow.

ASSESSMENT METHODS

For purposes of the mesohabitat assessment, the approximately 18 mile-long study area was broken into the two reaches agreed upon during the June 2013 field reconnaissance: Reach One – extending from the Parr Shoals dam downstream to the Palmetto Trail trestle crossing and Reach Two – extending from the trestle to the downstream end of Bookman Island (Figure 1). The study area was traversed by canoe/kayak or on foot at flows ranging from approximately 1,000 to 2,200[1] cubic feet per second (cfs), and mesohabitats occurring in each reach were classified into one of the six categories described above.

Upstream and downstream boundaries of each mesohabitat segment were documented using a Garmin 60cs Global Position System (GPS). Although not included in this report, field observations regarding dominant substrate, overall cover quality[2], and approximate channel width were recorded should this information be needed at a later date (e.g., during IFIM modeling efforts). Reference photos for each mesohabitat type were also taken at selected locations. GPS data were incorporated into a Geographic Information System (ArcGIS) and area polygons constructed and calculated for each mesohabitat segment (Figure 2).

RESULTS

Area and proportion of mesohabitats occurring in each reach are illustrated below in Figures 2-6 and summarized in Table 1. Reach One is dominated by run habitats, with an abundance of shoal habitat associated primarily with the bedrock outcroppings at the base of the Parr Shoals Dam (Table 1; Figure 3). Reach Two, which is depicted as Reaches 2a, 2b and 2c for illustration purposes (Figures 4-6), is dominated by pool habitats, with the remainder primarily consisting of nearly equal proportions of shoals, riffle and run habitats (Table 1). No significant backwaters were observed during the survey.

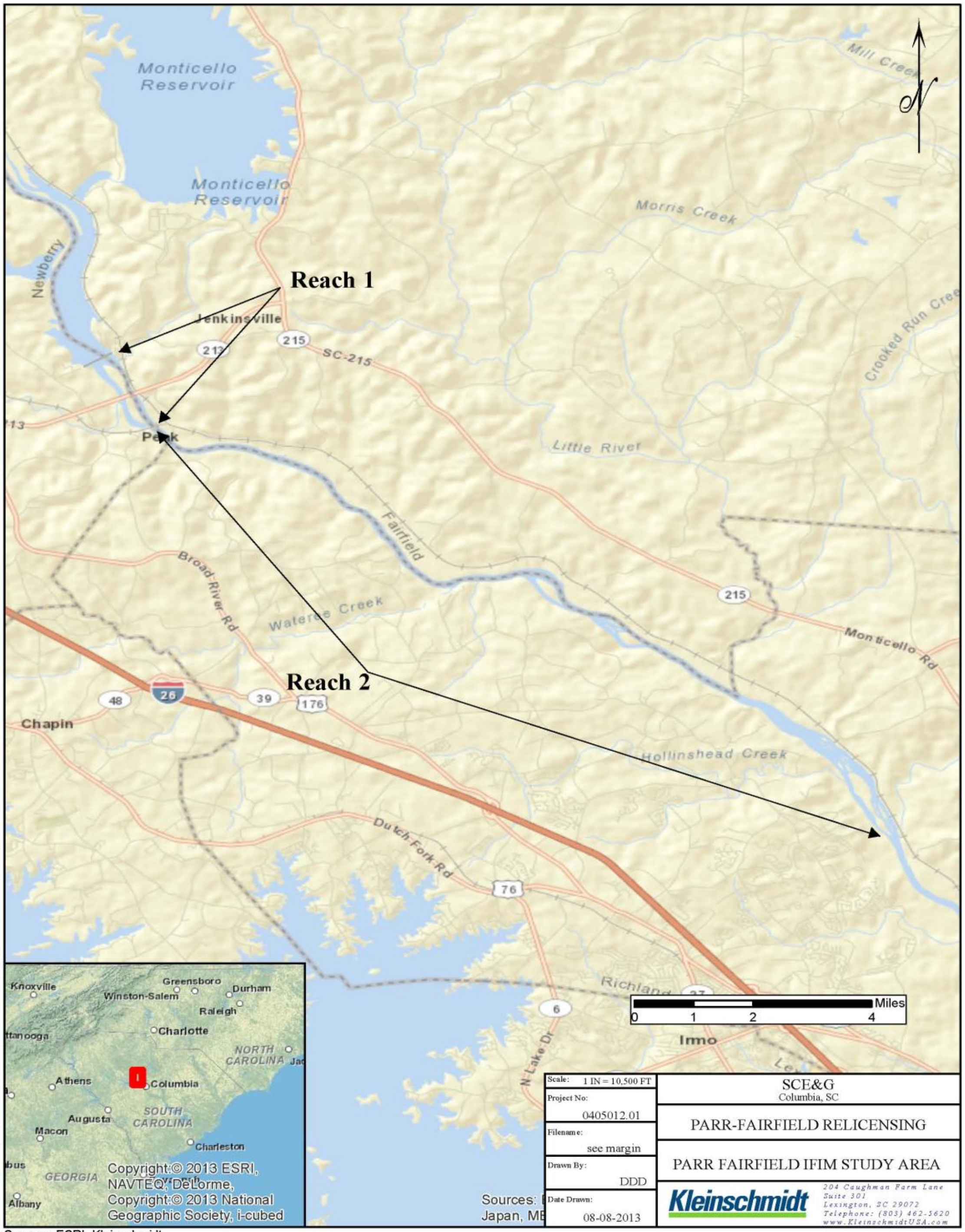
Table 1. Proportions of Mesohabitats Occurring Downstream of Parr Shoals Dam

	Glide	Pool	Riffle	Shoal	Run
Reach One	**4%**	**18%**	**0%**	**31%**	**47%**
Reach Two	**6%**	**28%**	**21%**	**25%**	**20%**

J:\455\086\Docs\001-Parr FF Mesohab Memo Report.docx

[1] Small portions of Reach One were also observed at approximately 4000 cfs during wrap-up of field work in late-November 2013.
[2] Refers to the relative density of object cover such as boulders, logs, etc.

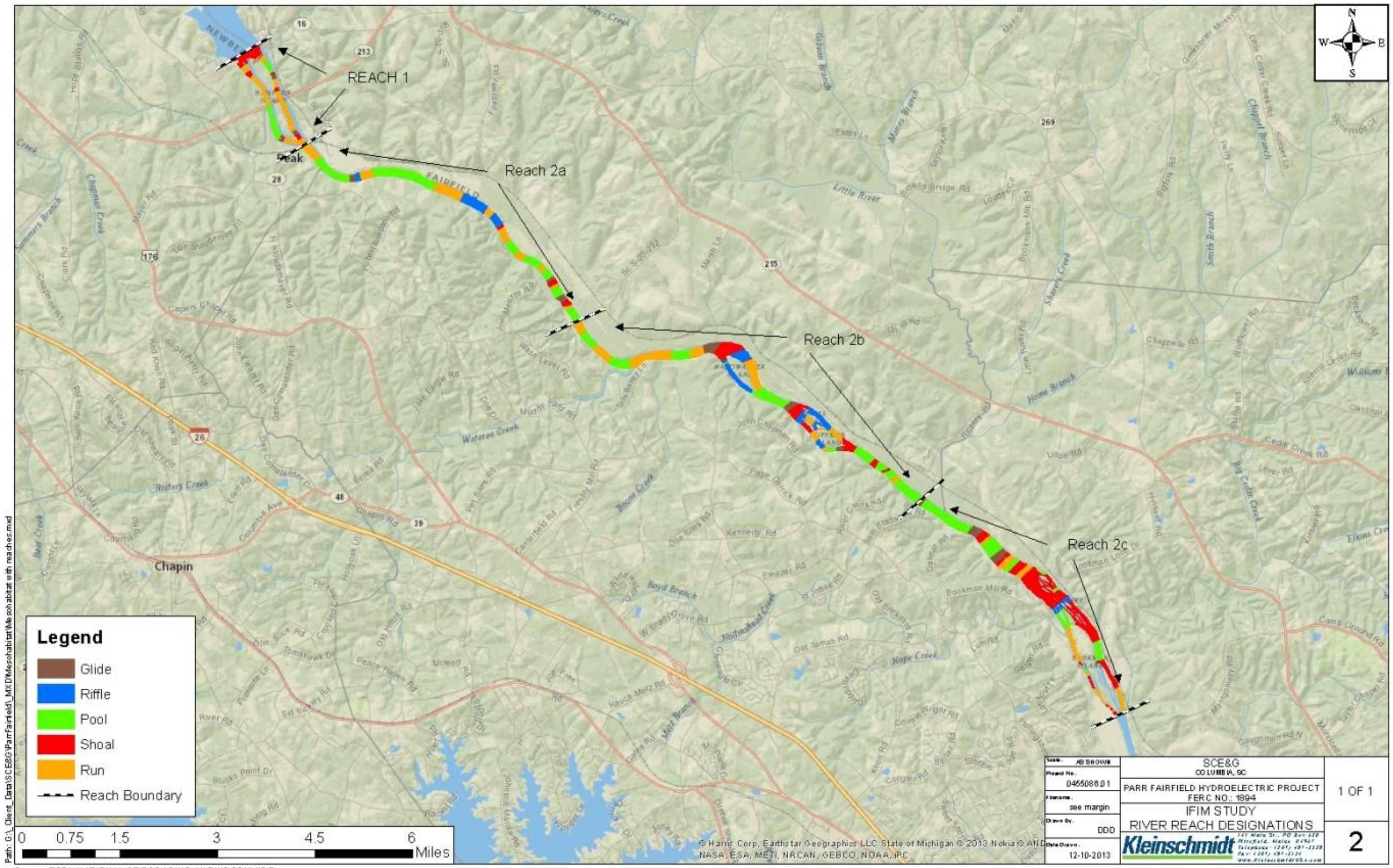
FIGURES



Path: G:_Client_Data\SCE&G\ParrFairfield_MXD\Parr IFIM Reaches.mxd

Sources: ESRI, Kleinschmidt

FIGURE 1 PARR-FAIRFIELD PROJECT, BROAD RIVER INSTREAM FLOW STUDY. IFIM STUDY REACHES



Source: ESRI, NATIONAL GEOGRAPHIC, KLEINDSCHMIDT

FIGURE 2 IFIM STUDY RIVER REACH DESIGNATIONS

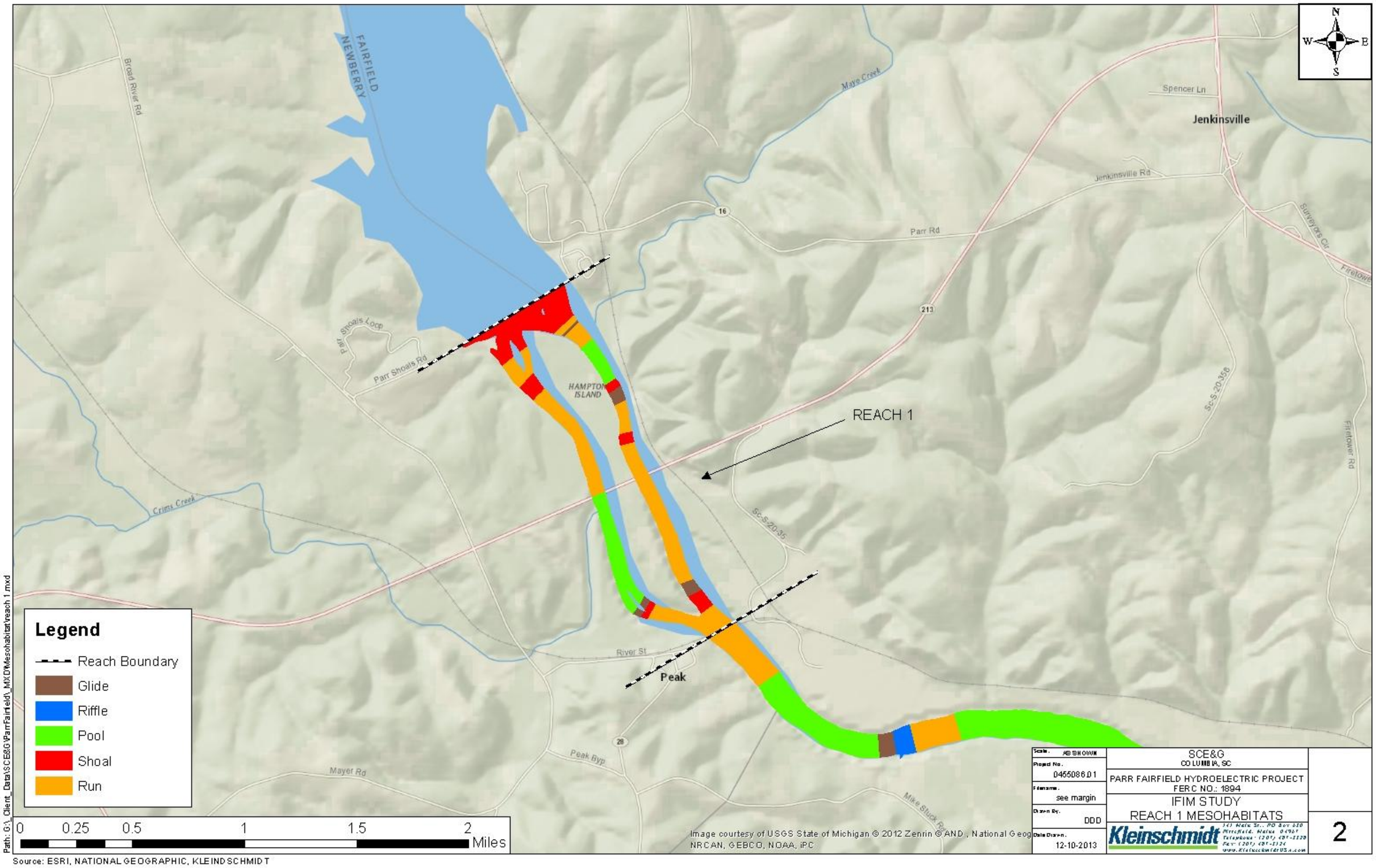
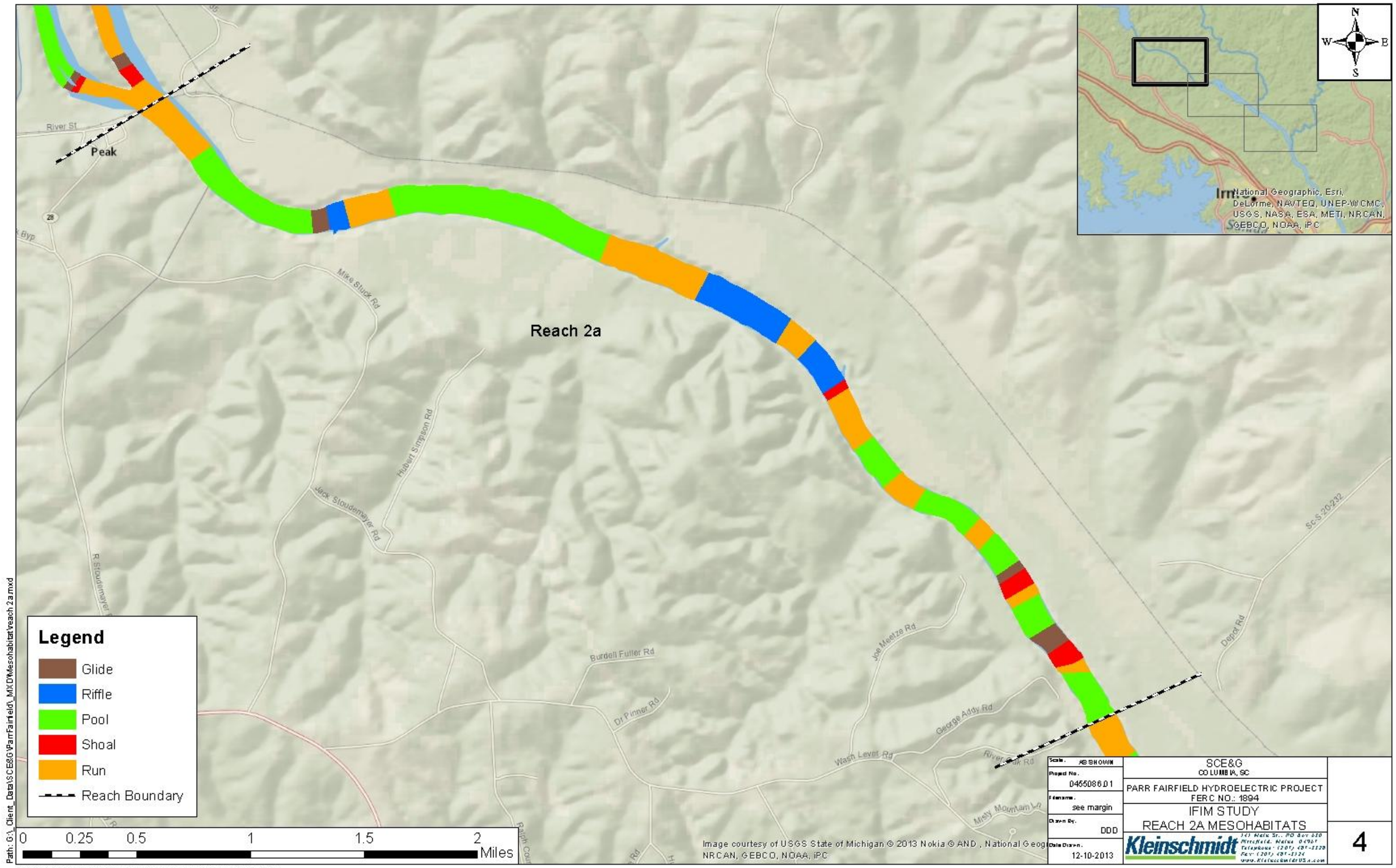
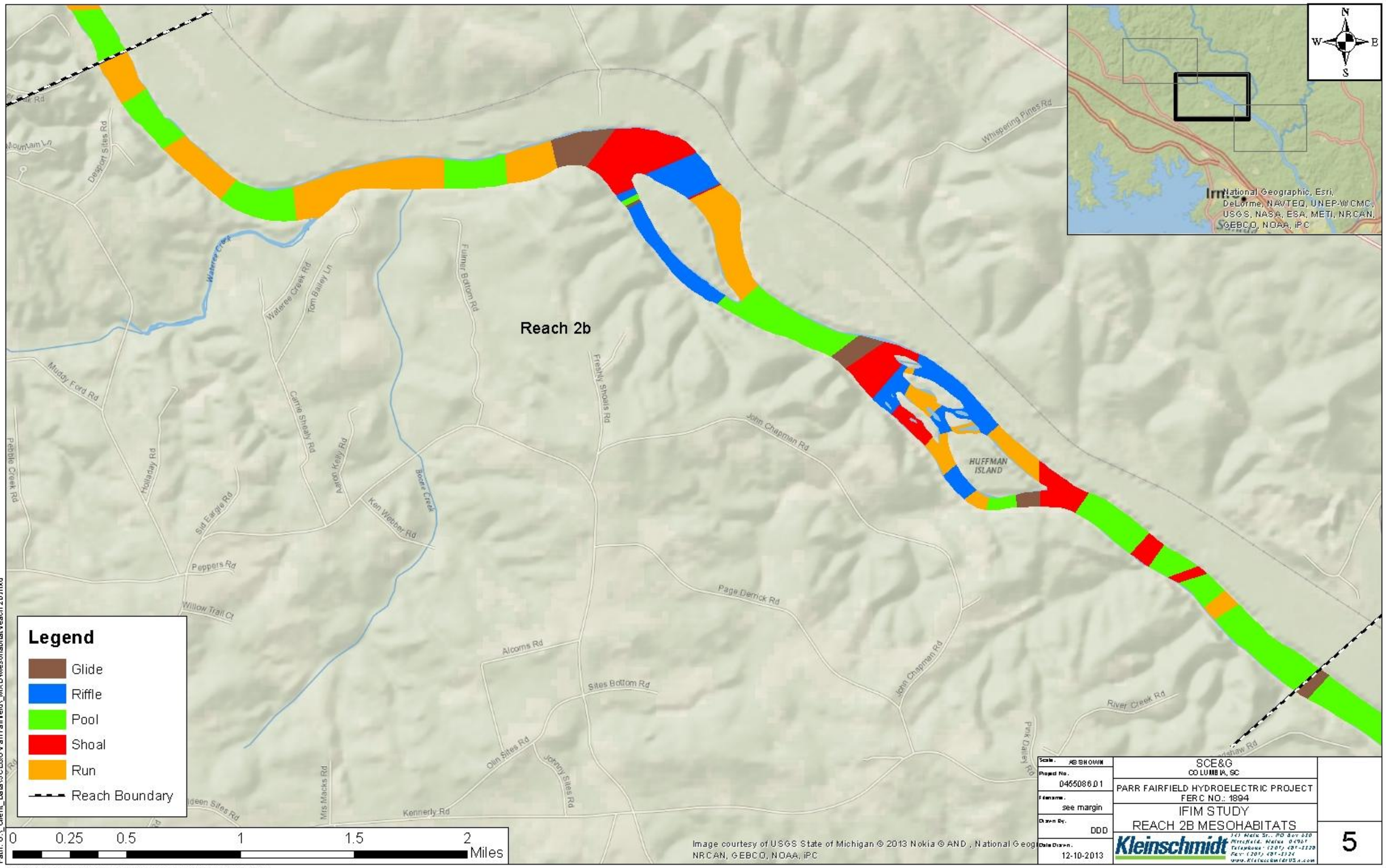


FIGURE 3 IFIM STUDY REACH 1 MESOHABITATS



Source: ESRI, NATIONAL GEOGRAPHIC, KLEINDSCHMIDT

FIGURE 4 IFIM REACH 2A MESOHABITATS



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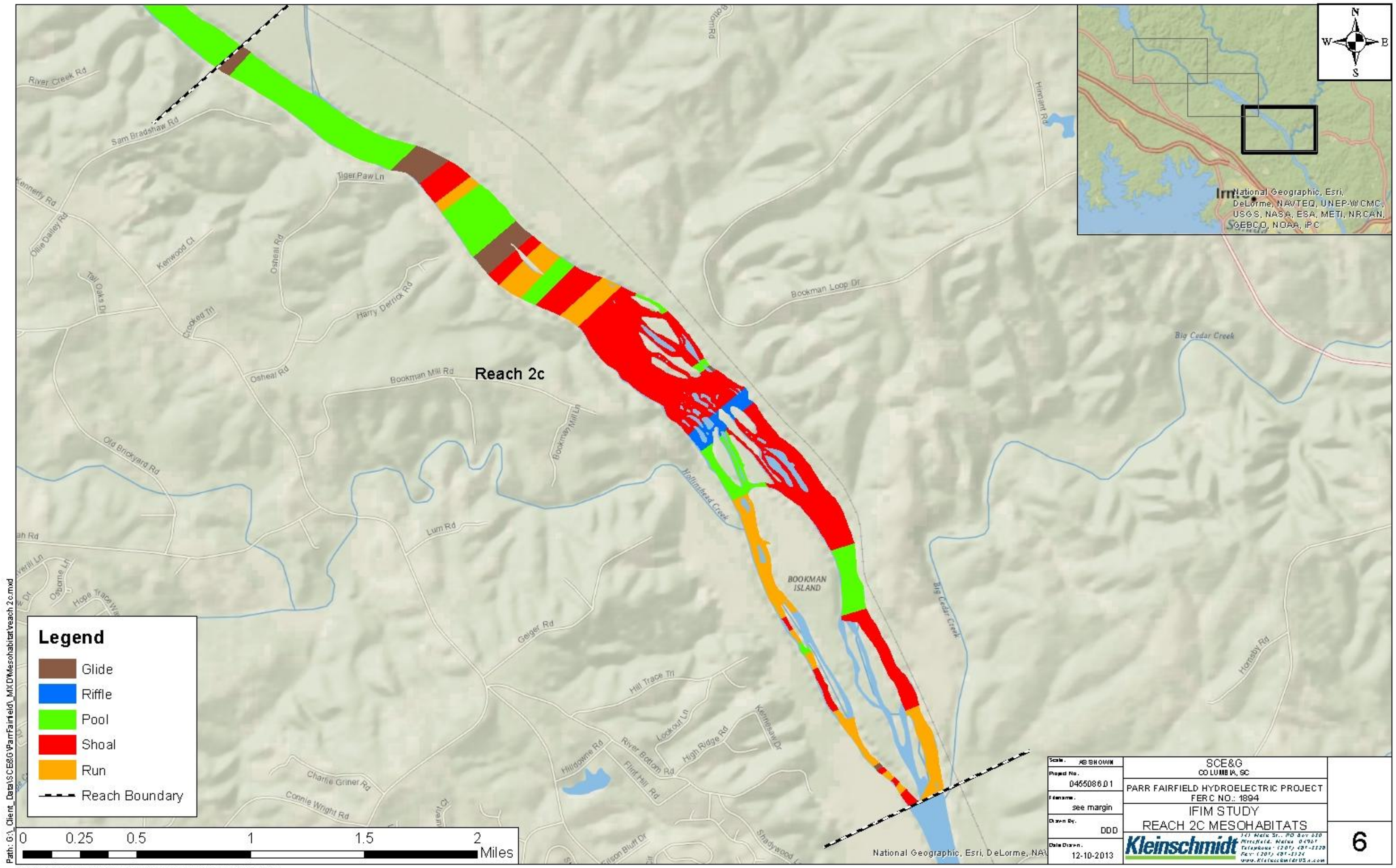
Source: ESRI, NATIONAL GEOGRAPHIC, KLEINDSCHMIDT

FIGURE 5 IFIM STUDY REACH 2B MESOHABITATS



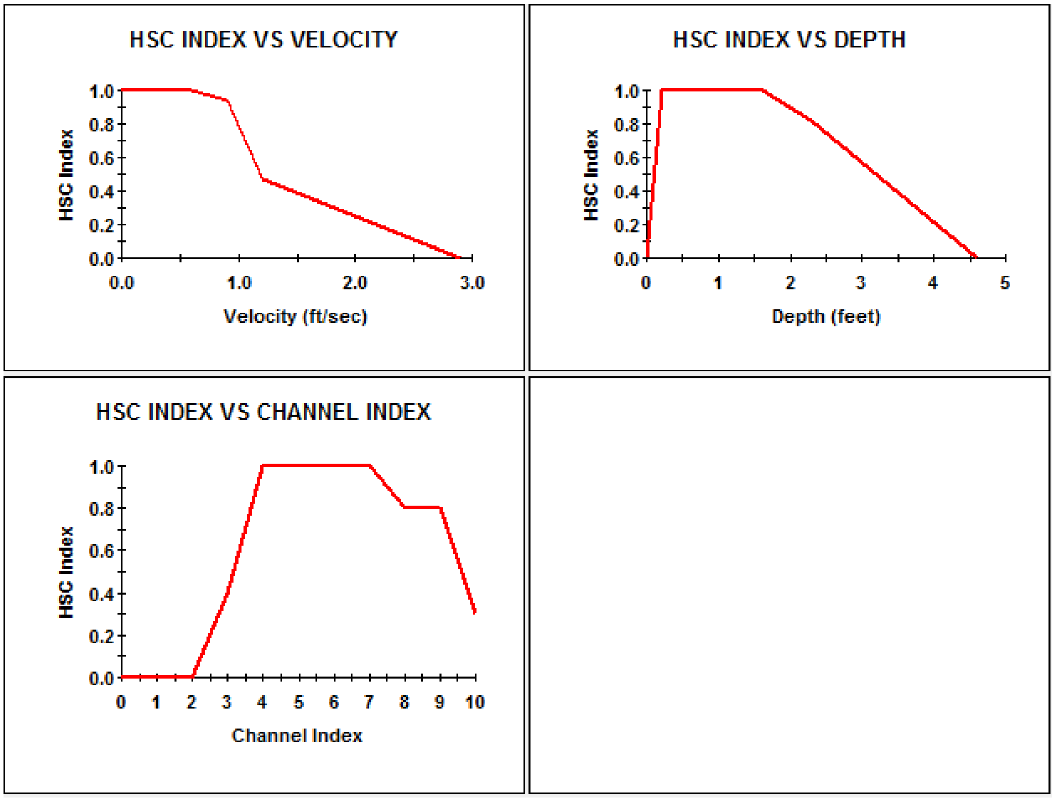
Source: ESRI, NATIONAL GEOGRAPHIC, KLEINDSCHMIDT

FIGURE 6 IFIM STUDY REACH 2C MESOHABITATS

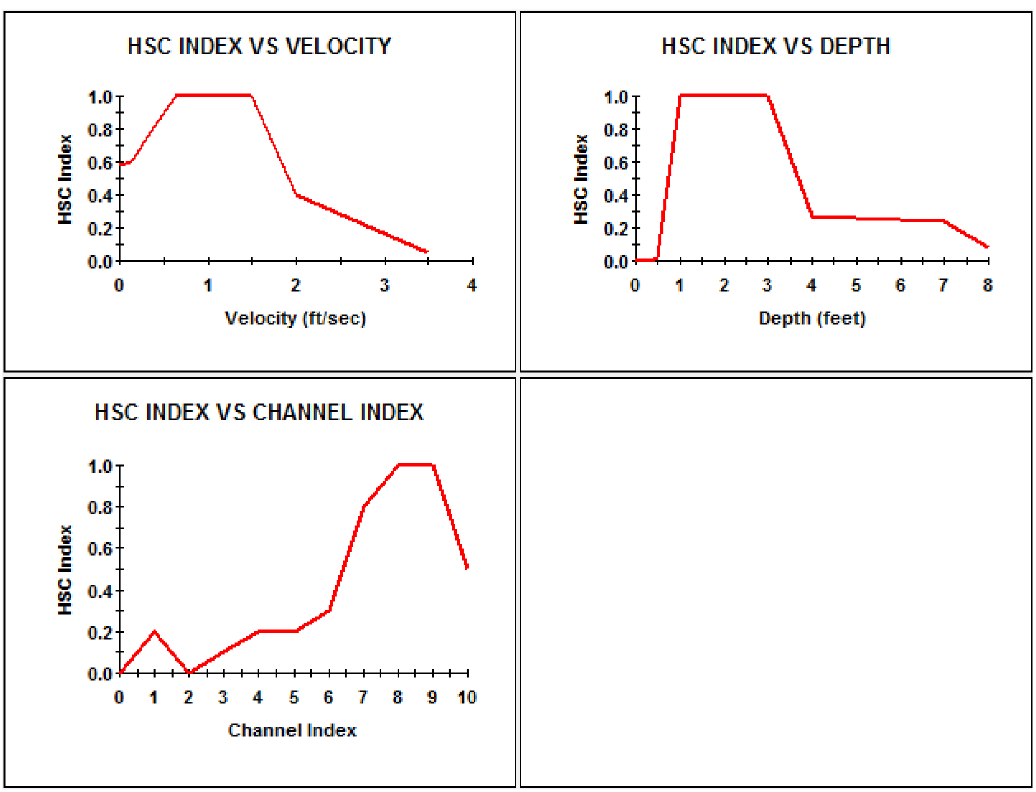
APPENDIX D

HABITAT SUITABILITY INDEX (HSI) CURVES

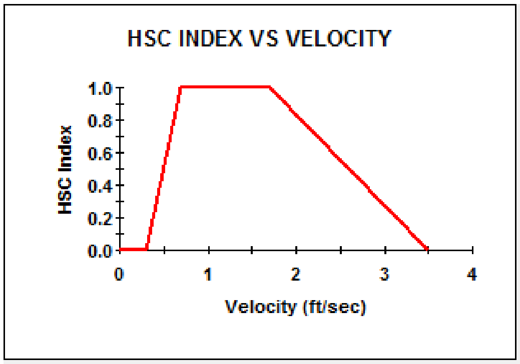
Smallmouth bass Fry

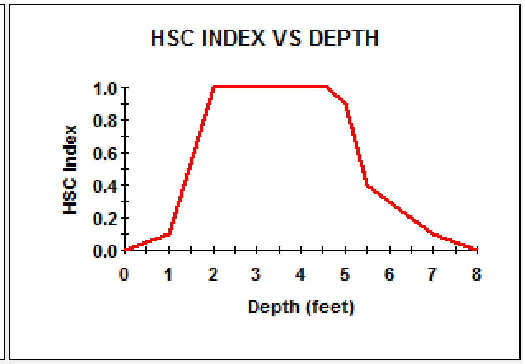


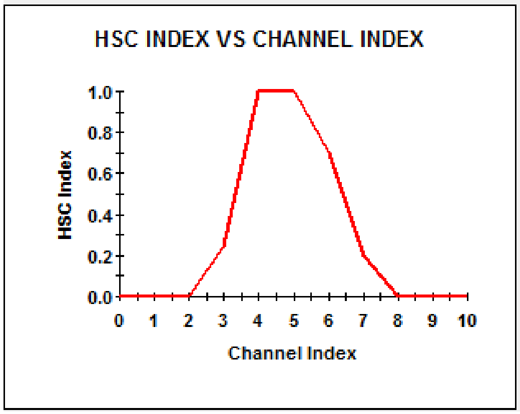
Smallmouth bass Juvenile



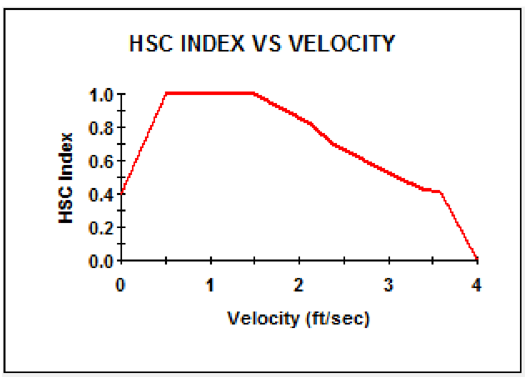
Smallmouth bass Spawning

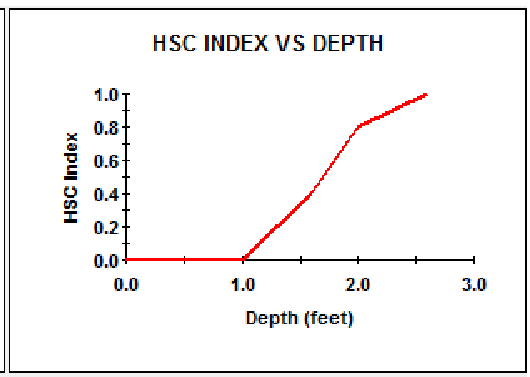


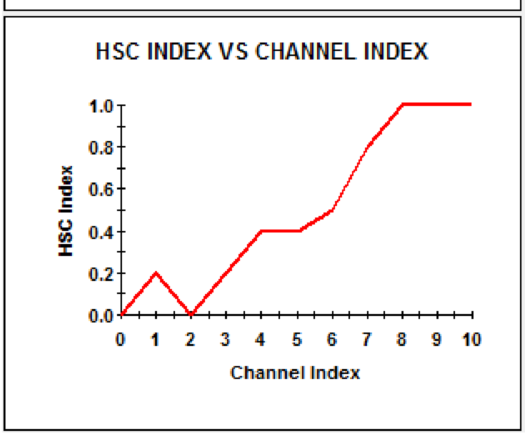




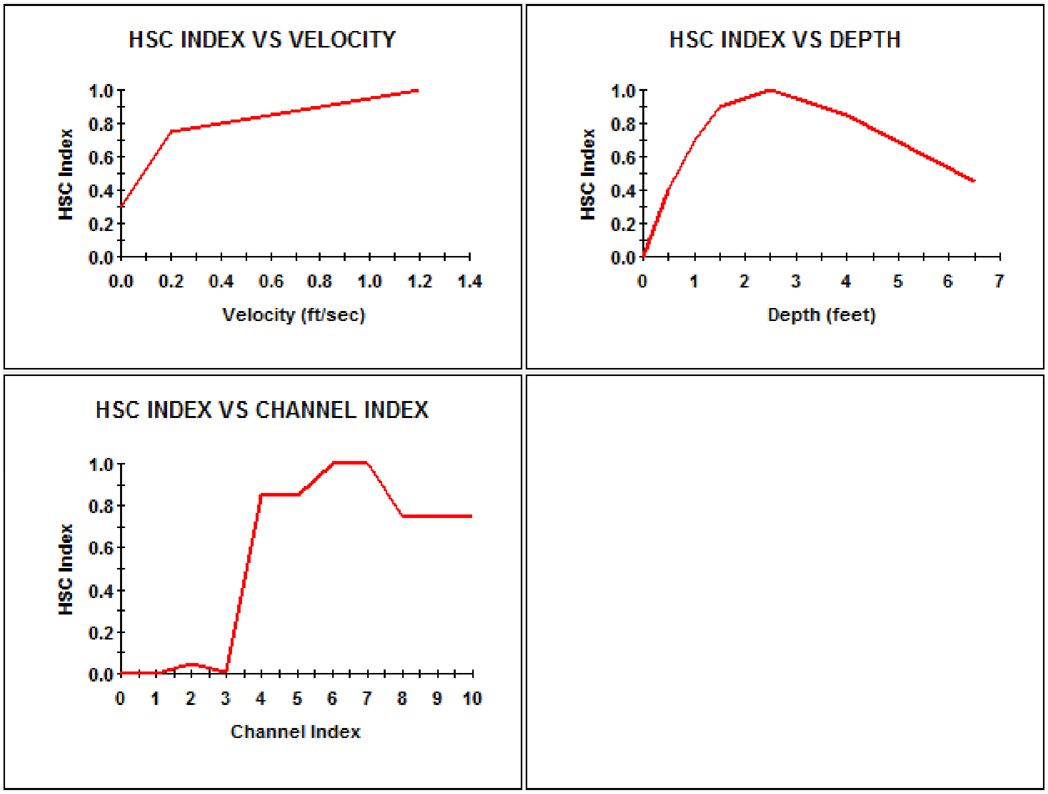
Smallmouth bass adult



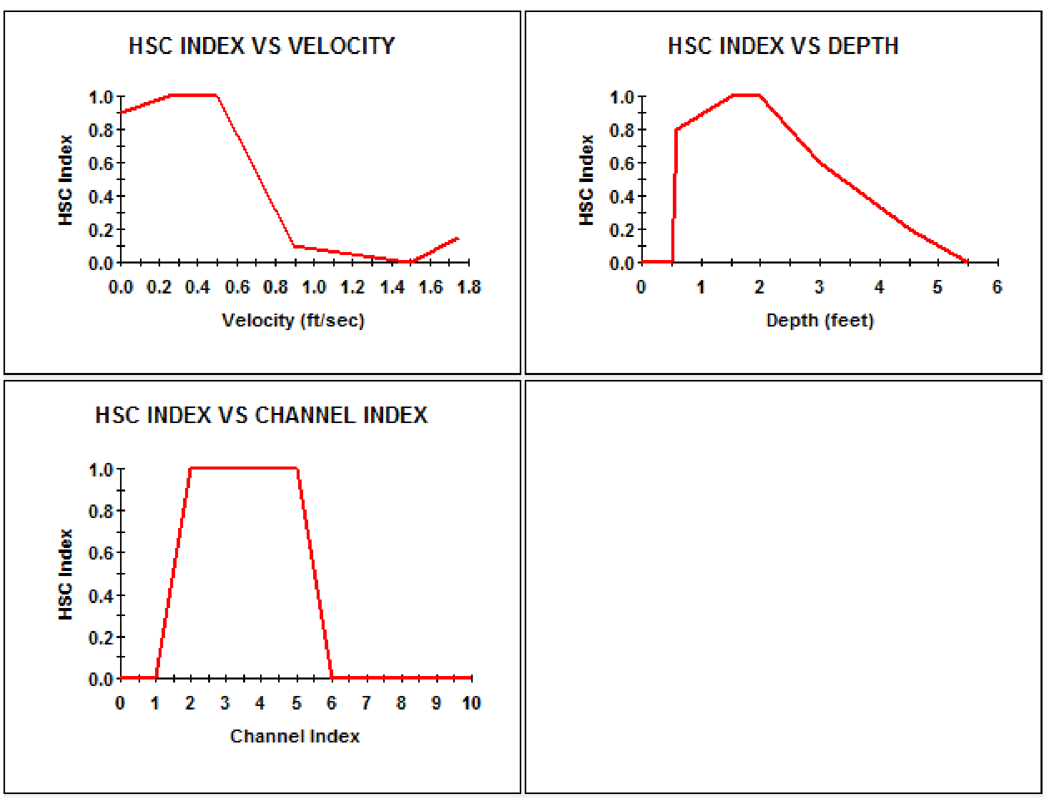




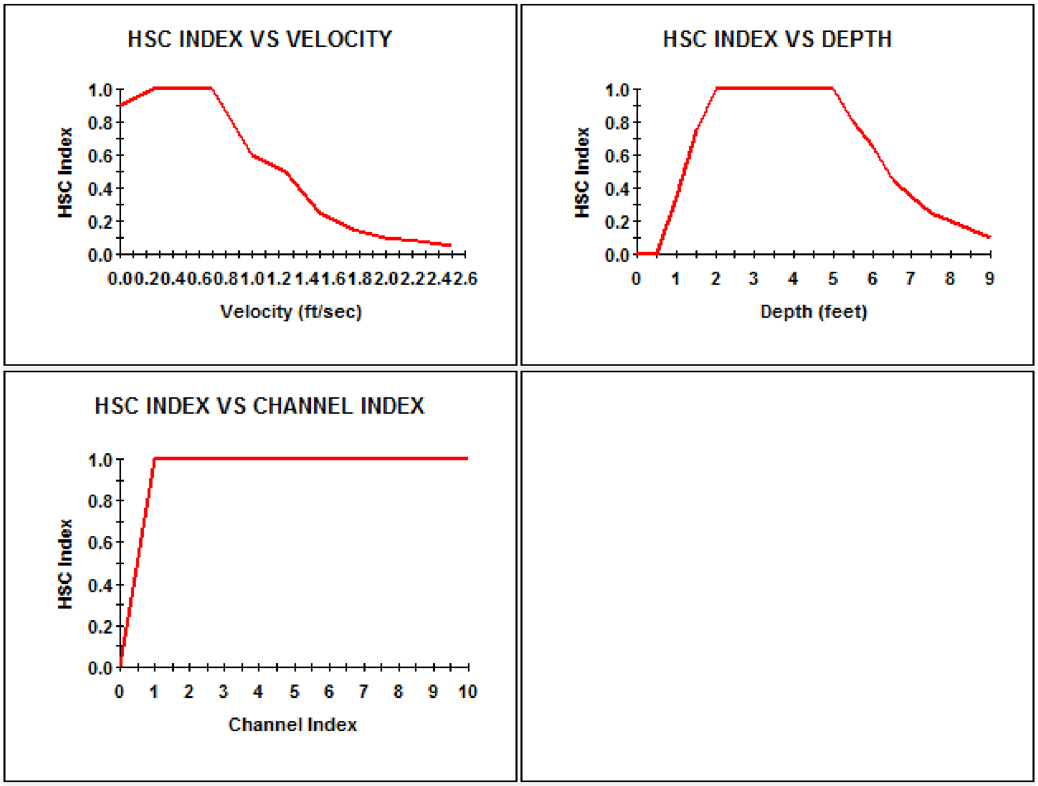
American Shad Spawning



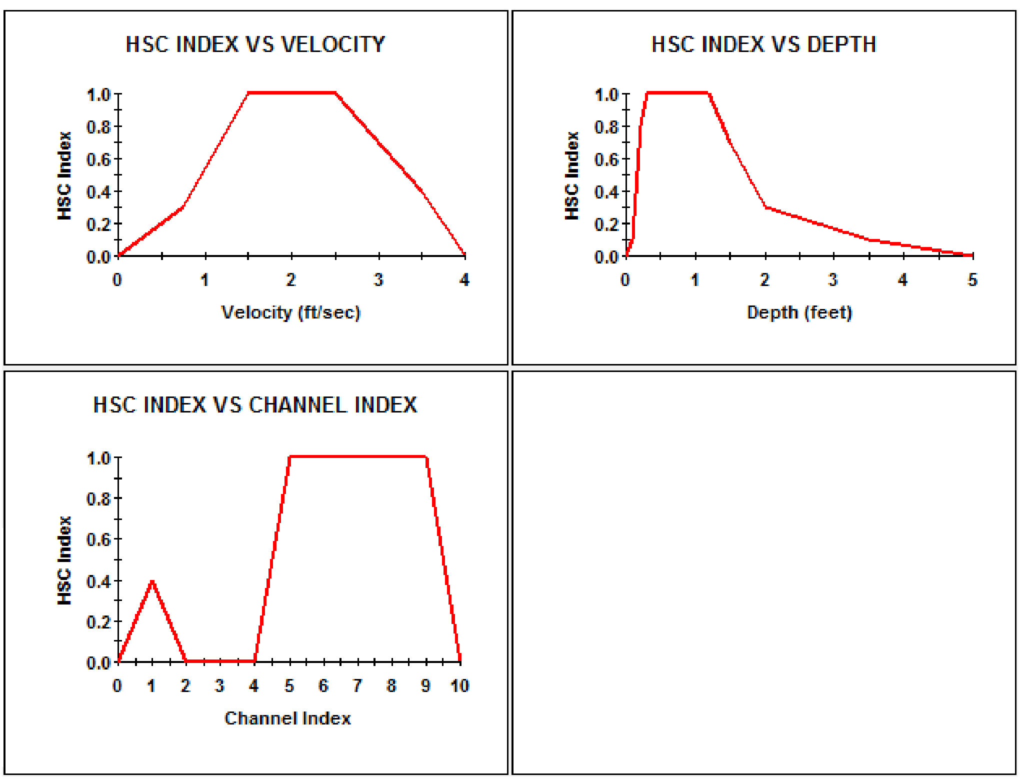
Redbreast Sunfish Spawning



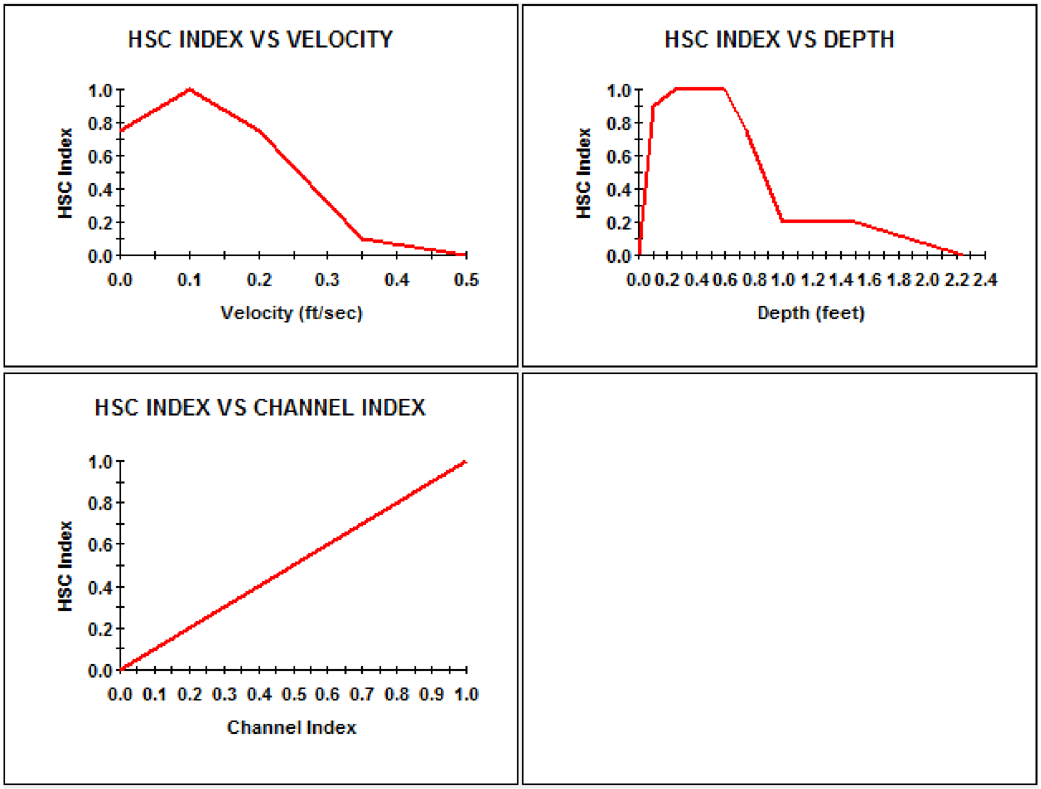
Redbreast sunfish Adult



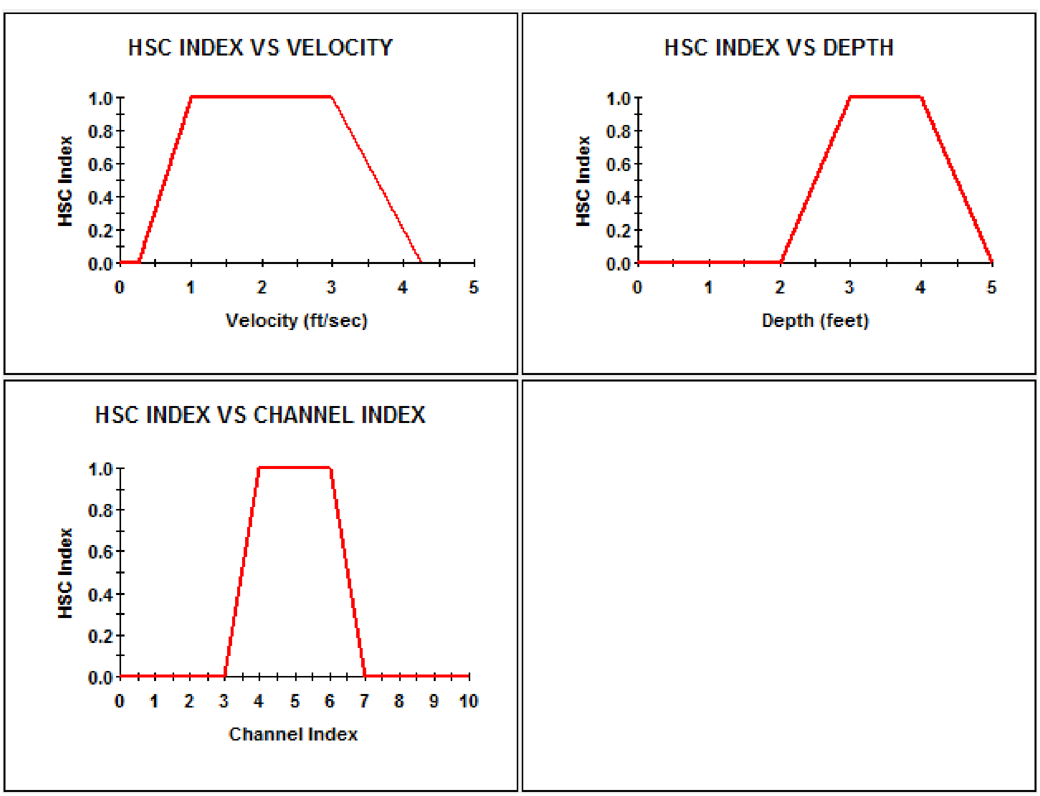
Shallow Fast



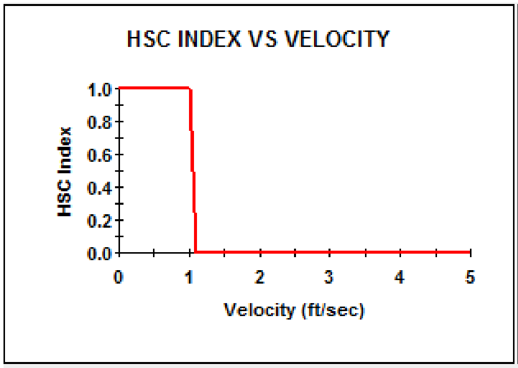
Shallow Slow

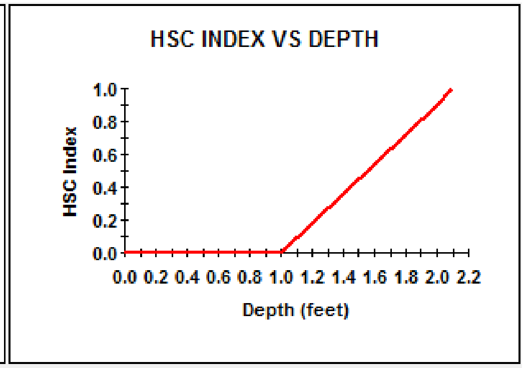


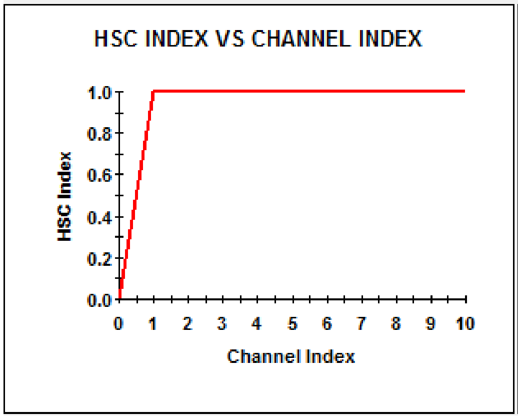
Deep Fast



Deep Slow


HSC INDEX VS VELOCITY
HSC Index
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
Velocity (ft/sec)


HSC INDEX VS DEPTH
HSC Index
1.0
0.8
0.6
0.4
0.2
0.0
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Depth (feet)


HSC INDEX VS CHANNEL INDEX
HSC Index
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
Channel Index

APPENDIX E

SITE PHOTOGRAPHS

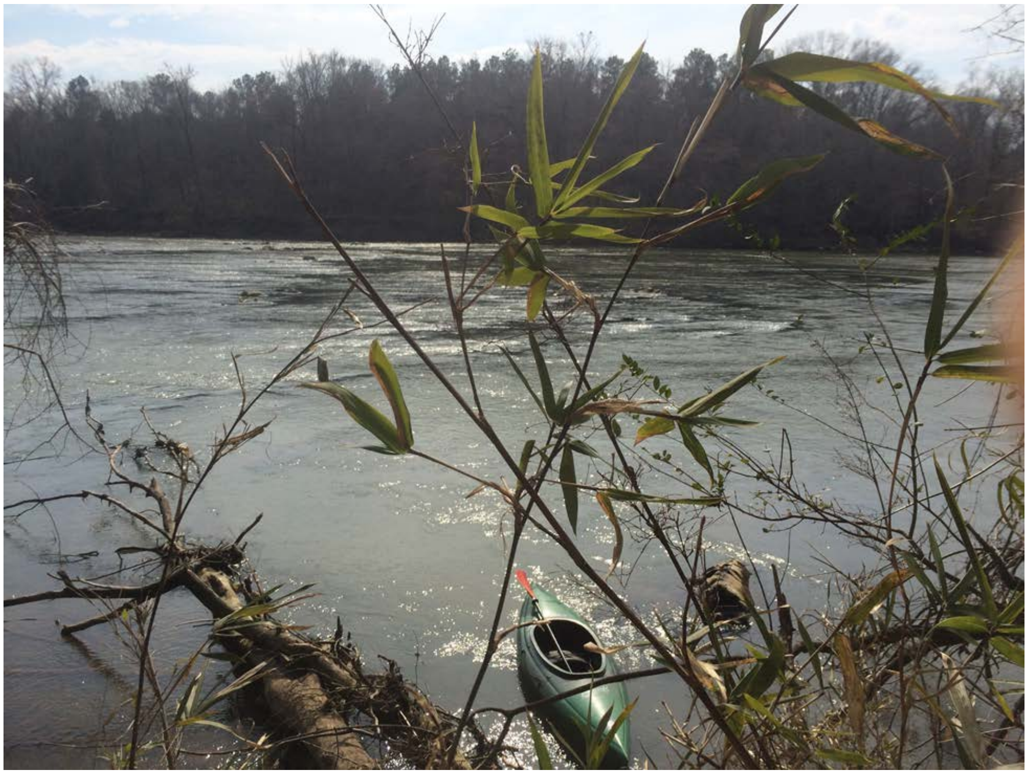
Site 1

Site 2

Site 3

Site 4

Site 5



Site 6

Site 7

Site 8

Site 9

Site 10