A Scientific Basis for the Reconnection of Savannah River Artificial Meander Cutoffs through Flow Releases and Physical Reconfiguration

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Abstract. Navigation improvements to the Savannah River in the late 1950's included the removal of 40 river bends, amounting to a steeper, straighter main channel that is 13% shorter. Hydrologic connectivity between natural oxbows, artificial meander cutoffs, and the Savannah River frequently has been cited as a management concern for recreational fishing access, game fish production, rare mussel conservation, and wildlife management. Releases from Thurmond Dam have the potential to affect numerous natural oxbows, artificial meander cutoffs, and sloughs for nearly 200 river miles. We quantified the volume of water required to be released from J. Strom Thurmond Dam in order to provide surface water connectivity between the mainstem and 25 backwater habitats (cutoffs, oxbows, and sloughs). The volume of water required for angler access was also quantified. We found that connectivity increases linearly with discharge until 5500 cfs, as does angler access until 6550 cfs. Quantitative results such as these can be used to guide management alternative development, especially during droughts. Furthermore, connectivity may be improved through physical reconfiguration of confluences. We identify ecologically-based criteria that can be used to quantify and prioritize cutoffs for these types of restoration activities.

INTRODUCTION

The Savannah River was dredged and straightened to improve river navigation in the 1950s. Since that time, there has been increased recognition of the importance of backwater habitats (meander cutoffs, natural oxbows, and sloughs) to native and non-native fishes, as well as the recreational fishery in the lower river. Loss of river bends and floodplain connectivity has likely limited nutrient processing and food availability (Junk et al. 1989), reduced forested wetland habitats (EuDaly 1999), and altered fish communities (Duncan et al. 2003) and mussel assemblages. A fisheries survey of the lower Savannah River showed that freshwater fishing pressure was six times greater than in the estuary; oxbows and cutoffs are fished preferentially over the mainstem, and species diversity was higher in flowing oxbows than in static ones (Schmitt and Hornesby, 1985). The fisheries study was completed nearly 30-years ago, but ongoing observations by wildlife managers in the field indicate that oxbows and cutoffs continue to provide a recreationally important fishery.

There has also been increased recognition of the effects of navigation improvements, especially the effects of river straightening at river bends. Straightening resulted in the loss of 13% of the rivers historic riverine habitat, resulting in a channel that has a higher slope and probably increased water velocities over the steeper, shorter channel segments. Loss of river bends, and possibly increased water velocities, have likely contributed to a reduction in the number of sandy point bars compared to rivers in nearby drainages. Point bars not only provide recreational opportunities (camping, fishing, sunbathing), but they also serve as nesting habitat for turtles, wildlife access points, and shallow water refugia from predatory fishes.

Loss of river bends is speculated to have lessened the amount of deep water habitat for adult sturgeon, refugia for juvenile sturgeon, mussel habitat, floodplain connectivity, and habitat variability. Collectively for these reasons, reconnection of cutoffs to the river was identified as a feasible restoration opportunity (Dodd 1993), ultimately leading to the restoration of cutoffs in the vicinity of the Savannah National Wildlife Refuge (ACOE 1998).

Most remaining cutoffs are isolated from the river at either the inlet or outlet, and as flows decrease, a

higher proportion of cutoffs become completely disconnected, for varying periods. Disconnection of oxbows can result in larger temperature swings, and dissolved oxygen levels that fall to 2.0 mg/L, potentially yielding inhospitable environments for fishes and mussels (Duncan et al. 2014). Disconnection of cutoffs temporarily can affect sedimentation and debris accumulation rates, especially at the inlet/outlet, thereby increasing potential of future disconnects. Disconnection of cutoffs, especially during droughts, has been a persistent concern by state and federal wildlife management agencies and conservation organizations, although little data existed to evaluate impacts.

Our study aims to quantify the number of cutoffs, oxbows, and sloughs that are connected to the river for each incremental flow increase. We anticipate that this information will be useful in informing the volume of water from Thurmond Dam required to provide connectivity and the consequences of changes to flow management. Furthermore, should funding for harbor deepening mitigation be directed toward cutoff reconnection, we identify a suite of restoration goals and environmental consequences that can be quantitatively used as site selection criteria.

METHODS

We selected natural oxbows, meander cutoffs, and sloughs that could be accessed during field surveys associated with other low flow studies dispersed throughout the lower river to estimate the discharge thresholds at which connectivity to the river mainstem occurs. Oxbow confluences were identified with maps, aerial photographs, and hydrology data in ArcGIS, and then field surveyed during periods of stable low flows. Because of the geomorphic variation across the range of confluences, multiple techniques were employed to characterize the confluence and identify the incipient point of oxbow flooding. Cross sections were conducted at confluences that were wadable or that would be inundated during wetter low-discharge periods. Cross sections were generally parallel to the mainstem flow direction along the topographic high points that control the flow of water between the oxbow and mainstem. River water surface elevation was also measured. At confluences that were not wadable, water depth was repeatedly measured from the motor boat using either a graduated surveyors rod or depth finder. In such instances, only the depth that would be the incipient point of flooding during extreme low flows was recorded. All elevation measurements were made with a TopCon laser level and local benchmarks.

For each location, the stage increase or decrease that would be necessary to reach the incipient point of flooding was calculated using a combination of data sources. Average daily discharge on the survey date was obtained from the nearest USGS gage: Savannah River at Augusta, Savannah River at Millhaven, and Savannah River near Clyo. The USGS discharge value was then used to calculate stage using the stage discharge relationship developed from stage recorders nearest to US Fish and Wildlife Service (FWS) monitoring sites. The stage increase or decrease required to reach the incipient point of flooding was added to the FWS stage to determine the elevation of the incipient point of flooding, and discharge was calculated using the FWS stage discharge relationship.

The discharge required for recreational fishing access into oxbows was calculated in a manner similar to the mainstem-cutoff connectivity threshold. We applied the South Carolina one-way navigation criteria for a minimum of a one foot depth across a 10 foot wide channel (de Kozlowski 1988). A full description of quantitative methods used to develop results can be found in Duncan et al. (2014).

The suite of restoration goals and environmental consequences that we identify in this paper come from multiple discussions, meetings, and documents over the past decade across non-governmental organizations, state, and federal agencies. We recommend that the list be considered a living document that can be used to stimulate discussions and further investigations. It is not intended to represent a consensus or an exhaustive suite of considerations.

RESULTS

River discharge thresholds at which connectivity to the river mainstem occurred were estimated at three natural oxbows, 19 meander cutoffs, and three sloughs. Our study examined connectivity and angler access to 448.9 acres. We estimate that natural oxbows, meander cutoffs, and sloughs in the Savannah River below Thurmond Dam account for 916.9 acres. We acknowledge that there may be additional floodplain lakes and sloughs not accounted for in this total because our focus was on natural oxbows and recent meander cutoffs in direct vicinity of the river mainstem. Nevertheless, our study accounts for approximately 50% of oxbow, cutoff, and slough acreage.

The number of oxbows (Fig. 1) and the acreage of oxbows connected to the river mainstem by either an inlet or an outlet increases nearly linearly until a threshold of 5,518 cfs. The threshold is driven by one meander cutoff and two natural oxbows (accounting for 10% of the oxbow acreage in this study), requiring >10,000 cfs to become connected to the river.

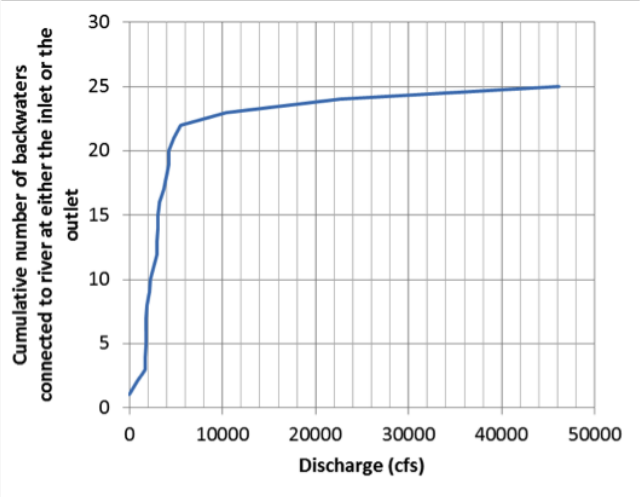

Figure 1: Cumulative number of natural oxbows, meander cutoffs, and sloughs connected to the river at either the oxbow inlet or outlet as a function of river discharge.

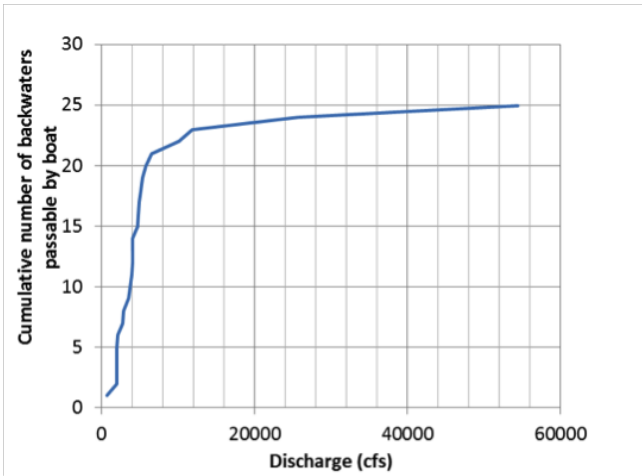

Figure 2: Cumulative number of natural oxbows, meander cutoffs, and sloughs passable by boat using the South Carolina 1-way criteria.

Similarly, the number of oxbows passable by boat increases linearly with discharge until 6550 cfs (Fig. 2). We collaboratively identified eight potential restoration goals, five potential adverse effects, and two logistical issues associated with reconnection efforts (Fig. 3). Although this list is not exhaustive, we expect that it conveys many of the primary considerations that have been identified at meetings and workshops.

DISCUSSION

Thurmond Dam outflow accounts for 60-90% of the baseflow discharge observed at the Millhaven USGS gage during drought, illustrating that Thurmond Dam drought operations have a large potential to influence downstream aquatic resources. As flows increases in the lower river, the number and acreage of oxbows, meander cutoffs, and sloughs connected to the mainstem increases in a nearly linear fashion for a majority of the sites until approximately 5500 cfs at the USGS Millhaven gage.

Angler access into these backwaters also increases as discharge increases in a nearly linear fashion until approximately 6,550 cfs at the USGS Millhaven gage. However, Thurmond Dam drought flows cited in the Drought Contingency Plan for Savannah River Basin projects range between 4,200 and 3100 cfs. At the lowest drought flow observed, 68% of the oxbow acreage remains connected to the mainstem, illustrating that a large proportion of the oxbows have surface water connectivity to the river during drought. Yet, angler access is limited to 32% of the oxbow acreage. These results illustrate that the effects of drought flow management on oxbow connectivity may be less severe than previously hypothesized, but that effects on angler access into oxbows is substantial.

The variation in the connectivity thresholds and hydrologic dynamics among oxbows, cutoffs, and sloughs illustrates that substantial hydrological variation exists across sites. This means that habitat conditions, including water quality, may vary substantially among natural oxbows, meander cutoffs, and sloughs, and that treatment of these waters for habitat management purposes may warrant further classification and characterization of habitat types. To that end, we suggest that hydrologic connectivity is but one of many quantifiable variables that can be used to identify and rank sites based on the potential to meet multiple reconnection-related goals while minimizing potential impacts, logistical constraints, and costs.

CONCLUSIONS

The results from this study address a research need identified during multiple interagency meetings. These data have been developed in a manner that should allow the US Fish and Wildlife Service, the US Army Corps of Engineers, and others to quantitatively evaluate flow management effects on oxbows and recreational fishing opportunities. The suite of restoration goals and environmental consequences that we identify in this paper are not exhaustive, and should be used to stimulate discussions and further investigations. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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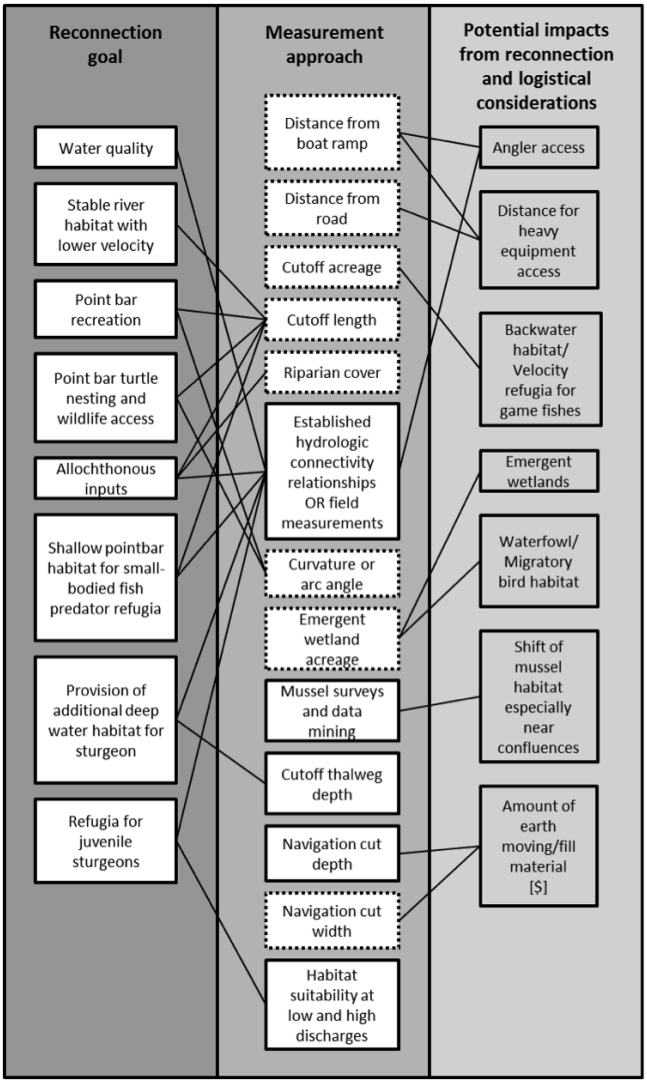

Figure 3: Potential cutoff reconnection goals, impacts and logistical considerations that can be measured and factored into cutoff site selection. Dashed boxes indicate measurements that can be made using GIS. This list is not intended to be exhaustive or a consensus. It is intended to capture points made in multiple meetings by multiple individuals in state and federal agencies, and non-governmental organizations.