WATER USE IMPACTS ON GEORGIA'S WATER RESOURCES AND THREATS FROM INCREASED WATER INTENSIVE ENERGY PRODUCTION

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Abstract. Georgia faces serious challenges in managing water resources and irreversible impacts to aquatic ecology. Georgia's fisheries and aquatic resources are in peril due to habitat degradation caused by water use for energy production, domestic purposes, agriculture, and industry. Water resources and the quality of aquatic life in Georgia's rivers are expected to degrade significantly with future water demands from a growing population and potential climate change impacts, including the potential for more severe and longer-lasting droughts.

In 2007, Georgia experienced one of its worst droughts in over a century, costing $1.3 billion in economic damage and prompting crisis responses. A vulnerable electricity system was also revealed. Power plants in the region, such as TVA's Browns Ferry nuclear plant in Alabama along the Tennessee River, reduced production due to high water temperatures and reduced river flows. The National Conference of State Legislators stated in 2008 that a higher risk of drought is a possible consequence of climate change and could impact Georgia's economy. Future energy choices that do not take droughts into consideration can affect Georgia's ability to cope in the future.

The magnitude of freshwater consumption to supply the domestic, industrial, agricultural, and energy demands of rapid human population growth in Georgia has already resulted in reduced in-stream flows, inter-basin transfers, and depletion of groundwater aquifers. If expansion of a water-intensive electricity system continues and Georgia utilities pursue this course, demands on Georgia's already stressed aquatic ecosystems are likely to increase. The expansion could include the construction of two new nuclear power reactors, in addition to the two existing reactors, at Plant Vogtle on the Savannah River near Augusta, which is operated by Southern Nuclear Company (SNC). Consequently, flow and environmental regimes of Georgia's rivers have undergone and will likely continue to experience dramatic changes causing and perpetuating a major decline in freshwater and diadromous fish populations (Warren et al. 2000; Duncan et al. 2003; Marcy et al. 2005).

The value of Georgia's water and aquatic resources should be integrated into government and corporate decision-making related to water use and energy management. Also, cumulative river corridor impacts and potential changes in precipitation as a result of climate change and subsequent impacts on Georgia's rivers need to be evaluated and factored into policy decisions.

INTRODUCTION

This paper considers a case study of a power plant proposal that could have major impacts on competing water uses and adverse impacts on fisheries and aquatic resources. It examines how current Georgia policies apply and offers insight on areas for closer attention by policy makers including whether current and proposed state water policy is adequately addressing these threats. Two proposed new Westinghouse AP1000 reactors at nuclear Plant Vogtle are estimated to use 55-88 million gallons of water per day from the Savannah River with 50-75% consumptive loss (Southern Nuclear, 2008). To put this consumptive water loss in perspective, with average per capita daily water use in Georgia at 75 gallons from surface and ground water sources, this means the two existing and two proposed reactors could use enough water to supply 1.4 to 2.3 million Georgians.[1] Further, reduced flows, entrainment, thermal and chemical discharge, and dredging from four operating nuclear reactors along with climate change effects may severely impact the Savannah River ecology and place important fisheries at further risk. This is a prime example of weighing water-intensive energy agendas against the value of Georgia's natural heritage and long-term water resources.

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[1] The average per capita daily water use in Georgia is 75 gallons from surface and ground water sources, http://water.usgs.gov/watuse/tables/dotab.st.html. Existing Vogtle nuclear reactors have similar water requirements. With water withdrawals for all 4 reactors (2 existing and 2 proposed) ranging from 110MGD to 178 MGD, that could mean the equivalent of 1.4-2.3 million residents.

WATER USE FOR ELECTRICITY IN GEORGIA

Georgia's electricity sector is the largest water user in the state, followed closely by agriculture (Fanning 2003). Most conventional power plants, especially coal and nuclear plants, withdraw large amounts of water to create and condense steam to power turbines, and not all of the water is returned. Some plants return less than half of the water they use. Most conventional power plants degrade water quality and reduce water availability, competing for water with other important uses vital to Georgia's economy and quality of life: drinking water supply, agriculture, industry, fishing, and recreational opportunities. Less water used for conventional power generation in Georgia means more water available for other crucial needs.

Less Water Intensive Energy Supply Options Exist. Georgia faces proposals to build more coal and nuclear plants even though less water-intensive, affordable energy solutions exist. When comparing types of energy generation, nuclear power has higher rates of both water withdrawal and consumption than coal and natural gas and far more than renewable energy sources such as wind, solar, and biomass (Hoffman, et. al. 2004; DOE 2006). For example, according to the Department of Energy's National Renewable Energy Laboratory, developing just 1000 MW of wind in Georgia instead of traditional power plants could save 1628 million gallons of water per year (NREL 2008).

A state study showed that reducing electricity use through energy efficiency measures has the immediate impact of reducing water required by power plants (GEFA 2006). Individual actions also help but have a smaller impact. For instance, EnergyStar appliances use less energy and water. EnergyStar washing machines use 50% less energy per load and 30-50% less water than a typical model. This saves water while saving consumers money.

Less Water Intensive Cooling Technologies Exist. Water withdrawals and consumption figures depend heavily on what types of cooling technologies are used. Power plants that use once-through cooling (i.e. do not have cooling towers), withdraw very large volumes of water while little water is consumed or lost because there is a negligible amount of evaporation. In contrast, power plants that use cooling towers (also known as "wet cooling") do not need to withdraw as much water, but have a higher rate of water consumption due to the evaporation from the cooling towers. The use of cooling towers is preferable to once-through cooling systems.

Water saving cooling technologies, such as dry cooling (also known as "air cooling"), are available and in use in the United States and other countries but no existing or proposed power plants in Georgia are pursuing them. The Environmental Protection Agency has stated in Clean Water Act 316(b) rulemaking that dry cooling is "appropriate in areas with limited water available for cooling or where the source of the cooling water is associated with extremely sensitive species" (U.S. NRC 2007). Extremely sensitive species have been identified in the Savannah River as described in this paper. Dry cooling technologies significantly reduce water use lessening the impacts on water resources in comparison to the use of traditional cooling towers. Overall, dry cooling can be a cost-effective and practical alternative to the proposed wet cooling system for the new reactors proposed for Plant Vogtle, especially in light of the drought conditions in Georgia. The potential for drought could compromise the availability of water necessary for a wet cooling system, especially during the summertime high demand period. This factor alone could compromise the reliability of the wet cooling system, making dry cooling more preferable (U.S. NRC 2009).

Proposed New Nuclear Reactors. Nuclear energy expansion in Georgia will increase water demand, exacerbate aquatic habitat degradation, and contribute to further decline of aquatic resources. The main sources of habitat degradation for the Savannah River as a result of the proposed nuclear expansion at Plant Vogtle are dredging and river channel alterations needed for construction and operation of new nuclear reactors and associated facilities, reduced river flow from large-scale water withdrawal needed for cooling, and increased temperature and pollutants from discharge of cooling water. Further, indirect sources of habitat alteration may result from additional construction of water control structures or changes in operation of upstream facilities to guarantee sufficient water quantities at facilities downstream.

The direct impacts to the aquatic environment from habitat alterations include altered river flow dynamics, geomorphology, and temperature regimes; reduced water quality; and increased pollutant concentrations. These changes in geomorphology and environmental factors affect the physiology and ecology of aquatic organisms, which in turn alters biotic interactions including food web dynamics (Osmundson et al. 2002; Deegan and Ganf 2008), intra-species dynamics (Grabowski and Isely 2007; Brown and Pasternak 2008), and inter-species relationships (Bogan et al. 2008).

In addition to the above, entrainment of aquatic organisms, particularly fish eggs and larvae, may affect recruitment and population abundance (Environmental Protection Agency 2001). The magnitude of aquatic habitat alterations and entrainment are dependent on the number and scale of operating nuclear reactors in a river basin, and type of cooling systems used (once-through versus re-circulating cooling system water consumption;

Barczak and Carroll 2007). Other considerations are number and vicinity of other sources of water withdrawal, and whether dams and water-control facilities are also present in the river basin, which will cause further deviation from natural conditions, especially if operations release pulsed-flow discharges.

GEORGIA'S FRESHWATER DIVERSITY

As a hotspot for freshwater diversity, Georgia hosts 280 fish species, 98 freshwater mussel species, and 70 crayfish species, ranking among the highest of all states in freshwater fish, mussel, and crayfish diversity (The New Georgia Encyclopedia 2003; Georgia Department of Natural Resources 2008). The Savannah River alone hosts 118 freshwater fish species (Marcy et al. 2005) and 24 freshwater mussels (Bogan et al. 2008). Similarly, the Apalachicola-Chattahoochee-Flint (ACF) and Ogeechee-Altamaha basins also host over 100 freshwater fish species (Marcy et al. 2005), and the ACF also hosts an impressive 38 freshwater mussel species (Abell 2000).

Watershed Decline. Watershed alterations to support the recent human population increase have resulted in the highest proportion of imperiled freshwater fauna of any region in North America (Warren et al. 2000; Jelks et al. 2008). In Georgia alone, 57 fish and 51 aquatic invertebrates are state protected (GA DNR), and over 50% of the 471 species of special concern use freshwater habitats (GA DNR). Jelks et al. (2008) identified the South Atlantic ecoregion, the location of the Savannah River and Plant Vogtle, as one of the five North American ecoregions having the highest number (31 – 58 fish species) of imperiled fish taxa (Jelks et al. 2008). Fish populations in the Savannah River are greatly reduced from their historical numbers (Duncan et al. 2003; Marcy et al. 2005).

The declines cited by fisheries experts are due to the incremental impacts from dams, urbanization, industrialization, and nuclear power facilities, including the operation of Plant Vogtle (Marcy et al. 2005). Recently, several species have exhibited some recovery or at least a halt in decline, which is likely due to increased awareness of fish ecology and of human impacts on fish populations that prompted conservation and management actions. For instance, the moratorium on striped bass *Morone saxatilis* harvest was lifted in 2005 (Georgia and South Carolina Departments of Natural Resources), and American shad *Alosa sapidissima* populations appear to have stabilized (Bailey et al. 2004). However, the moratorium on shortnose sturgeon *Acipenser brevirostrum* and Atlantic sturgeon *Acipenser oxyrinchus* remains due to severely depleted sub-populations in the Savannah River; the recovery of the robust redhorse *Moxostoma robustum* (Figure 1), a sucker once proclaimed extinct, is

Figure 1. Robust redhorse *Moxostoma robustum*, University of Georgia.

still in the early stages; and status of several species (American eel *Anguilla rostrata*, quillback *Carpiodes cyprinus* and highfin *Carpiodes velifer* carpsuckers, and brassy jumprock *Moxostoma* sp.) are still undetermined.

PROPOSED NEW NUCLEAR REACTORS' IMPACTS ON SAVANNAH RIVER BASIN

Potential Dredging Impacts on the Savannah River. In order to construct the proposed two new nuclear reactors at Plant Vogtle, the Savannah River channel from the existing site to the Port of Savannah (potentially more than 100 river miles) may require significant dredging to allow barging of construction materials and components. The Savannah River federal navigation channel has not been maintained/dredged since 1979.

Such dredging may (i) disrupt food web dynamics, affecting the aforementioned species, including the endangered shortnose sturgeon and rare robust redhorse (which are benthic feeders or bottom feeders), and (ii) affect spawning success of some of the aforementioned species, including the striped bass, and benthic spawners such as sturgeon and suckers. In fact, previous dredging activities have been cited as a cause for the decline of several Savannah River fish (Duncan et al. 2003), such as shortnose and Atlantic sturgeon (Shortnose Sturgeon Recovery Team 1998; Atlantic Sturgeon Review Team 2007).

Dredging may also degrade chemical aspects of water quality and re-suspend contaminants, which may then in turn be bioaccumulated by mussels and other organisms (Bellas et al. 2007). Further, dredging has been identified as a major cause for freshwater mussel decline from destruction of obligate benthic habitats, segregation from fish hosts, and suffocation (Ricciardi and Rasmussen 1999).

Savannah River Flow Alterations. Human-induced variation of flow regimes and velocities combined with increased entrainment mortality caused by operation of facilities such as Plant Vogtle (Marcy et al. 2005) are a primary cause for the decline of freshwater biodiversity (fish, mollusks, macroinvertebrates) in the United States (Williams et al. 1993; Master et al. 1998; Jelks et al. 2008). The cumulative impacts of having potentially four operating nuclear reactors at Plant Vogtle combined with other water withdrawals occurring in the Savannah River have the potential to compound existing stressors. The Savannah River Site (SRS), a Department of Energy nuclear weapons facility, is located across the river from Plant Vogtle and also withdraws significant amounts of water. The combined low-flow withdrawal from SRS and the four Plant Vogtle nuclear reactors may be as much as 10.2 percent of the total Savannah River flow. This could increase if SRS ever resumes historical operation levels that once consumed 9.8 percent of river flow (Marcy et al. 2005). Other water withdrawals upstream and downstream of Plant Vogtle also contribute to the cumulative impacts on aquatic species of the Savannah River.

Species Impacts. Flow reductions, leading to de-watering of benthic habitat have already been observed to reduce spawning success of Savannah River catostomids (Grabowski and Isely 2007). Also, flow fluctuation affects flow velocity, which is needed by fish species that broadcast semi-buoyant eggs that must remain suspended in the water column during egg development. Further, a reduced flow would also place more of the drift community at danger of entrainment due to river channel confinement. Many fish species' eggs and larvae are found in the river drift as they utilize the inertia of flowing water for passive transport due to lack of mobility and to save energy. The early life history stages of fish are the most susceptible to entrainment and thermal discharge because fish eggs have no mobility and larval fish have a very limited capacity for small-scale movement. Larval shortnose sturgeon, a federally endangered species, and a high number of American shad and blueback herring *Alosa aestivalis* larvae have been captured at SRS intake structures (Paller et al. 1986; Wike 1998), which are in the general area of Plant Vogtle's intake structures.

Another important consideration is the temporal and spatial variability of drift community composition and distribution (i.e. the pattern of egg, larval, and early juvenile stages of fishes and invertebrates). Studies have found that the drift community, including eggs and larvae of 34 fish species, were non-uniformly distributed and varied over time and space in the vicinity of Plant Vogtle (Nichols 1983; Wiltz 1983). These fish included sturgeon spp., sucker spp., American shad, and Savannah darter *Etheostoma fricksium*. Further, Paller et al. (1995) found a higher abundance of American Shad eggs along the Georgia bank than near the SRS intakes on the South Carolina bank, reaffirming the drift community is not uniformly distributed. The significance being that during periods of increased abundance and concentrated drifts, the potential for peaks in entrainment exist. For example, Wiltz (1983) found that American Shad eggs increased in number and constituted 45% of the drift community during the month of May and that larval suckers constituted as much as 37.5% of the drift also peaking in May. Further, risk of entrainment heightens if peak abundance coincides with low flows. Naturally, the peak of spawning usually coincides with high spring flows; however, this may not be the case during drought or river-regulation.

Thermal Impacts. A reduced river flow would also place more of the drift community at risk of thermal impacts also due to river channel confinement. Low water levels would confine organisms to smaller habitat, concentrating the number of organisms per unit of area in the vicinity of the thermal plume. Further, low flow reduces the river volume, and thus, the ability for the heat to dissipate. This confinement increases the vulnerability to thermal stress and mortality and could have differential impact from species to species. Thermal tolerance varies from species to species, and also across life history stages of individual species.

Some species may suffer high mortality. Thermal discharge temperature at Plant Vogtle is stated as 90 ºF. This temperature kills the early life history stages of several highly valued fish that would be found near the site, and most likely also cause mortality in many less-studied and lower valued Savannah River fish species. American shad eggs suffer mortality at 80.1 ºF, and larvae suffer mortality at 87 ºF (Stier and Crance 1985). The federally endangered shortnose sturgeon's eggs suffer mortality at 75 ºF, and larvae suffer mortality at 85 ºF (Crance 1986). Striped bass larvae suffer significantly elevated mortality when exposed to rapid changes in water temperature, such as that in a thermal discharge plume (Fay et al. 1983).

RECOMMENDATIONS AND SUMMARY

Currently, the State of Georgia has not put into practice energy policies that address sustainable watershed concepts. Although there have been extensive public concerns raised during the development of the statewide water management plan about excessive water use by Georgia's current electricity sector, the need for coordinated water and energy planning, and the need to consider water impacts when selecting future energy supply sources, initial draft plans do not reflect an appreciation of these concerns.

In looking toward opportunities to apply sustainable watershed concepts in statewide water and energy planning, the electric utility component of the Water Conservation Implementation Plan (WCIP) provides a starting place. The WCIP, which is currently proposed to be voluntary, is intended to provide various sectors, such as the electricity sector, detailed direction for realizing water conservation results necessary to achieve Georgia's vision of sustainable water management. This electricity sector component currently provides limited guidance to address the sector's impact on Georgia's water resources and warrants significant strengthening based on the type of issues raised in this paper.

There are many mechanisms that can position Georgia to have a reliable energy infrastructure while preserving its water resources. These can include adopting energy policies that place Georgia at an advantage during drought conditions; analyze and compare the water impacts and benefits of the different electric generation supply options; require water-saving energy measures such as energy efficiency and conservation; advance less water-intensive electricity supplies, such as wind, solar and some biomass; reject proposed utility plans to build more water-intensive coal and nuclear plants; foster well-coordinated and comprehensive state energy and water planning; support less water intensive cooling technologies for new power plants, such as dry cooling; and implement state forecasting for drought scenarios as a required component of the water withdrawal permitting process.

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