A WATER QUALITY ANALYSIS OF THE ALTAMAHA RIVER WITH A FOCUSED STUDY IN THE VICINITY OF JESUP, GEORGIA

by

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Abstract

The Altamaha River Basin of east-central Georgia is the largest watershed in the state. The river passes through some of the least developed and most biologically diverse regions; nevertheless, water quality in the basin is still threatened by widespread logging, local mining, numerous sewage treatment plants, a large paper mill, and a nuclear power plant. An analysis of basin-wide water quality was initially completed using data collected by Georgia's Adopt-A-Stream Program and the Georgia Department of Natural Resources Environmental Protection Division during the 2012 Paddle Georgia Trip. A more focused study was then conducted in the vicinity of the Rayonier Plant at Jesup in order to determine the effect of the plant's discharge on the overall water quality of the river. An analysis of a local blackwater tributary, Penholloway Creek, was also performed to compare tannin-rich natural stream water with Rayonier's tannin-rich effluent. This study initially found no significant areas of pollution or poor water quality based on the basin-wide Adopt-A-Stream data. However, the more focused study in the Jesup area showed significant water quality changes at and below outfall 002 of the Rayonier Plant. These included increases in turbidity, total dissolved solids, conductivity, alkalinity, and several ions as well as a decrease in dissolved oxygen levels. Combining the Jesup study data with the basin-wide data also indicated negative large-scale trends in water chemistry that could significantly impact downstream aquatic life. It was also found that the effluent was not similar in composition to the blackwater Penholloway Creek sample with the exception of low dissolved oxygen levels and high turbidity. Future studies of the biological impact of the effluent are needed.

Introduction

The purpose of this study was to analyze the water quality of Georgia's Altamaha River Basin as well as conduct a more focused study in the Jesup area. This focused study resulted from long-standing complaints by river advocates about pollution from the Rayonier Plant which is located at Jesup. The basin-wide analysis was done using data collected by Georgia's Adopt-A-Stream Program and the Georgia Department of Natural Resources Environmental Protection Division during the 2012 Paddle Georgia Trip. The focused study in the Jesup area was then completed in October 2012 by sampling at several locations upstream and downstream of the plant as well as an additional sampling at Penholloway Creek. This Penholloway Creek site was added to the study in order to compare and contrast a local blackwater stream to the Rayonier's effluent waste which the corporation has described as similar in physical and chemical properties to that of tannin-rich waters. Samples for the focused study were also sent to the University of Georgia Water Laboratory for more detailed analysis and confirmation of field results.

Background Information

The Altamaha River Basin is located in east-central Georgia. It is the largest watershed in the state covering an area of 13,600 square miles and extending approximately 137 miles from the confluence of the Ocmulgee and Oconee Rivers to the Atlantic Ocean (Loeffler and Meyer, 2013). The average discharge of the Altamaha River is 12 billion gal/day (USGS, 2012). The true watershed or drainage basin for the Altamaha River actually also includes the Ocmulgee and Oconee Basins to the west (Figure 1); however, these watersheds are classified

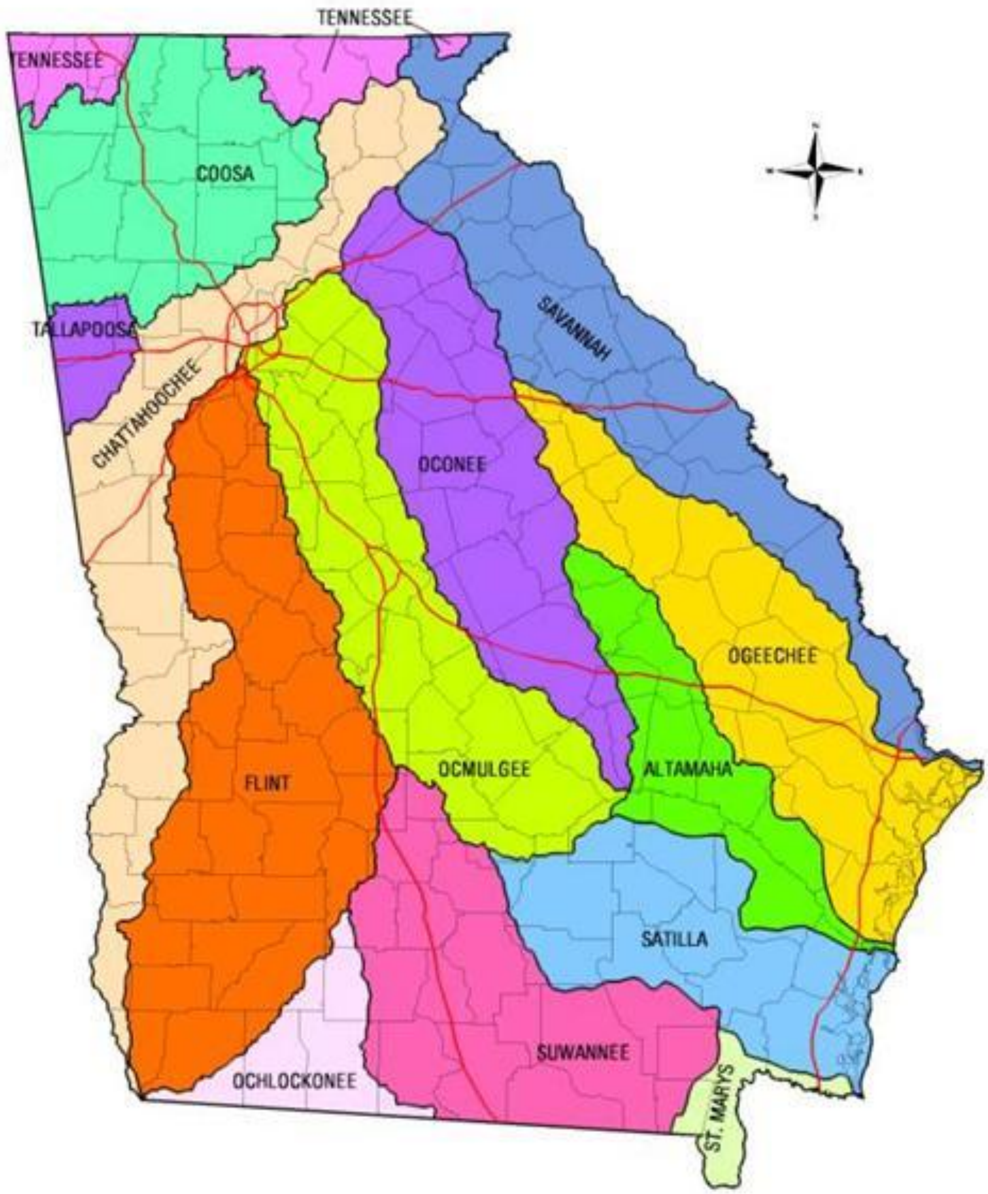

Figure 1. Location of the Altamaha River Basin in relation to other Georgia Watersheds (Department of Natural Resources – Environmental Protection Division, 2009)

as separate basins due to the large size and complex nature of the combined watersheds. In most references the Altamaha River Basin only refers to the drainage area below the confluence of the Ocmulgee and Oconee Rivers; nevertheless, it should be noted that water quality in the Altamaha Basin is also influenced by input from the Ocmulgee and Oconee Rivers. This study will focus on the Altamaha River Basin as shown in Figure 2.

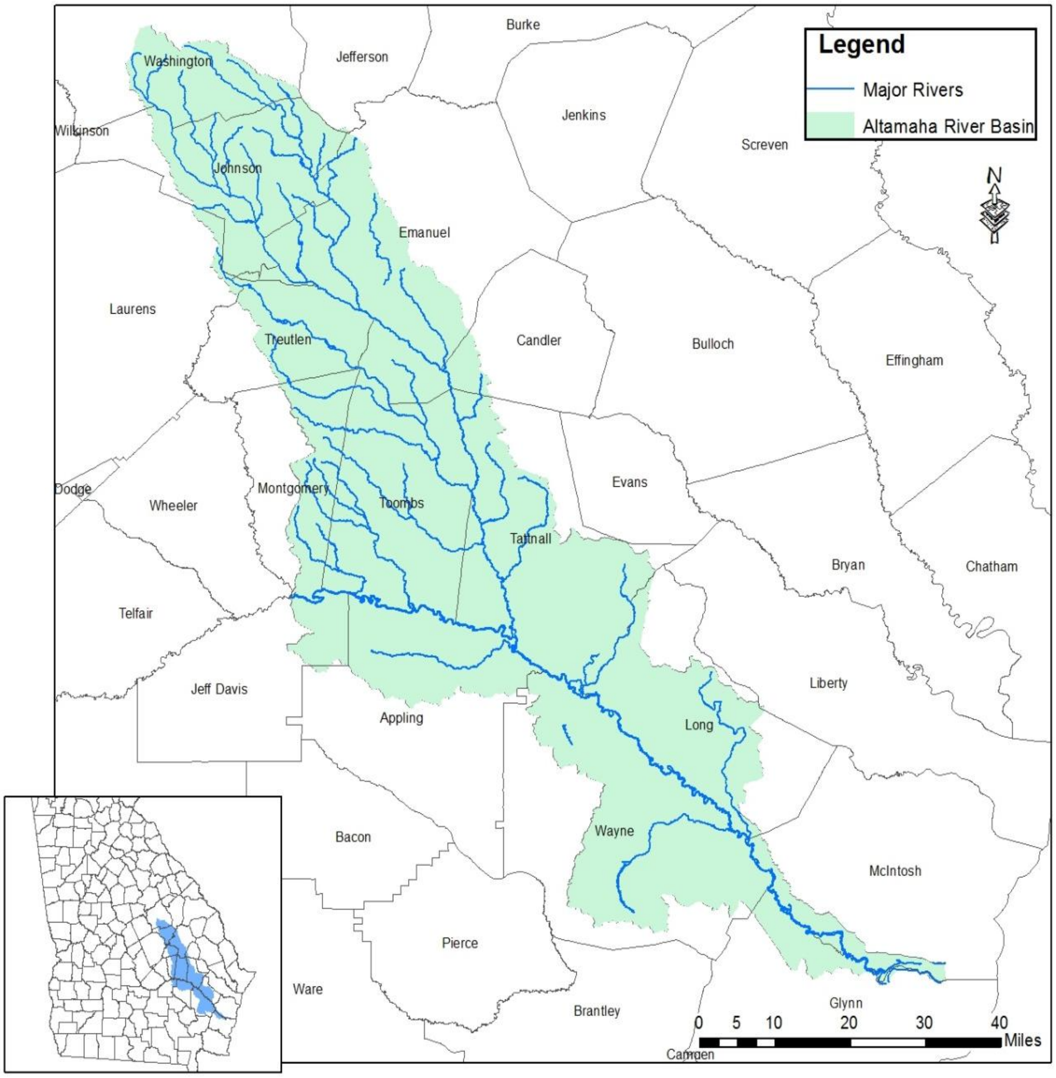

Figure 2. Map showing the location and extent of the Altamaha River Basin.

There is extensive biological diversity found in the Altamaha River Basin. In 1991, the Nature Conservancy initiated an ecological survey to determine the biological resources and potential threats to freshwater species in the Altamaha River (Loeffler and Meyer, 2013). Eleven endangered species of mussels and over one hundred and twenty species of rare or endangered plants or animals were identified. Seven of these mussel species cannot be found anywhere else in the world. In addition, about one third of Georgia's commercial and recreational fisheries are based out of the Altamaha. The effects of lower river flows and increasing salinity in the estuary have already had a significant impact and the volume and value of the catch has fallen considerably in recent years (GA River Network, 2013). In addition to aquatic life, the watershed provides habitats for the nesting and breeding of many species of migratory birds as well as several common game species.

The Altamaha River is an important water resource for a variety of reasons. Many Georgia residents and several industries utilize water from the Altamaha. The Altamaha River is used for a wide variety of recreational purposes such as fishing, swimming, and nature observation. Farmers use the river as a remote source of water for livestock and irrigation. Industrial uses for the river include nuclear power production, pulp mill operations, and wastewater treatment discharge. River water is used in the Jesup area for both industrial and municipal waste purposes. The Rayonier Performance Fibers plant and the Jesup Municipal Wastewater Treatment Facility both contribute effluent waste into the river. In addition, more than forty-four percent of the basin is covered by managed forests and forestry-related land cover. This industry accounts for a major part of the basin's economy (GA DNR – EPD, 2003). The Altamaha has been declared the seventh most endangered river in the United States due to the loss of water flow that has resulted from reservoirs and power plants along the shoreline (GA River Network, 2013).

Water quality in the Altamaha is influenced by a combination of natural and human-induced factors such as local geology, landcover and landuse. Local bedrock composition has a direct impact on turbidity, pH and water chemistry. The Altamaha Basin is located in part of the

Vidalia Upland and Barrier Island Sequence Districts of the Coastal Plain Geological Province (GA DNR – EPD, 2003). Approximately ninety percent of the basin is underlain by Coastal Plain sediments, mostly sands and clays. The remainder is largely underlain by Quaternary alluvium (Altamaha Council, 2011). The absence of limestone and crystalline bedrock and an abundance of fine-grained sediments and sedimentary rocks results in higher turbidity and more acidic water chemistry. Figure 3 shows the different rock and sediment types that underlie the basin.

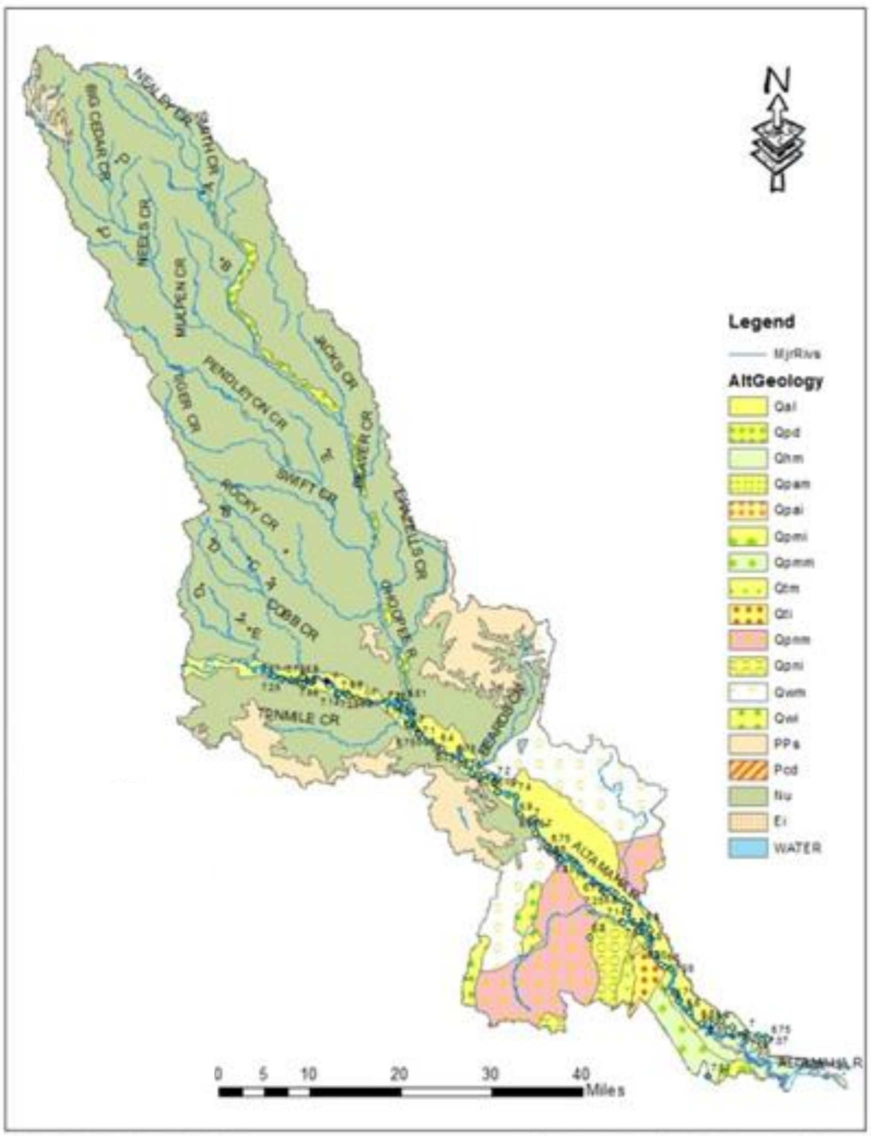

Figure 3. Geologic Map of Altamaha River Basin (GA Department of Natural Resources, 1976).

Lower relief in the Coastal Plain and slower flow rates on most tributaries also result in an abundance of organic-rich blackwater streams within the watershed that increase turbidity and lower pH and dissolved oxygen. Landcover for the Altamaha Basin is mainly forests, agriculture and wetlands with minimal urban use and pasture land (Figure 4). Approximately 56.4% of the basin landcover is forest cover, 28.7% is agriculture, 12.3% is wetlands, and 1.5% is urban landcover (USGS-DNR, 2003).

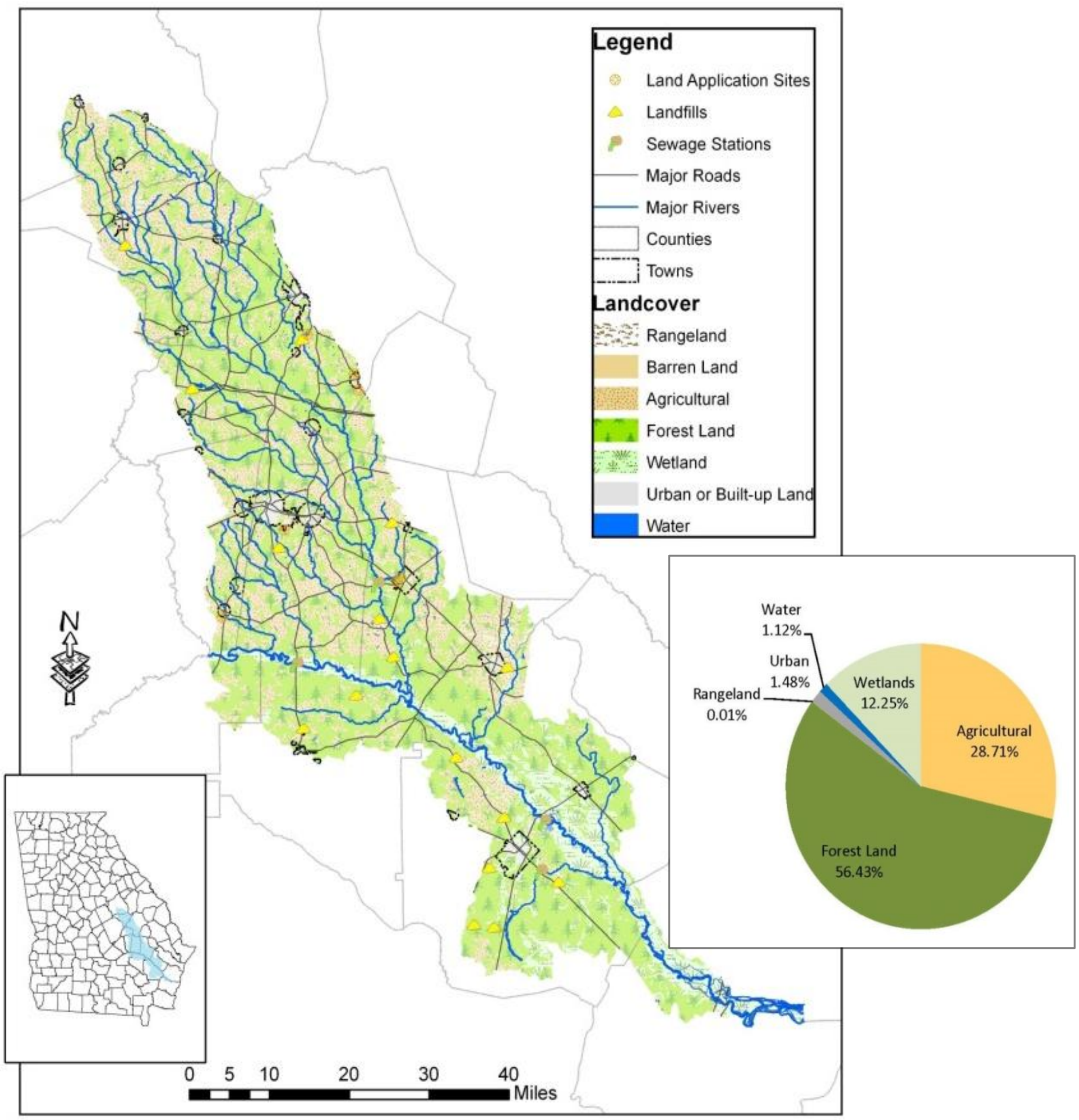

Figure 4. Landcover Map and Graph for the Altamaha River Basin (Data from USGS-Georgia DNR, 2003).

This project examined basin-wide data collected by the Georgia Adopt-A-Stream and Environmental Protection Division during the 2012 Paddle Georgia trip along the Altamaha River (GA Adopt-A-Stream, 2012). Paddle Georgia sample location sites are shown in Figure 4.

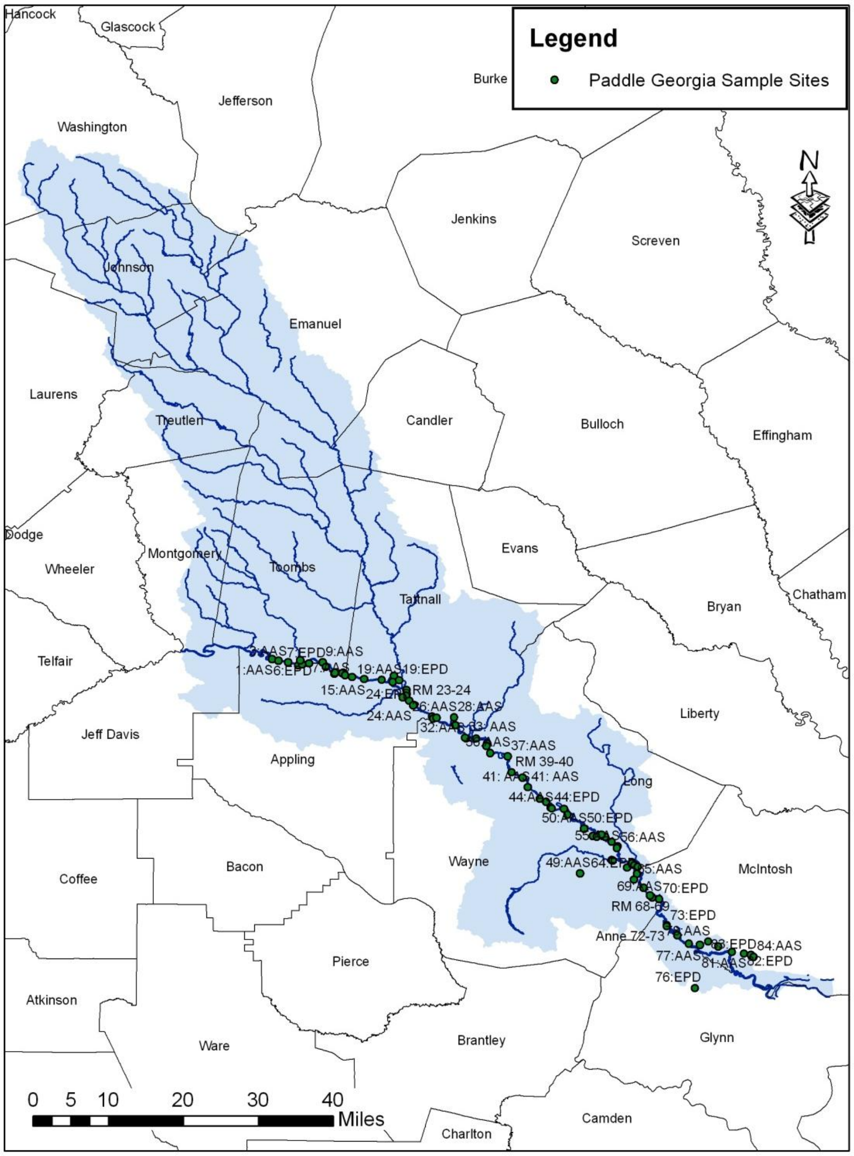

Figure 4. Location Map of Samples Sites for the Paddle Georgia Study (GA Adopt-A-Stream, 2012).

In addition to the Paddle Georgia basin-wide study, a section of the Altamaha near Jesup was selected as a focused study area due to concern about the impact of the large volume of industrial discharge by the Rayonier plant in combination with decreased flow rates and other environmental issues such as mining, clear-cutting and effluent from local sewage plants. The focused study area is located in the vicinity of the Rayonier Performance Fibers, LLC. Pulp Mill at Doctortown, Georgia. The plant currently releases a large volume of strongly-colored odoriferous effluent into the river at this location. There are currently two outfalls for the plant that are releasing effluent waste into the Altamaha River. These outfalls are designated Outfalls 001 and 002. Outfall 001 releases up to 9.49 million gallons per day into the Altamaha River, while outfall 002 releases up to 46.27 million gallons per day. There is an additional outfall which is proposed in Rayonier's EPA permit renewal application (EPA permit app GA0003620) that is designated as outfall 003. The combination of these three outfalls could result in a total effluent flow of 57.04 million gallons per day being pumped into the river (EPA permit app GA0003620). In this study, water quality data from the Jesup area were merged with the Paddle Georgia data to better understand regional water quality trends and the effects of the Rayonier discharge.

Procedures

To better understand the water chemistry of the Altamaha River at Jesup, samples were collected both upstream and downstream of the Rayonier facility. Sample sites were selected using satellite images and topographic maps. Two sites were selected at approximately .5 and 1 mile upstream of the Rayonier plant in order to measure baseline water quality before the effluent's introduction into the river. Four sites were also chosen at .25 miles downstream of outfall 001, directly adjacent to outfall 002, and approximately .5 and 1 mile downstream of outfall 002. Topographic maps and aerial photos were then labeled with proposed sites to be used in the field. All sample locations were registered in the field using hand-held GPS units. Average flow rate for the Altamaha River at Doctortown is 21,300 cfs; but during sampling flow rates were at a record low of 1,600 cfs (USGS). The effluent at outfall 002 is introduced to the stream through a large pipe which goes below the surface of the river and then through a mechanical device which disperses and mixes the effluent in plume-like bursts. This spreading device makes direct sampling of the effluent without dilution impossible. An additional sample site was selected at Penholloway Creek where it crosses Highway 23/27/341 bridge. The stream which is on the 305b list for dissolved oxygen levels merges into the Altamaha approximately fifteen miles downstream of the Rayonier Plant. This site was sampled in order to analyze and compare the water chemistry of a local blackwater stream with the dark-colored effluent-enriched river water. Figure 5 shows the sample locations for the focused Jesup study.

Samples were analyzed at each field location using techniques prescribed in the Georgia Adopt-A-Stream Biological and Chemical Monitoring Manual (Georgia Adopt-A-Stream, 2009).

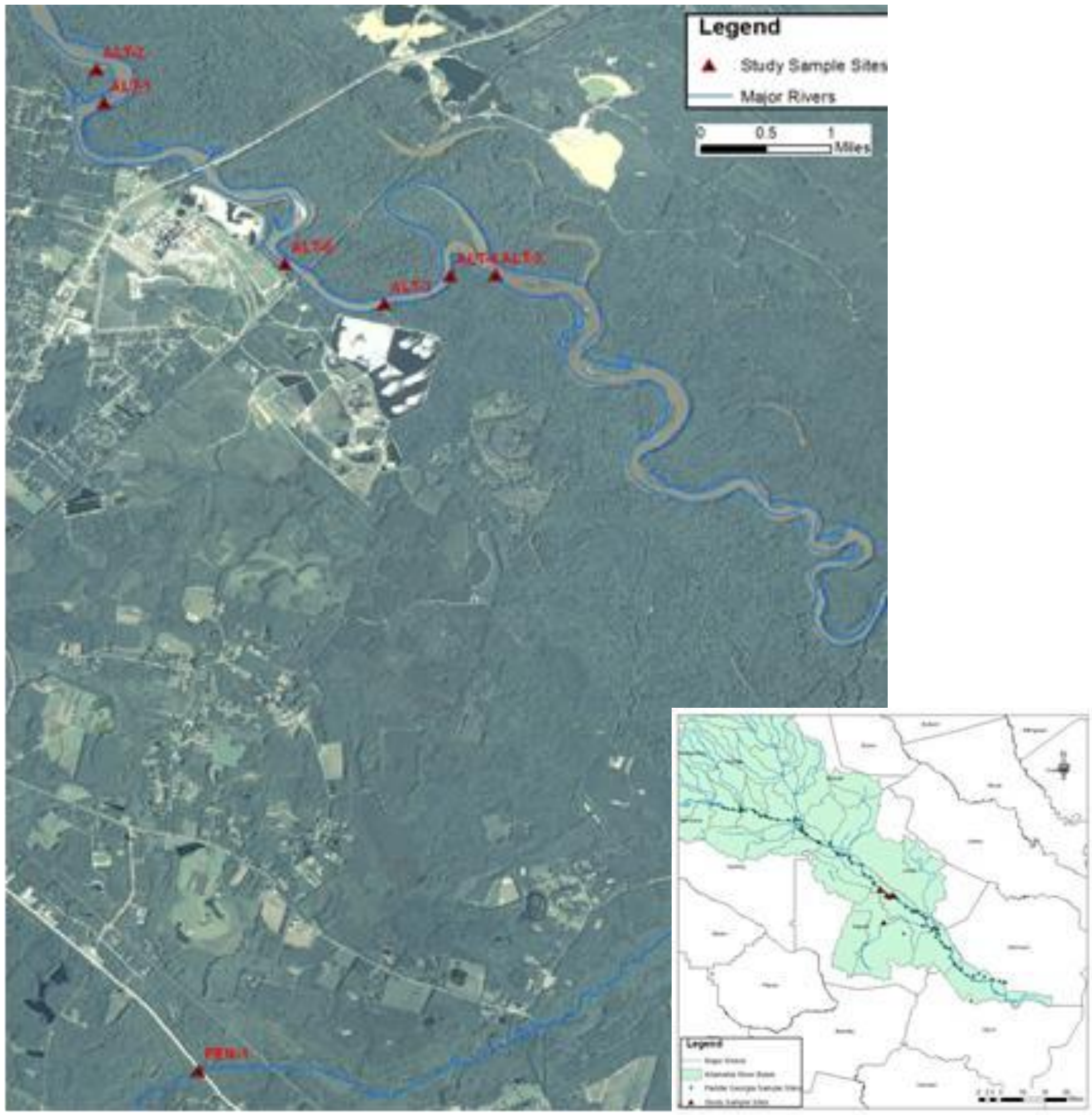

Figure 5. Location Maps for Jesup Area Sampling Sites (shown in red triangles).

Water was tested for pH, conductivity, DO, temp, nitrates, phosphates, alkalinity, and turbidity. Dissolved oxygen was determined using the Winkler titration technique. Phosphates levels were also determined using titration techniques. Alkalinity, pH, and nitrates, were analyzed by colorimetric techniques. Turbidity was measured using a Secchi dish. Temperature was measured midstream at a depth of approximately two feet while land temperature was measured in the shade. Water samples were also collected at each location for lab analysis.

Samples were collected in sterile 500 mL polypropylene bottles at mid-stream locations and water depths of approximately one to two feet. Samples were immediately refrigerated in order to prevent chemical degradation. Samples were shipped overnight in a refrigerated container and then analyzed by the University of Georgia Soil, Plant and Water Lab for pH, hardness, alkalinity, Aluminum (AL), Boron (B), Calcium (Ca), Carbon Dioxide (CO_2), Chloride (Cl), Chromium (Cr), Conductivity (specific conductance @ 25^o C), Copper (Cu), Fluoride (F), Iron (Fe), Magnesium (Mg), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Nitrate-Nitrogen (NO_3-N), Phosphate (PO_4), Phosphorus (P), Potassium (K), Silica (SiO_2), Sodium (Na), Sulfate (SO_4), Total Dissolved Solids (TDS), and Zinc (Zn). These analyses performed by the UGA lab were used in order to check the accuracy of the field measurements as well as expand the parameters and more specifically identify the chemical contents of the Rayonier Discharge.

Data

During the Paddle Georgia Trip of June 2012, Georgia Adopt-A-Stream members and the Environmental Protection Division of the Georgia Department of Natural Resources regularly sampled throughout the course of the Altamaha. All sites were analyzed for pH, conductivity, dissolved oxygen, turbidity and temperature. Many of the sites were also sampled and analyzed for alkalinity, hardness, phosphate, calcium, magnesium, manganese, potassium, sodium and several other elements. For this project, the resulting data were graphically plotted to show the distance downstream versus the measurement for that sample location to better display water quality change along the length of the river. The data were also displayed graphically using color symbols on basin maps for each measurement. Results of the data were averaged to establish baseline values for the Altamaha River. The Jesup study data were also averaged and evaluated using the downstream distance graphs. Table 1 shows the averages of several water quality important measurements for both the basin-wide and Jesup studies.

	Paddle Georgia Data		Jesup Study Data	
	Average	Range	Average	Range
pH	6.9	5.1 – 8.6	6.9	4.5 – 7.75
Dissolved Oxygen (ppm)	5.6	2 – 10	5.3	3.1 – 6.7
Conductivity (µs/cm)	272.9	60 – 5750	397.0	90 – 1020
Alkalinity (mg/L $CaCO_3$)	56	40 – 100	78	0 – 151
Phosphate (ppm)	13.5	5 – 40	0	0
Nitrate-Nitrogen (ppm)	0	0	0	0
Turbidity (JTUs)	11.8	0 – 150	7.2	4.1 – 50

Table 1. Average and Range of Water Chemistry Data for Basin-wide and Jesup Area Studies

All of the data for both Paddle Georgia basin-wide and the Jesup focused studies are shown in the Appendices. The following will discuss only water quality factors/measurements that show significant change and/or trends within the study area.

The pH of a sample measures the hydrogen ion concentration of the solution. Water that has a pH of 7 is considered neutral. Acidic water has a pH of less than 7, while basic water has a pH greater than 7. The pH required for most aquatic organisms to thrive is between 6.5 and 8.2 (GA DNR – EPD, 2009). The pH values observed in the Paddle Georgia data ranged from 4.1 to 8.1 and with an average of 7.2 and a standard deviation of 1.5. The pH values in the Jesup area ranged from 4.5 to 7.8 with an average of 7.0 and a standard deviation of 1.2. The Paddle Georgia data showed an increase in average pH in the vicinity of the Rayonier Plant, but the rise began before either of the outfalls. The Jesup data showed a pH increase from 7 to 7.75 at outfall 002 and levels remained constant at 7.75 for one mile downstream. Penholloway Creek had the lowest pH value at 4.5 which is expected because this is a blackwater stream with high organic debris content. Figure 6 shows pH values along the Altamaha River with the location of outfall 002 also shown.

Dissolved oxygen is the measure of the amount of oxygen which is in solution in the water. The levels of dissolved oxygen in a stream are a direct indicator of overall stream health. Dissolved oxygen is vital for aquatic organisms (USGS, 2012). In a healthy stream, dissolved oxygen levels of 5 to 6 ppm and above are necessary for normal growth and activity (GA DNR – EPD, 2009). The dissolved oxygen levels observed in the basin-wide study ranged from 2 to 10 ppm with an average of 5.56 ppm and a standard deviation of 1.29 ppm. The dissolved oxygen

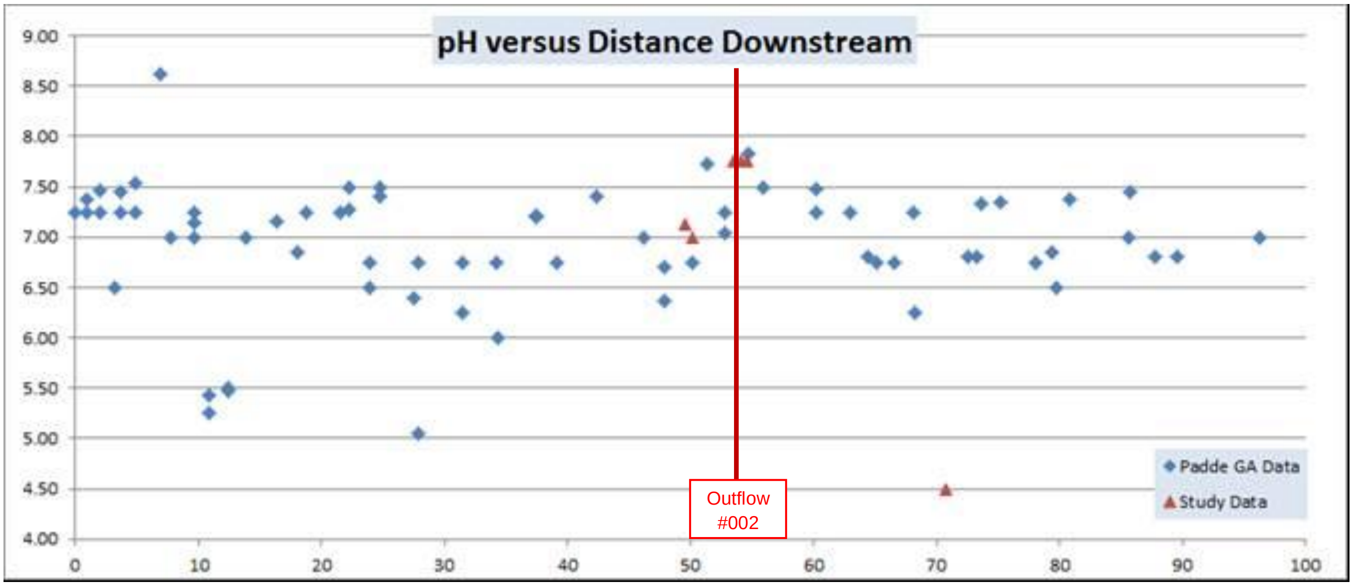

Figure 6. Plot of pH versus Distance Downstream for Basin-wide and Jesup data.

levels for the Jesup data ranged from 3.1 to 6.75 ppm with an average of 5.33 ppm and a standard deviation of 1.39 ppm. The Paddle Georgia data and the Jesup data showed an overall drop in dissolved oxygen levels at outfall 002. The Jesup data showed a more significant decrease with dissolved oxygen levels dropping to 4.1 ppm at outfall 002. Levels then increased to 6.4 ppm after traveling approximately 1 mile downstream. Penholloway Creek had the lowest levels of dissolved oxygen at 3.1 ppm. Low dissolved oxygen levels are typical of slow moving organic-rich streams such as Penholloway Creek. Figure 7 shows dissolved oxygen values along the Altamaha River with the location of outfall 002 also shown.

The conductivity of water is its ability to pass an electrical current. Conductivity levels in a sample reflect a range of source variables. Increases in conductivity are often seen due to high levels of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate, sodium, magnesium, calcium, iron, and aluminum. Conductivity in streams free from pollution

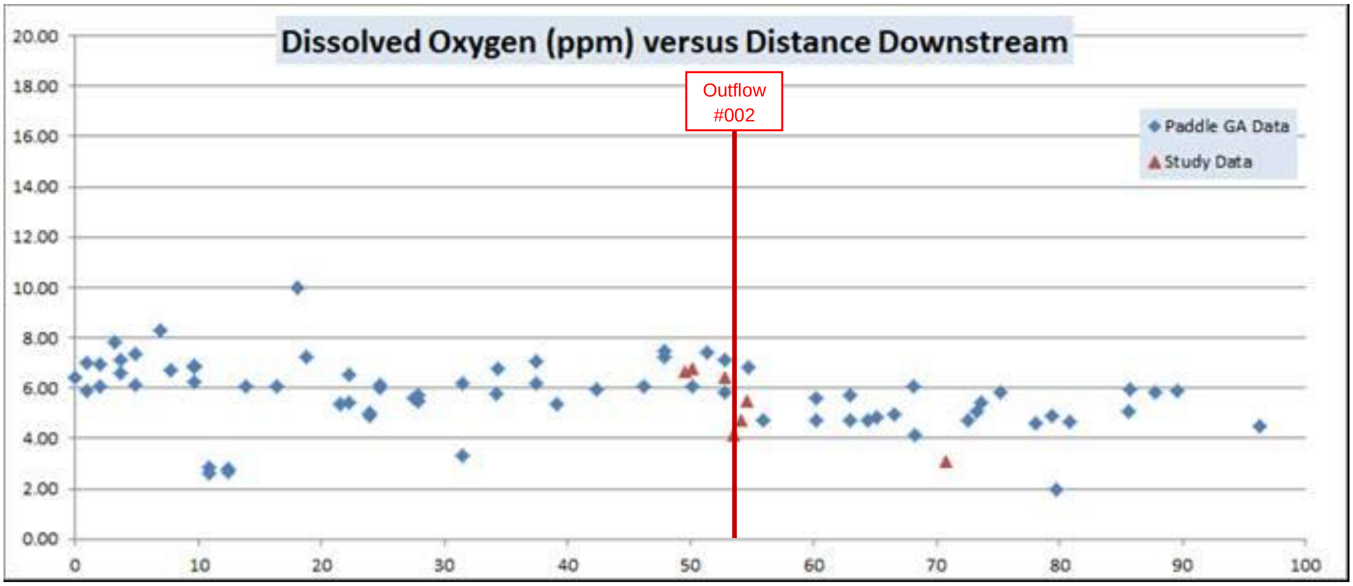

Figure 7. Plot of Dissolved Oxygen versus Distance Downstream for Basin-wide and Jesup data.

is regulated primarily by bedrock geology (U. S. EPA, 2012). Distilled water has a conductivity range of 0.5 to 3 µs/cm. The conductivity of most Georgia streams ranges from 0 to 1500 µs/cm. Studies show that streams which support mixed fisheries have a conductivity value between 50 and 500 µs/cm. Conductivity levels outside of this range may be an indication that the stream is unable to sustain some species of fish or macroinvertebrates. Industrial waters have been found to have conductivity measurements as high as 10,000 µs/cm (GA DNR-EPD, 2009). The conductivity levels observed in the Paddle Georgia data ranged from 60 to 5750 µs/cm with an average of 272.9 µs/cm and a standard deviation of 626.2 µs/cm. The conductivity levels in the Jesup data ranged from 90 to 1020 µs/cm and had an average of 397µs/cm with a standard deviation of 336.0 µs/cm. The Paddle Georgia data and the Jesup data both showed an overall increase in conductivity at outfall 002. The Jesup data showed a more significant increase to 1020 µs/cm at outfall 002. Conductivity values decreased to 390 µs/cm at approximately one mile downstream of the outfall. Penholloway Creek conductivity levels were measured at 90 µs/cm. Figure 8 shows conductivity values along the Altamaha River with the location of outfall 002 also shown.

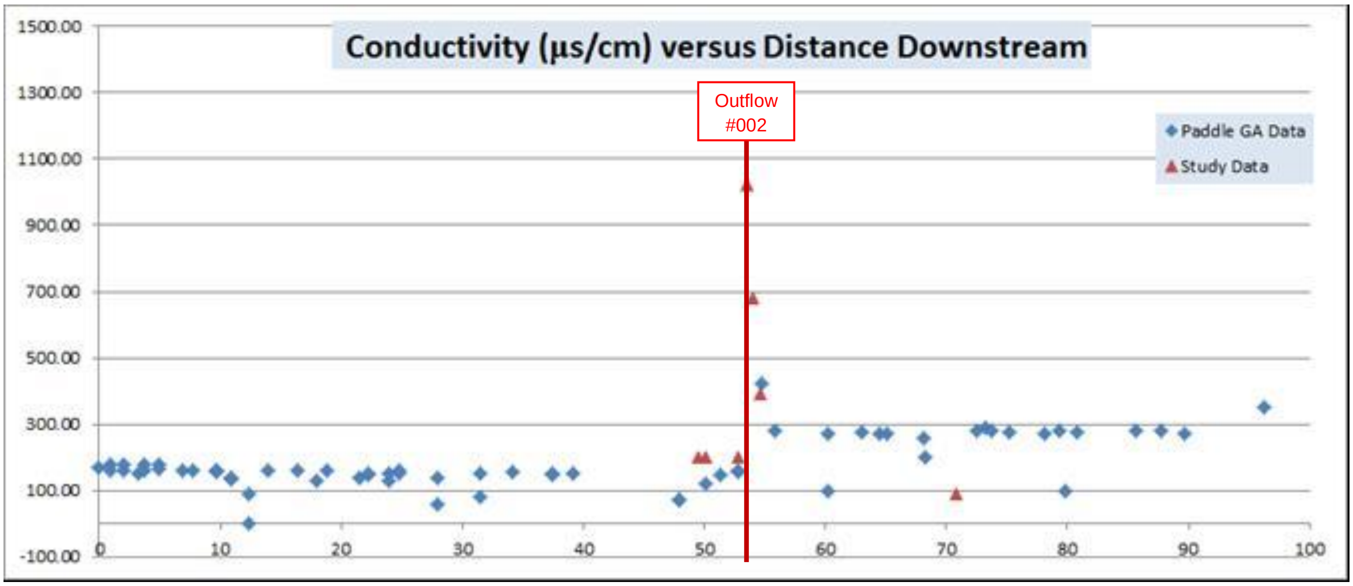

Figure 8. Plot of Conductivity versus Distance Downstream for Basin-wide and Jesup data.

Alkalinity is a value that describes the ability of water to neutralize acids. Alkaline compounds in water such as carbonates, bicarbonates, and hydroxides remove hydrogen ions and increase the pH. They normally do this by combining with the hydrogen ions to create new compounds. Determining alkalinity is important in assessing a stream's potential to neutralize acidic pollution from wastewater or acid rain. Alkalinity in streams is also affected by rocks and soils, salts, plant processes, and industrial wastewater discharge. Total alkalinity is measured by determining the amount of acid required to lower the water to a pH of 4.2. At this pH, the alkaline compounds in the water are used up. The alkalinity measurement is reported as milligrams per liter of calcium carbonate (U. S. EPA, 2012). Alkalinity levels observed in the

Paddle Georgia data ranged from 40 to 100 ppm with an average of 56 ppm and a standard deviation of 21.6. The alkalinity levels in the Jesup area ranged from 0 to 151 ppm with an average of 78 ppm and a standard deviation of 52.8 ppm. The Paddle Georgia data and the study field data both showed an overall increase in alkalinity at outfall 002. The Jesup area data showed a more distinct increase to 151 ppm at outfall 002. The alkalinity of Penholloway Creek was 0 ppm which is expected due to the low pH of this blackwater tributary. Figure 9 shows alkalinity values along the Altamaha River with the location of outfall 002 also shown.

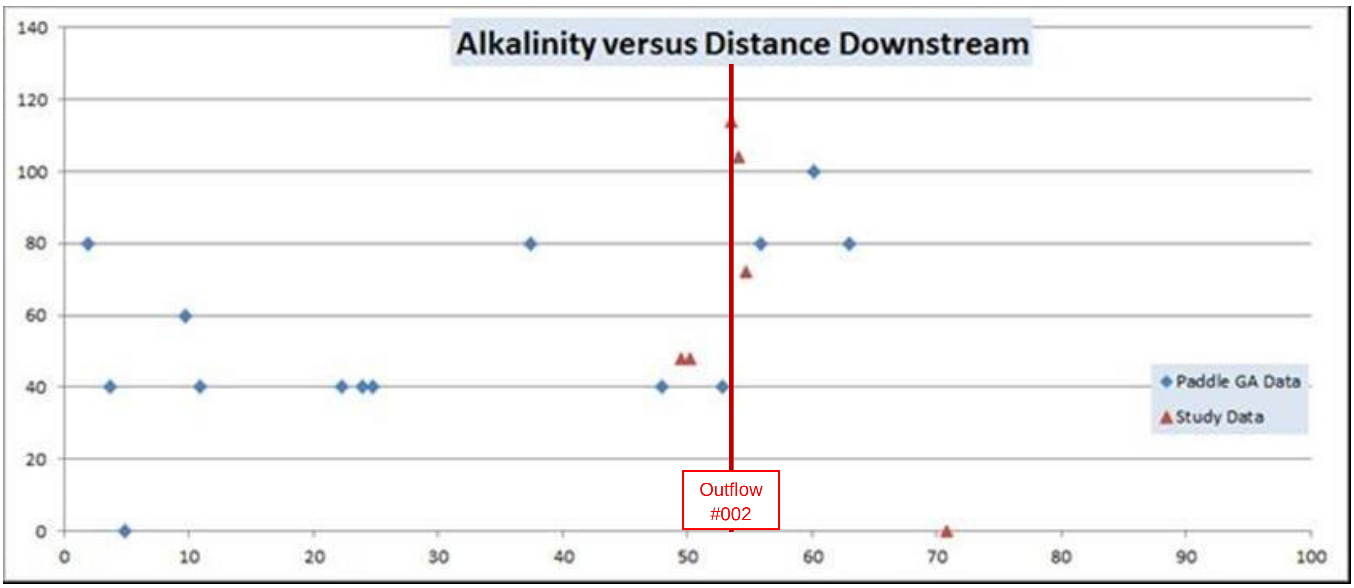

Figure 9. Plot of Alkalinity versus Distance Downstream for Basin-wide and Jesup data.

Total dissolved solids (TDS) and ion concentrations are often measured in water quality studies to obtain a more detailed and specific chemical analysis of potential pollutants. Dissolved solids include calcium, chloride, nitrates, phosphorus, iron, sulfur, and other ions and particles that will pass through a 2 micron filter. Elevated TDS levels can negatively affect the water balance in the cells of aquatic organisms (U. S. EPA, 2012) and can indicate elevated concentrations of organic and inorganic material. There are many factors that can affect the amount of total dissolved solids such as urban run-off, fertilizers, and effluent from wastewater treatment plants (Mitchell and Stapp, 1993). TDS data was not collected in the Paddle Georgia basin-wide study; however, TDS values from the Jesup study showed a change from 105 ppm upstream of outfall 002 to 372 ppm at outfall 002. At approximately one mile downstream, TDS levels dropped to 204 ppm. The elemental concentration of phosphate, potassium, chloride, sodium, sulfate, magnesium, and manganese also significantly increased at outfall 002. Figure 10 shows plots of total dissolved solids, potassium, phosphate and chloride values for Jesup

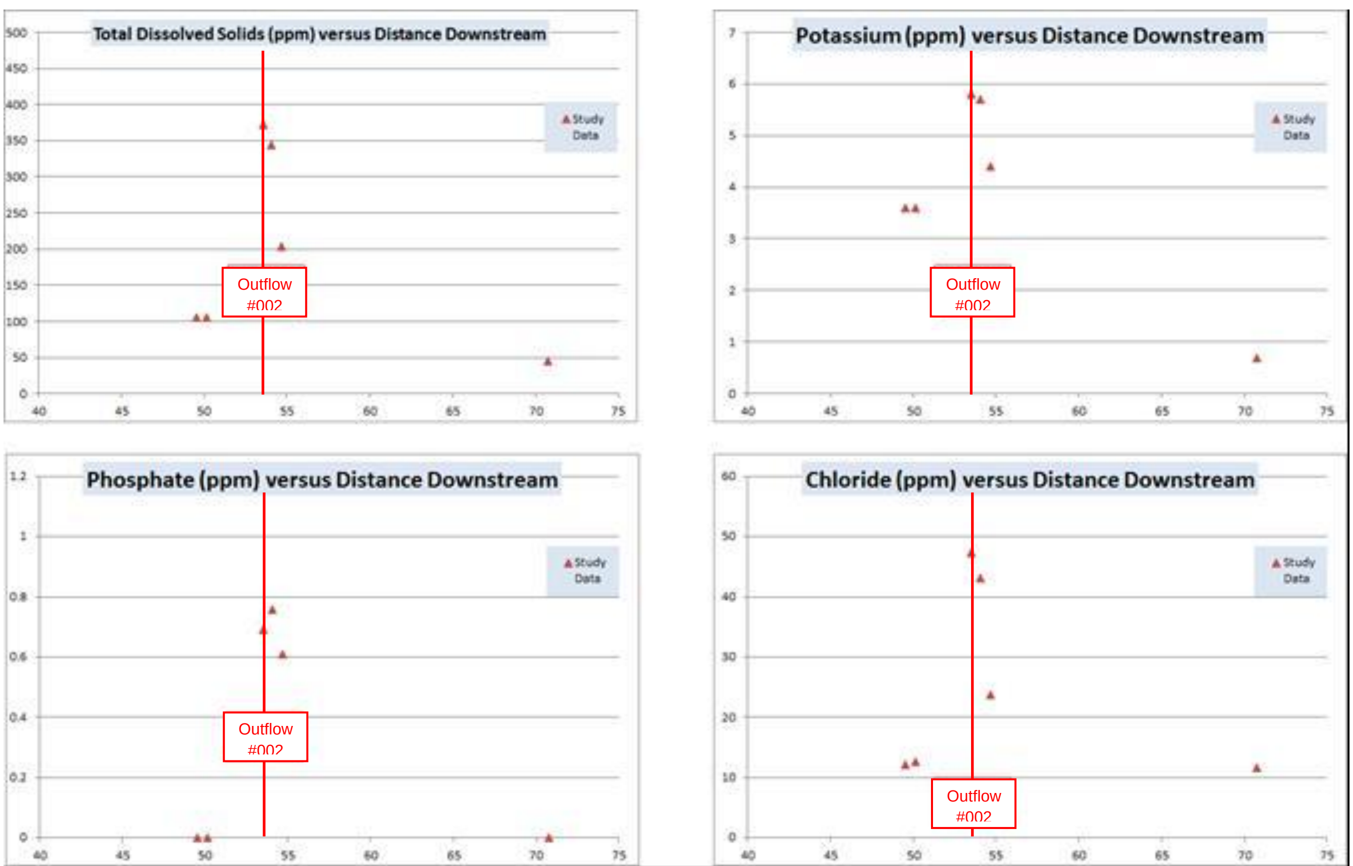

Figure 10. Plots of Total Dissolved Solids, Potassium, Phosphate and Chloride versus Distance Downstream for Jesup samples.

water samples.   In contrast to the discharge mixed water, the water sample from the blackwater Penholloway Creek had a much lower TDS concentration of 45 ppm. This indicates that local blackwater streams do not have high dissolved loads even with their typically low pH.

Turbidity is the measure of the relative clarity of water. High turbidity levels indicate a decrease in the ability of water to transmit light. Increases in turbidity are due to suspended solids in the water which range from clay, silt, and plankton, to industrial wastes and sewage. At higher turbidity levels water becomes unable to support diverse aquatic life (Mitchell and Stapp, 1993). Turbidity values observed in the Paddle Georgia data had a range of 0 to 150 JTUs with an average of 11.79 JTUs and a standard deviation of 18.06 JTUs. The Jesup study data had an average turbidity of 7.2 JTUs with a standard deviation of 1.5 JTUs, a maximum of 50 JTUs and a minimum of 4.1 JTUs. Figure 11 shows turbidity values along the Altamaha River with the location of outfall 002 also shown.   No consistent turbidity changes were seen in the

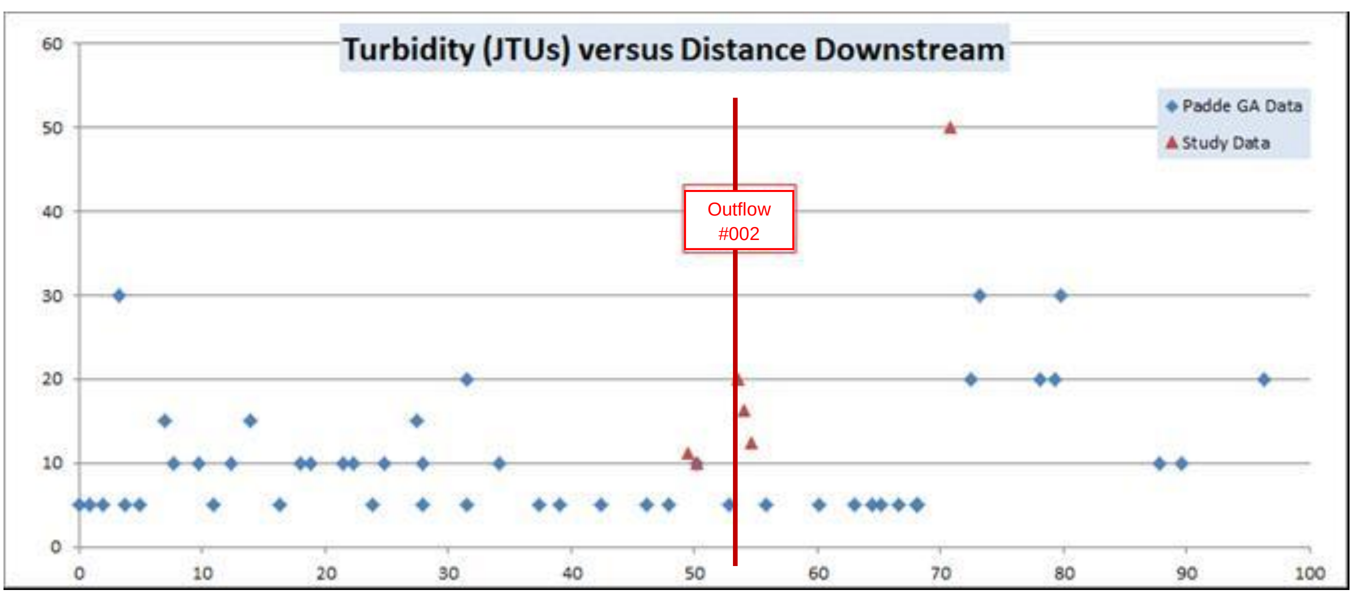

Figure 11. Plot of Turbidity versus Distance Downstream for Basin-wide and Jesup samples.

Paddle Georgia data within the study area; however a sharp increase from 10 to 20 JTUs at outfall 002 was observed in the Jesup data. Turbidity levels upstream of outfall 002 were consistent in both data sets. Penholloway Creek's turbidity level was measured at 50 JTUs reflecting the high tannin content of the water.

Discussion/Conclusions

Initial examination of the Paddle Georgia basin-wide data found no significant areas of pollution or threatened water quality. This was most likely due to the large sampling interval as well as the complex nature of the Altamaha River Basin. Analysis of the more detailed Jesup sample data however showed as significant decrease in several water quality factors. Turbidity, conductivity, dissolved oxygen, pH, and alkalinity all showed significant changes downstream of outfall 002. Increases in total dissolved solids and several other ions were also seen. When the Jesup data was combined with the basin-wide data large-scale trends were found that indicate a significant change in water quality downstream of the Rayonier outfall 002.

The most obvious change in visible water quality at Jesup involves turbidity. There was an overall increase in turbidity from 10 to 20 JTUs at outfall 002. Approximately one mile downstream of the outfall, levels had decreased to 12.50 JTUs, but were still somewhat elevated. The turbidity levels at Penholloway Creek were found to be even higher at 50 JTUs due to natural tannins that color this blackwater stream. Turbidity increases and stays high throughout the remaining course of the river downstream of Jesup where Penholloway Creek enters the Altamaha. The only EPA-required limit for the Rayonier discharge is color because discoloration resulting from added tannins is the only reported negative impact the discharge has on the stream water.

Conductivity levels showed a significant increase from outfall 002 to the Atlantic Ocean in the Paddle Georgia data. Conductivity for this basin-wide study averaged 142 µs/cm upstream of the outfall, and increased to an average of 252 µs/cm downstream of the outfall. Conductivity data from the Jesup study show an increase from 200 to 1020 µs/cm at outfall

002. Levels dropped back down to 390 µs/cm at approximately one mile downstream of the outfall. Penholloway Creek showed the lowest conductivity of all study area samples with a value of 90 µs/cm. This is significant because it indicates a major difference in the composition of tannin-rich water from blackwater streams and the brown-colored effluent from the Rayonier Plant.

Dissolved oxygen levels measured during the Paddle Georgia basin-wide study show a significant decrease beginning in the vicinity of outfall 002 and continuing approximately five miles downstream. The average basin-wide dissolved oxygen level of the Altamaha River above the Rayonier Plant is 5.9 ppm; whereas it decreases to 5.0 ppm between the Plant and the Atlantic Ocean. The Jesup data also showed that dissolved oxygen levels drop with a decrease from 6.65 ppm above the Rayonier plant to 4.15 ppm at outfall 002. The Environmental Protection Division recommends dissolved oxygen levels to be greater than 4 ppm and preferably no less than an average of 5 ppm (GA DNR-EPD, 2009). Dissolved oxygen levels of the Altamaha at outfall 002 are extremely close to the minimal acceptable limit. Penholloway Creek had even lower dissolved oxygen with a measurement of 3.1 ppm. Low dissolved oxygen levels are typical of blackwater streams due to their high content of organic debris. The downstream drop in dissolved oxygen in the Altamaha is most likely due to the combined effects of the effluent and Penholloway Creek.

Total dissolved solids and several ion levels significantly increased at outfall 002. This indicates the presence of dissolved organic and inorganic materials which could be potentially harmful to aquatic life in the Altamaha River downstream of the Rayonier Plant. Some of the increase in dissolved materials appears to result from the release of dissolved salts in the discharge. This would also account for the observed increase in conductivity in the discharge. None of these levels violated water quality standards for industrial discharge; although a future evaluation of the dissipation of these materials over an extended distance of the river would be useful in determining the long-term water quality effects.

Based on the limited alkalinity data collected during both the Paddle Georgia and the Jesup studies, it is difficult to delineate basin-wide changes; however, a significant increase in alkalinity was observed at outfall 002. This increase in alkalinity correlates with a slight increase in pH. The change in pH is less defined due to the variability of basin-wide pH values. One possible cause of the increased alkalinity and pH of the discharge could reflect the groundwater used in the industrial processes at Rayonier. Groundwater obtained from limestone-bearing aquifers is characterized by elevated alkalinity and pH. This alone does not seem to explain the elevated alkalinity of the discharge based on the increased concentrations of the dissolved salts described above.

Natural controls and influences on water quality such as bedrock geology and landcover were found to have a minimal effect on the water quality of the Altamaha River in comparison to human factors. An exception is the influx of blackwater streams that result in higher turbidity and lower dissolved oxygen, pH and alkalinity. The effluent from the Rayonier plant outfall 002 results in a measurable increase in turbidity, dissolved load and conductivity with a significant decrease in dissolved oxygen. The discharge could have a potentially devastating effect on the wildlife and ecosystem of the Altamaha River especially when combined with the negative impact of the natural blackwater streams that merge with the main channel. The high conductivity of the discharge as well as the total dissolved solids is indicative of chemical waste in the effluent, which was previously thought to only contain color changing tannins. The effect of the raised levels of potassium, chloride, sodium, magnesium, manganese, phosphate and sulfate from the discharge is uncertain. More detailed analysis of the effluent waste for organic and inorganic compounds such as chlorine compounds, which are used in the bleaching processes, would provide valuable information as to the cause of the increased total dissolved solids and conductivity. A biological analysis of macro-invertebrate diversity along the river is an additional study that would provide data on the effects of the additional chemicals and dissolved oxygen.

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References

Altamaha Council, 2011, Altamaha Regional Water Plan, Atlanta, Georgia.

Georgia Adopt-A-Stream, 2012, Paddle Georgia Water Quality Data for Altamaha River Basin: Georgia Department of Natural Resources Environmental Protection Division, Atlanta, Georgia.

Georgia Department of Natural Resources Environmental Protection Division, 2003, Altamaha River Basin Water Management Plan, Atlanta, Georgia.

Georgia Department of Natural Resources Environmental Protection Division, 2009, Georgia Adopt-A-Stream Biological and Chemical Stream Monitoring, Atlanta, Georgia.

Georgia River Network, 2013, Altamaha River, http://www.garivers.org/other-georgia-rivers/altamaha-river.html, Athens, Georgia.

Loeffler, Gretchen, Meyer, Judy L., 2013, University of Georgia River Basin Center, Altamaha River Basin, http://www.rivercenter.uga.edu/education/k12resources/basinsofga1.htm, Athens, Georgia.

Mitchell and Stapp, 1993, Field Manual for Water Quality Monitoring, Thomson-Shore, Inc. Dexter, Michigan.

U. S. Environmental Protection Agency, 2012, Monitoring and Assessing Water Quality, http://water.epa.gov/type/rsl/monitoring, Washington, D. C.

U. S. Geological Survey, 2012, National Water Information System: Web Interface – Daily Streamflow Conditions: http://waterdata.usgs.gov.