NUTRIENT AND SEDIMENT LOADING IN SOUGAHATCHEE CREEK AND THE IMPACTS ON AQUATIC BIOTA

Report submitted to West Point Stevens and the

Cities of Auburn and Opelika, Alabama

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EXECUTIVE SUMMARY

The Sougahatchee Creek headwaters arise just north of the city of Opelika, Alabama and flow westward to the Tallapoosa River (Yates Lake). The 217-mi² creek basin lies entirely within the Piedmont physiographic province. The Piedmont comprises a transitional area between the mostly mountainous Appalachians to the northeast and the relatively flat Coastal Plain to the southeast. The soils are finer-textured and lower in organic matter and nutrients than Coastal Plain soils. Rocky stream bottoms of boulder, cobble and gravel characterize streams in their natural, undisturbed condition.

In its headwaters, Sougahatchee Creek received nonpoint urban runoff from the twin cities of Auburn and Opelika, Alabama, about 4.5 mgd of municipal wastewater and another 1.3 mgd of treated textile wastewater. The predominant (67%) land cover within the basin was managed forest. The stream has had a long history of pollution problems and, in fact, is in much better condition today than it was 20-30 years ago. Nevertheless, Sougahatchee Creek continues to experience problems with excessive nutrient enrichment and sedimentation. It was one of the few Alabama streams to have two reaches (embayment of Yates Lake and an urban tributary) appearing on the State 303(d) List for impaired waters in 2001.

This study was designed to determine the current condition of Sougahatchee Creek and its tributaries and, to the extent possible, identify those factors within the basin having an adverse effect on water quality and biological health of the system. The specific objectives were to:

1. Measure concentrations and estimate annual loading of plant nutrients, total suspended solids and metals;
2. Examine physical habitat conditions of the streams and conduct bioassessments utilizing benthic macroinvertebrate communities;
3. Using GIS technology, examine and quantify land cover for the entire Sougahatchee Basin from 1993 and 2001 satellite imagery and aerial photography; and,
4. Using regression analysis, examine relationships between basin land cover, nutrient and sediment loading and biological condition of the streams.

Methods

Water quality sampling began in January 2001 and continued through December 2002. Samples were collected at three wastewater discharges, at nine mainstream Sougahatchee Creek locations and at 12 tributary stream locations on 40 days during the 2-year study. Sampling was concentrated during those months (November through April) normally receiving more rainfall. All samples were analyzed for nutrients (N and P), suspended solids, metals and biochemical oxygen demand. A USGS gage was in operation at Lee Co. Road 188 (station 8), but stream discharge at all other stations was measured on the day of sampling. Annual loading estimates for nutrients, suspended solids and metals were calculated utilizing constituent concentration, instantaneous stream discharge and mean daily discharge for each sampling location. Nonpoint source loading was estimated by subtracting measured point source loading from total loading.

At selected stream sites in the Sougahatchee Basin the physical habitat was assessed utilizing visual observations and a standard form that ranks bottom substrate and cover, flow conditions, sedimentation, bank stability and riparian vegetation. At these same sites the biological condition was assessed utilizing rapid bioassessment procedures approved by the US Environmental Protection Agency. This approach utilizes benthic macroinvertebrates sampled from multiple habitats (e.g., cobble and boulder, logs, root masses along undercut banks and leaf packs) at each site. From the composite sample of macroinvertebrates collected in the reach, six metrics such as total number of taxa and the EPT Index are calculated for a multi-metric assessment of biological condition. The biological condition is then calculated by determining the percent comparability of the site to that measured at a reference site (relatively undisturbed) from the same ecoregion. Reference sites were sampled during the same time period as the streams in the Sougahatchee Basin. The physical habitat assessment and determination of biological condition was conducted on two dates in the fall each year of the study.

Land cover for 1993 was obtained in grid format from the U. S. Geological Survey, National Land Cover Data and was developed using 1993 leaf-off and leaf-on Landsat thematic mapper satellite imagery. The 2001 land cover was classified from 2001 leaf-on and leaf-off Landsat 7 thematic mapper images. For both years, the numerous land cover classes were consolidated into eight primary land cover classes: water, urban/suburban, clearcut/barren, quarry/gravel pits, forest, pasture/grassland, tilled agriculture and wetlands.

Annual loads of select variables (SRP, TP, TN, TSS, $CBOD_5$) were converted to metric tons/km^2 yr^{-1} (annual load per unit watershed area) and then regressed against the various land cover classes. Tributary stream watersheds were regressed separately from Sougahatchee Creek mainstream watersheds. Biological metrics derived from the health of the macroinvertebrate community were also regressed against watershed land cover.

Water Quality

Meteorological conditions affect water quantity and water quality of streams and lakes. Both years of this study, 2001 and 2002, were warmer and dryer than normal. Attempts to measure nutrient and sediment loading of Sougahatchee Creek under drought conditions likely underestimated the contribution of nonpoint sources of pollution to the total load.

Mainstream Concentrations. The headwaters of Sougahatchee Creek were heavily influenced by activities and development in the urban areas of both Auburn and Opelika, Alabama. Treated effluent from two municipal wastewater treatment plants (WWTP), Opelika Westside (3.1 mgd) and Auburn Northside (1.4 mgd), and one industrial (textile) facility, West Point Stevens (1.3 mgd) entered Sougahatchee Creek in the upstream one-third of the basin. Waste from these facilities along with urban drainage and stormwater runoff from the cities of Auburn and Opelika caused an upstream peak in nutrient concentration. All nitrogen species peaked at mainstream station 6 (US Highway 280 bridge) and declined steadily downstream to station 12 near Reeltown, Alabama both years. Soluble reactive phosphorus and total phosphorus peaked at the first mainstream sampling location (station 8) downstream from the Auburn Northside WWTP (station 3) where the mean phosphorus concentration in the effluent was usually considerably higher than that measured in other waste effluents. Elements in relatively high concentration in one or more of the point source effluents (e.g. Ca, Na, K, Mg and B) peaked at upstream station 6 and declined progressively downstream. Other minerals, like barium, aluminum, iron and manganese, showed no clear concentration pattern from headwaters to the mouth of Sougahatchee Creek. Annual mean concentrations of total suspended solids (TSS) in Sougahatchee Creek were variable both years with highest concentrations at station 10 in 2001 and station 8 in 2002. Variation in TSS concentration was pronounced both within a station and between stations among years. WWTP's contributed relatively little sediment to Sougahatchee Creek.

Mainstream Loading. When total load was higher than point source load at a station, estimates of mean annual point and nonpoint source contributions to total load were calculated by subtracting the point source load (measured at the point source) from total load (measured at the stream sampling location). This approach assumes that all of a constituent entering a stream from a source travels all the way downstream to the mouth, an assumption that may not always hold true. Constituent loading was higher in 2001 than in 2002 because of the greater runoff and mean daily discharge that occurred that year. In 2001, total nitrogen (TN) load increased in a downstream direction from less than 7.0 metric tons (mt) at upstream station 4 to more than 233 mt at downstream station 12. The nonpoint source contribution of TN increased progressively downstream and the point source contribution decreased. In 2002, with lower hydraulic discharge, TN loading increased from less than 6 mt at station 4 to 130 mt at station 10 and then decreased downstream to 120 mt at station 12. Nonpoint source TN contributions were generally lower in 2002 than in 2001.

Soluble reactive phosphorus (SRP), the form of phosphorus most readily available for plant use, is usually found in higher concentrations in point sources, particularly municipal WWTP effluent, than in nonpoint sources. This fact, along with the tendency of phosphorus to associate with settlable solids resulted in SRP loads at stations downstream from the point sources that were less than the sum of the point sources. This made it impossible to estimate the nonpoint source contribution of SRP load at stations 8-12. There was an 80% reduction in the SRP load from West Point Stevens between 2001 and 2002.

Total phosphorus (TP) loading of Sougahatchee Creek was similar to trends observed for TN loading for 2001 and 2002. In 2001, with higher runoff and discharge conditions, TP annual loads increased in a downstream direction from 0.3 mt at station 4 to 33.3 mt at station 12. The nonpoint source contribution of TP increased progressively downstream and the point source contribution decreased. In 2002, annual TP loads increased from station 4 (0.2 mt) to station 10 (17.5 mt) and then decreased at stations 11 and 12 (16.0 mt). Nonpoint source contributions at the two downstream stations (11 and

12) were higher in 2001 than in 2002. TP load in the West Point Stevens waste effluent was 36% lower in 2002 than in 2001.

In 2001 and 2002 West Point Stevens contributed most of the sodium load measured in the creek. In addition, sodium load increased 3.5 times in the Opelika WWTP effluent between 2001 and 2002. Potassium loading at mainstream sampling stations increased progressively in a downstream direction during both 2001 and 2002. Nonpoint source contributions of potassium ranged between 50 and 67% in 2001 and between 15 and 46% in 2002.

Concentrations of total suspended solids (TSS) in point source effluents were relatively low and typically contributed <10% of the TSS load at any of the mainstream sampling stations in 2001 and 2002. TSS loads increased progressively in a downstream direction with a substantial increase between stations 9 and 10 during both years. Ropes Creek enters Sougahatchee Creek just upstream of station 10 and appeared to be the cause of this increased TSS load. The likely source of this sediment was extensive forest clear cuts on the watershed of Ropes Creek and its tributaries. Point source TSS concentrations were lower in 2002 than in 2001, led by a 55% reduction in West Point Stevens effluent.

Tributary Concentrations. Throughout the Sougahatchee Basin, concentrations of variables measured in the tributary streams were probably of nonpoint source origins, except for Pepperell Branch. Pepperell Branch was sampled at two locations, station 15 upstream of the West Point Stevens wastewater outfall (station 1) and station 16 downstream of the outfall. This point source effluent was relatively high in some of the water quality variables measured and therefore, station 16 frequently had the highest concentrations of all of the tributary streams. Urban streams in Opelika and Auburn had the highest total nitrogen concentrations, while stations in the downstream tributaries generally had lower concentrations. Also, higher phosphorus concentrations were found in streams draining urban areas than in those draining forested and agricultural watersheds. Station 14, Rocky Brook Creek (Opelika City Park) had particularly high SRP concentrations. Even though annual mean stream discharge measured at the USGS gage was over twice as high in 2001 compared to 2002, mean annual total suspended solids (TSS) concentrations were higher in 2002 at almost every tributary station than levels measured in 2001. This difference probably reflected, in part, the fact that during 2002 we managed to arrive at the streams during the rising limb of the hydrograph more often than we did during 2001. Also, maximum TSS concentrations were much higher in 2002 than in 2001. Each year of the study highest TSS concentrations were found in urban tributaries in Opelika and Auburn probably as a consequence of development on the watersheds.

Tributary Loading. Except for Pepperell Branch, loading to the tributary streams in this study was apparently related primarily to nonpoint sources on the watersheds. Also, for all constituents, mean annual loading was higher in 2001 than in 2002 because of the greater mean daily discharge that occurred that year. In 2001, Pepperell Branch (station 16) had the highest mean annual total nitrogen (TN) loading followed by

Loblockee Creek. In 2002, Loblockee Creek had the highest TN loading followed by Pepperell Branch at station 16. The high loading measured at station 21 in Loblockee Creek was directly related to the fact that discharge in this stream was higher than that measured in any of the other tributary stations. Stations 14 and 20 also had major contributions to TN loading both years. Mean annual soluble reactive phosphorus loads were higher in Pepperell Branch (station 16) during both years than in all other tributaries. Total phosphorus load was higher in Pepperell Branch (station 16) than in Loblockee Creek (stations 20 and 21) in 2001 but Loblockee Creek (stations 20 and 21) had the highest load in 2002. Loblockee Creek (stations 20 plus station 21) led all tributaries in mean annual total suspended solids loads during both years. Cane Creek (station 22) was the second leading contributor of TSS to Sougahatchee Creek among the tributaries sampled. Forest clear-cuts on the Loblockee and Cane Creek watersheds apparently represented a major nonpoint source contribution of sediment to these streams. In addition, TSS loading from the Loblockee Creek watershed was the primary reason for the high total phosphorus loading. Much of this phosphorus enters streams bound to sediment particles. Among the smaller streams, station 17, draining the lower Fisheries Station, and station 14, Rocky Brook Creek (Opelika City Park), were also consistently high nonpoint source contributors of TSS to Sougahatchee Creek.

Our data clearly showed that concentrations of TSS throughout Sougahatchee Creek, and TP and TN in those downstream areas dominated by nonpoint sources, increased in concentration as rainfall and stream discharge increased. In addition, we were unable to consistently sample streams on the rising limb of the hydrograph following a rainfall pulse. Our data suggested that this likely resulted in additional underestimation of nonpoint source contributions to Sougahatchee Creek. Thus, the unusually dry conditions that existed during 2001 and 2002 resulted in a conservative estimate of annual nonpoint source loading to Sougahatchee Creek.

Physical Habitat

The physical assessment of each station revealed three sites that were suboptimal when compared to the reference stream. One was the 2nd-order site, station 18; one was the 3rd-order site, station 15; and one was the 4th-order site, station 6. All of these sites exhibited heavy sediment deposition primarily by runoff from the urban subwatersheds. The sedimentation reduced habitat diversity in the streams and provided less cover for macroinvertebrate colonization. All other stations were ranked as optimal, meaning that healthy aquatic communities would be expected at these locations.

Biological Assessment

During 2001 a total of 193 taxa were collected from all stations while during 2002 the number of taxa totaled 190. The term taxa refers to different species of macroinvertebrates collected in our samples, although not all are identified to the species level. A taxon is the lowest level to which an organism could be identified. Each year the fauna was remarkably similar with aquatic insects comprising 88 to 90% of the macroinvertebrates collected. The remainder of the fauna consisted mostly of oligochaetes, crayfish, snails, mussels, amphipods and isopods. The dipteran Family Chironomidae (midges) was the most diverse group of macroinvertebrates each year comprising 34 to 36 % of the total number of taxa. Of the six metrics calculated from macroinvertebrate samples we found three to be the most useful in explaining changes in these communities in the Sougahatchee Basin. The three metrics were the total number of species (taxa richness), the EPT Index (the number of insect taxa in the Ephemeroptera, Plecoptera and Trichoptera that are more sensitive to pollution), and the Hilsenhoff Biotic Index (HBI). Typically in unpolluted streams taxa richness and the EPT Index are relatively high compared to impacted streams. However, the method of calculating the HBI is such that the higher this value, the more polluted the stream.

Second-Order Streams. The biological condition of second-order sites did not compare favorably with the reference stream on any date except for stations 20 and 24. On 3 of the 4 sample dates macroinvertebrate communities at station 24 were ranked as nonimpaired, but for station 20 only one date was nonimpaired. Higher nitrate concentrations and sedimentation probably contributed to the impairment measured at these 2nd-order sites.

Third-Order Streams. The biological condition of third-order sites in Pepperell Branch at stations 15 and 16 was moderately impaired on all dates. Concentrations of nitrogen and phosphorus at station 16, below the West Point Stevens outfall, greatly exceeded those measured upstream from the outfall and apparently represented a major point source impact to macroinvertebrate communities at station 16. However, the EPT and HBI metrics reflected poor stream quality at both stations 15 and 16. In addition to the high nutrient concentrations at station 16, heavy sediment deposition was evident at station 15 and greatly reduced habitat available for colonization by macroinvertebrates.

Fourth-Order Streams. The biological condition for station 3A, just downstream from the Northside WWTP, was non-impaired in October 2001, but on each of the other sample dates this station ranked as slight to moderately impaired. On all dates the physical habitat at station 3A exhibited a high degree of sedimentation. Rocky substrates were covered with sediment at this site although woody debris, root masses, and gravel provided some stable habitat for macroinvertebrate colonization. Nutrient concentrations (both nitrogen and phosphorus) reaching station 3A would have been high because of the point source discharges upstream and partially explain why macroinvertebrate communities were impaired on 3 of 4 dates.

The biological condition at station 6 was slight to moderately impaired on each date. Nutrient concentrations at this station were high from upstream point sources and helped explain the poor biological condition observed. At station 7 the biological condition was non-impaired during October 2001, but for each of the remaining dates this site was slightly impaired. For stations 6 and 7 the high nutrient concentrations plus heavy sediment deposition appeared to represent the primary factors impacting macroinvertebrate communities.

The metrics calculated for macroinvertebrate communities at stations 8, 9, 11 and 12 compared favorably with those from the reference stream except for the November date in 2001. In fact, occasionally metrics from these stations exceeded those measured in the reference stream (Hatchet Creek). Except for the November 2001 date the biological condition measured at stations 8, 9, 11, and 12 was assessed as non-impaired. During November 2001, each of these stations was found to be slightly impaired.

In assessing the biological condition of sites in the Sougahatchee Basin, nutrient concentrations existing at the stations apparently had a greater impact on macroinvertebrate communities than the loading. Loading rates are closely related to discharge, which increased as catchment area (or impervious land cover) increased. Mainstream stations in Sougahatchee Creek showed definite improvement in biological condition downstream beginning with station 8 near Loachapoka. Relatively high concentrations of nutrients, $CBOD_5$ and minerals from point source inputs were critical in the Sougahatchee Basin because stations closest to the effluent discharge from the waste treatment facilities of Opelika, Auburn and West Point Stevens consistently exhibited the most biological impairment. Additionally, nonpoint source runoff of sediment to the stream contributed to habitat degradation that was part of the reason for the impaired macroinvertebrate communities found at stations 6, 7 and 3A.

Landscape Analysis

Changes in land cover occurred in the Sougahatchee Creek Basin during an 8-year period from 1993 to 2001. In 2001, the basin as a whole had about 67% forest, 12% clearcut, 7% urban, 7% tilled agriculture, 5% grassland and 1% each water and wetland. Forest and grassland coverage declined 17.3% and 1.1%, respectively, from 1993 to 2001. Increases in coverage during this time span were clearcut/barren (10.4%), urban/suburban (4.2%) and tilled agriculture (3.4%). These trends document the effects of increased human activities in the basin as a result of population growth. Lee County is one of the fastest-growing counties in Alabama.

Landscape Effects on Stream Loading and Biological Condition

Based on regression analyses, loading of $CBOD_5$, SRP, TN and TP in both 2001 and 2002 increased significantly (positive regression slope; $p<0.05$) as urban coverage of the basin increased. Loading of TSS was not significantly ($p>0.05$) related to urban coverage. On the other hand, increases in forest cover in the basin resulted in decreased loading of $CBOD_5$, SRP, TN and TP in Sougahatchee Creek. TSS loading was not significantly ($p>0.05$) related to forest coverage of the basin. The only land cover that was significantly ($p<0.05$) related to TSS loading was grassland. Increases in grassland coverage would be expected to decrease TSS loading of the mainstream Sougahatchee Creek. However, grassland cover was less than 6% of the Sougahatchee Creek Basin in 2001.

For the twelve tributary streams, variations in urban, forest and grassland coverage of the watersheds did not significantly ($p>0.05$) influence loading of $CBOD_5$, SRP, TN, TP or TSS during either year. One possible explanation for this disconnect between land cover and tributary stream loading was the lack of rainfall during 2001 and 2002 needed to mobilize sediment particles and nutrients from the watersheds to the streams.

Based on the regression equations for the mainstream Sougahatchee Creek Basin, increases in forestland cover and decreases in urban land cover would improve water quality and reduce loading of nutrients and $CBOD_5$. However, trends in the basin are for increasing urban growth (4.2% increase from 1993 to 2001) and decreasing forest cover (17.3% decrease from 1993 to 2001).

The biological assessment of streams in the Sougahatchee Basin established that several metrics exhibited significant correlations with landscape cover. For mainstream stations in 2001, a significant regression ($p<0.05$) between the Hilsenhoff Biotic Index (HBI) and land cover was found for all cover types. The HBI was positively correlated (positive regression slope) with urban and grassland cover, but negatively correlated (negative regression slope) with forest cover. The HBI is a metric that relates nutrient enrichment to impacts on macroinvertebrate communities. Higher HBI values are associated with nutrient enrichment. The significant positive regression ($p<0.05$) between the HBI and urban cover in 2001 indicated high nutrient concentrations associated with these stations, thus impairment of the biota. The trend between the HBI and urban cover was positive in 2002 although not quite significant ($p = 0.056$). The significant negative correlation between the HBI and forest cover indicated watersheds with fewer nutrients, thus less impairment to the biological communities. In 2002 the HBI regression was significant ($p<0.05$) only for forest and grassland cover. However, the significant positive regression between forest cover and the EPT Index during 2002 was important. This finding meant that as forest cover declined on the watershed, the EPT taxa (aquatic insects that are more sensitive to pollutants than most other macroinvertebrates) also declined. Or conversely, the watersheds in the basin with greater forest cover had streams with higher numbers of EPT taxa. Additionally, analysis for 2001 showed a positive relationship between the number of EPT taxa and forest cover although the probability values, while not significant, were close to the $p=0.05$ level. Also, correlation analysis showed that the EPT taxa and urban cover in both years exhibited a negative relationship as expected, although the probability values were not significant.

The regression analyses for the tributary streams provided more consistent relationships between metrics and land cover than those for mainstream sites. For example, we found significant regressions ($p<0.05$) between the EPT Index, HBI and Biological Condition score for urban and forest cover during both years of the study. This was also true for the taxa richness metric in 2002. Regressions between metrics and grassland cover were not significant ($p>0.05$) on any date. All of the tributary watersheds were smaller than those of the mainstream stations and for most land cover fell into one or two categories that dominated the watershed. Two land cover types, forest and urban, showed the strongest relationships with macroinvertebrate communities and stream health. Watersheds with the most urban land cover were found to have the poorest biological condition, while those watersheds with the most forest cover had the healthiest macroinvertebrate communities.

In this study of nutrient and sediment loading in the Sougahatchee Basin, and impacts to the macroinvertebrate communities, results at both mainstream and tributary stations reflected similar relationships to land cover type. Urban and forest cover showed the strongest relationship with these variables, whether considering nutrients, sediments or macroinvertebrates. Also, the relationships were strongest among the tributary watersheds where one particular land cover dominated. Mainstream stations are influenced by a greater diversity of land cover types upstream of a given site, all of which are integrated into the quality of the stream environment as the water flows through Sougahatchee Creek into Yates Lake on the Tallapoosa River.