# Comparing flow and sediment dynamics in an urban and forested stream in the Lower Coastal Plains of South Carolina

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**ABSTRACT**. The quantity of sediments transported by a stream is a critical component of stream ecosystem health and fluvial function. With burgeoning urbanization on the South Carolina coast, the impacts of sediment laden storm flows from these hardened tracts of land to streams can devastate riparian ecosystems. Typical sediment control measures treat all sediment in the water column as a pollutant, a function of anthropogenic activity on the landscape. However, while all streams naturally transport some amount of sediment, excessive sediment inputs can be detrimental to stream ecosystem health. Geomorphologic assessments of a reference stream and a degraded urban stream were carried out in the Coastal Plain region in South Carolina. The two streams provide information at both ends of the development spectrum, giving insight into how storm flows may be managed so that natural fluvial function of the stream is maintained. Channel morphology, flow rates and suspended sediment loads were measured to obtain an estimate of total sediments transported by the two stream systems. Comparisons between the two streams and the implications of this research on the management of stream systems in the face of urbanizing watersheds in the Coastal Plain physiographic region were examined.

## INTRODUCTION

The management of South Carolina's coastal streams has attained critical status as burgeoning development places increasing demands on riparian ecosystems. Increased runoff rates, sediment loads and attending water quality impairment have proved to be a great challenge to those who seek to preserve and maintain the integrity of riparian ecosystems in the region.

The low gradient, shallow water table, coarse-grained watersheds of coastal South Carolina present a unique hydrologic landscape to urban planners, stormwater managers and other regulatory personnel. Residential development, industrial operation, and tourism related commercial activities have seen explosive growth in recent decades (Tufford et al., 2003). The negative impacts of development upon riparian function have been widely documented in various geographic settings and at multiple spatial scales.

Coastal watersheds in South Carolina are the second largest destination for tourists, only exceeded by Florida (Allen et al., 1999). A greater understanding of how hydrologic alterations affect the unique coastal landscape of South Carolina would facilitate the development of low impact best management practices to both protect human life and maintain essential ecological services.

To arrive at a better understanding of the flow and suspended sediment dynamics in an urbanizing lower coastal plains watershed, a stream impacted by urban development (Crabtree Canal) was compared to a stream in an undeveloped watershed (Upper Debidue Creek) that shared similar hydro-climatic conditions. The comparison of flow and sediment transport offered a framework for evaluating the impacts of urbanization on riparian ecosystems in coastal South Carolina.

## PROJECT OBJECTIVES

The project objectives were to quantify suspended sediment exported from an urban and an undeveloped watershed in coastal SC.

## PROJECT DESCRIPTION

Located near Conway, SC, Crabtree Canal is a subwatershed of the Waccamaw River and is a third order stream with a drainage area of approximately 46 km² at its confluence with the Kingston Lake Swamp drainage network (Figure 1). Land cover classifications show that 18.2% of the watershed is developed; 25.4% is forested; 30.6% is pasture or cultivated crops and 25.8% is classified as wetlands. The dominant soil type present in the study site are Meggett loams and Wahee fine sandy loams, that are poorly draining soils characterized as hydrologic type D soils. The downstream reaches of Crabtree Canal are tidally influenced and also affected by backwater effects from the Waccammaw River. To remedy urban flooding problems in Conway, the US Army Corps of Engineers straightened and reshaped the channel to a large trapezoidal shape in the 1960's and thereby also disconnected the main channel from its natural floodplain.

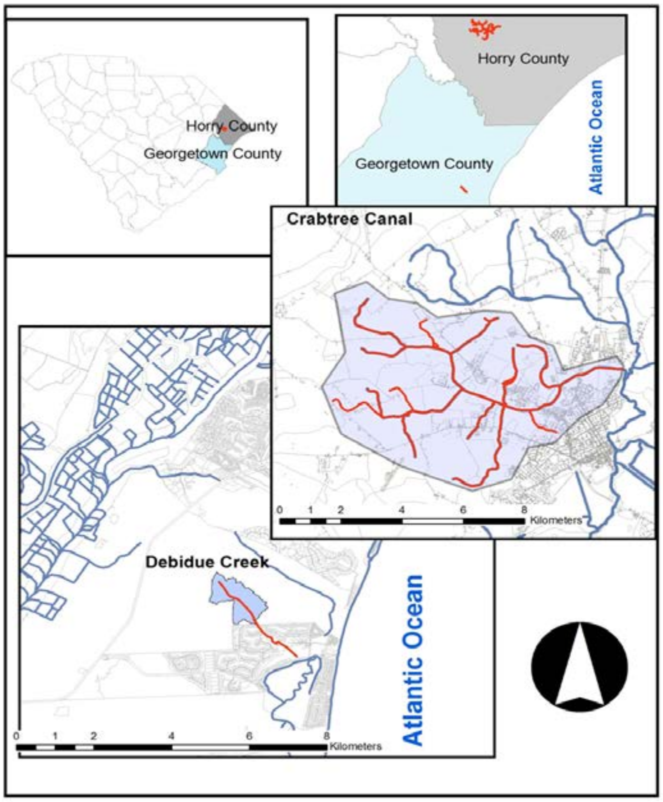


Figure 1: Map of the Eastern coast of South Carolina showing the location of two coastal plains watersheds, Crabtree Canal (Horry County) and Upper Debidue Creek (Georgetown County).

Crabtree Canal is currently on the 303(d) list for fecal coliforms, and appeared on the list for dissolved oxygen (DO) for 2000. High levels of turbidity following rain events are being recorded by a USGS sensor on the Crabtree Canal (USGS 02110701 Crabtree Swamp at Conway, SC). An analysis of turbidity data recorded between 9/26/05 to 12/17/07 at this gage showed that daily mean values for turbidity contravened the SC DHEC water quality standard (50 NTU) 10% of the time. These results would put the site at 'level of concern' per TMDL criteria. A US EPA 319 project (Libes and Bennett, 2004) also found high TSS/VSS loading following rain events. It is likely that if SC DHEC were to sample more frequently than it's monthly (now one every other month) rate, Crabtree Canal would be considered impaired with respect to suspended sediments. A similar analysis of daily mean DO (USGS data) for the same time period showed that the SC DHEC water quality standard was contravened for 23% of the days analyzed. The Crabtree Canal could therefore be classified as being at a level of concern for both turbidity and dissolved oxygen by SC DHEC.

Evidence of bank instability and mass-wasting is widely seen in the Crabtree Canal system. The watershed has undergone considerable urbanization in the last few decades (Figure 2). Typical consequences of unmanaged urbanization include increased peaks and volumes of stormwater runoff. Crabtree Canal was originally channelized to drain wetlands for the enhancement of agriculture. The process of channel maintenance is often performed with earth moving equipment used to dredge the bottom of the channel to ensure channel conformity with standard engineering design.

Upper Debidue Creek (UDC) is a first order stream about 50km due south of Crabtree Canal located on a coast parallel peninsula known as the Waccammaw Neck. This stream is relatively unimpacted and drains a tract of land called Bannockburn plantation with a watershed area of 1 km². The stream flows through the former plantation that has now been set aside in conservation and managed primarily for hunting. UDC is bordered on the east by the Atlantic Ocean and on the west by Highway 17 that acts as a catchment divide. The stream flows off the Bannockburn plantation property into a development, where a series of impoundments and tidal gates regulate flow; beyond its regulated reach, the stream discharges into the North Inlet tidal estuary and eventually into the Atlantic Ocean. The general topography is characterized by hydric Leon sands that are classified as hydrologic class B or D, depending on whether the soil profile is drained or not. High points on the watershed comprise well drained sands, while riparian margins comprise poorly draining soils. Habitat types in Bannockburn Plantation comprise forested wetlands, upland pine forests, non-forested wetlands, and riparian zones. UDC has well defined banks, a sandy bed, and a well-connected floodplain.

## METHODS

### Flow measurement

Flow data from Crabtree Canal were collected by a USGS real-time gaging station (USGS 02110701). Parameters of interest to this study and available for public download were: stage, average velocity, rainfall, and turbidity; data measured at 15-minute intervals. Fifteen-minute discharge data (not downloadable) were obtained for the entire period of record directly from USGS, and comprised raw discharge data that reflect the semi-diurnal tidal variation at the gaging station, and filtered data. Raw discharge data were filtered by USGS personnel using a low-pass filtering algorithm. At UDC, flow rates were measured using a modified 2-ft Parshall flume.

### Discrete suspended sediment sampling

At both study sites automatic water samplers (ISCO® 6712) were programmed to collect time-paced composite samples, triggered by rainfall. The samplers collected 250-ml aliquots every 30 minutes, with four aliquots composited per sample bottle and representing two hours of flow in the canal; the time between the first and last sample collected was 48 hours. The intake nozzle of the sampler was set at an elevation of about 0.5m above the stream bed. At the time of sample retrieval post-storm, two additional samples were collected; one via the autosampler intake nozzle and the other using a width-depth averaged sampler. This step allowed for establishing bias between sampler intake and the stream as a whole. At Crabtree Canal, a width-depth averaged sample was obtained by compositing several vertically integrated isokinetic samples collected at uniformly spaced intervals across a bridge deck adjacent to the sampling site. The vertically integrated samples were obtained using a US DH-48 suspended sediment sampler. Since UDC is a much smaller stream, a single vertically averaged sample collection was obtained for every sampled storm. Samples were analyzed in the lab per standard methods for suspended sediment concentration (SSC) and organic fraction by loss on ignition.

### Estimating suspended sediment loading rates

By establishing a regression relationship between SSC values measured during storm sampling and continuous turbidity measurements, long-term turbidity measurements were converted to SSC values that extended beyond the period of sampling. All SSC values were then converted to instantaneous loading rates by multiplying SSC by corresponding flow values. Instantaneous loading rates were then integrated over the period of record to estimate total suspended sediment yield from the watersheds.

## RESULTS AND DISCUSSION

### Storm sampling

Five storms were sampled in Crabtree Canal (Figure 3), and six storms in UDC (Figure 4). Site-specific linear regression models relating turbidity to SSC were statistically significant; a linear model explained 79% of the variation of turbidty with SSC at Crabtree (Figure 5a) and another regression model explained 90% of the variation of turbidity with SSC at UDC (Figure 5b). A comparison of measured SSC values from the two watersheds revealed that over the period of sampling, concentrations of suspended sediment in the water column were at least an order of magnitute greater in Crabtree compared to UDC (Figure 6).

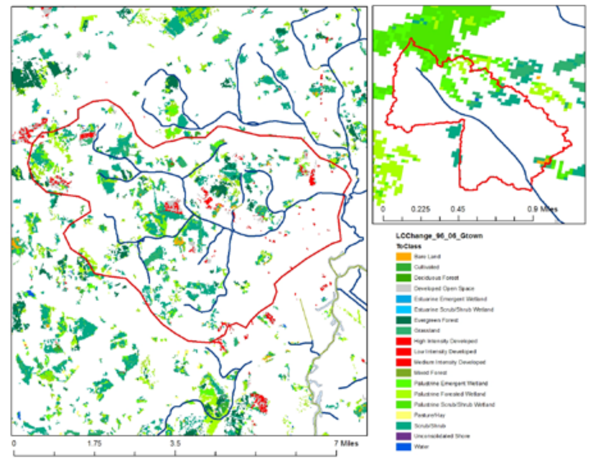

Figure 2: Landcover change in the urban (Crabtree) and undeveloped (UDC) watersheds between 1996 & 2006.

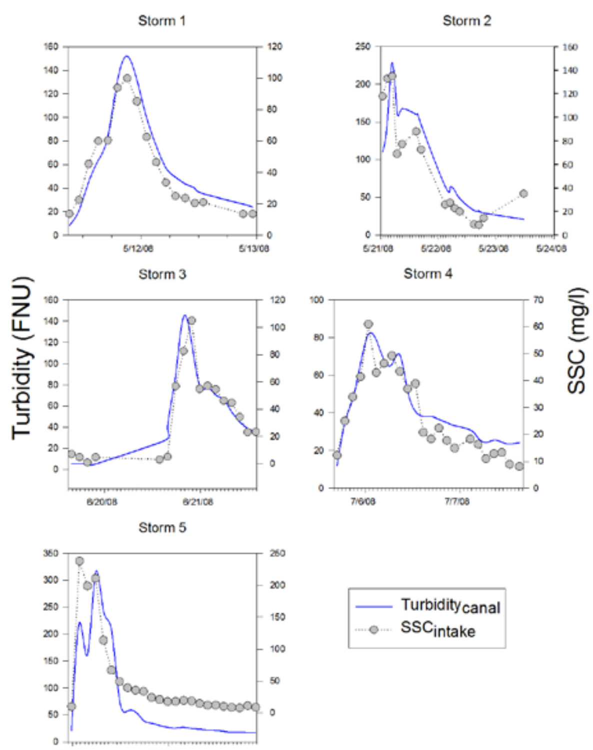


Figure 3:Turbidity and SSC for 5 storms at Crabtree Canal.

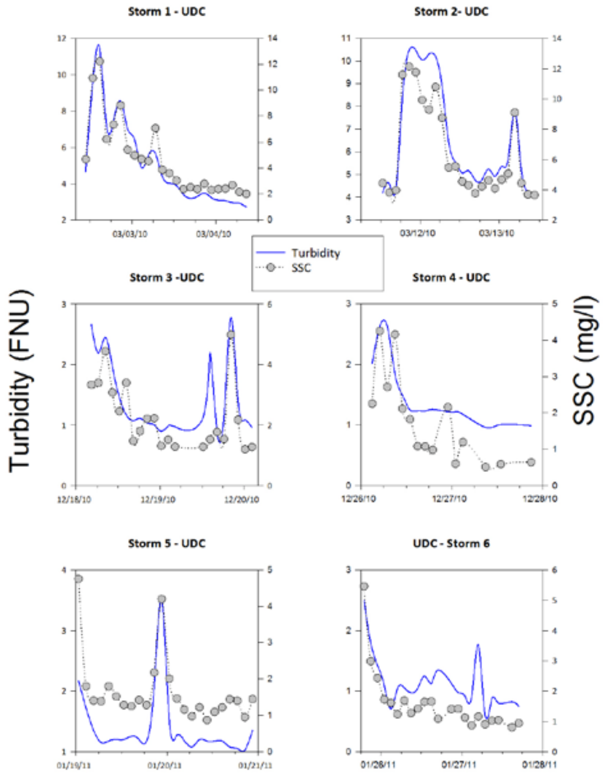


Figure 4: Turbidity and SSC for 6 storms at Upper Debidue Creek.

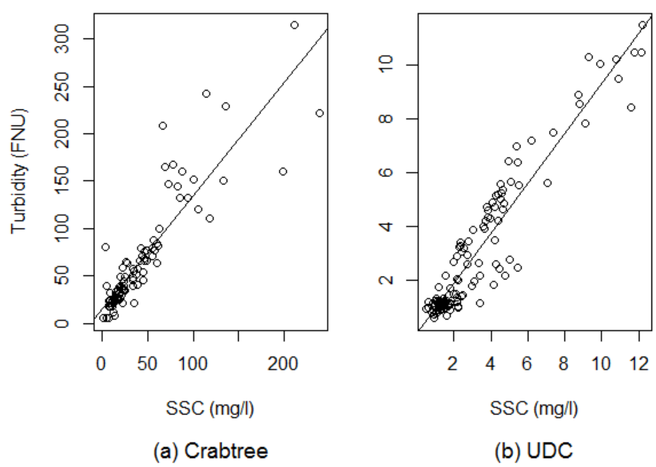


Figure 5: Turbidity versus SSC and linear regression models to explain data variation at both sites.

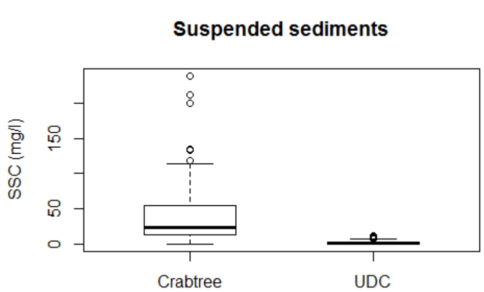


Figure 6: Measured SSC from the two sites showing the considerable difference between sites.

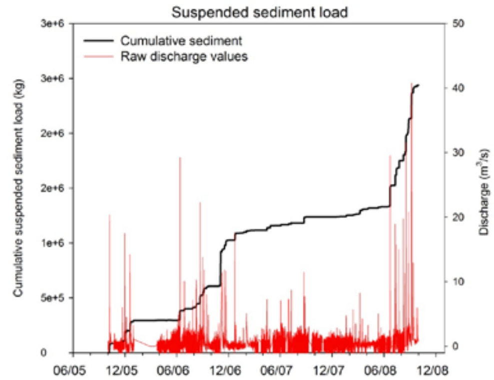


Figure 7: Estimated suspended sediment loading over the period of available data at Crabtree Canal.

By aggregating calculated sediment loading over the available flow and turbidity data from the two watersheds (e.g. Figure 7 that shows cumulative sediment yield in Crabtree Canal), the unit sediment yield (unit sediment yield = annual average of sediment per unit area of watershed) for Crabtree and UDC was estimated to be 5.3 and 1.4 tons/km$^2$/year respectively.

The results from this study show the considerable difference in suspended sediment yield from the two watersheds. The incision of Crabtree Canal due to the combination of watershed urbanization and traditional maintenance practices has served to disconnect the channel from its floodplain further exacerbating channel instability. Recent restoration measures on Crabtree Canal and efforts to minimize the dredging of sediments from the channel bottom are likely to limit the amount of sediment being exported from Crabtree Canal watershed. Continued data collection and additional monitoring of the system is warranted.

## LITERATURE CITED

Allen, J.S., K.S. Lu, T.D. Potts. 1999. A GIS-based analysis and prediction of parcel land-use change in a coastal tourism destination area. In: Proceedings of the World Congress on Coastal and Marine Tourism. Vancouver, British Columbia, Canada.

Libes, S. M. and J. Bennett. 2004. Section 319 Nonpoint Source Pollution Control Program Project Final Report FY 99-03: Identification and Mitigation of Non-Point Sources of Fecal Coliform Bacteria and Low Dissolved Oxygen in Kingston Lake and Crabtree Canal (Waccamaw River Watershed). 119 pp. EPA Grant # C 9994629-99.

Tufford, D.L., C.L. Samarghitan, H.N. McKellar Jr., D.E. Porter, J.R. Hussey. 2003. Impacts of urbanization on nutrient concentrations in small southeastern coastal streams. *Journal of the American Water Resources Association*. 39(2): 301-312.