MODELING LOW-ORDER WATERSHED FRESHWATER CONTRIBUTIONS TO ESTUARIES ALONG THE GEORGIA COAST

Isabelle D. McCurdy and James B. Deemy

AFFILIATION: Department of Natural Sciences, College of Coastal Georgia, Brunswick, GA 31525
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Abstract. Low-order watersheds are an understudied component of coastal hydrology relative to the area the systems occupy along coastlines. These low-order watersheds could represent substantial hydrologic and water quality contributions to the estuaries and sounds in which they discharge. Our objectives were to 1) map low-order watersheds (first- and second-order) that terminate directly into estuaries and sounds along the Georgia coast; 2) estimate monthly precipitation / evapotranspiration balances for each watershed; and 3) compare the collective contribution of these low-order watersheds to larger nearby watersheds terminating within the same estuary. Our focal areas of analysis are the coastlines along Glynn and Camden Counties, Georgia. Elevation data (10-m) was downloaded from the USGS Earth Explorer data portal. These data serve as input for modeling watersheds in ArcMap 10.6. Monthly rainfall data was interpolated from NOAA Precipitation Data Frequency Server gauging stations along the coast. Evapotranspiration was collected from UGA Extension Service. Precipitation and evapotranspiration were combined to generate a monthly water budget estimate for each watershed. Water budgets were used in combination with land use / land cover-based runoff estimates to model freshwater contributions to streams terminating in the estuaries and sounds. Our preliminary analysis indicates several dozen low-order watersheds in each county. These watersheds span a range of magnitudes and dominated by a variety of land uses and land covers. We believe that the modeling framework we have developed could also be applied in other regions with frequent low-order watersheds along the coastline.

INTRODUCTION

A watershed is defined as an area of land in which all of the incoming precipitation drains (i.e., "sheds") to the same place – toward the same body of water or the same topographic low area (e.g., a sinkhole) – as a result of its topography (Edwards et al., 2015). As streamflow is directly related to watershed size, we utilize the Strahler stream-order classification to identify the relative size of the watersheds that house these streams (Strahler, 1957).

First- to third-order streams are the lowest tributaries and are considered headwaters. Headwaters are commonly thought of as the beginnings of increasingly complex networks of streams. Along the coast, the lowest-order catchments can behave differently, as many empty directly into wetlands instead of a higher-order streams.

These lowest-order watersheds frequently dot the coastline in between river mouths and are often overlooked in terms of runoff contributions. Though comparatively low, their frequency is notable; headwaters are the most numerous streams, comprising 53% of total stream length in the contiguous U.S. (Nadeau & Rains, 2007).

Considering this information, it is possible that lowest-order watersheds contribute a notable freshwater discharge into coastal wetland systems. Our objectives involve identifying lowest-order coastal watersheds and calculating their potential freshwater output to coastal wetlands to understand the relevance of these seemingly minute contributions, in order to determine if identification of these watersheds would inform a more accurate calculation of freshwater output to wetland systems.

METHODS

The focal area of analysis for our pilot study was the Lower Georgia Coast near Brunswick, the Satilla and St. Marys Rivers (Figure 1). These river mouths are primarily in the Turtle River basin, with some low interruption from the Satilla River basin. In order to determine freshwater input, identification and mapping low-order watersheds was first required. Elevation data (10-m) was downloaded from the USGS Earth Explorer data portal.

Using this data as an input, flow direction and flow accumulation maps were generated from the elevation rasters using ArcMap 10.6. To delineate lowest-order watersheds, pour points were identified, with selection based on distance from river mouth and observable changes in vegetation that indicate freshwater-saltwater interactions.

Higher-order watersheds were eliminated from analysis to ensure only lowest-order watersheds were mapped. Monthly rainfall data was interpolated from NOAA Precipitation Data Frequency Server gauging stations along the coast. Evaporation data was collected from UGA Extension Service. Using ArcMap, the size of each watershed was logged and used in conjunction with precipitation and evapotranspiration data to calculate a monthly water budget estimate for each watershed.

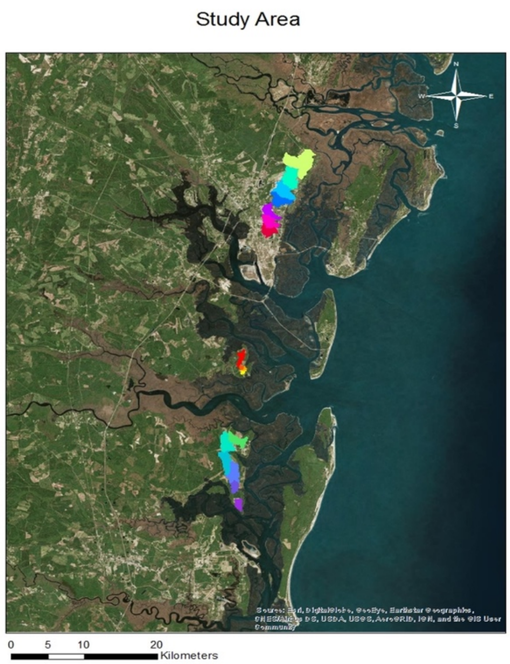

Figure 1. Smallest-order watersheds of the Lower Georgia Coast

RESULTS AND DISCUSSION

Seven low-order watersheds were identified in Brunswick, four below the Satilla River, and six above the St. Mary's River. In the spring months, evapotranspiration greatly exceeded precipitation, but in late summer to early fall precipitation exceeds evapotranspiration. For all three focal areas there was a positive freshwater output rate primarily in August, the early fall and mid-winter months, these would be ideal times to generate water budgets regarding freshwater output.

These low-order watersheds cover much of the coastline, but shallow topographic relief creates challenges in delineating these features. Although lowest-order watersheds outflows make up a relatively low input to coastal waters, their outflows may provide important freshwater inputs to local estuarine ecosystems.

Before completing this pilot study, future plans to further this study include identifying low-order watersheds along the entire Georgia coast, generating water budgets for each individual watershed, and compiling these results to compare with pre-existing water budgets in-order to determine the freshwater contributions lowest-order watersheds make overall.

Following analysis, the seasonal nature of the mean water balances may indicate a need to observe these watersheds on-site. Monitoring base flow and runoff over a series of months at the study areas would help to identify whether these streams are permanent or intermittent. The characteristics of each study area is also conveniently specific for studying the effects of land use on freshwater runoff.

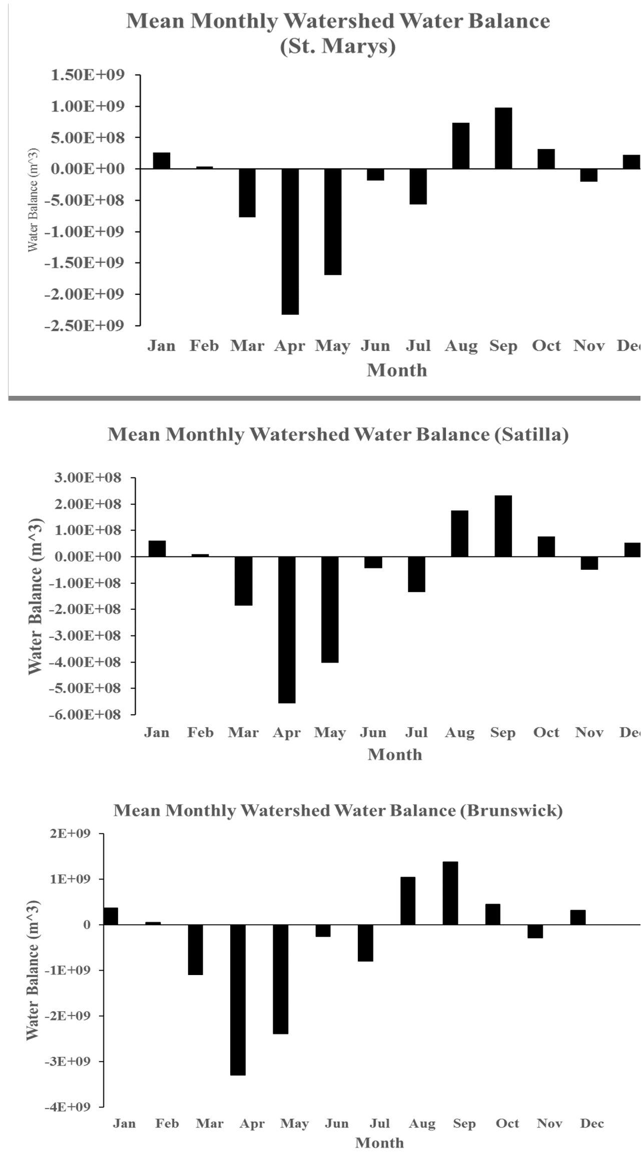

Figure 2. Water balances averaged over lowest-order watersheds. Top: St. Mary's River, Middle: Satilla River, Bottom: Brunswick.

The Brunswick area watersheds are primarily urban, the Satilla area watersheds are primarily industrial, and the St. Marys area watersheds are primarily agricultural. Comparing water quality between these three adjacent areas could help further understanding the impacts of land use on coastal ecosystems.

CONCLUSIONS

After delineating these low-order watersheds along the lower Georgia coast study area, it is apparent that these watersheds are insignificant in size, when considered individually. However, as previously stated, headwaters make up over half of stream length in the U.S. These low catchments maybe be extraneous on a singular level, but collectively they make any impact we have yet to fully understand.

Further investigation of the behavior these watersheds exhibit would give insight to the contributions they are making to coastal wetland systems, such as freshwater output, non-point source pollution, and sediment/organic transport. The possible impact on wetlands should be impetus enough to begin assessing low-order watersheds whenever possible, to find trends in these low watershed-wetland interactions.

ACKNOWLEDGEMENTS

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