

Watershed Management Planning for the Murrells Inlet Estuary using GIS: Delineation, Assessment, Identification, and Solutions for Fecal Coliform Loading

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ABSTRACT. Nonpoint source impacts from fecal coliform bacteria and the resulting closures of shellfish harvesting grounds has increased the awareness and concern in the Murrells Inlet community. The Murrells Inlet watershed, which extends from the Huntington Beach State Park in Georgetown County to the southern end of Surfside Beach in Horry County, is an elongated watershed with no major incoming freshwater tributary. The watershed is approximately 14.5 square miles. South Carolina Department of Health and Environmental Control (SCDHEC) approved a TMDL in 2005 to assess fecal coliform impairment within the inlet. In 2008, the community group Murrells Inlet 2020 (MI2020) sponsored a volunteer water monitoring program in partnership with Coastal Carolina University (CCU), Horry, and Georgetown County. When SCDHEC released the 2011 Shellfish report it resulted in the closure of approximately 241 acres of shellfish harvesting grounds on the south end of the inlet. This prompted MI2020 to endorse the development of a watershed-based plan that was funded in part by EPA Section 319 and 604(b) grants provided by SCDHEC.

The Earthworks Group was a major contributor of services as part of the local grant funding match. Our role included the application of engineering and GIS to address fecal coliform loading within the estuary. Our GIS centric approach included assessing several key areas. First was the development of a LiDAR surface model which was used to define the overall watershed. These data were supplemented by stormwater infrastructure information provided by both counties to further define 53 subwatersheds ranging in size from 632.9 to 4.7 acres. There are 25 subwatersheds situated along the Murrells Inlet shoreline with runoff entering the inlet via overland sheet flow.

Subwatersheds were analyzed using the SCS Runoff Curve Number (CN) method with a 2 year storm event and Time of Concentration (Tc) flow paths. To generate curve numbers a localized Land Use Land Cover (LULC) data layer was created and integrated with USDA NRCS

Soils data for the watershed to provide a curve number data layer. This process was also replicated using almost 20 year old historic NAPP color infrared aerial photography. The final application of these data were to prioritize subwatersheds based upon the location of their outfalls in relation to SCDHEC monitoring stations within the inlet with the goal of identifying areas of concern for Best Management Practice implementation.

This watershed-based planning effort will provide the framework for water quality solutions within the Murrells Inlet estuary that are likely to aid in reducing fecal coliform loading from subwatersheds that discharge near the higher priority SCDHEC monitoring stations. Suggested improvements which could easily be implemented watershed-wide that would quickly begin benefiting the estuary include pet waste stations and educational outreach. The plan also provides engineered solutions that could be implemented with additional funding.

INTRODUCTION

The Murrells Inlet Watershed Based Plan (WBP) is the result of an almost two year effort that started in 2011 when SCDHEC revised Shellfish classifications within Murrells Inlet. These revisions changed many areas that had previously been approved to conditionally approved and further increased the areas of restricted classification on the southern end of the estuary. After guidance from CCU, MI2020 was advised that a WBP could help determine why these changes were occurring. As a result, MI2020 approached Horry and Georgetown County during the spring of 2012 about partnering on a plan. Coincidentally, after the counties agreed to join SCDHEC announced grant funding opportunities for communities interested in pursuing watershed management plans. However, these opportunities stipulated that involvement from a Council of Governments (COG) was required. Shortly thereafter, the WRCOG agreed to oversee the plan. In June 2012,

WRCOG applied for a Section 319 Watershed-based Plan Development Grant which was awarded in October 2012. EARTHWORKS then became involved as a significant contributor of services to fulfill a portion of the local grant funding match. Other key stakeholders included Grand Strand Water and Sewer Authority (GSWSA), and Georgetown County Water and Sewer District (GCWSD). Lastly, and as equally important, the Steering Committee reached out and sought input from local residents.

The plan's main concern is the impact fecal coliform bacteria concentrations are having on the Eastern Oyster (*Crassostrea virginica*) which is prompting shellfish bed restrictions and closures. Oysters are a distinct part of the local culture of Murrells Inlet, which is widely regarded as the most economically important shellfish producing area along the northern South Carolina coast (WRCOG 2014).

This WBP sought to identify sources of fecal coliform bacteria impacting water quality in and around the oyster beds. Then, over a 20 year period, the WBP recommends ways to improve water quality by reducing fecal coliform loadings. In 2005 SCDHEC drafted a Total Maximum Daily Load (TMDL) report for the Murrells Inlet watershed that identified non-point sources of pollution as the main contributor to eight monitoring sites failing to meet the fecal coliform standard at that time. The standard established in the TMDL requires an 80% reduction in bacteria loads in order to comply with the water quality standard for shellfish harvesting which is implemented nationwide under the National Shellfish Sanitation Program as overseen by the US Food and Drug Administration (FDA) (WRCOG 2014).

Additional goals include highlighting the history of the Murrells Inlet fisheries industry while promoting the cultural, economic, and outdoor recreational benefits associated with shellfish harvesting sustainability. The plan's final goal was to increase the public's environmental sensitivity awareness regarding the shellfish harvesting areas and protecting water quality within the inlet (WRCOG 2014).

The primary goal of EARTHWORKS services included providing baseline spatial data and analysis, and technical assistance needed to quantify localized hydrology entering the estuary along with how land use issues within the watershed were impacting fecal coliform levels. EARTHWORKS was also fully engaged in all other stakeholder level aspects of the planning process as well.

The Murrells Inlet watershed generally extends from the Huntington Beach State Park and North Litchfield portions of Georgetown County to the Garden City Beach and the southern tip of Surfside Beach in Horry County along the Hwy 17 corridor.

The currently accepted primary delineation is the U.S. Geological Survey (USGS) 12-digit Hydrologic Unit Code (HUC), named Main Creek, for Murrells Inlet which has the classification number 030402080308 (Seaber *et al.* 2007). This HUC consists of approximately 10,049 acres and is seen in Figure 1.



Figure 1 – USGS 12-digit HUC

METHODS

The current 12-digit HUC classification was derived from information which lacks sufficient localized stormwater infrastructure as well as decent base topography. Therefore, our first step was to develop a higher resolution base topographic layer. This layer was created using Light Detection and Ranging (LiDAR) data provided by Horry and Georgetown Counties and became the foundation for delineating an accurate watershed.

Further, previous delineations have only included the overall watershed. Because of variability within the coliform data found between monitoring stations from the northern and southern ends of the estuary, it was determined that further sub-delineations would be required to meet our goal of localized data specific to each monitoring station. This subwatershed approach was imperative because a review of the historical monitoring yielded the need to focus resources on addressing fecal coliform loads at monitoring stations which remained consistently above the Shellfish Fecal Coliform water quality standard.

LiDAR data were processed from 3-dimensional point cloud data LAS (Laser) files using ESRI ArcGIS into a singular mosaic ArcInfo 32 bit floating point grid file. A grid is a raster array of equally sized square cells, in this case 5'x5'. Digital Elevation Model (DEM) grids are particularly beneficial in spatial modeling and hydrologic flow analysis.

At this point the DEM was processed using ArcGIS Spatial Analyst hydrology tools. Because it is best to use a dataset free of sinks (ESRI 2014), the raw DEM file was processed to fill sinks which smoothes irregularities. The smoothed DEM provides a more accurate representation of overall flow and became the base for a flow accumulation grid. A flow direction grid was also created to account for direction of flow by determining

the direction of steepest descent from each cell (ESRI 2014).

Stormwater infrastructure data obtained from both Horry and Georgetown Counties included pipes, ditches, catch basins, manholes, and junction boxes. Most of these data were obtained in GIS format although there were also hardcopy engineering plans that were digitized and manually input into the final watershed maps included in the WBP.

With the requisite input data layers processed, a base watershed layer was created using the watershed tool. The default watershed size was initially set to a mean of 10 acres so that substantially smaller neighborhood-sized subwatersheds could be delineated and then assessed relative to county stormwater infrastructure data. These watersheds ranged in size from 57 acres, the largest, to a less than 1 acre sized subwatershed. The watershed tool processed total areas flowing to a given outlet or pour point, typically the lowest points within the mean 10 acre area. Often these areas would terminate at locations where stormwater infrastructure information indicated an existing structure or conveyance.



Figure 2 – Overall Murrells Inlet watershed

The final overall watershed area, seen in Figure 2, is approximately 9,248 acres or 14.5 square miles. The estuary comprises approximately 2,938 acres with the remaining 6,310 acres consisting of upland areas that contribute stormwater runoff to the estuary. Our primary goal was to isolate, as much as possible, areas within the watershed which were contributing to the variability found between the coliform levels at monitoring stations from the northern to southern ends of the estuary.

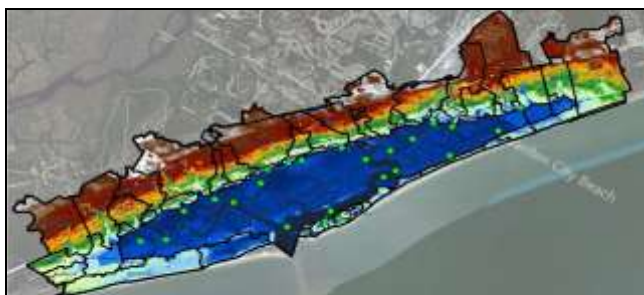


Figure 3 – Subwatersheds with SCDHEC monitoring stations

As a result the overall watershed was subdivided into 53 subwatersheds (Figure 3) ranging in size from the largest, the 632 acre Melody basin to the smallest, the 4.7 acre Boat Landing subwatershed. All of the subwatersheds were named based upon recognizable local landmarks, streets, neighborhoods, or other community features that would distinguish them with the residents.

The originally delineated 815 subwatersheds were combined into larger subwatersheds based upon their eventual outfalls into the estuary. There were 21 subwatersheds, of the final 53 subwatersheds, with no singular outfall location into the inlet. These subwatersheds are primarily those directly adjacent to the estuary and consist of directly discharging overland flow.

These larger final subwatersheds were important because the steering committee designated the SCDHEC monitoring stations with priority levels by tier. For example, Tier One sites were those that have not met the 90th Percentile nor Geometric Mean standard for the entire assessment period of the long term trend analysis.



Figure 4 – Subwatersheds with prioritization

Station 04-16 as displayed above in Figure 4, a Tier One site, can be seen relative to the closest contributing subwatersheds. In this example those watersheds were Mariner/Wesley, Coquina, and Wachesaw. At 408.8 acres, Mariner/Wesley is the fourth largest subwatershed discharging into the estuary and a significant contributor to hydrology that courses past Station 04-16. Knowing which subwatersheds discharge into the estuary closest to the monitoring stations showing impairment allowed the steering committee to assess targeted BMP implementation options.

Land use and historic land use change were also analyzed in conjunction with United States Department of Agriculture (USDA) soil survey data with the goal of developing a set of curve number data layers for 1994 and 2012 with the goal of illustrating changes in overland flow based upon development.

The USDA Soil Conservation Service (SCS) developed the Curve Number (CN) method to help determine rainfall runoff rates during storm events. They

are calculated by evaluating the hydrologic classification given to soil groups in conjunction with the type of land use present.

Land use/Land Cover (LULC) data are available through USGS, as well as through SCDNR as part of the National Wetland Inventory/LULC data set. These data, while valuable, were heavily outdated and created at 1:24000 scale which didn't provide the localized mapping resolution required to prepare an accurate CN layer.

The LULC was used as a starting point and cropped to the overall watershed and then edited extensively by manually creating polygons for all of the varying types of residential and commercial development and forested areas as seen in the 2012 natural color aerial imagery. Further these data were joined with impervious data available from Horry County. Impervious data from Horry County included paved roads, sidewalks, driveways, parking lots, and building footprints. Impervious data were not available from Georgetown County. Therefore street centerline data were used to create a paved road layer with widths based upon road type. While LULC classifications are designed to account for the impervious nature of a given land use, having additional impervious data provided a more accurate stormwater runoff representation.

To assess changes in land use properties over time, the processes described in the previous paragraph were recreated with polygons derived from 1994 National Aerial Photography Program (NAPP) Color Infrared (CIR) aerial photographs. Impervious data from current county data sets were removed if those features were not present at that time.

With the base LULC layers completed, the final step to create a CN data layer was to join these data with the USDA SCS soils data available online through SCDNR. Each soil series is designated with an engineering property for that soils type. For example, a Type A soil is highly permeable whereas a Type D soil is far less permeable.

When soils data were combined into the new CN layer it became possible to create a new attribute within the data to express CN per polygon. These attributes were derived from the TR55

CN table, seen simplified for display in Table 1 (USDA 1982).

Other data layers that were assessed included septic and sewer system information gathered from GCWSD and GSWSA. Particular attention was given to the locations of pump stations which were closest to the estuary and SCDHEC monitoring stations.

DISCUSSION

To understand fecal coliform loading into the estuary it was paramount that an accurate assessment of stormwater drainage be obtained. During rainfall events water that doesn't infiltrate into the ground becomes runoff that flows across the surface and into ditches, streams, or other stormwater conveyances before eventually reaching the closest main waterbody. Most conventional storm sewer systems do not have treatment mechanisms; therefore runoff carrying debris, sediment, bacteria, or other non-point source contaminants is discharged into the inlet.

Impervious surfaces halt groundwater infiltration which leads to higher surface runoff rates and volumes. As development changes the natural hydrology within a watershed, there is increasing pressure to retrofit existing stormwater infrastructure to cope. Balancing water quality and water quantity requirements in the design of stormwater infrastructure in new developments continues to provide challenges for engineers and stormwater managers.

In addition to the subwatershed information, the CN data were beneficial to stormwater engineers when calculating cursory discharge figures for each subwatershed. These discharge rates were valuable in understanding the rate at which coliforms were arriving into the estuary. Understanding how CN values work can be thought in terms of permeability, which is the rate at which the ground can absorb rainfall before overland sheet flow begins to occur. Soils with high permeability (Type A) that can retain more water during rainfall events, if found in a forested area with no impervious surfaces, would have a very low CN value (e.g. 30). A 30 value means that the landscape will retain and release water from the watershed slowly.

Comparatively, an area of Medium Density Residential (1/4 acre lots) land use with poorly drained soils (Type D) would have a much higher Curve Number Value (e.g. 87). Those areas would more rapidly release water if there was a lack of onsite retention. Finally, fully impervious surfaces such as asphalt parking lots, driveways, and roads are designated with the highest Curve Number (e.g. 98). These areas exhibit the highest runoff rates following rain events because water

Land Use Description	TR55 Curve Numbers				
	% Imperv. Areas	A	B	C	D
Agricultural	64	75	82	85	
Commercial	85	89	92	94	95
Forest		30	55	70	77
Grass/Pasture		39	61	74	80
High Density Residential	65	77	85	90	92
Industrial	72	81	88	91	93
Low Density Residential	25	54	70	80	85
Open Spaces		49	69	79	84
Parking and Paved Spaces	100	98	98	98	98
Residential 1/8 acre	65	77	85	90	92
Residential 1/4 acre	38	61	75	83	87
Residential 1/3 acre	30	57	72	81	86
Residential 1/2 acre	25	54	70	80	85
Residential 1 acre	20	51	68	79	84
Residential 2 acres	12	46	65	77	82

Table 1 – TR55 Curve Numbers

immediately begins flowing across them with no infiltration (WRCOG 2012).

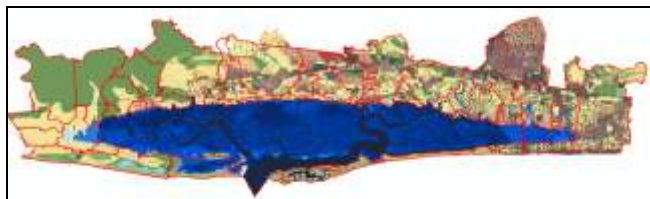


Figure 5 – Curve Number layer with subwatersheds

The overall curve number layer is seen above in Figure 5. In this figure it is apparent that the south-end of the watershed is less developed meaning fewer impervious surfaces, which are indicated by the higher concentrations of yellow and green. This should allow for bacteria die-off or infiltration into the soil before being washed into the inlet. This happens because the rate at which the bacteria arrive in the inlet via stormwater runoff is lessened, increasing their die-off rate through additional sunlight/UV exposure. Also, longer exposure to the soil profile via infiltration increases the chances that fecal coliform will adsorb to soil particles lessening their odds of arriving into the estuary. However, the wildlife and waterfowl concentration on the south-end is higher because these natural habitats become a migration point for other animals from the developed areas in the inlet (WRCOG 2014).

Areas of the inlet's east and west shorelines, and on the north-end, have greater development indicated by the browns and grays, resulting in more impervious surfaces. These impervious surfaces cause the water carrying the bacteria to arrive in the inlet more quickly without natural filtration. Additionally, more fresh water inputs into the inlet reduce salinity which allows bacteria to survive longer (WRCOG 2014).

CONCLUSIONS

GIS software and the ever increasing complexity and resolution of spatial data continues to provide watershed planners, scientists, and engineers with analytical tools to develop continually more creative solutions for watershed improvements. While a subwatershed approach is not a new concept, our ability to synthesize all of the differing data sets and present them in ways that the stakeholders and community could understand was greatly beneficial. The strong baseline dataset helped focus the efforts of all involved more effectively.

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