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An ASABE Meeting Presentation

Paper Number: 083971

Rainfall-Runoff Modeling of the Chapel Branch Creek Watershed using GIS-based Rational and SCS-CN Methods

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Written for presentation at the
2008 ASABE Annual International Meeting
Sponsored by ASABE
Rhode Island Convention Center
Providence, Rhode Island
June 29 – July 2, 2008

Abstract. *Chapel Branch Creek (CBC), located within the Town of Santee adjacent to Lake Marion in Orangeburg County, SC, is listed on the SC 2004 303(d) list of impaired waterbodies due to elevated levels of nitrogen (N), phosphorus (P), chlorophyll-a, and pH. In this study, using a GIS-based approach, two runoff modeling methods, the Rational and SCS-CN methods, have been applied to the (~1600 ha) CBC watershed to estimate both event storm runoff and peak runoff rates. Rainfall intensities from five observed storms were used in the models together with the runoff coefficients and curve numbers (CN) for various land use categories obtained by digitizing (1:5000 scale) 2005 NAIP aerial photos of 1-m resolution. In order to test the models, results were compared to the observed peak flow rates and runoff for storm events recorded at sampling location 7 (SL-7), which drains an area of ~583 ha within the watershed. Results of this study show that a weighted low C-value (Rational Method) and a weighted Q (SCS-CN method) yield the most accurate estimates of peak runoff rates. The peak rates estimated by the SCS-CN method were in better agreement with the observed data than the Rational Method. In addition, both the estimated runoff depths and the peak flow rates were more accurate when aggregated by sub-unit within the catchment than when calculated for the whole drainage catchment using the SCS-CN method.*

Keywords. Hydrologic modeling, Peak runoff rate, Runoff depth, Curve Number, Runoff Coefficient

Introduction

The main objective of this paper is to examine the ability of the Rational and SCS-CN methods of rainfall-runoff modeling for predicting storm event outflows in a mixed land use watershed. The Chapel Branch Creek (CBC) watershed drains an approximately 1200 acre land area in the South Carolina coastal plain. This study looks at the modeling and validation of the models in a ~583 ha sub-watershed (SL-7). Both models use the latest GIS-based spatial data including the 1:5000 scale NAIP land use imagery for characterizing the watershed. Implications of this work to the full watershed can be found in Mihalik, 2007.

The Rational Method, a simple empirical formula used to estimate peak runoff rates for small watersheds, was developed by Mulvaney in the UK in 1851 and introduced to the US by Kuichling in 1889 (Burian, 1999). It is the most widely used uncalibrated equation, relating peak discharge to drainage area, rainfall intensity, and a runoff coefficient (McCuen, 1998). Despite some limitations including those related to drainage area size and runoff coefficients (see Mihalik, 2007), the Rational Method is appreciated for its simplicity, and has been used in rainfall-runoff analyses for over 100 years.

Wiles and Levine (2002) studied the effects of changes in land use on hydrology within the Swan Creek Watershed located in Lucas County, Ohio using highly detailed land use and hydrography mapping. Runoff modeling for this study was performed using a modification of the Rational Method, proposed by Rossmiller (1980). The chosen runoff methodology for this study generally over-estimated the amount of water flowing to the outlet when compared to previous studies of the watershed. It was suggested that the over-estimation may have been due to inherent differences in the input parameters used in the models.

The SCS-CN method is an event-based model developed by the USDA Soil Conservation Service (SCS). A curve number (CN) is a land cover index for a given land and soil type to determine the amount of rainfall that infiltrates into the ground and the amount that becomes runoff for a specific storm event (USDA, 1986). The SCS-CN method is the most common technique for estimating storm runoff volume (Zhan and Huang, 2004). Many watershed models, including the USDA Agricultural Research Service (ARS) SWAT model (Arnold et al., 1998), incorporate this method for determining runoff despite some of its limitations including: no explicit accounting for the effect of antecedent moisture conditions, difficulty in separating storm runoff from the total discharge hydrograph, and peak runoff rate is not obvious.

To convert runoff volume to peak runoff rate, the SCS Graphical Peak Discharge formula is used (USDA, 1986). This method should only be used when the CN is greater than or equal to 50 and the time of concentration (the time it takes for surface runoff to travel from the hydraulically farthest portion of the watershed to the outlet) is between 0.1 and 10 hrs.

Zhan and Huang (2004) describe the development and application of the ArcCN Runoff tool, an extension of ESRI ArcGIS software which can be applied to determine curve numbers and calculate runoff or infiltration for a storm event within a watershed. Zhan and Huang also suggest that the implementation of a precipitation time series and the consideration of factors such as dry and wet antecedent moisture conditions (for CN parameters) would improve the predictions of the ArcCN Runoff tool.

Methodology

Site Description

Chapel Branch Creek watershed is located within the upper coastal plain region of Orangeburg County, South Carolina, adjacent to Lake Marion and near the Town of Santee and

Interstate highway I-95 (Figure 1). The CBC watershed drains a land area of ~1600 ha (4000 acres) at the SC-014 outlet located ~1.5-3 km upstream of Lake Marion in the northeast quadrant (USDA, 2007). Topography of the watershed is characterized by flat lands at about 36.6 m (or 120 ft) a.m.s.l. in the upstream areas with somewhat steeper topography (25.9 to 30.5 m or 85 to 100 ft a.m.s.l.) on the downstream section near Lake Marion (USDA, 2007). Interstate 95 (I-95) and SC Highway 15 (SC 15) run north-south through the Town of Santee (located within the watershed). Similarly, Highways SC 301 and SC 6 run east-west in the southern boundary and through the Town of Santee, respectively. The watershed incorporates complex land use patterns with residential, commercial, and industrial areas interspersed among agricultural and forested lands. Most of the forested lands are located within Santee State Park on the left bank of the CBC. There are two golf courses and a wastewater treatment plant located along the eastern boundary of the drainage area (USDA, 2007). The soils in the watershed are dominated by moderately to somewhat poorly-drained Goldsboro-Lynchburg series sandy clay loam on most of the agricultural areas in the west and southwest and somewhat well-drained Neeses series sandy clay loam to the west and east (SCS, 1988).

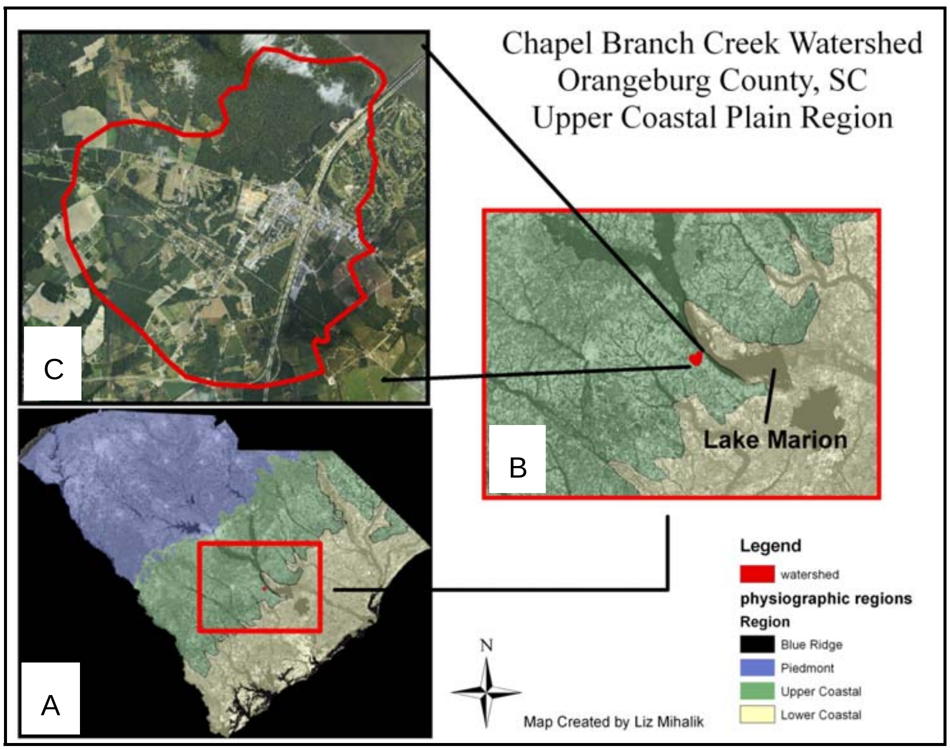


Figure 1. CBC study site, upper coastal plain region - Orangeburg County, SC. (A) Watershed in relation to physiographic regions of SC. (B) Watershed drains to lower coastal plain and Lake Marion. (C) 2005 NAIP aerial photo of CBC watershed (Town of Santee in center of watershed).

GIS and Watershed Characterization

The version of Geographic Information Systems (GIS) used in this study was ArcGIS 9.1. Spatial data layers (aerial photography, hydrology, hypsography, soils, topography, and digital elevation models) were collected from a number of sources (Mihalik, 2007).

The first step for CBC watershed characterization was to enhance the existing elevation data using USGS topographic digital line graph (DLG) data, local surveys, and other sources including the US Army Corps of Engineers' (USACE) surveys in digital forms. All data sets were projected to the same coordinate system and integrated to provide a vector topographic coverage that could be interpolated to a raster digital elevation model (DEM) for use in the runoff modeling. In addition to topography, the three quadrangles of hydrology, hypsography, and soils data were each appended and dissolved in the GIS to form the datasets useful for delineating and modeling the watershed, Figure 2(a).

The main watershed boundary was derived from a number of data sources including the retrieved South Carolina Department of Transportation boundary (SC DOT, 2004), vector topography, and the DEM. In the GIS, both the *flow direction* and *flow accumulation* tools were used to create stream lines. The watershed boundary could then be digitized to include the area drained by these streams. A site visit, along the eastern section of the watershed, confirmed the boundary was altered by drainage ditching, which modified the stream routing derived from the DEM. Once the watershed boundary was determined, all layers were clipped to this boundary.

Subwatersheds were delineated similarly to the main watershed boundary. Based on the *flow direction/flow accumulation* tools, the main watershed boundary was cut into subwatersheds using the *cut polygon* feature (Spatial Editor). A site visit verified drainage of streams along the eastern boundary. Pourpoints (or outlets) were added at stream nodes and each subwatershed was given a number corresponding to the proper drainage outlet.

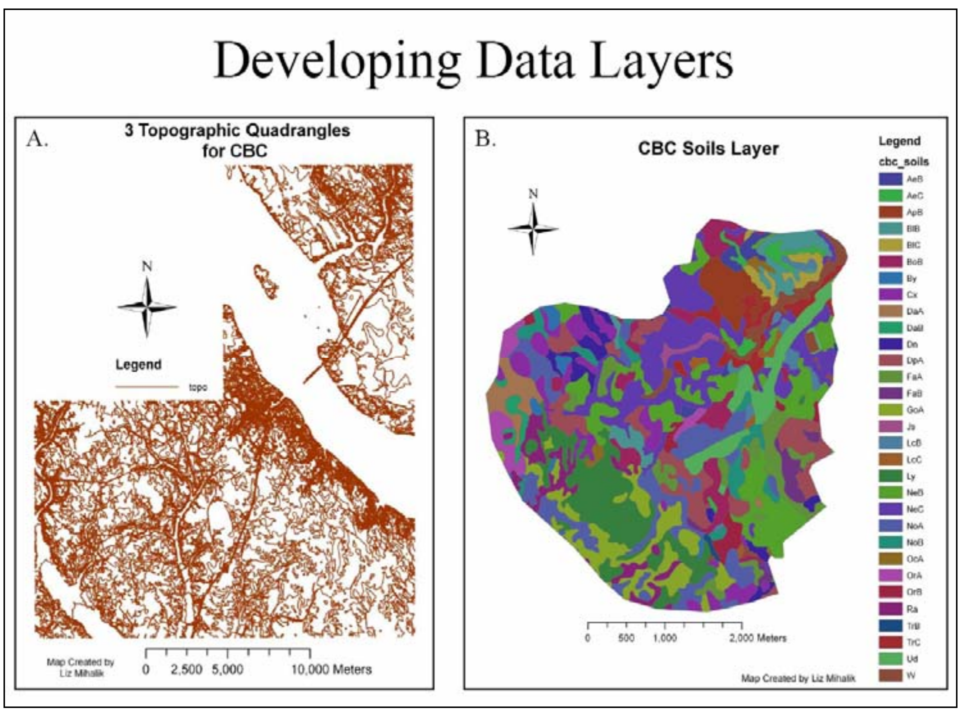


Figure 2. A. Three digital topographic quadrangles containing the CBC watershed. B. SSURGO Soils Data Layer (31 different soil types in CBC watershed).

To obtain accurate runoff results, it was necessary to develop a detailed land use map based on high-resolution, NAIP aerial photography (2005 imagery with 1-meter resolution), to identify areas associated with various land use characteristics within the watershed. Impervious transportation surfaces including roads, parking lots, driveways, and paved trails were mapped along with buildings, water bodies, golf courses/fairways, forested areas, agricultural fields, open water and swimming pools, sand traps, beaches, and bare ground (including construction sites). Digitizing was completed at the 1:5000 scale, or less to create a final land use map in the GIS utilizing *union, integrate, dissolve*, and *update* tools. Once the detailed land use map was completed, it was intersected with both the subwatershed and soils layers to create a single data layer for use in runoff modeling. This layer had subwatershed, soil, and land use information coded for every polygon in the map.

Figure 2(b) shows the SSURGO soils data layer which characterizes the CBC watershed. There are 31 different soil types within the watershed. More information on these soils can be found online at: http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/.

Hydrologic Measurements

Rainfall data collected from three automatic and corresponding manual rain gauges at the study site were analyzed in Microsoft Excel for daily, hourly, and monthly time periods (Mihalik, 2007); however, only rain data from the Town Hall gauging station was used for modeling. One (2006) observed storm was identified to test the Rational and SCS-CN methods on the entire CBC watershed, and four observed storms (2007) were identified to test the models on the SL-7 drainage area only. Daily rainfall data (assessed using Pivot Tables) were used to identify the days with the greatest amount of rainfall and the greatest hourly intensity for each storm (Mihalik, 2007).

Streamflow data was collected at the SL-7 gauging station and calculated for four observed (2007) storms (March 1, March 16, April 15, June 20), which were identified based on rainfall volume and the peaks illustrated on the stage level graph recorded at SL-7 (see Mihalik, 2007). Volume was estimated based on the flow rate (cfs) graph in Figure 3.

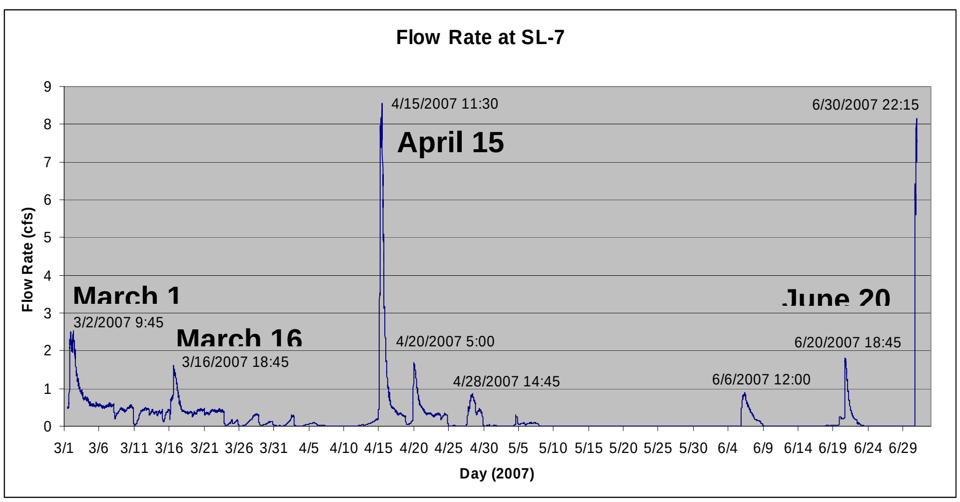


Figure 3. Flow rate (cfs) recorded at SL-7.

Runoff Models

Runoff models including the Rational Method and the SCS-CN method were applied to the entire CBC watershed for one observed storm - August 21, 2006. These results can be used to determine potential "hotspots" within the watershed where the most runoff will be generated during a storm. These areas may also contribute the most to sedimentation and nutrient loadings within the Chapel Branch Creek.

Table 1 shows the literature derived C-values (Fetter, 1994; McCuen, 1998; Purdue, 2007; NJ DOT, 2001; CT DOT, 2003), from low to high, used in the Rational Method. Fields were added into the attribute table for each C category. Based on land use type, appropriate C-values were inserted into each field to allow for low, average, and high runoff estimates. A field was added to the attribute table for area (A) and was calculated in acres by multiplying [Shape area (in m^2)] by [0.0002471] for unit conversion. A field was added for each observed storm intensity (I), which was input in inches per hour. Three fields were added to the attribute table for low, average, and high peak runoff rate (Q_p) for each of the observed storms to be modeled. Peak runoff rate was calculated for each column based on the Rational Method formula. For the observed storm, low, average, and high Q_p maps were created for the entire watershed.

Table 1. C-values derived from literature.

Land Use	C-low	C-average	C-high
Agriculture	0.08	0.25	0.41
Bare ground	0.05	0.35	0.65
Building	0.75	0.85	0.95
Forest	0.05	0.15	0.25
Golf course	0.25	0.5	0.74
Grass/Lawn	0.05	0.2	0.35
Impervious Transportation	0.7	0.83	0.95
Open Water	0	0	0
Sand Traps	0.05	0.1	0.14
Swimming Pool	0	0	0

Once the ArcCN Runoff tool was loaded into ArcMap, the CN value for golf course turf (obtained from USDA-NRCS, Urban Hydrology for Small Watersheds TR-55, 1986) was added to the land use index table. The next step was to automatically generate curve numbers for the rest of the land uses within the SL-7 area (based on land use and soils data) by matching land use categories to the index table in the curve number database. The ArcCN Runoff tool was run for the August 21, 2006 observed storm (in/hr) for comparison with the Rational Method peak runoff results. While the SCS-CN method does not consider time distribution, in order to compare this method with the Rational Method, it was assumed that the runoff volume produced by the model occurred within a one hour time frame. A field was added into the attribute table to compute CN runoff from in/hr to cubic feet per second (cfs). The following unit conversion was used: [(Runoff/12) (Shape area (in m^2) x 10.76)] / (60 x 60).

Testing Runoff Models: SL-7 Drainage Area

The Rational Method was applied to the SL-7 drainage area using four (2007) observed rain storms in order to predict peak runoff rate (cfs) at this outlet and to compare these results with observed streamflow data. Peak runoff rate (Q_p) at the SL-7 outlet was estimated using two different procedures. The first procedure was to calculate Q_p for each sub-unit, and aggregate the values to obtain a total Q_p for SL-7. Peak runoff rate was also calculated for the SL-7 drainage area (583.2 hectares, 1441.1 acres), as a whole. Two weighted C-values were calculated, based on parcel area, using the C-average and C-low values. Weighted C-low values were chosen (Table 2) in addition to the weighted average C-values because the

Rational Method is known to over-predict; the pre-developed C-factor is conservatively high for peak flow calculations (Hamilton County Soil and Water Conservation District, 2005). According to Wiles and Levine (2002), lower C-values are recommended for storm sizes of less than 25-year return period. Area, storm intensity, and weighted C-value were used to calculate Q_p in the GIS. These estimates were then compared to observed flow data at SL-7 and error magnitude was calculated.

Table 2. Weighted C-values for each sub-unit and entire SL-7 drainage area.

Sub-unit	12	13	16	17	18	19	21	22	whole
Weighted C-Low	0.01	0.023	0.012	0.02	0.018	0.013	0.009	0.008	0.113

The ArcCN Runoff tool was applied to the SL-7 drainage area for the observed storms, each of which occurred in 24 hours (in/day). In order to obtain runoff volume (Q), a weighted Q, based on parcel area, was calculated in the GIS for each of the storms. The weighted runoff volumes were summed for each sub-unit and calculated for the entire SL-7 drainage area. To convert runoff volume to peak runoff rate, the SCS Graphical Peak Discharge formula was used (USDA, 1986). The pond factor, in this equation was set to '1' because all ponds within the watershed were assigned a CN value of '0' prior to calculation of the weighted CN. As with the Rational Method, Q_p results from the Graphical Peak Discharge method were first summed by sub-unit, then aggregated to obtain an estimated SL-7 peak runoff rate. This method was also applied to the SL-7 watershed, as a whole, to obtain a Q_p estimate for the SL-7 outlet. These predictions were then compared to observed SL-7 flow data (shown in the following section).

Results and Discussion

The Digital Elevation Model (DEM) (1:24,000 scale) was enhanced in the GIS using USGS and USACE digital topographic maps (Mihalik, 2007). The techniques of using the gridded points with the new points developed from the topographic maps increased the data density on the map, allowing for better interpolation and increased vertical resolution in the final DEM (enhanced cell size from 30x30 to 10x10).

Watershed and subwatershed (25 units) boundaries were created in the GIS and are shown in Figure 4(a). Boundaries were developed using the enhanced DEM, and flow directions were modified (ditching) as needed based on field information. These boundaries were developed to allow for calculations to be made using the Rational and SCS-CN methods.

The detailed land use map, shown in Figure 4(b), was analyzed to determine the area of each identified land use. The map was also used to compare impervious to pervious land cover within the watershed, for subsequent rainfall-runoff assessment. Land area results show that the CBC watershed is primarily dominated by forest (Santee State Park is partially within the watershed), followed by residential grass/lawn cover, and agriculture. Additionally, the watershed is covered by approximately 9.6% impervious surface (i.e. roads, parking lots, driveways, buildings, houses, and impervious trails that could be mapped at the 1:5000 scale).

Studies have shown that watersheds with an excess of 10% impervious surface are often considered ecologically impaired showing signs of environmental stress related to stream degradation (Federal Interagency Stream Restoration Working Group, 1998; Zielinski, 2002). With just under 10% impervious surface, CBC is at the threshold of becoming an "ecologically impaired stream." However, there is currently much construction taking place within the watershed. Many of the bare ground areas identified in the land use analysis are under construction. If only half of the bare ground area is converted to impervious surface, the CBC watershed will exceed the 10% threshold suggesting a higher risk for human-induced water quality degradation.

Figure 4(c) shows the drainage and hydrography of the CBC watershed prior to field verification. The northeastern-most point of the CBC hydrography layer is the outlet into Lake Marion. The red line in Figure 4(c) represents the drainage ditching connecting the eastern streams to the main network. All streams above the red line and those outside the watershed boundary were removed. After field verification some higher order streams were found to be non-existent and were removed. Figure 4(d) shows the hydrography layer after field verification.

The Rational Method and the SCS-CN method were used to predict runoff based on greatest hourly rainfall intensity (for the entire watershed) and 24-hour rainfall intensity (SL-7 drainage area) for one (2006) and four (2007) observed storms (Table 3). The August, 2006 storm was run on the entire CBC watershed using both models to identify hotspots within the watershed. Model prediction capability could not be assessed using this storm as streamflow data was not recorded during this time.

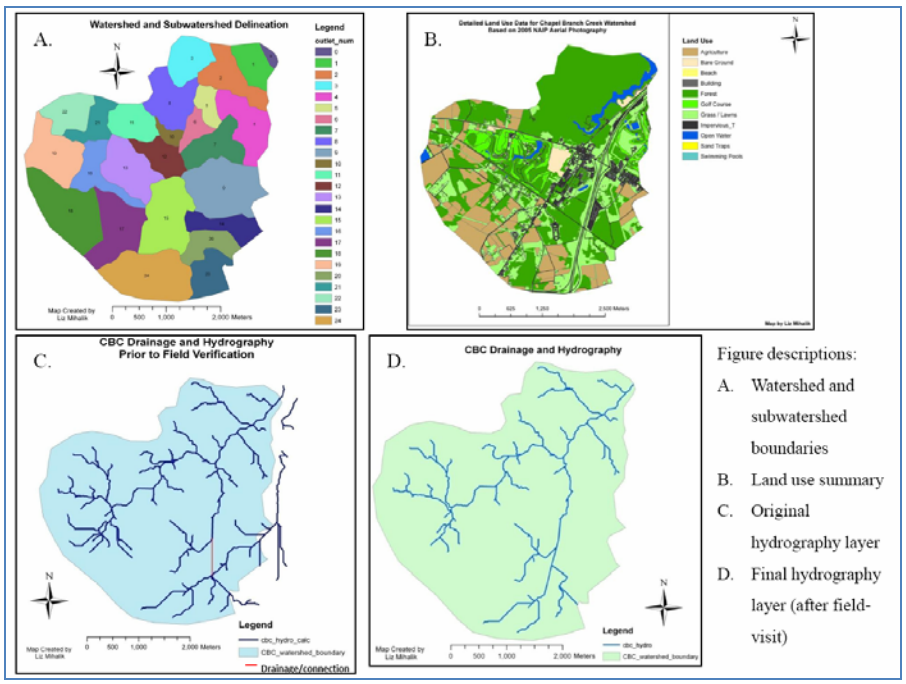


Figure 4. A. Watershed and subwatershed boundaries (25 units); B. Land use summary; C. Hydrography layer prior to field-verification; D. Hydrography layer after field-verification.

Table 3. Observed rainfall intensities (Town Hall gauge) to be run with the Rational and SCS-CN methods and discharge measurements to evaluate model predictive capability.

date	in/24hr	in/hr	Runoff Volume (in)	Peak Discharge (cfs)
21-Aug 06	3.11	2.75	------	------
1-Mar 07	0.65	0.23	0.07	2.54
16-Mar 07	0.63	0.27	0.03	1.6
15-Apr 07	2.46	0.7	0.11	8.56

20-Jun 07	1.69	1.38	0.02	1.8

Rational Method - August 21, 2006

The August 21, 2006 low peak discharge map (low C-values) based on the Rational Method (in cfs/acre) is shown in Figure 5. The greatest peak runoff rate (orange) clearly follows the impervious surfaces including Interstate I-95, highway SC-6, and the more developed, central area of the watershed, which includes the Town of Santee. The green areas throughout the watershed represent low runoff areas with high infiltration rates. For average and high peak discharge maps (using average and high C-values), see Mihalik, 2007.

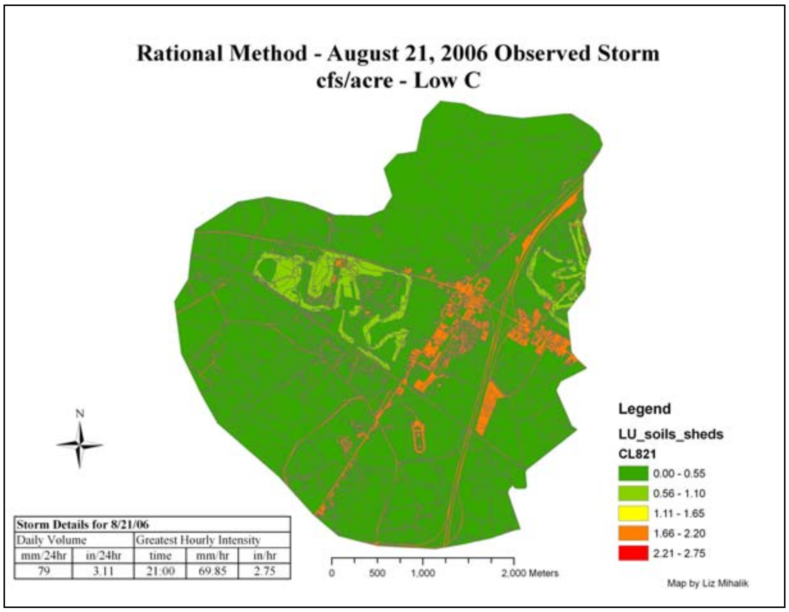
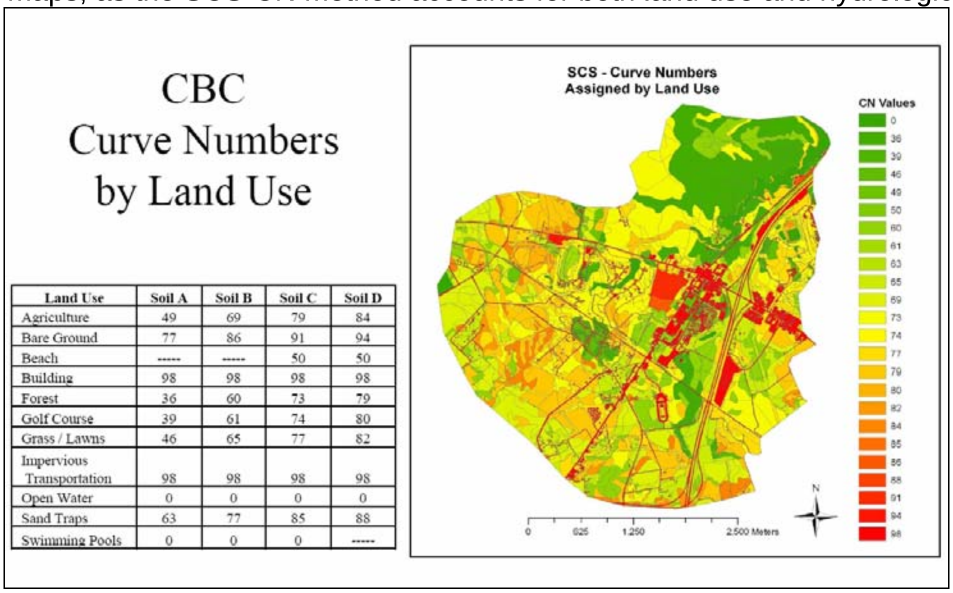


Figure 5. Distribution of cfs/acre simulated by the Rational Method for the August 21, 2006 observed storm (2.75 in/hr) using low-C values.

SCS-CN Method - August 21, 2006

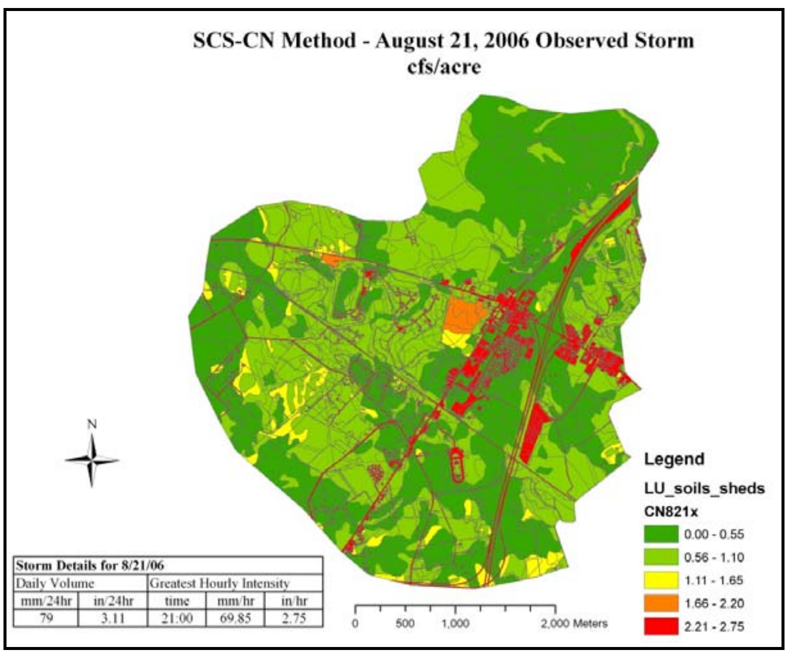
The ArcCN Runoff Tool automatically assigned curve numbers (CN) (Figure 6) to each land parcel based on the land use and hydrologic soils information within each parcel. High curve numbers correspond to the urbanized central portion of the watershed (red and orange), which has the potential to generate the greatest amount of runoff in a storm event. The lowest curve numbers (green) correspond to the forested area in the northern portion of the watershed, which generates little runoff. Figure 6 also displays assigned CN values based on land use and hydrologic soil group. As the soil group moves from A to D, CN values get larger (greater runoff), which corresponds to poorly drained soils.

Figure 7 illustrates peak runoff rates (cfs/acre) for the August 21, 2006 storm using the SCS-CN method. High curve numbers (red), corresponding to high runoff/low infiltration areas, outline transportation routes and the developed portion of the watershed (centrally located). Much of the southern portion of the watershed is characterized by agriculture. Curve numbers in this area appear to be in the middle to high-end of the CN spectrum, likely resulting from more poorly draining soils than those characterizing the northern (green) portion of the watershed (Santee State Park). This runoff map is slightly different from the Rational Method peak runoff maps, as the SCS-CN method accounts for both land use and hydrologic soil group.



Land Use	Soil A	Soil B	Soil C	Soil D
Agriculture	49	69	79	84
Bare Ground	77	86	91	94
Beach	-----	-----	50	50
Building	98	98	98	98
Forest	36	60	73	79
Golf Course	39	61	74	80
Grass / Lawns	46	65	77	82
Impervious Transportation	98	98	98	98
Open Water	0	0	0	0
Sand Traps	63	77	85	88
Swimming Pools	0	0	0	-----

Figure 6. Illustration of CBC curve numbers assigned to land parcels by ArcCN Runoff Tool. Table shows CN values by land use and hydrologic soil type.



Storm Details for 8/21/06				
Daily Volume		Greatest Hourly Intensity		
mm/24hr	in/24hr	time	mm/hr	in/hr
79	3.11	21:00	69.85	2.75

Figure 7. Distribution of cfs/acre simulated by the SCS-CN method for the August 21, 2006 observed storm (2.75 in/hr).

Case Study: SL-7 Drainage Area

Figure 8 displays the ~583 hectare (1441 acre) SL-7 drainage area (within the CBC watershed) and the area (acres) associated with each land use category. Over 60% of the area is characterized by forest and agriculture. Less than 6% of the drainage area is characterized by impervious surface indicating that this part of the stream may have less potential to be "ecologically impaired" compared to the whole watershed with nearly 10% impervious surface.

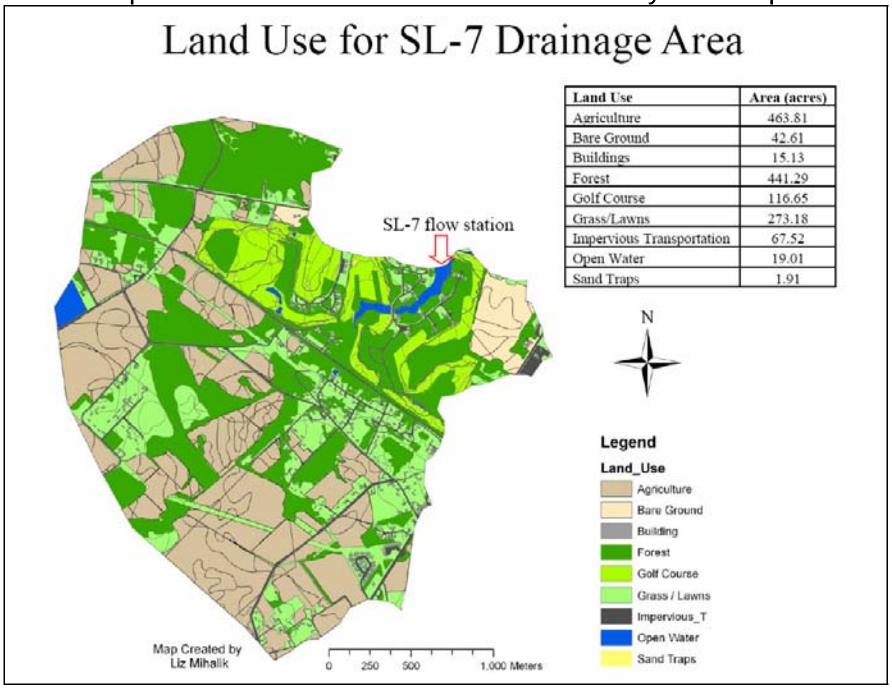


Figure 8. Land use summary for SL-7 drainage area.

Rational Method

Peak runoff rate estimates were obtained from the Rational Method using both the weighted average and weighted low C-values (Table 4), as the Rational Method is known to over-predict. The weighted low-C values proved to better predict peak runoff rate, reducing Q_p estimates by over 50 percent below the weighted average C-value estimates. In addition, Q_p estimates were about 7 times lower when aggregated by sub-unit than when calculated for the total SL-7 drainage area. Table 5 shows the percent error between estimated and observed Q_p rates using the weighted low C-values and sub-unit aggregation technique.

Table 4. Rational Method peak flow estimates (SL-7 outlet) for observed 2007 storms using a weighted C-low, by sub-unit.

Sub-unit	**Q_p-cfs (3/1/07)**	**Q_p-cfs (3/16/07)**	**Q_p-cfs (4/15/07)**	**Q_p-cfs (6/20/07)**
12	0.3	0.3	0.8	1.6
13	1.1	1.2	3.2	6.3
16	0.4	0.5	1.2	2.3
17	1.1	1.2	3.2	6.3
18	1.3	1.5	3.8	7.5
19	0.7	0.8	2.0	4.0
21	0.2	0.2	0.6	1.2
22	0.3	0.3	0.8	1.5
Total Q_p	**5.1**	**6.0**	**15.6**	**30.8**
whole	**37.5**	**44.0**	**114.0**	**224.7**

This table shows that even when using the low C-values, the Rational Method still over-predicts. This method performs reasonably well however, considering that it is a simple, lumped parameter model and does not take into account a number of natural processes including antecedent moisture conditions and channel routing. Additionally, the high percent error associated with the June 20th storm is likely due to the spatial variability resulting from the use of one rain gauge (Town Hall) to characterize rainfall for the entire SL-7 subwatershed. When rain data was evaluated, much variability was observed between the three gauges for the 6/15/07 – 6/22/07 time period (Mihalik, 2007).

SCS Graphical Peak Discharge Method

The difference between predicted runoff volume, using the SCS Graphical Peak Discharge method, and observed runoff volume was assessed. The March 1, 2007 storm was under-predicted by the model while the last three storms were over-predicted. While some explanation may be due to soil moisture conditions, pond effects (pond directly upstream of SL-7) play a role in water storage and likely affected observed runoff, as well as the spatial variability of rain data (likely the result of the large over-prediction for the June 20th storm). Peak runoff rates for the observed storms, were estimated using both a mean-average Q and a weighted Q (weighted by sub-unit). Peak runoff rate results for the observed storms using the weighted Q (Q_w) prove to better estimate observed peak runoff rates than the use of a mean-average (Q_{ma}). Table 5 shows the percent error between observed and estimated Q_p values using the Q_w Graphical Peak Discharge method. Estimated Q_p values in this table were obtained by aggregating Q_p by sub-unit, as this method resulted in more accurate runoff rates. While Q_{ma} consistently over-predicted peak runoff rate, the Q_w technique occasionally under-predicted peak runoff rate. Figure 3 provides some insight into antecedent moisture conditions (not accounted for in Graphical Peak Discharge method) that would have affected observed runoff. While there is no recorded flow data prior to March 1, 2007, Figure 3 illustrates a higher water stage level in March (typical in the spring) suggesting more saturated soil conditions, perhaps leading to greater *observed* peak runoff and lower *estimated* peak runoff. Conversely, prior to the April 15th storm, the stage level dropped perhaps resulting in lower *observed* peak runoff and higher *estimated* peak runoff. The stage level before the June 20th storm was fairly low as well, and may explain an over-estimation of peak runoff rate. Over-estimation is also likely due to spatial variability of rain data. Table 5 shows the best estimating technique for the Rational Method (weighted C-low) and the Graphical Peak Discharge method (Q_w) compared to the observed results. While the Rational Method better predicted the April 15, 2007 storm, overall the Graphical Peak Discharge method better predicted peak runoff rate.

Table 5. Comparing predictive capability of the Rational and SC S-CN methods (using best estimating technique for each).

Date -2007	**Observed -cfs**	**Rational Method Qp-cfs (C-low)**	**SCS-CN Qp -cfs (Weighted Q)**	**% Error (C-low)**	**% Error (Weighted Q)**
1-Mar	2.54	5.13	1.06	101.9	-58.3
16-Mar	1.6	6.03	0.99	276.9	-38.1
15-Apr	8.56	15.63	39.62	82.6	362.9
20-Jun	1.8	30.81	13.36	1611.7	642.2

Summary, Conclusions, and Recommendations

This study, on the Chapel Branch Creek (CBC) watershed, located near the Town of Santee in Orangeburg County, South Carolina, evaluated two commonly used rainfall-runoff models (the Rational and SCS-CN methods) for predicting watershed runoff dynamics. This study is unique in that it makes use of a highly detailed land use map (derived from 2005 NAIP aerial imagery) and tests the above mentioned models within an understudied region, the low-gradient South Carolina Coastal Plain. Model predictive capability for peak runoff rate and storm volume (SCS-CN method only) was examined by comparing estimated results with flow data measured for four storm events (March - June 2007) at one location (SL-7) within the watershed. In this study, model parameters including the land use coefficient (C-value) in the Rational Method, the curve number (CN) in the SCS-CN method, and the runoff volume variable (Q) in the SCS-CN Graphical Peak Discharge method were weighted to properly adjust values based on land parcel area. Results of runoff simulations demonstrated herein, using the methods mentioned above, may provide initial insights into potential hotspots and ecologically sensitive areas within the CBC watershed. Finally, this study provided an initial background for identification of the runoff source areas and many of the parameters (in particular GIS spatial data) necessary for characterizing the watershed, which will be used to ultimately develop a TMDL (for N and P) to restore water quality within the Chapel Branch Creek.

The detailed land use analysis of this study showed that the CBC watershed is just under 10% impervious surface (approximately 9.4%). However, if the bare-ground areas within the watershed (most are currently under construction) are converted to impervious surface, the watershed will likely exceed the 10% threshold in the near future. The detailed land use data and subsequent runoff modeling results from this study allow for selecting or pinpointing runoff prone areas (even at a smaller scale than the subwatershed) for prioritizing BMPs and identifying the areas at greatest risk for human induced water quality degradation.

Results of this study have shown that a weighted low C-value yields better estimates of peak runoff rate (Q_p) than the use of a weighted average C-value. It was also found that more accurate results are obtained when aggregating Q_p by sub-unit rather than the calculation of Q_p for the entire SL-7 drainage area. It was also demonstrated that the use of a mean-average runoff volume (Q) calculated for each sub-unit with subsequent calculation of peak flow rate does not yield as accurate results as when a weighted Q (calculated for each sub-unit) is combined with a weighted CN (for each sub-unit). Additionally, estimated Q_p rates are more accurate when aggregated by sub-unit than when calculated for the whole drainage area (SL-7).

Overall, it was found that the SCS Graphical Peak Discharge method (using Q_w) better estimated peak runoff rate than the weighted low C-value using the Rational Method. This is not surprising, considering that the CN method is slightly more complex than the Rational Method by taking into account additional parameters such as initial abstraction (I_a) and time of concentration (T_c). This method would likely predict better for the SL-7 drainage area if an accurate pond estimate were incorporated, as well as the effect of antecedent moisture condition.

Acknowledgements

This work was supported by a grant based on a cooperative agreement between the Forest Service Center for Forested Wetlands Research (CFWR) and the College of Charleston (COFC). The actual funding for this project to the CFWR was provided by the SC Department of Health and Environmental Control through a US EPA Section 319 Grant. The authors would also like to acknowledge the contributions of Dr. Tom Williams and Dr. Dan Hitchcock of Belle Baruch Research Institute, Meredith Murphy of SC DHEC, as well as Andy Harrison, Hydrotech at the CFWR and David Joyner, former graduate student at COFC for assisting in hydro-meteorologic instrumentation and data collection at the site.

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