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Estimating Soil Storage Capacity for Stormwater Modeling Applications

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ABSTRACT: The capacity of surface soil layers to store infiltrated stormwater becomes an important parameter in some situations (e.g., when the water table reaches the ground surface, which is a common occurrence throughout Florida). Current methods for estimating soil storage capacity are often based on very general characteristics. For instance, the Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service, SCS) runoff curve number method uses a predetermined soil storage capacity based on the assigned hydrologic soil group and land use category. Since the soil storage capacity is more dependent on other variables (e.g., water table depth and specific soil properties), more accurate estimates can be made using characteristic soils data. This paper presents various methods for estimating soil storage capacity using pertinent data that are readily available in tabular and digital format. These methods are evaluated using NRCS/SCS soil survey data for counties in central and northwestern Florida.

INTRODUCTION

Infiltration and percolation within surface soil layers are among the physical processes that are most important to hydrologists. Infiltration involves the downward movement of excess rainfall into the unsaturated zone and is of primary interest in the study of surface water hydrology. Percolation involves the downward movement of water from the unsaturated zone into the saturated zone and is of primary interest in the study of groundwater hydrology. The local terrain delineates the boundary between the ground surface and the unsaturated zone and the water table differentiates the unsaturated and saturated zones. The rainfall rate, infiltration capacity, and water table depth determine how much water infiltrates into the unsaturated zone and the percolation capacity of the saturated zone determines how much water stays there. The amount of water in the unsaturated zone affects the rate of flow either way.

Due to the difference in time scales of infiltration and percolation rates, among other things, the study of surface and ground water hydrology are often separate and distinct analyses. The common ground between these disciplines is the unsaturated zone. Often, the study of surface water hydrology treats this zone as an infinite sink, where infiltration is assumed to be free of the rate and volume limitations imposed by a dynamic, rising water table. Likewise, the study of groundwater hydrology often treats the unsaturated zone as an infinite source, where percolation is assumed to be free of the rate and volume limitations imposed by the dynamic response of water in the unsaturated zone due to rainfall. As a result, the interdependencies of the hydraulics in both unsaturated and saturated zones are often ignored.

Soil storage capacity is defined in this paper as the volume of soil pores in the unsaturated zone that is available to store infiltrated stormwater. This capacity depends on a number of factors, including the physical and chemical properties of the soil, water content of the soil, and the depth to the water table or some other confining layer. Soil properties vary vertically within the surface profile, spatially even within relatively small areas, and in time as the soil water content changes during and after rainfall events.

The soil storage capacity is an important practical consideration throughout Florida, where it is common to have sandy soils with highly variable groundwater conditions and large volume storm events. Under these circumstances, the soil storage capacity (expressed as a depth over a unit area) can range anywhere between 0 and 20 inches. Typical summer convective storms often yield more rainfall than the available capacity. As a result, soil pores in the unsaturated zone fill up quickly (effectively raising the water table to the surface), infiltration ceases, and further rainfall becomes runoff. At a minimum, sub-surface flow is no longer governed by infiltration equations: rather, it becomes part of the groundwater flow regime, where percolation rates are often at least an order of magnitude less than infiltration rates. The presence of a high water table will therefore invalidate the often-used assumption of an infinite sink, since the depth of the unsaturated zone is greatly restricted. At some point, the rising water table will limit the rate of infiltration by filling the available soil storage capacity.

Popular infiltration methods include the Green-Ampt, Horton, and Holtan equations. These equations were developed with no explicit dependency on the water table. As a result, the parameters for these equations are sometimes modified beyond realistic values (e.g., during calibration) in an attempt to account for a reduced soil storage capacity, even though they are somewhat different phenomena. The NRCS/SCS offers an improvement by incorporating the soil storage capacity into the curve number method (described later in this paper). However, this method is based on very general characteristics such as land use and hydrologic soil group.

The Environmental Protection Agency's Hydrological Simulation Program – FORTRAN (HSPF, Johanson, et al., 1984) and the StormWater Management Model (SWMM, Huber and Dickinson, 1988) are examples of hydrology models that can simulate the soil storage capacity for single storm events or continuous simulation. When modeling single events, it is important to choose an initial soil storage capacity value that is appropriate for the conditions being modeled. For example, rainfall events that were preceded by a long, dry period would have a higher value of soil storage capacity, and rainfall events that were immediately preceded by another storm event would feature a lower initial value of soil storage capacity. Likewise, adjustments could be made to account for either shallow or deep groundwater levels. Adjusting soil storage capacities based on antecedent moisture conditions is similar to what is done for infiltration parameters.

The purpose of this paper is to present and evaluate methods for estimating the soil storage capacity of specific soil types. These methods are based on available NRCS/SCS soil survey data, which includes characteristic soil and water properties, and water table depth information.

METHODOLOGY

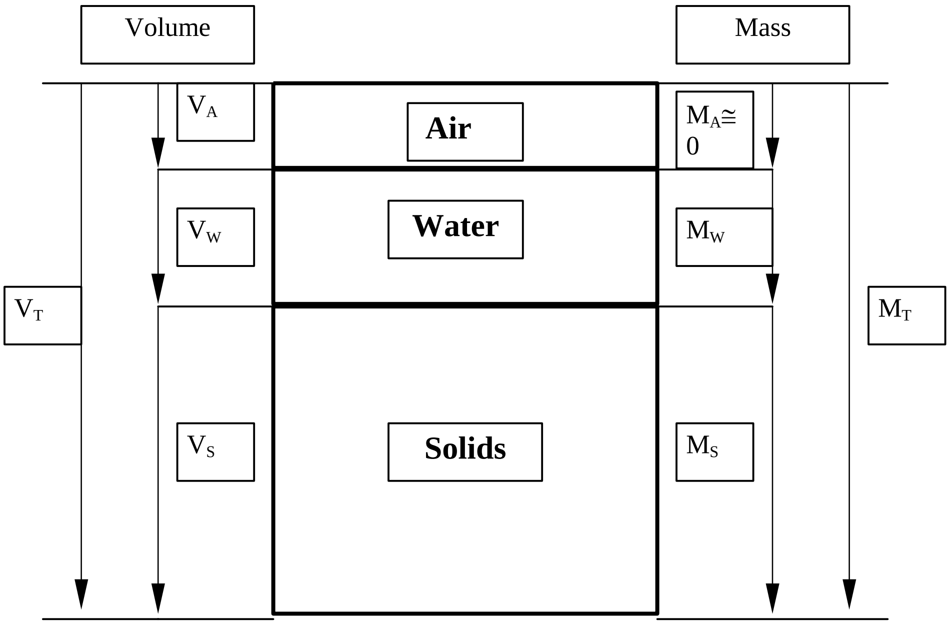
Soil is a complex, multi-phase, heterogeneous system of various gases, liquids and solids and as a result, the concept of soil can be interpreted in many different ways. For surface water hydrology analysis, the most important soil properties are the amount and rate of passage of infiltrated rainfall through the surface layers of soil. In particular, the soil storage capacity requires a detailed look at the relationship of water content to the soil void space.

Figure 1 illustrates the volume and mass components of air, water and solid particles within a soil sample. The mass of air is often considered negligible. The volume of the void space is therefore the total volume of air and water, and the mass within this void space is simply the mass of water. The definition of key terms are also listed in Figure 1, most notably:

- Water content, w, the ratio of water mass to solids mass
- Porosity, η, the ratio of void space to total volume
- Degree of saturation, S_r, the ratio of water volume to void space
- Moist bulk density, ρ_T, the ratio of soil mass to soil volume

Figure 2 shows a conceptual moisture profile for two soil types (adapted from Figure X-6, page 551 in Huber and Dickinson, 1988). The horizontal axis represents the water content and the vertical axis represents the soil sample condition, expressed by the degree of saturation and by the energy potential of the soil. The degree of saturation ranges from oven-dry ($S_r = 0$, i.e., no water) to complete saturation ($S_r = 1$, i.e., no air). Two points are commonly used to denote intermediate values of the degree of saturation: the wilting point and the field capacity. These values are based on the energy potential of water, as indicated by the moisture tension measured in the soil sample. The water content at the wilting point is often determined at a moisture tension of approximately 15 atm and represents the point at which plant roots cannot draw any more water from the void space. The water content at the field capacity is often determined at a moisture tension between 0.1-0.7 atm, depending on the soil type. Field capacity represents the maximum amount of water that a soil can hold against gravity, that is, the point at which gravity movement stops and all drainable water has percolated.

The water content range between oven-dry and the wilting point defines hygroscopic water, which represents water that is unavailable to plants (since the roots cannot overcome the high pressure). The water content between the wilting point and field capacity defines capillary water, which represents water that is readily available to plants. Finally, the water content between field capacity and complete saturation defines gravitational water, which represents water that is quickly drained by gravity (and is effectively unavailable to plants).



V_A = Air volume
V_W = Water volume
V_S = Solids volume
$V_T = V_A + V_W + V_S$

M_A = Air mass (zero)
M_W = Water mass
M_S = Solids mass
$M_T = M_W + M_S$

Water content, $w = M_W/M_S$
Porosity, $\eta = (V_A+V_W)/V_T$
Void ratio, $e = (V_A+V_W)/V_S$
Degree of saturation, $S_r = V_W/(V_A+V_W)$

Water density, $\rho_W = M_W/V_W$
Solids density, $\rho_S = M_S/V_S$
Moist bulk density, $\rho_T = M_T/V_T$
Specific gravity, $G_S = \rho_S/\rho_W$

Figure 1
Soil Phase Diagram and Definitions

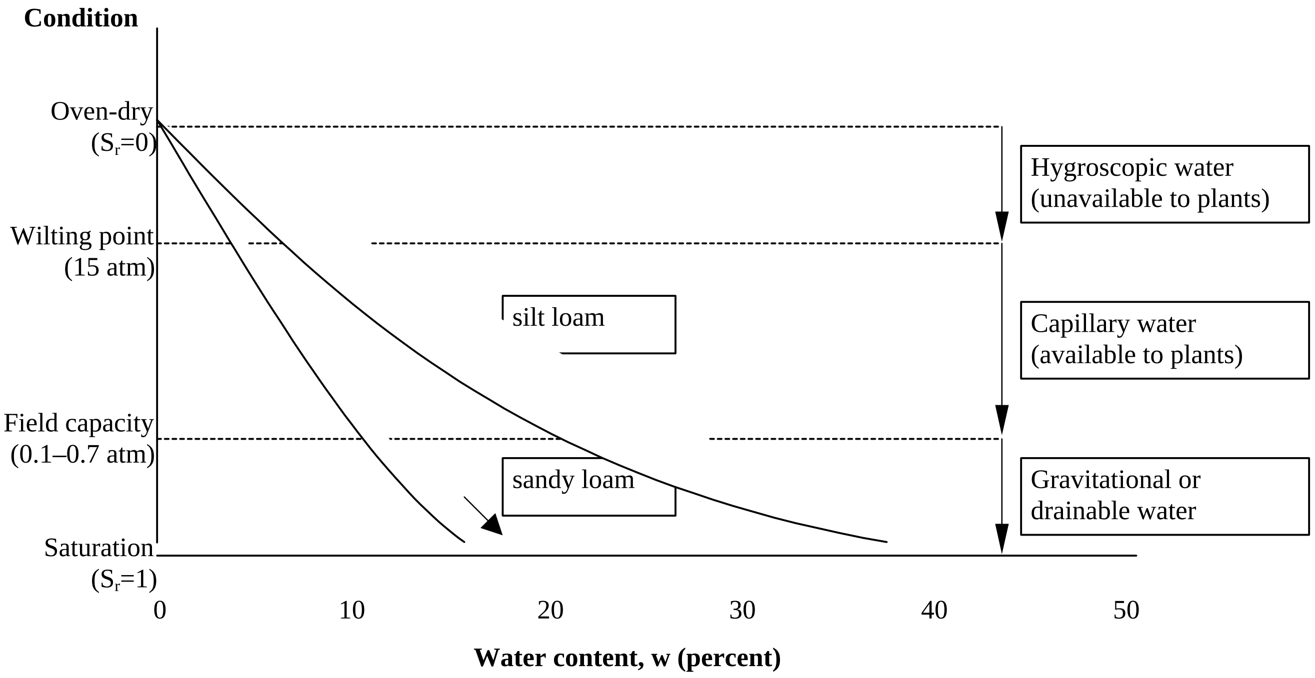


Figure 2

Water Content Relationships in Soil Void Space

Soil storage capacity, therefore, quantifies the ability of a specific soil to hold gravitational water and can be determined by taking the difference between the water content at field capacity and at complete saturation. When this difference is expressed in terms of the volume (i.e., porosity), it is commonly referred to as the drainable porosity. The soil storage capacity is then simply the product of the drainable porosity and the depth of the unsaturated zone. From the key term definitions shown in Figure 1, two useful equations can be derived:

At complete saturation (S_r=1),

$$w = \frac{\rho_S - \rho_T}{G_S(\rho_T - \rho_W)}, \tag{1}$$

and for all values of S_r,

$$\eta = 1 - \frac{\rho_T}{\rho_S(w+1)}. \tag{2}$$

Where w is the water content (% by weight),
η is the porosity (% by volume),
ρ_S is the soil particle (solids) density (g/cm^3),
ρ_T is the moist bulk density (g/cm^3),
ρ_W is the water density (g/cm^3),
and G_S is the specific gravity of the soil particle (dimensionless).

Published soil survey reports from NRCS/SCS are available for counties throughout Florida. Soil types within the county are categorized by a unique soil map symbol and soil name, collectively referred to in this paper as the soil map unit. Each soil survey includes data related to soil and water properties for all soil map units, which are commonly grouped into the following tables:

- Physical analyses/properties of selected soils. This table includes detailed physical, chemical and mineralogical properties based on laboratory analyses of selected soils at various depths below the ground. Soils in each map unit are generally subdivided into 4 to 8 layers, down to a typical depth of 80 inches. For each layer, the particle size distribution, moist bulk density, and water content at 10 kPa, 33 kPa, and 1500 kPa (approximately 1/10 atm, 1/3 atm, and 15 atm, respectively) are tabulated.
- Physical and chemical properties of the soil. This table includes estimates of the moist bulk density, based on field observations and on laboratory test data for these and similar soil types. Soils in each map unit are generally subdivided into 1 to 5 layers, down to a typical depth of 80 inches. For each layer, moist bulk density estimates are expressed as a range of values (e.g., 1.45-1.60 g/cm^3).
- Soil and water features. This table includes the hydrologic soil group (HSG) and the seasonal high water table (HWT) depth for each map unit. There are four HSG categories: Group A, B, C, and D. Group A soils have a high infiltration potential and low runoff potential, and Group D soils have a low infiltration potential and a high runoff potential. Group B and C soils are designated in between these two categories. Dual soil groups indicate infiltration properties that depend on local

drainage activities. For example, Group A/D indicates poorly drained soils that could be well drained in the vicinity of roadside ditches or swales, which tend to draw down the groundwater levels. Open water features represent entirely impervious surfaces and are not assigned to a specific HSG. The HWT depth was measured in feet below the surface and represents the highest sustained elevation of the saturated zone. Often, a range of depths is given along with an estimate of the duration in months.

Not all county soil surveys include the detailed survey data (first table type listed above), due to a lack of field measurements. Even soils surveys that do include the detailed survey data do not include data for all soil map units. The second and third table types are standard NRCS/SCS soil survey tables and include data for all soil map units. For this study, the soil storage capacity was determined from available soil survey data in two ways: using both detailed and standard survey data. In addition, results determined using the detailed survey data were used to develop relationships between the soil storage capacity, HSG, and HWT depth.

RESULTS AND DISCUSSION

Soil Storage Capacity Based on Detailed Soil Survey Data

Table 1 shows the soil storage capacity calculation for a single soil map unit within Polk County, based on detailed NRCS/SCS soil survey data. The soil map unit, bottom depth of layer, percentage of total sand, moist bulk density, and water content at 10 kPa and 33 kPa were taken from the NRCS/SCS tabular data (Table 19, pages 223-226 in SCS, 1990). The water content at saturation was calculated using equation (1) by assuming soil particle and water densities of 2.65 g/cm^3 and 1.00 g/cm^3, respectively (that is, the specific gravity of the soil particle is 2.65). The same assumptions were used in equation (2) to determine the porosity at various water content values. The drainable porosity was then calculated as the difference between the porosity at saturation and at the field capacity. According to NRCS/SCS laboratory methods, the field capacity for sandy soils (total sand content greater than 85%) is indicated by the water content at a moisture tension of 10 kPa. For other soils (total sand content less than 85%), the field capacity is indicated by the water content at a moisture tension of 33 kPa.

Table 1
Calculation of Soil Storage Capacity Using Detailed Soil Survey Data

Soil Map Unit	Bottom Depth (in)	Total Sand	Moist Bulk Density (g/cm^3)	Water Content			Porosity			Drainable Porosity (in/in)	HSG	HWT Depth (in)	Storage Capacity (in)
				At Sat'n	At 10 kPa	At 33 kPa	At Sat'n	At 10 kPa	At 33 kPa				
2 Apopka fine sand	7	95%	1.60	66.0%	9.4%	6.0%	63.6%	44.8%	43.0%	18.8%	A	72	14.27
	21	96%	1.56	73.5%	5.7%	4.0%	66.1%	44.3%	43.4%	21.8%			
	35	97%	1.44	103.8%	10.3%	8.4%	73.3%	50.7%	49.9%	22.6%			
	51	96%	1.51	84.4%	4.5%	2.8%	69.1%	45.5%	44.6%	23.6%			
	61	80%	1.63	61.1%	15.3%	12.8%	61.8%	46.7%	45.5%	16.3%			
	80	54%	1.67	55.2%	21.3%	19.8%	59.4%	48.0%	47.4%	12.0%			

The hydrologic soil group and estimate of the seasonal high water table depth were taken from the NRCS/SCS tabular data (Table 17, pages 217-221 in SCS, 1990). For this study, dual soil groups were treated as Group D. Of the 97 soil map units studied, a total of 5 were Group A/D soils and 18 were Group B/D soils. The HWT depth listed in Table 1 is the average value of the range reported in the soil survey. For this study, a maximum value of 72 inches was used where the HWT depth was reported in the soil survey as greater than six feet, and a minimum value of 6 inches was used where the HWT depth was reported as zero or above the ground surface. The final column in Table 1 shows the soil storage capacity for the map unit, calculated as the sum of the product of drainable porosity times the layer depth for all layers above the HWT.

Soil storage capacities were calculated using this methodology for 97 soil map units in six Florida counties, including:

- 13 map units in Bay County (northwest Florida)
- 15 map units in Citrus County (west central Florida)
- 11 map units in Hernando County (west central Florida)
- 25 map units in Leon County (northwest Florida)
- 19 map units in Pasco County (west central Florida)
- 14 map units in Polk County (central Florida)

Table 2 shows the average measured water content at field capacity (for the 10 kPa and 33 kPa measurements combined), grouped by HSG. This average was determined for each layer of all soil map units included in the detailed survey data, representing a total of 626 layers. Results varied somewhat by county. Overall, the water content of Group A soils ranged from 5 to 8 percent and Group B, C, and D soils ranged from 7 to 19 percent. For all counties combined, Group A soils had an average water content of 7 percent and Group B, C, and D averaged between 13 and 14 percent as shown in the final column of Table 2.

Table 2
Average Water Content at Field Capacity by Hydrologic Soil Group

HSG	Bay Co.		Citrus Co.		Hernando Co.		Leon Co.		Pasco Co.		Polk Co.		All Counties	
	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average
A	29	5.0%	34	7.6%	40	7.4%	60	8.2%	41	7.8%	29	5.4%	233	7.1%
B	14	9.6%	0		0		28	15.2%	0		0		42	13.3%
C	12	6.9%	32	16.1%	6	15.0%	25	12.4%	53	13.1%	16	7.4%	144	12.6%
D	15	9.5%	17	18.6%	29	14.5%	58	14.9%	49	15.6%	39	12.3%	207	14.4%
Total:	70		83		75		171		143		84		626	

No correlation was found between the average water content at field capacity and the moist bulk density. In addition, no correlation was found between the average water content at field capacity and the bottom depth of the layer (expressed as a percentage of the HWT depth).

Table 3 shows the average soil storage capacity calculated using the detailed soil survey data methodology described above, grouped by HSG. Results also varied slightly between counties. Overall, the soil storage capacity for Group A soils ranged from 14 to 15 inches. Group B soils were 10 inches in both Bay County and Leon County, however the sample size was very small (2 and 4, respectively). Group C and D soils ranged from 5 to 7 inches and 1 to 3 inches, respectively. For all counties combined, the average soil storage capacity for Group A, B, C, and D soils was 14.5, 10.0, 6.4, and 2.0 inches, respectively, as shown in the last column of Table 3.

Table 3
Average Soil Storage Capacity by Hydrologic Soil Group

HSG	Bay Co.		Citrus Co.		Hernando Co.		Leon Co.		Pasco Co.		Polk Co.		All Counties	
	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average
A	5	14.5	7	15.1	6	14.8	9	13.6	6	14.5	6	14.9	39	14.5
B	2	9.6	0		0		4	10.2	0		0		6	10.0
C	2	7.0	5	6.7	1	5.6	4	5.3	7	6.3	3	7.2	22	6.4
D	4	2.9	3	3.3	4	1.3	8	2.1	6	1.6	5	1.4	30	2.0
Total:	13		15		11		25		19		14		97	

The NRCS/SCS has developed methods for computing runoff during rainfall events based on measurements in many small experimental watersheds (SCS, 1972). With these methods, runoff is related to the rainfall according to a runoff curve number, which is selected based on land use type and HSG. The relationship between curve number and the soil storage capacity is:

$$S = \frac{1000}{CN} - 10 . \tag{3}$$

Where S is the soil storage capacity (in),
and CN is the runoff curve number (dimensionless).

In order to apply NRCS/SCS methods to conditions when the unsaturated zone initially contains more water than at the measured field capacity (e.g., due to recent rainfall and/or high groundwater conditions), various antecedent moisture conditions have been defined, including:

- AMC_{dry}, when total rainfall over the previous 5 days is less than 1.4 inches
- AMC_{norm}, when total rainfall over the previous 5 days is between 1.4 and 2.1 inches
- AMC_{wet}, when total rainfall over the previous 5 days is greater than 2.1 inches

Equivalent curve numbers can then be determined for either dry or wet conditions based on the following NRCS/SCS empirical equations:

$$CN_{dry} = \frac{4.2 \times CN}{10 - 0.058 \times CN} , \tag{4}$$

and

$$CN_{wet} = \frac{23 \times CN}{10 + 0.13 \times CN} . \tag{5}$$

Where CN is the runoff curve number under AMC_{norm} conditions,
CN_{dry} is the equivalent runoff curve number under AMC_{dry} conditions,
and CN_{wet} is the equivalent runoff curve number under AMC_{wet} conditions.

Considering the detailed soil survey data includes measurements of the water content at field capacity, the methodology described in this study represents an estimate of the soil storage capacity under AMC_{dry} conditions. Equation (3), according to NRCS/SCS methodology, applies to AMC_{norm} conditions. In order to compare results between these two methods, a common AMC condition must be determined.

Table 4 shows the average soil storage capacity values from Table 3 for the various AMC conditions, grouped by HSG. These values were computed by combining equation (3) with either equation (4) or (5) for the appropriate AMC conditions. These values are compared to a range of typical values obtained in watershed master planning studies throughout Florida (CDM, 1994). Values calculated from the detailed survey data in this study generally lie within the range of typical values shown. The runoff curve number for AMC_{norm} conditions was determined from equation (3) and compared to typical NRCS/SCS values. A range of curve numbers for "Pasture or Range Land" land uses is given in the final column of Table 4. The minimum value identifies a "good condition" and the maximum value identifies a "poor condition". The values calculated from the detailed survey data in this study generally lie within this range.

Table 4

Soil Storage Capacities under Various Antecedent Moisture Conditions

HSG	Soil Storage Capacity (in)						Curve Number	
	Detailed Survey Data[1]			Typical Values[2]			(AMC_{norm})	
	AMC_{dry}	AMC_{norm}	AMC_{wet}	AMC_{dry}	AMC_{norm}	AMC_{wet}	Calc'd[3]	Typical[4]
A	14.5	6.1	2.6	4.3-12.0	3.4-5.4	1.8-2.1	62	39-68
B	10.0	4.2	1.8	3.4-9.0	2.8-4.0	1.3-1.5	70	61-79
C	6.4	2.7	1.2	2.3-7.0	1.8-3.0	0.8-1.0	79	74-86
D	2.0	0.8	0.4	1.3-3.0	1.0-1.3	0.5-0.7	92	80-89

Notes:

1. Based on AMC_{dry} values determined in this study (average for all counties in Table 3).
2. From Table 4-3, Standard Infiltration Parameters for Pervious Areas (CDM, 1994).
3. Calculated using equation (3) with AMC_{norm} value described in note 1.
4. From Table 5.5.2, Runoff Curve Numbers for Selected Land Uses (Chow et al., 1988).

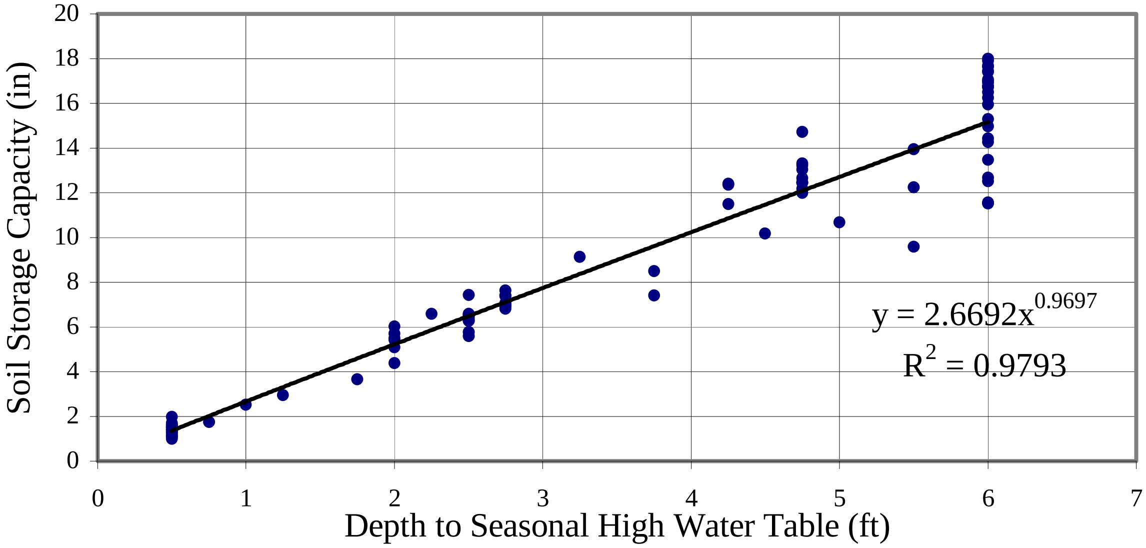
Finally, soil storage capacity values determined using the detailed survey data were compared to the observed HWT depth. Figure 3 illustrates a good correlation between the soil storage capacity and the HWT depth indicated for the soil map units studied. For all counties (97 data points), the best-fit regression curve ($R^2 = 98\%$) was a power equation of the form:

$$S = 2.67H^{0.97}. \tag{6}$$

Where S is the soil storage capacity (in),
and H is the HWT depth (ft).

Figure 3 also reveals the limits of the minimum and maximum HWT depth assumptions in this study (i.e., values reported in the survey as less than 6 inches were given a value of 0.5 feet, and values reported as greater than 72 inches were given a value of 6 feet).

Figure 3
Soil Storage Capacity as a Function of the Seasonal High Water Table Depth



For the sandy soils commonly found within the South Florida Water Management District (SFWMD), the NRCS/SCS developed standard profiles that relate soil storage capacity to the HWT depth (SFWMD, 1994). In addition, soil storage capacities were modified to better reflect development activity, whereby native soil values were reduced by 25 percent to account for the reduction in void spaces due to the compaction of earthwork operations. Table 5 shows the soil storage capacity under AMC_{dry} conditions determined using equation (6) and under AMC_{norm} and AMC_{wet} conditions determined by combining equations (3), (4), and (5) as described previously. These values are compared to the SFWMD typical values for both natural (native soils) and developed (disturbed soils) conditions. It appears that at shallow HWT depths, the AMC_{wet} values calculated from the detailed survey data in this study generally match the typical values shown. However, at deeper HWT depths, the AMC_{dry} values match the typical values shown.

Table 5
Soil Storage Capacities under Various Seasonal High Water Table Depths

HWT	Soil Storage Capacity (in)				
Depth	Detailed Survey Data[1]			Typical Values	
(ft)	AMC_{dry}	AMC_{norm}	AMC_{wet}	Natural[2]	Developed[3]
1	2.7	1.1	0.5	0.6	0.5
2	5.2	2.2	1.0	2.5	1.9
3	7.7	3.3	1.4	6.6	5.0
4	10.2	4.3	1.9	10.9	8.2

Notes:
1. Based on AMC_{dry} values determined using equation (6).
2. From table in Basis of Review, Section 8.4.2 (SFWMD, 1994).
3. From table in Appendix 6, Part C (SFWMD, 1994).

Soil Storage Capacity Based on Standard Soil Survey Data

Table 6 shows the soil storage capacity calculation for a single soil map unit within Polk County, based on standard NRCS/SCS soil survey data. The soil map unit, bottom depth of layer, and range of moist bulk densities were taken from the NRCS/SCS tabular data (Table 16, pages 211-216 in SCS, 1990). For this study, the average moist bulk density was used in the calculations. The water content at saturation was calculated using equation (1) and the soil particle and water density assumptions that were discussed earlier. An estimate of the water content at the field capacity was required in order to calculate the porosity values, since water content values at specific moisture tensions are not given in the standard NRCS/SCS tabular data. In this case, a value of 5.4 percent was chosen, which represents the average water content for all Group A soils in Polk County using the detailed soil survey data methodology, as shown in Table 2. The porosity at saturation and at the estimated water content was calculated using equation (2), and the drainable porosity was calculated as the difference between these two values.

The hydrologic soil group and estimate of the seasonal high water table depth were taken from the NRCS/SCS tabular data (Table 17, pages 217-221 in SCS, 1990) as described earlier. The final column in Table 6 shows the soil storage capacity for the map unit, calculated as the sum of the product of drainable porosity times the layer depth for all layers above the HWT. The soil storage capacity calculated using this methodology was 15.77 inches, which is approximately 10 percent greater than the value calculated using the detailed soil survey data methodology.

Table 6
Calculation of Soil Storage Capacity Using Standard Soil Survey Data

Soil Map Unit	Bottom Depth (in)	Moist Bulk Density (g/cm^3)			Water Content		Porosity		Drainable Porosity (in/in)	HSG	HWT Depth (in)	Storage Capacity (in)
		Min	Max	Average	At Sat'n	Estimated	At Sat'n	At Estimate				
2	51	1.45	1.60	1.53	80.9%	5.4%	68.2%	45.4%	22.8%	A	72	15.77
Apopka	80	1.55	1.75	1.65	58.1%	5.4%	60.6%	40.9%	19.7%			

Soil storage capacities were calculated using this methodology for 86 soil map units in five Florida counties. Hernando County data could not be used since moist bulk density estimates were not included in the standard soil properties (Table 15, pages 132-135 in SCS, 1977).

Figure 4 shows the comparison between soil storage capacities obtained using the standard and detailed soil survey data methodologies described in this paper. When results were grouped according to county, the computation using the standard survey data came within 10 percent on average for all counties compared to results using the detailed survey data. As mentioned earlier, the standard soil survey data methodology requires an estimate of the water content at field capacity. The same outcome (results within 10 percent on average for all counties) was obtained regardless of whether the water content was estimated using the specific county average or the average for all counties as shown in Table 2.

Figure 4
Soil Storage Capacity Comparison between Standard and Detailed Soil Survey Data

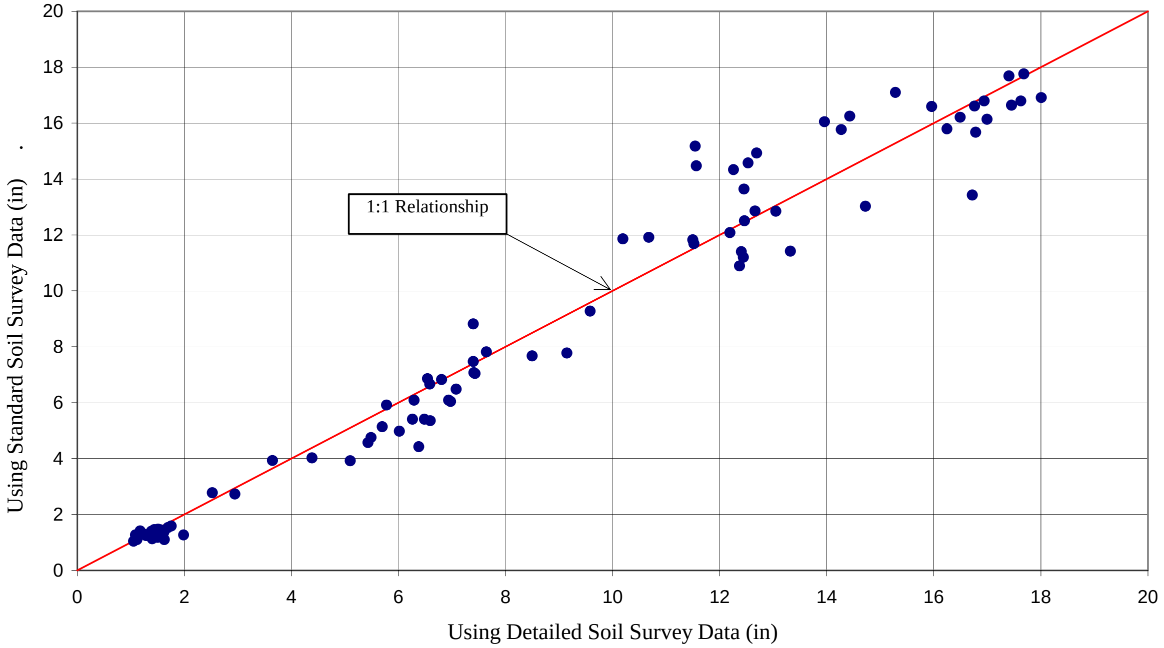
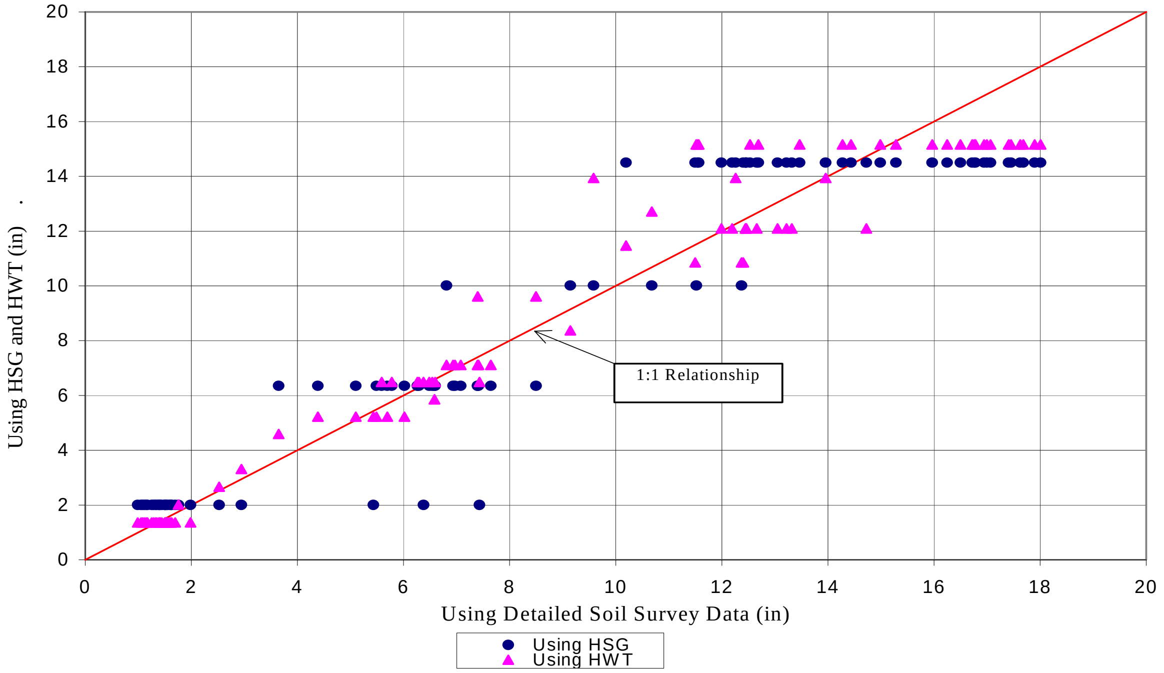


Figure 5
Soil Storage Capacity Comparison between HSG/HWT and Detailed Soil Survey Data



Soil Storage Capacity Based on Hydrologic Soil Group and Seasonal High Water Table Depth

As described previously in this paper, relationships between the soil storage capacity, HSG, and HWT were investigated. A simple method for estimating the soil storage capacity is to apply a constant value for a given HSG using the average values shown in the last column of Table 3. Another simple method is to apply equation (6), which relates storage capacity to HWT depth.

Figure 5 compares the soil storage capacities estimated using the two simple methods with the results using the detailed soil survey data methodology. Results were widely scattered for HSG throughout the range of storage capacity values and less scattered for HWT, except at the deeper HWT depths. For all 97 soil map units, values computed by HSG ranged from –73 to +102 percent of the values determined using the detailed soil survey data methodology. Likewise, values computed by HWT depth ranged from –31 to +46 percent of the “true” soil storage capacity. Based on these observations, it appears that HWT depth is a better indicator of the soil storage capacity than HSG.

SUMMARY AND CONCLUSIONS

The purpose of this paper was to evaluate methods for estimating the capacity of soils to store infiltrated stormwater based on available soil survey data. The methods presented in this paper offer an improvement over existing methods (e.g., the NRCS/SCS runoff curve number equation and standard SFWMD soil profiles), since the existing methods are based on very general soil, land use, and water table characteristics. Soil storage capacity values were computed for 97 soils in six Florida counties and results compared favorably with typical published values.

The most accurate method involves the use of detailed NRCS/SCS soil survey data. However, the necessary data are not always available for every soil map unit. In practice, either additional soil survey information would be required or an alternate method would need to be selected. An alternative method was developed that uses standard NRCS/SCS soil survey data, which are available for all soil map units. To use this method, an estimate of the water content at field capacity is required. For this study, the water content was estimated based on the average value for each hydrologic soil group (determined using the detailed survey data) and was shown to provide a reasonable estimate of the soil storage capacity. Furthermore, simple methods for estimating the soil storage capacity were developed based on the hydrologic soil group and on the depth to the seasonal high water table. These methods required the least amount of data and computational effort, but were shown to be the least accurate.

Finally, a number of practical considerations should be taken into account when applying the methods presented in this paper:

- The methods developed in this study apply to dry antecedent moisture conditions. Storm events include both historical storms (e.g., specific tropical storms) and design storm events (e.g., the 25-year/24-hour storm). For historical storms, the soil storage capacity must be adjusted to reflect the appropriate antecedent condition (e.g., normal or wet). Normal antecedent conditions are commonly used for design applications.

- The NRCS/SCS soil survey data are based on measurements of native, undisturbed soil samples. These data might not apply in urbanized areas where, for example, new soil has been imported for landscaping activities or earthwork operations have resulted in significantly compacted soil.
- For this study, the water table depth was taken as the average of the range reported in the NRCS/SCS soil survey. If available, it is better to use local well data, since localized water table depths may vary widely from the general soil survey range.
- For this study, dual soil groups (e.g., Group A/D and B/D) were treated as Group D soils. This assumption might not be valid in situations where drainage activities assist in drawing down the local water table.

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