SAN ANTONIO, TEXAS CURVE NUMBER STUDY

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INTRODUCTION

Pape-Dawson Engineers collaborated with American Forests (AF) to calibrate the NRCS Curve Numbers (CN) that are estimated and applied within the CITYgreen software. CITYgreen is typically used with standard TR-55 curve numbers applied based on soil type and land cover. The project area covers the City of San Antonio and its Extra-Territorial Jurisdiction (ETJ) (Figure 1). The effort was part of a larger Urban Ecosystem Analysis (American Forests 2008) performed by AF in 2008 to document landcover changes, estimate benefits of urban tree canopy and ultimately assist City staff with establishing tree canopy goals for new development.

Background

San Antonio lies within one of the most climatologically active regions in the world known as Flash Flood Alley. The region is prone to extreme rainfall events triggered by cold fronts colliding with warm moist low level flow from the Gulf of Mexico. The Balcones Escarpment which is a 600 to 700 ft geologic uplift creates orographic lift adding to the intensity of precipitation events. The escarpment abuts the Edwards Aquifer Recharge Zone which is characterized by karst solution cavities and very high infiltration rates especially within creeks that have incised into the limestone outcrops. This geologic framework produces extreme variability in infiltration rates and difficulty estimating curve numbers from standard soil maps.

The majority of the city lies downstream from the steep limestone hills that naturally generate runoff at rates of four plus cfs per acre. Within this setting, land cover and storm water management are intricately linked and critically important to protect life and property. The City of San Antonio has actively managed stormwater for the last two decades but faces a daunting task where 24-hour, 100-year design rainfall exceeds ten inches. The city is now looking to incorporate passive management by increasing tree canopy and open space to reduce runoff and improve water quality.

Watershed Selection

Five basins were originally selected for calibration based on the locations of USGS stream gage stations in Bexar County. Two of the watersheds in Eastern Bexar County are not completely within the City of San Antonio ETJ which eliminated them from consideration. The remaining three basins are defined by the three USGS stream gages listed in Table 1.

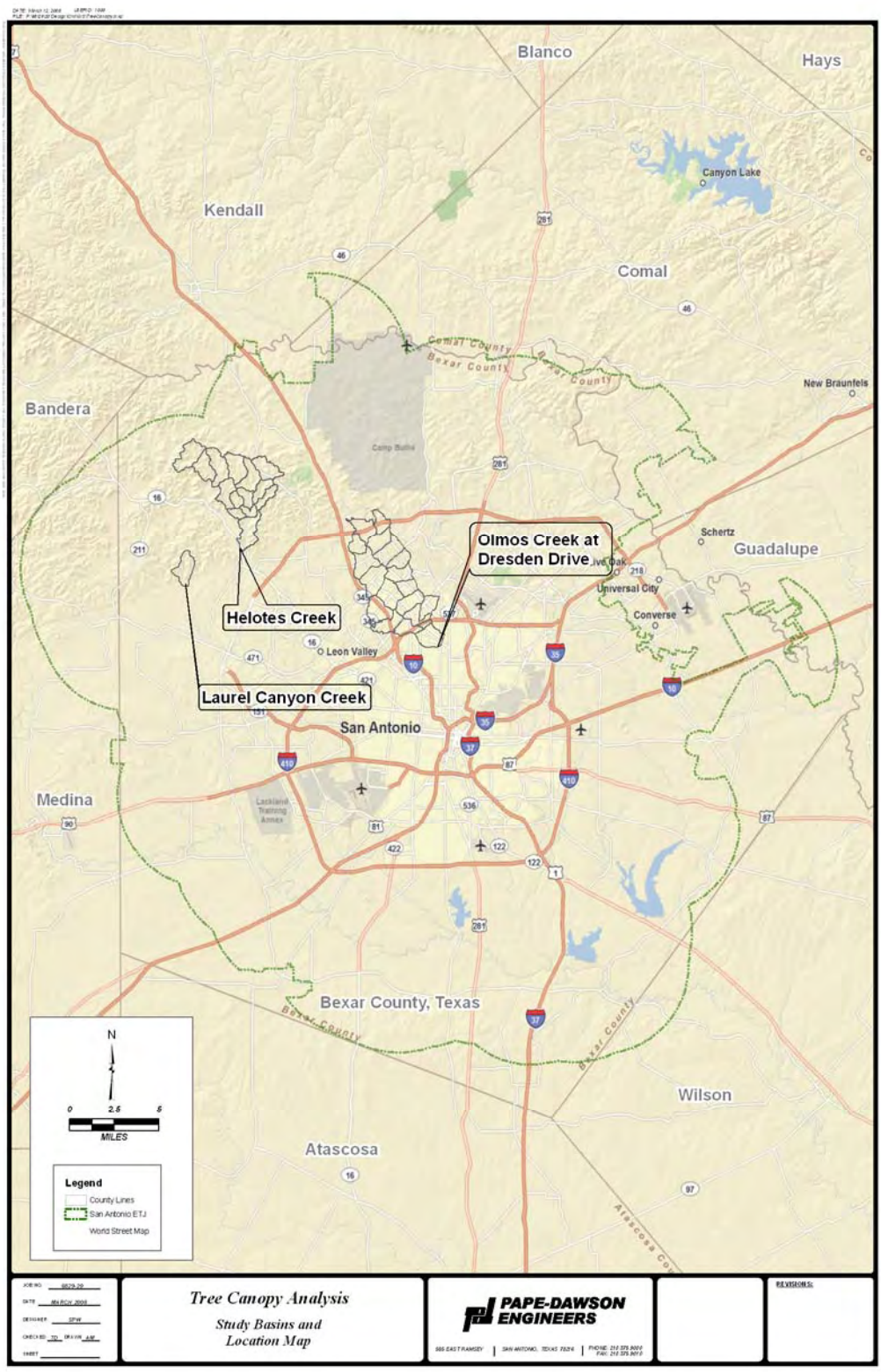

Figure 1 Study Basins within the City of San Antonio ETJ

Table 1 USGS Stream Gages Used in Analysis

Stream Gage Number	Name	Drainage Area Square Miles	Period of Record
08180942	Laurel Canyon Ck nr Helotes TX	0.79	2002-08
08181400	Helotes Ck nr Helotes TX	15.0	1969-08
08177700	Olmos Ck at Dresden Dr San Antonio TX	21.2	1947-08

The watersheds range in size from 0.8 to 21.2 square miles and vary from undeveloped to approximately 50 percent urbanized. Table 2 lists the average hydrologic parameters for each watershed.

Table 2 Summary Hydrologic Parameters

Basin	Area (sq. mi.)	# of model subwatersheds	Basin Length (mi)	TR-55 Base CN	Percent Impervious
Laurel Canyon	0.79	1	1.5	77	0
Helotes Creek	15.0	13	9.5	74	4
Olmos Creek	21.2	19	10.8	76	51

HYDROLOGIC MODELING AND ANALYSIS

Recent detailed HEC-HMS hydrologic models were prepared for the Bexar County FEMA Map Modernization Project. The San Antonio River Authority (SARA) led the project and City of San Antonio staff provided additional review and oversight. As one of the FEMA study contractors, Pape-Dawson was heavily involved in developing the Bexar Regional Watershed Management (BRWM) modeling methodologies used. The model for each watershed was obtained from the San Antonio River Authority and truncated to the location of the stream gage. The models were verified for accuracy of the routing, curve number and impervious cover values. The models were set up to produce calibration runs using NEXRAD data that was provided by SARA. These models are considered the best available for the region and use the SCS curve number approach and Synder Unit Hydrograph for computing runoff. The City of San Antonio Unified Development Code (UDC) specifies the Curve Number for each hydrologic soil group. The UDC lists TR-55 Table 2-2c values for brush in fair condition as baseline curve numbers and impervious cover percentage is increased to reflect development within the watershed. This simplified approach is sufficient for applications where impacts of new development are calculated.

Storm Events

Major storm events which included significant local and regional flooding occurred in 1997, 1998, 2002, 2004 and 2007. These events range from 5-yr to 500-year return interval events.

Precipitation gage data, NEXRAD precipitation estimates, and stream gage data have been collected for most of these events. The precipitation gage data includes information from Lackland Air Force Base, NWS sites, and the Edwards Aquifer Authority. Stream gage records are not available for events where the gage was flooded or rendered inoperable. NEXRAD estimates are missing for some periods where the radar site was not operational most notably during the October 1998 event.

Methodology

The initial approach relied on calibrating the hydrologic models to the observed storm events based on volume, timing, and peak flow. While the first day calibration was accurate, the TR-55 curve number approach is applicable only for 24 hr. storm events, not continuous simulation over several days. The simulation results for successive days of a multi-day event were less and less accurate (Figure 2). Further calibration runs with varying curve numbers validated the observation that the curve numbers are not static throughout a storm event. The interaction of the Edwards Aquifer Recharge Zone on the upper parts of the study watersheds may explain the relatively rapid recovery in infiltration capacity of the soil after heavy rainfall periods.

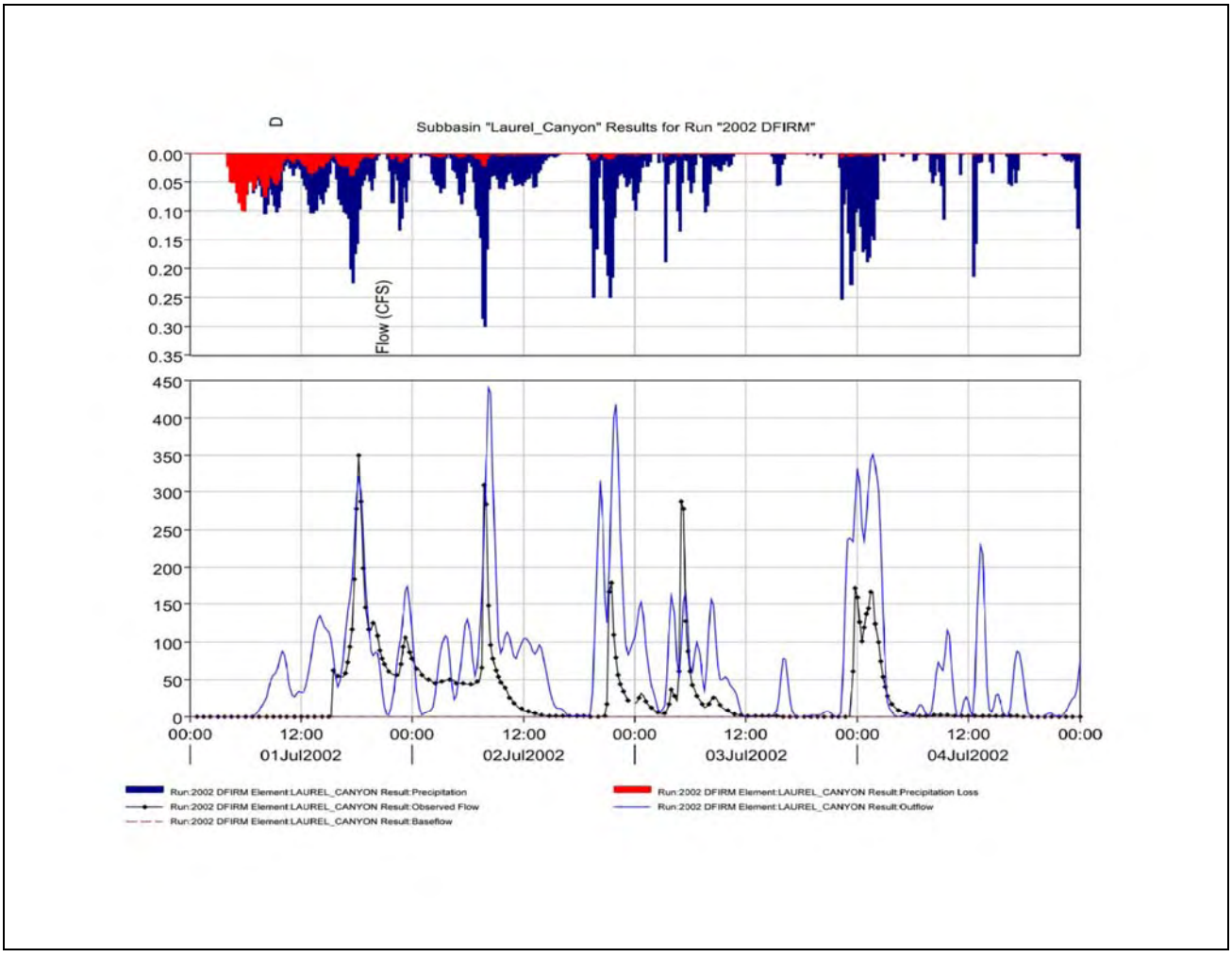

Figure 2 – Laurel Canyon – HEC-HMS Results (blue) vs observed (black).

Based on the initial observations, a modified approach which computed the curve number purely from volumetric comparison of rainfall versus runoff on a daily basis was considered. This approach allowed for using more storm events and increased the curve number calibration points. The results for selected storms for each study basin are presented in Tables 3 – 5.

Event Date	Rainfall (in)	Runoff (in)	CN
7/1/2002	5.23	1.83	65.27935653
7/2/2002	5.16	2.16	70.05221936
7/3/2002	2.88	0.91	75.52059231
7/4/2002	2.67	0.77	75.38176578
7/5/2002	2.53	0.73	76.37566051
11/22/2004	2.537994406	0.42905515	68.73011137
8/15/2007	0.090501399	N/A	N/A
8/16/2007	6.585487413	0.867751473	42.54455087
8/17/2007	0.2	N/A	N/A

Table 3 SB-1 Laurel Canyon Creek

Event Date	Rainfall (in)	Runoff (in.)	CN
6/21/1997	3.5	0.53	59.96437
6/22/1997	5.6	2.58	71.00049
10/17/1998	5.90263717	1.8	59.28654
10/18/1998	4.35	3.35	90.96625
10/19/1998	0.75	0.62	98.7825
7/1/2002	5.847416814	1.56	56.68862
7/2/2002	3.885699353	1.74	77.23302
11/22/2004	3.18	0.44	61.11617
3/12/2007	1.545848838	0.04707	66.01712
3/13/2007	0.613342156	0.128822	91.25369
3/14/2007	1.560383983	0.148641	72.9794
8/16/2007	7.32	3.71	68.36607

9/4/2007-9/5/2007	3.57	2.12061	85.52318

Table 4 SB-2 - Helotes Creek

Event Date	Rainfall (in)	Runoff (in)	CN
6/30/2002	2.18	0.47	74.81063
11/1/2004	1.406437541	0.867	94.197
11/17/2004	3.26	1.57	81.76751
11/22/2004	3.21	2.14	89.56934
3/13/2007	1.53	0.765322	91.01244
3/14/2007	2.289569781	0.960195	84.08653
8/16/2007	5.735123045	3.18884	76.37675

Table 5 SB-3 - Olmos Creek

Based on the information in Tables 3-5 representative curve numbers were determined as shown below. The average watershed curve number calculated from all observations for a watershed was used as a guide.

Stream Gage Number	Name	Curve Number
08180942	Laurel Canyon Ck nr Helotes TX	75
08181400	Helotes Ck nr Helotes TX	74
08177700	Olmos Ck at Dresden Dr San Antonio TX	82

Table 6 Representative Curve Numbers for Selected watersheds.

RESULTS

American Forest determined the land cover and soil group for each watershed above the stream gage using GIS techniques for the five cover classes: Impervious, Open Space, Trees, Urban Bare, and Water. Table 7 lists the percentage of each cover class for the study basins.

Number	Impervious	Open Space Grass Trees	Trees	Urban Bare	Water	Total	C soil	D soil

	%	%	%	%	%		%	%
8180942	0.19	5.84	93.94	0.03	0	100.00	0	100
8181400	3.19	20.01	72.93	3.66	0.21	100.00	0	100
8177700	31.01	14.57	50.78	3.5	0.14	100.00	42.5	57.5

Table 7 Land Cover and Hydrologic Soils for selected basins.

The curve numbers in Table 2 of TR-55 were used as initial values to determine if the selected values in Table 6 could be matched. The technique of redistributing the curve numbers was used to match the selected curve numbers.

The redistributed curve numbers for the selected watersheds are shown in the following table.

Number	Selected curve numbers	Redistributed curve numbers
8180942	75	75
8181400	74	76
8177700	82	81

Table 8 Comparison of the curve numbers.

It was assumed that the redistributed cure numbers represent the conditions measured by the selected storms. It is recognized that the variation is acceptable given the variation in the basic data. The curve number aligner was then used to determine the curve number for other soil groups since only hydrologic soil group C and D soils occurred in the sample watersheds. The resulting aligner is shown as Figure 3.

The curve numbers that should be used in CITY Green for San Antonio for the five land cover classes is shown in the following table.

Soil Group	Impervious (5000)	Open Space Grass Trees (7000)	Trees (10000)	Urban Bare (12100)	Water (13000)
a	98	21	23	79	100
b	98	50	51	86	100
c	98	66	68	91	100
d	98	74	75	93	100

The values in ( ) are the land cover codes

Table 9 Recommended curve numbers to use in CITYgreen for San Antonio

CONCLUSIONS

The curve numbers in Table 9 were used within the CITYgreen software to estimate the impact of land use changes on stormwater runoff and water quality. Annual estimates of carbon sequestration, pollutant removal and stormwater reduction were assigned costs to determine the avoided costs attributable to urban tree canopy.

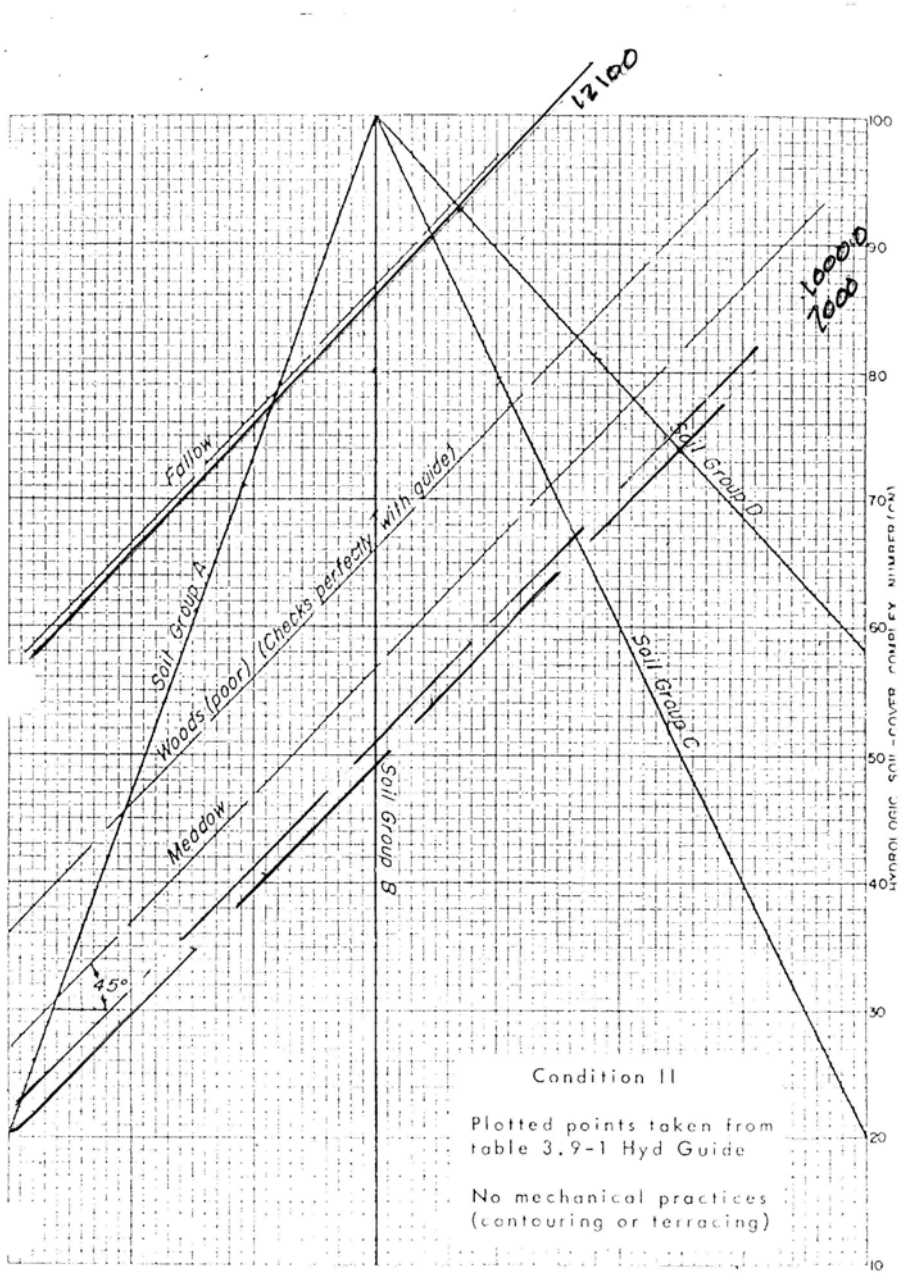

Figure 3 Curve Number Aligner

REFERENCES

American Forests (2008). Urban Ecosystem Analysis: San Antonio, Texas. American Forests, Washington, D.C.

City of San Antonio (2009), Unified Development Code, City of San Antonio, San Antonio, TX