INVER GROVE HEIGHTS
Northwest Area

Appendix E

Curve Number Derivation

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Curve Number Derivation

Appendix E

A brief summary of the process of determining the applicable CNs for the NWA is described in this appendix, for more detail; see the NWEA Modeling Report, 2006.

Contents

I. Introduction

This section provides detail on the establishment of the hydrologic parameters to be used in the stormwater runoff calculations. The hydrologic parameters used to model runoff in the Northwest Area (NWA) of Inver Grove Heights have been calibrated based on monitoring data collected within the NWA and the monitoring data indicate that the standard hydrologic parameters (state and national data) should not be used for analysis within the NWA. Many of the state and national methods are designed to be used for large storms, in watersheds with large runoff fractions, and may not be appropriate for smaller rainfall events or smaller runoff fractions.

The SCS method and the Green-Ampt method were analyzed during the in the Inver Grove Heights NWA modeling process. SCS methodology is the principal methodology discussed in this section because it is the predominant method used by design engineers. Other runoff calculation methods may be accepted at the City Engineer's discretion, however sufficient documentation exhibiting the merits of another method and its hydrologic parameters within the NWA must be exhibited for such an exception to be warranted.

II. Modeling Methodologies Examined

SCS Method. The accuracy of the SCS methodology is described in the National Engineering Handbook, Part 630.1003, "Accuracy". This section states that the most common use of the SCS method is to "determine a design discharge [25-year, 100-year, probable maximum flood (PMF)] based on a synthetic rainstorm."[1] The probable maximum flood is the "flood that can be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in a region."[2] The PMF analysis uses extreme rainfall events that coincide with the worst-case scenarios for other hydrologic conditions. The National Engineering Handbook later states that the SCS method performed "poorly in cases where the runoff was a small fraction of the rainfall; i.e., the CNs are low or rainfall values are small."[3] The monitored runoff from the NWA in Inver Grove Heights was a very small fraction of the rainfall at all of the monitored locations. Therefore it would be expected that the SCS values would poorly reflect the actual runoff that occurred in the NWA.

Green-Ampt Method. While the SCS method has a standard set of state and national approved values, the Green-Ampt method has a large range of values that are used for runoff analyses. The SCS method also boils all the parameters into one value used for calculation, a curve number; while Green-Ampt method applies three variables in the runoff calculations. These variables all relate to soil properties; average capillary suction (S_u), initial moisture deficit (IMD) and saturated hydraulic conductivity (K_s). By far the most variable (and sensitive) of these parameters is K_s. The values recommended by the modeling software, XP-SWMM, have calibrated well in previous analyses, and were used as the starting point in the modeling process.

III. Comparison of Runoff Calculation Methods

Another important consideration in the transformation of Green-Ampt parameters to SCS, is an analysis of how each method calculates runoff. Table E.1 outlines the variables used for each method.

Table E.1. Hydrology Volume Calculation Variable Comparison

Green-Ampt	Area	% Impervious	Soil Type	Slope	Width
SCS*	Area	% Impervious	Soil Type	Land Cover	

*NOTE: Time of concentration is not shown because it does not affect the runoff volume, only the rate of runoff, whereas in Green-Ampt method, the slope and width parameters do affect the volume of runoff.

Green-Ampt methodology differs from SCS because it uses the slope and width for generation of runoff volume while SCS uses land cover. Theoretically, this difference is accentuated in areas with limited directly connected impervious surface and steep slopes, as prevalent in the NWEA, where using solely the land cover (as SCS methodology does) would result in minimal runoff, while using solely the width and steep slopes (as Green-Ampt does) should yield more runoff.

Because the soils in the NWA allowed such a small amount of runoff and because the Green-Ampt method does not account for the land use function, the hydraulic conductivity of the soil was increased by 50%. This resulted in a very good calibration to the large 6.4" rainfall event that was monitored.

IV. Green-Ampt to SCS Parameter Conversion

Using the aforementioned revisions and updating the model, the basin levels calibrated closer to monitored data. The model is still marginally conservative and generally overestimates the volume of runoff coming from the landscape. Table E.2 shows the output of the now calibrated Green-Ampt model after it was run for a 5-year, 24-hour rainfall event.

Table E.2. Green-Ampt Model Output

XP-SWMM Output	[3.6" Rainfall Event (5-year)]								
Subcatchment	EP-016a	EP-034	EP-036a	EP-066a	EP-071	EP-102a	EP-104	F-022	SP-7
Area (acres)	96.9	38.1	20.2	32.5	45.8	29.1	41.6	30.8	19.9
Percent Impervious	25.3	3.9	17.1	0	9.8	26.1	4.2	58.7	0
Total Rainfall (in)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Pervious Area									
Total Runoff Depth (in)	0.03	0.07	0.31	0.04	0.16	0.02	0.11	0.09	0.13
Total Area									
Total Runoff Depth (in)	0.90	0.21	0.86	0.04	0.49	0.92	0.11	2.07	0.13
CN (no vol. adjustments)	41	44	53	42	48	40	46	45	47
CN (MN Hydrology Guide)	65	67	67	53	62	70	71	60	62

The output of Table E.2 was generated because the five-year rainfall event (3.6" of rain in 24 hours) has been chosen as the design event for IGH. The goal of the conversion is to have curve numbers that generate similar volumes to those generated by the calibrated Green-Ampt model.

The runoff depth from pervious surfaces (row 5) was used to back-calculate an equivalent curve number to match the model results. That equivalent curve number is shown in row 7. The curve number calculated using the standard Minnesota Hydrology Guide curve numbers is shown below the calibrated values (bottom row). The values recommended by the MN Hydrology Guide are, on average, 16 units larger than those indicated by the calibrated model. Clearly, using the curve numbers from the MN Hydrology Guide overestimates the volume of runoff that actually occurs in the Inver Grove Heights system for the relevant rainfall event. Therefore, some type of adjustment needed to be made to the recommended guide values so the SCS method can become appropriate.

V. Conclusion

Essentially the NWA soils and land cover produce much less stormwater runoff than predicted using the traditional Green-Ampt or SCS hydrologic parameters. Both methods predict more runoff volume than actually occurred as documented by the monitoring of basins in 2005. This indicates that the soils are actually allowing much less water to run off (infiltrating more) than similar soils in analogous Minnesota locations.

One means of quantifying this phenomenon is by using the hydrologic soil type values. Curve numbers are calculated by land cover and assigned based on A, B, C, or D type soils. “A” (sandy) soils allow maximum infiltration, while “D” (clayey) soils allow minimal infiltration. The vast majority of the soils in the NWA of Inver Grove Heights are “B” type soils. Many of these “A” and “B” soils in the NWA were re-classified as an “A/B” type soil based on many soil characteristics. The methodology used in making these modifications can be found in the May 12, 2006, “Northwest Expansion Area Hydrologic & Hydraulic Analysis Update and Gun Club Lake Modeling Report”. This resulted in an improved fit to the monitored volume generated during the 6.4” monitored rainfall event.

The Antecedent Moisture Condition (AMC) was also examined as a possibility for a curve number calibration for the NWA. The AMC is an adjustment factor used to modify the recommended curve numbers based on ground moisture conditions at the beginning of a rainfall event. The AMC is similar to the Green-Ampt parameter of initial moisture deficit, however it is traditionally assigned based on geographical area and not by soil type. There are three classes of AMC; the average condition is Class II, while drier conditions use Class I and wetter conditions use Class III. It was examined to determine if the soils in Inver Grove Heights infiltrate so well that a Class I AMC should be used to reflect the drier soil conditions. However, Class I AMC overcompensated by applying a curve number well below what the monitoring data indicated was occurring. A curve number averaging the AMC I and the AMC II values was developed, however this yielded results almost identical to the upgrading of soil classes previously discussed. The upgrading of soil classes is the more appropriate methodology, considering that more than two inches of rain had fallen within the ten days preceding the 6.4”, October 4-5, rainfall event to which the model was calibrated, indicating that the conditions were not “drier”. Any lack of moisture in the soil is due to the high capacity of the soil to infiltrate and not due to the Antecedent Moisture Condition.

Table E.5 gives a breakdown of the areas by cover type found in the subwatersheds with monitored basin data. The far right column indicates the curve number that would be used in the permitting process (calculated based on values shown in Table E.4), while the “Pervious Composite Target” column is the CN that was back-calculated from the calibrated model values. The highlighted cells indicate the accuracy the model had in mimicking the monitored levels, identifying whether the subwatershed model over predicted the runoff generated, under predicted it, or came very close to matching the actual runoff volume. The “MN Hydrology Guide CN” column shows the curve number that would be calculated using standard values (shown in Table E.3).

VI. Additional Considerations

Impervious surfaces that are directly connected to the downstream drainage feature are to be modeled independently of the pervious land cover or the impervious surfaces which have runoff directed over the pervious soils. The directly connected impervious surfaces should not composited (for more detail, see

Pretreatment section in Chapter 7 and the Example Site Design in Chapter 9). The XP-SWMM (RUNOFF) Green-Ampt method does not combine impervious surfaces and pervious surfaces; neither should they be combined in SCS methodology. This modeling method does not accurately reflect the calibrated model.

Table E.3. Pervious MN Hydrology Guide Recommended ARC II Curve Numbers

	1	2	3	4	5	6
	Meadow	Woods	Woods & Meadow	Agricultural	Urban Open Space	Wetland*
Condition:	Fair	Fair	Good	Good	Good	N/A
A	35	36	32	51	39	75
A/B*	45	48	45	59	50	76
B	56	60	58	67	61	78
C	70	73	72	76	74	83
D	77	79	79	80	80	85

*Calculated average of A & B type soils, not found in MN Hydrology Guide
*Wetland values not assigned CN in MN Hydrology Guide

(orange)	Overestimates runoff
(yellow)	Underestimates runoff
(white)	Good estimation

Table E.4. IGH Recommended Curve Numbers

	1		2		3		4	5		6
	Meadow		Woods		Woods & Meadow		Agricultural	Urban Open Space		Wetland*
Soil Type	Undisturbed	Graded	Undisturbed	Graded	Undisturbed	Graded	Cultivated	Undisturbed	Graded	N/A
A	33	35	34	36	30	32	48	39	50	75
A/B*	35	45	36	48	32	45	51	50	61	76
B	45	56	48	60	45	58	59	61	74	78
C	56	70	60	73	58	72	67	74	80	83
D	70	77	73	79	72	79	76	80	80	85

Table E.5. Subwatershed Acres by Cover Type & Soil Type

	Acres of Cover Type						5-year, 24-hour Rainfall Event			
Soil Type	Meadow	Woods	Woods & Meadow	Agricultural	Graded Urban Open Space	Wetland*	TOTAL ACRES	Pervious Calibrated Target	MN Hydrology Guide CN	IGH Curve Number
EP-016a							73.1	41	50	38
A							0.0			
A/B	17.1	8.8	27.0			0.3	53.1		46	34
B	5.2	1.2	11.5			2.2	20.0		60	49
EP-034							38.1	44	57	47
A	0.9		0.4				1.3		34	32
A/B	2.6	2.2	2.5	7.2		0.2	14.7		53	43
B	4.3	3.5	8.2	4.1	0.7	1.3	22.1		61	51
EP-036a							20.2	53	59	49
A							0.0			
A/B	1.1		0.3			0.1	1.4		46	36
B	10.9	0.2	3.0	3.6		1.1	18.7		60	50
EP-66a							32.5	42	50	40
A	0.5						0.5		35	33
A/B	18.1	0.6	2.4	4.0			25.1		47	37
B	5.3	0.3	0.1	1.4			7.0		58	48
EP-71							44.6	48	60	50

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	1	2	3	4	5	6
	Meadow	Woods	Woods & Meadow	Agricultural	Urban Open Space	Wetland*
Condition:	Fair	Fair	Good	Good	Good	N/A
A	35	36	32	51	39	75
A/B*	45	48	45	59	50	76
B	56	60	58	67	61	78
C	70	73	72	76	74	83
D	77	79	79	80	80	85

*Calculated average of A & B type soils, not found in MN Hydrology Guide
*Wetland values not assigned CN in MN Hydrology Guide

(orange)	Overestimates runoff
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	1		2		3		4	5		6
	Meadow		Woods		Woods & Meadow		Agricultural	Urban Open Space		Wetland*
Soil Type	Undisturbed	Graded	Undisturbed	Graded	Undisturbed	Graded	Cultivated	Undisturbed	Graded	N/A
A	33	35	34	36	30	32	48	39	50	75
A/B*	35	45	36	48	32	45	51	50	61	76
B	45	56	48	60	45	58	59	61	74	78
C	56	70	60	73	58	72	67	74	80	83
D	70	77	73	79	72	79	76	80	80	85

Table E.5. Subwatershed Acres by Cover Type & Soil Type

	Acres of Cover Type						5-year, 24-hour Rainfall Event			
Soil Type	**Meadow**	**Woods**	**Woods & Meadow**	**Agricultural**	**Graded Urban Open Space**	**Wetland***	**TOTAL ACRES**	**Pervious Calibrated Target**	**MN Hydrology Guide CN**	**IGH Curve Number**
EP-016a							73.1	*41*	50	**38**
A							0.0			
A/B	17.1	8.8	27.0			0.3	53.1		46	34
B	5.2	1.2	11.5			2.2	20.0		60	49
EP-034							38.1	*44*	57	**47**
A	0.9		0.4				1.3		34	32
A/B	2.6	2.2	2.5	7.2		0.2	14.7		53	43
B	4.3	3.5	8.2	4.1	0.7	1.3	22.1		61	51
EP-036a							20.2	*53*	59	**49**
A							0.0			
A/B	1.1		0.3			0.1	1.4		46	36
B	10.9	0.2	3.0	3.6		1.1	18.7		60	50
EP-66a							32.5	*42*	50	**40**
A	0.5						0.5		35	33
A/B	18.1	0.6	2.4	4.0			25.1		47	37
B	5.3	0.3	0.1	1.4			7.0		58	48
EP-71							44.6	*48*	60	**50**
A							0.0			
A/B	3.3	0.2	4.4	4.9	0.1		12.9		50	40
B	5.0		9.6	13.8		3.3	31.8		64	55
EP-102a							29.1	*40*	57	**49**
A							0.0			
A/B	8.2		1.5	10.7		2.3	22.7		55	46
B	1.6		1.5	0.8		2.4	6.4		66	59

EP-104							41.6	*46*	61	**51**
A							0.0			
A/B	0.8		1.0	9.4			11.2		57	48
B	3.5		12.2	14.7			30.4		62	52
F-022							16.4	*45*	54	**43**
A							0.0			
A/B	0.0	0.9	5.2				6.1		45	33
B	1.7	0.2	7.3			1.1	10.3		60	49
SP-7							19.8	*47*	55	**46**
A							0.0			
A/B		3.1	3.2		0.2		6.5		47	35
B		2.3	8.4	0.3	2.4		13.4		59	51

[1] National Engineering Handbook. Part 630. 210-VI-NEH, July 2004. pg. 10-19.
[2] American Meteorological Society Web page Glossary. http://amsglossary.allenpress.com/glossary.
[3] National Engineering Handbook. Part 630. 210-VI-NEH, July 2004. pg. 10-19.