

DRAINAGE AND STORM WATER QUALITY PLAN AND SUPPORTING CALCULATIONS

FOR

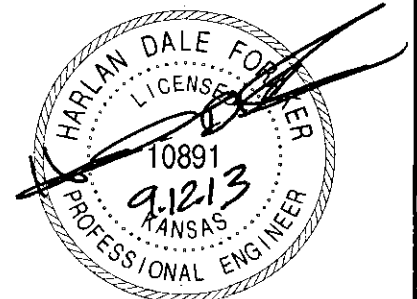
**QUIKTRIP 15TH ADDITION
CENTRAL & OLIVER
WICHITA, KANSAS**

**PREPARED FOR:
QUIKTRIP CORPORATION
4705 SOUTH 129TH EAST AVENUE
TULSA, OK 74134**

SEPTEMBER 12TH, 2013

PREPARED BY:

**CERTIFIED ENGINEERING DESIGN, P.A.
1935 WEST MAPLE
WICHITA, KANSAS 67213-3311
(316)262-8808 PHONE
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Mr. Scott Lindebak, P.E., (Con't)
QUIKTRIP 15TH ADDITION
September 12th, 2013

CERTIFIED ENGINEERING DESIGN, P.A

1935 West Maple
Wichita, KS 67213-3311
(316)262-8808 Office
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LETTER OF TRANSMITTAL

DATE: September 12th, 2013

TO: Mr. Scott Lindebak, P.E.
Engineering Division
City of Wichita
8th Floor, City Hall
455 N. Main
Wichita, KS 67202

RE: Drainage Plan
QUIKTRIP 15th Addition
Wichita, KS

FROM: Harlan D. Foraker, P.E. *HDF*

cc: Jake Petras, Real Estate Project Manager, QuikTrip Corporation

I. TAB 1 – PROJECT NARRATIVE:

Discussion of Development

The goal of this report is to analyze the existing drainage patterns and design the proposed drainage system to serve the QUIKTRIP 15th Addition site in Wichita, KS. This site is located at the northwest corner of Central & Oliver. This current site is developed and consists of an existing QT site, a commercial site, and a residential area.

The proposed improvements include the demolition of the existing site and adding a QuikTrip building with concrete pavement parking and gas canopy area. The estimated disturbed area is around 2.08 acres. Proposed conditions will cause an increase in the amount of impervious area by 0.15 acres. The total area of the property is 1.68 acres. An aerial photograph of the proposed plat site is located in the Appendix.

Offsite Conditions

There are two small off-site areas that drain onto the site. These areas are labeled X1 and X2 on the Existing Drainage Map in the Appendix. The proposed improvements will accommodate these offsite drainage areas and allow them to drain through the proposed QuikTrip site.

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Description of Best Management Practices

A stormwater pollution prevention plan (SWPPP) will be developed for erosion control purposes. The disturbed area of the QT site will be surrounded with silt fence, and the existing curb inlets located on the surrounding streets will have curb inlet protection. A construction entrance is located on the south end of the site. The proposed curb inlets located on site will also have curb inlet protection. An erosion control plan will be sent and approved by KDHE.

Hydrologic Calculations

The rational method was used to compute the peak discharges for existing and proposed conditions. Rational 'C' Factors were assigned to the existing site and proposed improvements from the City of Wichita Storm Water Manual. The Soil Conservation Service TR-55 manual was used to compute the time of concentration for the drainage areas. A design assumption was made as follows: that the minimum time of concentration is 15 minutes. Soil Types were determined from the Natural Resource Conservation Soil Survey website. The SCS soil type present on the site is the Urban-Land Farnum Complex. This soil is an unrated SCS soil. For the purpose of the drainage plan, this soil will be assumed as a SCS Type D soil.

Hydraulic Analysis

The proposed storm sewer system was designed with the rational method. The 10-yr design storm was selected to size the storm sewer system. The spreadsheet used in the design of the system is shown in the Appendix.

Ground Water Elevations

According to the Kansas Geological Survey's Kansas Water Well Database, the static water surface elevation of the ground water in this area is around 10-15 ft below the existing ground.

Summary of Runoff Calculations

The proposed runoff calculations cause a small increase in peak discharges for all storm series when compared with existing runoff calculations. However, since the increase in impervious area is less than 1 acre, detention is not required. Table 1 shows existing and developed runoff calculations.

Existing & Developed Peak Runoff - Rational Method	
Description	Q (cfs)
Combined Existing Runoff (2 yr.)	5.64
Combined Existing Runoff (5 yr.)	6.81
Combined Existing Runoff (10 yr.)	8.11
Combined Existing Runoff (25 yr.)	9.49
Combined Existing Runoff (100 yr.)	12.21
Combined Developed Runoff (2 yr.)	5.94
Combined Developed Runoff (5 yr.)	7.13
Combined Developed Runoff (10 yr.)	8.41
Combined Developed Runoff (25 yr.)	9.82
Combined Developed Runoff (100 yr.)	12.46
<i>*All runoff values include offsite drainage</i>	

TABLE 1 – EXISTING AND DEVELOPED RUNOFF CALCULATIONS

II. TAB 2 – EXISTING CONDITIONS RUNOFF CALCULATIONS

Existing Conditions

The existing site has been divided into four sub-basins. Two extra sub-basins outline the offsite drainage areas. Most of the site drains from west to east across the site. There is no existing storm sewer within the site property boundary. All drainage sheet flows across the site where it exits the drives and enters into the city storm sewer system along both Oliver and Central street.

A summary of the existing drainage calculations can be seen in Table 2. The existing drainage basins can be seen on the Existing Drainage Map located in the Appendix.

Existing Peak Runoff - Rational Method						
Description	Percent Impervious (%)	C	Tc	I (in./hr)	Area (acres)	Q (cfs)
Existing Basin A (2 yr.)	91	0.82	15	3.83	0.55	1.73
Existing Basin A (5 yr.)		0.82	15	4.56	0.55	2.06
Existing Basin A (10 yr.)		0.84	15	5.22	0.55	2.41
Existing Basin A (25 yr.)		0.84	15	6.06	0.55	2.80
Existing Basin A (100 yr.)		0.87	15	7.37	0.55	3.53
Existing Basin B (2 yr.)	79	0.75	15	3.83	0.52	1.49
Existing Basin B (5 yr.)		0.76	15	4.56	0.52	1.80
Existing Basin B (10 yr.)		0.79	15	5.22	0.52	2.14
Existing Basin B (25 yr.)		0.80	15	6.06	0.52	2.52
Existing Basin B (100 yr.)		0.84	15	7.37	0.52	3.22
Existing Basin C (2 yr.)	63	0.66	15	3.83	0.43	1.09
Existing Basin C (5 yr.)		0.68	15	4.56	0.43	1.33
Existing Basin C (10 yr.)		0.72	15	5.22	0.43	1.62
Existing Basin C (25 yr.)		0.73	15	6.06	0.43	1.90
Existing Basin C (100 yr.)		0.80	15	7.37	0.43	2.54
Existing Basin D (2 yr.)	42	0.54	15	3.83	0.19	0.39
Existing Basin D (5 yr.)		0.57	15	4.56	0.19	0.49
Existing Basin D (10 yr.)		0.63	15	5.22	0.19	0.62
Existing Basin D (25 yr.)		0.65	15	6.06	0.19	0.75
Existing Basin D (100 yr.)		0.75	15	7.37	0.19	1.05
Offsite Basin X1 (2 yr.)	100	0.87	15	3.83	0.16	0.53
Offsite Basin X1 (5 yr.)		0.87	15	4.56	0.16	0.63
Offsite Basin X1 (10 yr.)		0.88	15	5.22	0.16	0.73
Offsite Basin X1 (25 yr.)		0.88	15	6.06	0.16	0.85
Offsite Basin X1 (100 yr.)		0.89	15	7.37	0.16	1.05
Offsite Basin X2 (2 yr.)	92	0.82	15	3.83	0.13	0.41
Offsite Basin X2 (5 yr.)		0.83	15	4.56	0.13	0.49
Offsite Basin X2 (10 yr.)		0.85	15	5.22	0.13	0.58
Offsite Basin X2 (25 yr.)		0.85	15	6.06	0.13	0.67
Offsite Basin X2 (100 yr.)		0.87	15	7.37	0.13	0.83

Table 2 – Existing Runoff Calculations

The combined 100-yr peak discharge for the existing site is 12.21 cfs.

III. TAB 3 – DEVELOPED CONDITIONS RUNOFF CALCULATIONS

Developed Conditions

The proposed plat site is divided into eight sub-basins. Three extra sub-basins outline the offsite drainage areas. Existing sub-basin X2 was divided into two sub-basins

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labeled X2 and X3 for developed conditions. The proposed site incorporates a storm sewer system that runs along the north and east parts of the site draining sub-basins B, C, D, G, H, X1, X2, and X3. Sub-basins A, E, and F drain to the surrounding streets and do not utilize the proposed storm sewer system. One of the existing city curb inlets will be relocated to the south and a new SWS manhole will be located in place of it due to the location of the proposed drive entrance on Oliver Street. Another city inlet will be changed to a curb inlet and relocated due to the location of the proposed drive entrance on Central street.

A summary of the developed drainage calculations can be seen in Table 3. The developed drainage basins can be seen on the Developed Drainage Map located in the Appendix.

Developed Peak Runoff - Rational Method						
Description	Percent Impervious (%)	C	Tc	I (in./hr)	Area (acres)	Q (cfs)
Developed Basin A (2 yr.)	50	0.59	15	3.83	0.02	0.05
Developed Basin A (5 yr.)		0.61	15	4.56	0.02	0.06
Developed Basin A (10 yr.)		0.67	15	5.22	0.02	0.07
Developed Basin A (25 yr.)		0.68	15	6.06	0.02	0.08
Developed Basin A (100 yr.)		0.77	15	7.37	0.02	0.11
Developed Basin B (2 yr.)	96	0.85	15	3.83	0.56	1.82
Developed Basin B (5 yr.)		0.85	15	4.56	0.56	2.17
Developed Basin B (10 yr.)		0.86	15	5.22	0.56	2.51
Developed Basin B (25 yr.)		0.86	15	6.06	0.56	2.92
Developed Basin B (100 yr.)		0.88	15	7.37	0.56	3.63
Developed Basin C (2 yr.)	100	0.87	15	3.83	0.13	0.43
Developed Basin C (5 yr.)		0.87	15	4.56	0.13	0.52
Developed Basin C (10 yr.)		0.88	15	5.22	0.13	0.60
Developed Basin C (25 yr.)		0.88	15	6.06	0.13	0.69
Developed Basin C (100 yr.)		0.89	15	7.37	0.13	0.85
Developed Basin D (2 yr.)	62	0.65	15	3.83	0.53	1.32
Developed Basin D (5 yr.)		0.67	15	4.56	0.53	1.62
Developed Basin D (10 yr.)		0.72	15	5.22	0.53	1.99
Developed Basin D (25 yr.)		0.73	15	6.06	0.53	2.34
Developed Basin D (100 yr.)		0.80	15	7.37	0.53	3.12
Developed Basin E (2 yr.)	0	0.30	15	3.83	0.05	0.06
Developed Basin E (5 yr.)		0.35	15	4.56	0.05	0.08
Developed Basin E (10 yr.)		0.45	15	5.22	0.05	0.12
Developed Basin E (25 yr.)		0.48	15	6.06	0.05	0.15
Developed Basin E (100 yr.)		0.65	15	7.37	0.05	0.24
Developed Basin F (2 yr.)	100	0.87	15	3.83	0.05	0.17
Developed Basin F (5 yr.)		0.87	15	4.56	0.05	0.20
Developed Basin F (10 yr.)		0.88	15	5.22	0.05	0.23
Developed Basin F (25 yr.)		0.88	15	6.06	0.05	0.27

Developed Basin F (100 yr.)		0.89	15	7.37	0.05	0.33
Developed Basin G (2 yr.)	100	0.87	15	3.83	0.18	0.60
Developed Basin G (5 yr.)		0.87	15	4.56	0.18	0.71
Developed Basin G (10 yr.)		0.88	15	5.22	0.18	0.83
Developed Basin G (25 yr.)		0.88	15	6.06	0.18	0.96
Developed Basin G (100 yr.)		0.89	15	7.37	0.18	1.18
Developed Basin H (2 yr.)	6	0.84	15	3.83	0.17	0.55
Developed Basin H (5 yr.)		0.84	15	4.56	0.17	0.65
Developed Basin H (10 yr.)		0.85	15	5.22	0.17	0.75
Developed Basin H (25 yr.)		0.86	15	6.06	0.17	0.89
Developed Basin H (100 yr.)		0.88	15	7.37	0.17	1.10
Offsite Basin X1 (2 yr.)	100	0.87	15	3.83	0.16	0.53
Offsite Basin X1 (5 yr.)		0.87	15	4.56	0.16	0.63
Offsite Basin X1 (10 yr.)		0.88	15	5.22	0.16	0.73
Offsite Basin X1 (25 yr.)		0.88	15	6.06	0.16	0.85
Offsite Basin X1 (100 yr.)		0.89	15	7.37	0.16	1.05
Offsite Basin X2 (2 yr.)	13	0.80	15	3.83	0.08	0.25
Offsite Basin X2 (5 yr.)		0.80	15	4.56	0.08	0.29
Offsite Basin X2 (10 yr.)		0.82	15	5.22	0.08	0.34
Offsite Basin X2 (25 yr.)		0.83	15	6.06	0.08	0.40
Offsite Basin X2 (100 yr.)		0.86	15	7.37	0.08	0.51
Offsite Basin X3 (2 yr.)	100	0.87	15	3.83	0.05	0.17
Offsite Basin X3 (5 yr.)		0.87	15	4.56	0.05	0.20
Offsite Basin X3 (10 yr.)		0.88	15	5.22	0.05	0.23
Offsite Basin X3 (25 yr.)		0.88	15	6.06	0.05	0.27
Offsite Basin X3 (100 yr.)		0.89	15	7.37	0.05	0.33

Table 3 – Developed Runoff Calculations

The 100-yr combined peak discharge for the site is 12.46 cfs. This gives an increase in peak discharge of about 0.25 cfs for the 100-yr design storm.

Stormwater Quantity

The proposed increase in impervious area for developed conditions is 0.15 acres when compared to existing conditions. Detention is not required since the proposed increase in impervious area is less than 1 acre when compared with existing conditions.

Stormwater Quality

Since the proposed land disturbance will be greater than 1 acre, storm water quality is required for this site.

The proposed storm water quality calculations were computed to meet the redevelopment regulations in the City of Wichita "Storm Water Manual". The

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computed water quality volume and peak flow calculations can be seen in Table 4 and 5 below.

Water Quality Volume Calculation (WQv)		
$WQv = P \cdot Rv \cdot A / 12$		
Rv Calculation		
	Coeff.	Area
Rv, Undisturbed =	0	0
Rv, Disturbed =	0.25	0.29
Rv, Impervious =	0.95	1.39
Weighted, Rv =	0.83	
WQv Calculation		
Water Quality Rainfall Depth, P =	1.2	inches
Runoff Coeff., Rv =	0.83	
Drainage Area, A =	1.68	acres
Water Quality Volume, WQv* =	0.04	acre-ft
* Note volume reduced by 30% for redevelopment		

Table 4 – Water Quality Volume Calculations

Water Quality Peak Flow Calculation (Qwq)		
$Qwq = qu \cdot A \cdot Qwv \cdot Fp$		
Data		
Drainage Area, A =	1.68	acres
Time of Conc., Tc =	0.25	hrs
WQ Rainfall Depth, P =	1.2	inches
Runoff Coeff., Rv =	0.83	
Calculation		
WQ Prot. Volume, WQv =	0.996	inches
Calculated CN =	98.1	
S =	0.19	inches
la =	0.04	inches
la/P =	0.03	
qu =	740	cfs/sq. mi/in
Water Quality Peak Flow Rate, Qwq* =	0.58	cfs
* Note flow rate reduced by 30% for redevelopment		

Table 5 – Water Quality Peak Flow Calculations

The calculated water quality peak flow rate from the calculations above is 0.58 cfs. This has been reduced by 30% due to this property being a redevelopment project. A hydrodynamic separator will be used to treat the water quality flow rate from this property and will be sized at the time of development. This unit will need to treat 80% or more of the Total Suspended Solids (TSS).

The responsible party for maintenance of the hydrodynamic separator will be the property owner of this QuikTrip site.

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Channel Protection

Channel protection is not required because the total land disturbance is less than 5 acres.

IV. TAB 4 – FLOODPLAIN SUBMITTAL

FEMA Floodplain Boundary

There is no FEMA floodplain located on this property. A copy of the FEMA floodplain map is attached for review in the Appendix.

V. TAB 5 – FEDERAL, STATE, AND LOCAL PERMITS

A. US Army Corps of Engineers

Not Applicable

B. Kansas Department of Agriculture

Not Applicable

C. Federal Emergency Management Agency (FEMA)

Not Applicable

D. Kansas Department of Transportation

Not Applicable

E. Sedgwick County Right-of-way Permit

Not Applicable

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APPENDIX

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GENERAL MAPS

Aerial Photo

QT #389R
Central and Oliver
Wichita, Kansas
CED Job # 20132130







Map Scale: 1:704 if printed on A portrait (8.5" x 11") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

-  Area of Interest (AOI)
- Soils**
- Soil Rating Polygons**
-  Urban land-Farmum complex, 0 to 3 percent slopes
-  Not rated or not available
- Soil Rating Lines**
-  Urban land-Farmum complex, 0 to 3 percent slopes
-  Not rated or not available
- Soil Rating Points**
-  Urban land-Farmum complex, 0 to 3 percent slopes
-  Not rated or not available
- Water Features**
-  Streams and Canals
- Transportation**
-  Rails
-  Interstate Highways
-  US Routes
-  Major Roads
-  Local Roads
- Background**
-  Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Sedgwick County, Kansas
Survey Area Data: Version 8, Sep 20, 2012

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 18, 2010—Sep 27, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Name

Map Unit Name— Summary by Map Unit — Sedgwick County, Kansas (KS173)				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
5836	Urban land-Farnum complex, 0 to 3 percent slopes	Urban land-Farnum complex, 0 to 3 percent slopes	2.0	100.0%
Totals for Area of Interest			2.0	100.0%

Description

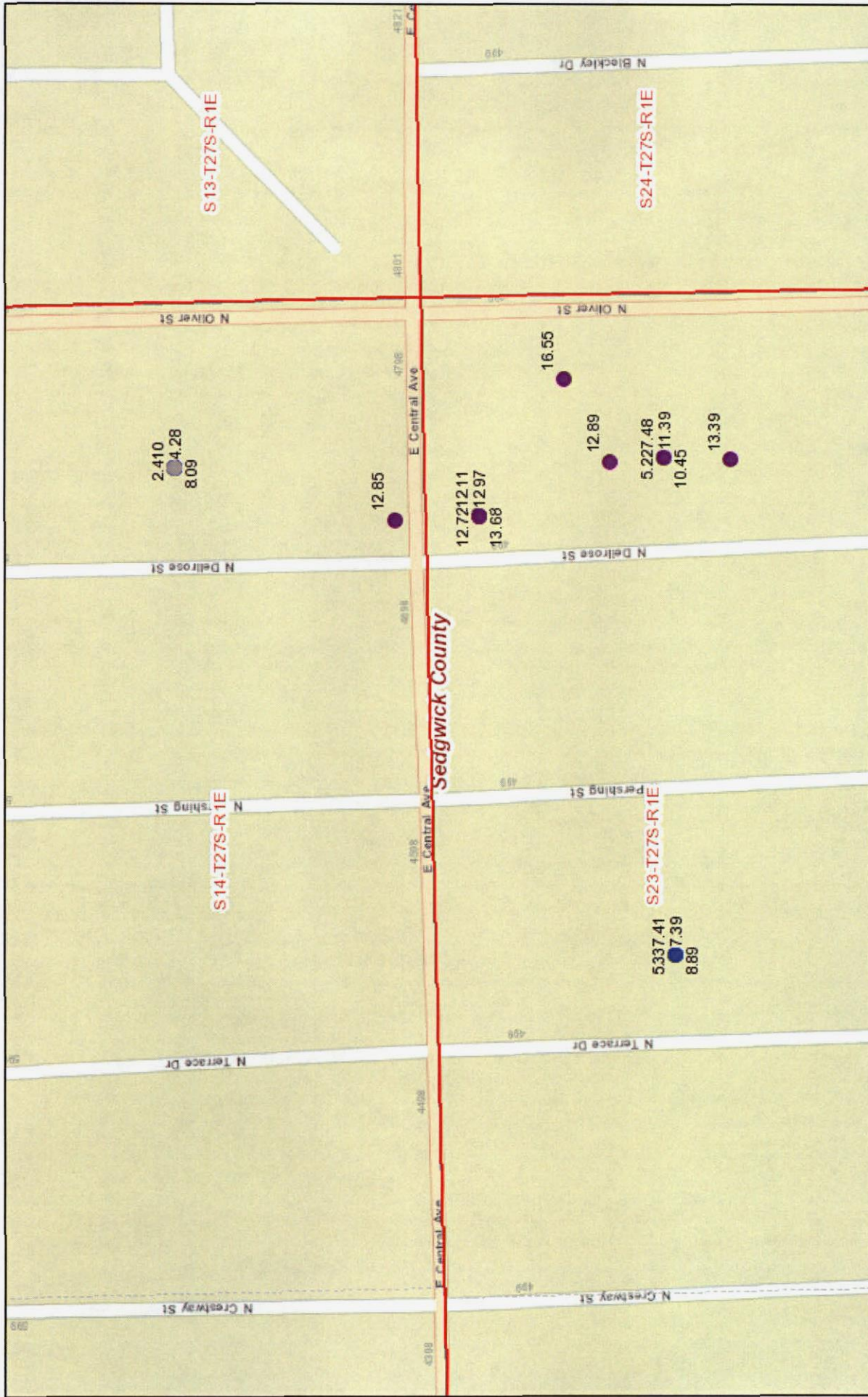
A soil map unit is a collection of soil areas or nonsoil areas (miscellaneous areas) delineated in a soil survey. Each map unit is given a name that uniquely identifies the unit in a particular soil survey area.

Rating Options

Aggregation Method: No Aggregation Necessary

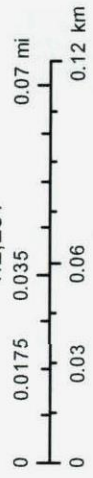
Tie-break Rule: Lower

Static Water Depth (ft)



September 11, 2013

1:2,257



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

MAP SCALE 1" = 500'



PANEL 0359E

FIRM

FLOOD INSURANCE RATE MAP SEDGWICK COUNTY, KANSAS AND INCORPORATED AREAS

PANEL 359 OF 700

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
ASTORBOROUGH, CITY OF	200491	0359	E
WICHITA, CITY OF	200328	0359	E

Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

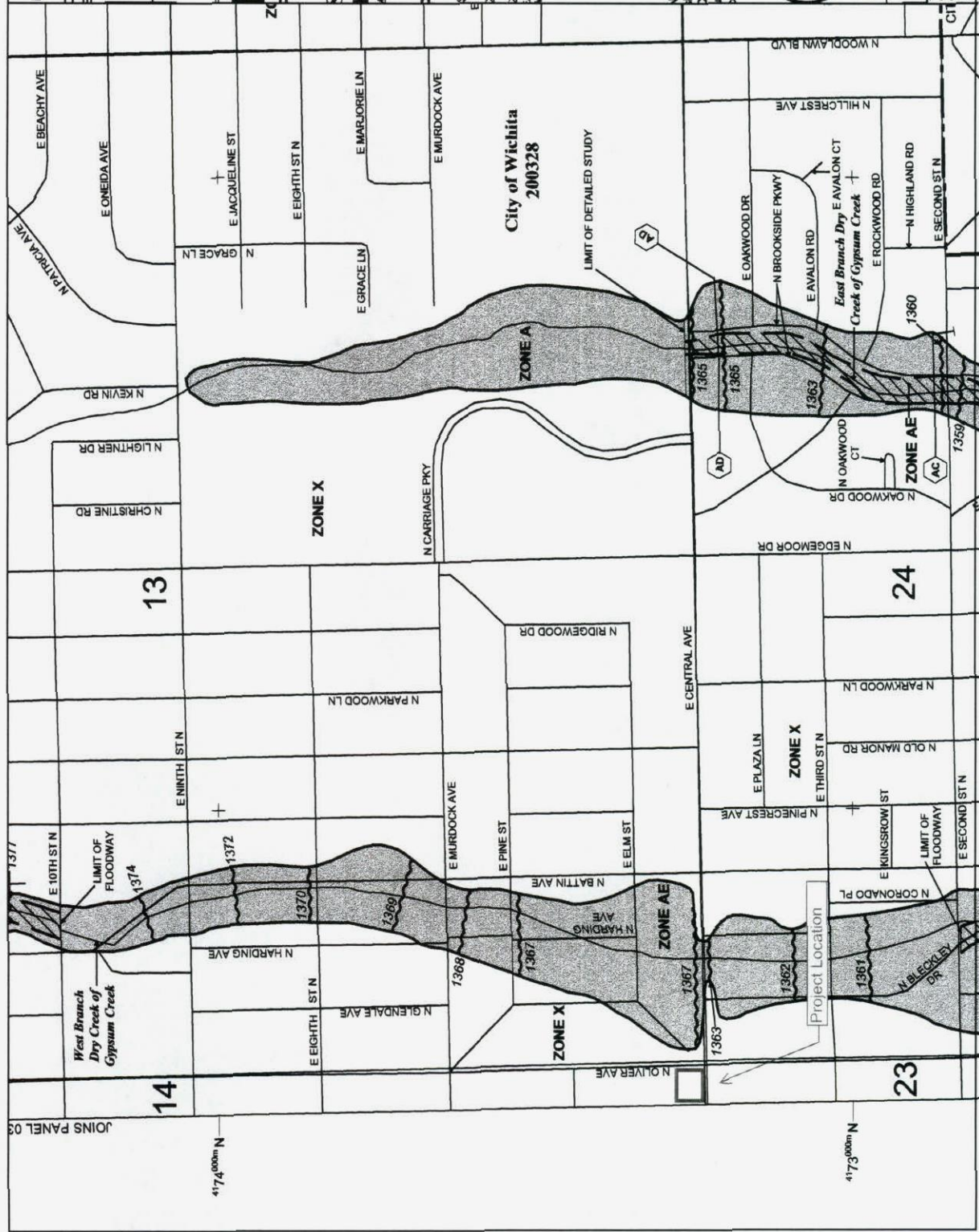


MAP NUMBER
20173C0359E

EFFECTIVE DATE
FEBRUARY 2, 2007

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes made to the map since the last time it was printed. For more information on the FIRM program, please visit the National Flood Insurance Program website at www.fema.gov. For the latest product information about National Flood Insurance Program flood maps, check the FEMA Flood Map Store at www.msc.fema.gov.



JOINS PANEL 03

4174,000m N

4173,000m N

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EXISTING AND DEVELOPED DRAINAGE MAPS

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PRELIMINARY STORM SEWER DESIGN

Storm Drain Computation Sheet

Project: QT #389
 Computed By: Logan Mills
 Checked By: Hattian Foraker
 Date: 9/11/2013

Str. ID	Drainage Area		Area "C"		Time of Concentration		Rainfall (in/hr)	Runoff (cfs)	Pipe Diameter (in)	Q Full (ft ³ /s)	Velocity		Sed. Time (min)	Manning's n	Pipe Material	Min. Slope (%)
	Length (ft)	Area (Ac)	Imp. (Ac)	Total (Ac)	Runoff Coefficient	Inlet (min)					System (min)	Full (ft/s)				
9	6	183	0.9	0.70	0.70	15	15.00	5.22	3.66	15	4.43	3.61	4.03	0.012	HDPE	0.40
6	5	146	0.22	1.12	0.19	15	15.76	5.08	4.53	15	4.95	4.03	4.57	0.012	HDPE	0.50
5	3	6	0.18	1.3	0.16	15	16.29	5.03	5.33	15	5.42	4.42	5.03	0.012	HDPE	0.60
3	2	8	0.56	1.86	0.48	15	16.31	5.08	7.78	18	8.05	4.55	5.19	0.012	HDPE	0.50
2	1	21	0	1.86	0.00	15	16.33	5.08	7.78	18	8.14	4.60	5.24	0.013	RCP	0.60
4	3	87	0.56	0.48	0.48	15	15.00	5.22	2.51	12	2.73	3.47	3.94	0.012	HDPE	0.50

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MISCELLANEOUS DRAINAGE INFORMATION

1988 Drainage Criteria Manual
City of Wichita, Kansas
Rainfall Intensity Table for Sedgwick County, KS

The following tabulation contains rainfall intensity in inches per hour as derived from ESSA Weather Bureau Technical Paper 40 Modified to NWS Hydro-35, 1977 During First Hour.

Table 1 Rainfall Intensity Table (Duration 15 min – 120 min)

DURATION, in hours	DURATION, in minutes	RETURN PERIOD						
		1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0.0833	5	4.18	5.57	6.53	7.41	8.52	9.48	10.32
0.1000	6	3.99	5.32	6.25	7.09	8.16	9.09	9.89
0.1167	7	3.81	5.09	5.99	6.81	7.84	8.74	9.50
0.1333	8	3.66	4.89	5.75	6.55	7.55	8.42	9.15
0.1500	9	3.52	4.70	5.54	6.31	7.28	8.13	8.83
0.1667	10	3.39	4.52	5.34	6.09	7.04	7.86	8.54
0.1833	11	3.27	4.36	5.16	5.89	6.81	7.61	8.27
0.2000	12	3.18	4.21	4.99	5.71	6.60	7.38	8.02
0.2167	13	3.05	4.08	4.84	5.53	6.41	7.17	7.79
0.2333	14	2.96	3.95	4.69	5.37	6.23	6.97	7.57
0.2500	15	2.87	3.83	4.56	5.22	6.06	6.78	7.37
0.2667	16	2.78	3.72	4.43	5.08	5.90	6.60	7.18
0.2833	17	2.71	3.61	4.31	4.95	5.75	6.44	7.00
0.3000	18	2.63	3.51	4.20	4.83	5.61	6.29	6.84
0.3167	19	2.56	3.42	4.10	4.71	5.47	6.14	6.68
0.3333	20	2.50	3.33	4.00	4.60	5.35	6.00	6.53
0.3500	21	2.44	3.25	3.90	4.50	5.23	5.87	6.39
0.3667	22	2.38	3.17	3.81	4.40	5.12	5.75	6.26
0.3833	23	2.32	3.10	3.73	4.31	5.01	5.63	6.13
0.4000	24	2.27	3.03	3.65	4.22	4.91	5.52	6.01
0.4167	25	2.22	2.96	3.57	4.13	4.81	5.41	5.90
0.4333	26	2.20	2.90	3.50	4.05	4.72	5.31	5.79
0.4500	27	2.16	2.84	3.43	3.98	4.63	5.21	5.69
0.4667	28	2.14	2.78	3.37	3.90	4.55	5.12	5.59
0.4833	29	2.11	2.72	3.30	3.83	4.47	5.03	5.49
0.5000	30	2.08	2.67	3.24	3.76	4.39	4.94	5.40
0.5167	31	2.05	2.62	3.19	3.70	4.32	4.86	5.32
0.5333	32	2.02	2.57	3.10	3.63	4.25	4.79	5.22
0.5500	33	1.99	2.52	3.05	3.57	4.18	4.71	5.14
0.5667	34	1.96	2.48	3.01	3.51	4.11	4.63	5.07
0.5833	35	1.93	2.44	2.98	3.46	4.05	4.56	5.00
0.6000	36	1.91	2.39	2.93	3.41	3.99	4.50	4.93
0.6167	37	1.89	2.35	2.88	3.36	3.93	4.43	4.86
0.6333	38	1.87	2.32	2.84	3.31	3.87	4.37	4.79
0.6500	39	1.85	2.28	2.80	3.26	3.82	4.31	4.73
0.6667	40	1.83	2.24	2.76	3.22	3.76	4.25	4.66
0.6833	41	1.81	2.21	2.72	3.17	3.71	4.19	4.60
0.7000	42	1.79	2.18	2.68	3.13	3.66	4.13	4.54
0.7167	43	1.77	2.14	2.64	3.09	3.61	4.08	4.49
0.7333	44	1.75	2.11	2.61	3.05	3.57	4.03	4.43

Table C-1 Rational C Values

Land Use or Surface Characteristics	Percent Impervious	Frequency			
		2	5	10	100
<u>Business</u>					
Downtown Areas	95	0.84	0.85	0.87	0.91
Neighborhood Areas	70	0.68	0.69	0.73	0.80
<u>Residential Single Family (Soil Group D)</u>					
1/8 Acre	50	0.57	0.61	0.66	0.79
1/4 Acre	38	0.50	0.54	0.62	0.76
1/3 Acre	30	0.46	0.50	0.59	0.73
1/2 Acre	25	0.42	0.48	0.56	0.72
3/4 Acre	22	0.42	0.46	0.55	0.71
1 Acre	20	0.41	0.45	0.54	0.71
<u>Residential Multi-Family (Soil Group D)</u>					
Multi-Unit (detached)	60	0.62	0.66	0.72	0.82
Multi-Unit (attached)	65	0.64	0.68	0.73	0.83
Apartments	75	0.70	0.73	0.79	0.86
<u>Residential Single Family (Soil Group C)</u>					
1/8 Acre	50	0.55	0.58	0.64	0.73
1/4 Acre	38	0.48	0.51	0.57	0.68
1/3 Acre	30	0.43	0.46	0.53	0.65
1/2 Acre	25	0.40	0.43	0.50	0.63
3/4 Acre	22	0.39	0.42	0.49	0.62
1 Acre	20	0.37	0.40	0.48	0.61
<u>Residential Multi-Family (Soil Group C)</u>					
Multi-Unit (detached)	60	0.60	0.63	0.69	0.77
Multi-Unit (attached)	65	0.63	0.66	0.71	0.79
Apartments	75	0.68	0.72	0.77	0.83
<u>Residential Single Family (Soil Group B)</u>					
1/8 Acre	50	0.52	0.54	0.59	0.67
1/4 Acre	38	0.44	0.46	0.52	0.61
1/3 Acre	30	0.39	0.41	0.47	0.57
1/2 Acre	25	0.36	0.38	0.44	0.54
3/4 Acre	22	0.34	0.36	0.42	0.52
1 Acre	20	0.33	0.35	0.40	0.51
<u>Residential Multi-Family (Soil Group B)</u>					
Multi-Unit (detached)	60	0.58	0.60	0.65	0.72
Multi-Unit (attached)	65	0.61	0.64	0.68	0.75
Apartments	75	0.67	0.70	0.74	0.80
<u>Single Family (Soil Group A)</u>					
1/8 Acre	50	0.47	0.50	0.54	0.60
1/4 Acre	38	0.39	0.41	0.45	0.52
1/3 Acre	30	0.33	0.35	0.39	0.47
1/2 Acre	25	0.30	0.31	0.35	0.44

Appendix C

Land Use or Surface Characteristics	Percent Impervious	Frequency			
		2	5	10	100
3/4 Acre	22	0.28	0.29	0.33	0.42
1 Acre	20	0.26	0.28	0.32	0.40
<u>Multi-Family (Soil Group A)</u>					
Multi-Unit (detached)	60	0.55	0.57	0.61	0.67
Multi-Unit (attached)	65	0.58	0.60	0.64	0.70
Apartments	75	0.65	0.68	0.72	0.77
<u>Industrial</u>					
Light Areas	70	0.68	0.69	0.73	0.80
Heavy Areas	80	0.74	0.76	0.79	0.84
<u>Playgrounds</u>					
	15	0.33	0.35	0.42	0.55
<u>Schools</u>					
	40	0.49	0.51	0.56	0.66
<u>Railroad Yard Areas</u>					
	30	0.43	0.45	0.50	0.62
<u>Undeveloped Urban Areas</u>					
Offsite Flow Analysis (when land use not defined)	45	0.52	0.54	0.59	0.68
<u>Streets</u>					
Paved	99	0.87	0.88	0.90	0.93
Gravel	00	0.24	0.26	0.33	0.48
<u>Drive, Parking Lots and Walks:</u>					
	96	0.87	0.87	0.88	0.89
<u>Roofs</u>					
	90	0.80	0.85	0.90	0.93
<u>Urban Lawn Areas (Soil Group A)</u>					
Slope less than 1%	00	0.08	0.09	0.13	0.23
Slope 1% to 4%	00	0.12	0.13	0.17	0.27
Slope more than 4%	00	0.16	0.17	0.21	0.31
<u>Urban Lawn Areas (Soil Group B)</u>					
Slope less than 1%	00	0.16	0.18	0.24	0.37
Slope 1% to 4%	00	0.20	0.22	0.28	0.41
Slope more than 4%	00	0.24	0.26	0.32	0.45
<u>Urban Lawn Areas (Soil Group C)</u>					
Slope less than 1%	00	0.24	0.27	0.35	0.51
Slope 1% to 4%	00	0.26	0.29	0.37	0.53
Slope more than 4%	00	0.28	0.31	0.39	0.55
<u>Urban Lawn Areas (Soil Group D)</u>					
Slope less than 1%	00	0.28	0.33	0.43	0.63
Slope 1% to 4%	00	0.30	0.35	0.45	0.65
Slope more than 4%	00	0.32	0.37	0.47	0.67

Table A-1 Roughness Coefficients (Manning's n) for Sheet Flow

Surface Description ¹	Manning's n
Smooth surfaces (concrete, asphalt, gravel or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover < 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses ^A	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods ^B	
Light underbrush	0.40
Dense underbrush	0.80

¹ Source: SCS, TR-55, Second Edition, June 1986.
^A Includes species such as bluestem grass, buffalo grass, grama grass, and native grass mixtures.
^B When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Table A-2 Manning's n Values

Street and Pavement Gutters ^{2k}	Manning's n	
Asphalt pavement	0.016	
Concrete gutter	0.016	
Concrete pavement	0.018	
Culverts and Storm Sewers ^{3o}	Roughness or Corrugation	Manning's n
Concrete Pipe	Smooth	0.013
Concrete Boxes	Smooth	0.013
Corrugated Polyethylene	Corrugated	Per manufacturer
Smooth Polyethylene	Smooth	0.011
Polyvinyl chloride (PVC)	Smooth	0.011

Artificial Channels ⁴		Depth Ranges		
Category	Lining Type	0-0.5 ft	0.5-2.0 ft	>2.0 ft
Grassed	Grass	0.050	0.040	0.035
Rigid	Concrete	0.016	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Gabions	0.030	0.030	0.030
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Temporary*	Woven Paper Net	0.016	0.015	0.015
	Jute Net	0.028	0.022	0.019
	Fiberglass Roving	0.028	0.022	0.019
	Straw with Net	0.065	0.033	0.025
	Curled Wood Mat	0.066	0.035	0.028
	Synthetic Mat	0.036	0.025	0.021
Gravel Riprap	1-inch D ₅₀	0.044	0.033	0.030
	2-inch D ₅₀	0.066	0.041	0.034
Rock Riprap	6-inch D ₅₀	0.104	0.069	0.035
	12-inch D ₅₀	-	0.078	0.040

Natural Channels	Manning's n
NATURAL STREAMS	
Main Channels	
1. Clean, straight, full, no rifts or deep pools	0.030
2. Same as "1", but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as "3", but some weeds and stones	0.045
5. Same as "4", lower stages, more ineffective slopes and sections	0.048
6. Same as "4" but more stones	0.050
7. Sluggish reaches, weedy, deep pools	0.070
8. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.100
Floodplain – Pasture	
1. Short grass	0.030
2. Tall grass	0.035
Floodplain – Cultivated Areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
Floodplain – Brush	
1. Heavy weeds scattered brush	0.050
2. Light brush and trees, in winter	0.050
3. Light brush and trees, in summer	0.060
4. Medium to dense brush, in winter	0.070
5. Medium to dense brush in summer	0.100
Floodplain – Trees	
1. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.100
2. Same as "1", but with flow in branches	0.120
3. Dense willows, summer, straight	0.150
<p>6. Lining designed for the interim condition, typically serving the needs of construction sequencing</p>	
<p>2. Source: HEC-22, 2001</p>	
<p>3. Source: Typical manufacturer data</p>	
<p>4. Source: HEC-15, 1988</p>	
<p>5. Source: HEC-RAS Hydraulic Reference Manual, 2008</p>	