PART III, ATTACHMENT 2

APPENDIX III-2C

INTERIM EROSION AND SEDIMENT CONTROL ANALYSIS

APPENDIX III-2C-1

Intermediate Cover Erosion Soil Loss Calculations

INTERMEDIATE COVER EROSION SOIL LOSS CALCULATIONS

Date Prepared:	11/11/2020
Made by:	EWT
Checked by:	JBF
Reviewed by:	CGD

1.0 OBJECTIVE

Design the interim (intermediate cover) erosion and soil loss controls for the proposed Hawthorn Park Recycling and Disposal Facility (RDF) in accordance with 30 TAC §330.305(d).

Per TCEQ regulatory guidance, erosion losses for worst-case intermediate cover slopes for the crown slopes and side slope shall not exceed 50 tons/acre/year.

2.0 METHOD

2.1 Permissible Non-Erodible Velocity

Sheet flow from the top dome is analyzed to verify that sheet flow velocity from the crown does not exceed the permissible non-erodible velocity based on soil and vegetation cover type. Sheet flow down the external embankment side slopes is also analyzed to verify that the permissible non-erodible velocity is not exceeded.

Sheet flows were calculated in accordance with procedures outlined in TR-55. For sheet flow of less than 300 feet, Manning's kinematic equation was used to calculate travel time:

$$\text{Travel Time, Tt} = \frac{0.007(nL)^{0.8}}{P^{0.5}s^{0.4}}$$

Tt = Travel time (hr)

n = Manning's roughness coefficient

L = flow length (ft)

P = 2-year, 24-hour rainfall (in)

s = slope of hydraulic grade line (land slope, ft/ft)

The travel time calculated with Manning's kinematic equation for sheet flow was then used in the travel time equation to calculate velocity for the sheet flow.

$$\text{Travel Time, Tt} = \frac{L}{3600V}$$

Tt = Travel time (hr)

L = flow length (ft)

V = average velocity (ft/s)

STATE OF TEXAS
2/12/21
CHARLES G. DOMINGUEZ
83247
LICENSED PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

INTENDED FOR PERMITTING PURPOSES ONLY

For Sheets 1 to 6

The travel time equation was rearranged to solved for velocity, V:

$$V = \frac{L}{3600Tt}$$

For flow paths greater than 300 feet in distance, the shallow concentrated flow equation for an unpaved surface from TR-55 was used.

$$V = 16.1345s^{0.5}$$

V = average velocity (ft/s)

s = slope (ft/ft)

2.2 Permissible Soil Loss

Erosion soil loss is calculated using methods outlined in the USDA's Predicting Rainfall Erosion Loss. Erosion soil loss is calculated using the Revised Universal Soil Loss Equation (RUSLE). The RUSLE equation:

$A = R\ K\ L\ S\ C\ P$, where:

A = Annual Soil Loss (tons/acre/year)

R = Rainfall-Runoff Erosivity factor

K = Soil Erodibility factor

L = Slope Length factor

S = Slope Steepness factor

C = Cover-management factor

P = Support practice factor

The equations for L and S come from Reference 5, the USDA Agriculture Handbook Number 703.

The equations to determine the length factor, L:

$$L = \left(\frac{\lambda}{72.6}\right)^m$$

λ is the horizontal project of plot length

$$m = \frac{\beta}{1+\beta}$$

β is rill erosion, and

$$\beta mod = \frac{11.16\ sin\theta}{3.0(sin\theta)^{0.8} + 0.56}$$

The equations to determine the slope factor, S, if length of slope is greater than 15 feet:

$$If\ slope < 9\%), \quad S = 10.8 \sin\theta + 0.03$$

$$If\ slope \geq 9\%), \quad S = 16.8 \sin\theta - 0.50$$

The other factors are determined using table references and other technical resources outlined in the assumptions section below.

3.0 ASSUMPTIONS

3.1 Permissible Non-Erodible Velocity

The permissible non-erodible velocity is 5 ft/s for vegetated surfaces and 3.75 ft/s for bare-soil loam surfaces. TR-55 travel time and velocity equations used the following:

- The 2-year, 24-hour precipitation is 5.00 inches
  - Rainfall data from Atlas 14 PFDS, local to project site
- Sheet flow coefficient n is 0.24 for grass-lined surfaces and 0.06 for bare soils
- External embankments are unpaved for shallow concentrated velocity calculation

3.2 Permissible Soil Loss

Using the intermediate cover design, site location, and information from references, the following are determined to be the factors used in the RUSLE equation:

Rainfall-runoff erosivity factor R = 450

- Estimated for the location of Hawthorn Park RDF site within Harris County, Texas from the Isoerodent Map of the Eastern U.S. (EPA), included as an attachment to this calculation package

Soil erodibility factor, K = 0.26:

- Access the Web Soil Map on the National Resources Conservation Services (NRCS) website to determine local soil types for the Hawthorn Park RDF project site as map unit symbols Ak, Ce, CyuA, Gp, and Gu and typical profile for soil type
  - Output from the interactive Web Soil Map is included as an attachment to this calculation package
- Use the soil texture type from the Web Soil Map and Table 1 from the Texas Natural Resource Conservation Commission (TNRCC) for approximate values of the K factor of loam (0.29) and fine sandy loam (0.24)
  - TNRCC Table 1 is included in this calculation package as an attachment

Approximate the K factor using weighted average for K factor and percent AOI:

$$K = \frac{38\% * 0.29 + 1.1\% * 0.24 + 56.7\% * 0.24 + 1.3\% * 0.29}{97.1\%} = 0.26$$

Slope length and steepness factors, L and S:

- 4% crown slope; 300 ft max length
- 4H:1V side slope, or slope = 25%
- See Section 4.2 for calculations for length and steepness factors

Cover management factor, C = 0.042:

- Assume percent of ground cover for interim = 60%, with no appreciable canopy, for interim conditions
  - 60 percent vegetative cover is recommended per TCEQ regulatory guidance
- Use C factor from Table 10 for 60% grass type cover
  - Table 10 is from Reference 2, excerpt included in this package as an attachment

Support practice factor, P = 1.0:

- Use P value for surface tracked with dozer equipment – rough surface from Table 10

4.0 CALCULATIONS

4.1 Permissible Non-Erodible Velocity

The top dome surface and side slope sheet flow calculations are below, for soil (n = 0.06):

$$\text{Travel Time, Tt} = \frac{0.007(nL)^{0.8}}{P^{0.5}s^{0.4}}$$

$$\text{Velocity} = \frac{L}{3600Tt}$$

Sheet Flow Velocity Calculations:

Area	% Slope	L (ft)	n	Tt (hrs)	Velocity (fps)
Top Slope	4%	300	0.06	0.115	0.73
Side Slope	25%	300	0.06	0.055	1.51

The top dome and external embankment surface shallow concentrated flow calculations are below for an unpaved surface:

$$\text{Velocity} = 16.1345s^{0.5}$$

Area	% Slope	Velocity (fps)
Top Slope	4%	3.23
Side Slope	25%	8.07

The velocities for the top dome and external embankments under sheet flow conditions are under the permissible non-erodible velocity.

Shallow concentrated flow for the top dome is under the permissible non-erodible velocity. Shallow concentrated flow for the side slope exceeds the permissible non-erodible velocity; therefore, temporary add-on berms are required at a maximum distance of 300 feet (75 vertical feet) spacing.

4.2 Permissible Soil Loss

The L factor and S factor are calculated for the crown (4% slope) and the 4H:1V side slopes (25% slope) below. The components of the L factor and L factor for the crown slope (4% slope) are calculated in the table below:

L and S Factor Calculations:

Area	% Slope	λ (ft)	θ°	sin(θ)	β_{mod}	m	L	S	LS
Top Slope	4%	300	2.29	0.0400	0.57	0.36	1.67	0.46	0.77
Sideslope	25%	300	14.04	0.2425	1.77	0.64	2.48	3.57	8.85

$$LS, top\ dome = 0.77$$

$$LS, external\ embankment = 8.85$$

The other factors R, K, C, and P used in the RUSLE equation are outlined in section 3.0 Assumptions.

RUSLE Calculations:

R	K	LS	C	P	A
450	0.26	0.77	0.042	1.0	3.78
450	0.26	8.85	0.042	1.0	43.49

$$A, top\ dome = 3.78\ tons/acre/year$$

$$A, external\ embankment = 43.49\ tons\ /\ acre/\ year$$

5.0 CONCLUSIONS

The proposed 4% top dome surface can achieve erosional stability during interim cover conditions with 60% of ground cover vegetation. Soil loss for the for the 4% top dome surface was calculated to be 3.78 tons/acre/year. The proposed external embankment side slopes can achieve erosional stability during interim cover conditions with 60% of ground cover vegetation and implementation of temporary storm water diversion berms spaced at maximum every 75 vertical feet or 300 feet horizontal. Soil loss for the external embankment side slopes was calculated to be 43.49 tons/acre/year.

Both top dome and external embankment soil erosion loss are below the limits of permissible soil erosion loss of 50 tons/acre/year.

6.0 REFERENCES

1) Fact Sheet 3.1 - Construction Rainfall Erosivity Waiver, Storm Water Phase II Final Rule. Office of Water. United States Environmental Protection Agency (EPA). January 2001

2) Predicting Rainfall Erosion Losses: A Guide to Conservation Planning, Agriculture Handbook Number 537, Science and Education Administration (SEA). United States Department of Agriculture (USDA). Revised August 1986

3) Web Soil Survey, National Cooperative Soil Survey. National Resources Conservation Service (NRCS). Accessed April 2020

4) Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook, Permits Section. Texas Natural Resource Conservation Commission (TNRCC). October 1993

5) Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), Agriculture Handbook Number 703. United States Department of Agriculture (USDA). January 1997

6) Precipitation Frequency Data Server (PFDS), Hydrometeorological Design Studies Center. National Oceanic and Atmospheric Administration (NOAA). September 2018

7) Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill, Waste Permits Division Regulatory Guidance. Texas Commission on Environmental Quality (TCEQ). May 2018

7.0 ATTACHMENTS

Figure 2. Isoerodent Map of the Eastern U.S. (Reference 1)

Table 10 C Factor (Reference 2)

Web Soil Survey Interactive Map and Output (Reference 3)

Table 1 K Factor (Reference 4)

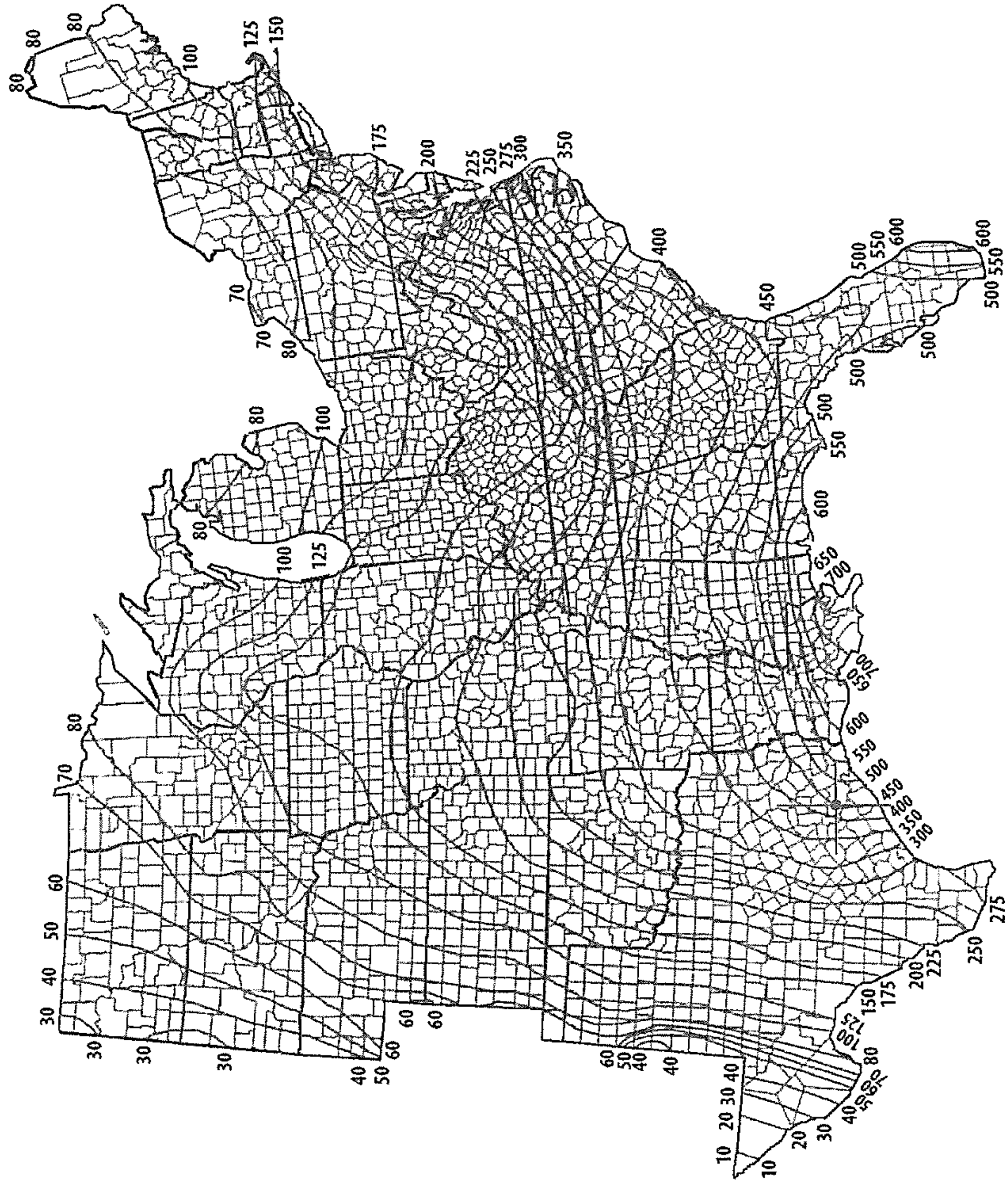
Atlas 14 Rainfall Precipitation Data (Reference 6)

APPENDIX III-2C-1

ATTACHMENTS

Figure 2. Isoerodent Map of the Eastern U.S. (EPA)
Table 10 – Factor C (USDA)
Web Soil Survey – National Cooperative Soil Survey (NRCS)
Table 1 – Approximate Values of Factor K (TNRCC)
Atlas 14 Point Precipitation Frequency Estimates (NOAA)

Figure 2. Isoerodent Map of the Eastern U.S.



EXCERPT FROM REFERENCE 1, APPENDIX III-2C-1
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA)

Note: Units for all maps on this page are hundreds ft•tonf•in(ac•h•yr)$^{-1}$

EXCERPT FROM REFERENCE 2, APPENDIX III-2C-1

tion and developmental areas can be obtained from table 5 if good judgment is exercised in comparing the surface conditions with those of agricultural conditions specified in lines of the table. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions. The procedure is then similar to that described for cropland.

Establishing vegetation on the denuded areas as quickly as possible is highly important. A good sod has a **C** value of 0.01 or less (table 5-B), but such a low **C** value can be obtained quickly only by laying sod on the area, at a substantial cost. When grass or small grain is started from seed, the probable soil loss for the period while cover is developing can be computed by the procedure outlined for estimating cropstage-period soil losses. If the seeding is on topsoil, without a mulch, the soil loss ratios given in line 141 of table 5 are appropriate for cropstage **C** values. If the seeding is on a desurfaced area, where residual effects of prior vegetation are no longer significant, the ratios for periods SB, 1 and 2 are 1.0, 0.75 and 0.50, respectively, and line 141 applies for cropstage 3. When the seedbed is protected by a mulch, the pertinent mulch factor from the upper curve of figure 6 or table 9 is applicable until good canopy cover is attained. The combined effects of vegetative mulch and low-growing canopy are given in figure 7. When grass is established in small grain, it can usually be evaluated as established meadow about 2 mo after the grain is cut.

C Values for Pasture, Range, and Idle Land

Factor **C** for a specific combination of cover conditions on these types of land may be obtained from table 10 (57). The cover characteristics that must be appraised before consulting this table are defined in the table and its footnotes. Cropstage periods and **EI** monthly distribution data are generally not necessary where perennial vegetation has become established and there is no mechanical disturbance of the soil.

Available soil loss data from undisturbed land were not sufficient to derive table 10 by direct comparison of measured soil loss rates, as was done for development of table 5. However, analyses of the assembled erosion data showed that the tended to completely different situations by combining subfactors that evaluate three separate and distinct, but interrelated, zones of influence: (a) vegetative cover in direct contact with the soil surface, (b) canopy cover, and (c) residual and tillage effects.

Subfactors for various percentages of surface cover by mulch are given by the upper curve of

TABLE 10.—*Factor **C** for permanent pasture, range, and idle land*[1]

Vegetative canopy		Cover that contacts the soil surface						
			Percent ground cover					
Type and height[2]	Percent cover[3]	Type[4]	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as

Soil Map—Harris County, Texas

EXCERPT FROM REFERENCE 3, APPENDIX III-2C-1

Map Scale: 1:6,460 if printed on B landscape (17" x 11") sheet.

Meters: 0 50 100 200 300

Feet: 0 300 600 1200 1800

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

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 1:20,000.

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:
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: Harris County, Texas
Survey Area Data: Version 21, Jan 8, 2020

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

Date(s) aerial images were photographed: Apr 26, 2017—Nov 10, 2017

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.

EXCERPT FROM REFERENCE 3, APPENDIX III-2C-1

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ak	Addicks-Urban land complex, 0 to 1 percent slopes	200.4	38.0%
Ce	Clodine-Urban land complex, 0 to 1 percent slopes	5.7	1.1%
CyuA	Cyfair-Urban land complex, 0 to 1 percent slopes	299.5	56.7%
GP	Pits, gravel	15.2	2.9%
Gu	Gessner occasionally ponded-Urban land complex, 0 to 1 percent slopes	7.0	1.3%
Totals for Area of Interest		**527.8**	**100.0%**

EXCERPT FROM REFERENCE 4, APPENDIX III-2C-1

TNRCC

Table 1 Approximate Values of Factor K for USDA Textural Classes

TABLE 1

Texture Class	Organic Matter Content		
	<0.5%	2%	4%
	K	K	K
Sand	0.05	0.03	0.02
Fine Sand	0.16	0.14	0.10
Very Fine Sand	0.42	0.36	0.28
Loamy Sand	0.12	0.10	0.08
Loamy Fine Sand	0.24	0.20	0.16
Loamy Very Fine Sand	0.44	0.38	0.30
Sandy Loam	0.27	0.24	0.19
Fine Sandy Loam	0.35	0.30	0.24
Very Fine Sandy Loam	0.47	0.41	0.33
Loam	0.38	0.32	0.29
Silt Loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy Clay Loam	0.27	0.25	0.21
Clay Loam	0.28	0.25	0.21
Silty Clay Loam	0.37	0.32	0.26
Sandy Clay	0.14	0.13	0.12
Silty Clay	0.25	0.23	0.19
Clay	0.13 - 0.29		

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

NOAA Atlas 14, Volume 11, Version 2
Location name: Houston, Texas, USA*
Latitude: 29.8531°, Longitude: -95.5602°
Elevation: m/ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.496** (0.376-0.656)	**0.581** (0.444-0.759)	**0.718** (0.547-0.943)	**0.832** (0.625-1.11)	**0.990** (0.719-1.36)	**1.11** (0.786-1.57)	**1.23** (0.851-1.79)	**1.37** (0.918-2.03)	**1.55** (1.00-2.38)	**1.69** (1.07-2.67)
10-min	**0.786** (0.595-1.04)	**0.921** (0.703-1.20)	**1.14** (0.869-1.50)	**1.33** (0.995-1.77)	**1.58** (1.15-2.17)	**1.78** (1.26-2.51)	**1.97** (1.36-2.86)	**2.17** (1.46-3.23)	**2.43** (1.58-3.74)	**2.62** (1.66-4.14)
15-min	**1.00** (0.759-1.32)	**1.17** (0.893-1.53)	**1.44** (1.10-1.89)	**1.67** (1.25-2.22)	**1.97** (1.43-2.71)	**2.21** (1.56-3.12)	**2.45** (1.69-3.55)	**2.71** (1.82-4.03)	**3.06** (1.99-4.71)	**3.33** (2.11-5.26)
30-min	**1.44** (1.09-1.90)	**1.67** (1.27-2.19)	**2.05** (1.56-2.69)	**2.36** (1.77-3.14)	**2.78** (2.01-3.80)	**3.10** (2.18-4.36)	**3.43** (2.36-4.97)	**3.80** (2.55-5.66)	**4.33** (2.82-6.68)	**4.77** (3.02-7.54)
60-min	**1.89** (1.43-2.50)	**2.21** (1.69-2.89)	**2.73** (2.08-3.59)	**3.17** (2.38-4.22)	**3.77** (2.73-5.15)	**4.22** (2.97-5.93)	**4.70** (3.24-6.81)	**5.26** (3.54-7.85)	**6.11** (3.97-9.43)	**6.82** (4.32-10.8)
2-hr	**2.28** (1.73-3.00)	**2.77** (2.10-3.55)	**3.51** (2.68-4.58)	**4.17** (3.15-5.54)	**5.13** (3.74-7.00)	**5.90** (4.18-8.28)	**6.76** (4.68-9.76)	**7.80** (5.26-11.6)	**9.40** (6.13-14.5)	**10.8** (6.85-17.0)
3-hr	**2.48** (1.89-3.26)	**3.10** (2.33-3.92)	**4.00** (3.06-5.19)	**4.84** (3.66-6.41)	**6.08** (4.45-8.29)	**7.12** (5.07-9.99)	**8.31** (5.76-12.0)	**9.74** (6.58-14.4)	**12.0** (7.82-18.4)	**13.9** (8.86-21.9)
6-hr	**2.85** (2.18-3.73)	**3.69** (2.76-4.58)	**4.88** (3.73-6.28)	**6.02** (4.57-7.93)	**7.77** (5.72-10.6)	**9.28** (6.65-13.0)	**11.1** (7.70-15.9)	**13.2** (8.92-19.4)	**16.4** (10.8-25.1)	**19.3** (12.3-30.1)
12-hr	**3.26** (2.51-4.24)	**4.32** (3.21-5.28)	**5.78** (4.43-7.40)	**7.22** (5.50-9.47)	**9.46** (7.01-12.9)	**11.4** (8.25-16.0)	**13.8** (9.62-19.7)	**16.5** (11.2-24.1)	**20.6** (13.6-31.4)	**24.2** (15.5-37.7)
24-hr	**3.71** (2.86-4.81)	**5.00** (3.72-6.04)	**6.75** (5.20-8.60)	**8.51** (6.51-11.1)	**11.3** (8.42-15.3)	**13.8** (9.99-19.2)	**16.7** (11.7-23.7)	**19.9** (13.6-29.0)	**24.7** (16.2-37.3)	**28.6** (18.4-44.5)
2-day	**4.22** (3.26-5.43)	**5.78** (4.28-6.90)	**7.87** (6.08-9.97)	**10.0** (7.68-13.0)	**13.4** (10.1-18.3)	**16.6** (12.1-23.2)	**20.1** (14.1-28.5)	**23.6** (16.1-34.2)	**28.4** (18.8-42.7)	**32.1** (20.8-49.7)
3-day	**4.60** (3.57-5.91)	**6.30** (4.69-7.51)	**8.58** (6.65-10.8)	**10.9** (8.39-14.1)	**14.5** (11.0-19.8)	**18.0** (13.2-25.1)	**21.7** (15.3-30.7)	**25.3** (17.3-36.6)	**30.1** (19.9-45.0)	**33.6** (21.8-51.9)
4-day	**4.93** (3.83-6.32)	**6.68** (5.01-8.00)	**9.07** (7.05-11.5)	**11.5** (8.84-14.8)	**15.2** (11.5-20.7)	**18.6** (13.7-26.0)	**22.4** (15.8-31.6)	**26.0** (17.9-37.6)	**30.8** (20.4-46.1)	**34.4** (22.3-53.0)
7-day	**5.69** (4.44-7.28)	**7.50** (5.70-9.07)	**10.0** (7.83-12.7)	**12.5** (9.67-16.1)	**16.3** (12.4-22.0)	**19.7** (14.5-27.3)	**23.4** (16.6-33.0)	**27.1** (18.6-39.0)	**31.9** (21.2-47.6)	**35.6** (23.1-54.6)
10-day	**6.34** (4.96-8.10)	**8.19** (6.28-9.96)	**10.8** (8.48-13.7)	**13.4** (10.4-17.2)	**17.2** (13.0-23.1)	**20.6** (15.2-28.4)	**24.2** (17.2-34.0)	**27.9** (19.2-40.0)	**32.7** (21.8-48.7)	**36.4** (23.7-55.8)
20-day	**8.39** (6.59-10.7)	**10.3** (8.05-12.7)	**13.2** (10.4-16.7)	**15.9** (12.4-20.4)	**19.8** (15.0-26.4)	**23.1** (17.1-31.6)	**26.6** (19.0-37.2)	**30.1** (20.9-43.2)	**34.8** (23.3-51.7)	**38.4** (25.1-58.6)
30-day	**10.1** (7.97-12.8)	**12.1** (9.56-15.1)	**15.3** (12.1-19.2)	**18.0** (14.1-23.1)	**22.0** (16.7-29.1)	**25.3** (18.6-34.4)	**28.6** (20.5-39.9)	**32.0** (22.3-45.8)	**36.5** (24.6-54.2)	**40.0** (26.2-60.9)
45-day	**12.6** (9.98-16.0)	**14.8** (11.8-18.6)	**18.4** (14.6-23.1)	**21.4** (16.7-27.3)	**25.5** (19.3-33.6)	**28.7** (21.1-38.8)	**31.8** (22.8-44.3)	**35.0** (24.5-50.0)	**39.2** (26.4-58.0)	**42.4** (27.8-64.3)
60-day	**14.9** (11.8-18.8)	**17.3** (13.9-21.7)	**21.3** (17.0-26.7)	**24.5** (19.2-31.1)	**28.7** (21.7-37.6)	**31.8** (23.5-42.9)	**34.8** (25.0-48.4)	**37.8** (26.5-54.0)	**41.7** (28.2-61.6)	**44.5** (29.3-67.5)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

EXCERPT FROM REFERENCE 6, APPENDIX III-2C-1
NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION (NOAA)

APPENDIX III-2C-2

Intermediate Cover Soil Berm Calculations

Date Prepared: 11/11/2020
Made by: EWT
Checked by: JBF
Reviewed by: CGD

INTERMEDIATE COVER STORM WATER DIVERSION BERM CALCULATIONS

1.0 OBJECTIVE

Calculate the maximum allowable drainage area contributing to the temporary storm water diversion berms (or, add-on berms) for the Hawthorn Park Recycling and Disposal Facility (RDF).

Determine the adequacy of the temporary add-on berms for the 25-year, 24-hour design storm.

2.0 METHOD

Temporary storm water diversion berms were designed so that the permissible non-erodible velocity of 5 ft/s is not exceeded for the 25-year design storm. The temporary storm water diversion berms have typical triangular cross-sections with a minimum depth of 2 ft, side slopes of 4:1 and 2:1, and a longitudinal slope of 2% (or 0.02 ft/ft).

With the maximum allowable velocity, cross-section design, and channel slope, the maximum peak discharge for an add-on berm was back-calculated using the Manning's Equation.

STATE OF TEXAS
2/12/21
CHARLES G. DOMINGUEZ
83247
LICENSED PROFESSIONAL ENGINEER

For sheets 1 to 4; Appendix III-2C-2

GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

INTENDED FOR PERMITTING PURPOSES ONLY

Manning's Equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

where:

Q = Flow Rate (cfs)

A = Cross-sectional area of flow (ft^2)

R = Hydraulic radius (ft)

S = Slope (ft/ft)

n = Manning's coefficient

The HydraFlow Express software uses the Manning's equation with manual input for flow rate, slope, and Manning's coefficient n to calculate area of flow, wetted perimeter, hydraulic radius, depth of flow, and velocity of flow.

The peak discharge (or flow rate) was iteratively entered into HydraFlow express to determine peak discharge while remaining under the permissible non-erodible velocity or within channel capacity and allowing for at least 0.5 ft of freeboard. When a flow velocity $\leq$ 5 ft/s or channel capacity was reached, the input value for flow rate Q (cfs) is taken to be the peak discharge.

With the peak discharge, Q, from Manning's Equation, the Rational Method was used to solve for the maximum contributing drainage area.

Rational Method Equation: $Q = C\,I\,A$

where:

Q = Flow Rate (cfs)

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area (acre)

The Rational Method equation is rearranged to solve for area, A:

$$A = \frac{Q}{C\,I}$$

After the maximum contributing drainage area was calculated, spacing and length of the add-on berms were determined using basic area equations.

3.0 ASSUMPTIONS

The following assumptions and parameters were used in the design of the intermediate cover storm water diversion berms:

3.1 Manning's Equation

- Manning's equation assumes open channel flow
- Manning's roughness coefficient n is 0.035 for grass-lined surfaces
- Triangular drainage swale side slopes are 2H:1V and 4H:1V; 2% longitudinal slope

3.2 Rational Method

- Runoff coefficient C is 0.7 for grass-lined side slopes
- The rainfall intensity, I (in/hr), is for a 10-minute duration storm
- I_{25} = 9.47 in/hr
  - The rainfall intensity is from the National Oceanic and Atmospheric Administration (NOAA)'s Atlas 14 precipitation frequency data servers local to the Hawthorn Park RDF

4.0 CALCULATIONS

4.1 Manning's Equation

HydraFlow Express software is used to calculate Manning's Equation for the design temporary storm water diversion berm. Through iteration, the peak discharge is determined to be Q_{25} = 32.1cfs. The velocity is under 5 ft/s and available freeboard for the triangular channel cross-section created by the temporary add-on berm is 0.50 ft. Full output from HydraFlow Express is included as an attachment to this appendix.

Input for HydraFlow Express:

Q (cfs)	Slope (ft/ft)	Side Slope(s)	Depth (ft)	n
32.1	0.02	2.0 ; 4.0	2.0	0.035

Output Summary from HydraFlow Express:

Q (cfs)	Flow Depth (ft)	Velocity (fps)
32.1	1.50	4.76

4.2 Rational Method

The maximum contributing drainage area, from Rational Method, using C = 0.70, I_{25} = 9.47 in/hr, and calculated peak discharge Q (from Manning's Equation above):

$$Area, A = \frac{Q}{C\ I} = \frac{32.1}{0.70 * 9.47} = 4.84\ acres$$

The maximum drainage area to a temporary storm water diversion berm is 4.84 acres, or approximately 210,830 sqft using conversion 1 acre = 43,560 sqft.

5.0 CONCLUSIONS

During site operations, the maximum allowable drainage area for an add-on berm is 4.84 acres. Storm water downchutes should be constructed at the termination of the diversion berm or in the same location where the final cover downchutes are located if possible. Calculations for interim condition storm water downchutes are provided in Appendix III-2C-3.

The exact conditions of the various interim conditions are impossible to predict due to changes in construction, but the design temporary add-on berms will be adequate to handle run-off with 0.50-ft of freeboard for areas up to 4.84 acres in area.

Based on the soil erosion calculations in Appendix III-2C-1, the intermediate temporary add-on berms can be placed at a maximum spacing of 300 feet along the slope (i.e. 75 feet vertical spacing). For this scenario, the add-on berms can be a maximum length of 702 feet.

Horizontal Spacing (ft)	Vertical Spacing (ft)	Length of Berm (ft)	Area (sqft)	Area (AC)
300	75	702	210,600	4.83

6.0 REFERENCES

1) Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill, TCEQ Regulatory Guidance, TCEQ. May 2018

2) Precipitation Frequency Data Server (PFDS), National Oceanic and Atmospheric Administration (NOAA). September 2018

3) Urban Hydrology for Small Watersheds Technical Release 55 (TR-55), Conservation Engineering Division, Natural Resources Conservation Services (NRCS). United States Department of Agriculture (USDA). June 1986

7.0 ATTACHMENTS

Atlas 14 Rainfall Precipitation Data (NOAA)

HydraFlow Express – Temporary Add-on Berms

APPENDIX III-2C-2

ATTACHMENTS

Atlas 14 Point Precipitation Frequency Estimates (NOAA)
HydraFlow Express – Temporary Add-On Berms

NOAA Atlas 14, Volume 11, Version 2
Location name: Houston, Texas, USA*
Latitude: 29.8531°, Longitude: -95.5602°
Elevation: m/ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**5.95** (4.51-7.87)	**6.97** (5.33-9.11)	**8.62** (6.56-11.3)	**9.98** (7.50-13.3)	**11.9** (8.63-16.3)	**13.3** (9.43-18.8)	**14.8** (10.2-21.5)	**16.4** (11.0-24.4)	**18.5** (12.0-28.6)	**20.2** (12.8-32.0)
10-min	**4.72** (3.57-6.23)	**5.53** (4.22-7.22)	**6.85** (5.21-9.00)	**7.95** (5.97-10.6)	**9.47** (6.90-13.0)	**10.7** (7.55-15.1)	**11.8** (8.17-17.2)	**13.0** (8.75-19.4)	**14.6** (9.47-22.4)	**15.7** (9.96-24.9)
15-min	**4.01** (3.04-5.30)	**4.67** (3.57-6.12)	**5.76** (4.39-7.57)	**6.66** (5.00-8.87)	**7.90** (5.74-10.8)	**8.84** (6.25-12.5)	**9.80** (6.76-14.2)	**10.8** (7.28-16.1)	**12.2** (7.94-18.8)	**13.3** (8.43-21.0)
30-min	**2.88** (2.18-3.80)	**3.34** (2.55-4.37)	**4.09** (3.12-5.38)	**4.71** (3.53-6.28)	**5.56** (4.03-7.60)	**6.19** (4.37-8.71)	**6.85** (4.72-9.93)	**7.59** (5.11-11.3)	**8.66** (5.63-13.4)	**9.54** (6.04-15.1)
60-min	**1.89** (1.43-2.50)	**2.21** (1.69-2.89)	**2.73** (2.08-3.59)	**3.17** (2.38-4.22)	**3.77** (2.73-5.15)	**4.22** (2.97-5.93)	**4.70** (3.24-6.81)	**5.26** (3.54-7.85)	**6.11** (3.97-9.43)	**6.82** (4.32-10.8)
2-hr	**1.14** (0.866-1.50)	**1.38** (1.05-1.77)	**1.76** (1.34-2.29)	**2.09** (1.57-2.77)	**2.57** (1.87-3.50)	**2.95** (2.09-4.14)	**3.38** (2.34-4.88)	**3.90** (2.63-5.79)	**4.70** (3.06-7.23)	**5.39** (3.42-8.48)
3-hr	**0.827** (0.630-1.09)	**1.03** (0.777-1.31)	**1.33** (1.02-1.73)	**1.61** (1.22-2.13)	**2.03** (1.48-2.76)	**2.37** (1.69-3.33)	**2.77** (1.92-3.99)	**3.25** (2.19-4.80)	**3.99** (2.61-6.13)	**4.64** (2.95-7.28)
6-hr	**0.477** (0.365-0.623)	**0.617** (0.461-0.765)	**0.815** (0.623-1.05)	**1.01** (0.762-1.33)	**1.30** (0.955-1.77)	**1.55** (1.11-2.17)	**1.85** (1.29-2.65)	**2.20** (1.49-3.24)	**2.74** (1.80-4.20)	**3.22** (2.05-5.03)
12-hr	**0.271** (0.208-0.352)	**0.358** (0.267-0.438)	**0.479** (0.368-0.614)	**0.599** (0.456-0.786)	**0.785** (0.582-1.07)	**0.949** (0.685-1.33)	**1.14** (0.799-1.63)	**1.37** (0.929-2.00)	**1.71** (1.13-2.61)	**2.01** (1.29-3.13)
24-hr	**0.155** (0.119-0.200)	**0.208** (0.155-0.252)	**0.281** (0.217-0.358)	**0.355** (0.271-0.463)	**0.469** (0.351-0.639)	**0.573** (0.416-0.802)	**0.694** (0.487-0.987)	**0.828** (0.565-1.21)	**1.03** (0.677-1.56)	**1.19** (0.768-1.85)
2-day	**0.088** (0.068-0.113)	**0.120** (0.089-0.144)	**0.164** (0.127-0.208)	**0.208** (0.160-0.271)	**0.279** (0.211-0.381)	**0.345** (0.253-0.483)	**0.418** (0.295-0.593)	**0.492** (0.336-0.713)	**0.592** (0.391-0.889)	**0.669** (0.432-1.03)
3-day	**0.064** (0.050-0.082)	**0.087** (0.065-0.104)	**0.119** (0.092-0.151)	**0.151** (0.116-0.196)	**0.202** (0.153-0.276)	**0.249** (0.184-0.349)	**0.301** (0.213-0.426)	**0.351** (0.241-0.508)	**0.418** (0.276-0.626)	**0.467** (0.303-0.721)
4-day	**0.051** (0.040-0.066)	**0.070** (0.052-0.083)	**0.095** (0.073-0.119)	**0.119** (0.092-0.155)	**0.158** (0.120-0.215)	**0.194** (0.143-0.271)	**0.233** (0.165-0.329)	**0.271** (0.186-0.391)	**0.321** (0.213-0.480)	**0.358** (0.232-0.552)
7-day	**0.034** (0.026-0.043)	**0.045** (0.034-0.054)	**0.060** (0.047-0.075)	**0.074** (0.058-0.096)	**0.097** (0.074-0.131)	**0.117** (0.087-0.163)	**0.139** (0.099-0.196)	**0.161** (0.111-0.232)	**0.190** (0.126-0.283)	**0.212** (0.138-0.325)
10-day	**0.026** (0.021-0.034)	**0.034** (0.026-0.042)	**0.045** (0.035-0.057)	**0.056** (0.043-0.072)	**0.072** (0.054-0.096)	**0.086** (0.063-0.118)	**0.101** (0.072-0.142)	**0.116** (0.080-0.167)	**0.136** (0.091-0.203)	**0.152** (0.099-0.232)
20-day	**0.017** (0.014-0.022)	**0.022** (0.017-0.027)	**0.028** (0.022-0.035)	**0.033** (0.026-0.042)	**0.041** (0.031-0.055)	**0.048** (0.036-0.066)	**0.055** (0.040-0.078)	**0.063** (0.044-0.090)	**0.073** (0.049-0.108)	**0.080** (0.052-0.122)
30-day	**0.014** (0.011-0.018)	**0.017** (0.013-0.021)	**0.021** (0.017-0.027)	**0.025** (0.020-0.032)	**0.031** (0.023-0.040)	**0.035** (0.026-0.048)	**0.040** (0.028-0.055)	**0.044** (0.031-0.064)	**0.051** (0.034-0.075)	**0.055** (0.036-0.084)
45-day	**0.012** (0.009-0.015)	**0.014** (0.011-0.017)	**0.017** (0.014-0.021)	**0.020** (0.015-0.025)	**0.024** (0.018-0.031)	**0.027** (0.020-0.036)	**0.029** (0.021-0.041)	**0.032** (0.023-0.046)	**0.036** (0.024-0.054)	**0.039** (0.026-0.060)
60-day	**0.010** (0.008-0.013)	**0.012** (0.010-0.015)	**0.015** (0.012-0.019)	**0.017** (0.013-0.022)	**0.020** (0.015-0.026)	**0.022** (0.016-0.030)	**0.024** (0.017-0.034)	**0.026** (0.018-0.037)	**0.029** (0.020-0.043)	**0.031** (0.020-0.047)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical

NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION (NOAA)

HYDRAFLOW EXPRESS

TEMPORARY ADD-ON BERMS

HAWTHORN PARK RDF

Channel Report

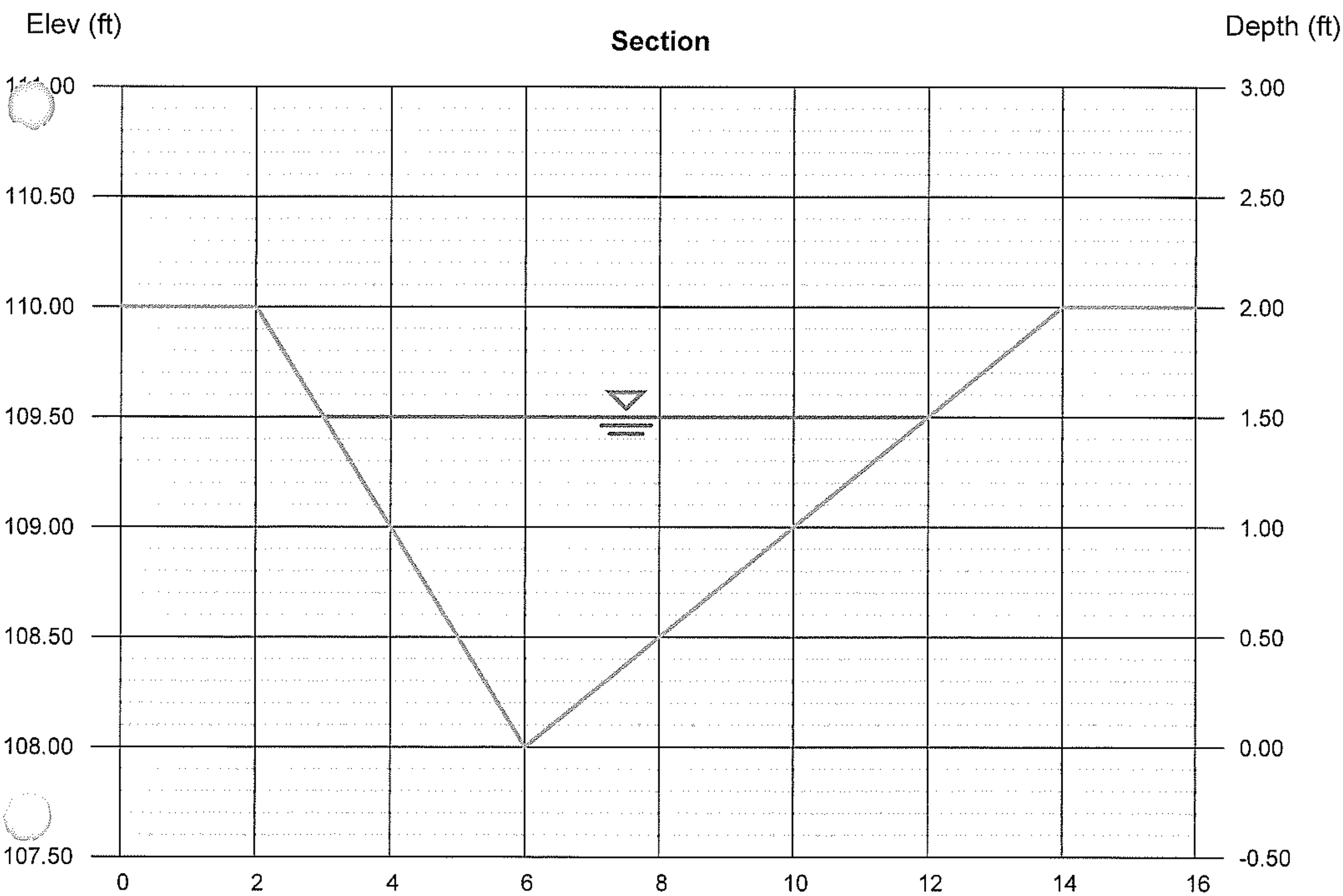
HydraFlow Express Output
Appendix III-2C-2

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc.

Wednesday, Aug 26 2020

mporary Add-On Berms

Triangular		**Highlighted**	
Side Slopes (z:1)	= 2.00, 4.00	Depth (ft)	= 1.50
Total Depth (ft)	= 2.00	Q (cfs)	= 32.10
		Area (sqft)	= 6.75
Invert Elev (ft)	= 108.00	Velocity (ft/s)	= 4.76
Slope (%)	= 2.00	Wetted Perim (ft)	= 9.54
N-Value	= 0.035	Crit Depth, Yc (ft)	= 1.49
		Top Width (ft)	= 9.00
Calculations		EGL (ft)	= 1.85
Compute by:	Known Q		
Known Q (cfs)	= 32.10		



APPENDIX III-2C-3

Intermediate Cover Downchute Calculations

INTERMEDIATE COVER STORM WATER DOWNCHUTE CALCULATIONS

Date Prepared:	11/11/2020
Made by:	EWT
Checked by:	JBF
Reviewed by:	CGD

1.0 OBJECTIVE

Calculate the maximum allowable drainage area contributing to the temporary storm water downchutes for the Hawthorn Park (RDF).

Determine the adequacy of the temporary downchute for the 25-year, 24-hour design storm. The temporary storm water downchute design for the Hawthorn Park Recycling and Disposal Facility (RDF) should convey the 25-year design storm with a minimum of 0.50-ft of freeboard.

2.0 METHOD

Temporary storm water downchutes were designed to convey run-off collected by the temporary storm water diversion berms analyzed in Appendix III-2C-2. The downchutes have trapezoidal cross-sections with side slopes of 2H:1V, bottom width of 5 ft, depth of 2 ft, and a longitudinal slope no greater than the design side slope grade of 25% (4H:1V). The maximum downchute grade of 25% was used in this analysis.

With the downchute geometry, the maximum peak discharge for the intermediate downchute was back-calculated using the Manning's Equation. The Rational Method was used to calculate the drainage area for a given peak discharge.

Manning's Equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

where:

Q = Flow Rate (cfs)

A = Cross-sectional area of flow (ft^2)

R = Hydraulic radius (ft)

S = Slope (ft/ft)

n = Manning's coefficient

Rational Method Equation:

$$Q = C\ I\ A$$

where:

Q = Flow Rate (cfs)

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area (acre)

STATE OF TEXAS
2/12/21
CHARLES G. DOMINGUEZ
83247
LICENSED
PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

INTENDED FOR PERMITTING PURPOSES ONLY

For Sheets 1 to 3;
Appendix III-2C-3

3.0 ASSUMPTIONS

The following assumptions and parameters were used in the design of the intermediate cover storm water downchutes. The target maximum velocity is 35 fps for the geomembrane-lined downchute.

3.1 Manning's Equation

- Manning's roughness coefficient n is 0.012 for plastic-lined surfaces (geomembrane)

3.2 Rational Method

- Runoff coefficient C is 0.7 for side slopes
- Rainfall intensity for a 10-minute duration storm I_{25} = 9.47 in/hr
  - The rainfall intensity is from the National Oceanic and Atmospheric Administration (NOAA)'s Atlas 14 precipitation frequency data servers local to the Hawthorn Park RDF

4.0 CALCULATIONS

4.1 Manning's Equation

HydraFlow Express software was used to simulate the Manning's Equation for the design section of the temporary downchute. Through iteration, the peak discharge for a plastic-lined temporary downchute was determined to be Q_{25} = 109.9 cfs. The limiting factor was the velocity.

Input Summary for HydraFlow:

Q (cfs)	Slope (ft/ft)	Side Slope(s)	Bottom Width (ft)	Channel Depth (ft)	n
109.9	0.25	2.0 ; 2.0	5.0	2.0	0.012

Output Summary from HydraFlow Express:

Q (cfs)	Flow Depth (ft)	Velocity (fps)
109.9	0.52	34.99

4.2 Rational Method

The maximum contributing drainage area, from Rational Method, using the calculated peak discharge Q:

Rational Method – Area:

Q_{25} (cfs)	C	I_{25} (in/hr)	Area (ac)
109.9	0.7	9.47	16.57

5.0 CONCLUSIONS

During site operations, the maximum allowable drainage area for a temporary downchute is 16.57 acres. Storm water downchutes should be constructed where the final cover downchutes are located if possible, or at the termination of the temporary storm water diversion berms. Calculations for intermediate cover storm water add-on berms are provided in Appendix III-2C-2.

The temporary storm water downchutes must be spaced so that the maximum contributing area does not exceed 16.57 acres for the design downchute geometry.

6.0 REFERENCES

1) Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill, TCEQ Regulatory Guidance, TCEQ. May 2018

2) Precipitation Frequency Data Server (PFDS), National Oceanic and Atmospheric Administration (NOAA). September 2018

3) Hydraulic Design Manual, Texas Department of Transportation (TxDOT). September 2019

7.0 ATTACHMENTS

Atlas 14 Rainfall Precipitation Data (NOAA)

Hydraulic Design Manual (TxDOT)

HydraFlow Express – Temporary Downchutes

APPENDIX III-2C-3

ATTACHMENTS

Atlas 14 Point Precipitation Frequency Estimates (NOAA)
Hydraulic Design Manual (TxDOT)
HydraFlow Express – Temporary Downchutes

NOAA Atlas 14, Volume 11, Version 2
Location name: Houston, Texas, USA*
Latitude: 29.8531°, Longitude: -95.5602°
Elevation: m/ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	5.95 (4.51-7.87)	6.97 (5.33-9.11)	8.62 (6.56-11.3)	9.98 (7.50-13.3)	11.9 (8.63-16.3)	13.3 (9.43-18.8)	14.8 (10.2-21.5)	16.4 (11.0-24.4)	18.5 (12.0-28.6)	20.2 (12.8-32.0)
10-min	4.72 (3.57-6.23)	5.53 (4.22-7.22)	6.85 (5.21-9.00)	7.95 (5.97-10.6)	9.47 (6.90-13.0)	10.7 (7.55-15.1)	11.8 (8.17-17.2)	13.0 (8.75-19.4)	14.6 (9.47-22.4)	15.7 (9.96-24.9)
15-min	4.01 (3.04-5.30)	4.67 (3.57-6.12)	5.76 (4.39-7.57)	6.66 (5.00-8.87)	7.90 (5.74-10.8)	8.84 (6.25-12.5)	9.80 (6.76-14.2)	10.8 (7.28-16.1)	12.2 (7.94-18.8)	13.3 (8.43-21.0)
30-min	2.88 (2.18-3.80)	3.34 (2.55-4.37)	4.09 (3.12-5.38)	4.71 (3.53-6.28)	5.56 (4.03-7.60)	6.19 (4.37-8.71)	6.85 (4.72-9.93)	7.59 (5.11-11.3)	8.66 (5.63-13.4)	9.54 (6.04-15.1)
60-min	1.89 (1.43-2.50)	2.21 (1.69-2.89)	2.73 (2.08-3.59)	3.17 (2.38-4.22)	3.77 (2.73-5.15)	4.22 (2.97-5.93)	4.70 (3.24-6.81)	5.26 (3.54-7.85)	6.11 (3.97-9.43)	6.82 (4.32-10.8)
2-hr	1.14 (0.866-1.50)	1.38 (1.05-1.77)	1.76 (1.34-2.29)	2.09 (1.57-2.77)	2.57 (1.87-3.50)	2.95 (2.09-4.14)	3.38 (2.34-4.88)	3.90 (2.63-5.79)	4.70 (3.06-7.23)	5.39 (3.42-8.48)
3-hr	0.827 (0.630-1.09)	1.03 (0.777-1.31)	1.33 (1.02-1.73)	1.61 (1.22-2.13)	2.03 (1.48-2.76)	2.37 (1.69-3.33)	2.77 (1.92-3.99)	3.25 (2.19-4.80)	3.99 (2.61-6.13)	4.64 (2.95-7.28)
6-hr	0.477 (0.365-0.623)	0.617 (0.461-0.765)	0.815 (0.623-1.05)	1.01 (0.762-1.33)	1.30 (0.955-1.77)	1.55 (1.11-2.17)	1.85 (1.29-2.65)	2.20 (1.49-3.24)	2.74 (1.80-4.20)	3.22 (2.05-5.03)
12-hr	0.271 (0.208-0.352)	0.358 (0.267-0.438)	0.479 (0.368-0.614)	0.599 (0.456-0.786)	0.785 (0.582-1.07)	0.949 (0.685-1.33)	1.14 (0.799-1.63)	1.37 (0.929-2.00)	1.71 (1.13-2.61)	2.01 (1.29-3.13)
24-hr	0.155 (0.119-0.200)	0.208 (0.155-0.252)	0.281 (0.217-0.358)	0.355 (0.271-0.463)	0.469 (0.351-0.639)	0.573 (0.416-0.802)	0.694 (0.487-0.987)	0.828 (0.565-1.21)	1.03 (0.677-1.56)	1.19 (0.768-1.85)
2-day	0.088 (0.068-0.113)	0.120 (0.089-0.144)	0.164 (0.127-0.208)	0.208 (0.160-0.271)	0.279 (0.211-0.381)	0.345 (0.253-0.483)	0.418 (0.295-0.593)	0.492 (0.336-0.713)	0.592 (0.391-0.889)	0.669 (0.432-1.03)
3-day	0.064 (0.050-0.082)	0.087 (0.065-0.104)	0.119 (0.092-0.151)	0.151 (0.116-0.196)	0.202 (0.153-0.276)	0.249 (0.184-0.349)	0.301 (0.213-0.426)	0.351 (0.241-0.508)	0.418 (0.276-0.626)	0.467 (0.303-0.721)
4-day	0.051 (0.040-0.066)	0.070 (0.052-0.083)	0.095 (0.073-0.119)	0.119 (0.092-0.155)	0.158 (0.120-0.215)	0.194 (0.143-0.271)	0.233 (0.165-0.329)	0.271 (0.186-0.391)	0.321 (0.213-0.480)	0.358 (0.232-0.552)
7-day	0.034 (0.026-0.043)	0.045 (0.034-0.054)	0.060 (0.047-0.075)	0.074 (0.058-0.096)	0.097 (0.074-0.131)	0.117 (0.087-0.163)	0.139 (0.099-0.196)	0.161 (0.111-0.232)	0.190 (0.126-0.283)	0.212 (0.138-0.325)
10-day	0.026 (0.021-0.034)	0.034 (0.026-0.042)	0.045 (0.035-0.057)	0.056 (0.043-0.072)	0.072 (0.054-0.096)	0.086 (0.063-0.118)	0.101 (0.072-0.142)	0.116 (0.080-0.167)	0.136 (0.091-0.203)	0.152 (0.099-0.232)
20-day	0.017 (0.014-0.022)	0.022 (0.017-0.027)	0.028 (0.022-0.035)	0.033 (0.026-0.042)	0.041 (0.031-0.055)	0.048 (0.036-0.066)	0.055 (0.040-0.078)	0.063 (0.044-0.090)	0.073 (0.049-0.108)	0.080 (0.052-0.122)
30-day	0.014 (0.011-0.018)	0.017 (0.013-0.021)	0.021 (0.017-0.027)	0.025 (0.020-0.032)	0.031 (0.023-0.040)	0.035 (0.026-0.048)	0.040 (0.028-0.055)	0.044 (0.031-0.064)	0.051 (0.034-0.075)	0.055 (0.036-0.084)
45-day	0.012 (0.009-0.015)	0.014 (0.011-0.017)	0.017 (0.014-0.021)	0.020 (0.015-0.025)	0.024 (0.018-0.031)	0.027 (0.020-0.036)	0.029 (0.021-0.041)	0.032 (0.023-0.046)	0.036 (0.024-0.054)	0.039 (0.026-0.060)
60-day	0.010 (0.008-0.013)	0.012 (0.010-0.015)	0.015 (0.012-0.019)	0.017 (0.013-0.022)	0.020 (0.015-0.026)	0.022 (0.016-0.030)	0.024 (0.017-0.034)	0.026 (0.018-0.037)	0.029 (0.020-0.043)	0.031 (0.020-0.047)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical

NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION (NOAA)

where:

A = section area of flow, sq. ft. or m^2

T = width of water surface, ft. or m

d = depth of flow, ft. or m

D = pipe diameter, ft. or m

the $\cos^{-1}(\theta)$ is the principal value in the range $0 \leq \theta \leq \pi$.

Use Equation 6-3 to determine uniform depth. For most shapes, a direct solution of Equation 6-3 for depth is not possible. The Slope Conveyance Procedure discussed in Chapter 7 is applicable. For rectangular shapes, area, A, and wetted perimeter, WP are simple functions of flow depth. For circular pipe, compute area using Equation 6-17, and compute wetted perimeter using Equation 6-19. For other shapes, acquire or derive the relationship from depth of flow, area, and wetted perimeter.

Refer to the table below for recommended Manning's roughness coefficients for conduit.

$$WP = D\cos^{-1}\left(1 - \frac{2d}{D}\right)$$

Equation 6-19.

Roughness Coefficients

The following table provides roughness coefficients for conduits.

Recommended Culvert Conduit Roughness Coefficients

Type of Conduit	n-Value
Concrete Box	0.012
Concrete Pipe	0.012
Smooth-lined metal pipe	0.012
Smooth lined plastic pipe	0.012
Corrugated metal pipe	0.015-0.027
Structural plate pipe	0.027-0.036
Long span structural plate	0.031
Corrugated metal (paved interior)	0.012
Plastic	0.012-0.024

HYDRAFLOW EXPRESS

TEMPORARY DOWNCHUTES

HAWTHORN PARK RDF

Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc.

Thursday, Sep 10 2020

mporary Downchutes (Geomembrane)

Trapezoidal	
Bottom Width (ft)	= 5.00
Side Slopes (z:1)	= 2.00, 2.00
Total Depth (ft)	= 2.00
Invert Elev (ft)	= 108.00
Slope (%)	= 25.00
N-Value	= 0.012

Calculations	
Compute by:	Known Q
Known Q (cfs)	= 109.90

Highlighted	
Depth (ft)	= 0.52
Q (cfs)	= 109.90
Area (sqft)	= 3.14
Velocity (ft/s)	= 34.99
Wetted Perim (ft)	= 7.33
Crit Depth, Yc (ft)	= 1.91
Top Width (ft)	= 7.08
EGL (ft)	= 19.56