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SHEETFLOW CALCULATION REFERENCE SHEET FOR VINEYARD/ORCHARD DEVELOPMENT

INTRODUCTION

Agricultural site development and in particular Vineyard and Orchard site development in Sonoma County is administered by Agricultural Commissioner pursuant to Sonoma County Code Chapter 11 Grading, Drainage, and Vineyard and Orchard Site Development and the BMP Manual for Agricultural Erosion and Sediment Control. As described in Chapter 11, management of stormwater, maintaining natural offsite drainage patterns, prevention of soil loss, and limiting post-development run-off are required elements of project design. According to the BMP Manual, drainage systems should be designed to maintain natural sheet flow and use vegetated swales as an option to drain pipe whenever possible. Given the above, for Level II VESCO projects incorporating sheet flow in the drainage design, the Agricultural Commissioner provides the following method and approach to assess length and time of concentration of sheet flow. The equations and approaches presented below will guide designers on drainage characteristics needed to manage runoff and control soil erosion using sheet flow. This method is not intended to produce a rigid or required solution to the determination of sheet flow length. It is intended to provide guidance on when a limit of sheet flow may occur and alert designers to make other assessments necessary to minimize erosion caused by flow concentration. Consideration of onsite soil characteristics need to be developed by the designers on a site by site basis. Velocity of flow and soil erodibility should be evaluated. The approach defined in the document is intended to provide guidance to designers of when further assessments of erosion potential caused by concentration of flow should be considered. The provided equations only estimates the time of concentration within the defined limits of sheet flow. At the transition from sheet flow to shallow concentrated flow, these equations are no longer applicable and hydrologic design consistent with Chapter 11, the BMP Manual, and local engineering practice, will be required on a project by project basis.

BASIC HYDROLOGY

Utilizing a project scale topographic map, develop a hydrologic map of the project site which reflects existing drainage patterns, including ephemeral swales which convey shallow concentrated flow (<0.1 foot depth of flow). Measure proposed sheet flow lengths and slope gradient within each hydrologic unit to the down slope location where concentrated flow is evident. Analyze hydrologic conditions following the method based on findings from the "Assessment of Kinematic Wave Time of Concentration" by McCuen and Spiess (1995). Where the proposed site design exceeds the limits of sheet flow, provide additional engineering justification that proposed sheet flow lengths will not trigger concentrated flow patterns resulting in the formation of rills/gullies for the design precipitation event.

McCuen and Spiess sought a method to determine validity and limits for the kinematic wave equation for determining time of concentration for sheet flow. One of the variables in the wave equation was flow length, which had limited technical justification and or basis for selection of appropriate length in practice. McCuen and Spiess, through analytical means and correlation to field data, developed the following limit relationship for use by designers to improve determination of sheet flow length and thereby the resulting time of concentration of the sheet flow regime.

$$\frac{nL}{\sqrt{s}} \leq 100 \text{ , where}$$

n = Manning's n

L = sheet flow length (foot)

s = slope (foot/foot)

Table 1: Manning's n values for sheet flow

Surface Description		$\boldsymbol{n}$
Smooth Surface		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	0.24
	Bermudagrass	0.41
Range (natural)		0.13
Woods	Light Underbrush	0.40
	Dense Underbrush	0.80

*Table adapted from USDA Technical Release 55 (USDA, 1986)

Where this ratio conforms to the above limit, the following kinematic wave equation for time of concentration (Tc) may be used:

$$Tc = \frac{0.93}{i^{0.4}} \left(\frac{nL}{\sqrt{s}}\right)^{0.6} \text{ , where}$$

i = rainfall intensity (inch/hour)

This equation requires an iterative solution. An estimated time of concentration (denoted as tc) would be selected for the watershed in question. The IDF curve for the watershed would be entered with the estimated tc, and desired return period, and resulting rainfall intensity (i) taken from the IDF curve and entered into the above equation. When the calculated Tc is equal to the estimated tc (Tc ≅ tc), the iteration has converged to a solution. The IDF curve prepared by the Sonoma County Water Agency (SCWA) is included below.

Chart 1: Sonoma County Water Agency IDF Curve (SCWA, 1983)

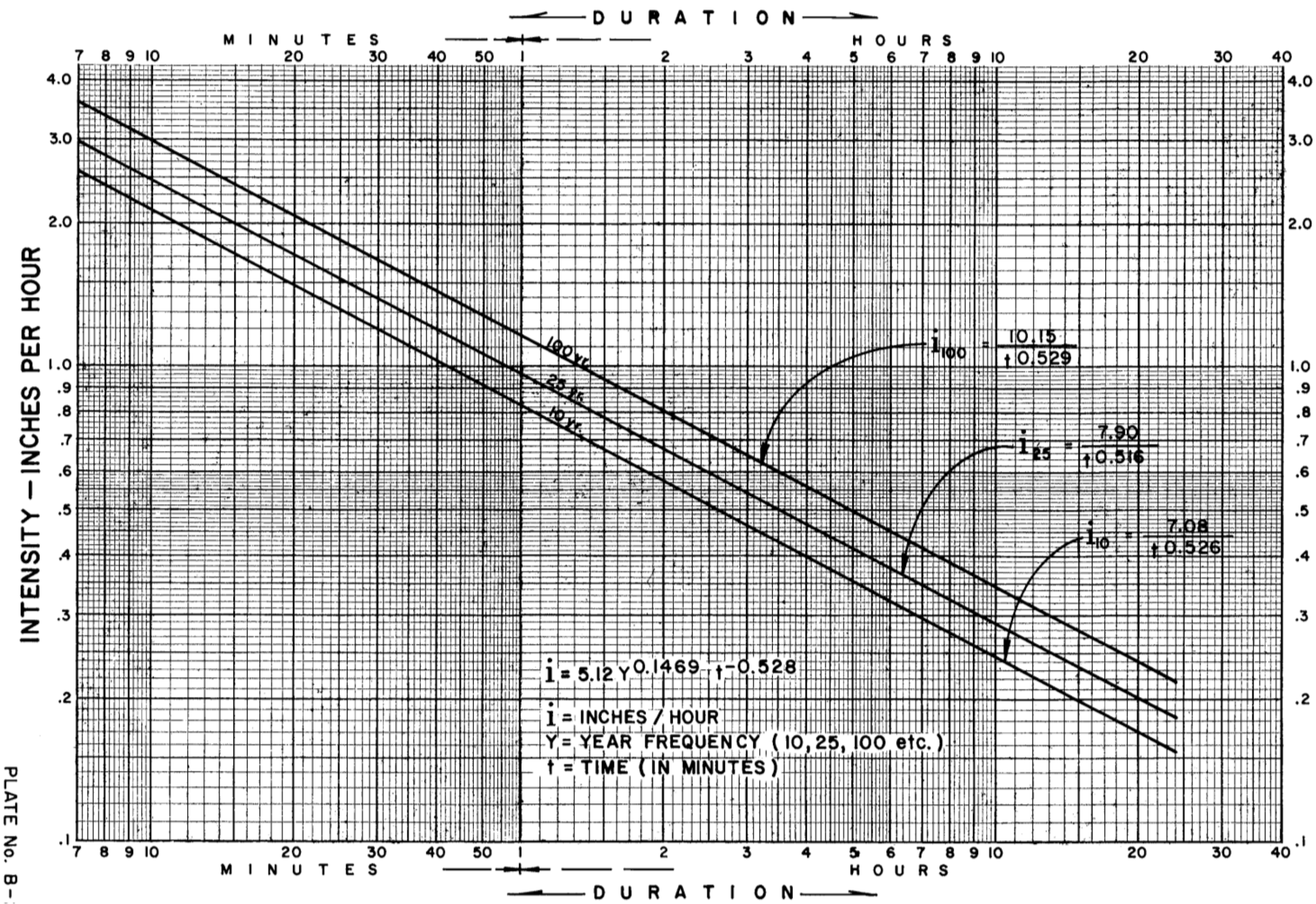

PLATE No. B-

EXAMPLE PROBLEMS

These equations are useful in assessing proposed designs on developing design criteria. Consider the following examples:

Example 1: A sloped area (s = 0.35) is covered in cultivated Bermuda grass (n = 0.41) and has a total length of 1,000 feet. Does sheet flow exist on this slope?

Use limit equation:

$$\frac{nL}{\sqrt{s}} \leq 100$$

Check ratio:

$$\frac{0.41(1000)}{\sqrt{0.35}} = 693 > 100$$

No sheet flow, concentrated flow likely.

Example 2: Using the same scenario as Example 1, calculate the approximate the sheet flow length.

$$L = \frac{100\sqrt{s}}{n} = \frac{100\sqrt{0.35}}{0.41}$$

$$\underline{L = 144\ feet}$$

Consider drainage improvements for each 144 foot increment.

Example 3: Using the same scenario, what is the time of concentration (Tc) for the calculated sheet flow length?

$$Tc = \frac{0.93}{i^{0.4}}\ (100)^{0.6}$$

From SCWA IDF curve, 25 year return period, estimate tc = 15 minutes → i = 2.0 inch/hour:

$$Tc = \frac{0.93}{2.0^{0.4}}\ (100)^{0.6} = 11\ min \neq 15\ min$$

Try tc = 20 minutes → i = 1.7 inch/hour:

$$Tc = \frac{0.93}{1.7^{0.4}}\ (100)^{0.6} = 12\ min \neq 20\ min$$

Try tc = 10 minutes → i = 2.45 inch/hour:

$$Tc = \frac{0.93}{2.45^{0.4}}\ (100)^{0.6} = 10.3\ min \cong 10\ min$$

$$\underline{Tc = 10\, min}$$

Example 4: For the same scenario, what surface treatment would be required to support sheet flow of 1,000 foot increments?

$$n = \frac{100\sqrt{s}}{L} = \frac{100\sqrt{s}}{1000}$$

$$\underline{n = 0.06}$$

Develop site with “fallow” surface ($n =$ 0.05).

Example 5: For the same scenario, what surface treatments would be required to support drainage controls at 500 foot increments?

$$n = \frac{100\sqrt{s}}{L} = \frac{100\sqrt{s}}{500}$$

$$\underline{n = 0.12}$$

Develop site with modified range surface ($n =$ 0.13 close to 0.12).

References

McCuen, R.H. and Spiess, J.M., 1995, Assessment of Kinematic Water Time of Concentration”, Journal of Hydrologic Engineering, ASCE, 121(3): 256-266.

SCWA, 1983, Flood Control Design Criteria Manual for Waterways, Channels and Closed Conduits, Sonoma County Water Agency, August 1983, Plate No. B-2.

USDA, 1986, Urban Hydrology for Small Watershed – Technical Release 55, United Stated Department of Agriculture, June 1986, Table 3-1.