CHAPTER 12.0 OPEN CHANNELS

12.1 Introduction

This chapter includes criteria and procedures for the design of open channels in the County. In the Standards, open channels are classified as swales, roadside ditches, or naturalized channels. Swales can be used to convey onsite runoff to a design discharge point, typically a water quality/storage facility or a major drainageway. Swales can also be used to route offsite runoff around a site. In general, swales are sufficient for conveying discharges from contributing areas less than 130 acres. Roadside ditches are primarily intended to convey roadway runoff to a major drainageway. Naturalized channels are generally considered to be major drainageways designed to convey larger flows with a more defined baseflow/low-flow channel and floodplains.

12.2 Design Criteria and Considerations – Swales

12.2.1 Type

Swales can either be grass or riprap-lined, depending on conditions. Grass swales are preferred wherever conditions allow because they provide greater infiltration and filtration benefits and less maintenance requirements compared to riprap-lined swales.

12.2.2 Design Event and Freeboard

All swales shall be designed to convey the 100-year peak discharge. A minimum of 18” of freeboard must be provided above the 100-year water surface elevation to the top of the bank or adjacent property lines (whichever is more restrictive).

12.2.3 Cross-Section

A trapezoidal cross section is recommended for swales as it is the most efficient shape for conveyance and minimizes erosional forces. The bottom width should be at least 2 feet wide and side slopes should be 5:1 (H:V) or flatter for grass swales and 2.5:1 (H:V) or flatter for riprap-lined channels. If these criteria are followed, the swale capacity charts provided in Figure 12-1, Figure 12-2Figure 12-3Figure 12-4 may be used for determining the type of swale for each application.

12.2.4 Hydraulic Design Requirements

12.2.4.1 Grass Swales

Grass swales shall be designed according to the criteria provided in Table 12-1 to maintain stability and reduce erosion potential. In addition, proper soil preparation and revegetation shall adhere to the criteria and guidelines provided in the *Revegetation* chapter of the Standards.

Table 12-1. Hydraulic design criteria for vegetated (grass) swales

Parameter	Erosive Soils	Erosion Resistant Soils
Maximum Velocity (2-year)	3.5 ft/sec	5.0 ft/sec
Maximum Velocity (100-year)	5.0 ft/sec	7.0 ft/sec
Maximum Froude Number (2-year)	0.5	0.7
Maximum Froude Number (100-year)	0.6	0.8

In some circumstances, grade control structures and/or riprap lined swales may be necessary. Refer to the *Hydraulic Structures* chapter of the Standards for design criteria on grade control structures.

12.2.4.2 Riprap-Lined Swales

Riprap-lined swales may use either soil riprap or void-filled riprap designs. Soil riprap is conducive to vegetation growth as the riprap voids are filled with topsoil. Void-filled riprap uses a well-graded mix of cobbles, gravels, sands, and soil to emulate a more natural streambed-like channel.

Design of riprap-lined swales requires determination of proper riprap size. Figure 12-1 through Figure 12-4 are swale stability charts showing the type of riprap to be used for various configurations of swale flowrate, longitudinal slope, bottom width, flow depth and side slope. Additional discussion on the development and application of the stability charts are available in the *Open Channels* chapter of the MHFD Manual.

If those conditions do not apply, the engineer may use alternative sizing methods. One method for riprap-lined swales with longitudinal slopes generally 2% or less is Equation 12-1 below (Hughes et al, 1983):

Equation 12-1

$$d_{50} \geq \left[\frac{VS^{0.17}}{4.5(G_s - 1)^{0.66}}\right]^2$$

Where:

V = mean channel velocity (ft/sec)
S = longitudinal channel slope (ft/ft)
d_{50} = mean rock size (ft)
G_s = specific gravity of rock (minimum = 2.50, typically 2.5 to 2.7)

Several methods for sizing riprap on steep slope conditions are suggested and discussed in the *Open Channels* chapter (see Rocks and Boulders section) in the MHFD Manual. Construction notes and specifications for riprap projects are available in the Rock and Boulders section as well as the MHFD website Resource Library. https://mhfd.org/resources/specifications/

12.2.5 Common Area Lots, Outlots and Easements

The County requires all swales to be placed in common area lots, outlots or easements. See related policy statement in CHAPTER 3.0.

12.3 Roadside Ditches

Roadside ditches shall follow the design criteria set forth for swales, with the following exceptions:

1. The ditch capacity shall be dictated by the allowable encroachment criteria set forth in the *Streets* chapter of the Standards.
2. Alternative cross-sections (besides trapezoidal) may be used where necessary to meet available space or other constraints.
3. Drainage easements are not required if the 100-year water surface elevation is fully contained within the right-of-way.

12.4 Naturalized Channels

Major drainageways, defined as drainageways receiving runoff from contributing areas greater than 130 acres, shall be designed according to the naturalized channels criteria and guidelines set forth in the *Open Channels* chapter of the MHFD Manual and the County's floodplain regulations.

12.5 Hydraulic Analysis

All open channel designs shall be supported by a proper hydraulic analysis. In most cases, swale and roadside ditch design can be performed using Manning's Equation for uniform flow conditions. Multiple engineering design software packages such as FlowMaster, Autodesk SSA, HEC-15 and EPA SWMM support application of this method. HEC-RAS may be required for more detailed analysis, particularly for naturalized channels where bridges, culverts and other crossings can significantly affect hydraulics and where flood extents may need to be mapped.

12.5.1 Manning's Equation

Manning's Equation for uniform flow conditions is generally sufficient for swale and roadside design. The County Engineer will accept results from common engineering software packages that implement Manning's Equation.

Equation 12-2

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

Where:

Q = discharge (cfs)
n = Manning's roughness coefficient (see Roughness Coefficient sections below)
A = cross sectional area (ft^2)
R = hydraulic radius (ft/ft)
S = friction slope (ft/ft) (approximated by channel invert slope for normal depth calculation)
The channel velocity (ft/s) can be computed as V = Q/A.

The Froude number can be computed as follows:

Equation 12-3

$$Fr = \frac{V}{\sqrt{gD_h}}$$

Where:

Fr = Froude number (dimensionless)
g = gravitational acceleration (32.2 ft/s^2)
T = top width of flow area (ft)
D_h = hydraulic depth = A/T (ft)

12.5.2 Hydraulic Modeling

A more detailed analysis using software with one- or two-dimensional modeling capability will likely be required by the County for hydraulic analysis of naturalized channel projects. HEC-RAS remains a widely used and accessible program, and the engineer is encouraged to review the HEC-RAS modeling guidelines provided in the *Open Channels* chapter of the MHFD Manual as well as the HEC-RAS Hydraulic Reference Manual provided by the US Army Corps of Engineers. The County also has published guidelines for hydraulic analysis in its Floodplain Development Guide to support applications for floodplain permits. Other software, such as the U.S. Bureau of Reclamation's Sedimentation and River Hydraulics—Two-Dimension (SRH-2D) model, may be used with the County Engineer's approval.

12.5.3 Roughness Coefficients

Roughness coefficients are integral to open channel flow calculations and must be selected appropriately.

Table 12-2 provides typical roughness coefficients for various conditions. The engineer is responsible for field-verifying the conditions prior to use of the values in calculations.

Table 12-2: Typical roughness coefficients (based on Table 8-5 in MHFD Manual)

Location and Cover	For Velocity, Froude No., and Shear Stress Calculations	For Water Surface Elevation and Depth Calculations
Main Channel (bankfull channel)		
Sand or clay bed	0.03	0.04
Gravel or cobble bed	0.035	0.07
Vegetated Overbanks		
Turfgrass Sod	0.03	0.04
Native Grasses	0.032	0.05
Herbaceous wetlands (few or no willows)	0.06	0.12
Willow stands, woody shrubs	0.07	0.16

Roughness coefficients for void-filled or soil riprap-lined channels may be estimated using the equation below.

Equation 12-4

$$n = 0.0395 d_{50}^{1/6}$$

12.6 Submittal Requirements

Drainage Reports shall include the following information (at a minimum) to document swale design:

- Plans shall show location, type and ownership of all swales,
- Plans shall include cross-sections showing bottom width, top width, side-slope, maximum water surface elevation and freeboard,
- Summary tables showing swale discharges, velocities and Froude numbers,
- Documentation of all equations, parameter values and calculations,
- Schematics showing pipe network used in modeling software (if applicable), and
- Print outs of modeling software inputs and outputs.