

CHAPTER 1: INTRODUCTION

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1. INTRODUCTION

1.1 BACKGROUND

In 1987, Florida Department of Transportation (FDOT) published the Drainage Manual as a three volume set: Volume 1 - Policy; Volumes 2A and 2B - Procedures; Volume 3 - Theory.

In October 1992, the FDOT revised Volume 1 - Policy to Volume 1- Standards and designated Volumes 2A, 2B, and 3 as general reference documents.

In January 1997, the FDOT renamed Volume 1 - Standards to “Drainage Manual”. In the years that followed, the FDOT developed numerous handbooks to replace Volumes 2A, 2B, and 3 of the original 1987 Drainage Manual. With this, the Drainage Manual was maintained as a “standards” document while the handbooks provided guidance addressing drainage design practice, analysis and computational methods, along with design aids and reference material.

In 2016, the Department consolidated the handbooks into the Drainage Design Guide. Chapters 2 through 10 of the Drainage Design Guide each represent a handbook in previous form. The appendices of the handbooks, with a few exceptions, were incorporated as appendices in the Drainage Design Guide. Whereas, the remaining handbook appendices were inserted into the appropriate chapter of the Drainage Design Guide.

1.2 PURPOSE

The Drainage Design Guide is a reference for designers, which provides guidelines for common drainage and stormwater aspects of FDOT projects. The guidelines do not replace the need for professional engineering judgment or preclude the use of other information. These guidelines are suggested or preferred approaches, not requirements. The Drainage Manual provides minimum standards and governs over the Drainage Design Guide, when discrepancies are noted between both documents.

The technical information in these guidelines is written by Central Office Drainage and is then reviewed and commented upon by the district drainage engineers. The district drainage engineer has the final project specific decisions concerning the application of these guidelines, especially given the subjective judgment required to do good drainage design. If you have project specific questions on this material, please collaborate with your district drainage engineer.

1.3 REVISIONS

Any comments or suggestions concerning this handbook may be made by e-mailing the [State Drainage Engineer](#). The FDOT will routinely make revisions to keep the Drainage Design Guide consistent with other FDOT documents and to reflect changes and trends in drainage design.

1.4 DEFINITIONS OF TERMS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
Abstraction	Hydrologic processes that remove water from precipitation before it becomes surface runoff; types include evaporation, infiltration, transpiration, interception, depression storage, and detention storage.
Abutment	The portion of a bridge containing the embankment at each end of the bridge. Abutments may be sloped or vertical.
Accretion	The build-up of land or bottom elevation.
ADA	Americans with Disabilities Act
Aggradation	The build-up of a stream bed over time along the entire stream reach due to deposition of sediments eroded from the channel or banks farther upstream in the watershed.
Annulus	The area between the outside of a pipe and the precast opening in which the pipe is placed.
ASTM	American Society for Testing and Materials
Attenuation	In flood control: to temporarily hold back or store stormwater to control the rate of discharge. Also, see Detention.
Backwater	Backwater is defined as the increase of water surface elevation induced upstream from a bridge, culvert, dike, dam, another stream at a higher stage, or other similar structures; or as conditions that obstruct or constrict a channel relative to the elevation occurring under natural channel and floodplain conditions.
Bay	In coastal hydrology: a recess in the shore or an inlet of a sea between two capes or headlands; a bay is not as large as a gulf, but larger than a cove.
Berm	An embankment typically used for containment or separation of water.
BMP	Best Management Practice. Refers to standard practices used to improve stormwater quality prior to discharge.
CFS	Cubic Feet per Second

Channel section	The cross section of a channel taken at an angle perpendicular to the direction of water flow in the channel.
Conveyance	A measure of the carrying capacity of a channel or pipe section. Often denoted as “K”. $K = Q/(\text{slope})^{0.5}$.
Coefficient of permeability	A measure of the rate of flow of water through a medium (soil, membrane, fabric, etc.) under a given hydraulic gradient in units of length/time (i.e., ft/day; cm/sec).
Critical depth (D_c)	The depth associated with the minimum total energy for a particular flow rate in a particular cross section. The flow depth can drop through critical depth at the outlet of a pipe section if the water surface downstream is low enough.
Critical duration	As defined by Rule 14-86.002 F.A.C.: “Critical Duration” means the length of time of a specific storm frequency that creates the largest volume or highest rate of net stormwater runoff (post-improvement runoff less pre-improvement runoff) for typical durations up through and including the 10-day duration for closed basins and up through the 3-day duration for basins with positive outlets. The critical duration for a given storm frequency is determined by calculating the peak rate and volume of stormwater runoff for various storm durations and then comparing the pre-improvement and post-improvement conditions for each of the storm durations. The duration resulting in the highest peak rate or largest net total stormwater volume is the “critical duration” storm (volume is not applicable for basins with positive outlets). See Chapter 9 for additional discussion.
Cross drain	A structure supporting a public roadway that crosses transversely over a watercourse.
Curve number	A dimensionless site-specific runoff parameter developed by the (former) Soil Conservation Service (now Natural Resources Conservation Service) to empirically estimate rainfall excess; it accounts for infiltration losses and initial abstractions.

Darcy's Law	Darcy's Law characterizes the flow through porous media, assuming that the viscosity, temperature, and density of the fluids are constant. The flow rate is a function of the proportionality constant (coefficient of permeability), the hydraulic gradient, and the flow area; $Q = k i A$.
Degradation	The lowering of land or bottom elevation. In stream stability assessment, the lowering occurs through natural erosion of sediment without sufficient incoming sediment to replenish.
DEM	Digital Elevation Model
Department	Florida Department of Transportation
Depth of flow	The vertical distance between the lowest point of a channel section and the free surface.
Detention	To temporarily hold back or store stormwater to control the rate of discharge. Normally, the term "Wet Detention" is associated with water quality treatment. Sometimes the term is used for flood control attenuation.
Drainage Manual	Refers to the current release of the Florida Department of Transportation Drainage Manual
Diurnal tide	The diurnal tide is represented by one high tide and one low tide per day.
Diversion structure	For stormwater treatment, a diversion structure may be used to divert the "first flush" of stormwater to a facility for treatment.
Drainage basin	A subdivision of a watershed.
Duration	The time from beginning to end of a rain storm event used to perform runoff calculations.
Ebb phase	The period when the water level of the tide is falling.
ECB	Erosion Control Blanket. A temporary degradable mat composed of natural or polymer fibers used to reduce erosive impact in low-velocity ditches during short periods of construction. (See Ch. 3.)
Environmental Resource Permit (ERP)	Conceptual approval granted via an individual or general permit for a surface water management system issued pursuant to Part IV, Chapter 373, Florida Statutes.
Estuary	A body of water affected by tidal influence as well as freshwater inflows from a riverine system.

Exfiltration	The loss of water from a drainage system as a result of percolation or absorption into the surrounding soil.
Exfiltration trench	A subsurface system consisting of a conduit, such as a perforated pipe, surrounded by natural or artificial aggregate that temporarily stores and filters stormwater runoff. Also known as a French Drain.
Fabric formed revetments	Woven fabric forms that are filled with concrete grout. These include Filter Point Linings and Articulating Block Mats.
FDEP	Florida Department of Environmental Protection
FDM	FDOT Design Manual
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
Flood	Inundation of land by water to depths greater than typically occur during a normal wet season. See Chapter 4 for definitions of: Design, Base, Greatest, and Overtopping Floods.
Flood hydrograph	A continuous plot of the surface runoff flow rate versus time. The volume is equal to the volume of water contained in the rainfall excess hyetograph.
Flood phase	The period when the water level of the tide is rising.
FM	Florida Method of Testing Materials. This is the standard FDOT method of testing materials.
Frequency	In hydrology, frequency is the inverse value of the anticipated recurrence interval. A 4-percent chance of recurrence (of rainfall or flood event) in any year is referred to as a 25-year frequency.

Froude Number (Fr) The Fr value is the dimensionless ratio of inertial forces to gravity forces. If Fr values are less than 1, gravity forces dominate and the open channel is said to be operating in the sub-critical range of flow. If Fr values are greater than 1, inertial forces dominate and the open channel is said to be operating in the super-critical range of flow.

$$Fr = \frac{v}{(gL)^{1/2}}$$

Full flow friction loss For pipes flowing full, the full flow friction loss is the full flow friction slope times the pipe length.

Full flow friction slope The slope obtained from Manning's Equation using an area equal to the full cross sectional area of the pipe and a flow rate equal to the design flow rate.

$$S = [Qn / (1.49AR^{2/3})]^2$$

Where:

Q = design flow rate

A & R = based on full cross section area of pipe

Gabions Wire mesh forms filled with stones. These include mattresses and baskets.

Gutter drain A pipe, used along steep slopes, to convey stormwater from shoulder gutter inlets on elevated roadways to drainage conveyance systems below at a much lower elevation.

HEC Hydraulic Engineering Circular. Produced by the FHWA.

HGL Hydraulic grade line. In open channel flow, it is the water surface along the channel reach. In pressure flow, it is a theoretical line connecting hydraulic gradient points (points to which the water would rise in a tube or inlet connecting the flow pipe to atmospheric pressure) along the flow path.

HG Hydraulic gradient. The difference in water surface divided by the flow distance (dimensionless value often expressed in percent).

Hindcast To retrospectively employ measured data to develop a model wind or wave field for a specific historical event.

Hydraulic conductivity	The ratio of discharge perpendicular through a unit area per unit of head (i.e., cfs/ft ² - ft).
Hydraulic depth	The ratio of the water flow cross section area to top width. $D = \frac{A}{T}$
Hydraulic head	The difference in water surface (i.e., potential energy) available to drive flow (between an inlet and an outlet; upstream to downstream; through a filter, etc.)
Hydraulic radius	The ratio of the water flow cross sectional area to its wetted perimeter. $R = \frac{A}{P}$
Hydrology	The science dealing with the disposition of water on the Earth.
Hyetograph	A graphical representation of the distribution of rainfall over time.
Infiltration	Abstraction process in which water flows or is absorbed into the ground.
Infiltration rate	The maximum rate at which water can enter the soil from the surface under specified conditions. The units are length per time.
Inlet	In coastal hydrology: a short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water.
Intensity	The rate of precipitation, usually in inches/hour.
Karst	A geological term to describe a landform underlain by highly porous limestone rock with solution channels. Springs, disappearing streams, and sinkholes are typical of Karst topography. "Closed basins" are associated with Karst topography.
LiDAR	Light Detection And Ranging. This is a remote-sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system—generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Manning's Equation	A formula used to estimate the average velocity of a liquid flowing in a conduit that does not completely enclose the liquid, i.e., open channel flow .
MHW	Mean High Water. The average height of tidal high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is semi-diurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.
MHHW	Mean Higher High Water. The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made to derive the equivalent datum of the National Tidal Datum Epoch. For locations with diurnal tides—one high tide and one low tide per day—this datum will be unavailable. At most locations, there are semi-diurnal tides—the tide cycles through a high and low water level twice each day, with one of the two high tides being higher than the other and one of the two low tides being lower than the other.
MLW	Mean Low Water. The average height of the low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All low water heights are included in the average where the type of tide is either semi-diurnal or mixed. Only lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as mean lower low water.

MLLW	Mean Lower Low Water. The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made to derive the equivalent datum of the National Tidal Datum Epoch. For locations with diurnal tides—one high tide and one low tide per day—this datum will be unavailable. At most locations, there are semi-diurnal tides—the tide cycles through a high and low water level twice each day, with one of the two high tides being higher than the other and one of the two low tides being lower than the other.
MSL	Mean Sea Level. The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch. Shorter series are specified in the name; i.e., monthly mean sea level and yearly mean sea level.
MTL	Mean Tide Level. The arithmetic mean of mean high water and mean low water.
Minor losses	All losses that are not due to friction. Generally, these are energy losses due to changes or disturbances in the flow path. Minor losses include entrance, exit, bend, and junction losses.
Neap tide	Tide of decreased range occurring semi-monthly as the result of the moon being in quadrature.
NFIP	National Flood Insurance Program. Administered by the Federal Emergency Management Agency (FEMA) pursuant to 44 Code of Federal Regulations (CFR) parts 59 through 80. Part 65 pertains to mapping of Special Hazard Areas.
NHW	Normal High Water. For bridge hydraulics, the water stage associated with a flow that has a 43-percent chance of recurrence (2.33-year frequency) in a given year. In some cases, stain lines may be used to estimate NHW.

Non-uniform flow	A flow condition where the depth of flow changes with respect to distance along a channel or conduit. Non-uniform flow may be classified as either rapidly varied or gradually varied. Rapidly varied flow also is known as a local phenomenon, examples of which include the hydraulic jump and hydraulic drop. The primary example of gradually varied flow occurs when sub-critical flow is restricted by a culvert or storage reservoir. The water surface profile caused by such a restriction generally is referred to as a backwater curve.
Normal depth	The depth of flow in a channel determined by the channel properties and physical slope using Manning's Equation. The solution is not direct because the channel depth is unknown and, therefore, requires an iterative process using trial and error to solve implicitly for depth.
NRCS	Natural Resources Conservation Service (formerly Soil Conservation Service)
NTDE	National Tidal Datum Epoch. The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20 years to 25 years. Tidal datums in certain regions with anomalous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.
NWFWMD	Northwest Florida Water Management District
Open channel flow	Fluid flow in which the liquid surface is subject to atmospheric pressure (i.e., has an open or free water surface). Open channel conditions are the basis for most hydraulic calculations.
Overland flow	Water that travels over the ground surface to the stream channel, usually limited to a maximum length of 100 feet.

Physical velocity	The velocity in a pipe that is flowing full, but not under pressure. This condition is sometimes called gravity full flow and the velocity is determined from Manning's Equation. Actual velocity may be greater than or less than physical velocity depending on actual flow conditions.
Positive outlet	As defined by Rule 14-86.002 F.A.C.: A point of stormwater discharge into surface waters that, under normal conditions, would drain by gravity through surface waters ultimately to the Gulf of Mexico, the Atlantic Ocean, or into sinks or closed lakes provided the receiving water body has been identified by the appropriate Water Management District as functioning as if it recovered from runoff by means other than transpiration, evaporation, percolation, or infiltration.
Prismatic channel	An artificial channel with non-varying cross section and constant bottom slope.
Recovery time	For stormwater facilities; the time it takes to recover the volume of water stored above the facility control elevation.
Regression equation	A statistical method that correlates peak discharge with physical features such as watershed area and stream slope.
Retention	To retain stormwater and prevent any surface water discharge. The retained stormwater is either infiltrated into the ground or evaporated.
Riverine flow	For bridge hydraulics, those crossings with no tidal influence during the design storm, such as (a) inland rivers, or (b) controlled canals with a salinity structure oceanward intercepting the design hurricane surge.
Runoff	Precipitation remaining after appropriate hydrologic abstractions have been accounted for.
Runoff coefficient	Empirical parameter used to calculate rainfall excess as a fixed percentage of precipitation; it accounts for interception, surface storage, and infiltration.
Scour	Erosion of streambed material, typically at hydraulic conveyance. See Chapters 5, 4, and 3.
Scupper	A drain used on a bridge deck that has a free discharge (as opposed to drainage collected in a pipe system or down-drain).

Semi-diurnal tide	Two high tides and two low tides per day.
SFWMD	South Florida Water Management District
SHWT	Seasonal High Water Table. Elevation to which the ground and surface water can be expected to rise due to a normal wet season.
Side drain	A side drain conveys non-public access roads across roadside swales or ditches.
Significant wave height	The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered.
SJRWMD	St. Johns River Water Management District
Skimmer	A continuous baffle around a discharge structure or weir that skims floatable debris and oil upstream while allowing flow under the lower edge toward the discharge structure.
Spit	A small point of land or a narrow shoal projecting into a body of water from the shore.
Spread	The horizontal distance of the stormwater flowing down a pavement and gutter section from the face of the gutter to the water's edge.
Spring tide	A tide that occurs at or near the time of the new or full moon and which rises highest and falls lowest from the mean sea level.
SRWMD	Suwannee River Water Management District
Stage	The elevation or vertical distance of the free surface above a given point.
Standard Plans	Standard Plans for Road and Bridge Construction
State water quality standards	Water quality standards adopted by the state pursuant to Chapter 403, Florida Statutes.
Steady flow	A flow condition where the discharge or rate of flow at any location along a channel or conduit remains constant with respect to time. The maintenance of steady flow in any channel reach requires that the rates of inflow and outflow be constant and equal.

Storm surge	A long wave generated offshore that may propagate into coastal bays and estuaries. The five components of storm surge are: wind setup, atmospheric pressure setup, Coriolis effect, wave setup, and the rainfall effect.
Stormwater injection wells	Wells used for stormwater runoff disposal into pervious underground soils or the water table.
Swell	Wind-generated waves that have traveled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch.
SWFWMD	Southwest Florida Water Management District
t_c	Time of concentration. The time required for runoff to travel from the hydraulically most distant point of a watershed to the design point.
Tailwater	The water surface elevation at the downstream end of a hydraulic conveyance.
Thalweg	In hydraulics, the line joining the deepest points along a flow path.
Tidally dominated flow	For bridge hydraulics, crossings where the tidal influences are dominated by the design hurricane surge. Large bays, ocean inlets, and open sections of the Intracoastal Waterway typically are tidally dominated so much so that even extreme rainfall events have little influence on the design flows in these systems.
Tidally influenced flow	Flows in tidal creeks and rivers opening to tidally dominated waterways are affected by both river flow and tidal fluctuations. Tidally affected river crossings do not always experience flow reversal; however, backwater effects from the downstream tidal fluctuation can induce water surface elevation fluctuations up through the bridge reach.
TN	Total nitrogen. Various species of nitrogen, both particulate and dissolved.
Top width	The width of the channel section at the free surface.
TP	Total phosphorus. Various species of phosphorus, both particulate and dissolved.

Treatment	Generally referring to stormwater management practices to improve the quality of stormwater discharged.
Treatment volume	The volume of runoff usually associated with the first flush of pollutants, which must be retained, detained, or filtered to remove pollutants and improve discharge water quality.
TRM	Turf Reinforcement Mat. A long-term, non-biodegradable mat composed of synthetic fibers used to increase erosion resistance in ditches during long periods of construction. (See Ch. 3.)
Turbulent flow	A flow condition where the viscous forces are weak relative to the inertial forces. In turbulent flow, the water particles move in irregular paths that are neither smooth nor fixed, and the result is a random mixing motion. Turbulent flow is the most common type occurring in roadway drainage facilities.
Underdrain system	For stormwater management facilities; a system of perforated pipes below a pond that are designed to lower the groundwater table to facilitate pond volume recovery, and/or to filter stormwater runoff prior to discharge.
Uniform flow	A flow condition where the mean velocity and depth of flow are constant with respect to distance along a channel or conduit of constant cross section, slope, and roughness. When the requirements for uniform flow are met, the depth of flow for a given discharge is defined as the normal depth of flow.
Unsteady flow	A flow condition where the discharge at any location in the channel changes with respect to time. During periods of stormwater runoff, the inflow hydrograph to an open channel is usually unsteady. However, in practice, open channel flow is generally assumed to be steady at the discharge rate for which the channel is being designed (i.e., peak discharge of the inflow hydrograph).
USDW	Underground source drinking water. An aquifer that contains a total of dissolved solids concentration of less than 10,000 milligrams per liter or parts per million (ppm).

Velocity head	<p>The velocity head represents the kinetic energy of the fluid per unit volume and is computed by:</p> $h_v = \frac{\alpha Q^2}{2g A^2}$ <p>Where α is the kinetic correction factor for non-uniform velocity distribution.</p> <p>Or, ignoring the effect of a non-uniform velocity distribution, velocity head is $v^2/2g$</p>
Watershed	An area bounded peripherally by a drainage divide that concentrates runoff to a particular watercourse or body; the catchment's area or drainage basin from which the waters of a stream are drawn.
Watershed lag time	Time from the center of mass of the rainfall excess to the runoff hydrograph peak.
Wave height	The vertical distance between a wave's crest and the preceding trough.
Wave radiation stress	Excess flow of momentum in the horizontal plane due to waves.
Wave runup	The vertical distance above the still water level where breaking waves propel water up a sloping surface.
Wave setup	Vertical increase in the water surface above the still water level near shore due to onshore mass transport of water due to wave radiation stresses.
Wave shoaling	Transformation of wave profile due to inshore propagation.
Weir	A flow restriction with a fixed flowline, width, and height; used to control discharge from a stormwater management facility.
Well casing	A well casing serves as a lining to limit discharge to the aquifer. It also provides structural support against caving materials outside the well. Materials commonly used are wrought iron and steel.
Wetted perimeter	The length of the line of intersection of the channel wetted surface with a cross-sectional plane perpendicular to the direction of flow.
Wind set-down	The vertical drop below the still water level on the windward side of a water body due to wind stresses on the surface of the water.

Wind setup	The vertical rise above the still water level on the leeward side of a water body due to wind stresses on the surface of the water.
Wind wave	Waves being formed and built up by the wind.
WMD	Water Management District