BMP Design Aids

Equations / Programs

- Rational Method
- Manning's Equation
- Outlet Discharge Equations
- ODOT CDSS
- SCS Curve Number
- Hydrograph and Pond Routing Programs
- USGS StreamStats

Training Intent

- Introduction and overview of various design aids (equations and programs)
- Not a detailed training on how to use each one

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Rational Method

- **For peak flow rate only**
- **Q = CiA**
- **Q: flow rate (cfs)**
- **C: coefficient of runoff**
- **i: rainfall intensity (in/hr)**
  - Based on time of concentration
  - Sheet flow, shallow concentrated flow, and open channel or pipe flow
- **A: tributary area (ac)**

Rational Method

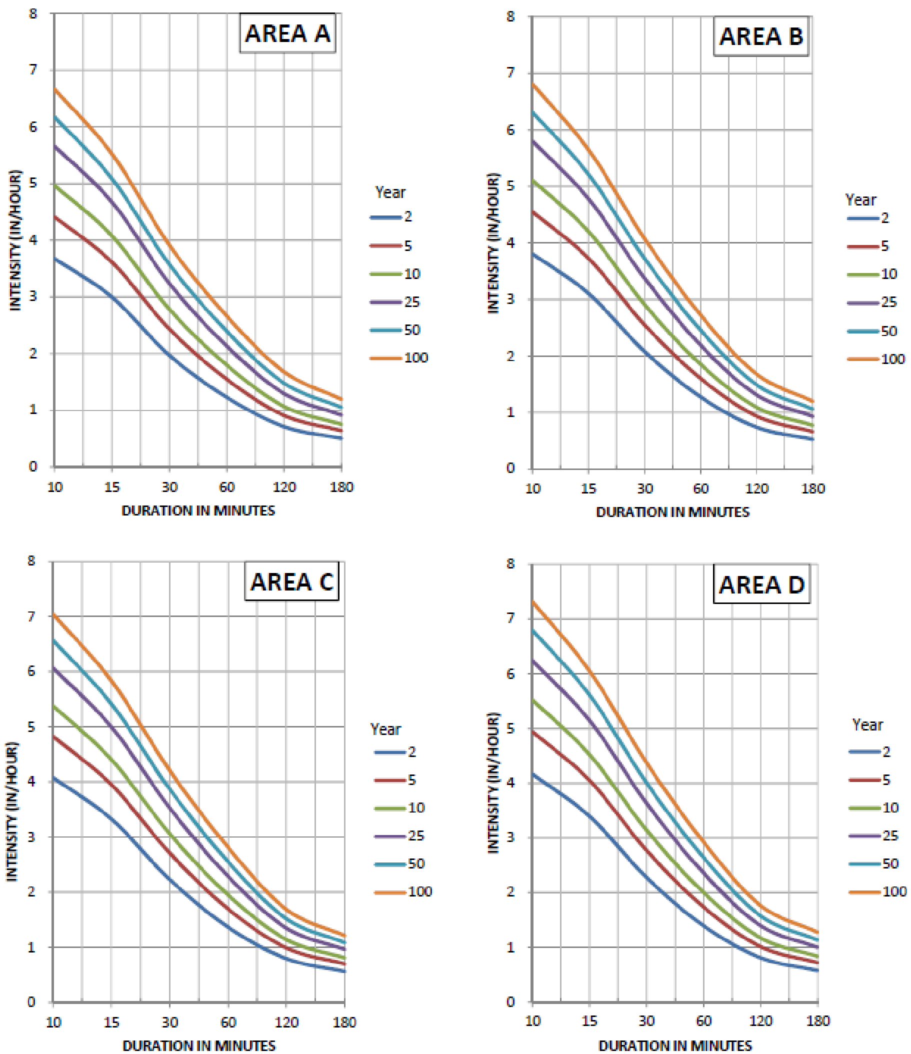
- $Q = CiA$
- C:

Table 1101-2

Types of Surface	Coefficient of Runoff "C"
Pavement & paved shoulders	0.9
Berms and slopes 4:1 or flatter	0.5
Berms and slopes steeper than 4:1	0.7
Contributing areas	
Residential (single family)	0.3-0.5
Residential (multi-family)	0.4-0.7
Woods	0.3
Cultivated	0.3-0.6

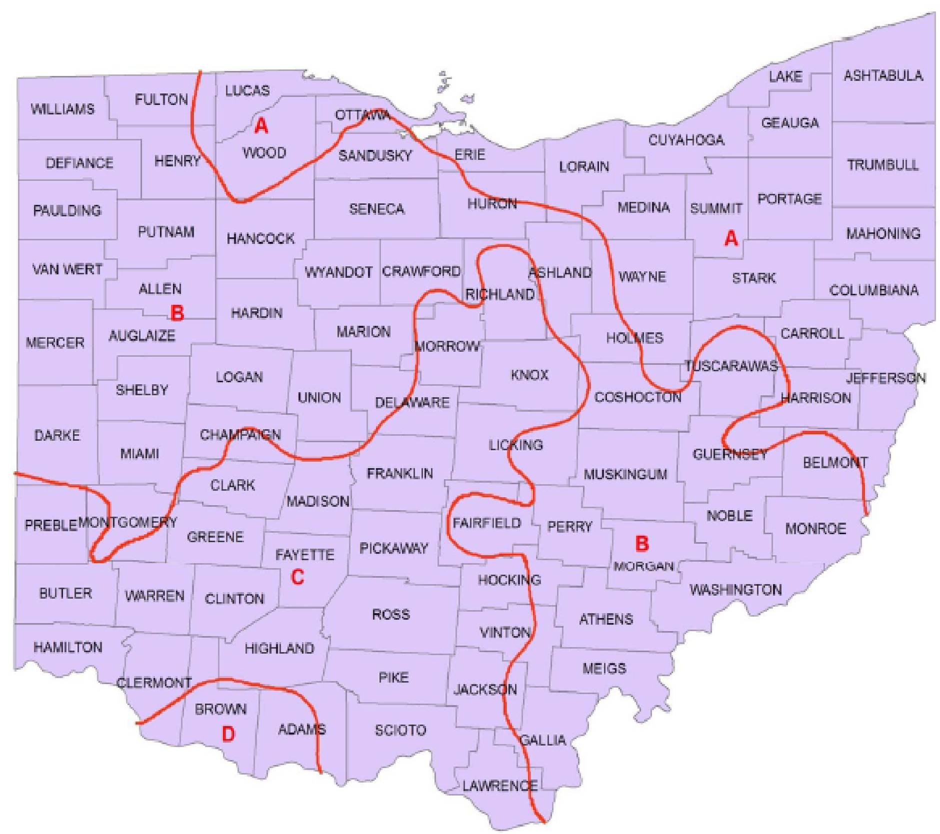
Rational Method

Rainfall Intensity-Frequency-Duration Curves	1101-2 Reference Section 1101.2.4



Refer to General Notes - Figures 1101-2 through 1101-3

Rainfall Intensity-Frequency-Duration Curves	1101-3 Reference Section 1101.2.4



Refer to General Notes - Figures 1101-2 through 1101-3

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Manning's Equation

Manning's Equation:

$$Q = \frac{1.49}{n} * AR^{2/3} * S^{1/2}$$

Where:

Q = flow rate (cfs)

n = Manning's Roughness Coefficient (0.15 for Vegetated Biofilter)

A = Cross section area of flow (ft^2)

R = Hydraulic Radius (ft) (Area / Wetted Perimeter)

S = Longitudinal Slope of ditch (ft/ft)

Manning's Equation

Table 1102-3

Type of Lining	Roughness Coefficient
Bare Earth	0.02
Seeded	0.03
Sod	0.04
Item 670	0.04
Erosion Control Matting	0.04
Concrete	0.015
Bituminous	0.015
Grouted Riprap	0.02
Tied Concrete Block Mat	0.03
Rock Channel Protection	0.06 for ditches 0.04 for large channels

1104.4.5 Pipe Roughness Coefficient

A Manning's "n" of 0.015 shall be used for sewers 60 inches in diameter and under, and 0.013 for larger sewers. The basic "n" value for smooth pipe, concrete, vitrified clay, bituminous lined corrugated steel or thermoplastic is 0.012. The increased values are recommended for sewers to compensate for minor head losses incurred at catch basins, inlets and manholes located in a storm sewer system.

Manning's Equation

- **Program or Spreadsheet Calculation**
  - Use bisection method (trial and error)
- **Inputs:**
  - Channel geometry and slope
  - Manning's roughness coefficient
  - Flow rate
- **Results:**
  - Normal depth
  - Velocity

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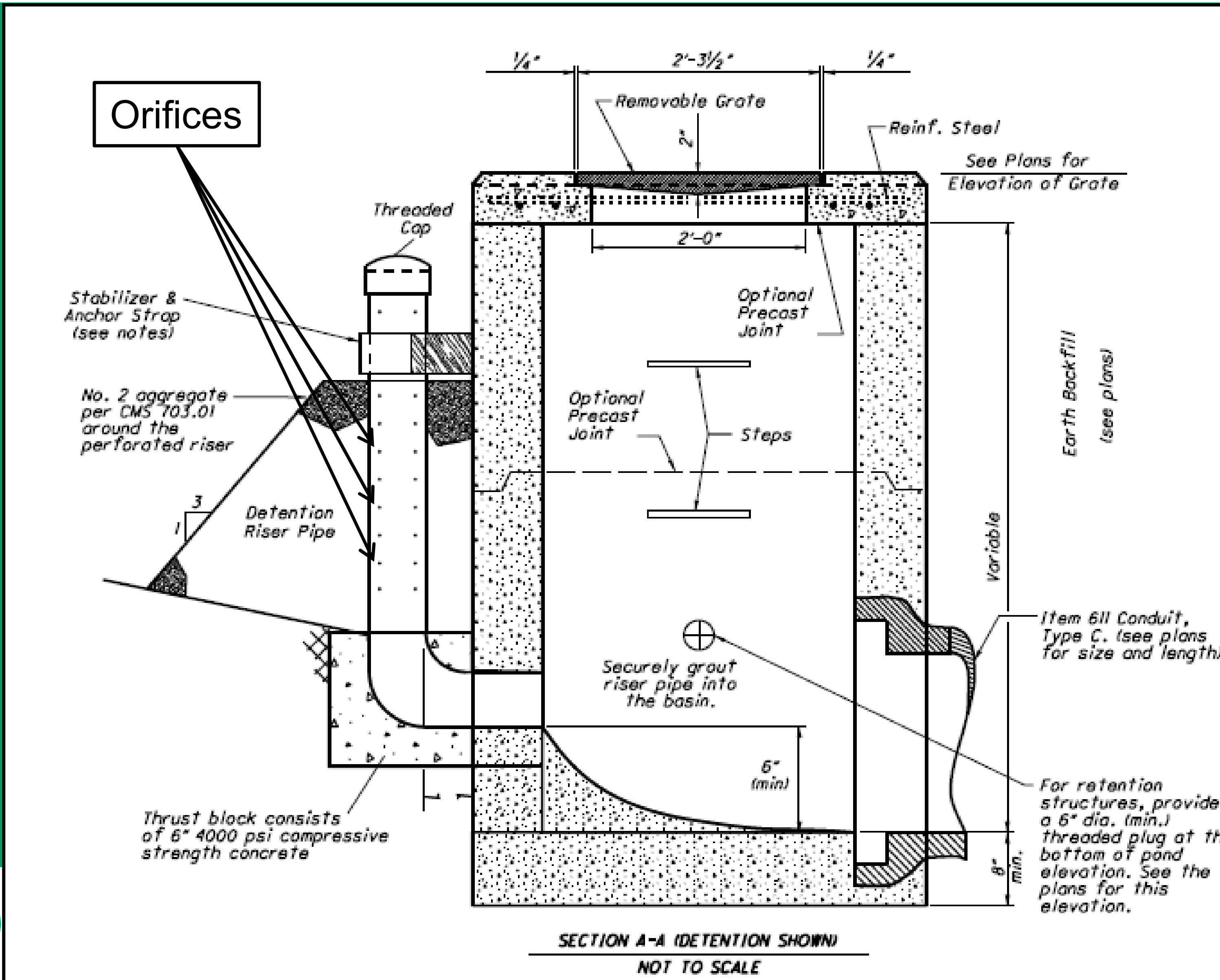
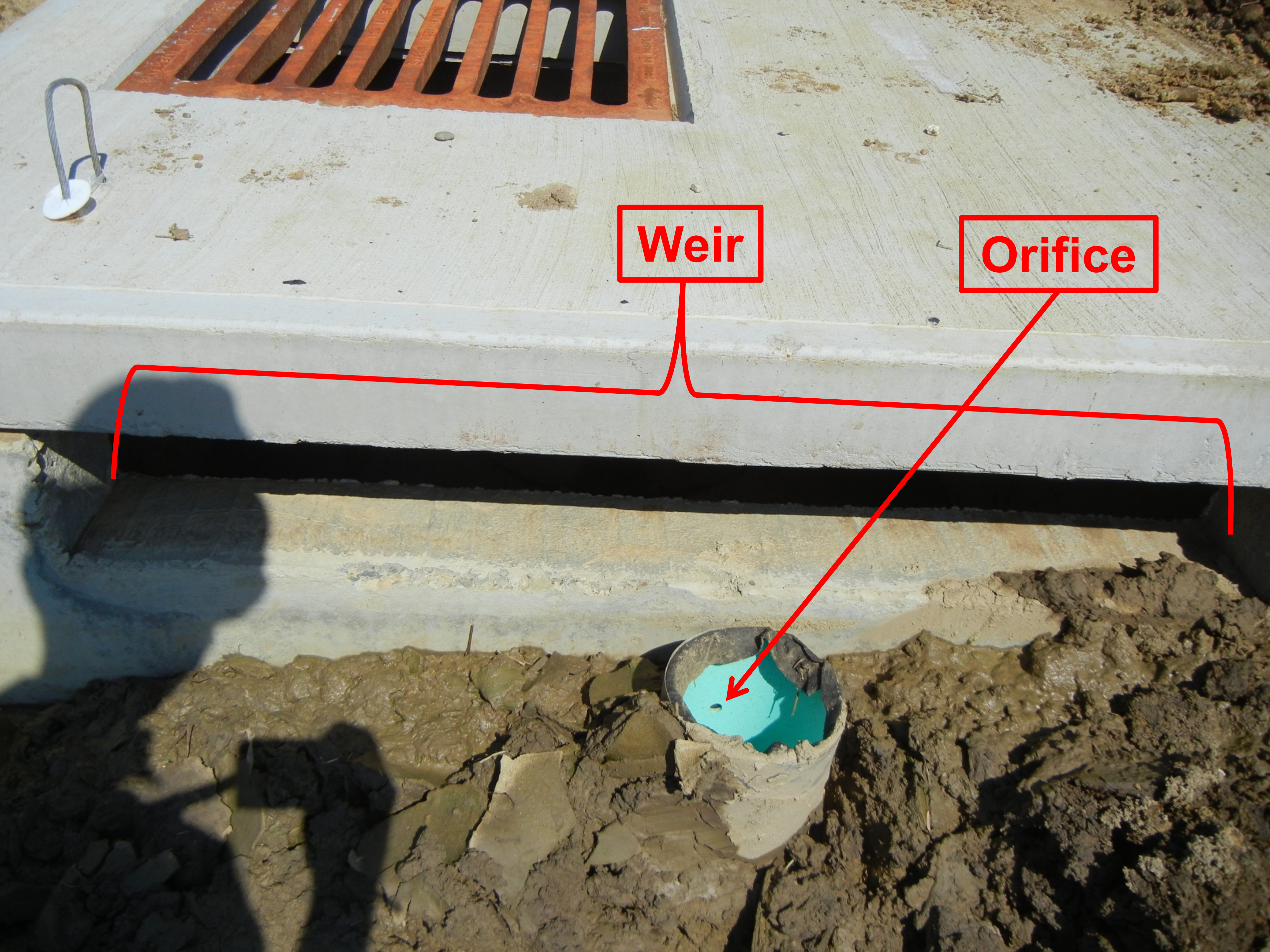
Discharge Equations

- Orifice flow
- Weir flow

Orifices



Orifices
¼"
2'-3½"
¼"
Removable Grate
2"
Reinf. Steel
See Plans for Elevation of Grate
Threaded Cap
2'-0"
Stabilizer & Anchor Strap (see notes)
Optional Precast Joint
No. 2 aggregate per CMS 703.01 around the perforated riser
Optional Precast Joint
Steps
Earth Backfill (see plans)
3
1
Detention Riser Pipe
Variable
Item 611 Conduit, Type C. (see plans for size and length)
Securely grout riser pipe into the basin.
6" (min)
For retention structures, provide a 6" dia. (min.) threaded plug at the bottom of pond elevation. See the plans for this elevation.
Thrust block consists of 6" 4000 psi compressive strength concrete
8" min.
SECTION A-A (DETENTION SHOWN)
NOT TO SCALE


Weir
Orifice

Orifice Flow

The equation for a single orifice is:

$$Q = A \cdot C \cdot \sqrt{64.4H}$$

where:

A = Area of orifice (ft^2)

H = Head on orifice as measured to the centerline of the orifice (ft)

C = Orifice coefficient

Table 1117-4

Orifice Coefficient Guidance	
C	**Description**
0.66	Use for thin materials where the thickness is equal to or less than the orifice diameter.
0.80	Use when the material is thicker than the orifice diameter.
From CALTRANS, Storm Water Quality Handbooks, Project Planning and Design Guide, September 2002.	

Weir Flow

- **L&D Vol. 2, 1102.3.4**

protruding feature of the basin is not objectionable. The capacity of the side inlet catch basin window, for unsubmerged conditions, may be determined by the standard weir equation:

$$Q=CLH^{3/2}$$

where C is a weir coefficient, generally 3.0, L is the length of opening in feet, H is the distance from the bottom of the window to the surface of the design flow in feet. The catch basin grate is

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ODOT CDSS

CDSS is a hydraulic design software developed by ODOT

- C – Culvert Design
- D – Ditch Design
- SS – Storm Sewer Design

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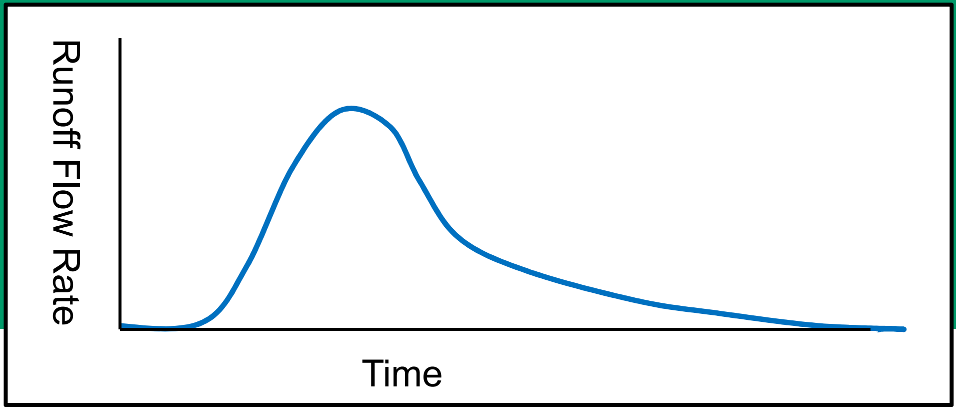
SCS Curve Number

- Technical Release 55 (TR-55)
- Technical Release 20 (TR-20)
- Urban Hydrology for Small Watersheds
- Determines runoff depth (inches)
- Combines with unit hydrograph theory
- Produces runoff hydrographs
  - Peak flow and total volume

SCS Curve Number

- CN: depth of runoff abstracted
- Total P – Abstracted P = Runoff Depth
- Runoff Depth * Area = Runoff Volume
- NRCS unit hydrograph gives runoff volume a shape (distribution over time)
- Produces a full runoff hydrograph



SCS Curve Number

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{[eq. 2-1]}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{[eq. 2-3]}$$

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

SCS Curve Number

Table 2-2a Runoff curve numbers for urban areas 1/

Cover type and hydrologic condition	Average percent impervious area 2/	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) 4/		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) 5/		77	86	91	94

Cover description / Curve numbers for hydrologic soil group

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SCS Curve Number

- **Analyses that require a full hydrograph**
  - Pre vs. post volumes (CSO areas)
  - Routing a design storm through a detention basin, bioretention cell, or infiltration trench
- **Still gives peak flow rate, but will likely be slightly different from Rational Method**

Equations / Programs

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Hydrograph and Pond Routing Programs

- **Many different programs**
  - Different inputs
  - Different calculations
  - Different limitations
- **Know your tool before you use it**

Common Hydraulics and Hydrology Software Options

Design Calculations

- Basic Pipe or Open Channel Capacity Calcs.
- Basin Inlet/Outlet
- Peak Flow and HGL

Software:
- Hydraflow Express
- Bentley CulvertMaster
- Bentley FlowMaster
- Urban Drainage HY22
- HY-8, ODOT CDSS

HEC

- Steady/Unsteady Flow
- Open Channels
- Some Sediment Transport/Quality
- Often used in FEMA Floodplains

Software:
- HEC-1
- HEC-HMS
- HEC-2
- HEC-RAS
- GEO-RAS

Simple Stormwater Routing Models

- Normal Gravity Sewer, Detention Pond Design
- Hydrology and Hydraulics Combined
- Rational/TR-55/SCS Hydrology
- Manning’s/Orifice/Weir Hydraulic Calcs.
- Some Quality Calculations Available

Software:
- HydraFlow Hydrographs
- HydraFlow Storm Sewers
- Bentley StormCAD
- Bentley PondPack
- HydroCAD

Robust Stormwater Routing Models

- Complex Drainage Systems that have:
    - tail water, reverse flow, pump stations, surface flooding
- Horton/Green-Ampt Hydrology
- Hydrodynamic and Kinematic Wave Hydraulic Calcs.
- Detailed Quality Calculations Available

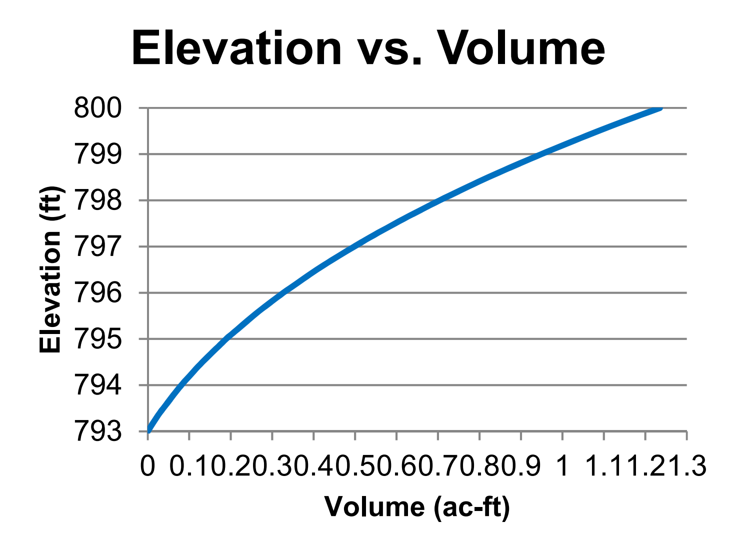
Software:
- EPA SWMM
- Bentley CivilStorm
- AutoDesk SSA
- PCSWMM
- XP SWMM

PondPack and HydroCAD

- **Inputs for runoff hydrograph**
  - Area
  - Curve number, land use, or runoff coefficient
  - Time of concentration
  - Design storm frequency
- **Produces runoff hydrograph**
- **Then route that hydrograph into your BMP**

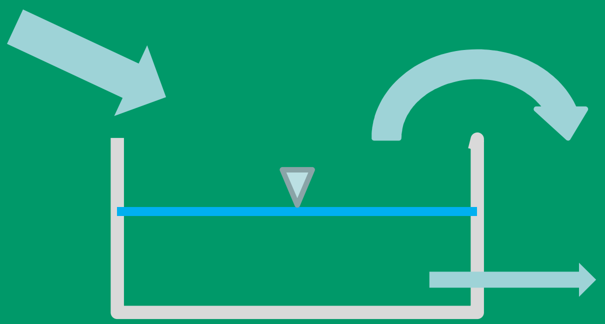
PondPack and HydroCAD

- **Inputs for BMP**
  - Stage vs storage curve (elevation vs. volume)
- **Inputs for BMP discharge**
  - Stage vs. depth curve
  - Each outlet
    - WQ orifices
    - Weirs, catch basin grates
    - Overflow weirs
    - Discharge pipe
  - Downstream constraints (tailwater)



PondPack and HydroCAD

- **Two types of analyses**
  - Hydrograph routing
  - Drawdown analysis
- **Split event into many short pieces and calculate:**
  - Volume entering
  - Volume leaving
  - Volume and depth in basin



PondPack and HydroCAD

- Make sure you have all of the potential discharge conveyances
- Make sure the BMP storage information in the model matches the design sheets
- Make sure the modeled discharge conveyance characteristics match the design sheets and site, including tailwater
- Make sure the results make sense

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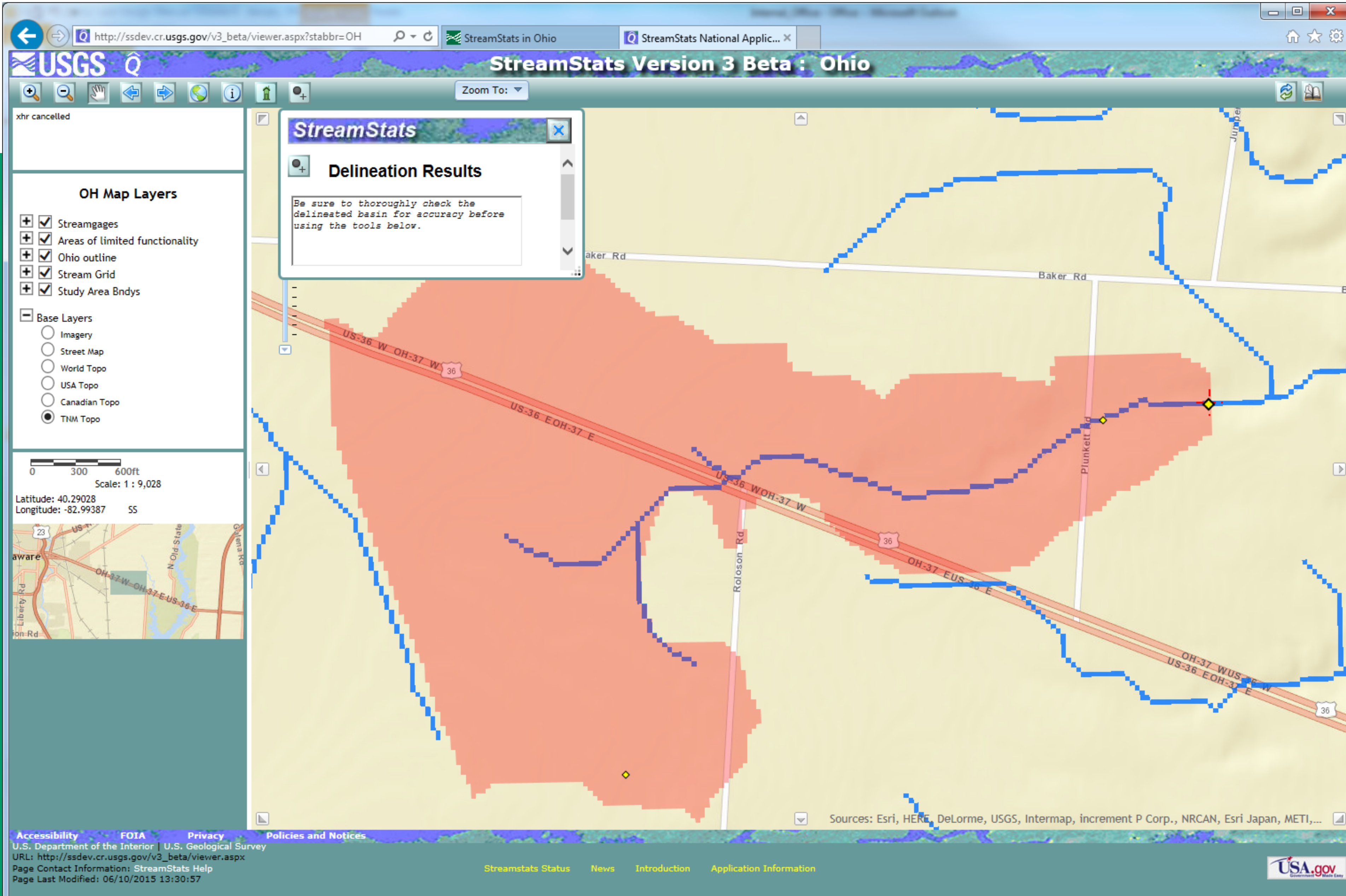
http://ssdev.cr.usgs.gov/v3_beta/viewer.aspx?stabbr=OH
StreamStats in Ohio
StreamStats National Applic...
USGS
StreamStats Version 3 Beta : Ohio
Zoom To:
xhr cancelled
OH Map Layers
Streamgages
Areas of limited functionality
Ohio outline
Stream Grid
Study Area Bndys
Base Layers
Imagery
Street Map
World Topo
USA Topo
Canadian Topo
TNM Topo
0 300 600ft
Scale: 1 : 9,028
Latitude: 40.29028
Longitude: -82.99387
StreamStats
Delineation Results
Be sure to thoroughly check the delineated basin for accuracy before using the tools below.
Baker Rd
US-36 W OH-37 W
US-36 E OH-37 E
Roloson Rd
Plunkett Rd
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI,...
Accessibility FOIA Privacy Policies and Notices
U.S. Department of the Interior | U.S. Geological Survey
URL: http://ssdev.cr.usgs.gov/v3_beta/viewer.aspx
Page Contact Information: StreamStats Help
Page Last Modified: 06/10/2015 13:30:57
Streamstats Status News Introduction Application Information
USA.gov

StreamStats Flow Statistics Report - Internet Explorer provided by Ohio-DNR

http://ssdev.cr.usgs.gov/v3_beta/FTreport.htm?state=OH&workspaceID=OH20150610114334740000&flowtypes=PeakFlo

(dimensionless)	0.86	0.24	1.12

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Mean and Percentile Basin Characteristics

100% Low Flow LatLE 41.2 wri02 4068 (0.4 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	0.4	0.12	7422
Percent Forest (percent)	2.18	0	99.1
Percent Storage from NLCD1992 (percent)	0	0	19
Mean Annual Precipitation (inches)	37	34	43.2
Streamflow Variability Index from Grid (dimensionless)	0.86	0.25	1.13
Latitude of Basin Centroid (decimal degrees)	40.2832	38.68	41.2
Longitude of Basin Centroid (decimal degrees)	83.0011	80.53	84.6

Peak Flows Streamflow Statistics

Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	51.2	ft3/s	37	2.1	25.7	102
PK5	90.4	ft3/s	35	3.3	47.1	174
PK10	119	ft3/s	34	4.4	61.8	228
PK25	155	ft3/s	35	5.9	79.2	305
PK50	183	ft3/s	37	6.8	90.9	368
PK100	211	ft3/s	38	7.5	102	436
PK500	276	ft3/s	42	8.6	123	618

http://pubs.usgs.gov/sir/2006/5312/
Koltun_ G.F._ Kula_ S.P._ and Puskas_ B.M._ 2006_ A Streamflow Statistics (StreamStats) Web Application for Ohio: U.S. Geological Survey Scientific Investigations Report 2006-5312_ 62 p.

Mean and Percentile Streamflow Statistics

100%

Equations / Programs

- **Rational Method**
  - Peak flow rate only
- **Manning's Equation**
  - Flow conditions (velocity and depth) at a given flow rate
- **Outlet Discharge Equations**
  - Flow rate at a given outlet shape and hydraulic head
- **ODOT CDSS**
  - Hydraulic design of culverts, ditches, and storm sewers
- **SCS Curve Number**
  - Full runoff hydrograph (flow rate over time and full storm volume)
- **Hydrograph and Pond Routing Programs**
  - Full hydrograph, detention, peak flow rate, and draw down analyses
- **USGS StreamStats**
  - Peak design storm flow rates as well as other stream statistics

Questions ?

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