# UD-Detention Workbook

CASFM Lunch and Learn

February 3, 2016

# URBAN STORM DRAINAGE

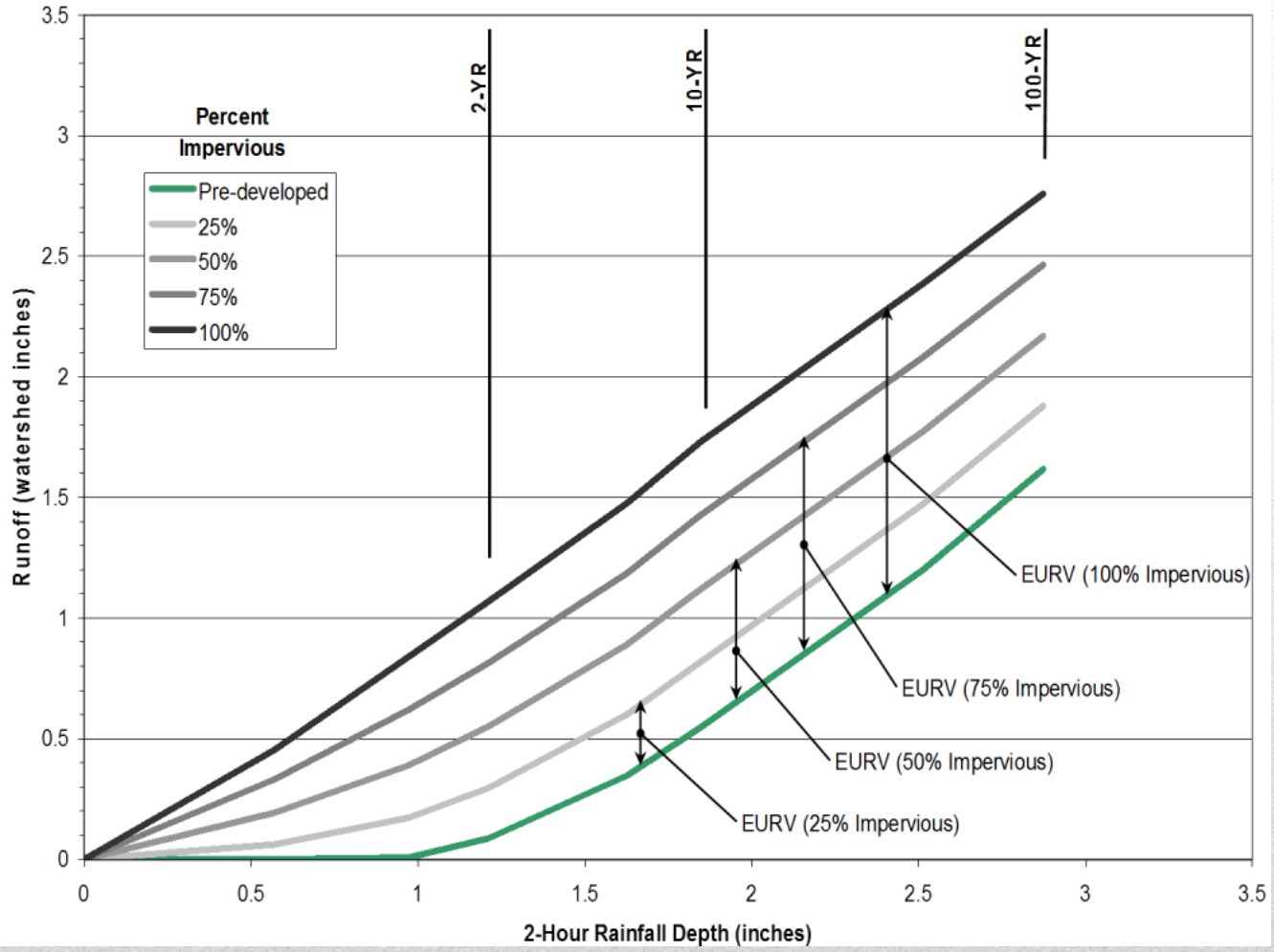
VOLUME 2

## CRITERIA MANUAL

STRUCTURES, STORAGE, AND RECREATION

1. Detailed discussion on FSD (Took out everything else)
2. Took out FAA Procedure.
3. Added guidance for incorporating FSD within different WQ BMPs.

# Chapter 12, Storage




# Full Spectrum Detention

**EURV**. Equations 12-1, 2 and 3 may be used to find EURV in watershed inches for specific soil types.

$$EURV_A = 1.68i^{1.28} \quad \text{Equation 12-1}$$

$$EURV_B = 1.36i^{1.08} \quad \text{Equation 12-2}$$

$$EURV_{C/D} = 1.20i^{1.08} \quad \text{Equation 12-3}$$

Where:

$EURV_K$ = Excess urban runoff volume in watershed inches ($K$ indicates NRCS soils type),
$i$ = Imperviousness ratio (a decimal less than or equal to 1)

# New EURV Equations

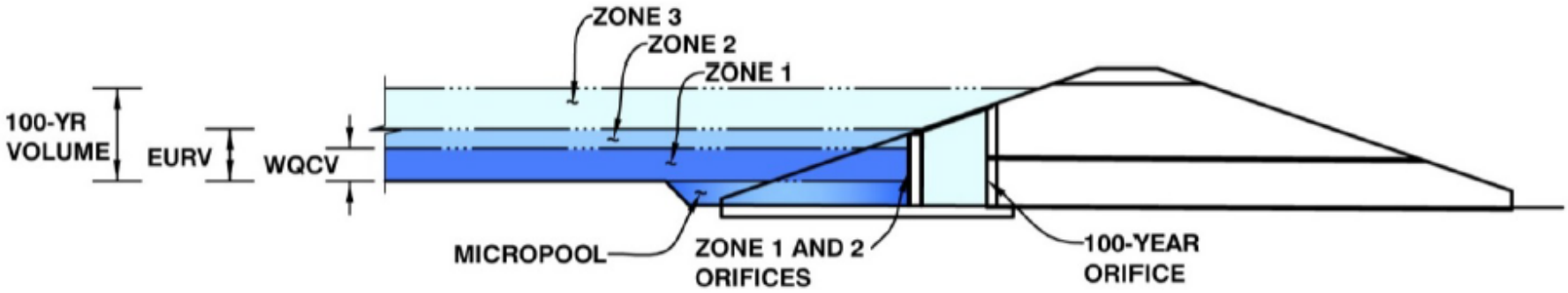



**Figure 12-6. Extended detention basin combined with full spectrum detention**

**Table 12-1. Extended detention basin combined with full spectrum detention**

| Zone | Volume | Drain Time of Zone, hrs | Maximum Release Rate |
|---|---|---|---|
| 1 | 40-hr WQCV | 40 | Based on drain time |
| 2 | EURV minus (40-hr WQCV)) | 12 to 32[1] | Based on drain time |
| 3 | 100-yr minus EURV | Based on release rate | 0.9(predevelopment $Q_{100}$) |

[1]Colorado law requires 97% of the 5-year event to drain within 72 hours.

# Extended Detention Basin

# Retention Pond

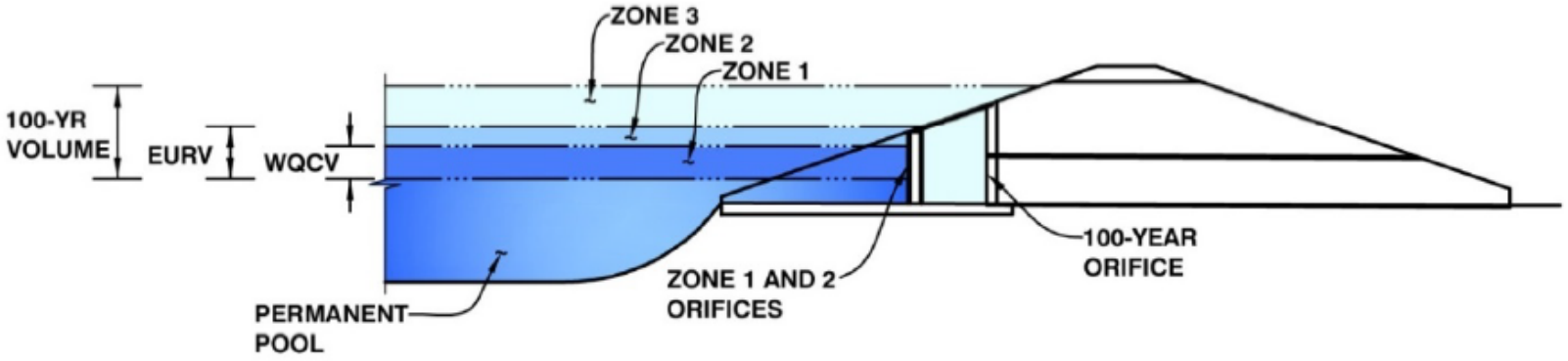



**Figure 12-7. Retention pond combined with full spectrum detention**

**Table 12-2. Retention pond combined with full spectrum detention**

| Zone | Volume | Drain Time of Zone, hrs | Maximum Release Rate |
|---|---|---|---|
| 1 | 12-hr WQCV | 12 | Based on drain time |
| 2 | EURV minus 12-hr WQCV | 12 to 60[1] | Based on drain time |
| 3 | 100-yr minus EURV | Based on release rate | 0.9(predevelopment $Q_{100}$) |

[1]Colorado law requires 97% of the 5-year event to drain within 72 hours.

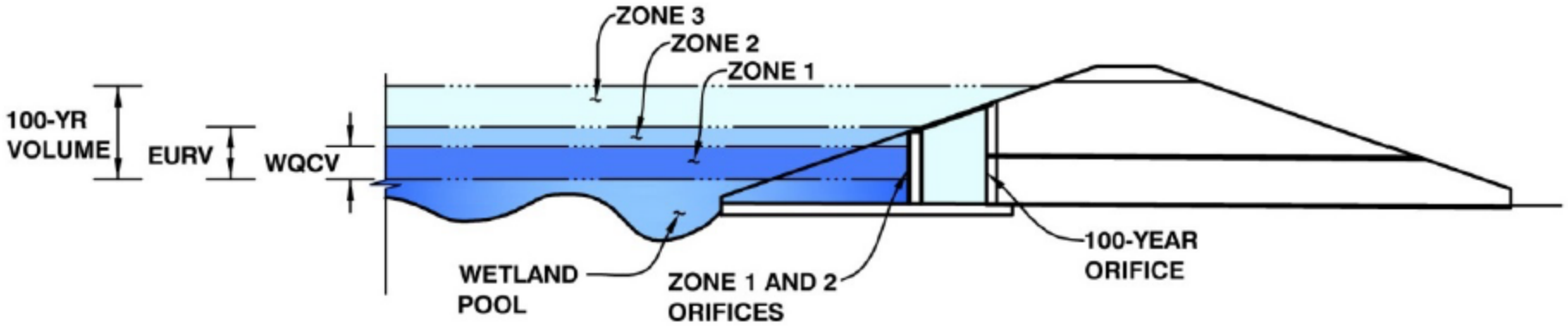



**Figure 12-8. Constructed wetland pond combined with full Sspectrum detention**

**Table 12-3. Constructed wetland pond combined with full spectrum detention**

| Zone | Volume | Drain Time of Zone, hrs | Maximum Release Rate |
|---|---|---|---|
| 1 | 24-hr WQCV | 24 | Based on drain time |
| 2 | EURV minus 24-hr WQCV | 12 to 48[1] | Based on drain time |
| 3 | 100-yr minus EURV | Based on release rate | 0.9(predevelopment $Q_{100}$) |

[1]Colorado law requires 97% of the 5-year event to drain within 72 hours.

# Constructed Wetland Pond

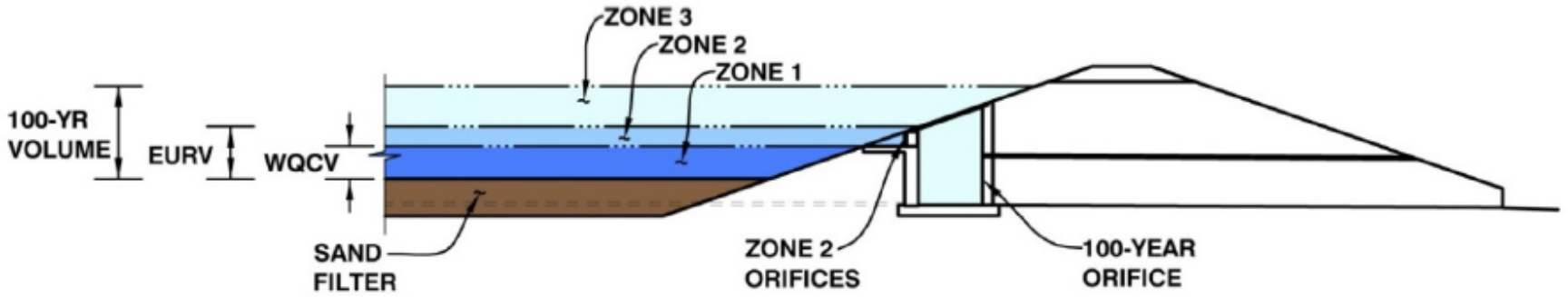
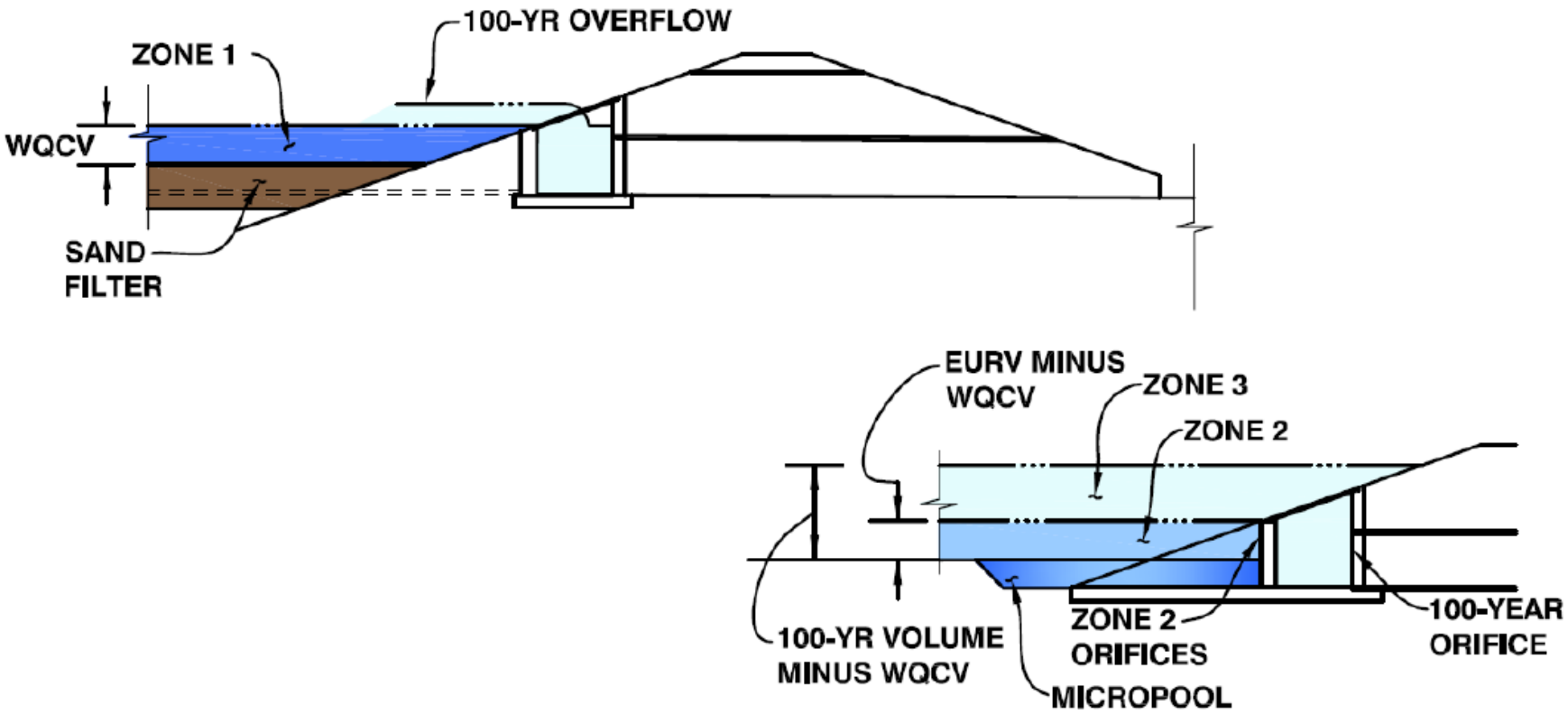



**Table 12-4. Sand filter or bioretention facility combined with full spectrum detention**

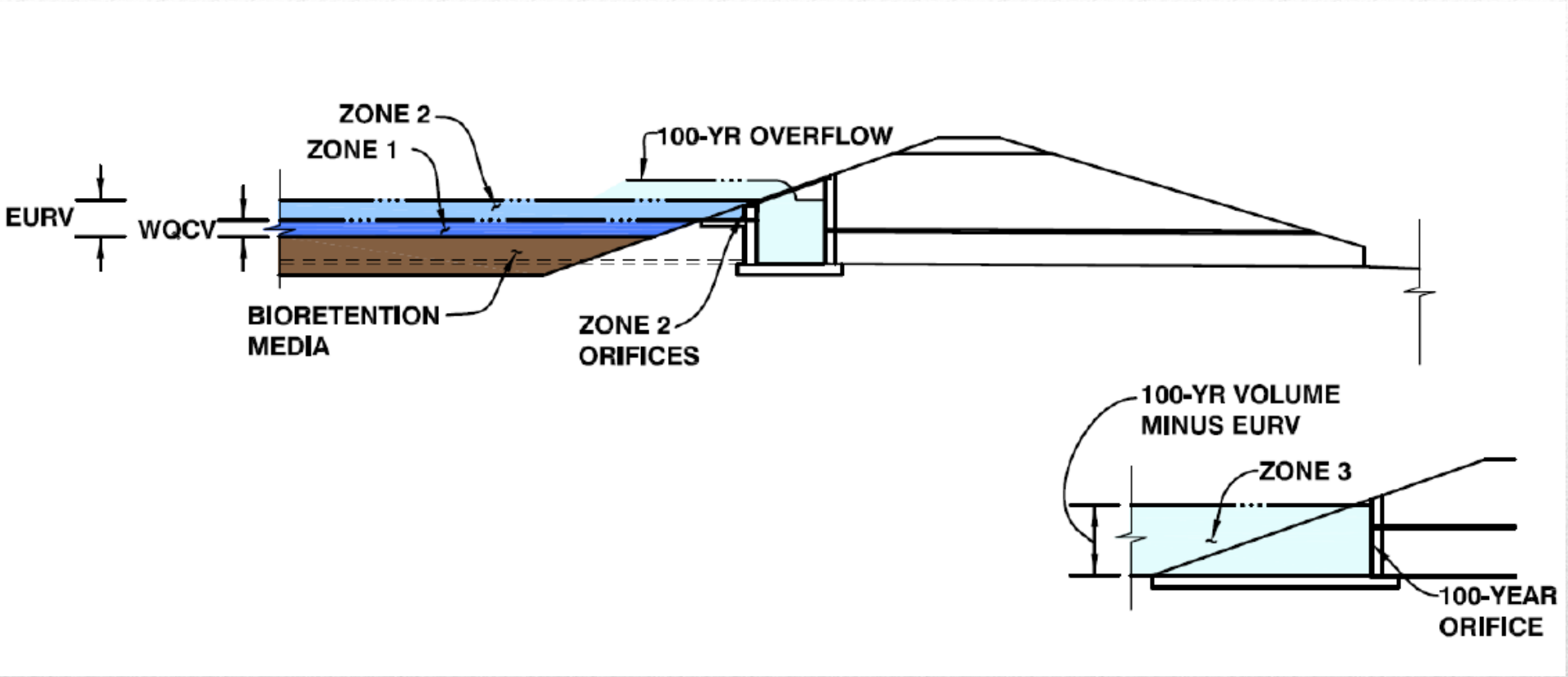
| Zone | Volume | Drain Time of Zone, hrs | Maximum Release Rate |
|---|---|---|---|
| 1 | 12-hr WQCV | 12 | Based on drain time |
| 2 | EURV minus 12-hr WQCV | 12 to 32[1] | Based on drain time |
| 3 | 100-yr minus EURV | Based on release rate | 0.9(predevelopment $Q_{100}$) |

[1]Colorado law requires 97% of the 5-year event to drain within 72 hours.

# Sand Filter or Bioretention




# Other Configurations




# Other Configurations

# Research (available at www.udfcd.org):

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

Paul A. Hindman, Executive Director
2480 W. 26th Avenue, Suite 156B
Denver, CO 80211-5304

Telephone 303-455-6277
Fax 303-455-7880
www.udfcd.org

TECHNICAL MEMORANDUM

FROM: Ken A. MacKenzie, P.E., UDFCD Master Planning Program Manager

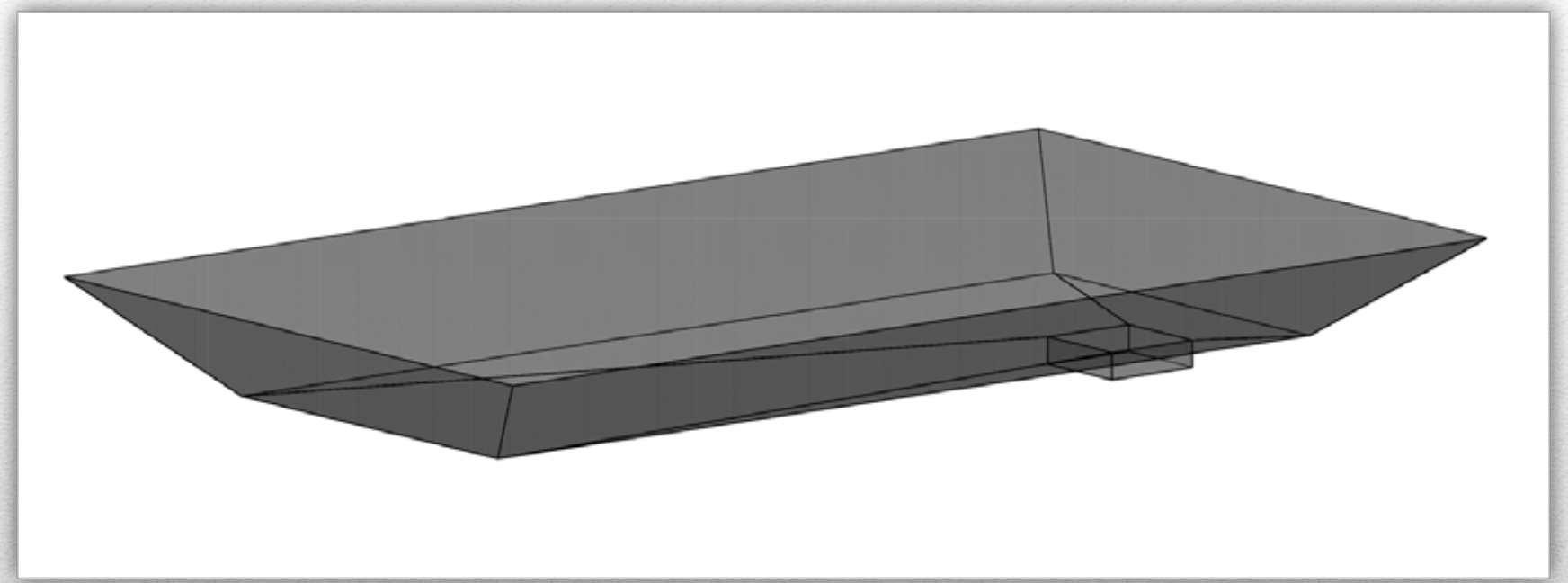
SUBJECT: Inflow Storm Hydrograph Shaping for Detention Design

DATE: December 17, 2015

The purpose of this memorandum is to document the development of the storm hydrograph shaping method built into the UD-Detention and UD-FSD workbooks. When the UD-FSD workbook was

# How UD-Detention Works

## Basin Modeling



# How UD-Detention Works

## Inflow Hydrographs

- 16,000 inflow hydrographs in a hidden library.
- Program selects one for each of the 9 return periods based on expected runoff volume, a function of:
  - watershed area
  - imperviousness
  - NRCS hydrologic soil group

# How UD-Detention Works

# Inflow Hydrographs

- After hydrographs are selected for each of the 9 return periods, they are adjusted in magnitude and length based on expected peak runoff runoff rate, a function of:
  - watershed shape factor ($L^2/A$)
  - watershed slope
  - At each time step, QADJ = Q(Adj. Factor)
  - At each time step, $\Delta t_{ADJ} = \Delta t$ / (Adj. Factor)
- Hydrograph volume is conserved.

**Hydrologic Routing Methods**

- Kinematic Wave
- Dynamic Wave
- Muskingum
- Muskingum – Cunge
- Modified Puls
  - aka Level-Pool or Storage-Indicator Method
  - Ideal for Reservoir Routing

# How UD-Detention Works

## Modified Puls Routing Method

Continuity Equation:

$$I - O = \frac{dS}{dt}$$

Finite difference form of Continuity Equation:

$$\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} = \frac{S_2 - S_1}{\Delta t}$$

# How UD-Detention Works

## Modified Puls Routing Method

Algebraic transformation of finite difference form of Continuity Equation:

$$I_1 + I_2 + \left(\frac{2S_1}{\Delta t} - O_1\right) = \frac{2S_2}{\Delta t} + O_2$$

In this form, all variables on the left-hand side are known at a given time.

# How UD-Detention Works

- Bioretention Basins
- Sand Filter Basins
- Basins in series
- EDBs/Constructed Wetlands/Retention Ponds (WQCV only)
- EDBs/Constructed Wetlands/Retention Ponds (2-Stage Design)
- EDBs/Constructed Wetlands/Retention Ponds (FSD)

# UD-Detention can analyze…

- FSD Extended Detention Basin
- Sand Filter with WQCV, 5-year and 100-year control
- Bioretention WQCV only basin with downstream FSD basin (basins in series)

# Examples

# • FSD Extended Detention Basin

**Required Volume Calculation**

| | | |
|---|---|---|
| Extended Detention Basin (EDB) = | EDB | |
| Watershed Area = | 20.00 | acres |
| Watershed Length = | 1,500 | ft |
| Watershed Slope = | 0.020 | ft/ft |
| Watershed Imperviousness = | 65.00% | percent |
| Percentage Hydrologic Soil Group A = | 0.0% | percent |
| Percentage Hydrologic Soil Group B = | 0.0% | percent |
| Percentage Hydrologic Soil Groups C/D = | 100.0% | percent |
| Desired WQCV Drain Time = | 40.0 | hours |
| Location for 1-hr Rainfall Depths = | UDFCD Default | |

**EXTENDED DETENTION BASIN WITH 3 ZONES**

| | | |
|---|---|---|
| Zone 1 Volume (WQCV) = | 0.424 | acre-feet |
| Zone 2 Volume (EURV - Zone 1) = | 0.832 | acre-feet |
| Zone 3 Volume (100-year - Zones 1 & 2) = | 1.063 | acre-feet |
| Total Detention Basin Volume = | 2.319 | acre-feet |
| Initial Surcharge Volume (ISV) = | 55 | ft^3 |
| Initial Surcharge Depth (ISD) = | 0.33 | ft |
| Total Available Detention Depth ($H_{total}$) = | 5.00 | ft |
| Depth of Trickle Channel ($H_{TC}$) = | 0.50 | ft |
| Slope of Trickle Channel ($S_{TC}$) = | 0.005 | ft/ft |
| Slopes of Main Basin Sides ($S_{main}$) = | 4 | H:V |
| Basin Length-to-Width Ratio ($R_{L/W}$) = | 3 | |

Clear Input Parameters (Including Tables)

| | Stage (ft) | Zone Volume (ac-ft) | Outlet Type | |
|---|---|---|---|---|
| **Zone 1 (WQCV)** | 2.33 | 0.424 | Orifice Plate | Orifice Plate |
| **Zone 2 (EURV)** | 3.59 | 0.832 | Orifice Plate | Orifice Plate |
| **Zone 3 (100-year)** | 5.00 | 1.063 | Weir&Pipe (Restrict) | Weir and Pipe (w/ Restrictor Plate) |
| | | 2.319 | **Total** | |

**User Input: Overflow Weir (Dropbox) and Grate (Flat or Sloped)**

| | Zone 3 Weir | Not Selected | |
|---|---|---|---|
| Overflow Weir Front Edge Height, Ho = | 3.59 | N/A | ft (relative to bottom of basin at Stage = 0 ft) |
| Overflow Weir Front Edge Length = | 5.00 | N/A | feet |
| Overflow Weir Slope = | 0.00 | N/A | H:V (enter zero for flat grate) |
| Horiz. Length of Weir Sides = | 5.00 | N/A | feet |
| Overflow Grate Open Area % = | 70% | N/A | %, grate open area / total area |
| Debris Clogging % = | 50% | N/A | % |

**User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)**

| | Zone 3 Restrictor | Not Selected | |
|---|---|---|---|
| Depth to Invert of Outlet Pipe = | 2.50 | N/A | ft (distance below bottom of basin at Stage = 0 ft) |
| Outlet Pipe Diameter = | 24.00 | N/A | inches |
| Restrictor Plate Height Above Pipe Invert = | 15.40 | | inches |

Size Outlet Plate to match 90% of Predevelopment 100-year Peak Runoff Rate

**User Input: Emergency Spillway (Rectangular or Trapezoidal)**

| | | |
|---|---|---|
| Spillway Invert Stage= | 5.00 | ft (relative to bottom of basin at Stage = 0 ft) |
| Spillway Crest Length = | 27.00 | feet |
| Spillway End Slopes = | 4.00 | H:V |
| Freeboard above Spillway = | 1.00 | feet |

**Routed Hydrograph Results**

| Design Storm Return Period = | WQCV | EURV | 2 Year | 5 Year |
|---|---|---|---|---|
| One-Hour Rainfall Depth (in) = | 0.53 | 1.07 | 0.95 | 1.34 |
| Calculated Runoff Volume (acre-ft) = | 0.424 | 1.256 | 0.996 | 1.595 |
| ONAL Override Runoff Volume (acre-ft) = | | | | |
| Inflow Hydrograph Volume (acre-ft) = | 0.423 | 1.255 | 0.996 | 1.594 |
| velopment Unit Peak Flow, q (cfs/acre) = | 0.00 | 0.00 | 0.01 | 0.29 |
| Predevelopment Peak Q (cfs) = | 0.0 | 0.0 | 0.3 | 5.8 |
| Peak Inflow Q (cfs) = | 8.8 | 25.9 | 20.6 | 32.9 |
| Peak Outflow Q (cfs) = | 0.2 | 0.3 | 0.3 | 3.7 |
| tio Peak Outflow to Predevelopment Q = | N/A | N/A | N/A | 0.6 |
| Structure Controlling Flow = | Plate | Plate | Plate | Overflow Grate 1 |
| Max Velocity through Grate 1 (fps) = | N/A | N/A | N/A | 0.2 |
| Max Velocity through Grate 2 (fps) = | N/A | N/A | N/A | N/A |
| to Drain 97% of Inflow Volume (hours) = | 40 | 84 | 72 | 87 |
| to Drain 99% of Inflow Volume (hours) = | **40** | 84 | 72 | 87 |
| Maximum Ponding Depth (ft) = | 2.28 | 3.52 | 3.15 | 3.77 |
| ea at Maximum Ponding Depth (acres) = | 0.61 | 0.70 | 0.67 | 0.72 |
| Maximum Volume Stored (acre-ft) = | 0.395 | 1.208 | 0.955 | 1.386 |

**User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation BMP)**

| | | |
|---|---|---|
| Invert of Lowest Orifice = | 0.00 | ft (relative to bottom of basin at Stage = 0 ft) |
| Depth at top of Zone using Orifice Plate = | 3.59 | ft (relative to bottom of basin at Stage = 0 ft) |
| Orifice Plate: Orifice Vertical Spacing = | 14.40 | inches |
| Orifice Plate: Orifice Area per Row = | N/A | inches |

Size Plate to match WQCV Drain Time

**User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)**

| | Row 1 (required) | Row 2 (optional) | Row 3 (optional) | Row 4 (optional) | Row 5 (op |
|---|---|---|---|---|---|
| Stage of Orifice Centroid (ft) | 0.00 | 1.20 | 2.40 | | |
| Orifice Area (sq. inches) | 1.88 | 1.88 | 8.00 | | |

**Routed Hydrograph Results**

| Design Storm Return Period = | WQCV | EURV | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year |
|---|---|---|---|---|---|---|---|---|
| One-Hour Rainfall Depth (in) = | 0.53 | 1.07 | 0.95 | 1.34 | 1.64 | 2.02 | 2.32 | 2.61 |
| Calculated Runoff Volume (acre-ft) = | 0.424 | 1.256 | 0.996 | 1.595 | 2.088 | 2.796 | 3.322 | 3.899 |
| OPTIONAL Override Runoff Volume (acre-ft) = | | | | | | | | |
| Inflow Hydrograph Volume (acre-ft) = | 0.423 | 1.255 | 0.996 | 1.594 | 2.087 | 2.796 | 3.322 | 3.899 |
| Predevelopment Unit Peak Flow, q (cfs/acre) = | 0.00 | 0.00 | 0.01 | 0.29 | 0.49 | 0.93 | 1.17 | 1.47 |
| Predevelopment Peak Q (cfs) = | 0.0 | 0.0 | 0.3 | 5.8 | 9.8 | 18.5 | 23.5 | 29.4 |
| Peak Inflow Q (cfs) = | 8.8 | 25.9 | 20.6 | 32.9 | 43.0 | 57.8 | 68.8 | 80.9 |
| Peak Outflow Q (cfs) = | 0.2 | 0.5 | 0.4 | 3.6 | 11.4 | 23.0 | 25.7 | 26.5 |
| Ratio Peak Outflow to Predevelopment Q = | N/A | N/A | N/A | 0.6 | 1.2 | 1.2 | 1.1 | 0.9 |
| Structure Controlling Flow = | Plate | Plate | Plate | Overflow Grate 1 | Overflow Grate 1 | Overflow Grate 1 | Outlet Plate 1 | Outlet Plate |
| Max Velocity through Grate 1 (fps) = | N/A | N/A | N/A | 0.2 | 0.6 | 1.3 | 1.4 | 1.5 |
| Max Velocity through Grate 2 (fps) = | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Time to Drain 97% of Inflow Volume (hours) = | 40 | 69 | 63 | 72 | 72 | 72 | 72 | 72 |
| Time to Drain 99% of Inflow Volume (hours) = | 40 | 70 | 63 | 72 | 72 | 72 | 72 | 72 |
| Maximum Ponding Depth (ft) = | 2.28 | 3.49 | 3.12 | 3.76 | 3.99 | 4.24 | 4.51 | 4.92 |
| Area at Maximum Ponding Depth (acres) = | 0.61 | 0.70 | 0.67 | 0.72 | 0.73 | 0.75 | 0.77 | 0.80 |
| Maximum Volume Stored (acre-ft) = | 0.395 | 1.181 | 0.934 | 1.378 | 1.538 | 1.723 | 1.936 | 2.259 |

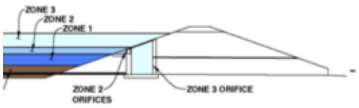
- Sand Filter with WQCV, 5-year and 100-year control

**Required Volume Calculation**

| | | |
|---|---|---|
| Sand Filter (SF) = | SF | |
| Watershed Area = | 3.00 | acres |
| Watershed Length = | 600 | ft |
| Watershed Slope = | 0.020 | ft/ft |
| Watershed Imperviousness = | 85.00% | percent |
| Percentage Hydrologic Soil Group A = | 0.0% | percent |
| Percentage Hydrologic Soil Group B = | 50.0% | percent |
| Percentage Hydrologic Soil Groups C/D = | 50.0% | percent |
| Desired WQCV Drain Time = | 12.0 | hours |
| Location for 1-hr Rainfall Depths = | Golden - School of Mines | |

## Stage-Storage Calculation

| | | |
|---|---|---|
| Zone 1 Volume (WQCV) = | 0.072 | acre-feet |
| Zone 2 Volume (5-year - Zone 1) = | 0.218 | acre-feet |
| Zone 3 Volume (100-year - Zones 1 & 2) = | 0.120 | acre-feet |
| Total Detention Basin Volume = | 0.410 | acre-feet |
| Initial Surcharge Volume (ISV) = | N/A | ft^3 |
| Initial Surcharge Depth (ISD) = | N/A | ft |
| Total Available Detention Depth ($H_{total}$) = | 4.00 | ft |
| Depth of Trickle Channel ($H_{TC}$) = | N/A | ft |
| Slope of Trickle Channel ($S_{TC}$) = | N/A | ft/ft |
| Slopes of Main Basin Sides ($S_{main}$) = | 3 | H:V |
| Basin Length-to-Width Ratio ($R_{L/W}$) = | 6 | |




Clear Input Parameters (Including Tables)

| | Stage (ft) | Zone Volume (ac-ft) | Outlet Type | |
|---|---|---|---|---|
| Zone 1 (WQCV) | 1.04 | 0.072 | Filtration Media | Filtration Media with Underdrain |
| Zone 2 (5-year) | 3.12 | 0.218 | Circular Orifice | Vertical Orifice (Circular) |
| Zone 3 (100-year) | 3.97 | 0.120 | Weir&Pipe (Restrict) | Weir and Pipe (w/ Restrictor Plate) |
| | | 0.410 | Total | |

**ITH 3 ZONES**

**t (typically used to drain WQCV in a Filtration BMP)**

ert Depth = 3.00 ft (distance below the filtration media surface)

Diameter = 1.24 inches

Calculate Underdrain Orifice Diameter to match WQCV Drain Time

**Calculated Parameters for Underdrain**

Underdrain Orifice Area = 0.0 $ft^2$

Underdrain Orifice Centroid = 0.05 feet

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### User Input: Vertical Orifice (Circular or Rectangular)

| | Zone 2 Circular | Not Selected | |
|---|---|---|---|
| Invert of Vertical Orifice = | 1.04 | N/A | ft (relative to bottom of basin at Stage = 0 ft) |
| Depth at top of Zone using Vertical Orifice = | 3.12 | N/A | ft (relative to bottom of basin at Stage = 0 ft) |
| Vertical Orifice Diameter = | 4.50 | N/A | inches |

**User Input: Overflow Weir (Dropbox) and Grate (Flat or Sloped)**

| | Zone 3 Weir | Not Selected | |
|---|---|---|---|
| Overflow Weir Front Edge Height, Ho = | 3.12 | N/A | ft (relative to bottom of basin at Stage = 0 ft) |
| Overflow Weir Front Edge Length = | 3.00 | N/A | feet |
| Overflow Weir Slope = | 3.00 | N/A | H:V (enter zero for flat grate) |
| Horiz. Length of Weir Sides = | 3.00 | N/A | feet |
| Overflow Grate Open Area % = | 70% | N/A | %, grate open area / total area |
| Debris Clogging % = | 50% | N/A | % |

**User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)**

| | Zone 3 Restrictor | Not Selected | |
|---|---|---|---|
| Depth to Invert of Outlet Pipe = | 3.10 | N/A | ft (distance below bottom of basin at Stage = 0 ft) |
| Outlet Pipe Diameter = | 12.00 | N/A | inches |
| Restrictor Plate Height Above Pipe Invert = | 5.00 | | inches |

**User Input: Emergency Spillway (Rectangular or Trapezoidal)**

| | | |
|---|---|---|
| Spillway Invert Stage= | 4.00 | ft (relative to bottom of basin at Stage = 0 ft) |
| Spillway Crest Length = | 10.00 | feet |
| Spillway End Slopes = | 4.00 | H:V |
| Freeboard above Spillway = | 1.00 | feet |

**Routed Hydrograph Results**

| Design Storm Return Period = | WQCV | EURV | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | 500 Year |
|---|---|---|---|---|---|---|---|---|---|
| One-Hour Rainfall Depth (in) = | 0.53 | 1.07 | 1.01 | 1.42 | 1.67 | 1.91 | 2.26 | 2.54 | 3.13 |
| Calculated Runoff Volume (acre-ft) = | 0.072 | 0.268 | 0.212 | 0.311 | 0.377 | 0.449 | 0.543 | 0.624 | 0.789 |
| OPTIONAL Override Runoff Volume (acre-ft) = | | | | | | | | | |
| Inflow Hydrograph Volume (acre-ft) = | 0.072 | 0.268 | 0.211 | 0.310 | 0.377 | 0.449 | 0.542 | 0.624 | 0.788 |
| Predevelopment Unit Peak Flow, q (cfs/acre) = | 0.00 | 0.00 | 0.01 | 0.23 | 0.41 | 0.85 | 1.09 | 1.38 | 1.94 |
| Predevelopment Peak Q (cfs) = | 0.0 | 0.0 | 0.0 | 0.7 | 1.2 | 2.6 | 3.3 | 4.1 | 5.8 |
| Peak Inflow Q (cfs) = | 1.5 | 5.5 | 4.3 | 6.3 | 7.7 | 9.1 | 11.0 | 12.7 | 16.0 |
| Peak Outflow Q (cfs) = | 0.1 | 0.7 | 0.6 | 0.7 | 0.9 | 1.9 | 3.5 | 3.9 | 7.3 |
| Ratio Peak Outflow to Predevelopment Q = | N/A | N/A | N/A | 1.1 | 0.7 | 0.7 | 1.1 | 0.9 | 1.2 |
| Structure Controlling Flow = | Filtration Media | Vertical Orifice 1 | Vertical Orifice 1 | Vertical Orifice 1 | Overflow Grate 1 | Overflow Grate 1 | Overflow Grate 1 | Outlet Plate 1 | Spillway |
| Max Velocity through Grate 1 (fps) = | N/A | N/A | N/A | N/A | 0.0 | 0.2 | 0.4 | 0.4 | 0.4 |
| Max Velocity through Grate 2 (fps) = | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Time to Drain 97% of Inflow Volume (hours) = | 12 | 19 | 18 | 19 | 20 | 20 | 20 | 20 | 20 |
| Time to Drain 99% of Inflow Volume (hours) = | 12 | 19 | 18 | 19 | 20 | 20 | 20 | 21 | 21 |
| Maximum Ponding Depth (ft) = | 0.88 | 2.42 | 2.02 | 2.71 | 3.14 | 3.42 | 3.63 | 3.86 | 4.22 |
| Area at Maximum Ponding Depth (acres) = | 0.08 | 0.11 | 0.10 | 0.12 | 0.13 | 0.14 | 0.14 | 0.15 | 0.16 |
| Maximum Volume Stored (acre-ft) = | 0.059 | 0.205 | 0.162 | 0.240 | 0.294 | 0.331 | 0.360 | 0.393 | 0.448 |

- Bioretention WQCV only basin with downstream FSD basin (basins in series)

## Required Volume Calculation

| | | |
|---|---|---|
| Rain Garden (RG) - Bioretention = | RG | |
| Watershed Area = | 5.00 | acres |
| Watershed Length = | 700 | ft |
| Watershed Slope = | 0.020 | ft/ft |
| Watershed Imperviousness = | 75.00% | percent |
| Percentage Hydrologic Soil Group A = | 0.0% | percent |
| Percentage Hydrologic Soil Group B = | 100.0% | percent |
| Percentage Hydrologic Soil Groups C/D = | 0.0% | percent |
| Desired WQCV Drain Time = | 12.0 | hours |
| Location for 1-hr Rainfall Depths = | UDFCD Default | |

Depth Increment = ft

| Stage - Storage Description | Stage (ft) | Optional Override Stage (ft) | Length (ft) | Width (ft) | Area (ft^2) | Optional Override Area (ft^2) | Area (acre) | Volume (ft^3) | Volume (ac-ft) |
|---|---|---|---|---|---|---|---|---|---|
| **Media Surface** | -- | 0.00 | -- | -- | -- | 3,267 | 0.075 | | |
| | -- | 1.00 | -- | -- | -- | 5,600 | 0.129 | 4,378 | 0.100 |
| | -- | 6.00 | -- | -- | -- | 5,600 | 0.129 | 32,433 | 0.745 |
| | -- | | -- | -- | -- | | | | |

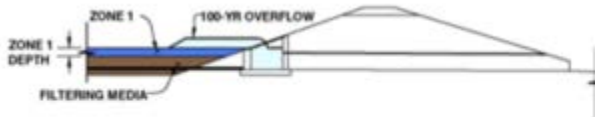
## Stage-Storage Calculation

| | | |
|---|---|---|
| Zone 1 Volume (WQCV) = | 0.100 | acre-feet |
| Select Zone 2 Storage Volume (Optional) = | | acre-feet |
| Select Zone 3 Storage Volume (Optional) = | | acre-feet |
| Total Detention Basin Volume = | 0.100 | acre-feet |

**Total detention volume is less than 100-year volume.**

Clear Input Parameters (Including Tables)

| | Stage (ft) | Zone Volume (ac-ft) | Outlet Type | |
|---|---|---|---|---|
| **Zone 1 (WQCV)** | 0.99 | 0.100 | Filtration Media | Filtration Media with Underdrain |
| **Zone 2** | | | Not Utilized | Zone 2 Not Utilized |
| **Zone 3** | | | Not Utilized | Zone 3 Not Utilized |
| | | 0.100 | **Total** | |




**FILTERING BMP WITH ZONE 1 ONLY**

**User Input: Orientation at Underdrain Outlet (typically used to drain WQCV in a Filtration**

| | | |
|---|---|---|
| Underdrain Orifice Invert Depth = | 3.00 | ft (distance b |
| Underdrain Orifice Diameter = | 1.45 | inches |

**User Input: Emergency Spillway (Rectangular or Trapezoidal)**

| | | |
|---|---|---|
| Spillway Invert Stage= | 1.00 | ft (relative to bottom of basin at Stage = 0 ft) |
| Spillway Crest Length = | 20.00 | feet |
| Spillway End Slopes = | 4.00 | H:V |
| Freeboard above Spillway = | 1.00 | feet |

## Detention Basin Outlet Structure Design

Reset hydrographs to default values from workbook

Outflow Hydrograph Workbook Filename:

Use relative path name

Export Outflow Hydrographs to a blank workbook for later use in a downstream UD-Detention Workbook

**Storm Inflow Hydrographs**

The user can override the calculated inflow hydrographs from this workbook with inflow hydrographs developed in a separate program.

| | SOURCE | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK |
|---|---|---|---|---|---|---|---|---|---|---|
| Time Interval | TIME | WQCV [cfs] | EURV [cfs] | 2 Year [cfs] | 5 Year [cfs] | 10 Year [cfs] | 25 Year [cfs] | 50 Year [cfs] | 100 Year [cfs] | 500 Year [cfs] |
| 5.17 min | 0:00:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0:05:10 | 0.00 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.05 |
| Hydrograph | 0:10:20 | 0.13 | 0.50 | 0.35 | 0.52 | 0.65 | 0.84 | 0.98 | 1.12 | 1.42 |
| Constant | 0:15:31 | 0.30 | 1.20 | 0.83 | 1.25 | 1.59 | 2.06 | 2.42 | 2.79 | 3.59 |
| 0.967 | 0:20:41 | 0.83 | 3.32 | 2.31 | 3.47 | 4.39 | 5.67 | 6.67 | 7.69 | 9.84 |

Open new workbook…

**Required Volume Calculation**

| | | |
|---|---|---|
| Extended Detention Basin (EDB) = | EDB | |
| Watershed Area = | 5.00 | acres |
| Watershed Length = | 700 | ft |
| Watershed Slope = | 0.020 | ft/ft |
| Watershed Imperviousness = | 75.00% | percent |
| Percentage Hydrologic Soil Group A = | 0.0% | percent |
| Percentage Hydrologic Soil Group B = | 100.0% | percent |
| Percentage Hydrologic Soil Groups C/D = | 0.0% | percent |
| Desired WQCV Drain Time = | 40.0 | hours |
| Location for 1-hr Rainfall Depths = | UDFCD Default | |

**Stage-Storage Calculation**

| | | |
|---|---|---|
| Zone 1 Volume (EURV-WQCV) = | 0.289 | acre-feet |
| Zone 2 Volume (100-year - Zone 1) = | 0.366 | acre-feet |
| Select Zone 3 Storage Volume (Optional) = | | acre-feet |
| Total Detention Basin Volume = | 0.655 | acre-feet |
| Initial Surcharge Volume (ISV) = | 16 | ft^3 |
| Initial Surcharge Depth (ISD) = | 0.33 | ft |
| Total Available Detention Depth ($H_{total}$) = | 4.00 | ft |
| Depth of Trickle Channel ($H_{TC}$) = | 0.00 | ft |
| Slope of Trickle Channel ($S_{TC}$) = | 0.019 | ft/ft |
| Slopes of Main Basin Sides ($S_{main}$) = | 4 | H:V |
| Basin Length-to-Width Ratio ($R_{L/W}$) = | 2 | |

| | Stage (ft) | Zone Volume (ac-ft) | Outlet Type | Clear Input Parameters (Including Tables) |
|---|---|---|---|---|
| e 1 (EURV - WQCV) | 3.08 | 0.289 | Circular Orifice | Vertical Orifice (Circular) |
| Zone 2 (100-year) | 4.00 | 0.366 | Weir&Pipe (Restrict) | Weir and Pipe (w/ Restrictor Plate) |
| Zone 3 | | | Not Utilized | Zone 3 Not Utilized |
| | | 0.655 | Total | |

**Calculated Parameters for Underdrain**

filtration media surface)

| | | |
|---|---|---|
| Underdrain Orifice Area = | N/A | $ft^2$ |
| Underdrain Orifice Centroid = | N/A | feet |

# (Drain EURV-WQCV in 12 hours)

**User Input: Vertical Orifice (Circular or Rectangular)**

| | Zone 1 Circular | Not Selected | |
|---|---|---|---|
| Invert of Vertical Orifice = | 0.00 | N/A | ft (relative to bottom of basin at Stage = 0 ft) |
| Depth at top of Zone using Vertical Orifice = | 3.08 | N/A | ft (relative to bottom of basin at Stage = 0 ft) |
| Vertical Orifice Diameter = | 3.17 | N/A | inches |

**User Input: Overflow Weir (Dropbox) and Grate (Flat or Sloped)**

| | Zone 2 Weir | Not Selected | |
|---|---|---|---|
| Overflow Weir Front Edge Height, Ho = | 3.08 | | ft (relative to bottom of basin at Stage = 0 ft |
| Overflow Weir Front Edge Length = | 4.00 | | feet |
| Overflow Weir Slope = | 4.00 | | H:V (enter zero for flat grate) |
| Horiz. Length of Weir Sides = | 4.00 | | feet |
| Overflow Grate Open Area % = | 70% | | %, grate open area / total area |
| Debris Clogging % = | 50% | | % |

**ser Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)**

| | Zone 2 Restrictor | Not Selected | |
|---|---|---|---|
| Depth to Invert of Outlet Pipe = | 0.20 | | ft (distance below bottom of basin at Stage |
| Outlet Pipe Diameter = | 18.00 | | inches |
| Restrictor Plate Height Above Pipe Invert = | 6.00 | | inches H |

Size Outlet Plate to match 90% of Predevelopment 100-year Peak Runoff Rate

**User Input: Emergency Spillway (Rectangular or Trapezoidal)**

| | | |
|---|---|---|
| Spillway Invert Stage= | | ft (relative to bottom of basin at Stage = 0 ft) |
| Spillway Crest Length = | | feet |
| Spillway End Slopes = | | H:V |
| Freeboard above Spillway = | | feet |

**User Input: Emergency Spillway (Rectangular or Trapezoidal)**

Size Outlet Plate to match 50% of Predevelopment 100-year Peak Runoff Rate

| | | |
|---|---|---|
| Spillway Invert Stage= | 3.80 | ft (relative to bottom of basin at Stage = 0 ft) |
| Spillway Crest Length = | 8.00 | feet |
| Spillway End Slopes = | 4.00 | H:V |
| Freeboard above Spillway = | 1.00 | feet |

**Routed Hydrograph Results**

| Design Storm Return Period = | WQCV | EURV | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | 500 Year |
|---|---|---|---|---|---|---|---|---|---|
| One-Hour Rainfall Depth (in) = | 0.53 | 1.07 | 0.95 | 1.34 | 1.64 | 2.02 | 2.32 | 2.61 | 3.29 |
| Calculated Runoff Volume (acre-ft) = | 0.125 | 0.414 | 0.285 | 0.434 | 0.556 | 0.730 | 0.867 | 1.008 | 1.316 |
| OPTIONAL Override Runoff Volume (acre-ft) = | | | | | | | | | |
| Inflow Hydrograph Volume (acre-ft) = | 0.053 | 0.346 | 0.218 | 0.366 | 0.488 | 0.661 | 0.798 | 0.940 | 1.247 |
| Predevelopment Unit Peak Flow, q (cfs/acre) = | 0.00 | 0.00 | 0.01 | 0.19 | 0.38 | 0.86 | 1.12 | 1.43 | 2.01 |
| Predevelopment Peak Q (cfs) = | 0.0 | 0.0 | 0.1 | 1.0 | 1.9 | 4.3 | 5.6 | 7.1 | 10.1 |
| Peak Inflow Q (cfs) = | 0.1 | 8.5 | 4.6 | 9.1 | 11.5 | 16.4 | 20.4 | 24.0 | 30.9 |
| Peak Outflow Q (cfs) = | 0.1 | 0.4 | 0.4 | 0.4 | 1.2 | 3.1 | 4.8 | 6.5 | 10.0 |
| Ratio Peak Outflow to Predevelopment Q = | N/A | N/A | N/A | 0.5 | 0.6 | 0.7 | 0.9 | 0.9 | 1.0 |
| Structure Controlling Flow = | Vertical Orifice 1 | Vertical Orifice 1 | Vertical Orifice 1 | Vertical Orifice 1 | Overflow Grate 1 | Overflow Grate 1 | Overflow Grate 1 | Outlet Plate 1 | Spillway |
| Max Velocity through Grate 1 (fps) = | N/A | N/A | N/A | N/A | 0.1 | 0.2 | 0.4 | 0.5 | 0.5 |
| Max Velocity through Grate 2 (fps) = | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Time to Drain 97% of Inflow Volume (hours) = | 8 | 11 | 9 | 12 | 14 | 14 | 14 | 14 | 14 |
| Time to Drain 99% of Inflow Volume (hours) = | 8 | 11 | 9 | 12 | 14 | 14 | 14 | 14 | 14 |
| Maximum Ponding Depth (ft) = | 0.30 | 2.94 | 2.40 | 3.00 | 3.29 | 3.52 | 3.66 | 3.78 | 4.05 |
| Area at Maximum Ponding Depth (acres) = | 0.00 | 0.27 | 0.18 | 0.28 | 0.34 | 0.39 | 0.42 | 0.45 | 0.49 |
| Maximum Volume Stored (acre-ft) = | 0.000 | 0.249 | 0.133 | 0.268 | 0.355 | 0.442 | 0.495 | 0.552 | 0.676 |