RETENTION BASIN EXAMPLE	1113-4
	REFERENCE SECTION 1113

Given:

- Total Tributary Area = 7.5 ac
  - Tributary Area within Existing R/W = 5.8 ac
  - Tributary Area, Impervious, Outside of R/W = 0.0 ac
  - Tributary Area, Pervious, Outside of R/W = 1.7 ac
  - Tributary Area, Pavement and Paved Shoulders = 1.5 ac
  - Tributary Area, Berms and Slopes 4:1 or Flatter = 6.0 ac
- Rainfall Area B
- Time of Concentration, t_C = 25 min (calculation shown in this example)

Calculate the water quality volume WQ_V:

- WQ_V = (R_V * P * A) / 12
- P = 0.90 in
- A = 7.5 ac
- R_V = 0.05 + 0.9 * i
  - i = impervious area divided by the total area (within the BMP drainage area)
  - The area within existing ODOT right-of-way is considered impervious area for the purpose of post-construction BMP design considerations. (L&D Vol 2, Sec. 1111.6.1)
  - i = $\frac{5.8\ ac + 0.0\ ac}{7.5\ ac}$ = 0.773
- R_V = 0.05 + 0.9 * 0.773 = 0.746
- WQ_V = (0.746 * 0.90 in * 7.5 ac) / 12
- WQ_V = 0.42 ac-ft

Determine the minimum volume of the detention pool and the permanent pool:

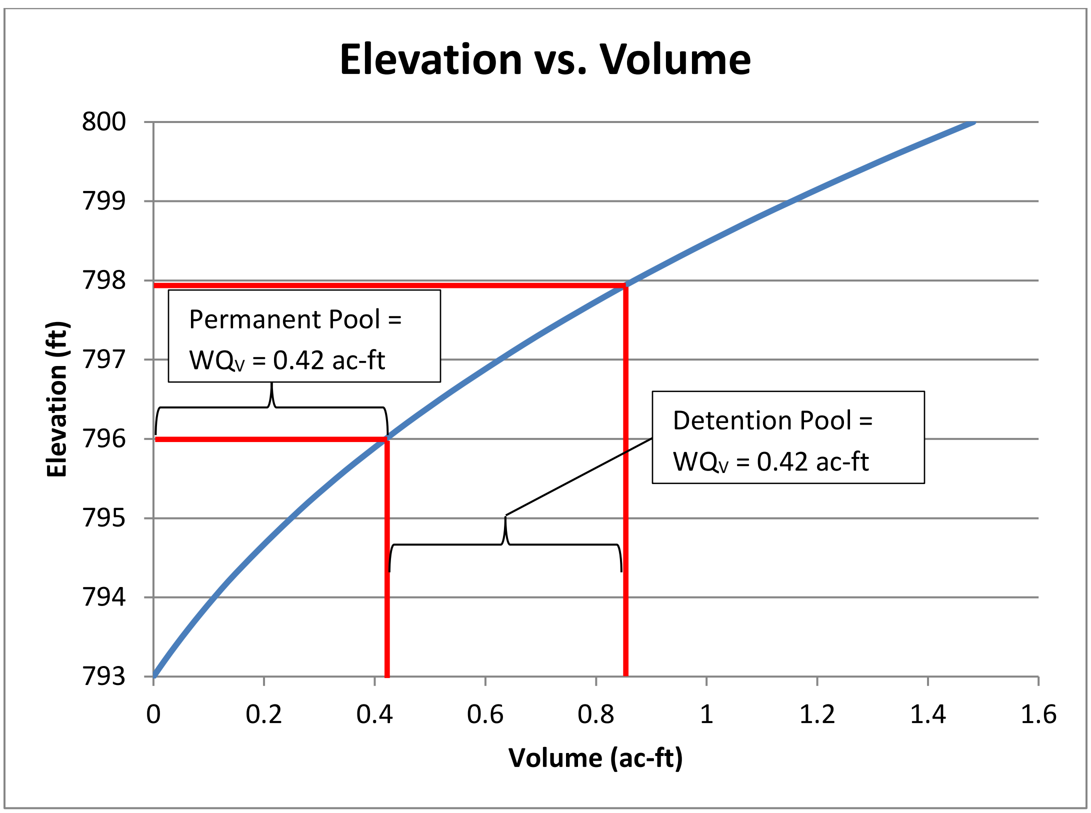
- Retention Basins have an upper storage volume (detention pool) that is above the water quality discharge and is designed to drain in 24 hours or more. The minimum detention pool volume is equal to the WQ_V.
- Detention pool volume = 0.42 ac-ft
- Retention Basins have a lower storage volume (permanent pool) that is permanently full of water, below the water quality discharge point. The minimum permanent pool volume is equal to the WQ_V.
- Permanent pool volume = 0.42 ac-ft
- If there were a forebay, sized at 10% of the WQ_V, that would be included 0.42 ac-ft of the permanent pool.

Layout a retention basin configuration that meets the following requirements:

- Maximum 4:1 side slopes
- Include provisions for vehicle access
- Length to width ration of at least 3:1

Elevation vs. Volume Table:

Elevation (feet)	**Storage** (acre-feet)	**Elevation** (feet)	**Storage** (acre-feet)	**Elevation** (feet)	**Storage** (acre-feet)
793	0	795.4	0.313	797.8	0.817
793.2	0.02	795.6	0.347	798	0.869
793.4	0.041	795.8	0.383	798.2	0.923
793.6	0.063	796	0.42	798.4	0.978
793.8	0.086	796.2	0.458	798.6	1.035
794	0.11	796.4	0.498	798.8	1.093
794.2	0.135	796.6	0.539	799	1.154
794.4	0.162	796.8	0.582	799.2	1.216
794.6	0.19	797	0.626	799.4	1.28
794.8	0.219	797.2	0.671	799.6	1.345
795	0.249	797.4	0.718	799.8	1.413
795.2	0.28	797.6	0.767	800	1.482



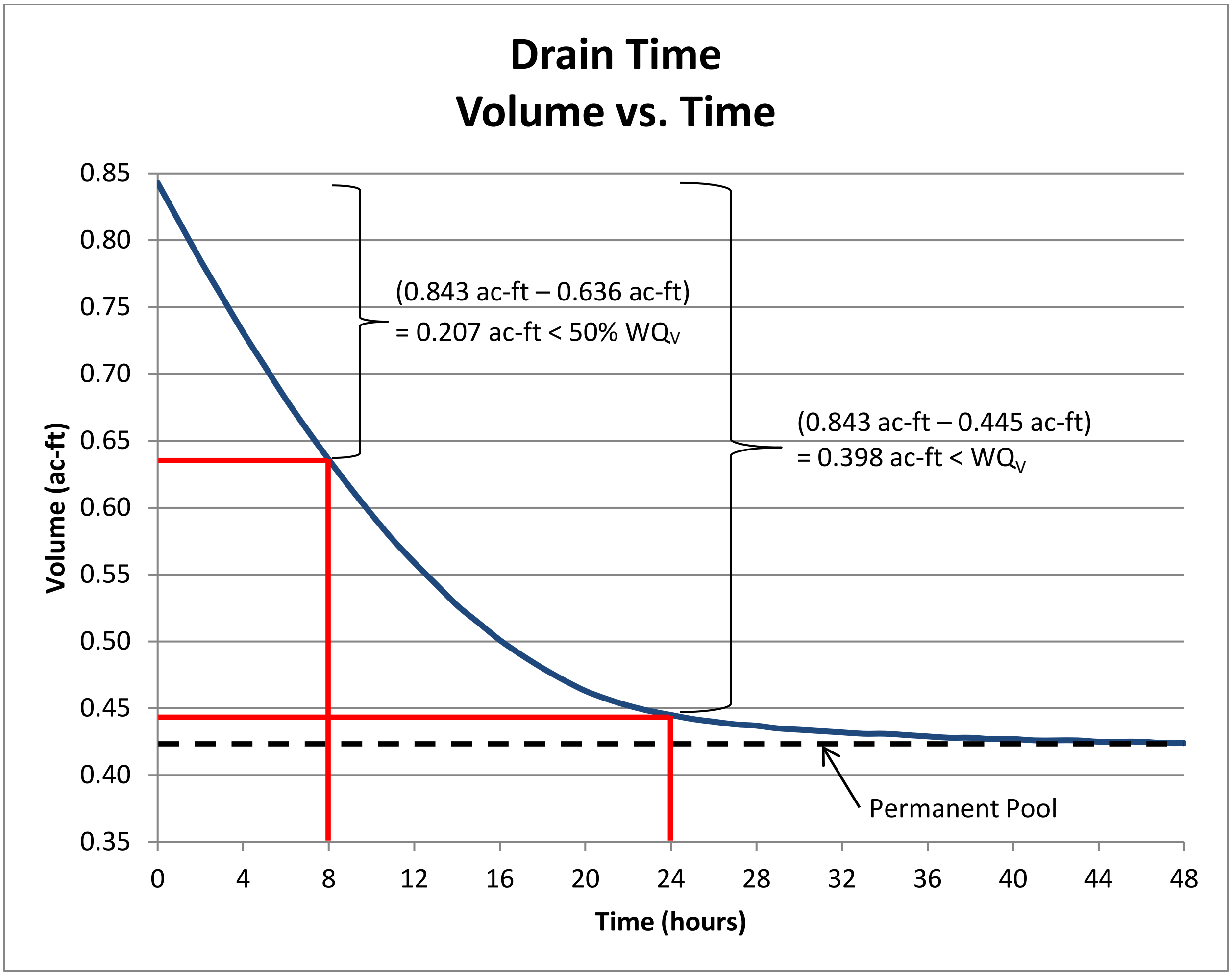
- The permanent pool elevation is set at 796.0 ft.
  - 0.42 ac-ft of storage is permanently ponded.
  - 0.42 ac-ft is equal to or greater than the WQ_V (0.42 ac-ft); therefore, it is acceptable.
- The detention pool volume is between 797.9 ft and 796.0 ft.
  - 0.84 ac-ft – 0.42 ac-ft = 0.42 ac-ft
  - 0.42 ac-ft is equal to or greater than the WQ_V (0.42 ac-ft); therefore, it is acceptable.

Design the Retention Basin Water Quality Outlet:

- The minimum discharge time of the WQ_V (in the detention pool) is 24 hours with no more than 50% of the WQ_V being released from the retention basin in the first one-third of the 24 hour drain time.
- WQ_V = 0.42 ac-ft; must take 24 hours or longer to drain
- 50% or less of the WQ_V (i.e. 0.21 ac-ft) must be drained in 8 hours or more.
- Choose one 3.2 inch diameter circular orifice at an elevation of 796.0 ft.
- Calculate the drawdown curve.
  - This calculation can be done by hand by creating a stage vs. discharge table and interpolating between values, but it is generally easier to use a model to simulate runoff through a retention basin such as PondPack or HydroCAD.
- Do not route a design storm hydrograph through a retention basin to determine the drawdown curve. Start the simulation with the water surface at a level equivalent to the WQ_V storage (for this example, at an elevation of 797.90). Then allow the pooled water filling the detention pool to drain by gravity out of the water quality outlet structure. Include all retention basin outlets that would affect this drawdown curve. Include any downstream constraints such as tailwater or limiting conveyance downstream. For this example, there is no tailwater and there is a free discharge from the retention basin.

Retention Basin Drawdown Hydrograph:

Time (hours)	**Storage** (acre-feet)	**Elevation** (feet)	**Discharge** (cfs)	**Time** (hours)	**Storage** (acre-feet)	**Elevation** (feet)	**Discharge** (cfs)
0	0.843	797.9	0.36	19	0.471	796.26	0.1
1	0.814	797.79	0.35	20	0.463	796.23	0.08
2	0.785	797.67	0.34	21	0.457	796.19	0.07
3	0.758	797.56	0.33	22	0.452	796.17	0.05
4	0.731	797.45	0.31	23	0.448	796.15	0.04
5	0.706	797.35	0.3	24	0.445	796.13	0.04
6	0.681	797.24	0.29	25	0.442	796.12	0.03
7	0.658	797.14	0.27	26	0.44	796.11	0.02
8	0.636	797.05	0.26	27	0.438	796.1	0.02
9	0.615	796.95	0.25	28	0.437	796.09	0.02
10	0.595	796.86	0.23	29	0.435	796.08	0.01
11	0.576	796.78	0.22	30	0.434	796.08	0.01
12	0.559	796.69	0.2	31	0.433	796.07	0.01
13	0.543	796.62	0.19	32	0.432	796.07	0.01
14	0.527	796.54	0.18	33	0.431	796.06	0.01
15	0.514	796.48	0.16	34	0.431	796.06	0.01
16	0.501	796.42	0.15	35	0.43	796.05	0.01
17	0.49	796.36	0.13	36	0.429	796.05	0.01
18	0.48	796.31	0.11				

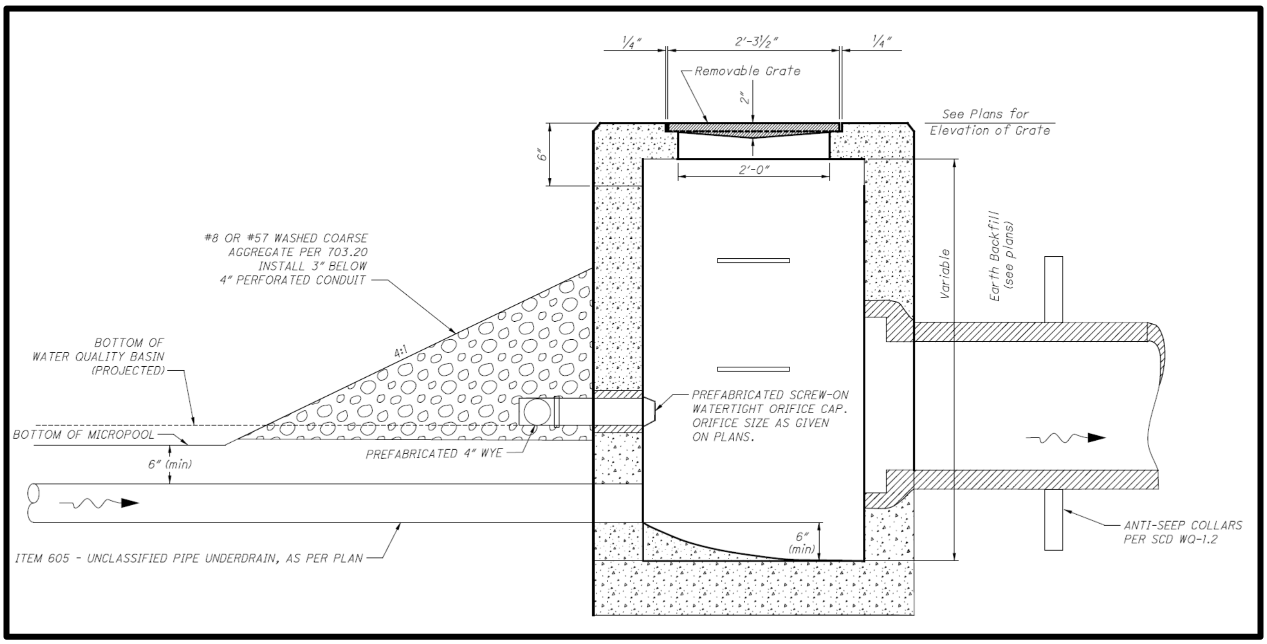


- In 24 hours, the volume goes from 0.843 ac-ft to 0.445 ac-ft.
  - 0.843 ac-ft – 0.445 ac-ft = 0.398 ac-ft
- WQ_V = 0.42 ac-ft
  - 0.42 ac-ft $\geq$ 0.398 ac-ft. It takes longer than 24 hours to drain the WQ_V; therefore, it is acceptable.
- In 8 hours, the volume goes from 0.843 ac-ft to 0.636 ac-ft.
  - 0.843 ac-ft – 0.636 ac-ft = 0.207 ac-ft
- 50% WQ_V = 0.21 ac-ft
  - 0.21 ac-ft $\geq$ 0.207 ac-ft. It takes longer than 8 hours to drain 50% of the WQ_V; therefore, it is acceptable.

Size the Primary Retention Basin Outlet:

- There are three main parts of a typical retention basin discharge structure:
  - Water quality outlet(s)
  - Primary outlet
  - Overflow weir
- The primary retention basin outlet normally consists of a catch basin grate, catch basin side inlets, and the conduit that conveys discharges from the retention basin during all but the least frequent precipitation events.
- The primary outlet should be sized to convey the 10% AEP design storm.

ODOT Water Quality Catch Basin Detail (WQ-1.1):



Determine the 10% AEP design flow rate:

- For the purposes of post-construction BMP calculations, all existing right-of-way is to be considered impervious. For the purpose of general conveyance sizing, runoff coefficients should be calculated using Table 1101-2 in ODOT's L&D Vol. 2.
- Q = CiA

  Calculate the weighted C value:

  1.5 acres of tributary area are pavement and paved shoulders: C = 0.9

  6.0 acres of tributary area are berms and slopes 4:1 or flatter: C = 0.5

  $C_{weighted} = \frac{1.5\ ac*0.9+6.0\ ac*0.5}{7.5\ ac} = 0.58$

  Determine the precipitation intensity:

  Rainfall Area B

  t_C = 25 min

  (The time of concentration is given in this example as 25 minutes because there is significant overland flow over grassed area. The time of concentration should be calculated for each site based on the site-specific flow path. 25 minutes would likely be too high of a value if the detention basin were receiving flow from a piped system. See the time of concentration calculations below.)

  L&D Vol. 2, Figure 1101-2: Area B, 10% AEP storm, 25 min t_C: i = 3.4 in/hr

- Q = 0.58 * 3.4 in/hr * 7.5 ac = <u>14.79 cfs</u>

  Time of Concentration (t_C) Calculations:

  - t_C = Time of overland flow (t_O) + Time of shallow concentrated flow (t_S) + Time of channel flow (t_C)
  - Overland Flow (t_O)
    - $t_O = \frac{1.8(1.1-C)(L)^{1/2}}{s^{1/3}}$
    - C = Runoff Coefficient (0.58 for this example)
    - L = Distance to most remote location in drainage in feet (max. 300 ft.) (200 ft. in this example)
    - s = Overland slope (percent) (0.33% in this example)
    - $t_O = \frac{1.8(1.1-0.58)(200)^{1/2}}{0.33^{1/3}}$ = **19.16 minutes**
  - Shallow Concentrated Flow (t_S)
    - V_S = Velocity of shallow concentrated flow (ft/sec) = $3.281ks^{0.5}$
    - k = Intercept Coefficient (L&D Table 1101-1) = (0.457 in this example)
    - s = Overland slope (percent) (0.33% in this example)
    - $V_S = 3.281 * 0.457 * 0.33^{0.5}$ = 0.86 ft/sec
    - Length of shallow concentrated flow = 200 ft.
    - t_S = 200 ft. / 0.86 ft/sec = 233 sec = **3.88 minutes**

- Channel Flow (t_C)
  - Manning's Equation: V = $\frac{1.49r^{2/3}s^{1/2}}{n}$
  - V = velocity in the channel (ft/sec)
  - r = hydraulic radius (0.69 ft. in this example)
  - s = channel slope (0.01 ft/ft in this example)
  - n = Manning's Roughness Coefficient (L&D Vol. 2, Table 1102-3) (0.03 in this example)
  - V = $\frac{1.49*0.69^{2/3}*0.01^{1/2}}{0.03}$ = 3.88 ft/sec
  - Channel length = 500 ft. (for this example)
  - t_C = 500 ft. / 3.88 ft/sec = 129 sec. = **2.15 minutes**
- $t_C = t_O + t_S + t_C$ = 19.16 + 3.88 + 2.15 = 25.19 minutes. Use t_C = **25 minutes**

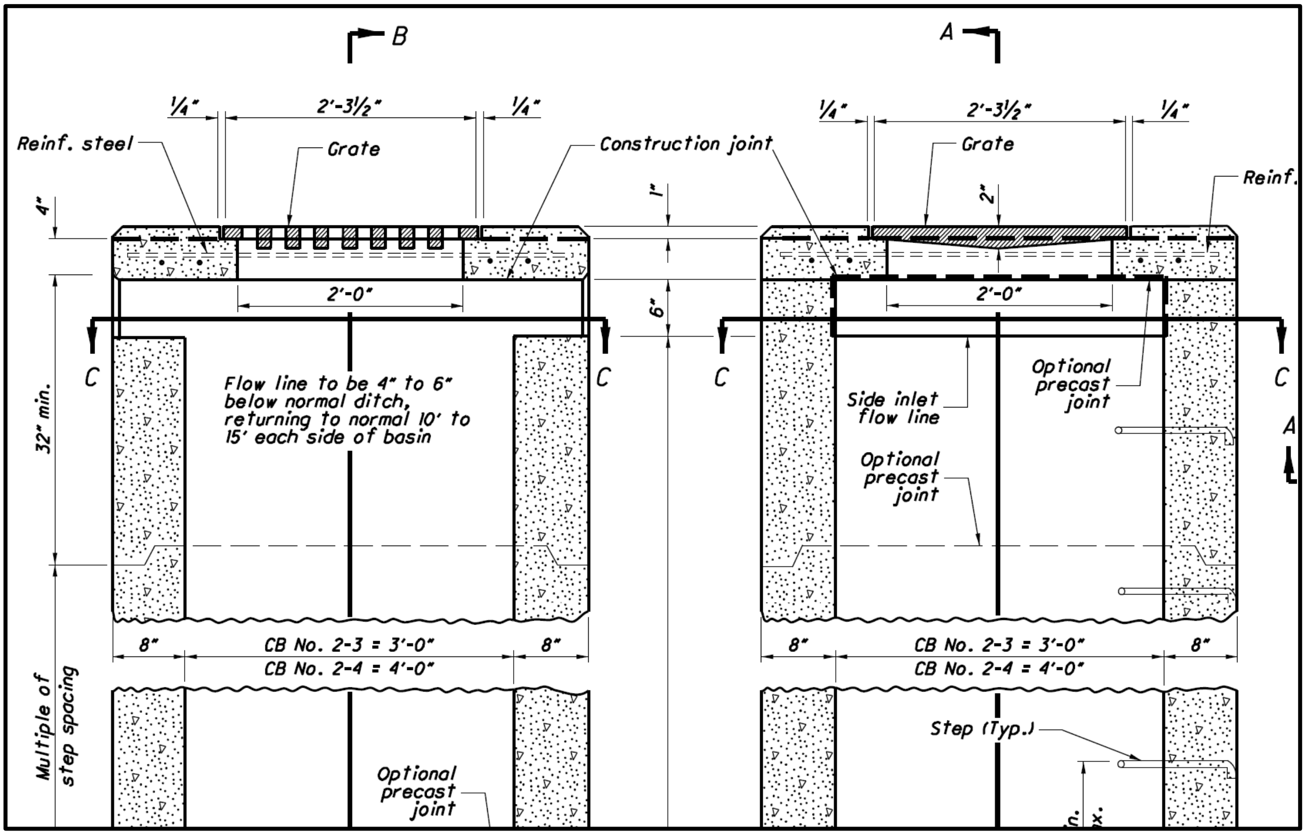
Size the primary retention basin discharge conduit:

- The discharge conduit must be large enough to convey the 10% AEP design storm, keeping the maximum hydraulic grade line within the crown of the pipe.
- This example has the following conduit characteristics:
  - Conduit slope = 0.005 ft/ft
  - No Tailwater; free discharge
  - Pipe Roughness Coefficient = 0.015 (L&D Vol. 2, Section 1104.4.5)
- The minimum conduit size that conveys the 10% AEP design flow (14.79 cfs) with the given characteristics is a 24-inch diameter pipe.

Set the catch basin grate elevation:

- The WQ_V fills the retention basin to an elevation of 797.9 ft. At water surface elevations of 797.9 ft and below, all discharge should pass through the water quality outlet. (In this example, the water quality outlet is one 3.2 inch diameter orifice at 796.0 ft.)
- The ODOT standard water quality catch basin detail (SCD WQ-1.1) calls for either Catch Basin No. 2-3 or 2-4 depending on the outlet pipe size. Both catch basins have a 6-inch high side inlet that is either 3 or 4 feet wide depending on the catch basin. See the detail:

ODOT Catch Basin No. 2-3 and No. 2-4:



- The elevation of the invert of the side inlets should be set at the WQ_V elevation (the top of the detention pool). Therefore, any volume above the WQ_V may discharge into the catch basin through the side inlets or grate.
- The elevation of the top of the grate is 1 foot above the elevation of the side inlets.
  - <u>Side inlets bottom elevation = 797.9 ft</u> (Top of WQ_V)
  - <u>Catch basin grate elevation = 798.9 ft</u>

Set the catch basin invert Elevation:

- Set the catch basin invert elevation to the lower of:
  - 6 in below the orifice invert
    - 796.0 – 0.5 = 795.5
  - Invert of the discharge conduit
    - 795.0
  - <u>Catch basin invert elevation = 795.0 ft</u>

Set the Overflow Weir Invert Elevation:

- The 10% AEP design flow rate (14.79 cfs) should pass fully through the primary discharge. Therefore, no flow should discharge from the overflow weir until the 10% AEP design flow rate has been exceeded.
- Set the overflow weir invert elevation just high enough above the catch basin grate such that the full 10% AEP design flow rate is conveyed through the primary discharge.
- For this example, the primary discharge pipe is sized at 24 inches in diameter; therefore, Catch Basin No. 2-3 is appropriate.
- Catch Basin No. 2-3 has the same grate as Catch Basin No. 2-2B.
- The water quality catch basin has three openings to allow runoff inside: two side inlets and a Grate No. 2-2-B.
- Use the orifice equation with 6" X 36" openings for the two side inlets.
- Use L&D Vol. 2, Figure 1102-1 to determine the flow rate through a No. 2-2-B grate.
- According to the orifice equations and the grate flow figure, at an elevation of 799.0, the three outlets combined should convey approximately 15.2 cfs, which is just above the required flow rate of 14.79 cfs.
- <u>Set the overflow weir elevation at 799.0 ft</u>.

Size the Emergency Overflow Weir and Set the Top of Basin Elevation:

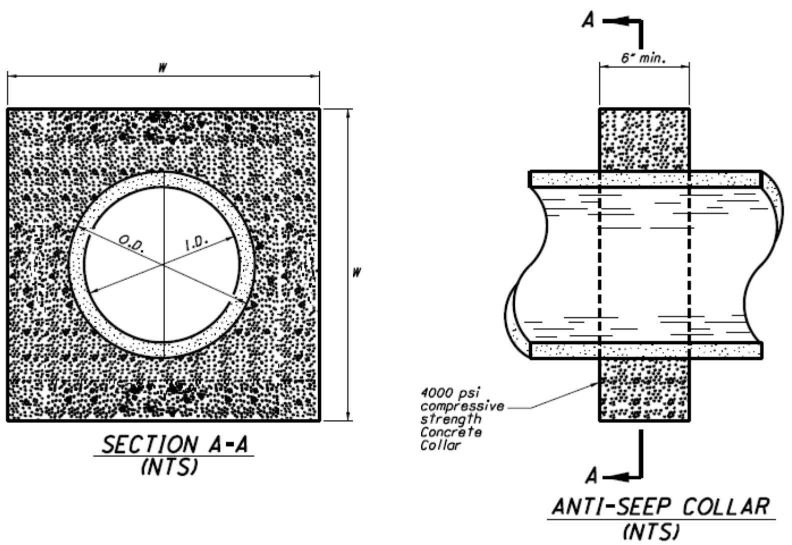
- L&D Vol. 2, Section 1104.3.2 states that the hydraulic grade line should be checked for the 4% AEP storm.
- Calculate the design flow rate for each design storm:
  - 4% AEP intensity @ t_C = 25 min and Rainfall Area B: 3.8 in/hr
  - 4% AEP design flow rate: Q = CiA = 0.58 * 3.8 in/hr * 7.5 ac = 16.53 cfs
- Calculate the required weir length for each design storm flow:
  - Emergency overflow weir elevation = 799.0 ft
  - Assume a top of retention basin elevation = 799. 5 ft
  - Maximum height overflow weir = 799. 5 ft – 799.0 ft = 0.5 ft
  - Weir equation: $Q = C*L*H^{1.5}$
    - C = 3
    - H = 0.5
    - L = ?
  - Length of a weir: $L = \frac{Q}{C * H^{1.5}}$
  - 4% AEP: $L = \frac{16.53}{3 * 0.5^{1.5}} = 15.6$ ft
- Provide a <u>16 ft wide overflow weir</u>.
- The <u>top of basin elevation is 799.5 ft</u>.

- The overflow weir length could be reduced by increasing the top of basin elevation. Or the top of basin elevation can be lowered by increasing the overflow weir length. The 4% AEP design flow rate must fully pass through the overflow weir without overtopping the detention basin.
- Flow rates greater than the 4% AEP design flow rate may overtop the detention basin uncontrolled.
- Provide erosion protection at the overflow weir, to the bottom of the berm, and continuing downstream if there is erosion potential.

Design Anti-Seep Collars:

- Anti-seep collars reduce the conveyance of flow along pipe bedding, outside of a conduit and increase the flow path for the seepage of water. This helps protect the berm above the discharge conduit from a retention basin from internal erosion.

ODOT Standard Drawing WQ-1.2



DIAMETER (I.D.) (FT.)	CONCRETE (C.Y.) DIMENSION OF COLLAR W X W (FT.)		
	3X3	4X4	5X5
1	0.15	0.28	0.45
2	N/A	0.24	0.40
3	N/A	N/A	0.33

- Calculate the saturated zone length along the conduit (Ls)
    - Ls = Y(Z+4)[1+S/(0.25-S)]
    - Y = depth of water during the 10% AEP storm
    - Z = slope of embankment
    - S = slope of conduit
- Maximum elevation at 10% AEP storm = 799.0 ft
- Conduit elevation = 795.0 ft
- Y = 799.0 ft – 795.0 ft = 4.0
- Z = 4
- S = 0.005
- Ls = 4.0(4+4)[1+0.005/(0.25-0.005)] = 32.65 ft
- ΔLs = 0.15*Ls = 0.15 * 32.65 ft = 4.9 ft

- Total Projection: P = W – D
  - W = 2ft + 2 ft diameter + 2 ft = 6 ft
  - P = 6 ft – 2 ft = 4 ft
- Number of collars = ΔLs / P = 4.9 ft / 4 ft = 1.23
  - Minimum of 2 collars per outlet conduit
  - <u>Use 2 anti-seep collars</u>
- Place both anti-seep collars in the saturation zone (within 32.65 feet of front edge of berm).
- Spacing between collars: between 10 and 25 feet

Additional Considerations:

- Vegetate the sides of the retention basin that are above the permanent pool with Item 670 Slope Erosion Protection per L&D Vol. 2, Section 1113.4.
- The 6" diameter underdrain (as per plan) called out in SCD WQ-1.1 should not be included in retention basins.
- For all open water carriers at each inlet and discharge from a retention basin, check the shear stress and ensure appropriate lining per L&D Vol. 2, Section 1102.3.2.
- For all discharges into or out of a retention basin, ensure that appropriate rock channel protection is included per L&D Vol. 2, Section 1105.2.5.
- Include calculated retention basin ponding elevations in the calculation of the hydraulic grade line for the upstream conveyance system per L&D Vol. 2, Section 1104.3.2.
- Attempt to locate structures outside of designated flood plains. If a retention basin encroaches on a flood plain, follow the flood assessment requirements in L&D Vol. 2 Section 1005.
- Ensure that safety criteria are met in the clear zone per L&D Vol. 1, Section 600.2.
- Ensure that no more than one foot of permanent standing water is located within the clear zone without barrier protection, per L&D Vol. 1, Section 601.1.1.
- Engage local project stakeholders in potential public safety considerations associated with retention basins.
- Develop a plan for how regular maintenance will be performed.
  - Vehicle access
  - Mowing
  - Removal of woody vegetation
  - Regular unclogging of the water quality outlet