Design Example
Residential Subdivision

Rhode Island Stormwater Design and Installation Standards Manual – December 2010

Public Training

March 22, 2010

Richard Claytor, P.E.
Horsley Witten Group, Inc.
508-833-6600

Horsley Witten Group, Inc.

Appendix D: Site Specific Design Examples

Design Example #1 Reaper Brook Estates

- Hypothetical Location: Smithfield, RI, discharge to Reaper Brook (1st-order stream) near the Stillwater River, a Warm Water fishery;
- Total site area, (A) = 80.5 acres; two study points at two outfalls;
- Site Soils Type: 100% HSG "B"; Recharge Factor, F = 0.35. Loamy-sand soils with average depth to groundwater ~ 10.0 feet.

Original Design Plan

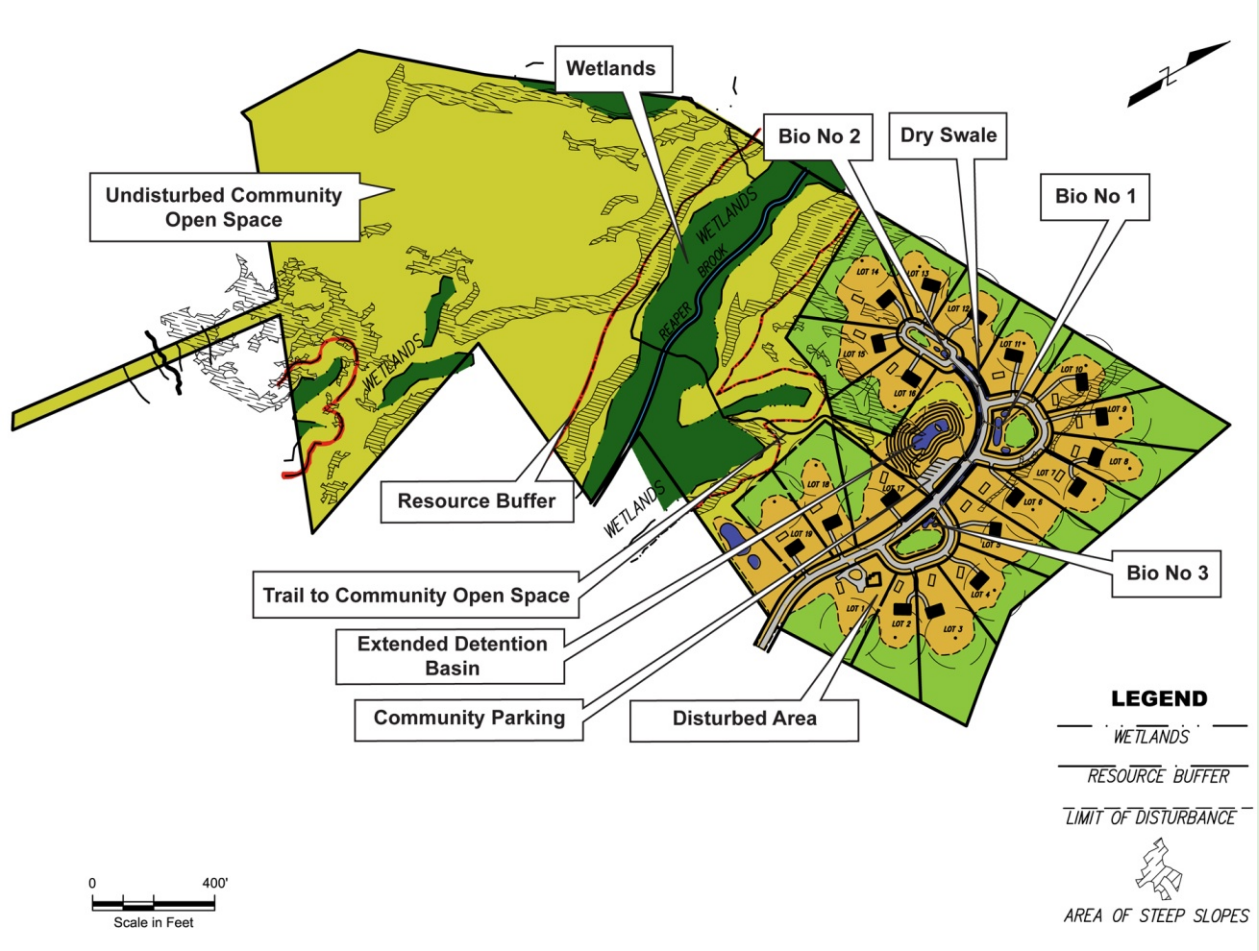
The Original Plan results:

- 19 single-family lots (min lot size = 2.75 ac, avg. lot size = 3.32 ac);
- 28.0 acres of disturbed area;
- 15.38 acres of open space (outside of lot areas);
- 3,200 linear feet of street;
- 5.51 acres of impervious cover (roads, houses, and driveways).

LID Site Planning and Design

- Avoid Impacts
  - Maximize undisturbed open space;
  - Maximize protection of waterways and wetlands;
  - Minimize clearing and grading/soil compaction;
- Reduce Impacts
  - Provide low maintenance vegetation;
  - Minimize impervious surfaces;
  - Maximize runoff time of travel (t_c);

Conservation Subdivision Design Plan



- 19 single family lots (min lot size = 1.1 ac and avg lot size =1.37 acres);
- 20.3 acres of disturbed area;
- 51.7 acres of open space (outside of lot areas);
- 2,500 linear feet of street;
- 3.83 acres of impervious cover (road, houses, driveways, and community parking lot).

Horsley Witten Group, Inc.

1. Strategies to Avoid the Impacts

A. Preservation of Undisturbed Areas

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ Limits of disturbance clearly marked on all construction plans.
- ☒ Mapped soils by Hydrologic Soil Group (HSG).
- ☒ Building envelopes avoid steep slopes, forest stands, riparian corridors, HSG D soils, and floodplains.
- ☒ New lots, to the extent practicable, have been kept out of freshwater and coastal wetland jurisdictional areas.
- ☒ Important natural areas (i.e., undisturbed forest, riparian corridors, and wetlands) identified and protected with permanent conservation easement.
- ☒ Percent of natural open space calculation is provided.
- ☒ Other (describe):

Explain constraints when a strategy is applied and/or proposed alternatives in space below:

Design completely preserves one whole side of the project. Open space is accessed by a community trail system, steep slopes are avoided except in a few isolated locations, natural vegetation is preserved in cul-de-sac and eyebrow islands.

B. Preservation of Buffers and Floodplains

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following:

- ☒ Applicable vegetated buffers of coastal and freshwater wetlands and perennial and intermittent streams have been preserved, where possible.
- ☒ Limits of disturbance included on all construction plans that protect applicable buffers
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

All lots are located out of wetland and riverbank buffers; limits of disturbance are clearly marked on all plans.

C. Minimized Clearing and Grading

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Site fingerprinting to extent needed for building footprints, construction access and safety (i.e., clearing and grading limited to 15 feet beyond building pad or 5 feet beyond road bed/shoulder).
- ☒ Other (describe):

Explain constraints and/or proposed alternatives in space below:

Clearing extends beyond houses to construct OWTS, wells, and grade a minimum yard area for each lot.

D. Locating Sites in Less Sensitive Areas

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ A site design process, such as conservation development, used to avoid or minimize impacts to sensitive resources such as floodplains, steep slopes, erodible soils, wetlands, hydric soils, surface waters, and their riparian buffers.
- ☐ Development located in areas with least hydrologic value (e.g., soil groups A and B)
- ☐ Development on steep slopes, grading and flattening of ridges has been avoided to the maximum extent practicable.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

The project was developed as a CDS. Sensitive areas have been avoided to the maximum extent practicable. Site soils are uniformly HSG B, thus hydrologic value is not a specific factor. Site itself consists of very steep slopes, and thus, will require significant grading, but the steepest slopes have been avoided.

E. Compact Development

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ A site design technique (e.g., conservation development) used to concentrate development to preserve as much undisturbed open space as practicable and reduce impervious cover.
- ☒ Reduced setbacks, frontages, and right- of- way widths have been used where practicable.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

See response to item D, above. Setbacks all reduced. R/W remains at 50 feet per town requirements.

F. Work with the Natural Landscape Conditions, Hydrology, and Soils

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ Stormwater management system mimics pre-development hydrology to retain and attenuate runoff in upland areas (e.g., cuts and fills limited and BMPs distributed throughout site; trees used for interception and uptake).
- ☒ The post-development time of concentration (t_c) should approximate pre-development t_c.
- ☒ Flow velocity in graded areas as low as practicable to avoid soil erosion (i.e., slope grade and/or length minimized). Velocities shall not exceed velocities in Appendix B, Table B-2.
- ☐ Plans show measures to prevent soil compaction in areas designated for Qualified Pervious Areas (QPAs) for better infiltration.
- ☐ Site designed to locate buildings, roadways and parking to minimize grading (cut and fill quantities)
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

For the most part, the site has been designed to retain natural features. Flow velocities are as low as possible for graded swales, and t_c as long as possible by draining through bioretention facilities and dry swales. QPAs for disconnected rooftop runoff undisturbed were possible in rear yards. Building and driveways located to avoid steep slopes, and street designed to minimize cuts and fills.

2. Strategies to Reduce the Impacts

A. Reduce Impervious Cover

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

☒ Reduced roadway widths	☐ Reduce driveway areas	☐ Reduced building footprint
☐ Reduced sidewalk area	☒ Reduced cul-de-sacs	☐ Reduced parking lot area
☐ Other (describe):		

Explain constraints and/or proposed alternatives in space below:

Roads designed with 20 foot paving width; 3-foot shoulders; and swales with 2 foot bottom width, 2.5:1 side slopes and 1 foot depth. Cul-de-sacs are looping lanes or eyebrows with open islands, sidewalks are not proposed, but pedestrian wood-chip trail connects project to undisturbed community open space.

Stormwater Design Components

- Required Design Criteria;
  - Recharge (Re_v);
  - Water Quality (WQ_v);
  - Channel Protection (Cp_v);
  - Overbank Control (Q_p) – 10 and 100 Yr Storms;
- Warm water fishery, no downstream hazards;
- Downstream analysis not required (20.3 acres and < 50% impervious)

LID Site Planning and Design

- Manage Impacts
  - Infiltrate precipitation near the source;
  - Disconnect impervious cover; and
  - Source controls to minimize or prevent exposure of pollutants

BMP Selection Criteria

- Recharge: (infiltration, filtering, open channels);
- Water Quality: (WVTS, infiltration, filtering, open channels, green roofs);
- Conveyance, Channel Protection and Overbank Flood Protection (WVTS, detention basins, vaults)

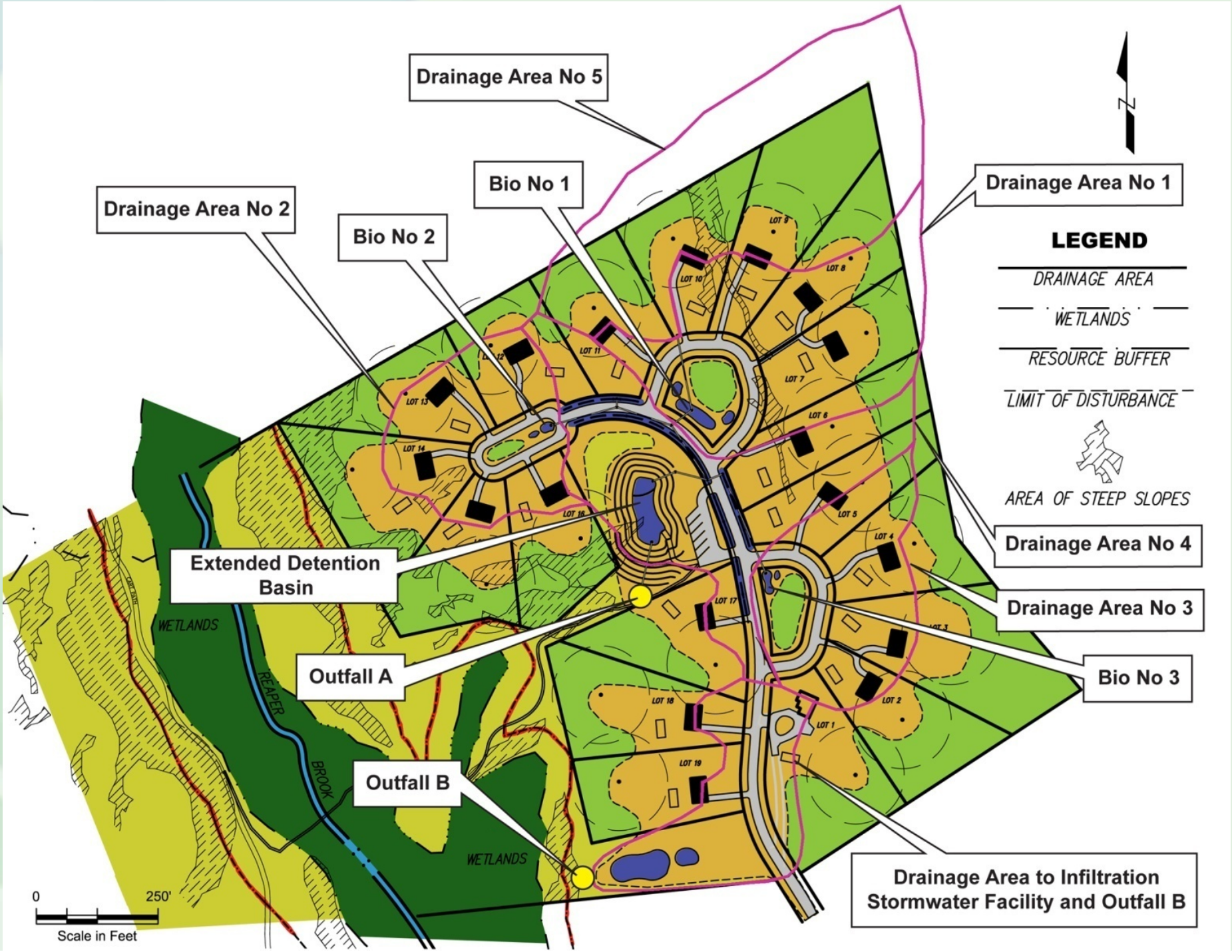
Selected BMPs

- Recharge:
  - Bioretention facilities and dry swale;
  - (could have used QPAs for rooftop runoff or dry wells).
- Water Quality:
  - Bioretention facilities and dry swale;
  - (could have used infiltration trenches, WVTS, porous pavement, maybe a sand filter).

Selected BMPs

- Channel Protection and Overbank Flood Protection:
  - Dry Extended Detention Basin (for both Cp_v and Q_P);
  - (could have potentially used a wet basin, WVTS);
  - DA too large for infiltration basin, underground storage not appropriate for residential subdivision.

Drainage Area Map



Base Data Summary

Location: Smithfield, RI, discharging to Reaper Brook (1st-order stream) near the Stillwater River, a Warm Water fishery.

Total parcel site area, (A) = 80.5 acres; two study points at two outfalls[1]. Outfall A has a post-development drainage area of 20.83 acres, Outfall B has a post-development drainage area of 2.33 acres.

Measured Impervious Area, I = 3.83 acres (3.36 acres at Outfall A; 0.47 acres at Outfall B).

Site Soils Type: 100% "B"; Recharge Factor, F = 0.35. Loamy-sand soils with average depth to groundwater ~ 10.0 feet.

Summary of Hydrologic Data[2]

Rainfall Depths		
1-year, 24-hour, Type III	=	3.1 inches
10-year, 24-hour, Type III	=	5.0 inches
100-year, 24-hour, Type III	=	8.9 inches
Post-development Conditions:		
Drainage Area:	=	20.83 acres[1]
1-year, 24-hour peak discharge	=	10.3 cfs
1-year, 24-hour runoff volume	=	0.68" = 1.173 ac-ft = 51,096 ft^3
10-year, 24-hour peak discharge	=	39.4 cfs
100-year, 24-hour peak discharge	=	105.4 cfs
Pre-development Conditions:		
Drainage Area	=	15.3 acres[3]
10-year, 24-hour peak discharge	=	11.1 cfs
100-year, 24-hour peak discharge	=	44.9 cfs

Required Storage Volumes (for Re_v and WQ_v)

Given Base Data in Table D-1 (for Outfall A):

The Recharge Volume (Re_v) is calculated using the equation from Section 3.3.2: For HSG B soils, F = 0.35 and I = 3.36 ac:

- Re_v = (1")(F)(I)/12 = (1")(0.35)(3.36 ac)/12 = **.098 ac-ft (= 4,269 ft^3)**

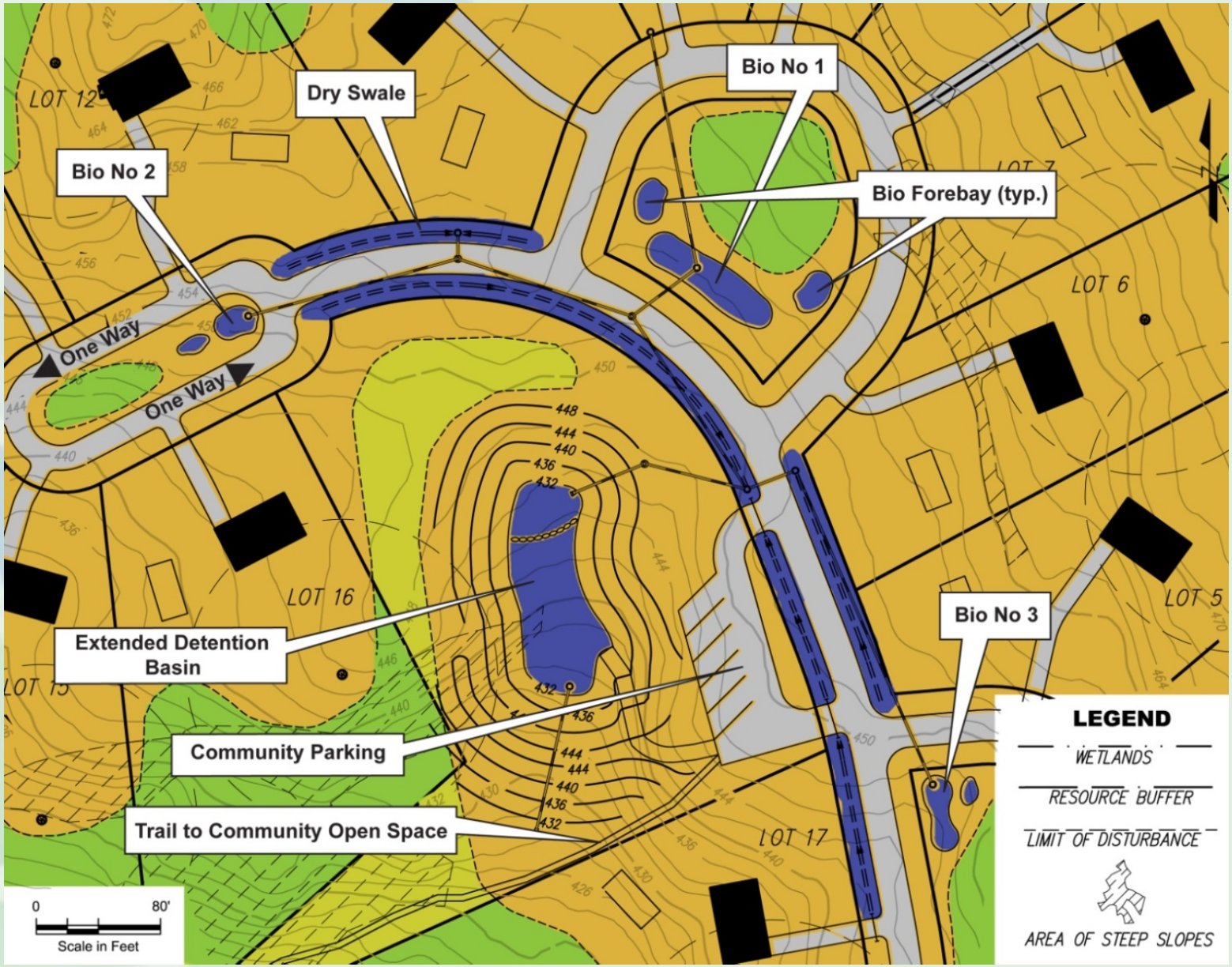
The Water Quality Volume (WQ_v) is calculated using the equation from Section 3.3.3: For I = 3.36 ac:

- WQ_v = (1.0")(I)/12 = 1.0" (3.36 ac)/12 = **0.28 ac-ft (12,197 ft^3)**

Check WQ_v > minimum req'd 0.2" for disturbed area (14.4 acres) draining to Outfall A:

  - WQ_v min = 0.2"(14.4 ac)/12 = 0.24 ac-ft; which is less than the computed value, so use 0.28 ac-ft

Bioretention, Dry Swales and Detention Basin



Horsley Witten Group, Inc.

Residential bioretention

Size Bioretention Required Surface Area (ft^2)

Bioretention facilities are sized in accordance with the treatment requirements in Section 5.5.4 according to the following equation:

$$A_f = (WQ_v)\ (d_f) \ / \ [(k)\ (h_f + d_f)\ (t_f)]$$

Where:

- A_f = Surface area of filter bed (ft^2)
- d_f = Filter bed depth (ft)
- k = Coefficient of permeability of filter media (ft/day)
- h_f = Average height of water above filter bed (ft)
- t_f = Design filter bed drain time (days) (2 days is the maximum t_f for bioretention)

Using Bioretention Area No. 2 (Bio 2) as an example, where the Drainage Area = 2.42 acres, and the impervious area = 0.51 acres:

Compute WQv = (1") 0.51 ac/12"/ft = 0.0425 ac-ft = 1,851.1 ft^3

For a filter bed depth of 2.5 feet, a k of 1 ft/day, and maximum head of 9" (average head of 4.5") and a 2-day drain time:

A_f = 1,851.1 ft^3(2.5 ft)/[(1.0 ft/day)(0.375 ft + 2.5 ft)(2 days)] = **805 ft^2**

Set overflow inlet elevation 0.75 ft above bioretention bottom elevation, round-up surface area to **850 ft^2**.

Size Sediment Forebay

Min Volume = 25% of WQ_v

= 0.25 (1,851 ft^3) = 462.8 ft^3

Min Surface Area (A_s) = 5,750 (Q)

Where Q = discharge from DA = $\%WQ_v$/86,400 sec

= 462.8 ft^3/86,400 sec

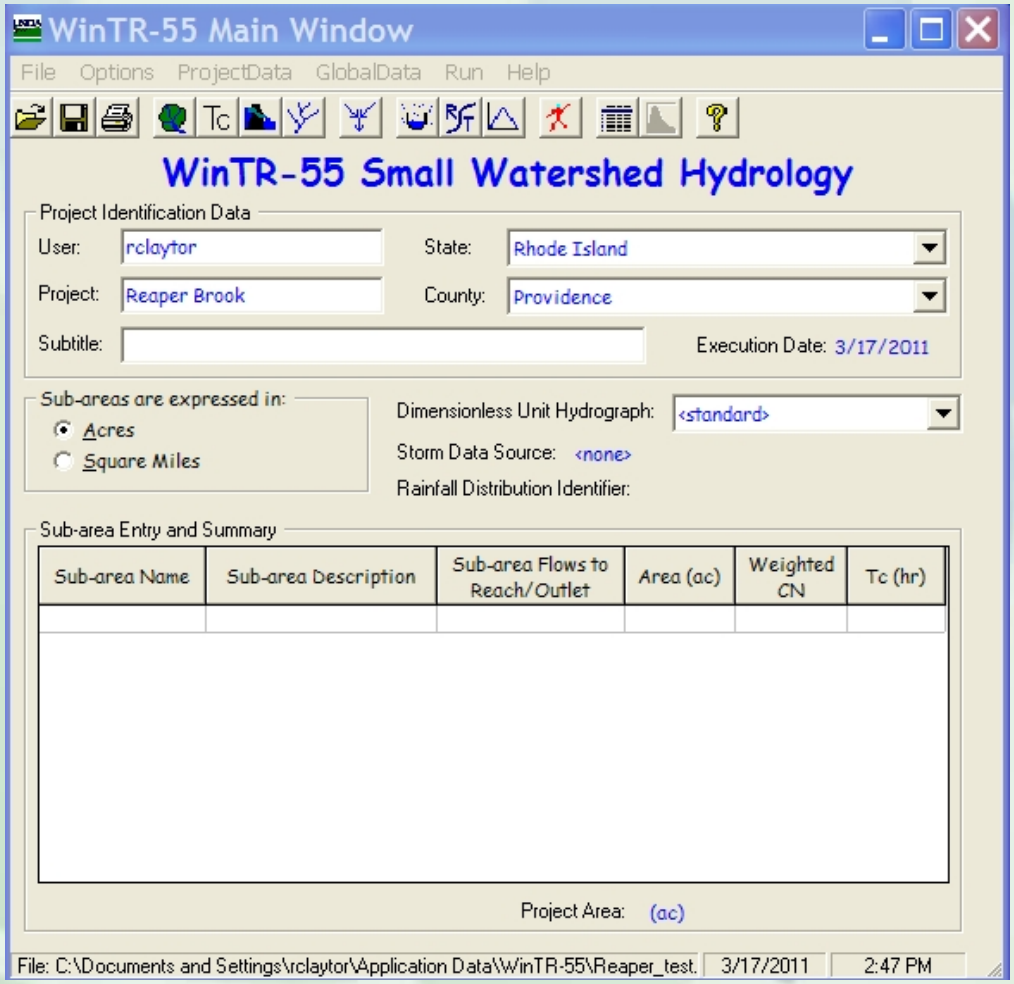
= 0.0054 cfs

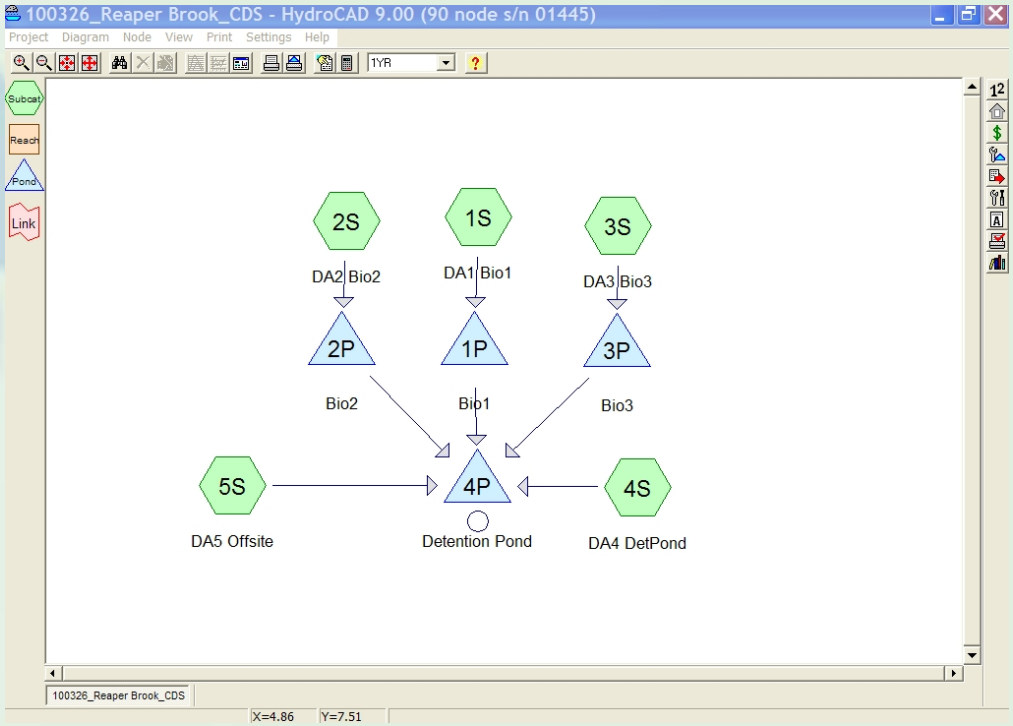
A_s = 5,750 (.0054) = 30.8 ft^2

Hydrology/Hydraulics
(Models and Such)

- NRCS Methods are required for estimating volumes/rates of runoff for treatment and attenuation (rational method ok for conveyance systems).
- Representative variables include:
  - Drainage area
  - Hydrologic soils group
  - Curve Number (CN)
  - Rainfall amount (P)
  - Antecedent Moisture Cond.
  - Orifice equation & coeff.
  - Land Use
  - Time of concentration (t_c)
  - Runoff Coefficient (C)
  - Return frequency (Year)
  - Rainfall Distribution (Type)
  - Weir equation & coeff.

Models and Such





Horsley Witten Group, Inc.

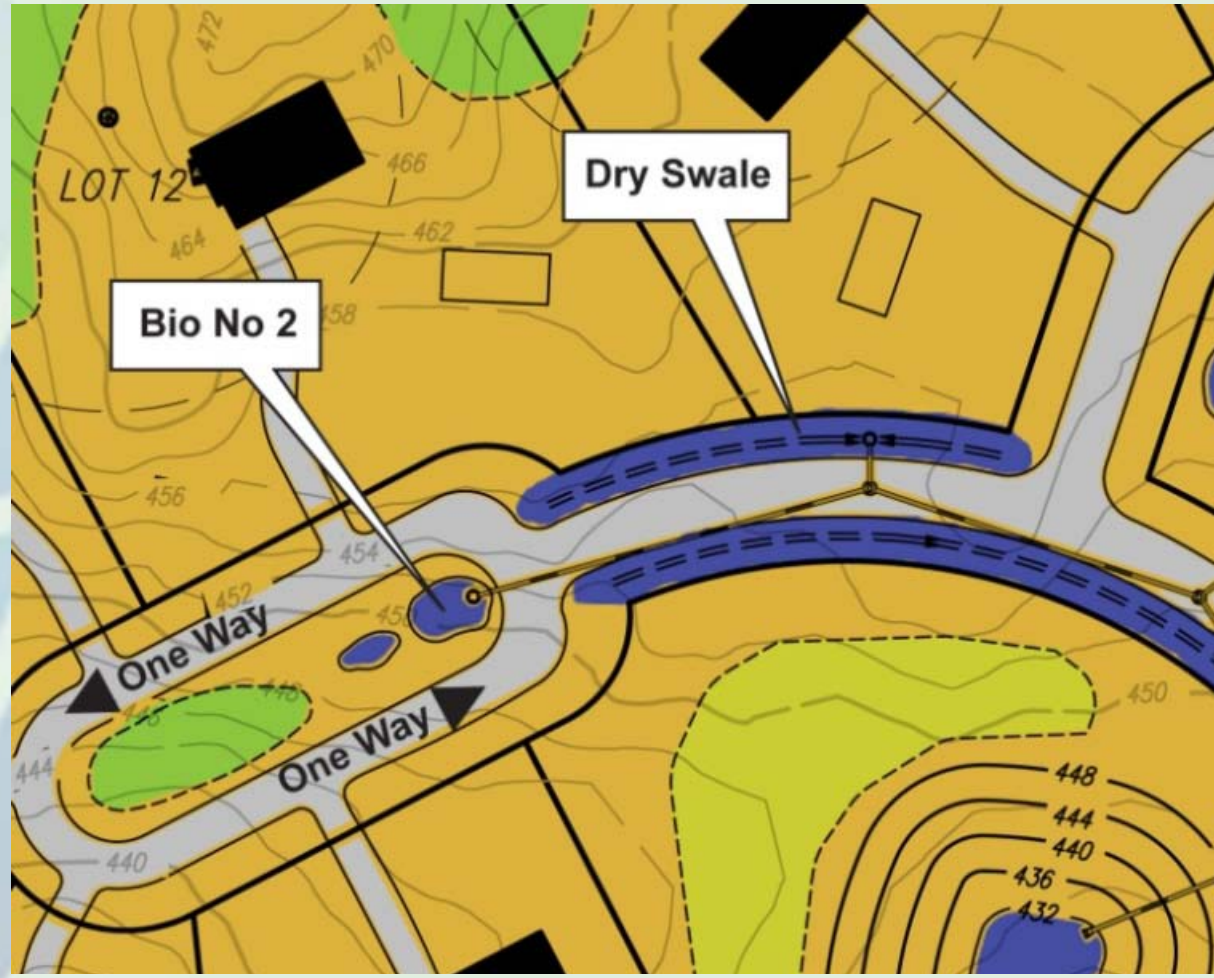
Model Bioretention Hydraulics (Example for Bio2)

1. Compute WQ_f

Adjust the CN to generate runoff equal to WQ_v:

$CN = 1000 / [10 + 5P + 10Q - 10(Q^2 + 1.25\,QP)^{½}]$

2. Calculate DA runoff volume in (inches): Q = (0.0425 ac-ft/2.42 ac)(12”/ft) = 0.211 inches
3. Run HydroCAD with the exfiltration outlet structure with constant velocity = 2.41”/hour. This is the recommended rate for loamy-sand soils



HydroCAD Output (WQ_v)

Summary for Pond 2P: Bio2

Inflow Area = 2.420 ac, 0.00% Impervious, Inflow Depth = 0.22" for WQv event
Inflow = 0.50 cfs @ 12.10 hrs, Volume= 0.044 af
Outflow = 0.06 cfs @ 13.83 hrs, Volume= 0.044 af, Atten= 88%, Lag= 103.9 min
Discarded = 0.06 cfs @ 13.83 hrs, Volume= 0.044 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.03 hrs
Peak Elev= 447.63' @ 13.83 hrs Surf.Area= 1,090 sf Storage= 612 cf

Plug-Flow detention time= 105.0 min calculated for 0.044 af (100% of inflow)
Center-of-Mass det. time= 104.9 min (1,000.8 - 895.9)

Volume	Invert	Avail.Storage	Storage Description
#1	447.00'	2,516 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

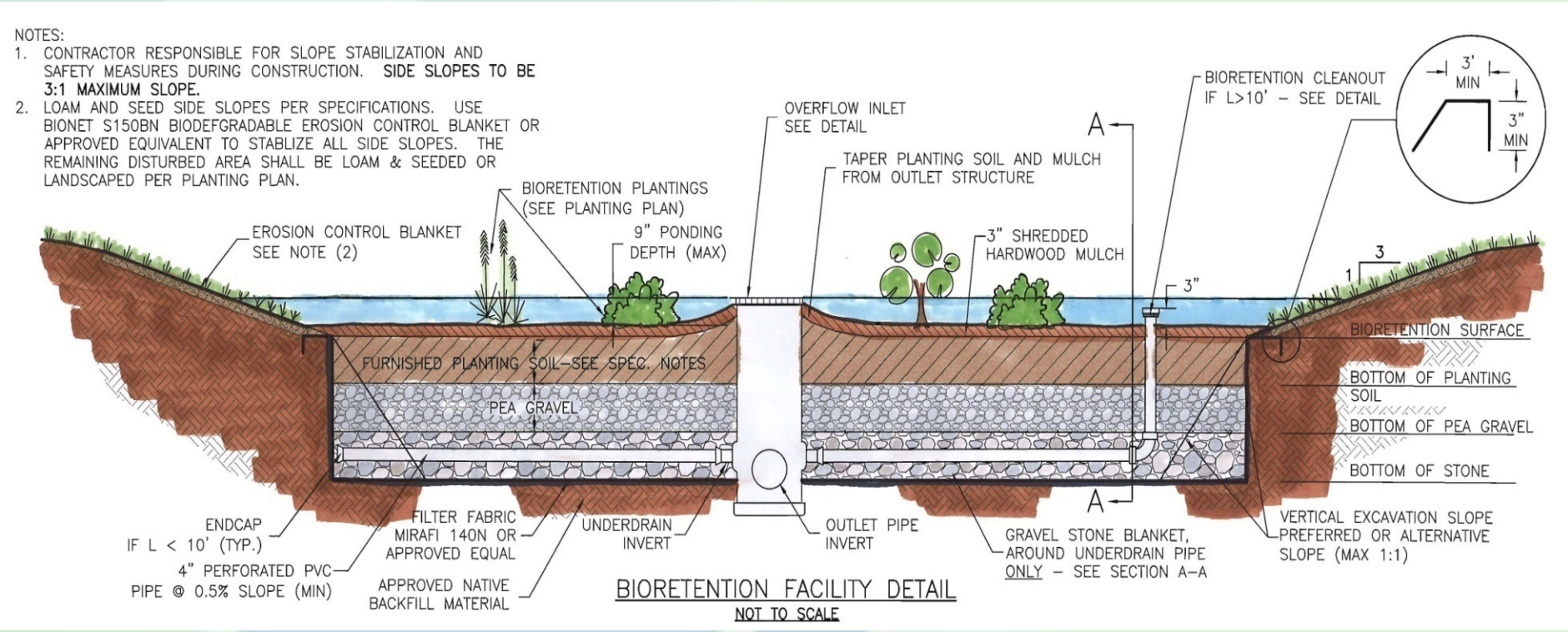
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
447.00	850	0	0
447.75	1,135	744	744
449.00	1,700	1,772	2,516

Device	Routing	Invert	Outlet Devices
#1	Discarded	447.00'	**2.410 in/hr Exfiltration over Surface area**
#2	Device 3	447.75'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	443.00'	**18.0" Round Culvert** L= 260.0' RCP, square edge headwall, Ke= 0.500 Outlet Invert= 439.00' S= 0.0154 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior

Discarded OutFlow Max=0.06 cfs @ 13.83 hrs HW=447.63' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.06 cfs)

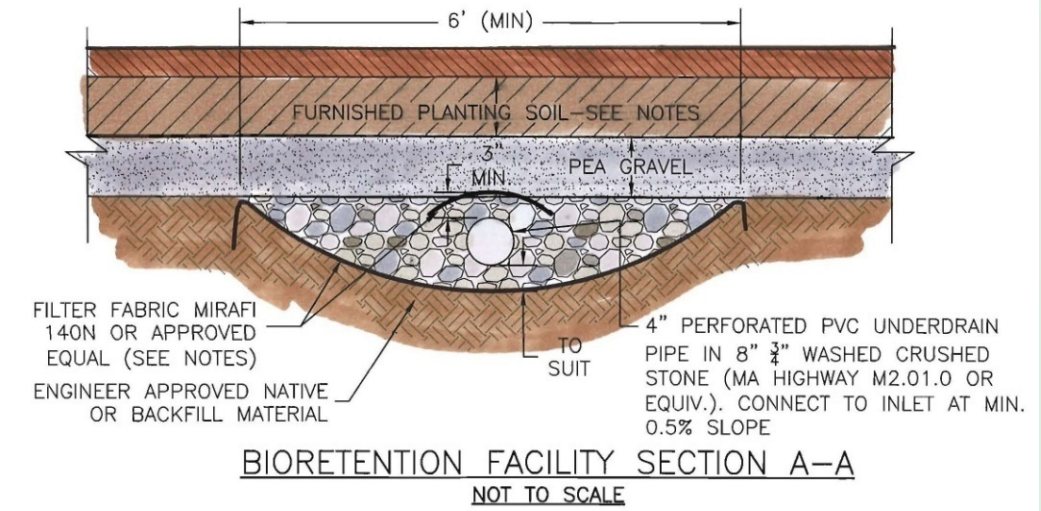
Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=447.00' (Free Discharge)
└─**3=Culvert** (Passes 0.00 cfs of 14.46 cfs potential flow)
└─**2=Orifice/Grate** (Controls 0.00 cfs)

Bioretention: Typical Details



BIORETENTION FACILITY DETAIL

NOT TO SCALE



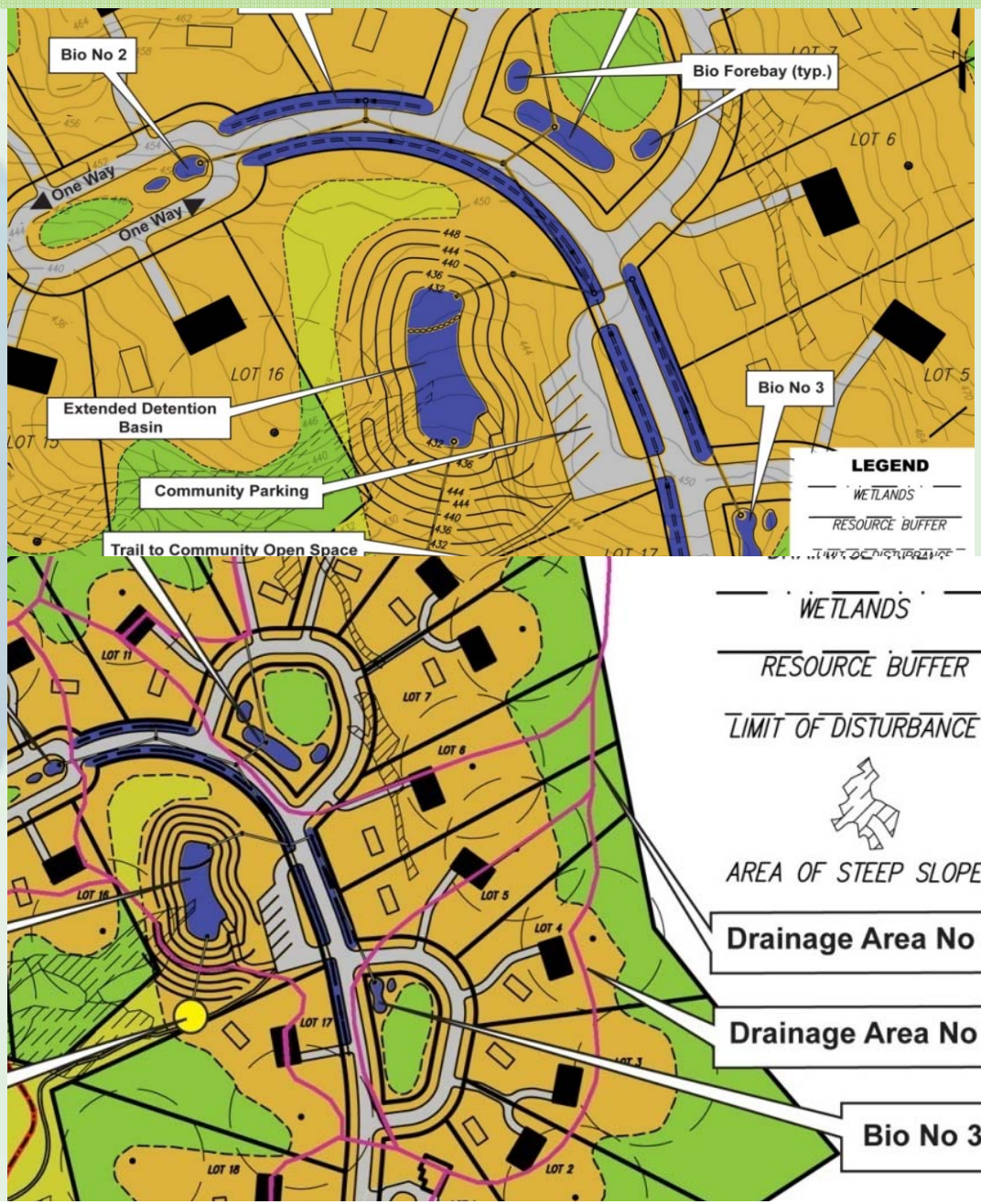
BIORETENTION FACILITY SECTION A–A

NOT TO SCALE

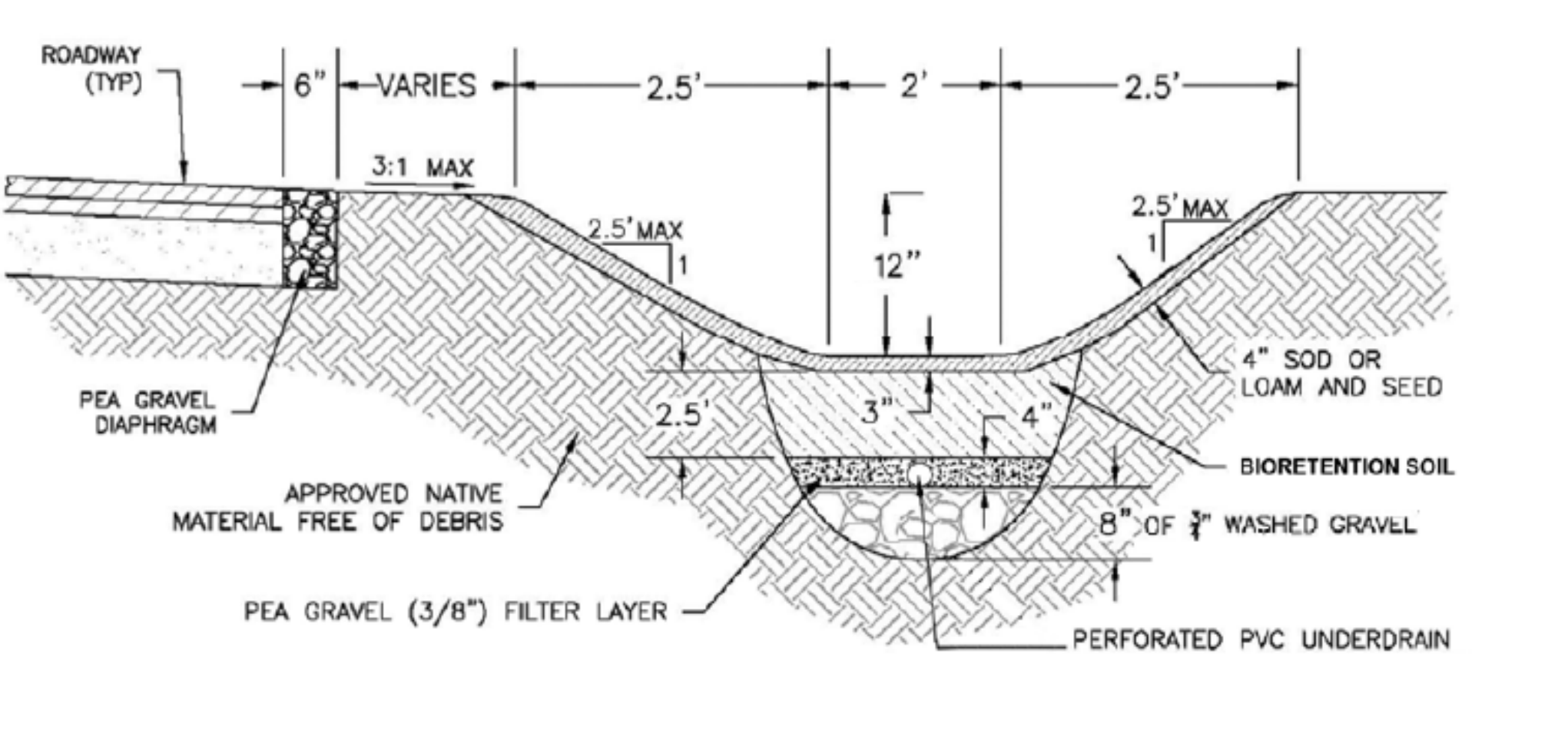
Horsley Witten Group, Inc.

Size Dry Swales for Water Quality Treatment

1. Compute WQ_v for DA #4
2. $WQ_v = (1'')(1.1\ ac)/12''/ft = 0.093\ ac\text{-}ft = 3{,}993\ ft^3$
3. $A_f = WQ_v(d_f)/[k(h_f + d_f)(t)]$
   $= 3{,}993\ ft^3\ (2.5')/[1.0'/day(0.25' + 2.5')(2\ days)] = 1{,}815\ ft^2$
4. For Dry Swales with 2 ft bottom width; Length = $1{,}815\ ft^2/2\ ft$ = 907.5 ft
5. 950 feet are provided > 907.5 OK
6. Set Minimum slope = 1.0%
7. Set drainage inlets 6″ above swale bottom.
8. Provide underdrain system
9. Check erosive velocities & capacity



Dry Swale Typical Section



Check Swale Flow Capacity

- For erosive velocity during 1-year storm

  $Q_{1\text{-yr}} = 5.3$ cfs

- For flow capacity during 10-year storm

  $Q_{10\text{-yr}} = 13.7$ cfs

Note: flow rates from HydroCAD Results for DA #4

Confirm Re_v has been achieved

% Volume Method:

Required Re_v = 0.098 ac-ft (= 4,269 ft^3)

Confirm infiltrating bioretention facilities combined volume > 4,269 ft^3

Provided Re_v = 0.179 ac-ft (= 7,798 ft^3)

% Area Method:

Required Re_a = (F)(I) = (0.35)(3.83 ac) = 1.34 ac

Confirm area draining to infiltrating bioretention facilities > 1.34 ac

Provided Re_a = 1.96 impervious acres

Extended Detention Basin
For Cp_v and Q_p Controls

Req'd $Cp_v = 0.65\ (V_r) = 0.65\ (38{,}725\ ft^3) = 25{,}171\ ft^3$

(short-cut method)

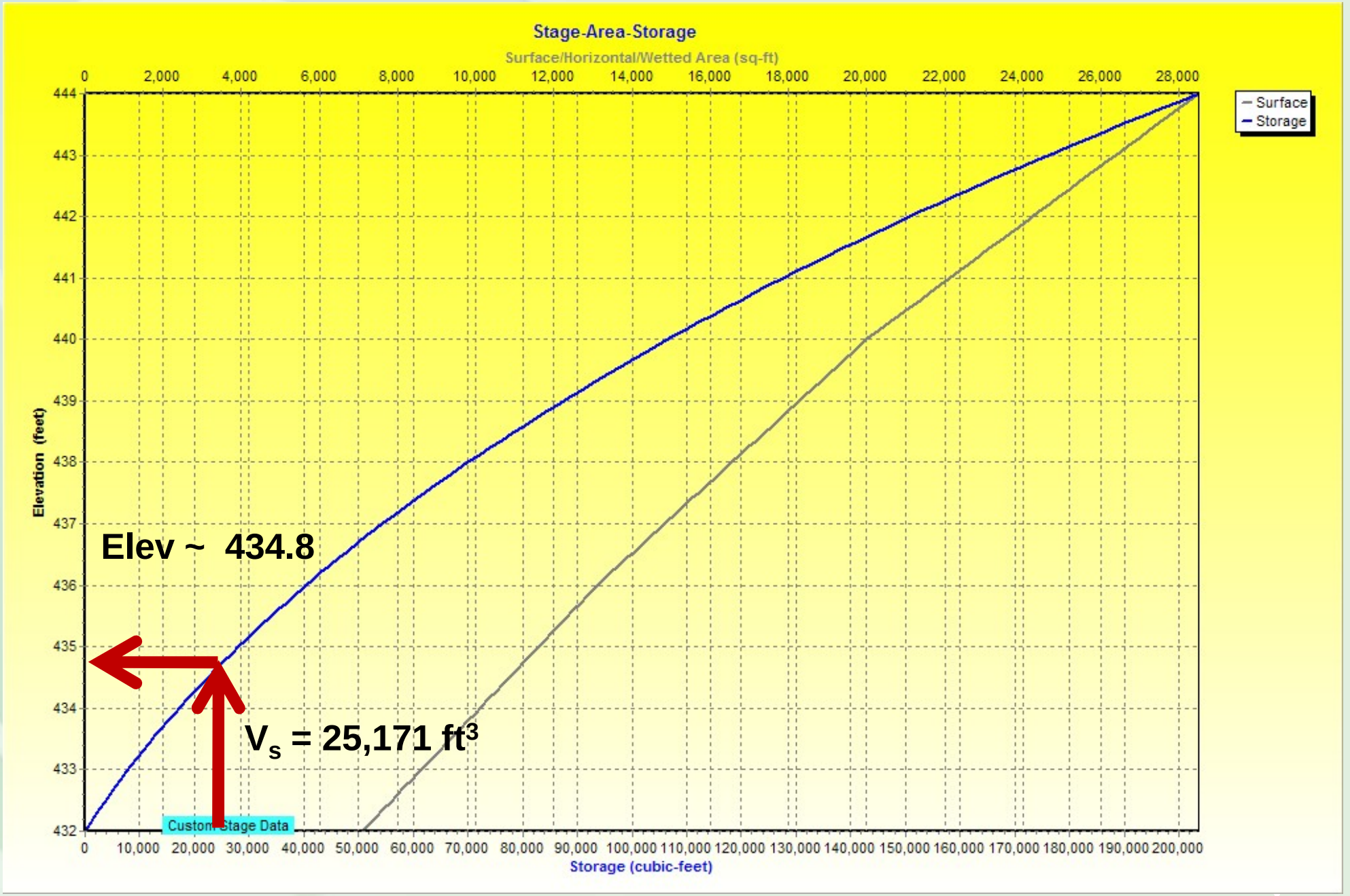
For 24 hour Extended Detention (ED); average outlet release of the 1-year INFLOW VOLUME

= 38,725/24 hr(3600 sec/hr) = 0.45 cfs

ED Basin Grading

Typical ED Basin (with Micro-pool)

ED Basin Volume



Size Outlet Devise for Cp_v

Size Orifice for 24 ED

Approx. Average Head (ft)

h_{avg} = (434.8 -432.0)/2 = 1.4 ft

Orifice Equation: $Q_{CPv} = C(A)(2g*h_{avg})^{1/2}$

0.45 cfs = $0.6(A)(64.4*1.4)^{1/2}$

A = 0.08 ft^2 = $\pi D^2/4$: D = 0.32' = 3.84”

Use D = 3.0” (will provide conservative detention time)

HydroCAD Output (Cp_v)

Summary for Pond 4P: Detention Pond

Inflow Area = 20.830 ac, 19.18% Impervious, Inflow Depth = 0.51" for 1YR event
Inflow = 9.51 cfs @ 12.16 hrs, Volume= 0.889 af
Outflow = 0.39 cfs @ 17.39 hrs, Volume= 0.534 af, Atten= 96%, Lag= 313.8 min
Primary = 0.39 cfs @ 17.39 hrs, Volume= 0.534 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.03 hrs
Peak Elev= 434.86' @ 17.39 hrs Surf.Area= 11,396 sf Storage= 26,486 cf

Plug-Flow detention time= 503.2 min calculated for 0.534 af (60% of inflow)
Center-of-Mass det. time= 396.9 min (1,254.6 - 857.7)

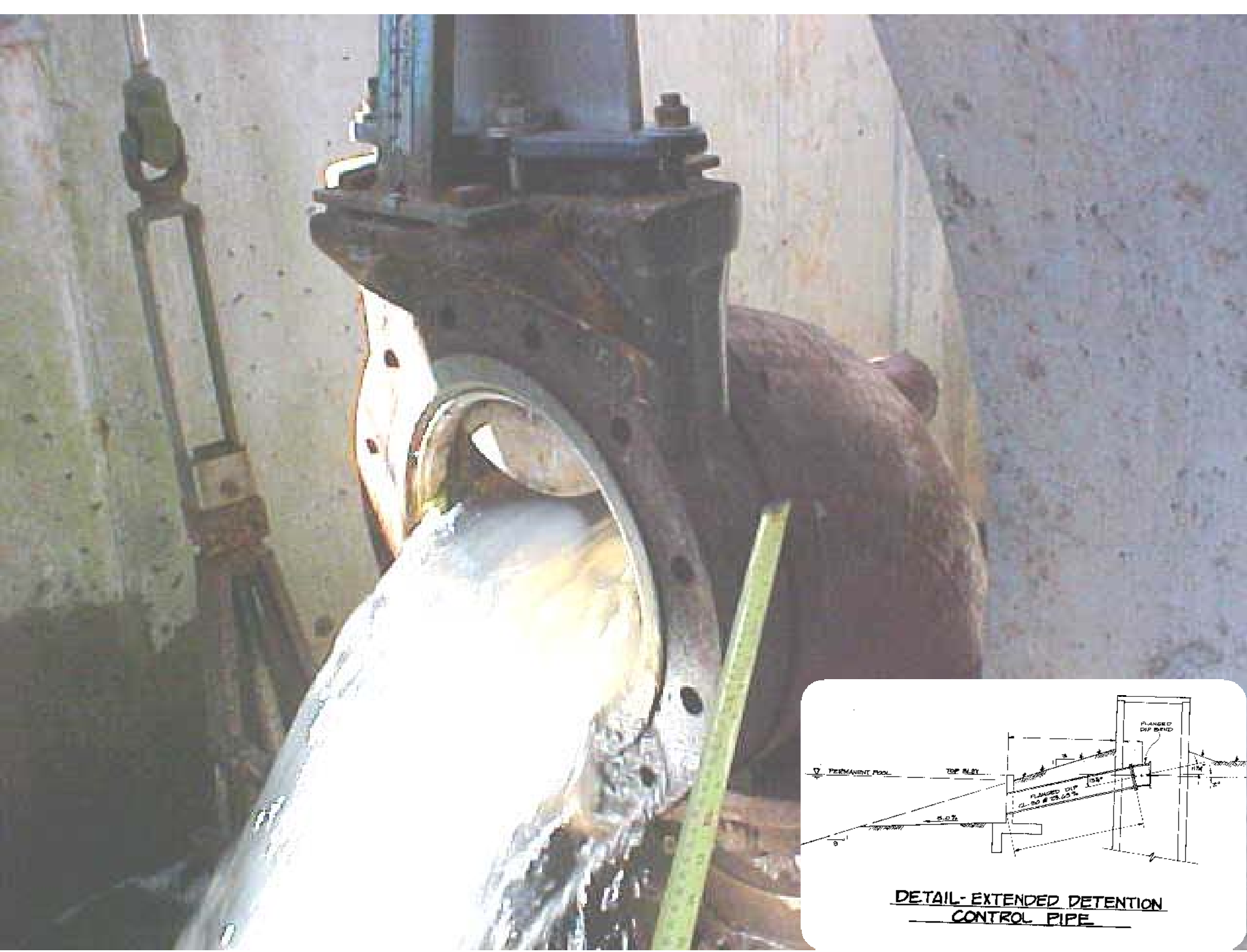
Volume	Invert	Avail.Storage	Storage Description
#1	432.00'	203,600 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
432.00	7,100	0	0
436.00	13,100	40,400	40,400
440.00	20,000	66,200	106,600
444.00	28,500	97,000	203,600

Device	Routing	Invert	Outlet Devices
#1	Device 4	432.00'	**3.0" Vert. Orifice/Grate** C= 0.600
#2	Device 4	434.90'	**24.0" W x 12.0" H Vert. Orifice/Grate** C= 0.600
#3	Device 4	437.00'	**36.0" W x 12.0" H Vert. Orifice/Grate** C= 0.600
#4	Primary	428.00'	**21.0" Round Culvert** L= 110.0' RCP, square edge headwall, Ke= 0.500 Outlet Invert= 426.00' S= 0.0182 '/' Cc= 0.900 n= 0.013 Concrete pipe, straight & clean

Primary OutFlow Max=0.39 cfs @ 17.39 hrs HW=434.86' (Free Discharge)
└4=**Culvert** (Passes 0.39 cfs of 28.34 cfs potential flow)
  ├1=**Orifice/Grate** (Orifice Controls 0.39 cfs @ 7.97 fps)
  ├2=**Orifice/Grate** (Controls 0.00 cfs)
  └3=**Orifice/Grate** (Controls 0.00 cfs)

Inc.



DETAIL- EXTENDED DETENTION CONTROL PIPE

Extended Detention Basin
For Q_p Controls

Size outlets for Q_p controls (10 and 100-year storms)

- Criteria requires attenuation of post-development flows to the pre-development flow:
  - $Q_{10\text{-pre}}$ = 11.1 cfs
  - $Q_{100\text{-pre}}$ = 44.9 cfs

1. Calculate 10-year release rate and req'd storage

Q_p (10-year) Outlet and Storage

- $Q_{10\text{-out}}$ = 11.1 cfs – 0.5 cfs = 10.6 cfs

(the 0.5 cfs is the flow out of the 3" Cp_v orifice at the estimated 10-year elevation)

Size Orifice

Estimated Head (ft): h = (436.5 – (434.9 + .05) = 1.1 ft

Orifice Equation

$Q_{10\text{-out}} = C(A)(2g*h)^{1/2}$

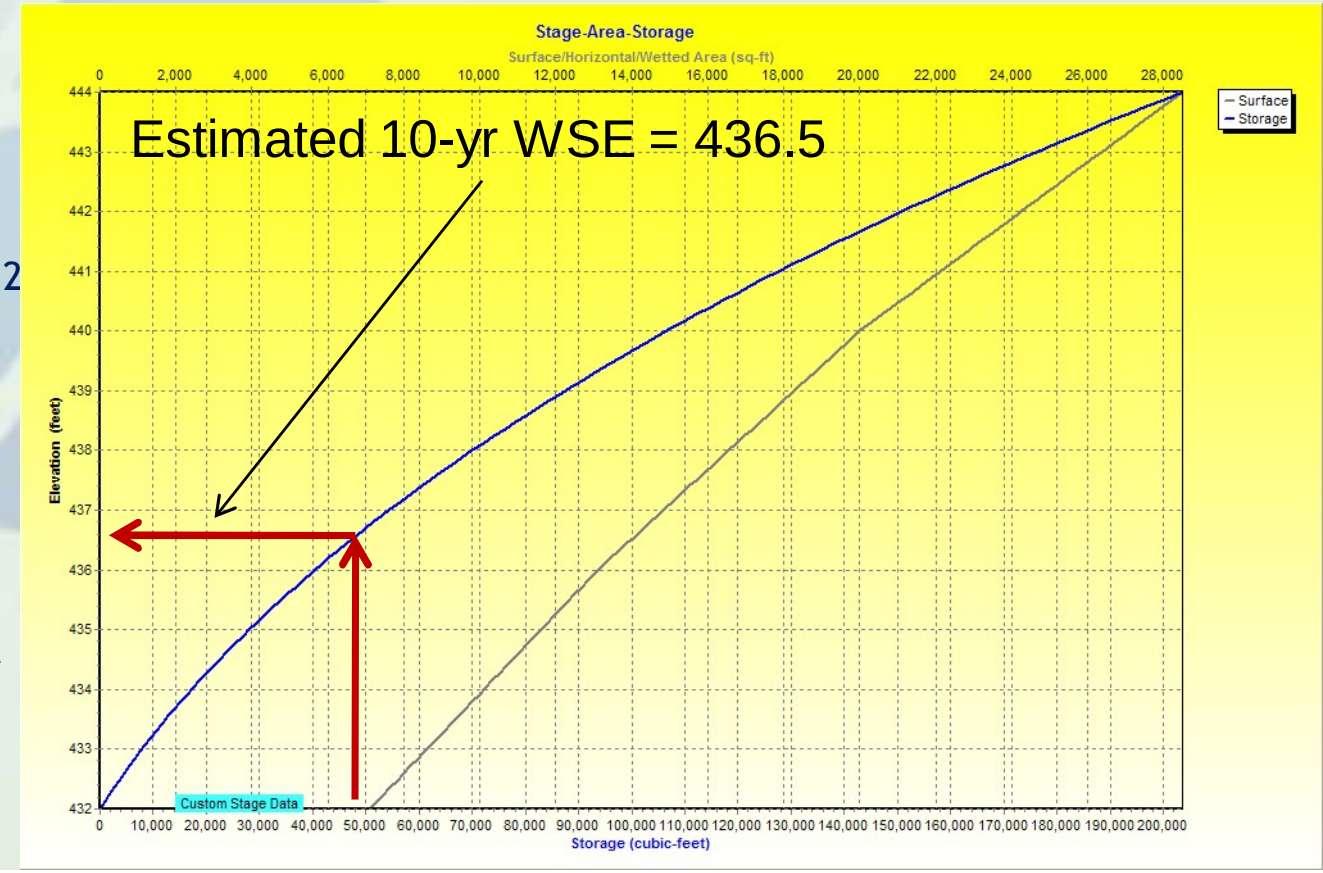
$10.6 \text{ cfs} = 0.6(A)(64.4*1.1)^{1/2}$

$A = 2.1 \text{ ft}^2$: for 12" high slot

l = 2.1' = 25.2"

Use 24.0" x 12" vert. slot

Elevation = 434.9



HydroCAD Output (Q_{p-10})

Summary for Pond 4P: Detention Pond

Inflow Area = 20.830 ac, 19.18% Impervious, Inflow Depth = 1.67" for 10YR event
Inflow = 39.44 cfs @ 12.10 hrs, Volume= 2.906 af
Outflow = 10.74 cfs @ 12.55 hrs, Volume= 2.457 af, Atten= 73%, Lag= 27.0 min
Primary = 10.74 cfs @ 12.55 hrs, Volume= 2.457 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.03 hrs
Peak Elev= 436.55' @ 12.55 hrs Surf.Area= 14,050 sf Storage= 47,876 cf

Plug-Flow detention time= 179.1 min calculated for 2.455 af (84% of inflow)
Center-of-Mass det. time= 116.9 min (957.7 - 840.7)

Volume	Invert	Avail.Storage	Storage Description
#1	432.00'	203,600 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
432.00	7,100	0	0
436.00	13,100	40,400	40,400
440.00	20,000	66,200	106,600
444.00	28,500	97,000	203,600

Device	Routing	Invert	Outlet Devices
#1	Device 4	432.00'	**3.0" Vert. Orifice/Grate** C= 0.600
#2	Device 4	434.90'	**24.0" W x 12.0" H Vert. Orifice/Grate** C= 0.600
#3	Device 4	437.00'	**36.0" W x 12.0" H Vert. Orifice/Grate** C= 0.600
#4	Primary	428.00'	**21.0" Round Culvert** L= 110.0' RCP, square edge headwall, Ke= 0.500 Outlet Invert= 426.00' S= 0.0182 '/' Cc= 0.900 n= 0.013 Concrete pipe, straight & clean

Primary OutFlow Max=10.74 cfs @ 12.55 hrs HW=436.55' (Free Discharge)
└─**4=Culvert** (Passes 10.74 cfs of 32.08 cfs potential flow)
  ├─**1=Orifice/Grate** (Orifice Controls 0.50 cfs @ 10.13 fps)
  ├─**2=Orifice/Grate** (Orifice Controls 10.24 cfs @ 5.12 fps)
  └─**3=Orifice/Grate** (Controls 0.00 cfs)

Extended Detention Basin
For Q_p Controls

Size outlets for Q_p controls (10 and 100-year storms)

- Criteria requires attenuation of post-development flows to the pre-development flow:
  - $Q_{10\text{-pre}}$ = 11.1 cfs
  - $Q_{100\text{-pre}}$ = 44.9 cfs

2. Calculate 100-year release rate and req'd storage

Q_p (100-year) Outlets and Storage

- $Q_{100\text{-out}}$ = 44.9 cfs (subtract lower structure releases)

Set Top of Weir of Outlet Control Structure

Set top above 10-year elev, say 437.0

Estimated Head (ft): h = (440.5 - (437.0 + 0.5) = 3.0 ft

Size Outlet Pipe to Control 100-year release rate

Orifice Equation: OCS

Q = 44.9 - (18.5 + 0.7) = 25.7 cfs

$Q_{100\text{-out}} = C(A)(2g*h)^{1/2}$

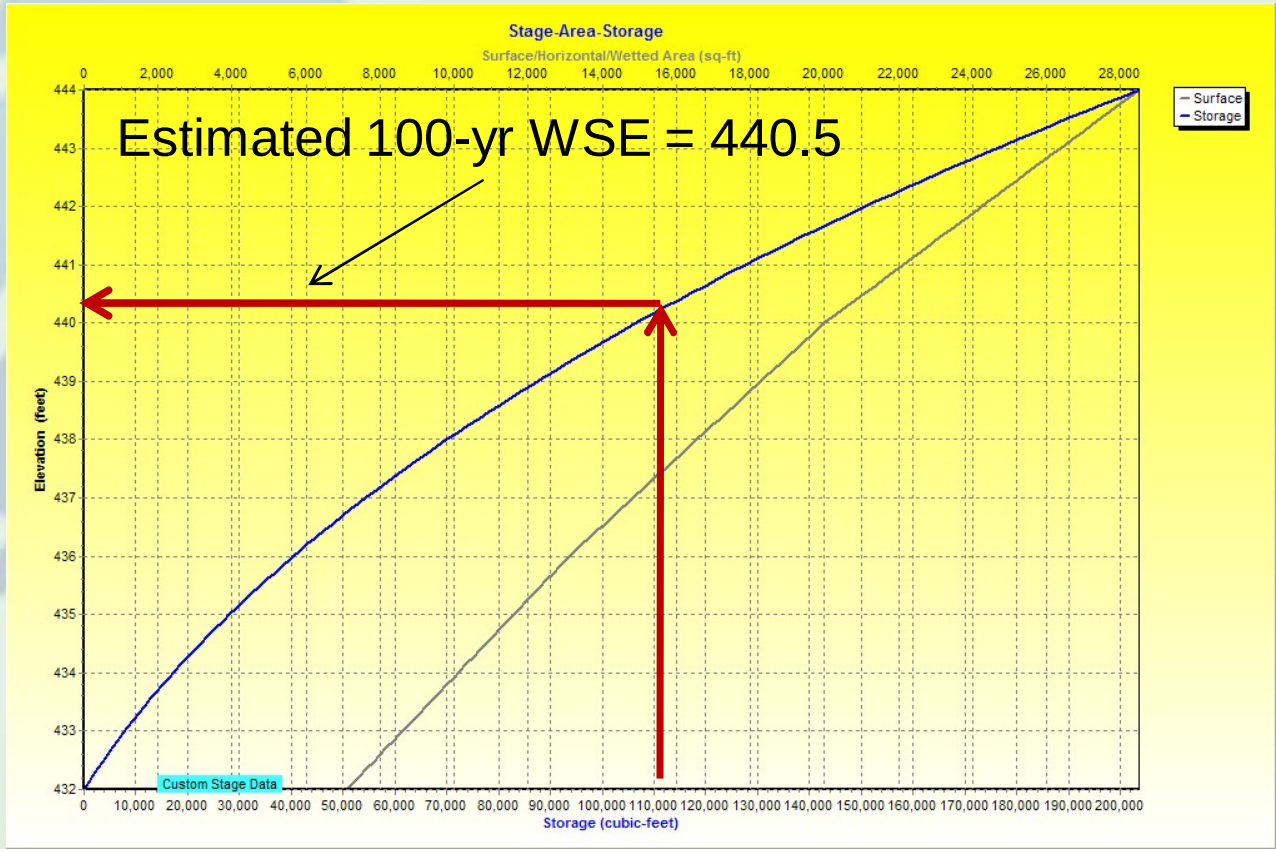
25.7 cfs = $0.6(A)(64.4*3.0)^{1/2}$

A = 3.08 ft^2: for 12" slot

l = 3.08' = 37"

Use 36.0" x 12" vert. slot

Elevation = 437.9

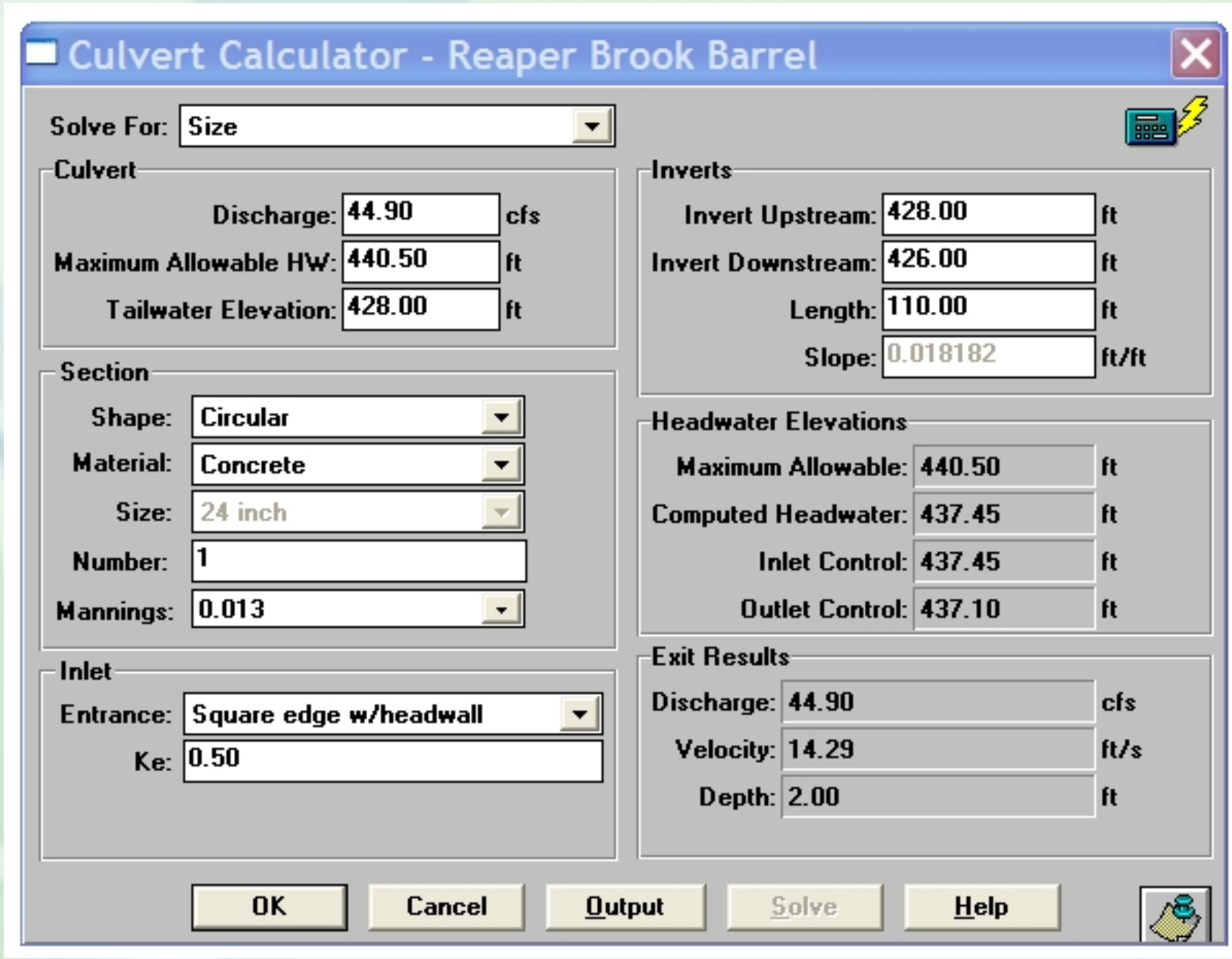


Q_P (100-year) Outlets
Continued

- $Q_{100\text{-out}}$ = 44.9 cfs; size outlet pipe

- Trial and error in HydroCAD (or other generally accepted TR-55/TR-20 H/H software);
- Culvert Software;
- "Old School" Culvert Nomographs.

Culvert Software



Horsley Witten Group, Inc.

Old School

PROJECT: _____ DESIGNER: _____

DATE: _____

HYDROLOGIC AND CHANNEL INFORMATION

Q_1 = _____ TW_1 = _____

Q_2 = _____ TW_2 = _____

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}
Q_2 = CHECK DISCHARGE, SAY Q_{50} OR Q_{100})

SKETCH

STATION : _____

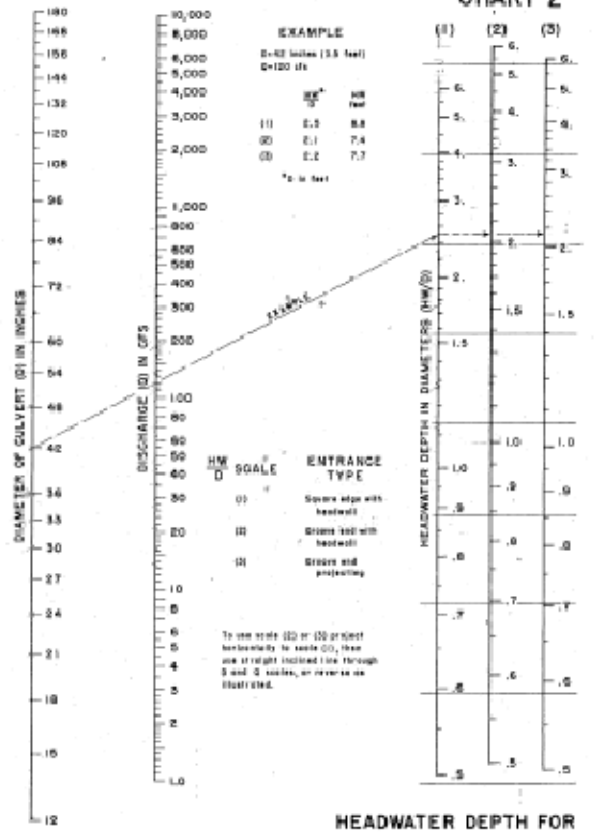
MEAN STREAM VELOCITY = _____

MAX. STREAM VELOCITY = _____

CULVERT DESCRIPTION (ENTRANCE TYPE)	Q	SIZE	HEADWATER COMPUTATION										CONTROLLING HW	OUTLET VELOCITY	COST	COMMENTS
			INLET CONT.		OUTLET CONTROL HW=H + h_0 −LS$_0$											
			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c+D}{2}$	TW	h_0	LS$_0$	HW				

SUMMARY & RECOMMENDATIONS:

CHART 2

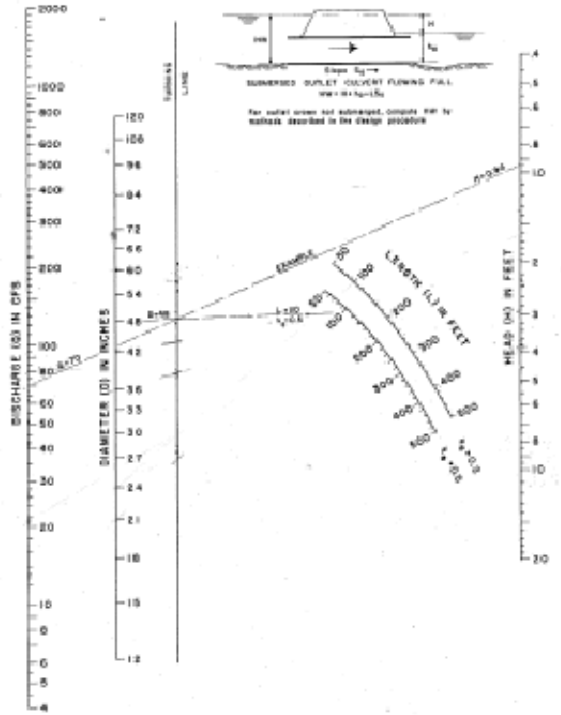


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

HEADWATER SCALES 2 & 3 REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 9-



HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n=0.012

Hor

HydroCAD Output (Q_{p-100})

Summary for Pond 4P: Detention Pond

Inflow Area = 20.830 ac, 19.18% Impervious, Inflow Depth = 4.75" for 100YR event
Inflow = 105.40 cfs @ 12.11 hrs, Volume= 8.240 af
Outflow = 38.96 cfs @ 12.44 hrs, Volume= 7.766 af, Atten= 63%, Lag= 20.3 min
Primary = 38.96 cfs @ 12.44 hrs, Volume= 7.766 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.03 hrs
Peak Elev= 440.53' @ 12.44 hrs Surf.Area= 21,134 sf Storage= 117,575 cf

Plug-Flow detention time= 91.8 min calculated for 7.759 af (94% of inflow)
Center-of-Mass det. time= 61.9 min (884.2 - 822.3)

Volume	Invert	Avail.Storage	Storage Description
#1	432.00'	203,600 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
432.00	7,100	0	0
436.00	13,100	40,400	40,400
440.00	20,000	66,200	106,600
444.00	28,500	97,000	203,600

Device	Routing	Invert	Outlet Devices
#1	Device 4	432.00'	**3.0" Vert. Orifice/Grate** C= 0.600
#2	Device 4	434.90'	**24.0" W x 12.0" H Vert. Orifice/Grate** C= 0.600
#3	Device 4	437.00'	**36.0" W x 12.0" H Vert. Orifice/Grate** C= 0.600
#4	Primary	428.00'	**21.0" Round Culvert** L= 110.0' RCP, square edge headwall, Ke= 0.500 Outlet Invert= 426.00' S= 0.0182 '/' Cc= 0.900 n= 0.013 Concrete pipe, straight & clean

Primary OutFlow Max=38.96 cfs @ 12.44 hrs HW=440.53' (Free Discharge)
└**4=Culvert** (Barrel Controls 38.96 cfs @ 16.20 fps)
  └**1=Orifice/Grate** (Passes < 0.69 cfs potential flow)
  └**2=Orifice/Grate** (Passes < 21.81 cfs potential flow)
  └**3=Orifice/Grate** (Passes < 25.12 cfs potential flow)

Summary of Results

Table D-3 Design Example Summary of Results

Criteria	Required	Provided	Practice Notes
Recharge Volume (Re_v)	0.098 ac-ft	0.178 ac-ft	3 exfiltrating bioretention facilities
Water Quality Volume (WQ_v)	0.28 ac-ft	> 0.28 ac-ft[1]	3 bioretention facilities and dry swale system
Channel Protection volume (CP_v)	0.58 ac-ft	0.61 ac-ft peak release rate= 0.4 cfs	Dry extended detention basin peak elev. = 434.9 ft
Overbank Protection (Q_p)	Pre-development peak: $Q_{p\text{-}10}$= 11.1 cfs $Q_{p\text{-}100}$ = 44.9 cfs	Post-development basin peak release rate: $Q_{p\text{-}10}$= 10.7 cfs $Q_{p\text{-}100}$ = 39.0 cfs	Detention storage 10-yr peak elev.= 436.6 ft 100-yr peak elev.= 440.5 ft

[1] Because bioretention is a flow-through device the storage volume of these facilities must be at least ¾ of the computed WQ_v, yet total volume of infiltration plus dry swale volume exceeds 0.28 ac-ft.

3. Strategies to Manage the Impacts

A. Disconnecting Impervious Area

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Impervious surfaces have been disconnected to QPAs to the extent possible.
- ☒ Other (describe):

Explain constraints and/or proposed alternatives in space below:

Rooftops from several lots will drain to QPAs but no specific credit has been calculated.

B. Mitigation of Runoff at the point of generation

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ Roof runoff has been directed to a QPA, such as a yard or vegetated area.
- ☒ Roof runoff has been directed to a lower impact practice such as a rain barrel or cistern.
- ☐ A green roof has been designed to reduce runoff.
- ☒ Small-scale BMPs applied at source.
- ☒ Other (describe):

Explain constraints and/or proposed alternatives in space below:

Open section road provided instead of closed section with dry swale.

C. Stream/Wetland Restoration

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Historic drainage patterns have been restored by removing closed drainage systems and/or restoring degraded stream channels and/or wetlands.
- ☐ Removal of invasive species.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

Stream is currently in stable condition, and wetlands are pristine.

D. Reforestation

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ Low maintenance landscaping and native vegetation has been proposed.
- ☒ Trees are proposed to be planted or conserved to reduce runoff volume, increase nutrient uptake, and provide shading and habitat.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

E. Source Control

☐ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☒ Source control techniques such as street sweeping or pet waste management have been proposed.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

Aggressive pet waste management will be implemented, and enforced in neighborhood association rules to increase effectiveness of stormwater treatment system.

Other Design Features

- Some rooftops drain to Qualified Pervious Areas (QPAs);
- Open space is commonly owned (i.e., community open space);
- Retained native vegetation where possible (note cul-de-sac islands);
- Meets well and septic separation distances.