# Rhode Island Stormwater Design and Installations Standards Manual

Public Workshop

BMP Design – Critical Elements

March 22, 2011

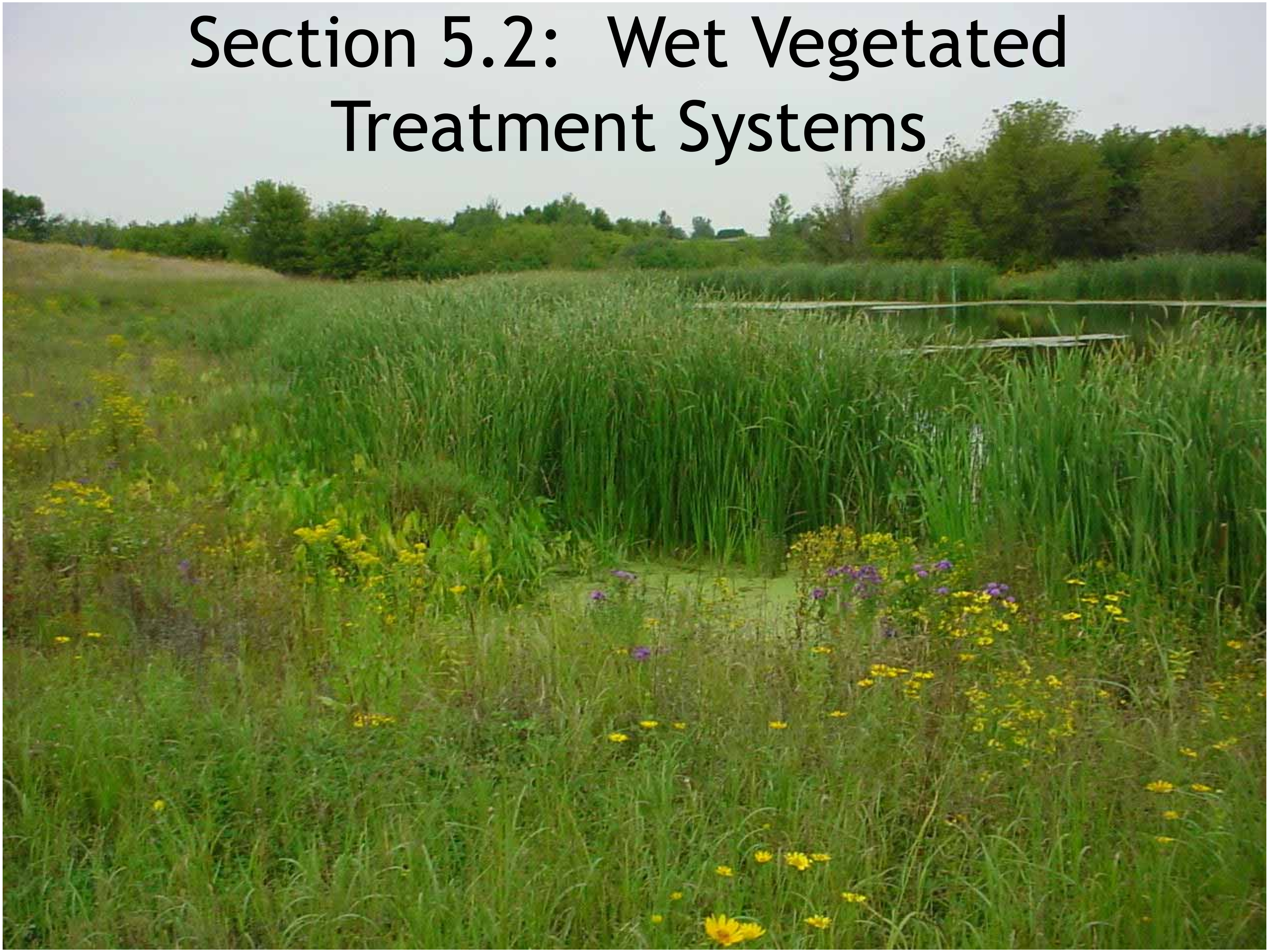
# Presentation Outline

- Water Quality
- Pretreatment
- Storage

# Minimum Design Criteria

- Required Elements and Design Guidance
  - If required elements can't be met, select a different BMP
- Six Categories
  - Feasibility
  - Conveyance
  - Pretreatment
  - Treatment
  - Landscaping
  - Maintenance

# Section 5.2: Wet Vegetated Treatment Systems



# WVTS: Design Notes

Approved WQ BMPs

- Shall not be located within jurisdictional waters, except may be allowed in previously developed upland buffers
- Restricted in cold-water fisheries watersheds
  - Discharges prohibited w/in 200 ft of jurisdictional waters
  - Beyond 200 ft, discharge up to the $CP_v$ through an underdrained gravel trench outlet
- LUHPPL runoff requires a 3-ft separation to gw, no separation distance required for non-LUHPPL runoff
- Permanent pool volumes shall not be included in storage calcs for peak flow management ($CP_v/Q_p$)

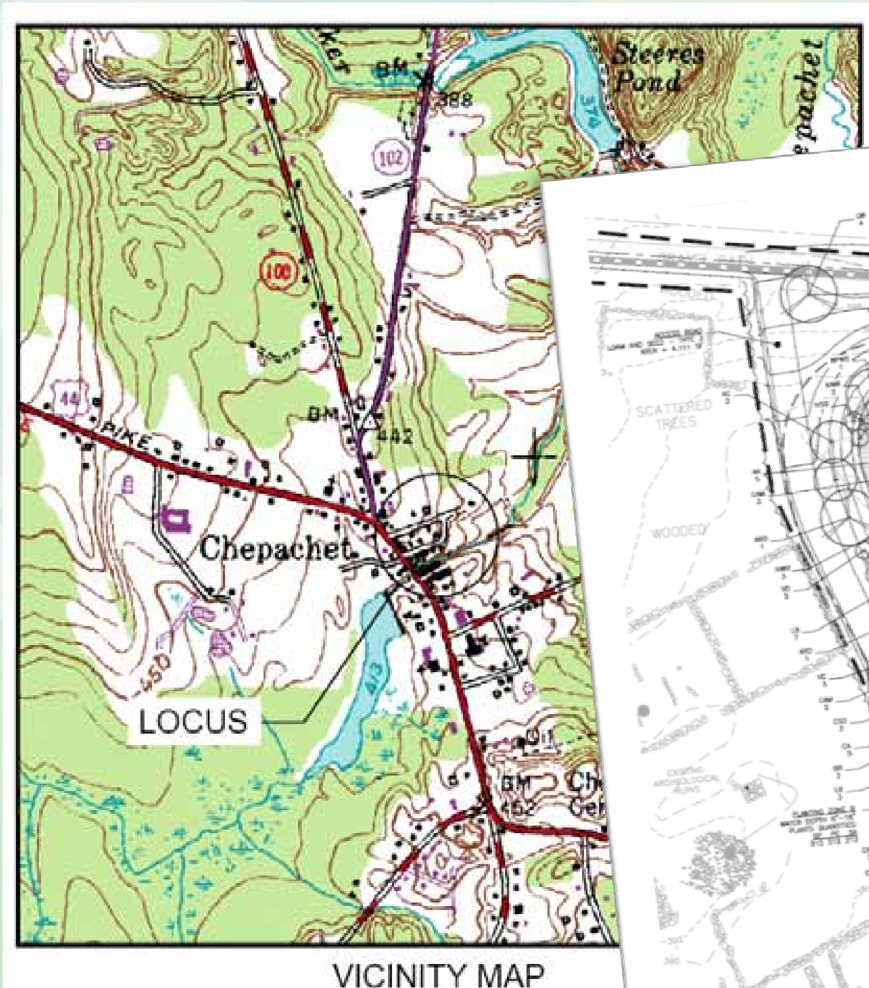
# Shallow WVTS: Design Notes

Approved WQ BMPs

- Min flowpath of 2:1 (length to width)
- High surface area to volume ratio
  - Pretreatment (10% of WQv)
  - Deepwater zones (25% of WQv)
  - Remaining 65% WQv combination of shallow pool and ED
- Shallow depths over most of surface area
  - 35% 6 inches or less
  - 65% 18 inches or less
- Complex internal microtopography, including aquatic benches
- Plant with emergent vegetation
- Consumes most land of any BMP
  - 1.5% of DA

# Example – Chepachet, RI

Approved WQ BMPs




VICINITY MAP

## Approved WQ BMPs

| WET VEGETATED TREATMENT SYSTEM CALCULATIONS | REQUIRED | PROVIDED | UNITS |
|---|---|---|---|
| **DRAINAGE AREAS AND WATER QUALITY VOLUME** | | | |
| TOTAL CONTRIBUTING DRAINAGE AREA (10 Ac. MIN.) | n/a | 439,520 | sf |
| | n/a | 10.1 | acres |
| TOTAL IMPERVIOUS AREA (Tanyard/Oil Mill) | n/a | 65,300 | sf |
| | n/a | 1.5 | acres |
| TOTAL IMPERVIOUS AREA (RIDOT System Per Commonwealth) | n/a | 190,800 | sf |
| | n/a | 4.4 | acres |
| TOTAL IMPERVIOUS AREA | n/a | 256,100 | sf |
| | n/a | 5.9 | acres |
| RUNOFF DEPTH FOR WATER QUALITY VOLUME (WQv) | 1.00 | 1.00 | in |
| | | | |
| **TREATMENT VOLUME REQUIRED (WQv)** | **0.49** | | **ac-ft** |
| | **21,342** | | **cf** |
| **PRETREATMENT** | | | |
| SEDIMENT FOREBAY (10% OF WQv) | 2,134 | 4,499 | cf |
| | 0.05 | 0.10 | ac-ft |

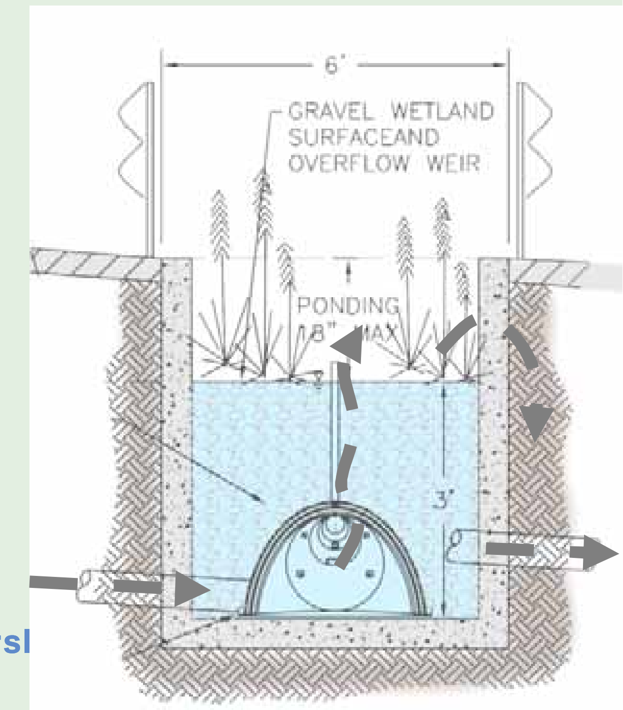
Approved WQ BMPs

| | | | |
|---|---|---|---|
| **TREATMENT** | | | |
| MIN. SURFACE AREA OF WVTS (1.5% of Drainage area) | 6,593 | 9,570 | sf |
| | 0.15 | 0.22 | acres |
| DEEPWATER ZONE VOLUME (25% of WQv) | 5,335 | 5,988 | cf |
| | 0.12 | 0.14 | ac-ft |
| HIGH MARSH AREA - 0"-6" DEPTH (35% of total surface area) | 2,307 | 3,373 | sf |
| | 0.05 | 0.08 | acres |
| TOTAL MARSH AREA - 0"-18" DEPTH (65% of Total Surface Area) | 4,285 | 6,097 | sf |
| | 0.10 | 0.14 | acres |
| **GEOMETRY** | | | |
| LENGTH | n/a | 185 | ft |
| WIDTH (average) | n/a | 45 | ft |
| WIDTH (maximum) | n/a | 80 | ft |
| RATIO (average) | 2 to 1 | 4 to 1 | L:W |
| RATIO (maximum) | 2 to 1 | 2 to 1 | L:W |
| **CHANNEL PROTECTION VOLUME (CPv)** | | | |
| RUNOFF VOLUME FROM 1-YR, 24-HR, TYPE III STORM (Vr) | n/a | 17,860 | cf |
| | n/a | 0.41 | ac-ft |
| CPv (0.65 x Vr) | 11,609 | 13,565 | cf |
| | 0.27 | 0.31 | ac-ft |
| LENGTH OF UNDERDRAINED GRAVEL TRENCH | 35 | 36 | lf |

# Gravel WVTS: Design Notes

Approved WQ BMPs

- Min. length-to-width ratio 1:1, min. flowpath (L) of 15 ft
- Pretreatment: 10% WQv
- Remaining 90%, a combination of one or more basins/chambers filled with gravel and open ED
- Outlet invert just below gravel surface
- Surface area must be minimum 0.35% of DA
- May use organic soil
- Plant with emergent vegetation

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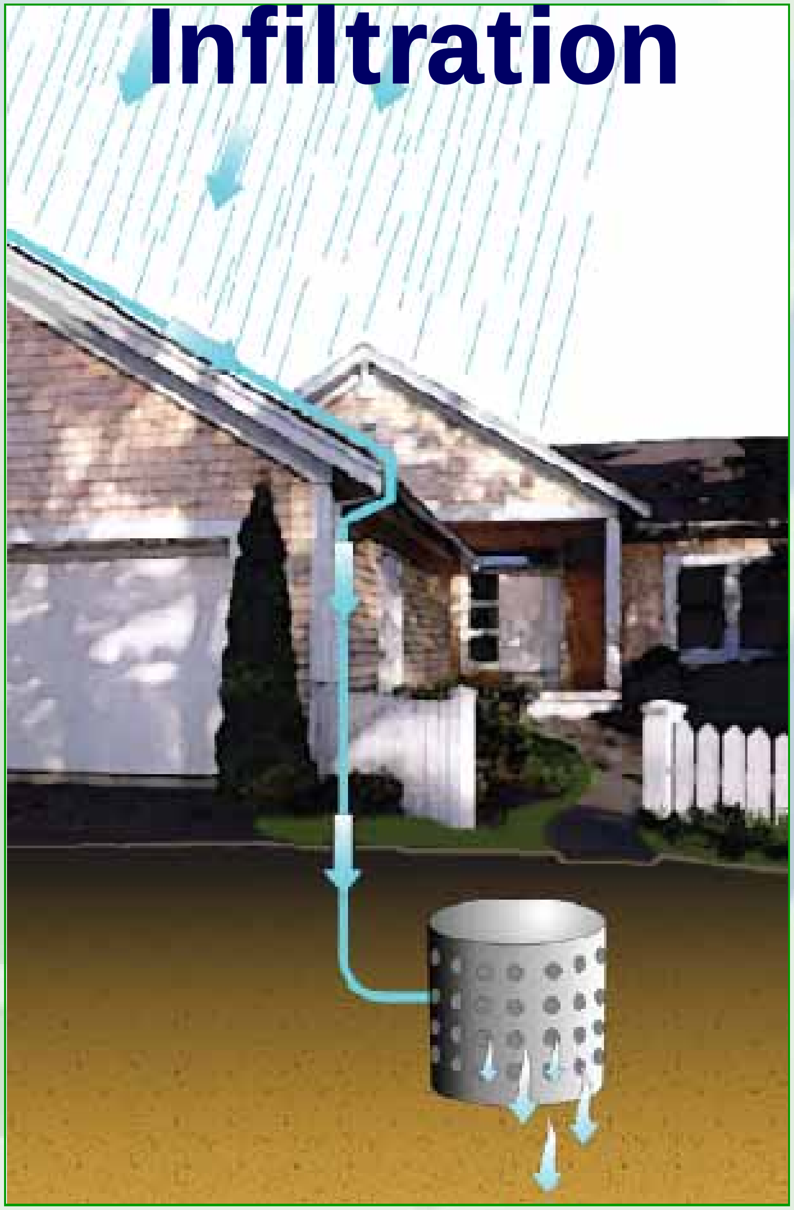
# Section 5.3: Infiltration



# Infiltration - Design Notes

Approved WQ BMPs

- Field verification of soil permeability/texture essential
- Pretreatment essential – minimum 25% of WQv
- Bottom of infiltration facility cannot be located in fill*, must have 3' separation from gw and bedrock*
- Size based on design infiltration rates (Table 5-3)
- Guidance: Keep drainage areas to each practice small, may reduce some potential problems

* Reduced requirements for residential areas (2')

**Table 5-3 Design Infiltration Rates for Different Soil Textures (Rawls et al., 1982)**

| USDA Soil Texture | Design Infiltration Rate ($f_c$) (in/hr) | Design Infiltration Rate ($f_c$) (ft/min) |
|---|---|---|
| Sand | 8.27 | 0.0115 |
| Loamy Sand | 2.41 | 0.0033 |
| Sandy Loam | 1.02 | 0.0014 |
| Loam | 0.52 | 0.0007 |
| Silt Loam | 0.27 | 0.0004 |

# Design Notes (cont'd)

- Cannot be used if contributing drainage is a LUHPPL
- Higher maintenance burden
- Stabilize site prior to installation
- Must meet variety of setbacks* (Table 5-2)
- May be used for larger storm events if infiltration rate > 8.3 in/hr**, mounding analysis may be required

* Reduced requirements for small-scale BMPs in res. areas

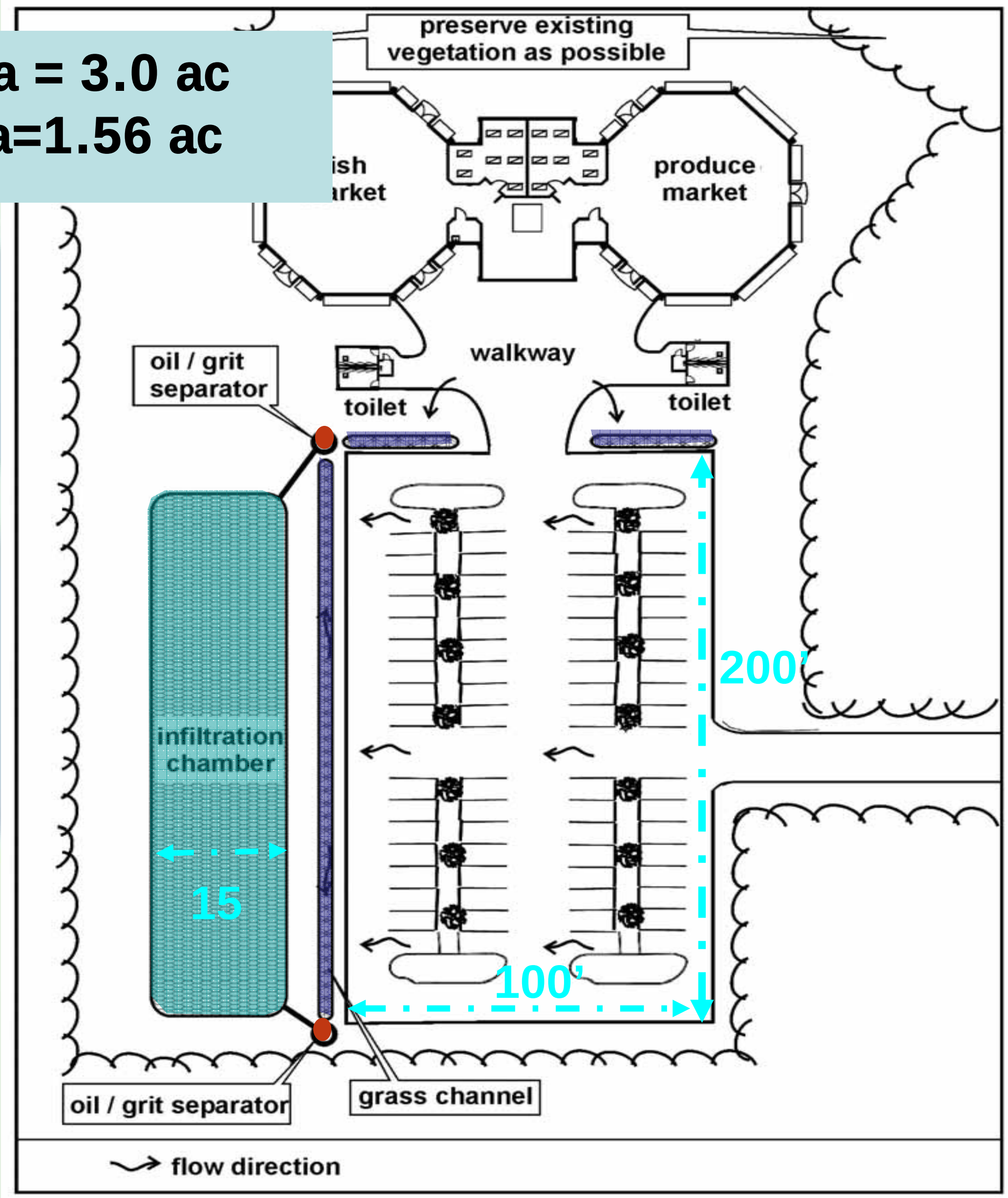
** 100% WQv treatment required by separate BMP in these areas

# Sample Calculations

Approved WQ BMPs

**Total Disturbed Area = 3.0 ac**
**Impervious Area=1.56 ac**

The Sunshine Market is a hypothetical commercial development consisting of a fish and produce market. It is located in Charlestown, RI and discharges to Green Hill Pond. On-site soils are Windsor loamy sand (HSG "A").



# Required Volume Calculations

- Compute required $Re_v$ based on A soils and Sect 3.3.2

$$Re_v = [(1") (F) (I)] / 12$$
$$= [(1") (0.6") (1.56 ac)] (1ft/12in)$$
$$= \underline{0.08 \text{ ac-ft} = \sim 3{,}500 \text{ cf}}$$

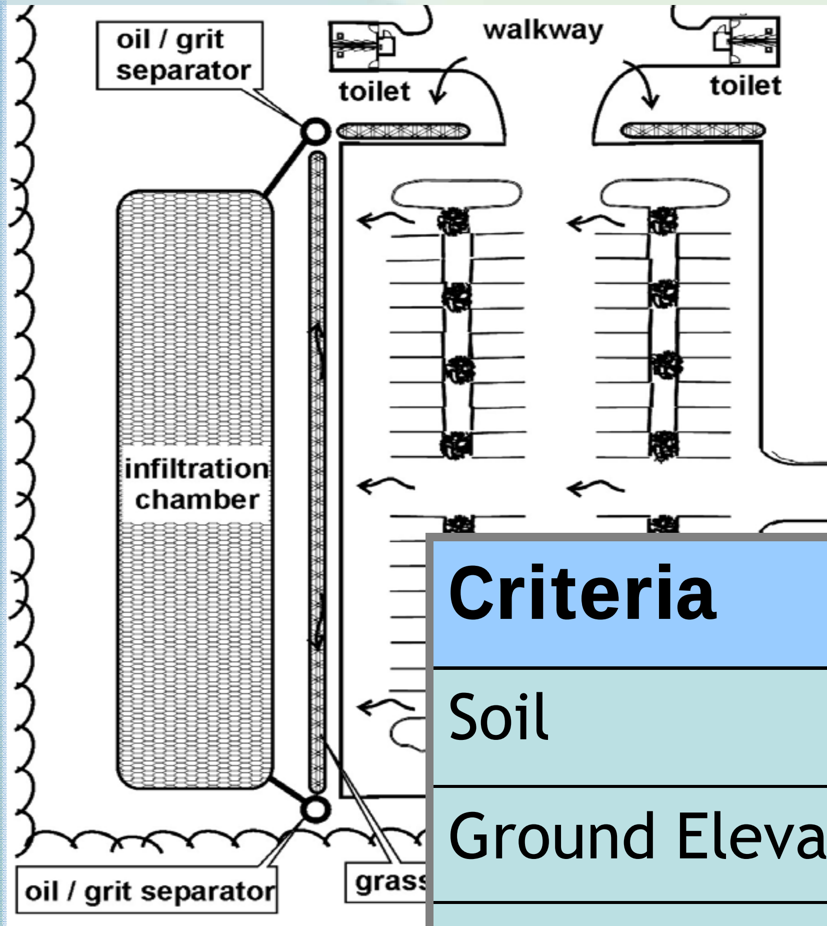
- Compute $WQ_v$

$$WQ_v = [(1") (I)] / 12$$
$$= [(1")(1.56 ac)] (1ft/12in)$$
$$= \underline{0.13 \text{ ac-ft} = \sim 5{,}700 \text{ cf}}$$

$$\text{Min. } WQ_v = [(0.2")(DA)] / 12$$
$$= [(0.2")(3.0 ac)] (1ft/12in)$$
$$= \underline{0.05 \text{ ac-ft} = \sim 2{,}200 \text{ cf}}$$

- $Cp_v$ and $Q_p$ are **waived** since site discharges to coastal waters with tide effects

Approved WQ BMPs




# Site Data

| Criteria | Value |
|---|---|
| Soil | Loamy Sand |
| Ground Elevation at BMP | 20' |
| Seasonal High Groundwater | 9' |
| Soil slopes | <1% |

# Infiltration Chambers Design

Horsley Witten Group, Inc.

# Design Criteria for Infiltration Chambers

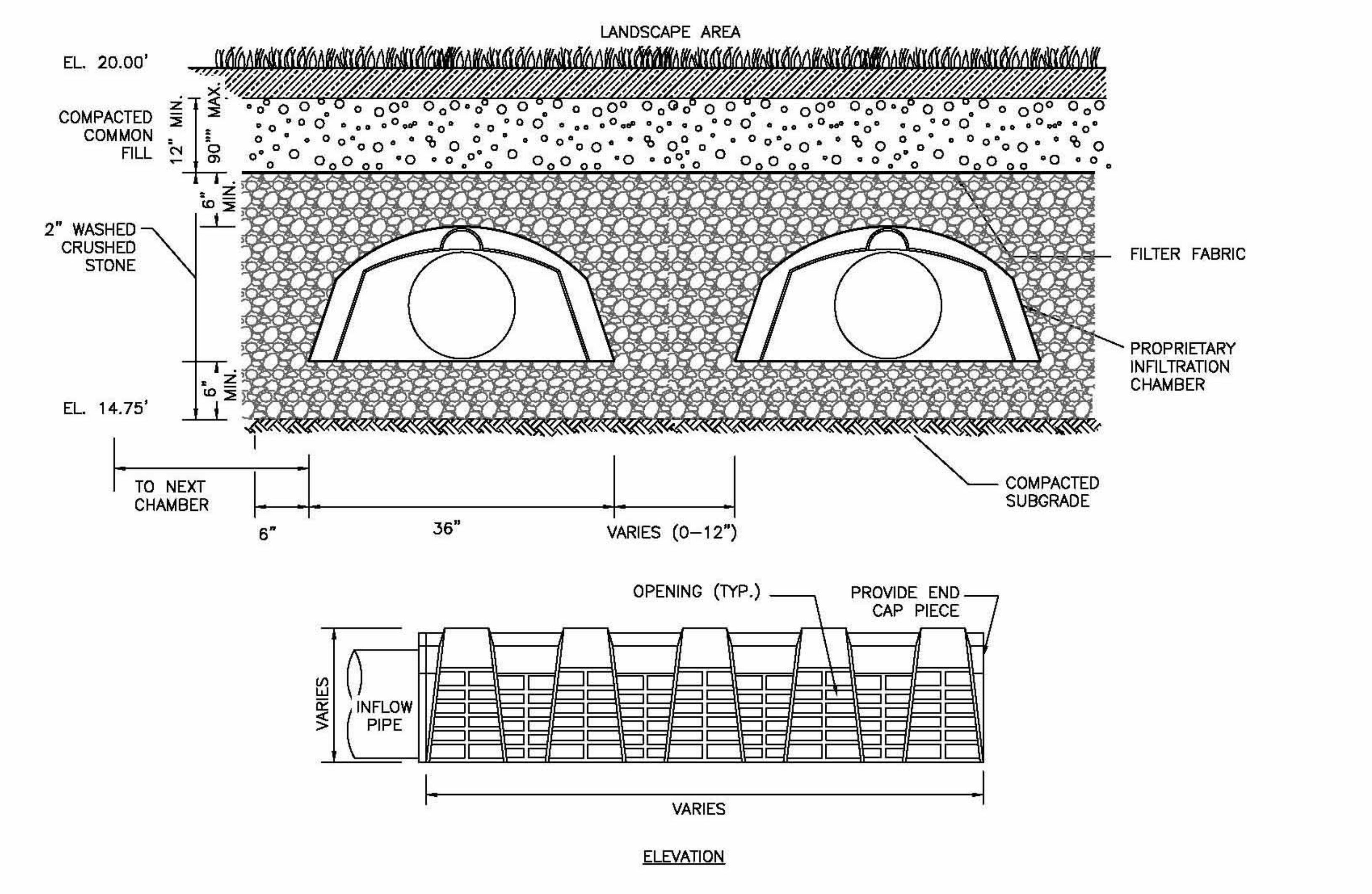
| Criteria | Status |
|---|---|
| Infiltration rate ($f_c$) greater than or equal to 0.5 inches/hour. | Design infiltration rate is 2.41 inches/hour. OK. |
| Soils have a clay content of less than 20% and a silt/clay content of less than 60%. | Loamy sand meets both criteria. |
| Infiltration cannot be located in fill soils. | Not fill soils. OK. |
| Hotspot runoff shall not be infiltrated. | Not a hotspot land use. OK. |

# Design Criteria, cont'd

| Criteria | Status |
| --- | --- |
| The bottom of the infiltration facility must be separated by at least 3 feet vertically from the SHGT. | Elevation of seasonally high water table: 9' Elevation of BMP location: 20'. The difference is 11'. Thus, the facility can be up to 8' deep. OK. |
| Infiltration facilities must be located 50 feet horizontally from coastal features. | Chamber >50' from all coastal features. OK. |
| Maximum contributing area generally 5 acres or less. | Area draining to facility is < 5 acres. OK. |
| Setback 25 feet down-gradient from structures. | Chamber edge >25' from all structures. OK. |

# Cross-section Views of Chambers

Approved WQ BMPs



# Sizing Equation for Infiltration Chambers

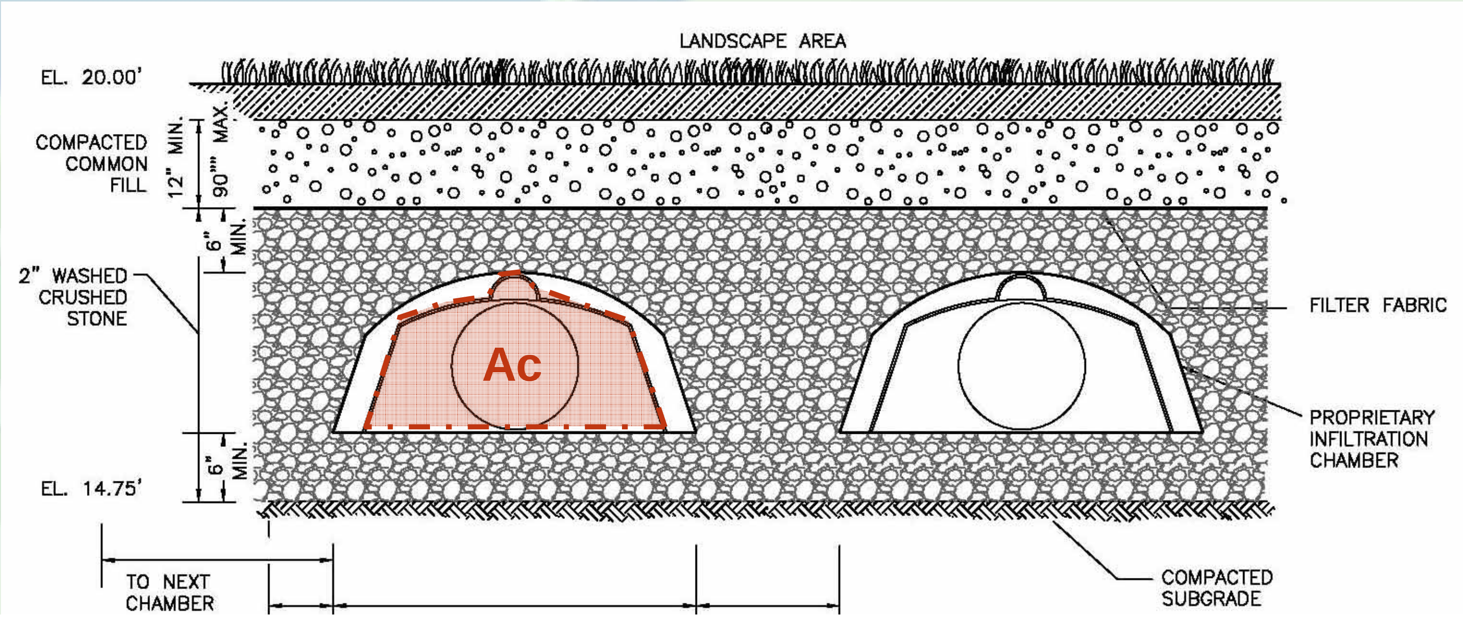
Infiltration chambers can generally be sized by the equation below:

$$V = L * [(w * d * n) - (\# * A_c * n) + (\# * A_c) + (w * f_c * T / 12)]$$

*Where:*

V = design volume (e.g., WQv) (cf)
L = Length of infiltration facility (ft)
w = Width of infiltration facility (ft)
H = Depth of infiltration facility (ft)

\# = Number of rows of chambers
$A_c$ = Cross-sectional area of chamber
n = Porosity (assume 0.33)
$f_c$ = **Design** infiltration rate (in/hour)
T = Fill time in hrs



# Solve for Length of Facility

Assume that:

n = 0.33
d = 4 feet
f = 2.41 inch/hour (*Table 5.2*)
T = 2 hours (*use default value unless site-specific data exists*)
$A_c$ = 3.5 sf (*supplied by manufacturer*)
\# = 15 ft / 3.25 ft (*supplied by manuf.*) =
*4.6, only 4 rows can fit*


Solve for **Length** given that we have 15' of width that we want to use at our site.

*Therefore:*

**L = 5,700 ft³/[(15'*4' *0.33)-(4*3.5 ft² *0.33)+(4*3.5 ft²)+(15'*2.41 in/hr*2 hr/12)]**

$$L = 5{,}700\ ft^3 / [(19.8\ ft^2) - (4.6\ ft^2) + (14\ ft^2) + (6.0\ ft^2)]$$

**L = 162 ft**

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# Final Sizing

Approved WQ BMPs

Add one foot to each end to give room for a stone buffer (more or less depending on manufacturer's specifications).

→ Facility dimensions will be **15' x 164'.**

Check to ensure that there is sufficient room for the infiltration chamber facility alongside proposed parking lot. The proposed parking lot is 200 ft long, **Ok.**

# Section 5.3: Permeable Paving

Two main categories:

- Porous asphalt and pervious concrete
- Pavers
    1. Permeable solid blocks (min. void ratio 15%) or reinforced turf
    2. Solid blocks with open-cell joints>15% of surface
    3. Solid blocks with open-cell joints<15% of surface with 1" surface storage

# Permeable Pavements – Design Notes

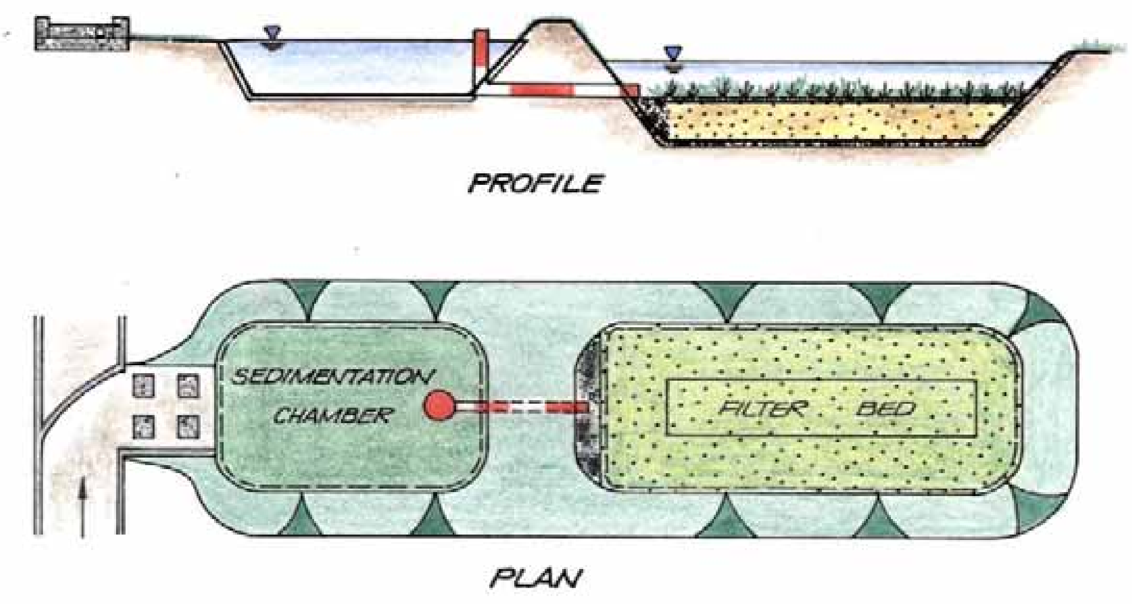
Approved WQ BMPs

- May be used as infiltration and/or detention system
- For infiltrating practices:
  - Field verification of soil permeability/texture essential
  - Bottom of facility cannot be located in fill* and must have 3' separation from gw and bedrock*
  - Size based on design infiltration rates (Table 5-3)
  - Cannot be used if contributing drainage is a LUHPPL
  - Must meet variety of setbacks* (Table 5-4)
- Frequent maintenance necessary to retain permeability (vacuum)
- Use on low traffic/speed areas with gentle slopes (<5%)
- Generally not designed to accept runoff from other areas

* Reduced requirements for resid. areas

# Section 5.5: Filtering Practices

- Sand/organic filters
- Bioretention areas/Tree filters



Approved WQ BMPs

# Filter Sizing Equation

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

$A_f$ = surface area of filter bed ($ft^2$)

$d_f$ = filter bed depth (ft)

$k$ = coef 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 recommended)

# Sand/Organic Filter: Design Notes

Approved WQ BMPs

- Pretreatment essential (25% WQv)
- Sized for temporarily holding at least 75% of WQv, including pretreatment
- Minimum depth of 18” (12” allowed in some instances)
- Use conservative permeability coef. (3.5 ft/day for sand, 2 ft/day for peat, and 8.7 ft/day for leaf compost)
- Need maintenance access to filter bed
- Useful to treat LUHPPL runoff

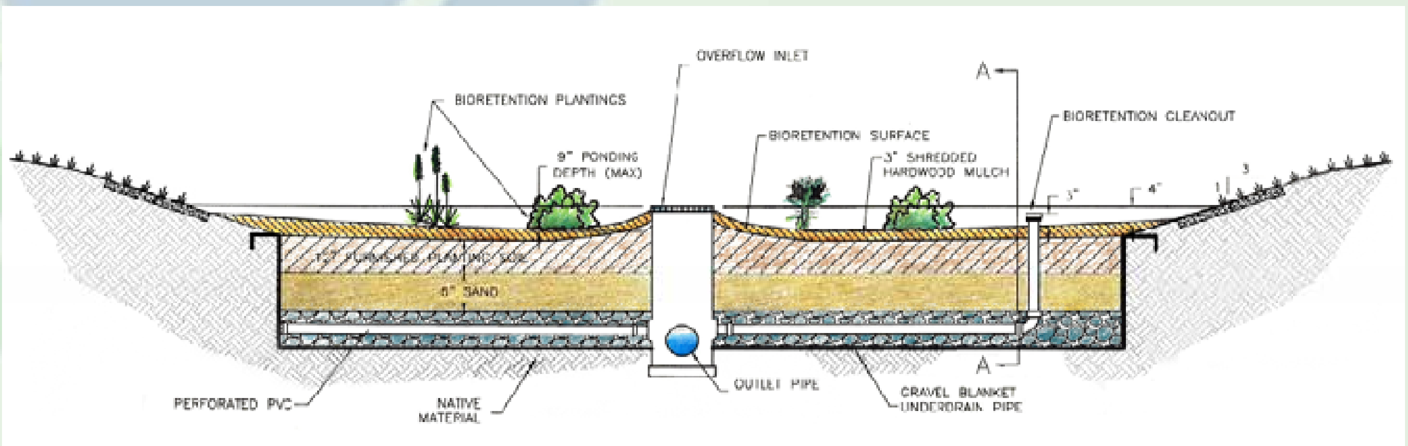
# Bioretention: Design Notes

- Pretreatment essential (25% WQv)
- Sized for temporarily holding at least 75% of WQv, including pretreatment
- 6”-9” ponding above surface
- Typically, 2’-4’ planting soil bed (12” allowed in some instances)
- Specific engineered soil media
- Use a conservative permeability coefficient
- Detailed landscape plan

# Bio Planting Soil and Mulch



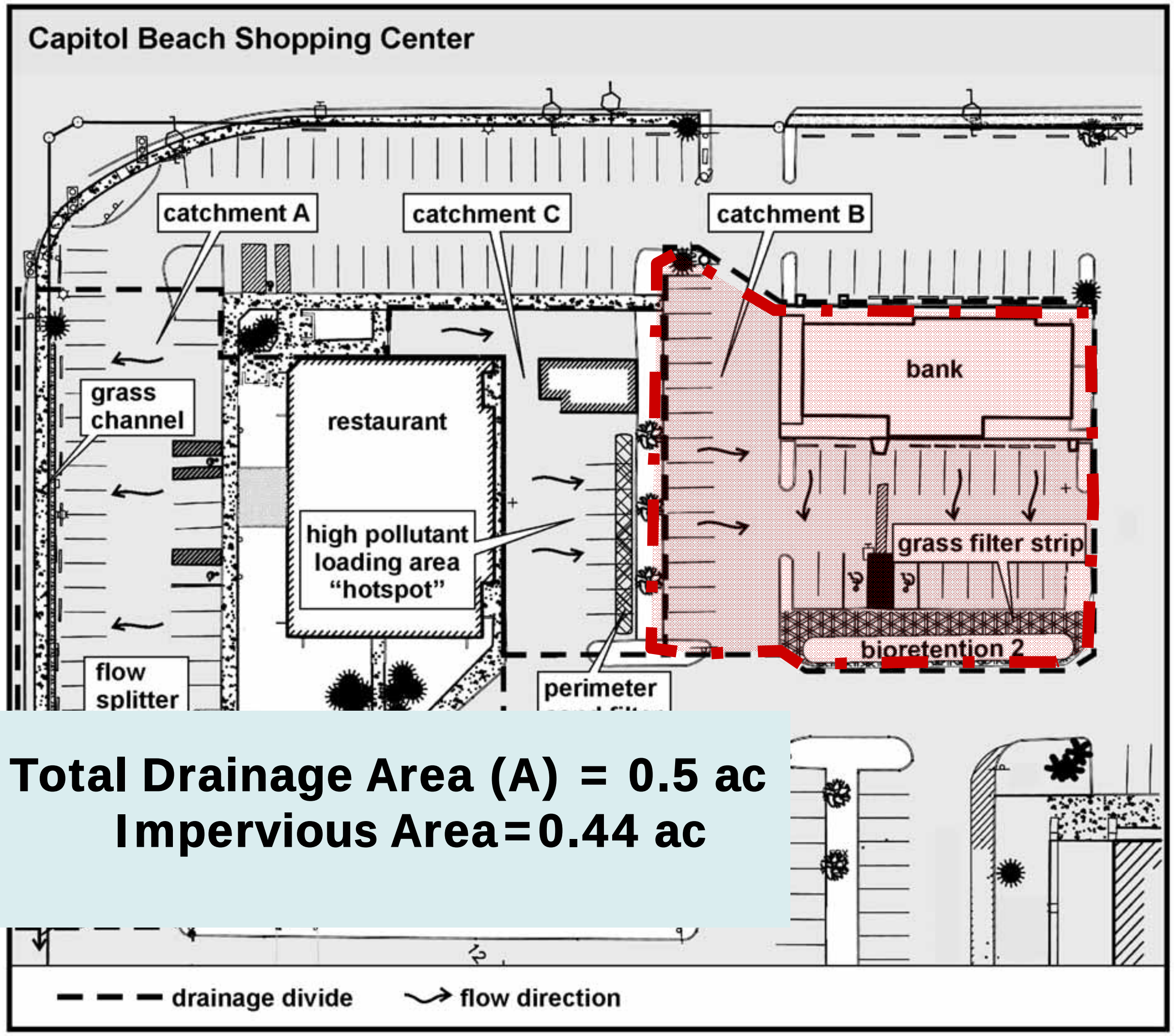
- Loamy Sand to a Sandy Loam
  - 85-88 % sand
  - 8-12 % silt
  - 0-2 % clay
  - 3 to 5 % organic matter
- Add well-aged, well-aerated leaf compost (20% by volume) for bios with shallow media depths (<2')
- Layer of well-aged, shredded hardwood mulch



# Bio - Sample Calculations

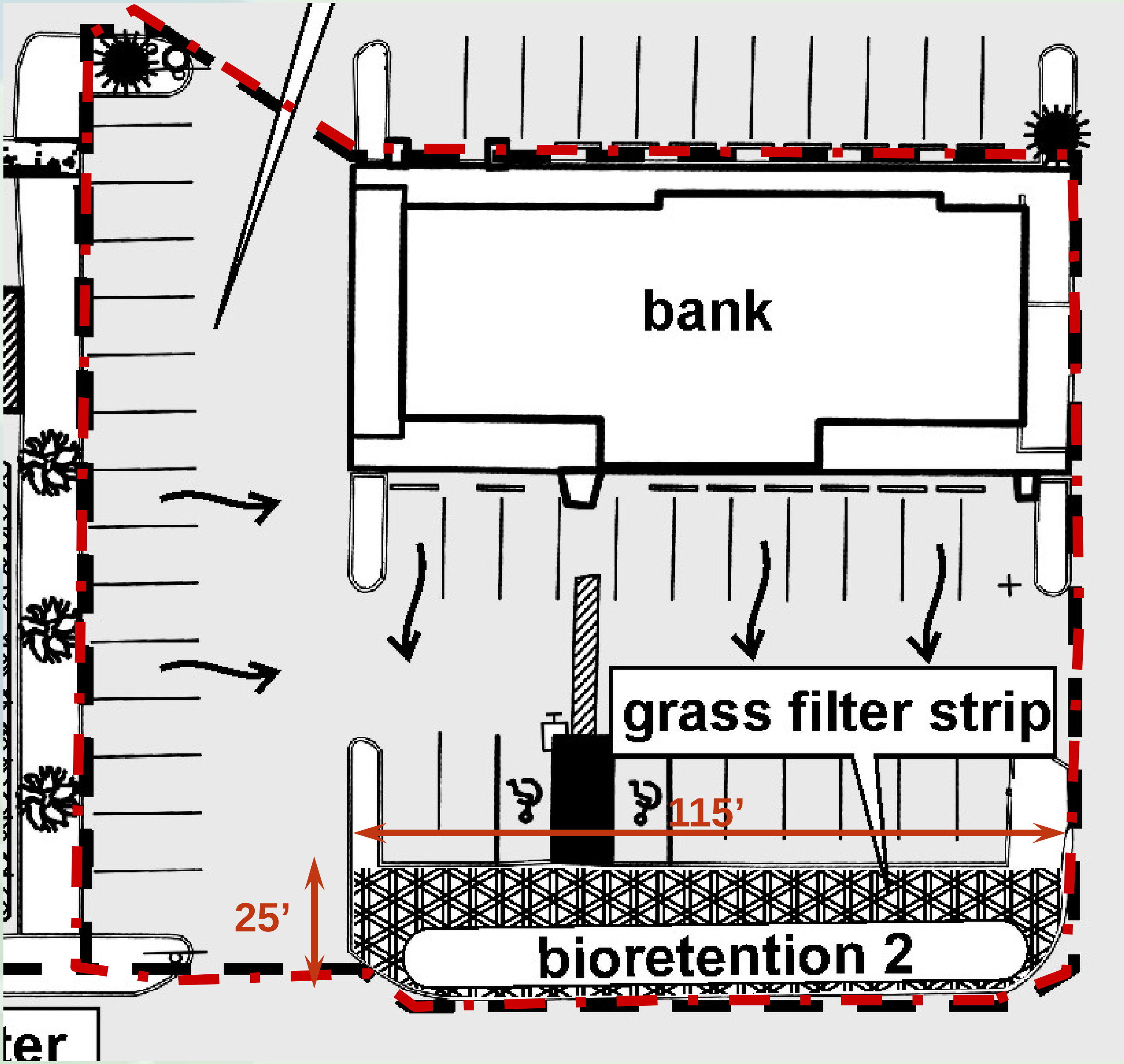
**Approved WQ BMPs**

Capitol Beach Shopping Center is a hypothetical proposed development with a restaurant and bank. It is located in downtown Providence and discharges to the Providence River.




**Total Drainage Area (A) = 0.5 ac**
**Impervious Area=0.44 ac**

# Approved WQ BMPs



# Site Specific Data:

Approved WQ BMPs

- Site discharges to a large river (i.e., 4th-order or larger stream);
- On-site soils are "Paxton-Urban land Complex" (HSG C);
- Existing low point elevation at practice location is 10.0 ft; and
- Soil boring observations show seasonal high groundwater table at 2.0 ft.

# Required Volume Calculations

Approved WQ BMPs

**Compute required $Re_v$ based on C Soils and Sect. 3.3.2**

$Re_v$ = [(1") (F) (I)] / 12

= [(0.25")(0.44 ac)] (1ft/12in)

= **0.009 ac-ft = 390 cf**

**Compute $WQ_v$**

$WQ_v$ = [(1") (I)] / 12

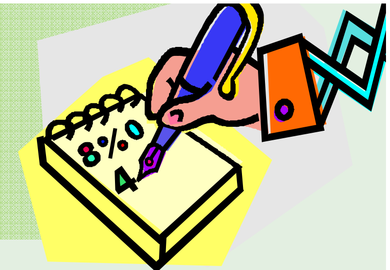
= [(1")(0.44 ac)] (1ft/12in)

**= 0.037 ac-ft = 1,610 cf**

- $Cp_v$ and $Q_p$ are waived since site discharges to a large river
- Bioretention will be designed without an impermeable liner to allow for infiltration.

Approved WQ BMPs

# Bioretention Sizing Equation



Use sizing equation and values provided in **Section 5.5.4**:

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

$A_f$ = surface area of filter bed ($ft^2$)

$d_f$ = filter bed depth (ft) (2–4 ft, depending on site constraints)

$k$ = coef of permeability of filter media (1 ft/day)

$h_f$ = ave. ht of water above filter bed (ft) (*1/2 of ponding depth*)

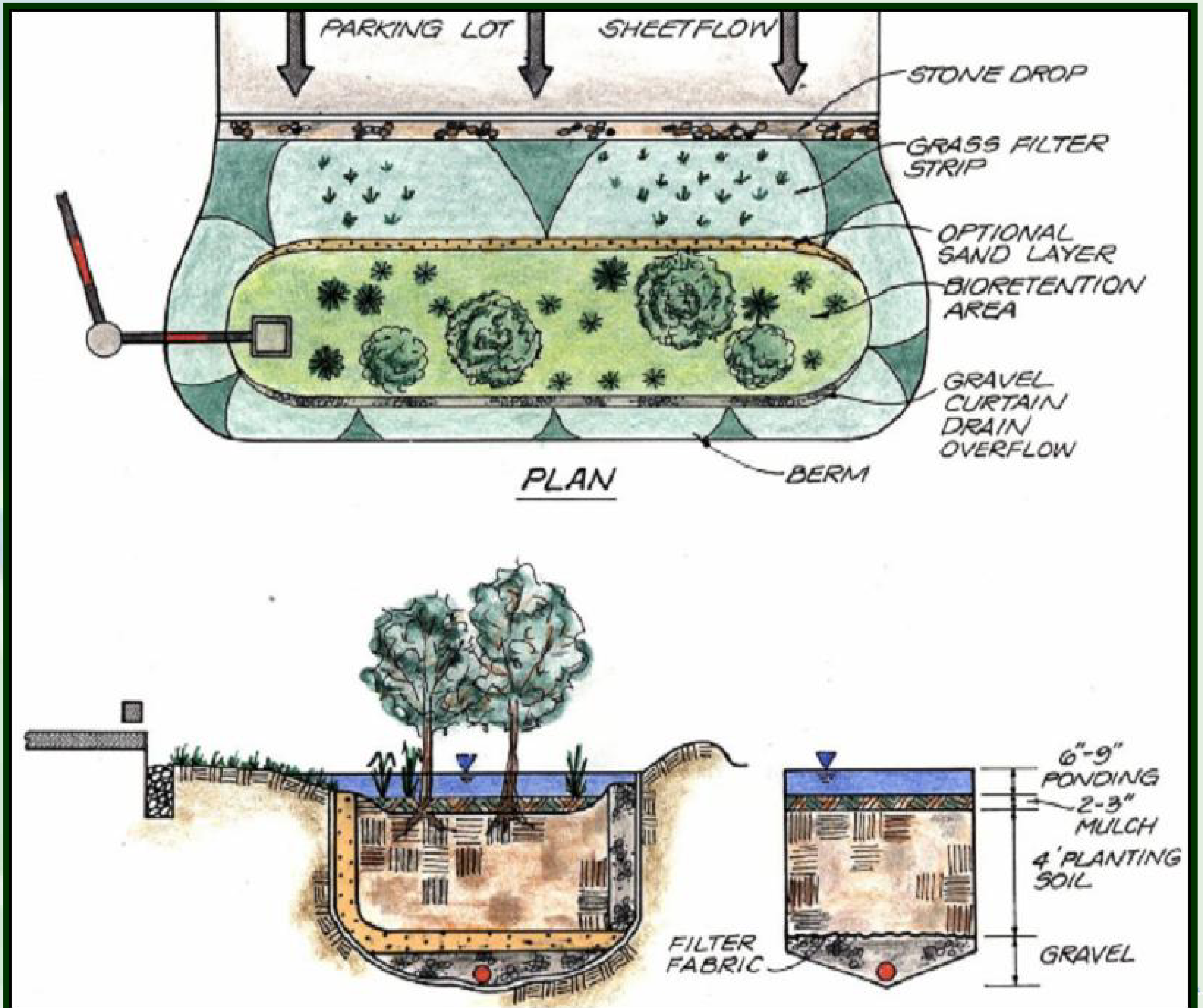
$t_f$ = design filter bed drain time (days) (*2 days recom.*)

$$A_f = (1{,}610\ ft^3)\ (4')\ /\ [(1'/day)\ (0.25' + 4')\ (2\ days)]$$

(With $d_f$ = 4', k = 1.0'/day, $h_f$ = 0.25', $t_f$ = 2 days)

**$A_f$ = 760 sq ft**

# Approved WQ BMPs



# Final Sizing

Approved WQ BMPs

- Use width = 10’.
- Given a surface area requirement of 760 sq ft

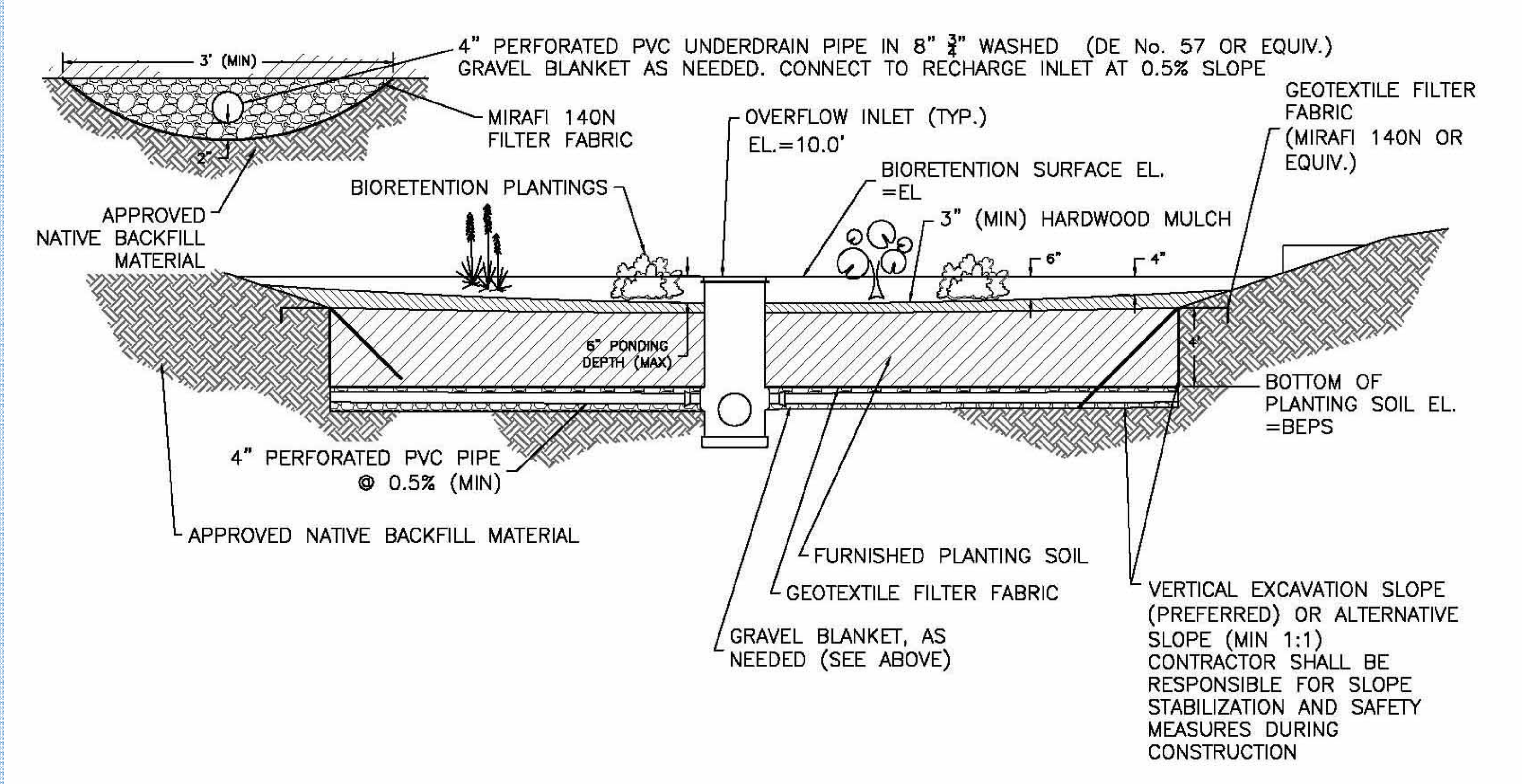
Facility dimensions will be **10’ x 76’.**

- Check to ensure that there is sufficient room for the bioretention inside parking lot island. The proposed island is 115 ft long, **Ok.**

# Cross-section of Bioretention

Approved WQ BMPs

Set top of facility at 10', with the top of berm at 11'. The facility is 5' deep from rim to bottom of planting area, which will allow 3' of clearance above the SHGT.



# Section 5.6: Green Roofs Design Notes

Approved WQ BMPs

- Designed to manage WQv without bypass
- Safely convey runoff from larger storm events to a downstream drainage system
- No pretreatment required

# Section 5.7: Open Channels

# Dry Swale: Design Notes

Approved WQ BMPs

- Pretreatment: 10% WQv
- Use filter sizing equation
- 2 ft ≤ Bottom Width ≤ 8 ft


(c) DRY SWALE

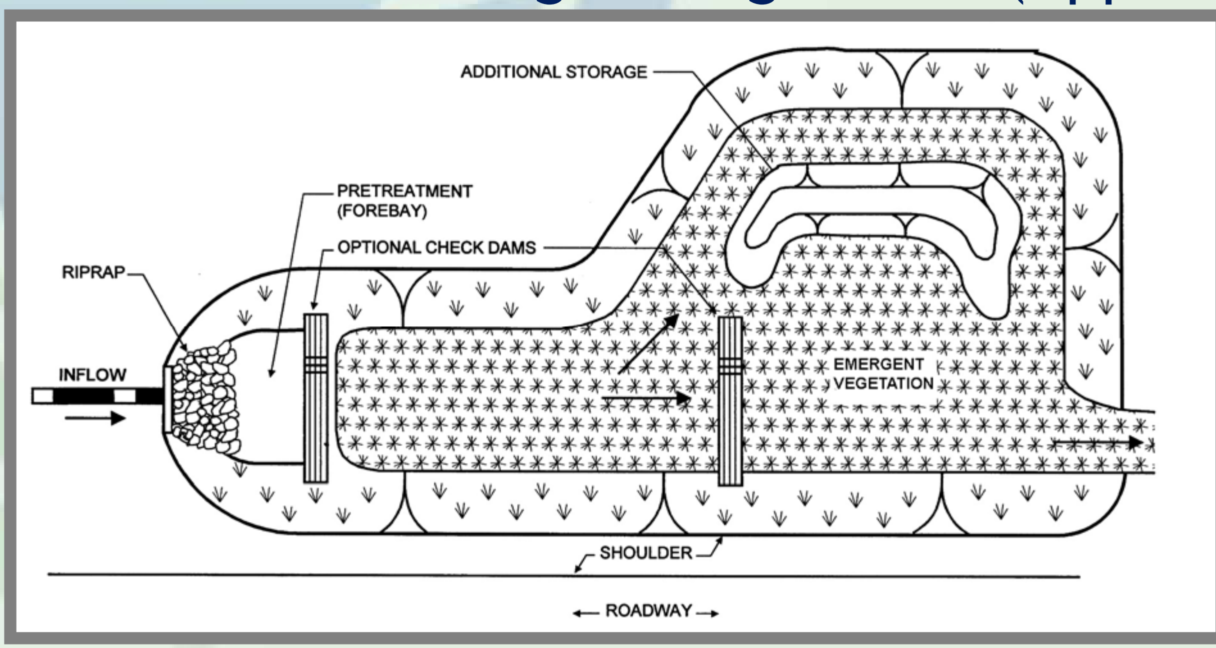
- Minimum 30” engineered bio soil (12” allowed in some instances)
- Maximum 12” deep average surface ponding depth
- Select the most appropriate native seed mix for expected swale conditions (Appendix B)
- Do not use on slopes greater than 4% w/o cells or checkdams
- Erosion control fabric for steeper grades
- May need some topsoil, fertilization, and irrigation to get grass established


Dry Swale

Approved WQ BMPs

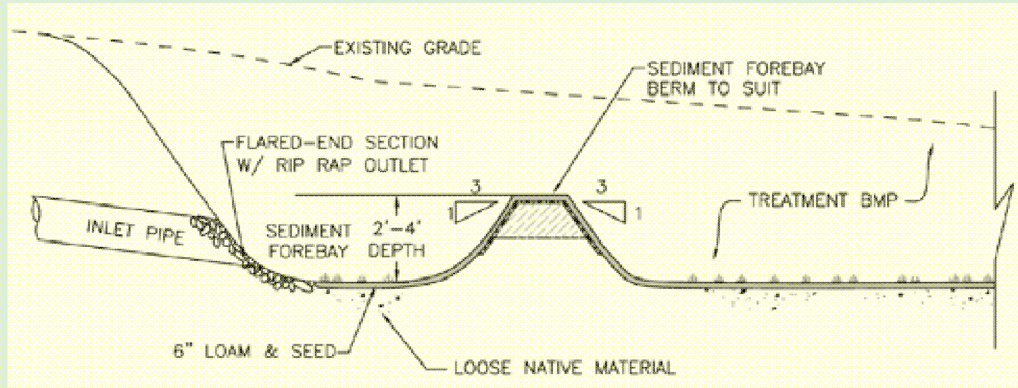
# Wet Swale: Design Notes

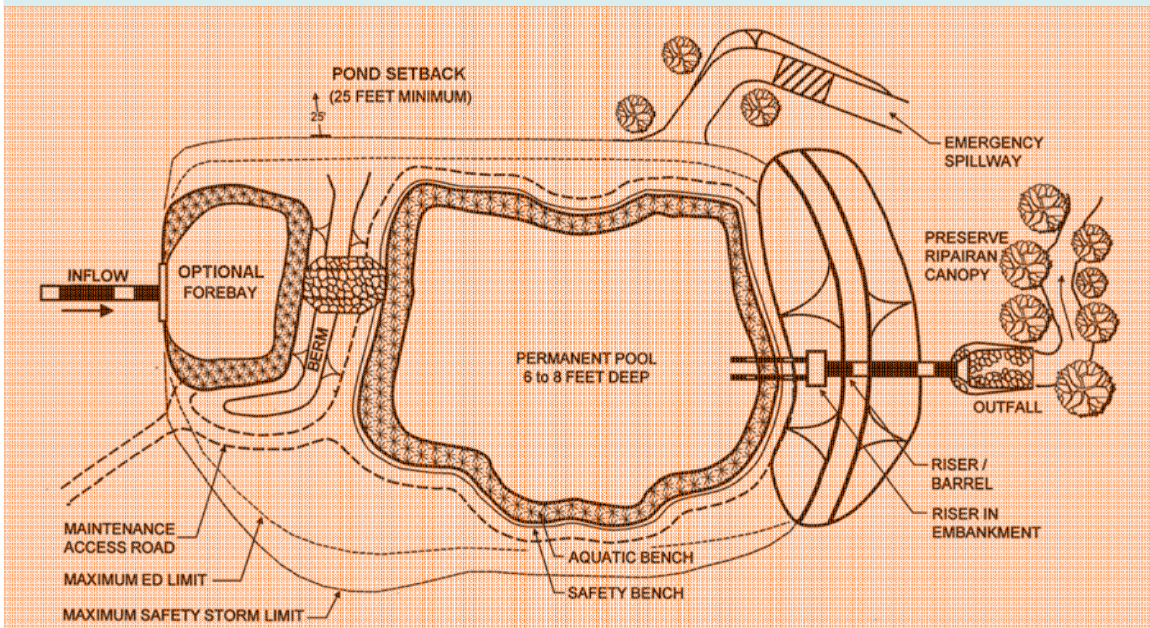
- Constructed in groundwater
- Pretreatment: 10% WQv
- Permanent pool may be included in WQv calculations
- 2 ft ≤ Bottom Width ≤ 8 ft
- Generally, <1% slope
- Planted with emergent vegetation (Appendix B)



# Practices Approved for Other Criteria

- Pretreatment Practices – Chapter 6
  - Grass Channel
  - Filter Strips
  - Sediment Forebay
  - Deep Sump Catch Basins
  - Proprietary Devices




- Storage Practices – Chapter 7
  - Stormwater Basins
  - Underground Storage Devices
  - Infil. for Recharge/Storage

# Pretreatment


Ch 3

- Pretreatment Standards

Ch 5

- Approved BMPs for WQ Treatment
  - WVTS, infiltration, filters, green roofs, channels
  - Design requirements
  - Recommended design guidance

Ch 6

- Pretreatment Practices
  - Cannot be used alone to meet WQ
  - Grass channels, filter strips, sediment forebay, deep sump catch basins, proprietary devices

# Stormwater Standards

Pretreatment

Standard 3

"…Pretreatment is required for water quality treatment practices where specified in the design guidelines within Chapter Five…"

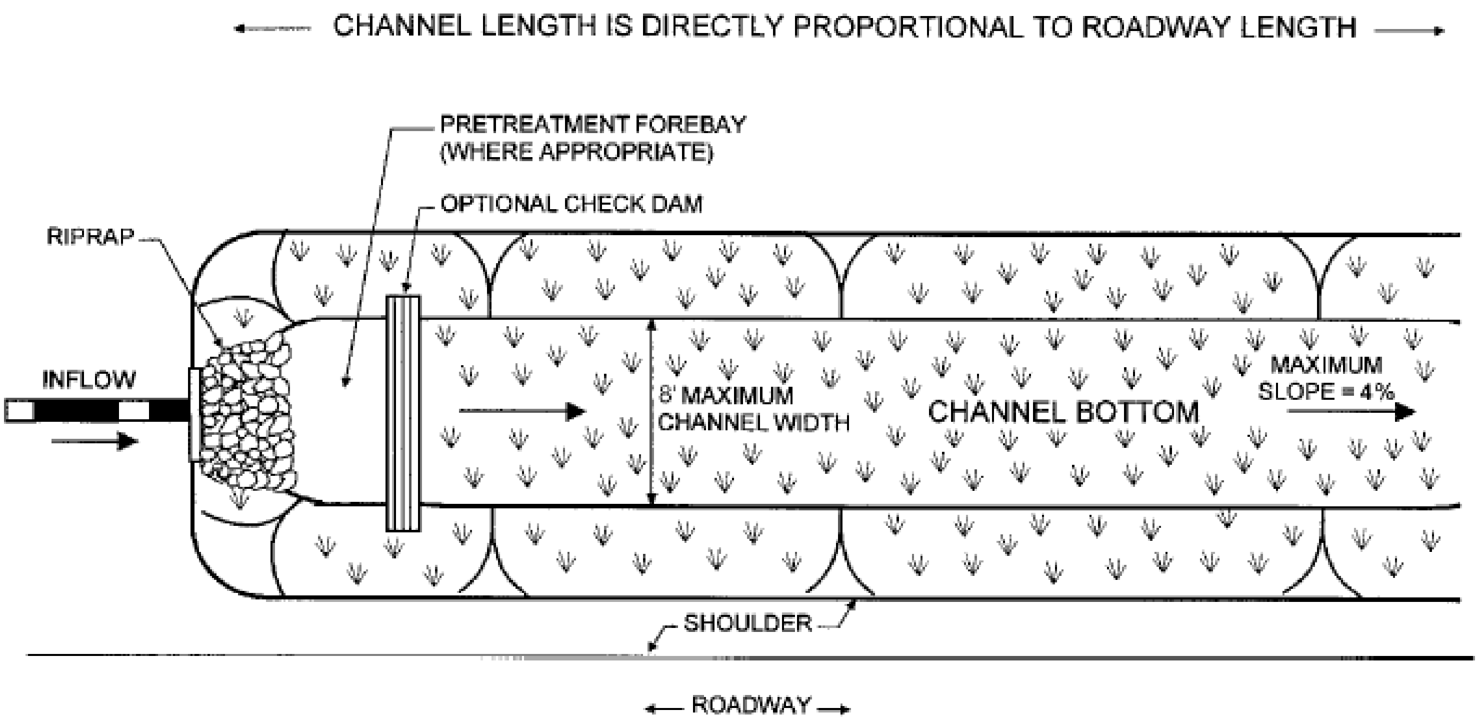
# BMP Pretreatment Requirements

| BMP Group | Required $\%WQ_v$ | Notes |
|---|---|---|
| **WVTS** | 10% | • Provided at each inlet, unless inlet provides <10% of inflow |
| **Infiltration** | 25% | • Grass channel, filter strip, sediment forebay, proprietary device<br>• Deep sump catch basin combined with one of the following:<br>– Upper sand layer; or<br>– Washed pea gravel (1/8” to 3/8”)<br>• Not required for permeable pavements (unless there is “run-on”) or drywells |
| **Filtering Practices** | 25% | • Deep sump catch basins may not be used as sole pretreatment. |
| **Green Roofs** | Not Applicable. No pretreatment required for direct rainfall. | |
| **Open Channels** | 10% | • forebays/checkdams at pipe inlets and/or driveway crossings.<br>• filter strip |

# Grass Channels

Pretreatment BMPs

Figure 6-1 Grass Channels

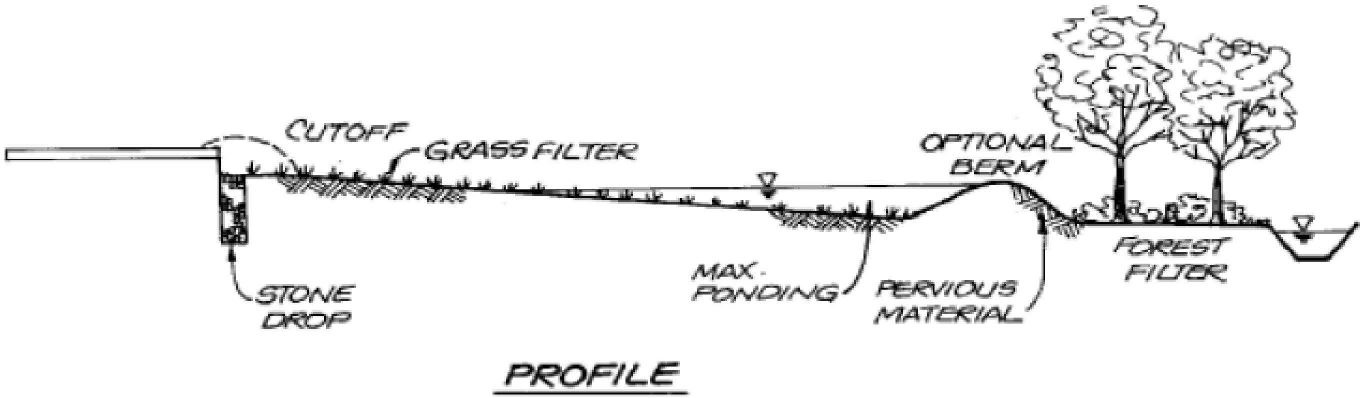



* Gentle side slopes and dense vegetation can increase pretreatment

PLAN VIEW

**Pretreatment BMPs**

# Filter Strip




Source: Claytor and Schueler, 1996

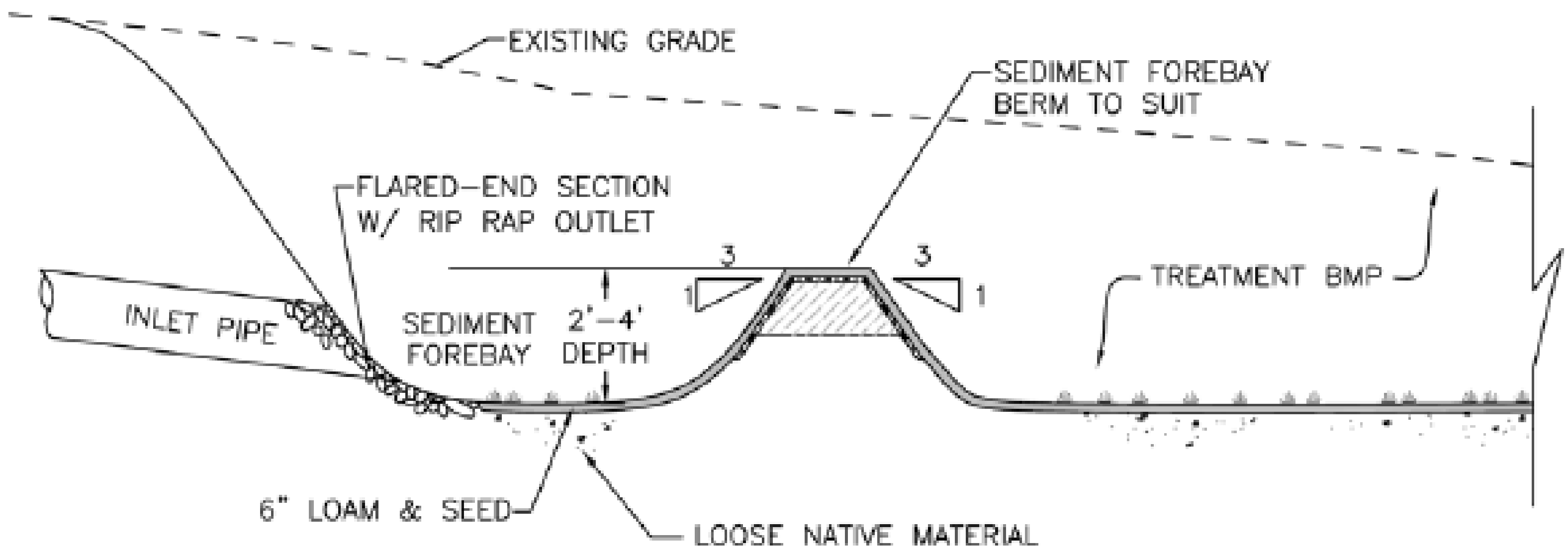
**Table 6-1 Guidelines for Filter Strip Pretreatment Sizing**

| Parameter | Impervious Parking Lots | | | | Residential Lawns | | | |
|---|---|---|---|---|---|---|---|---|
| Maximum Inflow Approach Length (ft) | 35 | | 75 | | 75 | | 150 | |
| Filter Strip Slope (%) | <2 | >2 | <2 | >2 | <2 | >2 | <2 | >2 |
| Filter Strip Minimum Length (ft) | 10 | 15 | 20 | 25 | 10 | 12 | 15 | 18 |

# Sediment Forebay

Pretreatment BMPs

Figure 6-3 Sediment Forebay

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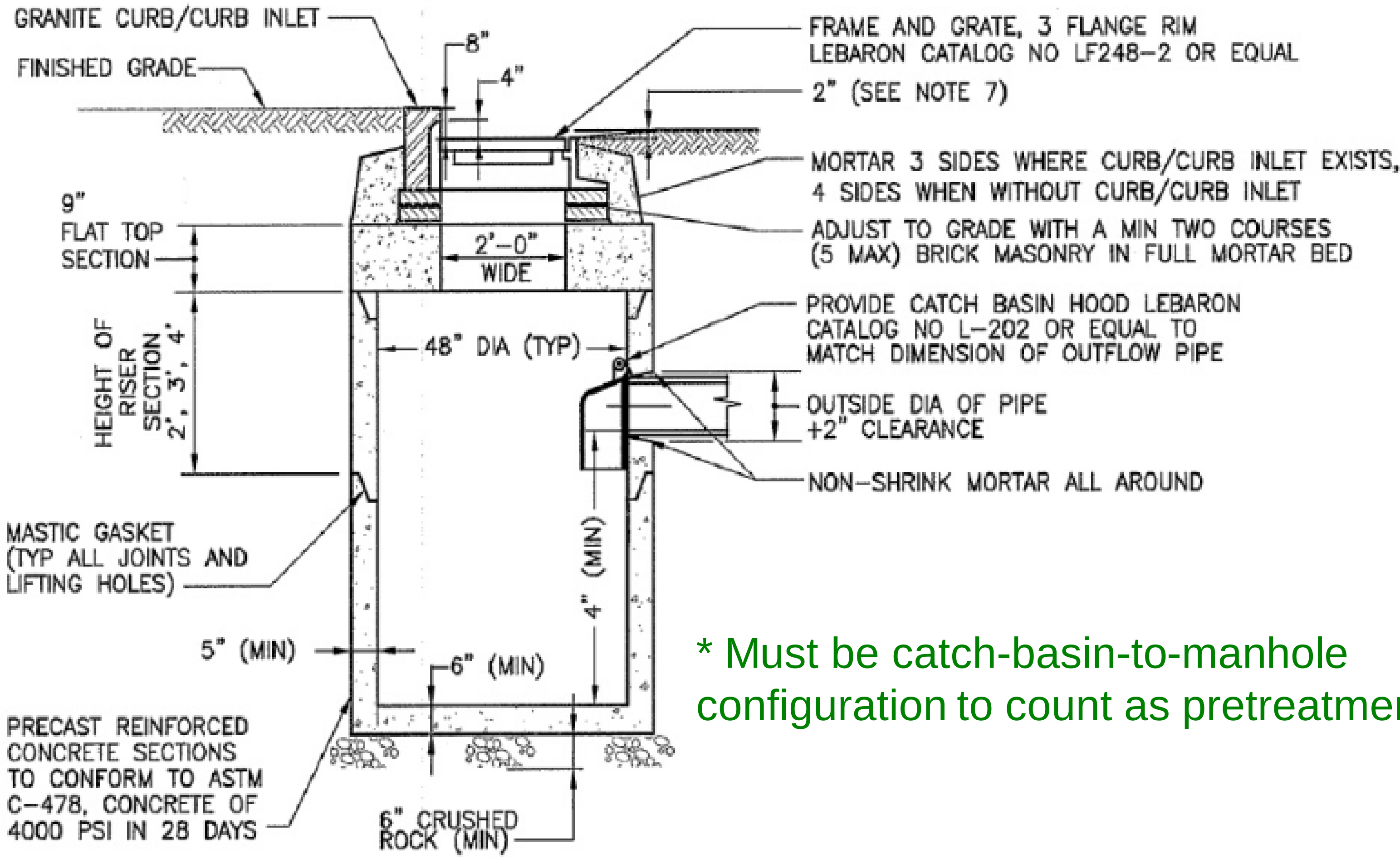
# Deep Sump Catch Basin

Pretreatment BMPs

Figure 6-4 Deep Sump Catch Basin (MADEP, 2008)

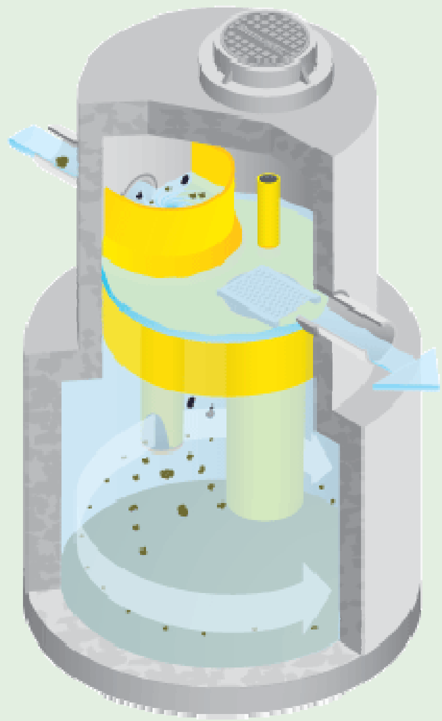



* Must be catch-basin-to-manhole configuration to count as pretreatment

# Proprietary Devices

Pretreatment BMPs

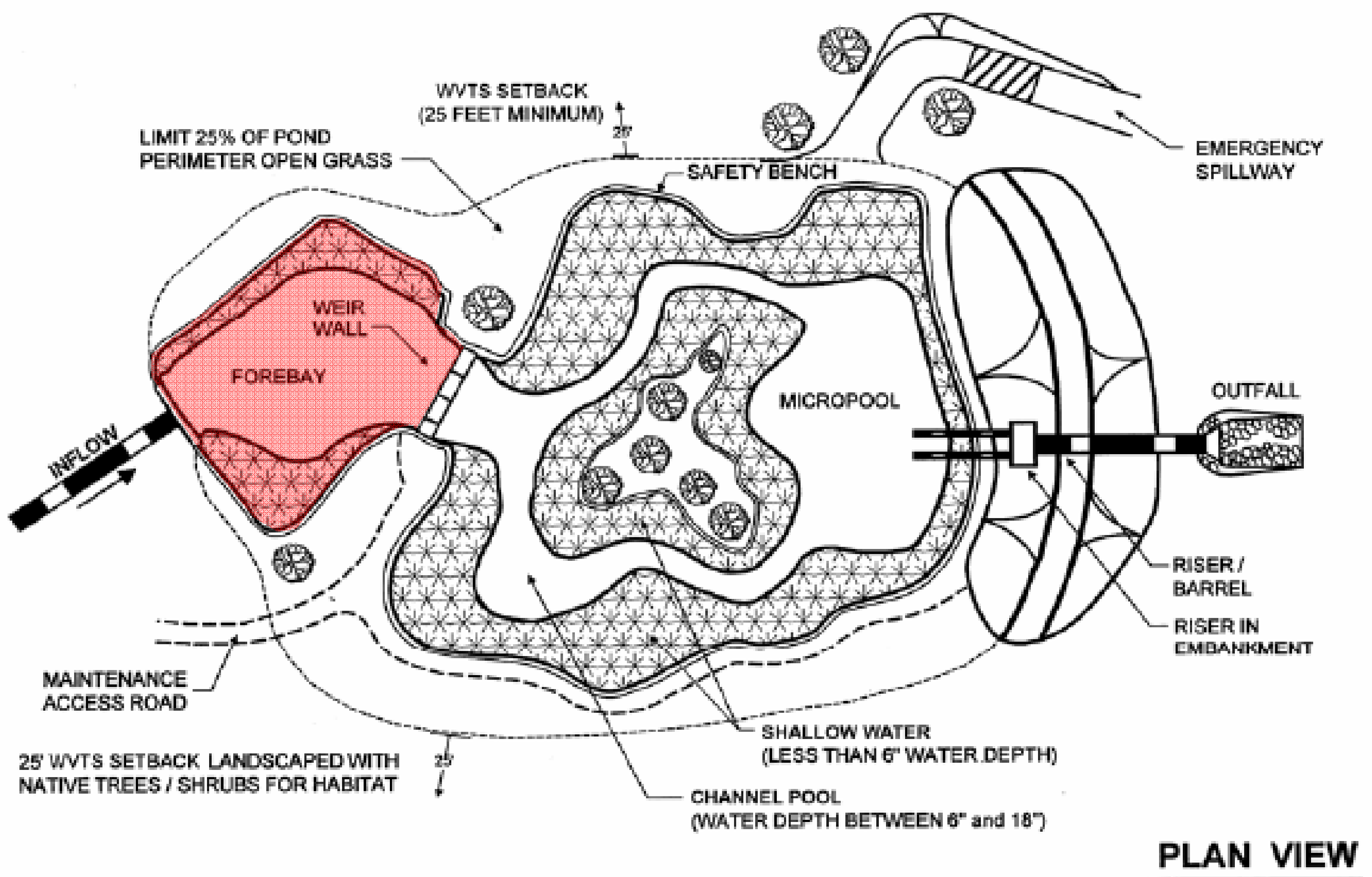
- Must have third-party verified 25% TSS removal rate
- Flow-thru devices must be designed to handle entire $WQ_f$
- Must be designed as off-line (or have internal bypass) to allow large flows to bypass system
- Oil/grit separators great for LUHPPLs



Stormceptor®
Extended oil storage (EOS) system

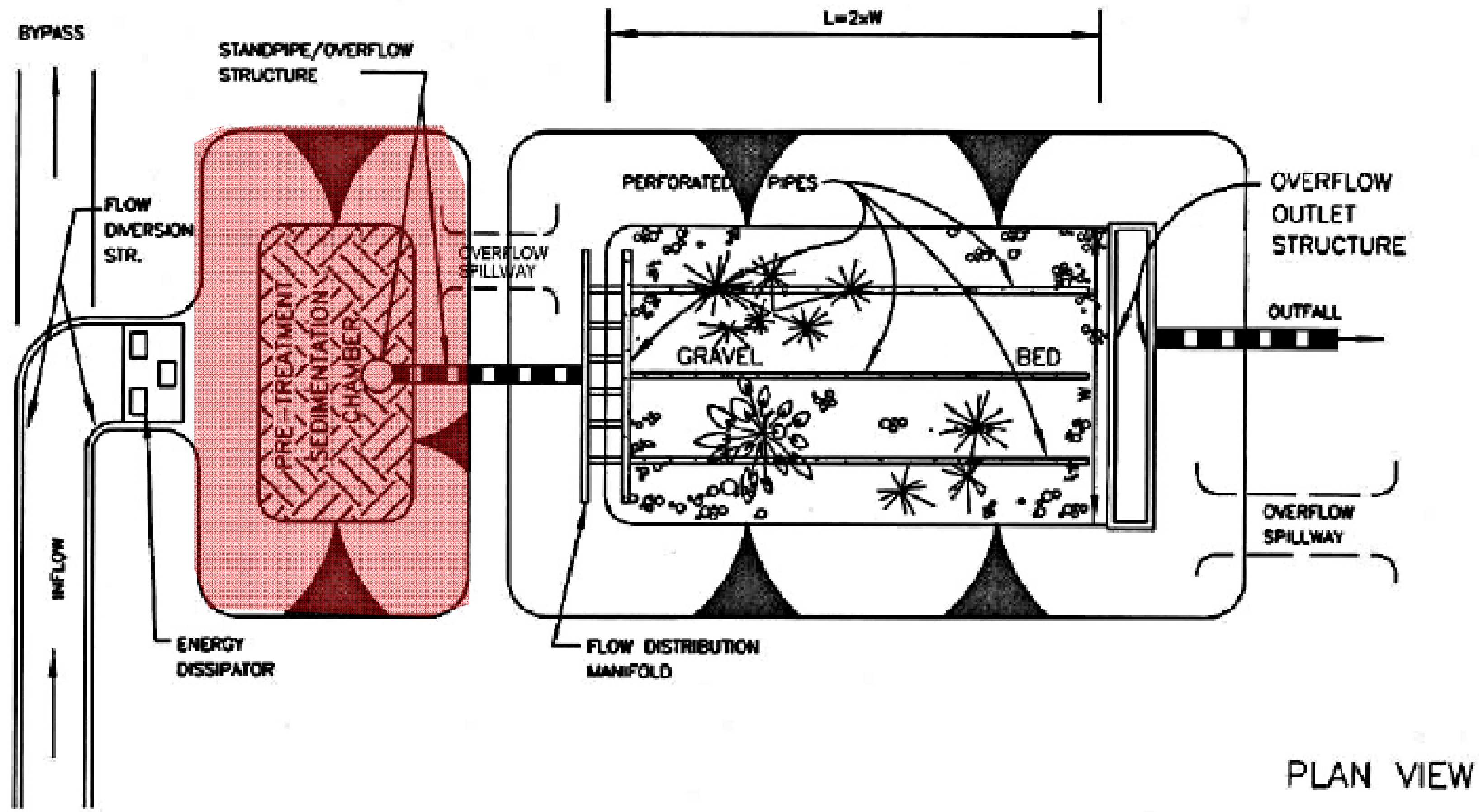
# WVTS: Shallow WVTS

Figure 5-1 Shallow WVTS



# WVTS: Gravel WVTS

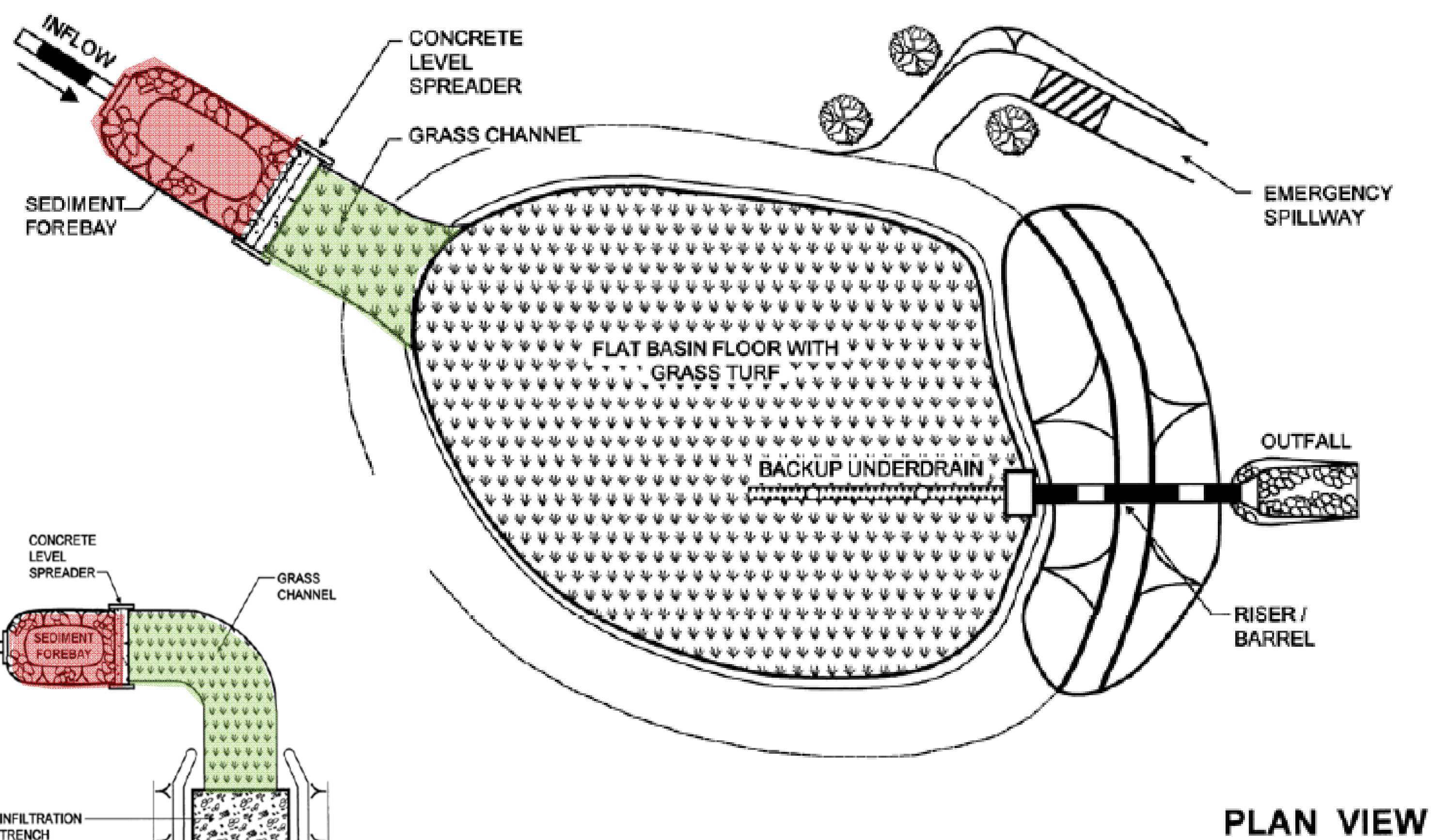
Figure 5-2 Gravel WVTS – Alternative 1

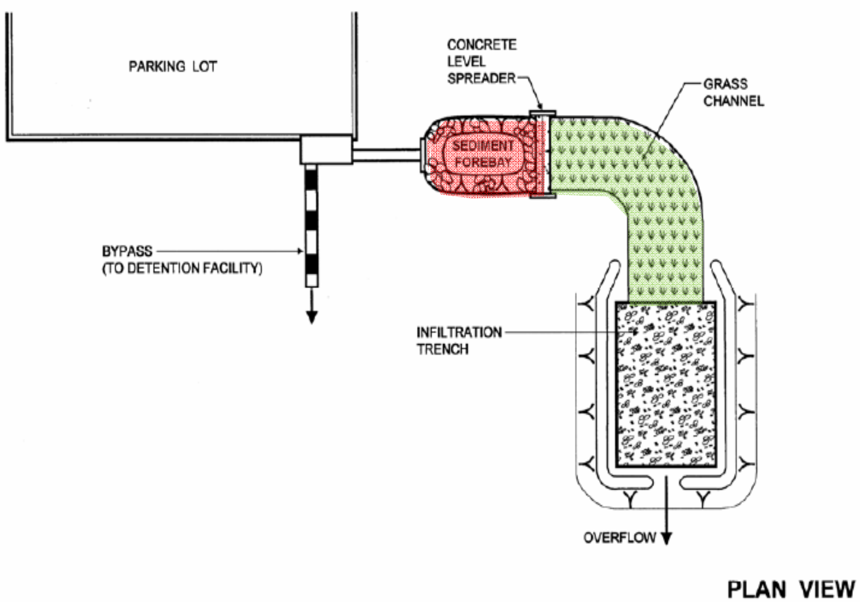


# Infiltration: Basins & Trenches



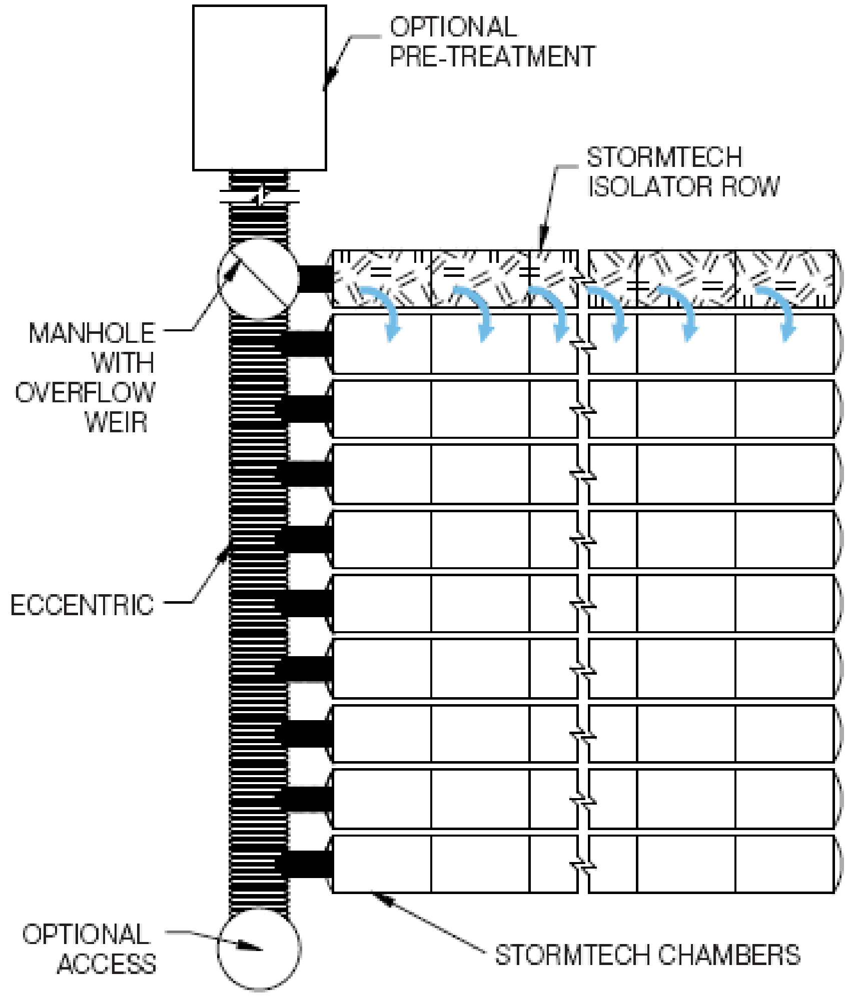
Figure 5-6 Infiltration Basin



# Infiltration: Chambers

StormTech Isolator Row with Overflow Spillway
(not to scale)

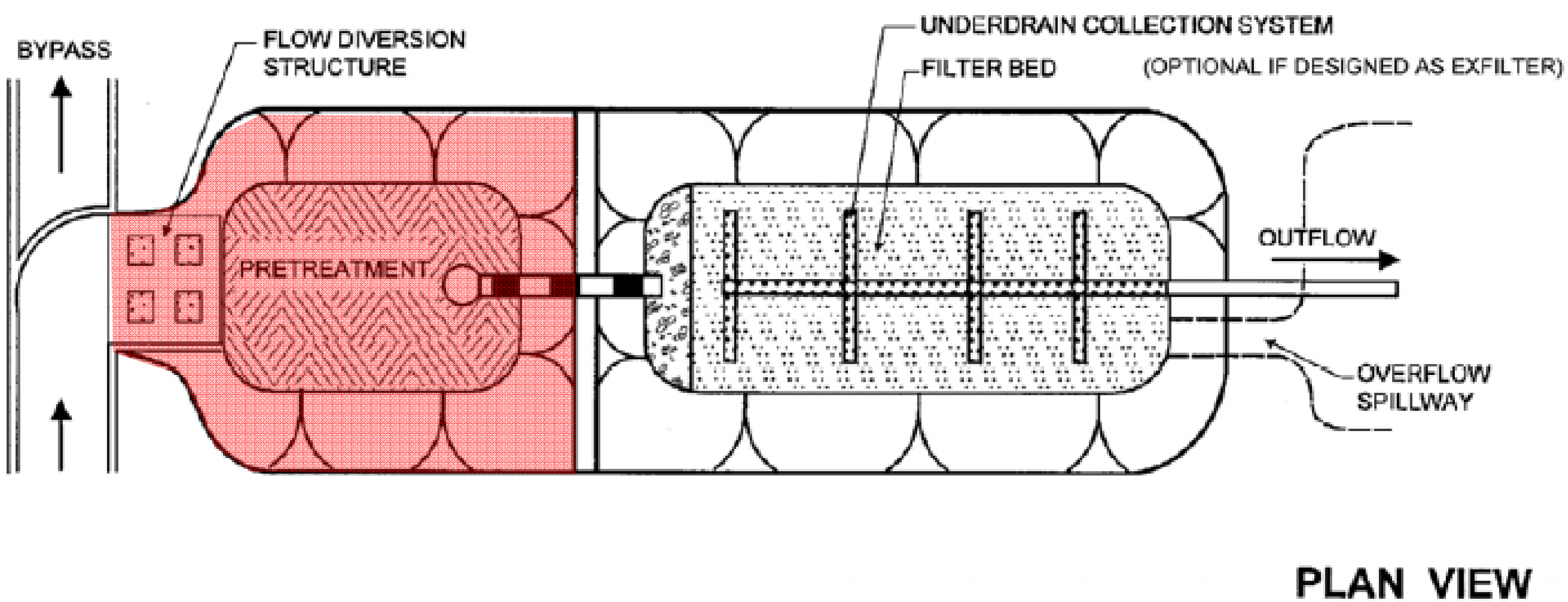



Isolator™ Row O&M Manual
StormTech® Chamber System for Stormwater Management

Horsley Witten Group, Inc.

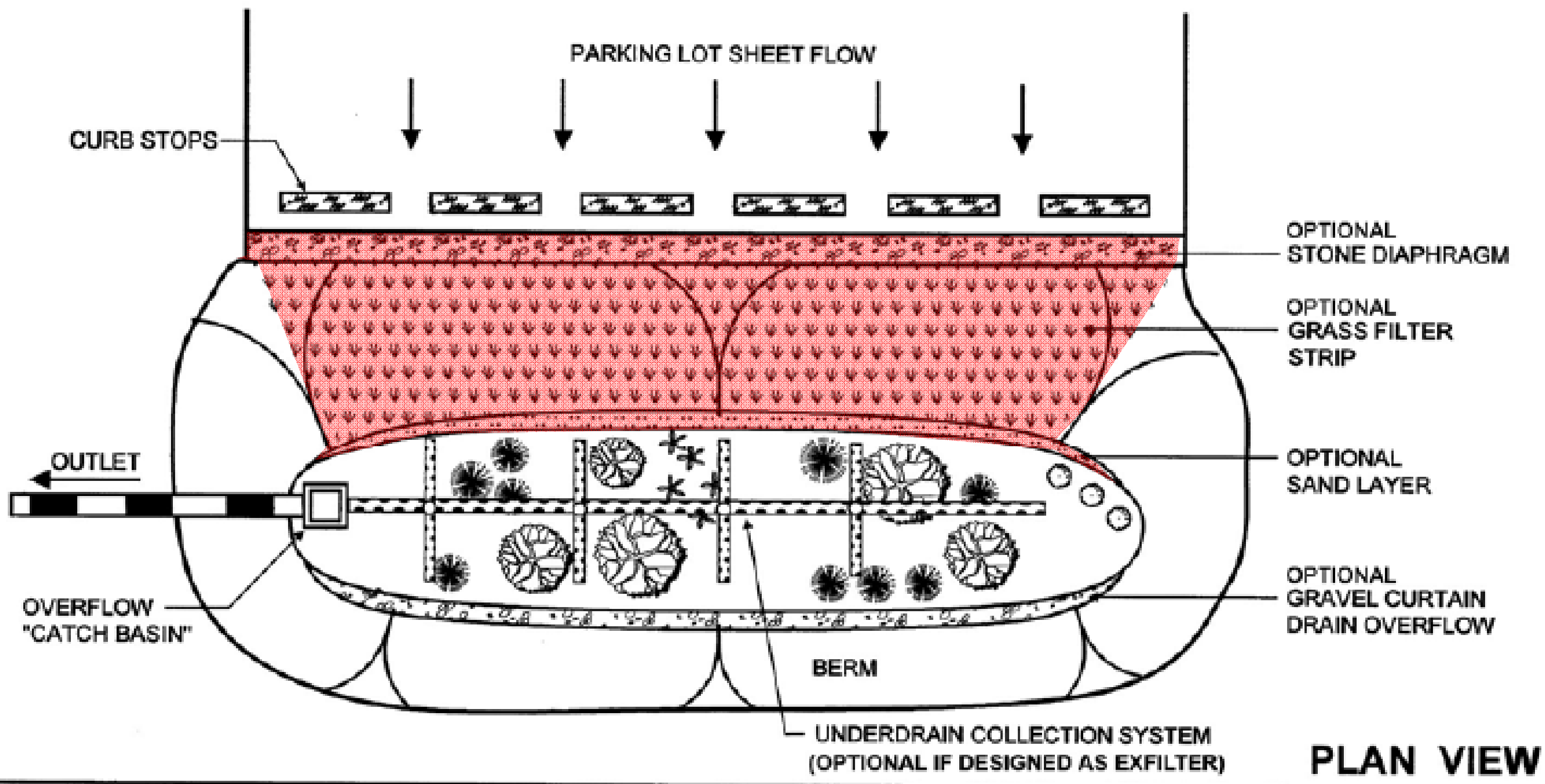
# Filters: Sand & Organic Filter

Figure 5-12 Sand Filter



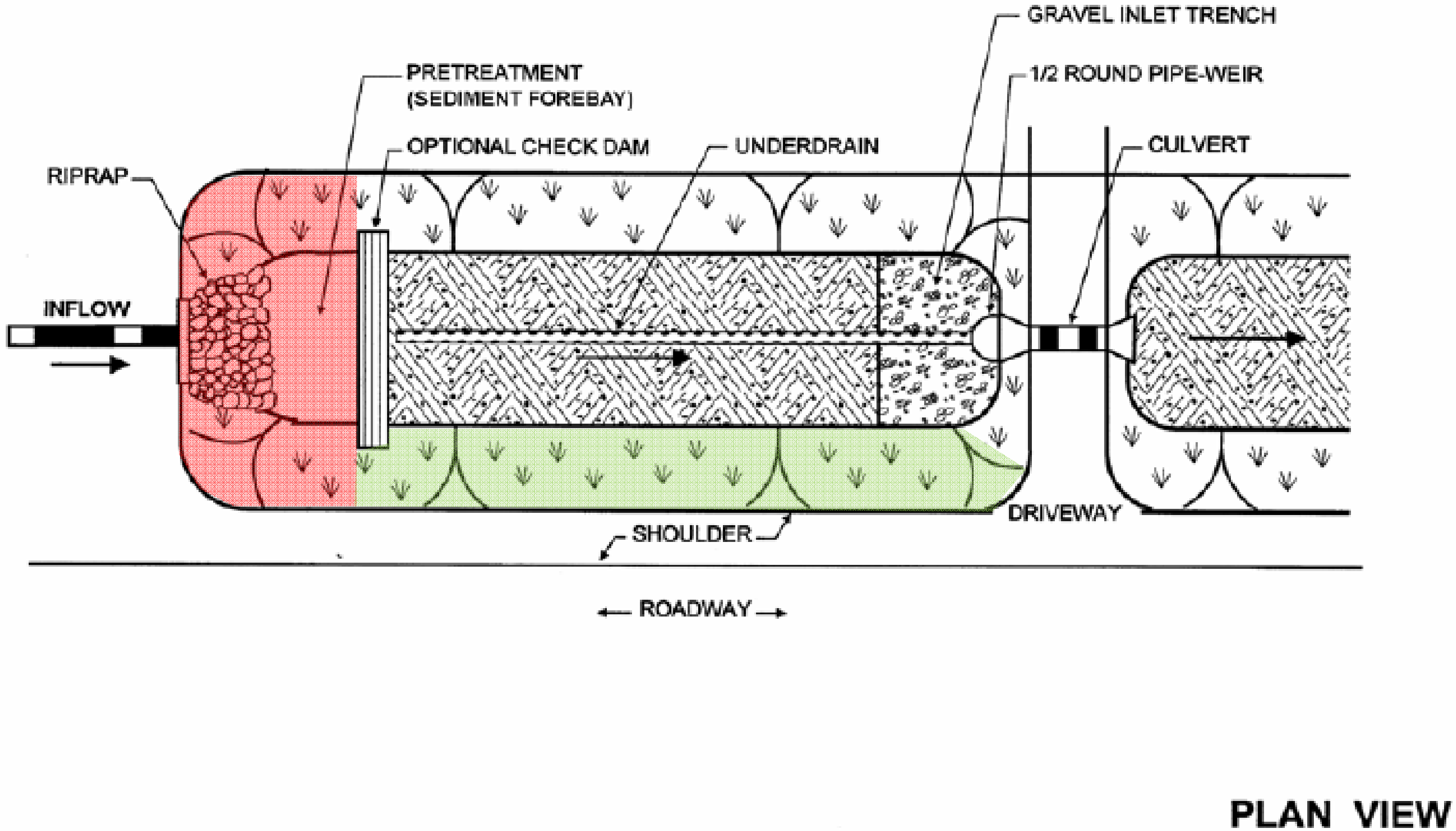
# Filters: Bioretention

Figure 5-14 Bioretention



# Open Channels

Figure 5-17 Dry Swale



# No pretreatment required

Approved WQ BMPs

- Filters: Green roofs
- Infiltration: Permeable Pavers (unless there is "run-on"
- Infiltration: Dry Wells

# Storage


Rhode Island Stormwater Design and Installation Standards Manual

December 2010

Rhode Island Department of Environmental Management and

CRMC

Coastal Resources Management Council

Ch 3

- Quantity Standards

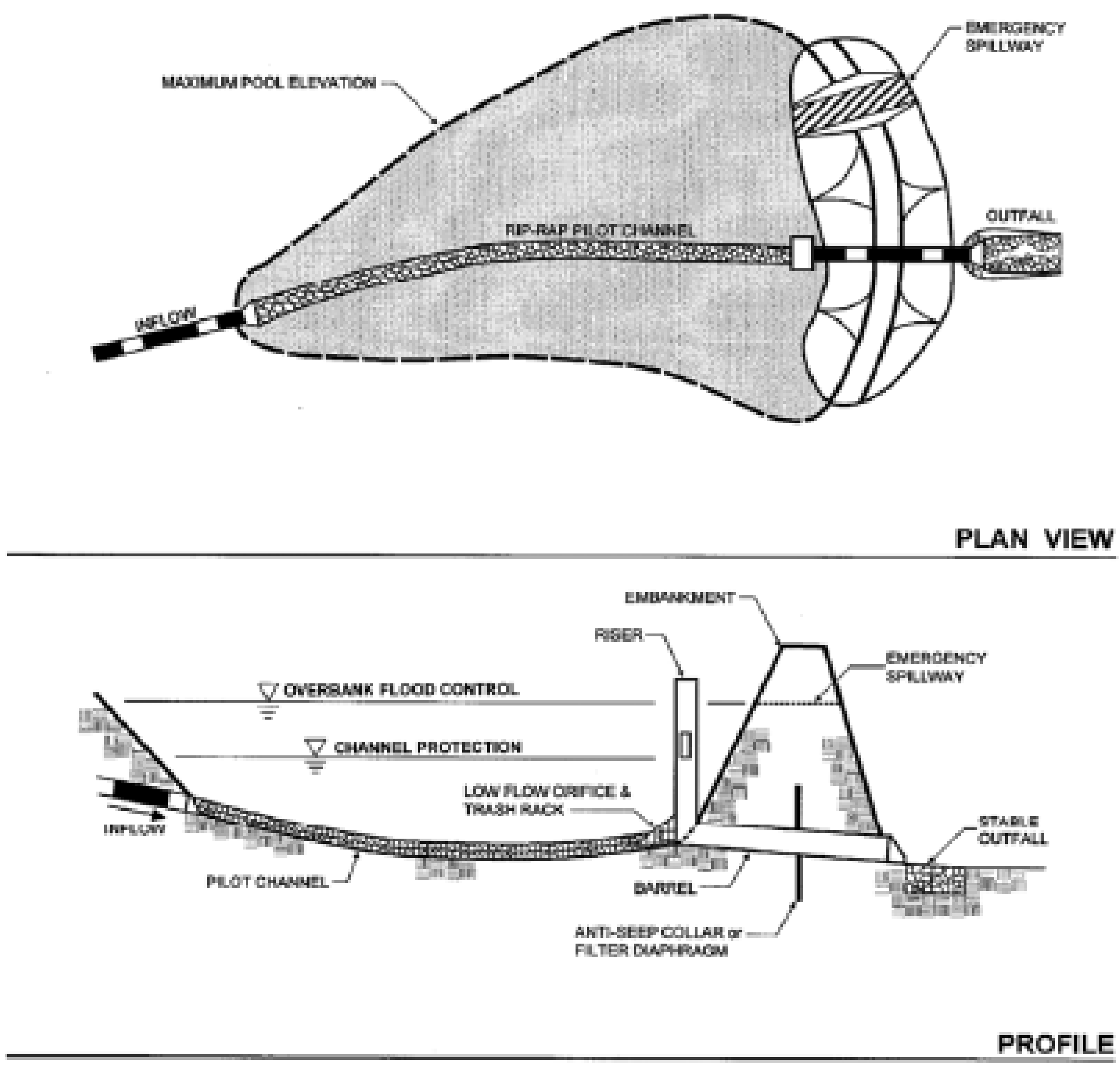
Ch 7

- Storage Practices
  - Cannot be used alone to meet WQ
  - Stormwater basins, underground storage facilities, and high-rate infiltration for recharge/storage only

# Stormwater Basins

Storage BMPs

Figure 7-1 Dry Extended Detention Basin




- •Min. DA of 25 acres for wet basins, unless in gw
- •Permanent pool not included in storage calcs
- •Cold-water fishery restrictions

# Enhanced Treatment

**Using Basins for Additional Pollutant Loading Reduction**

In order to use the removal rates for basins as listed in Appendix H.3 (Pollutant Loading Analyses) Table H-4, the following design criteria must be met.

**Pretreatment**

Required Elements

- Each basin shall have a sediment forebay or equivalent upstream pretreatment. The forebay shall be sized to contain 10% of the water quality volume ($WQ_v$) sized per Chapter 6. The forebay storage volume counts toward the total $WQ_v$ requirement.

**Treatment**

Required Elements

- The minimum detention time for the $WQ_v$ shall be 24 hours.
- Storage for the channel protection volume ($CP_v$) and the $WQ_v$ shall be computed and routed separately (i.e., the $WQ_v$ cannot be met simply by providing $CP_v$ storage for the one-year storm).
- Provide water quality treatment storage to capture the computed $WQ_v$ from the contributing drainage area through a combination of permanent pool and extended detention, as outlined in Table 7-1.

**Table 7-1. Minimum Required Storage Volumes for Basins Used for Enhanced Pollutant Removal**

| Design Variation | %$WQ_v$ | |
|---|---|---|
| | Permanent Pool | Extended Detention |
| Dry Extended Detention Basin | 20% min. | 80% max. |
| Wet Extended Detention Basin | 50% min. | 50% max. |

Design Guidance

- Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, extended detention, and shallow water).

**Minimum Basin Geometry**

Required Elements

- The minimum length to width ratio for a basin shall be 1.5:1 (i.e., length relative to width).
- Provide a minimum Drainage Area: Surface Area Ratio of 75:1.
- Incorporate an aquatic bench that extends up to 15 feet inward from the normal edge of water, has an irregular configuration, and a maximum depth of 18 inches below the normal pool water surface elevation (see Figure 5-5).

Design Guidance

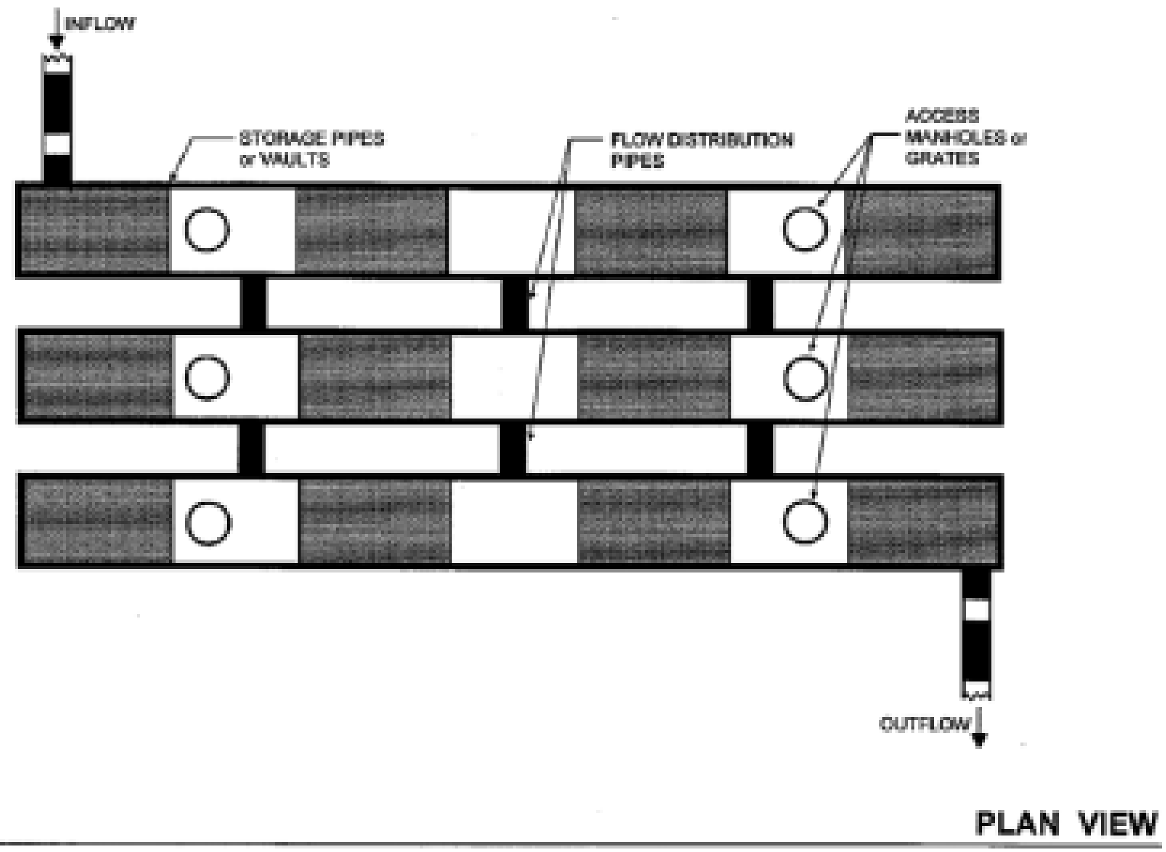
- To the greatest extent possible, maximize flow path through the system, and design basins with irregular shapes.

- To use basins for additional pollutant loading reduction, must design according to info on pg. 7-4

# Underground Storage Devices

Storage BMPs

Figure 7-3 Underground Storage Vault

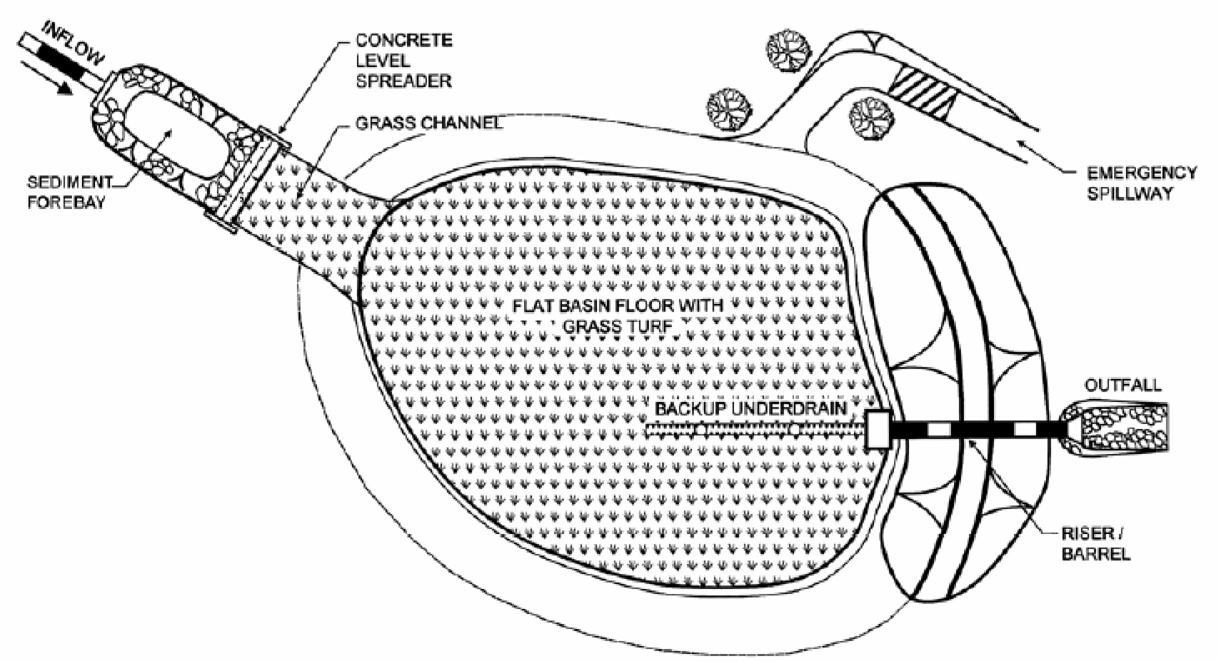



- Max. DA generally 25 acres
- Sufficient access points shall be provided
- No cold-water fishery restrictions

# Infiltration (Recharge/Storage Only)

Storage BMPs

Figure 5-6 Infiltration Basin




PLAN VIEW

- Sites with infiltration rates >8.3 in/hr
- Mounding analysis may be required
- May be constructed in suitable fill

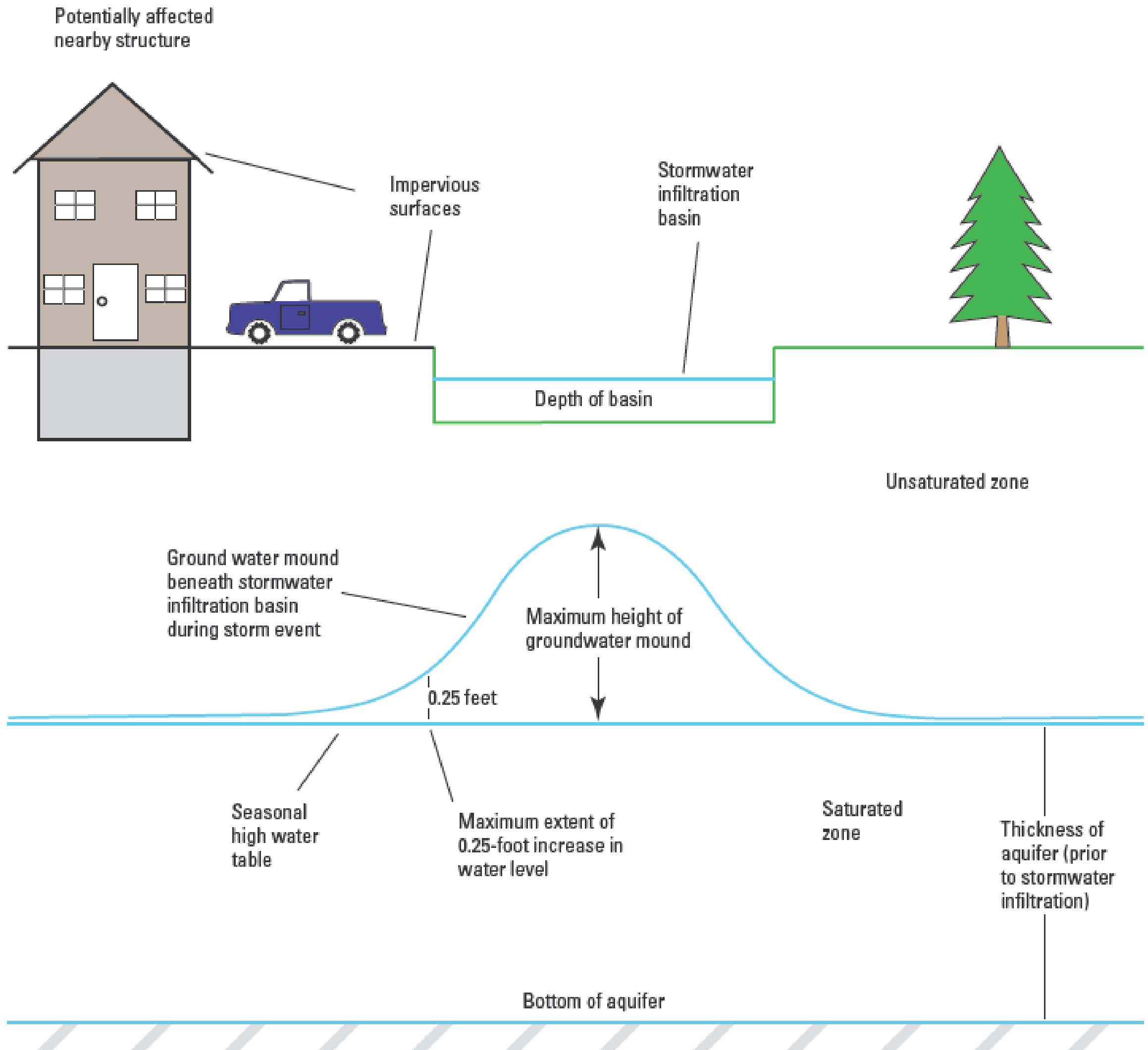
# Mounding Analysis

Storage BMPs

- When is it required?
  - Infiltration of stormwater (except for residential rooftops ≤ 1,000sf) AND
  - Separation to SHGT < 4' AND
  - On-line practice accepting runoff from the 10-year storm event and greater
- What does it tell us?
  - Feasibility of proposed BMP
  - Effect on nearby structures, OWTSs, etc.
- How is it done?
  - Hantush Method or equivalent

Storage BMPs

# Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins




http://pubs.usgs.gov/sir/2010/5102/

Scientific Investigations Report 2010–5102

Storage BMPs

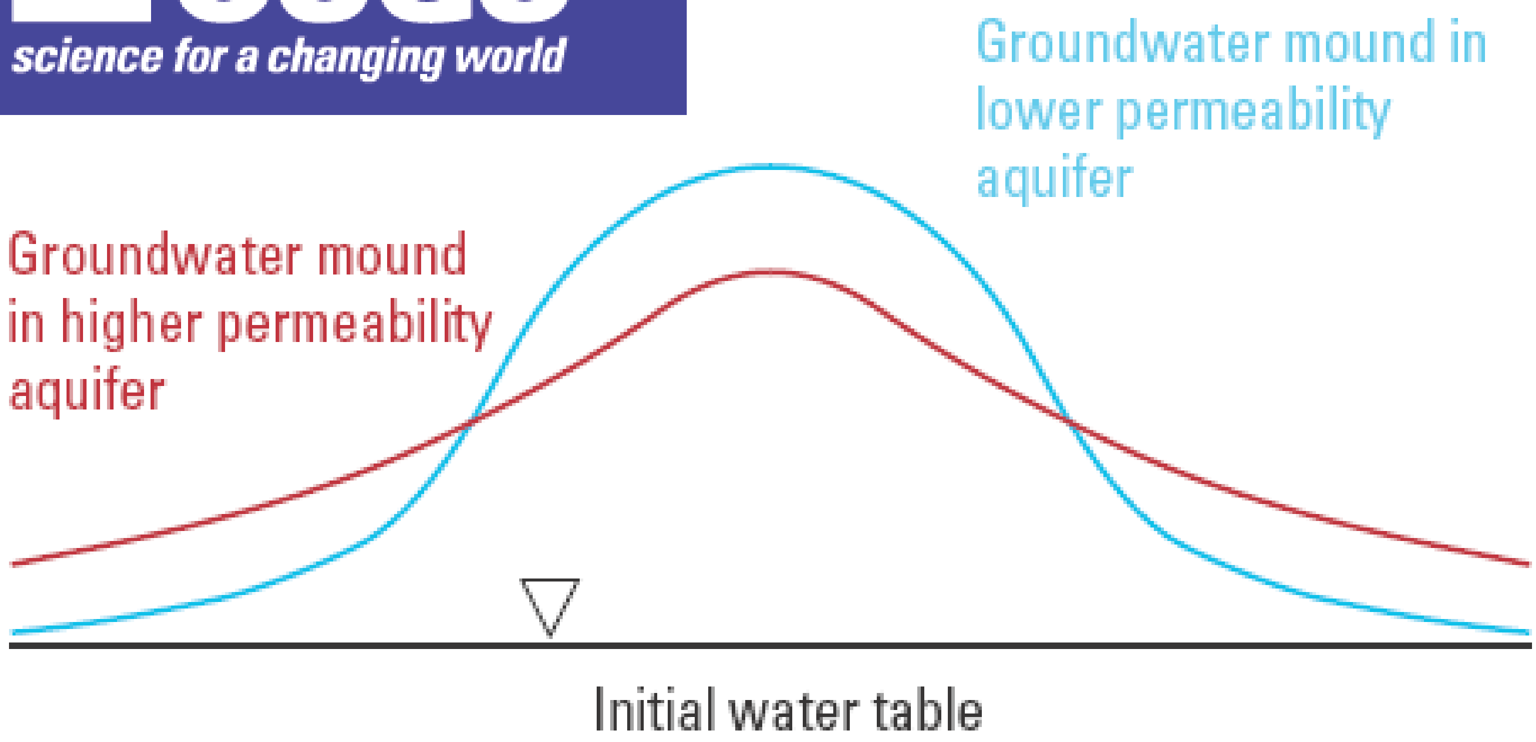



**Figure 6.** Schematic diagram showing relative shape of groundwater mounding in aquifers of higher and lower soil permeability.

# Questions?