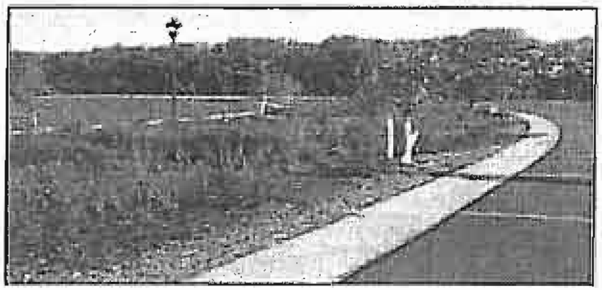
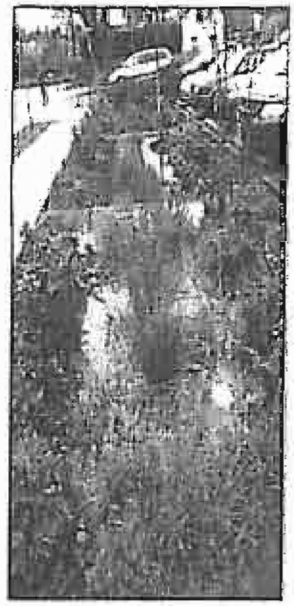
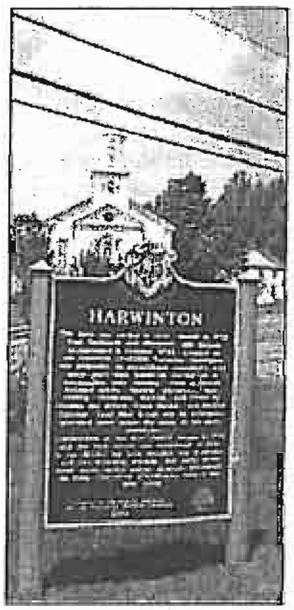
HARWINTON

Recommended Low Impact Development Techniques







Design & Construction Standards

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These design & construction standards contain information developed by Steven Trinkaus, PE including results of independent observations of LID systems in the field. This document also includes information on Low Impact Development obtained from highly regarded sources, such as academic institutions other technical manuals . These sources are identified where this material has been used.

This project was made possible by a grant from the Connecticut Department of Environmental Protection through the Farmington River Enhancement Grant Program.

The grant is intended to support the formation of a local committee to:

- review existing municipal regulations and ordinances, and
- draft recommended changes to remove barriers to low impact development (LID) and create opportunity for low impact development practices to be employed in Harwinton.

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APPENDICES:

1.0 Purpose of these Recommended Low Impact Development Techniques

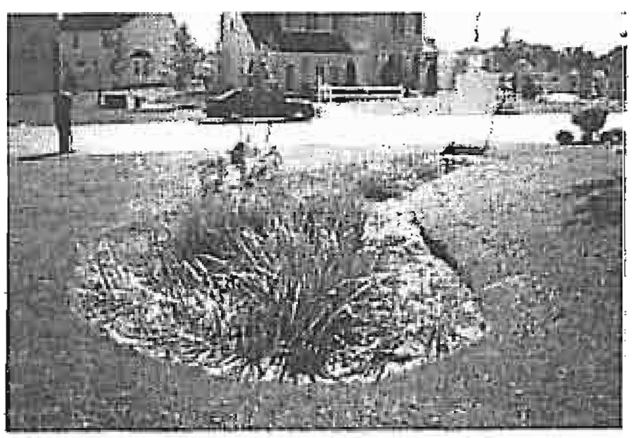
The purpose of these recommended low impact development techniques is to provide the design and construction specifications to guide the application of Low Impact Development (LID) treatment systems in the Town of Harwinton. These design and construction specifications have been assembled based on significant research and field observations of LID systems in the field.

These recommended low impact development techniques will be used by four main groups; design engineers, municipal land use agencies and staff, and reviewers for regulatory programs. Design engineers are the group that will use these recommended low impact development techniques the most. The design engineers should familiarize themselves with all the design specifications and calculations, where required, to ensure that the selected LID system(s) will perform correctly in the field and provide their intended environmental benefit.

Low Impact Development represents a paradigm shift of the current processes which drive the development process. It is very important that the professionals and individuals who will use these recommended low impact development techniques understand the concepts which created LID. Educational resources for Low Impact Development are provided in a separate document entitled "Public Educational Materials on Stormwater Management and Low Impact Development in the Town of Harwinton." The use of LID strategies and techniques can reduce the cost of stormwater infrastructure between 20-40% on average (EPA, 2007) while minimizing or eliminating the environmental impact of development on the natural environment.

2.0 List of BMPS for Groundwater Recharge and Water Quality Treatment

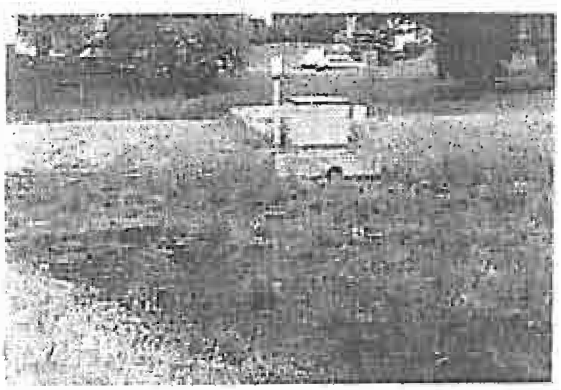
FILTERING SYSTEMS



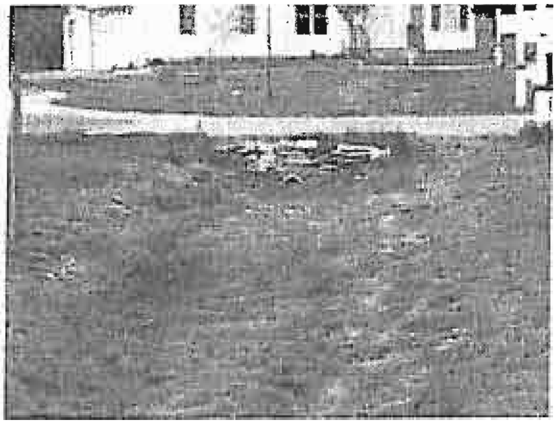
Bioretention: A shallow depression with vegetation that treats stormwater as it filters through a specific soil mixture. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 2.0.a – Bioretention System

Tree Filter: A Bioretention system contained within a precast unit for use in retrofit situations in a commercial environment.
Figure 2.0.b – Filterra Tree Filter (www.filterra.com)

Surface Sand Filter: This system treats stormwater by the removal of coarse sediments in a sediment chamber or forebay, which is easily maintained prior to the stormwater filtering through a surface sand matrix. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 2.0.c – Surface Sand Filter (UNHSC)



Organic Filter: This filtering practice uses an organic soil component such as compost or a sand/peat moss mixture to filter the stormwater. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 2.0.d – Organic Filter



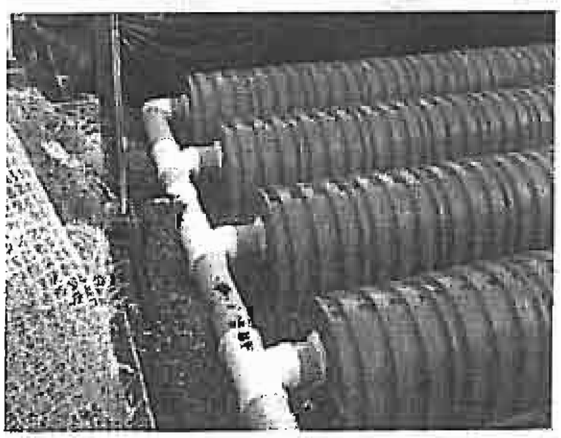
Dry Swale: These are vegetated open swales or depressions which are specifically designed to detail and infiltrate stormwater into the underlying soils. They use a modified soil mixture to enhance the infiltrative capacity of the system. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 2.0.e – Dry Swale (UCONN NEMO)

INFILTRATION SYSTEMS

Infiltration Trenches: These are infiltration practices that store water volume in open spaces in a chamber or within the void spaces of crushed stone or clean gravel prior to the water being infiltrated into the underlying soils. These practices are permissible for runoff from residential roofs or small commercial roofs (<3,000 sq.ft.). For larger commercial roofs, pre-treatment via one of the filtering systems list above must be provided prior to discharge into this type of infiltration system.

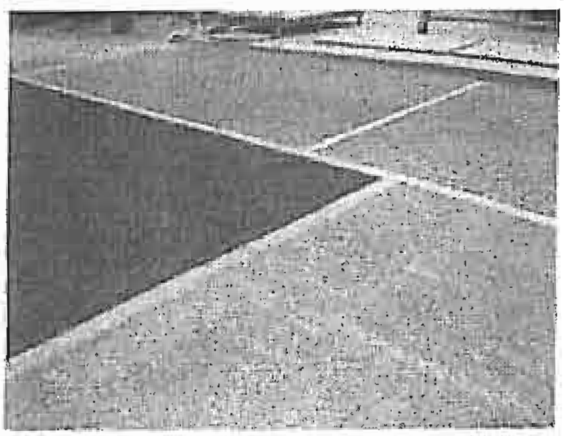
2.0.f – Infiltration Trench (www.washco-md.net)



Infiltration Chambers: These are infiltration practices that store water volume in open spaces both within the chamber and the void spaces in the crushed stone.

Figure 2.0.g – Infiltration Chamber (www.tritonsws.com/Images/case-studies)

Infiltration Basin: This is an infiltration practice that stores stormwater in a flat, vegetated surface depression prior to infiltrating into the underlying soils.
Figure 2.0.h – Infiltration Basin – (www.wash-md.net)



Alternative Paving Surfaces: These are practices that will store and filter stormwater in the void spaces of a clean gravel base prior to infiltrating into the underlying soils.
Figure 2.0.i – Porous Pavements (www.stormwaterenvironments.com)

2.1 List of BMPs for Water Quality Treatment

WET VEGETATED TREATMENT SYSTEMS

Extended Detention Shallow Marsh: A stormwater basin that provides treatment by the utilization of a series of shallow, vegetated permanent pools within the basin in addition to shallow marsh areas.
Figure 2.1.a – Extended Detention Shallow Wetlands (www.wetlands.com.au)

Subsurface Gravel Wetlands: A stormwater system where water quality is provided by the movement of stormwater through a subsurface, saturated bed of gravel with the soil surface being planted with emergent vegetation.
Figure 2.1.b – Subsurface Gravel Wetlands (UNHSC)

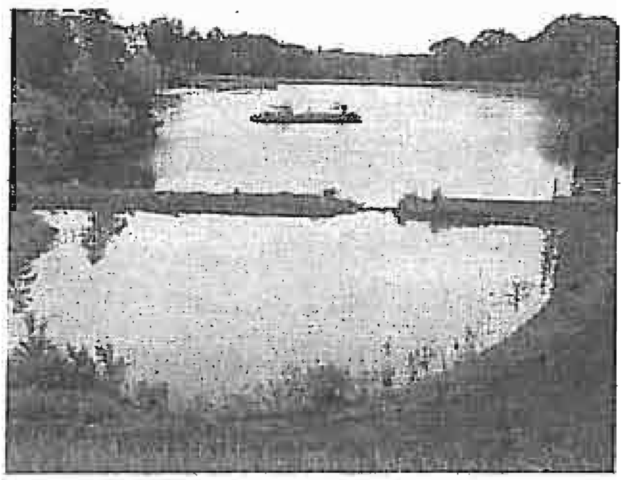
Pond / Wetland System: A treatment system which combines the shallow, vegetated aspects of a marsh with at least one pond component.
Figure 2.1.c – Pond/Wetland System (www.starenvironmentalinc.com)

Wet Swale: This is a vegetated depression or open channel designed to retain stormwater or intercept groundwater to provide water quality treatment in a saturated condition.
Figure 2.1.d – Wet Swale (Dr. Bill Hunt, NCSU)

2.2 List of BMPs for Pretreatment for Water Quality Systems

Filter Strips: These vegetated systems that are designed to treat stormwater from adjacent impervious area which occurs as overland flow. These systems function by slowing flow velocities, which allows the removal of sediments and other pollutants.

2.2.a – Filter Strip (www.trinkausengineering.com)



Sediment Forebay: This is a depressed vegetated area prior to a larger stormwater treatment facility which will trap coarse sediments and reduce maintenance requirements of the larger treatment facility.

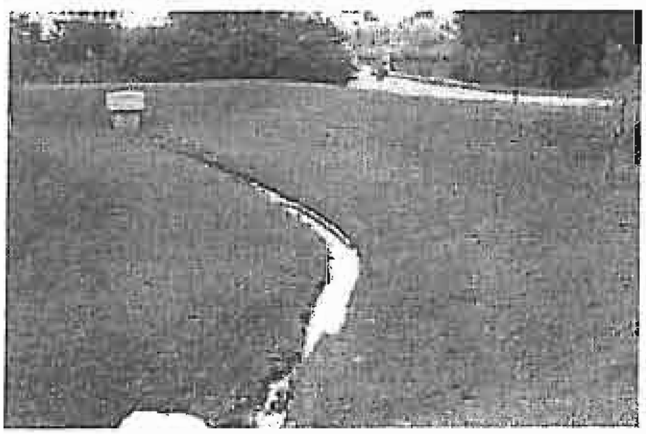
Figure 2.2.b – Sediment Forebay (www.vwrrc.vt.edu)

Deep Sump Catch Basin: These systems are modified structures that are installed as part of a conventional stormwater conveyance system. They are designed to trap trash, debris and coarse sediments. While the hooded outlet provides the potential to trap oil and grease, frequent maintenance is required to remove the oils from the water surface.

Proprietary Treatment Devices: These are manufactured systems which were engineered to provide a cost-effective approach to stormwater quality in a contained space. These systems include oil/grit separators, hydrodynamic separators, and a wide range of filter systems with specialized media. Research by the Center for Watershed Protection, University of New Hampshire Stormwater Center in the past few years have shown that many of these systems are not able to achieve the water quality goals as specified in Section 4.3.3. They may be appropriate for pretreatment in some situations. In order to use a proprietary treatment device, independent research documentation must be provided to justify the pollutant removal efficiency.

2.3 List of BMPs for Water Quantity Control

Wet Extended Detention Pond: This practice is primarily designed to address stormwater quantity increases. They have a deep permanent pool, but do not effectively remove stormwater pollutants. These systems may be located in areas of seasonally high groundwater.
Figure 2.3.a – Wet Extended Detention Pond (NCSU)



Dry Detention Pond: This practice has a dry bottom and is also designed to address changes in stormwater quantity only.
Figure 2.3.b – Dry Detention Pond (www.dhn.iihr.uiova.edu)

3.0 Design & Construction Standards for LID Systems

There are six categories for required design elements and guidelines for each type of stormwater recharge, water quality, pretreatment and water quantity systems. The categories are feasibility, conveyance, pretreatment, sizing criteria, treatment and maintenance. The following pages provide detailed design parameters for each type of LID treatment system to be used to address stormwater issues in the Town of Harwinton.

As the LID approach to stormwater management focuses on treating runoff at its source, both short term and long term maintenance of these systems are very important. Legally binding maintenance agreements for these LID systems must be prepared and filed in the Office of the Town Clerk for the Town of Harwinton. Each maintenance agreement must include the maintenance requirements as specified for each system. A maintenance agreement format is provided in Appendix "B".

Table 3.0.a has been developed to assist the design engineer in determining the optimum configuration of treatment system(s) to meet stormwater and water quality goals as specified in the Town of Harwinton Zoning and Subdivision Regulations.

Table 3.0.a – Stormwater System Matrix

Stormwater Treatment Device Selection Matrix

Stormwater Treatment Systems	GRv	WQv	PT	FP
FILTERING SYSTEMS				
Bioretention (page 14)	■	■		
Tree Filter (page 17)	■	■		
Surface Sand Filter (page 19)	■	■		
Organic Filter (page 21)	■	■		
Dry Swales (page 23)	■	■		
INFILTRATION SYSTEMS				
Infiltration Trenches (page 25)	■	■		
Infiltration Chambers (page 27)	■	■		
Infiltration Basins (page 29)	■	■		
Alternative Paving Surface (page 31)	■	■		
WET VEGETATED TREATMENT SYSTEMS				
Extended Detention Shallow Wetlands (page 34)		■		■
Subsurface Gravel Wetlands (page 36)		■		
Pond / Wetland System (page 38)		■		■
Wet Swales (page 40)		■		

PRETREATMENT FOR WATER QUALITY SYSTEMS				
Filter Strip (page 42)				
Sediment Forebays (page 44)				
Deep Sump Catch Basins (page 46)				
Proprietary Treatment Devices (page 48)				
WATER QUANTITY CONTROL				
Wet Extended Detention Pond (page 50)				
Dry Detention Pond (page 52)				

GRv: Groundwater Recharge Volume
WQv: Water Quality Volume
PT: Pretreatment
FP: Flood Protection

3.1 – BIORETENTION (GRv & WQv)

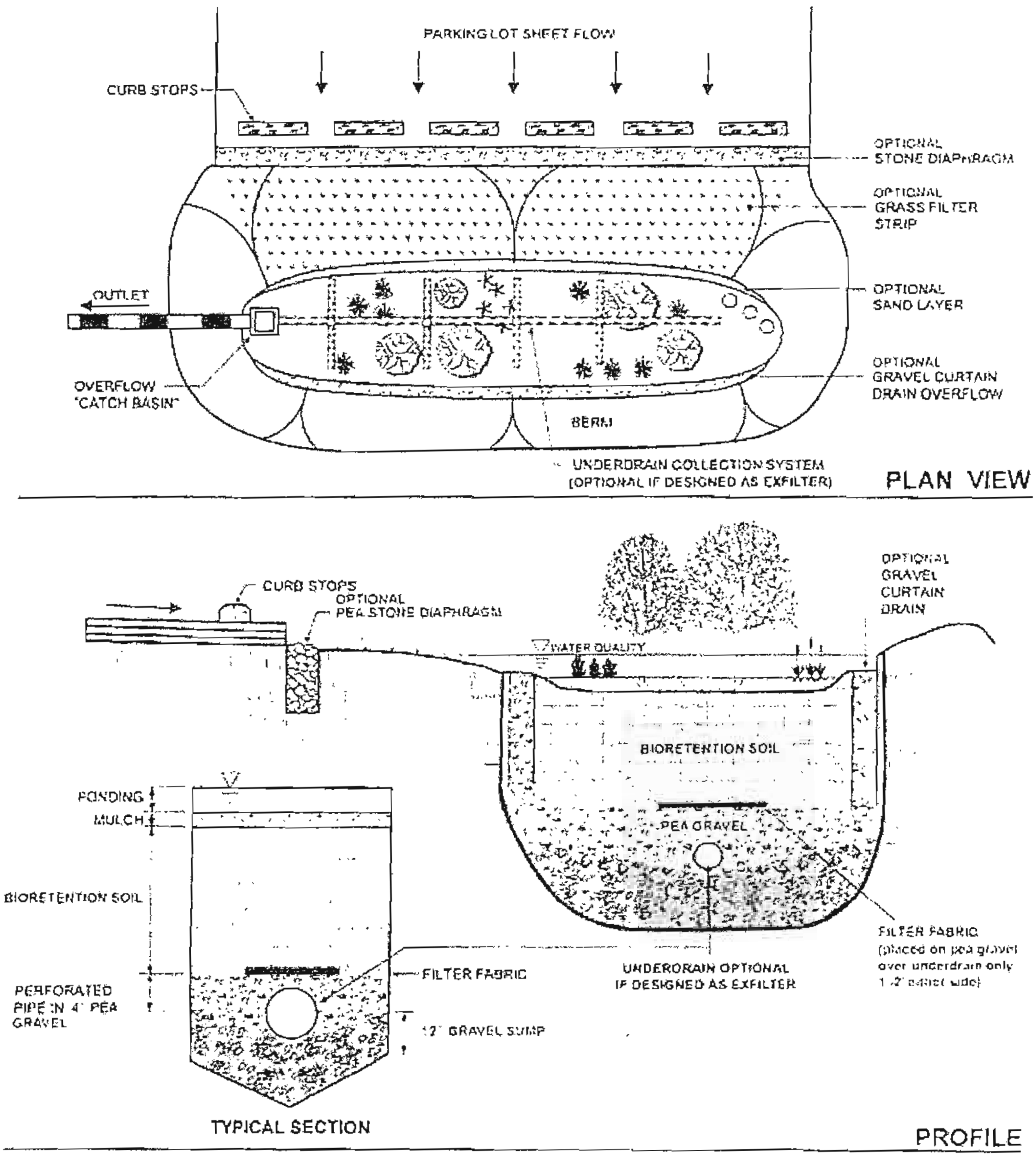


Figure 3.1 – Typical Bioretention (RI DEM, 2010)

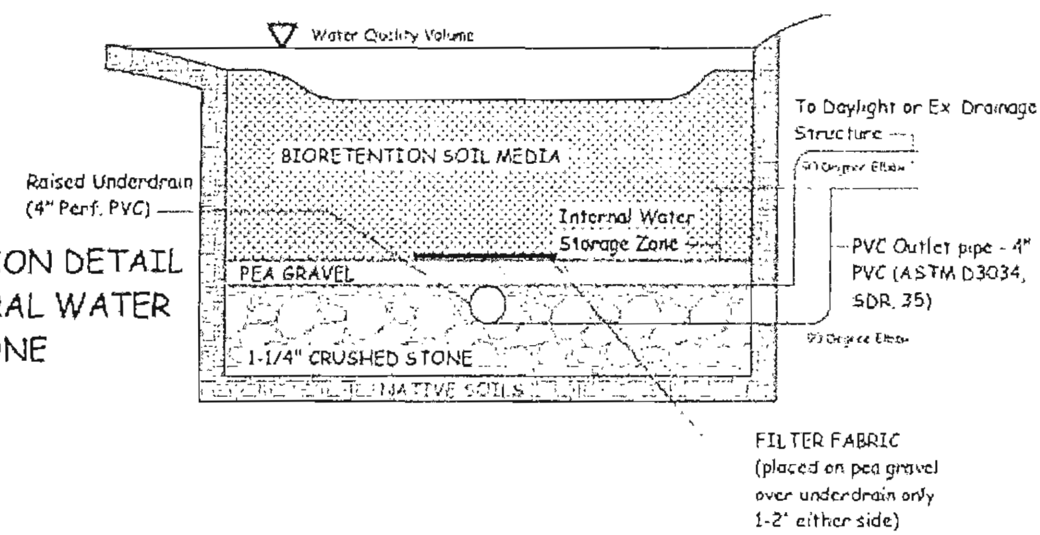
Table 3.1 – Bioretention Design Parameters

Design Parameter	Residential Roof or Driveway Runoff	Runoff from Commercial Roof	Runoff from Commercial Driveway or Parking Area
Deep Test Pit	Yes, min. 6' in depth	Yes, min. 8' in depth	Yes, min. 8' in depth
Percolation Test	Yes, 24-30" deep	Yes, 30-36" deep	Yes, 30-36" deep
Depth of Soil Media	18"	24"	36"
Separation to SHGW from bottom of soil media	12" for A Soils 6" for B & C Soils*	24" for A Soils 18" for B & C Soils*	24" for A Soils 18" for B & C Soils*
Underdrain (raised)	Not required for A & B soils Required for C Soils	Not required for A soils Required for B & C Soils	Not required for A soils Required for B & C Soils
Depth of Pea Gravel Layer above underdrain	3"	3"	3"
Depth of 1-1/4" crushed stone for underdrain layer	12"	12"	12"
Enhanced Nitrogen Removal (Internal Water Storage)**	Saturate bottom 6" of Soil Media Layer	Saturate bottom 12" of Soil Media Layer	Saturate bottom 12" of Soil Media Layer
Overflow Provisions – Top of pipe set at max. ponding depth	No, for A Soils Yes, for B & C Soils	No, for A Soils Yes, for B & C Soils	No, for A Soils Yes, for B & C Soils

* Separation to SHGW may be reduced by 50% provided that the surface ponding depth is reduced by 50% and the surface area of the bioretention facility is increased accordingly.

** See Detail below for Internal Water Storage Design

BIORETENTION DETAIL
WITH INTERAL WATER
STORAGE ZONE
N.T.S.



Required Design Elements for Bioretention

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level for systems serving roads, parking lots & commercial roofs.
- Vertical separation from bottom of soil media to SHGW shall conform to the requirements found in Table 7.0.c
- The maximum drainage area to a bioretention system shall be five (5) acres.
- Deep test pit and percolation test must be performed within 15' of proposed Bioretention system.

CONVEYANCE:

- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- Conveyance to the facility shall overland flow from the adjacent land area or via a 4-6" drain pipe (roof drain outlet) onto a pad of field stones to dissipate flow velocities.

PRETREATMENT:

- Pretreatment shall be required for runoff from connected impervious areas as flow across a vegetated filter strip or grass swale to the facility. A gravel diaphragm can be used for the discharge of sheet flow from the edge of a parking facility.
- No pretreatment is required for runoff from residential or small commercial building roofs (4,000 sq.ft. or less).

SIZING CRITERIA:

- The maximum permissible ponding depth shall be 12"(1.0') for a Class A soil, 9"(0.75') for a Class B soil and 6"(0.50') for a Class C soil. Bioretention systems shall not be permitted in Class D soils.
- The surface area of the bottom of the bioretention system shall be determined by the following equation:

SA = (WQv)/hf where:

SA = Surface area of filter bed (square feet)
WQv = Calculated water quality volume (cubic feet)
hf = Depth of ponding above soil surface in feet (use values above per soil class)

TREATMENT:

- The bioretention facility must fully contain 100% of the required WQv for the contributing area.
- Depth of soil media shall be as specified in Table 7.0.c.
- Soil media shall have a **P-Index** (Phosphorous Index) of 0 – 30 (A low P-Index creates an enhanced environment to remove phosphorous from stormwater)
- Soil Mixture shall consist of sand (85%), Compost (10%), Organic soil (5%) [organic soil shall have no more than 2% clay].
- Mulch layer shall consist of well aged (6-12 month old) shredded hardwood mulch and shall only be placed around plant stems.
- A detailed planting plan shall be provided for each bioretention system.
- Only native plants shall be used. Appropriate plants for the hydrologic conditions shall be taken from the plant lists found in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the bioretention system (gravel storage zone, gravel filter course and modified soil mixture).
- The design engineer shall provide an as-built plan of the bioretention system along with a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.
- Facilities shall be inspected annually for proper growth of plant material. Dead plants shall be removed and replaced during the first two growing seasons. Plants shall be pruned as needed.
- Mulch shall be reapplied as needed to maintain a 2" thick layer around the plant stems.

3.2 – TREE FILTER (GRv & WQv)

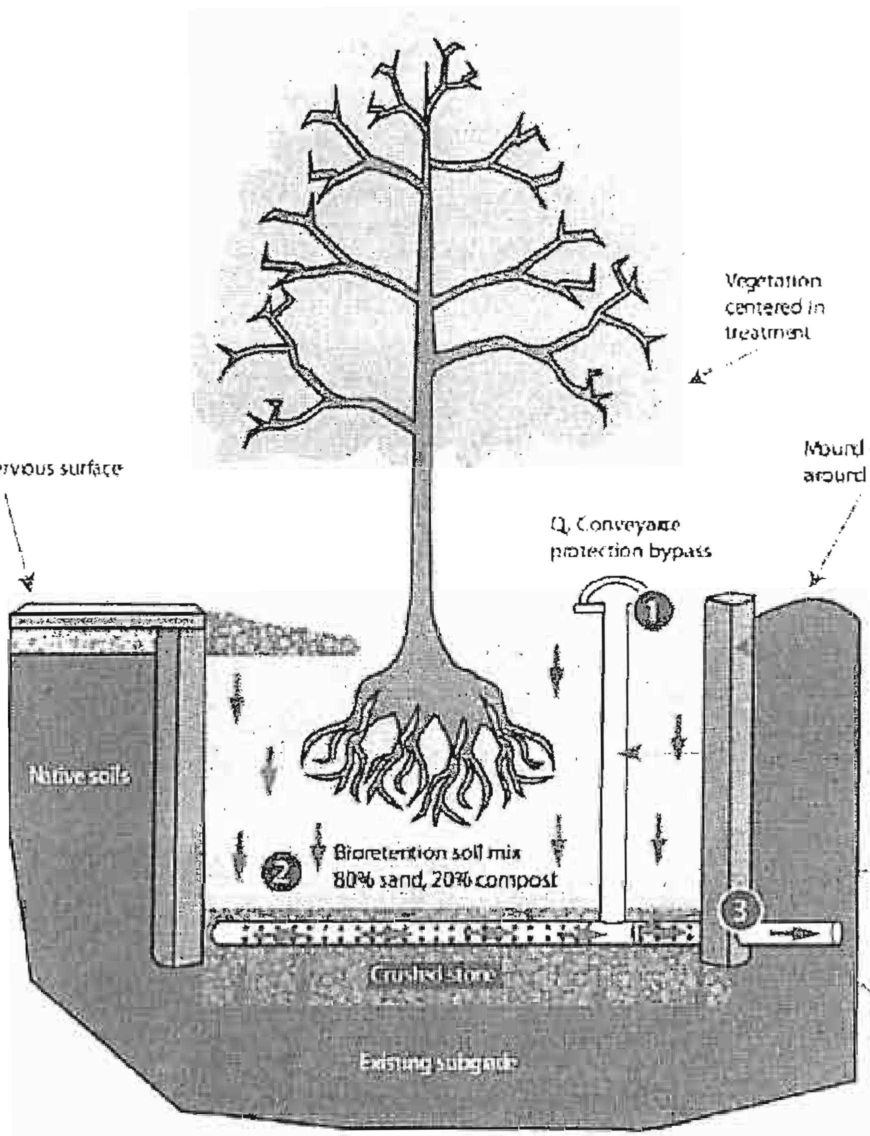


Figure 3.2 - Tree Filter (UNHSC)

Required Design Elements for Tree Filter Systems

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to a tree filter shall be 5,000 square feet (0.12 acres)

CONVEYANCE:

- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- At a minimum the underdrain pipe shall consist of 6" perforated PVC pipe. The minimum diameter of the overflow pipe shall be 6". The overflow pipe shall be sized to convey the Channel Protection Flow for each particular system.

PRETREATMENT:

- No pretreatment is required for a tree filter.

SIZING CRITERIA:

- The maximum permissible ponding depth shall be 12".
- A minimum surface area for ponding within the tree filter is 36 square feet (6' x 6').
- The stone reservoir, consisting of ¾" washed crushed stone (no fines) shall be 24" in depth.

TREATMENT:

- The tree filter system must fully contain 100% of the required WQv.
- Minimum depth of soil mixture shall be 48".
- Soil Mixture shall consist of sand (80%), and Compost (20%).
- Mulch layer shall consist of well aged (6-12 month old) shredded hardwood mulch and shall only be placed around tree stem.
- Only deciduous tress shall be used. Appropriate tree species shall be taken from the plant lists found in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the tree filter system (gravel storage zone, and modified soil mixture).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.
- Facilities shall be inspected annually for proper growth of tree. Plants shall be pruned as needed.
- Mulch shall be reapplied as needed to maintain a 2" thick layer around the plant stems.

3.3 - SURFACE SAND FILTER (GRv & WQv)

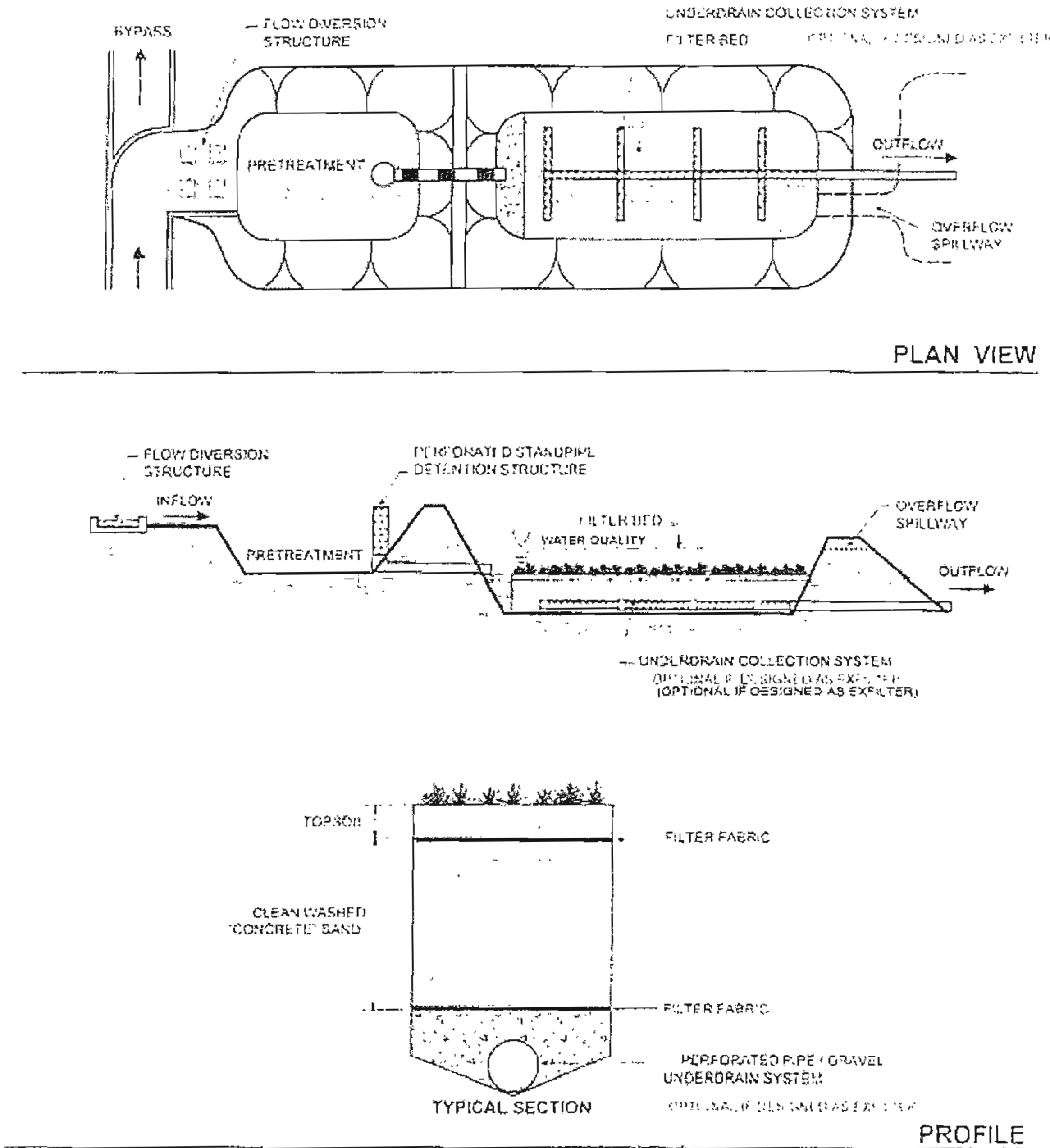


Figure 3.3 – Surface Sand Filter (RI DEM, 2010)

Required Design Elements for Surface Sand Filters

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to a surface sand filter shall be ten (10) acres.

CONVEYANCE:

- Surface sand filter must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Only WQv shall be directed to "off-line" filter with by-pass for larger flows.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- The surface sand filter shall have an underdrain unless it is a fully exfiltrating system.

PRETREATMENT:

- Pretreatment shall be provided by a sediment forebay. The pretreatment area shall provide 25% of the required WQv.

SIZING CRITERIA:

- The surface area of the sand filter shall be determined by the following equation (RI DEM, 2010):

Af = (WQv)*(df)/[(k)*(hr + df)*(tf)] where:

Af = Surface area of filter bed (square feet)
WQv = Calculated water quality volume
df = Filter bed depth (sand media) (feet)
k = Coefficient of sand media, use k=3.5 ft/day
hf = Depth of ponding above soil surface in feet
tf = Design filter bed drain time (days), use tf = 1.0 for surface sand filter

TREATMENT:

- The surface sand filter including the pretreatment component must fully contain 100% of the required WQv. A porosity value of 0.33 shall be used to determine the storage volume within the media. Storage volume within the media can be used to meet the WQv requirement.
- Sand meeting ASTM C-33 specification must be used for filter media.
- Contributing area to surface sand filter must be permanently stabilized prior to directing runoff to filter.
- Minimum depth of sand shall be 24".
- A minimum diameter of 4" shall be used for the underdrain pipe.
- Surface of sand filter shall be planted with appropriate grass mixture. Grass must be able to sustain periods of frequent drought and inundation. See list in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the sand filter system (gravel storage zone, and sand treatment zone).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.
- Removal of sediment from forebay when accumulated depth is 6".
- The surface of the filter shall be inspected every six months and trash/debris removed.
- If water is ponding for more than 2.0 days, the surface has likely become clogged with fine sediments. The surface shall be raked to a depth of 2" and reseeded. If clogging still occurs, the top 3" of material shall be removed and replaced with new sand meeting the design specification and reseeded.
- Facilities shall be inspected annually for proper growth of grass material.
- Grass shall be maintained at a height of 3 – 4".

3.4 - ORGANIC FILTER (GRv & WQv)

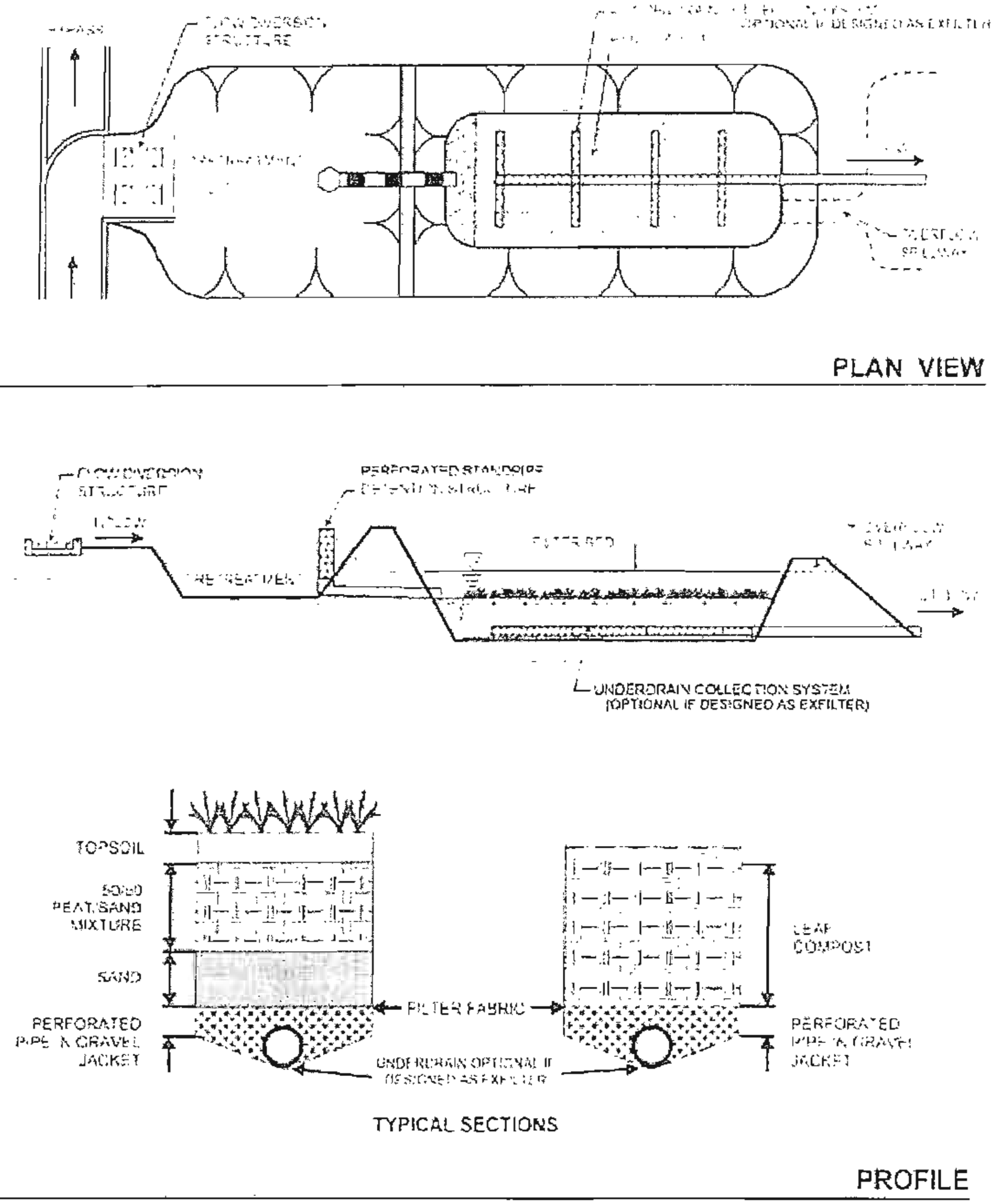


Figure 3.4 – Organic Filter (RI DEM, 2010)

Required Design Elements for Organic Filters

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to an organic filter shall be ten (10) acres.

CONVEYANCE:

- Organic filter must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Only WQv shall be directed to "off-line" filter with by-pass for larger flows.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- The organic filter shall have an underdrain unless it is a fully exfiltrating system.

PRETREATMENT:

- Pretreatment shall be provided by a sediment forebay.
- 25% of the required WQv shall be provided by a sediment forebay.

SIZING CRITERIA:

- The surface area of the organic filter shall be determined by the following equation (RI DEM, 2010):

Af = (WQv)*(df)/[(k)*(hr + df)*(tf)] where:

Af = Surface area of filter bed (square feet)
WQv = Calculated water quality volume
df = Filter bed depth (sand media) (feet)
k = Coefficient of sand media, use k=3.5 ft/day, for peat use k = 2.0 ft/day, and for leaf compost, use k = 8.7 ft/day
hf = Depth of ponding above soil surface in feet
tf = Design filter bed drain time (days), use tf = 2.0 for organic filter

TREATMENT:

- The organic filter including the pretreatment component must fully contain 75% of the required WQv. A porosity value of 0.33 shall be used to determine the storage volume within the media. Storage volume within the media can be used to meet the WQv requirement.
- Soil mixture for organic filter shall be either a mix of sand/peat mix or leaf compost. Peat shall be a reed-sedge hemic peat (partially decomposed).
- Contributing area to organic filter must be stabilized prior to directing runoff to filter.
- Minimum depth of media material shall be 24".
- A minimum diameter of 4" shall be used for the underdrain pipe.
- Surface of organic filter shall be planted with appropriate grass mixture. Grass must be able to sustain periods of frequent drought and inundation. See list in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the organic filter system (gravel storage zone, and media treatment zone).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.
- Removal of sediment from forebay when accumulated depth is 6".
- The surface of the organic shall be inspected every six months and trash/debris removed.
- If water is ponding for more than 4.0 days, the surface has likely become clogged with fine sediment. The top 6"(minimum) of material shall be removed and replaced with new media meeting the design specification and re-planted.
- Facilities shall be inspected annually for proper growth of grass material.
- The height of vegetation on the surface of an organic filter shall not exceed 18".

3.5 – DRY SWALES (GRv & WQv)

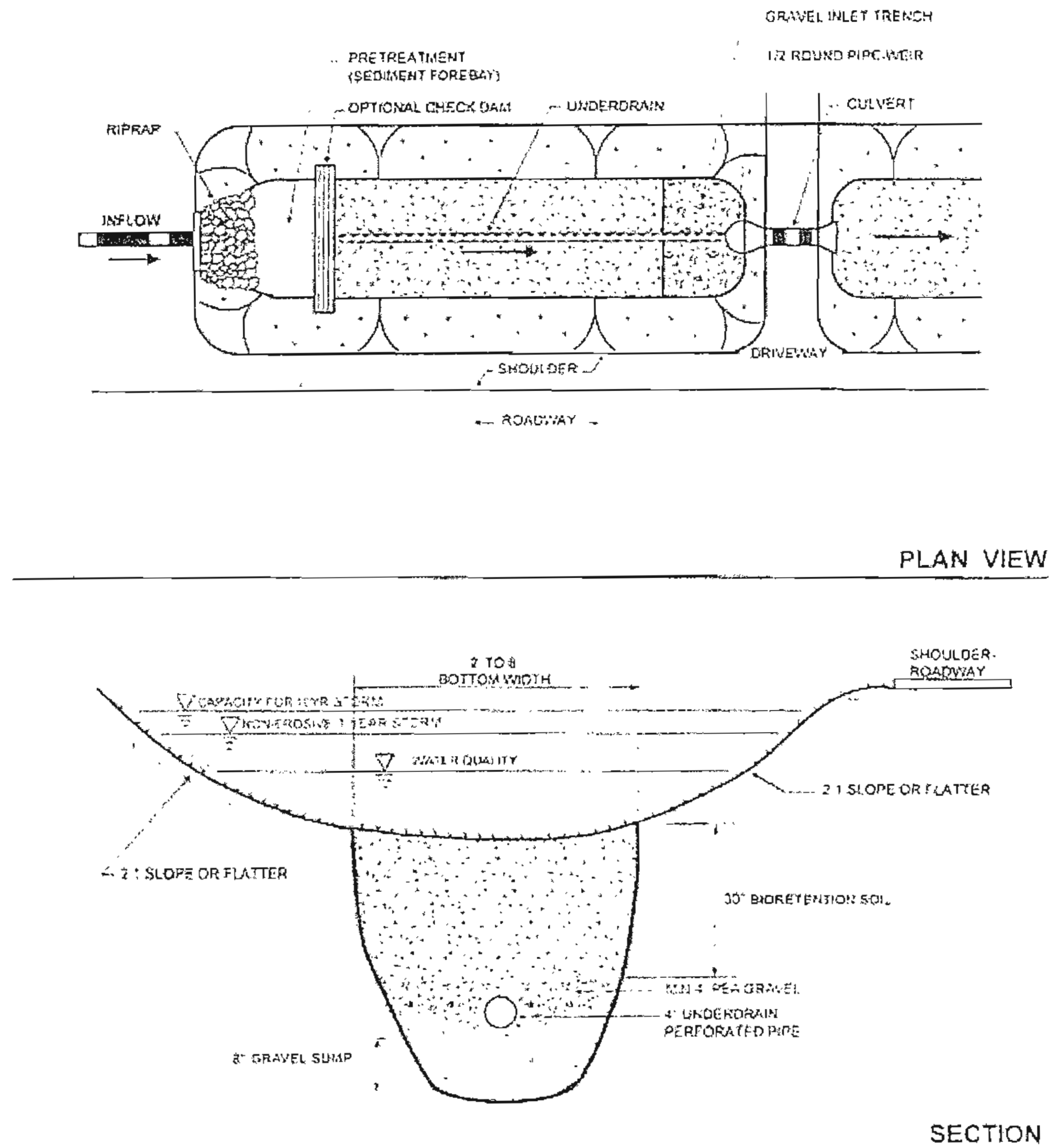


Figure 3.5 – Dry Swale (RI DEM, 2010)

Required Design Elements for Dry Swales

FEASIBILITY:

- Maximum slope along flow length shall be 4.0% without check dams.
- Invert of underdrain pipe (if provided) or bottom of soil mixture shall be at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to a dry swale shall be five (5) acres to one inlet.
- Primary use is along linear systems, such as roads, residential development and pervious areas, such as ballfields.

CONVEYANCE:

- Swale shall be able to handle 10-year, 24-hour peak rate from contributing area.
- Swale side slopes shall be a minimum of 3:1. If there are space constraints, then 2:1 slopes may be used.
- Non-erosive velocities shall be provided (3-5 fps) for 1-year, 24-hour storm event.
- Temporary ponding within the dry swale shall drain within 48 hours. If necessary, an underdrain shall be utilized to achieve this requirement. An underdrain is not required if it is a fully exfiltrating system.

PRETREATMENT:

- Pretreatment shall be required as ponding behind stone check dams located within the swale itself.
- Flow across a vegetated filter strip along a road shall be appropriate pretreatment measure.
- 10% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- The surface area of the filter bed (bottom of swale) shall be determined by the following equation (RI DEM, 2010):

  Af = (WQv)*(df)/[(k)*(hr + df)*(tf)] where:
  - Af = Surface area of filter bed (square feet)
  - WQv = Calculated water quality volume
  - df = Filter bed depth (sand media) (feet)
  - k = Coefficient of bioretention soil mixture (1.0 feet/day)
  - hf = Average height of water above swale surface (feet)
  - tf = Design filter bed drain time (days), use tf = 2.0 for dry swale

- Bottom width of swale shall not be greater than eight (8) feet nor less than two (2) feet.

TREATMENT:

- Soil Mixture shall consist of sand (85%), compost (10%), organic soil (5%) [organic soil shall have no more than 2% clay].
- Appropriate grass mixtures shall be used for the bottom and side slopes of a Dry Swale.
- Contributing area to dry swale must be stabilized prior to directing runoff to Filter.
- Minimum depth of bioretention soil mixture shall be 30".
- Surface of dry swale shall be planted with appropriate grass mixture. Grass must be able to sustain periods of frequent drought and inundation. See list in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the organic filter system (gravel storage zone, and media treatment zone).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.
- Shall be inspected annually and after storms greater than 1-year, 24-hour storm event
- Removal of sediment, when accumulation exceeds 25% of the WQv storage value.
- Vegetation shall be mowed as necessary to maintain 4-6" height. Woody vegetation shall be removed from the dry swale.
- If ponded water is regularly observed more than 48 hours after a rainfall event, then the surface shall be roto-tilled to a depth of 12" and reseeded.

3.6 - INFILTRATION TRENCHES (GRv & WQv)

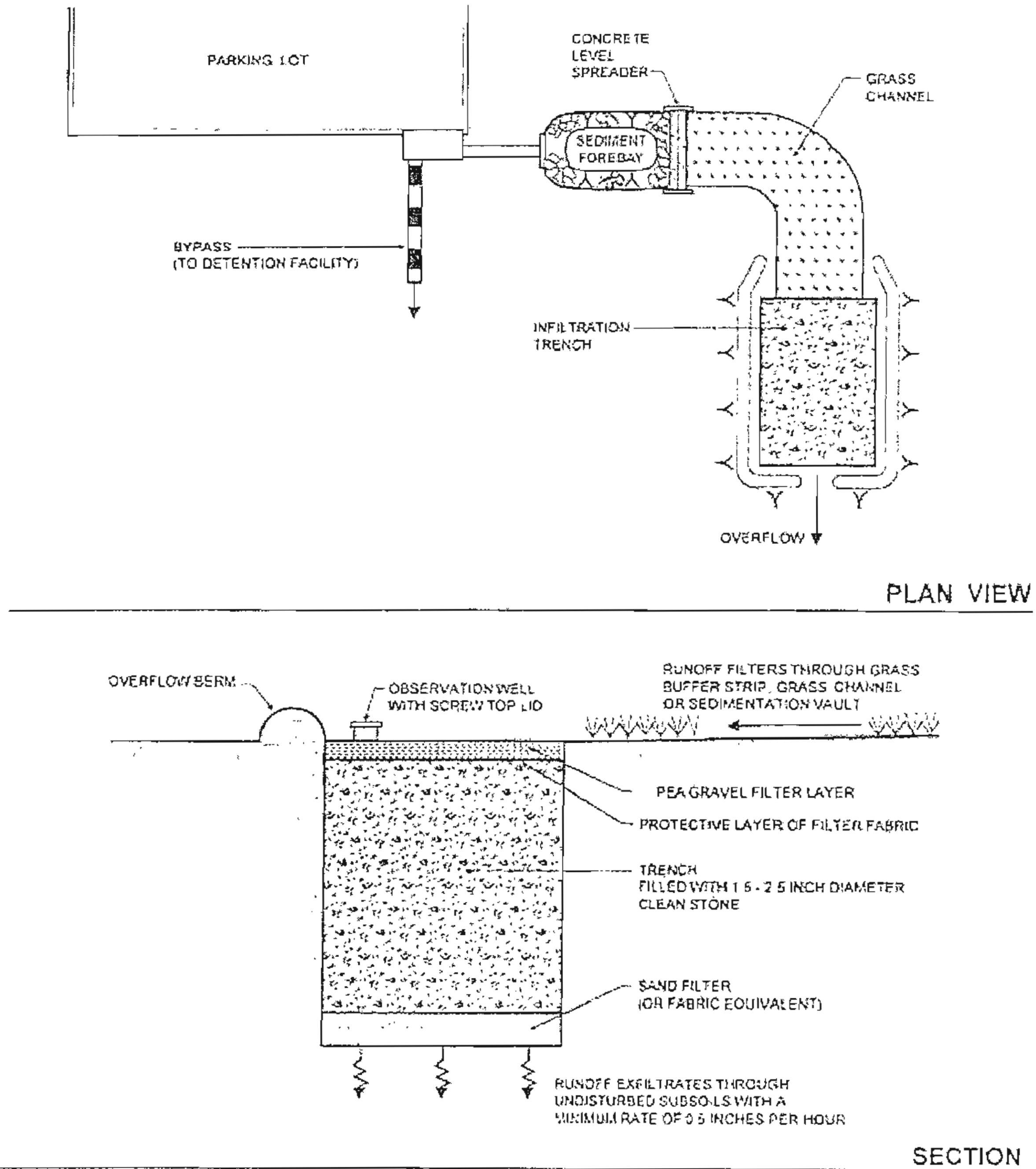


Figure 3.6 – Infiltration Trench (RI DEM, 2010)

Required Design Elements for Infiltration Trench

FEASIBILITY:

- Three (3) foot vertical separation from bottom of infiltration trench to SHGW and bedrock. For residential applications, this separation can be reduced to two (2) feet.
- Must be installed on slopes < 15%.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- The maximum drainage area to an infiltration trench shall be five (5) acres.

CONVEYANCE:

- Infiltration trench must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- All infiltration trenches shall be designed to fully dewater the entire WQv 48 hours after the rainfall event.

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay.
- 25% of the required WQv shall be provided by an appropriate pretreatment system.
- Flow velocities from pretreatment system to infiltration must be non-erosive for 1-yr storm event.
- The sides of the infiltration trench shall be lined with a non-woven filter fabric to prevent soil piping.

SIZING CRITERIA:

- The bottom area of an infiltration trench shall be determined by the following equation (RI DEM, 2010):

$$Ap = V / (ndt + fct/12)$$ where:

Ap = Surface area at the bottom of the trench (square feet)
V = Design volume (WQv) (cubic feet)
n = Porosity of gravel fill (use 0.33)
dt = Trench depth (feet)
fc = Design infiltration rate (in/hr)
t = Time to fill trench (hours), assume t = 2.0

TREATMENT:

- Infiltration trench shall be designed to fully exfiltrate the entire WQv through the bottom of the trench only.
- Design Infiltration rates (fc) for above sizing equation shall be taken from the following table.

Table 3.6 Design Infiltration Rates for Various Soil Textures (Rawls et al., 1982)

USDA Soil Texture	Design Infiltration Rate (fc) (in/hr)
Sand	8.27
Loamy Sand	2.41
Sandy Loam	1.02
Loam	0.52
Silt Loam	0.27

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- Infiltration trenches shall never be used for sediment control during an active construction period.
- The area of the infiltration trench must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration trench.
- Inspections of an infiltration trench shall be made after any storm greater than the 1-year, 24-hour storm.
- The design engineer shall oversee the preparation of the area and the installation of the stone filter.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.

3.7 – INFILTRATION CHAMBERS (GRv & WQv)

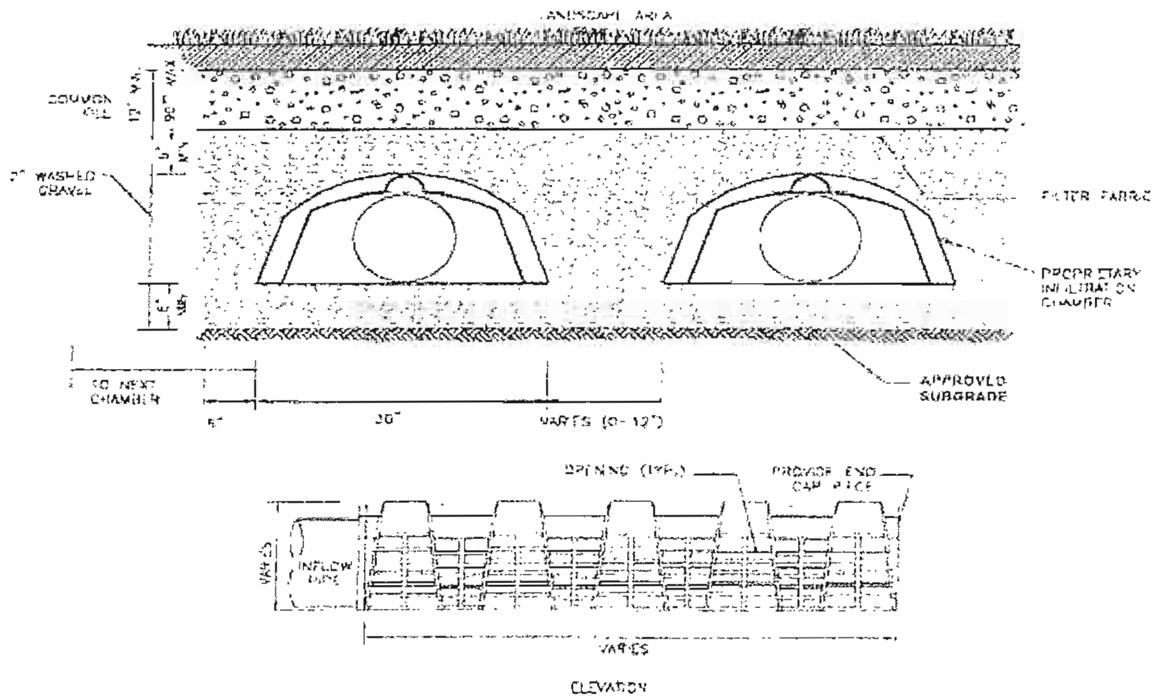


Figure 3.7.a – Infiltration Chamber (RI DEM, 2010)

Table 3.7.b Minimum Setbacks for Infiltration Systems (horizontal measurement in feet) (RI DEM 2010)

	Infiltration Systems for Single Family Residential Uses	Infiltration Systems for all other uses
Public Potable Water Supply Well (Drilled)	200	200
Public Potable Water Supply Well (Gravel well)	400	400
Private Potable Wells	25	100
Potable Water Supply Reservoir	100	200
Streams which are tributary to Water Supply Reservoir	50	100
Other Surface Waters	50	50
Top of 15%+ Slopes	50	50
Buildings (up-gradient)	10	25
Buildings (down-gradient)	10	50
On-site Subsurface Sewage Disposal Systems	25	25

Note: These setback requirements shall apply to Infiltration Trenches, Infiltration Chambers, and Infiltration Basins

Required Design Elements for Infiltration Chambers

FEASIBILITY:

- Three (3) foot vertical separation from bottom of crushed stone under the infiltration chambers to SHGW and bedrock. For residential applications, this separation can be reduced to two (2) feet.
- Must be installed on slopes < 15%.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification.
- The maximum drainage area to infiltration chambers shall be five (5) acres.

CONVEYANCE:

- Infiltration chambers must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- All infiltration chambers shall be designed to fully dewater the entire WQv 72 hours after the rainfall event.

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay for infiltration chambers. This requirement shall not apply to runoff from a residential roof.
- 25% of the required WQv shall be provided by an appropriate pretreatment system for infiltration chambers.
- The sides of the infiltration chambers shall be lined with a non-woven filter fabric to prevent soil piping.

SIZING CRITERIA:

- One method to calculate the storage volume of manufactured chambers is as follows (RI DEM, 2010):

$V = L^*[(wdn) - (\#Acn) + (\#Ac) + (wfct/12)]$ where:

V = Design volume (WQv) (cubic feet)
L = Length of infiltration facility (feet)
w = Width of infiltration facility (feet)
d= Depth of infiltration facility (feet)
\# = Number of rows of chambers
Ac = Chamber cross sectional area (square feet) (see manufacturers specifications)
n = Porosity (use 0.33)
fc = Design infiltration rate (in/hr)
t = time to fill chambers (use 2 hours for design)

TREATMENT:

- Infiltration chambers shall be designed to fully exfiltrate the entire WQv through the bottom of the facility only.
- Design infiltration rates (fc) for above sizing equation shall be taken from Table 7.6 above.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- Infiltration chambers shall never be used for sediment control during an active construction period.
- The area of the infiltration trench must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration chambers.
- The design engineer shall oversee the preparation of the area and the installation of the infiltration chambers.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.

3.8 – INFILTRATION BASIN (GRv & WQv)

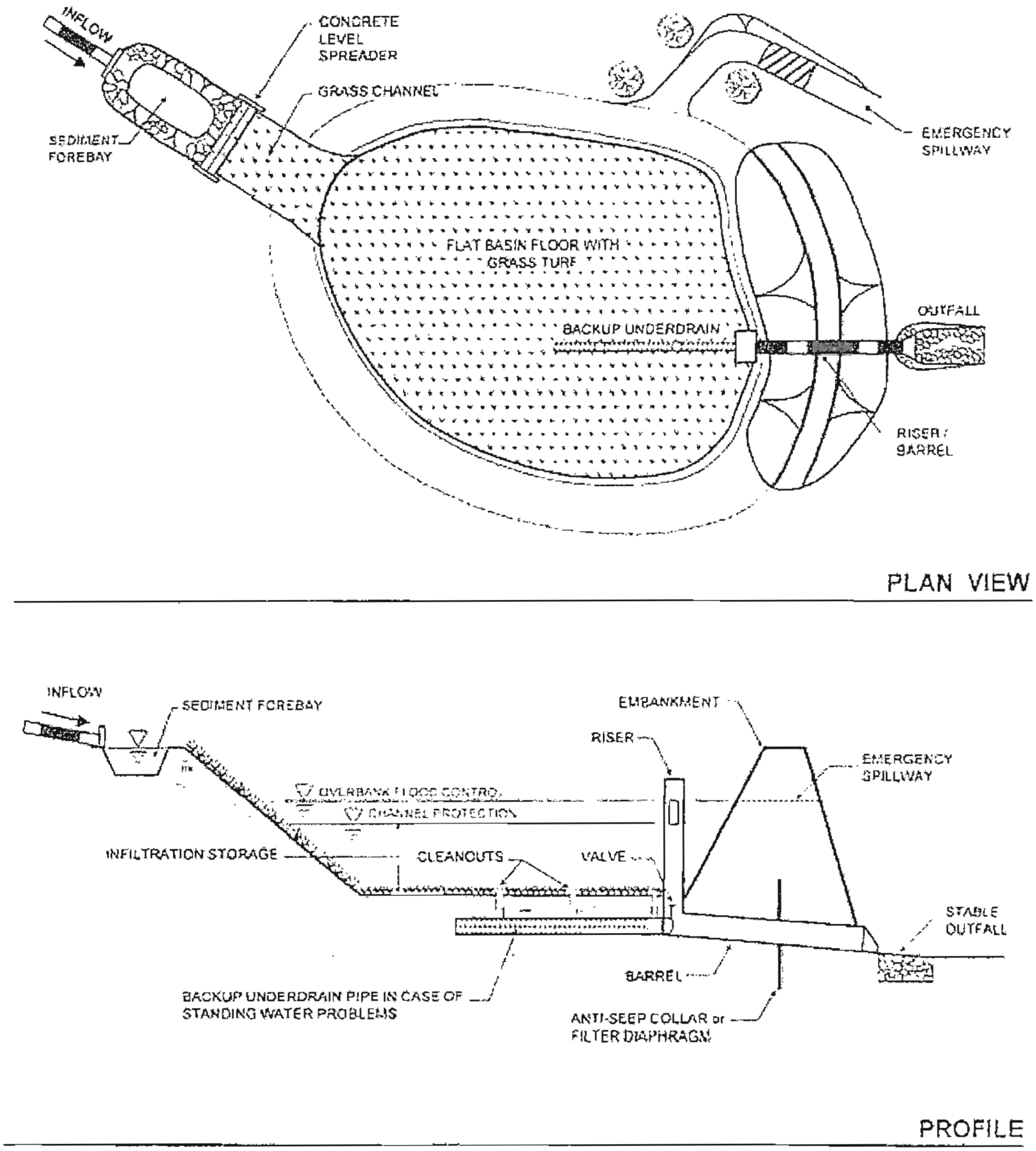


Figure 3.8 – Infiltration Basin (RI DEM, 2010)

Required Design Elements for Infiltration Basin

FEASIBILITY:

- Three (3) foot vertical separation from bottom of infiltration trench to SHGW and bedrock.
- Must be installed on slopes < 15%.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- The bottom of the infiltration basin shall be constructed in either the A or B soil horizon.
- The maximum drainage area to an infiltration trench shall be ten (10) acres.

CONVEYANCE:

- Infiltration basin must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- Infiltration basins shall be designed to fully dewater the entire WQv 48 hours after the rainfall event.

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps)
- A minimum of 25% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- Maximum ponding depth above soil surface shall be 2'.
- The bottom area of an infiltration basin shall be determined by the following equation:

Ab = V/d Where:

Ab = Surface area at the bottom of the basin (square feet)
V = Design Volume (WQv)
d = Depth of basin (feet)

TREATMENT:

- If the in-situ soil infiltration rate is greater than 8.27 in/hr, then the entire WQv shall be fully treated by an appropriate measure prior to the infiltration basin.
- Infiltration basin shall be designed to fully exfiltrate the entire WQv through the bottom of the basin only.
- Design infiltration rates (fc) for above sizing equation shall be taken from Table 7.6 above.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- Infiltration basins shall never be used for sediment control during an active construction period.
- The area of the infiltration basin must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration basin.
- If there is an accumulation of organic debris or sediment on the surface of the basin, the top 6" shall be removed, and the exposed soil surface roto-tilled to a depth of 12". After this work has been done, the bottom of the basin shall be restored to its original condition.
- Inspections of an infiltration basin shall be made after any storm greater than the 1-year, 24-hour storm.
- The design engineer shall oversee the preparation of the area and the construction of the infiltration basin.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.

3.9 – ALTERNATIVE PAVING SURFACES (GRv & WQv)

Refer to UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds (http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_spec_10_09.pdf)

Open Course Pavers with gravel or topsoil/grass

Required Design Elements for Open Course Pavers

FEASIBILITY:

- Three (3) foot vertical separation from bottom of reservoir base to SHGW and bedrock.
- Use on gentle slope (<5%)
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- The bottom of the reservoir base shall be constructed in either the A or B soil horizon.

CONVEYANCE:

- Open course pavers shall only treat runoff generated from the actual area of the practice. Runoff from adjacent areas shall not to be treated by the open course pavers.
- Open course paver systems shall fully dewater the entire WQv 24 hours after a storm event.

PRETREATMENT:

- Pretreatment is not required for open course pavers.
- Frequent maintenance is required to prevent clogging of the open course pavers.

SIZING CRITERIA:

- The surface area of the open course pavers shall be determined by the following equation (RI DEM, 2010):

$Ap = V / (n8dt + fct/12)$ Where:

Ap = Surface area (square feet)
V = Design volume (WQv) (cubic feet)
n = Porosity of gravel (assume 0.33)
dt = Depth of gravel base (feet)
fc = Design infiltration rate (in/hr), see Table 7.6
t = Time to fill (hours) (use 2 hours for design purposes)

TREATMENT:

- Topsoil mix shall consist of 50% sand, 35% compost and 15% native soils. Alternative surface shall be pea gravel.
- Open course paver systems shall fully exfiltrate the entire WQv through the bottom of the practice.
- The reservoir course shall be 12 – 24" in depth. The base course shall consist of native bank run sand and gravel. It shall be sufficiently compacted to provide the required bearing capacity.
- Area of open course pavers must be protected from compaction and erosion during the construction period.
- This system is best used with other systems to address other stormwater issues such as flood protection.
- Vegetation used with open course pavers shall be drought tolerant species.
- To account for the use of open course pavers in hydrologic models in determining the Channel Protection Flow and Flood Protection Flow rates, the following Curve Number values shall be applied.

Table 3.9.a – Curve Numbers for Infiltrating Permeable Pavement Surfaces (MDE, 2009)

Reservoir Depth	Hydrologic Soil Group			
(inches)	A	B	C	D
6	76	84	93	-
12	62	65	77	-
>12	40	55	70	-

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of open course pavers shall never be used for sediment control during an active construction period.
- The area of the open course pavers must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the open course pavers.
- Attach rollers to bottom of plows to prevent the catching of paver edges during snow removal operations.
- Do not stockpile snow on areas of open course pavers.
- The design engineer shall oversee the preparation of the area and the Installation of the alternative paving surface.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found In the Design Technical standards and installed in accordance with the approved plans.

Permeable Pavement or Porous Concrete

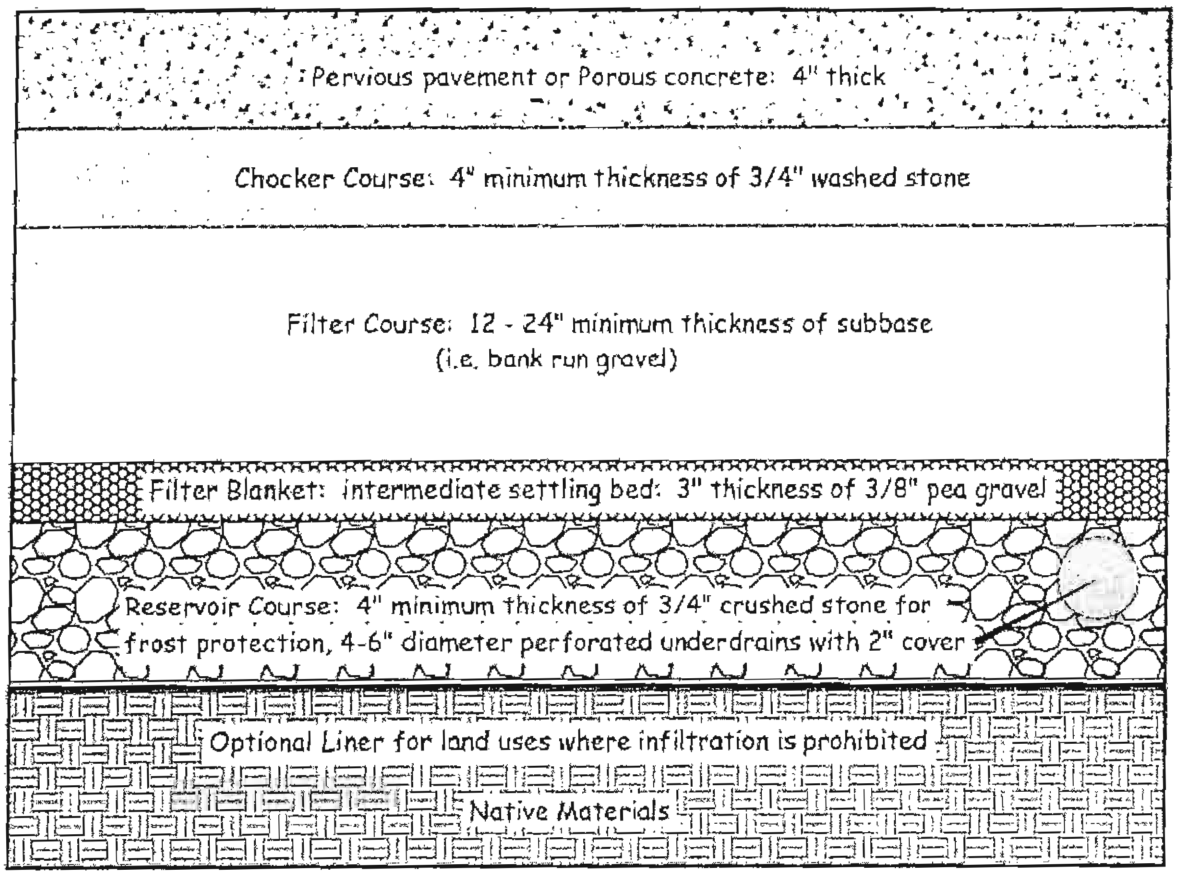


Figure 3.9 – Permeable Pavement (UNHSC)

Required Design Elements for Permeable Pavement or Porous Concrete

FEASIBILITY:

- Three (3) foot vertical separation from bottom of reservoir base to SHGW and bedrock.
- Use on gentle slope (<5%)
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- The bottom of the reservoir base shall be constructed in either the A or B soil horizon.

CONVEYANCE:

- Permeable pavement or porous concrete shall only treat runoff generated from the actual area of the practice. Runoff from adjacent areas shall not to be treated by permeable pavement or porous concrete. These systems shall fully dewater the entire WQv 24 hours after a storm event.

PRETREATMENT:

- Pretreatment is not required for permeable pavement or porous concrete.
- Frequent maintenance is required to prevent clogging of the permeable pavement or porous concrete.

SIZING CRITERIA:

- The surface area of the permeable surface shall be determined by the following equation (RI DEM, 2010):

$$Ap = V / (n8dt + fct/12)$$ Where:

Ap = Surface area (square feet)
V = Design volume (WQv) (cubic feet)
n = Porosity of gravel (assume 0.33)
dt = Depth of gravel base (feet)
fc = Design infiltration rate (in/hr), see Table 7.6
t = Time to fill (hours) (use 2 hours for design purposes)

TREATMENT:

- Permeable pavement or porous concrete shall fully exfiltrate the entire WQv through the bottom of the practice.
- The reservoir course shall be 12 – 24" in depth. The reservoir course shall consist of native bank run sand and gravel. It shall be sufficiently compacted to provide the required bearing capacity. A filter blanket shall be provided between the filter course and the reservoir course.
- An impermeable liner with an underdrain may be provided if underlying soils lack adequate infiltrative capacity for WQv.
- This system is best used with other systems to address other stormwater issues such as flood protection.
- To account for the use of open course pavers in hydrologic models in determining the Channel Protection Flow and Flood Protection Fflow rates, see Table 7.9 above.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of permeable pavement or porous concrete shall never be used for sediment control during an active construction period.
- The area of the permeable pavement or porous concrete must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of permeable pavement or porous concrete.
- Every three months, the permeable surface shall be vacuum swept to minimize the potential of clogging.
- Do not stockpile snow on areas of permeable pavement or porous concrete.
- Sand shall not be applied to permeable pavement or porous concrete surface.
- The design engineer shall oversee the preparation of the area and the installation of permeable pavement or porous concrete.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and installed in accordance with the approved plans.

3.10 – EXTENDED DETENTION SHALLOW WETLANDS (WQ treatment)

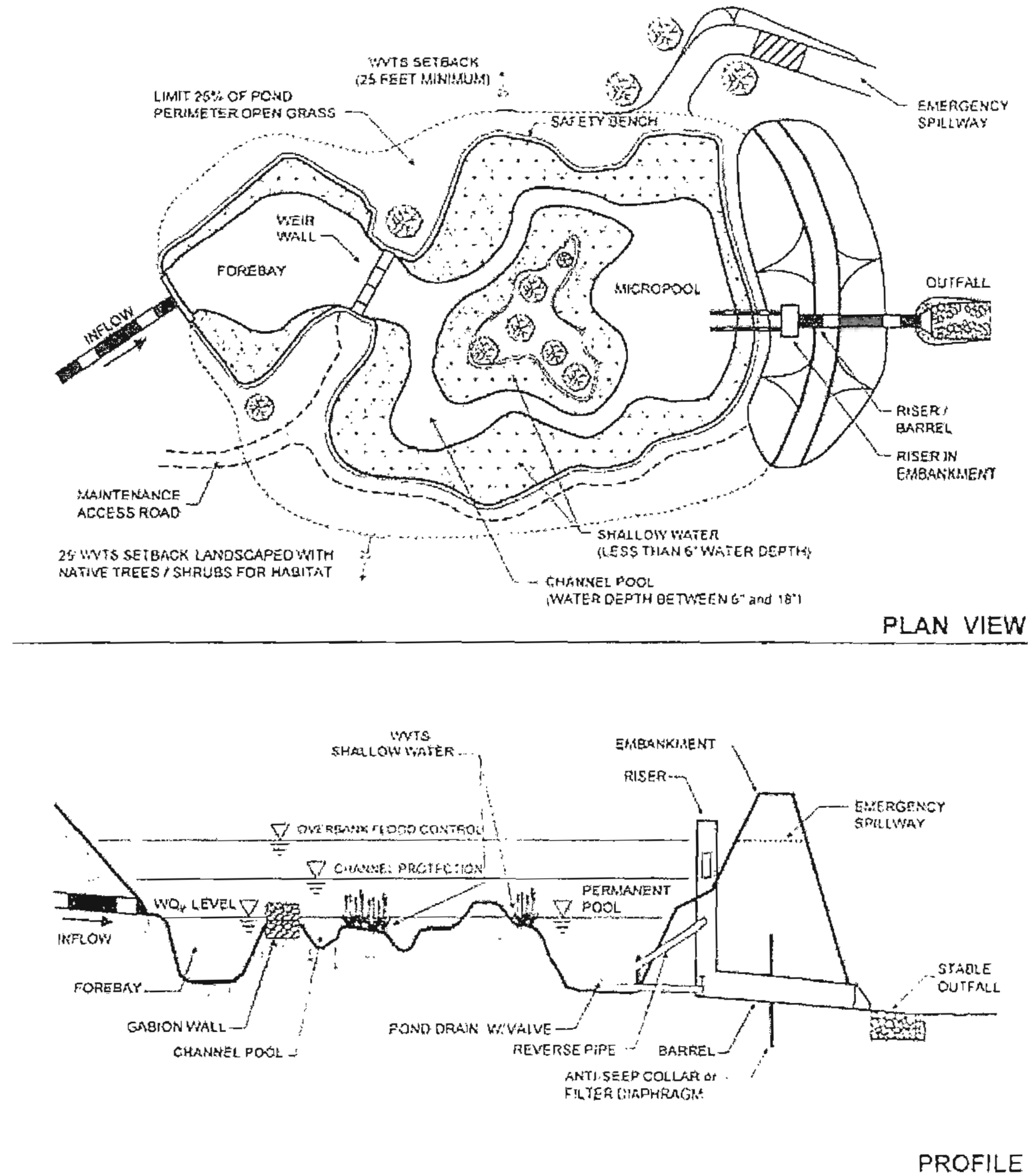


Figure 3.10 – Extended Detention Shallow Wetland (RI DEM, 2010)

Required Design Elements for Extended Detention Shallow Wetland

FEASIBILITY:

- Shall not be located within limits of delineated inland wetlands and watercourses.
- Siting shall be done in such a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The minimum drainage area to an extended detention shallow wetlands shall be ten (10) acres.

CONVEYANCE:

- Flows within the system shall be maximized by the use of islands and submerged berms.
- Discharges from the basin shall be directed toward an established watercourse wherever possible. Appropriately designed outlet protection (2002 Guidelines for Soil Erosion and Sediment Control) shall be provided. The outlet protection shall be sized for the 10-year, 24 hour peak rate discharge.
- Non-erosive velocities shall be provided (3-5 fps) shall be provided for all discharges.

PRETREATMENT:

- A sediment forebay, designed in accordance with the specifications found In Section 8.5 shall be provided for the basin. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by a sediment forebay.
- If there is more than one inlet, then each inlet shall have a sediment forebay.

SIZING CRITERIA:

- The surface area of an extended detention shallow wetland shall be a minimum of 1.5% of the tributary drainage area. Curvilinear configurations shall be used for the basin.
- 65% of the total surface area of the basin shall have a depth of less than 18".
- 35% of the total surface area of the basin shall have a depth of less than 6".
- Deep water areas within the basin shall provide a minimum of 25% of the required WQv, where the depth is greater than 4.0'.
- The minimum length to width ratio shall be 3:1 from inlet to outlet.

TREATMENT:

- If site conditions permit, the extended detention shallow wetland shall be located "off-line". If this is not feasible, then both the Channel Protection Flow and Flood Protection requirements shall be designed into the basin.
- Appropriate vegetation shall be specified for all of the various hydrologic regimes within the basin.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of an Extended Detention Shallow Wetland.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Appropriate access easements for maintenance shall be provided for the basin.
- Inspections of the basin shall be made annually and after all storm events greater than the 1-year, 24 hour event.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Slopes of the basin shall be inspected for erosion and stability on an annual basis. Areas of concern shall be repaired promptly as required.

3.11 - SUBSURFACE GRAVEL WETLANDS (WQ Treatment)

Refer to UNHSC Subsurface Gravel Wetland Design Specifications
(http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_gravel_wetland_specs_6_09.pdf)

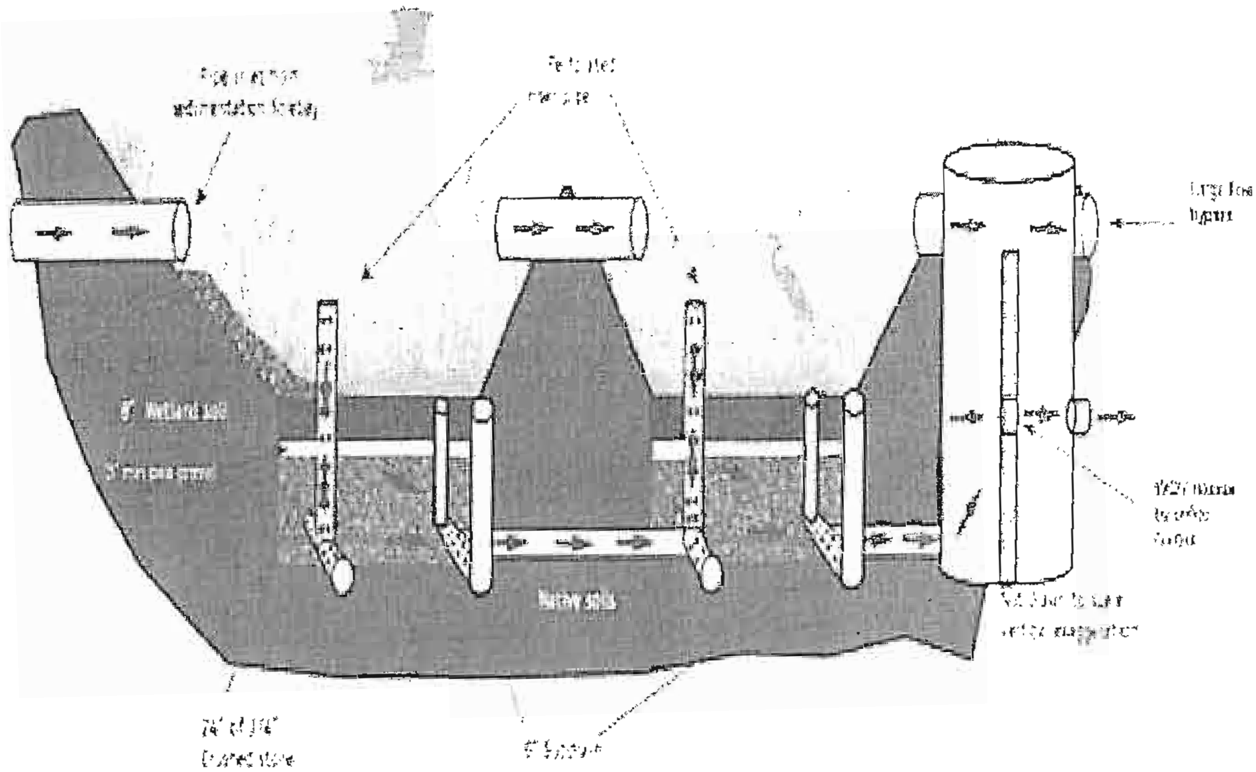


Figure 3.11 – Subsurface Gravel Wetland (UNHSC)

Required Design Elements for Subsurface Gravel Wetlands

FEASIBILITY:

- Shall be located in soil with low infiltrative capacities or the system bottom & sides shall be lined with impermeable liner or soil with permeability being less than 0.03 ft/day.
- Must be installed on slopes < 5%. Level sites are best.
- The maximum drainage area to an Infiltration trench shall be ten (10) acres.

CONVEYANCE:

- Subsurface gravel wetland can be designed as "online" system. System can also provide required Channel Protection Flow above WQv.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).

PRETREATMENT:

- Pretreatment shall be provided with a sediment forebay (Section 7.15).
- Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).

SIZING CRITERIA:

- Forebay provides 10% of the required WQv, each treatment cell provides 45% of the required WQv. The full required WQv must be retained and filtered through the system.
- The invert of primary outlet pipe shall be set 4" below surface of wetland soil to maintain saturated conditions.
- An overflow outlet shall be provided with adequate capacity to handle the peak rate of the 10-year, 24-hour storm event.

TREATMENT:

- Top layer of system is growing media (wetland soil) shall be eight (8) inches in depth with zero slope.
- Intermediate layer is pea gravel three (3) inches thick.
- Treatment layer is 24" in thickness of ¾" crushed stone.
- Berms and weir shall be constructed of non-conductive soils to prevent seepage or piping.
- Length to width ratio for gravel treatment shall be 0.5 (L:W) with a minimum length of fifteen (15) feet.
- Vertical perforated risers shall direct stormwater to treatment layer. Top of vertical riser shall be set at water surface elevation where WQv is provided. Minimum diameter of vertical riser shall be six (6) inches, can be increased to eight (8) inches to minimize clogging potential.
- Vegetation shall consist of obligate and facultative wetland species consisting of grasses, forbs, shrubs.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of an Subsurface Gravel Wetland.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Inspect system to ensure that the ponded water drains down to the soil surface within 24-72 hours after any storm event greater than 1.2" of rain in 24-hours.
- Inspect plants, water plants during 1st year, replace plants as needed, ensure good root establishment across the wetland surface during 1st two years.
- Check stability of slopes during 1st year, repair as needed.
- Inspect inlets, vertical riser pipes and outlet system twice a year.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Remove decaying vegetation, litter and debris.

3.12 – POND / WETLAND SYSTEM (WQ Treatment)

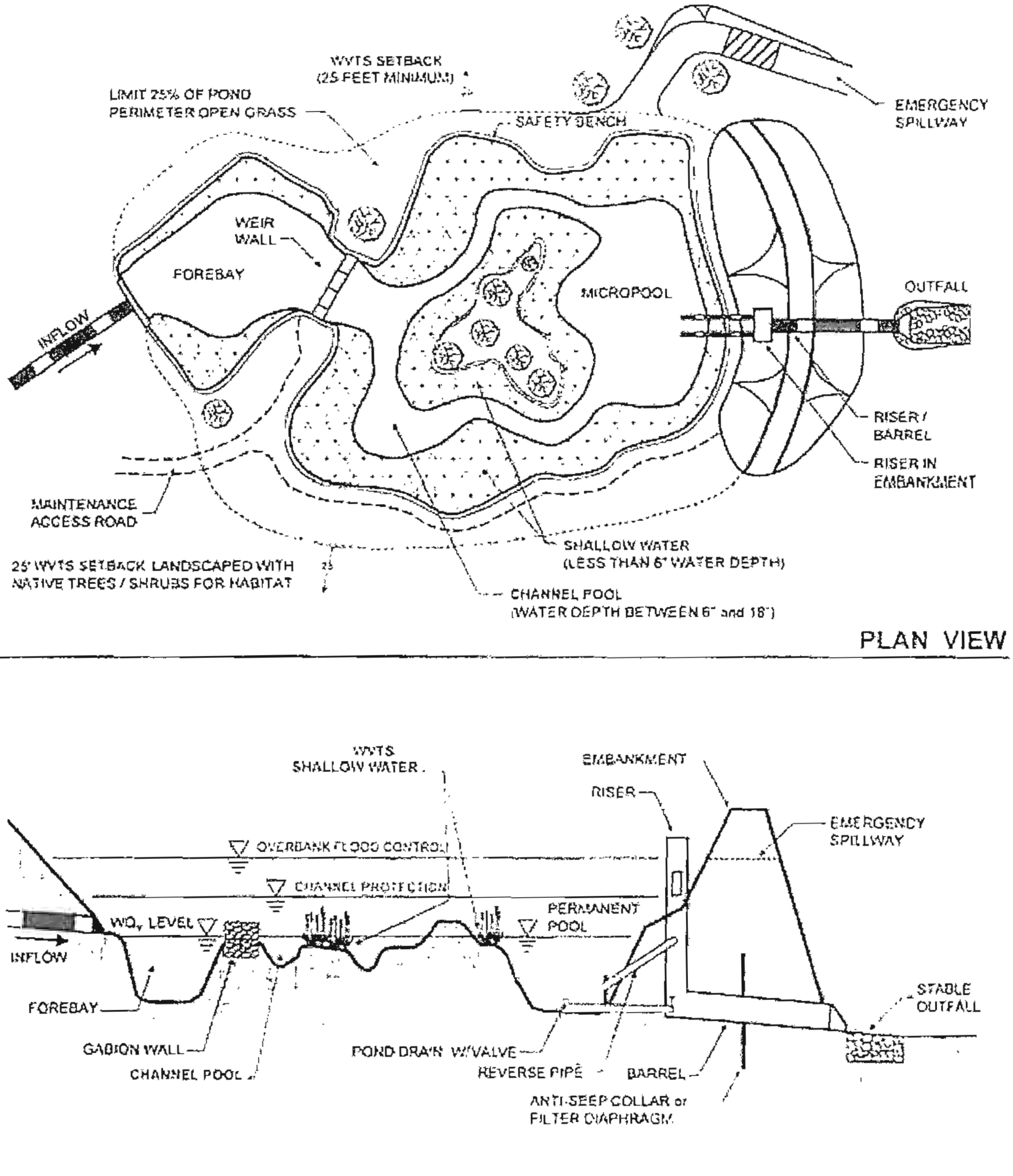


Figure 3.12 Pond / Wetland System (RI DEM, 2010)

Required Design Elements Pond / Wetland system

FEASIBILITY:

- Shall not be located within limits of delineated inland wetlands and watercourses.
- Siting shall be done in such a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The minimum drainage area to a pond / wetland system shall be twenty five (25) acres.

CONVEYANCE:

- Flows within the system shall be maximized by the use of submerged berms and microtopography.
- Discharges from the basin shall be directed toward an established watercourse wherever possible. Appropriately designed outlet protection (2002 Guidelines for Soil Erosion and Sediment Control) shall be provided. The outlet protection shall be sized for the 10-year, 24 hour peak rate discharge.
- Non-erosive velocities shall be provided (3-5 fps) shall be provided for all discharges.

PRETREATMENT:

- A sediment forebay, designed in accordance with the specifications found in Section 8.5 shall be provided for the basin. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by a sediment forebay.
- If there is more than one inlet, then each inlet shall have a sediment forebay.

SIZING CRITERIA:

- The surface area of an extended detention shallow wetland shall be a minimum of 1.5% of the tributary drainage area. Curvilinear configurations shall be used for the basin.
- The outlet pool shall also provide a minimum of 10% of the required WQv and shall be 4-6' in depth.
- 35% of the total surface area of the basin shall have a depth of less than 6".
- 50% of the total surface area of the basin shall have a depth of less than 18".
- The minimum length to width ratio shall be 3:1 from inlet to outlet.

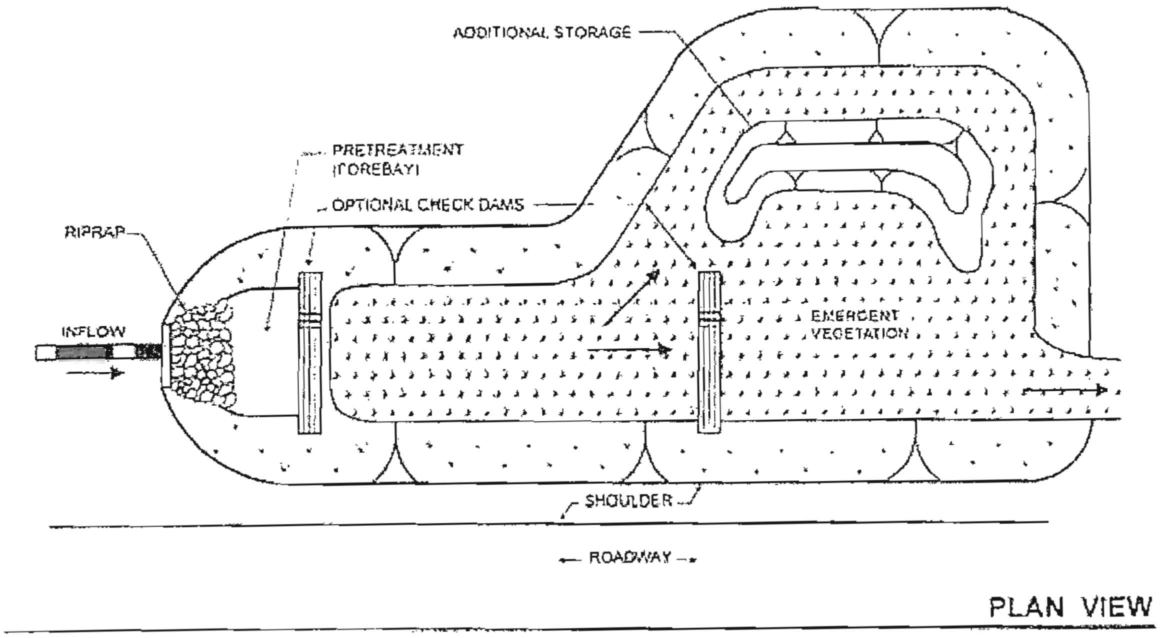
TREATMENT:

- Long, irregular flow paths shall be created by the location and height of the marsh components to increase contact time with vegetation and enhance pollutant removal.
- Appropriate vegetation shall be specified for all of the various hydrologic regimes within the basin.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Pond / Wetland System
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Appropriate access easements for maintenance shall be provided for the basin.
- Inspections of the basin shall be made annually and after all storm events greater than the 1-year, 24 hour event for the first year.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Slopes of the basin shall be inspected for erosion and stability on an annual basis. Areas of concern shall be repaired promptly as required.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration basin.
- Vegetation in the basin shall be inspected annually for two growing seasons. Plants shall be replaced during this period as necessary.

3.13 – WET SWALES (WQ Treatment)



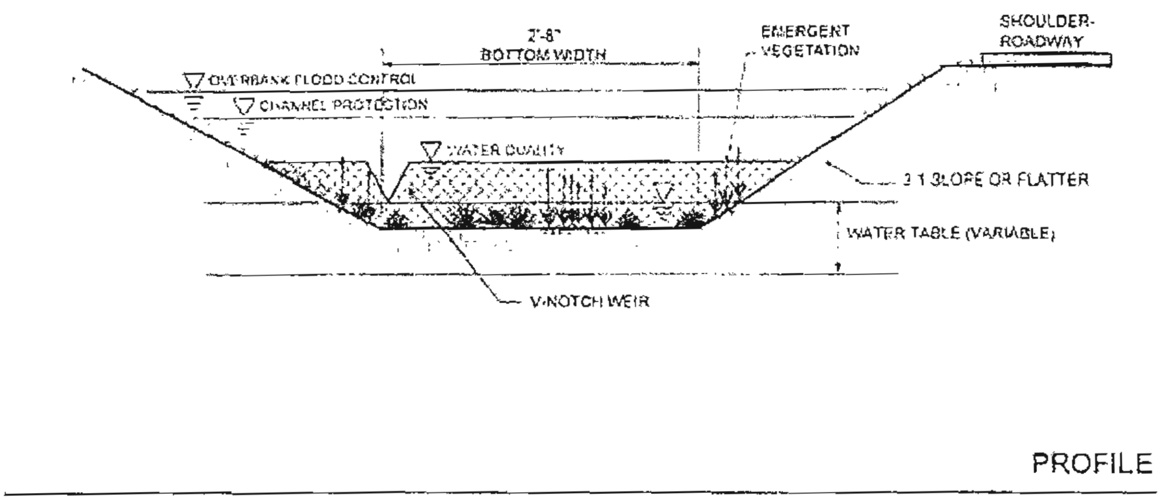


Figure 3.13 Wet Swale (RI DEM, 2010)

Required Design Elements for Wet Swales

FEASIBILITY:

- Maximum slope along flow length shall be 4.0% without check dams.
- Wet swales must intercept shallow groundwater level.
- The maximum drainage area to a wet swale shall be five (5) acres.
- Primary use is along linear systems, such as roads, residential development and pervious areas, such as ballfields.

CONVEYANCE:

- Swale shall be able to handle 10-year, 24-hour peak rate from contributing area.
- Swale side slopes shall be a minimum of 3:1. If there are space constraints, then 2:1 slopes may be used.
- Non-erosive velocities shall be provided (3-5 fps) for 1-year, 24-hour storm event.

PRETREATMENT:

- Pretreatment shall be required as ponding behind stone check dams are located within the swale itself.
- Flow across a vegetated filter strip along a road shall be an appropriate pretreatment measure.
- 10% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- The required WQv shall be provided as surface ponding within the wet swale. The length, width and depth shall be designed to achieve this requirement.
- Wet swales shall be designed to provide for a maximum 12" ponded depth.
- Bottom width of swale shall not be greater than eight (8) feet nor less than two (2) feet.

TREATMENT:

- Appropriate emergent plants shall be used for the bottom and side slopes of a wet swale.
- Contributing area to wet swale must be stabilized prior to directing runoff to the wet swale.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Wet Swale.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- The Wet Swale shall be inspected annually and after storms greater than 1-year, 24-hour storm event.
- Sediment shall be removed when accumulation exceeds 25% of the WQv storage value.
- Plant shall be inspected annually for 1st two growing seasons. Dead or dying plants shall be replaced as necessary.

3.14 – FILTER STRIPS (Pretreatment)

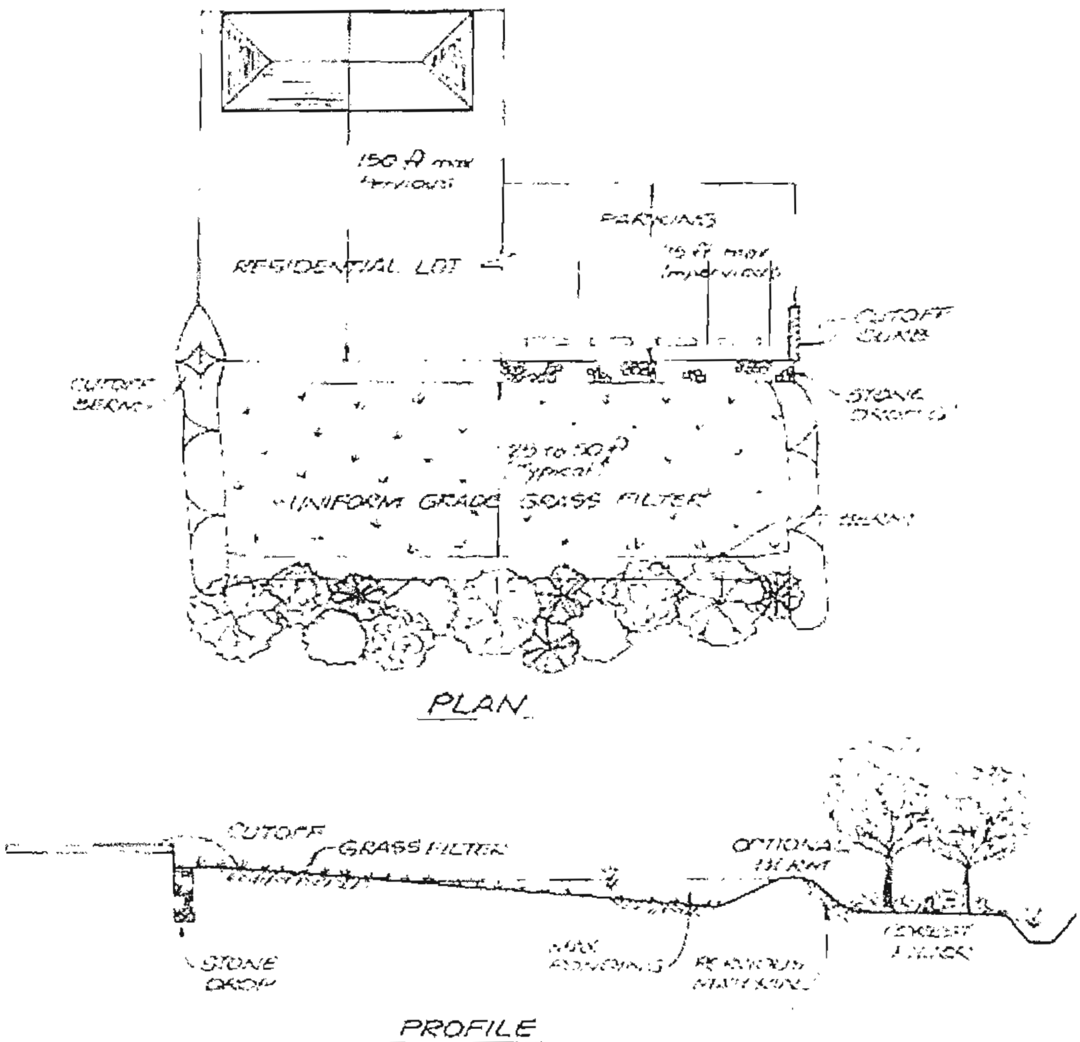


Figure 3.14 - Filter Strip (RI DEM, 2010)

Required Design Elements for Filter Strip

FEASIBILITY:

- The best application for filter strips is for treating stormwater from roads, small parking areas and roof runoff.
- They can be used as a pretreatment system for other stormwater practices.
- Maximum contributing area to a single filter strip is 0.5 acres.

CONVEYANCE:

- Flows across filter strips must occur as overland flow.
- A stone diaphragm or concrete edge shall be used to ensure uniform overland flow from impervious area.
- If no edge treatment is used, the top of the soil mixture shall be set a minimum of 1" below the pavement edge to allow runoff to "fall off" the impervious edge onto the fliter strip.

PRETREATMENT:

- This is a pretreatment system.

SIZING CRITERIA:

- Filter strips shall not be permissible on soils with high clay content.
- Filter strips shall be designed in accordance with the following Table.

Table 3.14.a – Sizing Criteria for Filter Strips

Design Parameter	Impervious Area	Pervious Area
Max. allowable flow length	75'	150'
Filter Strip Slope	4.0%	4.0%
Min. length of filter strip	35'	15'

TREATMENT:

- Sediment is trapped within the grass matrix. If a stone diaphragm is used, this will improve the removal of sediment.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Filter Strip.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Grass must become established as soon as possible. If one species does not grow well, it shall be promptly replaced with an alternative species.
- The majority of trapped sediment will occur at the beginning of the filter strip. Sediment shall be removed from this area on an annual basis.
- The area of the filter strip must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the filter strip.
- The height of the grass shall be maintained at 4".

3.15 – SEDIMENT FOREBAYS (Pretreatment)

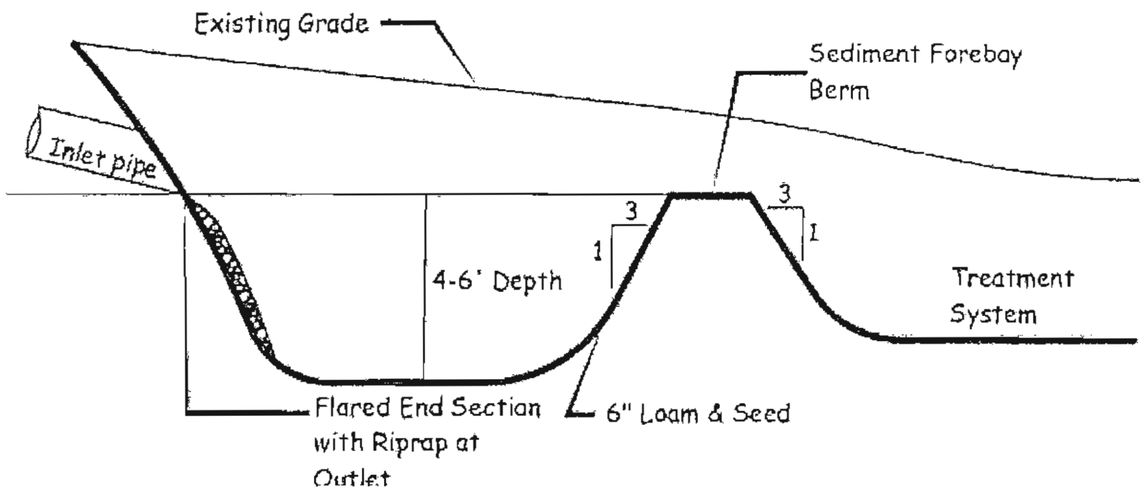


Figure 3.15 - Forebay (RI DEM, 2010)

Required Design Elements for Sediment Forebay

FEASIBILITY:

- This is a pretreatment practice whose primary purpose is to minimize maintenance requirements of other stormwater treatment systems.
- The sediment forebay shall be made part of another stormwater treatment system and shall not be constructed as a stand alone device.

CONVEYANCE:

- A riprap pad shall be utilized at the inlet to the forebay to reduce flow velocities to non-erosive levels (3-5 fps).

PRETREATMENT:

- This is a pretreatment system for other stormwater management practices.

SIZING CRITERIA:

- A minimum of 10% of the required WQv shall be provided within the sediment forebay.
- The length to width ratio of the sediment forebay shall be 3:1. If site constraints exists this ratio may be reduced to 2:1.
- The forebay shall be a minimum of four (4) feet in depth with a preferred depth of six (6) feet.
- A barrier shall separate the sediment forebay from the treatment facility. The barrier shall be armored as necessary to prevent erosion.
- The invert of the inlet pipe shall be set at the water surface elevation for 10% of the WQv.
- The outlet from the sediment forebay shall be designed in an appropriate manner to convey the flow. This could be a culvert, weir or spillway.
- The outlet elevation must be set, so that the 10% of the required WQv is provided below this elevation.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the installation of a sediment forebay.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Access must be provided to the sediment forebay to facilitate removal of accumulated sediments.
- A fixed vertical marker shall be installed in the sediment forebay to allow the depth of sediment to be easily measured and observed.
- The depth of the sediment in the forebay shall be inspected annually and removed when the depth is more than 25% of the total depth of the sediment forebay.

3.16 – DEEP SUMP CATCH BASIN (Pretreatment)

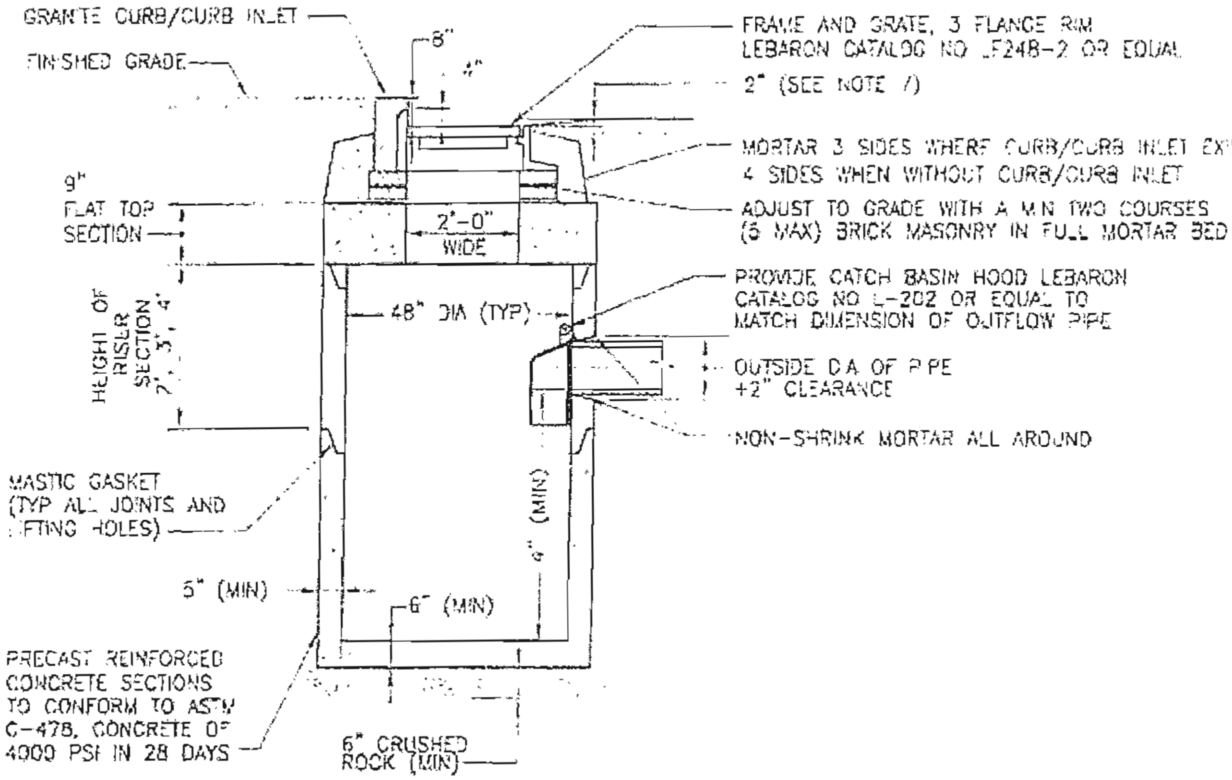


Figure 3.16 - Deep Sump Catch Basin (RI DEM, 2010)

Required Design Elements for Deep Sump Catch Basins

FEASIBILITY:

- A deep sump catch basin shall be used in a catch basin to manhole alignment as a by-pass.
- The maximum drainage area to a deep sump catch basin shall be 0.5 acres.

CONVEYANCE:

- The deep sump catch basin will see the Water Quality Flow.
- Larger flow rates will by-pass this structure by the utilization of the manhole configuration.
- Hooded outlets shall be used on all deep sump catch basins to trap litter and lighter than water emulsions.

PRETREATMENT:

- This is a pretreatment system.

SIZING CRITERIA:

- The invert of the outlet pipe from a deep sump catch basin shall be set a minimum of four (4) feet above the bottom of the structure.
- The hooded outlet shall be installed in such a manner as to facilitate the easy removal and replacement of the hood.

TREATMENT:

- Coarse grained sediments will settle out in the deep sump.
- Litter and lighter than water emulsions (oils and grease) will be trapped on the water surface by the hooded outlet.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The Design Engineer shall inspect the installed Deep Sump Catch Basin and certify that the required design elements have been provided.
- Inspections shall be made twice a year (fall and spring).
- Sediment shall be removed when it has reached two (2) feet in depth.
- Sufficient access into the structure shall be provided from the grate to facilitate maintenance.

3.17 – PROPRIETARY TREATMENT DEVICES (Pretreatment)

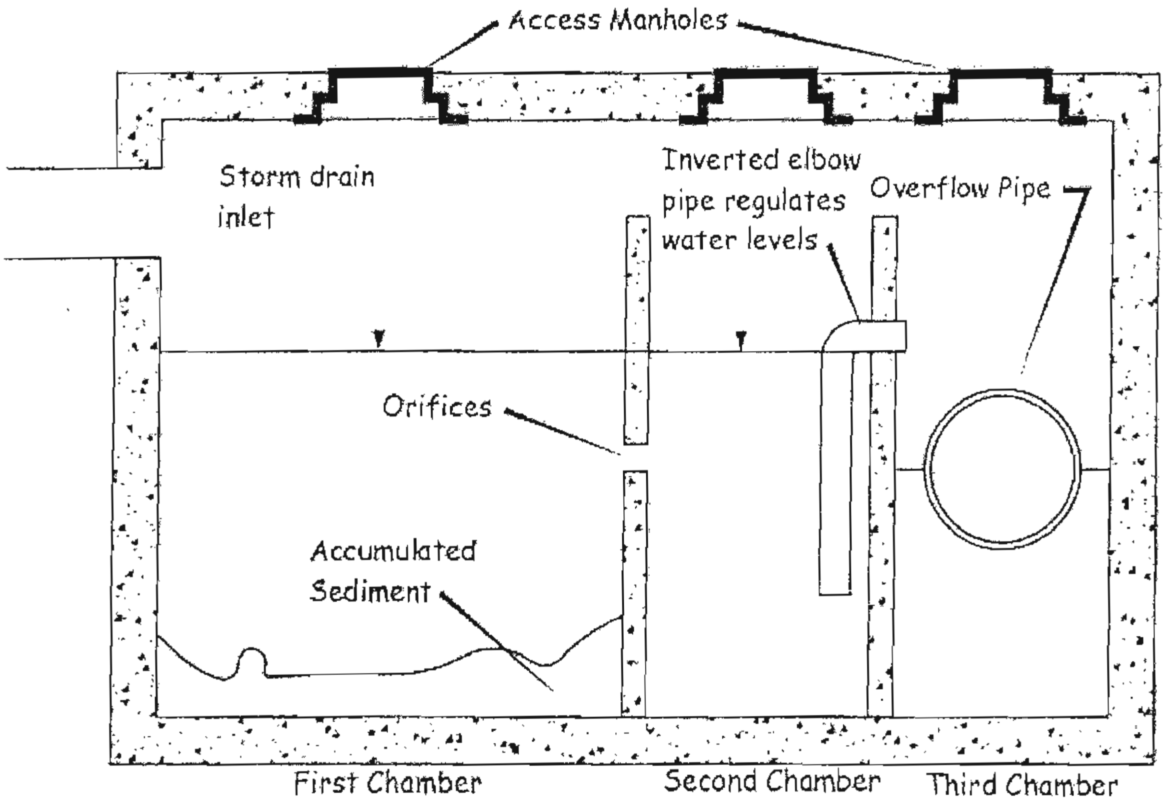


Figure 3.17 - Oil Grit Separator (Mass Highway 2004)

Required Design Elements for Proprietary Treatment Devices

FEASIBILITY:

- System must be capable of removing a minimum of 25% of Total Suspended Solids to be considered an appropriate pretreatment device. This requirement must be independently verified and supported by necessary written documentation.
- Systems must be designed in accordance with the manufacturer's specifications.
- Contributing area to system shall not exceed one (1) acre of impervious area.

CONVEYANCE:

- System shall be designed as "off-line" to treat full water quality flow. Flows in excess of the water quality flow shall be by-passed around the system.

PRETREATMENT:

- This is a pretreatment device.

SIZING CRITERIA:

- The full water quality flow must be treated by the system.
- A minimum detention time of 60 seconds is required for the water quality flow.

TREATMENT:

- These devices are capable of trapping coarse sediments, litter and lighter than water emulsions by proprietary treatment systems by each manufacturer.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the installation of an Oil Grit Separator.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Maintenance shall be performed in accordance with manufacturer's requirements.
- The devices shall be sited in such a manner as to provide quick, easy access for emergency removal of oils.
- Inspections shall be performed twice a year and cleaned twice a year.
- Debris removed from these systems is considered a hazardous material and must be removed and disposed off by a properly licensed contractor.

3.18 – WET EXTENDED DETENTION POND (Water Quantity Control)

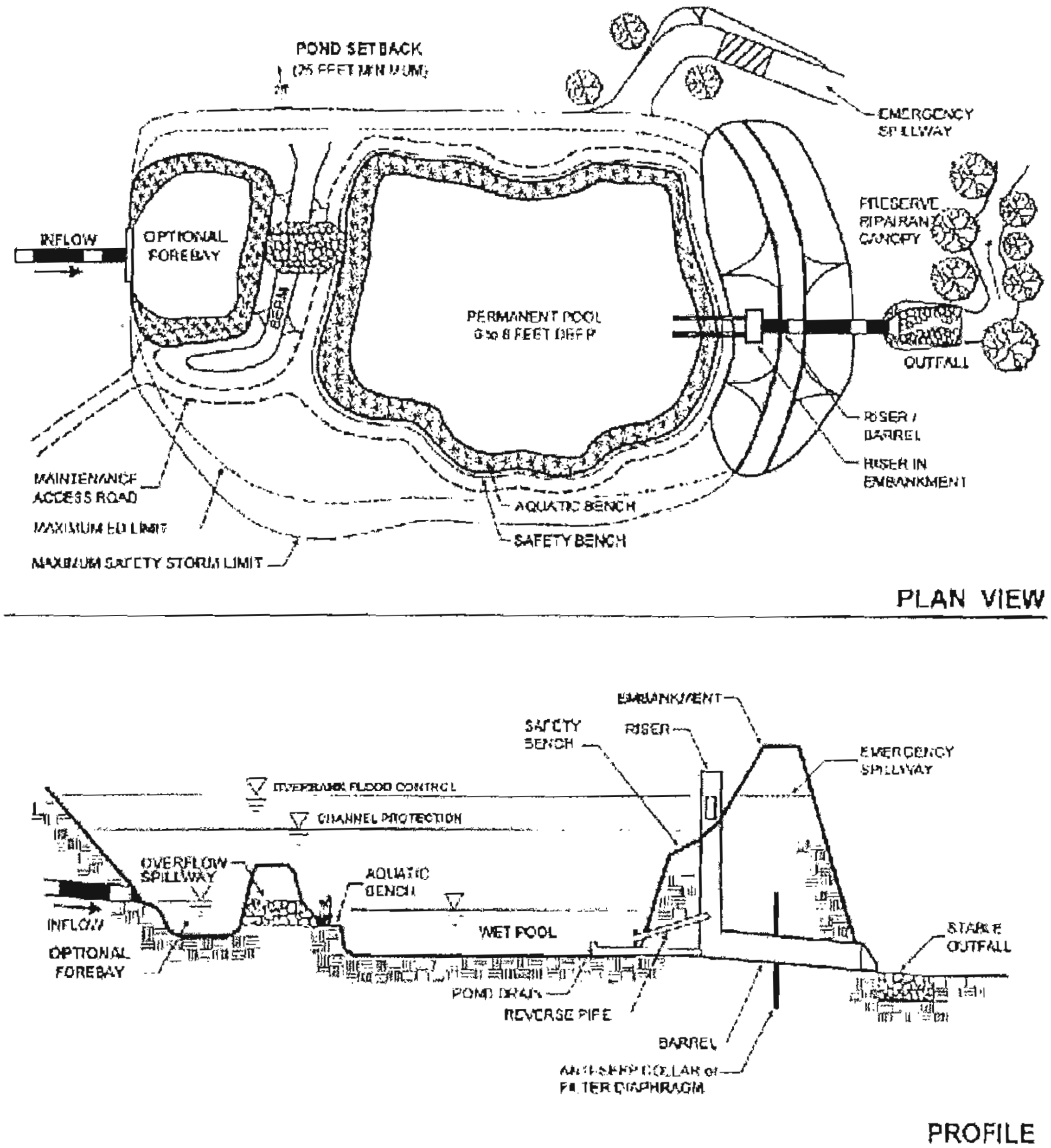


Figure 3.18 - Wet Extended Detention Pond (RI DEM, 2010)

Required Design Elements for Wet Extended Detention Pond

FEASIBILITY:

- Shall not be located within limits of delineated Inland wetlands and watercourses.
- Siting shall be done in a such a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The minimum drainage area to a Wet Extended Detention Pond shall be twenty five (25) acres.

CONVEYANCE:

- The outlet of the inlet pipe shall be stabilized to provide non-erosive velocities.
- Discharges from the basin shall be directed toward an established watercourse wherever possible. Appropriately designed outlet protection (2002 Guidelines for Soil Erosion and Sediment Control) shall be provided. The outlet protection shall be sized for the 10-year, 24 hour peak rate discharge.
- Non-erosive velocities shall be provided (3-5 fps) for all discharges.
- An emergency spillway, sized to handle the 100-year, 24-hour storm event must be provided.

PRETREATMENT:

- A sediment forebay, designed in accordance with the specifications found in Section 8.5 shall be provided for the basin. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by a sediment forebay.
- If there is more than one inlet, then each inlet shall have a sediment forebay.

SIZING CRITERIA:

- The outlet control system of the wet extended detention pond shall provide for the Channel Protection Flow as well as meet the Flood Protection requirement.
- The wet extended detention pond shall not be considered as a water quality treatment system.
- Water quality treatment shall be provided upstream as an "off-line" system.
- The wet extended detention pond shall utilize curvilinear geometry.
- 65% of the total surface area of the basin shall have a depth of less than 18".
- 35% of the total surface area of the basin shall have a depth of less than 6".
- Deep water areas within the basin shall provide a minimum of 25% of the required WQv, where the depth is greater than 4.0'.
- The minimum length to width ratio shall be 3:1 from inlet to outlet.

TREATMENT:

- If site conditions permit, the extended detention shallow wetland shall be located "off-line". If this is not feasible, then both the Channel Protection Flow and Flood Protection requirements shall be designed into the basin.
- Appropriate vegetation shall be specified for all of the various hydrologic regimes within the basin.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the construction of a Wet Extended Detention Pond.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- Appropriate access easements for maintenance shall be provided for the pond.
- Inspections of the basin shall be made annually and after all storm events greater than the 1-year, 24 hour event.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Slopes of the pond shall be inspected for erosion and stability on an annual basis. Areas of concern shall be repaired promptly as required.
- Inspections of the wet extended detention pond shall be made after any storm greater than the 1-year, 24-hour storm.

3.19 – DRY DETENTION POND (Water Quantity Control)

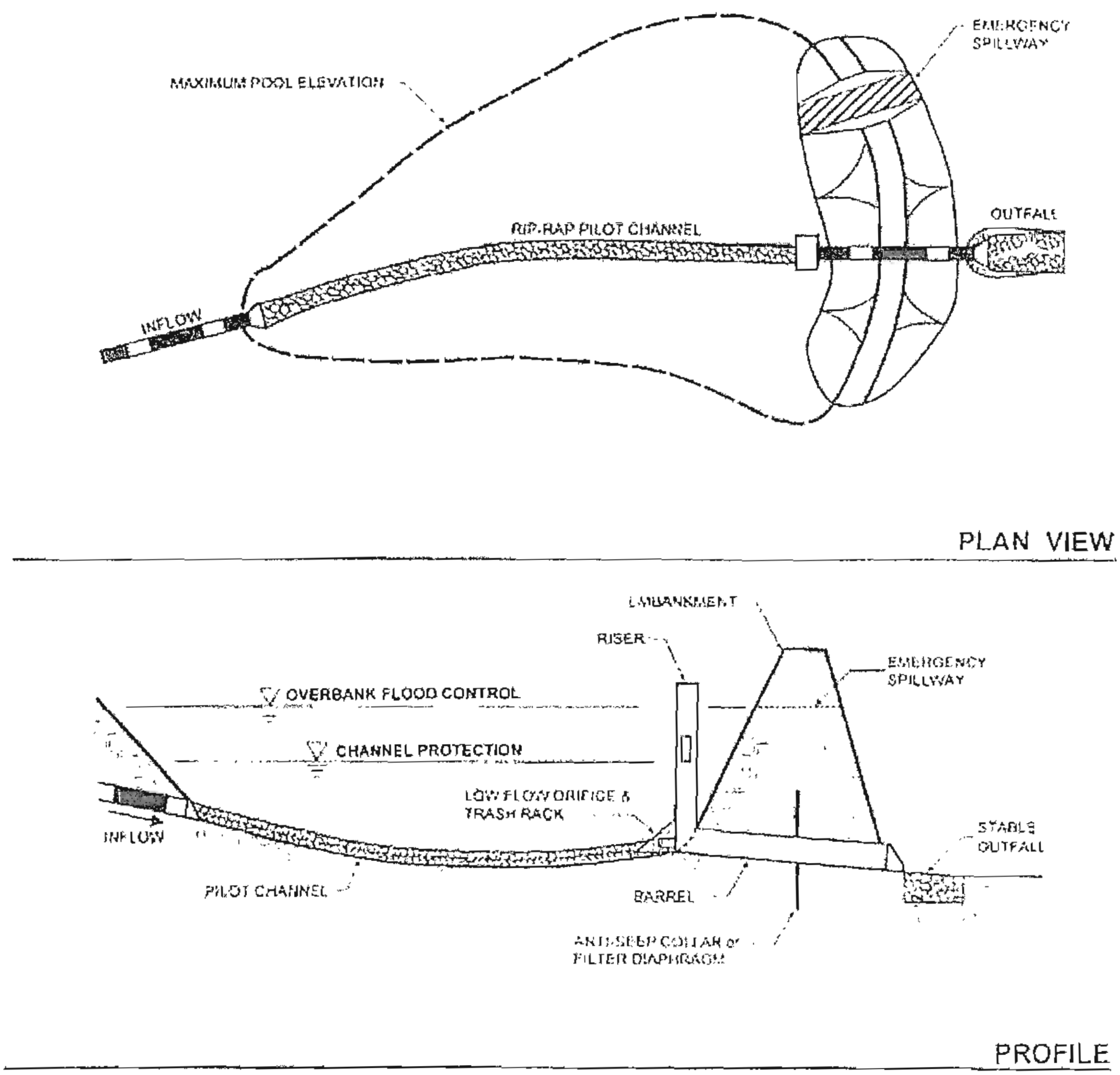


Figure 3.19 - Dry Detention Pond (RI DEM, 2010)

Required Design Elements for Dry Detention Pond

FEASIBILITY:

- Must be installed on slopes < 15%.
- Shall not be located within limits of delineated Inland wetlands and watercourses.
- Siting shall be done in a such a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The maximum drainage area to a dry detention basin shall be twenty five (25) acres.

CONVEYANCE:

- Infiltration basin must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- The storage capacity of a dry detention pond shall be sufficient to detain the increases in the peak rate of runoff for the 10-year, 24-hour storm and potentially the 100-year, 24-hour storm event as necessary.

TREATMENT:

- A dry detention pond is used for water quantity control only.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the installation of a Dry Detention Pond.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Technical standards and constructed in accordance with the approved plans.
- A dry detention pond can be used for sediment control during an active construction period.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration basin.
- If there is an accumulation of organic debris or sediment on the surface of the basin, it shall be removed and the area reseeded.
- Inspections of a dry detention basin shall be made after any storm greater than the 2-year, 24-hour storm.

4.0 Pollutant Renovation Analysis

If an applicant is requested by either the Planning Commission, Zoning Commission or Inland Wetlands Commission to demonstrate the effectiveness of a LID treatment system to remove pollutants to achieve the following pollutant removal performance goals (table 4.0.a) from post-development stormwater, then a pollutant loading analysis shall be provided in accordance with the values and calculations found in this section. A pollutant renovation analysis calculates the pollutant loads on an annual basis for the pollutants of concern for both the pre-development and post-development conditions and then demonstrates the effectiveness of the stormwater treatment system to reduce the pollutant load from the post-development runoff.

Table 4.0.a Pollutant Removal Performance Goals

Pollutant Type	Minimum Pollutant Removal Rate
Total Suspended Solids	80%
Total Nitrogen	35%
Total Phosphorous	40%
Zinc	65%
Total Petroleum Hydrocarbons	70%
Dissolved Inorganic Nitrogen	35%

In order to achieve the pollutant removal efficiencies stated in Table 4.0.a for a particular practice, the practice must be designed and constructed in accordance with all of the required parameters as found in Section 3.0. Table 4.0.b will assist the designer in choosing the most appropriate treatment system(s) to achieve the pollutant removal goals found in Table 4.0.a.

Table 4.0.b – Treatment System Matrix

POLLUTANT REMOVAL RATING	Excellent	Very Good	Good	Fair	Poor
Pollutant Removal Efficiency	80 – 95%	70 – 80%	55 – 70%	40 – 55%	< 40%
Color Coded System					

Stormwater Treatment System Pollutant Removal Selection Matrix

Stormwater Treatment Systems	TSS	TN	TP	Zn	TPH	DIN
FILTERING SYSTEMS						
Bioretention (page 14)						
Tree Filter (page 17)						
Surface Sand Filter (page 19)						
Organic Filter (page 21)						
Dry Swales (page 23)						

INFILTRATION SYSTEMS						
Infiltration Trenches (page 25)						
Infiltration Chambers (page 27)						
Infiltration Basins (page 29)						
Alternative Paving Surface (page 31)						
WET VEGETATED TREATMENT SYSTEMS						
Extended Detention Shallow Wetlands (page 34)						
Subsurface Gravel Wetlands (page 36)						
Pond / Wetland System (page 38)						
Wet Swales (page 40)						
PRETREATMENT FOR WATER QUALITY SYSTEMS						
Filter Strip (page 42)						
Sediment Forebays (page 44)						
Deep Sump Catch Basins (page 46)						
Proprietary Treatment Devices (page 48)						
WATER QUANTITY CONTROL						
Wet Extended Detention Pond (page 50)						
Dry Detention Pond (page 52)						

TSS: Total Suspended Solids
TN: Total Nitrogen
TP: Total Phosphorous
Zn: Total Zinc
TPH: Total Petroleum Hydrocarbons
DIN: Dissolved Inorganic Nitrogen

Pollutant Concentrations per Land Use Type:

Table 4.0.c provides concentrations of the pollutants of concern for common land uses. All concentrations are in mg/l.

Table 4.0.c – Pollutant Concentration per Land Use Type

	Pollutant Concentration (mg/l)					
Land Use	TSS	TP	TN	Zn	TPH	DIN
Large Lot Residential (1 unit/5-10 ac)	60	0.38	2.1	0.161	0.50	0.51
Low Density Residential (1 unit/5 ac – 2 units/ac)	60	0.38	2.1	0.161	0.50	0.51
Medium Density Residential (2-8 units/ac.)	60	0.30	2.1	0.176	1.25	0.344
High Density Residential (8+ units/ac.)	60	0.30	2.1	0.218	1.5	0.344
Commercial	58	0.25	2.6	0.156	3.0	0.324
Industrial	80	0.23	2.1	0.671	3.0	0.569
Institutional (schools, churches, etc)	58	0.27	2.0	0.186	3.0	0.521
Open Urban Land	50	0.25	1.3	0.0	0.0	0.0
Transportation (roads only)	99	0.25	2.3	0.156	3.0	0.375
Deciduous Forest	90	0.10	1.5	0.0	0.0	0.215
Evergreen Forest	90	0.10	1.5	0.0	0.0	0.215

Land Use	Pollutant Concentration (mg/l) TSS	TP	TN	Zn	TPH	DIN
Mixed Forest	90	0.10	1.5	0.0	0.0	0.215
Brush	90	0.38	1.5	0.0	0.0	0.215
Wetlands	0.0	0.38	1.5	0.0	0.0	0.10
Beaches	0.0	0.10	1.5	0.0	0.0	0.0
Bare Ground	1000	0.38	1.5	0.0	0.0	0.0
Row & Garden Crops	357	1.0	2.92	0.0	0.0	0.65
Cropland	357	1.0	2.92	0.0	0.0	0.215
Orchards/vineyards/horticulture	357	1.0	2.92	0.0	0.0	0.215
Pasture	145	0.38	2.2	0.0	0.0	0.65
Feeding Operations	145	0.38	2.2	0.0	0.0	0.8
Agricultural building, breeding & training facilities	145	0.38	2.2	0.0	0.0	0.8

Pollutant Removal Efficiencies for Treatment Systems:

Pollutant removal efficiencies are taken from the best available data for each type of treatment system. The sources of this information include the Center for Watershed Protection, the University of New Hampshire Stormwater Center, the EWRI/ASCE BMP Database, and the Massachusetts Stormwater Technical standards.

Table 4.0.d - Pollutant Removal Efficiencies (percent removal)

Type of System	Pollutant Removal Efficiencies (percent)					
	TSS	TN	TP	Zn	TPH	DIN
Extended Detention Shallow Wetlands	69	56	39	0	0	35
Subsurface Gravel Wetland	99	90	56	99	99	98
Pond/Wetland System	71	19	56	56	0	40
Wet Extended Detention Pond	80	35	55	69	0	36
Infiltration Basin	90	60	65	88	90	50
Infiltration Trenches/Chambers	80	55	60	99	99	50
Bioretention/Rain Garden (avg)*	90	17	5	99	99	44
Surface Sand Filter	87	32	59	77	98	33
Organic Filter	88	41	61	89	0	35
Dry Swale w/filter berms	50	0	8	50	81	0
Wet Swale	75	40	40	33	0	41
Vegetated Filter Strip	68	40	45	88	0	0
Permeable Pavement	99	0	60	75	99	0
Porous Concrete	97	0	0	99	99	0
Standard Sump Catch Basin (24")	3	0	0	0	0	0
Deep Sump Catch Basins (48")	9	0	0	0	14	0
Oil / Grit Separator	0	0	0	17	0	47
LID Urban Planter	99	29	5	99	99	29
LID Curb Extension	99	29	5	99	99	29
Modular Wetland System	82	80	5	79	90	70
Filterra Bioretention System	85	40	60	62	80	40

(Values taken from A.P.L.E.T.S. water quality software by Steven Trinkaus, PE)

* with a P Index < 30, TP removal rate increases to 56%

* with Internal Water Storage Zone, TN removal rate increases to 44%

Equation and Process:

In 1987, Tom Schueler developed the Simple Method as a way to estimate pollutant loads for various chemical constituents on an annual basis. The Simple Method requires a small amount of information to be utiized; annual precipitation, pollutant concentrations, percent impervious cover and subwatershed areas. The formula of the Simple Method is as follows:

$L = [(P)(Pj)(Rv)]/12(C)(A)(2.72)$ or reduced to $L = 0.226(P)(Pj)(Rv)(C)(A)$, where

L = Pollutant load in pounds
P = Rainfall depth over desired time period (inches)
Pj = Factor that corrects P for storms that produce no runoff, use Pj = 0.9
Rv = Runoff coefficient, fraction of rainfall that turns to runoff,
$Rv = 0.05 + 0.009(I)$
I = Site Impervious coverage (percent)
C = Flow weighted mean concentration of pollutant (mg/l)
A = Area of site (acres)
0.226 = Unit Conversion Factor

The Simple Method provides reasonable estimates of changes in pollutant amounts resulting from different types of development. There are three aspects of the Simple Method that engineers need to keep in mind when using the equation.

1. It only estimates the pollutant load from storm events and does not consider pollutants from baseflow volumes. For large low density residential developments, where I < 5%, up to 75% of the annual runoff volume may be comprised of baseflow, the annual nutrient load associated with the baseflow may be equal to the annual load associated with the development.
2. Its primary usefulness is for calculating and comparing the relative storm water pollutant loads from various development concepts.
3. It provides an estimate of the pollutant loads that are likely close to the "true" but unknown value for a development project.

The Simple Method shall be used to calculate the pollutant load for the six pollutants required to be evaluated for stormwater discharges in the Town of Harwinton. The following process shall be followed for the calculation of the pollutant loads and the effectiveness of the stormwater treatment systems.

<u>Pre-Development Conditions:</u>

1. Delineate the watershed areas on the site for undeveloped conditions for each design point or point of interest. A design point would typically be the point where a watercourse or overland flow would leave the site boundary. A point of interest could also be the limit of a delineated wetland or watercourse, located within the site's boundary.
2. Label and determine the area of each watershed on the site.
3. Determine the type of land cover for each watershed area. (For a retrofit or redevelopment site, the design engineer needs to make an assumption as to the type of land use cover which existed on the site prior to any type of development)

4. Obtain annual rainfall amount in inches for the general location of the site.
5. Use the Simple Method to calculate the pollutants loads for the pre-development conditions.

Post-Development Conditions:

1. In order to fully integrate water quality into the site design, the type and location of the treatment systems need to be evaluated during the design phase and not at the end of the design period. The pollutant loading analysis should be prepared twice during the process; first during the Conceptual Design Phase in order to determine the type of treatment systems needed to achieve water quality goals. The second time is when the final site plan is complete and accurate values for impervious cover are available.
2. Prepare Conceptual Development Plan for project.
3. Delineate the watershed boundaries on the site for future conditions. Divide the watershed area into the area above the treatment system, which contributes to the treatment system, and the area below the treatment system.
4. Calculate area of each watershed area.
5. Based upon proposed land use, estimate impervious coverage within each watershed area above the treatment systems.
6. Calculate land area below the treatment system to the design point or point of concern. Only that area above the last treatment facility is run through the treatment system analysis. Pollutant loads from land below the last treatment system need to be calculated separately and can be added to the remaining load from the treatment system to determine the total load reaching the design point for future conditions. This is very important if TMDL limits are applicable to the receiving waterway.
7. Use the Simple Method to calculate preliminary pollutant loads for post-development conditions on the site based upon the Conceptual Development Plan.
8. After the loads have been calculated for post-development, use the pollutant removal efficiencies provided and the formula below to determine the type(s) of treatment systems needed to achieve water quality goals.
9. After the design engineer has determined what type of treatment system(s) are required, they can proceed with the final site design and incorporate the necessary storm water treatment system(s) as they prepare the final site design.
10. After the site design is complete, steps #3 through #8 are repeated with the accurate areas of the final watershed areas and impervious cover.

Pollutant Removal Calculation Procedure

1. (total load * 1st removal efficiency)
2. (total load – (load removed in #1))*2nd removal efficiency
3. (total load – (load removed in #1 + #2))*3rd removal efficiency
4. (total load – (load removed in #1 + #2 + #3))*4th removal efficiency ...

Total Percentage Removed by Treatment Systems

(load removed in #1+load removed in #2+load removed in #3....)/total load * 100

APPENDIX A
PLANT LIST FOR LID TREATMENT SYSTEMS

Plant List for LID Treatment Systems

There are six distinct hydrological planting zones for Low Impact Development Treatment Systems. Table B defines the hydrological characteristics of each planting zone.

Table A – Hydrologic Planting Zones

Zone #	Hydrologic Condition	Zone Description
1	1-6 deep permanent pool	Deep Water Pool
2	6 inches to 1 foot deep	Shallow Water Bench
3	Regularly inundated	High & Low Marsh
4	Periodically inundated	Riparian Fringe, Aquatic Bench
5	Infrequently inundated	Upland terraces within pond/wetland system
6	Rarely inundated	Upland slopes

ZONE 1 – Deep Water Pool

Trees and shrubs: not recommended for this zone

Herbaceous Plants:

Coontail	Submergent
Duckweed	Submergent/Emergent
Pond Weed	Submergent
Waterweed	Submergent
Wild Celery	Submergent

ZONE 2 – Shallow Water Bench

Trees and shrubs:

Buttonbush	Deciduous shrub

Herbaceous Plants:

Arrow arum	Emergent
Arrowhead, Duck Potato	Emergent
Blue Flag Iris	Emergent
Blue Joint	Emergent
Broomsedge	Perimeter
Bushy Beardgrass	Emergent
Cattail	Emergent
Duckweed	Submergent/Emergent
Hardstem Bulrush	Emergent
Long-leaved Pond Weed	Rooted Submerged Aquatic
Pickerelweed	Emergent
Sedges	Emergent
Soft-stem Bulrush	Emergent
Smartweed	Emergent
Herbaceous Plants:	
Soft Rush	Emergent
Switchgrass	Perimeter
Sweet Flag	Herbaceous

Wild Rice	Emergent
Wool Grass	Emergent

ZONE 3 – High & Low Marsh

Trees and shrubs:

Arrowwood Viburrium	Deciduous shrub
Bald Cypress	Deciduous tree
Black Ash	Deciduous tree
Black Willow	Deciduous tree
Buttonbush	Deciduous shrub
Elderberry	Deciduous shrub
Larch	Coniferous tree
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
River Birch	Deciduous tree
Silky Dogwood	Deciduous tree
Smooth Alder	Deciduous tree
Swamp White Oak	Deciduous tree
Winterberry	Deciduous shrub

Herbaceous Plants:

Arrow arum	Emergent
Arrowhead, Duck Potato	Emergent
Blue Flag Iris	Emergent
Blue Joint	Emergent
Broomsedge	Perimeter
Bushy Beardgrass	Emergent
Cattail	Emergent
Duckweed	Submergent/Emergent
Flat-top Aster	Emergent
Hardstem Bulrush	Emergent
Long-leaved Pond Weed	Rooted Submerged Aquatic
Pickerelweed	Emergent
Redtop	Perimeter
Sedges	Emergent
Soft-stem Bulrush	Emergent
Smartweed	Emergent
Soft Rush	Emergent
Switchgrass	Perimeter
Sweet Flag	Herbaceous
Herbaceous Plants:	
Wild Rice	Emergent
Wool Grass	Emergent

ZONE 4 – Riparian Fringe, Aquatic Bench

Trees and shrubs:

American Elm	Deciduous tree
Arrowwood Viburrium	Deciduous shrub

Bald Cypress	Deciduous tree
Black Ash	Deciduous tree
Black Gum	Deciduous tree
Black Willow	Deciduous tree
Buttonbush	Deciduous shrub
Eastern Cottonwood	Deciduous tree
Elderberry	Deciduous shrub
Larch	Coniferous tree
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
River Birch	Deciduous tree
Shadowbush	Deciduous shrub
Silky Dogwood	Deciduous tree
Slippery Elm	Deciduous tree
Smooth Alder	Deciduous tree
Swamp White Oak	Deciduous tree
Sweetgum	Deciduous tree
Winterberry	Deciduous shrub
Witch Hazel	Deciduous shrub

Herbaceous Plants:

Big Bluestem	Perimeter
Birdfoot deervetch	Perimeter
Blue Joint	Emergent
Broomsedge	Perimeter
Cardinal Flower	Perimeter
Fowl Bluegrass	Emergent
Green Bulrush	Emergent
Redtop	Perimeter
Tufted Hairgrass	Perimeter
Smartweed	Emergent
Soft Rush	Emergent
Swamp Aster	Emergent
Water Plantain	Emergent

ZONE 5 – Upland Terraces within Pond / Wetland Systems

Trees and shrubs:

American Elm	Deciduous tree
Bayberry	Deciduous shrub
Black Ash	Deciduous tree
Black Cherry	Deciduous tree
Black Gum	Deciduous tree
Black Willow	Deciduous tree
Buttonbush	Deciduous shrub
Eastern Cottonwood	Deciduous tree
Eastern Hemlock	Coniferous tree
Elderberry	Deciduous shrub

Green ash	Deciduous tree
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
River Birch	Deciduous tree
Shadowbush	Deciduous shrub
Silky Dogwood	Deciduous tree
Slippery Elm	Deciduous tree
Smooth Alder	Deciduous tree
Swamp White Oak	Deciduous tree
Sweetgum	Deciduous tree
Winterberry	Deciduous shrub
Witch Hazel	Deciduous shrub

Herbaceous Plants:

Annual Ryegrass	Perimeter
Big Bluestem	Perimeter
Cardinal Flower	Perimeter
Creeping Red Fescue	Perimeter
Redtop	Perimeter
Switchgrass	Perimeter

ZONE 6 – Upland Slopes

Trees and shrubs:

American Elm	Deciduous tree
Bayberry	Deciduous shrub
Black Cherry	Deciduous tree
Eastern Hemlock	Coniferous tree
Eastern Red Cedar	Coniferous tree
Elderberry	Deciduous shrub
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
Shadowbush	Deciduous shrub
Trees and shrubs:	
Sweetgum	Deciduous tree
White Ash	Deciduous tree

Herbaceous Plants:

Birdfoot deervetch	Perimeter
Cardinal Flower	Perimeter
Switchgrass	Perimeter

APPENDIX B
MAINTENANCE AGREEMENT FOR STORMWATER SYSTEMS

Note: The Stormwater Maintenance Agreement was reproduced from the New York State Stormwater Technical standards.

Stormwater Maintenance Agreement

Whereas, the Municipality of Harwinton ("Municipality") and the ________________________ ("facility owner") want to enter into an agreement to provide for the long term maintenance and continuation of stormwater control/treatment measures approved by the Municipality for the below named project, and

Whereas, the Municipality and the facility owner desire that the stormwater control/treatment measures be built in accordance with the approved project plans and thereafter be maintained, cleaned, repaired, replaced, and continued in perpetuity in order to ensure optimum performance of the stormwater systems. Therefore, the Municipality and the facility owner agree as follows:

1. This agreement binds the Municipality and the facility owner, its successors and assigns, to the maintenance provisions depicted in the approved project plans which are attached as Schedule A of this agreement.

2. The facility owner shall maintain, clean, repair, replace and continue the stormwater control/treatment measures depicted in Schedule A as necessary to ensure optimum performance of the measures to design specifications. The stormwater control/treatment measures shall include, but shall not be limited to, the following: catch basins, mechanical treatment systems, bioretention facilities, swales, sand or organic filters, infiltration systems, permeable pavement systems, subsurface gravel wetlands, constructed wetlands and ponds.

3. The facility owner shall be responsible for all expenses related to the maintenance of the stormwater control/treatment measures and shall establish a means for the collection and distribution of expenses among parties for any commonly owned facilities.

4. The facility owner shall provide for periodic inspection of the stormwater control/treatment measures on an annual basis, to determine the condition and integrity of the measures. Such inspection shall be performed by a Professional Engineer licensed by the State of Connecticut. The inspecting engineer shall prepare and submit to the Municipality within 30 days of the inspection, a written report of the findings including recommendations for those actions necessary for the continuation of the stormwater control/treatment measures.

5. The facility owner shall not authorize, undertake or permit alteration, abandonment, modification or discontinuation of the stormwater control/treatment measures except in accordance with written approval of the Municipality.

6. The facility owner shall undertake necessary repairs and replacement of the stormwater control/treatment measures at the direction of the Municipality or in accordance with the recommendation of the inspecting engineer.

7. The facility owner shall provide to the Municipality within 30 days of the date of this agreement, a security for the maintenance and continuation of the stormwater control/treatment measures in the form of (a Bond, letter of credit or escrow account).

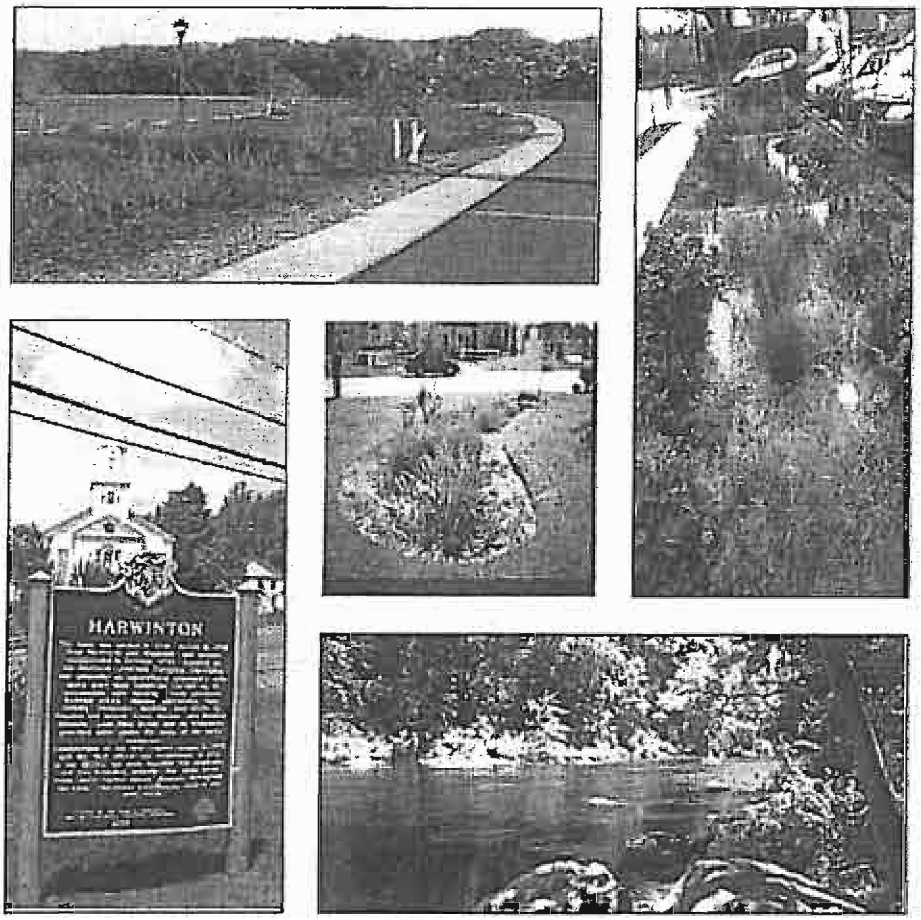
8. This agreement shall be recorded in the Town Clerks Office, Town of Harwinton together with Schedule A.

9. If ever the Municipality determines that the facility owner has failed to construct or maintain the stormwater control/treatment measures in accordance with the project plan or has failed to undertake corrective action specified by the Municipality or by the inspecting engineer, the Municipality is authorized to undertake such steps as reasonably necessary for the preservation, continuation, or maintenance of the stormwater control/treatment measures and affix the expenses thereof as a lien against the property.

10. This agreement is effective ______________________.

HARWINTON

Public Educational Materials on Stormwater Management & Low Impact Development



Planimetrics

Trinkaus Engineering, LLC
114 Hunters Ridge Road
Southbury, CT 06488
203-264-4558

This document contains information from authentic and highly regarded Low Impact Development sources, including results of independent observations of LID systems in the field by the author, Steven D. Trinkaus, PE. Sources are identified where this material has been used.

Reuse of any information contained in this document outside the Town of Harwinton shall provide a written acknowledgement to the document entitled "Harwinton, Public Educational Materials on Stormwater Management & Low Impact Development".

This project was made possible by a grant from the Connecticut Department of Environmental Protection through the Farmington River Enhancement Grant Program.

The grant is intended to support the formation of a local committee to:

- review existing municipal regulations and ordinances, and
- draft recommended changes to remove barriers to low impact development (LID) and create opportunity for low impact development practices to be employed in Harwinton.

Table of Contents

1.0 Overview of Water Resources in the Town of Harwinton

The Town of Harwinton is located eastern portion of Northwestern Connecticut. The western portion of the town is located in the Naugatuck River Watershed, while the eastern portion of the town is located in the Farmington River Watershed. It is a rural community with mostly residential development, along with some commercial development located along the Route 118 corridor.

The surface water quality for the majority of the town is rated Class A (known or presumed to meet water quality criteria which support designated uses such as potential drinking water supply, fish and wildlife habitat, recreational use, agricultural and industrial supply, and other legitimate uses including navigation) as stated on map entitled "Water Quality Classifications Map of Connecticut, compiled by James Murphy; 1987" prepared for the Connecticut Department of Environmental Protection.

The majority of the town has a GAA groundwater classification which means that the groundwater is suitable for direct human consumption without the need for treatment. This information was also taken from the above referenced map.

There are three main watercourses in Harwinton, Leadmine Brook and Rock Brook which are tributary to the Naugatuck River and Poland River which is tributary to the Farmington River. The Naugatuck River forms most of Harwinton's western boundary.

The Town of Harwinton has a strong desire to maintain the high quality of the surface and groundwater in their community.

2.0 Introduction

2.1. Purpose of the Document

The purpose of this document is to provide an understanding of the direct and indirect adverse impacts of development and stormwater on the natural environment. It is generally understood that stormwater, when not properly controlled can cause pollution and adverse impacts on our environment. These impacts range from increased flows, which cause erosion of natural stream channels; to closures of water recreational areas due to high bacteria counts in the water. This document also discusses the benefits of Low Impact Development (LID) strategies and how these strategies could help the Town of Harwinton minimize the adverse impacts from stormwater.

2.2 What is Stormwater Runoff

Before we can learn about LID concepts, we need to have an understanding of the natural hydrologic cycle and how development affects the hydrologic cycle and causes adverse impacts to our environment.

The natural hydrologic cycle shows how water travels through our environment in the many forms that provide a myriad of environmental benefits. It is a continuous cycle of the movement of water in our environment.

There are five key elements to the hydrologic cycle: condensation, precipitation, infiltration, runoff, and evapotranspiration/rainfall abstraction. These occur simultaneously and, except for precipitation, continuously. The NASA's Observatorium website provides the following definitions for each element of the Hydrologic Cycle:

A. Condensation is the process of water changing from a vapor to a liquid. Water vapor in the air rises mostly by convection. This means that warm, humid air will rise, while cooler air will flow downward. As the warmer air rises, the water vapor will lose energy, causing its temperature to drop. The water vapor then has a change of state into liquid or ice.
B. Precipitation is water being released from clouds as rain, sleet, snow, or hail. Precipitation begins after water vapor, which has condensed in the atmosphere, becomes too heavy to remain in atmospheric air currents and falls. In many cases, precipitation evaporates as it falls through the atmosphere and returns as water vapor.
C. Infiltration is that portion of the precipitation that reaches the Earth's surface and seeps into the ground. The amount of water that infiltrates the soil varies with the degree of land slope, the amount and type of vegetation, soil type and rock type, and whether the soil is already saturated by water. The more openings in the surface (cracks, pores, joints), the more infiltration occurs. Water that doesn't infiltrate the soil flows on the surface as runoff.
D. Runoff is the amount of rainfall which is left after evapotranspiration and infiltration occur. Under natural conditions, 10-30% of the annual rainfall becomes runoff. As impervious areas increase, both evapotranspiration and infiltration are reduced, thus increasing runoff.
E. Evapotranspiration is water evaporating from the ground and transpiration by plants. Evapotranspiration is also the way water re-enters the atmosphere. Evaporation occurs when radiant energy from the sun heats water, causing the water molecules to become so active that some of them rise into the atmosphere as vapor. Transpiration occurs when plants take in water through the roots and release it through the leaves, a process that can clean water by removing contaminants and pollution. Rainfall Abstraction is the physical process of interception of rainfall by vegetation, evaporation from land surfaces & upper soil layers, evapotranspiration from plants, infiltration of rainfall into the soil surface and surface storage within natural depressions. Rainfall abstraction can be estimated as a depth of water on a site. (http://physics.ship.edu/~mrc/astro/NASA_Space_Science/observe.arc.nasa.gov/nasa/earth/hydrocycle/hydro1.html)

When development occurs on a site, many changes to the hydrologic cycle will result from the disturbance of the natural land form, the creation of impervious surfaces and the application of chemical compounds which can adversely affect our environment. All of these changes affect the stormwater which is generated on the site.

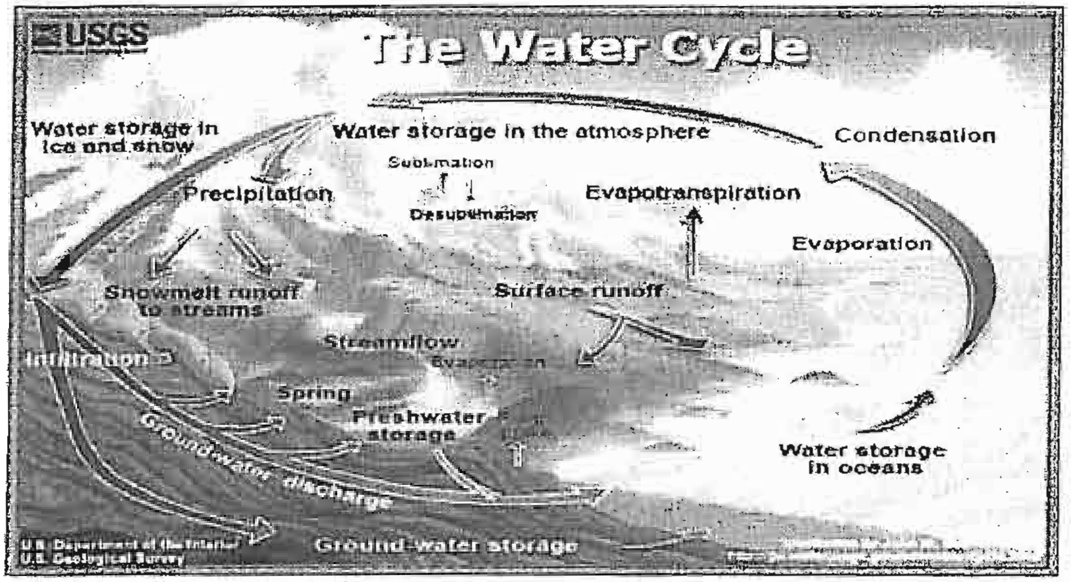


Figure 2.2.a – The Hydrologic Cycle

The 2004 Connecticut Stormwater Quality Document prepared by the CT DEP defines stormwater as follows:

"Storm water runoff is a natural part of the hydrologic cycle, which is the distribution and movement of water between the earth's atmosphere, land and water bodies. Rainfall, snowfall, and other frozen precipitation send water to the earth's surfaces. Storm water runoff is surface flow from precipitation that accumulates in and flows through natural or man-made conveyance systems during and immediately after a storm event or upon snowmelt. Storm water eventually travels to surface water bodies as diffuse overland flow, a point discharge, or as groundwater flow. Water that seeps into the ground eventually replenishes groundwater aquifers and surface waters such as lakes, streams and oceans. Groundwater recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water returned to the atmosphere through evaporation and transpiration to complete the cycle."

When the stormwater is being generated by the natural environment, there are very little adverse impacts associated with stormwater. However, when development occurs on the land, there are profound impacts that occur which can significantly modify the natural hydrologic cycle. The adverse impacts can be summarized as reduced rates of infiltration, reduced evapotranspiration, increased rates and volumes of runoff, and increased pollutant loads in the runoff. These changes can be seen in Figure 2.2.b.

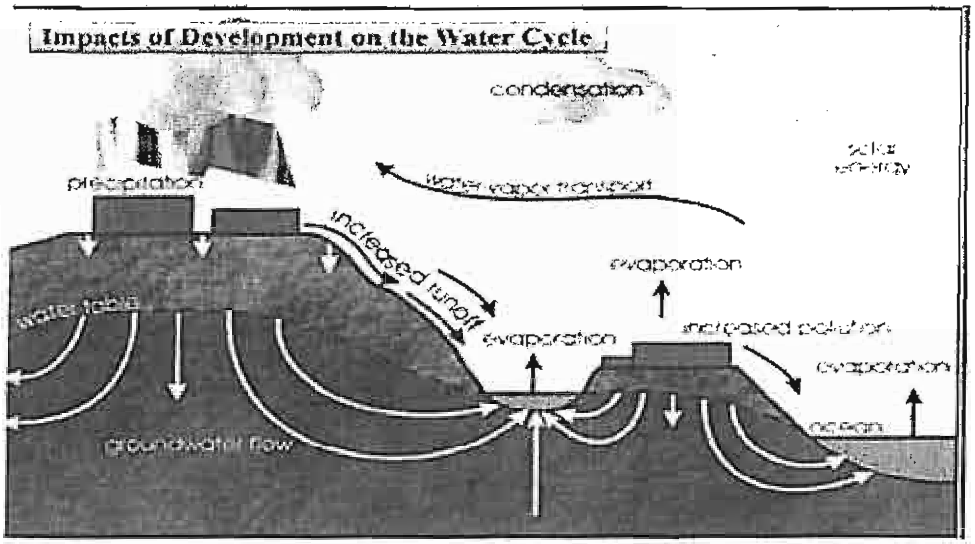


Figure 2.2.b – Changes to the Hydrologic Cycle as a result of development

It can be seen from Figure 2.2.c that as impervious cover increases, there is less base flow into the ground, less evapotranspiration from the vegetation and increased runoff from the impervious areas.

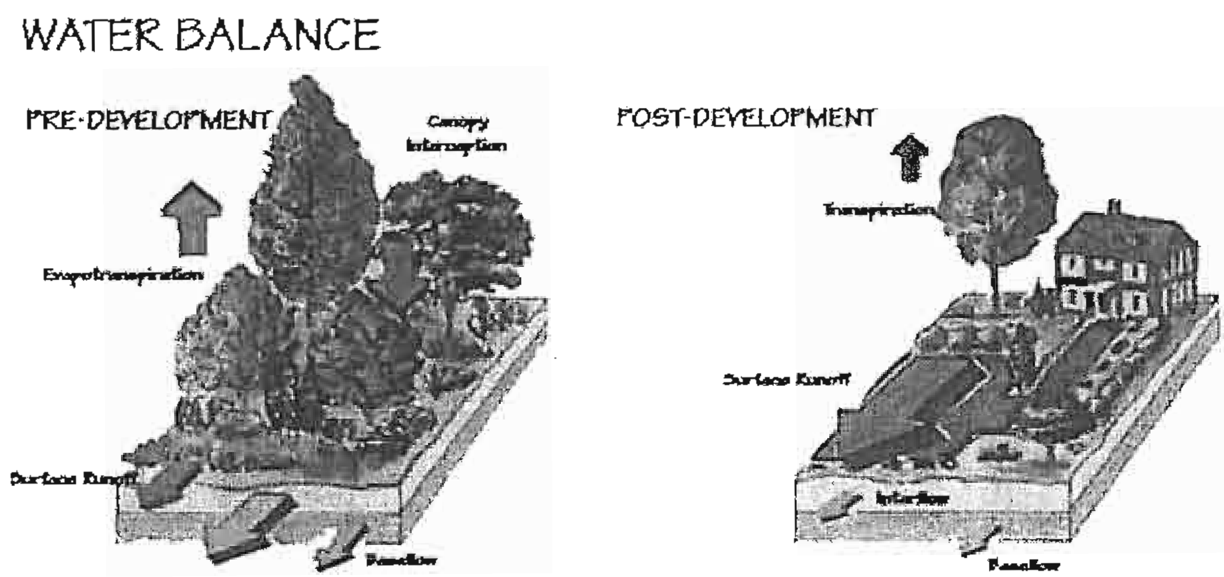


Figure 2.2.c – Effects of Impervious Cover on Water Balance

2.3 What are the Impacts of Development and Stormwater

Land development has the potential to create many adverse impacts on the environment both during the construction period and after construction has been completed. When land is cleared, and stripped of the natural organic layer on top of the soil, the soil loses its ability to infiltrate runoff, thus more runoff is created, which in turn increases the likelihood of erosion of the soil and subsequent sedimentation. After construction has been completed, the large, interconnected impervious area prevents rainfall from infiltrating into the ground. Because of this, more of the rainfall is converted to runoff, which is demonstrated in Figure 2.2.c.

While the addition of a small amount of impervious area on a single lot may not appear to create an issue, the cumulative impact of many small increases of impervious area can quickly become significant. It has been well documented that when the total impervious cover in a watershed is between 10% and 25% that the natural aquatic environment can be adversely affected. Once the impervious coverage exceeds 25% in a watershed, the adverse impacts to the aquatic ecological systems are often irreversible. There have been some studies which have shown that adverse water quality impacts can occur with impervious cover being between 5 – 7% (RI DEM Stormwater Document).

The following table highlights the typical percentages of impervious cover for various land uses.

Table 2.3.a – Typical Amounts of Impervious Cover Associated with Different Land Uses

Land Use	Percent Impervious Cover
Commercial & Business Districts	85%
Industrial	72%
High Density Residential (1/8 acre zoning)	65%
Medium-High Density Residential (1/4 acre zoning)	38%
Medium-Low Density Residential (1/2 acre zoning)	25%
Low Density Residential	
1 acre zoning	20%
2 acre zoning	12-16%
3 acre zoning	8%
5 acre zoning	5-8%
10 acre zoning	2.4%

(Source: RI DEM Stormwater Document, April 2010)

The 2004 CT DEP Stormwater Quality Document states the following adverse impacts which can occur in our environment due to changes in the Hydrologic Cycle:

Hydrologic:

- Increased runoff volume
- Increased peak discharges
- Decreased runoff travel time
- Reduced groundwater recharge
- Reduced stream baseflow
- Increased frequency of bankfull and overbank floods
- Increase flow velocity during storms
- Increase frequency and duration of high stream flows

Figure 2.3.a – Stream Channel Impact from increased runoff volumes (S. Hayden photo)

Stream Channel and Floodplain Impacts:

- Channel scour, widening and downcutting
- Streambank erosion and increased sediment loads
- Shifting bars of coarse sediment
- Burying of stream substrate
- Smothering of aquatic insects and fish eggs
- Loss of pool/riffle structure and sequence
- Man-made stream enclosures or channelization
- Floodplain expansion

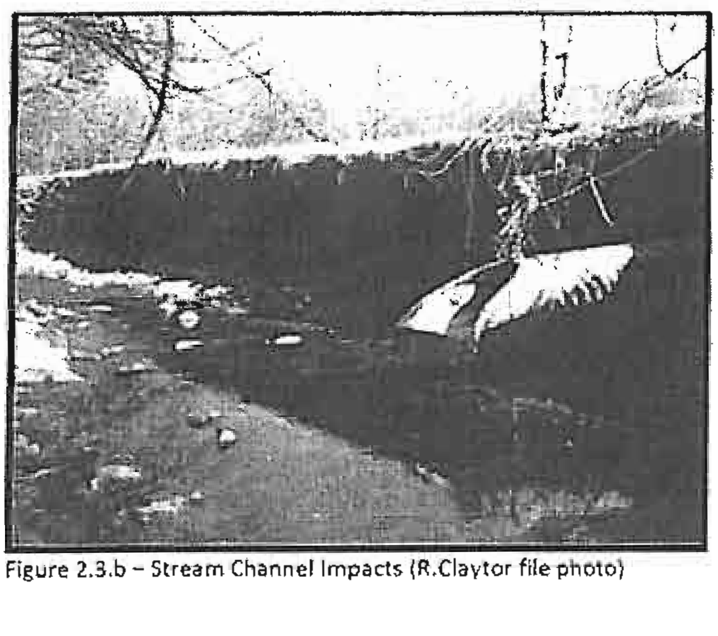


Figure 2.3.b – Stream Channel Impacts (R.Claytor file photo)

Figure 2.3.c – Deposition of sediment in a wetland (S. Hayden photo)

Water Quality Impacts:

- Excess Nutrients (Nitrogen and soluble phosphorous)
- Sediments
- Pathogens
- Organic Materials
- Hydrocarbons
- Metals
- Synthetic Organic Compounds
- De-icing Constituents
- Trash and Debris
- Thermal Impacts
- Freshwater discharge to estuarine systems

Figure 2.3.d – Nutrient impacts in freshwater river

The water quality impacts associated with storm water runoff is called non-point source pollution. The United States Environmental Protection Agency defines non-point source pollution as follows:

Non-point source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include:

A. *Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;*
B. *Oil, grease, and toxic chemicals from urban runoff and energy production;*
C. *Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;*
D. *Salt from irrigation practices and acid drainage from abandoned mines;*
E. *Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;*
F. *Atmospheric deposition and hydromodification are also sources of non-point source pollution.*

The most common pollutants which are found in non-point source runoff are Litter, Sediment and Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorous (TP), Metals, such as Zinc (Zn) and Copper (Cu), Hydrocarbons, Thermal Impacts, Oxygen demanding substances and Pathogens. Each pollutant and its impact on the natural environment are stated below.

<u>Litter</u>

Litter while not causing toxic impacts on the environment, the presence of litter is an aesthetic issue that is not well received by the public.

<u>Total Suspended Solids (TSS) and Sediment</u>

Total Suspended Solids are particles dissolved in water. In excessive amounts it causes turbidity in water. The turbidity blocks light in the water column which causes reduced photosynthesis, which in turn reduces the oxygen levels in the water. Coarse and fine sediments can clog the gravel substrate in breeding streams thus affecting the biological community ability to reproduce. Common sources of TSS and sediment are runoff from construction sites, winter sanding operations, atmospheric deposition and decomposition of organic matter, such as leaves.

<u>Nutrients</u>

Excessive levels of Phosphorous in fresh water are a concern as these nutrients encourage excessive growth of plants and algae. When these plants die, the decomposition of the organic matter reduces oxygen levels in the water, thus adversely affecting the biological community in the water body. Nitrogen, in the form of nitrate, is a direct human health hazard and an indirect hazard in some areas where it leads to a release of arsenic from sediments. While not a major concern for freshwater systems, nitrate can cause environmental impacts in tidal regions, even though the source of nitrate can be far away from coastal regions. When the algae dies and sinks to the bottom, its decomposition consumes oxygen, depriving fish and shellfish in those deep waters of oxygen, a condition known as hypoxia. Sources of nutrients are organic and inorganic fertilizers, animal manure, biosolids and failing sewage disposal systems.

Metals

Metals in non-point source runoff are very toxic to aquatic life. The adverse effects of metals are far reaching for both aquatic and human health. Many metals can bioaccumulate in the environment, which can affect higher living organisms. While the concentration of zinc or copper in stormwater generally is not high enough to bother humans, these same concentrations can be deadly for aquatic organisms. Many microorganisms in soil are especially sensitive to low concentrations of cadmium. Cadmium is also very harmful to humans. Chromium is very toxic to fish and can cause birth defects in animals.

Of the above discussed metals, zinc and copper are the two metals which are found dominantly in non-point source runoff. Metals commonly bind themselves to sediment and organic matter in stormwater and thus are transported to the receiving waters. Since natural rainfall is slightly acidic, metal roofs or components on the roof can be a significant source of the metal concentrations in stormwater.

Hydrocarbons

Total Petroleum Hydrocarbons are highly toxic in the aquatic environment, especially to aquatic invertebrates. The primary sources of petroleum hydrocarbons are oil, grease and gas spills, along with vehicle exhaust. Polycyclic Aromatic Hydrocarbons are also toxic to aquatic life. The primary source of these hydrocarbons is the incomplete burning of fossil fuels. PAH's generally deposited by atmospheric deposition on an impervious surface, especially large flat roof areas. When it rains, the accumulations of pollutants due to atmospheric deposition are carried off in the stormwater.

Thermal Impacts

Impervious surfaces, such as roofs and paved areas can heat up during sunny days and hold onto this heat. When rainfall occurs on these heated surfaces, the resulting runoff has its temperature raised. As this heated runoff is discharged into receiving waters, the temperature of the receiving water is raised to a level which can exceed the tolerance limits for fish and invertebrates, thus lowering their survival rates. Elevated water temperatures will also contribute to reduced oxygen levels in the water.

Oxygen Demanding Substances

Oxygen demanding substances are plant debris and soil organic matter which when they decompose in an aquatic environment require a significant amount of oxygen for the chemical reaction. This results in less available oxygen in the water for other aquatic organisms. Less than 5 mg O/l becomes harmful to fish.

Pathogens

Pathogens are bacteria and viruses, which can cause disease in humans. Most pathogens are found in discharges from overflowing sanitary sewers or in combined sanitary/stormwater systems. Both fecal coliform and enterococci are used as indicators for the presence of pathogenic organisms, yet their presence does not mean a pathogen is present, just that there is a higher risk of being present.

3.0 Overview of Low Impact Development

3.1 What is LID?

Low Impact Development (LID) is an ecologically friendly approach to site development and stormwater management that aims to mitigate development impacts to land, water and air. This approach emphasizes the integration of site design and planning techniques that conserve natural systems and hydrologic functions on a site.

The concept of Low Impact Development (LID) utilizes five major tools to reduce the impact of development on the environment. These primary tools are:

i. Encourage Conservation Measures,
ii. Reduce Impervious Areas,
iii. Slow runoff by using landscape features,
iv. Use multiple measures to reduce and cleanse runoff,
v. Pollution prevention

Each LID tool is enumerated below:

i. **Encourage Conservation Measures**
- Implement Open Space or Cluster Development Regulations to preserve large tracts of the site,
- Implement "Site Fingerprinting" to minimize land clearing & soil disturbance,
- Minimize soil compaction,
- Provide low maintenance landscaping & plant native species which will minimize the use of fertilizers and pesticides,
- Use Source Erosion Control measures

ii. **Reduce Impervious Areas**
- Disconnect impervious coverage to the maximum extent practical to encourage overland flow conditions across vegetated surfaces,
- Reduce pavement widths for local roads,
- Use Permeable Pavement, Porous Concrete, and Open Course Pavers for parking areas and other low traffic areas,
- Use Porous Concrete for sidewalks.

iii. **Slow runoff by using landscape features**
- Maintain Pre-Development Time of Concentration by long flow paths on vegetated surfaces;
- Minimize the extent of flow on impervious surfaces,
- Maintain and encourage overland flow conditions across vegetated areas for at least 75', where feasible.

iv. **Use multiple measures to reduce and cleanse runoff**

- Maintain pre-development infiltration rates by preserving those soils with moderate to high infiltrative capacities,
- Maintain existing vegetation to Maximum Extent Practical,
- Remove pollutants from runoff by flow thru vegetated systems, allow natural infiltration to occur,
- Encourage the use of rain gardens for roof runoff,
- Encourage the use of rain barrels or cisterns to collect & reuse runoff.

v. **Pollution prevention**

- Minimize applications of sand and salt on roads & parking areas,
- Use "Source Controls" such as weekly sweeping of large impervious areas,
- Minimize application of fertilizers on turf areas.

3.2 Measures to Evaluate the Effectiveness of LID

A primary objective of Low Impact Development is to mimic the pre-development hydrologic conditions on a site. At the current time, this objective is measured by two metrics. The first is the reduction of the post-development runoff volume to the pre-development runoff volume for the 90% rainfall event. The second metric is to match the Runoff Curve Numbers (RCN) for post-development conditions to pre-development conditions. Along with the matching of the RCN, it is also important to have the post-development time of concentration (Tc) match or closely approximate the pre-development Tc. By achieving this metric, there should be no or little change in the post-development runoff rate, which minimizes the need for detention facilities. In either case, the overall goal is to have a developed site mimic or come as close as possible to the pre-development hydrologic conditions. This condition is known as "Hydrologic Transparency".

3.3 Goals and Benefits of LID

The overriding goal of LID is to create developments which are in harmony with the natural environment while ensuring that the vision of the developer can also be achieved. The general goals for LID are listed below:

- Preservation of environmentally sensitive areas, and naturally vegetated systems to reduce changes to the hydrology of the watershed,
- Focus on maintaining natural drainage patterns as a key goal in the design of the site,
- Prevent direct adverse impacts to wetlands, watercourses (both perennial & intermittent), to the maximum extent practical,
- Minimize the extent of impervious cover and thus reduce the increases in runoff volume,

- ➢ Implement source controls for water quantity and water quality, while minimizing the extent of structural drainage systems,
- ➢ Create a landscape environment that is multi-functional for all users.

A primary benefit of LID is a better balance between Conservation of Natural Resources, Growth, Ecosystem Protection and the Public Health. There are many benefits associated with the adoption of Low Impact Development strategies for all of the stakeholders in the development field. The three primary stakeholders in the development field are the environment, the public, and the developer. The benefits of LID for each stakeholder group are stated below.

a. Environmental Benefits:
    i. Preserve the biological and ecological integrity of natural systems through the preservation of large extents of contiguous land,
    ii. Protect the water quality by reducing sediment, nutrient and toxic loads to the wetland/watercourse aquatic environments and also terrestrial plants and animals,
    iii. Reduce runoff volumes in receiving streams

b. Public Benefits:
    i. Increase collaborative public/private partnerships on environmental protection by the protection of regional flora and fauna and their environments,
    ii. Balance growth needs with environmental protections,
    iii. Reduce municipal infrastructure and utility maintenance costs (roads and storm water conveyance systems)

c. Developer Benefits:
    i. Reduce land clearing and earth disturbance costs, reduce infrastructure costs (roads, storm water conveyance and treatment systems),
    ii. Reduce storm water management costs by the reduction of structural components of a drainage system,
    iii. Increase quality of building lots and community marketability

4.0 Types of Low Impact Development Treatment Systems

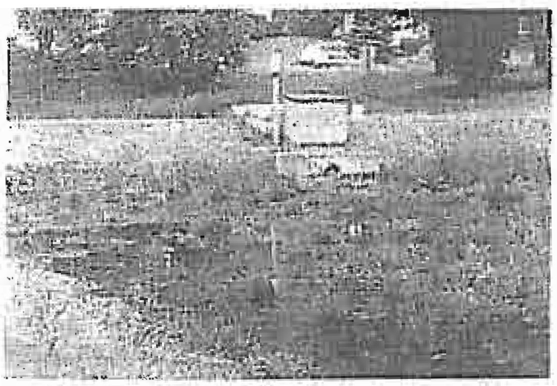
4.1 List of BMPS for Groundwater Recharge and Water Quality Treatment

FILTERING SYSTEMS

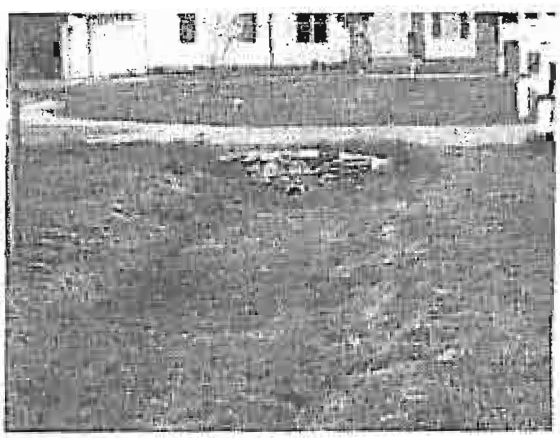
Bioretention: A shallow depression with vegetation that treats stormwater as it filters through a specific soil mixture. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 4.1.a – Bioretention System

Tree Filter: A Bioretention system contained within a precast unit for use in retrofit situations in a commercial environment.
Figure 4.1.b – Filterra Tree Filter (www.filterra.com)

Surface Sand Filter: This system treats stormwater by the removal of coarse sediments in a sediment chamber or forebay, which is easily maintained prior to the stormwater filtering through a surface sand matrix. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 4.1.c – Surface Sand Filter (UNHSC)



Organic Filter: This filtering practice uses an organic soil component such as compost or a sand/peat moss mixture to filter the stormwater. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 4.1.d – Organic Filter

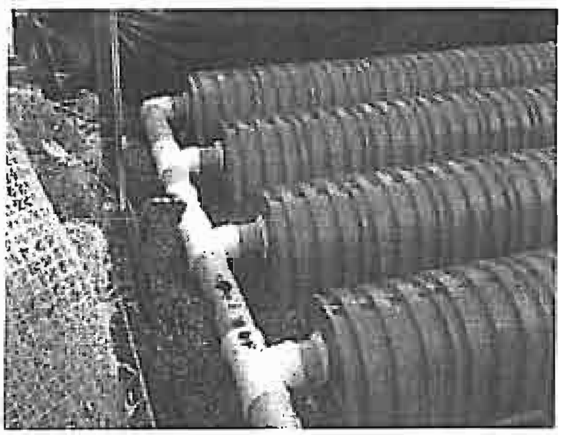


Dry Swale: These are vegetated open swales or depressions which are specifically designed to detail and infiltrate stormwater into the underlying soils. They use a modified soil mixture to enhance the infiltrative capacity of the system. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 4.1.e – Dry Swale (UCONN NEMO)

INFILTRATION SYSTEMS

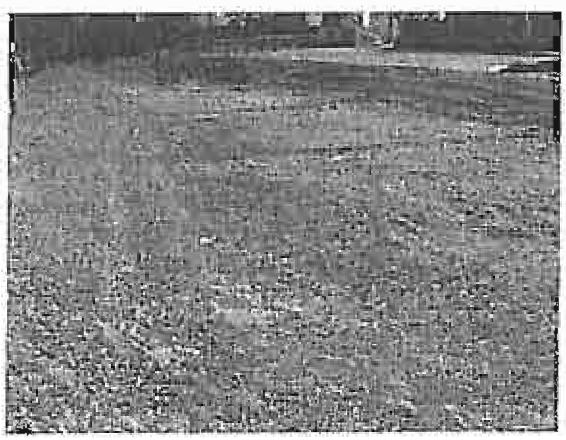
Infiltration Trenches: These are infiltration practices that store water volume in open spaces in a chamber or within the void spaces of crushed stone or clean gravel prior to the water being infiltrated into the underlying soils. These practices are permissible for runoff from residential roofs or small commercial roofs (<3,000 sq.ft.). For larger commercial roofs, pre-treatment via one of the filtering systems list above must be provided prior to discharge into this type of infiltration system.

4.1.f – Infiltration Trench (www.washco-md.net)



Infiltration Chambers: These are infiltration practices that store water volume in open spaces both within the chamber and the void spaces in the crushed stone.

Figure 4.1.g – Infiltration Chamber (www.tritonsws.com/Images/case-studies)



Infiltration Basin: This is an infiltration practice that stores stormwater in a flat, vegetated surface depression prior to infiltrating into the underlying soils.

Figure 4.1.h – Infiltration Basin – (www.wash-md.net)

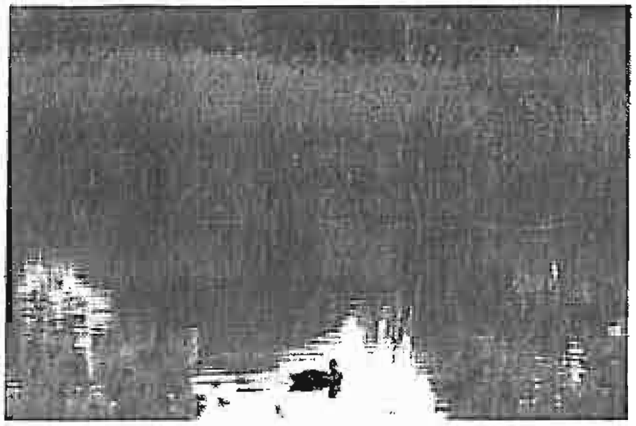
Alternative Paving Surfaces: These are practices that will store and filter stormwater in the void spaces of a clean gravel base prior to infiltrating into the underlying soils.
Figure 4.1.i – Porous Pavements (www.stormwaterenvironments.com)

4.2 List of BMPs for Water Quality Treatment

WET VEGETATED TREATMENT SYSTEMS

Extended Detention Shallow Marsh: A stormwater basin that provides treatment by the utilization of a series of shallow, vegetated permanent pools within the basin in addition to shallow marsh areas.
Figure 4.2.a – Extended Detention Shallow Wetlands (www.wetlands.com.au)

Subsurface Gravel Wetlands: A stormwater system where water quality is provided by the movement of stormwater through a subsurface, saturated bed of gravel with the soil surface being planted with emergent vegetation.
Figure 4.2.b – Subsurface Gravel Wetlands (UNHSC)



Pond / Wetland System: A treatment system which combines the shallow, vegetated aspects of a marsh with at least one pond component.

Figure 4.2.c – Pond/Wetland System (www.starenvironmentalinc.com)

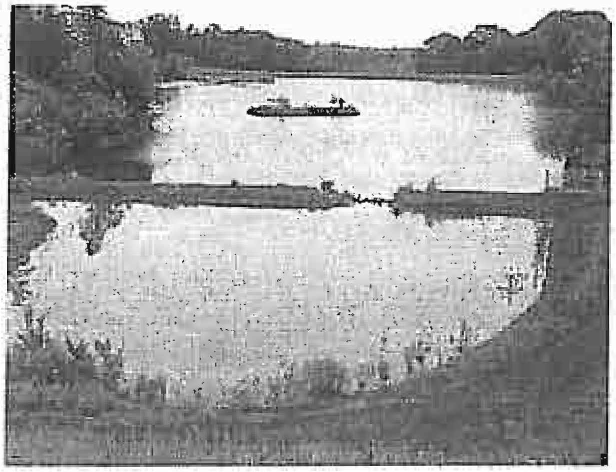
Wet Swale: This is a vegetated depression or open channel designed to retain stormwater or intercept groundwater to provide water quality treatment in a saturated condition.

Figure 4.2.d – Wet Swale (Dr. Bill Hunt, NCSU)

4.3 List of BMPs for Pretreatment for Water Quality Systems

Filter Strips: These vegetated systems that are designed to treat stormwater from adjacent impervious area which occurs as overland flow. These systems function by slowing flow velocities, which allows the removal of sediments and other pollutants.

4.3.a – Filter Strip (www.trinkausengineering.com)

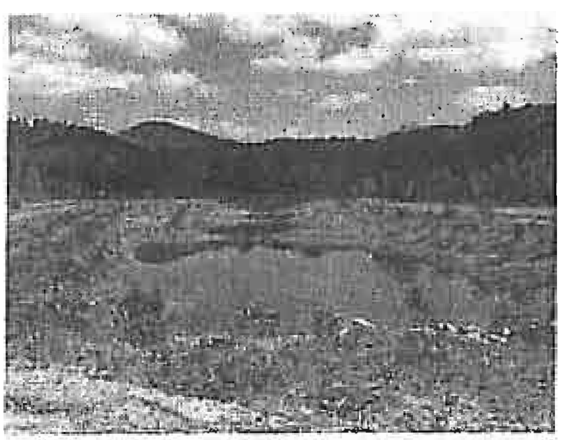


Sediment Forebay: This is a depressed vegetated area prior to a larger stormwater treatment facility which will trap coarse sediments and reduce maintenance requirements of the larger treatment facility.
Figure 4.3.b – Sediment Forebay (www.vwrrc.vt.edu)

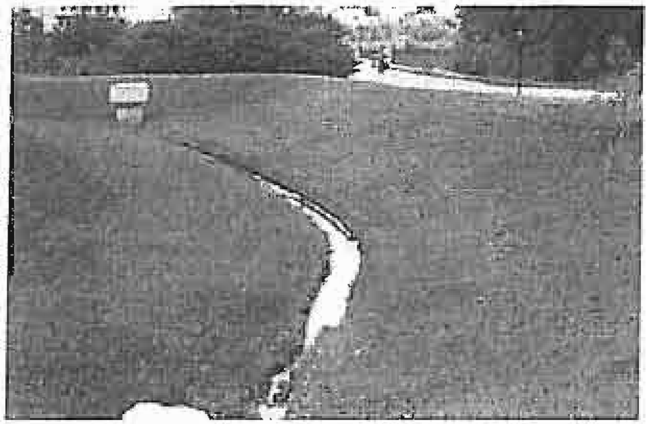
Deep Sump Catch Basin: These systems are modified structures that are installed as part of a conventional stormwater conveyance system. They are designed to trap trash, debris and coarse sediments. While the hooded outlet provides the potential to trap oil and grease, frequent maintenance is required to remove the oils from the water surface.

Proprietary Treatment Devices: These are manufactured systems which were engineered to provide a cost-effective approach to stormwater quality in a contained space. These systems include oil/grit separators, hydrodynamic separators, and a wide range of filter systems with specialized media. Research by the Center for Watershed Protection, University of New Hampshire Stormwater Center in the past few years have shown that many of these systems are not able to achieve the water quality goals as specified in Section 4.3.3. They may be appropriate for pretreatment in some situations. In order to use a proprietary treatment device, independent research documentation must be provided to justify the pollutant removal efficiency.

4.4 List of BMPs for Water Quantity Control



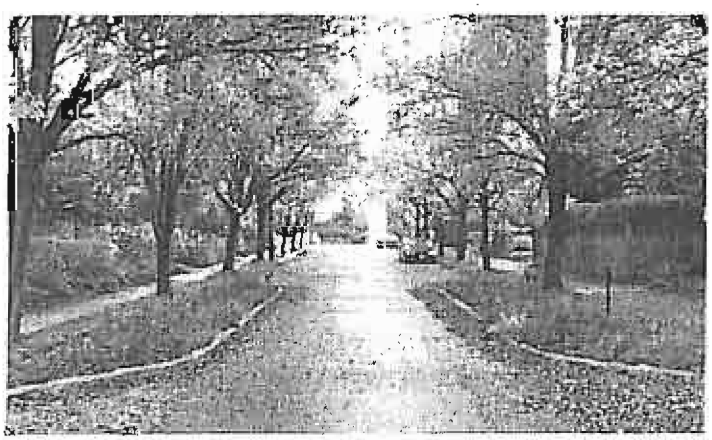
Wet Extended Detention Pond: This practice is primarily designed to address stormwater quantity increases. They have a deep permanent pool, but do not effectively remove stormwater pollutants. These systems may be located in areas of seasonally high groundwater.
Figure 4.4.a – Wet Extended Detention Pond (NCSU)



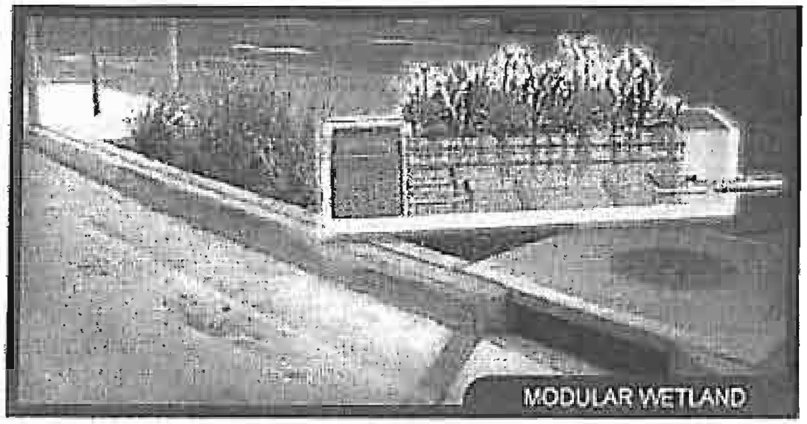
Dry Detention Pond: This practice has a dry bottom and is also designed to address changes in stormwater quantity only.
Figure 4.4.b – Dry Detention Pond (www.dhn.iihr.uiova.edu)

4.5 List of BMPs for Commercial Water Quality Retrofits

LID Urban Planter: These systems provide a "greening" of the urban streetscape while providing pollutant attenuation and potential reductions of runoff volume
Figure 4.5.a – LID Urban Planter (City of Portland, OR)

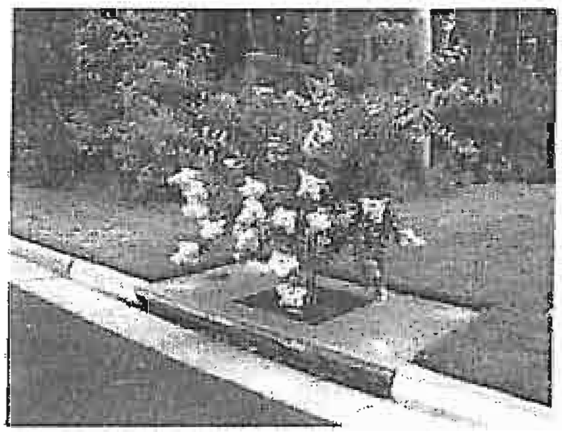


LID Curb Extension: These systems are used to reduce runoff volumes by infiltration as well as pollutants from runoff. They provide a "greening" benefit to any green in addition to a traffic calming device
Figure 4.5.b – LID Curb Extensions (City of Portland, OR)



Modular Wetland System: This system provides treatment of urban runoff in a small footprint. It utilizes the benefits of a Gravel Wetlands along with proprietary filters to remove pollutants.

Figure 4.5.c – Modular Wetland (modularwetland.com)



Filterra Bioretention System: This system is a bioretention facility for urban applications. By the flow through a proprietary media, the amount of pollutants in urban runoff is reduced.

Figure 4.5.d – Filtera Bioretention (Filterra.com)

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