EVERGREEN COMMONS DRIANAGE DESIGN

The Design approach for the project is to provide extensive water quality treatment and direct the treated stormwater runoff to the northwest corner of the property to the Isolated Wetland area. Based on initial meetings with the Newburyport Conservation Commission there is a desire to improve this area by excavating down to the average groundwater elevation and plant this area with wetland vegetation to create a native wetland resource area that could serve as habitat for birds and other wildlife. This would also provide final polishing of the stormwater runoff after the extensive up gradient treatment systems. The project is designed to comply with the Massachusetts Stormwater Standards within a Zone II wellhead protection area. As such the treatment systems are designed to accommodate a water quality volume of 1" over all paved surfaces. The following treatment systems are proposed.

- Boyd Drive – All drainage from Boyd Drive will be directed to a *Constructed Stormwater Wetland.* This provides 80% removal of total suspended solids and up to 55% removal of Nitrogen, 60% phosphorus, 85% metals, and 75% pathogens (coliform, e coli).
- Evergreen Bio-Retention Areas 1-3 – These are shallow landscaped gardens designed to drain dry between rain events. These areas will be landscaped and visually appealing while providing 90% total suspended solids removal. Bio-retention areas also provide up to 50% removal of Nitrogen, 90% phosphorus, 95% metals.
- These treatment areas are directed to a lined stormwater wet basin prior to flowing into the isolated wetlands where the clean stormwater runoff will slowly percolate back into the groundwater.

See attached DEP Stormwater guidelines for details of the provided low impact design stormwater design featured with this project. The calculations below indicate the required sizing and provided areas for each.

WATER QUALITY VOLUME REQUIRED

DRAINAGE AREA	ROADWAY (S.F.)	DRIVEWAYS (S.F.)	TOTAL PAVEMENT (S.F.)	1" WATER QUALITY VOLUME (C.F)
BOYD DRIVE	71,100	32,200	103,300	8,608
BIO RETENTION AREA 1	33,335	7,150	40,405	3,375
BIO RETENTION AREA 2	22,010	7,150	29,160	2,430
BIO RETENTION AREA 3	37,366	11,700	49,066	4,089

WATER QUALITY VOLUME PROVIDED

BOYD DRIVE CONSTRUCTED STORMWATER WETALND –13,000 SF AVERAGE DEPTHS OF 12" = 13,000 C.F.
BIO RETENTION AREA 1 – 6,000 S.F AVERAGE DEPTH 0.6' = 3,600 C.F.
BIO RETENTION AREA 2 – 5,000 S.F. AVERAGE DEPTH 0.6' = 3,000 C.F.
BIO RETENTION AREA 3 – 8,000 S.F. AVERAGE DEPTH 0.6' = 4,800 C.F

Constructed Stormwater Wetlands

Description: Constructed stormwater wetlands are stormwater wetland systems that maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Constructed stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like extended dry detention basins and wet basins, constructed stormwater wetlands must be used with other BMPs, such as sediment forebays. There is also an innovative constructed wetland—the gravel wetland—that acts as a filter. Information on the gravel wetland is presented at the end of this section.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	If properly designed, can provide peak flow attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS Removal	Provides 80% TSS removal when combined with sediment forebay for pretreatment
5 - Higher Pollutant Loading	May be used as treatment BMP provided basin bottom is lined and sealed
6 - Discharges near or to Critical Areas	Do not use near cold-water fisheries. Highly recommended for use near other critical areas.
7 - Redevelopment	Suitable if sufficient space is available.

Pollutant Removal Efficiencies
- Total Suspended Solids (TSS) - 80% with pretreatment
- Total Nitrogen - 20% to 55%
- Total Phosphorus - 40% to 60%
- Metals (copper, lead, zinc, cadmium) - 20% to 85%
- Pathogens (coliform, e coli) - Up to 75%

Advantages/Benefits:
- Relatively low maintenance costs.
- High pollutant removal efficiencies for soluble pollutants and particulates.
- Removes nitrogen, phosphorus, oil and grease
- Enhances the aesthetics of a site and provides recreational benefits.
- Provides wildlife habitat.

Disadvantages/Limitations:
- Depending upon design, more land requirements than other BMPs.
- Until vegetation is well established, pollutant removal efficiencies may be lower than anticipated.
- Relatively high construction costs compared to other BMPs.
- May be difficult to maintain during extended dry periods
- Does not provide recharge
- Creates potential breeding habitat for mosquitoes
- May present a safety issue for nearby pedestrians
- Can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools.

Constructed Stormwater Wetlands

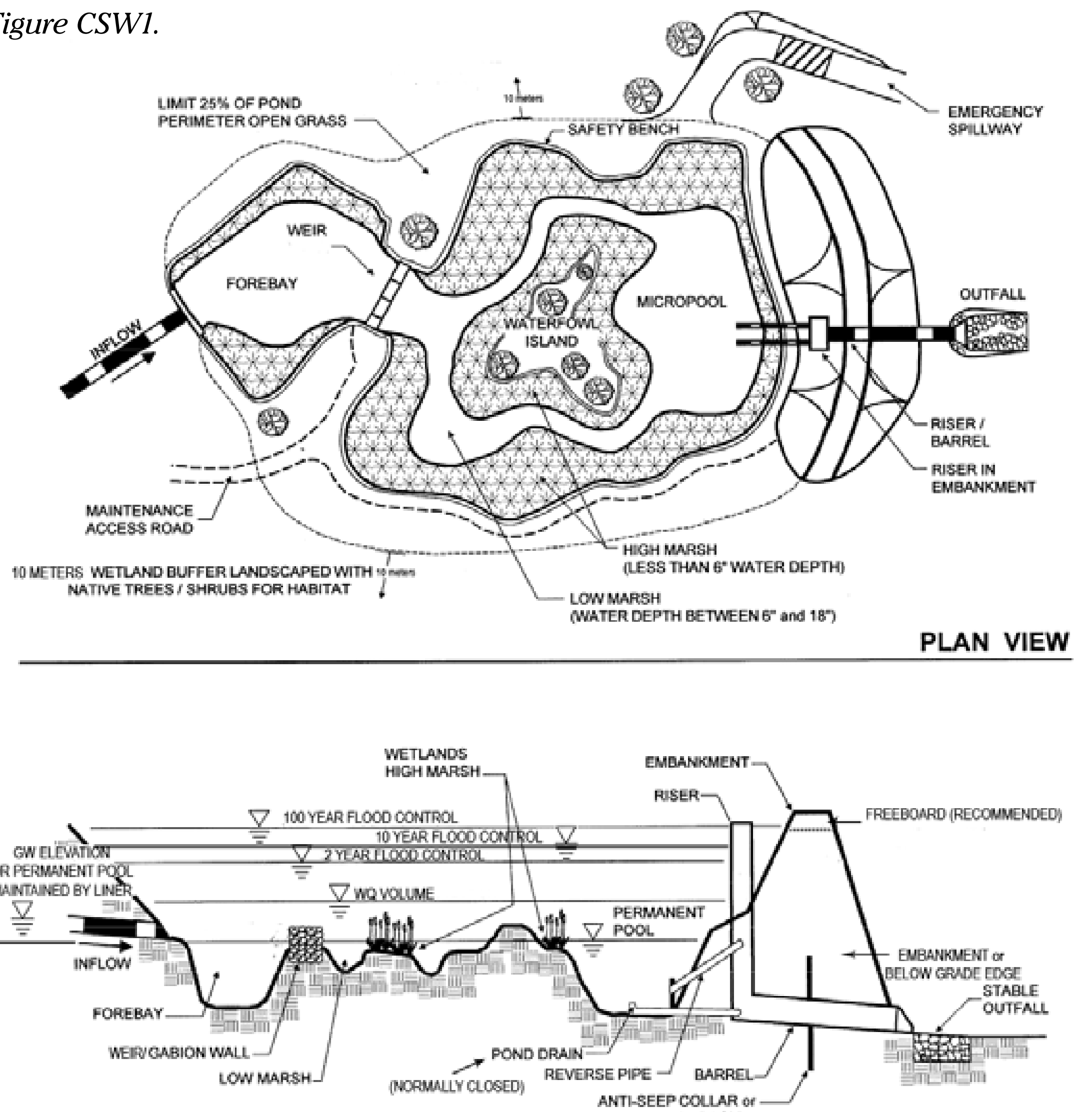
The Five Basic Types of Constructed Stormwater Wetlands

Like wet basins, most constructed stormwater wetlands require relatively large contributing drainage areas and dry weather base flows. Ten acres is the minimum contributing drainage area, although pocket type wetlands may be appropriate for smaller sites, if sufficient groundwater flow is available. There are five basic constructed wetland designs: 1) Shallow Marsh, 2) Basin/Wetland (formerly Pond/Wetland) 3)Extended Detention (ED) Wetland, 4) Pocket Wetland, and 5) Gravel Wetlands. In addition to these designs, there is a sixth type known as a subsurface gravel wetland. However, due to the lack of performance data, MA currently does not recognize subsurface gravel wetlands as having a presumed TSS removal credit.

Shallow marsh systems

Most shallow marsh systems consist of pools ranging from 6 to 18 inches deep during normal conditions. Shallow marshes may be configured with different low marsh and high marsh areas, which are referred to as cells. Shallow marshes are designed with sinuous pathways to increase retention time and contact area. Shallow marshes may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time.

Figure CSW1.

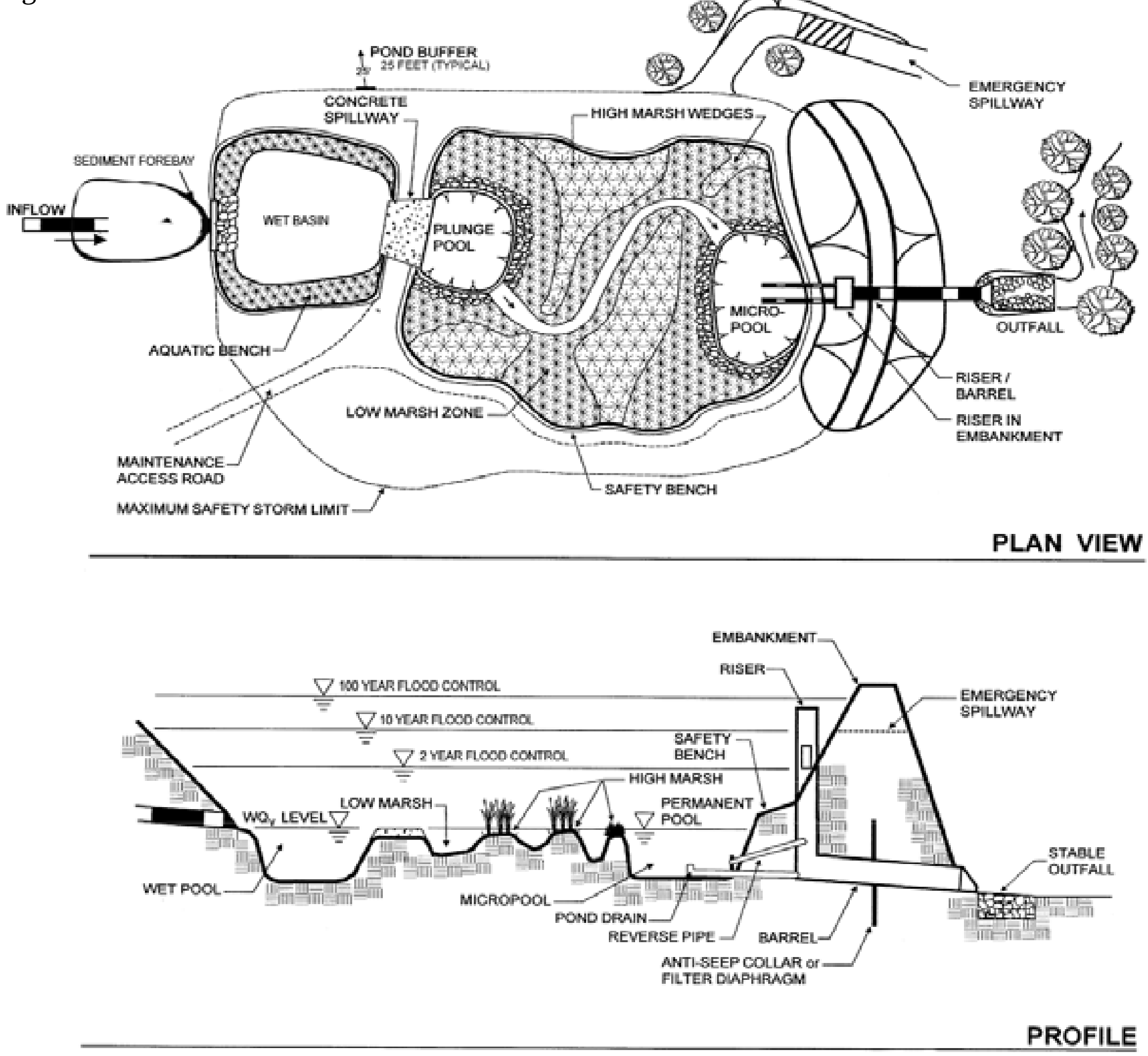


Shallow Marsh Constructed Stormwater Wetland adapted from Schueler 1992

Basin/wetland systems (formerly pond/wetland system)

Multiple cell systems, such as basin/wetland systems, use at least one wet basin along with a shallow marsh component. The first cell is a sediment forebay that outlets to a wet basin, which removes particulate pollutants. The wet basin also reduces the velocity of the runoff entering the system. Stormwater then travels to the next cell, which contains a plunge pool. The plunge pool acts as an energy dissipator. Shallow marshes provide additional treatment of runoff, particularly for dissolved pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other stormwater wetland systems.

Figure CSW2.



Basin/Wetland Constructed Stormwater Wetland adapted from Schueler 1992

Applicability

Never use constructed stormwater wetlands to manage runoff during site grading and construction. Site constraints that can limit the suitability of constructed stormwater wetlands include inappropriate soil types, depth to groundwater, contributing drainage area, and available land area. Soils consisting entirely of sands are inappropriate unless the groundwater table intersects the bottom of the constructed wetland or the constructed stormwater wetland is installed over the sand to hold water. Where land area is not a limiting factor, several wetland design types may be possible. Consider pocket wetlands where land area is limited.

Do not locate constructed stormwater wetlands within natural wetland areas. These engineered stormwater wetlands differ from wetlands constructed for compensatory storage purposes and wetlands created for restoration or replication. Typically, constructed stormwater wetlands will not have the full range of ecological functions of natural wetlands. Constructed stormwater wetlands are designed specifically to improve water quality. Note that constructed stormwater wetlands do not create any additional wetland resource area or buffer zones as discussed in Volume 1, Chapter 2.

Before designing and siting constructed stormwater wetlands, investigate soil types, depth to bedrock, and depth to water table. Medium-fine texture soils (such as loams and silt loams) are best at establishing vegetation, retaining surface water, facilitating groundwater discharge, and capturing pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation (such as sandy soils), consider using an impermeable liner. Liners are also required where the potential for groundwater contamination from runoff is high, such as from sites with high potential pollutant loads.

At sites where bedrock is close to the surface, high excavation costs may make constructed stormwater wetlands infeasible. Table CSW.1 lists the recommended minimum design criteria for constructed stormwater wetlands.

Effectiveness

A review of the existing performance data indicates that the removal efficiencies of constructed stormwater wetlands are significantly higher than the removal efficiencies of dry extended detention basins. Indeed constructed stormwater wetlands are among the most effective treatment practices.

To preserve their effectiveness, MassDEP requires placing a sediment forebay as pretreatment for all constructed stormwater wetlands.

Studies indicate that removal efficiencies of constructed stormwater wetlands decline when they are covered by ice or receive runoff derived from snow melt. Performance also declines during the non-growing season and the fall when vegetation dies off. Expect lower pollutant removal efficiencies until vegetation is re-established.

One preferred wetland installation is to combine an off-line stormwater wetland design, for runoff quality treatment, with an on-line runoff quantity control, because large surges of water can damage wetlands. Further, the shallow depths required to maintain the wetlands conflict with the need to store large volumes to control runoff quantity.

Planning Considerations

Carefully evaluate sites when planning constructed stormwater wetlands. Investigate soils, depth to bedrock, and depth to water table before designing, permitting, and siting constructed wetlands. Proponents must consider a “pond-scaping plan” for each constructed stormwater wetland. The plan must contain the location, quantity and propagation methods for the wetland plants as well as site preparation and maintenance. The plan should also include a wetland design and configuration, elevations and grades, a site/soil analysis, estimated depth zones, and hydrological calculations or water budgets. The water budget must demonstrate that a continuous supply of water is available to sustain the constructed stormwater wetland. Develop the water budget during site selection and then check it after the preliminary site design. The water budget analysis must be based on the Thornwaite method, arranging data in a “bookkeeping” or “spreadsheet” format. The water budget must take into account prcipitation, runoff, evaporatranspiration, soil moisture, and groundwater inputs. Drying periods of longer than two months adversely affect the richness of the plant community, so make sure that the water budget confirms that the drying time will not exceed two months.

Table CSW.1
Recommended Design Criteria for Stormwater Wetlands Designs

Design Criteria	Shallow Marsh	Basin/Wetland	ED Wetland	Pocket Wetland	Gravel Wetland (Surface)
Minimum Drainage Area (acres)	≥ 25	≥ 25	≥ 10	≥ 1 to 10	SEE SPECIFICATIONS
Constructed Wetland Surface Area/Watershed Area Ratio[1]	≥ 0.02	≥ 0.01	≥ 0.01	≥ 0.01	
Length to Width Ratio (minimum)	≥ 2:1	≥ 2:1	≥ 2:1	≥ 2:1	
Extended Detention (ED)[2]	NOT ALLOWED	OPTIONAL	YES	OPTIONAL	
Allocation of WQv Volume (wet pools[3]/low and high marsh/ED) in %	30/70/0	70/30/02	20/30/50	20/80/02	
Allocation of Surface Area (wet pools[3]/low marsh/ high marsh/semi-wet) in %	15/40/40/5	45/25/25/5	10/40/40/10	10/45/40/5	
Sediment Forebay[4]	REQUIRED	REQUIRED	REQUIRED	REQUIRED	
Micropool	REQUIRED	REQUIRED	REQUIRED	REQUIRED	
Outlet Configuration	Reverse slope pipe or hooded broad crested weir	Reverse slope pipe or hooded broad crested weir	Reverse slope pipe or hooded broad crested weir	Hooded broad-creasted weir	
Target Allocations	Shallow Marsh	Basin/Wetland	ED Wetland	Pocket Wetland	
	% Surface Area				
Sediment Forebay[4]	5%	0%5	5%	5%	
Micropool	5%	5%	5%	5%	
Deep Water Channel	5%	40%	0%	0%	
Lo Marsh	40%	25%	40%	45%	
High Marsh	40%	25%	40%	40%	
Semi-Wet	5%	5%	10%	5%	
	% WQv Volume				
Sediment Forebay[4]	10%	0%5	10%	10%	
Micropool	10%	10%	10%	10%	
Deep Water Channel6	10%	60%	0%	0%	
Lo Marsh	45%	20%	20%	55%	
High Marsh	25%	10%	10%	25%	
Semi-Wet	0%	0%	50% (ED)	0%	

[1]Constructed Wetland Surface Area includes wet pool, deep water channel, marshes, and semi-wet zone.
[2]ED volume shall be an additional volume above the WQv (except for the ED Wetland)

[3]Wet Pool = Forebay+Micropool+Deep Water
[4]Sediment Forebay for 1/2-inch WQv is 20% of WQv. Only 10% of that Volume may be included in the Constructed Wetland.
[5]Basin Wetland Forebay: Forebay sizing must not be counted as part of WQv. Sediment Forebay Volume = 0.1-inch x Impervious area

[6]Includes "basin" volume in Basin/Wetland Design

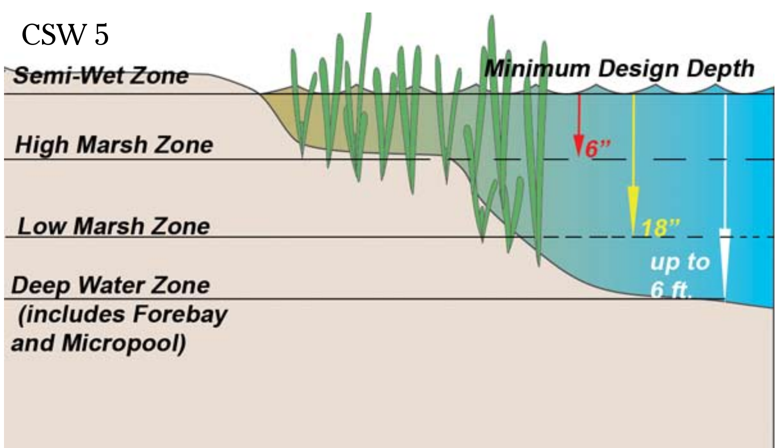
Design

Constructed stormwater wetlands may be designed as on-line systems with permanent pools for both treatment and storage of peak flows. Constructed stormwater wetlands can also be designed as off-line systems with high flows routed around the wetland. The basic constructed stormwater wetland design sizing criteria is set forth in Table CSW.1. Whether designed as an on-line or off-line system, a constructed stormwater wetland must be sized for the required water quality volume.

The ratio of the surface area of the constructed stormwater wetland to longer flow paths through the constructed stormwater wetlands to the contributing watershed area must meet the criteria specified in Table CSW.1. The reliability of pollutant removal tends to increase as the ratio of constructed stormwater wetlands area to watershed area increases.

Design the constructed stormwater wetlands with the required proportion of "depth zones." Each of the constructed wetland designs other than the gravel wetland, has depth zone allocations, which are given as a percentage of the stormwater wetland surface area. Target allocations for these constructed wetland designs are listed in Table CSW.1. The four basic depth zones are (see figure CSW 5):

CSW 5



Deepwater zone

From 1.5 feet to six feet below normal pool elevation. This zone supports little emergent vegetation, but may support submerged or floating vegetation. This zone can be further broken down into forebay, micropool and deepwater channels.

Low marsh zone

Ranges from 6 inches to s18 inches below the normal pool elevation. This area is suitable for growing several emergent wetland plant species.

High marsh zone

Ranges from the normal pool elevation to 6 inches below normal pool elevation. This zone will support a greater density and diversity of emergent wetland species than the low marsh zone. The high marsh zone must have a higher surface area to volume ratio than the low marsh zone (see table CSW.1).

Semi-wet zone

This zone includes those areas above the normal pool elevation that are intermittently inundated and that can be expected to support wetland plants.

Design each constructed stormwater wetland with the required proportion of treatment volumes, which have been represented as a percentage of the three basic depth zones (pool, marsh, extended detention). Table CSW.1 specifies the allocations of treatment volume per zone.

Increase the contact time over the surface area of the marsh, thereby improving treatment efficiency. The constructed stormwater wetland must be designed to achieve a dry weather flow path of 2:1 (length: width) or greater.

Prepare a water budget to demonstrate that the water supply to the constructed stormwater wetland is greater than the expected loss rate. The water budget must be based on the Thornwaite method.

Provide extended detention (ED) for smaller storms. Schueler 1992 lists the following design standards for ED wetlands:

•The volume of the extended detention must be no more than 50% of the total treatment volume.

•The target ED detention time for this volume must be 12 to 24 hours.

- Use V-shaped or proportional weirs to ensure constant detention time for all storm events.
- Extended detention is defined here as the retention and gradual release of a fixed volume of stormwater runoff. For ED wetlands less than 100 acres, the extended detention volume can be assumed to fill instantaneously for design purposes.

- Use a reverse slope pipe and increase the actual diameter of the orifice to the next greatest diameter on the standard pipe schedule. The pipe must be equipped with a gate valve.
- Protect the ED orifice from clogging.
- Make the maximum ED water surface elevation no greater than three feet above the normal pool elevation.

Design each constructed stormwater wetland with a separate cell near the inlet to act as a sediment forebay. Design the forebay with a capacity of at least 10% of the total treatment volume, normally 4 to 6 feet deep. Provide a direct and convenient access for cleanout.

Surround all deep-water cells with a safety bench that is at least ten feet wide, and zero to 18 inches below the normal water depth of the pool.

Place above-ground berms or high marsh wedges at approximately 50-foot intervals, and at right angles to the direction of the flow to increase the dry-weather flow path within the wetland.

Include a four- to six-foot deep micropool before the outlet to prevent the outlet from clogging. Provide a micropool capacity of at least ten percent of the total treatment volume. Use a reverse slope pipe or a hooded, broad-crested weir for outlet control. Locate the outlet from the micropool at least one foot below the normal pool surface.

To prevent clogging, install trash racks or hoods on the riser. To facilitate access for maintenance, install the riser within the embankment. Install anti-seep collars on the outlet barrel to prevent seepage losses and pipe failures. Install a bottom drainpipe with an inverted elbow to prevent clogging and to facilitate complete draining of the wetland for emergency purposes or routine maintenance. Fit both the outlet pipe and the bottom drainpipe with adjustable valves at the outlet ends to regulate flows. Design embankments and spillways in accordance with the state regulations and criteria for dam safety.

All constructed stormwater wetlands must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

Provide an access for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, through public or private rights-of-way. Make sure this access extends to the forebay, safety bench and outflow structure and never crosses the emergency spillway, unless the spillway has been designed and constructed for this purpose.

Locate vegetative buffers around the perimeter of the constructed stormwater wetland to control erosion and provide additional sediment and nutrient removal for sheet flow discharging to the constructed stormwater wetland.

Construction

A seven-step process to prepare a wetland bed prior to planting (Shueler 1992):

1. Prepare final pond-scaping and grading plans for the constructed stormwater wetland. At the same time, order wetland plant stocks from aquatic nurseries.
2. Once the constructed stormwater wetland volume has been excavated, grade the wetland to create the major internal features (pool, aquatic bench, deep water channels, etc.).
3. Because deep subsoils often lack the nutrients and organic matter needed to support vigorous plant growth, add topsoil and/or wetland mulch to the wetland excavation. If available, wetland mulch is preferable to topsoil.
4. After the mulch or topsoil has been added, grade the constructed stormwater wetland to its final elevations. Temporarily stabilize all wetland features above the normal pool. After final grading, close the pool drain to allow the pool to fill. MassDEP recommends evaluating the wetland elevations during a standing period of approximately six months to assess how the constructed stormwater wetland responds to storm flows and inundation, where the pond-scaping zones are located, and whether the final grade and micro-topography will persist over time.
5. Before planting, measure the constructed stormwater wetland depths to the nearest inch to confirm planting depth. If necessary, modify the pond-scape plan at this time to reflect altered depths or availability of plant stock.
6. Aggressively apply erosion controls during the standing and planting periods. Stabilize the vegetation in all areas above the normal pool elevation during the standing period (typically by hydroseeding).
7. Dewater the constructed stormwater wetland at least three days before planting, because a dry wetland is easier to plant than a wet one.

Wetland Vegetation

Establishing and maintaining wetland vegetation is important when creating a constructed stormwater wetland. Horner et al. (1994) recommend the following actions when constructing stormwater wetlands:

- In selecting plants, consider the prospects for success over the specific pollutant removal capabilities and plant species growing in nearby natural wetlands. Plant uptake is an important removal mechanism for nutrients, but not for other pollutants. The most versatile genera for pollutant removal are *Carex, Scirpus, Juncus, and Lemna.* Consult the NRCS plant database to determine if the plant is appropriate. The NRCS database lists the plants prohibited for sale in Massachusetts.
- Select native species, avoiding those that are invasive. Because diversification will occur naturally, use a minimum of species adaptable to the various elevation zones within the stormwater wetland.
- Give priority to perennial species that establish themselves rapidly.
- Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod).
- Match site conditions to the environmental requirements of plant selections.
- Take into account hydroperiod and light conditions.
- Give priority to species that have already been used successfully in constructed stormwater wetlands and that are commercially available.
- Avoid using only species that are foraged by the wildlife expected on site.
- Establish woody species after herbaceous species.
- Where applicable, add vegetation that will achieve other objectives, in addition to pollution control.

Plants will develop best when soils are enriched with plant roots, rhizomes, and seed banks. Use "wetlands mulch" to enhance the diversity of the plant community and speed its establishment. Wetlands mulch is hydric soil. This mulch is available where wetland soils are removed during cleaning and dredging of drainage channels, swales, sedimentation basins, dry detention basins, and infiltration basins. Wetland soils are also available commercially. The upper 5.9 inches of donor soil should be obtained at the end of the growing season, and kept moist until installation. Drawbacks to using wetlands mulch are the unpredictable content, limited donor sites, and the potential for the introduction of exotic, opportunistic species. Wetland plants are commercially available through wetland plant nurseries.

Maintenance

Unlike conventional wet basin systems that require large-scale sediment removal at infrequent intervals, constructed stormwater wetlands require small-scale maintenance at regular intervals to evaluate the health and composition of the plant species.

Proponents must carefully observe the constructed stormwater wetland system over time. In the first three years after construction, inspect the constructed stormwater wetlands twice a year during both the growing and non-growing seasons. This requirement must be included in the Operation & Maintenance plan. During these inspections, record and map the following information:

- The types and distribution of the dominant wetland plants in the marsh;
- The presence and distribution of planted wetland species;
- The presence and distribution of invasive wetland species (invasives must be removed);
- Indications that other species are replacing the planted wetland species;
- Percentage of standing water that is unvegetated (excluding the deep water cells which are not suitable for emergent plant growth);
- The maximum elevation and the vegetative condition in this zone, if the design elevation of the normal pool is being maintained for wetlands with extended zones;
- Stability of the original depth zones and the micro-topographic features; and
- Accumulation of sediment in the forebay and micropool; and survival rate of plants (cells with dead plants must be replanted).

Maintenance of Sediment Forebay

Another important maintenance activity is regulating the sediment loading into the constructed stromwater wetland. All constructed stormwater wetlands are required to have a sediment forebay. Sediment accumulating in wetlands reduces water depths, changes the growing conditions for emergent plants, and alters the wetland plant community. Most sediment should be trapped and removed by the forebay or other type of basin before it reaches the wetland. The sediment forebay should be cleaned once a year.

Gravel Wetland

The gravel wetland consists of a series of horizontal flow through treatment cells preceded by a sediment forebay. The University of New Hampshire (UNH) has developed specifications that allow the gravel wetland to treat the required water quality volume; 10% in the forebay and 45 % in each treatment cell. The UNH design calls for excess runoff to overflow into an adjacent swale with side slopes graded at 3:1 or flatter.

Treatment occurs in each cell as stormwater passes horizontally through the microbe rich gravel substrate. The wetland is designed to continuously saturate at a depth that begins four inches below the treatment's surface. This design permits treatment and vegetation growth. To generate this condition, UNH designs the device with an outlet pipe that has an invert 4 inches below the surface.

For information on gravel wetland design, see http://www.unh.edu/erg/cstev/fact_sheets/TUG.pdf.

References
Shuler, Thomas, 1992. Design of Stormwater Wetlands Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Middle Atlantic Regions, Metropolitan Washington Council of Governments, Washington, D.C.

Carleton, J.N., Grizzard, T.J., Godrej, A.N., and Post, H.E., 2001, Factors Affecting the Performance of Stormwater Treatment Wetlands, Water Research, Volume 35, No. 6, pp 1552-1562

UNH Stormwater Center, 2005, Gravel Wetland Fact Sheet, www.unh.edu/erg/cstev/fact_sheets/gravel_wetland.pdf

Bioretention Areas & Rain Gardens

Description: Bioretention is a technique that uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells (also called rain gardens in residential applications) are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter.

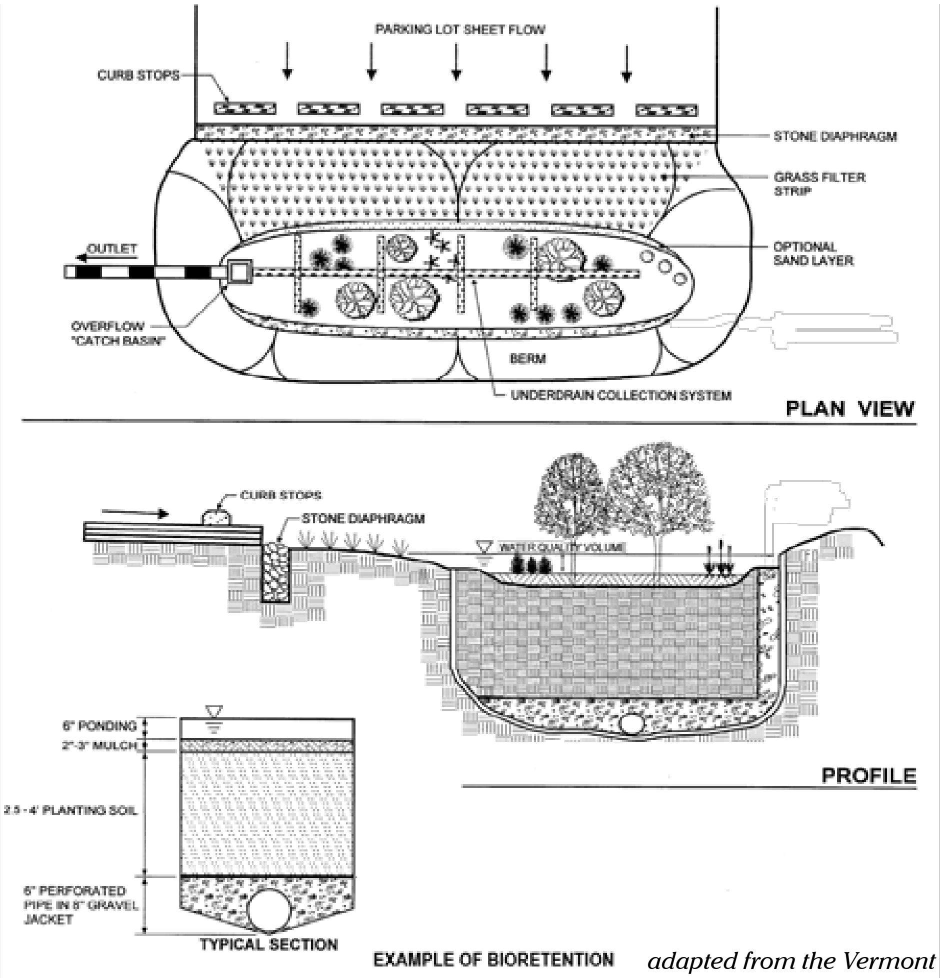
There are two types of bioretention cells: those that are designed solely as an organic filter filtering bioretention areas and those configured to recharge groundwater in addition to acting as a filter exfiltrating bioretention areas. A filtering bioretention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other best management practices, or the municipal storm drain system. An exfiltrating bioretention area has an underdrain that is designed to enhance exfiltration of runoff into the groundwater.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	N/A
3 - Recharge	An exfiltrating bioretention area provides groundwater recharge.
4 - TSS Removal	90% TSS removal credit with adequate pretreatment
5 - Higher Pollutant Loading	Can be used for certain land uses with higher potential pollutant loads if lined and sealed until adequate pretreatment is provided. Adequate pretreatment must include 44% TSS removal prior to infiltration. For land uses that have the potential to generate runoff with high concentrations of oil and grease such as high intensity use parking lots and gas stations, adequate pretreatment may also include an oil grit separator, sand filter or equivalent. In lieu of an oil grit separator or sand filter, a filtering bioretention area also may be used as a pretreatment device for infiltration practices exfiltrating runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.
6 - Discharges near or to Critical Areas	Good option for discharges near cold-water fisheries. Should not be used near bathing beaches and shellfish growing areas.
7 - Redevelopment	Suitable with appropriate pretreatment

Pollutant Removal Efficiencies

• Total Suspended Solids (TSS)	90% with vegetated filter strip or equivalent
• Total Nitrogen	30% to 50% if soil media at least 30 inches
• Total Phosphorus	30% to 90%
• Metals (copper, lead, zinc, cadmium)	40% to 90%
• Pathogens (coliform, e coli)	Insufficient data



adapted from the Vermont Stormwater Manual

Special Features:

- Can be lined and sealed to prevent recharge where appropriate
- Adequate pretreatment is essential
- Not recommended in areas with steep slope
- Depth of soil media depends on type of vegetation that is proposed
- Soil media must be 30 inches deep to achieve removal of nitrogen

Advantages/Benefits:

- Can be designed to provide groundwater recharge and preserves the natural water balance of the site
- Can be designed to prevent recharge where appropriate
- Supplies shade, absorbs noise, and provides windbreaks
- Can remove other pollutants besides TSS including phosphorus, nitrogen and metals
- Can be used as a stormwater retrofit by modifying existing landscape or if a parking lot is being resurfaced
- Can be used on small lots with space constraints
- Small rain gardens are mosquito death traps
- Little or no hazard for amphibians or other small animals

Disadvantages/Limitations:

- Requires careful landscaping and maintenance
- Not suitable for large drainage areas

Maintenance

Activity	Frequency
Inspect and remove trash	Monthly
Mow	2 to 12 times per year
Mulch	Annually
Fertilize	Annually
Remove dead vegetation	Annually
Prune	Annually

Bioretention Areas & Rain Gardens

Not all bioretention cells are designed to exfiltrate. Only the infiltration requirements are applicable to bioretention cells intended to exfiltrate.

Applicability

Bioretention areas can provide excellent pollutant removal for the "first flush" of stormwater runoff. Properly designed and maintained cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall. Distributed around a property, vegetated bioretention areas can enhance site aesthetics. In residential developments they are often described as "rain gardens" and marketed as property amenities. Routine maintenance is simple and can be handled by homeowners or conventional landscaping companies, with proper direction.

Bioretention systems can be applied to a wide range of commercial, residential, and industrial developments in many geologic conditions; they work well on small sites and on large sites divided into multiple small drainage areas. Bioretention systems are often well suited for ultra-urban settings where little pervious area exists. Although they require significant space (approximately 5% to 7% of the area that drains to them), they can be integrated into parking lots, parking lot islands, median strips, and traffic islands. Sites can be retrofitted with bioretention areas by replacing existing parking lot islands or by re-configuring a parking lot during resurfacing. On residential sites, they are commonly used for rooftop and driveway runoff.

Effectiveness

Bioretention areas remove pollutants through filtration, microbe activity, and uptake by plants; contact with soil and roots provides water quality treatment better than conventional infiltration structures. Studies indicate that bioretention areas can remove from 80% to 90% of TSS. If properly designed and installed, bioretention areas remove phosphorus, nitrogen, metals, organics, and bacteria to varying degrees.

Bioretention areas help reduce stress in watersheds that experience severe low flows due to excessive impervious cover. Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe.

Decentralized bioretention cells can also reduce the size of storm drain pipes, a major component of stormwater treatment costs. Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide windbreaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

Planning Considerations

Filtering bioretention areas are designed with an impermeable liner and underdrain so that the stormwater may be transported to additional BMPs for treatment and/or discharge. Exfiltrating bioretention areas are designed so that following treatment by the bioretention area the stormwater may recharge the groundwater.

Both types of bioretention areas may be used to treat runoff from land uses with higher potential pollutant loads. However, exfiltrating bioretention areas may be used to treat runoff from land uses with higher potential pollutant loads, only if pretreatment has been provided to achieve TSS removal of at least 44%. If the land use has the potential to generate runoff with high concentrations of oil and grease, other types of pretreatment, i.e., a deep sump catch basin and oil grit separator or a sand filter, is required prior to discharge of runoff to an exfiltrating bioretention area. A filtering bioretention area may also be used as a pretreatment device for an exfiltrating bioretention area or other infiltration practice that exfiltrates runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.

To receive 90% TSS removal credit, adequate pretreatment must be provided. If the flow is piped to the bioretention area a deep sump catch catch basin and sediment forebay should be used to provide pretreatment. For sheet flow, there are a number or pretreatment options. These options include:

- A vegetated filter strip, grass channel or water quality swale designed in accordance with the specifications set forth in Chapter 2.
- A grass and gravel combination. This should consist of at least 8 inches of gravel followed by 3 to 5 feet of sod. (source: North Carolina Stormwater Manual, 2007, http://h2o.enr.state.nc.us/su/documents/Ch12-Bioretention_001.pdf)
- Pea diaphragm combined with a vegetated filter strip specially designed to provide pretreatment for a bioretention area as set forth in the following table. (source: Georgia Stormwater Manual and Claytor and Schuler 1996)

Dimensions for Filter Strip Designed Specially to Provide Pretreatment for Bioretention Area

Parameter	Impervious Area				Pervious Areas (lawns, etc.)			
Maximum inflow approach length (feet)	35		75		75		100	
Filter strip slope (max=6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter strip minimum length (feet)	10	15	20	25	10	12	15	18

Bioretention areas must not be located on slopes greater than 20%. When the bioretention area is designed to exfiltrate, the design must ensure vertical separation of at least 2 feet from the seasonal high groundwater table to the bottom of the bioretention cell.

For residential rain gardens, pick a low spot on the property, and route water from a downspout or sump pump into it. It is best to choose a location with full sun, but if that is not possible, make sure it gets at least a half-day of sunlight.

Do not excavate an extensive rain garden under large trees. Digging up shallow feeder roots can weaken or kill a tree. If the tree is not a species that prefers moisture, the additional groundwater could damage it. Size the bioretention area using the methodology set forth in Volume 3.

Design

Size the bioretention area to be 5% to 7% of the area draining to it. Determine the infiltrative capacity of the underlying native soil by performing a soil evaluation in accordance with Volume 3. Do not use a standard septic system (i.e., Title 5) percolation test to determine soil permeability.

The depth of the soil media must be between 2 and 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil and that excavations deeper than 4 feet become expensive. The depth selected should accommodate the vegetation. If the minimum depth is used, only shallow rooted plants and grasses my be used. If there is a Total Maximum Daily Load that requires nitrogen to be removed from the stormwater dischrges, the bioretention area should have a soil media with a depth of at least 30 inches, because nitrogen removal takes place 30 inches below the ground surface. If trees and shrubs are to be planted, the soil media should be at least 3 feet.

Size the cells (based on void space and ponding area) at a minimum to capture and treat the required water quality volume (the first 0.5 inch or 1 inch of runoff) if intended to be used for water quality treatment (Stormwater Standard No. 4), the required recharge volume if used for recharge (Stormwater Standard No. 3), or the larger of the two volumes if used to achieve compliance with both Stormwater Standards 3 and 4.

Cover the bottom of the excavation with coarse gravel, over pea gravel, over sand. Earlier designs used filter fabric as a bottom blanket, but more recent experiences show that filter fabric is prone to clogging. Consequently, do not use fabric filters or sand curtains. Use the Engineered Soil Mix below.

Engineered Soil Mix for Bioretention Systems Designed to Exfiltrate

- The soil mix for bioretention areas should be a mixture of sand compost and soil.
  - o 40 % sand,
  - o 20-30% topsoil, and
  - o 30-40% compost.

- The soil mix must be uniform, free of stones, stumps, roots or similar objects larger than 2 inches. Clay content should not exceed 5%.
- Soil pH should generally be between 5.5-6.5, a range that is optimal for microbial activity and adsorption of nitrogen, phosphorus, and other pollutants.
- Use soils with 1.5% to 3% organic content and maximum 500-ppm soluble salts.
- The sand component should be gravelly sand that meets ASTM D 422.

Sieve Size	Percent Passing
2-inch	100
¾-inch	70-100
¼-inch	50-80
U.S. No. 40	15-40
U.S. No. 200	0-3

- The topsoil component shall be a sandy loam, loamy sand or loam texture.
- The compost component must be processed from yard waste in accordance with MassDEP Guidelines (see http://www.mass.gov/dep/recycle/reduce/leafguid.doc). The compost shall not contain biosolids.

On-site soil mixing or placement is not allowed if soil is saturated or subject to water within 48 hours. Cover and store soil to prevent wetting or saturation.

Test soil for fertility and micro-nutrients and, only if necessary, amend mixture to create optimum conditions for plant establishment and early growth.

Grade the area to allow a ponding depth of 6 to 8 inches; depending on site conditions, more or less ponding may be appropriate.

Cover the soil with 2 to 3 inches of fine-shredded hardwood mulch.

The planting plan shall include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasional saline conditions due to road salt, and extended dry periods. A list of plants that are suitable for bioretention areas can be found at the end of this section. To avoid a monoculture, it is a good practice to include one tree or shrub per 50 square feet of bioretention area, and at least 3 species each of herbaceous perennials and shrubs. Invasive and exotic species are prohibited. The planting plan should also meet any applicable local landscaping requirements.

All exfiltrating bioretention areas must be designed to drain within 72 hours. However, rain gardens are typically designed to drain water within a day and are thus unlikely to breed mosquitoes.

Bioretention cells, including rain gardens, require pretreatment, such as a vegetated filter strip. A stone or pea gravel diaphragm or, even better, a concrete level spreader upstream of a filter strip will enhance sheet flow and sediment removal.
Bioretention cells can be dosed with sheet flow, a surface inlet, or pipe flow. When using a surface inlet, first direct the flow to a sediment forebay. Alternatively, piped flow may be introduced to the bioretention system via an underdrain.

For bioretention cells dosed via sheet flow or surface inlets, include a ponding area to allow water to pond and be stored temporarily while stormwater is exfiltrating through the cell. Where bioretention areas are adjacent to parking areas, allow three inches of freeboard above the ponding depth to prevent flooding.

Most bioretention cells have an overflow drain that allows ponded water above the selected ponding depth to be dosed to an underdrain. If the bioretention system is designed to exfiltrate, the underdrain is not connected to an outlet, but instead terminates in the bioretention cell. If the bioretention area is not designed to exfiltrate, the underdrain is connected to an outlet for discharge or conveyance to additional best management practices.

Construction

During construction, avoid excessively compacting soils around the bioretention areas and accumulating silt around the drain field. To minimize sediment loading in the treatment area, direct runoff to the bioretention area only from areas that are stabilized; always divert construction runoff elsewhere.

To avoid compaction of the parent material, work from the edge of the area proposed as the location of an exfiltrationg bioretention cell. Never direct runoff to the cell until the cell and the contributing drainage areas are fully stabilized.

Place planting soils in 1-foot to 2-foot lifts and compact them with minimal pressure until the desired elevation is reached. Some engineers suggest flooding the cell between each lift placement in lieu of compaction.

Maintenance

Premature failure of bioretention areas is a significant issue caused by lack of regular maintenance. Ensuring long-term maintenance involves sustained public education and deed restrictions or covenants for privately owned cells. Bioretention areas require careful attention while plants are being established

Bioretention Maintenance Schedule

Activity	*Time of Year*	*Frequency*
Inspect & remove trash	Year round	Monthly
Mulch	Spring	Annually
Remove dead vegetation	Fall or Spring	Annually
Replace dead vegetation	Spring	Annually
Prune	Spring or Fall	Annually
Replace entire media & all vegetation	Late Spring/early Summer	As needed*

** Paying careful attention to pretreatment and operation & maintenance can extend the life of the soil media* and seasonal landscaping maintenance thereafter.

In many cases, a landscaping contractor working elsewhere on the site can complete maintenance tasks. Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.

Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly. Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year (spring and fall).

Proper selection of plant species and support during establishment of vegetation should minimize—if not eliminate—the need for fertilizers and pesticides. Remove invasive species as needed to prevent these species from spreading into the bioretention area. Replace mulch every two years, in the early spring. Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch. A summary of maintenance activities can be found on the previous page.

Because the soil medium filters contaminants from runoff, the cation exchange capacity of the soil media will eventually be exhausted. When the cation exchange capacity of the soil media decreases, change the soil media to prevent contaminants from migrating to the groundwater, or from being discharged via an underdrain outlet. Using small shrubs and plants instead of larger trees will make it easier to replace the media with clean material when needed.

Plant maintenance is critical. Concentrated salts in roadway runoff may kill plants, necessitating removal of dead vegetation each spring and replanting. The operation and maintenance plan must include measures to make sure the plants are maintained. This is particularly true in residential subdivisions, where the operation and maintenance plan may assign each homeowner the legal responsibility to maintain a bioretention cell or rain garden on his or her property. Including the requirement in the property deed for new subdivisions may alert residential property owners to their legal responsibilities regarding the bioretention cells constructed on their lot.

Cold Climate Considerations

Never store snow in bioretention areas. The Operation and Maintenance plan must specify where on-site snow will be stored. All snow dumps must comply with MassDEP's guidance. When bioretention areas are located along roads, care must be taken during plowing operations to prevent snow from being plowed into the bioretention areas. If snow is plowed into the cells, runoff may bypass the cell and drain into downgradient wetlands without first receiving the required water quality treatment, and without recharging the groundwater.

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Wet Basins (formerly wet retention ponds)

Description: Wet basins use a permanent pool of water as the primary mechanism to treat stormwater. The pool allows sediments to settle (including fine sediments) and removes soluble pollutants. Wet basins must have additional dry storage capacity to control peak discharge rates. Wet basins have a moderate to high capacity to remove most urban pollutants, depending on how large the volume of the permanent pool is in relation to the runoff from the surrounding watershed.

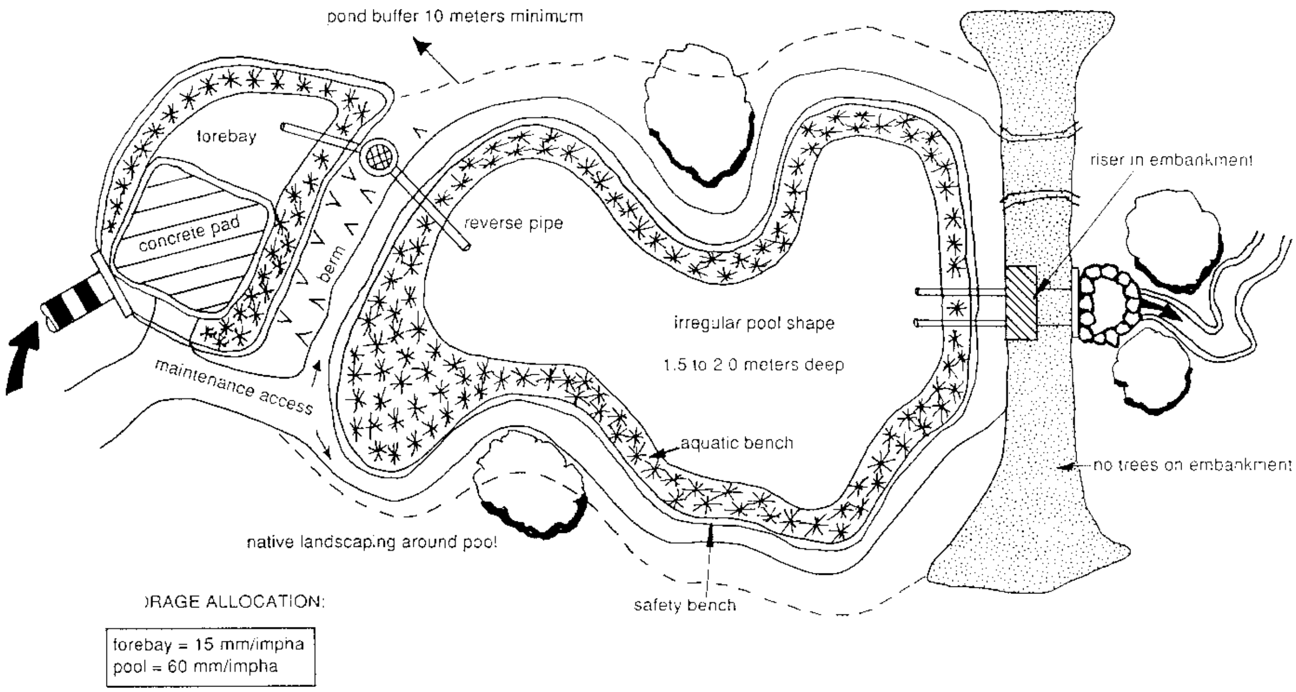
Ability to meet specific standards

Standard	Description
2 - Peak Flow	Can be designed to provide peak flow attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS Removal	80% TSS removal credit when combined with sediment forebay as pretreatment.
5 - Higher Pollutant Loading	May be used as treatment BMP provided basin bottom is lined and sealed. For some land uses with higher potential pollutant load, may require pretreatment by oil grit separator, sand filter or equivalent prior to discharge to wet basin
6 - Discharges near or to Critical Areas	Do not use for discharges to cold-water fisheries
7 - Redevelopment	Not usually suitable.

Advantages/Benefits:
- Capable of removing both solid and soluble pollutants
- Capable of removing nutrients and metals
- Aesthetically pleasing BMP.
- Can increase adjacent property values when properly planned and sited.
- Sediment generally needs to be removed less frequently than for other BMPs.
- Can be used in retrofits

Disadvantages/Limitations:
- More costly than extended dry detention basins.
- Larger storage volumes for the permanent pool and flood control require more land area.
- Infiltration and groundwater recharge is minimal, so runoff volume control is negligible.
- Moderate to high maintenance requirements.
- Can be used to treat runoff from land uses with higher potential pollutant loads if bottom is lined and sealed.
- Invasive species control required

Pollutant Removal Efficiencies
- Total Suspended Solids (TSS) — 80% with sediment forebay
- Total Nitrogen — 10% to 50%
- Total Phosphorus — 30% to 70%
- Metals (copper, lead, zinc, cadmium) — 30% to 75%
- Pathogens (coliform, e coli) — 40% to 90%



adapted from Schueler, 1992

Maintenance

Activity	Frequency
Inspect wet basins to ensure they are operating as designed	At least once a year.
Mow the upper-stage, side slopes, embankment and emergency spillway.	At least twice a year.
Check the sediment forebay for accumulated sediment, trash, and debris and remove it.	At least twice a year.
Remove sediment from the basin.	As necessary, and at least once every 10 years

Special Features

MassDEP requires a sediment forebay as pretreatment to a wet basin.

LID Alternative

1. Design measures to reduce impervious areas, shrinking the size of the wet basin
2. Use if LID site design credits for the water quality volume requirement (Stormwater Standard 4)
3. Decentralized Stormwater Management System that uses vegetative filter strips to direct stormwater runoff to BMPs located throughout the site

Wet Basins

A wet basin may be created by constructing an embankment or excavating a pit. The primary component of a wet basin is the deep, permanent pool, but other components, such as a shallow marsh, may be added to the design *(see basin/ wetland design in constructed wetlands section).* MassDEP requires a sediment forebay as pretreatment to a wet basin. The sediment forebay plus the wet basin collectively are credited with an 80% TSS removal rate.

The basic operation of a wet basin allows incoming stormwater to displace the water present in the pool. This stormwater remains until displaced by runoff from another storm event. Increased retention time allows particulates, including fine sediments, to settle out of the water column. The permanent pool also serves to protect deposited sediments from resuspending during large storm events. Another advantage of wet basins is the biological activity of algae and fringe wetland vegetation, which reduces the concentration of soluble pollutants. Wet basins may be designed with a multi-stage outlet structure to control peak rate discharges from different design storms. When properly designed and maintained, wet basins can add recreation, open space, fire protection, wildlife habitat, and aesthetic values to a property.

Applicability

Generally, dry weather base flow and/or large contributing drainage areas are required to maintain pool elevations. The minimum contributing drainage area must be at least 20 acres, but not more than one square mile. Sites with less than 20 acres of contributing drainage area may be suitable only if sufficient groundwater flow is available. Use wet basins at residential, commercial and industrial sites. Because wet basins remove soluble pollutants, they are ideal for sites where nutrient loadings are expected to be high. In such instances, source controls must also be implemented to further reduce nutrient loadings.

Investigate soils, depth to bedrock, and depth to water table before designing a wet basin. At sites where bedrock is close to the surface, high excavation costs may make wet ponds infeasible. If the soils on site are relatively permeable or well drained, such as a soil type in Hydrologic Group A (as defined by the Natural Resource Conservation Service), it will be difficult to maintain a permanent pool. In this situation, it may be necessary to line the bottom of the wet pond to reduce infiltration. Designing wet basins for multiple storms will provide peak rate control. In such instances, design the upper stages of wet basins to provide temporary storage of larger storms (i.e., 10, 25, and 100-year 24-hr. storms). Wet basins are generally ineffective in controlling the post-development increase in runoff volume, although some infiltration does occur, as well as evaporation in summer months.

Planning Considerations

Evaluate soils and depth to bedrock before designing a wet basin. At sites where bedrock is close to the surface, high excavation costs may make wet basins infeasible. If the soils are permeable (A and B soils), heavy drawdown of the basin may occur during dry periods. In these situations, compact the basin soils or install a liner at the bottom of the basin to minimize the potential for drawdown. Specifications for basin materials include (in order of decreasing costs):

- 6-inch clay
- Polyvinyl liner
- Bentonite
- 6 inches of silt loam or finer material

To be effective in reducing peak runoff rates, locate the basin where it can intercept most of the runoff from the site, typically a low elevation that is near freshwater wetlands. Like all stormwater best management practices, wet basins must not be constructed in wetland resource areas other than isolated land subject to flooding, bordering land subject to flooding, land subject to coastal storm flowage, and riverfront area. Select a location that can accommodate the need to attenuate peak discharge rates without adversely impacting nearby wetland resources.

It is preferable to create the wet basin by excavating a pit below the grade of land. When this is not feasible, an earthern embankment can be created. Embankments or dams created to store more than 15 acre-feet, or that are more than 6 feet high, are under the jurisdiction of the Massachusetts Department of Conservation and Recreation (DCR) Office of Dam Safety and must be constructed, inspected, and maintained according to DCR guidelines.

Design

See the following for complete design references:
Wet Extended Detention Pond Design: Step by Step Design. 1995. Claytor.

Volume and geometry are the critical parameters in a wet basin design; the relationship of the volume in the permanent pool to the contributing runoff volume directly affects pollutant removal rates. Generally, bigger is better; however, after a certain threshold level, increasing the pool size results in only marginal increases in pollutant removal. The permanent pool must be sized at a minimum to hold twice the water quality volume (this is equivalent to a VB/VR of 2) when a wet basin is designed to provide peak rate attenuation in addition to water quality treatment. The peak rate volume is an additional volume above the permanent pool. The permanent pool volume must not be counted as part of the volume devoted to storage associated with peak rate attenuation. When designing a wet basin to also accommodate peak rate attenuation, a multiple stage outlet must be included as part of the design.

Make the minimum contributing drainage area at least 20 acres, but no more than one square mile. Sites with less than ten acres of contributing drainage area may be suitable if sufficient groundwater flow is available to maintain the permanent wet pool.

Pool depth is an important design factor, especially for sediment deposition. Use an average pool depth of 3 to 6 feet. Settling column studies and modeling analyses show that shallow basins remove more solids than deeper ones. However, resuspension of settled materials by wind action might be a problem in shallow basins that are less than two feet deep. Depths greater than eight feet may cause thermal stratification. Stratified pools tend to become anoxic (low or no oxygen) more often than shallower ponds. If possible, vary depths throughout the basin.

Providing deeper pools can provide fish habitat. It may be advantageous to introduce fish to the wet basins to reduce mosquito breeding. When designing wet basins to support fish, a fisheries biologist should be consulted. Fish habitat features may include trees to provide shading over the deeper depths. Selection of trees should be done carefully to avoid embankment or sidewall failure.

Use intermittent benches around the perimeter of the basin for safety and to promote vegetation. Design the safety bench to be at least ten feet wide and above normal pool elevations. Make the aquatic bench at least ten feet wide and maintain depths of 12 to 18 inches at normal elevations to support aquatic vegetation. Shallow depths near the inlet will concentrate sediment deposition in a smaller, more accessible area. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects.

Use a minimum pool surface area of 0.25 acres. Enhance the performance of the wet basin by enlarging the surface area to increase volume, instead of deepening the pool, although this increases water temperatures and evaporation rates. The original design of wet basin depths and volumes should take into account the gradual accumulation of sediment. Accumulating sediment in the pool will decrease storage volume and reduce pollutant removal efficiency.

Wet Basin Design Criteria

Factor	Criteria
Maximum Drainage area	$\geq$20 acres unless sufficient groundwater flow
Permanent Pool Volume	$\geq$2 x WQv (equivalent to Vb/Vr ratio of 2)
Minimum Pool Surface Area	$\geq$0.25 acres
Minimum Length to Width Ratio	$\geq$3:1
Mean Permanent Pool Depth	3 to 6 feet
Maximum Permanent Pool Depth	8 feet
Maximum Pool Slopes	$\leq$3H:1V
Maximum Safety & Aquatic Bench Slopes	$\leq$2H:1V
Perimeter Accessway Width	$\geq$15 feet
Perimeter Vegetative Buffer	$\geq$25 feet
Sediment Forebay	Required (not included in wet basin sizing)
Pool Drain (for maintenance purposes)	Required maximum pool drain time: 40 hours

MassDEP requires a sediment forebay to pretreat stormwater before it enters the wet basin. Forebays trap sediment before the runoff enters the primary pool, effectively enhancing removal rates and minimizing long-term operation and maintenance problems. Removing sediment from the forebay is easier and less costly than from the wet basin pool, so design sediment forebays for ease of maintenance. Hard bottom forebays make sediment removal easier. Make forebays accessible by heavy machinery to faciltate maintenance.

To avoid reducing the pollutant removal capability and to maximize travel distance, locate the inflow points as far from the outlet structure as possible. To maximize stormwater contact and retention time in the pool, use a length to width ratio of at least 3:1.

Set the invert elevation of the inlet pipe at or below the surface of the permanent pool, preferably within one foot of the pool. Pipes discharging above the pool can erode the banks and side slopes. Design all inflow points with riprap or other energy dissipators to reduce inflow velocities.

Establish wetland vegetation on the aquatic bench to enhance the removal of soluble nutrients, facilitate sediment trapping, prevent sediment resuspension, provide wildlife and waterfowl habitat, and conceal trash and debris that may accumulate near the outlet. Six to eighteen inches of water depth are needed for wetland vegetation growth.

Make the slopes of the pools no steeper than 3:1. Flatter slopes help to prevent bank erosion during larger storms and facilitate routine bank maintenance tasks, such as mowing. Flat slopes also provide for public safety, and allow easier access. In addition, design the sides of the pool that extend below the safety and aquatic benches to the bottom of the pool at a slope that will remain stable, usually no steeper than 2:1 (horizontal to vertical).

Design the invert of the wet basin outlet pipe to convey stormwater from approximately one foot below the pool surface and to discharge into the riser in the pond embankment. To prevent clogging, install trash racks or hoods on the riser.

To facilitate access for maintenance, install the riser within the embankment. Place anti-seep collars or filter and drainage diaphragms on the outlet barrel to prevent seepage and pipe failure. Make the vital parts of the structure accessible to maintenance personnel during normal and emergency conditions. Install a bottom drainpipe to allow complete draining of the wet basin in case of emergencies or for routine maintenance.

Fit both the outlet pipe and the bottom drain pipe with adjustable valves at the outer end of the outlet to permit adjustment of the detention time, if necessary.

To prevent scour at the outlet, install a flow transition structure, such as a lined apron or plunge pad, to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area.

Design embankments and spillways to conform with DCR Dam Safety regulations, if applicable. All wet basins must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure.

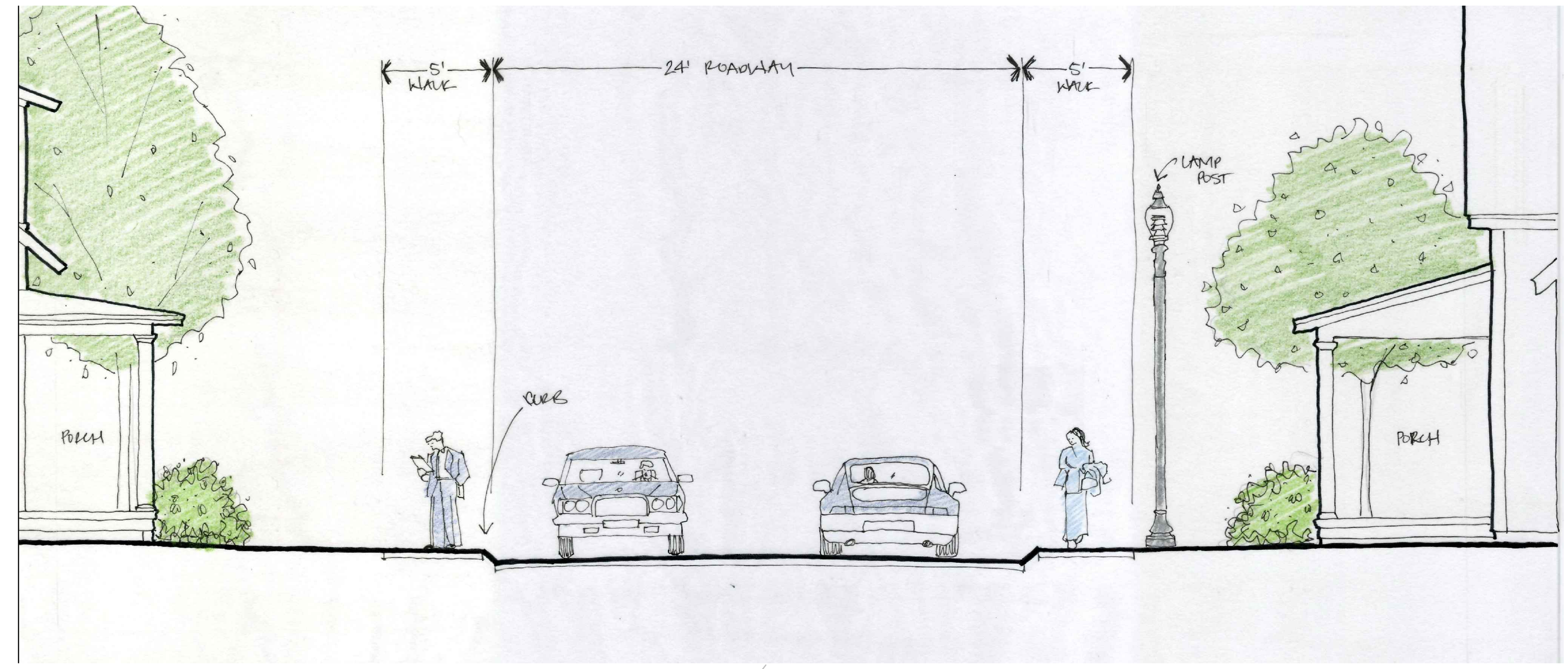
Provide an access way for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, by public or private right-of-way. Equipment that will be used for maintenance must be capable of using this access-way. This access should extend to the forebay, safety bench, and outflow structure and should never cross the emergency spillway, unless the spillway has been designed for that purpose. Place vegetative buffers around the perimeter of the wet basin to control erosion and remove additional sediment and nutrients. The vegetative buffer must be at least 33 feet (10 meters). Vegetation must be designed to prevent the introduction of invasive species.

Maintenance

Inspect wet basins at least once per year to ensure they are operating as designed. Inspect the outlet structure for evidence of clogging or excessive outflow releases. Potential problems to check include: subsidence, erosion, cracking or tree growth on the embankment, damage to the emergency spillway, sediment accumulation around the outlet, inadequacy of the inlet/outlet channel erosion control measures, changes in the condition of the pilot channel, erosion within the basin and banks, and the emergence of invasive species. Make any necessary repairs immediately. During inspections, note any changes to the wet basin or the contributing watershed area because these may affect basin performance. At least twice a year, mow the upper-stage, side slopes, embankment and emergency spillway. At this time, also check the sediment forebay for accumulated material, sediment, trash, and debris and remove it. Remove sediment from the basin as necessary, and at least once every 10 years. Providing an on on-site sediment disposal area will reduce the overall sediment removal costs.

References

Galli, J. 1990, Thermal Impacts Associated with Urbanization and Stormwater Best Management Practices. Prepared for the Maryland Department of Environment, Baltimore, MD, by the Metropolitan Council of Governments, Washington, D.C.



ROADWAY SECTION

SCALE: 1"=5'

WATER QUALITY TREATMENT AREA SIZING CALCULATIONS

WATER QUALITY VOLUME REQUIRED

DRAINAGE AREA	ROADWAY (S.F.)	DRIVEWAYS (S.F.)	TOTAL PAVEMENT (S.F.)	1" WATER QUALITY VOLUME (C.F)
BOYD DRIVE	71,100	32,200	103,300	8,608
BIO RETENTION AREA 1	33,335	7,150	40,405	3,375
BIO RETENTION AREA 2	22,010	7,150	29,160	2,430
BIO RETENTION AREA 3	37,366	11,700	49,066	4,089

WATER QUALITY VOLUME PROVIDED

BOYD DRIVE CONSTRUCTED STORMWATER WETALND – 13,000 SF AVERGE DEPTHS OF 12" = 13,000 C.F.
BIO RETENTION AREA 1 – 6,000 S.F AVERAGE DEPTH 0.6' = 3,600 C.F.
BIO RETENTION AREA 2 – 5,000 S.F. AVREGAE DEPTH 0.6' = 3,000 C.F.
BIO RETENTION AREA 3 – 8,000 S.F. AVERAGE DEPTH 0.6' = 4,800 C.F.

MIN. LOT AREA= 10,000 S.F.
MIN. SETBACK FRONT= 15 FT
SIDE= 10 FT
REAR= 15 FT

TOTAL LOT AREA= 1,604,739 S.F - 36.84 Ac.
AVG. SLOPE = 9%

TOTAL DEVELOPMENT AREA= 641,417 S.F. - 14.72 Ac.

TOTAL OPEN SPACE AREA= 963,322 S.F.- 22.12 Ac. (60.0%)

TOTAL LOT AREA OUT OF ILSF= 1,382,308 S.F. - 31.73 Ac.

TOTAL UPLAND OPEN SPACE= 749,949 S.F. - 17.22 Ac. (54.3%)
(AREA OUT OF ILSF)

OSRD ROADWAY LAYOUT WAIVERS FROM THE RULES AND REGULATIONS GOVERNING THE SUBDIVISION OF LAND

1. WIDTH OF ROADWAY RIGHT-OF-WAY (40' PROPOSED)
2. SIDEWALK PLANTING STRIP
3. MINIMUM CENTERLINE CURVE RADIUS (125' PROPOSED)
4. STREET TREES PLANTED 50' ON CENTER

LEGEND

- ISOLATED LAND SUBJECT TO FLOODING (ILSF)
- ISOLATED WETLAND AREA TO BE IMPROVED
- PROPOSED STORMWATER MANAGEMENT SYSTEMS TO BE UPGRADED
- TEST PIT LOCATION
- STORMWATER FLOW PATH

N
NORTH

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PROJECT TEAM

18 BOYD DRIVE, NEWBURYPORT, MA
FOR
EVERGREEN COMMONS, LLC

PROJECT INFO

REV	DESCRIPTION	DATE
4	PRELIM. DRAINAGE	12/7/2016
3	FULL THROUGH ROAD	10/18/2016
2	P.B. REVIEW	9/14/2016
1	LANDSCAPE ISLAND, TRAIL	8/17/2016

STAMP:

OSRD SKETCH PLAN

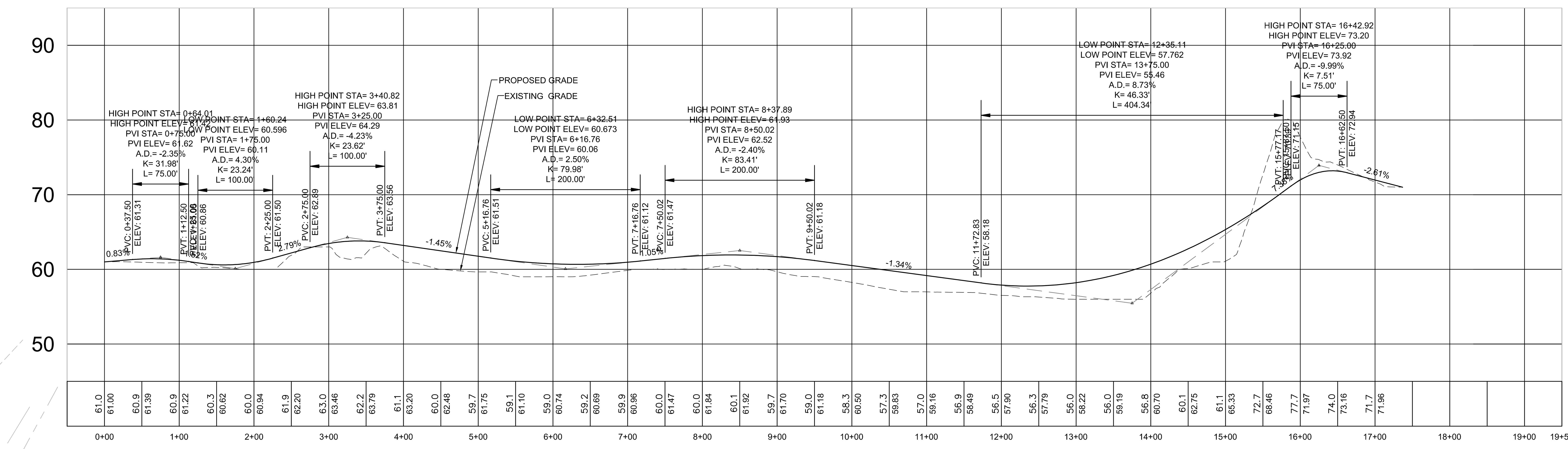
SHEET NAME:

2

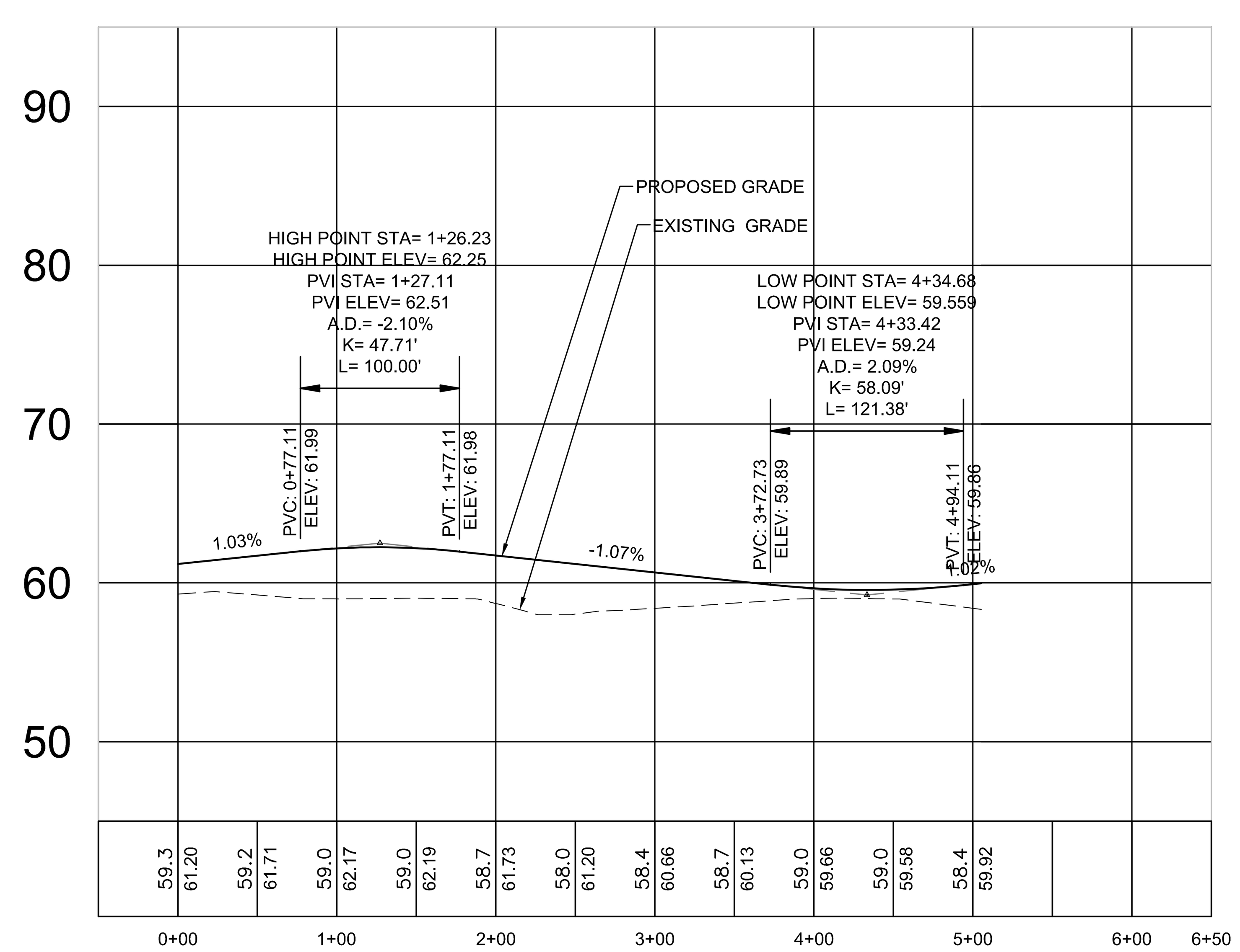
SHEET NO:

DR BY: SSW
CHK BY: SBS
PROJ NO: 2015-063
DATE: JULY 20, 2016
SCALE: 1"=80'

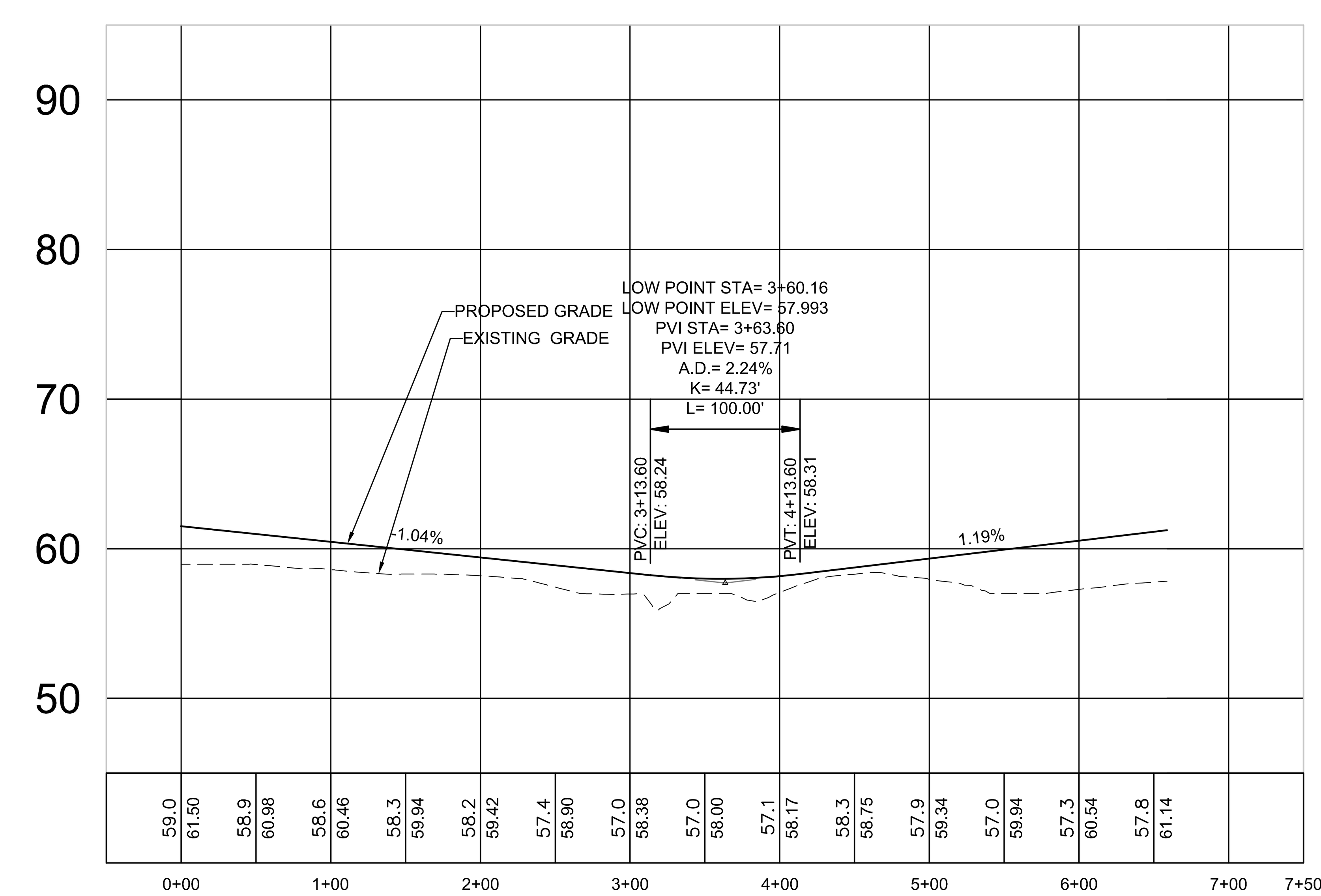
Profile of Road A



Profile of Road B



Profile of Road C



ROADWAY PROFILES

SCALE: HORZ:1"=80'
VERT: 1"=8'

N

NORTH

Design Consultants, Inc.
CIVIL ENGINEERS and LAND SURVEYORS
120 Middlesex Avenue, Suite 20
Somerville, MA 02145
617-776-3350p 617-776-7710f

PROJECT TEAM

18 BOYD DRIVE,
NEWBURYPORT, MA
FOR
EVERGREEN
COMMONS, LLC

PROJECT INFO

REV	DESCRIPTION	DATE

STAMP:

OSRD SKETCH
PLAN
PRELIMINARY
PROFILES

SHEET NAME:

3

SHEET NO:

DR BY: SSW
CHK BY: SBS
PROJ NO: 2015-063
DATE: DEC. 7, 2016
SCALE: AS-NOTED