Water Quality Swale

Description: Vegetated open channels designed to capture and infiltrate stormwater runoff within a dry storage layer beneath the base of the channel.

Advantages/Benefits:
- Stormwater treatment combined with conveyance
- Reduced runoff volume
- Reduced peak discharge rate
- Reduced Total Suspended Solids (TSS)
- Reduced pollutant loading
- Reduced runoff temperature
- Groundwater recharge (if soils are sufficiently permeable)
- Reduces runoff velocity
- Promotes infiltration

Disadvantages/Limitations:
- Cannot be used on steep slopes
- High land requirement
- Problems with installation can lead to failure
- Minimum 2 foot separation from groundwater and bedrock is required
- Geotechnical testing required

Selection Criteria:

40% – 60% Runoff Reduction Credit

Land Use Considerations:

- X **Residential**
- X **Commercial**
- X **Industrial**

Maintenance:
- Maintain grass height (if turf)
- Remove sediment from forebay and channel
- Remove accumulated trash and debris
- Re-establish plants as needed

M **Maintenance Burden**
L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

Water quality swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or dense, landscape planting. The water quality swale is a soil filter system that temporarily stores and then filters the desired Treatment Volume (T_v). Water quality swales rely on a pre-mixed soil media filter below the channel that is identical to that used for bioretention.

The major design goal for water quality swales is to maximize runoff volume reduction and pollutant removal. To this end, designers may choose to go with the baseline design (Level 1) or choose an enhanced design (Level 2) that maximizes pollutant and runoff reduction. If soil conditions require an underdrain, water quality swales can still qualify for the Level 2 design if they contain a stone storage layer beneath the invert of the underdrain. **Table 5.1** outlines the Level 1 and 2 water quality swale design guidelines. Local simulation modeling supports these runoff reduction credits for the mentioned contributing drainage area (CDA) to surface area ratios.

SECTION 2: PERFORMANCE

The overall runoff reduction capabilities of water quality swales in terms of the Runoff Reduction Method are summarized in **Table 5.1**. Water quality swales create a good environment for runoff reduction, filtration, biological uptake, and microbial activity, and provide high pollutant removal. Water quality swales can become an attractive landscaping feature with high amenity value and community acceptance.

Table 5.1. Runoff Volume Reduction Provided by Water Quality Swales		
Stormwater Function	**Level 1 Design**	**Level 2 Design**
Runoff Volume Reduction (RR)	40%	60%
Treatment Volume (Tv) Multiplier*	1.0	1.10

*Incorporated into LID Site Design Tool calculations
Sources: CSN (2008) and CWP (2007)

SECTION 3: TYPICAL DETAILS

See Appendix 5-B and 5-C for required standard notes and applicable details for use in construction plans.

SECTION 4: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

Water quality swales can be applied in most soils or topography, since runoff simply percolates through an engineered soil bed and can be returned to the stormwater system if the infiltration rate of the underlying soils is low. Key considerations with water quality swales include the following:

Infiltration/Soils. Infiltration is a key component of Low Impact Development (LID) design. Infiltration testing shall be required for all water quality swale locations (see **Section 6.1**). Soil conditions do not constrain the use of water quality swales but can affect the design requirements. Hydrologic Soil Groups (HSG) should be determined from NRCS soil data. For more information on soil types go to: http://websoilsurvey.nrcs.usda.gov/app/. Alternative HSG classifications will be considered when supporting reports from a licensed soil scientist or geotechnical engineer are provided.

Available Space. Planners and designers can assess the feasibility of using water quality swales based on a simple relationship between the contributing drainage area and the corresponding required surface area. Water quality swale footprints can fit into relatively narrow corridors between utilities, roads, parking areas, or other site constraints. Water quality swales should be approximately 3% to 10% of the size of the contributing drainage area, depending on the amount of impervious cover.

Accessibility. Water quality swales require periodic maintenance and must be accessible to various types of equipment. A path of travel for equipment no less than twelve feet in width with a maximum slope of 3:1 must be provided for the water quality swale. The path of travel shall be along no less than 50% of the perimeter of the water quality swale and must be accessible by common equipment and vehicles at all times.

Elevation Considerations. Water quality swales are best applied when the grade of contributing slopes is less than 2%. Terracing or other inlet controls may be used to slow runoff velocities entering the facility. Water quality swales are fundamentally constrained by the invert elevation of the existing conveyance system to which the practice discharges (i.e., the bottom elevation needed to tie the underdrain from the water quality swale into the storm drain system).

Subsurface Constraints. Vertical constraints such as retaining walls, structures, or other impermeable barriers are limited to a maximum of 50% of the water quality swales perimeter. Water quality swales subgrade shall always be separated from the water table and bedrock. Groundwater intersecting the filter bed can lead to possible groundwater contamination or failure of the water quality swales facility. A separation distance of 2 feet is required between the bottom of the excavated water quality swales area and the seasonally high ground water table and/or bedrock.

Utilities. Designers must ensure that future tree canopy growth in the water quality swales area will not interfere with existing overhead public utility lines. Public underground utilities and associated easements shall not be located within the water quality swales footprint. Local utility design guidance shall be consulted in order to determine clearances required between storm water infrastructure and other dry and wet utility lines. Private utilities should not be located within the water quality swale when possible.

Contributing Drainage Area. The maximum impervious contributing drainage area to a water quality swale should be 2.5 acres. When water quality swales treat larger drainage areas, the velocity of flow through the surface channel often becomes too great to treat runoff or prevent erosion in the channel. Similarly, the longitudinal flow of runoff through the soil, stone, and underdrain may cause hydraulic overloading at the downstream sections of the water quality swale.

Hotspot Land Uses. Runoff from hotspot land uses should not be treated with infiltrating water quality swales without appropriate pretreatment and MWS staff approval. For additional information on stormwater hotspots, please consult **Section 7.3**.

Floodplains. Water quality swales shall be constructed outside the limits of the 100-year floodplain. Flood waters from the 100-year event or smaller shall be prohibited from entering the water quality swale underdrain or overflow system.

Irrigation or Baseflow. The planned water quality swale shall not receive baseflow, chlorinated wash-water or other such non-stormwater flows, except for irrigation as necessary during the first growing season for the survival of plantings within the water quality swale (see **Section 10.2**).

Setbacks. It is not recommended to place water quality swales immediately adjacent to structures. To avoid the risk of seepage, a licensed professional engineer should be consulted to determine the appropriate setbacks necessary to prevent water quality swale infiltration from compromising structural foundations or pavement. At a minimum, water quality swales should be located a horizontal distance of 100 feet from any water supply well and 50 feet from septic systems.

Applications. Water quality swales are generally suited for medium-to-high density residential, commercial and institutional developments. It should be noted that special care must be taken to provide adequate pre-treatment for water quality swales in space-constrained high traffic areas. Typical locations for water quality swales could include parking lot features and unused pervious areas on a site. Water quality swales are not intended for ROW applications (see GIP-02).

SECTION 5: DESIGN CRITERIA

5.1 Soil Infiltration Rate Testing

One must measure the infiltration rate of subsoils at the subgrade elevation of the water quality swale. If the infiltration rate exceeds 0.5 inch per hour, an underdrain should not be utilized. If the infiltration rate of subsoils is greater than 0.1 inch per hour and less than or equal to 0.5 inch per hour, underdrains will be required. If the infiltration rate is 0.1 inch per hour or less water quality swales shall not be used. On-site soil infiltration rate testing procedures are outlined in **Appendix 4-A**. The number of soil tests varies based on the length of the water quality swale:

- ≤50 linear feet = 2 tests
- >50 linear feet = 2 tests + 1 test for every additional 50 linear feet

A separation distance of 2 feet is required between the bottom of the excavated water quality swale and the seasonally high ground water table and/or bedrock.

For sites with large amounts of cut or fill it may not be practical to perform infiltration testing prior to grading the site. In these cases, a mass grading permit will be required.

5.2 Sizing of Water Quality Swales

5.2.1 Stormwater Quality

Sizing of the surface area (SA) for water quality swales is based on the computed Treatment Volume (T_v) of the contributing drainage area and the storage provided in the facility. The required surface area (in square feet) is computed as the Treatment Volume (in cubic feet) divided by the equivalent storage depth (in feet). The equivalent storage depth is computed as the depth of media, gravel, and surface ponding (in feet) multiplied by the accepted porosity (see **Table 5.2**). All layer depths shall be uniform with regard to surface area. See **Section 6.6** for material specifications.

Table 5.2 Water Quality Swale Typical Section for Water Quality Calculation

Infiltration (i)	i > 0.5"/hr (no underdrain permitted)		0.1"/hr< i ≤0.5"hr (underdrain required)		
Layer	**Level 1 (inches)**	**Level 2 (inches)**	**Level 1 (inches)**	**Level 2 (inches)**	**Porosity Value (n)**
Average Ponding	0-6				1.0
Surface Cover*	Varies				N/A
Media	18-36	24-36	18-36	24-36	0.25
Choker	3	3	3	3	0.40
Reservoir	0-9	9	9	9	0.40
Sump*	0	0	0	12	N/A
* Cannot be used in De and surface area calculations.					

The equivalent storage depth for Level 1 is therefore computed as:

Equation 1.1. Water Quality Swale Level 1 Design Storage Depth

$$\text{Equivalent Storage Depth} = D_E = n_1(D_1) + n_2(D_2) + \cdots$$

$$D_E = (1.5 \text{ to } 3 \text{ ft.} \times 0.25) + (1 \text{ ft} \times 0.40) + (0 \text{ to } 0.5 \text{ ft.} \times 1.0) = 0.78 \text{ to } 1.65 \text{ ft.}$$

Where n_1 and D_1 are for the first layer, etc.

And the equivalent storage depth for Level 2 is computed as:

Equation 1.2. Water quality swale Level 2 Design Storage Depth

$$D_E = (2 \text{ to } 3 \text{ ft.} \times 0.25) + (1 \text{ ft.} \times 0.40) + (0 \text{ to } 0.5 \text{ ft.} \times 1.0) = 0.9 \text{ to } 1.65 \text{ ft.}$$

While this method is simplistic, simulation modeling has proven that it yields a total storage volume equivalent to 80% total average rainfall volume removal for infiltration rates from 0.5 in/hr through 1.2 in/hr.

Therefore, the Level 1 Water quality swale Surface Area (SA) is computed as:

Equation 1.3. Water quality swale Level 1 Design Surface Area

$$SA \text{ (sq. ft.)} = (T_v - \text{the volume reduced by an upstream SCM}) / D_E$$

And the Level 2 Water quality swale Surface Area is computed as:

Equation 1.4. Water quality swale Level 2 Design Surface Area

$$SA \text{ (sq. ft.)} = [(1.10 * Tv) - \text{the volume reduced by an upstream SCM}] / D_E$$

Where:

SA = Minimum surface area of water quality swale filter (sq. ft.)
D_E = *Equivalent Storage Depth (ft.)*
T_v = Treatment Volume (cu. ft.) = [(1.0 in.)(R_v)(A)*3630]

5.2.2 Stormwater Quantity

It is recommended that rain events larger than the 1-inch storm bypass water quality swales to prevent additional maintenance burden. However, if designed with sufficient volume and appropriate outlet structures, peak attenuation control may be provided by the water quality swale. Hydrologic calculations utilizing the SCS method may be necessary to demonstrate pre versus post peak flow rates.

Adjusted CN. With infiltration rates greater than 0.5 inch per hour (see Section 6.1), the removal of volume by water quality swales changes the runoff depth entering downstream flood control facilities. An approximate approach to accounting for the removal of volume is to calculate an "effective SCS curve number" (CN_{adj}), which is less than the actual curve number (CN). CN_{adj} can then be used in hydrologic calculations and in routing. This method is detailed in Volume 5 Section 3.2.5. Additional volume can be provided by increasing the depth of media, stone, or approved proprietary storage products.

5.2.3 Water Quality Swale Geometry

Design guidance regarding the geometry and layout of water quality swales is provided below.

Shape. A trapezoidal shape is preferred for water quality swales for aesthetic, maintenance and hydraulic reasons. Swales should have a bottom width of from 4 to 8 feet to ensure that an adequate surface area exists along the bottom of the swale for filtering. If a swale will be wider than 8 feet, the designer should incorporate berms, check dams, level spreaders or multi-level cross-sections to prevent braiding and erosion of the swale bottom.

Side Slopes. The side slopes of water quality swales should be no steeper than 3H:1V for maintenance considerations (i.e., mowing). Flatter slopes are encouraged where adequate space is available, to enhance pre-treatment of sheet flows entering the swale.

Swale Longitudinal Slope. The longitudinal slope of the swale should be moderately flat to permit the temporary ponding of the Treatment Volume within the channel. The recommended swale slope is less than or equal to 2% for a Level 1 design and less than or equal to 1% for a Level 2 design. Slopes up to 4% are acceptable if check dams are used. The minimum recommended slope for an on-line water quality swale is 0.5%. Refer to **Table 5.3** for check dam spacing based on the swale longitudinal slope.

Velocity Consideration. The bottom width and slope of a water quality swale should be designed such that the velocity of flow from a 1-inch rainfall will not exceed 3 feet per second. The swale should also convey the 2- and 10-year storms at non-erosive velocities with at least 6 inches of freeboard. The analysis should evaluate the flow profile through the channel at normal depth, as well as the flow depth over top of the check dams. Check dams may be used to achieve the needed runoff reduction volume, as well as to reduce velocities.

Table 5.3. Typical Check Dam (CD) Spacing to Achieve Effective Swale Slope

Swale Longitudinal Slope	LEVEL 1	LEVEL 2
	Spacing[1] of 12-inch High (max.) Check Dams[2] to Create an Effective Slope of 2%	Spacing[1] of 12-inch High (max.) Check Dams[2] to Create an Effective Slope of 0 to 1%
0.5%	–	200 ft. to –
1.0%	–	100 ft. to –
1.5%	–	67 ft. to 200 ft.
2.0%	–	50 ft. to 100 ft.
2.5%	200 ft.	40 ft. to 67 ft.
3.0%	100 ft.	33 ft. to 50 ft.
3.5%	67 ft.	30 ft. to 40 ft.
4.0%	50 ft.	25 ft. to 33 ft.

[1] The spacing dimension is half of the above distances if a 6-inch check dam is used.
[2] Check dams require a stone energy dissipater at the downstream toe.

Check dams. Check dams must be firmly anchored into the side-slopes to prevent outflanking and be stable during the 10-year storm design event. The height of the check dam relative to the normal channel elevation should not exceed 12 inches. Each check dam should have a minimum of one weep hole or a similar drainage feature so it can dewater after storms. Armoring may be needed behind the check dam to prevent erosion. The check dam must be designed to spread runoff evenly over the water quality swale's filter bed surface, through a centrally located depression with a length equal to the filter bed width. In the center of the check dam, the depressed weir length should be checked for the depth of flow, sized for the appropriate design storm (see **Figure 5.2**). Check dams should be constructed of wood, stone, or concrete.

Ponding Depth. Drop structures or check dams can be used to create ponding cells along the length of the swale. The maximum ponding depth in a swale during the 10-year storm event should not exceed 12 inches at the most downstream point.

5.3 Pre-treatment

Pretreatment facilities must always be used in conjunction with water quality swales to remove floatables and sediment to prevent clogging and failure. Every infiltration practice must include multiple pretreatment techniques, although the nature of pretreatment practices depends on the type of flow received. Pre-treatment measures should be designed to evenly spread runoff across the entire width of the water quality swale. Several pre-treatment measures are feasible, depending on the scale of the water quality swale and whether it receives sheet flow, shallow concentrated flow or deeper concentrated flows. The number, volume and type of acceptable pretreatment techniques needed for the types of receiving flow are found in **Table 5.4**. See Appendix 5-C for applicable details for use in construction plans.

Volumetric pretreatment practices, such as forebays, are sized based on a percentage of the required treatment volume of the GIP. The percentage requirement for the pretreatment practice will vary depending on the design level of the GIP and is exclusive of the required treatment volume for the GIP. Exclusive, in this application, is defined as being separate from the required treatment volume of the GIP. The volume provided by pretreatment practices cannot be included in the calculation for overall treatment volume provided by the GIP.

Table 5.4. Required Pretreatment Elements for Infiltration Practices

Flow Type	Level 1 Facility Options	Level 2 Facility Options
Point/ Concentrated	**Forebay** – 15% pretreatment volume (exclusive) – enhanced check dam (TDOT EC-STR-6A) – flat bottom without stone **Proprietary structure (MWS approval)**	**Forebay** – 25% pretreatment volume (exclusive) – enhanced check dam (TDOT EC-STR-6A) – flat bottom without stone **Proprietary structure (MWS approval)**
Sheet	Gravel diaphragm to grass filter strip (15' *with maximum 3:1 slope*)	
Upstream GIP	Outlet protection may be required at upstream GIP outfall	

5.4 Conveyance and Overflow

For On-line Water Quality Swales: Water quality swales when designed as an on-line practice must have enough capacity to convey runoff from the 100-year design storms at non-erosive velocities, and contain the 10-year flow within the banks of the swale. An overflow structure can be incorporated into on-line designs to safely convey larger storms. Overflow systems within water quality swales should be in compliance with the Stormwater Management Manual, Volume 2, Section 8.

Off-line Water Quality Swales: Off-line designs are preferred. One common approach is to create an alternate flow path at the inflow point into the structure such that when the maximum ponding depth is reached, the incoming flow is diverted past the facility. In this case, the higher flows do not pass over the filter bed and through the facility, and additional flow is able to enter as the ponding water filtrates through the soil media.

Another option is to utilize a low-flow diversion or flow splitter at the inlet to allow only the Treatment Volume to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency.

5.5 Water Quality Swale Material Specifications

Table 5.5 outlines the standard material specifications used to construct water quality swales.

Table 5.5. Water Quality Swale Material Specifications		
Material	**Specification**	**Notes**
Surface Cover	• River stone • Coir or jute matting • Erosion control matting[1] • Turf	Surface cover can be optional depending on the densities of the plantings provided. [1]Where velocities dictate, use woven biodegradable erosion control matting durable enough to last at least two growing seasons.
Filter Media Composition	Filter Media to contain (by volume): • 70% - 85% sand; • 10%-30% silt + clay, with clay ≤ 10%; and • 5% to 10% organic matter	The volume of filter media based on 110% of the plan volume, to account for settling or compaction. Contact staff for testing procedures.
Geotextile	Use a non-woven geotextile fabric with a flow rate of > 110 gal./min./ft² (e.g., Geotex 351 or equivalent)	Apply only to the sides, above the underdrain (2'-4' wide strip) and beneath the check dams. AASHTO M288-06, ASTM D4491 & D4751
Choker Layer	#8 or #89 clean washed stone	Meet TDOT Construction Specifications.
Reservoir Layer	#57 clean washed stone	Meet TDOT Construction Specifications.
Underdrain	6-inch dual wall HDPE or SDR 35 PVC pipe with 3/8-inch perforations at 6 inches on center	AASHTO M 252 Place perforated pipe at base of reservoir layer.
Cleanout	6-inch SDR 35 PVC pipe with vented cap	Provide cleanouts at the upper end of the underdrain.
Observation Well	6-inch SDR 35 PVC pipe with vented cap and anchor plate	Number of wells equals the number of test pits required for infiltration testing (see Appendix 1-A)
Sump Layer	#57 clean washed stone	Meet TDOT Construction Specifications.
Check Dams	• Wood[1] • Gabions • Rock[2] • Concrete	All check dams shall include weep holes. [1]Wood used for check dams shall consist of pressure treated timers or water-resistant tree species. [2]See TDOT Standard Drawing EC-STR-6.

5.6 Landscaping and Planting Plan

Level 1 water quality swales may utilize turf cover or a landscape plan. A landscaping plan similar to bioretention must be provided for each level 2 water quality swale.

Level 1water quality swales using turf cover should be seeded at such a density to achieve a 90 % turf cover after the second growing season. Performance has been shown to fall rapidly as vegetative cover falls below 80%. Water quality swales should be seeded and not sodded. Seeding establishes deeper roots and sod may have muck soil that is not conducive to infiltration (Storey et. al., 2009). Maximum flow velocities for certain types of turf grass are located in Table 5.6.

Table 5.6. Maximum Permissible Velocities for Turf Cover

Cover Type	Velocity (ft./sec.)
Bermuda grass	4.5
Grass-legume mixture	3
Kentucky bluegrass tall fescue	2.3
Red fescue	1.9

Water quality swales using a landscape plan must address 100% of the planting area and achieve a surface area coverage of at least 75% in the first two years. Designers should choose ornamental grasses, herbaceous plants, or trees that can withstand both wet and dry periods and relatively high velocity flows for planting within the channel. Minimum landscape plan elements shall include the proposed planting plan for the surface area of the water quality swale, the list of planting stock, sources of plant species, sizes of plants, and the planting sequence along with post-nursery care and initial maintenance requirements. Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. **Appendix 5-D** lists native plant species suitable for use in water quality swales.

Landscaping plans must be prepared by a qualified Landscape Architect. The Landscape Architect shall certify the planting plan with certification statement, located on the water quality swale planting plan. Standard certification statement can be found in **Appendix 5-B**.

SECTION 6: SPECIAL CASE DESIGN ADAPTATIONS

6.1 Shallow Bedrock and Groundwater Connectivity

Many parts of Nashville have shallow bedrock, which can constrain the application of deeper water quality swales (particularly Level 2 designs). In such settings, other GIPs may be more applicable. For more information on bedrock depths download the GIS data set from: http://water.usgs.gov/GIS/metadata/usgswrd/XML/regolith.xml.

6.2 Steep Terrain

In areas of steep terrain, water quality swales can be implemented as long as a multiple cell design is used to dissipate erosive energy prior to filtering. This can be accomplished by terracing a series of water quality swale cells to manage runoff across or down a slope. The drop in elevation between cells should be limited to 1 foot and armored with river stone or a suitable equivalent. A greater emphasis on properly engineered energy dissipaters and/or drop structures is warranted.

6.3 Karst Terrain

Karst regions are found in much of Middle Tennessee, which complicates both land development and stormwater design. Infiltrative practices shall not be used in any area with a high risk of sinkhole formation.

6.4 Hotspots

Stormwater hotspots are operations or activities that are known to produce higher concentrations of stormwater pollutants and/or have a greater risk for spills, leaks or illicit discharges. Water quality swale designs shall not be used in any area with a hotspot designation without appropriate pretreatment, impermeable barriers, and MWS staff approval. Staff may also require additional treatment for runoff from hotspots.

SECTION 7: CONSTRUCTION

7.1 Construction Erosion Prevention and Sediment Control

Construction Stage EPSC Controls. Water quality swales should be fully protected by silt fence or construction fencing, particularly if they will provide an infiltration function (i.e., have no underdrains). Ideally, water quality swale areas should remain *outside* the limits of disturbance during construction to prevent soil compaction by heavy equipment. Sediment traps or basins may be located within the water quality swale excavation limits during construction. However, these must be accompanied by notes and graphic details on the erosion prevention and sediment control (EPSC) plan specifying that the maximum excavation depth at the construction stage must be at least 1 foot above the post-construction subgrade elevation. The plan must also show the proper procedures for converting the temporary sediment control practice to a water quality swale, including dewatering, cleanout and stabilization.

Excavation. The proposed site should be checked for existing utilities prior to any excavation. It is very important to minimize compaction of both the base of the water quality swale and the required backfill. When possible, excavators should work from the sides of the water quality swale to remove original soil. If the water quality swale is excavated using a loader, the contractor must use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires will cause excessive compaction resulting in reduced infiltration rates and is not acceptable. Compaction will significantly contribute to design failure.

7.2 Construction Sequence

The following is a typical construction sequence to properly install a water quality swale, although the steps may be modified to adapt to different site conditions.

Step 1. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed water quality swale. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 2. Installation should begin after the entire contributing drainage area has been stabilized by vegetation. The designer should check the boundaries of the contributing drainage area to ensure it conforms to original design. Additional EPSC may be needed during swale construction, particularly to divert stormwater from the water quality swale until the filter bed and side slopes are fully stabilized. Pre-treatment cells should be excavated first to trap sediments before they reach the planned filter beds.

Step 3. Excavators or backhoes should work from the sides to excavate the water quality swale area to the appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the water quality swale area.

Step 4. The bottom of the water quality swale should be ripped, roto-tilled or otherwise scarified to promote greater infiltration.

Step 5. Place an acceptable filter fabric on the underground (excavated) sides of the water quality swale with a minimum 6-inch overlap. Place the stone needed for storage layer over the filter bed. Perforate the underdrain pipe and check its slope. Add the remaining stone jacket, and then pack #57 stone to 3 inches above the top of the underdrain, and then add 3 inches of choker stone as a filter layer.

Step 6. Add the soil media in 12-inch lifts until the desired top elevation of the water quality swale is achieved. Wait a few days to check for settlement, and add additional media as needed.

Step 7. Install check dams, driveway culverts and internal pre-treatment features, as specified in the plan.

Step 8. Install erosion control fabric where needed, spread seed or lay sod, and install any temporary irrigation.

Step 9. Plant landscaping materials as shown in the landscaping plan, and water them weekly during the first 2 months. The construction contract should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.

Step 10. Conduct a final construction inspection and develop a punch list for facility acceptance. Then log the GPS coordinates for each water quality swale and submit them to MWS.

SECTION 8: AS-BUILT REQUIREMENTS

After the water quality swale has been constructed, the owner/developer must have an as-built certification of the water quality swale conducted by a registered Professional Engineer. The as-built certification verifies that the GIP was installed per the approved plan. The following items shall be provided in addition to the as-built requirements found in SWMM Volume 1.

1. Landscape Architect letter certifying that the SCM plantings have been installed in general conformance with the approved grading plans and, with proper maintenance, should achieve 75% coverage within the first two years.
2. The Engineer shall include a copy of the GIP summary table found in Appendix 1-E.
3. Supporting documents such as invoices and media test results shall be included in the submittal package.

SECTION 9: MAINTENANCE

9.1 Maintenance Document

The requirements for the Maintenance Document are in Appendix C of Volume 1 of the Manual. They include the execution and recording of an Inspection and Maintenance Agreement or a Declaration of Restrictions and Covenants, and the development of a Long-Term Maintenance Plan (LTMP) by the design engineer. The LTMP contains a description of the stormwater system components and information on the required inspection and maintenance activities.

9.2. Maintenance Inspections

Annual inspections are used to trigger maintenance operations such as sediment removal, spot revegetation and inlet stabilization. The following is a list of several key maintenance inspection points:

- Add reinforcement planting to maintain 95% turf cover or vegetation density. Reseed or replant any dead vegetation.
- Remove any accumulated sand or sediment deposits on the filter bed surface or in pretreatment cells.
- Inspect upstream and downstream of check dams for evidence of undercutting or erosion, and remove trash or blockages at weepholes.
- Examine filter beds for evidence of braiding, erosion, excessive ponding or dead grass.
- Check inflow points for clogging, and remove any sediment.
- Inspect side slopes and grass filter strips for evidence of any rill or gully erosion, and repair as needed.
- Look for any bare soil or sediment sources in the contributing drainage area, and stabilize immediately.

Ideally, inspections should be conducted in the spring of each year.

9.3 Routine Maintenance and Operation

Once established, water quality swales have minimal maintenance needs outside of the spring clean-up, regular mowing, and pruning and management of trees and shrubs. The surface of the filter bed can become clogged with fine sediment over time, but this can be alleviated through core aeration or deep tilling of the filter bed. Additional effort may be needed to repair check dams, stabilize inlet points and remove deposited sediment from pre-treatment cells.

SECTION 10: REFERENCES

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APPENDIX 5-A

INFILTRATION SOIL TESTING PROCEDURES

I. Test Pit/Boring Procedures

1. The number of required test pits or standard soil borings is based on proposed infiltration area:
   - **≤50 linear feet = 2 tests**
   - **>50 linear feet = 2 tests + 1 test for every additional 50 linear feet**
2. The location of each test pit or standard soil boring should correspond to the location of the proposed infiltration area and be performed in in situ soils.
3. Excavate each test pit or penetrate each standard soil boring to a depth at least 2 feet below the bottom of the proposed infiltration area.
4. If the groundwater table is located within 2 feet of the bottom of the proposed facility, determine the depth to the groundwater table immediately upon excavation and again 24 hours after excavation is completed.
5. Determine the USDA or Unified Soil Classification system textures at the bottom of the proposed infiltration area and at a depth that is 2 feet below the bottom. All soil horizons should be classified and described.
6. If bedrock is located within 2 feet of the bottom of the proposed infiltration area, determine the depth to the bedrock layer.
7. Test pit/soil boring stakes should be left in the field to identify where soil investigations were performed.

II. Infiltration Testing Procedures

1. The number of required infiltration tests is based on proposed infiltration area:
   - **≤50 linear feet = 2 tests**
   - **>50 linear feet = 2 tests + 1 test for every additional 50 linear feet**
2. The location of each infiltration test should correspond to the location of the proposed infiltration area.
3. Install a test casing (e.g., a rigid, 4 to 6-inch diameter pipe) to the bottom of the proposed infiltration area. Record the testing elevation.
4. Remove all loose material from the sides of the test casing and any smeared soil material from the bottom of the test casing to provide a natural soil interface into which water may percolate. If desired, a 2-inch layer of coarse sand or fine gravel may be placed at the bottom of the test casing to prevent clogging and scouring of the underlying soils. Fill the test casing with clean water to a depth of 2 feet, and allow the underlying soils to presoak for 24 hours.
5. After 24 hours, refill the test casing with another 2 feet of clean water and measure the drop in water level within the test casing after one hour. Repeat the procedure three (3) additional times by filling the test casing with clean water and measuring the drop in water level after one hour. A total of four (4) observations must be completed.
6. The infiltration rate of the underlying soils may be reported either as the average of all four observations or the value of the last observation. The infiltration rate shall be reported in terms of inches per hour along with the elevations and locations of the test pits. Locations shall be shown on site map.
7. Infiltration testing may be performed within an open test pit or a standard soil boring. After infiltration testing is completed, the test casing should be removed, and the test pit or soil boring should be backfilled and restored.

APPENDIX 5-B

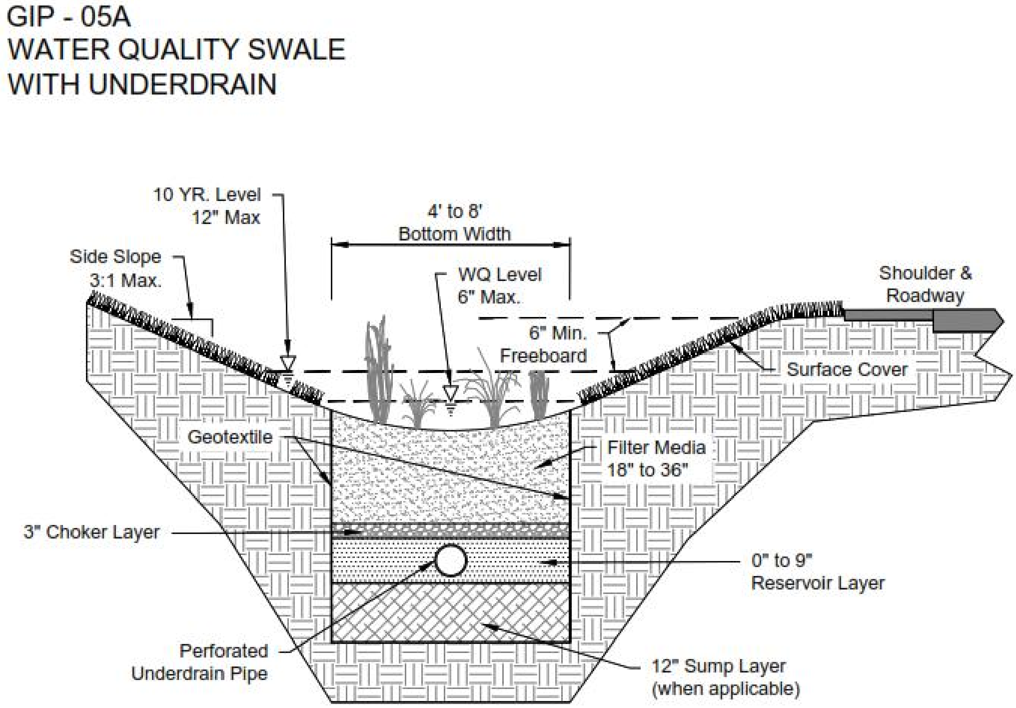
STANDARD NOTES

Required Water Quality Swale Notes:

- Contractor, Engineer, or Owners Representative shall notify MWS NPDES Staff at least 48 hours prior to the installation of the planting soil filter bed. At the completion of installation, the above referenced person will collect one sample per water quality swale for analysis and confirmation of the filter media as defined by GIP-05. Media testing not required when using a certified media product.
- I hereby certify that this water quality swale landscape plan is in keeping with the requirements listed in GIP-05 Section 5.7. Only native species and/or non-invasive species of plants were used in the design of this water quality swale landscape plan. This plan will achieve at least 75% surface area coverage within the first two years.
- Vehicular and equipment traffic shall be prohibited in the water quality swale area to prevent compaction and sediment deposition.

APPENDIX 5-C

STANDARD DETAILS



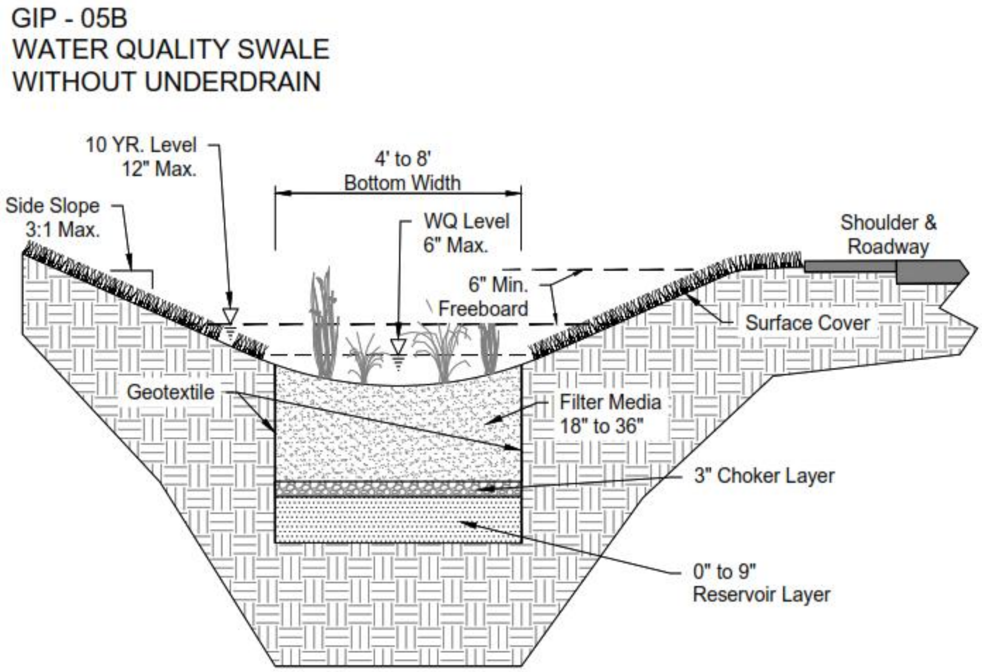


Figure 5.1. Typical Details for Level 1 and 2 Water Quality Swales

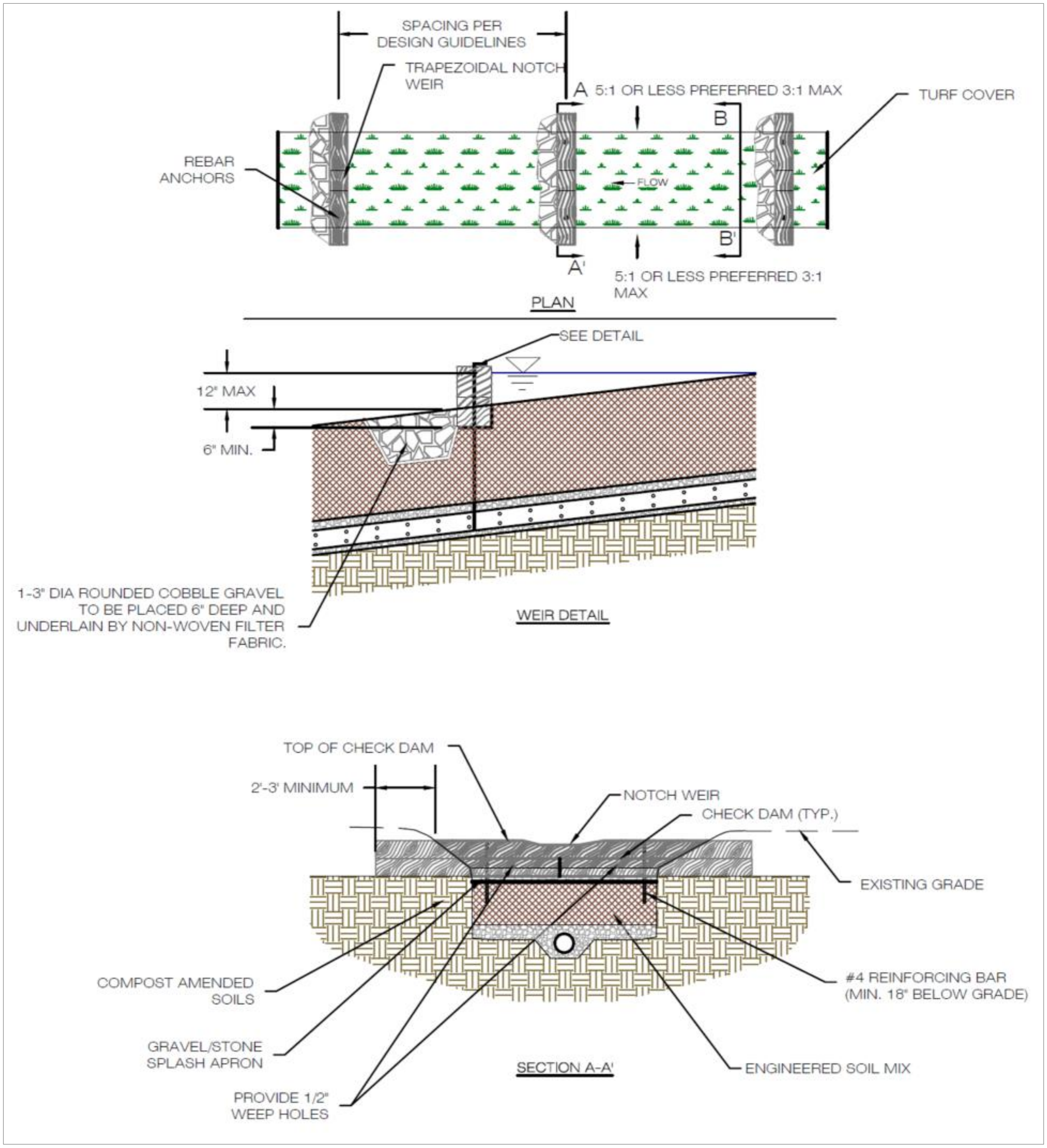


Figure 5.2. Typical Detail for Water Quality Swale Check Dam (source: VADCR, 2011; MWS edited 2020)

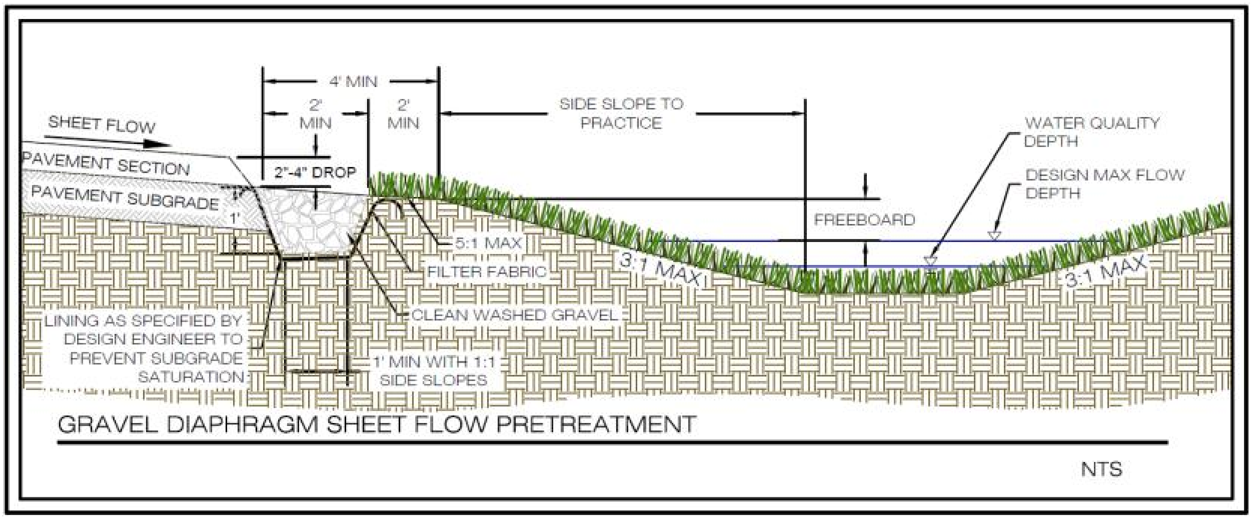


Figure 5.3: Pre-Treatment – Gravel Flow Spreader for Concentrated Flow (source: VADCR, 2011)

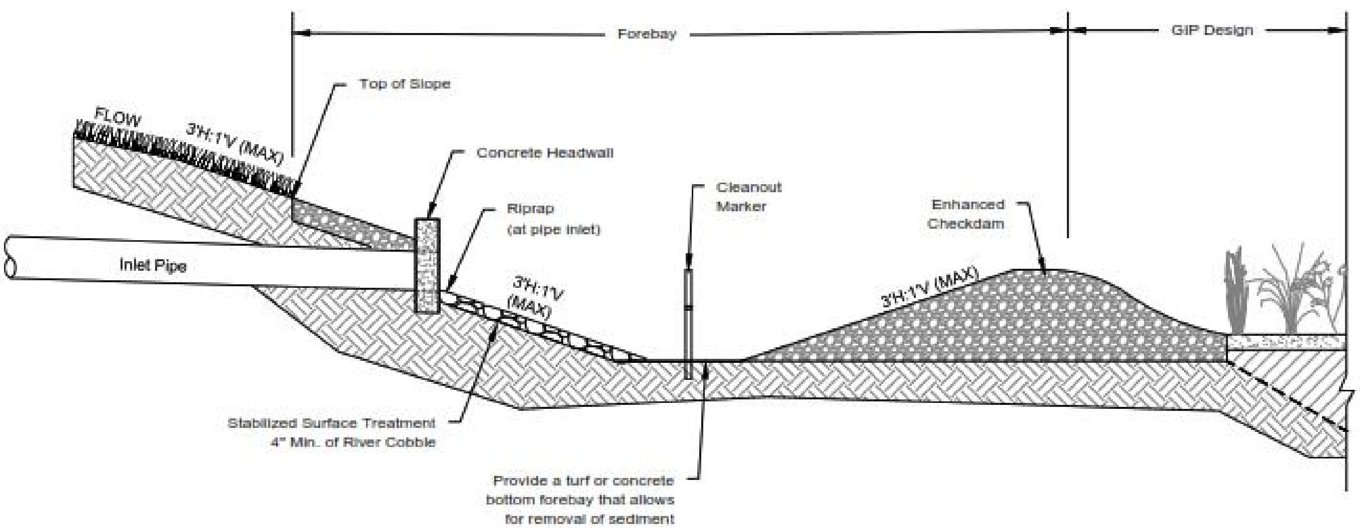


Figure 5.4: Forebay Detail

APPENDIX 5-D

NATIVE PLANTINGS

Popular Native Perennials for Water Quality Swales – Full Sun						
Latin Name	**Common Name**	**Size**	**Spacing**	**Moisture**	**Color**	**Height**
Asclepias incarnate	Marsh milkweed	Plugs – 1 gal.	1 plant/24” o.c.		Pink	3-4’
Asclepias	Purple milkweed	Plugs – 1 gal.	1 plant/18” o.c.		Purple	3’
Asclepias syriaca	Common milkweed	Plugs – 1 gal.	1 plant/18” o.c.		Orange	2-5’
Asclepias tuberosa	Butterfly milkweed	Plugs – 1 gal.	1 plant/18” o.c.		Orange	2’
Asclepias verdis	Green milkweed	Plugs – 1 gal.	1 plant/18” o.c.		Green	2’
Asclepias verdicillata		Plugs – 1 gal.	1 plant/18” o.c.		White	2.5’
Aster laevis	Smooth aster	Plugs – 1 gal.	1 plant/18” o.c.		Blue	2-4’
Aster novae-angliae	New England aster	Plugs – 1 gal.	1 plant/24” o.c.		Blue	2-5’
Aster sericeus	Silky aster	Plugs – 1 gal.	1 plant/18” o.c.		Purple	1-2’
Chamaecrista	Partridge pea	Plugs – 1 gal.	1 plant/18” o.c.		Yellow	1-2’
Conoclinium	Mist flower	Plugs – 1 gal.	1 plant/18” o.c.		Blue	1-2’
Coreopsis lanceolata	Lance-leaf coreopsis	Plugs – 1 gal.	1 plant/18” o.c.		Yellow	6-8’
Echinacea pallida	Pale purple coneflower	Plugs – 1 gal.	1 plant/18” o.c.		Purple	2-3’
Echinacea purpurea	Purple coneflower	Plugs – 1 gal.	1 plant/18” o.c.		Purple	3-4’
Eupatorium	Boneset	Plugs – 1 gal.	1 plant/24” o.c.		White	3-5’
Eupatorium	Sweet Joe-Pye Weed	Plugs – 1 gal.	1 plant/24” o.c.		Purple	3-6’
Iris virginica	Flag Iris	Plugs – 1 gal.	1 plant/18” o.c.		Blue	2’
Liatris aspera	Rough blazingstar	Plugs – 1 gal.	1 plant/18” o.c.		Purple	2-5’
Liatris microcephalla	Small-headed	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Purple	3’
Liatris spicata	Dense blazingstar	Plugs – 1 gal.	1 plant/24” o.c.	Wet-moist	Purple	1.5’
Liatris squarrulosa	Southern blazingstar	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Purple	2-6’
Lobelia cardinalis	Cardinal flower	Plugs – 1 gal.	1 plant/18” o.c.	Wet-moist	Red	2-4’
Monarda didyma	Bee balm	Plugs – 1 gal.	1 plant/24” o.c.	Wet-moist	Red	3’
Monarda fistulosa	Wild bergamot	Plugs – 1 gal	1 plant/18” o.c.		Purple	1-3’
Oenethera fruticosa	Sundrops	Plugs – 1 gal	1 plant/18” o.c.		Yellow	
Penstemon digitalis	Smooth white	Plugs – 1 gal	1 plant/24” o.c.		White	2-3’
Penstemon hirsutus	Hairy beardtongue	Plugs – 1 gal	1 plant/18” o.c.		White	1-3’
Penstemon smallii	Beardtongue	Plugs – 1 gal	1 plant/18” o.c.		Purple	1-2’
Pycanthemum	Slender mountain mint	Plugs – 1 gal	1 plant/18” o.c.		White	1.5-2.5’
Ratibida piñata	Gray-headed	Plugs – 1 gal	1 plant/18” o.c.		Yellow	2-5’
Rudbeckia hirta	Black-eyed Susan	Plugs – 1 gal	1 plant/18” o.c.		Yellow	3’
Salvia lyrata	Lyre-leaf sage	Plugs – 1 gal	1 plant/18” o.c.		Purple	1-2’
Solidago nemoralis	Gray goldenrod	Plugs – 1 gal.	1 plant/18” o.c.		Yellow	2’
Solidago rugosa	Rough-leaved	Plugs – 1 gal.	1 plant/18” o.c.	Wet	Yellow	1-6’
Veronacastrum	Culver’s root	Plugs – 1 gal.	1 plant/24” o.c.	Dry	White	3-6’
Veronia veboracensis	Tall ironweed	Plugs – 1 gal.	1 plant/24” o.c.		Purple	3-4’

Plant material size and grade to conform to “American Standards for Nursery Stock” American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1

Popular Native Perennials for Water Quality Swales – Shade						
Latin Name	**Common Name**	**Size**	**Spacing**	**Moisture**	**Color**	**Height**
Aquilegia canadensis	Wild columbine	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Pink	1-2.5'
Athyrium filix-femina	Lady Fern	1 gal.	1 plant/18" o.c.	Moist	Green	3'
Arisaema triphyllum	Jack-in-the-pulpit	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Green	1.5-2.5'
Arisaema dricontium	Green dragon	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Green	3'
Asarum canadense	Wild ginger	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red-brown	0.5-1'
Aster cardifolius	Blue wood aster	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	1-3'
Aster novae-angliae	New England aster	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Blue/ purple	3-4'
Aster oblongifolius	Aromatic Aster	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Blue/ purple	1.5-3'
Coreopsis major	Tickseed coreopsis	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Yellow	3'
Dryopteris marginalis	Shield Fern	1 gal.	1 plant/18" o.c.	Moist	Green	2-3'
Geranium maculatum	Wild geranium	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Pink	2'
Heuchera americana	Alumroot	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	1'
Iris cristata	Dwarf crested iris	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	4"
Lobelia siphilicata	Great blue lobelia	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Blue	1.5-3'
Lobelia cardinalis	Cardinal flower	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red	2-4'
Mertensia virginica	Virginia bluebells	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Blue	1.5'
Osmunda cinnamomea	Cinnamon Fern	1 gal.	1 plant/24" o.c.	Wet-moist	Green	3-4'
Phlox divericata	Blue phlox	Plugs – 1 gal.	1 plant/18" o.c.	moist	Blue	0.5-2'
Polemonium reptans	Jacob's ladder	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	15"
Polystichum acrostichoides	Christmas fern	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Evergreen	2'
Stylophoru diphyllum	Wood poppy	Plugs – 1 gal.	1 plant/18" o.c.		Yellow	1.5'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Popular Native Grasses and Sedges for Water Quality Swales						
Latin Name	**Common Name**	**Size**	**Spacing**	**Moisture**	**Color**	**Height**
Carex grayi	Gray's Sedge	1 gal.	1 plant/24” o.c.	Moist	Green	3’
Carex muskingumensis	Palm Sedge	1 gal.	1 plant/24” o.c.	Moist	Green	3’
Carex stricta	Tussock Sedge	1 gal.	1 plant/24” o.c.	Moist	Green	3-4’
Chasmanthium latifolium	Upland Sea Oats	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Green	4’
Equisetum hyemale	Horsetail	Plugs – 1 gal.	1 plant/18” o.c.	Wet	Green	3’
Juncus effesus	Soft Rush	Plugs – 1 gal.	1 plant/24” o.c.	Wet-dry	Green	4-6’
Muhlenbergia capallaris	Muhly Grass	1 gal.	1 plant/24” o.c.	Moist	Pink	3’
Panicum virgatum	Switchgrass	1-3 gal.	1 plant/48” o.c.	Moist-dry	Yellow	5-7’
Schizachyrium scoparium	Little Blue Stem	1 gal.	1 plant/24” o.c.	Moist-dry	Yellow	3’
Sporobolus heterolepsis	Prairie Dropseed	1 gal.	1 plant/24” o.c.	Moist-dry	Green	2-3’

Plant material size and grade to conform to “American Standards for Nursery Stock” American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Popular Native Trees for Water Quality Swales							
Latin Name	**Common Name**	**DT-FT**	**Light**	**Moisture**	**Notes**	**Flower Color**	**Height**
Acer rubrum	Red Maple	DT-FT	Sun-shade	Dry-wet	Fall color		50-70'
Acer saccharum	Sugar Maple		Sun-pt shade	Moist	Fall color		50-75'
Ameleanchier Canadensis	Serviceberry		Sun-pt shade	Moist-wet	Eatable berries	White	15-25'
Asimina triloba	Paw Paw		Sun-pt shade	Moist	Eatable fruits	Maroon	15-30'
Betula nigra	River Birch	FT	Sun-pt shade	Moist-wet	Exfoliating bark		40-70'
Carpinus caroliniana	Ironwood		Sun-pt shade	Moist		White	40-60'
Carya aquatica	Water Hickory	FT-DT	Sun	Moist	Fall color		35-50'
Cercus Canadensis	Redbud	DT	Sun-shade	Moist	Pea-like flowers, seed pods	Purple	20-30'
Chionanthus virginicus	Fringetree		Sun-pt shade	Moist	Panicled, fragrant flowers	White	12-20'
Cladratis lutea	Yellowwood	DT	Sun	Dry-moist	Fall color	White	30-45'
Cornus florida	Flowering Dogwood		Part shade	Moist	Red fruit, wildlife	White	15-30'
Ilex opaca	American Holly	DT	Sun-pt shade	Moist	Evergreen	White	30-50'
Liquidambar styraciflua	Sweetgum	DT-FT	Sun-pt shade	Dry-moist	Spiny fruit		60-100'
Magnolia virginiana	Sweetbay Magnolia		Sun-pt shade	Moist-wet	Evergreen	White	10-60'
Nyssa sylvatica	Black Gum		Sun-Shade	Moist	Fall color		35-50'
Oxydendrum arboretum	Sourwood		Sun-pt shade	Dry-moist	Wildlife	White	20-40'
Platanus occidentalis	Sycamore	FT	Sun-pt shade	Moist	White mottled bark		70-100'
Quercus bicolor	Swamp White Oak	DT	Sun-pt shade	Moist-wet	Acorns		50-60'
Quercus nuttalli	Nuttall Oak	DT	Sun	Dry-moist	Acorns		40-60'
Quercus lyrata	Overcup Oak	FT	Sun	Moist	Acorns		40-60'
Quercus shumardii	Shumard Oak	DT	Sun	Moist	Acorns		40-60'
Rhamnus caroliniana	Carolina Buckthorn		Sun	Moist	Black fruit		15-30'
Salix nigra	Black Willow	FT	Sun-pt shade	Moist-wet	White catkins	Yellow	40-60'
Ulmus americana	American Elm	DT-FT	Sun-pt shade	Moist			
Salix nigra	Black Willow	FT		Moist-wet	White catkins	Yellow	40-60'

Size: min. 2" caliper if not reforestation.
DT: Drought Tolerant FT: Flood Tolerant

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

APPENDIX 5-E

AS-BUILT REQUIREMENTS

A printer friendly version of this table can be found on the MWS Development Services website or by request.

Forebay Number:

	Design	As-Built
Top of Bank Elevation		
Top of Check Dam		
Bottom of Forebay		
Surface Area, SF		
Pretreatment Volume, CF		
ALL Elevation shall be NAVD88		

Water Quality Swale Number:

	Design	As-Built
Treatment Volume (Tv), CF		
Surface Area, SF		
Top of Bank Elevation		
Channel Slope		
GIP Surface Elevation (Upstream)		
Check Dam Height, FT		
Channel Drop, FT		
GIP Surface Elevation (Downstream)		
Depth of Media, FT		
Depth of Stone, FT		
ALL Elevation shall be NAVD88		

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