TECHNICAL REPORT

MODULAR WETLAND SYSTEM LINEAR STORMWATER TREATMENT SYSTEM OVERVIEW

Prepared for
Alisa Richardson
Rhode Island Department of
Environmental Management

Prepared by
Modular Wetland Systems, Inc.

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Prepared for
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EXECUTIVE SUMMARY

Installation of the monitored MWS-Linear for TAPE testing in Portland, Oregon.

Modular Wetland System - Linear filtration system (MWS-Linear) is a water quality treatment system consisting of a pre-treatment chamber, a media cartridge pre-filter, a wetland biofiltration chamber, and an outlet control device. The system is housed in a precast concrete vault and can be designed in numerous configurations including piped, curb or grated inlet structures.

Since 2007, the MWS-Linear has been used throughout the United States and Australia to address stringent stormwater regulations. During this time various third party independent hydrologic and water quality monitoring studies have been performed on the MWS-Linear. In 2010, a system was approved and installed in Portland, Oregon to test under the Washington State TAPE protocol. An approved consultant was hired to conduct this monitoring to obtain performance data to support the issuance of a General Use Level Designation (GULD) for the MWS-Linear by the Washington Department of Ecology (Ecology). Monitoring was performed in accordance with procedures described in *Guidance for Evaluating Emerging Stormwater Treatment Technologies; Technology Assessment Protocol – Ecology (TAPE)* (Ecology 2011).

TAPE field testing was completed in May of 2013. The MWS-Linear met the treatment benchmarks for TSS, phosphorus and dissolved metals. It's the first system to achieve these benchmarks for all three. The system was tested over a two year period. The system was able to meet these benchmarks at loading rates up to 121 inches an hour or 1.21 gallons per minute per square foot surface area. Mean values for TSS removal were 85%. The d50 for the TSS was between 8 and 30 microns. Mean values for total phosphorus removal were 64%. Other removal efficiencies from the TAPE testing and other third party independent field tests are discussed in more detail in Appendix A & B. The performance data shows that the MWS-Linear meets the required removal efficiencies set forth in Minimum Standard 3: Water Quality of the Rhode Island Stormwater Design and Installation Standards Manual (December 2010). The manual states the BMP was be able to remove 85% TSS, 60% of pathogens, 30% of total phosphorus, and 30% of total nitrogen.

DESCRIPTION OF SYSTEM

The Modular Wetland Systems - Linear (MWS-Linear) is a structural stormwater treatment system developed by Modular Wetland Systems, Inc. The MWS-Linear utilizes a multi-stage treatment processes, including a pre-treatment chamber that houses a settling basin and a media cartridge pre-filters that are designed to remove coarse to fine sediment and hydrocarbons from entering the subsequent wetland chamber. The wetland chamber media provides chemical and biological filtration and secondary physical filtration. This system is housed in a modular precast concrete structure that can be designed in many inlet configurations. The MWS-Linear provides water quality treatment of captured flows through the processes of separation, sedimentation, filtration, adsorption, absorption, sequestration, volatilization, ion exchange, biological remediation, and uptake.

The MWS-Linear stormwater filtration system provides water quality treatment of captured flows through several physical, biological, and chemical unit processes. This section describes the system's physical components, treatment processes and removal mechanisms, sizing methods, expected treatment capabilities, expected design life, and required maintenance procedures.

System Overview

The MWS-Linear can be used in a variety of configurations, including curb, grate, and vault-type (piped), offline-DVERT, downspout and volume based designs (Figures 1, 2, 3, 4, 5 and 6). New construction and stormwater retrofit projects can utilize the modular design of the MWS-Linear in place of standard catch basin structures, rain gardens, bioretention cells, media filters, or other treatment devices. A variety of inlet, bypass, and wetland chamber designs are available for the MWS-Linear and can be easily be adapted for different stormwater drainage system designs and needs. However, the hydraulics within the system itself and the treatment processes are the same for each of these configurations.

Stormwater runoff enters the MWS-Linear via pipe, curb, or grate opening. For the MWS-Linear with a grate or curb-type opening, a catch basin filter insert facilitates the removal of gross solids and floatable trash prior to the stormwater entering the pre-treatment chamber. For the MWS-Linear with pipe openings, stormwater enters the pre-treatment chamber directly. The pre-treatment chamber is specifically designed to settle out trash and litter, gross solids, and suspended sediment. Stormwater is then treated by the media cartridge pre-filters, which removes several pollutants, fine TSS, and hydrocarbons to protect the wetland chamber from clogging. After the stormwater moves through the media cartridge pre-filter, it enters the wetland chamber, which acts as a biofilter and is the main treatment component of the system. The MWS-Linear processes stormwater horizontally through the biofiltration media contained within the wetland chamber. Within this wetland chamber, a combination of physical, chemical, and biological mechanisms remove additional particulate and soluble pollutants. Treated runoff leaving the wetland chamber is controlled by a downstream orifice

or flow control structure in the discharge chamber and leaves the system via the discharge chamber piping. The hydraulic conductivity of the biofiltration media contained within that wetland chamber is higher than the set orifice rate. In this manner the biofiltration media has a built-in hydraulic safety factor to ensure sustained treatment flow rates.

Physical Components

The MWS-Linear consists of a series of treatment components, beginning with a catch basin filter insert (for grate and curb-type configurations), a pre-treatment chamber, the BioMediaGREEN pre-filter, and finishing with a wetland chamber and discharge chamber. The discharge chamber collects flow from the wetland chamber and internal bypass pipes or weirs (if applicable) and routes stormwater to the outlet pipe.

The BioMediaGREEN can easily be removed and replaced from the media cartridge pre-filters to maintain the treatment performance within an acceptable range; the catch basin filter insert, pre-treatment chamber, and media cartridge pre-filter improve the wetland chamber performance by minimizing the pollutant loading on the biofiltration media. The primary components of the MWS-Linear are described in the following sections.

The figures below show the various configurations the system is available in. Curb type configurations are generally used for streets and other right-of-way scenarios. The curb type configuration is also useful for some parking lot applications. The grate type configuration is generally used in parking lot and industrial applications. This configuration is optimal for receiving sheet flow from flat areas. In addition to the inlet configurations the MWS-Linear is able to accept inflow pipes from various upstream drainage structures. The unique horizontal flow biofiltration bed allows inflow pipes to enter the system several feet underground. This feature alone sets the system apart from traditional “tree-in-a box” type bioretention systems.

The MWS-Linear is also available in downspout configurations as the system can be installed as a partially or fully raised planter. An internal bypass weir is available on some models to allow for online installations. The MWS-Linear is also a perfect BMP for retrofit applications. Since water can be piped into the system it’s simple to connect it to existing catch basins. This is accomplished by using a large trough system (DVERT) that’s installed inside the existing basin and allows the “first flush” or low flows to be intercepted as water enters the basin and diverted to the MWS-Linear quickly and efficiently. The DVERT trough can be installed without interfering with the peak flow capacity of the existing basins.

Because of the system’s ability to intercept runoff via pipe several feet below finish surface it can be used in post-detention configurations also known as volume based configuration. In this manner the system, in conjunction with pre-detention, is capable of treating the water quality volume over an extended period of time. The system can be paired with underground detention systems, wet ponds or extended detention basins.

Figure 1. Curb Type Configurations.

Figure 2. Grate Type Configurations.

Figure 3. Vault Type Configurations – Piped from Upstream Locations.

Figure 4. Downspout Configurations.

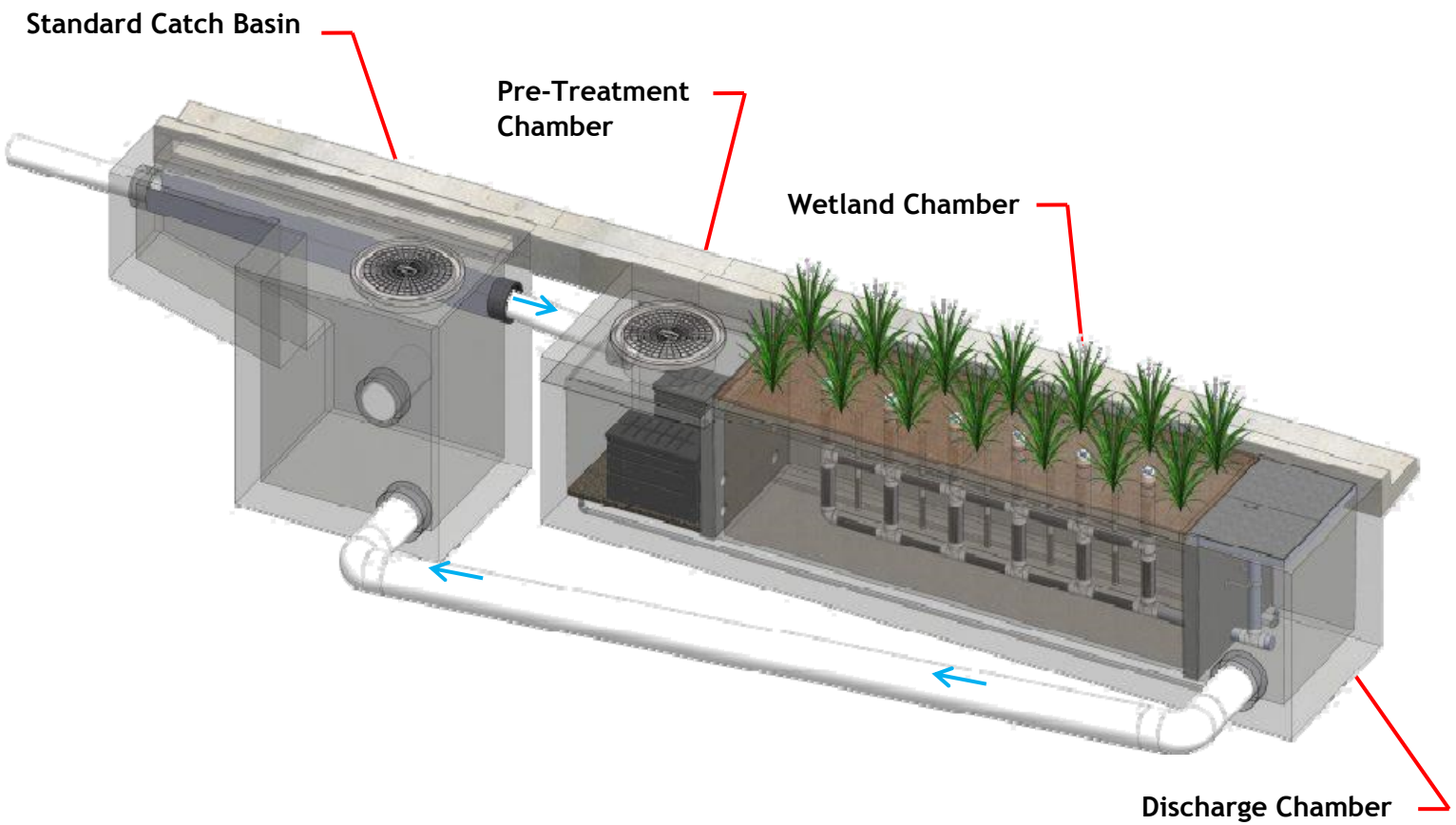

Figure 5. Offline/Retrofit Configurations – Utilizing the DVERT Trough

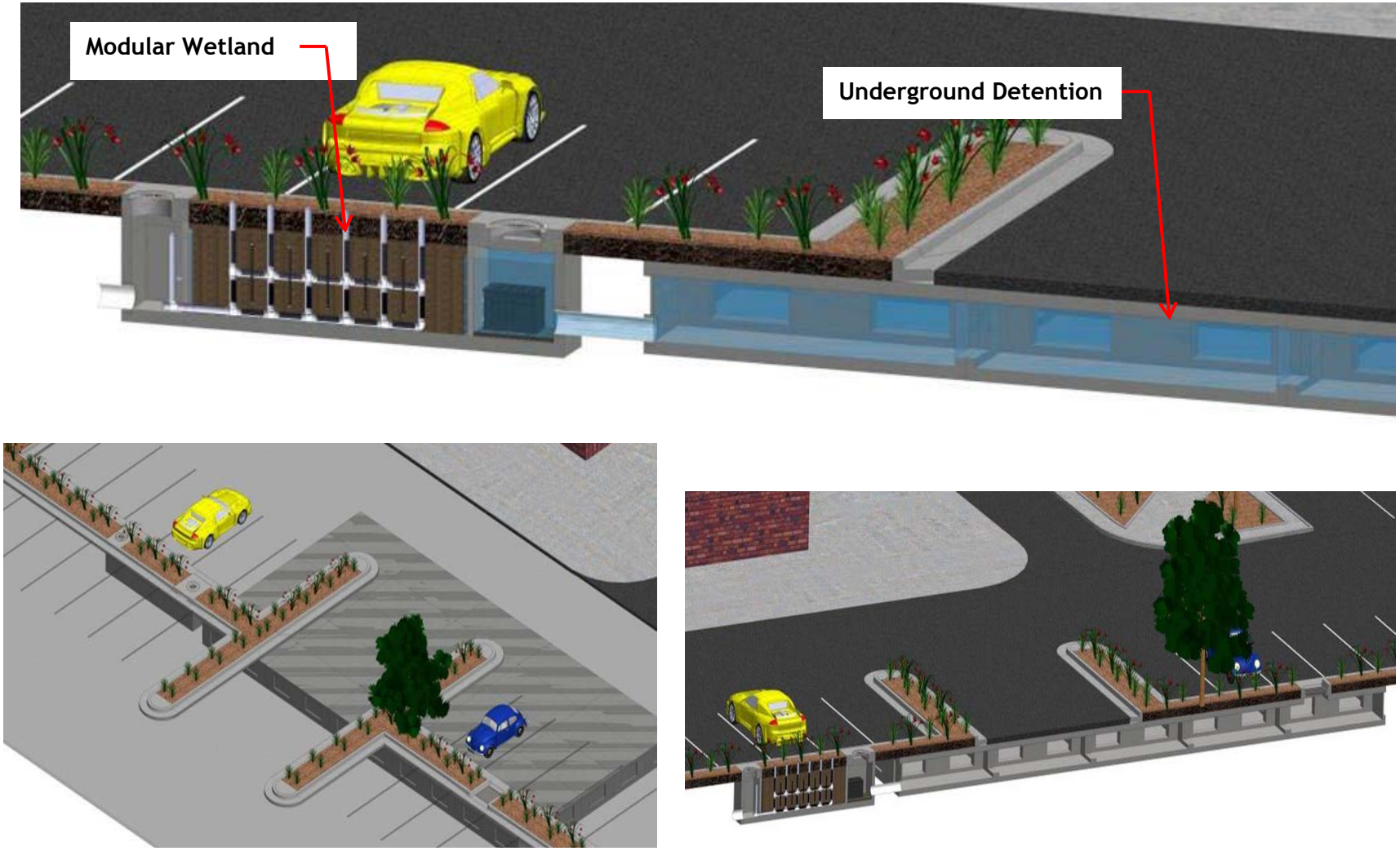

Figure 6. Volume Based Configuration – Installed Downstream of Detention

Structure

The MWS-Linear is a modular, precast concrete structure. Each MWS-Linear concrete structure is available in numerous lengths and widths to accommodate flow or volume requirements. There are several alternative configurations and the MWS-Linear can be adapted to a variety of site conditions. Each complete unit weighs approximately 9,000 to 70,000 pounds and requires a boom crane for installation.

Runoff can enter the system via built-in grate or curb inlet or enters directly into the pre-treatment chamber via pipe. The system has been designed to accommodate different depths without changing biofiltration media thickness or stormwater detention time. The system's horizontal flow biofilter and inlet configurations also allow it to be utilized in volume-based configurations downstream of storage BMPs, such as detention basins, ponds, or underground facilities.

The MWS-Linear is constructed with non-corrosive materials. All internal piping is SD35 or SD40 PVC. Catch basin filter insert components, including mounting hardware, fasteners, support brackets, filtration material, and support frame are constructed of non-corrosive materials (316 stainless steel and UV protected/marine grade fiberglass). Fasteners are stainless steel and the primary filter mesh is stainless steel welded screens. Media cartridge pre-filters are constructed of high strength HDPE. Mounts are constructed of stainless steel. BioMediaGREEN is absorptive rock substrate and is inert and non-corrosive. The drain down filter cover is constructed of high strength HDPE and the hinge and mount are constructed of stainless steel.

Inlet

The MWS-Linear is available with a built-in grate or curb opening and/or can accept runoff via pipe. In the grate or curb type configuration, a catch basin filter is mounted directly under the opening to intercept trash and debris as well as coarse or large sediment. The size and shape of the catch basin filter varies from model to model. The catch basin filter utilizes progressively finer screen sizes to facilitate removal and maintain flow rates. It also possesses built-in internal openings for bypassing higher flows.

Pre-Treatment Chamber

The pre-treatment chamber is located below the inlet. The settling area within this chamber has been specifically designed to provide secondary pre-treatment of stormwater to settle large and coarse suspended solids.

Media Cartridge Pre-Filter

The media cartridge pre-filter is designed to house BioMediaGREEN but can use other various types of filter media. BioMediaGREEN is a proprietary engineered filter media made of a unique combination of inert, naturally occurring minerals. The BioMediaGREEN is designed as lightweight porous blocks, which are then cut into 1- by 1-centimeter cubes, and are packed into eight (8) separate cells around a center drain tube in each filter cartridges (Figure 5).

This natural product is non-combustible, stable, biodegradable, and inert, having no known adverse effects on the environment.

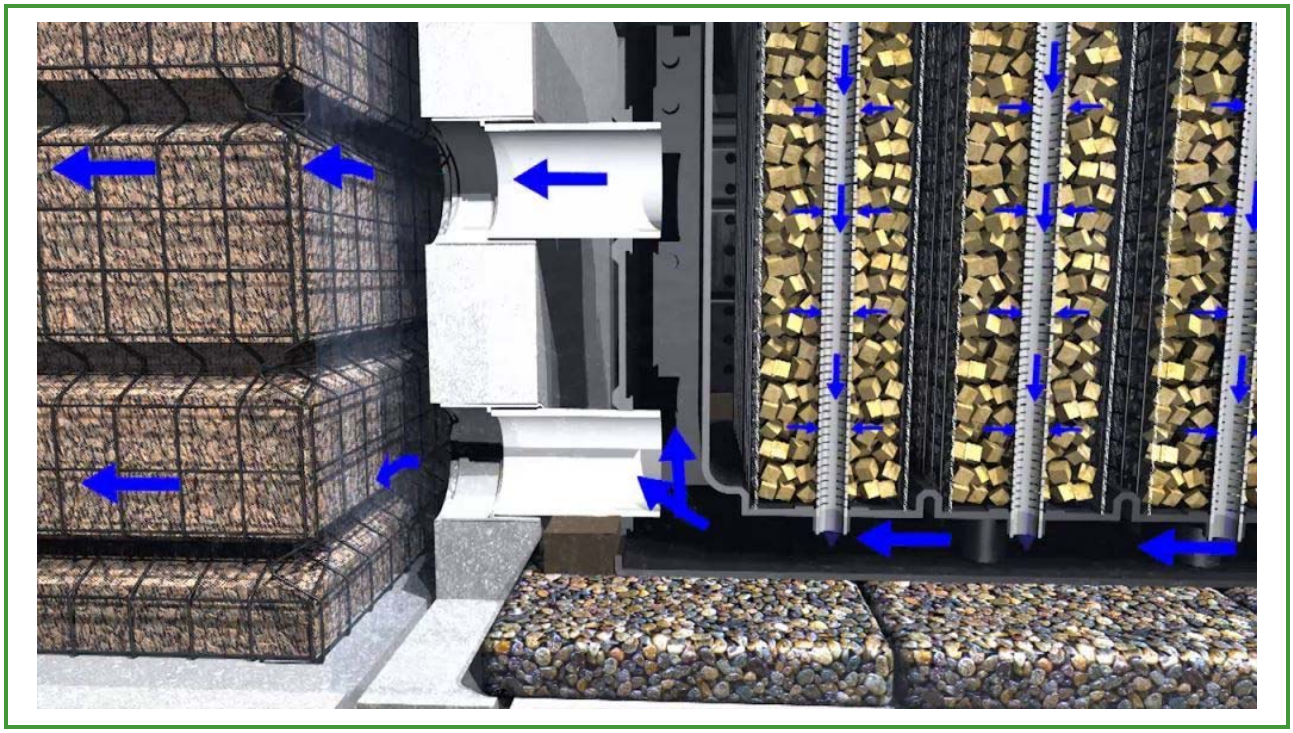

Figure 7. Rendering of Media Cartridge Pre-filters (Right) and Water Routing into the Wetland Chamber (Left).

The highly porous nature of BioMediaGREEN allows stormwater to easily flow around and through the cubes. The hydraulic conductivity of BioMediaGREEN is rated at 595 inches per hour, but stormwater also flows around each cube, so the actual hydraulic conductivity of the cartridges is much higher than the stated flow above.

BioMediaGREEN cubes also contain a high surface area to volume ratio, which promotes elevated levels of physical, chemical, and biological processes to treat stormwater. BioMediaGREEN filter cubes are designed to capture high levels of soluble and insoluble pollutants and hydrocarbons, including oils and grease, gasoline, diesel, polycyclic aromatic hydrocarbons (PAHs), and other organic chemicals. BioMediaGREEN cubes have the physical ability to block and filter trash, litter, vegetative matter, sediment, total suspended solids (TSS), total and dissolved metals, nutrients, and bacteria.

Maintenance of the media cartridge pre-filter is simple, and only requires access to the pre-treatment chamber (cartridges do not need to be removed for maintenance). To maintain, the lid of the cartridge is removed, the used BioMediaGREEN cubes are removed from each cell within the cartridge, the cartridge housing cleaned, new BioMediaGREEN cubes added, and the cartridge lid replaced. BioMediaGREEN cubes are light green in color when new, and turn a darker color as pollutants and sediment are absorbed onto its surface from untreated stormwater. Maintenance crews can easily determine if the filter cubes need replacement by

virtue of this color change. The BioMediaGREEN cubes can typically be disposed of in an ordinary landfill (local regulations may apply).

The number and size of media cartridge pre-filters is customizable and can range from one to dozens depending on the treatment flow rate. Most common MWS-Linear models contain just one or two cartridges.

Stormwater Conveyance into Wetland Chamber and High Flow Bypass

After stormwater has passed through the pre-treatment chamber's settling area and media cartridge pre-filter, it is transferred out of the cartridge into a series of 4-inch diameter PVC SD35 manifolds (Figure 5) that lead to the wetland chamber's peripheral void area (known as the inlet water transfer system and described in the next section).

The MWS-Linear is available with one or more high flow bypass pipes near the top of the pre-treatment chamber for internal bypass. External bypass configurations are also available. All bypass configurations are used to convey stormwater around the wetland chamber and to the discharge chamber or downstream tie-in points. High flow bypass occurs when the MWS-Linear's flow capacity is exceeded. Alternative bypass configurations are also available for smaller and larger MWS-Linear models that include a built-in internal bypass weir wall. Since the wetland chamber is separated from the pre-treatment and discharge chamber, internal bypass has no effect on performance. Therefore, the wetland chamber only experiences the orifice controlled water quality flow rate, as determined during MWS-Linear sizing for each specific contributing drainage area.

Wetland Chamber

The wetland chamber is the primary stage of water treatment for the MWS-Linear. The system employs an innovative peripheral (perimeter) 2" void area on all four sides of the biofiltration media that extends to at least the height of the wetland chamber's operating hydraulic gradient level (HGL). This is known as the inlet water transfer system. Incoming stormwater surrounds the biofiltration media bed within the void space and migrates towards a series of vertically extended underdrain or collection piping located in the center of the cell. This is known as the outlet water transfer system. As such, it operates similar in fashion to a radial cartridge filter. The horizontal flow path through the media from an outside perimeter maximizes the available surface area and thus, treatment flow capacity. Because flow through the media is horizontal, the media thickness from influent point to effluent point remains constant, regardless of the height of the wetland chamber. Therefore, shallow or deeper systems can be specified without compromising treatment efficiencies associated with downward flow systems such as rain garden, bioretention systems and the like – all of which require the removal of media to accommodate shallow requirements.

The wetland chamber is filled with an engineered organic-free sorptive biofiltration media called WetlandMedia. The WetlandMedia is designed to maximize physical, chemical, and biological treatment processes along with supporting live vegetation. The WetlandMedia also includes a layer of plant propagation media above the active treatment zone to help with

establishing vegetation. For example, the MWS-Linear Model #MWS-L-4-21 has a wetland chamber that is 4 feet wide by 13.8 feet long and has a physical chamber height of 4 feet. The overall O.D. dimensions of this model including the concrete vault, pre-treatment, and discharge chamber is 5 by 22 by 4.8 feet. The active media surface area of the wetland chamber for this model is 117 square feet at standard height. Radial subsurface flow through the WetlandMedia provides a combination of physical, chemical, and biological filtration processes for treatment of stormwater before it enters the discharge chamber. As interstitial voids in the media begin to slowly accrete suspended solids from the stormwater, the media becomes more carbon and nutrient rich. This results in more vigorous plant growth and increased micro-biological processing of the stormwater. The ecosystem that develops around the roots of the plants (or rhizosphere) is a complex combination of oxygen rich bacteria, fungi, and carbonaceous plant material. Biological growth and oxygen rich organisms mobilize, metabolize, and decompose influent pollutants and contribute to the overall treatment performance of the MWS-Linear.

After stormwater passes through the WetlandMedia it enters a series of perforated, 4-inch diameter, SD35 PVC outflow chamber transfer pipes, located along the chamber's central axis (Figure 3). The vertically extending perforated under drain pipes join to a common solid horizontal pipe manifold along the bottom of the wetland chamber. This pipe collects sub-surface flow from the wetland chamber and conveys the treated stormwater to the discharge chamber through an orifice that regulates treatment flow and loading rates through the wetland chamber.

Wetland Chamber Vegetation

A wide variety of upland or wetland plant species can be planted on the surface of the wetland chamber. Vegetation can be selected based on aesthetics, local climatic conditions, traffic safety, and maintenance considerations. However, adequate time (months) is necessary to allow for the plant roots and eco-biological organisms to colonize and to be well established within the wetland chamber.

The standard MWS-Linear has a physical height of 4.13 feet, yet can be made as shallow as 2' feet or as deep as 7' with an open planter. The MWS-Linear utilizes a specialized blend of high grade sorptive media. It contains no organics and utilizes a special layer of plant establishment media. This perfect blend allows for rapid and robust plant establishment. The system can utilize a wide variety of vegetation from small trees, shrubs, grasses and other types of plants. Supplemental irrigation is recommended for at least the first 3 to 6 months. If native drought plants are used ongoing irrigation may not be necessary. Appendix F provides a partial list of plants that can be used in the system. Many other plants can also be used. Please contact the manufacturer to see if a particular plant can be used in the system.

Discharge Chamber

The discharge chamber collects treated stormwater from the outlet water transfer system as well as stormwater from high flow bypass pipes or weirs. The outlet water transfer system connects to the discharge chamber via a 4-inch PVC pipe to an orifice or flow

control structure housed in the discharge chamber (Figure 3). The orifice is set to discharge stormwater at a calculated treatment flow rate equal to and not exceeding the design wetland loading rate given the media surface area for any size or height system. For example, the orifice insures the system is operating at 100 in/hr or 1.03 gpm at peak capacity and never at a higher flow rate to ensure optimal performance. The flow through the orifice is also much less than the hydraulic conductivity of the media itself and therefore providing a built-in safety factor against potential clogging over several years or operation. Flows collected in the discharge chamber are routed to a discharge pipe.

Treatment Mechanisms

The MWS-Linear provides water quality treatment of captured flows through physical, chemical, and biologic unit processes. Runoff treatment is achieved through screening, sedimentation, filtration, absorption, adsorption, sequestration, sorption, biological remediation, and uptake.

Screening

For MWS-Linear grate-type systems, the catch basin insert located at the inlet intercepts the majority of floatable and gross solids, trash and litter, and coarse sediment before entering the pre-treatment chamber. The catch basin insert filter is designed with multiple levels of various screen sizes to remove pollutants.

Sedimentation

The MWS-Linear contains a pre-treatment chamber below the inlet, and has been designed to promote gravity or hydrodynamic settling of entrained particles. Settling of large particles in the pre-treatment chamber improves the system's performance as well as extends the life of the media cartridge pre-filter. The amount of sedimentation is a function of particle density, size, water density and viscosity, internal turbulence, and residence time.

Filtration

Particulates are physically removed from suspension as they contact the BioMediaGREEN contained within in media cartridge pre-filter(s). Pollutant removal rates achieved through the cartridges alone are a function of the stormwater composition, flow, and pre-treatment effectiveness. Filtration is also the primary physical unit process or mechanism in the wetland chamber. The 3- to 5-millimeter WetlandMedia in the wetland chamber creates a non-linear and torturous flow path which enhances contact between the stormwater and the various filtration media.

Adsorption

Unlike filtration, where physical processes control removal of sediment from suspension, adsorption relies on opposing surface charges of the BioMediaGREEN filter media and wetland chamber media and dissolved constituents to remove pollutants from stormwater. The BioMediaGREEN filter media is designed with a high surface area so that the binding sites

are not exhausted through its expected life cycle. In addition, both the WetlandMedia and the BioMediaGREEN possess a high cation exchange capacity that promotes the effective removal of positively charged dissolved pollutants (including transition and heavy metal ions) from the incoming stormwater.

Biological Remediation

Bacterial growth, supported by the root system in the wetland chamber, performs a number of treatment processes. These vary as a function of moisture, temperature, pH, salinity, and pollutant concentrations. Biologically available forms of nitrogen, phosphorus, and carbon are actively taken into the cells of vegetation and bacteria, and used for metabolic processes (i.e., energy production and growth). Nitrogen and phosphorus and many heavy metals common to stormwater are actively taken up as micronutrients that are vital for a number of cell functions, growth, and energy production. These biological processes remove metabolites from the media during and between storm events, making the media available to capture more nutrients from subsequent storm events.

Aerobic and anaerobic soil organisms in the wetland chamber break down, decompose, sequester, and volatilize a wide array of organic compounds into less toxic forms or completely break them down into carbon dioxide and water (Means and Hinchee 1994). Bacteria can also cause metals to precipitate out as salts, bind them within organic material, and accumulate metals in nodules within the cells. Finally, plant growth may metabolize many pollutants, sequester them or rendering them less toxic (Reeves and Baker 2000).

Site Requirements

Necessary Soil Characteristics

Specific underlying soil characteristics are not required for the MWS-Linear, since it is a self-contained, watertight system and is fully enclosed. However, the manufacturer does require that the MWS-Linear system be installed on a level bed of gravel 6 inches in depth (see Installation Manual). The system can be installed with open holes in the bottom of the discharge chamber to transfer treated stormwater to soils below to maximize infiltration if desired.

Hydraulic Grade Requirements

The MWS-Linear is completely passive and requires a minimum of 4.13 feet fall from the top of the unit to pipe invert outlet for standard models. Taller and shorter units are available for areas with limited fall conditions. For piped flows, water entering the system can come in with as little as 6 inches of flow between inflow pipe and outflow pipe. At the same time, the internal the internal or external bypass must be at an elevation equal to the operating hydraulic gradient level (HGL) of the system. Bypass can be either internal or external depending on the site specific configuration. Surface bypass occurs with curb or grate type configurations where a secondary basin in installed just downstream of the MWS-Linear to intercept all flows above its treatment capacity. For pipe flows, an internal or external bypass

pipe(s) or weir can be used at the proper elevation. This amount of fall ensures that the maximum wetland surface area is utilized in the MWS-Linear for maximum performance. The MWS-Linear can also accept runoff from upstream storage basins in a volume based configuration.

Depth to Groundwater Limitations

Since it is fully enclosed, the MWS-Linear does not have depth to groundwater limitations.

Utility Requirements

The MWS-Linear system is a passive system that requires no power, and has a free-draining outfall to an appropriate water conveyance or storage system (e.g., wet pond, storm sewer, or underground infiltration).

Intended Application

The MWS-Linear is intended to be used for stormwater filtration in applications ranging from industrial and commercial to high and low density residential settings. Depending on the land use, maintenance frequency may have to be adjusted accordingly. For instance, the pre-treatment chamber including the media cartridge pre-filter will likely have to be more frequently maintained when treating high ADT roadway versus residential street runoff.

Pretreatment Requirements

There are no pretreatment requirements for the MWS-Linear since the system includes a built-in multi-stage pre-treatment system. However, in applications where heavy sediment loading is anticipated from upstream basins connected to the MWS-Linear via pipe the use of catch basin filters or standard sumped catch basins can be helpful.

Current Installations

As of August 2013, there are 168 MWS-Linear installations nationwide. Appendix A provides the location, land use, and size of each of these installations. There is currently installations in California, Oregon, Washington, Florida, Virginia, Maryland, Pennsylvania, Washington DC, Texas among others.

SIZING METHODOLOGY

Laboratory testing of the MWS-Linear indicates high levels of pollutant removal performance at a loading rate of 100 inches an hour or 1.03 gallons per minute per square foot (gpm/sq ft) of surface area of the WetlandMedia inside the wetland chamber. The media cartridge pre-filter operates at a loading rate of up to 3 gpm/sq. ft. of surface area when providing

pre-treatment for the wetland chamber. The MWS-Linear is sized based upon total available WetlandMedia surface area similar to other biofiltration or cartridge type systems. The MWS-Linear is available in over nine standard models, each model containing different size wetland chambers. Since the MWS-Linear is a horizontal flow biofilter, its operation is similar to a radial cartridge. Influent stormwater fills the void area around the biofiltration bed (WetlandMedia) bed in the wetland chamber up to a specific operating level or height. The surface area of the biofiltration bed is calculated by adding all perimeter lengths by the operating height of the biofiltration bed. An orifice or flow control structure is housed downstream of the wetland chamber in the discharge chamber. The size of the orifice is calculated based upon a target-loading rate of 1.03 gpm/sq ft of surface area, with the maximum loading rate not to exceed the maximum flow rate for the three media cartridge pre-filters. The maximum water level before bypass is set to meet the required or desired operating level of the wetland chamber.

Rhode Island Sizing

The MWS-Linear is sized to meet State of Rhode Island design criteria. The result is capture and treatment for 90 percent of runoff from average annual storm events. This approach was adopted by Rhode Island in 1993 and is similar to water quality sizing elsewhere in the United States. The 90 percent of the average annual storm events is equivalent to the runoff associated with the first 1.2 inches of rainfall over the impervious surface (i.e., 1 inch of runoff) (CWP, 2007). These criteria are intended to remove the majority of pollutants in stormwater runoff at reasonable cost by capturing and treating runoff from small, frequent storm events that account for a majority of the annual pollutant load.

The MWS-Linear can be sized using the water quality volume (with upstream pre-detention) or the water quality flow (standalone). Section 3.3.3 of the 2010 Rhode Island Stormwater Design and Installation Manual provides guidance on how to calculate water quality flow and water quality volume. The following tables list the treatment flow (table 1) and treatment volume (table 2) of each MWS-Linear model. A Modular Wetland System, Inc. representative can assist with the sizing process upon request.

Table 1. MWS-Linear Sizing Table for Rhode Island - Flow Based Design.			
Modular Wetland System Linear Model Numbers	**ID Dimensions (feet)**	**Total Wetland Media Surface Area (sf)**	**Maximum Treatment Capacity (cfs)**
MWS-L-4-4	4 x 4	23	0.052
MWS-L-4-6	4 x 6	32	0.073
MWS-L-4-8	4 x 8	50	0.115
MWS-L-4-13	4 x 13	66	0.144
MWS-L-4-15	4 x 15	76	0.175
MWS-L-4-17	4 x 17	90	0.206
MWS-L-4-19	4 x 19	103	0.237
MWS-L-4-21	4 x 21	117	0.268
MWS-L-8-8	8 x 8	100	0.230
MWS-L-8-12	8 x 12	151	0.346
MWS-L-8-16	8 x 16	201	0.462

Notes:

1. The Modular Wetland is sized based upon its TAPE approved flow rate of 100 in/hr.

Table 2. MWS-Linear Sizing Table for Rhode Island - Volume Based Design[3].				
Modular Wetland System Linear Model Numbers	**ID Dimensions (feet)**	**Total Wetland Media Surface Area (sf)**	**Recommended Maximum Water Quality Volume (cu ft) with 24 Hour Drain Down Time**	**Recommended Maximum Water Quality Volume (cu ft) with 48 Hour Drain Down Time**
MWS-L-4-4	4 x 4	23	1140	2280
MWS-L-4-6	4 x 6	32	1712	3423
MWS-L-4-8	4 x 8	50	2518	5036
MWS-L-4-13	4 x 13	66	3131	6261
MWS-L-4-15	4 x 15	76	3811	7623
MWS-L-4-17	4 x 17	90	4492	8984
MWS-L-4-19	4 x 19	103	5172	10345
MWS-L-4-21	4 x 21	117	5853	11706
MWS-L-8-8	8 x 8	100	5036	10072
MWS-L-8-12	8 x 12	151	7554	15109
MWS-L-8-16	8 x 16	201	10073	20145

Notes:

1. Sizing table based upon agency accepted standard sizing procedures for volume based BMPs.
2. The Modular Wetland is sized based upon a reduced flow rate of 25 in/hr to account for the increased time required to treat the water quality volume.
3. This sizing method requires pre-storage to hold the water quality volume.

Expected Treatment Capabilities

The MWS-Linear is designed to remove gross solids, suspended solids, heavy metals, petroleum hydrocarbons, bacteria, and nutrients from stormwater. A combination of field and laboratory tests have been conducted on the MWS-Linear and the media cartridge pre-filter BioMediaGREEN. Specifically, in 2007 a scaled-down laboratory test was conducted to assess the performance of the MWS-Linear system; the same year, a separate laboratory test was conducted to assess the performance of the BioMediaGREEN alone. Subsequent to these tests, a full-scale field test of the MWS-Linear system was conducted in California to evaluate removal of several stormwater pollutants of concern, including total suspended solids, phosphorus, and total and dissolved metals. The results from these experiments indicated that the combination of the media cartridge pre-filter containing BioMediaGREEN and MWS-Linear WetlandMedia removed greater than 80 percent total suspended solids, 70 percent dissolved copper, 88 percent dissolved zinc, and 70 percent total phosphorus. Additional information about previous studies of the MWS-Linear and BioMediaGREEN can be found in the Conditional Use Level Designation (Herrera 2011a) for the MWS-Linear, which was filed with the Washington State Department of Ecology in May 2011.

Estimated Design Life

The non-consumable structural components of the MWS-Linear system are designed to last 25 years or more before needing maintenance or replacement of internal components. The concrete structure of the system has a user life of over 50 years. The manufacturer recommends that, on average, the pre-treatment chamber be maintained every 6 to 12 months. The manufacturer also recommends that the pre-filter media be replaced every 6 to 24 months depending on loading conditions. If pollutant loading is abnormally high, however (e.g., due to roadway sanding, construction runoff, or when installed at Industrial sites), the maintenance requirements of the pre-treatment chamber and media cartridge pre-filter will increase. Maintenance on the wetland chamber is not expected for many years, as the media cartridge pre-filter will prevent sediments and hydrocarbons from entering and eliminate sediment built up and clogging. Due to the high variation of loading conditions from site to site, it is recommended that first year inspections are done to assess the loading condition of the site on the MWS-Linear. Based upon this first year of observation, a site-specific maintenance frequency can be established.

INSTALLATION

The MWS-Linear is a precast watertight concrete structure. The internal components are pre-assembled prior to delivery to the installation site. The system is delivered on a flatbed truck. The installer or contractor will need to provide a crane capable of off-loading the unit and placing it into the ground. Prior to delivery, the appropriate excavation should be completed, and the bottom 6 inches backfilled and leveled using the appropriate and recommended material compacted to 95 percent of maximum density.

Prior to installation, all inlets are blocked and wetland chamber covered to prevent construction sediment contamination from the site. Backfilling should be performed in a careful manner, bringing the appropriate fill material up in 6-inch lifts on all sides. Precast sections shall be set in a manner that will result in a watertight joint. In all instances, installation of the MWS-Linear shall conform to ASTM specification C891 *Standard Practice for Installation of Underground Precast Utility Structures*, unless directed otherwise in contract documents.

OPERATION AND MAINTENANCE

Every installed MWS-Linear unit is to be maintained by the Supplier, or a Supplier approved contractor for at least the first year. The cost of this service varies among outside service providers. The MWS-Linear is a multi-stage self-contained treatment train for stormwater treatment. Each stage is designed and intended to protect subsequent stages from clogging. Stages include screening, separation, cartridge media filtration, and biofiltration. The biofiltration stage can contain various types of vegetation or plantings. Annual inspection is required to evaluate plant health and trim excess vegetation. The maintenance procedures are described below.

1. **Clean Catch Basin Filter** – Screening is provided by a catch basin filter. The filter will contain coarse sediment, trash, and other floatables. Sediment capacity is reached at 2 cubic feet for the curb style inlet and 4 cubic feet for the drop or grated inlet configuration (varies with smaller and larger models). The filter removes gross solids, including litter, and sediment greater than 200 microns. The cleaning procedure is easily done by hand or with a small industrial vacuum device. This filter is located directly under the manhole cover or grate for easy access.

2. **Clean Pre-Treatment Chamber** – separation occurs in the pre-treatment chamber's settling area located directly under the curb or grated inlet. This chamber has a capacity of approximately 21 cubic feet for trash, debris, and sediments for most model sizes (varies with smaller and larger models). The chamber targets total suspended solids and particulate metals and nutrients. Cleaning the settling area can

be performed with a standard vacuum truck or hand held industrial shop vacuum. This chamber is located directly under the manhole or grate access cover for easy access into the chamber.

3. **Replace Pre-Filter Cartridge Media (BioMediaGREEN™)** – Initial filtration is provided by a horizontal flow cartridge filter utilizing BioMediaGREEN media. Media life depends on local sediment loading conditions and can easily be replaced and disposed of without any equipment. The BioMediaGREEN media is held within the media cartridge pre-filters that are housed in the pre-treatment chamber. Entry into the pre-treatment chamber is required to replace the BioMediaGREEN media. The lid of the media cartridge pre-filter is removed by loosening two bolts. Once removed maintenance personnel have unimpeded access to each media cage housing the BioMediaGREEN which can be quickly removed by hand or with a vacuum truck. Once old BioMediaGREEN is removed new material, provided is pre-weighed bags, is dropped into the media cage housings. Once completed, the cartridge lid is replaced and bolts tightened on the lid of the media cartridge pre-filter.

4. **Replace Drain Down Filter Media (BioMediaGREEN™)** – An optional drain down filter, similar in function to the media cartridge pre-filter is located in the discharge chamber. This filter allows any standing water from the pre-treatment chamber to drain from under the pervious pavers through the small filtration cartridge located in the discharge chamber. The drain down device addresses any vector issues, by eliminating all standing water within the MWS-Linear. Replacement of media can be performed by hand.

5. **Trim Vegetation** – The MWS-Linear utilizes multiple plants in the wetland chamber to enhance pollutant removal. The vegetation will need to be maintained (trimmed) as needed and is done as part of regular site landscaping or system maintenance. Modular Wetland Systems, Inc. recommends that the plantings are never given any fertilizer to promote plant growth or health.

6. **Evaluate Flow Hydraulic Conductivity** – The system's flow characteristics can be assessed from the discharge chamber. This inspection for adequate flow capacity should be done during a rain event. By inspecting and viewing the discharge chamber, the flow out of the system can be easily observed or measure. If flow out of the orifice is too low, it could indicate media cartridge pre-filter fouling and maintenance may need to be provided to the BioMediaGREEN as described above.

7. **WetlandMedia Maintenance** – biofiltration is provided by an advanced horizontal flow vegetated wetland chamber. This biofilter contains a mix of sorptive media, known as WetlandMedia, which is designed to supports abundant plant and biological life. The life of this media can be up to 20 years when properly maintained. The peripheral void area surrounding the perimeter of the WetlandMedia can be accessed to remove any surface clogging. The vertical risers in the middle of the WetlandMedia can also be accessed and water injected to backwash the WetlandMedia. These features allow the wetland chamber to be fully maintained to ensure the WetlandMedia will not need to

be replaced for many years. If full flow capacity cannot be restored by these steps, the WetlandMedia can be replaced.

8. **WetlandMedia Replacement** - Removal of spent WetlandMedia can be done with a shovel nose of any vacuum truck. Replacement of the WetlandMedia, although not anticipated for 20 years, is done by adding new WetlandMedia from a number of vendor supplied supersacs and added to fill the wetland chamber to recommended levels.

Reliability

The MWS-Linear is a robust water quality system designed to withstand a variety of conditions in the field. The media cartridge pre-filter containing BioMediaGREEN is designed to capture sediment and hydrocarbons and subsequently clog before the WetlandMedia in the biofiltration or wetland chamber. Once the pre-filter clogs, flow capacity decreases and the influent flows are routed around the wetland chamber through the external or internal bypass mechanism until the unit is maintained. The likelihood of this occurring is also significantly reduced by the design of the bypass. If a MWS-Linear begins to clog, it will go into bypass before flushing built up pollutants from the media(s) as bypass occurs around these mechanisms and not through their chambers. The pre-treatment chamber can also be fitted with an optional drain down system to prevent any standing water conditions in the chamber between storm events. This can be used in areas where vector control may be an issue. The current flow capacity of the MWS-Linear can easily be monitored by observing flow into the discharge chamber. Various instrumentation can be used to verify the flow rate through the system. If the system is operating at less than 100 percent, treatment flow capacity maintenance procedures can be performed in the pre-treatment chamber.

Modular Wetlands Systems, Inc. warranties that the materials used to manufacture its products will be able to withstand and remain durable to environmental conditions for a period of 5 years from the date of purchase. All other proprietary stormwater systems on the market today only offer a 1-year limited warranty.

Other Benefits

Unlike many precast stormwater treatment devices, the MWS-Linear has a vegetative component that can add aesthetics to any streetscape. The plants in the wetland chamber perform an important filtration function while also adding an aesthetically pleasing element to what may otherwise be a barren urban context. Though the aesthetic aspects of the technology are in no way assessed herein, they are mentioned here as an element that may be of interest to municipalities serving the many landscape interests of their citizens.

CONTACT INFORMATION

Corporate Headquarters

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Rhode Island Authorized Distributor

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APPENDIX A

TAPE Testing Summary & Approval

TAPE PERFORMANCE SUMMARY

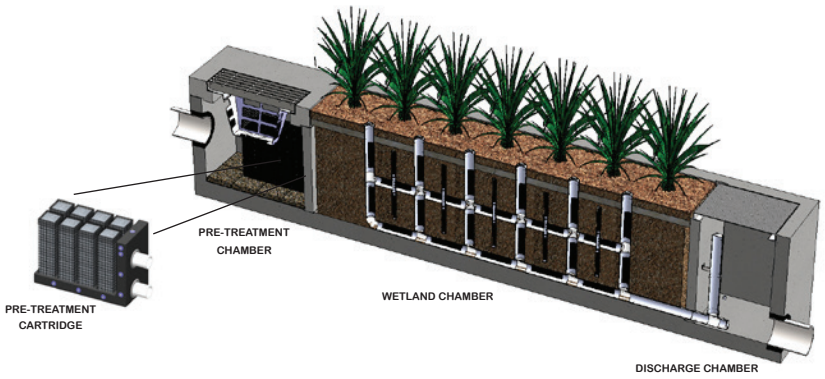
MWS-LINEAR 2.0

Application: Stand Alone Stormwater Treatment Best Management Practice
Type of Treatment: High Flow Rate Media Filtration and Biofiltration (dual-stage)

DESCRIPTION

Modular Wetland System Linear 2.0 (MWS-L 2.0) is an advanced dual-stage high flow rate media and biofiltration system for the treatment of urban stormwater runoff. Superior pollutant removal efficiencies are achieved by treating runoff through a pre-treatment chamber containing a screening device for trash and larger debris, a separation chamber for larger TSS and a series of media filter cartridges for removal of fine TSS and other particulate pollutants. Pre-treated runoff is transferred to the biofiltration chamber which contains an engineered ion exchange media designed to support an abundant plant and microbe community that captures, absorbs, transforms and uptakes pollutants through an array of physical, chemical, and biological mechanisms.

MWS-L 2.0 is a self-contained treatment train that is supplied to the job site completely assembled and ready for use. Once installed, stormwater runoff drains directly from impervious surfaces through an built-in curb inlet, drop in, or via pipe from upstream inlets or downspouts. Treated runoff is discharged from the system through an orifice control riser to assure the proper amount of flow is treated. The treated water leaving the system is connected to the storm drain system, infiltration basins, or to be re-used on site for irrigation or other uses.



TAPE PERFORMANCE

Modular Wetland System Linear 2.0 (MWS-L 2.0) completed its TAPE field testing in the spring of 2013. The Washington DOE has approved the system under the TAPE protocol. The MWS-Linear has met the performance benchmarks for the three major pollutant categories as defined by TAPE: Basic Treatment (TSS), Phosphorus and Enhanced (dissolved zinc and copper). It is the first system tested under the protocol to meet the benchmarks for all three categories.

Pollutant	Avg. Influent (mg/L)	Avg. Effluent (mg/L)	Removal Efficiency	Notes
Total Suspended Solids	75.0	15.7	85%	Summary of all data meeting TAPE parameters pertaining to this pollutant. Mean of 8 microns.
Total Phosphorus	0.227	0.074	64%	Summary of all data meeting TAPE parameters pertaining to this pollutant.
Ortho Phosphorus	0.093	0.031	67%	Summary of all data meeting TAPE parameters for total phosphorus.
Nitrogen	1.40	0.77	45%	Utilizing the Kjeldahl method (Total Kjeldahl nitrogen). Summary of all data during testing.
Dissolved Zinc	0.062	0.024	66%	Summary of all data meeting TAPE parameters pertaining to this pollutant.
Dissolved Copper	0.0086	0.0059	38%	Summary of all data meeting TAPE parameters pertaining to this pollutant.
Total Zinc	0.120	0.038	69%	Summary of all data during testing.
Total Copper	0.017	0.009	50%	Summary of all data during testing.
Motor Oil	24.157	1.133	95%	Summary of all data during testing.

NOTES:
1. The MWS-Linear was proven effective at infiltration rates of up to 121 in/hr.
2. A minimum of 10 aliquots were collected for each event.
3. Sampling was targeted to capture at least 75 percent of the hydrograph.

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MODULAR WETLANDS™
Nature & Technology Working Together In Perfect Harmony™

WASHINGTON STATE DEPARTMENT OF ECOLOGY

June 27, 2011

CONDITIONAL USE LEVEL DESIGNATION FOR BASIC TREATMENT and PILOT USE LEVEL DESIGNATION FOR ENHANCED TREATMENT

For the

MWS-Linear Modular Wetland

Ecology's Decision:

Based on MWS-Linear's application submissions, Ecology hereby issues the following use level designation:

1. Pilot use level designation (PULD) for the MWS-Linear Modular Wetland Stormwater Treatment System for Enhanced treatment
   - Sized at a hydraulic loading rate of 1 gallon per minute (gpm) per square foot (sq ft) of surface area.
2. Conditional use level designation (CULD) for the MWS-Linear Modular Wetland Stormwater Treatment System for Basic treatment
   - Sized at a hydraulic loading rate of 1 gallon per minute (gpm) per square foot (sq ft) of surface area.

The use level designation expires on January 1, 2014 unless extended by Ecology, and is subject to the conditions specified below.

Ecology's Conditions of Use:

Applicants shall design, install, and maintain the MWS - Linear Modular Wetland Stormwater Treatment System units to comply with these conditions:

1. The MWS – Linear Modular Wetland Stormwater Treatment System units must be designed, assembled, installed, operated, and maintained in accordance with Bio Clean Environment Services applicable manuals and documents and the Ecology Decision.
2. The MWS - Linear Modular Wetland Stormwater Treatment System units are approved for Basic and Enhanced treatment at the hydraulic loading rate listed above at the 15-minute water quality design flow rate (as specified in Ecology's most recent Stormwater Manual), as calculated using the latest version of the Western Washington Hydrology Model or other Ecology-approved continuous runoff model. Note that if you use Single event methods to estimate runoff flow rates, Figures 9.6a and 9.6b of the 2005 Stormwater Management

Manual for Western Washington should be used to adjust the peak single event flowrate for calculation purposes. This is done by dividing the peak 10 minute flow rate predicted by the single event method by the ratio indicated in Figure 9.6a for on-line designs, or Figure 9.6b for offline designs. The 6-month, 24-hour rainfall amount for the project site must be known to identify the appropriate ratio. The adjusted flowrate is then used to determine the Model of the MWS - Linear Modular Wetland Treatment system to be used. Note: This method is not applicable for Eastern Washington.

Systems installed in Eastern Washington must use the appropriate design flow rate from the Stormwater Management Manual for Eastern Washington (SWMMEW).

3. Bio Clean Environment Services commits to submitting a QAPP for BER review and Ecology approval by January 31, 2012 that meets the TAPE requirements for attaining a GULD for basic and enhanced treatment for the MWS - Linear Modular Wetland unit. Additional QAPPs must be reviewed and approved by the BER and Ecology for each field site in Washington State. The sites chosen (maximum of five for the PULD and ten for the CULD) should be reflective of the product's treatment intent.
4. Local jurisdictions must file a "Pilot Level Technologies Notice of Intent" form with the Department of Ecology prior to authorizing The MWS - Linear Modular Wetland Stormwater Treatment System for a pilot use level application.
5. Bio Clean Environment Services shall complete all required testing and submit a TER for BER and Ecology review by September 30, 2013.
6. Bio Clean Environment Services may request Ecology to grant deadline or expiration date extensions, upon showing cause for such extensions.
7. Discharges from the MWS - Linear Modular Wetland Stormwater Treatment System units shall not cause or contribute to water quality standards violations in receiving waters.

Applicant: *Bio Clean Environmental Services, Inc*
Applicant's Address: *P.O. Box 869*
Oceanside, CA 92054

Application Documents:

- Original Application for Conditional Use Level Designation, Modular Wetland System, Linear Stormwater Filtration System Modular Wetland Systems, Inc., January 2011
- Quality Assurance Project Plan: Modular Wetland system – Linear Treatment System performance Monitoring Project, draft, January 2011.
- Revised Application for Conditional Use Level Designation, Modular Wetland System, Linear Stormwater Filtration System Modular Wetland Systems, Inc., May 2011

Applicant's Use Level Request:

- Conditional Use Level Designation (CULD) for Basic and Enhanced treatment in accordance with Ecology's 2005 Western Washington Stormwater Manual.

Applicant's Performance Claims:

- The MWS – Linear Modular wetland is capable of removing a minimum of 80-percent of TSS from stormwater with influent concentrations between 100 and 200 mg/l.
- The MWS – Linear Modular wetland is capable of removing a minimum of 50-percent of Total Phosphorus from stormwater with influent concentrations between 0.1 and 0.5 mg/l.
- The MWS – Linear Modular wetland is capable of removing a minimum of 30-percent of dissolved Copper from stormwater with influent concentrations between 0.003 and 0.020 mg/l.
- The MWS – Linear Modular wetland is capable of removing a minimum of 60-percent of dissolved Zinc from stormwater with influent concentrations between 0.02 and 0.30 mg/l.

TAPE Program Recommendations:

The TAPE Program finds that:

- Bio Clean Environment Services should be given the opportunity to demonstrate, through additional laboratory and field-testing, whether the MWS - Linear Modular Wetland Stormwater Treatment System filter system can attain Ecology's Basic and Enhanced treatment goals.

Findings of Fact:

- Capability to remove 99percent of total suspended solids (using Sil-Co-Sil 106) in a quarter-scale model with influent concentrations of 270 mg/L.
- Capability to remove 91percent of total suspended solids (using Sil-Co-Sil 106) in laboratory conditions with influent concentrations of 84.6 mg/L at a flow rate of 3.0 gpm per square foot of media.
- Capability to remove 93-percent of dissolved Copper in a quarter-scale model with influent concentrations of 0.757 mg/L.
- Capability to remove 79-percent of dissolved Copper in laboratory conditions with influent concentrations of 0.567 mg/L at a flow rate of 3.0 gpm per square foot of media.
- Capability to remove 80.5-percent of dissolved Zinc in a quarter-scale model with influent concentrations of 0.95 mg/L at a flow rate of 3.0 gpm per square foot of media.
- Capability to remove 78-percent of dissolved Zinc in laboratory conditions with influent concentrations of 0.75 mg/L at a flow rate of 3.0 gpm per square foot of media.

Issues to be addressed by the Company:

1. The MWS - Linear Modular Wetland Stormwater Treatment System must show that it can reliably attain the minimum percent removal criteria for Basic and Enhanced treatment for runoff found on local highways, parking lots, and other high-use areas at the design-operating rate in accordance with the Ecology TAPE protocols. Bio Clean Environment Services should test a variety of operating rates to establish conservative

design rates. Pollutant loading capacities should also be determined to better predict maintenance cycles.

2. The system should be tested under normal operating conditions, such that the settling basin is partially filled with pollutants. Results obtained for "clean" systems may not be representative of typical performance.
3. Calculation of treatment efficiency shall be in accordance with the 2011 Revision of the *Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE).*
4. A discussion of treatment efficiency (percent removed) as flow rates change shall be included in the Technical Evaluation Report.
5. Field-testing should be conducted at sites that are indicative of the treatment goals.
6. Testing should be conducted to obtain information about maintenance requirements in order to come up with a maintenance cycle.
7. Loading tests should be conducted on the units to determine maximum treatment life of the system.

Technology Description:

Download at www.biocleanenvironmental.com

Contact Information:

Applicant: Greg Kent

Bio Clean Environment System, Inc.
P.O. Box 869
Oceanside, CA 92054
gkent@biocleanenvironmental.net

Applicant website: www.biocleanenvironmental.com

Ecology web link: http://www.ecy.wa.gov/programs/wg/stormwater/newtech/index.html

Ecology: Douglas C. Howie, P.E. Water Quality Program (360) 407-6444
douglas.howie@ecy.wa.gov

APPENDIX B

Installation Manual

Installation Guidelines for Modular Wetland System

Delivery & Unloading/Lifting

1. Modular Wetland Systems, Inc. shall deliver the unit(s) to the site in coordination with the Contractor.

2. The Contractor will require spreader bars and chains/cables to safely and securely lift the main structure, lids and risers (if applicable). Modular Wetlands will supply a set of suitable lifting hooks, knuckles, shackles and eye bolts with each project at no extra charge.

3. The main structure and lid can be lifted together or separately.

   Please see Modular Wetland Weights and Lifting Details. Contact Modular Wetlands for additional lifting details.

Inspection

1. Inspection of the Modular Wetland unit and all parts contained in or shipped outside of the unit shall be inspected at time of delivery by the site Engineer/Inspector and the Contractor. Any non-conformance to approved drawings or damage to any part of the system shall be documented on the Modular Wetland shipping ticket. Damage to the unit during and after unloading shall be corrected at the expense of the Contractor. Any necessary repairs to the Modular Wetland unit shall be made to the acceptance of the Engineer/Inspector.

Site Preparation

1. The Contractor is responsible for providing adequate and complete site/inlet protection when the Modular Wetland unit is installed prior to final site stabilization (full landscaping, grass cover, final paving, and street sweeping completed).

2. The Contractor shall adhere to all jurisdictional and/or OSHA safety rules in providing temporary shoring of the excavation.

3. The Contractor or Owner is responsible for appropriately barricading the Modular Wetland unit from traffic (in accordance with local codes).

Installation Guidelines for Modular Wetland System

Installation

1. Each unit shall be constructed at the locations and elevations according to the sizes shown on the approved drawings. Any modifications to the elevation or location shall be at the direction of and approved by the Engineer.

2. The unit shall be placed on the compacted sub-grade with a minimum 6-inch gravel base matching the final grade of the curb line in the area of the unit. The unit is to be placed such that the unit and top slab match the grade of the curb in the area of the unit. Compact undisturbed sub-grade materials to 95% of maximum density at +1% to 2% of the optimum moisture. Unsuitable material below sub-grade shall be replaced to site engineer's approval. Please see Modular Wetlands Weights and Lifting Details. Contact Modular Wetlands for guidance where slope exceeds 5%.

3. Once the unit is set, the internal wooden forms and protective silt fabric cover must be left intact (if WetlandMedia pre-installed). The top lid(s) should be sealed onto the box section before backfilling, using a non-shrink grout, butyl rubber or similar waterproof seal. The boards on the top of the lid and boards sealed in the unit's throat must NOT be removed. The Supplier will remove these sections at the time of activation.

4. Outlet connections shall be aligned and sealed to meet the approved drawings with modifications necessary to meet site conditions and local regulations. The correct outlet will be marked on the Modular Wetland unit.

5. Backfilling should be performed in a careful manner, bringing the appropriate fill material up in 6-inch lifts on all sides. Precast sections shall be set in a manner that will result in a watertight joint. In all instances, installation of the Modular Wetland unit shall conform to ASTM specification C891 "Standard Practice for Installation of Underground Precast Utility Structures" unless specified otherwise in contract documents.

6. It is the responsibility of the Contractor to provide curb and gutter and transition to the Modular Wetland unit for proper stormwater flow into the system through the throat, pipe or grate opening. A standard drawing of the throat and gutter detail is available in the following section; however the plans and contract documents supersede all standard drawings. Several variations of the standard design are available. Effective bypass for the Modular Wetland System is essential for correct operation (i.e. bypass to an overflow at lower elevation).

Installation Procedure

A set of lifting hooks, shackles, knuckles and eye bolts are provided by Modular Wetlands with the first delivery of every project.

The contractor **MUST** provide all rigging And lifting apparatus, such as all cables and chains or straps.

It is the contractor's responsibility to provide suitable lifting equipment to off-load the Modular Wetland unit.

Modular Wetland units are designed to be off-loaded using the contractor's spreader bar.

1. Apply Butyl Tape Seal

Apply butyl tape seal along the top of the box section. Butyl tape seal is provided with every unit.

Modular Wetland installed protective throat board and installed silt fabric must be left in place to protect the unit from construction sediment.

2. Unload and Set Box

Unload the Modular Wetland unit
the prepared hole with appropriate sub-grade.*

* Compacted sub-grade with a minimum
of six inches of gravel base which must match
the final grade of curb line the area of the unit.

3. Set Top On Box

Set the top slab on the box.

The Contractor is responsible for providing
adequate and complete site/inlet protection
when the Modular Wetland is installed prior
to final site stabilization (full landscaping,
grass cover, final paving, and street sweeping
completed).

4. Connect Outfall Pipe

The correct outlet will be marked on the
Modular Wetland.

Invert of outlet pipe **MUST** be even
with the floor of the system.

5. Install Curb & Gutter

It is the responsibility of the Contractor to provide curb and gutter and transition to the Modular Wetland for proper flow into the system through a 5”- 7” throat opening. A standard drawing of the throat and gutter detail in the following section. CONTRACTOR RESPONSIBLE FOR GROUTING IN ANY VISIBLE LIFTING POINTS.

6. Activation

Activation is performed **ONLY** by Modular Wetland personnel.

Activation can occur once the project site is fully stabilized (full landscaping, grass cover, final paving and street sweeping completed) and there is a 5” - 7” throat opening.

Call 760-433-7640 to schedule your activation.

NOTE: WetlandMedia Installation

For Larger models (MWS-L-4-13 and above) the system will be delivered without WetlandMedia pre-installed to minimize pick weight and prevent contamination of the media during construction. For these models the WetlandMedia will be delivered in bulk or in super sacks. It will be responsibility of the contractor to fill the system with the WetlandMedia during the installation process. Installation of the WetlandMedia can be done after the unit is fully installed to avoid contamination. See following pages for details.

WetlandMedia Install (if applicable)

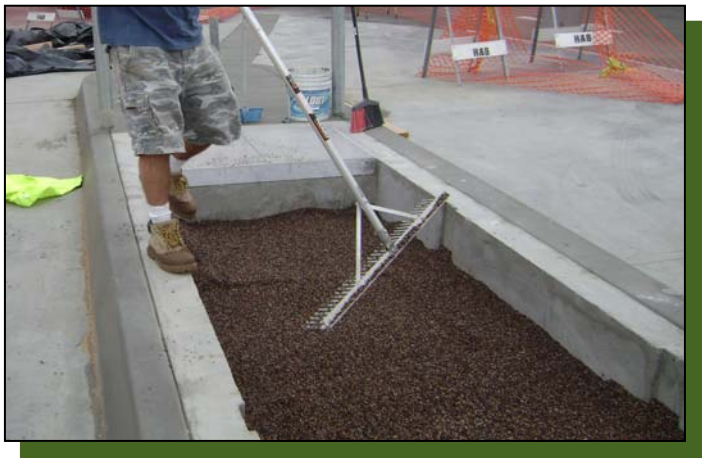
1. Fill WetlandMedia

Position super sack of WetlandMedia over wetland chamber. Bottom of sack should not be more than 2’ above top of system. Open sack and fill evenly*.

* One to several hundred cubic yards of WetlandMedia will be required based upon the model number and size of the system. For large scale jobs WetlandMedia will be delivered in bulk and will require a bobcat of similar to fill the system. All equipment is the responsibility of the contractor.

2. Install Plant Propagation Layer

Fill WetlandMedia up to 9” below the top of the wetland chamber. Level out the WetlandMedia as shown. Ensure that the level does not vary more than one inch or plant growth will be affected.



3. Install Plant Propagation Layer

Utilize plant propagation blocks provided by the manufacturer. Each block is approximately 40” by 6” by 3” thick. Blocks shall be placed side by side and end to end and cover the entire length and width of the wetland chamber unless specified.

4. Finish Filling WetlandMedia

After plant propagation blocks are installed repeat step 1 and fill the system to the top of the wetland chamber as shown. WetlandMedia must be filled within 2” of the top of the unit.

5. Planting

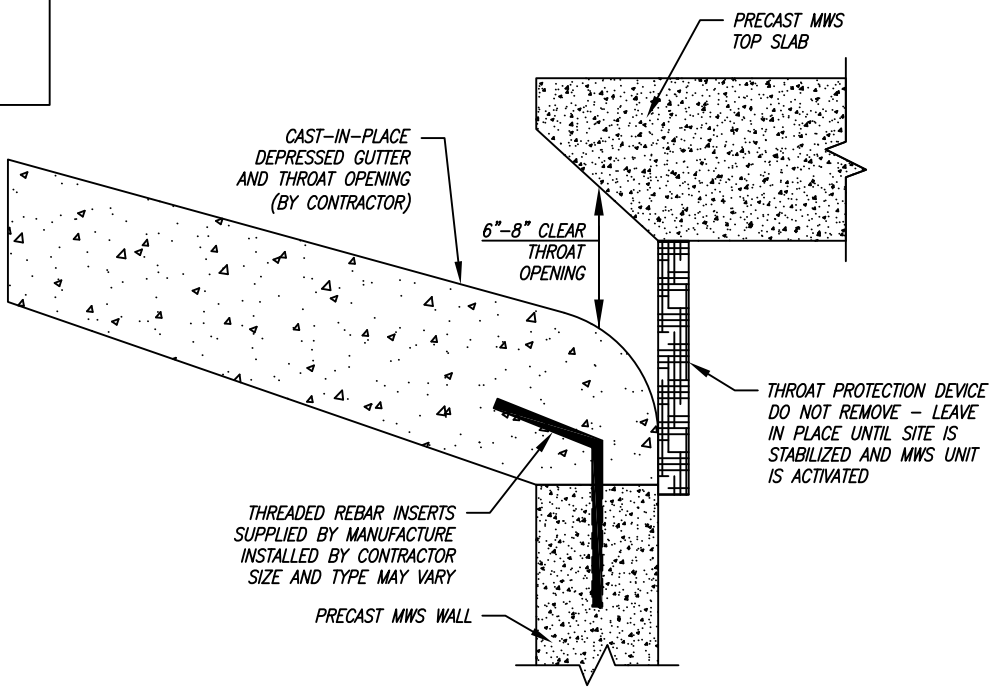
After system is filled with WetlandMedia planting of vegetation can begin. Utilizing 1 gallon plants dig down until The plant propagation blocks are reached. Remove plant and it’s root ball from the container. Set the bottom of the root ball on the tops of the blocks. Fill hole back in with WetlandMedia. After planting a thorough watering of the plants is necessary. The plant propagation blocks must be saturated to provide a water source for the plants during the establishment phase. It is recommended that hand watering is done three times a week for the first two months. Hand water can be supplemented with drip or spray irrigation after the second week. Please call the manufacturer for more details on plants, planting arrangement and irrigation options.

NOTE: planting is required on all units, including units delivered with WetlandMedia pre-installed.

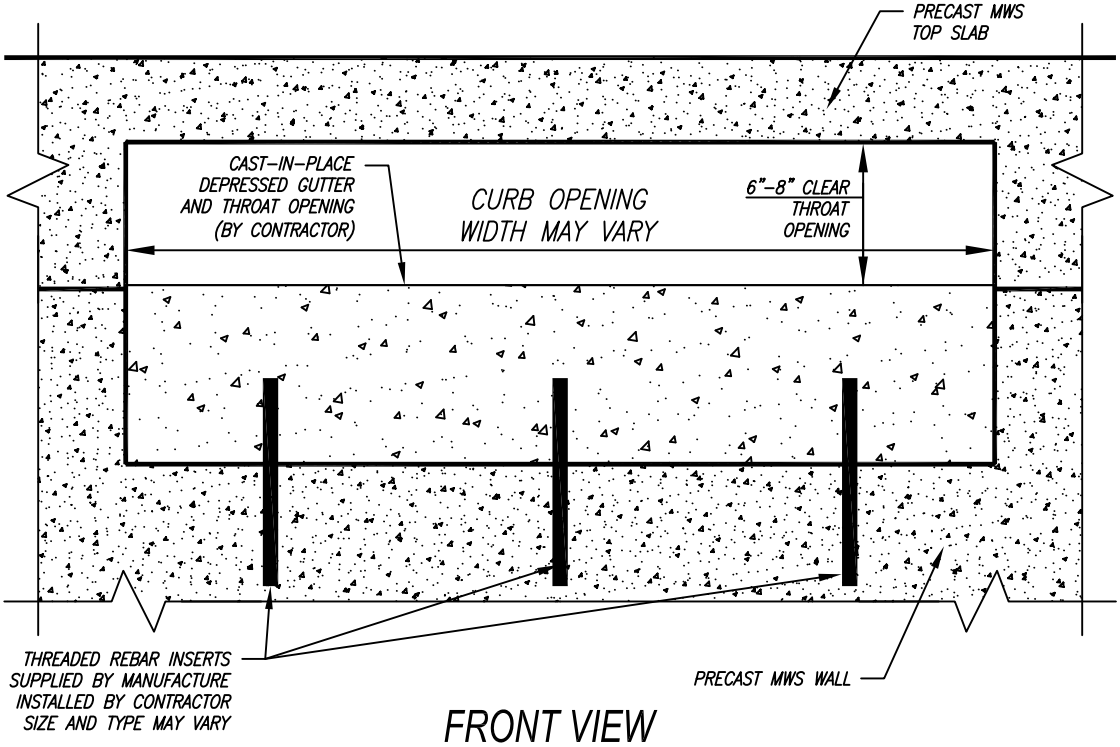
Curb and Gutter Details

Modular Wetland System, Inc.
P. 760.433-7640
F. 760-433-3176
E. Info@modularwetlands.com

www.modularwetlands.com



SECTION VIEW
STANDARD MODULAR WETLAND CURB OPENING



FRONT VIEW
STANDARD MODULAR WETLAND CURB OPENING

MODULAR WETLAND SYSTEMS INC.
P.O. BOX 869
OCEANSIDE, CA 92049
www.ModularWetlands.com

	NAME	DATE
DRAWN	John	5/3/13
EDITED		

TITLE: MWS LINEAR 2.0 CURB INLET DETAILS

COMMENTS:

SIZE	DWG. NO.	REV

SCALE NTS	UNITS = INCHES	SHEET 1 OF 1

Weights and Lifting Details

Modular Wetland System, Inc.
P. 760.433-7640
F. 760-433-3176
E. Info@modularwetlands.com

www.modularwetlands.com

MWS-L 2.0 Max Pick Weights

Model #	Size (O.D)	Size (I.D)	Unit Weight (lbs)	Media Weight (lbs)	Total Weight (lbs)
MWS-L-4-4	5' x 5'	4' x 4'	7500.0	1607.7	9107.7
MWS-L-4-6 MWS-L-4-6.5	5' x 7' 5 x 7.5'	4' x 6' 4' x 6.5'	11,000 11,500	1798.9	12,619.2 13,119.2
MWS-L-4-8	5' x 9'	8' x 4'	12500	3966	16466
MWS-L-4-13	5' x 14'	13' x 4'	21200	5895	27095
MWS-L-4-15	5' x 16'	15' x 4'	23700	8039	31739
MWS-L-4-17	5' x 18'	17' x 4'	26500	10182	36682
MWS-L-4-19	5' x 20'	19' x 4'	28300	12326	40626
MWS-L-4-21	5' x 22'	21' x 4'	30000	14470	44470
MWS-L-6-8	7' x 9'	6' x 8'	24000	6109	30109
MWS-L-8-8	9' x 9'	8' x 8'	32000	8253	40253
MWS-L-8-12	9' x 13'	8' x 12'	44000	12540	56540
MWS-L-8-16	9' x 17'	8' x 16'	47000	16828	63828
			Max Pick Weight if Shipped Without Media Installed		Max Pick Weight if Shipped With Media Installed

Note: All weights listed hereon are standard max pick weights, actual pick weights may vary based upon state and local regulations and variation in concerte and rebar standards. For project specific pick weights contact the manufacturer prior to shipping of the unit(s). Is is the contractors responsibility to off-load the unit with an adequate size crane. Units are shipped with WetlandMEDIA in superbags and installed by contractor.

When Available see project contract terms, if lifting points are on the inside of the unit due to custom designs or installations requiring pionts to be on the inside the media will be shipped in bags and the contractor will be reponsibile to install after the unit is installed. For example, units places against a wall.

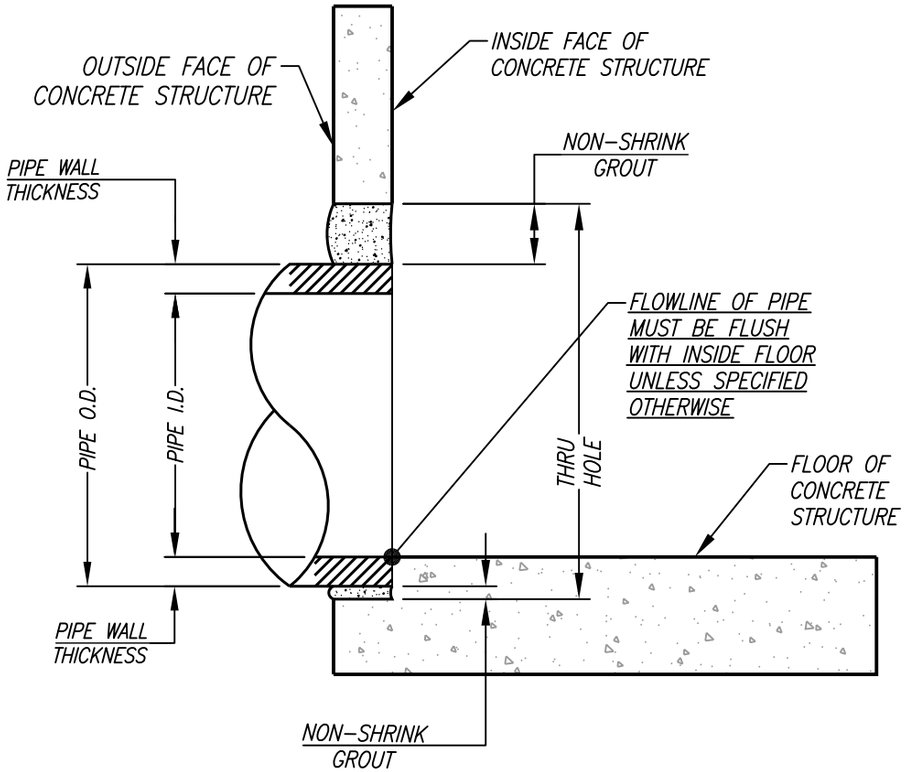
For Questions or Comments Please Call 888-566-3938 or email: info@modularwetlands.com

MODULAR WETLANDS™

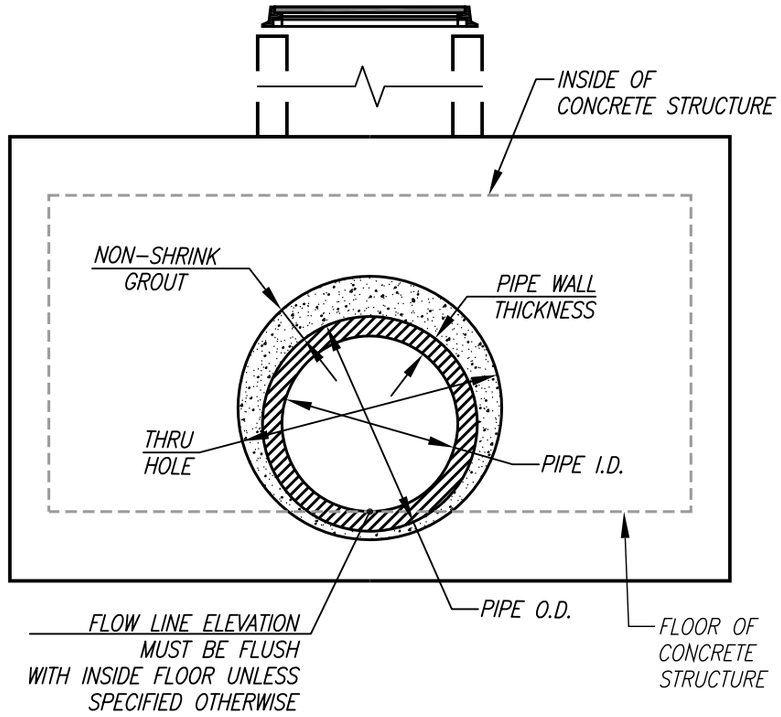
Connection Details

Modular Wetland System, Inc.
P. 760.433-7640
F. 760-433-3176
E. Info@modularwetlands.com

www.modularwetlands.com



ELEVATION VIEW



END VIEW

INSTALLATION NOTES

1. ALL CONNECTION PIPES SUPPLIED AND INSTALLED BY CONTRACTOR. MODULAR WETLAND UNIT WILL BE DELIVERED WITH A THRU HOLE AND ITS THE CONTRACTORS RESPONSIBILITY TO SUPPLY PIPE, AND ALL LABOR AND MATERIAL TO CONNECT PIPE AND SEAL UNIT WATER TIGHT INCLUDING BUT NOT LIMITED TO GROUT, CONCRETE LUG, REBAR, PLUG, ANCHORS, COUPLER, FITTINGS AND/OR ALL SUPPORT AND CONNECTING HARDWARE.
2. ALL CONNECTIONS ARE TO BE FLUSH WITH THE INSIDE SURFACE OF THE CONCRETE STRUCTURE. (CAN NOT INTRUDE BEYOND FLUSH) ALL PIPE FLOWLINES SHALL BE FLUSH WITH INSIDE FLOOR UNLESS SPECIFIED OTHERWISE.
3. ALL GROUT AND/OR CONCRETE SHALL BE NON–SHRINK AND MEET OR EXCEED LOCAL PIPE CONNECTION STANDARDS.
4. REFER TO AGENCY SPECIFICATIONS WHERE APPLICABLE.

MODULAR WETLANDS

PIPE CONNECTION
STANDARD DETAIL

APPENDIX C

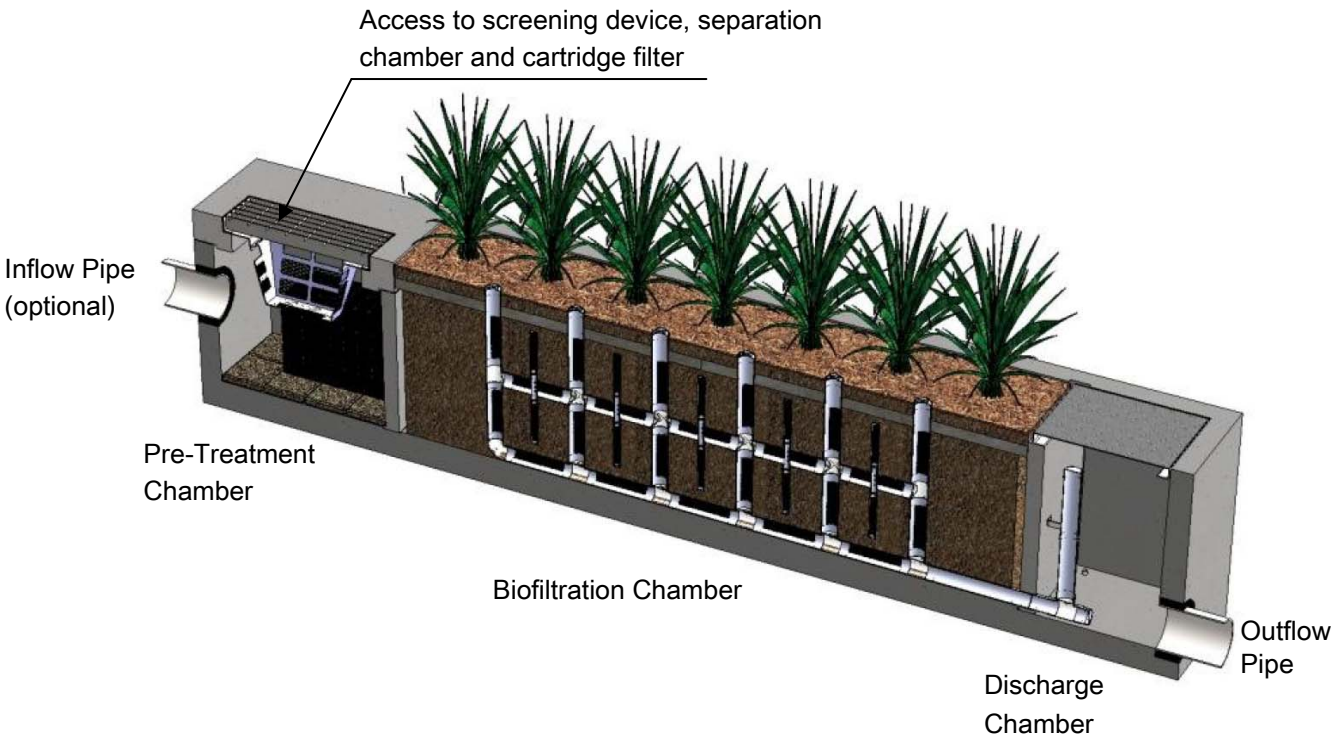
Maintenance Manual

Maintenance Guidelines for Modular Wetland System - Linear

Maintenance Summary

- Remove Sediment from Separation Chamber – average maintenance interval is 12 to 24 months.
  - (*10 minute average service time*).
- Replace Cartridge Filter Media – average maintenance interval 12 to 24 months.
  - (*10-15 minute per cartridge average service time*).
- Trim Vegetation – average maintenance interval is 6 to 12 months.
  - (*Service time varies*).

System Diagram



Maintenance Procedures

Separation Chamber

1. Perform maintenance procedures of screening device listed above before maintaining the separation chamber.
2. With a pressure washer spray down pollutants accumulated on walls and cartridge filters.
3. Vacuum out Separation Chamber and remove all accumulated pollutants. Replace screening device, grate or manhole cover when completed.

Cartridge Filters

1. Perform maintenance procedures on screening device and separation chamber before maintaining cartridge filters.
2. Enter separation chamber.
3. Unscrew the two bolts holding the lid on each cartridge filter and remove lid.
4. Remove each of 4 to 8 media cages holding the media in place.
5. Spray down the cartridge filter to remove any accumulated pollutants.
6. Vacuum out old media and accumulated pollutants.
7. Reinstall media cages and fill with new media from manufacturer or outside supplier. Manufacturer will provide specification of media and sources to purchase.
8. Replace the lid and tighten down bolts. Replace screening device, grate or manhole cover when completed.

Maintenance Notes

1. Following maintenance and/or inspection, it is recommended the maintenance operator prepare a maintenance/inspection record. The record should include any maintenance activities performed, amount and description of debris collected, and condition of the system and its various filter mechanisms.

2. The owner should keep maintenance/inspection record(s) for a minimum of five years from the date of maintenance. These records should be made available to the governing municipality for inspection upon request at any time.

3. Transport all debris, trash, organics and sediments to approved facility for disposal in accordance with local and state requirements.

4. Entry into chambers may require confined space training based on state and local regulations.

5. No fertilizer shall be used in the Biofiltration Chamber.

6. Irrigation should be provided as recommended by manufacturer and/or landscape architect. Amount of irrigation required is dependent on plant species. Some plants may require irrigation.

Maintenance Procedure Illustration

Separation Chamber

The separation chamber is located directly beneath the screening device. It can be quickly cleaned using a vacuum truck or by hand. A pressure washer is useful to assist in the cleaning process.

Cartridge Filters

The cartridge filters are located in the Pre-Treatment chamber connected to the wall adjacent to the biofiltration chamber. The cartridges have removable tops to access the individual media filters. Once the cartridge is open media can be easily removed and replaced by hand or a vacuum truck.

Trim Vegetation

Vegetation should be maintained in the same manner as surrounding vegetation and trimmed as needed. No fertilizer shall be used on the plants. Irrigation per the recommendation of the manufacturer and or landscape architect. Different types of vegetation requires different amounts of irrigation.

Maintenance Report

Modular Wetland System, Inc.
P. 760.433-7640
F. 760-433-3176
E. Info@modularwetlands.com

www.modularwetlands.com

Inspection Report
Modular Wetlands System

Project Name _____

Project Address _____
(city) (Zip Code)

Owner / Management Company _____

Contact _____ Phone ( ) –

Inspector Name _____ Date ____/____/____ Time _____ AM / PM

For Office Use Only
(Reviewed By)
(Date)
Office personnel to complete section to the left.

Type of Inspection ☐ Routine ☐ Follow Up ☐ Complaint ☐ Storm Storm Event in Last 72-hours? ☐ No ☐ Yes

Weather Condition _____ Additional Notes _____

Inspection Checklist

Modular Wetland System Type (Curb, Grate or UG Vault): _____ Size (22', 14' or etc.): _____

Structural Integrity:	**Yes**	**No**	**Comments**
Damage to pre-treatment access cover (manhole cover/grate) or cannot be opened using normal lifting pressure?			
Damage to discharge chamber access cover (manhole cover/grate) or cannot be opened using normal lifting pressure?			
Does the MWS unit show signs of structural deterioration (cracks in the wall, damage to frame)?			
Is the inlet/outlet pipe or drain down pipe damaged or otherwise not functioning properly?			
Working Condition:			
Is there evidence of illicit discharge or excessive oil, grease, or other automobile fluids entering and clogging the unit?			
Is there standing water in inappropriate areas after a dry period?			
Is the filter insert (if applicable) at capacity and/or is there an accumulation of debris/trash on the shelf system?			
Does the depth of sediment/trash/debris suggest a blockage of the inflow pipe, bypass or cartridge filter? If yes, specify which one in the comments section. Note depth of accumulation in in pre-treatment chamber.			Depth:
Does the cartridge filter media need replacement in pre-treatment chamber and/or discharge chamber?			Chamber:
Any signs of improper functioning in the discharge chamber? Note issues in comments section.			
Other Inspection Items:			
Is there an accumulation of sediment/trash/debris in the wetland media (if applicable)?			
Is it evident that the plants are alive and healthy (if applicable)? Please note Plant Information below.			
Is there a septic or foul odor coming from inside the system?			

Waste:	**Yes**	**No**
Sediment / Silt / Clay		
Trash / Bags / Bottles		
Green Waste / Leaves / Foliage		

Recommended Maintenance	
No Cleaning Needed	
Schedule Maintenance as Planned	
Needs Immediate Maintenance	

Plant Information	
Damage to Plants	
Plant Replacement	
Plant Trimming	

Additional Notes:

2972 San Luis Rey Road, Oceanside, CA 92058 P (760) 433-7640 F (760) 433-3176

Inspection Form

Modular Wetland System, Inc.
P. 760.433-7640
F. 760-433-3176
E. Info@modularwetlands.com

www.modularwetlands.com

Cleaning and Maintenance Report
Modular Wetlands System

Project Name _____

Project Address _____
(city) (Zip Code)

Owner / Management Company _____

Contact _____ Phone ( ) –

Inspector Name _____ Date ____/____/____ Time _____ AM / PM

Type of Inspection ☐ Routine ☐ Follow Up ☐ Complaint ☐ Storm Storm Event in Last 72-hours? ☐ No ☐ Yes

Weather Condition _____ Additional Notes _____

For Office Use Only
(Reviewed By)
(Date)
Office personnel to complete section to the left.

Site Map #	GPS Coordinates of Insert	Manufacturer / Description / Sizing	Trash Accumulation	Foliage Accumulation	Sediment Accumulation	Total Debris Accumulation	Condition of Media 25/50/75/100 (will be changed @ 75%)	Operational Per Manufactures' Specifications (If not, why?)
	Lat: Long:	MWS Catch Basins						
		MWS Sedimentation Basin						
		Media Filter Condition						
		Plant Condition						
		Drain Down Media Condition						
		Discharge Chamber Condition						
		Drain Down Pipe Condition						
		Inlet and Outlet Pipe Condition						

Comments:

2972 San Luis Rey Road, Oceanside, CA 92058 P. 760.433.7640 F. 760.433.3176

APPENDIX D

Plant List

Modular Wetland System - Linear® Plants for Hardy Zone 6

Common Name ***Latin Name***	**Sun**	**Hardy Range**	**Height**	**Flower Color**
Japanese sweet flag, Japanese rush *Acorus gramineus*	full sun to partial shade	USDA Zones 6-9	.5 to 1.5 feet	green
drooping sedge, weeping sedge *Carex pendula*	partial shade	USDA Zones 5-9	2 to 4 feet	green
Japanese blood grass, cogongrass, kunai *Imperata cylindrica*	full sun to partial shade	USDA Zones 5-9	2 to 4 feet	green
cattail, reed-mace *Typha latifolia*	full sun	USDA Zones 2-11	3 to 9 feet	brown
Oshima sedge, Oshima kan sedge *Carex oshimensis*	full sun to partial shade	USDA Zones 5-9	1 to 2 feet	brown
little bluestem, seacoast bluestem *Schizachyrium scoparium*	full sun to partial shade	USDA Zones 3-9	.5 to 3 feet	brown
Vetiveria zizanioides (L.) Nash Vetiver Grass	full sun	USDA Zones 5-11	2 to 8 feet	green
giant wild rye *Leymus condensatus*	full sun	USDA Zones 3-11	4 to 8 feet	brown
Gulf muhlygrass, mist grass, hairawn muhly *Muhlenbergia capillaris*	full sun to partial shade	USDA Zones 5-10	2 to 3 feet	pinkish purple
horsetail, scouring rush, E. prealtum *Equisetum hyemale*	full sun to light shade	USDA Zones 3-11	2 to 4 feet	n/a

lavender *Lavandula L.*	sun	USDA Zones 5-10	1 to 2 feet	purple
big bluestem, turkey foot bluestem *Andropogon gerardii*	sun	USDA Zones 3-9	4 to 6 feet	red
switchgrass, prairie switchgrass *Panicum virgatum*	full sun to partial shade	USDA Zones 4-9	3 to 4 feet	green/white
indiangrass, yellow indiangrass *Sorghastrum nutans*	full sun to partial shade	USDA Zones 3-9	2 to 6 feet	redish/brown
sea oats, Chasmanthium paniculatum *Uniola paniculata*	full sun to partial shade	USDA Zones 6-10	3 to 6 feet	golden/brown
Cape lily, Powell's crinum lily *Crinum X powellii*	full sun to partial shade	USDA Zones 6-11	3 to 4 feet	white/pink
purple coneflower *Echinacea purpurea*	full sun to partial shade	USDA Zones 3-9	2 to 3 feet	pink
Joe Pye weed, queen-of-the-meadow *Eupatorium fistulosum*	full sun to partial shade	USDA Zones 3-9	3 to 10 feet	pink/purple
whirling butterflies, white gaura *Gaura lindheimeri*	full sun to partial shade	USDA Zones 5-10	2 to 4 feet	white/pink
oxeye sunflower, false sunflower *Heliopsis helianthoides*	full sun to partial shade	USDA Zones 2-9	3 to 5 feet	yellow
daylily *Hemerocallis hybrids*	full sun to partial shade	USDA Zones 2-10	1 to 3.5 feet	various
summer snowflake, giant snowflake *Leucojum aestivum*	full sun to partial shade	USDA Zones 4-9	1 to 2 feet	white

rose campion, mullein pink, Dusty Miller *Lychnis coronaria*	full sun to partial shade	USDA Zones 5-8	2 to 3 feet	violet/red
Russian sage *Perovskia atriplicifolia*	full sun	USDA Zones 5-9	3 to 5 feet	purple
Adam's needle, bear grass, weak-leaf yucca *Yucca filamentosa*	full sun	USDA Zones 5-10	3 to 5 feet	white
brome hummock sedge *carex bromoides*	full sun to partial shade	USDA Zones 2-10	1 ft	green

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The Modular Wetland System - Linear® standard 22' long system will require 18 to 20 plants. Different size systems will require different plant quanitities; please contact us for detailed information.

The plants listed are tolerant to drought and have deep roots to allow for ehanced pollutant removal.

These plants are subject to availability in local areas. If you would like to use a different plant please contact us. We will work with you to ensure the chosen plants work with the projects current landscape theme.

The Modular Wetland System - Linear® should be irrigated like any other planter area. The plants in the system must receive adequate irrigation to ensure plant survival during periods of drier weather. As with all landscape areas the plants within the Modular Wetland System - Linear will require more frequent watering during the establishment period.

For more information please contact at: 760-433-7640 or email: info@modularwetlands.com

Modular Wetland System - Linear® Plants for Hardy Zone 7

Common Name ***Latin Name***	**Sun**	**Hardy Range**	**Height**	**Flower Color**
Japanese sweet flag, Japanese rush *Acorus gramineus*	full sun to partial shade	USDA Zones 6-9	.5 to 1.5 feet	green
drooping sedge, weeping sedge *Carex pendula*	partial shade	USDA Zones 5-9	2 to 4 feet	green
Japanese blood grass, cogongrass, kunai *Imperata cylindrica*	full sun to partial shade	USDA Zones 5-9	2 to 4 feet	green
cattail, reed-mace *Typha latifolia*	full sun	USDA Zones 2-11	3 to 9 feet	brown
Oshima sedge, Oshima kan sedge *Carex oshimensis*	full sun to partial shade	USDA Zones 5-9	1 to 2 feet	brown
little bluestem, seacoast bluestem *Schizachyrium scoparium*	full sun to partial shade	USDA Zones 3-9	.5 to 3 feet	brown
Vetiveria zizanioides (L.) Nash Vetiver Grass	full sun	USDA Zones 5-11	2 to 8 feet	green
giant wild rye *Leymus condensatus*	full sun	USDA Zones 3-11	4 to 8 feet	brown
society garlic, pink agapanthus *Tulbaghia violacea*	full sun to full shade	USDA Zones 7-10	1.5 to 3 feet	lavender
Gulf muhlygrass, mist grass, hairawn muhly *Muhlenbergia capillaris*	full sun to partial shade	USDA Zones 5-10	2 to 3 feet	pinkish purple

Lindheimer's muhlygrass, blue muhlygrass *Muhlenbergia lindheimeri*	full sun	USDA Zones 7-11	2 to 4 feet	purple to gray
horsetail, scouring rush, E. prealtum *Equisetum hyemale*	full sun to light shade	USDA Zones 3-11	2 to 4 feet	n/a
lavender *Lavandula L.*	sun	USDA Zones 5-10	1 to 2 feet	purple
big bluestem, turkey foot bluestem *Andropogon gerardii*	sun	USDA Zones 3-9	4 to 6 feet	red
palm sedge *Carex phyllocephala*	full sun to full shade	USDA Zones 7-10	1 to 2 feet	green
feather grass, Mexican needle grass *Nassella tenuissima*	full sun to partial shade	USDA Zones 7-11	2 to 3 feet	green/brown
switchgrass, prairie switchgrass *Panicum virgatum*	full sun to partial shade	USDA Zones 4-9	3 to 4 feet	green/white
indiangrass, yellow indiangrass *Sorghastrum nutans*	full sun to partial shade	USDA Zones 3-9	2 to 6 feet	redish/brown
sea oats, Chasmanthium paniculatum *Uniola paniculata*	full sun to partial shade	USDA Zones 6-10	3 to 6 feet	golden/brown
Cape lily, Powell's crinum lily *Crinum X powellii*	full sun to partial shade	USDA Zones 6-11	3 to 4 feet	white/pink
purple coneflower *Echinacea purpurea*	full sun to partial shade	USDA Zones 3-9	2 to 3 feet	pink
Joe Pye weed, queen-of-the-meadow *Eupatorium fistulosum*	full sun to partial shade	USDA Zones 3-9	3 to 10 feet	pink/purple
whirling butterflies, white gaura *Gaura lindheimeri*	full sun to partial shade	USDA Zones 5-10	2 to 4 feet	white/pink
oxeye sunflower, false sunflower *Heliopsis helianthoides*	full sun to partial shade	USDA Zones 2-9	3 to 5 feet	yellow

daylily *Hemerocallis hybrids*	full sun to partial shade	USDA Zones 2-10	1 to 3.5 feet	various
summer snowflake, giant snowflake *Leucojum aestivum*	full sun to partial shade	USDA Zones 4-9	1 to 2 feet	white
rose campion, mullein pink, Dusty Miller *Lychnis coronaria*	full sun to partial shade	USDA Zones 5-8	2 to 3 feet	violet/red
Russian sage *Perovskia atriplicifolia*	full sun	USDA Zones 5-9	3 to 5 feet	purple
Adam's needle, bear grass, weak-leaf yucca *Yucca filamentosa*	full sun	USDA Zones 5-10	3 to 5 feet	white
brome hummock sedge *carex bromoides*	full sun to partial shade	USDA Zones 2-10	1 ft	green

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For more information please contact at: 760-433-7640 or email: info@modularwetlands.com