Stormwater Components and Design Toolbox

Waterfront Typologies | Outfall Typologies
Storage | Soils | Plants | Aesthetics

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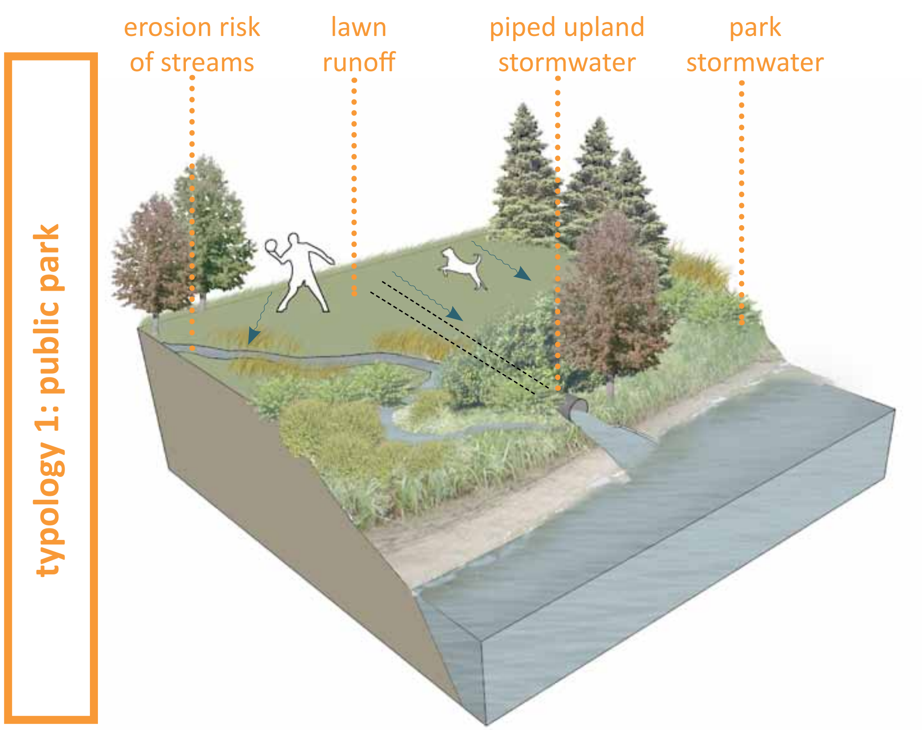
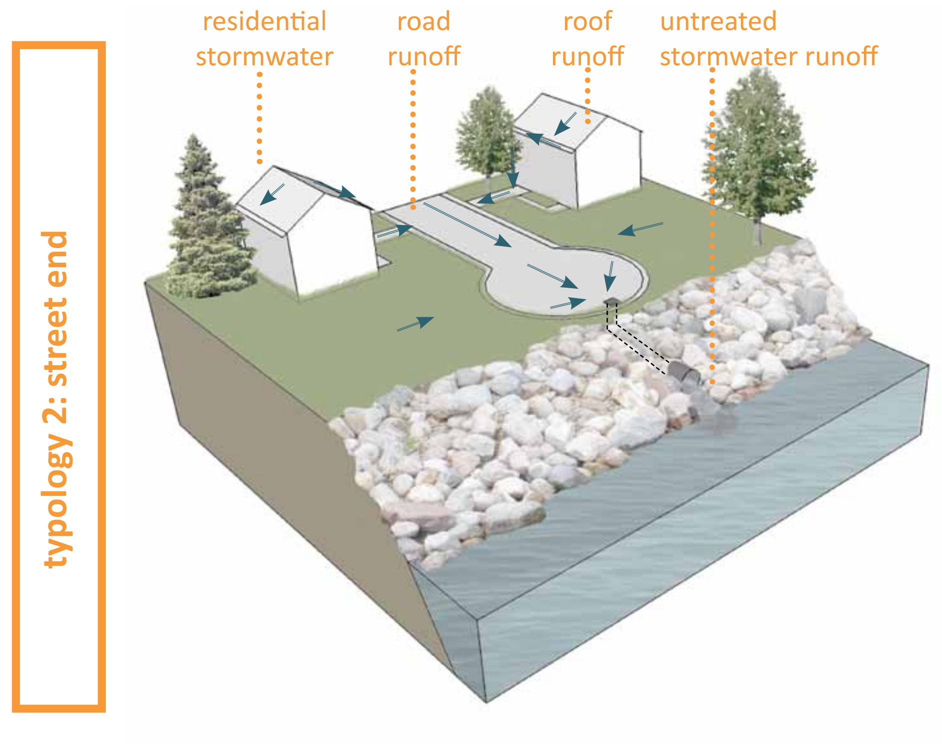
WATERFRONT TYPOLOGIES

To design successful stormwater projects on waterfronts it is helpful to have some information about the general characteristics of these complex landscapes. Here we focus on land use, slope and outfall configurations. There are a number of additional elements to consider when designing for waterfronts and of course each site has its own conditions that will need to be evaluated, however the following information provides a basis for initiating and inspiring the design process.



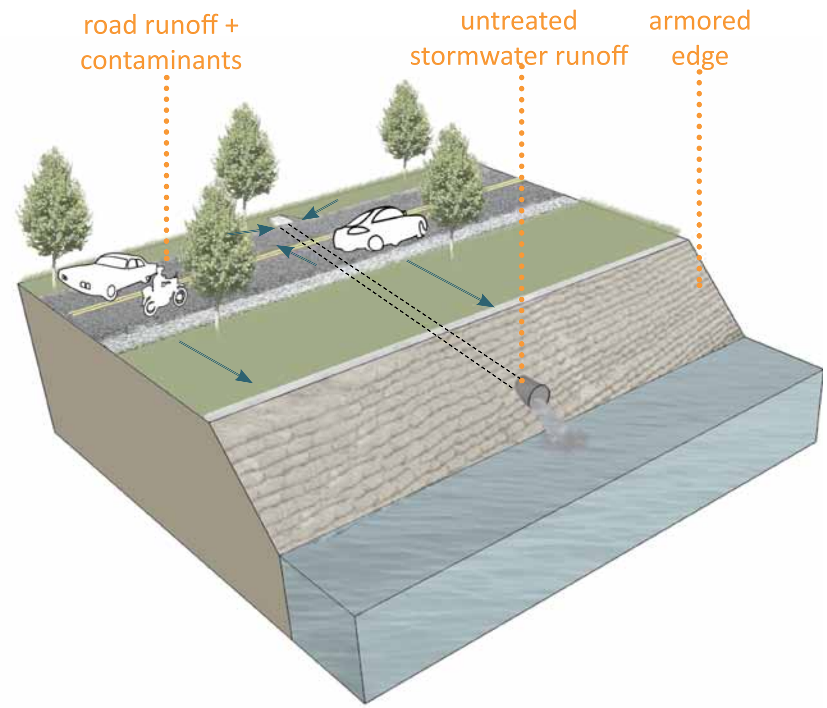


Public parks along waterfronts provide ample opportunity to reconfigure the site to incorporate stormwater treatment while also considering public use and habitat.

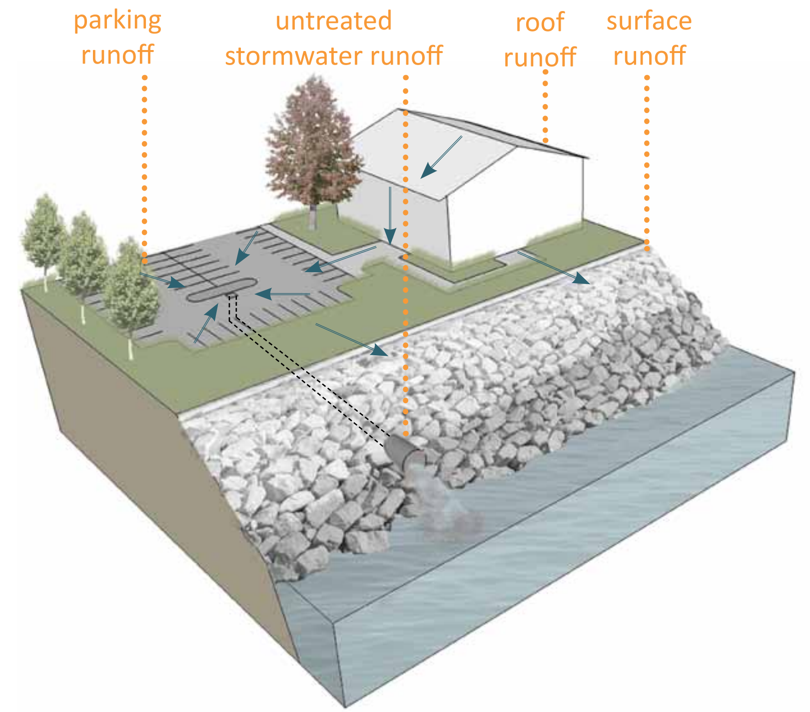
Street ends are typically confined spaces that often provide informal public use. Stormwater treatment may be limited due to space, however integrated systems should create solutions that respond to the site and public needs and perhaps inspire a treatment train up the wateshed.

WATERFRONT TYPOLOGIES

TYPOLOGY 3: ROADWAY



TYPOLOGY 4: STRUCTURE | PARKING

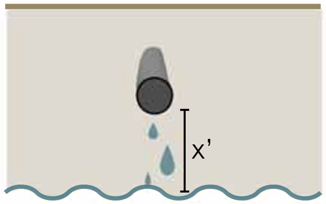


Roadways pose the most challenge due to their structural requirements that often require a piping system underground and due to the high levels of pollutants typical of roadways. Roadways also disconnect the upland from the waterfront that challenges public access and especially habitat connectivity. Solutions will have to be creative and patient.

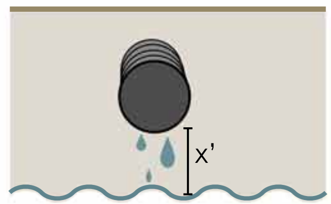
Built structures and parking areas may also limit available space for stormwater treatment while also contributing pollutants through runoff. Stormwater recycling for reuse in the building might be one solution, as well as new approaches to parking and building may also lend to treatment and other benefits.

OUTFALL TYPOLOGIES

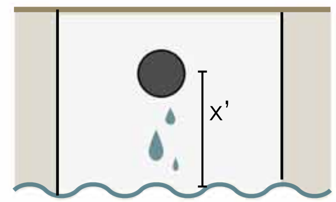
elevated pipe



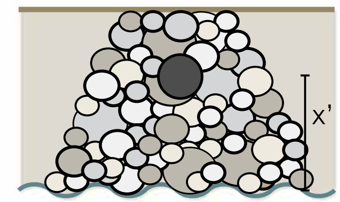
1 small diameter ~6" exposed pipe



2 large diameter ~5' exposed pipe

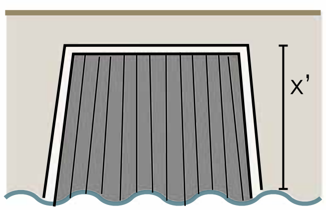


3 elevated in concrete armament/headwall

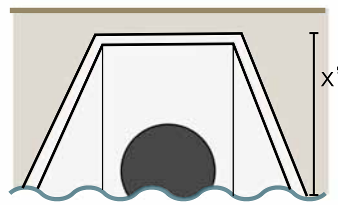


4 elevated in rocky armament/headwall

water level pipe

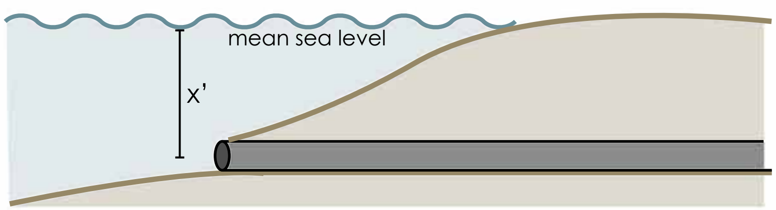


1 grated culvert

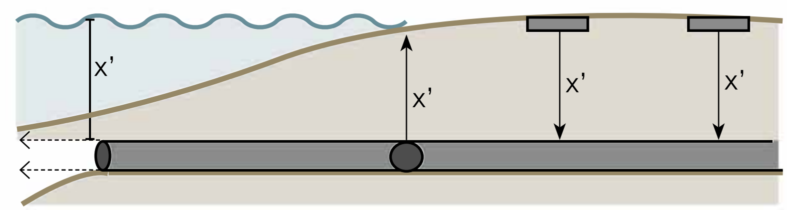


2 wingwall culvert

subwater pipe



1 pipe below mean sea level



2 elevation (x) of outfall below surface will affect design recommendations

STORMWATER STORAGE AND REUSE

To accommodate stormwater storage certain rainwater harvesting systems have been developed to intercept and store runoff. These systems can easily be adapted for waterfronts. Often these systems utilize filtration devices to allow non-potable reuse in buildings or for irrigation. The following is a brief summary of current storage systems that can also be utilized for waterfront stormwater systems.

Modular storage basin

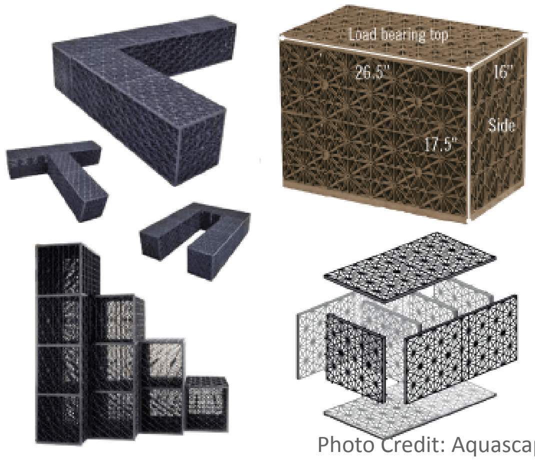


Photo Credit: Aquascape

Underground modular plastic tanks assembled by hand on-site, thereby reducing shipping and equipment costs. Can create any shape or size to fit project needs. Designed for vehicular loads up to 38 psi. Unaffected by molds, algae, soil-bourne chemicals and bacteria.

Components: EPDM rubber membrane, submersible re-circulation pumps, flexible PVC poping, overflow infiltration module, irrigation system, liner. Each module is 26.5"L x 16"W x 17.5"H, 32 gallons, 15.4 lbs.

Capacity: 500-3000 gallon kits. unlimited expansion capacity.

Concrete vault


Photo Credit: Contech Construction Products

Available in standard prefabricated sizes or can be custom fabricated to any storage capacity or shape. Concrete has a very long shelf life and high strength under load bearing surfaces, however they are expensive to transport, build and install. Concrete is a recyclable material.

Components: Cast in place or precast concrete vault with lining, piping, pumps or filters as needed, irrigation system.

Capacity: cast in place has unlimited capacity.

Above ground bladder


Photo Credit: Earth Systems NW

Above ground flexible soft surface storage device. Can be easily hid under structures such as porches or configured vertically in a water fence. Bladders can be linked together and fabric is puncture resistant. Larger systems can have a heavy gague galvanized steel frame and are wrapped in a geotextile blanket.

Components: concrete pad or compacted earth, piping and diversion overflow, galvanized steel frame, geotextile blanket, air vent, sac couplings, irrigation system. Can be as low as 2.5' tall.

Capacity: 720 gallons each water fence, up to 5,000 gallons for horizontal bladders

Sub-surface storage tanks

Photo Credit: John Deere Green Tech

Made from different materials. Polyethylene tanks are manufactured from a "food contact" grade polyethylene resin, are safe for storage of potable water and are resistant to corrosion and UV protected. Light-weight modules can be handled with a small excavator or skid steer loader. Pump assemblies can meet any irrigation flow demand. Tanks do not need to be insulated and won't freeze. Can withstand vehicular loads when installed beneath concrete.

Components: Storage tank, fine mesh vortex filters with built in first flush diversion, leaf and debris basket strainers, automatic self-cleaning filtration, pumps, control panel, manways, risers and lids, chloronators, turbidity filters and UV treatment options. 8" diameter interconnected manifold assemblies.

Capacity: Fiberglass tanks up to 50,000 gallons. Polyethylene tanks 2,000 gallon modules up to 30,000 capacity.

Tubed water storage chamber

Photo Credit: RainTech

Tubular porous corrugated "core elements" provide both structure and pore space. Curved modular design allows for infinite capacities or shapes to fit any need. Core has a 100-plus year life, is made in the United States and is made from 100% post-consumer recycled material. All materials can be placed by hand and unassembled kits allow for reduced shipping and equipment costs

Components: core elements, pipe sleeve clamps, pump and pump well, overflow, water table drain, impermeable liner, geotextile fabric, seal tape, irrigation system, optional serviceable sediment filter or fire fill well. Each core is 4" diameter, 10' long

Capacity: standard packages come in 2,500 - 10,000 gallons. Unlimited expansion capacity.

Above ground cistern

Photo Credit: Leslie Batten

Above ground cisterns can be a variety of materials:
Fiberglass: light weight, reasonably priced, long lasting, vertical or horizontal, Polyethylene: most common, lightest in weight, easy to transport, Wood lined with plastic: more aesthetic but more expensive, Galvanized sheet metal: corrosion resistant, lightweight, Concrete: poured in place or precast, most versatile to construct, Ferrocement: low cost and durable, similar to concrete but walls can be as thin as 1", Stone and Mason: very expensive and labor intensive.

Components: Tank, concrete pad, piping, pump, irrigation system, UV lining or UV filter.

Capacity: Fiberglass: 50-15,000 gallons
Polyethylene: 50-10,000 gallons
Wood: 700-37,000 gallons
Metal: 150-2500 gallons
Concrete, Ferrocement, Stone and Mason: unlimited capacity.

SOILS

Soils are the most important component of stormwater treatment systems. Soil physical, chemical and biological properties determine the effectiveness of soil stormwater treatment.

Physical: Pore size determines infiltration rate of stormwater through the soil media, which essentially determines the drainage rate of the system. In technical terms, this is called the Hydraulic Conductivity (K). The desired infiltration rate for most LID BMPs is 2-4 inches per hour. Infiltration is discussed in more detail under Retention Time.

Chemical: Three chemical properties of soils contribute to pollutant filtration efficacy of LID systems: cation exchange capacity, pH, and organic material content. Cation Exchange Capacity (CEC) is the charge associated with soil particles that establishes the soil's ability to adhere certain pollutants based on charge. Smaller particles like clay have more binding sites than larger particles like sand, thus clay is better suited for binding heavy metals and other ions to their surfaces and restricting the continued movement of the pollutants through the media. However, due to the fine texture of clay particles the infiltration rate or K value is very low meaning very little water will pass by these particles reducing adhesion. Soil pH also affects pollutant adhesion properties as it determines whether certain pollutants are dissolved or are particulate bound. Ion exchange is also affected by the state the ion is in because it will have a different charge as a solid than it will in a dissolved state. All chemicals react differently under different pH values, organic material content and even presence of other metals, or nutrients. For instance, phosphorus removal is best achieved with high pH and low organic matter, while metals are best removed with low pH and high organic matter (Clark and Pitt 2011). This is an important consideration when designing BMPs for pollutant filtration as there will be filtration trade offs between the different stormwater derived pollutants. Soils are an amazing reservoir that can bind and store metals and other ions for several decades before they become saturated and no longer contribute to the filtration process (Horner 2010). However, it is not recommended to keep pollutants in the soil media, as slight changes in conditions such as to the pH can cause the pollutants to become re-suspended.

Biological: Soil Organisms

Within the top twelve inches of soil a diverse community of algae, bacteria, fungi, actinimycetes, and protozoans work to mineralize compounds into usable forms for plants and animals, or release into the atmosphere (Minton 2002). Microorganisms are largely credited with decomposing organic material but research shows they are also critical for nutrient and even metal transformation. For instance, two different types of bacteria are required to metabolize nitrates into ammonium, a usable form of nitrogen for plants. This process requires both anaerobic conditions for denitrification and aerobic conditions for nitrification. Phosphorus is similarly degraded by microorganisms into a usable form for plant uptake. Metals such as iron can be also be transformed by bacterial processes and dissolved into solution for plant uptake or to form metal complexes. Bacterial metabolism also contributes to the degradation of organic pollutants such as petroleum hydrocarbons, phenols, phthalate esters, PCBs, pesticides and herbicides (Minton 2002). Larger soil organisms such as worms also help transform sediments trapped in the aggregate interstitial spaces into organic matter that can then be further broken down by microorganisms and plants, or manually removed to prevent nutrient loading from the treatment facilities.

Retention time (Hydraulic residence time):

The length of time water is held within a facility determines water quality treatment capacity, especially for certain pollutants. Stormwater treatment design should encourage slowing water down to allow particulates and sediments to settle out of the water column and to filter through the soil media and/or plants. Longer retention time allows greater sedimentation, and contact time with soils that increases removal of certain soluble pollutants. Longer retention times can be achieved through shallow and wide basins, or deep and narrow basins. If infiltration is the goal soil hydraulic capacity will need to be carefully studied and prepared to achieve the desired retention time and infiltration rate. If the site relies on an underdrain to convey water into another treatment unit or to the municipal water system the sizing and complexity of the treatment system will need to be carefully analyzed. Retention time needs to be carefully evaluated for standing water that may pose safety and health risks.

SOIL RECOMMENDATIONS

The following is an excerpt from the Low Impact Development Technical Guidance Manual for Puget Sound (2005):

- The texture for the soil component of the bioretention soil mix should be loamy sand (USDA Soil Textural Classification).
- The final soil mix (including compost and soil) should have a minimum long-term hydraulic conductivity of 1.0 inch/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80 percent compaction per ASTM Designation D 1557 (Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort) (Tackett, 2004). Infiltration rate and hydraulic conductivity are assumed to be approximately the same in a uniform mix soil.
- The final soil mixture should have a minimum organic content of 10 percent by dry weight per ASTM Designation D 2974 (Standard Test Method for Moisture, Ash and Organic Matter of Peat and Other Organic Soils) (Tackett, 2004). Currently, gravelly sand bioretention soil mixtures for bioretention areas are being developed and installed to provide adequate infiltration rates at 85 to 95 percent compaction. While designers anticipate good performance from this specification, the mix may be slightly less than optimal for plant growth and has not been tested long-term for plant health performance.
- Achieving the above recommendations will depend on the specific soil and compost characteristics. In general, the recommendation can be achieved with 60 to 65 percent loamy sand mixed with 35 to 40 percent compost or 30 percent sandy loam, 30 percent course sand, and 40 percent compost.
- The final soil mixture should be tested by an independent laboratory prior to installation for fertility, micronutrient analysis, and organic material content. Soil amendments per laboratory recommendations (if any) should be uniformly incorporated for optimum plant establishment and early growth (Tackett, 2004).
- Clay content for the final soil mix should be less than 5 percent.
- The pH for the soil mix should be between 5.5 and 7.0 (Stenn, 2003). If the pH falls outside of the acceptable range, it may be modified with lime to increase the pH or iron sulfate plus sulfur to lower the pH. The lime or iron sulfate must be mixed uniformly into the soil prior to use in bioretention area (Low Impact Development Center, 2004).
- Soil depth should be a minimum of 18 inches to provide acceptable minimum pollutant attenuation and good growing conditions for selected plants. A minimum depth of 24 inches should be selected for improved phosphorus and nitrogen (TKN and ammonia) removal. Deeper soil profiles (> 24 inches) can enhance phosphorus, TKN and ammonia removal (Davis, Shokouhian, Sharma and Minami, 1998). Nitrate removal in bioretention cells can be poor and in some cases cells can generate nitrate due to nitrification (Kim et al., 2003). See under-drain section for design recommendations to enhance nitrate removal. Deeper or shallower profiles may be desirable for specific plant, soil, and storm flow management objectives.
- The soil mix should be uniform and free of stones, stumps, roots or other similar material > 2 inches.
- To reduce transportation and disposal needs, on-site excavated soil, rather than imported soil, can be used. However, using on-site excavated soil for the amended soil mix may reduce control over gradation,

organic content, and final product performance, can increase project costs, and can complicate construction logistics when attempting to blend soil mix components in restricted space or during winter months (personal communication, Tracy Tackett). If on-site excavated soil is used, representative samples should be tested for gradation and adjusted, if necessary, to attain adequate infiltration capability.

- The above guidelines should provide a soil texture, organic content, and infiltration rate suitable to meet Ecology's SSC-6 "Soil Physical and Chemical Suitability for Treatment" recommendations for designing infiltration systems. A soils report evaluating these parameters should be provided to verify the treatment capability of the soil mix.

Compost:

One means for improving soil conditions is to amend the soil with compost. Compost re-introduces organic matter that helps to re-establish infiltration capacity, micro-organisms, and nutrients for plants.

Per the LID Technical Guidance Manual for Puget Sound (2005): Organic soil amendment, suitable for landscaping and stormwater management, should be a stable, mature compost derived from organic waste materials including yard debris, manures, bio-solids, wood wastes or other organic materials that meet the intent of the organic soil amendment specification. Compost stability indicates the level of microbial activity in the compost and is measured by the amount of CO2 produced over a given period of time by a sample in a closed container. Unstable compost can render nutrients temporarily unavailable and create objectionable odors.

Compost quality can be determined by examining the material and qualitative tests. A simple way to judge compost quality is to smell and examine the finished product, which should have the following characteristics (WORC, 2003):

- Earthy smell that is not sour, sweet or ammonia like.
- Brown to black in color.
- Mixed particle sizes.
- Stable temperature and does not get hot when re-wetted.
- Crumbly texture.

Care should be taken to avoid contaminating the site with pollutants or nutrients that might be derived from the compost, especially upstream of an impaired water body.

The following is a list of soil components designed to assist with stormwater management through soil amendments.

Filterra Bioretention Unit

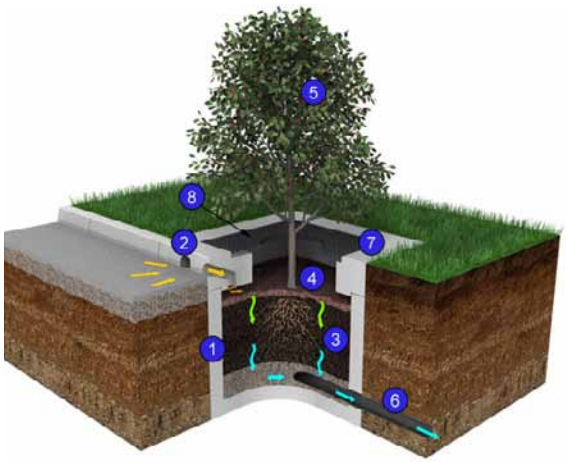


Photo Credit: Filterra

An off-the-shelf product that is compact and utilizes vegetation and an engineered soil media filter to remove pollutants from stormwater.

Components: Contained planting bed, appropriate vegetation, inlet, underdrain, Filterra media. Requires design assistance from manufacturer.

Performance: Removes total suspended solids, oil and grease, bacteria, petroleum hydrocarbon, copper, zinc, and nutrients. Requires annual maintenance.

Was approved by Washington State Dept of Ecology for General Use Level Designation.

Soure: FIlterra

Compost Filter Sock

Photo Credit: EPA

A mesh tube filled with composted material that is placed perpendicular to sheet-flow runoff to control erosion. Its oval to round cross-sectional shape, provides a three-dimensional filter that allows cleaned water to flow through while detaining the pollutants. Compost filter socks can be planted to increase long-term functionality. Industry practice for compost filter devices is that drainage areas do not exceed 0.25 acre per 100 feet of device length and flow does not exceed one cubic foot per second. Compost filter socks can be used on steeper slopes with faster flows if they are spaced more closely, stacked beside and/or on top of each other, made in larger diameters, or used in combination with other stormwater BMPs.

Components: mesh tube, compost (may need to use a blower to fill tube), stakes

Performance: total suspended solids, nutrients, herbicide, bacteria, and motor oil.

Source: Environmental Protection Agency

Compost Blanket

Photo Credit: EPA

2 inches of compost added to disturbed soils to prevent erosion, allow infiltration through the more permeable layer, and encourages seed germination and plant re-establishment.

Components: compost, tools to distribute compost

Performance: total suspended solids, metals, oil, grease, nutrients, herbicides, pesticides.

Source: Environmental Protection Agency

Compost Dam

Photo Credit: EPA

A trapezoidal shaped berm of compost placed perpendicular to sheet flow runoff. Can be vegetated to increase longevity and functionality.

Components: compost, tools to distribute compost

Performance: total suspended solids, metals, oil, grease, nutrients, herbicides, pesticides.

Source: Environmental Protection Agency