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*"The following is a compilation of design information pertaining to potential stormwater impacts on groundwater resources"*

# OREGON STORMWATER MANAGEMENT GUIDELINES

*A Review of Alternatives for Surface & Groundwaters*


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# *Oregon Stormwater Management Guidelines*

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## *Note to The Reader:*

This document outlines different methods available to remove pollutants from stormwater prior to discharging to groundwater resources. A wide range of types are included as alternatives to the use of injection wells. DEQ hopes that this compilation will assist developers and jurisdictions in choosing designs based on the site limitations and types of pollutants to be treated.

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# Oregon Stormwater Management Guidelines

## 1 BACKGROUND

Treatment facilities use a variety of mechanisms to remove pollutants from stormwater — sedimentation, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Most are designed to deal with conventional pollutants (TSS, heavy metals, and fecal coliform), and nutrients (suspended and dissolved nitrates and phosphorous). Nutrients are of concern for ground and surface water.

The following is a compilation of design information pertaining to potential stormwater impacts on groundwater resources. Included is information on limitations, types of pollutants treated, soils, suitable sites, and benefits. There are several basic types of treatment systems; those covered in this document include: infiltration, detention, retention, biofiltration, retrofitting, and others. General information on the facility type is given first and is followed by specific data (as available).

Use of two types of treatment facilities at a site, one after the other (in a chain or train), will increase effectiveness [8,9]. King County advocates setting core and special requirements to be used for specific sites. The size of the sites, regulated for stormwater, varies from 5,000 square feet in King County.

Erosion and sediment control (ESC) during development of a site is also necessary because erosion rates associated with uncontrolled construction sites are much higher than normal rates — often a thousand or more times that of undeveloped land. The erosion rate increases during construction due to the removal of soil cover, alteration of soil characteristics, and changes in site topography. These vastly accelerated erosion rates, together with the higher rates of typical urbanized areas, result in excessive deposition of sediment in wetlands, streams, springs, and drainage facilities. This excessive erosion and consequent sediment deposition can result in devastating impacts to surface water used for salmonid spawning, drinking water, destruction of wetlands, ponds and lakes due to inadvertent infilling, and flooding due to obstruction of drainage ways. Sensitive areas should be protected with additional restrictions and basin-wide restrictions may apply.

The 1997, ACWA stormwater report showed that in Oregon, urban stormwater is likely contributing to water quality standards being exceeded. It also demonstrated that the existing data base of information was adequate to characterize stormwater quality associated with specific land uses. The order of increasing pollution concentrations by land use types were: open space, residential, commercial, in-stream industrial, transportation, and in-pipe industry. This can assist planners in reevaluating existing vacant land zoning designations particularly in water quality limited basins.

In planning for site development, the developer will need to determine, in an operation plan, the type of protection to be provided to the receiving water (pollutants to be controlled and levels of control to be achieved) during construction and operation. Conveyance systems (such as piping, culverts, outfalls, swales, and ditches) or channels that take water to the infiltration system, detention, retention, and biofiltration facility need to be designed to convey the existing tributary off-site runoff and the developed on-site runoff.

Stormwater treatment facilities in the Pacific Northwest generally require the design parameter to be for either a 2- 10- 25-year or 100-year, 24-hour storm event depending upon the site location and potential for pollution. Localized and long-term groundwater impacts are of concern as they affect or relate to the movement of water on or near the surface, such as stream base flow, wetlands, springs, infiltration systems, and wells.

The protection of groundwater quality is becoming an issue of concern, and increased safeguards are being required. Groundwater contamination by stormwater has been found most often in areas using large dry wells to infiltrate stormwater, especially in commercial and industrial areas (12,18). An applicant should check with local water purveyors to determine if there are sole source aquifers, wellhead or groundwater protection zones, or aquifer recharge areas that may impose additional requirements. If federal, state, or local restrictions apply to protect groundwater, the most stringent should be used.

## 2 INFILTRATION FACILITIES

Any type of catchment system that releases water through infiltration into the soil and groundwater reduces surface runoff, limiting erosion, and recharging groundwaters that supply wetlands, streams and drinking wells. *Infiltration is not considered adequate to protect the drinking water source (surface and groundwater) unless a second treatment system is included* (1,2,8,9,12,14,18). Other additional requirements are suggested if a development discharges into a natural or mitigated wetland, lake, drinking water source, wellhead protection area, groundwater management area, water quality limited stream, or other sensitive waterbodies (2,8,18). General information on these facilities is given first and is followed by specific types.

### ❶ Infiltration Systems

Infiltration systems include ponds, trenches, vaults, sumps, dry wells, roof downspouts, and porous pavement. Sumps, dry wells, and infiltration trenches are considered to be Underground Injection Control (UIC) wells regulated by the SDWA (18).

- Location of the facility is critical and must be based on the soil type and presence of organics if groundwater is to be protected.
- Not to be used in soils with low percolation, in fill, or soils with high silt/clay content.
- Best in sandy loams and loams.
- Gravely sands are not adequate for treatment.
- Should be used in line with other treatment systems prior to discharge or will pollute groundwater, wetlands, wells, and streams (2,7,8,18).
- Some designs are good for nutrient control.
- Suitable for medium and smaller sites, draining 50 or less acres (2).

- Not suitable for areas with high water tables — a high water table will act as a barrier and sharply reduce efficiency [2].

- Infiltration systems should not be located within on-half mile of a public water supply system dependent upon groundwater [1].

- Oregon currently limits the location of UIC injection wells to 500 feet or one-fourth of a mile of a drinking water system.

- Oregon's UIC program currently limits the use of sumps and dry wells to locations where there is an adequate confinement barrier or filtration media between the proposed injection well and aquifer used for drinking water. Wells cannot be deeper than 100 feet, must be built so that the can be temporarily plugged in the advent of a spill, cannot be used if toxic, hazardous chemicals, or petroleum products are stored or handled in the area served by the well or if the well serves parking lots. [23]

- EPA guidelines recommend a 4- to 10-foot minimum separation between the bottom of the UIC well and the seasonal high water table.

- King County advocates requiring soil reports, testing of infiltration rate and logs for all types of infiltration systems to verify the mapped soil survey [8]. The soil logs are then used to confirm that the seasonal high groundwater is at least 3 feet below the bottom of a proposed infiltration system. If doubt exists, then a winter investigation is required prior to permit approval.

- At a minimum, all infiltration facilities located within the 1-year capture zone of any well should provide a wet pond or water quality swale up stream of the infiltration facility. It is the responsibility of the applicant's engineer to locate such wells [8,9].

- Groundwater monitoring, prior to installaion of infiltration facilities, is advised in sensitive sites, if hazardous materials are being used/made or if hazardous and solid waste is being generated on site. Groundwater monitoring can also assist in tracking suspected declining groundwater quality [8].

- A liner may be required to protect groundwater in sensitive areas.

- To determine groundwater impacts, observation wells are suggested particularly if in the vicinity of a public water supplier [8].

- Not suitable near building foundations, septic tank systems, wetlands, or unstable slopes [2].

- Prone to rapid clogging and failure from sediment during construction and operations. Do not install until all lands in the site drainage have been stabilized. Needs to be used with a pretreatment system that filters out sediment and other coarse materials [2].

- Preferred design for Puget Sound since it both treats the pollution and allows for groundwater recharge — 1992 technology [2].

- Benefits: preserves the existing baseflow and recharge, reduces peak runoff and flooding, and less expensive [2,7]. Infiltration can decrease both peak rates and volumes while increasing summer stream baseflows and recharging aquifers.

- Most useful in the following situations: the proposed project discharges to a closed depression, or to a severely undersized conveyance system that restricts the runoff volume that can be accommodated, or the project is located in an area requiring runoff volume control due to flooding [8].

- Often fails due to: (a) inadequate soils resulting in a poorly designed system, (b) improper construction practices (compacted soils), (c) siltation (cannot deal with high loads) [2,7], and (d) location on unstable slopes and lack of maintenance [2].

- Other limitations include the very slow permeability rates of some soils and the need to prevent contamination of groundwater.

- At a minimum, semi-annual maintenance should be required [1].

- Removal efficiencies (averages): [6] May be less than accurate due to changes in technology; metals = 70% (100% if bonded to sediment, but misses soluble 30 to 40% which is the most toxic); nitrogen = 80%; and phosphorus = 80%.

- Only intended for runoff from residential areas, not for industrial use, and limited commercial use [7]. Should not be used in areas undergoing major development.

- Infiltration devices in the Portland-Lake Oswego-Clackamas Co-USA area are rarely viable due to unsuitable soils according to Brown and Caldwell [7].

- The discharge from a proposed project site must occur at the natural location so as not to be diverted onto, or away from the adjacent property [8].

- Proposed projects must provide runoff controls to limit the developed conditions peak rate runoff to the pre-development peak rates for specific design storm events based on the runoff from defined existing conditions [8]. More restrictive runoff rate controls are suggested for sensitive areas [8].

- Infiltration facilities should not be operated until all proposed improvements that control surface runoff are complete, particularly revegetation, and landscaping [8].

- A soils report and test boring should be required. The basic requirement is a minimum of 3 or 4 feet of permeable soil below the bottom of the infiltration facility (pond/ tank/trench, etc.) and at least 3 feet between the bottom of the facility and the maximum wet season water table [8,9].

- An overflow route should be identified in the event that the infiltration facility's capacity is exceeded or becomes plugged and fails. All overflow systems are to be designed to deal with a 100-year, 24-hour flood [8,9].

- Should be preceded by an oil spill control device to capture any oil or other floatable contaminants before they enter the facility. Should provide protection up to the 10-year design storm [8,9].

- Inflow to infiltration ponds/tanks and facilities should be pre-treated for sediment removal [8,9].

- Prior to excavation cordon off area to protect from construction traffic compaction.

- Excavation of infiltration system should be done with a backhoe working at "arms length" to minimize disturbance and compaction of the infiltration surface.

## ❷ Infiltration Trenches

Infiltration trenches have a moderate ability to remove pollutants—regulated as UIC Class V injection wells under the UIC program [23]. EPA advocates use of these facilities to dispose of stormwater only [18].

- Are not suitable on slopes, areas with a high water table, near foundations, or at sites likely to have high sediment loads.
- Depth to bedrock can also preclude this design or impermeable layers (glacial till) [2].
- Trenches are usually 2- to 10-feet deep backfilled with coarse stone, a filter (sand or compost), and underlain with filter fabric [7].
- Good for sites that offer linear layout [7].
- Low tech.
- Can be a hazard for children (drowning).
- Cost effective on smaller sites [11].
- Should be coupled with pre-treatment [11].
- Should not be located in an area where hazardous or toxic materials are stored, transported, or handled [18].
- Should not be located in any area (including loading docks) where an accidental spill of a hazardous or toxic liquid would drain into the facility [18].
- Disadvantage — they tend to clog with fine sediment slowing the rate of infiltration into the soil over time [18]. Failure rate within 5 years [11].

## ❸ Infiltration Basins/Ponds

Infiltration basins/ponds are depressions created by excavation, berms, or small dams that provide for short-term ponding and infiltration [7].

- Best when natural depressions or drainage ways already exist [7].
- Can serve up to a 50-acre drainage [7].
- Pollution removal ability is moderate, if working [11].
- Failure rate is 60–100 percent within 5 years [11].
- Siting dependent upon soils, depth to groundwater, slope, and sediment input [11].
- A soils report should be required that demonstrates through infiltration testing, soil logs, test pits, etc., that sufficient permeable soil exists on the site to allow the infiltration system to function. In addition, the design infiltration rate should be tested to provide an estimate of the potential outflow rates for existing areas proposed for infiltration [8].
- Construction costs are moderate [11].
- Best when inflow to pond is pre-treated for sediment removal [8,9] such as a pre-settling basin/pond.
- Runoff from adjacent paved areas/access road should be treated with filter strips or other BMPs before runoff enters the system.
- Do not place on unstable or steep slopes.

## ❹ Sumps/Tanks

Sumps/tanks are basically underground pipes or tanks with perforations (drains) that allow detained surface water to be infiltrated. Regulated as Class V injection wells under the UIC program [23].

- Often used with a catchment basin [2,8,9,12]; a holding tank which can be periodically pumped and allowed for wastewater disposal. Used to capture coarse sediments.

Marginal performance for treating stormwater and poor performance due to lack of maintenance, and clogging due to debris [2,8,9,12].

- Depending upon the composition of the waste (and adjacent land uses), it may also be hazardous [6].

- No ability to filter out pollutants must be preceded by treatment facility [2,6,7, 8,9,10,18].

- Public and private sumps need to be inventoried under the federal UIC program requirements, and must meet other requirements found in OAR 340-044-0050.

- If installed within a Wellhead protection area, the water system may become ineligible for state monitoring waivers granted under Federal Phase II/V monitoring regulations [18].

- To be used only when either a sewage system, or process wastewater treatment system is not available.

- Requires DEQ inventory registration prior to use to qualify as rule authorized, and in some instances may also require a WPCF permit.

- Bottom of the system should be at least 3 to 10 feet above the seasonal high groundwater level. Filter fabric should be placed over the top of the drain rock prior to backfilling [8,9,18] .

- All tanks/sumps should be a minimum of 20 feet from a structure, property line, easement, sensitive area, and septic system [8,9].

- Current Uniform Plumbing Code only stipulates a 10-foot setback from buildings and 5 feet from property line.

- Should be a minimum of 50 feet from any steep slope and should not be used on unstable slopes [8,9].
- Not to be used in a buffer zone surrounding waterbodies and wetlands.

- Tanks/sumps should be bedded and backfilled with washed drain rock that extends at least 1 foot below the bottom of the tank, at least 2 feet beyond the sides, and extends to the top of the tank. Filter fabric should be placed over the top of the drain rock prior to backfilling. [8,9]

- Should not be located in an area where hazardous or toxic materials are stored or handled [18].

- Should not be located in any area (including loading docks) where an accidental spill of a hazardous or toxic liquid would drain into the facility [18].

- To be used to dispose of stormwater only [18].

- When used with a catchbasin, see Section 3 (Retention and Detention).

- May be prohibited from some areas of critical concern.

- Not to be constructed in fill, soils with high silt/clay content, or in soils with low infiltration rates [18].

## ❺ Dry Wells

Shallow dry wells are usually 10 to 30 feet deep, often made of perforated concrete walls surrounded by gravel backfill and filter fabric, or they can be simple dug-holes filled with rock. Regulated as Class V injection wells under the UIC program [23].

- No ability to remove pollutants [2,7,8].
- Not to be used in a buffer zone surrounding waterbodies and wetlands [18].
- Need to be coupled with some sort of pretreatment, or will fill with sediment [7,18].
- Public and private wells need to be registered and inventoried under the Federal UIC program requirements prior to use (to qualify as rule authorized) [23].
- Should not be located in an area where hazardous or toxic materials are stored or handled [18].
- If installed within a Wellhead protection area, the water system may become ineligible for state monitoring waivers granted under Federal Phase II/V monitoring regulations [18].
- Should not be located in any area (including loading docks) where an accidental spill of a hazardous or toxic liquid would drain into the facility [18].
- To be used to dispose of stormwater only [18].
- Should not be used on unstable slopes and should have a minimum of 3 to 4 feet between the bottom of the dry well and the seasonal high water table [18].
- May be prohibited for some areas of critical concern.
- Not to be constructed in fill, soils with high silt/clay content, or in soils with low infiltration [18].

## ❻ Service Bay Drains

Drains or automotive service-bay floor grating that discharge to the ground are regulated as Class V injection wells under the UIC program [23].

- No treatment occurs prior to discharge.
- EPA classified as high risk due to pollution from hazardous wastes.
- Illegal in Oregon since 1991.
- Must close or connect to stormwater, holding facility, or city sewer line.

## ❼ Roof Downspout /Drains

Roof downspout/drains are small scale chambers or trenches intended to facilitate stormwater runoff from roofs, sometimes filled with gravel [7].

- For residential use only [1,2,8,9], provided suitable soils are present (coarse sands or cobbles, medium sand, fine sand/loamy, sandy loam, or loam).
- They are not designed to directly infiltrate any surface water that could transport sediments or pollutants, such as paved areas [8,9].
- Do not use on slopes (25%—4:1) and on unstable areas.
- Not allowed in fill material except engineered sand and gravel; should be in native soil.
- Must have a measured infiltration rate of not less than 3 inches per hour to be effective [8,9]. Limit use to certain SCS soil types.
- Roof downspout system should be at a minimum 30 feet from any water supply well [8].

- The downspout should be connected to trenches with filter fabric over the drain rock prior to backfilling. Once constructed, clearly mark the site — no vehicle traffic is to occur within 10 feet of the trench area. [8,9]. Trench length shall not exceed 100 feet from inlet sump. Trench is to be a minimum of 10 feet from any structure, and 50 feet from steep slopes [8].

## ❽ Infiltration Medias

Infiltration medias [1,2,12] select the filtration media to achieve the desired pollution removal goals/objectives and size the filter to achieve the desired run time before replacement of the media is needed. Filters are limited by clogging caused by suspended solids in stormwater. Pre-settling in general will reduce the clogging observed in filters and increases how long the filter will function; it also reduces color, BOD, and turbidity problems. When filters are allowed to dry between use, the flow rates increase.

### *Sandfilters:*

- In general, sandfilters have medium high levels of control for most pollutants when the stormwater is not treated. Can relatively easily flush out previously captured pollutants.
- Sandfilters are not an appropriate technology for dealing with hydrocarbons or metals [1] (associated with roads and parking lots), since there is no mechanism to remove *soluble metals* or hold hydrocarbons [WPT V1 #3]. Can filter out particles with *bound* or *attached metals*. Bound metals are not bioavailable so they are the least toxic to the environment. Up to 70 percent of the total metal concentration is usually bound, so the high metal removal rates are misleading. The soluble metals are the most hazardous [1].
- Possible that some metals could be removed in sediment build-up on surface of the filter [1].
- By the time that sediments build up, the filter is clogged [1].
- Best for removal of suspended solids [12].
- Potential for use to treat oil/gas runoff [2]. However, after testing for 6 years in a parking lot, inspection found the filter to be clogged. Oil, grease, and finer sediment have migrated into the filter to a depth of 3 inches [12].
- Best for single sites and drainage areas 50 acres and under [2,12].
- Can be precluded by slope, depth to bedrock, and high sediment loads [2].
- Not effective at removing nutrients [2] .
- Minimum depth of sand should be 18 inches [12].
- Should be used with pre-treatment such as a pre-settling basin or biofiltration swale.
- In sensitive areas (i.e., WQL/groundwater management areas) it may need to require a line to prevent leakage prior to treatment [2].

### *Activated Carbon:* [12]

- Long used in the chemical process industry and in hazardous waste clean-ups as an effective way to remove trace organics from liquids.
- Limited by the number of adsorption sites in the media.
- Ineffective at removing free hydrated metal ions.
- When combined with sand in general, very good control for most pollutants — for both treated and pre-settled stormwater.

### Peat/Compost Filters:

- Peat/compost filters are appropriate for dealing with road runoff (hydrocarbons) [1] [WPT V1 #3].
- They have a high organic content and do absorb larger quantities of hydrocarbons. They are able to retain them for a longer time [1].
- Can remove up to 90 percent of the soluble metals [1].
- Compost efficiency rates: turbidity (84%), suspended solids (95%), total volatile suspended solids (89%), COD (67%), settable solids (96%), total phosphorus (40%), total Kjeldahl nitrogen (56%), copper (67%), zinc (88%), aluminum (87%), iron (89%), and petroleum hydrocarbons (87%) [12].
- Compost needs to use deciduous fall leaves [1,2].
- Uses less land for treatment than most other facilities [2].
- Relatively new technology (6 years).
- Best when used for sediment removal, particulate nutrients, organic carbon, hydrocarbons, and some heavy metals [WPT V1 #1]. TDS increases, however, due to leaching. Exports soluble nutrients (nitrate/phosphorus).
- Requires annual/biennial removal, disposal, and replacement of the compost layer.
- Sedimentation can reduce the effectiveness (permeability).
- Peat alone is good to filter nutrients, bacteria (lowers effluent pH) and organic waste metals, but alone will increase the turbidity significantly [12].
- Peat/compost increases the color of runoff after filtration.

### Peat-Sand Filter (PSF): [12]

- Grass over 12–18 inches of peat supported by a 4-inch mix of sand, and peat supported by 20–24 inches layer of fine to medium sand. Under the sand is gravel and the drainage pipe.
- Biological filtration system (aerobic).
- Removal efficiency: suspended solids (90%), total phosphorus (70%), total nitrogen (50%), BOD (90%), trace metals (80%), and bacteria (90%).
- A good grass cover will remove additional nutrients.
- Does the best with all filters when used with pre-settling.
- In general, medium to high level of control for most pollutants, for both untreated and pre-settled stormwater.

### Vegetated Rock or Rock-Reed Filters:

Vegetated rock or rock-reed filters use a shallow cell of rock and gravel in which wetland plants are rooted. Wastewater flow travels slowly between the rock pore spaces, where it is subject to settling, algal/plant uptake, and microbial breakdown (WPT V2 #2).

- Designed to treat subsurface flows — unlike most other systems.
- Off-line system with packed bed filter cells excavated into the soil (80’ width by 30’ length and 3’ deep). Each cell is sealed with a plastic liner and filled with crushed concrete or granite.

- Pretreatment is needed for sedimentation.

- Efficiency removal rates for TSS, total phosphorus, and fecal coliform approached or exceeded 80 percent, while inorganic and organic nitrogen range from 60 to 75 percent (high rate), and moderate to low rates for organic carbon, orthophosphorus, TDS, and metals (soluble / particulates).

- Crushed concrete performs better than granite.

- Unplanted concrete cells performed better than planted cells.

## 3 RETENTION AND DETENTION (R/D) FACILITIES

These facilities basically provide storage for increased surface water flow runoff resulting from development. Detention is the collection and temporary storage of surface water with the outflow rate restricted. Retention is the collecting and holding of surface and stormwater outflow occurring through evapotranspiration, and implies permanent storage [8].

The general categories include: wet ponds, constructed wetlands, presettling basins, dry ponds, wet vault/tank, and catchment basins. Other additional requirements are suggested if a development discharges into a natural or mitigated wetland, lake, drinking water source area, wellhead protection area, groundwater management area, water quality limited waterbody, or other sensitive waterbodies [2,8].

In general, efficiency is improved by extending the detention period [2,10]. These facilities provide pretreatment or primary treatment of stormwater for conventional pollutants (particulate only) and nutrients (dissolved and particulate — nitrates and phosphorus). Detention can be fairly effective for the removal of urban pollution associated with small storms through gravity sedimentation.

If near a road way or parking area, these facilities can accumulate heavy metals (lead, zinc, and copper), the heavier the traffic the higher the accumulation. In such case, the multiple use functions of the facility should be limited due to the environmental health hazards, access should be restricted (fence), post warning signs (waterborne disease), and the basin may require dredging during maintenance cleaning, and the sediments should be treated as a hazardous waste. Sediment testing (elutriate) should be done prior to removal [2].

Significant concern exists regarding the potential contamination of groundwater resources (primarily potable) from inadequately treated surface water runoff that may be immediately infiltrated at water quality control facilities serving impervious areas of intensive use (such as arterial roadways, multi-family residences, commercial, manufacturing, and industrial land uses). To address these concerns, proposed facilities located in soils with a minimum infiltration rate or permeability of more than 9 inches per hour (0.15 inches per minute) must have a lining system to prohibit infiltration under the water quality facility. Of course, infiltration facilities provided for peak runoff control would be located downstream of these and any other water quality control facility. [8,9]

In general, facilities should be at a minimum: (a) 20 feet from buildings, property lines, vegetation buffers; (b) 100 feet from septic tank/drainfield [2]; (c) 50 feet from steep slopes [2]; (d) at least 100 feet or the 1-year capture zone from a well [8]; and (e) not located in dedicated public right-of-way areas or unstable slopes [8,9].

All R/D facilities must take into overflows (bypass) into consideration. Overflows may result from higher intensity or longer duration storms than the design storm or can result from plugged orifices or inadequate storage due to sediment build up. Pond/wetland overflow system should provide controlled discharge of the 100-year, 24-hour design storm event for the developed site conditions without over topping any part of the pond embankment or exceeding the capacity of the emergency spillway. The design should provide controlled discharge directly downstream. Do not place R/D facilities where the overflow could damage downslope building [2], impact public health, safety and welfare, property and wildlife habitat [8,9].

## ❶ Wet Ponds/Constructed Wetland

They are constructed by a combination of excavation and/or berming. Wetponds and constructed wetlands are the preferred form of R/D due to water quality benefits (effectiveness), ease of inspection, and maintenance access [2,8,9]. The basic types of constructed wetlands are: shallow marsh, a 2- or 3-celled pond/marsh, extended-detention wetland, and pocket wetland [5].

Stormwater treatment facilities are not considered waters of the state; however, their discharge is regulated in the same way as any treatment system. Created wetlands are built as mitigation for loss of wetlands under the *Clean Water Act*, Section 404, and are considered waters of the state. Created Wetlands are protected as natural wetlands and cannot be used for conveyance or treatment of wastewater, unlike constructed wetlands.

- Extended-detention wetland and pocket wetlands are less effective in pollution removal than other types [5].
- Should be lined when located over permeable soils for permanent pool maintenance [2]. Use a Bentonite clay (12" thick) or commercial heavy plastic pond liner (minimum 40 ml). Place a minimum of 18-inch thick compacted top soil over the liner prior to seeding [8,9].
- The permanent pool depth should be between 3 to 6 feet in depth, plus 1 foot of dead storage for sediment [8,9]. Six feet is the maximum depth or the pond will stratify in summer and create low oxygen conditions which result in the re-release of phosphorus and other pollutants[2]. In addition if the pond is deeper than 6 feet it will likely pollute the groundwater.
- Suitable for larger sites — up to 100 acres [2].
- Soils should be tested to determine suitability. Best in clay loams, silty clay loams, sandy clays, silty clays, and clays [2].
- Cannot be used in areas with shallow depth to bedrock or unstable slopes [2].
- Good for nutrient removal and conventional pollutants [2].
- Needs to have a shallow marsh system in association [2] to deal with nutrients.
- Should be multi-celled preferably three of equal sizes; the first cell should be 3 feet deep to trap coarse sediments and slow turbulence [2]. They need to be designed as a flow through facility, and the pond bottom should be flat to facilitate sedimentation [8,9].
- Needs to be designed with periodic maintenance in mind by using an overhead scooping device [2].
- Side slopes should be 2:1, not steeper than 3:1, and 10 to 20 feet in width. Length to width ratio of 5:1 is preferred [2], with a minimum ratio of 2:1 to enhance water quality benefits [8,9]. The longer length allows more travel time and opportunity for infiltration, biofiltration, and sedimentation [8,9].

- Pond berm embankments over 6 feet should be designed by a registered engineer. Berm tops should be 15 feet wide for maintenance access [8] and should be fenced for public safety.

- Shape should be long, narrow, and irregular since these are less prone to short circuiting, and are more effective and maximize the treatment area [2].

- Baffles can be used to increase the flow path and water residence time [2].

- Should have an overflow system/emergency spillway to deal with a 100-year, 24-hour flood, and a gravity drain [2,8].

- Retention ponds are not usually a cost effective method to provide peak runoff control, but are used to control the increased volume of runoff from a proposed project during construction [8].

- Catch basins can act as weirs when used to deal with overflowing [2,8,9].

- Maintenance is of primary importance**.** The city, county, an individual, or homeowners association must be responsible. Maintenance plan and schedule to be submitted. Needs to address removal of dead vegetation (that release nutrients) prior to the winter wet season , debris from trash racks, sediment monitoring in forbays, and in basin are likely to contain significant amounts of heavy metals and organics — regular testing is advised [2].

- Access to the wet pond is to be limited with a gate and signs posted [2].

- For mosquito control, either stock the pond with fish or allow it to be drained for short periods of time — do not kill the marsh vegetation [2].

- Constructed wetland is more complex, with more vegetation, and shallower with greater surface area; hydrologic factors (flow) play a larger part in siting.

- Off-line constructed wetlands, within the floodplain, can be beneficial for flood control, restore drainage characteristics, and habitat quality [1] through the reduction of sediment, nutrient levels (80%), and phosphorus.

- Selection of vegetation should be done by a wetland specialist [2].

- Oil/water separators can be used prior to the constructed wetland depending upon the surrounding land uses [2] .

- Benefits generally attenuate flows and recharge groundwater [2].

- Relatively low maintenance costs [5].

- More reliable than infiltration [5].

- Fence off for safety (children) and to protect plants/wildlife [8,9].

- Disadvantages/constructed wetlands [5]:

  (a) Constructed wetlands have a larger land requirement for equivalent service compared to a wet pond;

  (b) Relatively high construction costs;

  (c) Delayed efficiency until plants are well established (1 season).

- Buffer width — 25 to 50 feet [5] .

- Limit water level fluctuations, as they kill plants [5].

- Wetpond / wetland removal efficiencies [1, 6]:

  (a) Heavy metals = 40 to 80%;

  (b) Total Phosphorus = 40 to 80%;

  (c) Total Nitrogen = 40 to 60%;
  (d) TSS = 70%;

  (e) Sol. reactive phosphorus = 75%;

  (f) Nitrate = 65%;

  (g) Ammonia = -43;

  (h) COD = 2;

  (i) Total copper, lead, and zinc = 80 to 95%.

***NOTE:*** Higher efficiencies are associated with use of O/G trap, larger pond / marsh area, and volume.

## ❷ Presettling/Settling Basin

A presettling / settling basin is a type of detention facility. Can perform poorly as the result of filling and over-topping at a frequency greater than the design storm. This is due to the assumption that (event based) that the pond is empty when the event begins. Reality is that the ponds drain slowly and contain water for several days; it often rains for days on end, so when a large event occurs the full pond volume is not available. When the pond is full and it continues to rain, the potential for downstream flooding and erosion also increases. [2]

- Suitable for larger sites draining 0–100 acres.

- Puget Sound upgraded to a 7-day event when the 2-year, 24-hour ponds were found to be too small in 1992 [2].

- Usually used before an infiltration system [2].

- Best for the removal of suspended solids prior to discharge to another type of BMP for further treatment — infiltration, wetpond, and biofiltration [2,5,8].

- Width ration should be 3:1; baffles are suggested; a trash rack and sediment trap will need maintenance and should drain within 60 hours. A drop inlet structure is preferred near the front of the structure to remove heavy suspended material.

- Liners are suggested to prevent infiltration.

- Traps perform well over silt fences, filter strips, and hay bales [1] [WPT V1 #3 p. 95].

- Good only for sedimentation settling.

- Do not use on unstable slopes.

## ❸ Extended Detention Dry Pond

A extended detention dry pond is essentially a presettling basin [2]:

- Suitable for larger sites draining 0–100 acres.

- Best with clay loam, silty clay loam, sandy clay, silty clay, and clay soils.

- Can generally be located anywhere [2] except unstable slopes.

- Does not provide the same level of treatment as a wet pond, fairly good for oil and grease, metals, sediments, and nutrients.

- A viable option for retrofitting detention ponds serving existing developments.
- Locate associated catch basins in grassy areas.
- Enhances Landscaping.
- Same design parameters as for a presettling basin.

## ❹ Wet or Dry Vault/Tank

Wet or dry vault/tank are underground facilities for the storage of surface water. Tanks are generally constructed of corrugated pipe, and vaults are made of reinforced concrete (2,8,9). They provide the least amount of water quality benefits (biofiltration and biological activity), and therefor need to be preceded by a treatment facility (2,8,9).

- Suitable for smaller areas draining 0–5 acres (2).
- Can generally be located anywhere (2).
- Do not provide water quality treatment — only good for storage and sedimentation (2).
- Dry vaults should only be used after the stormwater has been treated (2).
- Due to their location underground, they are more difficult to inspect and maintain (2).
- Only allowed in small sites (2).
- 10 foot setback from structures, 50 feet from a steep slope, not allowed in fill, or unstable slopes (2).
- Best design: two cells with a baffle, length to width ratio of 3:1 (2).
- Tanks in moderately pervious soils with seasonally high groundwater are prone to floating. Need to be anchored or have ballast. (2,8).
- For maintenance, must have access (2); suggest a maximum depth to a tank invert of 20 feet, with a 36-inch minimum diameter riser-type manhole. Tank access should have a locking lid (8).
- Best when preceded by biofiltration facility (8,9).
- In-flow enters through a sump that is connected to a detention tank. The detention tank bottom is located 6 inches below the inlet and outlet to provide dead storage for sediment. A flow-through design is required for both tanks and vaults. (8,9) The flow-though design maximizes water quality treatment and will facilitate maintenance.

## ❺ Catch Basin Filter System

Often a catch basin is coupled with sump and sediment traps. It may also be used with an inlet device, prefiltering insert, and screens; see other facilities and retrofit (12). The inserts consist of several filtering trays suspended from the inlet grate. Common filters are charcoal, wood fibers, or fiberglass.

- Widely used at construction sites, industrial facilities, service stations, and marinas/moorage's.
- Retains small particles, partially effective with high levels of particulate heavy metals, oil/grease, and TSS (2,12). Moderate reduction in TSS and turbidity. However,

few pollutants are associated with these coarser solids.

- Efficiency: TSS (22%), Suspended solids (32%), Turbidity (38%), color (24%) with negative results (increases) for magnesium, calcium, and bicarbonate. Results not significant for volatile solids, conductivity, nitrates, and potassium.
- Disadvantage: When 60 percent full, the suspended solid deposition is in equilibrium with scour, and the capture efficiency is reduced to zero [12].
- Best in small basins and with treatment of highly turbid runoff prior to discharge to catch basin.
- Do not use on unstable or steep slopes [2].
- Usually used with vaults, tanks, sumps, or inverted (hood) inlet [2,8,9,12]. Inlet can be coupled with a filtration system; see Section 6 (Retrofit).
- Maintenance is critical and must be at least semi-annual. Require a maintenance schedule and plan for disposal [2].
- Insert maintenance is required quarterly and should be inspected more frequently during wet periods [18].
- Catch basins with a restrictor device (multiple orifice and weir/riser section) for controlling outflow can provide minimal control for floatables and petroleum based products [8].
- Size of catchbasin sump controlled by runoff rate, TSS concentration in runoff, and how often it will be cleaned out [12].
- To minimize groundwater pollution problems, be careful where infiltrating catch basins are used (residential areas) and pre-treat the infiltration water [12].

## ❻ Storm Treat System

Storm treat system uses a 4 by 9 chambered treatment tank (sedimentation and filtration) that discharges to a small constructed wetland, catch basin, swale, or sump near the pollution source. The system can captures and treat the first flush runoff when located high in the watershed and near the source of pollution. The number of units used depends upon the design storm, size of subdrainage area, and needed detention volume.

- Significantly smaller (5–10%) than other systems. Good for constrained sites, such as roadside wetlands.
- Discharge is slow enough for discharge to a constructed wetland or groundwater, so it can be located in low permeability soils with a high water table (self anchored).
- Closed system with no standing water (public health/safety issue) can be shut off in case of local spill.
- Requires sediment removal every 3 to 5 years by suction pump and annual inspections of skimmers and screens.
- Can connect to existing drainage structure — usually a catch basin, swale, or sump — to provide treatment.
- Removal efficiency: fecal Coliform (97%), TSS (99%), COD (82%), Total dissolved nitrogen (44%), Total petroleum hydrocarbons (90%), lead (77%), chromium (98%), phosphorus (89%), and zinc (90%).

### ❼ Multi-Chambered Treatment Train (MCTT)

Multi-chambered treatment train (MCTT) uses a catch basin/sump and two chambers: initial grit catch basin for large sedimentation and volatiles, main settling chamber (aeration and sorbent pillows) for the removal of fine sediment, associated toxicants, and floating hydrocarbons (settling time 1–3 days); and a sand/peat filter/ion exchange unit to remove filterable toxicants [12].

- Best in small isolated paved critical source areas (0.25 to 2.5 acres).
- Suggested for the following land uses: vehicle service facilities, convenience store parking areas, equipment storage areas, and salvage yards.
- Uses one-third area of a wet detention pond.
- Removal efficiencies: total toxicity (96%), filtered toxicity (98%), suspended solids (83 to 95%), COD (60 to 90%), turbidity (40 to 90%), lead (95%), zinc (85 to 90%), cadmium (90%), copper (65 to 90%), pyrene (75 to 85%), phosphorus (80 to 90%), ammonia (50%), and n-Nitro-di-n-proplamine (100%). Color increase by 25 to 50 percent and the pH decreased by 25 to 50 percent, and nitrate nitrogen had low removal rates.
- Very effective removal rates for both filtered and particulate stormwater toxicants and suspended solids.
- Very new technology, so costs are currently high, but are expected to drop with pre-fabrication. Can be used in retrofitting; preliminary experimental costs at a gas station were $54,000.
- Design is very site specific and highly dependent upon local rains (depth, intensity, and inter-event time). The size of the main chamber increases as the annual rain depth increases. The inter-event period and rain depth determines the specific runoff treatment volume requirements. Seattle requires a small MCTT because of the small rain depths for each rain.

## 4 BIOFILTRATION

The process relates to the simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater. Vegetation growing in the treatment system acts as a physical filter to settle out particles, slow flow rates, and acts as a biological sink. These facilities are able to remove dissolved heavy metals and phosphorus, and the biological soil activity can metabolize organics [1]. They are generally effective at removal of TSS, fine sediments, some non-soluble heavy metals, and some nutrients [8].

Biofiltration facilities can be installed prior to or following peak runoff rate control facilities but should always precede water quality ponds, vaults, or swales [8]. Biofiltration facilities should not be located in highly porous soils (gravely or coarse), since they have little treatment capacity alone and can be a threat to groundwater [2].

Critical factors include: retention time, adequate amount of vegetation, and soils of moderate texture [2]. Minimum vegetation height is 2 inches, and can be mowed in the summer to promote uptake. Roadside ditches can be viewed as potential biofiltration systems. Biofiltration systems are easy to inspect and maintain. However, do not use alone in areas with high sedimentation. Rock channels are not biofilters. Avoid over fertilization (leaching of nitrates into groundwater). Keep facility clear of excess sediments, lawn debris, and trash. Other additional requirements are suggested if a development discharges into a natural or mitigated wetland, lake, drinking water source, wellhead protection area, groundwater management area, or other sensitive waterbodies [2,8].

***NOTE:*** This is the preferred option for stormwater treatment used in most recent literature.

## ❶ Bioretention Swale

Bioretention Swale is an off-line system that: (a) captures sheet runoff; (b) directs through a grass filter strip or swale; then (c) to a sand trench; and (d) planting bed and ponding area for infiltration/evaporation (bioretention area) [1]. Swales basically act as filters for runoff from frequent storms. The principle form of treatment is settling out of pollutants and the use of vegetation to take up the dissolved fraction [8]. For best results, a swales should be designed to deal with the peak runoff for a 2-year, 24-hour storm event [8,9].

Use of a sand trench augments infiltration of the plants, slows velocities and evenly distributes the runoff, and facilitates the flushing of the pollutants from the soil (treats with a combination of microbial soil processes, infiltration, and use of natives to enhance stormwater). Grass buffer strips reduce velocities and filter particulates [1] [WPT V1 #3].

- Does well with first flush runoff, economically feasible, improves aesthetics, and has minimum environmental impacts. Best in median strips and parking lot islands [1].
- Organic topsoil layer is good for degrading petroleum solvents, heavy metals, nutrients, and hydrocarbons [1].
- Critical design elements: size of drainage area to be treated, location of bioretention areas, sizing guidelines, and calculate water budget [1,2].
- Biofiltration is suitable for smaller sites 10 or less acres [2].
- Needs a minimum width of 20 feet [18].
- Must be graded to create sheet flow — not a concentrated stream. Sheet flow decreases chance of gully erosion and distributes contaminants over a wider area [18]. Level spreaders (i.e., slotted curbs) can be used to facilitate sheet flow.
- Can be placed anywhere with careful site design [2].
- Do not use on steep, unstable slopes, or landslides.
- Can reduce peak flow rates [2].
- Best when used as the initial treatment and conveyance of stormwater [2].
- Good for nutrient removal and conventional pollutants [2].
- Can be installed prior to or following runoff control facilities, but should precede water quality treatment facilities such as ponds, vaults, or swales [8].
- Best at 200 feet in length, in tight spaces obtain more length by using a curved path.[2] Should have a maximum bottom width of 50 feet. One foot high check dams should be installed every 50 feet starting 20 feet downstream from the inflow point. [8].
- Good when used at an outfall [8], commercial development or road side.
- Removal efficiencies [6]:

  (a) TSS = 83 to 92%;

  (b) Lead = 67%;

  (c) Copper = 46%;

(d) Total phosphorus = 29 to 80%;

(e) Total zinc and aluminum = 63%;

(f) Dissolved zinc = 30%;

(g) Oil / grease / TPH = 75%;

(h) Nitrate-N = 39 to 89%.

## ❷ Vegetated Filter (Buffer) Strips

Vegetated filter (buffer) strips are best used on sites with sheet runoff , such as parking lots, being in-adequate to deal with sediment [1].

- Widths suggested for effectiveness are a minimum of 15 feet to a maximum of 30 feet [1,8,9].
- Best for smaller drainage basins, 5 acres or less [2].
- Not suitable on slopes or with shallow depth to bedrock [2].
- Only good for conventional pollutants — no nutrients.
- Cannot be used to convey larger storms, or concentrated flow discharges as their effectiveness will be destroyed plus they could become sources of pollution.
- Best for sheet flow; do not use on slopes over 10 percent.
- Best grasses is tall fescue, followed by western wheatgrass, annual or italian rye-grass, and kentucky bluegrass.
- Rectangular and V shapes are the least desirable.
- Design to create a low velocity, bent grass is not as good a filter.
- Curbing for impervious areas tributary to the filter strips should have a 1-foot gap every 5 feet [8].

# 5 OTHER FACILITIES

## ❶ Storm Drain Inlet Protection (SDIP)

Storm drain inlet protection (SDIP) are inlets in use during construction and operation are to be protected so that stormwater runoff does not enter the conveyance system without first being filtered to keep out sediment or otherwise treated [1].

- Adequate installation and maintenance is a critical issue, and are the #1 and #2.
- Causes of failures related to SDIP, stormwater sediment basins, and traps [1] [WPT V1 #3].
- Puget Sound advocates the use of small sediment traps, sumps, or filters at system inlets [2].
- King County uses only two options: (a) catch basin inserts (preferred), and (b) filter fabric protection over the grating (not under). These are easy to maintain and are not a hazard to traffic. Filter fabrics is likely to result in ponding of water above the catch basin, so use only where ponding will not be a traffic concern and where slope erosion will not result if the curb is over topped by ponded water. [8]
- Trapping sediment in a catch basin is unlikely to improve water quality; it is a last line of defense [8].

- Do not use in areas needing leaf control or having heavy trash loads, as they clog rapidly (12).

- Storm drain inlets downslope and within 500 feet of a disturbed area or construction entrance should be conveyed to a sediment pond (8).

- Goal is to find an inlet that: does not cause flooding when clogged with debris; does not force stormwater through the captured material; does not require frequent maintenance; and does not have adverse hydraulic head loss properties.

- Perforated inlets (making them infiltration devices) decrease stormwater runoff volume, peak flow rates, and discharges to surface water. However, problems occur with groundwater contamination and early failure of the infiltration capacity.

## ❷ Screens

- Adverse Slope Screen: Covers the outlet side of the a catch basin and is used to trap trash. This allows trapped material to fall into the sump instead of being forced against the screen by out-flowing water. Traps small and large litter.

- Bar Screen: self cleaning, for large litter, and best under curb openings.

## ❸ Catch Basin Inserts

These systems either hang from a drain inlet frame or are installed below the drain inlet. Most contain some sort of treatment mechanisms associated with sedimentation, adsorption, filtration, or gravitational separation of oil and water. They should also have a secondary or high flow outlet, through which water exceeding the treatment capacity can escape. (19)

- Modest TSS removals.

- Washout problems from first flush — problems increase with rain intensity.

- Susceptibility of accumulated sediments, to be re-suspended at low flow rates, can be corrected with an energy dissipater between gate and treatment area.

- Needs true bypass system to divert flows that exceed a 6-month event (limits the total flow to the treatment area).

- Test show little difference in sediment catchment with an insert versus none.

- Hydrocarbon removal rates vary between 30–90 percent when new, and decline to 30 percent, or less thereafter. Removal efficiency appears to drop when the units experience approximately 2 inches of accumulated rainfall.

## ❹ Catch Basin Prefiltering Insert

Catch basin prefiltering insert (Sages, Inc.) consists of a subsurface gravel and sand prefilter and an activated carbon filter. Helps to elimiate standing water between storms and elimiates mosquito problems. To prevent sediment from clogging the filter, the top of the tubing should be extended at least above the normal standing water level, and the tubing from the top of the unit to the catch basin bottom should be perforated and wrapped with filter fabric. The top of the Sage should be capped to prevent direct entry of water and sediment.

## ❺ Oil and Water Separators

There are three basic types: spill control (SC), API (longer retaining time), and coalescing plate (CPS). These systems are recommended for use in all pipe drainage systems conveying runoff from paved areas subject to vehicular use or storage of chemicals prior to discharge from the project site or into an open drainage feature [8,9].

- Floats and adheres to suspended solids [2].
- Urban residential runoff usually low flows [2].
- Suitable for smaller sites, draining 5 or less acres [2].
- Land uses include: industrial, transportation, log storage, airports, fleet yard, railroad, gas station, vehicle/equipment dealers and repair, construction, and petroleum storage [2].
- SC can be effective at retaining small spills but do not remove dispersed oil droplets because they have a short-residence time.
- SC type should be required when the site will have stored petroleum based products and spills are likely [2].
- API used where there is a relatively high likelihood of dispersed oil contamination [18].
- API/CPS should be used in areas with high traffic volumes [2,8,9] (2,500 vehicles per day) or at sites that are used for petroleum storage/transfer, heavy equipment storage, and maintenance [8,9].
- Cannot deal with sediment loads [2].
- Use in conjunction with detention, biofiltration or water quality treatment system to protect groundwater [8,9].
- CPS consist of a bundle of plates made of fiberglass or polypropylene installed in a concrete vault. The plates improve the removal of oil and fine suspended sediments and assist in concentrating the pollutants for removal.
- CPS require frequent inspection and maintenance to operate as designed.
- A mechanism should exist for the system to be bypassed, so the system can be taken off line for maintenance.
- King County requires for construction at sites of 5 or more acres.
- Oil and sediment removed from devices may qualify as hazardous waste and should be tested prior to disposal [18].
- Oil separators should be sized for a local 6-month, re-occurring 24-hour design storm. Larger storms should be diverted from the separators [18].

## ❻ Oil and Grit Separator (Water Quality Inlet)

An oil and grit separator (water quality inlet) typically consists of one or more chambers designed to allow a portion of sediments to settle out prior to entering a stormwater well. Some designs contain baffles. The separator slows inflowing water, and the amount of sediment removed is determined by the speed of the water flowing through it — relative to the depth of the separator [18].

- Effectiveness in separating dispersed petroleum products depends greatly on the design and holding time [18].
- This technology is not capable of effectively controlling runoff associated with metals and hydrocarbons. Hydrocarbon hot spots identified by monitoring include vehicle fueling, loading docks service/main-

tenance, parking areas, and salvage yards [1].

- Not effective alone in trapping pollutants.
- At least 24 hours of settling time are needed to reduce the pollutant loading.
- The on-line design promotes frequent re-suspension of previously deposited oil and sediments.
- If not properly designed and frequently cleaned, the separator will allow trapped sediments to be resuspended and pass out of the separator during subsequent flow events [18].
- Usual design flaws — insufficient treatment volume capability.
- Lack of maintenance often causes failure.
- Lack of disposal sites and costs.
- Sand filters are preferred as a better alternative with higher efficiency in removing pollutants and can deal with a higher volume of runoff, and are more easily maintained (WTP V1 #1).
- Prefab modules are generally undersized, but cannot deal with high flow rates found in PNW.
- Floating oil needs to be removed when the separator is cleaned and sediments from these devices may qualify as hazardous waste and should be tested prior to disposal [18].
- Advantages — standard practice, simple to construct, pre-fabricated and easy to maintain [18].
- Disadvantages — require periodic cleaning and maintenance, and frequent design flaws — not effective at treating many pollutants [18].
- Use in small impervious areas with a high potential for oily runoff — e.g., Gas stations, and industrial areas [18].
- Oil separators should be sized for a local 6-month, re-occurring 24-hour design storm. Larger storms should be diverted from the separators [18].

### ❼ Oil Absorbent Material

These pillows are used to absorb petroleum products when present in high concentrations.

- Can be left floating in separators and removed later during maintenance [18].
- Can minimize the amount of petroleum product passed onto an infiltration device.
- Small holding capacity limits amount of protection [18].
- Not suitable for sites with potential for a large spill [18].
- Not effective at removing dispersed oil [18].
- Inexpensive.

## 6 RETROFITS (1 – V1 #4)

This is a relatively new idea with many technologies rapidly becoming available.

- Conversion of detention facilities into stormwater wetlands.
- Addition of new treatment facility at upstream end of road culverts (concrete weir, micro pool, small wet pond, or stormwater wetland).

- Add a new treatment at the storm drain pipe outfall — such as: a flow splitter, sand filter, peat-sand filter, bioretention, wetland, or pond.

- Construct small instream facilities in the channel — small instream detention / sediment structures (small weirs, check dams), small ponds, and riparian areas.

- Construct on-site measures at the edge of parking areas — bioretention, sand filters, infiltration, vegetated swales, and compost filters.

- Construct new BMPs in highway right-of-way (usually have large open spaces available) for stormwater wetlands, ponds, vegetated swales, etc. Work particularly well in clover leaf open spaces.

- Other considerations:

  (a) Construction / maintenance access;
  (b) Utilities;

  (c) Protect existing wetlands and riparian areas;

  (d) Identify conflicting adjacent land uses and use to select BMPs;

  (e) Look for opportunities to combine projects;

  (f) Retrofit purpose and costs.

- Catch basin with sump and inlets — available retrofits (12).

  (a) EMCON inlet filter — a combination filter and micro-sedimentation device. When the filter fabric clogs, the stormwater overflows into a small rectangular weir, which acts as a sediment trap. Handles up to 300 gpm, but is meant only for sites where sediment is a concern. Filter fabrics clog quickly in field tests;

  (b) Soil Save stormwater filter unit (12) — uses a coarse geofoam filtering media between screening. Fits into an existing catchbasin. Best used to filter debris such as leaves and grass clippings. Prone to wash out due to collected solids.

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