Description

Underground stormwater BMPs include proprietary and non-proprietary devices installed below ground that provide stormwater quality treatment via sedimentation, screening, filtration, hydrodynamic separation, and other physical and chemical processes. Conceptually, underground BMPs can be categorized based on their fundamental treatment approach and dominant unit processes as shown in Figure UG-1. Some underground BMPs combine multiple unit processes to act as a treatment train.

Photograph UG-1. Installation of an underground BMP (Photo courtesy of Robert Pitt).

Historically, underground stormwater quality treatment devices have not been recommended based on UDFCD policies and criteria. This is due to several factors including problems with unmaintained or poorly maintained devices, remobilization by wash-out (scour) of accumulated pollutants during larger events, lack of performance data for underground devices in the region, and other issues discussed in this Fact Sheet. While underground flood-control detention is still discouraged, UDFCD has added this Fact Sheet to Volume 3 to provide criteria for determining when the use of underground BMPs may be considered for water quality. When surface BMPs are found to be infeasible, underground BMPs may be the only available strategy for satisfying regulatory water quality requirements, especially in highly built-up urban areas where water quality measures must be implemented as a part of a retrofit to meet regulatory requirements.

Underground BMPs should not be considered for standalone treatment when surface-based BMPs are practicable. For most areas of new urban development or significant redevelopment, it is feasible and desirable to provide the required WQCV on the surface. It is incumbent on the design engineer to demonstrate that surface-based BMPs such as permeable pavements, rain gardens, extended detention basins and others have been thoroughly evaluated and found to be infeasible before an underground system is proposed. Surface-based BMPs provide numerous environmental benefits including infiltration, evapotranspiration, groundwater recharge, aquatic habitat, mitigation of "heat island effect", and other benefits associated with vegetation for those that are planted. Be aware that some local governments prohibit the use of underground BMPs or impose requirements that go beyond this Fact Sheet.

Underground BMPs	
Functions	
LID/Volume Red.	Variable
WQCV Capture	Variable
WQCV+Flood Control	Variable
Fact Sheet Includes EURV Guidance	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Variable
Nutrients	Variable
Total Metals	Variable
Bacteria	Variable
Other Considerations	
Life-cycle Costs[4]	Moderate

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

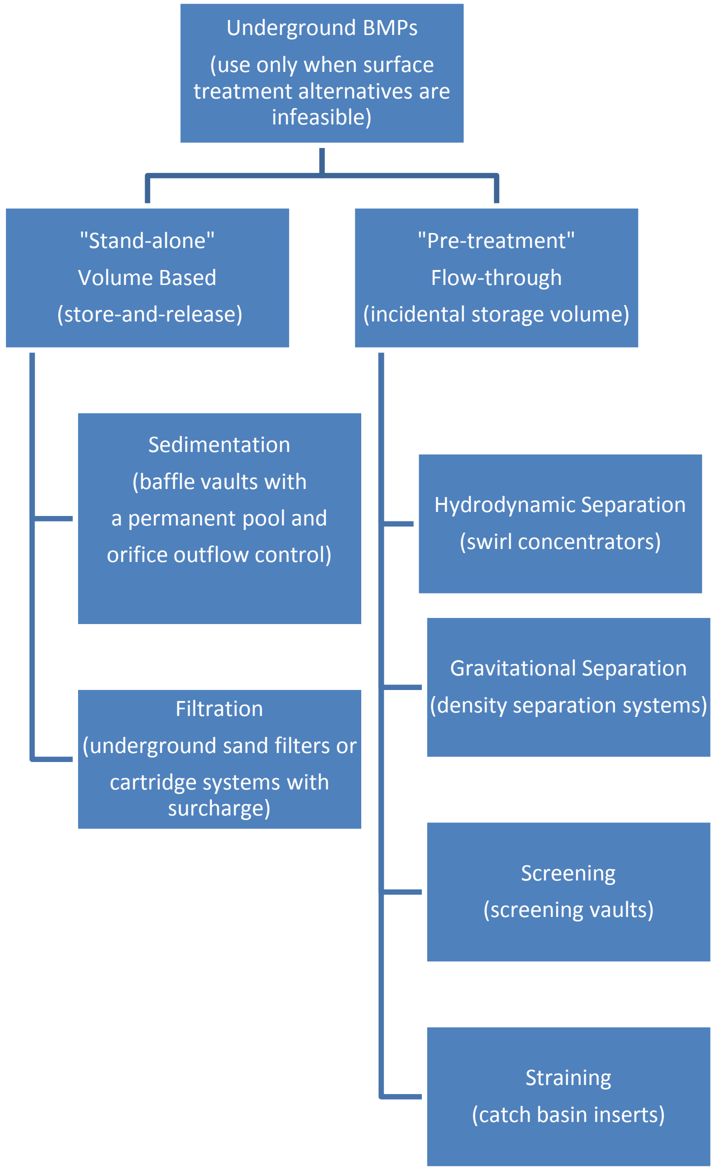

Figure UG-1. Classification of Underground BMPs

Site Selection

The most common sites for underground BMPs are "ultra urban" environments with significant space constraints. These could include downtown lot-line-to-lot-line development projects, transportation corridors, or small (less than 0.5 acre) redevelopment sites in urban areas. Important site features that must be considered include the following:

- **Depth to Groundwater**: Due to the potentially large displacement caused by an underground vault, if there is seasonally high groundwater, buoyancy can be a problem. Vaults can be sealed to prevent infiltration of groundwater into the underground system and these systems can be anchored to resist uplift. If seasonally high groundwater is expected near the bottom of an underground system, the engineer should evaluate the potential for infiltration of groundwater and uplift forces and adjust the design accordingly.

- **Proximity to Public Spaces**: As material accumulates in an underground system, there is potential for anoxic conditions and associated odor problems.

- **Gravity versus Pumped Discharge**: The ability to drain to the receiving storm sewer system via gravity is an important consideration. In some cases it may be necessary to pump discharge from an underground system; however, a gravity outfall is always reccomended if possible and some communities may not allow pumped systems. If a pumped system must be used, there should be redundancy in pumps, as well as a contingency plan in the event that a power outage disables pumps. Additionally, maintenance of the pump system should be identified as part of the water quality BMP in the maintenance plan. When BMP maintenance records are required by the MS4 permit holder, pump system maintenance records should also be included.

- **Access**: Equipment must be able to access all portions of the underground BMP, typically at multiple locations, to perform maintenance. As the size of the underground system increases, so must the number of access points.

Benefits

- Underground BMPs may be designed to provide pre-treatment and/or WQCV in space-constrained situations.

- There are many alternative configurations for proprietary and non-proprietary devices.

- Treatment train applications can be designed using different unit processes in series.

- Some underground BMPs, designed specifically for certain target pollutants, can be used to address a TMDL.

- Many underground devices can be effective for settling of particulates in stormwater runoff and gross solids removal.

Limitations

- Performance data for underground BMPs in the Denver area are limited.

- Maintenance is essential and must be performed frequently.

- Inspection and maintenance can require traffic control, confined space entry, and specialized equipment.

- Devices that do not provide WQCV do not qualify for standalone treatment.

- Gravity outfall may not be feasible in some situations.

- Many do not provide volume reduction benefits.

- Potential for anoxic conditions and odor problems.

- Not recommended when surface alternatives are feasible.

- **Traffic Loading**: Due to space constraints, in some situations, underground BMPs may be located in a right-of-way or other location where there may be traffic loadings. Many underground BMPs are or can be constructed for HS-20 traffic loading. Take additional measures when necessary to ensure that the BMP is designed for the anticipated loading.

- **Potential for Flooding of Adjacent Structures or Property**: For underground BMPs, it is important that the hydraulic grade line be analyzed to evaluate the potential for backwater in the storm sewer system. In addition, some types of underground BMPs, such as catch basin inserts, have the potential to clog and cause flooding if not frequently maintained.

Designing for Maintenance

All underground BMPs must be sized so that routine maintenance is not required more than once per year. The only exception to this is inlet inserts which may need to be cleaned as frequently as following each runoff producing event. **Because underground BMPs are generally less visible and more difficult to access than surface-based BMPs, regular maintenance and early detection of performance issues can be a challenge.**

Photograph UG-2. Maintenance access to all chambers of an underground BMP is an important design consideration. Photo courtesy of Robert Pitt.

When developing a design for an underground BMP, the engineer should ensure that all portions of the underground facility can be accessed with maintenance equipment. For multi-chambered systems, access should be provided to each chamber, and openings should be of sufficient size to accommodate the equipment recommended by the manufacturer or designer for maintenance.

Underground BMPs are generally considered confined spaces and OSHA confined space training typically will be required if a person must enter the underground BMP to perform maintenance. In all cases, a maintenance plan should be developed at the time that the underground BMP is designed.

The maintenance plan should specify, at a minimum, quarterly inspections with maintenance performed as needed based on inspections. The required inspection frequency may be reduced to biannually if, after two or more years, the quarterly regimen demonstrates that this will provide adequate maintenance. Local governments may consider requiring owners of underground BMPs to provide written inspection and maintenance documentation to better assure that required inspection and maintenance activities are taking place. When the BMP includes a pump system, pump inspection and maintenance records should also be included.

Questions to Ask When Considering an Underground BMP

Feasibility

- Are surface-based BMPs truly infeasible?
- Does the device help mitigate the adverse hydrologic impact of development?
- What are the pollutants of interest and are the treatment processes associated with the BMP expected to be effective for these pollutants?
- What is the whole life cycle cost of the BMP?

Location

- If applicable, is the device equipped for HS-20 traffic loading?
- Will the device be placed so that parked vehicles have potential to block access?

Performance

- Is stormwater monitoring required to demonstrate effectiveness of the BMP?
- Where else has a similar BMP been applied in the region? How effective was the application?
- Have independent, third-party data been collected to support performance claims?

Design

- Is pretreatment required?
- Should the device serve as a step in a treatment train instead of a standalone BMP?
- Are there mechanisms to minimize mobilization of accumulated pollutants?
- Is there a maximum drainage area recommended for the device?
- Is the device sized properly for the contributing drainage area and imperviousness?
- What is the head loss through the device for the full range of flow conditions?
- What are design water quality flow rates?
- How does the bypass operate when flow rates are greater than those for the water quality event?
- Have hydraulic grade lines been prepared for the device to evaluate potential surcharging and flooding?

Installation and Maintenance

- What support does the manufacturer provide for design, installation and/or maintenance?
- Who will be on-site during and after construction to ensure that the BMP has been installed correctly?
- What are the maintenance requirements, including access? Is the overall site plan compatible with assured long-term maintenance? Will the underground BMP be located in an easement to assure long-term access?
- What is the recommended maintenance frequency, and what is the cost and method of disposal for removed material?
- What parts of the BMP will need to be maintained and/or replaced (filter media, absorbent pillows, etc.) and what are the associated costs?
- What monitoring will occur?
- Are access openings large enough to accommodate the equipment that will be used to maintain the BMP?
- Who is responsible for inspection and maintenance?
- What proof of maintenance will be required of the owner to show that inspections and routine maintenance is performed?
- What level of effort is required to determine if the BMP is being maintained? Can this be done visually?
- Is there a contingency plan for failure of essential components (pumps, screens, obstructions in flow paths, etc.)?

Design Procedure and Criteria

Two primary options are available for underground BMPs:

1. **Underground BMPs Based on a Surface BMP design**: BMPs that satisfy the requirements for capture and slow release of the WQCV and that are based on and designed in substantial conformance with the criteria for surface-based BMPs described in this manual.

2. **Underground Proprietary BMPs**: Proprietary BMPs that satisfy the requirements for capture and slow release of the WQCV and provide a level of treatment for targeted pollutants that is comparable to that of the surface-based BMPs provided in this manual.

Underground BMPs Based on a Surface BMP Design

This class of underground BMP includes sand filter basins and retention facilities designed for below grade installation. The design must provide the WQCV and empty it over a time period of 12 hours or more. Not all of the surface-based BMPs that provide the WQCV can be adapted for underground use. For example, the vegetative components of a constructed wetland pond render it inadaptable to underground use. Underground extended detention basins are also problematic due to historical problems with remobilization of collected sediment and the difficulty of creating an effective underground micropool.

The most commonly used underground BMP to date in the UDFCD area is the underground sand filter. In addition to the criteria for an above ground sand filter, underground sand filters should meet the following criteria:

1. A pretreatment chamber for removal of coarse sediments with a volume equivalent to 0.10 times the WQCV should be provided. The pretreatment chamber must be separated from the sand filter chamber by baffles, and serves as the sediment forebay to reduce the frequency of maintenance required in the sand filter. Also consider incorporating a vertical baffle to trap oil and grease. This can be easily incorporated into the forebay and should be included where oil and grease are target constituents. Absorbent mats or booms could also be used for this purpose.

2. Where discharges from the BMP will be pumped, a separate outlet chamber is required from which the water passing through the filter layer can be pumped. The outlet pump must be sized to discharge at a rate such that the WQCV is released in no less than 12 hours.

3. For flows in excess of the water quality design event, a diversion must be sized so that excess flows bypass the sand filter chamber and the underground sand filter is not surcharged (in terms of depth or hydraulic grade line) beyond the WQCV maximum elevation.

4. Maintenance access must be provided to each chamber. Access must be sufficient to allow complete removal and replacement of the filter material. Allow for at least 6 feet of headroom (from the surface of the filter) to facilitate maintenance.

Underground Proprietary BMPs

There are numerous proprietary BMPs with wide variability in performance, design flow rates, unit processes, and volume of storage provided (if any). Sizing methodologies for proprietary devices vary from device to device—some are flow based, some are volume based, some consider surface/filter hydraulic loading, etc. As a result, this manual does not seek to provide a one-size-fits-all sizing methodology for proprietary BMPs. Instead, this manual provides a performance-based set of criteria for determining whether a proprietary BMP is acceptable for use.

To evaluate performance of an underground proprietary BMP, data should be provided to the local jurisdiction to demonstrate that anticipated BMP performance will be comparable to that of surface-based BMPs such as extended detention basins, constructed wetland basins, sand filter basins, or retention ponds. Underground BMPs approved for standalone treatment should be capable, on an annual basis, of producing effluent quality with a median TSS concentration of no more than 30 mg/L. This level of treatment is comparable to the long-term effluent median concentrations from the International Stormwater BMP Database for surface-based BMPs.

Data collected to substantiate performance of proprietary BMPs should meet the following criteria:

1. Testing must consist of field data (not laboratory data) collected in compliance with the criteria in Table UG-1. Laboratory studies and/or vendor-supplied studies without third party involvement or verification should not be considered. The Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations may provide additional useful information on development of a monitoring program for evaluation of underground BMPs. Information on the TARP program can be found in several locations on the internet, including http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/. Forthcoming field testing guidelines from the American Society of Civil Engineers Urban Water Resources Research Council (ASCE UWRRC) Task Committee developing Guidelines for Certification of Manufactured Stormwater BMPs (Sansalone et al. 2009) may also be applicable in the future.

2. Data collected in environments similar to the Colorado Front Range (i.e., semi-arid with freezing and thawing in the winter) are preferable. This is particularly important for flow based devices where differences in rainfall intensity and duration may affect performance.

3. Data should be collected and analyzed in accordance with the guidance provided in *Urban Stormwater BMP Performance Monitoring* (Geosyntec and WWE 2009; available online at www.bmpdatabase.org). When reviewing performance data, it is important to recognize that the use of percent removal may be more reflective of how "dirty" the influent water is rather than how well the BMP is actually performing (Jones et. al. 2008). Instead, look at effluent concentrations for a range of influent concentrations. **The device should have performance data that demonstrates the ability to meet a median TSS effluent concentration of approximately 30 mg/L or lower on an annual basis**.

4. Data should be collected or verified by independent third parties in accordance with good Quality Assurance/Quality Control (QA/QC) procedures.

Many studies have been conducted over the past decade to document the performance of underground BMPs. Sources of data that may be used to support using a proprietary BMP include the following:

- New Jersey Corporation for Advanced Technology (NJCAT) Technology Verification Program. (http://www.njcat.org/verification/protocol.cfm).
- Washington State Department of Ecology (2002). Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE), October 2002 (Revised June 2004), Publication Number 02-10-037. (http://www.ecy.wa.gov/biblio/0210037.html).
- International Stormwater BMP Database (www.bmpdatabase.org).
- University of Massachusetts Amherst Stormwater Technologies Clearinghouse (www.mastep.net).

- Wisconsin Department of Commerce & Wisconsin Department of Natural Resources (2007). Method for Predicting the Efficiency of Proprietary Storm Water Sedimentation Devices (1006), http://www.socwisconsin.org/pdf/Broad%20Review/Proprietary%20Stormwater%20Devices%20Std.-Draft6.pdf

- U.S. Environmental Protection Agency Environmental Technology Verification (ETV) Program http://www.epa.gov/etv/

Other data sources may also be acceptable, provided they meet the documentation criteria above.

Table UG-1. Field Monitoring Criteria for Evaluation of Proprietary Underground BMPs

Monitoring Plan Element	Criteria
Number of storm events	▪ Minimum of 10 with "complete" data sets (inflow and outflow quality and quantity data).
Parameters	▪ Inflow(s), Outflow(s) (volume and rate), Precipitation, TSS, TP, COD, Particle Size Distribution (minimum of 3 out of 10 events).
Quality Assurance/Quality Control (QA/QC)—monitoring plan	▪ Monitoring plan shall be developed in accordance with guidance from TARP or *Urban Stormwater BMP Performance Monitoring* (Geosyntec and WWE 2009) and shall satisfy USEPA requirements for a Quality Assurance Project Plan (QAPP).
QA/QC—laboratory analyses	▪ All analyses shall be performed by a qualified laboratory using USEPA standard analytical procedures.
Representativeness —sampling method	▪ Flow-weighted composite samples for event mean concentrations.
Representativeness—storm characteristics	▪ Aliquots from event shall bracket at least 2/3 of the volume of runoff and the peak of the hydrograph for each monitoring station.
Representativeness—precipitation depth	▪ All events monitored shall have a depth of at least 0.2 inches. ▪ At least 6 of the 10 events shall have total depths between 0.2 and 0.6 inches (targeted water quality storms). ▪ At least 2 of the 10 events shall have total depths > 0.6 inches—bypass quantity and quality shall be quantified and reported.
Representativeness—antecedent dry period	▪ For a storm to qualify as one of the 10 required events, the storm should be preceded by an antecedent dry period of at least 72 hours.
Data Analysis	▪ Data analysis shall follow procedures in *Urban Stormwater BMP Performance Monitoring* (Geosyntec and WWE 2009) or other established protocols such as TARP or the ASCE UWRRC Task Committee Guidelines for Certification of Manufactured Stormwater BMPs (Sansalone et al. 2009).

Depending on long-term median effluent concentrations from monitoring and whether or not the BMP provides the WQCV, a proprietary underground BMP will fall into one of three categories:

1. **Not recommended:** This category is for underground BMPs that have not demonstrated the ability to achieve an effluent median concentration for TSS of 30 mg/L or less over the long term. This category also may apply to BMPs that have a limited number of data points or studies that were not conducted in accordance with the criteria described above. Even if performance data are favorable, an underground BMP may be deemed unacceptable if a community determines that it is more difficult and/or expensive to maintain compared to a surface BMP alternative.

Stand-alone Treatment

Underground BMPs should meet three basic criteria when considered for stand-alone treatment:

- Capture and treat the WQCV.
- Drain the WQCV over approximately 12 hours.
- Demonstrate performance capable of meeting a median effluent concentration for TSS of 30 mg/L or less.

2. **Pretreatment:** This category is for underground BMPs that are constructed in series with other BMPs, the sum of which meet both the recommendation for capture and treatment of the WQCV over 12 hours or longer and also demonstrate performance capable of meeting a median effluent concentration for TSS of 30 mg/L or less. When the underground BMP does not meet the TSS effluent criterion it should be placed <u>upstream</u> of a BMP capable of meeting this criterion. Alternatively, this category also includes underground BMPs that are capable of meeting the 30 mg/L TSS median effluent benchmark but provide little, if any, surcharge storage/WQCV. BMPs in this category may be useful as an initial step in a treatment train approach to water quality.

3. **Standalone:** This category is for underground BMPs that demonstrate the ability to produce effluent with a median concentration of 30 mg/L TSS or less over the long term and provide the WQCV in accordance with UDFCD criteria. "Standalone" devices should be designed to provide release of the WQCV in no less than 12 hours. Furthermore, this category of BMP should only be used where it is determined that surface BMPs are not feasible.

See Figure UG-1 for typical types of underground BMPs that may fall into each category. UDFCD does not maintain a list of specific devices that fall into each of these categories. It is the responsibility of the designer to present relevant data, demonstrate that the criteria for data collection above have been satisfied, and identify the appropriate category for the BMP based on those data. Local governments should reserve the right to disallow underground BMPs, proprietary or not, at their discretion. In addition, a local government may require collection of additional monitoring data to demonstrate BMP performance, especially in situations where data from other geographic regions have been presented to justify use of the underground BMP. Finally, local governments may require agreements that run in perpetuity attached to the property served by the BMP, assuring that it will be inspected and maintained by the owner as required by the local government (or recommended by manufacturer) with a provision for taking over the inspection and maintenance if needed and back charging the owner.

Construction Considerations

Improper installation will cause poor performance of proprietary underground BMPs. This problem has been noted not only by manufacturers, but also by Colorado municipalities who have observed that the "as built" BMPs often vary significantly from the design. Most underground BMPs already face hydraulic challenges due to limited vertical fall and because of head losses, so they may be sensitive to slight changes in elevation. In addition, many of the proprietary underground BMPs require assembly of special baffling or patented inserts that may not be familiar to contractors.

For these reasons, it is important to discuss the installation of the underground BMP with the manufacturer prior to selecting a contractor so that the installation requirements are clearly understood. Construction observation by the design engineer, and, if possible, a manufacturer's representative is essential for proper installation. At a minimum, the installation should be inspected by the manufacturer's representative once completed. Any deficiencies of the installation identified by the manufacturer's inspection should be corrected immediately.