

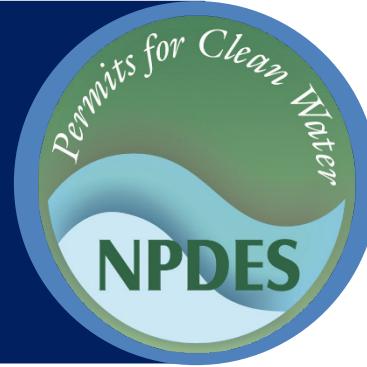


Stormwater Best Management Practice

Grassed Swales

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment

Subcategory: Infiltration



Description

In the context of stormwater controls to improve water quality, a grassed swale is a vegetated, open-channel management practice that treats and reduces stormwater flows for a specified water quality volume. As stormwater flows along these channels, the vegetation slows it down, allowing for sedimentation, soil filtration and/or infiltration into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale, bioswale and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch. They incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

Applicability

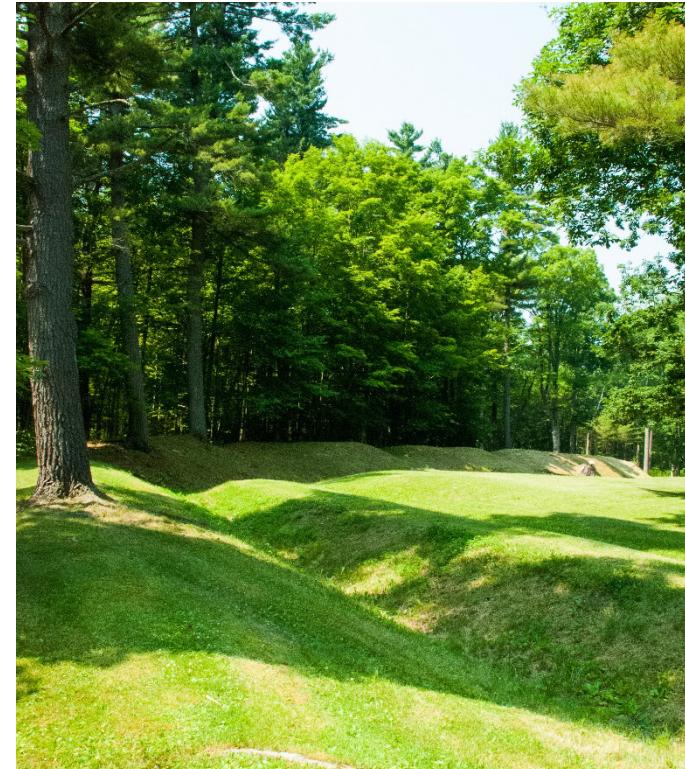
Planners can use grassed swales in most situations with some restrictions. Swales are linear practices, well-suited for treating stormwater from highways or residential roads. A swale is also useful as one stormwater control in a series of stormwater controls known as a treatment train: for instance, conveying water to a rain garden and receiving water from filter strips. Furthermore, swales can be integral parts of green infrastructure and better site design approaches¹; see the [Site Design and Planning Strategies](#) fact sheet for more information.

Regional Applicability

Planners can use grassed swales in most regions of the United States. In arid and semi-arid climates, however, planners should weigh the value of the practice against any water irrigation needs.

Urban Areas

Dense development in urban areas leaves little pervious surface. Grassed swales may not be well-suited to urban areas because they require a relatively large area of pervious surface.



A grassed swale directs the flow of stormwater and allows stormwater to infiltrate.

Stormwater Hot Spots

Stormwater hot spots are areas where certain land uses or related activities generate highly contaminated discharges with pollutant concentrations exceeding those typically found in stormwater. Typical examples include gas stations and industrial areas. Grassed swales should not receive stormwater from hot spots as they either infiltrate stormwater or intersect the groundwater table, so using them for treatment or conveyance of hot spot discharges could threaten groundwater quality.

¹ Better site design is a design strategy that aims to reduce impervious cover, preserve natural lands and capture

stormwater on-site. See the [Site Design and Planning Strategies](#) fact sheet for more information.

Stormwater Retrofit

A stormwater retrofit is a stormwater management practice (usually structural) that property owners put into place after development to improve water quality, protect downstream channels, reduce flooding or meet other specific objectives such as achieving compliance with a total maximum daily load waste load allocation.

One retrofit opportunity to consider involves incorporating grassed swale design features, such as flatter longitudinal slopes, to enhance the stormwater management functions of existing drainage ditches. Designers have traditionally planned ditches to rapidly convey stormwater. In ditches with high flow rates, it may be possible to incorporate features such as check dams (i.e., small dams along the ditch that trap sediment, slow stormwater flow, reduce erosion and promote infiltration) that effectively reduce the channel slope, thus reducing flow velocities and enhancing pollutant removal or infiltration.

Grassed swales may be a suitable retrofit opportunity in areas with ample space, such as lower-density residential areas or roadways with wire shoulders. However, using only grassed swales to retrofit an entire watershed would be expensive—grassed swales cannot treat large drainage areas, so installing a large number of them would be necessary.

Cold Water (Trout) Streams

Grassed swales are a good treatment option in watersheds that drain to cold water streams. They do not pond water for long and often infiltrate water. As a result, they do not typically subject standing water to solar warming.

Siting Considerations

Although grassed swales are generally broadly applicable, designers should consider the site conditions that come with different regions and land uses. These can restrict the choice of grassed swales (e.g., steep slopes, highly impermeable soils) and necessitate adaptations. Designers should also consider these site factors to ensure that this management practice is feasible at the site in question.

Drainage Area

Grassed swales should generally treat stormwater from drainage areas smaller than 1 acre. If they treat larger areas, the flows become too large to allow for any

stormwater treatment. For larger drainage areas, consider using wet/dry swales (see “Design Variations”), which generally have a higher level of engineering and can handle larger flows and pollutant loadings.

Slope

Sites with relatively flat slopes work best for grassed swales. Design documents generally recommend a 1 to 2 percent slope. Stormwater velocities within the channel become too high on steeper slopes, causing erosion and preventing infiltration or filtering in the swale. When site conditions require installing swales in areas with steeper slopes, designers can use check dams to reduce velocities and allow for temporary ponding.

Soils/Topography

Design engineers should evaluate the hydrologic soil group of the site during the design phase. Most soils are suitable for grassed swales, with some restrictions on the most impermeable soils (hydrologic soil group D). For impermeable soils, variations such as the dry swale (see “Design Variations”) replace on-site soils with a fabricated soil bed to ensure that stormwater infiltrates as it travels through the swale.

Groundwater

The required depth to groundwater depends on the type of swale (see “Design Variations”). In dry swales and grassed channels, design engineers should position the bottom of the swale at least 2 feet above the groundwater table to prevent prolonged saturation. In areas where groundwater contamination is a concern, designers may want to offset the swale from any water wells to provide a buffer from pollutants infiltrating nearby water sources. Conversely, the design of wet swales depends on standing water or a slow-flowing wet pool, which is achieved by intersecting the groundwater.

Design Considerations

Designers should consider several features to improve longevity and performance while minimizing maintenance burden. Although there are variations, some considerations are common to all grassed swale designs. An overriding similarity between the types of swales is cross-sectional geometry. Swales often have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1), though they can also have rectangular and triangular channels. Flat side slopes increase the wetted perimeter—the length along the edge of the swale cross section where stormwater

flowing through the swale contacts the vegetated sides and bottom. This design slows stormwater, and the added contact with vegetation encourages sorption, filtering and infiltration. Flat side slopes also let stormwater entering from the sides of the swale receive some pretreatment along the side slope.

In addition to treating stormwater for water quality, it is important that grassed swales convey flows from larger storms safely. Typical designs allow the stormwater from the 2-year storm to flow through the swale without causing erosion. Swales should also have the capacity to convey larger storms (typically a 10-year storm) safely (Philadelphia Water, 2018).

Design Variations

The subsections below discuss three variations of open channel practices: grassed channels, dry swales and wet swales. Grassed channels are the smallest variation, and design engineers can implement them as a standalone practice. Dry and wet swales are larger and, due to their size, should include pretreatment in the form of a small forebay or filter strip at the front of the swale to trap incoming sediments. For pretreatment of stormwater entering the sides of a dry or wet swale, designers can incorporate a pea gravel diaphragm (a small trench that contains river-run gravel) along the length of the swale. Other features that enhance the performance of grassed swales are a flat longitudinal slope (generally between 1 and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the flow velocity within the channel. The dense vegetation also helps reduce velocities, protects the channel from erosion, and acts as a filter to treat stormwater. When selecting vegetation, consider native plants, flow velocities, sunlight, deicing material tolerance, ponding depth and ponding duration.

Grassed Channel

Grassed channels generally treat smaller drainage areas of 1 acre or less. Compared to design variations that treat larger drainage areas, they typically require flatter slopes and do not require pretreatment. Of all the options, grassed channels are the least expensive and require the least engineering, but they also provide the least reliable pollutant removal. Designers use grassed channels effectively as pretreatment to other structural stormwater practices. A major difference between the grassed channel and many other structural practices is the method designers use to size the practice. Design engineers size most stormwater management practices

by volume, whereas they typically size grassed channels to limit peak flow velocities from a design storm. Maximum velocity and design storms vary by region, but they are often 1 foot per second for the 10-year, 24-hour storm event (e.g., MDE, 2009).

Dry Swale

Dry swales are larger than grassed swales and similar in design to bioretention practices; see the [Bioretention \(Rain Gardens\)](#) fact sheet for more information. Practitioners typically use these designs to treat drainage areas of 1 to 5 acres. They generally incorporate fabricated soil beds, unless native soils have high enough infiltration rates (e.g., hydrologic soil group A or B). When using a fabricated soil bed, a sand/soil mix meeting minimum permeable requirements replaces the native soil. Drawdown requirements vary regionally but required drain time is typically 24 to 48 hours. Design engineers may specify an underdrain system, which consists of a perforated pipe encased by a gravel layer under the soil bed. After the soil bed treats the stormwater, the stormwater flows into the underdrain, which routes it to the storm drain system or receiving waters. Installers can also amend the soil bed with materials that enhance pollutant removal, such as compost or media with high adsorption capacities (Hirschman et al., 2017).

Bioswales are a dry swale variation suitable for smaller drainage areas (generally less than 0.5 acres) and therefore do not need pretreatment. They are similar in design to a rain garden (a smaller version of a bioretention practice), with the main difference being that they infiltrate and convey stormwater, rather than solely infiltrating. Bioswales are typically vegetated and used by designers in urban areas. Accordingly, they have become a common green infrastructure alternative, where they not only provide for stormwater conveyance and treatment, but also increase aesthetic appeal.

Wet Swale

Wet swales intersect the groundwater and function similarly to a linear wetland cell (see the [Stormwater Wetland](#) fact sheet). Planners typically use wet swales to treat drainage areas of 1 to 5 acres. This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. When possible, designers should consider using native vegetation in the swale. In some cases, a companion or cover crop may be appropriate to help establish native species. There is also evidence that this design results

in potentially high pollutant removal. Wet swales are not common in residential or commercial settings because standing water may facilitate mosquito breeding.

Arid Climates

In arid or semi-arid climates, consider using drought-tolerant vegetation. It is necessary to balance the value of vegetated practices for water quality treatment against the cost of the irrigation water necessary to maintain them in arid and semi-arid regions.

Limitations

Grassed swales have some limitations, including the following:

- Grassed swales cannot treat a very large drainage area.
- Wet swales may become nuisances due to mosquito breeding if they take 3 or more days to drain. Allowing for constant flow, a permanent pool with natural predators (e.g., fish) or timely drainage reduces the chance of the swale becoming a mosquito breeding habitat (MPCA, 2018).

- Improper design or maintenance (e.g., not achieving proper slopes or failing to establish vegetation), grassed swales may result in very little to no pollutant removal.
- Generally, grassed swales reduce peak pollutant concentrations, but depending on their design, they may have very limited capacity to reduce total loadings in the long term.

Maintenance Considerations

Maintenance of grassed swales mostly involves litter control and maintaining the grass or wetland plant cover. Table 1 lists maintenance activities recommended by typical design documents. Some general recommendations include:

- Not using too much salt or sand around the swale during the winter months.
- Not applying fertilizer (consult a local nursery or botanist if plants aren't thriving).
- Not piling snow that can crush plants or leach deicing materials into the system.

Table 1. Typical maintenance activities for grassed swales.

Activity	Schedule
<ul style="list-style-type: none"> ■ Inspect pretreatment areas, such as a pea gravel diaphragm, for clogging. Make corrections as necessary. ■ Inspect grass along slopes for erosion and formation of rills or gullies. Make corrections as necessary. ■ Remove accumulated trash and debris. ■ Inspect and correct erosion problems in the sand/soil bed of dry swales. ■ Plant an alternative grass species if the original grass cover does not become established. ■ Evaluate vegetation health and replant if the vegetation is not sufficiently established or healthy. 	Annual (semiannual the first year)
<ul style="list-style-type: none"> ■ Rototill or cultivate the surface of the sand/soil bed of a dry swale if ponded water does not draw down within 48 hours. ■ Remove sediment buildup from the bottom of the swale if accumulation reaches 25 percent of the original design volume. 	As needed (infrequent)
■ Mow grass to maintain a height of 3 to 4 inches.	As needed (frequent seasonally)

Source: Clayton & Schueler, 1996

Effectiveness

Structural stormwater management practices can achieve four broad resource protection goals: pollutant removal, flood control, channel protection and groundwater recharge. Depending on the design

variation, grassed swales can help meet groundwater recharge and pollutant removal goals.

Groundwater Recharge

Grassed channels and dry swales can provide some groundwater recharge through infiltration. Note that wet swales generally make little, if any, contribution to groundwater recharge. Either high surrounding water tables limit infiltration or debris settled on the bottom of the swale impedes flow. When infiltration losses are a large portion of total incoming flow, analysts should interpret pollutant removal data accordingly. For example, even if effluent concentrations remain the same as influent concentrations, losses to infiltration represent removal of pollutant mass from surface water discharge pathways.

Pollutant Removal

The pollutant removal performance of swales depends on several factors, including velocity reduction, volume reduction and pollutant loading. In all cases, infiltration provides some amount of pollutant removal through volume reduction. Additionally, slowing flow velocity allows sediments, metals and bacteria to settle out of the water column. However, evidence suggests that while it is possible to reduce peak stormwater concentrations, the filter layer may not permanently bind pollutants. Long-term pollutant removal performance may therefore be negligible if stormwater flows can re-mobilize settled pollutants (Bäckström, 2006). Table 2 summarizes the results of several studies looking at the effectiveness of design variations.

Table 2. Grassed swale pollutant removal efficiency (percent removal) data.^a

Design Variations	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Metals	Bacteria	Source
Grassed channel	16–81	(67)–29	(12)–38 ^b	(60)–62	(50)–100	Goldberg, 1993; Cook, 2007; Clary et al., 2017
Dry swale	87	5–83	46–84	88–90	—	Harper, 1990; Carey et al., 2012
Wet swale	23–67	12–39	9–42 ^b	(35)–64	33	Koon, 1995; Carey et al., 2012; Clary et al., 2017

^a Values in parentheses indicate negative removal rates.

^b Some results only reflect nitrate concentrations.

While it is difficult to draw conclusions from such variable performances, grassed channels generally have poorer and less consistent removal rates than wet and dry swales. This is due in part to design standards focusing on flow conveyance rather than pollutant removal.

The removal efficiencies of metals and bacteria can be variable, as they are highly dependent on surrounding conditions. Swales often treat adjacent roadway discharge, which can be a significant source of metals from wear and tear of vehicle components like tires and brake pads. Swales may also be sources of bacteria, which can thrive in warm soils. Another factor that many studies do not account for is alternative sources of bacteria, such as local wildlife or pet waste. Signs identifying swales as stormwater controls leading to local receiving waters might encourage pet owners to pick up pet waste. Some municipalities have implemented ordinances requiring pet owners to remove pet waste

from public areas and stormwater conveyances. Cost Considerations²

Data to estimate the difference in cost between various swale designs are limited. One study (Carey et al., 2012) estimated the construction cost of grassed channels as being between \$0.85 to \$2.30 per cubic foot of storage capacity. Another study estimated total initial costs, including design and construction, as \$25,000 to \$50,000 per acre of impervious surface treated, with higher costs reflecting smaller practices such as bioswales (King & Hagan, 2011). In any case, pre-construction costs including design and permitting can be 20 to 40 percent of construction costs (Brown & Schueler, 1997; King & Hagan, 2011).

Long-term maintenance costs should be a consideration, since proper upkeep of the swale is critical to both its designed flow capacity and pollutant removal. Although

² Prices updated to 2019 dollars. Inflation rates obtained from the Bureau of Labor Statistics CPI Inflation Calculator Web site: <https://data.bls.gov/cgi-bin/cpicalc.pl>.

annual maintenance costs depend on the design variation, planners generally estimate them to be around 3 percent of construction costs or \$500 to \$1,500 per acre of impervious surface treated (King & Hagan, 2011).

It is important to assess construction costs in the context of larger design goals. Most development projects

require some type of stormwater conveyance. The construction of grassed swales is less expensive than concrete ditches or sewers and can also provide stormwater management benefits.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Disclaimer

This fact sheet is intended to be used for informational purposes only. These examples and references are not intended to be comprehensive and do not preclude the use of other technically sound practices. State or local requirements may apply.