Stormwater
The Journal for Surface Water Quality Professionals

FEATURES

A Simplified Integrated Design Concept for Filters

Part 1: Terminology

We don't commonly think of infiltration systems as filters. But they are.

By Gary R. Minton

What do all of the treatment systems in Figure 1 have in common? They are all filters. There are fewer true filter types than presented in Figure 1 due to name redundancy: different names for the same configuration. For example, the lineal, perimeter, Delaware, and street filter are the same configuration: a vault with two long, narrow-width chambers, one for pretreatment and one for the sand filtration with stormwater entering laterally rather than at one end of the structure.

We don't commonly think of infiltration systems as filters. But they are. We have an underdrain system of soil rather than pipes. The filter media is the native soil. But it is becoming more common to specify engineered media (e.g., bioretention). Consequently, the distinction between the "engineered filter" and "nature's filter" has blurred.

The degree of infiltration and evapotranspiration (I/ET) by the filter types has also blurred. Two decades ago, we had a distinct boundary: none with sand filters and all with infiltration systems. Today, a bioretention facility with underdrains in tight soils may have significant I/ET. We now have a continuum of I/ET as a percentage of incoming stormwater rather than simply the two extremes of none and all.

I have observed in manuals, articles, and reports, as well as in presentations and conversations at conferences, that the complexity of terminology itself leads to misperceptions and confusion over expected performance and to unnecessary and inappropriate distinctions in design procedures and criteria. This dynamic has led to inconsistencies in design procedures, often within the same manual. Examples are given in this article.

Figure 1

Engineers do not necessarily realize these differences and potential conflicts because we work within our own community, state, or province with an agreed terminology and set of design criteria. However, as it becomes increasingly common to trade experiences and field results across regions and borders, contradictions and miscommunication are becoming more frequent. A common and simplified set of terminology and design procedures is warranted. In this article, I propose a simplified concept for filters.

Presented here is Part 1 of a three-part series on stormwater treatment filters in the public domain. Our theme is simplification of terminology and consistency in design criteria. Part 1 covers terminology and provides recommendations toward simplification, with the aim of achieving greater clarity. Parts 2 and 3, to be presented in subsequent issues, will cover specific design criteria.

Current Filter Configurations

Table 1

Our focus is with filter systems in the public domain. Manufactured filters are excluded from this discussion. The various filter names are grouped by type in Table 1. Also presented in Table 1 are current design criteria drawn from about three dozen state, provincial, and community manuals in the United States and Canada. Note the many names used for what is essentially the same configuration. Also note the tremendous variation in design criteria for each filter type as well as between filter types.

The confusion over terminology and perceived differences where there are none has lead to differing conclusions as to where to place a particular system in manuals. Some manuals identify bioretention as a filter, placing it with the many variant configurations of the sand filter. Some manuals place bioretention by itself apart from any other grouping. Manuals sometimes place the dry swale with the sand filter; others with swales and filter strips; and, sometimes, all in the category of channels. Some manuals confuse the grass and dry swale. Some manuals contain both the organic and the bioretention filters, the former placed with and seen as a variant of the sand filter. Yet the specifications of sand and organic matter, even with a vegetative surface, are essentially the same for both filter types.

Table 2

The plethora of names for what often are essentially the same or similar filter types has lead to different sizing methods and/or criteria in the same manual. Table 2 illustrates this point by comparing the design criteria for bioretention and the dry swale, common to manuals that contain both systems. While essentially the same system, the design criteria are quite different.

Let's start with sand filters as the eldest of the filter family. Table 1 lists many alternative names. The rectangular basin is frequently referred to as the *Austin filter*, after the city where sand filters were first used, or the *partial* or *full sedimentation filter*, both names also originating from Austin and reflecting the degree of pretreatment. The porous landscape detention filter has no pretreatment; the same usually goes for the pocket filter.

The qualifier *organic* as applied to a filter in Table 1 is a relatively old term but still present in several manuals. Peat and/or compost is included to remove dissolved metals. There are several variants differing by media mix (all peat or sand/peat mix) and layering (one layer or two, with differing peat and sand mix in each).

Newer is the multichamber treatment train (MCTT). Its media specification is that of the organic filter, although activated carbon has been included. The pretreatment system differs significantly from the organic and sand filter basins. But is this sufficient to warrant a new name? Should not the sizing of the pretreatment element be a separate decision irrespective of the type of filter? The name *MCTT* is opaque, giving no indication of the presence of a filter. Inclusion of the term *treatment train* is confusing, as it otherwise commonly describes a system with two separate structures [e.g., a swale followed by a pond (Minton 2006)]. For both the organic and the MCTT, what we have is an amended sand filter; that is, an amendment is added to remove pollutants that are not removed by sand.

Figure 2

The dry swale is a narrow, long, sloped filter (Figure 2): hence the moniker swale. It has the physical appearance of the older grass swale. However, the dry swale is sized as a filter, with a live storage volume equal to the design water-quality volume (DWQV) like a sand filter or an extended detention basin. In contrast, the size of a grass swale (also called grassy, vegetated, biofilter, and landscape swale) is based on peak flow, not storm volume. Most importantly, these swales, as well as filter strips, are not filters. They are effectively shallow settling basins. In a few manuals, we have the distinction between a dry swale and an enhanced dry swale, the former with turf grass and the latter with shrubs as well. How do these systems differ from bioretention swales and slopes (or strips), which commonly come with shrubs but are recently being designed with turf grass rather than shrubs?

For several years, a maximum width of 8 feet has been commonly specified in several western United States manuals for grassy swales; this is appropriate, as it is critical the stormwater spread across the swale width as it enters to provide a low water depth essential to treatment. This is difficult to achieve if the grass swale is very wide. Some recent manuals in the eastern US also specify a maximum width of 8 feet for dry swales, likely drawn from the western US manuals' specifications for grass swales. But width is not a critical design element for dry swales, which temporarily store the stormwater.

Bioretention is an organic filter, altered by the inclusion of surface vegetation. The filter media for both filter types is essentially the same. Perhaps if the original organic filter included vegetation as a variant, the term *bioretention* would not have arisen. As with MCTT, the name *bioretention* is opaque, giving no indication of the presence of a filter. Different names for essentially the same system have led to oddities. One manual allows bioretention but not an organic filter, out of concern for freezing of the latter system. Yet both may have essentially the same media specification and therefore are equally susceptible to freezing.

What do we mean by *bioretention*? It has never been defined in the context of the treatment system. We would presume it is the removal of pollutants by biological processes: e.g., plant uptake and bacterial degradation or transformation. But this occurs in wet ponds, wetlands, and infiltration basins as well—in any system with biological activity. It is more appropriate to use the term *bioretention* as a collection of unit processes rather than unit operations (Minton 2007). Its use to name a unit operation is unfortunate.

To add to the confusion, some manuals and articles refer to the *bioretention swale*: a sloped bioretention cell. How does it differ from the dry swale? One system is quite specific as to the media; one is not. Design depths differ. The dry swale might be viewed as covered by turf grass whereas the bioretention cell is commonly viewed as covered with shrubs, as noted previously. But turf grass is now being specified for bioretention cells with no shrubs. And shrubs are being specified for dry swales. One manual refers to these as *enhanced dry swales*. Such inconsistencies have been found within the same manual.

Our final group in Table 1 is infiltration systems. In the past this group referred only to infiltration basins and trenches. We now have porous pavements. We have bioretention cells and dry swales without underdrains, soil permitting. We also have the rain garden when applying the concept to the individual home. We have bioinfiltration or infiltration swales, with other monikers depending on the manual. But these systems are without slope. They are called swales simply because of their narrow width. Why? At what width/length ratio does a basin become a swale? Why do we use the term *lineal* to identify a long, narrow sand filter but the term *swale* to define a long, narrow infiltration basin?

The distinction of whether something has significant infiltration has blurred, as noted previously. A bioretention cell or swale, dry swale, or rain garden without underdrains is placed in the infiltrator group. But these systems, even with underdrains, can apparently have considerable infiltration. Despite underdrains, the amount of I/ET can approach the volume performance goal (VPG) even in relatively tight soils. A design configuration most recently recommended is to place a gravel or sand layer of 18 inches beneath the elevation of the underdrains. This allows for temporary storage of stormwater, enhancing infiltration. And of course evapotranspiration plays an important but as yet not quantifiably well-defined role. Twenty years ago we had two distinct filter systems, one with no infiltration and one with sufficient infiltration to explicitly meet the VPG. We now have a continuum between these two extremes.

Recommendations to Simplify Terminology

Let's simplify terminology (Minton 2006). The intent is to minimize redundancy and to provide clarity. I offer several general but related guidelines. Remove duplicative names. Don't use a separate name just because the system is used in a different application: e.g., the gutter filter is simply a particular application of the lineal sand filter. Limit the use of the term *swale* to narrow systems with a distinct specified slope. Use names that are more explicit of the system: e.g., *filter swale* rather than *dry swale* and *bioretention filter* rather than *bioretention*.

Table 3

Table 3 presents my preference for filter names. The terminology is simple and explicit: rather staid but clear. Table 3 proposes the term *bioretention* be discontinued as a name for a unit operation. As noted previously, the term *bioretention* is better viewed as a unit process that occurs in most treatment systems. Each system in Table 3 has four variants differing by configuration, each of which can be bare or vegetated: basin, cell (very small basin), lineal, and swale (having a slope). The term *swale* is limited to a system with a horizontal slope. A sand filter need not have sand media per se. Crushed recycled glass has been used, with a graduation similar to ASTM C33. Perhaps the filter could be 100% zeolite or activated alumina or a combination to remove dissolved pollutants.

Table 3 presumes that the media will never be 100% organic matter (peat and organic filters) or 100% loam soil (bioretention). A sand mixture provides better filtration rates while not apparently reducing performance.

A distinction is made between filters that have inorganic and organic amendments. Although the inclusion of both is not currently done, it could be. For example, nutrient removal is not stellar in the bioretention system. An inorganic amendment could be included to enhance removal.

A vegetated surface is always specified unless the filter is subsurface or in a semi-arid area, although even in semi-arid areas it should be possible to have a cover of native plants. The cover will be partial but will still provide benefits. For the soil filter (i.e., infiltration) Table 3 presumes a bare surface occurs where the soil is devoid of organic matter, either because of its coarseness as these soils are typically low in organics or because excavation typically removes the A soil layer where almost all of the organic matter resides. Some suggest replacing the lost organic matter in all cases (WDOE 2005).

Table 4

It is unlikely (and unfortunate, in my view) that *bioretention* as the name of a system will be discarded, given its widespread use. Table 4 provides an alternative structure that retains the term *bioretentio*n as currently used. The overall structure of terminology is somewhat more complex than that of Table 3 but doable. But we can be more explicit by saying *bioretention filter* rather than just *bioretention*. As with Table 3, Table 4 identifies names that should be discarded and relates targeted pollutants to the particular filter type.

Some things don't fit well in Table 4. How does an infiltration basin with specified media and a vegetated surface differ from a bioretention filter without underdrains placed in a well-drained soil? Bioretention variants have been filters or infiltrators, depending on the native soil. We could call the latter infiltration basins to distinguish from bioretention filters with underdrains (i.e., avoid using the term *bioretention* with fully infiltrating systems). Alternatively, the word *basin* can be used for the infiltration system but cell for the bioretention system, given that the latter are usually small.

For all systems in both Tables 3 and 4, the term *swale* is limited to systems with a slope. It is not clear, however, why a sloped swale is used as a filter (why not leave it flat?) except where the ground slopes, and a swale provides a more aesthetic solution. Otherwise, why not leave the filter flat and step down if necessary to fit the slope? The swale can be sized to hold the DWQV as with the current dry swale. However, I propose a new concept. The concept combines features of the West Coast grass swale and the East Coast dry swale. Field data support the view of many engineers that the grass swale does not likely meet the common 80% removal of total suspended solids (TSS) goal. Nor is the grass swale particularly effective at removing dissolved pollutants except to the extent that infiltration may occur, which is uncertain and variable between sites.

The effectiveness of the West Coast grass swale is improved by including porous filter media beneath, as for the dry swale. Underdrains are included if the native soil provides inadequate infiltration. Check dams are included to enhance the vertical draining of stormwater into the filter media. The dam can be porous with a mixed media to provide treatment for the portion of the stormwater that passes down the slope to the outlet. However, the filter swale is sized similarly to the grass swale, based on the peak of the design event rather than the volume. Width is determined using Manning's equation, as with the grass swale. Length is based on residence time, as with a grass swale. The limitation with the grass and dry swales is their substantial length. Therefore, a residence time of five minutes is proposed, rather than the common criterion of nine minutes for the grass swale. The outcome is a smaller but more effective system. The improved treatment by filtration and the check dams compensates for the shorter length.

Summary

Let's simplify our terminology using names that are more explicit: e.g., *filter swale rather than dry swale*; *bioretention filter rather than bioretention*. I believe this simplification and clarification will lead to more consistent design procedures and criteria and less confusion in the discourse between practitioners. How is this to be achieved? I hope that as state manuals are updated, their authors will begin to use a consistent set of terms, mostly likely that outlined in Table 4.

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SW March/April 2008

Figure 1. Filter Treatment Systems		
Bioretention	Bioretention Cell	Bioretention Swale
Rain Garden, Dry Swale	Organic Filter	Austin Sand Filter
Delaware Sand Filter	Partial Sedimentation Filter	Full-Sedimentation Filter
Lineal Sand Filter	Perimeter Sand Filter	Delaware Sand Filter
Pocket Filter	Sand Filter Extended Detention Basin	Multichamber Treatment Train
Infiltration Basin	Infiltration Trench	Ecology Embankment
Enhanced Dry Swale	Water-Quality Swale	Underdrain Soil Filter
Porous Landscape Detention	Bioinfiltration	Infiltration Swale
Bioretention Swale	Gutter or Street Filter	

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Table 3. Author's Preferred Terminology for Public Domain Filters

Proposed Filter Type[a]	Surface[b]	Targeted Pollutant	Media Depth	Names Discarded	Comments
Sand filter[c] *With underdrains*	Bare	Sediment (TSS), particulate pollutants, TPH	12 inches	Austin, partial and full sedimentation, perimeter, Delaware, street, sand filter extended detention	
	Vegetated	Above plus bacteria, dissolved metals, toxic organics, as well degradation of TPH and organics	12 inches including turf soil		
Amended inorganic sand filter *With underdrains*	Bare	Sediment (TSS), particulate pollutants, and dissolved pollutant depending on the amendment	Minimum 12 inches	Ecology embankment	Amendments: activated alumina, phosphorus; zeolite, metals, nitrogen; activated carbon, toxic organics
	Vegetated	Above plus bacteria, dissolved metals, as well degradation of TPH and organics	Minimum 12 inches		
Amended organic sand filter *With or without underdrains*	Bare	Sediment (TSS), particulate pollutants, TPH, bacteria, dissolved metals		Organic, MCTT, peat	Amendments: compost, peat, loam soil. Activated carbon is organic but placed with above to distinguish the use of more natural materials like peat
	Vegetated	Above plus temperature reduction and volume reduction, as well degradation of TPH and organics	Varies with pollutant	Bioretention, dry/ enhanced swale, underdrain soil filter, porous landscape detention, underdrain soil filter	
Soil filter[d] *Without underdrains*	Bare[e]	Sediment (TSS), particulate pollutants, TPH, temperature, and volume reduction	Appropriate depth to seasonal groundwater level		
	Vegetated	Above plus bacteria, dissolved pollutants such as metals, phosphorus, and nitrogen, as well degradation of TPH and organics		Bioinfiltrator, infiltration swale	

a. Variants for each type could be basin, cell (very small basin), lineal, swale (having a slope).
b. Bare surface occurs if filter is subsurface or located in semi-arid area unless irrigation water is available.
c. Crushed recycled glass with a graduation similar to ASCM C33 is an alternative media as is perlite.
d. The soil original to the site. Any of the first three filter types can be placed on the bottom of the infiltration device where the soil is coarse, particularly if there is need to protect a drinking water aquifer.
e. It is assumed that the soil is relatively coarse, and contains little organic matter due to excavation of the A layer of soil, hence it cannot support vegetation.

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Table 4. A More Likely Scenario of Terminology					
Filter Type[a]	**Media**	**Surface[b]**	**Targeted Pollutant**	**Media Depth**	**Names Discarded**
Sand filter[c] *With underdrains*	Sand	Bare	Sediment, particulate pollutants, TPH	12 inches	Austin, partial and full sedimentation, perimeter, Delaware, street, sand filter extended detention, organic, MCTT, peat
		Vegetated	Above plus bacteria, dissolved metals, toxic organics, as well degradation of TPH and organics	12 inches including turf soil	
Sorbative filter *With underdrains*	Coated sand, activated alumina, zeolite, activated carbon, compost, peat	Bare	Sediment, particulate pollutants, and dissolved pollutant depending on media	As above but could be deeper if needed for capacity	Austin, partial and full sedimentation, perimeter, Delaware, street, sand filter extended detention, organic, MCTT, peat
		Vegetated	Above plus bacteria, dissolved metals, toxic organics, degradation of TPH and organics		
Bioretention filter[d] *With or without underdrains*	Sand/organic mix	Bare	N/A		Bioretention, dry swale, underdrain soil filter, porous landscape detention, underdrain soil filter
		Vegetated	Sediment, particulate pollutants, TPH, bacteria, dissolved metals, temperature, volume reduction, as well degradation of TPH and organics	Varies with target pollutant	
Infiltrator *Without underdrains*	Native soil	Bare[e]	Sediment, particulate pollutants, TPH	Appropriate depth to seasonal groundwater level	
		Vegetated	Above plus bacteria, dissolved metals, degradation of TPH and organics		Infiltration swale, bioinfiltrator
	Amended	Bare	Sediment, particulate pollutants, TPH, dissolved pollutant depending on amendment		
		Vegetated	Above plus bacteria, dissolved metals, degradation of TPH and organics		Infiltration swale, bioinfiltrator

a. Variants for each type could be basin, cell (very small basin), lineal, swale (having a slope). Also trench with infiltrator although this should be changed to lineal.
b. Bare surface occurs if filter is subsurface or located in semi-arid area unless irrigation water is available.
c. Crushed recycled glass with a graduation similar to ASTM C33 is an alternative media as is perlite.
d. Another possible and more explicit name is biological filter.
e. It is assumed that the soil is relatively coarse and contains little organic matter due to excavation of the A layer of soil, hence it cannot support vegetation.