Performance Enhancing Devices for Stormwater BMPs

Biochar

December 2018

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For:

Roadside Ditch Management & PEDs

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Chesapeake Stormwater Network

Funded By:

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Biochar

1. Definition & Applications

Biochar is produced by the pyrolysis (i.e., combustion at extreme heat with no oxygen) of biomass such as wood chips, poultry litter, switchgrass, and waste wood products (Law et al., 2014). In most applications, biochar is used as a soil amendment to boost soil water and nutrient retention. Other researchers have investigated whether biochar can sequester nutrients and metals since it produces a large porous surface area for pollutant adsorption and microbial processing. Depending on its parent feedstock, biochar is not expected to have the same nutrient leaching potential as other, more raw forms of carbon, such as peat or compost (Hirschman et al., 2017).

The use of biochar as a stormwater soil media amendment may not target specific pollutants. Most of the research on biochar for stormwater has been via laboratory studies, and documented pollutant removal has included ammonia, nitrate/nitrite, total phosphorus, and metals. The results are not consistent, and field applications are not widespread (Hodgins & Seipp, 2018). However, biochar does appear to enhance water retention and can provide a carbon source for denitrification (in systems designed to include that process), and thus is suitable for stormwater applications. Biochar can replace, in part or whole, the organic matter component in soil media, which has been shown to be a concern for nutrient leaching when used at high rates (e.g., greater than 5% of the media mix).

As with other PEDs, biochar can be considered for retrofits where the soil media will be replaced, improved, or amended. One example is from Carroll County, MD, where dry pond retrofits included sand filters amended with biochar. Another application used biochar to amend roadway vegetated filter strips, leading to reductions in runoff volumes and peak flows (Imhoff & Nakhli, 2017).

The salient question about biochar in stormwater applications is whether that material offers significant benefits compared to the material it is replacing in the stormwater system (e.g., compost, other carbon source), and whether those incremental benefits are worth the effort and cost to procure and transport the product. Some of that question revolves around the availability of sources (see section below), procurement, and transportation for biochar compared to what is likely to be a local source for other materials, such as compost. There will be more certainty about these questions as more applications are conducted in the Chesapeake Bay Watershed. Also, there is ongoing work to develop more localized sources, and that would change the calculus on the cost/benefit issue.

See **Section 7** for a list of qualifying conditions in order for a biochar amendment to qualify for enhanced nutrient removal as a performance enhancing device (PED).

2. Source Selection & Procurement

Sourcing an appropriate biochar material is an evolving process. Biochar production as an industry is growing into new applications, and there are many different feedstocks and processes. The following list from the U.S. Biochar Initiative may be a start, and additional research may also reveal other sources in closer proximity.

http://biochar-us.org/manufacturers-retailers

There are several general recommendations for stormwater applications (see **Table BCH-1)**:

- Use wood-based biochar products (preferably derived from hardwood). Other sources, such as from poultry litter, have the potential to leach nutrients.
- When using woody feedstocks, recommended production temperatures are 500 to 600 degrees Celsius.
- Pyrolysis times should be at least 3 hours to reduce accumulation of toxins, such as PAHs.
- Particle size is a significant variable, and will affect the drainage rate, reactive surface area, and binding sites. Recommended particle sizes are 0.5 to 3 mm. This approximately equates to 0% passing a number 36 standard mesh sieve and 100% passing a number 6 standard mesh sieve. Note that rinsing the biochar before incorporation will likely change the particle sizes, breaking up some of the larger particles. Therefore, biochar particle sizes can change over time due to environmental conditions (Imhoff & Nakhli, 2017). It is advisable that particle size analysis be done before and after rinsing, and professional judgement used for particles that fall outside the recommended ranges.

Table BCH-1. General Specifications for Biochar in Stormwater Applications

<table>
<tr><td rowspan="5">Biochar</td><td rowspan="5">Woody derived material</td><td>Sieve</td><td>Size</td><td>% Passing</td></tr>
<tr><td>No. 6</td><td>3 mm</td><td>100%</td></tr>
<tr><td>No. 36</td><td>0.5 mm</td><td>0%</td></tr>
<tr><td colspan="3">Production temperatures between 500 and 600 °C</td></tr>
<tr><td colspan="3">Pyrolysis time at least 3 hours</td></tr>
</table>

3. Material Testing

Testing should be conducted on representative samples to ensure that the biochar will not leach undesirable elements. Testing procedures should be adjusted to the biochar source (e.g., type of wood or other material). While there are not standard testing protocols, the following should be considered as part of a testing procedure:

- Polycyclic Aromatic Hydrocarbons (PAHs)
- Pathogenic bacteria, bacterial spores, viruses, protozoa
- Antimicrobial residues
- Nutrients
- Heavy metals
- pH, alkalinity

4. Mixing The Material

Biochar should constitute 5% to no more than 10% of the soil media by volume. Ideally, mixing will be done by a soil media vendor using appropriate mixing equipment to ensure that the overall soil media meets the applicable specifications. Some applications may want to mix the biochar into the soil or sand media at the site. However, lessons from sites that have attempted this indicate that it is difficult to achieve a consistent blend when amending in-place; only the top few inches to about a foot of media can be amended effectively.

Also, it may be necessary to confer ahead of time with the appropriate stormwater authority because applications that use biochar will have to adapt the specifications for organic matter and perhaps cation exchange capacity.

Some sources indicate that rinsing the biochar before mixing may help remove the hydrophobic coating on some biochars and reduce leaching of soluble compounds after incorporation. Laboratory studies have used deionized water (three rinsings at 1 part biochar to 50 parts DI water). The rinsed biochar was then oven-dried at 105 degree Celsius (Imhoff & Nakhli, 2017). It is not clear at this point whether this type of treatment is advisable for broader field applications and how it would be adapted to make it more feasible. In any case, some regimen of rinsing and drying prior to incorporation into the soil media is likely a good idea.

5. Risks

With proper testing, the risks of using biochar should be minimal. The most important risk is using biochar derived from feedstocks that will leach nutrients or biochar pyrolysis times that will lead to accumulation and possible leaching of toxins, such as PAHs. Biochar appears to bind up heavy metals for long periods of time, but metals leaching may be a potential risk in some cases. As stormwater applications that integrate biochar are relatively new, it is recommended that some monitoring take place to further evaluate these risks.

6. O&M Considerations

At this point, there are not enough field applications to indicate that vegetation plans or O&M procedures would change due to the addition of biochar. Again, this may change as applications spread throughout the Bay Watershed. With regard to vegetation, one factor to be aware of is if and how the biochar amendment may alter the pH of the soil media, perhaps increasing the alkalinity. If this is the case, the selection of plant species may have to consider the higher pH environment (or adding other amendments to adjust the pH to more optimal levels for vegetation).

One possible O&M issue is "recharging" the biochar as practices age and vegetation is removed and replaced. Based on the research, biochar sorption lifespans may be as long as the practice itself, but sorption capacities can possibly decrease over time.

For a practice that is undergoing major repairs, it would be worth considering removing the top layer of soil and replacing with a clean mix that contains new biochar. Also, BMPs in the Bay Watershed must undergo a verification process to ensure the BMP is still present and performing as designed (CSN, 2014). This verification is intended to take place every two permit cycles for MS4s, or every 9-10 years. For practices with biochar, this would be an ideal time to retest the soil media to determine if and how the biochar has sequestered certain pollutants and how particle sizes and other characteristics may have changed as the mixture endures a range of environmental conditions. Since there is not a long track record of biochar use for stormwater, this procedure would generate valuable data on the longevity of biochar in a blended media.

7. Qualifying Conditions for Biochar as a PED

The following conditions summarize the use of biochar to qualify for the PEDs pollutant removal credit:

- Sourced from qualified vendor as per the specifications in Section 2 of this fact sheet.
- Material tested as per Section 3.
- 5 to 10% of the soil or sand media by volume.
- Mixed consistently throughout media using appropriate mixing equipment.
- O&M plan that addresses adaptive management of vegetation and possible "recharging" of biochar, as per Section 6.

References

Chesapeake Stormwater Network. (2014). Urban Stormwater Verification Guidance. https://chesapeakestormwater.net/events/webcast-ms4-implementers-and-the-bay-tmdl-urban-bmp-verification/.

Hirschman, D.J., Seipp, B., Schueler, T. (2017). Performance Enhancing Devices for Stormwater Best Management Practices. Urban Stormwater Work Group. Center for Watershed Protection.

Hodgins, B. and Seipp, B. (2018). Bioretention System Design Specifications and "Performance Enhancing Devices" (Issue Paper). Center for Watershed Protection, Inc., Ellicott City, MD.

Imhoff, P.T. and Nakhli, S.A.A. (2017). Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways. Final Report for NCHRP IDEA Project 182. Transportation Research Board, The National Academies.

Law, N., Christianson, R., Hoffman, G., and Wong, C. (2014). A literature review to evaluate the effect of particulate sorbing media on pollutant removal efficiency of best management practices. Center for Watershed Protection. Ellicott City, MD.

Photos

Figure BCH-1: Pure Biochar

Figure BCH-2: Pure Biochar delivery via "Super Sacks"

Figure BCH-3: Integrating biochar into existing SWM sand filter.

Performance Enhancing Devices for Stormwater BMPs

Internal Water Storage

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Internal Water Storage (IWS)

1. Definition & Applications

Internal Water Storage (IWS) refers to a design alternative that allows water to pond, at least temporarily, within the underdrain and/or soil media layers of bioretention, dry swales, permeable pavement, or other stormwater practice. IWS is usually accomplished by modifying the underdrain configuration so that water ponds above the underdrain.

Research studies that tested IWS targeted enhanced removal of dissolved nitrogen (N), as traditional bioretention has a tendency to leach these forms of N. The dissolved N removal is due to the low-oxygen environment created by the IWS zone, which may lead to denitrification (Hirschman et al., 2017). However, the research also points to IWS as a mechanism to enhance runoff reduction, as the IWS promotes greater exfiltration out the sides and bottom of the practice. Exfiltration and infiltration can be enhanced by 10% to as much as 45% on an average annual basis compared to conventional designs (Winston, 2018). A recent analysis undertaken for the District Department of Energy and Environment indicated that most of the best performing bioretention practices from research studies included IWS, with enhanced runoff reduction serving as a chief pollutant removal mechanism (Hirschman et al., 2018).

IWS has also been recommended for retrofits where limited head is available to outlet the underdrain, such as a shallow catch basin. IWS allows the practice to achieve adequate depths of ponding and soil media, but with a shallower underdrain outlet.

IWS seems to enhance pollutant removal in soils that are somewhat limited for infiltration (clay loam, silt loam, etc.) (Brown & Hunt, 2011). In sandier soils, there may not enough residence time within the IWS for the same level of pollutant removal, but application in sandy soils will enhance runoff reduction.

It should be noted that several existing Chesapeake Bay state stormwater BMP specifications include an option for an enhanced (or Level 2) design using an elevated underdrain overlying a stone sump (D.C., Virginia, West Virginia). This is similar to IWS, but ponding with the sump design takes place below the underdrain versus above the underdrain with the IWS option (see difference between Figures IWS-1 through IWS-4 illustrating IWS versus Figure IWS-5 with the sump). While these design options appear very similar in terms of creating a temporary water storage zone, there are differences in how they function hydrologically and how incoming stormwater may be treated. The IWS option builds up head above the underdrain and may promote increased exfiltration. Also, the IWS design may treat more of the “new” incoming stormwater compared to the sump design.

Finally, some practices use impermeable liners due to high water table, karts, or other site conditions. These practices would not be candidates for IWS.

See Section 8 for a list of qualifying conditions in order for IWS to qualify for enhanced nutrient removal as a performance enhancing device (PED).

2. Creating the IWS Zone

As shown in Figure IWS-1, there are several options for creating IWS in a stormwater design. For purposes of maintenance access, it is advised to have the underdrain outlet in a storm structure (with manhole). The IWS can be achieved by:

1. Putting a weir wall in the storm structure, with the top elevation of the weir wall corresponding with the intended IWS elevation (see below). Note that the underdrain coming into the structure is at a 0% slope, which is a deviation from most current underdrain designs (Figure IWS-1).
2. In lieu of the weir wall, the underdrain outlet in the structure could be fitted with a simple L-fitting and non-perforated vertical extension of the underdrain (open at the top). As with the weir wall, the length of the extension corresponds to the intended IWS depth. This option is sometimes referred to as the "upturned elbow" (Figure IWS-2).
3. An additional option is to have the underdrain from the practice outlet at the invert of the manhole structure, but the pipe leaving the manhole structure set at the intended IWS elevation (Figure IWS-3).
4. For some practices, underdrain outlets may not go to a storm sewer structure. This may occur in less urban settings and/or where the underdrain "runs to daylight" at the ground surface. IWS can still be incorporated into this configuration by using the upturned elbow as the underdrain exits the practice or within the practice itself. For the purposes of marking the location of the upturned elbow for maintenance, it is advisable to put a vertical clean-out pipe with a cap at the location (Figure IWS-4).

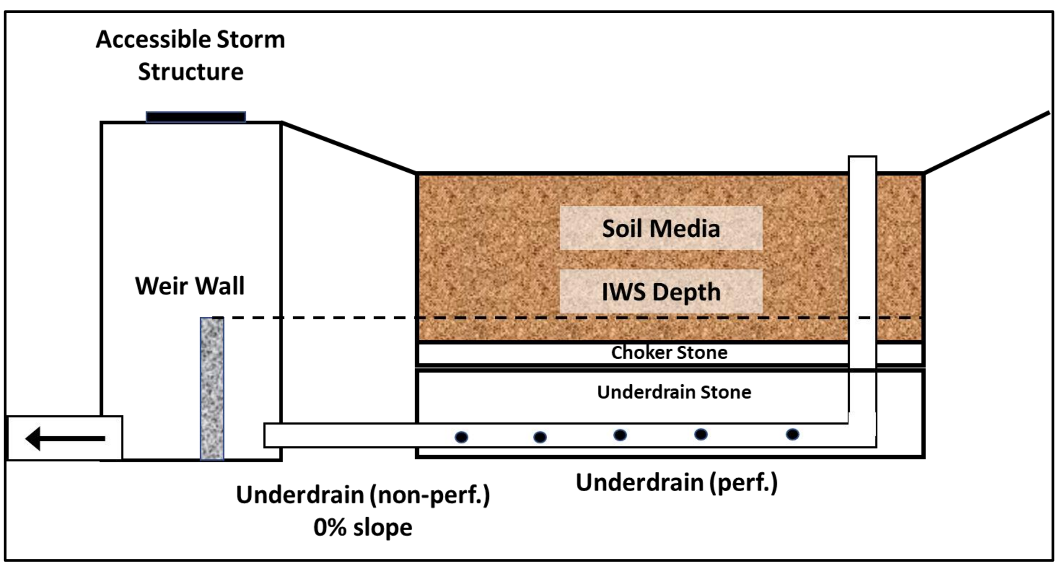

Figure IWS-1. Weir Wall in Storm Structure

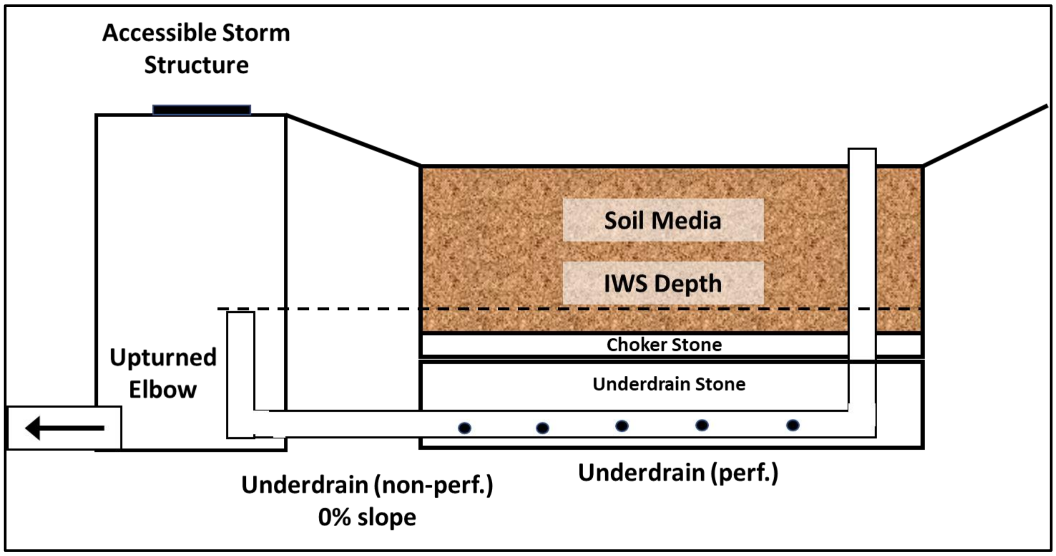

Figure IWS-2. Upturned Elbow in Storm Structure

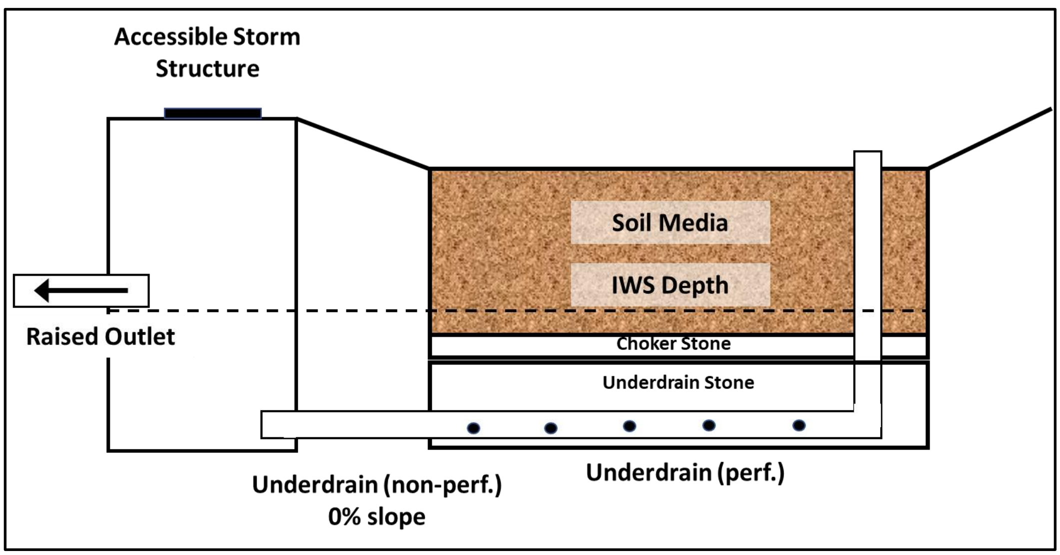

Figure IWS-3. Raised Outlet in Storm Structure

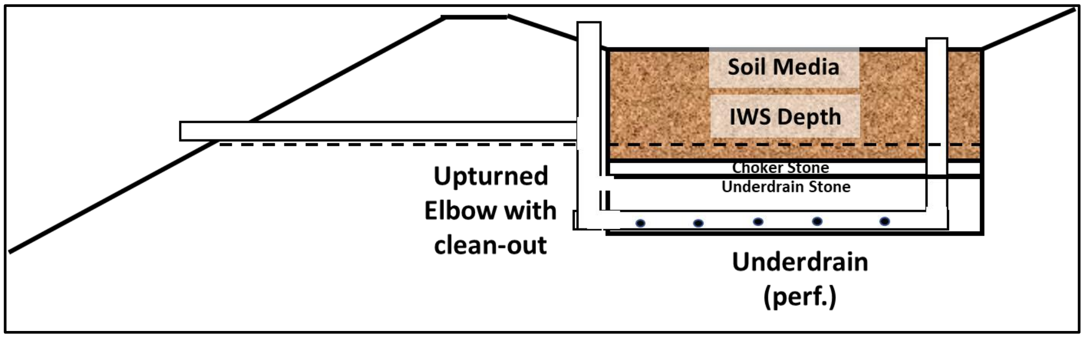

Figure IWS-4. Upturned Elbow in Underdrain that Runs to Daylight

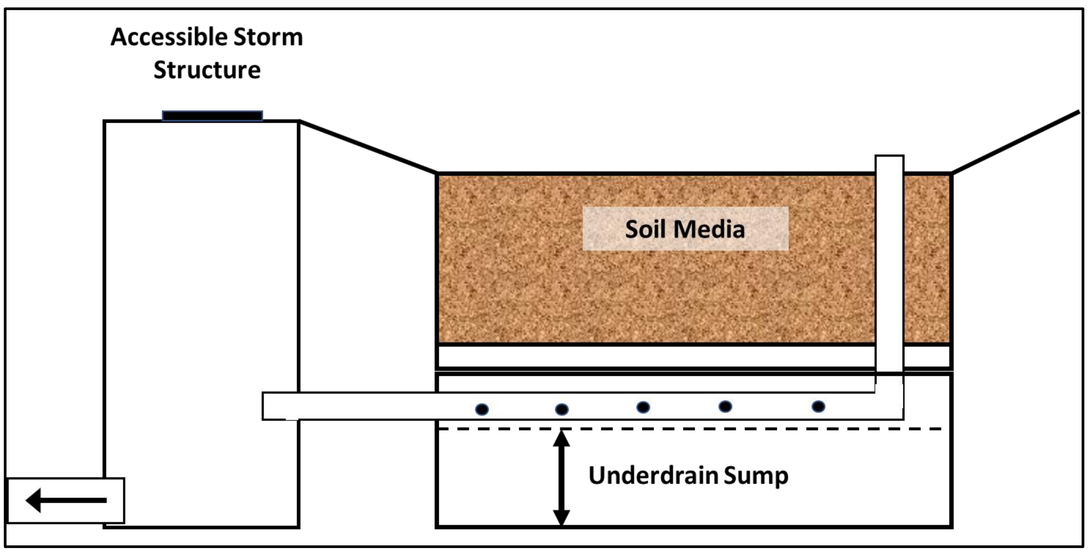

Figure IWS-5. Typical Configuration for Existing Enhanced/Level 2 Design With Underdrain Sump (this graphic is provided for comparison purposes, not as an additional IWS option; see description in "Definition & Applications" section)

3. Depth of IWS

Research does not indicate clearly the depth of the IWS zone. On one hand, if the IWS intercepts too much of the soil media layer, there is a risk that organic material or nutrients may leach out through the underdrain. On the other hand, for denitrification to take place, there must be a carbon source, suggesting that the IWS should intercept some of the soil media and not be confined to just the underdrain stone.

One recommendation that has been adopted in the updated North Carolina Stormwater Design Manual (NCDEQ, 2018; also Brown & Hunt, 2011) is to leave the top 18 inches of soil unsaturated to ensure proper plant growth and root development. That means that the IWS zone would start at least 18 inches below the top of the soil media layer. The resulting depth of IWS then depends on the total depth of the soil media and underdrain layers.

Soil media depths in the Bay states range from 18 to 36 inches, depending on the jurisdiction and whether practices qualify for Level 1 (standard) or Level 2 (enhanced) designs. Table IWS-1 provides recommendations for the depth of unsaturated soil above the IWS zone, and thus the total depth of IWS. These recommendations are intended to balance reducing the risk of nutrient leaching while providing enough carbon source for processing of N. IWS is not recommended for soil media depths at or around 18 inches, as there will not be adequate unsaturated soil media to allow the BMP to function.

For the deeper soil media depths (30 to 36 inches; enhanced or Level 2 designs), the table provides a range of values. The recommended depths depend on the type of vegetation (shallow versus deep-rooted) and the BMP's hydrologic and pollutant removal design objectives. In some cases, it will be important to optimize storage within the practice during a storm event, and IWS can temporarily take up some of this storage (suggesting a reduced IWS zone). On other hand, BMP objectives may tend more towards annual runoff reduction and pollutant removal, in which case expanding the IWS should be considered.

Table IWS-1. Recommended Depths of IWS Based on Depth of Soil Media

Soil Media Depth	Underdrain Layer Depth[1]	Unsaturated Soil Media Above IWS[2]	IWS Depth
18 inches	15 inches	N/A	N/A
24 inches	15 inches	18 inches	21 inches
30 inches	15 inches	18 to 24 inches	21 to 27 inches
36 inches	15 inches	24 to 30 inches	21 to 27 inches

[1] 15 inch underdrain layer assumed 12 inches of drainage stone topped with 3 inches of choker stone, which is a standard specification in the Bay states. If the underdrain layer deviates from this assumption, adjust the IWS depth accordingly. 15 inches can be considered the bare minimum for IWS depth, with some intersection of the soil media.

[2] In cases where there is a range, use the shallower unsaturated soil media layer (deeper IWS) for practices that use shallow-rooted vegetation and/or where annual runoff reduction and pollutant removal are primary design objectives. Use the deeper unsaturated soil media layer (shallower IWS) for practices that include some deeper-rooted vegetation and/or where maximizing capture during a fuller range of storm event depths and intensities is a more important design objective.

4. Filter Fabric/Geotextile

Over time, BMP designs have used less of these materials to function as separation barriers. Most Bay state specifications have substituted choker stone as a separation barrier between soil media and underdrain stone. Horizontal planes of filter fabric have been associated with blinding and clogging. It is still common to see filter fabric used along the sides of a BMP excavation, and some practices use a horizontal plane at the bottom of the excavation (not recommended).

Using IWS suggests eliminating the fabric along the sides of the excavation, as that is a main surface of exfiltration. Also, there is very little evidence of surrounding soils contaminating the engineered soil media, so the fabric may have limited utility in any case.

5. Construction Process

The construction process for IWS involves only minor modifications during underdrain installation. It may involve setting an additional storm structure with a weir wall or upturned elbow, as illustrated in Figures IWS-1 and IWS-2. Projects that use IWS should provide a record drawing showing as-built conditions and all relevant elevations.

6. Risks

Where Does the Water Go?

As with any practice that puts water into the ground, there may be concern with some of that water moving into basements, road fill, fill slopes, utility trenches, or other places where it is not desired. This is largely a matter of proper site selection and proper field location of wet and dry utilities and other features. With IWS, there will be more water moving through the sides of the practice, especially compared to a conventional underdrain design. Designers should ensure adequate soil mass and travel distance between the practice and any risk areas.

BMP Capacity During Storm Events

Table IWS-1 addresses this issue with regard to the recommended IWS depth. The research indicates that IWS will reduce runoff and associated pollutant loads on an average annual basis. For high intensity storm events, the storage occupied by the IWS zone means that there may be less storage available for incoming runoff versus a design where underdrain flow is activated during the storm event. The consequence is that there can earlier by-pass or flow directed through the overflow structure for certain individual storm events.

BMP design for water quality treatment has moved largely to average annual accounting, but some stormwater programs and/or specific locations may have more of a focus on individual storms (e.g., contain the 1-year or 2-year storm). In these cases, designers should evaluate the trade-offs in average annual and storm event hydrologic performance.

Mosquitos

The designs where the IWS depth is controlled within a storm structure is good for inspection and maintenance access, but, depending on how long water stays within the IWS zone between storms, may provide conditions for mosquito breeding This risk is probably more acute if the IWS draws down to just a few inches and that depth of water sits in the bottom of the structure, as that would be similar to existing storm structures that have a sump below the outlet pipe. This condition should be monitored during the summer months.

Combining IWS with Water Treatment Residuals (WTRs)

There has been some speculation about creating a “super BMP” by combining IWS with reactive media (see the profile sheet on Water Treatment Residuals -- WTRs). This is certainly a possibility. However, there is some risk that saturated soils will lead to increased leaching metals (Aluminum in the case of

WTRs). If this type of combination BMP is used, recommendations include: (1) incorporating WTRs into the soil media only above the IWS zone, or (2) using a treatment train approach, with practices in series using, alternately, IWS and WTRs in whatever order the designer may choose. The second option is preferred, as with #1, the WTRs can migrate down through the soil media to the IWS zone.

7. O&M Considerations

O&M considerations for IWS include the following:

- Monitor the typical time for the IWS to draw down. This will depend on the underlying and surrounding soils. In order to actualize the benefits of IWS, this should not happen too quickly (e.g., within 24 hours), but in most cases should occur prior to the next storm event (obviously, this would not apply for storm events that take place within several days of each other) or within 7 days.
- Monitor success of the vegetation. Vegetative health will depend on many factors aside from IWS. If roots become saturated, vegetation may show symptoms similar to drought conditions: wilting, leaf yellowing, and/or leaf drop. If this occurs, selectively check roots of different species to see if they are becoming saturated. If so, it may be a simple fix to lower the IWS level (e.g., cutting notch in the weir wall or cutting some length off of the upturned elbow). In many cases, IWS may promote plant growth due to providing more water availability between storm events.
- During routine inspections, check the integrity of underdrain clean-outs, upturned elbows, weir walls, and other components of the system.

8. Qualifying Conditions for WTR as a PED

The following conditions summarize the use of IWS to qualify for the PEDs pollutant removal credit:

- ☐ Use one of the IWS configurations shown in Section 2, with IWS depth as per guidance in Section 3.
- ☐ Eliminate filter fabric along sides of excavation (filter fabric should not be used on bottom of excavation as per most existing BMP specifications).
- ☐ Provide record drawing showing as-built IWS configuration and all associated elevations.
- ☐ Provide detailed O&M plan that addresses monitoring the drawdown rates of the IWS zone, health of vegetation to include possible signs of root saturation, possible nuisance conditions (e.g., mosquitoes), and structural integrity of underdrain components (see Section 7).

References

Brown, R. A. and Hunt, W. F. (2011) Underdrain configuration to enhance bioretention exfiltration to reduce pollutant loads. *Journal of Environmental Engineering*, 137(11), 1082-1091.

Hirschman, D.J., Hoffmann, G., Daniels, A., Hathaway, J. Lindow, K., Aguilar, M., Schueler, T., and Wood, D. (2018). Runoff Reduction Revisited. Prepared for: Government of the District of Columbia, Department of Energy & Environment.

Hirschman, D.J., Seipp, B., Schueler, T. (2017). Performance Enhancing Devices for Stormwater Best Management Practices. Urban Stormwater Work Group. Center for Watershed Protection.

North Carolina Department of Environmental Quality. (2017, 2018). North Carolina Stormwater Design Manual: https://deq.nc.gov/sw-bmp-manual.

Winston, Ryan (2018). Personal communication, 06/28/18.

Performance Enhancing Devices for Stormwater BMPs

Iron Amendments

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Iron Enhanced Sand Filtration

1. Definition & Applications

Iron (Fe) aggregate is an amendment that has been shown to capture soluble phosphorus from urban and agricultural stormwater in both laboratory (Erickson *et al.* 2007) and field applications (Erickson *et al.* 2012, 2017a, 2017b). The iron surface becomes positively charged as it oxidizes, then binds with negatively charged phosphate ions through surface adsorption. Field installations include a mixture of approximately 5% by weight iron aggregate (a.k.a. filings, shavings) with ASTM C-33 concrete sand (ASTM 2002) to create an **iron-enhanced sand filter (IESF)**.

IESFs can be installed as stand-alone filtration basins, as trenches installed adjacent to wet ponds, as horizontal-flow filters within ditch check dams, or as a component within a bioretention system. These applications can also be incorporated into BMP retrofits where soil media will be added or replaced as part of the retrofit process (e.g., converting or replacing older practices).

2. Source Selection & Procurement

Iron aggregate can be obtained from a variety sources and delivered in various amounts and containers. Common shipments include 50-pound bags or pallets with a 3000-pound sack (see Figure IESF-1).

Figure IESF-1: 3000-pound sack of iron aggregate.

There are several criteria required for the iron to effectively capture soluble phosphorus from urban or agricultural runoff, including the size distribution, reactivity with phosphate, and purity. These are described in detail below:

- When installed within concrete sand, iron aggregate must have a similar size gradation as the concrete sand (ASTM 2002). If the iron aggregate is smaller than the sand, it can wash out of the filter media during flow events. If the iron aggregate is larger than the sand, the effectiveness is reduced because the total surface area of large particles is less, and separation may occur if the media is fluidized. Table IESF-1 outlines a size distribution of iron aggregate commonly used in IESF.

Table IESF-1. Recommended Size Distribution for Iron Aggregate		
US Sieve Number	Opening Size (mm)	Percent Passing
4	4.75 mm	100%
8	2.36 mm	95 – 100%
16	1.18 mm	75 – 95%
30	0.600 mm	25 – 45 %
50	0.300 mm	0 – 10%
100	0.150 mm	0 – 5%

- The iron aggregate must be reactive with phosphate. Iron can exist in various mineralogical forms, some of which react with phosphate while others do not. It is recommended that the supplier or the builder provide proof that the iron material is reactive with phosphate, or submit a sample to an analytical lab to be tested for reactivity with phosphate. For a simple test, see Erickson *et al.* 2018.
- The iron aggregate must be of sufficient purity and lack contaminants of concern. Recommended thresholds for iron elemental analysis are provided in Table IESF-2. Material containing greater than these recommended thresholds should not be used or further processed until the proper level of purity is achieved. It is recommended that iron aggregate have a purity of at least 85% elemental iron to ensure adequate performance and longevity. In addition, iron aggregate that includes significant amounts of pollutants of concern (e.g., toxic metals) can leach these pollutants during the filtration process, resulting in pollution instead of treatment. Also, iron aggregates procured from machining facilities or other metalworking industries may have coatings or toxic contaminants or lubricants used in the machining process. Lubricants could contribute toxic petroleum or hydrocarbon-based pollutants. Many analytical laboratories are equipped to perform leaching experiments, which can identify the type and amount of pollutant that can be released when iron aggregates are exposed to clean water.

Table IESF-2. Recommended Thresholds for Iron Elemental Analysis	
Component	**Percent Composition[1]**
Metallic Iron[2]	> 85%
Total Carbon	< 4%
Manganese	< 1%
Sulphur	< 0.1%
Phosphorus	< 0.1%
Silicon	< 2%
Nickel	< 0.5%
Chromium	< 0.5%
Vanadium	Below Detection
Molybdenum	< 0.2%
Titanium	< 0.2%
Copper	< 0.2%
Aluminum	< 0.1%
Cobalt	Below Detection
Magnesium	< 0.01%
Boron	< 0.01%
Zinc	< 0.01%
Zirconium	< 0.01%
[1]These are based on testing so far but not absolute specifications [2]Must be reactive with soluble phosphate	

3. Design Variations

There are several design variations of iron enhanced sand filters (IESFs), several of which are described with performance data (Erickson *et al.* 2012, 2017b). A typical design schematic for a surface sand filter enhanced with iron aggregate is shown in Figure IESF-2. In this design variation, water is conveyed to a basin with IESF media in the bottom. Water stored in the basin moves vertically downward through the IESF media while particulates are captured on the surface and phosphate is adsorbed by the IESF media. Below the IESF media is a system of perforated pipe underdrains that collects treated water and delivers it to the outlet structure and subsequent conveyance system.

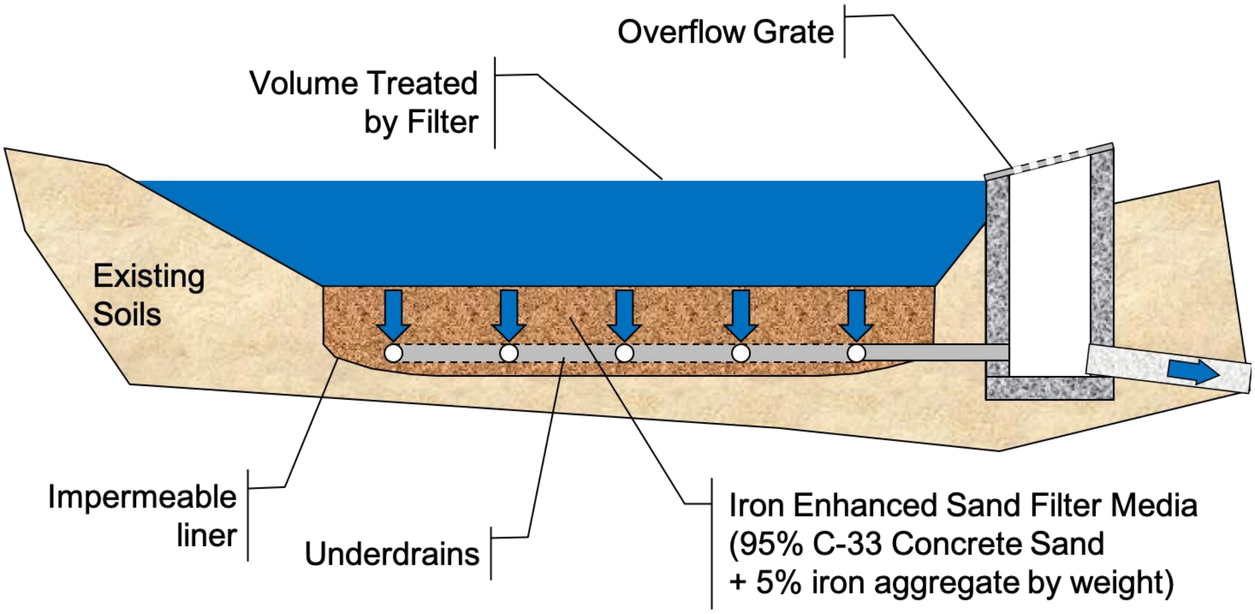

Figure IESF-2: Iron Enhanced Sand Filter Typical Schematic.

Another design variation that can be installed during initial construction or retrofit into an existing wet retention pond is the pond-perimeter IESF trench. A typical schematic for this design variation is shown in Figure IESF-3. In this design variation, water is captured by a wet retention pond to remove suspended sediment. When the water level increases above the normal water level, stored water flows into the pond-perimeter IESF trench, which captures particulates on the surface and phosphate on the IESF media. Treated water is collected by an underdrain that is connected to the outlet structure. The outlet structure for the pond is designed to force a volume of water to flow through the pond-perimeter IESF trench prior to overflowing the outlet structure from the pond.

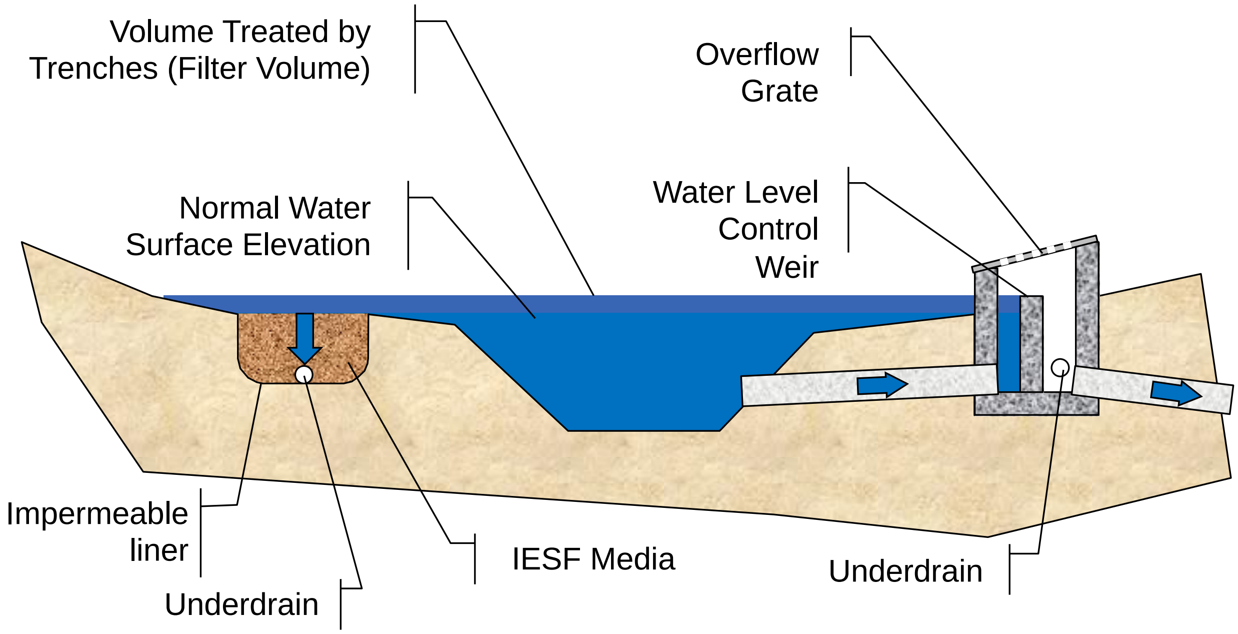

Figure IESF-3: Pond-Perimeter IESF Trench Typical Schematic.

Another design variation is to incorporate IESF media within the profile of a typical biofiltration practice, as shown in Figure IESF-4. In this variation, water is stored within a shallow basin and subsequently treated by a combination of bioretention media and IESF media to achieve particulate capture on the surface, metals, nitrogen, and polycyclic aromatic hydrocarbon capture and conversion within the biofiltration media (LeFevre *et al.* 2015), and phosphate capture within the IESF media. This application would involve modifying or offering an alternative in existing Bay jurisdiction bioretention design specifications.

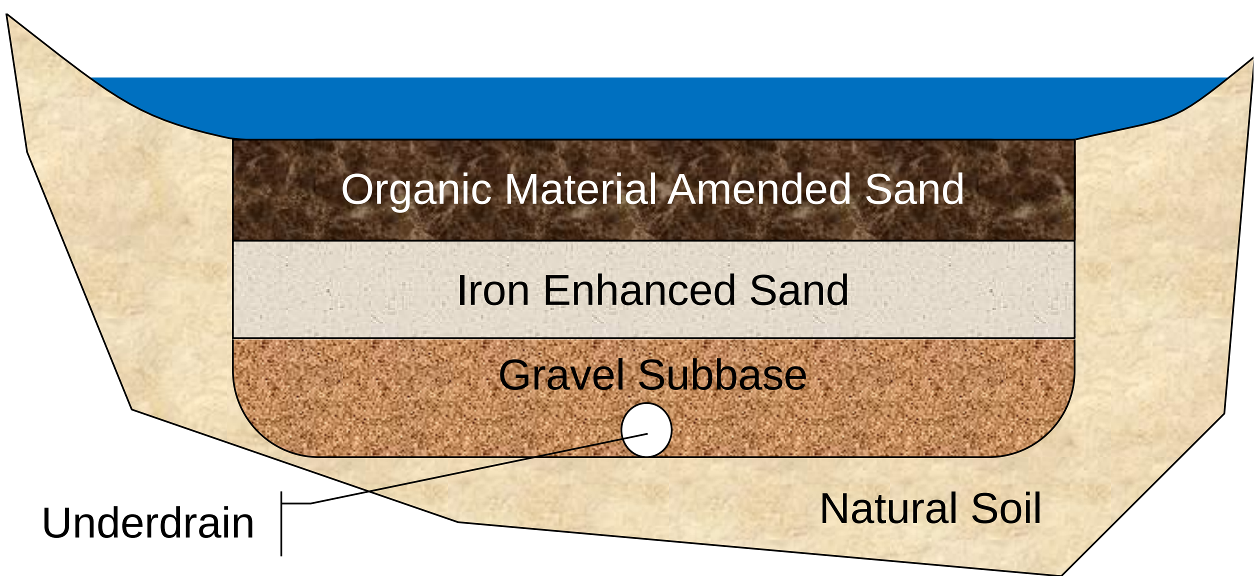

Figure IESF-4: Iron Enhanced Filtration Bioretention Typical Schematic.

Another design variation involves a modification of a typical ditch check dam design to include an IESF media within the center, which treats water as it flows horizontally through the ditch check dam and IESF media, as shown in Figure IESF-5. This design includes the benefits of the check dam (erosion prevention, infiltration promotion) and the IESF (particulate and phosphate capture). This design variation is currently (2018) under investigation at the University of Minnesota and more performance data will be made available in 2019. Preliminary results of field monitoring indicate that this design variation may not perform as well as other variations because most of the water is treated by the bottom of the filter, which may shorten the lifespan of the practice (Natarajan and Gulliver 2018). The maintenance of an IESF ditch check dam is similar to a conventional ditch check dam with the added maintenance activities described in Section 7 O&M Considerations below.

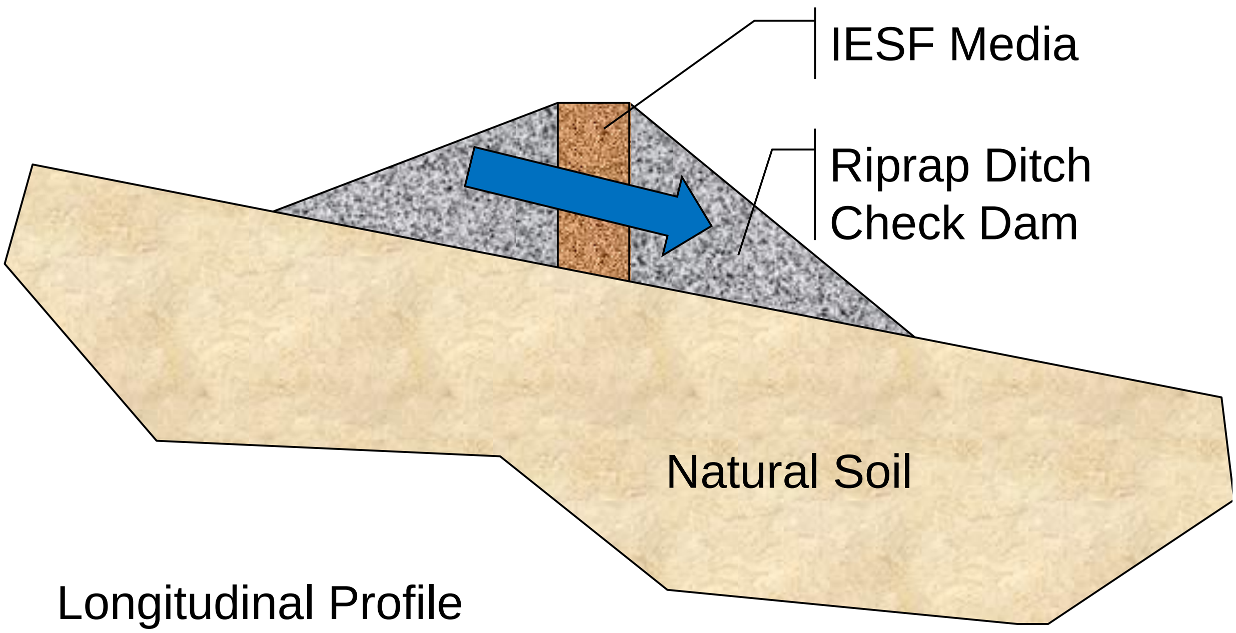

Figure 5: Iron Enhanced Filtration Ditch Check Dam.

4. Design Considerations

Design considerations for all of these design variations include underdrain elevation, draining and dry period, and access for maintenance. These considerations are outlined below.

- It is recommended that IESFs be designed such that the high-water level where the underdrains discharge is below the underdrain invert elevation. This will ensure that the downstream water cannot "backup" and inundate the underdrains and IESF media. Frequent and/or prolonged inundation of the IESF media can cause anoxic or anaerobic conditions within the IESF media, which may result in clogging.
- IESFs should be sized to allow rainfall events to drain quickly so a dry time of one or more days can occur prior to the next rainfall event. This is needed in order to allow the iron to oxidize during the dry interval.

- IESFs designs should limit the amount of organic material that is deposited on the IESF media surface. In pond-perimeter IESF trench applications and other situations associated with wet ponds or wetlands, organic matter such as algae or duckweed can be captured on the surface of the IESF media. This material can cause a biofilm to develop, which can limit complete draining and drying of the IESF and oxygen transfer into the media from the surface. In addition, this material will decompose over time causing a release of soluble phosphate at potentially high concentrations, which can overload the IESF system or exhaust the media prematurely.
- IESF designs should provide access for maintenance of the IESF surface, underdrains, and media. Equipment such as bobcats, excavators, and flatbed trucks may need access to the IESF to remove accumulated sediment from the surface. Maintenance recommendations are provided in Section 7, O&M Considerations.
- IESFs should be designed without vegetation within the IESF media (sand filter variation shown in Figure IESF-1). In the bioretention IESF variation (Figure IESF-3), it is recommended that vegetation be confined to the bioretention soil media layer or to the perimeter so that vegetation does not grow into the IESF media. In filter systems, vegetative roots grow towards the underdrains because of the collection and flow of water through the system. Many vegetation species lose 30% of their root mass annually, resulting in macropores within the soil. These macropores can cause short-circuiting of the IESF media, resulting in water that bypasses treatment and delivered directly to the underdrains.
- IESF practices should be designed with an emergency overflow or bypass to allow water to bypass the filter when the storage volume is exceeded of if the filter media is clogged.
- IESFs should have cleanouts connected to the underdrain system that are accessible from the surface of the IESF filter. These cleanouts should be sealed to prevent flow from the surface entering directly into the underdrain but can be opened to facilitate cleanout or flushing of the underdrains (e.g., threaded caps). It is recommended that bends in cleanout connections consist of two 45° bends instead of elbows, to allow for small cameras to be easily inserted into the underdrains for inspection.

5. Mixing & Layering the Material

Nearly all the documented failures of IESFs are a result of poor mixing or layering, typically during construction. Thus, proper mixing is critical for successful IESF installations. The following are considerations for mixing ratios and creating different layers within an IESF system.

- Iron aggregate should be mixed at a ratio of 5% iron aggregate with 95% clean washed sand, by weight. Studies have shown that iron ratios greater than 8% are susceptible to oxidized iron (rust), which can fill pore spaces between iron particles and cause clogging within the filter media (Erickson and Gulliver 2010). The weight ratio can be approximated using the bulk density of iron and the bulk density of sand, though bulk density values should be verified with the supplier prior to ordering and shipment.
- The iron aggregate should be mixed thoroughly with sand to form a homogeneous filter media in both horizontal and vertical directions. Some suppliers can mechanically mix iron with sand prior to delivery. For large sites, mixing prior to delivery may be the most cost effective. For small sites, mixing can be completed on site during installation by placing incremental layers

(typically 3 inches) of sand with iron added and then rototilling the iron into each incremental layer.

- The IESF media layer should be at a depth of approximately 12 – 18 inches. As the depth of the IESF media increases, so does the total weight of iron within the filter and subsequently the IESF filter will have a longer lifespan. Increasing the depth, though, also requires longer times for full draining of the IESF media.
- The surface sand filter IESF design (Figure IESF-1) should have a 2 to 5-inch layer of clean sand on top of the IESF at the filter surface to allow for maintenance. This clean sand layer can be removed along with accumulated sediment or organic matter and replaced with clean washed sand without reducing the capacity of the iron to capture phosphate. Any design variations that do not have an exposed surface of the IESF (e.g., ditch check dam or bioretention IESF) do not require this maintenance layer.

6. Risks

Iron is a ubiquitous element in the Earth's crust, though high iron concentrations in water can cause aesthetic concerns of odor, taste, and staining. Iron leaching from IESFs is common though minimal. Unpublished monitoring data has shown that iron concentration in the effluent from an urban IESF is below the U.S. EPA's secondary drinking water standard of 0.3 mg/L (https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals). There is a risk associated with leaching of other pollutants of concern if the iron aggregate contains a significant amount of a toxic pollutant that can leach during the treatment process. Leaching tests should be performed on the iron aggregate prior to installation to ensure these risks are minimized (see Section 2, Source Selection & Procurement).

IESFs can clog due to accumulated sediment or organic matter on the surface, frequent or prolonged inundation, or poor mixing of the iron aggregate. Risks associated with clogging include premature exhaustion of the IESF media or failure of the filter media, requiring complete rehabilitation of the IESF media.

7. O&M Considerations

The maintenance recommendations for IESFs (Erickson *et al.* 2018) include the following:

- IESFs should be inspected between quarterly and annually, depending upon the quantity of water filtered, and after any event that exceeds a 2-year return period. These inspections will identify any indications of sediment accumulation, infrastructure failure, excessive vegetation, erosion, or other maintenance concerns. When documented over time, inspections will also determine the frequency of other maintenance activities.
- Depending on the contributing area, trash and debris may need to be removed annually or more frequently.
- Remove obstructions to outlet structures and underdrain systems as needed.
- Remove vegetation from filter surface as needed.
- Perform testing to determine filtration rates whenever visual inspection or other assessment indicates the need.

- Remove retained sediment, typically the top 2 – 5 inches of discolored surface media. Typically, this will occur once every five to ten years in stable watersheds or once per year in unstable (i.e., erosive) watersheds.
- Effluent sampling and analysis of enhanced media should occur annually or whenever media performance is in question.

BMPs in the Bay Watershed must undergo a verification process to ensure the BMP is still present and performing as designed (CSN, 2014). This verification is intended to take place every two permit cycles for MS4s, or every 9-10 years. For IESF practices, this would be an ideal time to retest the soil media and ensure that (reactive) Iron and other key constituents are still present and to possibly add new Iron amendments to the media. Since there is not a long track record of IESF use in the Bay Watershed, this procedure would generate valuable data on the longevity of IESFs.

8. Qualifying Conditions for IESF as a PED

The following conditions summarize the use of iron aggregate to qualify for the PEDs pollutant removal credit:

- Procured to meet all the criteria described in Section 2 Source Selection & Procurement of this fact sheet; material must be dried before mixing into soil media.
- Designed to meet all the recommendations provided in Section 3. Design Considerations of this fact sheet.
- A written O&M Plan, including a specific party responsible for maintenance, following the recommendations provided in Section 7 O&M Considerations of this fact sheet.

References

ASTM. (2002). “Standard specification for concrete aggregates.” ASTM C33, West Conshohocken, PA.

Chesapeake Stormwater Network. (2014). Urban Stormwater Verification Guidance. https://chesapeakestormwater.net/events/webcast-ms4-implementers-and-the-bay-tmdl-urban-bmp-verification/.

Erickson, A.J., Gulliver, J.S., and Weiss, P.T. (2007). "Enhanced Sand Filtration for Storm Water Phosphorus Removal." Journal of Environmental Engineering, 133(5), pp. 485-497. http://dx.doi.org/10.1061/(ASCE)0733-9372(2007)133:5(485)

Erickson, A.J. and J.S. Gulliver. (2010). "Performance Assessment of an Iron-Enhanced Sand Filtration Trench for Capturing Dissolved Phosphorus." St. Anthony Falls Laboratory Project Report #549. Prepared for the City of Prior Lake. University of Minnesota, Minneapolis, MN. http://purl.umn.edu/115602

Erickson, A.J., Gulliver, J.S., and Weiss, P.T. (2012). "Capturing Phosphates with Iron Enhanced Sand Filtration." Water Research. 46(9), pp. 3032-3042. http://dx.doi.org/10.1016/j.watres.2012.03.009

Erickson, A.J., Gulliver, J.S., and Weiss, P.T. (2017a). "Phosphate Removal from Agricultural Tile Drainage with Iron Enhanced Sand." Journal of Water Special Issue: Additives in Stormwater Filters for Enhanced Pollutant Removal. http://dx.doi.org/10.3390/w9090672

Erickson, A.J., V.J. Taguchi, and J.S. Gulliver. (2018). "The Challenge of Maintaining Stormwater Control Measures: A Synthesis of Recent Research and Practitioner Experience." Journal of Sustainability Special Issue, 10, 3666. http://dx.doi.org/10.3390/su10103666

Erickson, A.J., Weiss, P.T., and Gulliver, J.S. (2017b). "Monitoring and Maintenance of Phosphate Adsorbing Filters." Journal of Environmental Engineering Special Issue: Environment and Sustainable Systems: A Global Overview. http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29EE.1943-7870.0001296

LeFevre, G.H., K.H. Paus, P. Natarajan; J.S. Gulliver, P.J. Novak, and R.M. Hozalski. (2015). "A Review of Dissolved Pollutants in Urban Stormwater and their Removal and Fate in Bioretention Cells." Journal of Environmental Engineering, 141 (1). http://dx.doi.org/10.1061/(ASCE)EE.1943-7870.0000876.

Natarajan, P. and J.S. Gulliver. (2015). Assessing Iron-Enhanced Swales for Pollution Prevention. SAFL Project Report No. 576, University of Minnesota, Minneapolis, MN, September 2015. http://hdl.handle.net/11299/175560.

Additional Photos

Figure IESF-6: Typical Surface Iron Enhanced Sand Filter

Figure IESF-7: Typical Pond-Perimeter Iron Enhanced Sand Filter

Figure IESF-8: Typical Bioretention with Iron Enhanced Sand Filter (Photo ©Barr Engineering)

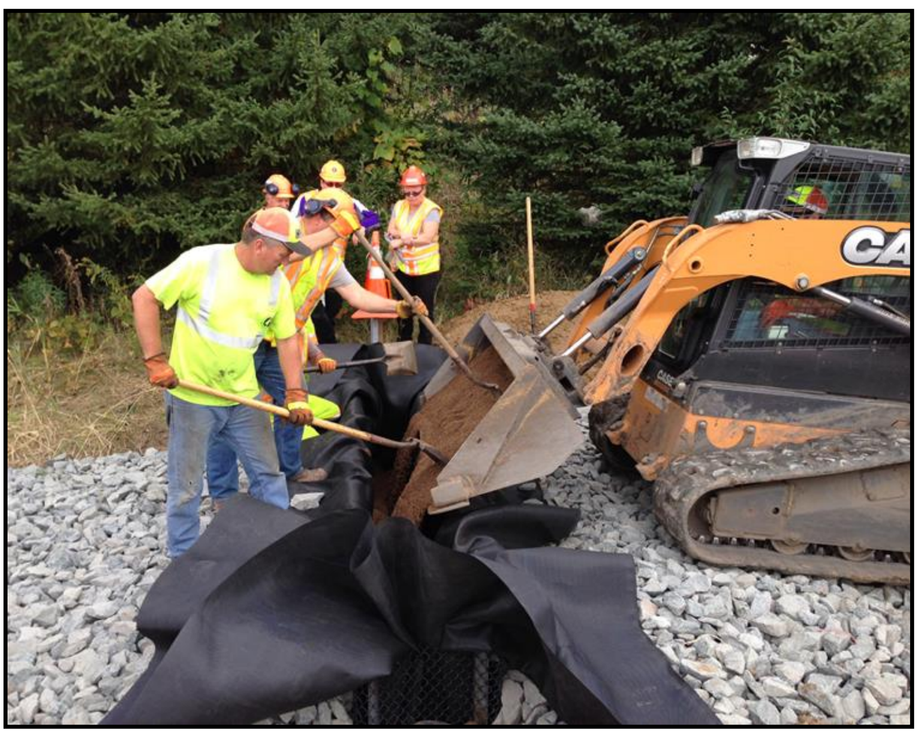

Figure IESF-9: Filling the Iron Enhanced Sand Portion of a Ditch Check Dam Variation

Performance Enhancing Devices for Stormwater BMPs

Enhanced Vegetation

December 2018

Prepared By:

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For:

Roadside Ditch Management & PEDs

Center for Watershed Protection, Inc.

Chesapeake Stormwater Network

Funded By:

Chesapeake Bay Trust

Enhanced Vegetation

1. Definition & Applications

Vegetation is commonplace and expected in many stormwater BMPs. However, the strategic importance of vegetation for runoff reduction and pollutant removal has not been fully acknowledged, and there is no unified guidance for planting design and long-term maintenance to support volume and pollutant removal objectives.

Research indicates that the presence of plants enhances other nutrient removal mechanisms. The below ground microbial community associated with plant roots plays a key role in immobilizing dissolved nutrients during the wet and dry cycles encountered in stormwater practices. As plants mature, their root systems maintain or even increase the hydraulic conductivity of the media and the practice as a whole. Researchers suggest that plants with a deep, thick, and dense root system enhance dissolved nutrient removal. Deep-rooted prairie plant species such as big bluestem, Joe Pye weed, and switchgrass performed well in several experiments (Hirschman et al., 2017).

Since vegetation is a major component of the living system of a stormwater BMP, there should be flexibility in the original plant palette as well as how the plant community is managed through the life of the practice. Historically, planting designs for stormwater practices have either been ignored, mismanaged, or treated as static over time. Enhanced planting design and management as a performance enhancing device (PED) can be incorporated with initial installations or as retrofits of practices where the existing vegetation is not healthy, is difficult to maintain, is leading to nuisance conditions, or other factors.

That said, there are many design professionals and planting strategies across the Bay Watershed. This fact sheet will introduce one approach that can be considered an integrated planting design and adaptive management framework to fulfill PEDs objectives for stormwater as well as providing ecosystem services.

The approach includes:

- Initial planting with densely-planted layers modelled on local natural plant communities (mostly eastern grassland types with the above and below-ground biomass as described above).
- Intensive management during the first several growing seasons.
- Adaptive management addressing successional adaptation of plant communities over time and, as a general rule, annual cutting in late February.

This fact sheet is not a how-to guide on this approach, and actual implementation will require a team approach with qualified professionals (see Section 7, “Finding Help”). However, this fact sheet does outline a conceptual framework and resources for those interested in learning more. The approach is derived largely from the work of Floyd (2018a, 2018b), Rainer and West (2015), Nassauer (1995), and Weaner and Christopher (2016), as well as the curriculum of the Chesapeake Bay Landscape Professional certification program and Virginia Department of Game & Inland Fisheries Habitat Partners© Program (see Section 8, “Resources”).

The approach can be adapted or scaled to a particular application, and the design team should discuss how the approach, or some of its components, can be used to enhance the planting plan and its management over time. See **Section 9** for a list of qualifying conditions in order for enhanced vegetation design and management to qualify for increased nutrient removal credit as a PED.

2. Initial Planting Design

Existing Bay jurisdiction stormwater manuals and specifications are not prescriptive about planting design and offer a range of options and very generic plant lists. Some of the planting "templates" in existing standards include:

- Turf cover (with or without trees)
- Perennial garden (with or without shrubs)
- Tree, shrub, herbaceous
- Meadow

Depending on the initial design and how it is managed, each option can lead to expected and unexpected outcomes. In some cases, the resulting stormwater landscape can be difficult to maintain or even create nuisance conditions. For many BMPs in the Bay Watershed, there is no cohesive long-term or adaptive management strategy.

A more unified design/adaptive management approach could focus on a natural plant community prairie system. These systems are adapted to undergo periodic disturbance and alternate periods of dry and wet, conditions that are apt for the stormwater context. The strategy involves identifying and observing local plant communities that can serve as references for the stormwater landscape being created. The general principles for establishing and managing this type of plant community are outlined below:

- Use local natural plant communities as reference landscapes.
- Provide dense cover of the BMP surface with layers of vegetation.
- Intensely manage the plantings for the first 3 growing seasons.
- Use an adaptive management approach for long-term O&M.

<u>Reference Landscapes for Stormwater</u>

As near as possible, the local reference landscapes should replicate a variety of site conditions at the location of the stormwater landscape.

Several site factors to note include:

- Soil chemistry (especially cations and exchange capacity, for which there are indicator species)
- Soil moisture, drainage, texture
- Elevation
- Aspect
- Topography, Slopes
- Quality and duration of light

It is critical to note here that many stormwater landscapes (e.g., bioretention) will be using an engineered soil media based on state specifications, and this soil media is dissimilar in many ways from the existing and/or native, soil on a site. In essence, the existing soil will be excavated, removed, and replaced with several feet of an “exotic” mix that will influence the type and long-term health of any vegetation that is planted. In many places in the Bay Watershed, the imported soil mix will be very well-drained (high sand content), outfitted with an underdrain (promoting even more rapid drainage), and may have less organic content than any existing site soils. With regard to the plant community, the imported, well-drained soil media as well as the existing site soils at the margins of the practice both play a role in selecting a reference landscape in order to maximize ecosystem services. Both will exercise a powerful affect on the plant community that will flourish within the stormwater landscape.

The stormwater landscape must tolerate short periods of inundation, but also longer periods of dry or even drought conditions. Therefore, for stormwater landscape applications, the reference natural plant community should be from places where these conditions exist. The best examples are low areas and swales and ditches in the upland prairies observed in powerline rights-of-way. Others may include plant communities on well-drained floodplains and small fragments of natural plant communities along roadsides, in areas with groundwater discharge, in ditches and low meadows, and other similar sites.

The reference plant community may or may not have a deep layer of relatively sandy soil; the important thing is that the vegetation has a diverse array of species that associate with each other in the given environment. The reference site will likely not be free of invasive or non-native species, so the task is to find the plant associations that do exist at the site. This will likely require the assistance of a trained professional (see Section 7).

<u>Plant Communities, Not Individual Species</u>

The focus here is on the natural plant <u>community</u>, and not just individual native plant species. Many designs incorporate an assemblage of native plants, but the selected plants may not ever associate with each other as part of a natural plant community. This means that the ecosystem benefit is diminished, as many ecosystem services derive from the co-evolution of micro-organisms, insects, birds, other wildlife, and associations found in the plant community. Underground, root systems from the various members of a community occupy different depths and niches, creating a more functional hydrologic regime. The natural plant community modelling concept is designed to help replicate, at least to a greater degree, these ecosystem services (Floyd, 2018a, 2018b; see also Rainer & West, 2015 for a design concept based on plant communities).

Over time, a designer may identify a range of reference natural plant communities, some large and some mere fragments of a previous landscape. Once a good species list is developed from these communities, the stormwater landscape can be developed using some (but clearly not all) of the reference community species. Design elements to consider are the inclusion of a dense ground cover layer consisting of sedges, rushes, low grasses, creeping forbs, or other ground covers that will fill the spaces between other plants and may have diverse root morphologies. Other layers can include plants that add seasonal interest or structure (Rainer & West, 2015). Shrubs and trees can provide structure, as guided by the reference landscapes. Some species may be dominant while other occupy margins, low wet spots, drier berms, or small patches.

There is no hard-and-fast rule for the number of species to include, and the scale of the practice, desired aesthetics, and maintenance capabilities may guide this decision. Methodologies for ecosystem modeling suggest that stormwater landscapes can strive to include at least 30 species for many applications. However, this decision will also be influenced by the skill of maintenance crews and public acceptance. In some cases, the initial design can start with a simpler approach consisting of several species of locally well-recognized native plants. Diversity and complexity can be added over time as the stormwater landscape is managed and crews increase their skill levels with this type of native landscape. Also, some native (and some non-native) species will colonize the stormwater landscape over time, so diversity and complexity may be part of an adaptive management approach (see Section 5).

The number of plants used per species may vary widely by species, with the dominant species comprising a majority of the selected plants. Other species may be represented by fewer plants, but the important thing is to introduce them into the system. Over time, the dominance or rarity of species will sort itself out if there is adequate diversity in the initial palette.

Cover the BMP Surface Area with Vegetation – Green Mulch

Another important point is the initial planting density. If using plugs, they should be planted as densely as possible (e.g., 6 inches on-center, 4 per square foot) to provide a good jump start and reduce the "open" space between plantings that are attractive areas for invasives to encroach. If using other herbaceous plant stock, plant as densely as reasonable. It is also recommended to use an appropriate seed mix to supplement the plantings. Note that this type of planting scheme may only need an initial thin layer of mulch, if any, or a suitable matting (e.g., jute or coir). The design can even dispense with initial mulching if a seed mix is used to supplement planted stock. The strategy is intended to eliminate the need for typical, annual re-mulching, as the ground will covered by "green" mulch in the form of densely growing and layered plants. Note that mulch is carbon heavy, may change the chemistry of the soil in unfavorable ways, and can recruit for non-native or invasive species.

Certainly, not all of the selected plants will survive or thrive, but the concept is to provide a jump start for a plant community to develop and evolve. This dense planting scheme can increase initial costs, but, if properly managed, will reduce subsequent maintenance needs and costs and result in a successful well-managed stormwater landscape.

3. Source Selection & Procurement

There is an increasing number of nurseries that offer native plants. The link below has a partial list by state.

https://www.fws.gov/chesapeakebay/BayScapes/bsresources/bs-nurseries.html

Aside from the nurseries on this list, there may be other local or regional sources of native plants. Consulting your state's native plant society, or a local chapter, may be beneficial. Consider the following when looking for a source of high quality native plants:

- Purchase "sets" that are, in effect, natural communities of plants
- Comprised of species that co-evolved in the region.
- Produced to capture the range of appropriate, adaptive genetic diversity.
- Locally produced and sourced.
- Consist of straight natives and not necessarily native cultivars (cultivars of native plants bred for color, shape, bloom time, height, or other characteristics deemed desirable in the landscape trade).

- Grown without neonicotinoids.

Also keep in mind that availability for some species may be limited, and sourcing native plants may require a longer lead time compared to most landscape products. Larger projects have found it advantageous to contract with a native plant nursery to grow the desired species and quantities. This type of arrangement may take a year or more lead time prior to actual planting.

4. Management During First Several Growing Seasons

The first three years of maintenance and management are the most critical for this type of planting scheme and require maintenance crews trained to recognize PED planting strategies and native plants versus invasive plants. The following is general guidance for this three year period, based on Floyd (2018b).

Year 1

- Assuming a late winter planting start, leave no ground unplanted. Use vegetation as a substitute for mulch, plant as densely as the budget will allow, and infill with a carpet of seeds (of appropriate species for the project)
- Spot weeding: remove non-natives/invasives once/month through the growing season. Maintenance crews should be trained to recognize which plants should stay and those that should be removed.
- Cut to 4 to 6 inches through the growing season (every 4 to 6 weeks or so). As a PED strategy, it is important to evaluate carefully how many of the cuttings to remove from the BMP (e.g., for off-site composting). On one hand, the vegetation will have sequestered nutrients that can be removed from the system. On the other hand, leaving some cuttings will aid in the fuller development of a healthy plant and soil ecosystem. It is advised to consult a qualified professional to gain insight on the right balance.
- Keep volunteer native species based on successional management plan.
- Overseed in the Fall.

Year 2

- Spot weeding: remove non-native/invasives periodically, as needed.
- Overseed in the Spring, as needed based on a gap-fill assessment. In some cases, seeds can be collected from site itself to fill gaps.
- Cut to 4 to 6 inches through July (again, evaluate the efficacy of removing at least some of the cut vegetation from the system).
- Fill in gaps: continue to add plants and make adjustments.
- Keep volunteer native species based on successional management plan.
- Overseed in the Fall, as needed based on gap-fill assessment.

Year 3

- Spot weeding: remove non-native/invasives periodically, as needed.
- Allow full growth (don’t cut through the entire year, and only in late February thereafter).
- Assess need to fill any additional gaps.

- After the growing season, intensive management can be relaxed, letting the plant community evolve, while maintaining the edge.

5. Long-Term/Adaptive Management

In theory, if the three-year intensive management outlined above is followed, the natural plant community will evolve and will result in a dense planting that covers the surface area of the practice and provides complex structure, allowing fewer opportunities for invasives to colonize. The natural or managed succession within the plant community is an adaptive rather than static management approach that can reduce long term maintenance when compared to managing the planting plan as a static condition.

There are several tasks that should be conducted as part of a long-term adaptive management strategy:

- As desired, keep succession at bay by cutting back every 1 to 3 years in late February, and removing some of the cut vegetation if it cannot be mulched and left on site. Cut back woody growth every 3 to 5 years; woody plants add diversity and cover for the plant community, and should be maintained in a lower growing condition than is typical of many existing BMPs.
- Monitor invasives and non-native species, keeping in mind that complete eradication may be very difficult; 3 to 5% surface cover is normal for these situations.
- Make sure to keep a discernable edge so that it is clear that even the "wildest" native landscape is deliberate and is being cared for. Edges can be demarcated by a mowed strip, low fence or wall, or similar boundary that shows the intentional hand of humans in the landscape (Nassauer, 1995) .
- Keep a check on winter salt and sand inputs and remove accumulated slag, as necessary, at the end of the winter season. The O&M may have to include ongoing outreach and education of the road and transportation crews.

Also, importantly, monitor the landscape regularly and be willing to adapt the maintenance plan to changing conditions in plant growth, aesthetics, and property management objectives. For instance, some tree canopy may be desired, but complete canopy will shade out the herbaceous layer that thrived with more sunlight. It may be necessary to adapt the original planting design by planting more shade-tolerant native species under the canopy. Also, keep in mind that some species will become dominant in the community (maybe 5 or 6 species). Others will occur in patches or even become rare, but this reflects the evolution of a natural plant community. If the community is tending towards only a few dominant species, it may be necessary to re-evaluate the community and do some selective removal and replanting/reseeding with additional species that are good matches for the plant community (this does not mean continuing to replant species that are <u>not</u> doing well at the site).

The key is that the plant community is monitored on an annual basis and deliberate adaptations made based on design objectives.

Also, BMPs in the Bay Watershed must undergo a verification process to ensure the BMP is still present and performing as designed (CSN, 2014). This verification is intended to take place every two permit cycles for MS4s, or every 9-10 years. For vegetated practices, this would be an ideal time to revisit the original planting design, evaluate performance and issues encountered, and conduct any recommended redesign or replanting as part of an adaptive management scheme.

6. Risks

Vegetation may be an inherently low risk aspect of BMPs. However, if ones considers poor public perception and possible nuisance conditions to be risk factors, then vegetation is the most important component of a BMP. Public perception can be improved through informed design decisions and techniques, such as “Cues to Care” (Nassauer, 1995) or the systematic approach of Rainer and West (2015). Community education and outreach can be key components of public acceptance and of a long-term O&M plan for these sites. Misinformed or poorly-trained maintenance crews can also result in improper vegetation management and failure of this technique. Also, a poorly-performing vegetative community will affect runoff reduction and pollutant removal capabilities.

An additional risk to the vegetative community may be inputs of salt and sand in the winter. Monitoring this should be part of the long-term O&M plan.

7. Finding Help

This fact sheet outlines a fairly sophisticated approach for BMP planting design and management, and one that will require not only professional knowledge but also resources and a skilled workforce. While this may be intimidating to some, the point is to build broader collaborations between stormwater and landscape professionals and incorporate aspects of the approach into projects as opportunities arise.

The Chesapeake Bay Landscape Professional (CBLP) certification is a program of the Chesapeake Conservation Landscape Council (CCLC): https://cblpro.org/. The website also has a directory of professionals who have become certified in basic conservation and BMP landscaping with a focus on maintenance (Level 1) or the more advanced certification in design and/or installation (Level 2). The CBLP program may be a good place to start to find qualified professionals or build collaborations. This is not the only stormwater or green infrastructure certification program, but is one focused on the Chesapeake Bay and landscaping issues for stormwater BMPs.

The “Resources” section below provides additional links and organizations for native plants and plant communities.

8. Resources

Maryland Natural Communities
www.dnr2.maryland.gov/wildlife/Pages/plants_wildlife/nhpnatcomm.aspx

Natural Communities of Virginia
http://www.dcr.virginia.gov/natural-heritage/natural-communities/nctoc

Terrestrial and Palustrine Plant Communities of Pennsylvania
http://www.naturalheritage.state.pa.us/fikebook.aspx

Wild Vegetation of West Virginia
http://www.wvdnr.gov/Wildlife/Factsheets/default.shtm

Guide to Delaware Vegetation Communities
http://www.wrc.udel.edu/wp-content/heritage/NVCS/Guide-to-Delaware-Vegetation-Communities-Winter-2013.3.pdf

Ecological Communities of New York State
https://www.dec.ny.gov/docs/wildlife_pdf/ecocomm2014.pdf

Native Plant Center, Chesapeake Bay Region. Alliance for the Chesapeake Bay
www.nativeplantcenter.net

Virginia Department of Game & Inland Fisheries, Habitat Partners Program
https://www.dgif.virginia.gov/wildlife/habitat/

Definitions of native and exotic in Federal Register Executive Order 11987
www.archives.gov/federal-register/codification/executive-order/11987.html

USDA-NRCS definitions of native, non-native, invasive, naturalized, etc.
www.nrcs.usda.gov/wps/portal/nrcs/detail/ct/technical/ecoscience/invasive/?cid=nrcs142p2_011124

USDA NRCS PLANTS database
www.plants.usda.gov/java/

Maryland Native Plant Society
www.mdflora.org

Digital Atlas of the Virginia Flora
http://www.vaplantatlas.org/

Flora of Virginia
www.floraofvirginia.org

Virginia Natural Heritage Database
www.vanhde.org/species-search

Flora of Pennsylvania
www.paflora.org

The Flora of Delaware Online
http://www.dnrec.delaware.gov/fw/NHESP/information/Pages/PlantCommunities.aspx

Center for Urban Habitats
https://centerforurbanhabitats.com/

Chesapeake Riverwise Manual
www.stormwater.allianceforthebay.org/riverwise-communities-manual

Kennan K, and Kirkwood N. (2015). PHYTO: Principles and Resources for Site Remediation and Landscape Design. Routledge. New York.

9. Qualifying Conditions for Vegetation as a PED

The following conditions summarize the use of vegetation to qualify for the PEDs pollutant removal credit:

- As a general concept, model planting design on local natural plant communities. Provide diversity, layers of plants, and diversity of root morphologies.
- Initial plantings should aim to provide quick cover of the BMP surface area using densely-planted plugs, other plant stock, and overseeding with an appropriate seed mix (based in general terms on the reference natural plant communities).
- The O&M plan should include detailed management for the first three growing seasons; see Section 4 for guidance.
- The O&M plan should also address longer-term adaptive management of the plant community and periodic evaluation of plant health and shifts in the community (see Section 5). Engage qualified professionals in developing and implementing the O&M plan.

References

Chesapeake Stormwater Network. (2014). Urban Stormwater Verification Guidance. https://chesapeakestormwater.net/events/webcast-ms4-implementers-and-the-bay-tmdl-urban-bmp-verification/.

Floyd, D. (2018a). Ecosystem Modeling: Using Natural Plant Communities as Models for Landscape Design. Center for Urban Habitats. https://centerforurbanhabitats.com/. Continuing Education Workshop sponsored by: Virginia Department of Game & Inland Fisheries, Virginia Habitat Partners, Chesapeake Bay Landscape Professional. Powerpoint presentations.

Floyd, D. (2018b). Stormwater Landscapes: Using Natural Plant Communities for Design. Center for Urban Habitats. https://centerforurbanhabitats.com/. Continuing Education Workshop sponsored by: Virginia Department of Game & Inland Fisheries, Virginia Habitat Partners, Chesapeake Bay Landscape Professional. Powerpoint presentations by D. Floyd and D. Hirschman.

Hirschman, D.J., Seipp, B., Schueler, T. (2017). Performance Enhancing Devices for Stormwater Best Management Practices. Urban Stormwater Work Group. Center for Watershed Protection.

Nassauer, JI. (1995). Messy Ecosystems, Orderly Frames. Landscape Journal. 14(2): pp. 161-170

Rainer, T. and West, C. (2015). *Planting in a Post-Wild World: Designing Plant Communities for Resilient Landscapes.* Timber Press. Portland, OR. ISBN 978-60469-553-3.

Weaner L, and Christopher, T. (2016). *Garden Revolution: How Our Landscapes Can Be a Source of Environmental Change.* Timber Press. Portland, OR. ISBN 9781604696165.

Photos

Figure VEG-1. Example of Bioretention plant community modeled on local natural plant community.

Performance Enhancing Devices for Stormwater BMPs

Water Treatment Residuals

January 2019

Prepared By:

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For:

Roadside Ditch Management & PEDs

Center for Watershed Protection, Inc.

Chesapeake Stormwater Network

Funded By:

Chesapeake Bay Trust

Water Treatment Residuals (WTRs)

1. Definition & Applications

WTRs are the residuals from the drinking water treatment process. The material consists largely of solids derived from the raw water source, as well as flocculants used to promote settling of the solids. The flocculants typical consist of alum as well as an aluminum polymer (Polymeric Flocculant). Depending on the treatment plant, WTRs can also contain other water treatment by-products, including fluoride, filter backwash, lime, and/or activated carbon. The by-products can also contain small amounts of zinc or ortho-phosphorus.

Most treatment plants consider WTRs to be a by-product that must be hauled away, disposed of, or used for other purposes, such as land application. Using WTRs for stormwater could provide an alternative beneficial use.

WTRs can be used as an amendment to incorporate into roadside ditches or to blend into soil media used in other stormwater BMPs, such as bioretention and dry swales. WTRs can be incorporated into BMP retrofits where soil media will be added or replaced as part of the retrofit process (e.g., converting older practices or adding bioretention to a dry pond). Research indicates that WTRs can enhance a BMP's effectiveness in removing dissolved forms of phosphorus, and may have benefits for other pollutants (Hirschman et al., 2017).

See **Section 7** for a list of qualifying conditions in order for WTR amendments to qualify for enhanced nutrient removal as a performance enhancing device (PED).

2. Source Selection & Procurement

As almost every drinking water treatment plant generates WTRs, there are abundant opportunities to collect the product. Selecting an appropriate source requires some up-front investigation. The following considerations apply to selecting an appropriate source:

- The preferred WTRs will consist of raw water source solids and flocculants, and not a lot of additional by-products, especially those like ortho-P that would be detrimental for stormwater applications.
- The plant has a process to dry the material. The most effective process may be centrifuges, but many plants also use belt presses. For the plant, the purpose of drying the material is to allow it be hauled away in trucks. Some plants stockpile the material on-site for limited amounts of time, which allows for additional drying. At the plant, WTRs have the consistency of *play-dough*, but will continue to dry out if left exposed to air for several days. The dried material will have hardened blocks or clumps mixed with sand and fines. For stormwater applications, the vendor or party responsible for mixing into the soil media should ensure that the material can be incorporated evenly into the other soil mix components.
- The WTRs are relatively close to the application (e.g., location where the soil media is mixed) to reduce haul costs.
- Collecting and transporting WTRs can be authorized through the permits or contracts that the drinking water utility may hold with regulatory agencies (for handling/disposal) or third-party vendors (for alternative uses).

Visiting the plants and interviewing the managers and operators is recommended. Beyond finding suitable material, there are likely administrative steps and coordination with the local water utility. Many will have existing hauling contracts in place or other end-uses for the WTRs and permits from state regulatory agencies for handling the material. It will take some time to work through the process to obtain the WTRs in sufficient quantities for the intended application.

Several questions to ask the water utility manager include:

- What materials besides solids from the water source and alum go into the residuals ?
- What is being done with the existing WTRs? Are there contracts in place for hauling, disposal, and/or some other beneficial use?
- Is there a drying process? If so, what is it and is the average percent dry solids known? Is the processed (post-drying) material stored on-site for some length of time?
- On average, how much is generated on a daily basis? Are there seasonal differences or major differences in composition depending on weather events?
- Are environmental permits in place for handling, hauling, or disposal of the material? If so, what is the regulatory agency that manages the permit?
- What would be the process for obtaining occasional loads to use for stormwater applications? Who would be in a position to approve such a use?

The feasibility of using a certain WTR source will derive from these questions and additional follow-up discussions.

3. Material Testing

Representative samples of WTRs to be used for stormwater applications should be tested at a certified laboratory to confirm content. The purpose of testing is to ensure that the material has enough of the advantageous parameters (e.g., reactive aluminum) and acceptable levels of constituents that may have negative consequences for vegetation and/or receiving waters (e.g., zinc, phosphorus, soluble salts).

Another reason for testing is to check the fractions of sand, silt, and clay, and the texture classification so that soil media vendors (or those responsible for mixing the soil media component materials at sites) can incorporate the appropriate fraction of WTRs while meeting overall state-specific soil media specifications.

Table WTR-1 lists a variety of parameters that can be commonly tested at certified laboratories, and the expected ranges for WTRs. The ranges in the table are derived from WTR testing at three drinking water treatment plants across the Bay Watershed. Note that the ranges are expected values, but WTRs in other localities may not be within these ranges, as WTRs will vary based on the source water and the treatment process. This does not necessarily mean that the material is unacceptable for use, but may trigger a discussion with the plant manager or operator to see why a value may appear to be high or low. Weather conditions will also affect the results, so testing several times per year is recommended. A qualified soil scientist can also be consulted about results from a particular drinking water plant.

The table also provides notes, such as state soil media specifications for a particular parameter in the total mix. This refers to the standards that must be met once the sand, fines, and organic matter are blended together. This information may be relevant because soil media vendors will have to account for WTR components to ensure that the total mix still meets the relevant standards. In addition to ensuring the correct particle size distributions and other testing for the total mix, vendors may also want to conduct some type of permeability test on the mix to ensure adequate drainage though the media (e.g., ASTM D2434, which is currently expired, adapting ASTM E2396 used to measure permeability for green roofs, or perhaps a simpler equivalent). It is very important to know permeability of the media under various conditions, and thus field performance of the product.

Table WTR-1. Expected Ranges for WTRs

Parameter	**Expected Range[1]**	**Notes[2]**
Aluminum (ppm)	1800 – 3000; most will in 2500 range	This is aluminum content but not necessarily aluminum that is reactive (available for sorption of pollutants); further research is needed to develop common methods for isolating reactive Al.
Sand (%)	45 -- 80	State specifications for total mix have high sand content: 75 to 90%.
Silt (%)	20 -- 55	State specifications for total mix generally 10 – 20% fines & maximum of 10% clay.
Clay (%)	1 -- 7	
Texture Classification	Sandy Loam, Loamy Sand, or Silt Loam	Largely depends on solids from raw water source and perhaps recent weather/turbidity of source water.
Organic Matter (%) ASTM D2974	27 -- 45	State specifications can range from 1.5 to 4% by weight (Walkley-Black method) in total mix, although there is some debate about the efficacy of this standard and the long-term fate of OM in the media. In any case, vendors should anticipate OM from WTRs if mixing in.
Dry Solids (%)	18 -- 27	
pH	6.8 – 7.5	
Nitrogen Release (lb/A)	Approx. 130	
Mehlich III Extractable (ppm of P)	2 -- 5	Some state specifications for total mix are 18-40. The WTR values in this table are low, and would be expected to range based on the source water, weather, etc.
Calcium (ppm)	600 -- 2300	May be higher in areas with limestone or where lime is added to residuals for odor control.
Magnesium (ppm)	50 – 380	
Potassium (ppm)	30 -- 60	
Sodium (ppm)	60 -- 85	

Table WTR-1. Expected Ranges for WTRs		
Parameter	**Expected Range[1]**	**Notes[2]**
Iron (ppm)	40 -- 80	
Zinc (ppm)	1 – 14	
Soluble Salts (mmhos/cm)	0.15 – 0.30	MD specification for total mix is < 500 ppm (approx. 0.8 mmhos/cm).
Dry Loose Bulk Density (dried, ground, sieved) (g/cm3)	0.60 – 0.80	Lab methods vary, so values will also vary depending on method.
[1] Ranges were derived from testing of WTRs in Washington D.C., Richmond, VA, and Charlottesville, VA. WTRs in other localities may deviate from these values. In cases where there are significant deviations, it is recommended to discuss the values with the plant manager or operator. [2] Column includes information on general ranges for the total mix of soil media. Depending on the specification, the total mix includes sand, fines, and organic matter in specific proportions. The values noted for a given parameter do not apply to every Bay jurisdiction, so it advised to check state-specific specifications to check if certain ranges apply for a given parameter.		

4. Mixing The Material

Various research studies have recommended using WTRs at 5% by mass or 10 to 12% by volume. There is likely not enough research to hone in on an exact recommended ratio. Ten percent by volume seems like a supportable number for initial stormwater applications.

There are two ways to incorporate WTRs into a media mix:

1. Blend the WTRs as a soil media component into the other components. This means that the WTRs would be more-or-less consistently blended throughout the media. This method may be the most straight-forward for vendors that supply a “finished” product at the point of use. It also means, theoretically, that adsorption would take place throughout the soil media column.
2. Incorporate the WTRs into the top 12 to 16 inches of soil media at the site. This would assume that the WTRs are supplied to the site independent from the soil media and would need to be tilled in by the contractor. This is probably less desirable from the perspectives of construction process and quality control. The engineer of record would have to specify the amount of each material (soil media and WTRs), the incorporation method, and how the finished mix would meet state-specific specifications. However, research does indicate that blending WTRs into the top layer of soil media can be effective for removal of dissolved forms of phosphorus (Liu & Davis, 2014).

5. Risks

WTRs appear to have minimal risks. Potential risks include potential leaching of aluminum oxides into receiving waters, WTRs affecting hydraulic conductivity of the soil media (e.g., slow drainage or clogging), and aluminum affecting plant growth and development.

For the first concern, aluminum mobility is associated low pH environments (e.g. < 5), and stormwater tends to be only slightly acidic. As a general rule, pH levels greater than 5.5 should be maintained over time to reduce the risk of leaching, and periodic monitoring is warranted to test for aluminum oxides/polymers in the underdrain discharge. With regard to hydraulic conductivity, there is currently no evidence that WTRs would affect the ability of water to drain through the soil media. Most WTRs consist largely of sand and silt, so compositions are fairly consistent with the overall soil media.

Aluminum can certainly stress plant growth and development in acidic soils, so the pH of the combined soil media should be a screening criteria. Based on the values in **Table WTR-1**, WTR pH ranges from slightly acidic to slightly alkaline. If these values hold true for other WTR sources, plant toxicity should not be large concern.

Aluminum leaching, potential clogging, and potential plant toxicity should be monitored and evaluated as WTR amendments become more widely applied.

6. O&M Considerations

At this point, there are not enough field applications to indicate that vegetation plans or O&M procedures would change due to the addition of WTRs. Again, this may change as applications spread throughout the Bay Watershed. One possible O&M issue is "recharging" the WTRs as practices age and vegetation has to be removed and replaced. Some research indicates that WTR sorption lifespans may be as long as the practice itself, but there is certainly a possibility that sorption capacities would decrease over time.

For a practice that is undergoing major repairs, it would be worth considering removing the top layer of soil and replacing with a clean mix that contains new WTRs. Also, BMPs in the Bay Watershed must undergo a verification process to ensure the BMP is still present and performing as designed (CSN, 2014). This verification is intended to take place every two permit cycles for MS4s, or every 9-10 years. For practices with WTRs, this would be an ideal time to retest the soil media and ensure that (reactive) Aluminum and other key constituents are still present (see Table WTR-1) and to possibly add new WTRs to the top layer of media. Since there is not a long track record of WTR use, this procedure would generate valuable data on the longevity of WTRs in a blended media.

7. Qualifying Conditions for WTR as a PED

The following conditions summarize the use of WTRs to qualify for the PEDs pollutant removal credit:

- Sourced from appropriate water treatment plant using guidance from Section 2 of this fact sheet; material must be dried before mixing into soil media.
- Material tested as per Section 3 and Table WTR-1; note that the constituent ranges are based on limited testing, and professional judgement (e.g., soil scientist) should be used to evaluate specific results.
- Incorporate into soil media at 10% by volume; preferred mixing by qualified vendor using appropriate mixing equipment.
- Detailed O&M plan that addresses monitoring of health of vegetation to include possible signs of Aluminum toxicity, adaptive management of vegetation, and possible "recharging" of WTRs, as per Section 6.

Acknowledgements

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References

Chesapeake Stormwater Network. (2014). Urban Stormwater Verification Guidance. https://chesapeakestormwater.net/events/webcast-ms4-implementers-and-the-bay-tmdl-urban-bmp-verification/.

Hirschman, D.J., Seipp, B., Schueler, T. (2017). Performance Enhancing Devices for Stormwater Best Management Practices. Urban Stormwater Work Group. Center for Watershed Protection.

Liu, J., & Davis, A. P. (2014). Phosphorus speciation and treatment using enhanced phosphorus removal bioretention. *Environmental science & technology*, 48(1), 607-614.

Graphics

Figure WTR-1. Centrifuges used to dry WTRs at a water treatment plant

Figure WTR-2. Post-centrifuge WTRs being loaded onto contractor trucks to haul away for land application

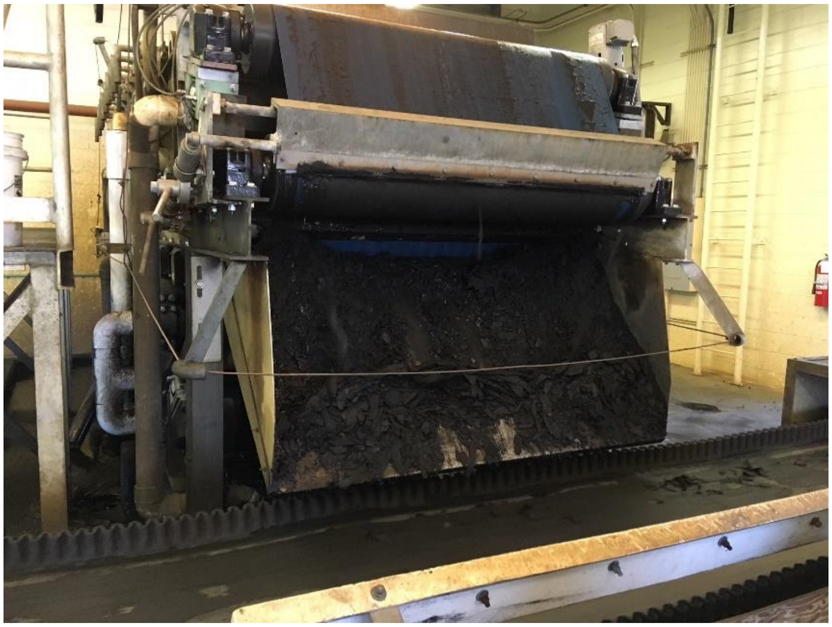


Figure WTR-3. Belt press used to dry WTRs at a smaller water treatment facility

Figure WTR-4. Stockpiled WTRs awaiting transport, which allows for some extra drying time

Ditch Elimination

1. Description

Ditch elimination involves eliminating a roadside ditch to: reduce or eliminate flow volumes introduced into the streams, reduce or eliminate sediment runoff to the stream, and disconnect the road network from the stream network (Penn State, 2005a). This is accomplished by raising the road profile, removing berms, and out-sloping the road to move water to areas where there is high infiltration capacity and native vegetation, which can trap sediment and restore natural drainage patterns. Ditch elimination can also be accomplished and supported through the use of cross-pipes to move water from upslope sides of the road to the downslope side of the road.

Out-sloping

- Out-sloped road surfaces drain water from the entire width of the road toward the fill-bank or down-slope side. The road is shaped to avoid collection or concentration of water in a ditch. Minor overland sheet flow can flow across the road. Out-sloping is useful on roads where concerns about winter icing are minimal or side-slopes are gentle (Penn State, 2005b).

Cross-pipe

- Cross-pipes are culverts used to carry only road drainage under the roadway. Cross-pipes must be outletted to natural vegetation where water can settle out sediment and infiltrate (Penn State, 2006). Cross-pipes must occur a minimum of every 500 feet; however, increasing road slopes required more cross pipes to ensure less water in the upslope road ditch and less water flowing out of each individual downslope pipe outlet. Additional guidance on cross-pipe design considerations can be found in USDA Forest Service document 9777 1812-SDTDC, *Relief Culverts* (Johnson et.al, 1997).

Ditch elimination is a unique roadside ditch management practice because it involves removal of the ditch, therefore management and maintenance of the ditch in the future is eliminated however, the road surface condition, slope, and crown become the focus of maintenance inspections and activities. These new maintenance activities typically involve using road grading and compacting equipment to maintain the road surface and shape as opposed to back-hoe, grade-all, or other excavation equipment used to "clean-out" or reshape a ditch. Ditch elimination results in water sheet flowing into the surrounding landscape and therefore some maintenance activities may include using large leaf blowers to blow organic debris and loose soil away from the road preventing it from building up and creating a barrier to sheet flow.

2. Practice Feasibility

Ditch elimination can be applied on most soils and topography since runoff is simply directed to infiltrate into the surrounding landscape. Key constraints of ditch elimination vary and include the following:

Current Conditions

- The road must be a dirt or gravel road that is incised on one or more sides with concentrated runoff flowing down the road bed or in ditches adjacent to the road.

Available Space

- The design elevation of the road surface must allow sheet flow runoff into the surrounding landscape; therefore, additional space on one or both sides of the road is generally needed. These adjacent pervious areas receiving sheet flow must be a suitable distance from the stream network, based on slope, to ensure sheet flow runoff is infiltrated.

Topography

- Pervious areas adjacent to the road receiving road runoff must have a shallow stable slope to allow for safe sheet flow that will not concentrate and form down gradient gullies or ditches.

Slope

- In order to achieve sediment load reductions, the road must be sufficient to generate sediment movement (≥ 3%), but no greater than 12% where achieving sheet flow discharge is not feasible.

Soil Condition

- Soil conditions generally do not constrain the use of this practice; however, impermeable soils in Hydrologic Soil Group (HSG) C or D require additional disconnection area to insure infiltration and restoration of natural drainage patterns.

Material Availability

- Raising the road profile generally requires large amounts of low-cost, nearby fill material. Suitable fill material includes:
    - Native shale/rock
    - Concrete waste
    - Mining spoils

3. Elimination Methods

This practice generally requires little formal design elements to construct. Design details for construction of this type of project includes a map showing start and end points of ditch elimination, locations and amounts of road fill, locations and sizes of cross pipes and other drainage features, water features (streams, wetlands, etc.), topography or flow directions, and intersecting roads and driveways. Figure 1 shows a detailed example plan for ditch elimination, simpler designs (aerial photo with notes, GIS, etc.) may be allowed as long as they provide the required information.

FIGURE 1: TYPICAL PLAN FOR DITCH ELIMINATION

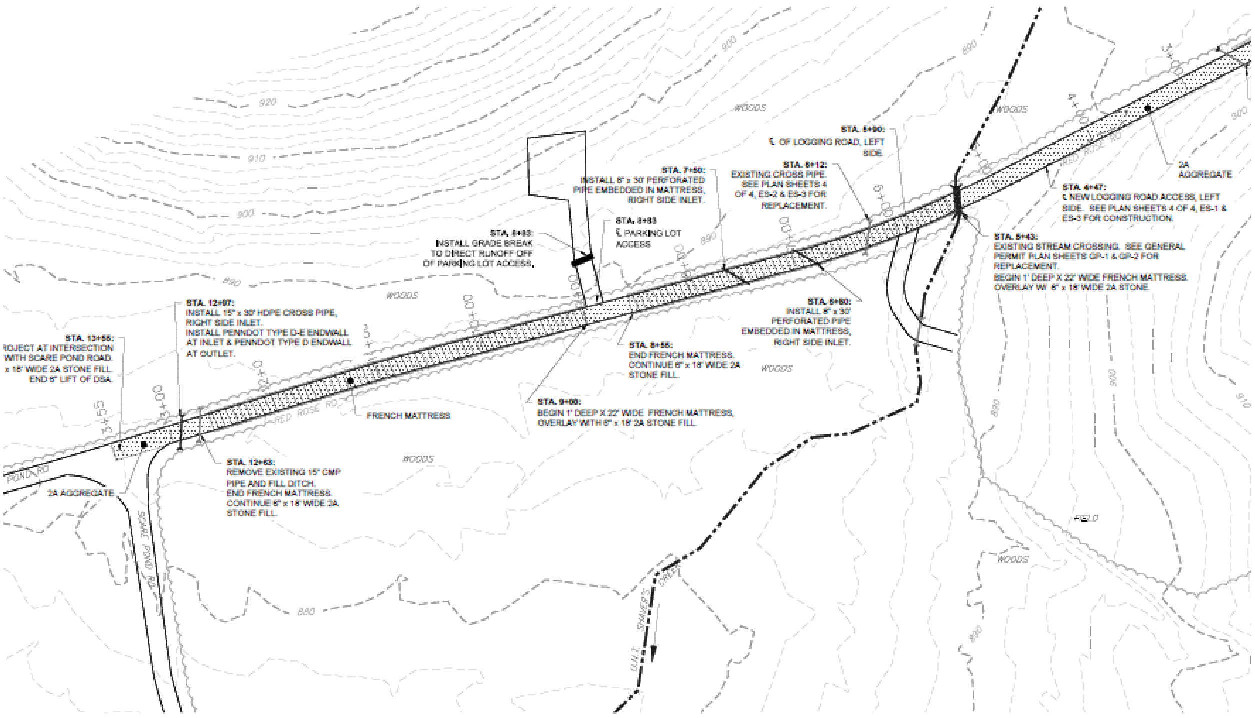
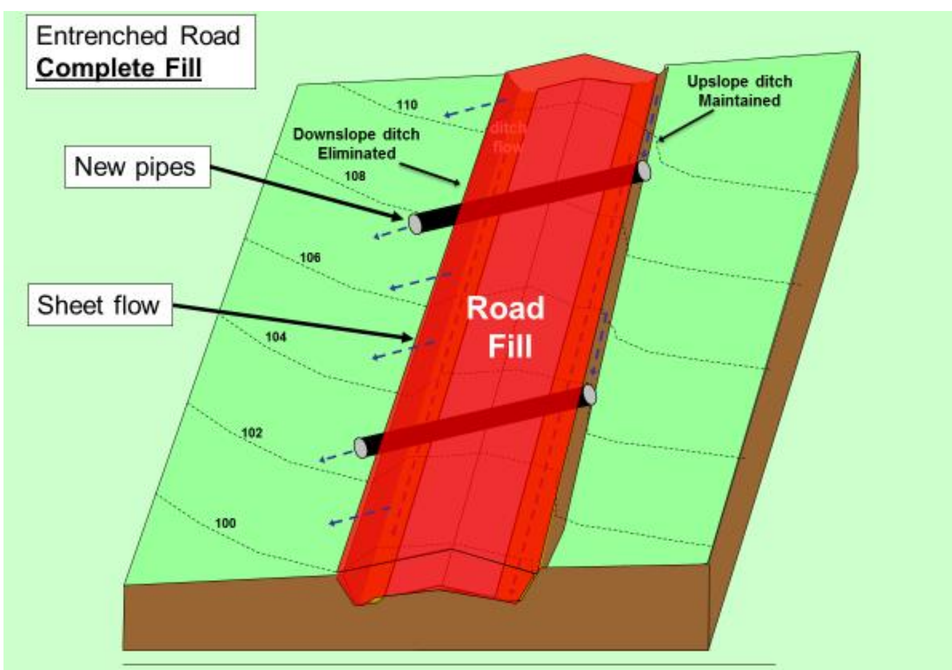


FIGURE 2: CENTER FOR DIRT AND GRAVEL ROAD STUDIES EXAMPLE DIAGRAM



3.1 Construction Sequence

The following identifies the critical stages of construction where an intermediate inspection is recommended and represents important elements for ensuring the success of the ditch elimination (Penn State, 2005c).

1. Identify suitable nearby fill material.
    - *Note: If using a recycled or industrial by-product, ensure the material does not pose any danger or require special handling.*
2. Prepare the existing road base by ensuring it has the proper crown or outslope.
    - *Optional: Install Geotextile to ensure solid road base.*
3. Fill material should be placed in 8-inch maximum lifts.
4. Compact each lift and ensure the final lift has proper crown or outslope of ½-inch to ¾-inch per foot.
5. Place cross-pipes if needed to drain upslope ditch; be sure to place pipes as low as possible.
    - *Note: Cross pipes should have a minimum of 1-foot of cover and 2% slope.*
6. Fill road section to ensure connection with surrounding landscape.
    - *Note: For outsloped roads ensure the highest point on the road cross section is on the uphill side of the road*
7. Place and compact final driving surface, ensuring proper crown or outslope.

3.2 Construction Inspection

Inspections during and immediately after construction are needed to ensure that the ditch elimination project is in accordance with the standard design and implementation procedures. Use a detailed inspection checklist that requires sign-offs by qualified individuals and critical stages of construction to ensure that the contractor's or roadcrew's interpretation of the plan is consistent with standard practice requirements. A construction inspection checklist should:

- Check the condition of the existing road base to confirm it meets specifications and has the appropriate slope or crown
- Check the fill material to ensure that it is confirms with the project specifications and is free of any unwanted foreign or contaminated material
- Verify the proper depth and coverage of fill material
- Verify that each lift has been properly compacted
- Check all cross pipes have been installed at the proper locations, using appropriate pipe material, and have suitable coverage
- Verify adequate coverage of vegetation where sheet flow from the road is directed
- Verify that new surface aggregate meets specifications
- Check driving surface for compaction, slope, and crown

The project should also be inspected after the first major rain event. The post-storm inspection should focus on whether the desired sheet flow off the road is occurring and the project objectives are still being met.

3.3 Procedures for Acceptance

Project acceptance is a visual inspection that takes place after the first major rain event after the construction phase is over to make sure the road surface and infiltration areas are functioning as intended. If so, the practice is accepted by the local roads department and should be reported to the proper stormwater management authority. Post-construction acceptance should also include as-built drawings showing:

- Start and end of the ditch elimination project
- Locations and lengths of road fill sections with fill depths
- Locations of geo-separation fabric, cells, and/or grids
- Locations, types, and sizes cross pipes showing inlet and outlets
- Locations, types, and sizes of stream culvert pipes
- Locations of diversion swales
- Locations of other drainage improvements
- Direction of sheet flow

The local approval authority should keep detailed inspection reports describing any needed maintenance. If any issues are found, identify a timeframe for repair and conduct a subsequent inspection to ensure completion of repairs.

A written inspection report is part of every inspection and should include:

- The date of inspection
- Name of Inspector
- The condition of:
    - Road surface condition
    - Road crown
    - Road slope
    - Adjacent pervious areas
    - Cross-pipes
    - Any other item that could affect the proper function of the ditch elimination practice
- Description of needed maintenance

4. Sediment and Nutrient Crediting Protocol

4.1 Credit Calculations

The sediment load produced by gravel roads is based on the area of road being managed multiplied by the appropriate Road LandClass.

Total Road Area (acres)= Length of Road (feet) * **16 (default road width)** /43560

or for crowned roads with cross pipes

Total Road Area (acres)= Length of Road (feet) * **8 (half the default road width)** /43560

Total Road TSS Load (tons/year) = (Total Road Area * TSS Load for Road LandClass)

The Total Road TSS Load is multiplied by the load reduction values in Table 1 or 2 to determine the tons of sediment removed.

It is suggested that a simplified default loading rate based on Bay-wide average loads (Chesapeake Bay Program, 2018) and the assumption that the gravel road averages 16 feet wide be made available to simplify reporting requirements. Default Bay-wide average loading reduction rates for Non-regulated Road, MS4 Road, and CSS Road are shown in Table 1.

TABLE 1: PROPOSED DEFAULT LOADING RATES FOR DITCH ELIMINATION

LandClass	Bay-wide average load TSS Load (tons/acre)	Road Length (feet)	Road Area (acres)[1]	Load (tons/year)	Lbs/ft
Non-regulated Road	1.49	1	0.00036731	0.00055	1.095
MS4 Road	0.94			0.00035	0.691
CSS Road	1.08			0.00040	0.793

[1] Road area based on 16-foot road width identified in Simpson Et. Al.

The credit is calculated by applying the removal efficiencies provided in Table 2 and Table 3 (adjusted based on road slope) to the TSS loads produced by the Road LandClass provided in Table 1 multiplied by the area of road impacted.

The credit outlined in Table 2 would be applied to the portion or section of road where the ditch is eliminated by raising the road profile and sheet flow discharge is achieved.

TABLE 2: DITCH POLLUTANT REMOVAL EFFICIENCIES FOR COMPLETE DITCH ELIMINATION

Ditch Elimination/Raising Road Profile				
Pollutant		**Sediment**	**Total N****	**Total P****
	Slope (%)			
Removal Rate*	3	29%	0%	0%
	4	43%	0%	0%
	5-6	56%	0%	0%
	6+	63%	0%	0%
*Sediment removal rates based on UMD/MAWP recommendations found in Simpson et.al. and adjusted using WEPP model runs by the Center for Dirt and Gravel Road Studies and grouped using Jenks Natural Breaks Optimization.				
**No nutrient removal is expected for ditch elimination since the road is not fertilized.				

The credit outlined in Table 3 would be applied when—due to site constraints—the ditch is only eliminated on one side and cross-pipes are used to convey water to the downslope side of the road. The credit applies the portion or section of road draining to side of the road where cross-pipes are needed to covey water to adjacent natural vegetation/cover.

TABLE 3: DITCH POLLUTANT REMOVAL EFFICIENCIES FOR DITCH ELIMINATION WITH CROSS-PIPES

Ditch Elimination/Cross-Pipe Installation				
Pollutant		**Sediment**	**Total N****	**Total P****
	Slope (%)			
Removal Rate*	3	19%	0%	0%
	4-6	24%	0%	0%
	7-9	27%	0%	0%
	10+	30%	0%	0%
*Sediment removal rates based on WEPP model runs by the Center for Dirt and Gravel Road Studies and grouped using Jenks Natural Breaks Optimization.				
**No nutrient removal is expected for cross-pipe installation since the road is not fertilized.				

4.2 Credit Example

Table 4 is an example of a 3,000-foot road with some variation in slope. In this example, fill material was added and a new driving surface installed which grade matches the adjacent landscape and provides complete sheet flow runoff from the road surface into vegetation with sufficient area to infiltrate.

TABLE 4: EXAMPLE #1 CREDIT CALCULATION USING DEFAULT RATES

Total Road Center Line Length (feet)	Road Width (feet)*	Slope (%)	Land Class	TSS Load Reduction Efficiency	Load Reduction (lbs./yr.)
800	16	4	Non-regulated Road (1.09 lbs./ft)	43%	376.54
2200	16	5		56%	1348.53
		Total Load Reduction from Ditch elimination			**1725.06**
3000				***Pounds/ft.***	***0.58***
** Assumes default road width of 16 feet.*					

Table 5 is an example of a 3,000-foot road with some variation in slope. In this example, due to topography half the new driving surface grade matches the adjacent landscape and provides sheet flow runoff from the road surface into vegetation. The other half of the road drains to upslope side of the road, which is drained using cross-pipes to covey water under the road to the adjacent landscape for infiltration.

TABLE 5: EXAMPLE #2 CREDIT CALCULATION USING DEFAULT RATES

Total Road Center Line Length	**Road Width***	**Slope (%)**	**Land Class**	**TSS Load Reduction Efficiency**	**Load Reduction (lbs/year)**
3000	8	5	Non-regulated Road (1.09 lbs/ft)	56%	919.45
3000	8	5		24%	248.60
		Total Load Reduction from Ditch elimination			**1168.04**
3000				***Pounds/ft.***	***0.39***
** Assumes default width crowned-road with half the road surface draining to downslope side and half draining upslope side of the road with cross pipes installed following guidance found in Relief Culverts (Johnson et.al, 1997).*					

1. Maintenance and Visual Indicators

Routine maintenance checkups occur annually as part of regular maintenance visits and are used to immediately correct minor maintenance problems. The checkups are also used to provide quality control on maintenance activities and to determine whether the road crew needs to schedule a follow up visit to repair moderate maintenance problems.

Table 6: Defining Numeric Triggers to Classify ditch elimination Maintenance Conditions

#	INDICATOR	Pass	Minor	Moderate	Severe
1	Driving Surface	No change to driving surface.	Erosion occurring to less than 10% of the surface	Erosion occurring to less than 25% of the road	Erosion occurring to 25% or greater of the surface
2	Flow Distribution	100% of flow leaving road surface is sheet flow	75% of flow leaving road surface is sheet flow	Less than 50% of runoff leaving the road is sheet flow	Less than 25% of the runoff leaving the road is sheet flow
3	Sediment/Aggregate Movement	No movement of aggregate or sediment buildup	Few isolated areas of deposition and aggregate movement	Windrows and/or wheel tracks divert flow parallel to road gully's less than 1" inches deep	Gully erosion greater that 1" deep occurring to or adjacent to road surface.
4	Crown/Outslope Integrity	No change to slope	Crown/ outslope deviates by 5%	Crown/outslope deviates by 10%	Crown/outslope deviates by 15%
5	Adjacent Vegetative Cover	Dense vegetation (90%) or undisturbed forest floor	Isolated bare spots	Vegetation cover of 75% or more (not forest)	Vegetation cover less than 75% (not forest)
6	Road Drainage	Road drainage features functioning as designed	Isolated location of maintenance recommended, functioning	Road drainage elements not conforming to standards maintenance; required	Road drainage elements not functioning as designed, restoration required

5.1 Typical Maintenance Procedures

Shoulder Maintenance/Berm Removal

- The objective is to keep the surface smooth so that moving vehicles can leave the main roadway safely, and also to assure that water from the road will move across the shoulder and into the ditch or landscape. It is particularly important to remove the accumulated winter maintenance abrasives or lose road material from the shoulders to prevent water from being trapped on the road surface.

Blading

- Remove potholes, corrugations, and other surface defects, rendering the surface smoother and safer to travel on. Blading is usually preceded by scarification to a depth slightly deeper than the deepest surface defects. Blading should be used to establish a cross-slope of 4%–6% (½ to ¾ inch per foot) for good drainage and to reduce the development of potholes in the aggregate surface.

Re-graveling

- The addition of aggregate materials to re-establish the crown and grade of the road, needed periodically to make up for materials that have been lost due to traffic, water erosion, dusting, and blading losses.

2. Verification Procedures

Inspection of this practice is needed to verify that the ditch has been eliminated and runoff water is infiltrating into the surrounding landscape and therefore can continue to earn its pollutant reduction credits, in the context of either a local or Bay-wide TMDL. The inspection should occur a minimum of **once every 3 years** and include comparison to the as-builts and field assessments. Verification uses a subset of the list of visual indicators that assess the hydrologic function and pollutant removal capability of the RDM practice, by answering three simple questions:

1. Does it still physically exist? i.e., can you find it and are the road surface conditions and cover in the adjacent pervious area still functioning?
2. Is water exiting the road and infiltrating into the landscape as it was originally designed?
3. Is the maintenance condition sufficient to still support its pollutant reduction functions?

TABLE 7: PERFORMANCE VERIFICATION INDICATORS

	Visual Indicator	Task/Investigation
Pass	Road surface is connected to surround landscape, water can sheet flow off road	None
Minor	Some concentrated flow along or down road surface; most runoff exits road as sheet flow; no impact to stream network	Make note and check on next maintenance
Moderate	Moderate concentrated flow along or down road resulting in road surface erosion	Maintain shoulder, crown and outslope
Severe	Road incision is occurring and or ditch is emerging; concentrated runoff has little access to surrounding landscape and is discharging to the stream network	Re-establish road surface connection to surrounding landscape; use geotextile if chronic problem; check for and eliminate run-on from offsite water sources (lanes, trails, etc.)

References

Chesapeake Bay Program. (2018). Phase 6 Watershed Model: Section 2 – Average Loads
Final Model Documentation for the Midpoint Assessment.
https://cast.chesapeakebay.net/FileBrowser/GetFile?fileName=P6ModelDocumentation%2F2%20Average%20Loads%202018%2005%2022.pdf

Cornell Local Roads Program. (2012) Local Roads Research And Coordination Council Manual: Guidelines for Rural Town and County Roads. New York LTAP Center. Ithica, NY. https://cornell.app.box.com/v/clrp-pb-mgrtcr

Johansen, D. K., Copstead, R., & J. Moll. (1997). Relief Culverts. USDA Forest Service. San Dimas, CA: Author. https://www.fs.fed.us/biology/nsaec/assets/reliefculverts.pdf

Penn State University, Center for Dirt and Gravel Roads Studies. (2005a). Technical Bulletin: Raising the Road Profile.
https://www.dirtandgravel.psu.edu/sites/default/files/General%20Resources/Technical%20Bulletins/TB_Raising_Road_Profile.pdf

Penn State University, Center for Dirt and Gravel Roads Studies. (2005b). Technical Bulletin: Crown & Cross-Slope.
https://www.dirtandgravel.psu.edu/sites/default/files/General%20Resources/Technical%20Bulletins/IB_Crown_and_Cross_Slope.pdf

Penn State University, Center for Dirt and Gravel Roads Studies. (2005c). Technical Bulletin: Raising the Road Profile.
https://www.dirtandgravel.psu.edu/sites/default/files/General%20Resources/Technical%20Bulletins/TB_Raising_Road_Profile.pdf

Penn State University, Center for Dirt and Gravel Roads Studies. (2006). Technical Bulletin: Pipes-An Overview
https://www.dirtandgravel.psu.edu/sites/default/files/General%20Resources/Technical%20Bulletins/IB_Pipes_Overview.pdf

Ditch Retrofit

1. Description

Roadside ditch management (RDM) retrofits are stormwater best management practices (BMPs) that are used to store, treat, and infiltrate runoff by creating ponding and replacing existing ditch soil with more permeable material. The RDM retrofits in this guidance include specifications that are less stringent than traditional retrofits such as bioretention because of the limited site constraints that ditches pose. For practices that are offline or do not meet the parameters in this guide, traditional retrofits should be considered [1]. RDM retrofit practices include converting existing ditches to one of the types outlined in Table 1.

TABLE 1: DESCRIPTION OF RDM RETROFITS

Retrofit	Description
Sand Layer Swale [2]	Existing ditch soil is replaced with a layer of sand, a layer of topsoil, and vegetated on the top.
Dry Swale [3]	Existing ditch soil is replaced with filter media, which is a mixture of sand, soil, and organic material, and vegetated on the top.
Wet Swale [4]	Linear wetland cells that intercept shallow groundwater to maintain a wetland plant community.

Performance Enhancing Devices (PEDs) can be added to any of these practices to improve performance. PEDs include incorporating biochar, water treatment residuals, and other media enhancements to the normal media of the retrofits.

2. Retrofit Feasibility, Site Selection, Practice Selection

2.1. Retrofit Feasibility

Depending on site characteristics, retrofits practices may be applied. Key constraints of ditch retrofits include:

Existing Ditch Stability

- The velocity of water from the drainage area should not exceed the permissible velocity for channels lined with vegetation cover. It is recommended that the velocity of flow from a 1-inch rainfall not exceed 3 feet per second. This is to prevent the ditch from eroding, which can cause the treatment to fail. If the existing ditch vegetation can currently handle most rainfall events, the ditch is likely stable. The contributing drainage area should be stable without any actively eroding soils or bare patches (have 95% groundcover/forest cover). In cases such as agricultural areas where this may not be possible, erosion and sediment controls or pretreatment must be used to minimize the amount of sediment entering the practice. If the existing ditch is eroding and it is suspected that the velocity of the incoming water is too high, either install inlet protection such as riprap, or select an alternative site. Instructions to calculate velocity can be found in the VA DEQ Stormwater Design Specification No 3. Grass Channel, page 11 (Manning's Equation) [5].

Available Space

- Practices should have a trapezoidal or parabolic bottom of at least 2 feet, with side slopes 3:1 or flatter on the road side and side slopes 2:1 or flatter on the opposing side.

Longitudinal Slope.

- Ditch retrofits are limited to longitudinal slopes of less than 4%, unless check dams are used. Slopes steeper than 4% create rapid runoff velocities that can cause erosion and do not allow enough contact time for infiltration or filtering, unless check dams are used.
- Longitudinal slopes of less than 2% are ideal and may eliminate the need for check dams. However, channels designed with longitudinal slopes of less than 1% should be monitored carefully during construction to ensure a continuous grade, to avoid flat areas with pockets of standing water [5]. Additionally, ensure that the inlet and outlet grade will allow for positive flow in and out of the practice.

Utilities

- For all roadside ditch projects, utilities are a concern. Designers should call the local utility locate services to mark the lines and consult local utility design guidance for the required horizontal and vertical clearance between utilities and the channels. Typically, utilities can cross grass channels if they are specially protected (e.g., double-casing) or are located below the channel invert.

2.2. Site Selection

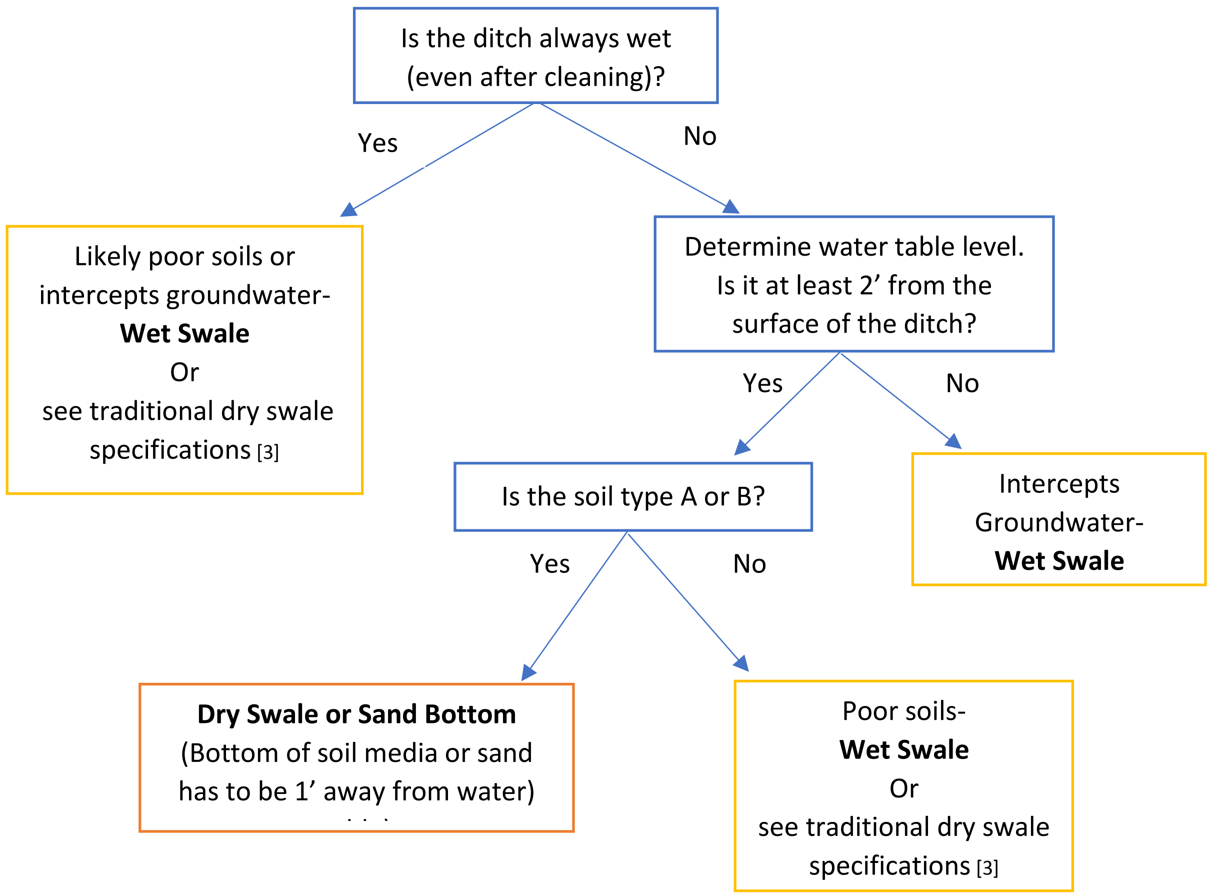
The follow are characteristics of an ideal potential retrofit site:

- Limited underground utilities and/or can be avoid.
- Limited overhead utilities that can interfere with construction equipment and require utility pole setbacks.
- Less than 2% longitudinal slope.
- Wide right of way.
- Ditch bottom and excavation depth accessible outside of ditch.
- 3:1 side slopes or flatter.
- Stable upslope conditions.
- Currently eroding ditches. (If the cause of the erosion is unknown or will not be remediated, it should not be chosen as a retrofit site).
- Sites that currently require frequent maintenance if the issue can be resolved through a retrofit. (If it problem is unknown or will not be remediated, it should not be chosen as a retrofit site).
- Areas that receive low amounts of sediment.
- Adding check dams would not significantly impact the hydraulic capacity of the ditch (will not cause flooding).

2.3. Retrofit Type Selection

Below is a decision chart to help narrow down the type of retrofit best suited for a site. Ditch retrofits are not limited to the practices mentioned in this guide; traditional retrofits can also be used, but typically have more stringent requirements. The specifications for traditional BMPs can be found at the end of this guidance.

Figure 1: Ditch Retrofit Decision Chart



Some other parameters to consider include those listed in Table 2.

Table 2: Site Parameters

Parameter	Dry Swale	Wet Swale	Sand Layer
Maintenance	Low- mowing	Medium- high variety of plants	Low- mowing
Vegetation	Grasses/Perennials	Wetland plants (taller)	Grasses
Cost	Medium	Low	Medium
Potential for long term standing water	Low	High	Low

Soils

- Dry swales and sand layers perform best if they are constructed in permeable soils, such as Hydrologic Soil Group (HSG) A and B. Wet swales work best in less permeable Hydrologic Soil Group (HSG) C or D soils or if the water table is high. If soils have low permeability, it is best to install a wet swale, install an underdrain (see Dry Swale specification [3]), or find an alternative site. Soil information can be found on the NRCS Web Soil Survey or an infiltration test can be performed (Appendix 8-A of Stormwater Design Specification No. 8 Infiltration [6]). If the existing ditch currently holds water for and extended amount of time, even after cleaning, it is likely to be a less permeable soil (C or D), and therefore a wet swale should be chosen.

Depth to Water Table

- The location of a dry swale or sand layer should be in a ditch where the water table is a minimum of 1 foot below the bottom of the practice. If the water table is high, a wet swale should be considered. If the depth to water table is uncertain, a small well can be dug to estimate the water level. Using an auger, dig a 4-foot-deep hole in the ditch. If the hole fills in with soil, a PVC pipe can be inserted to maintain the structure of the hole. After 24 hours, determine if there is water in the well and if the bottom of the practice will be at least 1 foot from the water surface.

FIGURE 3: PVC MONITORING WELL

FIGURE 2: MONITORING HOLE DUG VIA AUGER

3. Design Parameters and Construction Sequence

Ditch retrofits require a few design elements to properly construct. Design details for construction of this type of project include a map showing start and end points of ditch retrofit, cross section of the retrofit (include side slope, depth of media, type of media, width of ditch, and ponding depth), number and location of check dams, longitudinal slope, and flow direction. Simple designs (aerial photos with hand drawn designs, notes, GIS, etc.) may be allowed if they provide the required information. Table 3 contains design parameters for ditch retrofits.

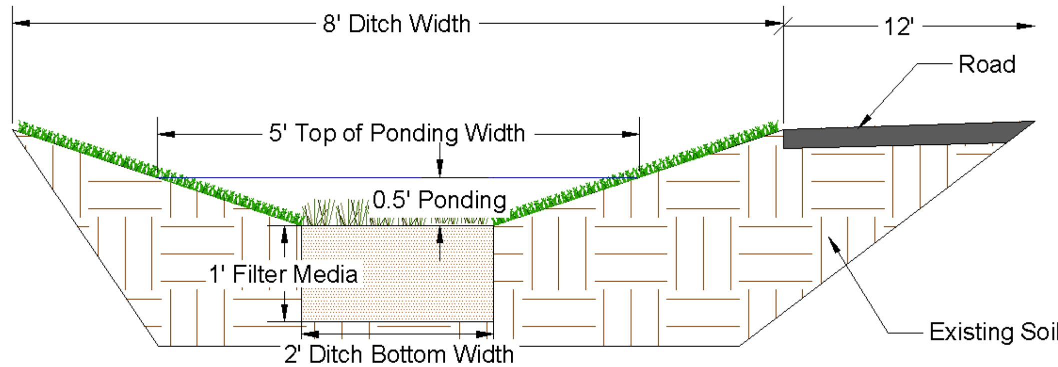
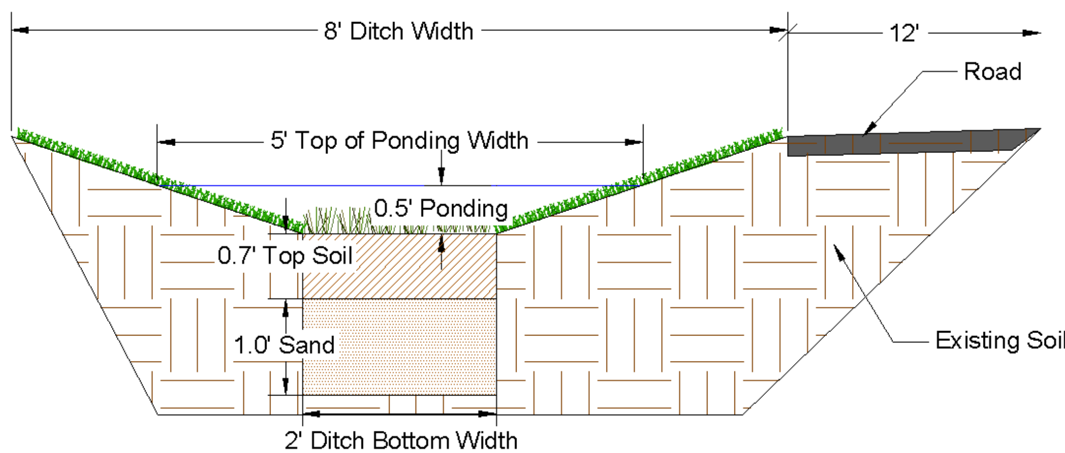
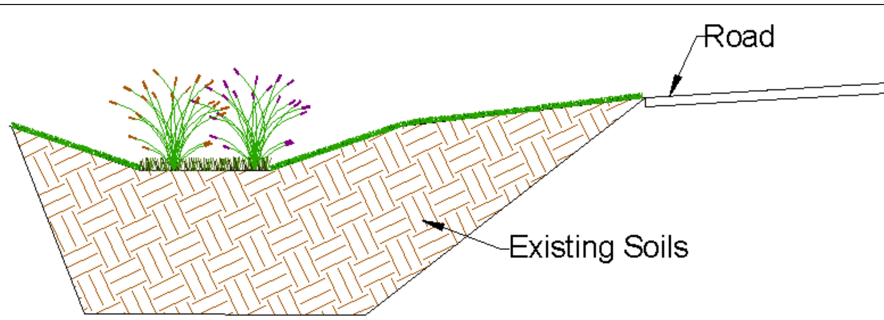
TABLE 3: DESIGN PARAMETERS

Parameter	Specification
Side Slope	3:1 or flatter on road side, 2:1 or flatter on non-road side
Inlet and outlet protection	Provide riprap apron at all inlets and outlets
Longitudinal Slope	Less than 4%, or use check dams
Width of Bottom of Ditch	Minimum 2 feet
Media Depth	Dry Swale: 12-24" of filter media Sand Layer Swale: 12-24" of sand below 8" topsoil layer Wet Swale: N/A
Media Specification	Dry Swale Filter Media: 85-88% sand, 8-12% soil fines, 3-5% organic matter in form of leaf compost; USDA soil types loamy sand, sandy loam, or loam Sand Layer: Clean AASHTO-M-6 or ASTM-C-33 concrete sand
Erosion Control Matting	For higher velocity and steep slopes, erosion control matting may be necessary to protect the soils and seeds
Ponding Depth	The maximum ponding depth in a ditch should not exceed 12 inches at the most downstream point
Vegetation	Dry Swale and Sand Layer Swale: Include vegetation that can withstand both wet and dry periods as well as relatively high velocity flows within the channel. Salt tolerant grass species and denser grasses are preferable. Grass species should have the following characteristics: A deep root system to resist scouring; a high stem density with well-branched top growth; water-tolerance; resistance to being flattened by runoff; and an ability to recover growth following inundation. Bermudagrass, Kentucky bluegrass, reed canary grass, tall fescue, grass-legume mixture, red fescue (See VA DCR Stormwater Design Specification No.3 Grass Channel [5] and No.10 Dry Swales [3] or local grass channel/dry swale design guidelines). Wet Swale: Choose grass and wetland plant species that can withstand both wet and dry periods as well as relatively high velocity flows within the channel. Salt tolerant grass species and denser grasses are preferable (See VA VEQ Stormwater Design Specification No 13 Constructed Wetland [7] for vegetation selection or local stormwater guidance).
Check Dam	Check dams must be used for retrofits, unless an alternative method for ponding is included in the design. See VA DEQ Stormwater Design Specification No.10 Dry Swales, Section 6.3 for spacing (typically 50-200 feet apart).
Performance Enhancing Devices	Incorporate 10% by volume of the PED. See the Performance Enhancing Devices Final Report for more information [6].

3.1. Design Examples

Table 3 illustrates cross section examples of the different types of retrofit practices.

Table 4: Design Examples

Dry Swale	
Sand Layer	
Wet Swale	

<table>
<tr>
<td>Check Dams</td>
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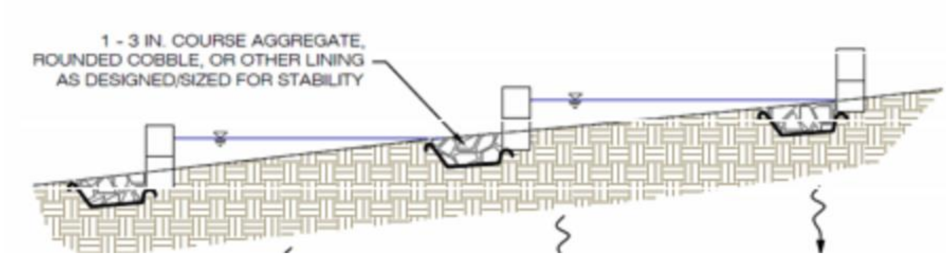
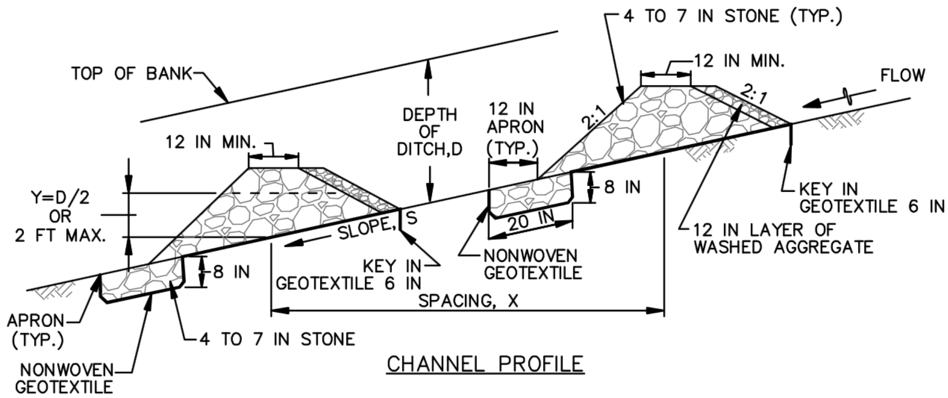


[5]


[7]
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3.2. Construction Sequence

FIGURE 4: FILTER SOCK AT THE END OF A RETROFIT

Provide erosion and sediment controls according to the local requirements. Some examples include straw wattles or filter sock around the outlet of the retrofit.

The following is a typical construction sequence to properly install a retrofit, although the steps may be modified to adapt to different site conditions.

1. Installation should only begin after there is no active erosion upslope. Additional E&S controls may be needed during construction, particularly to divert stormwater from the retrofit until the filter bed and side slopes are fully stabilized.
2. (Optional) If the side slopes and width of the ditch do not meet the parameters described in this guidance, it is best to reshape the ditch first and allow it to stabilize before excavating for media replacement. Flatter side slopes and a wider bottom are more stable and less prone to disturbance from equipment during excavation. Unstable side slopes can lead to clogging of the soil media, decreasing the lifespan of the retrofit.
3. Excavators or backhoes should work from the sides to excavate the retrofit area to the appropriate design depth and dimensions. Excavating equipment should have buckets with adequate reach so they do not have to sit inside the footprint of the retrofit area. If the full length of the retrofit cannot be finished within one day, work in sections (ex. 50’ in length) that can be completed and stabilized with matting at the end of each day.

4. (Dry swale, sand layer) The bottom of the retrofit should be ripped, roto-tilled, or otherwise scarified to depth of at least 6 inches to promote greater infiltration.
5. (Dry swale, sand layer) Obtain filter media or sand that meets the specifications and apply in 12-inch lifts until the desired top elevation is achieved.
6. (Sand layer only) Add 8 inches of top soil on top of the sand layer to reach the desired top elevation. This top soil layer is to support plant grow in the ditch.
7. (Optional) To incorporate PEDs:
    a. Wet Swale: Till the bottom of the ditch to a depth of 1 foot and incorporate amendments according to the PED Section.
    b. Sand Layer: Incorporate amendments according to the PED Section in the sand and top soil layer
    c. Dry Swale: Incorporate amendments according to the PED Section in the filter media
8. Install check dams, inlet and outlet protection, culverts, and other features. Fill material used to construct check dams should be placed in 8- to 12-inch lifts and compacted to prevent settlement.
9. Prepare planting bed for specified vegetation, install erosion control matting, and spread seed (Figure 5).
10. Inspect the ditch after a significant rain event to ensure that the practice is stable. Also inspect the ditch to make sure the vegetation is established and survives during the first growing season following construction.

FIGURE 5: INLET PROTECTION AND EROSION CONTROL MATTING (CURLEX®)

3.3. Construction Inspection

Inspections during and immediately after construction are needed to ensure that the retrofit is built in accordance with the standard designs and parameters. Use a detailed inspection checklist that requires sign-offs by qualified individuals at critical stages of construction to ensure that the contractor's or roadcrew's interpretations of the plan are consistent with standard practice requirements. A construction inspection checklist should include:

- Check the filter media or sand media to confirm that it meets specifications and is installed to the correct depth.
- Check elevations such as inverts for the inflow and outflow points, elevation of the various layers, and the ponding depth provided between the surface of the filter bed and the check dams.
- Verify the proper coverage and depth vegetation or soil matting has been achieved following construction, both on the filter bed and the side-slopes.
- Inspect the check dams to verify that they are properly installed, stabilized, and working effectively.

- Check that outfall protection/energy dissipation measures at concentrated inflow and outflow points are stable.

The project should also be inspected after the first significant rain event. The post-storm inspection should focus on whether the desired flow is occurring, and the project objectives are still being met. Also, inspectors should check that the retrofit drains completely within a 72-hour drawdown period (except wet swales). Minor adjustments are normally needed as a result of this post-storm inspection (e.g. spot reseeding, gully repair, added armoring at inlets or outfalls, and check dam realignment).

Procedures for Acceptance

Project acceptance is a visual inspection that takes place after the first major rain event after the construction phase is over to make sure it is still working and meeting its project objectives. If so, the practice is accepted by the local stormwater management authority. Post-construction acceptance should also include an as-built drawings or sketch showing:

- Start and end of the ditch retrofit project
- Type of retrofit
- Depth and type of replaced media
- Dimensions of new ditch
- Number of check dams and ponding depth

The local approval authority should keep detailed inspection reports describing any needed maintenance. If any issues are found, identify a timeframe for repair and conduct a subsequent inspection to ensure completion of repairs.

A written inspection report is part of every inspection and should include:

- The date of inspection;
- Name of inspector;
- The condition of:
    - Side slopes
    - Main bed
    - Ponding elevation
    - Check dams
    - Inlet and outlets
    - Soil permeability
    - Vegetation
    - Any other item that could affect the proper function of the stormwater management system
- Description of needed maintenance

4. Sediment and Nutrient Crediting Protocol

4.1. Credit Calculations

The Bay Program provides retrofit performance curves to calculate sediment and nutrient credit for traditional retrofits. Retrofits are classified as either stormwater treatment (ST) or runoff reduction (RR), and depending on the classification, different curves are used.

To determine the runoff volume treated by a retrofit practice, the volume of water held in the practice and the impervious area treated is required. The standard equation used to determine the amount of runoff volume (inches) treated at the site is:

$$\text{Runoff Depth Captured per Impervious Acre (inches)} = \frac{RS(12)}{IA}$$

Where:

RS = Runoff Storage Volume (cubic feet)
IA = Impervious Area (square feet)

The runoff storage volume includes the water stored in ponding and in the soil media layers. The simplest estimate of the storage volume is:

Depth of filter media x length of ditch x width of ditch x 0.25 (porosity of filter media)
+
Depth of ponding x length of ditch x width of ditch

The simplest way to estimate the impervious area draining to the retrofit is to use the area of the road draining parallel to the ditch (length of road x distance from crown to edge of road).

Table 5 shows the type of retrofit, which adjustor curve to use, and also what is included in the runoff storage volume.

Table 5: Retrofit, Classification and How to calculate storage Volume

Retrofit	Adjustor Curve	Runoff Storage Volume
Sand Layer	ST	Ponding + Media Storage
Dry Swale	RR	Ponding + Media Storage
Wet Swale	ST	Ponding Only

To use the retrofit curves, take the ***runoff depth captured per impervious acre*** value and find where it intersects either the RR or ST curve. The y-axis value will be the removal rate. Nitrogen, phosphorus and sediment each have their own graphs. Retrofit curve equations are provided in Table 6 below for ease of use. Enter the ***runoff depth captured per impervious acre*** as the x value and the output, y, is the removal rate for the corresponding pollutant.

Table 6: Retrofit Curve Equations

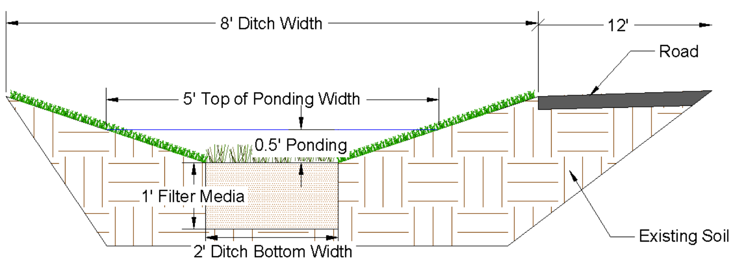
TN	RR	$y = 0.0308x^5 - 0.2562x^4 + 0.8634x^3 - 1.5285x^2 + 1.501x - 0.013$
	ST	$y = 0.0152x^5 - 0.131x^4 + 0.4581x^3 - 0.8418x^2 + 0.8536x - 0.0046$
TP	RR	$y = 0.0304x^5 - 0.2619x^4 + 0.9161x^3 - 1.6837x^2 + 1.7072x - 0.0091$
	ST	$y = 0.0239x^5 - 0.2058x^4 + 0.7198x^3 - 1.3229x^2 + 1.3414x - 0.0072$
TSS	RR	$y = 0.0326x^5 - 0.2806x^4 + 0.9816x^3 - 1.8039x^2 + 1.8292x - 0.0098$
	ST	$y = 0.0304x^5 - 0.2619x^4 + 0.9161x^3 - 1.6837x^2 + 1.7072x - 0.0091$

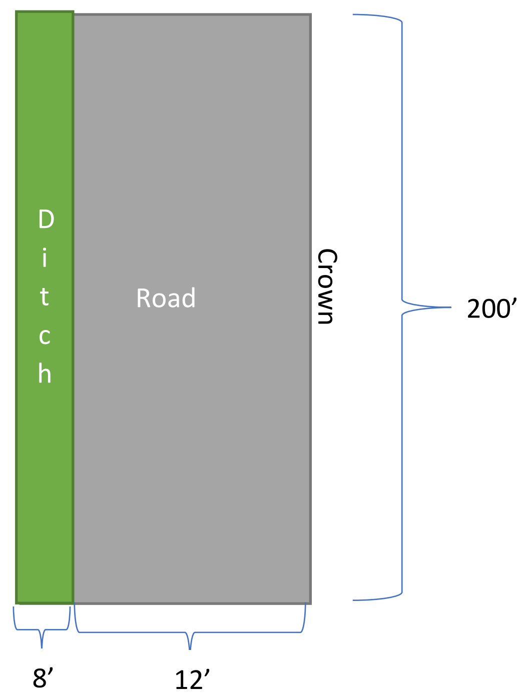
Once the removal rate is determined, the total load reduced can be calculated:

Removal rate (%) * Loading Rate (lbs./acre/yr.) * drainage area (acres) = Load Reduction

If there is more than one type of land use loading rate, a composite number should be used.

4.2. Credit Calculation Example





A dry swale is installed in a ditch that is 8-feet wide (total) and 200-feet long. The contributing drainage area is half of the road (from the road crown to the ditch edge), which is 12-ft by 200-ft.

The dry swale has 1 inch of media (porosity = 0.25) and the ponding depth is 0.5 inches.

Runoff Storage Volume (RS)= (1*2*200*0.25) + (2*0.5*200)

= 300 cubic feet[1]

Impervious Drainage Area = 200’ x 12’ = 2400 square feet

Runoff Depth Captured per Impervious Acre (inches) = 300 cubic feet * 12/ 2400 square feet = 1.5”

Using the equations in Table 6, the removal rate is:

Total Nitrogen Removal: 65%
Total Phosphorus Removal: 76%
Total TSS Removal: 82%

The loading rates can be found using the Chesapeake Assessment Scenario Tool (CAST) Model. For this example, the loading rates in Table 7 were used:

[1] The ponding calculation is simplified as a rectangular cross section. The more accurate ponding volume is the trapezoidal cross section x length of ditch, which would be (5+2)/2 * 200 = 450 cubic feet. Either value is acceptable.

TABLE 7: LOADING RATE FROM "FINAL MODEL DOCUMENTATION FOR THE MIDPOINT ASSESSMENT-5/11/2018" DOCUMENT

Land Use	N (lb./acre/yr.)	P (lb./acre/yr.)	TSS (ton/acre/yr.)
Developed Non-regulated Road	22.45	0.83	1.49

With the drainage area of 2,400 square feet (0.055 acres), the load reductions are shown in Table 8 below:

TABLE 8: LOAD REDUCTION CALCULATIONS

Nutrient	Removal Rate from RR Curves	Loading Rate from Table 6 (lbs./acre/yr.)	Load Reduction (lbs./yr.)
Nitrogen	65%	22.45	65%*22.45*0.055=0.8
Phosphorus	76%	0.83	76%*0.83*0.055= 0.04
TSS	82%	2980	82%*2980*0.055= 134

4.3. Performance Enhancing Devices (PEDs)

For retrofits that include performance enhancing devices, 10% is added to the retrofit curve removal rates for ST and RR practices for phosphorus and RR practices for nitrogen.

Using the previous dry swale example, Table 9 shows the load reductions if the filter media was amended with 10% biochar, the removal rates would be:

TABLE 9: LOAD REDUCTION CALCULATIONS WITH PEDS

Pollutant	No Biochar	With Biochar	Load Reduction (lbs./yr.)
Nitrogen	67%	67%+(10%*67%)=73.7%	0.91
Phosphorus	78%	78%+(10%*78%)=85.8%	0.04
TSS	84%	84%	138

Note that the 10% additional removal rate is applied both to phosphorus and nitrogen because a dry swale is an RR practice. If the practice was an ST practice (i.e. sand layer), it would only receive the extra 10% load reduction for phosphorus [6].

5. Maintenance and Visual Indicators

Routine maintenance checkups occur annually as part of regular maintenance visits and are used to immediately correct minor maintenance problems. The checkups are also used to provide quality control on maintenance activities and to determine whether the road crew needs to schedule a follow up visit to repair moderate maintenance problems.

TABLE 10: DEFINING NUMERIC TRIGGERS TO CLASSIFY DITCH RETROFIT MAINTENANCE CONDITIONS

INDICATOR		Pass	Minor	Moderate	Severe
1	*Inlet, side slope, bed, and outlet erosion*	*None*	*Some rill erosion*	Erosion *of 6" or less (or side slope 25% steeper than design)*	Erosion *of more than 6"(or side slope 50% steeper or more)*
		 Severe side slope erosion (almost vertical banks)			
2	*Inlet and outlet Obstruction*	*Free of sediment and debris*	*Less than 1" of sediment potentially blocking inlet/outlet*	*1-3" of sediment blocking the inlet/outlet*	*3" or more of blockage preventing most storms from getting into/out of ditch*
		 Severe inlet obstruction- 3" or more inches of blockage (riprap too high)			

<table>
<tr><th colspan="2">INDICATOR</th><th>Pass</th><th>Minor</th><th>Moderate</th><th>Severe</th></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Vegetation Cover</td><td>>90% cover</td><td>75-90% cover</td><td>50-75% cover</td><td>Less than 50% cover</td></tr>
<tr><td colspan="4">
Severe vegetation cover condition on side slopes</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Vegetative Maintenance</td><td>Well maintained, few weeds</td><td>Isolated areas need re-seeding or weeding</td><td>Needs major mowing and weed eradication</td><td>Needs major mowing or shrub/tree removal or replanting</td></tr>
<tr><td colspan="4">
Major vegetation maintenance- shrub removal</td></tr>
<tr><td>5</td><td>Check Dams</td><td>Good Condition</td><td>Minor sediment deposits, or down-gradient erosion</td><td>Some sediment deposits or down-gradient erosion</td><td>Problems are so severe that structure function is compromised</td></tr>
</table>

INDICATOR		Pass	Minor	Moderate	Severe
		 Minor check dam maintenance- small amount of leaves accumulating behind check dam			
6	*Sediment Deposition*	*None*	*A few isolated caking areas*	*Deposits up to 3" deep*	*Deposits more than 3" deep*
		 Minor sediment deposition  Major sediment deposition- Deposits up to 3”			

INDICATOR		Pass	Minor	Moderate	Severe
7	*Ponding Depth*	*Entire ponding depth matches design*	*10% difference from design*	*25% difference from design*	*>50% difference from design*
		 Minor ponding depth maintenance- less than 10% from design (need to know design ponding depth to determine rating)			

6. Verification Procedures

Performance verification inspections occur if the BMP is being used to achieve pollutant reductions needed to meet load allocations under a local and/or Bay-wide TMDL. This rapid inspection is done in conjunction with the local regulatory inspection to verify that the BMP still exists, is adequately maintained and is operating as designed. Verification inspections will typically occur once every other MS4 permit cycle (or about every 5 to 10 years). The inspection should include comparing the approved plans with the as-builts and field assessments.

Performance verification uses a subset of the list of visual indicators that assess the hydrologic function and pollutant removal capability of the ditch by answering three simple questions:

1. Does it still physically exist. i.e. can you find it and are the conditions and cover in the contributing drainage area still the same?
2. Is it still operating to treat and reduce runoff as it was originally designed?
3. Is the maintenance condition sufficient to still support its pollutant reduction functions?

Table 10 provides specific visual indicators that are used to answer the questions above. A “severe” maintenance problem detected for one or more of these indicators, means that the facility fails and will lose pollutant removal credits unless it is brought back into compliance (bioretention illustrated).

TABLE 10: PERFORMANCE VERIFICATION INDICATORS (BIORETENTION ILLUSTRATED)

Condition Type	Visual Indicators	Description
Hydrologic Condition	Severe inlet obstruction	Runoff is not able to get into ditch.
	Loss of surface ponding capacity	Runoff is not fully being treated.
	Severe erosion at outlet	Runoff is bypassing treatment.
	Standing water for an extended period of time (only dry swale or sand bottom)	Runoff is not fully being treated.
Maintenance Condition	Inadequate vegetative cover	Runoff is not fully being treated.
	Severe inlet, bed, or side slope erosion	Sediment delivery to filter bed.

References

[1] CSN, "Stormwater BMPs," [Online]. Available: https://chesapeakestormwater.net/training-library/stormwater-bmps/.

[2] VA DEQ, "Viriginia DEQ Stormwater Design Specification No. 12 Filtering Practices," 1 3 2011. [Online]. Available: https://www.vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/DCR%20BMP%20Spec%20No%2012_FILTERING%20PRACTICES_Final%20Draft_v1-8_03012011.pdf.

[3] VA DCR, "Virginia DCR Stormwater Design Specification No. 10 Dry Swales," 1 3 2011. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/02/DCR-BMP-Spec-No-10_DRY-SWALE_Final-Draft_v1-9_03012011.pdf.

[4] Virginia DCR, "Viriginia DCR Stormwater Design Specification No. 11 Wet Swale," 1 3 2011. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/02/DCR-BMP-Spec-No-11_WET-SWALE-_Final-Draft_v1-9_03012011.pdf.

[5] Viriginia DEQ, "Virginia DEQ Stormwater Design Specification No. 3 Grass Channels," 1 3 2011. [Online]. Available: https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/2017/11/BMP-Spec-No-3_GRASS-CHANNELS_v1-9_03012011.pdf.

[6] B. Seipp, T. Schueler and D. Hirschman, "Final Report- Performance Enhancing Devices for Stormwater Best Management Practices," 24 4 2017. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2017/05/APRIL-26-FINAL-PED-DOCUMENT.pdf.

[7] MDE, "Details from the 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control-Stone Check Dam," 2011. [Online]. Available: http://www.mde.state.md.us/programs/water/StormwaterManagementProgram/Pages/2011_ESC_details.aspx.

Roadside Ditch Management Stabilization

1. Description

Roadside ditch management (RDM) stabilization is important to maintain proper water conveyance in ditches. If ditches are not stable, it can jeopardize the structure of the ditch, impacting water conveyance and water quality. Restoring an eroding ditch that was an active source of sediment decreases the amount of sediment exported to downstream waters. The practice involves stabilizing the side slopes and ditch channel and rapidly establishing dense vegetative cover to prevent further ditch erosion. Often referred to as" stabilized drainage way", this practice is frequently specified in most state erosion and sediment control manuals, new roadway and ditch construction criteria, and forest road design manuals.

Practitioners generally use a trapezoidal or parabolic ditch geometry to decrease erosion potential. These shapes will make routine mowing easier and reduce the potential for erosion. After any cleaning or excavation, stabilization measures—such as seeding, erosion control matting, or riprap— are important. Depending on factors such as velocity, slope, or drainage area, different types of stabilization methods are used. Check dams or wattles can be used to slow water flow through a steep ditch, decreasing the erosive forces. If the practices are successfully performed on an existing unstable ditch, sediment load reduction credit can be calculated for the ditch.

2. Practice Feasibility

2.1. Stabilization Feasibility

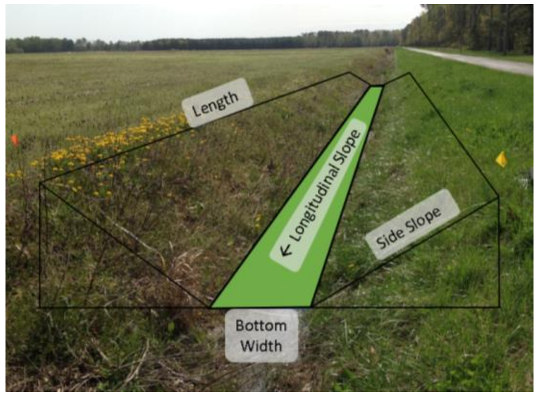
Depending on the site characteristics, stabilization methods may be applied. Key constraints include:

Existing Ditch Stability

- Only currently unstable ditches can receive credit after it is stabilized. Ditches are typically unstable due to existing ditch conditions or after ditch cleaning. Ditches that have high flow rates may need additional engineering outside the scope of this guidance. It is recommended that the velocity of flow from a 1-inch rainfall not exceed 3 feet per second for vegetated ditches. If the channel cannot handle the velocity of the incoming water, other types of lining can be used.

Available Space

- To ensure stability, a ditch should have a trapezoidal or parabolic bottom with side slopes 3:1 or flatter on the road side and side slopes 2:1 or flatter on the non-road side



Utilities

- For all roadside ditch projects, utilities may be a concern. If digging is necessary, call the local utility location services to mark the lines and consult local utility design guidance for the required horizontal and vertical clearance between utilities and the channels. Typically, utilities can cross grass channels if they are protected (e.g., double-casing) or are located below the channel invert.

3. Stabilization Methods

Stabilization generally requires little formal design elements to implement. Most of the methods have been established for erosion and sediment controls during construction. These methods can be used after ditch cleaning or on existing eroding ditches. One of the most cost-effective ways to implement these practices is to incorporate them into existing ditch maintenance, such as cleaning sediment from ditches (scraping), replacing culverts, or vegetation management. To receive credit for stabilizing a ditch, the ditch bed and side slopes must be fully vegetated with at least 95% cover or have other appropriate ditch lining to decrease soil erosion. Due to the variability of ditches, different methods may be needed to stabilize a ditch. Some common methods include:

- Minimum of 3:1 slope on the road side (2:1 on a non-road side)
- 2-foot wide ditch bottom elevation
- Inlet and outlet protection
- Trapezoidal or parabolic bottom
- Check dams

Stabilization should occur immediately after cleaning the ditch, including hydroseed or seed and mat the side slopes and bottom of the ditch. Inlet protection can be added to transitional areas, such as when concrete lining turn into a grass ditch or an agricultural pipe enters a ditch. Below are different ditch stabilization methods for different scenarios.

3.1. Ditch Stabilization Methods During Ditch Cleaning

When ditches need to be cleaned, activities should start on the upgrade section first and should not occur when substantial precipitation is predicted. If vegetation is removed during cleaning, it is important that there is sufficient time for the vegetation to regrow. The types of equipment used for cleaning and excavation also impact the stability of the ditch. If the equipment is not fit for the shape of the ditch, it could lead to over-ditching (i.e. removing more of the ditch than necessary). Over-ditching should be avoided, as this increases ditch instability.

FIGURE 1: EXAMPLE OF OVERDITCHING- STEEP SIDE SLOPES

Other ditch stabilization best management practices during cleaning include:

- Wait until soils are dry before maintenance to decrease erosion. If excavation is necessary, ensure that stabilization will be successful (either through vegetation or other controls)
- Avoid maintenance 24 hours before or after a rain event. Cleaning and vegetation establishment should be scheduled for late spring/early summer for best results.
- Use erosion and sediment control BMPs to prevent erosion during maintenance
- Remove excavated soil from site.
- Heavy equipment should be operated on the paved road to minimize disturbance
- Seed immediately after cleaning (hydroseed, hydromulch, seed and matting)
- Use a seed mix that is fit for the site (shade, wet, sun tolerant)
- Use temporary erosion and sediment controls to decrease sediment leaving site before vegetation is established (filter log, check dam, erosion control matting, etc.)
- Maintain 3:1 or flatter side slopes

3.2. Ditch Stabilization Methods Using Vegetation

The majority of ditch stabilization methods will be using vegetation. The first step is to seed the unstable ditch with a tailored native species mix. This will provide above-ground vegetation with increased filtration and erosion control, a variety of root structures for infiltration, erosion control, and sequestering nutrients, and resources for pollinator species. Follow seeding with lightly raking or rolling into soil. The best time for seeding is in late fall to early winter. This timing allows for seed to cold-stratify naturally in place and germinate when conditions are right for each species. Seeds can be sown with a light layer of hydromulch (300 lbs/acre), then covered with second layer of hydromulch and tackfier at (900 lbs/acre) The first layer of hydromulch acts as a marker to where seeds have been applied, while the second layer helps to hold seed and slope in place. Another method is to sow seeds by hand, then cover with hydromulch or erosion control blanket as site conditions dictate.

Control weed height during the first growing season once vegetation reaches 18’’–24” by trimming back to 6-inches to 8-inches tall 3–4 times as needed over the growing season. Control weed height during the second and third growing season by trimming back to 2” early spring, then maintaining at 12’’–15” tall by trimming 3–4 times as needed over the growing season. Time the mowing to fit with recommended mowing windows as indicated for established ditch mowing. Strategic height reduction prevents weeds from becoming dominant and allows enough sunlight to reach natives, which is especially critical first season. Timing is also important for protecting Monarch butterflies. Herbicides should be applied during the correct prescribed time at rates identified on the label.

3.3. Ditch Stabilization Methods Using Ditch Lining

If vegetation is not able to survive the velocity of the water entering the ditch, other types of lining may be required. The stability of a ditch is based on the permissible velocity and allowable tractive force (shear stress) on the ditch lining.

$$\tau_d = \gamma d s$$

Where:
τ_d= shear stress in channel at maximum depth (lb/ft^2)
γ = unit weight of water (62.4 lb/ft^3)
d = depth of flow in channel (ft)
s= channel slope (ft/ft)

Examples of ditch lining include:

Table 1: Lining Type

Lining Type	Lining	Permissible Velocity (ft/sec)	Permissible Shear Stress (lbs/sq. ft)	Source
Vegetation	Long native grasses	4-6	1.2-1.7	[1]
	Short native and bunch grass	3-4	0.7-0.95	[1]
Rolled Erosion Control Products	Straw with net	1-3	1.5-1.65	[2]
	1-in Gravel	2.5-5	.33	[1]
	12-in d50 riprap	10-13	5.1	[1]
Hard Surface	Gabions	1-19	10	[1]

Refer to your local erosion and sediment control manual for more information on channel lining.

3.4. Procedures for Acceptance

Project acceptance is a visual inspection that takes place about 12 months after ditch stabilization methods have been implemented to make sure it is still working and meeting its landscaping objectives. If so, the practice is accepted by the local roads department and should be reported to the proper stormwater management authority. Post stabilization acceptance should also include as-built drawings or sketches showing

- Start and end of the ditch stabilization
- Width of unstable ditch
- Type of seed mix used
- Other types of stabilization techniques

The local approval authority should keep detailed inspection reports describing any needed maintenance. If any issues are found, identify a timeframe for repair and conduct a subsequent inspection to ensure completion of repairs.

A written inspection report is part of every inspection and should include:

- The date of inspection;
- Name of inspector;
- The condition of:
    - Vegetation
    - Side slopes
    - Main bed
    - Inlet and outlet
    - Check dams and erosion and sediment control practices, if applicable
    - Any other item that could affect the proper function of the stormwater management system
- Description of needed maintenance

4. Sediment and Nutrient Crediting Protocol

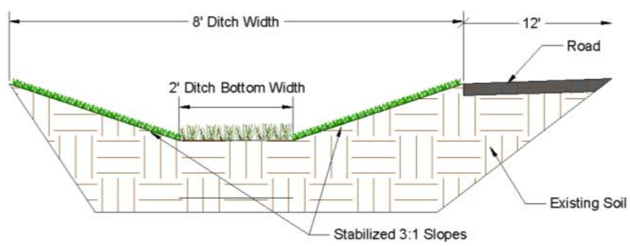
The Chesapeake Bay Program has sediment and nutrient credit protocols for various best management practices. Ditch stabilization is NOT a practice that has a protocol specifically for it; therefore, crediting methods from erosion and sediment control (ESC) are used [3]. The current credit for Level1 ESC is 74% for sediment only. Level 1 was chosen over Level 2 because it is unlikely that all the Level 2 ESC Practices will be performed with ditch stabilization. For ESC, nitrogen and phosphorus do not receive credit because there is evidence that the fertilizer used to establish vegetation could be a source of nutrients.

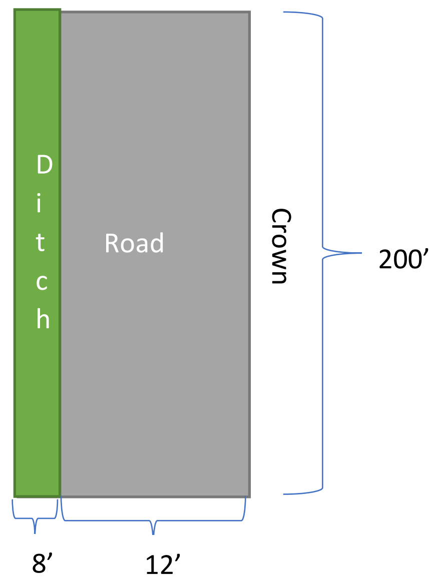
The following equation can be used to find the load reduction:

Removal rate (%) * Loading Rate (lb/acre/yr) * drainage area (acres) = Load Reduction (lb/yr)

The drainage area is the area of the stabilized ditch.

Credit Calculation Example





A ditch was stabilized after sediment was removed from the bottom. The ditch is 8' wide (total) and 200' long.

The loading rates can be found using the Chesapeake Assessment Scenario Tool (CAST) Model. For this example, the following loading rates are used:

TABLE 2: LOADING RATE FROM "FINAL MODEL DOCUMENTATION FOR THE MIDPOINT ASSESSMENT-

Land Use	N (lbs/acre/year)	P (lbs/acre/year)	TSS (tons/acre/year)
Developed Non-regulated Turf (ditch)	11.19	0.86	0.47

5/11/2018" DOCUMENT *[4]*

With the drainage area of 8'*200' = 1600 sf (0.037 acres), the load reduction can be calculated:

Pollutant	Removal Rate from Level 1 ESC	Loading Rate from Table 6 (lb./acre/yr.)	Load Reduction (lb./yr.)
TSS	74%	940	74%*940*.037= 25.6

5. Maintenance and Visual Indicators

Routine maintenance checkups occur annually as part of regular maintenance visits and are used to immediately correct minor maintenance problems. The checkups are also used to provide quality control on maintenance activities and to determine whether the road crew needs to schedule a follow up visit to repair moderate maintenance problems.

TABLE 3: DEFINING NUMERIC TRIGGERS TO CLASSIFY DITCH STABILIZATION MAINTENANCE CONDITIONS

Defining Numeric Triggers to Classify Ditch Stabilization Maintenance Condition					
#	**INDICATOR**	**Pass**	**Minor**	**Moderate**	**Severe**
1	Inlet and outlet erosion	None	Some erosion	Erosion of 6" or less	Erosion of more than 6"
2	Bed erosion	None	Some rill erosion	Gully erosion of 6" or less	Gully erosion of more than 6"
3	Side slope erosion	None	Some erosion	Erosion occurring to less than 25% of slope surface	Erosion occurring to more than 25% of slope surface
4	Vegetation Cover	>95% cover	75-95% cover	50-75% cover	Less than 50% cover
5	Vegetative Maintenance	Well maintained, few weeds	Isolated areas need re-seeding or weeding	Needs major vegetation control and weed eradication	Needs major vegetation control or shrub/tree removal or replanting

6. Verification Procedures

Inspection of this practice is needed to verify that the ditch has been stabilized and the ditch is not a source of sediment and therefore can continue to receive its pollutant reduction credits, in the context of either a local or Bay-wide TMDL. The inspection should occur a minimum of once a year and include comparing the as-builts and field assessments. Verification uses a subset of the list of visual indicators that assess the hydrologic function and pollutant removal capability of the RDM practice, by answering three simple questions:

1. Does it still physically exist. i.e. can you find it and are the conditions and cover in the contributing drainage area still the same?
2. Is it still operating to reduce erosion as it was originally designed?
3. Is the maintenance condition sufficient to still support its pollutant reduction functions?

Table 6 below indicates specific visual indicators that are used to answer the questions above. A "severe" maintenance problem detected for one or more of these indicators, means that the facility fails and will lose pollutant removal credits unless it is brought back into compliance.

TABLE 4: PERFORMANCE VERIFICATION INDICATORS

	Visual Indicator	**Task/Investigation**
Pass	Ditch is vegetated in all areas, including inlet, outlet, side slopes, and main bed.	None.
Minor	Small amounts of bare dirt, most of the water in the ditch runs through vegetation, no impact to stream network.	Make note and check on next maintenance inspection.

Moderate	Moderate amounts of bare dirt, scouring in main bed, signs of sediment moving downstream.	Re-establish vegetation, determine if additional stabilization techniques are required to prevent erosion.
Severe	Little or no vegetation in ditch, actively eroding sediment.	Re-establish vegetation, side slopes, and add additional stabilization techniques.

References

[1] Marin County, [Online]. Available: https://www.marincounty.org/~/media/files/departments/pw/mcstoppp/residents/fischenichstabilitythresholds.pdf.

[2] USDA, [Online]. Available: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17784.wba.

[3] Schueler T. et al, "Recommendations of the Expoert Panel to Define Removal Rates for Erosion and Sediment Control Practices," 14 4 2014. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/downloads/2014/04/WQGIT-APPROVED-ESC-EXPERT-PANEL-REPORT_LONG-04142014.pdf.

[4] "Chesapeake Bay Program Phase 6 Watershed Model- Section 2 - Average Loads Final Model Documentation for Midpoint Assessment," 11 5 2018. [Online]. Available: https://cast.chesapeakebay.net/FileBrowser/GetFile?fileName=P6ModelDocumentation%2F2%20Average%20Loads%202018%2005%2022.pdf.

Ditch Treatment

1. Description

Roadside ditch management (RDM) treatments are best management practices (BMP) that are used to treat and infiltrate runoff by improving the shape of the ditch or by changing the existing ditch soil with more permeable material or adding amendments to enhance pollutant removal (e.g., wood chips). Some RDM treatments have a corresponding traditional stormwater treatment, which have more stringent requirements that may be difficult to implement in ditches. RDM versions are designed specifically for ditches with less requirements than traditional BMPs (e.g., bioretention), and in turn, have different methods of crediting (see Section 4.1: Credit Calculations). Some of these practices are fairly new with limited published research. This guide summarizes the current information and potential methodology to credit the practice. The following is a list of treatment practices, defined by the Chesapeake Bay Roadside Ditch Management Team [1].

TABLE 1: DESCRIPTION OF RDM TREATMENT

Treatment	Description
Ditch Widening	Grass channel with trapezoidal or two-stage cross-section
Soil Amendment	Tilling a soil media amendment into existing soil to decrease compaction
Soil Replacement	Removing and replacing existing soil with soil media to promote greater pollutant removal

Soil media includes options like compost, woodchips, sand, or bioretention mix. Performance enhancing devices (PEDs) can be used as a soil amendment or used with a soil replacement (i.e. bioretention media with biochar). PEDs include incorporating biochar, water treatment residuals, and other media enhancements into the normal media specificaiton.

2. Treatment Feasibility, Site Selection, and Practice Selection

2.1. Treatment Feasibility

Depending on site characteristics, treatment practices may be applied. Key constraints of ditch treatment include:

Existing Ditch Stability

- The velocity of water from the drainage area should not exceed the permissible velocity for channels lined with vegetation cover. It is recommended that the velocity of flow from a 1-inch rainfall not exceed 3 feet per second. This is to prevent the ditch from eroding, which can cause the treatment to fail. If the existing ditch vegetation can currently handle most rainfall events, the ditch is likely stable. The contributing drainage area should be stable without any actively eroding soils or bare patches (have 95% groundcover/forest cover). In cases such as agricultural areas where this may not be possible, erosion and sediment controls or pretreatment must be used to minimize the amount of sediment entering the practice. If the existing ditch is eroding and it is suspected that the velocity of the incoming water is too high, either install inlet protection such as riprap, or pick an alternative site. Instructions to calculate velocity can be found in the VA DEQ Stormwater Design Specification No 3. Grass Channel, page 11 (Manning's Equation) [2].

Available Space

- Soil amendments and replacements are best suited for ditches where the main bed can be excavated without destabilizing the side slopes. If not possible (e.g., side slopes already unstable, ditch too narrow), additonal space will be required to reshape a narrow ditch with a trapezoidal or parabolic bottom, side slopes 3:1 or flatter on the road side, and side slopes 2:1 or flatter on non-road side.

Longitudinal Slope

- Ditch treatments are limited to longitudinal slopes of less than 4%. Slopes steeper than 4% create rapid runoff velocities that can cause erosion and do not allow enough contact time for infiltration or filtering. If slopes are steeper than 4%, ditch retrofits would be better practices to implement. Channels designed with longitudinal slopes of less than 1% should be monitored carefully during construction to ensure a continuous grade, in order to avoid flat areas with pockets of standing water [2]. Also ensure that the inlet and outlet grade will allow for positive flow in and out of the practice.

Utilities

- For all roadside ditch projects, utilities can be a significant constraint. Designers should call the local utility location services to mark the lines and consult local utility design guidance for the required horizontal and vertical clearance between utilities and the bottom of the practice. Typically, utilities can cross grass channels if they are specially protected (e.g., double-casing) or are located below the channel invert.

2.2.Site Selection

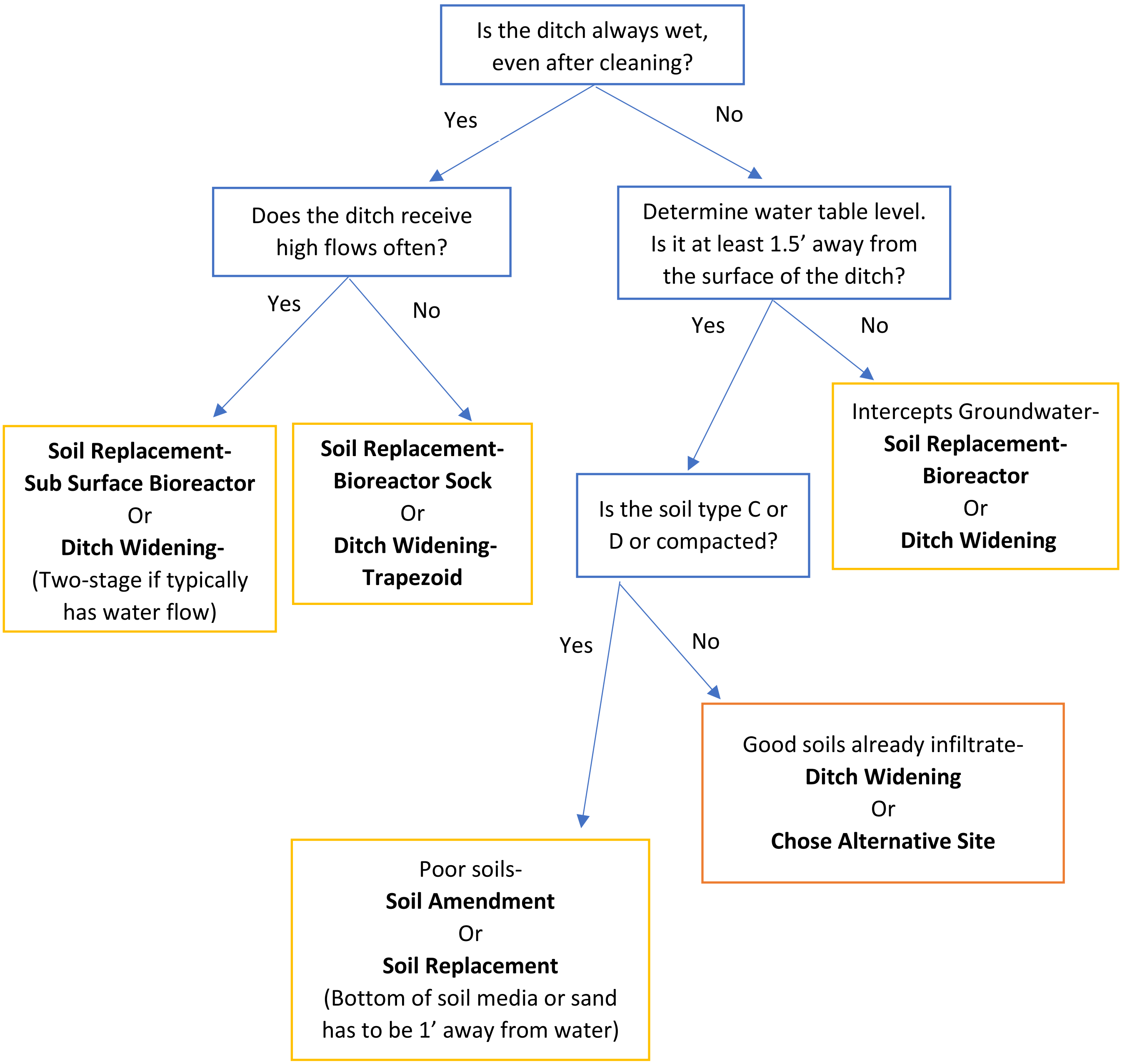
The follow are characteristics of an ideal potential treatment site:

- Limited/avoidable underground utilities
- Limited overhead utilities that can interfere with construction equipment and require utility pole setbacks
- Less than 2% longitudinal slope
- Wide right of way
- Ditch bottom and excavation depth accessible without entering ditch
- 3:1 side slopes or flatter
- The bottom of the ditch can be excavated without destabilizing the side slopes
- Stable upslope conditions
- Sites that currently require frequent maintenance may be a good candidate, if the issue can be resolved through one of these practices (if the cause of erosion is unknown or will not be remediated, it should not be chosen as a treatment site)
- Areas that receive low amounts of sediment

2.3.Treatment Practice Selection

Depending on site conditions and project goals, different treatment practices may be preferred. Figure 1 is a decision chart that may help in treatment selection.

FIGURE 1:DITCH TREATMENT DECISION CHART



Some other treatment practice parameters to consider are included in Table 2 below.

TABLE 2: PRACTICE PARAMETERS

Parameters	Ditch Widening	Soil Amendment	Soil Media Replacement
Easement required	Potentially	No	No
Cost	Medium	Low	Low-Medium
Can be built on high water table	Yes	No	No, except bioreactor
Maintenance Requirement	Low- Vegetation Control/Mowing	Low- Vegetation Control/Mowing	Medium- Mowing, minor erosion repairs
Water Quality Benefits	Low	Low	Medium
Can be implemented during routine maintenance	Potentially, depends on existing cross section	Yes	Potentially, depends on depth of media

Soils

- Soil amendments and soil replacements work best if they are improving infiltration of compacted soils or soils with low infiltration. If soils already have high infiltration rates, it may not significantly improve water quality treatment. If the existing ditch currently holds water for and extended amount of time, even after cleaning, it is likely due to a less permeable soil (C or D). Soil information can be found on the NRCS Web Soil Survey or infiltration and soil testing can be performed to determine the soil type (Appendix 8-A of Stormwater Design Specification No. 8 Infiltration) [3].

Depth to Water Table

- The location of bioreactors should be in a ditch where the bottom of the bioreactor intersects the water table. The bottom of soil amendments and replacements should be at least 1 foot away from the water table.
- If the depth to water table is uncertain, a small well can be dug to estimate the water level (Figure 3). Using an auger, dig a 4-foot-deep hole in the ditch. If the hole fills in with soil, a PVC pipe can be inserted to maintain the structure of the hole (Figure 3). After 24 hours, determine if there is water in the well and if the bottom of the practice will be at least 1 foot from the water surface.

FIGURE 2: AUGERED MONITORING HOLE

FIGURE 3: PVC MONITORING WELL

3. Design Parameters and Construction Sequence

Ditch treatment requires a few design elements to properly construct. Design details for construction of this type of project include a map showing start and end points of ditch retrofit, cross section of the retrofit (include side slope, depth and percentage of media, type of media, and width of ditch), longitudinal slope, and flow direction. Simple designs (aerial photos with hand drawn designs, notes, GIS, etc.) may be allowed as long as they provide the required information.

Table 3 contains a summary of design parameters for ditch treatment.

TABLE 3: DESIGN PARAMETER

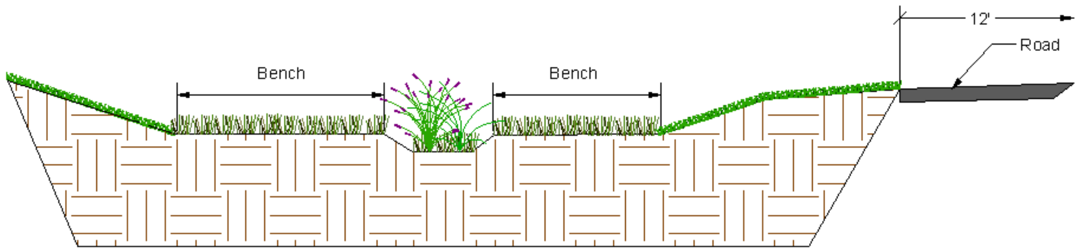
Parameter	Specification
All Treatment Practices	
Side Slopes (If reshaping ditch is necessary)	3:1 or flatter on road side, 2:1 or flatter on non-road side
Inlet and outlet protection	Provide riprap apron at all inlets and outlets
Longitudinal Slope	Less than 4%
Width of Bottom of Ditch	Minimum 2’ (except for two-stage ditch)
Erosion Control Matting	For higher velocity and steep slopes, erosion control matting may be necessary to protect the soils and seeds
Vegetation	Include vegetation that can withstand both wet and dry periods as well as relatively high velocity flows within the channel. Salt tolerant grass species and denser grasses are preferable. Grass species should have the following characteristics: A deep root system to resist scouring; a high stem density with well-branched top growth; water-tolerance; resistance to being flattened by runoff; and an ability to recover growth following inundation. Bermudagrass, Kentucky bluegrass, reed canarygrass, tall fescue, grass-legume mixture, red fescue See VA DCR Stormwater Design Specification No.3 Grass Channel [2] and No.10 Dry Swales [4] or local grass channel/dry swale design guidelines
Decompaction	After excavation, till the bottom of the ditch to a depth of 4-8 inches. Only till if soil is dry.

Performance Enhancing Devices	Incorporate 10% by volume of the PED. See the Performance Enhancing Devices Final Report for more information [5]
Bioreactor Only	
Woodchip Depth	Subsurface Bioreactor Only: Minimum of 2 feet and must intercept anaerobic conditions (low infiltration soils or high water table) Surface Bioreactor Only: Recommended 8"
Top Soil Depth	Subsurface Bioreactor Only: 8 inches
Woodchip Media	Woodchips free of fines, dirt, gravel, green material, ¼" to 1" [6]
Gravel Columns	Subsurface Bioreactor Only: #57 stone columns at beginning and end, and every 200'-250' in between. #57 stone columns are 2'x2'x depth of bioreactor. Riprap on top of column, flush with ditch bottom.
Soil Amendment Only	
Amendment Material	Compost: 2:1 Soil to compost ratio, 100% material must pass through half inch screen, organic material 35%-65%, carbon/nitrogen ratio less than 25:1, dry bulk density 40-50 lbs/cubic foot PEDs: 10% by weight Bioretention Media: 2:1 Soil to media ratio, 85-88% sand, 8-12% soil fines, 3-5% organic matter in form of leaf compost; USDA soil types loamy sand, sandy loam, or loam Sand: 2:1 Soil to sand ratio, Clean AASHTO-M-6 or ASTM-C-33 concrete sand
Soil Replacement Only	
Replacement Media	Media has to have a porosity of .25 or higher. Existing soils can be used if soil test is done to ensure that the existing soil is USDA soil types loamy sand, sandy loam, or loam and have a Mehlich III, range of 18 to 40 mg/kg P. Bioretention Media: 2:1 Soil to media ratio, 85-88% sand, 8-12% soil fines, 3-5% organic matter in form of leaf compost; USDA soil types loamy sand, sandy loam, or loam Sand: 2:1 Soil to sand ratio, Clean AASHTO-M-6 or ASTM-C-33 concrete sand PEDs: 10% by weight added to media
Shape Change- Two Stage Ditch Only	
All	See NRCS Code 582 for more information
Bench Width (2-stage only)	Each bench should be at least 3x width of ditch bottom[1]. The benches are not required to be the same width.

Table 4 illustrates cross section examples of the different types of treatment practices.

[1] https://agbmps.osu.edu/bmp/open-channeltwo-stage-ditch-nrcs-582 : This source says 3, but a bit wide for a roadside one https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17770.wba

TABLE 4: DESIGN EXAMPLES

<table>
<tr><th>Treatment</th><th>Design</th></tr>
<tr><td>Shape Change- Two stage ditch</td><td>


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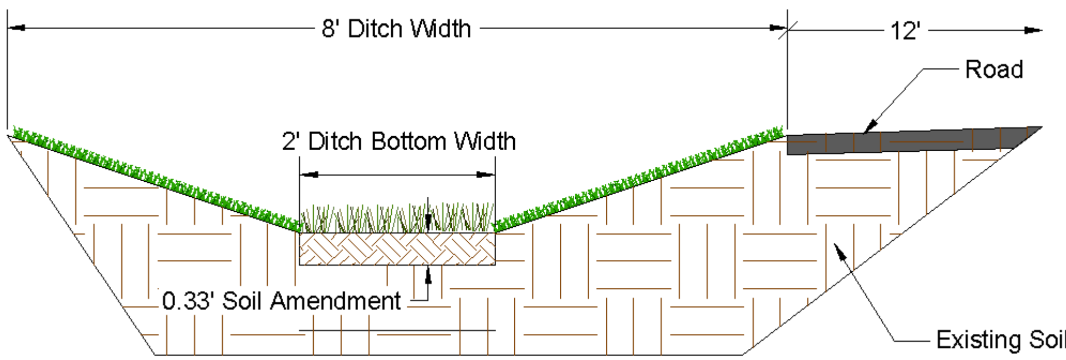

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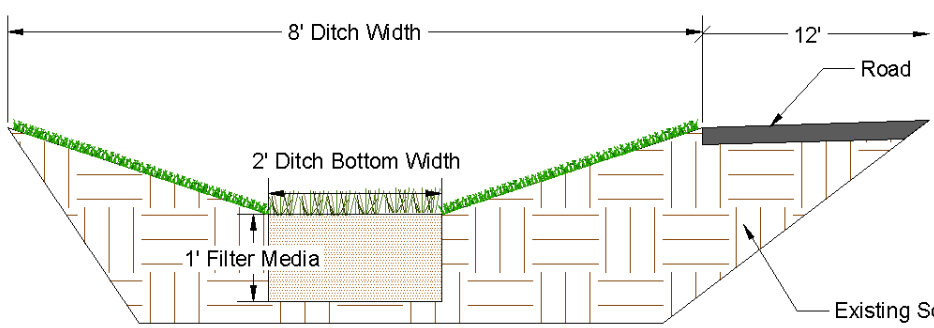
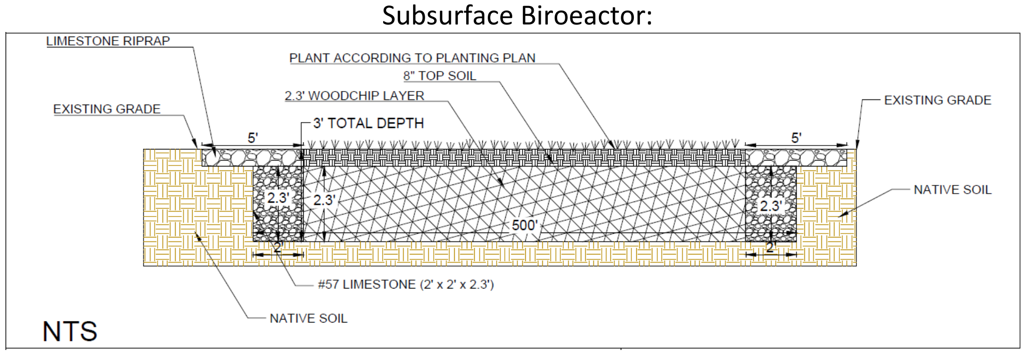
<tr><td>Soil Replacement</td><td>


</td></tr>
<tr><td>Soil Replacement - Bioreactors</td><td>
Subsurface Biroeactor:



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</table>

	Surface Bioreactor (bioreactor sock) [7] 

3.1.Construction Sequence and Inspection

Provide erosion and sediment controls according to the local requirements. Some examples include straw wattles or filter sock around the outlet of the treatment practice.

FIGURE 4: FILTER SOCK AT THE END OF A TREATMENT PRACTICE

The following is a typical construction sequence to install a treatment practice, although the steps may be modified to adapt to different site conditions.

1. Installation should only begin after there is no active erosion upstream. Additional E&S controls may be needed during construction, particularly to divert stormwater from construction until the filter bed and side slopes are fully stabilized.
2. (Optional) If the side slopes and width of the ditch do not meet the parameters described in this guidance, it is best to reshape the ditch first and allow it to stabilize before excavating for media replacement. Flatter side slopes and a wider bottom are more stable and less prone to disturbance from equipment during excavation. Unstable side slopes can lead to clogging of the soil media, decreasing the lifespan of the retrofit.
3. Excavators or backhoes should work from the sides to excavate the treatment area to the appropriate design depth and dimensions. Excavating equipment should have buckets with adequate reach so they do not have to sit inside the footprint of the treatment area. If the full length of the treatment cannot be finished within one day, work in sections (e.g., 50-feet in length) that can be completed with seeding and/or stabilization matting at the end of the day.
4. (Soil amendment, soil replacement) The bottom of the treatment should be ripped, roto-tilled or otherwise scarified to depth of at least 6 inches to promote greater infiltration.

5. (Soil replacement only) Obtain soil media that meets the specifications and apply in 12-inch lifts until the desired top elevation is achieved.
6. (Optional) To incorporate PEDs: Incorporate amendments according to the PED Section in the soil layer.
7. (Optional) Add 8 inches of top soil on top amended or replaced meida to reach the desired top elevation. This top soil layer is to allow for plants to grow in the ditch.
8. Prepare planting bed for specified vegetation, install erosion control matting, and spread seed (Figure 5)
9. Inspect the ditch after a significant rain event to ensure that the practice is stable. Also inspect the ditch to make sure the vegetation is established and survives during the first growing season following construction.

FIGURE 5: INLET PROTECTION AND EROSION CONTROL MATTING (CURLEX®)

Subsurface Bioreactor

Before installing the woodchips, excavate the existing ditch to install the gravel columns every 250 feet, with at least one at the beginning and one at the end. Fill in trench with #57 stone and a layer of riprap on top. Cover column with filter fabric until ditch is stabilized.

Surface Bioreactor (Bioreactor Sock)

The benefit of surface bioreactors is the simplicity in design and installation. To install, scrape down two inches into the ditch bottom to clear vegetation, level substrate, and create a small depression that captures water. Lay the bioreactor sock in the depression (polypropylene mesh filled with woodchips, closed off by zip ties) and insert rebar through the sock into the ground to secure.

3.2.Construction Inspection

Inspections during and immediately after construction are needed to ensure that the treatment practice is built in accordance with the standard designs and parameters. Use a detailed inspection checklist that requires sign-offs by qualified individuals at critical stages of construction to ensure that the contractor's or roadcrew's interpretation of the plan is consistent with standard practice requirements. A construction inspection checklist should include:

- Check the soil media to confirm that it meets specifications and is installed to the correct depth.
- Check elevations such as inverts for the inflow and outflow points, elevation of the various layers.
- Verify the proper coverage and depth vegetation or soil matting has been achieved following construction, both on the filter bed and the side-slopes.
- Check that outfall protection/energy dissipation measures at concentrated inflow and outflow points are stable.

The project should be inspected after the first major rain event. The post-storm inspection should focus on whether the desired flow is occurring and the project objectives are still being met. Also, inspectors should check that the treatment drains completely within a 72-hour drawdown period. Minor adjustments are normally needed as a result of this post-storm inspection (e.g. spot reseeding, gully repair, added armoring at inlets or outfalls, and check dam realignment).

Procedures for Acceptance

Project acceptance is a visual inspection that takes place after the first major rain event after the construction phase is over to make sure it is working and meeting its project objectives. If so, the practice is accepted by the local stormwater management authority. Post construction acceptance should also include an as-built drawing or sketch showing:

- Start and end of the ditch treatment project
- Type of treatment
- Depth and type of replaced media
- Dimensions of new ditch

A written inspection report is part of every inspection and should include:

- The date of inspection;
- Name of inspector;
- The condition of:
  - Side slopes
  - Main bed
  - Inlet and outlets
  - Soil permeability
  - Vegetation
  - Any other item that could affect the proper function of the stormwater management system
- Description of needed maintenance

4. Sediment and Nutrient Crediting Protocol and Design Example

4.1. Credit Calculations

The Chesapeake Bay Program has sediment and nutrient credit protocols for various best management practices. None of the ditch treatment practices have a protocol specifically for it; therefore, crediting methods from similar practices are used. It is assume all the treatment practices are stormwater treatment (ST).

To determine the runoff volume treated by a retrofit practice, the amount of water held in the practice and the impervious area treated is needed. The standard equation used to determine the amount of runoff volume in inches treated at the site is:

$$\text{Runoff Depth Captured per Impervious Acre (inches)} = \frac{RS(12)}{IA}$$

Where:

RS = Runoff Storage Volume (cubic feet)
IA = Impervious Area (square feet)

For soil amendments and replacements, the runoff storage volume is the water stored in the soil media layer.

RS = Depth of filter media x length of ditch x width of ditch x 0.25 (porosity of filter media)

$RS_{shape\ change}$ *= 2"/12 x length of ditch x width of ditch*

For shape change treatment, the runoff storage volume is the thin layer of water being trapped between the vegetation. For crediting, it is estimated to be 2 inches of ponding.

Table 5 summarizes how to calculate the runoff storage volume for the different treatment practices. Soil amendment has a maximum credit depth of 8 inches, as this is typically the maximum depth to easily amend. If deeper treatment is needed, soil replacement should be considered.

Table 5: Treatment and Crediting Reference

Treatment	**Runoff Storage Volume**
Shape Change	Ponding= 2" Maximum
Soil Amendment	Soil Amendment Depth = 8" Maximum
Soil Replacement	Soil Replacement Depth

To use the retrofit curves, take the ***runoff depth captured per impervious acre*** value and find where it intersects either the ST curve. The y-axis value will be the removal rate. Nitrogen, phosphorus and sediment each have their own graphs. Retrofit curve equations are provided in Table 6 for ease of use. Enter the ***runoff depth captured per impervious acre*** as the x value and the output, y, is the removal rate for the corresponding pollutant.

Table 6: Retrofit Curve Equations

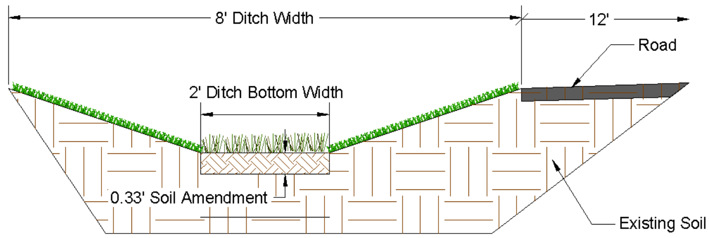
TN	$y = 0.0152x^5 - 0.131x^4 + 0.4581x^3 - 0.8418x^2 + 0.8536x - 0.0046$
TP	$y = 0.0239x^5 - 0.2058x^4 + 0.7198x^3 - 1.3229x^2 + 1.3414x - 0.0072$
TSS	$y = 0.0304x^5 - 0.2619x^4 + 0.9161x^3 - 1.6837x^2 + 1.7072x - 0.0091$

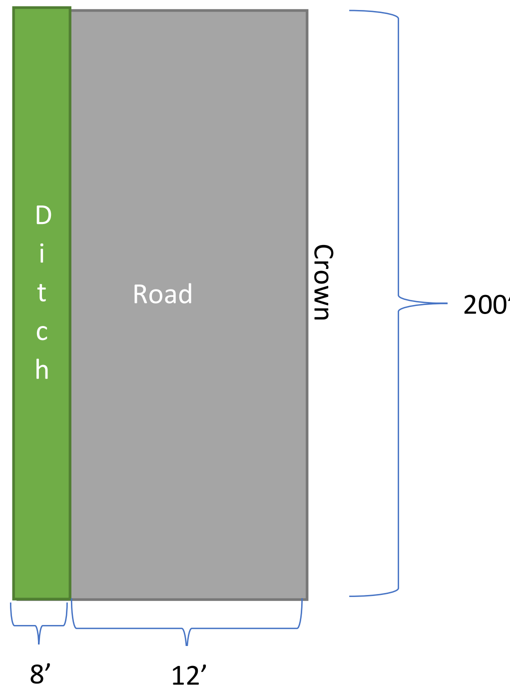
Once the removal rate is found, the total load reduced can be calculated:

Removal rate (%) * Loading Rate (lb/acre/yr) * drainage area (acres) = Load Reduction

If there is more than one type of loading rate land use, a composite number should be used.

4.2. Credit Calculation Example





A ditch receives a soil amendment with compost treatment and is mixed to a depth of 4 inches (0.33’). The ditch is 8’ wide (total) and 200’ long. The contributing drainage area is the road, which is 12’ by 200’. The DA is from the middle of the road (the crown) to the edge of the ditch.

Runoff Storage Volume (RS)= (0.33*2*200*0.25)

= 33 cubic feet

Impervious Drainage Area = 200’ x 12’ = 2400 square feet

Runoff Depth Captured per Impervious Acre (inches) = 33 cubic feet * 12/ 2400 square feet = 0.17”

Using the equations in Table , the removal rate is:

Total Nitrogen Removal: 11.5%
Total Phosphorus Removal: 18.1%
Total TSS Removal: 23.1%

The loading rates can be found using the Chesapeake Assessment Scenario Tool (CAST) Model. For this example, the loading rates from Table 7 were used:

TABLE 7: LOADING RATE FROM “FINAL MODEL DOCUMENTATION FOR THE MIDPOINT ASSESSMENT- 5/11/2018” DOCUMENT

Land Use	N (lbs/acre/year)	P (lbs/acre/year)	TSS (tons/acre/year)
Developed Non-regulated Road	22.45	0.83	1.49

With the drainage area of 2400 sf (0.055 acres), the load reduction can be calculated as shown in Table 8.

TABLE 8: LOAD REDUCTION CALCULATIONS

Pollutant	Removal Rate from ST Curves	Loading Rate from Table 6 (lbs/acre/year)	Load Reduction (lbs/year)
Nitrogen	11.5%	22.45	11.5%*22.45*0.055=0.14
Phosphorus	18.1%	0.83	18.1%*.83*0.055= 0.008
TSS	23.1%	2980	23.1%*2980*0.055= 37.9

4.3. Performance Enhancing Devices

Performance enhancing devices (PEDs) can be used as a soil amendment or used with a soil replacement (i.e. bioretention media with biochar). For treatments that include PEDs, 10% is added to the retrofit curve removal rates for phosphorus.

Using the previous soil amendment example, if the soil was amended with 10% biochar, the removal rates would be calculated as shown in Table 9.

TABLE 9: LOAD REDUCTION CALCULATIONS WITH PEDS

Nutrient	Compost Only, No Biochar	With Biochar	Load Reduction (lbs/year)
Nitrogen	11.5%	11.5%	0.14
Phosphorus	18.1%	18.1%+(10%*18.1%)=19.9%	0.009
TSS	23.1%	23.1%	37.9

5. Maintenance and Visual Indicators

Routine maintenance checkups occur annually as part of regular maintenance visits and are used to immediately correct minor maintenance problems. The checkups are also used to provide quality control on maintenance activities, determine whether the road crew needs to schedule a follow up visit to repair moderate maintenance problems.

INDICATOR		Pass	Minor	Moderate	Severe
1	*Inlet and outlet erosion*	*None*	*Some rill erosion*	Erosion *of 6" or less*	Erosion *of more than 6"*
		 Severe Erosion at Inlet			
2	*Side Slope and bed erosion*	*None*	*Some rill erosion*	Erosion *of 6" or less (or side slope 25% steeper than design)*	Erosion *of more than 6"(or side slope 50% steeper or more)*
		 Severe side slope erosion			

INDICATOR		Pass	Minor	Moderate	Severe
3	*Vegetation Cover*	*>90% cover*	*75-90% cover*	*50-75% cover*	*Less than 50% cover*
		 Severe vegetation cover condition on side slopes			
4	*Vegetative Maintenance*	*Well maintained, few weeds*	*Isolated areas need re-seeding or weeding*	*Needs major mowing and weed eradication*	*Needs major mowing or shrub/tree removal or replanting*
		 Major vegetation maintenance- shrub removal			

INDICATOR		Pass	Minor	Moderate	Severe
5	*Sediment Deposition*	*None*	*A few isolated caking areas*	*Deposits up to 3" deep*	*Deposits more than 3" deep*
		 Minor sediment deposition  Major sediment deposition- Deposits up to 3”			

6. Verification Procedures

Inspection of this practice is needed to verify that the ditch treatment has been implemented and runoff water is being treated and therefore can continue to earn its pollutant reduction credits, in the context of either a local or Bay-wide TMDL. The inspection should occur a minimum of once every 3 years and include comparing the as-builts and field assessments. Verification uses a subset of the list of visual indicators that assess the hydrologic function and pollutant removal capability of the RDM practice, by answering three simple questions:

1. Does it still physically exist. i.e. can you find it and are the conditions and cover in the contributing drainage area still the same?
2. Is it still operating to treat and reduce runoff as it was originally designed?
3. Is the maintenance condition sufficient to still support its pollutant reduction functions?

Table 10 provides specific visual indicators that should be used to answer the questions above. A “severe” maintenance problem detected for one or more of these indicators, means that the facility fails and will lose pollutant removal credits unless it is brought back into compliance.

Table 10: Performance Verification Indicators

Condition Type	Visual Indicators	Description
Hydrologic Condition	Severe inlet obstruction	Runoff is not able to get into ditch
	Severe erosion at outlet	Runoff is bypassing treatment
	Standing water for an extended period of time	Runoff is not fully being treated
Maintenance Condition	Inadequate vegetative cover	Runoff is not fully being treated
	Severe inlet or side slope erosion	Sediment delivery to filter bed

References

[1] Chesapeake Bay Roadside Ditch Management Team, "Draft Technical Memo," 2017.

[2] Viriginia DEQ, "Virginia DEQ Stormwater Design Specification No. 3 Grass Channels," 1 3 2011. [Online]. Available: https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/2017/11/BMP-Spec-No-3_GRASS-CHANNELS_v1-9_03012011.pdf.

[3] VA DEQ, "VA DEQ Stormwater Design Specification NO. 8 Infiltration," 1 1 2013. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/downloads/2014/04/VA_BMP_Spec_No_8_INFILTRATION_FINAL_Draft_v2-0_01012013.pdf.

[4] VA DEQ , "VA DEQ Stormwater Design Specification No. 10 Dry Swale," 1 3 2011. [Online]. Available: https://www.vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/DCR%20BMP%20Spec%20No%2010_DRY%20SWALE_Final%20Draft_v1-9_03012011.pdf.

[5] D. Hirschman, B. Seipp and T. Schueler, "Final Report- Performance Enhancing Devices for Stormwater Best Management Practices," 24 4 2017. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2017/05/APRIL-26-FINAL-PED-DOCUMENT.pdf.

[6] L. Christianson, "Woodchip Bioreactors for Nitrate in Agricultural Drainage," *Agriculture and Environment Extension Publications* , 2011.

[7] R.L. Schneider E. Chase S. Dunn W. Pluer N. Baker and S. Bloser, "Using Scaled-down Woodchip Bioreactors in Roadside Ditches to Filter out Dissolved Nitrate (Draft)," This work was funded through the U.S.D.A.'s Conservation Innovation Program, support from Bradford County Soil and Water Conservation District, USDA Hatch Grant to Cornell. Cornell University, Ithaca, NY; PA Center for Dirt and Gravel Roads, PA State Univ, 2018.

[8] D. Hirshman and B. Seipp. [Online]. Available: http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2017/05/APRIL-26-FINAL-PED-DOCUMENT.pdf.