APPENDIX FE

DESIGN, OPERATION, AND MAINTENANCE RECOMMENDATIONS FOR IRON-ENHANCED BMPS TO TREAT DISSOLVED PHOSPHORUS IN STORMWATER

DESIGN CONSIDERATIONS FOR IRON-ENHANCED SAND FILTERS (IESF)[1]

Based on research projects and field installations of IESFs in Minnesota, staff at University of Minnesota have made the following recommendations for the design and installation of IESFs:

- Clean, washed sand meeting ASTM C33 specifications shall be used for the IESF trench media.
- The iron-enhanced sand portion of the media shall be approximately 18 inches thick. While shallower depth filters are acceptable, they may not perform as well or last as long.
- The iron-enhanced sand media shall contain 5 to 8 percent iron shavings by weight mixed thoroughly throughout the entire media volume to make a mixture that is homogeneous vertically and horizontally. The iron shavings should have a similar size profile as the sand.
- The iron used for the IESF should be high purity and consist of at least 90 percent elemental iron. In addition, it should contain little to no toxic impurities, such as copper, cadmium, and lead. The iron should be reactive with phosphate. Iron, reactivity, and impurity content should be verified independently of the supplier to ensure purity and prevent leaching of contaminants into the filtered runoff. This should be done through laboratory analysis.
- The iron-enhanced sand media shall be covered by 2 to 5 inches of ASTM C33 sand. Non-routine maintenance shall include periodically removing 1 to 1.5 inches from the top of this layer, and replacing it with clean, washed ASTM C33 sand.
- The IESF shall have a layer of clean, washed ASTM C33 sand of at least 6 inches thick below the iron-enhanced sand media.
- The IESF media should be surrounded by an impermeable layer on all sides except the top.

---

[1] *Adapted from A.J. Erickson, P.T. Weiss, and J.S. Gulliver,* Monitoring an Iron-Enhanced Sand Filter Trench for the Capture of Phosphorus in from Stormwater Runoff, *University of Minnesota Saint Anthony Falls Laboratory Project Report No. 575, September 2015; A.J. Erickson,* Capturing Stormwater Nitrate and Phosphate with Sorptive Filter Media, *Ph.D. Dissertation, University of Minnesota, Minneapolis, Minnesota, July 2017; A.J. Erickson,* Performance Enhancing Devices for Stormwater BMPs—Iron Amendments, *Report to the Center for Watershed Protection, December 2018.*

- The design should limit the amount of organic material deposited on the IESF surface media.

- Stormwater should enter the IESF evenly and be distributed across the entire top surface to ensure widespread treatment and minimize the occurrence of small areas treating an unequal portion of the stormwater. Earthen berms and grading have been found to be imprecise, resulting in low areas that receive considerably more stormwater than the entire filter surface. A level spreader or manifold distribution system may be appropriate or necessary.

- The IESF should be sized so that it allows rainfall to drain quickly in order to allow a drying time of one to two days to occur prior to the next rainfall event.

- For maintenance considerations, a filtration rate of 10 centimeters per hour vertically down and through the IESF media can be used to estimate the IESF surface area needed to treat a known or estimated peak flow rate. The smaller the IESF surface area, the greater the frequency of required maintenance.

- For lifetime capacity considerations, a sorption capacity of 5 mg phosphorus per gram iron can be used to estimate the amount of iron needed to treat a known or estimated phosphorus load.

- The IESF must be allowed to drain. The outlet of the underdrain system below the IESF must be placed above the high-water elevation of the downstream conveyance system and/or waterbody to prevent inundation of the IESF.

- Underdrain size should be considered during design. All sites in the City of Prior Lake, Minnesota were designed and installed with 4-inch perforated underdrains. The flow rate for some of these sites appears to be limited by this pipe size, which results in longer drawdown times and the potential for anaerobic conditions to develop in the filter. Larger underdrain pipes could be used to avoid limiting the flow rate with the underdrain. If the flow rate is found to be too large such that performance is limited by contact time, a cap with an orifice smaller than the pipe could be added to the underdrain outlet.

- The design should provide access for maintenance of the filter surface, underdrains, and media. Equipment such as a bobcat, flatbed truck, or excavator may need access.

- The design should include clean-outs connected to the underdrain system that are accessible from the surface. They should use 45° bends rather than elbows to allow inspection using small cameras.

- The design should exclude vegetation from the IESF media. In filter systems, micropores formed by vegetation roots can short-circuit the media.

Design Considerations Specific to IESF Trenches Adjacent to Wet Ponds

- In order to prevent duckweed, algae, and other organics or solids from accumulating on the surface of the filter, the filter should be surrounded by an impermeable barrier or surface skimmer, or the design should incorporate a separate pretreatment cell containing only sand that discharges to the IESF trench. The top elevation of the barrier should be higher than the water level control weir crest in the catch basin so that flow will not overtop the barrier surrounding the filter during the design event. In order to allow pond water to flow onto the filter, a pipe should run from the pond, at a depth below the frost line, through the impermeable barrier to the surface of the IESF trench. A flow spreader or manifold system may be necessary to evenly distribute the water over the surface of the entire filter. The barrier, pipe, and elevations should be designed such that the treatment volume and routing are as intended, and structural integrity is protected.

Design Considerations Specific to IESF Ditch Check Dams[2]

Based on research projects and field installations of IESFs in Minnesota, staff at the University of Minnesota have made the following recommendations for the design of iron-enhanced ditch check dams.

- Sand coarser than ASTM C33 can be used.

- The IESF shall be rectangular in cross-section for ease of construction.

- The filter berm depth shall be 12 to 17 inches in the direction of flow.

[2] *Adapted from P. Natarajan and J.S. Gulliver,* Assessing Iron-Enhanced Swales for Pollution Prevention, *University of Minnesota Saint Anthony Falls Laboratory Project Report No. 576, September 2015; P. Natarajan, J.S. Gulliver, and P.T. Weiss,* Iron-Enhanced Swale Ditch-Checks for Phosphorus Retention: Final Report, *Minnesota Department of Transportation, July 2019.*

- The filter berm length perpendicular to the direction of flow shall extend across the ditch width. The filter shall be sufficiently long such that runoff does not flow around the filter.

- The filter berm height shall be at least 18 inches; however, the sizing shall be determined based on the site conditions.

- The filter media shall be filled within a woven geotextile enclosure in the berm. It is recommended that the filter media be installed within a single geotextile enclosure as one filter log in the ditch check berm. The single filter log-design is recommended since it uses less geotextile material and reduces the overall construction time and effort. This design also reduces the possibility of water seeping between multiple filter logs.

    - If a single filter log-design is not feasible for the site conditions, multiple filter logs shall be stacked to build the IESF berm. Two rows of filter logs shall be placed in a staggered pattern to allow for good overlap between the logs. A geotextile sheet covering all sides of the filter logs should be installed. Gaps between the outer geotextile cover and the filter logs and gaps between individual filter logs should be filled with loose IESF media.

- The IESF berm must be trenched into the ground to prevent flow-bypass underneath the filter media. The filter log should be installed at least 6 inches below the normal ditch bottom. If multiple filter logs are used, the bottommost filter logs shall be trenched into the ground.

- An impermeable liner shall be placed directly underneath the filter log.

- A frame shall be constructed around the filter berm to hold the filter log(s) in place. The frame will ease installation of the IESF media and prevent dislocation of the media during high-flow conditions and other disturbances.

- The edge of the filter log shall be properly sealed against the ditch side. This can be done by trenching the filter log to the ditch side. Alternatively, any gap present between the filter log and ditch side shall be filled with loose filter media and the sides backfilled with topsoil or sealed with clay. This is important to ensure that water does not bypass the filter log.

- Class I riprap shall be placed at a 1:10 slope on both the upstream and downstream sides of the filter log to form the check dam.

- If exposed aggregate is undesirable, the riprap check dam shall be covered with topsoil and sod. The topsoil shall consist of 60 percent C33 sand, 30 percent topsoil, and 10 percent peat moss, by volume. Compost shall not be used in the topsoil mixture as it can leach additional phosphorus into the water and reduce the overall effectiveness of the iron-enhanced ditch check dam. Covering with topsoil and sod may be undesirable, as this may leach phosphorus and reduce performance.

- If necessary, a porous drain tile shall be added on the downstream side of the ditch check dam to allow proper drainage of the water.

OPERATION AND MAINTENANCE

The following recommendations regarding operation and maintenance will enhance performance and increase the life of an IESF:

- The IESF should be inspected quarterly to annually, with inspections occurring more often when more water is filtered. The IESF should be inspected after any events with recurrence intervals of two or more years.

- Routine maintenance should be performed about four times a year.

- Routine maintenance involves removing trash and debris from the filter, removing vegetation growing on the surface of the filter, removing obstructions to underdrains and outlet structures, and raking the filter to break up the surface.

- Non-routine maintenance occurs as required by a change in performance. This may need to be done about once a year. This can often be detected through a reduction in the rate of infiltration into the filter.

- Non-routine maintenance may include:

- Removing the top 1 to 1.5 inches of sand and accumulated solids and organics that have been filtered and replacing with clean, washed sand.

- Breaking up any clumps of iron shaving conglomerates that have formed.

- Performing testing to determine the filtration rate.

- Removing retained sediment every five to ten years in stable watersheds and annually in unstable watersheds.

- Mixing the filter media from top to bottom in IESFs installed in ditch check dams. This should be done every other year.

- Replacement of filter media when its phosphorus sorption capacity is exhausted. This can be estimated by measuring the magnetic susceptibility of the medium.

- The filter must be allowed to dry between rainfall/runoff events. This will prevent the development of anaerobic conditions and will allow more phosphate adsorption sites to develop on the iron shavings. Iron clumping appears to be more prevalent when the filter remains submerged for more than two days.

#254103– CAPR-330 (Oak Creek Watershed) Appendix Fe
300-4010
JEB/LKH/mid
06/16/20, 6/8/21