

Stormwater Retrofitting Techniques for Water Quality Benefits

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Abstract

With the Advent of NPDES Stormwater Permits and increased environmental awareness, many municipalities are confronted with the daunting task of retrofitting existing developed areas which provide little or no water quality treatment for the stormwater runoff. For most areas of the Country, cleaning stormwater is a new concept. This paper will cover traditional as well as new techniques that can be used by engineers to design retrofit projects.

Background

Many studies have been performed documenting the pollutant loadings in stormwater runoff. The sources of this pollution are many including greases, oils and heavy metals from cars, yard clippings, fertilizers, pesticides, and pet wastes from yards, dirt and trash from streets and parking lots, dirt and erosion from construction sites and improper storage and use of toxic material at industrial sites.

Methods

Florida has instituted stormwater treatment methods such as retention ponds for approximately the last 15 years. These regulations apply to new development where ample land is available for treatment methods such as retention ponds. These ponds are designed to provide 80%-90% pollutant removal.

The first step in pond design is an analysis of rainfall records for the area. In Florida we get about 50 inches of rainfall a year and 90% of the rainfall events are 1" or less. In other words, we get a great number of small storms which tend to occur almost daily during the summer. Therefore the standard for treatment is to create pond volumes which will hold the runoff from 1" of rainfall, although many municipalities require the equivalent of 1" of runoff over the drainage area as a higher standard. Systems discharging to protected waters such as shellfish areas or drinking water supplies are required to retain 1.5 inches of runoff or more. A similar analysis should be performed for each locale in question.

Depending on soil and groundwater conditions, various designs can be used. The most efficient design is an offline dry retention pond. The pond diverts the first 1" or more of runoff containing the majority of the pollutants into a dry retention pond. After the pond fills, the remaining rainfall bypasses the pond and flows to a second detention pond if flood control is desired. The water in the dry pond percolates into the ground allowing the pollutants to filter out.

Retention ponds trap a certain volume of water, which does not leave the site. These ponds are generally used for stormwater treatment. Detention ponds temporarily store runoff and then slowly bleed that volume down via an orifice or weir over several days. Detention ponds can be used for stormwater treatment, for flood attenuation or both.

If the groundwater is low but the soils do not percolate well, an offline dry detention pond may be used which slowly bleeds the detention volume down over several days allowing pollutants to settle out. If the ground water is not at least 2 feet below the pond there may end up being cattail problems since these ponds stay wet so long due to the time required for the groundwater mounding to dissipate through lateral percolation.

If the grades do not allow an offline system, an online dry pond can be used where a designated volume will be stored below a weir and excess water will flow over the weir at a designated rate. Online ponds are not as efficient as offline ponds since pollutants can be intermingled with excess flows leaving the pond.

Often a dry pond is not feasible due to soil or groundwater conditions. In those cases, wet ponds are used which have a permanent pool volume. These ponds can be offline or online. They are designed to detain a certain volume and slowly bleed that volume down via an orifice or weir over several days. This allows the suspended pollutants to settle out and biological reaction to remove dissolved nutrients.

The challenge in retrofitting built out areas is that usually there is little or no land available for ponds. There are various options in these areas depending on available revenues and the desired treatment level. Since these methods are newly developed, there is little data on removal efficiencies and maintenance intervals play a crucial role in the treatment effectiveness.

Underground vaults can be used for detention ponds, which allows normal usage over their tops. Large access ways must be provided for maintenance. These can be nearly as efficient as ponds, except for biological treatment, but are extremely expensive and difficult to maintain. They are rarely used except in commercial or downtown areas where land values are extremely high.

Exfiltration pipes may be used where porous soil and low groundwater conditions occur. These are perforated pipes in gravel beds which percolate a desired retention volume into the ground. They are highly efficient when used as offline systems but are not very cost effective. These systems have higher maintenance and limited life spans, just like septic tank laterals, since the soil pores will eventually clog. For this reason, they should not be used under pavement. In order to extend their lives, sediment sumps should be used at all inlets to keep dirt out of the pipes and skimmers should be used at pipe openings, to keep dirt out of the pipes. Skimmers should be used at pipe openings to keep oils and trash out of the pipes. Since these systems are not designed for conveyance capabilities, skimmers over pipe openings do not impede significant flows.

Retention volumes can be created in roadside swales by constructing concrete ditch blocks [weirs] in the swales. Earthen ditch blocks erode easily and do not last long. This is feasible when there is a low groundwater table, permeable soils, and ditch capacity to raise the water surface during storms.

Baffle boxes are another technique used to trap sediments, floating trash, and yard clippings. They are basically large septic tanks constructed in-line with existing pipes and therefore require no new right-of-way. Many heavy metals attach to suspended solids so they are also trapped in the box.

Baffle boxes are our most commonly used method for retrofitting. The weirs in the box are set at pipe invert elevations so as to not impede flows in high water down and allow sediments to fall out and be trapped in the chambers. Trashes screens catch floating debris but are hinged at the top to swing out if the way in high flow situations. Manways are built over each chamber, which allow for access for cleaning with a vacuum truck to reach them. The

removed sludge is not considered hazardous and may be dumped anywhere vacuum trucks normally dump. Accumulation rates vary with each location and depend on many factors such as rain intervals and intensities, yard mowing practices, drainage basin size, abundance of trees which drop leaves in streets, land use, soil characteristics, landscape practices, flow velocities, etc. Some baffle boxes will fill every few weeks, collecting over 50,000 pounds of dirt a month, while others fill only twice a year.

It is important to have a monthly inspection and cleaning program for baffle boxes as well as other devices. They should be cleaned before the chambers become full or a large storm will resuspend some of the dirt and floating trash and carry it out to the receiving water body. Monthly cleanouts are recommended for this reason, as well as to remove stagnant water before it turns anaerobic with odor problems.

We are currently undergoing research to determine optimum box sizing and shapes as well as quantifying the pollutant load of grass clippings and how they release their nutrient load in water with time. Testing has shown these baffle boxes to be about 90% efficient in suspended solids removal.

The costs of a baffle box vary depending on pipe size, utility relocation and pavement repair. Often an existing inlet is replaced with a baffle box but the box may also be placed behind the inlet to preserve the street and/or utilities. The cost of most installations will be between \$20,000 and \$30,000.

For locations with small flow rates, a fiberglass inlet weir has been developed which fits inside of existing curb inlets and manholes. The weir has a trash screen allowing it to trap dirt, yard clippings and floating trash. Flows under 4 cfs will flow through the weir while higher flows will flow over the weir to minimize upstream flooding. The fiberglass weirs are purposely designed to leak water through cracks so as to slowly release trapped water but not the sediments. Original designs used a concrete weir but the orifices kept clogging leading to septic, smelly conditions after a few weeks of dry weather. This effluent then washed out in high flows. Also grass clippings washed over the top every time sprinklers drained into the street and through the inlet. The fiberglass weir solves these problems.

These installations cost only \$500-\$600 and are nondestructive to existing systems. The tradeoff is that they need frequent maintenance or the trapped pollutants will be washed out in high flows. Cleaning out can be performed with a vacuum truck, a small pump and storage unit on a truck, or by hand if the manholes are dry. Once again efficiency depends on rain intensities and cleanout intervals.

For grated inlets another device called a grate inlet trash box has been developed which drops into the existing inlet and traps dirt, trash and oils. The box has filter cloth covered drain holes in the bottom allowing it to dry out between storms. The specially designed lid acts as a skimmer keeping floating trash in the box as well as holding an oil absorbent pad which removes oil in the runoff. The box is designed as an orifice with flow through bypass holes and still retain trash. The main concern in determining the box size is to keep the bottom of the box above outfall pipes. No tools or materials are needed, making for a two minute installation at a cost of approximately \$500. These come in a wide variety of common sizes.

Another inexpensive treatment method is to construct an inlet with no outflow pipe to be used as a sediment trap in a gutter line. It will fill up with the water and dirt. Using a weep hole will keep the inlet dry.

While engineers like to have simple numbers for removal efficiencies for treatment facilities, the complexity of the situation makes this difficult. The variables of loading rates,

cleaning intervals, rainfall intensities and pipe velocities have so far defied simple analysis. In addition, the main pollutants trapped, such as large grit rolling along the bottom of the pipes, yard clippings and floating trash are invisible to most testing techniques.

At outfalls or in canals, trash screens can be constructed out of fencing to trap floating debris. As long as velocities are low, head losses should be minimal. The fence bottom should be above the ditch bottom for better hydraulics. Vinyl coated fences are recommended to minimize corrosion.

Erosion in open channels is a major source of sediment deposition. This erosion can be replaced by stabilizing the slopes or by piping the channels. Sediment sumps can be placed in channels to collect dirt for regular removal.

Summary

In summary, retrofitting existing storm drain systems is a new field of civil engineering, which presents many challenges. Traditional designs and attitudes will need to change with these new demands on our engineering skills. Environmental mandates will force us to work more closely with governmental entities to create cost effective stormwater treatment methods. A willingness to experiment will lead to the development of many new treatment methods. Along with the construction of these systems must come a commitment to maintain them or they will be useless.