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# DESIGN AND IMPLEMENTATION OF A FOREBAY-POND-WETLAND SYSTEM FOR URBAN STORMWATER TREATMENT IN SOUTH TEXAS

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**ABSTRACT** Urban stormwater runoff water quality is increasingly becoming a major contributor to nonpoint source water pollution for 21st century development. It can not only become a cause of flooding if not properly managed during storm events, but also is a cause of water pollution through runoff containing sediment and materials. Natural and semi-natural water and wastewater treatment technologies can provide effective water quality improvement and quantity control. Over the past several years, best management practices, including detention basins, biofilters and constructed wetlands, have been very successful in removing total suspended solids and pollutants from wastewater. A sequential treatment system including a forebay, pond, and wetland has been proposed to incorporate the merits of these approaches and improve runoff water quality. Hydraulic detention time, attached growth media and vegetation were three important parameters identified in the designs to help optimize system performance.

**Keywords:** Stormwater, Forebay, Pond, Wetland, McAllen

**INTRODUCTION** Urban stormwater is a major non-point source of aquatic pollution, causing widespread environmental degradation and potential health risk (Novotny and Olem, 1994; Marsalek et al., 1999). The runoff contains significant loading of heavy metals, petroleum hydrocarbons, pesticides, sediment, and nutrients (Hall and Anderson, 1988; Davis et al., 2001). If contaminated stormwater is not properly managed during storm events, the pollutants such as non-biodegradable metals can accumulate in the local ecosystem, leading to adverse effects on human health and the environment, such as acute toxicity and potential carcinogenic damage (Wu and Zhou, 2009).

In order to improve the quality of large volumes of stormwater, various best management practices (BMPs) have been employed to control runoff volume and pollution loading, such as retention and infiltration systems used for collection, and infiltration and transport of stormwater into groundwater systems (Walsh, 2000). Performance evaluation and modeling of existing BMPs is critical for project management, public acceptance and future BMP designs. Although individual reports of BMPs are useful in specific locations, for various BMPs with a robust change of physical, chemical and/or biological operating processes, comparative analysis and dynamic modeling of water quantity and quality is needed to provide a more comprehensive knowledge basis for predicting and planning water quality treatment and innovation (Scholes et al.; Barrett, 2008).

The detention basin, retention pond, wetland basin and wetland channel are mainly structural types of BMPs. The differences among these types are the size and shape of pond and wetland. However, they have very similar structures: forebay, pond and wetland. Usually the forebay, as the first part of a pond and wetland system, is underestimated for its importance in the total water treatment process. Although the pond and wetland have different hydrologic, hydraulic and botanic characteristics (Wong, 1999), they can be used sequentially in a complementary manner. At many northern temperate locations, pond-wetland systems have demonstrated reliable long-term performance (Kadlec, 2003). Thus, the extension to a forebay-pond-wetland system is proposed and investigated to illuminate the specific functions of different sections and their complementary performance toward water quality improvement, even with the challenges presented through a semiarid climate application such as South Texas

**DESIGN OF FOREBAY-POND-WETLAND SYSTEM** A sequential treatment system including forebay, pond, and wetland has been proposed to incorporate the benefits of each natural system based treatment technique and develop optimization strategies for the entire system performance (Fig. 1).

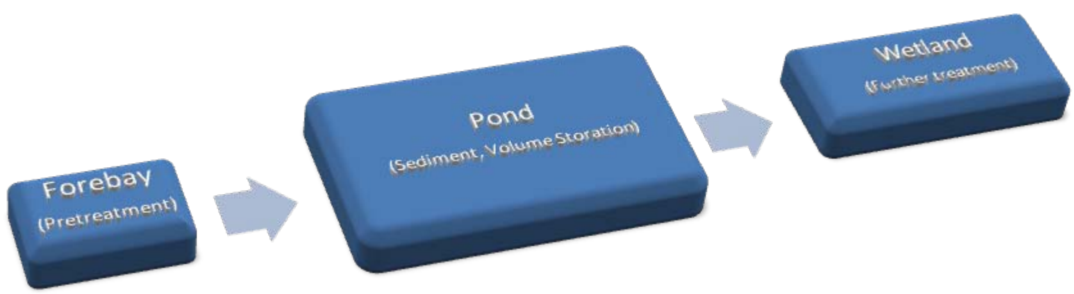


Figure 1 Schematic diagram of forebay-pond-wetland system

**Forebay** A forebay is a small reservoir connecting the channel and basin or other BMP facility. It serves to dissipate inflow energy, store some flow volume and trap coarse solids, and thus is usually used for pretreatment. In order to improve pollutant removal efficiencies, several accessory structures are often added such as oil and grit separators, and baffle boxes and screens. More important, the pretreatment function of forebay can reduce the sediment cleaning frequency of pond and wetland, make the maintenance easier and extend the operational life of BMPs. However, due to the small areas often available and the diversity of forebay design situations, there are no detailed accepted handbooks on forebay design and planning as of yet. Some findings from pond and wetland surveys in North Carolina have suggested that forebay designs should include separate energy dissipation and sedimentation sections (Johnson, 2007). For runoff pretreatment, the design must be flexible according to the specific location and objectives.

**Pond** In stormwater management, ponds are constructed basins with greater depth and without the vegetation of wetlands. Ponds typically have two parts, a permanent pool and a temporary pool. This treatment approach has two main functions, water storage and solid sedimentation. Water interception with this system can decrease the impact of peak flow during heavy storm events on subsequent wetland structures, and balance the loss of pervious surface area for infiltration.

The primary treatment process in ponds is physical sedimentation, but also biological and chemical uptake, and other pollutant transformations can be significant (Wong et al., 1999). Solid sedimentation is governed by particle size, flow velocity and hydraulic retention time. Some contaminants are heavily associated with solid particles such as phosphorous or carbonaceous materials.. When the solids settle, these contaminants are also removed from the water column. Some microbes in water and pond bottoms can digest these pollutants as substrates. However, the sediment accumulation and heavy metal enrichment at pond bottoms are important for the safety design, operation and maintenance (Färm, 2001).

**Wetland** The wetlands approach to water quality treatment includes the natural wetland and constructed wetland. This approach provides many ecosystem services, such as water management, biological habitat, aesthetics and educational parks (Costanza et al., 1997). Natural wetlands also play an important role in watershed water management and regional biodiversity protection. Constructed wetlands mimic natural wetlands, but their implementation avoids damage to natural wetlands. Due to the multi-functional nature of wetlands, more and more artificial wetlands are being constructed as one type of BMPs.

Constructed wetlands also are often classified into two types: surface flow wetlands (SFW) and subsurface flow wetlands (SSF). Wetlands use a combination of physical, chemical and biological processes to remove pollutants. Similar to the pond, solids can be settled by gravity, and some contaminants can react or be taken up by biota.. Vegetation can stabilize the bed surface, provide a filtration effect, transfer the oxygen, influence the flow and particles and finally increase the removal rate (Brix, 1997). Fecal bacteria, BOD and suspended solids in the secondary effluent from domestic wastewater were removed effectively in the constructed wetland experiments located in Kentucky, USA (Karathanasis et al., 2003). Vegetation management, such as the use of hummocks and harvesting, can be important for achieving and maintaining the optimal treatment function of wastewater treatment wetlands (Thullen et al., 2005). The depth distributions and vegetation density are vital parameters in determining the mixing extent and treatment performance (Carleton and Montas, 2007). However, particle sizes and flow characteristics are important factors in influencing particle trapping efficiency (Deletic and Fletcher, 2007).

**SYSTEM IMPLEMENTATION IN SOUTH TEXAS** There are two forebay-pond-wetland systems being constructed in the City of McAllen, Texas, USA. The construction of the McAuliffe School BMP is already complete (Fig. 1), and the design and implementation of the Morris School BMP is underway (Fig. 2).

**McAuliffe The** McAuliffe School BMP design has four parts, one forebay, two ponds and one wetland. The forebay is a small scale grass swale, with a screen inserted between the inlet and forebay. The two ponds have enough volume to detain a high intensity storm event. The wetland is primarily a subsurface flow wetland.


Figure 2. Aerial imagery of the McAuliffe School BMP, Feb. 10, 2009

**Morris The** Morris School BMP is proposed to have three parts, one forebay, one pond and one wetland. One baffle boxes will be installed in the channel, which can remove sediment, floatables, suspended particles, and associated pollutants from storm water. The wetland will adopt the surface flow wetland type.

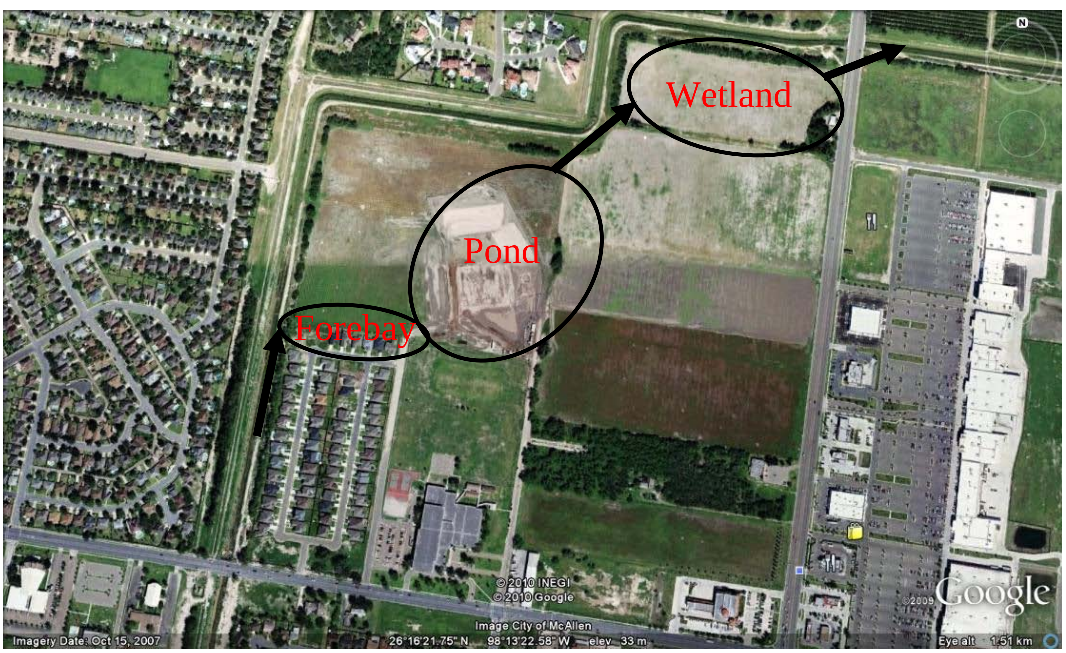

Figure 3. Aerial imagery of the Morris School BMP, Feb. 10, 2009

**CONCLUSIONS** In order to remove contaminants in storm runoff, a forebay-pond-wetland system has been proposed and implemented at two locations in South Texas, USA. The forebay area is used as pretreatment step to increase the total performance and service life of pond and wetland. Both the ponds and constructed wetlands were designed to settle suspended solids and allow for some decay of active contaminants and nutrients. The ponds also have a significant volume storage function. Native vegetation has been planted in the wetland areas to enhance its positive role in the removal of sediment and pollutionl.

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