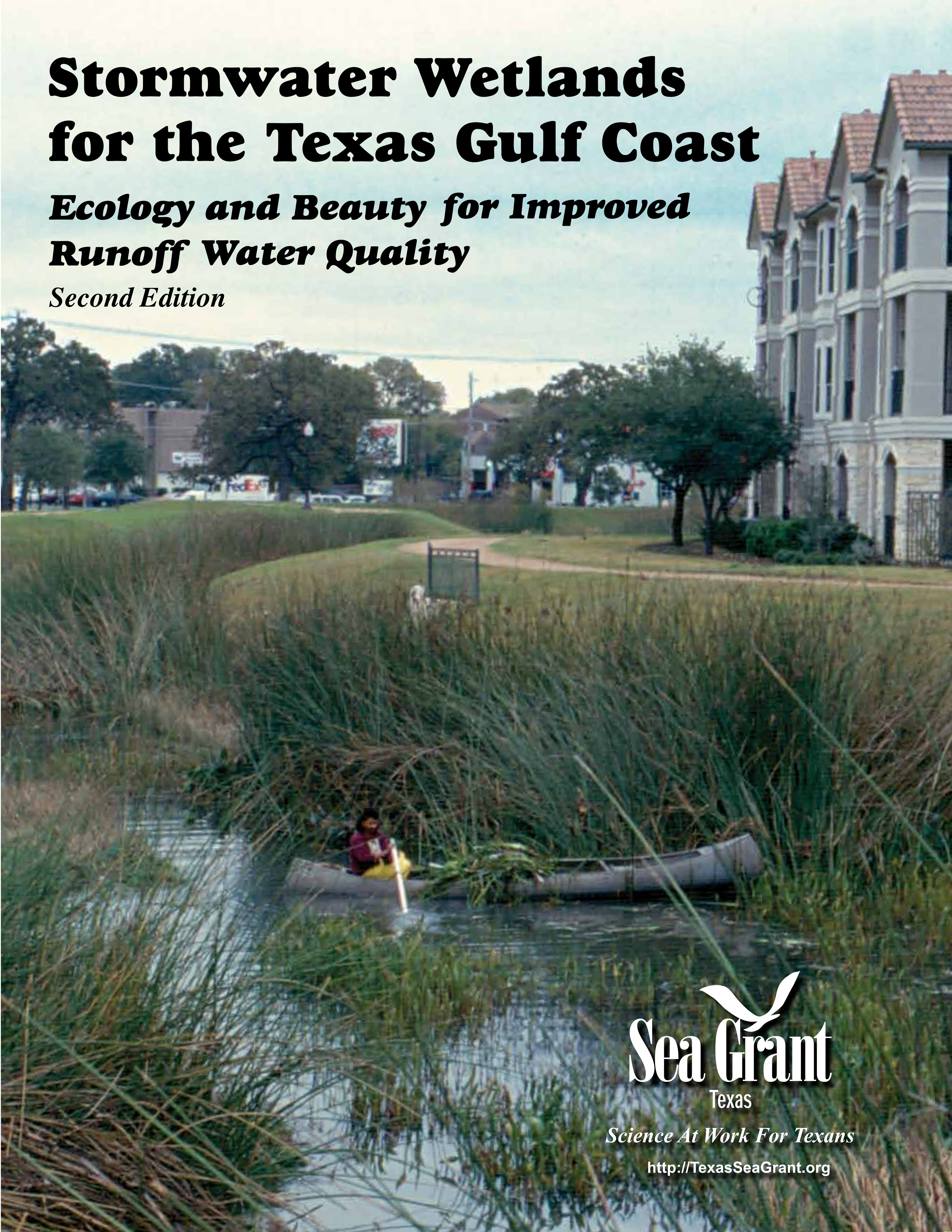
Stormwater Wetlands for the Texas Gulf Coast

Ecology and Beauty for Improved Runoff Water Quality

Second Edition



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A single-purpose stormwater conveyance system. Note that this feature is along the backyards of these residences. A drain like this provides no water quality treatment and likely detracts from adjacent property values. Deer Park, Texas. Photo by John Jacob.

This stormwater conveyance is just as artificial as that in the photo above, but the wetland edges clean water and add to the value of the adjacent property. Houston, Texas. Photo by John Jacob.

Wetlands and Stormwater Detention: A Natural Partnership

Stormwater wetlands are emerging as one of the very best ways to clean up polluted stormwater on the Texas Gulf Coast. Wetlands are abundant in our area because we are so flat and wet, and they play a critical role in our natural ecology. And because we are so flat and wet, we have developed a very extensive stormwater detention and conveyance system. Wetlands can easily be engineered into this system — a marriage of engineering and nature that could be our best bet for meeting water quality goals in the face of rapid population growth on the coast. This marriage would also beautify our communities and help to restore some of the functions of the natural wetlands we have lost.

This publication introduces the concept of stormwater wetlands. It explores how well we might expect them to work in our area, and then reviews the major issues associated with this management practice. Stormwater wetlands can be built as stand-alone facilities, but we assume here that few if any stormwater wetlands would be built independent of a floodwater detention facility.

Our stormwater detention and conveyance system can easily be adapted to accommodate stormwater wetlands, adding beauty, habitat, and clean water to our communities.

This shallow detention area could easily be configured for a stormwater treatment wetland, transforming an area with little beauty or functionality into a community amenity. Photo by Marissa Sipocz.

Wetlands play important roles in Gulf Coast ecosystems: they serve as natural detention basins[1], they naturally cleanse water coursing through them, they provide important habitat for wildlife, and they are an important part of the beauty of the coastal prairie that is our home. They are, in effect, part of our "***green infrastructure,***" an infrastructure just as important to us as the "***gray infrastructure***" of bridges, roads, etc., that makes life possible on the Gulf Coast. We can't live without either of these kinds of infrastructure.

A marriage of our green and gray infrastructures could provide a very affordable and effective solution for polluted stormwater.

Drainage is an indispensable part of our gray infrastructure, and it was usually one of the very first modifications to the landscape made by early settlers. There are very few places where one can farm or build a house on the flat-lying Gulf Coast without imposing some kind of drainage. Today we not only have ditches for draining the land, we have a very extensive drainage network in most of our communities for accommodating fairly heavy storm events. This system includes a complex network of swales, ditches, and detention basins. Up until recently, these drainage facilities were built for one purpose only—to drain the land and to keep stormwater from flooding residences and businesses. These drains for the most part serve their intended function. They are often marvels of engineering, but not much to look at in terms of natural beauty (see top of page 2). They also do very little in terms of water quality or ecology, and may in fact degrade water quality.

We have been able to live on the Gulf Coast for quite some time without worrying about water quality, but with burgeoning coastal populations, it is now a *major* concern. Stormwater entities such as municipalities are increasingly required to treat their stormwater as a point source[2] of pollution. We can expect those requirements to become more stringent over time, as we continue to grow.

A marriage of our green and gray infrastructures could provide a very affordable and effective solution for polluted stormwater. Wetlands can be easily retrofitted into just about any existing stormwater facility, and with a little extra input (detailed below), new stormwater facilities can be designed to take full advantage of stormwater treatment wetlands. It is a rare stormwater facility, in fact, that does not have some wetland vegetation already established in it.

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1 At an average depth of 6 or so inches, and assuming 30% natural freshwater wetland coverage, there are about 15 acre-feet of wetland detention volume per 100 acres on a typical Texas Upper Gulf Coast landscape.

2 Point sources of pollution are those which have a discrete and definable source — there is an "end of the pipe" associated with this kind of pollution, as opposed to non-point source or runoff pollution. Most of what comes from stormwater is of course runoff pollution, but when that runoff enters a storm conveyance system (*e.g.*, a municipal separate storm sewer system or MS4 in stormwater jargon), runoff is converted into a point source of pollution, with all of the regulatory implications associated with it.

Restored natural wetland, Sheldon Lake State Park. Photo by Diane Humes.

Just What Is a Wetland, and How Does It Work?

A wetland is not a pond. There may be some open water patches in a wetland, but for the most part a wetland is just that: *wet land*. Wetlands are transition areas—they have both aquatic and terrestrial features. They are dominated by vegetation adapted to life in saturated soil conditions. Wetlands do not have to be saturated or wet all the time. In fact, most of our freshwater wetlands on the Gulf Coast dry out completely in the summer and yet continue to perform their functions year after year.

Wetlands clean water in a variety of ways. First, many pollutants, particularly sediment, are filtered out by the plants themselves. Second, wetlands have a unique biogeochemistry that transforms pollutants into less harmful forms (see Table 1). Nitrate (NO_3^-),

Median Pollutant Removal Efficiency, Stormwater Treatment Wetlands	
Pollutant	Median % removal efficiency
Total Suspended Solids	72
Total Phosphorous	48
Soluble Phosphorous	25
Total Nitrogen	24
Nitrate/Nitrite	67
Bacteria	78

From Center for Watershed Protection, 2007. Note that these are median removal efficiencies, which can be highly variable.

for example, is transformed into harmless nitrogen gas (N_2). Many of these transformations take place in microbial biofilms that are found both on the soil surface as well as on plant surfaces. Plant uptake and photodegradation remove or transform a number of pollutants. Pathogens may be removed through microbial predation as well as solar disinfection. In short, wetlands are complex reactors that we are only beginning to understand. Their treatment potential, however, is well understood and documented in the literature.

This stormwater detention pond provides some limited stormwater treatment, but it is not a wetland, it does not perform as well as a wetland for water treatment, and it does not have the aesthetic and natural values that a wetland has. Photo by John Jacob.

A typical stormwater detention facility, dug deep (more than 20 feet here) to minimize horizontal extent. A wetland capable of treating runoff from the contributing area to this facility would have to be as much as 20-30% larger in horizontal extent. Note that some wetland vegetation is present in the very bottom of this basin. This basin is probably very near the depth of the water table in the area. Photo by John Jacob.

This detention basin in the Houston area is much shallower than the one on page 6. A fully functional wetland could easily have been designed for this facility, which is less than 10 ft. deep. Some wetland vegetation near the ponded water is present, but almost all of the bottom is very well drained and dry. The inlets on the left mark the side of the basin. The cage on the right shields the outlet. Photo by John Jacob.

Design Elements for Stormwater Wetlands

To design a wetland that will effectively treat stormwater, there are five major steps: (1) selecting a suitable site, (2) including the appropriate features, (3) sizing the wetland, (4) designing the outlet structure, and (5) selecting the right plants. We first consider these elements in terms of designing a wetland in conjunction with a new detention basin, and then we address these issues for retrofitting a stormwater wetland into an existing detention basin.

1. Site Selection

The location of the floodwater detention basin will be the primary determinant of where the stormwater wetland will go, but requirements for the wetland should also be considered in the overall location. For example, high permeability soils (*i.e.*, sands and sandy loams) should be avoided, and the wetland site should be easily accessible for maintenance. The outlet of the wetland will need to be aligned with the drainage pathway of the detention basin.

Wetlands are complex natural reactors that remove pollutants through both filtration and transformations.

Engineered stormwater wetland at US Hwy 290 and Kickapoo Road, outside of Houston, Texas. This wetland dries out in the summer and is mowed by TXDOT at their regular intervals. Photo by John Jacob.

2. Sizing the Wetland

The single most important issue that determines how well a stormwater wetland works is the size of the wetland relative to the contributing watershed.

The single most important issue that determines how well a stormwater wetland works is the size of the wetland relative to the contributing watershed. The larger the wetland, the more effective it is going to be in removing pollutants. The ideal situation is to retain and treat a 90th percentile storm[3] for at least two full days before another storm arrives. The 90th percentile storm for the Upper Gulf Coast of Texas is about 2 inches of rainfall. For most developed areas on the upper Texas Gulf Coast, the size of a fully effective treatment wetland should be between 5% and 10% of the contributing watershed[4].

In a retrofit situation, it is very unlikely that a 5-10% wetland-to-watershed ratio could be achieved. But it is important to remember that any wetland area added to a detention basin will still provide some significant pollutant removal.

Detention basins designed from the start to incorporate stormwater treatment wetlands will very likely need to be significantly larger than

[3] i.e., 90% of all storms are smaller than this.

[4] Basic parameters: 1-foot treatment depth, 90th percentile rainfall event (1.8 inches), 60% imperviousness in contributing watershed (calculations following Kadlec and Wallace, pp. 649-650).

basins designed for floodwater detention alone. The size of a standard detention basin is determined by the detention volume requirement of the drainage or stormwater district. In Harris County, for example, 0.55 acre-feet are required for every acre of development.

Most developers will build a detention basin as deep as possible to minimize land costs. A 100-acre development (fully developed) would thus require 55 acre-feet of detention volume. A 10-foot-deep basin could provide the needed volume with 5.5 acres of land, while a 20-foot-deep basin would only require 2.75 acres of land. (These calculations assume a 90-degree vertical side slope, which is never the case, so additional land would be required.) That same 100-acre subdivision would need at least 5, and preferrably 10 acres of flat area for an optimal wetland that could treat most of the stormwater runoff. The point here is that land required for detention alone will be significantly less than the land needed for optimal wetland treatment.

A fully-functional stormwater wetland needs to be about 5-10% of the contributing watershed in size.

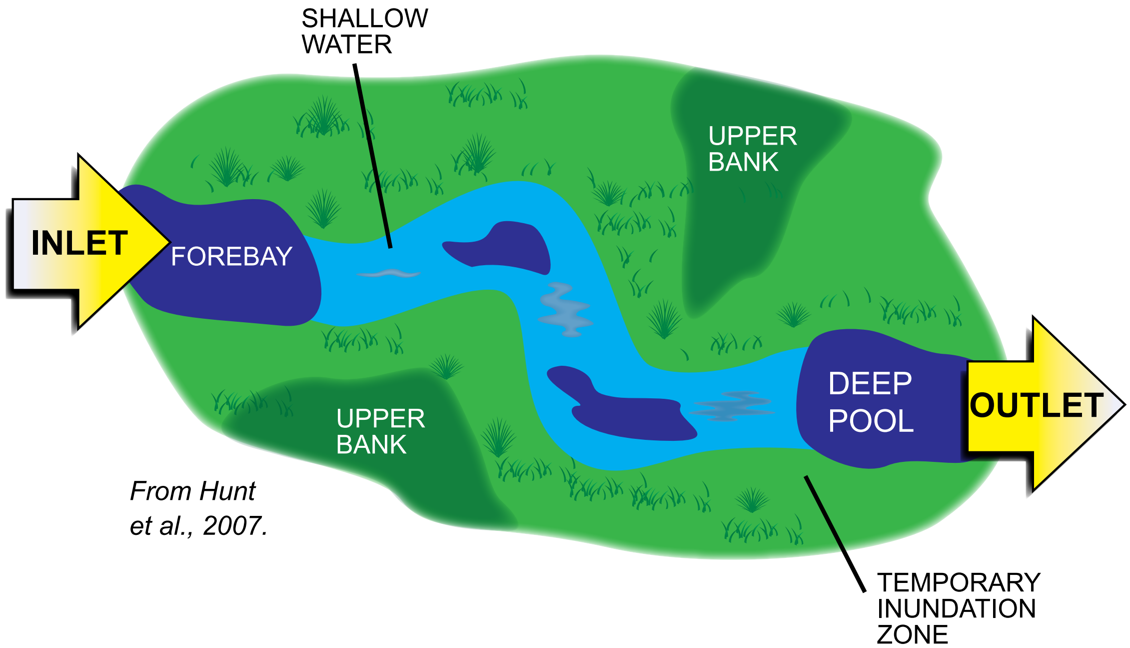
Incorporating a properly sized stormwater wetland into a detention basin will increase land costs for a developer. On the other hand, consider the land values of the property adjacent to the stormwater wetland in the photo on the cover versus the values of the properties adjacent to the sterile drainage ditch on the top of the page 2.

A very important consideration is that significant water quality can be obtained even if the wetland cannot be sized for maximum effectiveness. If only 30-40% of the maximum pollutant reduction potential can be achieved, it is still a valuable contribution, in addition to its beauty and ecological values.

3. Wetland Features

To be effective, constructed wetlands need to simulate natural wetland features as well as account for the variable stormwater flow they receive. For example, a forebay will dissipate the runoff energy and collect the large particles in the runoff, which simulates deep pools often found in natural wetlands. The forebay should be 10-15% of the total area of the wetland and be easily accessible for periodic cleanout. The remaining deep pools should be distributed along the main pathway of the water. These provide an aerobic environment for nitrate removal, extra retention, and refuge for aquatic organisms during droughts. The deep pools, including the forebay, are usually 18-30 inches deep and should account for 20-25% of the total

Constructed Wetland Features



From Hunt et al., 2007.

area of the wetland. A shallow water area, which constitutes the main course of the water, provides connection between the pools for aquatic life; the shallow water area is 2-4 inches deep and makes up around 40% of the total wetland area. The temporary inundation zone of the basin is the primary wetland treatment zone. It is designed to hold water, about 1 foot deep, for at least a few days after the storm. The side slopes of the upper banks need to be no steeper than 3:1 and should be vegetated with plants that help stabilize soil and that can survive under much drier conditions. If necessary, erosion control measures can be installed on the banks.

Flashboard riser, acting as a weir, with an orifice for slowly draining the temporary inundation zone. Photo Bill Hunt.

4. Outlet Structure

Stormwater wetlands typically have a two-outlet system. The first is an overflow spillway (usually a 1-foot weir) placed at the top of the treatment wetland elevation. This will allow all water above the 1-foot elevation in the wetland (essentially the full stormwater detention volume) to drain fast so that the wetland vegetation has a greater chance of survival. The second outlet, below the weir, is made with several orifices, or holes, designed to slowly drain 8-10 inches of standing water above the shallow water zone and below the overflow spillway. The orifices create a slow-draining system that allows for a higher retention time and therefore a longer treatment time.

5. Vegetation Selection

Unlike naturally occuring wetlands and wastewater treatment wetlands, stormwater wetlands have relatively dramatic and frequent changes in water depth. Water depth at any particular point in the shallow water zone can increase from 3 to 15 inches and back again to 3 inches in as few as three days. Therefore, designers should include multiple species of wetland vegetation in each area and monitor their survival. A good wetland plant reference list is the Texas Parks and Wildlife Department's Texas Plant Information Database, which can be found at: http://tpid.tpwd.state.tx.us/ecological_regions.asp.

Retrofitting an Existing Detention Basin

One way to incorporate stormwater treatment into the drainage system is to retrofit existing detention basins. If you look closely, you will find many basins already have wetland characteristics and can be converted relatively easily. It is important to remember that the basin must still be able to serve its flood control purposes after wetland construction. Engineering a wetland treatment volume into the bottom of an existing detention basin invariably involves removing some of the detention volume. Most detention basins are designed with some additional volume beyond what is required, so the few acre-feet required for the treatment wetland may not be a problem in most cases.

If a basin has been built small and deep, you will likely not achieve full treatment for a 90th percentile storm; however, do not let that deter you, because some treatment is better than no treatment.

An engineer will need to design a system of channels, pools, and ponding areas that will house wetland vegetation and an outfall structure that will hold water in the wetland treatment zone and allow it to slowly drain over the course of 48 hours or so. Retrofit projects can offer design challenges, but these can be overcome with a little creativity. For instance, if a basin is designed with concrete pilot channels, it is best to remove these, but they can be left if water can be forced off the concrete and into the wetland areas.

The outfall structure that releases stormwater from the wetland can be the most expensive portion to retrofit. A basin with a weir or simple outflow pipe is easy to retrofit with flash board risers or a v-notch weir to regulate the flow of water; however, if there is an existing concrete weir structure, it could be costly to upgrade.

Many basins already have wetland characteristics and can be converted relatively easily.

Cost and Maintenance

All costs considered here assume the stormwater treatment wetlands would be built or retrofitted into a stormwater detention facility. Moving soil is the most significant cost of building a detention basin or wetland from scratch, but is not included below because it would be required anyway, with or without a stormwater treatment wetland.

Design and engineering costs could run as high as $8,000-$15,000 per acre of wetland. Grading over and above that required for a detention basin could cost up to an additional 5-10%. Expenses for retrofit grading and construction could be as much as $5,000-$15,000 an acre. Installing vegetation will cost $10,000-$20,000 an acre. The outlet structure construction will cost about $10,000-$15,000 an acre.

A wetland in a detention basin designed for a wetland might thus require about $40,000 an acre over and above the cost of the detention basin itself. A retrofit wetland would likely require at least $50,000 an acre, because of the additional grading.

Maintenance would be similar to that required for a pond. Most stormwater treatment wetlands have a forebay constructed just upstream from the wetland itself. Periodic dredging (about every 2-5 years) would be required to maintain the depth of the small forebay. Vegetation would have to be managed to avoid or remove plant species known to harbor

Wetlands within the Stormwater Detention Basin at Willow Waterhole. Photo courtesy Harris County Flood Control District.

A smooth wetland fringe of bull rushes and other wetland plants adjacent to a side slope at the Willow Waterhole Stormwater Detention Basin in Houston, Texas. The photo was taken during the 2011 drought. Photo courtesy of Harris County Flood Control District.

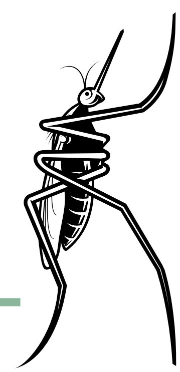
mosquitos (cattails, for example). It is best to design the wetland so that it periodically dries out and can be mowed, which is one of the best ways to control brush. Alternatively, a permanently inundated wetland also helps reduce brush infestation.

Health and Safety Issues

Mosquitoes are a problem only if the stormwater treatment wetland is poorly designed and poorly maintained. Consult the detailed manuals in the references section on page 16 for design specifications. For example, properly designed wetlands will include some deeper zones of permanent water where mosquito fish (*Gambusia*) can be stocked. Certain kinds of vegetation that provide habitat for mosquitoes are to be avoided. See the *Mosquito Control for Stormwater Facilities* publication for more detail.

Areas of deeper water can be a concern for drowning. A shallow shelf along the edge of the deeper zone provides an important safety buffer.

Snakes and other wildlife will be a natural part of stormwater treatment wetlands. Small children should not be allowed to wander these areas alone.



Mosquitoes are not an issue in well-designed stormwater wetlands.

Brays Bayou was once a beautiful coastal stream. Today it serves strictly as stormwater conveyance. This bayou would have to have been modified in any case to accommodate all the new development, but the modification could have included a wider floodplain to accommodate wetlands. Photo courtesy Harris County Flood Control District.

Buffalo Bayou in Houston was modified to some degree, but a natural edge was preserved that provides both aesthetic and functional components, and is in fact iconic of this part of Houston. Incorporating stormwater treatment wetlands into our stormwater detention and conveyance system can add this kind of character to all of our communities. Photo Airborn Imaging.

Ecological and Cultural Values

Marrying stormwater treatment wetlands and the stormwater drainage and conveyance system is a way to put nature back in our front yard. Single-purpose, trapezoidal drains are something we want in the "back yard" — out of sight and out of mind (see the top photo on page 2). When we incorporate natural features into detention basins and drainage channels, they can become a neighborhood amenity, and could actually increase property values, much as a park does for adjacent land (Crompton, 2005). Incorporating wetlands into a stormwater system restores at least some of the habitat and landscape functions lost to development. Birds in particular are attracted to wetlands. "Industrial-strength" channels and basins could be transformed into ribbons of lush vegetation that add character to our community and provide an opportunity for contact with nature for all of our citizens. Marrying stormwater wetlands with our existing and yet-to-be built drainage infrastructure will allow us to improve water quality as well as quality of life as we add beauty and ecological functionality to our communities.

Well-designed stormwater wetlands could provide an immediate connection for urban residents to the natural beauty of the Gulf Coastal Plain, and would likely increase adjacent property values as well.

Restored prairie pothole wetland at Sheldon State Park, an example of natural beauty that can be engineered into our stormwater detention facilities. Photo by Marissa Sipocz.

References:

Apperson, C.S., W.F. Hunt, S. Kennedy, and B.A. Harrison. 2005. Occurrence and relative abundance of mosquitoes in stormwater BMP facilities in North Carolina. *Journal of the American Mosquito Control Association*. No. 6-7, 315-321.

Center for Watershed Protection. 2007. National Pollutant Removal Database. Ellicot City, MD.

Crompton, J.L. 2005. The impact of parks on property values: Empirical evidence from the past two decades in the United States. *Managing Leisure*. (10) 203-218.

Hunt, W.F., C.S. Apperson, and W.G. Lord. 2005. Mosquito control for stormwater facilities. Urban Waterways factsheet series. North Carolina State University Cooperative Extension.

Hunt, W.F., M.R. Burchell, J.D. Wright, and K.L. Bass. 2007. Stormwater wetland design update: Zones, vegetation, soil, and outlet guidance. Urban Waterways factsheet series. North Carolina State University Cooperative Extension.

Hunt, W.F., and B.A. Doll, 2000. Designing stormwater wetlands for small watersheds. Urban Waterways factsheet series. North Carolina State University Cooperative Extension.

Hunt, W.F., and B. Lord. 2006. Maintenance of stormwater wetlands and wet ponds. Urban Waterways factsheet series. North Carolina State University Cooperative Extension.

Kadlec, R.H., and S.D. Wallace. 2009. Treatment wetlands. CRC Press. Boca Raton, FL.

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COVER PHOTO: Stormwater drainageway in Austin, Texas. This stormwater feature adds beauty, wildlife habitat and water quality improvement to this neighborhood. Photo by John Jacob.

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