Design Considerations

- Area Required
- Slope
- Water Availability
- Aesthetics
- Environmental Side-effects

Targeted Constituents	Removal
Sediment	High
Nutrients	Med
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High
Flow Control	High

CASQA
CALIFORNIA STORMWATER QUALITY ASSOCIATION®

Description

Constructed wetlands are engineered, shallow-water ecosystems designed to treat stormwater runoff. Stormwater should never be diverted into a natural wetland. Natural wetlands should be protected from the adverse effects of development, including impacts from increased stormwater runoff. Natural wetlands provide stormwater and flood control benefits on a regional scale. Constructed wetlands are effective in terms of pollutant removal and they also offer aesthetic and habitat value.

California Experience

The City of Laguna Niguel in Orange County has constructed several wetlands, primarily to reduce bacteria concentrations in dry weather flows. The wetlands have been very successful in this regard. Even though there is not enough perennial flow to maintain the permanent pool at a constant elevation, the wetland vegetation has thrived. The Los Angeles County Department of Public Works successfully implemented a constructed wetland on the banks of the Los Angeles River that restores wildlife habitat and improves water quality. The Dominguez Gap Wetland is able to maintain a permanent pool by diverting low flows from the Los Angeles River.

Constructed wetlands provide some reduction for many of the pollutants regulated by the State and Regional Water Boards.

Figure 1. Dominguez Gap Constructed Wetland in Los Angeles, CA.

Advantages

- Provides stormwater treatment and can be designed to meet hydromodification management requirements.
- Can provide substantial wildlife habitat and recreational/educational opportunities.
- Offers significant water quality improvement across a broad spectrum of constituents including dissolved nutrients.
- Typically support mosquito predation, therefore require fewer vector control efforts.

Limitations

- Limited use in semi-arid climates where supplemental water would be required to maintain water levels.
- Can occupy large footprint; depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.

Performance

The processes that impact the performance of constructed wetlands are essentially the same as those operating in wet ponds and similar pollutant reduction would be expected. One concern about the long-term performance of wetlands is associated with the vegetation density. If vegetation covers the majority of the facility, open water is confined to a few well defined channels. This can limit mixing of the stormwater runoff with the permanent pool and reduce the effectiveness as compared to a wet pond where a majority of the area is open water. Dense vegetation can reduce nutrient reductions after the first several years of operation (Faulkner and Richardson, 1991). Table 1 below details expected effluent concentrations and removal processes for each pollutant constituent.

Table 1. Typical pollutant removal for constituents and removal processes

Pollutant	Typical Removal	Median Effluent Concentration[1]	Removal Processes	References
Sediment	High (70-90%)	9.4 mg/L	Settling, sorption, filtration	Geosyntec Consultants and Wright Water Engineering 2012; Scholes 2007; Backstrom, 2003
Metals	Medium	TCd: 0.17 µg/L, TCu: 3.38 µg/L, TPb: 1.32 µg/L, TZn: 20.0 µg/L	Removal with sediment, sorption	Geosyntec Consultants and Wright Water Engineering 2012; Struck 2006; Hafeznezami 2012
Total phosphorus	Medium	0.093 mg/L	Settling, sorption, plant uptake if sufficient vegetation	Geosyntec Consultants and Wright Water Engineering 2012; Scholes 2007; Burton 2002
Total nitrogen	Medium (44-77%)	TN: 1.19 mg/L, TKN: 0.82 mg/L, $NO_{2,3}$-N: 0.09 mg/L	Plant uptake if sufficient vegetation, denitrification	Geosyntec Consultants and Wright Water Engineering 2012; Hammer and Knight 1994; Scholes 2007
Bacteria	High	Enterococcus - 390 (MPN/100 mL) E. coli - 637 (MPN/100 mL) Fecal Coliform - 1031 (MPN/100 mL)	Microbial degradation, sorption, filtration, predation	Geosyntec Consultants and Wright Water Engineering 2012; Scholes 2007; Ellis et al. 2003; Davies 2000; Arias 2001
Trash	High	*N/A*	Filtration (media treatment depth of 1.5 feet) and/or outlet screen	Barrett et al. 2013

[1] Underlined effluent concentrations were (statistically) significantly lower than influent concentrations, as determined by statistical hypothesis testing on the available sampled data.

Suitability and Design

Constructed wetlands are best suited to drainage areas greater than approximately 5 acres and where base flow rates or other channel flow sources are relatively consistent year-round. Wetlands consume about 3 to 5 percent of the land that drains to them, which is relatively high compared with other stormwater management practices. In areas where land value is high, this may make wetlands an infeasible option. The constraints of each site dictate the appropriate sizing and footprint. Fundamental constructed wetland design components are as follows:

- Capture volume determined by local requirements or 85 percent of the annual runoff volume.
- Incorporate a multi-pool design, including energy dissipation in inlet design and a sediment forebay to reduce volume over 24 to 72 hours.

Table 2. Cost of design components and associated considerations

Component	Cost	Design Consideration
Excavation	$5.00–$15.00/ft^2	Multi-zone design to incorporate: deep pool (15–20% of area), transition area (10-15%), shallow pool (40%), temporary ponding (30-40%), and optional upland storage area. Water depth not to exceed 4 feet.
Fine Grading	$0.25/ft^2	The minimum length-to-width (L:W) ratio should be 2:1, but L:W should be maximized by creating a sinuous flow path and placing the outlet as far from the inlet as possible.
Soil Media Topsoil	$1.35/ft^2	Apply 1 to 4 inches to support plant growth. Depth depends on specified plantings and underlying soil characteristics. Soil representative of productive, well-drained soils in the area. It shall be free of material detrimental to plant growth (e.g. stones > 1 inch diameter). Low phosphorus (TP < 15 ppm) with pH 5.5–7.
Hydraulic Restriction Layer Filter fabric Clay 30-mil liner Concrete barrier	 $0.45/ft^2 $0.65/ft^2 $0.35/ft^2 $12.00/ft^2	If inter-storm rate of water loss exceeds supply from groundwater, baseflow, or runoff ensure water is maintained in permanent poolsby use of hydraulic restriction layer
Vegetation	$1.25–$3.50/ft^2	Rich with vegetation (no more than 50% of surface area). Primarily annual and perennial

Component	Cost	Design Consideration
		wetland plants specific to the water depth they would experience.

Constructed wetlands can be designed as either on-line or off-line facilities. For on-line facilities, the principal and emergency spillways must be sized to provide 1.0 foot of freeboard during the 25-year event and to safely pass the 100-year flood. The embankment should be designed in accordance with all relevant specifications for small dams. When the pond is designed as an off-line facility, a splitter structure is used to isolate the water quality volume. The splitter box, or other flow diverting approach, should be designed to convey the 25-year event while providing at least 1.0 foot of freeboard along pond side slope.

Pond Configuration

Effective wetland design displays complex micro-topography (i.e., multi-zone design, Figure 4). Multi-zone design can be broken down according to depth:

A. Deep Pools: 15–20% of wetland surface area (including forebay), 18 to 36-inches deep.

B. Transition: 10–15% of wetland surface area, transition between deep pool and shallow water, 12–18 inches deep, maximum slopes of 1.5:1.

C. Shallow Water: 40% of wetland surface area, 3- to 6-inches-deep, flat or 6:1 slope (at least 6-foot radius around all deep pools to provide safety shelf).

D. Temporary Ponding: 30–40% of wetland surface area, up to 12-inches-deep, 3:1 slopes.

E. Detention Storage/Upland: Additional ponding depth can be provided for peak flow mitigation, as needed. Depth should generally not exceed 4 feet above the permanent pool elevation. The minimum length-to-width (L:W) ratio should be 2:1, but L:W should be maximized by creating a sinuous flow path and placing the outlet as far from the inlet as possible.

If the entire design volume cannot be stored in a single location or if utility conflicts are apparent, wetland pockets can be distributed between several locations and connected with vegetated channels and/or buried conduit. An emergency spillway should be provided to safely bypass extreme flood flows.

A sediment forebay (i.e., pretreatment) should be used to isolate gross sediments before they reach the large permanent pool to simplify sediment removal. The sediment forebay should consist of a separate cell formed by an earthen berm, gabion, or loose riprap wall. The forebay should be sized to contain 10% of the permanent pool volume and should be at least 3 feet deep. Exit velocities from the forebay should not be erosive. Direct maintenance access should be provided to the forebay. The bottom of the forebay may be hardened (concrete) to make sediment removal easier. A fixed vertical sediment depth marker should be installed in the forebay to measure sediment accumulation. Ponds should be designed with a maintenance access to the forebay. In addition, ponds should generally have a drain to draw down the pond for vegetation harvesting or the more infrequent dredging of the main cell of the pond.

Construction costs associated with constructed wetlands vary considerably. Much of this variability can be attributed to the degree to which the existing topography will support a constructed wetland, the complexity and amount of concrete required for the outlet structure, and whether it is installed as part of new construction or implemented as a retrofit of existing storm drain system.

Vegetation

Constructed wetlands generally feature relatively uniformly vegetated areas with depths of one foot or less and open water areas (25-50 percent of the total area) no more than about 1.2 m (4 feet) deep, although design configuration options are flexible. Wetland vegetation is comprised generally of a diverse, local aquatic plant species. A list of some wetland vegetation native to California is presented in Table 3. Climatic considerations local to the wet pond should indicate which native vegetation is most appropriate.

Table 3. List of Wetland Vegetation native to California

Botanical Name	Common Name
Baccharis Salicifolia	Mule Fat
Frankenia Grandifolia	Heath
Salix GoodingII	Black Willow
Salix Lasiolepis	Arroyo Willow
Samucus Mexicanus	Mexican Elderberry
Haplopappus Venetus	Coast Goldenbrush
Distichis Spicata	Salt Grass
Limonium Californicum	Coastal Statice
Atriplex Lentiformis	Coastal Quail Bush
Baccharis Pilularis	Chaparral Broom
Mimulus Longiflorus	Monkey Flower
Scirpus Californicus	Bulrush
Scirpus Robustus	Bulrush
Typha Latifolia	Broadleaf Cattail

Maintenance

Inspect facility after first large storm to determine whether the desired residence time has been achieved. Vegetation harvesting in the summer is recommended. In certain cases, more frequent plant harvesting may be required by local vector control agencies. Where permitted by the Department of Fish and Game or other agency regulations constructed wetlands may be stocked with mosquito fish (Gambusia spp.) to enhance natural mosquito and midge control.

Figure 2. Constructed wetland inlet.

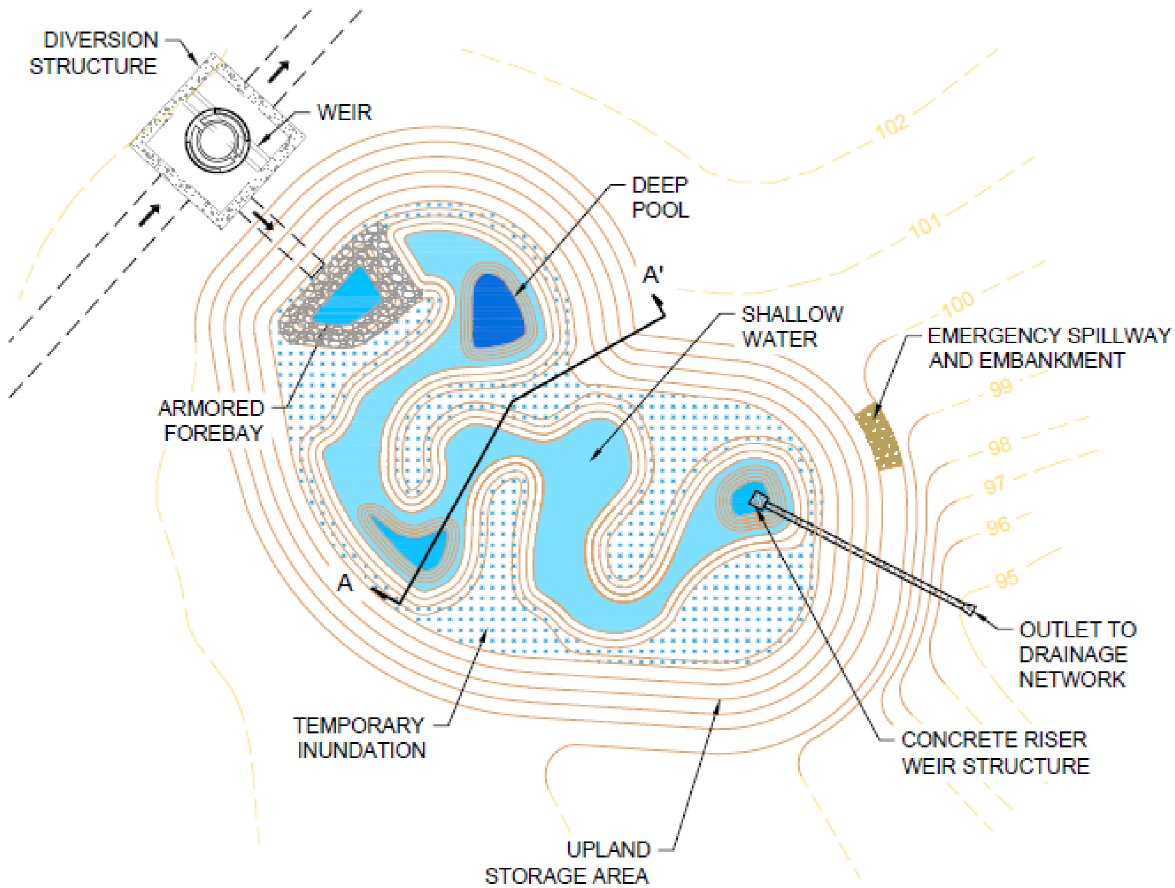
Figure 3. Example of a forebay as pretreatment for a constructed wetland.

Table 4. Typical maintenance activities and associated costs and frequency

Frequency	Cost	Activity
Routine Maintenance (required monthly to every 2 years)		Remove excess sediment, trash, and debris across the surface, inlet, and outlet. Check for and stabilize erosion. Pruning and mowing overgrown vegetation that interferes with access, or safety. Inspect structural integrity of the outlet
Routine (small)	$0.44/ft^2	
Routine (medium)	$0.34/ft^2	
Routine (large)	$0.24/ft^2	
Intermediate Maintenance (maintenance required every 6 to 10 years)		Remove accumulated sediment in the forebay and regrade when accumulated sediment exceeds 10 percent of the basin volume.
Intermediate (small)	$1.47/ft^2	
Intermediate (medium)	$1.41/ft^2	
Intermediate (large)	$1.40/ft^2	
End of Life Replacement (service life of 20 years)		Excavate to the depth of soil media. Test soil for excessive soil contamination of common stormwater pollutants (e.g. metals, nutrients). Continue to remove underlying soil if pollutants exceed standard for contaminated soil. Replace with clean soil.
Replacement (small)	$8.19/ft^2	
Replacement (medium)	$6.43/ft^2	
Replacement (large)	$5.99/ft^2	
Note: Small System = 500 ft^2; Medium System = 2000 ft^2; Large System = 4000 ft^2		

Trash maintenance not only plays a role in the functionality of the constructed wetland but also in the aesthetics and public perception of the constructed wetland (and of all BMPs). Part of maintaining positive perception among the public is the visibility of a well-maintained BMP. This positive perception can self-perpetuate further support for integrated stormwater management practices and therefore further investment in regular maintenance.

Schematic



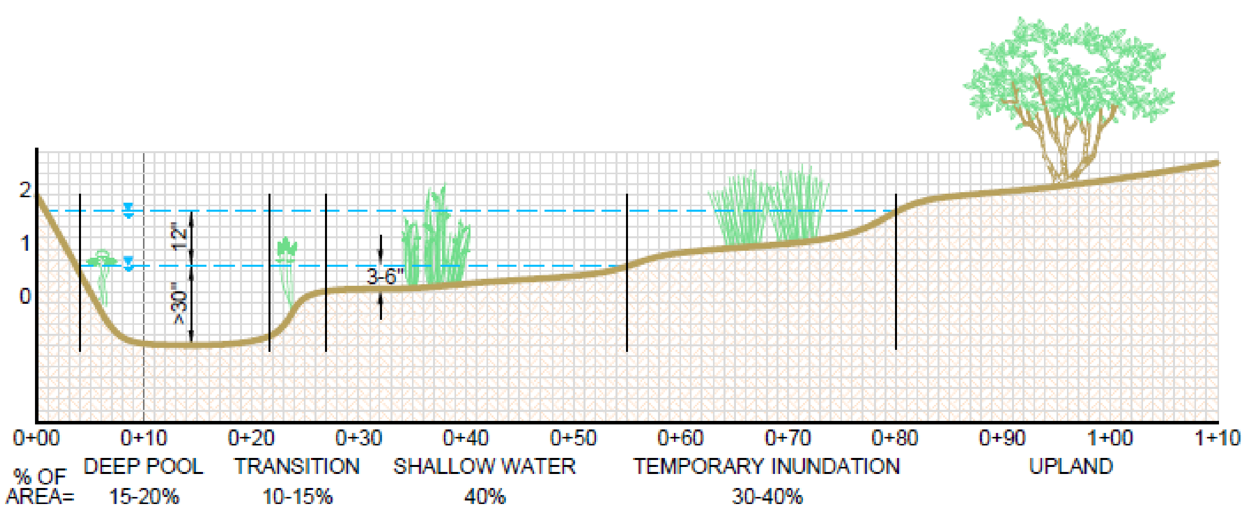


Figure 4. Constructed Wetland Schematic.

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