Meeting Multiple Objectives in Stormwater Treatment at Freedom Park

James S. Bays and Margaret Bishop

Freedom Park is a 50-acre water quality improvement project in Naples treating stormwater from the urban 961-acre Gordon River watershed. Constructed pond, wetlands, and restored wetland habitats are integrated into a passive park setting of trails, boardwalks, educational facilities, and natural landscaping. Operated by the Collier County Growth Management Division and the Parks and Recreation Department, the system uses wetlands to reduce nitrogen and phosphorus in water pumped from ditches draining the watershed.

A versatile educational facility supports multiple civic functions that sustain a steady increase in visitor use. Since system startup in October 2009, water quality samples have been collected during the June to October rainy season to assess concentration reductions in nitrogen, phosphorus, and trace metals. Annual review of the ecological monitoring transects in the restored section of the park has been conducted to document the effectiveness of removal of non-native vegetation, a common management technique in south Florida. This article summarizes key findings of monitoring during the period from 2009 through 2013 and documents how Freedom Park provides an illustrative example of a treatment wetland project that provides multiple ecological and social benefits.

James S. Bays is with CH2M HILL in Tampa and Margaret Bishop is with Collier County Government in Naples.

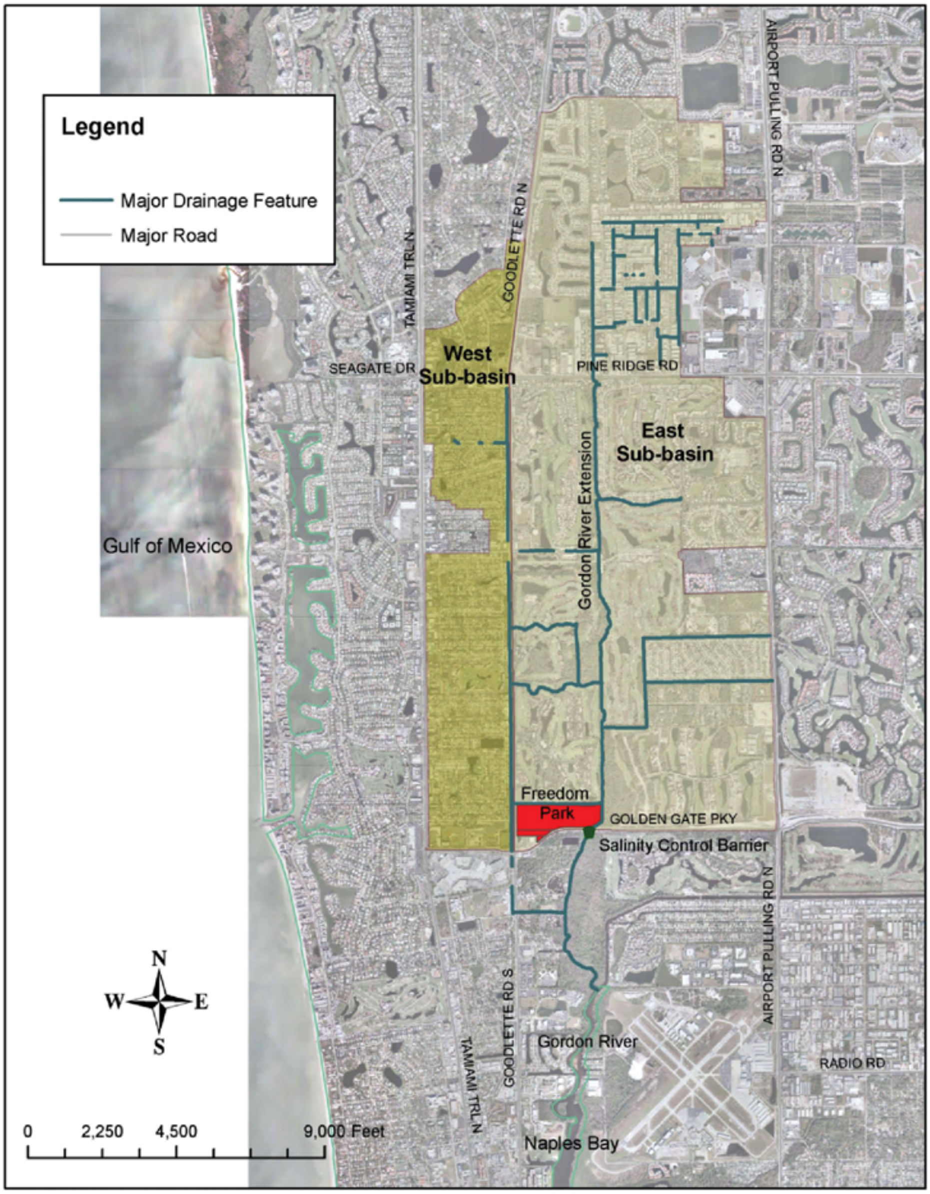

Figure 1. Freedom Park Location: Watershed and Major Drainage Features
(Source: Collier County Growth Management Division)

The Gordon River discharges to Naples Bay, a subtropical estuary in southwest Florida. The highly urbanized watershed of the Gordon River totals 1,762 ha (4,362 acres) in area and includes a significant proportion of the City of Naples. Extensive drainage systems accelerate runoff to the river and estuary, which exhibit classic symptoms of eutrophication and urban pollution. Two large sub-basins comprise the Gordon River watershed, which is divided east-west by urban arterial highway Goodlette-Frank Road: the 389-ha (961-acre) West Sub-Basin and the 1,377-ha (3,401-acre) East Sub-Basin (Figure 1). The project area is sited to treat flow conveyed by the drainage ditch parallel to Goodlette-Frank Road.

As shown in Figure 1, Gordon River has been modified significantly. Ditches extending north and east in the East Sub-Basin have increased the aerial extent of the watershed. An adjustable tidal barrier, located immediately downstream of Freedom Park, has been in place since the 1970s to prevent salinity intrusion.

The West Sub-Basin is predominantly residential land use (72 percent) and the East Sub-Basin is approximately 40 percent residential and 21 percent recreational land as a golf course (Table 1).

The Florida Department of Environmental Protection (FDEP) has determined that the river and its watershed are impaired. To address these impacts, the Gordon River Master Plan was developed in 2002, which quantified watershed loadings and appropriate best management practices suitable for detaining runoff and improving water quality in stormwater discharges, with the objective of reducing loading to downstream Naples Bay.

The 20-ha (50-acre) Fleischmann Tract, located near the terminus of the watershed, was identified as an appropriate location for placement of a water storage and treatment facility. About two-thirds of the parcel was an abandoned orange grove; the remainder consisted of a drained cypress floodplain swamp, infested with exotic Brazilian pepper and other non-native plants.

The county purchased the Fleischmann Tract in 2004 with funds that were reimbursed with a grant from the Florida Communities Trust. Significant financial support was provided by the South Florida Water Management District (SFWMD). Freedom Park cost $30.5 million, of which land acquisition was $19.2 million, design was $1.3 million, and construction was $10 million. The project was funded by $6 million from Florida Communities Trust for construction, $1.5 million from SFWMD for design and construction, $10 million from the SFWMD Big Cypress Basin allocation for property purchase, $2.7 million from transportation impact fees, and $10.3 million in ad valorum taxes for design, purchase, and construction.

Through this project, the county was responding to a long-standing community interest to conserve the property from development, while creating an opportunity to achieve the stormwater management objectives established by the master plan.

The project was designed to accomplish the following goals:

- Develop a stormwater management facility that will reduce pollution in the Naples Bay and Gordon River, and alleviate flooding within the Gordon River Basin.
- Create an aesthetically pleasing passive educational/recreation park facility, which not only minimizes environmental impacts but also helps create a natural habitat of native flora and fauna.

Table 1. Gordon River Watershed Land Use Composition
(Source: Collier County Growth Management Division)

	West Sub-basin		East Sub-basin		Total	
Land Use	**Hectares**	**%**	**Hectares**	**%**	**Hectares**	**%**
Residential, Low Density	55.7	14.4	54.6	4	110.2	6.2
Residential, Medium Density	197.7	50.8	329.9	24	527.7	29.9
Residential, High Density	30.1	7.7	159.9	11.6	190.0	10.8
Commercial and Services	58.5	15	38.6	2.8	97.1	5.5
Industrial	0.0	0	149.4	10.9	149.4	8.5
Institutional (schools)	14.0	3.6	21.7	1.6	35.7	2.0
Recreation (golf courses)	6.7	1.7	289.4	21	296.2	16.8
Open Land and Upland	0.0	0	109.9	8	109.9	6.2
Ponds, Lakes, and Waterways	7.9	2	71.8	5.2	79.7	4.5
Wetlands	4.9	1.3	124.0	9	128.9	7.3
Major Roads	13.6	3.5	26.1	1.9	39.7	2.2
Land Use Totals (Area and Percent)	389.1	100	1376.9	100	1766.0	100

Figure 3. Freedom Park Wetlands in Naples

Ecological Innovation: Building from Everglades Experience

The design of the project began in June 2005, and construction began in December 2007. The project was substantially complete in June 2009 and the grand opening was held in October 2009. Freedom Park includes full-scale demonstrations of constructed treatment wetlands and natural wetland restoration techniques, including the design of a stormwater pond, constructed treatment marshes, wetland restoration, upland plantings and passive recreational park facilities, and a 232-m^2 (2,500-sq-ft) environmental education facility. Siting Freedom Park in urban Naples required new access roads and modifications to improve site stormwater conveyance.

The treatment system consists of a 1.9-ha (4.7-acres) pond for stormwater storage, followed by 2.7 ha (6.7 acres) of constructed marshes designed to enhance stormwater polishing by submerged aquatic vegetation and native herbaceous marshes that remove harmful pollutants from the stormwater and river water prior to discharge to the on-site natural wetlands (Figure 3). The shallow (15-30 cm; 0.5-1.0 ft) marshes are populated with native emergent marsh species, including pickerelweed, spikerush, sawgrass, duck potato, and fireflag (Figure 4). Deep marshes (1.3 m; 4 ft) include white water lily, as well as native species of submersed aquatic vegetation, and are interspersed within each wetland for hydraulic, habitat, and solids storage benefits.

Borrowing Everglades-type passive stormwater treatment technologies, the terminal marsh zone of Wetland Cell C is built on a shallow layer of limestone to encourage periphyton growth for enhanced phos-

Continued on page 48

Continued from page 47
phorus removal by a passive periphyton marsh (Bays et al, 2001).

Water is pumped from contributing ditches during the wet season using a 3,785-Lpm, or 1,000-gal-per-min (gpm), pump station to the pond, which is sized to store over 14 megaliters (ML), or 3.7 mgal, equivalent to the volume captured during a once-in-25-year storm event. Water flows through the pond by gravity to and through 2.7 ha (6.7 acres) of constructed wetlands.

Figure 4. Typical View of Freedom Park Wetland Vegetation. Deep zones are fringed by floating-leaved aquatics, such as water lily (upper part of photo). Emergent marsh zones are vegetated with native freshwater marsh species, including fireflag, pickerelweed, spikerush, sawgrass, and duck potato (lower part of photo).

Flow from the constructed wetlands discharges passively to 5.8 ha (14.35 acres) of restored cypress floodplain swamp contiguous to the Gordon River.

A second 946-Lpm (250-gpm) pump station takes water from the Gordon River during periods of low flow to the wetlands for additional treatment, and as a hydration source. This second mode of treatment is designed to contribute to reduction of base flow loads to Naples Bay and support year-round use of the site.

Hydraulic Operation

The natural seasonal variation in runoff from the watershed drives the hydraulic operation of the constructed wetland system. Figure 5 illustrates the typical seasonal operation of the Freedom Park wetlands.

Consistent measurement of flows at the inflow pump station began in 2009, and the data from 2010-2011 are considered to be good estimates of pump-station flows, in general. Inflow meter values compared directly in 2011 to separate meter measurements made by strapping a National Institute of Standards and Technology (NIST) flow meter onto the inflow pipe in the pump, and were found to be within an error range of at least 10 percent (T. Denison, pers. comm., 2012).

In 2010, during the rainy-season months of July to November, nearly 568 ML (150 mgal) of stormwater runoff were pumped into Lake A to be treated by the wetland cells. During the same period in 2011, almost 681 ML (180 mgal) of stormwater runoff were pumped into Lake A. Only about 76 ML (20 mgal) of stormwater runoff were pumped into Lake A during the dry season months of December to June, for a total of about 757 ML (200 mgal) of stormwater runoff pumped in for the year.

Flow measurements from the Gordon River pump station are preliminary, given the limited time the system has been in operation, but the amount of water being pumped into the constructed wetland system from Gordon River is minor compared to the substantial amount of stormwater runoff inflow described. Only about 23 ML (6 mgal) of water were pumped into the constructed wetland system from the Gordon River pump station during the 2011 calendar year, with about 15 ML (4 mgal) of that being pumped in during the July through November rainy season.

Representative flow data are summarized in Table 2. Hydraulic loading to the wetland system ranged from 8.1-9.7 cm/d (3-4 in./day) to <1 cm/d (<0.4 in./day) during the dry season. Over 2011, the weighted average hydraulic loading rate was 4.5 cm/d, a rate greater than recent average hydraulic loading to the Everglades stormwater treatment areas (STAs), which ranged from 0.6 to 2.6 cm/d (0.2-1.0 in./d) across the different STAs (SFWMD, 2014).

The hydroperiod of the constructed wetlands are highly seasonal, with standing water present and only predominating during pumping in the summer wet season. Continuous water-level records during 2012 in Wetland C indicated an inundation duration of 111 days, or approximately 30 percent, with an average marsh depth of 60 cm during inundation. Standing water was present continuously from mid-June through the end of October, with periods of standing water averaging two weeks in December, March, and April in response to seasonal frontal storms.

In the restored wetlands, hydroperiod measurements for 2012 showed a similar duration from June through October, but average water depths were shallower (15 cm; 0.5 ft), with frequent peaks of 45 cm (1.5 ft).

Water Quality Performance

The project was designed to reduce phosphorus and nitrogen concentrations in stormwater and pumped river base flow. Figures 6 and 7 show time series of inflow-outflow data collected between 2008-2013 for total phosphorus (TP) and total nitrogen (TN), respectively. Water samples have been typically collected during the summer rainy season when water is being pumped through the wetland, and are representative of normal operating conditions. Median concentrations of TP have been reduced 84 percent from 0.210 mg/L in the watershed stormwater to a wetland outflow of 0.033 mg/L. Outflow TP concentrations have ranged from 0.011 mg/L to 0.090 mg/L, in contrast to inflow TP, which has ranged from four to 10 times greater, from 0.10 mg/L to 0.33 mg/L, with one spike up to 1.77 mg/L. This performance range is consistent with the Everglades STAs, where period of record inflow average concentrations have been reduced by 74 percent from 0.140 mg/L to 0.037 mg/L (SFWMD, 2014).

The TN showed a 41 percent reduction in median concentrations from 1.47 mg/L

Continued on page 50

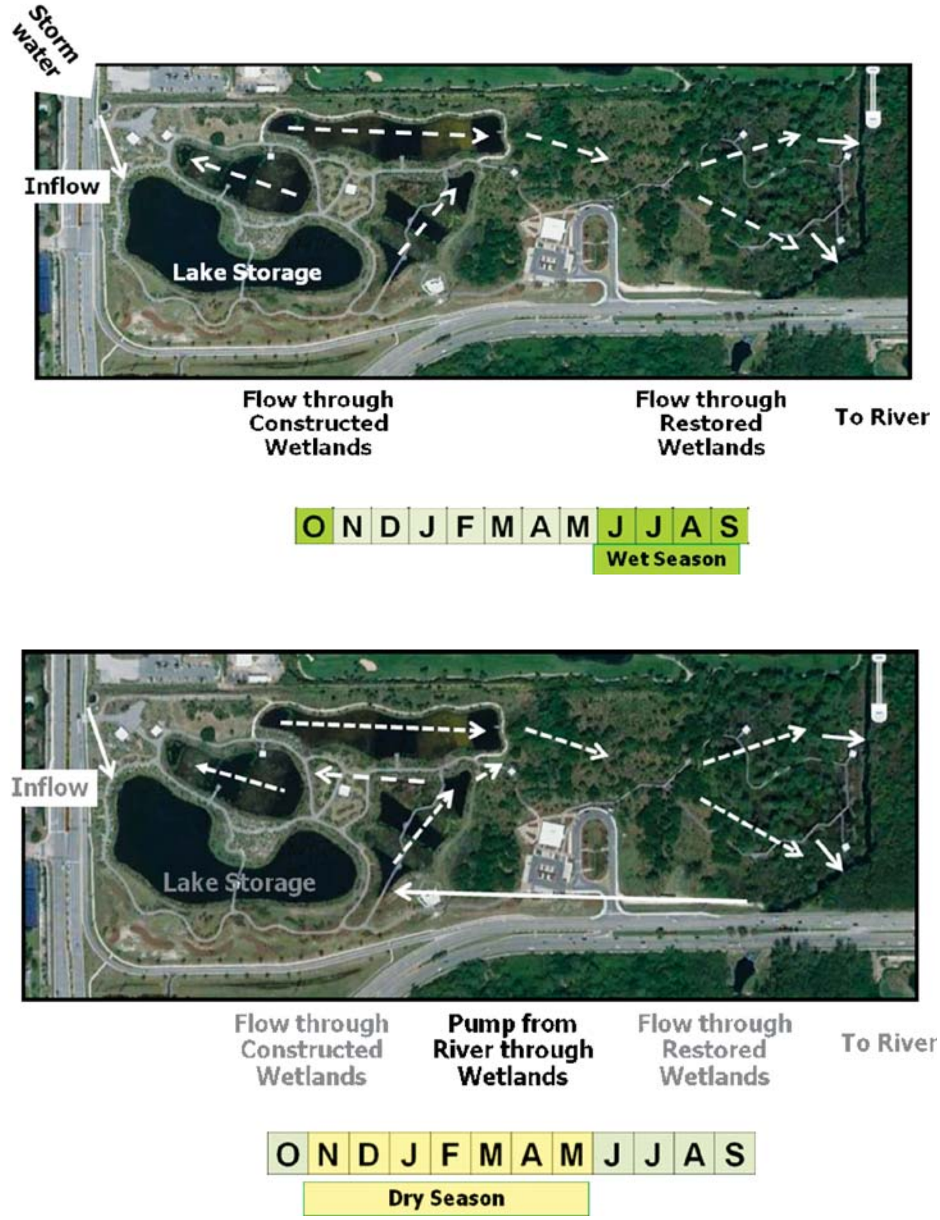

Figure 5. Seasonal Modes of Operation. Stormwater from the watershed drainage provides the primary source of water through the wet season (June-November) and as significant rainfall occurs during the remainder of the year. For the dry season (December-May), a lesser amount is pumped from the Gordon River to the lake.

Table 2. Pumped Flow Summary, 2010-2011

Season	Year	Gallons ($x10^6$)	m^3	m/season	cm/d
Jul-Nov	2010	150	567,750	12.28	8.08
Jul-Nov	2011	180	681,300	14.74	9.70
Dec-May	2011	20	75,700	1.64	0.77
Total	2011	200	757,000	16.38	4.49

Continued from page 49

to 0.87 mg/L. Outflow nitrogen concentrations are predominantly organic nitrogen, and represent the attainable background. Outflow concentrations ranged from 0.53 mg/L to 1.27 mg/L, consistent with the concept that constructed wetland TN reductions are constrained to an irreducible background of organic nitrogen contributed by internal cycling (Kadlec and Wallace, 2009). In contrast, stormwater inflow concentrations ranged approximately two times more from 1.11 mg/L to 2.31 mg/L.

When sampled in 2011 and 2012, the median TP concentration in the Gordon River downstream of the discharge from the wetland was significantly lower in the river (0.10+0.03 mg/L) than in the stormwater (0.21+0.05 mg/L; $p<0.05$). Median stormwater TN concentrations of 1.58+0.35 mg/L were significantly greater than the river TN of 1.21+0.31 mg/L difference ($p<0.05$). Given that the stormwater historically was conveyed directly to the river without the benefit of treatment, and that both East and West watersheds contributing to the Gordon River are similar in land use, the relatively lower TN and TP concentrations in the river suggest that the treatment wetland discharge is contributing to a cumulative reduction in river nutrient load to the bay.

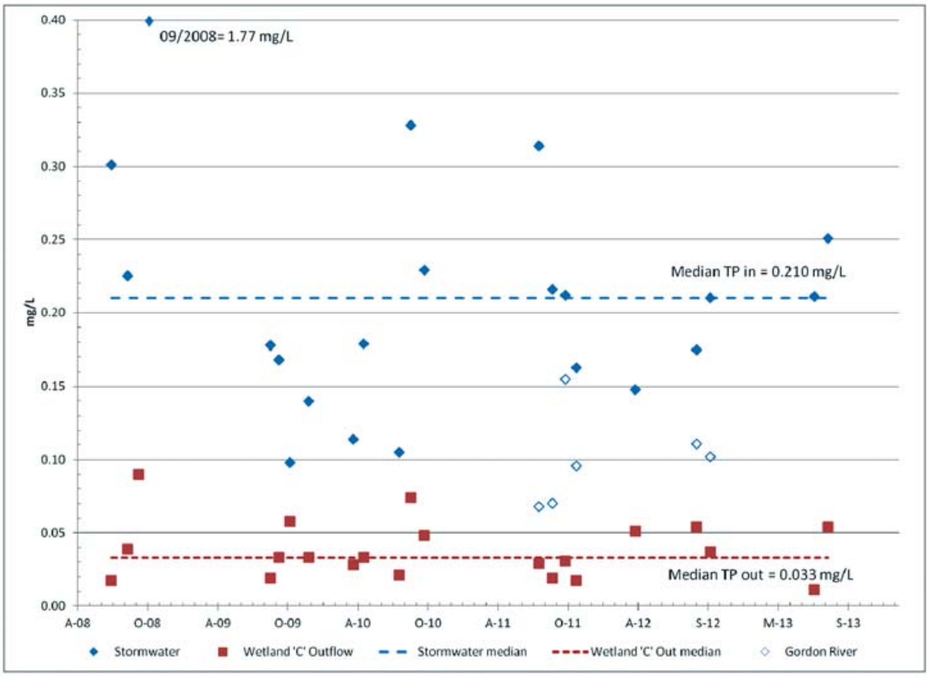

Figure 6. Total Phosphorus Inflow and Outflow Concentrations: 2008-2013

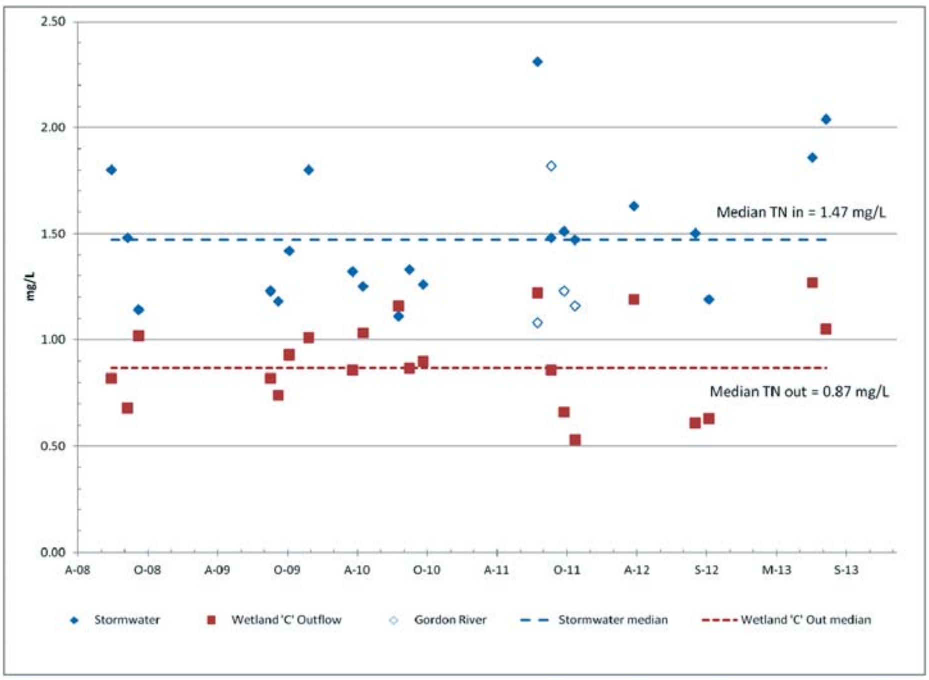

Figure 7. Total Nitrogen Inflow and Outflow Concentrations: 2008-2013

These performance values are consistent with other treatment wetlands receiving similar inflow mass loading with similar inflow concentrations (Kadlec and Wallace, 2009). The TP removal rate for 2012 averaged 1.34 $g/m^2 \cdot yr$ for 2012, consistent with Everglades STAs TP removal rates of 0.3 to 1.7 $g/m^2 \cdot yr$ (SFWMD, 2014). The TN removal rate of 9.4 $g/m^2 \cdot yr$ is consistent with removal rates for similarly loaded wetlands; wetlands receiving urban stormwater at an average hydraulic loading rate (HLR) of 5.4 cm/d achieved a 45 percent reduction on average (Kadlec and Wallace, 2009).

Inflow stormwater concentrations did not exceed state water quality standards for common metal contaminants in stormwater, but significant reductions were observed through the wetland. Measured reductions in median inflow concentrations for arsenic, copper, iron, and zinc have averaged 39, 35, 75, and 60 percent, respectively; median outflow concentrations were 5.16, 1.44, 51.3, and 5.05 µg/L, respectively. The final concentrations of all nutrients and metals are consistent with expectations of "background" concentrations for constructed marshes in this region, and well below observed ecological effects thresholds.

Other parameters monitored simultaneously with the nutrient parameters include dissolved oxygen and chlorophyll *a*. Table 3 provides an overview of representative samples taken during 2011. Dissolved oxygen is typically greater discharging from the wetland system than entering, and well above the state water quality standard. This difference can be attributed to the loss of oxygen demanding materials from the inflow, the passive aeration occurring in extensive open deep water zones, and the abundance of periphyton and submersed aquatic vegetation near the outlet. The reduction in chlorophyll *a* is attributable to wetland reduction of nutrients.

Site Wetland Restoration Progress

As part of the conceptual intent of the project, existing wetlands on the property would be restored through removal of non-native plant species, and planting with native species would supplement site biodiversity. As a specific requirement of the Environmental Resource Permit issued by SFWMD, the minor impact necessary to 0.2 ha (51 acres) of altered wetlands on-site would be mitigated by the restoration of 5.1 ha (12.5 acres) of on-site habitat, including 4.25 ha (10.5 acres) of wetland and 0.8 ha (2.0 acres) of uplands. The restored area would be placed under a conservation easement and managed in perpetuity. Water discharged from the treatment wetlands diffuses through the restored wetland, providing a supplemental source of hydration on a rainfall-driven schedule.

Six transects are monitored at representative locations within the natural wetland habitats on-site (Johnson Engineering, 2008). Non-native plant removal activities performed after each annual report targeted non-native species with an objective of suppression of regrowth.

Following the initial baseline characterization monitoring, non-native species were manually removed, follow-up control efforts were implemented, and supplemental plantings completed. By the third year, the canopy composition had returned to an assemblage of native wetland trees, including cypress, cabbage palm, red maple, white mangrove, and Carolina willow, and shrubs such as wax myrtle and groundsel, completely replacing the non-native cover of Brazilian pepper, earleaf acacia, downy rose myrtle, and other species once abundant in the area (Johnson Engineering, 2011).

In response to the extensive non-native plant control activities during the site restoration, median total canopy cover declined from 91 to 43.5 percent. With the canopy opened, and additional saplings planted, the median total cover has steadily increased since the time zero monitoring to approximately 65 percent. Similarly, the reduction in non-native species in the overstory canopy opened up the groundcover to a more natural light environment. Groundcover was variable, but generally low during the baseline monitoring. Median groundcover values have increased from 37 percent during baseline to 76 percent. The total number of groundcover species ranged from 25 to 36 by transect during the third-year monitoring.

Table 3. Dissolved Oxygen and Chlorophyll *a* in 2011 (Average + St. Error)

	Dissolved Oxygen (mg/L)	Chlorophyll a (ug/L)
Stormwater	5.11±1.48	14.08±3.68
Gordon River	5.86±1.53	11.19±4.67
Wetland Outflow	7.64±1.45	4.56±1.04

Figure 8. Interpretive Center, Freedom Park

Operation and Maintenance

Operating costs totaled $54,580 for 2011; of this, the power cost to operate the pond and wetland pumps totaled $10,600. The remainder of the cost is attributable primarily to vegetation management to control non-native species colonization of the constructed and natural wetlands, a common recommendation in subtropical Florida and one that is necessary to meet state wetland permit requirements.

A Vital, Growing Resource to the Community

The education facility includes restrooms, six lookout pavilions, water fountains, and walking trails (Figure 5). Educational and information signage is available throughout the park. Workshops were conducted with the public during the design process to capture community input. The proximity of the project to other significant environmental centers on the Gordon River, such as the Conservancy of Southwest Florida, provides a cumulative regional benefit.

The project combines wetlands, habitats, trails, boardwalks, observation gazebos, educational facilities, and extensive indigenous landscaping within a passive park setting. The sustainably designed 232-m^2 (2,500-sq-ft) educational center provides a center of activity to the park and is both an origin and destination to site visitors. The park hosts 1,158 m (3,800 ft) of boardwalks and 3.2 km (2 mi) of walking trails. Elevated forest boardwalks allow visitors easy access to the restored cypress floodplain habitats. Multiple pavilions are located throughout the restored wetland for shade, resting, and birding.

Public use of the park is extensive and increasing. Annual total visitor counts have increases steadily from 18,540 in 2010 to over 24,000 in 2013. These values are presumed to be underestimates, as tallies are for a 40-hour staff work week and do not include after-hour totals. The number of users can vary six-fold daily, from 50 per day in the summer to 300 per day in the winter.

Continued on page 52

Continued from page 51

Collier County Parks and Recreation offers over 40 programs with over 1000 participants in the educational facility. The park supports volunteer efforts, and arrangements can be made to utilize the educational facility by the public for meetings after dusk. A farmer's market is held at the interpretive facility on weekends. High-quality interpretive signs are located along all trails and wildlife observations are kept by volunteer interpretive staff.

As measures of the value of the site to the public and the stormwater treatment community, Freedom Park received "Design of the Year" in 2009 from Southeast Construction magazine, "Project of the Year" in 2010 from the Florida Association of County Engineers, and the "Stormwater Excellence" award in 2011 from the Florida Stormwater Association.

Conclusions

Freedom Park is a successful example of an innovative natural stormwater facility design that provides multiple benefits, while achieving new standards of wetland park landscape design. As a stormwater treatment system, Freedom Park detains stormwater before discharge to the Gordon River, lessens chronic flooding concerns in adjacent neighborhoods, and improves river water quality by wetland treatment of stormwater and baseflow. As an ecological system, Freedom Park restores and rehydrates rare subtropical bald cypress floodplain swamp wetlands, and conserves upland and wetland habitats for public open space in a developed urban area. As a community asset, the park is a valued facility well-suited for a range of passive recreational uses, and serves as a state-of-the-art public center for environmental education and nature study.

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