Natural Wetlands for Stormwater Management At NASA's Kennedy Space Center VAB Complex

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In 2002 the National Aeronautics and Space Administration (NASA) constructed a natural wetland stormwater management system as part of a project to replace temporary trailer housing with a new office building in the Vehicle Assembly Building (VAB) area at the John F. Kennedy Space Center. Several small stormwater wet detention ponds were proposed to meet permitting requirements for the new structure, which was named Operations Support Building (OSB) II, but the land area needed for treatment ponds would have required expensive relocation of personnel and existing underground utilities.

An alternative stormwater management system was designed, permitted, and constructed—a system that relied on pretreatment of surface runoff in swales and canals and final polishing in previously impacted natural wetlands.

An existing 63-acre wetland on the south side of the OSB II building site offered an ideal setting for natural stormwater attenuation. Ditching and surrounding land-use alterations had historically changed the hydrology and ecology of this mixed wetland-plant community, and predesign studies indicated that it was technically feasible to enhance the functional wetland attributes of the system by augmentation with treated stormwater.

A number of important ecological benefits were anticipated as a consequence of utilizing this natural wetland for stormwater attenuation. Originally constructed in the 1960s before regulatory requirements for stormwater treatment, the VAB area incorporated minimal attenuation or treatment of stormwater runoff from buildings, roads, and parking lots. Prior to the OSB II project, stormwater runoff from the larger VAB area sheet-flowed into a ditch that ran along the northern edge of the existing wetland area.

In addition to routing stormwater away from OSB II, this ditch had two detrimental functions. First, it discharged untreated stormwater without significant retention or water-quality treatment directly into the barge turning basin, which is connected to the Banana River, since designated as an Outstanding Florida Water (OFW). The turning basin was constructed to allow barge access from the Atlantic Ocean to the Kennedy Space Center. When the north ditch, barge turning basin, and barge canal were constructed, they provided a man-made connection between the 63-acre wetland and waters of the state.

Second, in concert with other drainage efforts in the natural wetland, this canal altered the wetland's natural water regime by accelerating drying of the wetland during low rainfall periods.

This project provides a potential win-win situation since it will 1) treat stormwater from the OSB II site and larger grandfathered VAB area, 2) restore the natural wetland hydroperiod, 3) improve downstream water quality in the Banana River OFW, and 4) reduce avoidable OSB II costs.

Structural modifications comprising the VAB natural wetland stormwater management system consist of two ditch blocks, six level-lip inlet spreaders, and an outlet control structure. The two ditch blocks hold stormwater runoff in the north ditch and the contiguous Instrumentation Road ditch, preventing short-circuiting to the turning basin. Adequate detention time is provided in these canals to allow preliminary treatment of stormwater before it flows into the natural wetland via the six evenly spaced level-lip inlet spreaders.

A low berm and weir were constructed near the outlet of the wetland to allow greater retention of storm flows and the gradual release of this water downstream. This outlet control structure consists of a level-lip weir with a one-foot-deep notch designed to allow a storm event bleed-down time of about 96 hours (four days). Water is detained within the wetland during peak storm events, resulting in the potential for water-quality polishing, peak-flow attenuation, and increased hydroperiod in the wetland plant communities. Polished water from the natural wetland stormwater management system ultimately discharges via the outlet control structure to the barge turning basin and out to the Banana River.

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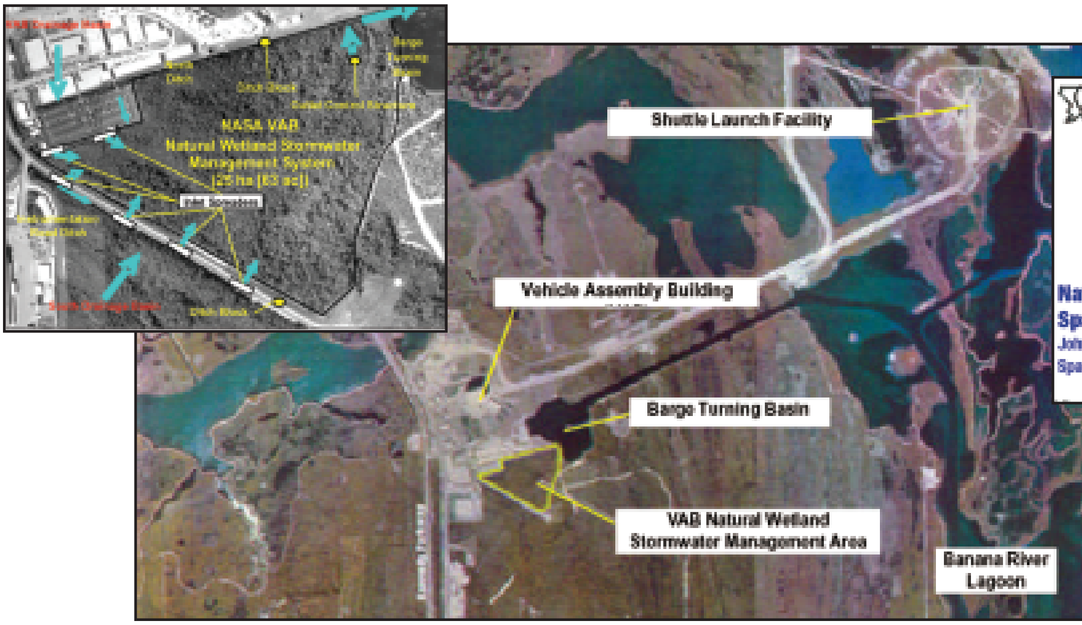
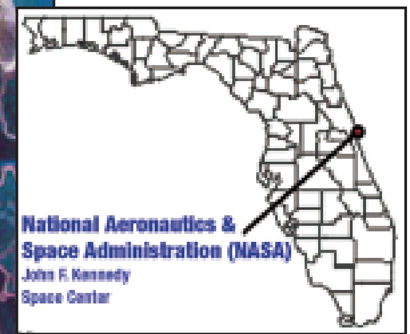
Cost Savings

The system was designed, permitted, and constructed for $353,000. The project immediately saved NASA $3 million by not relocating personnel and utilities in order to construct traditional stormwater ponds. A 20-year life-cycle cost study that took into account design, permitting, construction, post-construction permit monitoring, additional costs for structural backfill material, additional operation and maintenance costs, not moving personnel, and not relocating utilities indicated a $2.2 million savings.

NASA's Vehicle Assembly Building at the Kennedy Space Center is being served by an ecologically engineered stormwater management system.





The NASA VAB Natural Wetland Stormwater Management System is located at the Kennedy Space Center in Brevard County, Florida.

Monitoring Requirements

The Environmental Resource Permit (ERP) issued for this project has specific monitoring requirements to determine the effectiveness of the stormwater management system for providing water-quality and wetland benefits. Surface-water hydrology and water quality are quantified to determine water and pollutant mass balances within the project boundaries. Biological monitoring assesses changes to the existing wetland plant communities, as well as the effects of the project on populations of threatened and endangered species.

Surface-Water Monitoring Plan

In April 2002, four digital pressure-transducer water-level recorders were installed at the north ditch, within the wetland, upstream of the discharge weir, and downstream near the outfall to the barge turning basin. Each recorder was installed on a 5-cm (2-in) well casing sitting on the ground surface (except the internal wetland recorder, which is buried in the ground to monitor water levels above and below ground). The recorders were set to measure and record water levels every two hours.

Water-level data were first downloaded in May 2002 before the completion of construction to examine hydrologic patterns at the four water-level stations prior to the discharge of stormwater to the wetland. Water-level data continue to be downloaded on a quarterly basis since the stormwater management system became operational. Water levels were also measured quarterly at staff gauges located adjacent to the continuous water-level recorders at the time the water-level data were downloaded from the recorders. The staff gauge data provided a visual quality-control check for confirmation of the water-level recorder measurements. In addition, water levels were measured at staff gauges in each of six vegetation monitoring plots semiannually when vegetation was monitored.

Water mass balances were estimated to determine the volume of water entering and exiting the stormwater wetland system. Inflows to the wetland originated as runoff from the VAB complex (VAB drainage basin = 51 acres) and as runoff from a larger undeveloped watershed and natural wetland south of Instrumentation Road (south drainage basin = 188 acres). These inflow volumes were estimated based on rainfall, basin areas, and standard runoff coefficients.

Outflows from the wetland project can occur at two locations: from the outlet control structure and as overflows at high-water stage over the ditch block in the north ditch. Flows at these locations were estimated based on upstream and downstream water-level measurements and estimated weir characteristics.

Rainfall data were recorded by NASA adjacent to the project site. Daily evapotranspiration (ET) is estimated from pan evaporation data reported at Lisbon, Florida (Coop ID 085076, NOAA), using a pan factor of 0.77 (Kadlec and Knight, 1996).

Five water-quality sampling stations were established to characterize surface-water quality in the pretreatment ditches (north ditch and Instrumentation Road ditch stations), an interior station within the wetland, at the outfall of the wetland, and downstream of the wetland at the edge of the barge turning basin. Baseline water-quality samples were first collected in April 2002 to characterize preconstruction water-quality conditions. Since the project became operational in July 2002, water-quality samples have been collected quarterly.

Field measurements for pH, specific conductance, dissolved oxygen (DO), and temperature were made when surface-water samples were collected. Surface-water samples were collected into prepreserved sampling containers. A duplicate sample and samples for laboratory quality control were also collected during each quarterly event.

The following analyses were performed on the surface-water samples: oil and grease, five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), orthophosphate, total phosphorus (TP), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total hardness, mercury (Hg), arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn).

Pollutant mass balances were estimated for TP, total nitrogen (TN), NH_4-N, NO_3-N, organic nitrogen, BOD_5, and TSS. Mass balances were calculated by multiplying the surface-water concentrations by estimated flows from the water balance to estimate loads. From these estimated inflow and outflow loads, estimated water-column load reduction efficiencies were calculated to determine how much assimilation capacity exists in the wetland for assessing the effects of current and future stormwater discharges. Rainfall constituent concentration inputs were estimated from Kadlec and Knight (1996) for the above parameters.

Internal biological cycling of carbon, nitrogen, and phosphorus were not estimated for these mass balances. In this respect, the estimated mass balances are "black box" estimates that evaluate only inputs and outputs in the water column and do not include all flows such as atmospheric exchanges of car-

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One of the six level-lip spreaders that distribute pretreated stormwater runoff into the VAB Wetland.

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bon and nitrogen, and internal cycling of nutrients from the water and soil to the trees and back to the water as leaf litterfall. These internal cycles are especially significant when stormwater pollutant mass loading rates are low, as they were during the first year of system operation. Outflow water quality is expected to be near ambient conditions under low inflow concentrations and loading rates.

Biological Monitoring Plan

Six vegetation monitoring stations were established prior to construction of the stormwater management system to document any habitat changes that may result from the addition of stormwater. Vegetation monitoring quadrats (10 x 10 m or 33 x 33 ft) were established in six different vegetation communities, including mesic hardwood hammock, forested hardwood wetland, oak/palmetto upland, emergent marsh, cabbage palm hammock, and wetland shrub.

Baseline vegetation data were collected in April 2002 prior to construction of the stormwater management system to document preconstruction vegetative conditions. Since project startup, vegetation has been monitored twice each year, in the fall and spring. All canopy and subcanopy trees were marked with a numbered aluminum tag, assessed for condition, and measured for diameter at breast height (DBH). Shrub and herbaceous plants were monitored at the same times each year using a line-intercept method to estimate percent cover.

Initial observations of the presence or absence of wildlife species listed as endangered, threatened, or of special concern (i.e., listed species) were made during the post-construction time period. Since project start-up, observations of listed species were made in conjunction with all semiannual vegetation monitoring events.

First-Year Operational Monitoring Results

Water Levels

Water levels in the VAB natural wetland stormwater management system rose following the end of construction in response to the new control elevations and the onset of the normal summer rainy season. Based on a comparison of limited baseline wet- and dry-season data, average water levels appear to have risen from about 9 to 46 cm (0.3 to 1.5 ft) as a result of the project.

Lower water levels were again measured in May 2003 following the normal spring dry period. Based on periodic staff gauge readings, standing water was not recorded in the oak/palmetto flatwoods or in the cabbage palmetto uplands, which are the driest of the plant communities. Saturated soil conditions were observed in the mesic hardwood hammock during the first year, and shallow surface water less than 15 cm (0.5 ft) deep and saturated soil conditions were noted in the forested hardwood hammock. The shrub wetland plant community station was flooded with an average water depth of about 22 cm (0.72 ft), and the emergent marsh station near the wetland outflow had an average water depth of 67 cm (2.2 ft) during the first operational year.

Water Mass Balance

A water mass balance was estimated for the first operational year from July 2002 through June 2003. This water balance indicated that the wetland received an average daily inflow of about 3,939 m^3/d (1.0 mgd), with a daily peak inflow about 30 times higher than the average flow. About one-fourth of this water was from the NASA VAB complex, and the remainder was from the semi-natural watershed located south of the wetland. Almost all of this water flowed through the wetland, resulting in a total estimated surface-flow hydraulic loading rate of 1.5 cm/d (4.1 in/wk) and a maximum monthly hydraulic loading rate of 3.1 cm/d (8.5 in/wk).

The nominal hydraulic retention time in the VAB natural wetland stormwater management system was estimated to be 3.8 days, based on average wetland water levels and inflows during the first year of operation. Before this project was implemented, water was intercepted by the ditches rather than allowed to enter the wetlands and short-circuited around the wetland. Water-retention time in the ditches was probably a few hours before it discharged to the barge turning basin. That hydraulic alteration has now been eliminated with construction of the ditch block in the north ditch. This water balance indicated that the majority of this flow was traveling as gradual sheetflow through the wetland and only a small flow (less than 0.5 percent) bypassed the wetland directly to the barge turning basin.

Surface-Water Quality

Quarterly surface-water quality data from the first year of operation indicated that inflow stormwater runoff quality from the NASA VAB area was generally quite good. Concentrations of BOD, TSS, and nitrogen forms were all near normal surface-water background levels at the point of discharge into the wetland and at various points through the wetland flow path. Concentrations of phosphorus were somewhat elevated in the pretreatment ditch (average 295 μg/L) but were significantly reduced as water flowed through the wetland (average 79 μg/L at the outfall). Concentrations of BOD_5, TSS, and TN were essentially at normal wetland background concentrations at the outflow weir. None of the concentrations for trace metals or hydrocarbons were elevated in the stormwater runoff or in the wetland.

Pollutant Mass Balances

Mass loads of all constituents except phos-

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One of four water level recorders at the VAB Wetland Site.

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phorus were higher from the south drainage basin than from the VAB area. Although there were similar constituent concentrations in the inflow from both drainage basins, the higher overall inflow volume from the south drainage basin contributed to the higher mass loads. Based on these estimates, there was a slight increase in the mass of BOD and TSS with flow through the wetland (negative mass removals) and positive mass removals for TKN, NO_3-N, TN, TP, and orthophosphate.

Of most significance from a water-quality improvement standpoint were the estimated 19-percent mass removal of NO_3-N and 43-percent mass removal of TP. Wetlands have a background, irreducible concentration for all of these parameters, and the slight concentration increases seen for BOD and TSS are typical of systems receiving low input loads. These increasing loads reflect leaf fall and decomposition resulting from primary productivity of the indigenous vegetation in the wetland.

Wetland inflow samples reflect typical water-quality conditions in the pretreatment system and are not a direct reflection of water quality of the untreated runoff; however, routine water-quality sampling can miss the effects of actual storm events and the "first flush" loading of pollutants from developed landscapes. For this reason, the inflow concentrations estimated in this study may underestimate the inflow pollutant mass loads to the wetland, and the wetland mass removals may be greater than those estimated in this study.

Data for the first operational year indicated that the VAB natural stormwater management system was working as expected. Relatively low pollutant loads from the VAB drainage basin remained after water had been trapped and treated in the pretreatment system surrounding the wetland. After detention and treatment, this cleansed water discharged into the wetland, where residual pollutants were naturally assimilated prior to discharge of water at background surface-water quality conditions to the downstream receiving waters. The natural stormwater management area provided significant potential for polishing stormwater quality before discharging into the barge turning basin, and ultimately to the Banana River.

<u>Vegetation</u>

Overall, positive trends were documented in the canopy and subcanopy vegetation after the first operational year and suggested that the introduction of stormwater did not have a deleterious effect on the tree species. Instead, typical survival and growth occurred during the first year of operation. No tree mortality was observed in the six vegetation monitoring plots; however, early tree senescence was noted in nine individuals, primarily Carolina willows. This species will continue to be closely monitored to assess its response to the increased hydroperiod. An increase in basal area of 0.7 to 3.3 m^2/ha was measured in all monitoring plots with canopy and/or subcanopy trees. This increase in canopy and subcanopy basal area represented net positive growth during the first year of stormwater input, as well as recruitment of a few new individuals into the shrub-size category.

The Outlet Water Control Structure consists of a level-lip weir with a bleed-down notch and a skimmer.

Groundcover was assessed both qualitatively and quantitatively to determine if changes were occurring to the wetland during the first year of stormwater management. Groundcover vegetation is likely to be most sensitive to changes in water regime, and it is considered likely that groundcover within the wetland will change in response to the intentional increased hydration resulting from this project.

There were no consistent trends in groundcover vegetation after the first year of operation. Some vegetation monitoring plots experienced an overall increase in groundcover vegetation, while other plots experienced variable changes or decreases in groundcover vegetation. There were also inconsistent patterns among different vegetation species. Some species increased in dominance, other species declined in dominance, and still other species fluctuated in dominance. It is suspected that groundcover species responded disparately to stormwater input; however, this dataset is probably too limited to draw any specific conclusions regarding future groundcover trends.

Continued vegetation monitoring will provide a clearer pattern of these trends in the future. Control structures were designed to allow a minimal increase of water depth in the wetland. Multiple inspections during the first year of operation showed that the drier sites such as the oak/palmetto upland and cabbage palm hammock are high enough topographically to not experience inundation as a result of stormwater input.

<u>Threatened and Endangered Species</u>

The natural wetland stormwater management system offers over 63 acres of diverse forested habitat for a number of different wildlife species. Observations revealed wildlife usage by both listed (i.e., endangered, threatened, or species of special concern) and nonlisted species.

The pretreatment ditches provide good foraging habitat for listed wading birds such as little blue heron, snowy egret, white ibis, and wood stork, all of which were observed in these ditches on various occasions. American alligator, listed as a species of special concern by the Florida Fish and Wildlife Conservation Commission and as threatened by the U.S. Fish and Wildlife Service, is a permanent resident in the pretreatment ditches. The osprey is commonly observed flying over the wetland site and has been seen perched next to the pretreatment ditches. Although not specifically observed, other listed species could utilize the natural stormwater treatment site.

First-Year Summary

The VAB natural wetland stormwater management system represents a compatible multiuse wetland project. First-year operational data indicate that the pretreatment/wetland system is providing enhanced protection of downstream water quality. In addition, hydrological data indicate that normal wetland water levels have been reestablished by the project and that plant communities are beginning to recover to more characteristic obligate wetland plant species.

Wetland restoration is being promoted by this project as a result of the need for more effective stormwater management. Many of Florida's natural wetlands have been previously impacted by drainage and adjacent development. Incorporation of some of these wetlands into carefully designed stormwater management systems has the potential to enhance wetland functional values while maximizing the benefits of dollars spent on environmental protection.

References

- *Kadlec, R.H. and R.L. Knight. 1996. Treatment Wetlands. CRC Press/Lewis Publishers, Boca Raton, FL. 893 pp*