RESTORING THE EVERGLADES

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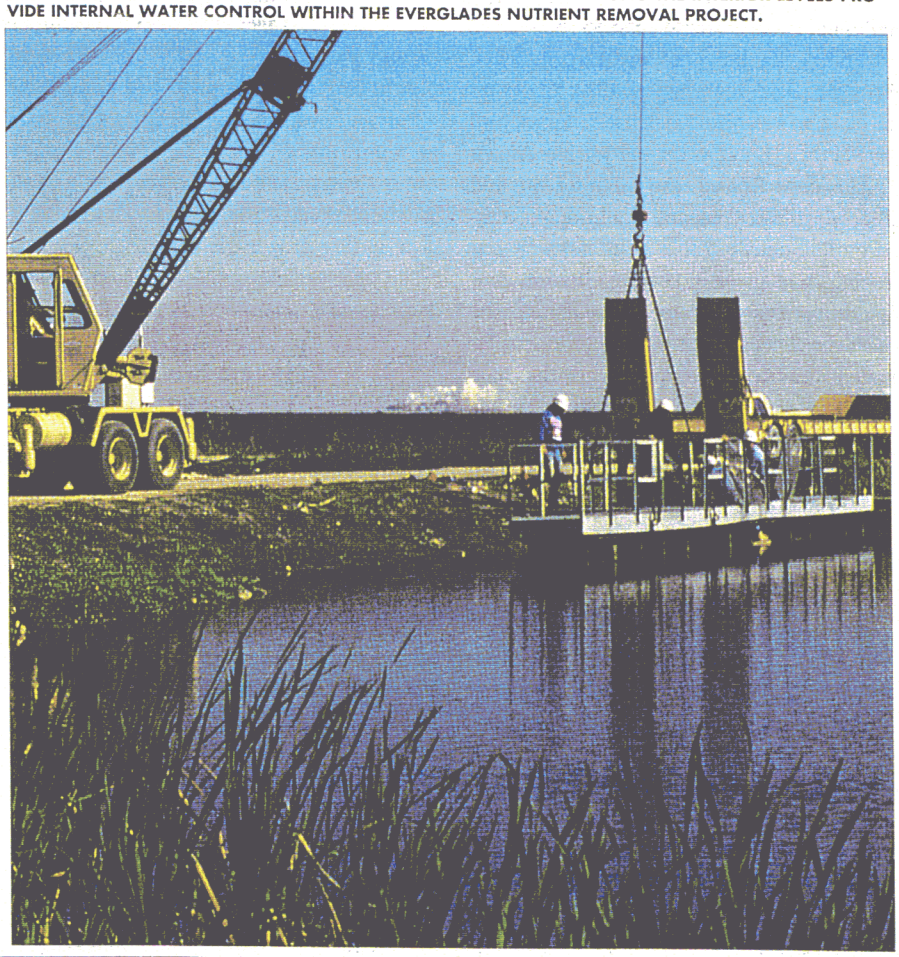
Are constructed wetlands an effective management strategy for restoring and protecting Florida's Everglades from phosphorus overenrichment caused by agricultural storm-water runoff? A recently completed 4,000 acre project—the largest of its kind so far—could answer that question, and serve as the model for a much larger system, provided political, financial and legal obstacles stalling the Everglades Protection Project can be resolved.

The ecosystem of Florida's Everglades supports a variety of rare, threatened and endangered species and associated communities whose survival depends on the natural cycles of water and nutrients under which the system was originally formed. These natural cycles included very low nutrient levels, with particularly low levels of phosphorus. Historically, rainfall probably represented the primary source of all nutrients in the Everglades, and is still a source in areas located away from storm-water discharges.

In recent decades, however, increasing volumes of phosphorus-enriched water have been pumped into the Everglades and have upset the system's natural balance. Most of this water comes from the 700,000 acre Everglades Agricultural Area (EAA) situated between Lake Okeechobee and the Everglades. Between 1979 and 1988, approximately 220 tons of phosphorus was discharged annually into the Everglades water conservation area from the EAA.

Phosphorus overenrichment from agricultural runoff is one of a range of water-quality, land-use and water-distribution problems confronting the Everglades that the South Florida Water Management District is moving to address. Phosphorus overenrichment can change water quality,

THIRTY-EIGHT 72 IN. CULVERTS WITH FLASHBOARD RISERS LOCATED ALONG THE INTERIOR LEVEES PROVIDE INTERNAL WATER CONTROL WITHIN THE EVERGLADES NUTRIENT REMOVAL PROJECT.



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vegetation, algae, oxygen levels, sediments and even disrupt the food chain. Adverse biological effects caused by changes in water chemistry due to the presence of phosphorus could have serious repercussions throughout the south Florida ecosystem.

Along with on-the-farm best management practices to reduce phosphorus use, one way to restore the system's natural balance could be constructed wetlands that would biologically remove phosphorus from agricultural runoff water before it enters the Everglades. This concept is currently receiving its most extensive demonstration yet in the $13.85 million Everglades Nutrient Removal (ENR) Project, developed by the South Florida Water Management District on approximately 4,000 acres of state-owned land formerly leased for sugarcane production.

The land's location was well suited: it was near a major pump station (S-5A) that drained a 230 sq mi section of the EAA containing some of the highest phosphorus concentrations. More important, the parcel borders the Arthur R. Marshall Loxahatchee National Wildlife Refuge, a protected wildlife area and outstanding Florida Water experiencing cattail infestation and other related water-quality problems associated with agricultural storm-water runoff.

Design was initiated in 1989, with construction beginning in 1991. Structural components were completed in September 1993, and the project is currently in the start-up phase.

Over the past 20 years, nationwide research and practical application have demonstrated the ability of wetlands to remove nutrients from surface waters. The extent of the nutrient uptake is a function of a number of factors, including nutrient loading, water-quality characteristics, hydrology, water depth, soil type, vegetation, decomposition, pH, microbial/algal communities and hydraulic retention time.

Wetland-treatment systems have been primarily used to treat wastewater effluent, with total phosphorus concentrations reduced by 20–90% in some systems. However, the use of wetlands for nutrient removal is still an evolving science, and no storm-water–removal project of this scale has been attempted before.

The ENR Project is a crucial component of the district's comprehensive Everglades restoration effort, which is still in the planning stage. The current plan calls for developing approximately 35,000 acres of constructed wetlands to remove phosphorus from water entering the Everglades. The ENR Project—at about 10% the size of these proposed storm-water–treatment areas (STAs)—will provide the opportunity to evaluate and refine operation and maintenance of a full-scale constructed wetland.

PROJECT COMPONENTS

When fully operational, the ENR Project will divert roughly 100,000 acre-ft per year (one-third of the water from the S-5A basin agricultural area) to the constructed wetland. This phosphorus-enriched water will flow through the wetland for an average of 15–20 days, at an average depth of 1.5–3 ft. Phosphorus will be removed by naturally occurring biological, chemical and physical processes within the wetland soils, algae

TWO SETS OF 15 RESEARCH CELLS WILL BE USED TO EVALUATE THE EFFECT ON NUTRIENT-REMOVAL PERFORMANCE OF VARIABLES SUCH AS HYDRAULIC LOADING RATES, NUTRIENT LOADING RATES AND PLANT DENSITY. EACH CELL IS ABOUT THE SIZE OF A FOOTBALL FIELD.

EVERGLADES CLEANUP: SWIM OR SINK?

The 4,000 acre wetland constructed for the Everglades Nutrient Removal (ENR) Project is intended as a demonstration project for a system approximately 10 times larger outlined in Florida's Everglades Surface Water Improvement and Management (SWIM) plan, approved in March 1992. However, while the ENR Project has advanced steadily through construction and to the beginning of operations, progress toward the larger project has been marred by disputes between federal and state agencies with agricultural interests blamed for high levels of phosphorus that threaten the Everglades.

Last July, it appeared that these disputes had been settled. In what U.S. Interior Secretary Bruce Babbitt called a "tremendous step toward the restoration of a unique and important ecosystem," a statement of principles was signed by all parties setting out the framework for a $465 million restoration plan. It called for a 40,000 acre system of six constructed wetlands to biologically remove phosphorus from water entering the Everglades, payments of $322 million by growers over 20 years and 25% reductions in on-farm phosphorus runoff within two years.

The agreement suspended lawsuits brought in 1992 by growers challenging the SWIM plan. However, negotiations to implement the agreement broke off in December, over the extent to which participation would protect agricultural interests from future taxes, regulatory activities and mandated restoration efforts. The growers were also reportedly angered by a restoration proposal included in a federal interagency scientific report that would have involved flooding about 200,000 acres of existing farmland. According to Bob Walker, an Interior Department spokesperson, the proposal was simply one among a number of options described in the report "and not one likely to succeed."

Tom Martin, executive director of the National Audubon Society Everglades Restoration Campaign, says that one problem with the plan is that the contribution from the growers won't cover the costs of restoration. To remedy that, environmental groups are collecting signatures to place a referendum on the November ballot calling for a 1¢ tax on processed sugar that would be dedicated to Everglades restoration.

In January, the Interior Department reached a separate agreement with one of the growers, Flo-Sun, Inc., under which the company agreed to make payments suggested in the July agreement, cease funding litigation and drop objections to a regional water-treatment system. The announcement of the agreement also noted that the department would "continue our fight against other industry parties in court and in the regulatory arena in step with Governor [Lawton] Chiles and the South Florida Water Management District."

At press time, the dispute seemed headed back to the courts. A state hearing is scheduled for April. In the meantime, the state is proceeding with work on the Everglades Protection Project, for which the district has been instructed by the governor to begin acquiring land.—*JP*

and plants. The primary long-term phosphorus-removal mechanism is peat accretion, which will create more organic soil. We estimate that water entering the project will average about 175 parts per billion (ppb) of phosphorus. Outflow is targeted to be approximately 50 ppb once the project has reached full operational performance.

The total size of the ENR Project is 3,975 acres, of which 3,680 acres is constructed wetlands. Of the project's $13.85 million final cost, $11.86 million came from Florida Power & Light mitigation funds, plus another $623,000 in cost sharing on an interior levee that will be used for a transmission-line alignment. The agricultural industry provided $1 million, through the EAA Environmental Protection District. Finally, $430,000 came from lease income, after project officials and S.N. Knight & Sons, the farmers that had leased the property previously, worked out a transition plan under which the acreage of farmland was reduced as construction proceeded, allowing farming to continue on the rest.

Four flow-through wetland cells are contained within the project. The site is triangle-shaped, with a transverse levee running through the center dividing the project into east and west treatment trains, each consisting of a flow-way cell for initial phosphorus removal and a polishing cell for final polishing. At the head of the project lies a 135 acre buffer cell that distributes influent water to the flow ways.

The east flow-way cell is 1,200 acres and is vegetated by volunteer recruitment of cattails and other indigenous species. The water then flows into a 900 acre polishing cell vegetated by a combination of volunteer recruitment and contract planting. Approximately 810,000 individual plants of six different types of native marsh vegetation, including sawgrass, arrowhead and maidencane, were planted. To compare planted vs. natural growth, planting was done in a checkerboard pattern, with the "black" squares planted and the "red" ones left open for indigenous species. Plant density varied from 3.5 ft on center to 10.5 ft, to allow competitive studies on growth fill-in and nutrient-removal performance.

The 1,100 acre west flow-way cell is also vegetated by volunteer recruitment, and it leads to a 400 acre open-water polishing cell, where exclusion of emergent and floating plants will encourage growth of algal communities. One question we will answer is what intensity of vegetation management is required to maintain the open-water cell. The primary objective of developing two different polishing cells is to conduct a side-by-side comparison of the nutrient-removal effectiveness of the open-water and vegetated polishing cells.

CONSTRUCTION

There are two distinct areas of construction involved in building the ENR Project. One is constructing the structural elements, and the other is establishment of the vegetation required for the wetland cells.

Structural elements include:

- A 2.2 mi canal to connect the inflow pump station of the ENR Project to the existing West Palm Beach Canal. A battery of culverts were installed at the confluence to maintain access along an existing county road. Due to stability concerns regarding the close proximity of the refuge's perimeter levee, composed of high organic content, blasting through the dense limestone caprock was avoided. The contractor for the $1.1 million project, Westwind Contracting, Inc., Pembroke, Fla., used a large backhoe for excavation. A maintenance berm was constructed on the west side of

the canal to provided maintenance access to the existing Florida Light & Power power line, which was temporarily severed by the new canal.

- A 7.5 mi perimeter levee designed to keep water within the constructed wetlands. The perimeter levee consists of a core of select fill of blasted and compacted limestone, placed on a limestone caprock after the overlying muck was removed. The side slopes vary from 1:3 to 1:8 and are composed of organic material. Levee height varies depending on the design water elevation of the interior cells, ranging from 6.5 ft to 5.2 ft relative to adjacent ground, and is higher in the north than in the south.
- A 30–50 ft wide, 10–12 ft deep seepage-collection canal outside the perimeter levee to minimize impacts to adjacent agricultural neighbors. Excavation of the seepage canal provided the borrow for the crushed limestone core of the perimeter levee. Following demucking of the soil to caprock, the dense limestone was blasted to excavate the canal. Contractor for the perimeter and interior levees and the seepage canal, which had a combined cost of about $5.2 million, was Ranger Construction Industries, West Palm Beach, Fla. Work also included planting vegetation in the east polishing cell.
- The center transverse levee that separates the east and west flow-through wetlands, constructed of random material. In an unusual aspect of the project, we reconfigured the interior levee to provide the alignment for a future electric transmission line for Florida Power & Light, which contributed additional funds to the project in return. Earthen power pads extending 150 ft into the marsh have been placed on top of the levee every $\frac{1}{4}$ mi to accommodate poles and power lines.
- Axial flow pumps powered by electric motors that convey water into and out of the project. The six 100 cfs inflow pumps are colocated with three seepage-return pumps with a combined capacity of 200 cfs, and discharge into the 135 acre buffer cell at the head of the project. Operational flexibility was a key design criterion, so the pumps can be operated via on-site controls or from a central operations center in West Palm Beach through the district's microwave telemetry network. Harry Pepper & Associates constructed the $4.1 million inflow and outflow pump stations. Six pumps with a combined capacity of 450 cfs convey the constructed wetland's treated water to the refuge's perimeter, or rim, canal via a 300 ft discharge canal.

A critical research component of the ENR Project is the construction of two sets of 15 test cells built within the east flow-way and polishing cells. The test cells, a half-acre each in size and hydraulically independent, will be used for a number of controlled experiments to examine variables in nutrient-removal technology. Variable phosphorus loading, natural regrowth versus replanting, water depth and flow rates are some factors that will be examined. Test-cell results will be critical in guiding the fine-tuning of the ENR Project performance. Contractor for the $1.573 million research cells was Bergeron Land Development, Hollywood, Fla.

Once the project is fully operational, peak nutrient-removal performance could be reached within two to five years.

One unique feature of the ENR Project is that it will allow the district to evaluate and implement management strategies for optimizing phosphorus retention on three levels: in the laboratory; in the test cells; and in the full-size treatment cells. Operation, maintenance, research, modeling and monitoring associated with the ENR Project will provide essential information to the district for the management of future STAs.

Conceptual design of the civil works for the ENR project, as well as final design for the perimeter levee, supply canal and pumping stations was by Burns and McDonnell, Kansas City, Mo. The district's engineering division designed the interior levees and research test cells. The treatment-system design was initiated by Post Buckley Schuh and Jernigan, Orlando, Fla., and completed by the district's Everglades systems research division. The agency conducted multiple outside peer reviews of civil-works and treatment-area designs.

CURRENT STATUS

With construction complete, the ENR Project is presently holding water on-site during the start-up phase, while the marsh vegetation establishes itself and residual phosphorus concentrations in the soil stabilizes. As of early 1994, initial start-up of marsh vegetation is proceeding successfully. The cells have been flooded with 1.5–2.5 ft of water, and the result has been a proliferation of natural growth from seeds carried into the project from nearby natural areas by the wind and birds, and possibly from the seed bank embedded in the formerly agricultural soil. Cattails are the dominant species in the east and west flow-way cells, as they thrive on the marsh's phosphorus-enriched conditions. The different species planted in the 810 acre east polishing cell are also proliferating.

The extensive monitoring program will document meteorologic, hydraulic, water-quality and vegetation-related parameters. The primary goal of the monitoring program is to provide the data necessary to identify and evaluate the fundamental mechanisms of short-term and long-term nutrient removal within a constructed wetland. Once these processes are understood more clearly, the goal will be to optimize the treatment performance of the wetland by refining the operational strategies of the ENR Project and subsequent large-scale systems. The test cells will allow for implementation of alternative strategies prior to application at the full-scale project level. An additional purpose of the monitoring program is to satisfy the operational permit requirements. Monitoring and research equipment are now being installed.

Once the project is fully operational, peak nutrient-removal performance could be reached within two to five years as we optimize the project's operation. By this summer, the district hopes to meet its plant-coverage and on-site phosphorus-concentration objectives and begin discharging treated water into the Loxahatchee Refuge. According to the best available information, the ENR Project could annually remove approximately 22 tons of phosphorus from storm-water runoff presently entering the refuge.

The authors are all with the South Florida Water Management District. Gary Goforth, P.E., M.ASCE is director of the project management division in the construction management department. James Best Jackson, P.E., is overall construction project manager for the Everglades Nutrient Removal Project. Larry Fink is a supervising professional-environmental scientist with the research appraisal division.