U.S. Department of the Interior
U.S. Geological Survey

Vegetation Affects Water Movement in the Florida Everglades

Introduction

The Florida Everglades is a vast, diverse wetland ecosystem characterized by small ground-surface slopes, slowly moving surface waters, and dense aquatic vegetation oth submersed and emergent vegetation are found in sawgrass and cattail marshes (fig. 1), wet prairies, and sloughs. The south Florida ecosystem has been greatly altered during the last 100 years. A complex water-management system that includes levees, canals, pumps, and water-control structures now regulates flooding and provides a steady supply of fresh water to urban areas and agriculture. Drainage projects have diverted much of the water that originally flowed slowly southward from Lake Okeechobee through the Everglades. Restoration and management of the Everglades ecosystem requires understanding and manipulating the amount and timing of water flows throughout the ecosystem.

Figure 1. USGS technician using an acoustic Doppler current meter in a sawgrass marsh in the Everglades.

The spatial and temporal distribution of water and water-borne contaminants in the Everglades must be understood if degradation of the ecosystem is to be halted and reversed. To understand how water moves through the Everglades, it is necessary to quantify the forces affecting the flow. The resistance exerted on the flow by the vegetation through which the water moves is one of the dominant but least understood forces affecting Everglades surface-water flows.

The aquatic vegetation of the Everglades affects both the depth of water and the rate at which it moves. The presence of living and dead plant material in the water column creates drag forces on the moving water. Water flows most slowly and the water-surface slope is largest in areas where vegetation is most dense.

Plan of Study

U.S. Geological Survey (USGS) hydrologists and ecologists are conducting studies to quantify vegetative flow resistance to improve numerical models of surface-water flow. For use in the models, vegetative flow resistance must be expressed in terms of parameters describing the flow and the vegetation. These parameters include the flow velocity through the vegetation, the water depth, the slope of the water surface, and the type, geometric characteristics, and density of the vegetation.

Both indoor flume and field measurements are being conducted to develop methods for evaluating the resistance of relatively uniform stands of vegetation and to identify the most appropriate parameters for representing resistance due to vegetation types typically found in the Everglades. By using computer models, remote-sensing techniques, and geographical-information-system tools, empirical expressions will be developed to define flow resistance in areas of mixed vegetation of variable density. Such expressions will quantify flow resistance at scales appropriate for large-scale hydrodynamic models or regional hydrologic models. These expressions for flow resistance will be tested by comparing results from computer flow models with measurements in selected areas of the Everglades.

Figure 2. Hook gages being used to measure water-surface elevation in sawgrass during a flow experiment in the tilting flume at Stennis Space Center, Mississippi.

Indoor Flume Experiments

The USGS tilting flume at Stennis Space Center, Mississippi, is being used to determine the flow resistance of uniform stands of sawgrass (Cladium jamaicense) and cattail (Typha domingensis). For the initial study, uniform, dense stands of sawgrass were grown in pans that were fit snugly into the flume to form a 200-foot-long, 6-foot-wide artificial sawgrass ecosystem. The depth of water in the flume is controlled by adding or removing metal plates (stop logs) at the downstream end. Experiments are being conducted for five flow depths between 6 inches and 2.5 feet, for mean cross sectional velocities between 0.001 and 0.15 foot per second, and for three plant densities. For each experiment, the flow rate, flow depths, and water-surface elevations (fig. 2) are measured. The water-surface slope (equivalent to the energy loss per unit length of channel) is calculated from the water-surface elevations, and vegetative resistance is computed from the flow rate, mean depth, and slope.

During each experimental series, the vegetation in the flume is sampled to determine, as a function of distance from the bed, biomass per unit area, the number of stems and leaves per unit area, and leaf and stem width. The number of culms (basal stems composed of many closely packed leaves) and leaves per square foot are shown for each of four horizontal layers for the experiments of January 1996 in figure 3. The relation between the vegetation characteristics and flow resistance is being explored.

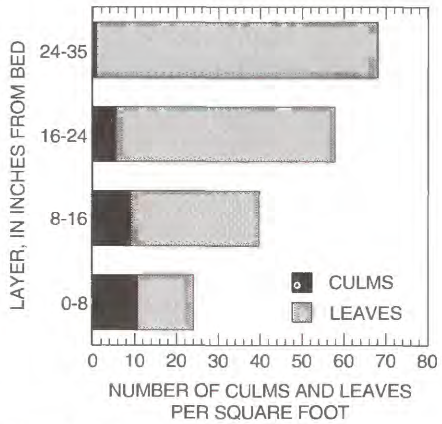

Figure 3. Number of culms and leaves per square foot for each of four horizontal layers of vegetation for the experimental series of January 1996.

Field Measurements

Field measurements are being made at several locations in the Everglades where sawgrass is the dominant plant. Factors such as the presence of periphyton (a thick floating mat of algae anchored to plants in the water column) and a litter layer (dead plant material at the bottom of the water column) are best studied in the field because they are difficult to reproduce in the laboratory.

An acoustic Doppler current meter is used to measure flow velocities that can be as small as a few hundredths of an inch per second. To determine water-surface slopes, an 8-foot-long, transparent, plastic pipe with a short elbow at one end is positioned horizontally just below the water surface and parallel to the flow direction with the elbow at the upstream end. The velocity in the pipe is a function of the characteristics of the pipe and the difference in water-surface elevations at the entrance and exit. A ping-pong ball filled with water, to achieve neutral buoyancy, is used to measure the pipe flow velocity, from which the water-surface slope can be determined. Water-surface slopes as small as 1 inch in a mile can be determined using this technique. Other methods of measuring velocities and water-surface slopes are also being investigated.

Vegetation is sampled at sites where hydraulic measurements are made to explore the dependence of flow resistance on vegetation characteristics. In contrast to this direct technique for sampling vegetation, another USGS project is using indirect methods, including videography, to determine whether vegetation can be sufficiently characterized by remote-sensing techniques to estimate flow resistance.

Anticipated Schedule

- 1995: Begin development of marsh-hydraulics model. Construct artificial sawgrass ecosystem in indoor flume.
- 1996: Conduct experiments with sawgrass in indoor flume. Collect and analyze flow-resistance data for sawgrass in Everglades during dry and wet seasons.
- 1997: Conduct flow-resistance experiments with cattails in indoor flume. Begin flow-resistance parameter-aggregation study. Begin data collection in a water-conservation area.
- 1998: Complete data collection.
- 1999: Complete modeling.

Planned Products

- Hydraulic model of constructed cattail marsh.
- Report summarizing flow-resistance results from flume and field studies for sawgrass and cattails.
- Report summarizing vegetative-flow-resistance results for large-scale surface-water models.
- Hydraulic model of a water conservation area.

Initial Results

Manning's *n*, an empirical coefficient commonly used to express flow resistance in open channels, is plotted as a function of velocity for the flume measurements of January 1996 in figure 4. The plot shows that for a uniform stand of sawgrass with no litter layer, the value of *n* increases with flow depth. At a fixed depth, Manning's *n* is relatively constant for velocities between 0.05 and 0.15 foot per second but increases as the flow velocity approaches zero.

Results of field efforts are not yet available. However, the first field measurements have shown that instruments are available with the capabilities needed to determine flow resistance for small, relatively uniform stands of vegetation in the field.

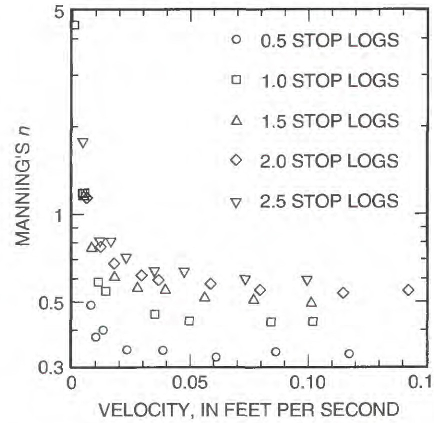

Figure 4. Manning's *n* plotted as a function of velocity for the flume measurements of January 1996. A stop log corresponds to 1 foot of depth.

USGS Role in Restoration of the South Florida Ecosystem

Quantifying the effects of vegetation on the movement of surface water in the Everglades is necessary for the development of accurate numerical flow and water-quality models that can be used to evaluate restoration alternatives. In undertaking laboratory, field, and theoretical studies to define the flow-resistance characteristics of Everglades vegetation, the USGS is playing a key role in providing reliable model parameters to Federal and State agencies involved in managing the Everglades ecosystem.

For More Information

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