Prepared in cooperation with

Pinellas County, Southwest Florida Water Management District, and Tampa Bay Water

Strength in Numbers: Describing the Flooded Area of Isolated Wetlands

Why describe the flooded area of isolated wetlands?

- To identify changes in flooded area that signal changes in the acreage of wetland vegetation
- To summarize wetland water levels into a regional view of wetland status
- To help identify wetland/ground-water interactions
- To provide information that can be used to increase the similarity of mitigation wetlands and natural wetlands

Introduction

Thousands of isolated, freshwater wetlands are scattered across the **karst**[1] landscape of central Florida. Most are small (less than 15 acres), shallow, marsh and cypress wetlands that flood and dry seasonally. Wetland health is threatened when wetland flooding patterns are altered either by human activities, such as land-use change and ground-water pumping, or by changes in climate. Yet the small sizes and vast numbers of **isolated wetlands** in Florida challenge our efforts to characterize them collectively as a statewide water resource. In the northern Tampa Bay area of west-central Florida alone, water levels are measured monthly in more than 400 wetlands by Tampa Bay Water and the Southwest Florida Water Management Distirct (SWFWMD). Many wetlands have over a decade of measurements.

The usefulness of long-term monitoring of wetland water levels would greatly increase if it described not just the depth of water at a point in the wetland, but also the amount of the total wetland area that was flooded. Water levels can be used to estimate the flooded area of a wetland if the elevation contours of the wetland bottom are determined by **bathymetric mapping**.

Despite the recognized importance of the flooded area to wetland vegetation, bathymetric maps are not available to describe the flooded areas of even a representative number of Florida's isolated wetlands. Information on the bathymetry of isolated wetlands is rare because it is labor intensive to collect the land-surface elevation data needed to create the maps.

Five marshes and five cypress wetlands were studied by the U.S. Geological Survey (USGS) during 2000 to 2004 as part of a large interdisciplinary study of isolated wetlands in central Florida. The wetlands are located either in municipal **well fields** or on publicly owned lands (fig. 1). The 10 wetlands share similar geology and climate, but differ in their ground-water settings. All have historical water-level data and multiple vegetation surveys.

A comprehensive report by Haag and others (2005) documents bathymetric mapping approaches, the frequency of flooding in different areas of the wetlands, and the relation between flooding and vegetation in these wetlands. This fact sheet describes bathymetric mapping approaches and partial results from two natural marshes (Hillsborough River State Park Marsh, and Green Swamp Marsh) and one impaired marsh (W-29 Marsh) that is located on a municipal well field and is affected by ground-water withdrawals. (fig. 1).

Wetland Perimeters

Defining wetland perimeters is fundamental to creating the bathymetric maps. At 9 of the 10 wetland sites in this study, a **saw palmetto fringe** delineated the perimeter of the wetland and defined the elevation corresponding to 100 percent flooded

[1]Terms defined in the glossary are in **bold print** where first used in this fact sheet.

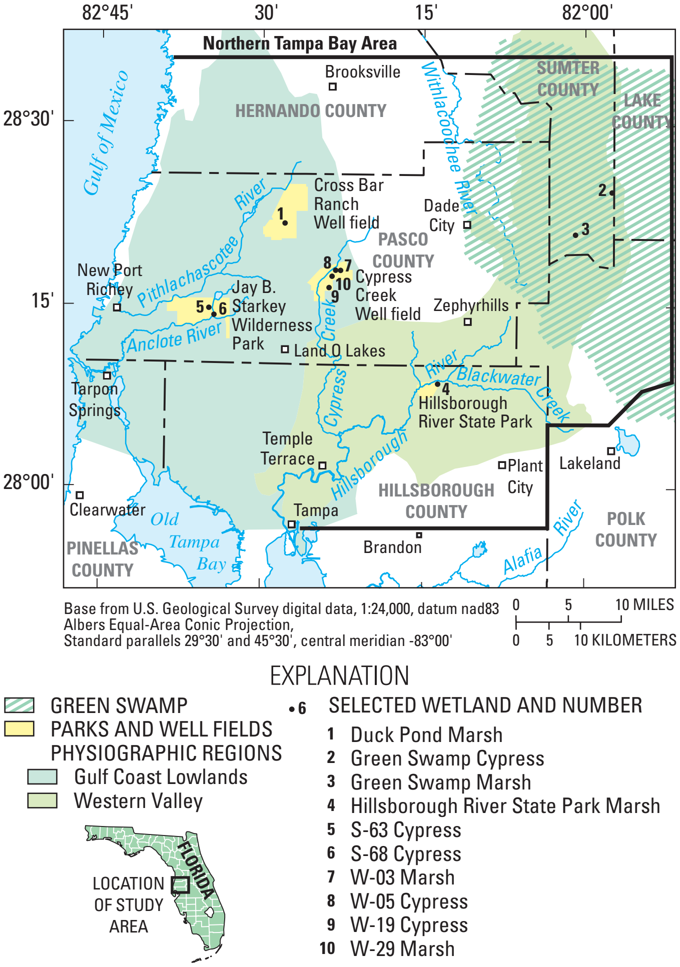

Figure 1. Location of study wetlands in the northern Tampa Bay area, west-central Florida.

area (fig. 2). The palmetto fringe was shown in separate studies by the SWFWMD to be a dependable indicator of a wetland boundary in the study area. At one wetland where the palmetto fringe and other vegetative indicators were absent, the presence of hydric soils was used to delineate the perimeter.

Areas determined for four of the cypress wetlands and five of the marshes in this study were compared to wetland areas in the National Wetlands Inventory (NWI) that were mapped by the U.S. Fish and Wildlife Service using aerial photointerpretation. The comparison indicates a greater discrepancy in the NWI area estimates for marsh wetlands than for cypress wetlands of this size. For four of the five marshes, the NWI area differed by 25 to 35 percent from USGS study estimates. Areas for the four cypress wetlands and the remaining marsh wetland differed by 8 percent or less.

Wetland Bathymetry

Bathymetric maps of the 10 wetlands were created using two principal approaches, because the wetlands differ in their depth, size, extent of flooding, and density of vegetation. Wetland water levels (in elevations relative to the National Geodectic Vertical Datum of 1929) were read from staff gages and monitored using electronic water-level recorders.

For the five wetlands that were dry at the time of the measurements, **total station** surveying equipment was used to survey land-surface elevations. This method was precise and readily generated a high density of measurements ranging from 62 to 18 points per acre.

At three wetlands, where water was present over approximately 100 percent of the wetland area, land-surface elevations were derived at fewer points by subtracting measured water depths from the elevation of the water surface. Measurements were made along lines or transects through the wetland. A digital global positioning sytem (GPS) instrument or distance measurements were used to determine the location of measuring points. At wetlands that were partially flooded, a combination of these two approaches was used.

Land-surface elevations were interpolated between measured points using spatial-interpolation software. Elevation contour lines typically were drawn at 0.5-foot contour intervals. Flooded area and volume were calculated and graphed for various stages between dry and full. The results for a 6.5-acre natural marsh, W-29 Marsh, are shown in figure 3.

The wetland contours revealed by bathymetric mapping showed that over certain ranges of stage, the flooded area and volume changed substantially with small changes of stage. For 7 of the 10 wetlands, including W-29 Marsh, the area versus stage curves were S-shaped instead of parabolic (fig. 3). Generally, the wetland area changed most over the lowest ranges of stage. The flat bottoms of most of the wetlands resulted in a large increase in wetted area with a small increase in wetland stage.

In contrast, as the flooded area approached the perimeter (near 100 percent inundation), a large increase in wetland stage and volume was required to produce a relatively small increase in wetland surface area. For example, adding 3.0 acre-feet of water to W-29 Marsh when it is dry would flood 63 percent of the total surface area, but doubling the volume of water in the wetland would inundate only 18 percent more area (fig. 3).

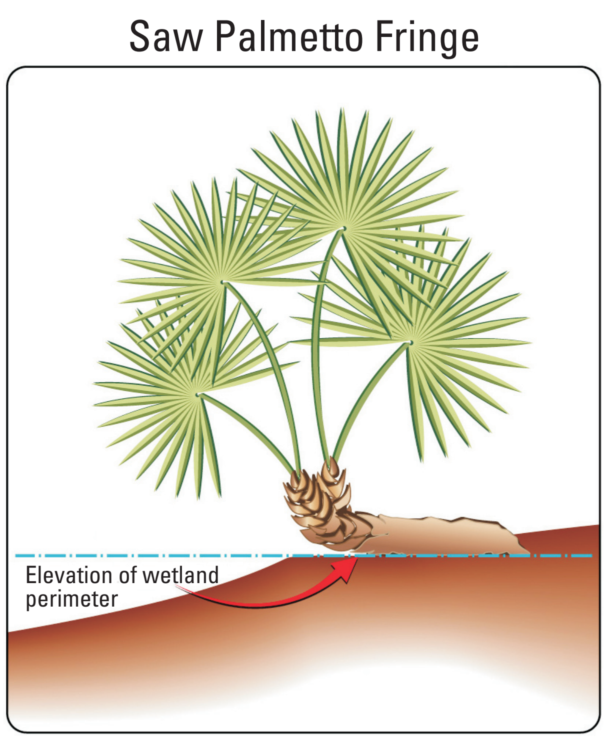

Figure 2. Saw palmetto fringe at edge of wetland. (Image courtesy of Southwest Florida Water Management District.)

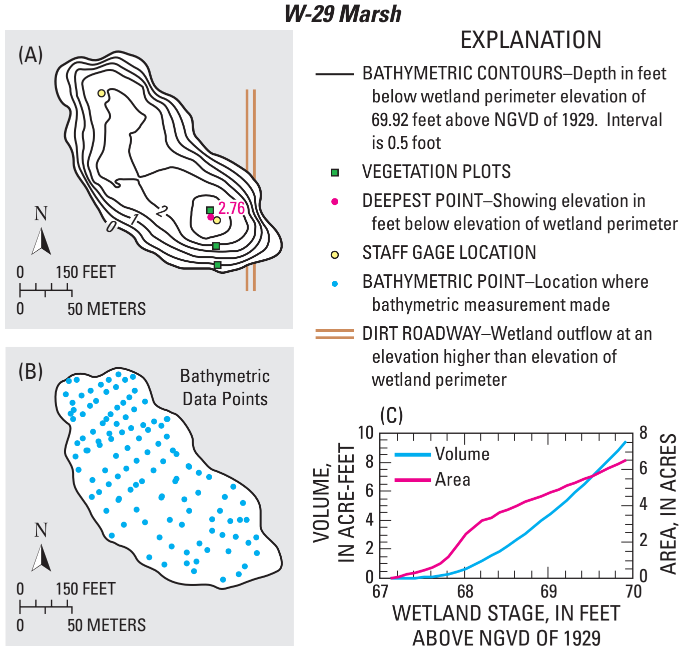

Figure 3. (A) Wetland bathymetric contours, (B) density of bathymetric data points, and (C) stage-volume and stage-area curves for W-29 Marsh.

Potential Effects of Mapping Approach

The approach used to collect elevation data in wetlands can effect the resulting bathymetric map, and therefore our understanding of flooded area and volume at different water levels. To gain insights into the effect of different mapping approaches on flooded area, three mapping approaches were applied to an oblong wetland, Marsh W-29, and the resulting bathymetric maps were compared. The results of the detailed total-station surveying approach are shown in figure 4a, and the results of the two simple approaches are shown in figures 4b and 4c.

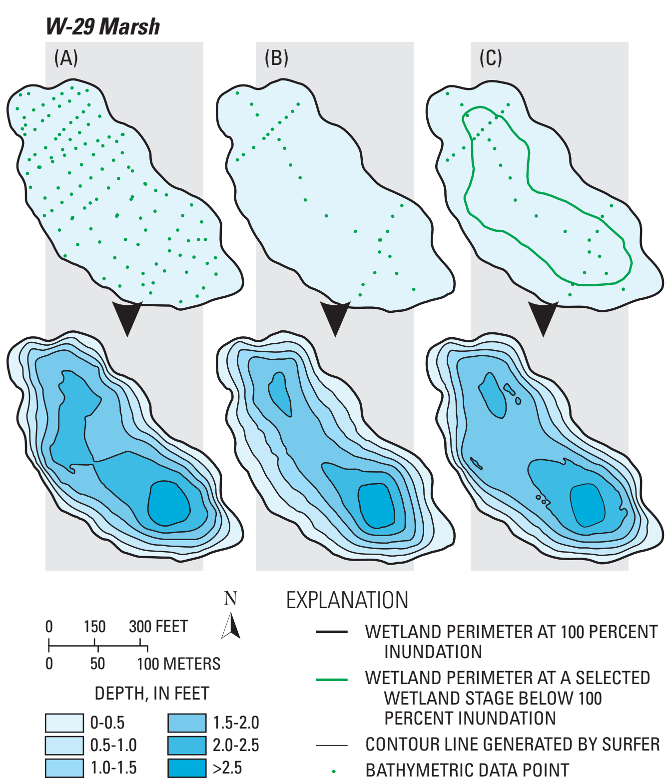

Figure 4. Contour lines developed for W-29 Marsh from (A) all bathymetric data points, (B) a subset of bathymetric data points along three transect lines, and (C) a subset of bathymetric data points along three transect lines and a contour line.

The first of the two simpler mapping approaches eliminated most of the elevation data points collected by total-station surveying, leaving three lines of points (fig. 4b). This approach reduced the average density of elevation points from 18.2 to 4.6 points per acre.

The second of the simpler approaches assumes that the outline of the flooded area at some stage between dry and the perimeter is known (fig. 4c). This elevation contour is added to the three lines of data points. For W-29 Marsh, an elevation contour was selected from the suite of contours developed for this wetland. In the field, however, the data points defining a contour line could be collected by using a digitial GPS unit to map the water's edge.

The results of the comparisons show that the simplest approach (fig. 4b) missed a substantial amount of information, particularly about the nonlinear changes in the flooded area with stage. Contouring sparse data points along transects resulted in a more linear interpolation of the elevation between data points than actually existed. As a result, wetland area and volume over certain ranges in water level were 50 to 100 percent lower than the more detailed total-station approach (fig. 5). Adding a single elevation contour to the transect data greatly improved the agreement with the detailed mapping approach.

Choosing the appropriate density of data points needed to determine wetland bathymetry depends on the intended use of the data. For example, a simple approach that uses fewer data points could be sufficient when comparing the percentage of flooded area in multiple wetlands over the same time period, as illustrated in figure 6. In contrast, a detailed approach that uses as many data points as possible would benefit a wetland water-budget study that must closely account for changes in wetland volume over time. All three methods applied here were subject to similar bathymetry measurement errors attributable to the vegetative cover and the rough surface of the wetland landscape.

Uses for Wetland Flooded-Area Data

Once stage-area curves are generated from bathymetric data, they can be used to expand routine observations of wetland stage into routine observations of wetland flooded area. Flooded area, expressed as a percentage of the total wetland area, is a versatile and descriptive measurement that can be tracked over time for an individual wetland or compared across a population of wetlands.

Recording flooded area over time at a given wetland has another advantage. Observations can be analyzed statistically to describe the length of time that different areas of the wetland were flooded. Summarizing the flooded-area data in this manner results in what Haag and others (2005) refer to as **flooded-area frequency** distributions. These distributions can characterize the amount of time different areas of wetlands were flooded in a given year or historical time period (fig. 7).

Ideally, wetland mitigation using **augmentation** or other means could attempt to re-establish natural wetland flooding cycles. This would entail not only timing the presence or

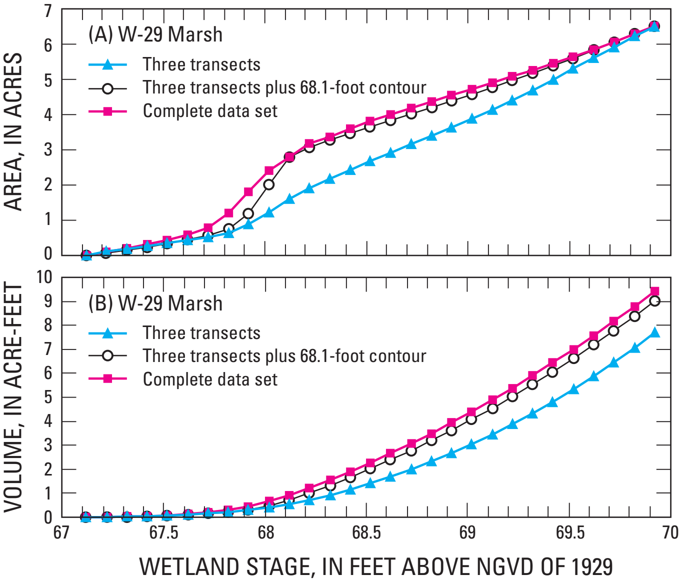

Figure 5. Effects of a reduced density of bathymetric data points at W-29 Marsh on (a) stage-area and (b) stage-volume relations.

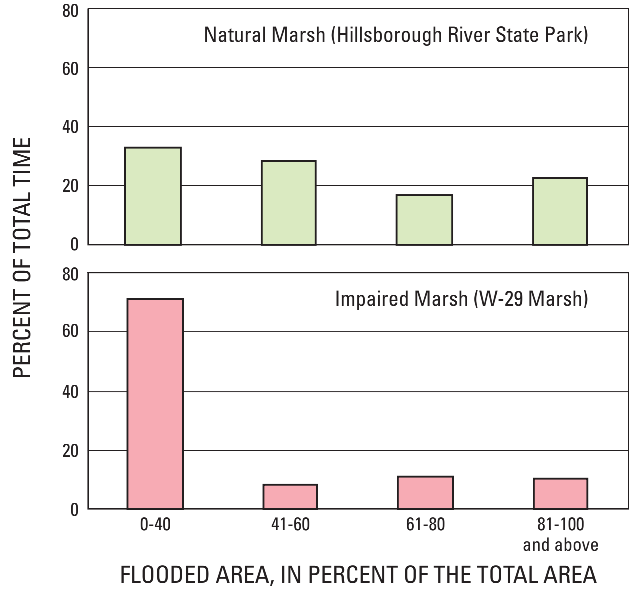

Figure 7. The frequency of flooding in different areas of a natural marsh and an impaired marsh for the 16-year period from 1988 to 2003 (marsh locations are shown on fig. 1).

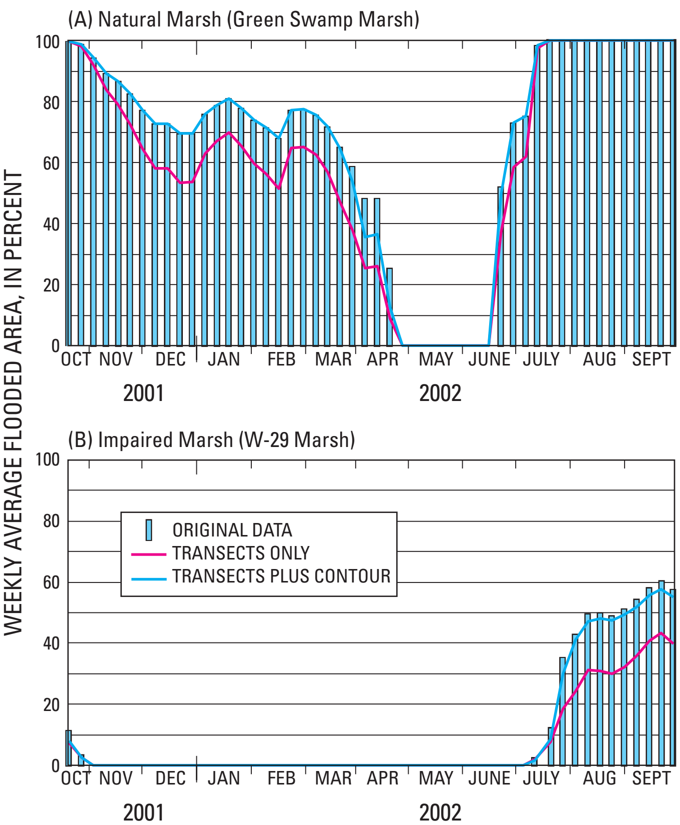

Figure 6. Weekly average flooded area at a natural marsh and an impaired marsh for the same time period, using three bathymetric mapping approaches.

absence of water at the deepest point in the wetland, but also restoring the natural frequency of flooding across a range of wetland elevations. Improved information on wetland stage, area, and volume, would enable water managers to recommend target stages to flood predetermined wetland surface areas with a certain frequency. Bathymetric data for wetlands of different sizes also could be used to help construct artificial wetlands with a range of bottom depths comparable to natural wetlands.

Bathymetry and long-term stage data can be used to characterize the flooded-area frequencies in natural wetlands for a given year, for different climatic cycles, and for longer historical periods. The contrast in flooded-area frequencies of natural wetlands and impaired wetlands could indicate which impaired wetlands would make the best candidates for mitigation. By comparing the flooded-area frequencies of natural wetlands to historically augmented wetlands, a quantitative guidepost could be established for evaluating the success of mitigation efforts.

Reference

Haag, K.H., Lee, T.M., and Herndon, D.C., 2005, Bathymetry and Vegetation in Isolated Marsh and Cypress Wetlands in the Northern Tampa Bay Area, 2000-2004: U.S. Geological Survey *Scientific Investigations Report 2005-5109*, 49 p.

Glossary of Terms

Augmentation—adding water from an external source to increase the water level in a surface-water body

Bathymetric mapping—mapping the water depth of the wetland

Flooded-area frequency—the percent of the time when water covers some part of the wetland bottom

Isolated wetland—a wetland with no apparent surface-water connection to streams, rivers, estuaries, or the ocean

Karst—a region underlain by limestone that contains solution cavities and where the physical features of the land surface include large and small depressions

Saw-palmetto fringe—a long-lived terrestrial plant that occurs in the transition zone between wetlands and the surrounding uplands

Total station—an optical instrument used in modern surveying that can determine angles and distances from the instrument to the points to be surveyed

Well field—an area developed by a local or regional water authority where ground water is withdrawn from the aquifer and sent to a treatment and distribution system

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