

Assessment of groundwater hydrology at Sand Island, Gulf Islands National Seashore

Introduction

There are proposals to mine/dredge part of Sand Island to provide sand for restoration work at Ship Island. We knew there is a wetland area on the western part of Sand Island. My original objective was to evaluate whether removal of the northeastern part of Sand Island could be accomplished while maintaining the hydrologic conditions that support the wetland area on the western part of the island. My initial analysis concludes that the northeastern part of the island could be removed with little to no adverse impact to the wetland area surrounding the open pond on the western part of the island. This would approximately coincide with the Corps of Engineers proposal to remove 3.7 mcy from the island.

Several additional wetland areas were discovered during a field trip to the island on April 23. If all of those wetland areas are to be protected from hydrologic disturbance, then there is no part of the island that can be removed.

Groundwater underlying an ocean island

The general groundwater hydrology of a freshwater lens underlying an ocean island has been thoroughly investigated and described by many researchers. The elevation of the water table underlying an elongated barrier island can be estimated by methods described in. [Fetter, C.W., 2001, Applied Hydrogeology, 4th ed., pp. 335-337]. The height of the water table above sea level, h , at any distance, x , from the shoreline can be calculated from:

$$h^2 = \frac{w[a^2 - (a - x^2)]}{K(1 + G)}$$

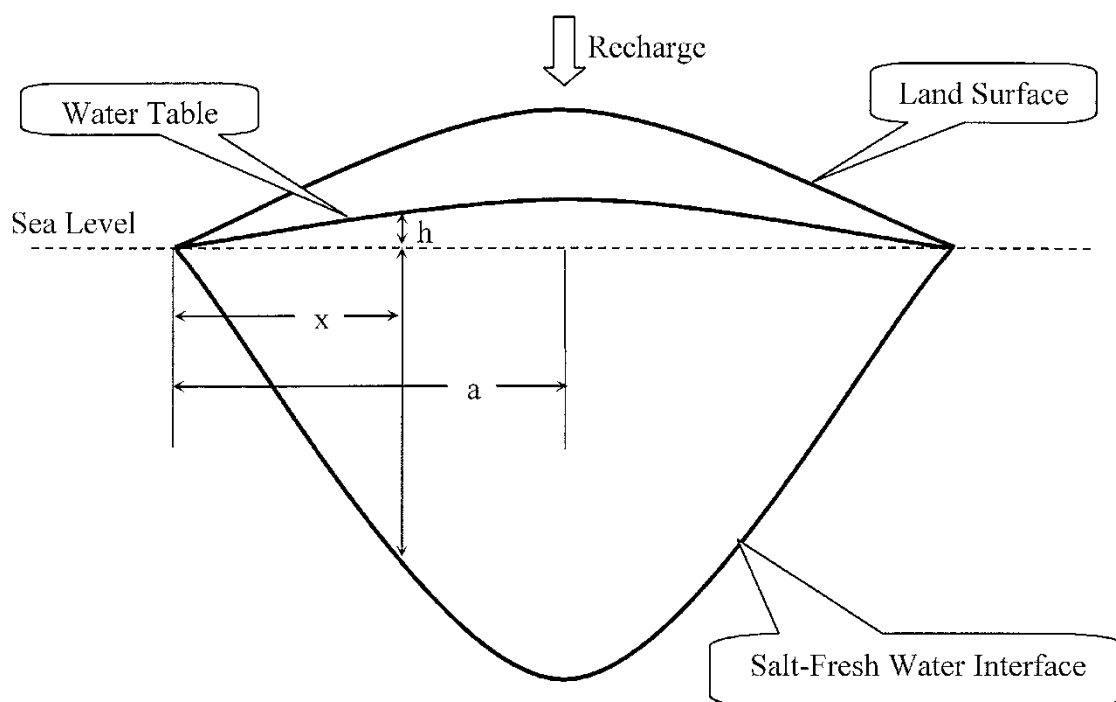
Where;

- w is the recharge rate to the aquifer (L/T, length/time)
- K is the hydraulic conductivity (L/T, length/time)
- a is the radius of the island (the width of the island is $2a$) (L, length)
- G is a ratio of the freshwater density to the difference between the densities of saltwater and freshwater,

$$G = \frac{\rho_w}{\rho_s - \rho_w} = 40$$

ρ_w is the density of freshwater, 1.000 gm/cm^3

ρ_s is the density of salty groundwater, 1.025 gm/cm^3



For a circular island with a radius of R, the formula becomes;

$$h^2 = \frac{w(R^2 - r^2)}{K(1 + G)}$$

Where h is the elevation of the water table at any distance, r from the center of the island.

The elevation of the water table is controlled by the recharge rate and the hydraulic conductivity of the sand aquifer and the width or diameter of the island. We could assume average values for those variables and make calculations, but it would only be an estimate of average conditions and would provide no indication of the variability of the water table elevation or the frequency-duration of inundation or high water table conditions in the vicinity of the wetlands.

Figure 1 shows a simple depiction of average water table elevations that might occur across the island. Figure 2 shows how the average water table elevation might change with different values for the hydraulic conductivity of the sand aquifer or the recharge rate from infiltration of rainfall. The average water table elevation will be higher as the hydraulic conductivity becomes smaller because there is more resistance to flow, requiring a higher head to push water from the interior part of the island to the shoreline. Also, the water table elevation increases as the recharge rate increases.

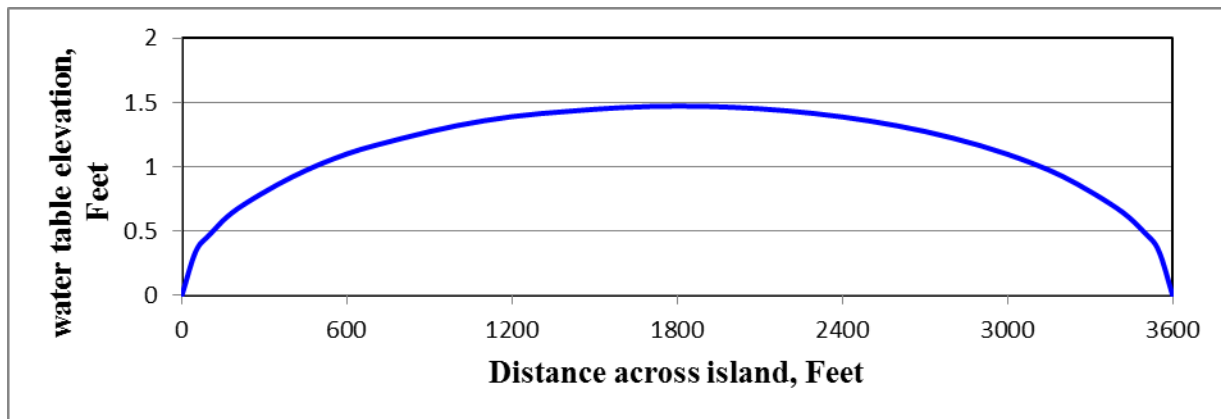


Figure 1. Average water table elevation across an ocean island.

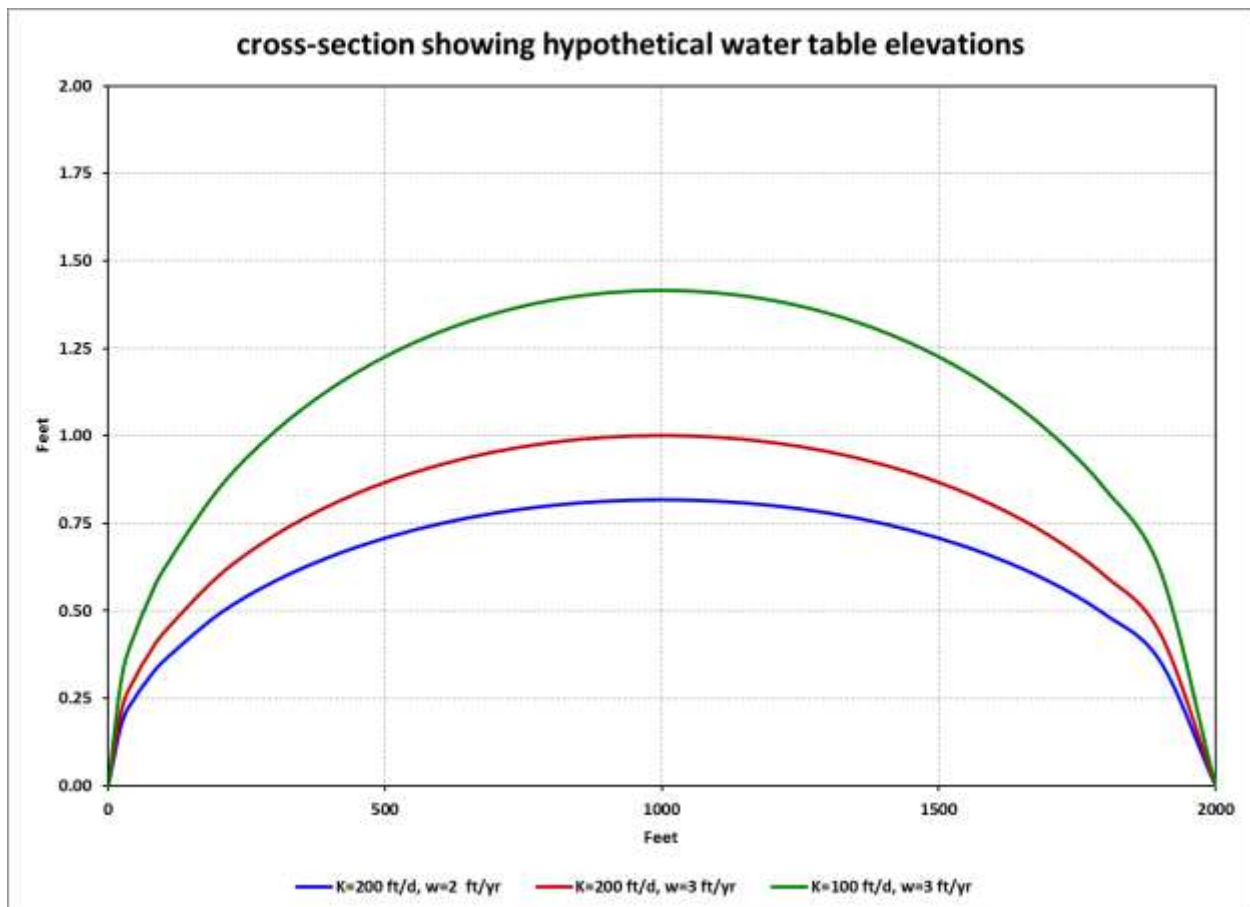


Figure 2. Average water table elevation across an ocean island showing the effect of varying hydraulic conductivity and recharge rate.

Figure 3 shows the effect of reducing the size of the island on the water table elevation. As the width or diameter of the island decreases, the water table elevation is lower.

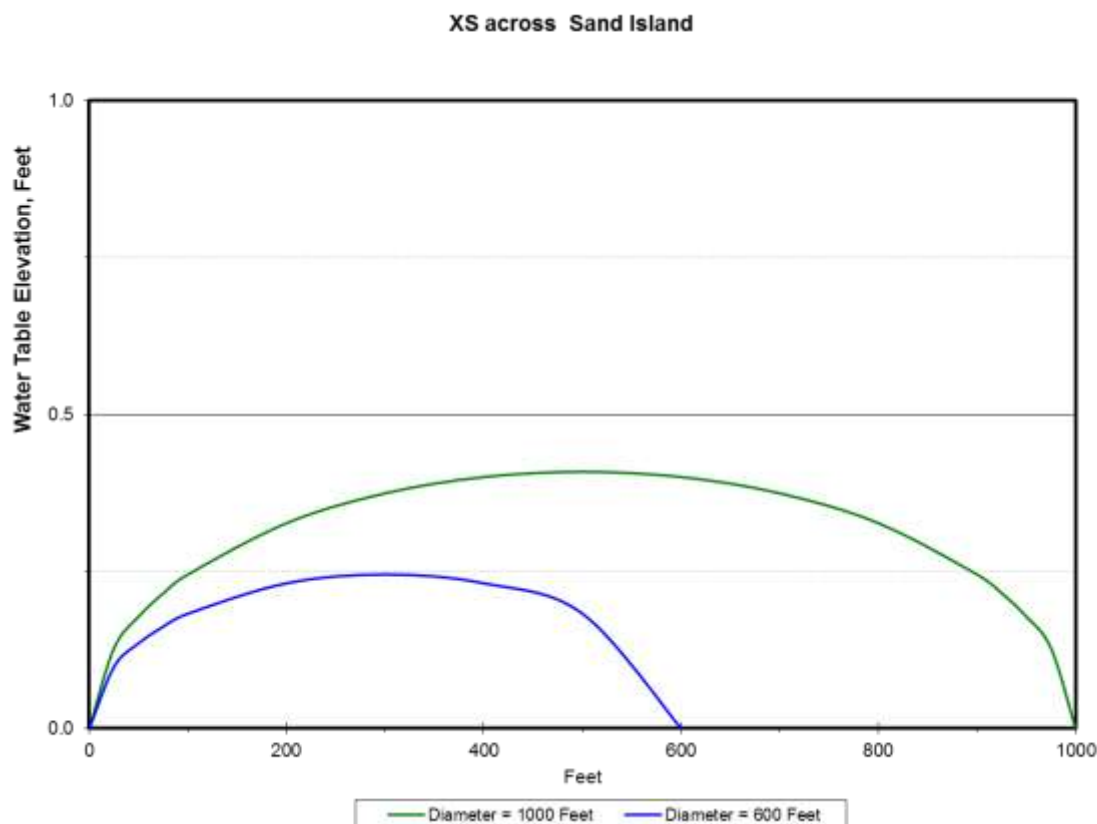


Figure 3. Average water table elevation for two islands of different width/diameter.

At this time we have no site-specific information regarding the water table elevation on the island. We can assume that the hydrogeologic conditions and the size of the island are sufficient for development of a freshwater groundwater lens having a frequency-duration for the water table elevation that will support the wetland area. Reducing the size of the island would result in a lower water table, possibly low enough to cause the wetland area to become dry.

The limiting dimension to maintaining the current water table elevation is the north-south distance, the shortest dimension of the island. Increasing the east-west distance of the island does not affect the water table elevation as groundwater in more distant parts of the island flows toward the nearest shoreline rather than following some longer flowpath to the wetland area. Thus, we can estimate the contributing area for groundwater flow to the wetland by drawing a circle centered on the wetland and having a diameter equal to the width of the island (Figure 4).

If we are only concerned about maintaining the freshwater resource under the island to the extent that it will continue to support the wetland on the western part of the island, then we need only to maintain the island at its current width (or radius) in the vicinity of the wetlands. We don't need to keep the entire east end of the island. Groundwater in that area flows toward the ocean rather than toward the wetlands. In a sand aquifer such as is likely to occur at Sand Island, groundwater under the island will take the shortest route to the ocean.



Figure 4. Estimated contributing area for groundwater flow to the wetland area on the western part of Sand Island. The two circles are initial estimates of the minimum and maximum areas of groundwater contribution.

Additional wetland areas were identified during the field trip to the island on April 23. These newly identified wetland areas are in the central part of the island and the interdunal ridges toward the northeast part of the island. If those wetland areas are to be afforded the same protection, then additional buffer areas are needed, similar to the preceding discussion, resulting in protection areas as shown in Figure 5.



Figure 5. Estimated groundwater protection areas for all of the wetland areas on Sand Island.

Future studies

Currently we have no site-specific information regarding the groundwater hydrology of the freshwater lens underlying Sand Island. If we are to seriously consider removing part of the island, while still protecting the groundwater source for the wetland on the western side of the island, then site-specific studies will be needed to provide a better estimate of the area that could be mined and to evaluate the impact of removing part of the island.

At least five groundwater monitoring wells would be needed (Figure 6). Three of these wells would be placed along a north-south transect of the island, approximately through the pond at the wetland area. Two more wells would be needed about 800 feet east of this transect in the vicinity of the heavily vegetated area in the center of the island. These wells might be constructed using a vibracore drilling technique to allow recovery of core samples to assess the underlying stratigraphy and obtain sand samples for grain-size analyses. There might be reason to complete the monitoring wells with well screen from the water table to 20 feet deep (or more) to allow depth profiling of groundwater conductivity/salinity.

The monitoring wells should be equipped with dataloggers to provide a continuous record of groundwater levels at the various locations across the island. The surface water elevation of the pond should be similarly monitored continuously. A recording precipitation gage will be needed if that data is not available from a nearby source.

After 2-3 months, we should have enough data to begin development of a groundwater flow model for the island. Complete development and calibration of the computer model will require 6-8 months of data. Our confidence in the model will increase as more data are acquired and the model is adapted to match observed field conditions.



Figure 6. Initial estimate of locations for groundwater elevation monitoring wells.

Summary

1. The eastern-northeastern part of Sand Island can probably be removed without adverse impact to the groundwater supply for the wetland area on the western part of the island.
2. Assessment of the potential impact of removing the eastern part of the island will require installation of several monitoring wells, continuous monitoring of water levels for 3-6 months, and development of a computer model of groundwater flow. A realistic minimum time to conduct the investigation and produce a report is one year.
3. Protection of the groundwater supply for the wetland areas in the central and northeastern part of the island would preclude removal of any part of the island.