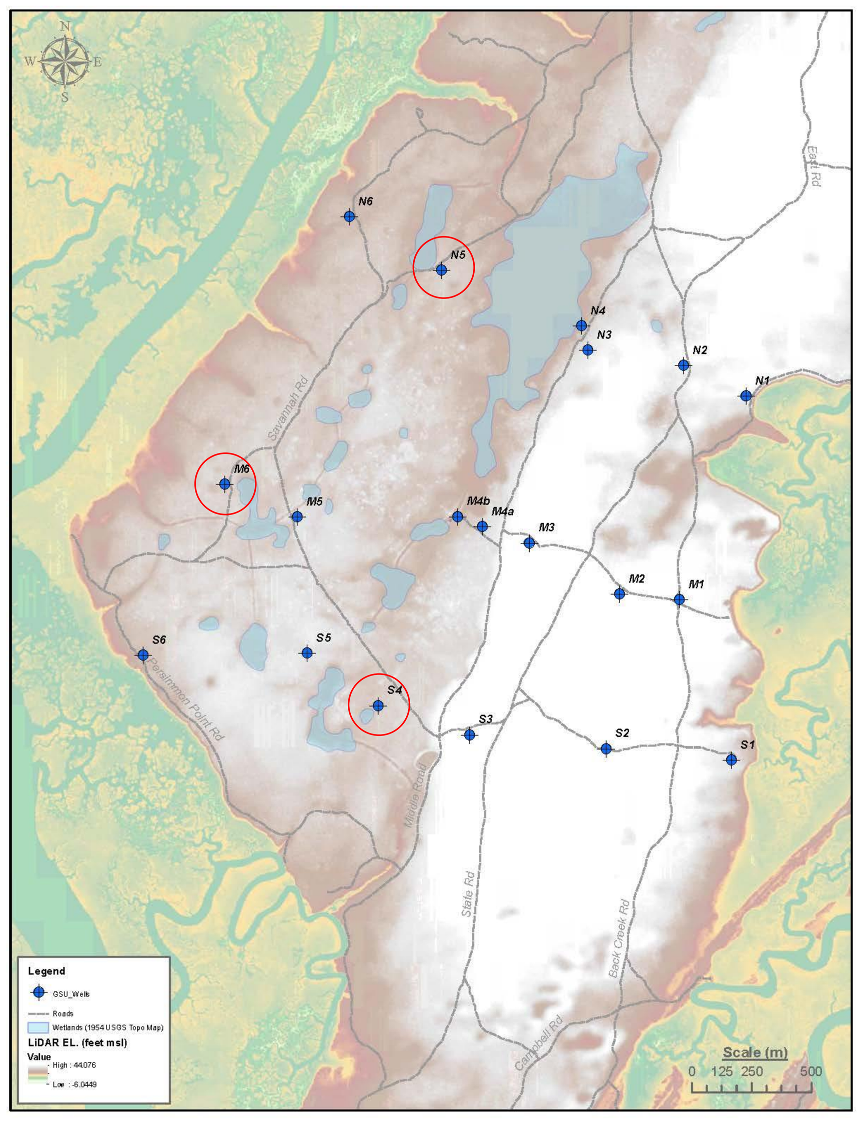
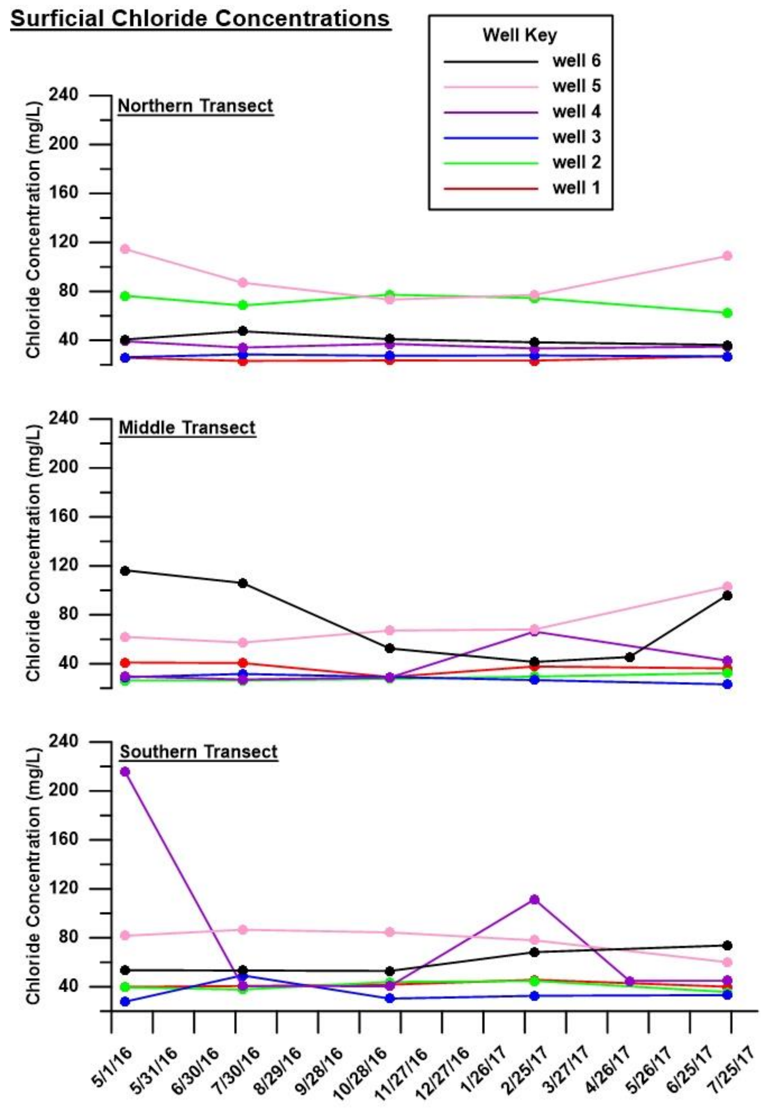
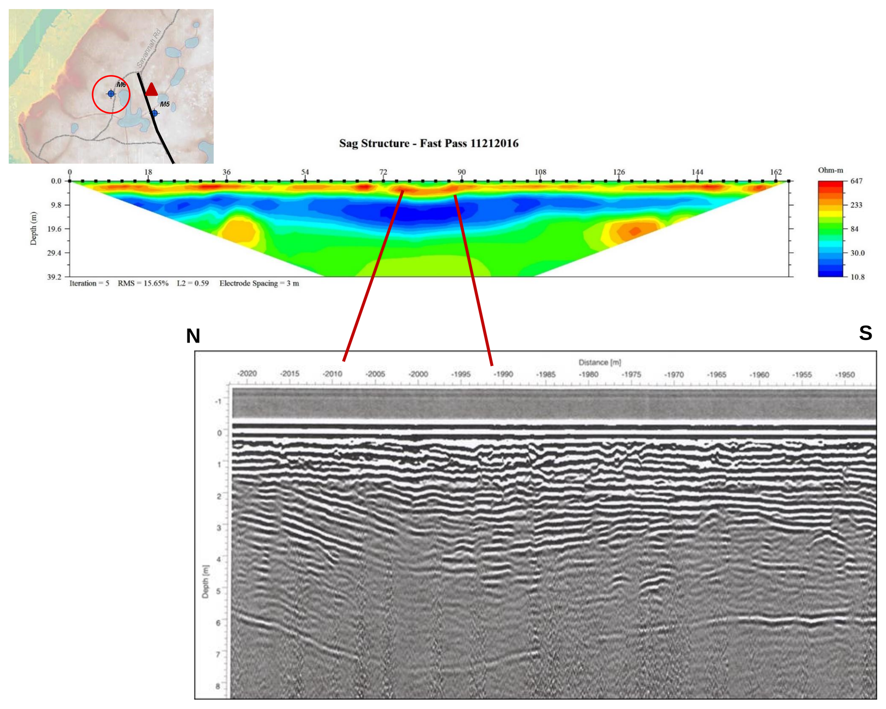
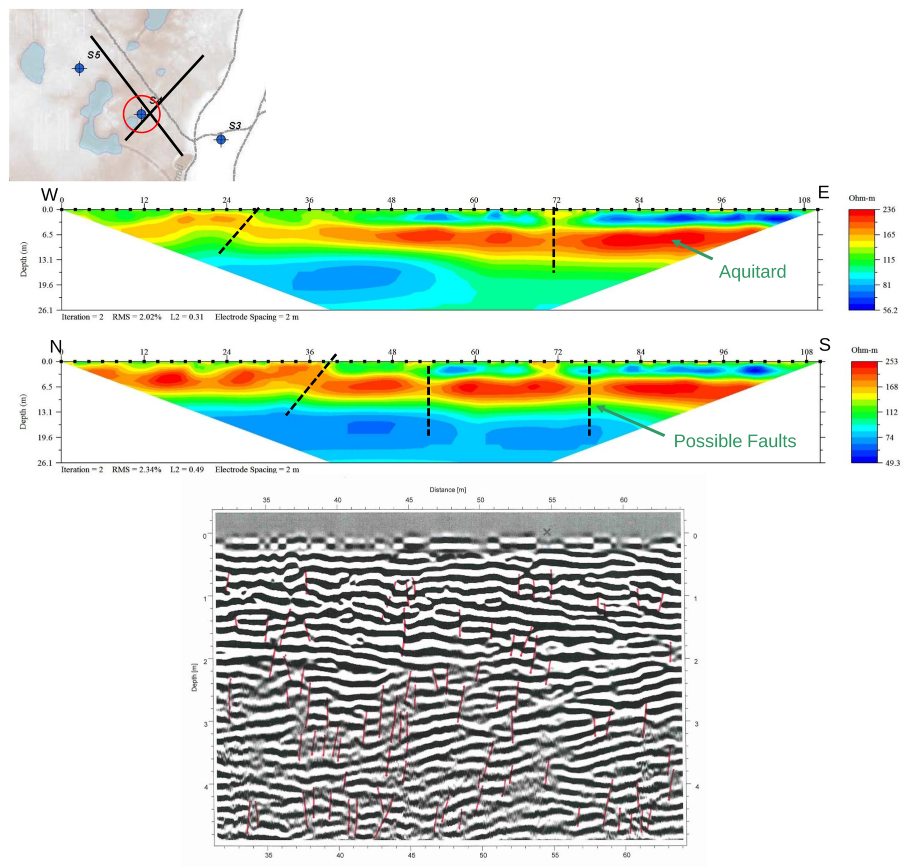
Recent Hydrogeologic Data



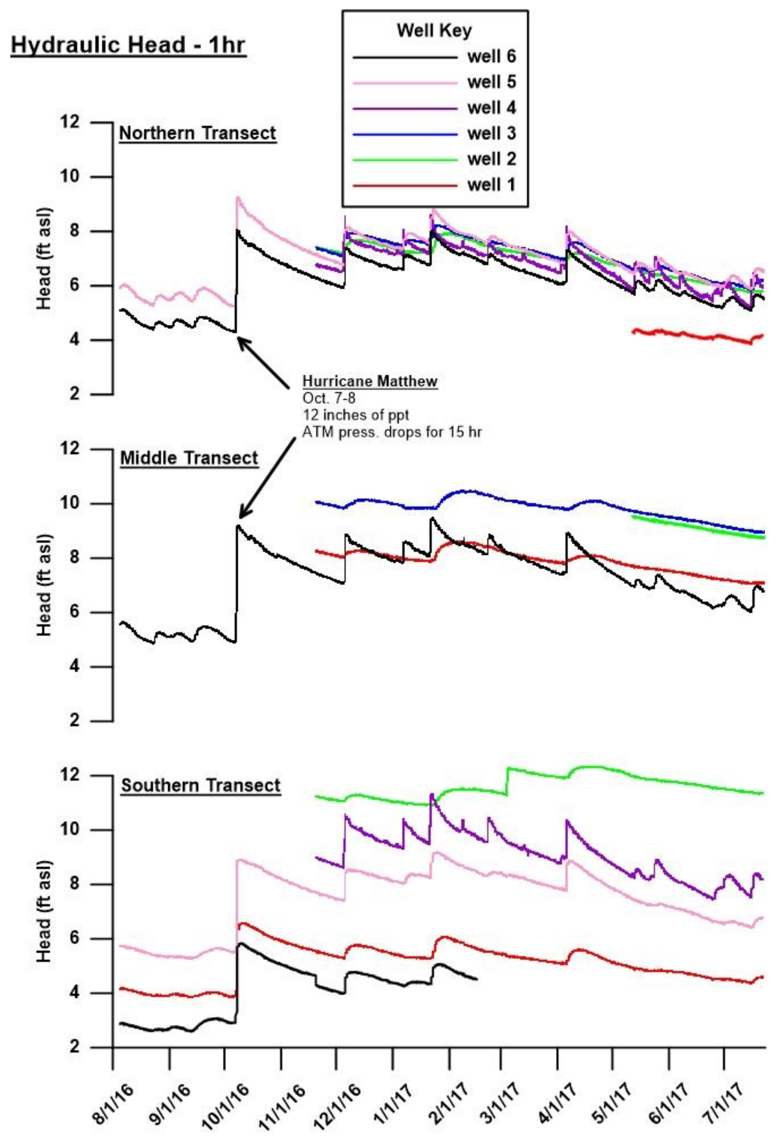


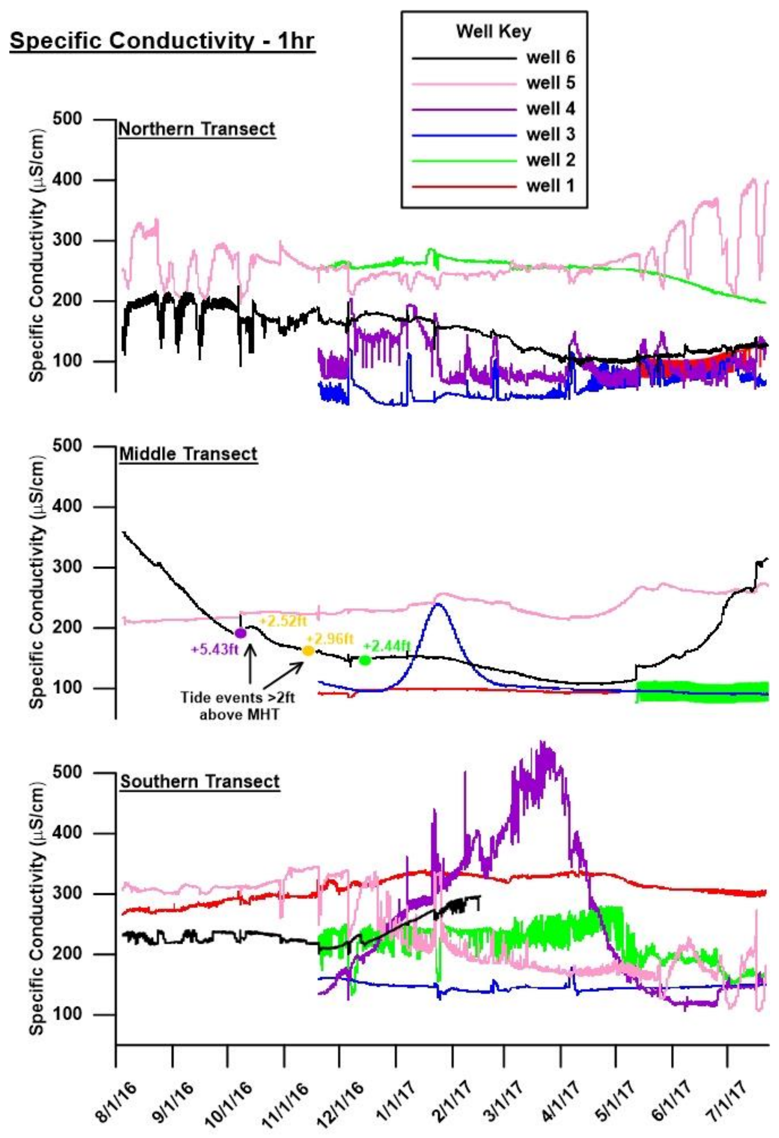
To test the hypothesis that saltwater intrusion is occurring along preferred groundwater pathways, 12 additional surficial wells were added in 2016 (left-map). The study site now consists of three parallel transects with a total of 18 wells. Note that the middle transect represents the original E-W transect of the study and that M6 is the original well 4. Quarterly chloride concentrations from all 18 wells (right-plot) reveal that wells N5, M6, and S4 (circled red on map) show significant temporal variations in chloride. In contrast, most of the other wells show relatively small variations in chloride; even those located near the margins of the island. This indicates that in the vicinity of wells N5, M6, and S4, saltwater intrusion is occurring along preferred pathways.





Because the strongest evidence of saltwater intrusion was found at sites M6 and S4, electrical resistivity (ER) and ground penetrating radar (GPR) surveys were performed at these sites to help understand the subsurface geology. Both the ER and GPR profiles near M6 (left) show the presence of a sag structure about 2-8 meters below land surface. At S4, the profiles reveal what appear to be several faults and fault-related structures. It is hypothesized that these features are related to reactivated basement faulting, the effects of which have propagated up through the coastal plain sequence.

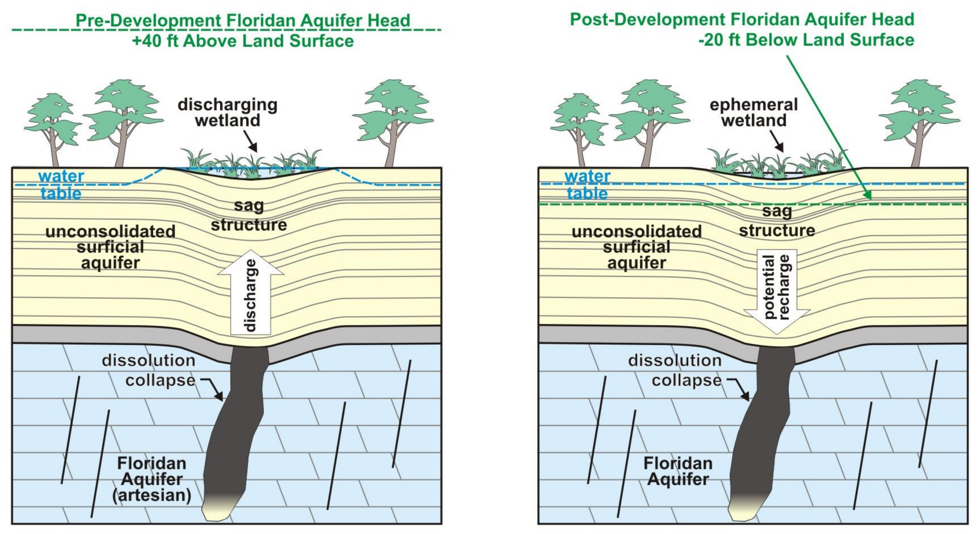




In August, 2016, we began installing data loggers in select wells in order to provide hydraulic head (left) and specific electrical conductivity data (right) at 1-hr intervals. Similar to what we observed with quarterly chloride data, the hi-resolution conductivity plots show evidence of saltwater intrusion at wells N5, M6, and S4. As in the initial study, tidal events greater than 2 ft above mean high-tide were plotted on the conductivity curve of well M6 (right). Note that the first large tidal event was associated with Hurricane Matthew (Oct. 7-8, 2016), whereas the other large tides were astronomical in nature. Based on these data, we interpret that unusually large tides drive saltwater into surficial aquifer in the vicinity of well M6 along fractures and faults associated with the sag structure identified on ER and GPR profiles. Similarly, large tides drive saltwater into S4 via the fractures and faults found on ER and GPR profiles. Although ER and GPR profiles have yet to be performed at N5, we suspect similar permeable pathways will be found there as well.

Conclusions

Based on more than 6 years of head, specific conductivity, and chemical data from the surficial aquifer on St. Catherines Island, we hypothesize that unusually large tidal events periodically drive saltwater along permeable pathways into geographically restricted parts of the aquifer. Moreover, ER and GPR surveys indicate that the pathways are associated with sag structures and faults in the underlying sedimentary units. It is also hypothesized that these sag structures and faults are related to collapsed solution cavities and reactivated basement faults that have propagated up through the coastal plain sequence over geologic time.



Meyer et. al. 2009

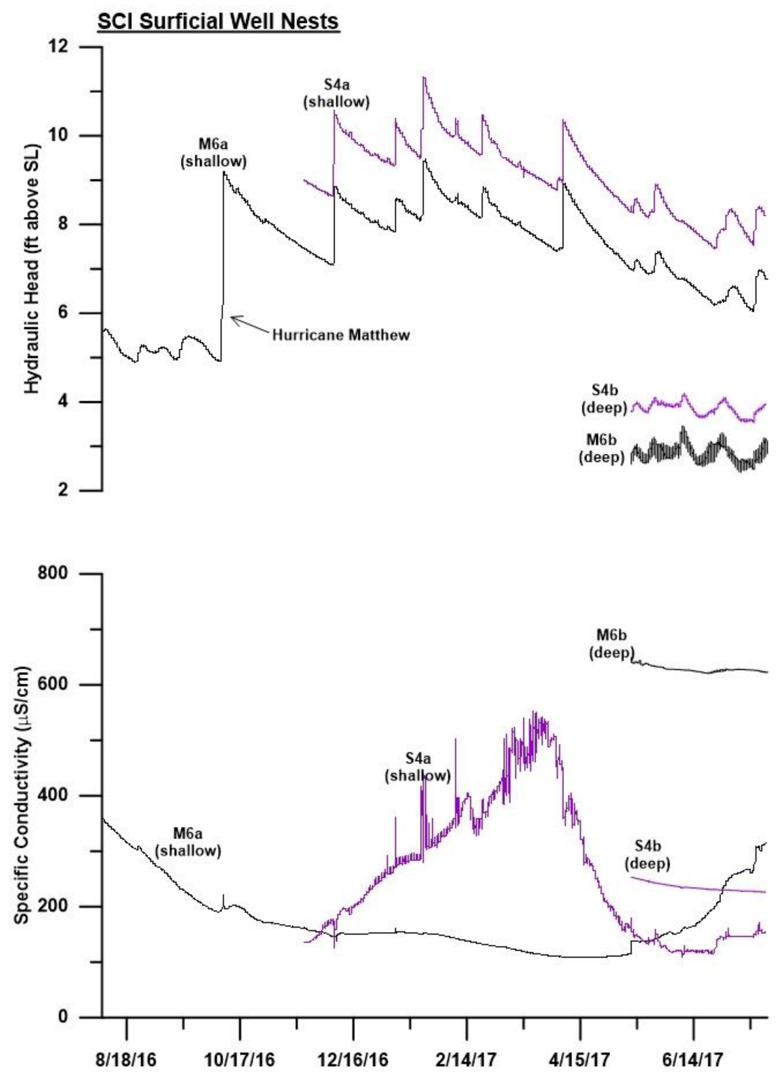
Statesboro, Georgia, 2010

As indicated in our conceptual model (left), prior to modern pumping withdrawals from the deep carbonate system known as the Floridan aquifer, the vertical hydraulic gradient in coastal Georgia was upwards. Thus, artesian water from the Floridan naturally flowed upward along existing joints and faults. Solution voids would form in the limestone overtime, some of which eventually collapsed, creating sag structures and faults in the overlying units, similar to those found in the ER and GPR profiles of this study. Because of their more permeable nature, these collapse features and faults would act as a vertical conduit, allowing large volumes of artesian water to flow upwards, creating springs and freshwater wetlands at the surface. Due to major pumping withdrawals from the Floridan aquifer, the vertical gradient beneath St. Catherines is now downward. Therefore, the conduits today have the potential to allow water from the surface environment to migrate down into the Floridan aquifer.

A modern example of a collapse conduit within the Coastal Plain is shown in the photo (right). This sinkhole formed in 2010 and is located about 70 miles from the coast in Statesboro, Georgia. At this site, approximately 400 ft of clastic sedimentary units overlie the carbonate rocks of the Floridan aquifer system. One can infer then that a large solution cavity collapsed within the carbonate sequence, and that this overlying sinkhole actually represents a vertical conduit at least 400 ft in length. We hypothesize that these types of solution collapse features, and associated fractures and faults, are related to basement tectonics and reactivated faults and are relatively common throughout the coastal plain.

Future Work

Vertical well nest at site S4



In order to help identify and track future intrusions of saltwater into the surficial aquifer, a set of deep wells were recently installed at sites M6 and S4. Each site now has a vertical well nest (left) consisting of a shallow (20 ft) and deep (45 ft) well. As with the 18 shallow wells in the study, the deep surficial wells are instrumented with head and conductivity data loggers and will undergo quarterly water sampling and chemical analysis. Preliminary data from the two nests (right) show that the hydraulic response of the shallow wells to precipitation and tides is nearly identical. The response of the two deep wells also mirror each other, but the head at M6 is clearly more sensitive to daily tides. With respect to specific conductivity, early data show that groundwater from the deeper part of the surficial aquifer at both M6 and S4 is more saline than the baseline (non-intrusion) salinity in the shallower parts of the aquifer. Therefore, it's possible that the source of saltwater intrusion at these sites is a combination of modern seawater and more brackish water from the deeper parts of the surficial aquifer. Additional sampling and mixing analysis using piper diagrams should enable us to better define the saltwater source. Finally, we plan to install vertical nests and run ER and GPR surveys at other sites showing strong evidence of saltwater intrusion in order to better refine our conceptual model of saltwater intrusion on the island.

Acknowledgements

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References

Barlow, P.M, 2003, Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast, *USGS Circular 1262.*
Chowns, T.M. and Williams, C.T., 1983, Pre-Cretaceous rocks beneath the Georgia Coastal Plain – Regional Implications, *USGS Prof. Paper 1313-L.*
Dillion, W. P., Klitgord, K.D., and Paull, C.K, 1983, Mesozoic development and structure of the continental margin of South Carolina, *USGS Prof. Paper 1313-N.*
Meyer, B.K., Keith-Lucas, T., Bishop, G.A., Thomas, D.H., Hayes, R.H., Sanger, M., and Vance, R.K., 2009. Digital Atlas of St. Catherines Island, Georgia. *St. Catherines Research Consortium Publication CD-1*
Reichard, J.S., Nelson, B.R., Vance, R.K., Meyer, B.K, 2014, Evidence for Saltwater Intrusion in the Upper Floridan Aquifer on St. Catherines Island, Georgia, *Southeastern Geology*, v 50, n. 4, p. 109-122.