A Hydrogeophysical Investigation of the Shallow Sandy Aquifers in the Oak Openings Region of Northwest Ohio

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Abstract

The Oak Openings Region of Northwest Ohio has a unique shallow sandy aquifer that is responsible for the wet prairie ecosystem above it. However, groundwater flux and contaminant transport within the 1 – 3 m thick sandy aquifer and a potential flow exchange with the deeper carbonate aquifer in the post glacial regional aquifer system are not well understood. In this study, integrated geophysical methods involving electrical resistivity tomography (ERT) and ground penetrating radar (GPR) are co-located to delineate the sandy aquifer unit at the Stranahan Arboretum and the Sandhill Crane Wetland sites in Toledo and Swanton, Ohio. Parallel ERT profiles were acquired using a SuperSting R8 resistivity meter with a dipole-dipole configuration and unit electrode spacing of 1 m while the GPR profiles were acquired using a PulseEKKO Pro 250 MHz radar system. Additionally, we obtained soil samples extending to a depth of 2.5 m at six locations on three of the profiles at each site. The sand samples were analyzed for their grainsize and to estimate the hydraulic conductivity (K) of the aquifer. Multiple slug tests were also used to estimate the variation in K. We found that the sandy aquifer is somewhat disconnected at the Stranahan Arboretum, with the thickest lenses around 10 - 40 m on the ERT profiles while a continuous and thicker sand sequence is observed at the Sandhill Crane site. The sandy aquifer is underlain by clay-rich silt and glacial till respectively who's hydraulic leakance controls potential vertical fluxes. The average grain size of the sands was between 0.285-0.33 mm, suggesting fine to medium-grained sands. The average K ranged from 2×10^{-4} to 9×10^{-4} m/s, with generally larger K values found in sands sampled from the thickest lenses. Overall, the correlation of higher K values within thicker sand lenses suggests that in these areas, groundwater would be able to flow more easily, and the aquifer could be more easily contaminated than thinner, less connected sand units. We hope to continue this research and improve K estimates and conceptual models to help devise better plans to protect the groundwater resources and ecosystems of the OOR.

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Background

- Northwest Ohio's Oak Openings region is responsible for shallow sandy aquifers which feed a unique ecosystem
- Sandy aquifers have not been clearly delineated
- Groundwater flux and contaminant transport not well understood

Research Questions

- What is the structure of the shallow sandy aquifer?
- How is water flowing within the sands?

Methods

Figures 1-3. Sandy soil core, GPR mobile device, and ERT device at the Stranahan Arboretum site during data collection

- Collected nine parallel colocated electrical resistivity (ERT) and ground penetrating radar (GPR) profiles at Stranahan Arboretum
- Soil cores were taken at areas where the sand was expected to be the thickest based on higher ERT values
- Conducted a sieve analysis on sand samples in order to estimate hydraulic conductivity of the sands using Shepherd's method

Geophysical Results

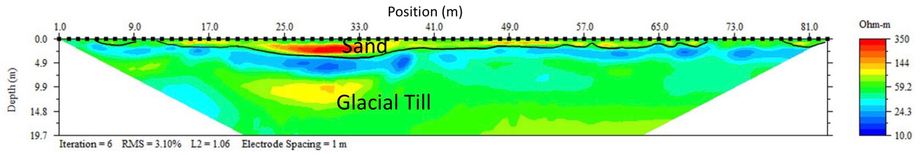


Figure 4. ERT Profile 2 example delineates the area of thick sand between ~10-40 m laterally and between 0.6-2.5 m depth with resistivity up to 350 ohm-m

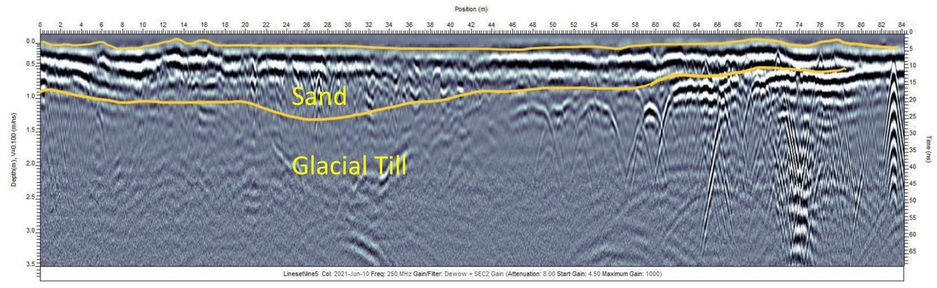


Figure 5. GPR Profile 2 example delineates the thinner, more disconnected sections of the aquifer

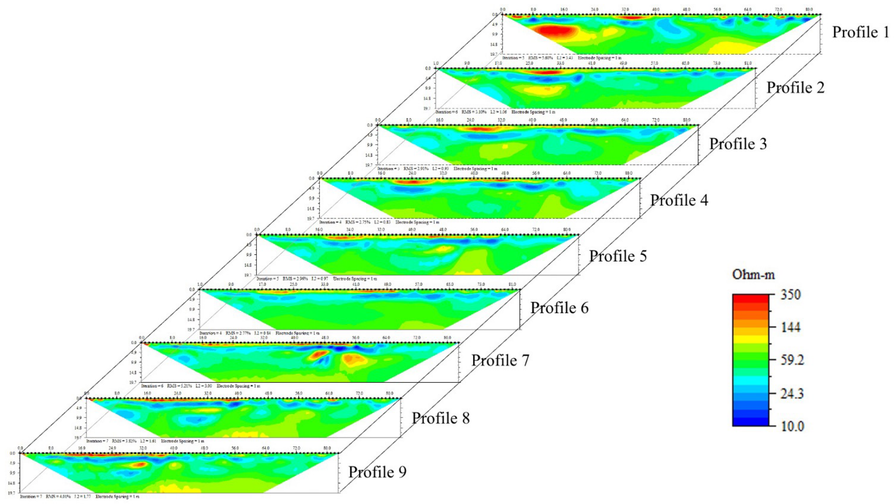
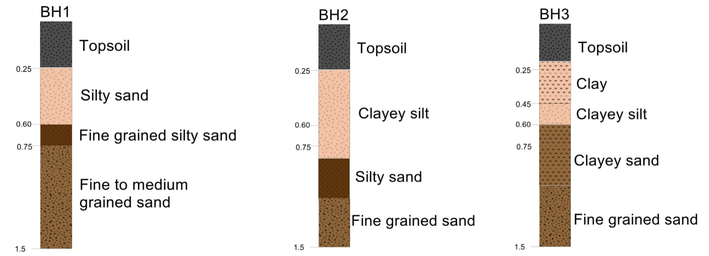


Figure 6. 3D model of all nine 2D ERT profiles which show that the sand extends laterally across all profiles with lower resistivity layers above and below it, suggesting lower permeability clayey or silty layers that could inhibit vertical contamination of the aquifer (confirmed by borehole log Fig. 7)

Grainsize Analysis and K Estimates



Figures 7. Borehole logs from Profile 9 at meter 18 (BH1), Profile 5 at meter 23 (BH2), and Profile 2 at meter 30 (BH3

Figures 8. Profile 2 example grain size graph (values between 0.285-0.33 m)

- K estimates range between 2.15-7.95 x 10^-4 m/s
- Higher K and associated transmissivity (T) values correlate with thicker sand lenses

Conclusions and Acknowledgments

- Sandy aquifer is somewhat discontinuous, with thicker sections between ~10-40 m and a maximum depth of 2.5 m
- Clayey and silty layers above and below the sandy layer could protect it from vertical contamination
- K and T values vary, with higher values associated with thicker sand lenses, which are thus more susceptible to contamination
- In the future, we plan to calculate more hydraulic properties and revise existing K estimates to improve groundwater modeling

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