The hydrostratigraphy of wetlands in the Cumberland District of Daniel Boone National Forest, Kentucky

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Introduction

Although many perched aquifer wetlands have been identified in the Cumberland District of Daniel Boone National Forest (DBNF) in recent years, research is just beginning to help us understand their geologic signatures[1]. In addition to these natural ridge-top wetlands, there have been hundreds of constructed wetlands added to the landscape of DBNF in the past 30 years as part of an effort to save and increase critical wetland habitat. However, these wetlands are perennially full, unlike natural ridge-top wetlands which are ephemeral, and because of their extended hydroperiod, constructed wetlands have become conduits and habitats for invasive species[2]. The US Forest Service intends to begin restoring these constructed areas to function more like the natural ridge-top wetlands. However, to begin “deconstructing” these constructed wetlands, more knowledge is needed about both the constructed and natural ridge-top wetlands’ geologic properties. The purpose of this study is to investigate and compare the geologic controls of water flow in natural and constructed ridgetop wetlands by quantifying hydraulic conductivity (K) and determining belowground hydrostratigrahic structure.

Methods

Five constructed and six natural study wetlands were chosen in Rowan, Menifee, and Morgan Counties, Kentucky within the Cumberland District of DBNF. The wetlands ranged in size, depth, age, and construction.

K was measured in the field for each of the wetlands using a MiniDisk tension infiltrometer, and Slug tests were also utilized when possible. The Slug tests were analyzed using the Bauwer-Rice method, and data from slug tests conducted in 2017 and 2018 augmented this study’s database. Falling head permeameter tests (FHP) were run in the laboratory on a KSAT machine using cores taken from the field. These cores were also used to measure dry bulk density and the soil texture of each wetland. Soil texture was analyzed using a settling from suspension method.

Two natural wetland areas were chosen as sites for hydrostratigraphic mapping. Cores to bedrock were drilled on a transect that crossed the center of the wetland area, and their GPS locations were recorded. The depth of the O-horizon, A-horizon, B-horizon, aquiclude clay layer, and bedrock was delineated, and the soil was described using color and texture. Soil samples were taken to be analyzed for texture. The soil layers’ depths were plotted in Excel based on the elevation topography of the transect from ArcGIS, and then the maps’ stratigraphy was drawn using Inkscape, a vector graphics editor.

Results

Hydraulic Conductivity (K)

Natural wetlands had a higher K than constructed wetlands ($p<0.001$). They also had a narrower range of K values when compared to constructed wetlands (Figure 1), and their K measurements were more precise across test types (Figure 2).

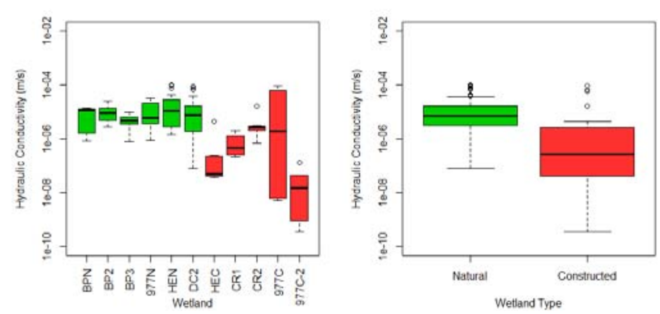

Figure 1. (A) Comparison of all K measurements for each wetland (B) Comparison of all K measurement for each wetland type.

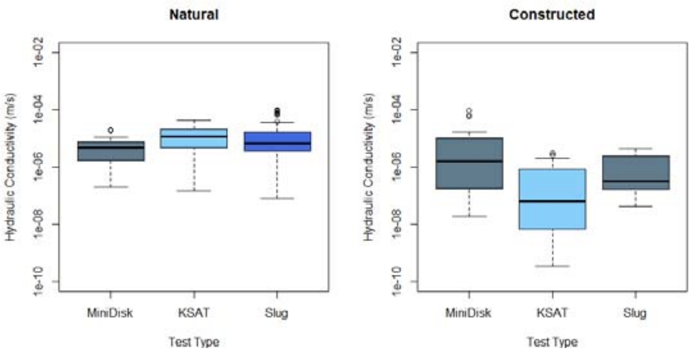

Figure 2. Comparison of test types' determination of K at natural (A) and constructed wetlands (B).

Soil Testing

The soil texture of the constructed wetlands was determined to be clay or silty clay while naturals soils were classified as clay loam, silt loam, silty clay loam, or loam. The dry bulk density of the natural wetlands was lower than that of the constructed wetlands ($p<0.001$).

Hydrostratigraphy

The cross sections revealed bedrock depressions and a grey clay layer overlaying the bedrock under each of the wetlands on the transects, and water levels were overlain on the maps to visualize the systems' aquifers (Figure 3, 4).

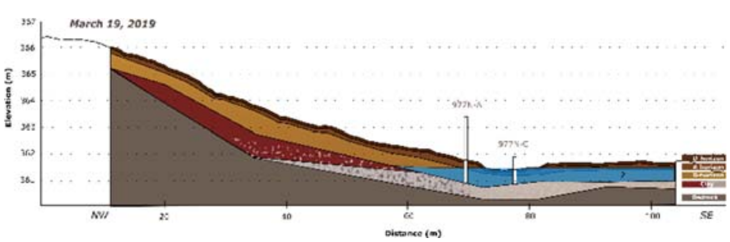

Figure 3. 977N wetland cross section. The water overlay shows aquifer on March 19, 2019 as determined from the water level readings from wells on the transect.

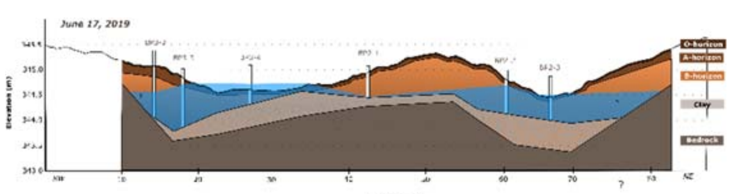

Figure 4. BP wetlands cross section. The water overlay shows aquifer on June 17, 2019 as determined from the water level readings from wells on the transect.

Conclusions

Significant differences were found between natural and constructed wetlands. The known construction methods would account for the constructed wetlands' higher clay content in their soil matrix and their increased bulk density. These residuals would also cause the constructed wetlands' K to be lower.

The methods of measuring K were more precise in natural wetlands. The Minidisks' measurements were generally higher in the K range due to its ability to measure unsaturated hydraulic conductivity. The Slug tests gave a precise number, but its methodology makes it a difficult tool to use in comparisons of many sites. The KSAT also has its drawbacks as it requires a non-insitu methodology. However, it seemed to give the most precise measurements, and it also showed the most difference between wetlands and wetland types.

Due to the heterogeneity of the surface and subsurface, the cross sections are only representative of the wetland transects. Ideally, a three-dimensional model should be built. However, mapping showed that the bedrock layer closely followed the surface topography and that the wetlands were underscored by a gray clay layer that seem to be dictating the systems' aquifers and water flow. More maps will be necessary to determine if there are any hydrogeomorphic trends in the natural wetland systems.

References

1) Malzone, J.M., Sweet, E.G., Bell, A.C., Minzenberger, G.L. (2019) Geomorphic Controls of Perched Groundwater Interaction with Natural Ridge-Top Depressional Wetlands. Accepted with major revisions.
2) Denton, R., & Richter, S. (2013). Amphibian communities in natural and constructed ridge top wetlands with implications for wetland construction. *Journal of Wildlife Management, 77*(5), 886-896.

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