VISTACLARA INC.
NMR GEOPHYSICS

High-resolution NMR investigation of near surface soils at Ebey Island, WA.

Motivation

Coastal and riverine zones are dynamic environments where complex natural processes significantly influence the stability and resilience of nearby infrastructure. Coastal areas are continually reshaped by tidal cycles, sediment movement, and strong interactions between groundwater and surface water, as well as between freshwater and saltwater.

These processes, combined with human development, pose ongoing challenges for managing and protecting coastal infrastructure, especially when it comes to erosion control under constant hydrodynamic forces. Similarly, riverine systems evolve over time due to weather events, climate change, and the presence—or absence—of flood control infrastructure, all of which play a critical role in shaping these landscapes and the infrastructure they support.

Precise characterization of the hydrologic and geo-mechanical properties of the shallow subsurface at coastal and riverine zones is critical for the design of infrastructure and environmental projects in these areas. In many cases, common geotechnical techniques cannot directly or precisely provide hydrologic parameters of greatest need such as soil type classification, moisture content and bulk porosity, and permeability. On other hand, manual core sampling methods are invasive and thus there is a risk of significant disturbance of collected core samples that are used in laboratory investigations.

Vista Clara, Inc. manufactures a full suite of high-resolution NMR Geophysical Tools to provide geotechnical and environment specialists operating in the field of coastal and riverine infrastructure with a detailed understanding of the hydrogeological properties of the shallow formation including hydraulic conductivity, permeability, and effective porosity to benefit construction, restoration, and maintenance projects.

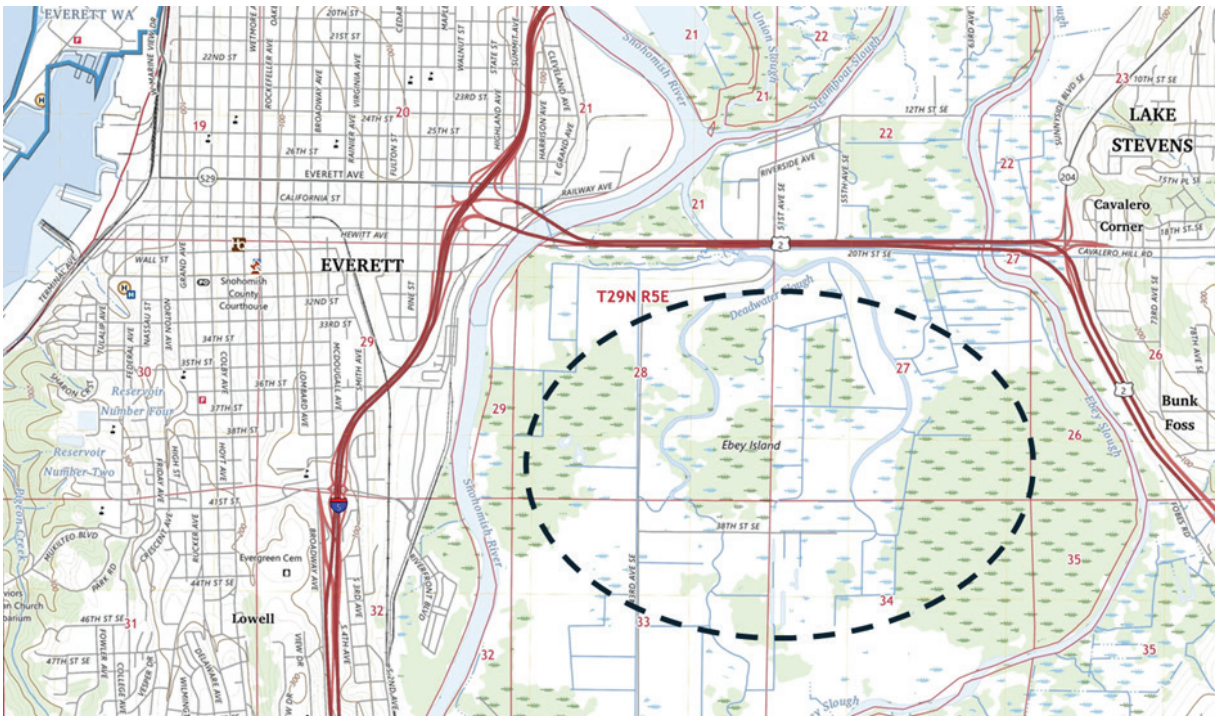

Figure 1. Map of Ebey Island, WA.

Technical Approach

The main goal of this study was to compare NMR-measured hydrogeologic results obtained using different high-resolution NMR tools.

The NMR investigation was conducted at Ebey Island, WA. This site is in the Snohomish River estuary near Everett, WA, USA. The site is associated with a very shallow water table and a network of actively maintained dikes.

NMR borehole logging measurements were performed using Vista Clara's Dart™ DP140N (Numax) and DP140J (JMax) direct push probes. Measurements of the formation hydrogeologic properties were taken by deploying the NMR tools within open core holes or temporally installed 1.5-inch ID PVC well to the depth of 5 ft. (1.5m). NMR measurements of the freshly extracted core sample were also performed using the Helios Trek sensor.

A core sample having total length of about 1.2 ft, was extracted by applying probe slide hammer to a depth of approximately 3 ft. This core sample was scanned immediately in the field using the Helios Trek system, using a measuring step size of 1 inch.

Figure 2. Obtaining soil core sample by slide hammer and scanning the soil core using Helios Trek system.

NMR borehole measurements were performed within a 2-inch open hole created by extracting the core sample. We used the high-resolution DP140J probe with a vertical resolution of 1.5 inches to log this shallow open core hole.

Figure 3. Deployment of DP140Jmax probe within ~2-inch open hole.

Next, we used a hand-deployable auger to create a temporary access well at a distance of about 3 ft from the open core hole. The well was logged with the DP140J (vertical resolution of 1.5 inches) and DP140N (vertical resolution of 5 inches) probes to collect high resolution measurements of moisture content, pore-size distribution, and permeability. An additional temporary access well was created at the distance of about 20 ft from the first one and logged with DP140N probe. Following NMR logging, the temporary wells were extracted from the ground.

Figure 4. Deployment of DP140Jmax probe within temporally installed PVC well created by a 1.5-inch diameter hand-deployable PVC auger.

Results

The core sample length was significantly shorter than the depth to which the slide hammer was deployed. This is possibly due to significant compaction and displacement of the soft organic soils at this site. NMR results obtained from Helios Trek system revealed negligible content of mobile water and decreasing content of total water at shallower depths, in comparison to the NMR logging results.

This result indicates significant disturbance of the sample caused by the coring procedure, suggesting it may not accurately represent the actual in-situ formation.

Very good correlation was observed between the NMR logging results obtained from using the DP140J probe in the open core hole vs. the temporally installed well, indicating that the hand-deployable auger created a minimal disturbance to the formation.

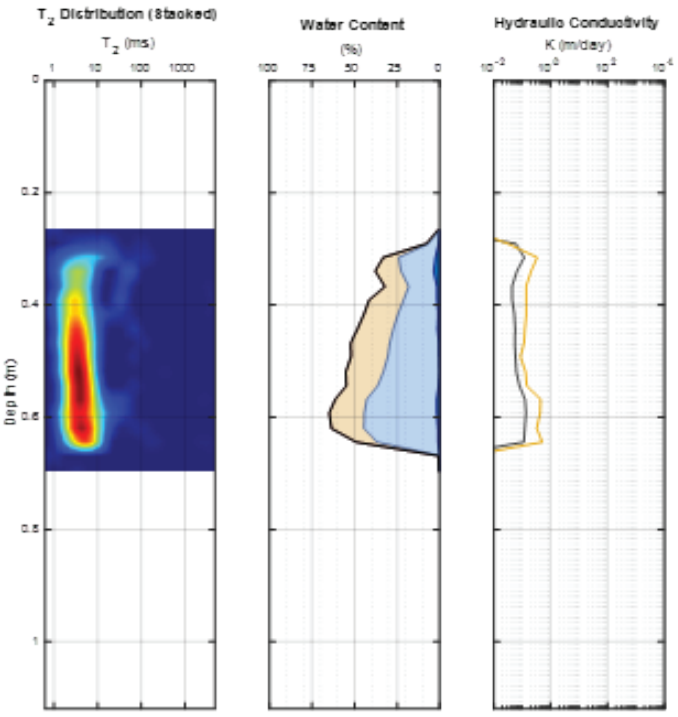

Figure 5. NMR results obtained by scanning the freshly extracted core sample with Helios Trek.

In addition, similar results were obtained when both the DP140J and DP140N were used to collect NMR data within the temporally installed well. Here, slightly smoother plots were produced by the DP140N Numax probe, due to its higher signal to noise ratio and lower vertical resolution, as compared to the DP140J JMax probe. In general, very high volumetric water content values of up to 80% were measured at this location. The site is mostly characterized by very soft silty-type sediments (~40%), less than 25% of clay-bound water that was decreasing with increasing depth, and about 15% of mobile water content, likely associated with water within organic material at this site.

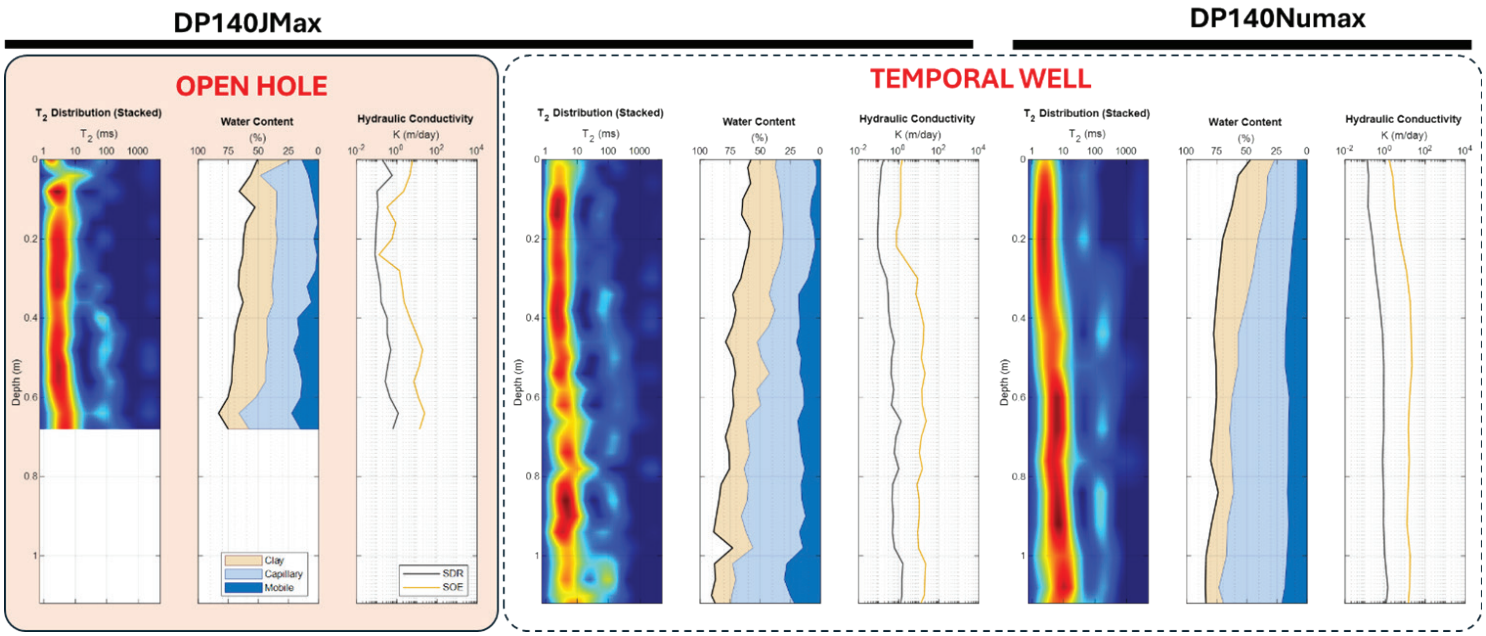

Figure 6. NMR logging results obtained by DP140JMax and DP140Numax probes deployed within open hole or temporally installed PVC well.

Slightly lower total water content of about 60% and smaller content of clay-bound water were observed from NMR logging results obtained from the second temporal access well.

However, relatively consistent hydrogeology of the shallow soil formation was observed across this site at Ebey Island, WA, that is characterized by high silt and organic soil content.

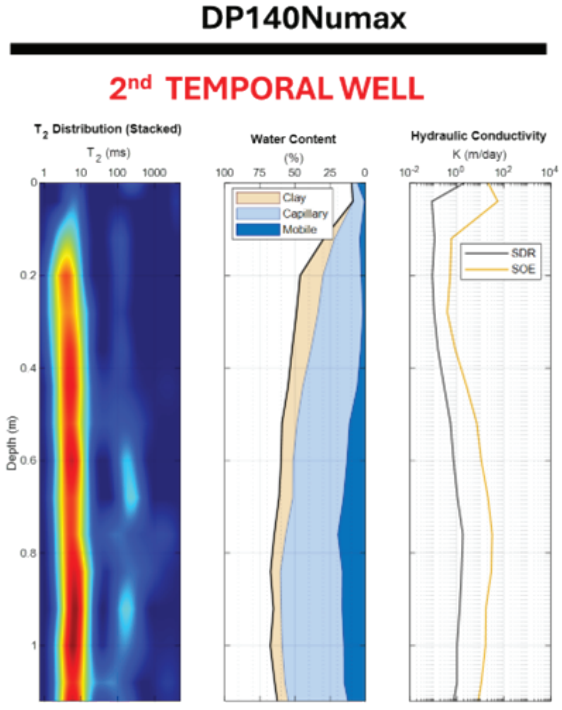

Figure 7. NMR logging results obtained by DP140Numax probe deployed within the 2nd temporally installed PVC well.

Takeaways

A key result from this case study indicates significant disturbance of the extracted core sample, which does not accurately represent the formation of interest. This may pose a significant risk for many geotechnical projects, where design models rely on soil characteristics obtained in laboratory settings using core samples.

In contrast, hand-deployable solutions used for the installation of temporary wells for Dart NMR logging cause only negligible disturbance to the formation, which was found not to affect the NMR measurements. Crucially, Dart logging probes enable direct, precise, and high-resolution measurements of critical hydraulic properties in shallow formations, beyond the zone affected by well installation disturbances.

This successful deployment of Vista Clara, Inc., Dart™ Direct Push probes provides direct measure of hydraulic properties of shallow formation. Deploying Dart™ logging probes offered by Vista Clara, Inc, provides a quick, accurate, and high-resolution solution for detailed understanding of shallow hydrogeologic properties.

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