Cone Penetrometer 3-D Characterization of Y-12 Site to Determine the Hydrological, Geological and Biogeochemistry Best Sites for ENIGMA Subsurface Observatories

T.C. Hazen[1,2], **E.R. Kelly**[1]* (ekelly14@vols.utk.edu), A. Putt[1], K. Walker[1], D.C. Joyner[1], K. Lowe[2], M. Rodriguez Jr[2], M.W. Fields[3], R. Chakraborty[4], X. Wu[4], D. Stahl[5], T. Lie[5], M.W.W. Adams[6], F. Poole[6], P.J. Walian[4], J. Zhou[5], J. Van Nostrand[5], T.R. Northen[4], J.-M. Chandonia[4], A.P. Arkin[4,8] and **P.D. Adams[4,8]**

[1]University of Tennessee, Knoxville; [2]Oak Ridge National Lab, Oak Ridge**,** [3]Montana State University, Bozeman; [4]**Lawrence Berkeley National Lab, Berkeley**; [5]University of Washington, Seattle; [6]University of Georgia, Athens; [7]University of Oklahoma, Norman ; [8]University of California at Berkeley.

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Project Goals: ENIGMA -Ecosystems and Networks Integrated with Genes and Molecular Assemblies use a systems biology approach to understand the interaction between microbial communities and the ecosystems that they inhabit. To link genetic, ecological, and environmental factors to the structure and function of microbial communities, ENIGMA integrates and develops laboratory, field, and computational methods. The Cone Penetrometer field study overarching aim was to get a detailed view of lithology of the subsurface in Area 3 next to S-3 ponds disposal site to select the best sites for installing subsurface observatories for follow-on ENIGMA studies. Additional aims were to: 1. Create groundwater flow model of Area 3 that shows nitrate concentration, 2. Analyze impacts of groundwater rate and flow direction on geochemical parameters and nitrate concentration in Area 3, 3. Analyze impact of subsurface lithology on nitrate concentration in Area 3, and 4. Analyze impact of subsurface lithology on DOC concentration in Area 3.

Over 16 days, a 131-push cone penetrometer grid was completed across the 2,600 square meters of Area 3 with subsurface lithology mapped from 1m to 11m below ground surface (mean=5.9m). In addition, 34 sediment samples were collected near select pushes. Each 0.6m core was collected within 2 to 9.5m below ground surface and consisted primarily of clay. Cores were subdivided into 292 subsamples for: metals, C, N, DOC, DON, biomass, pH, nitrate, nitrite, isotopic fractionation, 16S/18S sequencing, Geochip, respiration, and metabolomics. Groundwater in wells in this area were also measured during the cone penetrometer activity for: DO, pH, temperature, conductivity, redox, salinity, nitrate, depth to water and vector for groundwater flow and rate with colloidal boroscope. The cone penetrometer survey provided a detailed view of the unconsolidated sediment layers of Area 3. This study was conducted to evaluate the interaction between groundwater, different sediment types, and biogeochemistry in order to identify the locations of the future subsurface observatories for ENIGMA. Sediment types, cone pressures, and geochemical data can be mapped to find the extent of subsurface sediment layers with the intention of identifying pathways of flow and recharge. Pushes were

driven to refusal by stiff fine grained material or rock. In the northern section of Area 3, refusal was reached around 4m and the layers most likely contributing to flow are those high in sand and gravel with detectable radiation measured on an in-field Geiger counter. Moving southward, the distance to refusal increased linearly with some pushes extending to 12m indicating a southward slope in the direction of a low-order surface stream. The well-defined gravel layers of the north appear to be mixed in the southern and central section's where mixed sand layers are abundant. The sands include gravely sands, silty sands, and clayey sands with shifting sedimentary composition indicating heterogeneity within the layers. Initial models of the lithology suggest these layers are connected although the central section had a reduced number of pushes due to existing infrastructure. The cone penetrometer study also revealed a large number of localized discontinuous clay and silty clay lenses with limited horizonal and vertical extent. This high-resolution study of the sediment types will benefit our future investigations and current understanding of the transport, storage, and fate of both organic and inorganic substrates in Area 3.Water levels, colloidal borescope vectors, and geochemical measurements were gathered in combination with the stratigraphy data to investigate the possible locations for future multi-level subsurface observations. Because of the large number of wells (102) in Area 3 it allowed measurements before, during and after cone penetrometer pushes near these wells. This demonstrated that the cone penetrometer pushes had no effect on adjacent well water level, vector for flow direction and rate of flow or for DO, pH, temperature, conductivity, redox, salinity, and nitrate. To our knowledge this is the first time this has been demonstrated for a cone penetrometer survey.

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