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Seismic imaging of esker structures from a combination of high-resolution broadband multicomponent streamer and wireless sensors, Turku-Finland

Georgiana Maries (1), Elina Ahokangas (2), Joni Mäkinen (2), Antti Pasanen (3), and Alireza Malehmir (1)

(1) Uppsala University, Dept. of Earth Sciences, Sweden (georgiana.maries@geo.uu.se; alireza.malehmir@geo.uu.se), (2) Turku University, Dept. of Geography, Finland (eliaho@utu.fi; jonmak@utu.fi), (3) Geological Survey of Finland (GTK), Kuopio, Finland (antti.pasanen@gtk.fi)

Eskers and glaciofluvial interlobate formations, mainly composed of sands and gravels and deposited in winding ridges, define the locations of glacial melt-water streams. These sediments, porous and permeable, form the most important aquifers in Finland and are often used as aggregates or for artificial aquifer recharge. The Virttaankangas interlobate suite and artificial aquifer recharge plant provides the entire water supply for the city of Turku and therefore an accurate delineation of the aquifer is critical for long term planning and sustainable use of these natural resources. The study area is part of the Säkylänharju-Virttaankangas Glaciofluvial esker-chain complex and lies on an igneous, crystalline basement rocks. To provide complementary information to existing boreholes and GPR studies at the site, such as identification of potential esker cores, planning for a water extraction, fractured bedrock and possible kettle holes, a new seismic investigation was designed and carried out during summer 2014.

Two seismic profiles each about 1 km long were acquired using a newly developed 200 m long prototype, comprising of 80-3C MEMs-based, landstreamer system. To provide velocity information at larger depths (and longer offsets), fifty-two 10-Hz 1C wireless sensors spaced at about every 20 m were used. A Bobcat mounted drop-hammer source, generating three hits per source location, was used as the seismic source. This proved to be a good choice given the attenuative nature of the dry sediments down to about 20 m depth. One of the seismic lines overlaps an existing streamer survey and thus allows a comparison between the system used in this study and the one employed before.

Except at a few places where the loose sands mixed with leaves affected the coupling, the data quality is excellent with several reflections identifiable in the raw shot gathers. First arrivals were easily identifiable in almost all the traces and shots and this allowed obtaining velocity information down to the bedrock, 50-80 m depth, using a diving-wave travel-time tomographic inversion method. The reflection data processing was challenging due to the large velocity contrasts between the dry sediments and the saturated ones. A careful velocity analysis was the key-processing step apart from filtering source-generated noise. The seismic refraction and reflection sections correlate well with the existing borehole information. Depth to the bedrock from the boreholes matches well the high velocity zones. A zone of low velocity associated with a flat reflection at about 20 m depth below the topography shows a good correspondence with the groundwater table. A major morphologically undetectable kettle hole (MUKH) is clearly observed in the reflection data as a concave reflectivity zone, with indication of normal faulting. The deposits show alternating coarse- and fine-grained sediments with channel structures representing subaqueous fans. An esker core is defined from a zone of reflectivity from coarser-grained materials overlaid by proximal fan sediments of the main aquifer.

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