Time-lapse electrical resistivity imaging (ERI) for embankment seepage monitoring

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In recent years measurement of resistivity variations over time i.e., time-lapse ERI, has been used to image subsurface processes, including the movement of water. The technique is of special interest for non-invasive investigation of seepage/leakage through embankment dams and levees where the resistivity of water seeping through these structures varies seasonally with both ion content and temperature. However, modelling and field trials are required to investigate the method's sensitivity and viability.

Since October 2019, a time-lapse ERI system has been operating at the Mactaquac Generating Station in New Brunswick, Canada, as part of a seepage monitoring research program sponsored by NB Power and NSERC. The system, employing 123 electrodes distributed over a 70 m x 25 m area adjacent to a concrete sluiceway structure, runs autonomously each night, yielding data that are typically averaged over one-week periods and subsequently inverted to yield weekly snapshots of the 3D resistivity distribution.

Over the past year, the system's sensitivity to variations in the dam's clay-till core has been substantially improved by incorporating electrodes buried under the road along the dam crest, robust data processing routines and improved topographic modelling. These changes have proven highly effective, as illustrated by data collected between September and December 2021, during which time the resistivity of water in the dam's reservoir more than doubled, allowing the water to be used as a resistive tracer that highlighted regions within the core that appeared to experience preferential flow. Recent data from April to August 2022 is yielding similar models albeit with a seasonal decrease in water resistivity instead. The most strongly anomalous region appears to be in the upper part of the core above ~8 m depth, in agreement with inferences from temperature monitoring in a borehole drilled into the concrete abutment immediately adjacent to the clay-till core. However, the resistivity change images have yet to be compensated for the fact that seasonal fluctuations in reservoir water temperature (and hence resistivity) also decline with depth.

With an adequately long monitoring time series, it may be possible to make order-of-magnitude estimates for seepage flux (and its spatial variation) by analysing the time lag between resistivity changes in the reservoir and in the dam core. While prior time-lapse ERI studies have been conducted using 2D imaging along a dam crest, the system at Mactaquac is novel for its 3D coverage and application to a dam abutment region.

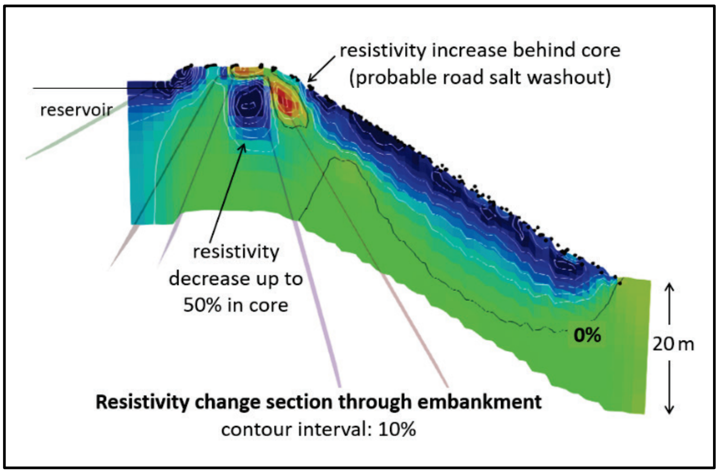

Figure: Cross-section through the embankment, adjacent to concrete structure, showing resistivity change between April 20 and August 19, 2022. A prominent resistivity decrease (dark blue) is evident in the upper core region below the crest.