Research in Hydrogeophysics

The Environmental Physics Group conducts research into physical and geophysical techniques that can advance the study of groundwater hydrology.

Electrical resistivity tomography (ERT)

Surface based electrical resistivity tomography is a technique which can be used as a means of detecting saline intrusion in coastal aquifers. We have previously used it to monitor the intrusion of acid water from Crater Lake into the tephra barrier created during the eruptions of Mount Ruapehu in 1995-6 (Figure 1). Less common is the use of cross-borehole resistivity tomography (CRT) which uses strings of electrodes embedded into an aquifer to provide a detailed picture of the movement of saline water during a tidal cycle (Figure 2).

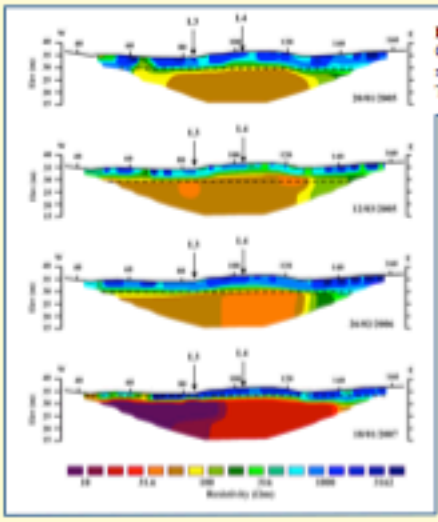

Figure 1: Development of the dc resistivity of the tephra barrier on Crater Lake, Mt. Ruapehu from 2005 to 2007. Low resistivity marks the intrusion of highly conductive lake water into the tephra. The barrier collapsed shortly after it became fully saturated.

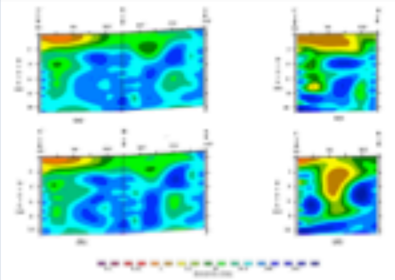

Figure 2: CRT results from electrode strings inserted into a beach. (a) and (b) resistivity structure at low and high tide respectively for a tidal range of 2 m. (c) and (d) the same for a tidal range of 4 m.

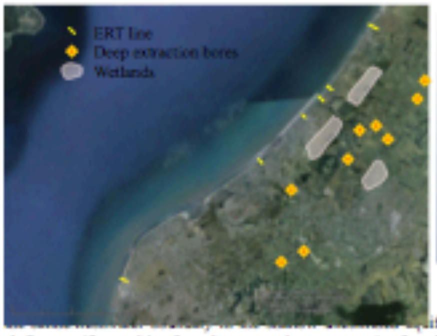

Figure 3: Location of repeat ERT transects along the Kapiti Coast, designed (1) to determine the seasonal variation in [illegible] aquifer, and (2) to monitor and assess saline intrusion into the shallow aquifer resulting from deep groundwater extraction from bores (red crosses) to the north-east of Waikanae.

Current research centres on understanding the saline intrusion risk on the Kapiti Coast. This arises partly from the numerous private shallow bores which extract water from the shallow unconfined aquifer. However, there is also a risk of intrusion resulting from the proposal to supplement the flow of the Waikanae River with water extracted from the deeper Waimea aquifer. Repeat ERT measurements (Figure 3) are being made at various locations along the Kapiti Coast, initially to determine the seasonal variation in the saline interface, and subsequently to monitor/measure the effect of groundwater extraction.

Spectral Induced Polarization (SIP)

Application of an alternating current to natural porous materials such as those that host aquifers produces an electrical response which is frequency dependent. In particular a phase difference occurs between the applied current and a measured potential difference. This arises from polarization effects that occur on the surfaces of pore spaces. The dependence of the phase response on grain size and pore geometry suggests that SIP measurements may be able to provide a surface based geophysical technique that can be used to measure the hydraulic properties of an aquifer, such as the hydraulic conductivity or permeability. These properties can generally only be measured locally by means of pumping tests on boreholes.

Laboratory measurements (Figure 4) of the SIP response of sands of differing grain sizes show that, in particular, the location of the peak in the phase response is highly sensitive to the grain size, occurring at higher frequency the smaller the grain size. Measurements of the permeability of the same sands show that a distinct correlation exists between the location of the phase peak (expressed as a relaxation time, τ) and the permeability, k (Figure 5).

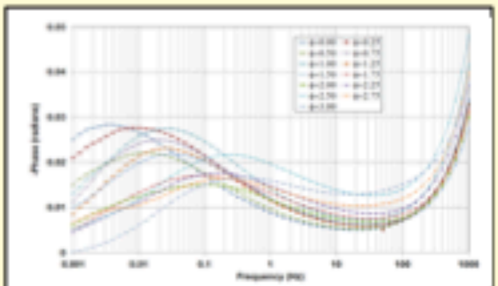

Figure 4: Results of SIP measurements made on sands of differing grain size, showing the dependence of the location of the phase peak on grain size. $\phi = 0.00$ corresponds to a grain size of 1 mm, $\phi = 3.00$ corresponds to a grain size of 0.125 mm.

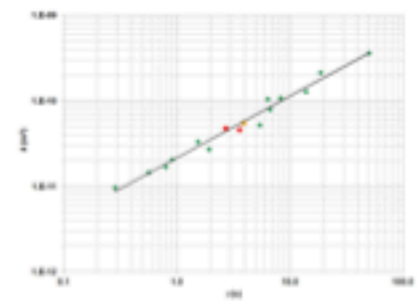

Figure 5: Correlation between the permeability and the SIP relaxation time obtained from laboratory measurements on sands typical of those found in New Zealand aquifers.

Current work involves extending the laboratory measurements to field based measurements. To do this a new instrument capable of providing an alternating currents of up to 1 A in amplitude over a frequency range from 1 kHz to 1 mHz is in the final stages of construction. Preliminary laboratory measurements to investigate how the SIP response varies with depth of current penetration in a medium with non-uniform grain size are also being made. These show (Figure 6) a variation in the location of the phase peak with the separation of the current electrodes.

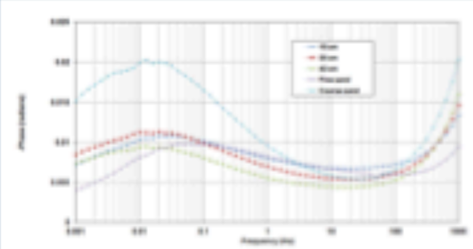

Figure 6: SIP response at various current electrode separations (in cm) over a medium with 5 cm thickness of fine sand overlying a coarse sand. The wider the separation of the current electrodes the deeper current penetrates into the medium and the closer the location of the phase peak gets to that for the underlying coarse sand.

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