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Environmental geophysics mapping salinity and water resources

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Abstract

Salinity and fresh water are two sides of the same coin, most conveniently measured by electrical conductivity; they can now be mapped rapidly in three dimensions using airborne electromagnetics (AEM). Recent developments in the calibration of airborne data against in-field measurements and additional information from radiometrics, magnetics and digital elevation models lend new insights into salinity, groundwater flow systems and water resources. Freshwater resources can be mapped, and salinity risk and the outcome of management interventions may be forecast, on the basis of the specific architecture of complete groundwater flow systems-enabling practical, cost-effective protection and development of water resources.

Keywords: Airborne geophysics; Electromagnetics; Salinity; Water resources management

1. Introduction

Across the dry regions of the world, fresh water resources are threatened by salinity: salt in the wrong place. In Australia, this is a legacy of a dry climate and sluggish drainage, probably exacerbated by changes in land use since European settlement; soil erosion and replacement of native vegetation with crops and pastures that use less water mean that more water is infiltrating to the groundwater, elsewhere irrigation applies more water than comes naturally, so rising water tables bring salt to the surface and into the rivers. It is argued that salinity can be arrested only by extensive land use changes and, even then, response times will often be 100 years or more (NLWRA, 2001).

But it is not all the same out there! To protect water resources, we need to know *where* the salt lies in the landscape, *how* it is mobilised, *what are the conduits* carrying it to streams and the ground surface, the *rate of delivery* now and under feasible management options, and if there are alternative water resources that may be exploited. Answers are emerging from a combination of: (1) airborne geophysics, mapping the salt stores, conduits and groundwater resources in three dimensions; (2) drilling to calibrate the patterns revealed by airborne surveys and to establish the nature of the aquifers; (3) modelling water and salt movement on the basis of the architecture of each groundwater flow system, to establish the risk of salinity and the outcomes of possible management interventions. With this information, cost-effective action on the ground can be tailored to specific situations.

2. Where is the salt and how much is there?

Salt is held as briny pore fluid in the soil and regolith, especially in clays. Recent advances in airborne electromagnetics (AEM) enable rapid mapping of salt and fresh water to more than 100 m below ground (Dent

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et al., 1999). The survey aircraft generates an electromagnetic field that penetrates the ground. This, in turn, induces a secondary current in conductive materials and the current induces a secondary electromagnetic field that is detected by a receiver towed behind the aircraft. The signals are translated into a three-dimensional map by conductivity depth imaging (CDI) or layered earth inversion (LEI).

Conventionally, these models are guided towards low conductivity values at the base of investigation, generally fresh rock, between 100 and 200 m depth. Recently, constrained inversion procedures have been developed to account for different field conditions, such as conductive basement (Lane et al., 2004), and field measurements of conductivity (EM39) and water table geometry from test bores. Initial CDIs generated by the EMFLOW model (McNae et al., 1998) exaggerate the near-surface conductivity. A much better representation may be achieved by: first, iteration of the specified transmitter terrain clearance, transmitter-receiver horizontal and vertical separation; and secondly, governing the maximum conductivity within the range actually measured (Christiansen, 2002). Fig. 1 shows part of the catchment of the Broken River between the Strathbogies Range to the south and the Shepparton Irrigation Area to the north; it contrasts modelled conductivity before and after calibration. A perfect match is not possible, because the 150 m radius footprint of the AEM system encompasses much more inherent variation than the 1 m radius footprint of the EM39 instrument, but r^2 was improved to 0.33–0.47 for the 0–5 and 5–10 m slices, rising to 0.87 for deeper layers. The significance of these advances cannot be exaggerated; earlier applications of AEM to salt mapping (Duncan et al., 1993) met with scepticism because of the imprecision and inaccuracy of the vertical dimension, especially in the near-surface layer; now, a detailed, accurate, three-dimensional picture of conductivity may be had at a cost of a US$ a hectare.

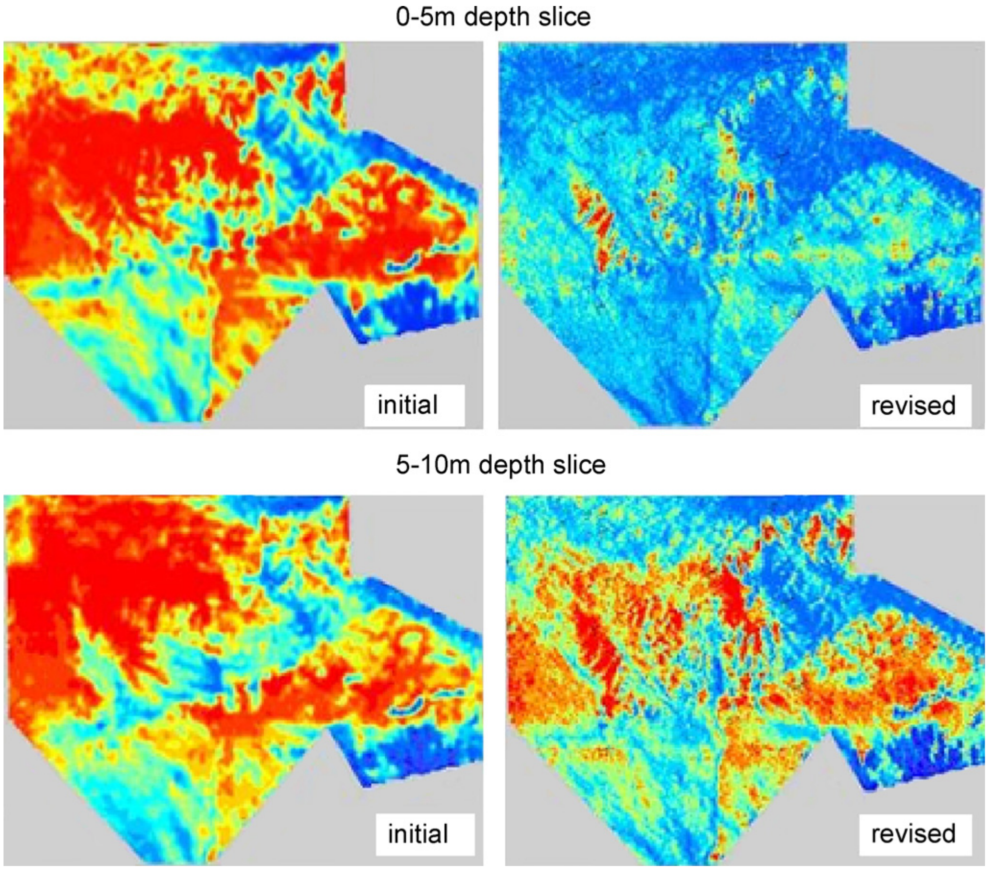

Fig. 1. Mid-Broken Catchment, Victoria. Initial and calibrated CDIs: blue indicates resistive materials and red indicates conductive. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)