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Instream TEM: unresolved questions

Welcome to *Preview* readers this month. Just a few days ago (in November when I was writing this column) I got into an email conversation with Volmer Berens and Roger Cranswick from the South Australian Department of Environment, Water and Natural Resources (SA DEWNR) and Tim Munday from CSIRO (Minerals Resources / Land and Water) about the interpretation of instream TEM data collected on the Murray River; they were looking specifically at some data that had been collected earlier this year.

As many of you would know, instream TEM is a subject close to my heart, having been involved with this type of data acquisition and analysis since 2004. For those of you who don't know what I am talking about, I think of instream TEM as basically floating a small, low-power, time-domain EM system off the back of a boat. For most of this work the transmitter loop is only 7.5 m × 7.5 m, and the receiver 2.5 m × 2.5 m, with the transmitter and receiver (in this case a Zonge NanoTEM system) set up to collect data in ~2 s bursts.

These data have been presented in some beautiful atlases (e.g. Telfer et al., 2004), developed as a result of collaboration between Australian Water Environments (AWE), Zonge Engineering and various SA Government agencies. After some investigation, it was determined that while the TEM was providing some information about hydrogeology under the river, much of the information was about the interaction between the river and the often saline groundwater immediately under the base of the river (Berens, 2006, Tan et al., 2007). One of the original motivations for the original work was to investigate the area adjacent to a number Salt Interception Scheme bores (see for example Forward (2004) for a description of SIS in SA) to evaluate whether the bore schemes were operating efficiently. The main question was whether the SIS bores adjacent to the river were removing all of the saline groundwater before that water had a chance to enter the Murray; did they need to be pumped harder or could they be pumped less?

Back to our email conversation, Volmer kicked off the conversation with: 'A colleague of mine [that was Roger] is working with recently acquired instream NanoTEM data and has asked an interesting question – has anyone defined the resistivity threshold that could be used to discriminate between losing and gaining river stretches?'. And after a few emails we realised that the answer is probably 'no'. Understanding whether a given stretch of river is 'losing' or 'gaining' is very important for understanding salt accession to the river, and we had been making this interpretation by examining the depth sections and the GIS images without having determined any objective 'rules' (or even 'rules of thumb').

Roger took the bull by the horns and did some simple analyses using Archie's Law (Archie, 1942). He made the usual assumptions, setting porosity to 35% and assuming that the sample was 100% saturated (not a bad assumption directly under the river). He then set the empirical constants to the 'usual' settings, i.e. m=1.3, n=2 and a=1. I then took one of the older instream EM data sets, collected in 2005 near Bookpurnong (which is near Loxton, in SA), and plotted the data using a 'rainbow' colour stretch that shows the variability in the data nicely, but doesn't encourage 'targeted' interpretation, as is the goal here.

I then plotted the data based on Roger's Archie's Law results, first assuming that the resistivity of the river was 20 ohm-m (about right from memory) – which I then dropped to 15 ohm-m to give myself a little salinity leeway from the 20. I then arbitrarily set the resistivity of saline groundwater to ≤5 ohm-m. Using that 15 ohm-m river water assumption Archie tells us (via Roger and the other assumptions that he made) that the resistivity of that river water and sediment package would be about 60 ohm-m. Then, using that 5 ohm-m saline groundwater assumption, Archie again tells us that the resistivity of the saline groundwater-sediment package should <20 ohm-m. Based on these two rules we would then say that anything on the conductivity depth section close to the river base that is <60 ohm-meter is likely

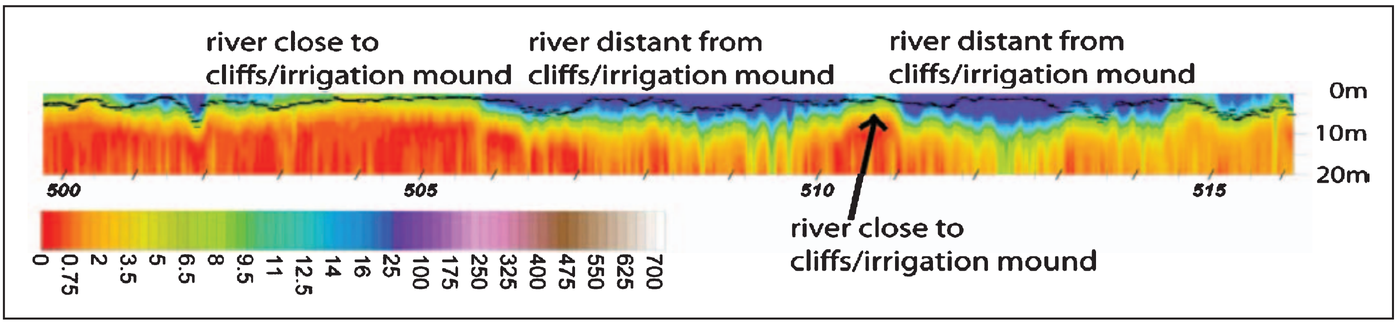

Figure 1. *Resistivity-depth section near Bookpurnong, on the Murray River, collected in 2005. Distance on the x-axis is in River Kilometres (and are used on Figure 2 as well). Depth of the river is indicated with the black dashed line. All of the orange has been interpreted as saline groundwater. In many places it is touching the base of the river (interpreted as gaining) and is never more than 5 m from the base of the river.*

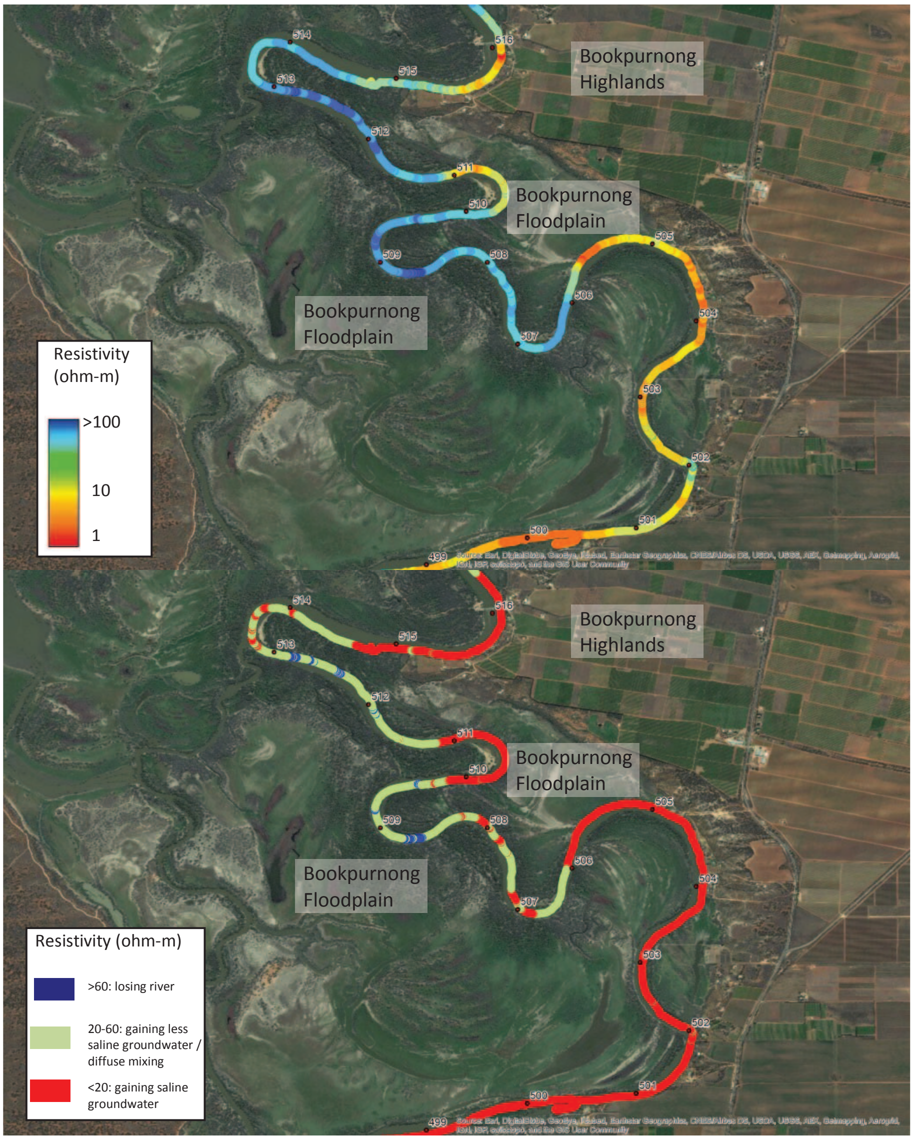

Figure 2. *Contoured river bottom resistivity data. In these GIS images, the trace of the river is shown using the resistivity value just below the bottom of the river from the conductivity sections in Figure 1. The top panel is how we usually show the data, while the bottom panel uses the colour scheme suggested by the collaborators*

to be influenced by saline groundwater and therefore the river is likely to be gaining groundwater.

Resistivities between 20 and 60 ohm-m are likely to be associated with zones of diffuse mixing (e.g. the saline groundwater is not in direct contact, but is still some distance from the river bottom). When resistivities are >60 ohm-m we would say that river is quite fresh and is likely to be losing to the underlying groundwater system. Figures 1 and 2 show and compare the results of this analysis. Personally, I think that the simplified three colour map is intriguing and may even be close to right. Looking at Figure 1, the conductivity-depth section for this part of the river, I would say that saline groundwater is not far from the river bottom along this entire stretch of river, and most of this stretch is gaining or will be soon (remember these data were collected in 2005). Interestingly SA Water agrees as they have built a major SIS through this stretch, based on this work, (and possibly more importantly) an extensive in-river salinity monitoring program, other hydrogeological studies and numerical modelling.

In the end, the question remains: have we come up with an improved classification scheme that makes interpretation simpler for this particular problem (and is it right)? Back to you Roger, Volmer and Tim…

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