Rate of success for a groundwater drilling program planned from AEM, Gascoyne River, WA

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SUMMARY

In a collaboration between Department of Agriculture and Food, Western Australia (DAFWA) and CSIRO, funded by the Western Australia Government's Royalties for Regions Program and the Gascoyne Foodbowl Project, the Gascoyne River AEM Aquifer and Groundwater Characterization Project was established with the aim of determining whether airborne electromagnetic (AEM) data can be employed to better map attributes of the unconfined alluvial aquifer beneath and adjacent to the ephemeral Gascoyne River.

One major aspect of the project was to produce drilling targets, based on interpretation of AEM data, for groundwater production. In this presentation, we briefly recapitulate our method and discuss the result of the drilling campaign that ensued. We show that our exploration targets have resulted in overwhelming success in the conversion of exploration wells to production bores; and that the production wells produce greater yields of better quality groundwater than previous campaigns that were conducted through step-out drilling.

We show that interpretation of the AEM inversions allowed us to map the aquitard layers that define the bottom of the Gascoyne River Old Alluvium aquifer system, determine the extent of the saltwater intrusion from the nearby Indian Ocean, and to calculate the overall volume of the aquifer system. These calculations allow us to provide estimates of total groundwater volume contained in the aquifer for sustainable production.

Key words: Groundwater, drilling, AEM, Gascoyne River.

INTRODUCTION

The Gascoyne River extends about 700 km inland from the coast of the Indian Ocean and the township of Carnarvon in the mid-northwest of Western Australia. This Gascoyne River AEM study is focussed on the western-most reach of the river, extending inland from Carnarvon for some 50 km, and is shown in Figure 1. The Lower Gascoyne River flows ephemerally along a well-confined singular, low-sinuosity channel, up to 1200 m wide, incised 3 m to 5 m into a laterally extensive Quaternary sequence of aggrading alluvial sediments (Dodson, 2008)

For the area considered in this study, groundwater is contained within a regional, unconfined to semi-confined alluvial aquifer system. The alluvial sediments have been grouped into two distinct aquifers in hydraulic connection with each other, namely the younger riverbed sand aquifer and the older alluvium aquifer. The riverbed sand aquifer, which is made up of the river bed-load of the Gascoyne River, ranges in thickness from 1 m to 12 m. It is an unconfined system and contains fresh (<500 mg/L TDS) groundwater, recharged through surface water from intermittent river flows.

The older alluvium comprises older fluvial materials and consists of alternating, discontinuous and irregular, unconsolidated to semi-lithified, thin beds of poorly sorted sand, gravel and clay with varying sand and silt fractions (Martin, 1990). In places the old alluvial aquifer is confined or semi-confined by clay drapes representing overbank deposits. The sand and gravel beds are laterally discontinuous, being laid down as channel lag deposits or point-bar river channel deposits, and the sedimentary textures vary over short distances (<5 m) both laterally and vertically (Skidmore, 1997). The older alluvium contains significant volumes of groundwater of varying quality, and away from the Gascoyne River, much of it is brackish to saline (1000 mg/L TDS to 6000 mg/L TDS). The groundwater stored in the younger alluvial aquifer also recharges the underlying older alluvial aquifer (Allen, 1972; Martin, 1990)

The groundwater flow system in the two alluvial systems is heterogeneous and anisotropic, bounded in the west by the saltwater interface at the Indian Ocean, and in the east by the Toolonga Calcilutite at Rocky Pool (approximately 50 km inland). The base of the older alluvial aquifer system is formed by the relatively impervious Toolonga Calcilutite or Palaeogene Cardabia Calcarenite.

As part of the collaboration between CSIRO and DAFWA, we commissioned an AEM survey to map the aquifer geometry of the Gascoyne River near Carnarvon, WA. In previous work, we explained our method of selecting an AEM system to fly the survey. We focussed on known boreholes in the region, using them as ground truth for forward and inverse modelling. We decided that the SkyTEM^{304} system was capable of achieving the project goals (Davis et al., 2013a). We then processed, inverted and interpreted the AEM data from a hydrogeophysical perspective, providing grids and comparisons of the AEM conductivity-depth models to the borehole information in the area, and produced a list of 71 targets, prioritised according to quality of target and distance from existing infrastructure (Davis et al., 2013b; Davis et al., 2013c). This presentation will explain our method of target location and discuss the results of a drilling campaign conducted based upon the targets provided (Davis et al., 2016).

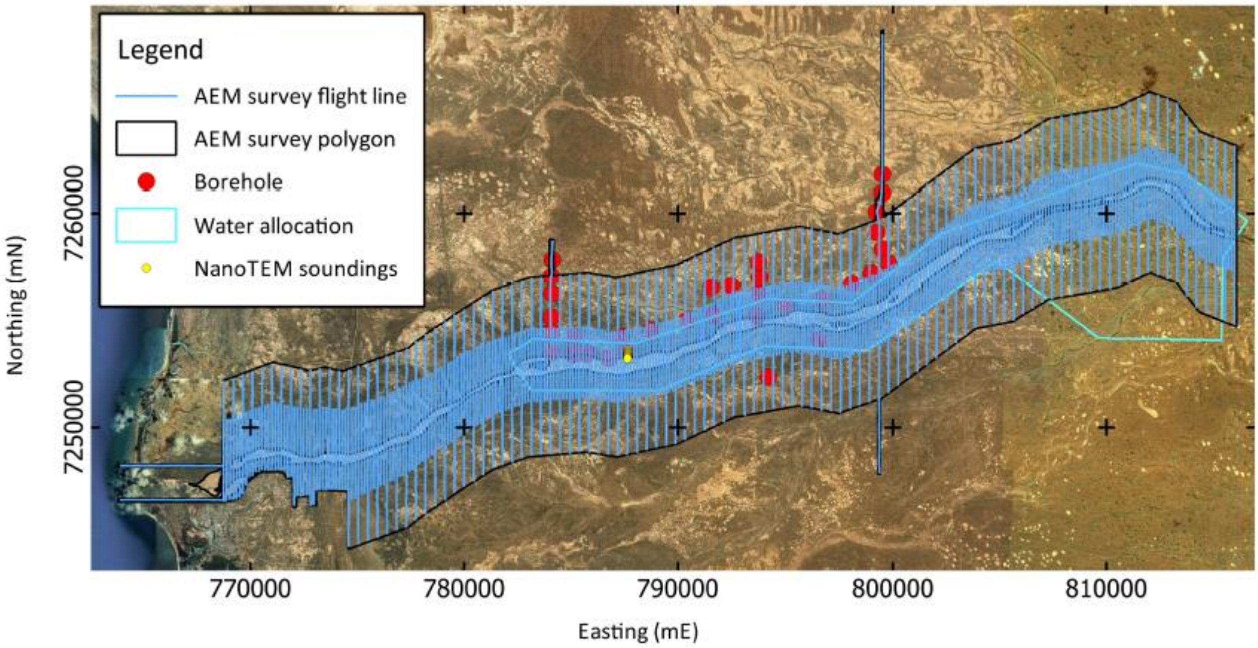

Figure 1: Gascoyne River AEM survey area. Flight lines are indicated with blue lines, boreholes with available lithology are indicted with red circles.

METHOD AND RESULTS

Beginning with all lithological descriptions in available borehole data that has a lithology record, we take each basic unit (limestone, siltstone, clay, silt, sand and gravel) and estimate the AEM conductivity value over the depth range that the unit occurs. The result is a series of histograms that shows the range of AEM conductivity values for the basic unit. This is shown in Figure 2 for each of the basic lithology units. We see that the most frequent soil types are clay and sand; and that they share a very similar distribution of conductivity values. The result of this is that there is no clear discrimination between sand and clay units based on AEM conductivity values alone.

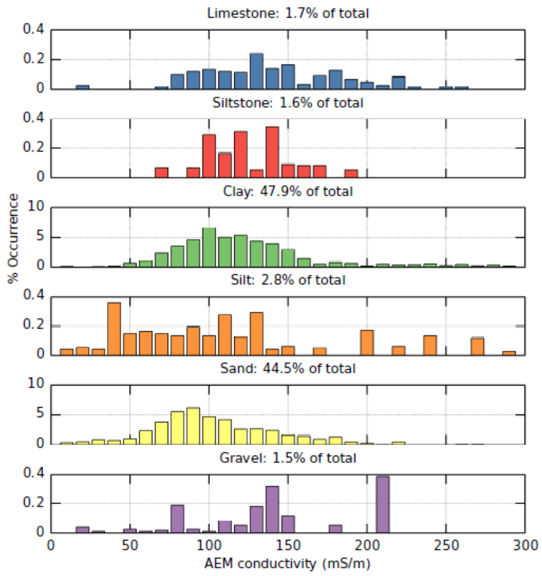

Figure 2: AEM conductivity for each basic lithology unit (limestone, silt, clay, siltstone, sand and gravel) derived from the borehole lithology records. AEM conductivity values are estimated from grids.

Despite there being no clear global relationship between soil lithology and AEM conductivity, we rely upon the hypothesis that in the region surrounding the Gascoyne River, and in the aquifer, the AEM conductivity will be driven primarily by the salinity of the groundwater itself. With this in mind, we searched for areas of low AEM conductivity in the conductivity-depth grids for the AEM survey. We start from the conductivity-depth grid that is beneath the groundwater table, and look for vertical as well as lateral connections in low values of AEM conductivity. The result, shown in Figure 3, is a map of low conductivity thickness contours. Each colour is graded according to being under a certain conductivity value (60, 80 and 100 mS/m), and the saturation of the colour indicates how thick the conductivity zone is. We chose drilling targets based upon thickest, low-conductivity volumes in the survey area. We prioritised the targets based upon the volume of the low-conductivity zone and proximity to existing infrastructure.

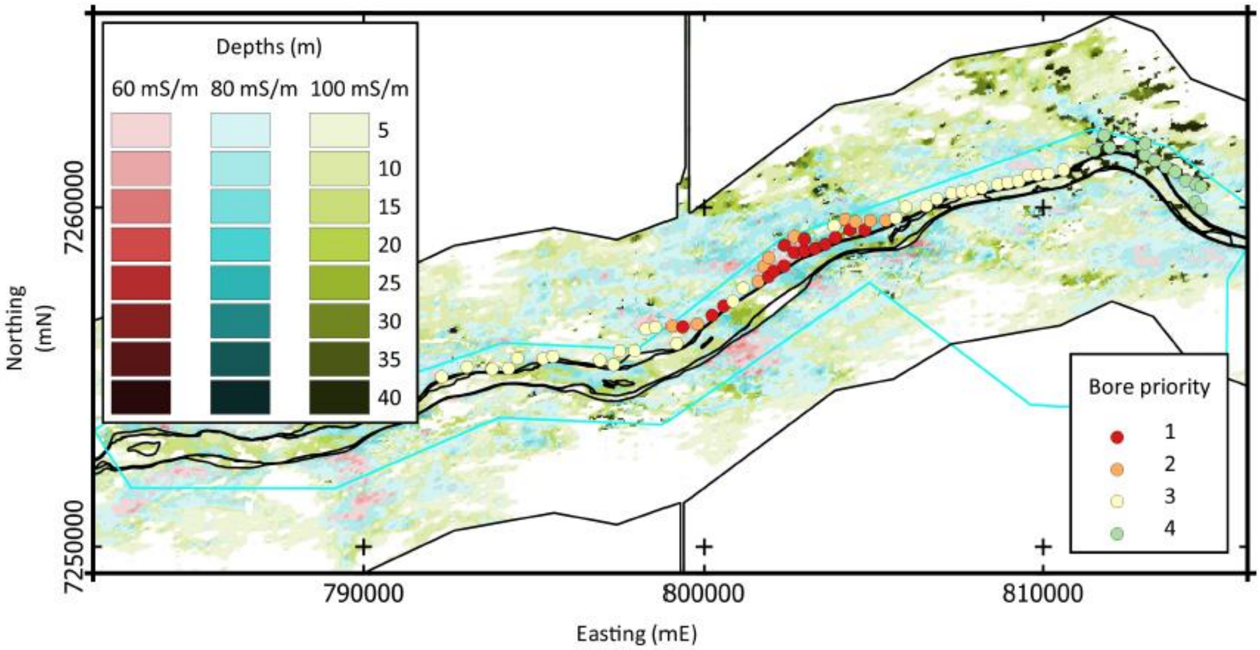

Figure 3: Groundwater exploration targets superimposed on the conductivity-contour depth grids. Target locations are coloured according to priority which is our guess at locations that have better quality groundwater.

In this project, we planned for a total of 71 exploration bores to be drilled. Of the bores drilled, 32 were chosen for conversion to production wells from our priority 1, 2 and 3 areas. (Global Groundwater, 2016). A break-down of production well success rates for each of the priority zones is shown in Figure 4. Taking a cut-off level of 5 l/s as a 'good' production bore, panel (a) shows that out of the 15 priority 1 target locations, 10 were chosen to be good enough for conversion into a production well. This gives a drilling success rate of 2:3. Panel (b) shows that out of 10 priority 2 targets, 8 were converted to production wells (4:5), and panel (c) shows that 10 production wells were chosen out of 32 priority 3 targets (~1:3). Panel (d) shows that there were 4 other production wells constructed from other non-priority wells chosen in the area. In total, the recommended pump rate for the 35 bores converted to production wells amounts to 580 L/s (50:1 Ml/d).

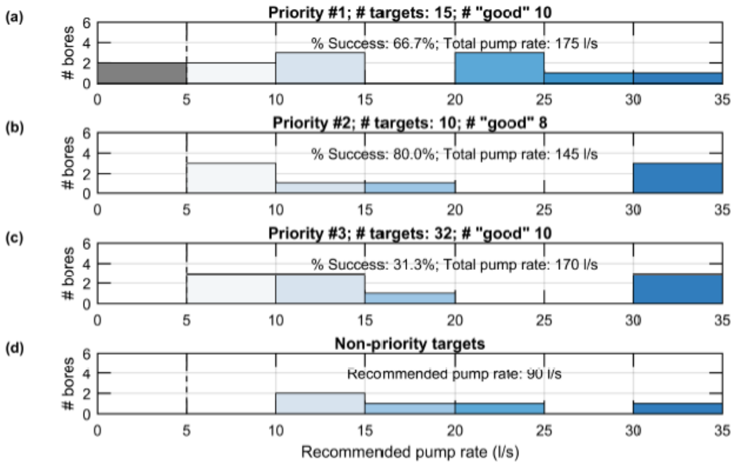

Figure 4: Success rate and distribution of recommended pumping of production bores for each exploration priority. (a) Priority 1 bores (66:7 %); (b) priority 2 bores (80 %); (c) priority 3 bores (34:4%); and (d) non-priority bores.

CONCLUSIONS

Our analysis shows that our rate of success for finding groundwater was very high. In our analysis of the rate of conversion of groundwater exploration boreholes to production well, we found that we had a success rate of 2:3 for priority 1 targets, 4:5 for priority 2, and 1:3 for priority 3. While priority 3 targets were less successful, this is still better than the traditional success rate of 1 in 5. Furthermore, we notice that the rate of recommendation for exploration bores to be converted to production wells is even greater, with 4/5 for priority 1 and 2 targets, 1/2 for priority 3, and 4/9 for priority 4 targets. These excellent results are unprecedented in our experience of groundwater exploration. In comparing the lithology interceptions from our new drilling campaign to those of the previous campaigns for groundwater exploration, we see that we have found greater amounts of clean aquifer-related materials such as sand, gravel and sandstone in our present results. The aquifer materials that we have screened for production wells are of consistently lower bulk electrical conductivity than all of the previous wells.

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