Groundwater Recharge Mapping with the Aid of A Helicopter-Borne Electromagnetic Survey

The Centre for Groundwater Studies in Australia conducted a DIGHEM electromagnetic survey in 1991 to assist in mapping groundwater recharge rates. The text below is an excerpt from a technical paper describing the results of the high resolution EM survey.

Cook, P.G., and Kilty, S. (1992)
Remote Sensing Groundwater Recharge with the
Aid of a Helicopter-Borne Elecgtromagnetic Survey.
Water Resources Research. In press.

Introduction

Groundwater recharge is one of the most difficult components of the water balance to measure. This is particularly the case in arid and semi-arid regions, where the recharge fluxes are very low, and water tables may be very deep. Unsaturated zone tracer methods are the most reliable methods for estimating recharge in these environments, but these provide only point estimates. Because of the cost involved in obtaining each point estimate of recharge, other means are often sought to infer the spatial variability, and hence to provide estimates of spatially averaged recharge. Ground-based electrical and electromagnetic (EM) methods have proven the most successful. These techniques rely on correlations between recharge rate, soil type and soil salt concentrations, to infer spatial variations in recharge.

Where estimates of recharge are required over very large regions, such as for input to groundwater flow models and development of land management schemes, surface electromagnetic methods become labour-intensive. In this paper, we evaluate the use of a helicopter-borne electromagnetic instrument to estimate spatial variations in groundwater recharge under dryland agriculture in a semi-arid area of South Australia.

Study Site Description

The area of study was located in the western Murray Basin, Australia. Mean annual precipitation is 340 mm, and potential evaporation approximately 1800 mm yr^{-1}. The water table occurs at 30 to 35 m depth, and geology consists of sands to sandy loams overlying limestone at 50 m.

Field Results and Discussion

To ground-truth the electromagnetic survey, 20 holes were drilled beneath flight lines, to depths of between 6 and 35 m. Gravimetric water content and soil water chloride concentration were measured on all samples. For each of the holes, groundwater recharge rates were estimated from this data using a transient chloride mass balance approach. Surface EM measurements were made with the Geonics EM31 induction meter. This instrument has an operating frequency of 9800 Hz, and a skin depth of approximately 4.5 m.

A comparison of earth apparent electrical conductivities measured by the DIGHEM system at 56,000 Hz, and those measured with the surface system was made along one transect (Figure 1). The comparison is not a precise means of evaluating the aerial system, as the spatial resolution and skin depth for the two systems are somewhat different. Nevertheless, the similarity of the patterns obtained with the different instruments provides some confidence in the resolution of the airborne system.

The correlation between recharge and apparent electrical conductivity observed with the DIGHEM system at 56,000 Hz, is comparable to that measured with surface instruments on the larger scale. The decrease in accuracy compared with surface systems is relatively small. Aerial electromagnetic methods would appear to be the most useful for identifying broad categories of low, moderate, and high recharge.

When used in conjunction with a more thorough drilling program, electromagnetic methods may be used to provide estimates of average aerial recharge. They have the advantage, in that they can be used to provide complete cover of an area, whereas even detailed drilling may fail to identify small areas of localized recharge, which may be very significant on a regional scale.

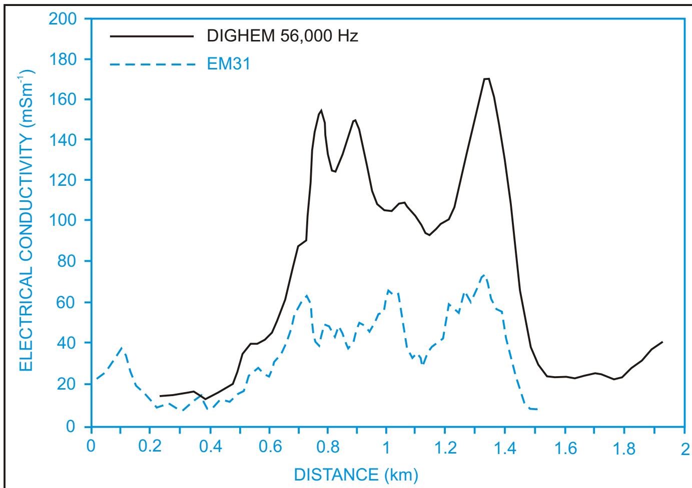

Figure 1: Comparison of apparent electrical conductivity measured with surface (Geonics Em31) and aerial (DIGHEM^{IV} at 56,000 Hz) electromagnetic systems.

Conclusions

In Australia, ground-based electromagnetic methods are becoming increasingly used to map spatial variations in groundwater recharge. When the areas involved become very large, however, surface methods become labour intensive. In this case, aerial methods are better suited to rapid survey work. In this short paper, we have shown that there is little loss of accuracy in moving from surface to aerial electromagnetic techniques.

When they are used in conjunction with other data sets, electromagnetic methods may provide detailed information on hydrologic processes, not easily obtainable with the other methods. In particular, they are likely to be most useful in identifying sites for subsequent drilling.

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