Estimating groundwater recharge rate in the lower Macintyre

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The arid and semi-arid regions of the world are being relied upon to provide increasing amounts of agricultural products. This involves increasing dependence on irrigation. In many cases irrigation inefficiency has led to water loss through deep drainage and groundwater recharge.

Deep drainage is the process whereby the excess water of infiltration over evapotranspiration drains beneath the rootzone. The deep draining water which continues to flow downward toward the groundwater table is known as groundwater recharge.

In the irrigated cotton growing areas of southeast Queensland and northwestern New South Wales, irrigation efficiency is increasingly becoming an important natural resource management issue because of the increasing number of instances where shallow perched water tables are causing problems with respect to water logging and in isolated instances, soil salinity

Relatively inexpensive methods need to be developed to determine areas where excessive groundwater recharge may be problematic. One such approach is the use of chloride mass-balance (CMB) models (see box story).

These models are used to calculate groundwater recharge based on the volume of water applied and the ratio of chloride concentrations in the water and the soil.

This article demonstrates the results of a jointly funded research project (Australian Cotton CRC, CRDC and Natural Heritage Trust) carried out at the University of New South Wales (UNSW) in association with Border Rivers Food and Fibre.

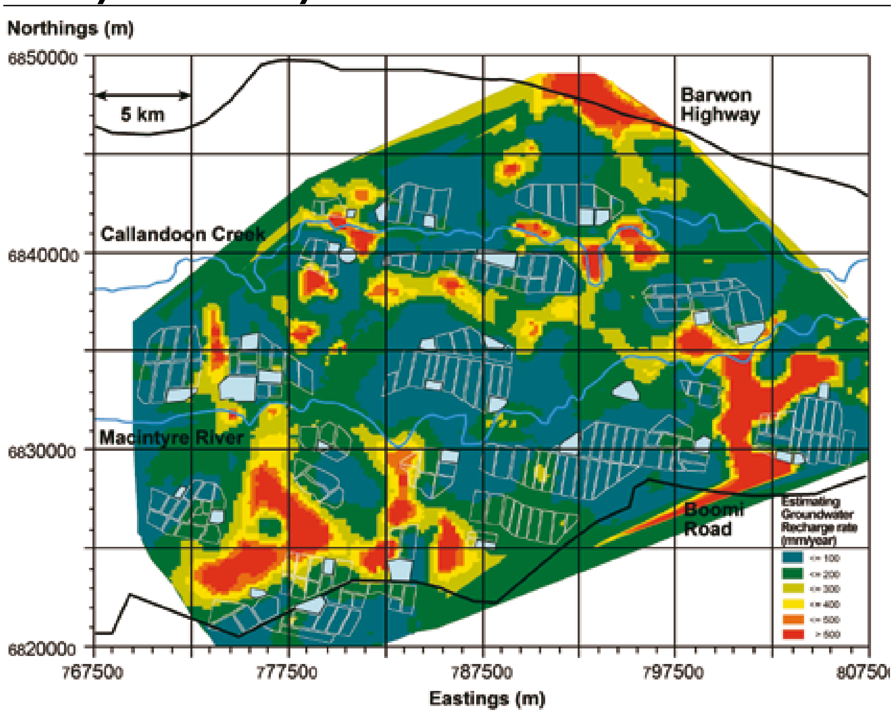
In the first instance and in order to determine suitable sampling locations, an electromagnetic (EM) induction survey was undertaken south of the township of Toobeah. The study area straddles the Queensland-NSW border and includes approximately 15,000 hectares of irrigated cotton.

In total over 1200 measurement sites were visited. From these measurements, 24 sites were selected and cores were drilled to a maximum depth of 12 metres. Soil samples were collected at one metre intervals and analysed for various soil properties including chloride content (C).

Given only 24 sites would be available to predict GWR across a total area of over 40,000 hectares, a relationship was established between estimated GWR rate and EM34 signal data collected at each of these sites. This enabled estimates of GWR at each of the 1200 sites where only EM34 signal data was available.

Figure 1 shows the spatial variation in estimated GWR across the Toobeah dis-

FIGURE 1: Spatial distribution of estimated groundwater recharge rate (GWR — mm per year) beneath irrigated cotton fields (I = 600 mm per year) in the Toobeah district in the lower Macintyre River valley



trict. It is evident that the GWR beneath irrigated cotton fields is low (that is, less than 100 mm per year). This is particularly the case for landholdings located in the central part of the Toobeah district on either side of the Macintyre River.

The reason for the lower estimates of GWR is most likely attributable to higher and deeper clay content in the soil and vadose zone. In the central part of the district and north of the Macintyre River, clay content was generally greater than 50 per cent and varied from a minimum thickness of 1.5 metres to five metres thick.

Conversely, GWR is much higher in many dryland areas. This is the case in the south western part of the Toobeah district, where recharge exceeds 100 mm per year. In these areas, higher values of GWR (greater than 100 mm per year) coincide with the location of many of the current and relic stream channels which are characterised by sandier sediments.

From the irrigation standpoint, it should be noted that many of the large earthern water reservoirs in the district are located in areas adjacent to where GWR exceeds 300 mm per year.

This would appear to be of concern given a shallow saline water table is suspected in the western part of the district. The resultant map and inferences made suggest further research is required given the simulation for estimating GWR was based on an irrigation volume (that is, I) of 600 mm per year per hectare and not 1800 to 2400 mm per year as one might expect beneath a water reservoir.

From a practical point of view it is also recommended that many of the water reservoirs located in areas adjacent to where GWR was high (that is, 300 mm per year) be surveyed using detailed EM transects in conjunction with soil sampling.

This should be done even if there is no immediate evidence of the presence of a saline water table, as the deep draining water may be recharging groundwater in the western part of the district. In addition, the reservoirs should be investigated in order to determine where gains in water use efficiencies may be achievable.

CHLORIDE MASS BALANCE MODEL

Chloride mass balance models are one way to measure groundwater recharge.

The model requires information on:

- The volume of input water in the form of rainfall and/or irrigation (that is, 'I' in mm);
- Concentration of chloride in rainfall and/or irrigation (that is, Ci in mg per litre); and,
- The average chloride concentration in the vadose zone (that is, Cz in mg/l).

The chloride mass balance is then calculated by entering the above information into the equation which gives an estimate of groundwater recharge rate (GWR).

$GWR = I \times Ci/Cz$

When using the model it is assumed the profile is at steady state. That is, chloride entering the profile is equal to the amount of chloride leaving the profile. The estimation of GWR rate across a district can be enhanced by coupling estimates with more easily obtained information.

The chloride data for each core was averaged (Cz) and entered into the GWR model. In addition, it was assumed that the volume of irrigation water applied annually (that is, I) was equal to 600 mm. This is equivalent to six megalitres per hectare per annum. In addition, it was assumed that recharge as a result of precipitation was negligible.

A one off measurement of chloride content of the Namoi River water produced a chloride concentration of 45.29 mg per litre. This was assumed to be equivalent to that available to irrigators in the Macintyre River valley and was used (that is, Ci). These values were used to estimate GWR rate using the chloride mass balance model for each of the cores obtained from irrigated cotton growing fields.