



Using piezometric data to determine area-wide annual net recharge: Analysis for the Coleambally Irrigation Area

E.W. Christen, A. Prasad and S. Khan



CSIRO Land and Water, Griffith NSW 2680
Technical Report 39/00, July 2000

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Christen E.W., Prasad, A. and Khan, S.

CSIRO Land and Water
PMB No 3
Griffith NSW 2680
(02) 69601500

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Citation Details:

Christen, E.W., Prasad, A. and Khan, S. (2000) Using piezometric data to determine area-wide annual net recharge: Analysis for the Coleambally Irrigation Area. Technical Report 39-00. CSIRO Land and Water, Griffith, NSW, 2680.

Available on the web: www.clw.csiro.au/publications/technical2000

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SUMMARY

Area wide analysis of recharge from irrigation is a key indicator of water management strategies. Usually individual hydrographs are analysed or areas with watertables at certain depths are measured. This method of calculating volumes of recharge on the basis of developing piezometric surfaces allows area wide trends in recharge to be analysed.

It was found that net recharge always occurs in the summer period. This was found to be dissipated by net discharge that always occurred over the winter period. Thus summer recharge is highly correlated to the discharge that occurred during the previous winter period. These discharge processes are made up of evapotranspiration, discharge to surface drains and deep leakage to aquifers. Since discharge during the winter season is important, consideration of steps to enhance this process by promoting winter cropping to use stored water and winter rainfall and ensuring good surface drainage to rapidly remove rainfall run off could be useful management options.

The effect of the analysis period on net recharge was found to be important. Currently the analysis conducted for environmental reporting by irrigation companies is from September to September of each year. This analysis provides an assessment of net recharge integrating the summer recharge period and the winter discharge period. It is suggested that the March to March analysis provides a better understanding of the impact of changes in irrigation management over the summer period. Also it is important to monitor the March to September period to assess the amount of discharge that has occurred over the winter period.

Acknowledgements

We acknowledge funding from Coleambally Irrigation Corporation and the Australian Centre for International Agricultural Research. Thanks also to all those at Coleambally Irrigation Corporation for providing data.

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1.0 Introduction

Recharge to the groundwater is a critical element in the water balance and groundwater hydrology of any irrigated area. Recharge can be estimated at a point scale or at a regional scale. In understanding trends and the effectiveness of Land and Water management Plans it is useful to have estimates of recharge at a regional scale. The amount of recharge in any one year can be estimated by water balance studies such as those undertaken by van der Lely (1994). In this type of analysis it is necessary to account for all sources of recharge such as that due to irrigation of crops, channel leakage and rainfall. In order to assess the impact of such recharge an account has then to be made of the 'losses' from the groundwater system, such as evaporation from the watertable, leakage to deeper aquifers and lateral leakage out of the irrigated area. Comparing these to the assessed recharge gives the 'net' recharge, i.e. the change in groundwater status over a period of time.

With the water balance method it is rather difficult to assess the net recharge as there are a number of factors that are not well known such as deep leakage, lateral leakage and rates of evaporation from watertables.

This report details a new method for assessing net recharge which uses the fluctuation in the groundwater levels from beginning to end of the irrigation season. To undertake this method groundwater surfaces at different times are developed for the whole irrigation region using the network of piezometers and interpolation. The net recharge can then be assessed for a period by subtracting the later surface from the earlier. The resultant groundwater surface is the change in the region over that whole time period. This can be used in conjunction with estimates of soil porosity to assess volumetric changes in the groundwater.

The Coleambally Irrigation Area was used to assess whether this method could be usefully used to investigate changes in the regional groundwater condition and trends in recharge over time.

2.0 Methodology

To estimate the net recharge a simple method was used whereby at each monitoring time i.e. March and September a groundwater surface for the entire CIA (approx. 80,000 ha) was developed using the contouring software 'SURFER'. Data for 230-250 piezometers less than 12m deep was used for the period 1990 to 1999. To establish the net recharge between each subsequent period the volume change between the two surfaces was determined using SURFER, this volume being that of the soil. The volume was then multiplied by the effective porosity (assumed to be 0.05) to calculate the change in the volume of groundwater.

The data were gridded to the following specifications:

X range (easting)	366100m – 433000m
Y range (northing)	6115400m – 6174320m
dX = 669m	dY = 669m

The default gridding method i.e. Krigging was used with a linear variogram model. After gridding the mesh was blanked out with a digitized map of CIA. The blanking operation ensures that data outside the boundary of CIA is ignored in any calculations. Piezometric data gridded and blanked thus formed each piezometric surface. Such surfaces were determined for March and September of each year. When a groundwater surface of a succeeding year is deducted from the surface of the previous year this gives the net volume change between the two times. If the volume change is positive then net recharge has occurred and if the volume change is negative then net discharge has occurred. These calculations are based upon the assumption that the piezometer readings represent the watertable level, see assumptions below.

2.1 Assumptions used in the analysis

- 1) The analysis is based upon the assumption that piezometers less than 12m deep accurately reflect the watertable level. This is likely to be the case but in some areas where aquifer confinement occurs to a greater or lesser degree then the validity of this assumption will vary.
- 2) The effective porosity value used will affect the magnitude of the values estimated here but will not affect whether the result is net recharge or net discharge and it will not affect the trend over time as this methodology is based upon differences. However, this analysis uses a uniform effective porosity for the whole area. This will also create errors as the same piezometric rise/fall in a clayey soil and sandy soil will be assessed to be as the result of the same volume of net recharge, which is not the case.
- 3) This is an area wide lumped analysis, thus it is important to remember that the results represents an average of the whole irrigation area. This can be strongly influenced by large rises or falls in particular subregions.

Using the above method, four analyses of net recharge were calculated:

1. Net annual recharge (Sept): volumetric watertable difference between September of given year and September of preceding year.
2. Net Seasonal Recharge (Summer): volumetric watertable difference between March of a given year and September of the preceding year i.e. volumetric addition during irrigation season.
3. Net Seasonal Discharge (Winter): volumetric watertable difference between March and September of each year i.e. volume of water dissipated during the non-irrigated period.
4. Net annual recharge (March): volumetric watertable difference between March of given year and March of preceding year

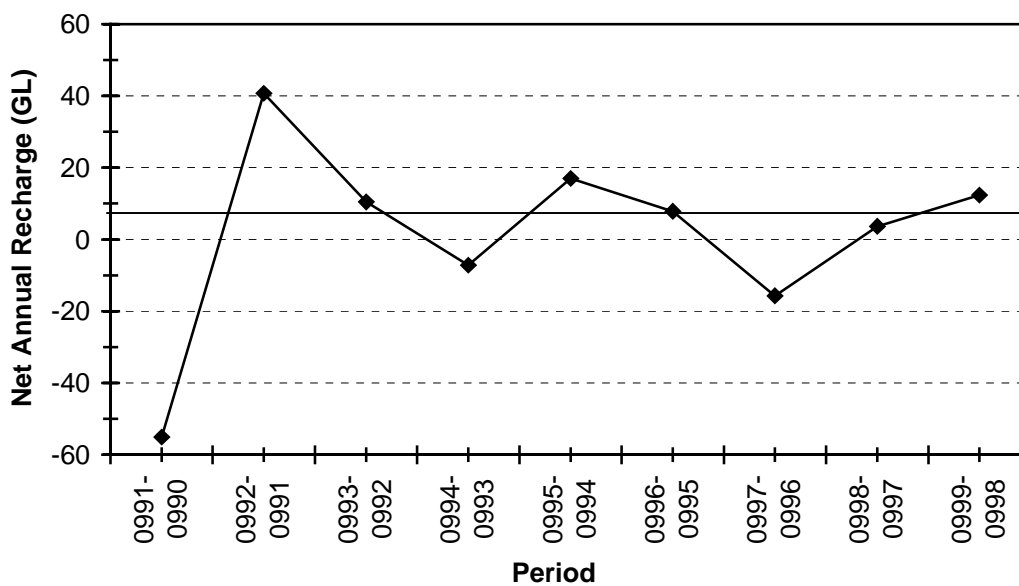
Recharge was also analysed against irrigation supplies, rainfall and evapotranspiration to determine if any linkages were apparent. A factor of 0.9 was assumed for calculating net infiltrated or effective rainfall and also applied to evapotranspiration. This factor is based upon calculations contained in the CIA Environmental Report 1998, CIC (1998).

3.0 Results

3.1 Net Annual Recharge

Figure 1 shows the graph of net annual recharge in the Upper Shepparton (US) from September to September.

Figure 1. Annual net recharge (Sept.-Sept.)

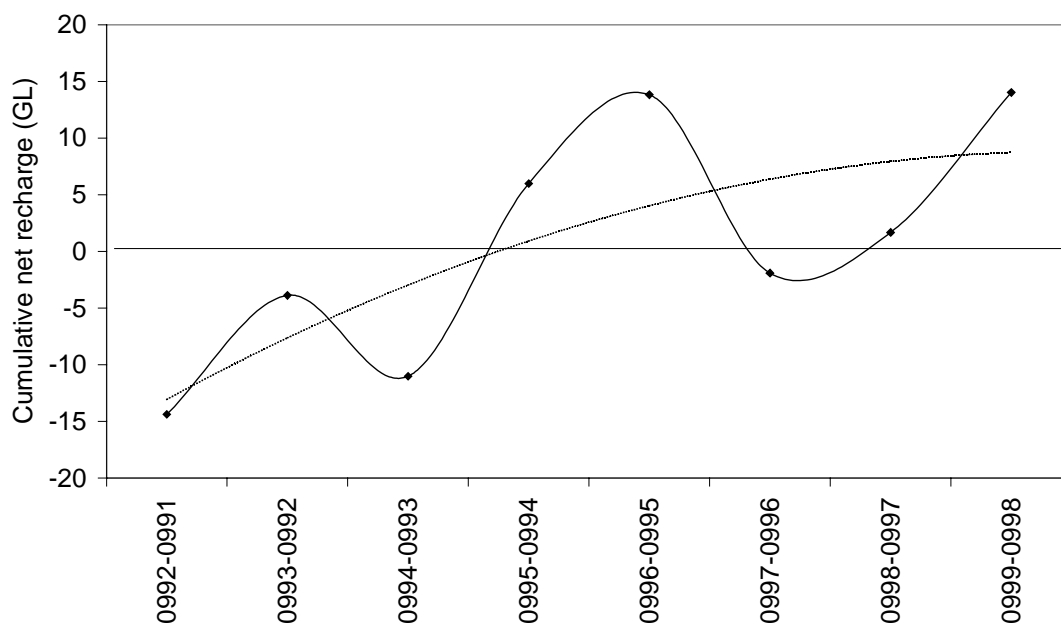


In figure 1 we see that annual net recharge was strongly negative in 1990/91, i.e. there was overall discharge of groundwater. This was probably due to a 25% reduction in rice growing and a very dry year, a record deficit of 95 GL between evapotranspiration and irrigation plus rainfall. The following year 1991/92 was a particularly wet year leading to a marked net recharge.

The net annual recharge appears in general to fluctuate between periods of net recharge and periods of negative net recharge, i.e. discharge. It appears that there are important years when annual net recharge is strongly negative, i.e. net discharge. This occurred in 1996/97, 1993/94 and 1990/91. These years are followed by years of net recharge that undoes the benefits of the discharge in the previous year.

However, the trend is still that of an overall annual net recharge as can be seen from a plot of cumulative annual net recharge in figure 2. The overall linear trend from 1991/95 until 1998/99 has been an annual net recharge of about 4GL/year. Figure 2, suggests that the amount of annual net recharge is decreasing.

Figure 2. Cumulative annual net recharge



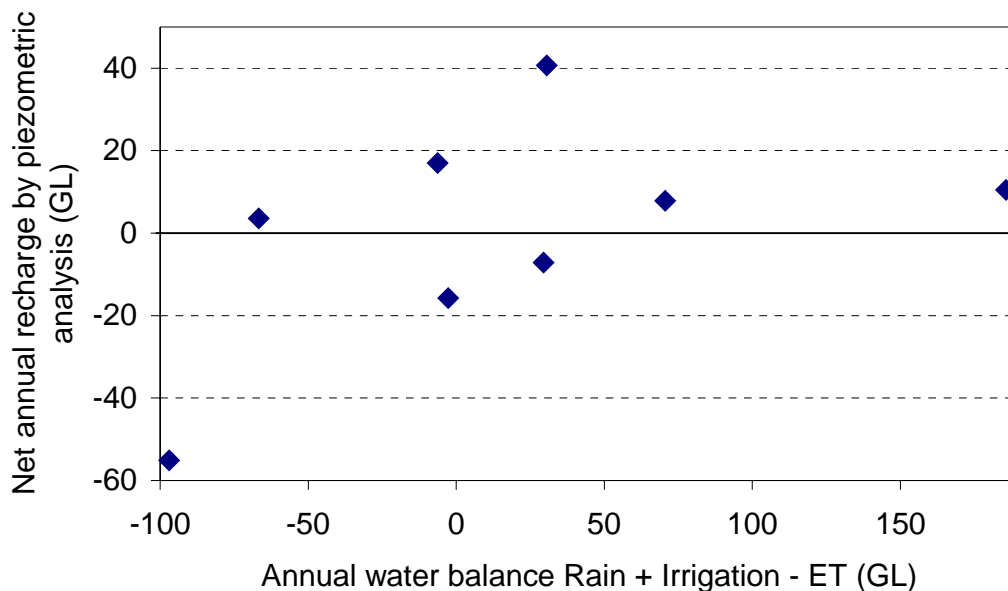
In overall terms it appears that there is a significant fluctuation between net recharge and net discharge. So to determine if the CIA net recharge management strategy is being effective an analysis of periods considerably longer than one year is necessary. Understanding this fluctuation is useful in that this can assist managers in providing a target for net recharge management - the recharge in the year(s) following a discharge year should not exceed the discharge in that discharge year. This is net recharge

management applied to a longer analysis period that can help deal with the annual fluctuation.

3.1.1 Effect of irrigation and rainfall

Figure 3 shows the Net Annual Recharge plotted against total supply (Irrigation + 0.9 x Rainfall less 0.9 x Evapotranspiration).

Figure 3. Annual net recharge and rainfall + irrigation

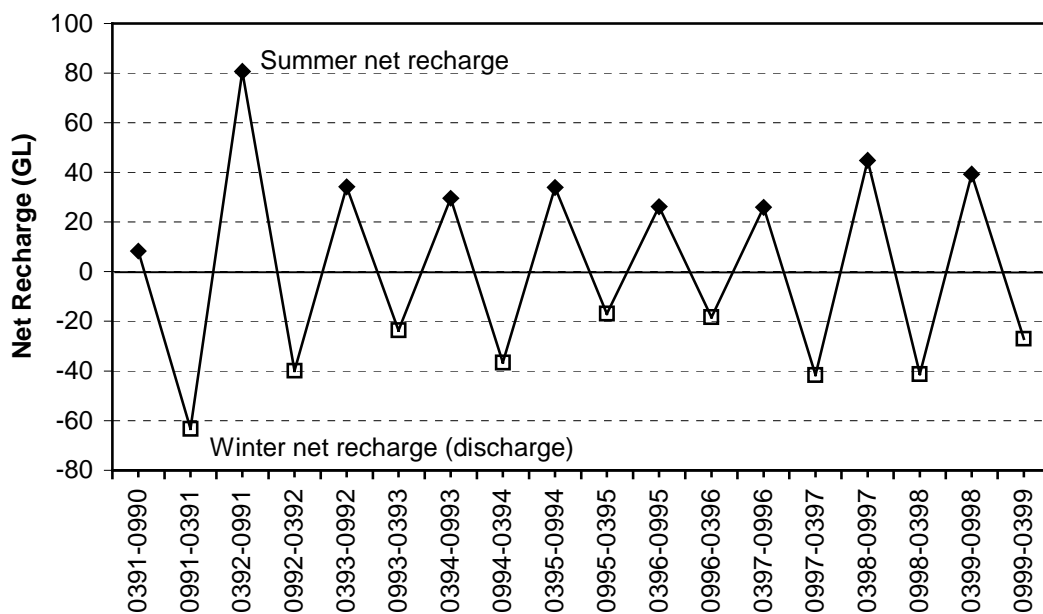


There is only a very weak correlation between the net water surplus or deficit and net recharge in the Upper Shepparton aquifer. This indicates that the net recharge is not entirely a function of the particular season, but may be also a function of the conditions in the previous year. The total irrigation supply is driven by evapotranspiration, and thus high irrigation levels do not necessarily result in high recharge levels. Also, the timing of crop water use and the timing and duration of rainfall are critical in recharge processes, and not accounted for in gross annual estimates.

3.2 Seasonal Recharge / Discharge

Figure 4 shows seasonal net recharge between September 1990 and September 1999. Recharge always occurs during the summer and discharge always occurs in the following winter period. Seasonal net recharge and discharge between summer and winter are generally in balance, except for the period September 1990 to March 1992.

Figure 4. Seasonal net recharge summer (Sep – Mar) and winter (Apr - Aug)



This seasonal balance between summer net recharge and winter net discharge accounts for the relatively stable watertable levels over the last ten years. The large winter discharge in 1991 was due to very dry conditions in that year, a record deficit of evapotranspiration minus rain. This is followed by smaller fluctuations until 1997 and 1998 where there was increased discharge followed by commensurate greater recharge. This was due to two low rainfall years. Although there appears to be an overall stability to the system consideration should be given to the effect on the region of high rainfall years in which recharge may be high and discharge low.

Figure 5 shows net recharge during the irrigation period (September – March) plotted against net recharge (discharge) during the following non-irrigation period (March –

September). There is little correlation between the summer net recharge and following winter net recharge (discharge). This emphasizes that whatever net recharge takes place during the irrigation period is not always dissipated during the following non-irrigation period. The aquifer capacity to dissipate recharge is limited and also depends on the previous year trends. However it does seem that the net winter recharge is always a discharge that could then be used as a target for summer seasonal recharge.

Figure 5. Winter net recharge (discharge) (Apr–Aug) as a function of net recharge in the previous irrigation season (Sep–Mar)

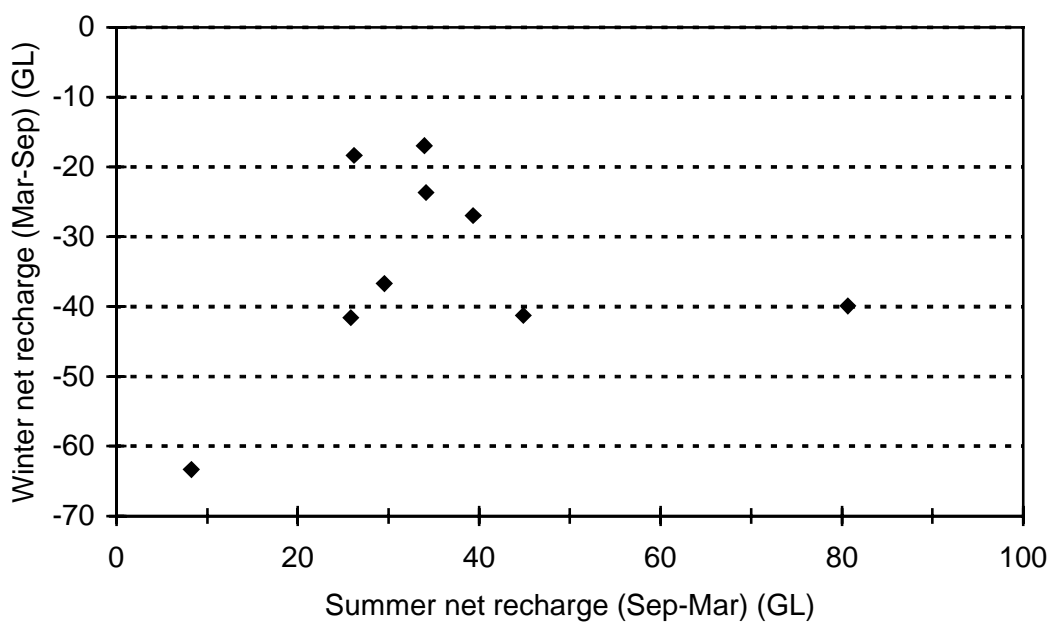


Figure 6 shows that the summer recharge is very similar to the discharge that occurred over the previous winter period. This indicates that the summer net recharge is a function of the previous winter net discharge. This is more obvious in figure 7, which shows that the summer recharge is similar to the previous winter's discharge, except for the large value of 80GL recharge which is 17GL greater than the previous winter's discharge. The average difference between summer recharge and winter discharge is only 5GL with a standard deviation of 2.7GL (excluding the 80GL value). This relationship perhaps could be used to give an indication of potential net recharge over the summer season, or the net recharge target (not to be exceeded).

Figure 6. Net recharge in winter and following summer

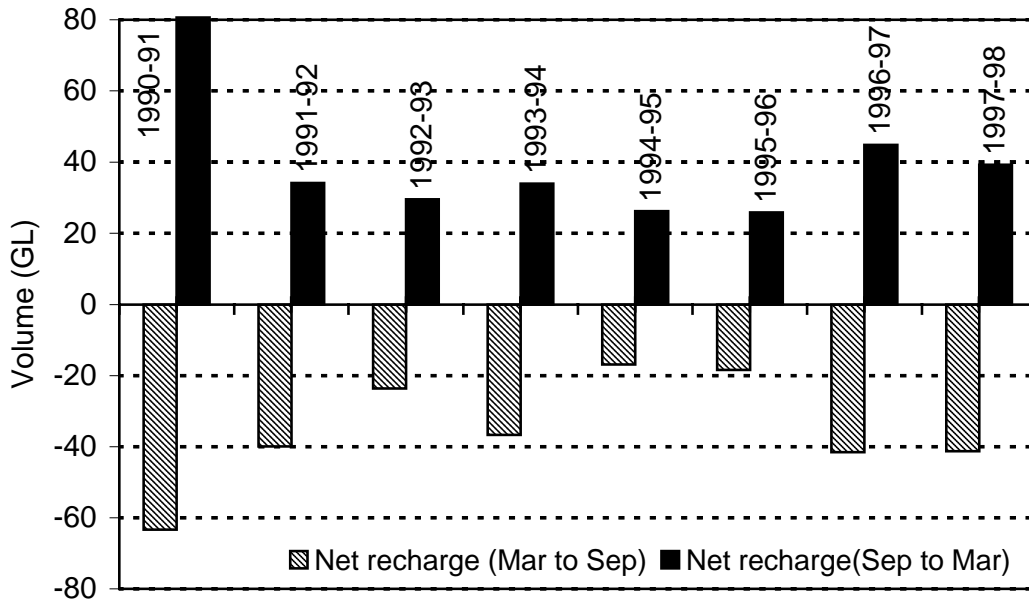
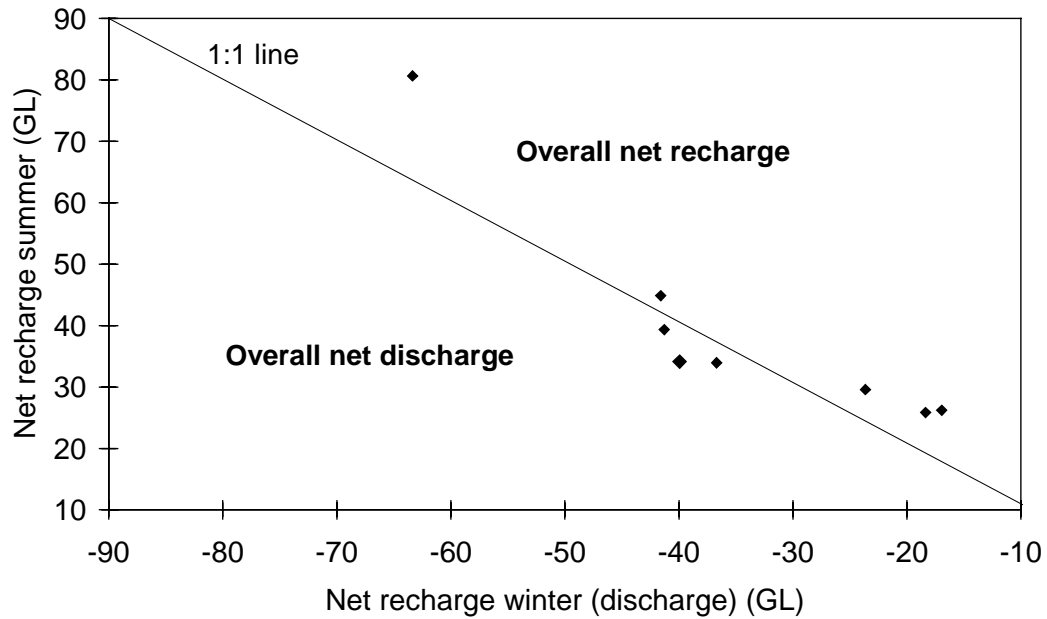


Figure 7. Summer net recharge as a function of winter net recharge (discharge)



These results indicate how dependent the system is upon the winter discharge period. This suggests that perhaps there should be greater effort regarding net recharge management in this period to promote discharge from the system and prevent recharge. Factors such as promoting rapid run off of winter rainfall from paddocks and drains and also the growing of winter active crops would assist.

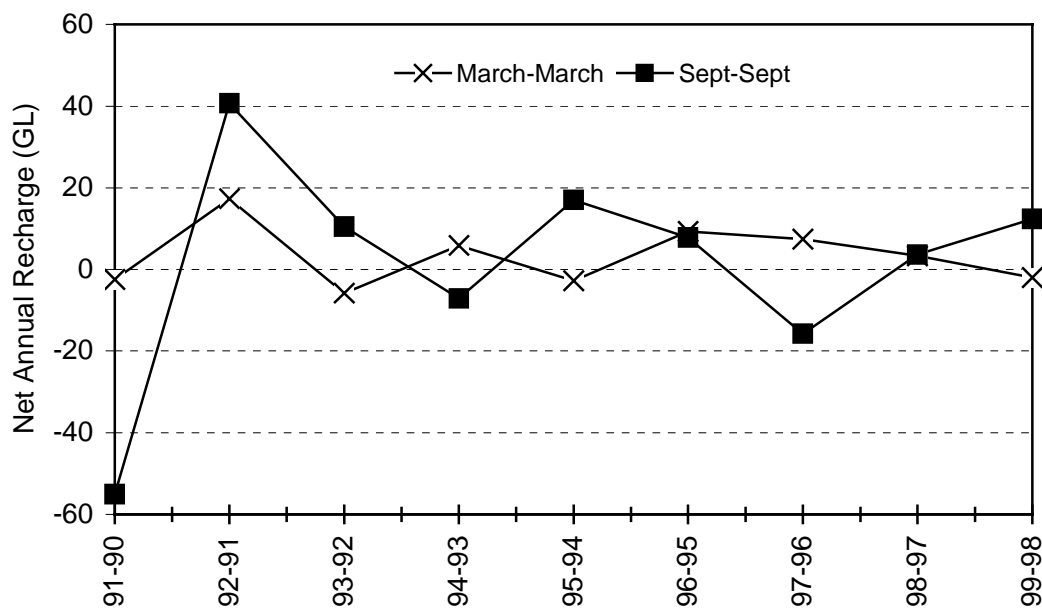
3.3 Time period selected for net recharge analysis

The effect of the analysis period on net recharge may be important. Currently the analysis conducted for environmental reporting by irrigation companies is from September to September of each year. The rationale for this is that by September the localised effects of irrigation have dissipated within the aquifer system and as such these readings are more representative of the area wide effect of irrigation. However, using the September readings for comparison may actually mask the true effect of the irrigation season in that over the winter period there is the opportunity for discharge from the groundwater system, not just a local dissipation of groundwater mounds within the aquifers. Depending upon the climate during winter the level of discharge can be large or small, figure 4, the amount of discharge depending upon winter seasonal conditions, further masking the effect of the irrigation season.

Thus it may be that the March readings are actually those that most represent the impact of irrigation on the groundwater system. Whatever the analysis period the changes will overall be the same but the detection of long-term trends may be quite different. Further, net recharge management involves decreasing net recharge from irrigation, therefore the impacts of irrigation need to be identified to determine whether management to reduce net recharge is achieving desired goals. In order to investigate this annual net recharge was calculated on a March to March basis, figure 8.

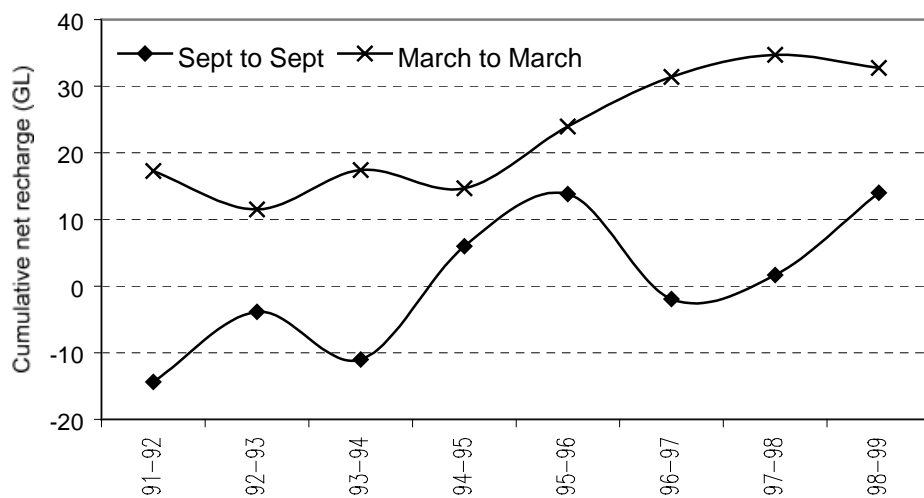
The analysis over the March to March period shows much smaller fluctuation than the September to September period analysis, the net result being the same. It may be easier to accept smaller year to year variations in annual net recharge as found with the March analysis than the large swings associated with the September analysis. This is because the March to March analysis is comparing a point in time that is dominated by the recent irrigation activity, not complicated by the following winter conditions. Interestingly the March analysis shows a steady decline in annual net recharge since 1995-96, whereas the September analysis has a sharp decline followed by increasing levels of net recharge.

Figure 8. Annual net recharge March to March and September to September



Cumulative annual net recharge shows a different pattern in a March to March analysis compared to September to September, figure 9. Again it fluctuates less and shows annual net recharge as relatively stable over the last three years.

Figure 9. Cumulative net annual recharge March to March and September to September



4.0 Conclusions

This method of using differences in groundwater surfaces to estimate regional recharge across irrigation areas provides some useful new insights into groundwater behaviour and trends in recharge across seasons. Specific conclusions relating to the Coleambally Irrigation area are:

1. Summer irrigation season results in net recharge and the winter period results in negative net recharge (discharge). The balance of these determines watertable status in the area
2. Annual net recharge has been reducing in recent years; however, September analysis suggests a rising trend again in the last two years. The March analyses suggest a peaking of recharge in 1997/98 followed by the possible beginning of a declining trend. Longer time series is required to assess the accuracy of this analysis.
3. The winter net recharge (discharge) can give an indication of the allowable net recharge in the following irrigation season. In cases of wet winters this will reduce the allowable net recharge in the following summer.
4. Discharge during the winter season is important and consideration of steps to enhance this process by promoting winter cropping to use stored water and winter rainfall and ensuring good surface drainage to rapidly remove rainfall run off could be useful management options.
5. Analyses of recharge trends on the basis of the March to March period appear quite different to those of the September to September period. Careful consideration needs to be given as to the appropriate method that will highlight management impacts. The March analysis will provide more information on irrigation management and net recharge management during the irrigation season, whilst the September analysis provides information on the overall net recharge. Analysis of change from March to following September will provide information on winter season recharge management strategies.

5.0 References

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Van der Lely, A. (1994). Coleambally L&WMP regional options. Dept. Water Resources Technical report No. 94/17. Leeton, NSW.