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GROUNDWATER FLOWS AND GROUNDWATER – SURFACE WATER INTERACTIONS IN THE CORANGAMITE CMA REGION

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INTRODUCTION

The Corangamite Catchment Management Authority (CMA) region occupies an area of 13,340 km^2 in south-western Victoria, and consists of four major river basins, namely Moorabool River, Barwon River, Lake Corangamite and Otway Coast. The region is of high economic value to the State with much of the land area supporting agricultural and forestry industries. Central to the area, and occupying some 46% of it, is the Victorian Volcanic Plain (VVP) bio-region (Figure 1), which is characterised by a volcanic plain originally vegetated mainly by native grasses and open woodlands with many natural wetlands (Taylor *et al.*, 2003). The VVP is recognised as an ecologically significant region of Australia, mainly due to the remnant native grasslands and wetlands. Freshwater and saline wetlands are a significant and integral part of the region and some 27 of these are Ramsar listed, including Australia's largest, permanent, saline lake – Lake Corangamite. Altogether wetlands occupy 5% of the area and "support a rich array of unique flora and fauna" as well as representing "some of the most significant recreation and tourism attractions in the region" (CCMA, 2005).

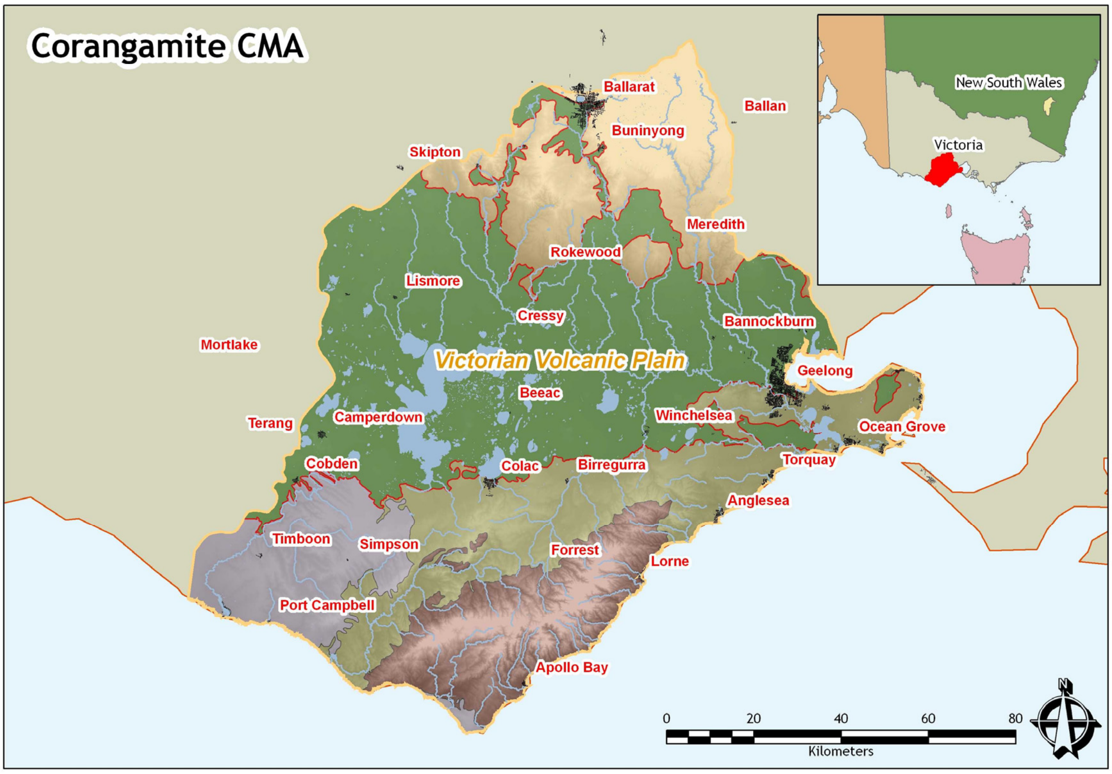

Figure 1. The Victorian Volcanic Plain area of the Corangamite CMA

Primary salinity is a feature of the Corangamite CMA region and the earliest historical records report shallow groundwater tables and saline lakes and drainage lines as existing features of the landscape (Dahlhaus and Cox, 2005). However secondary salinity is a growing regional issue and has led to a two-fold increase in the area of land salting in the past 200 years (CCMA, 2003). Increasing trends in salinity are now threatening agricultural lands and wetland habitats. The National Action Plan (NAP) for Salinity and Water Quality has listed the region as a priority area and funding has been provided for the development of salinity action plans. Two projects jointly funded by the NAP (through the Corangamite CMA) and the Cooperative Research

Centre for Landscape Environments and Mineral Exploration (CRC LEME) are currently being undertaken to augment scientific knowledge on salinity processes in the region and deliver a scientific basis for the development of salinity management plans. These are:

1. Defining groundwater flow systems on the basalt plains to accurately assess the risk of salinity and impacts of changed land use; and
2. Understanding the processes causing salinity of the groundwater dependent ecosystems of the CCMA.

DEFINING THE GROUNDWATER FLOW SYSTEMS

This project has been ongoing since April 2005 and is aimed at contributing to a better understanding of the hydrological processes across the volcanic plain in order to delineate where local, intermediate and regional groundwater flow systems dominate salinity processes (Smitt *et al.*, 2005b). Research activities have included data collection and collation, and the development of a groundwater model. The project is scheduled for completion by December 2006.

Much time and effort has been expended in acquiring, collating and cleaning the necessary spatial data (Smitt *et al.*, 2005a). Sources for lithological and groundwater chemistry data have included: the Corangamite Groundwater Monitoring and Research Database; the Victorian Groundwater Bore Database; the Victorian State Observation Bore Network; and the Victorian Geoscience Bore Database. Data quality was of an inconsistent and reduced quality and considerable time has been spent in standardising the data and bringing it into a uniform coordinate system, projection and datum. A robust dataset has been produced for spatial analysis in a GIS framework.

For the modelling phase of the project, the Groundwater Modelling System (GMS) was initially used to model the bore data and construct the numerical surfaces for the various attributes of the data. The Borehole Module of GMS has good graphics and visualisation that include the capability for three-dimensional animated displays. Due to the abundance and complexity of the lithological data, however, GMS was not found to be suitable for creating the numerical surfaces for each groundwater flow system (GFS) and these were created using Encom Discover and Vertical Mapper. The resulting grids form the components of a four layer model in MODFLOW – the numerical groundwater model adopted for this project.

Sampling and testing of bores has been carried out to determine the regional hydro-geochemical properties of the aquifers (Dighton *et al.*, 2006). The bores were selected to enable the spatial differences in groundwater chemistry of the geological formations below the research area to be determined. As well, bores were sampled along observed hydraulic gradients so that changes in groundwater chemistry along groundwater flow paths could be observed. The aim of this work was to validate the information previously collected and to augment the dataset upon which the groundwater model is being based.

Chemical analyses undertaken included both routine tests to determine pH, electrical conductivity and a suite of other analytes as well as specialised techniques which allow the age of the groundwater to be determined.

Using the extensive bore database which has now been assembled and validated, the layers of the groundwater model are now being developed. Figure 2 gives an overview of the many overlaying groundwater systems – local, intermediate and regional – of the region. Figure 3 to Figure 8 show the layers chosen for the GFS model. Figure 3 shows the surface of the base layer of the model, while in the following figures the subsequent layers are illustrated in stratigraphical order from the lowest to the highest. Only those groundwater flow systems considered influential in the salinity processes have been included.

A preliminary version of the groundwater model will be completed by the end of December 2006. The model may then be refined, particularly around the wetlands, once the findings of the project on assessing the groundwater dependence of wetlands (discussed below) are incorporated. The model will be a valuable tool for assisting the Corangamite CMA to predict the implications of salinity management practices for any given location. The impact of land use changes, such as an increase in the irrigation extraction areas on wetlands or development of groundwater extraction zones for public water supply on surrounding water resources, will be able to be assessed using the model.

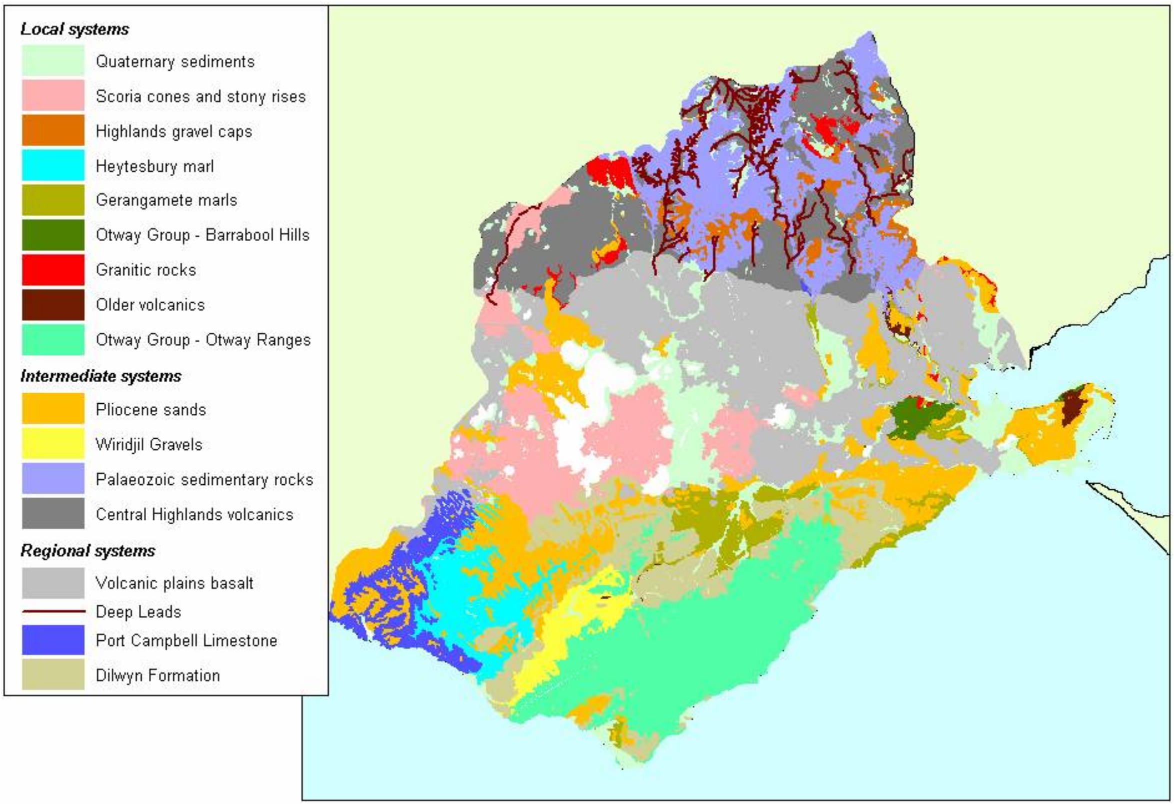

Figure 2. Local, intermediate and regional groundwater flow systems (Dahlhaus *et al.*, 2002)

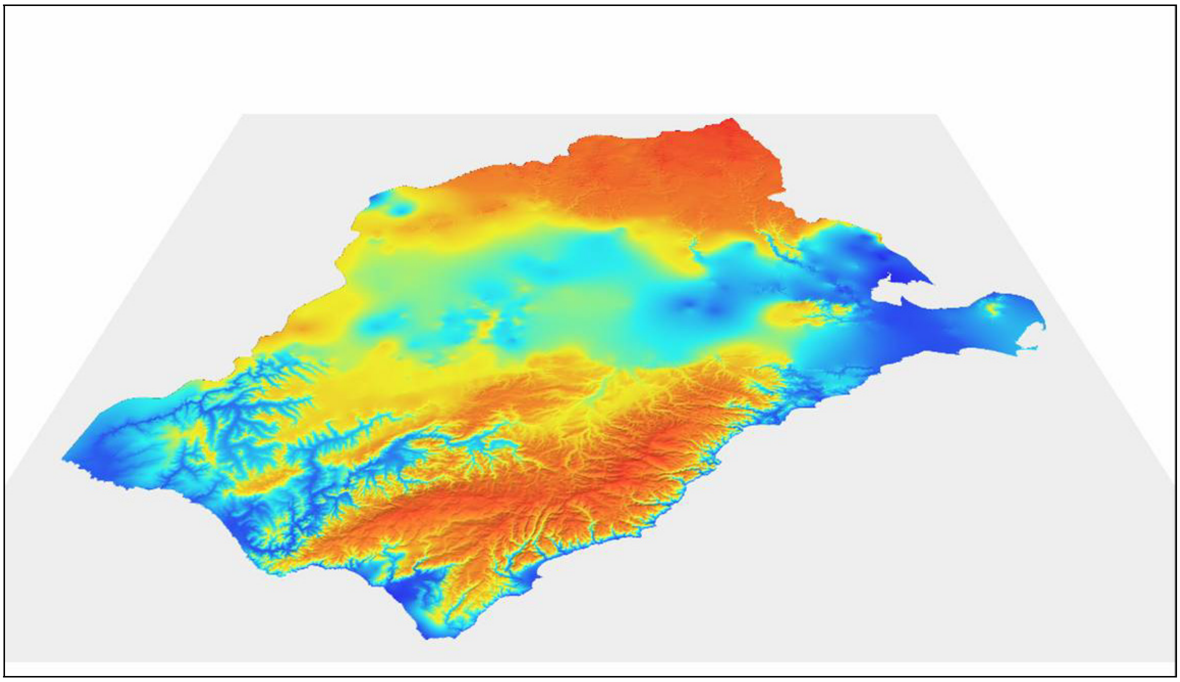

Figure 3. The base layer of the model shown as a perspective view

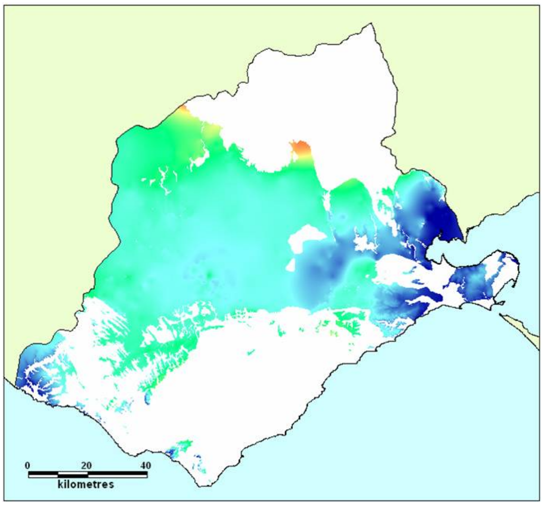

Figure 4. Model layer 1 – Pliocene sands regional system

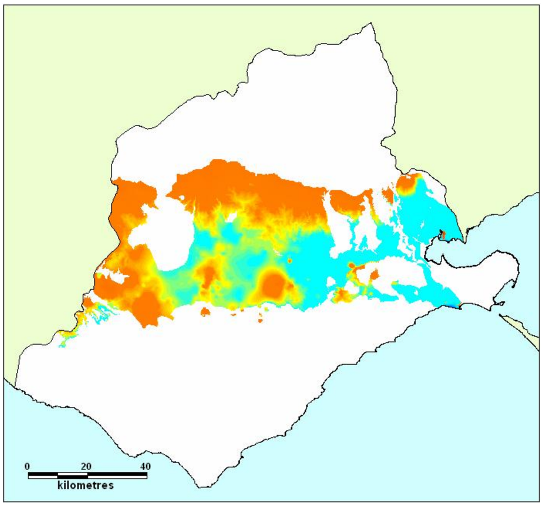

Figure 5. Model layer 2 – Plains basalt regional/intermediate system

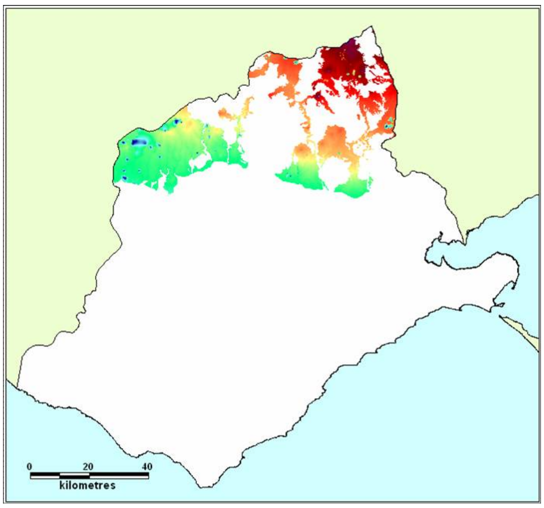

Figure 6. Model layer 3 – Highlands basalt intermediate/local system

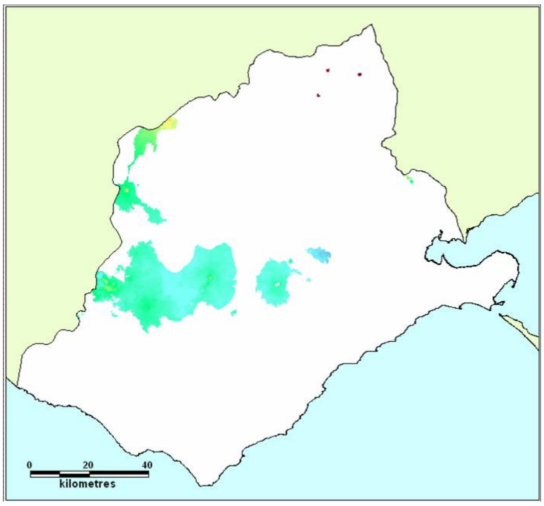

Figure 7. Model layer 4 – Scoria/stoney rises local system

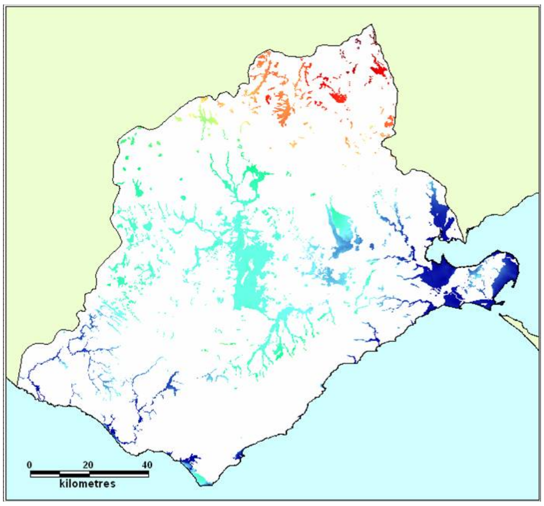

Figure 8. Model layer 5 – Alluvium local system

ASSESSING THE GROUNDWATER DEPENDENCE OF WETLANDS

This project commenced in January 2006 and work is progressing identifying and quantifying the groundwater dependence of the significant wetlands (groundwater dependent ecosystems) of the Corangamite CMA region. The project is due to be completed by December 2007.

The research area contains saline wetlands of national and international significance, of which the majority are found in the VVP bio-region of the catchment (Figure 1). Many of these are thought to be groundwater dependent to a greater or lesser degree. Changes to flow regimes through diversions or discharges, increased surface runoff from expanding urban areas and extensive groundwater extraction have all impacted on the salinity levels of the lakes and wetlands, compromising lake biota (Timms, 2005, Williams, 1992).

Very little research has been undertaken into establishing the groundwater dependence of the lakes and wetlands of the region. Coram, 1996, assessed water budgets and salt budgets for five lakes in the area of which four – Lakes Beeac, Colongulac, Gnarpurt and Murdeduke – reside in the Corangamite CMA region. This work concluded that precipitation and evaporation were the dominant controls on lake hydrology, with both groundwater and surface water contributing substantial masses of salt to the lakes. Adler and Lawrence, 2004, investigated groundwater – surface water interactions in relation to the drying of four of the Red Rocks Lakes. Their work pointed to groundwater extraction as the principle cause of lake desiccation.

GDE ranking

Work has been undertaken to identify the "priority" groundwater dependent ecosystems (GDEs) of the region (Barton *et al.*, 2006). More than 1500 wetlands have been listed for the Corangamite CMA region on the Victorian GIS-based inventory of wetlands. Of these a list of lakes with known names was compiled on the basis that the more significant wetlands of the region are those which have been labelled. Reservoirs and dams (i.e. man made water bodies dominated by surface systems) and coastal water bodies (i.e. those dominated by estuarine processes) were excluded from the list.

The remaining 144 listed wetlands were then ranked using an assessment method based on 11 administrative or policy documents relating to the conservation and preservation of Australian biodiversity and the natural environment. Amongst others, these included the Ramsar convention on wetlands, the Japan-Australian and China-Australia migratory bird agreements (JAMBA and CAMBA), the directory of important wetlands in Australia (EA, 2001) as well as State and Commonwealth listings of rare or threatened flora and fauna species.

Each wetland was assigned a "star" for each group in which it resides and the wetlands were then ranked on the basis of the total number of stars. The greater the number of stars the higher the ranking of the wetland.

Wetland sampling and analysis

As a first measure towards estimating the groundwater dependence of the ranked wetlands, a sampling field trip was undertaken in July 2006. Of the 46 lakes visited, almost half were either completely dried out or the water depth was very close to the lake bottom, making sampling impossible. Twenty-four samples were obtained and analysed for radon, stable isotopes and major ions.

Stable isotope results for the 24 lakes have been presented in δ^2H, δ^{18}O space in Figure 9 and compared with monthly isotopic data for Melbourne rain.

The work undertaken for the Groundwater Flow Systems project (discussed above) included the sampling and analysis of bores in the vicinity of many of the lakes. Results for the stable isotopes δ^2H and δ^{18}O for these groundwater samples (data not shown) have generally plotted within the domain of the average monthly values for Melbourne rainfall shown in Figure 9.

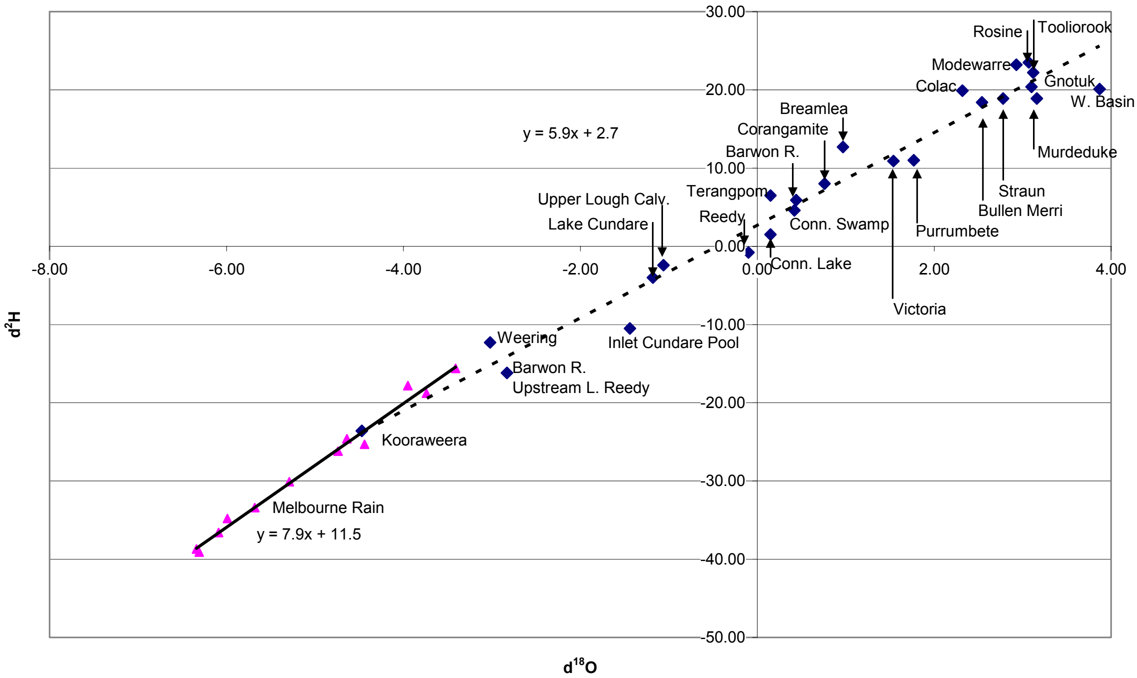

Figure 9. Lake stable isotopes together with average monthly values for Melbourne rain

Those lakes that lie further to the right along the trend line shown in Figure 9 have undergone a greater degree of evaporation relative to the rate of inflow. The lake water balance can be simply represented by a balance between the relatively light isotopic composition of inflow, and the tendency of evaporation to remove the lighter isotope preferentially to the heavier isotope thereby enriching the remaining water in the heavier isotope. In a semi-quantitative way the lakes increase in residence time (Residence time = total volume/total inputs) the further they lie to the right of line beginning at the Kooraweera point and ending at West Basin.

One can assume that the isotopic composition of groundwater is slightly more negative than surface water (refer to Figure 9) but for the purposes of this discussion it may be assumed to be indistinguishable. Therefore, the evaporation trend observed for the lakes in Figure 9 would be identical for the two types of inflow. However, if groundwater inflow were substantial and large, one could conduct an experiment where during a dry period without surface water inflows, say in summer, a time series of selected lakes would assist with determining if groundwater is a significant contributor by monitoring the isotope composition of lake water with respect to the theoretical path of evaporation.

Another way of expressing the data is to use the deuterium excess ($\delta_{xs} = \delta^2H - 8*\delta^{18}O$) which is a number that reflects the deviation of a given sample from the meteoric water line. Lower values indicate increasing influence of evaporation. Most of the groundwater samples have a deuterium excess of between 7 – 12, which is slightly less than the local meteoric water values of 13. The lake waters have a δ_{xs} between 5 and -5, and if there was a large flow-through of groundwater, then the δ_{xs} would be higher (that is approaching the groundwater δ_{xs} values). However plotting the δ_{xs} values data as a function of HCO_3^-/Cl^- (Figure 10) can at least qualitatively distinguish between the relative importance of surface water, groundwater and evaporation dominated lakes. Type 1: High δ_{xs}, low HCO_3^-/Cl^- - high groundwater flow-through; Type 2: Low δ_{xs}, low HCO_3^-/Cl^- - groundwater dominated, long residence time; Type 3: High δ_{xs}, high HCO_3^-/Cl^- – surface water dominated.

Additional sampling and analysis is being pursued to enable these concepts to be further explored.

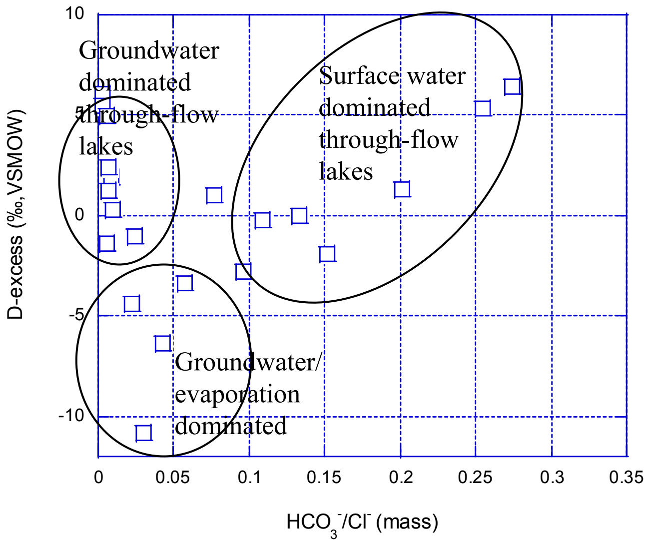

Figure 10. Deuterium excess versus HCO_3^-/Cl^- for the Corangamite CMA lakes

SUMMARY

The two projects currently being undertaken in the Corangamite CMA region are providing insight into the salinity processes of the area. The first project identifying and modelling the groundwater flow systems of the region is almost complete and a valuable tool has been developed which will better enable salinity risk due to land use changes to be assessed. The second project, assessing groundwater – surface water interactions with respect to the lakes, has commenced more recently and methods are being developed to quantify the groundwater dependence of the wetlands.

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Acknowledgements: Thanks is extended to Mr Phil Davies for the production of Figure 1.