EXECUTIVE SUMMARY

This report provides an update of groundwater monitoring results in the Campaspe Catchment, it complements the Campaspe Uplands Groundwater Monitoring brochure that was released in May 2001. Special reference has been made to salinity treatment in the catchment, with reports of two case studies where salinity mitigation measures have been implemented and their effectiveness investigated.

Strong groundwater fluctuations are a feature of the Sedimentary Hills and Rises land management units (LMUs). Such groundwater systems tend to be very responsive to rainfall, making it currently difficult to interpret long-term underlying trends. In contrast, groundwater in the Southern Granites LMU shows a slightly sub-dued response to climatic variation. Across the catchment, the low effective rainfall of the late 1990s has resulted in falling in waterlevels generally.

Groundwater pressures in the Campaspe Deep Lead (above Elmore) are noted to be rising on average between 11-14 cm/yr. The deep leads are not exposed at the surface and tend to be recharged by the relatively sluggish downward movement of water from overlying aquifers.

Salinity mitigation case studies have been documented for the Knowsley and Tooborac trial sites. At Knowsley, perennial pastures have demonstrated an ability to use sufficient soil moisture to minimise recharge, leading to sustainable steep watertable falls (in excess of 30 cm/yr). Falling trends have been sustained over a long period thus reduced rainfall is unlikely to explain the nature of the trend.

Groundwater monitoring has been in place at Tooborac since 1995. Perennial pasture and trees have been established in recharge areas in an attempt to reduce watertable excession. There has been an observed decrease in waterlevels at Tooborac since the site was set up, which is likely to be related to the low effective rainfall experienced since 1996, rather than the treatment itself.

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SALINITY GROUNDWATER MONITORING UPDATE FOR THE CAMPASPE CATCHMENT – with special reference to effectiveness monitoring

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1 INTRODUCTION

This report represents the first groundwater monitoring report for the community of the Campaspe Dryland Salinity Region (Figure 1). It provides an up-to-date interpretation of groundwater levels and hydrograph trends observed in the Department of Natural Resources and Environment (NRE) groundwater monitoring network that is relevant to the salinity program.

Special reference in this report is made to groundwater monitoring at two treated sites. Trial sites at Knowsley and Tooborac have salinity mitigation measures in place and are discussed in detail in this report.

2 GROUNDWATER MONITORING NETWORKS

2.1 Status of groundwater monitoring for salinity

Much of the groundwater monitoring (for salinity) occurring in the Campaspe dryland region was established during the 1980s and 1990s. There are two fundamental reasons for establishing such groundwater monitoring:

(i) to understand the character of groundwater flow; and

(ii) to detect long-term underlying groundwater trends in response to agricultural practices and varying land management regimes.

The initial networks were established in severe salinity affected areas such as the Colbinabbin Range, Axe Creek and Knowsley. Additional networks have been progressively installed where salinity has been recognised in more recent times, such as in the Sedimentary Hills land management unit (LMU) of Tooborac and Barfold areas. Some limited monitoring has also been established in the Southern Granites LMU at Baynton-Sidonia and Sutton Grange.

In recent years the reasons for monitoring have evolved further. As many of the community salinity strategies having been in the implementation phase for nearly ten years or more, there is a clear need to evaluate the effectiveness of the respective strategies. Groundwater monitoring of treated sites has assumed greater prominence.

2.2 Distribution of monitoring networks

There are approximately 180 NRE and community monitoring bores across the Campaspe region (Table 1) that are registered in the CLPR (Centre for Land Protection Research) salinity groundwater database.

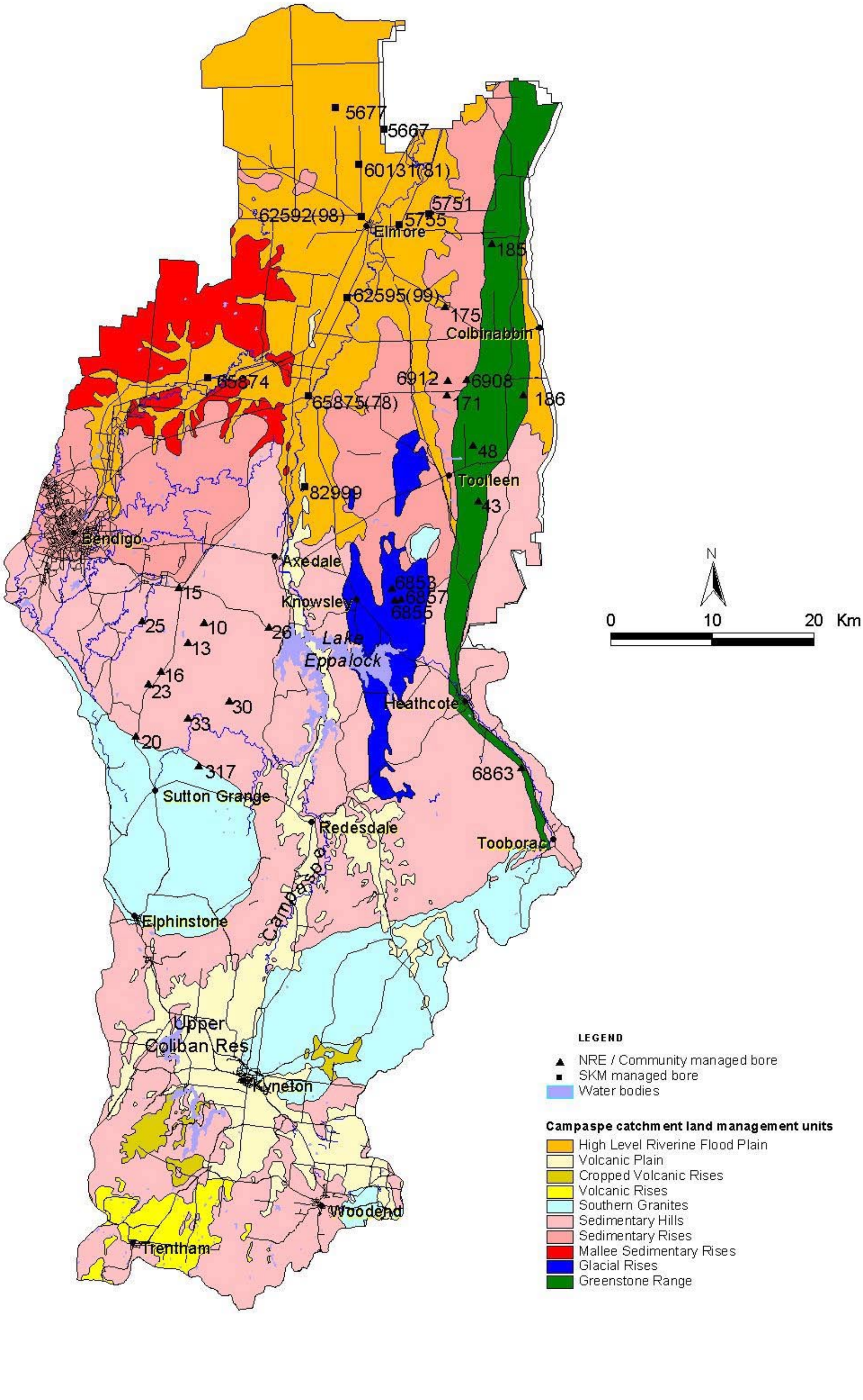

Figure 1 LMUs and key groundwater monitoring bores in the Campaspe Catchment.

Table 1 NRE and community groundwater monitoring network.

Monitored Region	*No. Piezometers*	*Monitor Type*
Heathcote	17	CLPR
Pipers Creek	1	Community Monitor
Sidonia	4	CLPR
Strathdale	7	CLPR
Sutton Grange	8	Community Monitor
Tooborac	6	CLPR
McIvor	9	CLPR
Axe Creek	31	CLPR/Community Monitor
Bagshot	31	CLPR
Barfold	9	Community Monitor
Baynton	4	Community Monitor
Bendigo	23	Community Monitor
Colbinabbin	31	CLPR

2.3 Monitor profile

2.3.1 NRE monitors

The NRE managed bores make up a large proportion of the groundwater monitoring program for salinity across the Campaspe Catchment. CLPR technical staff complete a component of the monitoring on a bi-monthly basis and are also responsible for the maintenance and upkeep of the NRE salinity groundwater monitoring network across the Campaspe Catchment.

2.3.2 Community monitors (volunteers)

Community monitors include Landcare members, schools, or interested individual community citizens. Community monitors are an integral part of the entire Campaspe Catchment groundwater monitoring program as their efforts provide essential input into the CLPR managed groundwater database. In total, 45 groundwater bores are monitored by community monitors in networks at Pipers Creek, Sutton Grange, Axe Creek, Bendigo, Baynton and Barfold.

2.3.3 Contracted monitors

Included in the Campaspe groundwater monitoring program are additional bores managed by Sinclair Knight Merz (SKM) on behalf of NRE. These bores are either monitored directly by SKM or by a sub-contractor.

These piezometers are most pertinent to monitoring groundwater conditions in the mid-reaches of the Campaspe Deep Lead system, especially in relation to groundwater extraction. They are concentrated in the districts of Diggora, Elmore and Barnadown.

2.4 Key bores

Key bores are a small subset of salinity monitoring bores that are selected primarily to satisfy groundwater reporting requirements for the salinity program. They are selected on the basis that their observed groundwater behaviour is representative of general watertable behaviour within the particular monitoring network. Currently there are 30 key bores that have been selected for the Campaspe region. This incorporates some bores from the SKM managed network.

There are, however, limitations to relying on the key bores alone. Although key bores can be used to provide a glimpse of general groundwater conditions, they are insufficient in themselves to define an adequate monitoring program. The size and heterogeneity of aquifer systems demands an extensive monitoring program to ensure these systems are comprehensively understood. A list of key bores for the Campaspe Salinity region can be found in Appendix 1.

3 SALINITY MONITORING REQUIREMENTS

The concepts of mandatory monitoring, effectiveness monitoring and background monitoring are discussed below.

3.1 Mandatory monitoring

Mandatory groundwater monitoring is theoretically the minimum number of groundwater bores in the monitoring network necessary to achieve monitoring objectives.

In most instances this will exceed a network defined by key bores alone, as key bores are mainly designed for periodical reporting requirements. Despite the increasing emphasis on mandatory monitoring such a program has not strictly been defined in the Campaspe Catchment. To date, monitoring efficiencies have been gained by reduction in monitoring frequency, rather than depletion of bores from the monitoring program.

Mandatory monitoring is a concept designed to ensure an efficient, relevant and cost effective monitoring program. Development of this could be a subsequent step for the Campaspe dryland groundwater monitoring program.

3.2 Background monitoring

In its totality, background monitoring reflects general catchment condition, and monitors groundwater response in relation to ‘normal’ catchment practices. In this way it allows a measure of groundwater response in the current scenario. The concept of background monitoring is important because it provides a baseline with which effectiveness monitoring (see below) can be compared.

3.3 Effectiveness monitoring

Effectiveness monitoring entails measuring watertable conditions in direct response to a specific local salinity treatment (e.g. Knowsley trial site). Normally a control bore is required (i.e. from the backgound monitoring component) to provide a basis for comparison of trends.

4 CURRENT CAMPASPE GROUNDWATER TRENDS

A primary aim of long-term groundwater monitoring is to detect groundwater trends that may be attributable to land use change or the adoption of certain land management practices.

Much of the NRE managed groundwater network is very young. For this reason it is not easy to determine underlying long-term groundwater trends. It is sometimes difficult to make an assessment, even with more than five years of data. On top of this, there is the 'abnormal' climatic events to account for, such as the extended dry period experienced during the mid to late 1990s. In recent times, falls in groundwater levels have been observed in numerous areas of Victoria, but these can rarely be attributed to improved land management strategies.

In this section hydrograph behaviour is discussed under aggregated land management unit (LMU) headings.

4.1 Sedimentary Hills and Rises LMUs

The Sedimentary Hills and Sedimentary Rises LMUs typically consist of low to rolling hills that are in part heavily forested, but otherwise grazed. The underlying geology consists of ancient, hard and fractured Ordovician sedimentary rock. NRE groundwater monitoring networks situated on the Sedimentary Hills and Rises LMUs occur at Axe Creek and the Wild Duck Creek sub-catchment.

Groundwater character is typified by high hydrograph responsiveness to rainfall (e.g. Mosquito Creek, bore no. 33 – Appendix 2), indicating that aquifers are actively recharging and providing a supply of water that can move and accumulate in low lying areas. These large fluctuations are indicative of high seasonal recharge through thin soils, with groundwater then moving laterally and accumulating in the lower landscape. This leads to rises in groundwater levels such as that seen in the hydrograph for bore no. 23 at Axe Creek (Appendix 2).

It is a feature of many upland areas that strong groundwater fluctuations are observed in hydrographs. Such groundwater systems are very responsive to rainfall, making it currently difficult to interpret subtle underlying long-term trends.

4.2 Volcanic Plains and Rises LMUs

The Volcanic Rises LMU comprise a central strip of the Campaspe region extending from Woodend to Malmsbury and along the course of the Campaspe River to the north of Axedale. The landscape is typified by gently undulating rises and steeply dipping valleys dissected by the Campaspe River. The geology of these units comprises of Quartenary basalt overlying Ordovician bedrock or Devonian granodiorite (in the east of the catchment). Minor trachyte occurs at Hanging Rock and the Camels Hump at the top end of the catchment.

Groundwater flow occurs laterally over large distances across the plains as regional groundwater flow (Kevin 1993). Minor salinity derived from sedimentary bedrock occurs on the contact between the Volcanic Plains and Sedimentary Hills LMUs (e.g. Barfold). It is likely that recharge across the plains discharging at this contact zone is contributing to salinity in these areas.

4.3 Alluvial and Riverine Plains LMUs

4.3.1 Surface alluvials

These units encompass the Goornong, Elmore and Rochester areas. The surface geology consists of alluvial clays and silts (of the Shepparton Formation) that overlie the buried channel deposits of the Campaspe Deep Lead and its tributaries.

Hydrographs from bore no. 65878(5) at Barnadown (Appendix 2) and bore no. 5755 at Elmore (Appendix 2) show a strong linear rising trend with little or no influence from seasonal or annual rainfall variation. This suggests there is a constant source of lateral groundwater accumulation from a regional source, particularly if there is little to no influence from 'effective rainfall' or low rainfall.

Recharge into the surface alluvial aquifer occurs either by direct infiltration of rainfall or infiltration of accumulated runoff generated from up-catchment rainfall episodes (e.g. flood events). Groundwater in the surface alluvium often seeps into the underlying sands and gravels of the deep leads.

4.3.2 Campaspe Deep Lead

The legacy of the ancient Campaspe River is the modern day Campaspe Deep Lead aquifer system. This consists of channel sands and gravels that are buried deeply below more recent alluvium and basalt. Groundwater pressures in the Campaspe Deep Lead up stream of Rochester are rising on average between 11-14 cm/yr. The deep lead hydrograph for bore no. 60131 at Diggorra (Appendix 2) shows a strong response to seasonal and annual rainfall but exhibits a strong underlying rising trend.

Groundwater accumulation is occurring via lateral throughflow from a regional source. Pressures in both the watertable and deep lead aquifers are rising. To a large degree, leakage from the Campaspe River and/or lateral groundwater flow from high watertable irrigation areas are responsible for pressure rises rather than simple general recharge across the plains.

The deep lead is not exposed at the surface and tends to be recharged by relatively sluggish downward movement from overlying aquifers. Generally, the overlying aquifers have a lower permeability than the deep lead itself. A lot of groundwater is stored in this system and is continually being recharged. This can be seen when groundwater pumping occurs. During pumping, a significant drop in the watertable which occurs, returns to its original level almost immediately after pumping ceases (e.g. bore no. 60131 at Diggorra).

4.4 Southern Granites LMU (and associated Metamorphic Ridges)

The Southern Granites LMU consists of undulating, sometimes rocky, hill country in moderate rainfall environments in the Elphinstone-Sutton Grange, Pipers Creek, Cobaw and Baynton areas. Local groundwater systems are mostly developed in the weathered material overlying the hard, fresh granite. High recharge occurs on the crests and upper slopes. Some limited groundwater flow also occurs in interconnected fractures developed in the hard granite.

Shallow perched watertables are prevalent with discharge occurring at the break-of-slope in the form of waterlogged depressions or springs (Kevin 1993). Hydrograph data from bore no. 317 (Appendix 2) at Sutton Grange shows a falling groundwater trend in response to rainfall events.

Surrounding the granite lie the metamorphic ridges. These represent fractured rock aquifers that occur on the contact zone between the granite and sedimentary material. These are prominent ridges comprising of rolling to steep hills (e.g. Big Hill) formed by contact metamorphism, which surrounds the granite (e.g. Mount Alexander).

4.5 Greenstone Range LMU

This unit comprises the narrow north-south trending belt of steeply inclined Cambrian rock, which extends from the rolling steep hills at Mount Camel in the north, to undulating rises at Tooborac in the south (Kevin 1993). This range is known as the Colbinabbin Range. The underlying geology consists of Cambrian greenstones, cherts and silicified shales. Shallow gradational and uniform soils occur on crests and upper slopes.

Localised groundwater flow is a feature of fractured greenstones. Large seasonal groundwater fluctuations are observed in bore no. 48 at the Colbinabbin Range and bore no. 43 at Toolleen (Appendix 2). These large fluctuations occur as a result of high recharge into the fractured greenstone. Recharge occurs along the entire length of the range with discharge occurring at the break-of-slope and along drainage lines at the base of the Colbinabbin Range. This is indicative of recharge through the thin soils with groundwater then moving laterally and accumulating in the lower landscape.

4.6 Glacial Rises LMU

The Permian glacial deposits extend in a belt to the north-east and south-east of Lake Eppalock and consist of gently undulating rises around the Knowsley and Heathcote districts. The glacial deposits consist of dense, low permeability tillite where groundwater movement is sluggish.

This landscape is typified by low permeability resulting in steep watertable rises and watertable mounding. Reduced hydraulic gradients at the break-of-slope result in groundwater discharge (Kevin 1993). At the Knowsley trial site, phalaris pastures have demonstrated their ability to use sufficient soil moisture to minimise recharge, leading to a sustained steep watertable fall in excess of 30 cm/yr (e.g. bore no. 6857 - Appendix 2). Using perennial pasture has been effective as the low permeability of the soil results in slow movement of groundwater through the soil profile, hence the perennial pasture is able to utilise a greater portion of the water recharging the watertable.

5 IMPACT OF CLIMATE ON TRENDS

An important factor to consider in groundwater trend interpretation is climatic variation. Key rainfall stations in the Campaspe region are at Bendigo, Elmore, Knowsley, Kyneton and Heathcote (see Appendix 3). These show that average rainfall across the Campaspe varies between 800 mm/yr in the uplands (e.g. Kyneton) to 450 mm/yr on the plains (e.g. Elmore).

Interestingly during the 1990s, despite the sequence of dry years, cumulative rainfall is actually above average for many rainfall stations. Understanding the impact of climatic variation on groundwater trends also means taking into consideration not just the annual rainfall, but how it falls during the year. More widely spaced rainfall events appear to have been the recent pattern, clearly reducing the probability for recharge and run off to occur. Despite close to average annual rainfall totals, the 'effective rainfall' is below average.

Groundwater systems in the Campaspe are very responsive to rainfall variation, which can be seen in hydrographs for bores in the catchment. For example, bore no. 65874 at Goornong (Appendix 2) shows short-term seasonal fluctuations sitting on a long-term rising trend. In contrast at Axe Creek (bore no. 15, Appendix 2), it is possible to rationalise that slightly falling levels are due to the overall dry conditions since the mid 1990s rather than improvements in land management.

6 EVIDENCE FOR SALINITY TREATMENT IMPACTS

The purpose of this section is to identify:

(i) where monitoring is in place in treated areas;

(ii) the reasons for this treatment; and

(iii) the effectiveness of the treatment.

6.1 Knowsley trial site

Location

Knowsley is located 30 kilometres east of Bendigo, on the McIvor Highway.

LMU and geology

Knowsley is situated on the Glacial Rises LMU, which consists of dense, low permeability glacial sediments consisting of tillite, conglomerates and sandstone. Soils are generally mottled yellow duplex type with a bleached A_2 horizon. The bleached A_2 indicates high lateral throughflow of water through this zone. Duplex soils occur throughout this unit but are thinner on hillcrests. Yellow clay subsoils occur both on the rounded crests and gentle slopes throughout the area.

Soil infiltration tests carried out by Kevin (1993) suggest that recharge occurs fairly evenly over the whole landscape. Discharge occurs at the break-of-slope, coinciding with drainage depressions (Figure 2).

History of the Knowsley trial site

Historically, land use at this site has been cereal cropping and sheep grazing. The expansion of soil salting and related tree deaths prompted the Soil Conservation Authority to investigate the causes in the early 1970s. The Knowsley trial site was initiated as part of the National Soil Conservation Program in 1987.

Environmental issue

The Knowsley landscape is unique as it exhibits salinity occurring in a low recharge, low permeability environment and groundwater flow in these glacial deposits is very sluggish. Despite the relatively low recharge this area is predisposed to steep watertable mounding due to the general sub-surface permeability constraint. The watertable throughout the catchment closely conforms to the landscape and local groundwater systems develop. This results in saline discharge at the break-of-slope and in drainage depressions.

Figure 2 Evidence of salinity in drainage lines at the Knowsley trial site.

Treatment and management

The treatment consisted of sowing the catchment to improved perennial pasture. Due to the high pH and waterlogging, lucerne was not an option. A mixture of phalaris, currie cocksfoot and sub-clover was sown. The area was intensely planted with native trees along the boundaries and fence lines (Figure 3). At this trial site approximately 70% of the site was covered with perennial pasture mixture, 20% with tree plantation and 10% with tall wheat grass. In the drainage lines, trees and tall wheat grass were planted (Figure 4).

Figure 3 Salinity remediation treatment at the Knowsley trial site.

Figure 4 Trees and tall wheat grass planted in saline drainage lines, Knowsley trial site.

The first plot of perennial pasture was established in 1970, the second in 1985 and then a plot of perennial pasture planted every year up until 1990. Twelve groundwater monitoring bores where installed in 1987.

Treatment effectiveness

At this site the phalaris pastures have demonstrated that they are able to use sufficient soil moisture to minimise recharge, leading to sustainable steep watertable falls in excess of 30 cm/yr (as seen at bore no. 6857 - Appendix 2). In the interpretation of this data it is important to remember the effect climatic variation will have on the watertable. There has been below average rainfall experienced in the region between 1996-2000 and it is important to keep this in mind when analysing the data.

6.2 Tooborac trial site

Location

The Tooborac trial site is 8 kilometres south of Heathcote on the Northern Highway.

LMU and geology

The Tooborac trail site is located on the boundary between two LMUs. The Sedimentary Hills/Rises and Greenstone Range LMUs. The Greenstone Range consists of Cambrian greenstone, shale and chert under red gradational soils with loamy topsoil. The Sedimentary Hills/Rises is made up of Ordovician sandstones and mudstones with mottled yellow duplex soils. This site itself is on the Sedimentary Hills LMU.

History of the Tooborac site

The Tooborac trial site was an initiative carried out by the McIvor Farm Advance Landcare Group, as a salinity demonstration site in 1993 (Figure 5).

Figure 5 Tooborac trial site (1993).

Saline discharge occurs at the break-of-slope, and perennial pasture and trees have been established in recharge areas in an attempt to reduce watertable accessions. Six groundwater monitoring bores were installed at the site in February and March 1993 prior to the establishment of the perennial pasture in September 1993.

Figure 6 shows the trial site when it was initially set up in 1993. Figure 7 shows the trial site in March 2000, seven years later. The saline discharge site can be seen in both Figures 6 and 7 at the break-of-slope, with the most notable difference being the tree growth on the crest of the hill.

Figure 6 Tooborac trial site (1993), newly planted trees and perennial pasture.

Figure 7 Tooborac trial site (2000), established trees and perennial pasture.

Environmental issue

These sedimentary hills have local groundwater systems that are confined within sub-catchments by low permeability weathered rock with salinity occurring at the break-of-slope due to reduced hydraulic gradients. When comparing Figures 6 and 7, the size and extent of the discharge has no noticeable increase or decrease.

Treatment and management

During the spring of 1993, phalaris was sown in the paddock below the tree plantation site. Lime trial strips where also put into place. In the following autumn Balansa clover and other sub-clovers where sown. Sheep graze these paddocks at regular intervals. The tree planting site is fenced off from stock and the trees have grown approximately 1-2 metres in height (as seen in Figure 7).

Treatment effectiveness

Since groundwater monitoring began in 1995, there appears to be a decrease in groundwater levels. This can be seen in bore no. 6863 at Tooborac (Appendix 2). Being a low rainfall area with low permeability slopes, the perennial pasture appears to have a positive effect. However, it is also possibly in response to the low effective rainfall experienced in the region during the late 1990s.

7 LIMITATIONS TO THE CURRENT DATA

The aforementioned groundwater trend summary is strongly biased by both the relative youth and distribution of the groundwater monitoring program. For instance, currently in the Campaspe dryland area, there are few bores lying in areas that would highlight the positive water use impacts of treatments (e.g. of perennial pasture and trees) being implemented by Landcare and other initiatives.

Although there are some positive outcomes of these treatments at the local scale, there is little doubt that at the catchment scale the collective area of salinity treatment is still minor and the effects of these treatments would not be expected to be observed in the background monitoring component.

As suggested earlier, a general weakness in the Campaspe groundwater monitoring program is the lack of monitoring of specific salinity treatments. In addition to effectiveness monitoring, an analysis of the distribution of groundwater monitoring in relation to the priority status of Campaspe sub-catchments suggests that there are a number of areas where additional background groundwater monitoring should be considered (Table 2). This is discussed in more detail in the next section.

Only through catchment-wide recharge control strategies will areas of saline discharge reduce significantly and water quality improve. However, in the Campaspe generally, local scale groundwater flow is common, so that treatment at the local level (e.g. recharge control in the upper landscape) may realistically lead to reduction of the watertable and improvement of discharge areas.

Table 2 Priorities for additional sub-catchment groundwater monitoring.

PRIORITIES FOR ADDITIONAL SUB-CATCHMENT GROUNDWATER MONITORING			
SUB-CATCHMENT AND DOMINANT LMUs	**GROUNDWATER MONITORING COVERAGE**	**COMMENT/ REQUIREMENTS**	**PRIORITY FOR ADDITIONAL MONITORING.**
BENDIGO/MYERS CREEK High Level Riverine Flood Plain and Sedimentary Hills/Rises	A concentration of NRE bores around Huntly and SKM bores scattered across the plains.	A good coverage of bores for this sub-catchment.	Low
CAMPASPE PLAINS High Level Riverine Flood Plain and Sedimentary Hills	Adequate coverage of SKM and NRE bores on the plains north of Elmore and Mt Camel Range	A few additional bores would complement the existing bore network.	Low
MT PLEASANT High level Riverine Flood Plain and Sedimentary Hills	Adequate coverage of bores along the Sedimentary Hills of Mt Camel Range	Additional bores west of Mt Pleasant would complement the current monitoring.	Low
CORNELLA Greenstone Range, High Level Riverine Flood Plain and Sedimentary Hills	A few bores located on the Mt Camel range.	Additional monitoring of the discharge sites east of Mt Camel would be beneficial.	Low
FOREST Glacial Rises and Sedimentary Hills	A good coverage of bores around the Knowsley trial site	Bore coverage is scarce elsewhere in the sub-catchment.	Low
AXE CREEK Sedimentary Hills	Excellent bore monitoring program in place with adequate coverage.	Not necessary for additional bores at this stage.	Low
MOSQUITO CREEK Sedimentary Hills	Only a few bores located within this catchment.	Additional bores would complement the whole of the Campaspe catchment	Low
MYRTLE CREEK Sedimentary Hills and Southern Granites	Very low coverage of bores	Additional bores within the granite would compliment the existing bores	High
LOWER COLIBAN Sedimentary Hills and Southern Granites	Very few monitoring bores within this sub-catchment	Additional bores would complement the whole of the Campaspe catchment	Low
WILD DUCK Sedimentary Hills, Volcanic Plain and Glacial Rises	A few monitoring bores located within this sub-catchment.	Additional bores placed in the Sedimentary Hills would complement the existing bore network.	Low
McIVOR Sedimentary Hills, Greenstone Range and Southern Granites	Monitoring bores are located around the Tooborac trial site.	Additional monitoring on other saline discharge sties along the southern end of the southern edge of the Greenstone	Low
UPPER COLIBAN Volcanic Rises/Plains and Sedimentary Hills	Few bores in this sub-catchment as salinity is not a problem	Additional bores in the Sedimentary Hills and the Volcanic Rises would complement the whole Campaspe monitoring program	High
UPPER CAMPASPE Volcanic Plains, Southern Granites and Sedimentary Hills	Poor bore coverage with some located at Barfold and on the Volcanic Plains near Five Mile Creek.	Additional bores, particularly in areas of geological contact as this appears to be salinity issues arise.	High
PIPERS CREEK Volcanic Plains, Southern Granites and Sedimentary Hills	Very few bores located in the granite where salinity and soil health are an issue.	Additional bores would increase groundwater knowledge in this part of the Campaspe Catchment	High

* The allocated priority does not correlate to existing salinity risk alone, but rather is a judgement based on current bore coverage as well as salinity risk.

8 BROAD RECOMMENDATIONS TO THE MONITORING PROGRAM

There is generally reasonable coverage of monitoring bores in the sub-catchments of the Campaspe Catchment north of Lake Eppalock. However bore coverage is average to poor in the Uplands region around Kyneton, Woodend and Malmsbury. Although historically these areas have few salinity problems, additional monitoring bores in these areas would increase the current knowledge of groundwater systems in the Campaspe Uplands. Refer to Table 2 for individual catchment requirements.

Importantly, existing groundwater monitoring needs to continue indefinitely in order to provide high quality data for the interpretation of groundwater levels across a range of landscapes, so that groundwater and salinity processes can be better understood.

A potential project for groups in the Campaspe Uplands region could involve mapping salinity discharge in their areas. It is important to re-map areas of salinity that were mapped more than 8-10 years ago, as keeping local catchment knowledge (and processes within the catchment) up to date will assist in more accurately determining possible salinity risk areas in the future. Priorities for increased monitoring are the Upper Campaspe, Pipers Creek, the Upper Coliban and Myrtle Creek sub-catchments (Table 2).

The development and success of large scale integrated projects is a new and innovative approach to salinity management and prevention. It involves at least four Landcare groups placing a joint application for National Heritage Trust funding to develop a land and water management plan for their sub-catchment area. Such a program was initiated by the Mid Loddon Sub-Catchment Management Group, and more recently, the Axe Creek Large Scale Integrated Project (discussed below).

8.1 Axe Creek Large Scale Integrated Project

This is the beginning of a new phase of salinity research that incorporates social issues, economic benefits and biodiversity. A large-scale integrated project has been developed into a Land and Water Management Plan for the Axe Creek sub-catchment. A committee has come together including representatives from the local shire, Campaspe Implementation Committee, North Central Catchment Management Authority, Landcare groups, Centre for Land Protection Research and NRE's Catchment and Agricultural Services to implement the project.

The project has developed as a result of a second generation Landcare bid for Axe Creek on behalf of the four Landcare groups in the catchment (North Harcourt/Sedgwick, Axe Creek, Lower Axe Creek and Longlea and District). The completion of the project should occur within 3-5 years with a 15 year plan containing recommendations addressing and monitoring short and long-term issues. Salinity is the overall driving force behind this project, linking local government, biodiversity and farm forestry to help tackle this problem, as well as provide some possible economic gain from the project in the long-term.

Sub-catchment integrated research projects like these are an excellent way of dealing with salinity and groundwater monitoring on a catchment scale. This type of approach demonstrates multiple natural resource benefits, significant landscape change and models sustainable farm planning principles. This type of approach to salinity research will incorporate the years of data collected to date, using it to develop a management plan for the Axe Creek sub-catchment and with continued monitoring will be able to gauge its effectiveness.

9 REFERENCES

Kevin, P.M. (1993) Groundwater and Salinity Processes in the Uplands of The Loddon River Catchment *Tech Rep No.5. Centre for Land Protection Research, Bendigo*

10 GLOSSARY

Aquifer

Rock or sediment saturated with groundwater, in which the groundwater is able to move relatively freely through spaces (or pores) between grains or along fractures.

Colluvium

Unconsolidated material at the bottom of a slope generally moved by gravity. It is usually unsorted, and its fragments range greatly in size.

Discharge

Where groundwater emerges from the ground. This may occur directly into a stream or take the form of a free running spring or saline soak.

Groundwater system - local

A flow path where groundwater travels only a short distance between its area of recharge and discharge. An example is where recharge (e.g. a hill) and discharge occur on the same property (e.g. a saline soak at the break-of-slope).

Groundwater system - intermediate

Intermediate between a local and regional groundwater system.

Groundwater system - regional

An extended groundwater flow path where groundwater may recharge (e.g. in an upland area) several hundreds of kilometres from where it discharges (e.g. on an alluvial plain).

Hydrograph

A plot of waterlevel (usually vertical axis) versus time (horizontal axis).

Key bore

A monitoring bore that has been chosen for groundwater trend reporting purposes, on the basis of it being representative of groundwater fluctuations in a particular monitored area.

LMU

Land Management Unit. An area of similar physical characteristics in terms of soils, geology, groundwater processes and climate.

Permeability

Describes the ability of material to transmit water. A loose sand is generally highly permeable whereas clay typically has low permeability.

Piezometer

A non-pumped groundwater monitoring bore that is used to measure the elevation and salinity of groundwater.

Recharge

The component of infiltrating rainwater that is able to move through the soil zone and into the watertable.

Watertable

The upper boundary of the groundwater system. Its shape is generally a subdued reflection of the topography

APPENDIX 1 LIST OF KEY BORES FOR THE CAMPASPE SALINITY REGION

BORE		AREA	LMU	POSITION	RECORD	DEPTH OF BORE	DEPTH TO WATER	TREND SUMMARY
No.	Manager		(or aquifer type)	in landscape		(m)	(m)	
5677	CLPR	Diggorra	High Level Riverine Flood Plain	N/A	Since 1977	31.5	4.0	Rising trend 1.5 cm/yr
60131	SKM	Diggorra	High Level Riverine Flood Plain	N/A	Since 1982	127.5	13.0	Rising deep lead pressures
62952	SKM	Elmore	High Level Riverine Flood Plain	N/A	Since 1992	N/A	10.0	Fluctuates with rainfall
5751	SKM	Elmore	High Level Riverine Flood Plain	N/A	Since 1977	20.0	8.5	Rising trend through 1990s
5775	SKM	Elmore	High Level Riverine Flood Plain	N/A	Since 1978	16.8	11.2	Rising trend 16 cm/yr
185	CLPR	Mt Burramboot	Greenstone Range	N/A	Since 1988	35.0	13.9	Falling trend since 1996
62595	SKM	Goornong	High Level Riverine Flood Plain	N/A	Since 1991	85.0	9.1	Rising trend 13 cm/yr
62599	SKM	Goornong	High Level Riverine Flood Plain	N/A	Since 1987	17.0	10.0	Fluctuates with rainfall
175	CLPR	Colbinabbin	Sedimentary Rises	N/A	Since 1988	84.0	19.0	Linear rising trend 25 cm/yr
65874	SKM	Goornong	High Level Riverine Flood Plain	N/A	Since 1985	9.0	2.5	Fluctuates with rainfall
6908	CLPR	Myola East	Sedimentary Hills/Greenstone Range	Roadside	Since 1989	N/A	7.6	Fluctuates with rainfall
186	CLPR	Cornella East	High Level Riverine Flood Plain	Roadside, on plain	Since 1988	61.0	2.5	Underlying rising trend
65875	SKM	Barnadown	High Level Riverine Flood Plain	N/A	Since 1985	64.0	15.8	Long- term linear rising trend
65878	SKM	Barnadown	High Level Riverine Flood Plain	N/A	Since 1987	18.0	9.9	Fluctuates with rainfall
171	CLPR	Colbinabbin	Sedimentary rises	N/A	Since 1988	N/A	8.9	Long-term linear rising trend
48	CLPR	Colbinabbin	Greenstone Range	Mid-slope	Since 1986	45.0	21.0	Fluctuates with rainfall
82999	SKM	Muskery	Cropped Sedimentary Rises	N/A	Since 1991	54.0	28.2	Linear rising trend
43	CLPR	Toolleen	Greenstone Range	Lower slope	Since 1985	90.0	3.8	Fluctuates with rainfall
6857	CLPR	Knowsley	Glacial Rises	N/A	Since 1987	N/A	7.0	Steep falling watertable 30 cm/yr
6855	CLPR	Knowsley	Glacial Rises	N/A	Since 1987	N/A	2.0	Fluctuates with rainfall
13	CLPR	Axe Creek	Sedimentary Hills	N/A	Since 1983	41.0	25.2	Long-term rising trend 5 cm/yr
16	CLPR	Axe Creek	Sedimentary Hills	N/A	Since 1983	50.0	3.0	Fluctuates with watertable
33	CLPR	Mosquito Creek	Sedimentary Hills	N/A	Since 1983	72.0	11.0	Fluctuates with rainfall
317	CLPR	Sutton Grange	Southern Granites	N/A	Since 1994	11.5	6.3	Falling groundwater trend
6863	CLPR	Tooborac	Greenstone Range	N/A	Since 1995	14.0	3.2	Falling groundwater trend
25	CLPR	Axe Creek	Sedimentary Hills	N/A	Since 1983	42.0	9.3	Underlying falling trend
23	CLPR	Axe Creek	Sedimentary Hills	N/A	Since 1986	200.0	2.5	Slight underlying rising trend
30	CLPR	Mosquito Creek	Sedimentary Hills	N/A	Since 1983	45.0	9.5	Fluctuates with rainfall