EXECUTIVE SUMMARY

This report is an update of groundwater monitoring results in the uplands region of the Loddon Catchment. The current groundwater monitoring program has an important role in helping to analyse groundwater trend behaviour in different Land Management Units (LMU's). Special reference has been made to salinity treatments in the region, with four case studies reported where salinity mitigation measures have been used and their effectiveness investigated.

A typical characteristic of the uplands groundwater systems is their high responsiveness to both seasonal (e.g. winter/spring rainfall) and annual rainfall variations (e.g. dry 1994). Although long term trends are generally not evident, it is clear that large seasonal slugs of recharge occur in the uplands that are likely to lead to accumulating groundwater in the lower landscape. This accumulation is expressed either as expanding areas of groundwater discharge, or greater rates of groundwater discharge.

An exception is at McIntyre (bore no. 6336 – Appendix 2), where short term seasonal fluctuations are clearly sitting on a long-term rising trend. The magnitude of the rising trend here (5 - 20 cm/yr) suggests that land use is the key factor influencing the trend rather than above average cumulative rainfall over the monitoring period. In other areas such as Nuggetty (bore no. 6503 – Appendix 2), it is possible to rationalise that slightly falling levels are due to lower effective rainfall since the mid 1990s rather than genuine improvements in land management.

Groundwater pressures in the upper to mid reaches of the Loddon Deep Lead are noted to be rising on average 7-10 cm/yr. The deep leads are not exposed at the surface and tend to be recharged by relatively sluggish downward movement from overlying aquifers.

A series of salinity mitigation measures have been carried out on treatment case studies at Black Range and McIntyre, including farm forestry and tall wheat grass planting. It is too early to detect if farm forestry has had any effect. However, the tall wheat grass appears to have helped alleviate the saline discharge by preventing the salt scald from increasing in size.

Anecdotal evidence suggests that lucerne planted on the Laanecoorie and Newbridge case study site have had a positive "mopping up" effect. Since lucerne was established, waterlogging has not been an issue. However, it is important to correlate groundwater information with climate during the 1990s. Despite close to average annual rainfall totals, "effective rainfall" is low.

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SALINITY GROUNDWATER MONITORING UPDATE FOR THE LODDON UPLANDS REGION – with special reference to effectiveness monitoring

June 2000

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1 INTRODUCTION

This report represents the third phase of the annual community monitoring report for the Loddon Dryland Salinity Region and is the first report that concentrates solely on the uplands region of the Loddon Catchment. For the purpose of this report, the uplands region is defined as the area of the Loddon catchment that lies south of the Calder Highway. The Uplands area includes monitoring networks such as Lexton, Moolort, McIntyre-Rheola, Black Range, Newstead and Maldon (Figure 1).

The report gives 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 salinity.

There is special reference in this report to the effectiveness of the groundwater monitoring network in detecting responses to salinity treatments. Properties in the Marong West, Laanecoorie and McIntyre areas have relatively long standing monitored salinity treatments in place.

2 MONITORING NETWORKS

2.1 Status of groundwater monitoring for salinity

Much of the groundwater monitoring (for salinity) occurring in the Loddon uplands was established during the 1980s and 1990s. The two fundamental reasons for establishing this groundwater monitoring were to:

(i) understand groundwater systems in a given area, and

(ii) to detect long term underlying groundwater trends in response to land clearing and agricultural practices.

Many of the earlier networks were established in salinity affected areas such as Lexton, Moolort, McIntyre-Rheola and the Black Range. In addition, younger monitoring networks have been progressively installed where salinity has been recognised in more recent times, such as in the granites of the Maldon-Ravenswood area and the sedimentary hills of the Castlemaine-Newstead area.

In recent years the reasons for monitoring have evolved. With many of the community salinity strategies having been in the implementation phase for five 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 about 170 NRE and community monitoring bores across the Loddon uplands salinity region (Table 1) that are registered on the Centre for Land Protection Research (CLPR) groundwater database.

In addition to the NRE managed and community groundwater monitoring networks, there are numerous Sinclair Knight Merz (SKM) managed piezometers. The SKM managed piezometers constitute regional groundwater monitoring for purposes other than just salinity. These are mostly relevant to monitoring groundwater extraction in the mid-reaches of the Loddon Deep Lead system and the volcanic cone terrain in the upper catchment (e.g. Mount Franklin and Spring Hill areas). Bores also exist to monitor the status of the mineral springs groundwater resource in the Daylesford - Hepburn area.

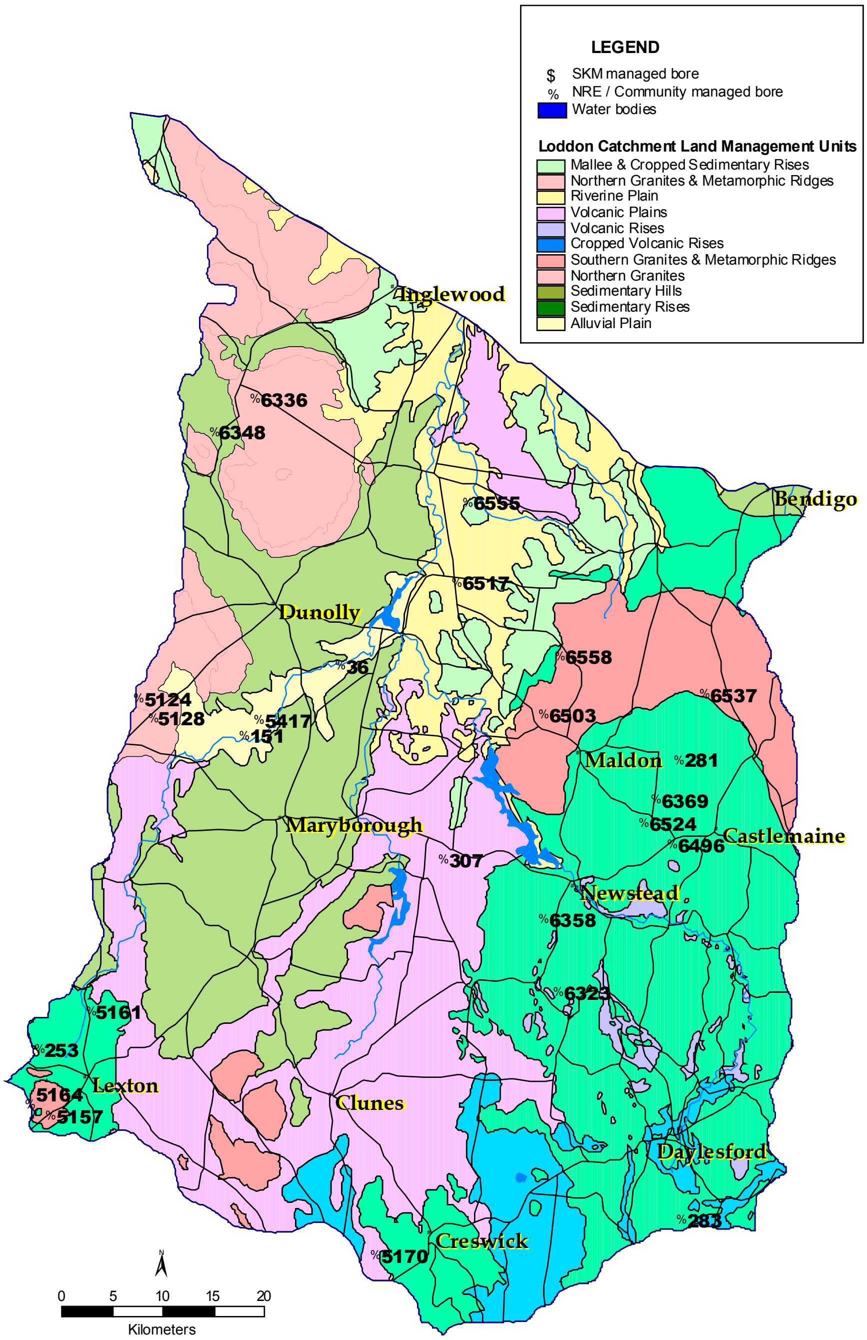

Figure 1 The Loddon uplands region, LMUs and selected key bores.

Table 1 Summary of the NRE managed and community groundwater monitoring networks.

Monitored Region	***No. Piezometers***	***Monitor Type***
Lexton	19	NRE(CLPR)
Creswick	14	Community Monitor
Daylesford	2	Community Monitor
Newstead	14	Community Monitor
Castlemaine	24	Community Monitor
Moolort	14	Community Monitor
Timor West	12	Community Monitor
Black Range	10	Community Monitor
Maldon	20	Community Monitor
Ravenswood-Lockwood	14	Community Monitor
Laanecoorie	8	Community Monitor
Marong West	6	Community Monitor
McIntyre – Rheola	6	Community Monitor
Laanecoorie	8	Community Monitor

2.3 Monitor Profile

2.3.1 NRE monitors

The NRE managed bores make up the large proportion of the groundwater monitoring bores across the Loddon Catchment. CLPR technical staff carry out monitoring on a bi-monthly basis and are responsible for the maintenance and upkeep of the groundwater monitoring network across the Loddon Catchment. However, the vast majority of the upland bores are monitored by the community.

2.3.2 Community monitors (volunteers)

Community monitors include Landcare members, schools and individual community citizens, all whom expend considerable effort to provide essential information for the CLPR groundwater database. As community monitors carry out the majority of salinity groundwater monitoring in the Loddon uplands region, they are an integral part of the entire Loddon Catchment groundwater monitoring program.

2.3.3 Contracted monitors

Included in the Loddon groundwater bore network are the bores managed by SKM. These bores are either monitored directly by SKM or a sub-contractor. These are an important asset, but generally not formally part of the salinity program.

2.4 Key bores

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

There are, however, limitations in relying just on the key bores. Although key bores can be used to provide a general glimpse of regional groundwater conditions, they are insufficient in themselves to define an adequate monitoring program. The size and heterogeneity of geological and aquifer systems demands an extensive monitoring program to ensure that these systems are comprehensively monitored and understood.

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 monitoring network necessary to achieve monitoring objectives. Mandatory monitoring is a concept designed to ensure an efficient, relevant and cost effective monitoring program.

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

3.2 Background monitoring

In its totality, background monitoring reflects general catchment condition, and generally represents groundwater response in relation to traditionally accepted catchment practices. For all intent and purposes, at the catchment scale, this represents a minimal change scenario. The concept of background monitoring is important because it provides a base line with which general effectiveness monitoring (see below) can be replaced.

3.3 Effectiveness monitoring

Effectiveness monitoring entails measurement of watertable conditions in direct response a specific local salinity treatment. Normally a control bore is required (i.e. from the background monitoring) to provide a basis for comparison of trends.

4 CURRENT LODDON UPLAND 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 are ‘abnormal’ climatic events to account for, such as the extended dry period experienced since the mid to late 1990s. In recent times, falls in groundwater levels have been observed in numerous areas of Victoria, but these rarely can be attributed to improved land management strategies that have clearly reduced recharge.

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

Long term groundwater trends may be more apparent in the lower lying parts of the uplands landscape where groundwater accumulation can readily occur. Even though trends may not be apparent in upper landscape bores, the identification of an excess recharge issue may have implications for lower landscape groundwater accumulation with increased rates of groundwater discharge.

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

4.1 Sedimentary Hills/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. Groundwater monitoring networks situated on the Sedimentary Hills/Rises LMUs occur at Lexton, Newstead, Castlemaine, Maryborough and Dunolly.

Groundwater character is typified by high hydrograph responsiveness to rainfall, indicating that aquifers are actively recharging and providing a volume of water that can move and accumulate in low lying areas.

Hydrograph patterns, typically reveals a maximum peak in 1989-90. The rainfall record indicates gradual increasing annual rainfall between 1990 and 1993. Hydrograph peaks appear to rise accordingly. The effect of the 1994 drought is evidenced by the troughs in the hydrograph as the water level drops in response to the low rainfall (e.g. bore no. 6496 – Appendix 2).

It appears that throughout the Sedimentary Hills/Rises LMUs, groundwater patterns are consistent with local to intermediate groundwater systems, which strongly recharge in the winter-spring. This behaviour is indicative of upland fractured rock systems where there is strong connectivity to surface climate processes due to generally thin soil development on the slopes.

An exception to the above is the trend observed in key bore 5164 (Appendix 2) near Lexton. This bore indicates an average rise of 13 cm/yr independent of the annual rainfall variation. Due to lack of seasonal fluctuation in the hydrograph, it appears that the watertable is filling via lateral accumulation from other areas rather than direct vertical recharge.

4.2 Volcanic Rises/Plains LMUs

These LMUs comprise the central part of the Loddon uplands region, extending from Ballarat through to Campbelltown, including Bald Hills, Moolort and Smeaton. The landscape is typified by gently undulating rises with scattered, but prominent volcanic cones. Groundwater generally moves through the basalt over a distance of some tens of kilometres before emerging in deeply dissected creek lines or where basalt thins. In addition to these intermediate to regional flow systems, localised groundwater flow cells emerge as springs at the base of volcanic cones.

Recharge occurs across the entire landscape, but greatest recharge occurs on the volcanic cones and stony rises where soils are thinnest or more permeable. Localised groundwater mounds develop under prominent volcanic cones due to preferential recharge in these areas.

Groundwater hydrographs in these LMUs show a strong response to seasonal and annual rainfall patterns. Peaks and troughs are very distinctive, indicating that recharge occurs quickly, possibly due to the porous nature of the basalts. This causes dramatic differences in the winter/summer groundwater levels, which is evidenced in hydrographs of bores 283 and 5170 (Appendix 2). The effect of the 1994 drought is characterised by the absence of a peak in the graph and a deep water level trough in the following summer/autumn.

Also worth noting is the apparent underlying rising trend to 1994 observed in key bore 5170. It is likely that this underlying trend is in fact a reflection of the rainfall pattern over this period rather than having any linkage to land use status.

4.3 Alluvial and Riverine Plains LMUs (including the Loddon Deep Lead)

4.3.1 Surface Alluvials

These units comprise the broad alluvial valleys such as the Bet Bet Creek and the mid reaches of the Loddon Valley. The surface geology consists of alluvial clays and silts (of the Shepparton Formation) that often overlies the buried channel deposits of the Loddon Deep Lead and its tributaries.

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

Groundwater hydrographs in the surface alluvials appear to generally indicate steady conditions throughout the period of monitoring, with no indication of any underlying long term rise. The influence of the wetter years of 1983, 1988 and 1989 is usually indicated as elevated spring hydrograph peaks in these years.

Where monitored, the surface alluvial system appears to exhibit only sluggish groundwater movement. This is reflected in the hydrographs of bores 6517/18 that indicate poor seasonal fluctuation. The permeability of the surface alluvials is generally low with recharge possibly more likely to occur from a singular or large rainfall/run-off event.

4.3.2 Loddon Deep Lead

The legacy of the ancient Loddon River is the Loddon 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 upper to mid reaches of the Loddon Deep Lead are noted to be rising on average 7-10 cm/yr. The deep lead hydrograph (bore no. 73672) shows only a minor response to seasonal and annual rainfall, but exhibits a strong underlying rising trend. The deep leads are not exposed at the surface and tend to be recharged by relatively sluggish downward movement from overlying aquifers. Generally, the overlying aquifers have a lower hydraulic conductivity so that the deep lead acts as a semi-confined aquifer.

4.4 Southern Granites LMU (and associated Metamorphic Ridges)

The Southern Granites LMU consists of undulating, sometimes rocky hill country in moderate rainfall environments of Ravenswood-Maldon (Harcourt Granodiorite), Mount Beckworth and Lexton. Localised groundwater systems are mostly developed in the sandy weathered material (colluvium) overlying the hard, fresh granite. Some limited groundwater flow also occurs in interconnected fractures developed in the hard granite (Kevin, 1993).

A veneer of low permeability clay covers much of the Harcourt Granodiorite, so that the bulk of the groundwater movement occurs within the top metre or two. Seasonal waterlogging is common.

Adjacent Metamorphic Ridges are fractured rock aquifers, occurring on the contact zone between the granite and Ordovician slates and sandstones. High recharge occurs on the crests and upper slopes of the metamorphic ridges. Groundwater transmission in the granite and metamorphic system is generally in local to intermediate scale flow cells.

Hydrographs for bores on in the Harcourt Granite generally show a subdued response to climatic variation. This indicates that there are possibly barriers to the downwards percolation of rainwater, so that shallow perched watertables and waterlogging are prevalent which can lead to soil salinisation (Heislers, 1997). However, other parts of this system exhibit greater permeability, such as indicated by more responsive bores at Ravenswood.

From key bores 6558, 6537 and 6503 (Appendix 2) there does not appear to be any obvious underlying long-term groundwater trend. The impact of the 1994 drought is noticeable, though the decline in water levels due to this event is not large.

4.5 Northern Granites LMUs (and associated Metamorphic Ridges)

The Northern Granites and Metamorphic Ridges LMUs take in rolling granite hills and scattered steep metamorphic rocky peaks such as at McIntyre-Rheola, Mt Moliagul, and Black Range. Much of the groundwater flow in granite terrain is restricted to the weathered clays overlying the hard, fresh rock. Some groundwater is transmitted through interconnected fractures in the fresh rock (Kevin, 1993).

A feature of the Northern Granites is a veneer of ferruginized tertiary gravel capping that remains preserved on many crests. Perched watertables and local groundwater systems are likely developed in the gravel capping, though most significant groundwater flow also likely to occur in the saprolite above hard unweathered granite (Kevin, 1993).

Monitoring on the Humbug Hills near McIntyre indicate unequivocal long term rises in groundwater. Long term linear trends typically average 5-20 cm/yr with trends tapering since the mid 1990s (e.g. bore nos. 6336 and 6348 – Appendix 2). An alternative hydrograph response is that of step rise behaviour in response to particularly wet periods, such as experienced at Black Range (e.g. bore nos. 5124 and 5128 – Appendix 2).

Table 2 Summary of Loddon Uplands groundwater trends.

LODDON UPLANDS GROUNDWATER TRENDS	
MONITORED REGION	GROUNDWATER TREND SUMMARY
Sedimentary Hills/Rises LMUs	
Lexton	mostly fluctuates with rainfall
Creswick (Bald Hills)	mostly fluctuates with rainfall
Newstead	mostly fluctuates with rainfall
Castlemaine (Muckleford)	mostly fluctuates with rainfall
Volcanic Rises LMU	
Creswick (Smeaton - Bald Hills)	fluctuates with rainfall
Volcanic Plains LMU	
Moolort	fluctuates with rainfall
Alluvium & Riverine Plains LMUs	
Loddon Deep Lead	consistently rising levels
Southern Granites & Metamorphics LMUs	
Maldon (Nuggetty Hills - Shelbourne)	slight fall, minimal response to rainfall
Ravenswood - Lockwood	steady, minimal response to rainfall
Northern Granites & Metamorphics LMUs	
McIntyre - Rheola	consistently rising levels
Black Range	step rise

(adapted from Heislers, 1996)

5 IMPACT OF CLIMATE ON TRENDS

An important factor to consider in groundwater trend interpretation is climatic variation. Key rainfall stations in the uplands region are at Lexton, Dunolly, Castlemaine and Maryborough (see Appendix 3). These show that the average rainfall across the Loddon varies between in excess of 600 mm/yr in the south to 450 mm/yr in the north.

Since 1982, annual rainfall across the mid and northern Loddon Uplands is typically above what would be expected on average (e.g. Castlemaine – Appendix 3). The exception is far south where the annual rainfall is near average (e.g. Lexton – Appendix 3).

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 means taking into consideration not just the annual rainfall, but how it falls during the year. Widely spaced rainfall events (rather than back to back) appears to have been the recent pattern, clearly reducing the probability for recharge and run-off. Despite close to average annual rainfall totals, "effective rainfall" is below average.

A typical characteristic of the uplands groundwater systems is their high responsiveness to both seasonal (e.g. winter/spring rainfall) and annual rainfall variations (e.g. dry 1994). Although long term trends are generally not evident, it is clear that large seasonal slugs of recharge occur in the uplands that are likely to lead to accumulating groundwater in the lower landscape, or to increases in groundwater discharge rates from non-expanding discharge sites.

Alternatively, at McIntyre (bore no. 6336 – Appendix 2), short term seasonal fluctuations are clearly sitting on a long-term rising trend. The magnitude of the rising trend here suggests that land use is the key factor influencing the trend rather than above average cumulative rainfall over the monitoring period. In contrast at Nuggetty (bore no. 6503 – Appendix 2), it is possible to rationalise that slightly falling levels are due to lower effective rainfall since the mid 1990s rather than improvements in land management.

6 EVIDENCE FOR SALINITY TREATMENT IMPACTS

The purpose of this section is to identify areas in the Loddon uplands where:

(i) groundwater monitoring is in place in treated areas, and

(ii) the history of salinity treatment can be documented to assist the interpretation of these monitored treatments.

6.1 Laanecoorie case study: Alluvial Plains LMU

Location

Laanecoorie, on the intersection of the Bridgewater-Maldon and Bendigo-Maryborough Roads.

Landholder: Geoff Curnow

Description

Broad alluvial valleys with a surface geology consisting of alluvial clays and silts of the Shepparton Formation that overlies the permeable sands and gravels of the Loddon Deep Lead (Heislers, 1996). The average annual rainfall for this area is 452 mm/yr.

Environmental issue

High watertables have never been an issue on this property (water level is 7 metres from surface). However, the landholder was concerned that it may rise in the future, with the possibility of salinity outbreaks occurring on his property. During wet years, low-lying areas of the property do become waterlogged. This has not been a problem in recent years due to the low effective rainfall.

Treatment

Lucerne was sown in 1993 in the "corner paddock" where the Maryborough-Bendigo Road crosses the Bridgewater-Maldon Road. Along with the lucerne, two groundwater monitoring bores where installed in this paddock to monitor the treatment effectiveness. The landholder was concerned about run-off from the neighbouring lucerne paddock that is irrigated. Dryland lucerne was planted in the corner paddock in an attempt to "mop-up" any excess water that would run off onto this paddock. It was also the intention to help keep the watertable from rising and aid in preventing soils becoming waterlogged during wet years.

Figure 2 Corner paddock with wheat stubble (right) and lucerne in adjacent paddock (left).

Management

The lucerne was sown once, but has been harvested 3-4 times over the past 5 years and grazed when not being grown for harvest. The corner paddock was re-sown to canola in 1998 and wheat in 1999 (Figure 2). The landholder plans to sow lupins, canola and wheat in rotation for the next 5 years.

Monitoring network

Four pairs of groundwater monitoring bores (eight bores in total) were installed in 1993. One pair is located in the corner paddock (bores 6517/18 – Appendix 2). The other three pairs are located in the paddock behind the homestead. These bores were also installed to monitor the impact of the lucerne on the watertable (Heislers, 1996). Depth to the watertable varies between 7 to 13 metres below the surface. Groundwater in this area fluctuates in response to seasonal rainfall, however, seasonal fluctuations are only subtle.

Treatment effectiveness

Anecdotal evidence suggests that lucerne has had a positive effect in "mopping up" run-off from the neighbouring paddock. Since lucerne establishment, waterlogging has not been an issue. However, it is important to correlate groundwater information with the climate during the 1990s. It cannot be ignored that since the 1994 drought, with the exception of spring 1996, effective rainfall has been low. The dry weather conditions have almost certainly been a contributing factor in the reduction of waterlogging.

6.2 McINTYRE CASE STUDY: NORTHERN GRANITES LMU

Location

McIntyre, Humbug Hills

Landholder: Merv Mason

Description

The underlying geology consists of granite and granodiorite, with a ferruginized Tertiary gravel capping remaining preserved on many crests, protecting up to 20 metres of underlying weathered rock (Kevin, 1993). The average annual rainfall for the area at nearby Rheola is 449 mm/yr.

Environmental issues

Salinity discharge occurs at and below the break of slope on the northern side of Llanely-Rheola Lane (Figure 3). Salinity also occurs on the southern side of the Llanelly-Rheola Lane on the river flats. Disturbance of the gravel capping (on the Humbug Hills) during the mining era may contribute to enhanced infiltration in this landscape, in addition to agricultural land management practices.

Figure 3 Severe salinity at and below the break of slope at McIntyre

Treatment

Up-slope from Llanelly-Rheola Lane, a farm forestry site was established (Figure 4). The first planting was in 1996 (seen here as the second tallest trees in the figure), and more recently in 1998 (smaller trees in the foreground). The 1998 planting consists of three species of Eucalyptus trees, 1100 in total, which were planted on the crest of the slope. The trees were planted on the southern side of the crest because of prevailing weather from the south-west. The trees were planted over 1.3 acres and include *Eucalyptus cladocalyx* (Sugar Gum), *Eucalyptus tricarpa* (Red Iron Box) and *Eucalyptus lecoxylon* (Yellow Gum). A single groundwater monitoring bore is located mid-slope, below the agroforestry site. This was in place before the trees where planted, originally to monitor the impact of an established phalaris pasture.

Figure 4 Farm forestry site (the trees in the foreground) at McIntyre .

Lucerne and Tall Wheat Grass were planted in the paddock south of Rheola Lane in the spring of 1999 as the salinity located in the lower lying section of the paddock was growing and of concern to the landholder. The lucerne and Tall Wheat Grass were planted for recharge control to hopefully reduce the spreading salt scald, in addition to producing fodder for stock (Figure 5).

Figure 5 Tall Wheat Grass and lucerne planted on the river flats at McIntyre.

Management

Phalaris and Cocksfoot (*Dactylis glomerata*) in the paddock surrounding the farm forestry site is grazed heavily. An incentive here would be to rest the paddock to see whether controlled management of Phalaris has any effect in reducing the amount of recharge. This is expected to be reflected in the hydrographs.

Monitoring network

Two additional groundwater monitoring bores were installed on the slope either side of Humbug Hills in 1998. One of these, as discussed above, is located in a phalaris based pasture, and down-slope from a tree belt.

Treatment effectiveness

It is too early to detect if the lucerne or farm forestry has had any effect. An important factor effecting water level in this area is climatic variation. The low effective rainfall from the mid 1990s has no doubt had an effect on water levels in the district.

6.3 Newbridge case study: Cropped Sedimentary Rises LMU

Location

Newbridge

Landholder: Peter Stone

Description

This district is typified by gently sloping cropped sedimentary rises. Underlying geology consists of hard fractured sedimentary rock (Ordovician slate, shales and sandstones). The soils are of shallow, stony gradational type. A thin apron of alluvial clays and silts of the Shepparton Formation overlaps the flanks of Sedimentary Rises. The average annual rainfall for the Newbridge district is 452 mm/yr.

Environmental issue

A salt scald is located in the roadside reserve beside the paddock (Figure 6). The salt scald has increased in size slightly over the past 10 years. It has not been as severe in the past three to four years due to low effective rainfall and a consequent drop in the watertable. Waterlogging is a major problem in sedimentary soils like these due to the shallow topsoil and thick underlying clay layer. Off interest is the observation that cereal crops perform better in a dry winter than a wet winter, with the best results occurring with rain in the autumn and spring (Stone[1], pers comm.).

Figure 6 Salinity on roadside reserve at Marong West.

Treatment

Twenty hectares of lucerne was planted in 1989 to combat the effect of increasing watertables and waterlogged soil. The lucerne was sown in the paddock up-slope to the salt discharge. The lucerne density is three to four stands per square metre (Figure 7).

Figure 7 Lucerne planted in 1989 at Marong West.

Management

The paddock is rotationally grazed. It is stocked for three weeks at a time during summer (or drier months) and one week during winter/spring. The paddock is then rested for 6 to 12 weeks. Another 36 hectares sown to lucerne in 1998.

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[1] P.Stone (land owner, Marong West), 31/3/2000.

Monitoring network

There are seven groundwater monitoring bores located between Newbridge and Marong for monitoring groundwater conditions on the flanks of the Cropped Sedimentary Rises. There is nine years of complete record available for three of these bores, there is little to no data available from the remainder. Of the piezometers with a complete record, key bore 6555 (Appendix 2) is included in this report.

Treatment effectiveness

Anecdotally, there has been no visible change in the landscape apart from a slightly increasing small salt scald occurring in the roadside reserve (Figure 6). However, due to the low effective rainfall of the late 1990s, the watertable has dropped enough for some plants to become established within the salt scald. The groundwater level in the bores fluctuates according to the seasonal and annual variation in rainfall. However, there has been more than a one metre drop in waterlevels (e.g. bore no. 6555) in the late 1990s. This is hoped to be a combined result of low effective rainfall in addition to the lucerne treatment. It is not easily possible to resolve the two impacts.

6.4 Black Range case study: Northern Granites & Metamorphic Ridges LMU

Location

Dunluce, on the Bealiba South Road.

Landholder: Alex and June Wiseman

Description

Consists of rocky, low rolling hills of Devonian granite and contact metamorphosed Ordovician slates and sandstones. Saline discharge, occurs at the break of slope, with recharge on the metamorphic ridges contributing to saline discharge in flat low-lying areas of the catchment (Figure 8).

Environmental issue

Salinity occurs in numerous spots around the property, including along drainage lines and gullies as well as at the break of slope. The salinity in Figure 8 is located in a major drainage line, which discharges into a creek at the bottom end of the property. It has been evident for 15 years or more and appears to be most prominent after a drought or period of low rainfall. The landholder believes the problem to be recharge from the surrounding metamorphic ridges.

Figure 8 Saline discharge in the main drainage line on the property.

Treatment

There have been numerous salinity remediation treatments carried out on this property over the past 20 years. In the late 1970s, a plot of lucerne was trialed with four different species of lucerne planted. This, however, did not survive the 1982 drought. In 1986, as part of Operation Branch Out, the hills and crests of the Black Range were re-vegetated with native trees (Figure 9). Although there were many trees lost, a large number have still managed to survive.

Figure 9 Planting on hill slopes as a salinity treatment showing a lower-slope planting of 1000 native trees.

Figure 9 shows a line of trees at lower-slope. These 1000 native trees were planted in 1997. The species planted were, Blue Gum, Red Gum and Native Pine. The creeks and gullies have also been planted with trees to help alleviate gully erosion that occurs after a heavy rainfall event (Figure 10). This stream appears to be of high energy, as there is a large amount of sediment shift. Trees lining the gully have been planted to help reduce the problem.

Figure 10 Trees planted along a high-energy stream on the property.

Tall Wheat Grass has been sown in the flats below the break of slope (Figure 11). The Tall Wheat Grass was planted in 1996 and is used as fodder for sheep. Figure 11 shows the succession of treatments that has occurred on this property. The hill crests planted in 1985, the row of native trees planted in 1997 (lower-slope) and Tall Wheat Grass on the flats in 1996.

Figure 11 Tall Wheat Grass planted on the flats at the base of the range.

Management

The land holder believes best result with the tall wheat grass actively "mopping up" excess groundwater occurs when it is well established. The landholder does not allow stock to feed on in for the first two years of its life to enable it to establish itself.

Monitoring network

There are ten groundwater monitoring bores located in the Black Range/Dunluce area, near the boundary of the granite and the metamorphic ridge (that comprises the Black Range). The groundwater record is 10 to 14 years in length. The key bores represented here are 5128 and 5124 (Appendix 2). Six bores are located across the hill above the salt scald and one deep bore located within the saline patch.

Treatment effectiveness

The Tall Wheat Grass appears to have helped alleviate the saline discharge. The landholder believes it helps the landscape as it covers the salinity and reduces the salt from spreading and if this work had not been carried out, it is likely that the saline scald would have increased in size at a much faster rate. The gullies and creeks which have been tree lined show some positive results, with the treatment slowing the erosion.

The bores located in the treated site and saline site show a fall in the water level since spring 1996. However the late 1990s were very dry years and would be the crucial factor contributing to low watertable levels.

7 LIMITATIONS IN THE CURRENT MONITORING PROGRAM

The afore mentioned groundwater trend summary is strongly biased by both the relative youth and distribution of the groundwater monitoring program. For instance, in the Loddon uplands, there are currently 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. The exception is the limited monitoring of perennial pastures and tree belts as outlined in Section 6. Even with these, treatment aspirations have changed significantly over time. A concerted effort is necessary to rectify this, as measurement of salinity plan effectiveness is a prime objective. Nevertheless, 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 Loddon Dryland Groundwater Monitoring Program is the lack of monitoring of specific salinity treatments. In addition to this lack of effectiveness monitoring, an analysis of the distribution of groundwater monitoring in relation to the priority status of Loddon Dryland sub-catchments (see Table 3) suggests that there are a number of areas where additional background monitoring of groundwater should be considered.

Only through catchment-wide recharge control strategies will areas of saline discharge reduce significantly and water quality improve. However, in the Loddon uplands 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.

8 RECOMMENDATIONS TO THE MONITORING PROGRAM

Investigations to date have provided a good understanding of groundwater and salinity processes in the Loddon catchment. It is important that the groundwater monitoring continues to provide high quality data for the interpretation of groundwater levels across a range of landscapes, and to gauge the success of salinity control options (Heislers, 1996).

Even though there is a strong network of bores established in the Loddon uplands additional " strategic" groundwater monitoring should continue to be implemented where monitoring is lacking.

A positive step for the Loddon uplands community would be to look at developing a high profile effectiveness monitoring program. An example of this approach is one adopted recently at Big Hill. This case study is discussed in Section 8.1. Other high priority sub-catchments for additional groundwater monitoring and salinity treatment are Bet Bet Creek (including Lexton), Middle/Joyce's Creek, Bulabul Creek or the Mid-Loddon (see Table 3).

Such a program could involve demonstration of a treated high exposure saline area. It could involve community, Landcare members and landholders with the support of a CLPR hydrogeologist, CAS pasture agronomists and Flora and Fauna officers (native vegetation).

The purpose of such a project would be to:

(i) engage a whole community approach to salinity control,

(ii) test currently used controls, and

(iii) investigate the development of different salinity control options.

The effectiveness of the treatments could be assessed over a number of years and hopefully help landholders, community and NRE staff to develop an even stronger understanding of salinity and groundwater regimes in the Loddon Uplands region.

Table 3 Priorities for additional sub-catchment groundwater monitoring.

PRIORITIES FOR ADDITIONAL SUB-CATCHMENT GROUNDWATER MONITORING				
SUB-CATCHMENT and dominant LMUs	**PRIORITY IN PLAN**	**GROUNDWATER MONITORING COVERAGE**	**COMMENT/ REQUIREMENTS**	**PRIORITY FOR ADDITIONAL MONITORING.**
BET BET CREEK Sedimentary Rises/Hills Volcanic Plains	HIGH	Concentrated NRE coverage at Lexton, Timor West and Black Range	Additional monitoring needed in Sedimentary Rises LMU, particularly Dunolly area	MEDIUM
TULLAROOP CREEK various	MEDIUM	Concentrated NRE monitoring at Bald Hills, Moolort and Nuggetty Hills	Additional monitoring needed in Sedimentary Rises LMU in vacinity of Talbot and Maryborough	MEDIUM
MIDDLE/JOYCES CREEK Sedimentary Hills Volcanic Rises	HIGH	NRE monitoring networks at Smeaton and Moolort	Additional monitoring recommended in Glengower-Campbelltown area	MEDIUM
UPPER LODDON Sedimentary Hills	LOW	Concentrated NRE monitoring in Castlemaine and Newstead areas	Probably sufficient monitoring. Perhaps some additional scattered background monitoring required.	LOW
MID-LODDON various	HIGH	NRE monitoring concentrated at Ravenswood, Lockwood and Maldon	Some additional monitoring on Basalt Plains required	MEDIUM
BULLABUL CREEK Northern Granites, Metamorphic and Sedimentary Rises	MEDIUM	NRE monitoring concentrated at McIntyre and Moliagul	Additional monitoring across Northern Granites LMU	HIGH

(adapted from Heislers, 1996)

8.1 Effectiveness monitoring at the Big Hill revegetation site

The Big Hill revegetation site is 670 hectares in size on the southern side of the Big Hill metamorphic aureole, Ravenswood. The Mid Loddon Sub-Catchment Management Group (MLSCMG) put in a successful bid for funding to complete a 3 year project titled 'Revitalising the Mid Loddon Sub-Catchment by reducing salinity and restoring bio-diversity'. The MLSCMG is made up of four Landcare groups; Upper Spring Creek Landcare Group Inc., Ravenswood Valley Landcare Group Inc., Nuggetty Landcare Group Inc., and West Marong Landcare Group Inc.

An important aim of the project is to limit rising watertables by planting deep-rooted perennial pasture/crops and local native species in recharge areas. There has been a substantial amount of money allocated for the installation of 15 groundwater monitoring bores for the Mid Loddon Sub-Catchment. A number of these bores are for monitoring the recharge control effectiveness of the revegetation at Big Hill.Saline discharge in this area was first mapped in the early 1990s by NRE staff.

Saline discharge at Big Hill was subsequently re-mapped in late 1999. Installation of new bores will compliment the discharge mapping with information that will help further develop the understanding of the groundwater and salinity processes occurring at Big Hill.

9 REFERENCES

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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 (eg. in an upland area) several hundreds of kilometres from where it discharges (eg. 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 LODDON UPLANDS SALINITY REGION

BORE		AREA	L.M.U.	POSITION	RECORD	DEPTH OF BORE	DEPTH TO WATER (below groundsurface)	TREND
No.	Man.		(or aquifer type)	in landscape		(m)	(m)	summary
253	NRE	Lexton	Sedimentary Hills	upperslope	mostly complete since '88	53	18.0	overall steady
5157	NRE	Lexton	Sedimentary Hills	not available	incomplete since '88	17.3	6.0	inconclusive
5161	NRE	Lexton	Sedimentary Hills	midslope	complete since '88	19.2	9.0	varies with rainfall
5164	NRE	Lexton	Sedimentary Hills	not available	mostly complete since '88	20	15.0	rising
6493	NRE	Castlemaine	Sedimentary Hills	valley base	complete since '89	6	2.0	varies with rainfall
6496	NRE	Castlemaine	Sedimentary Hills	midslope	complete since '89	20	12.0	varies with rainfall
6555	NRE	Newbridge	Sedimentary Rises	mid-lowerslope	complete since '91	21.5	4.0	inconclusive
5170	NRE	Bald Hills	Volcanic Rises	lowerslope	complete since '89	10.7	3.0	varies with rainfall
307	NRE	Long Swamp	Volcanic Plains	lowerslope	complete since '93	24	-2.5	varies with rainfall
6503	NRE	Nuggetty Hills	Southern Granites	midslope	incomplete since '91	21	5.0	inconclusive
6558	NRE	Shelbourne	Southern Granites	not available	complete since '90	21	4.5	inconclusive
6537	NRE	Ravenswood	Southern Granites	midslope	mostly complete since '92	15	4.2	inconclusive
6336	NRE	McIntyre	Northern Granites	mid-upperslope	complete since '84	11	7.0	overall rising
6348	NRE	Mt. Moliagul	Northern Granites & Metamorphic	lowerslope	complete since '83	8.1	3.0	overall steady
5124	NRE	Black Range	Northern Granites & Metamorphic	not available	complete since '85	6	4.0	inconclusive
5128	NRE	Black Range	Northern Granites & Metamorphic	not available	mostly complete since '80	2.33	1.0	inconclusive
151	NRE	Timor West	Riverine Alluvium	plain	incomplete since '82	72	3.5	inconclusive
6518(17)	NRE	Laanecoorie	Riverine Alluvium	plain	complete since '93	6	8.0	appears steady
283	NRE	Stewarts Ck.	Sedimentary Hills	midslope	complete since '97	27	4.5	insufficient data
6323	NRE	Sandon	Sedimentary Hills	midslope	complete since '94	15	2.5	varies with rainfall
6358	NRE	Newstead	Sedimentary Hills	midslope	complete since '94	23	6.0	varies with rainfall
6524	NRE	Muckleford	Sedimentary Hills	lowerslope	complete since '95	8.5	4.0	varies with rainfall
6369	NRE	Muckleford	Sedimentary Hills	midslope	complete since '94	19	7.0	varies with rainfall
281	NRE	Muckleford	Sedimentary Hills	mid-upperslope	complete since '94	0	8.7	varies with rainfall
36	NRE	Bet Bet Valley	Alluvial Plain	plain	mostly complete since '85	90	3.2	step up in '88-'89
5417	NRE	Timor West	Alluvial Plain	plain	mostly complete since '80	4.9	4.5	overall little change
92124	SKM	Newstead	Deep Lead aquifer	not available	complete since '79	57	2.8	gradual slight rise
73672	SKM	Laanecoorie	Deep Lead aquifer	plain	complete since '84	94	27.8	gradual linear rise