Managing on-farm and regional water and salt balances in Mona Park

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Cover Photograph:

File: PDE00684_028.jpg
Description: Furrow irrigation of newly planted sugar cane crop near Clare, QLD.
Photographer: Willem van Aken
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1 Acknowledgements

The authors would like to acknowledge the assistance provided by Graham Dumaresq from SunWater for providing information on the development history of Mona Park. Gary Jensen, Ian Duncan and Ray McGowan from NRMW, Garry Ham from BSES, Kumar Narayan from CSIRO, Tom McShane from BBIFMAC and Carl List are acknowledged for their ideas and help in conceptualising the Mona Park groundwater system. The co-operation and assistance provided by Mauro Garbuio and Malcolm Kelly is greatly appreciated. David Reid and Conservation Volunteers Australia have provided assistance monitoring the shallow groundwater bores. Tom McShane and CSIRO technical staff, Phil Whiddon, David Fanning, Joseph Kemei, Jamie Vleeshouwer, Aaron Hawdon and Rex Keen are thanked for their help setting up the field site.

This work was supported in part by the Queensland Department of Natural Resources Mines and Water (NRMW), CSIRO Land and Water and CRC IF.
2 Executive Summary

Since the establishment of the Burdekin Haughton Water Supply Scheme in 1987, some observation bores in the Mona Park district have experienced rapidly rising groundwater levels and rising salt concentrations. A field and desktop study was conducted to build understanding of the processes driving these trends.

It was anticipated that diffuse deep drainage and channel leakage were the dominant processes driving the rise in water tables.

A field site within the north-west portion of Mona Park with representative soils was established to measure diffuse deep drainage. Data on water usage were not available for this study. Hence it was not possible to predict the spatial distribution of deep drainage.

Field investigation into channel leakage was also not possible during this study. Anecdotal information suggests that channel leakage is occurring in the Burdekin Haughton Water Supply Scheme but the relative contribution of drainage arising from leaking channels as compared with diffuse deep drainage could not be quantified.

Anecdotal information about the Burdekin Haughton Water Supply Scheme and its historical development has been documented. Groundwater trends in Mona Park and surrounding regions have been interpreted within the context of the development history of the region.

A rapid and large response of the groundwater levels in some parts of Mona Park in early 2000 is attributed to the groundwater system changing behaviour from an unconfined aquifer to that of a semi-confined aquifer.

Following this event, announced groundwater allocations were increased to allow landholders to pump an unlimited quantity of groundwater. Since peaking in 2000, groundwater levels have declined somewhat in the Mona Park area. This is partly a function of the change in groundwater pumping allocations and partly a function of lower than average rainfall over the last few years. However, groundwater levels elsewhere in the Burdekin Haughton Water Supply Scheme have not declined as much and remain relatively stable.

It is unlikely that groundwater levels in Mona Park and the Burdekin Haughton Water Supply Scheme will be prevented from rising again during future wet periods with above average rainfall. This is because few farmers are able to substantially increase the quantity of groundwater they pump because of quantity and quality constraints.

Many farmers in the Mona Park district experience difficulty transmitting water to the end of their gravity fed furrow irrigated paddocks. This anecdotal information, together with preliminary lysimeter measurements suggest that diffuse deep drainage is a large component of the water balance. Mechanisms to encourage a reduction in furrow length and implementation of more efficient irrigation methods (including overhead and trickle delivery systems) still need to be investigated.

The use of engineering solutions to manage groundwater levels in Mona Park and the Burdekin Haughton Water Supply Scheme will also require the disposal of saline groundwater. It is likely that the quantity and quality of groundwater that would be required to be extracted precludes all of it being utilised for on-farm purposes. Groundwater pumping should continue but allocations be adjusted to meet specific management objectives.

Data quality and availability constrained investigations and prevented development of a fully calibrated groundwater flow model as part of this study. The process of developing and applying a calibrated groundwater model would provide considerable additional understanding of the Mona Park groundwater system and options for improved management of water delivery systems and irrigation practice. A geochemical analysis should also form part of future work in this area. This would help improve understanding of the processes by
which salts are accumulating in the groundwater and help identify the pathways by which they move.

Investigations into appropriate support and incentive mechanisms to facilitate sustainable and profitable farming enterprises did not proceed as part of this study as there was no suitable calibrated groundwater flow model which could be used to run various scenarios.

Specific recommendations arising from this study include:

- Conduct a geochemical investigation to identify source of salts and their pathways of movement.
- Continue deep drainage measurements using the lysimeter to gain further understanding of the root zone water balance.
- Investigate the benefits of reduced furrow lengths and more efficient delivery systems.
- Investigate channel leakage.
- Investigate rising groundwater levels in the Mulgrave region.
- Investigate options for disposal of saline groundwater.
- Resolve issues associated with accessing data.
- Re-visit the Digital Elevation Model for the Lower Burdekin.
- Instrument representative bores in the Burdekin Haughton Water Supply Scheme with data loggers to capture data at a finer resolution than that currently available through the NRMW database.
- Capture data from shallow observation bores installed as part of this study in the NRMW groundwater database.
3 Project Background and Objectives

Rising water tables and increasing groundwater salinity in the Mona Park area of the Burdekin Haughton Water Supply Scheme are causing concerns about the longer term viability of irrigation farming in this region. There is therefore urgent need to understand the issues involved, and to implement management strategies that will reverse these trends and so ensure a longer term sustainable future for individual farms and the region as a whole. This is likely to require a range of strategies, including on-farm water management, groundwater pumping and disposal of poor quality water (in the short term at least), and development of more effective conjunctive water use strategies.

Project objectives were to:
1. Ascertained the causes of rising water tables and salinity levels in the Mona Park area (deep drainage from irrigation, channel leakage, lateral groundwater flow).
2. Identify management strategies that meet required water table and salinity targets, and that lead to sustainable water and irrigation management practices (in collaboration with NRMW Staff)
3. Investigate appropriate incentive and support mechanisms that allow transition from the current deteriorating situation to one that is more sustainable and that supports profitable farming enterprises (NRMW to undertake this work as part of a suite of CRC IF activities)
4 Introduction

This final report for the Mona Park project documents the work performed with respect to the agreed Project deliverables and makes recommendations for future work in Mona Park and the Burdekin Haughton Water Supply Scheme (BHWSS).

Key information from the 2 proceeding milestone reports (i.e. Petheram et al. 2004a and Petheram et al. 2004b) has been captured in this report, enabling it to be read as a stand alone document. However, for more detailed information on earlier aspects of this study the reader is referred to the earlier milestone reports.

In the next section a description of the bio-physical features and historical development of the region is presented to provide context. This is followed by a brief description of the field work that was carried out to further understanding and support the modelling efforts. The historical groundwater trends observed in the Mona Park region are then related to historical developments in the BHWSS, field observations and anecdotal information recorded during the course of the investigation. This section provides the bulk of the discussion and analysis. Next, an attempt to build a numerical groundwater model of the Mona Park region is presented. This section details the conceptual model, the physical model structure and data deficiency issues encountered. Conclusions and recommendations for future work are presented at the end of the report. Media communications associated with this study are summarised in Appendix 1.

Reference to the Burdekin Haughton Water Supply Scheme is to that area west of the Burdekin River as illustrated in Figure 1. Prior to 2000 the region was referred to as the Burdekin River Irrigation Area.

The groundwater elevations for some observation bores in the NRMW groundwater data base are recorded using the Australian Height Datum (AHD) while others use the State Datum (STD). In the Lower Burdekin the difference between the two datum is negligible. Hence groundwater elevations in observation bores using the STD may be directly compared to those using the AHD.
**Regional description**

The biophysical aspects of the Lower Burdekin (Figure 1) are well documented (e.g. Arunakumaren et al. 2000, Lawrie et al. 2004) in existing literature and hence, an overview only is provided for context, and key references are listed for further reading. The land-use and developmental history of the BHWSS is reported in greater detail as this information is not documented in the existing literature in an easily digestible form and the information is central to interpreting groundwater trends and developing a numerical model of the region.

![Figure 1](image_url)  
*Figure 1* The lower Burdekin. Mona Park is outlined in red (BHWSS = Burdekin Haughton Water Supply Scheme)*
4.1.1 Climate

The average annual rainfall and evaporation in the Burdekin Delta is about 1000 mm/yr and 2080 mm/yr, respectively. However, rainfall is highly variable with annual totals ranging from 250 mm/yr to 2000 mm/yr. The implications of this are that as in many areas of Australia the concept of an average annual water balance is misleading. In addition to having a highly variable inter-annual rainfall, the Burdekin also exhibits a strongly seasonal trend, with two thirds falling between January and March (Figure 2), highlighting the need for models with small time steps that can account for the temporal variability.

**Figure 2** Average monthly rainfall (black) and average monthly evaporation (grey) recorded at Ayr DPI station.

**Figure 3** Annual rainfall at Claredale between 1901 and 2004.
4.1.2 Topography
Mona Park is situated on the Lower Burdekin flood plain. The surface elevation ranges from 18 m at the northern boundary to 26 m on the bank of the Burdekin River. To the north-east Mona Park is bounded by Mount Kelly (80 m AHD) and to the east by the deeply incised Burdekin River (Figure 4).

Figure 4 Images of the Lower Burdekin. The central figure shows a three dimensional representation of the Lower Burdekin, looking south. This figure has a 10 times vertical exaggeration. Mona Park is shown in red. Photos clockwise from top left are: Clare Weir, pumping station, Burdekin Falls Dam, Gladys Lagoon, Burdekin River, furrow irrigated Sugar Cane.
4.1.3 Geology

The geology and hydrogeology of the Lower Burdekin are well documented, though most studies have focused on the Delta (e.g. O’Shea 1967, McMahon et al. 2000, Arunakumaren et al. 2000, Lawrie et al 2004). Across the Lower Burdekin there is limited lateral continuity of any single sedimentary layer. A complex layering of sand and clay units exist, making it difficult to develop multi-aquifer conceptual models at a broad scale. Consequently many of the groundwater models developed for the Lower Burdekin conceptualise the system as a single-layer (i.e. unconfined where the minor variations are incorporated into single hydrostratigraphic units). Underlying the sedimentary layer is a basement of igneous origin and there is considered to be negligible flow of groundwater between the bedrock basement and the sediments.

While the upper alluvial deposits in the Delta have very little to no clay content, the BHWSS has an upper clay layer thickness of between 2.5 and 20 metres, and is typically in excess of 6 meters. Hence the assumption that the groundwater system in the BHWSS behaves as a single, unconfined unit (as per the Delta) is more tenuous. It is likely that the upper (semi-confining) clay layer in the BHWSS resulted from the deposition of clays and fine silts during overbank flow and will serve as an impediment to the vertical infiltration of water. Because of the spatial variation of the resulting soil types in the BHWSS there will be an inherent spatial variability in deep drainage.

Anecdotal information suggests that prior to European settlement, Mona Park was a swamp (Ray McGowan pers. comm. 2005).

4.1.4 Hydrology

Even though many groundwater modelling studies treat the groundwater systems in the Lower Burdekin (particularly the Delta) as unconfined, in the BHWSS the heavier upper soil layers suggest that the groundwater system could be semi-confined in places. Unless specific reference is made to confining behaviour, terms related to unconfined aquifers will be used (e.g. watertable rather than potentiometric head, specific yield rather than storativity) even though there may be ambiguity as to the behaviour of the system.

The gradient of the watertable in the BHWSS indicates a northward flow of groundwater towards the coast (Figure 5). With the introduction of surface water in 1987 groundwater levels across the BHWSS rose dramatically (see Section 6). While the groundwater flow direction remained northward (Figure 5) some areas appeared to experience greater rises in water level than others. One such area was Mona Park. This variability in water level rise is likely to be a function of many different factors, including differing development history, and differences in soil types, vegetation, irrigation efficiencies, channel leakages and aquifer heterogeneity.

Within the BHWSS there exists a good network of deep groundwater observation bores which are monitored on a bi-monthly basis by NRMW. Groundwater pumping in the BHWSS is limited to the Mona Park, old Clare, Jardine (regions are shown in Figure 6), and a small number of bores located in Northcote and Mulgrave (Figure 5). Away from the Burdekin River the density of groundwater pumping/production bores is lower, inferring lower transmissivity rates. Groundwater hydrographs from observation bores near the Burdekin River provide evidence that in some areas there is a direct connection between the groundwater system and the Burdekin River (see Section 6).

The surface water hydrology of the Mona Park region is such that surface water drains from east to west, where overbank floodwater from the Burdekin River flows into the Barratta Creek system. Events of this magnitude occur with an Average Return Interval (ARI) greater than 40 years.
Figure 5  Groundwater contour map of the BHWSS February 2005. Blue is high (i.e. 30 m, Gladys Lagoon) and red is low (i.e. 7 m). The white circles are groundwater pumping/production bores and the grey arrows indicate the direction of groundwater flow. The Mona Park boundary is illustrated by the blue polygon; the edge of the grey shaded area is the approximate location of the Burdekin River.
4.1.5 Land-use history

Important to improving our understanding and development of any groundwater model is an accurate description of the development history of the region. This is essential for developing an understanding of the factors contributing to historical trends and central to the establishment of initial conditions for a groundwater model.

Development of the Burdekin Delta

The Lower Burdekin was first settled in 1861 and the first sugar cane was grown in the Delta in 1879 (SKM 1993). Irrigation first commenced in 1885 when surface water from lagoons on the Pioneer Estate was used to irrigate cane. When the amount of cane grown on Pioneer Estate became limited by surface water supplies, the spear system for extracting groundwater was introduced to the Lower Burdekin by John Drysdale in 1887 (Credlin 1979). By the mid 1890's over 2000 ha of the delta was being irrigated using both surface and groundwater. In 1965/66 the North and South Burdekin water boards commenced pumping water from the Burdekin River (SKM 1996) and today the amount of land under irrigation in the Delta stands at over 35 000 ha.

Development of the left bank of the BHWSS

Irrigated agriculture didn’t arrive in the BHWSS until midway through the twentieth century. In July 1949 the first 10 of 40 irrigated tobacco farms opened at Clare under the solider resettlement scheme (i.e. Old Clare Figure 6). Prior to development of these farms the BHWSS had only been used for extensive grazing. The tobacco farms were irrigated using river water which was supplied by a network of channels and two river pumping stations (Credlin 1979). It has been hypothesised that these old supply channels may have lost a considerable quantity of water through leakage (Lukacs pers. comm. 2004). In 1964, with the collapse of tobacco farming in the area these farms converted to sugar cane. The area under irrigation in the BHWSS at this time was 2319 ha (QWR 1980).

In 1965 irrigated agriculture commenced in Mona Park (Figure 5) following subdivision of the land which was part of the Haughton Sugar Mill. Rather than pumping river water, irrigation water was sourced from groundwater, where each 26.3 ha Lot was allocated 95 ML (i.e. 3.6 ML/ha). Mona Park was the first area to extract ‘substantial’ quantities of groundwater for agriculture in the BHWSS. At the time other users of groundwater in the BHWSS were limited to the Burdekin Agricultural College (which started using limited amounts of groundwater in the 1970s) and a small number of users in the settlements of Jardine (0.25 ML/ha allocation), Northcote (0.25 ML/ha allocation) and Clare (very limited development). Today Mona Park still has the greatest density of production bores in the BHWSS.
By 1970 the area under irrigation in the BHWSS had grown to 5365 ha (Figure 7) and by 1978 it was 5789 ha (annual volumes of water diverted from the Burdekin River to the BHWSS increased to 47 048 ML and 58 383 ML in 1970 and 1978, respectively).

In 1979 the Clare Weir (8000 ML) was completed (storage commenced in 1978). In 1985 flap gates were installed which increased the capacity of the weir to approximately 15 500 ML. The Clare Weir was to provide a pumping pool for irrigation water for the proposed Burdekin Haughton Water Supply Scheme (BHWSS).

The BHWSS was realised in 1987 with the completion of the Burdekin Falls dam and the Haughton and Barratta main channels. These two channels supply water to customers between the Burdekin and Haughton rivers and the former supplements the Haughton River and Giru groundwater areas. Farms in the Jardine and Northcote regions did not receive

**Figure 6** Regions of the BHWSS. 1. Jardine and Northcote, 2 Northcote, 3 original Mona Park, 4 Mona Park –river water only, 5, Mona Park - surface water only (also know as New Clare), 6 Burdekin agricultural college, 7, Old Clare, 8 Mulgrave. Mona Park as it is known today is shown in red. Development histories of these regions are summarised in Table 1.
water from the BHWSS for several years after Mona Park was connected (about 1988). Anecdotal information suggests that farmers in Mona Park used in excess of their surface water allocations for the first few years until the Jardine and Northcote regions were connected by supply channels (Garry Ham pers. comm. 2005). In 1988/89 control of groundwater in the BHWSS reverted from SunWater to NRMW.

At the time of development it was estimated that across the scheme 12.5% of water applied for irrigation would return to the groundwater system. Hence, in an attempt to pre-empt any potential rise in the watertable, a conjunctive use policy was introduced in 1989 where most farmers were required to extract 1 part groundwater for every 8 parts of surface water applied, referred to as a nominal allocation. However, in practise, only about half the irrigated farms in the BHWSS are able to exploit commercial quantities of groundwater. Northcote and Jardine were given nominal allocations based upon estimates of the sustainable yield of the system. Nominal allocations for Clare were arbitrary. Table 1 illustrates how surface water – groundwater nominal allocations vary from region to region and have changed over time. The department of NRM&E adaptively managed the groundwater levels in the BHWSS through announced allocations, allowing farmers to pump a percentage greater or less than their nominal allocation. Announced allocations are a function of usage and groundwater and surface trends, and vary on a monthly basis and between districts. There is little documentation on how announced allocations have varied in time and space.

In the Mona Park district, which was a groundwater district prior to the BHWSS, nominal allocations vary between farmers. This is because some farmers (i.e. 6 lots) did not take up the initial offer of surface water supply, while some others only asked to be supplied in part. Because of water quality constraints, a number of these farmers have since requested full allocations of surface water but have been refused by SunWater on the grounds of lack of supply channel capacity.

During the 2000 wet season in an attempt to address the issue of rising watertables unlimited groundwater use allocations were announced. However, in reality only a limited number of farmers were able to capitalise on the increase in groundwater allocation (Ray McGowan pers. comm. 2005) because of groundwater system limitations (i.e. quantity and quality) and in some circumstances because production bore infrastructure was no longer in place. In 2004 ‘Water Permits’ were introduced on a trial basis, whereby if a farmer exceeded their allocation they could go into the department and get given a permit.

Today roughly 80% of the BHWSS is covered by sugarcane and it is estimated that 25% of the cultivated land will be fallow at any one time. Figure 7 illustrates the spatial development of the BHWSS between 1972 and 2004.
Figure 7  Satellite imagery of the BHWSS illustrating the spatial extent of development in 1972 (top) through to 2004 (bottom). Yellow outline illustrates Mona Park boundary. Dark green areas illustrate irrigated land. Source: Satellite imagery from the Australian Greenhouse Office.
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Table 1: History of allocations and key developments in the BHWSS. This table was generated from anecdotal information. GW and SW stand for groundwater and surface water respectively. Note in the Mona Park region some farmers do not receive the full allocation because they did not nominate to receive the full 8 ML at the time the scheme was being constructed.
5 Field work

Based upon experiences elsewhere in Australia it was anticipated that deep drainage beneath irrigated cane fields was a key factor contributing to rising groundwater levels in Mona Park. A limited field work program was carried out as part of this study to infer recharge at a range of scales. This section provides a brief description of the methods used.

5.1 Deep drainage estimation

Four different methods were used to estimate deep drainage at several different scales, where deep drainage is defined as the quantity of water passing below the root zone and is not necessarily equal to the amount of water actually recharging the groundwater system. The deep drainage field site is located in the north-western corner of Mona Park (Figure 8) and was selected because the soils were deemed to be representative of the Mona park area and the farmer was amenable to having one of his paddocks instrumented.

The paddock is 10 ha with row length and grade of 620 m and 1:500 m respectively. The paddock has been planted under sugar cane (variety Q127 and ratoon no. 1). The paddock is irrigated every 10-20 days using a 50/50 blend of channel and groundwater of approximately 1000 Electrical Conductivity Units (EC).

![Figure 8 Deep drainage field site at Mona Park (white oval). Red outline illustrates Mona Park boundary, white circles represent groundwater pumping wells. Lots are coloured by SunWater client number, and Lots shaded black within the Mona Park boundary use groundwater only.](image)
5.1.1 Recharge estimation methods

The five methods employed to estimate deep drainage were:

i. lysimetry
ii. deep drainage meters
iii. chloride analysis
iv. paddock scale water balance
v. SIRMOD

The field site was instrumented at three points (top, middle and bottom). At each point there is a lysimeter, drainage meter, advance meter (for SIRMOD), and soil sampling for the chloride balance. All data is remotely downloaded daily.

A weather station has been placed at the TOP position in the paddock, on an adjustable height tower. The weather station enables calculation of potential evapotranspiration for use in the water balance. A daily summary of the weather station data is available at:


5.1.2 Lysimetry

This study used constant suction monolithic lysimeters (i.e. 10 kPa) constructed and installed by Tom McShane (Trace Tec Pty. Ltd) (Figure 10). The lysimeters measure 30 cm in diameter and 1.5 m deep.

A pictorial method by which the lysimeters were installed in the paddock is presented in Petheram et al. (2004b). Preliminary measurements are presented in Appendix 2.

5.1.3 Deep drainage meter

The Deep Drainage (DD) Meters, developed by Paul Hutchinson (CLW) (Hutchinson and Bond, 2001) were installed along side each lysimeter. The DD Meter develops a $K(\psi)$ relationship throughout the season which is used to solve Darcy’s equation.

The latest prototype features 2 tube tensiometers combined in one instrument and measurement range increased to 20 kPa. Preliminary measurements are presented in Appendix 2.

5.1.4 Chloride analysis

This method measures the change in the amount of chloride in the profile over an irrigation season to infer deep drainage. This is done by taking soil samples at the beginning and end of the season and analysing the difference between the two readings which relates to the volume of water passed through the system.

At each of the three sites, 6 soil cores were taken at depths 0-10, 10-20, 20-30, 30-50, 50-75, 75-100, 100-150, and 150-200 cm.

5.1.5 Paddock scale water balance

Deep Drainage is being estimated by measuring the other components of the water balance equation:

\[
\text{Drainage} = \text{Irrigation} + \text{Rainfall} - (\text{Evapotranspiration} + \text{Runoff}) \pm \Delta\text{Soil Store}
\]
5.1.6 SIRMOD

All inputs for SIRMOD are being measured. SIRMOD is being used to estimate infiltration and deep drainage distribution along the length of the paddock.

Figure 9 Map of field site installations. The photograph insert has been rotated 90 degrees clockwise. The white cylinder in the photograph is the logger and tipping bucket housing.
Figure 10 Clockwise from top left, lysimeter and continuous soil core, drainage meter being packed, tipping bucket arrangement and suction tubes, soil sampling.
5.2 Future work

Even though great care was taken during the installation of the lysimeters, it is inevitable that some disturbance to the surrounding soil matrix occurred. Hence, it is anticipated that measurements made by the lysimeters two and three years after their installation would be more representative than those taken during the first year of measurement.

The lysimeter study has continued beyond the 2005 harvest as part of the SRDC project titled ‘Adopting systems approaches to water and nutrient management for future cane production in the Burdekin’ and future deep drainage measurements will be reported through this project.
5.3 **Shallow observation bores**

An elaborate network of groundwater monitoring bores exists within Mona Park and the BHWSS in general. These bores are monitored by NRMW on a bi-monthly basis. Within Mona Park all bar two observation bores are screened near the base of the aquifer. Bores vary in depth from 16-30 m and are accessing water far deeper than the top of the water table (5-10 m).

During the course of the investigation the opportunity arose to install shallow groundwater monitoring bores at low cost in conjunction with a groundwater community awareness program in the BHWSS.

Five shallow groundwater monitoring bores (i.e. to a depth of 6 m) were installed in the Mona Park area (Figure 11). Unfortunately the timing of the installation of these piezometers was such that they could not be utilised as part of this study. However, in the future these piezometers could aid the identification and understanding of perched watertables in the Mona Park region and allow groundwater to be sampled from shallow depths. This will complement the existing NRMW observation bore network. The shallow groundwater observation bore locations are provided in Table 2. The shallow observation bores were installed by Carl List.

<table>
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<tr>
<th>NRMW Bore Identification No.</th>
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<th>Northing</th>
<th>Surface elevation (mAHD)</th>
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Figure 11 Shallow groundwater observation bore locations (blue triangles). Each shallow observation bore is sited next to an existing ‘deep’ NRMW groundwater observation bore. Blue cross-hairs illustrate location of existing deep groundwater observation bores. The background image illustrates the depth to groundwater (April 2003) where red is shallow and blue is deep. Dark blue lines are the Barratta Creek (left) and the Burdekin River (right).
6 Qualitative interpretations of groundwater trends

To assist interpretation of the groundwater trends in the Mona Park region hydrographs from three NRMW observation bores have been plotted in Figure 12. One observation bore is located in Mona Park (Rn 12000128), one up-gradient in Clare (Rn 12000254) and one down-gradient in Jardine (Rn 11910113). These bores were selected because: (1) their groundwater hydrographs were deemed to be representative of each of their respective areas; (2) each hydrograph has more than 40 years of record; (3) the three bores are aligned along the regional groundwater flow path; and (4) prior to the development of the BHWSS each region had a very different land-use history (i.e. Mona Park has a long history of groundwater pumping, Jardine was largely undeveloped and used only for extensive grazing, and the Lots in Clare adjacent to the Burdekin River have a long history of surface water use).

1964 – 1988 (i.e. 1964 - B-B’ in Figure 12)

Prior to the development of the BHWSS (i.e. before 1987) groundwater levels in Mona Park and down gradient of Mona Park (i.e. Northcote and Jardine) mirrored rainfall trends. This is evident in the top two charts in Figure 12 where the groundwater hydrographs (i.e. blue dots) mirror the residual rainfall mass curve (i.e. sum of the mean monthly rainfall minus the rainfall for a particular month). A falling limb on the residual rainfall mass curve indicates a drier than average period, while a rising limb indicates a wetter than average period.

The groundwater level in the Mona Park observation bore (Rn 12000128) is more responsive than the groundwater level in the observation bore at Jardine (Rn 11910113), fluctuating between about 4 and 8 m compared with 4 and 6 m in the latter. Furthermore the Mona Park hydrograph is less ‘smooth’ than the Jardine hydrograph. This observation is deemed to be a function of the large volumes of groundwater being pumped for irrigation in Mona Park. During the dry years of the mid to late 60’s groundwater pumping in Mona Park kept the groundwater levels ‘artificially’ low. It is likely that there was a reduction in groundwater pumping during the wet years of the 1970’s which served to exacerbate the rise in groundwater levels. The irregular shape of the Mona Park hydrograph is due to seasonal demand for groundwater.

In the Clare area, prior to the BHWSS, groundwater levels show a more subtle response to rainfall. This is probably because Lots adjacent to the Burdekin River were already obtaining irrigation water from the river. That none of the hydrographs display a response to the construction of the Clare Weir (i.e. line A-A’ in Figure 12) is an indication that the storage behind the weir is not a key contributor to the elevated groundwater levels in the Mona Park region. This is supported by anecdotal information that the transmissivity of the groundwater system south of the town of Clare is very low (Carl List pers comm. 2005).
Figure 12. Selected hydrographs from Jardine, Mona Park and Clare. The left image illustrates BHWSS groundwater elevations in April 2003 where blue is high and red is low. NRMW observation bores are represented by black cross-hairs, the Burdekin River by the black line, Clare Weir by the black rectangle and Mona Park is shown by the blue polygon.

The charts on the right are three hydrographs from representative observation bores in Jardine (top), Mona Park (middle) and Clare (bottom). The dark blue points are groundwater level measurements, the thin black line is the residual rainfall mass curve, the red line is a running average of the residual rainfall mass curve, the horizontal green line represents the ground surface (note the ground surface at the Clare observation bore 12000254 does not appear on the bottom chart because it is 24.69 mAHD and off the scale) and the horizontal blue dashed line (middle chart) is the approximate height of the Burdekin River adjacent to Mona Park. The three vertical black lines A-A’, B-B’ and C-C’ indicate the completion of the Clare Weir, the introduction of surface water into the BHWSS and a change in groundwater pumping allocations respectively. The change in groundwater pumping allocations was such that farmers were allowed to pump unlimited amounts of groundwater.

The vertical shaded rectangles to the right of the hydrographs are a qualitative representation of the likely effective porosity in each observation bore. These were derived from the stratigraphy logs, with clay (i.e. low effective porosity) being dark and stones/boulders being the lightest shading. The ‘effective porosity’ logs correspond with the water level axis on the hydrographs. Observation bores 11910113, 12000128 and 12000254 are screened at approximately -6, -3.5 and -1.5 mAHD respectively.
1988 – 2000 (i.e. B-B' to C-C' in Figure 12)

The introduction of surface water into the BHWSS in the late 80s coincided with a wetter than average period due to tropical cyclones over three consecutive years. In response to these wet years in conjunction with the importation of surface water into the region a step change in watertable level is observed in all three hydrographs during this period (note that surface water was introduced to the Jardine and Northcote regions several years after Mona Park). However, the step change is most pronounced in the Mona Park observation bore. This is because prior to 1988 groundwater pumping in Mona Park had kept the groundwater levels ‘artificially’ low, enabling them to respond more rapidly to a decrease in discharge (i.e. groundwater pumping) and an increase in recharge (i.e. recharge greatly exceeds the discharge capacity). Anecdotal information suggests that in the late 80’s – early 90’s farmers in Mona Park used quantities of surface water in excess of their allocation (Garry Ham pers. comm. 2005). They were able to do this for several years until Jardine and Northcote were connected to the BHWSS. It is likely that they would have reduced their groundwater usage during this period and this would have exacerbated the groundwater response in the Mona Park area.

During the dry period in the early 90’s there was a plateau in the groundwater levels in Clare and Jardine. This is in contrast to observations made before the development of the BHWSS, where groundwater levels gently declined during dry periods. In a number of observation bores in Mona Park a slight decline in groundwater level is observed at this time, a function of groundwater pumping and baseflow to the Burdekin River.

Contour maps of the groundwater surface after 1990 show a persistent groundwater mound/ridge along the western boundary of Mona Park (Figure 13 B). This boundary coincides with a surface water supply channel, suggesting channel leakage may be occurring. This is supported by observations made at NRMW observation bore 12000127 (Figure 14) where the rising groundwater levels (even during dry periods) and falling salinity concentrations are consistent with what one would expect to observe with channel leakage. Channel flow information would provide confirmation that channel leakage is occurring and enable the volume of water to be quantified.

With the onset of a series of wet years in the late 1990s groundwater levels in all three regions steadily increased, culminating with a very rapid rise in response to a wet three month period in early 2000 (C-C’ in Figure 12). The response to the rainfall event in early 2000 in Mona Park was especially large and rapid, with groundwater levels increasing by as much as 4 m. This same response was not observed in observation bores outside of Mona Park, suggesting a localised and prominent groundwater mound had formed in Mona Park (Figure 13 A).
Key points to note about the watertable response in Mona Park to this event are: (1) the mound dissipated very quickly (Figure 12); (2) the centre of the mound had shifted east and was centred in the middle of Mona Park rather than along the western boundary, which is usually the case (Figure 13 B ); (3) the mound was very prominent; (4) piezometers along the western boundary of Mona Park (Figure 14) did not exhibit the same rapid response (e.g. bores 12000170, 12000198, 12000197 in Figure 14); and (5) never had such a rapid rise been observed in Mona Park or the BHWSS (Ray McGowan pers. comm. 2005).
Figure 14 Observation bores in Mona Park and the groundwater contour map, where green is high and pink is low. In the hydrographs the watertable elevations measurements are illustrated by blue squares and the salinity concentrations by the pink squares.
A possible explanation for the sudden, large rise in groundwater levels in many of the Mona Park observation bores in 2000 is that when the groundwater level reached a certain elevation the groundwater system changed behaviour from an unconfined aquifer to that of a semi-confined aquifer. In unconfined aquifers the storage term, specific yield, has a much greater value than the storativity (i.e. the storage term in a confined aquifer). This is because in an unconfined aquifer, releases from storage represent an actual dewatering of the soil pores while in a confined aquifer, releases from storage represent the secondary effects of decreasing fluid pressure (i.e. water expansion) and increasing effective stress (aquifer compaction). The implications of this at Mona Park are that if the groundwater system becomes locally confined, a given quantity of water (i.e. deep drainage) will bring about a much greater rise in head.

Evidence for this phenomenon can be seen in Figure 12, where the rapid rise in early 2000 appears to correspond with the advent of a confining clay layer (i.e. see bore log at far right of Figure 12). While it is acknowledged that there is a discrepancy in scale when comparing a groundwater level measurement (i.e. paddock scale) with a bore lithology log (point/plot scale) analysis of other observation bore data within Mona Park seem to support this hypothesis.

Figure 14 and Figure 15 illustrate that NRMW observation bores in Mona Park that do not exhibit the sudden spike in groundwater levels in early 2000 (i.e. west of Line A-A’ in Figure 15) coincide with areas identified as having higher infiltration as implied by the presence of soils with coarser texture. This is further supported by the lithology logs for these bores that indicate a consistent sandy profile without the upper clay layer evident in bore 12000128. It appears that the groundwater system in this section of Mona Park is largely unconfined. Hence when operating at the scale of Mona Park the groundwater system should be treated as semi-confined.

Bores east of 12000128 (i.e. east of Line A-A’ in Figure 15) all seem to have an upper clay layer. Anecdotal information that Mona Park was once a swamp points to the existence of a continuous upper layer of fine material within Mona Park. Such a layer would be necessary to observe confining behaviour. Interestingly two bores in very close proximity, one that exhibits the rapid response (i.e. 12000143) and one that doesn’t (i.e. 12000171) have a very steep hydraulic gradient between them (Figure 14) suggesting the groundwater system is heterogeneous and discontinuous in places. Note the low groundwater levels in 12000143 is partly a function of its proximity to the river but also due to the observation bore being sited next to a groundwater pump (Figure 5), evident by the discontinuous nature of the hydrograph since 1990 (Figure 14).

At Jardine, observations at bore 11910113 suggest that the groundwater level is still several meters below the upper clay layer (Figure 12). Interestingly the groundwater level in the Jardine region appears to have risen a greater amount during the wet period in the late 1990s than the wetter period during the late 80s, early 90s. This may partly be a function of the greater volumes of surface water used in Jardine in the late 90s but it may also be because of a reduction in specific yield as the material in the aquifer grades from sands and gravels to sandy clays. This texture change may not be sufficient to change the behaviour of the system from an unconfined to a confined groundwater system, but is probably sufficient to bring about a noticeable reduction in specific yield.
Figure 15  Soil water infiltration map (mm/year) and NRMW observation bores (black dots). Line A-A’ illustrates an imaginary boundary between observation bores in which a rapid response was observed in early 2000 (i.e. west of A-A’) and those in which a rapid response was not observed (i.e. east of A-A’). Mona Park is illustrated by the black polygon. The infiltration map was sourced from NRMW and is based on soil texture only (i.e. independent of water application rates or changes in soil chemistry which may alter the infiltration characteristics of the soil).
2000 to present (C-C’ to present in Figure 12)

Post 2000 groundwater allocations changed so that farmers could pump unlimited quantities of groundwater. In reality only a limited number of farmers in the BHWSS could take advantage of this change in allocation. This is because many were already constrained by the production capabilities of their production bores. Of those that had the capacity to increase their groundwater pumping many were limited by the quality of their groundwater with many farmers already utilising their optimum surface water – groundwater mix (Ray McGowan pers. comm. 2005). This optimum mix varies from farmer to farmer. The sudden reduction in the groundwater levels after 2000 is most likely a function of the change in behaviour of the groundwater system (i.e. changing back from confined to unconfined), an increase in groundwater pumping in the Mona Park area and lower than average rainfall. The large seasonal differences in groundwater levels post 2000 is thought to be partly a function of the increased groundwater pumping and partly because the groundwater level is fluctuating within a layer of lower specific yield (Figure 12). With fewer production wells in the Clare and Jardine districts, groundwater levels stabilised rather than fell during the lower than average rainfall years after 2000.

Interpretation of groundwater salinity trends in Mona Park

Groundwater salinity in Mona Park is typically between 1000 and 4000 EC. In many of the observation bores salt concentrations were observed to increase after the BHWSS was commissioned in 1987 (Figure 14). Relative to historical groundwater salinity observations made elsewhere in the BHWSS, groundwater salinity in Mona Park varied both spatially and temporally (see Appendix 3). Reasons for this include: (1) the long history of groundwater pumping in Mona Park; and (2) the long history of agricultural use (e.g. fertilizer application).

The reason that rising salinity concentrations seem to coincide with periods of increased recharge (i.e. during wet years and after the construction of the BHWSS) is not clear. However, it is speculated that it may be due to: (1) increased leaching of soluble salts stored in the unsaturated zone to the underlying groundwater system; and (2) rising groundwater levels dissolving soluble salts in the unsaturated zone. This trend is particularly apparent in the shallow piezometer observations in Figure 16 where salinity concentrations increase during wetter periods (i.e. mid-late 90s) and decrease during drier periods (i.e. 2000 to present), though admittedly the period of record is not long. It is thought that during these dry periods, salts re-accumulate in the unsaturated zone through evaporative concentration.

Most of the bores in Mona Park are screened near basement (i.e. about 20-25 m below surface) so concentration measurements are not necessarily representative of the groundwater concentrations at the watertable. Understanding how salts move in the saturated zone requires nested piezometers. Unfortunately there are few nested piezometer sites in the BHWSS.

Three nested piezometer sites were identified in the vicinity of Mona Park and roughly align along the regional groundwater flow path. One site is in the centre of Mona Park, one at the north-western corner of Mona Park and one is down gradient of Mona Park in Jardine. Data from these three sites have been plotted on Figure 16.

Unfortunately none of the nested sites measured salinity concentrations at multiple depths prior to the development of the BHWSS so there is little in the way of baseline data. However, it may be inferred from the middle piezometer at Site 2 (Rn 11910115), which has over 30 years of record, that prior to the development of the BHWSS salinity concentrations at a depth of 26 m were relatively stable. This is consistent with the salinity concentration trends observed in many of the NRMW observation bores in Mona Park which were screened slightly above basement (e.g. 11910129, 12000183, 12000173, 12000198, 12000127, 12000169). After the BHWSS was established in 1987 salinity levels started to fluctuate (Figure 14).
Figure 16 Hydrographs from three nested piezometers in Mona Park and Jardine. Site 1 corresponds with NRMW observation bore 12001287, Site 2 NRMW observation bores 11910114 (deep), 11910115 (medium) and 11910984 (shallow) and Site 3 NRMW observation bore 11910924. The left image illustrates groundwater elevation in April 2003 where blue is high and red is low. NRMW observation bores are represented by black cross-hairs, the Burdekin River by the black line and Mona Park is illustrated by the blue polygon. The top chart on the right is a plot of groundwater level against time for each of the three piezometer nests. The thin black line is the residual rainfall mass curve and the red line is a running average of the residual rainfall mass curve. The bottom chart is a plot of electrical conductivity against time for each of the three piezometer nests. The two vertical black lines A-A’ and B-B’ indicate the completion of the BHWSS and a change in groundwater pumping allocations allowing farmers to pump unlimited amounts of groundwater. Bore 12001287 is screened at 27 and 11 m, bores 11910114, 11910115 and 11910984 are screened at 40.5, 26, 12 m respectively and bore 12000924 is screened at 29.5 and 20.5.

At Site 1 in Figure 16 the salinity concentrations measured in the shallow piezometer (i.e. 11 m) are highly variable and generally higher than those measured in the deeper piezometer (i.e. 27 m). The large fluctuations in the groundwater salinity concentrations at the shallow Mona Park site (i.e. Site 1) are likely to be a function of the groundwater pumping in the area and the variable quality of the deep drainage water (i.e. with different farmers using different groundwater – surface water mixes and the SODIC nature of the soils).

At Site 2 the salinity concentration in the deeper piezometer (i.e. 40.5 m) remains relatively constant. The basement at this site is considerably deeper than elsewhere in Mona Park and this piezometer is screened at a depth greater than most production wells in the Mona Park region (i.e. 20 – 24 m Ray McGowan pers. comm. 2005). The salinity concentrations in the middle piezometer at Site 2 (i.e. 26 m) is consistently higher than in the shallow piezometer (i.e. 12 m). This indicates that the lateral re-distribution of salts is a dominant process.
At Site 3 the salinity concentrations in both the shallow (i.e. 20.5 m) and deep (i.e. 29.5 m) piezometers remained constant and essentially the same until the late 90s when the salinity concentrations in the shallow piezometer (only) started to rise. Why salinity concentrations in the groundwater only started to increase in the mid to late 90s is unclear.

In several observation bores located near production wells (e.g. 12000169, 12000143, 12000100) the groundwater salinity concentrations have been observed to rise very rapidly. This may be due to an ‘up-coning’ of basement salts. Another mechanism by which salts may be accumulating in the unsaturated and saturated zones is through the evaporative concentration of salts in the capillary fringe where the groundwater table approaches the ground surface (i.e. typically less than 2 m, though this will vary depending upon the soil type).

The processes by which salts are accumulating and moving through the saturated zone can be further understood by analysing groundwater chemistry data. This was beyond the scope of the current investigation.

Future trends and management options in Mona Park

Groundwater trends across the BHWSS have shown a steady rise in a stepwise manner (see figures in Appendix 3). With the exception of some bores in the Mona Park region, groundwater levels remain relatively static during dry periods and rise during wet periods. Based upon historical trends, groundwater levels are expected to continue to rise in the Jardine and Clare regions under future wetter regimes. However, the question remains; ‘under the current groundwater pumping allocations how will the groundwater levels in Mona Park respond to a wetter regime?’ A specific question like this is often best answered using appropriate modelling tools.

Based upon the qualitative understanding of the groundwater system and current farmer behaviour in the Mona Park region it is thought that under a wetter regime groundwater levels in Mona Park will continue to rise. This is because under a wetter regime there will be a lower demand for groundwater (i.e. decreased discharge capacity), increased recharge and potential for lateral inflows into Mona Park (i.e. because groundwater levels in the BHWSS in general will rise). Until the discharge capacity of the groundwater system equals recharge, groundwater levels will continue to rise.

To manage groundwater tables under a wetter regime, farmers will need to look at extracting greater volumes of groundwater and options for reducing diffuse deep drainage. Because many farmers in the Mona Park region seem to have already optimised their conjunctive use of surface water and groundwater with respect to yield (Ray McGowan pers. comm. 2005) mechanisms to encourage farmers to use more groundwater would need to be investigated. However, in many regions of Mona Park the groundwater quality is poor and further exploitation of ‘saline’ groundwater may accelerate the rate at which salts are concentrated in the unsaturated zone.

Beyond Mona Park there is potential to sink more production wells in Jardine, Northcote and the Agricultural College (Carl List pers. comm. 2005). This anecdotal information is supported by lithology logs recorded for a number of NRMW observation bores located in these areas. There is little capacity to increase groundwater pumping in Clare or Mulgrave.

In some regions of the BHWSS there is the risk of ‘up-coning’ of basement salts, particularly near basement highs like Mt Kelly. Anecdotal information suggests that several farmers who have sunk production wells in the vicinity of Mt Kelly abandoned the wells after only a couple of seasons because of rapidly increasing groundwater salinity in the wells (Carl List pers. comm. 2005). Appendix 4 presents hydrographs for several observation bores located on
the foot-slopes of Mt Kelly which show that very high salinity concentrations have been recorded in several of these observation bores (i.e. bores that may intersect fracture zones).

Before consideration is given to the mechanisms by which farmers might be compensated for lost production due to use of saline groundwater, the long term sustainability of prolonged groundwater pumping in the Mona Park region should be investigated. There is in our view still value in developing a groundwater model for the region, and this would be best achieved through co-operation by all stakeholders. Geochemical studies may further assist conceptualise the groundwater flow processes and identify those processes by which salts are accumulating and their pathways of movement.

An alternative to utilising the groundwater on-farm would be to dispose of the extracted groundwater to the Burdekin River. Depending on how and when this is done it could raise issues for downstream users and aquatic ecosystems. This could include the North and South Burdekin Water Boards which use water from the Burdekin River to recharge the groundwater system in the Delta via artificial recharge pits.

Another option would be to extract groundwater, store it and then dispose of it during periods of high flow in the Burdekin River. The Water Boards do not extract much water during high flow periods because the high suspended sediment loads associated with these events reduces the infiltration of their artificial recharge pits.

It is likely that deep drainage is a large component of the water balance (see Appendix 2), and there is potential to considerably reduce deep drainage. With a number of farmers in the Mona Park region experiencing difficulty transmitting water to the end of their furrows, one option for reducing deep drainage would be to reduce furrow lengths. However, many farmers are hesitant to do this because of the costs involved in reconfiguring the fields and increased harvesting costs.
Groundwater trends in Mulgrave

The fact that groundwater levels in Mulgrave are steadily rising at a rate of about 0.25 m/year is of real concern. This trend is particularly concerning because the groundwater at Mulgrave is generally of a very poor quality (i.e. greater than 4000 EC in many bores). Unlike trends observed in bores elsewhere in the BHWSS, groundwater trends in Mulgrave do not show a step change response to large rainfall events or changed management practise. The only observation bore with a long period of record (i.e. over 30 years) is Rn 12000181 which shows a remarkably steady rise since 1973.

Figure 17 NRMW observation bore 12000181. Blue dots are groundwater level observations; pink dots are groundwater salinity measurements. Groundwater elevation is 25 m STD (STD is the Queensland State Datum which in this case is roughly equivalent to the AHD).

Given that groundwater levels appear to have been rising in the Mulgrave region prior to any form of development, and that the rise has been very steady, the rising groundwater levels may be due in part to lateral flow from those Lots in Clare adjacent to the Burdekin River (Figure 6) that have been irrigating with river water since the 1950s. Anecdotal information suggests that the original supply channels connecting the tobacco farms to the river were particularly 'leaky'. Gladys Lagoon may be contributing to the rising groundwater levels in the Mulgrave district, although the very steep hydraulic gradients in the region suggest transmissivities are very low in a northerly direction. The groundwater flow direction from Gladys Lagoon appears to be greatest in a north-westerly direction along an old drainage line that flowed towards Barratta Creek (Figure 5). Mulgrave was beyond the geographic scope of this study but it is a region that has been identified through this study as requiring special attention.
7 Numerical Groundwater Model

7.1 Introduction

Groundwater models do not generate new knowledge but rather provide a tool by which information can be captured, organised and analysed in a systematic and structured manner. By organising our thinking in this way it allows us to test ideas for their reasonableness, provide an indication of the most sensitive parameters, and synthesise understanding by enabling extrapolation. Groundwater models are often expressed using mathematical algorithms because mathematics provides a logical expression of ideas and relationships of any degree of complexity.

Modelling objective

A key aim of having a groundwater model for the Mona Park area is to (1) establish whether groundwater levels in Mona Park are likely to increase under a wetter regime despite the change in groundwater pumping allocations, and (2) investigate the effectiveness of various on-farm management strategies to help focus future efforts.

We were unsuccessful in securing access to some data required to develop a suitable groundwater model, particularly water use data (i.e. diffuse deep drainage) and channel flow data (i.e. channel leakage) for the region of interest. These data are necessary to develop a calibrated groundwater flow model for the region. This section will outline the conceptualisation of the Mona Park groundwater system which is crucial to any future modelling work.

7.2 Model conceptualisation

The Mona Park groundwater system was initially conceptualised as an unconfined groundwater system with a single, unconfined layer. However, as understanding of the Mona Park groundwater system developed, the conceptualisation changed to a semi-confined system. This can be represented using a two layer system with the upper layer acting as a confining layer, where the upper layer is very thin in the unconfined area. The rationale for this is discussed in detail in Section 6.

7.2.1 Model domain

The numerical groundwater flow model for Mona Park was developed using MODFLOW (McDonald and Harbaugh 1988) and the pre and post processor PMWIN. Due to difficulties in establishing representative boundary conditions around Mona Park, the model domain extended about 7 kilometres to the north, west and south of the Mona Park boundary. The resulting model domain encompasses much of the ‘usable’ groundwater resource in the BHWSS (Figure 18).
The southern boundary has been conceptualised as a constant flux boundary changing to no-flow along the south-western and western boundaries. The placement of this boundary roughly coincides with a reduction in the transmissivity of the groundwater system at Mulgrave. The local driller Carl List who has drilled test holes throughout the Clare – Mulgrave area has indicated that south of Clare transmissivities are likely to be very low. Further evidence for the low transmissivity in this region are the steep groundwater gradients from Gladys Lagoon to the north (Figure 12), and the lack of response of the groundwater system in Mona Park and Clare to the storage behind the Clare Weir (Figure 12).

The constant flux at this boundary is expected to be quite low and it is thought that it decreases to the west, effectively becoming a no-flow boundary (Figure 5). The western boundary of the model is a no-flow boundary and roughly coincides with the Barratta Creek system. This boundary condition was established by analysing groundwater contour maps generated from data in the NRMW observation bore network.

The northern boundary has been conceptualised as a constant flux boundary. In the Jardine region (i.e. north of Mona Park) groundwater contours appear to align roughly parallel with the southern boundary. To the east the Burdekin River forms a constant head boundary above which there is another no-flow boundary. Prior to 1990 when the river level was above the groundwater level (Figure 12) some observation bores close to the river show a
strong correlation to the river level. Anecdotal information suggests that the connection between the river and the groundwater system is dependent upon preferential flow paths. Historically it had been observed that the groundwater levels in Mona Park only responded to the river when it reached a certain elevation (Ray McGowan pers. comm. 2005). With the exception of the boundary along the Burdekin River (i.e. whose position is fixed) all model boundaries have been placed far from the Mona Park boundaries to minimise the sensitivity of the results to the imposed boundaries.

7.2.2 Aquifer properties

Structural aquifer properties, such as surface elevation and basement were entered using the PMWIN interpolation tool.

No suitable DEM was available for the BHWSS region. The DEM obtained from NRMW was found to have a considerable number of artefacts and chronic streamline reinforcement errors (Appendix 5). A substitute DEM was generated using a smoothed version of the Shuttle Radar 3 arc second DEM in conjunction with surveyed observation bore elevations. A description of the method by which the DEM used in this study was generated is provided in Appendix 5. It is recommended that the high resolution DEM for the Lower Burdekin be re-visited.

Elevation data for the basement (i.e. bottom of layer 1) and confining layer (i.e. top of layer 2) were obtained from the NRMW observation bore lithology logs. These values were interpolated using the kriging function in PMWIN.

Little information on saturated hydraulic conductivity or specific yield exist for the BHWSS. To date, most of the groundwater modelling studies in the Lower Burdekin have focused on the Delta. Given the large differences between the Delta and the BHWSS caution is needed when transferring values between these two parts of the Lower Burdekin.

Opportunity exists to progress this work further in collaboration with the NRMW groundwater group.

7.2.3 Water data

Key information on water application, use and flows within the BHWSS and channel leakage were not available for this study. This meant it was not possible to calibrate a groundwater model of the Mona Park area. With a near infinite number of possible model parameter combinations, little value would be added to the analysis and qualitative understanding developed in earlier parts of this report through using an un-calibrated model.
8 Conclusions

The objectives of this study were to (1) ascertain the causes of rising water tables and salinity levels in the Mona Park area; (2) identify management strategies that meet required water table and salinity targets; and (3) investigate appropriate incentive and support mechanisms that allow transition from the current situation to a more sustainable system. The extent to which the above objectives were achieved is discussed below.

High levels of diffuse deep drainage and channel leakage appear to be the main factors leading to rising groundwater levels in Mona Park. Without access to information on surface water usage and channel flow it is not possible to partition the relative contribution of each of these processes and hence to quantify the likely impact of alternative management scenarios.

The prominent mound in Mona Park in early 2000 (Figure 13) is thought to be a result of the groundwater system changing behaviour to that of a confined system as the watertable reached the confining clay layer in the very wet period of 2000. Groundwater levels in Mona Park have since fallen somewhat but exhibit large seasonal fluctuations due to increased groundwater pumping and an apparent reduction in the effective porosity (i.e. specific yield) of the upper aquifer material.

A well calibrated groundwater flow model would provide a useful tool to help further analyse the groundwater system and the likely response to future wet or dry periods and changes in management practise. The groundwater model initiated as part of this study could not be calibrated or further developed because key data were not available to allow this to happen.

Qualitative analysis of groundwater trends in the Mona Park region suggest that under current management practices, groundwater levels in Mona Park will rise during future wet periods. Because of a reduction in specific yield and the confining nature of the material in the upper aquifer it is likely that unless groundwater levels fall further, future responses to increased recharge are likely to be rapid and large.

There is large potential to reduce diffuse deep drainage in the Mona Park region. This will require review of and if need be implementation of improved strategies for management of gypsum in the area and improved irrigation practices. This could involve: a reduction in field lengths; more efficient delivery systems (e.g. overhead or trickle irrigation); improved irrigation scheduling to meet crop water requirements and improved conjunctive water use rules (need to meet water quality targets for irrigation).

Other options for managing groundwater levels could involve dewatering arrays. This would require access to and application of a robust groundwater model to carry out analysis of the effectiveness of various options and if it was not possible to re-cycle this water, approval for the disposal of water of various qualities into the river system would need to be sought.

There is a need to know the likely impacts of the above options on the biophysical system before proceeding with work on incentive and support mechanisms to underpin longer term sustainability of Mona Park as a profitable and sustainable irrigation district.
9 Recommendations

Based on analysis and findings of this study we provide the following recommendations (in no particular order).

- **Conduct a geochemical investigation to identify the source of salts and their pathways of movement**

  The source of salts in the Mona Park region has not been established. It is recommended that a geochemical investigation be conducted to help identify the processes by which salts are accumulating in the groundwater system and their pathways of movement. This may provide further understanding as to the long-term sustainability of various water management practices in the region, and especially prolonged groundwater pumping in the region.

  While a long term record of chemical composition of groundwater from NRMW observation bores exists, these data have not been fully analysed. Furthermore, the last groundwater sampling for chemical analysis was in 2001 and because all bar 2 bores are screened near basement there is little information on the vertical distribution of salts in the saturated zone. The 5 shallow observation bores installed during the course of this investigation could be used to sample shallow groundwater. Information from these bores would complement the existing long-term data set.

- **Continue lysimeter deep drainage measurements**

  It is recommended that the lysimeter study in Mona Park be continued. It is likely that deep drainage measurements obtained with the lysimeters will be more representative of the general soil matrix after the first year. With the infrastructure already in place and the landholder amenable to changes in experimental design the opportunity exists to continue research at this site at minimal cost.

  Quantifying how water quality affects deep drainage in the BHWSS is an area of uncertainty, yet is potentially a key piece of information. The lysimeters could be used to measure the amount of deep drainage when using water of varying quality.

- **Reduce furrow length and investigate more efficient delivery systems**

  It will be difficult to arrest the rise in groundwater levels during ‘wet’ years. Hence, one must ensure that groundwater levels fall rather than stabilise during the dry years. Groundwater pumping may be part of the solution in some areas of the BHWSS. However, this will not be possible in many other areas. This limits these farmers ability to manage rising watertables by managing their rates of deep drainage. With many farmers in the vicinity of Mona Park subject soil sodicity problems and unable to ‘run’ irrigation water to the end of their paddocks, mechanisms to encourage farmers to reduce their furrow length and/or invest in more efficient delivery systems need to be investigated.

- **Investigate channel leakage**

  The Mona Park groundwater mound is often centred along the main supply channel beside Pelican Road suggesting that channel leakage may be contributing to the elevated groundwater levels in Mona Park. This is supported by salinity concentration measurements in some hydrographs (e.g. 12000127) and anecdotal information from a number of farmers elsewhere in the BHWSS that the some supply channels leak. It is suggested that further investigation into leakage from supply and drainage channels be conducted. Relative to other components of the groundwater balance channel leakage is a process that can be accurately quantified and relatively easily addressed with the right incentives.
• **Mulgrave region requires immediate investigation**

Mulgrave has been identified as an area of particular concern. Groundwater levels are currently 10 m below the ground surface but are steadily rising and the groundwater quality is very poor. Groundwater trends in the Mulgrave region are different to trends elsewhere in the BHWSS with groundwater levels rising steadily and not showing a step like response to rainfall or the introduction of irrigation.

The low transmissivity of the groundwater system indicates that the discharge capacity of the region is very low and it is unlikely that groundwater pumping alone would be a practical or economically viable method of managing groundwater levels. If groundwater levels continue to rise in Mulgrave, engineering solutions (i.e. drains) together with changed management practices may be the only viable way to regain control of groundwater levels. The cause of the rising trends and potential management solutions requires immediate attention. Farmers in the region are already seeking on-ground action.

• **Investigate options for disposal of saline groundwater**

Options for disposing of saline groundwater should be investigated. If groundwater levels are to be managed using engineering solutions like dewatering arrays or tile drains (e.g. Mulgrave) it is likely that because of its quantity and poor quality not all of the groundwater would be able to be used for irrigation.

• **Improve the quality and availability of data**

During the course of this study a number of data deficiencies and issues were identified. These need to be addressed to enable more rapid progress in developing understanding and more sustainable management strategies for the region:

- Ready access to water usage and channel flow/leakage information is essential for future modelling work.
- The current DEM available for the region has serious errors. The process by which this DEM was constructed needs to be re-visited and a new DEM created.
- Access to longitudinal river bed elevations downstream of the Clare Weir would assist with future surface and groundwater modelling activities in the Lower Burdekin.
- Deep drainage and lateral flow processes in much of the Lower Burdekin appear to operate over short timeframes (less than bi-monthly). It is recommended that several ‘representative’ observation bores in the BHWSS be instrumented with dataloggers. Data at a much finer resolution (i.e. hourly) would greatly improve conceptualisation of groundwater processes in the region. Dataloggers need only be installed for a number of years (i.e. one wet, one dry) to complement the existing NRMW groundwater database. The NRMW groundwater database may need to be modified to capture more than one data reading per day.
- Shallow observation bores installed as part of this study should be utilised in future investigations and their data captured in the NRMW groundwater database.
10 References


Hutchinson PA, Bond WJ (2001) Routine measurement of the soil water potential gradient near saturation using a pair of tube tensiometers.


PPK (2002). The proposed groundwater management strategy for the Burdekin Houghton Water supply Scheme.


11 Appendices

Appendix 1  Communications

The project has been relying on three groups of people to both gain data and understanding of the system and feedback results. These are the local farmers, SunWater and Natural Resource, Mines and Water.

A brief document was produced to provide local farmers with an explanation of the paddock monitoring equipment.

An article for Australian CANEGROWER was also prepared with John Sanderson (Sanderson Media) (Vol 26 No 22, November 1).
Document provided to farmers

*Big Question:* How much is on-farm water management contributing to the rising water tables in Mona Park?

**Method:**

1. To perform a paddock water balance – account for all water inputs and outputs. From this we can estimate deep drainage.
2. Install instruments to directly measure deep drainage
3. Take samples of water from beneath the root zone and analyse for fertiliser

**Instruments:**

At the top, middle and bottom of the field

1. **Lysimeter**

   Basically a rain gauge buried 1.5 m in the soil. It measures the volume of water draining through the soil.

   The lysimeter also collects water samples which can be analysed for fertiliser etc.

2. **Drainage Meter**

   The drainage meter is a new product still under development by CSIRO. Basically two tensiometers buried at different depths in the ground. The difference between them tells how quickly water is moving through the profile.
3. Chloride balance

The change in the amount of chloride in the profile over an irrigation season is another indication of how much deep drainage has passed through the profile.

This is done by taking soil samples at the beginning and end of the season and analysing the difference between the two readings which relates to the volume of water that has passed through the system.
Scientists probe deep drainage in sugar areas

Scientists are working with growers to understand and reduce deep drainage in Queensland’s irrigated sugarcane growing areas.

They have buried lysimeters, which operate like rain gauges, beneath the root zone of sugarcane.

Philip Charlesworth, Irrigation Scientist with CSIRO Land and Water, says that lysimeters measure water lost to the crop. Lost water leads to problems such as rising water tables, salinity and fertiliser/pesticides in groundwater. By measuring how much water is lost growers and researchers can work together to reduce it - and take rural water use efficiency to new heights.

The research is being part-funded by the State Government through Stage 2 of its Rural Water Use Efficiency Program and CSIRO. The work is contributing to the early success of the newly formed Cooperative Research Centre for Irrigation Futures.

“Better management of deep drainage and runoff can put valuable dollars in farmers’ pockets by keeping fertiliser on the farm where their crops can make use of it. It also provides a double win by keeping the nutrients out of the wetlands or sea, which are hot topics in North Queensland,” Dr Charlesworth said.

Grower Mauro Garbuio of Mona Park, in the Burdekin irrigation area near Ayr, has CSIRO lysimeters installed in one of his cane fields.

“We are all keen to save cents as well as dollars so we need to know what fertiliser to apply and the depth and method to be used. Also, some growers with a water shortage will appreciate learning about deep drainage,” Mr Garbuio said.

Some parts of the Burdekin irrigation area have water tables that rise at 0.5-1m per year. Many years of research have shown that shallow water tables can cause waterlogging and salt in the water can build up in the crop root zone.

The next step is to use predictive modelling to scale up the results to catchment level.

“As on-farm water management may be only one of the causes of rising water tables, we are also investigating the part played by leaking irrigation supply channels,” he said.

Water solutions are not easy to find, says grower

Some growers will have little or no ability to change farm practices because of the prohibitive costs associated with change, according to Burdekin grower Mauro Garbuio.

He said Mona Park growers had to cope with being partially or solely reliant on the underground aquifer. The variable quality of the water affected the clay soils, increasing subsurface drainage and compounding associated problems.

“Many of us also have a rising water table, inadequate mix of sustainable quality water and allocation, plus inconsistent and irregular rainfall because past decisions and current government policies are based on regular and average rainfall.”

Even though government studies have been done and some solutions proposed, no action has been taken.

He said that better knowledge of the deep drainage issue, including water quality and management practices, should provide growers with best practice techniques. This was essential, given that water was a major cost.

“Government needs to acknowledge that a lot of problems are site-specific and individual solutions need to be implemented rather than the current approach of finding one solution to solve all problems,” Mr Garbuio said.
Appendix 2 – Preliminary deep drainage measurements

Preliminary data from the lysimeters and deep drainage meters show drainage occurred soon after irrigating. For example, an irrigation event (equivalent to 90 mm) occurred on the 5/10/04 with drainage evident soon afterwards. Problems with the lysimeter data associated with the first two irrigations are most likely due to a faulty vacuum pump (identified as ‘logger error’ in the Figure).
Appendix 3 – Groundwater hydrographs in the BHWSS
Appendix 4 Groundwater hydrographs in the vicinity of Mt Kelly
Appendix 5  Artefacts and streamline reinforcement errors in existing DEM

Method by which DEM used in this study was constructed

The model domain was populated with elevation data obtained from the Shuttle Radar DEM of the Lower Burdekin. However, this DEM is very irregular and it was necessary to employ algorithms to smooth the data while maintaining abrupt changes in elevation (i.e. to capture the location of the river). The resulting DEM was compared against surveyed observation bore elevations. The shuttle radar was found to be consistently higher than the observation bore elevations, with the mean difference of 3.22m between the DEM and the observation bore elevations. Rather than warping the smoothed DEM to fit the observation bores it was decided to subtract 3 m from each elevation cell value. The resulting grid compared favourably to the observation bores in the vicinity of Mona Park.
End-of-Report