DWLBC REPORT

Padthaway Salt Accession Study. Volume two: Results

2005/15

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Padthaway Salt Accession Study. Volume two: Results

Jason van den Akker

Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

March 2006

Report DWLBC 2005/15

Government of South Australia
Department of Water, Land and Biodiversity Conservation

SENRCC
South East Natural Resource Consultative Committee

Knowledge and Information Division

Department of Water, Land and Biodiversity Conservation

25 Grenfell Street, Adelaide

GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6946
	International	+61 8 8463 6946
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.dwlbc.sa.gov.au	

ISBN 0-9775167-5-X

Preferred way to cite this publication

van den Akker, J., 2005. *Padthaway Salt Accession Study. Volume two: Results.* South Australia. Department of Water, Land and Biodiversity Conservation. DWLBC Report 2005/15.

FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

ACKNOWLEDGEMENTS

George Mackenzie (DWLBC) and Michael Williams (DWLBC) are acknowledged for their assistance with the installation of instrumentation and data collection throughout the investigation.

The cooperation of all the Padthaway Irrigators who participated in this study is acknowledged with thanks for permission to conduct this investigation on their property and assistance with data collection.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This report is the second of four volumes and details the results collected to date under Components 1, 2 and 3 of the Padthaway Salt Accession Study. A complete description of the background and approach to the project, as well as a full site description can be found in Volume 1, report book DWLBC 2004/61. The study area (Padthaway Prescribed Wells Area) is shown in Figure 1.1 and all field sites referred to in this report are shown in Figures 1.2 and 1.3 of this report for reference.

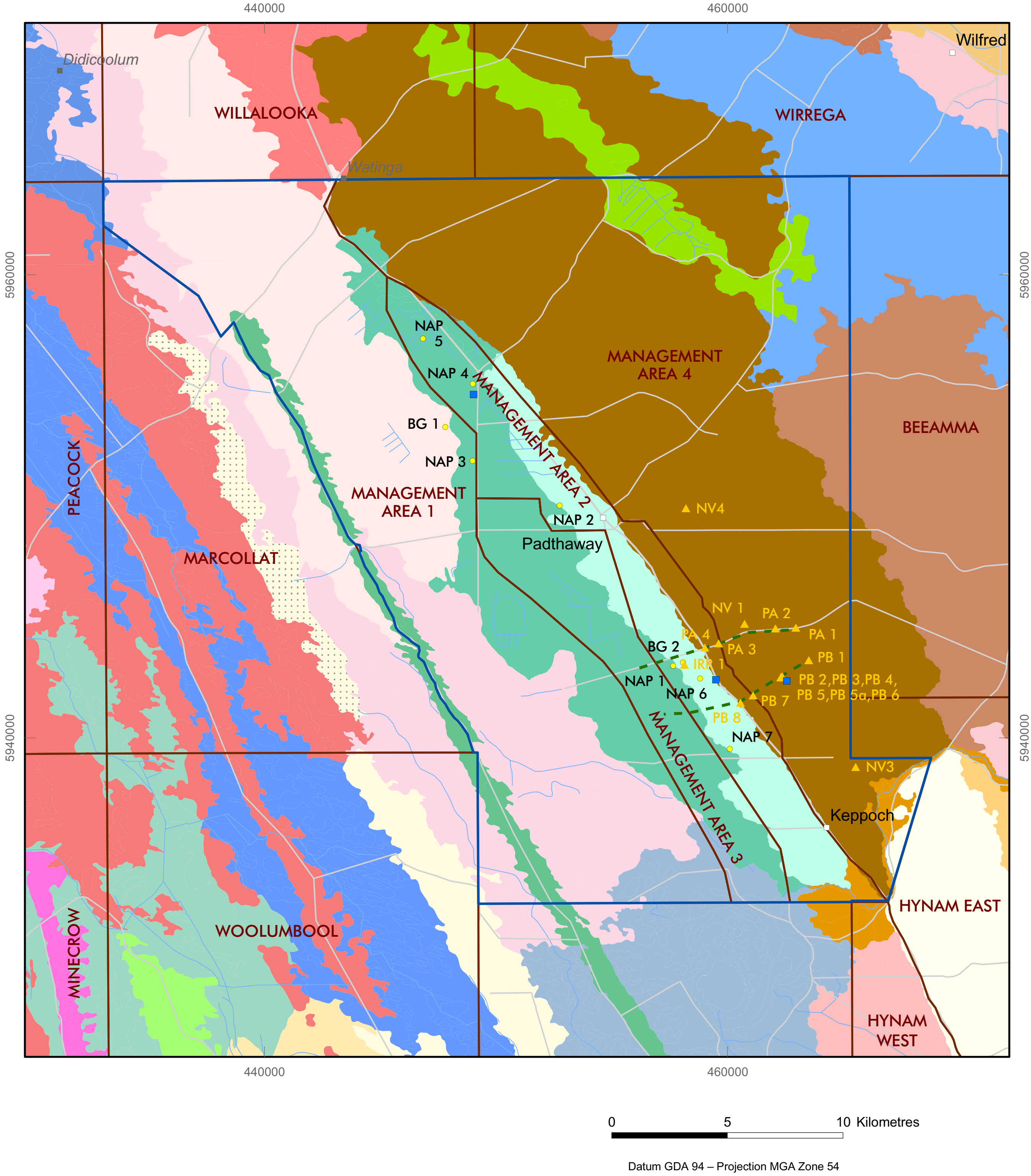
Results for Component 1 of the project (Naracoorte Ranges) are presented in Section 2 of this report. Here, soil core properties, classical hydrogeologic techniques, groundwater chemistry and geophysics (NanoTEM) are being used collectively to determine magnitudes and time scales of salt accession from the Naracoorte Ranges to the Padthaway Irrigation Area. As part of this, soil properties, gravimetric water content and soil water chloride data for each drill hole is currently being used in a model developed by CSIRO Land and Water to estimate cumulative recharge rates and salt fluxes from the unsaturated zone in the Naracoorte Ranges to the groundwater system. The data that is being used in this model is presented in section 2 of this report. The methodology and results of the modelling exercise itself is presented in a separate report (Wohling et al., 2005) and summarised in Volume 3 of this report series.

Once water and salt has moved through the unsaturated zone, it enters the groundwater system. Movement of salt through the groundwater system, from the Naracoorte Ranges into the Padthaway Irrigation area is being assessed using a combined approach of classical hydrogeologic techniques, groundwater chemistry and isotopic signatures and geophysics (NanoTEM). The results of analyses of groundwater samples from the Naracoorte Ranges for major ion composition, chloroflourocarbon (CFC) concentrations, and the stable isotopes of water, δ^2H and $\delta^{18}O$ are also presented in Section 2 of this report.

Data obtained for Components 2 and 3 of the project (Padthaway Flats) are presented in Section 3 of this report. These components aim to characterize and quantify the deep drainage of moisture and salt below irrigated vineyards as well as other types of irrigation (centre pivot and flood irrigation) within the main Padthaway Irrigation Area on the Padthaway Flats. At the vineyard experimental sites, NAP1, NAP2, NAP6 and NAP7 (see Figures 1.1 and 1.2 for site locations), the water balance approach is being adopted to quantify the hydraulic and salt fluxes to the water table on a vineyard scale. To accurately quantify the components that comprise the water and salt balance, CSIRO were engaged to accurately measure micrometeorological parameters and drainage at each of the viticulture sites. Detailed measurements (volumes and chemistry) of precipitation, irrigation, evapotranspiration, soil water content and drainage have been continuously recorded since July 2003 at these sites and the results to date are presented in Section 3 of this report.

A similar approach to that used to determine the water and salt fluxes under drip irrigation for the grape vines has been adopted to estimate deep drainage under the two other predominant irrigation types in the Padthaway Irrigation Area, flood and centre pivot irrigation. Irrigation application, groundwater extraction, precipitation and groundwater level measurements are continuously being recorded at one centre pivot site (NAP3) and two flood irrigation sites (NAP4 and NAP5) to quantify drainage and salt fluxes. The results of these measurements are presented in Section 3 of this report and the site locations are shown on Figures 1.1 and 1.3.

As part of Component 3 of the Padthaway Salt Accession Study, a chloride mass balance technique and the stable isotopic signatures of water (δ^2H and $\delta^{18}O$) are being used to provide additional independent methods for estimating irrigation drainage and evaporation under flood and centre pivot irrigation. To do this, monthly measurements of chloride, as well as occasional measurements of major ion chemistry and δ^2H and $\delta^{18}O$ in precipitation, irrigation water, soil water and groundwater are being measured at all experimental sites. The results of these analyses to date are presented in Section 3.



Padthaway Prescribed Wells Area

Unconfined groundwater management zone

NAP and CSIRO sites

Drillholes

Geophysical transect

Rain gauge – stable isotopes

Government of South Australia

Department of Water, Land and Biodiversity Conservation

SALT ACCESSIONS TO THE PADTHAWAY IRRIGATION AREA

SOIL TYPE AND INSTRUMENT LOCATION PLAN

June 2004

Figure 1.1

PIRSA Publishing Services 202561_004

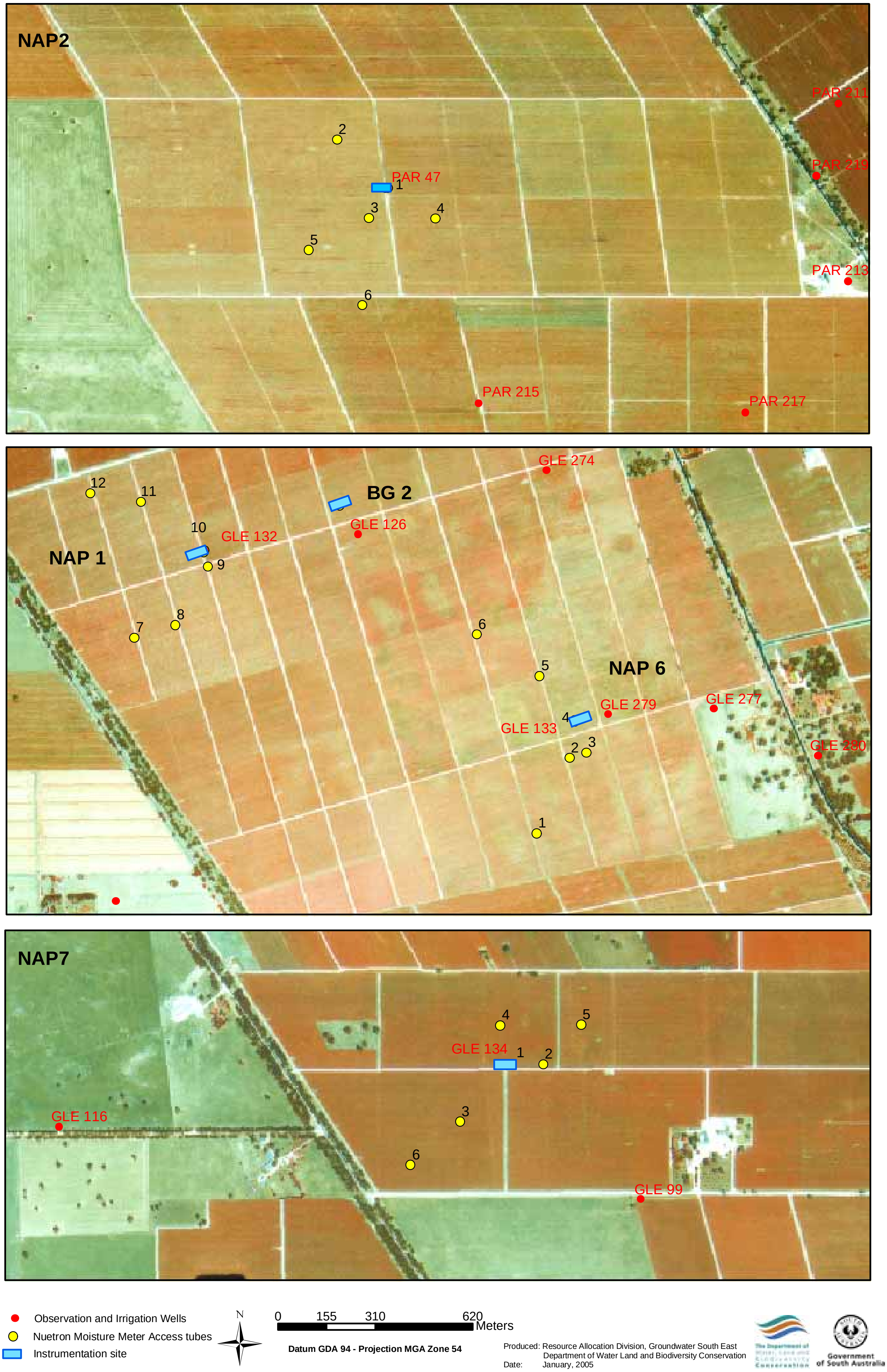


Figure 1.2 Site Plan at Vineyard Sites

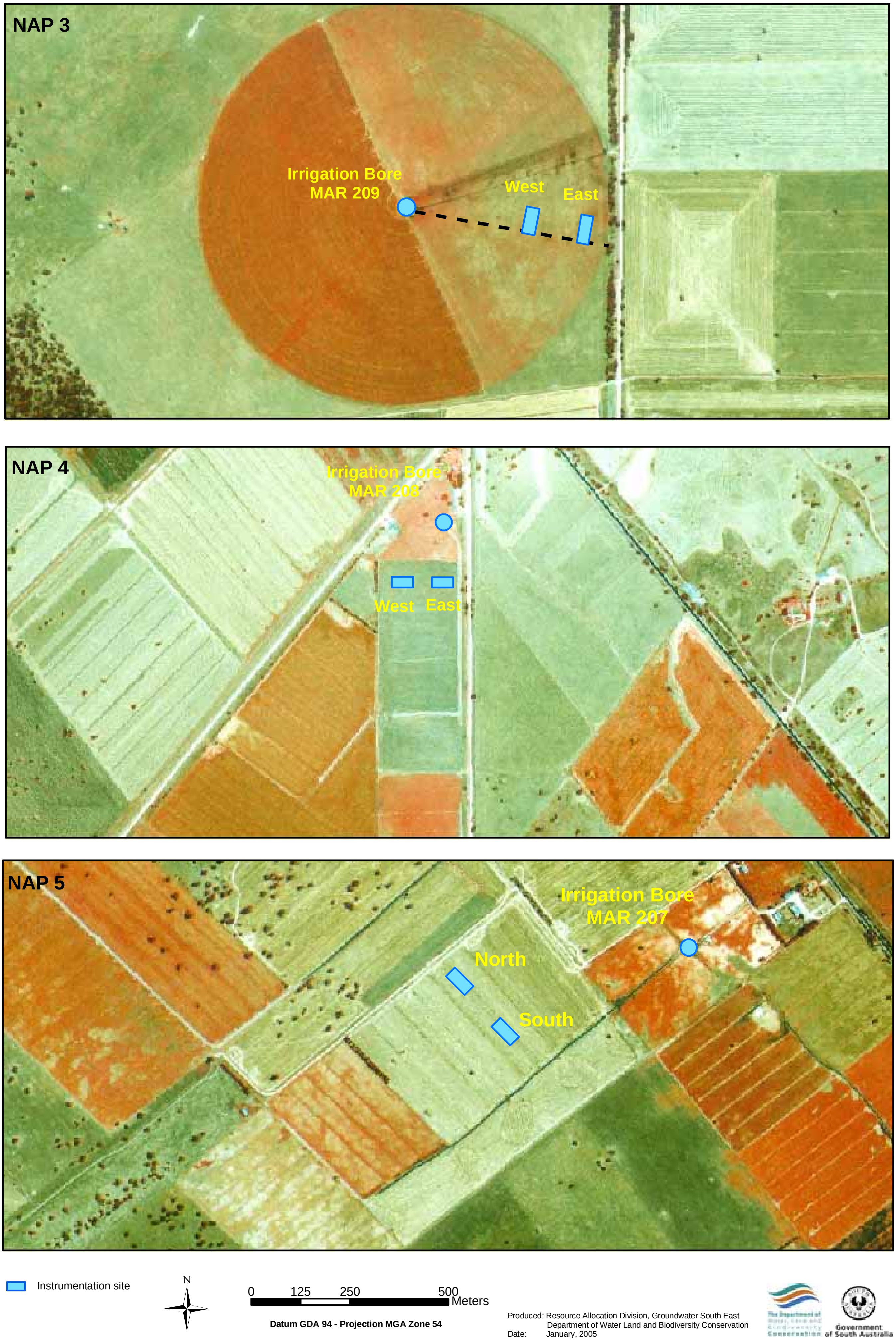


Figure 1.3 Site Plan of center pivot and flood irrigation sites

2. RESULTS FROM THE NARACOORTE RANGES (COMPONENT 1)

2.1 SOIL CORES

The results obtained from the soil cores, collected throughout the unsaturated zone and just below the water table in the Naracoorte Ranges are presented in Appendix A. The cores were analysed for gravimetric water content (Θ_g), soil water chloride $[Cl]_{sw}$ and soil water suction (SWP). These results are being used for modelling of recharge rates and salt fluxes to the water table by DWLBC and CSIRO Land and Water.

2.2 GROUNDWATER CHEMISTRY AND ISOTOPIC SIGNATURES

Groundwater samples were collected from the 14 piezometers and a range of existing observation wells in May 2003 and March 2005, using a Grundfos MP1 Submersible pump. The piezometers were pumped until three bore volumes had been purged and readings of pH, temperature and EC had become stable. The groundwater samples were analysed by CSIRO Land and Water for major ion chemistry (App. B), Chloroflourocarbons (CFC's) (Table 2.1), stable isotopes (δ^2H and δ^{18}O) (Table 2.2) and Carbon isotopes (δ^{13}C and ^{14}C) (Table 2.3). Combined, they will provide information on the age, recharge mechanisms and horizontal flow of groundwater from the Naracoorte Ranges to the Padthaway flat.

2.2.1 CHLOROFLUOROCARBONS

Chlorofluorocarbons (CFCs) have been released into the atmosphere over the last 50 years, and hence the presence of measurable concentrations of CFCs in groundwater reflect recent groundwater recharge (post-1965). The magnitude of CFC concentrations can then be used to infer groundwater residence times. Concentrations of CFC-11 and CFC-12 from each of the 14 observation wells in the Naracoorte Ranges and the inferred groundwater residence times (given as an average recharge date) are presented in Table 2.1. Calculations of CFC concentrations were based on a groundwater salinity of 1000–2000 mg/L. Calculation of equivalent atmospheric concentrations and apparent CFC-based groundwater residence times are based on assumed values of recharge temperature (12^{o}C, 285 K), recharge elevation (60 m) and excess air component. Based on these values, groundwater ages can be determined since 1965 with a precision of 3 years. The inferred recharge date of groundwater in the Naracoorte Ranges ranges from pre-1965 to 1975. This indicates that groundwaters are a mixture of recent recharge and evolved regional groundwater.

2.2.2 STABLE ISOTOPES (δ^2H AND δ^{18}O)

Stable isotopes of Hydrogen and Oxygen are being used in this investigation to provide information on evaporation and potentially on the origin and recharge mechanisms of groundwater. Rainfall samples from three rain-capturing devices have been taken on a monthly basis for the analysis of δ^2H and δ^{18}O. In addition, groundwater samples from 14 piezometers in the Naracoorte Ranges have been sampled and analysed for δ^2H and δ^{18}O compositions. All stable isotope results are presented in Table 2.2.

Table 2.1 Chlorofluorocarbons concentration and Groundwater Age in the Naracoorte Ranges

Sample	Measured CFC Concentration in Water		Equivalent Atmos Concentration		Apparent Age	
	CFC11 (pg/kg)	CFC12 (pg/kg)	CFC11 (pptv)	CFC12 (pptv)	CFC11 (years)	CFC12 (years)
GLE117	270	161	107	277	1975	1980
GLE118	37	<20	<25	<50	<1965	<1965
GLE119	52	60	<25	104	<1965	1969
GLE120	<25	28	<25	<50	<1965	<1965
GLE121	173	110	69	188	1972	1974
GLE122	99	53	39	90	1968	1968
GLE123	53	29	<25	<50	<1965	<1965
GLE124	<25	<20	<25	<50	<1965	<1965
GLE125	122	61	48	105	1969	1969
GLE127	115	56	46	96	1969	1968
GLE128	57	38	<25	65	1965	1965
GLE129	148	104	59	179	1971	1974
GLE130	32	24	<25	<50	<1965	<1965
GLE131	39	34	<25	59	<1965	1965

Table 2.2 Stable Isotopes δO^{18} and δ^2H

Sample ID	May 2003		March 2004	
	δ O18 ‰ rel SMOW	δ^2H ‰ rel SMOW	δ O18 ‰ rel SMOW	δ^2H ‰ rel SMOW
GLE53	-5.30	-31.5 -31.8		
GLE88	-5.35	-33.7 -33.5		
GLE100	-5.14	-31.4		
GLE131	-5.58 -5.60	-33.4		
GLE113	-4.41	-27.6		
GLE114	-4.38	-26.1		
GLE117	-5.11	-30.4	-5.44	-30.8
GLE118	-5.10	-30.6	-5.26	-31.5
GLE119	-4.83	-29.0 -29.2	-4.93	-28.0
GLE120	-4.73	-28.9 -29.2	-4.86	-29.0
GLE121	-5.27	-30.7	-5.55	-30.3
GLE122	-5.32	-30.5	-5.56	-30.2
GLE123	-5.24	-30.8	-5.49	-31.8
GLE124	-4.86	-28.1	-4.98	-30.7
GLE125	-5.70	-31.3 -30.9	-5.62	-33.7
GLE126	-5.10	-28.9		
GLE127	-5.37	-31.1	-5.54	-33.9
GLE128	-5.57	-30.9	-5.56	-31.9
GLE129	-5.62	-30.6	-5.59	-31.8

Table 2.3 Carbon isotopes ($\delta^{13}C$ and ^{14}C)

Sample	$\delta^{13}C$ ‰ PDB	^{14}C pMC±1σ
GLE117	-10.5	55.5 ± 1.3
GLE118	-9.5	36.5 ± 1.2
GLE119	-8.2	5.2 ± 1.0
GLE120	-8.0	11.8 ± 1.1
GLE121	-11.6	70.1 ± 1.4
GLE122	-11.4	61.4 ± 1.4
GLE123	-10.1	43.3 ± 1.3
GLE124	-8.1	101 ± 1.1
GLE125	-12.4	71.0 ± 1.4
GLE127	-10.8	54.1 ± 1.3
GLE128	-10.5	58.2 ± 1.3
GLE129	-11.3	73.8 ± 1.4
GLE130	-13.1	73.5 ± 1.5
GLE131	-13.0	82.9 ± 1.5

Figure 2.1 shows the δ^2H and $\delta^{18}O$ signatures of the rainfall and groundwater samples collected from the Padthaway area, plotted on a δ^2H vs $\delta^{18}O$ diagram, with a combined Meteoric Water Line for Melbourne and Adelaide shown for reference. The Meteoric Water Line is characteristic of a particular climatic and geographic area and is a line along which all rainfall samples will fall on a δ^2H vs $\delta^{18}O$ diagram. The location at which an individual rainfall sample plots along this line depends on factors that vary between rainfall events, such as rainfall amount, temperature at which precipitation occurs and storm track. The rainfall data collected to date from the Padthaway area plots along the Meteoric Water Line described above, suggesting that this line may be used to represent the long-term signature of Padthaway rainfall. Collection of data commenced after winter 2004 and hence, heavy winter rainfall, which would be expected to have a lighter (more negative) isotopic signature has not yet been captured. It is expected that, once these rainfall events have been captured, the data will extend further along the line in the negative direction. Groundwater samples from the Naracoorte Ranges (Bridgewater Formation) have a lighter isotopic signature than the rainfall samples collected to date, closer to what would be expected from heavy winter rainfall events. This suggests that the heavy winter rainfall events are the predominant source of groundwater in the area and this conclusion is supported by the fact that very little evaporation of water prior to recharge is indicated by the data. Such evaporation would manifest in a significant deviation of the groundwater data to the right of the Meteoric Water Line. Groundwater samples collected from shallow piezometers, which monitor the Padthaway Formation beneath the irrigation area, plot slightly to the right of the MWL, indicating a small but significant effect of evaporation. Groundwater becomes enriched with increasing distance down gradient, signifying the increased effects of evaporation along the flow path. The enrichment of water molecules containing the heavier isotopes (δ^2H and $\delta^{18}O$) only occurs during evaporation. In contrast, transpiration does not cause such enrichment, allowing the degree of evaporation on groundwater recharge to be assessed independently.

2.2.3 CARBON ISOTOPES (δ^{13}C AND ^{14}C)

Carbon has two stable isotopes, ^{12}C and ^{13}C, and one radioactive isotope, ^{14}C. Rainwater and hence recharge contain dissolved CO_2 from the atmosphere, with a ^{14}C content (as percent modern carbon, pmC) and a ^{13}C/^{12}C ratio (measured as δ^{13}C in units of ‰ V-PDB) similar to atmospheric values (^{14}C $\approx$ 100 pmC; δ^{13}C $\approx$ -7‰). Recharging groundwater is influenced by unsaturated zone processes such as biological activity and plant root respiration. This means that recently recharged groundwater has a ^{14}C content close to 100 pmC and quite a negative δ^{13}C signature close to –13‰. As groundwater moves through an aquifer, in isolation from the atmospheric source of carbon, its ^{14}C content decreases due to radioactive decay. Additionally, the dissolution of carbonate minerals leads to a further decrease in ^{14}C and an increase in the δ^{13}C signature towards 0 ‰ V-PDB.

A large range of carbon isotope signatures is observed in the groundwaters below the Naracoorte Ranges at Padthaway (Table 2.3). ^{14}C ranges from 5 pmC to approximately 82 pmC and δ^{13}C ranges between –13‰ and –8‰. This range indicates groundwaters that vary between predominantly recently recharged and more evolved regional groundwaters.

2.3 GROUNDWATER GEOPHYSICS

During June 2004, Zonge Engineering and Research Organisation conducted 2 NanoTEM resistivity surveys from the Naracoorte Ranges down onto the Padthaway Plain (Refer to Volume 1 for further details). The NanoTEM method measures the electrical resistivity of the sub surface. Figures 2.2 and 2.3 display contoured resistivity sections of transects A and B (along piezometer transects PA and PB shown in Fig. 1.1). The horizontal axis shows the distance along the ground surface, while the vertical axis shows the depth below the ground elevation. Different colours show areas of different resistivity. The ground resistivity is a function of water content, as well as the salinity of the water. A decrease in resistivity can result from an increase in the water content or from an increase in salinity of the contained water. Comparison of the resistivity results with measured groundwater salinities and aquifer properties can be used to calibrate the results and provide a spatial interpretation of both water content and salinity across the resistivity profile.

The water table elevation has been plotted on both surveys. Figures 2.2 and 3.3 clearly indicate that areas of higher resistivity (light blue to green colours 160–630 ohm-m) represent the unsaturated zone. Due to the lack of deep bores (>40 m) along the transect, it is difficult to relate the changes in resistivity, with actual changes in geology and groundwater salinity. Areas of data gaps and low resistivity along the Padthaway Flats are associated with interference from wire trellises in the vineyards and should be ignored.

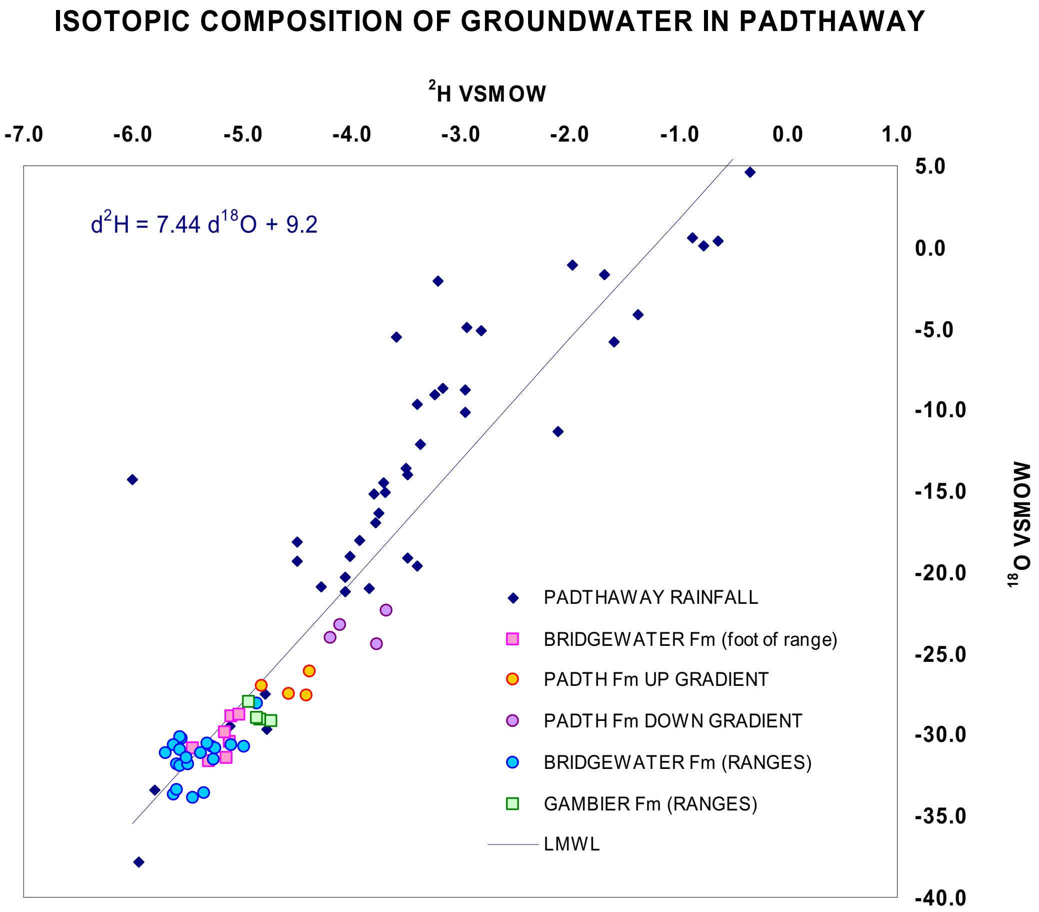
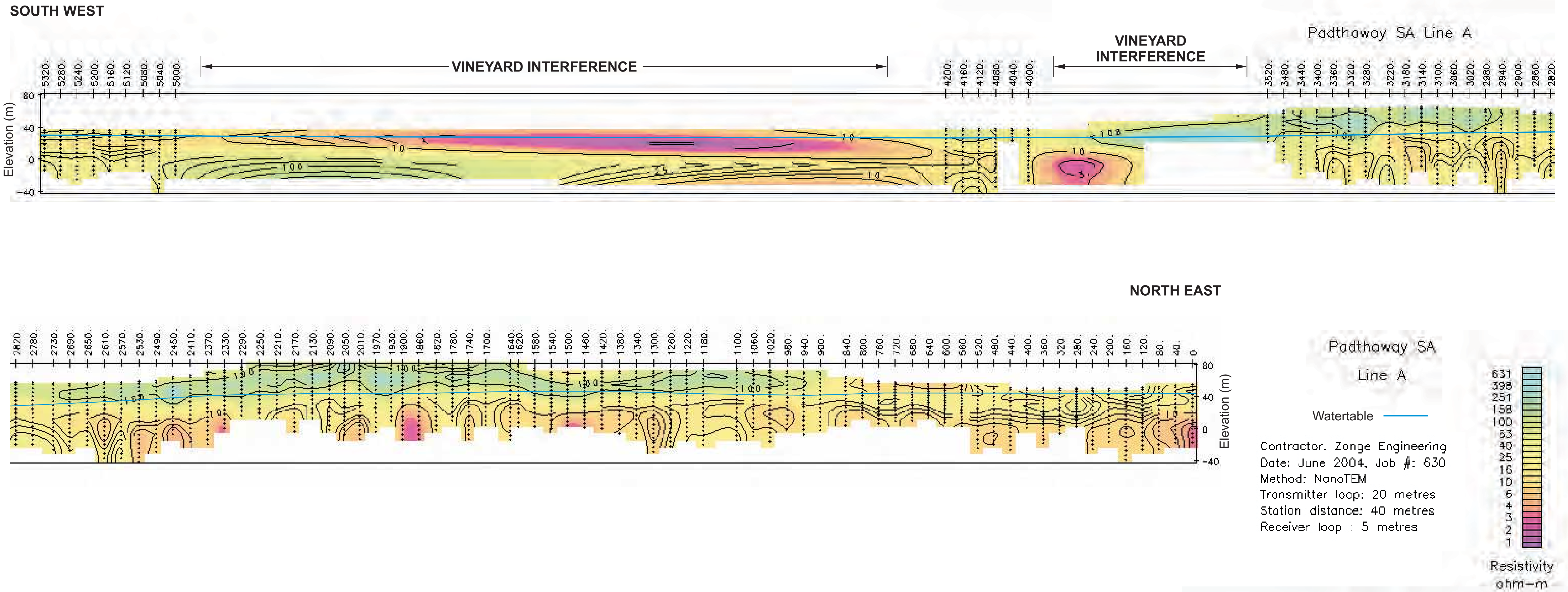


Figure 2.1 $\delta^{18}O$ and $\delta^{2}H$ compositions of precipitation and groundwater from the Padthaway Plains and the Naracoorte Ranges.



DWLBC

Padthaway SA Line A

1D Smooth-Model Inversion

Moving-in-loop TEM dB/dt Data

AUTHOR	DRAWN	DATE	SCALE	REPORT
ZONGE	ZONGE	14/03/05	1:10000	Job 630

REF: I3.m1d

Zonge

Figure 2.2 Groundwater Resistivity profile - Transect A

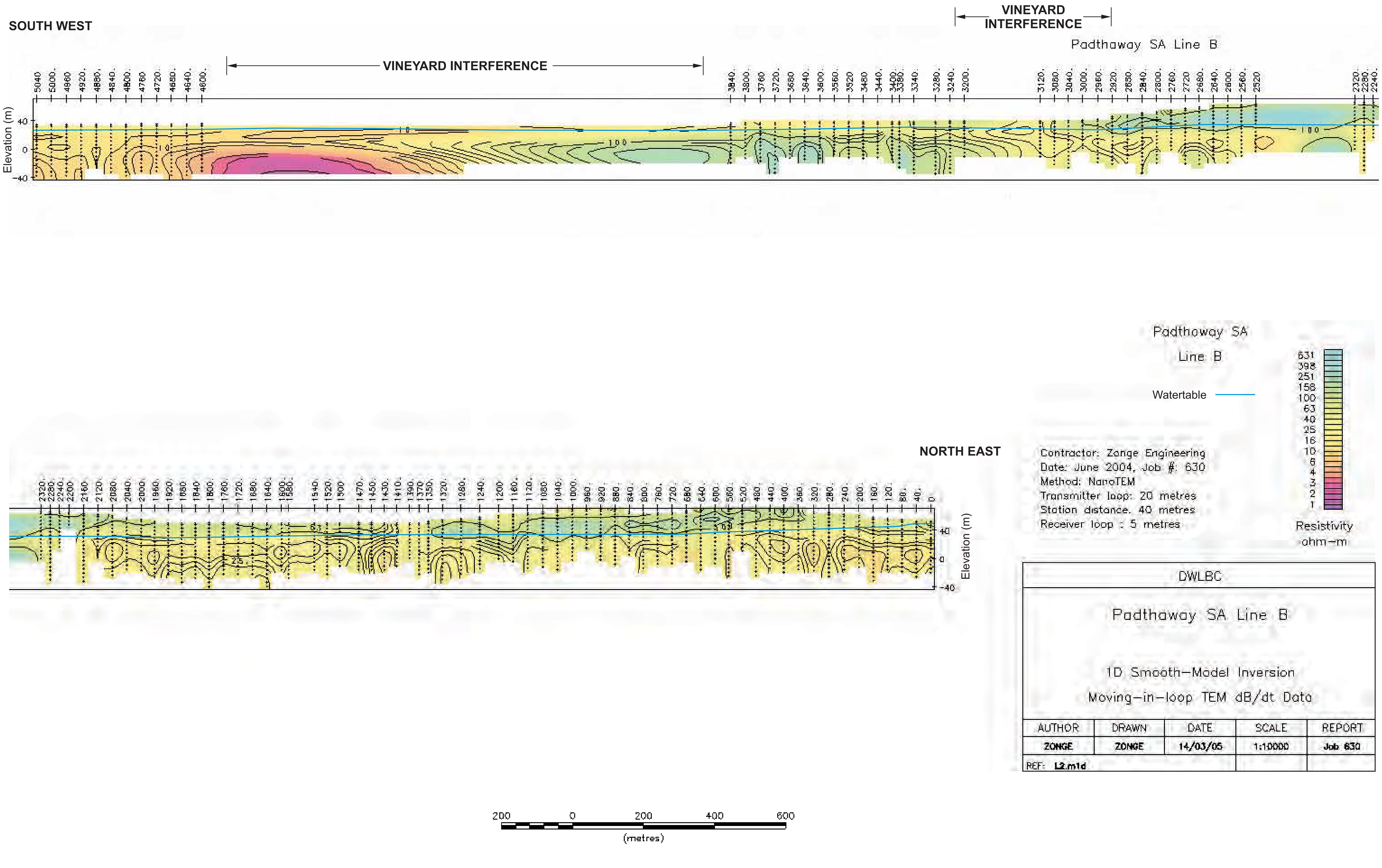


Figure 2.3 Groundwater Resistivity profile - Transect B

PIRSA 202772

3. RESULTS FROM THE PADTHAWAY PLAINS VINEYARD IRRIGATION SITES (COMPONENT 2)

3.1 RAINFALL MEASUREMENTS

Each irrigation site is equipped with two rain gauges, supplied by Agrilink and CSIRO. Weekly rainfall measurements obtained from the CSIRO and Agrilink Rain gauges are displayed for each experimental site for the period July 2003 to October 2005 (Figs 3.1, 3.2 and 3.3). Average historical yearly rainfall in the Padthaway district is 502 mm/yr. During 2004, experimental sites NAP 6 and 7 experienced average rainfall, while the remainder sites experienced below average rainfall (Table 3.1).

Table 3.1 Annual Precipitation 2004 (mm)

NAP 1	NAP 2	NAP 3	NAP 4	NAP 5	NAP 6	NAP 7
486* 418	436*	–	410	438	518* 516	501* 323

*CSIRO AWS - Combined Irrigation and precipitation

A rainfall gradient of ~5 mm/km exists over the study area. During 2004, the southern sites recorded 486–518 mm of rainfall, compared to 410–438 mm of rainfall recorded at the northern sites.

The rain gauges supplied by Agrilink at NAP 1 and 7 recorded unusually low rainfall when compared with the CSIRO Automatic Weather Stations (AWS), indicating that they were not functioning properly. Routine maintenance is currently being carried out on these stations.

3.1.1 RAINFALL CHLORIDE

The chloride concentration of rainfall is being measured at three sites across the study area on a monthly basis (Table 3.2). At all three sites, the contribution of chloride entering the system via rainfall is generally less than 5 mg/L. High chloride values are likely to be caused by evaporation in the capturing container and will be eliminated in the interpretation of this data. Steps have now been taken to eliminate evaporation from the capturing container for future samples.

Table 3.2 Chloride concentration in precipitation (mg/L)

SITE	Aug-04	Oct-04	Nov-04	Dec-04	Jan-05	Feb-05	Mar-05	Jun-05
NAP 4	4	5	3	5	14*	<5	10*	4
NAP 6	1	5	<1	3	9	16*	25*	5
NCTE Ranges	1	5	1	4	4	<5	<5	2

*Concentrated through evaporation

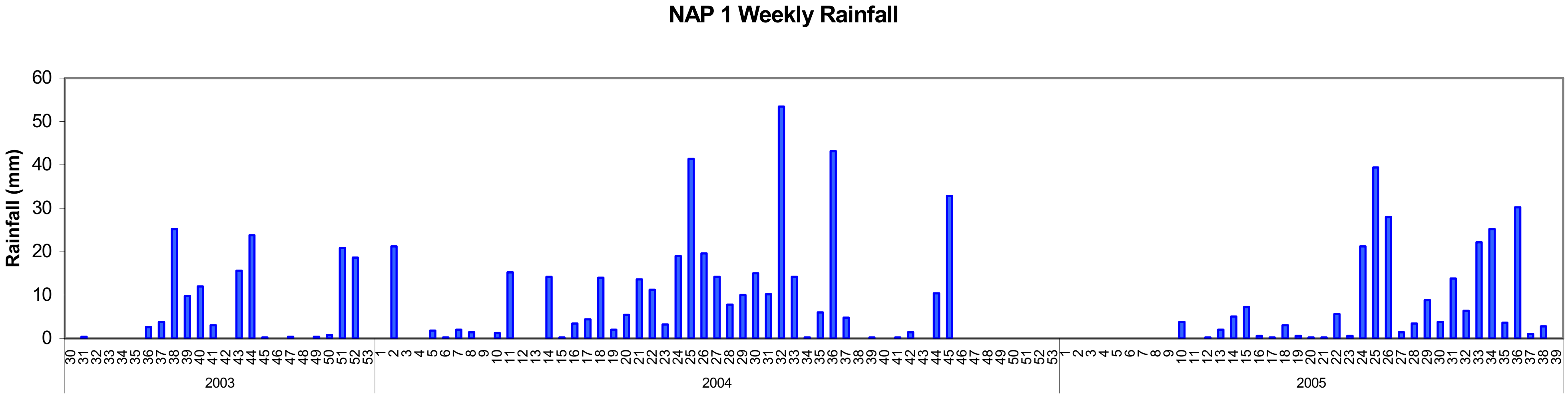


Figure 3.1 NAP 1, Weekly rainfall: Agrilink Rain Gauge

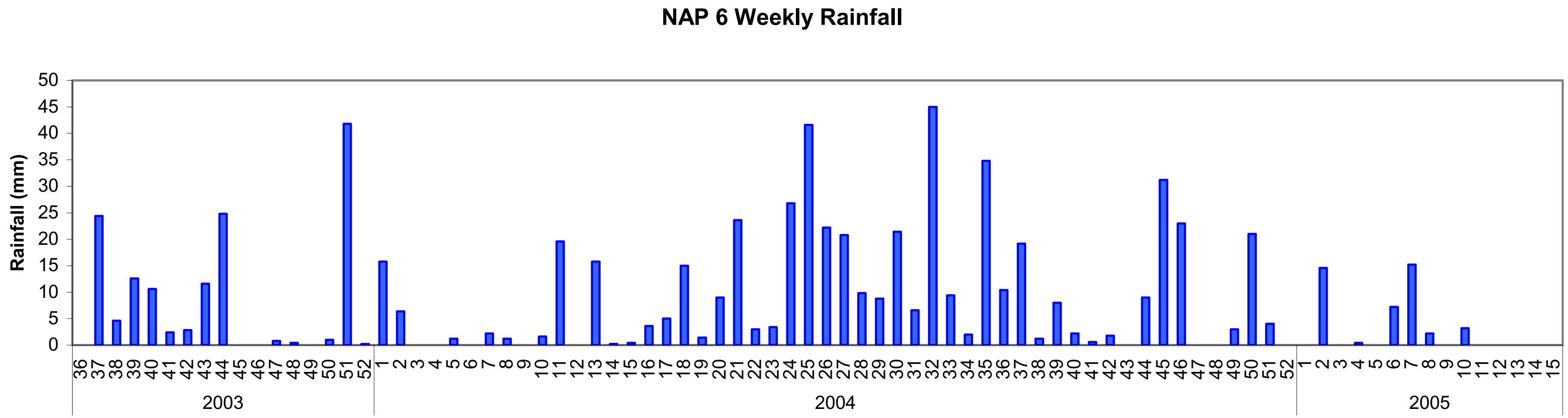


Figure 3.2 NAP 6, Weekly rainfall: Agrilink Rain Gauge

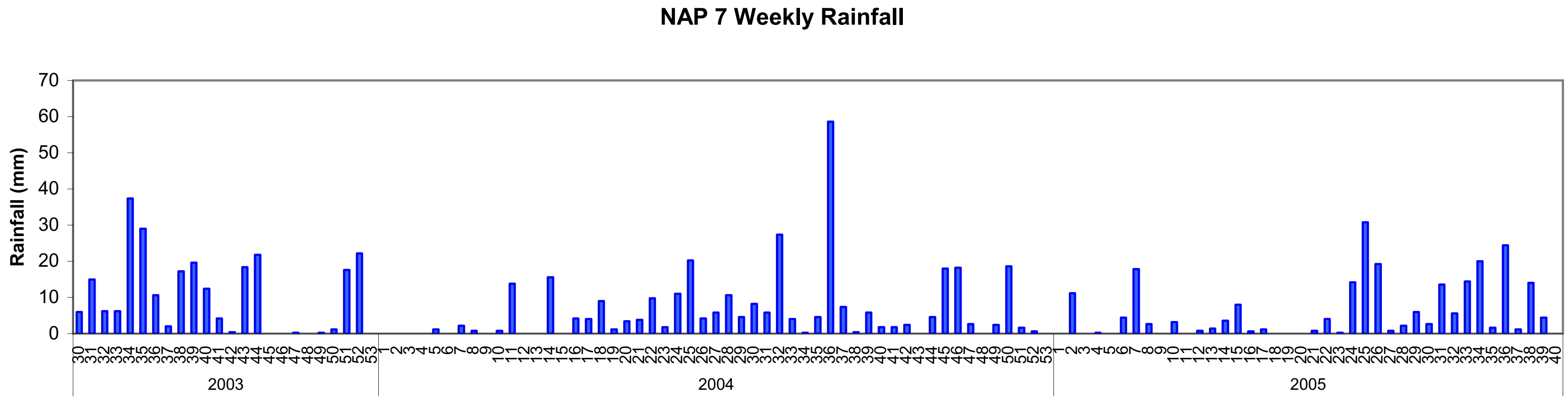


Figure 3.3 NAP 7, Weekly rainfall: Agrilink Rain Gauge

3.2 IRRIGATION MEASUREMENTS

At all 4 vineyard sites, the CSIRO Automatic Weather Stations (AWS) have been recording the duration of each irrigation event (irrigation time on/off). To determine the volume of irrigation applied, the average dripper flow rate was multiplied by the dripper density per hectare, multiplied by the duration of irrigation. The irrigation volumes for each vineyard site are displayed in Figure 3.4. To assess the performance of drippers, flow rate tests were undertaken throughout the blocks surrounding the instrumentation sites. 30 buckets were randomly placed under individual drippers to measure the total volume captured during 1 hour. The dripper flow rate tests for the blocks surrounding NAP 1, 6 and 7 show a gradual decrease in flow rate with distance from the main irrigation supply lines, indicating frictional loss with distance.

Irrigation volumes determined via the above method, were compared with volumes calculated by the vignerons. With the exception of NAP 1, our calculations were in close agreement (within 6%) with the volumes calculated by the vignerons.

At NAP 1, the average dripper delivery rate is 2.0 L/hr (Fig. 3.5). The block has a dripper density of 2778 drippers/ha. During the 2004/05 irrigation season there were 283 hours of irrigation. This equates to 160 mm of irrigation (Fig. 3.4), which is 25 mm lower than the total volume calculated by the vigneron (185 mm). The difference is likely to be related to an under estimation of dripper flow rate.

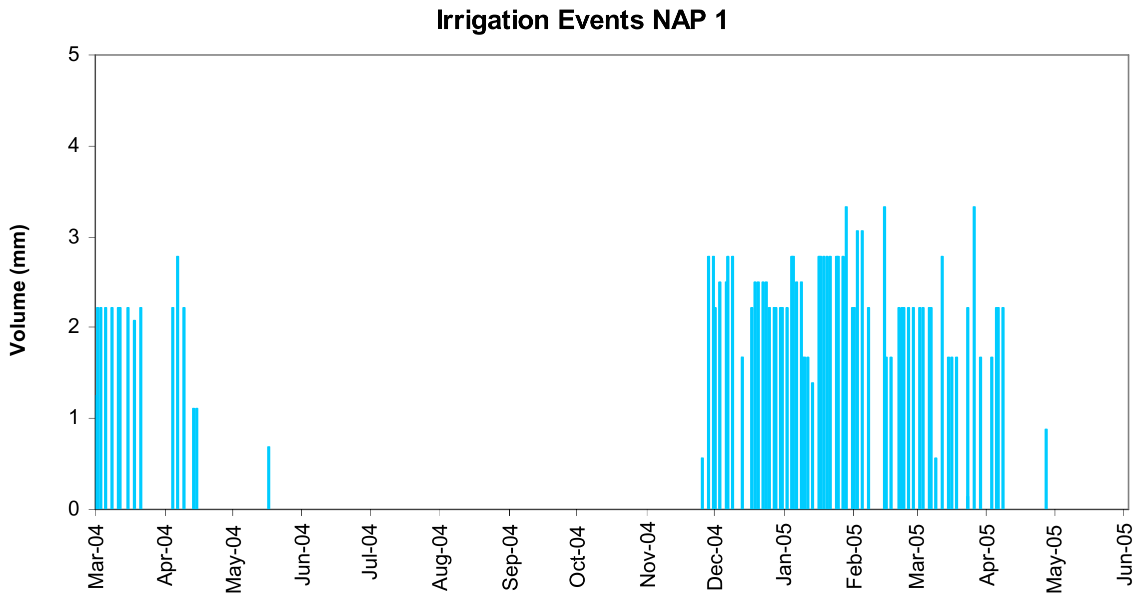
At NAP 2, the average dripper delivery rate is 1.66 L/hr (Fig. 3.5). The block has an average dripper density of 2888 drippers/ha. During the 2004/05 irrigation season there was 330 hours of irrigation. This equates to 160 mm of irrigation (Fig. 3.4), which is 10 mm lower than the total volume calculated by the vigneron (170 mm).

At NAP 6, the average dripper delivery is 2.54 L/hr (Fig. 3.5). The block has a dripper density of 2778. During the 2004/05 irrigation season there was 255 hours of irrigation. This equates to 179 mm of irrigation (Fig. 3.4), and is in very close agreement to the total volume calculated by the vigneron (172 mm).

At NAP 7, average dripper delivery is 1.8 L/hr (Fig. 3.5). The block has an average dripper density of 7475 drippers/ha. During the 2004/05 irrigation season there was 185 hours of irrigation. This equates to 248 mm of irrigation (Fig. 3.4), which is 10 mm lower than the total volume calculated by the vigneron (258 mm).

3.2.1 IRRIGATION CHLORIDE

The chloride concentration of irrigation water is being measured monthly throughout the irrigation season (Table 3.3). Irrigation water at NAP 1 is sourced from irrigation bore GLE273 located close to the Naracoorte Ranges and is of a lower salinity (~350 mg/L, TDS = 955 mg/L) than the groundwater used for irrigation at NAP 2 (~450 mg/l, TDS = 1160–1220 mg/L), NAP 6 (~500 mg/L, TDS = 1260 mg/L) and NAP 7 (~480 mg/l, TDS = 1172 mg/L). The investigation site at NAP 2 is supplied with water from a network consisting of three irrigation bores (PAR210, PAR213 and PAR219), all of which are similar in quality.



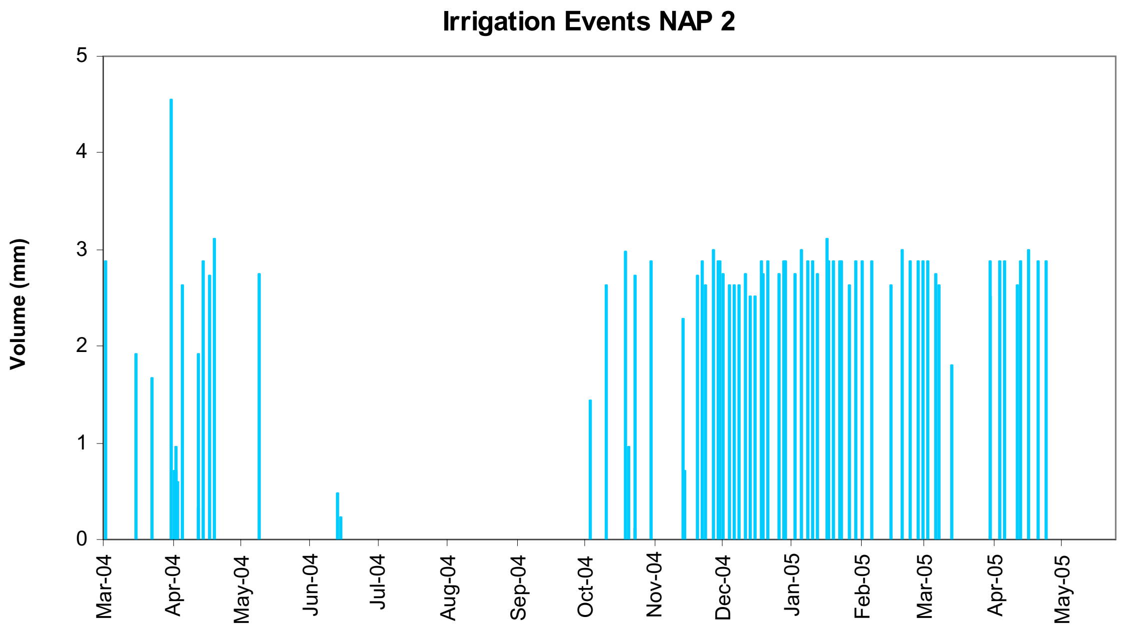
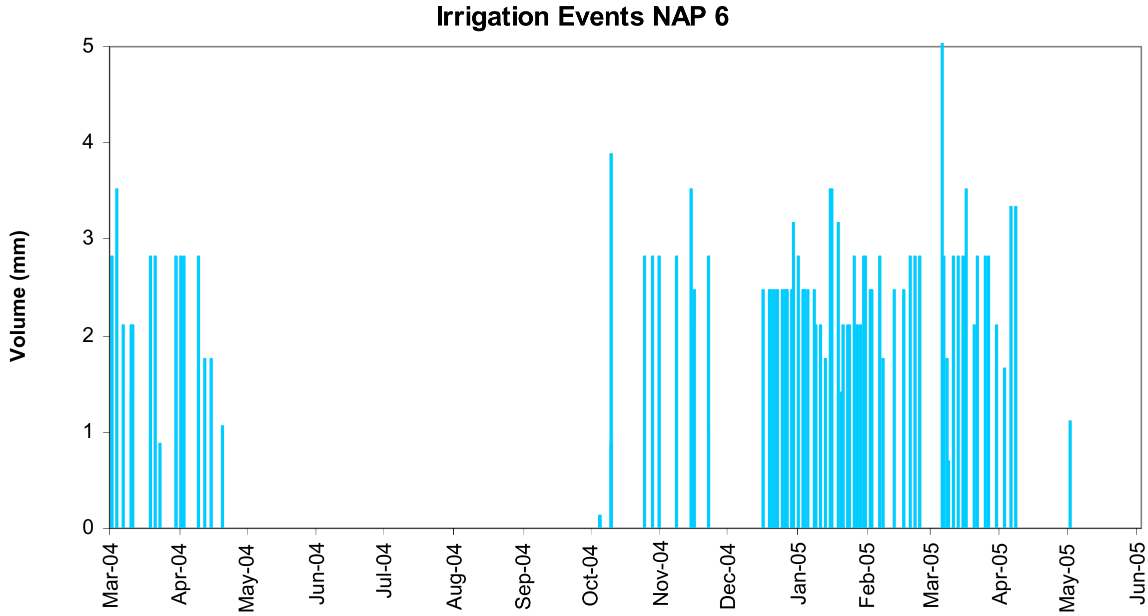


Figure 3.4 Time series of irrigation events at NAP 1 and NAP 2



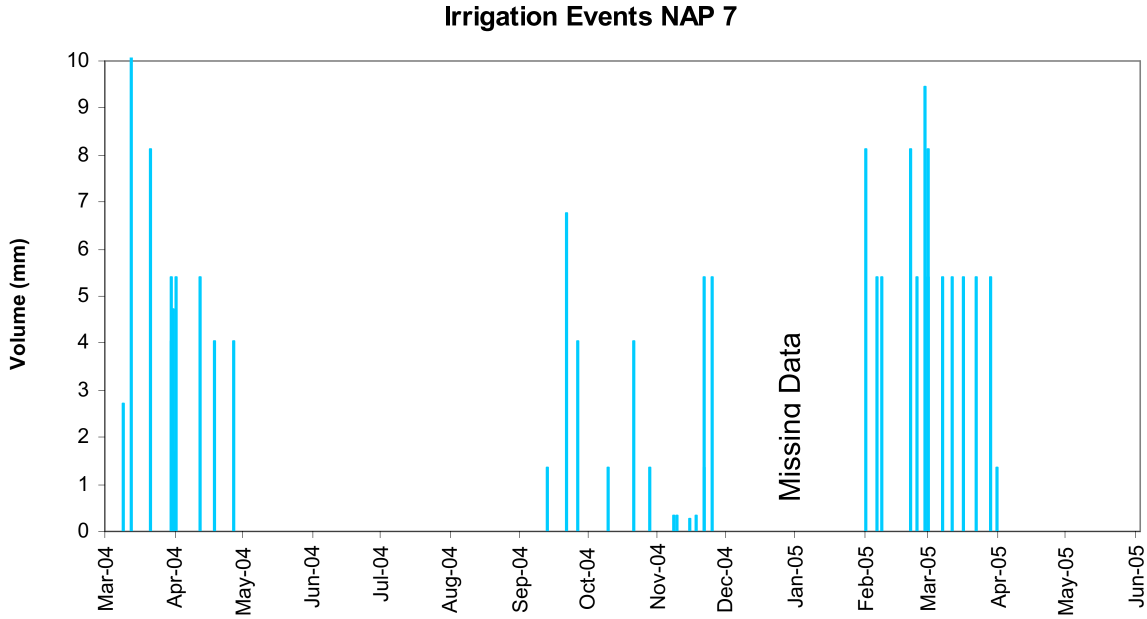
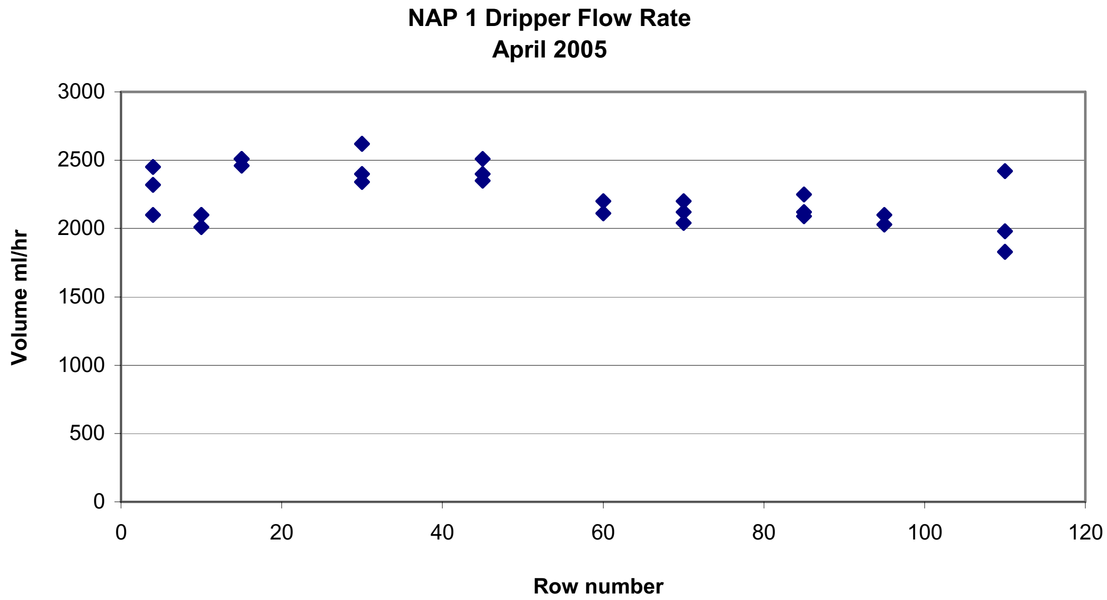


Figure 3.4 (continued) Time series of irrigation events at NAP 6 and NAP 7



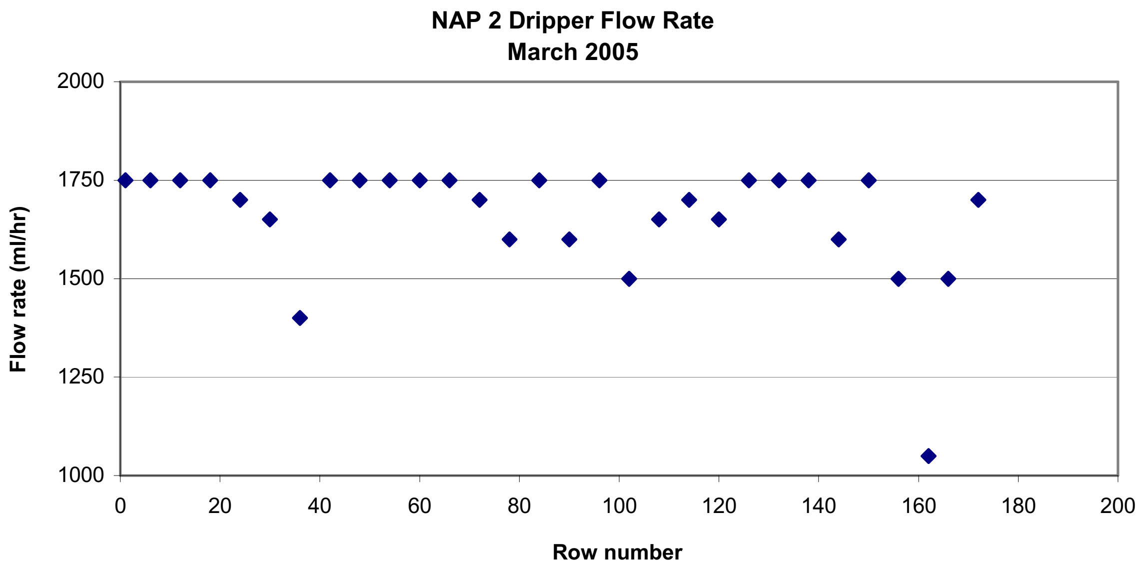
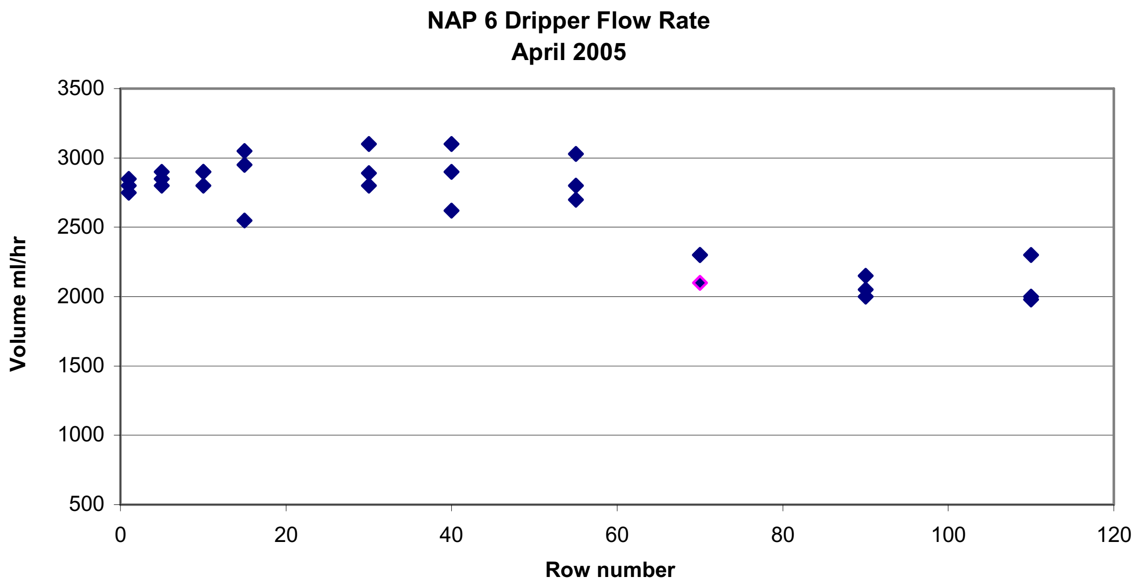


Figure 3.5 Dripper flow rate at NAP 1 and NAP 2



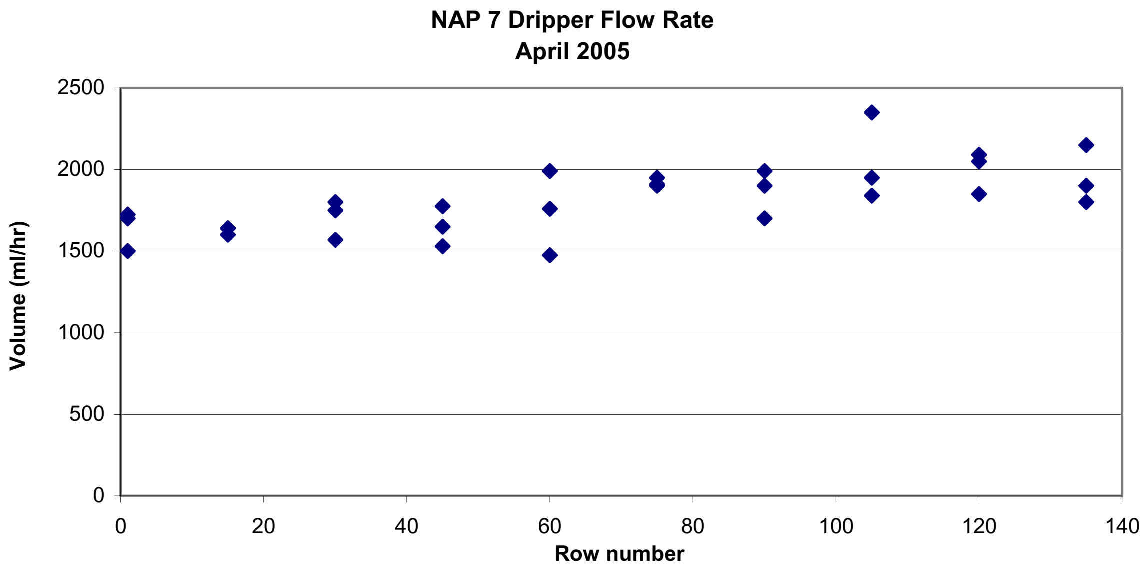


Figure 3.5 (Continued) Dripper flow rate at NAP 6 and NAP 7

Table 3.3 Chloride concentration in irrigation water (mg/L)

SITE	OBS NUMBER	Jan-04	Feb-04	Apr-04	Jun-04	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05
NAP 1	GLE 273	335	335	356	–	341	366	399	361	340
NAP 2	PAR 210	497	–	–	444	–	–	–	–	–
NAP 2	PAR 213	441	–	–	419	455	–	453	–	–
NAP 2	PAR 219	–	–	–	405	419	467	453	453	–
NAP 3	MAR 209	770	–	–	–	834	805	–	–	–
NAP 4	MAR 208	644	–	–	–	628	–	649	636	643
NAP 5	MAR 207	1200	–	–	–	1220	1260	1240	1250	–
NAP 6	GLE 279	497	505	510	–	511	503	493	528	–
NAP 7	GLE 287	454	–	–	–	–	488	495	–	486

The addition of fertiliser should also be considered, as in some cases fertiliser may contain a significant amount of chloride. The history of fertiliser application for each experimental site will be taken into consideration.

3.3 EVAPOTRANSPIRATION MEASUREMENTS

One CSIRO flux station along with 4 AWS (at each of the vineyard experimental sites) are being used to record direct measurements of vineyard water use on a paddock scale. Measurements began at NAP 6 in July 2003. Weekly rainfall and evapotranspiration from the flux station are presented in Figure 3.2. Over the life of the project the flux tower has been moved across different sites to sample a range of grape varieties, canopy architecture and soil type. The flux station was moved from to NAP 1 in August 2004 and then to NAP 7 in July 2005. The total actual evapotranspiration during 2004 at was 499 mm. Some of the results are summarised here. All results of the CSIRO vineyard water balance study will be included in a separate report being prepared by CSIRO.

3.4 SOIL WATER CONTENT

3.4.1 NEUTRON MOISTURE METER

Soil water content measured from the Neutron Moisture Meter is presented for vineyard sites NAP 1, 2, 6 and 7 (Figs. 3.7, 3.8, 3.9 and 3.10). Each site contains 12 neutron moisture access tubes (6 under the vine line and 6 within the inter row), spread across different grape varieties and soil types. Soil moisture measurements are being recorded at 50 cm increments to a depth of 3.45 m. For the 2003/04 season, measurements were taken monthly over the winter period and fortnightly over the irrigation period. During the 2004/05 season, the frequency was reversed to monthly over the irrigation season and fortnightly over the winter period.

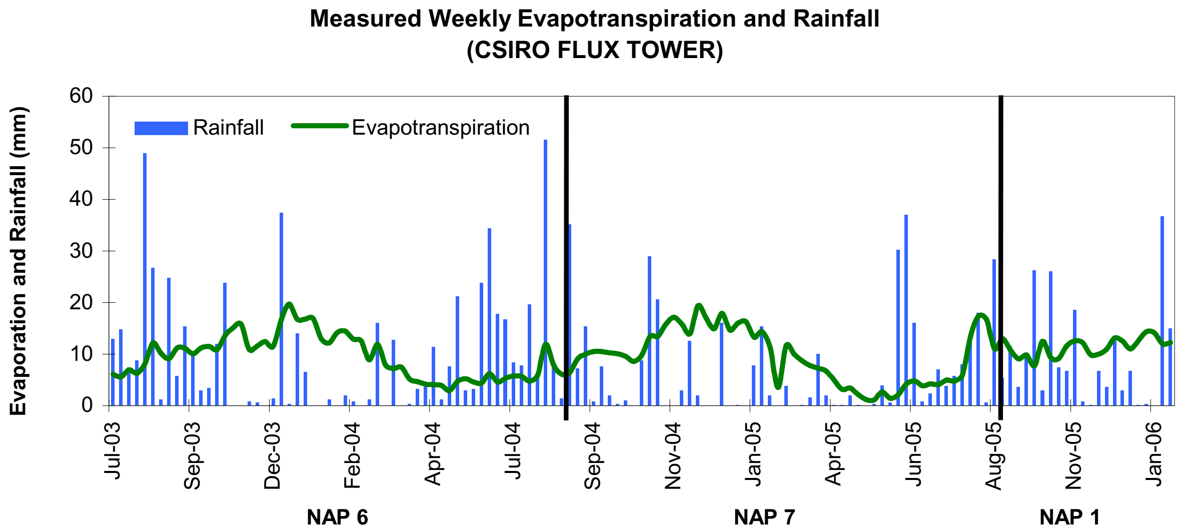


Figure 3.6 Weekly Evapotranspiration measured at NAP1, NAP6 and NAP7

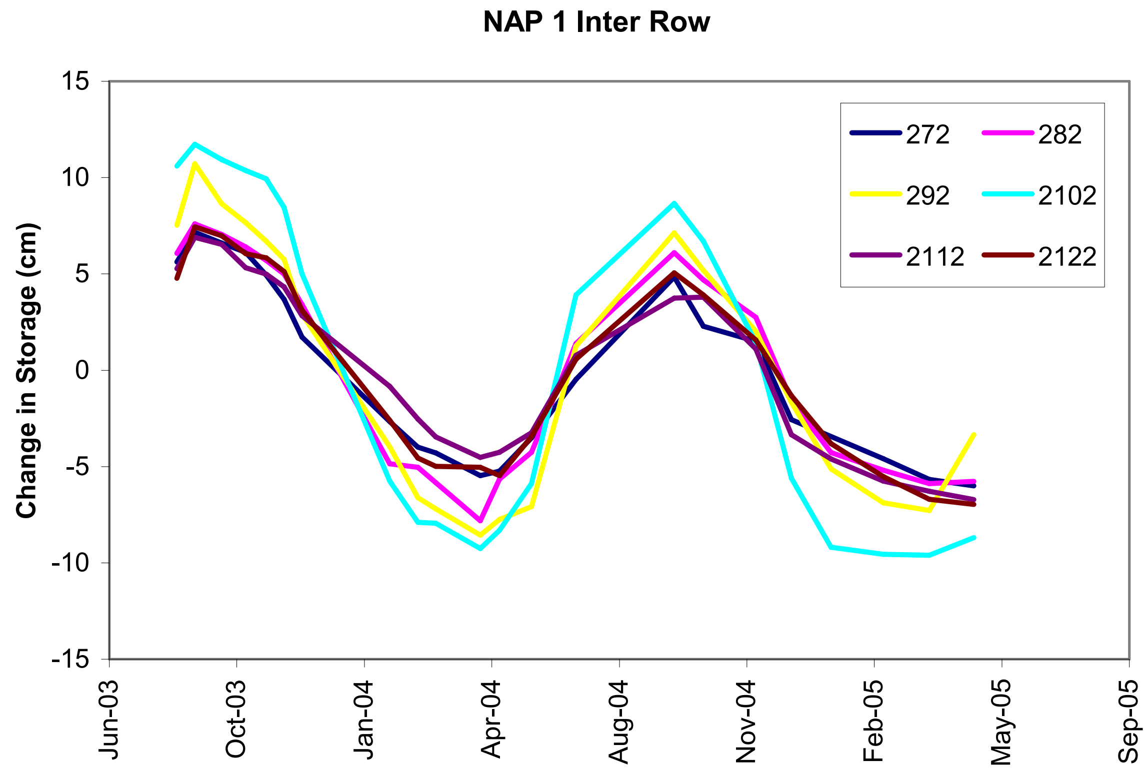
Figures 3.7, 3.8, 3.9 and 3.10 show the total change in stored water over the entire depth of the soil profile within the vine line and inter row. The data shows a seasonal amplitude in stored soil water of 40 to 80 mm and annual changes of about 0 to 20 mm. The stored soil water reaches its peak towards the end of winter (Aug to Sep), a period when drainage and salt movement is likely to occur and its lowest at the end of the growing season in May (Hutchinson Pers. Comm. 2004).

The greatest change in soil water occurs in the top 0.75 m of the soil profile. This depth corresponds to the topsoil. Below this depth lies a calcrete-topped limestone (Padthaway Formation). The large change in soil moisture at this depth is due to the presence of the bulk of the vine root system and influence of evaporation.

To calibrate the neutron probe readings to volumetric soil water content, two additional access tubes were installed at a cleared site near NAP 6, during March 2005 (MAP 2). One neutron access site was drilled within the root system of a large tree to represent a dry soil profile. The second neutron access site was drilled in an area where the soil profile can be easily 'wetted up' to field capacity. Once a number of neutron moisture readings have been recorded, soil cores will be retrieved during an excavation, to measure bulk density and gravimetric water content.

3.4.2 CAPACITANCE PROBES

The use of capacitance probes at NAP 2 and 6 provided a real time visual picture of the movement and change in soil water throughout the unsaturated zone and lag times of drainage after individual irrigation events (Figs 3.11 and 3.12). The greatest response from rainfall and irrigation is observed in the top 0.50 m (top soil). Below this depth, sensors are located within the limestone and indicate a gradual increase in soil moisture during January to April. It is not clear if this represents drainage as a result of irrigation and further interpretation is required.



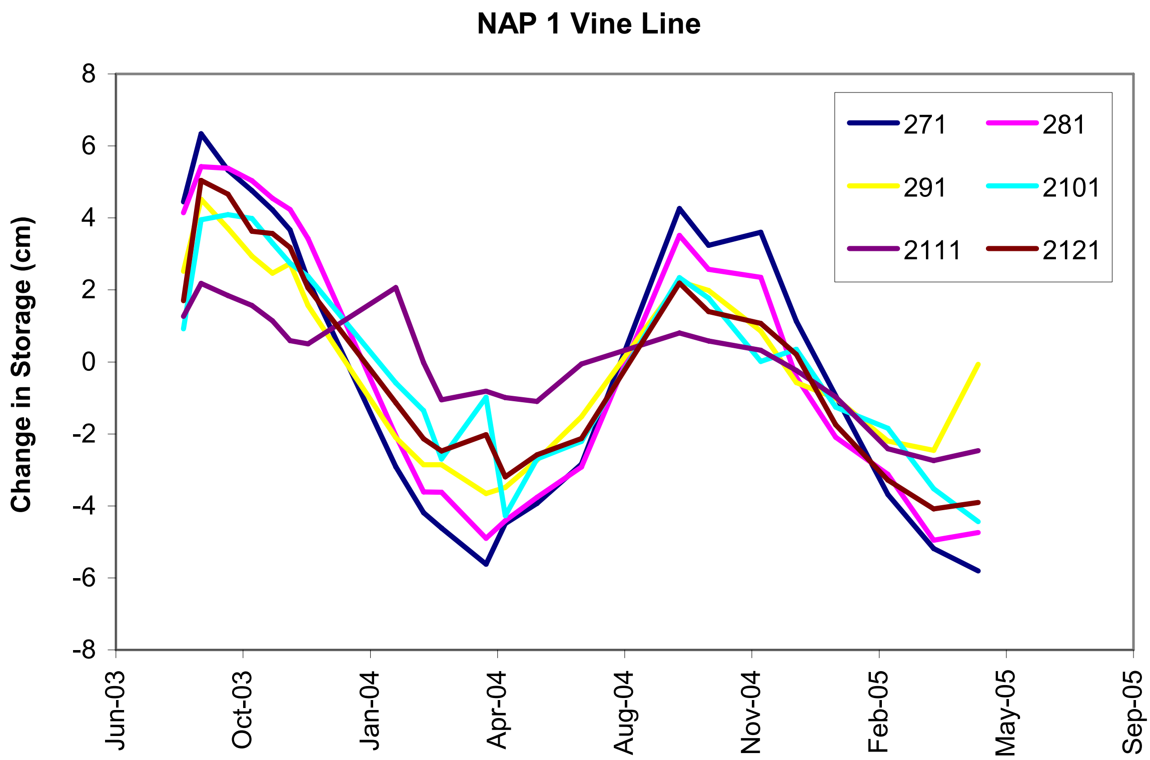
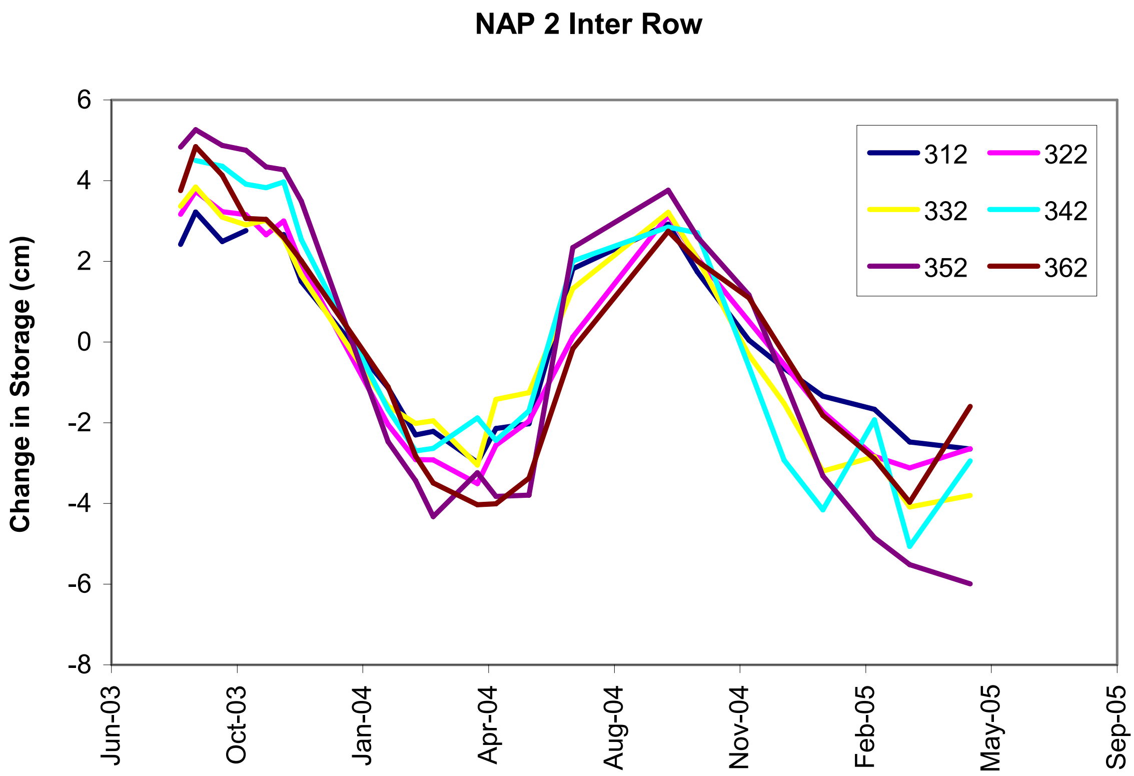


Figure 3.7 NAP 1, Total change in soil water content within the soil profile



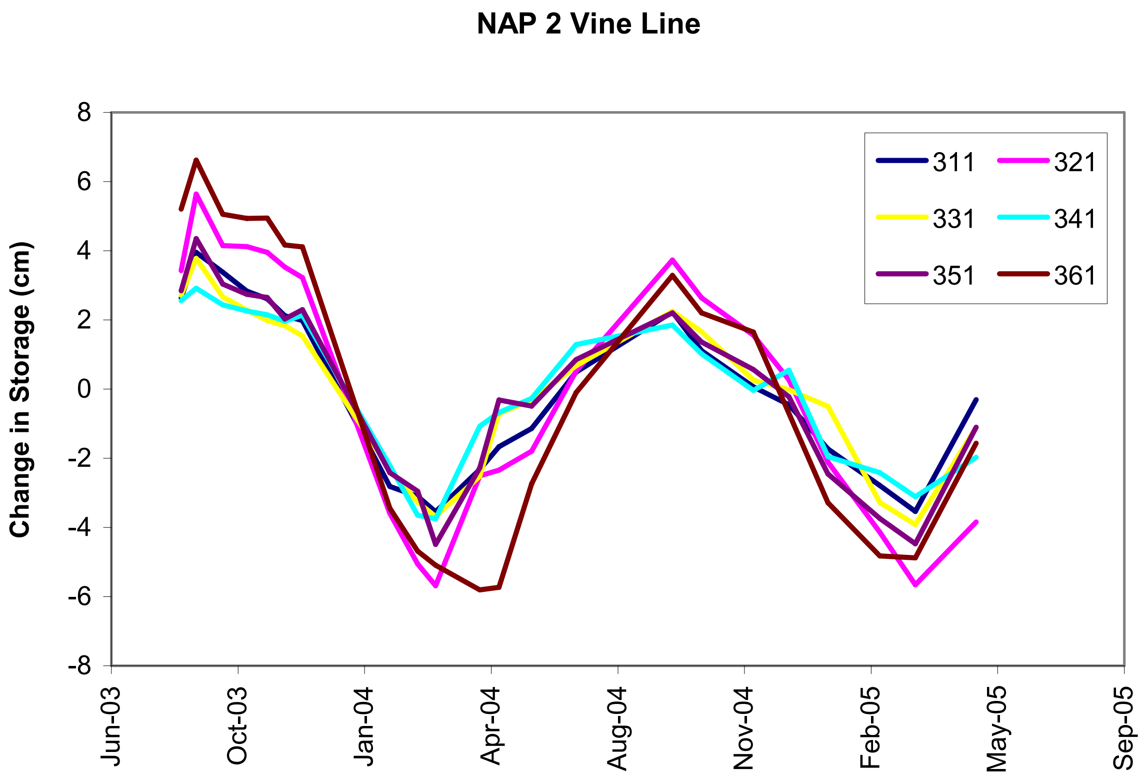


Figure 3.8 NAP 2, Total change in soil water content within the soil profile

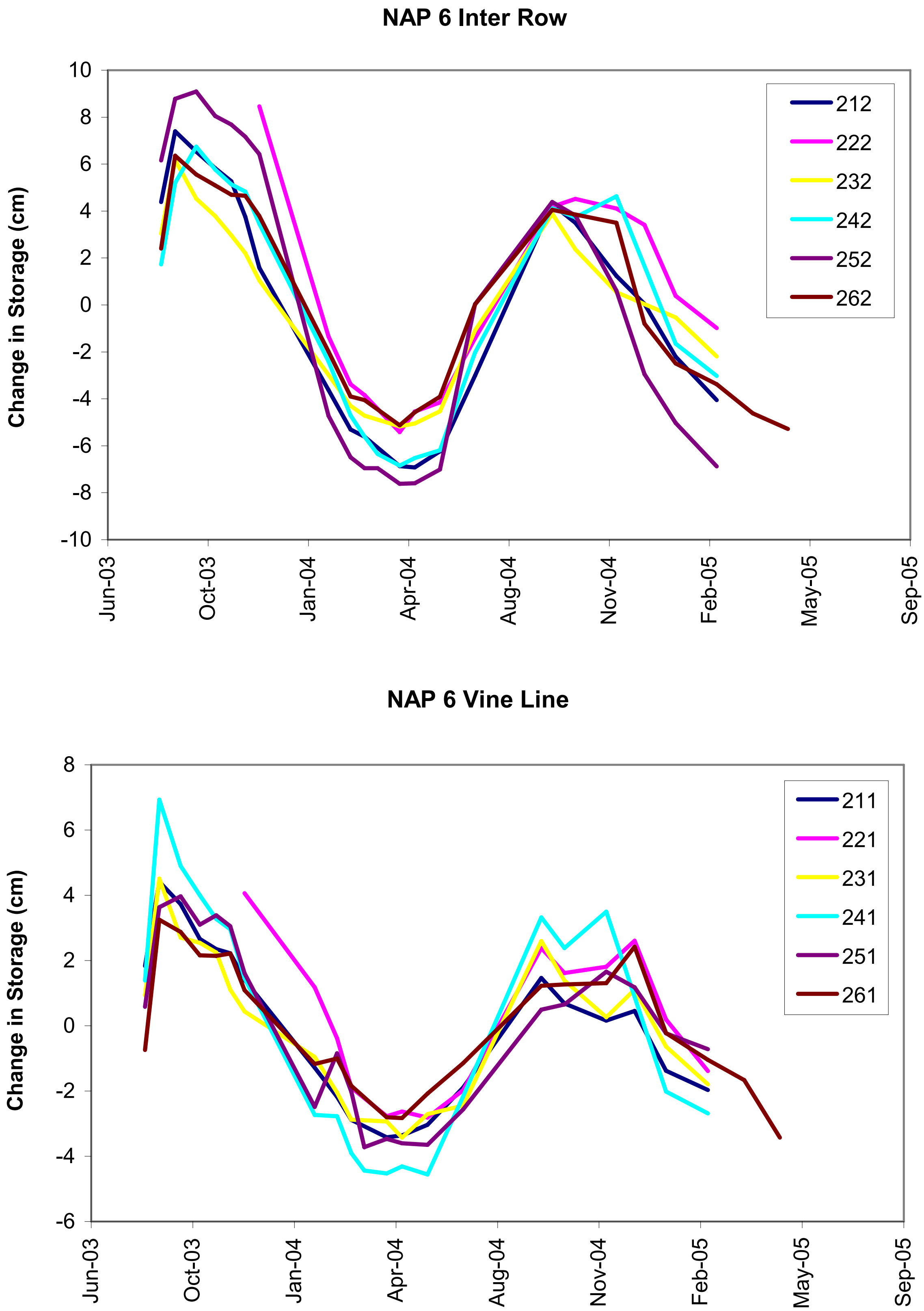
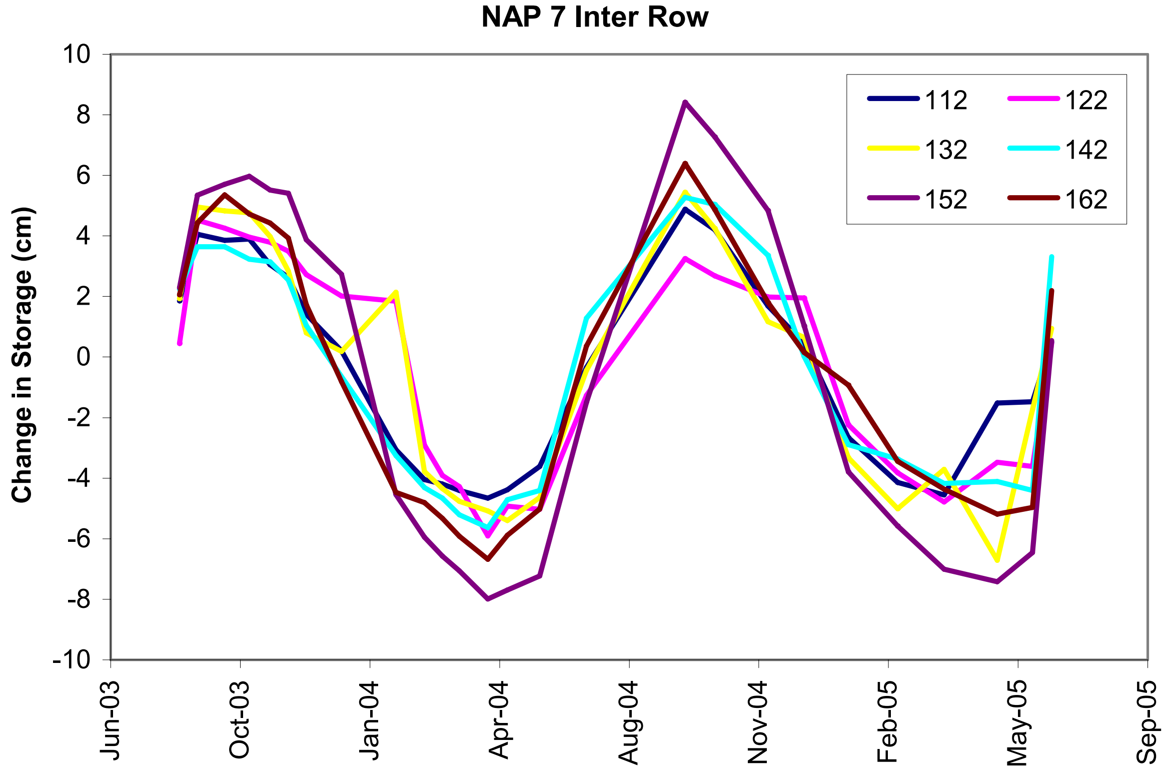


Figure 3.9 NAP 6, Total change in soil water content within the soil profile



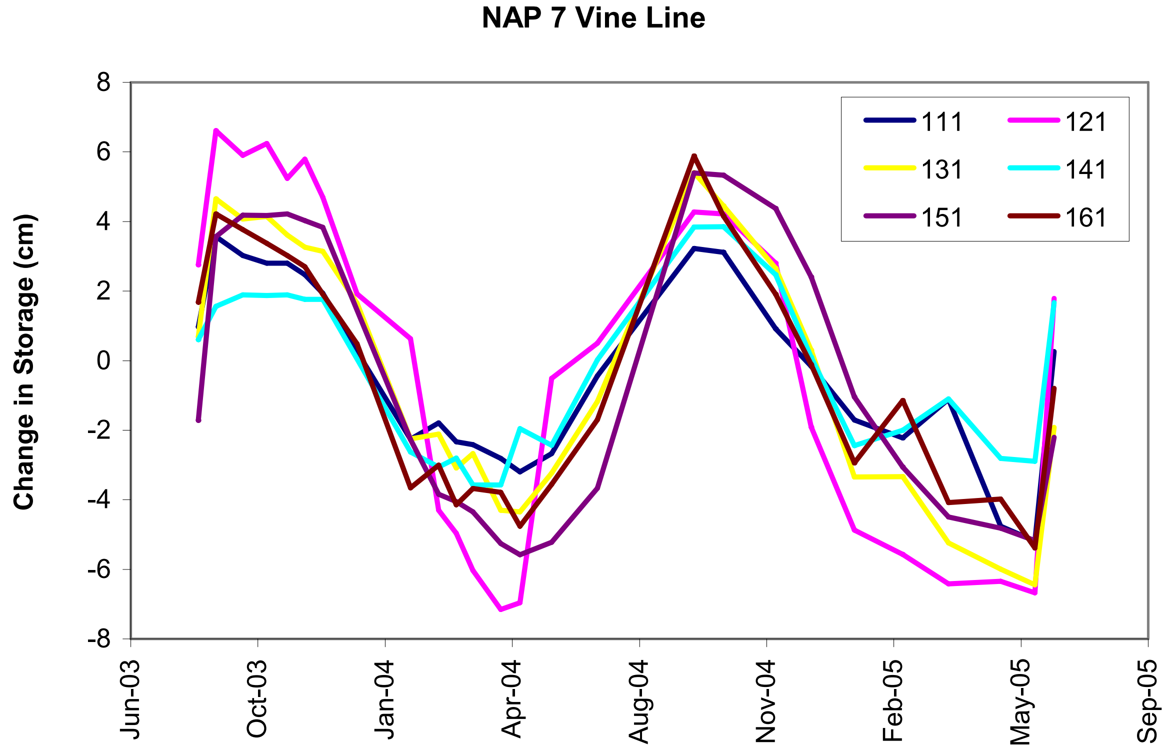


Figure 3.10 NAP 7, Total change in soil water content within the soil profile

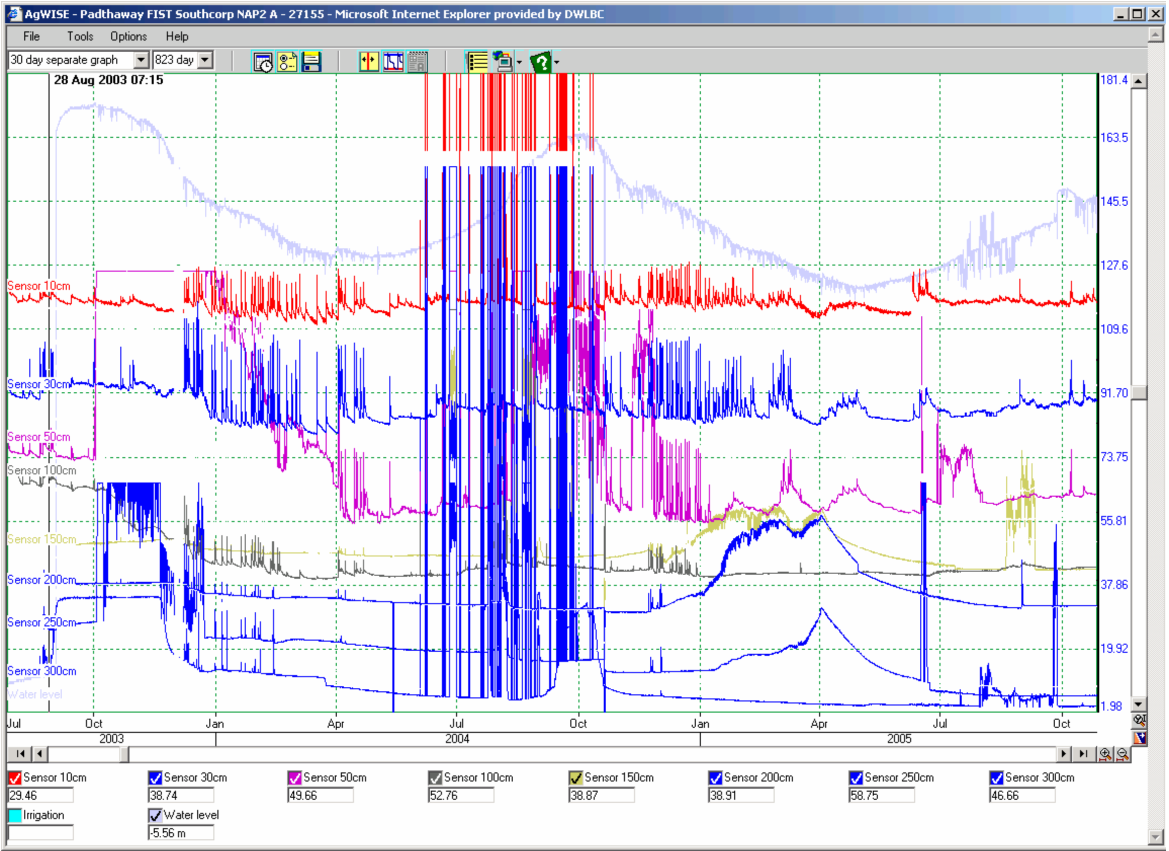
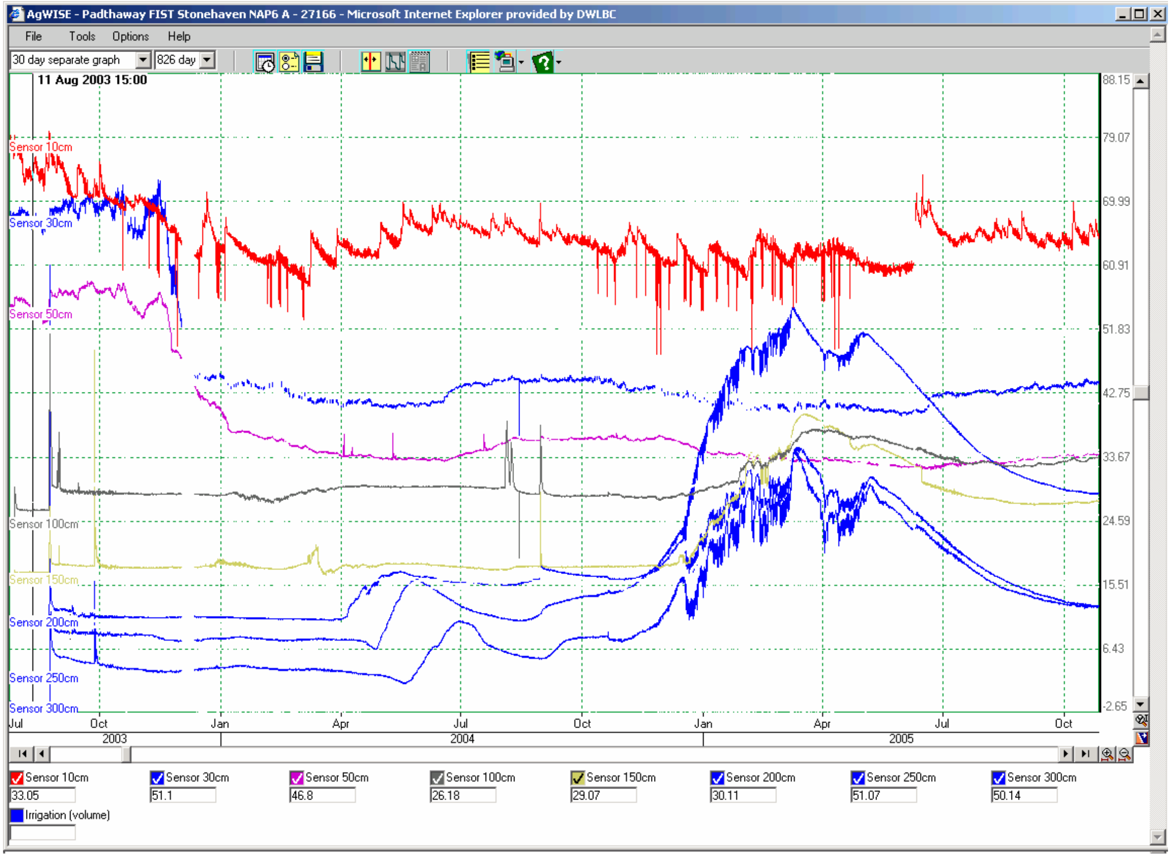


Figure 3.11 Soil moisture capacitance at NAP2A (above) and NAP2B (below)



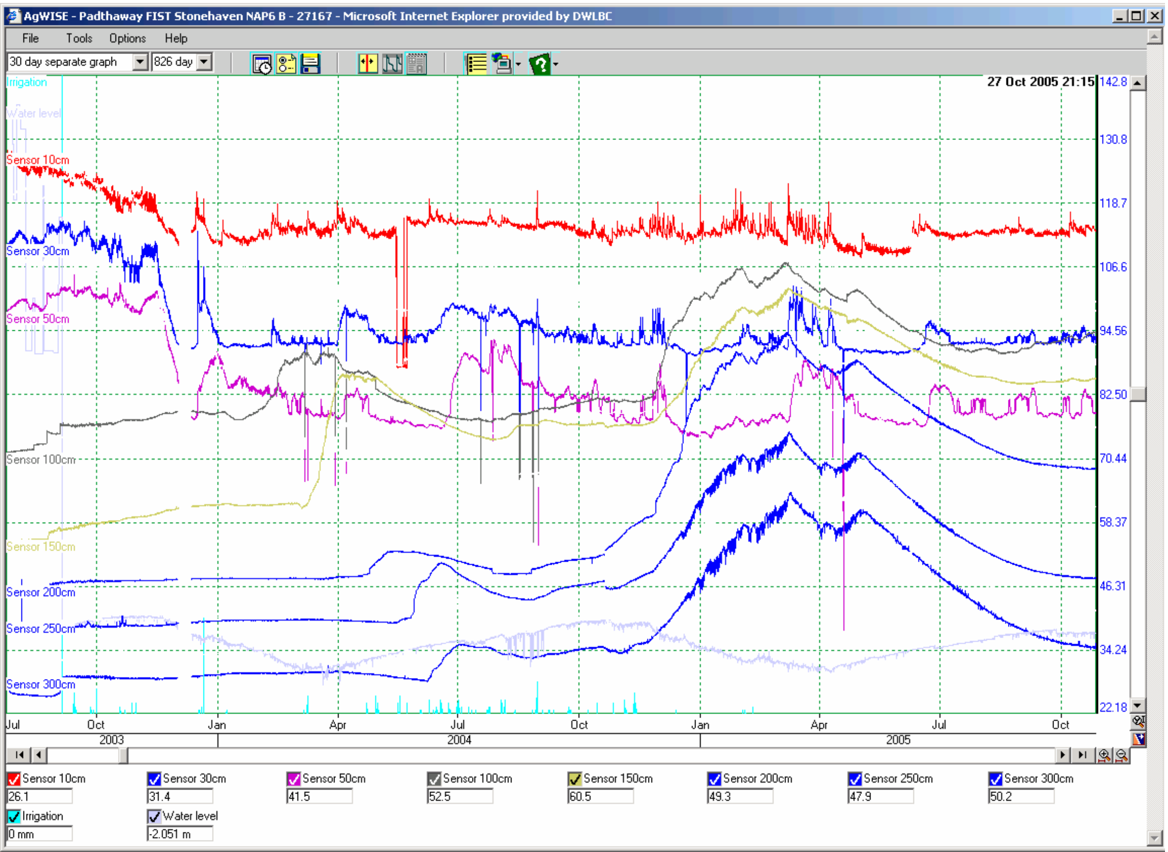


Figure 3.12 Soil moisture capacitance at NAP6A (above) and NAP6B (below)

Un-calibrated values from capacitance sensors at shallow depths are supportive of the NMM measurements, identifying periods of high water content from August to September and periods of greatest soil moisture deficit during February to May.

3.5 SOIL WATER SALINITY (CHLORIDE)

3.5.1 SUCTION LYSIMETERS

Monthly measurements of soil water salinity and chloride obtained from suction lysimeters under the vine row are presented for each vineyard experimental site (Figs 3.13, 3.14, 3.15 and 3.16 and tabulated in App. C) at depths of 0.30, 1, 2 and 3 m within the vadose zone. The extent of the root zone occurs at a depth of around 1 to 2 m. In some cases, data gaps exist due to insufficient amount of water being extracted out of the suction lysimeters.

The suction lysimeter data shows higher chloride concentrations at 1 m depth (root zone) across all sites, indicating a greater influence of evapotranspiration by the vines in the vine row. Soil water chloride measured in suction lysimeters in the root zone below the vines range between ~2000 mg/L and 4700 mg/L (average TDS = 3500 mg/L and 8060 mg/L).

A comparison of soil water chloride at the four vineyard sites shows that soil water chloride is highest at experimental sites NAP 1 and NAP 7 (2400–4700 mg/l, TDS = 3900–8060 mg/L) when compared to experimental sites NAP 2 (980–2600 mg/l, TDS = 2000–5200 mg/L) and NAP 6 (800–1200 mg/l, TDS = 2000–3500 mg/L). Both NAP 1 and NAP 7 overlay a similar soil type, comprised of mottled brown clay. Slower percolation may have lead to higher evapoconcentration within these soil types.

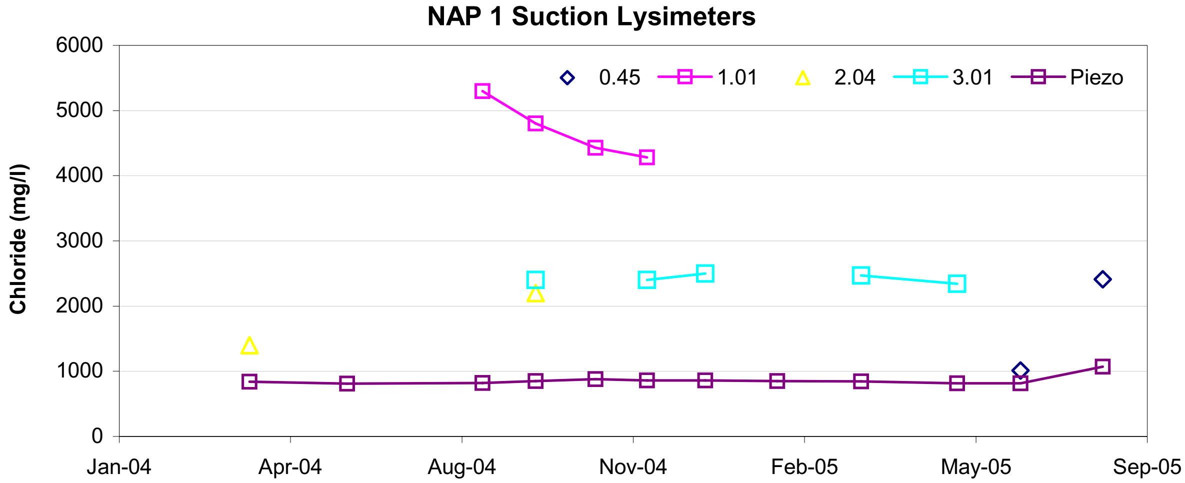
In general, slight changes in soil water salinity are observed in the top 1 m of the soil profile. At greater depths, limited data from all sites suggests soil water salinity is relatively constant throughout the year. Fluctuations in soil water salinity over the time scale of a year are negligible. Slight shifts in chloride concentration suggest slight build up and leaching of salt during the year, but the net effect on salt storage over time scales longer than a year is zero.

3.5.2 EXCAVATED CORE

At all vineyard sites soil cores were retried during an excavation in the vine row. Soil cores were analysed for practical size distribution (% clay, % silt and % sand), soil water chloride $[Cl]_{sw}$, Water content (θ_g) and soil water suction (SWP). These properties are tabulated in Appendix A. This data will assist in the development of unsaturated flow models under the irrigation sites. The methodology and results of the modelling will be presented in Volume 3.

The vertical distribution of soil water chloride measured from cores taken from the mid row along with soil water chloride collected from the lysimeters (vine row) suggest an active root system to a depth of 1 m at NAP 1 and 2 m at NAP 6 (Figs 3.17 and 3.18). The presence of a hard impermeable calcrete layer commonly found at the same depths may further concentrate the salts through evaporation from the surface of this layer.

The variability in the chloride maximums is attributed to the difference in soil type. NAP 1 overlays a mottled grey clay top soil (~0.50 m thick) and NAP 6 overlies a deeper Terra Rossa top soil (1.5–2 m thick).



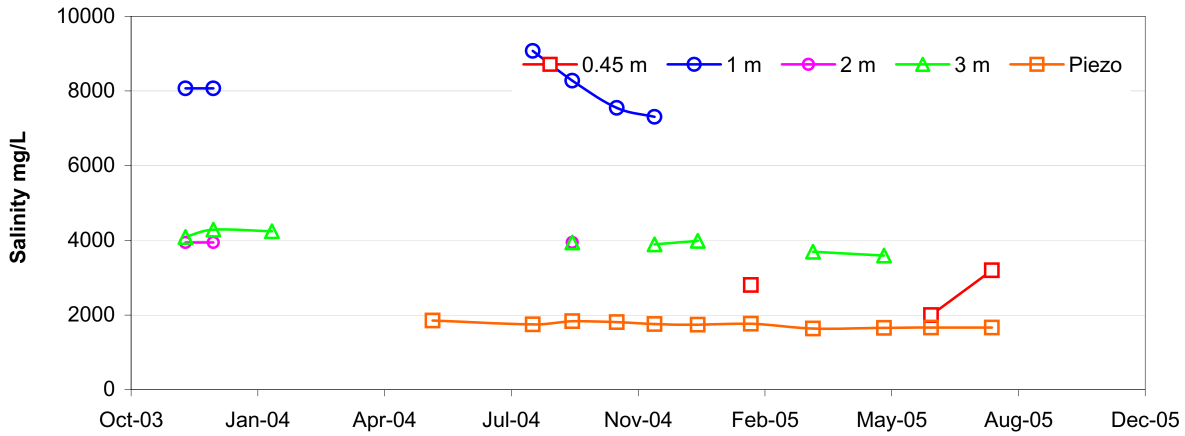
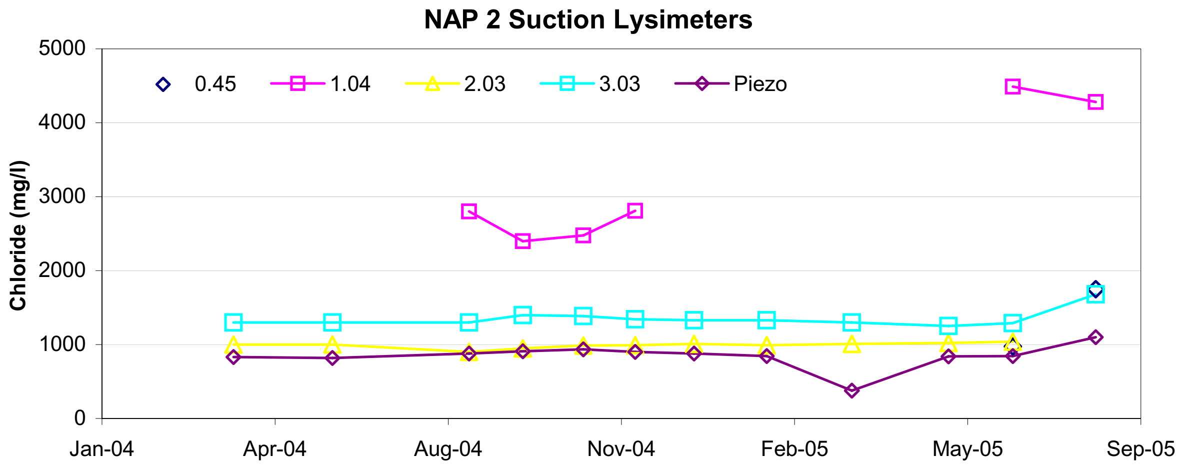


Figure 3.13 NAP 1, Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity



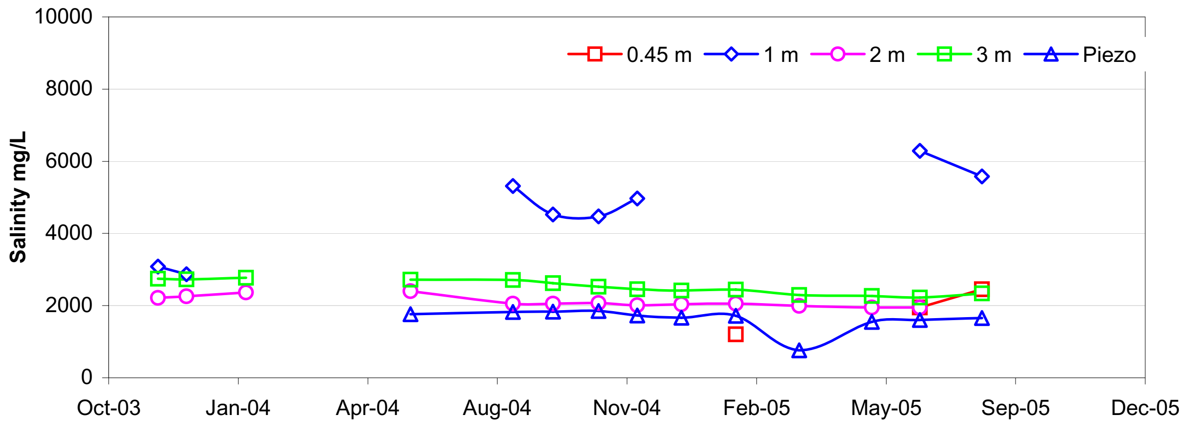
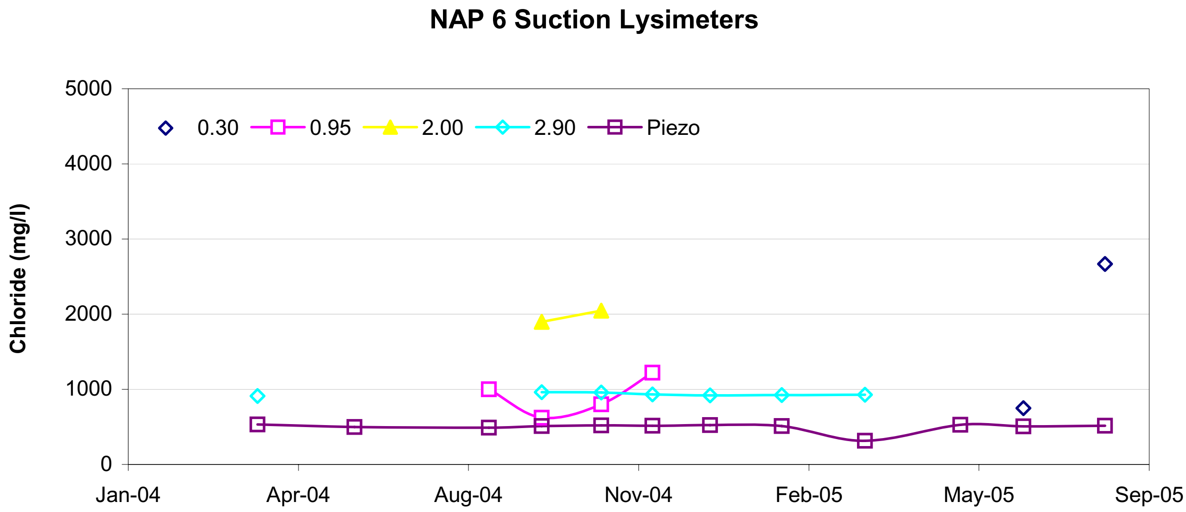


Figure 3.14 NAP 2, Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity



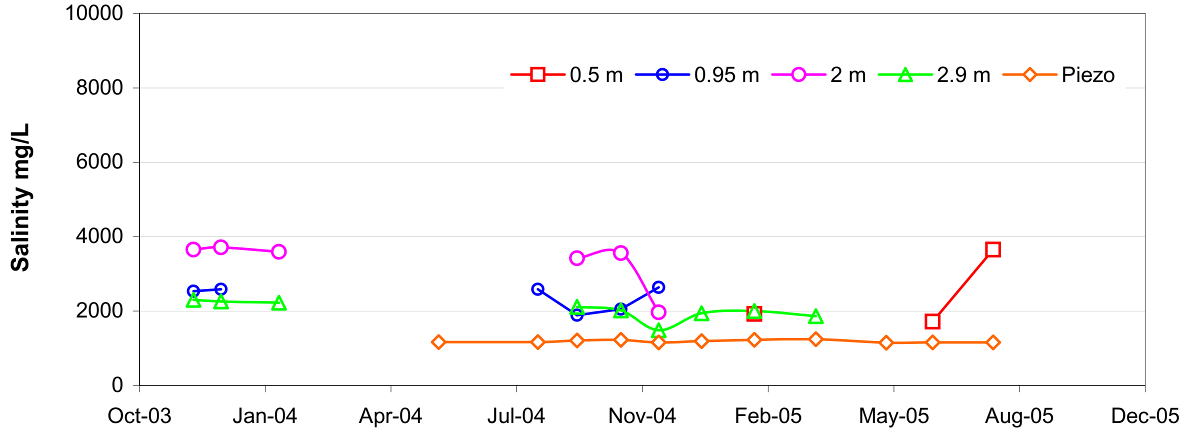
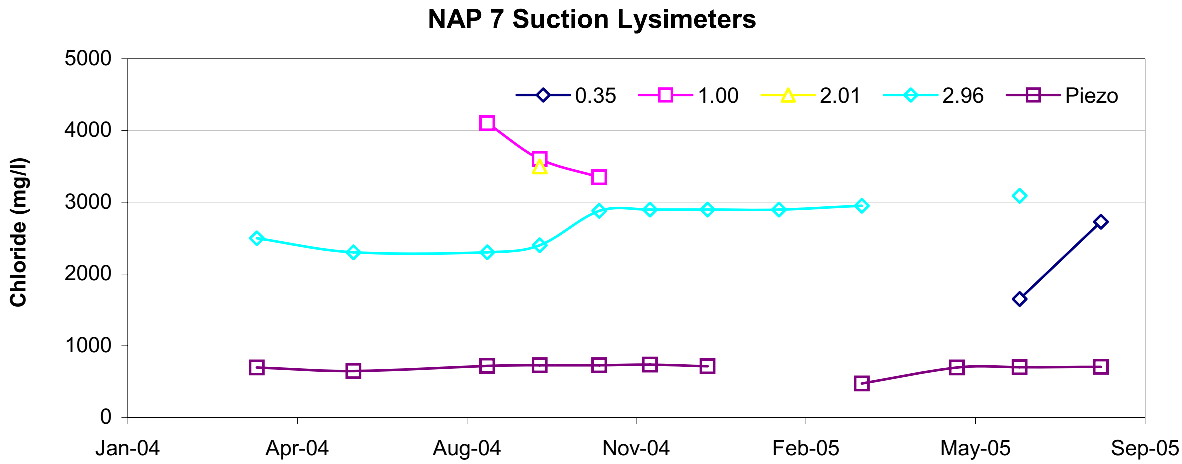


Figure 3.15 NAP 6, Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity



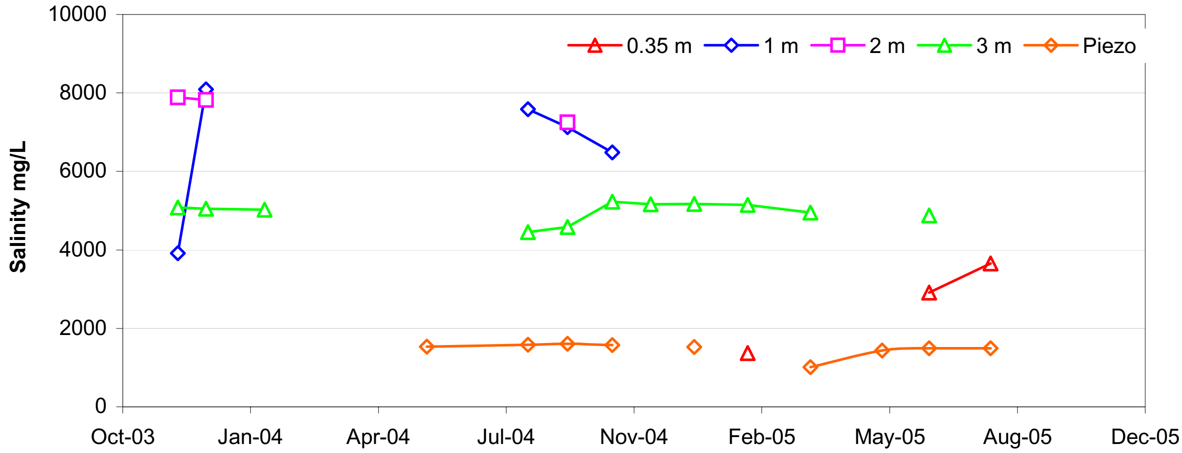


Figure 3.16 NAP 7, Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity

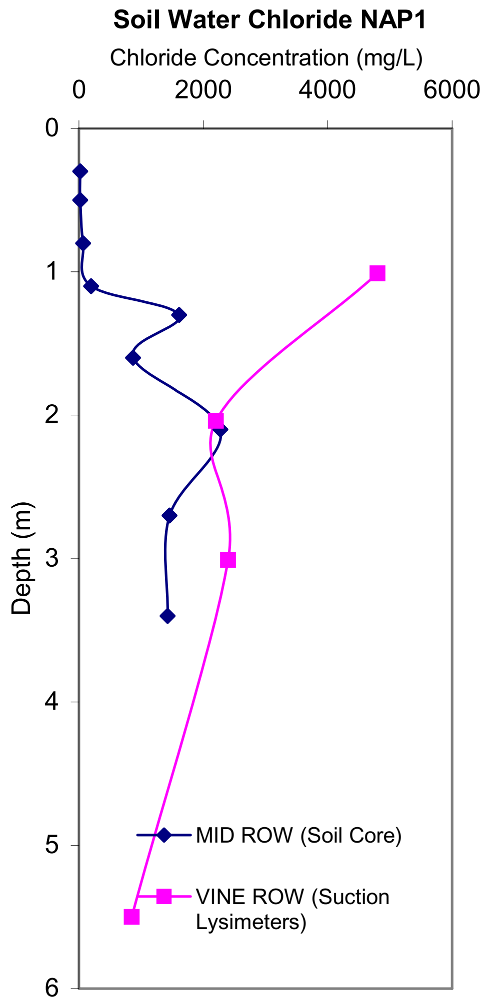


Figure 3.17 NAP 1, Vertical distribution of soil water chloride

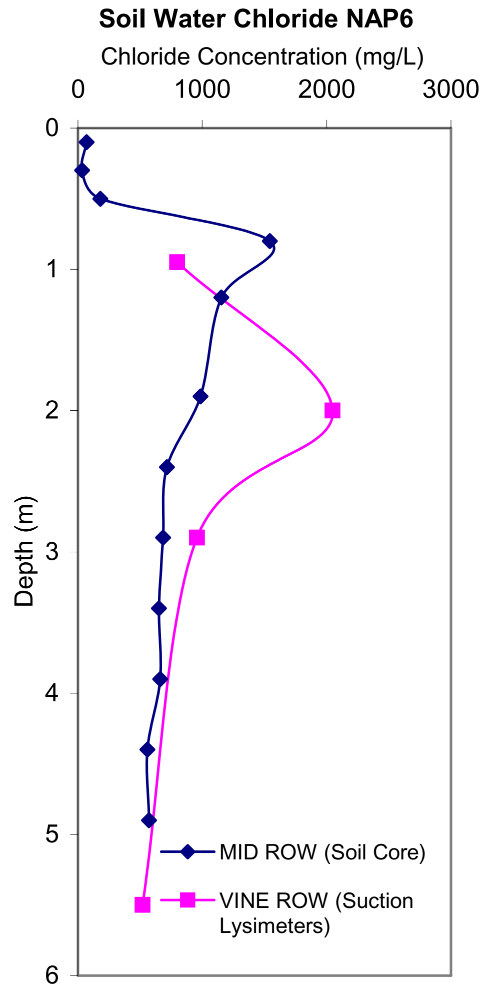


Figure 3.18 NAP 6, Vertical distribution of soil water chloride

A comparison of soil water chloride collected from the soil core (mid row) and suction lysimeters (vine line) indicate that the concentration of soil water chloride in the mid row is lower than soil water chloride under the vine line, as little or no irrigation reaches this area (Figs 3.17 and 3.18). Under the vine line, the salinity is higher as this part of the soil is regularly irrigated with groundwater. At NAP 6, the effects of ripping in the vine row might explain the presence of the chloride bulge, which exists at a greater depth (2 m) than observed in the mid row (1 m), thereby allowing deeper root growth and salt movement past the upper broken calcrete layer.

4. RESULTS FROM THE PADTHAWAY PLAINS CENTRE PIVOT IRRIGATION - NAP3 (COMPONENT 3)

4.1 IRRIGATION AND PRECIPITATION MEASUREMENTS

At The centre pivot site NAP3, 39 ha of lucerne is irrigated from irrigation well MAR 209. The irrigation water has an average chloride concentration of 800 mg/L (TDS = 1760 mg/L). Two rain gauges (East and West) have measured rainfall as well as irrigation application from each rotation of the centre pivot over the 2003/04 and 2004/05 irrigation seasons (Fig. 4.1). A lack of maintenance by Agrilink Pty Ltd has compromised the data, with the rain gauge located at the eastern site being more reliable than rain gauge at the western site.

Based on the amount of irrigation captured by the eastern rain gauge (minus the amount of rainfall measured at nearby experimental site NAP 4) 565 mm/ha of irrigation was applied in 2003/04 and 485 mm/ha of irrigation was applied in 2004/05.

A flow meter installed on the irrigation bore has failed to capture a complete season of groundwater extraction. The flow meter was replaced in October 2005 and irrigation volumes will be refined over the 2005/06 irrigation season.

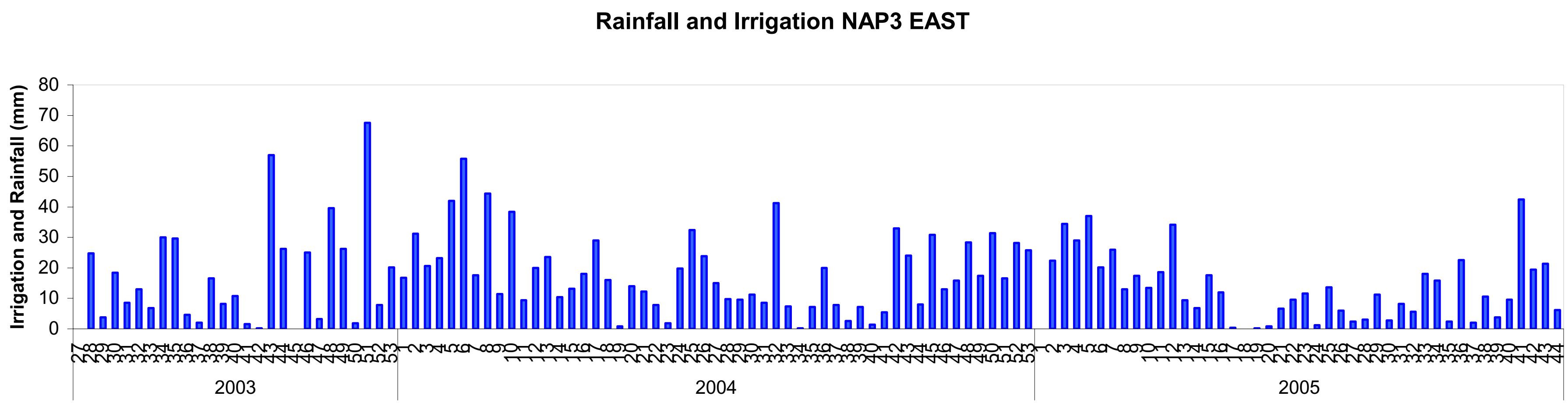
4.2 EVAPOTRANSPIRATION MEASUREMENTS

Estimates of evapotranspiration for lucerne were calculated using the FAO56 methodology from Class A Pan evaporation data provided by the Bureau Of Meteorology (refer to volume 1 for methodology). Monthly crop coefficients for lucerne were sourced from Desmier 1992. The total crop water use (ET) during 2004 was slightly above average ranging from 934 mm for lucerne seed and 1074 mm for lucerne hay (Fig. 4.2). Crop water use almost balances irrigation and rainfall during the irrigation season, which means that no drainage occurred during the period.

4.3 SOIL WATER CONTENT (CAPACITANCE PROBE)

The use of capacitance probes provided a real time visual picture of the movement and change in soil water throughout the unsaturated zone and lag times of drainage after individual irrigation events (Fig. 4.3). The greatest response from rainfall and irrigation are observed in the top 0.50 m (top soil). The c-probes show rapid drainage to a depth of 150 cm after each irrigation event.

Un-calibrated values from capacitance sensors at shallow depths identified periods of high water content from May to September, a period when drainage is likely to occur, and periods of greatest soil moisture deficit during October to January, a period when rainfall and irrigation is balanced by crop water use (ET).



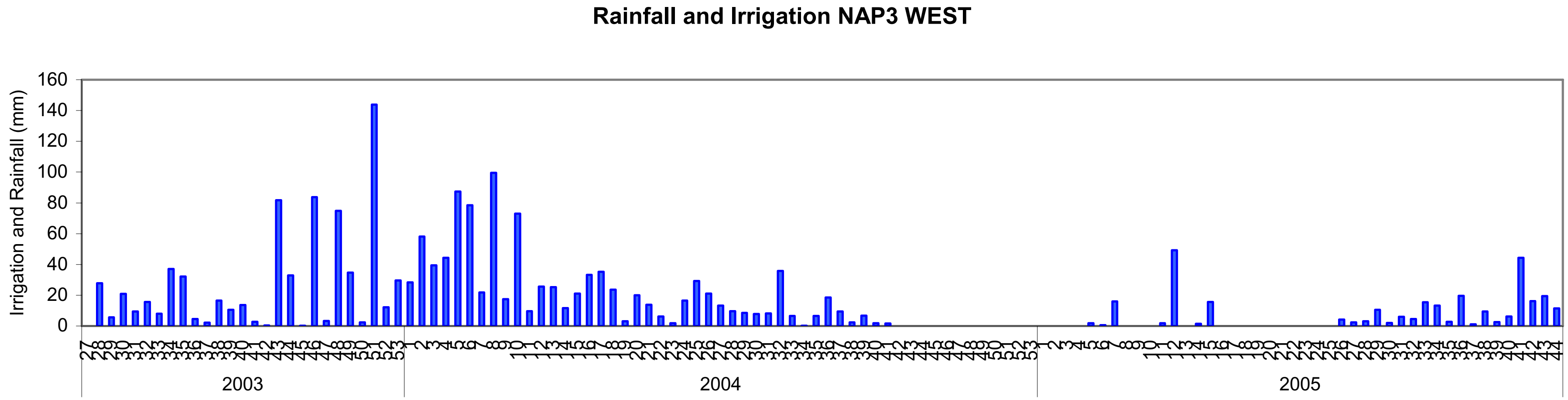


Figure 4.1 Weekly Rainfall and Irrigation

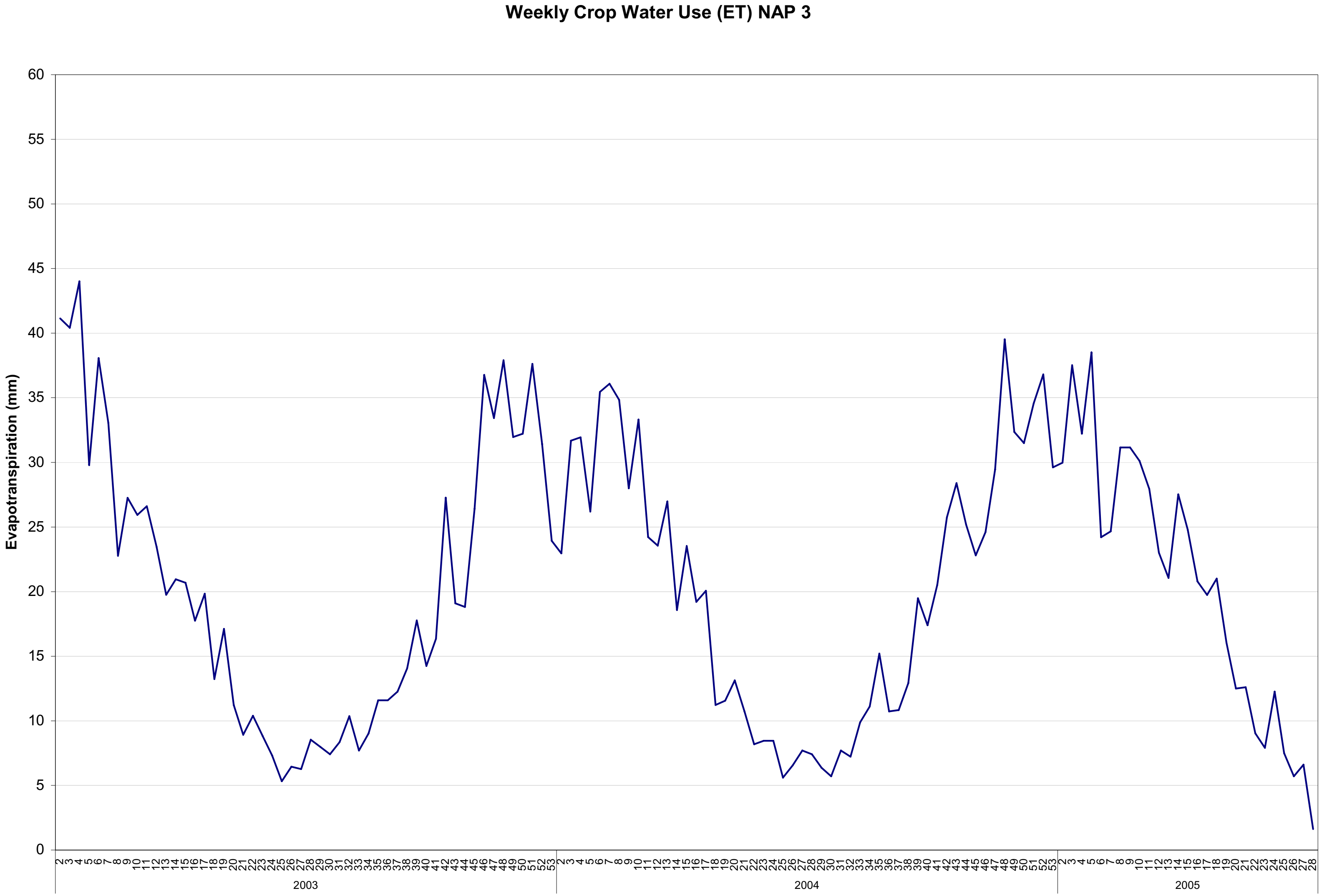


Figure 4.2 Crop Water use (ET) NAP3

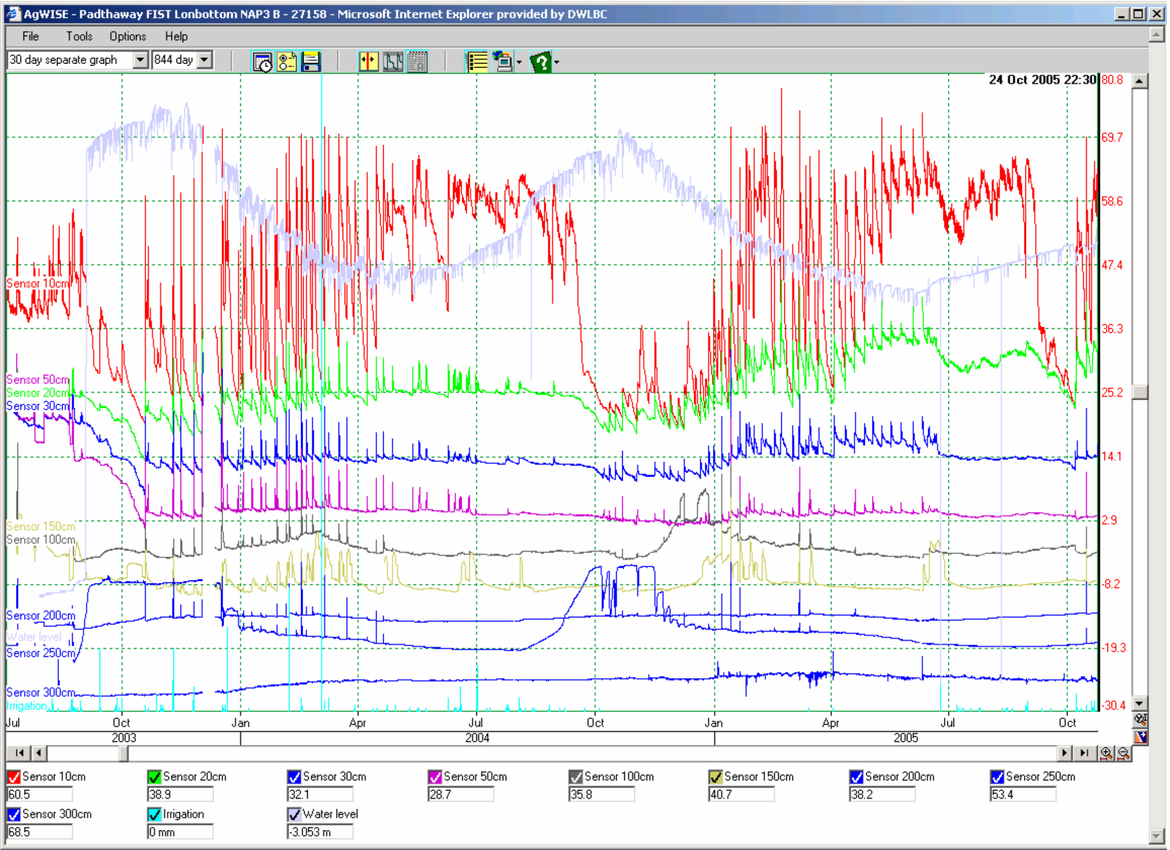


Figure 4.3 Soil moisture capacitance at NAP3 WEST (above) and NAP3 EAST (below)

4.4 SOIL WATER SALINITY (CHLORIDE)

4.4.1 SUCTION LYSIMETERS

Two sets of suction lysimeters at depths of 0.5, 1 and 2 m are positioned under the pivot at NAP3 (Fig. 1.3). In August 2004 an additional lysimeters was installed at a depth of 0.35 m. Monthly measurements of soil water salinity and chloride (mg/L) from suction lysimeters are presented for both the eastern and western sampling sites (Fig. 4.4).

The average soil water salinity at site NAP3 is two to three times greater than the concentration of irrigation water. The soil water chloride is slightly higher at the eastern site where it ranges from 1700 mg/L at 0.5 m to 3250 mg/L at 2 m (TDS = 3000–5850 mg/L), compared to the western site where the soil water chloride ranges from 2000 mg/l at a depth of 0.5 m to a maximum of 3500 mg/L at a depth of 2 m (TDS = 3130–4800 mg/L) (Fig. 4.4).

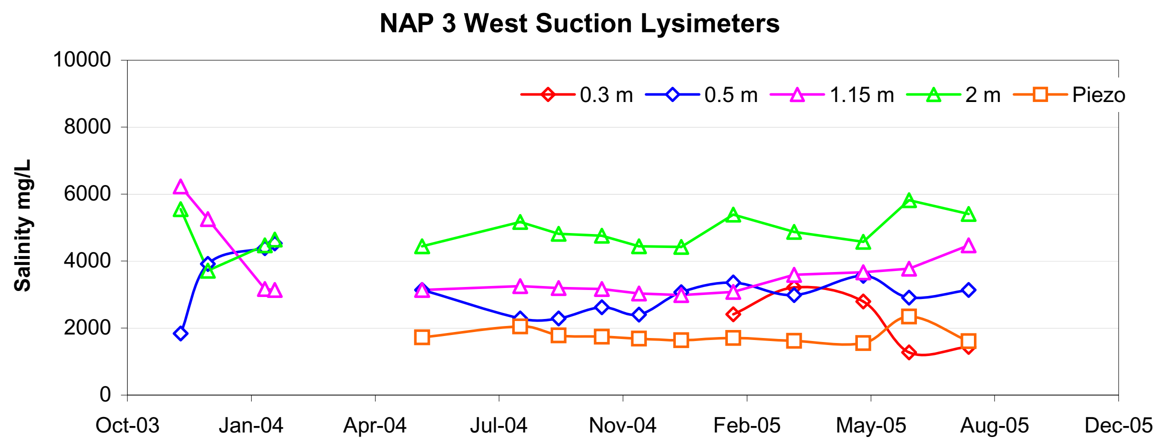
Seasonal fluctuations can be observed at depth, with a steady increase in salt concentration over the sampling period. The greatest increase in soil water salinity was observed during the irrigation season, in the 1 m lysimeter at both eastern and western sites, where the chloride concentration increased from 2000 mg/L in August 2004 to 4000 mg/L in June 2005.

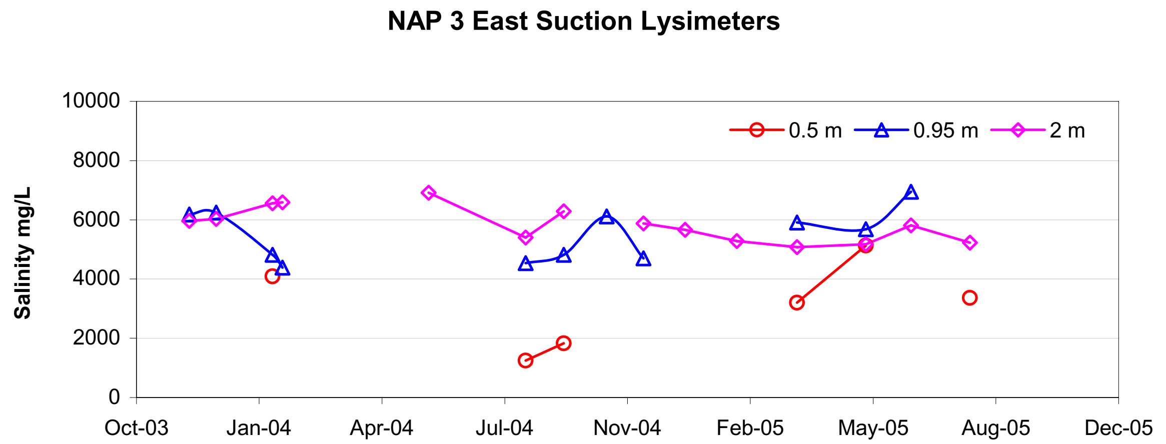
Additional sampling is required to determine whether this represents an actual increase in salt storage over time.

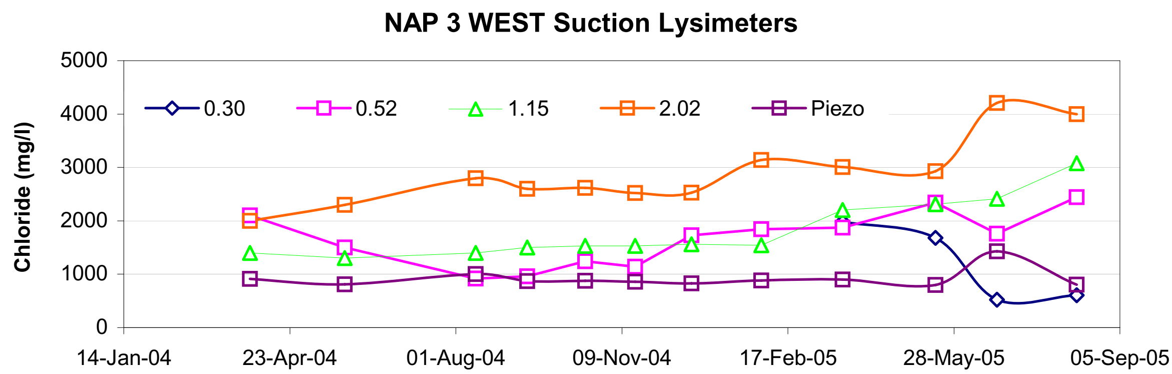
4.4.2 SOIL CORE

Soil cores were retrieved during the drilling for the installation of piezometers and analysed for soil water chloride, practical size distribution, water content and soil water suction, (refer to Volume 1 for methodology). Results from the analyses are presented in Appendix A.

The vertical distribution of chloride measured from cores indicates a high concentration of salt (chloride concentration of 1800 mg/l) at a depth of 1 m to 2.5 m (Fig. 4.5). Generally, the soil water chloride results obtained from the cores are in agreement with the soil water chloride obtained from the suction lysimeters shortly after coring.







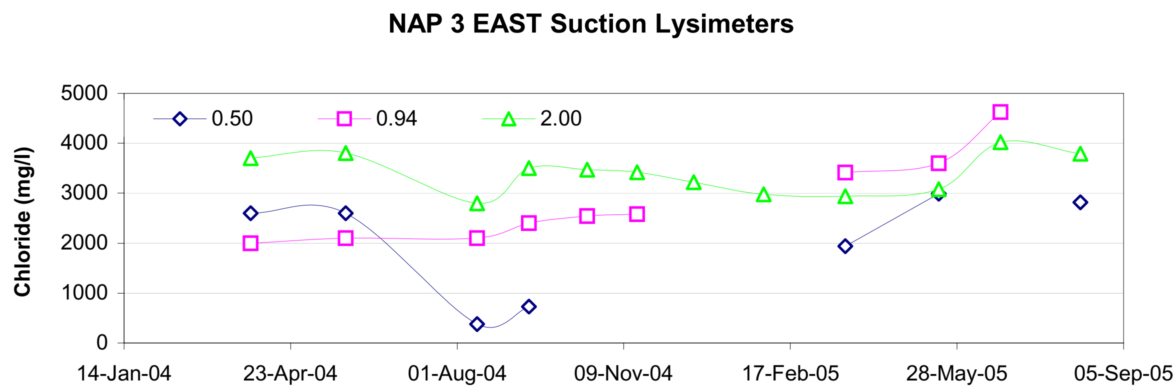


Figure 4.4 Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity

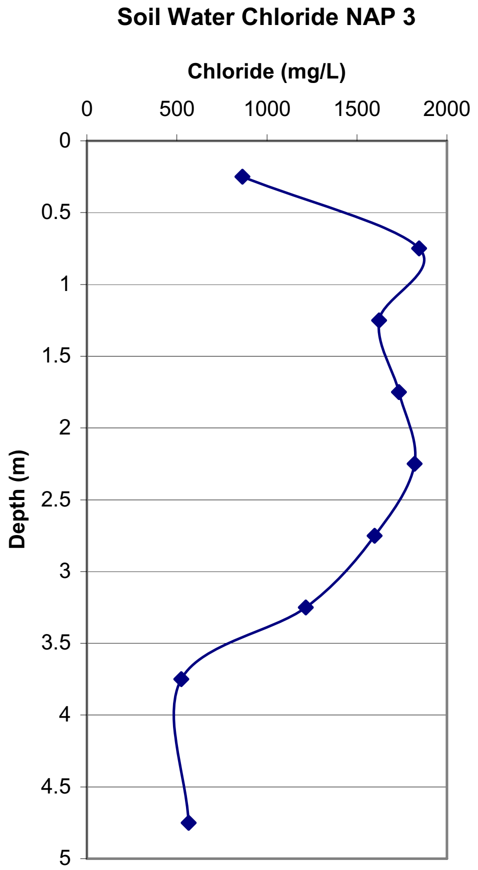


Figure 4.5 Vertical distribution of soil water chloride (Western Site)

5. RESULTS FROM THE PADTHAWAY PLAINS FLOOD IRRIGATION SITES NAP4 AND NAP5 (COMPONENT 3)

5.1 PRECIPITATION AND IRRIGATION MEASUREMENTS

A rain gauge at each site has been recording daily precipitation since July 2003 (Fig. 5.10). During 2004, NAP 4 and NAP 5 recorded below average rainfall of 410 mm and 438 mm respectively.

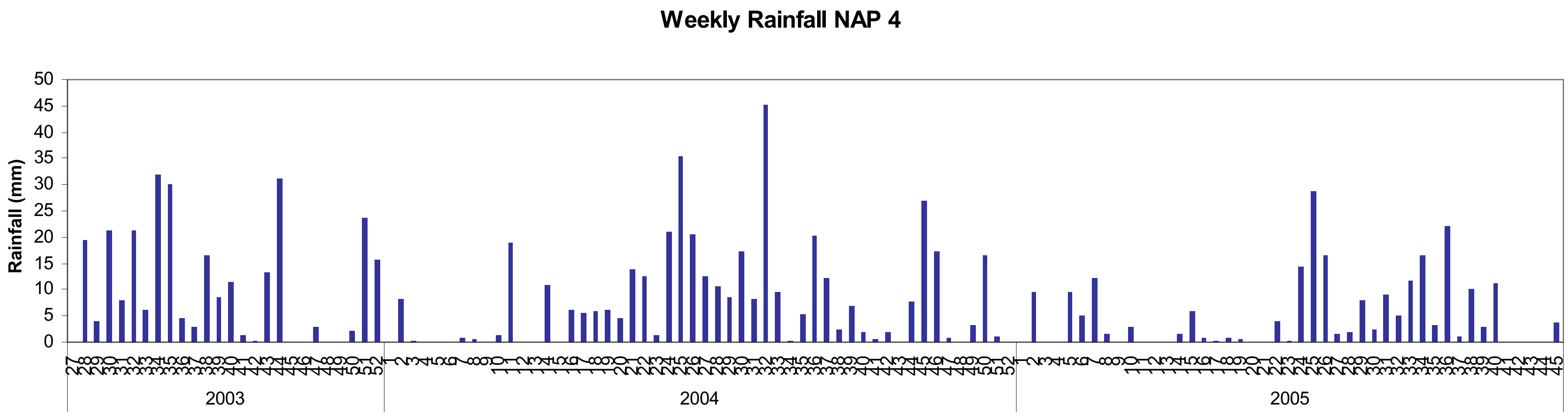
At flood sites NAP 4 and NAP 5, shaft encoders are used to measure irrigation volumes. The encoder measures the channel head of water, which flows past the sluice gate to the irrigation bay. To convert the head of water to a volume, rating curves for the irrigation discharge were developed by the DWLBC Hydrometric Service Group. A number of gaugings were performed at both sites across a range of flows, to represent the normal operating conditions when the channels are in use.

At NAP 4, the shaft encoder recorded 131 ML of water which irrigated 6.5 ha of pasture (2 irrigation bays), equating to 20 ML/ha. This was comparable to the total volume pumped out of irrigation bore MAR 208 (364 ML) divided by the total area (18 ha) irrigated (20.22 ML/ha). Daily flow volumes recorded during the 2004/05 irrigation season are presented in Figure 5.2.

The flow meter on irrigation bore MAR 208 recorded 364 ML of groundwater extraction over 2003/04 and 381 ML over 2004/05 (Fig. 5.3).

Due to an electrical fault, the shaft encoder at NAP 5 did not capture the first 2003/04 irrigation season. Individual irrigation events recorded during the 2004/05 irrigation season are presented in Figure 5.5. Due to the large distance between the irrigation bore and the shaft encoder, the relationship between the volumes of groundwater pumped from the irrigation bore and the head of water that passes through the sluice gate was difficult to determine. This resulted in a great deal of uncertainty in the volume of irrigation water applied to the individual irrigation bay.

Irrigation volumes for NAP 5 were determined from annual use returns (AWUR) and via the amount of groundwater extracted divided by the total area of pasture irrigated. Irrigation application was determined to be in the order of 20 to 22 ML/ha. The flow meter on irrigation bore MAR 207 recorded 604 ML and 906 ML of groundwater extraction over the 2003/04 and 2004/05 irrigation seasons respectively (Fig. 5.6).



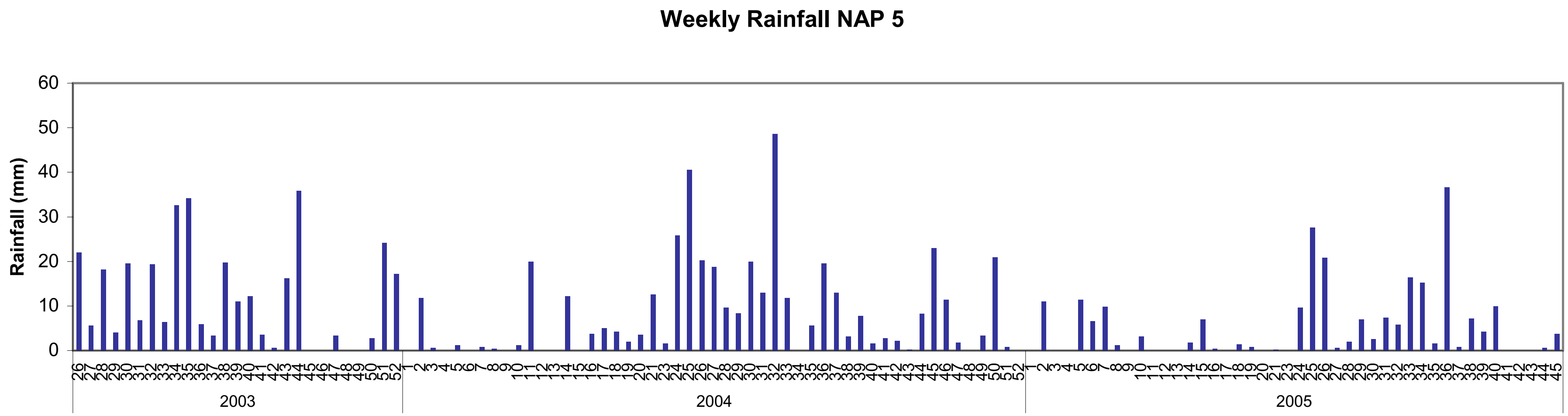


Figure 5.1 NAP 5, Weekly Rainfall

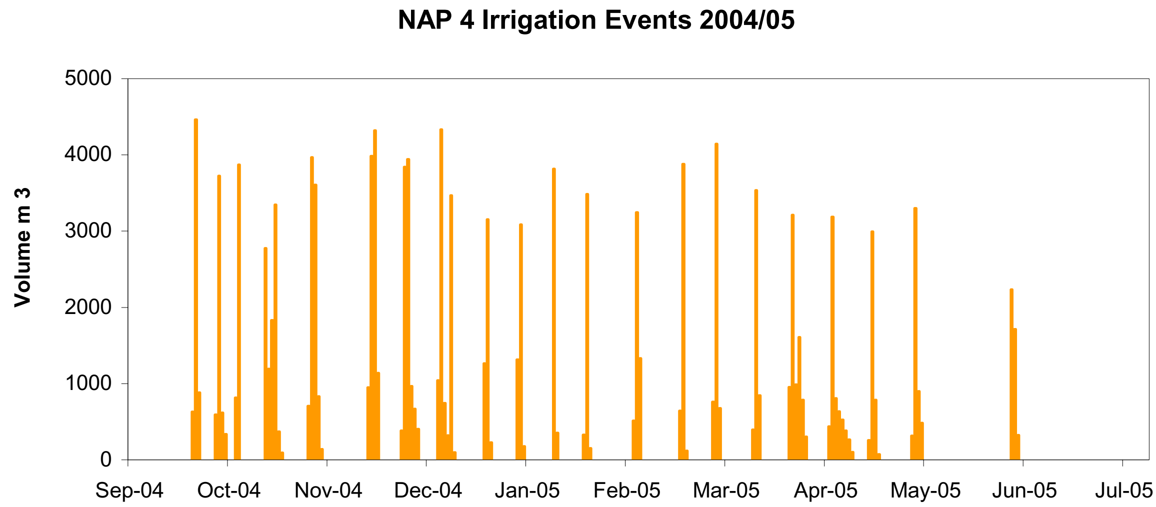


Figure 5.2 NAP 4, Time series of irrigation volumes

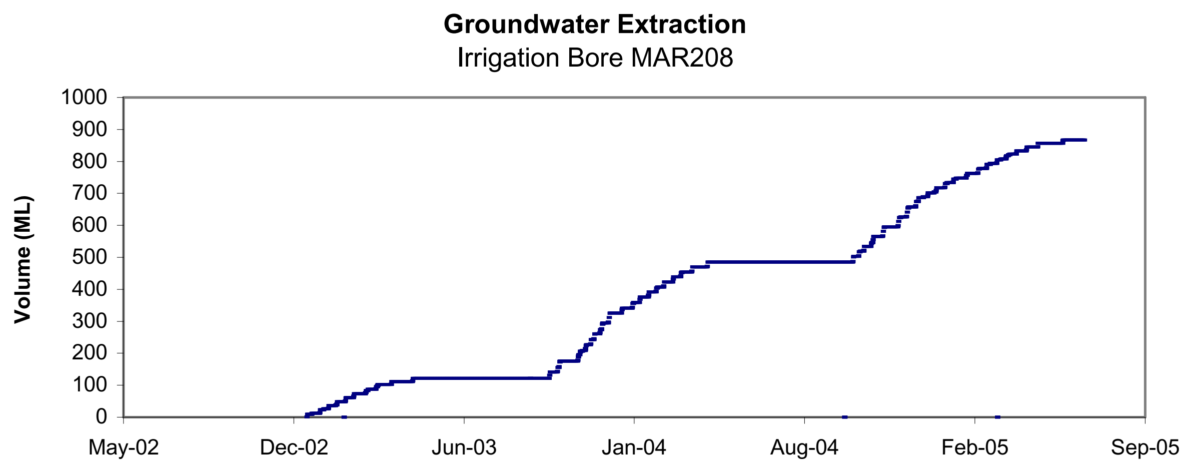


Figure 5.3 NAP 4, Groundwater extraction volumes

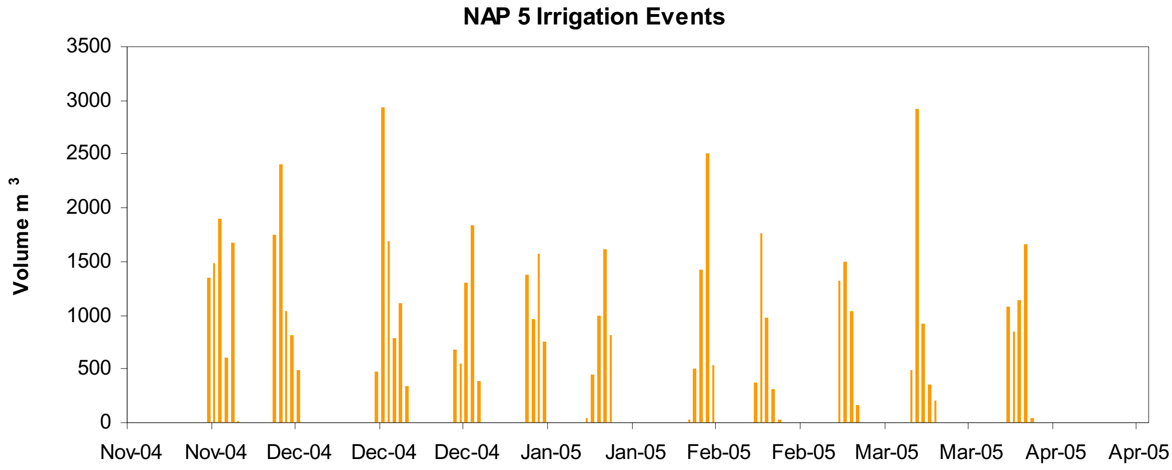


Figure 5.4 NAP 5, Time series of irrigation values

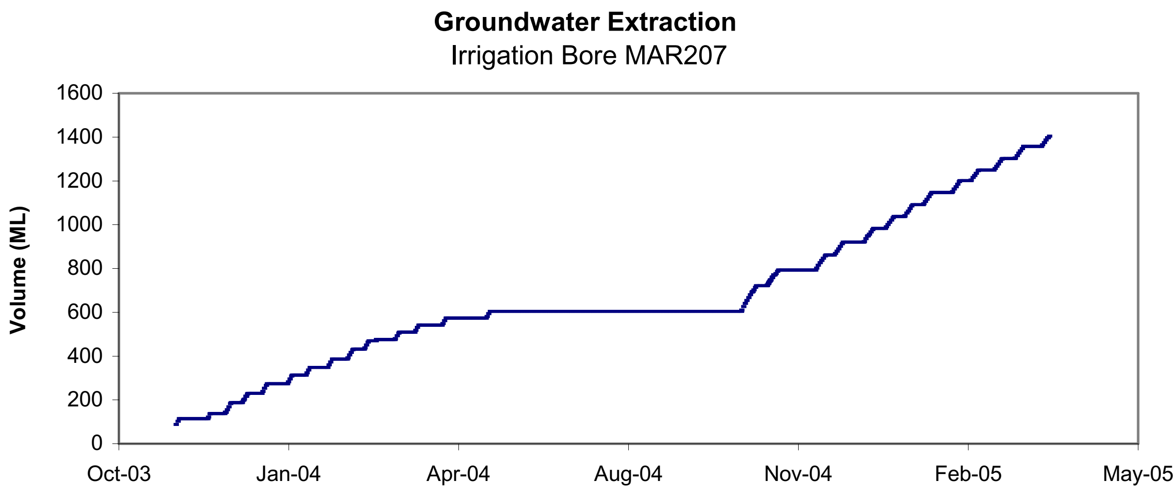


Figure 5.6 NAP 5, Groundwater extraction

5.1.1 IRRIGATION CHLORIDE INPUTS

The chloride concentration at both flood irrigation sites were measured monthly throughout the irrigation season (Table 3.3). The salinity of the irrigation water at NAP 5 (2730 mg/L) is more than double the salinity of irrigation water at NAP 4 (1400 mg/L).

5.2 EVAPOTRANSPIRATION MEASUREMENTS

Estimates of evapotranspiration or crop water use at the flood experimental sites were calculated via the FAO 56 methodology from Class A Pan evaporation data provided by the Bureau Of Meteorology (refer to Volume 1 for methodology). This was estimated to be 1149 mm/yr over the 2004/05 season (Fig. 5.7).

The limitation in using this method to calculate ET at the flood irrigation sites is that it only accounts for crop water use and not surface evaporation of irrigation water when applied.

To refine the above methodology, the degree of evaporation during irrigation can be determined through the use of stable isotopes δ^2H and δ^{18}O. By measuring the changes in isotopic composition in irrigation water, and soil water during irrigation delivery, it is possible to determine evaporation losses during irrigation.

5.3 SOIL WATER CONTENT (CAPACITANCE PROBE)

Capacitance probes at NAP4 and NAP5 show rapid drainage to the water table after each irrigation event. Spikes in Figures 5.8 and 5.9 represent deep drainage events as a result of winter rainfall (June to September) and irrigation (October to April).

5.4 SOIL WATER SALINITY (CHLORIDE)

5.4.1 SUCTION LYSIMETERS

Two sets of suction lysimeters at depths of 0.3, 1, 2 and 3m are position across the bays at both NAP4 and NAP5 (Fig. 1.3). Soil water salinity at flood irrigation sites NAP 4 and 5 is considerably lower than that of the centre pivot and dripper irrigation sites. Due to the higher volume of irrigation and rapid drainage after an irrigation event, soil water salinity under flood irrigation is uniform at depth and is closer to equilibrium with the irrigation water (Figs 5.10 and 5.11).

The soil water salinity at 1 m, 2 m and 3 m remained reasonably steady over the sampling period. Slight shifts in chloride concentrations can be explained by seasonal influences (such as the seasonal variability of evapotranspiration and rainfall) throughout the year, however the change over one year is negligible.

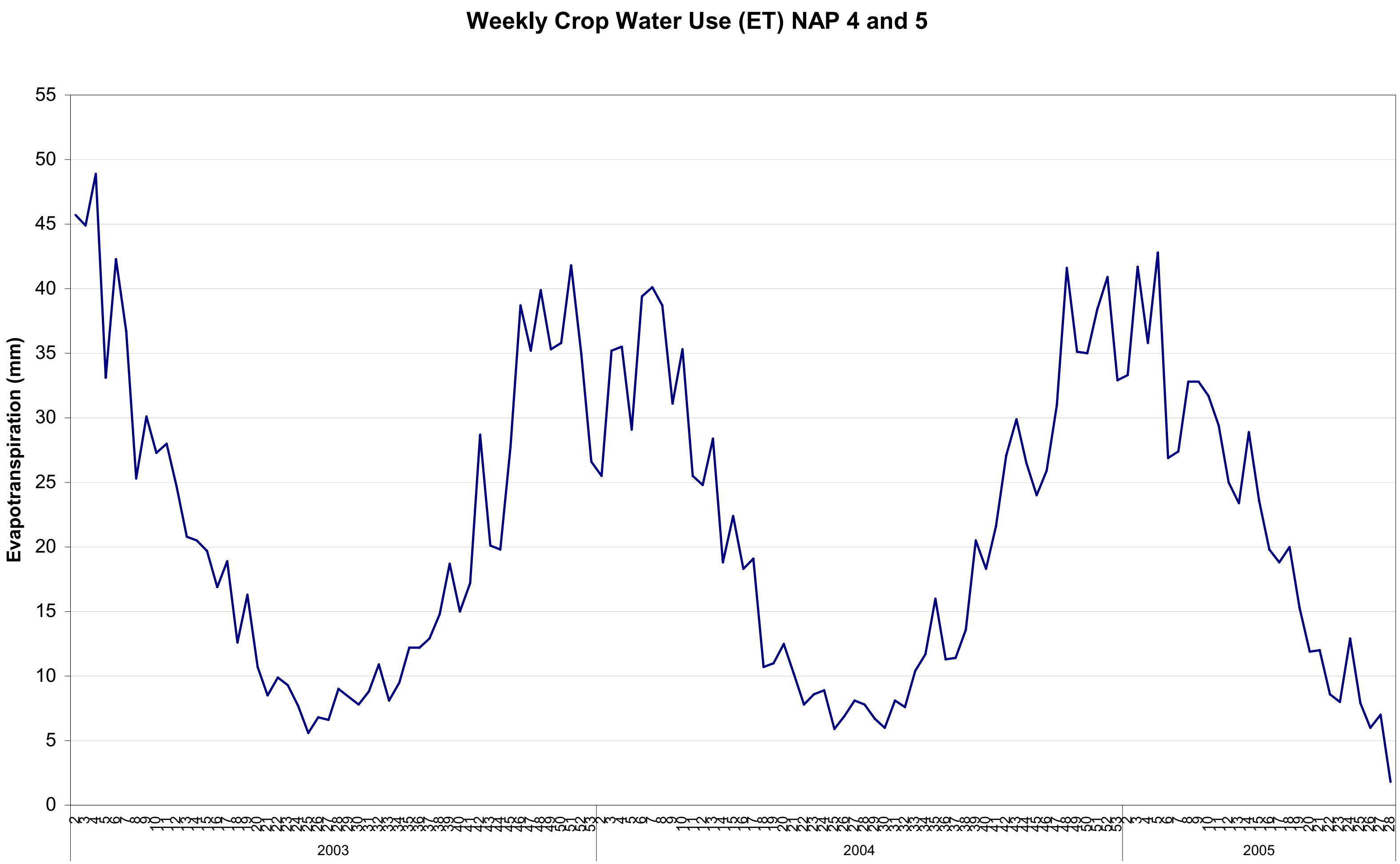
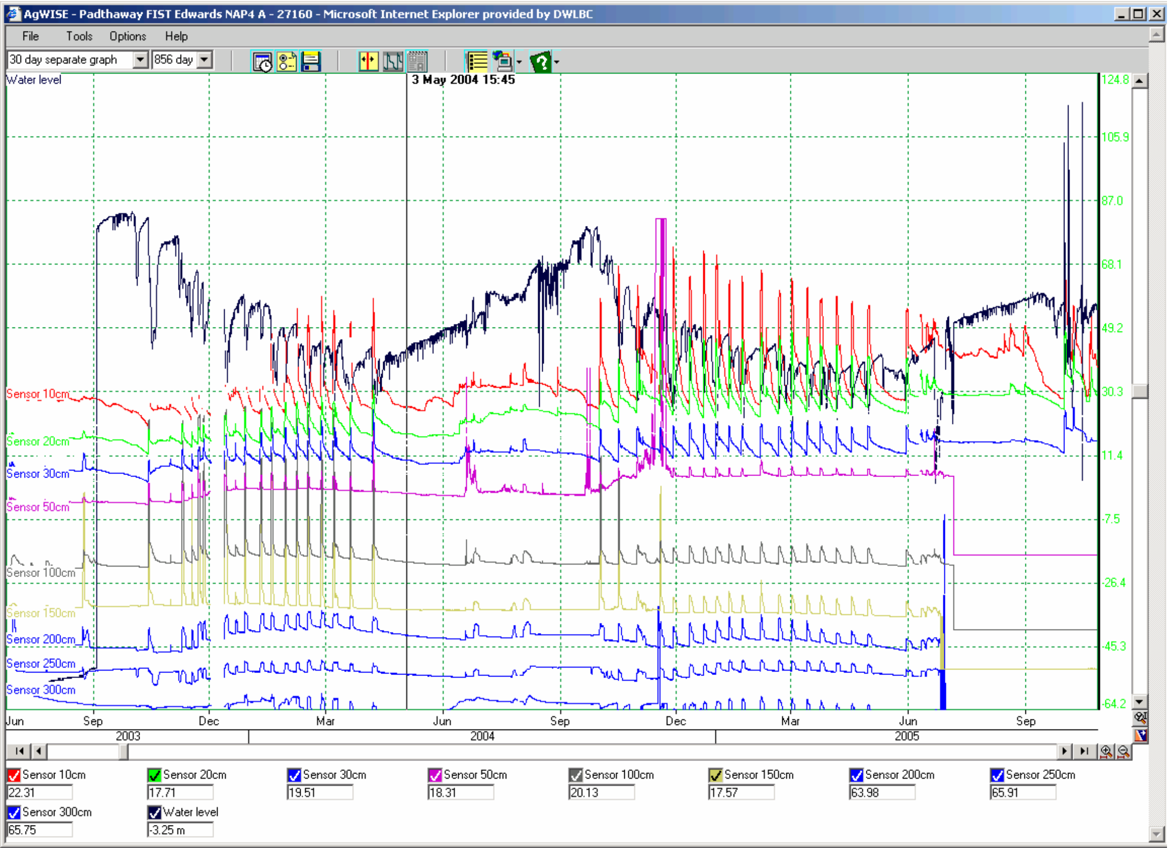


Figure 5.7 Crop water use (ET) at NAP4 and NAP5



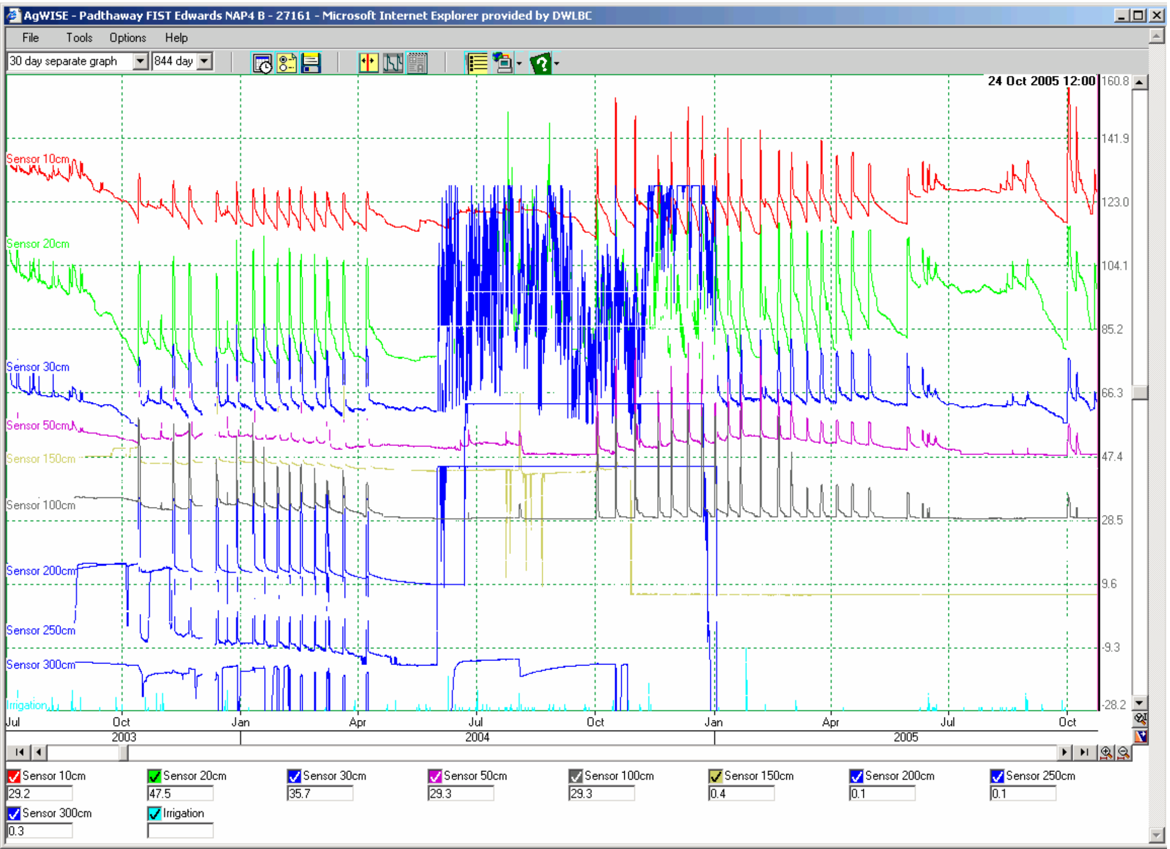


Figure 5.8 Soil moisture Capacitance at NAP4 East (above) and NAP4 West (below)

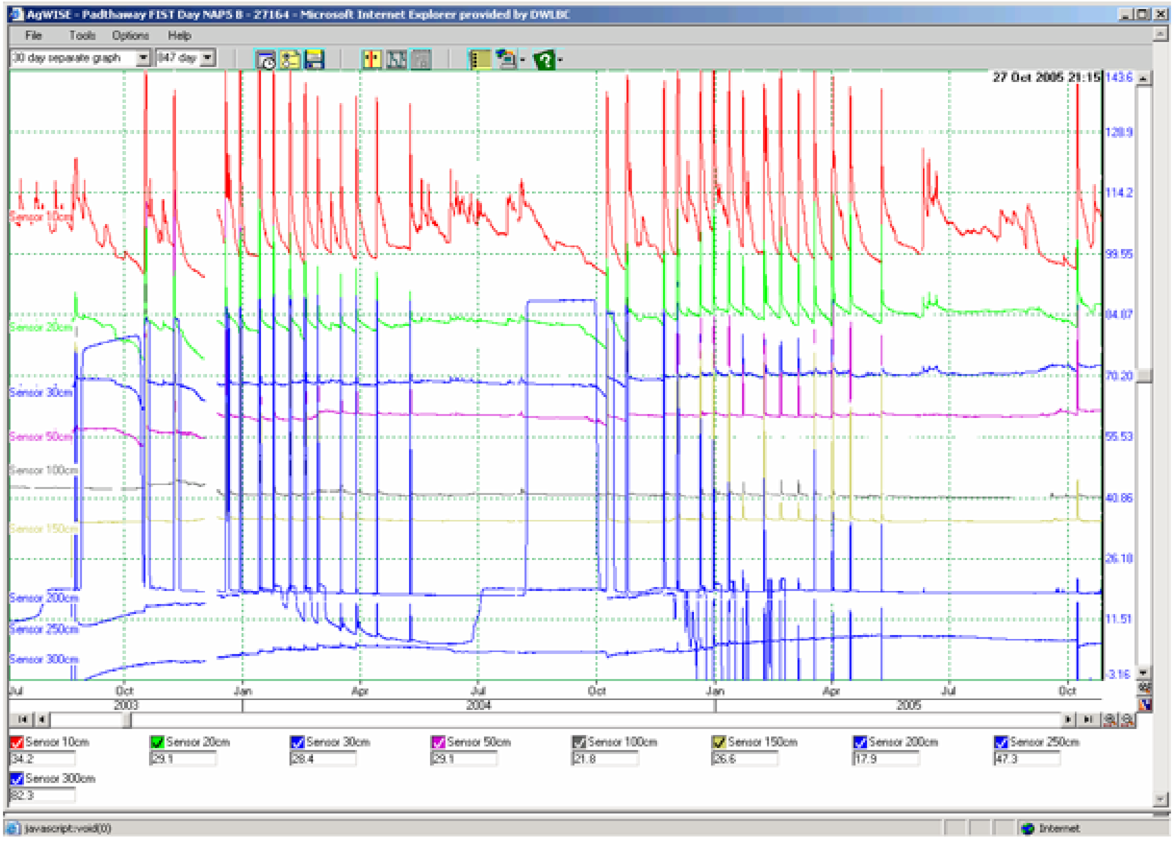
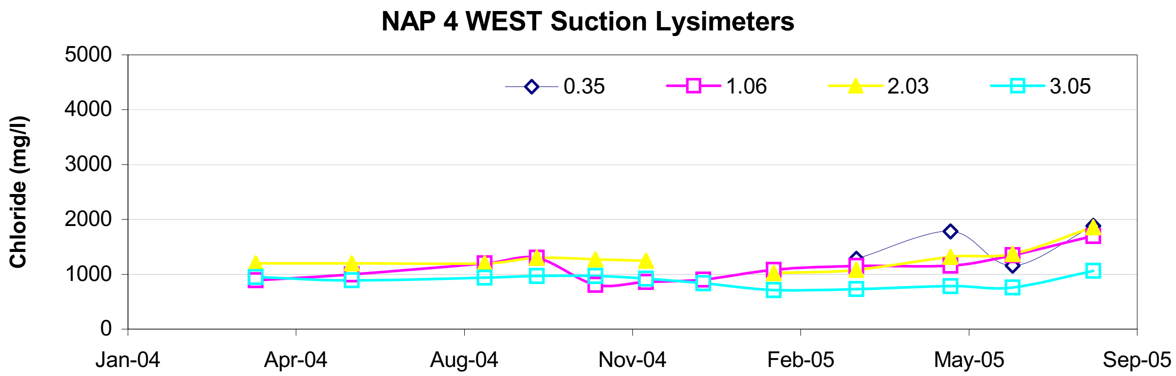
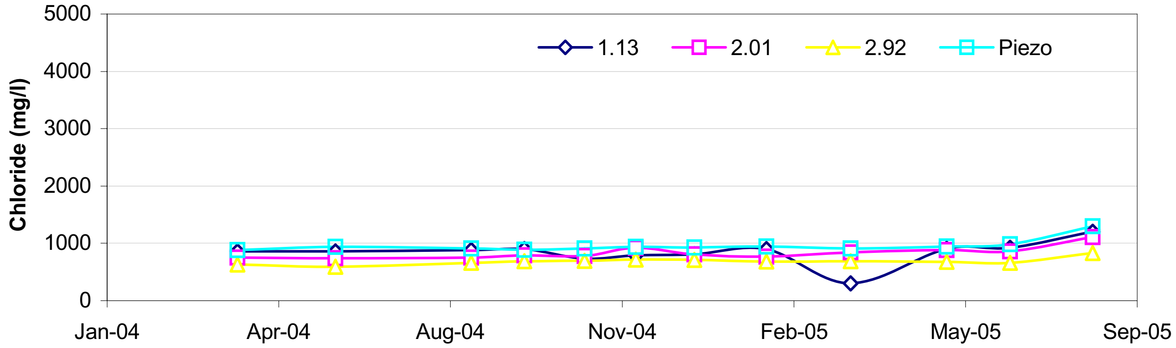
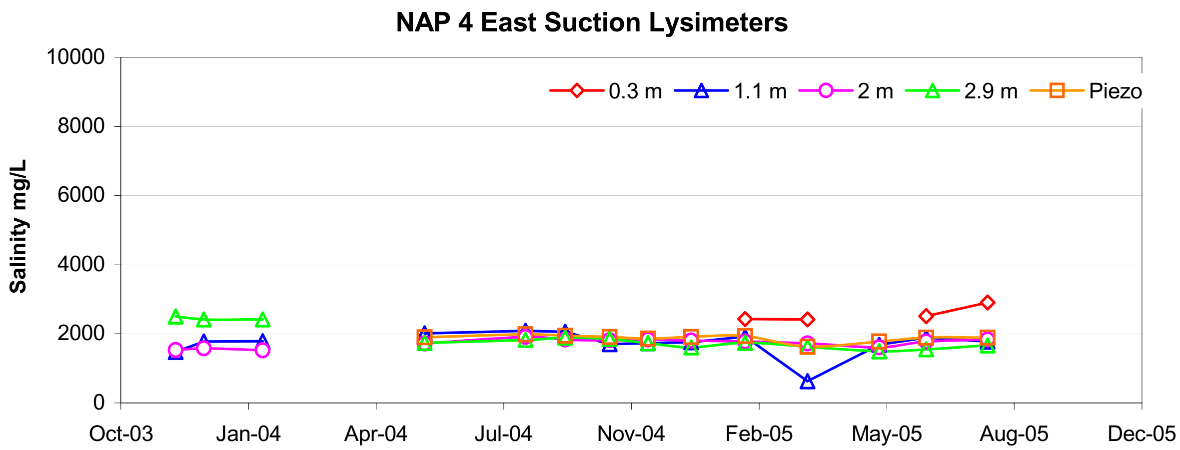


Figure 5.9 Soil moisture Capacitance at NAP5 North (above) and NAP5 South (below)







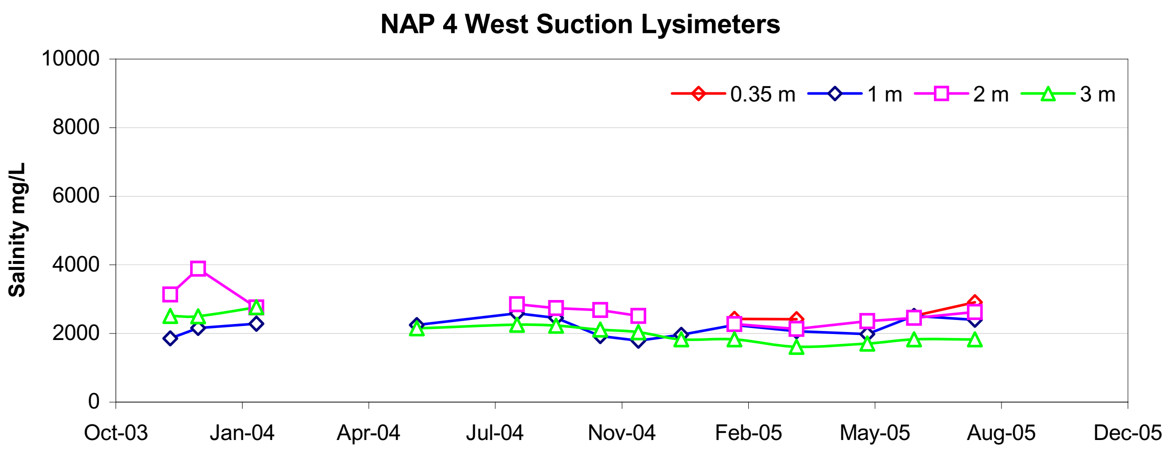


Figure 5.10 NAP 4, Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity

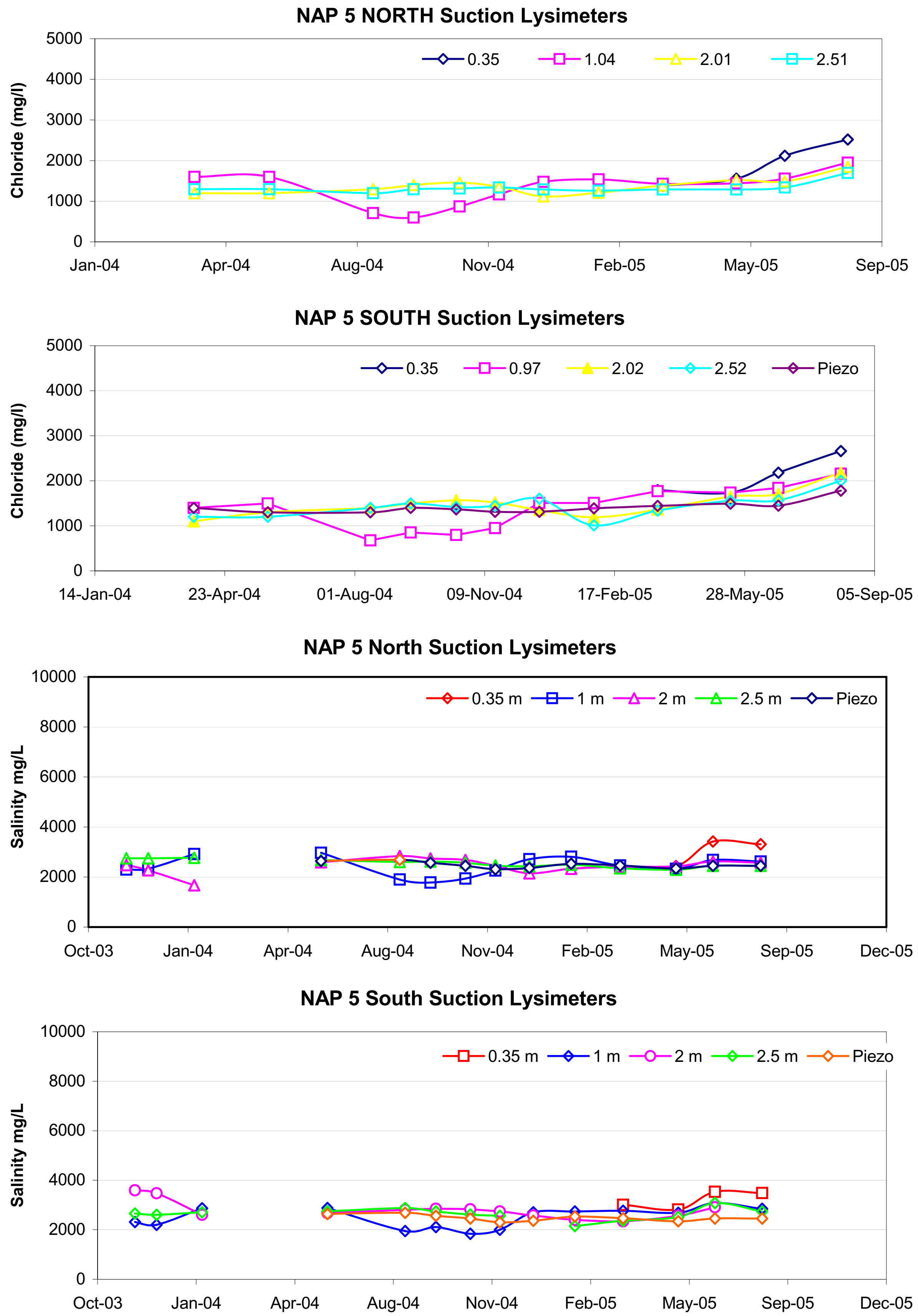


Figure 5.11 NAP 5, Soil water and groundwater salinity as a measure of Chloride and Electrical Conductivity

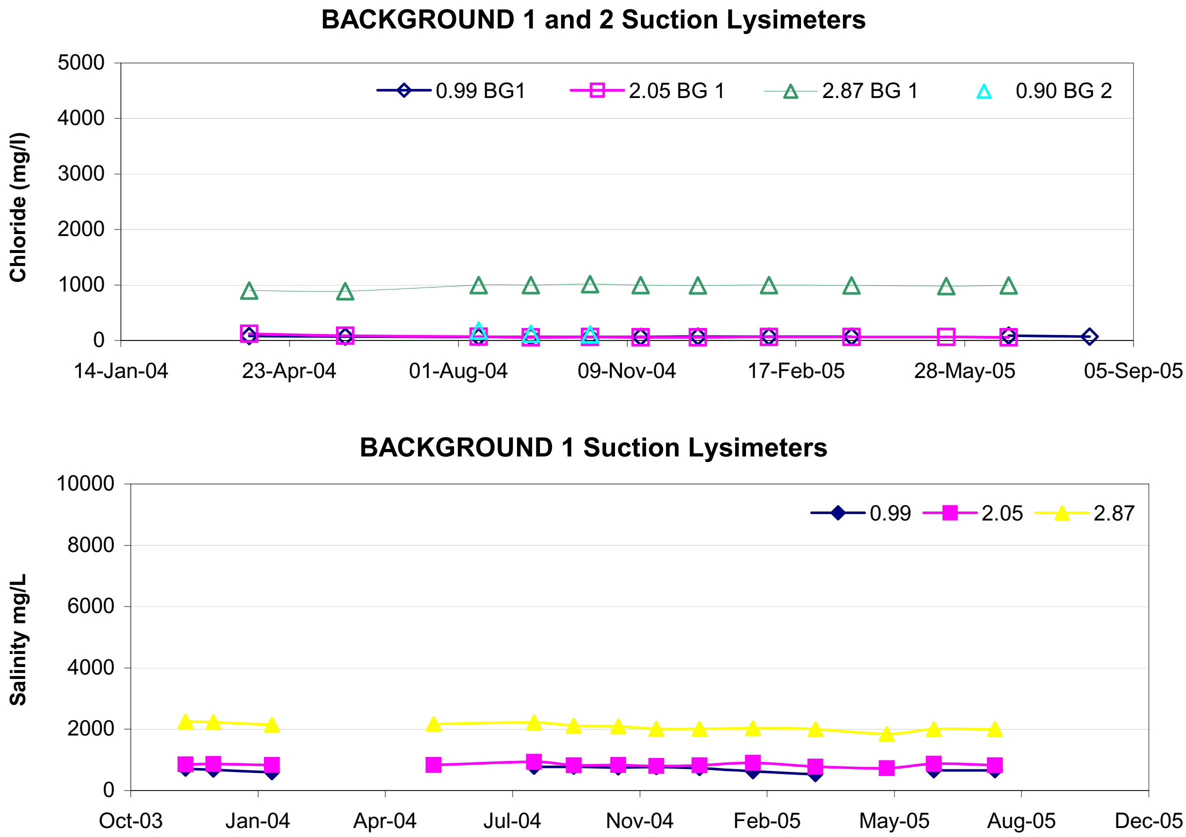


Figure 5.12 Soil water salinity as a measure of Chloride and Electrical Conductivity at Background site BG1

At NAP 5 the salinity of the soil water at depth across both southern and northern sampling sites is of a similar concentration to the irrigation water. This suggests that evaporation has not concentrated the water was it flows across the bay. At NAP 4, the salinity of the soil water is up to 300 mg/L higher than the irrigation water at the eastern site and is >600 mg/L higher than irrigation water at the western site. This suggests that evaporation has significantly concentrated the irrigation water as it flows across the bay (East to West). Factors such as a shallower soil type and narrower bay at NAP 5 have contributed to faster irrigation application resulting in a lower amount of evaporation.

Soil water chloride and salinity are also displayed for background site BG1 (located near NAP4). The concentration of the soil water chloride at depths of 1 and 2 is very low (<70 mg/L) and remains reasonably steady over time. The soil water chloride at 2.9 m is much higher (~900 mg/L) indicating that the lysimeter may be located within the capillary zone just above the water table.

5.4.2 SOIL CORE

The vertical distribution of chloride, measured from soil cores during drilling at NAP 4 and 5 show a chloride bulge at a depth of 1 to 2 m (Figs 5.13 and 5.14). This is possibly due to either an active root system at this depth or to the presence of a hard impermeable calcrete

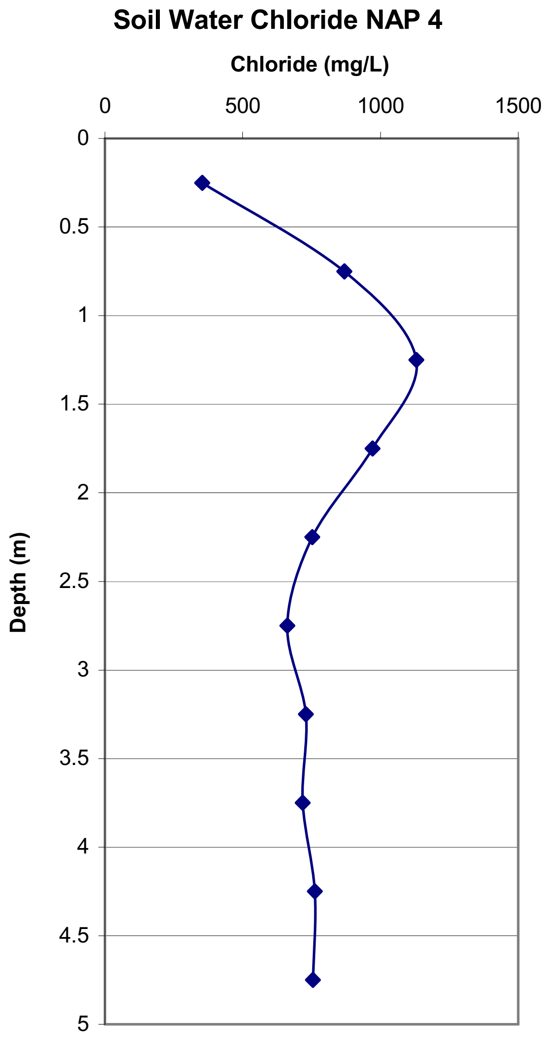


Figure 5.13 Vertical distribution of soil water chloride (Eastern Site)

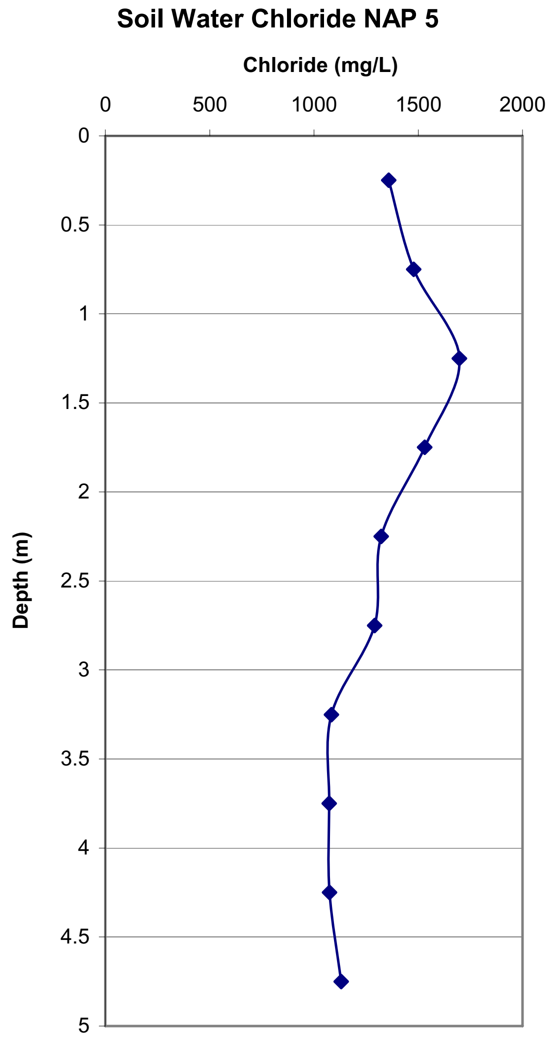


Figure 5.14 Vertical distribution of soil water chloride (Southern Site)

layer commonly found at this depth (which would further concentrate the salts through the effects of evaporation from the surface of this layer). The variability in soil water chloride (ranging from 800–1200 mg/L at NAP 4 and 1300–1700 mg/L at NAP 5) is attributed to differences in the salinity of irrigation water. The chloride concentration becomes uniform with depth on both profiles.

Generally, the soil water chloride obtained from the cores is in agreement with the soil water chloride obtained from the suction lysimeters at the same location.

5.5 GROUNDWATER LEVELS

Continuous groundwater level measurements have been recorded at all experimental sites. Daily averages of groundwater levels are displayed in Figure 5.15. Annual groundwater fluctuations at all sites range between 0.75 m and 0.85 m, being slightly lower over the 2004/05 season. Pumping influences at both flood experimental sites NAP 4 and 3 are clearly noticed, with individual draw down and recovery events occurring throughout the irrigation season. Under drip irrigation, the water table did not respond after any irrigation, indicating that the drip irrigation does not cause significant drainage past the root zone.

Historical groundwater levels for selected observation wells within the Padthaway Prescribed Wells Area (PWA) are included in Appendix D. Groundwater levels respond directly to rainfall as well as the influence of irrigation in areas where there is a shallow depth to water table. Below average rainfall experienced for the period 1993 to 2002 (and subsequent reduction in groundwater recharge) is believed to have contributed to the observed decline in groundwater levels (-0.10 m/yr) in Sub Areas 1, 2 and 3. Average rainfall over the preceding 3 years, has attributed to the stabilisation of groundwater levels observed in the majority of observation wells.

The observation wells within Sub Area 4 (Naracoorte Ranges) indicate a steady rise in water table (1–2 m) since monitoring began in the early 70s. This rise is due to the increase in vertical recharge to the water table following the clearance of native vegetation. A stabilisation in groundwater levels since 1993 suggest that groundwater levels may be approaching a new state of equilibrium.

5.6 GROUNDWATER SALINITY

On a regional scale, groundwater salinity increases towards the north. Monthly measurements of groundwater salinity and chloride for each experimental site are displayed in the suction lysimeter figures for each irrigation site above.

Slight seasonal changes in groundwater salinity can be explained by the leaching of soil stored salt during periods of drainage as well as the dissolution of salt store from the unsaturated zone as the water table rises during winter recharge periods.

Historic groundwater salinity for selected observation wells are presented in Appendix E. In general, groundwater salinity is increasing across the Padthaway Prescribed Wells area.

Groundwater salinity across the Padthaway Plains has been increasing at an average rate of 10–15 mg/L/yr. In recent times, observation wells along western margin of Management Area 2 (GLE 93, 99, 100, 101 and 102) show a decline in groundwater salinity.

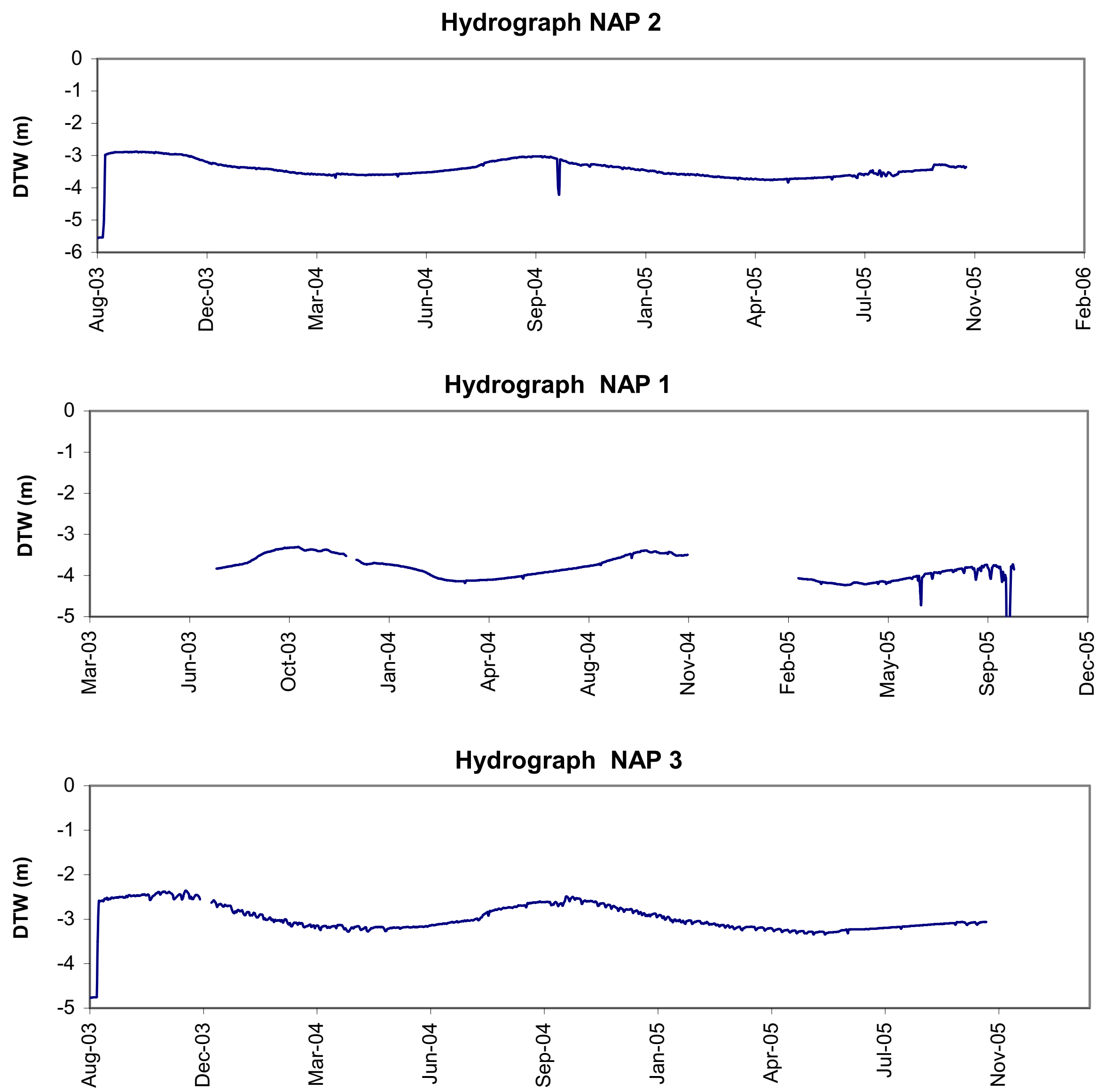


Figure 5.15 Hydrograph from the Unconfined Aquifer for each experimental site (daily averages of depth to water)

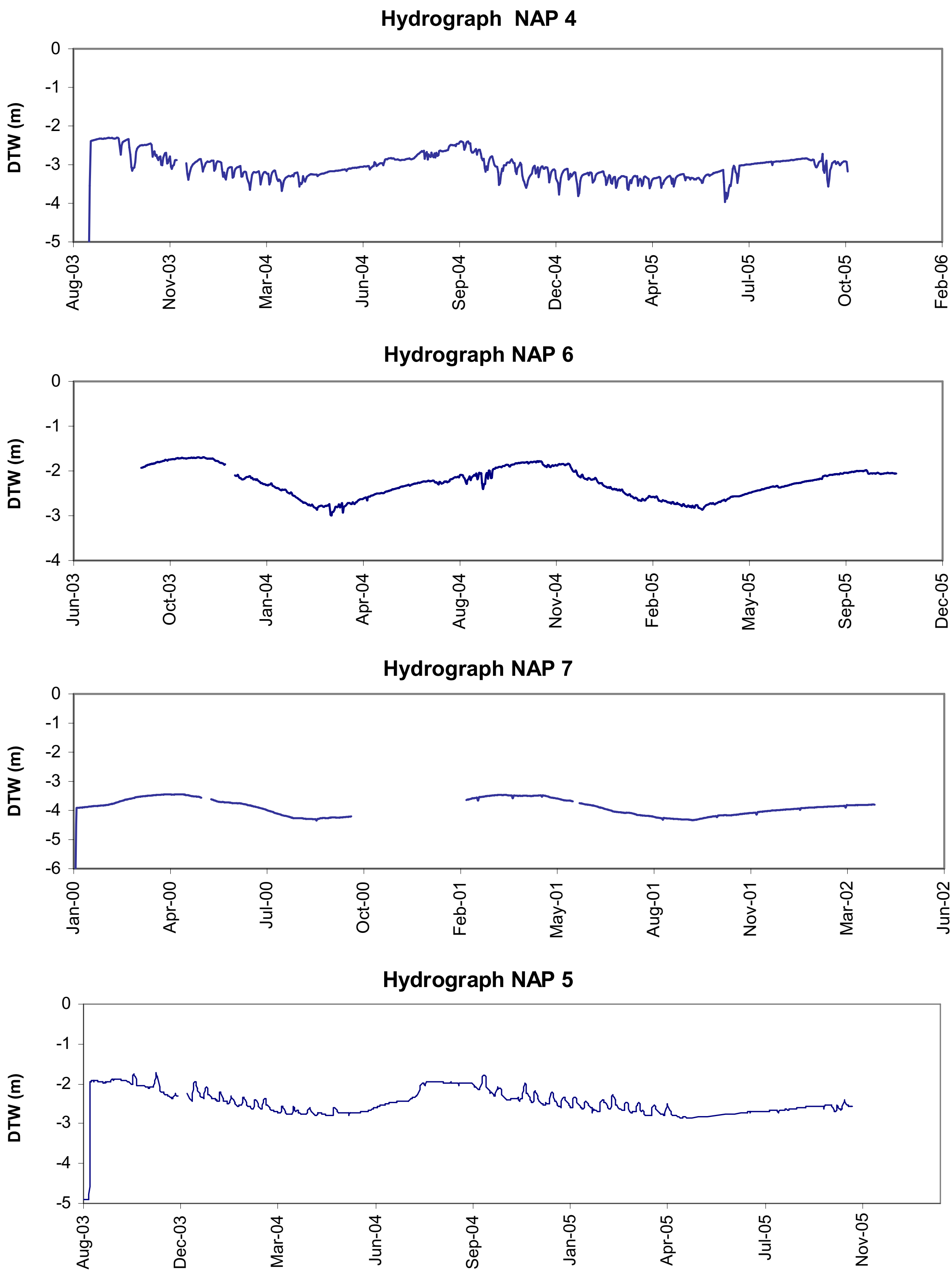


Figure 5.15 (Continued) Hydrograph from the Unconfined Aquifer for each experimental site (daily averages of depth to water)

APPENDICES

A. SOIL CORE PROPERTIES FROM THE NARACOORTE RANGES AND THE PADTHAWAY FLAT

Soil core physical properties in the Naracoorte Ranges

Sample ID	Depth Interval (m)	Theta g/g	Cl mg/L	SWP kPa	Log SWP	Sand %	Silt %	Clay %	% clay from wat cont
PB 5	0-0.5	0.0332	89.72	11.00	1.041393	99	0	1	3
	0.5-1	0.0466	70.01			99	2	0	6
	1-1.5	0.0460	50.29	5.00	0.69897			6	6
	1.5-2	0.0461	51.53			99	2	0	6
	2-2.5	0.0391	52.77	5.00	0.69897			0	4
	2.5-3	0.0417	55.73			100	0	0	5
	3-3.5	0.0425	58.70	5.00	0.69897			0	5
	3.5-4	0.0452	81.33			100	2	0	6
	4-4.5	0.0437	103.97	5.00	0.69897			0	5
	4.5-5	0.0521	83.14					0	8
	5-5.5	0.0691	62.31	5.00	0.69897	98	0	3	12
	5.5-6	0.0471	54.76					9	6
	6-6.5	0.0818	47.22	142.00	2.152288	83	1	16	15
	6.5-7	0.0492	47.69					11	7
	7-7.5	0.0679	48.15	166.00	2.220108			11	12
	7.5-8	0.0900	40.16			93	1	5	18
	8-8.5	0.0863	32.17	5.00	0.69897			11	17
	8.5-9	0.0949	29.85			83	0	17	19
	9-9.5	0.1112	27.52	8.00	0.90309			17	23
	9.5-10	0.1868	32.21			81	1	18	43
	10-11	0.1253	36.89	7.00	0.845098	76	0	24	27
	11-12	0.0708	34.85			89	1	10	13
	12-13	0.0695	32.81	55.00	1.740363			5	12
	13-14	0.0514	50.30			92	7	1	8
	14-15	0.0610	67.79	4.00	0.60206				10
	15-16	0.1353	67.79						29
PB 1	0-0.5	0.0333	119.05	8.00	0.90309	99	1	0	3
	0.5-1	0.0846	80.22			98	1	2	16
	1-1.5	0.0922	41.39	4.00	0.60206	90	0	10	18
	1.5-2	0.1473	37.47					33	33
	2-2.5	0.1487	33.55	62.00	1.792392	72	0	28	33
	2.5-3	0.1186	32.48						25
	3-3.5	0.0960	31.41	57.00	1.755875	82	0	18	19
	3.5-4	0.0914	26.20						18
	4-4.5	0.0920	20.99	44.00	1.643453				18
	4.5-5	0.0864	26.55			88	0	12	17
	5-5.5	0.0789	32.11	33.00	1.518514	87	0	12	15
	5.5-6	0.1131	57.33						24
	6-6.5	0.1195	82.55	3.00	0.477121				25
	6.5-7	0.1999	99.38			87	0	12	46
	7-7.5	0.1662	116.21	3.00	0.477121	90	1	10	38
	7.5-8	0.1996	103.39						46
	8-8.5	0.1720	90.57	3.00	0.477121				39
	8.5-9	0.1469	102.97			89	1	10	33

Sample ID	Depth Interval (m)	Theta g/g	Cl mg/L	SWP kPa	Log SWP	Sand %	Silt %	Clay %	% clay from wat cont
	9-9.5	0.2065	115.37	6.00	0.778151				48
	9.5-10	0.1723	185.01			96	2	2	39
	10-11	0.2388	254.65	7.00	0.845098				57
PB 7	0-0.5	0.0295	648.60	55.00	1.740363	95	4	2	2
	0.5-1	0.0707	380.17					13	13
	1-1.5	0.0961	111.75	5244.00	3.719663	69	1	30	19
	1.5-2	0.1184	226.89					31	25
	2-2.5	0.1188	342.03	3793.00	3.578983	68	1	31	25
	2.5-3	0.1600	653.93			56	3	41	36
	3-3.5	0.0977	965.82	2469.00	3.392521	64	11	25	20
	3.5-4	0.1026	887.07						21
	4-4.5	0.0936	808.31	3045.00	3.483587				19
	4.5-5	0.0500	878.54						7
	5-5.5	0.0537	948.77	11647.00	4.066214	72	4	24	8
	5.5-6	0.1213	899.67						26
	6-6.5	0.1102	850.57	2431.00	3.385785	75	3	22	23
	6.5-7	0.1043	937.82						21
	7-7.5	0.0392	1025.06	3143.00	3.497344	82	8	10	4
	7.5-8	0.0225	1215.65						0
	8-8.5	0.0127	1406.25						0
	8.5-9	0.0140	1380.38						0
	9-9.5	0.0134	1354.52	928.00	2.967548				0
	9.5-10	0.0096	1460.49			93	7	-1	0
	10-11	0.0124	1566.46	1114.00	3.046885				0
	11-12	0.0177	1215.23						0
	12-13	0.0200	864.00	1579.00	3.198382				0
	13-14	0.0207	1089.89						0
	14-15	0.0889	1315.79	664.00	2.822168	67	18	16	17
	15-16	0.0400	1553.24						5
	16-17	0.1190	1790.70	39.00	1.591065	72	11	17	25
	17-18	0.0804	3220.93						15
	18-19	0.0319	4651.16	315.00	2.498311				2
	19-20	0.0302	4704.76						2
	20-21	0.1461	4758.36	13.00	1.113943	83	7	10	32
	21-22	0.1177	5114.22						25
	22-23	0.0275	5470.09	98.00	1.991226				1
	23-24	0.0360	4577.99						3
	24-25	0.0692	3685.90	23.00	1.361728				12
	25-26	0.0379	3729.74						4
	26-26.5	0.0296	3773.58	24.00	1.380211				2
PA 1	0-0.5	0.0220	255.10	158.00	2.198657	94	1	5	0
	0.5-1	0.1144	1426.99			63	-1	38	24
	1-1.5	0.0427	2598.87	4013.00	3.603469			5	5
	1.5-2	0.0514	3974.33					8	8
	2-2.5	0.0858	5349.79	2620.00	3.418301	81	1	18	17
	2.5-3	0.0547	5591.24			85	2	13	8

Sample ID	Depth Interval (m)	Theta g/g	Cl mg/L	SWP kPa	Log SWP	Sand %	Silt %	Clay %	% clay from wat cont
	3-3.5	0.0684	5832.69	2357.00	3.37236				12
	3.5-4	0.0978	6659.73						20
	4-4.5	0.1018	7486.77	868.00	2.93852	80	1	19	21
	4.5-5	0.0656	7634.50			89	0	11	11
	5-5.5	0.0780	7782.23	6.00	0.778151				14
	5.5-6	0.1013	5802.11						21
	6-6.5	0.0971	3821.99	6.00	0.778151	88	-1	13	19
	6.5-7	0.0894	3049.36						17
	7-7.5	0.1068	2276.74	4.00	0.60206	91	-1	10	22
	7.5-8	0.0654	1693.92						11
	8-8.5	0.1275	1111.11	3.00	0.477121	91	0	9	27
	8.5-9	0.1534	990.27						34
	9-9.5	0.1765	869.44						40
PB 8	0-0.5	0.0555	404.41	117.00	2.068186	91	3	6	9
	0.5-1	0.0396	224.96					4	4
	1-1.5	0.1443	45.52	372.00	2.570543			32	32
	1.5-2	0.1574	56.63			65	1	34	35
	2-2.5	0.1612	67.74	206.00	2.313867			37	36
	2.5-3	0.1965	65.72			59	1	40	46
	3-3.5	0.1856	63.69	207.00	2.31597	61	3	36	43
	3.5-4	0.1809	71.97						41
	4-4.5	0.0281	80.25	423.00	2.62634				1
	4.5-5	0.0479	63.97			78	12	10	7
	5-5.5	0.0630	47.69	77.00	1.886491	77	11	13	11
	5.5-6	0.0463	44.02						6
	6-6.5	0.1123	40.34	59.00	1.770852	64	29	7	23
	7-7.5	0.0895	41.51						17
	7.5-8	0.1845	42.69	41.00	1.612784				42
	8-8.5	0.2416	58.05						57
	8.5-9	0.1622	73.42	37.00	1.568202	74	6	20	37
	9-9.5	0.1107	79.18						23
	9.5-10	0.0991	84.94	17.00	1.230449	87	5	8	20
	10-11	0.1050	207.35						22
	11-11.5	0.1385	329.76	4.00	0.60206				30
	11.5-12	0.1497	388.27			83	9	8	33
	12-13	0.1526	446.77	5.00	0.69897	82	10	8	34
	13-14	0.2021	435.11						47
	14-15	0.1312	437.99						28
	15-16	0.2772	440.87	4.00	0.60206				67
NV 1	0-0.5	0.0220	642.32	1440.00	3.158362	92	2	5	0
	0.5-1	0.1204	363.90	6120.00	3.786751	53	2	45	26
	1-1.25	0.1484	617.17					33	33
	1.25-1.5	0.0210	617.17					0	0
	1.5-2	0.0137	870.45	1671.00	3.222976	89	6	6	0
	2-2.5	0.0203	1178.95						0
	2.5-3.0	0.0144	1487.46	1368.00	3.136086	89	7	4	0

Sample ID	Depth Interval (m)	Theta g/g	Cl mg/L	SWP kPa	Log SWP	Sand %	Silt %	Clay %	% clay from wat cont
	3-3.5	0.0145	976.03						0
	3.5-4	0.0137	976.03						0
	4-4.5	0.0124	464.60	1394.00	3.144263				0
	4.5-5	0.0136	270.76	1517.00	3.180986	94	4	2	0
	5-5.5	0.0110	257.33						0
	5.5-6	0.0123	243.90	2335.00	3.368287				0
	6-6.5	0.0112	1128.66						0
	6.5-7	0.0111	2013.42	2860.00	3.456366	98	1	1	0
	7-7.5	0.0364	1256.71						4
	7.5-8	0.0178	500.00	1807.00	3.256958				0
	8-8.5	0.0289	402.34						2
	8.5-9	0.0266	304.69	2111.00	3.324488				1
	9-9.5	0.0184	218.13			91	5	4	0
	10-11	0.0192	131.58	544.00	2.735599				0
	11-12	0.0200	205.11						0
	12-13	0.0146	278.64	887.00	2.947924				0
	13-13.5	0.0144	2399.81			92	5	2	0
	13.5-14	0.0323	2399.81						3
	14-15	0.0459	4520.99	665.00	2.822822				6
	15-15.5	0.0276	4422.15						1
	16.5-17	0.0228	4323.31	2244.00	3.351023				0
	17-18	0.0202	4872.79						0
	18-19	0.0517	5422.26	297.00	2.472756	91	5	5	8
	19-20	0.0230	5333.16						0
	20-20.5	0.1930	5244.06	39.00	1.591065	56	6	38	45
	20.5-21	0.1229	5278.61						26
	21-21.5	0.0767	5313.16	16.00	1.20412				14
	21.5-22	0.0869	5249.41			90	5	4	17
	22-22.5	0.0734	5185.66	8.00	0.90309				13
	22.5-23	0.0863	3126.33						17
	23-23.5	0.0953	1067.00	4.00	0.60206	91	4	4	19
	23.5-24	0.1576	780.27						35
	24-24.5	0.1402	493.53	4.00	0.60206				31
	24.5-25	0.1749							40
PA 3	0-0.5	0.0180	2168.67	4353.00	3.638789	97	-1	3	0
	0.5-1	0.0122	1363.75			98	0	2	0
	1-1.5	0.0088	558.82	517.00	2.713491			0	0
	1.5-2	0.0109	543.12			97	3	1	0
	2-2.5	0.1039	527.43	1814.00	3.258637	66	1	33	21
	2.5-3	0.1527	640.92						34
	3-3.5	0.1654	754.41	2719.00	3.434409				37
	3.5-4	0.0691	475.36			73	11	16	12
	4-4.5	0.0728	196.31	1424.00	3.15351				13
	4.5-5	0.0694	199.70						12
	5-5.5	0.0294	203.08	2651.00	3.42341				2
	5.5-6	0.0235	277.10						0

Sample ID	Depth Interval (m)	Theta g/g	Cl mg/L	SWP kPa	Log SWP	Sand %	Silt %	Clay %	% clay from wat cont
	6-6.5	0.0145	351.12	2282.00	3.358316	92	5	3	0
	7-7.5	0.0126	323.71						0
	7.5-8	0.0144	296.30	1440.00	3.158362	96	1	2	0
	8-8.5	0.0129	283.46						0
	8.5-9	0.0153	270.62	776.00	2.889862				0
	9-9.5	0.0168	343.02						0
	9.5-10	0.0173	415.43	308.00	2.488551	97	1	2	0
	10-10.5	0.0181	477.99						0
	10.5-11	0.0137	540.54	1375.00	3.138303				0
	14.5-15	0.0097	882.35	818.00	2.912753				0
	15.5-16	0.0108	561.80						0
	16-17	0.0162	739.53						0
	17-18	0.0129	917.27	1053.00	3.022428				0
	18-19	0.0158	523.81						0
	19-20	0.0209	130.35	269.00	2.429752				0
	20-21.5	0.0242	136.76						0
	21.5-23	0.0256	143.17	44.00	1.643453				1
	23-24	0.0674	159.93			66	12	22	12
	24.5-26	0.0342	176.68	97.00	1.986772	91	4	5	3
PA 4	0-0.5	0.0177	1774.19	2323.00	3.366049	94	4	2	0
	0.5-1	0.0243	1242.05					0	0
	1-1.5	0.1421	709.90	2482.00	3.394802	67	1	31	31
	1.5-2	0.1181	1599.94					25	25
	2-2.5	0.1269	2489.98	1968.00	3.294025	68	2	29	27
	2.5-3	0.1257	2270.55						27
	3-3.5	0.1640	2051.11	1505.00	3.177536				37
	3.5-4	0.1737	2427.26						40
	4-4.5	0.1664	2803.42	809.00	2.907949				38
	4.5-5	0.2215	2910.45						52
	5-5.5	0.2593	3017.48	1221.00	3.086716				62
	5.5-6	0.2655	3204.22						64
	6-6.5	0.1015	3390.96	364.00	2.561101	70	9	22	21
	6.5-7	0.0489	3985.56						7
	7-7.5	0.0493	4580.15	668.00	2.824776				7
	7.5-8	0.0204	5252.37						0
	8-8.5	0.0260	5924.60	121.00	2.082785				1
	8.5-9	0.0336	5125.76						3
	9-9.5	0.0275	4326.92						1
	9.5-10	0.0329	4363.46						3
	10-11	0.0283	4400.00	925.00	2.966142				1
	11-12	0.0413	4226.29						5
	12-13	0.0549	4052.57	62.00	1.792392	87	8	6	8
	13-14	0.0809	2698.25						15
	14-14.5	0.0997	1343.92	16.00	1.20412	90	1	9	20
	14.5-15	0.1847	922.37						42
	15-15.5	0.2254	500.82	5.00	0.69897				53

Sample ID	Depth Interval (m)	Theta g/g	Cl mg/L	SWP kPa	Log SWP	Sand %	Silt %	Clay %	% clay from wat cont
	15.5-16	0.1578	445.65						35
	16-16.5	0.1601	390.47	3.00	0.477121				36
	16.5-17	0.2364	320.70	4.00	0.60206				56
	17-18	0.2288	326.24						54
	18-19	0.1900	331.77	5.00	0.69897	92	4	4	44
	19-19.5	0.1655	368.61						37
	19.5-20.5	0.1622	405.45	5.00	0.69897	96	3	2	37
PA 2	0-0.5	0.0239	1007.46	52.00	1.716003	99	0	1	0
	0.5-1	0.0290	544.97			99	0	1	2
	1-1.5	0.0359	82.49	4.00	0.60206			3	3
	1.5-2	0.0490	73.98			99	0	1	7
	2-2.5	0.1627	65.48	4.00	0.60206				37
	2.5-3	0.0946	150.87			87	2	11	19
	3-3.5	0.0916	236.26	39.00	1.591065				18
	3.5-4	0.1046	555.93						21
	4-4.5	0.0858	875.60	142.00	2.152288				17
	4.5-5	0.1163	1534.19						25
	5-5.5	0.1120	2192.78	230.00	2.361728	79	2	19	23
	5.5-6	0.1221	2668.05						26
	6-6.5	0.1181	3143.31	168.00	2.225309				25
	6.5-7	0.1072	3236.38			79	0	21	22
	7-7.5	0.1104	3329.44	59.00	1.770852				23
	7.5-8	0.2692	3397.46						65
	8-9	0.2469	3465.47	13.00	1.113943				59
	9-10	0.1933	2772.54	3.00	0.477121	78	3	20	45
	10-11	0.2277	2404.97						54
	11-12	0.2256	2037.40	5.00	0.69897	85	1	14	53

NAP 1, Soil physical properties

Depth increment (m)	THETA g/g	Cl mg/L in extract	Actual Cl mg/L	Dry sample	CO3 as Clay %	Caly %	Silt %	Fine Sand %	Coarse Total %	Matric Suction (kPa)
0.3	0.289	1.9	21.52	15.05	0.1	46.6	10.5	18.4	1.6	1195
0.5	0.221	1.4	19.40	16.18	18.5	48.6	4.2	15.7	1.9	242
0.8	0.280	5.2	66.81	13.81	18.5	44.6	3.0	9.3	2.7	58
1.1	0.267	15.1	194.57	14.57	31.7	27.0	4.9	6.1	1.1	17
1.3	0.155	88.2	1611.70	17.60	64.1	8.0	1.0	1.3	0.3	9
1.6	0.218	70.5	869.42	18.57	66.4	7.1	0.5	1.9	0.3	4
2.1	0.222	164.9	2272.33	16.34	63.4	7.7	1.5	5.3	0.3	4
2.7	0.208	89.4	1458.55	14.74	64.6	9.9	1.4	4.7	2.4	7
3.4	0.228	111.6	1427.69	17.15	63.0	8.7	1.3	3.6	0.7	3
3.7	0.187	92.0	1148.78	21.42	72.5	4.1	0.7	2.0	0.7	

NAP 2, Soil physical properties

Depth increment (m)	THETA g/g	Cl mg/L in extract	Actual Cl mg/L	Dry sample	A.D. Moist %	CO3 as CaCO3 %	Clay %	Silt %	Fine Sand %	Coarse Sand %	Total %
0.1	0.108	2.7	63.17	19.77	10.8		24.4	9.2	59.6	6.1	99.3
0.2	0.345	2.3	24.75	13.47	34.5		61.6	16.6	17.1	1.7	97.0
0.5	0.247	1.9	22.78	16.87	24.7	6.4	57.0	4.9	23.0	3.7	95.0
0.65	0.230	1.4	19.99	15.24	23.0	24.3	46.7	4.7	15.5	5.5	96.7
0.8	0.187	2.2	28.62	20.52	18.7	41.3	28.8	2.9	18.0	5.5	96.5
0.9	0.220	6.4	89.06	16.35	22.0	34.8	34.5	6.6	14.9	9.1	99.9

NAP 3, Soil physical properties

Depth	Depth from (m)	Depth to (m)	Depth interval	THETA g/g	Water in depth interval	cum water	Cl mg/L	Calc. TDS mg/L	SWP kPa	Sand %	Silt %	Clay %	% clay est from wat cont
0-0.5	0.00	0.50	0.50	0.32	0.2400	0.2400	864.31	2307.70	14.962	56.7	9.1	34.1	78
0.5-1	0.50	1.00	0.50	0.15	0.1125	0.3525	1845.64	4927.85				33	33
1-1.5	1.00	1.50	0.50	0.1	0.0750	0.4275	1622.24	4331.39				20	20
1.5-2	1.50	2.00	0.50	0.14	0.1050	0.5325	1733.10	4627.38	2.771	63.8	19.3	16.9	31
2-2.5	2.00	2.50	0.50	0.17	0.1275	0.6600	1820.55	4860.86	2.854				39
2.5-3	2.50	3.00	0.50	0.16	0.1200	0.7800	1598.72	4268.59		61.7	19.7	18.7	36
3-3.5	3.00	3.50	0.50	0.19	0.1425	0.9225	1216.05	3246.86	2.907				44
3.5-4	3.50	4.00	0.50	0.24	0.1800	1.1025	524.32	1399.93		60.4	17.1	22.5	57
4.5-5	4.50	5.00	0.50	0.21	0.3150	1.4175	565.86	1510.85	12.782				49

NAP 4, Soil physical properties

Depth	Depth from (m)	Depth to (m)	Depth interval	THETA g/g	Water in depth interval	cum water	Cl mg/L	Calc. TDS mg/L	SWP kPa	Sand %	Silt %	Clay %	% clay est from wat cont
0-0.5	0.00	0.50	0.50	0.22	0.1650	0.1650	353.43	943.66	6.281	74.3	5.5	20.2	52
0.9-1	0.90	1.00	0.10	0.2	0.1500	0.3150	869.26	2320.92					46
1-1.5	1.00	1.50	0.50	0.23	0.1725	0.4875	1130.29	3017.88	3.209	70.5	10.5	19	54
1.5-2	1.50	2.00	0.50	0.11	0.0825	0.5700	971.58	2594.11		85.9	3.3	10.8	23
2-2.5	2.00	2.50	0.50	0.2	0.1500	0.7200	752.68	2009.65	32.642	100	0	0	46
2.5-3	2.50	3.00	0.50	0.2	0.1500	0.8700	662.09	1767.79					46
3-3.5	3.00	3.50	0.50	0.17	0.1275	0.9975	730.11	1949.38	2.536	73.5	10.7	15.7	39
3.5-4	3.50	4.00	0.50	0.29	0.2175	1.2150	718.33	1917.95		58	12.4	29.6	70
4-4.5	4.00	4.50	0.50	0.26	0.1950	1.4100	762.74	2036.51					62
4.5-5	4.50	5.00	0.50	0.23	0.1725	1.5825	754.66	2014.94	11.46	60.3	15.6	24.2	54
													-6

NAP 5, Soil physical properties

Depth	Depth from (m)	Depth to (m)	Depth interval	THETA g/g	water in depth interval	cum water	Cl mg/L	Calc. TDS mg/L	SWP kPa	Sand %	Silt %	Clay %	% clay est from wat cont
0-0.5	0.00	0.50	0.50	0.23	0.1725	0.1725	1357.77	3625.25	4.723	68.1	8.5	23.4	54
0.9-1	0.90	1.00	0.10	0.21	0.1575	0.3300	1478.89	3948.64					49
1-1.5	1.00	1.50	0.50	0.21	0.1575	0.4875	1697.79	4533.11	3.096	65.1	11.6	23.3	54
1.5-2	1.50	2.00	0.50	0.23	0.1725	0.6600	1530.33	4085.98		55.7	16.5	27.9	41
2-2.5	2.00	2.50	0.50	0.18	0.1350	0.7950	1322.09	3529.98	15.834				62
2.5-3	2.50	3.00	0.50	0.26	0.1950	0.9900	1290.71	3446.19					67
3-3.5	3.00	3.50	0.50	0.28	0.2100	1.2000	1083.88	2893.95	10.344				62
3.5-4	3.50	4.00	0.50	0.26	0.1950	1.3950	1074.03	2867.65					44
4-4.5	4.00	4.50	0.50	0.19	0.1425	1.5375	1074.43	2868.72	34.404				112
4.5 +	4.50	5.00	0.50	0.45	0.3375	1.8750	1130.52	3018.50					-6

NAP 6, Soil physical properties

Depth increment (m)	THETA g/g	Cl mg/L in extract	Actual Cl mg/L	Dry sample	CO3 as Clay %	Clay %	Silt %	Fine Sand %	Coarse Total %	Matric Suction (kPa)
0.15	0.058	1.4	69.19	16.93	-0.2	12.9	7.7	60.7	10.3	1986
0.3	0.202	2	34.61	13.87	0.2	40.8	4.0	31.9	5.1	1344
0.5	0.214	15.2	179.96	19.69	52.5	11.2	1.4	6.6	1.0	24
0.8	0.203	112.8	1542.24	17.98	74.7	2.6	1.6	3.1	0.6	13
1.2	0.201	60.83	1153.39	13.10	69.7	5.8	2.3	4.0	0.3	12
1.9	0.159	54.89	986.52	17.46	58.4	11.1	4.3	5.2	0.8	19
2.4	0.137	34.04	716.03	17.35	74.8	7.7	3.0	3.3	1.8	18
2.9	0.132	37.38	684.11	20.67	70.8	10.0	1.0	4.2	3.5	21
3.4	0.089	22.04	650.53	18.96	54.8	8.5	1.8	4.6	9.6	22
3.9	0.082	22.27	661.22	20.61	78.6	6.9	1.1	3.7	0.6	20
4.4	0.144	30.06	559.78	18.65	54.8	9.8	2.9	6.0	2.7	11
4.9	0.135	37.76	570.57	24.49	35.2	9.3	1.5	5.2	3.5	6

NAP 7, Soil physical properties

Depth increment (m)	THETA g/g	Cl mg/L in extract	actual Cl mg/L	dry sample	A.D Moist %	CO3 as CaCO3 %	Clay %	Silt %	Fine Sand %	Coarse Sand %	Total %
0.1	0.131	1.8	31.93	21.74	13.1		12.5	7.6	62.9	16.2	99.2
0.25	0.108	1.5	28.78	24.35	10.8		15.0	8.5	62.3	14.4	100.2
0.4	0.370	4	40.87	13.22	37.0		75.0	7.6	12.8	3.4	98.9
0.55	0.350	4.1	42.93	13.64	35.0	64.4	26.7	1.2	5.9	1.4	99.6
0.9	0.268	6.3	81.06	14.51	26.8	68.0	22.6	2.9	2.7	0.8	96.9

IRR2, Soil physical properties

Depth	Depth from (m)	Depth to (m)	Depth Interval	THETA g/g	Water in depth interval	cum water	Cl mg/L	Calc. TDS mg/L	SWP kPa	Sand %	Silt %	Clay %	% Clay est from wat cont
0-0.5	0.00	0.50	0.50	0.09	0.0675	0.0675	78.54	209.71	7.182	94.6	2.2	3.2	18
0.5-1	0.50	1.00	0.50	0.05	0.0375	0.1050	42.85	114.40	–	98.8	0.5	0.7	7
1-1.5	1.00	1.50	0.50	0.05	0.0375	0.1425	52.20	139.38	3.449	–	–	–	7
1.5-2	1.50	2.00	0.50	0.06	0.0450	0.1875	87.69	234.13	–	–	–	–	10
2-2.5	2.00	2.50	0.50	0.06	0.0450	0.2325	255.80	682.99	7.419	–	–	–	10
2.5-3	2.50	3.00	0.50	0.07	0.0525	0.2850	398.21	1063.22	–	85.6	0.7	13.7	12
3-3.5	3.00	3.50	0.50	0.09	0.0675	0.3525	336.06	897.29	994	79.6	0.9	19.5	18
4-4.5	4.00	4.50	0.50	0.12	0.1800	0.5325	282.83	755.17	–	71.7	1.7	26.5	25
4.5-5	4.50	5.00	0.50	0.09	0.0675	0.6000	207.39	553.72	609.963	–	–	–	18
5-5.5	5.00	5.5	0.50	0.1	0.0750	0.6750	192.02	512.70	–	79.5	1.2	19.3	20
5.5-6	5.50	6.00	0.50	0.13	0.0975	0.7725	171.66	458.32	773.953	–	–	–	28
6-6.5	6.00	6.50	0.50	0.12	0.0900	0.8625	158.29	422.63	–	76.8	-0.5	23.7	25
6.5-7	6.50	7.00	0.50	0.12	0.0900	0.9525	118.49	316.38	220.389	–	–	–	25
7-7.5	7.00	7.50	0.50	0.12	0.0900	1.0425	120.14	320.77	–	–	–	–	25
7.5-8	7.50	8.00	0.50	0.07	0.0525	1.0950	239.81	640.28	61.883	88.8	-0.5	11.7	12
8-8.5	8.00	8.50	0.50	0.06	0.0450	1.1400	230.44	615.28	–	–	–	–	10
9-9.5	9.00	9.50	0.50	0.14	0.2100	1.3500	777.57	2076.11	–	–	–	–	31

**now IRR2

B. MAJOR ION CHEMISTRY FOR PRECIPITATION, IRRIGATION WATER, GROUNDWATER AND SOIL WATER

Chemical composition of ground water in the Naracoorte Ranges

Analyte grouping / Analyte	Units	GLE118 16/02/2005	GLE117 16/02/2005	GLE119 16/02/2005	GLE120 16/02/2005	GLE121 16/02/2005	GLE122 15/02/2005	GLE123 15/02/2005	GLE124 15/02/2005	GLE127 18/02/2005	GLE128 17/02/2005	GLE129 17/02/2005	GLE130 17/02/2005	GLE131 17/02/2005	GLE135 16/02/2005
EA010P: Conductivity by PC Titrator															
Electrical Conductivity @ 25°C	µS/cm	2150	2110	2650	2630	1560	1580	1850	2270	1730	1620	2200	3100	3180	1280
EA016: Non Marine - Estimated TDS Salinity															
TDS (est.)	mg/L	1400	1370	1720	1710	1010	1030	1200	1480	1120	1050	1430	2020	2070	833
ED037P: Alkalinity by PC Titrator															
Bicarbonate Alkalinity as CaCO3	mg/L	323	313	372	373	305	300	370	370	306	318	298	332	332	270
ED045P: Chloride by PC Titrator															
Chloride	mg/L	508	492	672	664	329	339	441	542	399	367	593	855	902	247
ED093F: Dissolved Major Cations															
Calcium	mg/L	129	126	149	147	107	103	116	129	120	120	160	192	129	95
Magnesium	mg/L	39	36	56	56	22	22	29	47	29	25	28	55	64	17
Sodium	mg/L	149	149	217	193	165	183	143	187	110	173	170	216	308	126
Potassium	mg/L	7	6	12	9	4	6	7	9	5	6	6	5	6	4
EG005F: Dissolved Metals by ICP-AES															
Sulphur as S	mg/L	22	19	35	34	14	15	15	29	12	12	13	20	21	10
EG020F: Dissolved Metals by ICP-MS															
Bromine	mg/L	1.3	1.3	1.8	1.7	0.8	0.8	1	1.4	1	0.9	1.3	2	2.2	0.7
EK057: Nitrite as N															
Nitrite as N	mg/L	<0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.013	<0.010
EK058: Nitrate as N															
Nitrate as N	mg/L	1.16	2.57	<0.010	<0.010	3.12	2.46	2	<0.010	0.938	0.764	0.764	0.568	0.204	3.14
EK059: Nitrite plus Nitrate as N (NOx)															
Nitrite + Nitrate as N	mg/L	1.16	2.58	<0.010	<0.010	3.12	2.46	2	<0.010	0.938	0.764	0.764	0.568	0.217	3.14

Chemical composition of Irrigation water and rainfall

Analyte grouping / Analyte	Units	IRRIGATION WATER										RAINFALL		
		GLE275 NAP1	PAR219 NAP2	PAR213 NAP2	MAR209 NAP3	MAR208 NAP4	MAR208 NAP4	MAR207 NAP5	GLE279 NAP6	GLE279 NAP6	GLE 287 NAP 7	NAP 6	NAP 4	RANGES
		14/12/2004	16/12/2004	16/12/2004	17/12/2004	07/12/2004	17/12/2004	17/12/2004	14/12/2004	17/12/2004	14/02/2005	17/12/2004	17/12/2004	17/12/2004
ED037P: Alkalinity by PC Titrator														
Bicarbonate Alkalinity as CaCO3	mg/L	250	316	243	193	252	257	272	262	238	317	12	26	27
ED040F : Dissolved Sulphate by ICPAES														
Sulphate as SO4 2-	mg/L	45	55	58	44	70	71	116	69	71	60	2	3	3
ED045P: Chloride by PC Titrator														
Chloride	mg/L	341	419	455	834	598	628	1220	504	511	495	3	5	4
ED093F: Dissolved Major Cations														
Calcium	mg/L	122	149	148	195	140	156	262	143	140	141	2	8	8
Magnesium	mg/L	30	42	39	75	48	55	83	47	45	38	<1	<1	<1
Sodium	mg/L	181	152	148	245	236	249	431	185	185	137	3	4	4
Potassium	mg/L	4	6	6	8	8	8	10	6	6	6	1	<1	2
EG005F: Dissolved Metals by ICP-AES														
Iron	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.13	- - -	- - -	- - -
Silica	mg/L	21.3	21.4	22	21.3	20.4	20.6	21.4	21.9	21.9		- - -	- - -	- - -
EG020F: Dissolved Metals by ICP-MS														
Bromine	mg/L	1.1	1.2	1.3	2.1	1.9	1.9	3.3	1.6	1.5	1.6	<0.1	<0.1	<0.1
EK057: Nitrite as N														
Nitrite as N	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	- - -	- - -	- - -
EK058: Nitrate as N														
Nitrate as N	mg/L	0.944	4.16	6.45	15	5.19	5.09	4.39	5.5	5.19	3.25	- - -	- - -	- - -
EK059: Nitrite plus Nitrate as N (NOx)														
Nitrite + Nitrate as N	mg/L	0.944	4.16	6.45	15	5.19	5.09	4.39	5.5	5.19	3.25	- - -	- - -	- - -
EN055: Ionic Balance														
Total Anions	meq/L	15.5	19.3	18.9	28.3	23.4	24.3	42.3	20.9	20.6	21.5	0.37	0.71	0.71
Total Cations	meq/L	16.6	17.6	17.2	26.8	21.4	23.3	38.9	19.2	18.9	21.2	0.28	0.59	0.64
Ionic Balance	%	3.26	4.37	4.7	2.74	4.43	2.05	4.16	4.16	4.37	0.23	- - -	- - -	- - -

Chemical composition of Soil Water and Groundwater

Sample ID	Alkalinity (as $CaCO_3$) mequiv./L	Cl mg/L	Ca mg/L	K mg/L	Mg mg/L	Na mg/L	S mg/L	Br^- mg/L	NO3 mg/L
NAP 1 - 2.4m	insuff.	1400*	insuff.	insuff.	insuff.	insuff.	insuff.	insuff.	
NAP 1 - Piezo	5.5	840	140	8.5	61	430	29	3.2	33
NAP 2 - 2.4m	4.7	1100	200	17	43	660	79	3.8	20
NAP 2 - 3.4m	4.3	1300	280	13	63	640	71	4.9	9
NAP 2 - Piezo	4.5	830	170	7.6	58	370	27	3.0	40
NAP 3 West - 0.9m	9.1	2200	260	44	90	1300	46	6.4	83
NAP 3 West - 1.4m	12.6	1500	110	36	82	1100	45	4.2	110
NAP 3 West - 2.4m	6.4	2200	400	24	170	830	44	5.8	<1
NAP 3 - Piezo	4.0	910	180	10	77	370	20	3.0	77
NAP 3 East - 0.9m	8.4	2600	150	59	130	1600	56	9.8	39
NAP 3 East - 1.4m	9.2	2200	240	37	150	1200	72	6.3	130
NAP 3 East - 2.4m	7.4	3700	400	69	340	1700	87	8.3	150
NAP 4 West - 1.4m	7.2	890	97	21	68	590	45	3.3	14
NAP 4 West - 2.4m	6.5	1400	62	22	76	940	70	4.9	12
NAP 4 West - 3.4m	8.9	950	120	16	54	730	58	4.0	99
NAP 4 East - 1.4m	7.3	860	130	6.7	60	490	33	3.1	48
NAP 4 East - 2.4m	7.1	750	120	16	57	430	30	2.8	34
NAP 4 East - 3.4m	9.0	630	90	7.5	43	530	97	2.2	11
NAP 4 - Piezo	4.6	880	150	6.9	62	460	33	3.4	53
NAP 5 North - 1.4m	6.9	1600	250	14	100	770	48	5.7	16
NAP 5 North - 2.4m	6.2	1200	170	15	73	620	34	4.4	18
NAP 5 North - 2.9m	8.0	1300	86	14	54	920	34	4.5	12
NAP 5 South - 1.4m	6.4	1400	240	7.1	94	710	45	5.3	12
NAP 5 South - 2.4m	7.8	1100	79	37	52	790	57	4.1	8
NAP 5 South - 2.9m	8.2	1200	69	23	48	860	49	4.3	6
NAP 5 - Piezo	4.6	1400	210	9.4	93	600	31	5.0	20
NAP 6 - 3.55m	7.0	980	110	19	31	710	64	3.0	14
NAP 6 - Piezo	4.0	530	77	5.6	43	270	24	2.1	27
NAP 7 - 3.4m	6.2	2500	320	38	170	1400	110	5.2	230
NAP 7 - Piezo	5.5	700	110	8.3	69	360	23	2.6	53
BG 1 - 1.4m	4.6	80	58	10	16	140	22	0.2	150
BG 1 - 2.4m	8.8	120	66	5.8	21	260	37	0.5	140
BG 1 - 3.2m	6.9	900	140	10	57	540	45	3.4	76

Chemical composition of groundwater

Analyte grouping / Analyte	Units	PIEZ0 NAP 1	PIEZ0 NAP 2	PIEZ0 NAP 3	PIEZ0 NAP 4	PIEZ0 NAP 5	PIEZ0 NAP 6	PIEZ0 NAP 7
		22/12/04	22/12/04	21/01/05	21/12/04	21/01/05	22/12/04	22/12/04
ED037P: Alkalinity by PC Titrator								
Bicarbonate Alkalinity as CaCO3	mg/L	286	206	213	310	279	267	281
Total Alkalinity as CaCO3	mg/L	286	206	213	310	279	267	281
M-Alkalinity	mg/L	286	206	213	310	279	267	281
ED040F : Dissolved Sulphate by ICPAES								
Sulphate as SO4 2-	mg/L	77	72	41	92	89	59	61
ED045P: Chloride by PC Titrator								
Chloride	mg/L	867	889	846	951	1360	531	748
ED093F: Dissolved Major Cations								
Calcium	mg/L	191	220	220	235	302	146	153
Magnesium	mg/L	74	66	77	70	95	48	82
Sodium	mg/L	305	277	235	341	456	190	266
Potassium	mg/L	12	9	9	8	10	6	10
EG005F: Dissolved Metals by ICP-AES								
Iron	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	mg/L	23.8	22.2	21.6	21	21.2	22.7	21.1
Sulphur as S	mg/L	26	26	15	33	32	22	22
EG020F: Dissolved Metals by ICP-MS								
Bromine	mg/L	2.5	2.5	2.3	2.7	3.6	1.8	2
EK058: Nitrate as N								
Nitrate as N	mg/L	7.07	8.49	15.9	10.4	4.73	5.53	10.9
EN055: Ionic Balance								
Total Anions	meq/L	31.8	30.7	29	34.9	45.8	21.6	28
		29.2	28.7	27.8	32.5	43	19.7	26.2
		4.21	3.36	2.12	3.54	3.19	4.56	3.24

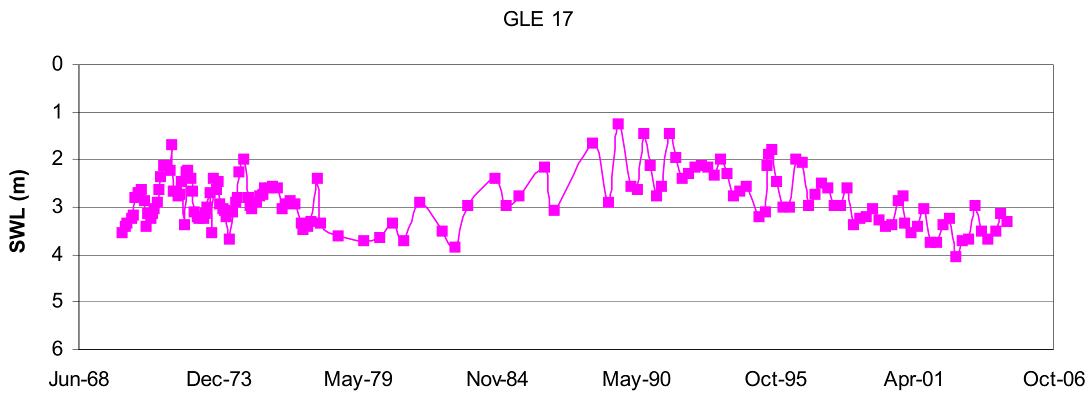
C. SUCTION LYSIMETER - SOIL WATER CHLORIDE AND SALINITY

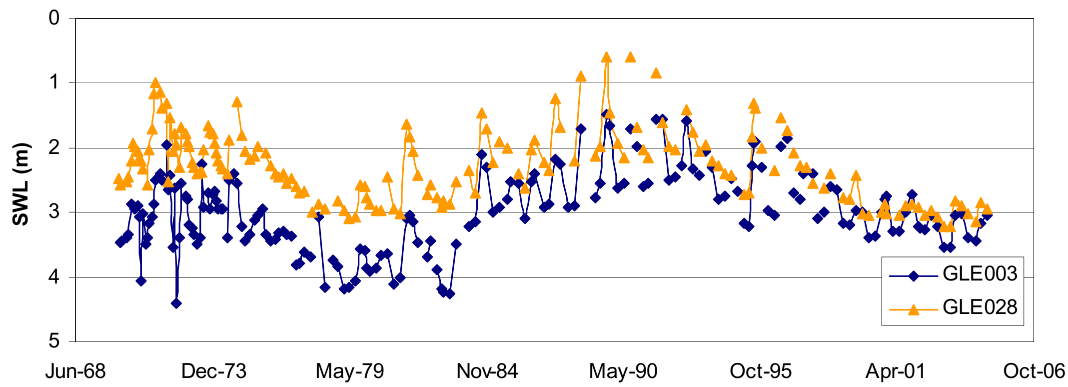
SALINITY (mg/L)	NAP1					NAP2					NAP3 West					NAP3 East					NAP4 West				NAP4 East				
Depth below Ground	0.45	1.01	2.04	3.01	Piezo	0.45	1.04	2.03	3.03	Piezo	0.30	0.52	1.15	2.02	Piezo		0.50	0.94	2.00		0.35	1.06	2.03	3.05	0.30	1.13	2.01	2.92	Piezo
13-Nov-03		8067	3943	4088			3080	2216	2750			1838	6232	5550				6184	5964			1860	3135	2511		1479	1529	2499	
05-Dec-03		8067	3943	4291			2869	2261	2732			3914	5250	3712				6244	6024			2165	3885	2499		1782	1585	2420	
20-Jan-04				4245				2369	2772			4378	3166	4466			4088	4816	6560			2284	2761	2767		1787	1523	2420	
28-Jan-04												4524	3138	4640				4378	6590										
30-Mar-04																													
26-May-04					1849			2403	2721	1765		3138	3138	4436	1725				6919			2244		2154		2015	1720	1742	1900
13-Aug-04		9076			1748		5315	2058	2710	1821		2284	3252	5168	2052		1244	4536	5403			2590	2852	2256		2086	1911	1827	1984
13-Sep-04		8280	3943	3943	1832		4524	2058	2624	1832		2284	3195	4816	1776		1832	4816	6291			2454	2738	2227		2058	1832	1889	1945
18-Oct-04		7545			1810		4471	2069	2528	1855		2619	3166	4757	1742			6113				1928	2687	2114		1703	1815	1849	1911
17-Nov-04		7310		3897	1759		4968	2013	2454	1731		2403	3029	4436	1680			4693	5876			1793	2516	2041		1731	1832	1731	1860
21-Dec-04				3984	1737			2035	2420	1664		3075	2989	4425	1641				5657			1962		1832		1759	1810	1607	1911
01-Feb-05	2806				1770	1205		2052	2443	1714	2409	3361	3080	5385	1703				5285		2426	2250	2278	1827	1860	1922	1776	1742	1939
22-Mar-05				3695	1635			1996	2290	760	3218	2989	3585	4874	1613		3201	5911	5074		2420	2063	2131	1613		633	1725	1630	1630
17-May-05				3597	1652			1951	2267	1546	2795	3557	3666	4576	1551		5132	5680	5168			1979	2363	1708		1686	1613	1495	1776
23-Jun-05	2001				1664	1945	6291	1945	2227	1607	1272	2909	3770	5816	2341			6949	5816		2511	2511	2454	1832		1889	1776	1551	1889
10-Aug-05	3200				1660	2450	5580		2341	1660	1439	3138	4466	5403	1607		3367		5226		2909	2397	2624	1832		1776	1832	1664	1889
SALINITY (mg/L)	**NAP5 North**					**NAP5 South**					**NAP6**					**NAP7**					**BG1**				**BG2**				
Depth below Ground	0.353	1.04	2.01	2.51		0.35	0.97	2.02	2.52	Piezo	0.50	0.95	2.00	2.90	Piezo	0.35	1.00	2.01	2.96	Piezo	0.40	0.99	2.05	2.87	0.50	0.90	1.97	3.05	
13-Nov-03		2301	2482	2750			2315	3597	2653			2533	3655	2301			3914	7884	5079			710	854	2250		Trace			
05-Dec-03		2326	2267	2750			2205	3476	2602			2585	3712	2261			8091	7824	5050			674	863	2233					
20-Jan-04		2921	1675	2767			2869	2607	2710				3597	2227					5021			591	838	2148					
28-Jan-04																													
30-Mar-04																													
26-May-04		2966	2590	2681			2881	2681	2752	2639					1166					1535			832	2171					
13-Aug-04		1900	2841	2602			1951	2812	2881	2687		2590			1172		7582		4454	1579		774	938	2227		1227			
13-Sep-04		1776	2739	2624			2114	2852	2738	2568		1889	3424	2114	1216		7129	7250	4582	1607		771	827	2114		1049			
18-Oct-04		1939	2676	2568			1843	2829	2613	2454		2058	3557	2024	1227		6482		5226	1574		749	832	2097					
17-Nov-04		2256	2454	2460			2001	2738	2568	2307		2636	1967	1490	1160				5162			766	799	2018					
21-Dec-04		2715	2154	2426			2704	2573		2363				1945	1199				5168	1529		732	821	2018					
01-Feb-05		2806	2335	2494			2738	2409	2154	2533	1928			2001	1227	1372			5150			627	904	2035					
22-Mar-05	2414	2465	2409	2352		3006	2772	2346	2363	2460				1866	1250				4950	1010		528	788	2001					
17-May-05	2437	2335	2426	2290		2818	2687	2568	2516	2341					1149					1434			727	1849					
23-Jun-05	3424	2681	2624	2454		3539	3080	2909	3080	2454	1720				1160	2909			4878	1495		660	882	2001	1495				
10-Aug-05	3310	2624	2568	2454		3482	2852		2738	2454	3655				1160	3655				1495		660	827	2001	1551				

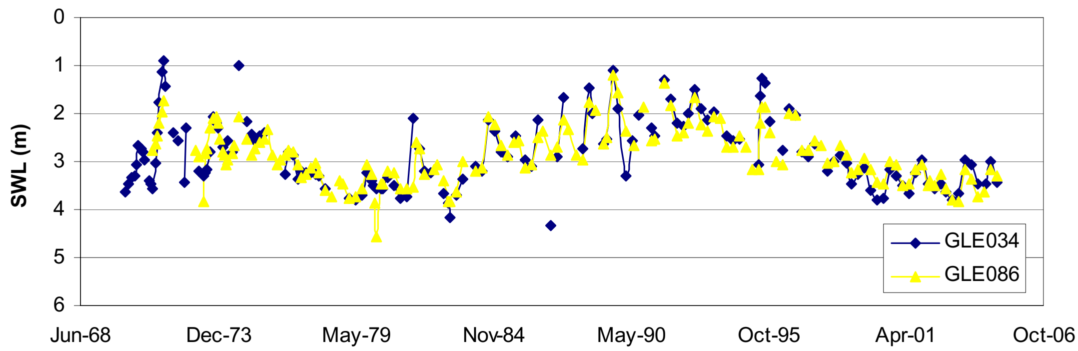
CHLORIDE (mg/L)	NAP1					NAP2					NAP3 West					NAP3 East					NAP4 West				NAP4 East				
Depth below Ground	0.45	1.01	2.04	3.01	Piezo	0.45	1.04	2.03	3.03	Piezo	0.30	0.52	1.15	2.02	Piezo		0.50	0.94	2.00		0.35	1.06	2.03	3.05	0.30	1.13	2.01	2.92	Piezo
30-Mar-04			1400		840			1000	1300	830		2100	1400	2000	910		2600	2000	3700			890	1200	950		860	750	630	880
26-May-04					810			1000	1300	820		1500	1300	2300	810		2600	2100	3800			1000	1200	890		860	740	590	940
13-Aug-04		5300			820		2800	900	1300	880		920	1400	2800	1000		380	2100	2800			1200	1200	940		880	750	660	910
13-Sep-04		4800	2200	2400	850		2400	950	1400	910		960	1500	2600	870		730	2400	3500			1300	1300	970		900	790	690	890
18-Oct-04		4431			877		2476	988	1385	933		1245	1532	2619	876			2540	3470			810	1270	970		734	779	696	910
17-Nov-04		4280		2400	860		2810	990	1340	902		1140	1530	2520	860			2580	3420			864	1250	920		790	920	717	940
21-Dec-04				2500	859			1010	1330	880		1730	1560	2530	831				3220			903		840		808	809	712	930
01-Feb-05					850			993	1330	846		1840	1540	3140	880				2980			1080	1020	711		897	768	683	945
22-Mar-05				2470	843			1010	1300	376	1980	1870	2200	3010	899		1940	3410	2940		1280	1150	1080	728		300	840	688	910
17-May-05				2340	817			1020	1250	838	1680	2340	2310	2930	799		2990	3600	3080		1780	1160	1320	782		906	883	679	948
23-Jun-05	1010				817	972	4490	1040	1290	845	524	1760	2410	4210	1430			4620	4020		1160	1350	1370	762		924	861	660	985
10-Aug-05	2410				1070	1750	4280		1680	1100	606	2440	3080	4000	804		2820		3790		1880	1700	1860	1060		1200	1110	831	1300

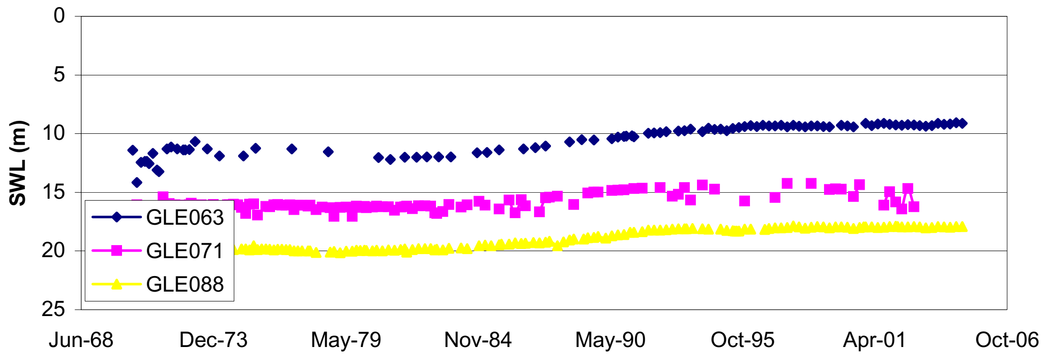
CHLORIDE (mg/L)	NAP5 North					NAP5 South					NAP6					NAP7					BG1				BG2				
Depth below Ground	0.35	1.04	2.01	2.51		0.35	0.97	2.02	2.52	Piezo	0.30	0.95	2.00	2.90	Piezo	0.35	1.00	2.01	2.96	Piezo	0.40	0.99	2.05	2.87	0.40	0.90	1.97	3.05	
30-Mar-04		1600	1200	1300			1400	1100	1200	1400				910	530				2500	700		80	120	900		Dry	Dry	Dry	
26-May-04		1600	1200	1300			1500	1300	1200	1300					500				2300	650		67	86	890		Dry	Dry	Dry	
13-Aug-04		710	1300	1200			680	1400	1400	1300		1000			490		4100		2300	720		65	68	1000		180	Dry	Dry	
13-Sep-04		600	1400	1300			850	1500	1500	1400		620	1900	960	510		3600	3500	2400	730		61	60	1000		120	Dry	Dry	
18-Oct-04		872	1460	1317			797	1571	1421	1366		799	2048	959	520		3346		2880	731		65	61	1017		107	Dry	Dry	
17-Nov-04		1170	1360	1340			950	1520	1440	1310		1220		930	514				2900	740		63	58	1000		Dry	Dry	Dry	
21-Dec-04		1480	1120	1290			1510	1350	1600	1310				920	522				2900	716		67	58	990		Dry	Dry	Dry	
01-Feb-05		1540	1210	1260			1510	1190	1010	1390				925	511				2900			67	61	999		Dry	Dry	Dry	
22-Mar-05	1380	1430	1390	1290		1790	1770	1360	1340	1440				929	317				2950	475		70	64	993					
17-May-05	1560	1440	1520	1290		1740	1740	1650	1560	1490					528					699			62	982					
23-Jun-05	2120	1560	1490	1340		2180	1840	1710	1570	1450	749				507	1650			3090	704		84	60	990	330				
10-Aug-05	2520	1950	1850	1700		2660	2160	2180	2000	1780	2670				515	2730				709		67	64	1330	320				

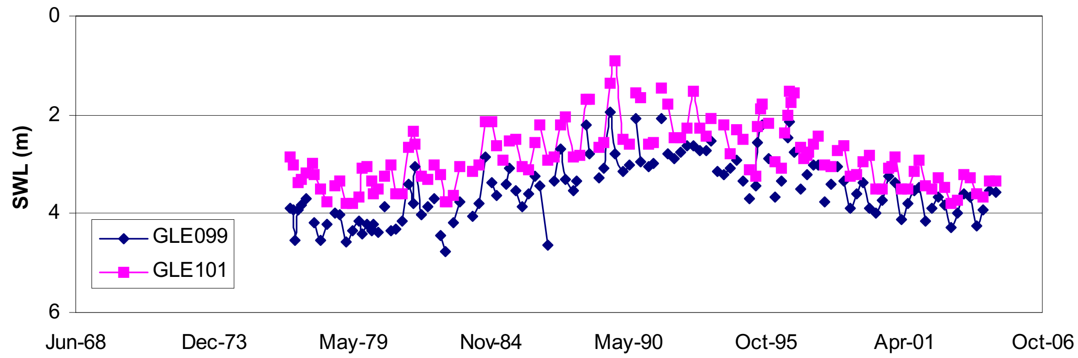
D. HYDROGRAPHS FROM THE UNCONFINED AQUIFER

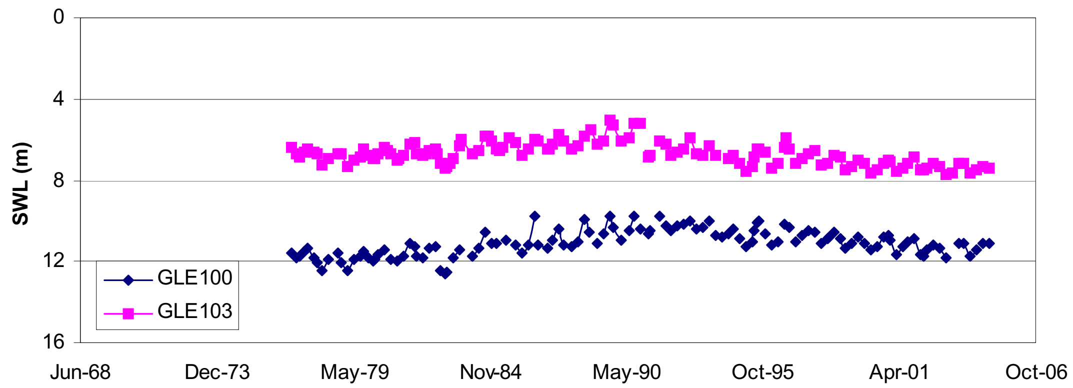


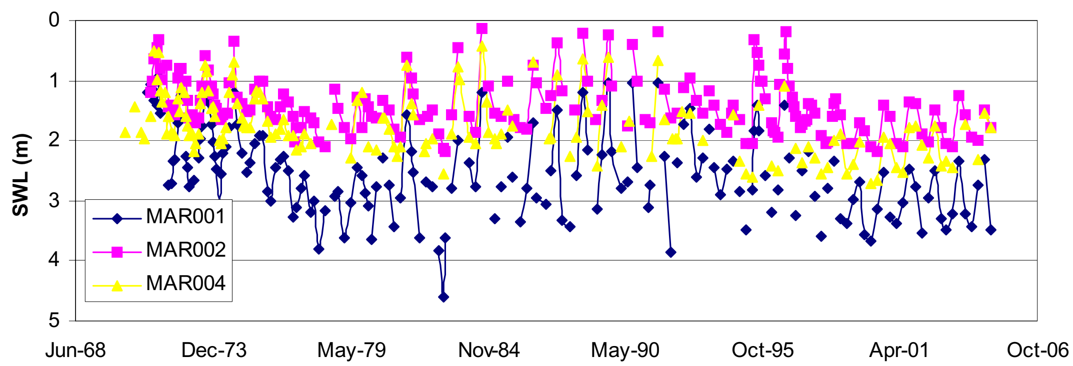


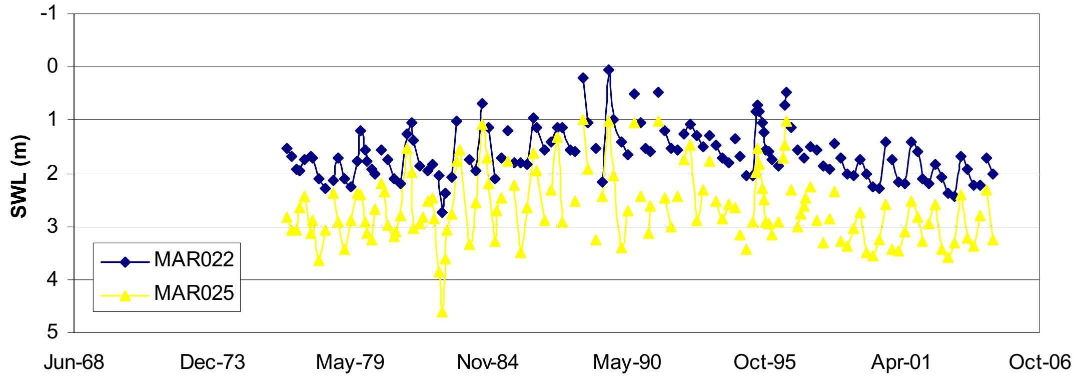


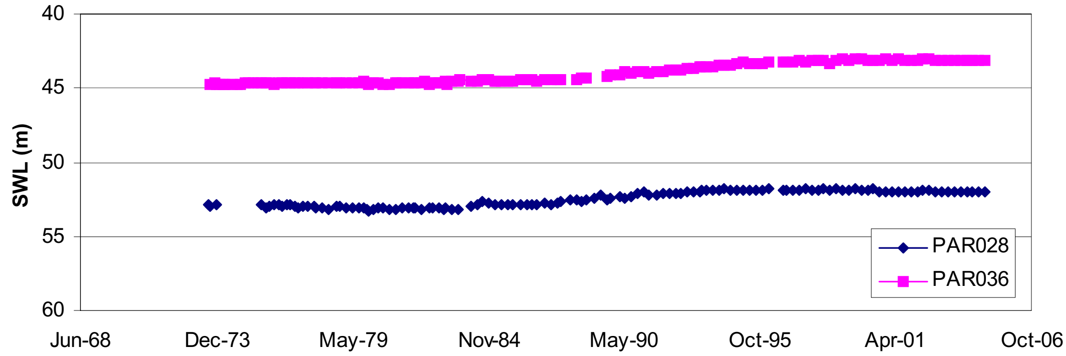

SWL (m)
0
5
10
15
20
25
GLE063
GLE071
GLE088
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

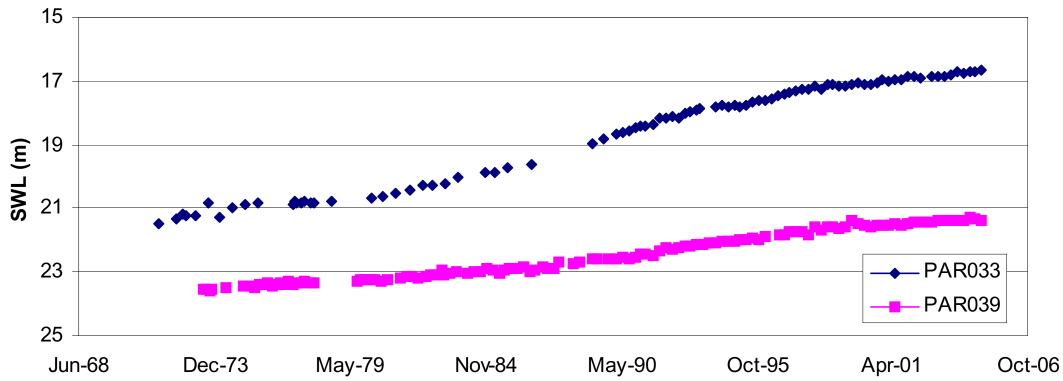

SWL (m)
0
2
4
6
GLE099
GLE101
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

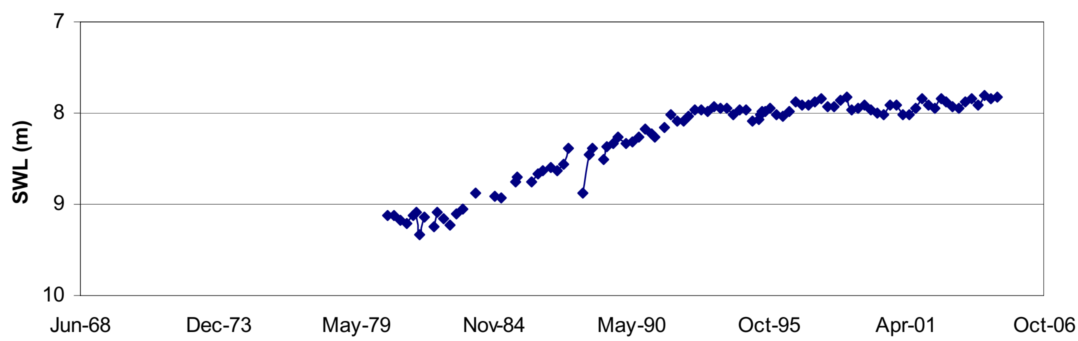

SWL (m)
0
4
8
12
16
GLE100
GLE103
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

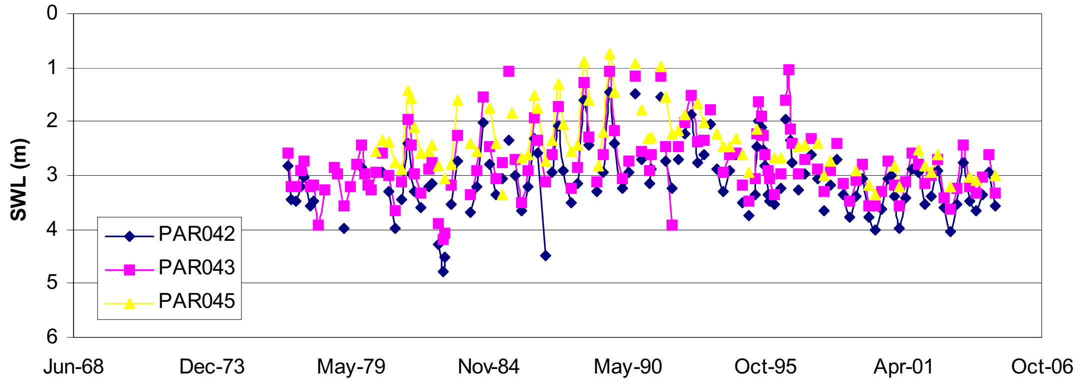

SWL (m)
0
1
2
3
4
5
MAR001
MAR002
MAR004
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06


SWL (m)
MAR022
MAR025
-1
0
1
2
3
4
5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

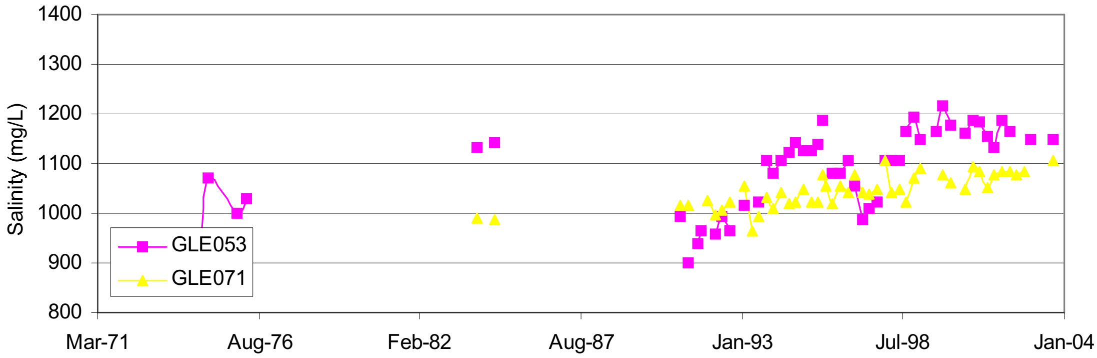

SWL (m)
PAR028
PAR036
40
45
50
55
60
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

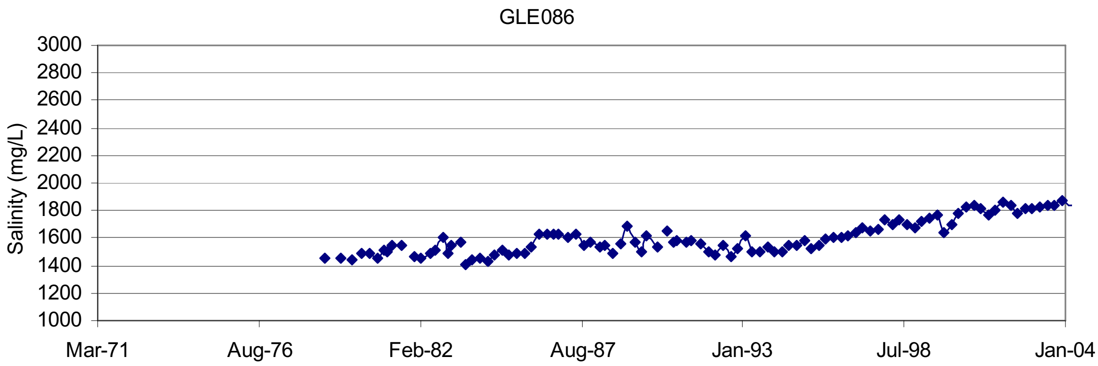

SWL (m)
PAR033
PAR039
15
17
19
21
23
25
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

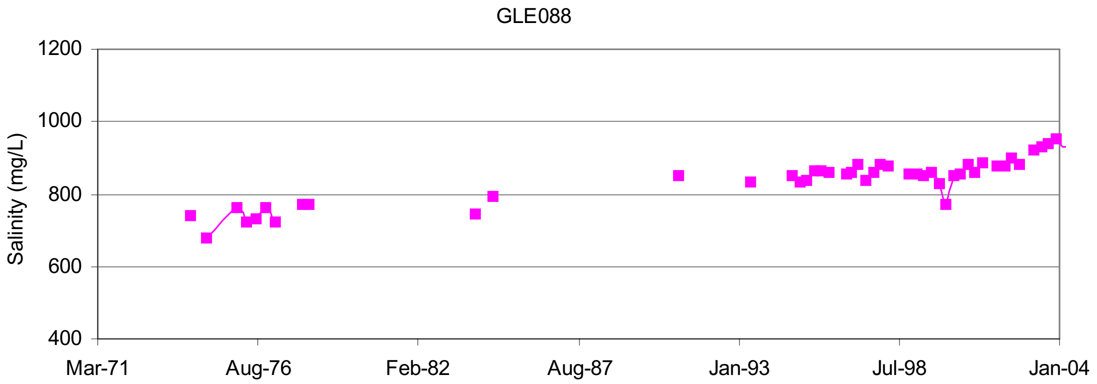

PAR046
SWL (m)
7
8
9
10
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

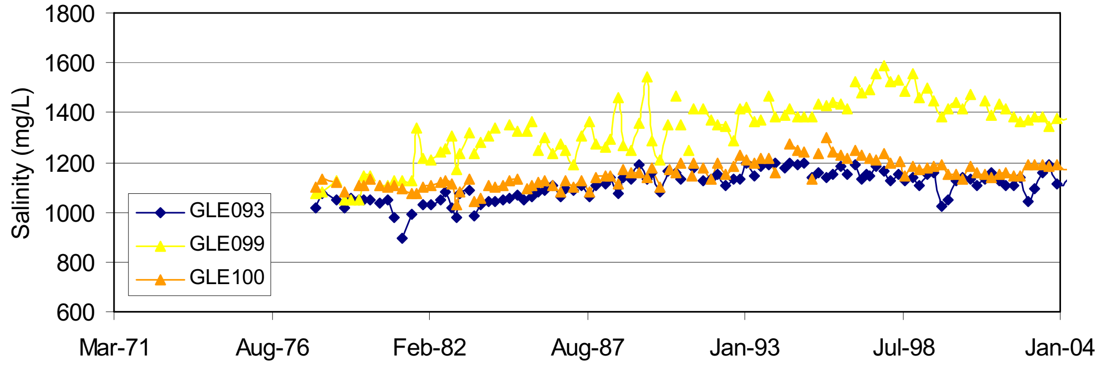

0
1
2
3
4
5
6
SWL (m)
PAR042
PAR043
PAR045
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Oct-06

E. TIME SERIES OF GROUNDWATER SALINITY FROM THE UNCONFINED AQUIFER

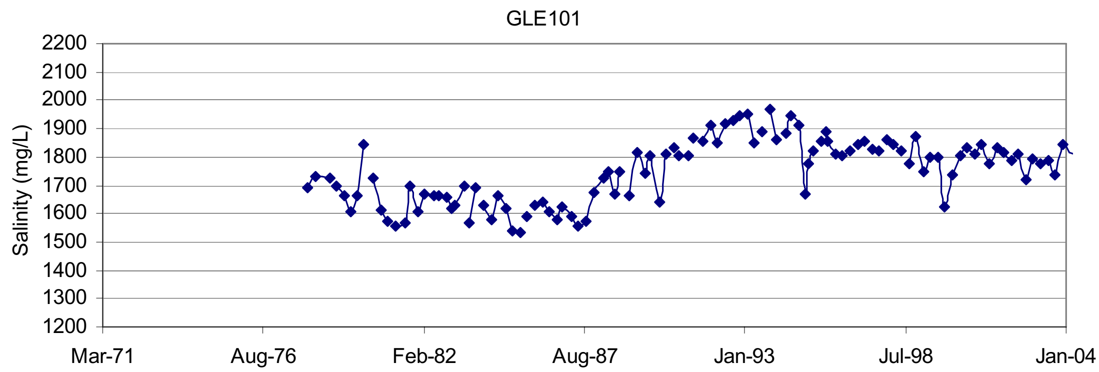




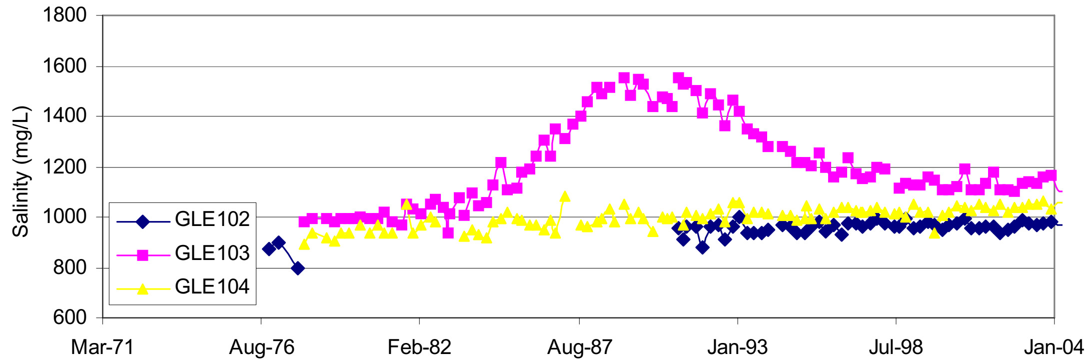




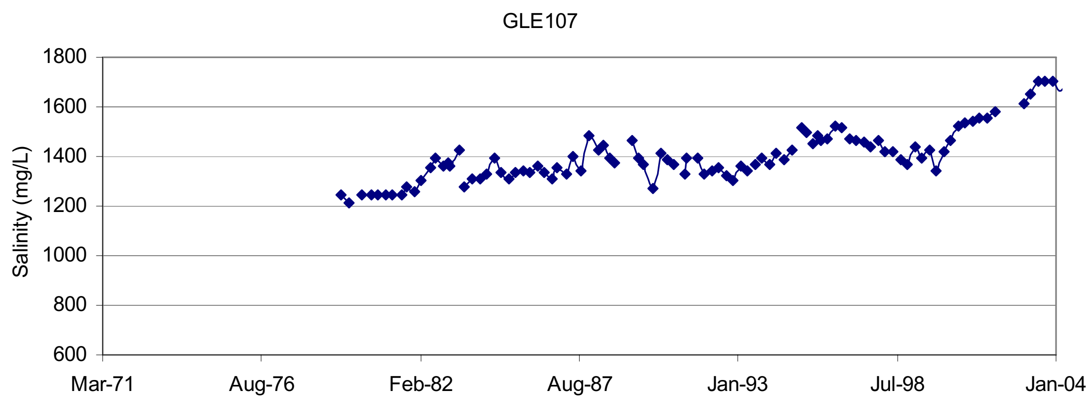
Salinity (mg/L)
1800
1600
1400
1200
1000
800
600
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
GLE093
GLE099
GLE100



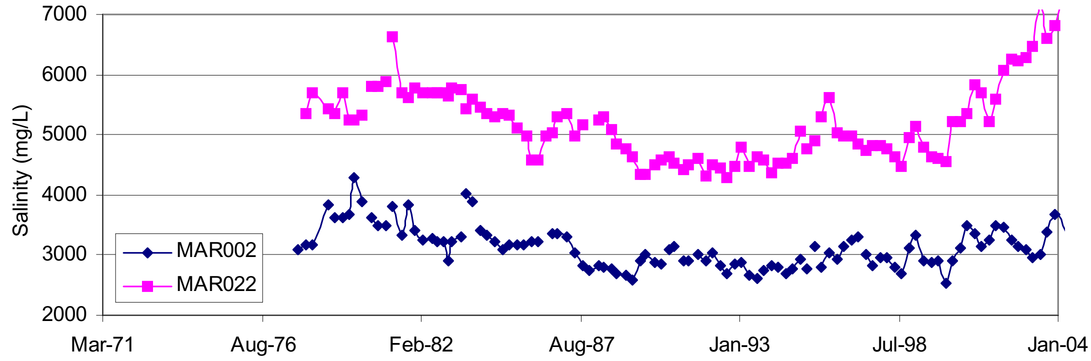
GLE101
Salinity (mg/L)
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04



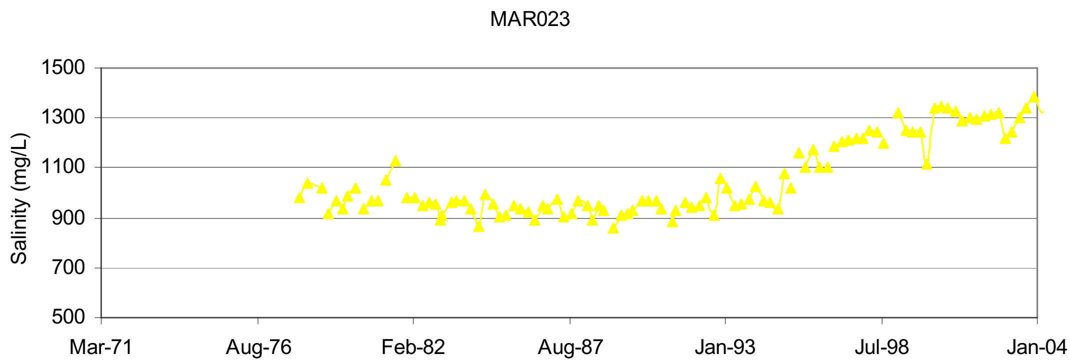
Salinity (mg/L)
1800
1600
1400
1200
1000
800
600
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
GLE102
GLE103
GLE104



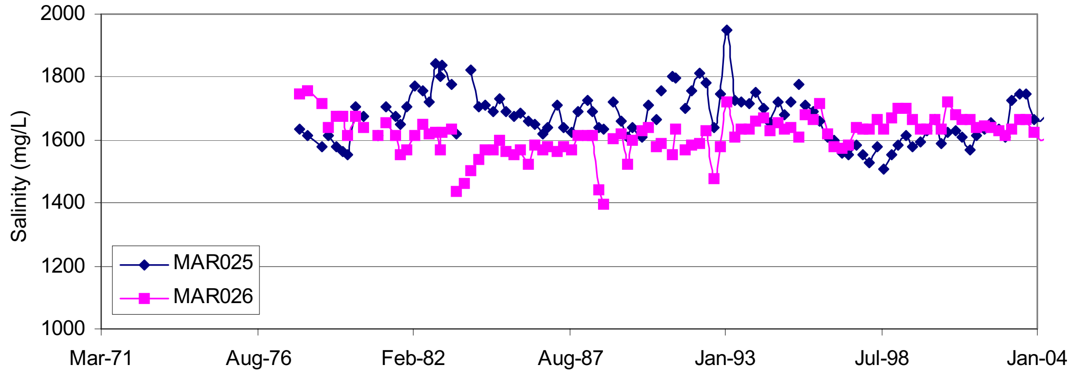
GLE107
Salinity (mg/L)
1800
1600
1400
1200
1000
800
600
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04



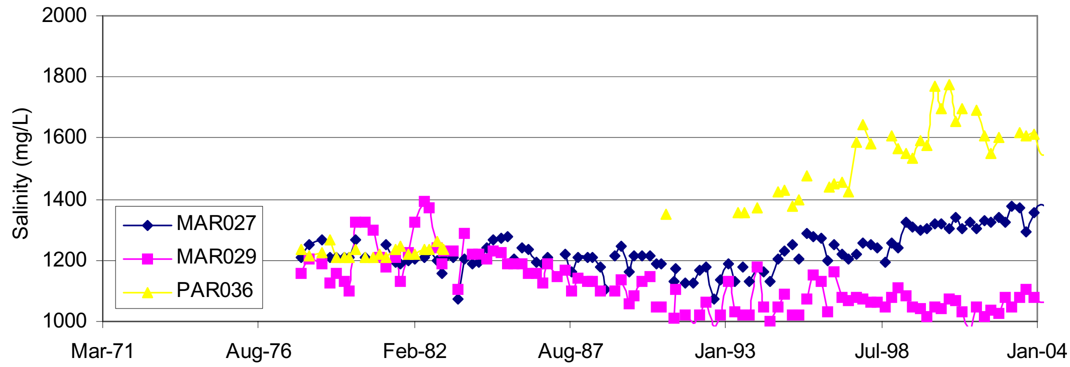
7000
6000
5000
4000
3000
2000
Salinity (mg/L)
MAR002
MAR022
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04



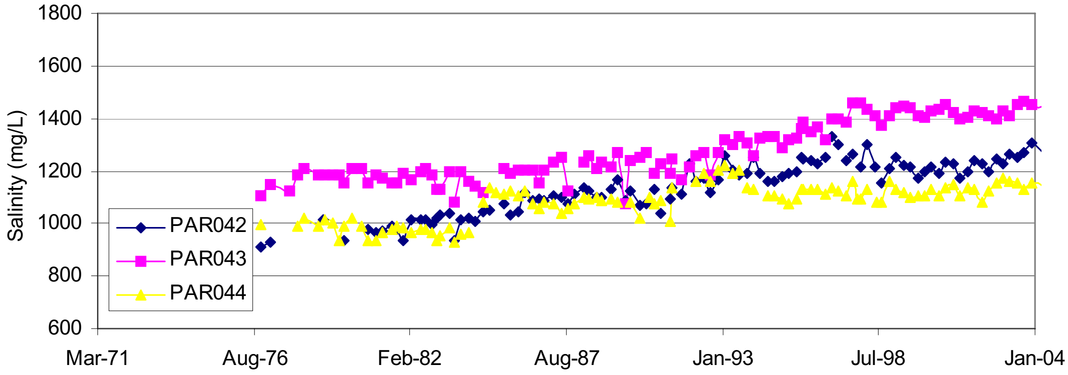
MAR023
1500
1300
1100
900
700
500
Salinity (mg/L)
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04



2000
1800
1600
1400
1200
1000
Salinity (mg/L)
MAR025
MAR026
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04



2000
1800
1600
1400
1200
1000
Salinity (mg/L)
MAR027
MAR029
PAR036
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04


1800
1600
1400
1200
1000
800
600
Salinity (mg/L)
PAR042
PAR043
PAR044
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	356 or 366 days	time interval

δD	hydrogen isotope composition
$\delta^{18}O$	oxygen isotope composition
^{14}C	carbon-14 isotope (percent modern carbon)
CFC	chlorofluorocarbon (parts per trillion volume)
EC	electrical conductivity (µS/cm)

GLOSSARY

Aquifer. An underground layer of rock or sediment which holds water and allows water to percolate through.

Aquifer, unconfined. Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Aquitard. A layer in the geological profile that separates two aquifers and restricts the flow between them.

Bore. *See well.*

Catchment. A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Catchment water management board. A statutory body established under Part 6, Division 3, s. 53 of the Act whose prime function under Division 2, s. 61 is to implement a catchment water management plan for its area.

Catchment water management plan. The plan prepared by a CWMB and adopted by the Minister in accordance with Part 7, Division 2 of the Water Resources Act 1997.

CWMB. Catchment Water Management Board.

DWLBC. Department of Water, Land and Biodiversity Conservation. Government of South Australia.

EC. Abbreviation for electrical conductivity. 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25 degrees Celsius. Commonly used to indicate the salinity of water.

Ephemeral streams / wetlands. Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

Evapotranspiration. The total loss of water as a result of transpiration from plants and evaporation from land, and surface waterbodies.

Gigalitre (GL). One thousand million litres (1 000 000 000).

GIS (geographic information system). Computer software allows for the linking of geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

Geological features. Include geological monuments, landscape amenity and the substrate of land systems and ecosystems.

Groundwater. *See underground water.*

Hydrogeology. The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See hydrology.)*

Integrated catchment management. Natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints.

Intensive farming. A method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or by mechanical means.

Irrigation. Watering land by any means for the purpose of growing plants.

Irrigation season. The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May.

Land. Whether under water or not and includes an interest in land and any building or structure fixed to the land.

Leaching. Removal of material in solution such as minerals, nutrients and salts through soil.

Megalitre (ML). One million litres (1 000 000).

ML. *See megalitre.*

MLR. Mount Lofty Ranges.

Model. A conceptual or mathematical means of understanding elements of the real world which allows for predictions of outcomes given certain conditions. Examples include estimating storm runoff, assessing the impacts of dams or predicting ecological response to environmental change.

Natural recharge. The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) *(See recharge area, artificial recharge.)*

Natural Resources Management (NRM). All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

Pasture. Grassland used for the production of grazing animals such as sheep and cattle.

Permeability. A measure of the ease with which water flows through an aquifer or aquitard.

PIRSA. (Department of) Primary Industries and Resources South Australia.

Prescribed well. A well declared to be a prescribed well under the Water Resources Act 1997.

PWA. Prescribed Wells Area.

PWCA. Prescribed Watercourse Area.

PWRA. Prescribed Water Resources Area.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

Surface water. (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Underground water (groundwater). Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Water allocation. (a) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence; (b) in respect of water taken pursuant to an authorisation under s. 11 means the maximum quantity of water that can be taken and used pursuant to the authorisation.

Water allocation, area based. An allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water use year.

Water allocation plan (WAP). A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

Water plans. The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act.

Water service provider. A person or corporate body that supplies water for domestic, industrial or irrigation purposes or manages wastewater.

Waterbody. Waterbodies include watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers.

Water-use year. The period between 1 July in any given calendar year and 30 June the following calendar year. This is also called a licensing year.

Well. (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

REFERENCES

Desmier, R.E., 1992, Estimation of the water requirements of irrigated crops in the Padthaway Proclaimed Region, South Australia.