DEPARTMENT OF MINES AND ENERGY
GEOLOGICAL SURVEY
SOUTH AUSTRALIA

REPORT BOOK 96/044

PADTHAWAY PROCLAIMED WELLS AREA
GROUNDWATER STATUS REPORT

by

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DEPARTMENT OF MINES AND ENERGY
GEOLOGICAL SURVEY
SOUTH AUSTRALIA

REPORT BOOK 96/9 DME NO 331/75

Padthaway Proclaimed Wells Area Groundwater Status Report

N WATKINS

The Padthaway Formation and Bridgewater Formation aquifers provide a high quality groundwater resource in the Padthaway Proclaimed Wells Area (PWA). The resource supports an irrigated agriculture and horticulture industry. Irrigation is concentrated mainly along the Keith-Naracoorte road to the north and south of Padthaway and currently comprises an area of 7 059 Ha with a gross annual production estimated to be in excess of $36 million. During the 1994/95 irrigation season, groundwater crop use was estimated to be 23 500 ML, about 67% of the total allocated groundwater volume of 34 952 ML. MESA monitoring data from observation wells in the area indicate that water table levels generally respond to rainfall trends. Longer term rises in water table levels are evident throughout some areas of the plain to the south of Padthaway, particularly wells located along the eastern edge of the plain, and within the adjacent Naracoorte Range. These are due respectively to increased groundwater outflow from the Naracoorte Range, and increased rainfall recharge following native vegetation clearance and the loss of high water use lucerne pastures during the 1970 s.

Of more concern is the groundwater quality monitoring data which indicates that groundwater salinity is increasing in the eastern parts of the more intensely irrigated areas by up to 45 mg/L annually. This is due predominantly to the recycling of groundwater for irrigation. Analytical modelling indicates groundwater salinities in the intensely irrigated strip north and south of Padthaway will continue to increase over the next 20 years to levels of up to 500 mg/L above current levels. Currently, the sodium content of some Padthaway wines is approaching the allowable limit for consumption in Europe and the continued rise in groundwater salinity has the potential to severely affect the viability of the export wine industry.

The Padthaway PWA has been divided into five subareas for the purpose of allowing the calculation of a water balance. The major inputs and outputs for the aquifer systems include groundwater inflow, rainfall infiltration, crop use, storage and groundwater outflow. Five options are described in this report to manage the groundwater resources and slow or stop the rate of salinity increase. These options include;

- **pumping from the Naracoorte Range upstream of the irrigation area**
- **pumping from deeper parts of the aquifer sequence**
- **artificially recharging the aquifers with surface water from Morambro Creek**
- **reducing groundwater use and/or increasing irrigation efficiencies**
- **the construction of a groundwater drainage/interception scheme**

The water balance has been used as a guide for assessment of these options. Further groundwater modelling is required to fully determine the impacts and effectiveness of each of the options. Modelling will also be required to test the validity of the predictions for groundwater salinity distributions described in this report.

INTRODUCTION

The Padthaway PWA is about 300 km south-east of Adelaide (figure 1) and extends over an area of 695 square kilometres in the Hundreds of Parsons, Glenroy and the north-eastern half of Marcollat within the County of MacDonnell.

The region is underlain by the Padthaway Formation and Bridgewater Formation aquifers which provide easily accessible and good quality groundwater. Groundwater is the main source of public, private and irrigation water supplies in the area. Groundwater resources in the region are proclaimed under the Water Resources Act (1990).

There are currently 93 separate irrigation licenses to take water within the Padthaway PWA with a total of 34 952 ML of groundwater allocated. The area irrigated during the 1994/95 season was 7 059 Ha with an estimated groundwater crop use of 23 500 ML.

Mines and Energy Resources South Australia (MESA) has been carrying out ongoing monitoring of groundwater levels and chemistry at numerous locations since the 1970's (figure 2). The monitoring shows that increasing salinity trends are associated with irrigation activities in some areas of the Padthaway PWA. MESA has carried out a review of the monitoring data to provide recommendations for groundwater management options to address these trends.

Previous investigations in the area have included analysis and reporting of pump testing by MESA (Harris, 1972), construction and reporting of a groundwater model (Close, et. al., 1981) and a review of groundwater monitoring data to December 1991 (Cobb, 1992). This report is intended to be a technical support document for a management plan currently being prepared for the area by The Department of Environment and Natural Resources (DENR).

LAND USE

As detailed in the management plan, the Padthaway PWA covers approximately 55 000 Ha, most of which comprises improved pastures for sheep and cattle grazing (figure 1). Irrigated agriculture and horticulture comprises the areas other major activity with a current gross annual production estimated to be in excess of $36 million. Irrigation totalled 7 059 Ha during the 1994/95 season with vines, pastures, grass seed and coriander accounting for over two thirds of the crop area. The irrigation is concentrated along the main Keith-Naracoorte road due to the combination of suitable soil types, good quality shallow groundwater and high well yields.

SURFACE WATER FLOW

The ephemeral Morambro Creek (figure 1) is the only natural watercourse in the Padthaway PWA and it displays very irregular flow characteristics. This flow has been monitored annually since 1973 at gauging stations at Padthaway and The Gap (figure 3). The data indicates the annual flow in Morambro Creek ranges from nil to about 12 500 ML, with an average of about 3 500 ML. The inconsistency of annual flow volume has implications for the cost and ability of this resource to augment groundwater supplies for salinity management in the irrigated areas.

HYDROGEOLOGY

Stratigraphy and Aquifer Properties

The geology of the area is described in Close et. al., 1981 and shown in Cobb and Barnett, 1994. In summary, the two main aquifers in the area are the Padthaway Formation, a white rubbly limestone, and the Bridgewater Formation, a yellow-brown sandy limestone or calcarenite. The Gambier Limestone and Mepunga Formation form deeper aquifers below the area (figure 4). The water table is within the Padthaway Formation beneath the interdune flats and within the Bridgewater Formation below the Naracoorte and Harper Ranges. The Padthaway Formation provides most of the groundwater for irrigation on the interdune flat. It ranges from 2 m to 14 m thick and is saturated to depths of between 6 m and 8 m. The depth of the water table on the plain generally ranges between 1 and 5 m. Salinity ranges from 800 mg/L to 2 000 mg/L in the intensely irrigated areas, grading up to 5 000 mg/L on the western fringes of the flat. Well yields of 5.5 ML/day to 23 ML/day have been recorded. The older Bridgewater Formation is the main aquifer in the Naracoorte Range. It is less productive than the Padthaway Formation, with well yields of 1.8 ML/day to 2.75 ML/day being recorded. Depth to this aquifer is 40 to 45 metres. The Keppoch Member, a clay aquitard which varies in thickness and permeability, underlies the Padthaway Formation in places. The Bridgewater Formation is confined in these areas.

The transmissivities of the two aquifers differ by up to an order of magnitude. Measured values range from 6 825 to 13 046 m^2/day for the Padthaway Formation and 1 123 to 2 678 m^2/day for the Bridgewater Formation (Close et. al., 1981). The locations of measured values are shown on figure 5. For the purposes of water budget calculations in this report, the Padthaway Formation is assumed to have a transmissivity of 10 000 m^2/day and a porosity of 20%. The Bridgewater Formation is assumed to have a transmissivity of 1 000 m^2/day, decreasing to 750 m^2/day at the eastern edge of the PWA due to thinning of the aquifer, and a porosity of 15%.

Groundwater Levels and Trends

Selected bore hydrographs are shown on figure 6 and the distribution of long term water level trends obtained from bore hydrograph records are shown on figure 7. Recent data confirms the conclusions of Cobb (1992) that water table levels on the flats west of the Naracoorte Range and for some distance into the hills generally respond to rainfall trends (MAR 022, GLE 028). On the plain north of Padthaway, water table levels over the last few years have been similar to that of the early 1970's. The slightly lower levels during the 1970's, can be attributed to a period of below average rainfall. The plain south of Padthaway shows similar responses, with the exception of some wells located along the eastern edge of the plain. These have had marginally higher water levels over the last few years which is inferred to be due to increased groundwater outflow from the adjacent Naracoorte Range.

The most obvious increasing water table levels are evident throughout the Naracoorte Range (PAR 033, GLE 088). This is interpreted to be due to increased rainfall recharge following native vegetation clearance. The loss of lucerne pastures during the 1970’s as reported in DENR, 1995, would also have contributed to the increased recharge. Similar trends in water table levels are evident in the Harper Range on the western side of the Padthaway plain (MAR 015).

A full set of hydrographs for the Padthaway PWA is included in appendix A.

Groundwater Salinity and Trends

Groundwater sampling and testing is carried out on 33 MESA observation wells and private wells at three monthly intervals. Most of these have been sampled since 1978. In addition, 53 private wells are sampled when possible during each irrigation season. Annual testing of the chemistry of groundwater from MESA observation wells has been undertaken since 1981 and contours of salinity and chloride concentrations for 1981 are shown on figures 8 and 9. These can be compared with the 1994 distributions on figures 10 and 11. The corresponding changes in chloride concentrations are contoured on figure 12.

The distribution of trends in salinity and chloride concentrations of selected observation wells are shown on figures 13 and 14 and selected time series salinity graphs are on figure 15. Data for all monitored wells is included in appendix B. The data indicates that in general groundwater salinity is increasing in the eastern part of the Padthaway PWA (PAR 042, GLE 100) and decreasing in the western part (MAR 002, MAR 022).

The recycling of irrigation water in the more intensely irrigated areas is interpreted to be the main factor causing an increase in groundwater salinity. The dissolving of salts from the soil profile with the recent rises in water table levels could also be adding to this. The increase in salinity varies between wells, with some showing increases of 45 mg/L annually.

Groundwater salinities have fallen in the western part of the area, probably due to an increase in the flow of less saline groundwater from the east (see salinity distribution, figure 10). The increasing groundwater salinity trends below the Naracoorte Range is associated with the rising water level trends observed in the Range. The increased recharge is possibly leaching salts from the soil profile into the water table. In general, annual salinity increases below the Range are up to 20 mg/L.

GROUNDWATER BUDGETS

Groundwater budgets have been calculated for each of the subareas 1, 2A, 2B,3 and 4 (figure 5) using the model shown on figure 16.

Groundwater Flow

The interpreted regional water table contours for September 1993 (end of winter) and March 1994 (end of summer) are shown on figures 17 and 18 respectively. Groundwater flow directions and the distribution of groundwater hydraulic gradients within the area are due to the transmissivity contrast between the Padthaway Formation and Bridgewater Formation aquifers, and evapotranspiration from the interdunal flat areas. Flow is to the southwest through the Naracoorte Range, to the north-west below the interdune flat and then westerly on approaching Harpers Range. The relatively steep hydraulic gradients through the Naracoorte and Harpers Ranges are a result of the lower transmissivity of the Bridgewater Formation. The flatter gradients across the interdune flat reflect the high transmissivity of the Padthaway Formation.

Average groundwater inflows and outflows for each of the subareas 1, 2A, 2B, 3 and 4, were calculated for the end of summer and winter of the '93/'94 season. These are summarised on figure 16.

Aquifer Recharge by Rainfall Infiltration

Within the Padthaway PWA the unconfined aquifers are recharged directly by local rainfall infiltration. Typically, rainfall recharge rates under lucerne and native vegetation are less than a few millimetres per year. The volume of rainfall recharge is greatly increased by land clearing and is also influenced by crop type, being much less below lucerne than annual crops or vines. Over the past 20 years, annual crops and vines have replaced lucerne crops with the result that recharge rates within the main irrigation areas have probably increased.

The recharge rates estimated by J. DeSilva (MESA, Naracoorte) beneath cleared agricultural land for each of the subareas are detailed in table 1, and the resulting annual volume recharge to the aquifers using the lower bound rates are shown on figure 16.

Table 1: Recharge Estimations

	SUB AREA				
Recharge Estimate	1	2A	2B	3	4
Lower (mm/year)	66	90	50	58	21
Upper (mm/year)	90	105	62	66	35

Crop Use

Groundwater use by irrigated crops within the intensely irrigated strip (I.I.S.) around Padthaway has been calculated using the established estimated irrigated crop water requirements. The estimated annual usage of groundwater in the I.I.S. and Padthaway PWA since proclamation in 1975/76 are shown on figures 19 and 20 respectively. Currently, 34 952 ML of groundwater is allocated in the Padthaway PWA. The area irrigated during the 1994/95 season was 7 059 Ha, using an estimated 23 500 ML of groundwater. Groundwater usage currently represents about 67% of the allocation for the area but this is likely to increase in the future as unused portions of allocations are developed or transferred. Within the I.I.S., it is likely that a higher percentage of allocated groundwater is used than for the whole PWA, although the recent establishment of young crops should result in a growth of groundwater crop use over the next few years.

Groundwater Storage

Estimates were made of the amount of groundwater going into storage within subareas 2B and 4 where long term rising water level trends of about 0.03 m/year and 0.05 m/year respectively, are observed. Storage volumes were obtained from the product of the measured area, average water level rise and assumed aquifer porosity (20% for the Padthaway Formation and 15% for the Bridgewater Formation). The resulting annual groundwater storage volumes of 735 ML and 7 950 ML for subareas 2B and 4 compare with the calculated volumes of groundwater currently in aquifer storage of $8.4x10^4$ ML and $1.7x10^6$ ML, respectively.

Salt Balance

An average salt balance calculation has been carried out for the five subareas based on the water balance and existing groundwater salinity distribution. The salt balance calculations;

- are consistent with some observed data which indicates significant increasing groundwater salinity trends within the I.I.S. (subareas 2A and 2B).
- indicate lower rates of salinity increases in subareas 3 and 4 which is supported by the monitoring data.
- confirm that the export of saline groundwater from subarea 1 and replacement with lower salinity groundwater from the east is causing significant salinity decreases over much of this subarea.

FUTURE GROUNDWATER QUALITY SCENARIOS AND IMPACTS ON IRRIGATION

Increasing salinity trends have been observed in some observation wells within the I.I.S. over the last 15 to 20 years. Projected groundwater salinities and chloride concentrations have been formulated for the years 2004 and 2014 based on linear extrapolations of these trends (figures 21 to 24). The linear projections follow the current monitored trends of increasing groundwater salinities within the I.I.S. and a fall in groundwater salinities in the western part of the area. Based on these predictions, groundwater salinities in excess of 1 500 mg/L can be expected to occur within a relatively large area south of Padthaway by the year 2004. An alternative method of predicting future salinity distributions has also been carried out. This method results in the levelling out of salinity as the system approaches a new equilibrium. Results of this analysis indicates the average groundwater salinity in the I.I.S. will increase to between 300 to 500 mg/L higher than current levels within the next 20 years. These results are consistent with the predictions for the year 2014 obtained by the linear extrapolation method (figure 23).

The I.I.S. is dominated by vineyard development and the expected impacts on vineyards would include a decrease in yield and increased concentrations of salts in the grape juice. This has the potential to render the wine produced unsuitable for sale, particularly to some export markets. The European limit is set at 60 mg/L free sodium and the Australian Food Standards set a maximum of 1 000 mg/L of sodium chloride for wine. Currently, the sodium content of some Padthaway wines is approaching the European limit.

Data and analysis of trends for both salinity and chloride up to the year 2014 are contained in appendix B.

SALINITY MANAGEMENT OPTIONS

Detailed below are five management options for irrigation within the I.I.S. which have the potential to decrease the salinity trends described above. The possible positive impacts, negative impacts and uncertainties associated with each are summarised in tables 2(a), 2(b) and 2(c).

Pumping from the Naracoorte Range

This option involves pumping good quality groundwater from the Bridgewater Formation aquifer to the east of the I.I.S. to replace existing groundwater withdrawals from within the I.I.S. The importing of lower salinity groundwater from the Naracoorte Range will at least slow the rate of salinity increases in the I.I.S. and also reduce the salt load returning to the aquifer in irrigation return flows. Groundwater modelling is currently being carried out to determine if this option will cause significant rises in local groundwater levels in the I.I.S.

The costs of pipelines and additional wells to offset significantly lower well yields compared to yields from the Padthaway Formation detract from this option, as does the possibility for competition for groundwater in the Range and interference with existing supplies. The cessation of pumping from below the I.I.S. will also result in increased groundwater throughflows to areas to the west which may cause rising groundwater levels and subsequent waterlogging in some places. The groundwater modelling currently being carried out will also attempt to quantify this process.

Pumping from Deeper Parts of the Aquifer Sequence

This option involves pumping from deeper sand and/or limestone layers below the Padthaway Formation, including the Bridgewater Formation, Gambier Limestone and Mepunga Formation. During the 1970's, a suite of observation bores were drilled and the groundwater salinity profile with depth was obtained. Data from wells GLE 86 and GLE 89 south of Padthaway indicate the salinity in the Padthaway Formation was originally lower than in the upper parts of the underlying Bridgewater Formation but is now higher. Pumping from the Bridgewater Formation would therefore result in a reduced salt load returning to the water table via irrigation return water. However, particularly in areas where the aquifers are hydraulically separated by the Keppoch Clay, this would significantly reduce one of the major outputs of the areas groundwater budget. This could cause rises in local groundwater levels and waterlogging of root zones within the I.I.S.

Well yields would almost certainly be reduced in comparison to present supplies. The cessation of pumping from the Padthaway Formation below the I.I.S. has the potential to cause increased groundwater throughflows to areas to the west. This may result in rising groundwater levels and waterlogging in some areas to the west.

As well as predictive groundwater modelling, field testing is required to determine salinity profiles with depth at a number of locations throughout the I.I.S. to fully assess this option.

Artificial Recharge From Morambro Creek

The harvesting of peak winter surface water flows for storage in aquifers and reuse during the irrigation season, is seen as a logical solution to protect groundwater resources and utilise an otherwise wasted resource. This option has the potential to provide some control of groundwater salinity increase through importing fresher water into the aquifer. The major drawbacks of this option are the high costs of constructing retaining dams and installing pipelines for distribution of the water, and the highly variable nature of the flow in Morambro Creek. Predictive groundwater modelling is also required to determine the extent of water table rises due to importing surface water.

Reduction in Groundwater Use and/or Increased Irrigation Efficiency

The nett effects of either of these options will be to minimise groundwater withdrawals in the I.I.S. to allow maximum dilution of the salt load returning to the aquifers in irrigation return water.

Groundwater Drainage/Interception Scheme

This option involves the removal of increasingly saline groundwater via an engineered drainage scheme, together with using better quality groundwater from the Naracoorte Range or from deeper aquifers below the I.I.S. A drainage scheme may also be required to remove excess water if surface water is imported from Morambro Creek. The scheme operation would need to be controlled to minimise the impacts of lowering of groundwater levels on nearby users. The cost of construction and proper disposal of the drained groundwater are other concerns associated with this option.

CONCLUSIONS AND RECOMMENDATIONS

Groundwater level and salinity monitoring data collected by MESA since the 1970's indicates that water levels are generally rising in the Padthaway PWA, although in some areas this is in response to increasing rainfall trends. The greatest rises are observed in the Naracoorte Range and are due to enhanced rainfall recharge following land clearance and the loss of high water use lucerne crops in the 1970's. Groundwater quality data shows that salinities in the eastern parts of the intensely irrigated strip are rising by as much as 45 mg/L annually. This has significant implications for loss of production and quality for the irrigated crops in the near future. Two different analytical methods have been applied to predict the future salinity distributions. The analyses indicate that the average groundwater salinity in the intensely irrigated areas may increase to levels of up to 500 mg/L higher than current levels within the next 20 years.

Several groundwater management options have been formulated to address the issue of rising groundwater salinity. These include importing groundwater from the Naracoorte Range, pumping from deeper parts of the aquifer sequence, artificially recharging the aquifers with surface water from Morambro Creek, reducing groundwater use and/or increasing irrigation efficiency and construction of a groundwater drainage/interception scheme. Each of these options have benefits, disbenefits and uncertainties associated with them. Groundwater modelling is currently being carried out to more fully determine the impacts of each option. In addition, a field program to determine salinity profiles with depth is required throughout the irrigated areas to confirm the presence of less saline groundwater in the deeper aquifers.

The following specific recommendations are made;

- Groundwater modelling to address the various salinity management options be progressed as a matter of priority. The modelling should also be expanded to test the validity of the predicted salinity distributions in this report.
- An investigation program to assess the viability of using the deeper parts of the aquifer sequence in the intensely irrigated strip of the Padthaway PWA be undertaken.
- The surface water resource of Morambro Creek should be more fully evaluated for its potential to mitigate the groundwater salinity increases in the intensely irrigated strip of the Padthaway PWA, particularly south and immediately north of Padthaway township.

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Close, AF, Smith, PKL and Ebsary, RM, 1981. Padthaway Groundwater Model Technical Report, March 1981. EWS Library Reference 80/21.

DENR, 1995. Draft Padthaway Management Plan. in prep.

Harris, BM, 1972. South East Water Resources Investigations, Padthaway Area Progress Report No. 3. MESA unpublished report RB 72/102.

Table 2(a): Summary of Salinity Management Options, Possible Positive Impacts

	Pumping from Naracoorte Ranges	Pumping from Deeper Parts of the Aquifer	Artificial Recharge from Morambro Creek	Reduction in Groundwater Use and/or Increased Irrigation Efficiency	Groundwater Drainage/Interception Scheme
Better quality	√	√	√		√
Reduced salt load returning to aquifer	√	√		√	
Replacement of increasingly saline groundwater with better quality			√		√
Some control of salinity increase			√	√	
Reduced pumping from I.I.S.[1]	√			√	

Notes: (1) Intensely Irrigated Strip

Table 2(b): Summary of Salinity Management Options, Possible Negative Impacts

	Pumping from Naracoorte Ranges	Pumping from Deeper Parts of the Aquifer	Artificial Recharge from Morambro Creek	Reduction in Groundwater Use and/or Increased Irrigation Efficiency	Groundwater Drainage/Interception Scheme
Waterlogging and rising water levels	√	√	√		
Continued salinity increase at reduced rate	√	√	√	√	√
Reduced well yields	√	√		√	
Lowering water levels					√
Construction cost	√		√		√
Competition for water in the Range and interference with existing supplies	√				
Reduced economic return	√	√	√	√	√

Table 2(c): Summary of Salinity Management Options, Uncertainties

	Pumping from Naracoorte Ranges	Pumping from Deeper Parts of the Aquifer	Artificial Recharge from Morambro Creek	Reduction in Groundwater Use and/or Increased Irrigation Efficiency	Groundwater Drainage/Interception Scheme
Waterlogging and rising water levels in western area	√	√	√		
Disposal of drainage water					√
Local community acceptance				√	√
Availability of surface water			√		
Interconnection between aquifer sub-units		√			

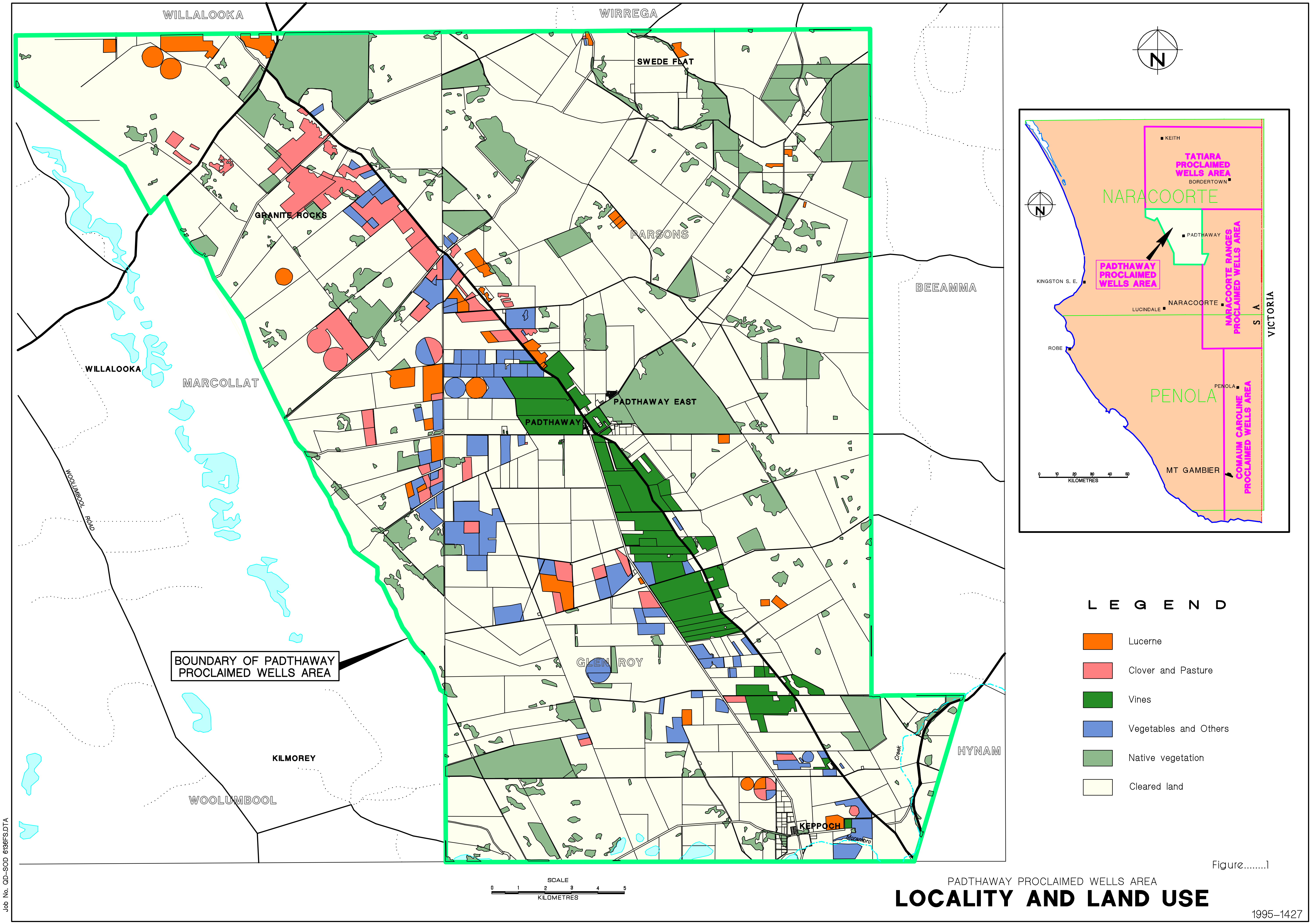


Figure........1

PADTHAWAY PROCLAIMED WELLS AREA

LOCALITY AND LAND USE

1995-1427

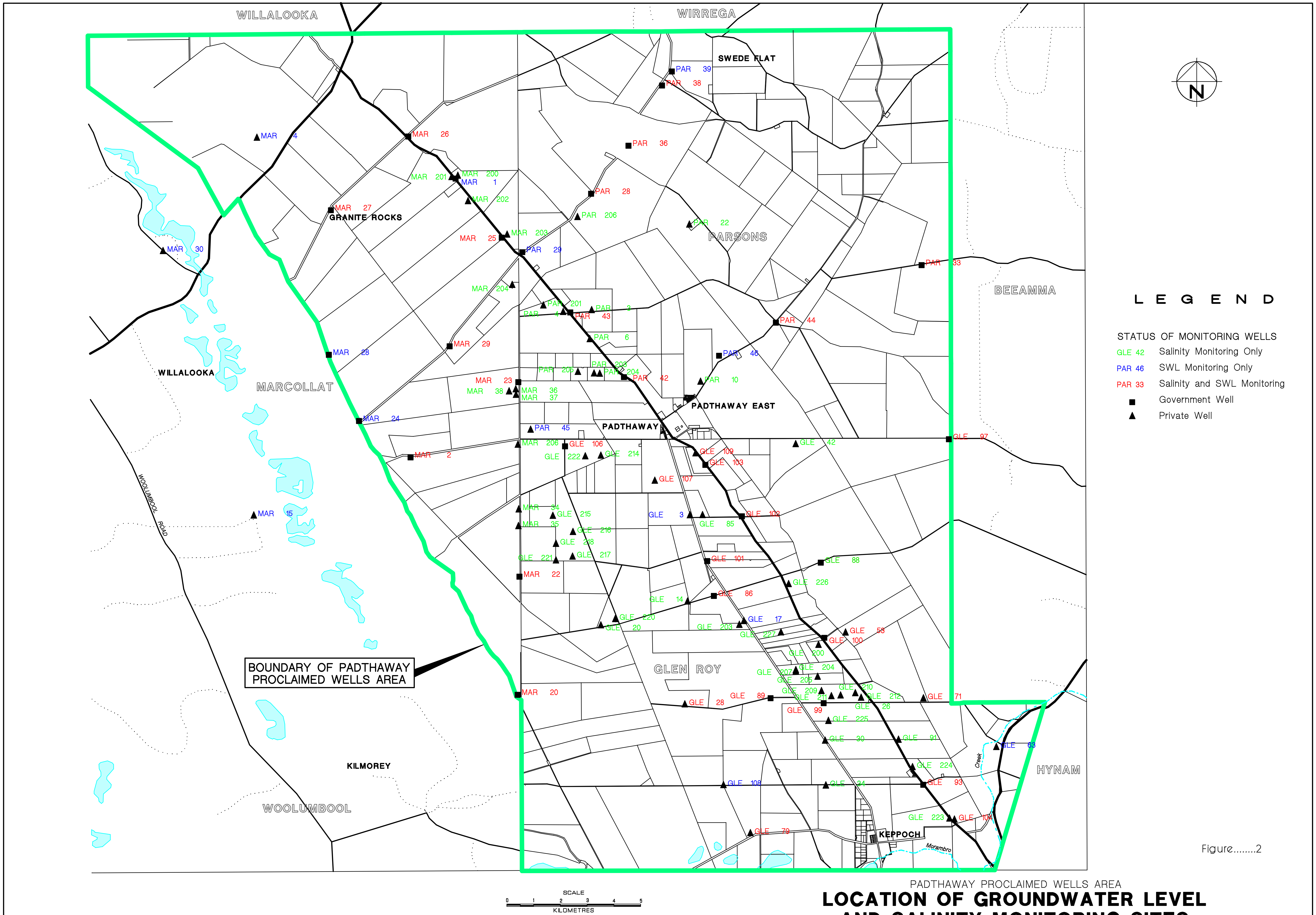


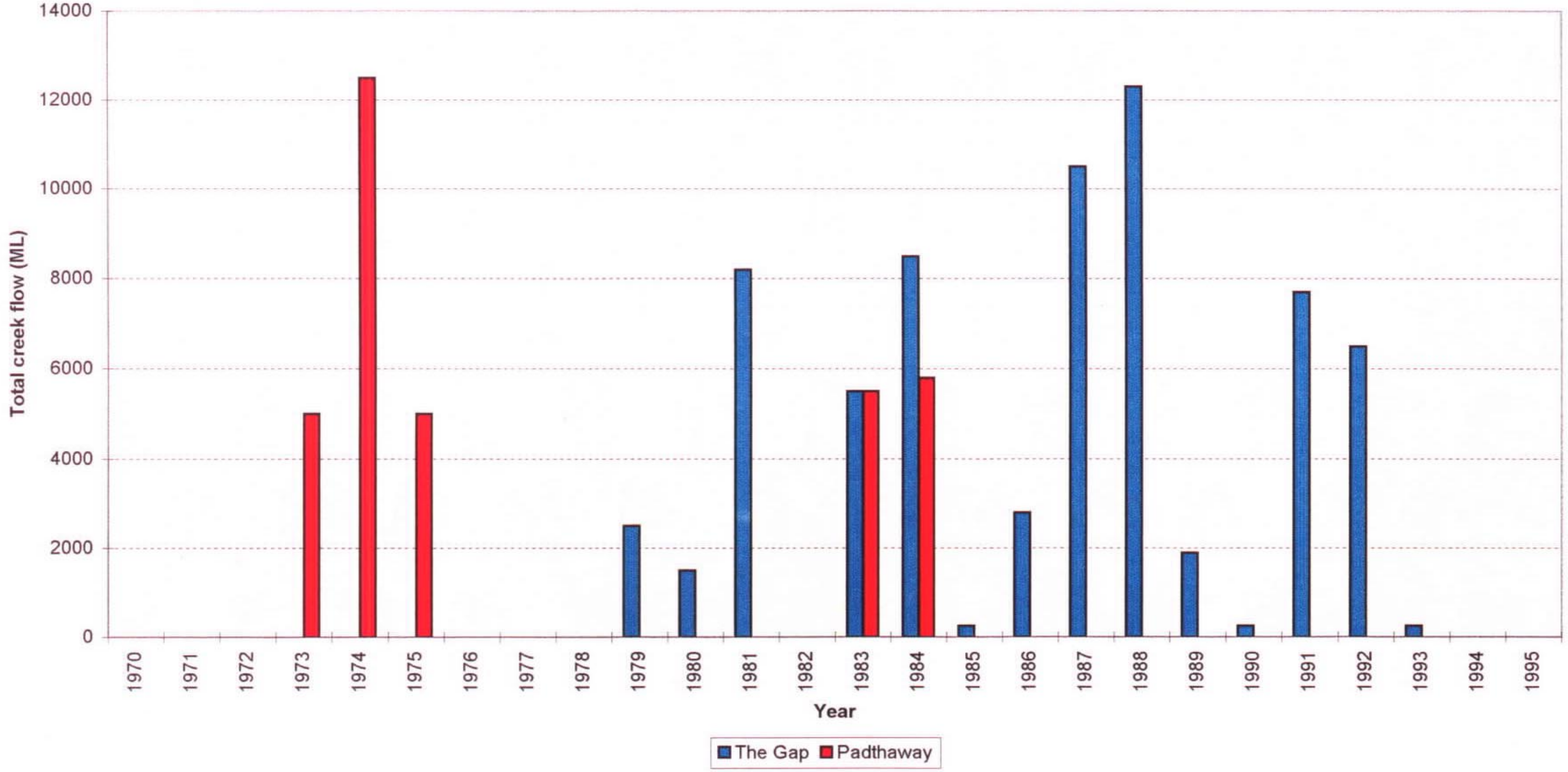
Figure.......2

PADTHAWAY PROCLAIMED WELLS AREA

LOCATION OF GROUNDWATER LEVEL AND SALINITY MONITORING SITES

1995–1428

Job No. QD-SOD 6136FS.DTA



Job No. 6136FS.XLS

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Figure.....3

PADTHAWAY PROCLAIMED WELLS AREA

MORAMBRO CREEK FLOW - 1972 to 1993

1995-1429

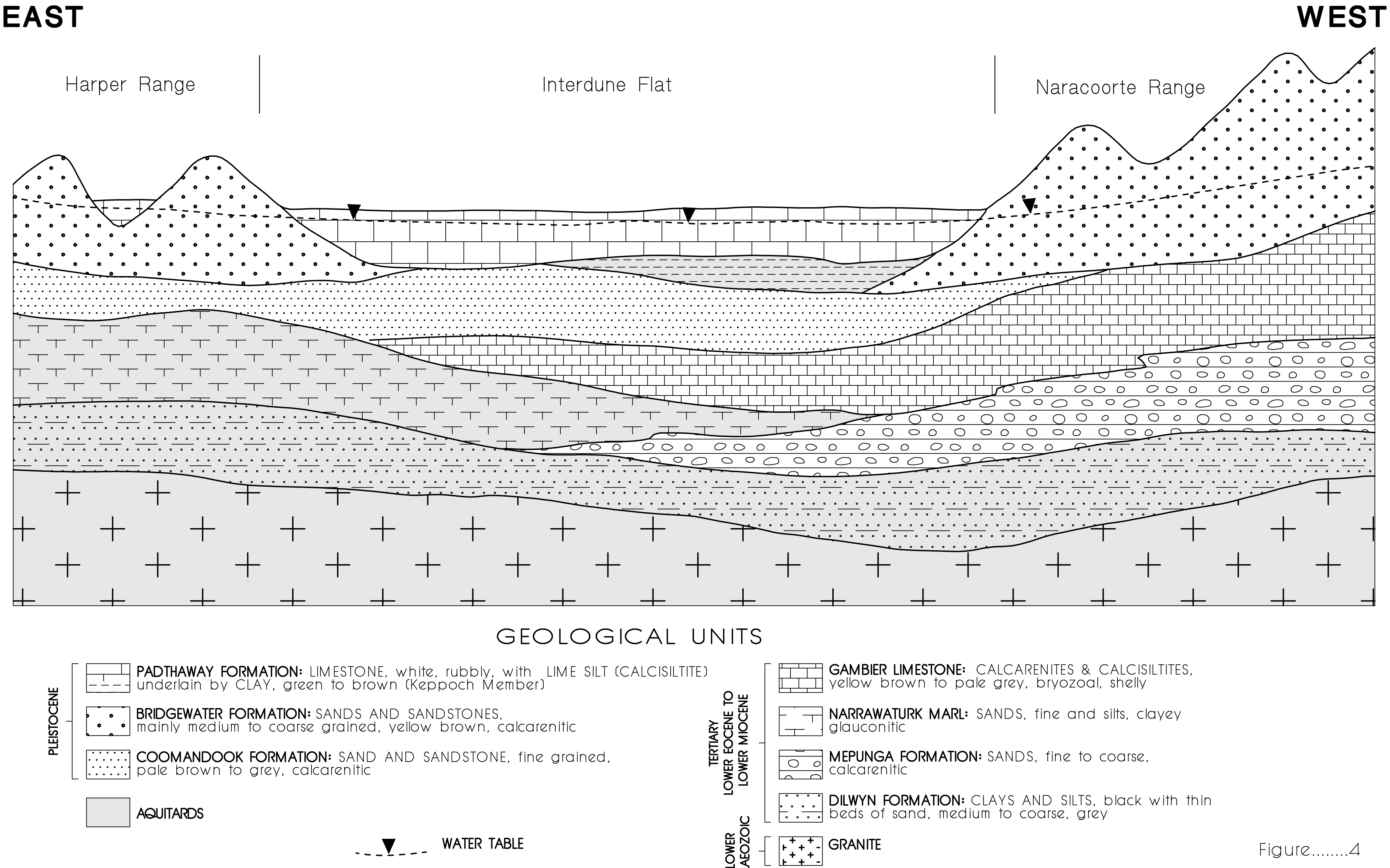

Figure........4

NOT TO SCALE

PADTHAWAY PROCLAIMED WELLS AREA

DIAGRAMMATIC GEOLOGICAL SECTION

1995–1430

Job No. 6136FS.DTA

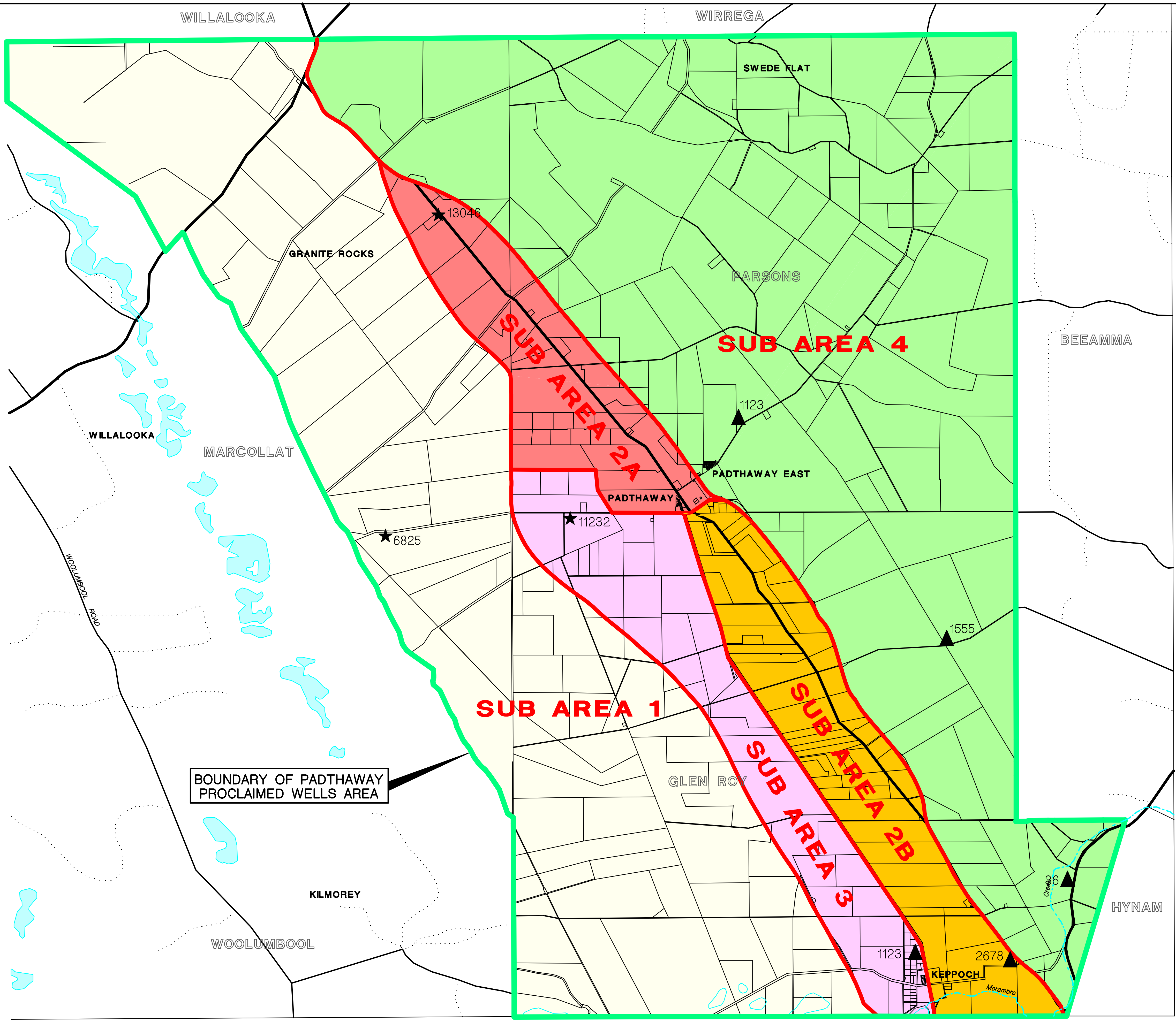

Figure........5

PADTHAWAY PROCLAIMED WELLS AREA

GROUNDWATER BUDGET SUB AREAS AND AQUIFER TRANSMISSIVITY VALUES

1995–1431

Job No. QD–SOD 6136FS.DTA

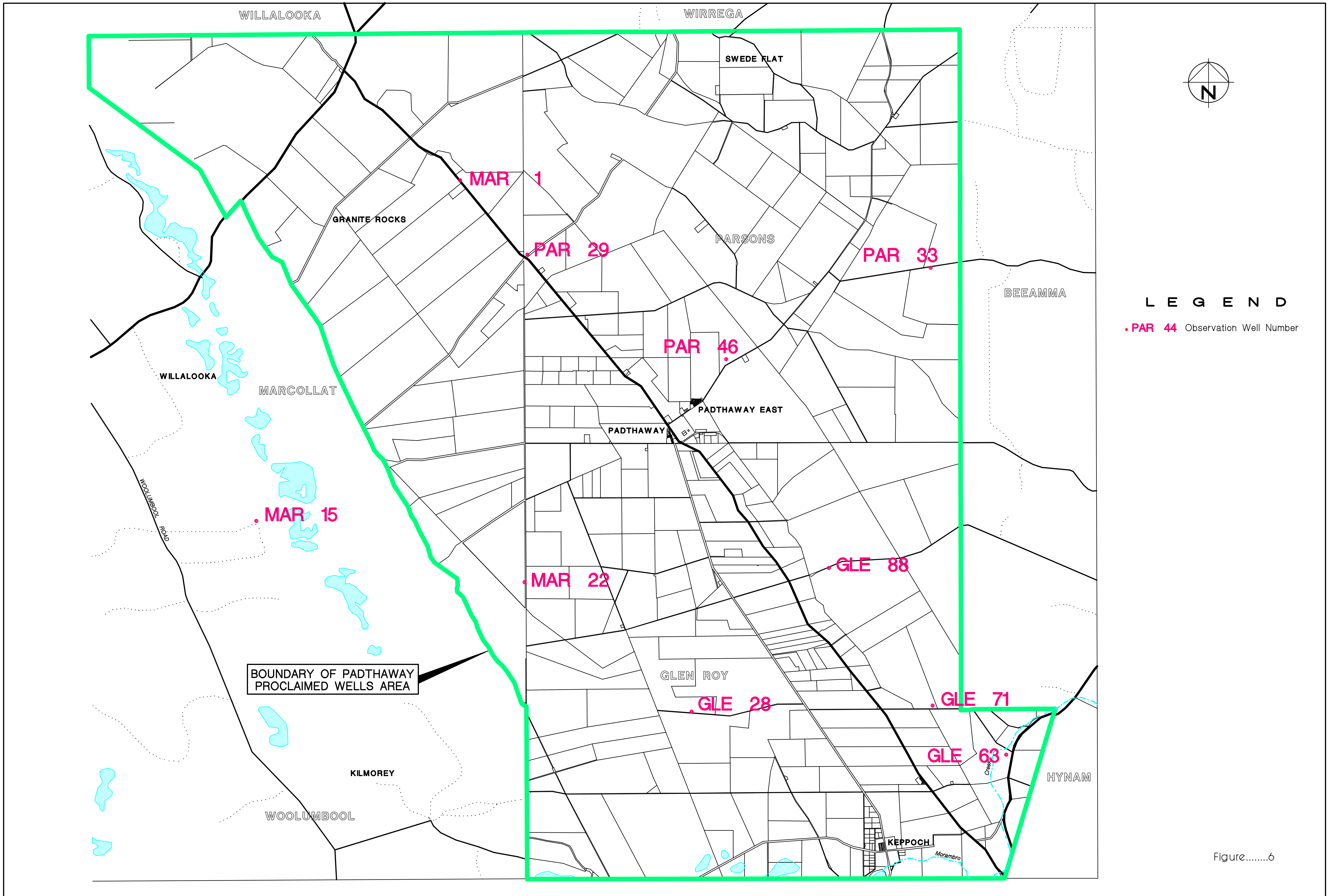

Figure........6

Job No. QD-SOD 6136FS.DTA

PADTHAWAY PROCLAIMED WELLS AREA

SELECTED GROUNDWATER LEVEL HYDROGRAPHS

1995-1432

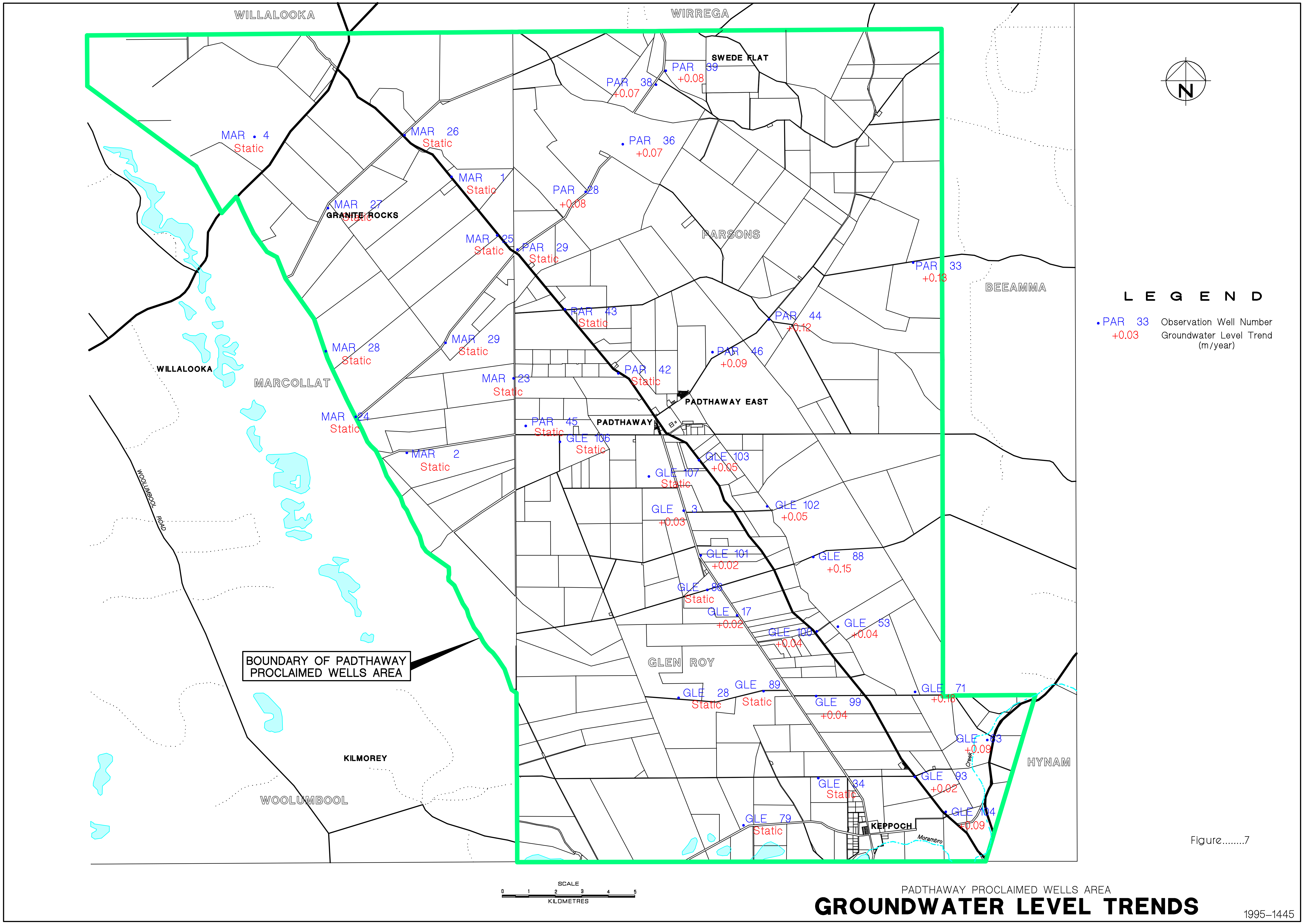

Figure........7

PADTHAWAY PROCLAIMED WELLS AREA

GROUNDWATER LEVEL TRENDS

1995–1445

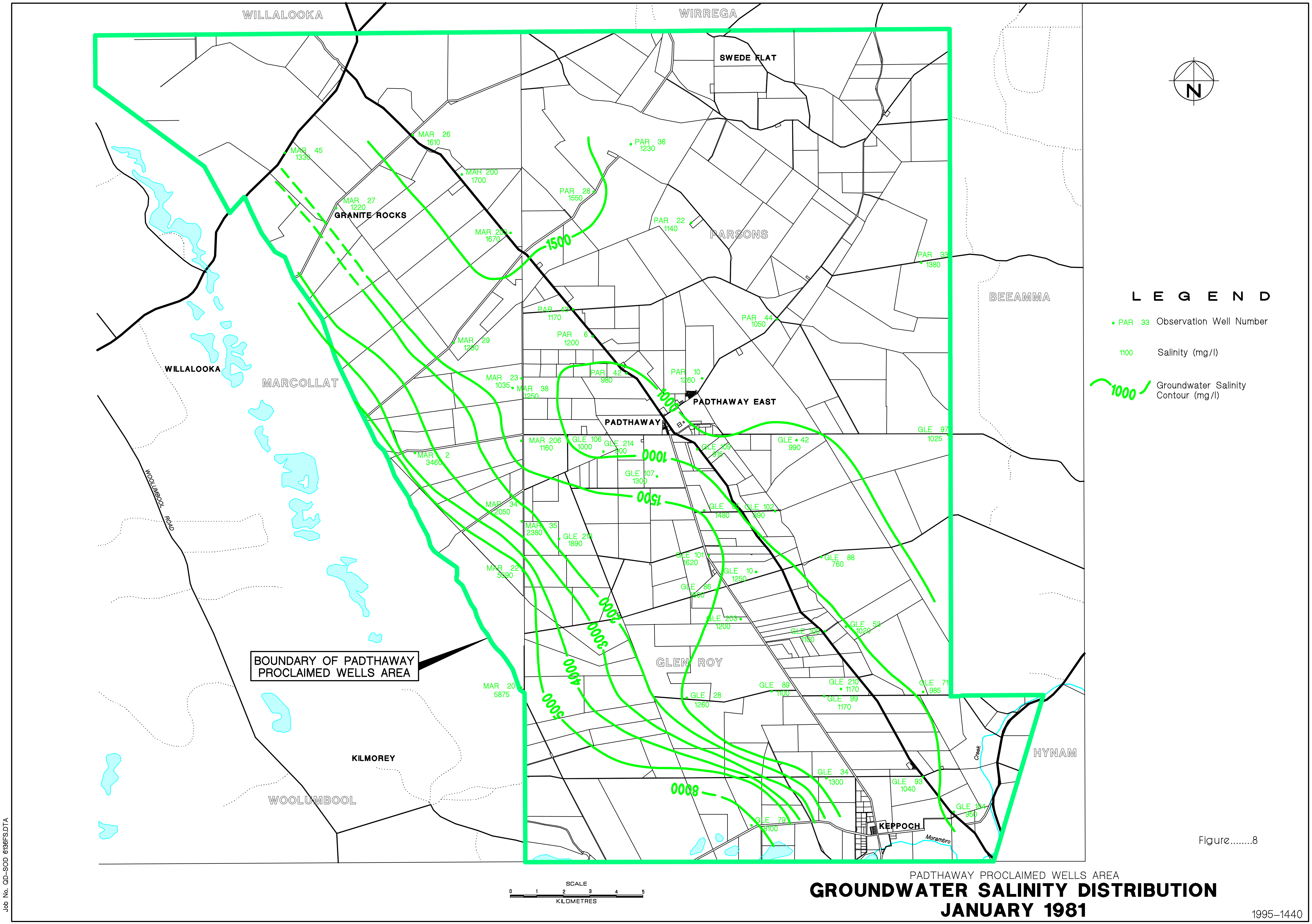

Figure........8

PADTHAWAY PROCLAIMED WELLS AREA

GROUNDWATER SALINITY DISTRIBUTION

JANUARY 1981

1995–1440

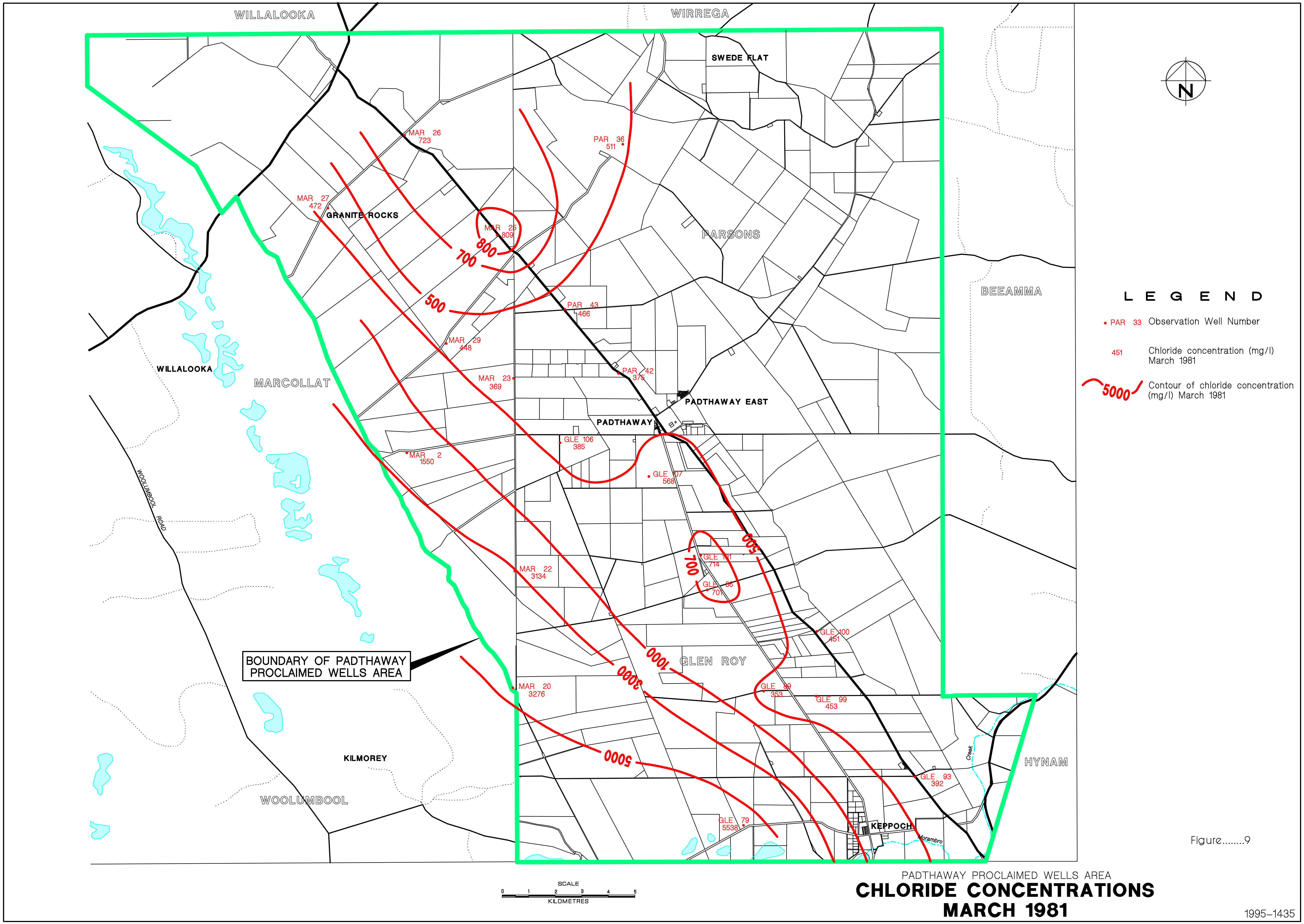

Figure.......9

PADTHAWAY PROCLAIMED WELLS AREA

CHLORIDE CONCENTRATIONS
MARCH 1981

1995-1435

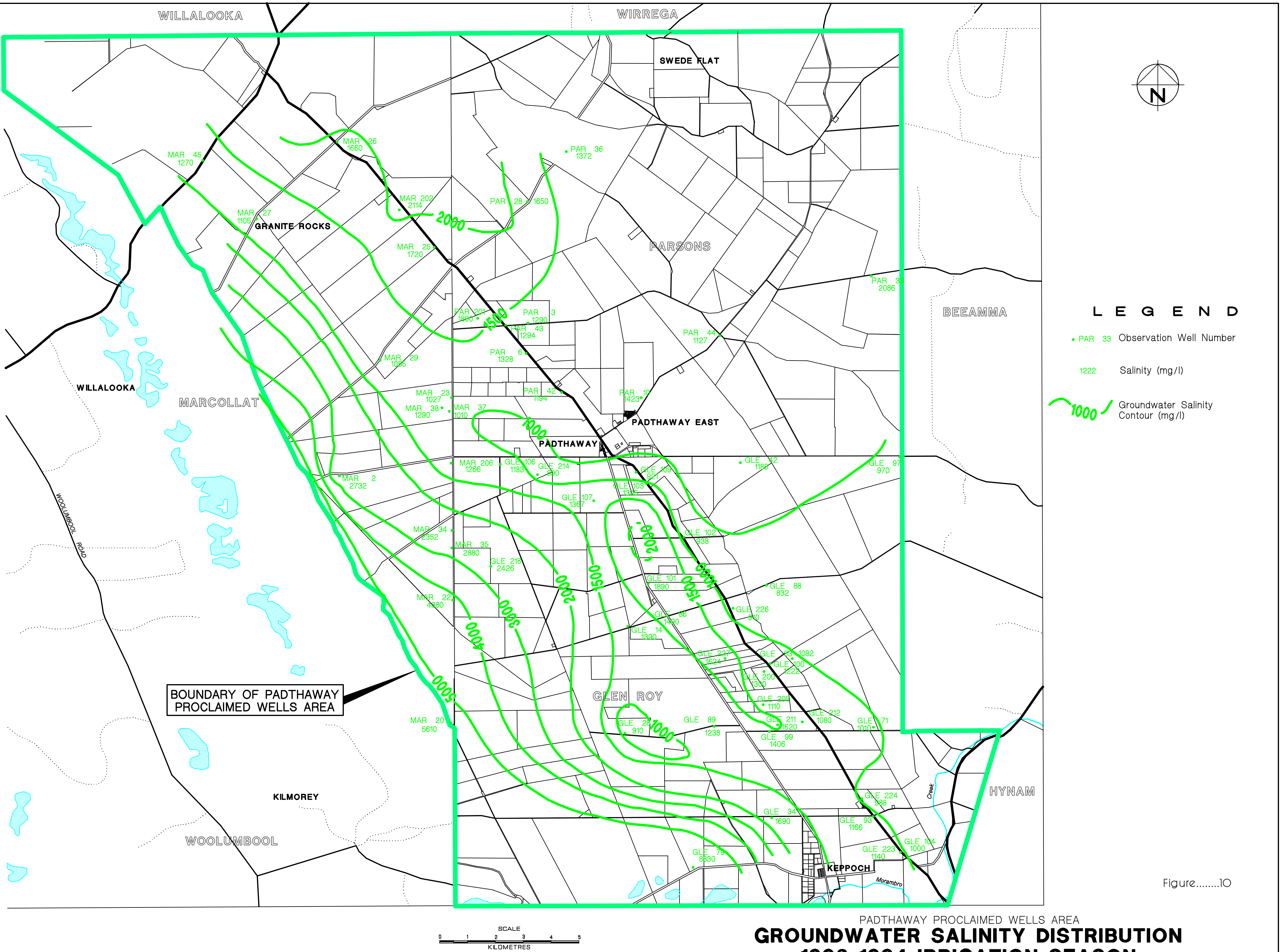

Figure........10

PADTHAWAY PROCLAIMED WELLS AREA

GROUNDWATER SALINITY DISTRIBUTION
1993-1994 IRRIGATION SEASON

1995–1441

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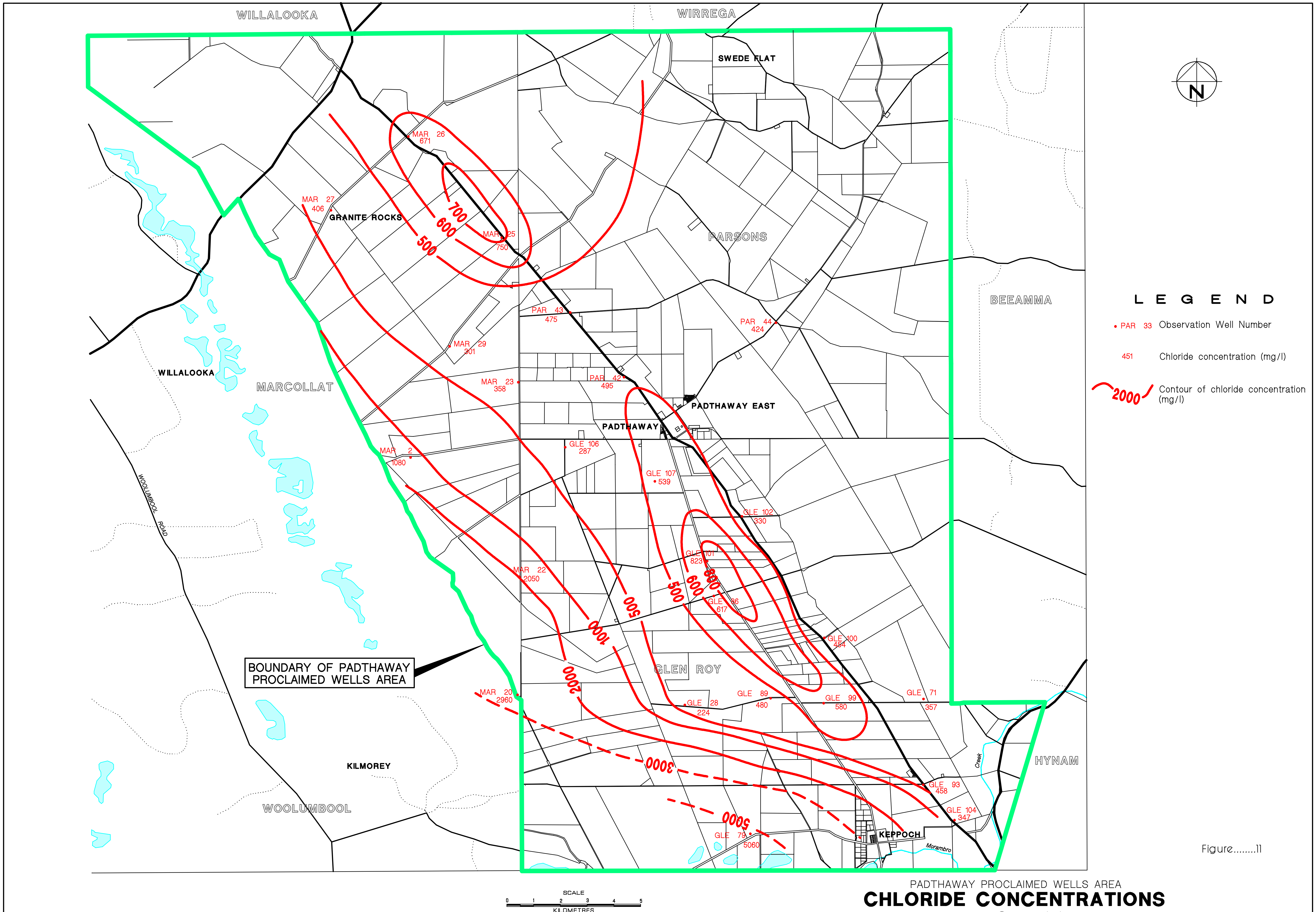

PADTHAWAY PROCLAIMED WELLS AREA

CHLORIDE CONCENTRATIONS
MARCH 1994

Figure.......11

1995–1436

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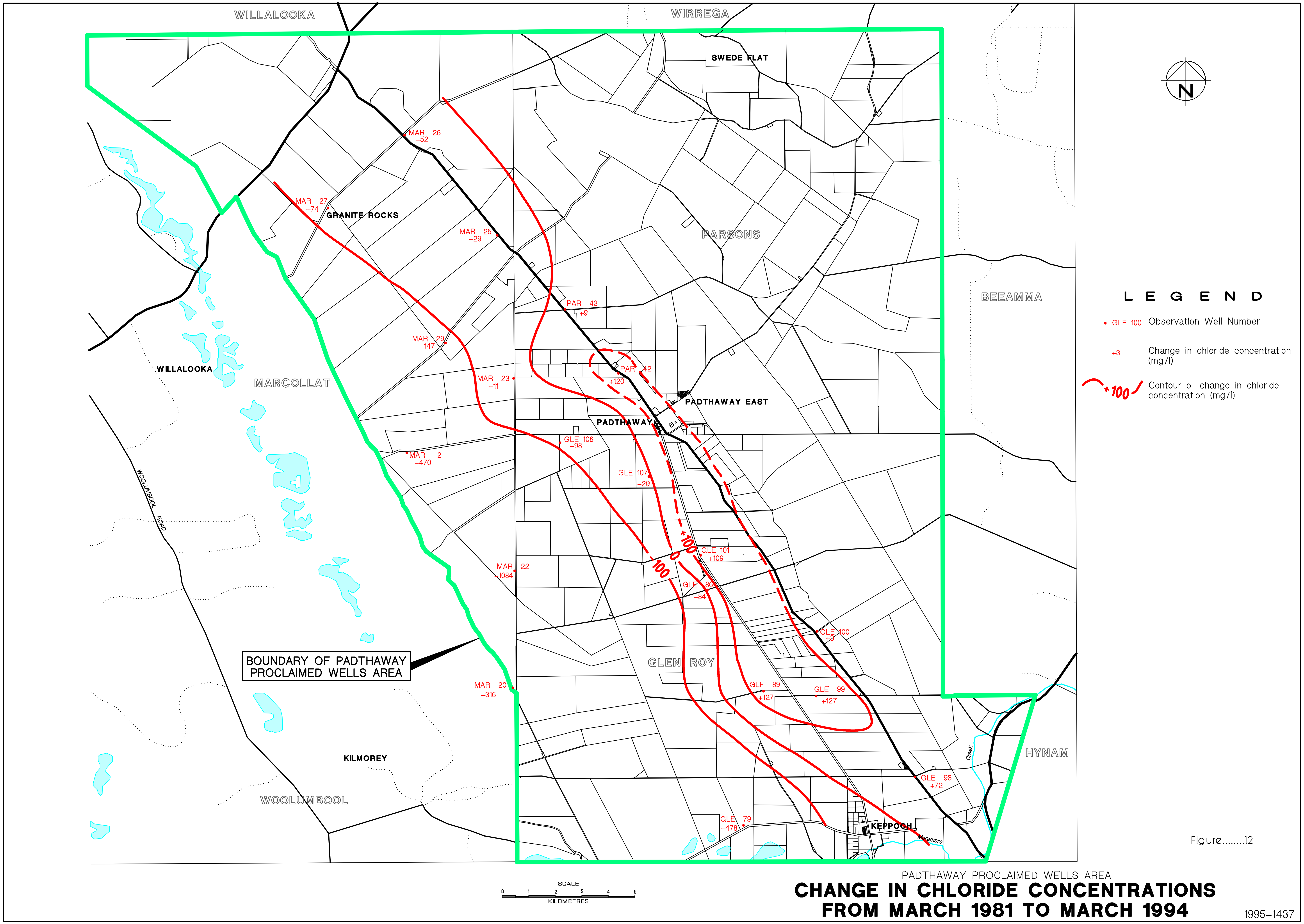


Figure........12

PADTHAWAY PROCLAIMED WELLS AREA

CHANGE IN CHLORIDE CONCENTRATIONS FROM MARCH 1981 TO MARCH 1994

1995-1437

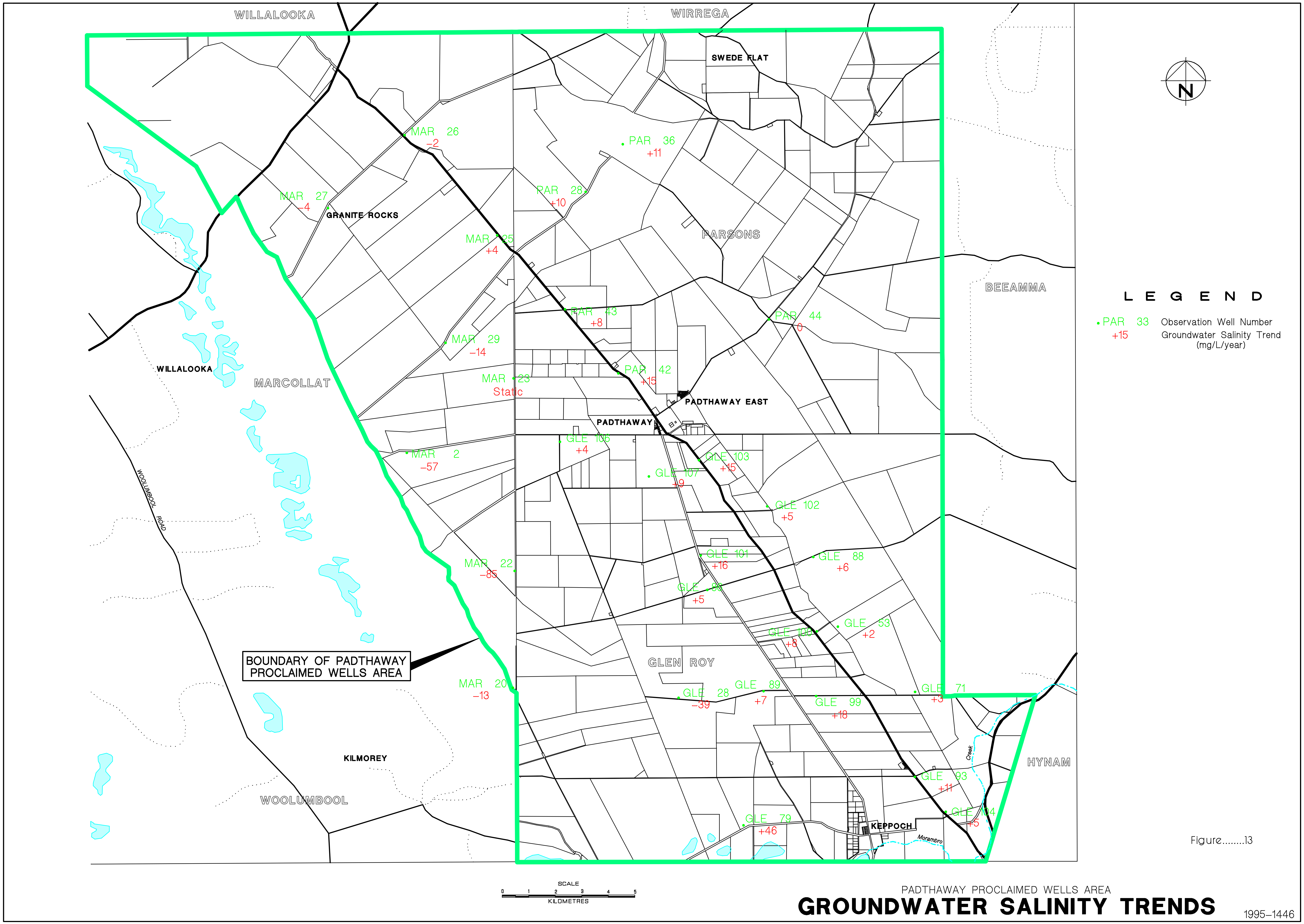


Figure........13

PADTHAWAY PROCLAIMED WELLS AREA

GROUNDWATER SALINITY TRENDS

1995–1446

Job No. QD-SOD 6136FS.DTA

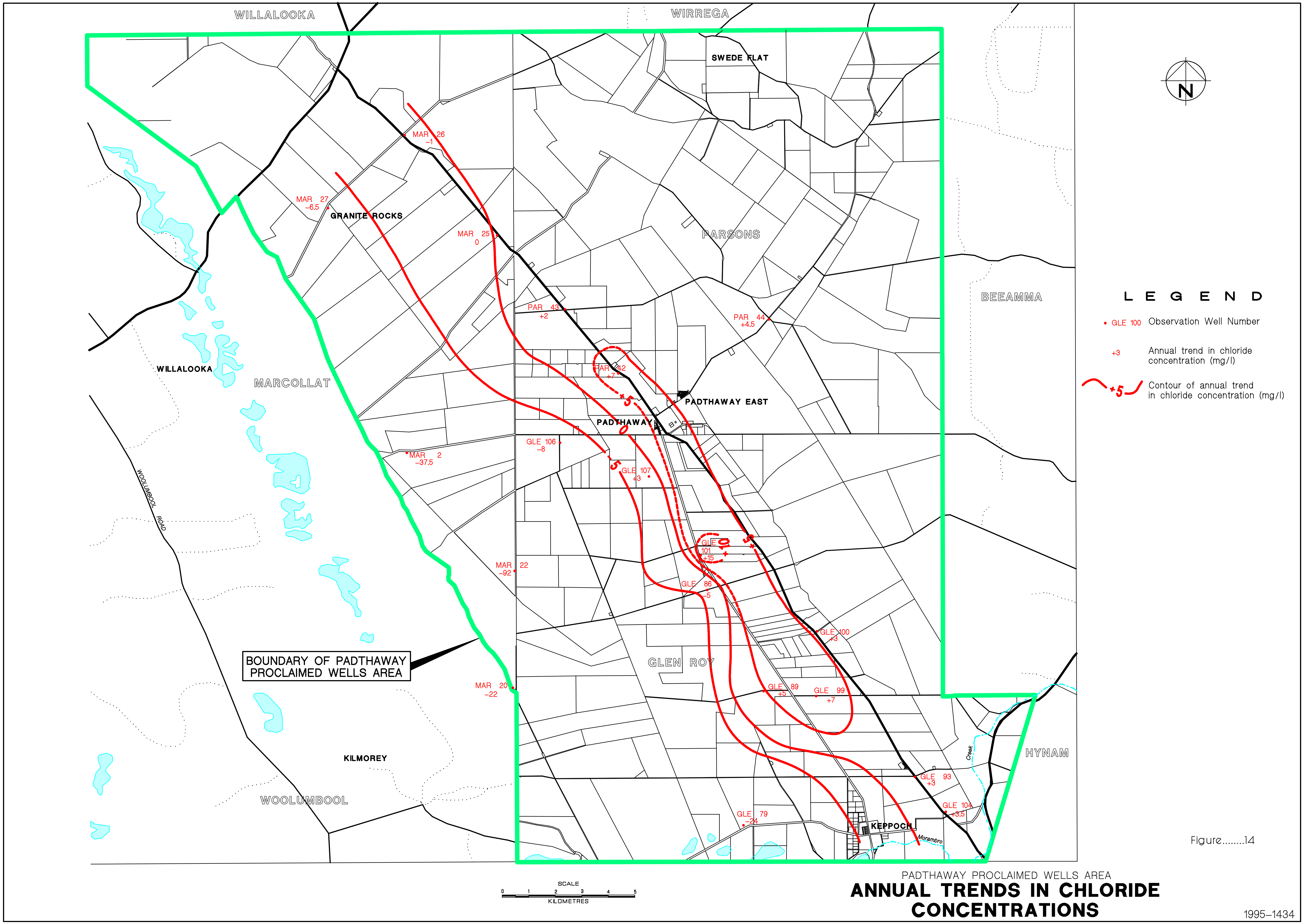


Figure........14

PADTHAWAY PROCLAIMED WELLS AREA

ANNUAL TRENDS IN CHLORIDE CONCENTRATIONS

1995–1434

Job No. QD-SOD 6136FS.DTA

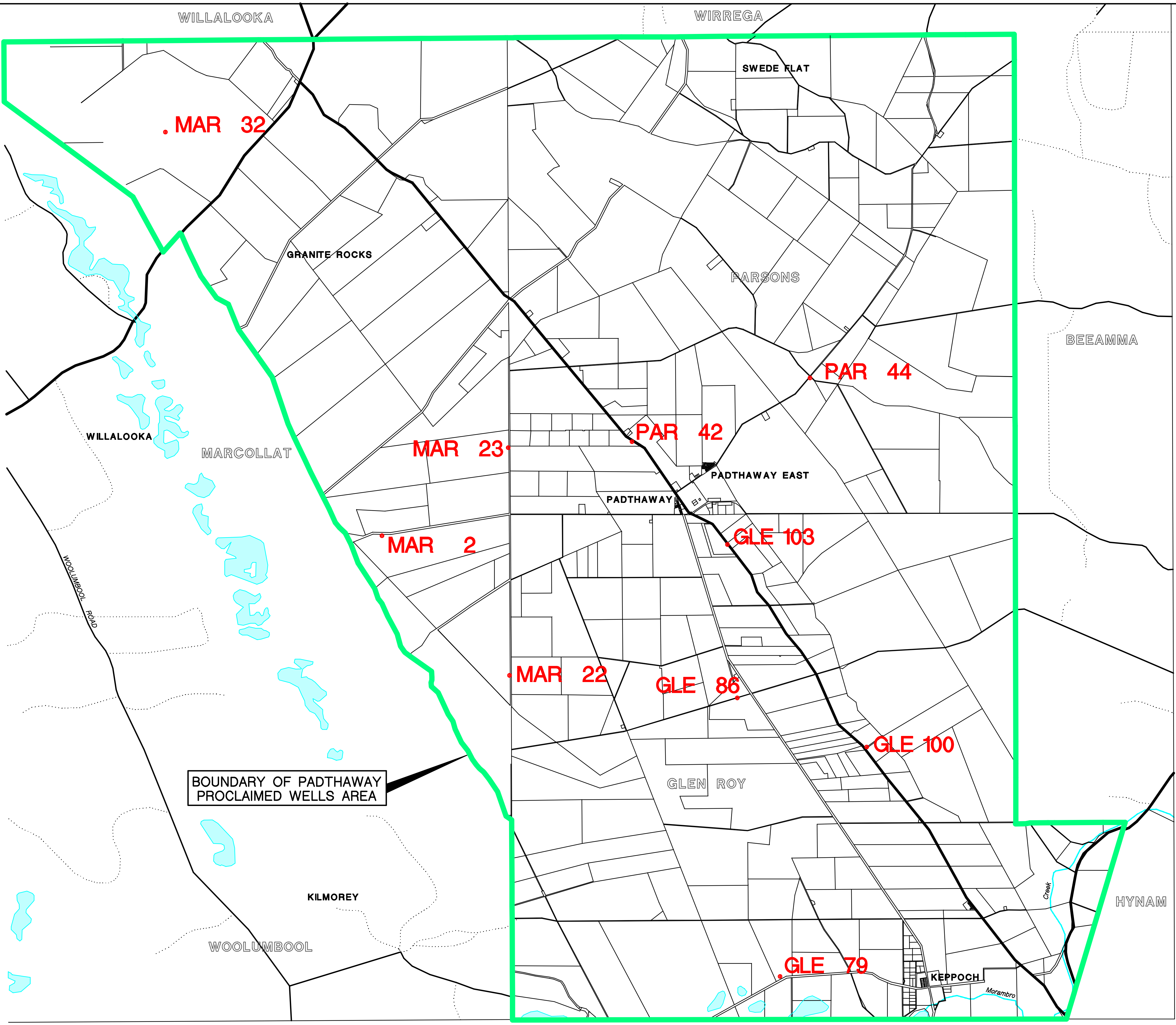


Figure.......15

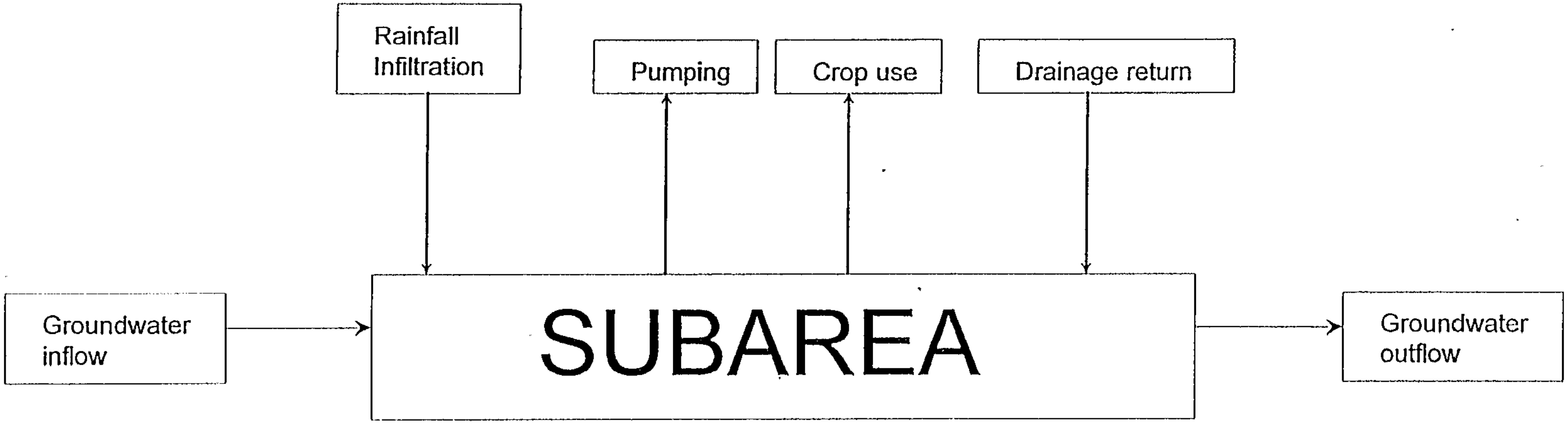
PADTHAWAY PROCLAIMED WELLS AREA

SELECTED SALINITY GRAPHS

1995–1433

Job No. QD-SOD 6136FS.DTA

Groundwater Budget Model and Estimation of Components



Note: Pumping = Crop use + drainage

	Item	Subarea 1	Subarea 2A	Subarea 2B	Subarea 3	Subarea 4	Totals
Inputs (ML/a)	GWI	23315	9423	13307	8170	27051	81267
	Rainfall	15774	3510	2450	2900	6678	31312
Total in							**112579**
Outputs (ML/a)	GWO	27325	6168	8170	8701	27409	77773
	Crop Use	8320	6850	6000	1430	900	23500
	Storage	0	0	735	0	7950	8685
Total out							**109958**

Notes:
GWI = groundwater inflow
GWO = groundwater outflow
Crop use from 1994/95 season

Assumed: For Bridgewater Formation, T = 750 m2/day at eastern edge of PWA
T = 1 000 m2/d elsewhere, porosity = 15%
For Padthaway Formation, T = 10 000 m2/day, porosity = 20%
Adopted lower bound recharge rates from table 1

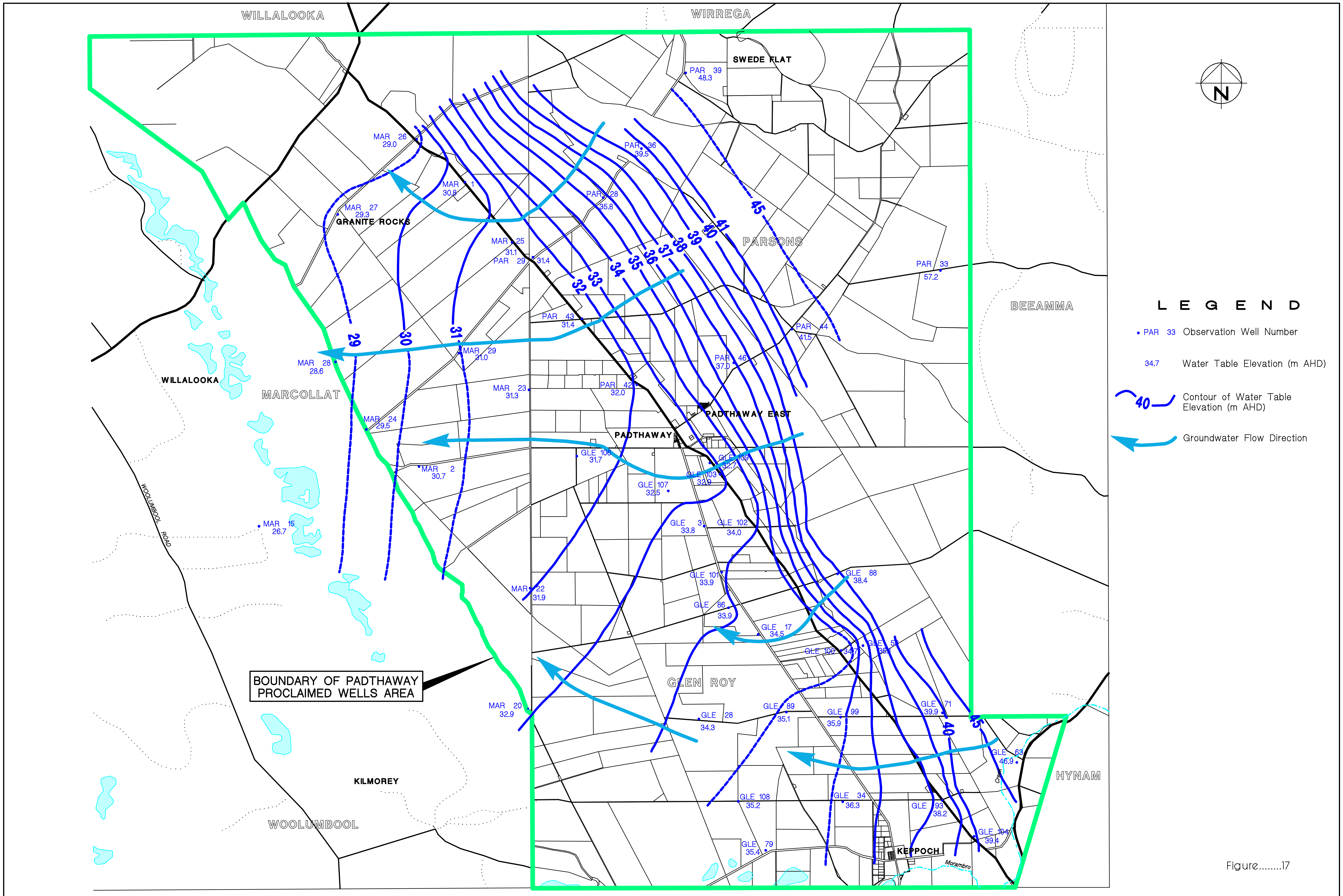
Figure........16

Job No. 6136FS.PRS

MINES and ENERGY
SOUTH AUSTRALIA

PADTHAWAY PROCLAIMED WELLS AREA
GROUNDWATER BUDGET MODEL

1995–1444



PADTHAWAY PROCLAIMED WELLS AREA

WATER TABLE CONTOURS
SEPTEMBER 1993

Job No. QD-SOD 6136FS.DTA

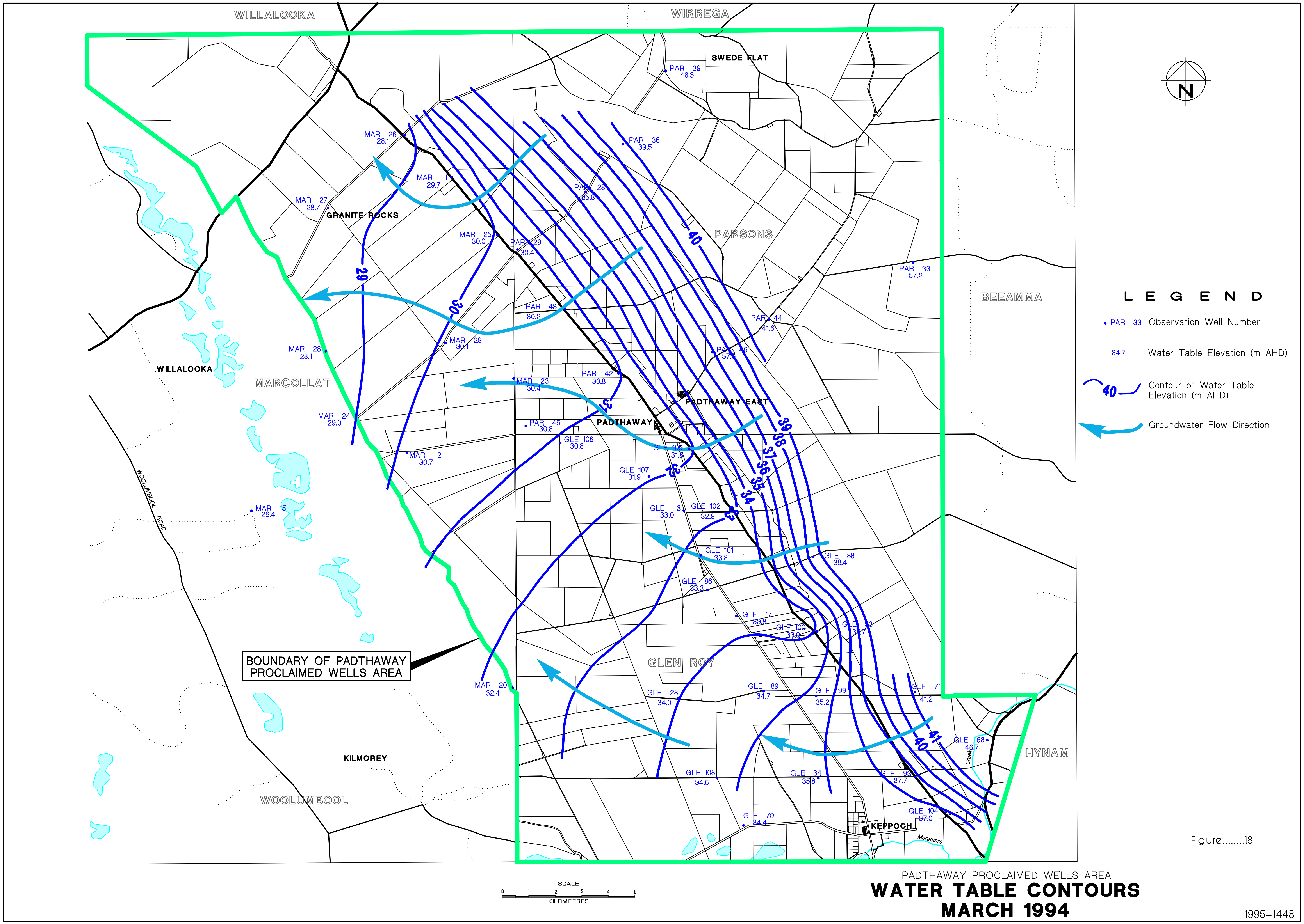
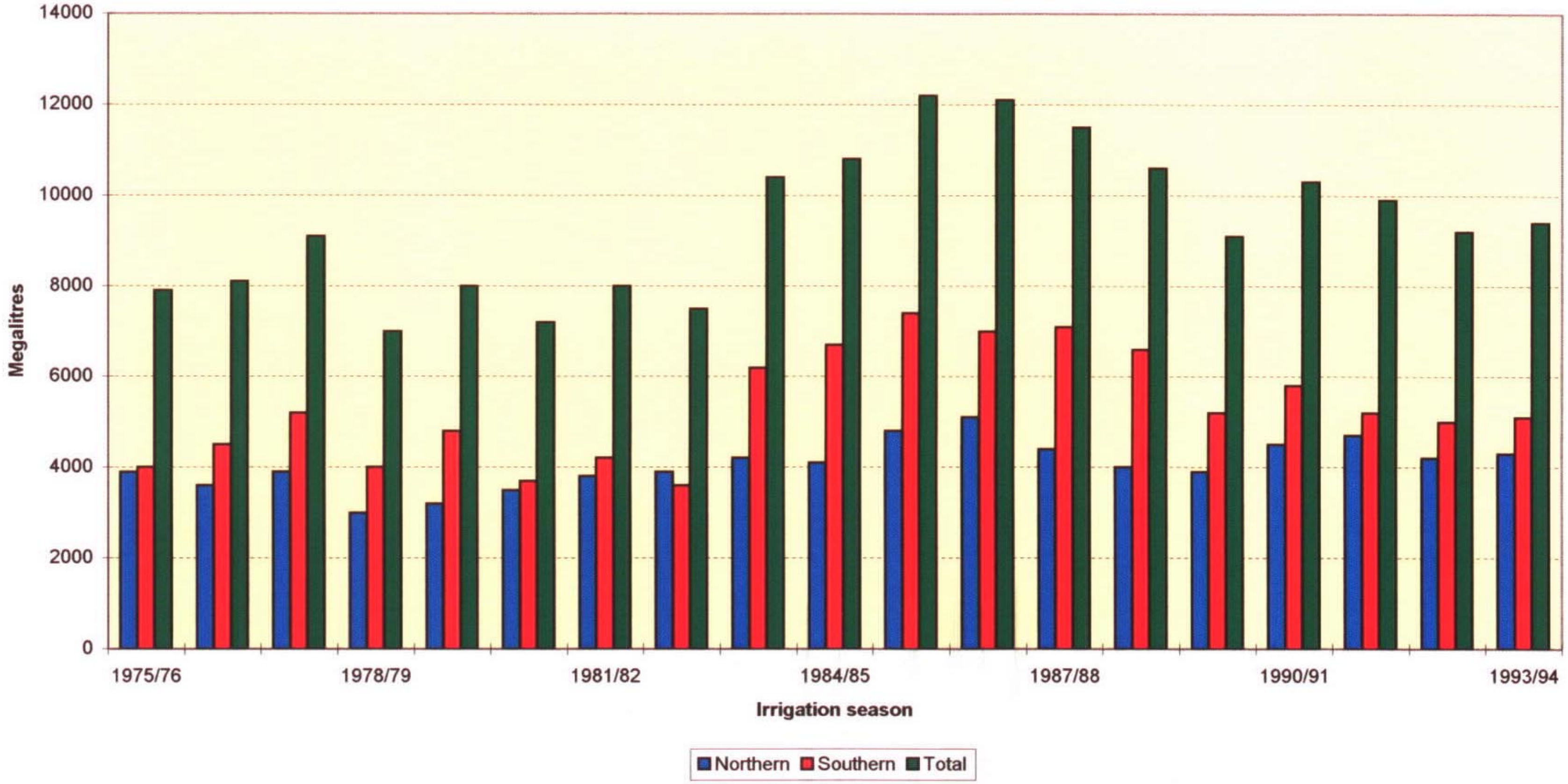


Figure........18

PADTHAWAY PROCLAIMED WELLS AREA

WATER TABLE CONTOURS
MARCH 1994

1995-1448



Job No. 6136FS.XLS

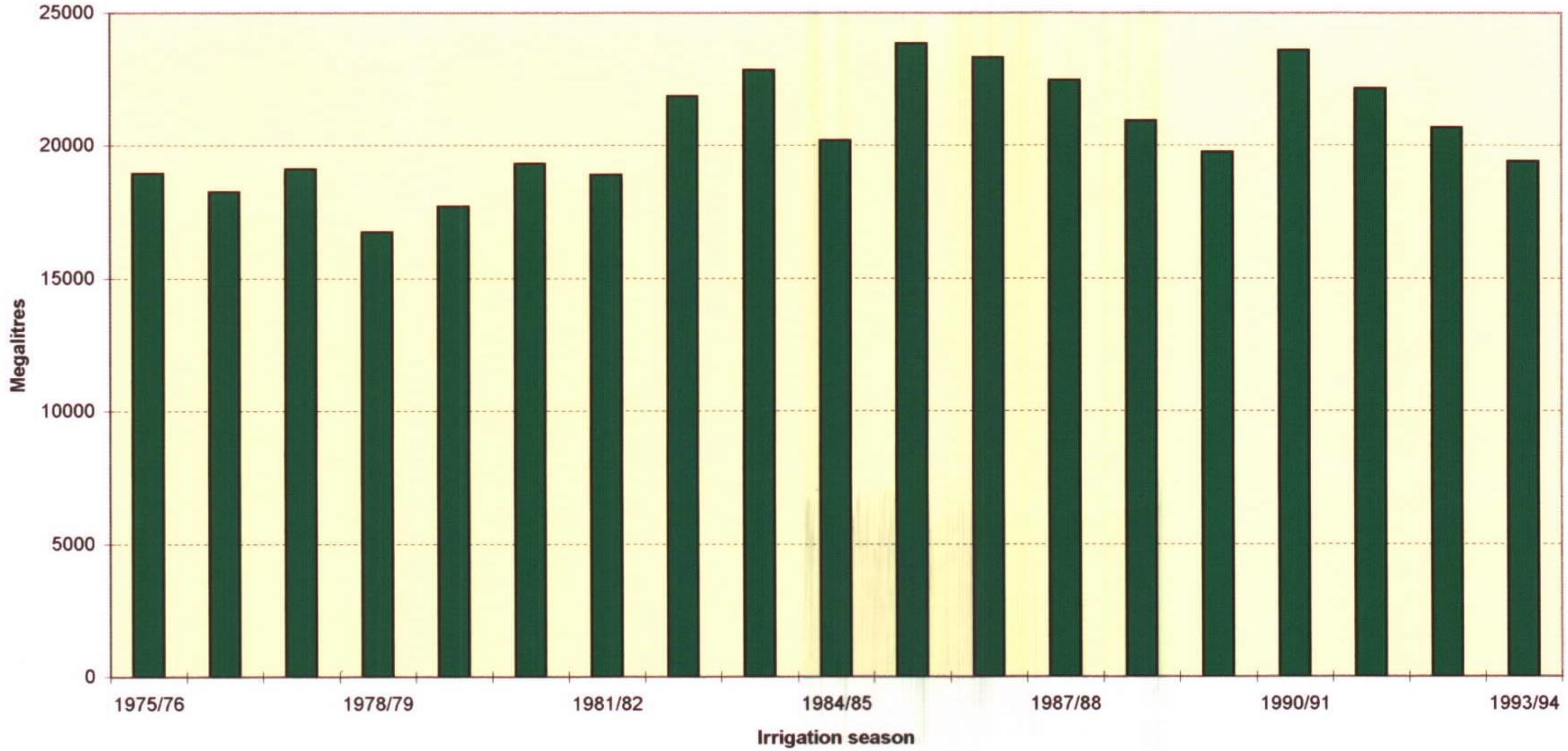
MINES AND ENERGY
SOUTH AUSTRALIA

PADTHAWAY PROCLAIMED WELLS AREA

GROUNDWATER USAGE
PADTHAWAY INTENSELY IRRIGATED STRIP

Figure.....19

1995-1449



Job No. 6136FS.XLS

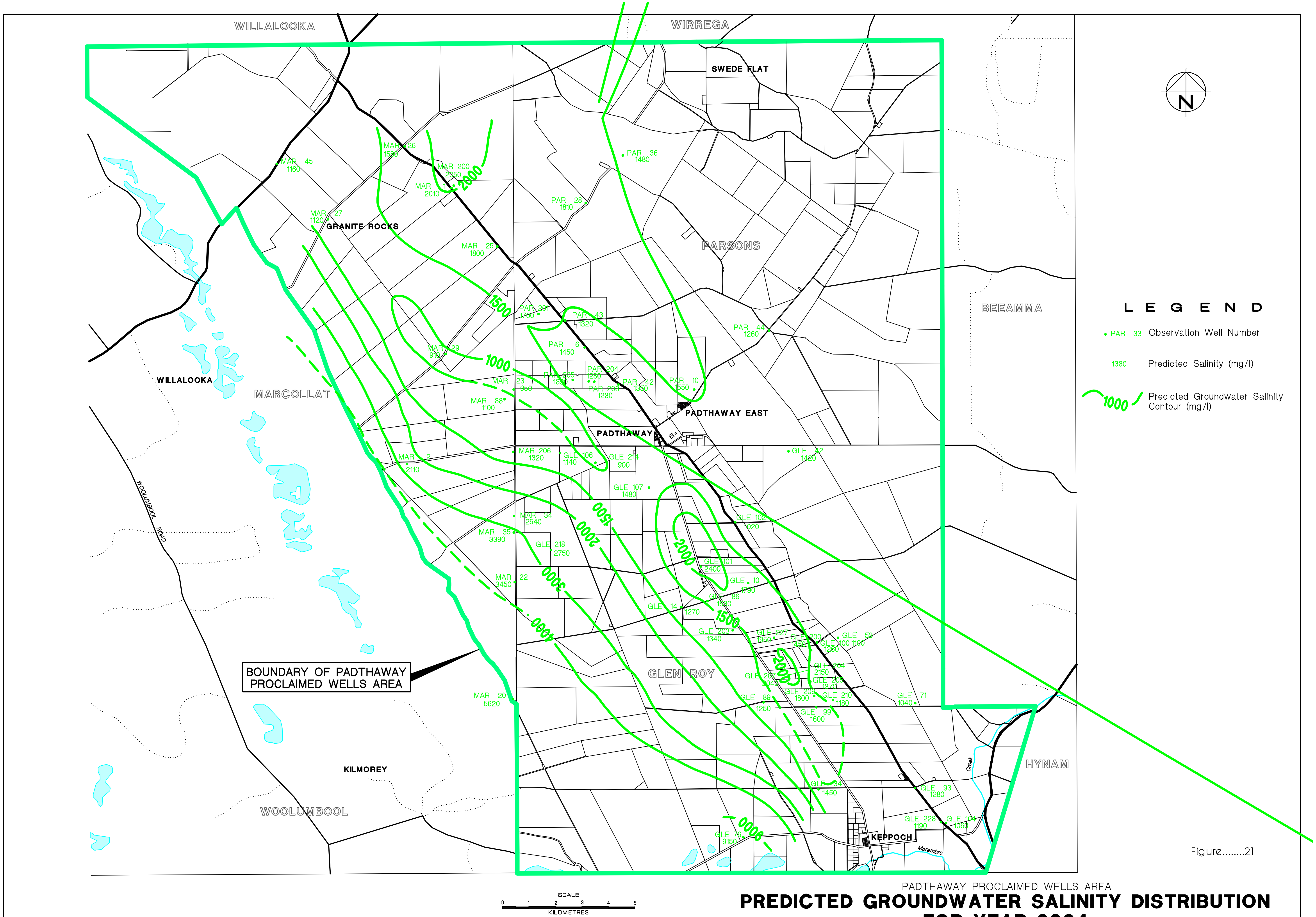
MINES AND ENERGY SOUTH AUSTRALIA

PADTHAWAY PROCLAIMED WELLS AREA

Figure.....20

GROUNDWATER USAGE
PADTHAWAY PROCLAIMED WELLS AREA

1995-1450



PADTHAWAY PROCLAIMED WELLS AREA

PREDICTED GROUNDWATER SALINITY DISTRIBUTION FOR YEAR 2004

1995-1442

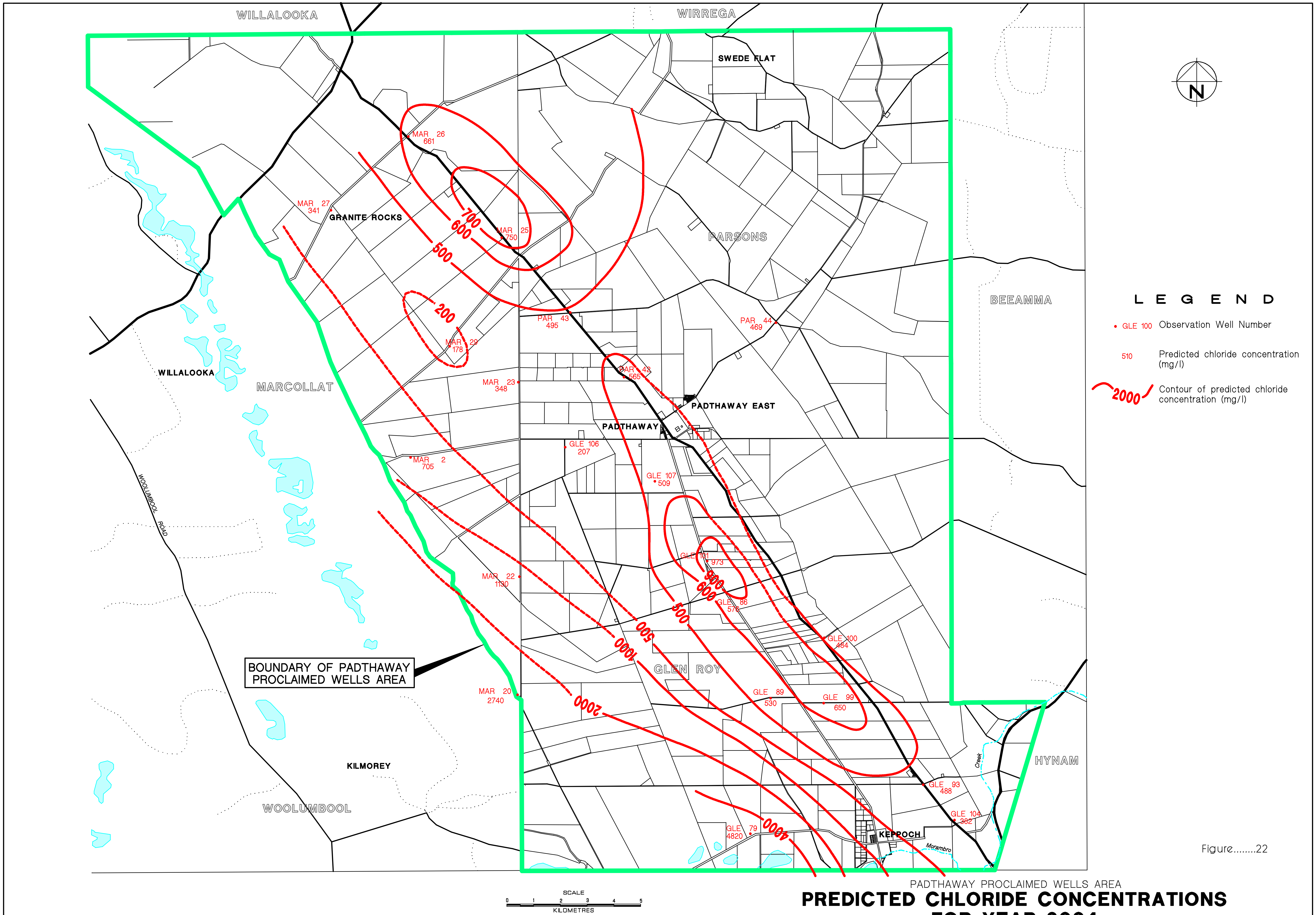


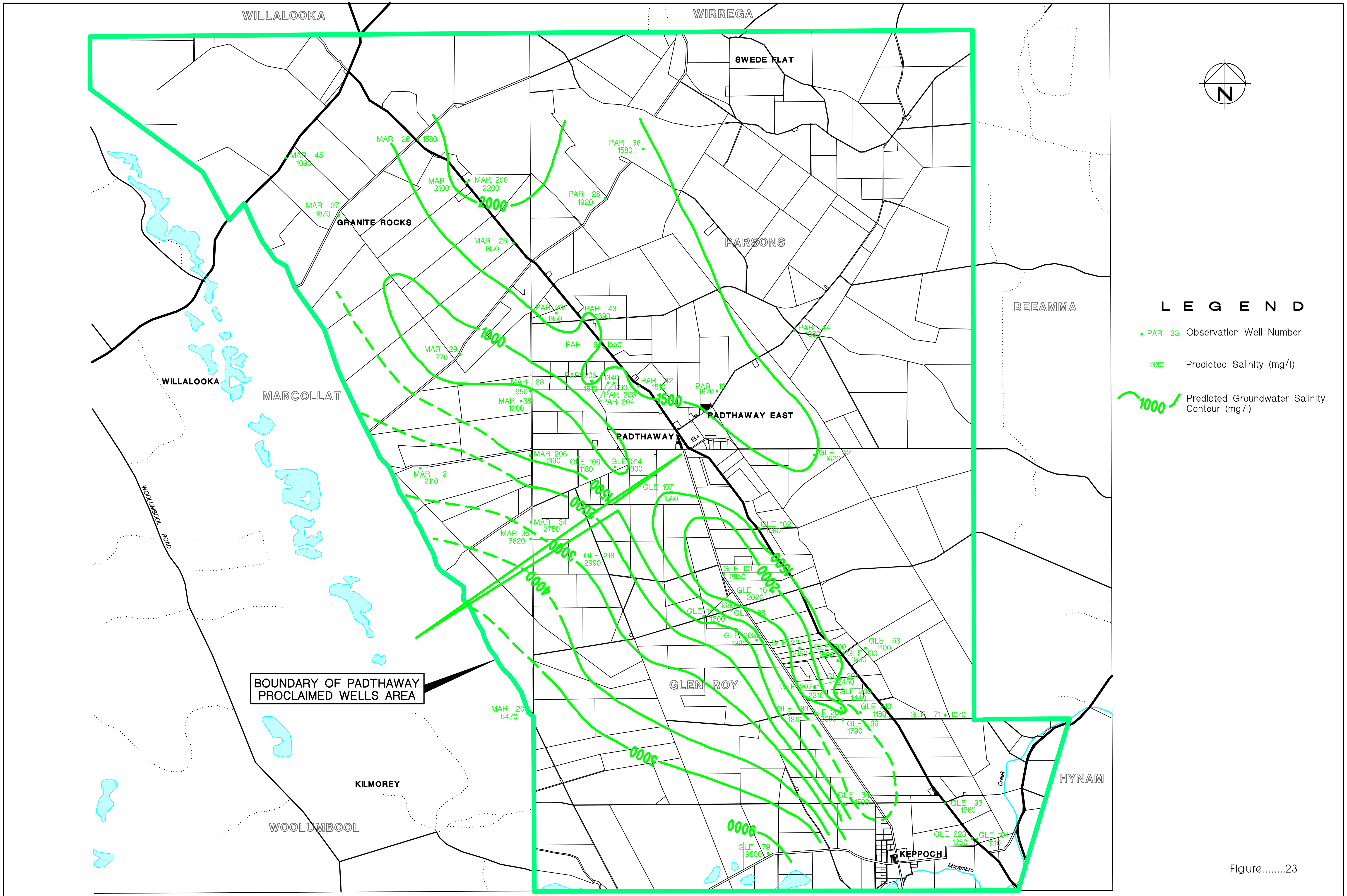
Figure........22

PADTHAWAY PROCLAIMED WELLS AREA

PREDICTED CHLORIDE CONCENTRATIONS FOR YEAR 2004

1995-1438

Job No. QD-SOD 6136FS.DTA



PADTHAWAY PROCLAIMED WELLS AREA

PREDICTED GROUNDWATER SALINITY DISTRIBUTION FOR YEAR 2014

1995–1443

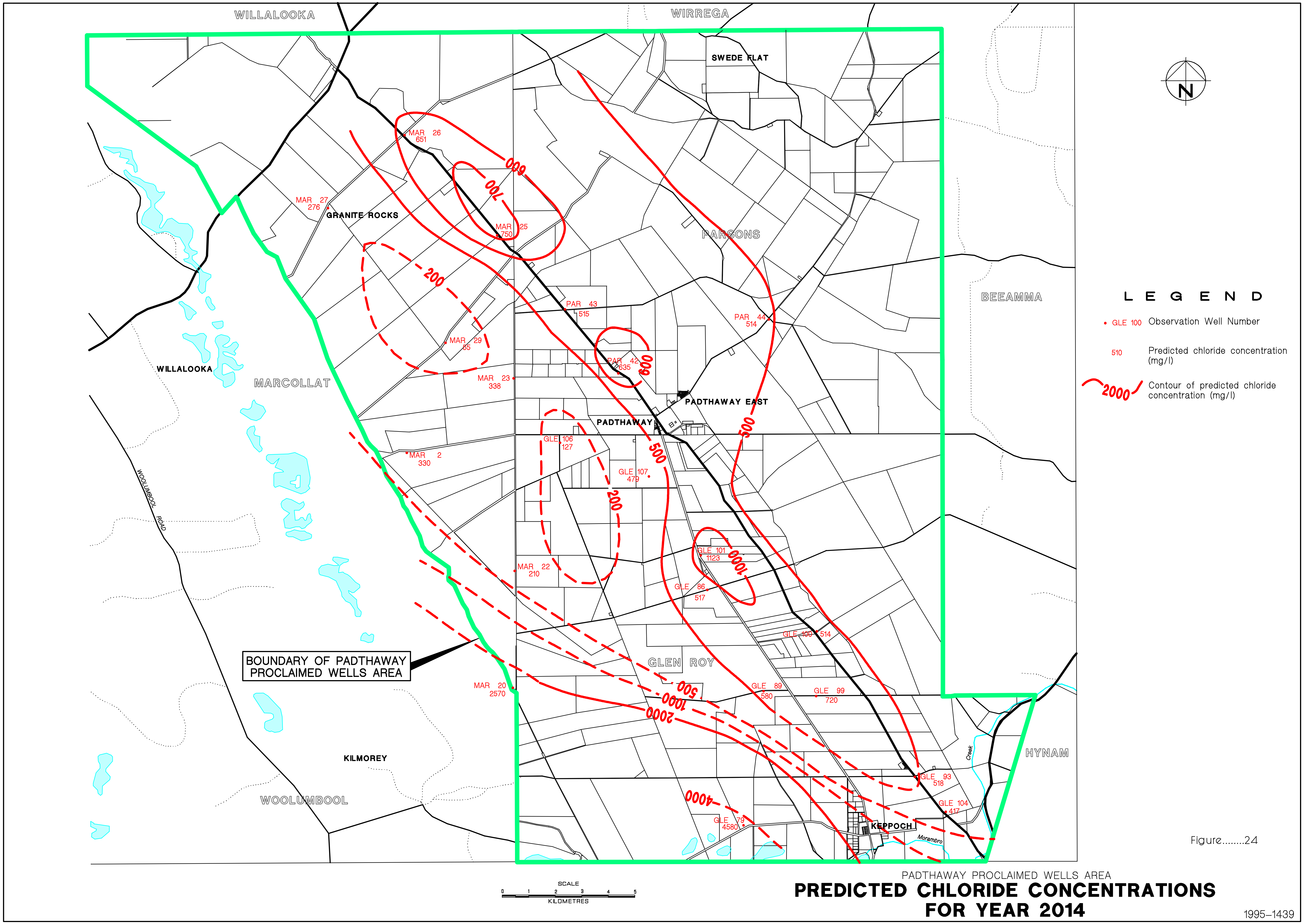


Figure.......24

PADTHAWAY PROCLAIMED WELLS AREA

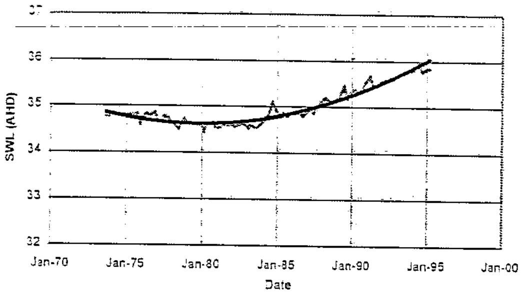
PREDICTED CHLORIDE CONCENTRATIONS FOR YEAR 2014

1995-1439

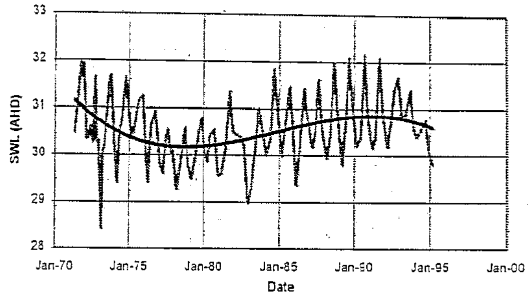
Appendix A

Bore Hydrographs

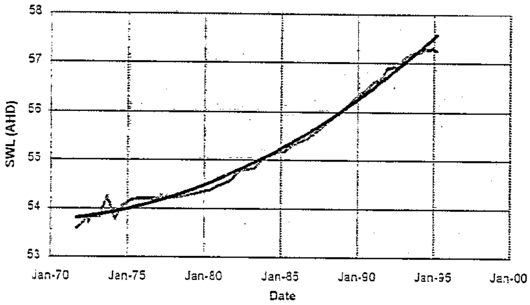
PAR 028



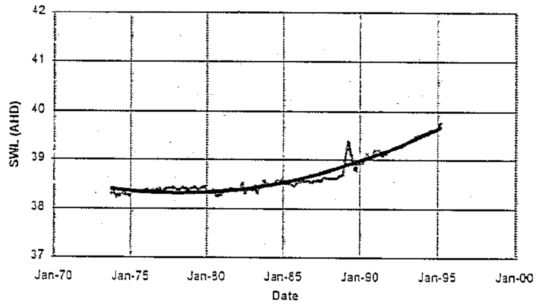
PAR 029



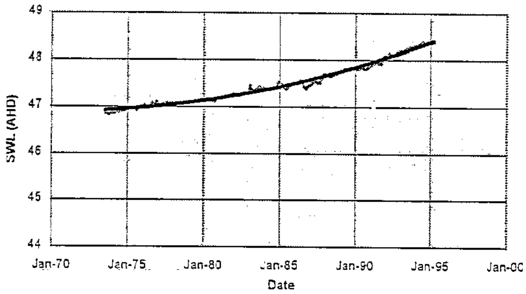
PAR 033



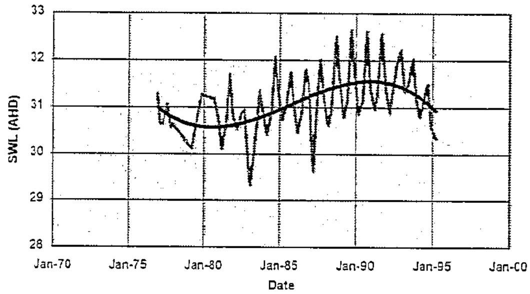
PAR 036



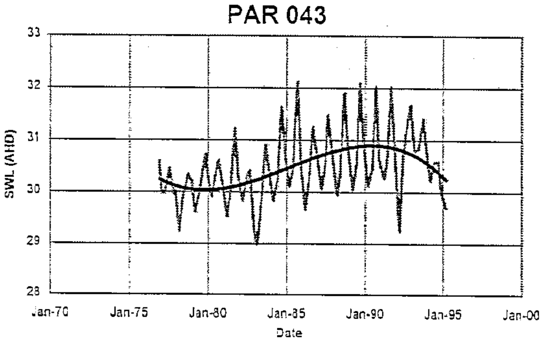
PAR 039



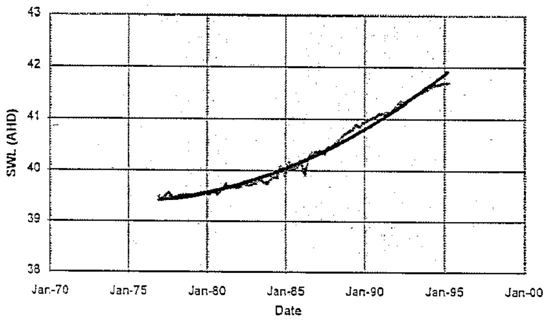
PAR 042



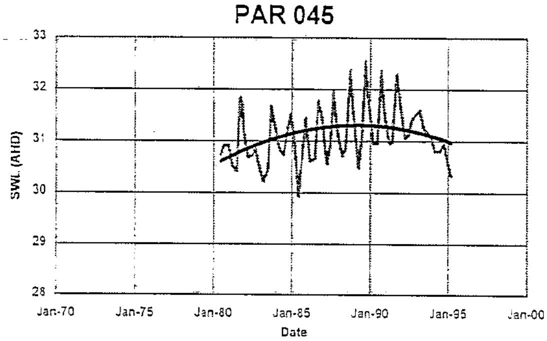
PAR 043



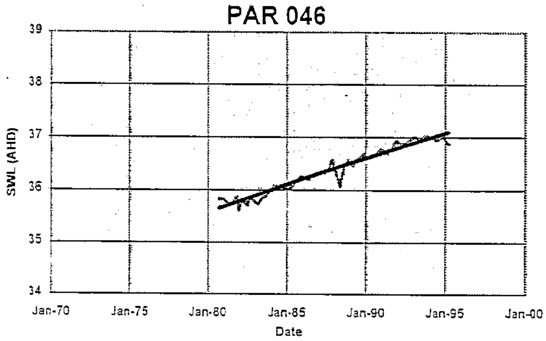
PAR 044

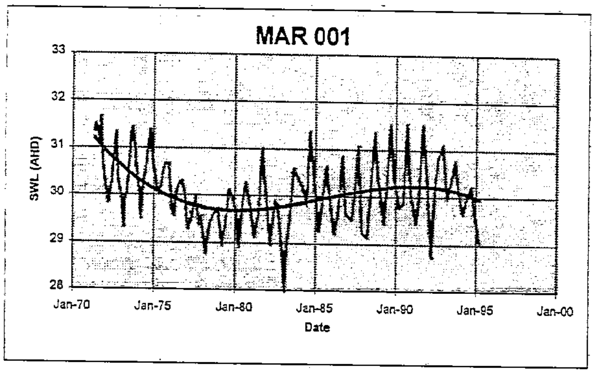


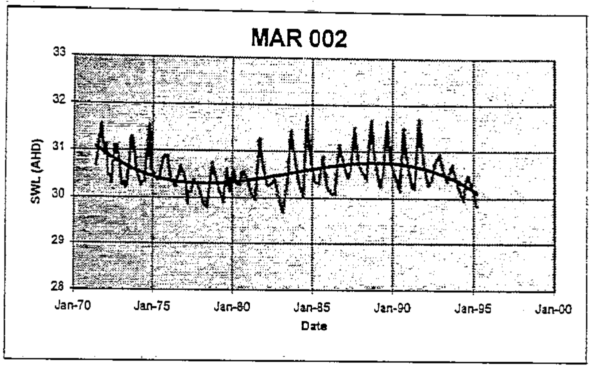
PAR 045



PAR 046




MAR 001
SWL (AHD)
Date


MAR 002
SWL (AHD)
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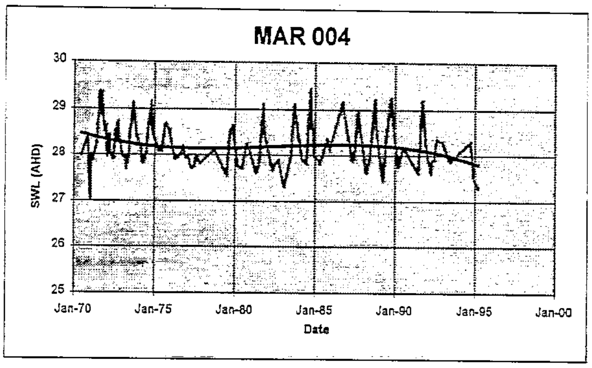
MAR 004
SWL (AHD)
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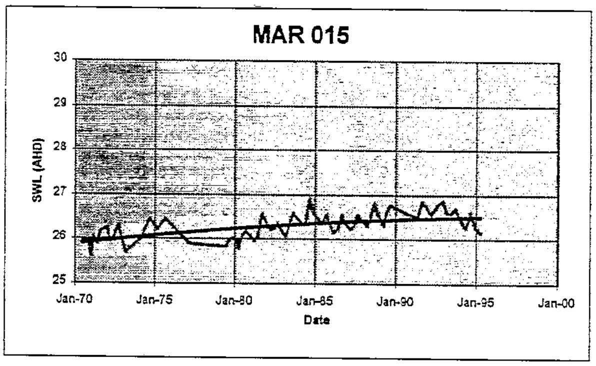
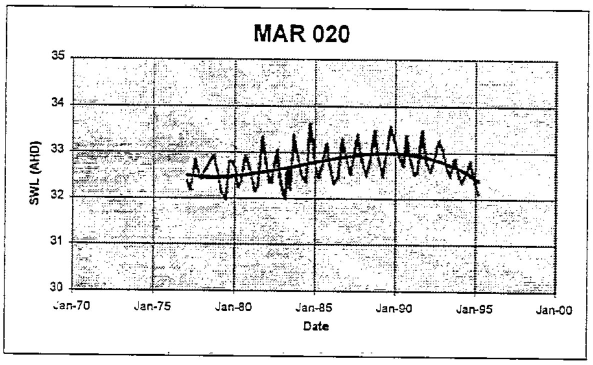

MAR 015
SWL (AHD)
Date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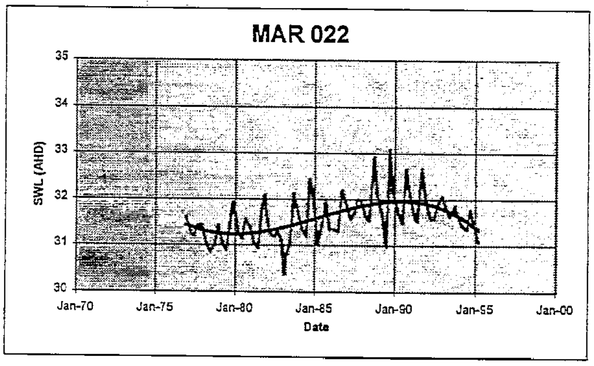
SWL (AHD)
Date


MAR 022
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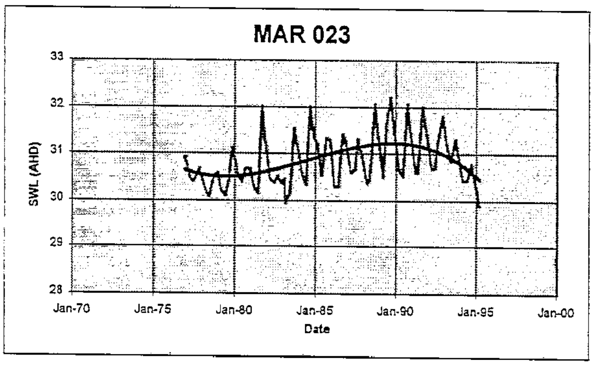
MAR 023
SWL (AHD)
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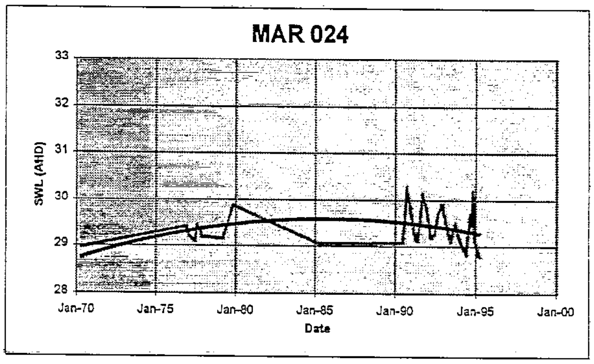
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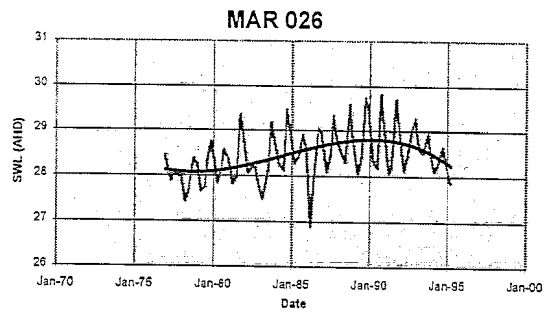
Date


MAR 026
SWL (AHD)
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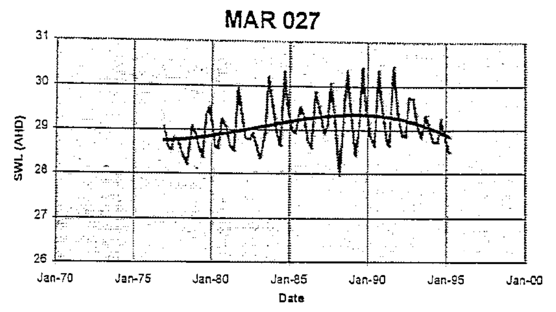
Jan-00
Date


MAR 027
SWL (AHD)
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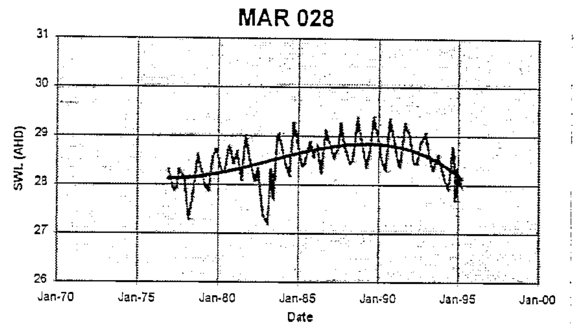
MAR 028
SWL (AHD)
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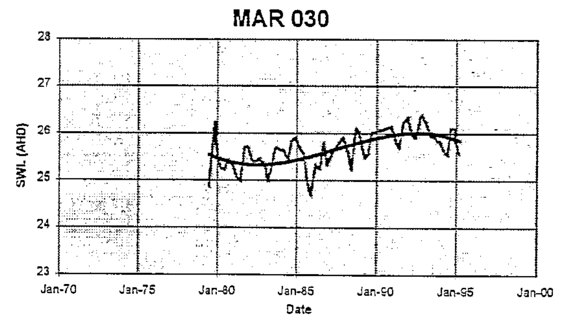
MAR 030
SWL (AHD)
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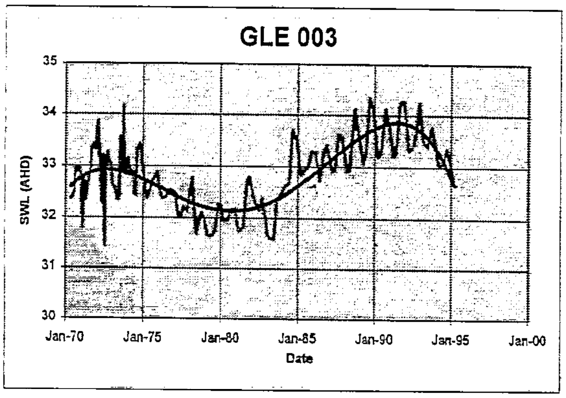
GLE 003
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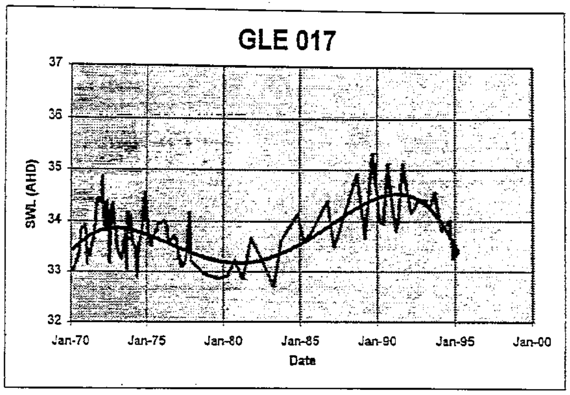
GLE 017
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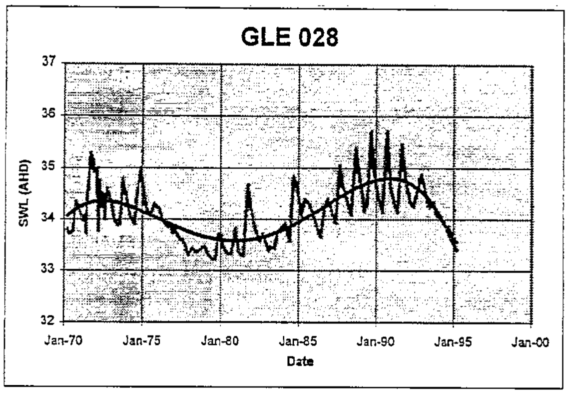
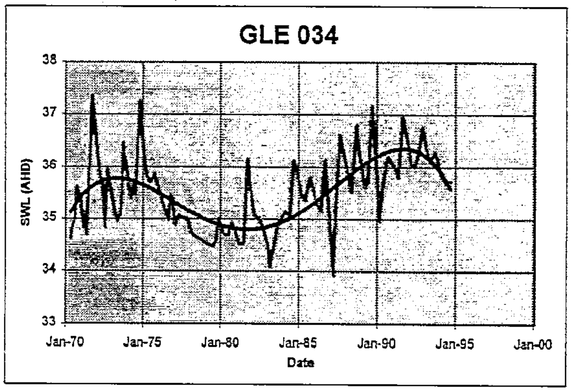
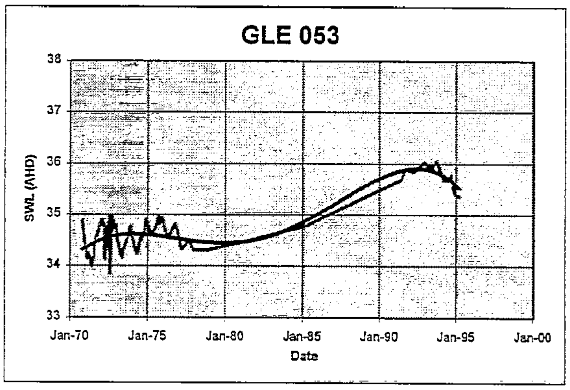
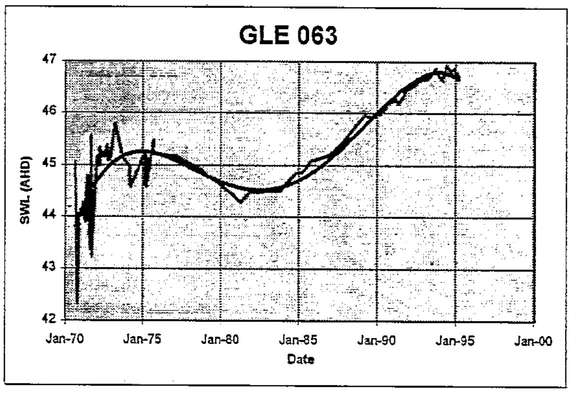

GLE 028
SWL (AHD)
Date


GLE 034
SWL (AHD)
Date


GLE 053
SWL (AHD)
Date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SWL (AHD)
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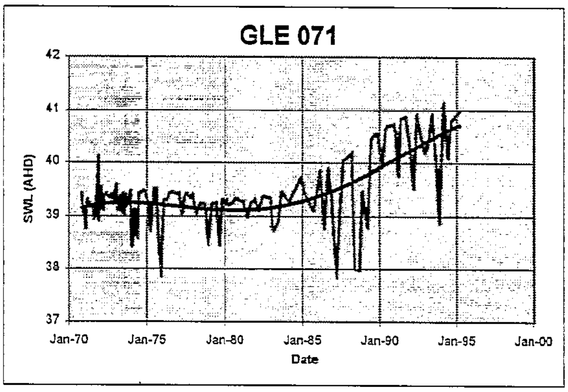
GLE 071
SWL (AHD)
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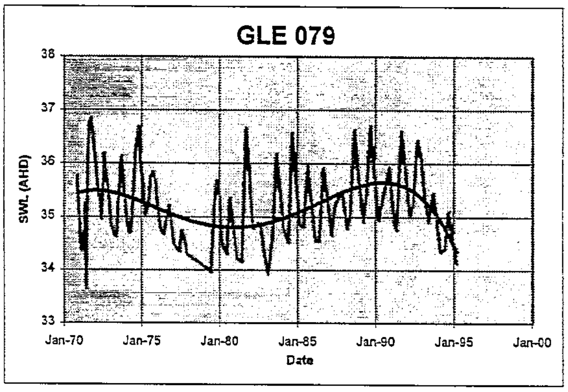
GLE 079
SWL (AHD)
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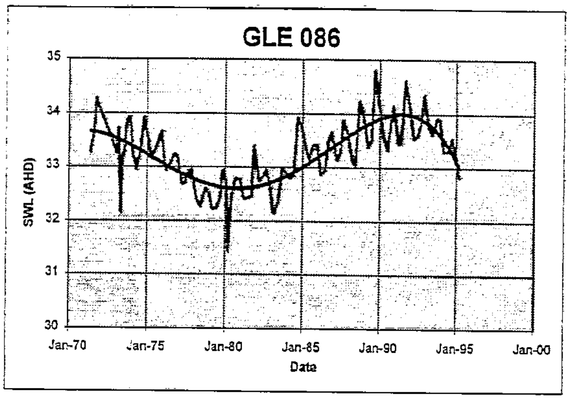
GLE 086
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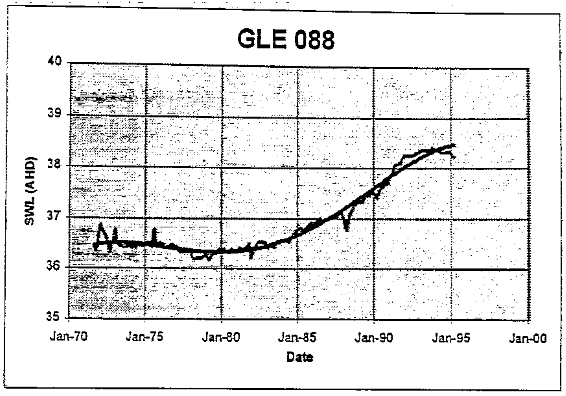
Jan-00
Date


GLE 088
SWL (AHD)
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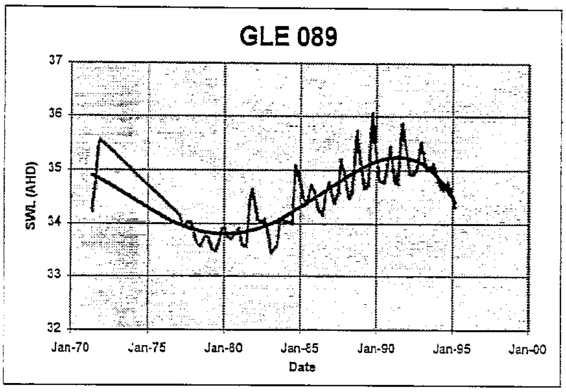
Jan-00
Date


GLE 089
SWL (AHD)
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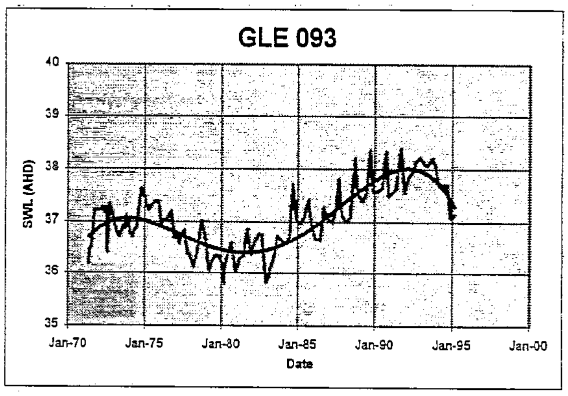
GLE 093
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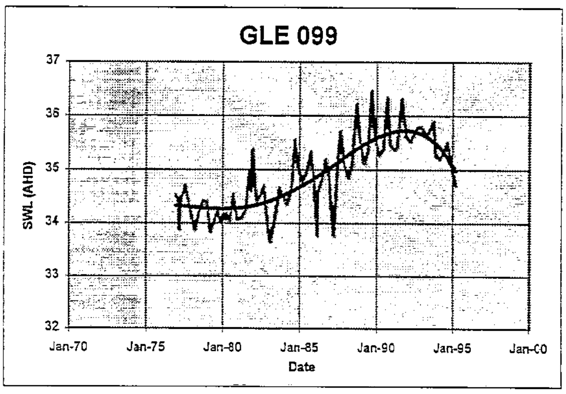
GLE 099
SWL (AHD)
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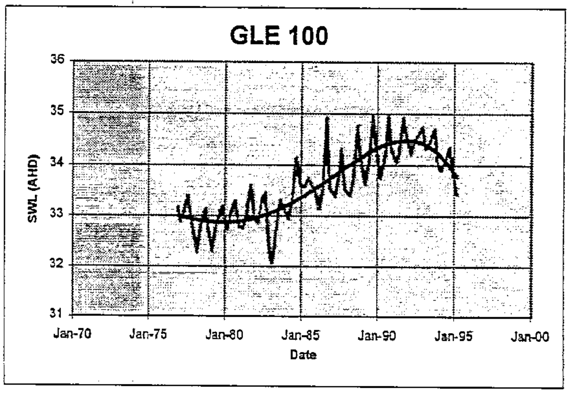
Date


GLE 100
SWL (AHD)
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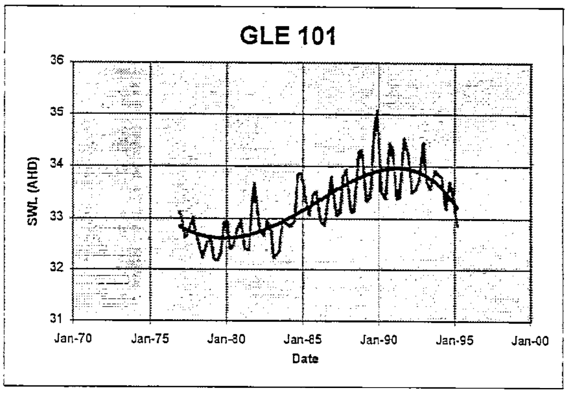
Jan-95
Jan-00
Date


GLE 101
SWL (AHD)
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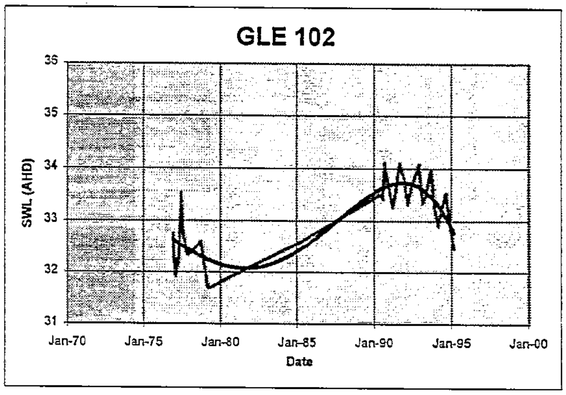
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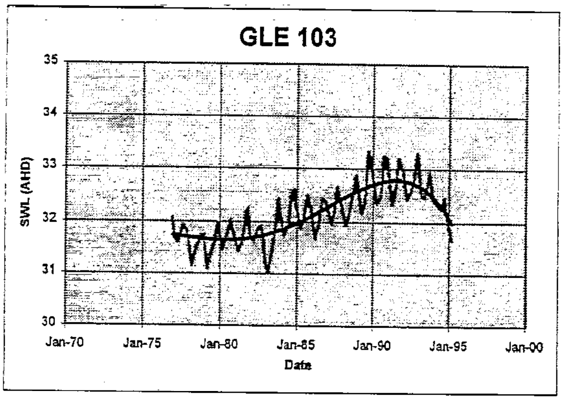
Jan-00
Date


GLE 103
SWL (AHD)
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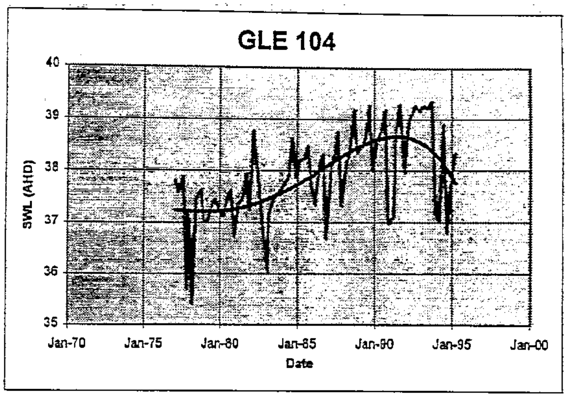
Jan-00
Date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SWL (AHD)
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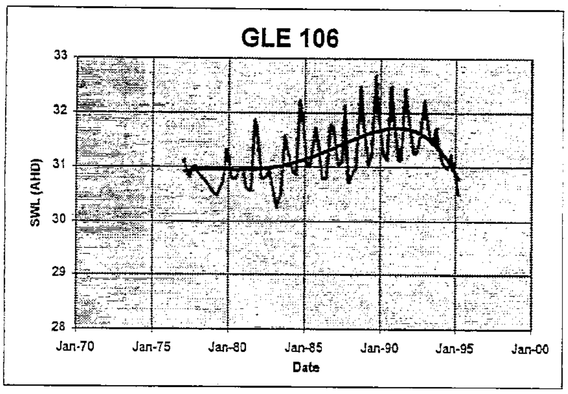
Jan-00
Date


GLE 106
SWL (AHD)
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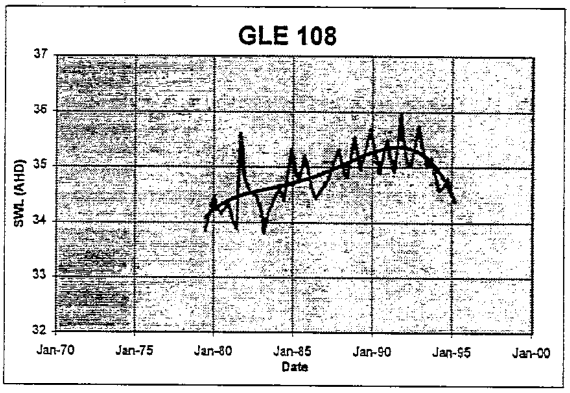
Jan-95
Jan-00
Date


GLE 108
SWL (AHD)
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Jan-70
Jan-75
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Jan-85
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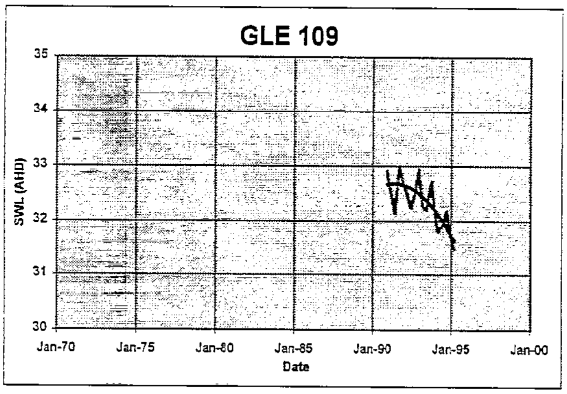
Jan-95
Jan-00
Date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SWL (AHD)
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Jan-70
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Jan-90
Jan-95
Jan-00
Date

Appendix B

Analysis of Trends for Salinity and Chloride

TABLE B1 PRIVATE IRRIGATION OBSERVATION WELLS
CURRENT AND PREDICTED SALINITIES (mg/L)

OBS WELL	TREND	1994	2004	2014
GLE 10	+23	1560	1790	2020
GLE 14	+3	1240	1270	1300
GLE 34	+5	1400	1450	1500
GLE 42	+20	1220	1420	1620
GLE 200	+11	1340	1450	1560
GLE 203	+5	1290	1340	1390
GLE 204	+30	1850	2150	2450
GLE 205	+7	1300	1370	1440
GLE 207	+27	1770	2040	2310
GLE 209	+25	1550	1800	2050
GLE 211	+17	1620	1790	1960
GLE 212	0	1180	1180	1180
GLE 214	0	900	900	900
GLE 218	+24	2510	2750	2990
GLE 223	+6	1130	1190	1250
GLE 227	+20	1750	1950	2150
PAR 4	+15	1550	1700	1850
PAR 6	+10	1350	1450	1550
PAR 10	+12	1430	1550	1670
PAR 203	-2	1250	1230	1210
PAR 204	+6	1220	1280	1340
PAR 205	+12	1270	1390	1510
MAR 34	+21	2330	2540	2750
MAR 35	+43	2960	3390	3820
MAR 37	-20	1000	1100	1200
MAR 45	-7	1230	1160	1090
MAR 200	+15	1900	2050	2200
MAR 206	+7	1250	1320	1390

TABLE B2 MESA OBSERVATION WELLS
CURRENT AND PREDICTED SALINITIES (mg/L)

OBS WELL	TREND	1994	2004	2014
GLE 28	-61	950	340(?)	
GLE 53	0	1100	1100	1100
GLE 71	+3	1010	1040	1070
GLE 79	+45	8700	9150	9600
GLE 86	+5	1580	1630	1680
GLE 89	+6	1190	1250	1310
GLE 93	+10	1180	1280	1380
GLE 99	+19	1410	1600	1790
GLE 100	+7	1190	1260	1330
GLE 101	+45	1950	2400	2850
GLE 102	+6	960	1020	1080
GLE 104	+5	1010	1060	1110
GLE 106	+4	1100	1140	1180
GLE 107	+8	1400	1480	1560
PAR 28	+11	1700	1 810	1920
PAR 36	+10	1380	1480	1580
PAR 42	+16	1190	1350	1510
PAR 43	+7	1250	1320	1390
PAR 44	+10	1160	1260	1360
MAR 1	+9	1920	2010	2100
MAR 2	-59	2700	2110	
MAR 20	-15	5770	5620	5470
MAR 22	-93	4380	3450	
MAR 23	0	950	950	950
MAR 25	+5	1750	1800	1850
MAR 26	0	1580	1580	1580
MAR 27	-5	1170	1120	1070
MAR 29	-14	1050	910	777

TABLE B3 MESA OBSERVATION WELLS
CURRENT AND PREDICTED CHLORIDE (mg/L)

OBS WELL	TREND	1994	2004	2014
GLE 28		224		
GLE 53		4O7		
GLE 71		357		
GLE 79	-24	5060	4820	4580
GLE 86	-5	617	576	517
GLE 89	+5	480	530	580
GLE 93	+3	458	488	51 8
GLE 99	+7	580	650	720
GLE 100	+3	454	484	514
GLE 101	+15	823	973	1123
GLE 102		330		
GLE 103	+14	470	610	750
GLE 104	+3.5	347	382	417
GLE 106	-8	287	207	127
GLE 107	-3	539	509	479
GLE 109		319		
MAR 2	-37.5	1080	705	330
MAR 20	-22	2960	2740	2520
MAR 22	-92	2050	1130	210
MAR 23	-1	358	348	338
MAR 25		750	750	750
MAR 26	-1	671	661	651
MAR 27	-6.5	406	341	276
MAR 29	-12.3	301	178	55
PAR 42	+7	495	565	635
PAR 43	+2	475	495	515
PAR 44	+4.5	424	469	514