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# WILLUNGA BASIN – STATUS OF GROUNDWATER RESOURCES 1998

by

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# WILLUNGA BASIN – STATUS OF GROUNDWATER RESOURCES 1998

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**The Willunga Basin is a complex multi-aquifer groundwater system supporting an area of high agricultural production. Because of the inter-connection between the various aquifers and surrounding basement rocks, the effects of significant withdrawals from one aquifer will ultimately impact on the other aquifers. Current monitoring data from the two major aquifers, the Maslin Sands and the Port Willunga Formation, continue to show a downward trend in groundwater levels. Analysis of the trends, both at maximum drawdown and maximum recovery, shows that the average rate of decline throughout the main pumping area of the basin is 0.8m per annum. Coupled with this decline in groundwater levels is a corresponding rise in salinity along the margins of the basin. The monitoring data shows that the basin is currently under stress, whereby extractions exceed the long-term sustainable yield.**

**The purpose of this review is to provide an updated appraisal on the status of the groundwater resources of the Willunga Basin. A re-evaluation of the water budget for the Willunga Basin shows discharge currently exceeds recharge by approximately 1 700 ML/yr. This mis-match between inflows and outflows is evident by the accelerated groundwater level decline and rises in salinity around the margins of the basin. From the data reviewed, it is recommended that a volumetric allocation be imposed that places a ceiling on volumes of groundwater that can be extracted for a period of three to five years, after which time a further review of the sustainable yield can be made.**

## INTRODUCTION

The Willunga Basin (Fig. 1) is an area of high agricultural production. The viticulture and almond industries, which are the principal agricultural pursuits in the basin, are supported by the groundwater resource. Groundwater also supplies most of the stock water needs and some industrial requirements in the area. This groundwater resource is being subjected to increasing pressure, principally through growth in viticulture.

Monitoring of groundwater level (piezometric) trends and salinity in the major aquifers of the Willunga Basin have been carried out by the Groundwater Program of Primary Industries and Resources South Australia (PIRSA) since the 1970s. After proclamation of the area in 1991 observation well networks have been continually upgraded in order to assist in defining the sustainable yield of the basin. All information currently held on PIRSA's corporate database for the Willunga Basin area has been updated. Some hydrochemistry sampling has been carried out to assist in defining recharge and discharge areas. This work is preliminary and will require subsequent infill sampling to aid in determining the degree of inter-aquifer flow.

The hydrochemistry analyses, together with the updated information from the database, form the basis for the construction of a numerical computer model for the basin. The numerical model will assist in further refining the estimates of the sustainable yield for the basin, and also allow simulation of the potential impacts on the aquifer of various management options.

## GEOLOGICAL HISTORY AND STRATIGRAPHY

The Willunga Basin is a sub-basin of the much larger St Vincent Basin which was formed by rejuvenated Palaeozoic faults during the continental separation of Australia and Antarctica in the Eocene period (Cooper, 1979). The basin is a thin wedge of mainly mid to late Tertiary and

Quaternary sediments deposited on the downthrown western side of the Willunga Fault (Fig. 2). The sedimentary sequence has not been strongly deformed; however, the sediments dip toward the southwest. All major aquifers outcrop at the surface (Fig. 2). Sediments of Permian age are also known to occur in the north eastern and western areas of the basin. The basin is underlain and bounded to the north, south and east by Late Precambrian and Cambrian age rocks of the Adelaide Geosyncline. The basement rocks are interbedded slates, quartzites and dolomites.

## HYDROGEOLOGY

The Willunga Basin is a complex multi-aquifer system. Groundwater is withdrawn from aquifer layers within the Quaternary and Tertiary sediments, and from the basement rocks. The groundwater system has been divided into four aquifer systems, Basement, Maslin Sands, Port Willunga Formation and Quaternary (Aldam, 1989). Marls and marly limestones of the Blanche Point Formation aquitard separate the Maslin Sands and Port Willunga Formation aquifers.

The most important sources of groundwater within the basin are the Maslin Sands and Port Willunga Formation aquifers (Aldam, 1989). More recently, an increasing number of wells have been targeting the basement rocks to provide useful supplies of groundwater, particularly to the east of the Willunga Fault.

Recharge to the sedimentary aquifers of the Maslin Sands and Port Willunga Formation occurs via direct rainfall infiltration (only over the outcropping areas), recharge from streams and outflow from the basement rocks.

Groundwater flows toward the coast from the north-east corner of the basin. The elevated basement areas to the north and east of the basin provide some recharge via lateral flow into the basin aquifers. Water quality deteriorates down gradient from 350 mg/L to 2 000 mg/L in the Port Willunga Formation and from less than 500 mg/L to more than 50 000 mg/L in the Maslin Sands (Fig. 3 and 4). Salinity of groundwater in the basement rock (Fig. 5) is between 1 000 and 2 000 mg/L over much of the basin. Along the margins of the basin, there are some isolated parts within the basement aquifer where water quality exceeds 2 000 mg/L as measured by total dissolved solids (TDS).

Well yields from the Port Willunga Formation typically lie in the range of 5 to 12 L/sec. Yields are generally lower from within the Maslin Sands. Well yields of up to 20 L/sec from the basement rocks have been recorded near McLaren Vale (Fig. 6).

From pumping tests, the broad scale transmissivity of the Port Willunga Formation aquifer typically ranges between 150 m/day and 200 m/day. Higher values have been measured but these are interpreted to reflect smaller scale local variabilities within the aquifer matrix. The transmissivity of the Maslin Sands aquifer typically has values ranging between 35 m/day and 50 m/day. One pumping test from the basement rocks outside of the basin indicated a fracture transmissivity of 44 m/day.

## CURRENT GROUNDWATER USAGE

Although five years of extraction records exist, the first year's records are considered unreliable as all wells had not been equipped with meters and some of the installed meters were known to be faulty. Therefore, the first year's records have been excluded from the dataset for the purposes of determining the average annual groundwater use. From the metering records, annual average groundwater use is determined to be 7 380 ML per annum.

The metered records of groundwater use for 1993 to 1997 have provided a definitive four-year record of the total groundwater abstracted to meet irrigation demand. Metering records are not available for the moratorium area, which adjoins the eastern boundary of the Willunga Basin Prescribed Wells area. Stock and domestic wells, together with industrial use are not currently metered. Metering of these sources of extraction may be required to more accurately quantify the available water resources for the region.

Total groundwater volumes extracted for irrigation purposes are presented in figure 7. Percentage volumes extracted from each aquifer are presented in figure 8.

The current area-based licensing system operating in the Willunga Basin Prescribed Wells Area does not provide for a maximum limit on groundwater abstraction. As there is no maximum limit imposed on the licence under an area based allocation

system, there is the potential to greatly exceed the estimated sustainable yield of the basin.
Evidence of this can be seen during the 1994-95 monitoring period (Fig. 7) when total groundwater abstraction from the basin exceeded 9 000 ML, approximately 1 500 ML more than the previously estimated sustainable yield. It should be noted that during 1994-95 drought conditions prevailed over much of the State.

Of the total volumes abstracted, 64% is drawn from the Port Willunga Formation, 20% from the Maslin Sands and 16% from the basement rocks (Fig. 8).

## GROUNDWATER MONITORING

Most of the piezometers are private production bores. Annual fluctuations of up to 15 metres are observed in the piezometers. These annual fluctuations are a function of both extraction rate from the bore and the transmissivity of the aquifer. These trends are indicative of the regional water level trends.

Because the aquifers are confined over much of the basin, there is no direct correlation between rainfall recharge and fluctuations in piezometric levels, apart from those areas where the aquifers crop out, or are very close to, natural ground surface. Evaluation of the rainfall trends against cumulative deviation from the mean indicates that rainfall has not deviated significantly from the mean over the past few years. Lower rainfall is therefore; not considered to be a significant contributing factor causing the increased rate of decline in water levels observed across the basin.

Analysis of the trends, both at maximum drawdown and maximum recovery, shows that more than half of all monitored wells have a declining water level trend. The maximum rate of decline is 0.8 metres per annum. Declines in the potentiometric surface for both the Port Willunga Formation and Maslin Sands correspond to the areas of greatest intensity of extraction (Figs. 9 and 10). These declining water levels indicate that extraction is greater than groundwater inflow into these parts of the aquifer.

Figure 11 illustrates the water level change in the basement aquifer over the period 1989-96 and shows some signs of localised stress eg observation well WLG 24 which has declined by 6.9 metres over this period.
The example hydrographs (Figs. 12 and 13) which are typical for the two aquifers show that the basin is under stress and that current extractions exceed the long-term sustainable yield. Between 1988 and 1993, the rate of decline was approximately linear; however, since 1993 groundwater levels have been declining more rapidly. This may be a reflection of the greater than normal abstraction levels during the irrigation season of 1994-95 (Fig.7).

As a result of the high extraction rates during 1994-95 it was difficult to predict with certainty if the change in slope of the water level decline was an artefact of the high extraction rate or if this trend would continue. The last two years of monitoring have confirmed that the decline in water level trends is continuing to steepen.

Prior to 1995, monitoring of salinity throughout the basin appears to have been carried out in an ad hoc fashion. Since the upgrade to the monitoring network, a significant number of wells have been added which include routine measurements of the groundwater quality on a bi-monthly basis. The period of monitoring is too short to infer any long-term changes in groundwater quality with certainty however; some generalities can be inferred from those wells that have longer term monitoring records.

Over the central portion of the basin, in both the Maslin Sands and Port Willunga Formation aquifers, salinity is increasing by approximately 10 mg/L (20 EC units per year) as shown in figure 14 for observation well WLG 47. Along the northern and coastal margin of the basin, salinity is increasing at a significantly higher rate.

The observed salinity increases along the margins of the basin may be caused by saline water that is expelled from within the confining bed. This occurs because the hydraulic pressure (which is the sum of the weight of the overlying rock strata plus fluids) is lower as a result of the declining groundwater levels, thereby allowing the remaining pore water to expand. This “additional” water that is released from within the clay lattice (elastic storage) is often more saline and therefore, contributes to rises in salinity within the aquifer.

Observation well WLG 88 completed in the Port Willunga Formation aquifer (Fig. 15), 1.25km inland from the coast has an annual increase in salinity of 30 mg/L. This increase may be an early indication of seawater intrusion into this part of the aquifer. Groundwater quality in this area currently exceeds 2 000 mg/L, and within ten years is likely

to exceed 2 500 mg/L at the present rate of increase.
Along the northwestern margin of the basin, salinity within the Port Willunga Formation is increasing at similar levels (Fig. 16), 30 mg/L per year. Groundwater quality in the Port Willunga Formation aquifer along this margin of the basin is currently 1 400 mg/L, and within ten years is likely to exceed 1 700 mg/L, which is approaching the upper limit for irrigation application to vines.

Along the same margin, salinity within the Maslin Sands is increasing at around 50 mg/L per year (Fig. 17), which suggests that within ten years salinity could exceed 2 200 mg/L. In the area around Blewitt Springs (Fig. 18), salinity within the Maslin Sands aquifer has been increasing at around 100 mg/L per year. Groundwater in this area already exceeds 2 200 mg/L, making it undesirable for irrigation of vines.

Groundwater, which is slowly increasing in salinity around the margins of the basin, will inevitably be drawn towards the areas of greatest irrigation intensity, thereby impacting on the water quality in these areas also.

## RECHARGE AND DISCHARGE

The components of the water budget for the Willunga Basin are illustrated diagrammatically in figure 19. Groundwater inputs to the Tertiary aquifer/s result from:

- local rainfall accessions over those areas where these formations crop out at the surface (Fig. 2),
- infiltration recharge during wet periods from streams; or,
- lateral inflow from the adjacent basement rocks.

The rate of recharge from the basement rocks will depend on the degree of hydraulic connection across the Willunga Fault, between the basement rocks and the Maslin Sands aquifer that overlies, but is separated from, the underlying basement rocks by a thin weathered zone.

The potentiometric surfaces for the three major aquifer systems indicate that in the upper reaches of the basin (east of McLaren Flat through to Kangarilla), vertical leakage occurs from the Maslin Sands upward into the Port Willunga Formation. West of McLaren Flat, the heads are reversed and leakage occurs downward from the Port Willunga Formation through the Blanche Point Formation aquitard into the Maslin Sands.
Any leakage through the Blanche Point Formation aquitard is considered to be a very small component of the overall water budget. As there is a potential for flow to occur albeit small, between the various aquifers, they are considered to be one interactive system for the purposes of determining the water budget.

Another small component of the overall water budget may result from return flows to the groundwater system via irrigation. This however, is only likely to occur over those parts of the basin where irrigation is applied directly onto the out cropping areas of the Port Willunga Formation and Maslin Sands, or where these aquifers lie within close proximity of the ground surface.

On the whole, it is considered that any recharge resulting from return flows via irrigation over the majority of the basin are likely to recharge only the shallow Quaternary aquifer. Therefore, this component of the water budget has not been included in the calculations of the water balance for the basement, Maslin Sands and Port Willunga Formation aquifers.

Losses from the aquifer system occur as a result of

- evapotranspiration,
- discharge to sea and,
- discharge to wells and streams.

Calculation of a sustainable yield for the resource depends on the quantification of the major components of the water budget.

## GROUNDWATER BUDGET

For a defined region, over a given period of time the inflow minus the outflow equals the change in storage. This balance is referred to as the groundwater budget and may be expressed as

$$R_g + I_g = ET_g + O_g \pm \Delta S_g \qquad \text{(Eqn. 1)}$$

Where
$R_g$ = groundwater recharge via infiltration
$I_g$ = lateral groundwater inflow
$ET_g$ = groundwater evapotranspiration
$O_g$ = groundwater outflow via discharge
$\Delta S_g$ = changes in groundwater storage

## Inflows – Rainfall Infiltration

In general, the hydrographs for the Maslin Sands and Port Willunga Formation aquifers do not correlate with rainfall trends because these aquifers are confined over much of the basin. However, the Port Willunga Formation crops out in a narrow band approximately 4 km wide between Port Willunga and Kangarilla. The Maslin Sands crop out principally along the length of the northern boundary of the basin and in the Kangarilla area. Where these formations crop out at the surface, direct infiltration of rainfall to the aquifers is a significant component of the water budget.

Total potential recharge from rainfall infiltration has been estimated using the chloride mass balance technique

$$R = \frac{Pptn \times Cl_p}{Cl_g}$$

(Eqn. 2)

Where
R = recharge
Pptn = mean annual rainfall (mm)
$Cl_p$ = chloride concentration in rainfall (mg/L)
$CI_g$ = chloride concentration in groundwater (mg/L)

The figure for chloride in rainfall was obtained from a study carried out by Kayaalp (1998) from which the total chloride concentration in rainfall equates to 8 mg/L. This figure was determined from a three-year study and is derived from the 'wet' chloride concentration in rainfall at the coast (Christies Beach) and a 'dry' chloride concentration from wind deposited sea salts.

Recharge from rainfall infiltration occurs only through those areas where the formations containing the aquifer crop out at the surface (Fig. 2). The Port Willunga Formation aquifer is recharged in the areas around McLaren Vale through to McLaren Flat. The Maslin Sands is recharged along a band approximately 4 km wide extending from north of McLaren Vale to Kangarilla. The basement aquifer is recharged in the hills in the northern and eastern parts of the basin where there is a thin veneer of overlying sediments.

Chloride in groundwater was used from full chemistry results, which have been carried out on samples taken from wells that intersected the respective formations in the outcropping areas.

Using equation 2, recharge from rainfall infiltration has been calculated to be 2 100, 900 and 1 050 ML/yr for the basement, Maslin Sands and Port Willunga Formation aquifers respectively (Table 1), providing a total recharge from rainfall infiltration to the aquifer system of 3 300 ML/yr.

| Aquifer | Outcrop Extent ($Km^2$) | Chloride Conc. (mg/L) | Recharge | Percent of mean Rainfall |
|---|---|---|---|---|
| Basement | 83.6 | 180 | 2 100 | 4.4 |
| MS | 36.4 | 182 | 900 | 4.3 |
| PWF | 51.5 | 226 | 1 050 | 3.5 |

Table 1. Rainfall recharge from Chloride.

Recharge from stream infiltration is difficult to quantify at present, as there are no stream gauging stations in the Willunga area to provide an indication of the baseflow to the streams. The majority of creeks in the Willunga Basin may provide recharge to the groundwater system in their upper reaches but it is considered that this infiltration is balanced by groundwater discharge in the lower reaches of the creeks.

Further work is required to quantify the degree of stream/groundwater interaction and forms the basis of a submission to the Natural Heritage Trust for funding to carry out the required work in conjunction with the Onkaparinga Catchment Water Management Board (OCWMB).

## Lateral Inflow

Lateral inflow into the sedimentary aquifers from the surrounding basement rock is considered to be the other major component of the water budget. Along the southern margin of the basin, the Willunga Fault is thought to be 'closed' along much of its length and therefore, acts as a barrier to any potential lateral inflow from the adjacent basement rocks. Evaluation of the salinity and potentiometric surface contours indicate that there may be sections along the fault that allow some water to move laterally into the basin, particularly in the Kangarilla area. However, this section would only be one to two kilometres long over the length of the fault.

Assuming that the fault allows transmission of groundwater over a 2km window along its length, the lateral inflow to the aquifer system can be calculated from the following equation

$$Q = (kAi)$$

(Eqn. 3)

Where

| | | |
|---|---|---|
| Q | = | volume of lateral flow |
| k | = | hydraulic conductivity |
| A | = | cross sectional area |
| i | = | hydraulic gradient |

This same equation can be used to determine the lateral inflow from the surrounding basement rocks along the northern and eastern margins of the basin.

The cross sectional area for input into the above equation is determined from the aquifer geometry. The hydraulic gradient has been determined from contoured water level information and the hydraulic conductivity determined from pumping tests.

Given these parameters, the lateral inflow into the basin is determined to be 3 080 ML/yr and 960 ML/yr for the Port Willunga and Maslin Sands aquifers respectively. Previous estimates of lateral inflow into the aquifer system (Skelt, 1989), have used estimates of the hydraulic conductivity for the respective formations, rather than using information derived from pumping tests.

Flow across the fault can be determined in the same manner as above. Assuming that the fault allows some transmission of groundwater over a 2km section along the length of the fault, the respective contributions to the groundwater system from flow across the fault are 440 ML/yr and 100 ML/yr for the Maslin Sands and Port Willunga Formation aquifers respectively.

## Outflows

Losses from the aquifer system of the Willunga Basin principally result from discharge to sea and discharge to wells. Losses resulting from evapotranspiration can only occur where water tables are shallow and an evaporative demand exists at the soil surface. Given that the depth to water for the Port Willunga and Maslin Sands aquifers over the majority of the basin is greater than 10 metres, losses from the system as a result of evapotranspiration are likely to be negligible and therefore, this element of the water budget can be ignored.

Similarly, whilst it is recognised that surface discharge from the Port Willunga Formation aquifer feeds Peddler Creek near McLaren Vale, and that the creek in Barker Gully southwest of Kangarilla is largely fed from groundwater discharge from the Maslin Sands and Basement aquifer, it is considered that these discharges are approximately in balance with recharge from the streams to the aquifer. However, as stated earlier in this report, the degree of surface and groundwater interaction across the basin is an area that requires further investigation.

The annual average discharge to wells from metering records is 7 380 ML/yr. Of this figure, approximately 64% (4 720 ML) comes from the Port Willunga Formation aquifer, 20 % (1 480 ML from the Maslin Sands, and 16% (1 180 ML) from the basement aquifer.

Discharge to sea has been calculated from the following equation (Hazel, 1975) which provides a first order estimate of the groundwater volumes discharged to sea.

$$qL = \frac{(Kz_o{}^2)}{2} \times \left( \frac{\rho_s - \rho_f}{\rho_f} \right)^2 \times 1 + \left( \frac{\rho_f}{\rho_s - \rho_f} \right)$$

(Eqn. 4)

Where

| | | |
|---|---|---|
| q | = | discharge |
| L | = | length of wedge |
| K | = | hydraulic conductivity |
| $z_o$ | = | depth of base below datum |
| $\rho_f$ | = | density of fresh water |
| $\rho_s$ | = | density of salt water |

Some assumptions have been made in determining the length of the intruded wedge for both the Maslin Sands and Port Willunga Formation aquifers. Observation well WLG 38, some 5 km inland from Aldinga Beach, is completed over the entire thickness of the Maslin Sands aquifer and encountered a salinity at the base of the aquifer of 30 000 mg/L (seawater is approximately 35 000 mg/L). This high salinity is therefore assumed to be a result of seawater intrusion to this point in the Maslin Sands aquifer. Based on this assumption, discharge to sea from the Maslin Sands aquifer is estimated to be 1 060 ML/yr.

In the case of the Port Willunga Formation, there are no observation wells adjacent to the coast and it cannot be determined with certainty if any saline intrusion into this aquifer is occurring. The rising salinities recorded in observation well WLG 88 (Fig.15) may be the early indications of seawater encroachment into this aquifer, so an assumption is made that saline wedge has intruded some 750 m inland. From equation 4, a discharge of some 1 820

ML/yr from the Port Willunga Formation to the sea was calculated.

The absence of monitoring wells in the Port Willunga Formation aquifer adjacent to the coast is another issue that needs to be addressed so that discharges from the Port Willunga Formation to the sea may be determined more accurately.

Having determined the major elements of the groundwater budget and cited reasons for omitting some elements (evapotranspiration and stream groundwater interaction), an aggregated water budget for the basin is as follows

| | | |
|---|---|---|
| Rainfall recharge | = | 4 050 ML/yr |
| Lateral inflow | = | 4 040 ML/yr |
| Flow across fault | = | 540 ML/yr |
| TOTAL | = | 8 630 ML/yr |
| Discharge to irrigation | = | 7 380 ML/yr |
| Discharge to sea | = | 2 880 ML/yr |
| TOTAL | = | 10 260 ML/yr |

From the above figures, total outflows are approximately 10 300 ML/yr, and total inflows are approximately 8 600 ML/yr the change in storage, which equals inflow minus outflow provides a deficit of 1 700 ML/yr.

Change in storage = 8 600 – 10 300 = -1 700 ML/yr

The aggregated water budget calculation shows a significant discrepancy between inflow and outflow, which is consistent with the declining groundwater levels observed in the monitoring wells.

Sub-division of the water budget by aquifer shows that inflow currently exceeds outflow only in the basement aquifer. Both the Maslin Sands and Port Willunga Formation aquifers show a deficit, principally as a result of discharge to wells.

**Basement Aquifer**

| | | |
|---|---|---|
| Rainfall recharge | = | 2 100 ML/yr |
| Lateral inflow | = | not applicable |
| Flow across fault | = | not applicable |
| TOTAL | = | 2 100 ML/yr |
| Discharge to irrigation | = | 1 180 ML/yr |
| Discharge to sea | = | unknown |
| TOTAL | = | 1 180 ML/yr |

For the basement aquifer where total inflow is equal to 2 100 ML/yr and total outflow is equal to 1 180 ML/year, the change in storage is equal to 920 ML/yr.

**Maslin Sands Aquifer**

| | | |
|---|---|---|
| Rainfall recharge | = | 900 ML/yr |
| Lateral inflow | = | 960 ML/yr |
| Flow across fault | = | 100 ML/yr |
| TOTAL | = | 1 960 ML/yr |
| Discharge to irrigation | = | 1 480 ML/yr |
| Discharge to sea | = | 1 060 ML/yr |
| TOTAL | = | 2 540 ML/yr |

For the Maslin Sands, where total inflow is equal to 1 960 ML/yr and total discharge is equal to 2 540 ML/year, the change in storage produces a deficit of 580 ML/yr.

**Port Willunga Formation Aquifer**

| | | |
|---|---|---|
| Rainfall recharge | = | 1 050 ML/yr |
| Lateral inflow | = | 3 080 ML/yr |
| Flow across fault | = | 440 ML/yr |
| TOTAL | = | 4 570 ML/yr |
| Discharge to irrigation | = | 4 720 ML/yr |
| Discharge to sea | = | 1 820 ML/yr |
| TOTAL | = | 6 540 ML/yr |

For the Port Willunga Formation, where total inflow is equal to 4 570 ML/year and total discharge is equal to 6 540 ML/yr, the change in storage produces a deficit of 1 970 ML/yr.

The water budget as presented in this report does not take into account industrial or stock and domestic use. Industrial use, coupled with stock and domestic use, will need to be quantified in order to allow an accurate apportionment of the available water resource. Because there are some elements of the water balance equation that still need to be qualified, the information presented provides an indicative assessment of the available groundwater resources based on the latest information.

## SUSTAINABLE YIELD

Previous estimates of the sustainable yield for the basin were based on the metered extractions of 1992-93, although these records only spanned the last part of the irrigation season. In the absence of any other data, the metered figures for 1992-93, coupled with the results from soil moisture monitoring were used to derive a sustainable yield for the basin of some 7 600 ML/yr and it is a figure that is still widely used today. This figure equates to a volumetric allocation of 180 mm. It should be noted that the current average annual usage is 7 380 ML, slightly less than the previous estimate of the sustainable yield.

Previous reviews of the sustainable yield for the Willunga Basin (Harris, 1994, Watkins, 1995) have all concluded that the current level of usage is marginally above the long term sustainable yield of the basin. These reviews have also concluded that any increase in withdrawal would cause an increase in the rates of water level decline in the aquifers. The previous two years of monitoring data have confirmed these conclusions.

Under the current extraction regime groundwater levels are still declining and in some localities water quality is deteriorating; therefore, it is considered that the figure of 7 600 ML/yr was an overestimate of the sustainable yield for the basin. This conclusion is supported by the calculation of the water budget for the basin which shows that discharge exceeds recharge by some 1 700 ML/yr.

One definition of the sustainable yield of a resource is:

*"the amount of naturally occurring groundwater that can be withdrawn from an aquifer on a continual basis economically, without impairing the native groundwater quality, without exceeding the natural recharge rate or creating an undesirable effect such as environmental damage"* (Fetter, 1988)

Based on the above definition and the indicative water budget as determined in the preceding section, it is apparent that the natural recharge rate to the basin is being exceeded. This will ultimately lead to a degradation of the native groundwater quality by saline intrusion, either from surrounding poorer quality groundwater or the sea. Evidence of degradation is already apparent in the Blewitt Springs area (Fig. 18) where groundwater quality has changed from <1 500 mg/L to >2 000 mg/L within the past eight years. These salinity trends suggest that ultimately the groundwater will be unsuitable for sustained irrigation.

Both the Maslin Sands and Port Willunga Formation aquifers show a deficit, principally as a result of discharge to wells. From this evaluation of the water budget, it is apparent that lateral inflow into the basin is the dominant form of accessions to the aquifers in the Willunga Basin. With the trend towards completing wells in the basement aquifer there is the possibility that some of the lateral inflow into the sedimentary aquifers is being redirected as discharge to wells. This will inevitably lead to a reduction in the volumes of water being transmitted between the surrounding basement rocks and the basin aquifers, further exacerbating the declines in groundwater levels within the Maslin Sands and Port Willunga Formation aquifers.

# MANAGEMENT OPTIONS

One element of the water budget over which some control can be exerted to balance the mismatch between inflow and outflow is the volume of groundwater extracted from the aquifers for irrigation. From the water budget calculations, the deficit is shown to be ~1 700 ML/year. If this figure is subtracted from the mean annual use by irrigators (7 380 ML/yr) the sustainable yield for the basin is determined to be approximately 5 700 ML/yr. In order to achieve this, it would require approximately a 20% reduction in the volumes currently extracted by irrigators.

It is probable that a 20% reduction in application rates may not provide some irrigators in the area with sufficient water to meet their demands, therefore options need to be examined on how best to manage the available groundwater and conjunctively use alternative sources of water that may be available.

A draft integrated water resource strategy for the Willunga Basin (Creswell, 1994) has identified several potential supplementary irrigation water sources. These include natural stream flows, urban stormwater and treated effluent. The potential exists to supplement the existing groundwater resource by artificially recharging the aquifers with water from these alternative sources. If the economics of establishing aquifer storage and recovery (ASR) are favourable, it has the potential to increase the volume of water available for irrigation or to slow the downward trends in water levels at the current groundwater extraction rates.

The draft water resource strategy for the Willunga Basin identified approximately 4 500 ML/yr discharges from Peddler Creek to the sea. The actual volumes that could be harvested from this source need to be quantified to allow sufficient flows to meet environmental demand. Other factors that need to be addressed are issues of riparian rights of downstream users, and property rights. However, if half of this flow is available for harvesting and injected into the aquifer this could provide a balance between current inflows and outflows from the aquifer system.

Creswell also identified that Christies Beach Wastewater Treatment Plant (WWTP) currently discharges some 8 800 ML/yr of treated effluent to the sea which may increase to 14 700 ML/yr by 2020. A further 3 100 ML of treated effluent may be available from smaller towns throughout the Southern Vales area. In addition, urban stormwater runoff is between 2 700 and 4 300 ML/yr, which may provide a further source of water that could be harvested for ASR.

Currently ASR in the Willunga Basin is confined to three trial sites, which harvest a small amount of the excess catchment runoff during winter and inject it into the aquifer via existing bores for reuse in the summer. However, harvesting stream flows for ASR may only benefit a small number of irrigators ie those who are fortunate enough to have surface water within close proximity to their irrigation demand. Alternatives are still needed to satisfy the demands of the majority of irrigators.

Some of these alternatives may include

- transferring surplus water from the Mt Bold Reservoir in winter and storing it in the aquifers via ASR for servicing the upper parts of the basin eg Blewitt Springs;

- surplus water could be transferred into the lower parts of the basin from the Myponga Reservoir to supplement irrigation demand;

- some effluent reuse is already being planned for the Basin from the Christies Beach WWTP. This could be expanded further to provide some 3 000 to 8 000 ML/yr of “new” water in conjunction with ASR, and injected along the coast, would prevent seawater intrusion and provide an increase in pressure across the aquifer.

- operating the basin with a sustained overdraft for a period of time to allow some of the pipeline or ASR schemes to become established.

This last strategy would require considerable planning and consultation with the community.

## CONCLUSIONS AND RECOMMENDATIONS

In summary, the groundwater situation in the Willunga Basin gives cause for concern. Average groundwater extraction (7 380 ML) over the past four years, as shown by the monitoring data is causing groundwater levels to decline and salinity levels in some parts of the basin to increase (eg. Blewitt Springs).

Along the margins of the basin salinity is increasing at a rate that will significantly impact on the beneficial use of the groundwater for irrigation within the next ten years.

Declining groundwater levels will

- impact on the costs required to pump the same volume of water as wells will need to be deepened with increased pumping costs;

- lower the hydraulic heads in the aquifer resulting in intrusion of saline water from surrounding areas and the sea and consequent increases in salinity within the aquifer;

- cause a deterioration in water quality that will impact on crop quality and yield.

The water budget presented in this report represents an indicative assessment based on the latest knowledge and information about the basin, and demonstrates that outflow currently exceeds inflow.

The hydrogeology of the basin is complex and the interactions between surface water and groundwater and between aquifers is yet to be fully investigated. These mechanisms need to be quantified to enable further refinements to the water budget.

Based on the information presented in this report, it is recommended that a volumetric allocation be set at a limit that ensures extractions from the aquifers do not increase, and that the long-term sustainable yield of the basin is not exceeded.

The proposed timeframe of three to five years would allow the Catchment Water Management Board to

- develop water allocation plans for the Southern Vales Prescribed Wells Area (including the adjoining moratorium area) and;
- assess options for enhancing the natural recharge by incorporating ASR as a management tool to sustain the long-term yield from the basin.

It is also recommended that a work program comprising the following aspects be undertaken

- further hydrochemical sampling of major and minor ions and natural isotopes to refine estimates of rainfall recharge and identify surface water and ground water interaction processes;

- review the existing monitoring networks and expand them in basement areas;

- construct piezometers along the coast to determine the location of the fresh/salt water interface in the Port Willunga Formation and Maslin Sands aquifers;

- further development of a computer numerical model to evaluate and quantify groundwater processes and to assist in managing the resource.

The above activities would be undertaken with a view to presenting

- an evaluation of ASR opportunities (based on the results of the trials currently in progress) by January/February 1999 to facilitate planning of strategies for ASR within the basin and;

- a re-appraisal of the sustainable yield from the basin by December 1999.

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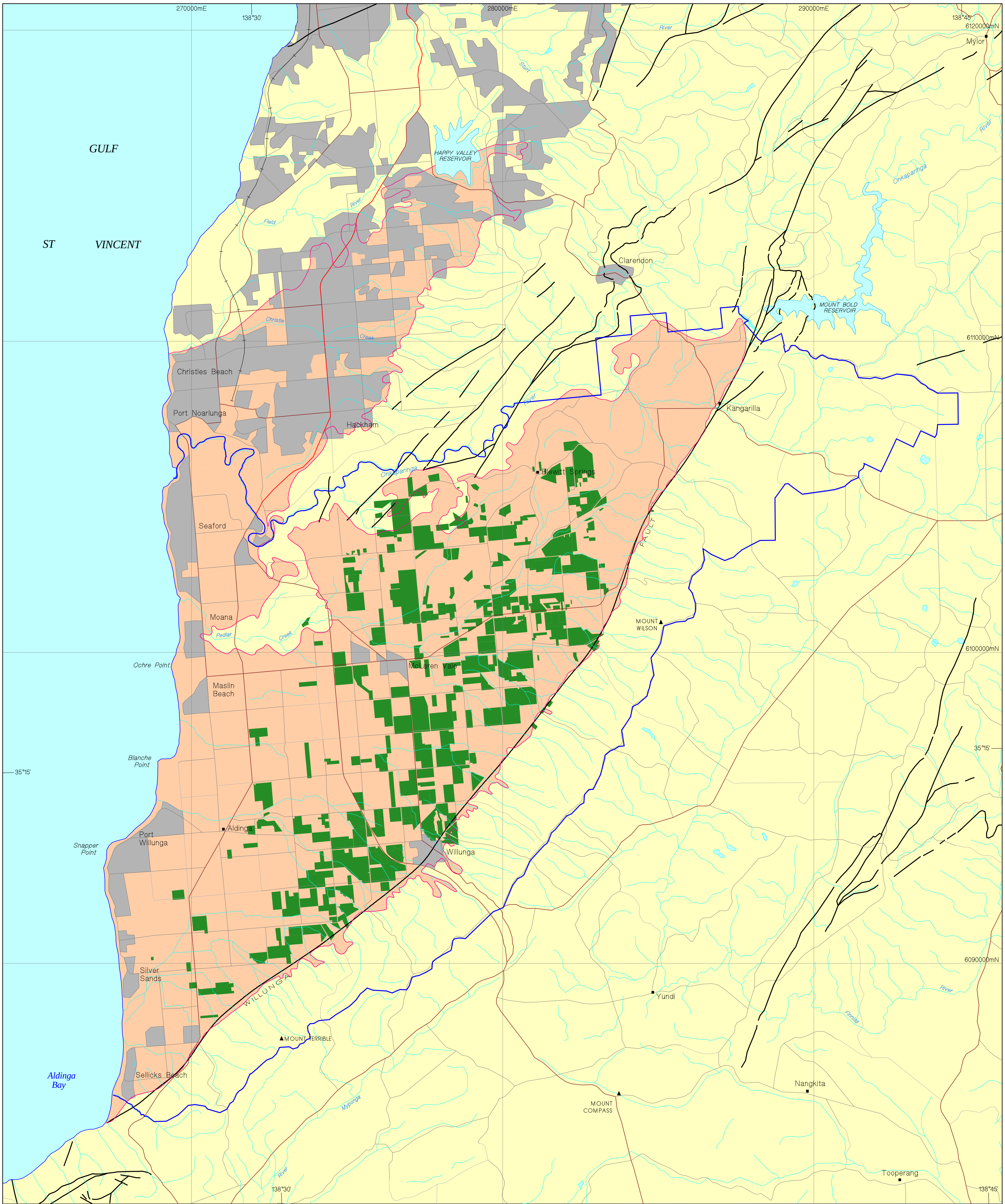



Boundary of Willunga and Noarlunga basins

Boundary of proposed Proclaimed Wells Area

Fault

Irrigated areas

Built up areas

0 1 2 3 4 5

KILOMETRES

Figure 1

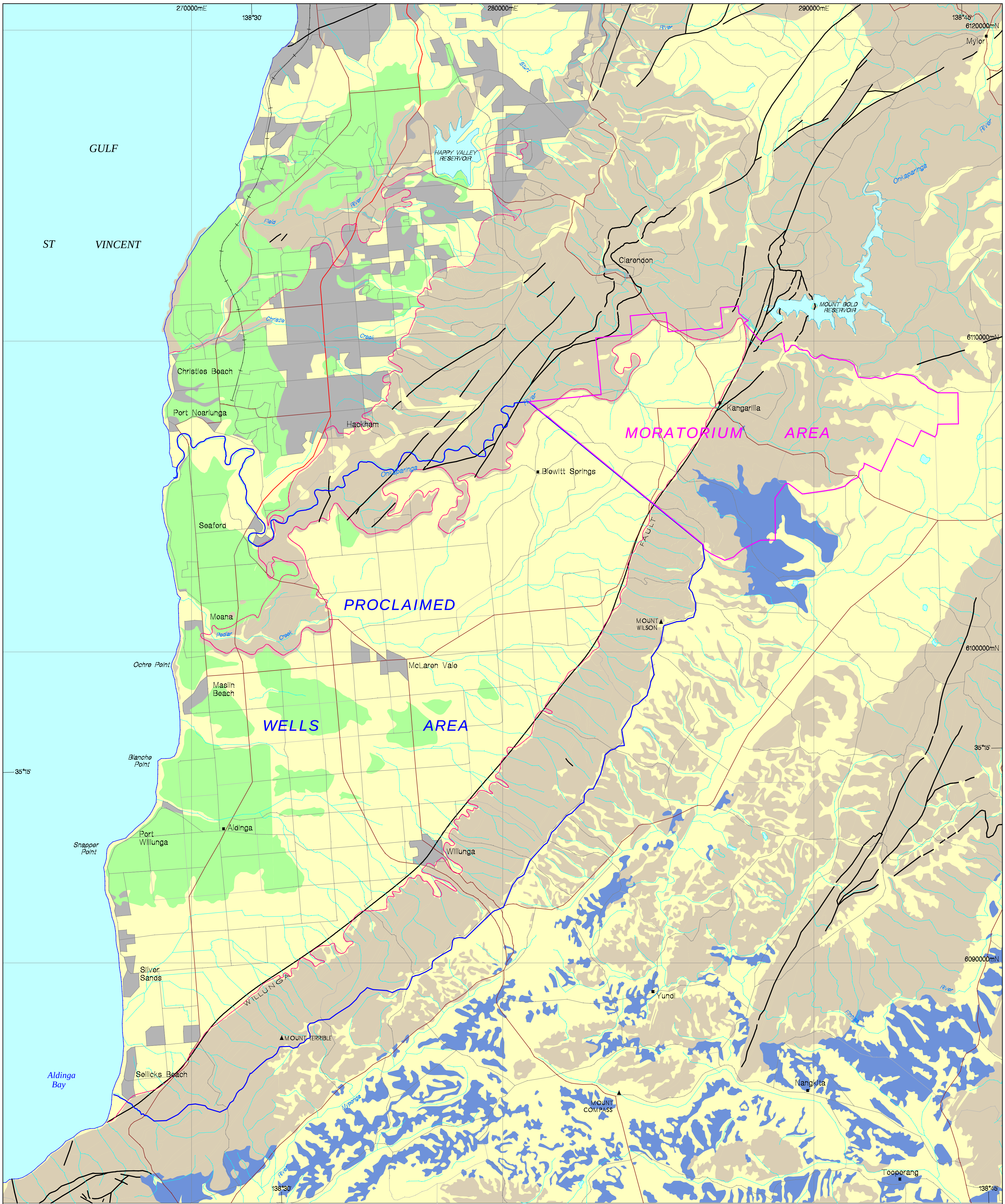
Water Sustainability in the Willunga and Noarlunga Basins

# LOCATION OF STUDY AREA

PRIMARY INDUSTRIES AND RESOURCES SA

QD7/100875PT.DTA

97-0536




Boundary of Willunga and Noarlunga basins

Boundary of proposed Proclaimed Wells Area

Moratorium Area

Quaternary outcrop

Tertiary outcrop

Permain outcrop

Fractured rock outcrop

Fault

0 1 2 3 4 5
KILOMETRES

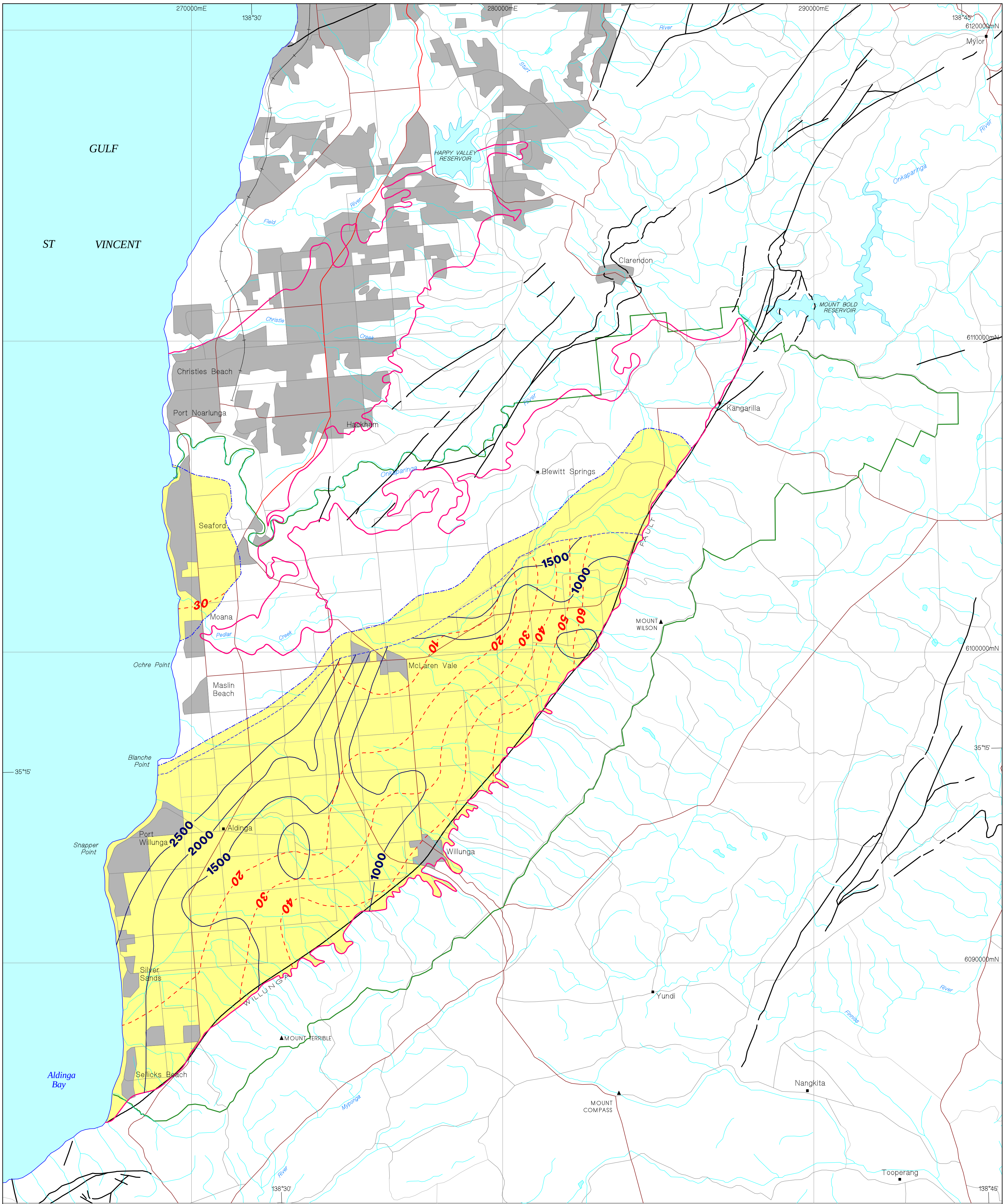
Figure 2
Water Sustainability in the Willunga and Noarlunga Basins

# GEOLOGY OF STUDY AREA

PRIMARY INDUSTRIES AND RESOURCES SA

QD7/100875PT.DTA

97-0539




| | |
|---|---|
| Boundary of Willunga and Noarlunga basins | Margin of water bearing Port Willunga Formation |
| Boundary of proposed Proclaimed Wells Area | Limit of Port Willunga Formation |
| Fault | Potentiometric surface (mADH) |
| | Salinity TDS |

0 1 2 3 4 5
KILOMETRES

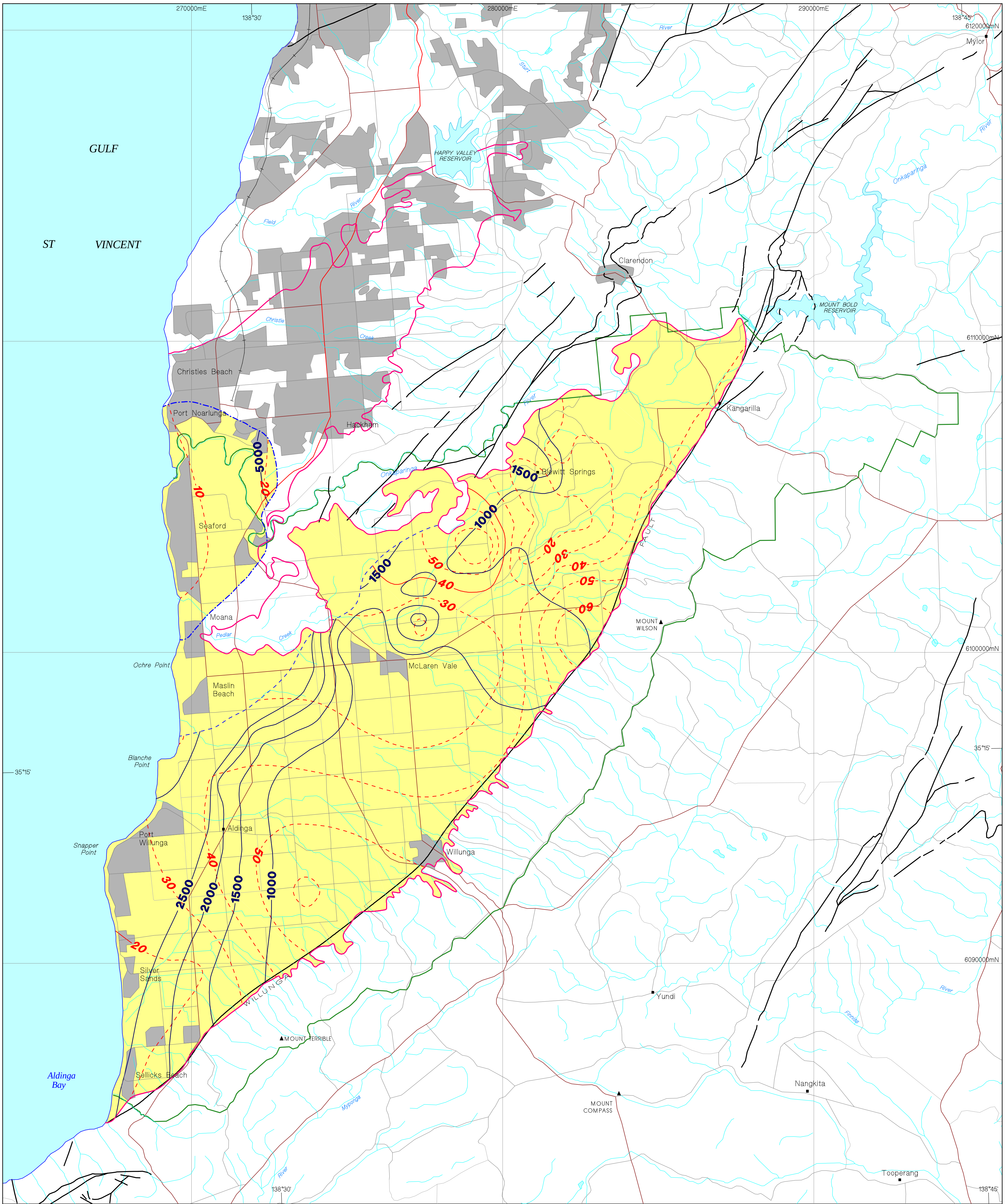
Figure 3
Water Sustainability in the Willunga and Noarlunga Basins

# SALINITY AND POTENTIOMETRIC SURFACE PORT WILLUNGA FORMATION

PRIMARY INDUSTRIES AND RESOURCES SA

QD7/100875PT.DTA

97-0540




0 1 2 3 4 5
KILOMETRES

| | |
|---|---|
| Boundary of Willunga and Noarlunga basins | Margin of water bearing Maslin Sands |
| Boundary of proposed Proclaimed Wells Area | Limit of Maslin Sands |
| Fault | Potentiometric surface (mAHD) 40 |
| | Salinity TDS 2000 |

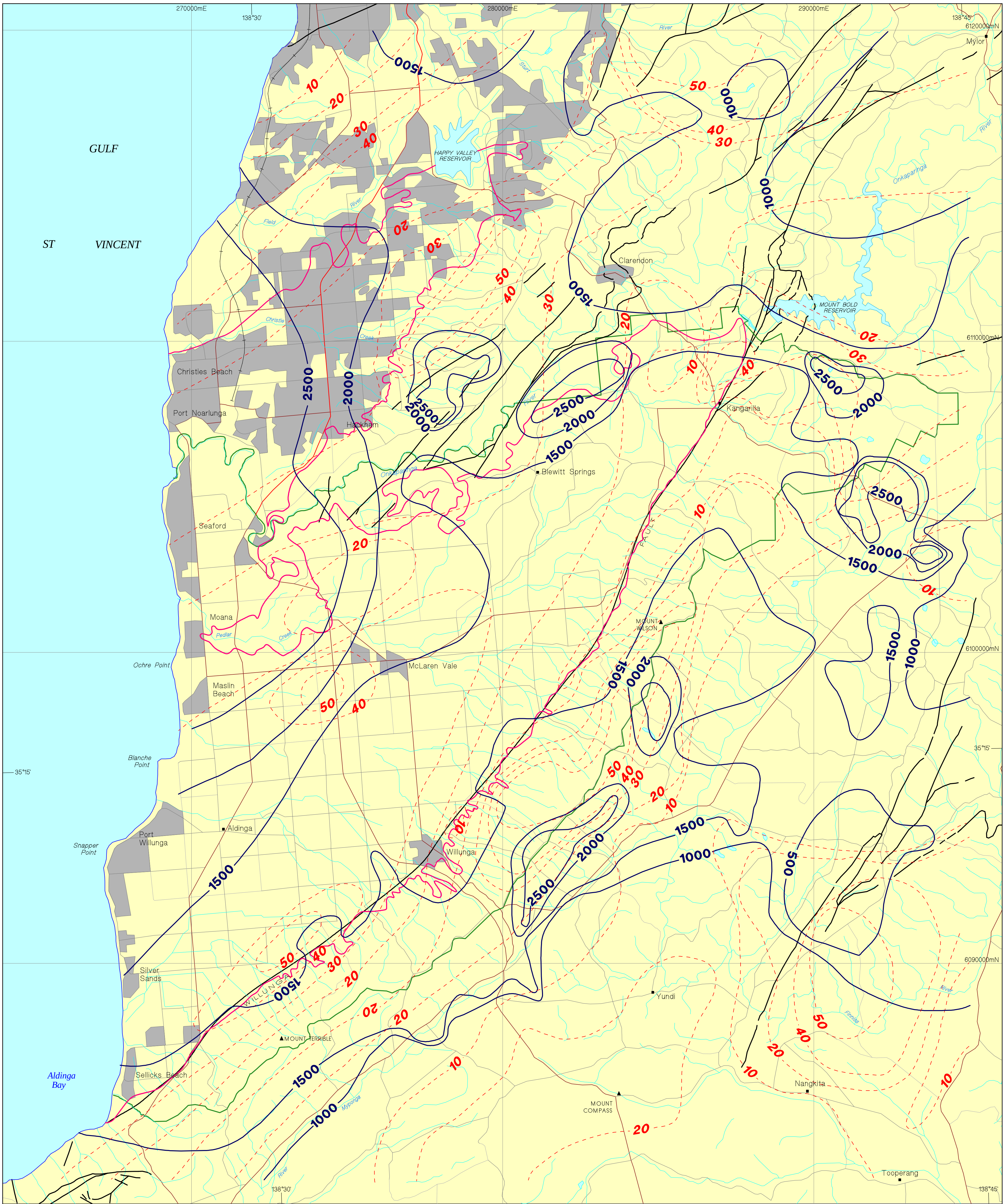
Figure 4
Water Sustainability in the Willunga and Noarlunga Basins

# SALINITY AND POTENTIOMETRIC SURFACE MASLIN SANDS

PRIMARY INDUSTRIES AND RESOURCES SA

QD7/100875PT.DTA

97-0541




Boundary of Willunga and Noarlunga basins

Boundary of proposed Proclaimed Wells Area

Fault

Potentiometric surface (mAHD) 20

Salinity TDS 500

0 1 2 3 4 5

KILOMETRES

Figure 5

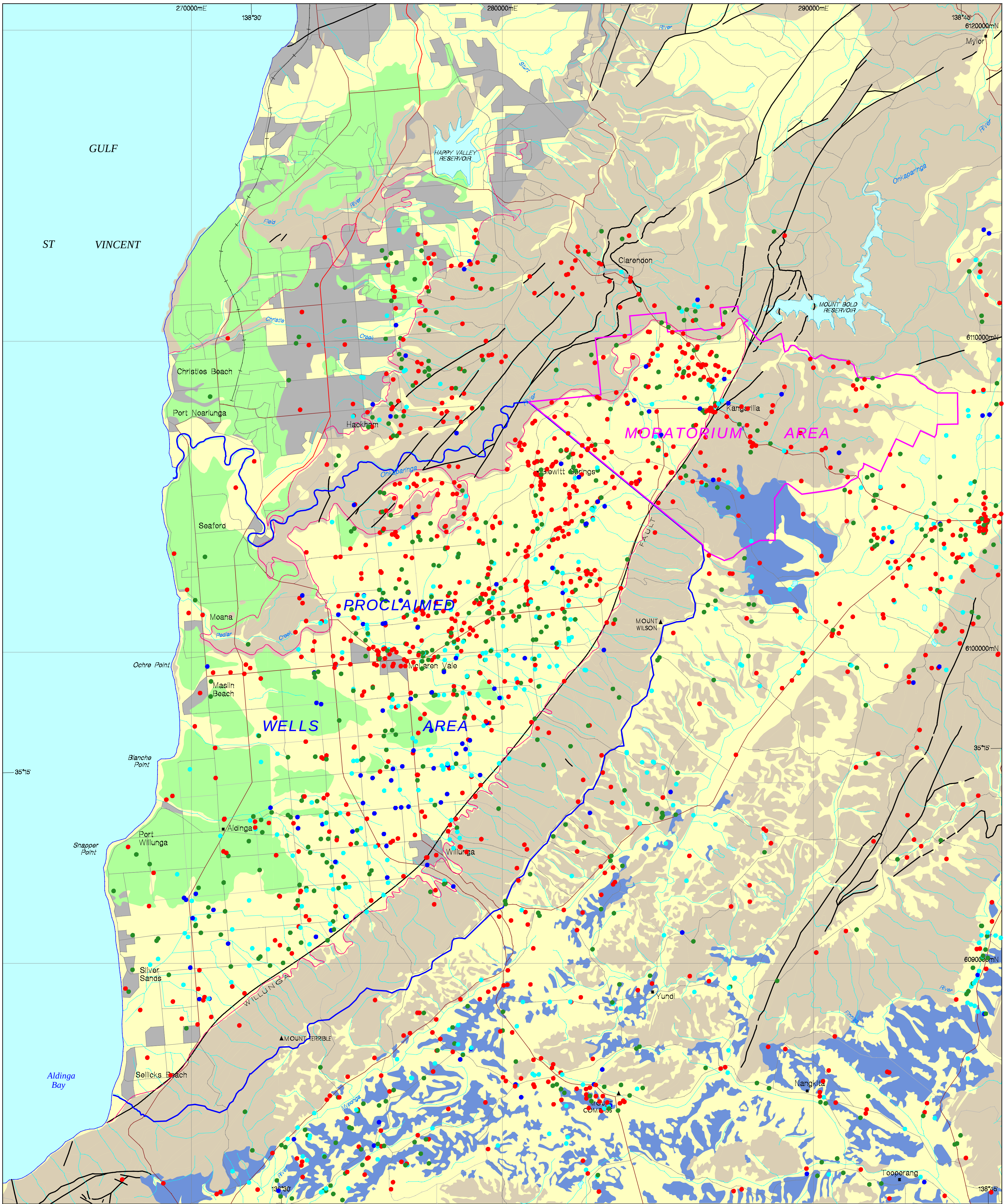
Water Sustainability in the Willunga and Noarlunga Basins

**SALINITY AND POTENTIOMETRIC SURFACE FRACTURED ROCK**

PRIMARY INDUSTRIES AND RESOURCES SA

QD7/100875PT.DTA

97-0542




Boundary of Willunga and Noarlunga basins

Boundary of proposed Proclaimed Wells Area

Moratorium Area

**GEOLOGY**

Quaternary outcrop

Tertiary outcrop

Permain outcrop

Fractured rock outcrop

Fault

**WELL YIELD (L/s)**

Less than 2

2 to 5

5 to 10

Greater than 10

0 1 2 3 4 5
KILOMETRES

PRIMARY INDUSTRIES AND RESOURCES SA

Figure 6

Water Sustainability in the Willunga and Noarlunga Basins

BORE YIELDS IN STUDY AREA

QD7/100875PT.DTA

97-0645

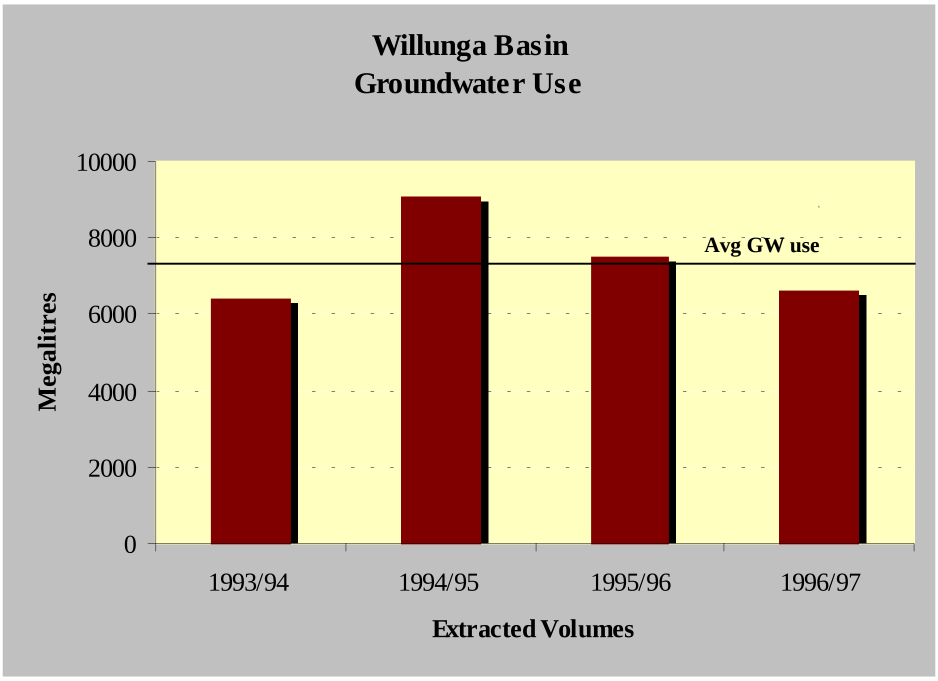



Figure 7. Willunga Basin Total Groundwater Use

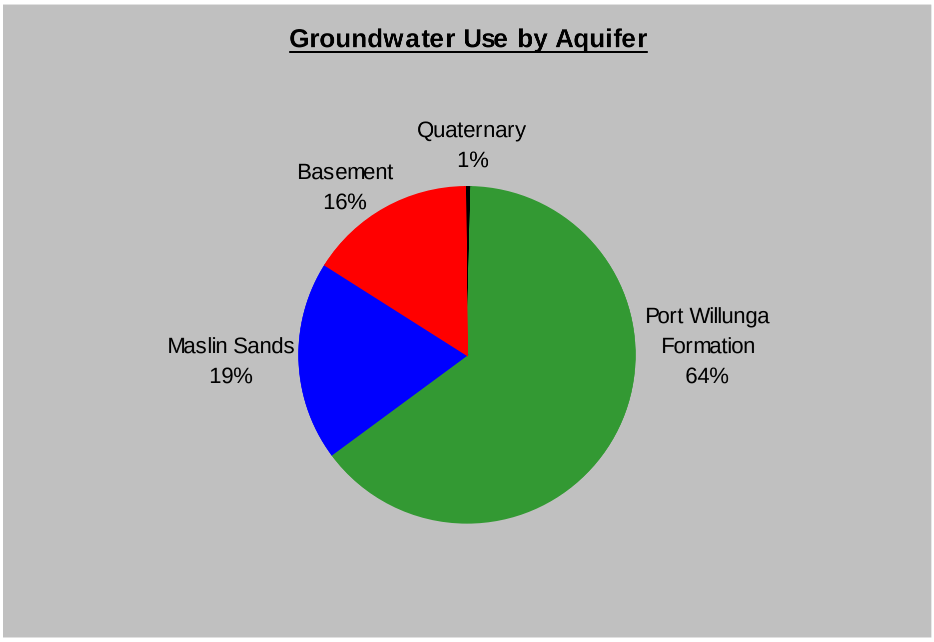
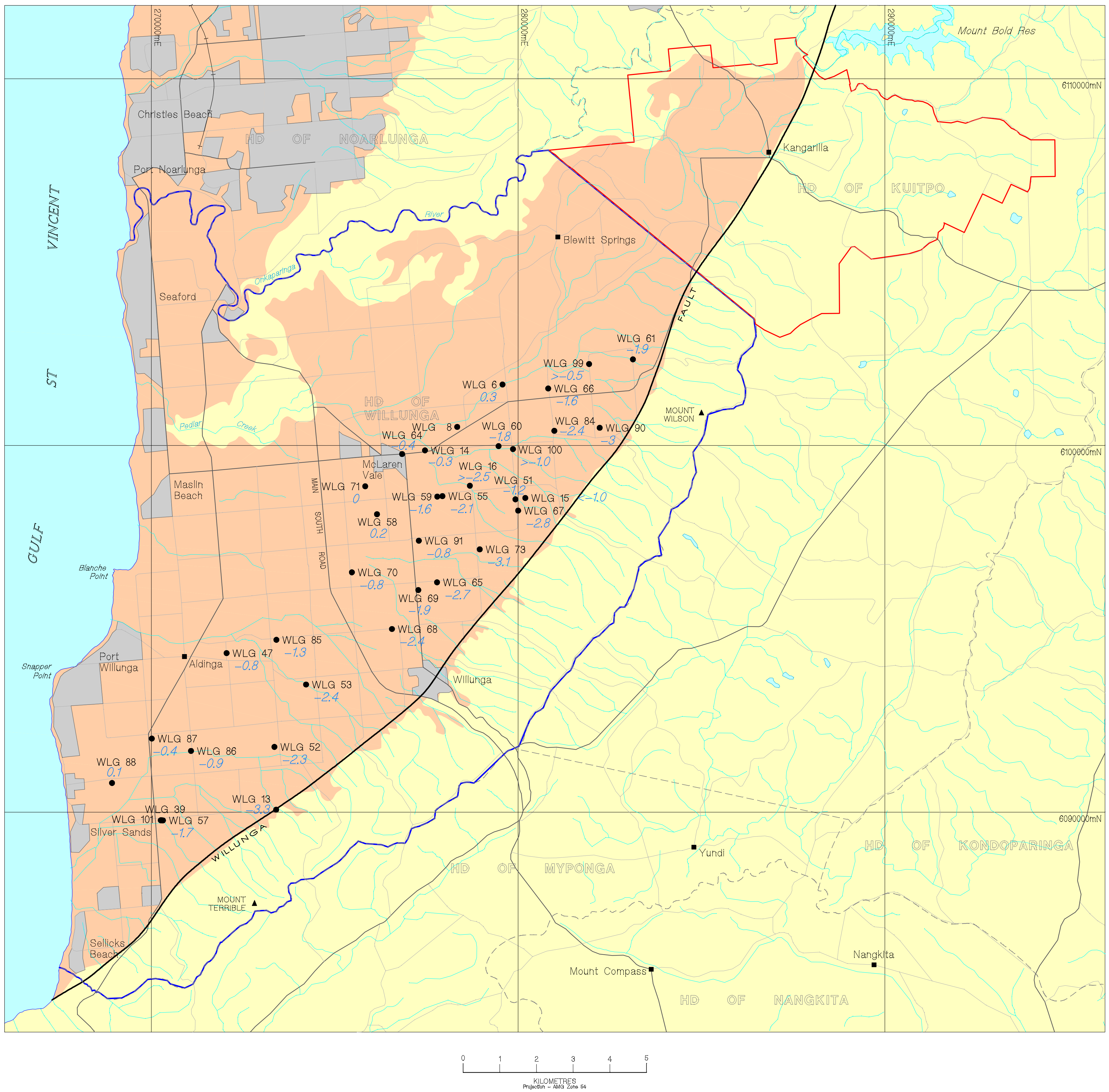



Figure 8. Percentage Volumes Extracted by Aquifer

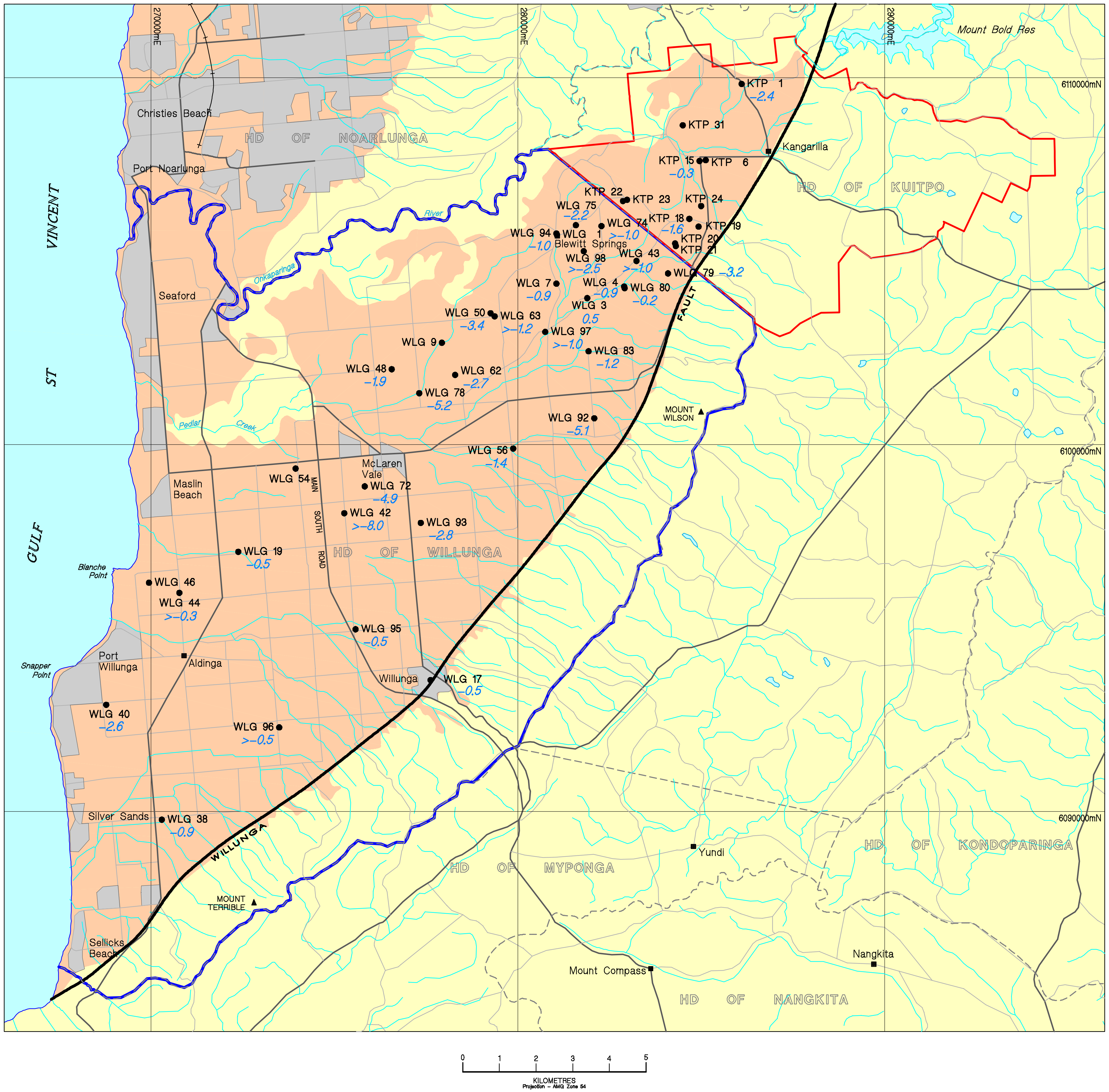


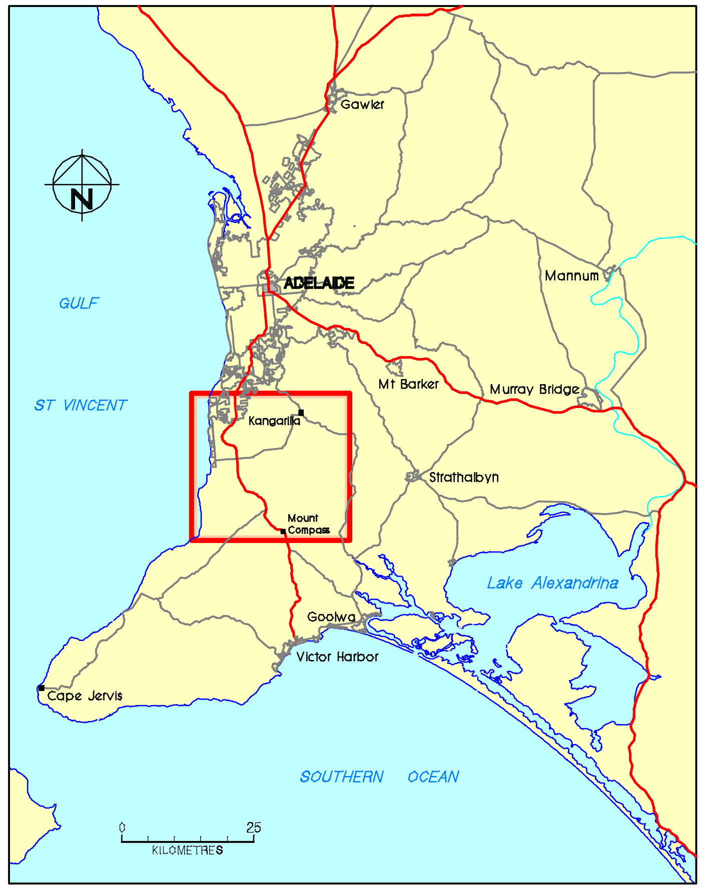


WILLUNGA BASIN GROUNDWATER INVESTIGATION

## Port Willunga Formation Aquifer
## WATER LEVEL CHANGE, 1989-1996

Figure 9




Willunga Basin Proclaimed Wells Area

Moratorium Area

Limit of Basin sediments

Built up area

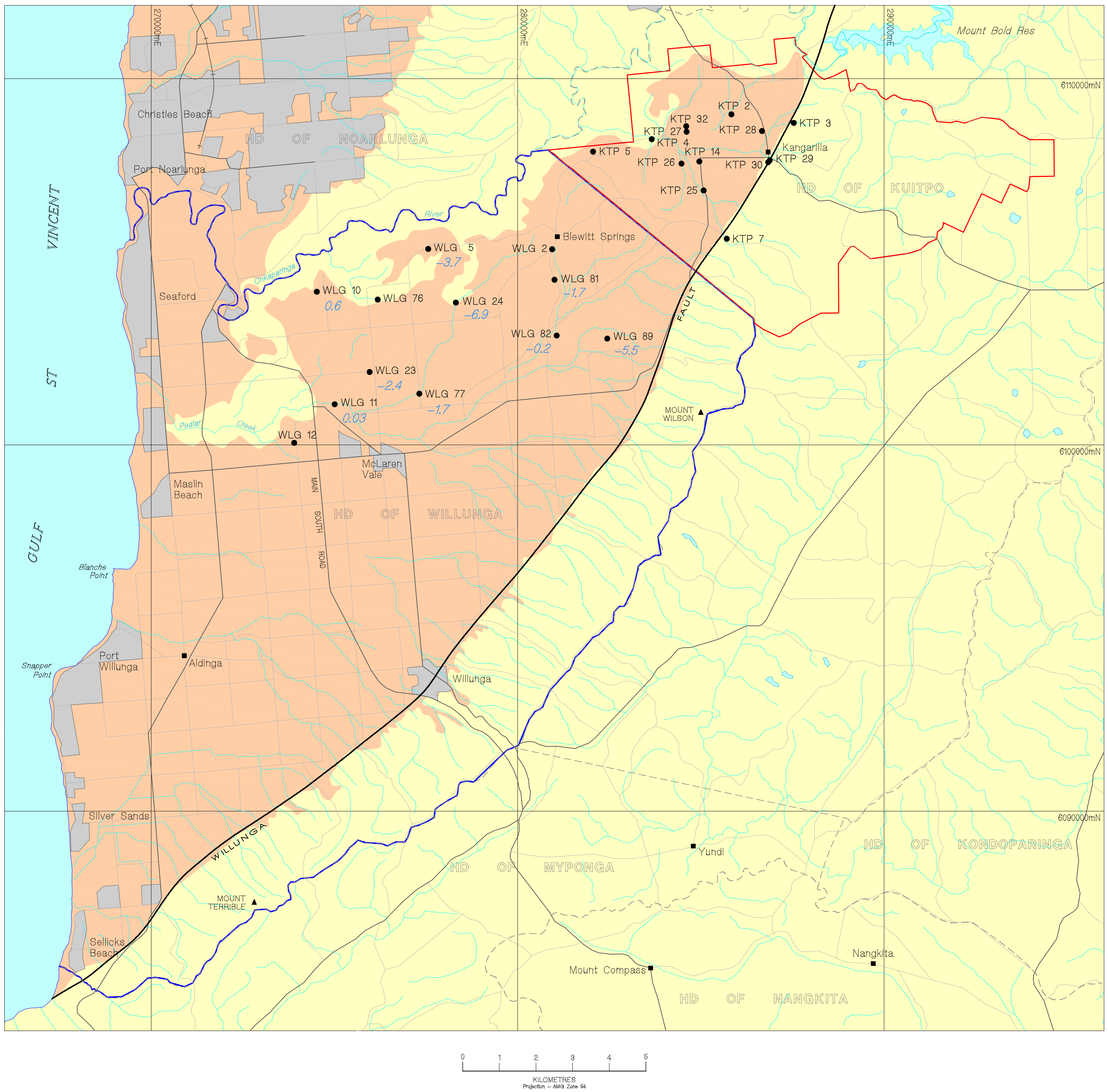
● WLG 93 −2.8 Observation well and number
Water level change in metres

WILLUNGA BASIN GROUNDWATER INVESTIGATION

**Maslin Sands Aquifer**
**WATER LEVEL CHANGE, 1989-1996**

QD6: 100912NW.DTA

97-0650 MESA





WILLUNGA BASIN GROUNDWATER INVESTIGATION

**Basement Aquifer**

**WATER LEVEL CHANGE, 1989-1996**

Figure 11

GD6: 100912NW.DTA

97-0652 MESA

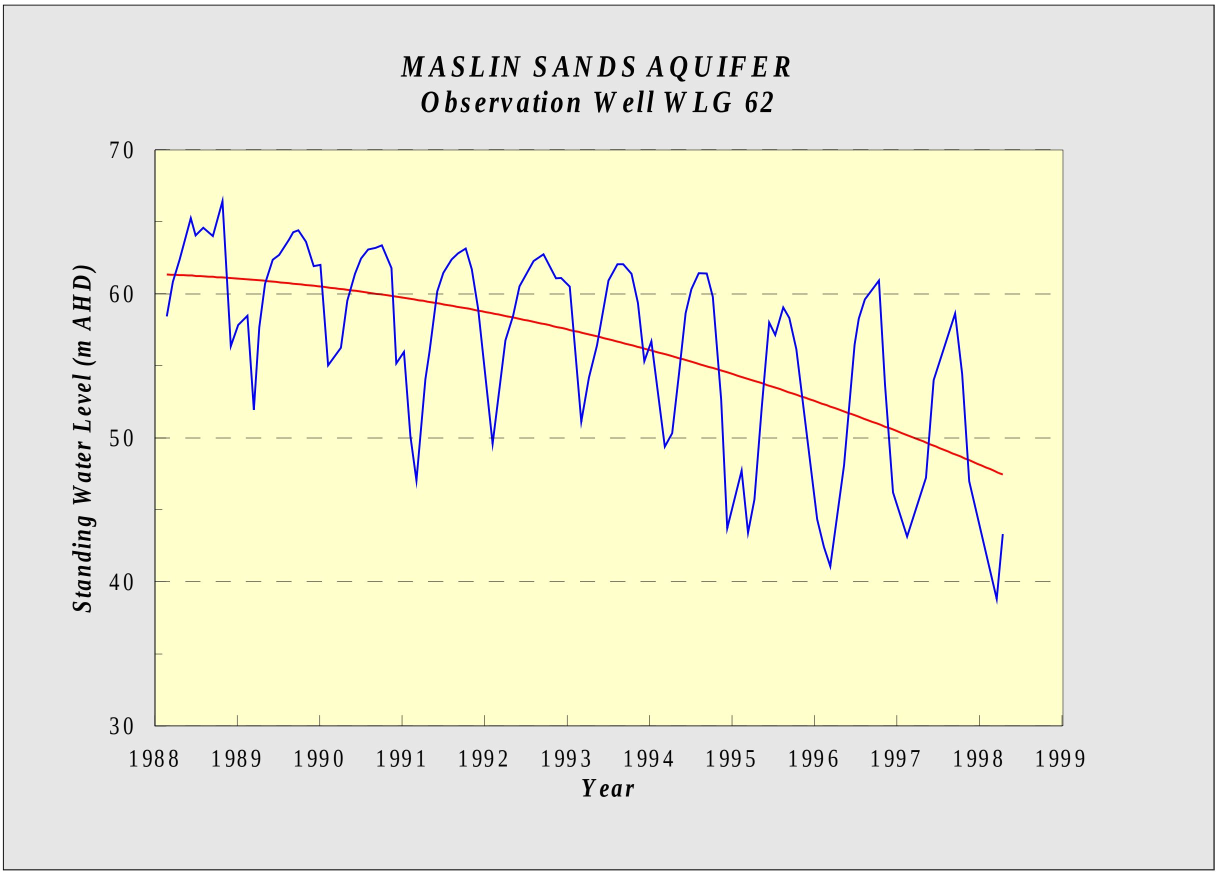



Figure 12. Hydrograph WLG-62 Maslin Sands.

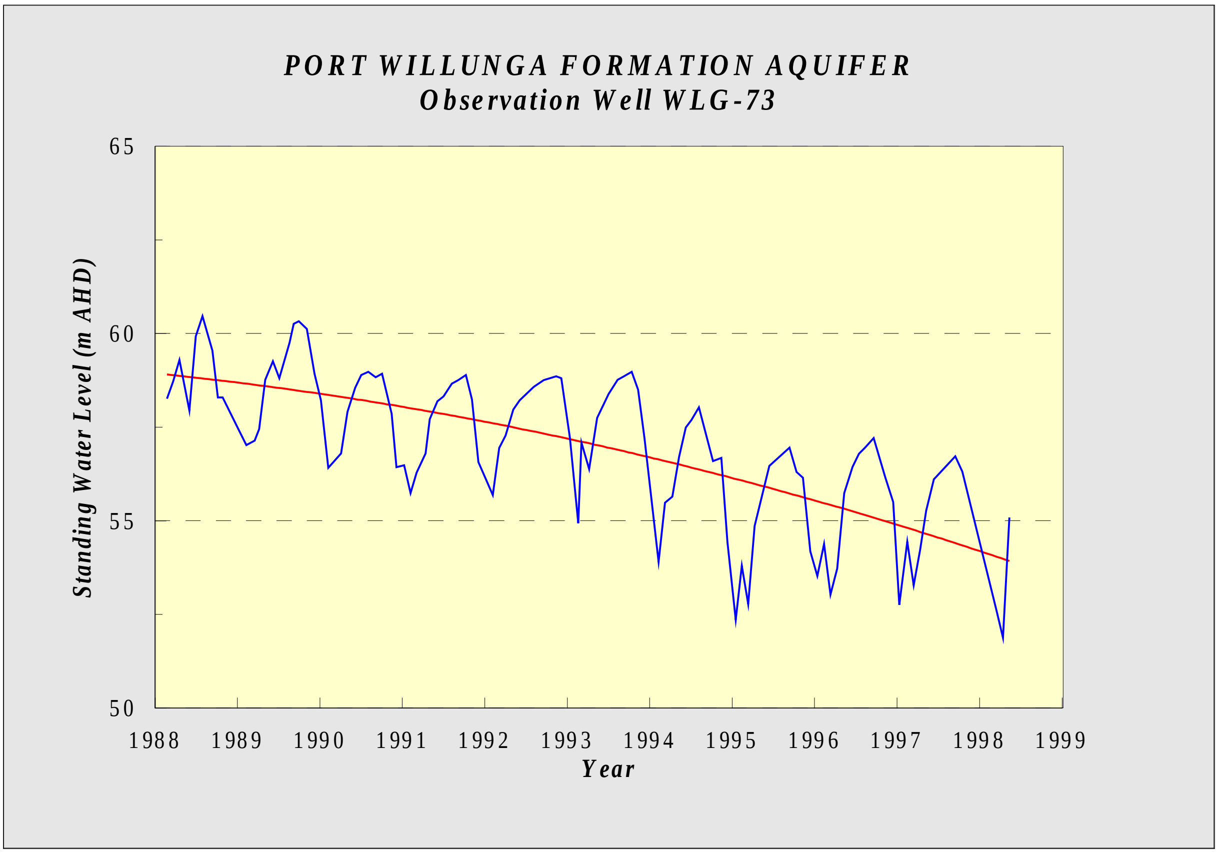



Figure 13. Hydrograph WLG-73 Port Willunga Formation

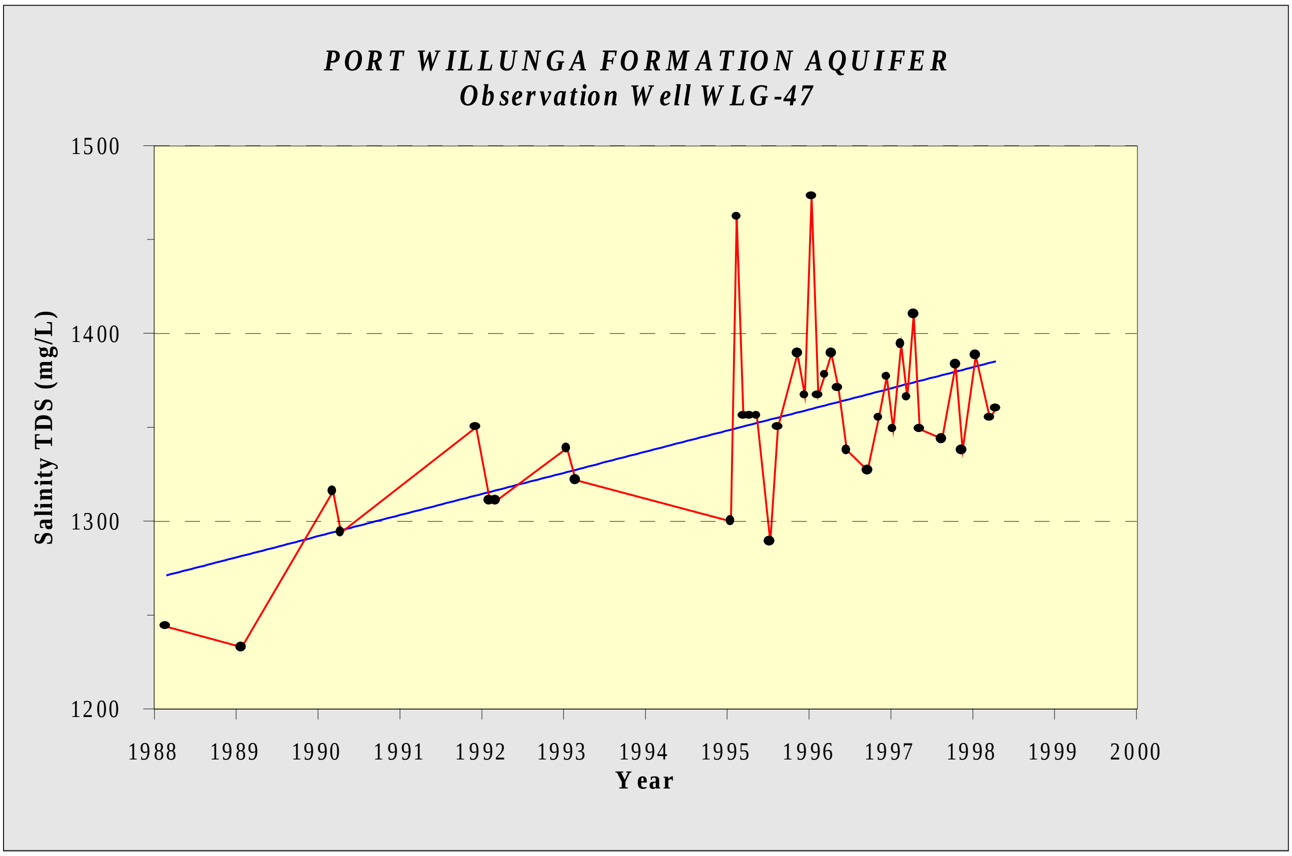



Figure 14. Salinity monitoring record for Observation Well WLG-47

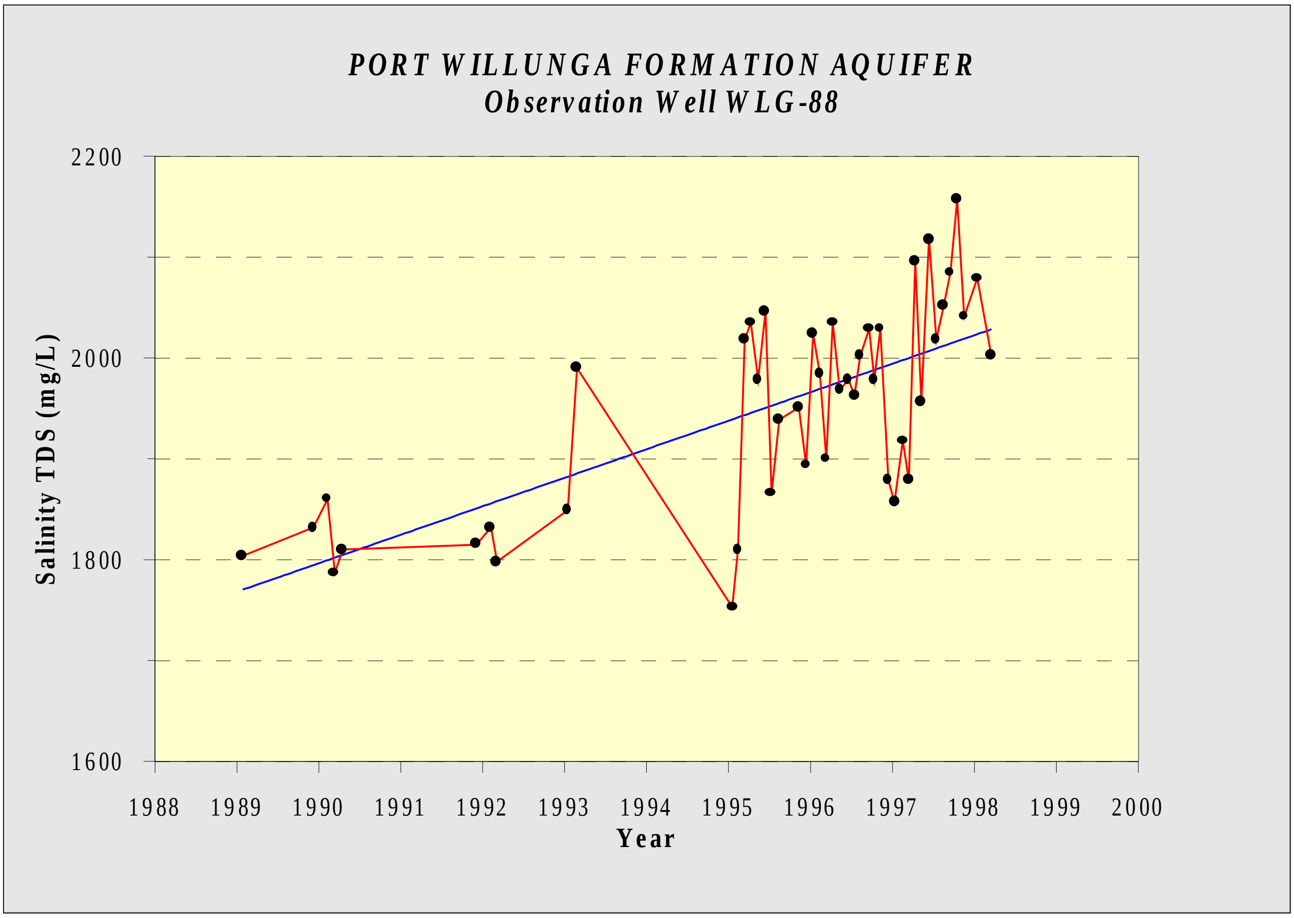



Figure 15. Salinity monitoring record for Observation Well WLG-88

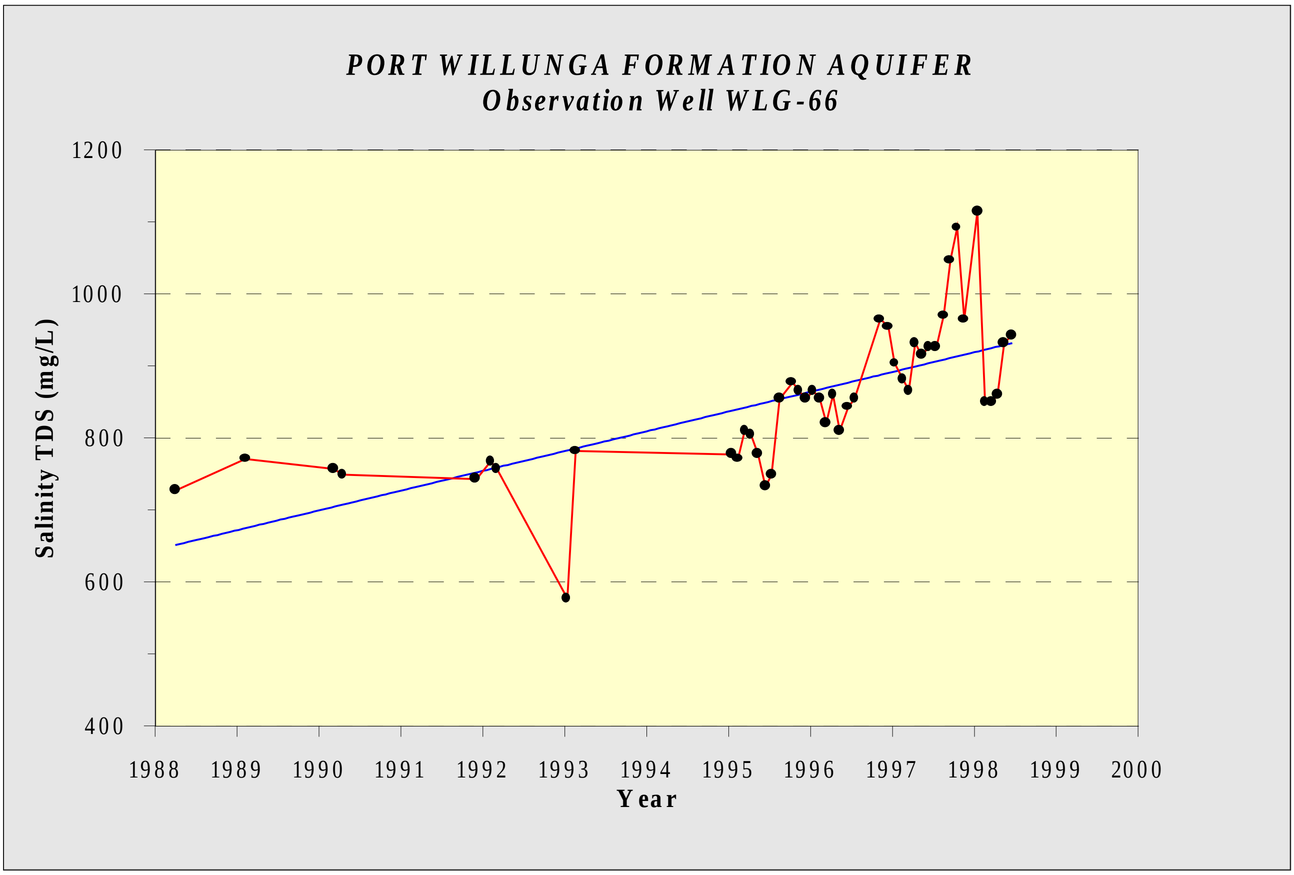



Figure 16. Salinity monitoring record for Observation Well WLG-66

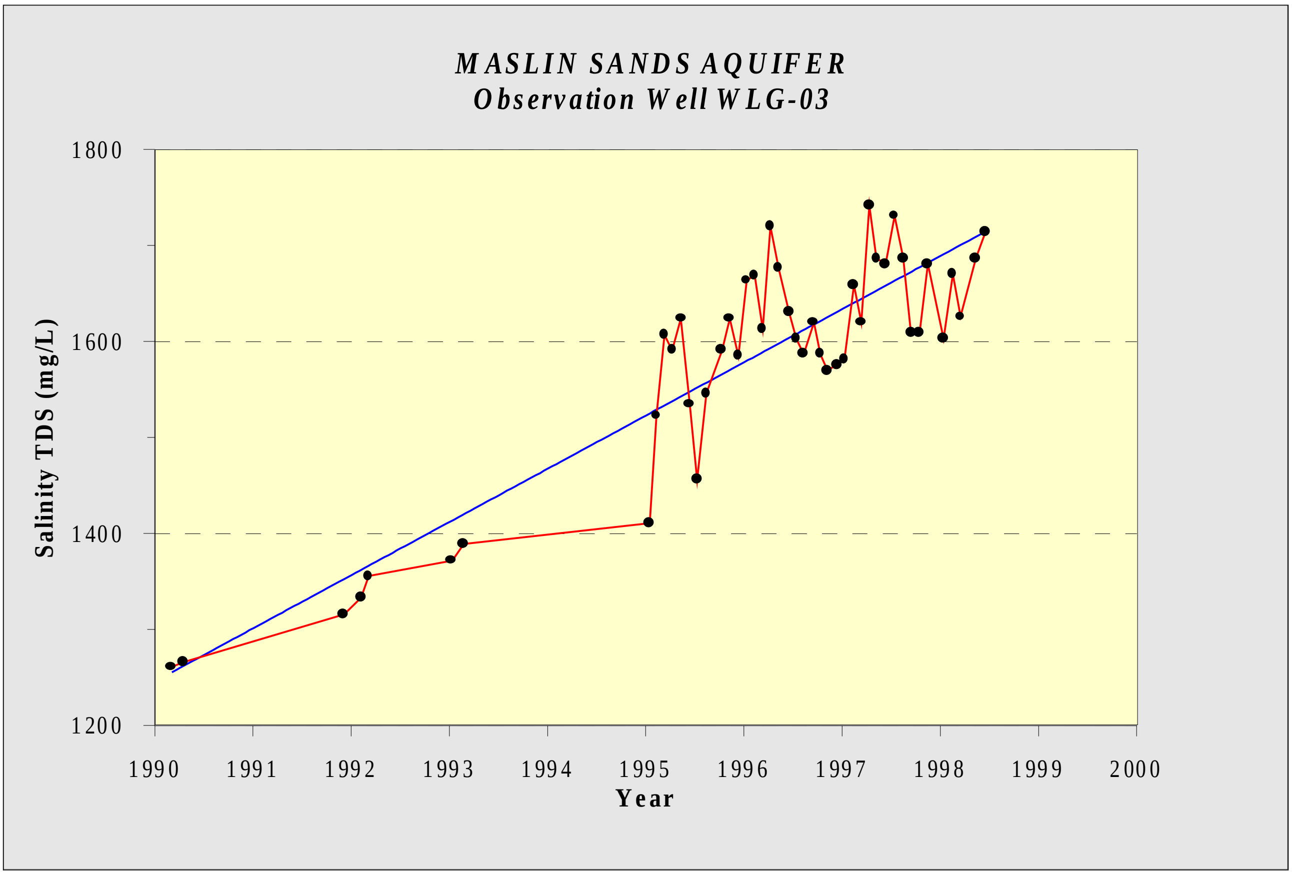



Figure 17. Salinity monitoring record for Observation Well WLG-03

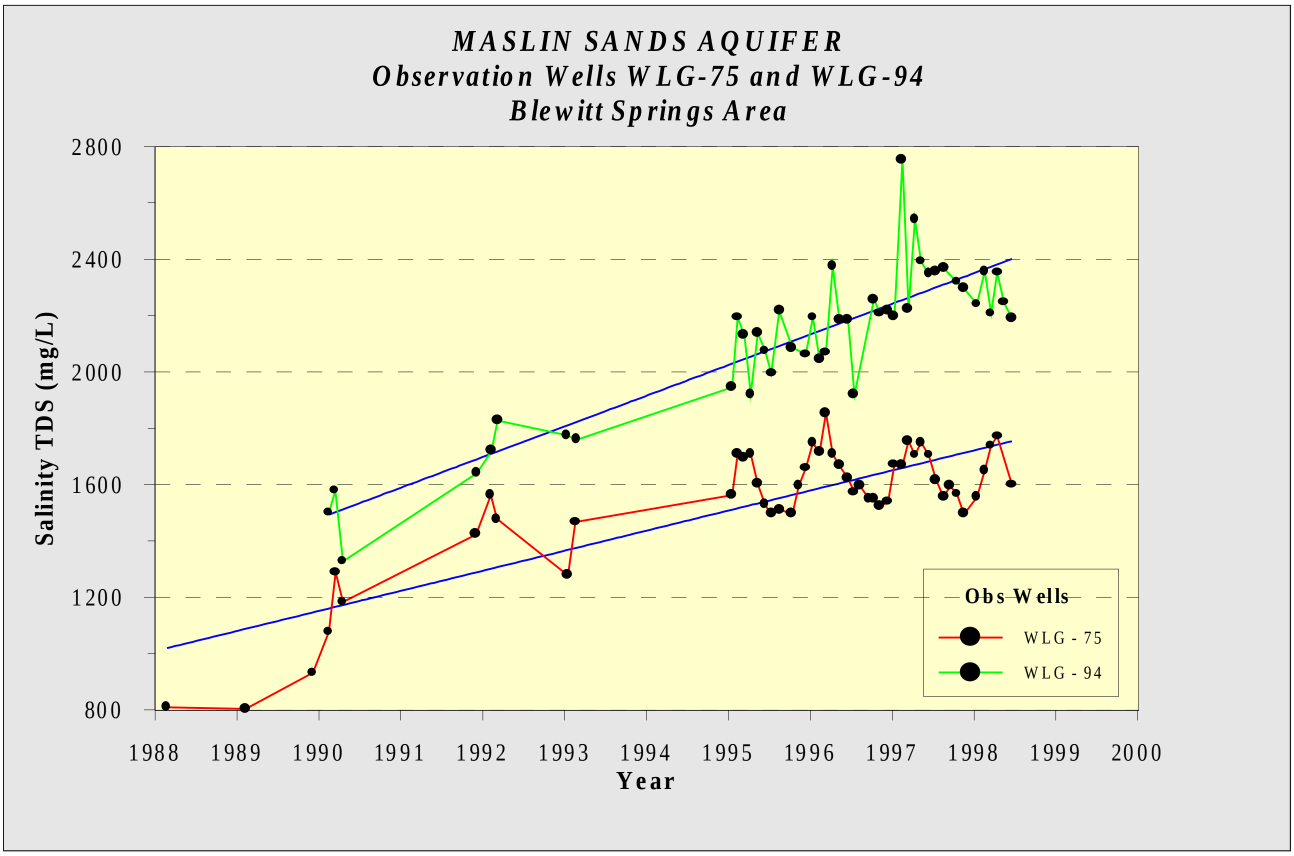



Figure 18. Salinity monitoring record for Observation Well WLG-75 and WLG-94

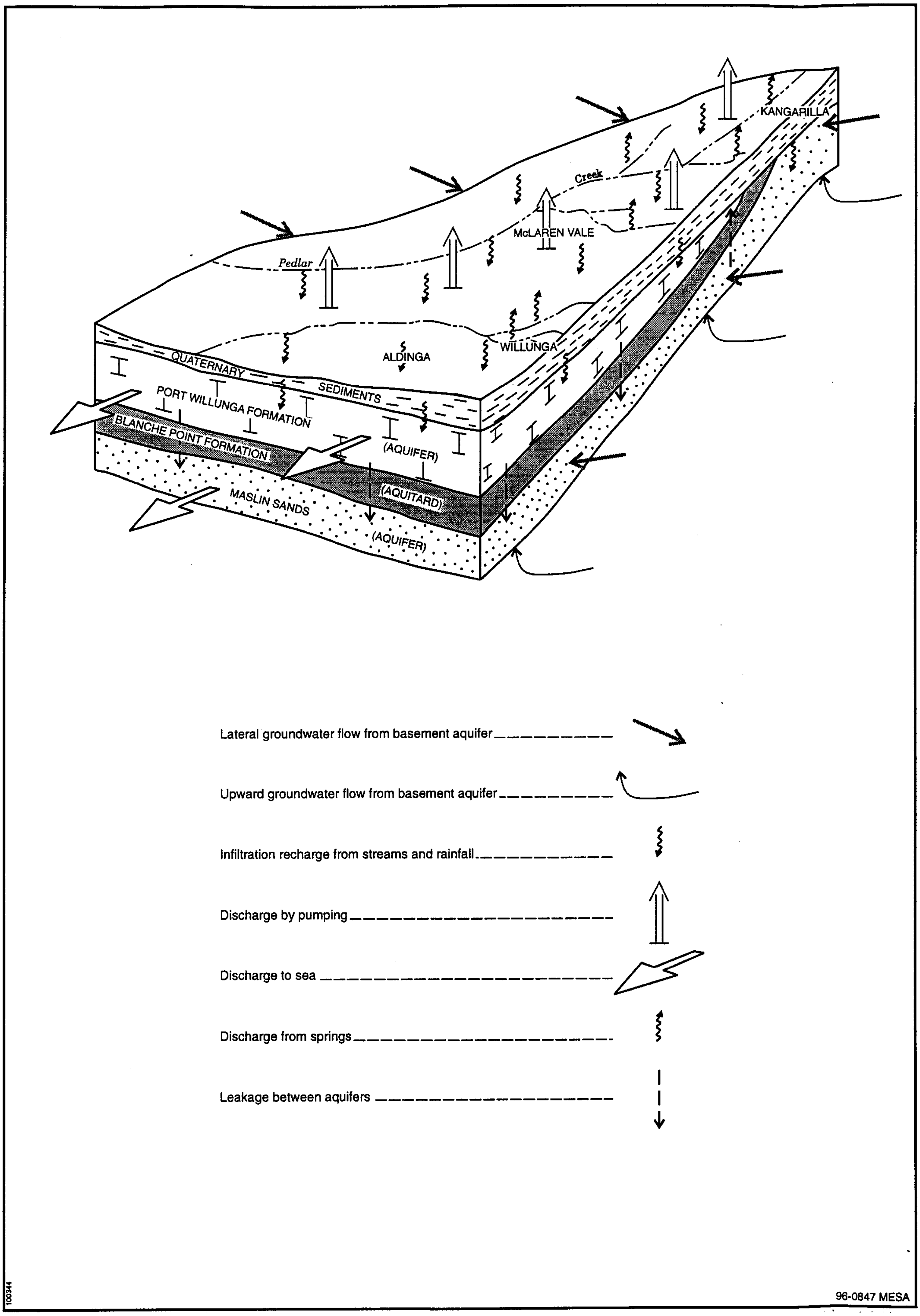



Figure 19. Willunga Basin Conceptual water balance model