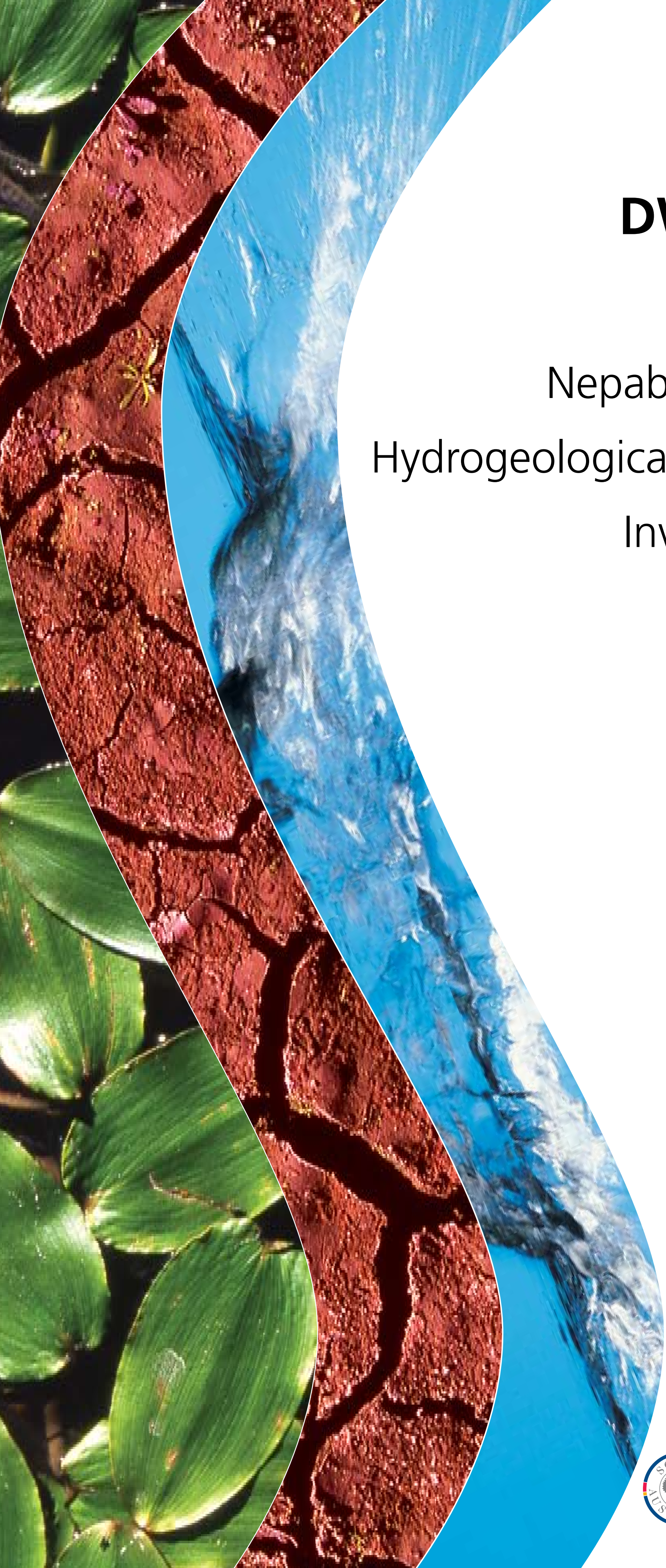

DWLBC REPORT

Nepabunna Community Hydrogeological and Geophysical Investigation Report

2008/24

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

Nepabunna Community Hydrogeological and Geophysical Investigation Report

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

May 2008

Report DWLBC 2008/24

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

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FOREWORD

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

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

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

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

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1. INTRODUCTION

1.1 PURPOSE

The aim of this project was to undertake site and geophysical investigations to target new groundwater supplies for the Aboriginal Community of Nepabunna. Currently the Nepabunna Community relies on two groundwater production wells for its non-potable water. One of these wells is used as the primary groundwater source for the community, the other well is a secondary source due to its limited supply capacity. This situation is a concern to SA Water which is the water supply operator.

1.2 THE COMMUNITY

The community of Nepabunna is located ~500 km north of Adelaide between Lake Frome and Lake Torrens in Northern Flinders Ranges (Fig. 1).

Nepabunna was established during the 1930s in an area with no large supply of permanent water; only a spring fed creek. Water supply has been a significant problem throughout the community's history (Pearce, Willis & Jenkin 2004).

Currently a dual reticulation system operates with groundwater from two production wells providing water for all non-potable uses, with rainwater providing the only potable supply.

Rainfall is highly variable and characterised by periods of drought, with occasional high rainfall events (Pearce, Willis & Jenkin 2004).

1.3 PROJECT BACKGROUND

In May 2006 the Department of Water, Land and Biodiversity Conservation (DWLBC) was commissioned by SA Water to commence investigations (that would precede a drilling program) into the hydrogeology of the Nepabunna area. The investigation included a background desktop study that would assist a geophysical survey to target areas suitable for a groundwater supply.

Logistical issues due to land access caused a delay in the completion of the survey.

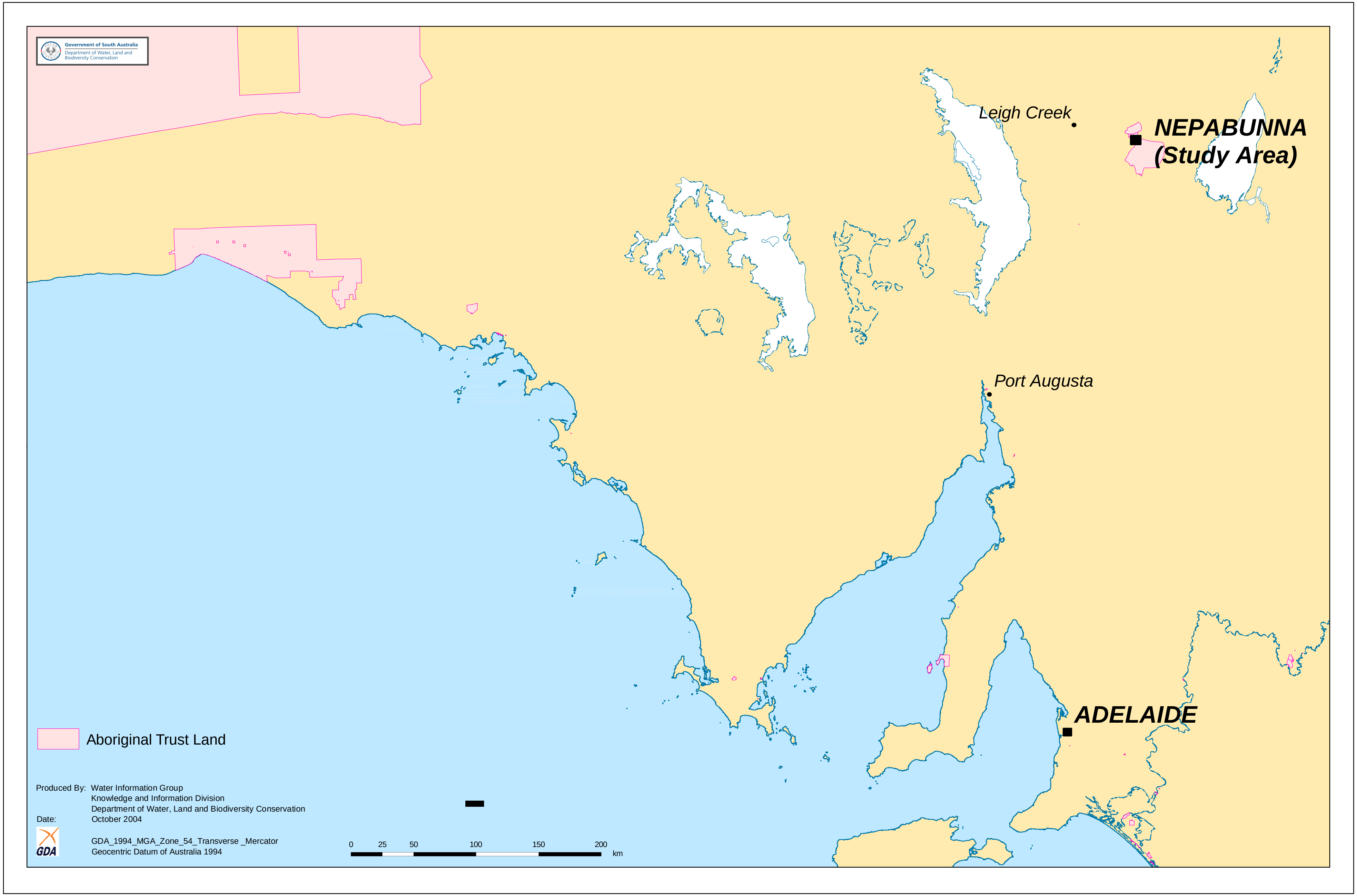


Figure 1. Locality of study area

2. HYDROGEOLOGY

The hydrogeological units of the area are discussed (Table 1) below. The table has been constructed using the published 'Copley' 1:250 000 map sheet (Coats et al. 1973) with the addition of some brief observations made during historical drilling programs.

Table 1. Hydrogeological units of the Nepabunna area

Unit		Lithology	Hydrogeology	Comments
Parara Limestone		Dark-grey, nodular, shaly limestones	Poor yields except when fracturing by faulting	No good recharges sites close to Nepabunna
Nepabunna Siltstone		Dark blue-grey calcareous siltstone, minor limestone	Up to 150 m^3/d in structurally favourable sites	Aquifer for current production wells
Wilkawillina Limestone	Upper	Interbedded limestones and siltstones	Poor yields	Where drilled, upper unit seems to be a poor prospect
	Lower	Clean massive limestones	Massive limestones may have moderate yields in places	The massive limestones (where crossed by major creeks) are maybe the best prospective target in the area
Parachilna Formation		Soft sandstones and shales	Contains moderate aquifers elsewhere in the Flinders Ranges	Intersected in well 6636-96, no supply
Uratanna Formation		Shales	No known drilling	Too far from Nepabunna to be of interest
Pound Quartzite		Hard silicified sandstones	Poor, hard drilling	Too far from Nepabunna to be of interest

(Read 1981)

The community of Nepabunna lies in a small syncline near the southern flank of the Nepabunna Synclinorium. In the area a number of minor faults have been identified. The faults appear to be relatively old as joints associated with them have been filled with calcite, while others appear to be open (Read 1981).

The dominant joint set has an approximate north-south strike and a near vertical dip. These can be seen as an outcrop in the Wilkawillina Limestone with a spacing of several metres. In the Nepabunna Siltstone similar joints occur but are closely spaced. Traces of the same set of joints can be seen on aerial photographs in the Parara Limestone with spacings of 10–30 m (Read 1981).

This joint system almost certainly provides both horizontal and vertical permeability, however few of these joints could be intersected by vertical drillholes. Some near horizontal joints occur, but are poorly developed. These may provide some permeability.

The most obvious feature in most outcrops is the steep-dipping east-west trending cleavage which has been developed parallel to the axial plane of folding. This is unlikely to have any hydrogeological importance (Read 1981).

The Wilkawillina Limestone as mapped on the Copley map sheet can be divided into at least two units. The lower unit consists of clean massive limestones (Fig. 2a) while the upper unit is interbedded with silty limestones, nodular limestones and calcareous siltstones (Fig. 2b).

Figure 2a. Lower unit of the Wilkawillina Limestone

Figure 2b. Upper unit of the Wilkawillina Limestone

Spatial representation of the regional geology of the Nepabunna area is illustrated in Figure 3a.

The massive limestones of the lower unit are the most prospective aquifers in the area (Read 1981 see Fig. 3b).

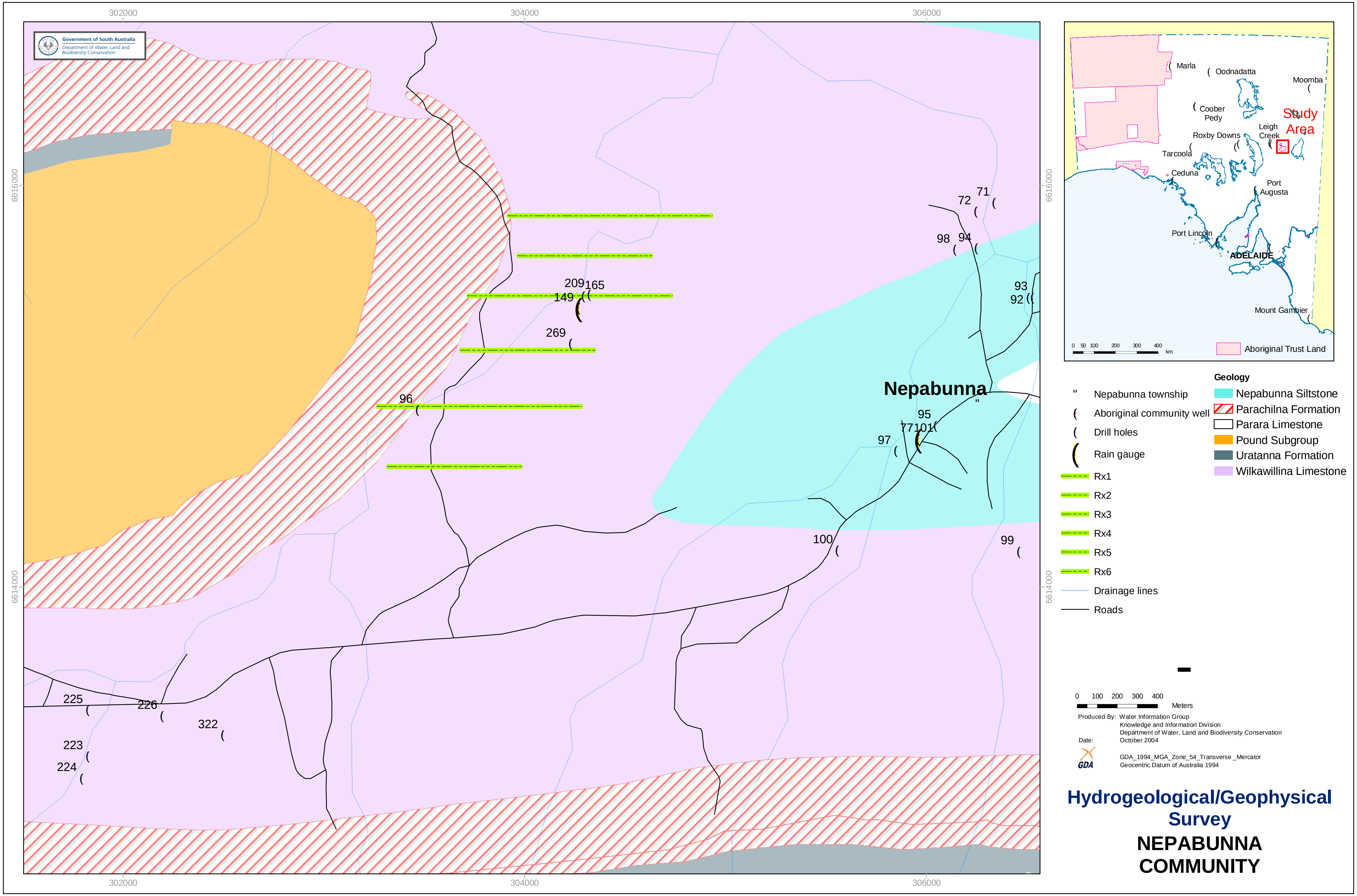


Figure 3a. Regional geology of Nepabunna area

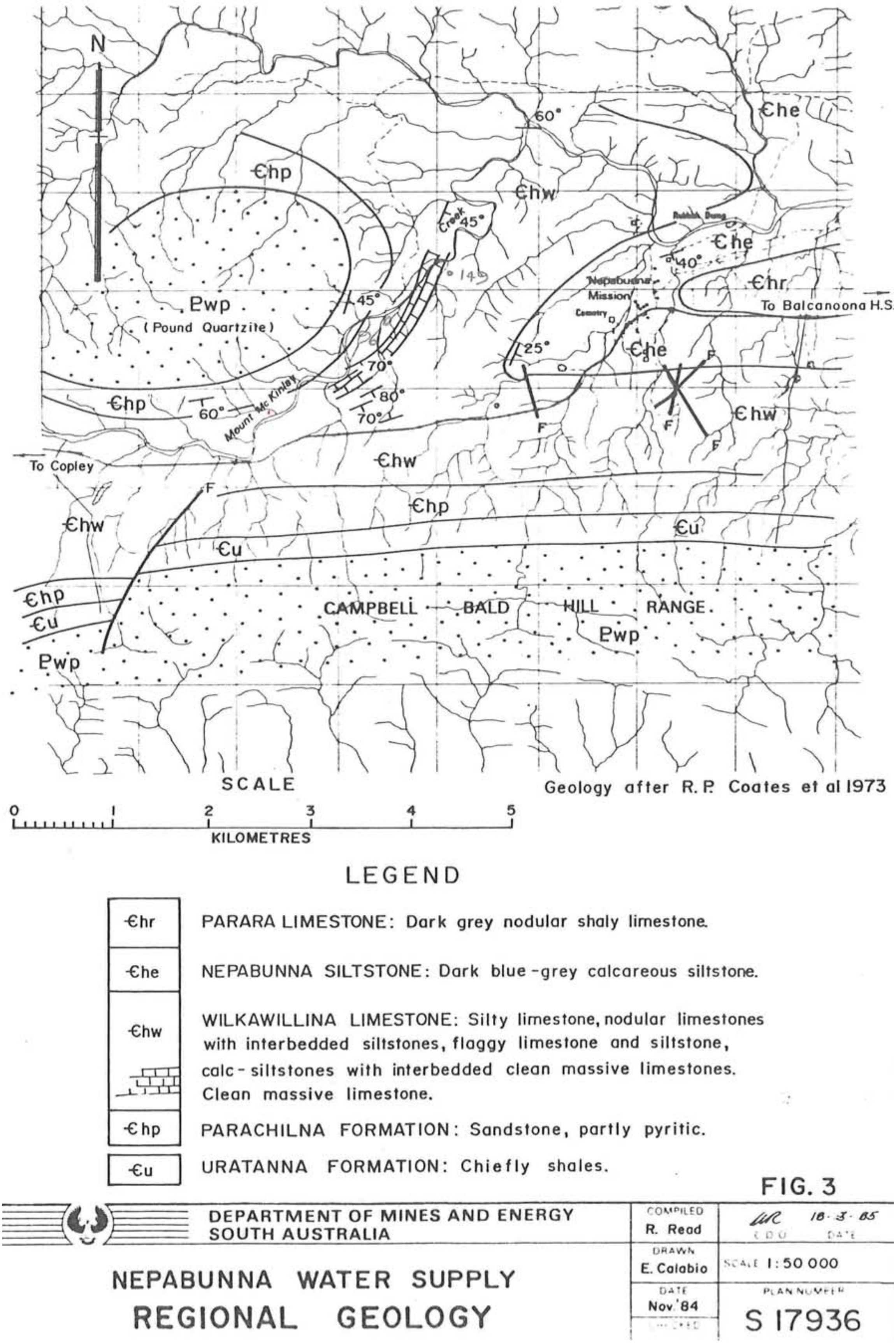


Figure 3b. Regional geology taken from Copley 1:250 000 map sheet with interpolation made by Read 1981

Table 2. Drillholes in close proximity to the Nepabunna Community

Unit Number	Easting	Northing	Drill Date	Depth (m)	Obs Date	DTW (m)	Obs Date	TDS (mg/L)	Geology	Comments
663600071	306337	6615915	—	17.1	Jun-67	9.1	1972	1200	Chw	—
663600072	306245	6615872	—	9.5	Jan-52	1.2	1972	700	Chw	—
663600077	305958	6614737	01-Jan-69	61.0	–	–	Aug-80	1105	Chn	Former prod. well 1969–80
663600092	306506	6615442	01-Jan-63	21.3	Jan-63	14.3	—	—	Chn	Formerly equipped with windmill
663600093	306527	6615445	01-Jan-61	—	—	—	—	—	Chn	Former prod. well
663600094	306248	6615689	—	106.0	—	—	—	—	Chw	Abandoned
663600095	306045	6614806	12-Aug-80	91.0	Aug-80	35.6	Aug-80	1300	Chn	Obs. well
663600096	303464	6614884	15-Aug-80	93.0	—	—	—	—	Chw/Chp	Backfilled/ abandoned
663600097	305846	6614679	22-Aug-80	64.0	Aug-80	37.1	Aug-80	1265	Chn	—
663600098	306141	6615682	31-Jul-80	63.0	–	–	Jul-80	1300	Chn	Backfilled/ abandoned
663600099	306460	6614178	04-Aug-80	91.0	Aug-80	24.2	Aug-80	1325	Chw	Backfilled/ abandoned
663600100	305556	6614184	05-Aug-80	27.0	Aug-80	17.0	Aug-80	2640	Chw	—
663600101	305958	6614738	08-Aug-80	64.0	May-06	48.1	Aug-80	1180	Chn	Prod. well (2.2L/s)
663600149	304266	6615391	13-May-83	120.0	May-06	53.8	Feb-89	1066	Chw	Prod. well (12L/s)
663600165	304291	6615450	11-May-89	65.2	May-89	48.0	—	—	Chw	Yield at drilling (2L/s). Status unknown
663600209	304320	6615459	15-May-89	101.6	May-89	48.0	May-89	959	Chw	Yield at drilling (20L/s). Status unknown
663600223	301823	6613158	08-Jun-96	165.0	—	—	—	—	Cu	—
663600224	301792	6613049	29-May-96	160.0	—	—	—	—	Cu	—
663600225	301823	6613389	29-May-96	146.0	—	—	—	—	Cu	—
663600226	302192	6613358	03-Jun-96	162.0	—	—	—	—	Cu	—
663600269	304228	6615214	12-Nov-99	140.0	Nov-99	90.0	Jun-02	1066	Cu	Yield at drilling (1L/s)
663600322	302494	6613263	21-Aug-01	169.0	Aug-01	96.0	Jun-02	944	Chn	Prod. well IGA WARTA, 1.4L/s

Datum is MGA94 using AMG Zone 54

Chw — Wilkawillna Limestone

Chn — Nepabunna Siltstone

Chp — Parachilna Formation

Cu — Uratanna Formation

3. SITE SELECTION

While the hydrogeology around Nepabunna and its wider area have not been greatly detailed, pervious drilling and prospecting for groundwater supply has identified the characteristics of various geological units (Table 2). For the purposes of this investigation and to target a specific site for a geophysical survey, the area has been categorised spatially into four different site locations (Fig. 4), namely ‘Middle Mount McKinlay Creek’, ‘Upper Mount McKinlay Creek’, ‘Lower Mount McKinlay Creek’ and the ‘Nepabunna Township’.

3.1 MIDDLE MOUNT MCKINLAY CREEK (WELLS 6636-96, 6636-149, 6636-165, 6636-209 AND 6636-269)

This area is most prospective because of the juxtaposition of recharge in the form of a creek with an extensive catchment. The massive limestone in this area is regarded as a reliable producer of groundwater due to a favourable fracture system. Moreover, it is only two kilometres from the community and is already linked by a rising main.

Well 6636-149 is the main water supply for the Nepabunna Community and has produced water at 1 L/s for many years without becoming stressed or lowering the standing water level. The salinity has been consistent at 900–1000 mg/L. The only problem appears to be loss of production due to the development of iron bacteria in the well.

It is expected that a second well in this area would be sustained at similar rates to well 6636-149, as airlift yields up to 12 L/s have been recorded. While they are approximate at best, they indicate a reasonable supply could be obtained.

All wells in this area, except the most recent (well 6636-269), encountered limestone. Geological records indicate that this well was constructed in shale to completion and yielded only a minor water supply.

Well 6636-96, drilled 700 m south-west of the other wells in this area, encountered limestone from 60 m to probably 81 m but lost circulation in very fractured and open rock (Read 1984).

Geological logs for wells 6636-209 and 6636-165 indicate limestone material to depth and both encountered water, with well 6636-209 producing an airlift yield estimate of 20 L/s. Well 6636-209 had been backfilled and a standpipe is all that remains. Well 6636-165, in virtually the same location, was abandoned at 65 m and so did not penetrate to the higher yielding levels of well 6636-149. Yields of 2 L/s have been recorded from airlifting.

Salinities in each of these wells were under 1000 mg/L. The status of each of these wells is unknown.

The area in the vicinity of well 6636-209 is a prospective location for further drilling. However, since the siting of well 6636-209 is within 100 m of the current production well (6636-149), the well is considered to be too close and may interfere with the current production well. A preferable option would be to site a well 300–400 m north-north-east of well 6636-209. To date, however, the limestone has not been mapped this far north. Surface geological mapping, geophysics and drilling in this area is recommended.

Access and clearance for siting a well within 500 m north of well 6636-149 is good. Beyond this distance the terrain is difficult to negotiate.

Alternatively, further investigations south of the current production well 6636-149 would be worthwhile since there are outcrops of the Wilkawillina Limestone exposed and the terrain is more accessible and flat. Hydrogeological data associated with well 6636-96, located in this area, is limited. However, it is possible that well 6636-96 was drilled around 100 m too far west and therefore missed intercepting the massive limestone.

The location of well 6636-269 could not be verified as there was no sign of a drill spoil at the location recorded in the State drillhole database.

3.2 UPPER MOUNT MCKINLAY CREEK (WELLS 6636-223, 6636-226 AND 6636-322)

In 1996, wells 6636-223 and 6636-226 were drilled into the siltstone to a depth of 146–165 m and produced little or no water.

Well 6636-322 (IGA Warta 2002A) encountered slate and fractured quartz from 90–169 m and is cased with a production zone between 136–165 m. Aquifer testing indicated an estimated yield of 1.4 L/s. The water is of acceptable salinity at 944 mg/L.

This area is prospective, at depths around 150 m however yields are likely to be low.

3.3 LOWER MOUNT MCKINLAY CREEK (WELLS 6636-71, 6636-72, 6636-92, 6636-93, 6636-94 AND 6636-98)

Well data in this area is very limited. Wells 6636-71 and 6636-72 were drilled in 1952. Salinity was tested in 1972 at 1183 and 699 mg/L respectively. Wells 6636-92 and 6636-94 were drilled and used as water supplies, then abandoned with little information retained. Well 6636-98 was drilled in siltstone to 63 m and abandoned.

The terrain is difficult to negotiate and the majority of the surrounding land is of cultural significance to the local population.

This area is not recommended as a prospective area.

3.4 NEPABUNNA TOWNSHIP (WELLS 6636-77, 6636-95, 6636-97, 6636-99 AND 6636-101)

All wells in this area are constructed into the Nepabunna Siltstone and are characterised by moderate yields diminishing within a few years, indicative of an aquifer system with limited recharge. Further utilisation will continue to dewater this aquifer.

Most of the limestone located here is present in thin bands (about 200 mm in width) with inter-bedded easily weathered silty material.

This site is not prospective.

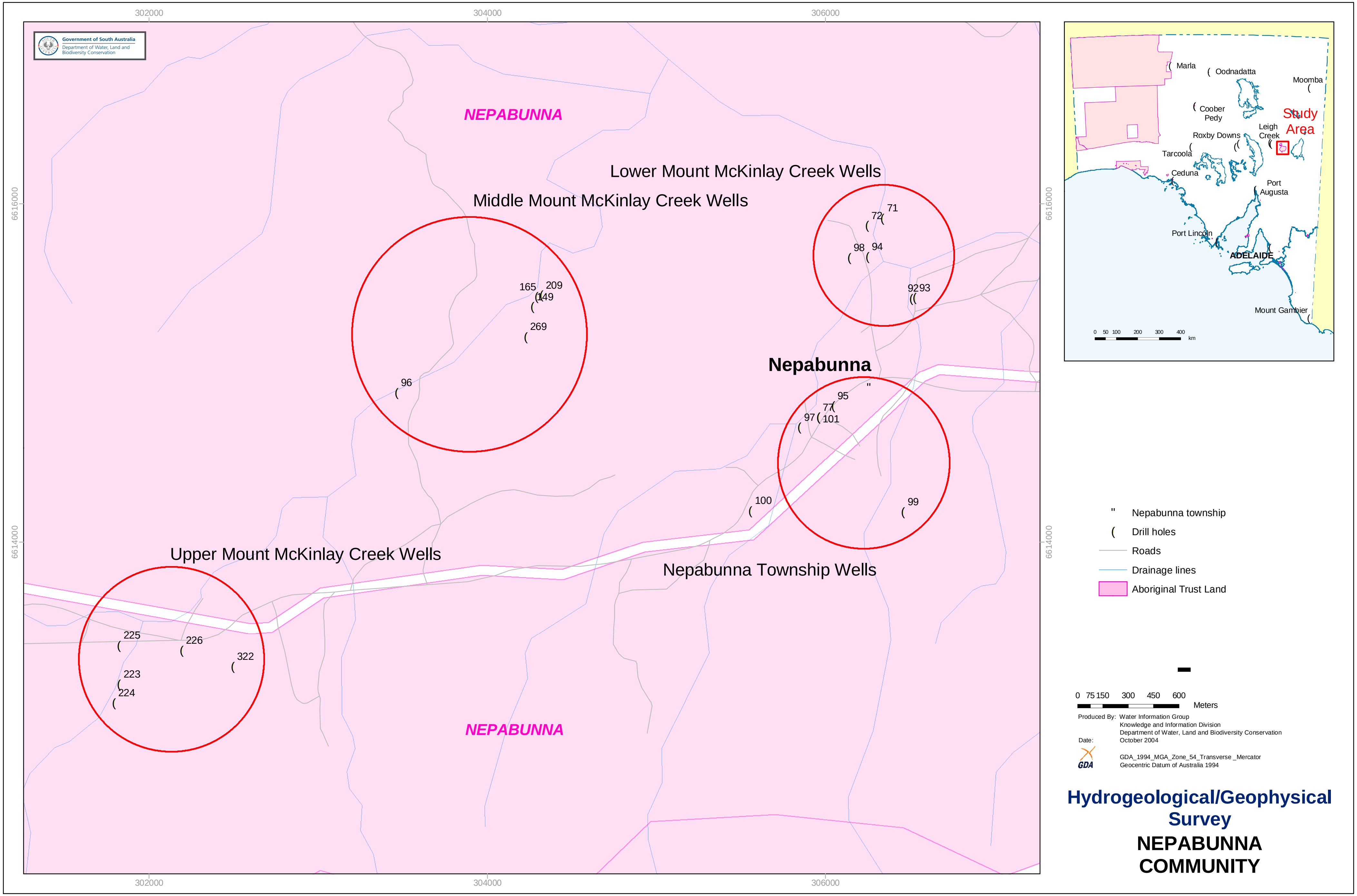


Figure 4. Locality of wells in the vicinity of Nepabunna

3.5 PREFERABLE SITE LOCATION

Due to time and budget constraints and based on the hydrogeological review of the area, the focus of the geophysical survey was to the north and south of the current producing well 6636-149, in the area referred to as Middle Mount McKinlay Creek. The massive limestone that resides within the Wilkawillina Limestone is the proposed target.

Based on existing information it is expected that:

- The depth of the prospective water bearing zones (massive limestone) be in the range 80–100 m.
- Anticipated salinity will be in the order of 1000 mg/L.
- Rates would be anticipated in the order of 1 L/s.
- The well construction method will consist of surface casing cemented at the ground surface and run at depth until the fracture zone. Provided the material is competent the well will be open-hole to the end of the drill hole.

4. GEOPHYSICAL SURVEY AND METHODOLOGY

Typically, geophysical survey techniques are non-evasive and can be used to identify infrastructure, geological and hydrogeological features below the natural surface. The aim of this survey was to identify suitable geology that would produce a reliable groundwater supply to support the Nepabunna Community.

Controlled source audio magnetotellurics (CSAMT) was chosen as the geophysical technique to help detect sources of groundwater beneath the natural surface (Zonge 1992). The technique requires the use of a transmitter and receiver(s). The receivers are typically positioned along a transect adjacent to the area of interest (in this case west of the Nepabunna township, see Fig. 5), where several transects can be made over the area of interest. The transmitter is generally positioned parallel, ~8 km north or south of the receiver transects. However in this case, due to limitations in the terrain of these areas, the transmitter was located 8 km east of the Nepabunna township (Fig. 6).

The transmitted fields were generated with a Zonge GGT-25 geophysical transmitter powered by a ZMG-30 generator system. The transmitter emits a current into the ground using electrodes positioned at each end of the transect (Fig. 6). Current ranged from 10.5 to 3.5 A throughout the survey.

The receiver(s), consist of a series of electrodes (porous pots filled with copper sulphate) and a magnetic field antennae (ANT-1B). They detect a signal response dependent on the underlying substructure. These series of electrodes are positioned along survey transect lines as seen in Fig. 4.

Survey receiver lines consisted of six east-west transects. Three of these transects were about 1 km in length while the remaining three were 675 m in length. The spatial orientation of the survey lines aim to detect the presence of a partially mapped north-south band of massive limestone.

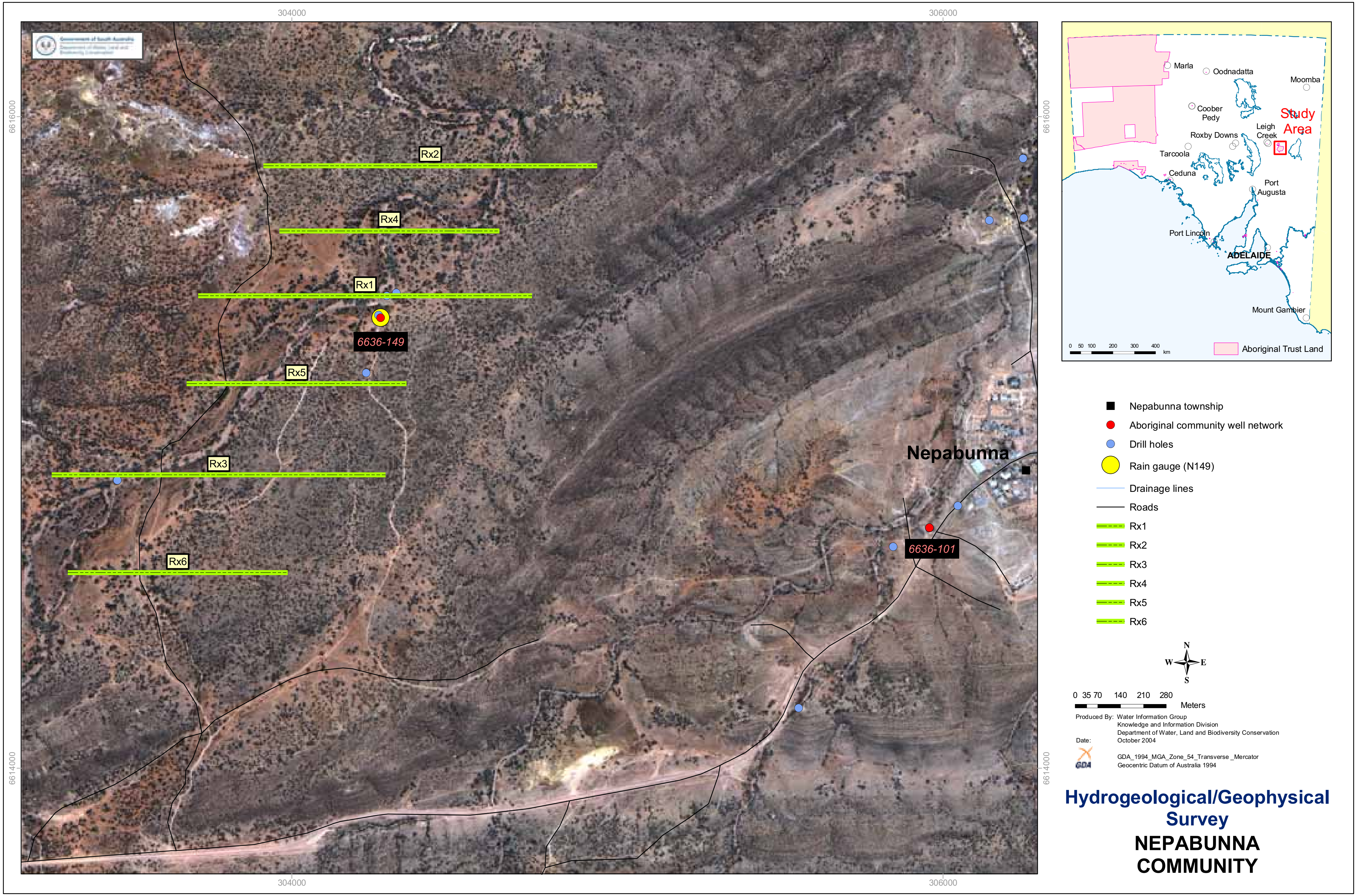


Figure 5. Location of the receiver transects, located west of the Nepabunna Community

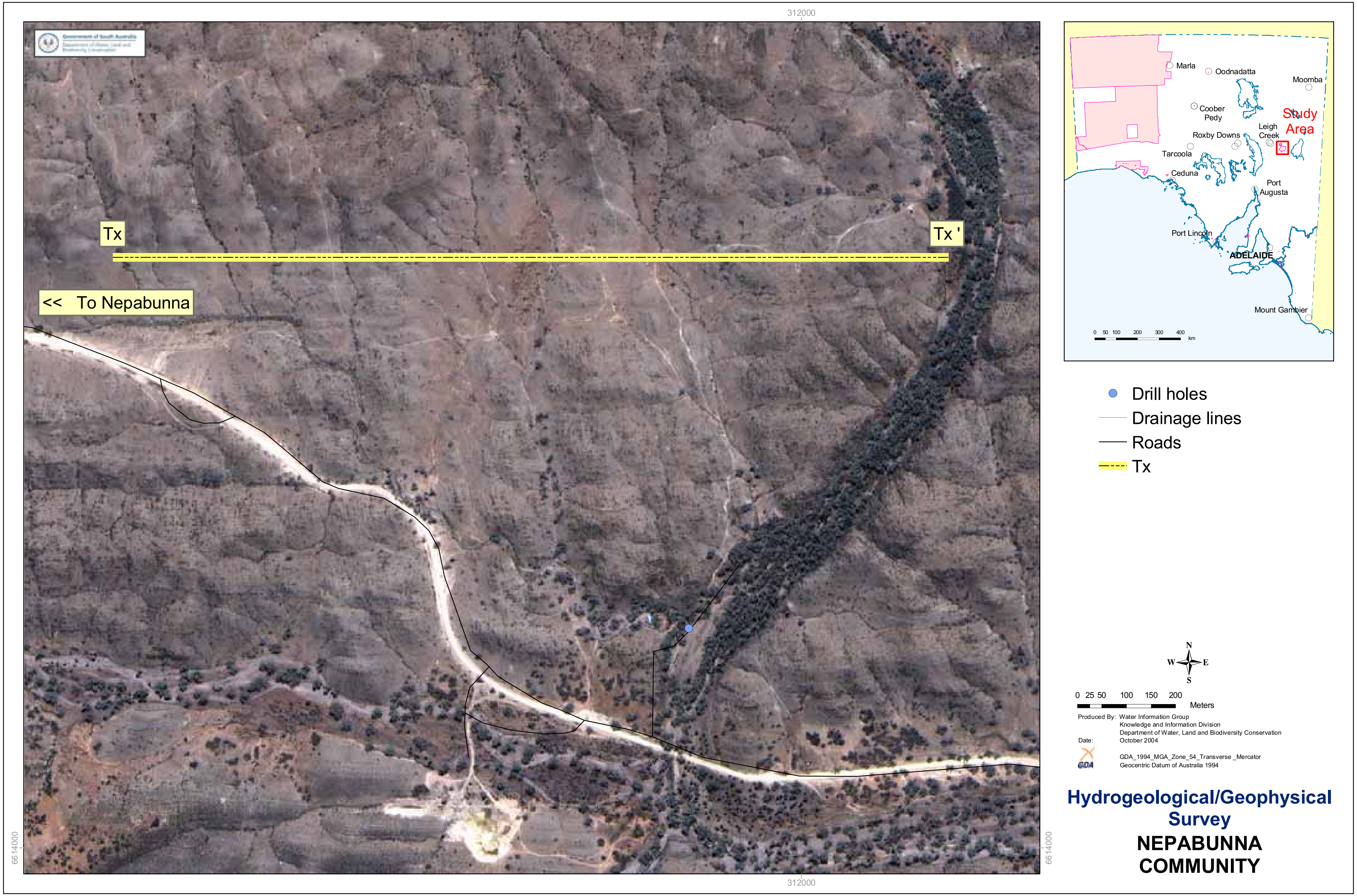


Figure 6. Location of transmitter site, located east of the Nepabunna Community

5. RESULTS

As discussed in the previous chapter, six transect lines were surveyed totalling 5.1 km of survey. Each of the survey lines was orientated east-west and parallel to the transmitting dipole. Scalar electric field data was recorded from seven receiving dipoles per set-up using an a-spacing of 25 m.

The data was processed by first averaging the repeat readings. The data was then reviewed on a station-by-station basis and all noisy data discarded.

The data was then inverted using the Zonge 1-D inversion program SCSINV whereby the CSAMT soundings are inverted to real depth 1-D resistivity sections (Mann 2006, 2007).

The details of the survey transects and data taken are presented in Table 3 below.

Table 3. Data summary of Nepabunna CSAMT survey

Line (Northing mN)	**Orientation** (°N)	**Frequency Range** (Hz)	**Transect Start** (Easting mE)	**Transect Finish** (Easting mE)	**Transect Length** (m)	**No. of Stations**
661**5850N**	90	8 to 8192	303912.5	304937.5	1025	42
661**5650N**	90	16 to 8192	303962.5	304637.5	675	28
661**5450N**	90	8 to 8192	303712.5	304737.5	1025	42
661**5180N**	90	16 to 8192	303677.5	304352.5	675	28
661**4900N**	90	8 to 8192	303262.5	304287.5	1025	42
661**4600N**	90	16 to 8192	303312.5	303987.5	675	28
Total number of stations						**210**
Total line kilometres						**5.1**

(Mann 2006, 2007)

Survey line 5450N was strategically positioned to run as close as possible to the existing town water supply well 6636-149. Since it is known that this well has a reliable supply and resides in the desirable (massive limestone) aquifer. The results from this survey line would act as a control for the remainder of the survey.

As discussed in Section 2 of this report discussing the geology in the Nepabunna area, the Wilkawillina Limestone can be divided into two separate units, upper and lower unit.

Water quality within each unit is similar in salinity and recorded in the range 1000–1200 mg/L (TDS). As there is no distinct contrast in salinity between the two units, the CSAMT technique will not be able to resolve the lower unit based upon salinity alone.

In terms of mineralisation, both units are similar in that they both contain large quantities of limestone. The only distinguishing feature between the two units is the inter-bedding siltstone in the upper unit.

Limestone, particularly in the case of the lower unit which has a crystalline structure giving rise to a clean fracturing system, is resistive by nature. Therefore with increased depth the resistive nature of the rock (owing to the clean fracturing system) will be dominant.

Therefore the target zone will be represented as resistive in the CSAMT survey transects.

Due to the crystalline structure and clean fracturing system in the lower unit, it is likely that the porosities of the two units will differ substantially, which in turn, through Archie's Law (Keller & Frischknecht 1966), has a bearing on the resistivity.

Porosity is the ratio between the volumes of the pores and that of the rock.

$$porosity = \frac{volume\,of\;\;pores}{volume\,of\;\;the\,rock}$$

Being a ratio, the porosity is expressed in a percentage (%).

A great deal of work has been done in correlating resistivity with water content for petroleum-bearing rocks. For these rocks, primarily porous sandstones and limestones, it has been observed that resistivity varies approximately as the inverse square of the porosity when the rock is fully saturated with water. This observation has led to the widespread use of an empirical function relating resistivity and porosity, known as Archie's Law:

$$\rho = a\rho_w\varphi^{-m}$$

where ρ is the bulk resistivity of the rock, ρ_w is the resistivity of the water contained in the pore structure, φ is the porosity expressed as a fraction per unit volume of rock and a and m parameters whose values are assigned arbitrarily to make the equation fit a particular group of measurements. For a first approximation a value of 1 may be assumed for a and a value of 2 for m.

According to Archie's Law, if the resistivity varies approximately as the inverse of the porosity, the higher the porosity the lower the resistivity and vice versa.

As discussed earlier in this section, the only distinguishing feature between the upper unit and the lower unit is the inter-bedded siltstone and therefore high content of siltstone in the upper unit compared to the lower unit. Siltstone by its nature tends to have a higher degree of porosity ($5\% < \varphi < 10\%$) whereas the massive limestone is a much lower porosity of less than 2% because of its crystalline structure (A Love [DWLBC] 2007, pers. comm.). Based on these values and using Archie's Law, the difference in resistivity is at least an order of magnitude greater in the lower unit than compared with the upper unit.

Hence it is likely that the massive limestone of the lower unit is likely to be depicted by a resistive feature.

On inspection of the data (note that a terrain correction has not been applied) on line 5450N, it shows a subtle resistive anomaly (100–120 ohm-m) at x = 4290 m (Fig. 8). This feature correlates with the position of well 6636-149 (304266mE, 6615391mN) and the production zone, recorded as 80–120 m, for that well. It is evident from the data that this resistive feature resides between two conductive features at x = 4214 and 4438 m. It is likely that this resistive feature depicts the massive limestone.

Using 5450N as a control, the same anomaly can be seen on line 5850N (Fig. 6) at x = 4240 m and on line 5650N (Fig. 7) at x = 4300 m.

Due to the geometry of the regional geological structure to the west of the area of interest, it is assumed that this massive limestone follows the same contour as depicted in Read (1981, see Fig. 3b). This being the case it is likely that the 1-D modelling of the geophysics depicts the massive limestone (characterised by a resistive anomaly) also at x = 4250 m on line

5180N (Fig. 9), at x = 4030 m on line 4900N (Fig. 10) and at x = 3825 m on line 4600N (Fig. 12).

The localities of these anomalies can be pieced together to map a north and south trending line (Fig. 13). This line is considered to demark the position of the massive limestone also called the lower unit limestone.

It should be noted that there are several other resistive anomalies present on each transect in the 25–100 m depth zone. It is likely that these may have resulted from localised basement uplift which in turn may have caused a certain degree of fracturing. These anomalies should be considered as secondary target zones only, as they do not fit the spatial characterisation of the massive limestone according to the existing production well (6636-149) and the geometry of the regional geological structure.

Transects 5850N, 5450N and 4900N each span over 1 km in length and cover a larger lateral extent then the remaining three transects. It can be clearly seen on the western edge of each of these lines that there is a conductive anomaly at surface to ~100 m depth (Figs 7, 9, 11). It is thought that these transects encroach the Parachilna Formation (Fig. 3a) consisting primarily of sandstone and partly pyritic material. It is this pyritic material that may influence such a conductive anomaly due to the conductive nature of pyrite.

From the Copley 1:250 000 map sheet (Coats et al. 1973), the geology is dipping by 70°E south of the control line and well 6636-149 (the 'southern' part of the study area), whereas the dip of structure is shallower at 45°E north of the control line (the 'northern' part of the study area). This means that greater depths may be encountered while drilling to intersect this massive limestone in the southern part of the study area.

The watertable is noted as also being deeper in the southern part of the study area. The IGA WARTA well that was drilled in 2002 and located in this southern area has a recorded depth to water of 96 m. Drill hole 6636-96, drilled in 1980, also provides some evidence of the depth of the watertable in this southern area as its geological log noted that while drilling, waterless cavities were encountered at depth.

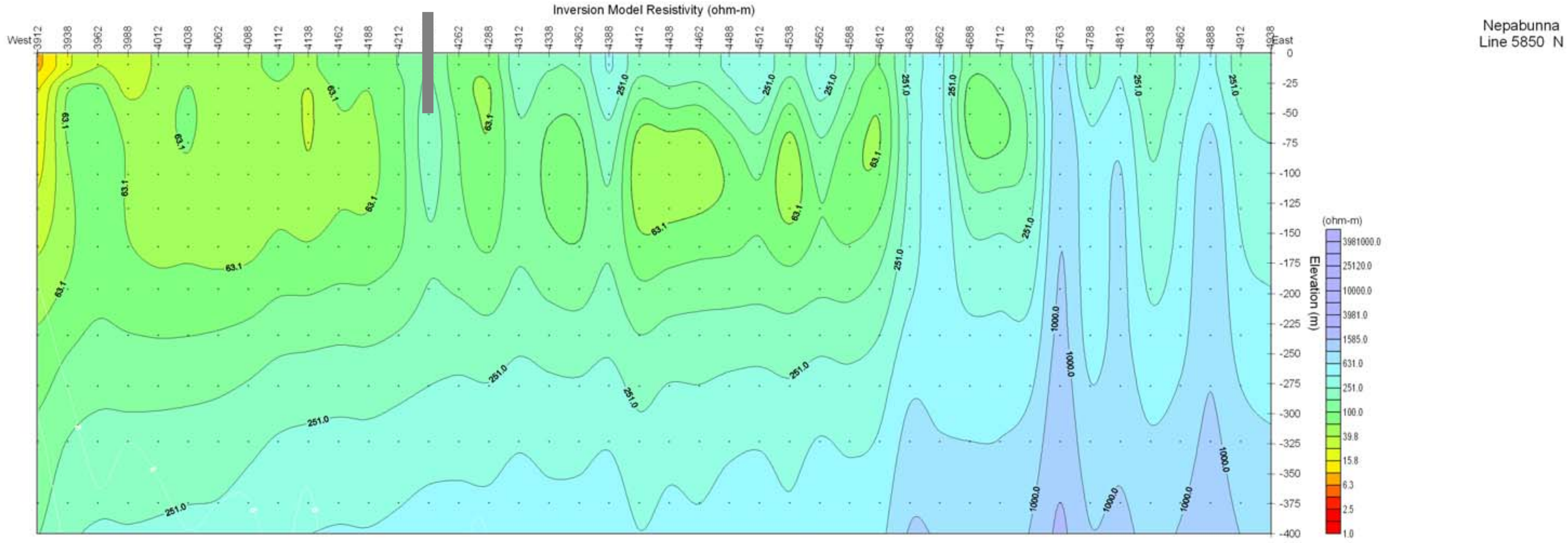


Figure 7. **Receiver transect line 5850N (site Rx 2, 6636 5850mN)**

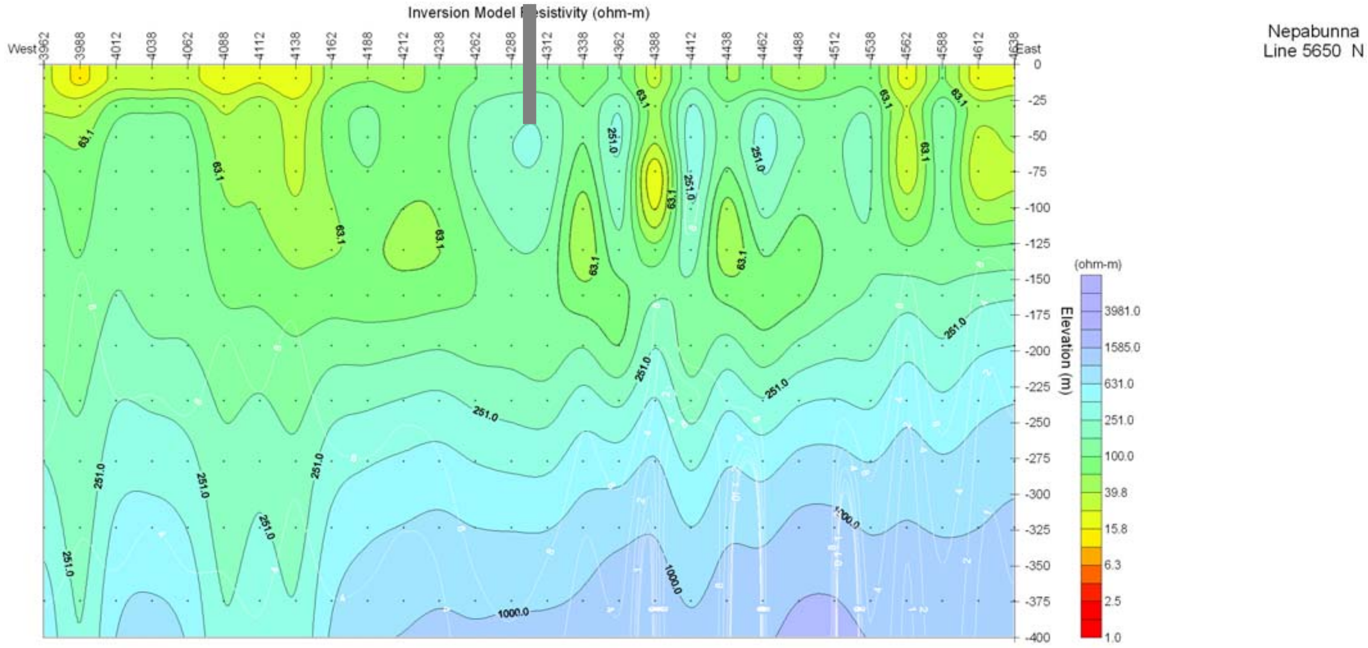


Figure 8. Receiver transect line 5650N (site Rx 4, 6636 5650mN)

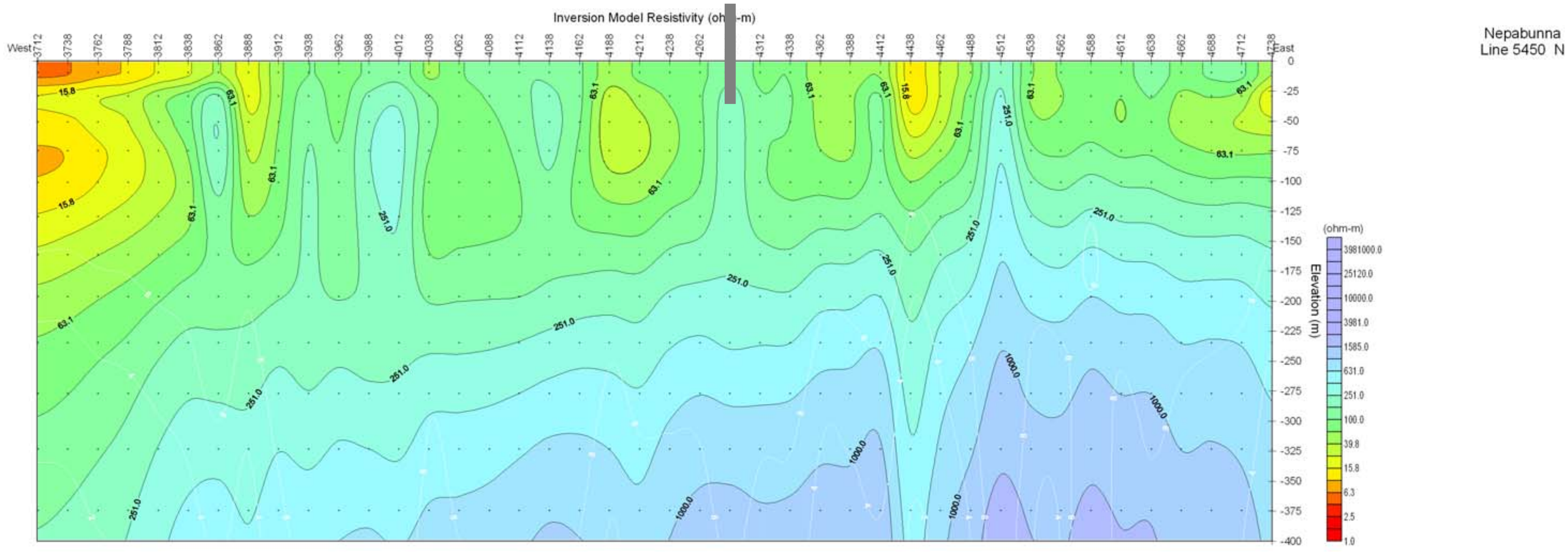


Figure 9. Receiver transect line 5450N (site Rx 1, 6636 5450mN)

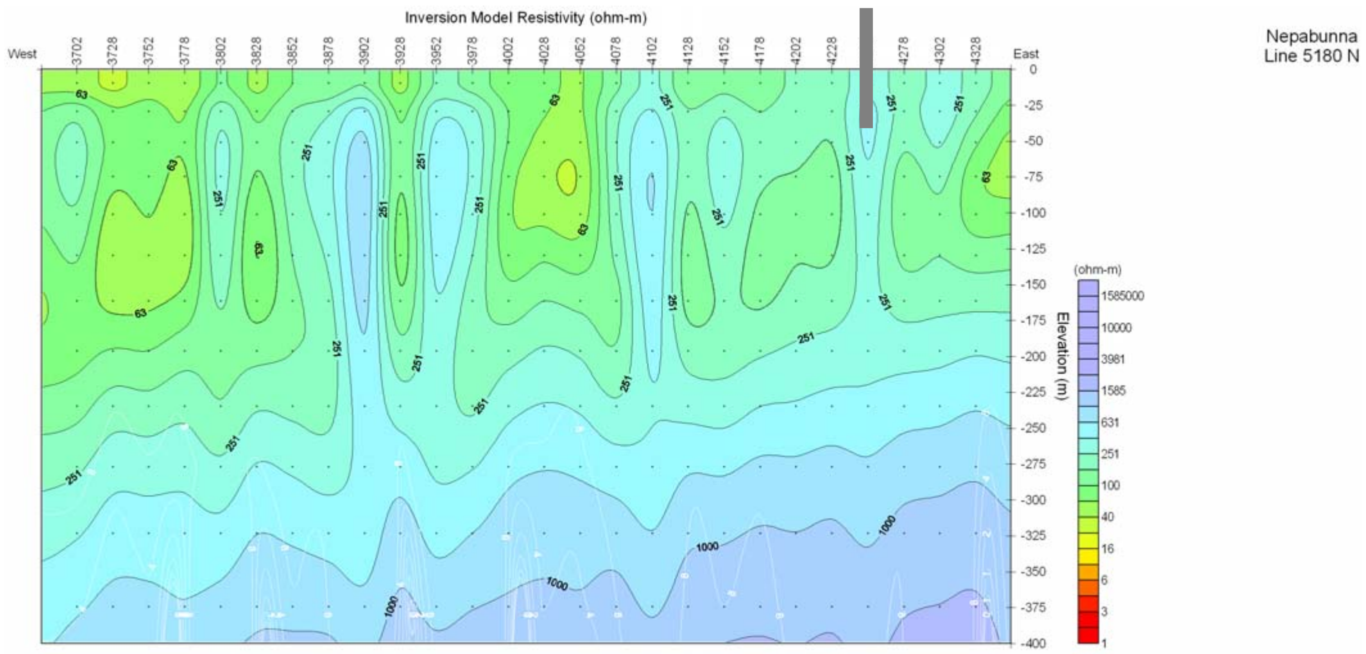


Figure 10. Receiver transect line 5180N (site Rx 5, 6636 5180mN)

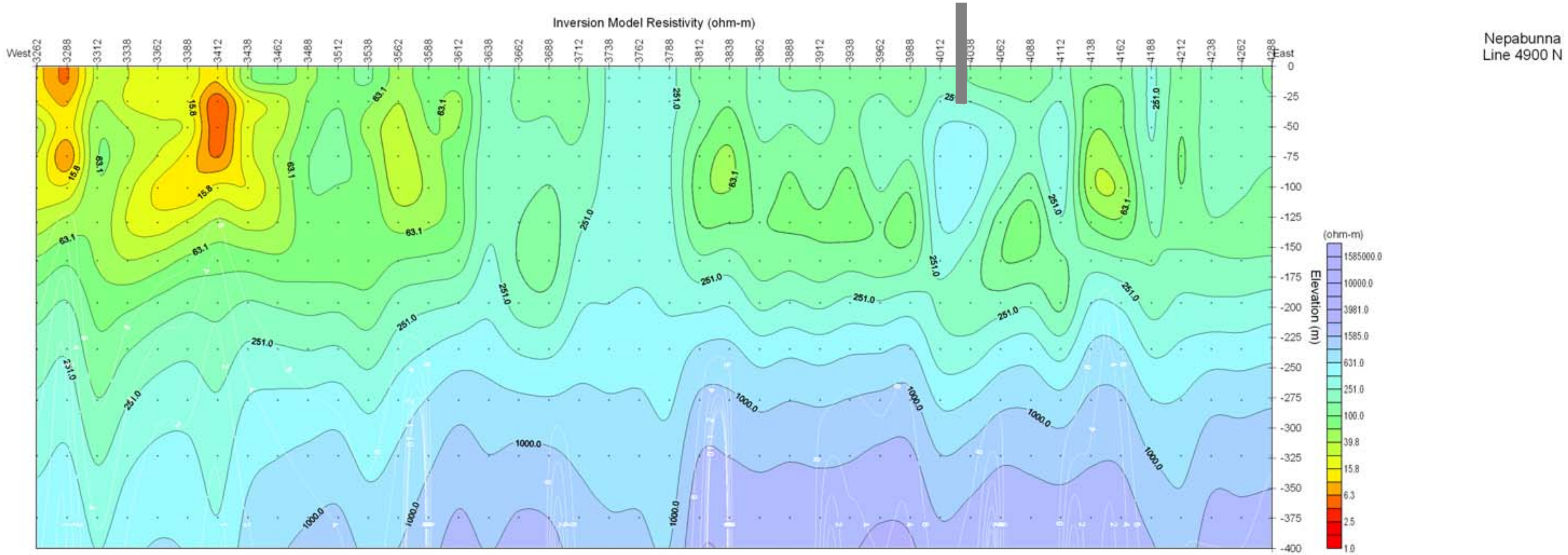


Figure 11. Receiver transect line 4900N (site Rx 3, 6636 4900mN)

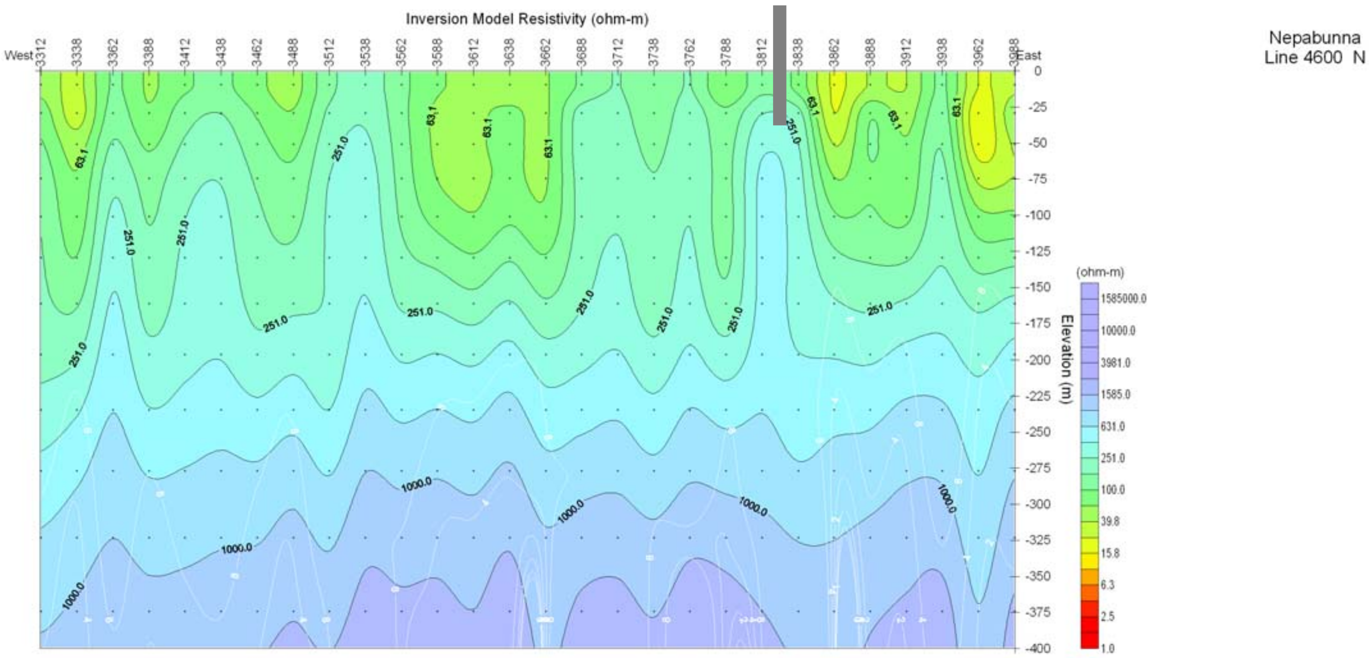


Figure 12. Receiver transect line 4600N (site Rx 6, 6636 4600mN)

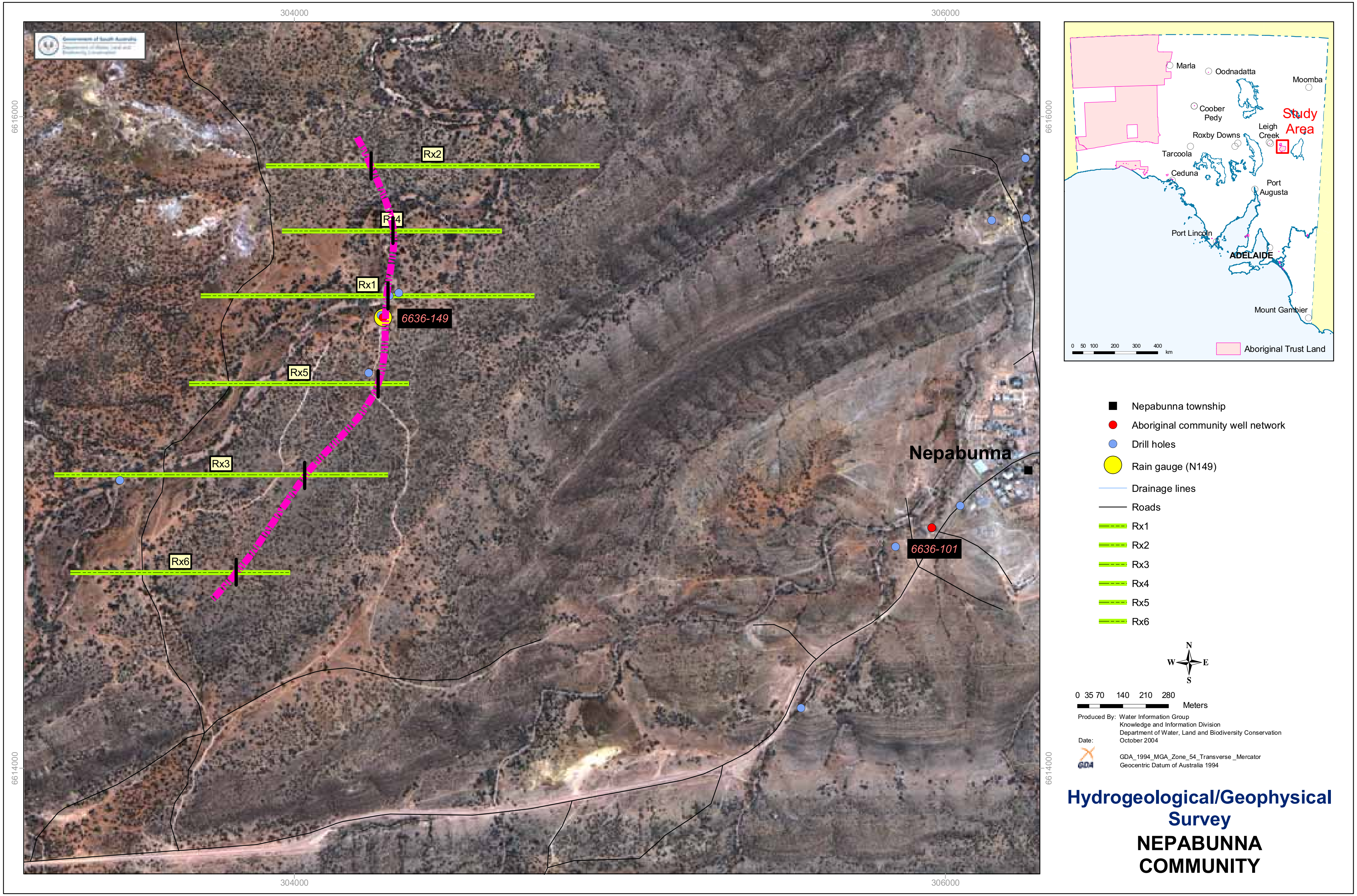


Figure 13. Location of receiver transects overlayed with massive limestone extent as depicted by CSAMT 1D modelling (Figs 7–12)

6. CONCLUSION

6.1 SUMMARY OF FINDINGS NOTED IN RESULTS

The geological environment in the area of interest, west of the Nepabunna Community, was not ideal for CSAMT. This is due to the target rock (lower unit of the Wilkawillina Limestone and generically termed massive limestone) having similar geophysical properties to its host rock (upper unit of the Wilkawillina Limestone).

It was first thought that the water contained within the fractures of the massive limestone would have a large enough volume to provide a conductivity contrast against its host rock. However, it was discovered due to the lack of a suitable volume of water, the resistive nature of the limestone coupled with very low porosity, that these facts overrode what conductive nature the water would have.

The survey transect that was conducted over an existing producing well (line 5450N) gave an indication of the resistive/conductive signature one might expect when detecting the presence of the massive limestone target. The geophysical technique using CSAMT 1D modelling was successful in depicting a subtle resistive anomaly, at x = 4290 m, with depths that correlate with the locality of the production zone (80–120 m) of the existing production well (6636-149).

This being the case, the other transects to the north and south can be used to map this resistive anomaly to the north-west and south-west following the geometry of the regional geological structure (Fig. 3a) in the area. The result of the geophysics modelling and interpolation of the massive limestone target is illustrated in Figure 13.

South of line 5450N, the resistive anomaly is not well defined due to several resistive anomalies appearing in the data. However to the north, the resistive anomaly of interest can be traced. According to the Copley 1:250 000 map sheet, the dip of the massive limestone is likely to be shallower (~45°E) to the north than that to the south where the dip approaches 70°E (Fig. 2b).

The presence of water is also deeper south of the current production well (6636-149). Evidence of this information is associated with drill hole 6636-96 which encountered substantial air filled (absence of water) cavities (or fracturing) at depths of 63–81 m. Further south, in the vicinity of the community of IGA WARTA (well 6636-322) the depth to water level is ~96 m.

The structural geology together with the geophysics and shallower depth to water-table, show that the northern part of the study area (north of well 6636-149 and line 5450N) is the best area to target for further investigation.

It should be noted that other resistive zones/anomalies do feature on the geophysical survey transects (Figs 7–12) between 25–100 m, particularly south of line 5450N as addressed above. It is not clear if they have any significance (i.e. if they represent the presence of the target unit). It is recommended that they be used as secondary target zones.

6.2 RECOMMENDATIONS

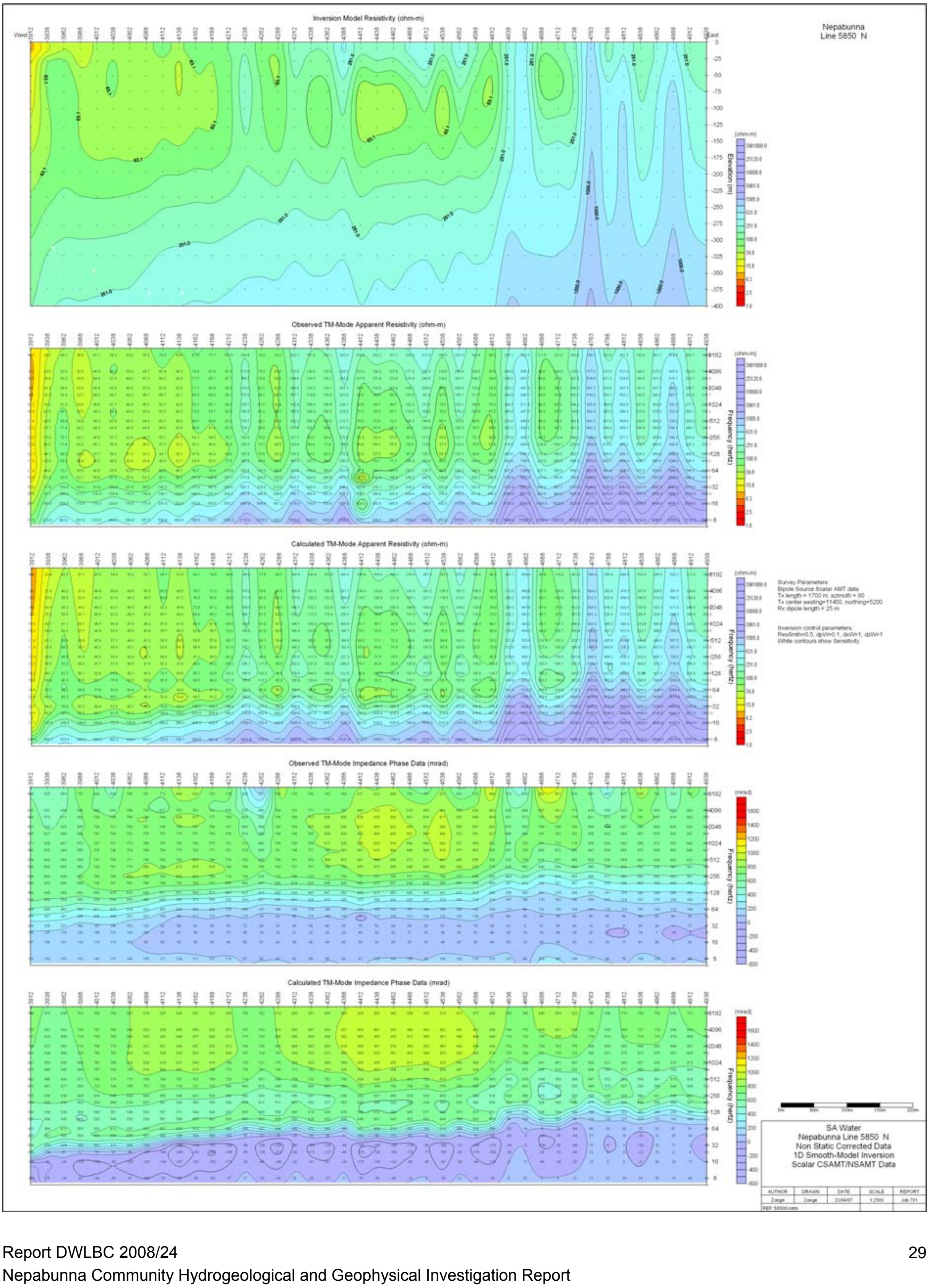
It is recommended that a drilling program to specifically target water should not be based primarily on these results since the geophysics is not definitive in this area.

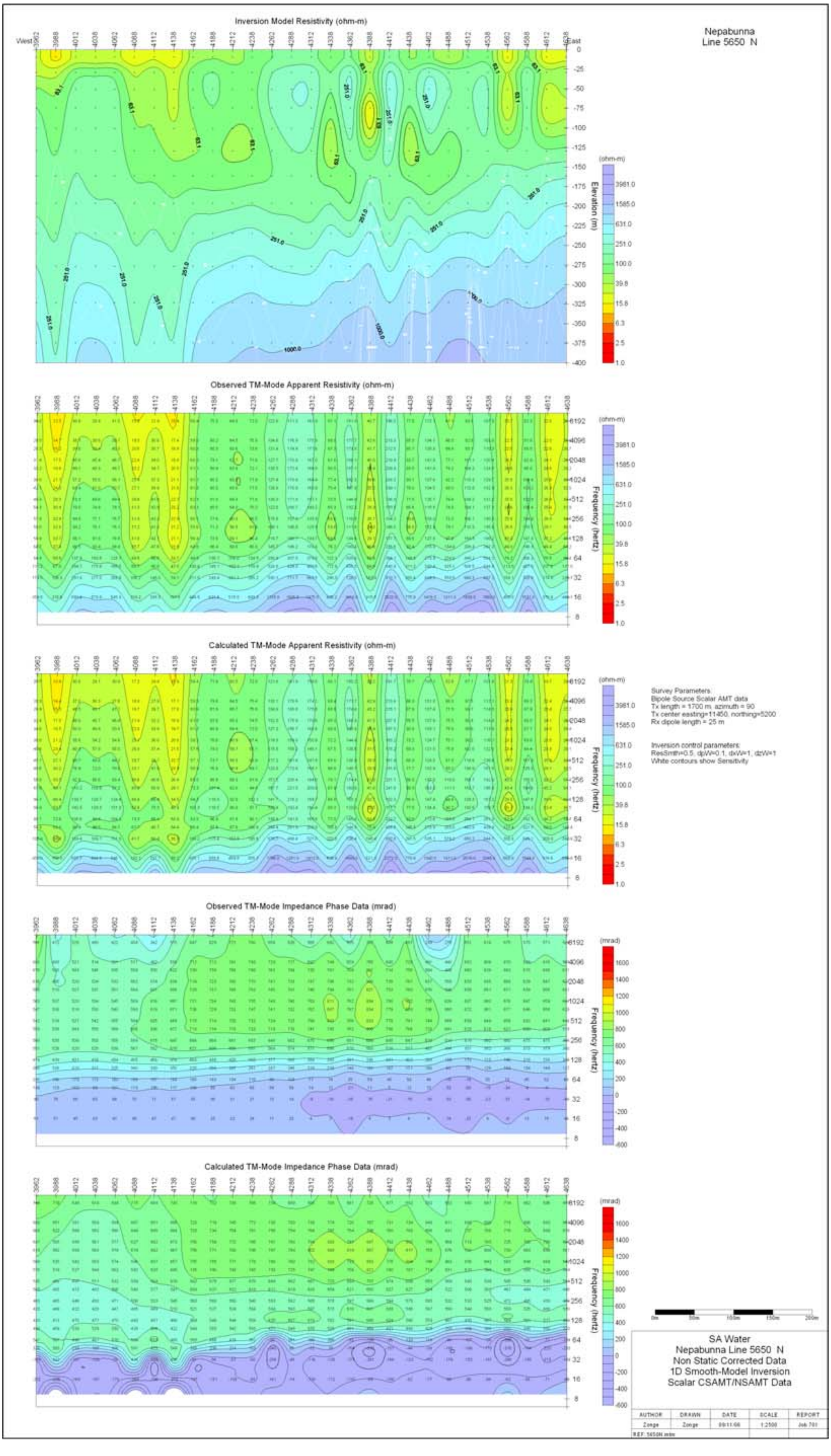
Further investigation is warranted before the commencement of a drilling program. These investigations should include:

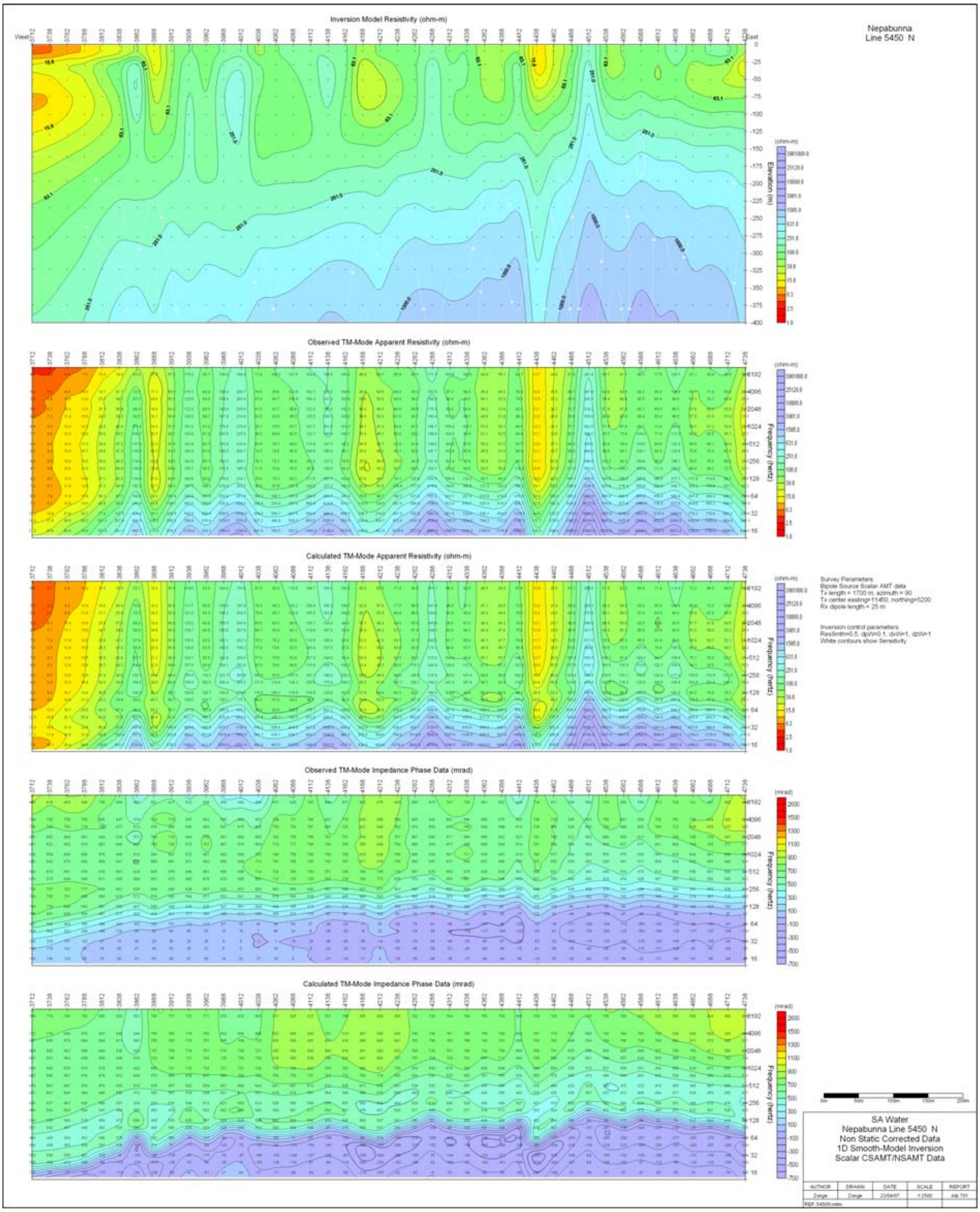
- An intensive and thorough geological mapping investigation, as the geology in the area at present is not well defined.
- A topographic survey along the six geophysical transects. This would allow a terrain correction for the CSAMT data and eliminate artefacts in the data cased by topography.
- A preliminary drilling program in the area north of production well 6636-149. The program should be designed to be inexpensive and quick targeting several locations, rather than a full scale drilling program for a water supply centred on one site.

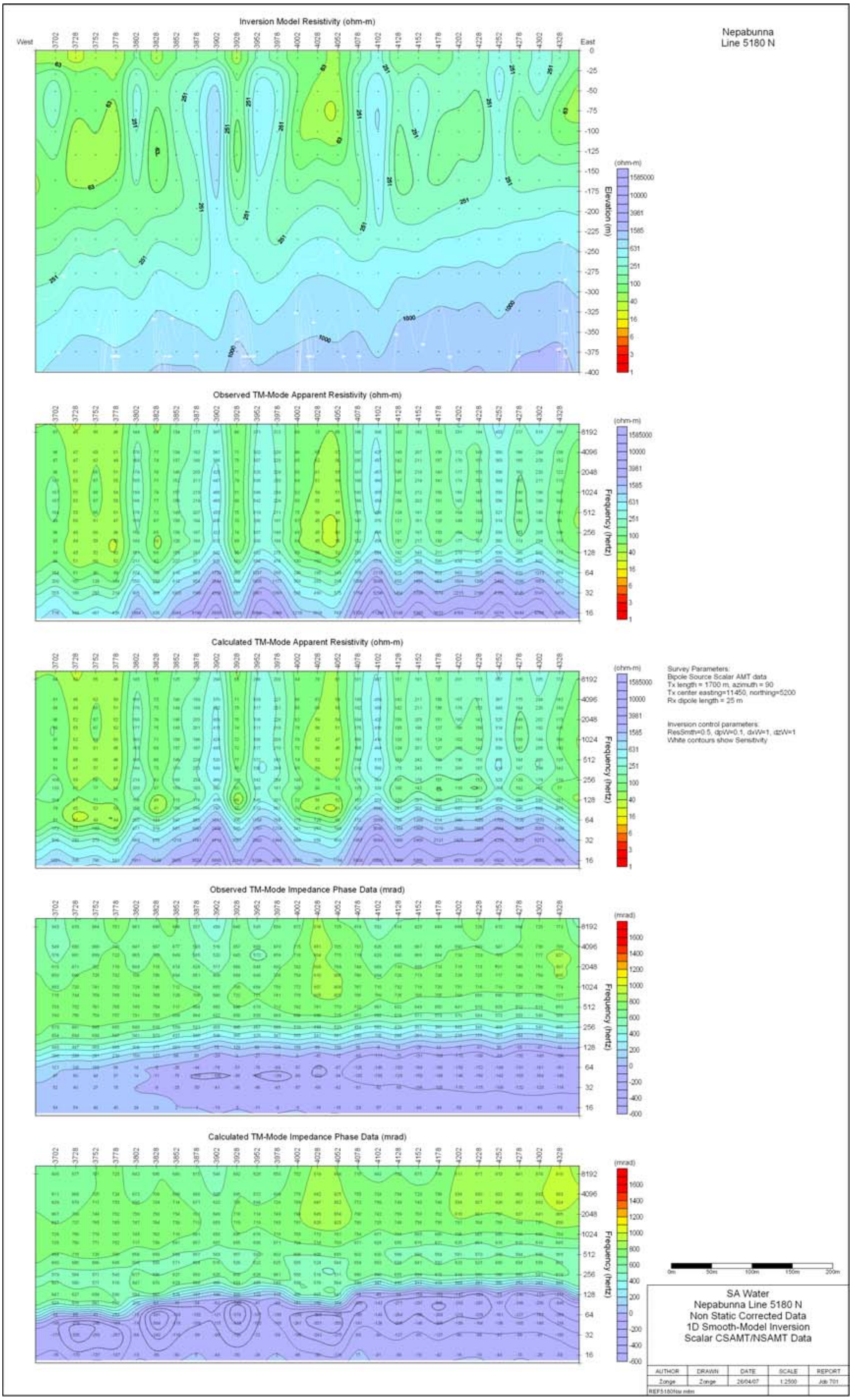
APPENDICES

A. CSAMT OUTPUT DATA PROFILES




Inversion Model Resistivity (ohm-m)
Nepabunna
Line 5650 N
Elevation (m)
Observed TM-Mode Apparent Resistivity (ohm-m)
Frequency (hertz)
Calculated TM-Mode Apparent Resistivity (ohm-m)
Survey Parameters:
Bipole Source Scalar AMT data
Tx length = 1700 m, azimuth = 90
Tx center easting=11450, northing=5200
Rx dipole length = 25 m
Inversion control parameters:
ResSmth=0.5, dpW=0.1, dxW=1, dzW=1
White contours show Sensitivity
Observed TM-Mode Impedance Phase Data (mrad)
Calculated TM-Mode Impedance Phase Data (mrad)
SA Water
Nepabunna Line 5650 N
Non Static Corrected Data
1D Smooth-Model Inversion
Scalar CSAMT/NSAMT Data
AUTHOR
DRAWN
DATE
SCALE
REPORT
Zonge
Zonge
1:2500


Nepabunna
Line 5450 N
Inversion Model Resistivity (ohm-m)
Observed TM-Mode Apparent Resistivity (ohm-m)
Calculated TM-Mode Apparent Resistivity (ohm-m)
Observed TM-Mode Impedance Phase Data (mrad)
Calculated TM-Mode Impedance Phase Data (mrad)
West
East
Elevation (m)
Frequency (hertz)
(ohm-m)
(mrad)
Survey Parameters:
Bipole Source Scalar AMT data
Tx length = 1700 m, azimuth = 90
Tx center easting=11450, northing=5200
Rx dipole length = 25 m
Inversion control parameters:
ResSmth=0.5, dpW=0.1, dxW=1, dzW=1
White contours show Sensitivity
SA Water
Nepabunna Line 5450 N
Non Static Corrected Data
1D Smooth-Model Inversion
Scalar CSAMT/NSAMT Data
AUTHOR
DRAWN
DATE
SCALE
REPORT


Inversion Model Resistivity (ohm-m)
West
East
Nepabunna
Line 5180 N
Elevation (m)
(ohm-m)
Observed TM-Mode Apparent Resistivity (ohm-m)
Frequency (hertz)
Calculated TM-Mode Apparent Resistivity (ohm-m)
Survey Parameters:
Bipole Source Scalar AMT data
Tx length = 1700 m, azimuth = 90
Tx center easting=11450, northing=5200
Rx dipole length = 25 m
Inversion control parameters:
ResSmth=0.5, dpW=0.1, dxW=1, dzW=1
White contours show Sensitivity
Observed TM-Mode Impedance Phase Data (mrad)
(mrad)
Calculated TM-Mode Impedance Phase Data (mrad)
0m
50m
100m
150m
200m
SA Water
Nepabunna Line 5180 N
Non Static Corrected Data
1D Smooth-Model Inversion
Scalar CSAMT/NSAMT Data
AUTHOR
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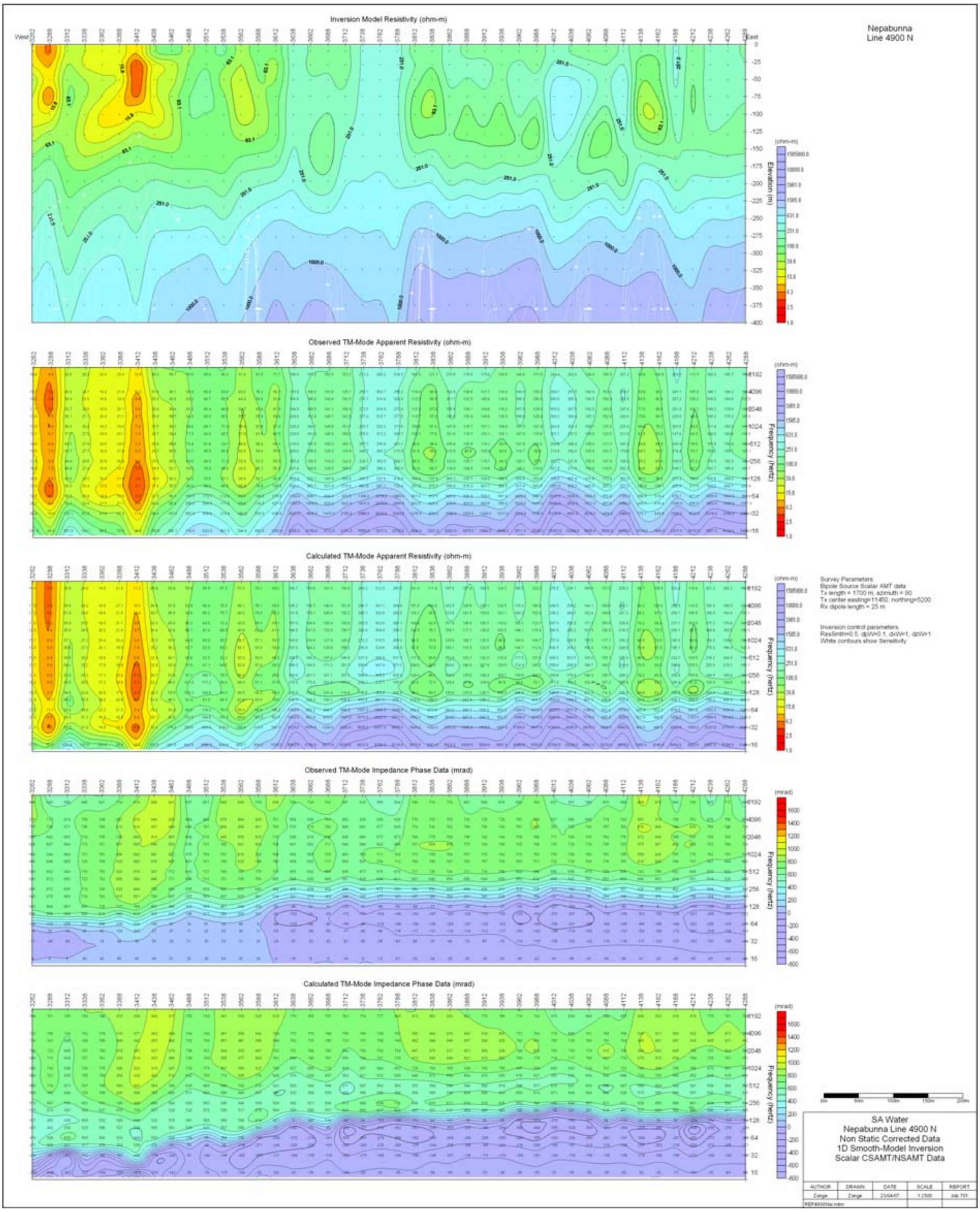

Inversion Model Resistivity (ohm-m)
Observed TM-Mode Apparent Resistivity (ohm-m)
Calculated TM-Mode Apparent Resistivity (ohm-m)
Observed TM-Mode Impedance Phase Data (mrad)
Calculated TM-Mode Impedance Phase Data (mrad)
Nepabunna
Line 4900 N
Survey Parameters:
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Rx dipole length = 25 m
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White contours show Sensitivity
SA Water
Nepabunna Line 4900 N
Non Static Corrected Data
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AUTHOR
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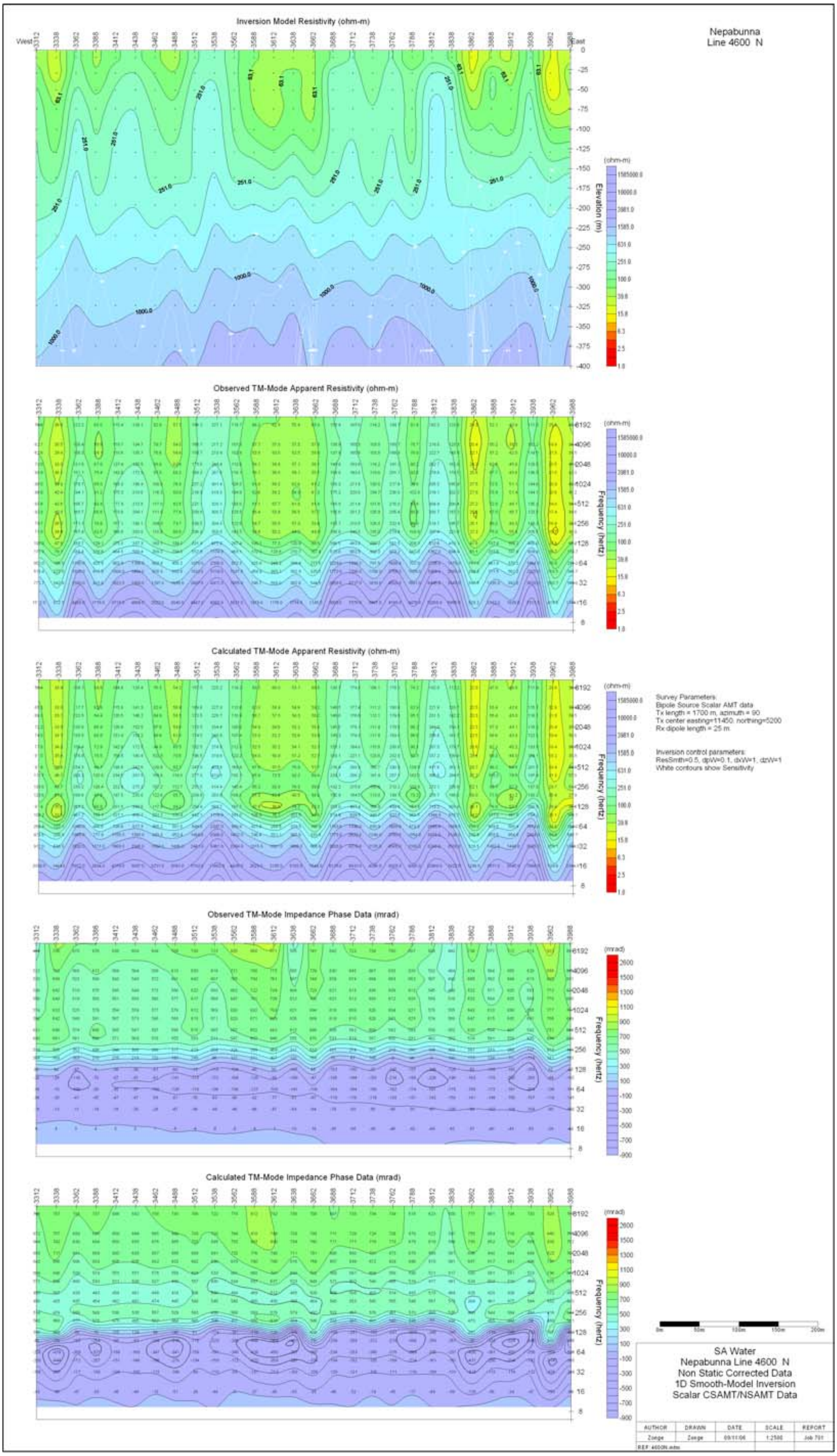
Inversion Model Resistivity (ohm-m)
Nepabunna
Line 4600 N
West
East
Elevation (m)
Observed TM-Mode Apparent Resistivity (ohm-m)
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Observed TM-Mode Impedance Phase Data (mrad)
Calculated TM-Mode Impedance Phase Data (mrad)
SA Water
Nepabunna Line 4600 N
Non Static Corrected Data
1D Smooth-Model Inversion
Scalar CSAMT/NSAMT Data
AUTHOR
DRAWN
DATE
SCALE
REPORT
Zonge
Zonge
09/11/06
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Job 701
REF: 4600N.mtm

UNITS OF MEASUREMENT

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

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

Shortened forms

~	approximately equal to
EC	electrical conductivity (µS/cm)
L/s	litres per second
mg/L	milligrams per litre
TDS	total dissolved solids (mg/L)

GLOSSARY

AHD — Australian Height Datum. The datum used for the determination of elevations in Australia. Zero AHD = mean sea level.

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

Aquifer test — A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resources available for development from the well

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

Datum — The reference point from which elevations are measured.

DTW — Depth to Water. The distance, in metres, from the reference point to the water-table.

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia)

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

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

Ground elevation — The elevation of the ground surface above the datum. Units are in mAHD. Sometimes referred to as the natural surface (NS).

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers; see also 'hydrology'

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

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

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

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

Permeability — A measure of the ease with which water flows through an aquifer or aquitard, measured in m^2/d

Potable water — Water suitable for human consumption such as drinking or cooking water

Reference elevation — The elevation of the reference point above the datum. Units are in mAHD. It is calculated by subtracting the DTW from the reference elevation.

Reference Point — The point from where the DTW is measured.

Rx — Receiver

SWL — Standing Water Level. The distance, in metres, from the ground surface to the water-table. It is calculated by subtracting from the DTW the difference of the reference and ground elevations.

TDS — Total dissolved solids (mg/L)

Tx — Transmiter

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

Well — (1) An opening in the ground excavated for the purpose of obtaining access to underground water. (2) An opening in the ground excavated for some other purpose but that gives access to underground water. (3) A natural opening in the ground that gives access to underground water

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