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Aquifer identification and characterisation for salinity control by shallow groundwater pumping: A case study of the Coleambally Irrigation Area

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Coleambally IRRIGATION

ACIAR The Australian Centre for International Agricultural Research

CSIRO Land and Water, Griffith NSW
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Summary

This report describes a pilot study undertaken to identify and characterise aquifers in the Riverine plain for salinity control by shallow groundwater pumping (<15m). In the Riverine plain the shallow aquifers are paleo channels (prior streams) surrounded by heavy clays and loams, these aquifers were found to be generally small in spatial extent and may be overlain with heavy clays. Aquifers ranged from 2-9m in thickness and occurred at 0 to 14m deep.

A methodology for identifying the potential presence of shallow aquifers was developed. Potential areas for shallow groundwater pumping were identified in southern Coleambally using soil survey data and bore log data. Soils data showed that there is a strong association between Cobram sandy loam and the presence of prior streams. Other soils that were found to have associations with shallow aquifers were Yamma loam, Coree clay loam, Danberry sand and Marah loam. There were also soils identified that were unlikely to show the presence of aquifers, these were Willbriggie clay, Yooroobla clay and Wunnamurra clay.

The use of the EM34 instrument for specific site investigations to assess the presence and extent of aquifer material was investigated. Typical EM readings obtained where sand was present were less than 110mS/m. Readings of more than 140mS/m were found to have little or no sand and therefore can be used to delineate areas with little likelihood of having suitable shallow aquifers for groundwater pumping. Readings between 110mS/m and 140mS/m indicate a possible presence of aquifer material.

Pump tests from previous studies the area showed that shallow groundwater pumping should be feasible. These aquifers were 4 to 7m thick and at pumping rates of 260 to 630m^3/day had drawdowns in the range of 0.4 to 1m at distances of 10 to 2400m from the pump after 4 to 8 hours of pumping. Overall, limited shallow groundwater pumping from these aquifers is possible, however how the impact of overlying clay on watertable response is not well known.

Aquifers suitable for shallow groundwater pumping for salinity control were not found in all areas so other drainage methods need to be investigated for these areas.

There is also the issue of managing drainage disposal. This non uniform distribution of aquifers and need for drainage disposal management indicates that regional planning is required before implementing shallow groundwater pumping for salinity control.

Acknowledgements

We acknowledge funding from Coleambally Irrigation Cooperative Ltd. and The Australian Centre for International Agricultural Research. The help and co-operation of Coleambally Irrigation Cooperative Ltd., Mr. Arun Tiwari and Mr. Don Murray in making available data and reference material is highly appreciated.

Table of Contents

List of Figures

List of Tables

1 Introduction

The subject of this report is to provide a process for identifying potential sites for shallow ground water pumping for salinity control within the Coleambally Irrigation Area (CIA). In September 2000, there was a large area of Coleambally with a water table within 1.5 metres of the land surface (Murray 2001). Soil and groundwater salinity has been surveyed and identified as a problem within the region (Murray 2001); therefore, it is important to investigate the possibility of groundwater pumping within the CIA.

The Riverine plain, in which the CIA is situated, is underlain by unconsolidated tertiary and quaternary sediments. These sediments can be divided into three main formations (Figure 1), the deepest being the Renmark or Olney formation from a depth of approximately 130-180m, This is overlain by the Calivil formation, starting at approximately 80 depth and the third formation is the Shepparton formation comprising of surface sediments down to approximately 80 metres. For the convenience of computation of net recharge targets the Shepparton formation has been arbitrarily further subdivided into two layers (Enever 1999), the upper layer is known as the Upper Shepparton (US), this makes up approximately the top 20 metres of the formation and the lower layer is known as the Lower Shepparton (LS). The Shepparton formation generally consists of clays and silty clays interspersed with winding sandy belts, these being the prior stream formations.

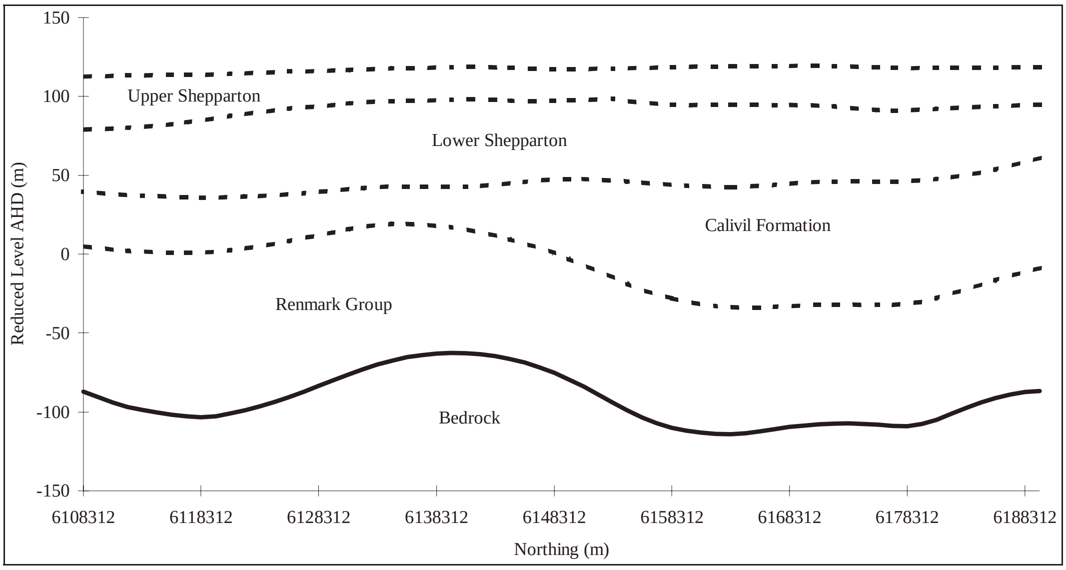

Figure 1. North to south transect through easting 396348(m)

2 Objectives

2.1 Mapping where aquifers lie

At present shallow aquifers are not mapped in detail in the Riverine Plain so there is no guidance as to the possible areas for pumping. Thus, there is a need to derive a methodology to assist in general identification and mapping of shallow aquifers for ground water pumping. This methodology should provide preliminary information regarding the presence of suitable aquifers that can then be further investigated by hydrogeological explorations.

2.2 Characterisation of aquifers

Apart from locating aquifers, it is necessary to understand the characteristics of the aquifers i.e., hydraulic properties, storages, thickness, and the depth at which they occur and lateral extent. This is necessary to gauge suitability for pumping and sustainability in the long term.

3 Part 1: regional assessment of potential shallow groundwater pumping areas

3.1 Aquifers

When trying to lower the watertable in an area by shallow ground water pumping it is necessary to locate aquifers in order to pump water from them. An aquifer can be defined as a saturated permeable geological formation that can store and transmit water at rates fast enough to supply reasonable amounts to pumping wells. In the Riverine Plain, unconsolidated sands and gravels are the most common materials that are classed as aquifers, these are the prior stream formations. In the Riverine Plain the shallow aquifers systems are more restricted in occurrence than the deep aquifers. They consist of coarse sediments deposited by prior streams. These aquifers can exist at any depth. The aquifers are sands, interbedded with confining layers (aquitards).

An aquitard is a geological unit of low permeability. It is permeable enough to transmit water slowly, however it will not transmit enough water at a reasonable rate to justify pumping from it. In the Riverine Plain, typical aquitards are clays and loams that are present above and below the prior stream aquifers.

There are three main types of aquifers; unconfined, confined and leaky.

An unconfined, or water table, aquifer is the closest to the land surface. They are not restricted by any confining layer above them and are bounded below by an aquiclude. This type of aquifer describes much of the Shepparton, from which shallow groundwater pumping will occur.

A confined aquifer is overlain and underlain by an aquiclude. The Renmark/Calivil and prior stream formations are not confined aquifers. These are actually leaky or semi-confined aquifers.

When selecting aquifers it is important to identify the properties suitable for shallow ground water pumping. The ideal properties of an aquifer for this are:

The aquifer should be shallow, preferably up to 8m deep for spear point pumping but up to 15m from the land surface is suitable if tube wells are used.

The aquifer must have good transmissive properties. Ideally, an aquifer made up of gravel, pebbles or coarse sand. However, as the prior stream formations are not extensive even layers of fine sand, sand/loam or sand/clay mixes may be useful.

The extent of the aquifer is important. The larger the aquifer the better, because when pumped it will have a greater effect in lowering the watertable across a wider area. It will also have a greater storage volume and hence make pumping more efficient.

It is important to assess whether or not the aquifer can sustain pumping over a long period of time and how quickly it recharges itself. From this it may be important to look at possible linkages to other aquifers. If aquifers are linked, there is the possibility of lowering the water table over a larger area.

It is also important to look at the layer overlying the aquifer. The aquifer should be either unconfined or leaky. This will depend upon depth and type of overlying material. A confined aquifer may not be useful, because the overlying layer will not allow for the transmittance of water through it, therefore having no effect on the lowering of the water table.

An important hydraulic parameter of the aquifers is the transmissivity. The transmissivity (T) of a confined aquifer is the hydraulic conductivity (K) multiplied by the thickness (b) of the aquifer. In an unconfined aquifer, the thickness (b) is classed as the vertical distance from the confining layer of the aquifer to the watertable.

3.2 Methods

The southeastern corner of the CIA was chosen as a study area to develop methodologies that can then be applied to the wider area. When trying to locate shallow aquifers it is important to recognise features that may give clues as to their possible location. The main features to look at are prior streams, depressions and sandpits. However, to try to get a clearer picture is also possible to look at surface soils and types of vegetation within the surrounding area. Various investigations were undertaken in order to locate potential aquifers. The technique used was to analyse bore logs for the presence of aquifer material and compare the position of the bores with good aquifer material with the presence of prior streams, sand pits, depressions, soil and vegetation maps. All these features are combined together to provide a picture of the study area.

The bore logs were mapped into a Geological Information System (GIS) together with all aforementioned features.

3.2.1 Bore logs

There are approximately 5000 bores that are identified on maps within and around the CIA; of these there are 1500 piezometers of which 783 are maintained by Coleambally Irrigation Co-operative Ltd (CICL).

Bore logs are kept at CICL and provide information about the types of materials present at each bore. They were created by drillers mainly during the 1950's and 1960's. As the bores were being drilled the material type, texture and colour was noted with depth. The bore logs were used to determine where suitable aquifer sites (prior streams) were at depths of less than 15 metres.

The data retrieved from the bore logs was input into geo-technical computer programs called QuickLog and QuickCross/Fence. These geo-technical programs create bore log, cross sections and fence diagrams. (The co-ordinates of some of the bores were found to be inaccurate, with an error of up to 100 metres).

This data of known aquifer material locations (prior streams) was then compared with various other data sets, in the following sections.

3.2.2 Soil Surveys

Soil surveys of the CIA have been undertaken by CSIRO and the Department of Water Resources (DWR). CSIRO surveyed northern CIA and the DWR surveyed the northwest and southern CIA. These surveys were carried out primarily to assist in the subdivision design of mixed farms (Stannard 1970). The surveys were used to ascertain whether the soils have any correlation with aquifer material laid down by prior streams.

The surveys show there are a number of soils that are associated with prior streams in which it would be expected to find sand and gravels for shallow groundwater pumping, Figure 2.

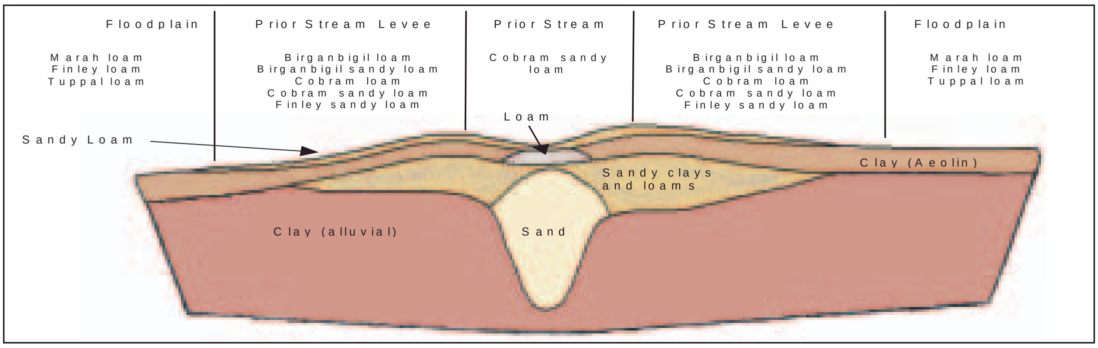

Figure 2. Location of soils with respect to a prior stream

Although these soils have associations with prior streams, it does not necessarily mean that they have underlying suitable aquifer material. However, knowing which soils do have these associations may provide an indication of where prior streams may lie.

Table 1 shows soil types that are found in the CIA associated with prior streams and depressions, for a detailed description and a typical profile of each see Stannard (1970).

SOIL TYPE	ABBREVIATION	ASSOCIATIONS	DESCRIPTION
Birganbigil Loam	B^g/L	Prior stream Levees	Heavy clay subsoil
Birganbigil Sandy Loam	B^g/SL	Prior stream Levees	Heavy clay subsoil
Bundure Loam	B^u	Depressions and prior stream courses	Becomes sandy with depth
Cobram Loam	C^o/L	Levee crests of prior streams	Becomes slightly sandy with depth, with a possible heavy clay layer
Cobram Sandy Loam	C^o/SL	Levee crests of prior streams	Becomes sandy with depth
Coree Loam	C^e/L	Depressions in the plain	Heavy clay subsoil, remaining of heavy texture to depth
Coree Clay Loam	C^e/CL	Depressions in the plain	Heavy clay subsoil, remaining of heavy texture to depth
Finley Loam	F^i/L	Prior streams	Becomes slightly sandy with depth, with a possible heavy clay layer
Finley Sandy Loam	F^i/SL	Crests of levees of prior streams	Slightly sandy at depth
Marah Loam	M^r	Occurs over broad areas near prior streams	Deep subsoil is of lighter texture
Tuppal Loam	T^p	Prior streams	Similar to Birganbigil loam
Yamma Loam	Y^a	Depressions close to prior streams	Similar to Marah loam

Table 1. Types of soils associated with prior streams and depressions

Locating these particular soils using the GIS ArcView program shows areas of major prior stream activity. Once these areas were located, the known positions of piezometers were overlayed onto the soils map. Piezometers overlapping soils that have associations with prior streams were then identified and their bore logs examined for suitable aquifer materials.

3.2.3 Prior Streams

Prior streams are important features when trying to locate suitable aquifer materials, due to their strong associations with permeable materials, i.e., sand, gravel and pebbles. Prior streams occur throughout the region and can appear as continuous or discontinuous features. Continuous prior streams are usually recognisable by their long winding features and by their channel and levee features. In the CIA, there is a system of continuous prior streams running in a general east to southwest direction. These were identified and mapped by Stannard (1970). These were digitised from a map that Stannard (1970) produced. The prior stream map was improved using the digitised surface soils data, by following the Cobram sandy loam to map the continuous prior streams. The original and new prior stream maps can be seen in Figure 3 and Figure 4.

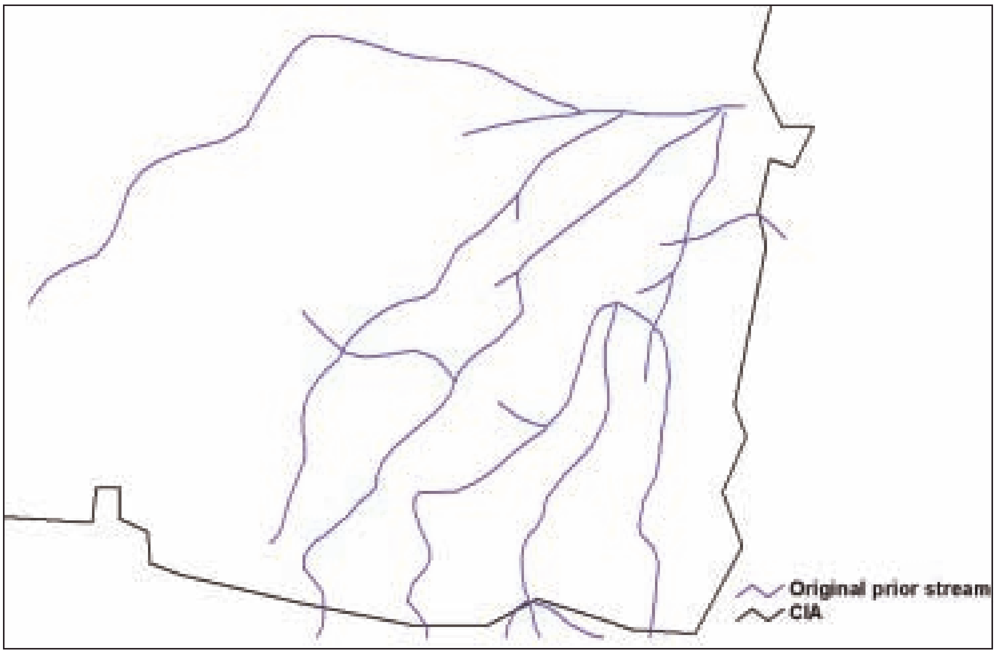

Figure 3. Original prior stream map (Stannard 1970)

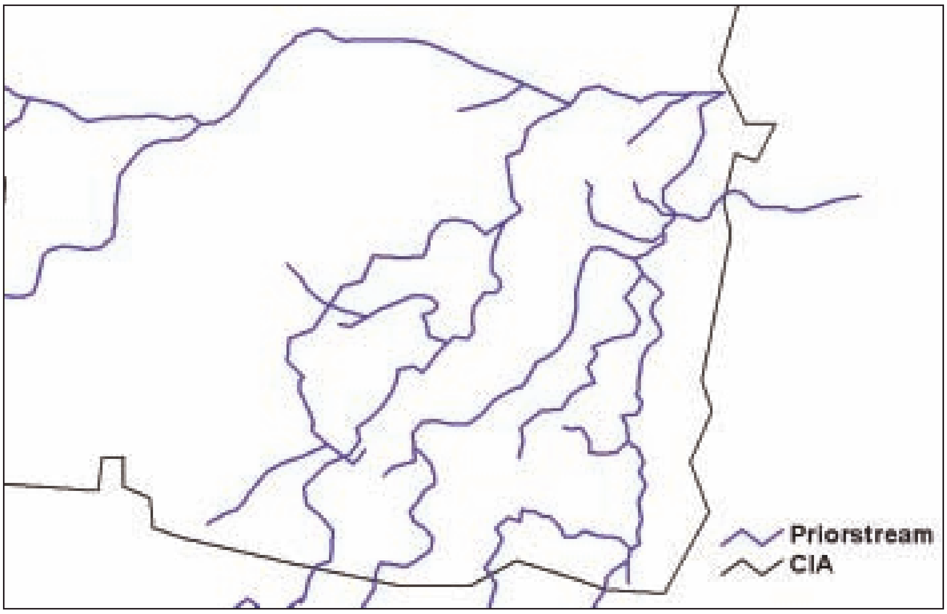

Figure 4. New prior stream map derived from soils map

By overlaying the position of the piezometers onto the prior stream map, it was possible to see where they intercept. The intercepting piezometers were then identified and their bore logs examined for suitable depths of sand and/or gravel.

3.2.4 Sand Pits

Sandpits are closely associated with prior streams as they are generally located on levee crests, areas that have a high sand content. Over the years, these areas have been identified and the sand has been excavated for use in construction. These areas are of interest, because they have strong associations with prior streams.

The sand pits in the area were mapped into ArcView using data provided by CICL. A report into the health of depressions was produced by Arthur Read (2000); in this report, the locations of all sand pits in the area were identified by Global Positioning System. The positions of the sandpits are shown in Figure 5.

Figure 5. Location of sand pits within the study area

3.2.5 Depression Maps

Depressions are a common feature of the CIA. They appear in two main forms, these being linear or circular depressions. Linear depressions tend to lie along natural drainage lines; they can also have been formed by prior streams. Little is known how a circular depression is formed, possibly from small surface irregularities that cause water to pool, (Read 2000).

Depressions are low-lying areas, therefore it is envisaged that there was water present in these areas some time in the past, thus there may be sandy layers deposited at some depth within the depressions. Bores located in and around depressions were analysed for the presence of permeable aquifer materials, Figure 6.

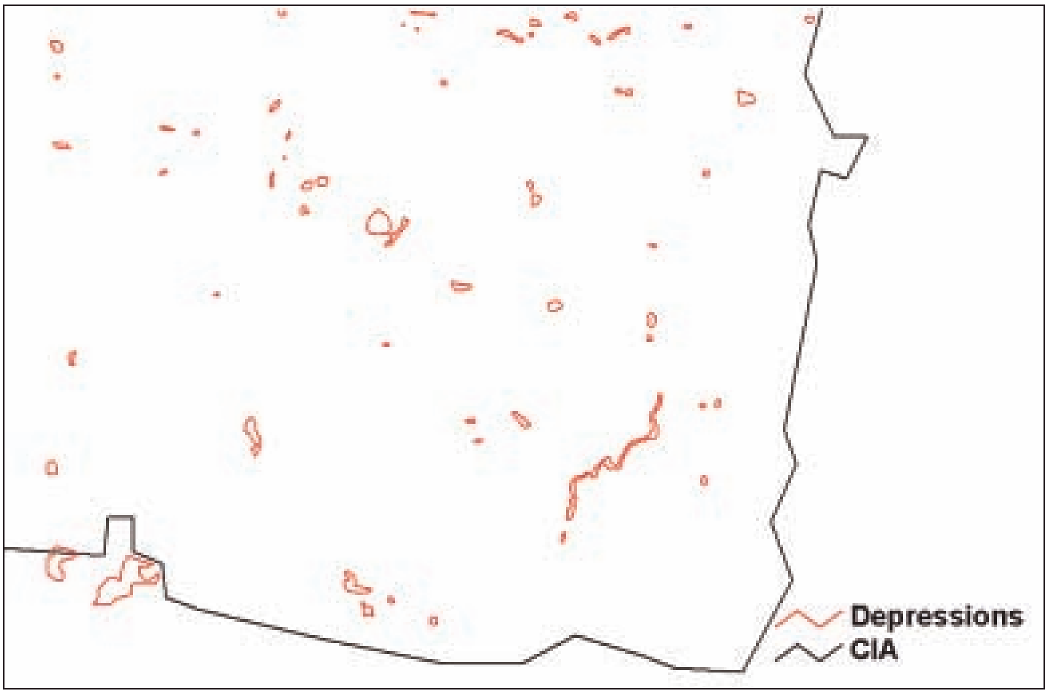

Figure 6. Location of depressions within the study area

3.2.6 Vegetation

Vegetation type can be used as an indicator of the texture of surface and subsurface soil, Figure 7 shows the vegetation map used.

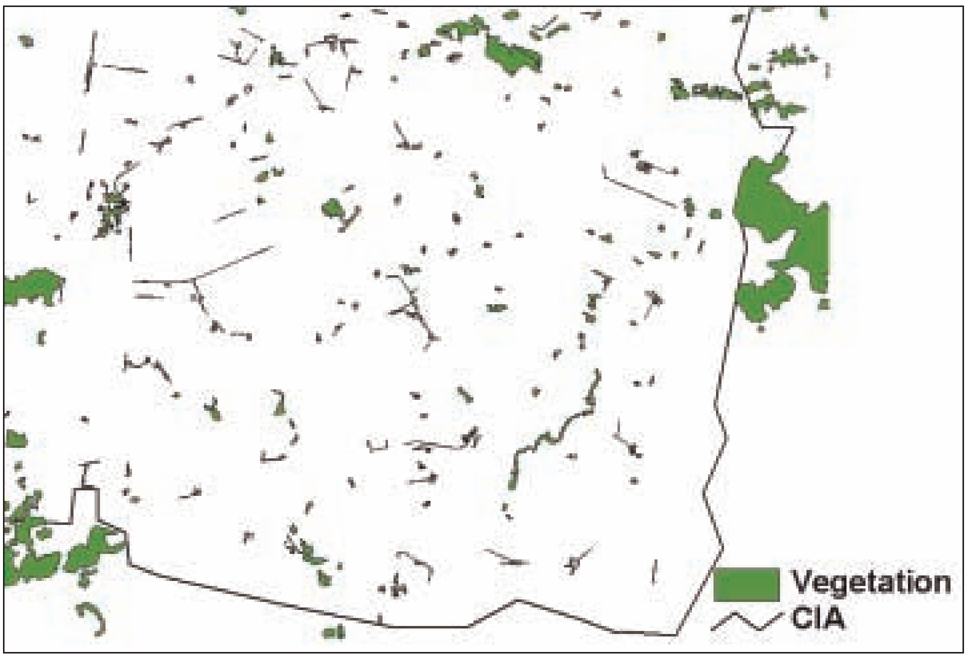

Figure 7. Location of Calytris pine and Black box vegetation in the CIA

Certain types of vegetation will grow in well-drained areas, whereas other types are more tolerant of wetter conditions. A number of trees and shrubs have associations with prior streams, the main and easily recognisable one being the Calytris pine tree. This is because it prefers to grow in well-drained areas. Black Box and Red Gum trees are associated with depressions.

3.3 Results

When identifying potential aquifers the surface soil, prior stream, depression and sand pit data together with the position of the bores were combined in GIS. This made identifying bores that lie along these features easier as all the information was incorporated in one layer.

After analysing the map, 188 bores were identified for investigation within the study area. They were generally located along or near prior streams, depressions and sand pits. However, bores in areas away from known prior streams, depressions and sand pits were investigated to check that there was no presence of permeable material in other areas. The bore logs were checked to ascertain whether there were significant (> 2 m of sand) permeable aquifer materials at shallow depth. Figure 8 shows the locations of the bores whose bore logs were used, a listing is provided in appendix 1

Any bore log that showed a depth of more than two metres of aquifer type material, coarse sand or gravel, were taken as possible sites for shallow pumping. Of the 188 bore logs that were examined, 72 showed possible useful aquifers.

Data for the depth to and thickness of the shallow aquifers were analysed for any correlation, (Figure 9).

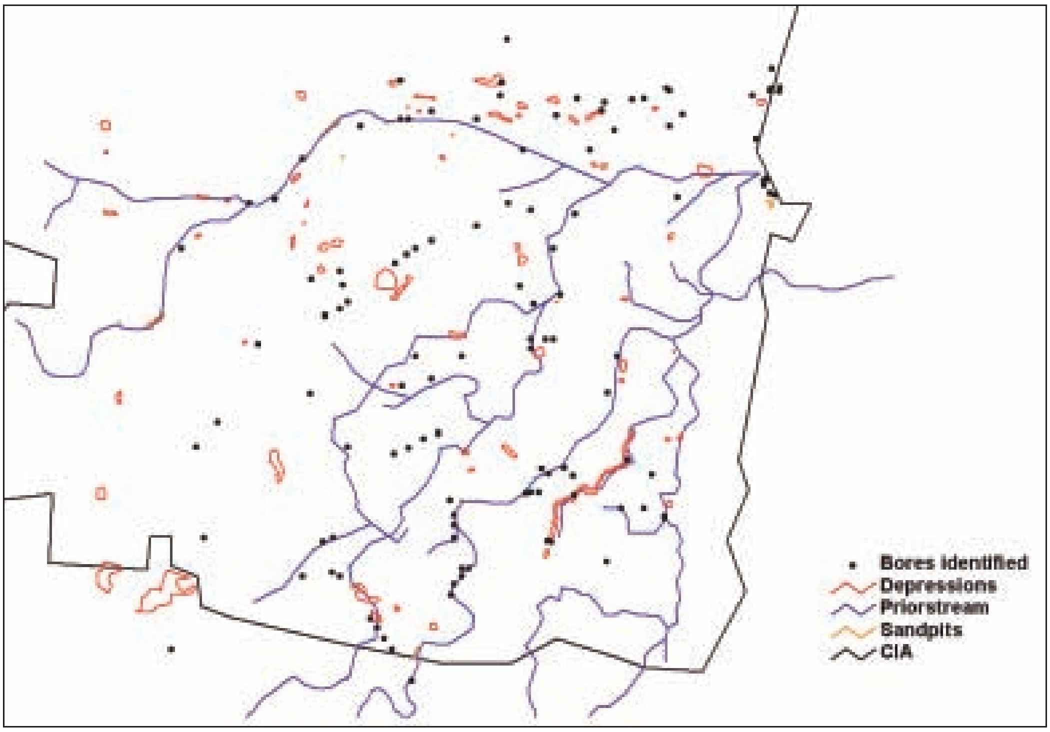

Figure 8. Location of bores used in study

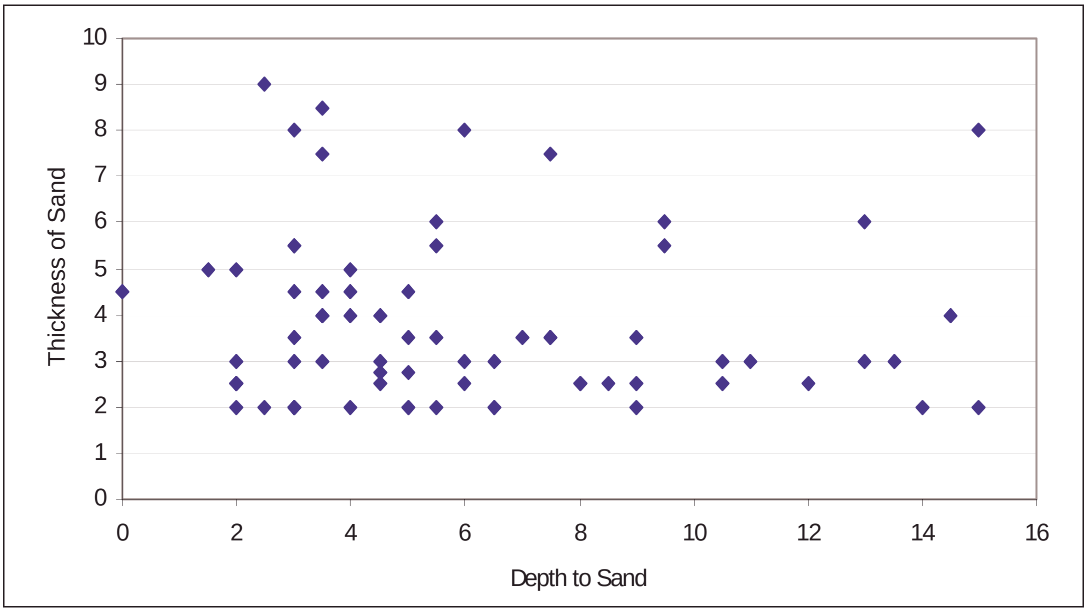

Figure 9. Depth to sand and thickness of sand layers in bores where >2m of sand was found

The data shows that aquifer material can occur at any depth in the top 15 metres and is of highly variable thickness. The maximum thickness of sand found was 9m, this occurred 2.5m from the soil surface and was situated in a prior stream. The average thickness of sand for the bores that showed 2m or more sand was 3.7m and the average depth to the sand was 5.8m. The bulk of bores with good thickness of sand struck sand at less than 10m deep. For pumping to be effective the overlying clay must not act as an aquitard, otherwise pumping may have little effect in lowering watertables.

3.3.1 Surface soils data

The surface soils data was compared to the bore log data. The percentage of bores with a suitable thickness of aquifer material in each soil type is shown in

Table 2. Figure 10 shows the frequency distribution of bores that had suitable aquifer material for each soil type.

Soil Type	Percentage of bores with > 2 m thickness of sand
Yamma loam (Ya)*	100
Cobram sandy loam (Co/SL0	91
Corree clay loam (Ce)	78
Danberry sand (Dy)*	67
Marah loam (Mr)	50
Tuppal loam (Tp)*	50
Birganbigil clay (Bg)	25
Willbriggie clay (We)	23
Cobram loam (Co/L)	20
Yooroobla clay (Yoo)*	20
Wunnamurra clay (Wm)*	0
Te*	0
Riverina clay (Ra)*	0

Table 2. Percentage of bores with suitable aquifer material in each soil

* Only a small amount of data for these soils

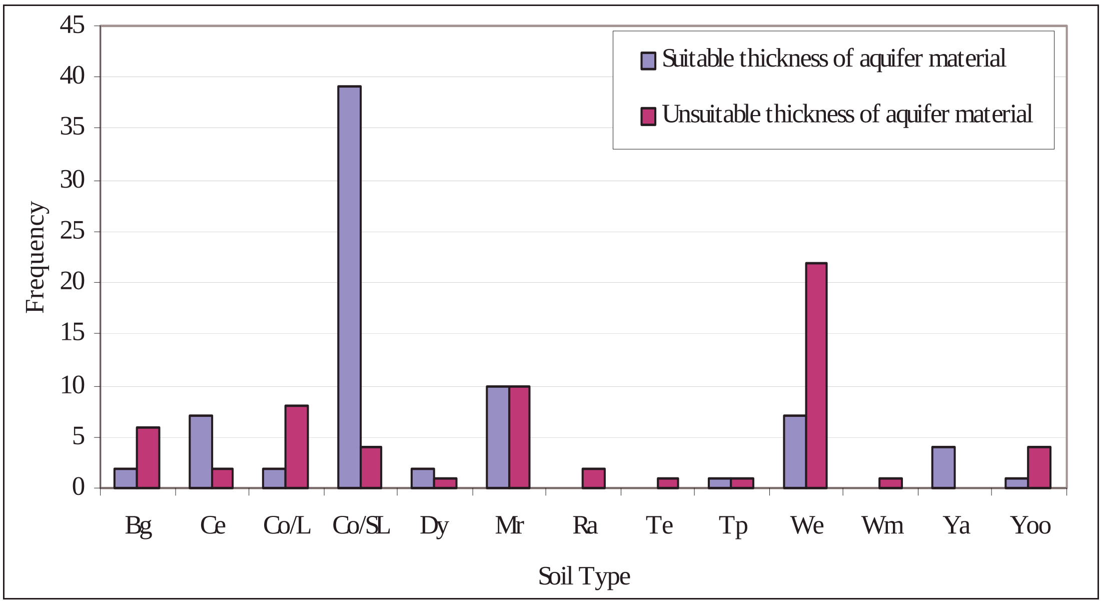

Figure 10. Bores in each soil type

It would appear from Table 2 and Figure 10 that the most likely soils that potential aquifers can be found in are Yamma loam (Ya) and Cobram sandy loam. Both of these soil types have strong associations with prior stream courses and are also found around depressions. Yamma loam and Cobram sandy loam has strong associations with a sandy subsoil, this is in agreement with the description by Stannard (1970).
Table 3 shows the thickness and depth to sand for the different soil types.

Soil type	Average thickness of sand (m)	Average depth to sand (m)
Dy*	5.3	6.3
Co/SL	4.3	5.3
Mr	3.5	5.4
We	3.1	9.1
Ya*	3.0	2.8
Ce	2.8	6.9
Bg	2.5	5.3
Co/L	2.3	13.5
Tp*	2.0	3.0
Yoo*	2.0	2.0

Table 3. Average thickness and depth to sand

* Only a small amount of data for these soils

This data shows that the bores situated in Yamma loam have an average thickness of sand of 3m occurring at an average depth of 2.8m from the surface. The bores situated in Cobram sandy loam showed that coarse sand occurred at an average depth of 5.3m and the average thickness of coarse sand was 4.3m. Therefore, aquifers found in these two soil types have the potential to be pumped, as the coarse sand is found at shallow depths (< 6m) with good thickness (between 2m and 5m thick)

Coree clay loam (Ce) and Danberry sand (Dy) are also areas where aquifers may be present, although the correlation is not as strong as Yamma and Cobram Sandy Loam. Although Coree clay loam is associated with depressions, Stannard (1970) states that it is associated with the Willbriggie clay series and therefore it is generally the case to find heavy clay subsoils in the profile of Coree clay loam.

Table 3 shows that the bores found in Coree clay loam have an average depth to coarse sand of 6.9m and an average thickness of coarse sand of 2.8m. The bores found in Danberry sand have an average thickness of sand of 5.3m occurring at an average depth of 6.3m. As before, the potential of pumping from aquifers found in Coree clay loam and Danberry sand is very good as the average depth to the sand in these soils was found to be less than 7m, making it suitable to install spear point pumps and the average thickness of the sand varies from 2.8m to 5.3m. Danberry sand occurs on level land adjacent to and in between sand hills. It is associated with having cemented sandy subsoil (Stannard 1970).

Marah loam (Mr) and Tuppal loam (Tp) are wide spread in the southern region of the study area. They occur over broad areas associated with prior streams (Stannard 1970). This is probably the reason why only 50% of the bores located in these soils have suitable depths of aquifer material. From Table 3 it can be seen that where coarse sand was found the average thickness varied from 3.5m (Marah loam) to 2m (Tuppal loam) and the average depth to the coarse sand varied from 5.4m (Marah loam) to 3m (Tuppal loam). There is still the potential to install spear point pumps aquifers found in these soils, but consideration must be given to the conductivity of the overlying material.

Birganbigil clay, Willbriggie clay, Yooroobla clay and Cobram loam are soils in which aquifer material is found but not in great amounts. Only 25% of all bores found in these soils showed any suitable aquifer material. Apart from Cobram loam, these soils are associated with having heavy clay subsoils. Cobram loam is associated with prior streams and levees. The subsoil of Cobram loam becomes slightly sandy with depth with a possible heavy clay layer.

Table 3 shows that the average depth to sand in these soils varies greatly from 2m (Yooroobla clay) to 13.5m (Cobram loam), the thickness of the sand varies from 2m (Yooroobla clay) to 3.1m (Willbriggie clay). However, due to the depth that some of the coarse sand occurs it is uncertain what effect that pumping will have on watertables due to the thick overlying heavy clay layers.

Wunnamurra clay (Wm) and Riverina clay (Ra) all have weak associations with aquifer materials. This was expected, as their profiles possess heavy clay at depth, hence no bores with sand were found in these soils. Figure 11 shows the soils that have been identified as possible areas where potential aquifers may be found; these being Yamma loam, Cobram sandy loam, Coree clay loam, Danberry sand, Marah loam and Tuppal loam.

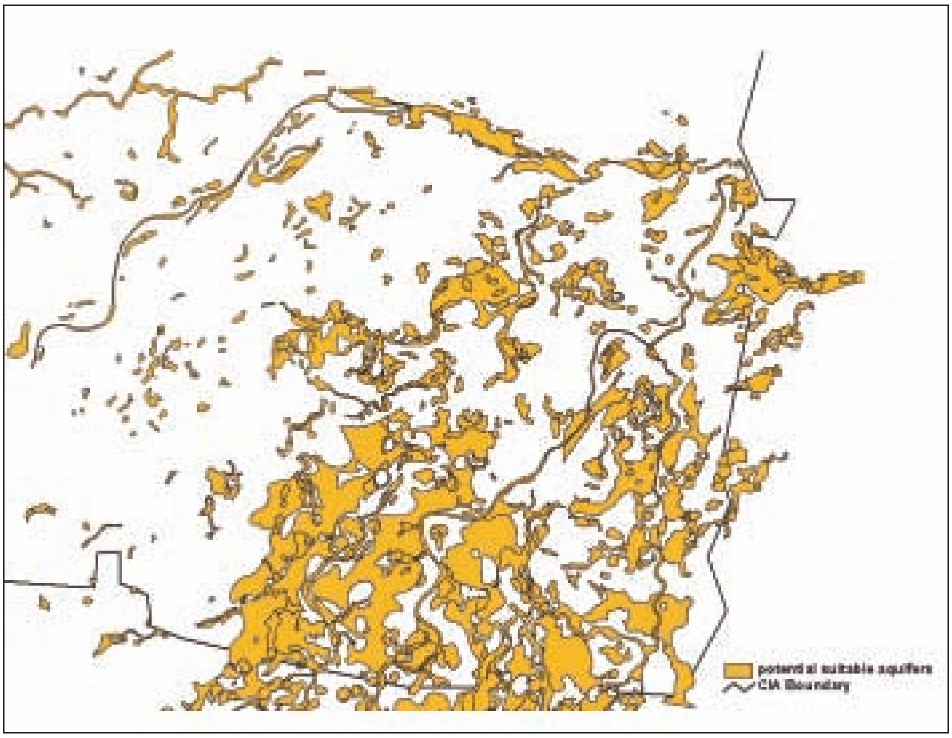

Figure 11. Areas, which have soils, identified as those that may be underlain with suitable aquifers for pumping

3.3.2 Prior Stream Maps

The GIS mapped data indicated that 36 bores lay directly along known prior streams, of which 21 showed possible aquifers present. The thickness of aquifer material varied from nil to 9m, Figure 12, with the average thickness being 3m. This average depth is influenced by the fact that of the 36 bores, 15 showed a thickness of aquifer material from nil to 1m. It is possible that these bores are actually some way away from the prior stream, hence the reason why no sand was present. The average thickness of the aquifer material, disregarding the bores with little or no aquifer material present, is 4.8m.

The depth to the sand found in and around prior streams varied from 1 – 13 metres with the average depth being 5.8m, Figure 13. The aquifer material found in the prior streams was mainly coarse sand and gravel with occasional pebbles.

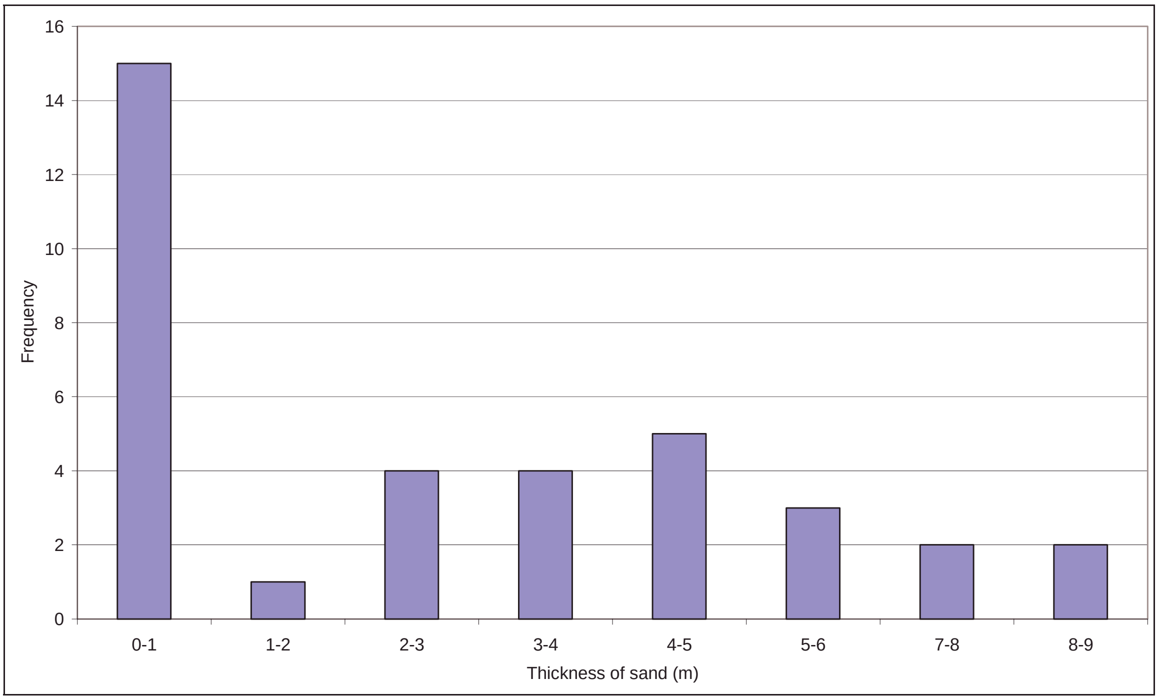

Figure 12. Thickness of sand for bores found at prior stream

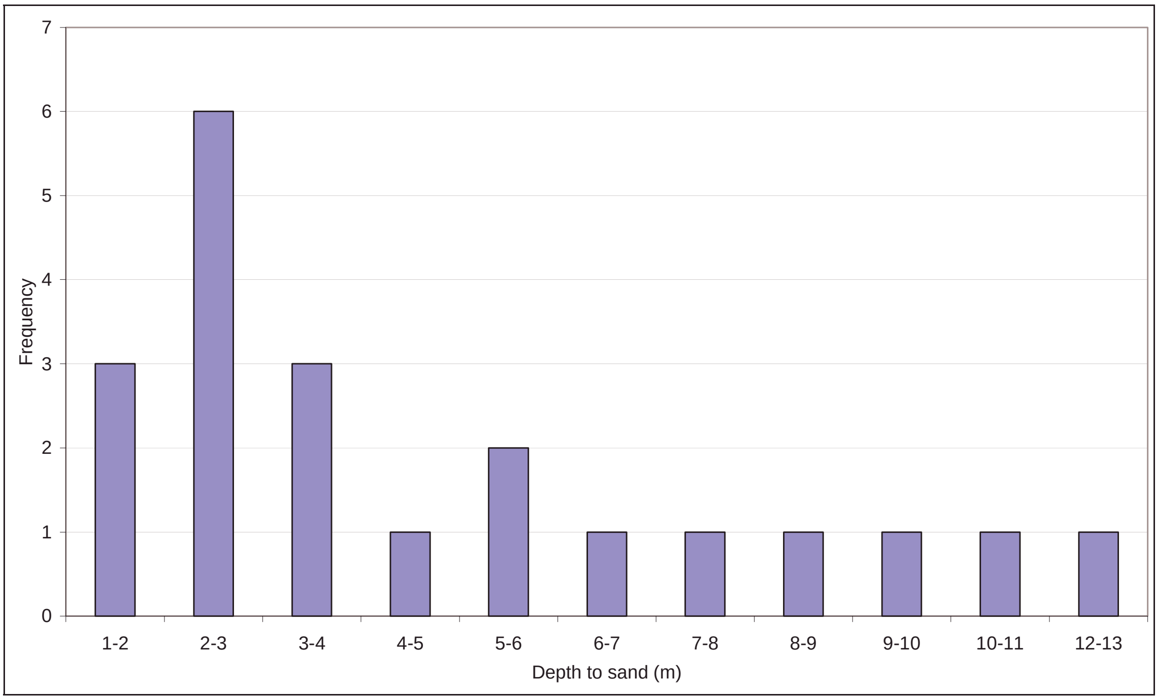

Figure 13. Depth to sand for bores found at prior streams

A typical cross section through a prior stream is shown in Figure 14.

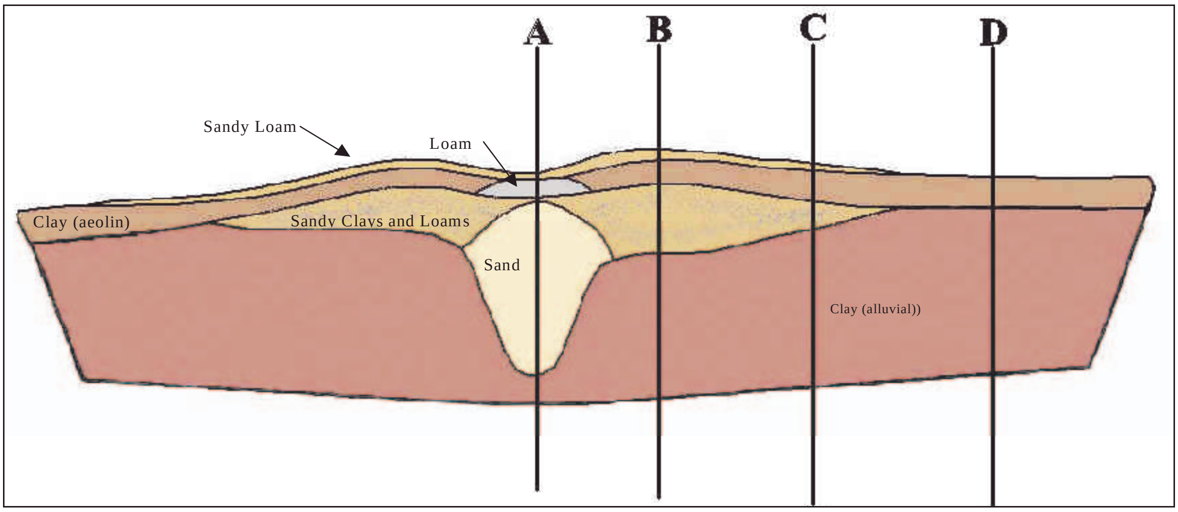

Figure 14. Cross section through a typical prior stream

Four bores have been identified that correlate best to positions A, B, C and D shown in Figure 15-18. Bore log 5430 (Figure 15) is situated in Co/SL directly in the prior stream channel, the depth to the sand is 2.5m and the thickness of sand is 9m. This was identified from the maps created using ArcView, this bore correlates well with position A in Figure 14. Bore 12234 (Figure 16) has the characteristics associated with the near levee of the prior stream; position B. There was only 4m of partly sandy material present. It was situated in a Marah loam. Bore 12652 (Figure 17) is situated along the far levee of the prior stream, position C, and has 8m of partly sandy material present. It is located in a Cobram loam soil. Cobram loam soils have associations with prior stream levees. Bore 4960 (Figure 18) is situated in the floodplain of the prior stream. Only heavy clays were found at this site, this correlates well with the cross section of the prior stream. These bore logs have been joined together to illustrate a cross section of a prior stream from the bore logs, Figure 19. It can be seen that there are similarities to Figure 14, there is a large sand mass in the centre of the prior stream and as you get further from the centre the material becomes partly sandy and then more clayey. Interestingly the sand in the bed of the prior stream may have clay separating it from the partly sandy material adjacent to it. However, this may only occur due to the particular selection of bore logs.

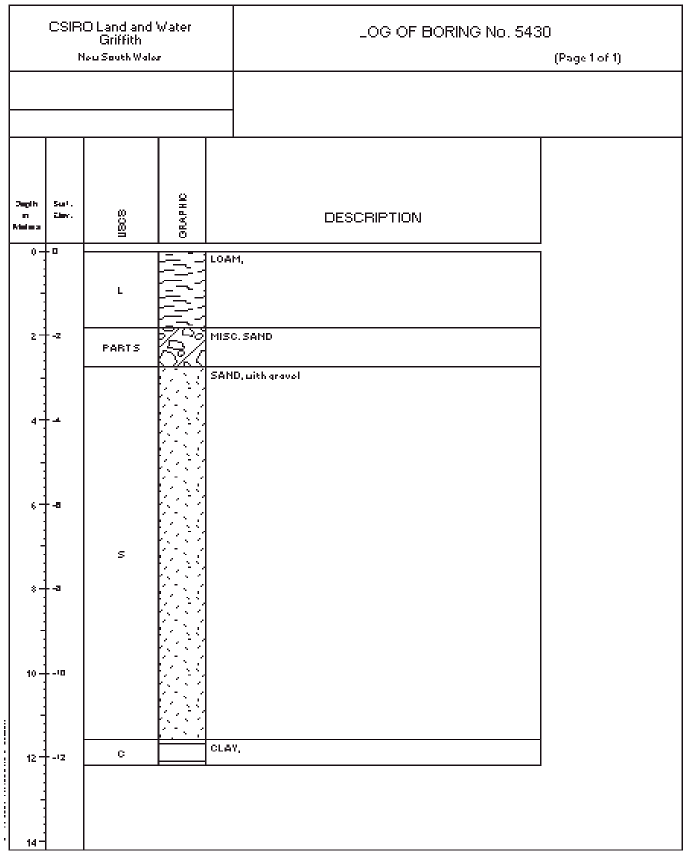

Figure 15. Profile of bore 5430, position A on figure 13

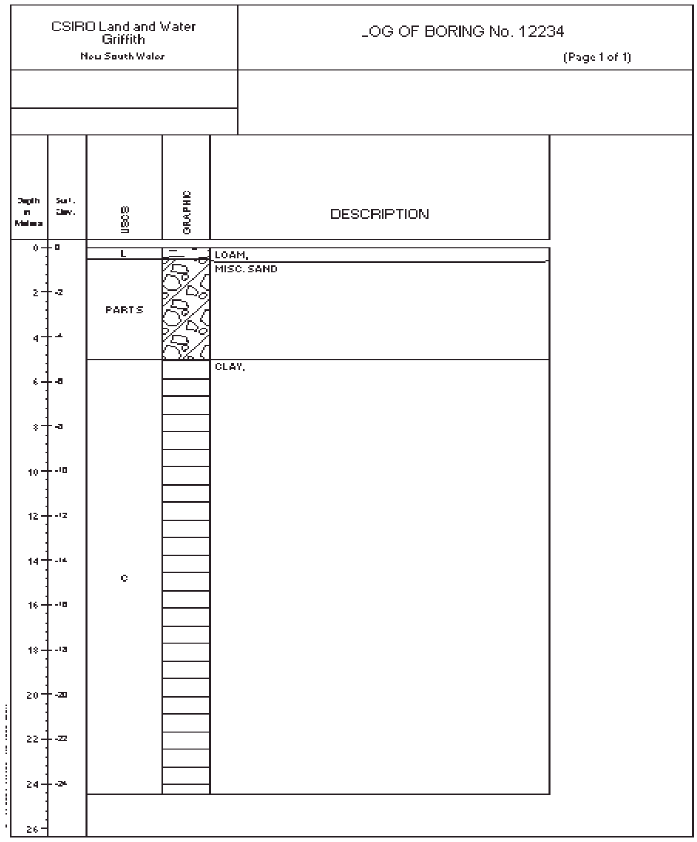

Figure 16. Profile of bore 12234, position B on figure 13

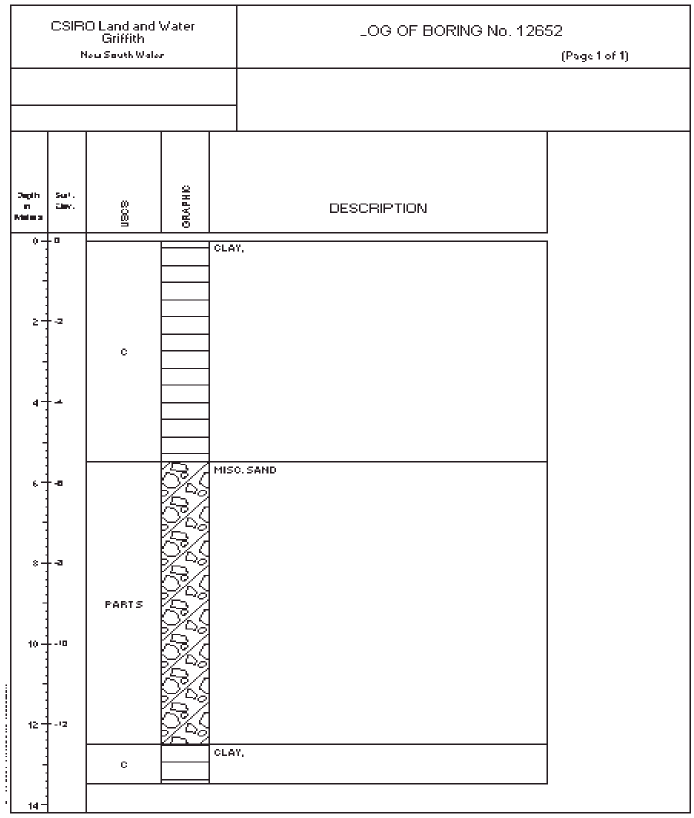

Figure 17. Profile of bore 12652, position C on figure 13

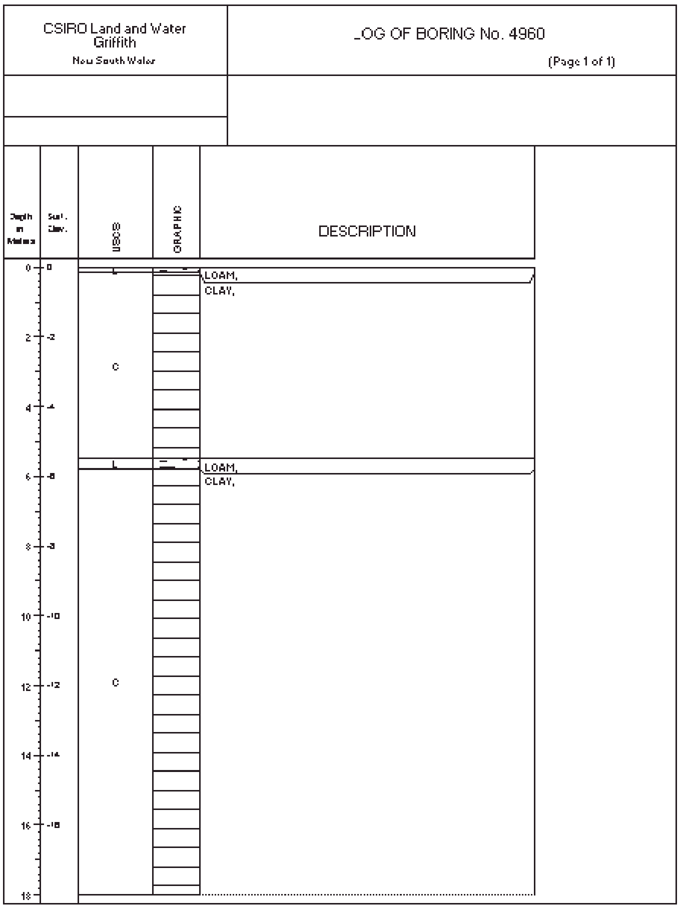

Figure 18. Profile of bore 4960, position D on figure 13

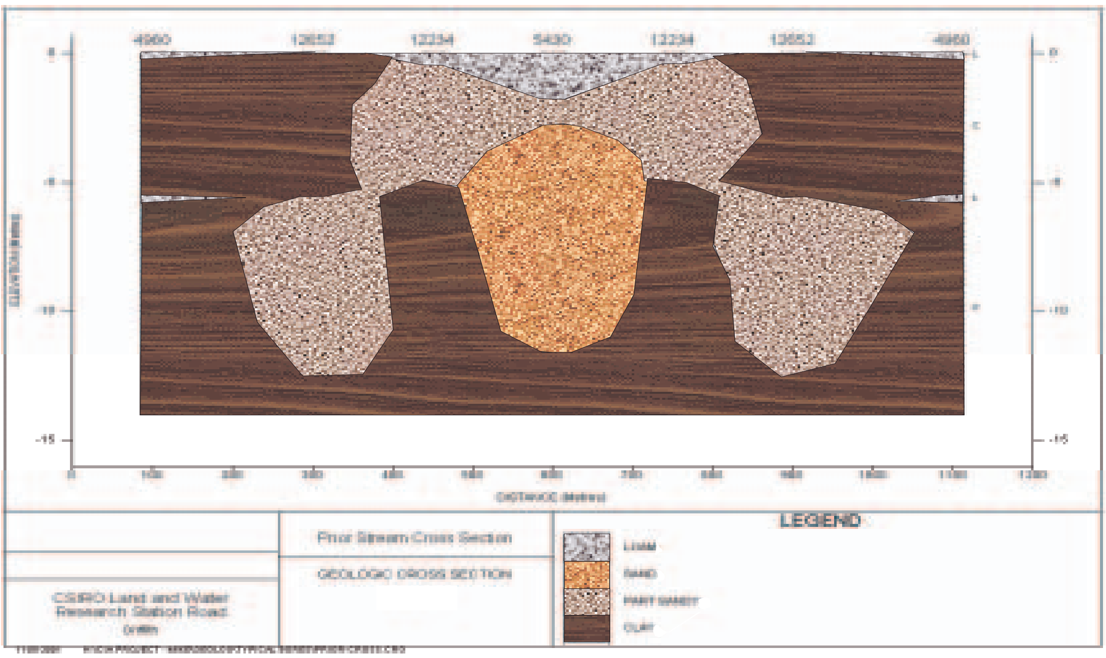

Figure 19. Cross section of bores situated near prior streams

3.3.3 Sand Pits

From Figure 20 it can be seen that the majority of sand pits are associated with prior streams. They lie directly in prior stream paths. There are five bores positioned near the sandpits. These were found to have large amounts of coarse sand and gravel present (4 - 9 metres thick) occurring at depths of 2 - 4 metres, Figure 21 – 24. All the bores were within 200 metres of the sandpits.

Figure 20. Location of sandpits with respect to prior streams

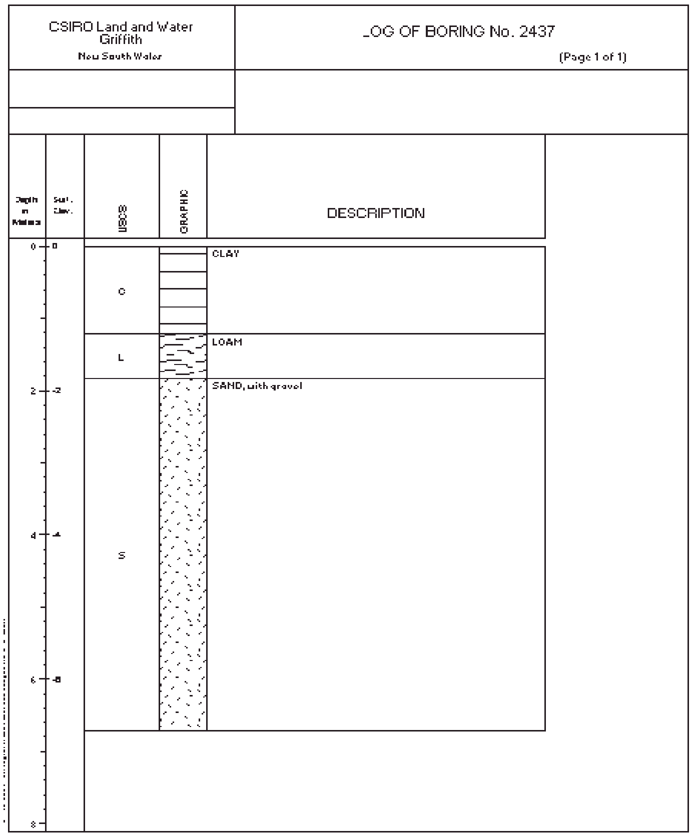

Figure 21. Profile of bore 2437

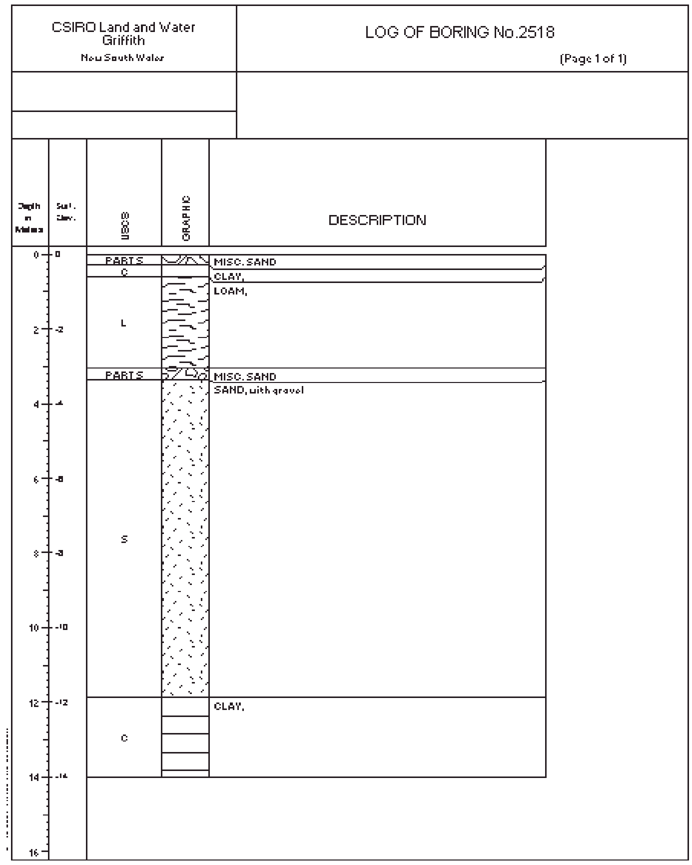

Figure 22. Profile of bore 2518

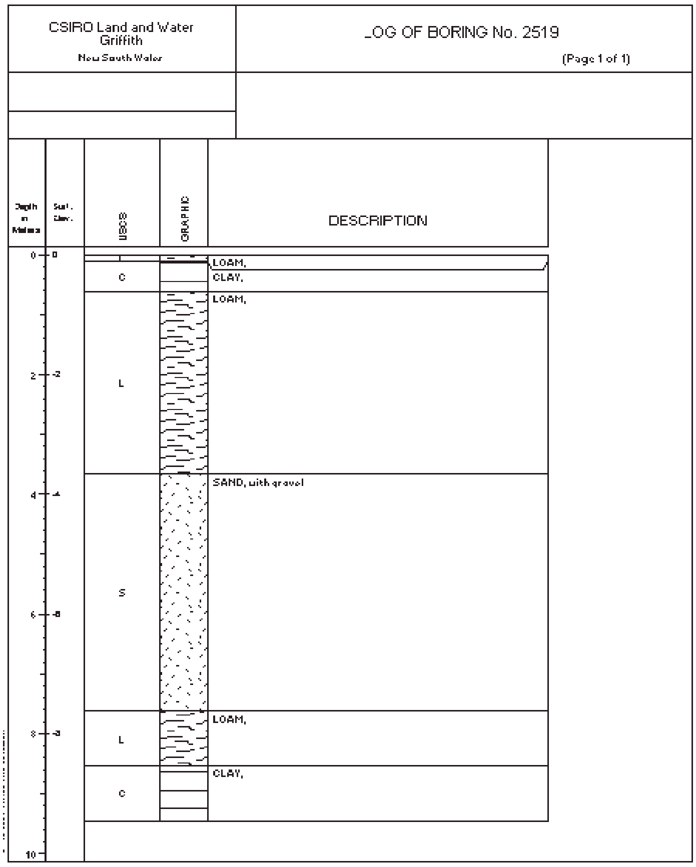

Figure 23. Profile of bore 2519

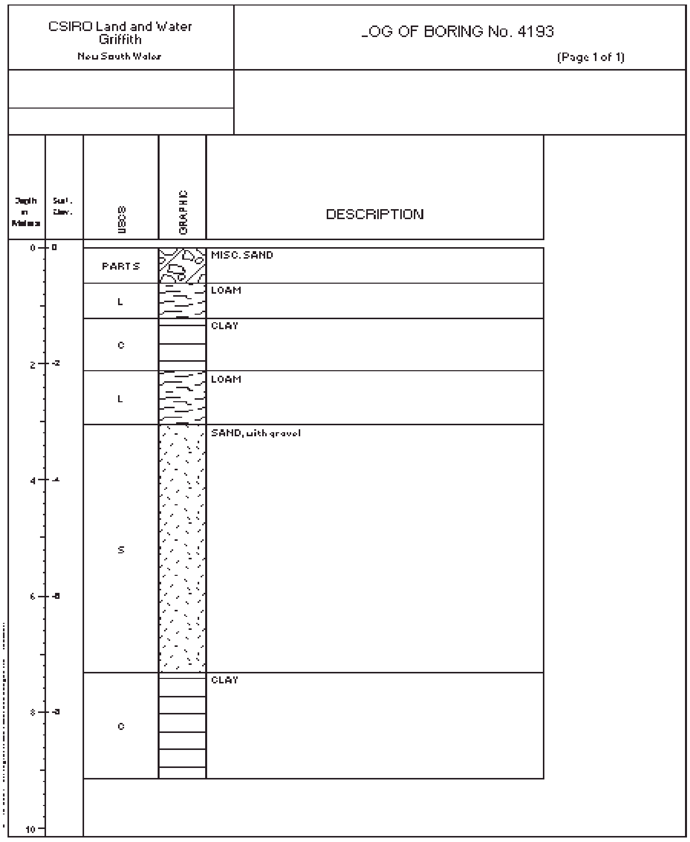

Figure 24. Profile of bore 4193

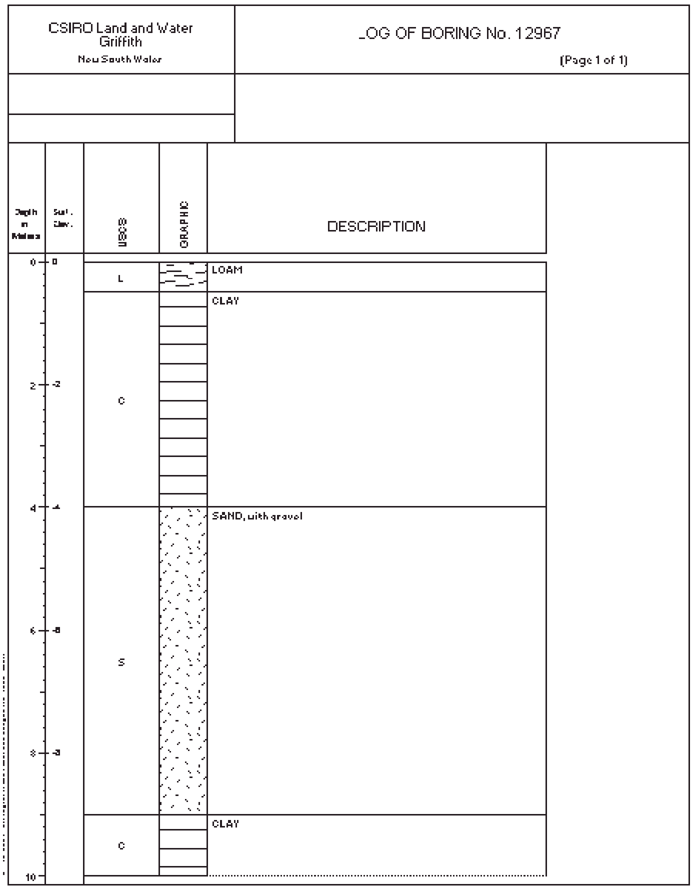

Figure 25. Profile of bore 12967

3.3.4 Depression Maps

Only five bores were situated in depressions. All of them showed potential suitable aquifers for shallow pumping. Table 4 shows the thickness of sand and depth from the ground surface. The thickness of the sand was approximately two metres, but was generally found at shallow depths (2 – 3 metres).

Thickness of Sand (m)	Depth to sand (m)
2	2
2	3
2.5	12
2.5	2
2.5	2

Table 4. Depth of aquifer material found in depressions

Depressions are low lying in the landscape and subject to waterlogging and salinity. The results indicate that it may be possible to undertake shallow groundwater pumping in these depressions.

3.3.5 Vegetation

The vegetation depressions are predominantly Black Box and Red Gum, (Read 2000). It was found that the main vegetation in prior stream areas was Calytris pine tree. This was expected as the pine trees flourish in well draining areas, Figure 26.

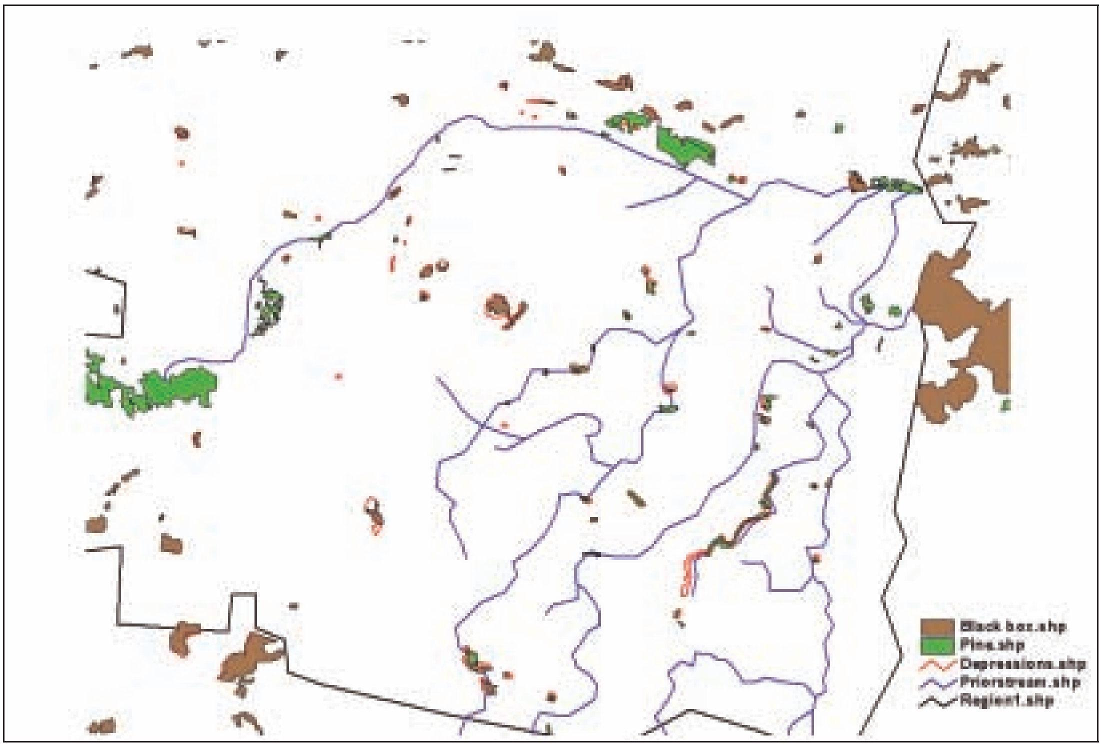

Figure 26. Vegetation correlated to prior streams and depressions

3.4 Discussion and conclusions to part one

From this study, it is possible to locate areas that have the greatest potential for shallow groundwater pumping.

- Soils data showed that there is a strong association with Co/SL and the presence of prior streams. Other soils that were found to have associations with shallow aquifers were Yamma loam, Coree clay loam, Danberry sand and Marah loam. There were also soils identified that were unlikely to show the presence of aquifers, these were Willbriggie clay, Yooroobla clay and Wunnamurra clay.

- Prior streams showed the presence of aquifers. However, it is not simply the case that if prior streams are present in the area then aquifers are present. It was found that 15 of the 36 bores identified in prior stream courses did not show good depths of aquifer material. However, the majority of aquifers identified in this study were found along prior stream courses.

- Sandpits have strong associations with prior streams. All bores in close proximity to the sand pits showed good depths of sand.

- Depressions showed the presence of aquifers. These were quite shallow (2 – 3 metres) with course sand approximately two metres thick. Thus, it may be possible to pump from depressions.

- The vegetation in the area correlated well with prior stream courses and depressions. As expected, Calytris pines were generally found along the path of prior streams and Black Box trees had strong associations with depressions. This is very useful when trying to locate these features.

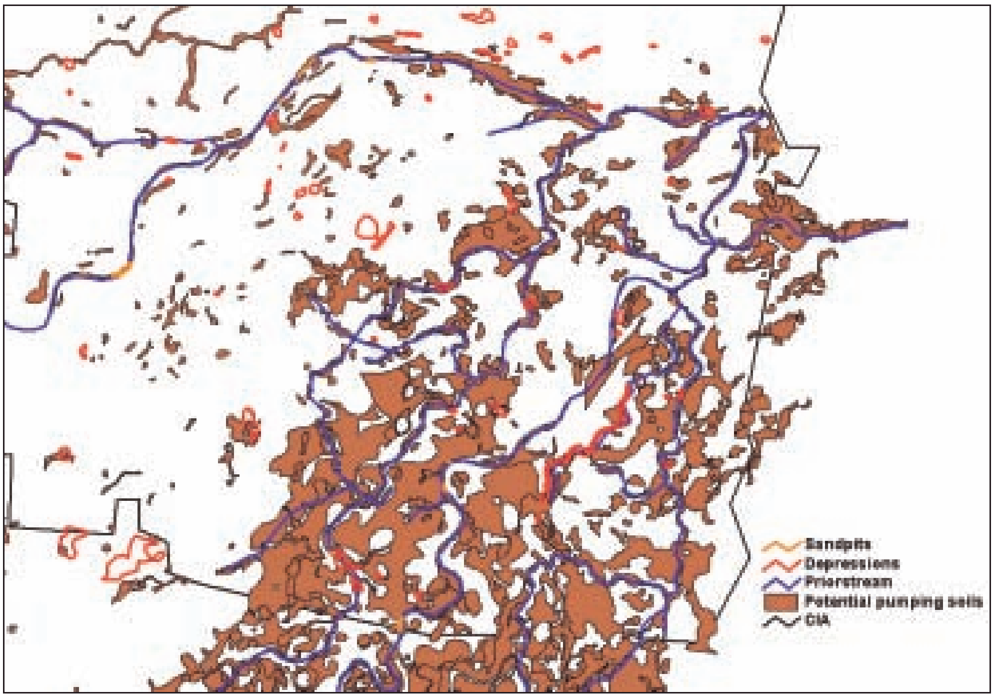

Figure 27. All features found to be associated with potential aquifers

Figure 27 shows all the features associated with potential sites where aquifers may be found. It can be seen that the greatest concentration of potential aquifer areas is in the southeastern corner of Coleambally.

3.4.1 Pumping constraints due to non uniform aquifer distribution

For implementation not only is a detailed understanding of the site specific aquifer geology required but also an assessment of the potential impacts of reuse of more saline water on the local area and downstream water users. This becomes extremely important if saline groundwater is disposed of by dilution into irrigation channels or directly or indirectly (by farm run off) into drainage channels. In this situation the increased irrigation or drainage water salinity will impact upon downstream users, thus threatening their productivity and sustainability. This is especially so if the downstream users are restricted in their access to groundwater pumping to control salinity. Restriction to shallow groundwater pumping is due to the absence of suitable aquifers. Figure 28 shows the southeastern section of the CIA with the areas where potential aquifers exist in the background. This is overlain by the channel supply network, over which there are two shaded areas, one being where aquifers for groundwater pumping are generally likely to be present and the other where aquifers are generally less likely to be present.

The area where there are poor prospects for finding suitable aquifers is generally at the tail end of the irrigation supply channels. This means that if saline water is disposed of into the supply channel it will be delivered to downstream users who have little opportunity of themselves implementing groundwater pumping. This being the case careful consideration is required of the equity issues associated with disposal of drainage water by dilution in irrigation channels. Even where the drainage water is reused on farm there is potential for the water to move off farm as surface runoff and thus increase the salinity of the drainage system. This will adversely affect downstream users of the drainage water.

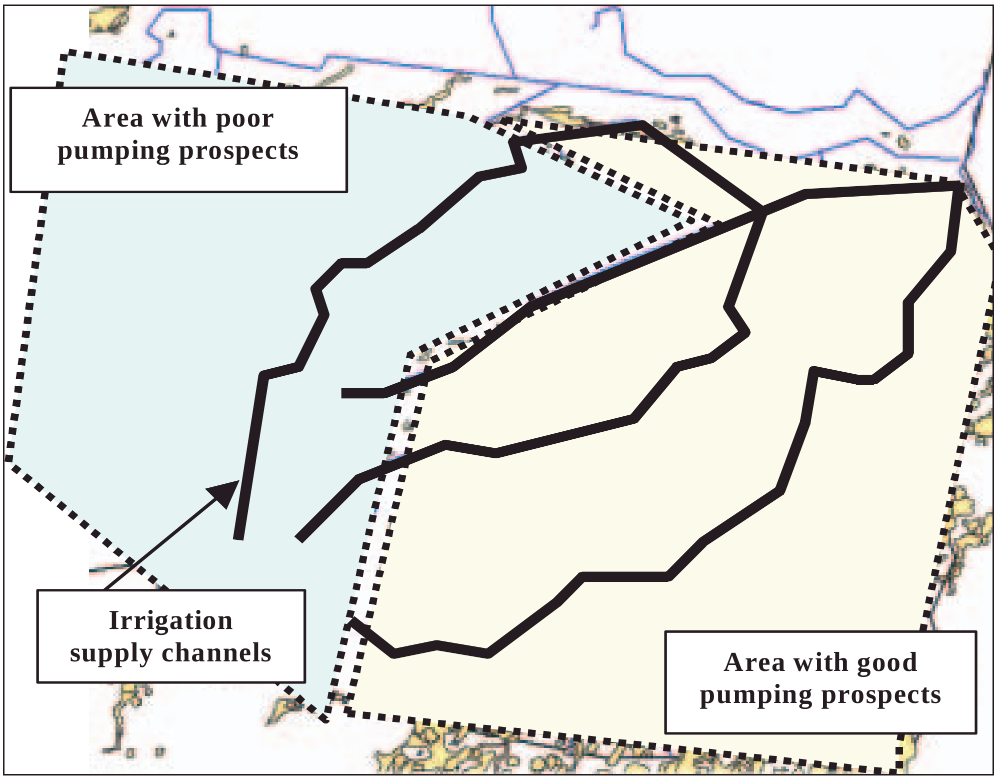

Figure 28. Potential upstream pumping areas and respective downstream receiving areas

Analysis of the spatial distribution of possible shallow aquifers and hence probable pumping sites has shown a very uneven distribution. This requires that area wide planning is undertaken before commencement of pumping to ensure that those in areas with restricted opportunities for drainage are not adversely affected. In the case study area most of the potential pumping area was at the upper end of the irrigation channel network, the tail end areas would have very restricted opportunity for groundwater pumping. Thus, serious consideration is required before allowing any increases in irrigation or drainage channel water salinity from upstream pumping and disposal (or runoff) as this may have severe impacts on the downstream users.

4 Part 2: Site investigation of aquifers

Having undertaken regional investigations to broadly identify areas that may be suitable for shallow groundwater pumping it is necessary to undertake local investigations. This needs to be a combination of drilling/use of bore logs, electromagnetic (EM) investigations and test pumping.

4.1 Cross sections using bore logs

The 77 bores with potential aquifer material, along with the feature maps are shown in Figure 29. Where there is a cluster of suitable bores provides possible sites for shallow pumping. The piezometer numbers, coordinates, thickness of sand, depth to sand and the type of surface soils they are situated in can be found in appendix 1.

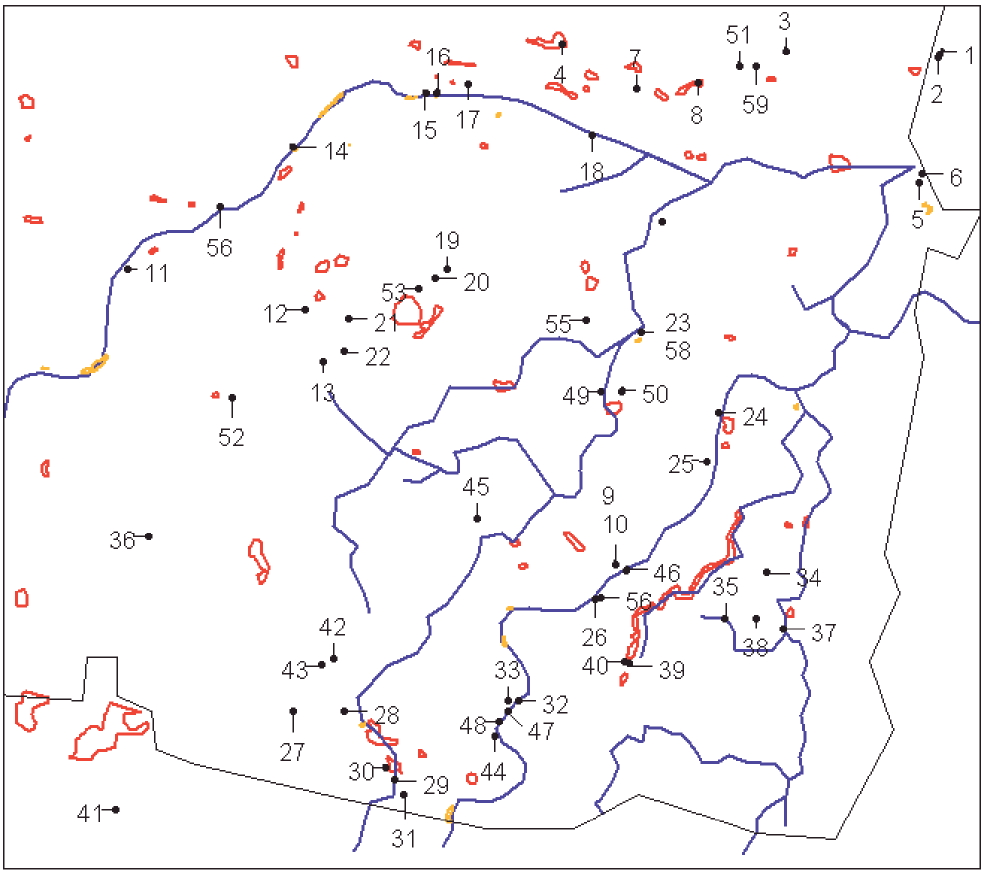

Figure 29. Location of sandy bores

Seven areas were chosen for further analysis, Figure 30. They were where suitable materials were shown in bores, in close proximity to each other and may be able to sustain shallow groundwater pumping. Further investigations i.e., drilling, EM surveys and pump tests need to be carried out on these sites to determine whether each area has the potential to sustain ground water pumping.

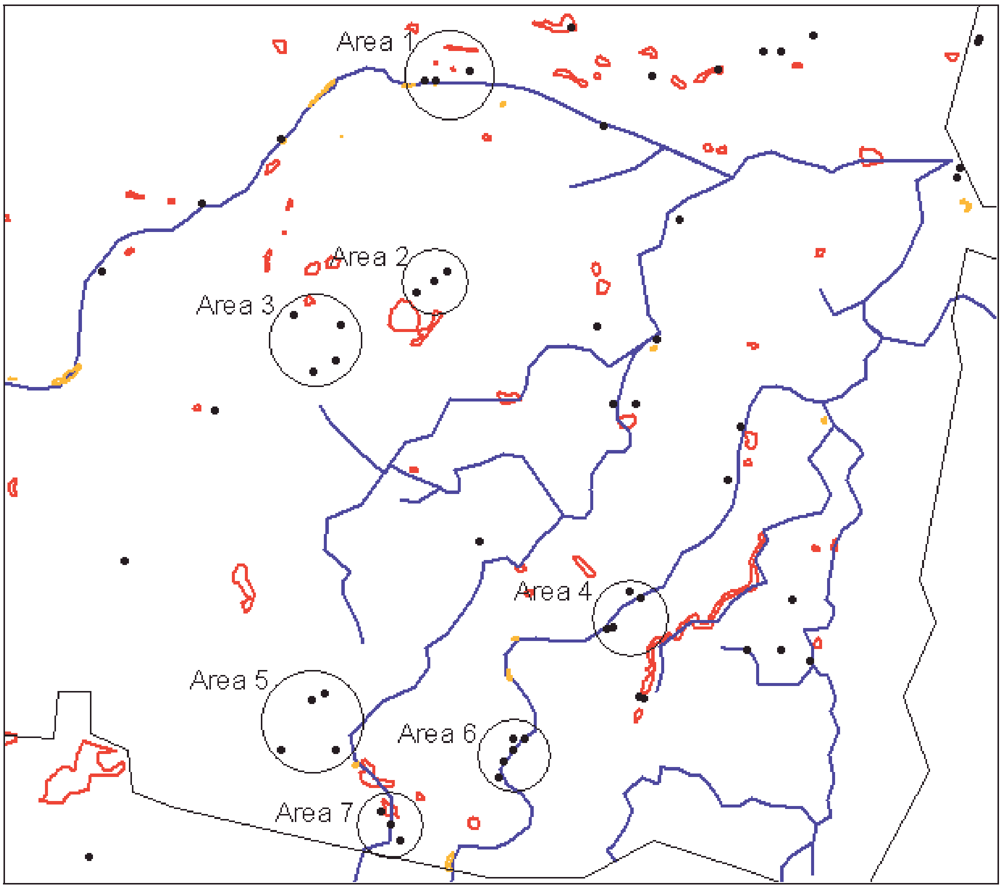

Figure 30. Possible aquifer sites

Area 1 is in close proximity to two sandpits, both of which contain water. The vegetation around the area comprises of mostly pine trees with a few Red Gums scattered close to the sandpits. A transect through the bores can be seen in Figure 31. The sandy material extends up to 3500m from the sand pit, but thins out to about 1m thick at about 1000m from the sandpit. It can be seen from Figure 31 that the overlying material close to the sandpit is loam, about 2 to 3m thick, but further away from the sand pit the overlying material being clay, approximately 6m thick. Due to this thick overlying clay, there may be little or no impact on the water tables due to its impermeability and therefore low transmissivity values. Close to the sandpit, 500 to

1000m on each side there is adequate thickness of sand at shallow depth and overlain by lighter material. Thus, it would seem that pumping from the sandpit is likely to have a significant impact at a 500 to 1000m radius and a much reduced impact up to 300m away.

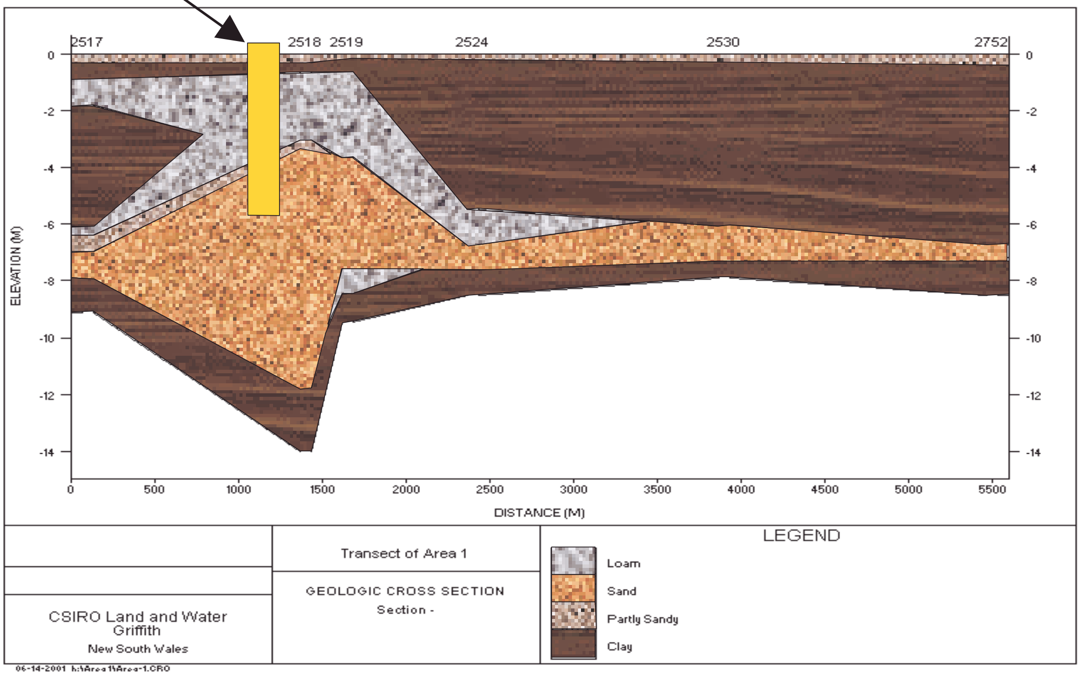

Figure 31. Cross section through area 1

Areas 2 and 3 are located along Hutchings and McDonald Road. These areas are situated where the water table is within 1.5 metres of the ground surface. Area 2 (Figure 32) shows an aquifer that is at least 4000m in extent and ranges from 2 to 4m in thickness. Area 3 (Figure 33) is not so good as the aquifers are deep and are only thin (1 to 2m thick) and once again overlain by a thick clay layer. The hydraulic properties of the partly sandy material need to be investigated. Then it will be possible to ascertain whether the partly sandy material can be treated as an aquifer or not.

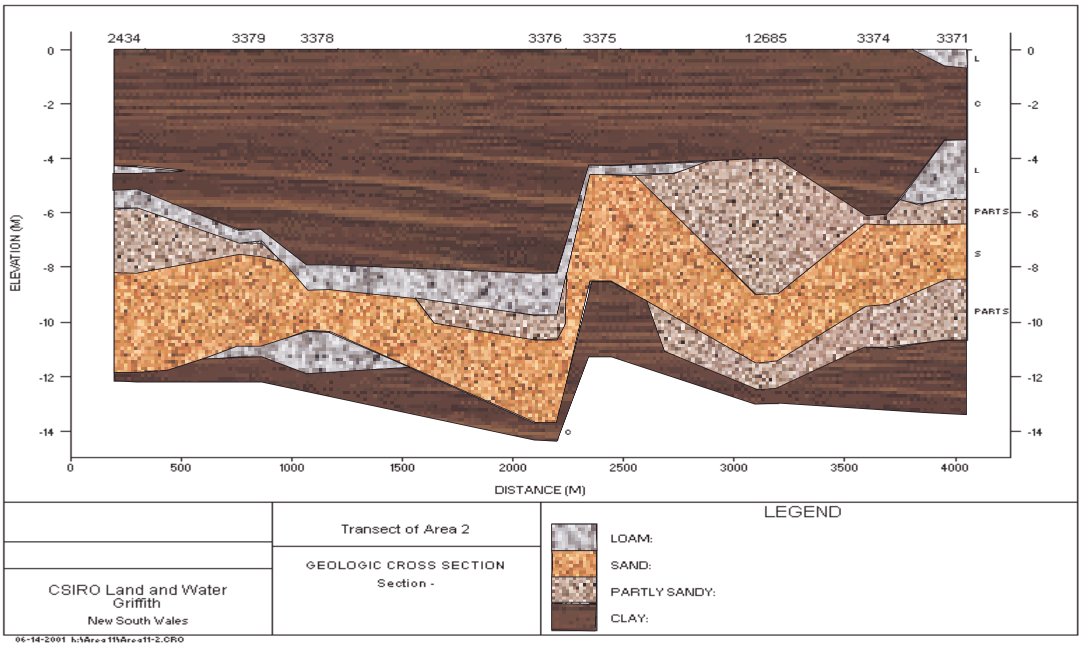

Figure 32. Cross section through area 2

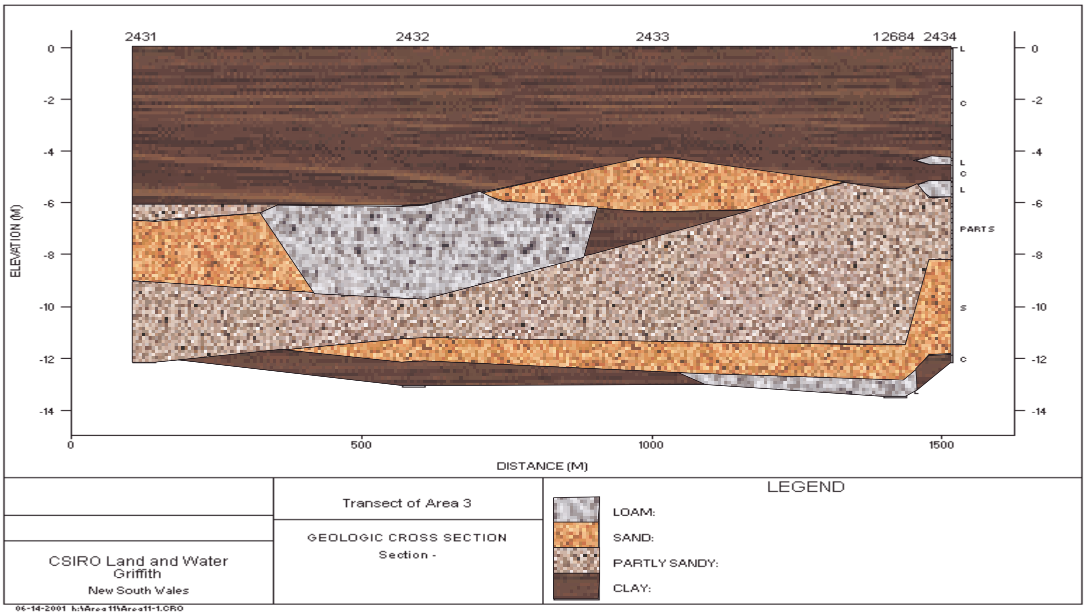

Figure 33. Cross section through area 3

Area 4 is situated along Gilbert and Leonard Road in close proximity to a prior stream. The bore data shows that there is sand present in the area, Figure 34. The bores do have a good thickness of aquifer material and the aquifer is located at a shallow depth so pumping for watertable control in this site has high potential. However, since there are not many bores in the area the extent of the possible aquifer system is not known. There is also a small amount of coarse sand (1 to 3m thick) located approximately 15m from the surface. This is probably the remnant of an older prior stream formation; it is unlikely to be worth pumping from as it is overlain by 15m of clay. Pumping will have little or no effect on lowering the watertable for salinity control from this small deep aquifer.

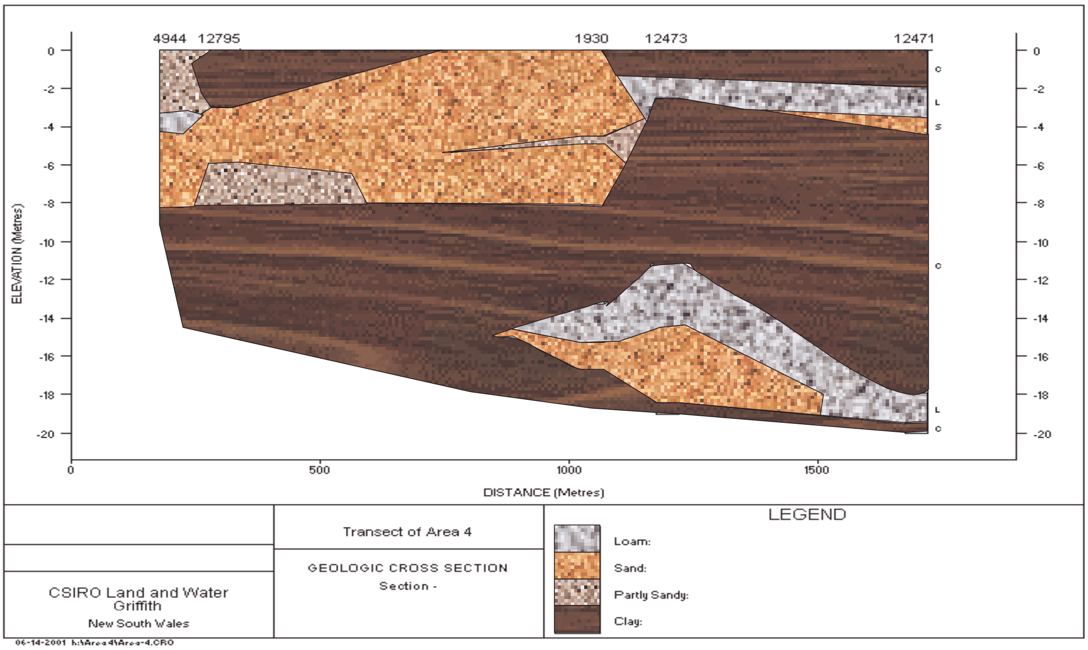

Figure 34. Cross section through area 4

Areas 5 and 7 are situated along Crosby and Desailly Road. Data that has been collected from the normal monitoring process and observations by CICL staff, landholders and Department of Agricultural staff show that this area has a soil salinity and watertable problem. Area 5 (Figure 35) shows a good potential aquifer system, bore numbers 4959 and 4998 have good thicknesses of sand near the surface. Bore 12420 is possibly linked to 4998 however they are 700 metres apart, therefore further investigations in the area are needed to identify whether the aquifers are linked. Bore 12419 shows two layers of sand; this could be due to prior streams overlapping, if aquifers are linked then the watertable drawdown over the area may be more widespread. Area 7 (Figure 36) shows two bores (4999 and 4969) situated in the same prior stream channel. This prior stream meanders around bore 5000. Its is probable that the sandy layers in bores 5000 and 5001 are connected, this is possibly a prior stream that has been overlayed by another more recent prior stream, evident in bores 4999 and 4969, or it could be that they are situated further away from the stream.

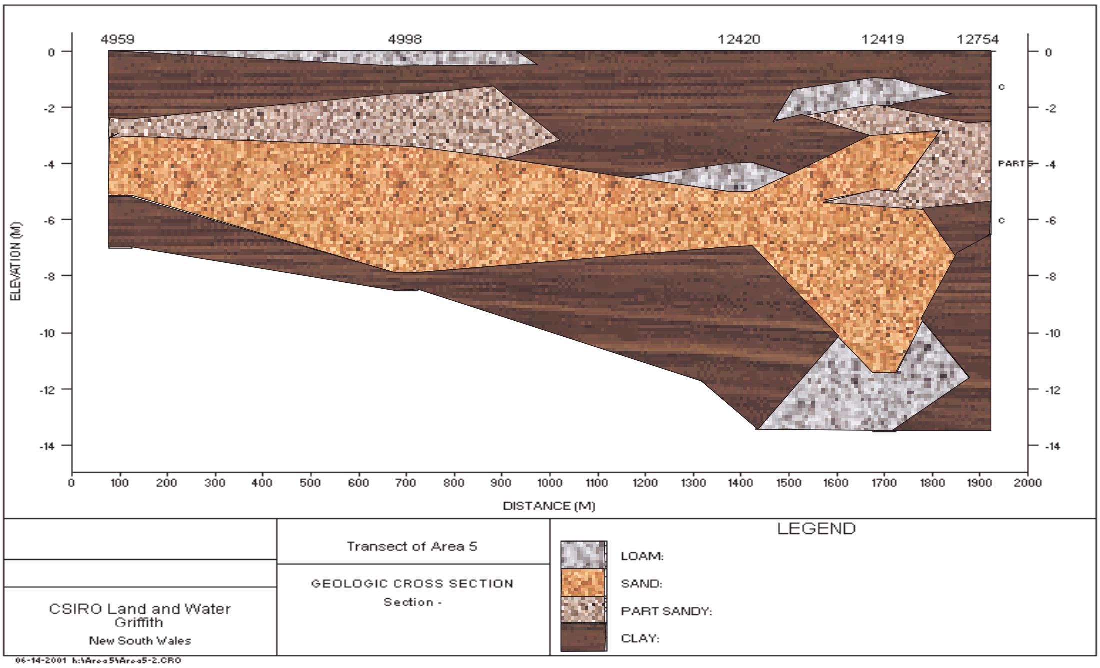

Figure 35. Cross section through area 5

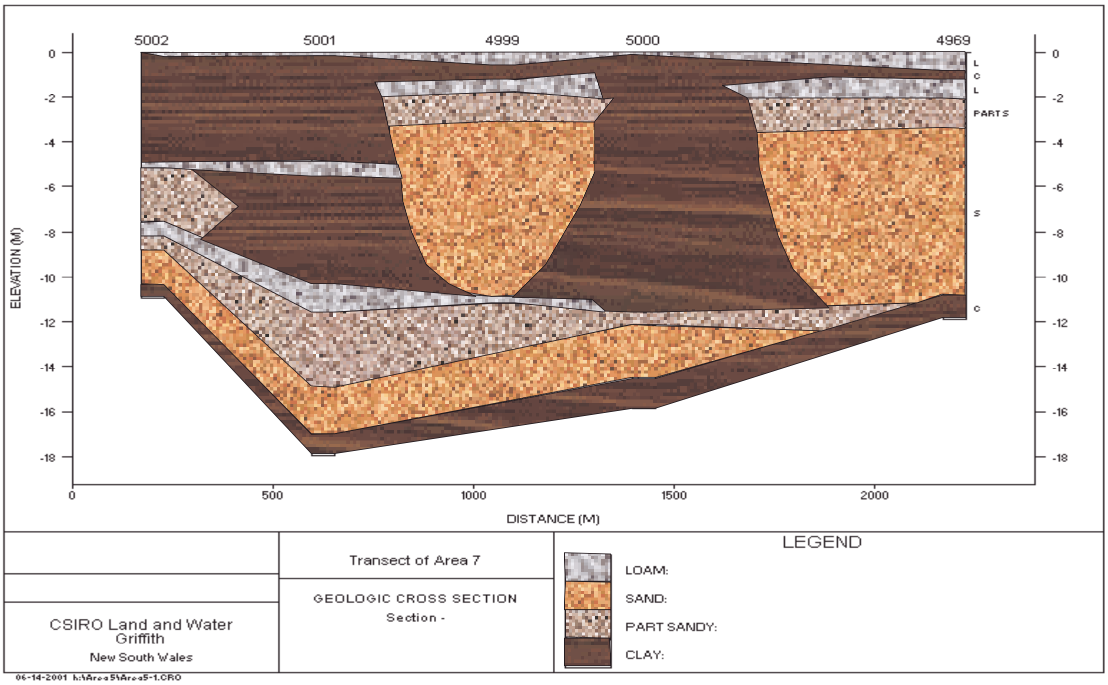

Figure 36. Cross section through Area 7

Area 6 (Figure 37) is located along Thurrowa Road. It is sandwiched between salinity problems approximately 1 km to the west and high water tables approximately 1 km to the east. The bores lie directly on the prior stream path. The transect is only 1 km across so this is not a very large area but it is probable that the aquifer system stretches further along the prior stream path. Pumping from this site should be useful as the aquifer is thick. There is an overlying clay layer, but its extent is not great. Further investigations should be undertaken to establish the extent and hydraulic properties of the aquifer system.

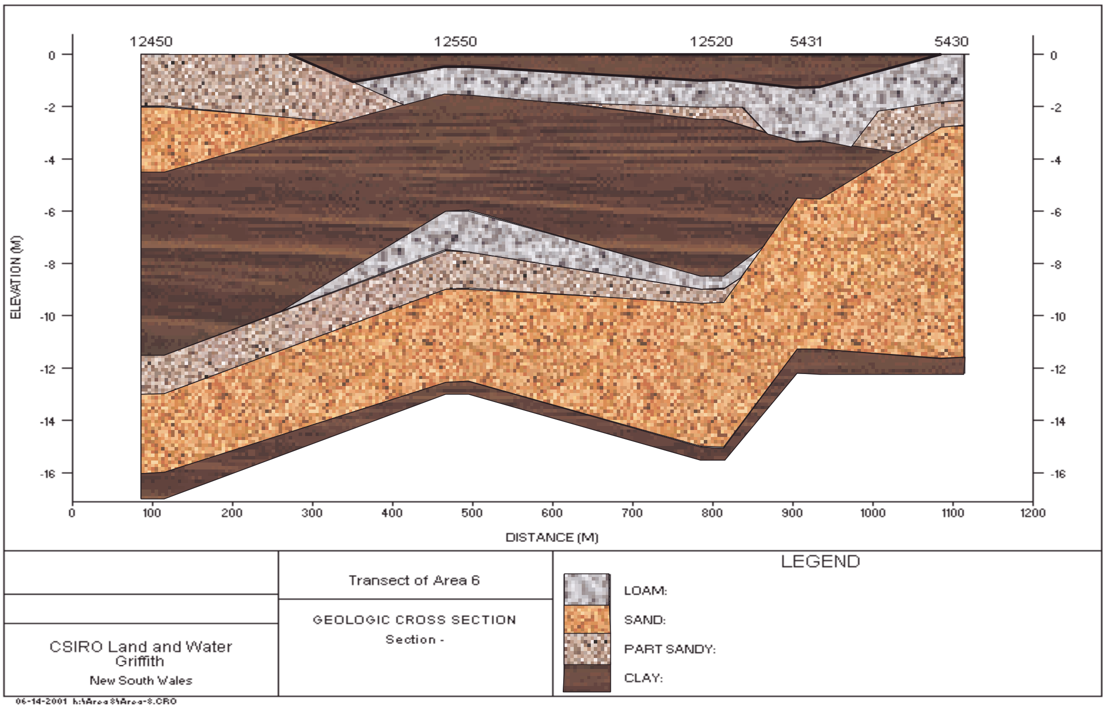

Figure 37. Cross section through area 6

4.2 EM34 Surveys

EM34 surveys can be used which measures the apparent electrical conductivity (ECa) of the whole soil i.e., soil, water and solids in situ, not simply the soil water electrical conductivity (EC). Thus, although salinity is the major factor affecting EM measurements, the effects of other soil properties, particularly texture and water content are also considered when interpreting EM results. Where salinity is low, the EM readings can be used to deduce profile texture. The aim of conducting these surveys was to ascertain the extent of the areas already identified as being potential sites for shallow ground water pumping.

When using the EM to find the texture of the underlying soils the change in conductivity of the soil will provide an idea of what type of material is underlying, e.g. low readings generally show that the area is of light textured soils, whereas high readings show up heavy textured soils. It must be noted that highly saline areas may mask the results. With the EM34 there are three coil separation lengths that can be used; these being 10, 20 and 40 metres, each separation penetrates the ground to different depths, Table 5. A coil separation of 10 metres was used, as it was only necessary to examine the top 15 metres of the soil profile. Readings were taken at 10 or 20 metre spacings. The instrument can be sensitive to large amounts of metal buried under ground, telephone cables and overhead power lines.

		DEPTH PENETRATION (m)	
		Horizontal Dipole	Vertical Dipole
COIL SEPARATION (m)	10	7.5	15
	20	15	30
	40	30	60

Table 5. Depth of response for EM34 at varying coil spacings

Five transects were conducted through areas 1, 2 and 6, to determine the lateral extent of the aquifers in these areas. Also EM34 values were compared against bore logs in order to develop some guidelines on which EM34 readings were likely to indicate the presence of pumpable aquifer material.

4.2.1 Transect A

Area 6 has been identified as a site for potential shallow groundwater pumping. A known prior stream runs through the area, EM34 transects were conducted across the area to identify the extent of the potential aquifer. Figure 38 shows transect A and B across the prior stream, the aim being to investigate the width of the prior stream.

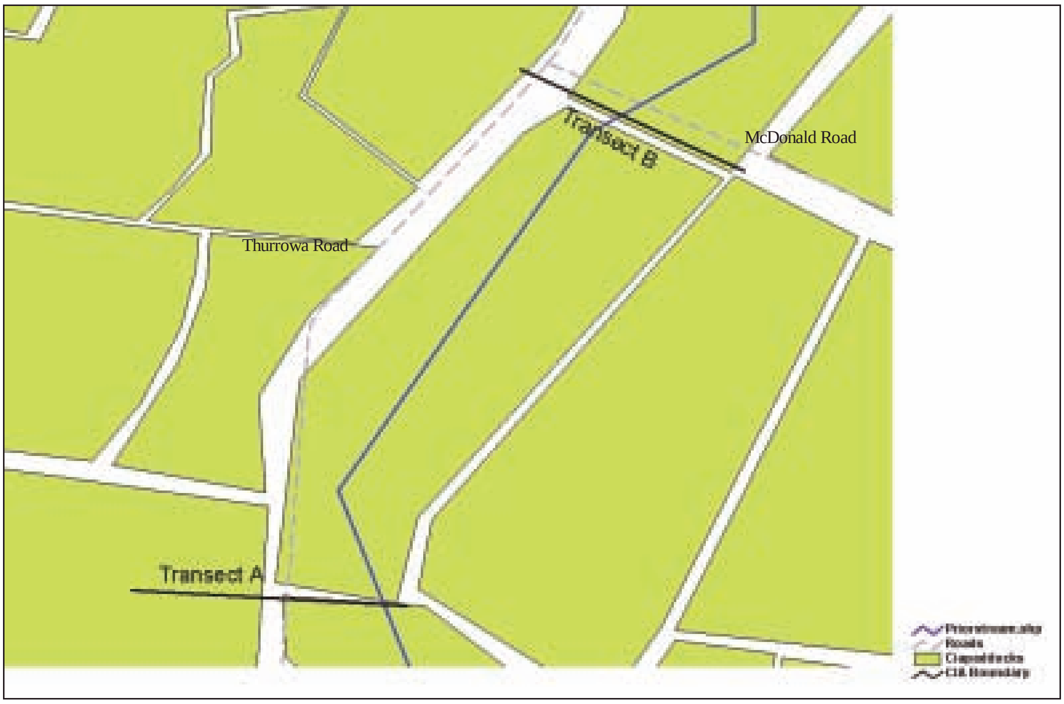

Figure 38. Transect A and B – area 6

Figure 39 shows the results gained by using the instrument in the vertical position (horizontal dipole).

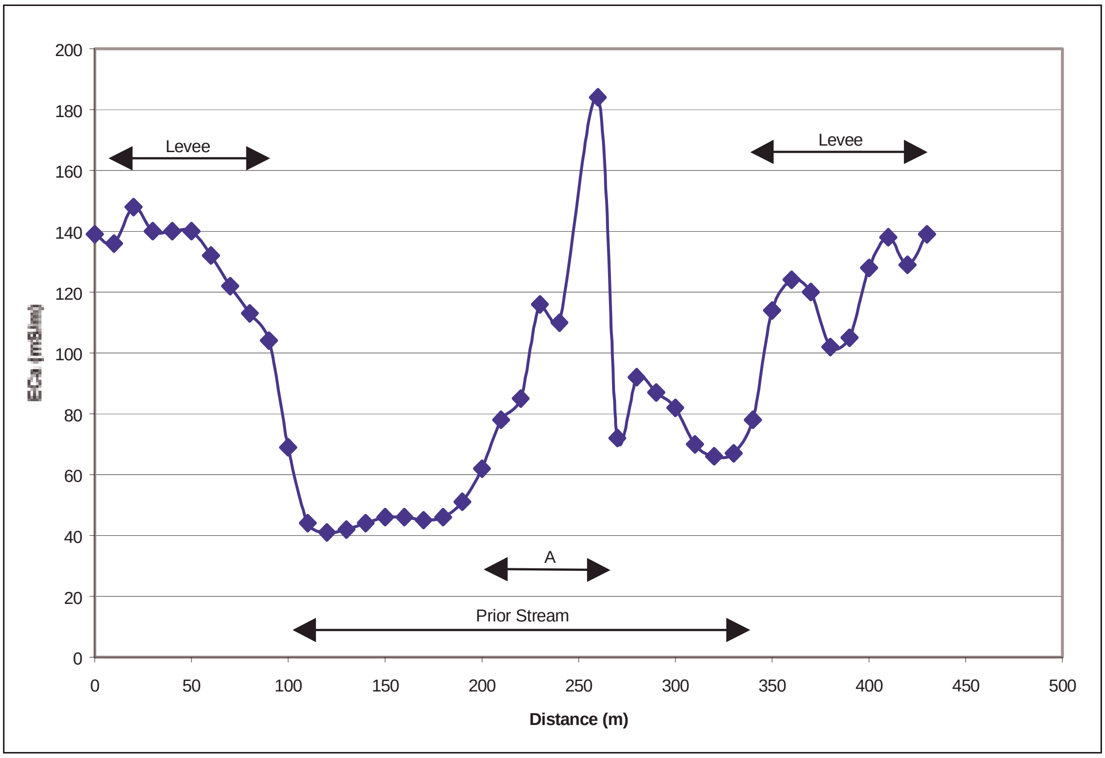

Figure 39. Transect A – Horizontal dipole

As the prior stream was crossed, the conductivity readings lowered, indicating that there is a lighter textured soil in the area. The results from the transects show that the prior stream is probably approximately 250m wide; this can be investigated further with some site drilling. The high values marked as A in Figure 39 were where the transect crossed Thurrowa road and a channel. The high values for this part of the transect are due to salinity rather than texture. This was supported by the presence of salt tolerant plants in the area. Using the vertical dipole, (Figure 40) the results were not as clear, possibly because the vertical dipole measures down to 15 metres so probably masking the prior stream. However if the vertical and horizontal results are compared (Figure 41) then a pattern can be seen with the vertical dipole, the readings start off high, then they drop as the prior stream is crossed, then at the other side of the prior stream they start to increase again.

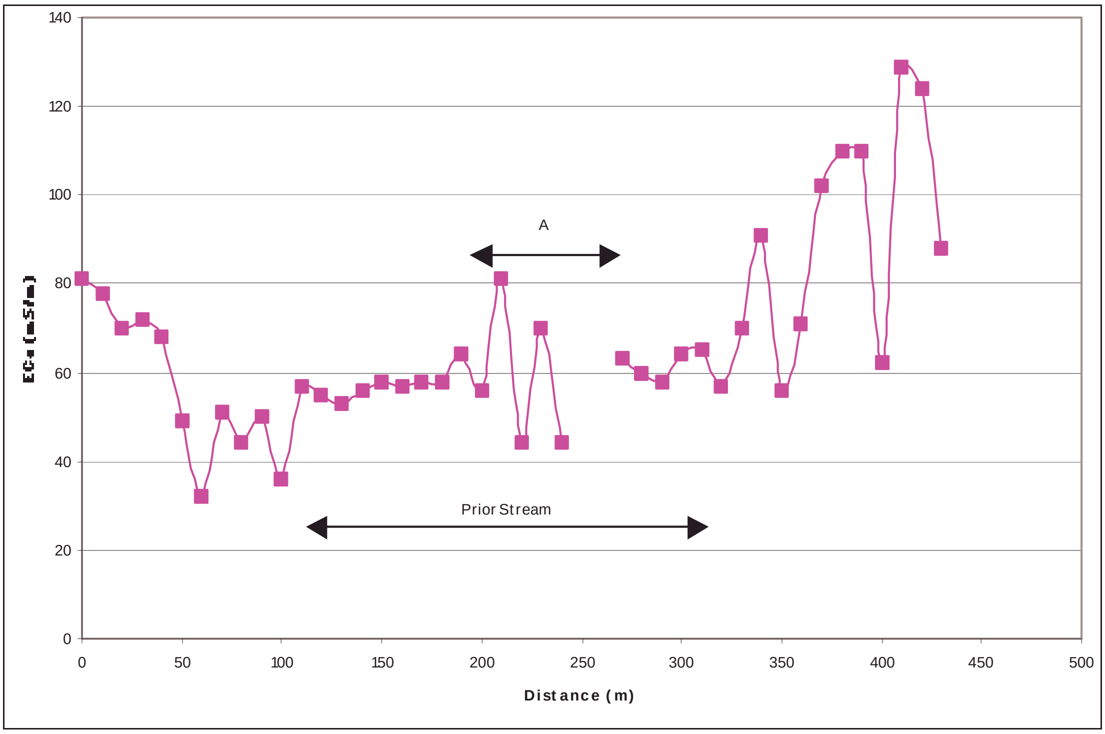

Figure 40. Transect A – Vertical dipole

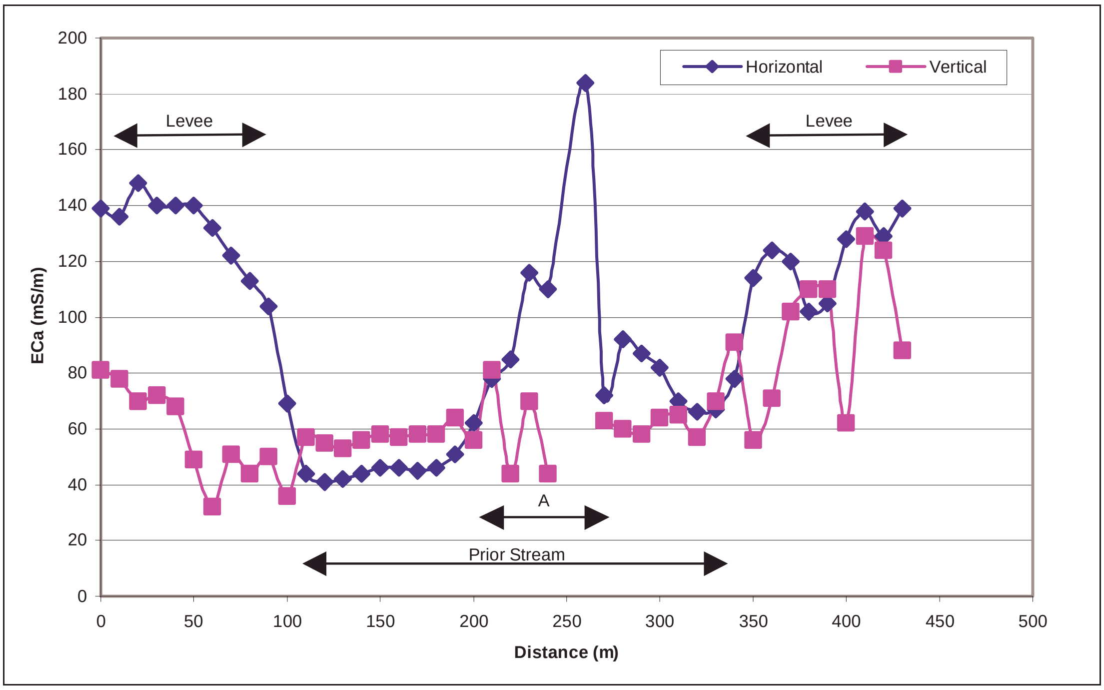

Figure 41. Transect A – Vertical and horizontal dipole

4.2.2 Transect B

Transect B was conducted along the northern side of farm 612, Figure 38, crossing the same prior stream as transect A. However, the results did not show any signs of prior stream material, there were some low readings but the presence of a prior stream is not clear, Figure 42, Figure 43 and Figure 44. Two bores (5430 and 5431) were crossed along transect B, their bore logs can be seen in Figure 45 and Figure 46. Bore 5430 has a thickness of sand of 8.5m occurring at a depth of 3m, this correlates well with the results for the horizontal dipole This is possibly because there were some underlying telephone cables in the area and that the survey was conducted in close proximity to McLarty road.

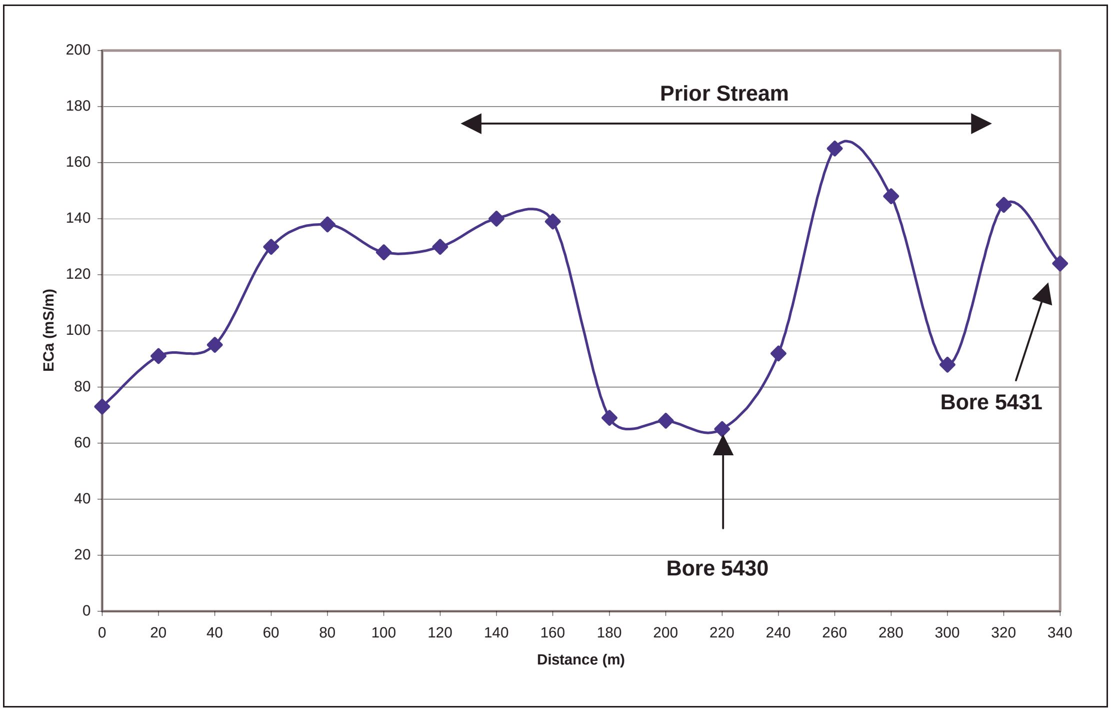

Figure 42. Transect B – Horizontal Dipole

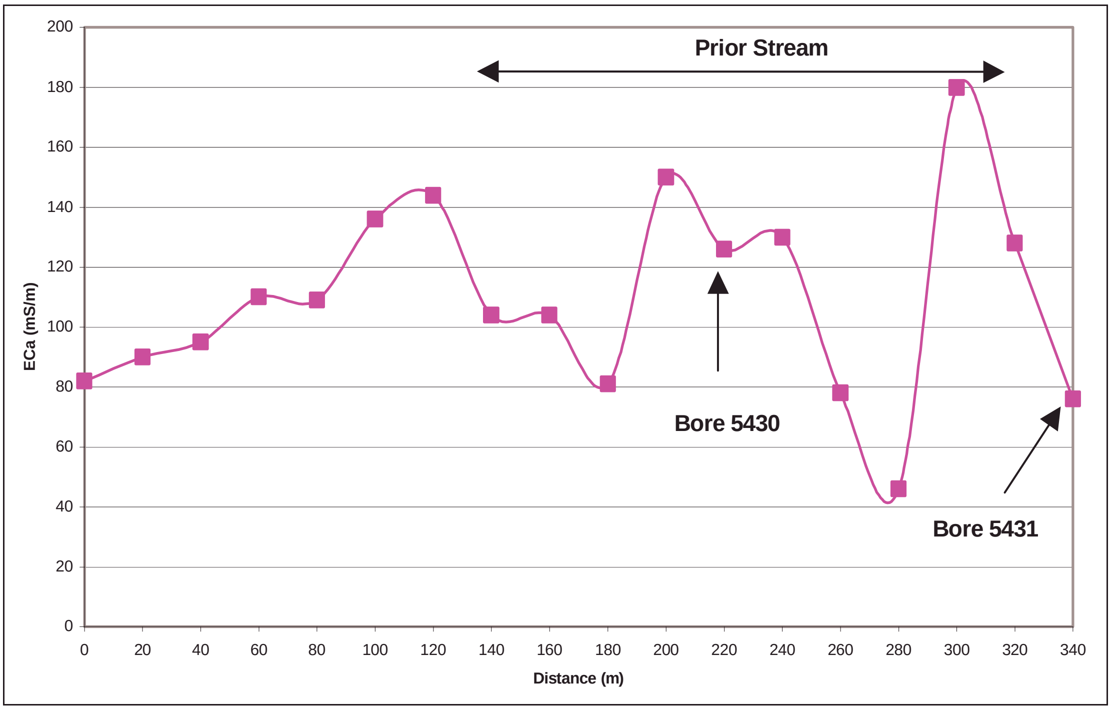

Figure 43. Transect B – Vertical dipole

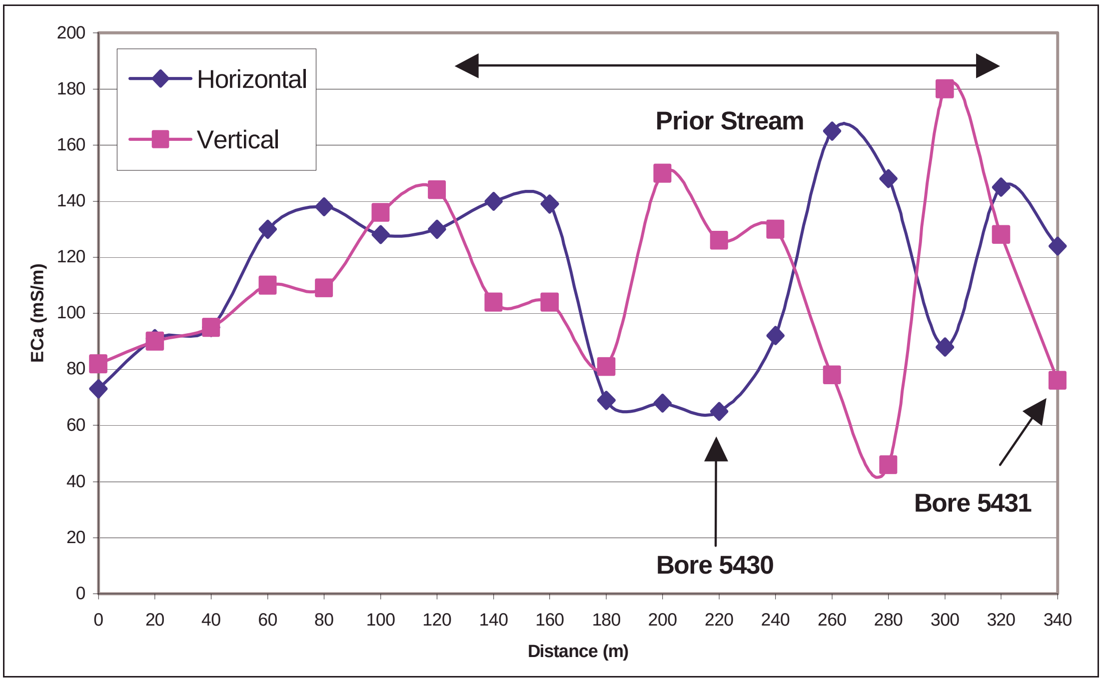

Figure 44. Transect B – Vertical and horizontal dipole

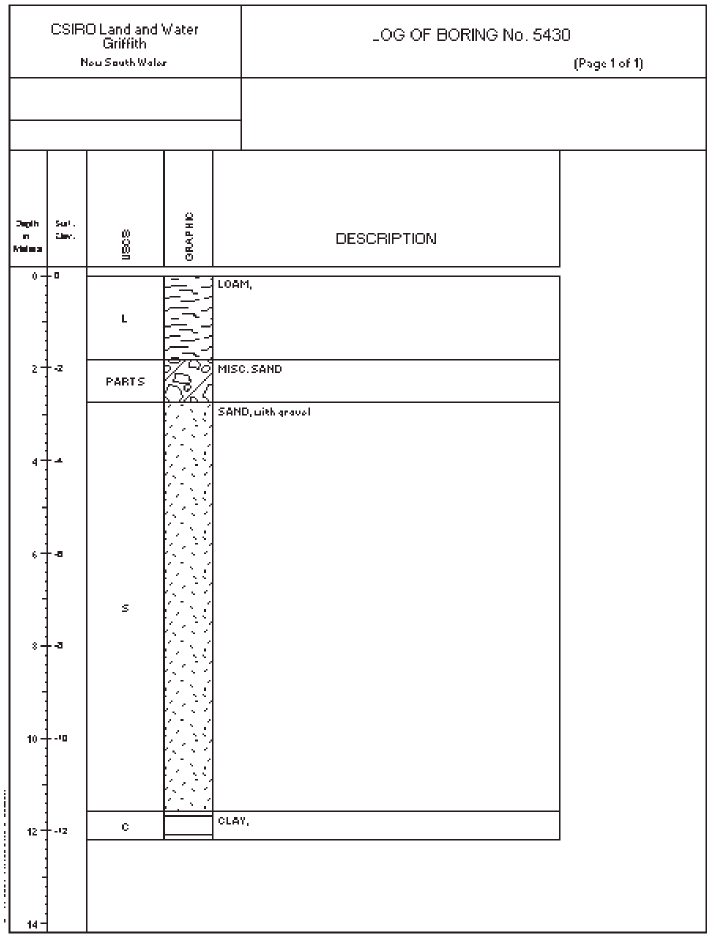

Figure 45. Bore log 5430

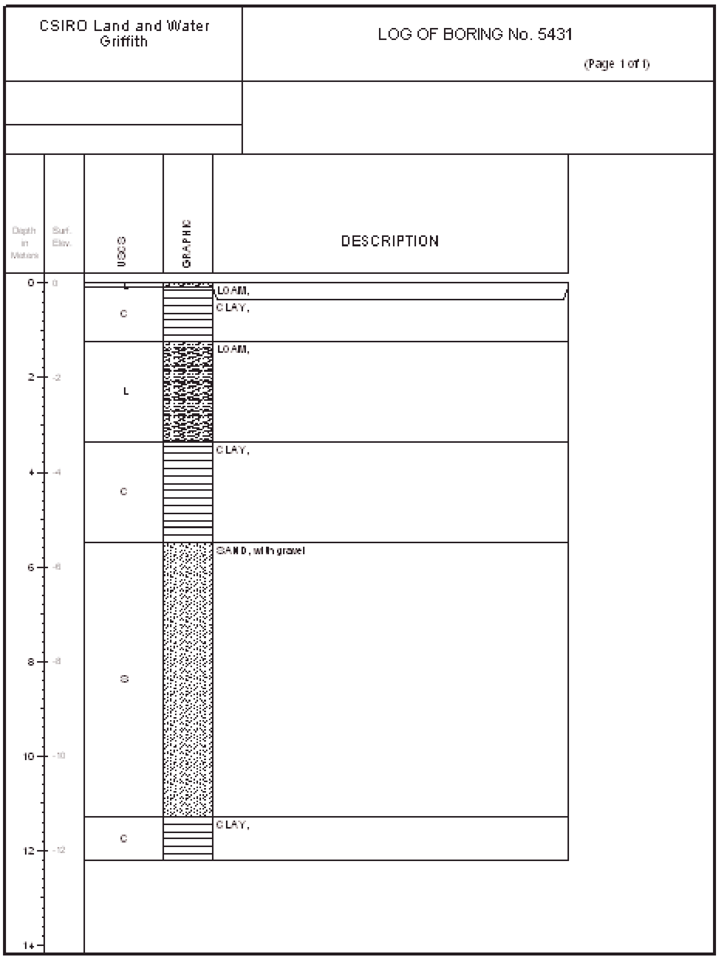

Figure 46. Bore log 5431

4.2.3 Transect C

Transect C was conducted through a large depression adjacent to areas 2 and 3 (Figure 47). Using the horizontal dipole resulted in very high EM values (Figure 48), this could be because this area is very saline and it is also known that there is a clay layer that extends from the surface to approximately 6 metres deep, these two factors combined will produce high conductivity readings. However, it is still possible to assess where the depression is when looking at Figure 48 as the higher readings show the depression, due to the depression being more saline than the surrounding area. The dips in the trace at 160m, 260m, and 480m are possibly small prior streams; however there are no prior stream maps or bore logs within the depression to support this.

The vertical dipole produced very low results (Figure 49). Given that this is a very saline area, the results were lower than expected as the EM primarily measures salinity. The results in the depression were lower than around the edges of the depression, possibly indicating that there is a permeable layer of sand situated under the heavy clay layer. There are no bore logs within the depression to confirm this.

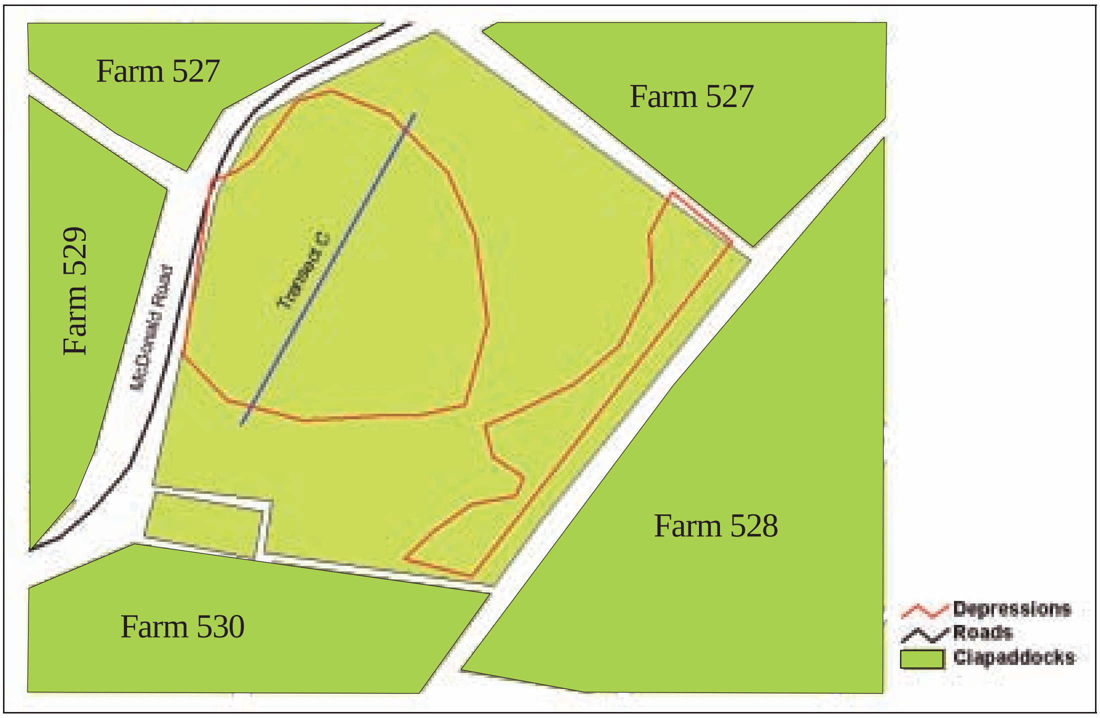

Figure 47. Transect C – Depression near McDonald road

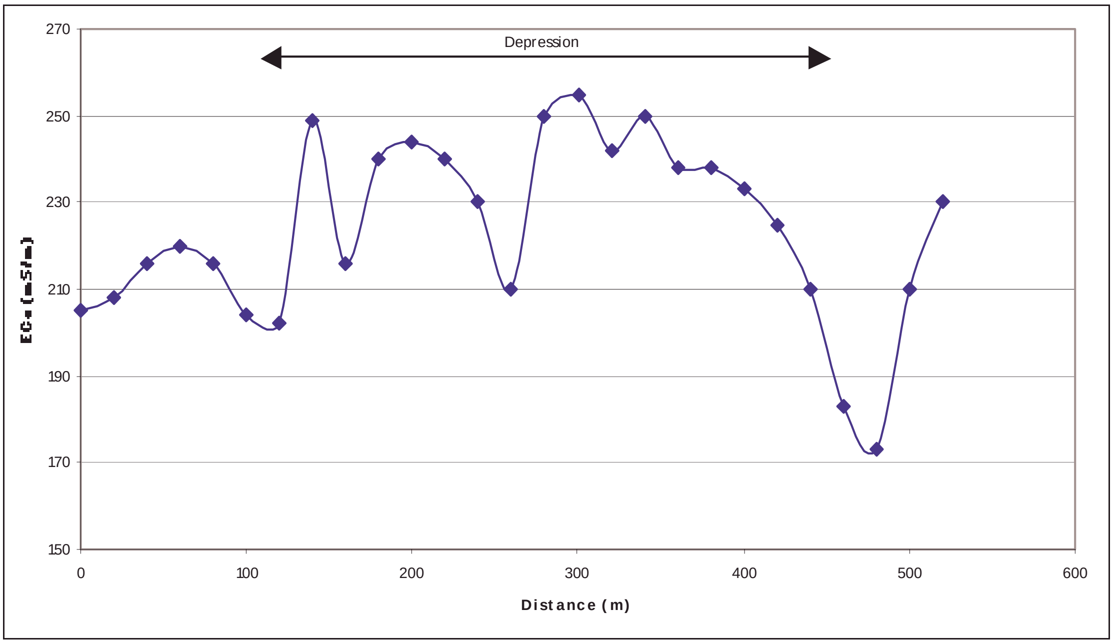

Figure 48. Transect C – Horizontal dipole

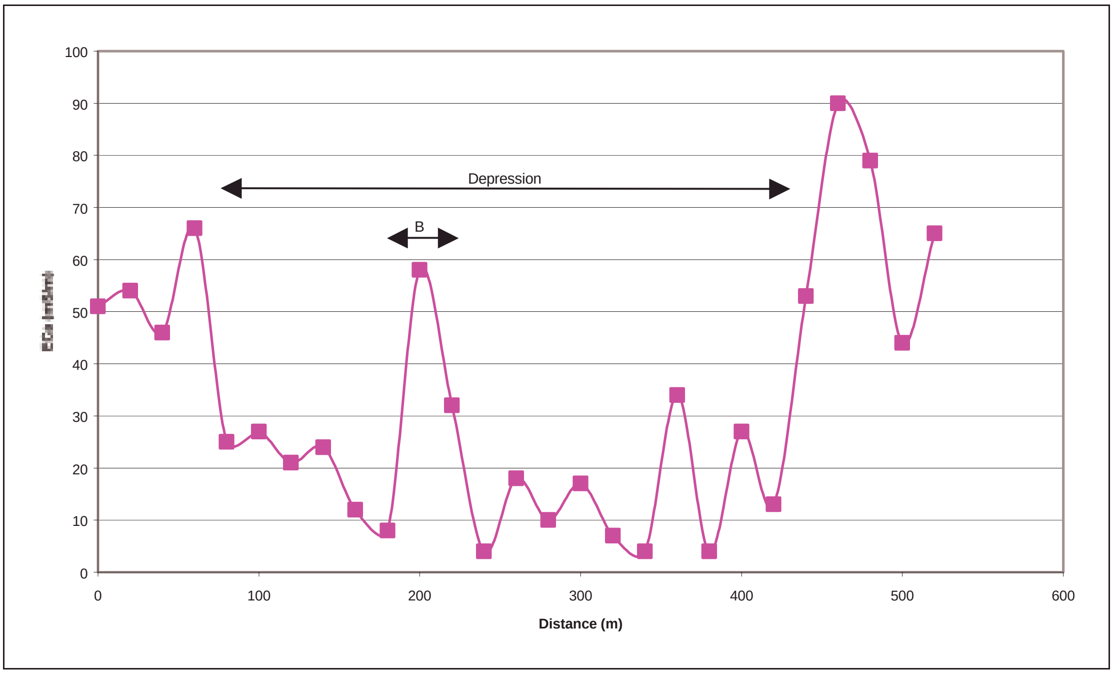

Figure 49. Transect C – Vertical dipole

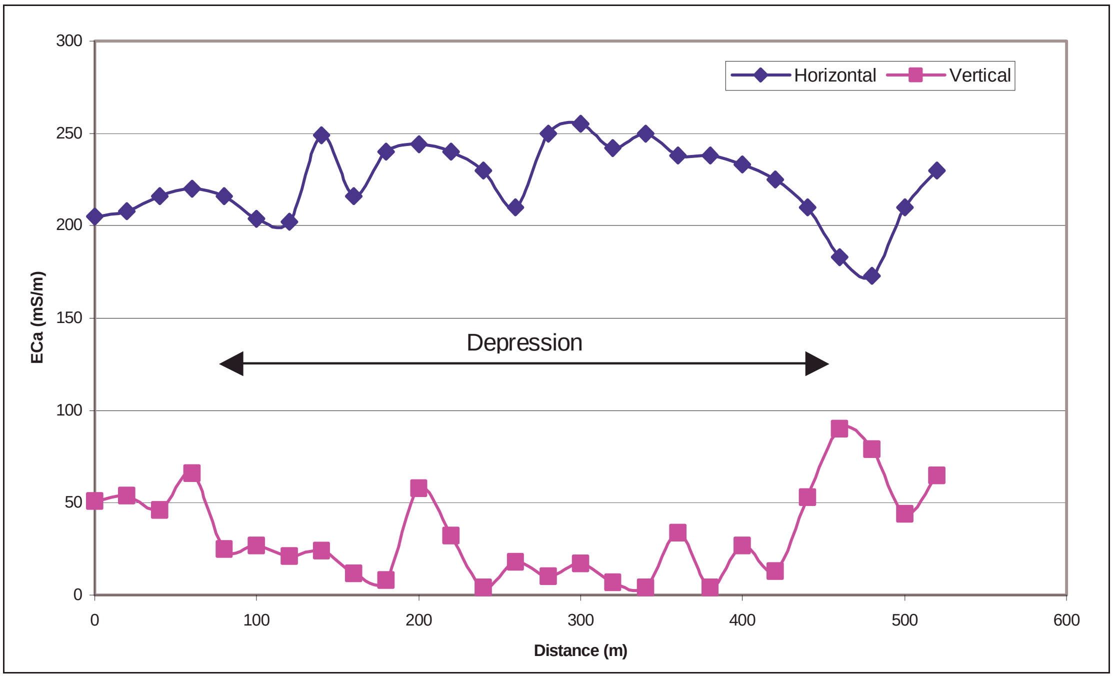

Figure 50. Transect C – Vertical and horizontal dipole

4.2.4 Transect D

Figure 51 – Figure 54 show the location and the ECa results for transect D taken in area 1. Transect D (Figure 51) intersects a known prior stream and runs adjacent to a

sand pit. The results from using the horizontal dipole (Figure 52) show the presence of a prior stream. It can be seen that the prior stream is approximately 250 metres wide. Using the instrument in the vertical dipole did not give as clear results (Figure 53) as obtained when using it in the horizontal position. This is because the vertical dipole reaches to a depth of 15 metres so the response is over a greater depth. This indicates that the sands are relatively shallow. However, when the vertical and horizontal results are plotted together (Figure 54) the prior stream can be seen in the vertical dipole. The readings start high, then drop on crossing the prior stream and then increase again on the other side of the prior stream. Area B shown in Figure 52 and Figure 54 is where the transect crossed a road. This is the most likely explanation as to the reason why the conductivity changes at these points.

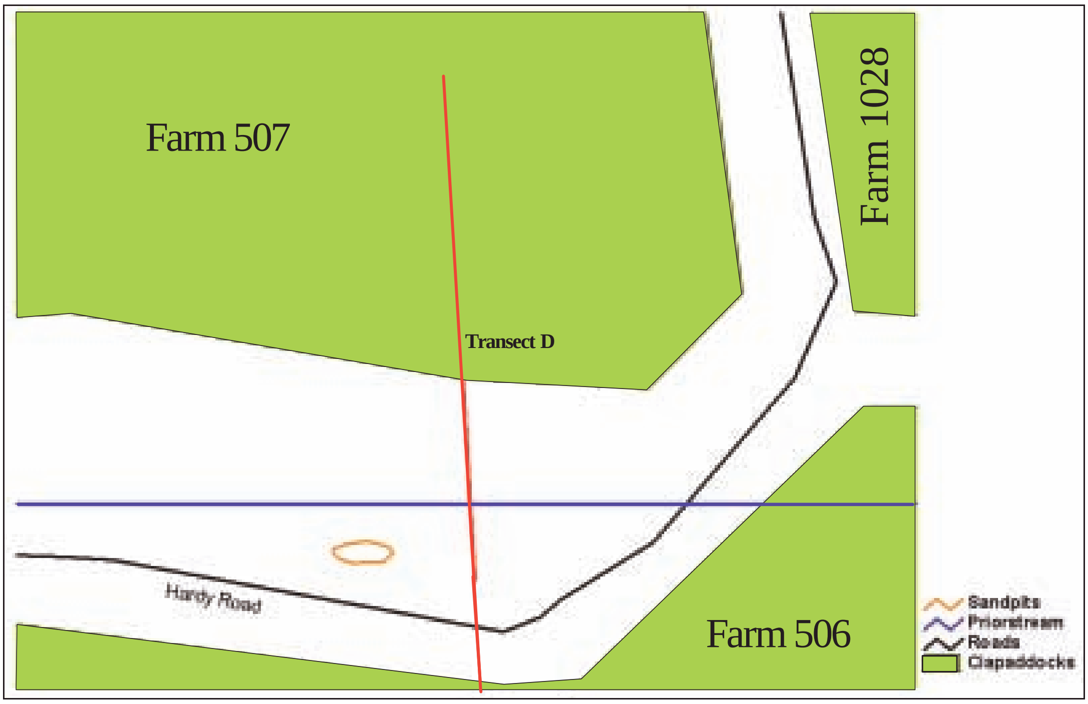

Figure 51. Transect D – Eastern side of sandpits in area 1, near Hardy rd.

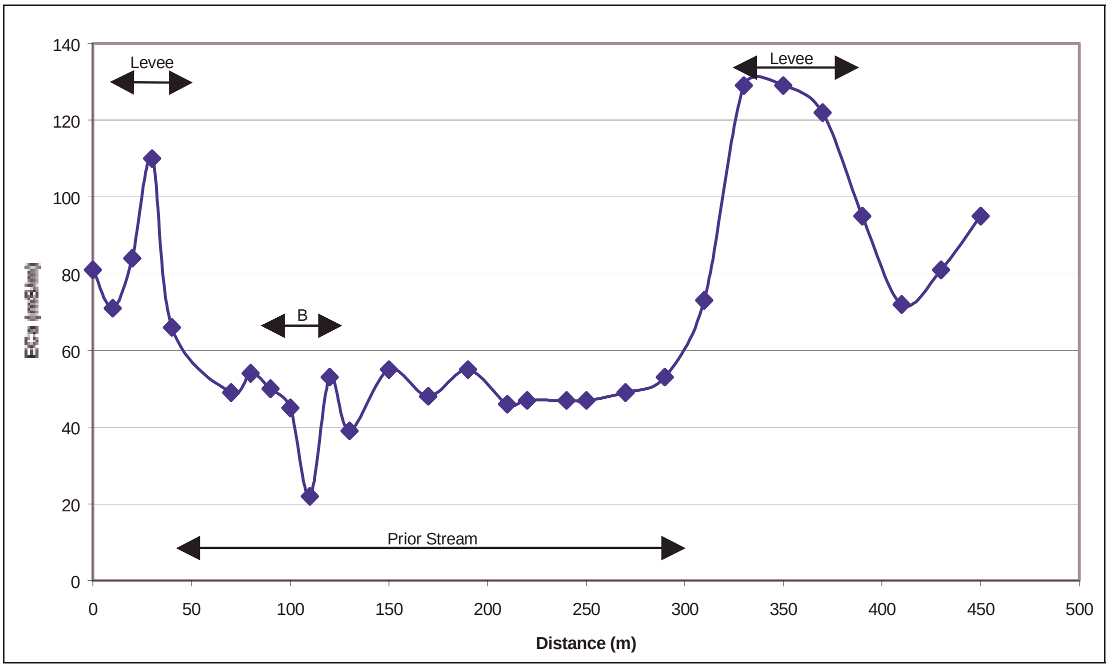

Figure 52. Transect D - Horizontal dipole

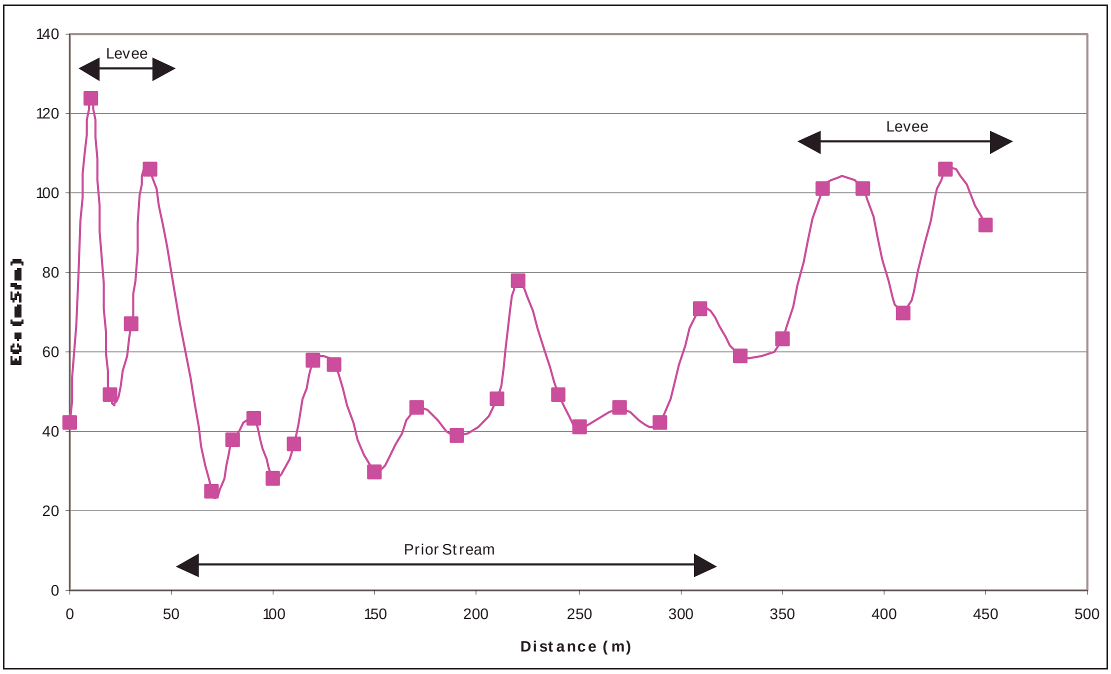

Figure 53. Transect D – Vertical dipole

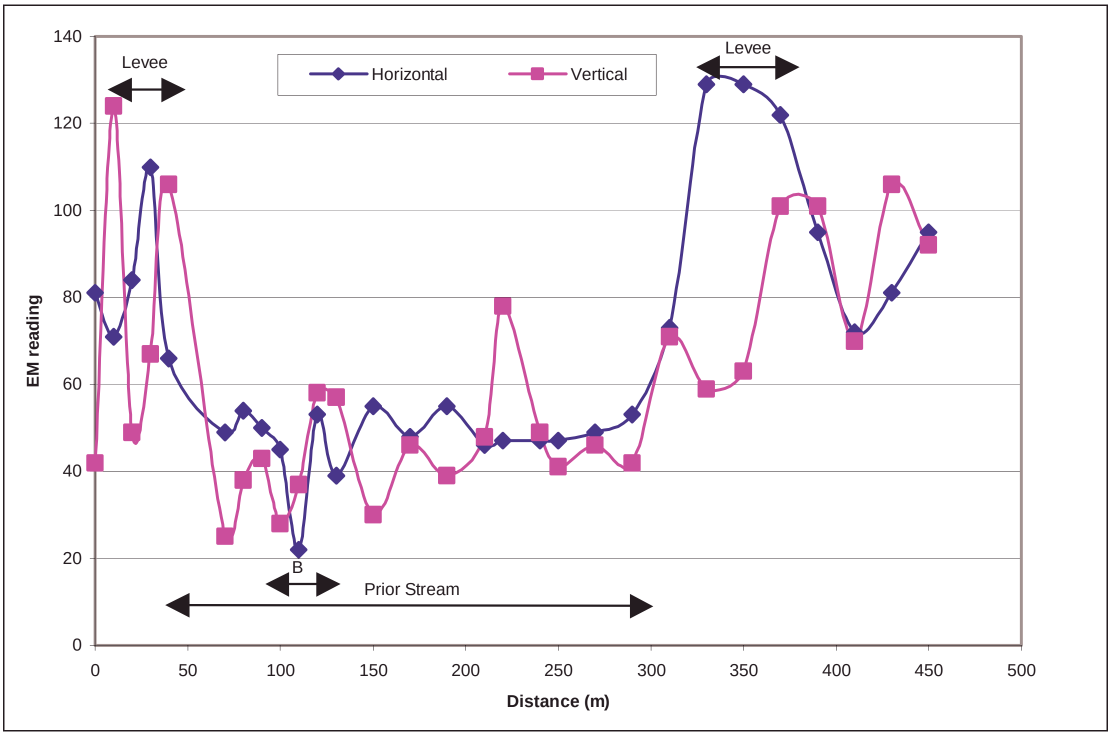

Figure 54. Transect D - Vertical and horizontal dipoles

4.2.5 Transect E

Transect E was conducted along the western side of the sandpits that were identified in area 1 (Figure 55). It crossed the same prior stream as transect D. The electrical conductivity results gained were all relatively low (40 to 80 mS/m) for both the horizontal and vertical dipole. This would therefore signify that this area was of light textured subsoil, pointing to the fact that there is a prior stream in the area. From Figure 56 to Figure 58 it can be seen that the prior stream is approximately 300 metres across. There is the possibility that the prior stream is even wider as the results do not get significantly high (> 120 mS/m) near the end of the transect to suggest the prior stream had been crossed. The area labelled C in Figure 56 to Figure 58 is an area where there could have been interference, possibly buried cables. There was nothing visible in the area to give any reasons why there was a significant change in the results at point C.

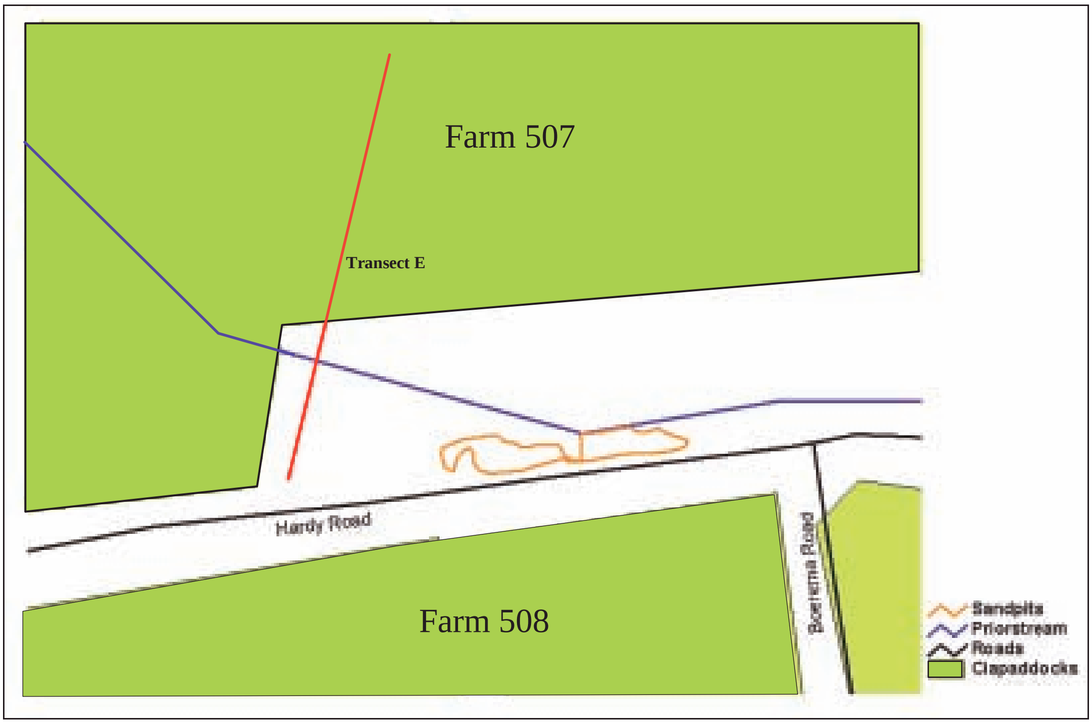

Figure 55. Transect E – Western side of sandpits in area 1

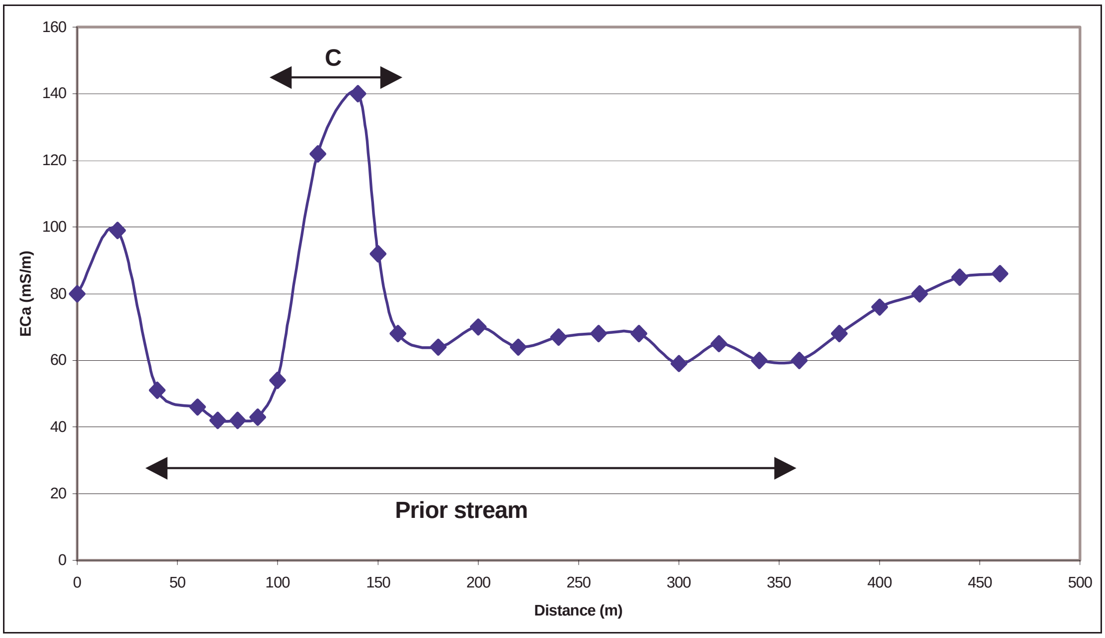

Figure 56. Transect E – Horizontal dipole

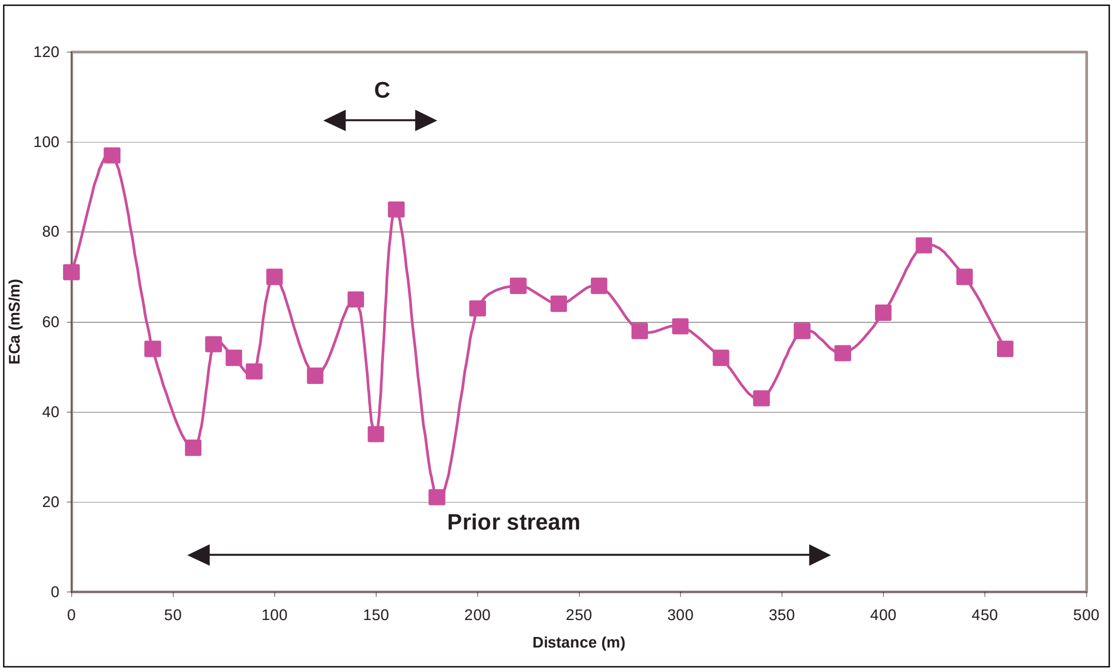

Figure 57. Transect E – Vertical dipole

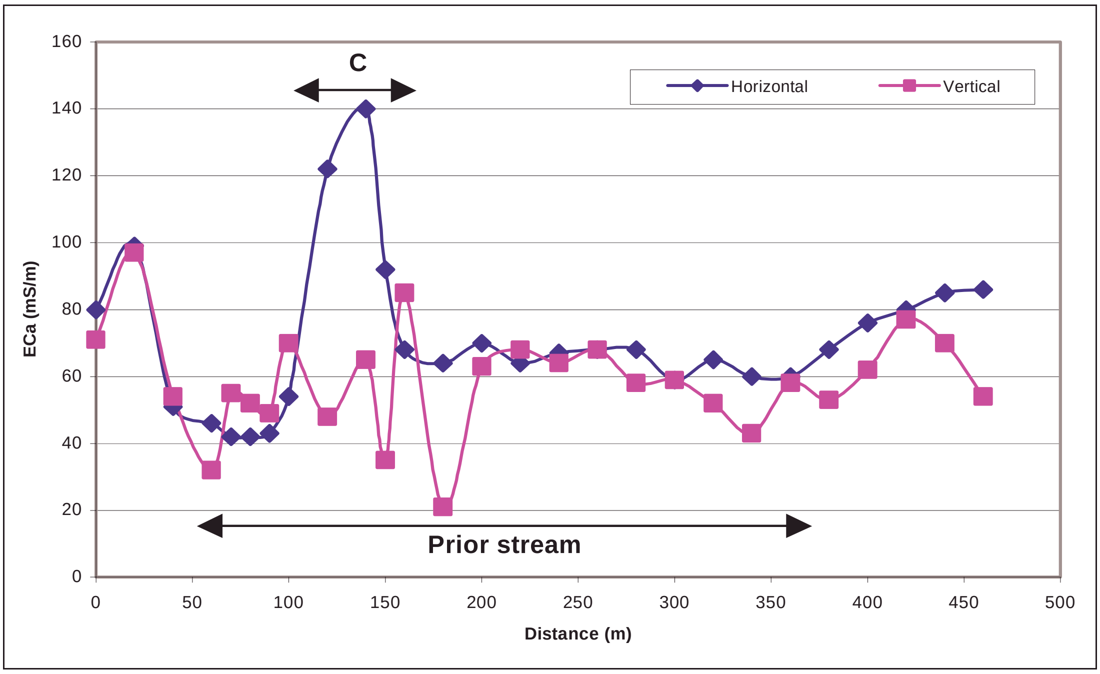

Figure 58. Transect E – Vertical and horizontal dipole

4.2.6 Transects around piezometers

The EM34 was used around piezometers to assess whether it is possible to have indicative values for the sandiness of an area. Readings around three piezometers were taken, these being numbers 12550, 5430 and 5431. Table 6 shows the readings of three transects taken around piezometer 12550 (Figure 59). The horizontal and vertical readings can be averaged to a horizontal reading of 134 mS/m and a vertical reading of 48 mS/m. It can be seen from Figure 60 that bore 12550 has 3½m of sand at a depth of 9m from the surface. Table 7 shows the results gained from transects taken around piezometer 5430 (Figure 61). It can be seen that although the area has a similar amount of sand present (Figure 62) the average results gained are not similar to those gained around bore 12550. Table 8 shows the EM results gained from transects taken around bore 5431 (Figure 63), again the cross section of bore 5431 (Figure 64) is very similar to bore 5430, however the average EM results are different.

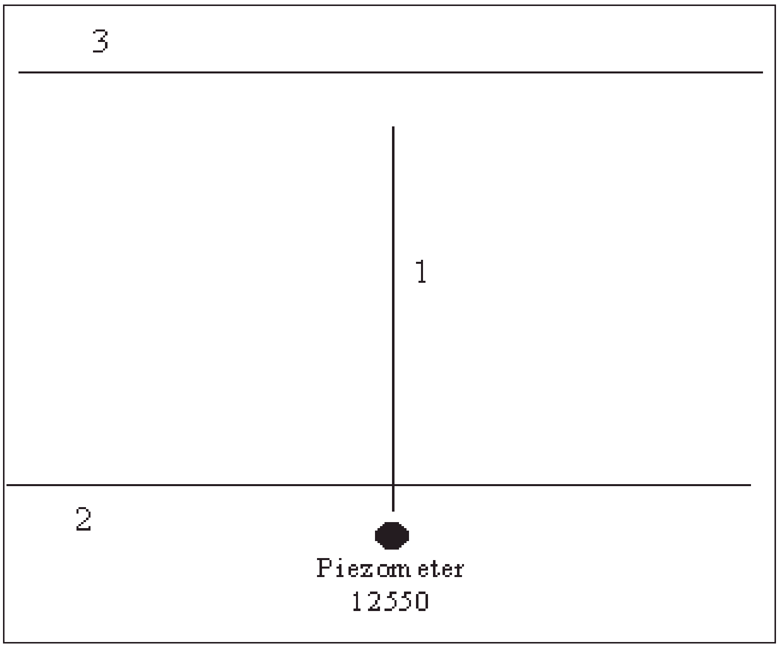

Figure 59. Location of EM transect around Piezometer 12550

		EM Reading (mS/m)	
		Horizontal Dipole	Vertical Dipole
10m Transect	1	140	48
	2	130	46
	3	132	50
Average		**134**	**48**

Table 6. Results of EM transects around piezometer 12550

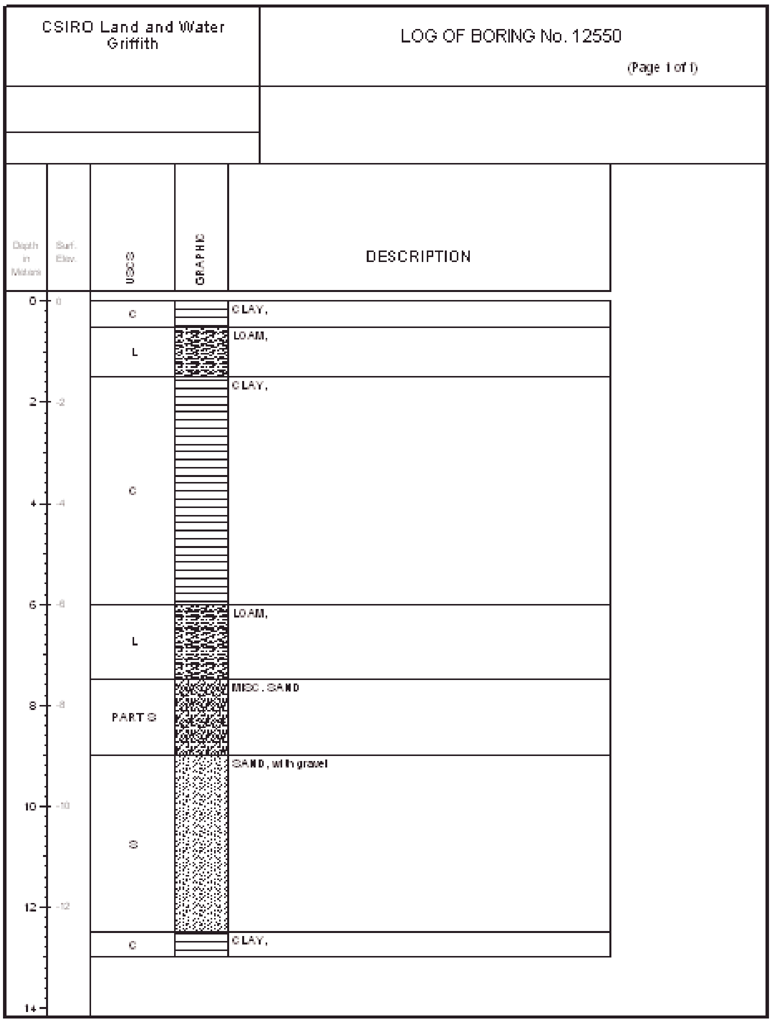

Figure 60. Bore log 12550

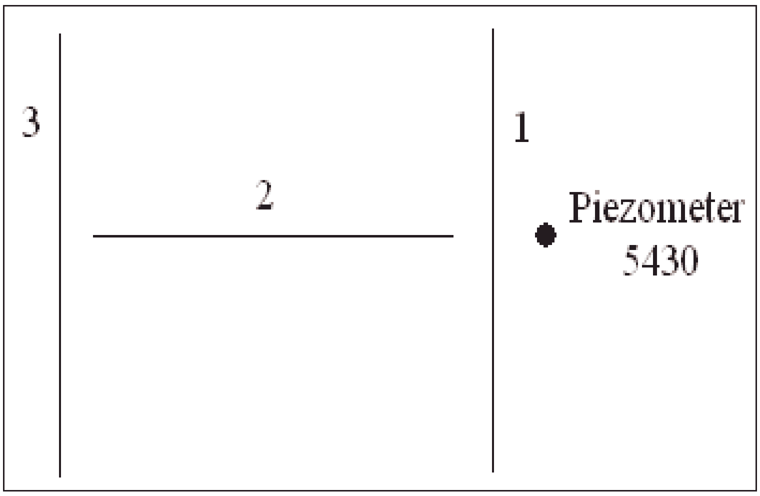

Figure 61. Location of transects around piezometer 5430

		EM Reading (mS/m)	
		Horizontal Dipole	Vertical Dipole
10m Transect	1	100	44
	2	52	54
	3	50	96
Average		**101**	**65**

Table 7. Results of EM transects around piezometer 5430

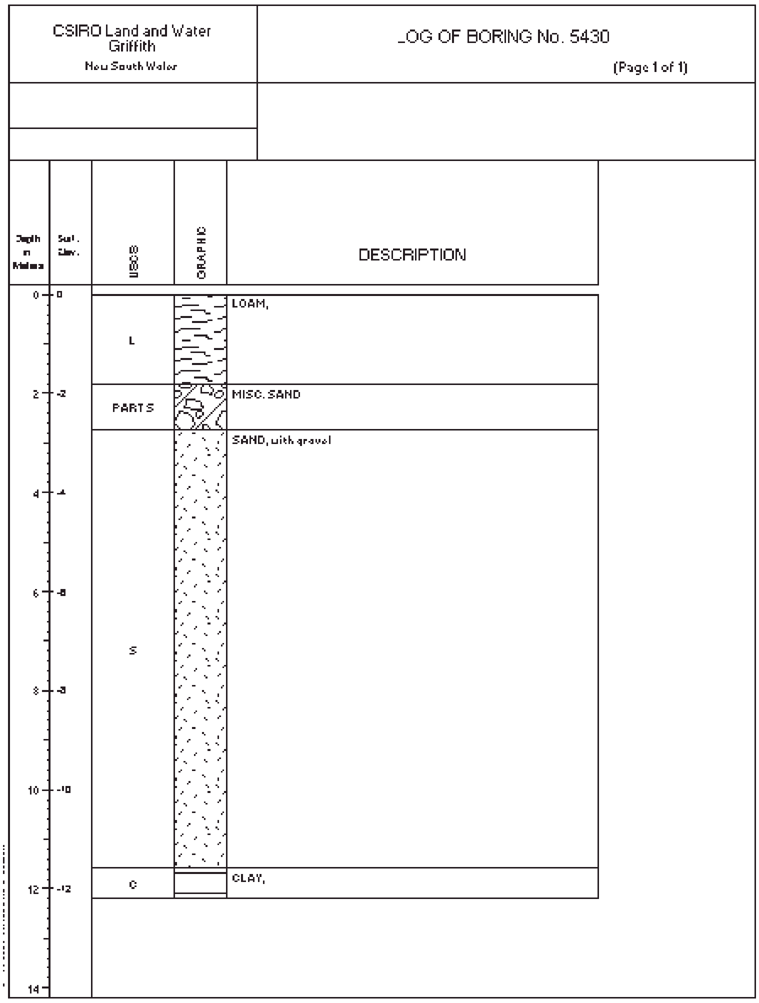

Figure 62. Bore log 5430

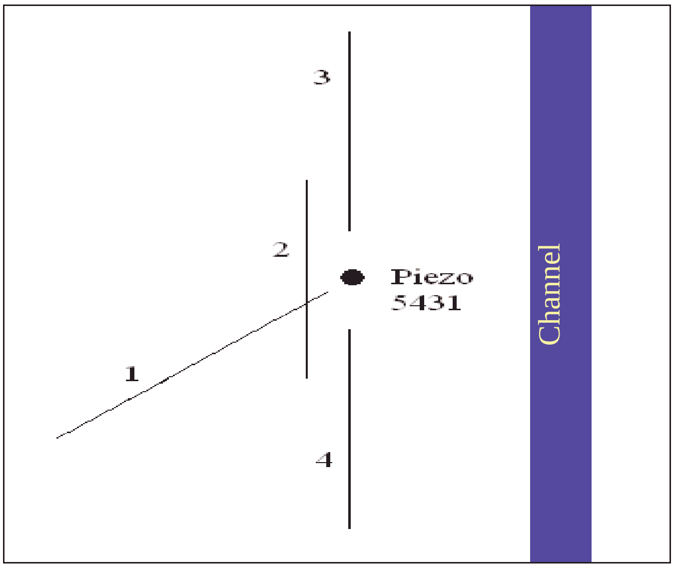

Figure 63. Location of transects around piezometer 5431

		EM Reading (mS/m)	
		Horizontal Dipole	Vertical Dipole
10m Transect	1	124	76
	2	135	110
	3	131	52
	4	158	78
Average		**137**	**79**

Table 8. Results of EM transects around piezometer 5431

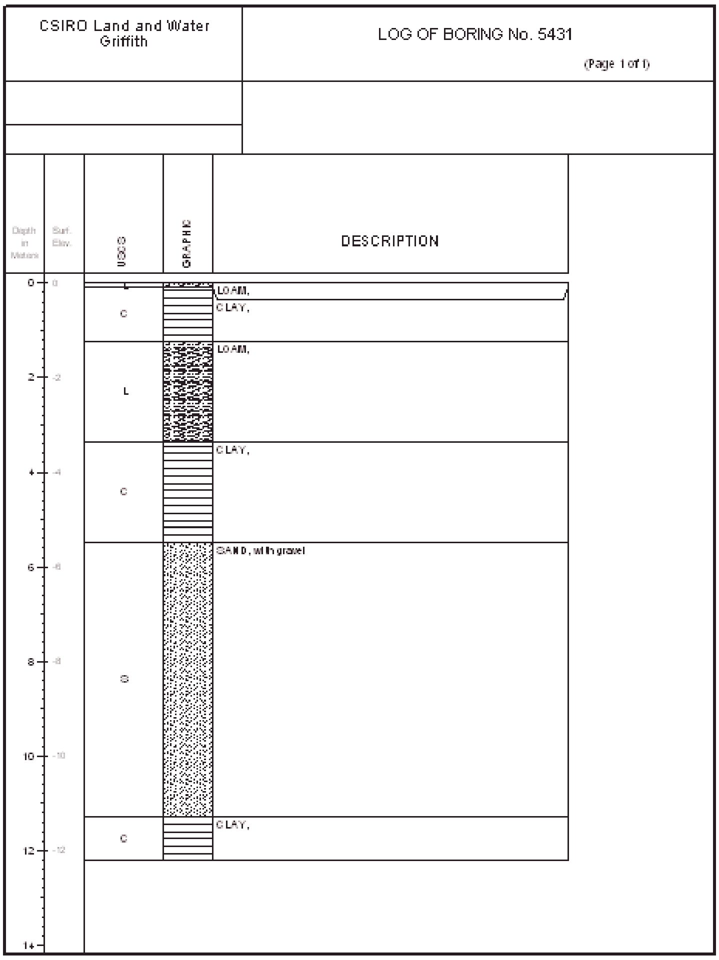

Figure 64. Bore log 5431

4.2.7 EM34 survey along Glenn/Leonard road.

An EM34 survey was also carried out along Glenn and Leonard road (Figure 65). The EM34 was used in the horizontal dipole mode with a spacing of 20m, therefore giving depth of response of 15m. The results can be seen in Figure 66. From Figure 66 it can be seen that the transect crossed a prior stream approximately 100m in width. As the prior stream was crossed the EM readings lowered from 100mS/m to 70mS/m, indicating a change in the texture of the material from a slightly heavy soil to a lighter textured soil, this can be confirmed by looking at bore log 12236 which the transect crossed (Figure 67). Bore 12236 shows a depth of coarse sand of 5.5m situated 3m from the surface. The readings in the centre of the prior stream remained around 70mS/m. When the other side of the prior stream was reached the EM readings started to increase towards 110mS.

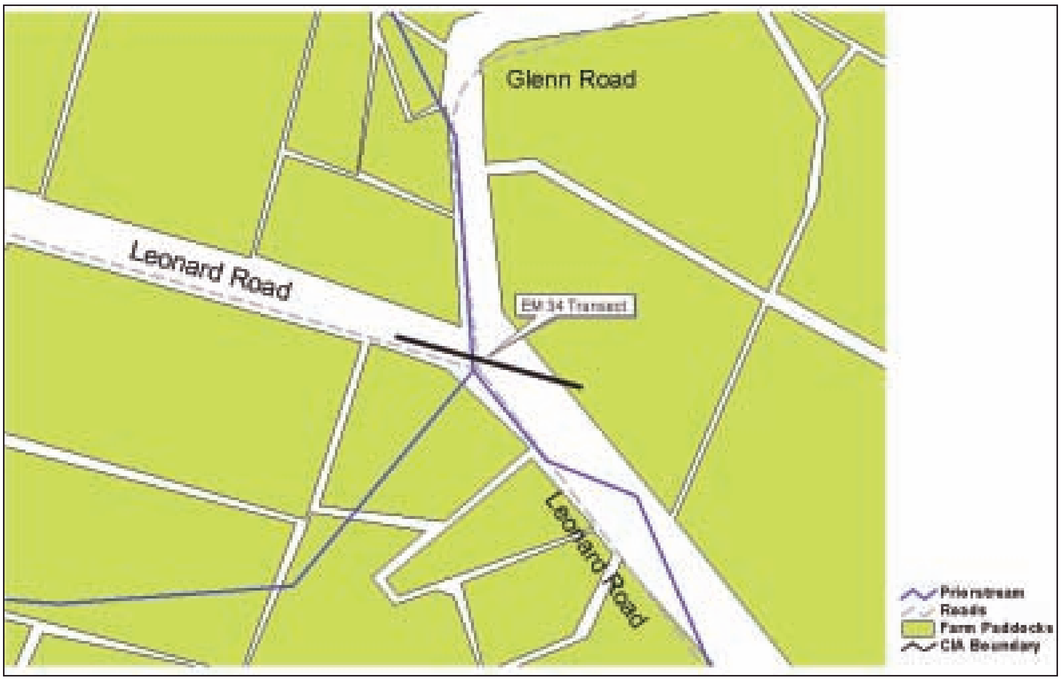

Figure 65. Location of EM34 transect – Glenn/Leonard Road

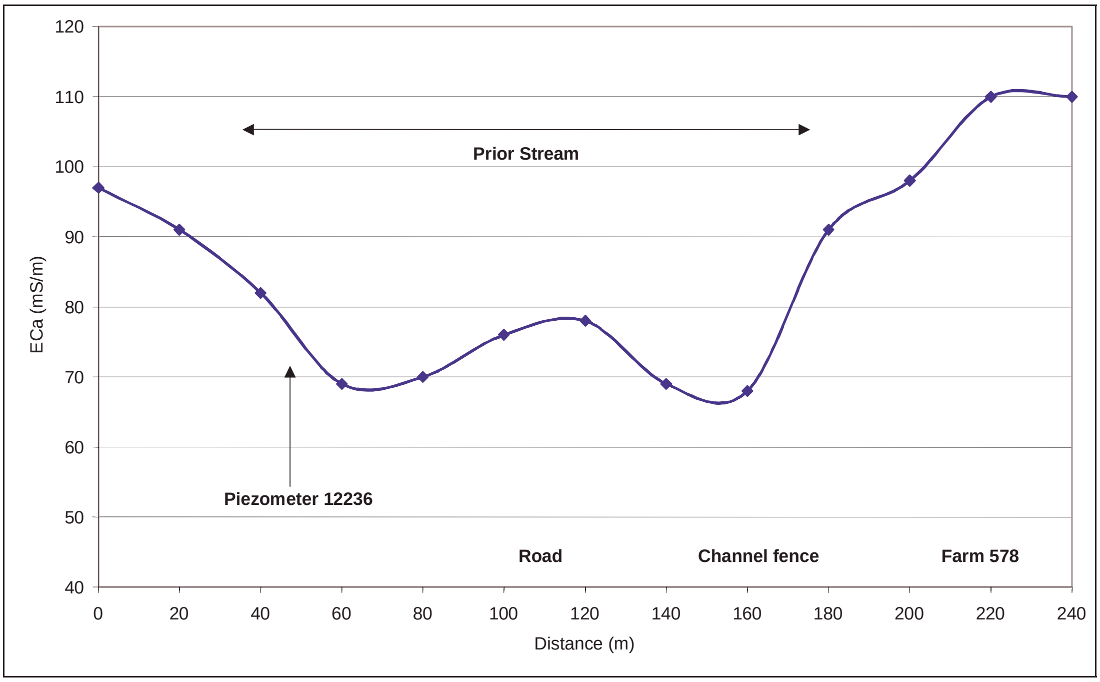

Figure 66. EM34 transect conducted across Glenn and Leonard road

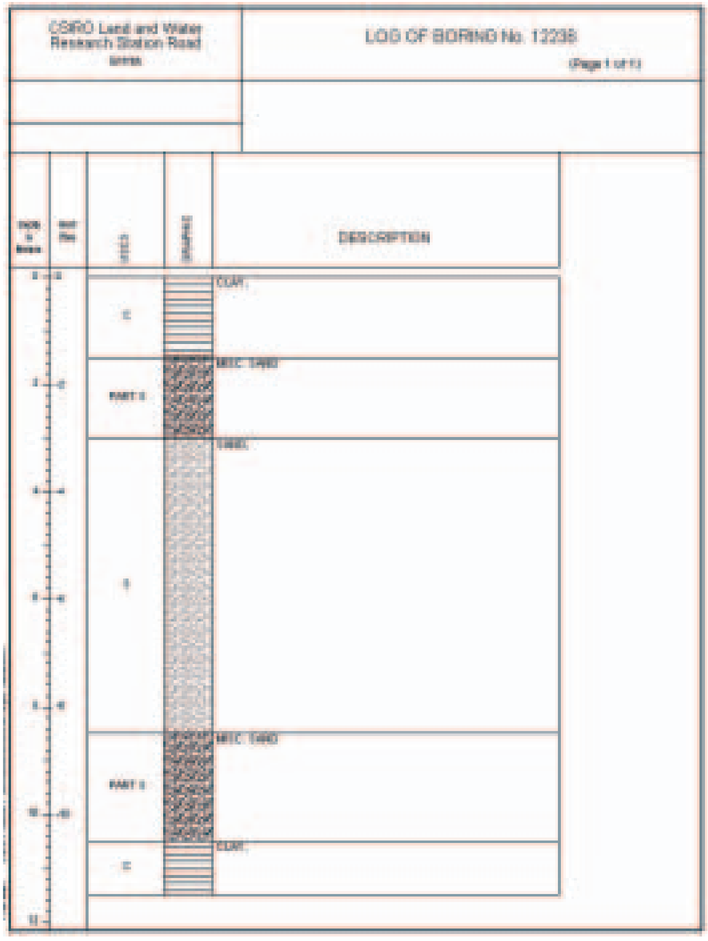

Figure 67. Bore log 12236

4.2.8 Analysis of data in technical report 92/13 (C.Bos) – EM34 surveys

EM 34 surveys were also carried out by C.Bos, as documented in the technical report 92/13. The EM34 was used in the horizontal dipole mode with a spacing of 20m, therefore giving depth of response of 15m.

In total 21 different transects of varying length were surveyed within the project area in Coleambally, Figure 68. There were two main EM34 transects carried out; section A, along Hannabus road and section B, along Elaroo road, Figure 69. All the other sections carried out were in close proximity to sections A and B. The results of these two sections, along with the bore numbers that the surveys crossed, can be seen in Figure 70 and Figure 71.

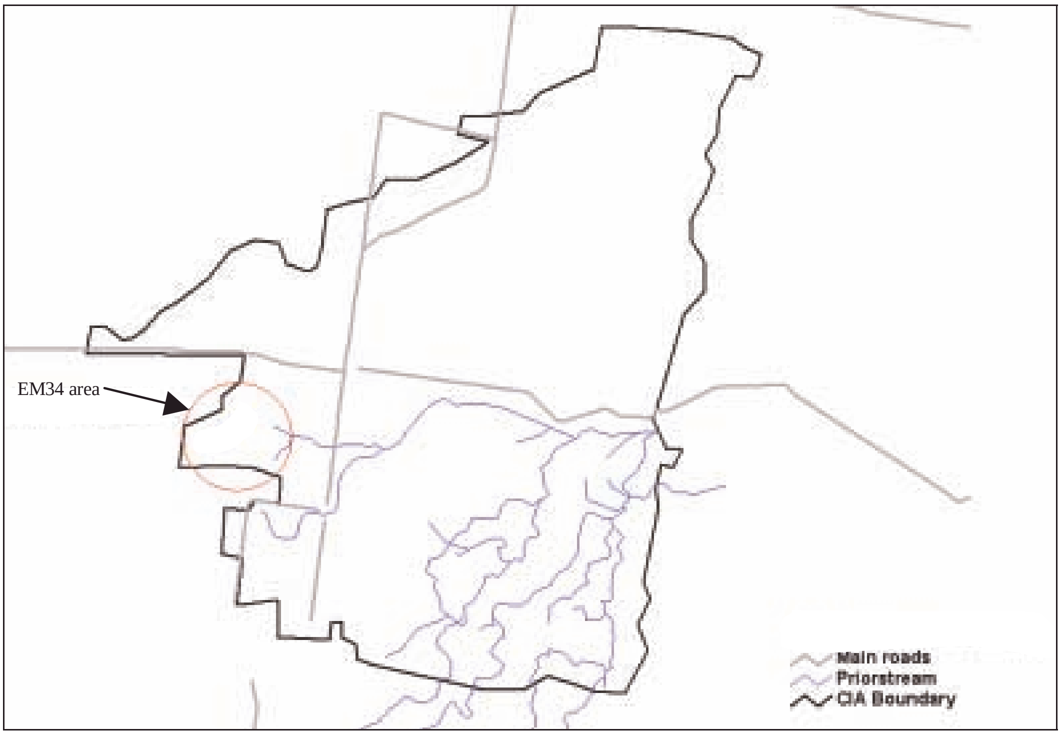

Figure 68. Location of report area within the CIA

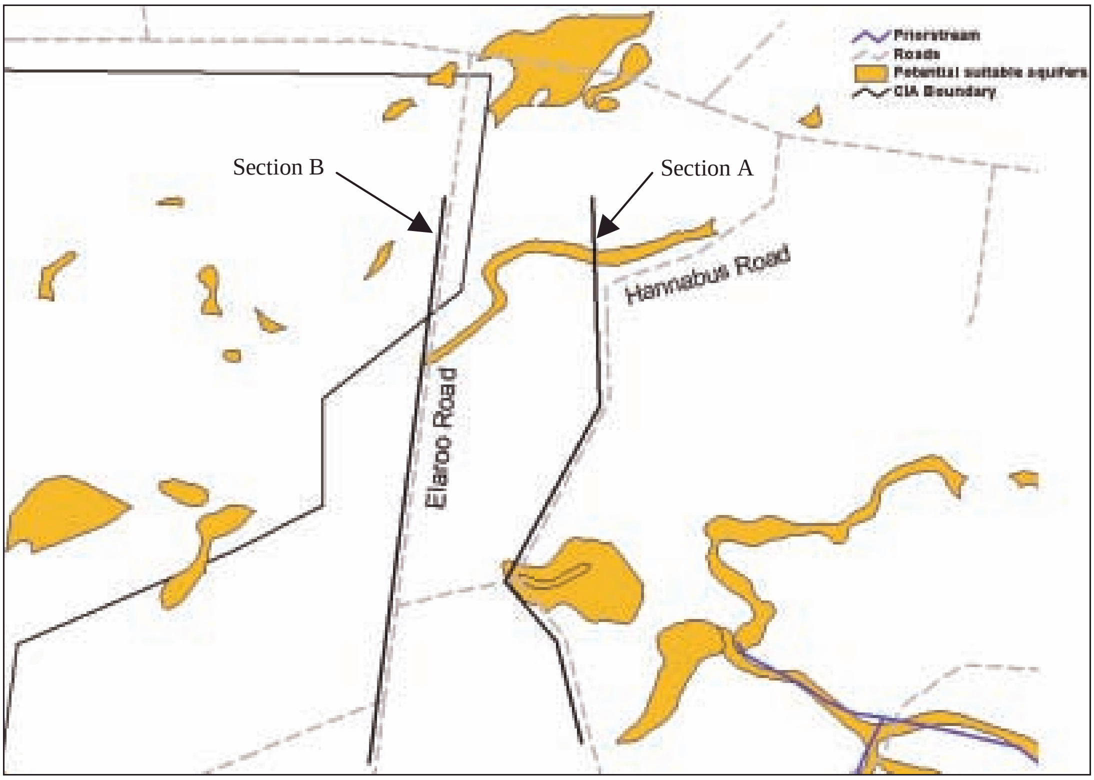

Figure 69. Location of main EM 34 sections with the project area

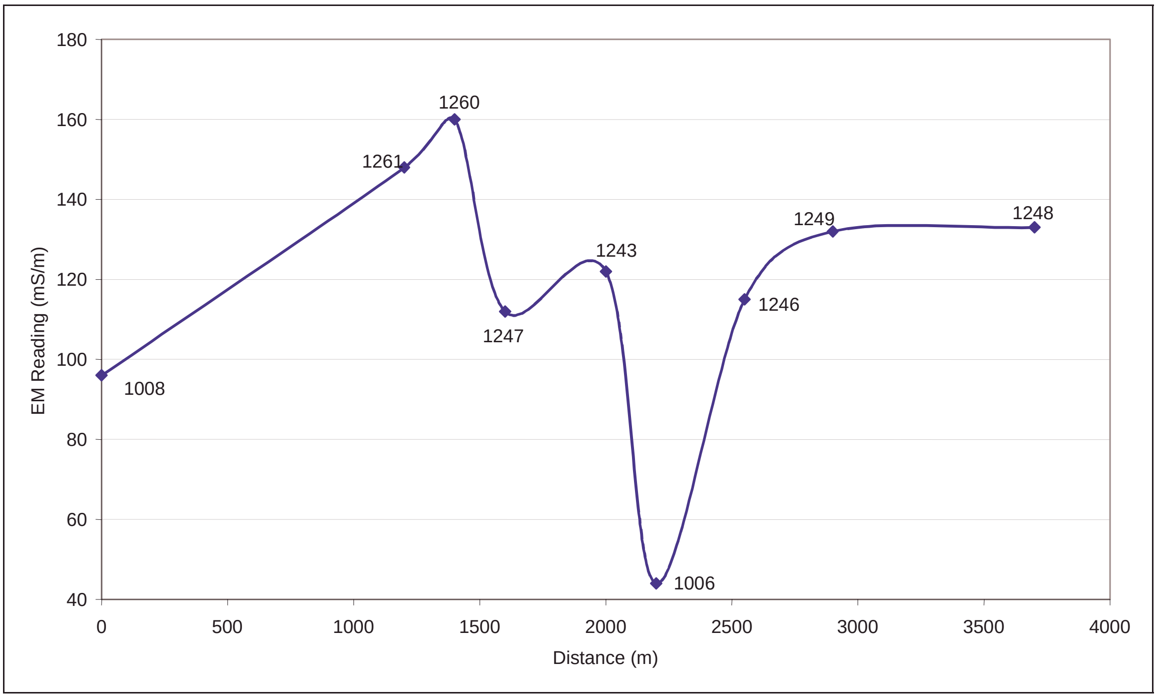

Figure 70. EM34 section A along Hannabus road and associated bore locations and numbers

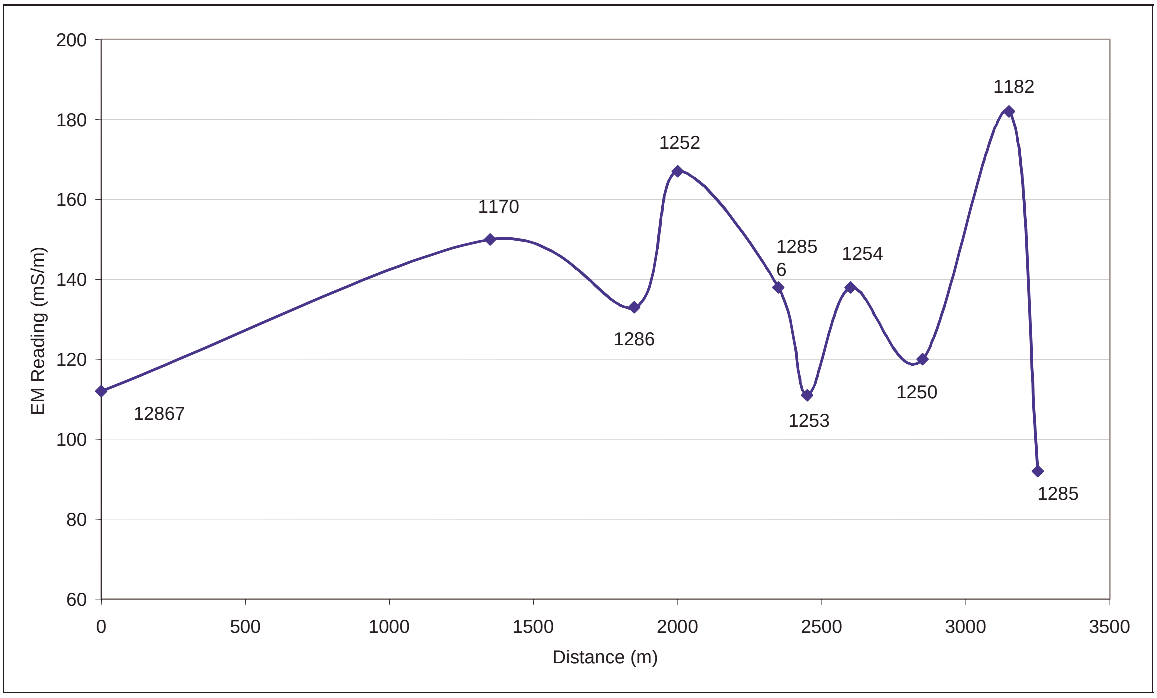

Figure 71. EM34 section B along Elaroo road and associated bore locations and numbers

4.3 Results of all EM34 surveys

In all the studies completed and the data from Bos (1992), 35 bores were surveyed with the EM34. Figure 72 shows the results of depth to sand and thickness of sand found at each bore versus the EM reading at each bore. The graph has been split horizontally into Areas 1, 2 and 3 and vertically by a blue and red line.

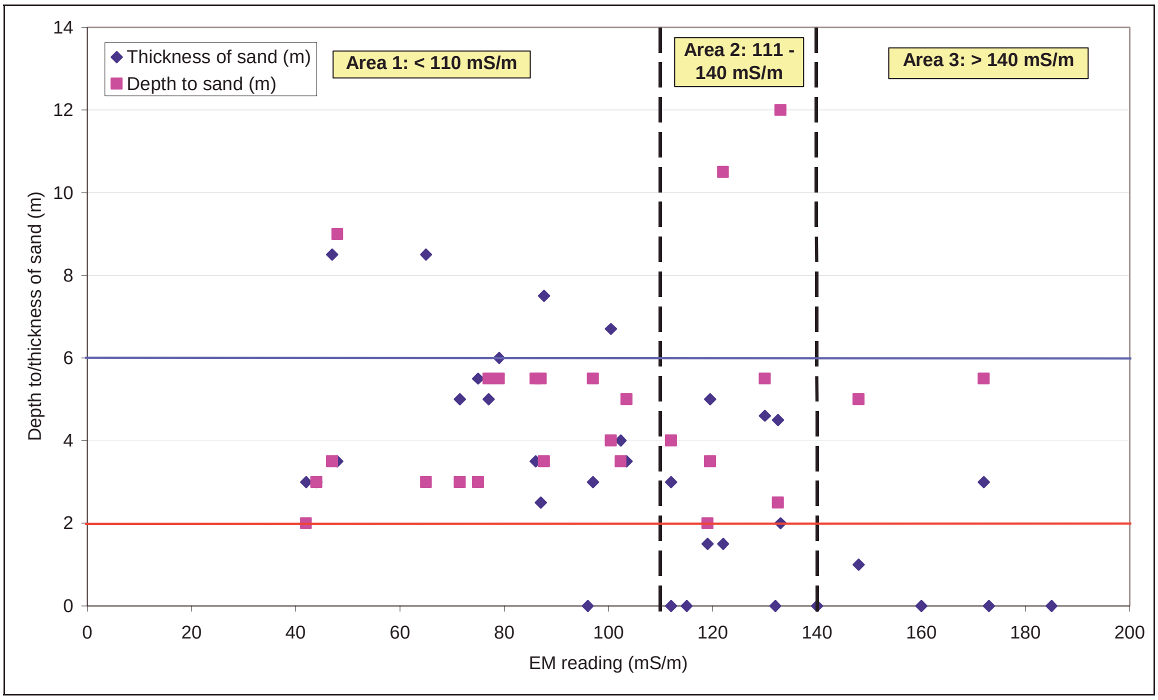

Figure 72. EM34 results for each bore surveyed

Area 1 shows the bores that had an EM reading of less than 110mS/m. It can be seen from Figure 72 that for an EM reading of less than 110mS/m it is likely that there will be sand in the area. The sand is likely to be greater than 2m thick (red line) and the depth to the sand is likely to be less than 6m from the soil surface (blue line).

Area 2 shows all bores that had an EM reading of between 111mS/m and 140mS/m. The results show that there is the possibility that sand is present, however a number of bores had little or no sand. Where sand is present then it is likely to be thicker than 2m and occur less than 6m from the surface.

Area 3 shows the bores that had an EM reading of greater than 140mS/m. In this range, it is very unlikely that sand will be found, however a very saline area can mask the presence of sand. Hence the reason why there is one bore with a thickness of sand greater then 2m in this range.

Table 9 confirms the findings of Figure 72. It shows that as the EM reading increases the average and median thickness of the sand decreases. It also shows that as the EM readings increase the average and median depth to the sand increases.

EM reading (mS/m)	Average thickness of sand (m)	Median thickness of sand (m)	Average depth to sand (m)	Median depth to sand (m)
< 110	4.8	4.5	4.3	3.5
111 - 140	2.3	1.8	6.6	4.0
> 141	0.8	0.0	5.3	5.3

Table 9. Average EM34 results for each bore surveyed

4.4 Conclusions to part two

Some cross sections showed that some of the aquifers present in the area varied from 500m to 4500m in extent. There were some sites where good potential aquifers for pumping were found, e.g., areas 1, 4, 5 and 6.

Some cross sections showed that some aquifers were overlain with up to 8m of clay, therefore probably limiting the effectiveness of pumping from the aquifer, although the exact impact is unknown, e.g., areas 2 and 3.

A number of cross sections showed significant amounts of partly sandy material, e.g. clayey sand, loamy sand and loamy clayey sands. The hydraulic properties of this partly sandy material need to be investigated to ascertain whether this is permeable and can be treated as aquifer material

EM34 surveys are generally site specific, however from the results gained from using the EM34 to a depth penetration of 15m it may be possible to predict the presence of sand just by looking at the EM reading. Although it is possible to predict the presence of sand from the EM reading, it is also necessary to assess the area being surveyed on its own merits and the results analysed from known facts about that area.

When using the EM34 with a depth penetration of 15m it is possible to say that if a result of less than 110 mS/m is recorded then the presence of sand at fairly shallow depths (< 6m) is likely. If a reading of between 111mS/m and 140mS/m is recorded then it is possible that sand is present however further information about the area would need to be collected to make a judgement on the presence of sand. If a reading of more than 140mS/m is recorded then the likelihood of the presence of sand is slim.

Generally as the EM readings increase, the depth to the sand increases, and the thickness of the sand decreases.

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