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The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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Summary

A groundwater study was carried out in and around the townsite of Piawaning. It aimed to accelerate the implementation of effective salinity management options. The study consisted of a drilling investigation, expansion of a piezometer network, a pumping test and a flood risk analysis.

The drilling investigation showed that the regolith could be divided into two categories: residuum over crystalline basement, and sediments over residuum over crystalline basement. The second profile category was found on the north-west, elevated side of a scarp which runs around the western and northern sides of the townsite. The first category was found below the scarp, to its east and south, and was the profile below the townsite. At the sites drilled, the sediments were up to 42 m thick and were partly consolidated. The base of the scarp appeared to coincide with the eastern edge of a basin within the crystalline basement rocks, and these features may correspond to a fault.

The piezometer network highlighted the shallowness of the watertable below the townsite (between about 1.0 and 1.5 m deep in winter 2000). North-west of the scarp, groundwater level depths in piezometers ranged between about 5 and 17 m, except in one shallow piezometer where the water level depth was only about 3 m for a short period in winter, and this piezometer was considered to be monitoring a seasonal perched watertable. The elevations of the groundwater levels at sites north-west of the scarp were about 8 m higher than those in the townsite (below the scarp). Groundwater seepage was evident in the face of the scarp at an elevation matching that of the groundwater levels to the north-west.

Yields estimated by air-lifting groundwater from the piezometers and observation bores indicated that the residual profiles had low yields (less than 20 m^3/day) and that the sediments had higher yields (over 100 m^3/day). Results from a pumping test carried out to the north-west of the scarp were not suitable for deriving aquifer parameters as the pumping rates which were used were too low.

The flood risk analysis indicated that the Piawaning townsite has a low risk of flooding during rainfall events of less than 50-year average recurrence interval, but that an event with a 100-year average recurrence interval would result in a considerable area of the town being under water.

The groundwater levels below the townsite are already very shallow, so they are unlikely to rise much further over the long-term. Salinity at Piawaning was thought to be influenced by catchment-scale processes rather than a localised groundwater system below the townsite. The form of the landscape indicates that the groundwater levels would be shallow below the townsite location even if the town was not there.

It was recommended that the current and future costs of salinity in the townsite be assessed and used to determine an appropriate level of investment in management schemes. However, approaches to reducing recharge within the townsite should be adopted where there were additional benefits in doing so.

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1. Introduction

The Rural Towns Program commissioned a groundwater study in Piawaning. It was part of a larger project (called the Community Bores Project) which covered 23 towns and aimed to accelerate the implementation of effective salinity management options.

For Piawaning, the groundwater study consisted of a hydrogeological investigation and a flood risk analysis. The hydrogeological investigation included a drilling program, the expansion of a piezometer network and a pumping test. This report documents background information for the town and its catchment (Section 2) and the hydrogeological and flood risk investigations (Sections 3 and 4). Recommendations for managing the salinity issues of the town are listed in Section 3.5.

2. Background information

Author: Russell Speed, Catchment Hydrology Group, Agriculture Western Australia

Piawaning is about 135 km north-north-east of Perth, 285 km south-east of Geraldton and 40 km south-east of Moora (Figure 2-1). The town has a population of about 10.

Piawaning is one of the smaller towns included in the Rural Towns Program, but is one of the most interesting from a hydrological viewpoint. The town is encompassed by a Department of Conservation and Land Management (CALM) reserve that is suffering severe degradation caused by shallow groundwater and groundwater discharge. Previous drilling (R. Speed, unpublished) established the presence of sediments (possibly Tertiary age) and this investigation sought to improve understanding of their role in contributing to townsite salinity.

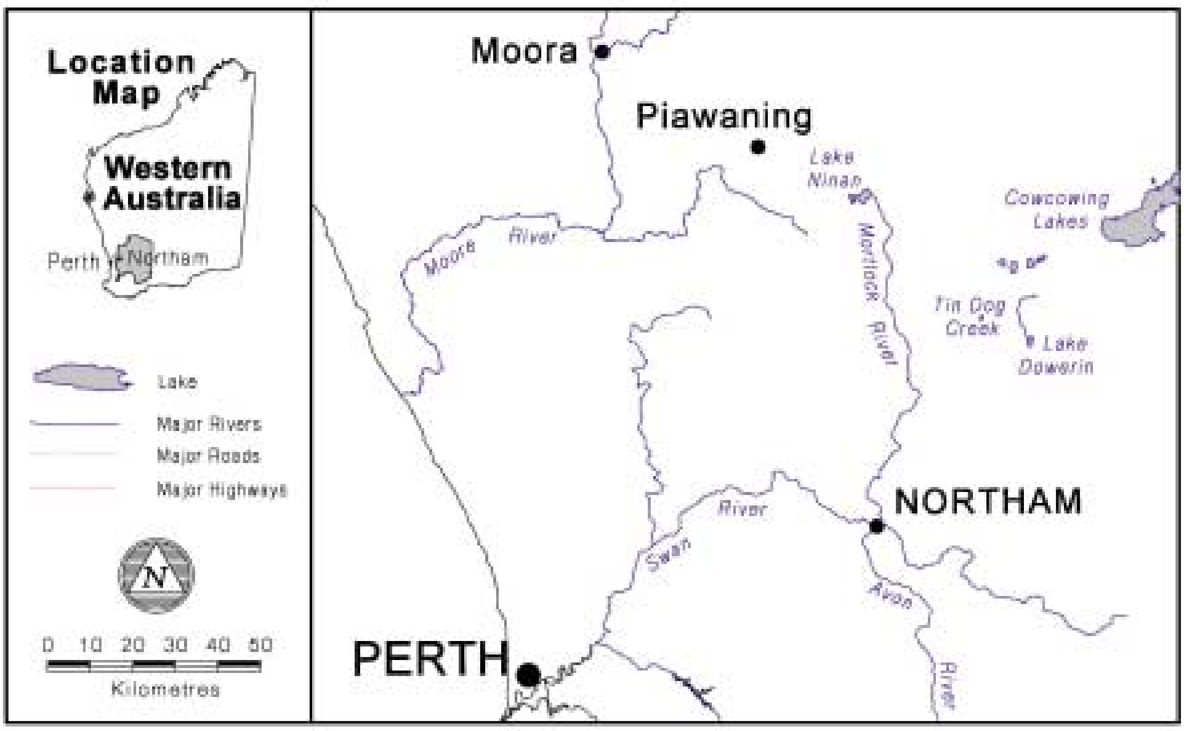

Figure 2-1. Location of Piawaning

2.1 Description of the town catchment

Piawaning townsite is adjacent to a saline drainage line at the outlet of a 2,570 ha catchment (Figure 2-2) that varies in elevation from 300 to 250 m above Australian Height Datum (AHD). All of the townsite lies between 250 and 252 m elevation.

The catchment is predominantly cleared for agriculture with only about 145 ha (5.6 per cent) of remnant native vegetation. About half of the native vegetation (about 75 ha) surrounds the townsite (Figure 2-2) and includes the CALM reserve. Much of this suffers severe degradation caused by shallow groundwater and discharge.

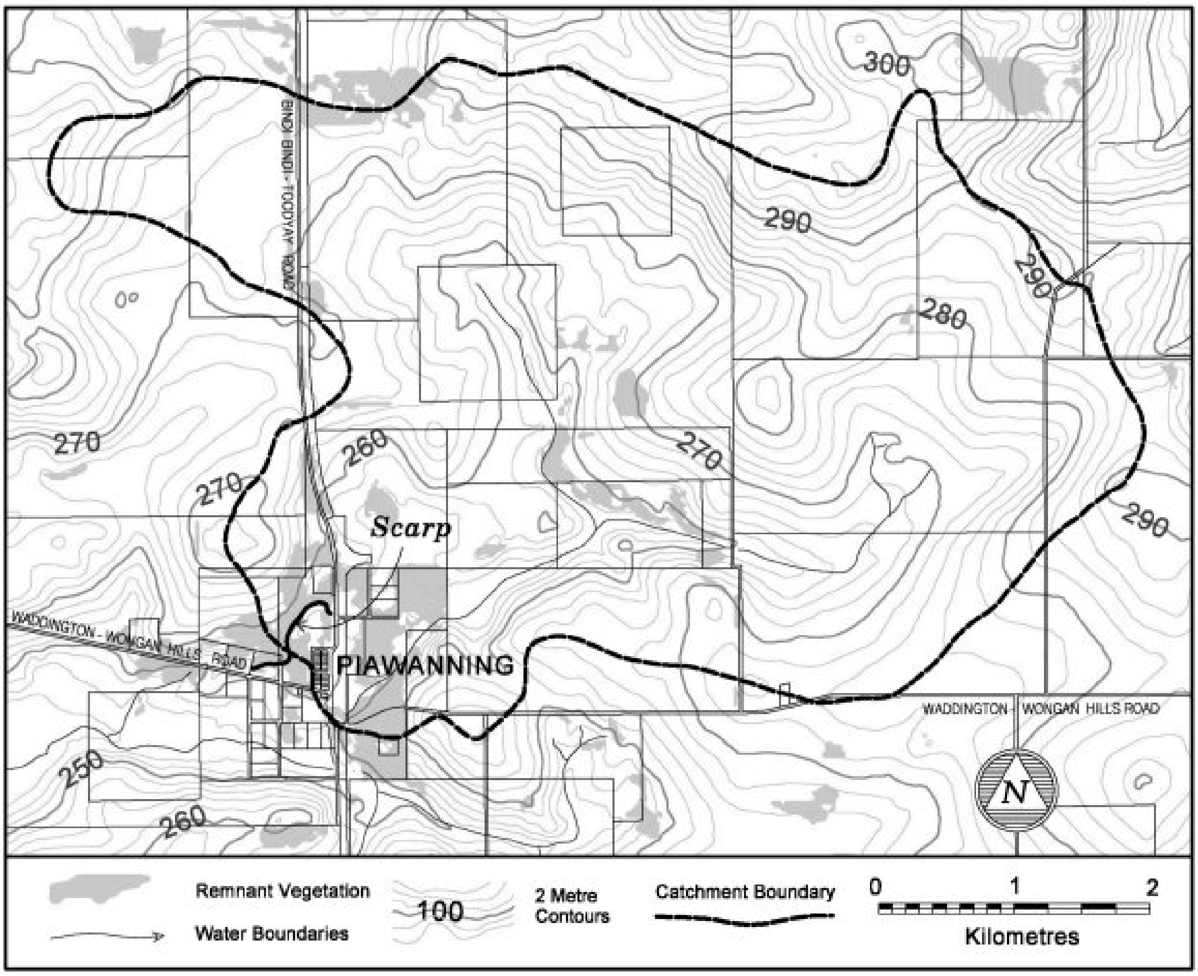

Figure 2-2. Location of the Piawaning townsite in its catchment, and the scarp to the north-west of the town

2.2 Geology

Piawaning townsite overlies Archaean basement of the Yilgarn Craton. The basement rock is predominantly granitic with dolerite dyke intrusions. However, drilling undertaken in 1998 (R. Speed, Agriculture Western Australia, unpublished) showed that the area behind a scarp to the north-west of the townsite (Figure 2-3) had at least 17 m of sedimentary profile. The upper part of the sedimentary sequence was pallid clay, implying a low energy depositional environment. The elevated position of the sediments indicated landscape inversion; that is, a low-lying depositional environment such as a lake bed now forms a hill overlooking the townsite and contemporary drainage system.

The sediments are considered to be of Tertiary age and possibly Eocene. Well-preserved leaf fossils and plant fragments occur in a fine-grained sandstone ridge in an upper landscape position east of Walebing, about 30 km north-west of Piawaning. The fossils have been dated as 44 million years old, falling within the Eocene epoch (Richard George, Agriculture Western Australia, pers. comm.).

2.3 Climate

Most rain in Piawaning falls in winter, and summers are hot and dry. Piawaning receives an annual average rainfall of 386 mm, 79 per cent from April to September inclusive (Bureau of Meteorology, pers. comm.). However, summer rainfall events can be significant: the highest recorded daily rainfall was 86 mm on 7 March 1934.

2.4 Drainage

The drainage system adjacent to the townsite has poor channel definition but is readily recognised by its saline nature. Piawaning townsite is in the midst of a groundwater discharge area (Figure 2-3). This gives the impression that Piawaning is encompassed by a swamp. However, the appearance of a swamp is a function of groundwater discharge rather than surface water accumulation.

2.5 Hydrogeology and salinity

As noted above, Piawaning townsite is in an area characterised by groundwater discharge. The processes causing and controlling discharge vary.

The saline drainage line to the east and south-east of the townsite is typical of wheatbelt salinity. A groundwater monitoring site (PB1, R. Speed, unpublished), was installed adjacent to this saline drainage line in May 1998 (Figure 2-3). The profile at site PB1 was 1.5 m of yellow sand over 15 m of residual pallid to yellow-brown gritty clay saprolite. Competent quartz-rich crystalline basement was intersected at 16.6 m depth. The profile was fully saturated with saline groundwater. Groundwater levels fluctuate in response to seasonal rainfall (Figure 2-3), but the proximity of the watertable to the ground surface and closeness of the site to the saline drainage line (the discharge area) imply that this area is in post-clearing hydrological equilibrium.

Swampy areas surround Piawaning townsite from the north to west. They appear to result from groundwater discharge from the sediments through seepage faces in the lower part of the vegetated scarp within CALM reserve (Figure 2-3).

Site PB2 (Figure 2-3) was drilled on top of the scarp in May 1998 (R. Speed, Agriculture Western Australia, unpublished). From about 2 m downwards, drilling intersected 14 m of pallid clay overlying very fine light grey sand. The very fine sand was unconsolidated and saturated, which caused difficulties with the rotary-air-blast drilling technique used. Drilling was terminated at 17 m depth and a piezometer was installed. In addition, a shallow observation bore was installed to about 5 m depth.

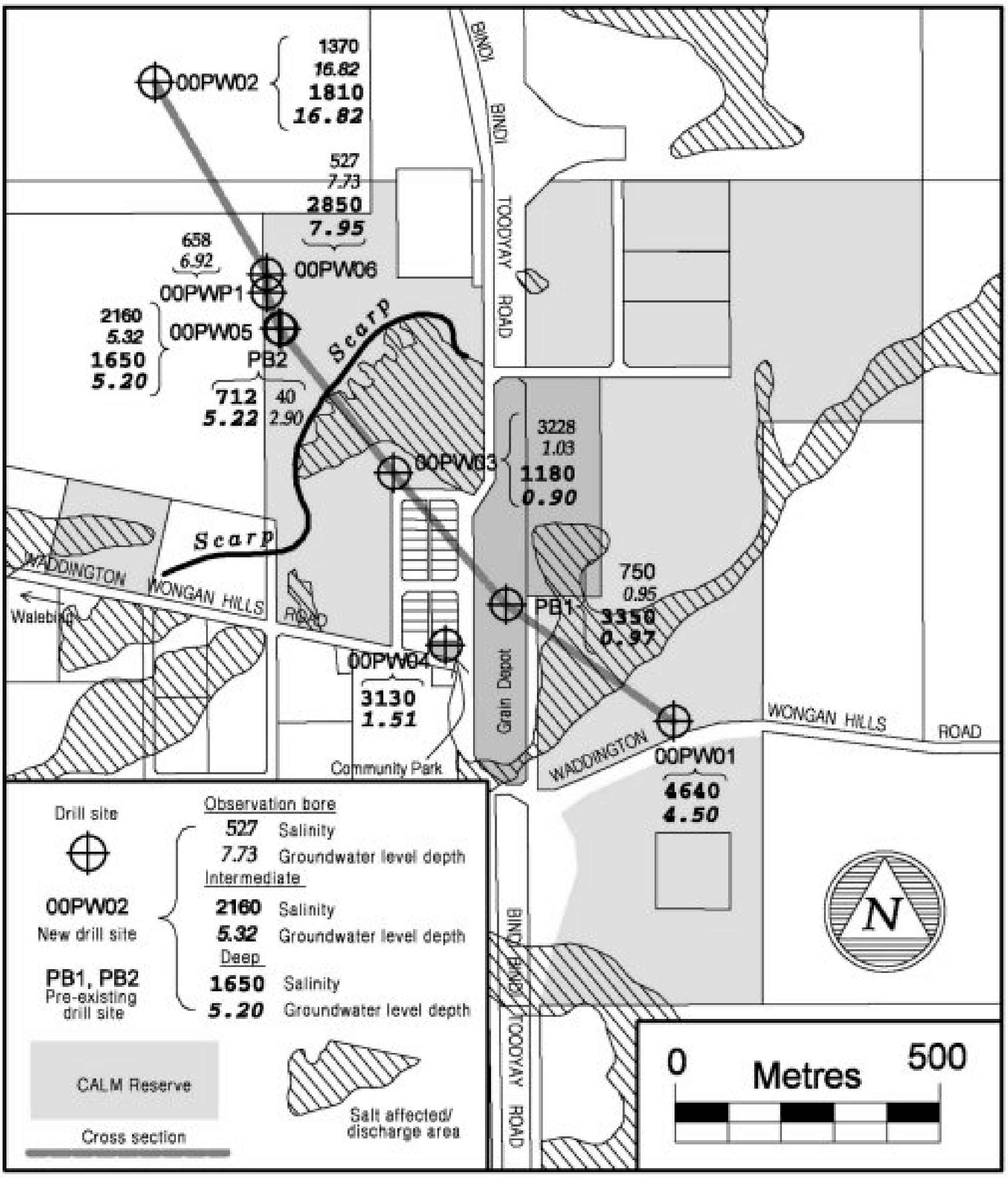

Figure 2-3. Groundwater level depths (in metres below ground) on 3 August 2000, electrical conductivity values (in milliSiemens per metre) for piezometers and observation bores on 27 July 2000, and locations of the cross-section in Figure 3-1

The ground elevation at site PB1 is about 249 m above AHD, and at PB2 is about 261 m above AHD. The hydrograph for piezometer PB2D (Figure 2-4) shows the depth to groundwater is less than 6 m and, therefore, at considerably higher elevation than Piawaning townsite. The hydrograph also implies that high rainfall in 1999 resulted in more recharge than discharge that year and it is not clear whether the resulting groundwater level rise will be permanent. Even though the rate of groundwater discharge through the vegetated seepage face was too low to drain all of the extra recharge, it is likely that the discharge rate increased in 1999, further degrading the remnant native vegetation.

A rapidly-draining watertable is monitored by observation bore PB2OB (Figure 2-4).

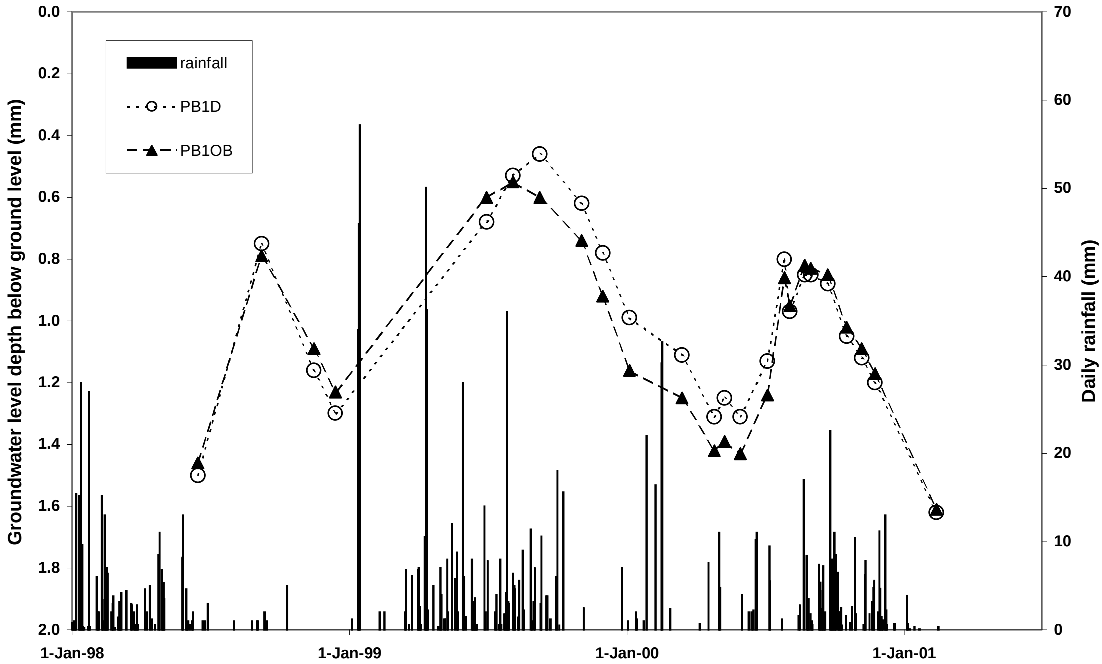

Figure 2-3. Hydrographs for piezometer and observation bore at site PB1

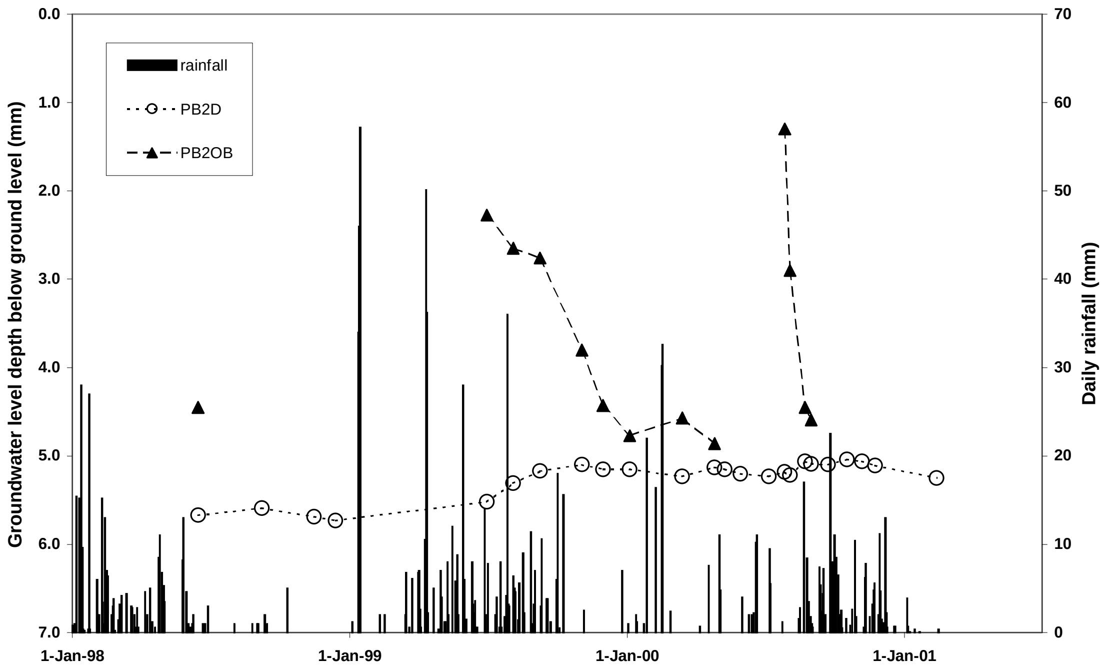

Figure 2-4. Hydrographs for piezometer and observation bore at site PB2

3. Drilling investigation

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3.1 Available information

The following information was available for the Piawaning townsite salinity investigation prior to the Community Bores Project:

- geological map at scale of 1:250,000, with explanatory notes (Carter and Lipple 1982);
- aerial photography taken in 1997 at nominal scale of 1:25,000 (obtained from Department of Land Administration);
- rectified satellite imagery from 1996 at scale of 1:100,000 (obtained from Department of Land Administration);
- 2-metre elevation contours generated from digital elevation models (produced by Spatial Resource Information Group, Agriculture Western Australia);
- cadastre (obtained from Department of Land Administration);
- drill hole data from two sites acquired in 1998 (R. Speed, Agriculture Western Australia, unpublished data);
- time-series groundwater data from two sites from June 1998 (R. Speed, Agriculture Western Australia, unpublished data).

3.2 Method

Seven sites (one production bore and six monitoring sites) were established for the investigation during July 2000. One or two piezometers were installed at each monitoring site (eight in total) and observation bores were installed at three sites.

3.2.1 Drill site selection

Drill sites were selected in a transect across the catchment incorporating the two existing monitoring sites (PB1 and PB2) and Piawaning townsite. The transect strikes approximately north-west to south-east (Figure 2-3).

Site 00PW02 was programmed on the crest of a hill in anticipation of intersecting the thickest sequence of sediments at this topographic location.

An additional site, 00PW04, was located in the community park on the corner of the Bindi Bindi–Toodyay Road and the road to Walebing to provide a community bore for the town (requested by the Community Bores Project).

The production bore site was selected after installation of the monitoring sites. Anticipated yield and the estimated relative elevation of profile characteristics and groundwater levels determined its position and depth.

3.2.2 Drilling methods

The monitoring sites were drilled by Drilling and Grouting Services Pty Ltd using reverse circulation air-core methods with a 141 mm-diameter bit. Cores up to 10 cm long were recovered from some lithified sections of the profile.

A pilot hole for the production bore was also drilled using reverse circulation air-core and a 141 mm-diameter bit. The rig was then converted to use mud-rotary methods and the hole was reamed out with a 216 mm-diameter tri-cone bit.

3.2.3 Piezometer, observation bore and production bore construction

Piezometers and observation bores were constructed with 50 mm-diameter class 12 PVC casing. The intake section was machine slotted. The production bore was constructed with 125 mm-diameter class 9 PVC casing.

Piezometers were screened over the bottom two metres. The annulus around the intake section was packed with '8x16' graded gravel (about 1.2 to 2.4 mm diameter). Bentonite pellets were used to seal the annulus above the screened interval. The annulus was then back-filled to ground surface with the graded gravel. Headworks were completed with a lockable steel collar set in cement.

Observation bores were screened over the bottom 2 metres (except 00PW03OB which has a four-metre screened interval) and the annulus back-filled to the surface with '8x16' graded gravel. Headworks were completed with a galvanised steel collar, with threaded end-cap, set in cement.

The production bore was screened over the bottom 24 m and the annulus back-filled to ground surface with '8x16' graded gravel. Headworks were completed with a lockable steel collar set in cement.

3.2.4 Drill sample analyses

Drill samples were collected and described over one-metre intervals. Descriptive logs were recorded and are available at <http://www.agric.wa.gov.au/environment /links/RMtechreports/>. Samples were oven-dried at 60°C.

A selection of samples was sent to Dr Lynne Milne, University of Western Australia, for pollen analysis to determine the age of the sediments.

Duplicate chip trays were prepared for all profiles. One set of chip trays is stored at the Geraldton office of Agriculture Western Australia; the other set was presented to the Shire of Victoria Plains at Calingiri.

3.2.5 Groundwater monitoring and sample analyses

Piezometers, observation bores and the production bore were developed by 'air-lifting' (that is, injecting compressed air down them) when there was sufficient groundwater at the completion of construction. Groundwater yields were estimated by timing how long it took to fill a bucket of known volume from water discharged from the constructed piezometer or observation bore by air-lifting.

Groundwater levels were measured and groundwater samples were collected as part of routine monitoring. Samples were analysed for electrical conductivity (EC) at Agriculture Western Australia laboratories in South Perth. Results are stored on the AgBores database.

3.2.6 Downhole logging

All drill sites were geophysically logged with a downhole electromagnetic conductivity probe and downhole gamma logger.

3.2.7 Surveying

All drill sites were surveyed using a differential global positioning system. Warren King and Co. (2000) quoted the accuracy to be ±30 mm horizontally and ±40 mm vertically for the towns they surveyed for the Community Bores Project.

The bore transect was also profiled using the global positioning system. These data were used to define the topographic surface profile for the hydrological cross-section.

3.2.8 Pumping test

A pumping test was carried out by Test Pumping Australia to establish aquifer parameters in the sediments. The test method is described in Appendix 1.

3.3 Results

3.3.1 Profile descriptions

Detailed drill logs are presented in <http://www.agric.wa.gov.au/environment/links/ RMtechreports/>. Downhole logging results are available from the author.

The profiles which were intersected, fell into two categories (illustrated in Figure 3-1). Below the scarp the profiles were essentially weathered in situ (i.e. residual) gritty clay saprolite over crystalline basement. Above the scarp, a significant thickness of sediments overlaid residual gritty clay saprolite and crystalline basement.

The saprolite-only profiles were mostly pallid to yellow-brown gritty clay and ranged in thickness from 17 m to 32 m.

Where sediments were present (i.e. north-west of the scarp), the thickness of the sedimentary profile varied markedly with elevation. The thickest sedimentary sequence (42 m) was intersected on the crest of the hill at site 00PW02. However, the characteristics of the sedimentary profiles were remarkably similar. Typically, the upper 10 m of the profile was clay or claystone. Underlying the clay was very fine light grey sand. Then, interbedded sequences of fine sand/sandstone, sandy clay and clay horizons were intersected. Sand horizons became dominant and coarser with depth over the lower few metres, grading to a basal gravel, typically 1 to 2 m thick with well-rounded quartz pebbles up to 20 mm in diameter. The basal gravel unconformably overlay residual light grey, grading to dark grey, gritty clay saprolite. The thickness of saprolite profiles underlying sediments ranged from 7 to 17.5 m.

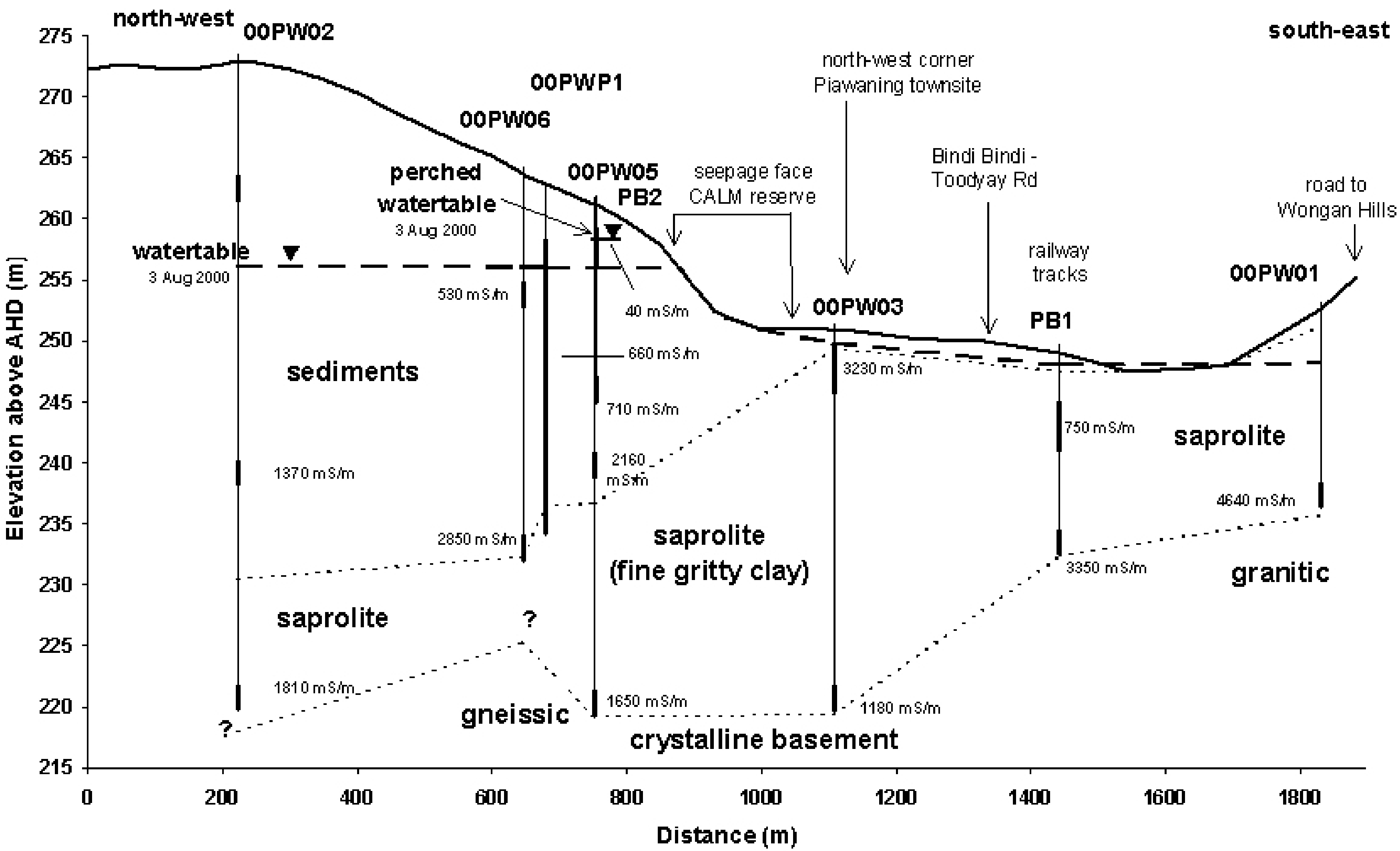

Figure 3-1. Hydrological cross-section along bore transect incorporating Piawaning townsite (see Figure 2-3 for location)

No pollen was found in the samples sent for examination.

The downhole gamma and electrical conductivity logs did not facilitate extrapolation of sedimentary horizons between drill sites. However, the gamma logs indicated a number of sand aquifers potentially separated by clay aquitards.

3.3.2 Groundwater data and systems description

Site, drilling, piezometer, observation bore and groundwater details are listed in Table 3-1 and the change in groundwater levels and salinities across the townsite are illustrated in Figure 2-3 and 3-1.

Watertable depth ranged from 0.95 m to 16.82 m below ground level on 3 August 2000. The shallowest watertable was measured at site PB1 adjacent to the saline drainage line. The greatest depth to the watertable was measured on the crest of the hill at site 00PW02 north-west of the townsite.

A perched watertable was recorded 2.90 m below ground in observation bore PB2OB on 3 August 2000.

The lowest groundwater salinity measured on 27 July 2000 was 530 mS/m in observation bore 00PW6OB which intersects sediments. The highest salinity was 4,640 mS/m measured in 00PW01D intersecting a saprolite profile east of the townsite and saline drainage line.

The elevation of the watertable within the sediments was about 8 m higher than within Piawaning townsite and the saline drainage line to the east (Figure 3-1).

Of the six sites with nested piezometers and observation bores, in winter 2000 groundwater elevations were approximately level in the deep and shallow holes at four sites (PB1 (Figure 2-3), 00PW02, 00PW03 and 00PW05), but the observation bores had higher heads at two locations (PB2 (Figure 2-4) and 00PW06). The monitoring records (stored in the AgBores database) showed that by the end of November 2000, PB2OB was dry as the water level had fallen rapidly, while that in PB2D changed relatively little. However, water level at site 00PW06 changed markedly during the same period. Of the four nested sites which had little head differences in winter 2000, only site 00PW03 showed a different head relationship in late November 2000, as the head in the shallow observation bore fell more sharply than that in the deep piezometer.

Table 3-1 shows that estimated yield from saprolite profiles, whether overlain by sediments or not, were all relatively low (less than 20 m^3/day). In contrast, the estimated yield from sediments was relatively high (greater than 100 m^3/day). The yield from the production bore, estimated during development, was greater than 400 m^3/day and the highest pumping rate used during the pumping test was about 500 m^3/day.

Table 3-1. Site, drilling, construction and groundwater details of the piezometers and the observation bores (groundwater levels are for 3 August 2000; groundwater samples were taken on 27 July 2000, except where date given in brackets)

Drill hole name	Easting (mE)	Northing (mN)	Ground elevation above AHD# (m)	Sediment thickness (m)	Depth drilled (m)	Screened interval elevation above AHD# (m)	Groundwater level depth bgl## (elevation above AHD#) (m)	Electrical conductivity (mS/m)	Estimated yield (m^3/day)
PB1D	441,260.2	6,587,855.6	249.0	0	16.6	232.5—234.5	0.97 (248.0)	3,350 (8/9/98)	negligible
PB1OB						241.0—245.0	0.95 (248.0)	750 (8/9/98)	
PB2D	440,835.4	6,588,377.0	261.1	17+		245.0—247.0	5.22 (255.9)	712 (12/10/99)	20
PB2OB						256.3—259.3	2.90 (258.2)	40 (12/10/99)	
00PW01D	441,575.7	6,587,634.8	252.6	0	17	236.4—238.4	4.50 (248.1)	4,640	negligible
00PW02D	440,595.7	6,588,844.5	272.9	42.5	55	219.8—221.8	16.82 (256.1)	1,810	15
00PW02I						238.2—240.2	16.82 (256.1)	1,370	140
00PW02OB						261.5—263.5	dry		
00PW03D	441,046.6	6,588,104.9	250.8	0	31.5	219.7—221.7	0.90 (249.9)	1,180	negligible
00PW03OB						245.7—249.7	1.03 (249.8)	3,230	
00PW04D	441,144.8	6,587,778.7	249.3	0	28	221.6—223.6	1.51 (247.8)	3,130	negligible
00PW05D	440,831.0	6,588,377.7	261.1	24.5	42	219.3—221.3	5.20 (255.9)	1,650	5
00PW05I						238.8—240.8	5.32 (255.8)	2,160	120
00PW06D	440,807.1	6,588,481.0	263.7	31.5	38.5	232.0—234.0	7.95 (255.8)	2,850	170
00PW06OB						252.8—254.8	7.73 (256.0)	527	
00PWP1	440,807.9	6,588,445.7	262.9	26.5	30+	234.2—258.2	6.92 (256.0)	658	430

Note: #: AHD – Australian Height Datum; ##: bgl - below ground level

The pumping tests (see Appendix 1) were not suitable for deriving aquifer parameters. The pumping rates used were very low and produced drawdowns of only 1.07 m at the end of the multi-rate test (Figure 3-2) and only 0.79 m after 24 hours of the constant rate test (Figure 3-3). No piezometers or observation bores were monitored during the tests.

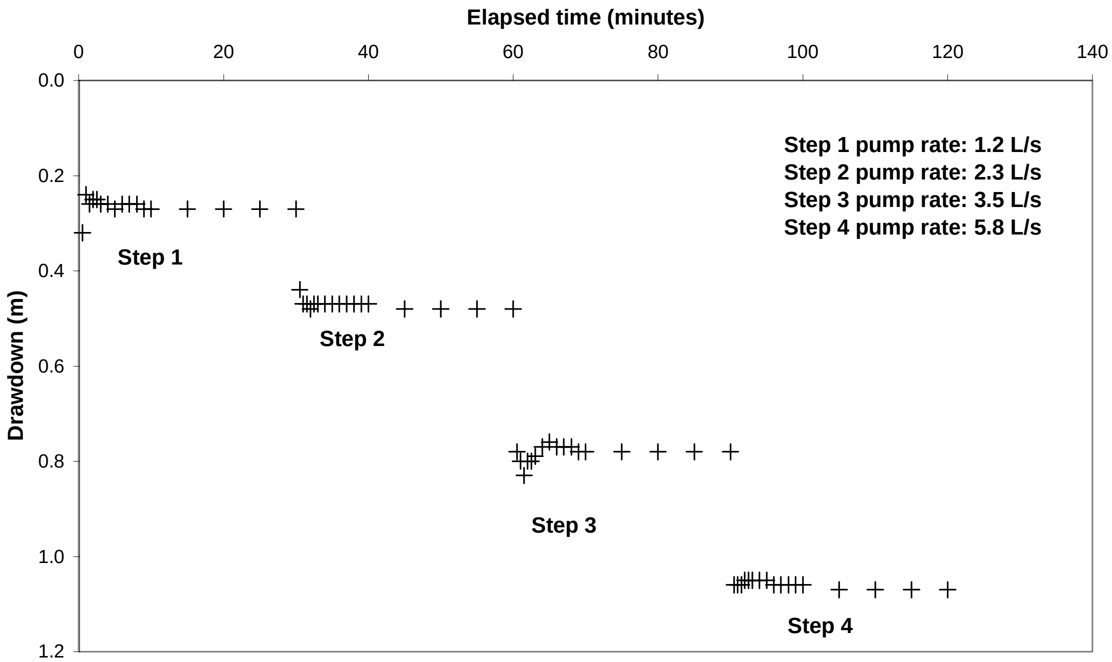

Figure 3-2. Drawdown versus time for multi-rate test

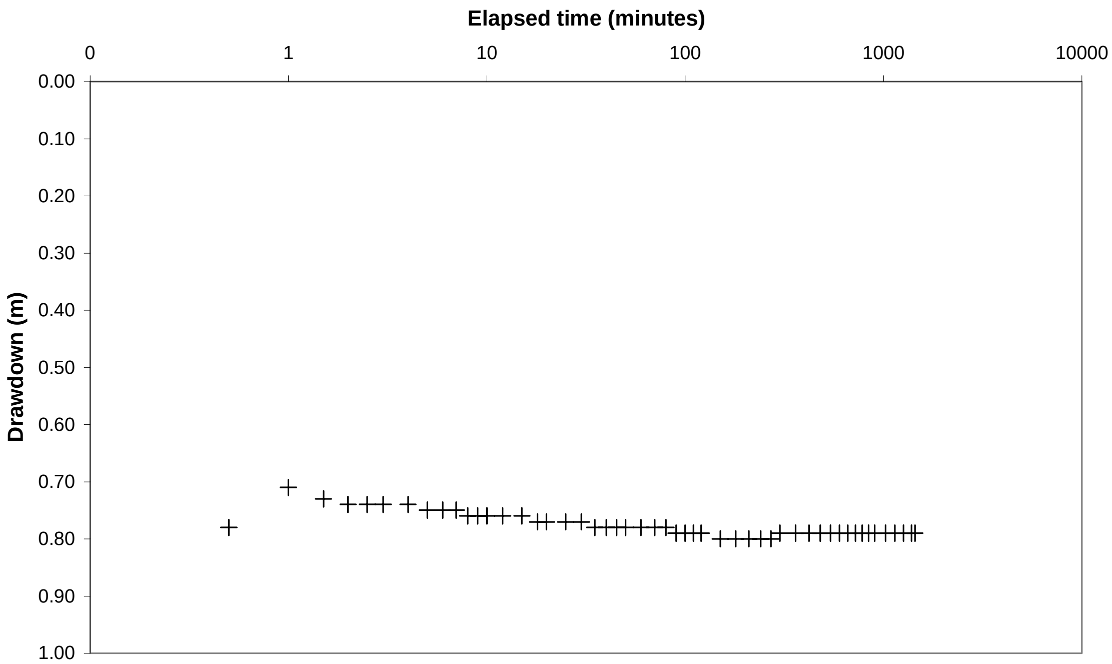

Figure 3-3. Production bore drawdown versus time for the constant rate test (pumping rate was 3.5 L/s)

3.4 Interpretation and discussion

3.4.1 Geology

A cross-section along the bore transect is presented in Figure 3-1 where the relative elevation of the sedimentary profile and groundwater systems is readily apparent. The greatest thickness of sediments at site 00PW02 is a function of both the highest ground surface elevation and the lowest top of saprolite surface elevation.

The base of the scarp appeared to coincide with the eastern edge of a basin within the saprolite and crystalline basement. The edge of the basin could be defined by a basement fault. Vertical displacement, upward to the west, may be the mechanism responsible for landscape inversion and preservation of low energy depositional sediments in an upper landscape position.

3.4.2 Recharge, groundwater flow and discharge

The recharge areas likely to affect the groundwater levels below the townsite are the townsite itself, cleared areas west of the scarp, and the large catchment to the north.

Most land in the catchment above the town and west of the scarp is under agriculture and it is likely that recharge below these areas has increased since clearing.

The clay and claystone forming the upper part of the sedimentary profile west of the scarp appeared impervious. This could imply that recharge to the sediments only occurs where the clay is absent. However, negligible lateral hydraulic gradients in the sediments imply static groundwater conditions. That is, there is little evidence of groundwater flow from a recharge area to a discharge area.

Some towns in the Community Bores Project have developed groundwater problems even though they are in locations which make it unlikely that cleared agricultural land has contributed to their groundwater systems. This implies that the recharge within a townsite can be substantial and can alone be the cause of groundwater problems. However, the Piawaning townsite is small compared to the other areas likely to be contributing to the groundwater below it, and it is likely that the groundwater levels would be shallow at that location even if the town was not there.

Therefore, salinity at Piawaning is thought to be influenced by catchment-scale groundwater systems rather than just townsite-scale processes.

3.4.3 Assessment of salinity risk

In November 2000, the watertable at the three monitoring sites within the townsite was within 2 m of the ground surface. When watertables are so shallow, they tend to rise following rainfall and then fall again, but do not have long-term rising trends. It is not known whether damage to private dwellings, community facilities and the grain depot in Piawaning will worsen greatly.

The elevation of the seepage face on the scarp within the CALM reserve coincides with the groundwater levels within the sediments. The absence of significant hydraulic gradients implies the sedimentary basin is simply filling with water from recharge and spilling out at the edges where the watertable intersects the topographic surface. If the groundwater levels rise west of the scarp, then the seepage face within the CALM reserve will migrate upslope.

3.4.4 Management approaches

There are two main approaches to dealing with high groundwater levels: treat the cause by reducing groundwater recharge; treat the problem by abstracting groundwater.

Although **reducing the recharge** within Piawaning townsite is unlikely to have a large impact on groundwater levels below the town, some methods of reducing recharge have other benefits (e.g. reduced water supply costs and dependence, less waste of good quality rainfall water, less infrastructure damage from floods and surface run-on) and so should be considered. There is little available information on recharge below the cleared land west of the scarp and in the large catchment north of the townsite, but it is likely that extensive agricultural areas affect the groundwater pressures below the town. Therefore, it is unlikely that reducing recharge below limited areas anywhere outside the townsite would be effective.

Groundwater abstraction by pumping from bores may be a viable option in some towns. However, groundwater drainage is unlikely to be effective as it only lowers groundwater levels along narrow zones either side of the drain. The groundwater pumping test in Piawaning was unsuccessful as the bore was pumped at a rate that was too low. Therefore, it is not known whether groundwater pumping would be an effective way to lower groundwater levels below Piawaning. However, if there is a fault below the scarp, it may be possible to locate a high yielding production bore closer to the edge of the townsite. As groundwater abstraction is expensive, may cause settlement damage to town buildings and infrastructure, and pumped water has to be carefully used or evaporated to avoid causing problems elsewhere, the option needs careful and thorough investigation before implementation.

3.5 Recommendations

1. Reduce townsite recharge where there are additional benefits in doing so by:
    - managing surface water to prevent localised flooding and ponding;
    - eliminating leaks in water pipes, drains, culverts;
    - planting local perennial species on vacant and grassed areas where the groundwater is not too saline; and
    - eliminating overwatering of gardens.
2. Measure groundwater levels in the monitoring network (especially those with water level depths greater than 2 m) and review them annually, and continue to do so for at least 10 years.
3. **Assess the current and future costs of groundwater damage in the townsite.**

4. Use the results of the second and third steps to determine whether to investigate groundwater abstraction further.

5. If groundwater abstraction is to be pursued, install a production bore and monitoring bores in the townsite, carry out a pumping test to determine whether pumping will be effective, and if so, determine number and locations of required production bores and the necessary pumping rates.

6. If the fifth step indicates pumping would be effective in lowering groundwater levels below the town, assess the geotechnical impacts that groundwater abstraction will have on townsite infrastructure.

7. Assess the options for use or disposal of the pumped groundwater.

8. Determine costs of the pumping system, the costs of the damage it may cause and the costs of use or disposal of the pumped water.

9. Decide whether to go ahead with groundwater abstraction.

4. Flood risk analysis

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4.1 Introduction

The town catchment (4,160 ha) is situated within the East Moore River Catchment which is a headwater of the Moore River Catchment (Figure 2-1).

The issues of surface water control and a rising watertable were highlighted during the wet years of 1995 and 1996. Roads within the town are badly affected by salinity and waterlogging, with concrete culverts disintegrating and road pavements failing.

4.2 Previous studies

A study by John Duff & Associates Pty Ltd (1999) dealt with waterlogging and salinity issues of the town. It concluded that surface run-off and groundwater flow from the catchment above the town were the main contributors to the watertable under the town. Most of the catchment is used for farming. Surface water management through the use of banks and drains was recommended.

4.3 Objective of this study and approach

The objective of this aspect was to assess the flood risk (high, moderate or low) for the town. This was done by calculating the peak flood flow generated by the agricultural catchment (at a point just downstream of the townsite) and the volume of run-off that could be generated within the townsite, and comparing these with the flow accumulation characteristics of the catchment.

The Urban Drainage Design (UDD) model was used to calculate peak flows for the catchment because it accounts for the spatial variation in flow rates across catchments, whereas some other methods (e.g. Rational and Time-Area approaches) assume flow is uniform across catchments. The UDD model also allows precipitation rate, catchment slope, surface roughness, interception, depression storage, infiltration and evaporation to be considered. The procedures used are discussed in detail in Ali *et al.* (2001).

The peak flood flows were calculated for 2-, 5-, 10-, 20-, 50- and 100-year average recurrence intervals (ARIs) based on historical events. The run-off volumes generated by pervious and impervious (i.e. high run-off generating) surfaces within the townsite were calculated for 20-, 50-, and 100-year ARIs.

4.4 Input data

The information required to run the model was drawn from available sources and from a site visit. Rainfall intensities were estimated from *Australian Rainfall and Runoff* (Institution of Engineers 1987) and catchment parameters were based on 2-metre elevation contours derived from a digital elevation model produced by the Department of Land Administration.

A grid of the study area was derived from the digital elevation model and this was used to predict flow directions, flow accumulations, streamlines, watershed boundaries, and slope and length of the streams. Details of the procedures used to create the grid of the study are given in Ali *et al.* (2001).

Observations made during the site visit and interpretations of aerial photographs and the elevation contours were used to derive the following:

- area of catchment (pervious and impervious);
- area generating high run-off;
- area generating high recharge;
- infiltration (maximum and minimum likely rates);
- roughness coefficient (Manning's n).

A report by Ali *et al*. (2001) contains descriptions of how the information was used in the UDD model and how run-off volumes for the town catchment were estimated.

4.5 Model calibration

The UDD model should be calibrated using measured flow data. However, there is no gauging station in the catchment that contains the town of Piawaning. Moora is the closest town to Piawaning for which reliable flow records are available. The calibration achieved for the UDD model for the town of Moora was assumed to be valid for Piawaning too.

4.6 Results

Peak flood flow results are summarised in Table 4-1. It was estimated that about 20 per cent of the townsite (total area 35 ha) consisted of high run-off generating areas (including roofs, roads, parking areas or heavy clay with low infiltration rates). Run-off volumes were calculated separately for the 'pervious' parts of the town and for the 'impervious' (i.e. high run-off generating) areas (Table 4-2) using run-off coefficients of 0.1 for the former and 0.9 for the latter.

Table 4-1. Peak flood flow for 2-, 5-, 10-, 20-, 50- and 100-year ARI storms for the catchment of the town of Piawaning

ARI (years)	Peak flood (m^3/s)
2	5
5	13
10	29
20	43
50	58
100	69

Table 4-2. Run-off volumes for the pervious and impervious areas of the townsite generated by rainfalls of various ARIs, durations and intensities

Average recurrence interval (years)	Rainfall duration (h)	Rainfall intensity (mm/h)	Rainfall (mm)	Run-off volume	
				pervious area (m^3)	impervious area (m^3)
20	1	30	30	800	1,900
	6	8.75	52.5	1,500	3,300
	24	3.25	78	2,200	4,900
50	1	38	38	1,100	2,400
	6	11.25	67.5	1,900	4,300
	24	4	96	2,700	6,100
100	1	43	43	1,200	2,700
	6	13	78	2,200	4,900
	24	4.75	114	3,200	7,200

4.7 Flood risk assessment

The criteria to classify a town's relative flood risk level were based on the calculated rates of flow, the *accumulation potential* of the townsite and the catchment above the town. The accumulation potential depends on the relative magnitudes of the potential inflows and outflows. The peak flood flows for the catchment for 20-, 50- and 100-year ARIs for storms of 24 hours duration were compared to the catchment area, the accumulation potential of the catchment and the flow generated within the townsite. Table 4-3 shows the flood risk to the town of Piawaning for 20-, 50- and 100-year ARI storm events of 24 hours duration.

Table 4-3. Flood risk to Piawaning townsite for 20-, 50- and 100-year ARI storm events of 24 hours duration

ARI (years)	Peak flood flow for entire catchment (m^3/s)	Volume of flood generated by townsite (m^3)	Accumulation risk	Flood risk	Overall flood risk
20	43	7,100	Low	Low	Low
50	58	8,800	Low	Low	Low
100	69	10,400	Low	Medium	Medium

4.8 Conclusion

Piawaning is at overall low risk from flooding from storm events with up to 50-year ARIs and at medium risk from storms with 100-year ARIs. There is minimal likelihood of flooding for most of the town infrastructure, except those areas of particularly low elevation that may be at risk from localised flooding. However, during a 100-year ARI storm event, a considerable area of the town would be under water.

4.9 Warning

The peak flood flow and run-off values estimated in this report should not be used as inputs for the design of any engineering structures such as drains, culverts or diversion banks as the input parameters used for this study would not be suitable for such uses. It is recommended that for any specific use the peak flood flow should be estimated again for the conditions existing in the catchment at that time. Detailed descriptions of the input parameters for this study and their limitations are in Ali *et al.* (2001).

5. Acknowledgments

Louise Hopgood, Dick Kelly, Ed Solin and Jim Prince helped collect the information for the hydrogeological investigation and Dick Kelly also helped to drill the two pre-existing monitoring sites (PB1 and PB2). Russell Speed would also like to acknowledge the drillers (Drilling and Grouting Services), in particular Marty Bolton, Marcus McArthur and Graham Young, for their professional and cooperative attitude and performance.

6. References

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7. Appendix 1: Pumping test

Author: Ron Colman, Test Pumping Australia

As part of the hydrological investigation of Piawaning, a pumping test was carried out in the production bore (00PWP1) aimed to establish aquifer parameters.

7.1 Method

Test Pumping Australia was contracted to carry out and analyse the pumping test.

There were two parts to the test, which were performed on 25 and 26 July 2000. The first part was a multi-rate test (i.e. a series of step increases in the pump rate with the discharge being maintained at a constant value within each step). The results were assessed before setting the pump rate for the second part, a constant rate test.

The static water level in the bore before the multi-rate test began was 8.32 m below the reference point (which was 0.85 m above ground level). The multi-rate test was conducted on 25 July 2000 with four 30-minute steps at discharge rates of 1.2, 2.3, 3.5 and 5.8 L/s.

The constant rate test started on 26 July 2000 and lasted 1,440 minutes (24 hours) at a pumping rate of 3.5 L/s (300 m^3/day). The drawdowns in the production bore were measured at intervals throughout. The rate of recovery of the water level in the bore was measured at the completion of the test.

During the tests, the flow rate was monitored using an orifice weir assembly and water levels were measured using an electric water level probe. Table 7-1 summarises relevant details.

Table 7-1. Details of the pumping test

Pump inlet depth below ground level	26 m
Available drawdown in production bore	18 m
Pump	electric submersible

7.2 Results

The total drawdown in the production bore at the end of the multi-rate test was only 1.07 m and at the end of the constant rate test was only 0.79 m.

Reliable analyses were not possible with the small drawdowns achieved.

Borehole	00PW01	RURAL TOWNS PROJECT

441575.65	UTM E	6587634.8	UTM N	252.63	UTM RL	UTM Grid:	

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	03/07/2000
Town:	PIAWANNING	Hole Depth (m):	17
Notes/Location:	Lower Slope. Amongst Salmon Gums in Calm Reserve above Saline Drainage	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

From m	To m	Geology	Moisture	Water Level
0	1	**Soil/Colluvium** Dark brown gravely loam - gravels are nodules of silcrete (?)		
1	2	**Soil/Colluvium** Brown loam grading to fine gritty pallid clay.		
2	3	**Saprolite** Fine gritty clay. White and orange mottled		
3	4	**Saprolite** Fine gritty clay. Light grey and brown.		
4	5	**Saprolite** Fine gritty clay. Yellow mottling.		
5	6	**Saprolite** Fine gritty clay. Red mottling.		07/07/2000 ▼
6	7	**Saprolite** Fine gritty clay. Golden brown and red.		
7	9	**Saprolite** Fine gritty clay. Golden brown and yellow - some larger quartz fragments <=5mm.		
9	10	**Saprolite** Fine gritty clay. Less larger grits.		
10	13	**Saprolite** Fine gritty clay.		
13	15	**Saprolite** Fine gritty clay. Harder - fragments of granitic basement.		
15	16	**Saprolite** Fine gritty clay. Abundant crystalline fragments - coarser grained (- 3-5mm).		
16.9	17	**Granitic Basement** Granitic basement. Feldspar and quartz - 3-5mm, and biotite mica.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield	SWL (m)	SWL 2 (m) 07/07/2000
00PW01	CLASS 12, 50MM PVC	16.97	0.7	2	8-16 Gravel, Bentonite Seal			5.48

Borehole	00PW02	RURAL TOWNS PROJECT

440595.65	UTM E	6588844.5	UTM N	272.9	UTM RL	UTM Grid:

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	03/07/2000
Town:	PIAWANNING	Hole Depth (m):	55
Notes/Location:	Crest of Hill, Above Calm Reserve & Townsite	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

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From m	To m	Geology	Moisture	Water Level
0	1	**Soil/Colluvium** Brown gravely (pisoliths - 10-20mm) loam.		
1	2	**Tertiary Seds** Orange and yellow fine gritty loam.		
2	3	**Tertiary Seds** Orange fine gritty clay.		
3	6	**Tertiary Seds** White clay - some red mottling.		
6	10	**Tertiary Seds** Off white clay. From 9-10m some browny red mottling.		
10	11	**Sands** Off white very fine clayey sand.		
11	16	**Sands** Very fine light grey sand. 13-14m Some small (-15mm) consolidated fragments. 15-16m band of orange very fine sand.		
16	17	**Sands** Brown and yellow brown clayey sand. Sand grains - 2-3mm.		
17	18	**Sands** light grey and white very fine sand.		05/07/2000 ▼
18	19	**Sands** Light brown sand - orange clayey band.		
19	20	**Sands** Light grey and brown very fine sandy clay.		
20	21	**Clay** Reddy brown, yellow and grey clay.		
21	22	**Sands** Pale yellow very fine sand then indurated deep red (iron rich) fine sandstone.		
22	23	**Sands** Indurated deep red (iron rich) fine sandstone. Good core recovery.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 05/07/2000
00PW02I	CLASS 12, 50MM PVC	35.44	0.71	2	8-16 Gravel, Bentonite Seal	14.4		17.53
00PW02B	CLASS 12, 50MM PVC	12.11	0.71	2	8-16 Gravel			
00PW02D	CLASS 12, 50MM PVC	53.85	0.71	2	8-16 Gravel, Bentonite Seal	14.4		17.52

Borehole	00PW02	RURAL TOWNS PROJECT

440595.65	UTM E	6588844.5	UTM N	272.9	UTM RL	UTM Grid:	

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	03/07/2000
Town:	PIAWANNING	Hole Depth (m):	55
Notes/Location:	Crest of Hill, Above Calm Reserve & Townsite	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

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From	To	Description
23	24	**Sands** Reddy orange brown sand. Sand grains -1mm.
24	25	**Sands** Orange brown sand.
25	26	**Sands** Yellow brown sand - becoming coarser (-1-2mm)
26	27	**Sands** Yellow grey sand.
27	28	**Sands** Grey sand.
28	29	**Sands** Grey sand then light grey clayey fine sand.
29	30	**Sands** Light grey clayey fine sand (or fine sandy clay!)
30	33	**Clay** Light grey sandy clay.
33	36	**Sands** Light grey clayey very fine sand (34-35m tending yellow). At 36m, during drilling, airlift - 170m3/day.
36	37	**Sands** Light grey sand.
37	38	**Sands** Sand - grainsize -1mm
38	39	**Sands** Sand - grains - 1-2mm, and up to 6-8mm.
39	41	**Sands** Coarse sand.
41	42	**Sands** Mainly coarse sand - thin band of white clay, large quartz pebbles, some -15mm and well rounded.
42	43	**Coarse Sand** Coarse sand - larger quartz pebbles then pallid saprolite. Quartz grits (<1mm) in white clay.

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 05/07/2000
00PW02I	CLASS 12, 50MM PVC	35.44	0.71	2	8-16 Gravel, Bentonite Seal	14.4		17.53
00PW02B	CLASS 12, 50MM PVC	12.11	0.71	2	8-16 Gravel			
00PW02D	CLASS 12, 50MM PVC	53.85	0.71	2	8-16 Gravel, Bentonite Seal	14.4		17.52

Borehole	**00PW02**		**RURAL TOWNS PROJECT**	
440595.65 UTM E	6588844.5 UTM N	272.9 UTM RL	UTM Grid:	
Hydrologist/Supervisor:	RUSSELL SPEED		Date Drilled:	03/07/2000
Town:	PIAWANNING		Hole Depth (m):	55
Notes/Location:	Crest of Hill, Above Calm Reserve & Townsite		Drill Method:	RC
			Hole Diameter:	141
			Driller:	

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From	To	Lithology
43	50	**Saprolite** Fine gritty (<=1mm) white clay.
50	52	**Saprolite** Light greeny grey gritty (<=1mm) clay, cored fragments of partially weathered basement - abundant mafic.dark green fine grained mineral.
52	54.9	**Saprolite** Mainly saprolite grits in steely grey return - abundant mafic mineral.
54.9	55	**Crystalline Basement** Competent crystalline basement - grainsize - 1-2mm.

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 05/07/2000
00PW02I	CLASS 12, 50MM PVC	35.44	0.71	2	8-16 Gravel, Bentonite Seal	14.4		17.53
00PW02B	CLASS 12, 50MM PVC	12.11	0.71	2	8-16 Gravel			
00PW02D	CLASS 12, 50MM PVC	53.85	0.71	2	8-16 Gravel, Bentonite Seal	14.4		17.52

Borehole	00PW03		RURAL TOWNS PROJECT
441046.57 UTM E	6588104.9 UTM N	250.84 UTM RL	UTM Grid:
Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	05/07/2000
Town:	PIAWANNING	Hole Depth (m):	31.5
Notes/Location:	Flats, below seepage face.	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

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From m	To m	Geology	Moisture	Water Level
0	1	**Soil/Colluvium** Light grey brown sand.		
1	2	**Saprolite** Yellow loam grading to gritty (<=1mm) white clay.		07/07/2000 ▼
2	3	**Saprolite** Gritty (grits<=1mm) white - light grey clay.		
3	4	**Saprolite** Gritty white clay grading to white clayey sand (sand grains - 1mm)		
4	5	**Saprolite** White very clayey sand (sand grains - 1mm).		
5	14	**Saprolite** White sandy (gritty) clay (sand/grits - 1mm)		
14	17	**Saprolite** Yellow brown gritty clay.		
17	19	**Saprolite** Light greeny brown gritty clay.		
19	31.4	**Saprolite** Dark greeny brown gritty clay. From 23m - increasing grits, some quartz + feldspar to 8mm. Increasing fragments of fresh granitic basement with depth. Quartz and feldspar grains - 2-3mm. Abundant mafic minerals.		
31.4	31.5	**Crystalline Basement** Competent crystalline basement.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield	SWL (m)	SWL 2 (m) 07/07/2000
00PW03D	CLASS 12, 50MM PVC	31.88	0.7	2	8-16 Gravel, Bentonite Seal			1.88
00PW03B	CLASS 12, 50MM PVC	5.89	0.73	4	8-16 Gravel			2.12

Borehole	00PW04		RURAL TOWNS PROJECT
441144.76 UTM E	6587778.7 UTM N	249.3 UTM RL	UTM Grid:

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	05/07/2000
Town:	PIAWANNING	Hole Depth (m):	28
Notes/Location:	Flats, Community Bore	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

From m	To m	Geology	Moisture	Water Level
0	1	**Soil/Colluvium/Silcrete** Lateritic duricrust		
1	3	**Silcrete** Silcrete		
3	12	**Saprolite** White fine gritty clay (grits <=1mm) some brown mottling. 9-10m Some yellow brown mottling Brown mottling increasing with depth.		07/07/2000 ▼
12	19	**Saprolite** Predominantly brown fine gritty clay.		
19	20	**Saprolite** Light greeny brown fine gritty clay.		
20	22	**Saprolite** Increasing grits - occassional granitic fragments up to - 15mm.		
22	23	**Saprolite** Gritty greeny brown clay.		
23	27.9	**Saprolite** Saprolite grits/fragments in dark greeny brown clay.		
27.9	28	**Crystalline Basement** Crystalline basement - abundant mafic/dark green mineral/s.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield	SWL (m)	SWL 2 (m) 07/07/2000
00PW04D	CLASS 12, 50MM PVC	28.43	0.7	2	8-16 Gravel, Bentonite Seal			3.49

Borehole	00PW05	RURAL TOWNS PROJECT

440830.96 UTM E | 6588377.7 UTM N | 261.13 UTM RL | UTM Grid:

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	06/07/2000
Town:	PIAWANNING	Hole Depth (m):	42
Notes/Location:	Mid Slope. Above scarp/seepage face.	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

From m	To m	Geology	Moisture	Water Level
0	2	**Soil/Laterite** Lateritic duricrust. 0-1m red/brown. 1-2m Golden brown.		
2	4	**Tertiary Seds** Red/brown indurated (lateritic) clay.		
4	5	**Silty & Sandy Clays** Red/brown indurated clay grading to indurated light grey brown silty clay.		
5	6	**Silty & Sandy Clays** Light grey/brown indurated silty clay.		07/07/2000 ▼
6	8	**Silty & Sandy Clays** Orange and red mottled light grey silty clay.		
8	10	**Silty & Sandy Clays** Light grey (pink and brown mottled) fine sandy clay.		
10	11	**Silty & Sandy Clays** White clay then light grey very fine sandy clay.		
11	12	**Silty & Sandy Clays** Light grey fine sandy clay.		
12	15	**Silty & Sandy Clays** Fine gritty white clay (grits <=1mm) Coarser grits (sand) from 14-15m.		
15	17.5	**Silty & Sandy Clays** Light grey clay.		
17.5	18	**Very Fine Sand** Light grey fine to very fine sand.		
18	19	**Sandy Clay** Light grey fine sandy clay.		
19	21	**Sands** Coarse sand (sand grains - 1-3mm)		
21	24	**Sands** Light grey clayey very fine sand. Thind hard band within 21-22m interval. 22-23m Some larger well rounded quartz pebbles. 23-24m Abundant well rounded polished quartz pebbles to 20mm - in coarser sand.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 07/07/2000
00PW05D	CLASS 12, 50MM PVC	45.52	0.7	2	8-16 Gravel, Bentonite Seal	3.6		5.96
00PW05B	CLASS 12, 50MM PVC	23.09	0.74	2	8-16 Gravel, Bentonite Seal	123		6.08

Borehole	00PW05		RURAL TOWNS PROJECT
440830.96 UTM E	6588377.7 UTM N	261.13 UTM RL	UTM Grid:

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	06/07/2000
Town:	PIAWANNING	Hole Depth (m):	42
Notes/Location:	Mid Slope. Above scarp/seepage face.	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

From	To	Lithology	Description
24	25		**Sands/Saprolite** Yellow sand with some large quartz fragmetns then light grey fine gritty clay with brown mottling. (Grits <=1mm).
25	32		**Saprolite** Light grey fine gritty clay (grits<=1mm).
32	33		**Saprolite** Grey fine gritty clay.
33	41.9		**Saprolite** Dark grey fine gritty clay. 35-37m. Fragments of partially weathered crystalline basement - abundant mafic mineral/s. 39-42m Abundant fragments of crystalline basement.
41.9	42		**Crystalline Basement** Competent crystalline basement. Abundant mafic/dark green mineral/s. Quartz and feldspar grains - 1-2mm.

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 07/07/2000
00PW05D	CLASS 12, 50MM PVC	45.52	0.7	2	8-16 Gravel, Bentonite Seal	3.6		5.96
00PW05B	CLASS 12, 50MM PVC	23.09	0.74	2	8-16 Gravel, Bentonite Seal	123		6.08

Borehole	00PW06		RURAL TOWNS PROJECT

440807.1 UTM E	6588481 UTM N	263.73 UTM RL	UTM Grid:

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	07/07/2000
Town:	PIAWANNING	Hole Depth (m):	38.5
Notes/Location:	Mid Slope. Above scarp/seepage face.	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

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From m	To m	Geology	Moisture	Water Level
0	1	**Soil/Laterite** gravely sandy loam (Pisoliths - 10-15mm).		
1	2.5	**Soil/Laterite** Orange brown lateritic loam then light grey clay.		
2.5	6.5	**Tertiary Seds** Light grey/cream clay - minor pink mottling.		
6.5	10	**Tertiary Seds** Cream claystone.		
10	11	**Clay** Pale reddy brown very fine sandy clay.		
11	12	**Clay** Orange very clayey sand then dark red brown very clayey sand.		
12	13	**Clay** Dark red brown very clayey sand.		
13	14	**Clay** Grading to dark red brown sandy clay with a band of cream claystone with dark red brown mottling.		
14	15	**Clay** Dark red brown sandy clay - indurated bands.		
15	17.5	**Clay** Light grey clay with strong red brown mottling.		
17.5	18	**Clay** Pale red brown clayey sand - less clay with depth.		
18	20	**Sand** Light grey very fine sand - coarser with depth (- 1-1.5mm)		
20	21	**Clay** Light brown clay.		
21	22	**Clay** Light grey very fine clayey sand.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 07/07/2000
00PW06D	CLASS 12, 50MM PVC	32.44	0.7	2	8-16 Gravel, Bentonite Seal	172		
00PW06B	CLASS 12, 50MM PVC	11.78	0.8	2	8-16 Gravel			

Borehole	**00PW06**	**RURAL TOWNS PROJECT**

440807.1	UTM E	6588481	UTM N	263.73	UTM RL	UTM Grid:	

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	07/07/2000
Town:	PIAWANNING	Hole Depth (m):	38.5
Notes/Location:	Mid Slope. Above scarp/seepage face.	Drill Method:	RC
		Hole Diameter:	141
		Driller:	

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From	To	Lithology	Description
22	23	**Clay**	Light very very fine sandy clay.
23	25	**Sand**	Pale yellow clayey sand - some larger rounded quartz pebbles - 6-8m.
25	27	**Sand**	Pale yellow sand - becoming coarser.
27	31	**Sand**	Coarse light grey sand. 29-30m some large well rounded pebbles - 50mm.
31	32	**Saprolite**	Coarse basal gravel of well rounded polished quartz then light grey brown fine grittty clay (saprolite).
32	36	**Saprolite**	Light grey brown fine gritty clay. Dark grey by 36m.
36	38.4	**Saprolite**	Dark grey fine gritty clay with fragments of partially weathered basement.
38.4	38.5	**Crystalline Basement**	Crystalline basement. Gneissic banded fabric elongate quartz and feldspar - 1-2mm + mafic mineral.

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield m3/d	SWL (m)	SWL 2 (m) 07/07/2000
00PW06D	CLASS 12, 50MM PVC	32.44	0.7	2	8-16 Gravel, Bentonite Seal	172		
00PW06B	CLASS 12, 50MM PVC	11.78	0.8	2	8-16 Gravel			

Borehole	00PWPB2		RURAL TOWNS PROJECT
440835.36 UTM E	6588377 UTM N	261.13 UTM RL	UTM Grid: AGD84

Hydrologist/Supervisor:	RUSSELL SPEED	Date Drilled:	6/07/2000
Town:	PIAWANNING	Hole Depth (m):	17
Notes/Location:		Drill Method:	RC
		Hole Diameter:	125
		Driller:	

From m	To m	Geology	Moisture	Water Level
0	0.2	**Sand and Gravel** Sand and lateritic gravel.		
0.2	1.9	**Laterite** Lateritic duricrust.		
1.9	9	**Mottled Clay** Red and white mottled fine gritty clay.		
9	16	**Sand** Fine to very fine light grey sand.		
16	17	**Sand** Very fine light grey sand.		

Hole	Casing Type	Casing m	AGL m	Screen m	Material Screened	Est. Yield	SWL (m)	SWL 2 (m)
00PWPB2D	CLASS 12, 50MM PVC	17.86	0.86	2				
00PWPB2B	CLASS 12, 50MM PVC	6.63	0.88	4				