Upper Murray Alluvium

Groundwater Management Area 015

Albury to Corowa

Groundwater Resources Status Report – **2008**

NSW Government

Department of Water & Energy

Publisher

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March 2009

ISBN 978 0 7347 5578 0

Acknowledgements

Written by Nimal Kulatunga. Thanks to Callan Pearson of the NSW Department of Environment and Climate Change for the preparation of GIS maps.

This publication may be cited as:

Kulatunga N., 2009, *Upper Murray Alluvium, Groundwater Management Area 015: Albury to Corowa, Groundwater Resources Status Report – 2008*, NSW Department of Water and Energy, Sydney

DWE 09_009

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Executive Summary

Upper Murray Alluvium, GMA 015 is one of the designated Groundwater Management Areas (GMA) of New South Wales, located on the NSW side of the Murray River between Hume Dam and Corowa. This is the second groundwater status report for this aquifer. It provides information on the current status of groundwater resources in GMA 015 area to resource managers, groundwater users and other interested groups and individuals. It also provides technical information for resource management decisions in the groundwater management area.

There are about 3-4 productive zones (aquifers) where groundwater occur to a depth of 100 m mainly in formations known as Lachlan and Shepparton Formations. The majority of the irrigation bores tap the deeper Lachlan aquifers while most of the stock and domestic bores extract groundwater from shallow Shepparton aquifers.

The Murray River and rainfall have been identified as the major recharge sources for the aquifers while irrigation leakage was identified as a minor recharge source as well. A groundwater flow model was developed in 2003/04. Some scenario runs have been done to determine the river losses for different levels of groundwater development as entitlements are activated. The model is due for an upgrade in late 2008/09. Annual groundwater recharge as determined by the groundwater model is 15,300 ML/yr, under the current level of development.

Total groundwater entitlements are 41,125 ML/yr (excluding stock and domestic licences) with 95% of the volume allocated for irrigation. The GMA 015 was embargoed in 2000 to prevent the growth in groundwater entitlements.

Groundwater usage has been moderate in relation to full entitlement. The highest recorded usage was just over 16,000 ML in 2006/2007. Just over 12,000 ML was used in 2007/08.

Groundwater pressure levels in all aquifers were generally steady except winter-summer fluctuations until the early 1990s. Thereafter, a rising pressure level trend was observed until the mid-1990s. Since then, a moderate decline of pressure of up to 25 cm/year has been observed in all aquifers.

The groundwater salinity of both Shepparton and Lachlan aquifers are generally fresh with salinity levels less than 800 µS/cm but there are higher salinity levels recorded in some of the bores. Groundwater contamination has not been a significant issue although some minor contaminated sites have been identified around Albury. No attempt has been made so far in GMA 015 to identify groundwater dependent ecosystems. Eight wetlands have been identified which may have a connection to the groundwater system but their dependency is unknown.

1.0 Introduction

This is the second groundwater status report for the Upper Murray Alluvium groundwater management area (GMA 015). The first status report was written in 2002. Prior to this, a number of technical reports were made to asses the alluvial aquifers between Albury and Swan Hill in the Riverine plain (WC & IC, 1986, and Pritchard & Jiwan, 1989). A further two comprehensive technical reports relevant to this area have been completed: an Albury City water supply investigation (Woolley, 1971); and an assessment of the groundwater resource potential of the unconsolidated sediments associated with the Murray River between Albury and Corowa (mainly covering the present GMA 015 area) (Williams, 1989).

The main objectives of this report are to:

1. Assess and document the current status of the groundwater resources in the GMA 015 and to provide information to resource managers, groundwater users and other interested groups and individuals;
2. Provide necessary technical information to formulate resource management policies and to assist in making resource management decisions including developing a groundwater sharing plan.

Groundwater Management Areas (GMAs) are generally distinct hydrogeological entities having their own hydrogeological characteristics.

Upper Murray Alluvium, GMA 015 is one of the designated Groundwater Management Areas (GMA) of New South Wales, located on the NSW side of the Murray River between the Hume Dam and Corowa **(Figures 1 and 2).** It covers an area of alluvium approximately 500 km^2 from the Murray River (southern boundary) to the foothills on the north. The western margin follows the Corowa-Urana Road. Howlong township and part of Albury city are located in the management area.

In August 1997, the New South Wales government announced a comprehensive Water Reform package in which groundwater was included as a major component. This was followed by the introduction of the Water Management Act 2000 with comprehensive features to manage water resources and establish water sharing plans for water sources in the state.

The GMA 015 groundwater system was embargoed in 1999 to prevent the growth in groundwater entitlements.

Groundwater in GMA 015 is currently regulated under the Water Act 1912. However over time, all groundwater resources of NSW are to be regulated by the Water Management Act 2000, including that of GMA 015. This will require the development of a Water Sharing Plan for 015 under the terms of the Act. This process is subject to some uncertainty at this time due to water planning initiatives emerging from the Australian Government's new role in managing the Murray-Darling Basin.

A groundwater flow model was completed in 2003/04 and is currently being reviewed to factor recent patterns of groundwater use and groundwater level changes. It is due to be reported in early 2009.

Figure 1: Regional Location of Groundwater Management Area 015

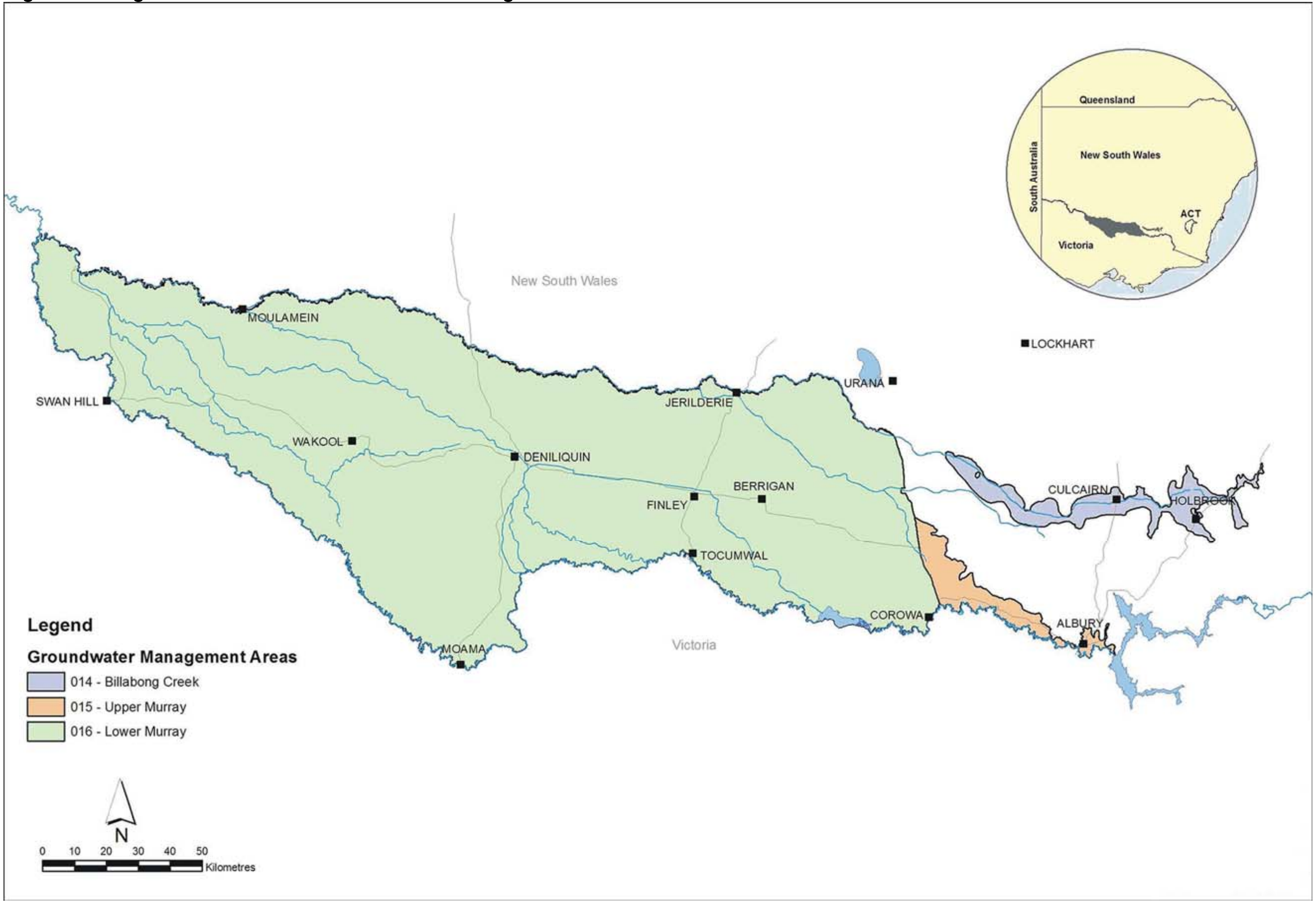
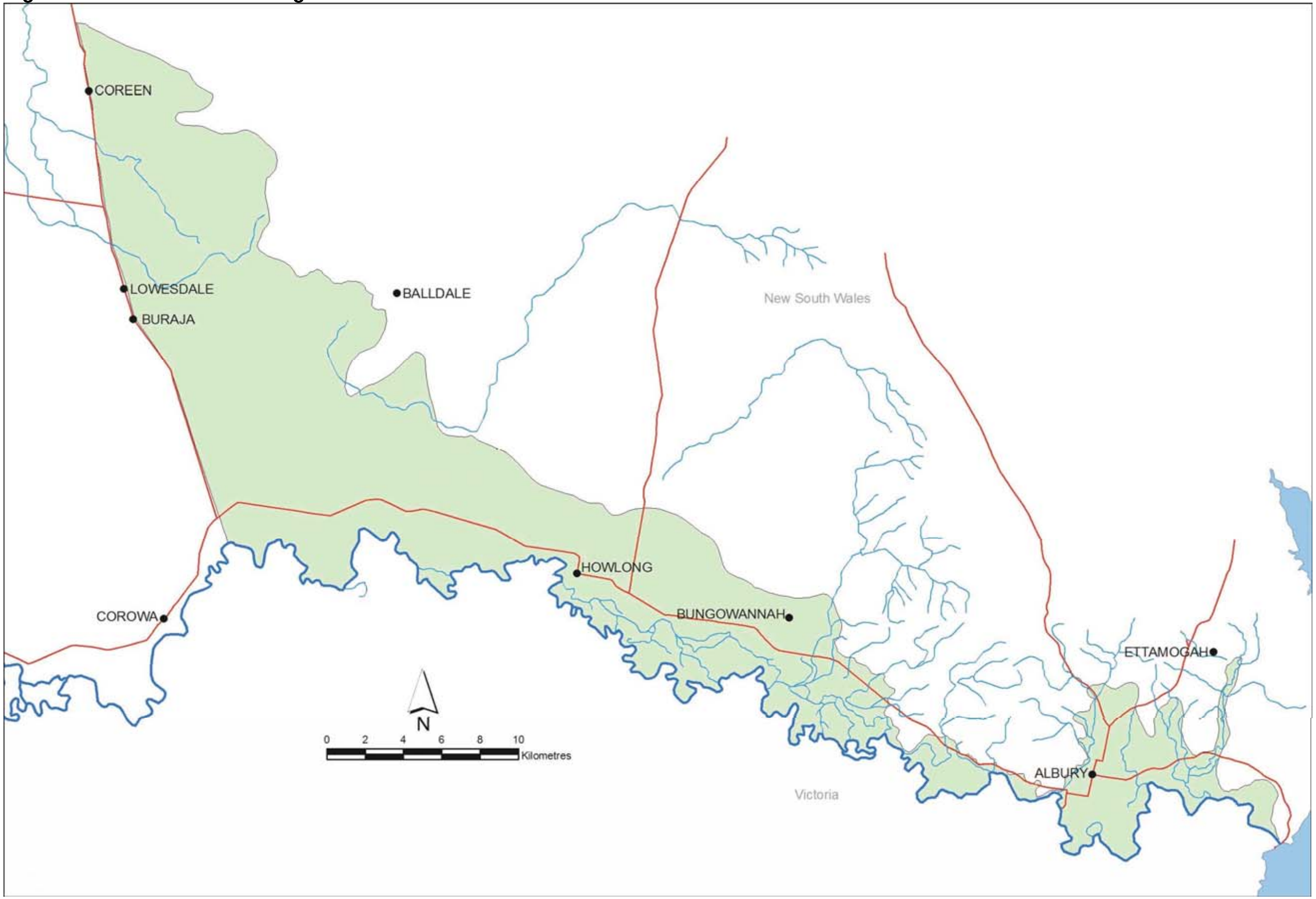


Figure 2: Groundwater Management Area 015



2.0 Hydrogeology

2.1 GEOLOGY

The Cainozoic sediments of the Murray River tract between Albury and Corowa overlie Palaeozoic metamorphic rocks and granites, and Permian sediments restricted to an area north of Corowa. The pre-Tertiary topography indicates that the river maintained its courses in a trench between the Palaeozoic rocks during the Cainozoic, and that at times of lower relative base level, it caused erosion in the small tributary valleys (Williams, 1989).

The oldest Cainozoic sediments in the area are correlated with the Olney Formation (part of the Renmark Group) to the west in the Murray Geological Basin in GMA 016. This formation has only limited distribution in remnant areas between Albury and Corowa **(Figure 3 - Hermitage Section)** and mainly consists of carbonaceous clay. It has maximum thickness in the area of about 35m (Williams, 1989).

The Lachlan Formation **(Figure 4 - Albury Aerodrome Line)** is equivalent to the Calivil Formation in the Murray Geological Basin to the west, consists of clay, fine sand to cobbles and various admixture of these. The formation is characterised by a grey colour. The sand and gravel are entirely made of quartz and are almost devoid of catchment rock types (Williams, 1989). The formation is up to 80m thick in the area and is overlain by younger alluvial deposits of finer texture.

The Shepparton Formation reflects a change in river morphology and possibly in climate. It is fluviatile, deposited by leveed streams which meander within the alluvial zone causing a build up of sediments (Williams, 1989). The Formation is up to about 80m thick in the area and varies between clay and gravel. The Formation is characteristically brown and yellow, and clays are generally restricted to areas away from the main Murray River tract. The lower part of the Formation has thick zones of sand and gravel.

Coonambidgal Formation **(Figure 5 – Quat Quatta)** is associated with the present streams or their recent ancestors and is inset within the present plain. The Formation for this reach of the Murray River has two inset terraces and an inset floodplain (Williams, 1989). The floodplain composes of sandy silt and clay and the terraces consist of sandy silt to silty gravel.

Sand dunes occur in close association with Coonambidigal Formation and form mounds up to about 12m from the plain and consist of well sorted, fine to medium quartz sand. The dunes were derived by the prevailing winds deflating the exposed point-bar sands.

Figure 3: Hermitage Cross-Section

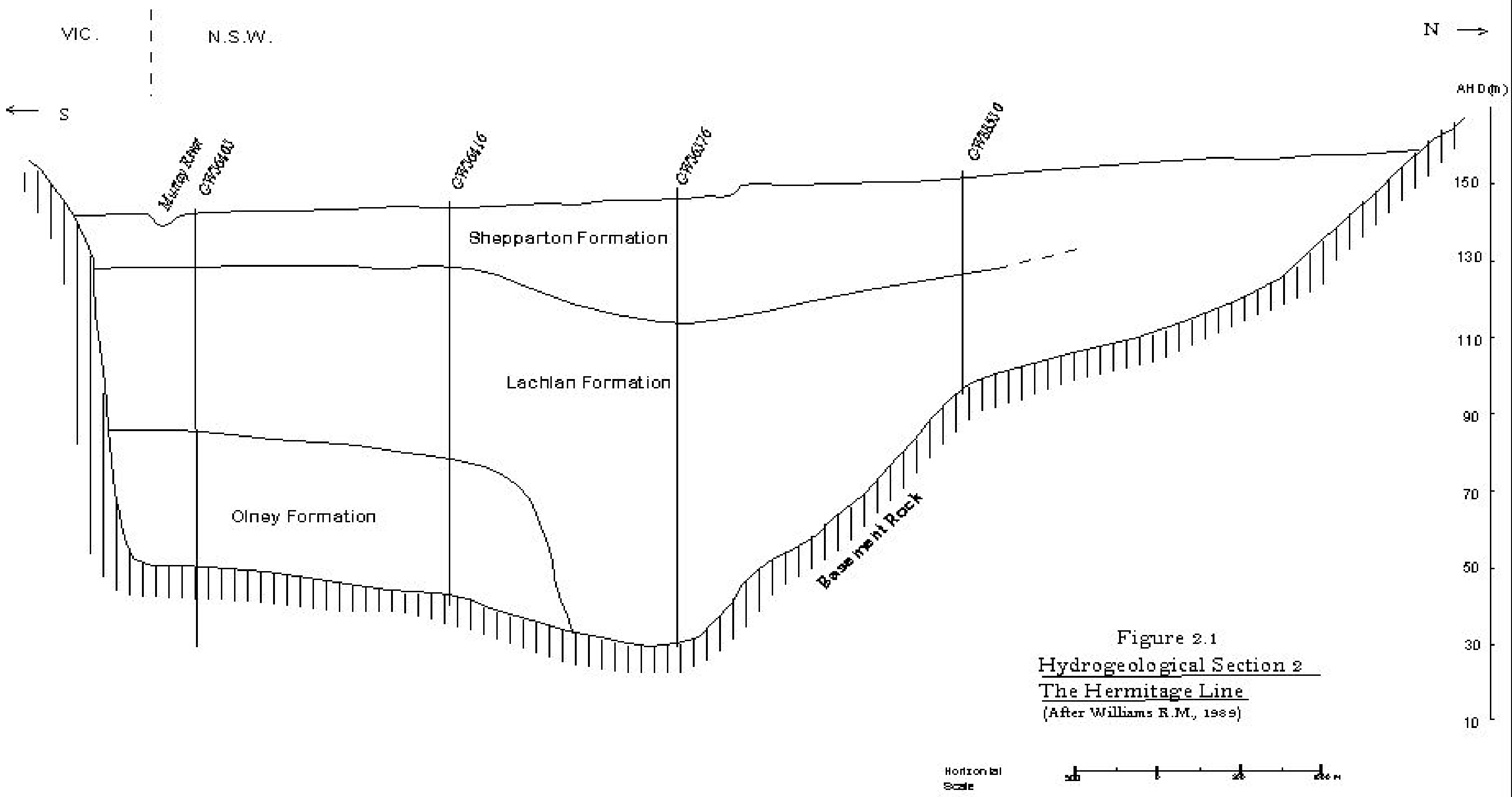


Figure 4: Albury Cross-Section

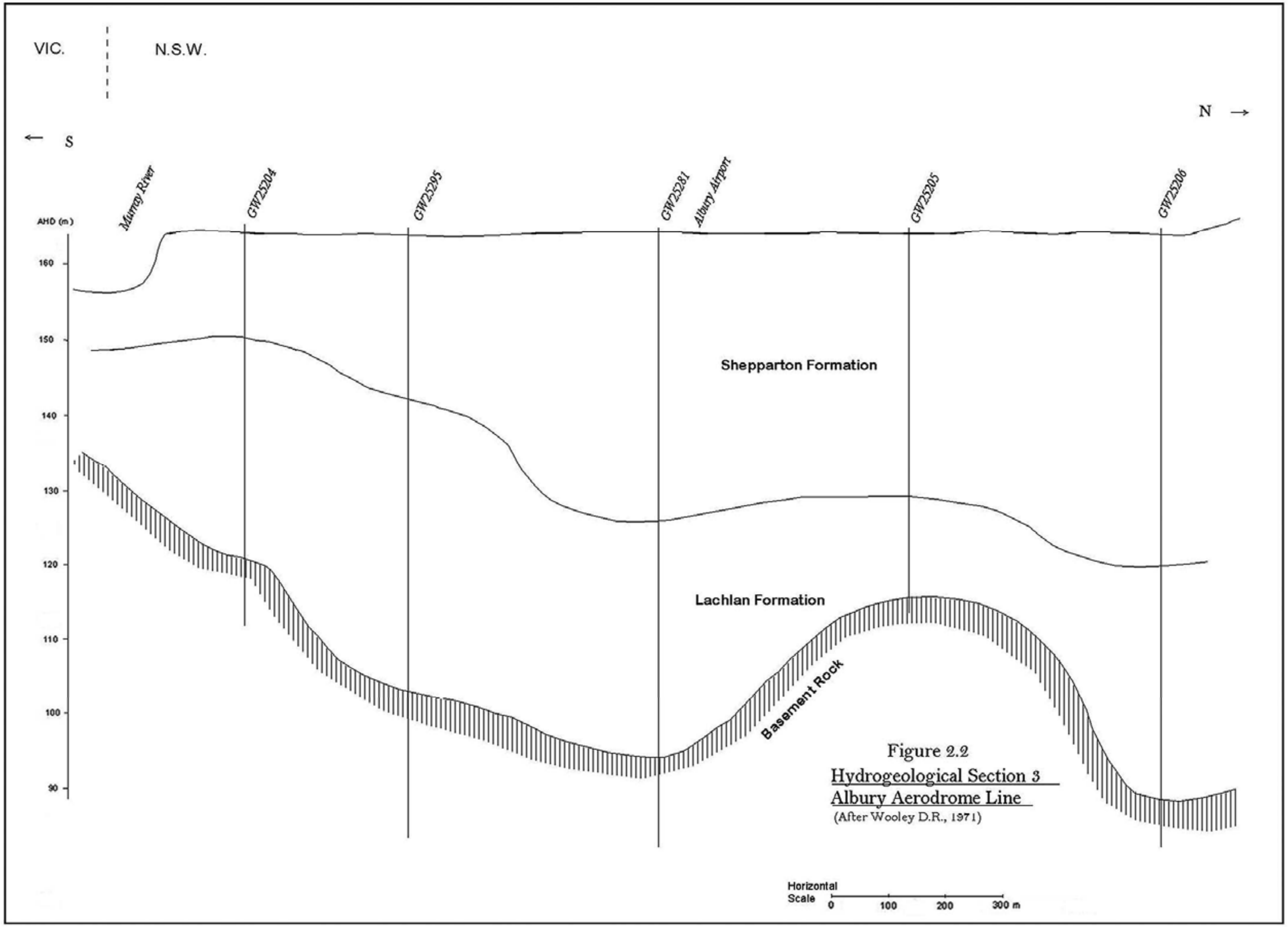


Figure 5: Quat Quatta Cross-Section

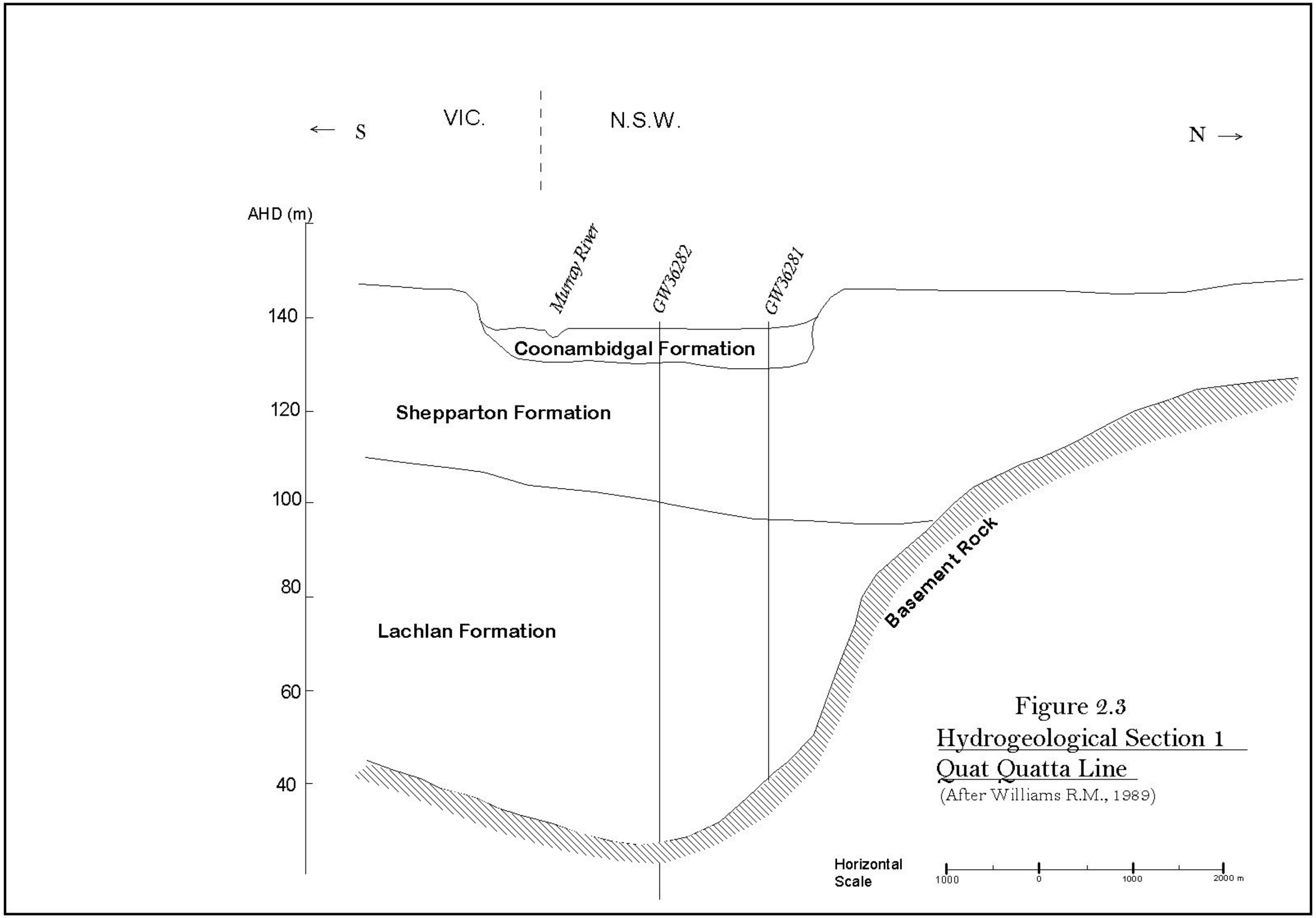
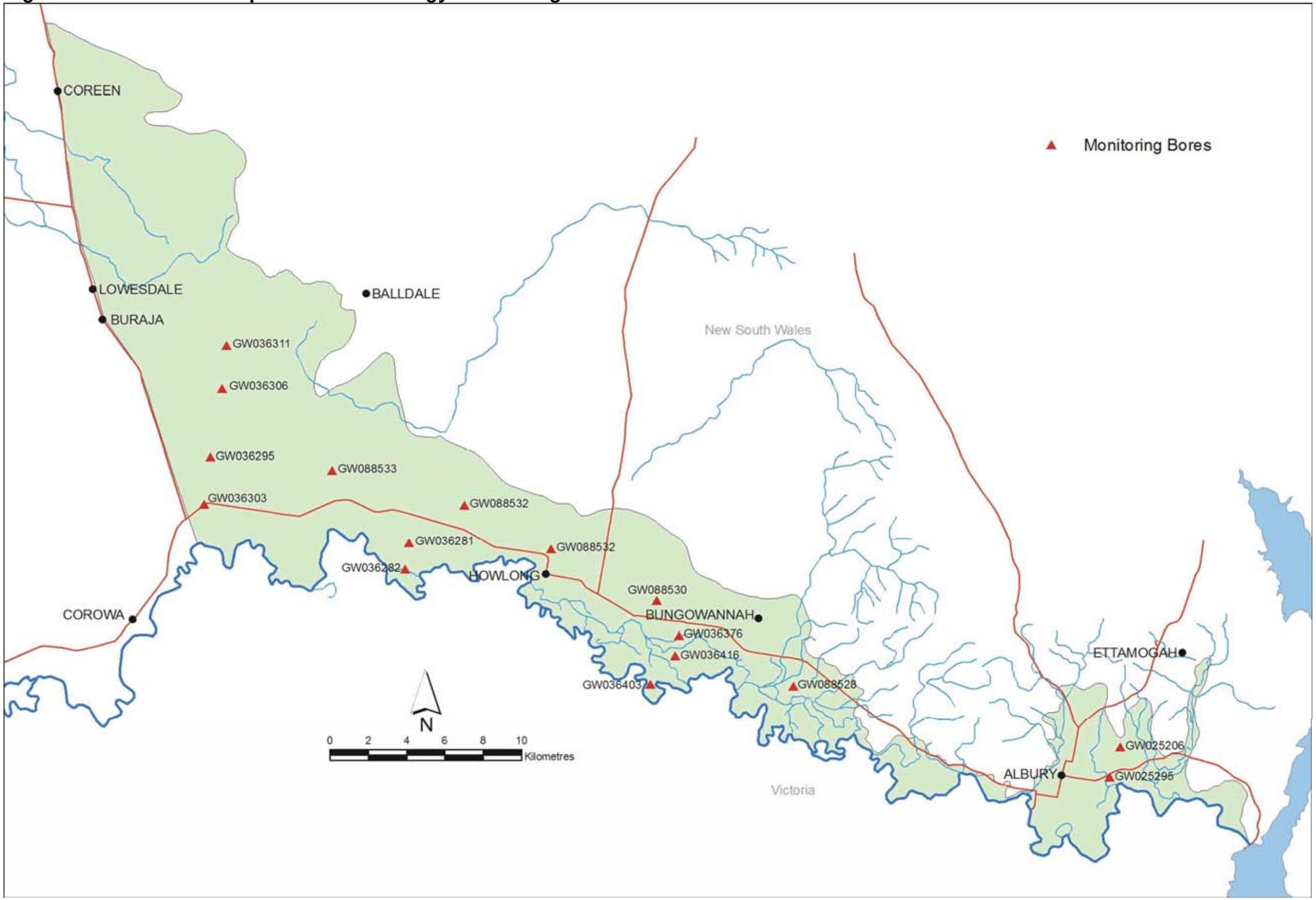


Figure 6: Location of Dept Water and Energy Monitoring Bores



2.2 GROUNDWATER OCCURRENCE

There are about 3-4 productive zones (aquifers) where groundwater occurs to a depth of about 100m in geological formations discussed in the Section above. The main aquifers are the quartz sand and gravel of the Lachlan Formation which have aquifer transmissivities up to 2000 m^2/day which has been estimated from DWE test bores (Williams, 1989). Some of the irrigation bores, which are tapping this aquifer, have the capacity to yield up to 10 ML/day.

The Shepparton Formation generally has much lower aquifer transmissivities up to about 250m^2/day. Some irrigation bores which obtain groundwater from the gravel and coarse sand in this formation have the capacity to yield up to about 3 ML/day. Aquifers in this formation provide water to the majority of stock and domestic bores in the management area.

The Coonambidigal Formation is generally clayey and silty, however some shallow bores for stock and domestic use obtain smaller supplies where there are coarser sediments in the profile close to the present Murray River tract in the plain. The Olney Formation is mainly clayey and has a limited extension in the area. There are no productive aquifers in this formation.

Generally all these aquifers are hydraulically connected therefore managed as one aquifer system. The main recharge is sourced from rainfall and river leakage and minor amount from irrigation leakage.

2.3 GROUNDWATER RESOURCE INVESTIGATION

The interest in groundwater availability in GMA 015 has expanded rapidly in recent time due to regular drought, the Murray Darling Basin Cap on new surface water extractions, and the increased demands from agriculture and industry and recreation.

Investigation drilling in the area first commenced around Albury in late 1960's in search of groundwater for Albury City water supply (Woolley, 1971). In the early 1970's, the drilling program was expanded to cover all the alluvium areas in the Murray Region under a statewide investigation project. These investigation bores have been converted to monitoring bores. Each site has multiple bores (nested sites), penetrating different aquifers at various depths. This enables the Department of Water and Energy (DWE) to measure groundwater pressure levels and quality in those aquifers. Five additional sites were added to the network in 2000. At present there are 16 nested monitoring sites in the Upper Murray GMA alluvium with 4 of these sites located in the Murray Geological Basin aquifers at the western edge of GMA 015 **(Figure 6)**.

The water levels of department's monitoring sites are measured quarterly and entered into the DWE groundwater database (GDS). Three of the nested sites have automatic data loggers installed to record continuous water levels. Data gathered during drilling projects along with observed data on water level and water quality are used to evaluate the groundwater resource potential, and to measure the impact of groundwater use and changes to recharge patterns.

2.4 HYDRODYNAMICS – SOURCE AND MOVEMENT OF GROUNDWATER

Three main sources of groundwater recharge have been identified in GMA 015. They are Murray River losses, rainfall and to a lesser extent, irrigation.

A desktop assessment was done in 1997-98 (Ross, 1999) to quantify the groundwater recharge component for groundwater management purposes. Ross used analytical equations assuming a uniform distribution of recharge characteristics in the area. Three percent of 650 mm of average annual rainfall was assumed to be the recharge component of rainfall, and it was computed as 9,700 ML/year.

A river reach of 61 km was assigned for the computation of the total river recharge. After a component of river recharge was assigned to the Victorian section of aquifer leakage from the river was estimated at 33,600 ML/year.

Recharge by irrigation leakage was not taken into account at the time because the landuse maps were not readily available during the assessment. However, the need to consider irrigation leakage was recognised at the time but it was considered to be small, compared to river and rainfall recharge. Ross (1999) estimated the total annual average recharge for GMA 015 to be 43,300 ML. This is the total recharge to the aquifer system comprised of Shepparton and Lachlan aquifers.

A groundwater flow model was developed during 2003/04 period. The Water balance indicates an annual average recharge of 15.3 GL from all sources, which reflects the development level at the time. This is a much lower volume than determined using the analytical calculations of Ross. The model is discussed in more detail in Section 5.

Groundwater flow in both the Shepparton and Lachlan formations is approximately from east to west as shown in **Figures 7 and 8** respectively. The Murray River is gaining groundwater from hard rock and alluvium aquifers between Hume Dam and Albury. However the river is losing water to the aquifer systems downstream of Howlong. Groundwater flow lines in the Shepparton Formation show the deviation from the Murray River to the northwest, particularly downstream of Howlong.

It should be noted here that the Murray Geological Basin aquifer system (GMA 016) which is downstream of the GMA 015 is in direct hydraulic connection with the GMA 015 aquifer system. The GMA 016 aquifer receives lateral recharge from groundwater leaving the GMA 015 system.

2.5 GROUNDWATER LEVEL TRENDS

Following the construction of the regional monitoring bore network in 1970's, it has been possible to observe the behaviour of groundwater levels in regional aquifers. Maintenance of this network of monitoring bores and also continuous monitoring of water level/pressure levels are extremely important in the resource evaluation and decision making process in managing the resource efficiently.

Hydrographs are diagrams which represent the change in groundwater levels over time. A hydrograph has been prepared for all monitoring bores in GMA 015 and are shown in the **Appendix,** placed in numerical order. The location of all monitoring bores are shown in **Figure 6**.

Groundwater pressure levels in both Shepparton and Lachlan Formation aquifers in the Albury area have been generally steady for last 30 years and there is no rising or declining trend shown in either aquifer **(GW025206 and GW025295)**.

The groundwater levels of both aquifers are generally at the same level, suggesting a strong hydraulic connection between the two.

Figure 7: Groundwater Level Contours and Flow – Shepparton Formation

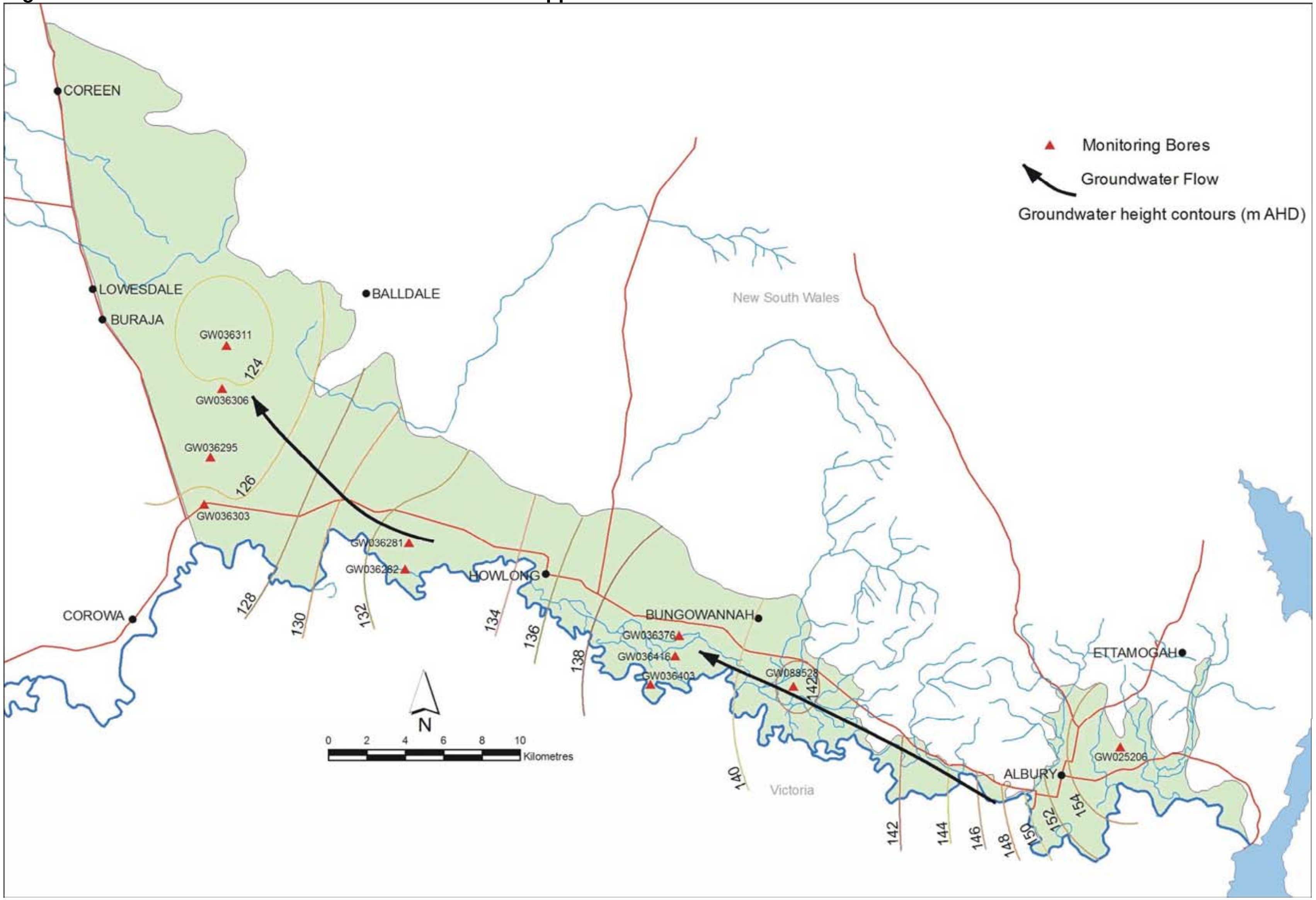
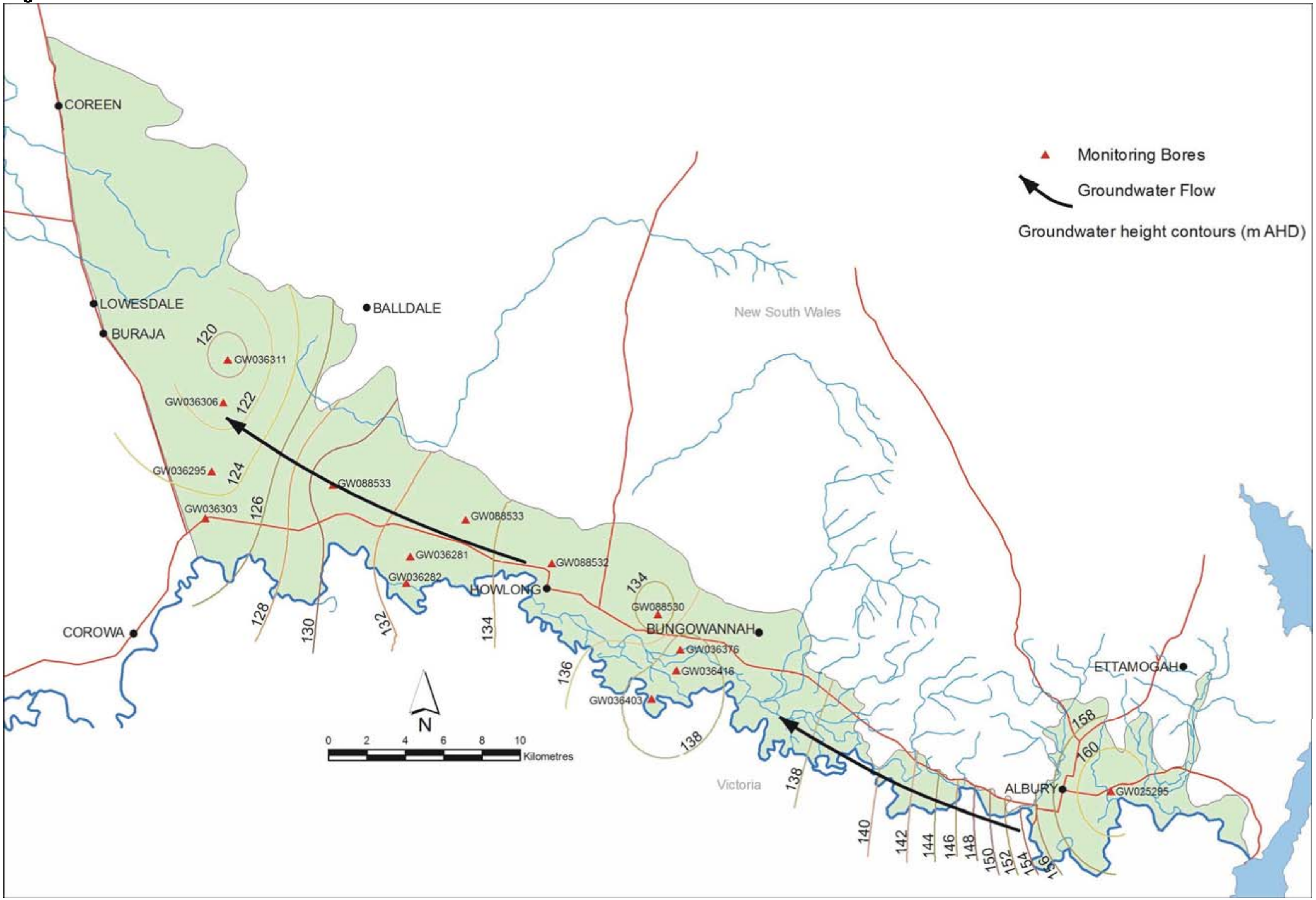


Figure 8: Groundwater Level Contours and Flow – Lachlan Formation



The hydrographs of monitoring bores in the Hermitage Section **(GW036376, GW036403 and GW036416)** between Albury and Howlong, show groundwater pressure level fluctuations up to 1.5m between summer and winter months. Water level responses of all shallow and deep aquifers to recharge and discharge are similar with identical fluctuations. The pressure level difference between shallow and deep aquifers however varies up to about 0.5m with pressure levels of deeper Lachlan aquifers staying above that of the Shepparton aquifers. This indicates a potential upward preferential leakage of water. Pressure levels in all aquifers were steady except for the winter-summer fluctuation until the early 1990's. Thereafter, a rising pressure level trend has been observed until mid 1990s. Since then, a decline of pressure of up to 25 cm/year has been observed in all aquifers.

The hydrographs of monitoring bores in the Quat Quatta Section **(GW036281 and GW036282)** between Howlong and Corowa, show pressure level fluctuations up to 7 m between summer and winter months. Water level responses of shallow and deep aquifers to recharge and discharge are not as similar as in Hermitage section but with a delayed response in some cases. Pressure level difference between shallow and deep aquifers is about one metre (winter water levels) with pressure levels of deep Lachlan aquifers staying below that of the shallow Shepparton aquifers. Groundwater pressure level trends show a similar trend to that of the Hermitage Section bores with a steady behaviour prior to 1990's, then a rising trend until 1993-94 and declining (about 25 cm/year) since then. The pressure level fluctuations in the deep Lachlan aquifers are about 7 m seasonally since 1997, due to increased groundwater development in the area.

Most of the pressure declines could be attributed to groundwater extractions. The reduction of basal leakage from shallow aquifers to deep aquifers is due to drought situations experienced in 1994/95, 1997/98 and 2006 - 2008.

2.6 GROUNDWATER QUALITY

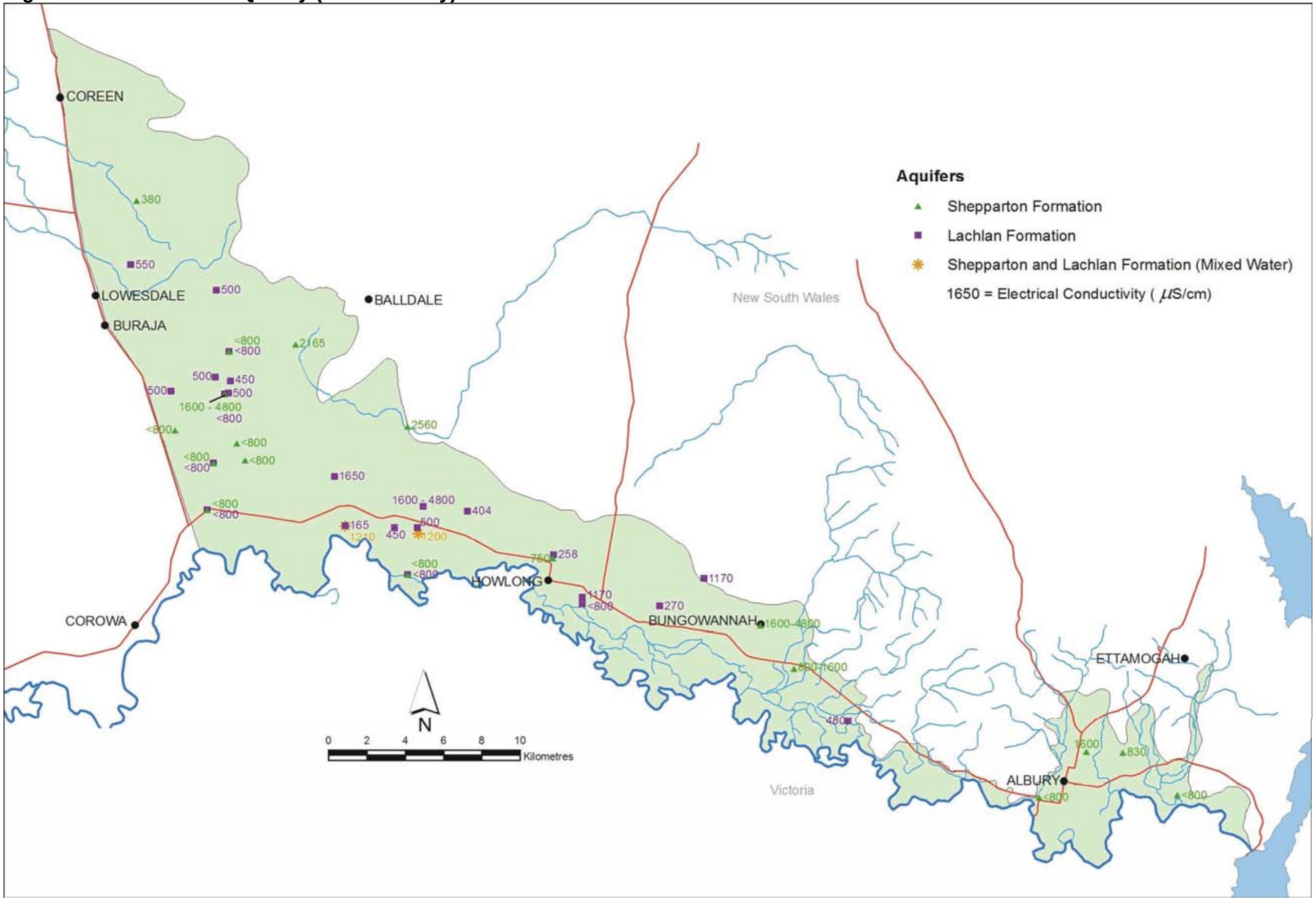
Groundwater salinity of both Shepparton and Lachlan Formation aquifers are generally fresh with salinity levels generally less than 800 μS/cm as shown in **Figure 9**. However there are higher salinity levels recorded in some of the bores. In the shallow watertable aquifer of the Shepparton Formation, there is a potential of having higher groundwater salinities due to low hydraulic conductivities and evapotranspiration effects.

Williams (1989) conducted a detailed assessment on groundwater chemistry from available bores at the time for both the Shepparton and Lachlan Formations and reported on the evolution process.

Iron in groundwater can be a problem for users in the area. The precipitation due to oxidation of ferrous ion to ferric ion causes discolouration (rusty colour) and also blockage of reticulation equipment. The source of iron is probably from igneous and sedimentary rocks as well as from the breakdown plant and animal waste (Williams, 1989).

Information available on groundwater contamination is less extensive. There are few known groundwater contaminated sites in the management area affected by point source pollution due to industrial activity. They are mainly in Albury. Some of the known sources are service stations, an oil recycling facility, and a commercial laundry and sewage disposal. NSW EPA has been working with these industries in the past few years to improve the situation. Groundwater contamination by diffused sources such as application of chemical fertilisers and pesticides in agricultural land is possible particularly in the area between Albury and Corowa. No study has been undertaken to assess the situation.

Figure 9: Groundwater Quality (Total Salinity)



3.0 Groundwater Licensing, Entitlement and Use

3.1 GROUNDWATER LICENSING

Groundwater access in GMA 015 is regulated under the Water Act 1912 and is administered by the NSW Department of Water and Energy (DWE). All bores must be licensed. Groundwater licences may be issued for a range of purposes including irrigation, town water supply, industrial, recreation, stock, domestic, farming, investigation and monitoring. High yielding bores (usually for non-stock and domestic purposes) are issued with 'renewable' licences for 5 years, are limited by a volumetric entitlement, and are metered.

3.2 HISTORY OF RESOURCE ALLOCATION

Prior to 1984, groundwater for irrigation was authorised based on irrigation area (and crops) and a volume wasn't specified on the licence. This was the practice for both groundwater and surface water entitlements at the time. These licences were converted to volumetric entitlements in 1984. Since 1984, all bore licences have been issued with volumetric entitlements.

Volumetric entitlements were determined on the basis of property area for irrigators while for the other uses such as town water, recreation and industry, entitlements were determined based on the requirement. The rate at which the entitlements were determined for groundwater irrigators prior to 1990 is not clear. Pritchard and Jiwan (1989) stated that the volumetric entitlement rate of 2 ML/ha would apply to the first 50 ha of the property and 1.5 ML/ha for additional areas above 50 ha of the property. However, after the introduction of a groundwater allocation policy for the Murray Geological Basin (west of GMA 015) in 1989/90, a similar policy was adopted in GMA 015. The surface water entitlement was also taken into account to keep the total hydraulic loading less than 6 ML/ha for an irrigation property.

A cautious approach was adopted after 1997 in determining the entitlements for irrigation. An entitlement to suit the 'need' was granted after 1997. The entitlement was further restricted based on a brief hydrogeological assessment on the resource availability and the bore density in the area. Subsequently, the groundwater system was embargoed in May 2000 for new irrigation licences.

Stock and domestic licences have small volumetric entitlements (typically 1 – 8 ML/yr), are not subject to a licence fee, and there is no metering and renewal requirement.

3.3 GROUNDWATER ENTITLEMENTS AND USAGE

Following the conversion of area based licences to volumetric entitlements in 1984, the total entitlement in GMA 015 was 7,656 ML. Between 1984 and 1998, entitlements grew at a gradual pace. In the season of 1998/99, the number of licences and the volume of entitlement grew significantly and this interest in groundwater continued until an embargo was placed on further new licences in May 2000.

Table 1 provides detail on the number of licences and the volume of entitlements within GMA 015. Groundwater entitlements total 41,125 ML/yr, the highest allocated purpose being irrigation.

Table 1: Licences and Entitlements

Purpose	No. of Licences	Entitlement (ML/yr)	% of Total
Irrigation	54	39,037	95
Industrial	23	1,142	2.8
Recreation	13	795	1.9
Town Water	4	151	0.4
Total	**94**	**41,125**	**100**

In addition to renewable licences, there are about 500 stock and domestic bore licences in the management area.

All high yield bores in GMA 015 are metered, and usage has been recorded since the 1990/91 irrigation season. **Figure 10** shows annual total use over 18 seasons. Usage was consistently below 1000 ML/yr before 1996/97, then grew steadily to around 5000 ML/yr in 2001/02.

Dry conditions and a reduction in surface water availability as seen groundwater use rise strongly since 2002. Just over 12,000 ML were extracted from GWA 015 in the 2007/08 water year. This is the second highest use ever recorded, behind the more than 16,000 ML used during the previous water year, 2006/07.

The locations of high yield bores are shown in **Figure 11**. The distribution and density of groundwater entitlements are shown in **Figure 12** in 2.5x 2.5 km grid cells. Entitlements are low in the area around Albury with less than 0.4 ML/ha. However downstream of Albury, this is increased up to 3.2 ML/ha, mainly due to higher entitlements for irrigation. Groundwater use is significantly below the full level of entitlement, with the greatest density of extraction occurring generally between Howlong and Corowa in a strip close to the Murray River **(Figure 13)**.

Figure 10: Groundwater Usage – GWMA 015

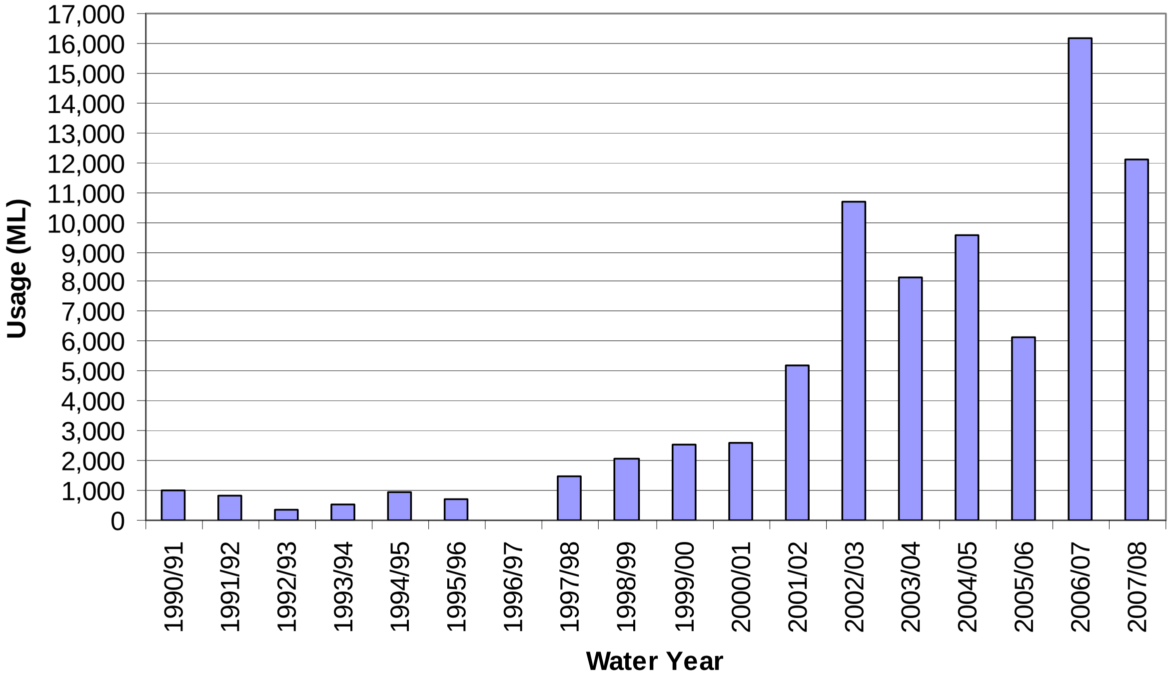


Figure 11: Location of High Yield Bores

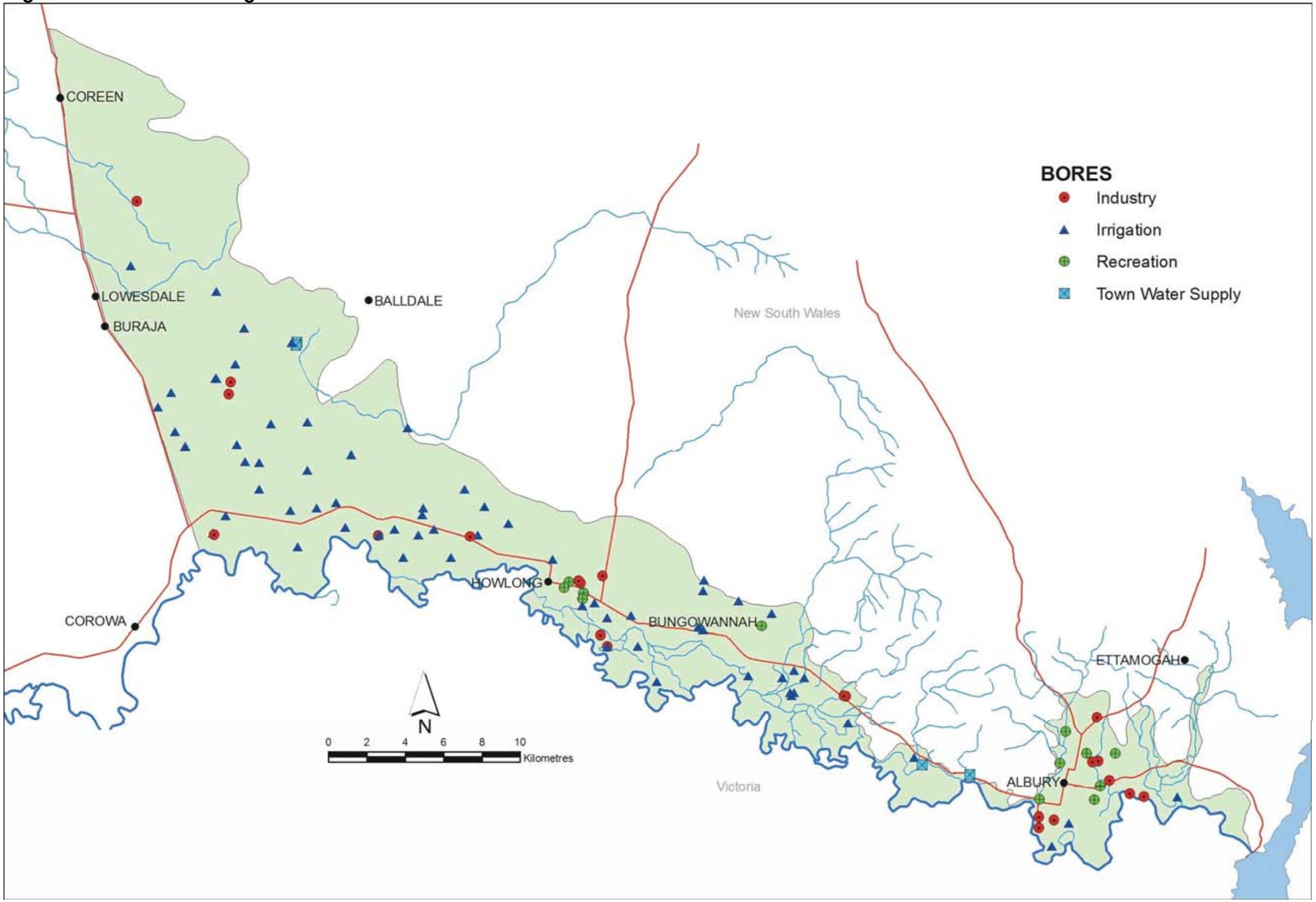


Figure 12: Density of Groundwater Entitlement

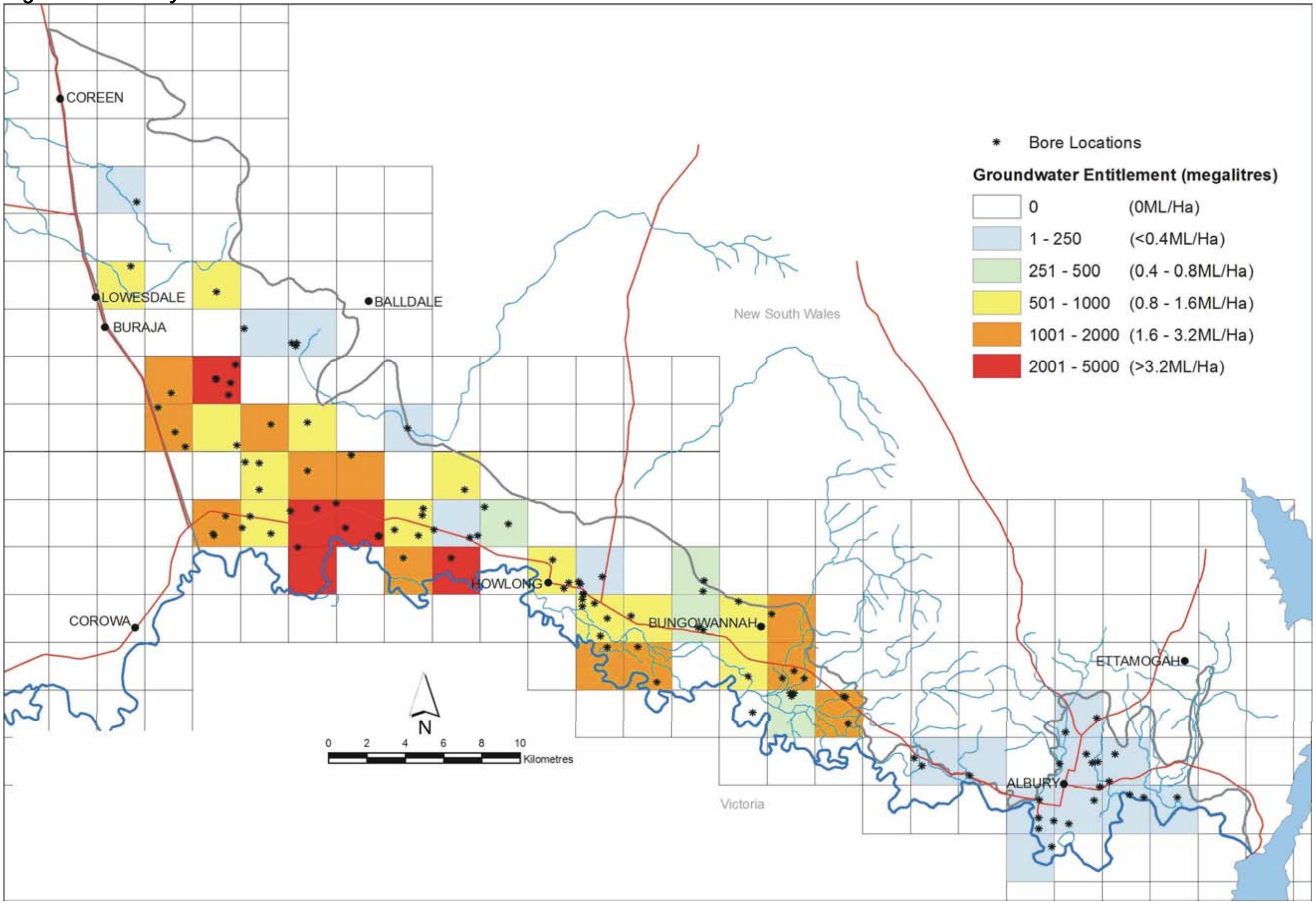
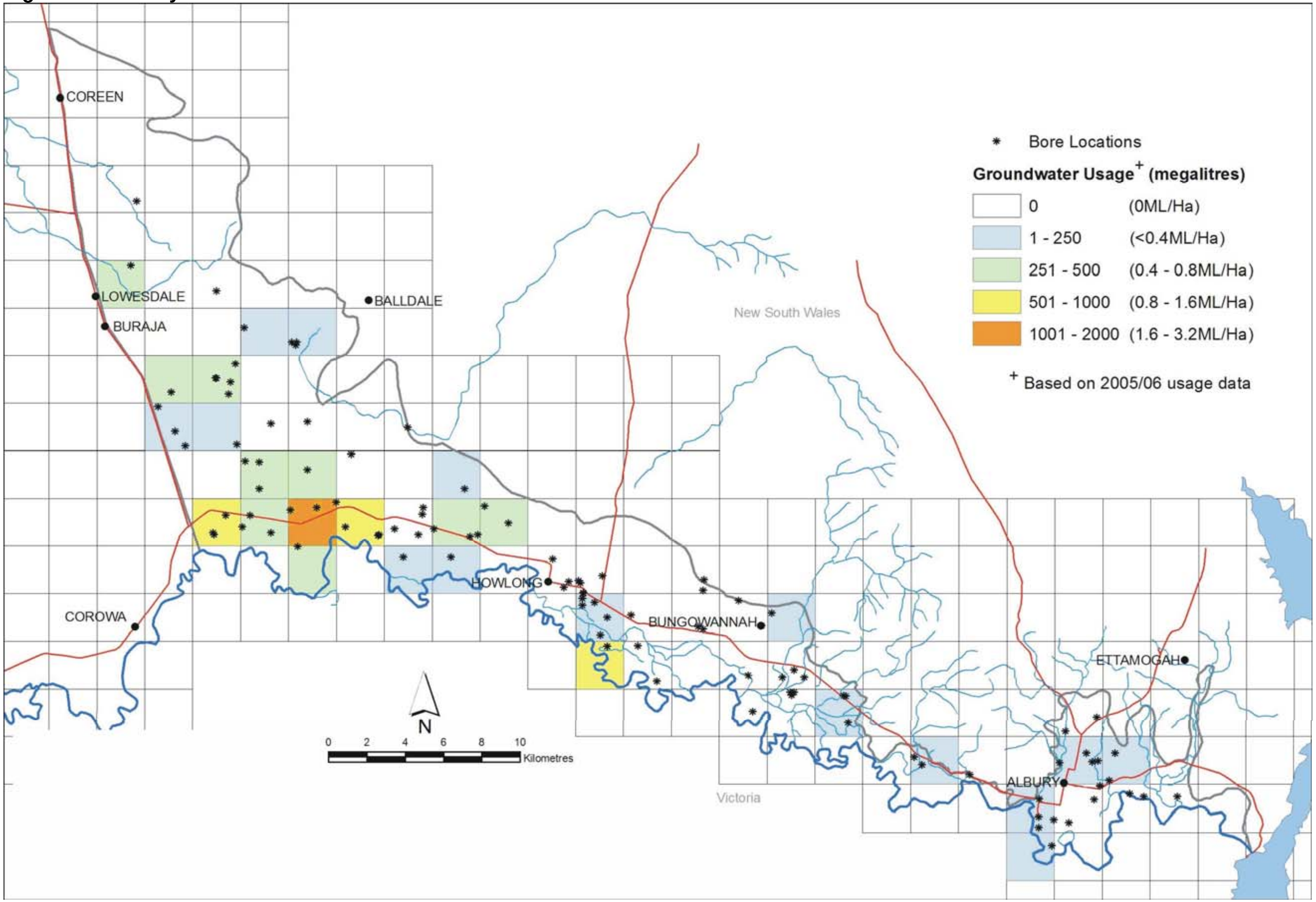


Figure 13: Density of Groundwater Use



4.0 Groundwater Management, Policy & Planning

4.1 SUSTAINABLE MANAGEMENT

Until the 1990s, management of the State's groundwater resources was generally focused on investigation and subsequent development. Little attention was paid on the impacts that extraction might have on its continuing availability and the possible impacts on the environment. Community and government attitudes to natural resources and their management have matured over the last decade or two. Concepts such as intergenerational equity (future resource availability), protection of bio-diversity and maintenance of essential ecological processes are now explicit in groundwater management planning.

The 'NSW State Groundwater Policy Framework Document', which was released as part of the 1997 Water Reforms, provides a clear NSW government policy direction on the ecological sustainable management of the state's groundwater resources. There are 3 component policies specified under the framework document. They are groundwater quantity management, groundwater quality protection and groundwater dependent ecosystems.

The 'NSW groundwater quantity management policy' highlights the need to manage the access to groundwater within the sustainable yield of a system so that the availability of the resource is sustained for all consumptive uses as well as the dependent ecological processes. For the purposes of groundwater management in NSW, sustainable yield is defined as "the groundwater extraction regime, measured over a specific planning timeframe, that allows acceptable levels of stress and protects the higher value uses that have a dependency on water".

4.2 MANAGING ENTITLEMENT AND USE

Over time, all groundwater sources in NSW, including GMA 015, will be regulated by the Water Management Act (2000) and will be managed under a Water Sharing Plan. Until this occurs, the aquifer will continue to be managed under the Water Act 1912.

An embargo on new licences has been in place in GMA 015 since 2000. A new Order was made on 4 July 2008 to Embargo any further applications for groundwater licenses in the entire Murray-Darling Basin portion of NSW (inland), excluding those areas covered by a Water Sharing Plan. The Order replaced all other Embargoes which were in place in parts of the Murray-Darling Basin at the time, including that in GMA 015.

For GWMA 015, the Order prohibits further applications for groundwater licences, apart from a number of exemptions including stock & domestic supply. Additional bores to access existing entitlements are also prohibited. Stock and domestic bores are allowed without restrictions

The temporary transfer of annual water allocations in GMA 015 is still permitted, however they are subject to the consent of State Water and DWE in relation to local groundwater and environmental impacts. Groundwater trading into areas close to the Murray River is restricted because of the connectivity of the aquifer to the river. The permanent transfer of water allocations in GMA 015 is not permitted. Groundwater allocations are not allowed to be traded into or out of GMA015 within NSW or interstate.

Unused allocation cannot be carried forward to the following water year, and licensees cannot bring forward or borrow the following year's allocations for the current water year.

These management arrangements are sufficient for the sustainability of the groundwater resource at present because usage is within the recharge estimates of the groundwater model, and groundwater levels are not declining significantly.

The current best estimate for the volume of total recharge to the GMA 015 groundwater system is 15,300 ML (15.3 GL)/yr. (See Section 5 below for details on the numerical modelling). Volumetric entitlements in GMA 015 total 41,125 ML/yr, plus there is an estimated annual requirement of between 500 and 1,000 ML/yr for stock and domestic use.

One of the main recharge source in GMA 015 area is the Murray River. Current usage volume is well below full entitlements, even given the recent very dry conditions. Stress exerted on the aquifer is probably not high enough currently to have a significant impact on aquifer dynamics, however increased use of groundwater will result in further induced leakage from the Murray River. An acceptable level of leakage needs to be determined in relation to the Murray Darling Basin cap on surface water (and pending Commonwealth Govt Basin Plan) as well as the physical capability of the aquifer to store and yield groundwater.

4.3 GROUNDWATER QUALITY PROTECTION

The NSW Groundwater Quality Protection provides a comprehensive set of policy principles for groundwater quality protection and also provides guidance for groundwater quality protection to resource managers.

One of the tools that can be used in groundwater quality protection is 'groundwater vulnerability mapping'. Maps can show areas at risk from groundwater contamination by certain development activities. Groundwater managers, developers, shire councils and consultants can use these maps to assess the potential of groundwater contamination in an area by a proposed or existing development, which will facilitate the planning process for such a development. The Department has developed a groundwater vulnerability map for GMA 015 and the DLWC Murray region (draft, 2001). It shows the most of the groundwater management area is under the vulnerability rating of either moderate or moderately high.

Some areas in Albury have been identified as potential groundwater contaminated sites by the NSW Department of Environment, Conservation and Climate Change, and therefore some industries have taken up remedial investigations and action. There is no information on the impact on groundwater by the application of chemical fertilisers and pesticides on agricultural land in the management area.

Groundwater usage is moderate in the management area as discussed above, therefore, the possibility of change in groundwater quality in any significant way is low. However in an increased groundwater use scenario, there is a possibility of mobilising salt into the alluvium aquifers along the northern foothills from hard rock aquifers particularly around Howlong in the West Hume Landcare area where dryland salinity is an issue. On the other hand higher groundwater use will induce the groundwater recharge by the river, freshening the alluvium aquifer close to the river.

4.4 GROUNDWATER DEPENDENT ECOSYSTEMS

Groundwater sustains a variety of ecosystems including wetlands and red gum forests and other terrestrial vegetation and in-stream ecosystems fed by groundwater. The NSW Groundwater Dependent Ecosystems Policy is specifically designed to protect ecosystems that rely on groundwater for their survival. The guiding principles that apply to the management of these ecosystems have major links to groundwater quantity management and quality protection principles. Also the identification of such systems is very important. When in a situation where such systems cannot be identified with confidence, or the degree of groundwater dependency is not known due to lack of scientific knowledge, precautionary principals should be applied to protect them until proven otherwise.

The Murray Wetlands Working Group has mapped the wetlands in the region. The group has identified eight wetlands that may have likely connection to groundwater, however their dependency on groundwater is unknown. Since the groundwater usage in the area is low, there is not much stress applied on the aquifer system to notice any significant water level fluctuations. Hence it is difficult to predict the dependency on groundwater of these wetlands.

The health of wetlands and terrestrial vegetation can be compared using sequence of areal photographs taken over the years, and for groundwater dependency, this can be compared with water levels, if water levels have changed significantly. These types of desktop assessments have been done elsewhere in the state. No attempt has been made so far in GMA 015 to identify groundwater dependent ecosystems. The environmental component of groundwater recharge therefore, can not be stated with any accuracy.

5.0 Groundwater Model

The numerical model consists of two layers representing the Shepparton and Lachlan Formations. The model calibration period was from 1980 to 2003.

A combination of increased pumping and below average rainfalls in the last five years of the calibration period has caused river leakage to increase and aquifer storage to decrease. Prediction scenarios made to evaluate the aquifer's response to increased pumping over the ten year period 2003 to 2013 indicate that the aquifer cannot sustain increased pumping over and above 50% of current property entitlements (about 40 GL) without causing significant storage declines and large drawdowns. Model scenario runs also revealed that increased groundwater pumping would derive most of the additional water from the Murray River.

The model is developed with Modflow 96 finite difference software (McDonald & Harbaugh 1988), using the Groundwater Vistas™ (Version 4) graphical user interface in a Windows environment. The model area extends from the Hume Dam in the east to Corowa in the west. The western boundary of the model is fixed along the Corowa-Urana road which forms the administration boundary of the GWMA 015. From the foothills in the north, the model domain extends south of the river towards the Murray Valley Highway in Victoria. The model consists of two layers representing the Shepparton and Lachlan Formations and covers the entire extent of the alluvium on both sides of the Murray River. The model calibration period is from July 1980 to June 2003. The main dynamic components of the model are rainfall recharge, groundwater extraction and river leakage (Mampitiya 2006).

Water balance details pertaining to the GWMA 015 aquifers indicate an annual average recharge of 15.3 GL from all sources. A combination of increased pumping and below average rainfalls in the last five years of the calibration period has caused river leakage to increase and aquifer storage to decrease.

Table 2: Estimated Net River Leakage (GL/yr) (Mampitiya 2006)

Year	Extraction = 15.5 GL/yr	Extraction = 23.3 GL/yr	Extraction = 31 GL/yr
03/04	5.5	7.0	8.4
04/05	5.0	7.5	9.5
05/06	3.3	6.1	8.6
06/07	5.7	8.8	11.6
07/08	4.4	7.3	10.0
08/09	4.5	7.5	10.3
09/10	3.8	6.7	9.6
10/11	6.1	9.3	12.5
11/12	5.7	8.7	11.7
12/13	7.4	10.3	13.5

Three different pumping scenarios (15.5, 23.3, and 31 GL/yr) were completed to examine the impact of increased extraction on the aquifer and leakage from the river. Prediction scenarios made to evaluate the aquifer’s response to increased pumping over the ten year period 2003 to 2013 indicate that the aquifer cannot sustain increased pumping over and above 50% of current property entitlements without causing significant storage declines and large drawdowns. Modelling also revealed that increased groundwater pumping would derive most of the additional water from the Murray River.

The groundwater model is scheduled to be upgraded late in 2008/09. Improvements will be attained by using recent water use and level data (post 2003), and a recalibration if required. The model is expected to improve the accuracy of the water balance, including volumes drawn from the Murray River, and to better formulate the affect of future groundwater pumping scenarios.

6.0 References

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7.0 Glossary

Alluvial, Alluvium – sediment deposited by the action of flowing water, in particular along river beds or flood plains, but not including lakes and seas. Commonly includes clay, silt, sand, gravel and cobbles, usually with organic matter.

Aquifer – a body of saturated rock or soil containing a system of interconnected voids from which significant or economic quantities of groundwater may be abstracted.

Bore – a work that is constructed with a lining of tubing, usually small diameter steel or PVC, which allows the inflow of groundwater for the purposes of abstraction, sampling or monitoring. (see Borehole).

Carbonaceous - composed of or containing carbon.

Electrical Conductivity (EC) – a measure of the ability of water to conduct an electric current between immersed electrodes. The value measured relates to the nature and amount of salts present in the sample (total dissolved solids) and increases with increasing concentration. Usually quoted in micro Siemens per centimetre (μS/cm).

Evapotranspiration – the loss of water from an area of land through the transpiration of water by plants and evaporation from the soil.

Formation – a fundamental unit used in the classification of rock or soil sequences, generally comprising a body with distinctive physical and chemical features.

Groundwater (Ground Water) – water contained within the voids and spaces in rocks or soils.

Head (Hydraulic Head, Static Head) – the energy contained within a column of water resulting from elevation or pressure. The static head is the height (above a standard datum, usually sea level) at which the surface of a column of water could be supported against the action of atmospheric pressure. Hydraulic head is commonly regarded as the sum of elevation head (topographic influences) and pressure head (depth effects).

Hydraulic Conductivity –a measure of the relative ease with which water may be transmitted through a body of soil or rock. Specifically, the flow per unit cross sectional area under a unit hydraulic gradient. (see Hydraulic Gradient; Transmissivity).

Hydraulic Gradient – the change in the static head over a distance in a given direction. (see Head).

Monitoring Bore – a bore used to measure groundwater levels, collect water quality samples, or both. May be an observation bore if installed for the purpose of monitoring variations during a pump-out test. (see Observation Bore).

Observation Bore – an installation constructed for the purpose of monitoring variations in parameters such as water levels and pressure changes, usually during a pump-out test. (see Monitoring Bore).

Palaeozoic – an era of geologic time extending between around 600 and 230 million years ago and including the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian Periods (see Era).

Piezometer – a pipe penetrating the subsurface, and intersecting water bearing zones, in which the elevation of a groundwater level (potentiometric surface) can be determined.

Potentiometric Surface (Piezometric Surface) – an imaginary surface representing the level to which groundwater will rise under the existing hydraulic head.

Production Bore – a bore from which significant or economic abstraction of groundwater may take place, either through pumping or artesian flow, and usually contributing to a town water supply.

Recharge – the addition of water, usually by infiltration, to an aquifer's saturation zone.

Salinity – The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million, ppm).

Transmissivity – the rate at which groundwater is allowed to pass through a section of the saturated thickness of an aquifer under the prevailing hydraulic gradient. Specifically applies to groundwater passing through a unit width of aquifer under a unit hydraulic gradient.

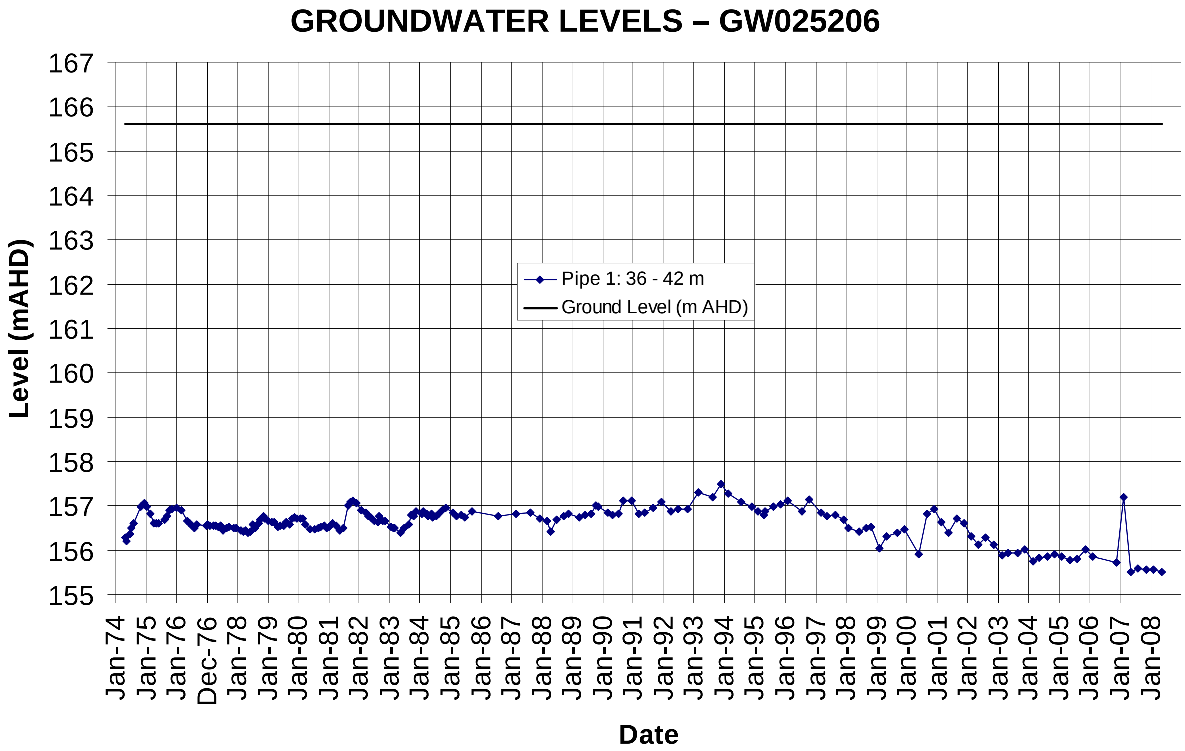
Unsaturated Zone – the part of a body of soil or rock separating the land surface and the water table and which contains a combination of air and water within the pore spaces or voids.

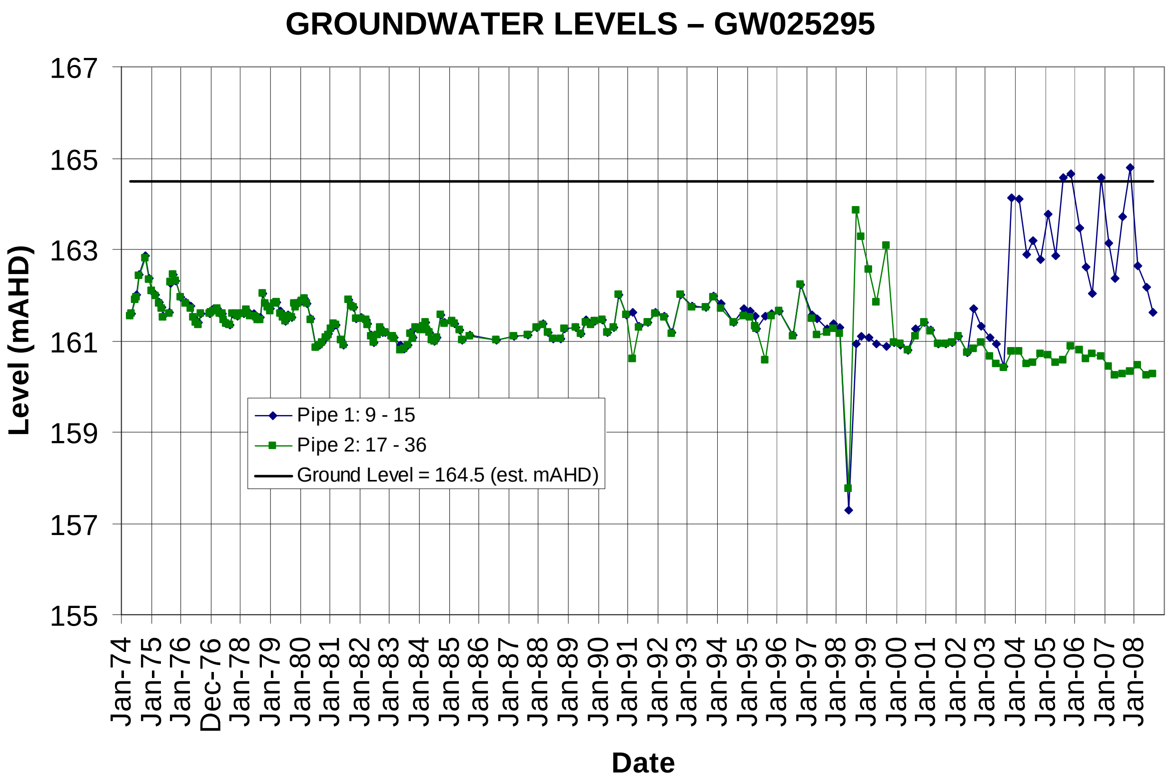
Water Bearing Zone – a zone or layer within the subsurface that contains water.

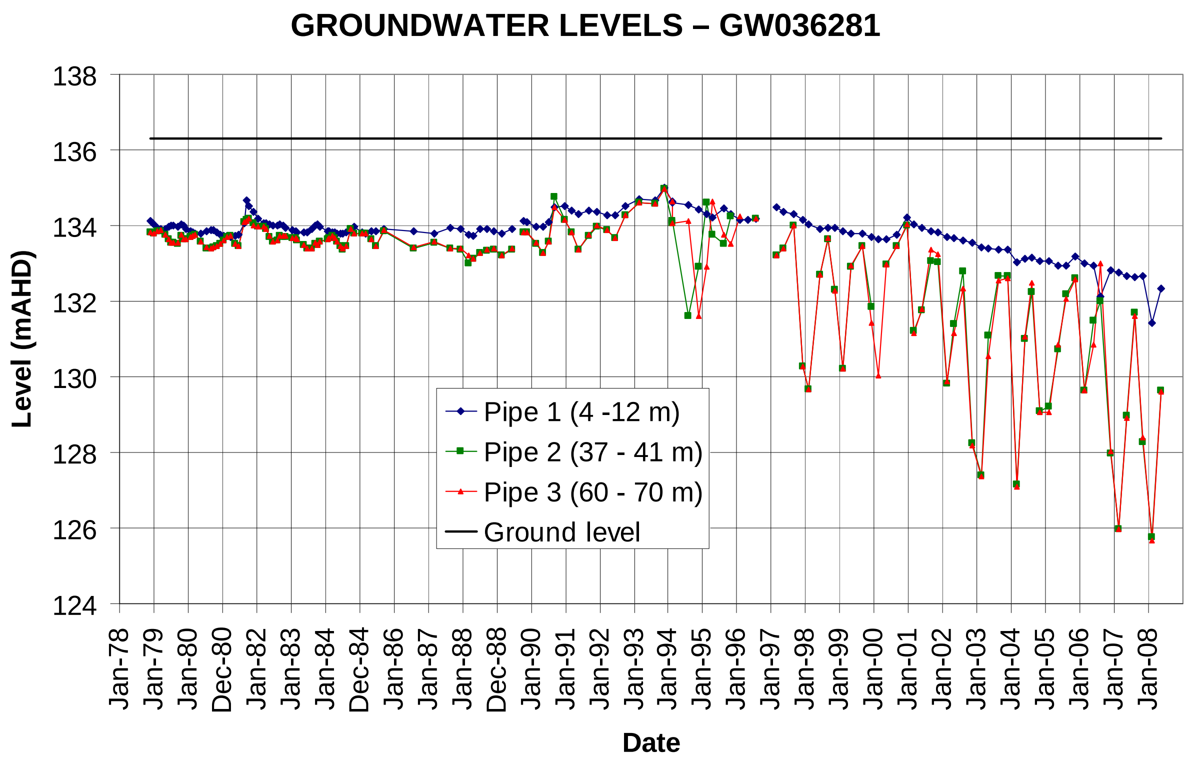
Water Table (Phreatic Surface) – the surface of a body of groundwater within an unconfined aquifer at which the pressure is atmospheric. The water table defines the boundary between the unsaturated zone (above) and the saturated zone (below) under unconfined conditions.

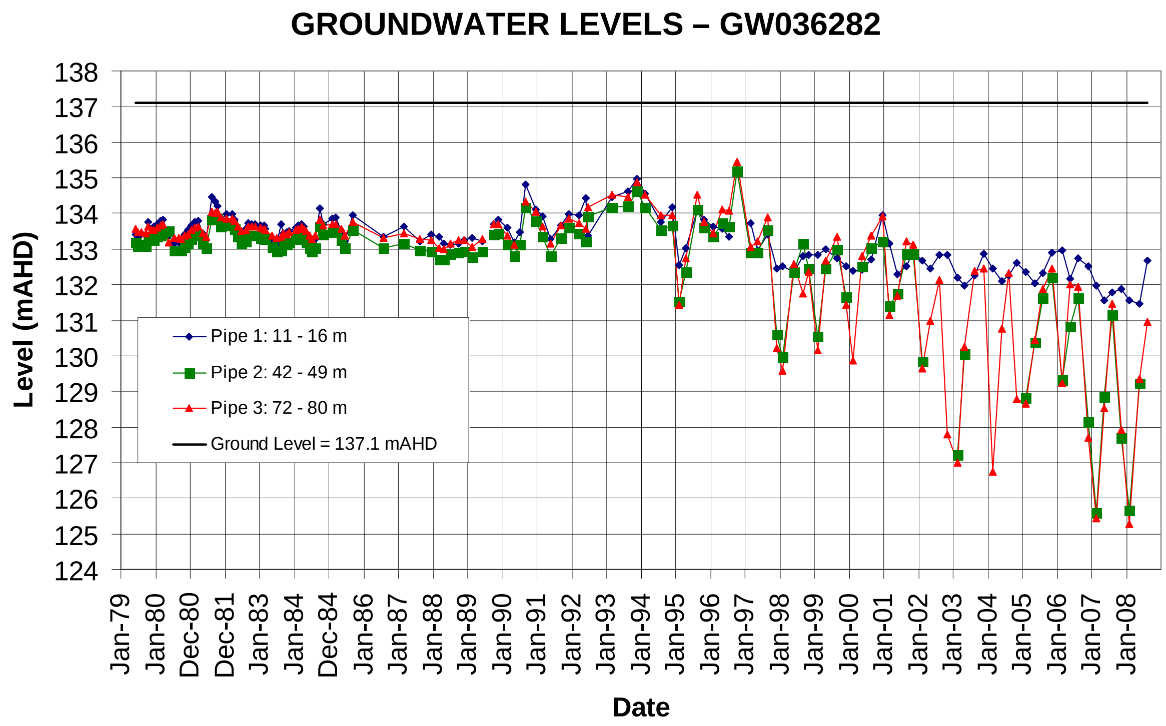
Yield – a measure of the economic volume of groundwater that can potentially be abstracted from an installation. Yield may also refer to the quantity of groundwater withdrawn from the installation at a given time.

Appendix: Groundwater Hydrographs






GROUNDWATER LEVELS – GW036281
Level (mAHD)
138
136
134
132
130
128
126
124
Pipe 1 (4 -12 m)
Pipe 2 (37 - 41 m)
Pipe 3 (60 - 70 m)
Ground level
Jan-78
Jan-79
Jan-80
Dec-80
Jan-82
Jan-83
Jan-84
Dec-84
Jan-86
Jan-87
Jan-88
Dec-88
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date


GROUNDWATER LEVELS – GW036282
Level (mAHD)
138
137
136
135
134
133
132
131
130
129
128
127
126
125
124
Pipe 1: 11 - 16 m
Pipe 2: 42 - 49 m
Pipe 3: 72 - 80 m
Ground Level = 137.1 mAHD
Jan-79
Jan-80
Dec-80
Dec-81
Jan-83
Jan-84
Dec-84
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
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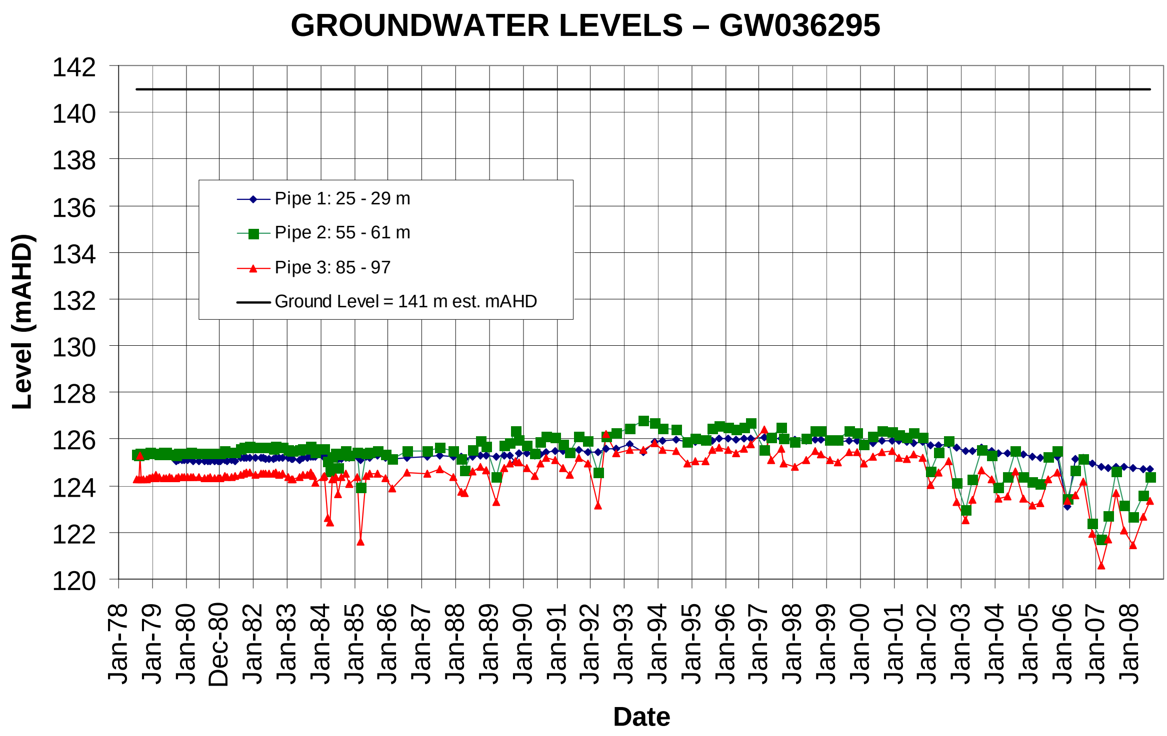
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date


GROUNDWATER LEVELS – GW036295
Pipe 1: 25 - 29 m
Pipe 2: 55 - 61 m
Pipe 3: 85 - 97
Ground Level = 141 m est. mAHD
Level (mAHD)
Date
142
140
138
136
134
132
130
128
126
124
122
120
Jan-78
Jan-79
Jan-80
Dec-80
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
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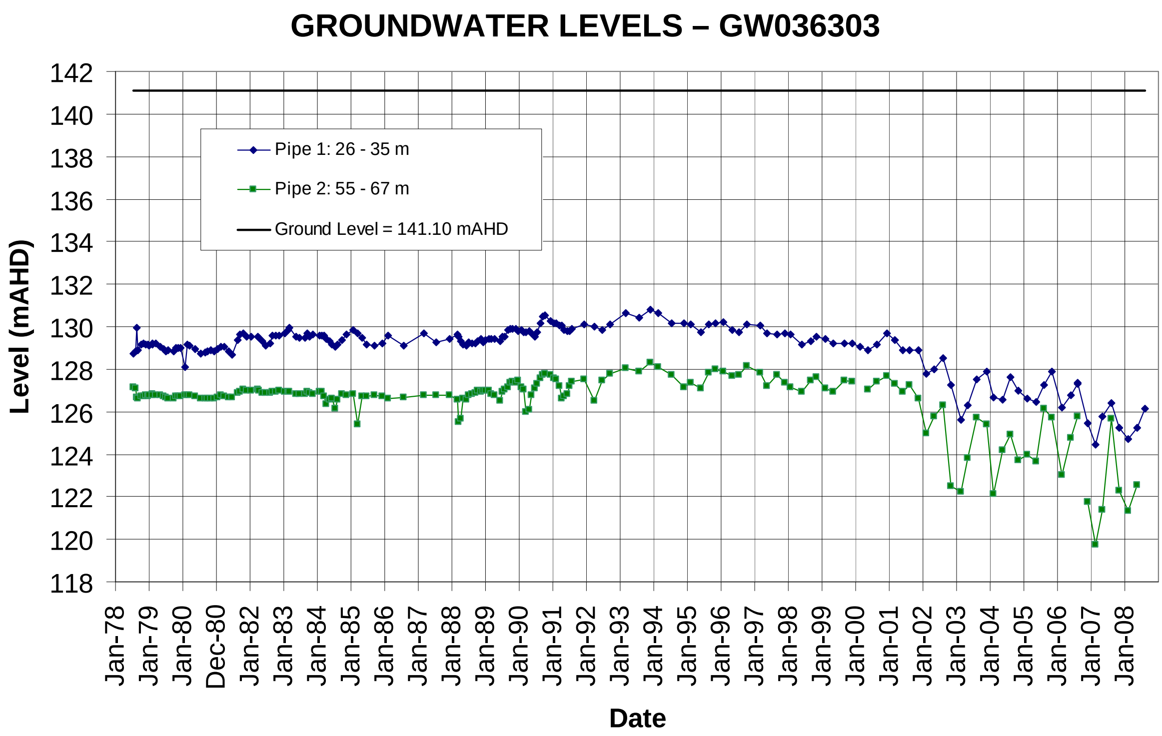
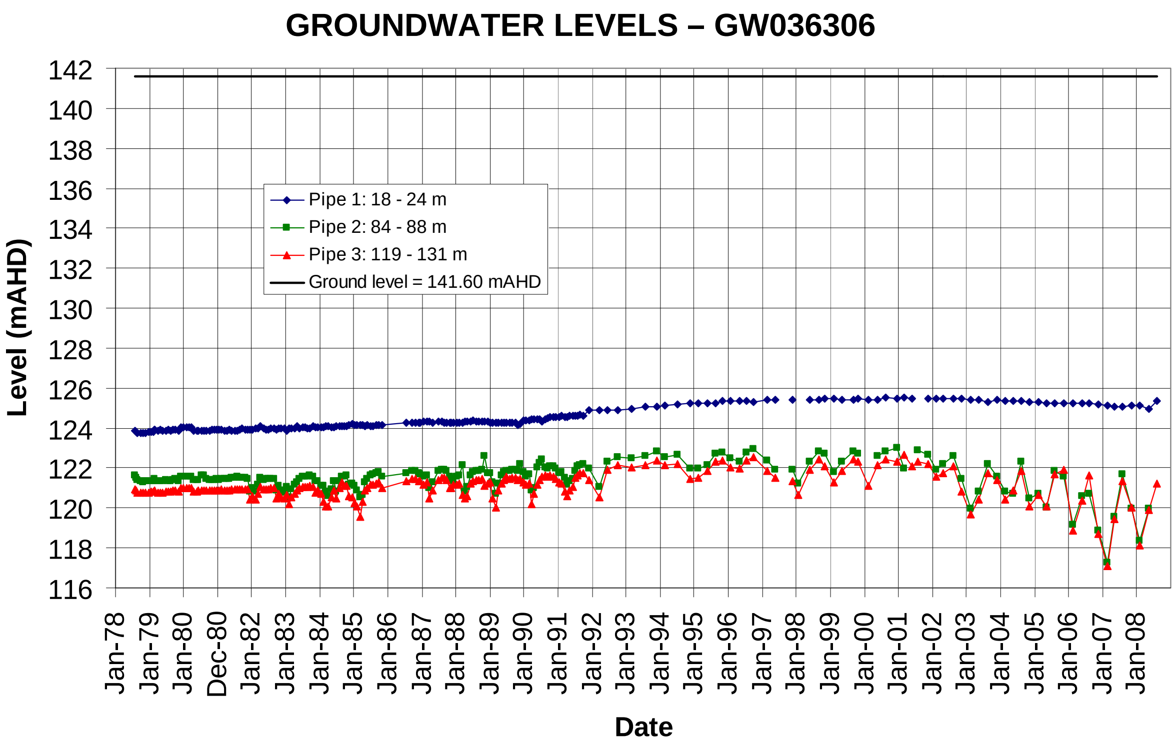
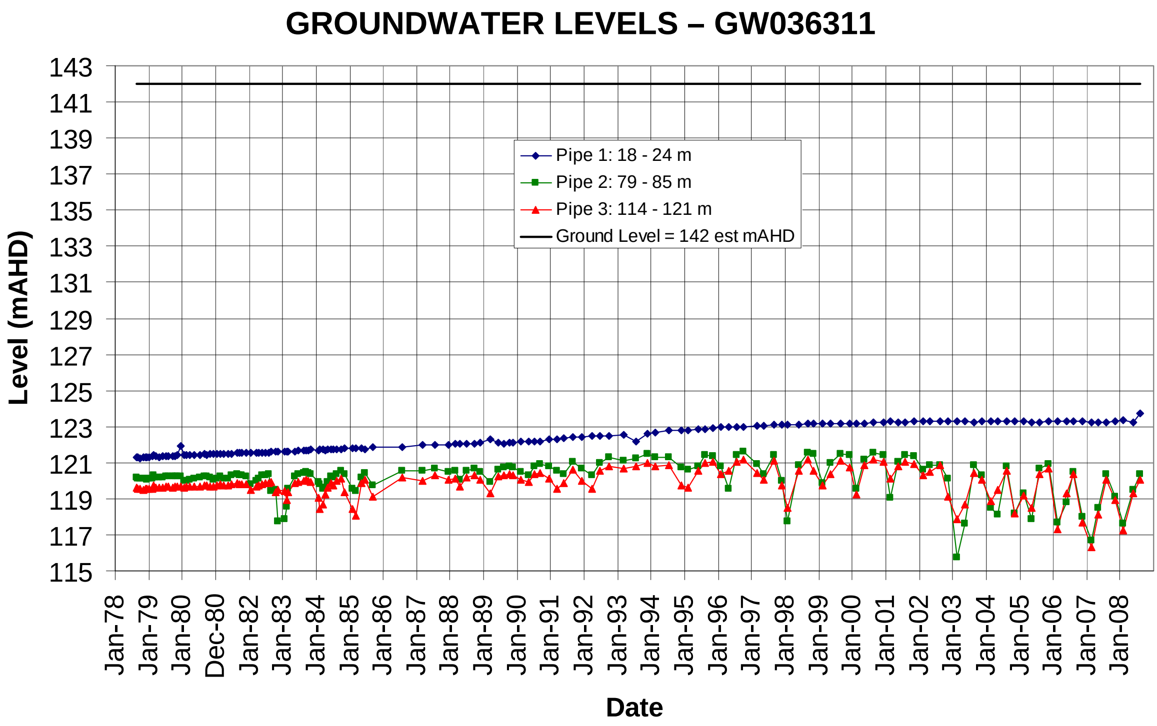
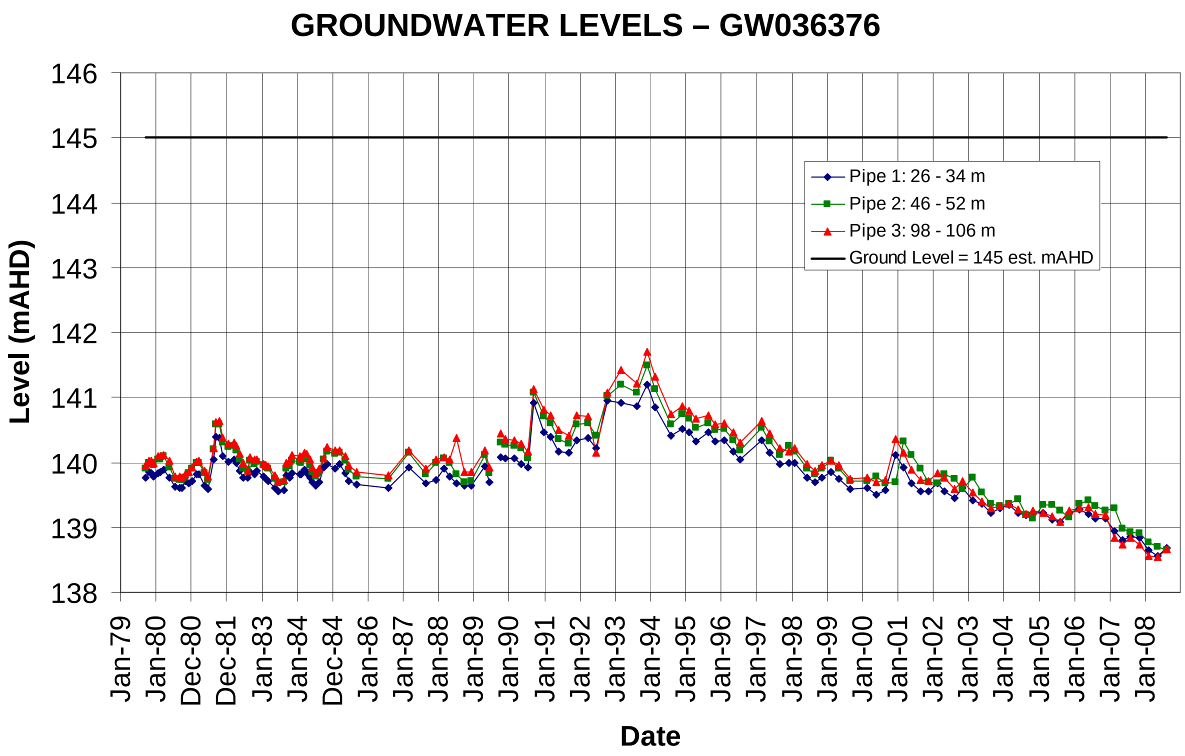
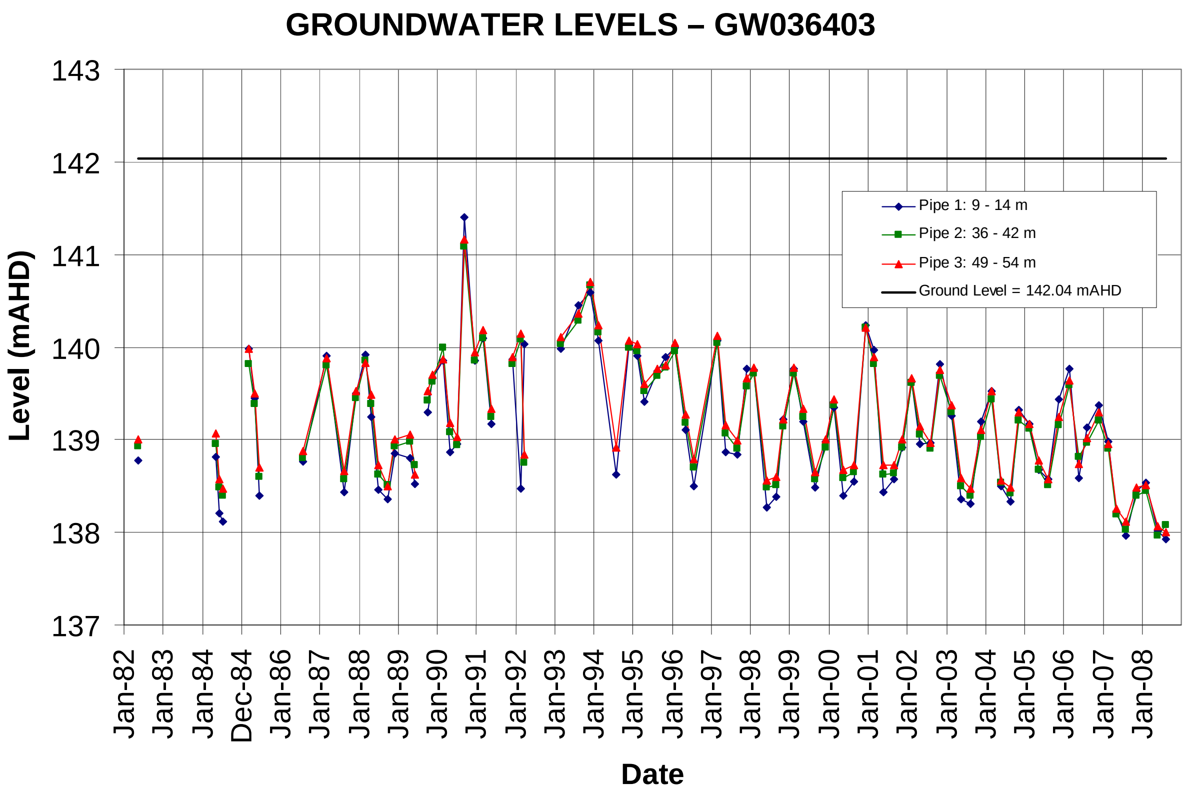
Jan-06
Jan-07
Jan-08


GROUNDWATER LEVELS – GW036303
Pipe 1: 26 - 35 m
Pipe 2: 55 - 67 m
Ground Level = 141.10 mAHD
Level (mAHD)
Date
142
140
138
136
134
132
130
128
126
124
122
120
118
Jan-78
Jan-79
Jan-80
Dec-80
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08

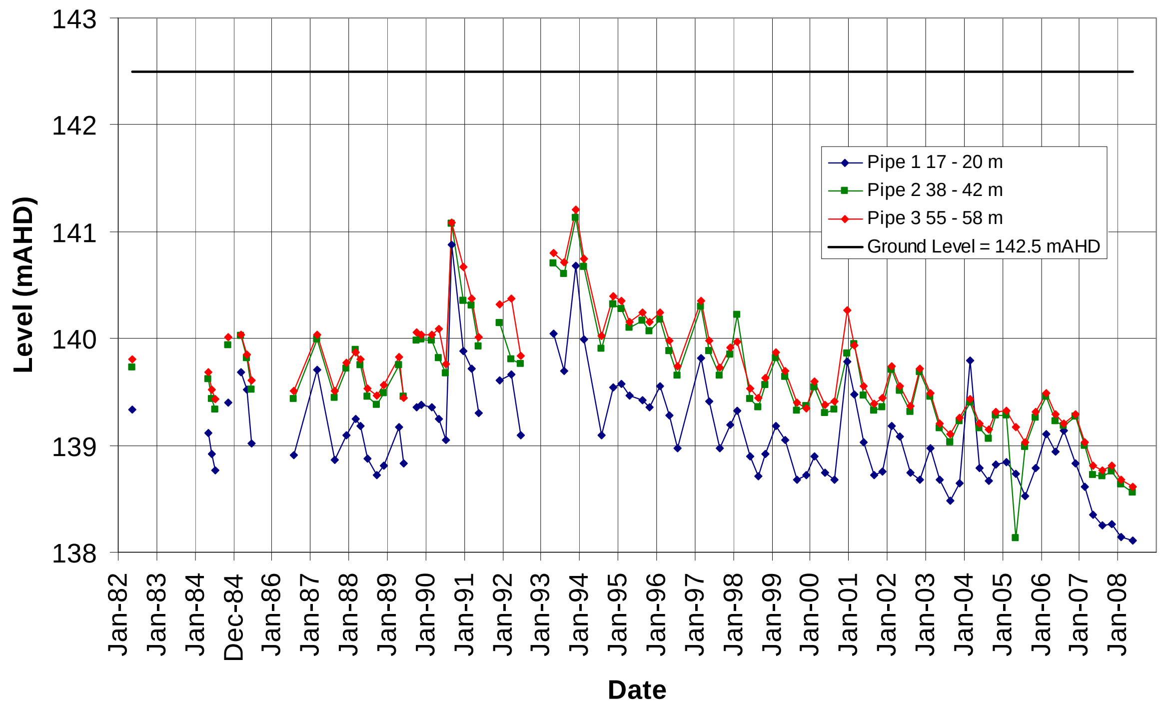

GROUNDWATER LEVELS – GW036306
Level (mAHD)
142
140
138
136
134
132
130
128
126
124
122
120
118
116
Pipe 1: 18 - 24 m
Pipe 2: 84 - 88 m
Pipe 3: 119 - 131 m
Ground level = 141.60 mAHD
Jan-78
Jan-79
Jan-80
Dec-80
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date


GROUNDWATER LEVELS – GW036311
Level (mAHD)
143
141
139
137
135
133
131
129
127
125
123
121
119
117
115
Pipe 1: 18 - 24 m
Pipe 2: 79 - 85 m
Pipe 3: 114 - 121 m
Ground Level = 142 est mAHD
Jan-78
Jan-79
Jan-80
Dec-80
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date

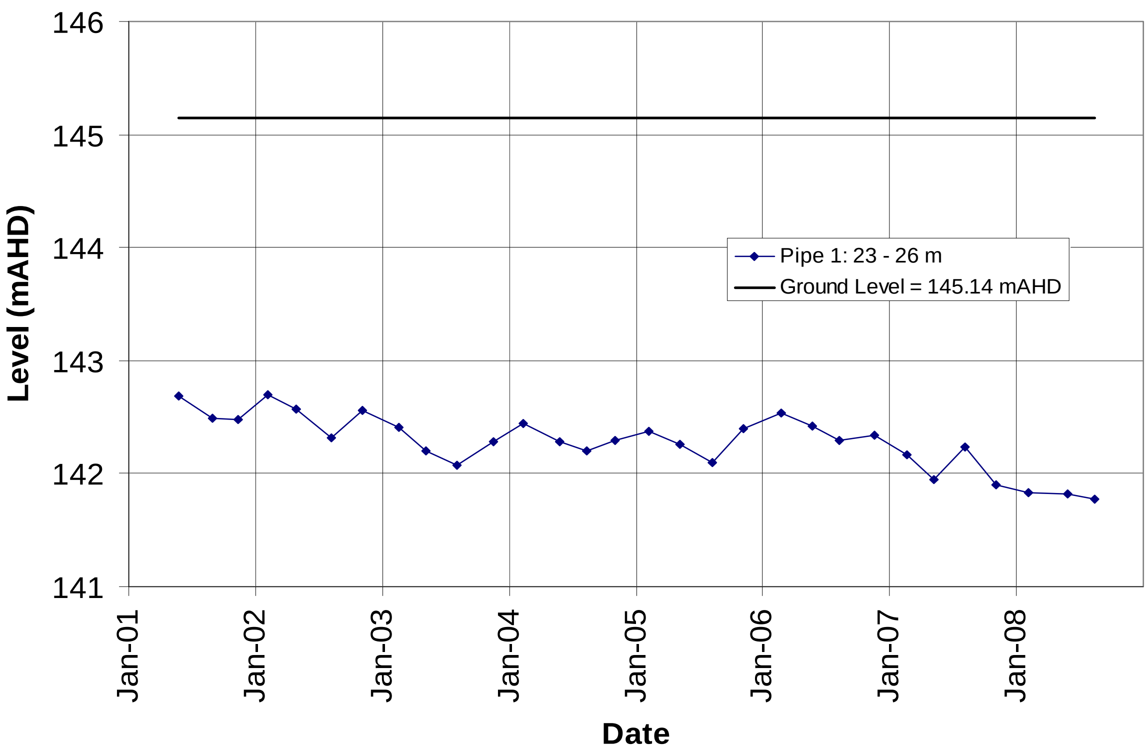

GROUNDWATER LEVELS – GW036376
Level (mAHD)
Date
Pipe 1: 26 - 34 m
Pipe 2: 46 - 52 m
Pipe 3: 98 - 106 m
Ground Level = 145 est. mAHD

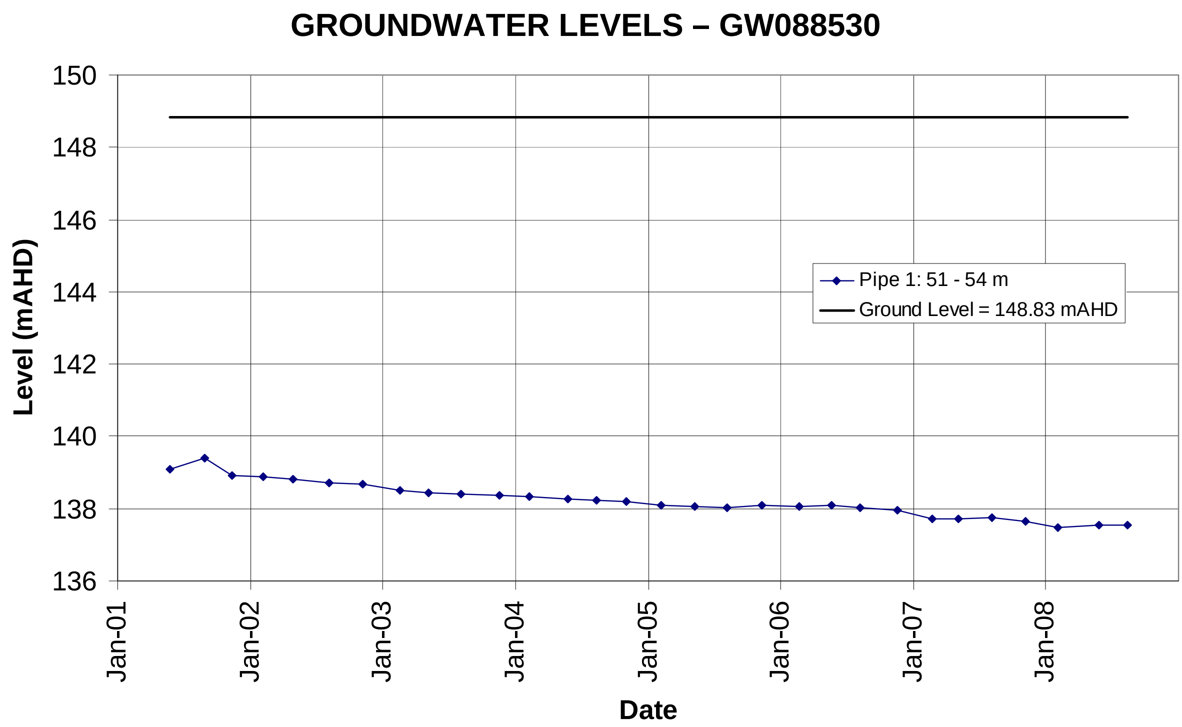

GROUNDWATER LEVELS – GW036403
Level (mAHD)
Date
Pipe 1: 9 - 14 m
Pipe 2: 36 - 42 m
Pipe 3: 49 - 54 m
Ground Level = 142.04 mAHD

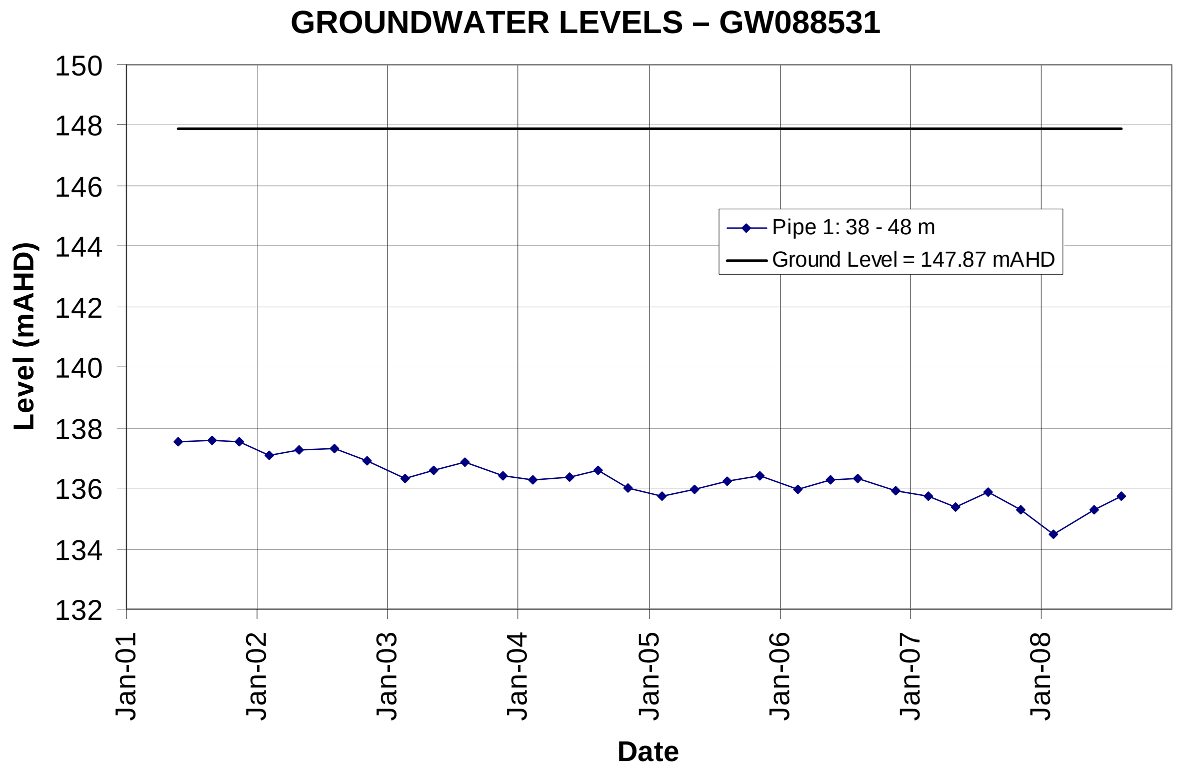
GROUNDWATER LEVELS – GW036416

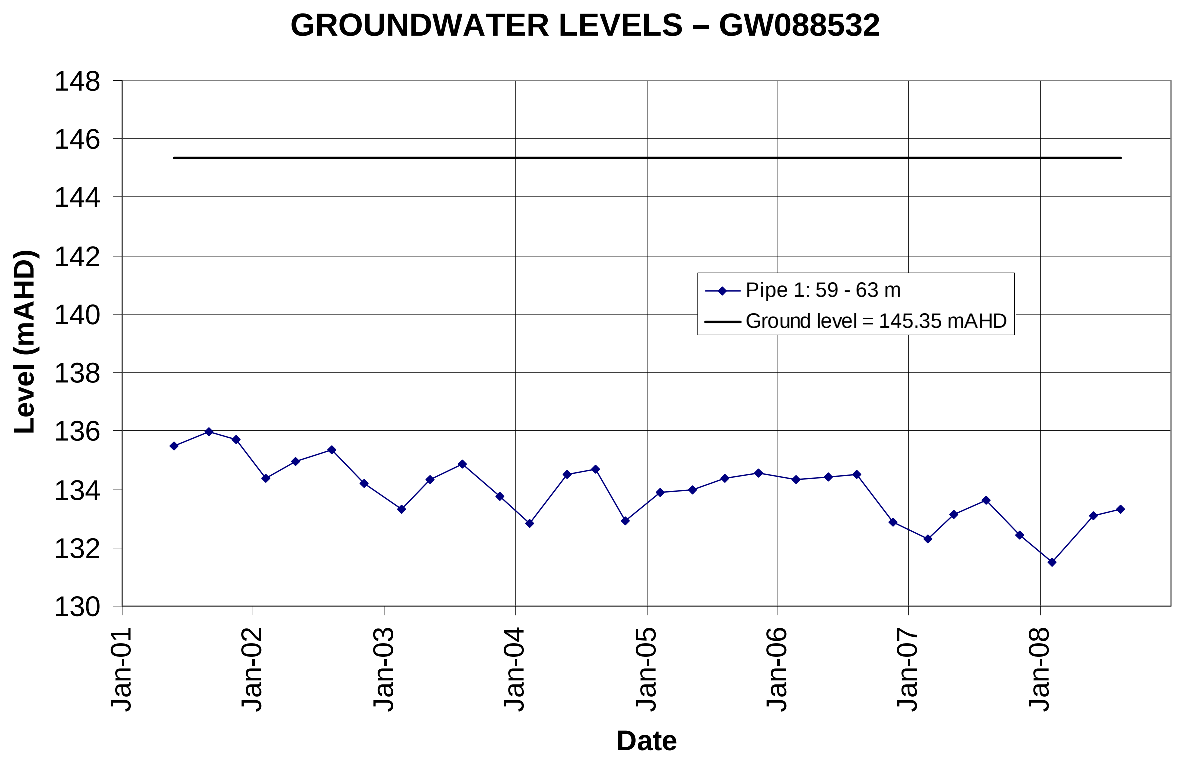


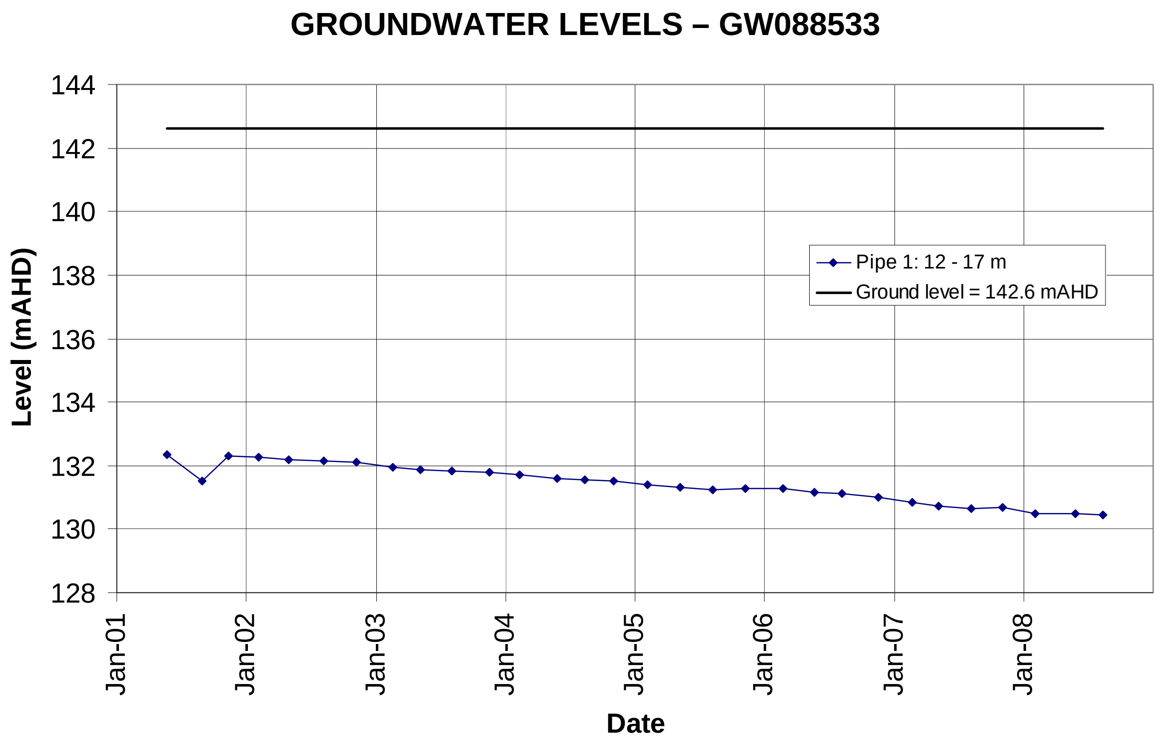
GROUNDWATER LEVELS – GW088528




GROUNDWATER LEVELS – GW088530
Level (mAHD)
150
148
146
144
142
140
138
136
Pipe 1: 51 - 54 m
Ground Level = 148.83 mAHD
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date


GROUNDWATER LEVELS – GW088531
Level (mAHD)
150
148
146
144
142
140
138
136
134
132
Pipe 1: 38 - 48 m
Ground Level = 147.87 mAHD
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date


GROUNDWATER LEVELS – GW088532
Level (mAHD)
148
146
144
142
140
138
136
134
132
130
Pipe 1: 59 - 63 m
Ground level = 145.35 mAHD
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date


GROUNDWATER LEVELS – GW088533
Level (mAHD)
144
142
140
138
136
134
132
130
128
Pipe 1: 12 - 17 m
Ground level = 142.6 mAHD
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Date