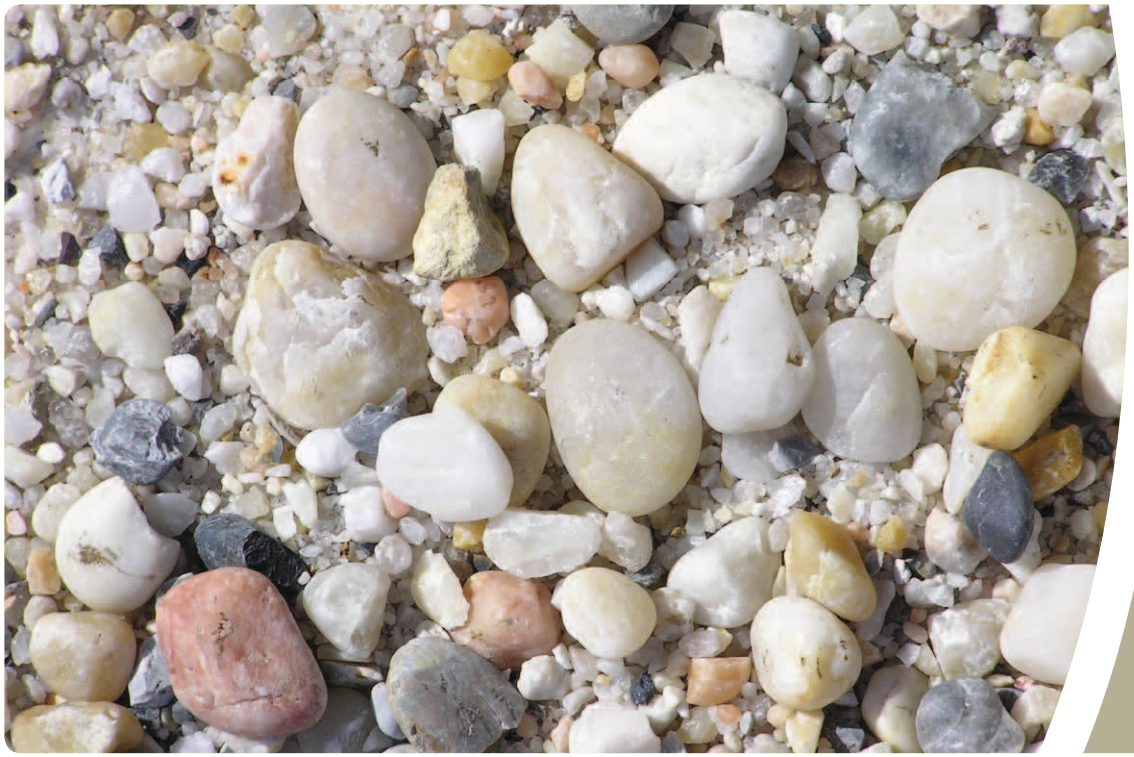
NSW GOVERNMENT | Office of Water

Upper Macquarie Alluvium

Groundwater Management Area 009

Groundwater Status Report – 2010



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Contents

1 Introduction ... 6

1.1 Location ... 6

2 Groundwater management ... 8

2.1 Licensing ... 8

2.2 Entitlement ... 9

2.3 Announcements and extraction limits ... 9

2.4 Transfers ... 9

2.5 Usage ... 10

3 Rainfall ... 13

4 Geology and hydrogeology ... 15

4.1 Regional geology ... 15

4.1.1 Lithology ... 15

4.1.2 Structure ... 15

4.2 Local geology ... 17

4.2.1 Quaternary alluvium ... 17

4.2.2 Tertiary alluvium ... 18

4.3 Hydrogeological cross sections ... 20

4.4 Aquifer parameters ... 29

4.5 Basement contours ... 29

4.6 Review of groundwater management area boundary ... 29

5 Groundwater levels ... 31

5.1 Overview ... 31

5.2 Hydrographs ... 31

5.3 Groundwater heads and flow directions ... 40

5.4 Long term sustainability ... 43

6 Groundwater quality ... 46

Tables

Table 1 Number and volume of temporary transfers in Upper Macquarie GWMA009 since 2003 ... 9

Table 2 Usage in the Upper Macquarie GWMA009 since 1980 ... 10

Table 3 Summary of palynological dating of Upper Macquarie sedimentary strata ... 18

Table 4 Summary of alluvial unit thicknesses and depths by section ... 20

Table 5 Hydraulic gradient between Quaternary and Tertiary alluvium ... 40

Table 6 Summary of groundwater conditions for areas experiencing drawdown and recovery decline ... 43

Table 7 Summary of electrical conductivity and salinity by formation ... 46

Figures

Figure 1 Location of the Upper Macquarie Groundwater Management Area 009 ... 7

Figure 2 Usage in the Upper Macquarie GWMA009 since 1980 ... 11

Figure 3 Distribution of average usage in the Upper Macquarie GWMA009 for the water years 2004 to 2009 ... 12

Figure 4 Average monthly rainfall for Dubbo and Wellington ... 13

Figure 5 Annual rainfall for Dubbo and Wellington ... 14

Figure 6 Cumulative deviation from mean annual rainfall at Dubbo and Wellington ... 14

Figure 7 Regional geology of the Upper Macquarie valley ... 16

Figure 8 Location of hydrogeological cross sections for Upper Macquarie GWMA009 ... 21

Figure 9 Hydrogeological cross section, A Dulla Dulla ... 22

Figure 10 Hydrogeological cross section, B Coolbaggie ... 22

Figure 11 Hydrogeological cross section, C Whylandra ... 23

Figure 12 Hydrogeological cross section, D Cooreena Road ... 23

Figure 13 Hydrogeological cross section, E Talbragar ... 24

Figure 14 Hydrogeological cross section, F Troy Bridge ... 24

Figure 15 Hydrogeological cross section, G Myall Street – North Dubbo ... 25

Figure 16 Hydrogeological cross section, H Hennessey Road – South Dubbo ... 25

Figure 17 Hydrogeological cross section, I Butlers Falls ... 26

Figure 18 Hydrogeological cross section, J Sandy Falls ... 26

Figure 19 Hydrogeological cross section, K Shepherds Hill ... 27

Figure 20 Hydrogeological cross section, L Terrabella ... 27

Figure 21 Hydrogeological cross section, M Geurie ... 28

Figure 22 Hydrogeological cross section, N Wellington ... 28

Figure 23 Depth to base of alluvium for the Upper Macquarie GWMA009 30
Figure 24 Location of groundwater monitoring sites and river gauging stations for GWMA009 32
Figure 25 Hydrograph for Wellington section 33
Figure 26 Hydrograph for Geurie section 33
Figure 27 Hydrograph for Shepherds Hill section 35
Figure 28 Hydrograph for Butlers Falls section 35
Figure 29 Hydrograph for Hennessey Road–South Dubbo section 37
Figure 30 Detailed Hydrograph for GW 025414 Hennessey Road section 37
Figure 31 Hydrograph for Troy Bridge section 38
Figure 32 Hydrograph for Cooreena Road section 38
Figure 33 Hydrograph for Coolbaggie section 39
Figure 34 Hydrograph for Dulla Dulla section 39
Figure 35 Groundwater heads and flow directions for Quaternary aquifer 41
Figure 36 Groundwater heads and flow directions for Tertiary aquifer 42
Figure 37 Hydrograph for GW036439 Butlers Falls section 44
Figure 38 Hydrograph for GW 021498 Hennessey Road section 44
Figure 39 Hydrograph for GW 025414 Hennessey Road section 45
Figure 40 Electrical conductivity of groundwater in Quaternary alluvium 47
Figure 41 Electrical conductivity of groundwater in Tertiary alluvium 48

Plates

Plate 1 Quaternary sand and gravel at 15m in GW273111 at Terrabella 19
Plate 2 Tertiary sand and gravel at 32m in GW273111 at Terrabella 19

Executive summary

This report describes the status of the groundwater resource of the Upper Macquarie Alluvium Groundwater Management Area (GWMA) 009 in 2010. The groundwater management history, licensing, entitlement, transfers, and usage for the water source are presented. The geology and hydrogeology of the alluvium and surrounding bedrock have been reviewed and updated. Hydrogeological cross sections and basement contours are presented and the management area boundary has been revised. Groundwater levels are presented and discussed in relation to long term sustainability, and a summary of groundwater salinity is presented.

The Upper Macquarie GWMA consists of alluvial deposits associated with the Macquarie River between Wellington and Brummagen Creek downstream of Dubbo, and forms part of the Murray Darling Basin. Groundwater from the Upper Macquarie Alluvium is used for irrigation, commercial, industrial, recreation, stock, and domestic purposes, and forms a significant component of the Dubbo town water supply. Groundwater licensing and management in the Upper Macquarie GWMA are currently conducted under the *Water Act 1912*. The Upper Macquarie alluvium will be incorporated into a water sharing plan that will be developed by the end of 2010. On commencement of the water sharing plan, the GWMA will be managed under the *Water Management Act 2000*.

In May 1992, due to growing concerns over increasing demand for entitlement and localised water level declines, the four parishes around Dubbo were embargoed for high yielding groundwater license applications. The remainder of the management area was embargoed for high yielding licence applications on March 2000. In July 2008, the 2000 embargo was replaced with a new embargo (Order 1) covering all inland aquifers, including GWMA009, where entitlements have reached, exceed or are likely to exceed their long term average extraction limit. In early 2010 there were 163 high yield licences and 136 property accounts in the management area, with a total entitlement of 33.7GL. Usage for the 2008/2009 water year was 13.7GL. Since 2003 there have been 43 temporary assignments of allocation.

Nine additional groundwater investigation and monitoring sites consisting of 14 bores were installed in the Upper Macquarie groundwater management area during 2009. Borehole geology and palynological dating has enabled stratigraphic differentiation and characterisation of Quaternary and Tertiary age sediments in the Upper Macquarie valley. The Quaternary alluvial units are characterised by an upper red silt and clay that ranges in thickness up to 20m but is generally between 5m and 15m in thickness and occurs across the majority of the management area. Underlying this unit is a polymictic variably ‘dirty’ sand and gravel to depths between 19m and 38m. The Tertiary alluvial units are characterised by predominantly monomictic cleaner sand and gravel interbedded with clays, organic clay and sand to depths between 43m and 75m. Fourteen hydrogeological cross sections have been developed for the management area showing the Quaternary and Tertiary units, base of the palaeovalley, basement geology and standing water level. Two areas were identified where the palaeovalley existed outside of the groundwater management area boundary. As a result of this improved geological understanding, the groundwater management area boundary has been modified.

Hydrographs showing groundwater levels and trends are presented for 19 representative sites throughout the management area. Groundwater is unconfined to partly confined in the upper aquifer (down to 25m), and becomes more increasingly confined with depth in the lower aquifer. Through most parts of the management area the upper and lower aquifers are in relatively good lateral and vertical hydraulic connection. Water levels throughout the aquifer responded to the main river flood events of 1990, 1998 and 2000. The near-river parts of the aquifer show strong rapid responses and the more distal parts of the aquifer show variably subdued and delayed responses. Groundwater heads demonstrate that the Macquarie River has a combination of gaining and losing reaches, and that this changes with flood recharge and drought events.

Seasonal pumping drawdowns between 1.5m and 6m are observed in the Butlers Falls, Hennessey Road, Dulla Dulla and Troy Bridge areas. Groundwater level trends have been relatively stable across most parts of the aquifer over the last four decades. However, long term declining trends are occurring in the Dulla Dulla, Coolbaggie and Hennessey Road areas. Groundwater levels in the Hennessey Road area have fallen up to 18m since commencement of monitoring in the early 1970s. Since the onset of the drought in 2002, groundwater levels have declined in all parts of the aquifer, with falls of between 0.5m and 9m.

At a regional scale, the groundwater flow direction in both the Quaternary and Tertiary aquifers correlates with that of surface drainage and is northwest from Wellington towards Dubbo and Narromine. Locally there has been a significant reversal in the regional hydraulic gradient between central Dubbo and the Hennessey Road area in south Dubbo where significant drawdowns are occurring due to extraction. In the Shepherds Hill to Ponto area groundwater heads in the Tertiary aquifer are lower than the Quaternary aquifer by 4m to 7m and at Terrabella there is a steep hydraulic gradient between the Little River area and the main valley also suggesting drawdown due to extraction.

Over the 27 year period of monitoring, groundwater storage in the Hennessey Road area has been depleted through extraction and is not being replenished by sufficient recharge to halt the declining water level trend. In March 2010 groundwater levels at monitoring bore GW21498 in the area had been drawn down to 75 per cent of the saturated thickness of the aquifer.

The majority of groundwater in GWMA009 has a relatively low salinity giving it a high beneficial use category of raw water for drinking water supply. However, in some parts of the GWMA the salinity is much higher and the water has a lower beneficial use falling into the upper end of the agricultural water category.

1 Introduction

1.1 Location

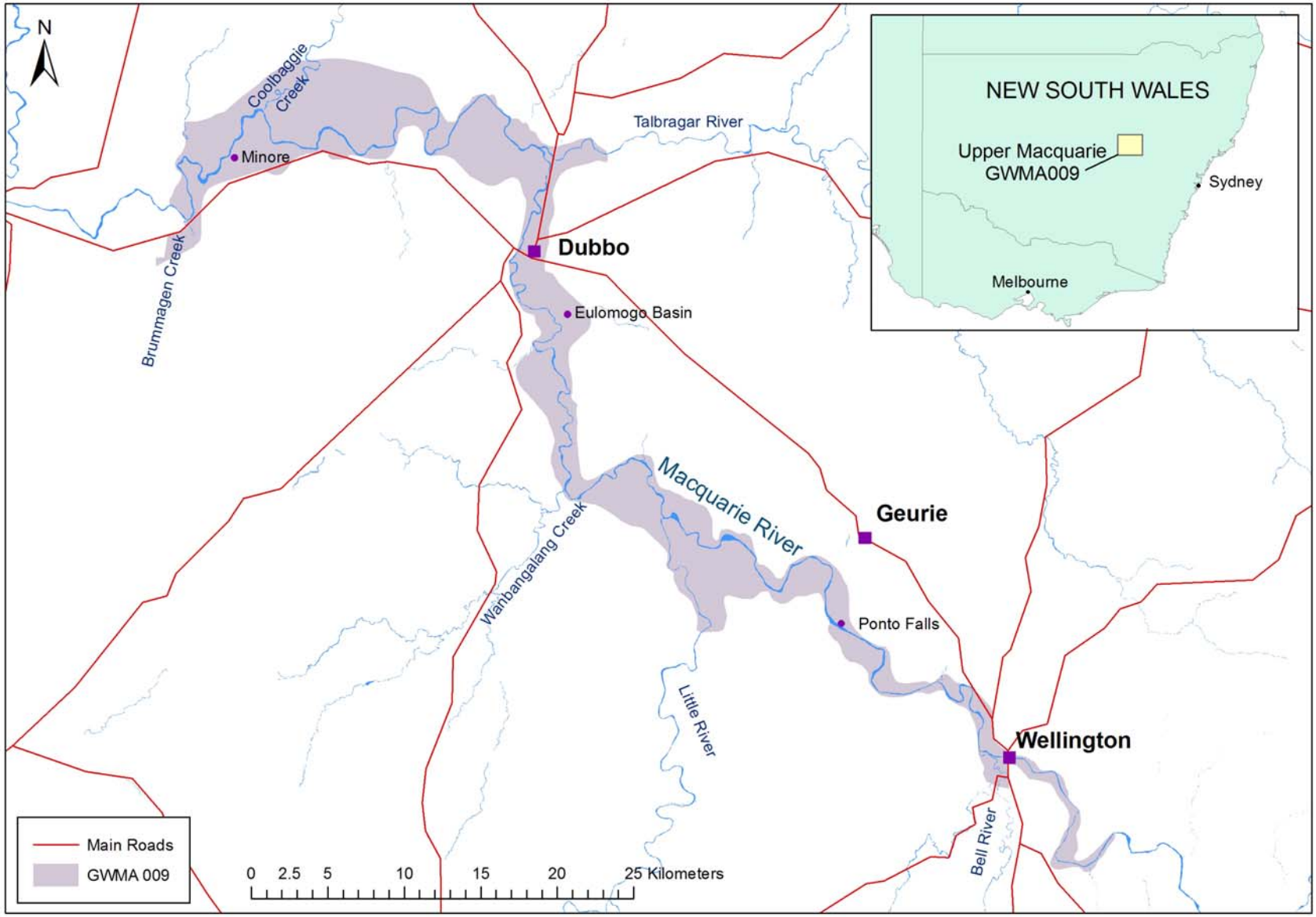
The Macquarie Valley is a large inland alluvial valley in central NSW that forms part of the Murray-Darling Basin. The Macquarie River has a number of tributaries including the Cudgegong, Bell, Little and Talbragar Rivers. The headwaters of the Macquarie originate in the Great Dividing Range and include the localities of Coolah, Rylstone and Oberon. The Macquarie River flows northwest through the Macquarie Valley and the Ramsar listed Macquarie Marshes to join the Darling River around 30 km downstream of Carinda in north-western NSW. Since 1967 flows in the Macquarie River have been regulated by Burrendong Dam upstream of Wellington.

Groundwater resources along specific reaches of the Macquarie and its tributaries are managed by the NSW Office of Water as separate groundwater management areas. The Upper Macquarie Groundwater Management Area (GWMA) consists of alluvial deposits associated with a section of the Upper Macquarie River. In October 2006 the section of GWMA009 downstream of Brummagen Creek was formally re-assigned to the Lower Macquarie GWMA008 Zone 6. This assignment was the result of hydrogeological review during development of the Lower Macquarie Water Sharing Plan. The Upper Macquarie GWMA covers 286.3 km^2. It extends from Brummagen Creek to 8km upstream of Wellington, and incorporates the urban areas of Dubbo and Wellington. The location of the GWMA is shown in Figure 1.

Upstream of Ponto Falls, the GWMA is confined by steeper hill and range terrain and the alluvial flats are limited to between 500m and 1km wide. Downstream of Ponto Falls the GWMA opens out and is flanked by gentle hillslopes with broader alluvial flats ranging 800m to 5km wide.

Groundwater from the Upper Macquarie Alluvium is used for irrigation, commercial, industrial, recreation, stock and domestic purposes, and forms a significant component of the Dubbo town water supply. Cotton, cereal and fodder crops, market gardening, viticulture and orcharding are irrigated from this groundwater source.

Figure 1 Location of the Upper Macquarie Groundwater Management Area 009



2 Groundwater management

Groundwater licensing and management in the Upper Macquarie Alluvium are currently conducted under the *Water Act 1912*. Over the last 10 years, groundwater management in the Upper Macquarie has involved monitoring of groundwater levels, assessment of licence and transfer applications, assessment of development applications, project specific collection of water quality data, collaboration with Dubbo City Council in relation to town water supply extraction, and provision of technical advice in regards to groundwater contamination events and other projects.

The National Water Initiative (NWI) commenced in 2004 and introduced water reforms requiring states to prepare statutory water plans. In NSW, water sharing plans are now being developed for water sources not currently managed under a plan.

Water sharing plans are being prepared to:

- clarify the rights of the environment, basic rights users, town water supplies and licensed users
- manage the cumulative impact of extraction
- facilitate the trading of water between users.

The Upper Macquarie Alluvium will be incorporated into a water sharing plan that will be developed by the end of 2010. On commencement of the water sharing plan, the GWMA will be managed under the *Water Management Act 2000*.

2.1 Licensing

In 1983 a policy was introduced to control the volumetric allocation of groundwater in the Lachlan, Murrumbidgee, Murray and Macquarie valleys (WRC, 1983), including that in the Upper Macquarie GMWA009.

In May 1992, due to growing concerns over increasing demand for entitlement and localised water level declines, the four parishes around Dubbo were embargoed for application for high yielding groundwater licences. The aim of this embargo was to protect existing users and the city's town water supply extraction areas.

In March 2000 the entire Upper Macquarie GMWA was embargoed under the *Water Act 1912* for high yielding license applications after new studies indicated that the aquifer was over allocated.

In July 2008 the 2000 embargo was replaced with a new embargo (Order 1) on licence applications covering all inland aquifers where entitlements have reached, exceed or are likely to exceed their long term average extraction limit. This embargo included the Upper Macquarie GWMA009. Under the embargo certain purposes are exempt including stock, domestic on landholdings greater than 12ha in reticulated areas, domestic on landholdings outside reticulated areas, and town water supply.

In early 2010 there were 163 high yield licences and 136 property accounts in the management area.

2.2 Entitlement

Prior to 2004, groundwater and surface water licences in the Upper Macquarie were linked by conjunctive use conditions and the volume of groundwater able to be taken was impacted by surface water allocation announcements. Conversion of conjunctive water licences was completed in July 2004 and for the Upper Macquarie Alluvium 50 per cent of the make up component was added to the base entitlement to give the final volumetric groundwater entitlement.

Volumetric groundwater entitlements have been issued for “high yield” purposes (for example irrigation, commercial, industrial, town water supply). Stock and domestic groundwater licences have a “low yield” purpose and have been issued without a volumetric entitlement. Nominal volumes will be assigned to stock and domestic purposes under the draft ‘Guidelines for Reasonable Take and Use of Water for Domestic Consumption and Stock Watering’ being developed to support the latest water sharing plan process.

Total entitlement for the Upper Macquarie GWMA009 is 33.7 GL. Entitlement since 1980 is shown on Figure 2.

2.3 Announcements and extraction limits

In years of water shortage an annual announcement may be made to limit the groundwater that may be taken on a licence to a percentage of the entitlement volume of that licence. There have been no annual announcements for groundwater in the Upper Macquarie Groundwater Management Area 009 other than announcements prior to 2004 that affected conjunctive licences.

A number of bores in the management area have had extraction volume or rate limits placed on them. These limits have been imposed to mitigate pumping impacts on the aquifer, river, NOW monitoring bores and neighbouring groundwater works.

2.4 Transfers

Temporary assignment of water allocation commenced in the 2003/2004 water year for the Upper Macquarie GWMA009. The number and volume of temporary transfers since 2003 is given in Table 1.

In September 2009 a policy was introduced to allow the transfer of groundwater entitlements and allocations for inland New South Wales water licence holders who are outside water sharing plan areas (NOW, 2009).

Table 1 Number and volume of temporary transfers in Upper Macquarie GWMA009 since 2003

Water year	Number of transfers	Volume (ML)
2003/04	1	280
2004/05	7	1599
2005/06	8	1921
2006/07	9	2108
2007/08	9	2291
2008/09	9	2209

2.5 Usage

Usage in the Upper Macquarie has increased since onset of the drought in 2002. Usage is presented in Table 2 and shown on Figure 2. The distribution of average usage for the five water years 2004 to 2009 is shown on Figure 3. Between 1995 and 1997 there was only partial metering of usage and prior to 1995 usage was unmetered. Records of town water supply usage since 1980 have been supplied by Dubbo City Council.

Table 2 Usage in the Upper Macquarie GWMA009 since 1980

Water Year	Usage (GL)	DCC Usage
1980/81	*4.1*	4.1
1981/82	*4.0*	4.0
1982/83	*2.6*	2.6
1983/84	*2.0*	2.0
1984/85	*3.3*	3.3
1985/86	*3.9*	3.9
1986/87	*3.0*	3.0
1987/88	*3.3*	3.3
1988/89	*3.2*	3.2
1989/90	*3.6*	3.6
1990/91	*3.8*	3.8
1991/92	*2.8*	2.8
1992/93	*3.1*	3.1
1993/94	*3.6*	3.6
1994/95	*1.8*	1.8
1995/96	2.8*	1.4
1996/97	2.3*	2.3
1997/98	15.2	2.7
1998/99	5.6	2.8
1999/00	5.3	2.3
2000/01	5.2	2.8
2001/02	6.8	2.7
2002/03	14.7	3.3
2003/04	13.3	2.5
2004/05	13.8	2.2
2005/06	12.0	1.8
2006/07	16.8	2.1
2007/08	15.1	2.1
2008/09	13.7	1.8

Notes:

1. Numbers in italics are DCC usage only
2. * = partial metering only

Figure 2 Usage in the Upper Macquarie GWMA009 since 1980

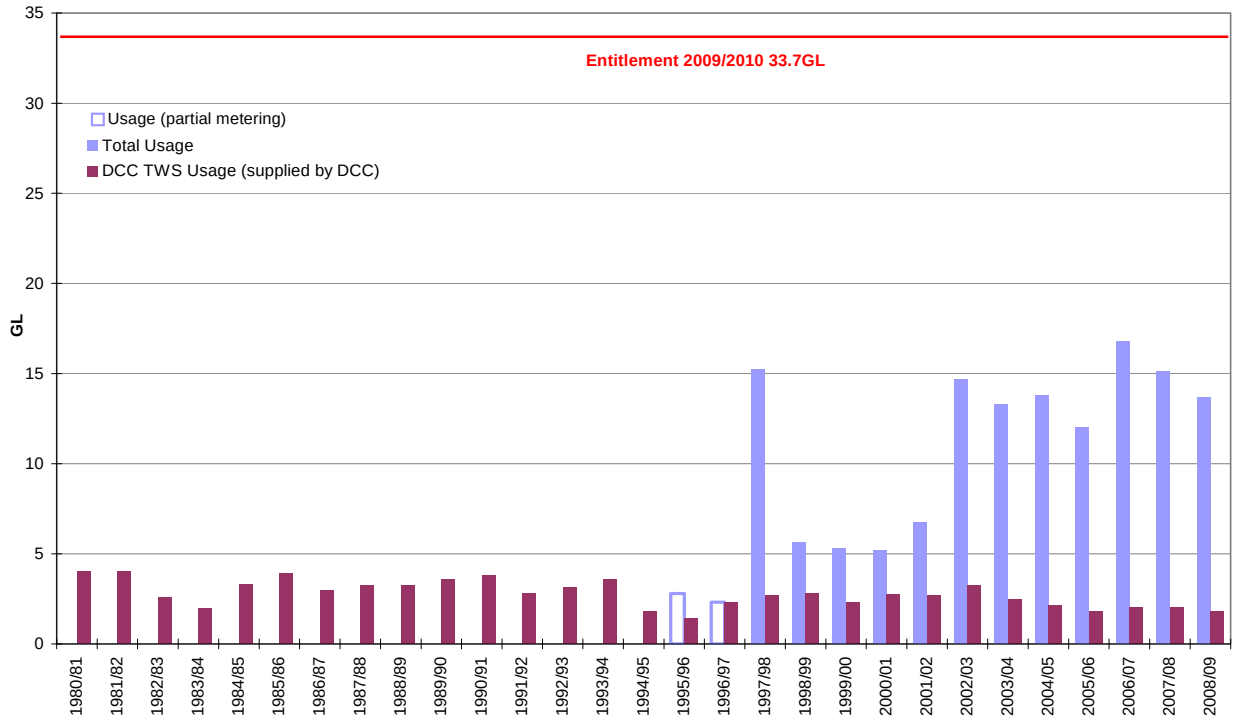
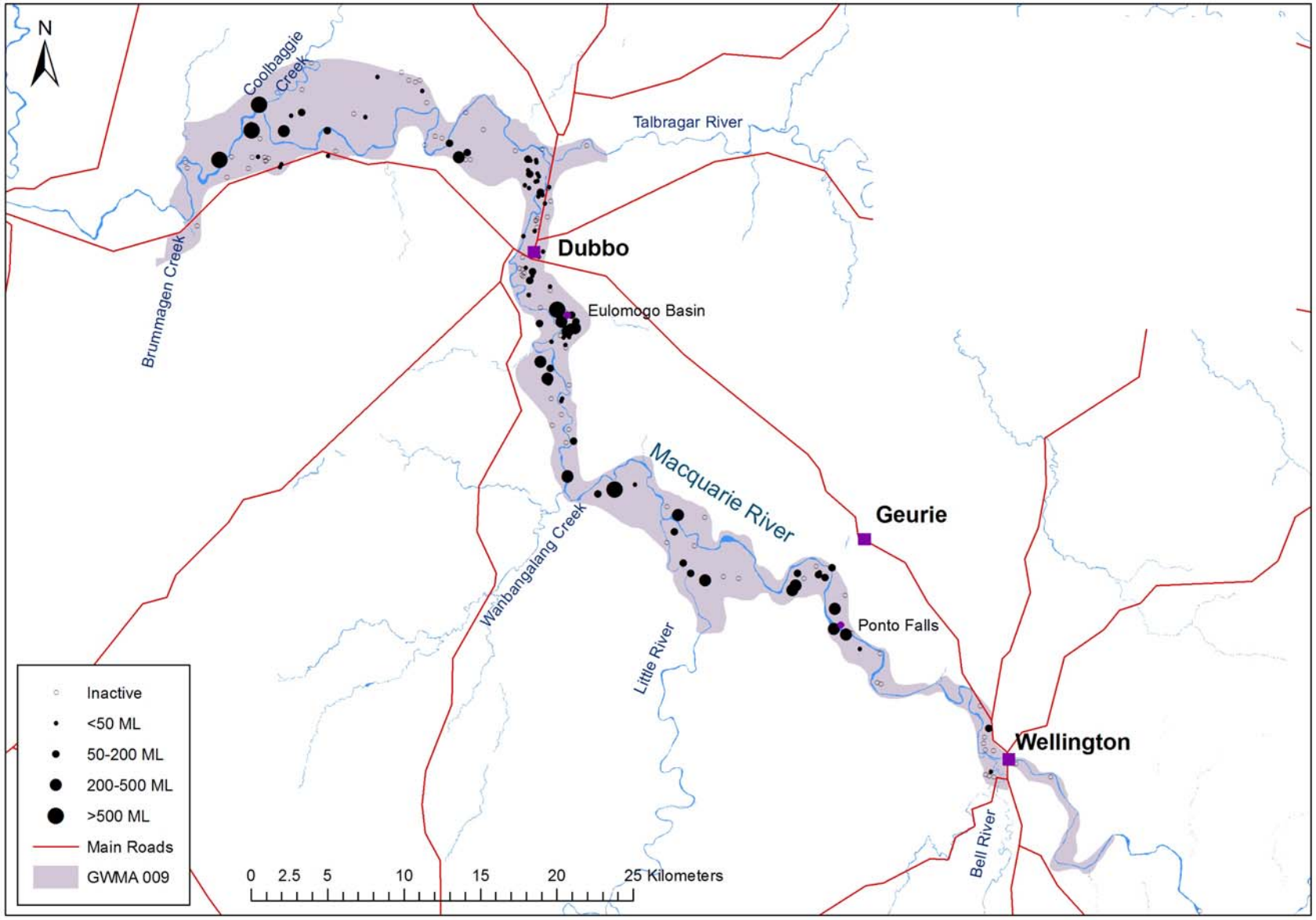


Figure 3 Distribution of average usage in the Upper Macquarie GWMA009 for the water years 2004 to 2009



3 Rainfall

Rainfall data for Dubbo and Wellington are provided by the Queensland Department of Natural Resources and the Australian Bureau of Meteorology. The Dubbo Darling Street climate station (065012) has 140 years of rainfall records since 1870, and the Wellington Agrowplow climate station (065034) has 128 years of rainfall records since 1882.

The Upper Macquarie valley has a semi-arid climate with slightly summer dominant rainfall. The average annual rainfall for Dubbo is 583.7mm and for Wellington is 614.8mm. Figure 4 shows average monthly rainfall for Dubbo and Wellington. Figure 5 shows annual rainfall for Dubbo and Wellington.

Figure 6 shows the cumulative deviation from mean annual rainfall for Dubbo and Wellington. This figure shows the deviation of actual annual rainfall from the mean annual rainfall. The slope of the curve indicates whether the area was experiencing a relatively wetter or drier time compared to the average for the period of record. For the periods1886-1895, 1950-1978 and 1983-2001 rainfall in Dubbo and Wellington tended to be more than the long term average. For the periods 1870-1885, 1896-1949, 1979-1982 and from 2002 onwards rainfall in Dubbo and Wellington tended to be less than the long term average.

Figure 4 Average monthly rainfall for Dubbo and Wellington

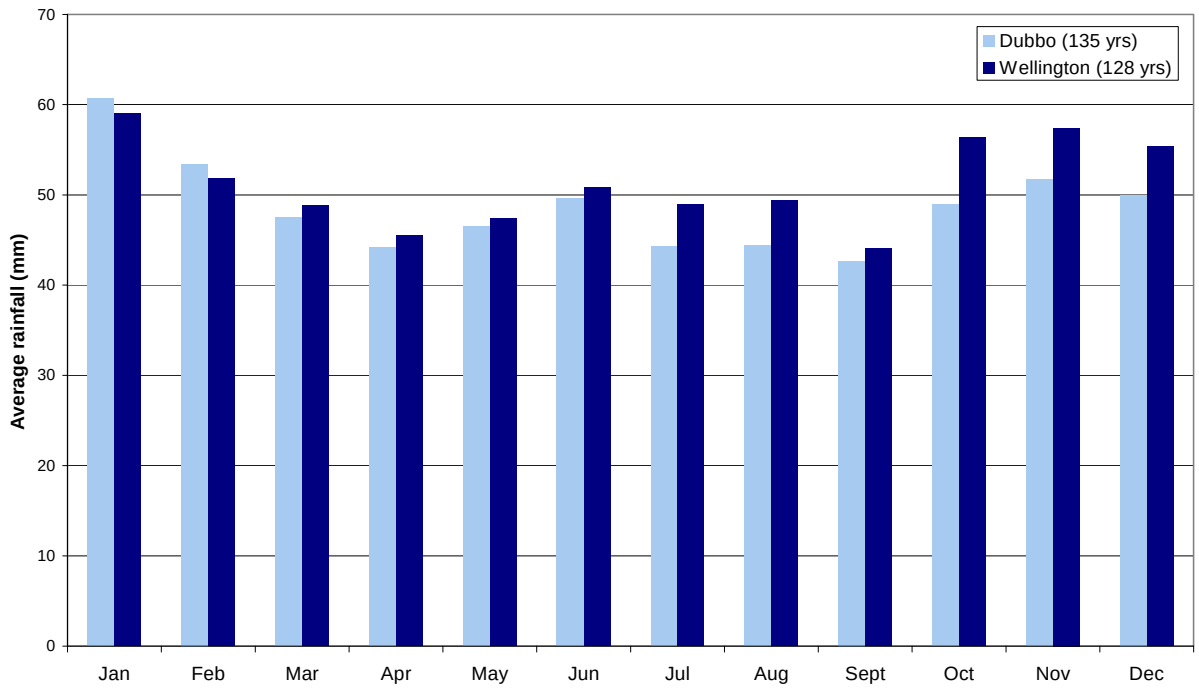


Figure 5 Annual rainfall for Dubbo and Wellington

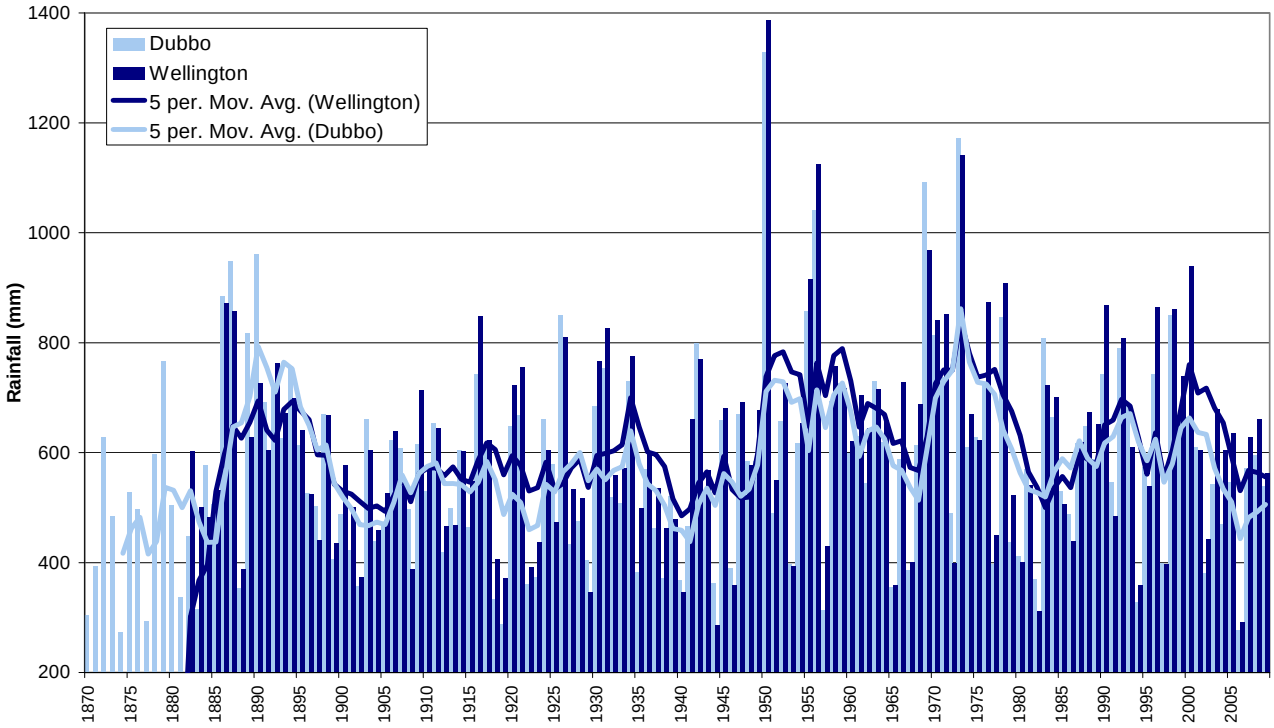
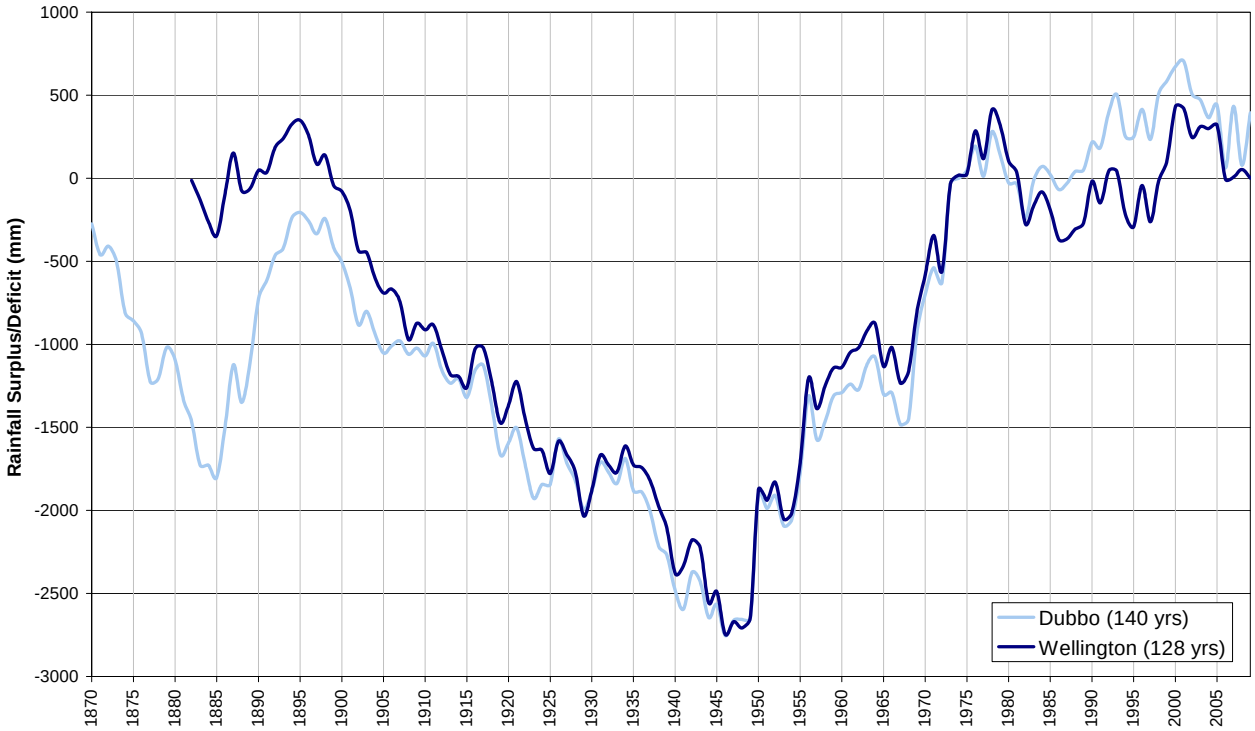


Figure 6 Cumulative deviation from mean annual rainfall at Dubbo and Wellington



4 Geology and hydrogeology

A review of previous studies and existing borehole geology was conducted in 2009. This review has been used to inform subsequent drilling investigations and this status report.

4.1 Regional geology

4.1.1 Lithology

(Adapted from Meakin and Morgan, 1999).

The regional geology of the Upper Macquarie valley is shown on Figure 7.

The oldest rocks in the Upper Macquarie valley belong to the Palaeozoic Lachlan Fold Belt and these form the basement south of Geurie and the southern side of the valley downstream of Minore. The Lachlan Fold Belt consists of a sequence of Ordovician to Permian volcanic and intrusive phases, interspersed with clastic and chemical sedimentary rocks which have been subjected to low grade metamorphism.

North of Geurie, basement is formed by gently dipping Mesozoic sedimentary units. The Triassic coarse to fine grained fluvial, lacustrine, deltaic and marine sediments were deposited in the Sydney-Gunnedah Basin. These are overlain by coarse to fine grained Jurassic and Cretaceous freshwater fluvial and lacustrine sediments deposited into the Surat Basin and form part of the Great Artesian Basin. Basalts and trachytes in the area previously thought to have been Tertiary have been dated as Triassic and Jurassic and may be stratigraphically conformable with the Mesozoic sedimentary sequence. These are physically difficult to distinguish from the Tertiary basalts and many are undated.

In the Cainozoic, a variety of unconsolidated alluvium, colluvium, lacustrine and aeolian sediments were deposited on slopes and valley floors by rivers, surface runoff, gravity, and strong westerly winds. Climatic change is reflected in the Cainozoic sedimentary sequence beginning with the deposition of gravels by a high-energy braided river system during more tropical climates and gradually diminishing in energy with the development of aridity in inland Australia.

In the Tertiary the existing geological sequence was intruded and partly covered by several phases of intraplate basaltic eruption. The basalts in the Dubbo-Brocklehurst area range in age from 12.3 to 14.3 million years and occur as isolated caps, plugs, and lava flows. The flows commonly occupy palaeovalleys and may be underlain by high-energy water bearing Tertiary gravels.

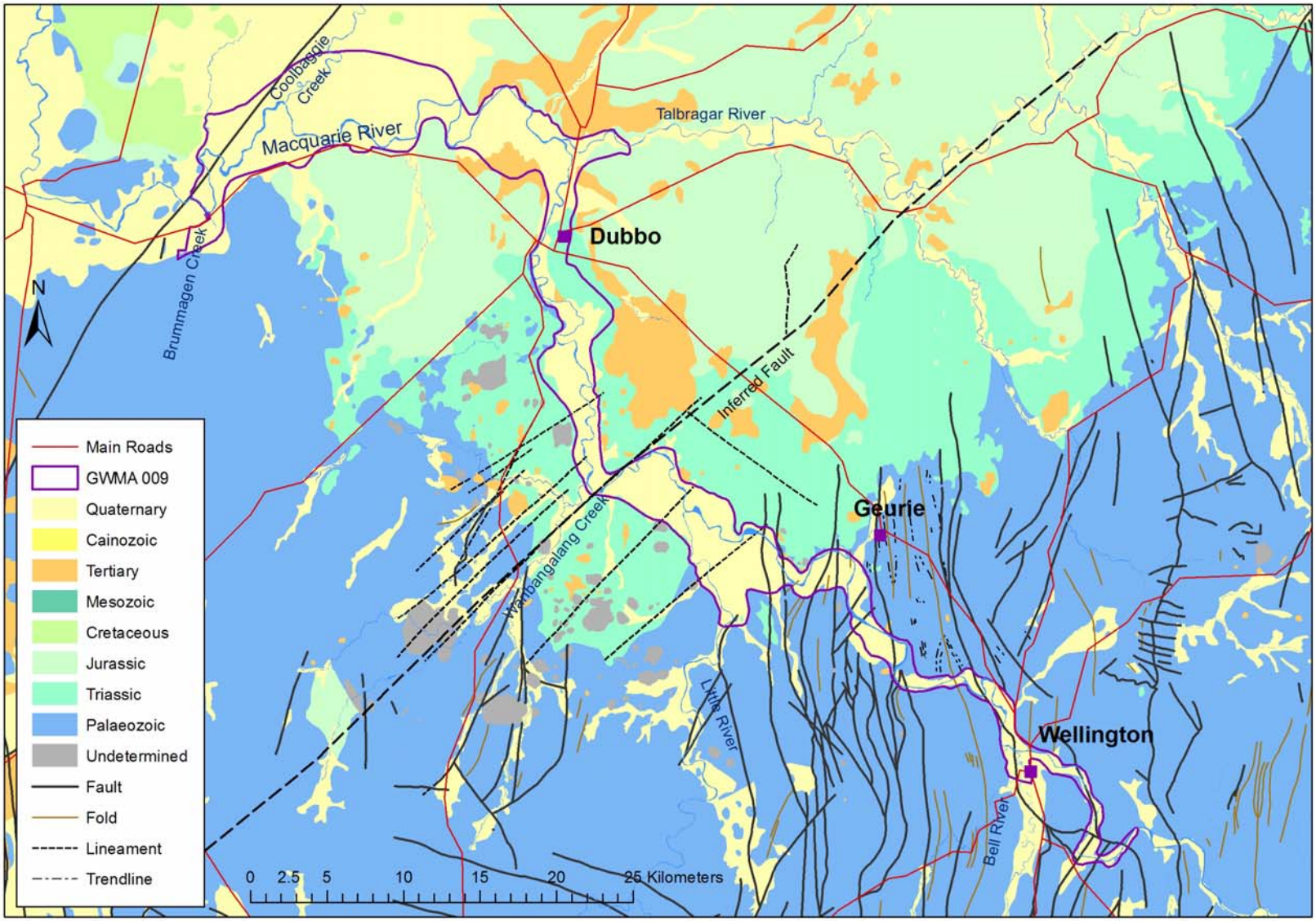
The sparse remnants of at least two widespread Tertiary depositional episodes are common in the Upper Macquarie area. These sediments are mainly coarse grained and consist of elevated terraces of polymictic gravels and younger lower-lying quartz gravels. The more elevated gravels are rounded but are less spherical than the lower level well-rounded quartz and chert pebble gravels.

Earlier Tertiary deposits have been later re-worked into the younger Quaternary fluviatile sequences and this has resulted in three or four Quaternary terraces. The current Macquarie River lies up to 15 metres below the adjacent alluvial plain.

4.1.2 Structure

The Palaeozoic Lachlan Fold Belt strata have been intensely folded and faulted resulting in a zone of linear fault bound north south trending units that partly control topography and drainage. Between Brummagen Creek and Geurie the published geological mapping (Morgan, 1999) shows a predominant north east trending set of lineaments and faults.

Figure 7 Regional geology of the Upper Macquarie valley



(Adapted from Morgan, 1999)

Fault zones are likely to have been reactivated several times throughout geological history during periods of crustal stressing and may extend tens or even hundreds of kilometres in strike length. These structures form regional zones of crustal weakness along which magma was intruded during the Mesozoic and Tertiary periods.

There are a number of places in the Upper Macquarie groundwater management area where Mesozoic and Cainozoic movements on these north east trending structures may have affected the course of the river, the depth of the palaeochannel and the height of adjacent alluvial terraces.

The Coolbaggie Creek is located along a major north east trending fault (Morgan, 1999) that is thought to bound a graben-like depression beneath the Coolbaggie Creek (Pirard, 1974). Unconsolidated sediments up to 75m thick have been encountered in boreholes in the area.

South of Dubbo, the Wambangalang Fault is a major north east trending fault interpreted from airborne magnetics to pass along the trace of the lower Wambangalang Creek towards the Macquarie River (Smithson, 2000). Recent movements on this fault appear to have caused displacement of the river's course by up to 10km. The build up of a broad alluvial area on the upstream side of the displaced Macquarie River suggests that the south eastern side of the fault may have been downthrown. The Wambangalang Fault is interpreted to extend northeast where it likely controls the course of the Talbragar River 50km to the northeast for approximately 25kms, and Boomley Creek 75km northeast.

In the Tertiary and Cainozoic periods of mild regional uplift, possible local downwarping and subsequent downcutting have contributed to the series of terraces in the Tertiary and Quaternary sediments.

4.2 Local geology

Nine additional groundwater investigation and monitoring sites consisting of 14 bores were installed in the Upper Macquarie GMWA during 2009. The geological information gained from these boreholes has enhanced the understanding of the stratigraphy of the alluvium and surrounding bedrock in the management area.

Borehole samples containing organic material were analysed by Dr Helene Martin (UNSW) for pollen and assessed for palynological age. The palynological dating has provided ages for materials recovered from the 2009 drilling investigations. When added to palynological ages derived from other studies, this has enabled the stratigraphic differentiation of Tertiary and Quaternary age sediments in the Upper Macquarie valley. A summary of palynological dating for the Upper Macquarie including new information and that from previous studies is given in Table 3.

4.2.1 Quaternary alluvium

The Quaternary alluvial units are characterised by an upper orange, red and brown silt and clay that ranges in thickness up to 20m but is generally between 5m and 15m in thickness and occurs across the majority of the management area.

Underlying this unit is a polymictic variably 'dirty' sand and gravel to depths between 19m and 38m. The gravels are typically sub-rounded to sub-angular ranging in size from granules (2000μm–5mm) to large cobbles (128mm–256mm) with median size of very large pebble (32mm–64mm). Clasts are 95 per cent lithic and are composed of orange, red, brown and cream sandstone, siltstone and meta-sediments and minor felsic to intermediate volcanics. The remaining 5 per cent is milky white and orange quartz. Plate 1 shows a typical example of the coarse fraction of the Quaternary alluvium near Terrabella.

Table 3 Summary of palynological dating of Upper Macquarie sedimentary strata

Bore number	Sample depth (m)	Age from palynology
GW30933	49 – 55	Late Miocene - Pliocene
	61.5 – 66.5	Late Miocene - Pliocene
	70 – 72	Mid Triassic
GW36492	21.5 – 22	Pliocene
GW36491	42 – 43.5	Late Miocene - Pliocene
GW36439	12 – 13	Pleistocene
	38 – 40	Mid Triassic
	40	Late Miocene - Pliocene
GW36442	24 – 30	Late Miocene - Pliocene
	36 – 38	Mid Triassic
GW36443	36 – 37	Late Miocene - Pliocene
GW36444	18 – 19	Late Miocene - Pliocene
GW21320	30.8 – 35.7	Late Miocene - Pliocene
GW36447	67 – 68.5	Mid Triassic
GW30890	19 – 20	Late Miocene - Pliocene
GS C-D	24 – 25	Late Miocene - Pliocene
	25 – 25.5	Late Miocene - Pliocene
GW273110*	21.3 – 22	Tertiary (less likely Quaternary)
GW273111*	38 – 39	Tertiary (less likely Quaternary)
	40.9 – 41.7	Tertiary (possibly early Pliocene)
GW273115*	28 – 29	Late Tertiary
	38.8 – 39.4	Tertiary (possibly mid-Miocene)
	39.6 – 39.8	Tertiary (possibly mid-Tertiary)
GW273120*	52 – 53	Tertiary (most likely late Tertiary)

* borehole drilled in 2009

4.2.2 Tertiary alluvium

The Tertiary alluvial units are characterised by predominantly monomictic cleaner sand and gravel interbedded with clays, organic clay and sand to depths between 43m and 75m (thickness 15m to 40m). The gravels are typically rounded to well rounded ranging in size from granules (2000μm- 5mm) to small cobbles (64mm–128mm) with median size of large pebble (16mm–32mm). Clasts are 90 per cent milky white orange and pink quartz. The remaining 10 per cent of clasts consist of orange, red, grey and black chert and minor meta-sediments. Plate 2 shows a typical example of the coarse fraction of the Tertiary alluvium near Terrabella.

The Quaternary-Tertiary alluvial boundary is usually distinct where both units are of reasonable thickness. The boundary is characterised by a change in clast colour and composition as described above, and is occasionally marked by fine grained organic sediments.

Where basement is formed by trachyte, the alluvium-basement boundary can be marked by green clays. However, the boundary is more difficult to identify where the underlying basement consists of weathered sedimentary strata. In general, the weathered basement is distinguished by its more consistent grey colour and in sandy units by the well sorted sand size quartz grains.

Plate 1 Quaternary sand and gravel at 15m in GW273111 at Terrabella

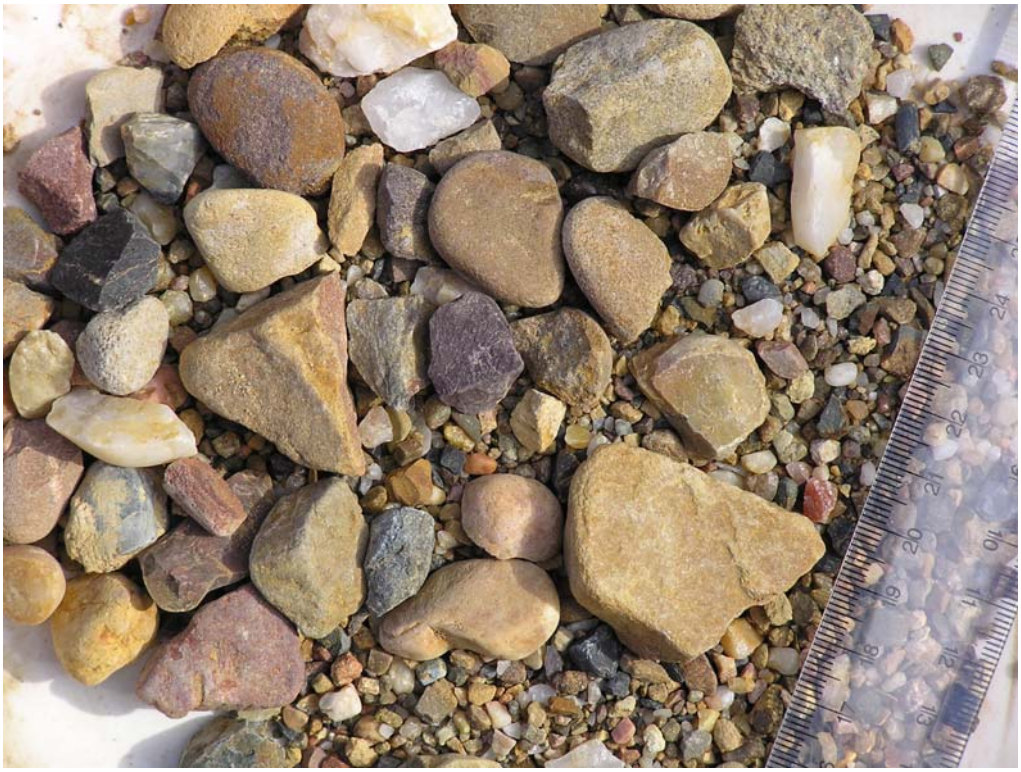


Plate 2 Tertiary sand and gravel at 32m in GW273111 at Terrabella

4.3 Hydrogeological cross sections

Fourteen hydrogeological cross sections have been developed based on information held in the NSW Office of Water's groundwater database, supplemented by information from the newly installed monitoring bores. The location of the cross sections is shown on Figure 8, and the cross sections are presented on Figure 9 to Figure 22. A summary of unit thicknesses and depths as indicated from the geological cross sections is given in Table 4.

Table 4 Summary of alluvial unit thicknesses and depths by section

Section	Quaternary upper clay min thickness (m)	Quaternary upper clay max thickness (m)	Quaternary total thickness/depth to (m/mbgl*)	Tertiary start depth (mbgl*)	Tertiary base (mbgl*)	Tertiary thickness (m)
A Dulla Dulla	9	18	35	35	75	40
B Coolbaggie	6	20	34	30	69	39
C Whylandra	6	18.5	30	30	41	11
D Cooreena Road	12	18	37	33	55	22
E Talbragar	13	17	27	27	46	19
F Troy Bridge	11	16	32	32	54	22
G Myall Street – North Dubbo	9	13	30	30	45	15
H Hennessey Road – South Dubbo	5.5	18	38	38	60	22
I Butlers Falls	6	13	24	24	54	30
J Sandy Falls	4	9	25	20	60	40
K Shepherds Hill	3.5	13	27	27	65	38
L Terrabella	2	10	21	21	57	36
M Geurie	3	14	19	19	43	24
N Wellington	8	20	21	21	45	24
Average	**7.0**	**15.5**	**28.6**	**27.6**	**54.9**	**27.3**
Maximum	**13**	**20**	**38**	**38**	**75**	**40**
Minimum	**2**	**9**	**19**	**19**	**41**	**15**

* metres below ground level

Figure 8 Location of hydrogeological cross sections for Upper Macquarie GWMA009

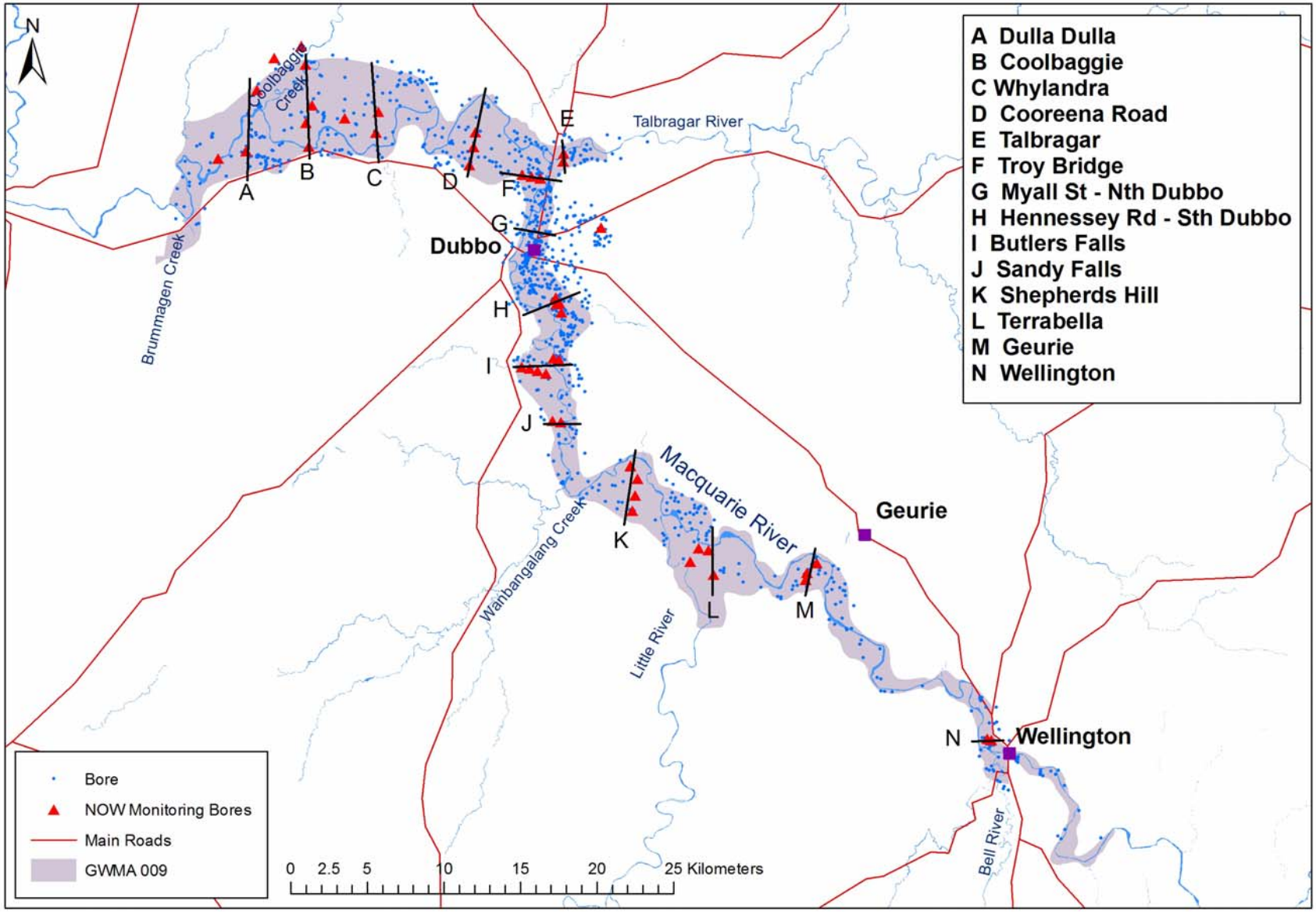


Figure 9 Hydrogeological cross section, A Dulla Dulla

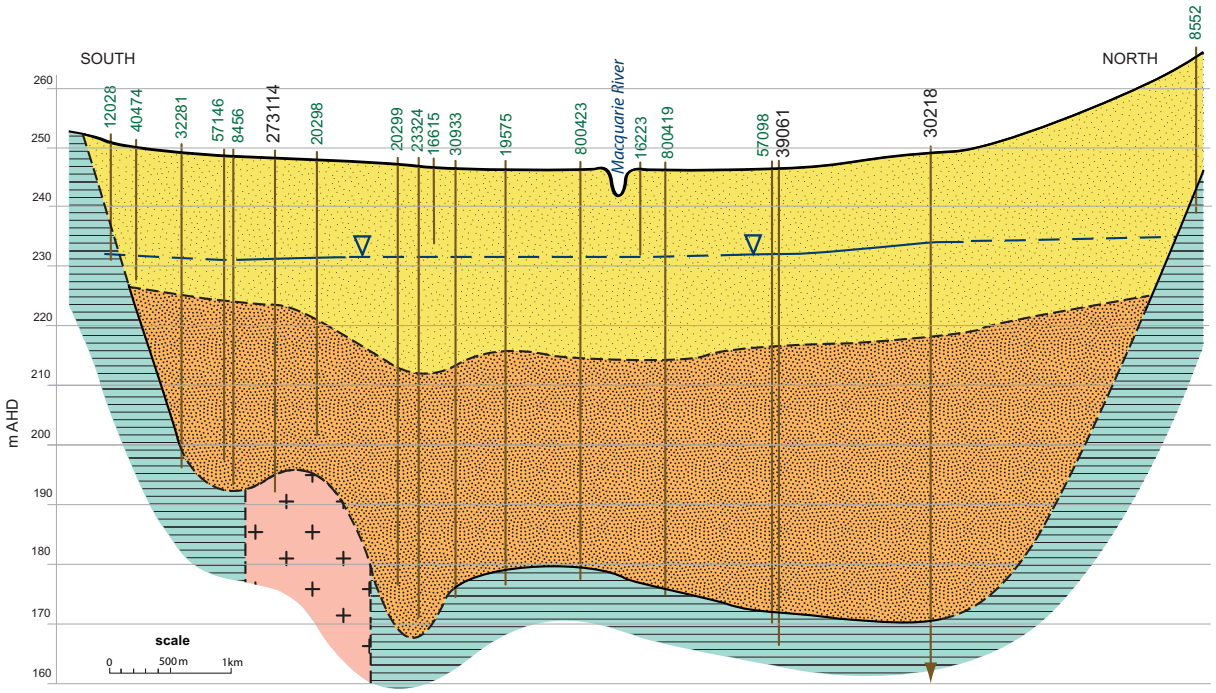
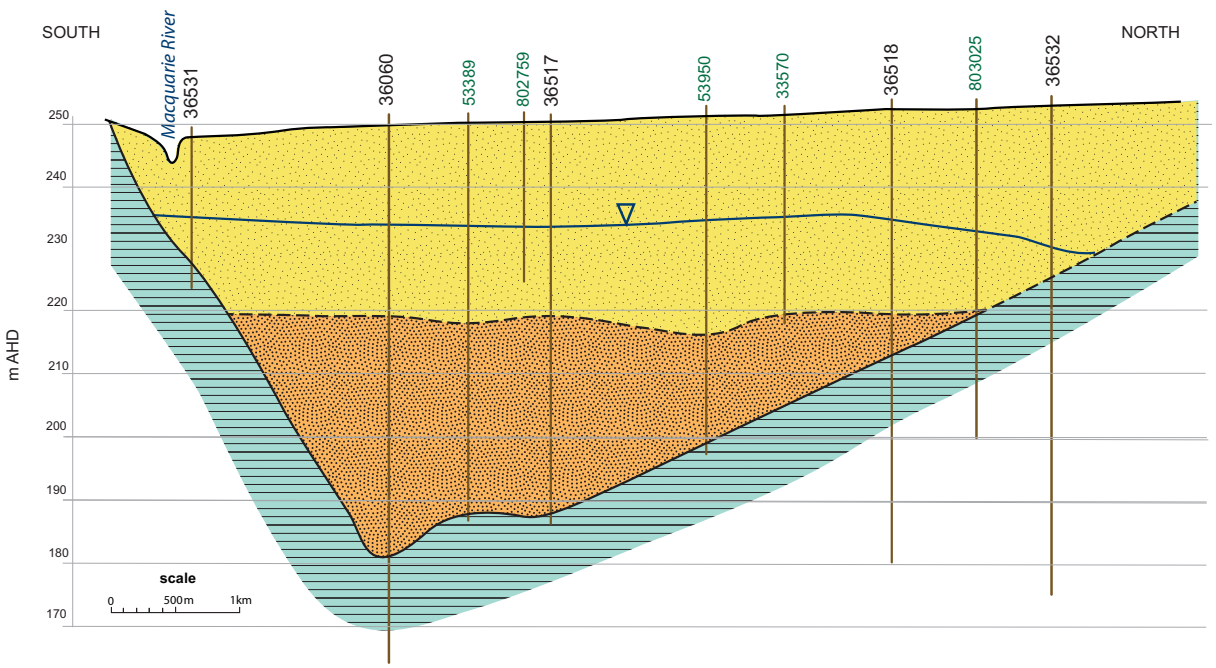


Figure 10 Hydrogeological cross section, B Coolbaggie



LEGEND

- Quaternary alluvium
- Tertiary alluvium
- Tertiary basalt
- Tertiary trachyte
- Mesozoic sedimentary rock
- Palaeozoic granite
- Palaeozoic felsic volcanic
- Palaeozoic meta-sedimentary rock
- Geological boundary
- Geological boundary (interpreted)
- Standing water level, Oct/Nov 2009 (shallowest screened formation)
- 222 NSW Office of Water monitoring bore
- 222 Private bore/well
- Trace of bore/well

Figure 11 Hydrogeological cross section, C Whylandra

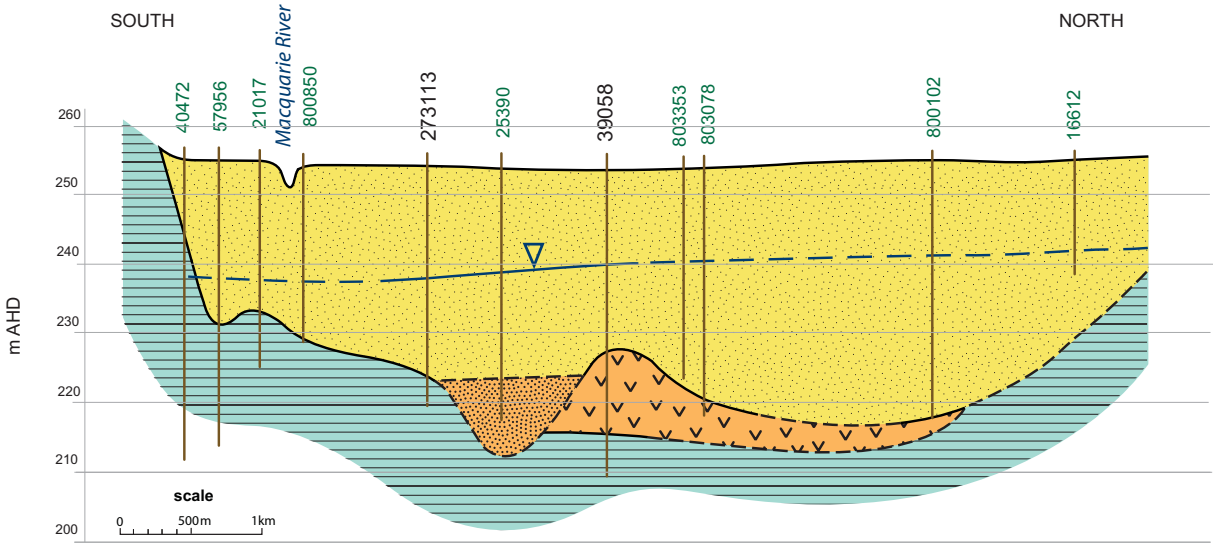
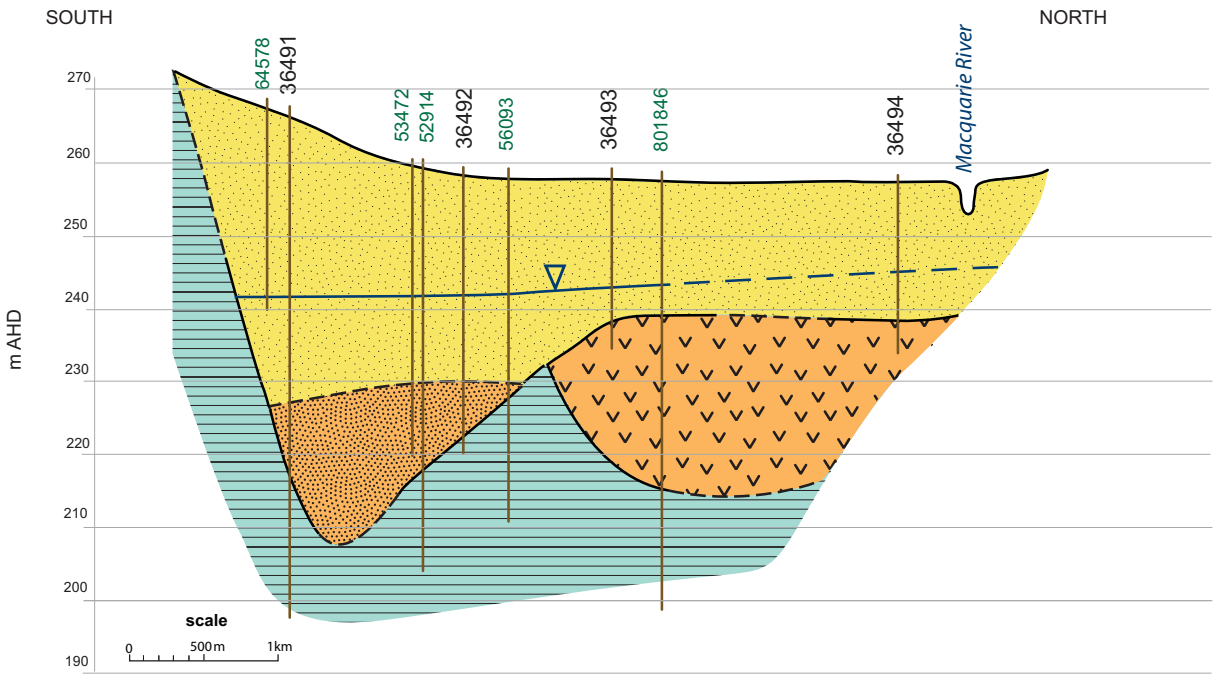


Figure 12 Hydrogeological cross section, D Cooreena Road



LEGEND

- Quaternary alluvium
- Tertiary alluvium
- Tertiary basalt
- Tertiary trachyte
- Mesozoic sedimentary rock
- Palaeozoic granite
- Palaeozoic felsic volcanic
- Palaeozoic meta-sedimentary rock
- Geological boundary
- Geological boundary (interpreted)
- Standing water level, Oct/Nov 2009 (shallowest screened formation)
- 222 NSW Office of Water monitoring bore
- 222 Private bore/well
- Trace of bore/well

Figure 13 Hydrogeological cross section, E Talbragar

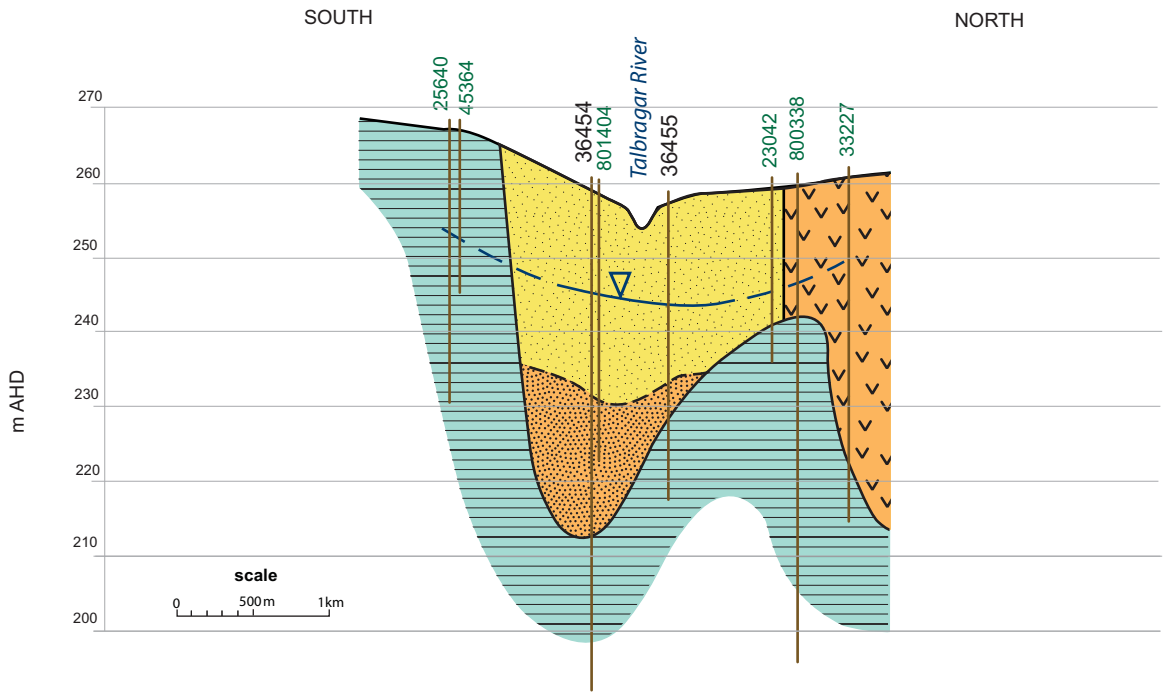


Figure 14 Hydrogeological cross section, F Troy Bridge

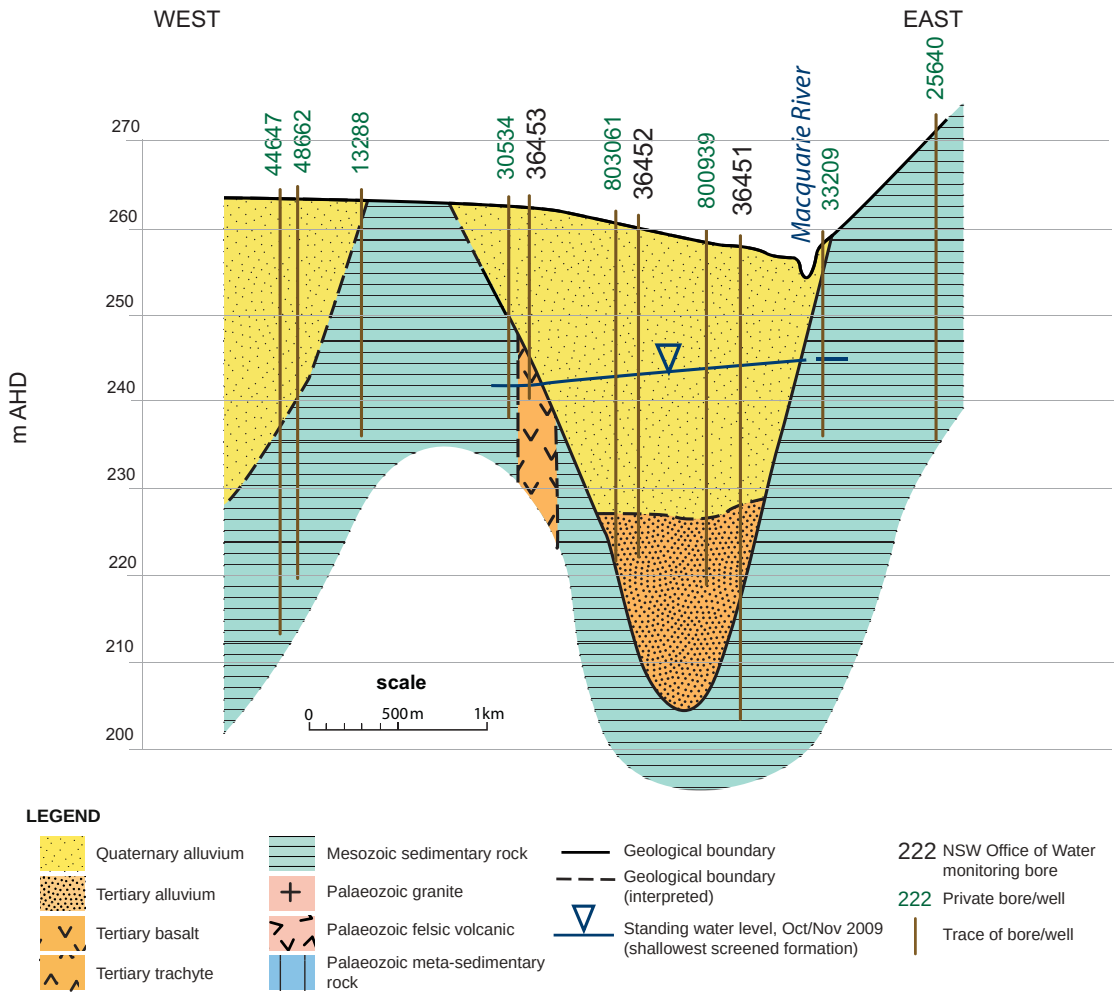


Figure 15 Hydrogeological cross section, G Myall Street – North Dubbo

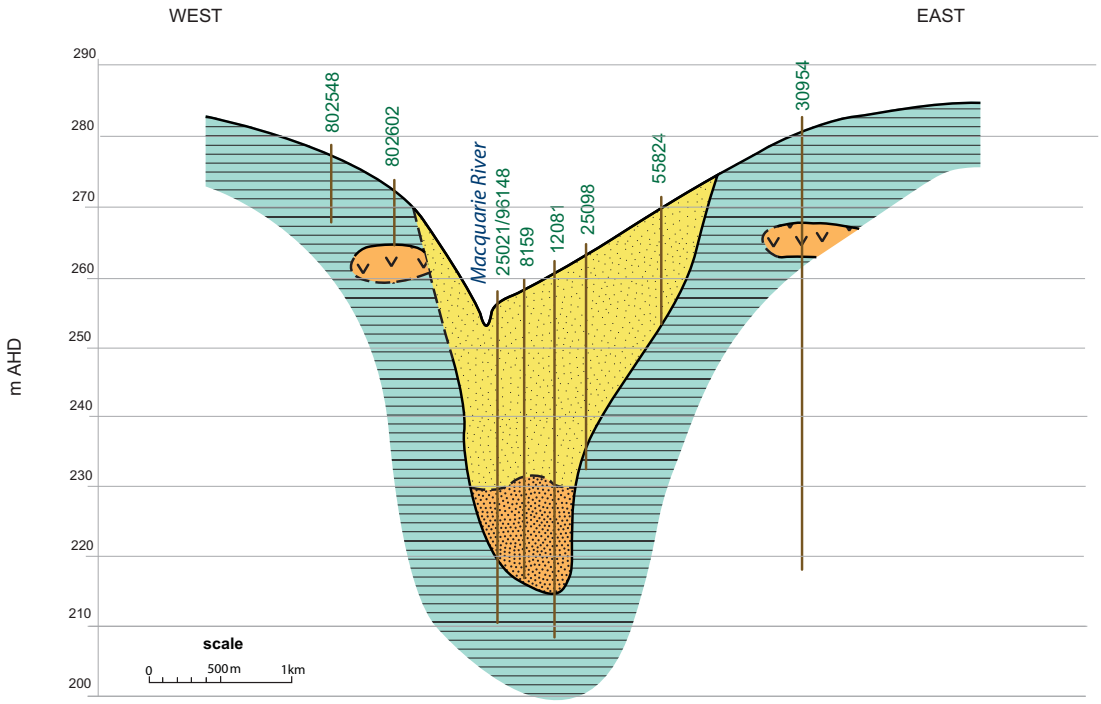


Figure 16 Hydrogeological cross section, H Hennessey Road – South Dubbo

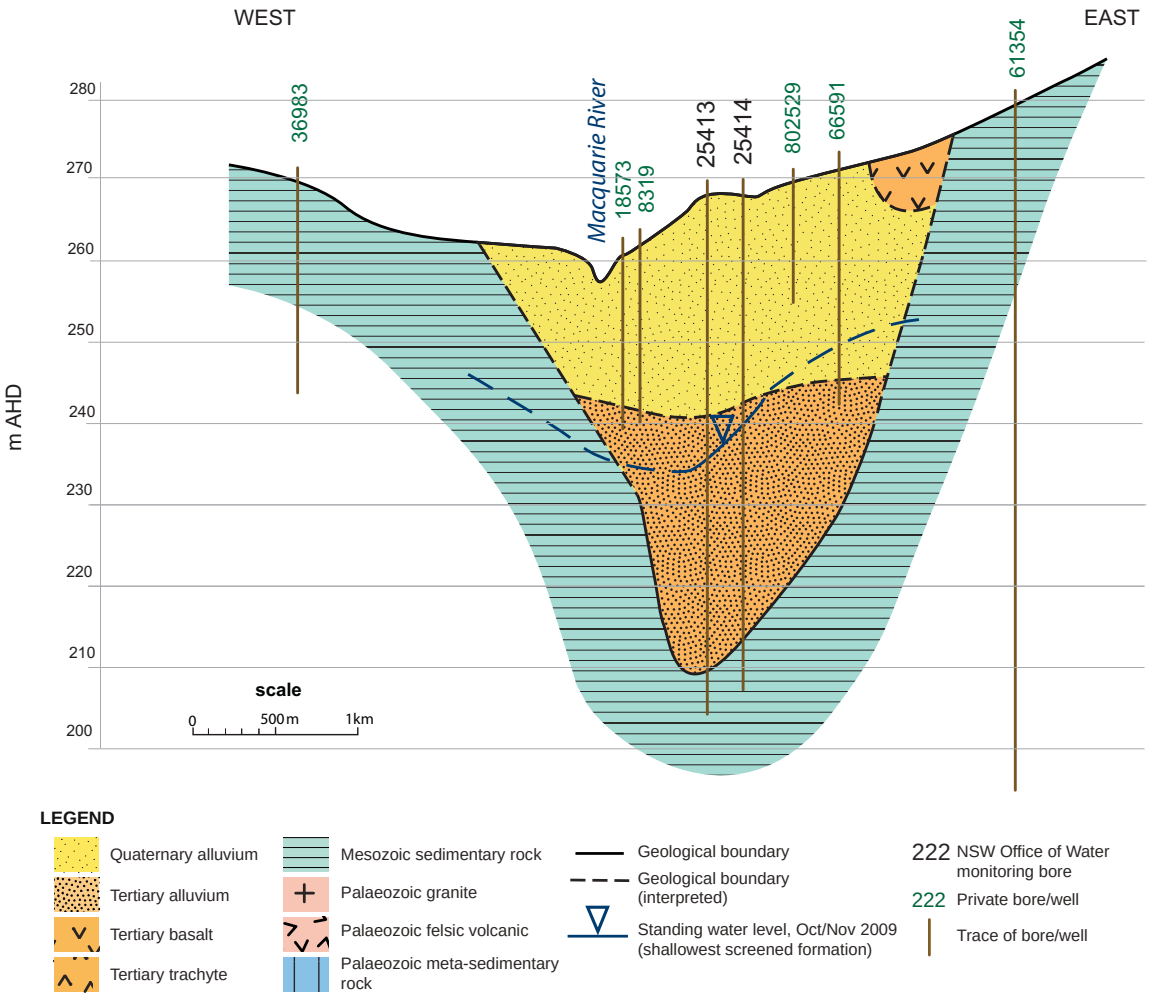


Figure 17 Hydrogeological cross section, I Butlers Falls

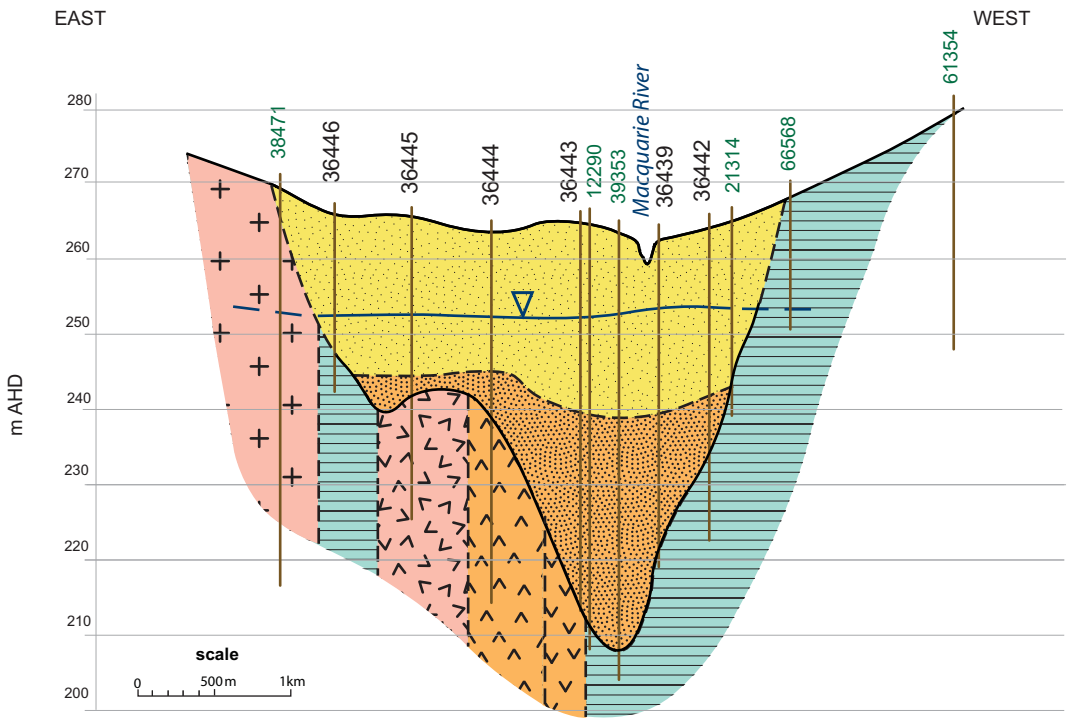


Figure 18 Hydrogeological cross section, J Sandy Falls

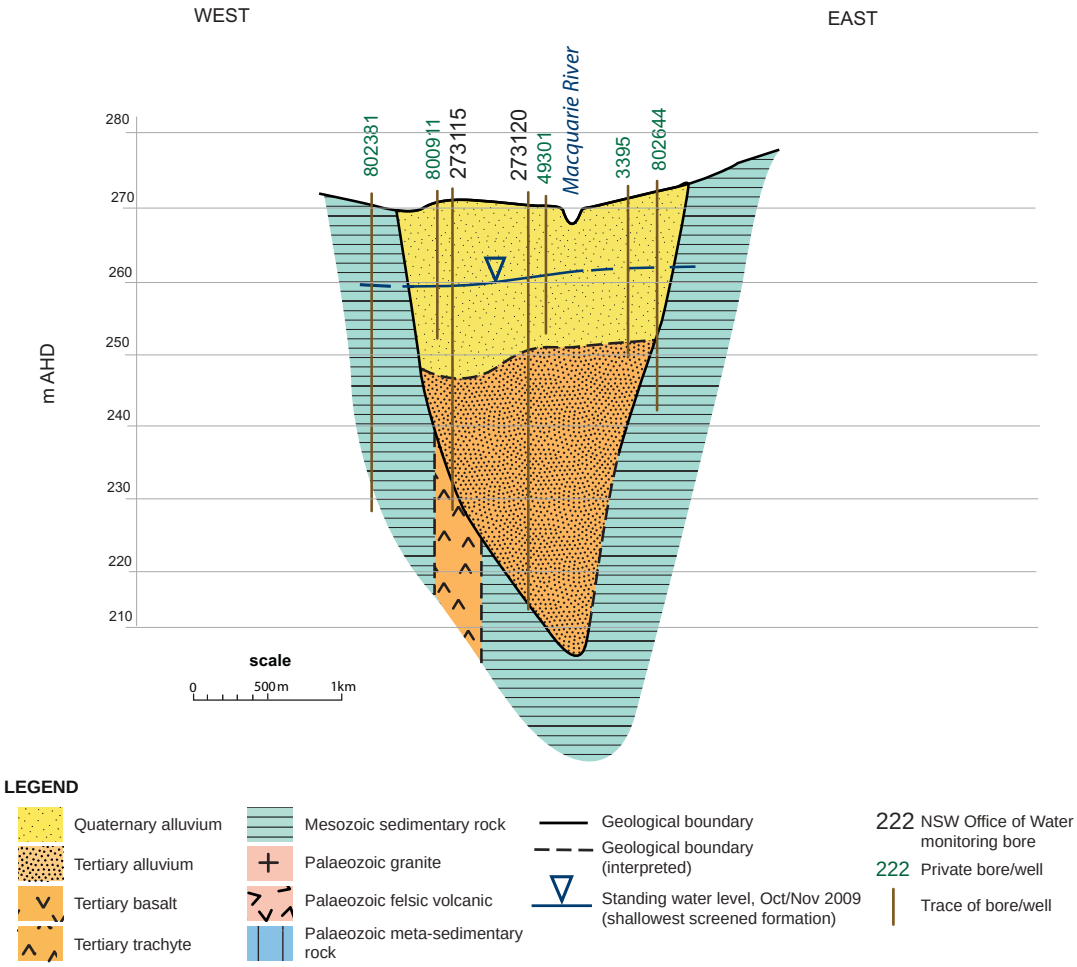


Figure 19 Hydrogeological cross section, K Shepherds Hill

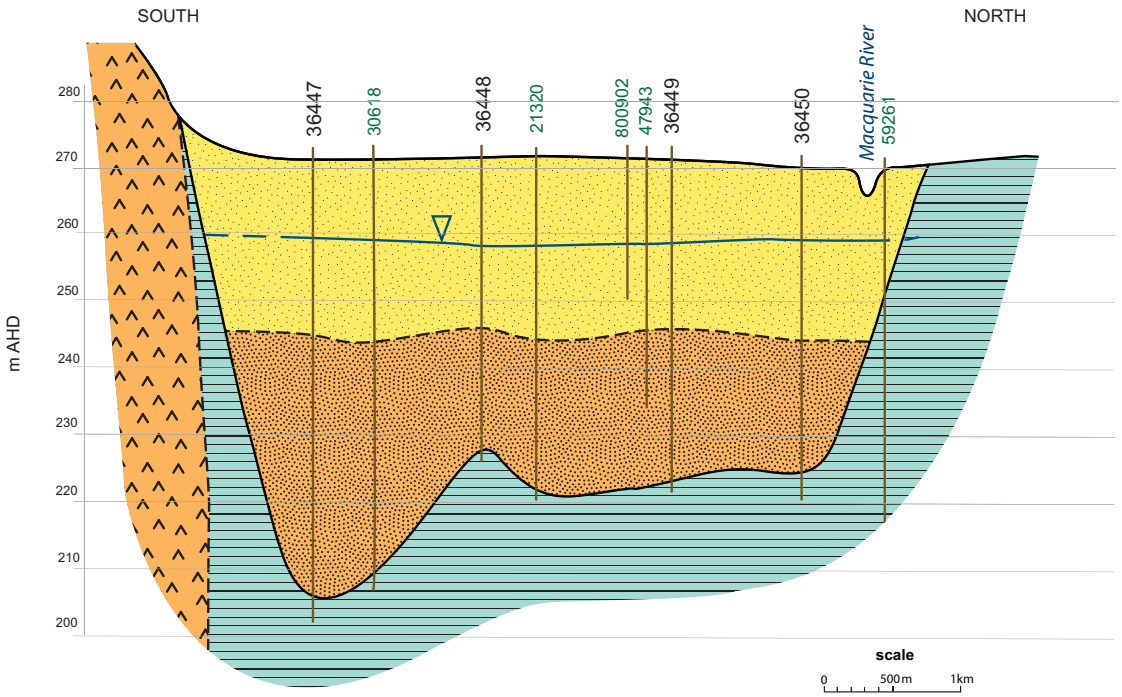


Figure 20 Hydrogeological cross section, L Terrabella

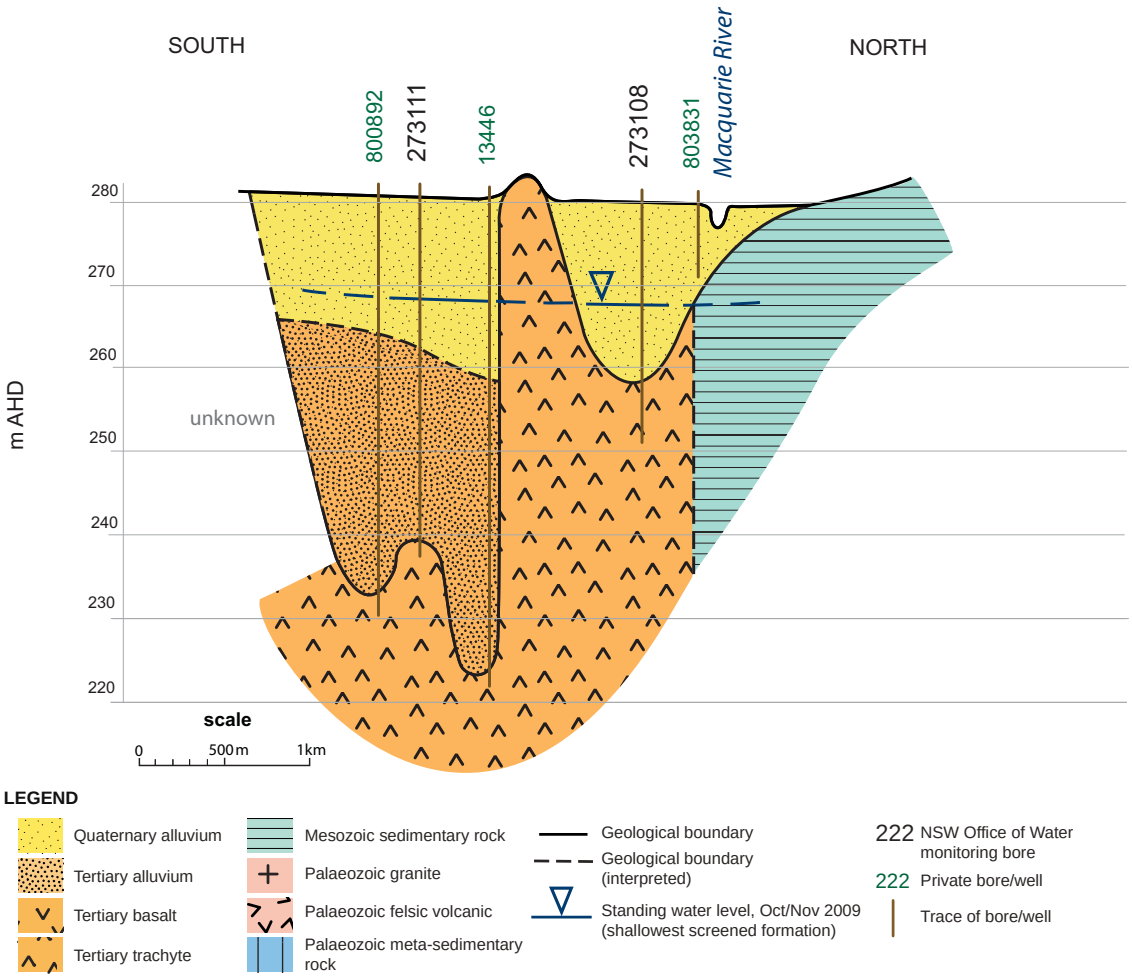


Figure 21 Hydrogeological cross section, M Geurie

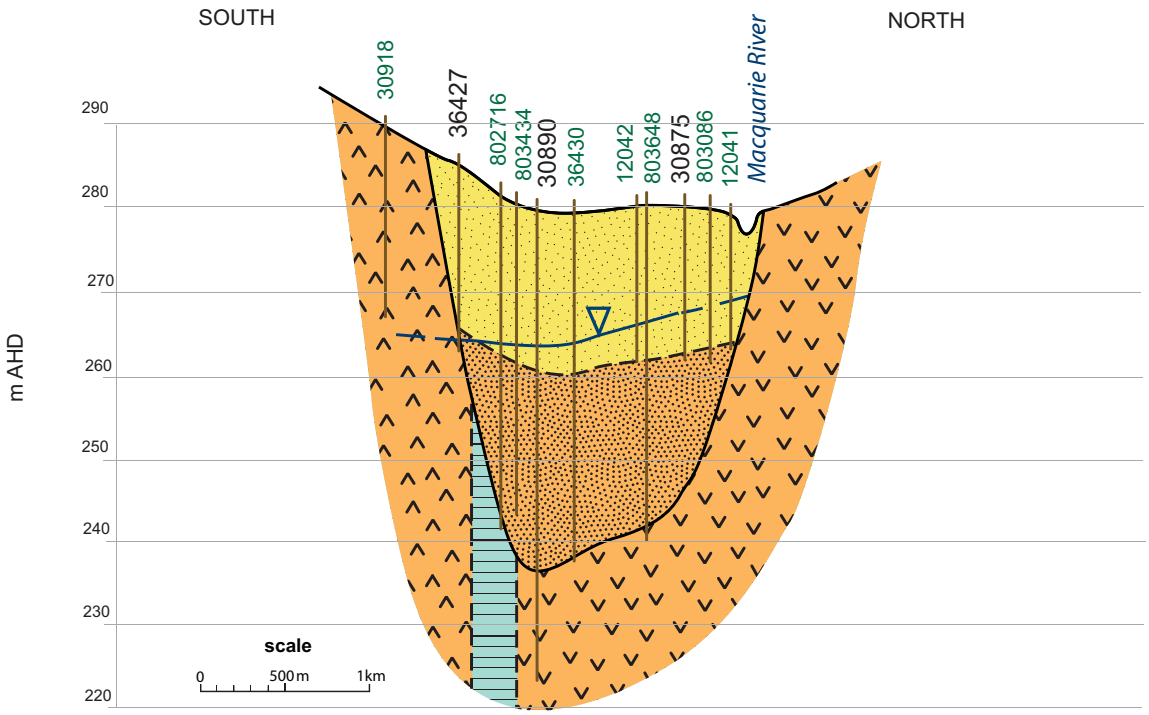
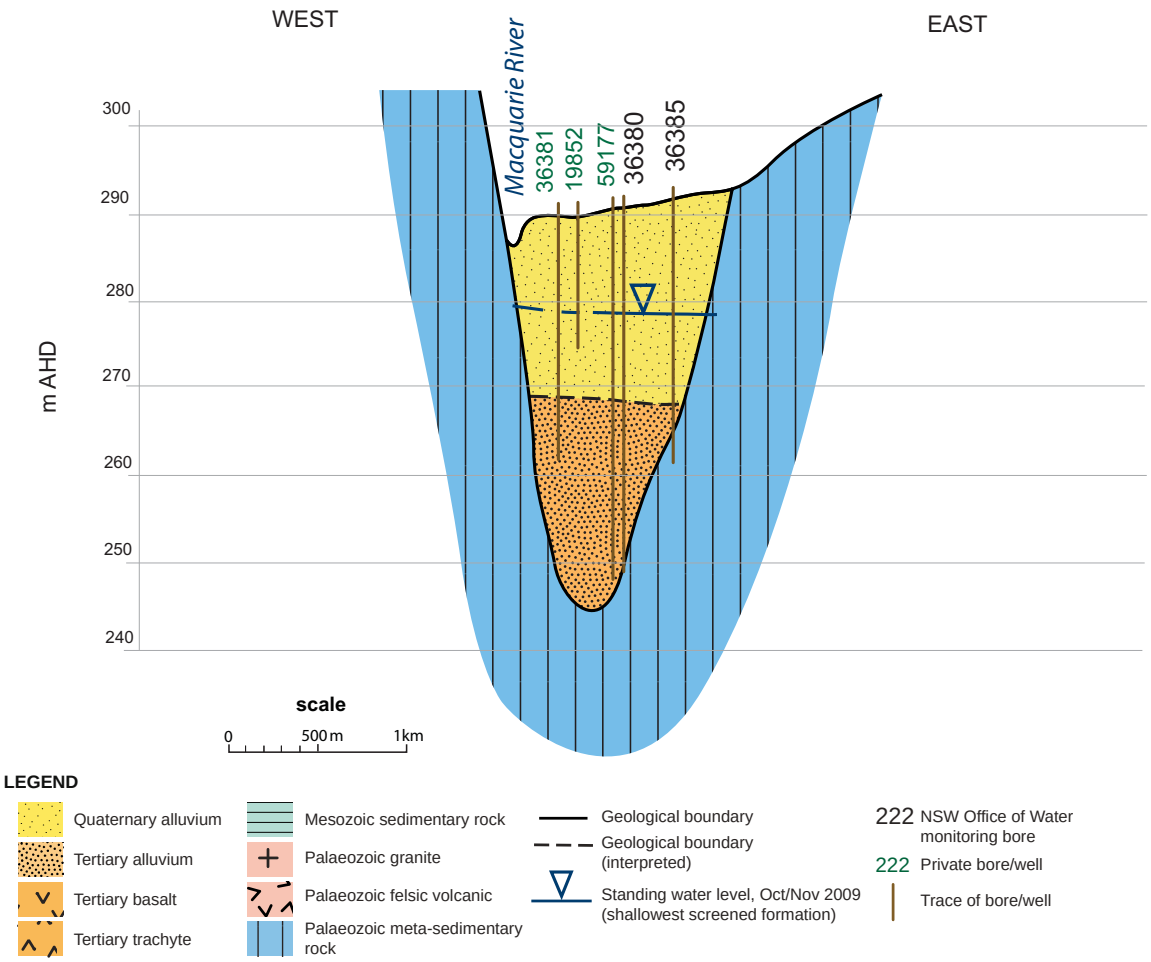


Figure 22 Hydrogeological cross section, N Wellington



4.4 Aquifer parameters

A range of transmissivity (T) values for the Upper Macquarie Alluvium are indicated from pump test data held in the NSW Office of Water's groundwater database. Transmissivities range between 8 and 800m^2/day and average around 300 to 400m^2/day. Yields range from below 5L/s to 120L/s and average around 15L/s in production bores. Yields are generally higher where the Tertiary sand and gravel formations are thickest.

4.5 Basement contours

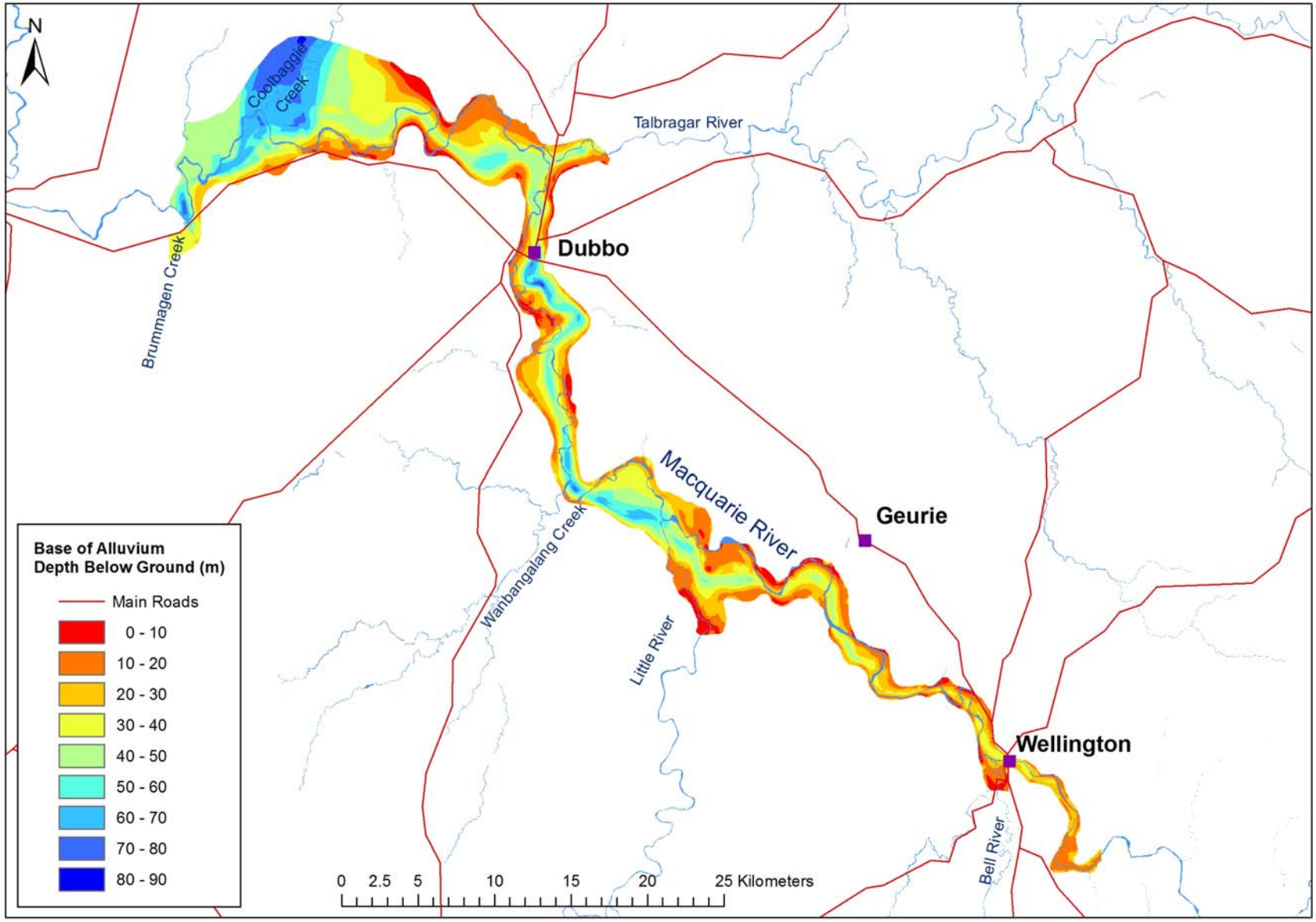
Development of cross sections and examination of borehole information from throughout the management area has allowed the construction of depth contours for the base of the alluvium, including the location of the palaeochannel. The depth to the base of the alluvium is shown in Figure 23.

4.6 Review of groundwater management area boundary

The review of geological information and development of base of alluvium contours has identified a number of locations where a revision of the management area was necessary. The revised boundary for the Upper Macquarie GWMA009 is shown in Figure 1. The most significant of these changes were:

- the inclusion of the newly differentiated palaeochannel and alluvium at the southern end of the Cooreena Road, Talbragar and Terrabella areas
- the exclusion of the Mesozoic sedimentary sequences under the eastern side of Dubbo
- the exclusion of fractured rock from the Wellington urban area.

Figure 23 Depth to base of alluvium for the Upper Macquarie GWMA009



5 Groundwater levels

5.1 Overview

Groundwater level monitoring commenced in the area in 1970, with additional monitoring sites being added up until 2009. The monitoring network consists of 65 bores at 45 sites. Manual monitoring has been conducted at a variety of intervals. Regular frequent monitoring occurs at four locations in the Hennessey Road Dubbo town water supply extraction area (Eulomogo Basin), where monitoring bores have been equipped with dataloggers since March 2009. Hydrographs have been constructed for selected sites showing representative groundwater behaviour in the area. Figure 24 shows the locations of all groundwater monitoring sites, representative monitoring sites and river gauging stations in the Upper Macquarie GWMA009.

Groundwater is generally unconfined in the upper aquifer down to 25m, but may be partly confined in places where the overlying silts and clays are thicker, more uniformly distributed and of lower permeability. The lower aquifer is unconfined to partially confined, and is likely to be more confined in its deepest sections below 55m. Through most parts of the management area the upper and lower aquifers are in relatively good lateral and vertical hydraulic connection.

Water levels throughout the aquifer responded to the main river flood events of 1990, 1998 and 2000. The near-river parts of the aquifer show strong rapid responses and the more distal parts of the aquifer show variably subdued and delayed responses. Groundwater heads demonstrate that the Macquarie River has a combination of gaining and losing reaches, and that this changes with flood recharge and drought events.

Long term groundwater level trends have been relatively stable across most parts of the aquifer over the last four decades. However, long term declining trends are occurring in the Dulla Dulla, Coolbaggie and Hennessey Road areas. Groundwater levels in the Hennessey Road area have fallen up to 18m since commencement of monitoring in the early 1970s.

Seasonal pumping drawdowns between 1.5m and 6m are observed in the Butlers Falls, Hennessey Road, Dulla Dulla and Troy Bridge areas.

Since the onset of the drought in 2002 groundwater levels have declined in all parts of the aquifer, with falls of between 0.5m and 9m. Prior to the drought there was generally little difference in hydraulic head between the upper and lower parts of the aquifer. Since 2002 some parts of the aquifer are showing changed lateral or vertical hydraulic gradients from those of the previous three decades. This is most likely due to the drought and to associated locally increased pumping stresses.

5.2 Hydrographs

Hydrographs are presented for nine section lines and representative monitoring sites. These hydrographs have been selected to illustrate both lateral and vertical groundwater conditions throughout the valley. Hydrographs for the representative monitoring bore sites are shown in Figure 25 to Figure 34.

Figure 25 shows data for three pipes at one site on the Wellington section. At this location the groundwater heads and behaviour are very similar at different depths in the aquifer indicating a good vertical hydraulic connection and little or no vertical hydraulic gradient. The aquifer has a rapid but moderate response to recharge events. Groundwater levels have been relatively steady over time, but are showing a slightly declining trend since onset of the drought in 2002, with a fall of around 0.5m since then.

Figure 24 Location of groundwater monitoring sites and river gauging stations for GWMA009

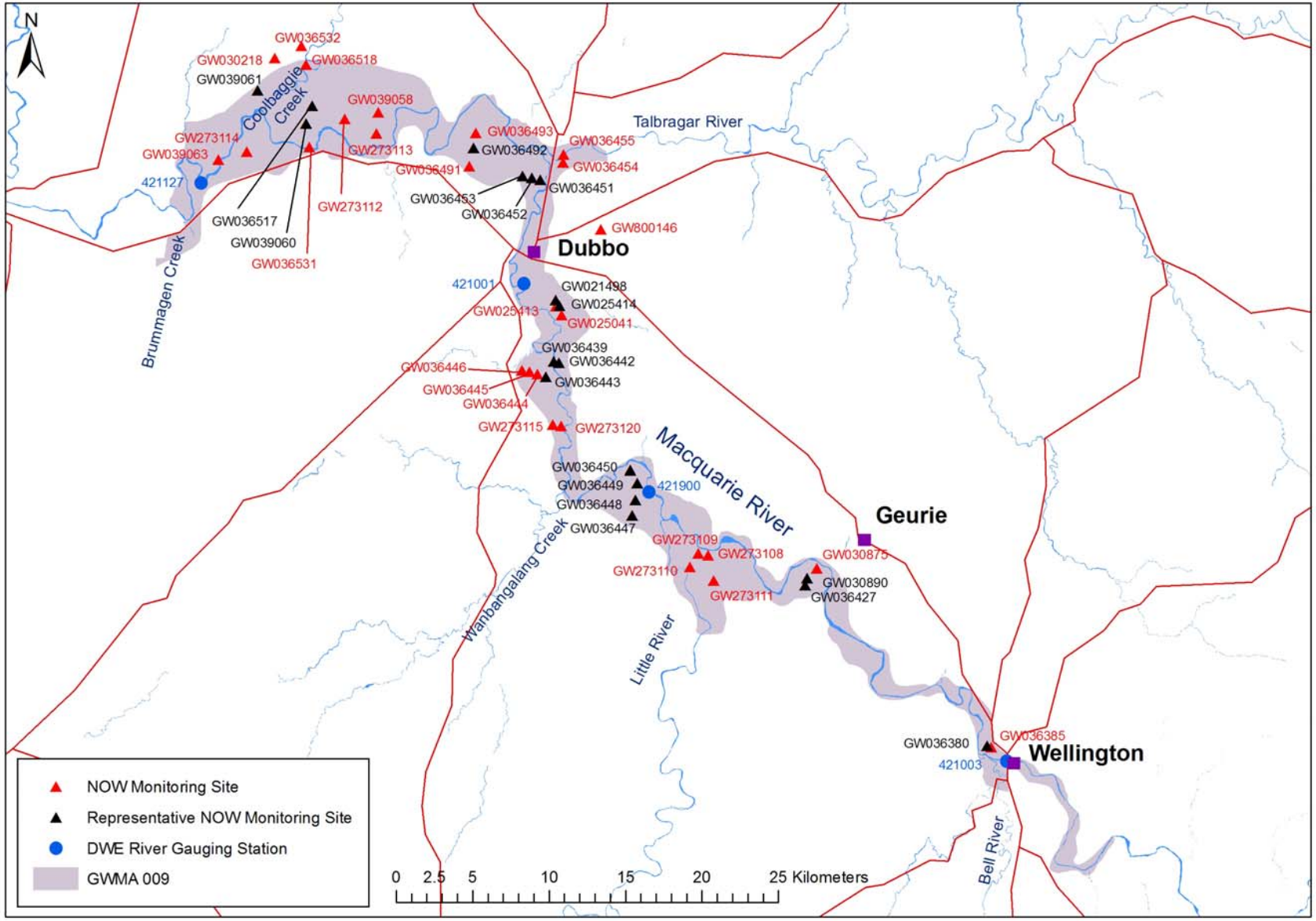


Figure 25 Hydrograph for Wellington section

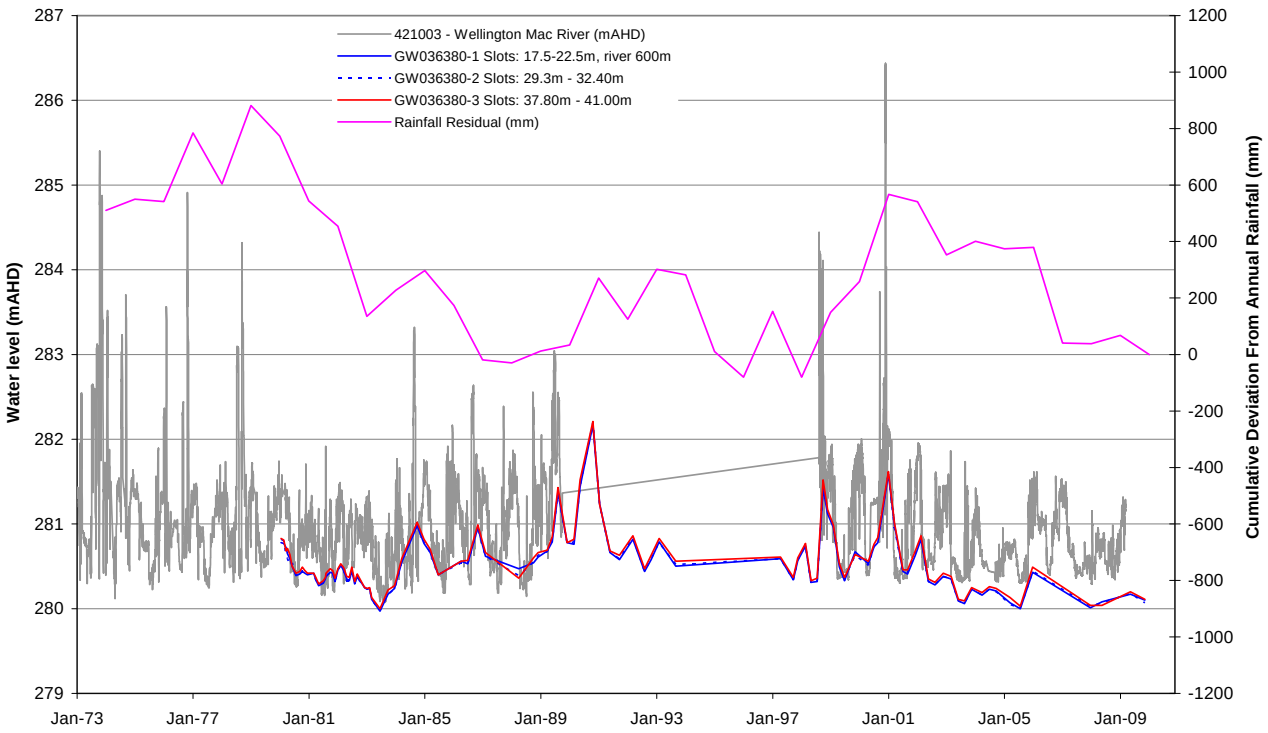


Figure 26 Hydrograph for Geurie section

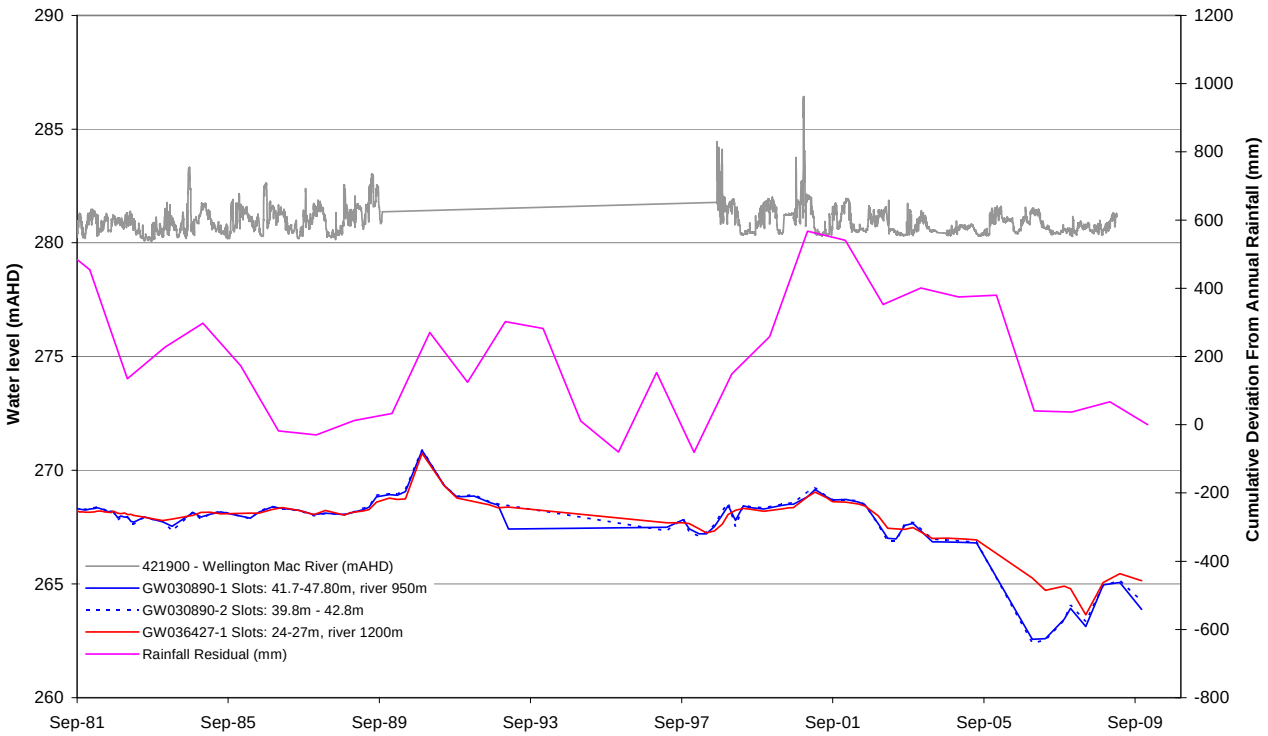


Figure 26 shows data for two pipes at one site and one pipe at a second site on the Geurie section. At this location the groundwater heads and behaviour are generally similar at different depths and locations in the aquifer. This indicates a good vertical and lateral hydraulic connection, with generally little or no vertical or lateral hydraulic gradient. The aquifer has a moderately subdued response to recharge events that may be explained by the relative distances of 950m and 1200m of the sites from the river. Groundwater levels have been relatively steady over time, but are showing a declining trend since onset of the drought in 2002, with a fall of around 4.5m since then. Since onset of the drought the part of the aquifer closer to the river is experiencing lower water levels than that further from the river. This may be related to increased pumping stress nearer to the river.

Figure 27 shows data for the shallow pipes at four sites on the Shepherds Hill section. The aquifer is in good hydraulic connection with the river at 380m away from it and shows a strong and rapid response to recharge events here. The response is less intense and shows a lag time that increases with distance and decreasing level of connection with the river. During recharge events the hydraulic gradient is generally away from the river and the groundwater system is gaining. During drier periods the hydraulic gradient is reversed and groundwater flow is from the distal aquifer (1800m from the river) towards the part of the aquifer nearer the river. At this location the generally similar groundwater responses indicate a relatively good lateral hydraulic connection across the aquifer. Groundwater levels have been relatively steady over time, but are showing a declining trend since onset of the drought in 2002, with a fall of around 2m since then.

Figure 28 shows data for two pipes at two sites and one pipe at a third site on the Butlers Falls section. Groundwater levels were relatively stable until the onset of the drought in 2002 after which all parts of the aquifer have experienced a declining trend. At 40m from the river both the upper and lower parts of the aquifer show a strong and rapid response to recharge that takes six to eight months to decay from major events. This indicates that the aquifer is in good hydraulic connection with the river at this location. Vertical groundwater heads indicate that there is a downwards hydraulic gradient and that groundwater would be flowing from the upper aquifer into the lower aquifer. At 380m from the aquifer the response to recharge is less pronounced but still moderately intense. At 625m from the river, the upper and lower aquifer both show a moderate response to recharge indicating that the aquifer is still moderately well connected with the river. The peak recharge response shows a lag of three to five months and this takes around 18 months from the original event to decay. At this distal location from the river a slight downwards hydraulic gradient occurs after early 2001. Lateral hydraulic heads show that groundwater is flowing from the aquifer near the river towards the distal parts of the aquifer. The relatively similar groundwater behaviour across the aquifer shows that a good lateral hydraulic connection exists in both the upper and lower parts of the aquifer. Seasonal pumping drawdowns are observed at 625m from the river with drawdowns of up to 5m. Similar but slightly less intense drawdowns in the upper aquifer indicate a relatively good vertical hydraulic connection and pumping from the lower aquifer would be inducing flow from upper parts of the aquifer. Across the river and 40m from it, pumping drawdowns of up to 3m are observed. Given the similar responses to recharge events it is likely that pumping from the lower part of the aquifer is inducing flow from the shallow aquifer. However this is masked by the immediate recharge from the river due to the strong hydraulic connection at this location.

Figure 27 Hydrograph for Shepherds Hill section

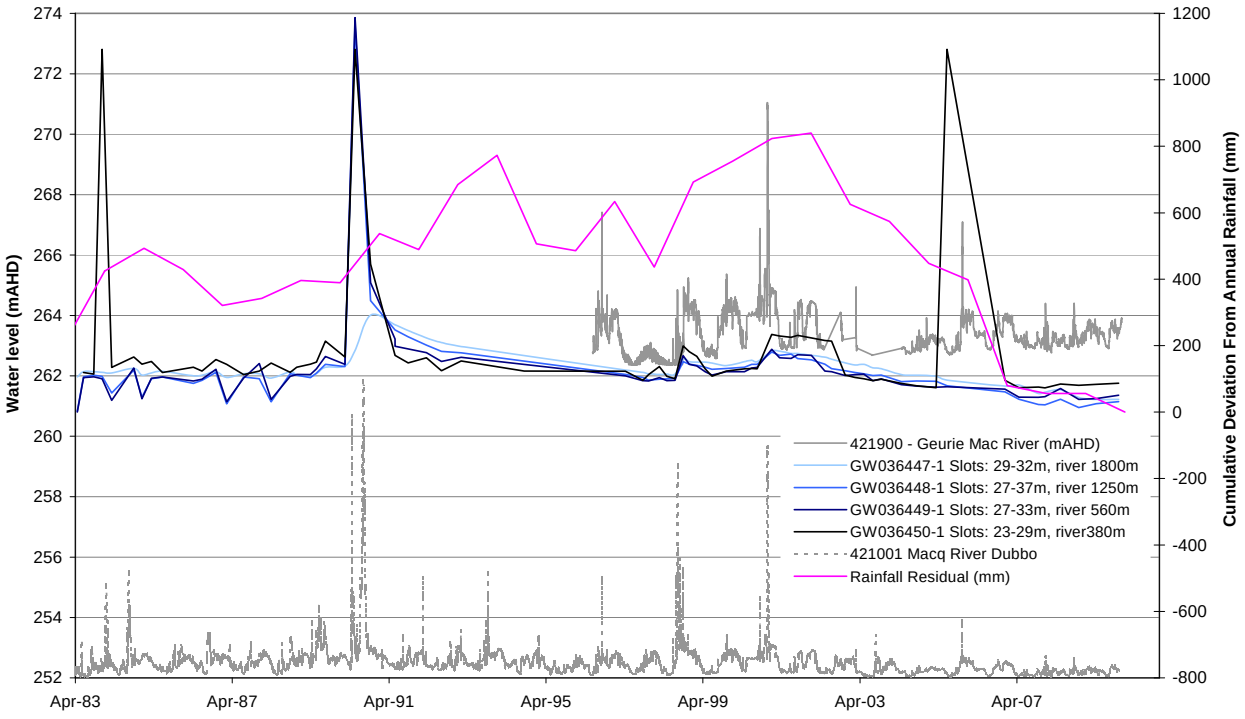


Figure 28 Hydrograph for Butlers Falls section

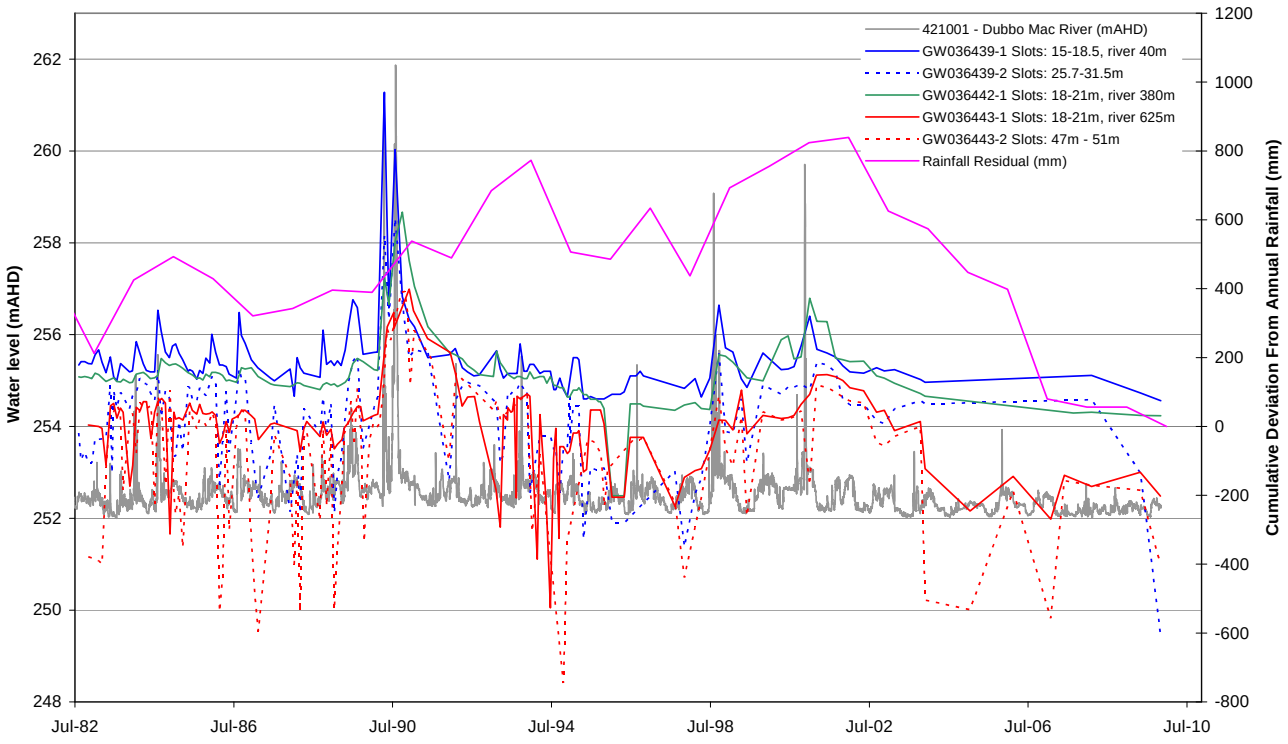


Figure 29 shows data for two pipes at two sites on the Hennessey Road-South Dubbo section. This area, part of the lower Eulomogo Creek drainage basin, is one of two principle extraction areas used for Dubbo's town water supply. Groundwater level behaviour indicates that at this location the aquifer is in good vertical and lateral hydraulic connection. Pumping drawdowns suggest that both upper and lower parts of the aquifer are at least partially confined. Groundwater levels at both sites show a long term declining trend since commencement of monitoring in the early 1970s. The upper and lower aquifers at both locations show little response to recharge events. This may be partly explained by the sites being over 800m from the river. Seasonal pumping drawdowns are observed at both sites with drawdowns up to 6m. Recovery [1]decline for both sites is around 16.5m.

Figure 30 shows the detailed recordings of water levels in the pumped aquifer at site GW025414 on the Hennessey Road section. This figure shows a consistent drawdown and recovery of around 2.1m associated with daily pumping and shut off of a nearby town water supply bore. Recovered water levels rise around 0.5m over one to two weeks following significant rainfall. Groundwater conditions for this area are discussed in more detail in Section 5.4.

Figure 31 shows data for the shallow pipes at three sites on the Troy Bridge section. The generally similar groundwater behaviour at these three sites across the aquifer indicates a moderate level of lateral hydraulic connection. The aquifer is in good hydraulic connection with the river at 250m away from it and shows a strong and rapid response to recharge events here. The response is more subdued and shows a lag time that increases with distance and decreasing level of connection with the river. Groundwater levels have been relatively steady over time, but are showing a declining trend since 2002, with falls of between 1.5m and 5m since then. Pumping drawdowns of up to 1.5m are observed near to monitoring bore GW36452. During recharge events the hydraulic gradient is generally away from the river and the groundwater system is gaining. During drier periods the hydraulic gradient is reversed and groundwater flow is from the distal aquifer (1500m from the river) towards the part of the aquifer nearer the river. Since the onset of the drought in 2002 the lateral hydraulic gradients have reversed, with groundwater heads now highest near the river and groundwater flow is towards the distal aquifer.

Figure 32 shows data for three pipes at one site on the Cooreena Road section. At this location, 1700m from the river, the very subdued and delayed response to recharge events suggests that the aquifer is in limited hydraulic connection with the river. Up to 3.5 years after the 1990 flood groundwater levels were still showing a recharge response that took a comparable time to drain from storage. Groundwater heads and behaviour are very similar at different depths in the aquifer, indicating a good vertical hydraulic connection and with no predominant vertical hydraulic gradient. Groundwater levels have been steady over time, but are showing a declining trend since onset of the drought in 2002, with a fall of around 2m since then. Since 2002 the upper part of the aquifer has experienced a more significant drop in water levels than the deeper parts of the aquifer and has created an upwards hydraulic gradient. This may be related to increased pumping stress in the upper aquifer.

Figure 33 shows data for two pipes at one site and one pipe at a second site on the Coolbaggie section. The similar groundwater behaviour at these two sites indicates a good level of lateral and vertical hydraulic connection. Even at distances of up to1600m away, the aquifer has a moderate level of hydraulic connection with the river. This is shown by the lower order response to recharge with a lag of several months that remains similar with distance from the river. Following recharge events groundwater drains from storage over several years.

[1] Where water levels do not recover to predevelopment level after each period of pumping.

In Figure 33 on the Coolbaggie section, groundwater heads indicate that groundwater flow is towards the river even during and after major recharge events. The vertical hydraulic gradient alternates between slightly upwards and slightly downwards with no discernable pattern. Groundwater levels show a slightly declining long term trend. Since 2002, water levels have been declining more strongly, with falls around 3.5m since then.

Figure 29 Hydrograph for Hennessey Road–South Dubbo section

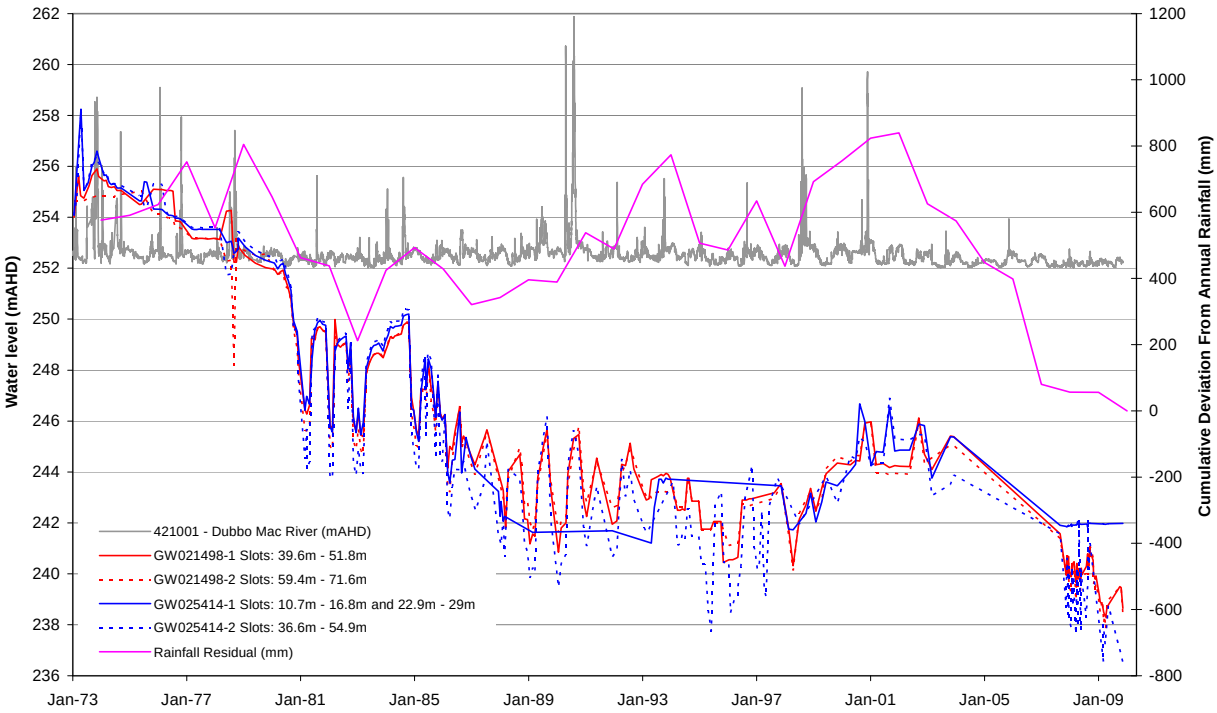


Figure 30 Detailed Hydrograph for GW 025414 Hennessey Road section

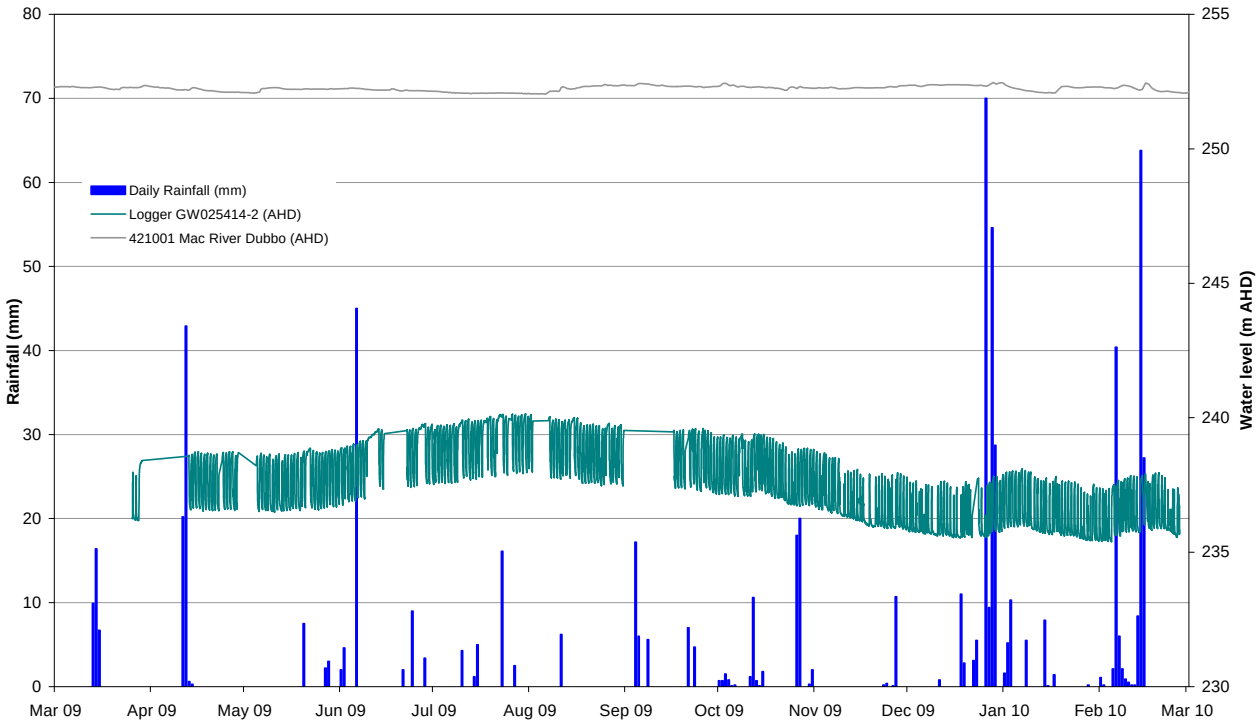


Figure 31 Hydrograph for Troy Bridge section

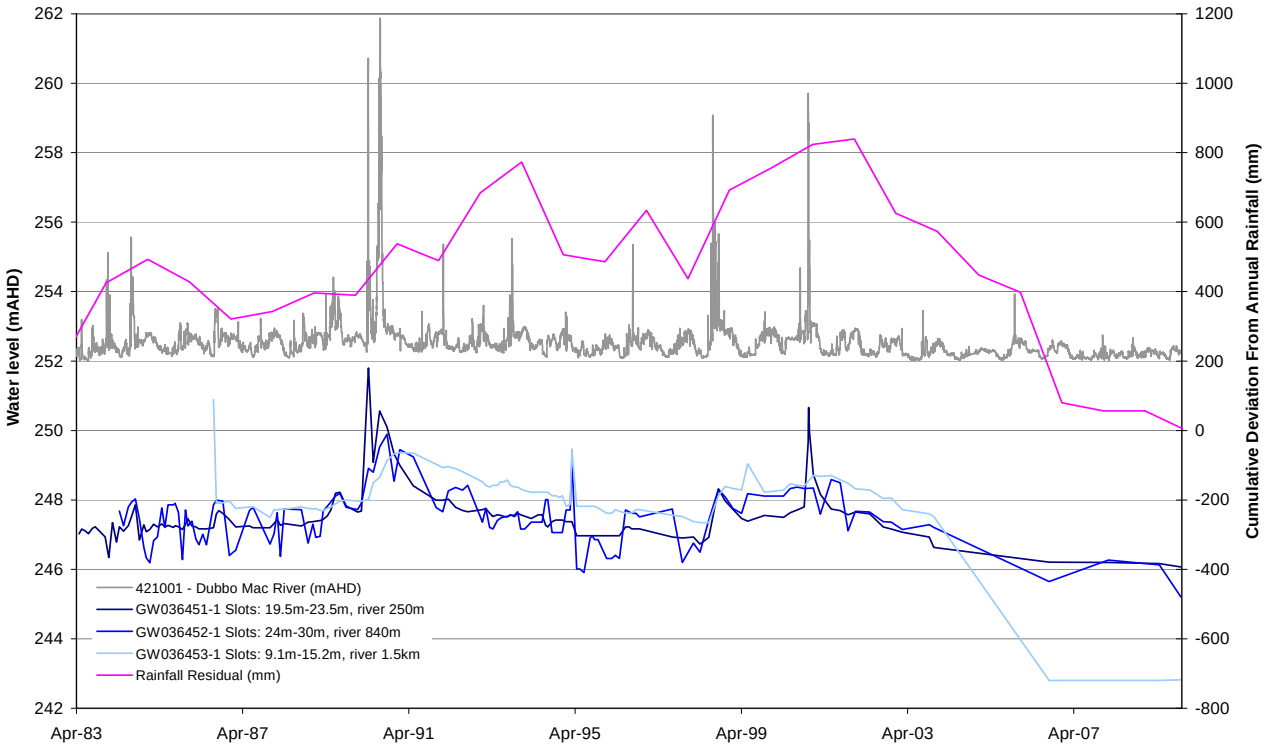


Figure 32 Hydrograph for Cooreena Road section

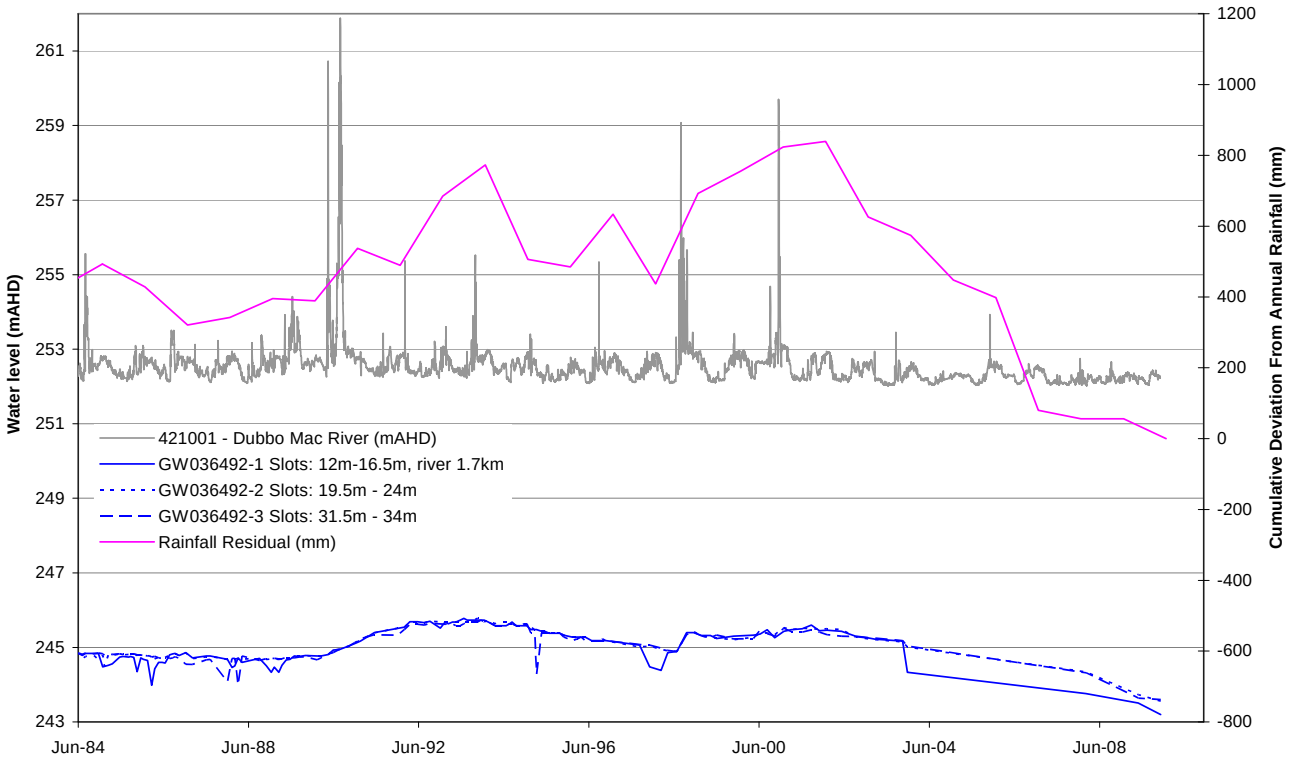


Figure 33 Hydrograph for Coolbaggie section

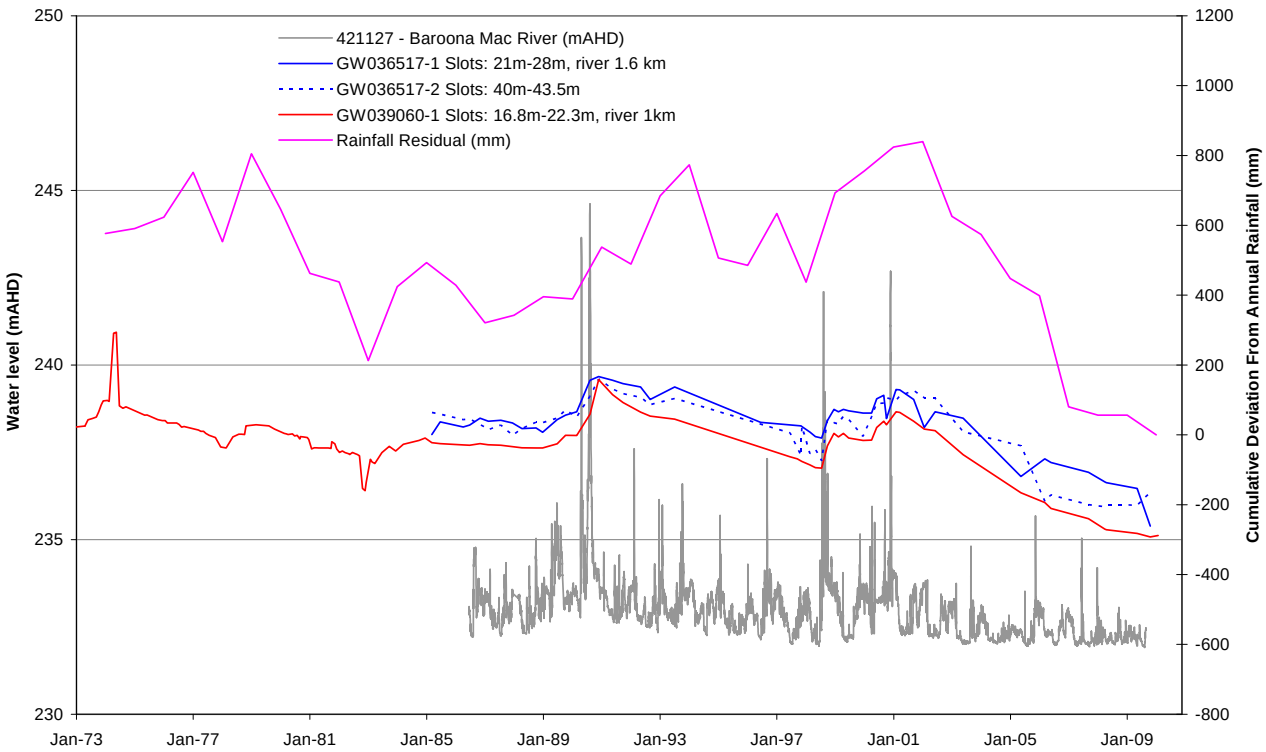
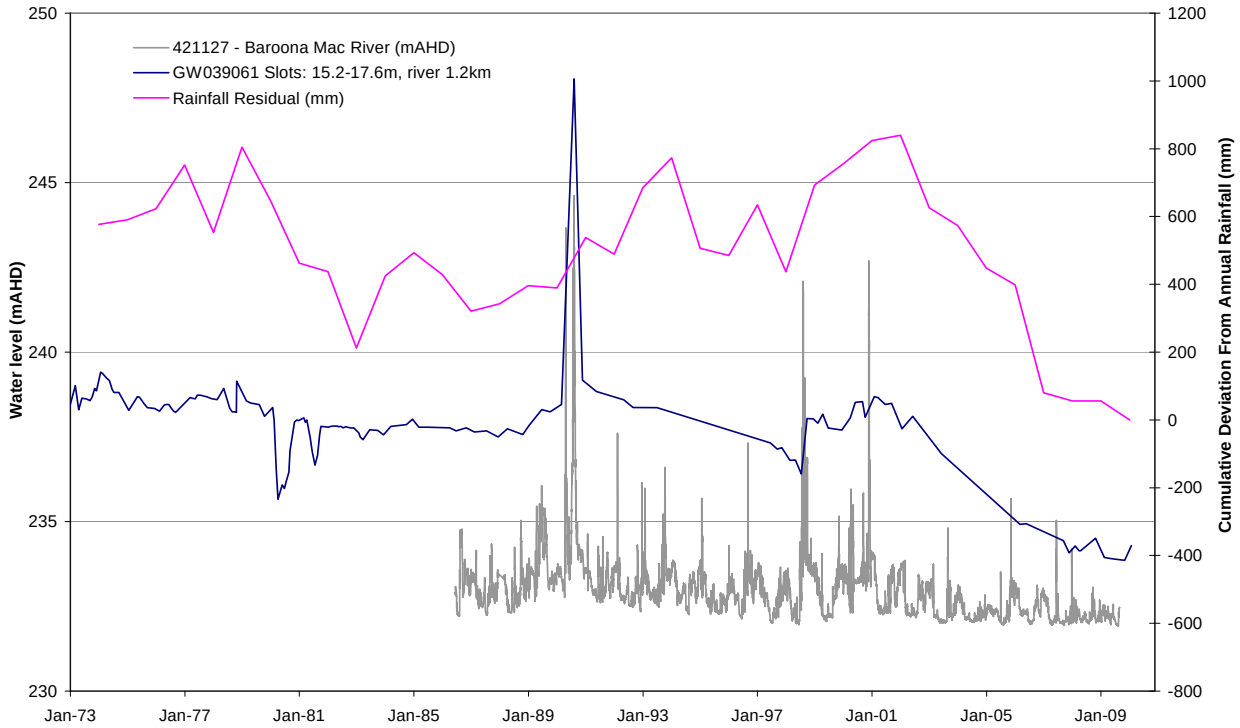


Figure 34 shows data for one pipe on the Dulla Dulla section. At 1200m away, the aquifer has a moderate level of hydraulic connection with the river. Apart from a strong and rapid response to the 1990 flood, the aquifer shows a subdued and delayed response to recharge and groundwater storage decays over a number of years following the recharge event. Groundwater levels show a slightly declining long term trend. Since 2002, water levels have been declining more strongly, with falls around 3.5m since then. Seasonal pumping drawdowns of up to 2.5m are observed in the early 1980s.

Figure 34 Hydrograph for Dulla Dulla section



5.3 Groundwater heads and flow directions

For sites with more than one pipe the vertical hydraulic gradient was calculated between the Tertiary and Quaternary screened zones. The vertical hydraulic gradients for the 11 bores with data for both Quaternary and Tertiary alluvium are given in Table 5. Upstream of Dubbo the average vertical hydraulic gradient is 1.37 indicating groundwater flow downwards from the Quaternary into the Tertiary aquifer. Downstream of Dubbo this is reversed with an average hydraulic gradient of -0.35 indicating groundwater flow from the Tertiary aquifer upwards into the Quaternary aquifer.

Groundwater heads for summer 2009/2010 were separated into Quaternary and Tertiary alluvium based on pipe screen depths. The groundwater heads were contoured and groundwater flow directions were derived. Groundwater head contours and groundwater flow directions for the Quaternary aquifer are shown on Figure 35 and Figure 36.

Table 5 Hydraulic gradient between Quaternary and Tertiary alluvium

Work number	Section	Hydraulic gradient (- value indicates upwards gradient)
GW273114	Dulla Dulla	-0.68
GW036517	Coolbaggie	-0.96
GW036532	Coolbaggie	0.26
GW273112	Rawsonville	-0.38
GW036491	Cooreena	0.02
GW036439	Butlers Falls	5.14
GW036443	Butlers Falls	1.48
GW273115	Sandy Falls	0.27
GW273120	Sandy Falls	0.68
GW273111	Terrabella	0.63
GW036380	Wellington	-0.01
Average		**0.59**

At a regional scale, the groundwater flow direction in both the Quaternary and Tertiary aquifers correlates with that of surface drainage and is northwest from Wellington towards Dubbo and Narromine. However, locally there has been a significant reversal in the regional hydraulic gradient between Dubbo and the Hennessey Road area.

Figure 35 and Figure 36 show that a steep hydraulic gradient occurs between Butlers Falls and the Hennessey Road area in both the Quaternary and Tertiary aquifers. Figure 36 shows a significant area of drawdown in the Tertiary aquifer, extending from the centre of Dubbo to the Hennessey Road-South Dubbo area. In this area the natural down-valley hydraulic gradient in the Tertiary aquifer has been reversed due to reduction of groundwater heads from pumping. Groundwater is now flowing from central Dubbo south towards the Hennessey Road area.

In the Shepherds Hill to Ponto area groundwater heads in the Tertiary aquifer are lower than the Quaternary aquifer by 4m to 7m. At Terrabella there is a steep hydraulic gradient between the Little River area and the main valley. Both of these situations suggest drawdown due to extraction.

Figure 35 Groundwater heads and flow directions for Quaternary aquifer

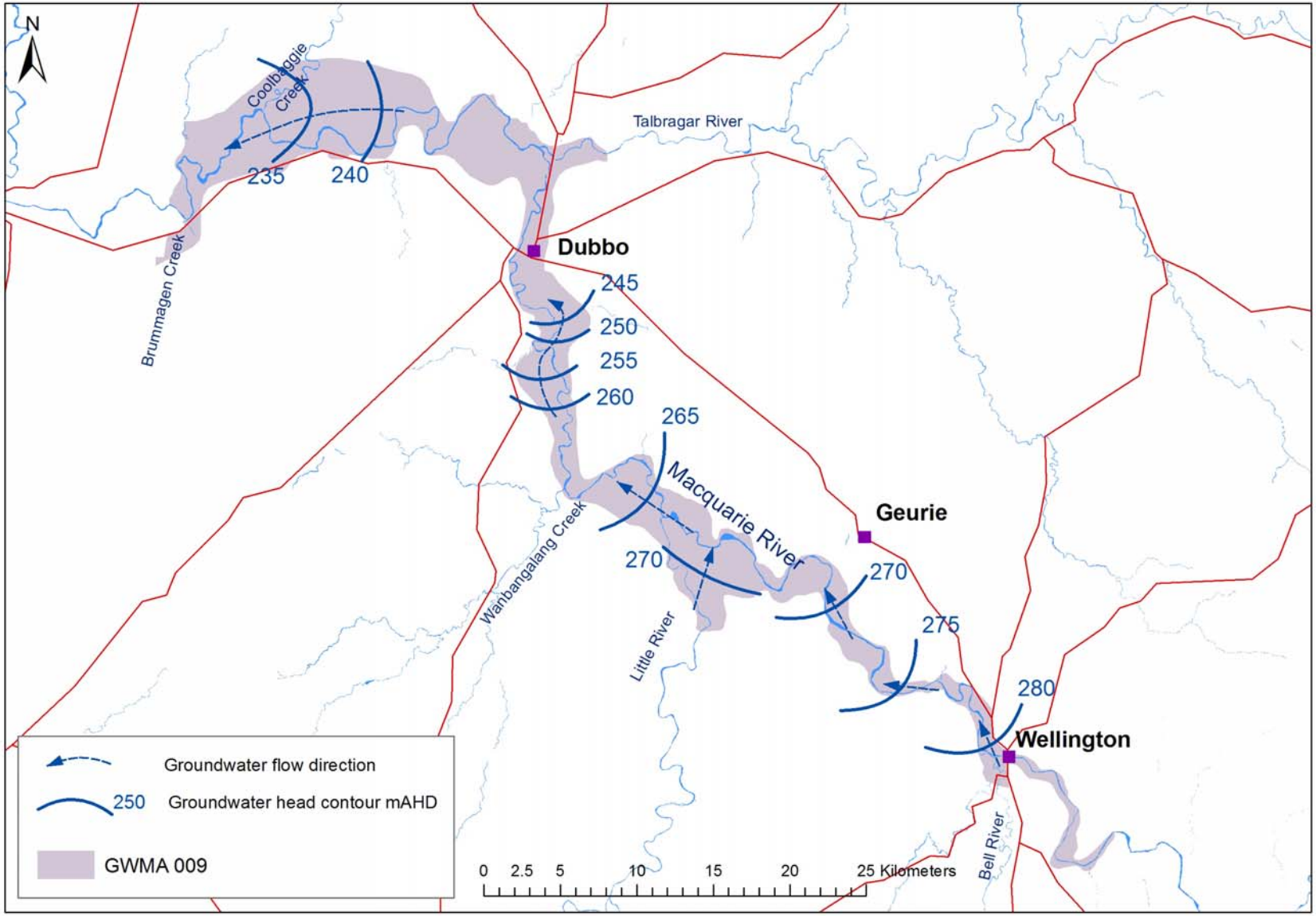
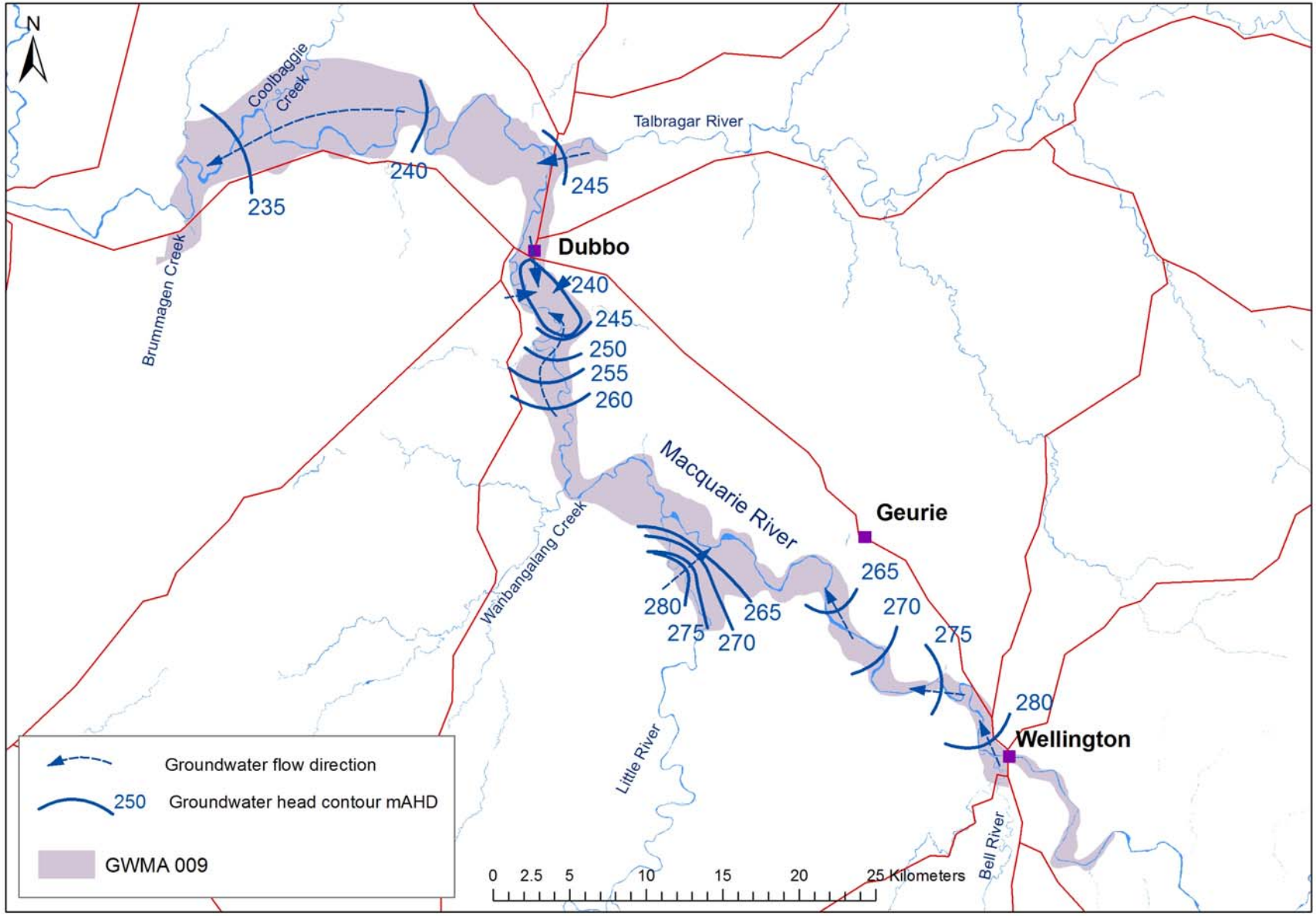


Figure 36 Groundwater heads and flow directions for Tertiary aquifer



5.4 Long term sustainability

In 1998, under the NSW water reforms, the Upper Macquarie alluvial aquifer was identified as having a medium level of risk from over-exploitation and contamination, with the area around Dubbo being specifically identified as having a high level of risk (DLWC, 1998).

In 2008 the CSIRO Sustainable Yields Project indicated that there was the potential for groundwater extraction to increase in many of inland NSW's aquifers including the Upper Macquarie, and that this could reduce surface water availability in future years.

Since commencement of groundwater extraction from the Hennessey Road area for town water supply, irrigation and stock and domestic use, the aquifer has experienced long term declining water levels. In May 1992, due to the continuing decline of groundwater levels, the four parishes around Dubbo were embargoed for application of new groundwater licences. In the mid-1990s, based on discussions with the then Department of Land and Water Conservation, Dubbo City Council reduced its groundwater extraction from the Hennessey Road area due to the falling water levels in the aquifer. Some recovery in groundwater levels occurred between 1996 and 2002. However they still remained lower than predevelopment levels by at least 10 metres.

Groundwater levels have declined further in the Hennessey Road Eulomogo Basin area since onset of the drought in 2002 and are currently at their lowest levels since monitoring commenced.

The Butlers Falls and Hennessey Road areas are experiencing longer-term [2]drawdown and [3]recovery decline. Over the 27 year period of monitoring, groundwater storage has been depleted through extraction and is not being replenished by sufficient recharge to halt the declining water level trend. Current groundwater levels for these areas are expressed in terms of [4]saturated thickness in Table 6 and are shown on Figure 37, Figure 38 and Figure 39. In March 2010 groundwater levels at monitoring bore GW21498 were at 75 per cent of the saturated thickness of the aquifer, and at monitoring bore GW25041 water levels were at 52 per cent of saturated thickness.

Table 6 Summary of groundwater conditions for areas experiencing drawdown and recovery decline

Location	Bore number	Predevelopment saturated thickness (m)	Saturated thickness at March 2010 (m)	Drawdown as a % of saturated thickness at March 2010
Hennessey Road – South Dubbo	GW21498	22.6	5.6	75
	GW25041	25.5	12.2	52
	GW25413	45.1	25.1	44
	GW25414	40.9	22.8	44
Butlers Falls	GW36439	24.5	17.9	27
	GW36443	40.5	36.5	10

[2] Drawdown is where groundwater levels are lowered due to extraction.
[3] Recovery decline is where the groundwater level does not recover to predevelopment level after a period of pumping or drought.
[4] The saturated thickness of an aquifer is defined as the thickness between the predevelopment groundwater level and the base of the aquifer. The saturated thickness is important because it controls the amount of available drawdown in bores and the depth at which pump intakes must be set.

Figure 37 Hydrograph for GW036439 Butlers Falls section

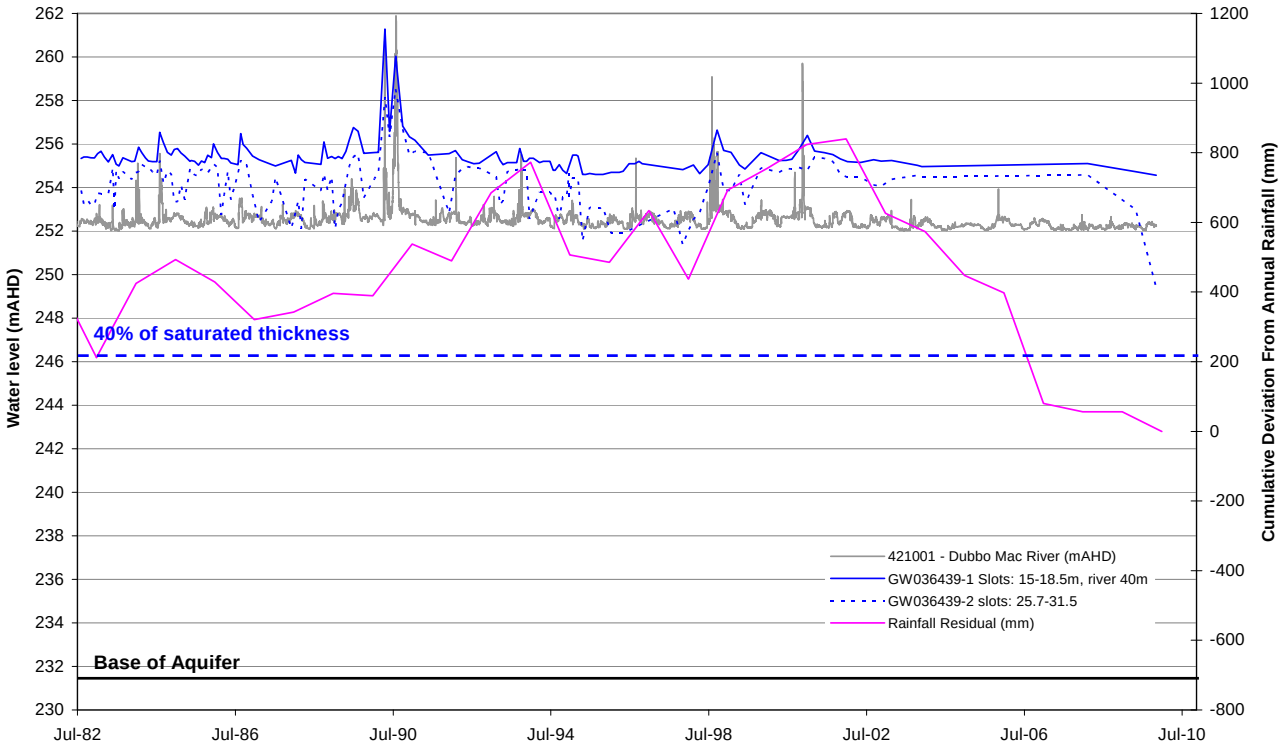


Figure 38 Hydrograph for GW 021498 Hennessey Road section

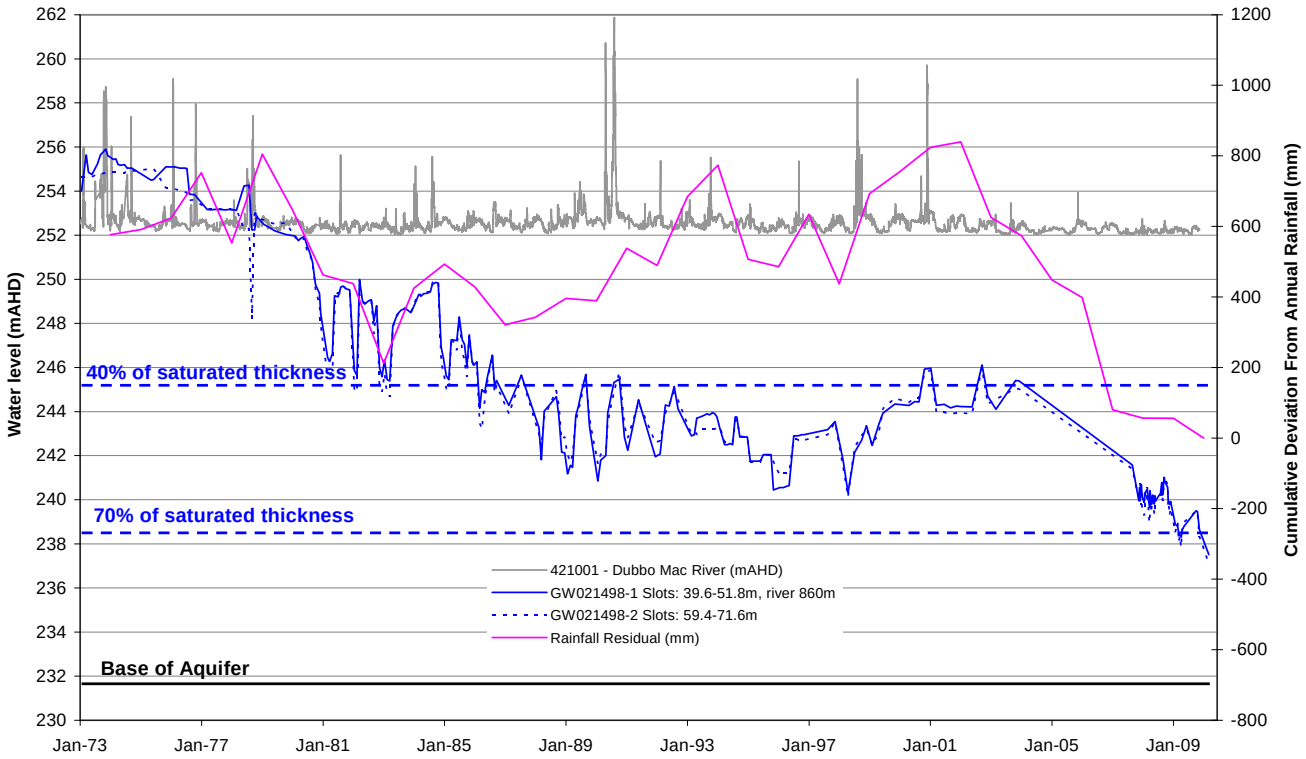
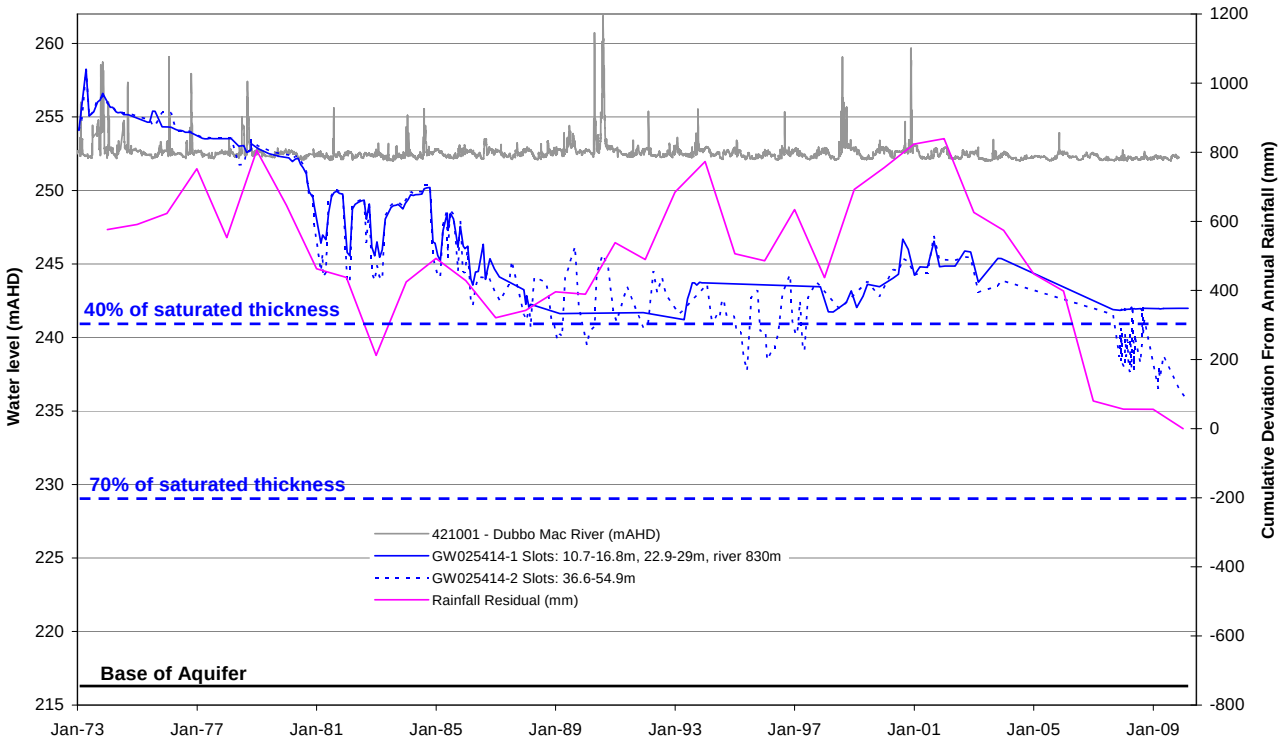


Figure 39 Hydrograph for GW 025414 Hennessey Road section



6 Groundwater quality

Groundwater electrical conductivity (a measure of salinity) was measured at all groundwater monitoring sites over summer 2009/2010. A summary of groundwater electrical conductivity and salinity is given in Table 7. The distribution of groundwater electrical conductivity for the Quaternary aquifer is shown on Figure 40 and for the Tertiary aquifer on Figure 41.

In general, water quality based on salt concentration is better in the lower Tertiary aquifer than in the upper Quaternary aquifer, and is better upstream of Dubbo than downstream. This is likely related to the high vulnerability of the unconfined Quaternary aquifer to pollution and contamination from land and urban run-off combined with throughflow from adjacent more saline basement groundwater systems. Higher salinity water may also be infiltrating down to the Quaternary aquifer as a result of the confluence of flows from the generally more saline Talbragar River. For the period July 1999 to July 2000 Macquarie River salt concentrations at Dubbo ranged between 250µS/cm and 680µS/cm, whereas salt concentrations for the Talbragar River at Elong Elong ranged between 650µS/cm and 1850µS/cm (DLWC, 2001). For the 18 month period from August 2008 to January 2010, the average of monthly samples when flowing show that the Macquarie River at Dubbo had a salt concentration of 305µS/cm compared with 674µS/cm for the Talbragar River at Elong Elong (Knight, C. 2010, pers. comm.,17 May).

Groundwater in the Quaternary alluvium upstream of Dubbo has a relatively low salinity placing it in high beneficial use categories between the desirable and higher limits for raw water for drinking water supply. Groundwater in the Quaternary alluvium downstream of Dubbo has a broader range of salinity with some very high values, and falls into beneficial use categories between the desirable limit for raw water for drinking water supply and the upper limit for for agricultural water. Groundwater in the Tertiary alluvium upstream of Dubbo has a relatively low salinity, placing it in the high beneficial use category of desirable limits for raw water for drinking water supply. Groundwater in the Tertiary alluvium downstream of Dubbo has a relatively low salinity placing it in the high beneficial use category of desirable limits for raw water for drinking water supply.

Table 7 Summary of electrical conductivity and salinity by formation

Formation	Location	Range of electrical conductivity (µS/cm)	Average electrical conductivity (µS/cm)	Range of salinity *(mg/L)	Average salinity *(mg/L)
Quaternary alluvium	Upstream of Dubbo	300 – 1718	896	192 – 1100	573
	Downstream of Dubbo	288 – 18700	2433	184 – 11968	1557
Tertiary alluvium	Upstream of Dubbo	251 – 832	479	161 – 532	307
	Downstream of Dubbo	312 – 804	519	200 – 515	332
Basement	Sandstone	599 – 15700	5309	383 – 10048	3398
	Basalt	1100 - 5410	3255	704 - 3462	208

* converted from electrical conductivity using 1µS/cm = 0.64mg/L.

Figure 40 Electrical conductivity of groundwater in Quaternary alluvium

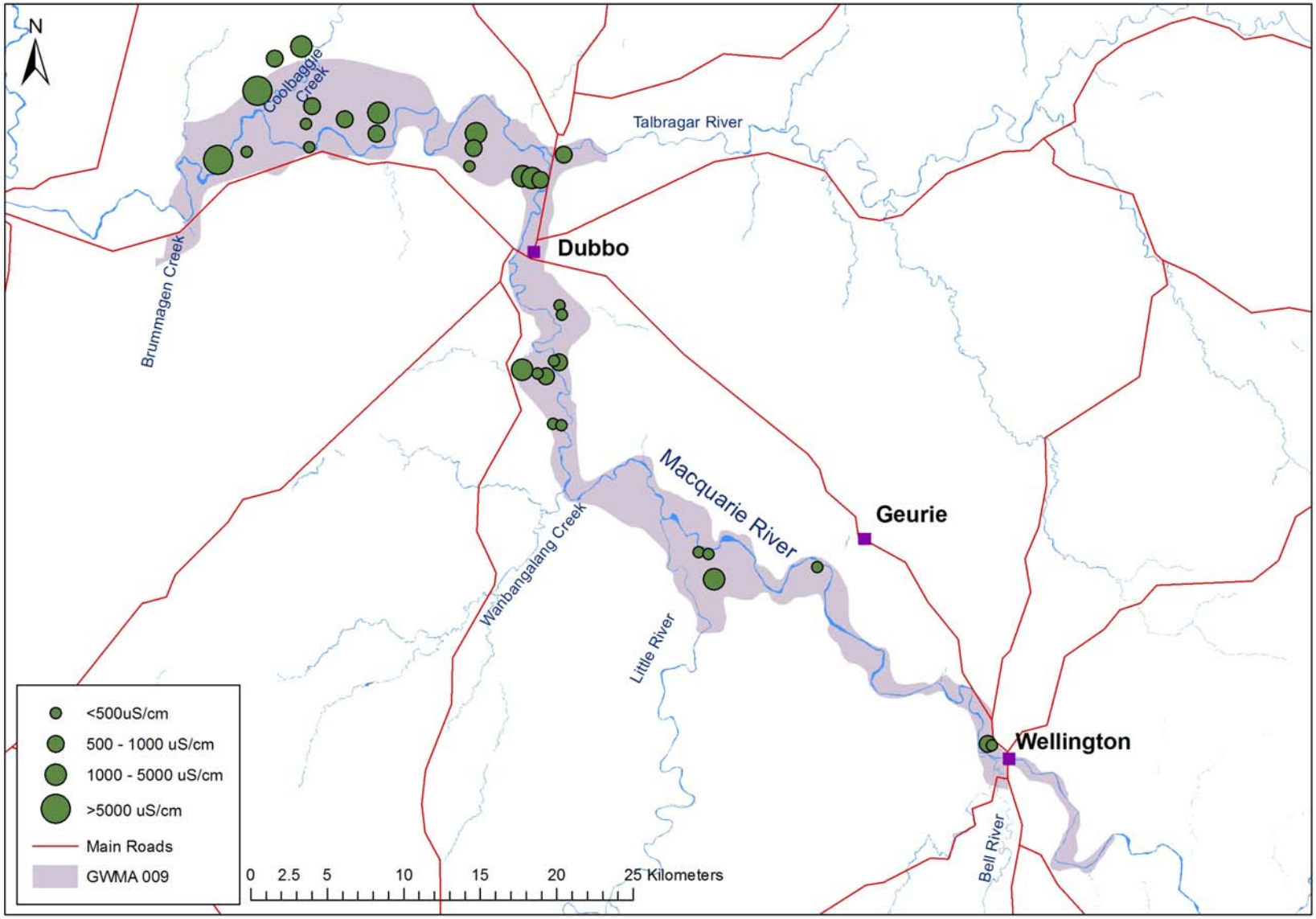
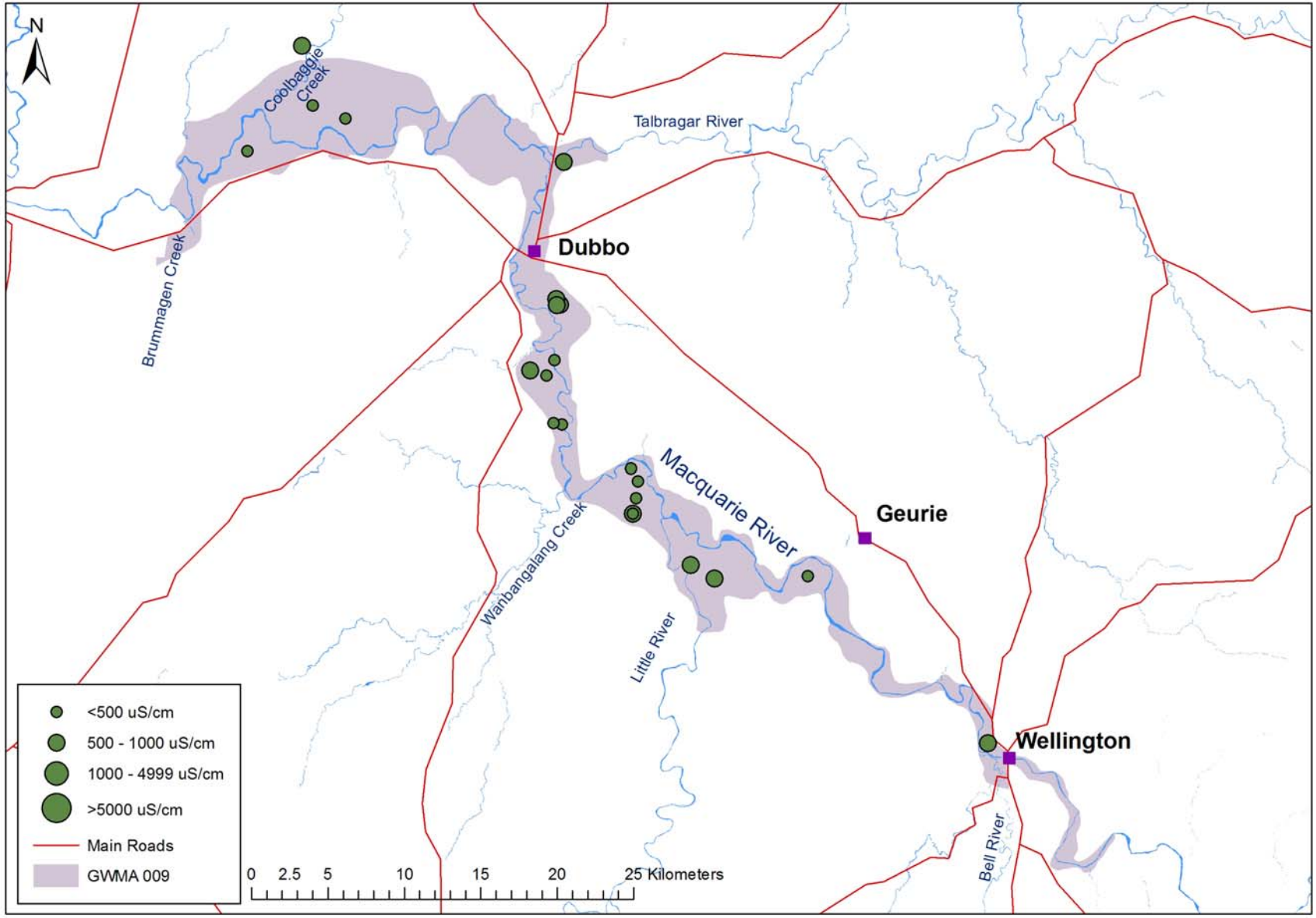


Figure 41 Electrical conductivity of groundwater in Tertiary alluvium



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