Groundwater connections between the Walloon Coal Measures and the Alluvium of the Condamine River

A Report for the

Central Downs Irrigators Limited

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1.0 Introduction

The Alluvial Plains of the Condamine River between Brookstead and Dalby are among the most productive of agricultural land in Australia. The area contains a mixture of both irrigated and dryland cropping, with water for irrigation obtained from groundwater resources, harvesting of overland flow and to a limited extent, the Condamine River. Water allocations are controlled, with demand heavily outstripping the available supplies.

Groundwater has been subject to restrictions on further development since the early 1970s, and over recent years, groundwater allocations have been reduced in an attempt to reduce use to the sustainable yield.

Any development or action that could impact on the yield of the groundwater resources of this region is a major concern to local landholders.

2.0 Geology

The alluvium of the Condamine River overlies the Clarence-Moreton geological Basin which is separated from the adjoining Surat Basin by the Kumbarilla Ridge, a sub-surface bedrock high. Both the Surat Basin and the Clarence Moreton Basin are part of the Great Artesian Basin. Figure 1 shows the structure of the Basins that underlie the Condamine River alluvial sediments

The sedimentary rocks that compose these large Basins generally slope to the west. The sediments lap over the Kumbarilla Ridge and are hydraulically connected over the ridge. They outcrop east of the ridge, with the younger formation, the Kumbarilla Formation generally outcropping to the west of the Condamine River, and the underlying formations outcropping further to the east, with much outcrop covered by the Condamine River alluvium. Closer to the Great Dividing Range, the basalts of the Main Range Volcanics also overlie the sediments of the Moreton-Clarence Basin.

The surface geology is shown on Figure 2. The main groundwater resources occur in the alluvial sediments and also in the basalt. Within the alluvium, the extent of the productive groundwater area is in central part. The western part of the mapped alluvium (as shown on the figure 2) is superficial and contains no large groundwater reserves.

The alluvium is up to 150 m deep, and consists of sand, gravel and clay. It has quite significant clay in its upper sequence and this inhibits direct recharge from rainfall. Over much of the area, the alluvium is underlain by the Walloon Coal Measures, the Formation that is targeted for Coal Seam Gas (CSG) production. In many areas, the Springbok Sandstone lies between the Walloon Coal Measures and the alluvium, but this is mostly identified by the coal company geologists. Most water wells intersect sandstone, shale or coal below the alluvium (as logged by the drillers) and this has historically been referred to as the Walloon Coal Measures. There is little data to identify if they have separate hydrological properties, but generally they appear to be hydrologically connected.

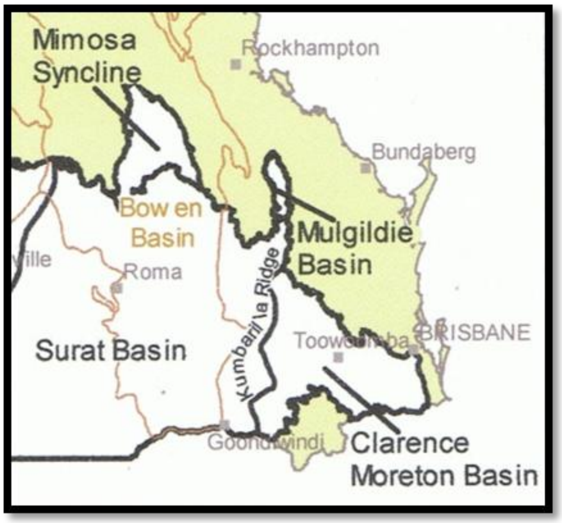

Figure 1 –Structure and Basins of the Eastern part of the Great Artesian Basin (From Queensland Government, 2005)

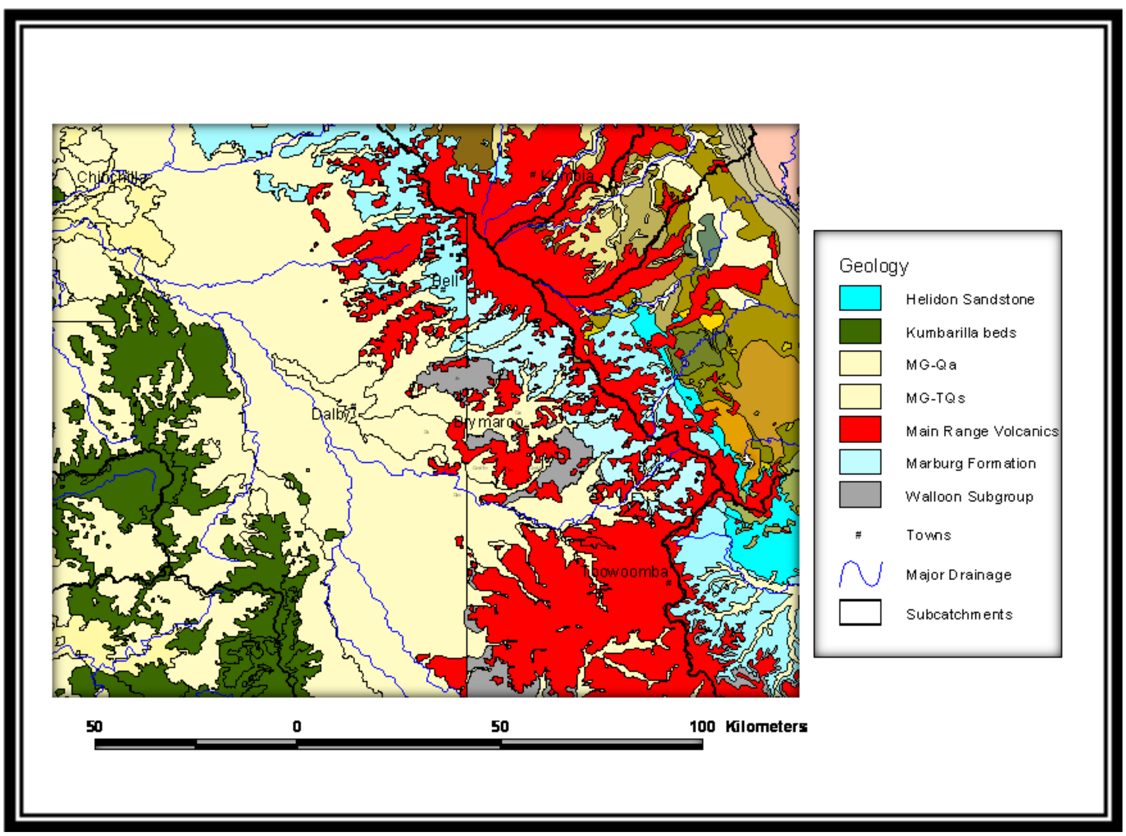

Figure 2 – Surface Geology of the Condamine Plains area. (From Queensland Department of Natural Resource and Mines)

The Walloon Coal Measures are reported to be up to 650 m thick (Exon, 1976). In this investigation area, the thickness is about 500 m at its maximum, but generally less. The formation consist of sandstone, siltstone, carbonaceous mudstone and coal, and lies conformably over the underlying Hutton or Marburg Sandstones. The coal seams vary in both thickness and quality, and often appear to not continuous. Figure 3 shows the relationship of the Walloon Coal Measures to the other Formations across this area. The alluvial sediments overlie these sediments.

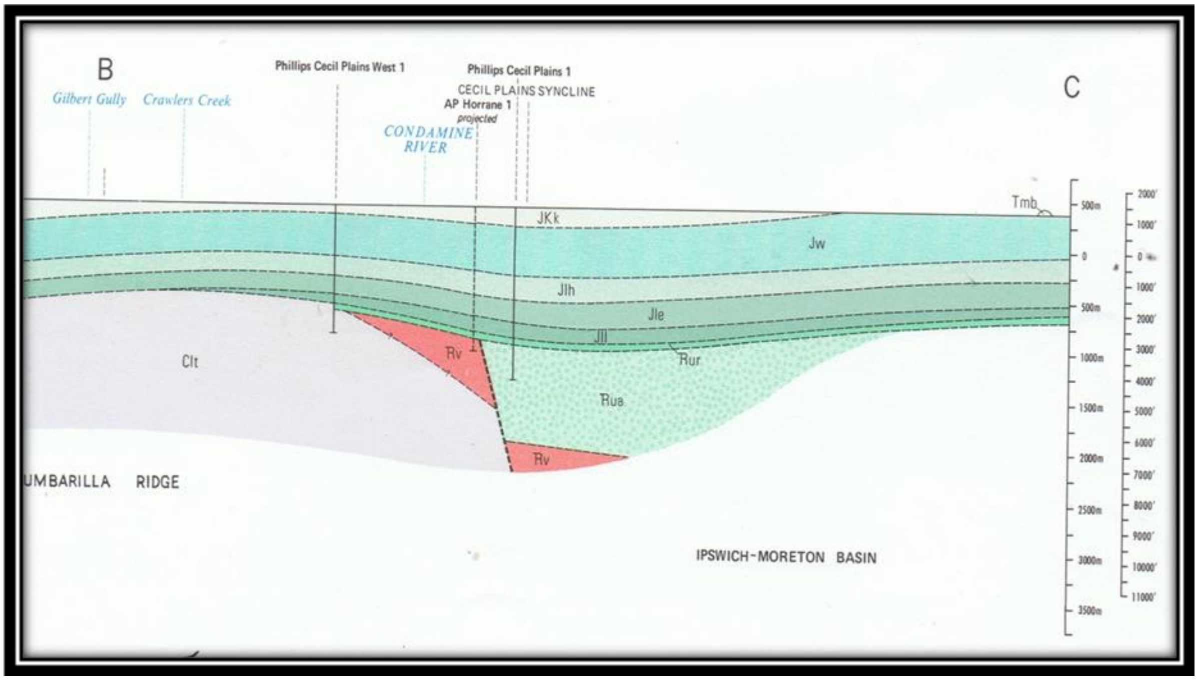

Figure 3 – Geological Section Through Cecil Plains to Mt Maria. (From Exon et al, 1972). The Kumbarilla Ridge at "B" separates the Surat Basin to the west from the Clarence Moreton Basin. The Walloon Coal Measures (Jw) overlies the Hutton Sandstone (Jlh) and other GAB sediments. The Condamine River alluvium has eroded a channel into the Kumbarilla Beds (JKk) and the Walloon Coal Measures and filled the eroded channel with clay, sand and gravel.

3.0 Hydrogeology

3.1 Alluvial Sediments

The alluvium of the Condamine River has been deposited in a broad valley, and consists of unconsolidated clay, silt, sand and gravel. The groundwater in the sand and gravel aquifers has been accessed since the early 1960s for irrigation purposes, but by the 1970s, it was obvious that groundwater was being used in excess of the rate of recharge. Groundwater levels were falling, and the Queensland Government introduced conditions on water licenses that restricted the drilling of new bores, metered the use of water from existing bores and imposed limits on use by the implementation of a water entitlement system. Several bores have been selected to show the rate of depletion of the groundwater. These are outlined in Table 1, with the bore locations shown on

Figure 4, and the plots of the water levels over time in Figures 5 (a) to 5 (f). Some of the shallow monitoring pipes have gone dry as the groundwater levels have fallen to below their bottom. All bores show a consistent downward trend, emphasising that use is in excess of the natural recharge.

Table 1 – Details of selected bores tapping the alluvial aquifers in the Condamine, with hydrographs shown on Figures 5(a) to 5(f).

Bore RN	Elevation	Latitude	Longitude	Log	Depth Shallow Pipe (B)	Depth Deep Pipe (A)
42230047	387.58	27°43'02"	151°26'23"	0 m-clay, minor sand		
				46.3 m-sand & gravel	49.7 m	
				49.5 m-clay, minor gravel		
				68.6 m-sand & gravel		73.2 m
				73.2 m-blue clay, sandstone (EOH 86m)		
42230062	369.04	27°41'43"	151°16'04"	0 m-clay, claybound sand, dry sand & gravel		
				15.2 m-sandy clay (moist)	18.0 m	
				18.3 m-sandy clay		
				24.1 m-sand & water (EOH 26.8m)		26.1 m
42230096	357.56	27°32'32"	151°15'50"	0 m-clay, claybound sand & gravel		
				14.0 m-silt & clay		
				22.3 m-clay	18.6 m	
				26.2 m-gravel & clay		
				31.1 m-clay (EOH 32m)		30.8 m
42230113	357.21	27°39'57"	151°19'42"	0 m-clay, sandy clay		
				19.5 m-sand, minor clay	23.8 m	
				24.1 m-layers of clay & sand & silt – some coarse sand layers (EOH 72.2m)		54.4 m
42230160	340.28	27°10'12"	151°13'39"	0 m-Sand, silty sand & sandy clay		58.6 m
				93.3 m-Sand & gravel with clay bands		
				124.4 m-Shale, coal and sandstone, (EOH 134.1 m).		
42230159	338.77	27°09'56"	151°12'54"	0 m-clay, sandy clay		
				59.5 m-silty sand & clay		
				65.3 m-clay, minor sandy layers		
				104.6 m-sand, minor clay (EOH 119.4m)		118.6 m
42230148	343.52	27°23'24"	151°15'35"	0 m-clay, sandy clay & gravel		
				33.2 m-sand & gravel	34.2 m	
				35.2 m-clay, sandy clay		
				48.2 m-sand & gravel, some clay		54.0 m
				58.2 m-sandstone (EOH 76.2m)		

Figure 4 – Location of selected alluvial bores

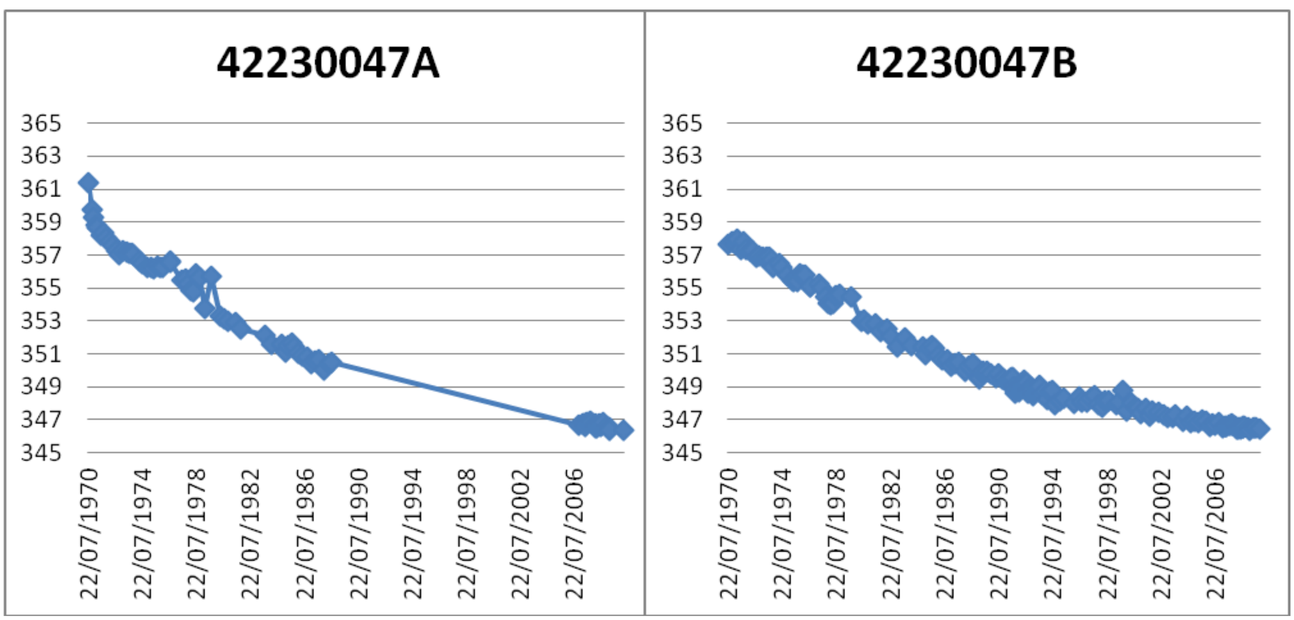

Figure 5 (a) – Bore 42230047 Hydrographs; 42230047A pipe seated at 314.4 m; 42230047B pipe seated at 337.9 m.

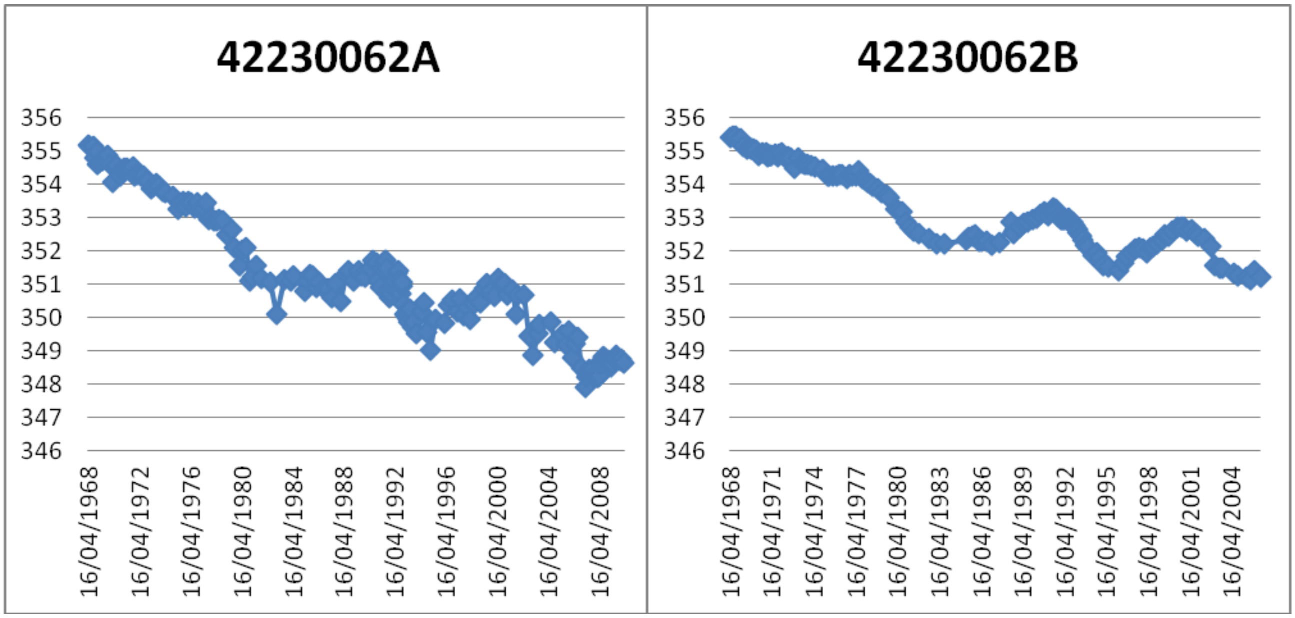

Figure 5 (b) – Bore 42230062 Hydrographs; 42230062A pipe seated at 342.9 m; 42230062B pipe seated at 351.0 m.

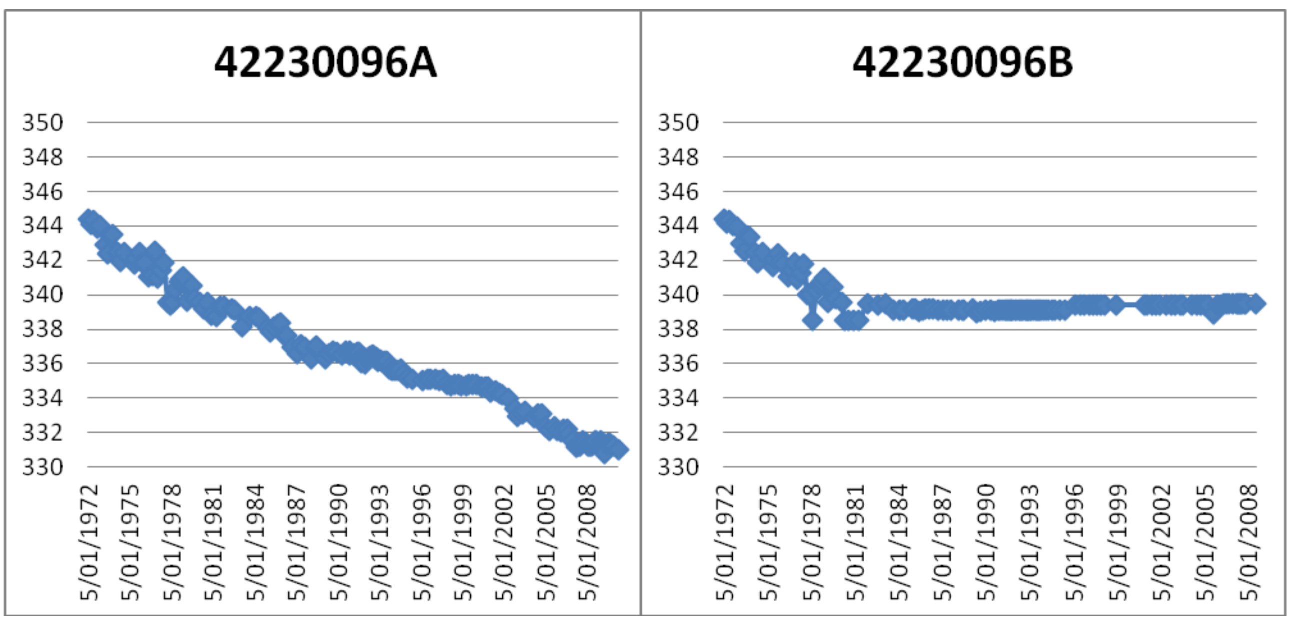

Figure 5 (c) – Bore 42230096 Hydrographs; 42230096A pipe seated at 326.76 m; 42230096B pipe seated at 339.0 m.

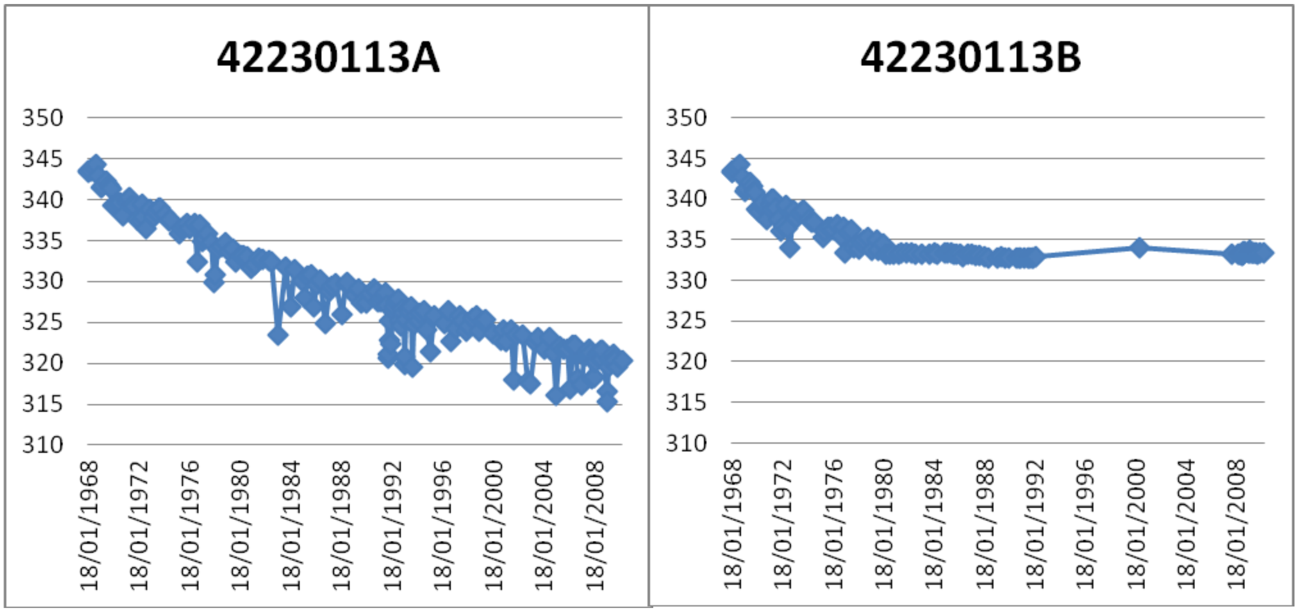

Figure 5 (d) – Bore 42230113 Hydrographs; 42230113A pipe seated at 302.8 m; 42230113B pipe seated at 333.4 m.

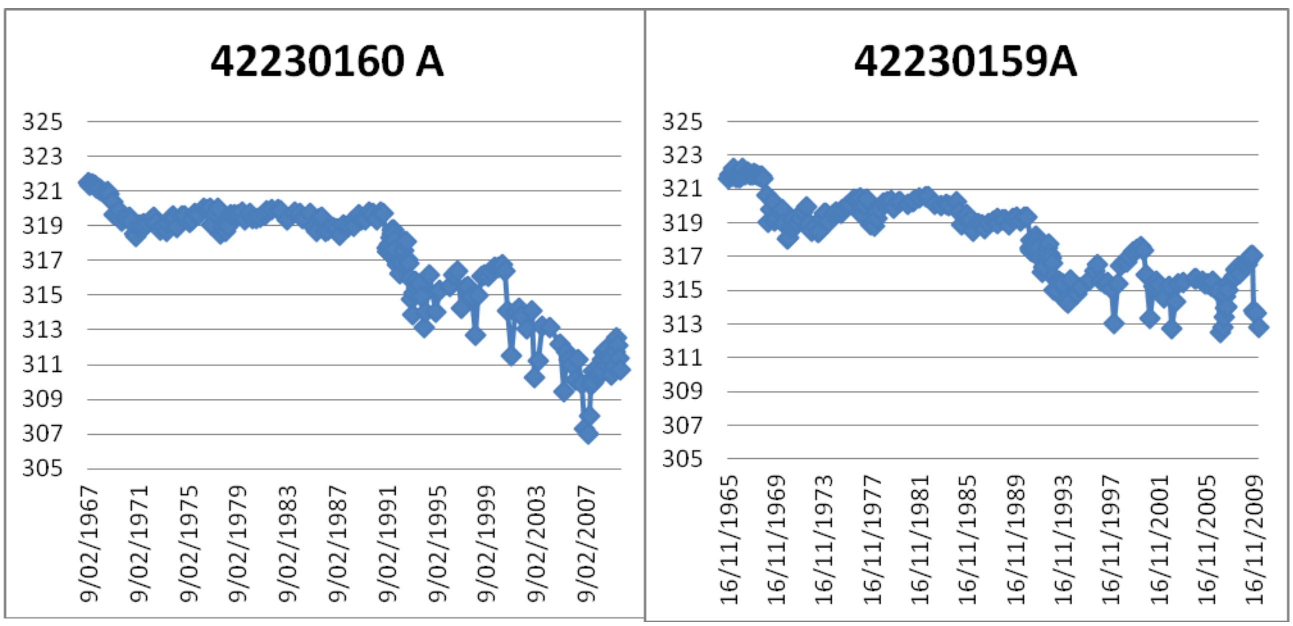

Figure 5 (e) – Bore 42230160A hydrograph; pipe seated at 281.7 m; 42230159A hydrograph, pipe seated at 220.2 m.

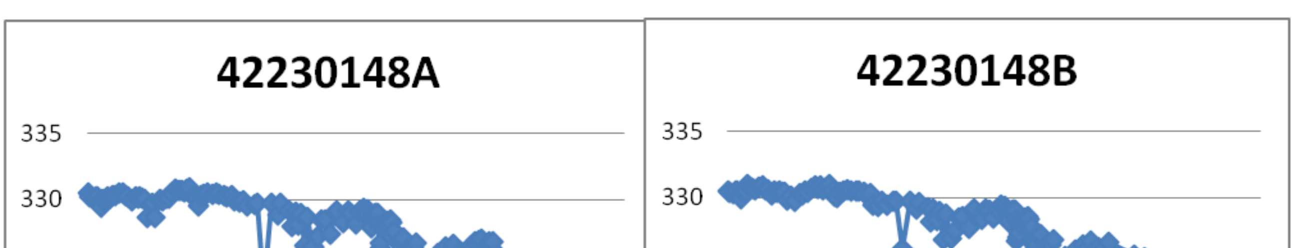

Figure 5 (f) – Bore 42230148 Hydrographs; 42230148A pipe seated at 289.5 m; 42230148B pipe seated at 309.3 m.

SKM (2002) carried out an investigation of the alluvial area between Pittsworth and Dalby, basically the current area of concern. Their estimate of groundwater use at that time (2001) was 40,000 ML. Irrigation bores in the Condamine Groundwater Management Area are all metered, but a small part of the SKM investigation was outside this area.

Although groundwater is supplemented by supplies from other sources (harvesting of overland flow, river diversions etc), in drought times the groundwater is often the only reliable source of irrigation water for the landholders. SKM constructed a groundwater flow model of the area, and following calibration of the model came up with the figures for the groundwater water balance in the modelled area of the alluvium, in Table 3.

Table 3 – SKM (2002) calibrated Groundwater Water Balance.

WATER IN (ML / YEAR)		WATER OUT (ML / YEAR)	
Rainfall recharge and Irrigation recharge	20402	Groundwater pumping	44379
River recharge	11539	Down-catchment aquifer flow	12568
Abandoned channel recharge	0	Leakage to basement	0
From eastern flank	1604		
From up-catchment aquifer	1163		
From western flank	441		
From Oakey Creek alluvium	0		
TOTAL	**35149 ML/YEAR**	**TOTAL**	**56479 ML/YEAR**

This indicated that there is some 21,330 ML of groundwater coming out of the system in excess of that which is replaced by recharge and other processes. Included in the "in" processes is inflow from the eastern and western flanks. This is water from adjoining/underlying formations as a positive gradient existed between the groundwater in the underlying formation (Walloon Coal Measures) and the alluvium. In this report, SKM estimated this as 2045 ML/Year.

SKM considered that at that time, there was only transfer of groundwater into the alluvium from other formations, not transfer out to the surrounding formations.

3.2 Walloon Coal Measures

The Walloon Coal Measures contains consolidated sediments – sandstone shale, mudstone and coal. Its depositional environment was in swamps, lakes and sluggish streams (Exon, 1976). However, most of these sediments contain poor quality water, probably derived from remnant salt from salt water intrusions into the swamps during deposition. In addition, generally the sandstones have a low permeability, and supplies from these are usually quite small – stock water supplies only. The coal seams contain the most water – in their fractures and joints. Water in the coal can be variable in quality, with some reasonable quality in some areas, but mostly it is brackish to saline.

Because these sediments have never been treated as a significant resource for water, its resources have been poorly monitored. Very few bores have been constructed to monitor either water levels or quality. The bores that access the Walloons and are monitored are shown on Figure 6, with water level plots shown in Figures 7(a) to 7 (e).

Of interest is the east – west line of bores 42231211 to 42231214. The bores closest to the alluvial edge show a fall in water level, with the fall decreasing away from the alluvial edge until bore 42231214 shows a rising trend.

Bore 42231390, located in the Walloon Coal Measures under the alluvium west of Dalby, shows a falling trend since 1990, very comparable to the nearby by alluvial bore 42230160. Other Walloon bores to the east of the river show some falls (e.g. 42231358, 42231135), though bore 42231340 shows a slight rise.

It is evident that the geology of the Walloon Coal Measures is complex, with non-continuous beds, thickening and thinning of layers (shales, sandstone and coal) and varying hydraulic connections between layers. However, based on the very limited hydrological information available, it appears that the formation does act as a single unit with one piezometric surface and with general movement of groundwater to the west.

Figure 6 – Location of bores monitoring the Walloon Coal Measures

Figure 6(a) - The area covering bores 42231211 to 42231214 in Figure 6 has been enlarged.

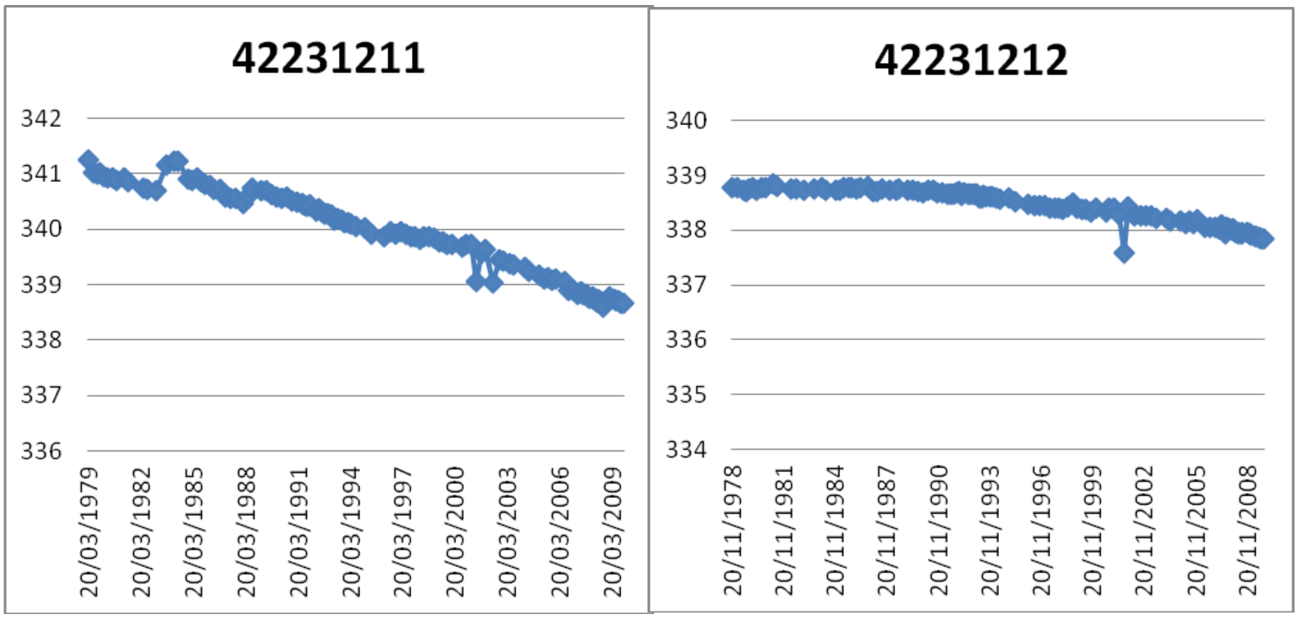

Figure 7(a) – Hydrographs for Bores 42231211 and 42231212, tapping the Walloon Coal Measures

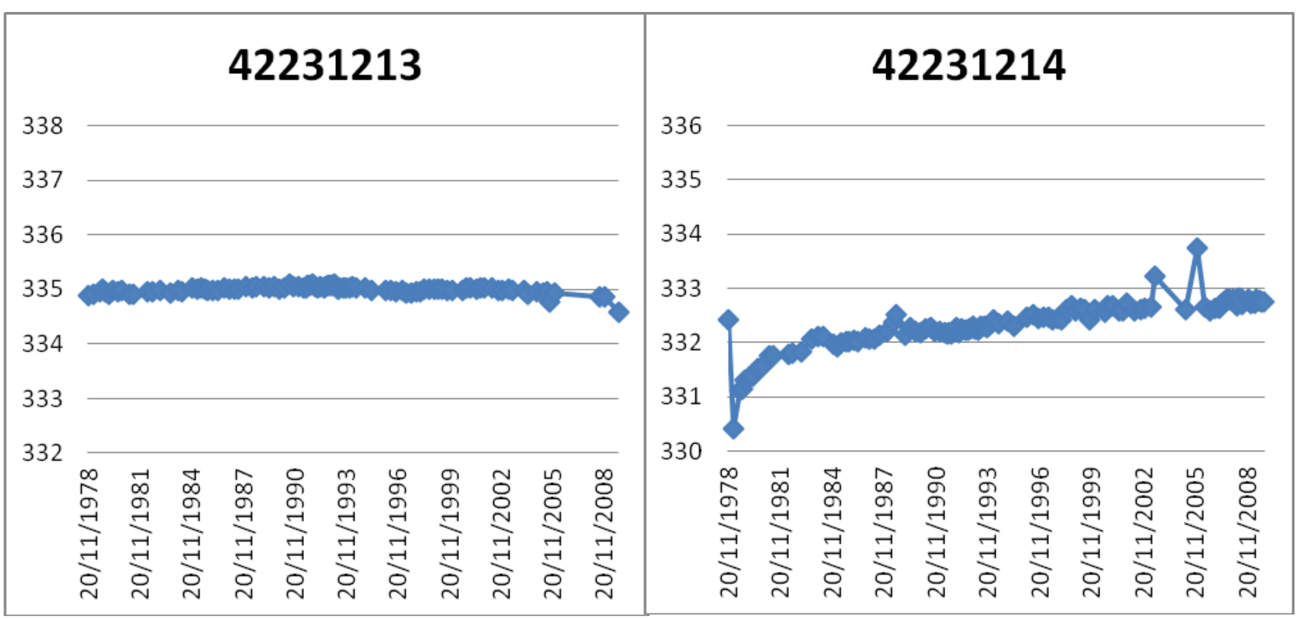

Figure 7(b) – Hydrographs for Bores 42231213 and 42231214, tapping the Walloon Coal Measures

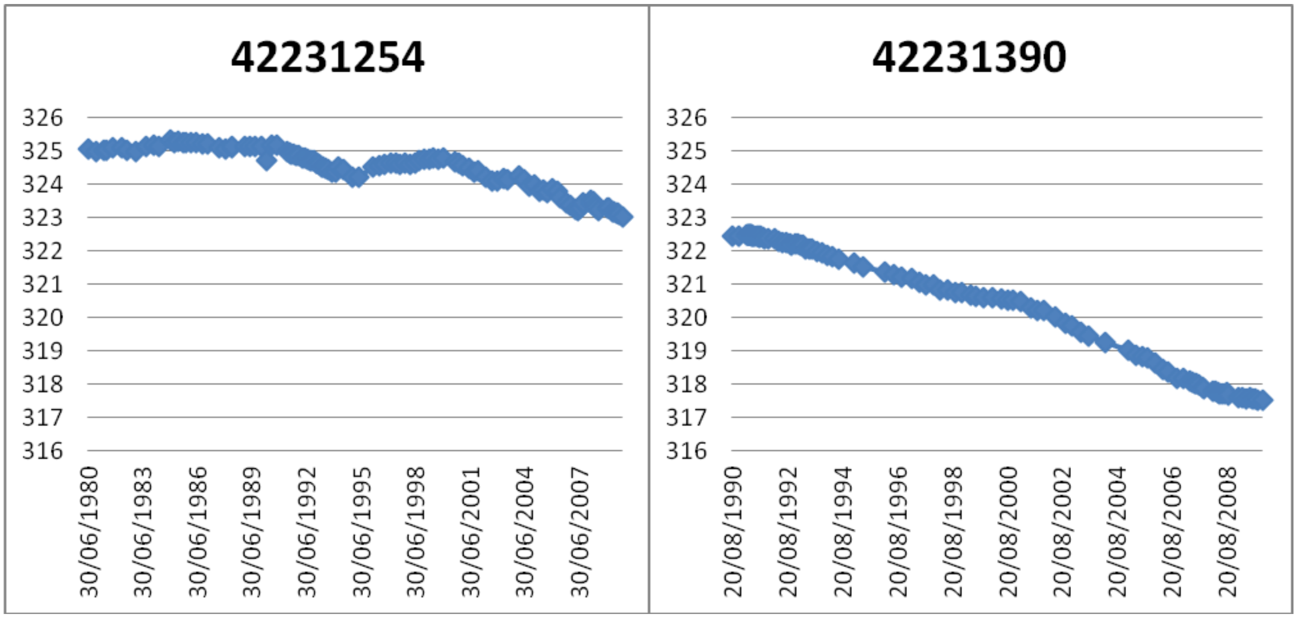

Figure 7(c) – Hydrographs for Bores 42231254 and 42231390, tapping the Walloon Coal Measures

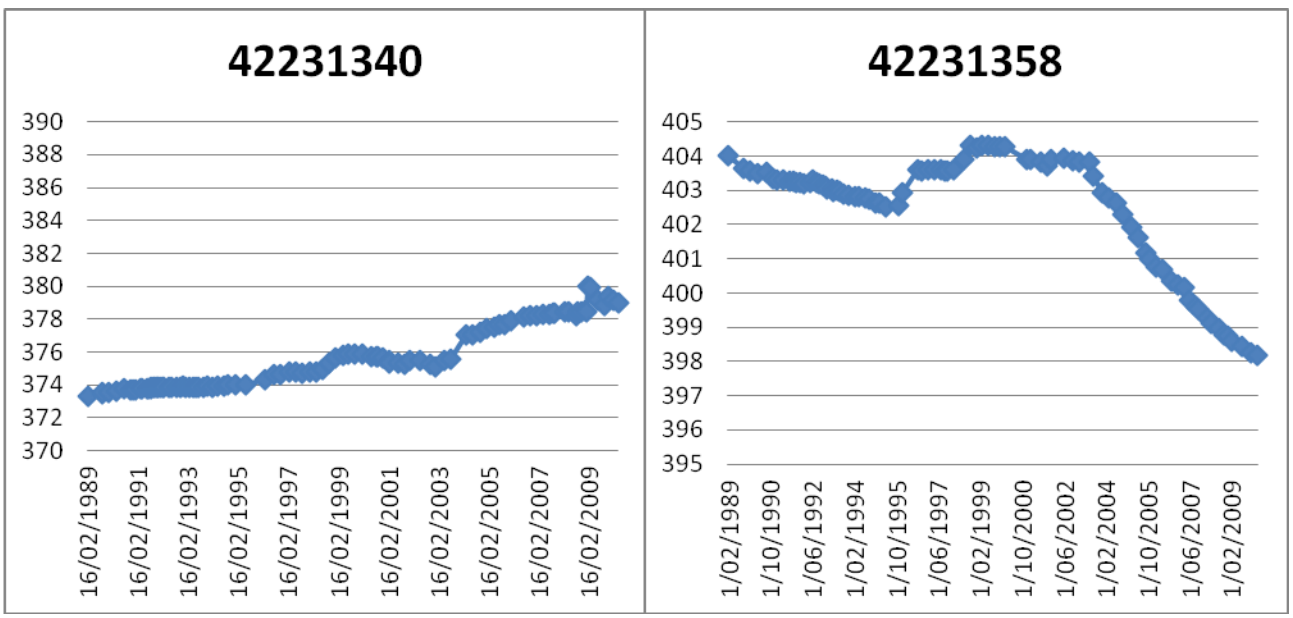

Figure 7(d) – Hydrographs for Bores 42231340 and 42231358, tapping the Walloon Coal Measures

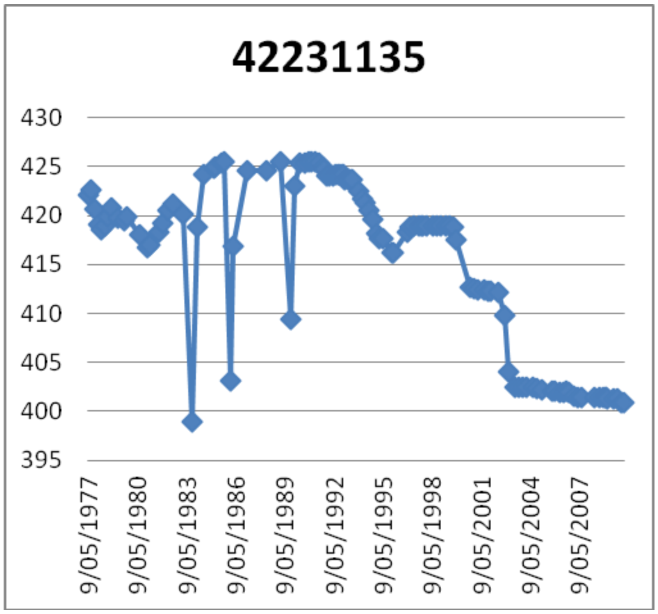

Figure 7(e) – Hydrographs for Bores 42231135, tapping the Walloon Coal Measures

3.3 Water Quality

There are significant differences in the water quality of these two formations. The alluvial sediments generally will contain much younger water, and be subject to more localised recharge. It would be expected to contain much better water quality than the Walloon Coal Measures, which has limited local recharge, and contains remnant salt.

There was a significant program of water sampling conducted by DERM (or its predecessor, QWRC) in 1988. There has not been such an extensive sampling program since then, and the 1988 data has been used in this analysis.

<u>3.3.1 Alluvial Groundwater Quality</u>

Table 4 contains an abbreviated water analysis from the alluvial bores that are shown on Figure 8. This figure also contains the electrical conductivity measurements of the water and these highlight the change in water quality in the alluvium in a downstream direction. (The electrical conductivity provides a guide to the total dissolved salts, with sea water having a conductivity of about 55,000 µS/cm, and the maximum for general human consumption about 1,500 µS/cm). There is generally little within the alluvial sequence that will drastically change groundwater quality – natural recharge is from rainfall and stream flow, both providing good quality water with low salt content. The recharge figures from SKM (2002) indicate that over 90% of recharge comes from these sources. The increase in dissolved salts (indicated by the conductivity readings in Figure 8) has to be caused by the inflow of poor quality water from underlying strata – mostly the Walloon Coal Measures, with inflow from both the edges of the alluvium and upwards from the bottom. There may be a small amount from concentration of salt in the soil water by evapotranspiration.

The increase in the dissolved salt content in the downstream alluvium is almost totally due to an increase in the sodium and chloride concentration.

Table 4 – Water Quality in the Alluvial sediments

Bore Number	Conductivity (µS/cm	Total Dissolved Solids (mg/l)	Sodium Adsorption Ratio	Na*	Ca*	Mg*	HCO_3*	Cl *	SO_4*
42230047A	910	553	3.3	115	43	29	390	125	7
42230047B	810	543	3.3	115	39	33	420	105	4
42230062A	495	308	3.5	77	20	10	245	39	2
42230096A	660	416	4.5	110	25	12	340	51	7
42230096B	950	615	5.2	160	40	20	395	135	12
42230113A	700	434	2.6	84	32	29	385	39	15
42230148A	1800	1055	7.6	290	36	45	435	350	73
42230148B	3200	1882	15.3	600	32	51	445	780	165
42230159A	6200	3730	16.5	1100	67	160	365	2050	125
42230160A	6000	3600	16.0	1050	94	140	325	1950	160

* = Concentration in milligrams/litre (mg/l)

Figure 8 – Location of alluvial bores ("A" pipes only), with the conductivity in µS/cm shown in brackets.

3.3.2 Walloon Coal Measures Water Quality

The water quality in the Walloon Coal Measures varies from reasonable and suitable for stock to some that has a conductivity greater than 10,000 µS/cm and is unsuitable for most purpose. The quality generally appears to be better east towards Toowoomba, which is to be expected, as the groundwater flow direction is from the east to the west (i.e. away from the area of recharge). There are many properties that do rely on bores in the Walloon Coal Measure for stock water, but anomalies occur in some areas with some bores having very poor quality. This is probably due to isolated pockets or lenses where historically there may have been virtually no through flow to flush out or dilute salt. Exposure of such lenses either by bores or from erosion may release these salts. Table 5 gives the quality in the Walloon bores, with their location and conductivity shown on Figure 9.

The east – west line of bores tapping the Walloon Coal Measures, bores 42231211 to 42231216 (refer section 3.2) show an increase in conductivity further from the alluvial edge. The conductivity varies from 1200 µS/cm near the alluvium to 14,000 µS/cm further away, indicating past interaction of the groundwater in the alluvium with that in the Walloons.

Table 5 – Water Quality in the Walloon Coal Measures

Bore Number	Conductivity (µS/cm	Total Dissolved Solids (mg/l)	Sodium Adsorption Ratio	Na*	Ca*	Mg*	HCO_3*	Cl *	SO_4*
42231135A	1100	610	12	220	12	9	495	4	2
42231211A	1200	730	5.9	190	38	25	405	195	19
42231212A	1500	890	17.5	300	8	8	165	395	33
42231213A	4200	2420	16.0	740	63	62	310	1250	80
42231214A	3000	1680	26	600	24	10	295	880	2
42231216A	14000	8414	35	2750	220	150	250	5100	37
42231254A	17500	11000	49	3700	93	205	0	6500	360
42231255A	8800	5130	12	1200	400	205	190	3150	8
42231340A	24500	18154	26	4550	920	850	280	10000	1650
42231358A	1250	719	5.1	180	53	25	370	225	27

* = Concentration in milligrams/litre (mg/l)

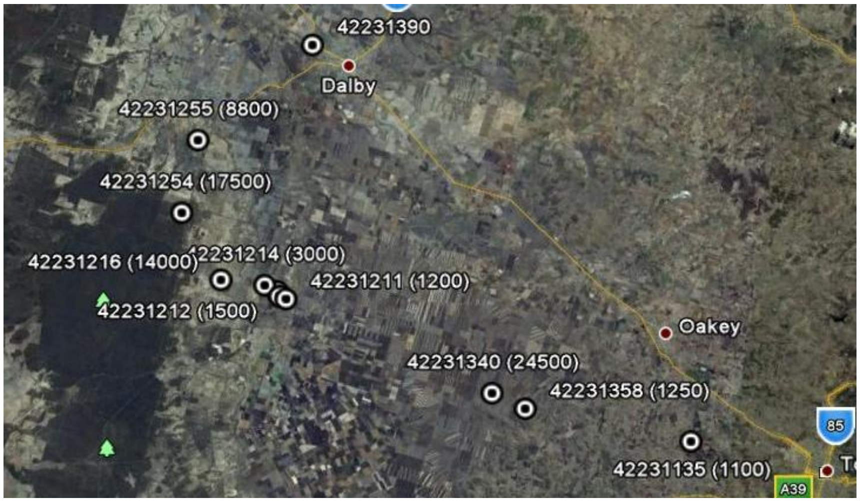

Figure 9 – Location of Walloon Coal Measure bores, with the conductivity in μS/cm shown in brackets.

4.0 Interaction between the Groundwater in Alluvium and the Walloon Coal Measures

The groundwater in the alluvium recharges mostly from rainfall infiltration and from the river. SKM (2002) calculated that, in their project area, recharge from the river and from rainfall and from irrigation water penetration amounts to 31,941 ML/year out of a total recharge of 35,139 ML/year. Groundwater movement is basically downstream, but a depression in the piezometric surface has developed as a result of water pumped from the aquifer for irrigation purposes. Figure 10, from SKM 2002, shows the surface as it was in 2001, with the depression in the surface evident.

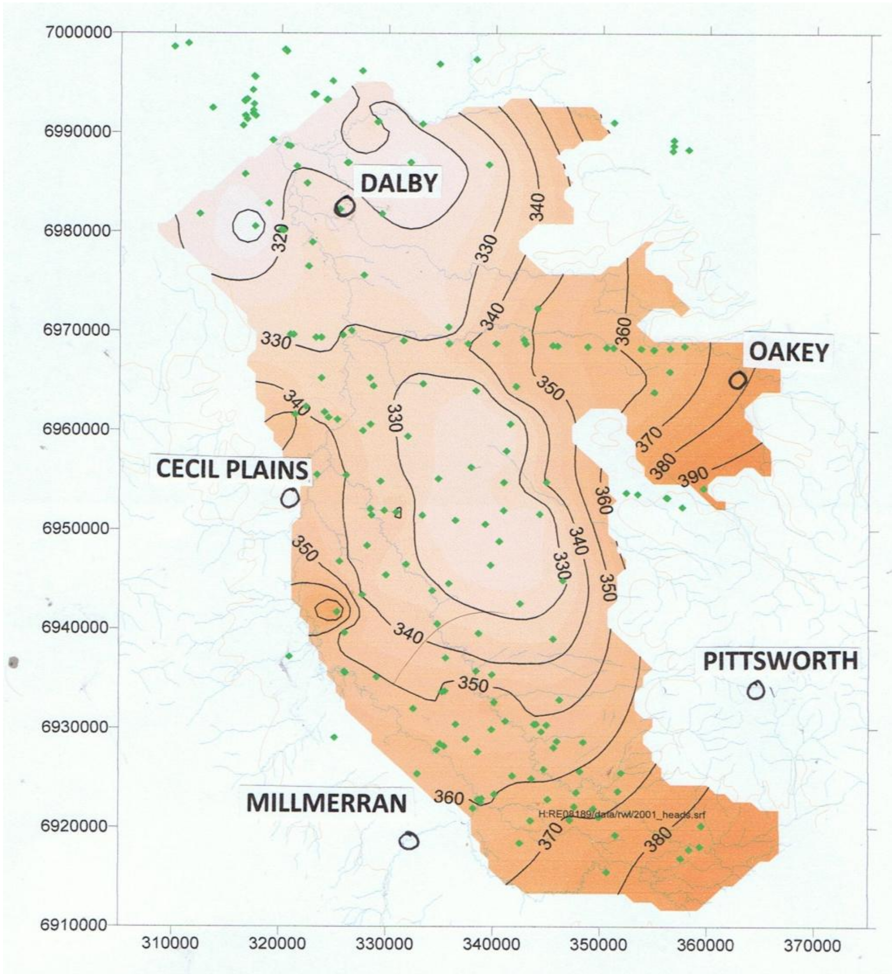

Figure 10 – The piezometric surface in the Condamine alluvium in 2001. (From SKM, 2002)

The contours of the groundwater piezometric surface in the Walloon Coal Measures is difficult to derive as there are few dedicated monitoring bores from which accurate information can be obtained. Hence data from private bores that tap these sediments have been used, but the water levels are spread over several years, thus affecting the contour accuracy. However they do give a very good indication of the direction of flow of the groundwater and are shown in Figure 11. Flow is to the west, with evidence that there is vertical discharge into the overlying alluvium of Oakey Creek (near the centre of this figure) and into the Condamine River alluvium (in the north west of the figure), where the streams have cut into the Walloon strata.

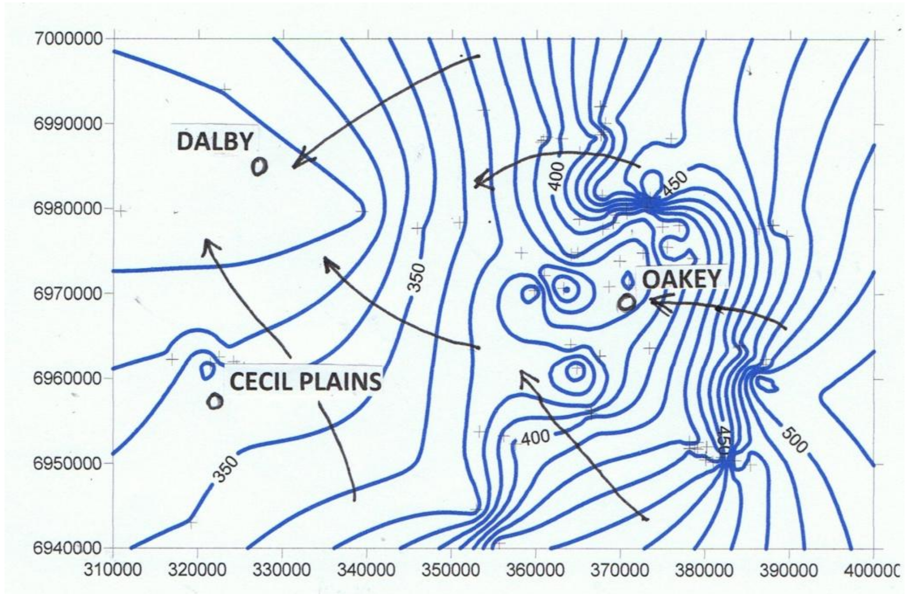

Figure 11 – Contours of the Piezometric surface in the Walloon Coal Measures.

Vertical discharge of groundwater from sediments in the Great Artesian Basin (GAB) has been well recorded. Initial investigation were carried out by Woods et al (1990) in investigations into discharge from the GAB near Lake Eyre in South Australia and their work has been widely utilised. Cox and Barron (1998) consider that up to 45% of the total discharge from the GAB can be accounted for by upward leakage. Welsh (2006), in the calibration of a transient model of the GAB, calculated a maximum vertical leakage of 88 mm per year out of parts the Basin, with an average leakage of 0.9 mm per year. However, for any leakage to occur there must be an upward gradient – the head of the groundwater in the underlying sediments must be greater than the head in the receiving bed (in this area, the Condamine River alluvium). If the head is higher in the overlying aquifer (the alluvium), the flow will be reversed, with the flow away from the higher head to the formation with the lower head, in this case, the Walloon Coal Measures.

Some work on this has been carried out on the hydraulic connections between GAB sediments and overlying alluvial sediments in southern Queensland. A detailed investigation into the possible effects of use from the GAB across the New South Wales – Queensland border (Sinclair et al, 2000) resulted in conclusive evidence that the alluvium of the Dumaresq/McIntyre River acts as a drain for discharge of water from the GAB. A similar conclusion was recently reached concerning discharge from the Walloon Coal Measures along Hodgson Creek. In both these cases, the higher head was in the deeper Great Artesian Basin sediments, and so the flow was to the alluvium.

In order to compare the relative groundwater heads between the alluvium and Walloon Coal Measures, an East – West section has been drawn, as shown on Figure 12.

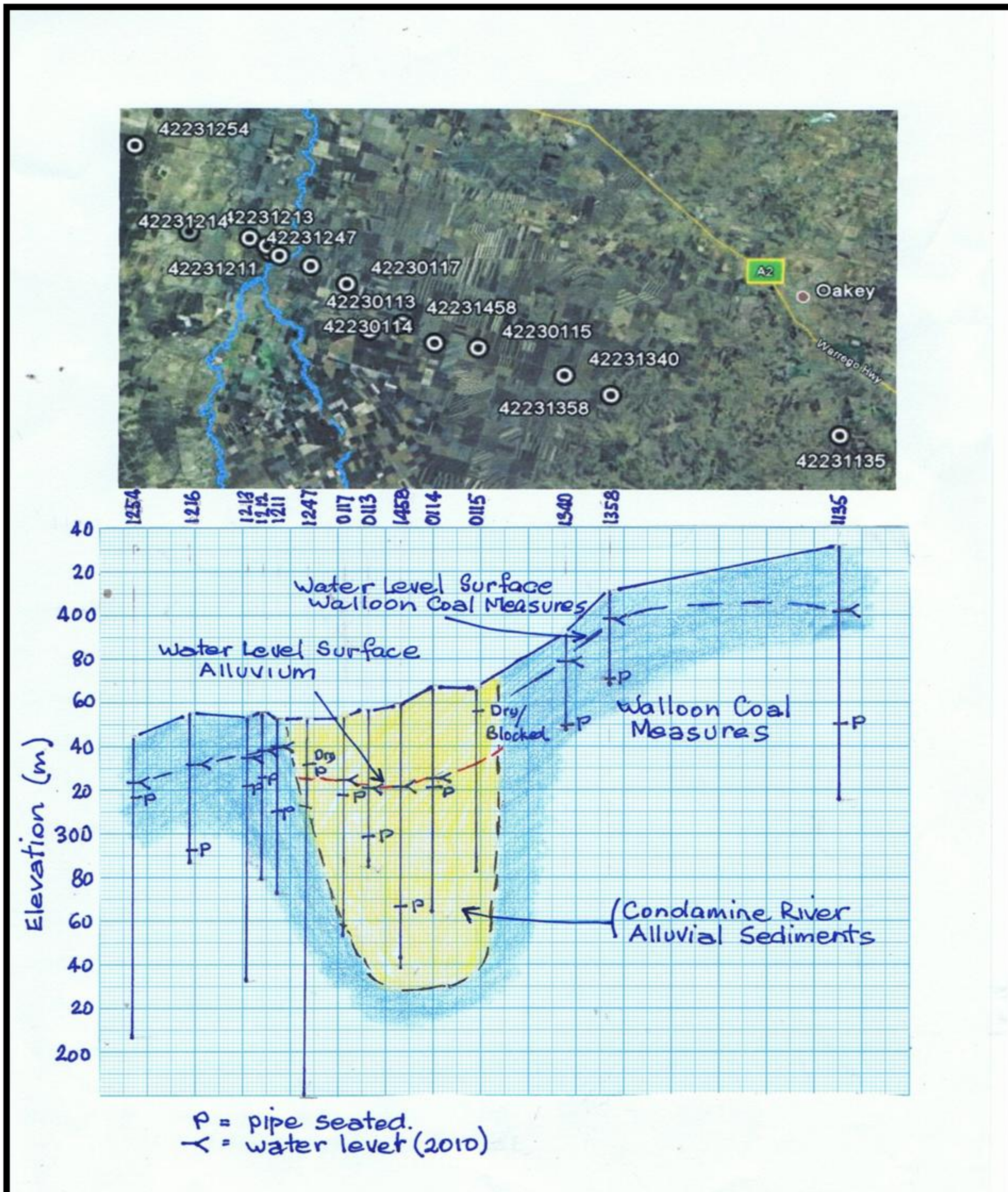

Figure 12 – East West Section showing the incision of the Condamine River into the Walloon Coal Measures and the groundwater level in each, with bore locations. The bores in the section have been projected from the plan above.

This section clearly shows that the Condamine River has carved an old valley into the underlying Mesozoic sediments, predominantly the Walloon Coal Measures. Although the Coal Measures consists of multiple layers sandstone, shale, siltstone and coal beds which vary in thickness, there appears to be one main piezometric surface. The section in figure 12 indicates that the monitoring bores are of quite different depths, but the water levels form a consistent level that slopes to the west. This surface is interrupted by the Condamine River alluvium. The groundwater surface in the alluvium is lower than that in the Walloons, and therefore a gradient exists between the two groundwater systems. This gradient would promote movement of groundwater from the Walloons into the alluvium.

Before there was development of the area and subsequent groundwater use, the two groundwater systems would have developed a type of equilibrium. There would have been some interaction between the two systems, dependent mostly on seasonal conditions. The majority of discharge, though, would be from the less permeable Walloons into the alluvium, resulting in a general mixing of the two waters in the alluvium. The quality of the groundwater decreases downstream, as shown in Figure 8, with the addition of more saline water.

The fall in water levels in the alluvium that has resulted over the last 40 years has increased the gradient between the two. This appears to have induced a fall in the water levels in the Walloons as well, especially those close to the alluvial edge or penetrating the Walloons beneath the alluvium (e.g. Bore 42231390). There is insufficient use of water from the Walloon Coal Measures for the use to cause these observed water level falls. The water is used mostly for stock, with the odd bores that tap the formation near the alluvium equipped with low producing wind mills.

The hydraulic connection between the two groundwater systems will cause water to move when a gradient exists. The water quality deterioration in the alluvium is indicative of movement from the Walloon Coal Measures to the alluvium. Should the gradient be reversed, it would be expected that movement of groundwater would be from the alluvium to the Walloon Coal Measure aquifer.

5.0 Rate of Groundwater Movement

There is very little data on which even rough estimates of water movement from one formation to another can be based. It basically depends on the permeability of the strata through which the groundwater has to move and the head difference that is driving the movement.

Horizontal movement of groundwater along individual beds can usually be calculated, as bores tapping the aquifers (the permeable horizontal beds) can be tested and the transmissivity and permeability of the aquifer calculated. Vertical permeability through what are generally considered to be confining beds is very small by comparison and movement much slower

Interaction of groundwater between the two formations will occur from horizontal movement at the edges where the alluvium has cut down into the Coal Measures, and also from vertical movement where the formations are in contact at the bottom of the alluvium. The latter can be significant if more permeable beds directly underlie the alluvium.

The permeability or hydraulic conductivity of the strata between the water in the Walloon Coal Measures and the alluvium can only be estimated at this stage. Golders Associates, (2009), modelled the likely impact of Coal Seam Gas extraction in the Surat Basin. They quote K values for the coal beds in the Walloon Coal Measures at about 1.4 m/day, and for the aquitard layers, 1×10^{-1}

to 1 x 10^{-4} m/day. These values are for horizontal hydraulic conductivity. They state that vertical values are considered to be between 100 to 1000 time less, due to the horizontal bedding of the sediments.

The beds that are in contact where the formations adjoin plays a very large part in the rate of movement from one formation to the other. Obviously contact between sand and gravel in the alluvium with more permeable beds such as sandstone and fractured coal in the Walloons will result in more movement of groundwater than through clay and shale.

Some testing needs to be carried out in order to determine the permeability of the sediments that separate the coal seams that will be dewatered from the alluvial sediments that contain the groundwater that is used for irrigation. It is essential that this possible transfer of water from the alluvium to the coal seams that contain the gas and will be dewatered be quantified. There has been movement from the Walloon Coal Measures to the alluvium in the past, and with the decrease in pressure in the Walloons, this reversal of gradient must have an effect.

Because the hydraulic conductivity of some beds is so low, there could be a substantial time lag between the commencement of the gradient reversal and the equilibrium rate of transfer of water.

6.0 Conclusions

From a detailed examination of available data on bores in the Cecil Plains area, it is concluded that:

- The alluvium of the Condamine River is incised into the Walloon Coal Measures
- The groundwater levels in the alluvium are generally falling, and have been trending downwards for the past 40 years
- The water levels in the alluvium are lower than those in the Walloon Coal Measures
- Water quality information points to a transfer of water from the Walloons to the alluvium
- If water can move from the Walloons to the alluvium, if the gradient is reversed, groundwater will move in the other direction
- There is insufficient information available on the likely dewatering level or the hydraulic conductivity of the beds between the coal seams and the alluvium for volumes of flows to be calculated.
- Because of the very real likelihood of movement of groundwater from the alluvium to the Coal Measures, more data is required to allow the calculation of the volumes that could be involved.
- A program should be instigated to obtain the data required - the permeability of the various strata that lies between the alluvium and the coal seams, water levels in the Walloon Coal measures, volumes that will be pumped etc.

7.0 Recommendations

From the findings in this report it is recommended that the following investigation be undertaken:

1. A comprehensive monitoring network be established to obtain heads at various depths in the Walloon Coal Measures. It is considered that bores with monitoring pipes isolated at depths of about 50 m, 150 m and 300 m (depending on strata) need to be constructed to a high standard. Site locations and total number of those monitoring bores are dependent on possible mining locations.

2. A number of bores to monitor the Walloon Coal Measures underlying the alluvium should also be constructed.

3. A study be undertaken to determine the horizontal and vertical permeability of various beds in the Walloon Coal Measures.

4. A groundwater flow model be developed and calibrated. The model would link the alluvial and Walloon aquifers, possibly using the existing alluvial model and using data obtained from 1, 2 and 3 above for the development of a Walloon model. The model could then be used to simulate the long-term changes and impact that the mining of Coal Seam Gas would have on the alluvial groundwater resources of the area.

5. That a decision on mining of Coal Seam Gas directly underlying the Condamine alluvium be dependent on the results of this study into the likely impacts.

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