8.0 Review / tabulation of groundwater data across the Galilee Basin study area tenements

The surface and subsurface geology varies considerably from the steeply dipping rocks near the faulted basin margin in the north and east, to the relatively flat lying sediments in the west, to the complex stratigraphic relationships at the edge of the Maneroo Platform. The analysis of the subsurface geology, groundwater stratigraphy, groundwater levels and groundwater quality was further complicated by the pattern of tenure ownership. Specifically, the GBOF member tenements are rarely contiguous. Additionally, there was a need to process and present the data in a manner that adequately protects the GBOF members' confidentiality. Furthermore, the tenements are in different stages of development.

The subsurface geology, groundwater stratigraphy, groundwater levels and groundwater quality data are presented and discussed for each of the active tenements in the following sections.

8.9 Summary of available data for ATP 813

The geographical centre of ATP 813 is located approximately 250 km north-north-east of Aramac (Figure 1.2). The southern portion of the 4,119 km^2 tenement is drained to the west by Aramac Creek. The northern portion of the tenement is drained to the west by Reedy Creek, the principal outlet from the ephemeral Lake Galilee. Lake Dunn and Lake Mueller are also located within the tenement boundaries (Figure 1.2).

8.9.1 Surface geology for ATP 813

The majority of the ATP 813 is covered with a thin layer of Quaternary alluvium (Figure 3.1). The Tertiary age Wondoola beds have been mapped as exposed along the major drainages by GSQ (Figure 3.1). The Ronlow beds outcrop on the eastern side of the tenement. Extensive north to south oriented outcrop Doncaster Member of the Wallumbilla Formation, occur in the tenement centre. The contact between the Doncaster Member and the younger Coreena Member of the Wallumbilla Formation is exposed in the south central portion of ATP 813. The younger Toolebuc Formation and Allaru Mudstone are exposed along the south-western tenement edge.

8.9.2 Exploration well drilling history for ATP 813

Eight exploration wells have been drilled within ATP 813 (Table 8.41). The exploration wells have been mainly drilled to explore for CSG resources. Two wells have been drilled to define the stratigraphy of ATP 813. The exploration wells were drilled to define the CSG potential on the tenement between 1993 and 2010.

The lithological details for the stratigraphic bores are not recorded in QPED for tenement ATP 813. Well completion reports are available for only two wells from Queensland Digital Exploration Reports (QDEX). Therefore, the subsurface assessment for ATP 813 has been supplemented using unpublished data.

Table 8.41 Drilling summary for ATP 813

Attribute		Count
Total number of wells		8
Type of wells	Stratigraphic	2
	Coal Seam Gas	6
Earliest spud date	23-Sep-93	
Latest spud date	2010	
Depth shallowest wells (m bKB)	64	
Depth deepest wells (m bKB)	1,301	
Average wells depth (m bKB)	932	

8.9.3 Water bore drilling history for ATP 813

DERM records 201 registered water bores within ATP 813 (Table 8.42). The first bore was drilled in 1891 (RN 1202) and the most recent bore was drilled on 27 October 2008 (RN 146099). The shallowest bore was drilled to 4.6 m bGL (RN 1038) and the deepest bore was drilled to 1,005 m bGL (RN 69980). The average bore depth is 183 m bGL.

Table 8.42 Summary of DERM registered water bores within ATP 813

Attribute		Count
Total number of bores		201
Type of bore	Artesian Bore--ceased to flow	7
	Artesian Bore--condition unknown	0
	Artesian Bore--controlled flow	23
	Artesian Bore--uncontrolled flow	13
	Subartesian facility	158
Bore Status	Abandoned and destroyed	67
	Abandoned but usable	0
	Existing	130
	Proposed	4
Earliest drill date	RN 1202	1891
Latest drill date	RN 146099	27-Oct-2008
Number of water bores in QPED		0
Depth of the shallowest bore (m bGL)	RN 1038	4.6
Depth of the deepest bore (m bGL)	RN 69980	1,005
Average bore depth (m bGL)		183

The water bores on this tenement are dominantly subartesian, and based on surface geology, likely to be screened in the shallow Quaternary alluvium, Tertiary sediments or the component sediments of the upper Rolling Downs Group sediments. There are 43 current or former artesian bores within ATP 813. Seven bores have ceased to flow and the flow is uncontrolled at 13 bores.

8.9.4 Subsurface geology for ATP 813

As noted above, there are limited well control data available to define the deep subsurface geology at ATP 813. The following discussion of the ATP 813 subsurface is based on details from Splitters Creek 1 (Table 8.43). The summary data presented in Table 8.43 are presented as they have been recorded in Splitters Creek 1 well completion report (QPED, 2011). Note that several formations that are documented elsewhere may not be presented in the stratigraphic details contained in Table 8.43.

The available data suggests that the basal Jurassic unconformity lies very near the surface along the eastern edge of the tenement (Table 8.43). The map of the basal Jurassic unconformity is shown on Figure 3.5. The Moolayember Formation / Hutton Sandstone contact outcrops or subcrops just east of

ATP 813. The basal Jurassic unconformity has been encountered at greater than 400 m bGL in recently drilled exploration wells in the western portion of ATP 813.

Table 8.43 Type stratigraphy for ATP 813—EAA Splitters Creek 1

Depth to formation top (m bKB)	Depth to formation bottom (m bKB)	Basin	Formation name	Age
1.4	426	Galilee Basin Sequence	Moolayember Formation	Middle Triassic
426	515		Clematis Sandstone	Middle Triassic
515	754		Rewan Formation	Late Permian to Early Triassic
754	826		Betts Creek beds	Late Permian
826	905		Colinlea Sandstone	Late Permian
905	992		Aramac Formation	Late Carboniferous to Early Permian
992			Jochmus Formation	

The Permian unconformity was encountered at 826 m bKB in Splitters Creek 1 (Table 8.43). Recent drilling has encountered the Permian unconformity at depths ranging from 800 to over 950 m bGL. The Permian unconformity outcrops to the east of ATP 813 near the margin of the Galilee Basin study area.

The depth to the sediments and aquifers present within ATP 813 is a function of the tenement location over the Koburra Trough. The deepest aquifers and the underlying coal seams correspond to the deepest portions of the Koburra Trough. The shallowest occurrence of the Permian unconformity is found near the eastern limit of the Koburra Trough.

The location of the aquifers present within ATP 813, relative to the coal measures, changes from east-to-west. In the east, the Eromanga Basin aquifers are absent (Table 8.43) but the Galilee Basin aquifers, the Clematis and Colinlea Sandstones, are present. The Clematis Sandstone overlies the 230 m thick Rewan Formation in the east. The Rewan Formation, which separates the Clematis Sandstone from the Aramac Coal Measures and Betts Creek beds, thickens slightly to the west. The Colinlea Sandstone has been logged at the base of the Betts Creek beds in Splitters Creek 1 well but has not been logged in the wells located further to the west.

The Eromanga Basin aquifers, which are absent in the east, occur in the western portion of the tenement. Significant thicknesses of the Hutton, Adori and Hooray Sandstones have been logged. However, the depth and distribution of the water bores tapping the aquifers underlying ATP 813 suggests the Eromanga Basin aquifers can be tapped at comparatively shallow depths.

8.9.5 Aquifers within ATP 813

Bores within the noted aquifers and water-bearing sediments are taken from water quality, pump test and and water level tables found in the DERM GWDB (2010). These data are not tabulated in this report, thus, bore quantities presented in this report will not necessarily be reflected in the aquifer summary text. The following Eromanga Basin aquifers and water-bearing sediments may be present within ATP 813 (Appendix D, Table D.1 and Appendix E, Table E.1):

- Winton Formation (1 bore);
- Mackunda Formation (no bores identified);
- Allaru Mudstone (no bores identified);
- undifferentiated Wallumbilla Formation (17 bores);
- Coreena Member of the Wallumbilla Formation (no bores identified);
- Doncaster Member of the Wallumbilla Formation (4 bores);
- Ronlow beds (25 bores);
- Hooray Sandstone (1 bore);
- Adori Sandstone (no bores identified); and
- Hutton Sandstone (2 bores).

The following Galilee Basin aquifers and water-bearing sediments may be present within ATP 813:

- Moolayember Formation (no bores identified);
- Clematis Sandstone (2 bore);
- Rewan Formation (2 bores);
- Colinlea Sandstone (no bores identified);
- Betts Creek beds (no bores identified);
- Aramac Formation (no bores identified); and
- Jochmus Formation (no bores identified).

The above list of aquifers and potentially water-bearing strata has been compiled based on data in the DERM GWDB (2010) and the stratigraphic data detailed in the well completion reports for ATP 813.

8.9.6 Groundwater level summary for ATP 813

Over 200 depth to groundwater observations have been made within ATP 813 (Table 8.44). Groundwater level data are available for four formations. Seventeen bores are attributed to the undifferentiated Wallumbilla Formation and two bores are attributed to the Doncaster Member of the Wallumbilla Formation (Table 8.44). More depth to groundwater observations have been recorded from bores screened in the Ronlow beds than from bores screened in the other formations.

The groundwater level measurements range from an observation made in 1960 to the last recorded observation made in 2010. Groundwater levels from the Ronlow beds have considerable range (Table 8.44). Depth to groundwater in the Ronlow beds ranges from artesian to over 100 m bGL. This range reflects the considerable change in not only the aquifer thickness but also confining layer thicknesses across the tenement.

The groundwater flow direction assessment for the three of the aquifers present within ATP 813 is based on groundwater contours presented on Figure 6.19, Figure 6.20 and Figure 6.21. The groundwater flow in the Rolling Downs Group aquifers, Cadna-owie Formation / Hooray Sandstone aquifer and Hutton Sandstone aquifer is to the south-west towards the Maneroo Platform.

Table 8.44 Summary of groundwater levels from water bores within ATP 813

Basin	Formation name	Measurement period		Count	Depth to groundwater (m bGL)				
		Start	End		Ave	Max	Min	Range	Median
Eromanga Basin Sequence	Wallumbilla Formation	1-Oct 1905	9-Mar 1992	17	-20.3	-0.9	-51.5	50.6	-21.3
	Doncaster Member of the Wallumbilla Formation	28-May 1898	21-Oct 1990	2	-19.5	-10.9	-28.0	17.14	
	Ronlow beds	1-Jan 1910	11-Feb 2000	183(1)	-81.1	1.6	-115.8	117.42	-84.7
	Hooray Sandstone	01-Jan 1909		1	15.8				
Galilee Basin Sequence	Rewan Formation	08-Mar-1960	19-Aug-1960	2	-43.7	-40.8	-46.6	5.8	

(1) Note that 168 of these readings are from the same bore, RN 100320001, consistently recording between -84.6 and -84.74

8.9.7 Summary of DERM GWDB flow and pumping test data for ATP 813

Pumping test data was received for 58 water bores in DERM GWDB (2010) for ATP 813 (Figure 6.23). The aquifers and water-bearing units have been identified for 22 water bores in this tenement. The first flow test was conducted on a bore in 1891 and the most recent was conducted on 13 October 2010 (DERM GWDB, 2010). Fewer observations were recorded after 1975.

These bores have been identified as tapping the following aquifers and water-bearing units:

- Doncaster Member of the Wallumbilla Formation;
- undifferentiated Wallumbilla Formation;
- Hooray Sandstone;
- Ronlow beds;
- Hutton Sandstone; and
- Clematis Sandstone.

The changes in aquifer pressure and depth to groundwater over time were assessed by plotting the discharge upon arrival at the bore (Figure 8.26), changes in the static groundwater level (Figure 8.27) and changes in calculated static groundwater level observations (Figure 8.28).

Groundwater discharge for bores screened in the Doncaster Member of the Wallumbilla Formation decline rapidly from 48 L/s per bore in 1909 to 4 L/s per bore in 2004 (Figure 8.26). Groundwater discharge from bores screened in the Ronlow beds exhibit a similar decline. The groundwater discharge recorded from bores screened in the Hooray Sandstone decline from 22 L/s per bore to 15 L/s per bore between 1920 and 1970.

Static groundwater levels are relatively consistent for observations recorded at bores drilled in the Wallumbilla Formation (Figure 8.27).

The calculated static groundwater levels for bores drilled in the Ronlow beds have increased (Figure 8.28). However, no clear trend is evident in either the static groundwater levels of the calculated static groundwater levels.

The non-linear decline of the aquifer pressures is typical of an artesian system response to development. That is, the initial pressures are the highest and decline very rapidly following development. The rate of decline will level off as the aquifer pressure declines. If the bores are allowed to flow and not shut-in, the flow will continue to depressurise the aquifer until artesian flow ceases. The response near the end of the static groundwater level chart and the calculated static groundwater level chart shows a slight increase in aquifer pressure that is possibly the result of shutting in or abandoning artesian bores.

Figure 8.26 Bore discharge (L/s) at arrival for ATP 813 water bores with data, 1900 to 2010

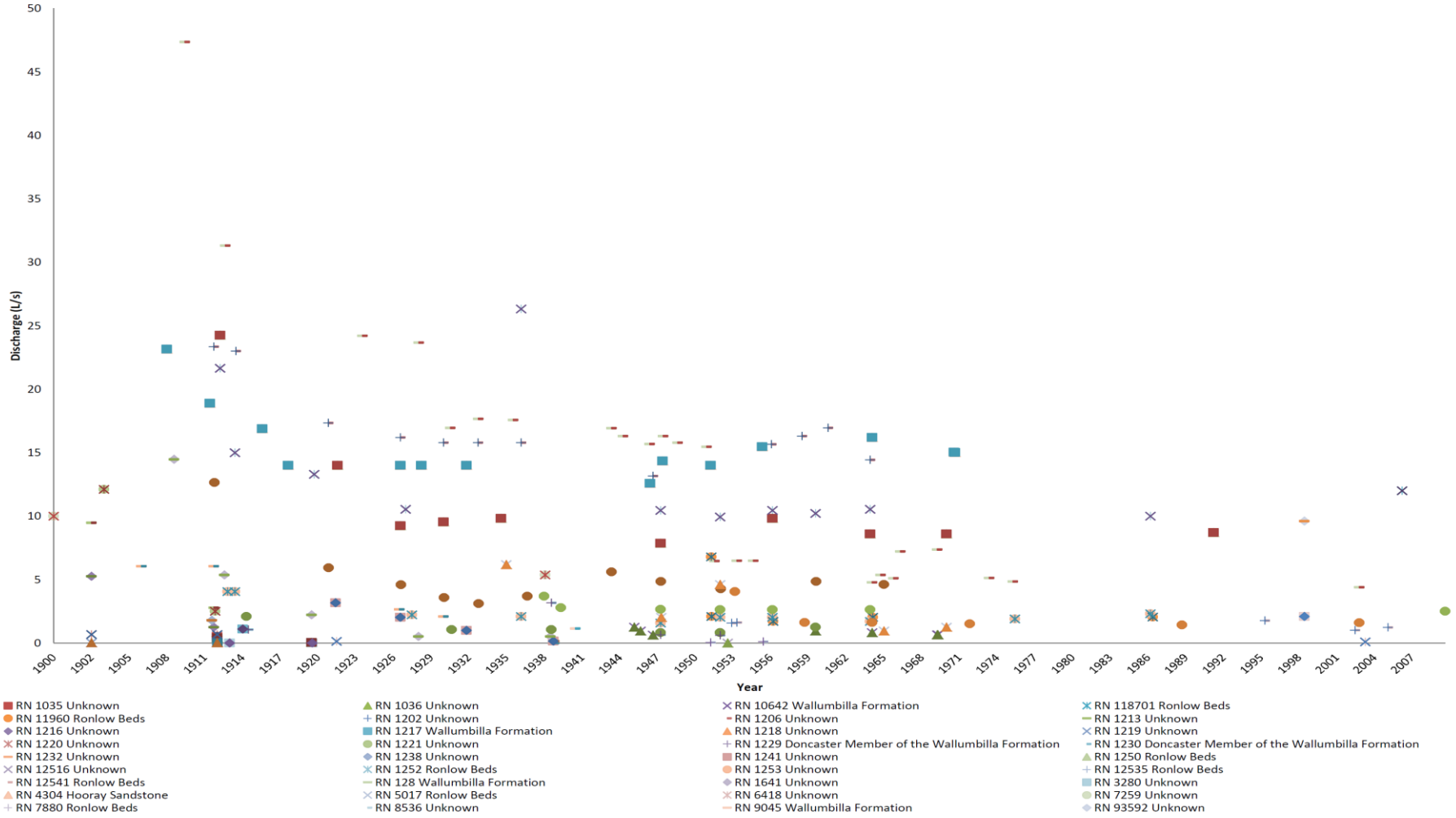


Figure 8.27 Static groundwater levels for ATP 813 water bores with data, 1900 to 2010

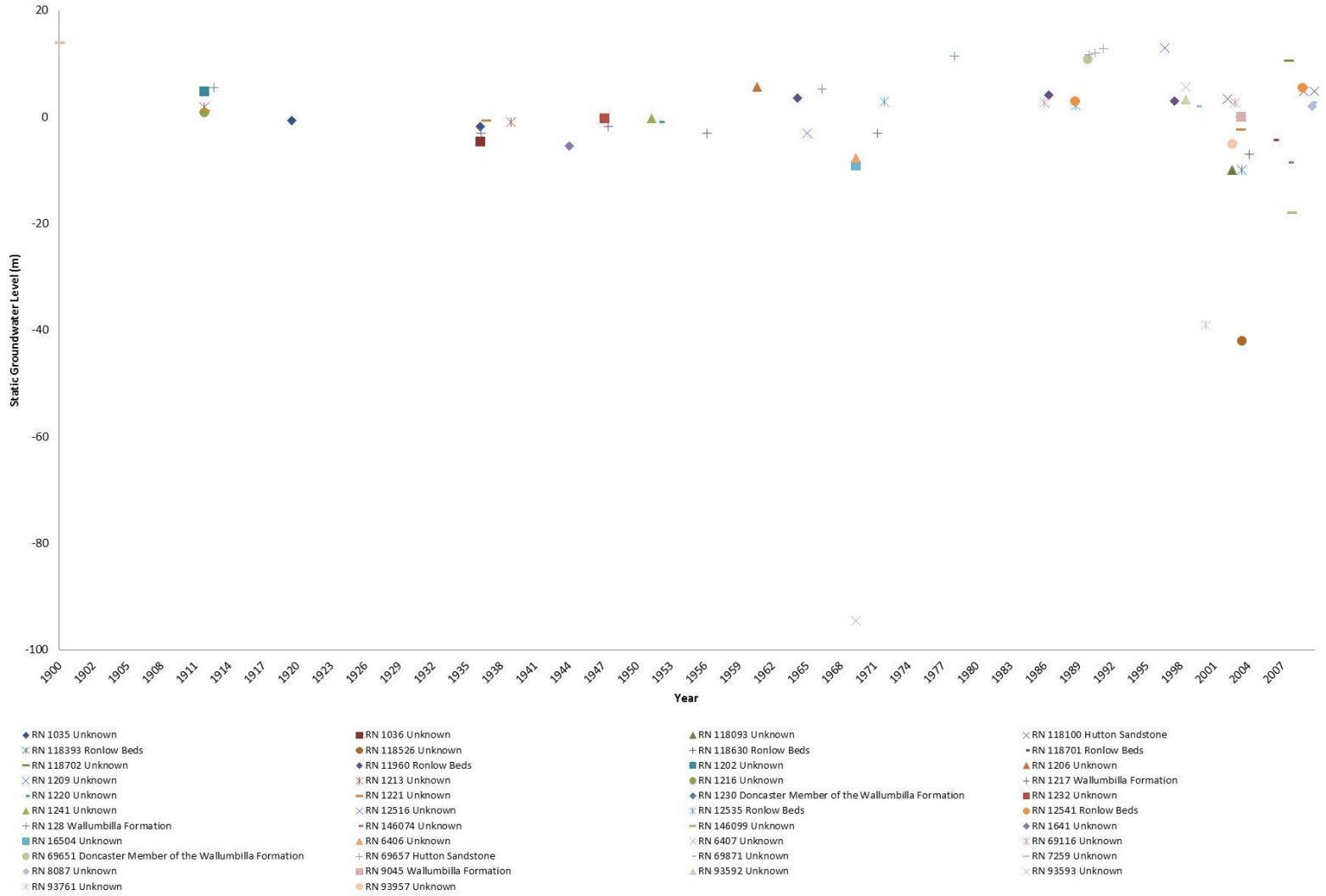
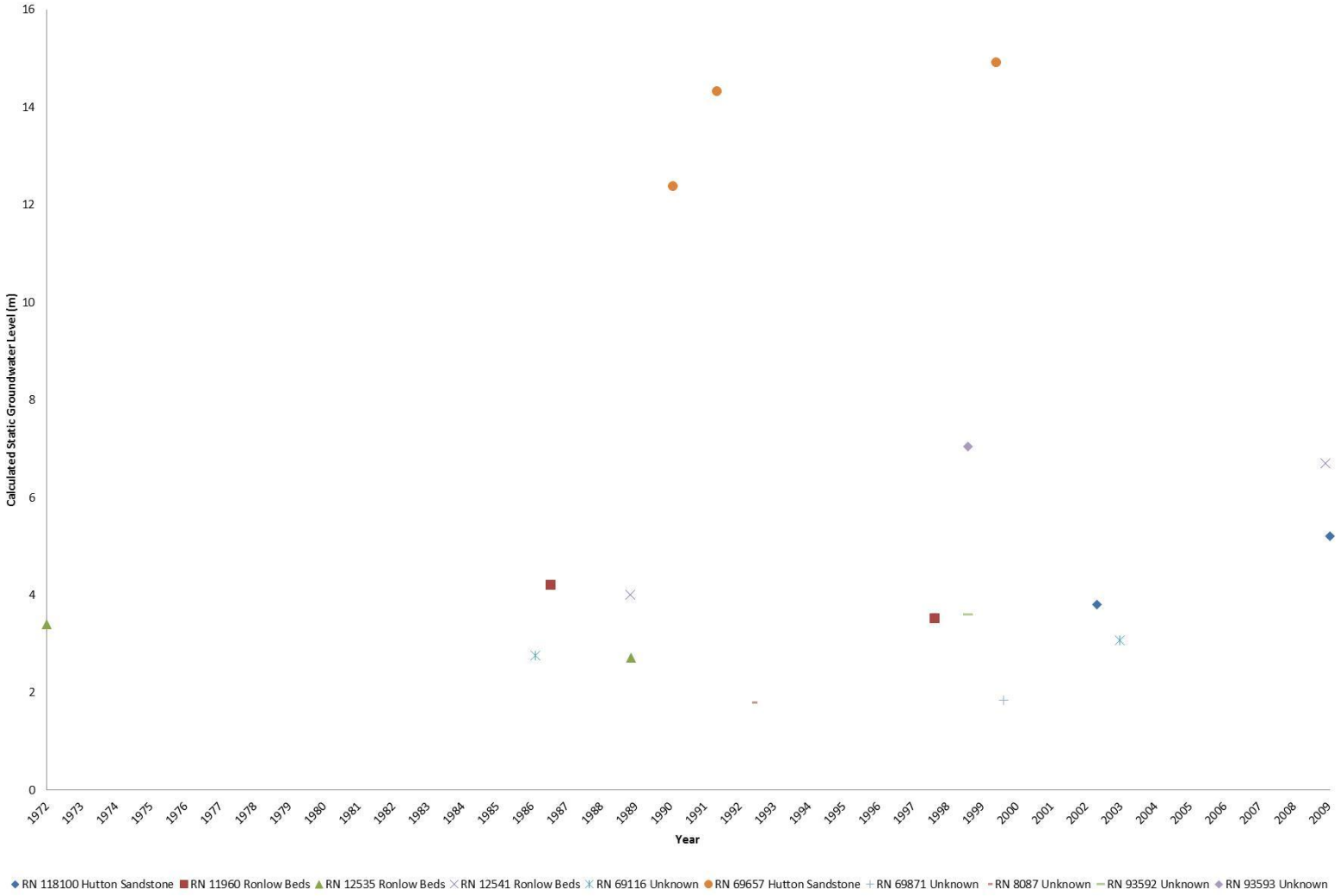


Figure 8.28 Calculated static groundwater levels for ATP 813 water bores with data, 1900 to 2010



8.9.8 Groundwater quality within ATP 813

Excluding results from drill stem tests, laboratory chemical analysis data are available for groundwater samples drawn from six aquifers or water-bearing sediments present within ATP 813 (Table 8.45a and Appendix Table E-1). Groundwater quality samples from the Permian coal measures were available for analysis from petroleum exploration drilling, shown in (Table 8.45b and Appendix E-1), but excluded from the discussion below.

The depth of the water bore screen or casing perforations, ranges from 14 to 375 m bGL. These comparatively shallow bores tap aquifers and water-bearing units ranging from the Wallumbilla Formation to the Rewan Formation.

Groundwater quality samples were obtained from between 14 and 495 m bGL:

- The groundwater pH varied between 6 and 9;
- Total dissolved solids ranged from 154 to 10,341 mg/L (brackish);
- Electrical conductivity value ranged from 300 to 5,188 µS/cm;
- Sodium ranged from 49 to 3,219 mg/L;
- Calcium ranged from below the detection limit to 656 mg/L;
- Chloride ranged from 25 to 4,660 mg/L;
- Fluoride ranged from 0.05 to 6.3 mg/L;
- Bicarbonate ranged from 18 to 6,963 mg/L;

Both the maximum and minimum values for total dissolved solids, sodium and fluoride were recorded in the Wallumbilla Formation.

The constituent loads in the groundwater samples obtained from the Wallumbilla Formation and the Ronlow beds were higher than the constituent loads in the groundwater samples obtained from the Hutton and Clematis Sandstones.

The Piper diagram presented on Figure 8.29 contains groundwater samples collected from DSTs performed during exploration well drilling and water bores. The DST samples were all collected from either the Late Permian Betts Creek beds or the Early Permian Aramac Coal Measures.

The samples from DSTs should not be used for further groundwater analyses. Results from these samples indicate mixing with drilling fluids, which contain potassium. Therefore, these DST samples had insufficient clean-up to accurately represent true formation waters.

The groundwater quality samples from aquifers other than the Permian aquifers can be classed as sodium / bicarbonate type waters.

Figure 8.29 Piper diagram of the summary groundwater quality results from aquifers present within ATP 813

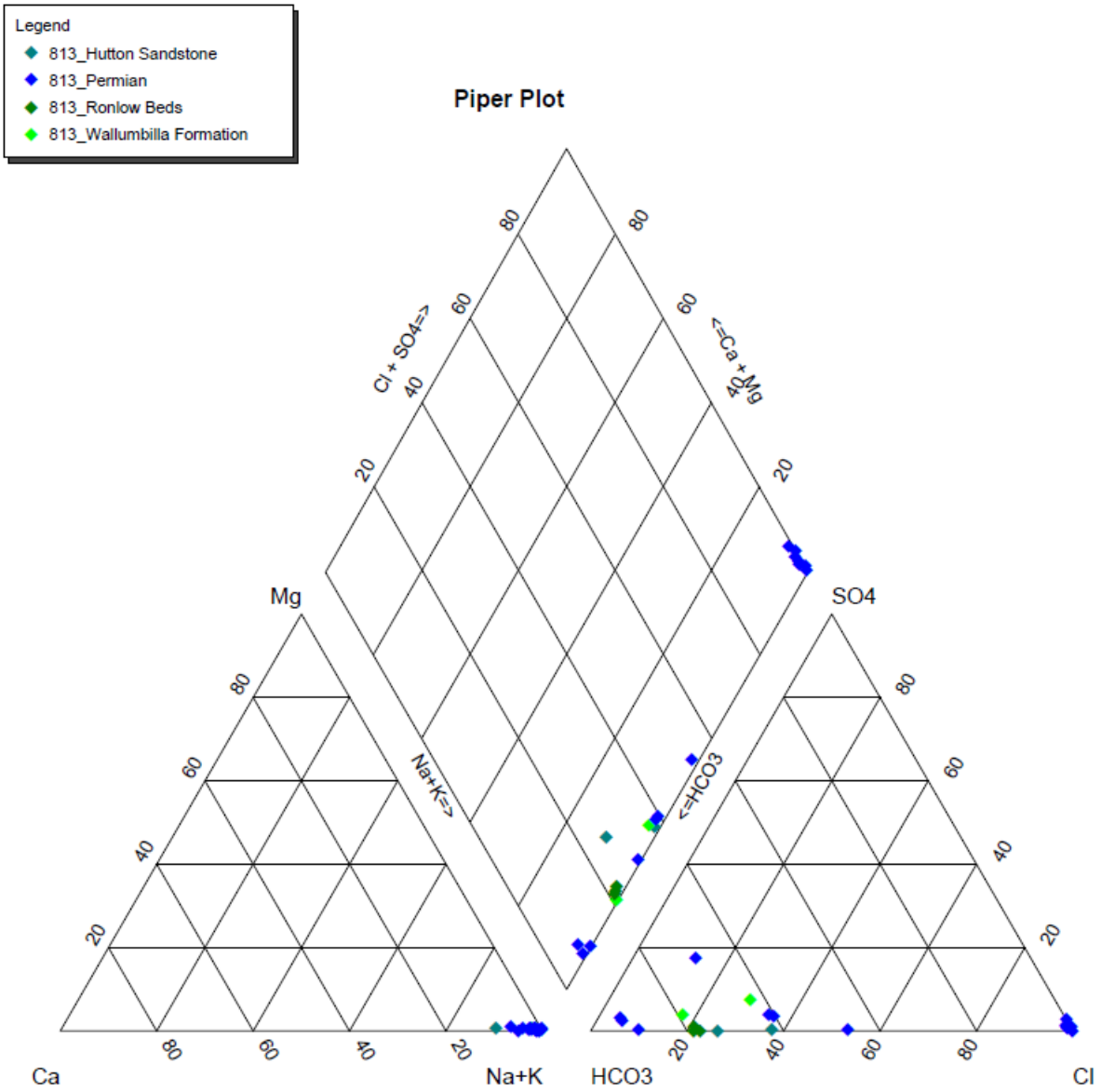


Table 8.45a Groundwater quality data summary ATP 813

Basin	Identified aquifer or water- bearing sediment	Statistic	Depth of Sample (m bGL)	Conductivity (µS/cm)	pH	Hardness (mg/L Ca)	Alkalinity (mg/L)	Total Dissolved Solids (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Iron (mg/L)	Manganese (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)	Zinc (mg/L)
Eromanga Basin Sequence	Wallumbilla Formation	Total number	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
		Number of tests	13	17	17	7	17	15	17	11	17	13	7	3	16	11	17	17	4	12	2
		Average	95	623	8.1	61	550	1,009	323	21.0	15.4	5.4	0.1	ND	676	24.0	235	0.7	16.1	18.5	0.0
		Maximum	178	1,700	9	761	6,056	10,341	3,219	203	200	63.2	1	ND	6,963	207	2,838	6.3	186	176	0.04
		Minimum	30	300	7	1	13	154	49	1	0.4	ND	ND	ND	125	ND	25	0.05	ND	ND	ND
	Doncaster Member of the Wallumbilla Formation	Total number	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Number of tests	4	5	5	4	5	5	5	3	5	5	2	1	5	1	5	5	1	5	2
		Average	16	586	7.6	33	98	355	112	5	6	3	0.09	0.41	118	5	119	0.23	1	12.7	0.04
		Maximum	19	730	8	40	244	423	161	6	11.2	4.9	ND	ND	288	5	150	0.4	0.6	17	0.05
		Minimum	14	480	6	27	43	309	98	3	2	0.7	ND	ND	52	ND	81	0.1	ND	4	ND
	Ronlow beds	Total number	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
		Number of tests	25	25	28	12	30	27	31	17	30	21	12	6	24	23	31	30	3	15	1
		Average	190	835	8	361	207	748.1	213	5	29	26	ND	ND	267.8	24.304	259	0.65	1	69	0.01
		Maximum	375	5,188	9	3,521	490	8,403	1,890	32	656	457	ND	ND	580	127	4,660	2.0	1	708	0.01
		Minimum	40	320	7	12	31	199	62	1	ND	ND	ND	ND	ND	1	27	0.05	ND	ND	ND
	Hooray Sandstone	Total number	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		Number of tests	2	2	2	2	2	1	2	1	2	2	1	1	2	1	2	2	1	0	1
		Average	329	468	7.5	33	182	275	94	6	12	0.6	ND	ND	220	2	42	0.6	0.4	--	0.04
		Maximum	495	480	8	39	184	275	98	6	14	1	ND	ND	224	2	47	0.6	0.7	--	0.04
		Minimum	162	455	7	26	180	275	90	6	10	0.1	ND	ND	215	2	36	0.5	ND	--	0.04
	Hutton Sandstone	Total number	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		Number of tests	2	3	3	1	3	3	3	3	3	3	2	2	3	3	3	3	0	1	0
		Average	341	665	8	25	222	397	148	5.3	4.6	0.3	0.3	ND	265	2.7	81	1.0	--	0.4	--
		Maximum	342	795	8	25	253	457	175	8	9.2	0.4	1	ND	301	4	101	1.19	--	1.2	--
		Minimum	340	433	8	25	169	279	95	4	2	0.2	ND	ND	200	2	41	0.63	--	ND	--
Galilee Basin Sequence	Rewan Formation	Total number	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		Number of tests	2	2	2	2	2	2	2	0	2	2	1	0	2	0	2	2	0	2	0
		Average	75	743	7.5	58	135	430	148	--	6.0	10.5	12.0	--	165	--	157.5	0.2	--	21.0	--
		Maximum	92	755	8	90	255	462	182	--	8	17	12	--	311	--	200	0.25	--	38	--
		Minimum	58	730	7	26	15	398	114	--	4	4	12	--	18	--	115	0.1	--	4	--

Table 8.45b Drill stem test groundwater quality data summary ATP 813

Basin	Identified aquifer or water- bearing sediment	Statistic	Depth of Sample (m bGL)	Conductivity (µS/cm)	pH	Hardness (mg/L Ca)	Alkalinity (mg/L)	Total Dissolved Solids (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Iron (mg/L)	Manganese (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)	Zinc (mg/L)
Galilee Basin Sequence	undifferentiated Permian	Total Number	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		Number of Tests	2	0	0	0	0	15	15	15	15	15	0	0	15	15	15	0	0	15	0
		Average	1,176	--	--	--	--	33,919	1,760	28,420	337	42	--	--	800	360	23,776	--	--	307	--
		Maximum	1,176	--	--	--	--	87,375	9,540	107,000	1,300	150	--	--	3,740	2,810	91,000	--	--	880	--
		Minimum	1,176	--	--	--	--	474	127	5	2	0	--	--	10	1	29	--	--	1	--

8.9.9 Summary for ATP 813

Currently, much of the available subsurface information for ATP 813 has not been publicly released, however, the available data suggest that the underlying structure of the Koburra Trough influences the subsurface aquifer occurrence and interburden thickness.

The Eromanga Basin aquifers are absent in the eastern part of ATP 813. However, the individual Eromanga Basin aquifer formations are nearly 100 m thick in the west where the Hooray, Hutton, and Adori Sandstones, are separated from each other and the underlying coal measures by the Westbourne, Birkhead, Moolayember and Rewan Formations.

In the eastern portion of the tenement, the Clematis Sandstone overlies the 230 m thick Rewan Formation, separating the Clematis Sandstone from the underlying Aramac Coal Measures and Betts Creek beds. The Rewan Formation thickens slightly to the west. The Colinlea Sandstone has been logged at the base of the Betts Creek beds in the east, but has not been logged in the bores holes drilled to the west.

The water bores drilled within ATP 813 are generally shallow, tapping the upper Eromanga Basin aquifers, such as the Wallumbilla Formation, in the west and Galilee Basin aquifers such as the Rewan Formation in the east, where they are present closer to the surface.