Appendix 3: Stratigraphic framework development and wireline picking standardisation

Surat Basin Mapping Industry Priorities Initiative Project

Stratigraphic framework development and wireline picking standardisation

Luke Hauck and Sally Edwards

Geological Survey of Queensland
Department of Natural Resources and Mines

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1.0 Stratigraphic Picking Rationale and Correlation

1.1 Introduction

As part of the 2015 round of the Industry Priorities Initiative under the Future Resources Program of the Department of Natural Resources and Mines, a proposal to sub-divide and then map the Injune Creek Group of the Surat Basin was submitted. The aim of the project is to map the outcrop extents of key formations of interest to coal seam gas (CSG) companies. Figure 1 shows the stratigraphy of the Surat Basin and the formations discussed in the rationale below.

The key formations comprising the primary focus of the project are the Springbok Sandstone and the Walloon Coal Measures, although other work on some overlying and underlying formations will also be undertaken. This additional work includes examining the wireline characteristics of the Westbourne Formation and Hutton Sandstone to assist with consistent formation picking. Some work may be undertaken on the Eurombah and Durabilla formations to determine their extent(s); if they are the same lithological formation; and if they are members of the Walloon Coal Measures or separate formations.

The eastern Surat Basin is extensively overlain by recent alluvium and Tertiary basalt cover units which are included in the project scope but excluded from this investigation. They are often not the target of geophysical logging efforts and consequently no logging data is available over these units.

Academia, industry and government organisations utilise various formation picking methodologies and rationale to identify these formations from geophysical wireline logs. Companies involved in the project (Arrow Energy, Origin Energy, QGC, Santos and Senex Energy) as well as the Office of Groundwater Impact Assessment (OGIA) have submitted stratigraphic re-picks of wireline logs for sixteen key wells identified over the area that intersect these formations and provide a series of representative local 'type sections' across the Surat Basin study area. The purpose of this exercise was to identify any significant method variability, identify variability in lateral extent of formations, and standardise picks for these formations such that a consistent picking rationale and stratigraphic framework could be utilised throughout all phases of the project.

1.2 Methodology

A set of comprehensive guidelines or rationale was needed to assist with wireline log picking for the formations of interest in the Surat Basin, which can then be applied to future Surat Basin exploration. The Geological Survey of Queensland (GSQ) has worked with the coal seam gas companies to develop the following rationale. This section summarises how the rationale has been developed.

The rationale incorporates information on lithological and depositional environments for each formation and uses this knowledge to determine where the lithological and depositional changes associated with each formation occur in the wireline log set for a particular well. References used to compile this information include: *The Surat and Bowen Basins of South-East Queensland* (Green, 1997); *Surat Underground Water Impact Report* (Coal Seam Gas Water, 2012) and *Description of the OGIA Geological Model and Datasets* (OGIA, 2015).

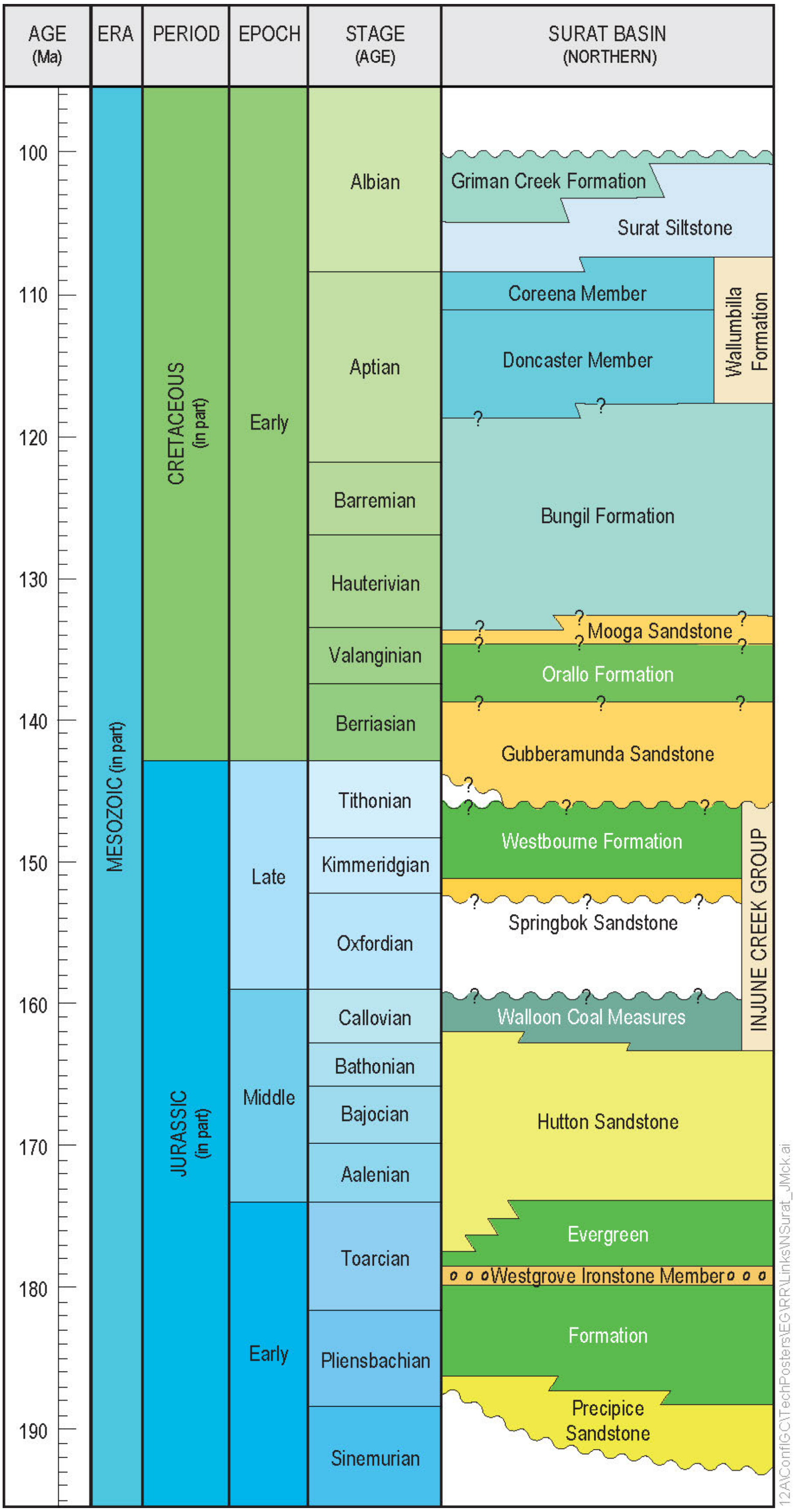

Figure 1 – Stratigraphic table of the Surat Basin (McKellar, 2015, personal communication).

Using the guidelines presented below in this document, 'blind' picking (that is, utilising no previous picking information) was performed on a set of 'type' wells from across the basin to test the applicability of the method. Wireline re-picks from companies and OGIA, in addition to the original Well Completion Report picks, were then summarised in Microsoft Excel and statistical tools employed to analyse the variance in the data. This highlighted potential outliers and constrained those picks that were in agreement. The re-picks were then compared with the GSQ 'blind' picks and checked again for agreement.

Following this analysis, minor adjustments were made to improve the consistency and precision of the GSQ 'blind' picks and a regional correlation across the northern and eastern extents of the Surat Basin was constructed in Paradigm's software *GeoLog*.

1.3 Rationale and Guidelines for formation picks

1.3.1 Hutton Sandstone

The Hutton Sandstone was deposited by meandering streams on a broad floodplain (Green, 1997). It consists mainly of fine to medium grained, well sorted, sublabile to quartzose sandstone with interbedded siltstone, shale, minor mudstone and coal (Green, 1997; Coal Seam Gas Water, 2012). It can be sub-divided into an upper interval characterised by thick high resistivity sandstones and the lower interval being more thinly interbedded sandstone and siltstones.

The lower Hutton Sandstone contains predominantly sublabile sandstones with low to medium gamma-ray log responses that do not stand out on the resistivity log (OGIA, 2015). The interbedded finer grained rocks have medium to high gamma-ray log signatures and noisy resistivity logs (OGIA, 2015).

The upper Hutton Sandstone is characterised by thick quartzose sandstones with low-gamma-ray and high resistivity log responses that have a sharp base and top (OGIA, 2015). The rocks between the thicker sandstones consist of interbedded siltstone and sandstone producing noisy resistivity and moderate gamma-ray log responses (OGIA, 2015).

The top of the Hutton Sandstone is marked by an abrupt or short gradual increase in the average resistivity baseline from the overlying Walloon Coal Measures or the Eurombah/Durabilla Formation when present, reflecting the lithological change to quartzose sandstones. Throughout the formation the resistivity log is generally noisier than that observed within the overlying Eurombah/Durabilla Formation and Walloon Coal Measures.

Blocky, low gamma-ray sandstones dominate the upper Hutton Sandstone and the described resistivity response at the top of the formation is commonly associated with a relatively thick, low gamma-ray sandstone unit. The average baseline gamma-ray response is markedly lower than observed within the overlying formations and increases toward the base of the formation with increasing siltstone content. The sonic and density logs are generally quiet with faster velocities over the sandier intervals (Green, 1997).

1.3.2 Eurombah/Durabilla Formation

Currently, coal seam gas companies divide the Surat Basin so that the Eurombah Formation occurs in the east and the Durabilla Formation occurs in the west. It is uncertain whether lithological changes exist which may justify differentiation or assimilation of the two formations, thus further work is required. Some authors, including Green (1997), doubt its validity as a unit separate from the Walloon Coal Measures due to the presence of andesitic detritus which is common within the Injune Creek Group, but absent in the underlying Hutton Sandstone (Green, 1997). However recent work has proposed a differentiation of this unit as many of the coal seam gas wells that target the Walloon Coal Measures intersect the top of the Eurombah/Durabilla Formation and it forms a very useful regional marker (OGIA, 2015). Consequently it is described in this rationale as a separate unit from the rest of the Walloon Coal Measures.

The Eurombah/Durabilla Formation is defined by some (e.g. OGIA, 2015) as the interval containing minimal coal between the top of the Hutton Sandstone and the first (basal) coal seam of the Taroom Coal Measures. It comprises thick, fine to coarse grained, labile to sublabile sandstones and interbedded mudstones (Green, 1997). The sandstones are reportedly more labile than the underlying Hutton Sandstone, but less labile than those of the overlying coal measures (Green, 1997). The Eurombah/Durabilla Formation was deposited as overbank deposits (Exon, 1976) in a predominantly fluvial environment with periods of rapid sedimentation (Green, 1997) resulting in a series of fining-upwards sequences that can be observed on the gamma-ray log.

Where the lowermost coal of the Taroom Coal Measures is not clearly defined on the density log, the top of the Eurombah/Durabilla Formation was picked at the base of the coaly interval that coincides with a blocky, low gamma-ray response fluvial sandstone on the wireline log (OGIA, 2015).

The general gamma-ray log response of the Eurombah/Durabilla Formation features blocky low gamma-ray sandstones frequently disturbed by thin, high gamma-ray response mudstones and carbonaceous units. The overall gamma-ray response is less variable and features more subdued, gradual fining-up or -down sequences than the overlying coal measures. Irregular and infrequent low density coaly intervals contrasted against a relatively flat, non-variable density baseline are also characteristic of the Eurombah/Durabilla Formation.

1.3.3 Walloon Coal Measures

The Walloon Coal Measures were deposited as coal swamps within a high sinuosity fluviatile environment (Exon, 1976; McLeod-Hodgson and Kempton, 1981). They consist of very fine to medium grained argillaceous sandstone, siltstone, mudstone and coal (Green, 1997; OGIA, 2015). Historically and within Green (1997), the coal measures are located within the upper half to three-quarters of the formation and the mudstones, siltstones and lithic sandstones that form the Eurombah/Durabilla Formation comprise their lower unit. This rationale does not include the Eurombah/Durabilla Formation within the Walloon Coal Measures. In this exercise the base of the Walloon Coal Measures is considered to be at the base of the lowermost coal seam, as it corresponds with the change in lithology defining the Eurombah/Durabilla Formation (see above).

The top of the Walloon Coal Measures is unconformably overlain by the Springbok Sandstone, indicated by a sharp gamma-ray baseline increase over the Walloon Coal Measures, representing the lithological change from the coal-rich, mudstone-dominated Walloon Coal Measures to the channel-dominated Springbok Sandstone. The top of the Walloon Coal Measures is considered to be at the top of the uppermost coal or thick mudstone or siltstone interval below the low gamma-ray sandstones of the Springbok Sandstone (OGIA, 2015).

Additionally, the top of the Walloon Coal Measures generally features a relatively thick unit of high gamma-ray mudstone or siltstone. This is clearly differentiated from the blocky, low gamma-ray channel sandstone at the base of the Springbok Sandstone. Where the baseline increase in the gamma-ray log is not readily apparent, the top of the Walloon Coal Measures was picked at the top of the uppermost coal below the sandstone base of the overlying Springbok Sandstone.

The basal sandstone in the Springbok has a higher resistivity baseline log response than sandstones in the Walloon Coal Measures below, which may also be used to define the boundary in many areas where this basal Springbok Sandstone is thin (OGIA, 2015). The difference in response between long- and short-spaced resistivity over the Walloon Coal Measures is larger than the difference over the Springbok Sandstone and this geophysical characteristic helped constrain the boundary between the two formations.

1.3.4 Springbok Sandstone

A review of recent CSG well logs and stratigraphic drilling by the Geological Survey of Queensland and the Bureau of Mineral Resources shows the Springbok Sandstone to be of highly variable thickness across the Surat Basin. It consists mostly of feldspathic, lithic-rich sandstone with calcareous cement, minor interbedded siltstones and mudstones and thin coal seams. The sandstones range in grain size from fine to coarse although some very coarse grained, poorly sorted, pebbly beds also occur (Green, 1997). A scoured base to the Springbok Sandstone in some areas and a significantly different lithology when compared with the Walloon Coal Measures, implying a period of suspended deposition and extensive erosion, suggesting an unconformity is present (Green, 1997).

The Springbok Sandstone was deposited mainly by streams with overbank and swamp deposits (Exon, 1976). Overbank and swamp deposits become less frequent towards the top of the formation, indicating that streams became less energetic (Exon, 1976). Lithic sandstones are present in the north and east of the basin, while in the south sandstones are more quartzose (Green, 1997).

The lower Springbok sandstones are coarse to very coarse grained with an erosional base and exclude significant siltstones or coal seams (OGIA, 2015). This basal sandstone has a higher resistivity log response than sandstones in the underlying Walloon Coal Measures and therefore was used to define the boundary in many areas where the unit is thin (OGIA, 2015). The average baseline of the sonic log is higher over the Springbok Sandstone than the underlying coal measures and is higher still over these coarser lower sands. This lower Springbok Sandstone unit of coarser sand is equivalent to the Proud Sandstone of the Roma area (Green, 1997).

The Springbok Sandstone is generally characterised by a relatively low gamma-ray response compared to the finer grained sediments in the overlying Westbourne Formation and underlying Walloon Coal Measures. The gamma-ray log highlights the variable lithic to quartzose composition of the sandstones. In some wells, the lowermost part of the Westbourne Formation is sandy and the boundary between it and the Springbok Sandstone is transitional. In these wells the top of the Springbok Sandstone can be picked where there is an increase in the gamma-ray baseline. But for consistency, it is suggested that the top of the Springbok Sandstone be picked where the siltstone and mudstone units begin to dominate both the gamma-ray and resistivity logs.

The top of the Springbok Sandstone has been picked on gamma-ray and resistivity peaks in CSR Ebony 2 (Green, 1997, figure 38, page 89) and on gamma-ray peaks solely in SOC Bogong 1 (Green, 1997, figure 39, page 89). An insignificant resistivity peak accompanies the gamma-ray pick in SOC Bogong 1. The current study has investigated methods to improve consistency within well picks such as these and so it is recommended that the boundary between the Springbok Sandstone and Westbourne Formation be picked where a decrease in resistivity baseline accompanies an increase in average gamma-ray baseline, indicating a change in lithology from primarily sandstone to mudstone/siltstone. This follows the work by OGIA for their geological model for the Surat Basin (Coal Seam Gas Water, 2012; OGIA 2015), where a lithological distinction is made between the Springbok Sandstone and Westbourne Formation, the latter being described as a mudstone and siltstone dominated unit with little sand.

As the Springbok Sandstone is defined to include all the significant coal seams in the Springbok-Westbourne interval, when the formation cannot be differentiated from the gamma-ray and resistivity logs, the top of the Springbok Sandstone may be picked off the density and sonic logs at the top of the first significant coal within this interval.

1.3.5 Westbourne Formation

The Westbourne Formation type section in the Eromanga Basin consists of interbedded shales and siltstones and very fine grained quartzose sandstone interpreted to have been deposited in a lacustrine environment (Green, 1997). In the Surat Basin, the formation is similar but contains a higher proportion of very fine grained quartzose sandstone (Green, 1997). As discussed above, OGIA (2015) have re-defined the Westbourne Formation to be predominantly siltstone- and mudstone-dominated. The interval from the base of the Springbok Sandstone to the top of the Westbourne Formation commonly displays a relatively constant thickness in adjacent wells, whereas across the Surat Basin the thicknesses of the individual formations may vary greatly.

The Westbourne Formation typically has low average resistivity log values, except over the sandstone units which have moderate resistivity (OGIA, 2015). Sonic logs over the Westbourne Formation are highly variable depending on the amount of mudstone/siltstone in the formation, but have a slightly higher average baseline than those over the Springbok Sandstone and may show increases in velocity towards the top of the formation.

The gamma-ray log values are uneven but tend to increase toward the top of the Westbourne Formation, reflecting increasing mudstone/siltstone content, which is terminated by the lower, less noisy gamma-ray baseline of the Gubberamunda Sandstone (OGIA, 2015). The sharp contrast between the gamma-ray logs produced by these two formations defines the top of the Westbourne and provides a useful regional marker.

1.3.6 Gubberamunda Sandstone

While not a specific formation of interest within the Surat Basin Mapping Project, the Gubberamunda Sandstone is included for thoroughness.

The Gubberamunda Sandstone consists of medium and coarse grained, poorly cemented quartzose sandstone with lesser amounts of conglomerate and fine grained clastic sediments deposited in a high-energy, fluviatile (braided and meandering stream) environment (Green, 1997; OGIA, 2015).

The Gubberamunda Sandstone typically has a higher average resistivity compared with the underlying Westbourne Formation. Resistivity decreases near the top of the Gubberamunda Sandstone, where the top is defined as the first occurrence of a low resistivity siltstone at the base of the overlying Orallo Formation.

The sonic log is relatively stable with an occasional slight increase in velocity towards the top of the formation. This may be reflecting increased cementation of the upper portion of the formation or a change to cleaner sandstones. The lower gamma-ray wireline log response reflecting the higher sand content contrasts sharply with the Westbourne Formation below which has a lower sand content.

The Gubberamunda Sandstone was consistently well defined within the Queensland Petroleum Exploration Data (QPED) company formation tops database due to its importance as a regional aquifer, so that only minor adjustments occurred to achieve consistent picks within the OGIA dataset (OGIA, 2015).

2.0 Discussion

2.1 Nomenclature

In some current literature, the Walloon Coal Measures are still referred to as the 'Walloon Subgroup'. The name 'Walloon Subgroup' is not considered appropriate as the members within the coal measures are not continuous across the entire Surat Basin which must be the case for the coal measures to be a considered as a subgroup (John McKellar, 2015 pers comm.). The stratigraphic name for this formation in the Geoscience Australia database is 'Walloon Coal Measures'. Therefore in this rationale, as used in the earlier work undertaken by the GSQ and OGIA, the name Walloon Coal Measures is used.

The distinction between the Eurombah Formation and the Durabilla Formation is not well understood. Some organisations use the terms interchangeably, whereas other organisations provide different definitions and locations. Traditionally the Geological Survey of Queensland has considered the Eurombah Formation to be the basal formation of the Walloon Coal Measures. For the purposes of this exercise, the term 'Eurombah Formation' was used (due to character limitations in *GeoLog*) when constructing the correlation. Various Geological Survey of Queensland publications recognise the 'Eurombah Formation' as a described formation with a type section, whereas the 'Durabilla Formation' has not been described or assigned a type section. While this issue has not been resolved within this rationale, whether the Eurombah and Durabilla formations are one and the same or separate formations, is an objective to be considered as part of the Surat Basin Mapping Project.

Currently the Walloon Coal Measures definition includes the Eurombah Formation, Taroom Coal Measures, Tangalooma Sandstone and Juandah Coal Measures. This rationale has considered a separate description (by lithology and geophysical log) of the Eurombah/Durabilla Formation which distinguishes it from the rest of the coal measure units as discussed in Section 1.3.2. This concurs with the OGIA (2015) rationale where the Eurombah/Durabilla Formation is treated as a separate formation, as well as with CSG companies who differentiate it for use as a regional marker.

2.2 Statistical analysis

The statistical analysis involved simple derivation of the average, variance and standard deviation for all the re-picked formation boundaries submitted to the GSQ by the participating coal seam gas companies and by OGIA (Appendix 1). This analysis revealed that wireline log picks for most of the formations were in general agreement between the companies and GSQ, with OGIA formation picks tending to be outliers within the statistics. This is likely to be due to OGIA re-defining how formations were picked and correlated for their regional-scale geological model. Their methods were defined to best suit their objective of consistency in formation boundaries across their basin scale correlation for hydrogeological assessment purposes.

A notable difference was the placement of the top of the Springbok Sandstone, with up to 100m of difference between OGIA and industry picks for some wells. OGIA have re-defined the Westbourne to be a siltstone-mudstone dominated unit and the Springbok-Westbourne boundary is transitional, rarely showing a sharp change in wireline log character.

In some wells, the top of the Walloon Coal Measures also featured a higher degree of variation than other formations. It is apparent from literature and discussions with industry and academia that there has been a high degree of variability in the past regarding the definition of the top of this formation. This is due to the poor definition of which coal seam is considered the topmost in the Walloon Coal Measures as the overlying Springbok Sandstone is defined to include all the significant coal seams in the Springbok-Westbourne interval. A distinct increase in gamma-ray response over the Walloon Coal Measures was the primary method used in this exercise to determine the top of formation, aided by the resistivity log character to constrain the Walloon-Springbok boundary.

2.3 Key findings from the regional correlation

Using the methodology described above to define formation boundaries using wireline logs, a correlation (Appendix 2) of sixteen 'type' wells was constructed in *GeoLog* by the GSQ to demonstrate any regional trends within the key formations across the northern and eastern extents of the Surat Basin. The top of the Eurombah Formation was used as the datum for the correlation following its use by companies as a regional marker (outlined in Section 1.3.2).

From this correlation, the Springbok Sandstone shows highly variable thickness across the basin. Within the northern extent of the basin, the Springbok Sandstone tends to lack a distinct change in both gamma-ray and resistivity responses that can help identify the top of the formation. Additionally, due to the Westbourne being near surface in the northern Surat Basin, the presence of casing and often a lack of multiple wireline tools being used made interpretation of the Springbok-Westbourne boundary difficult.

The Walloon Coal Measures tend to thicken in the east of the basin with a number of wells penetrating what could be interpreted as local coal depocentres. In the wells from the northern Surat Basin, the top of the formation is relatively easy to pick as there is an abrupt lithological change and increased frequency and thickness of coal packages from the overlying Springbok Sandstone. This is easily seen on the gamma-ray, density and sonic logs. Toward the east, this abrupt change in log signatures lessens as the Walloon Coal Measures begin to feature less thick but more frequent sandstone units, subduing the wireline log response to become more similar to that of the overlying Springbok Sandstone.

This regional scale correlation highlighted minor inconsistencies between company picks across larger areas. Given that company correlations occur at much smaller 'field scales' and formation boundary consistency is much easier across smaller areas, the inconsistency of wireline picks between companies was expected and did not have a significant impact on this component of the project.

3.0 Conclusion

This component of the Surat Basin Mapping Industry Priorities Initiative project reviewed the stratigraphy of the Injune Creek Group and provided a stratigraphic framework on which subsequent phases of the project can be based. A wireline picking rationale was developed for key formations and applied to a set of sixteen 'type' wells selected across the northern and eastern Surat Basin. A subsurface correlation was then constructed to assess any regional trends within these formations across the basin.

There remains some contention about various aspects of the stratigraphy, including the inclusion or exclusion of the Eurombah/Durabilla Formation within the Walloon Coal Measures; the lithological distinction between the Eurombah Formation and the Durabilla Formation, if any; and the definition of the top of the Springbok Sandstone. These issues will be discussed further as part of the project deliverables.

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Appendix 1 – Statistical analysis results

WELL NAME	AZP Kato 3											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation	6.30		0.00	6.30				4.20	8.82	2.97	6.30	
Springbok Sandstone	104.37		93.73	103.55				100.55	23.37	4.83	105.69	103.00
Walloon Coal Measures (Top JCM)	165.65		112.07	166.41				148.04	647.14	25.44	166.27	154.00
Eurombah Formation				322.00				322.00	0.00	0.00	322.00	317.00
Hutton Sandstone												
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	BOW Taringa South 3											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation											N/A	
Springbok Sandstone	See Comment		0.00					0.00	0.00	0.00	1.00	1.00
Walloon Coal Measures (Top JCM)	See Comment	13.49	33.94	50.33				32.59	227.11	15.07	34.61	82.00
Eurombah Formation		219.69	212.44	226.62				219.58	33.52	5.79	211.26	211.00
Hutton Sandstone			268.87					268.87	0.00	0.00	250.83	
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	BOW Carnarvon 3											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation											1.00	1.00
Springbok Sandstone	35.07							35.07	0.00	0.00	32.95	35.07
Walloon Coal Measures (Top JCM)	113.48		45.77					79.63	1146.16	33.86	110.17	110.00
Eurombah Formation			329.09					329.09	0.00	0.00	318.88	324.00
Hutton Sandstone			368.60					368.60	0.00	0.00	365.16	366.00
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	VIP Indy 2											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation	7.10		0.00	7.10				4.73	11.20	3.35	7.10	7.10
Springbok Sandstone	100.93		49.02	101.67	57.40			77.26	587.01	24.23	48.81	97.00
Walloon Coal Measures (Top JCM)	116.14	82.81	113.24	112.68	112.78			107.53	154.38	12.42	116.21	112.00
Eurombah Formation		323.50		358.29	356.19			345.99	253.71	15.93	356.03	356.12
Hutton Sandstone												
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	QGC Dione 7											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation			0.00					0.00	0.00	0.00	N/A	
Springbok Sandstone	0.75		56.31	0.75				19.27	685.98	26.19	0.75	17.17
Walloon Coal Measures (Top JCM)	117.75		118.39	159.88				132.01	388.53	19.71	117.68	110.00
Eurombah Formation	338.90		333.96	339.74				337.53	6.50	2.55	339.74	354.00
Hutton Sandstone												
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME OCA Guluguba 1

	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	**Well Completion Report**	**OGIA**	**Arrow**	**Senex**	**Origin**	**QGC**	**Santos**	**Average**	**Variance**	**Std.Dev**	**Luke**	**Sally**
Cover	0.00							0.00	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation			6.34					6.34	0.00	0.00	N/A	
Springbok Sandstone	99.00		26.42	41.00				55.47	982.71	31.35	1.00	19.05
Walloon Coal Measures (Top JCM)	117.00		56.35	113.29	55.47	114.90		91.40	841.25	29.00	148.75	115.09
Eurombah Formation	430.00		418.06	394.52	405.59	429.28		415.49	189.01	13.75	425.00	
Hutton Sandstone	507.00	503.22	502.31	501.50		483.33		499.47	68.69	8.29	503.08	
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AEL Yeronga 1												
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	**Well Completion Report**	**OGIA**	**Arrow**	**Senex**	**Origin**	**QGC**	**Santos**	**Average**	**Variance**	**Std.Dev**	**Luke**	**Sally**
Cover	0.00							0.00	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone	5.00		5.00	5.00				5.00	0.00	0.00	5.00	5.00
Westbourne Formation	126.52		80.52	107.48	128.30			110.71	370.31	19.24	107.50	84.40
Springbok Sandstone	259.18		259.18	170.19	175.82			216.09	1860.49	43.13	160.16	160.07
Walloon Coal Measures (Top JCM)	320.22		320.22	321.30	315.47	321.00		319.64	4.53	2.13	320.55	320.00
Eurombah Formation	693.90		693.90	686.27	683.32	694.13		690.30	21.11	4.59	686.62	694.00
Hutton Sandstone	769.72		769.72	786.05		785.58		777.77	64.79	8.05	785.74	786.07
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AUS Condabri 14											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation			1.09	14.40				7.75	44.29	6.66	1.00	
Springbok Sandstone	118.80		60.35	90.70	38.47			77.08	924.17	30.40	33.33	88.00
Walloon Coal Measures (Top JCM)	197.53	105.10	111.51	143.10	172.41	213.37		157.17	1668.95	40.85	197.53	197.00
Eurombah Formation	478.38	456.22	455.84	470.43	456.63	481.94		466.57	118.61	10.89	469.77	473.00
Hutton Sandstone	534.98	519.71	540.24	540.55		521.30		531.36	82.67	9.09	534.00	525.00
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	QGC Lawton 4											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation	4.00		51.51	4.00				19.84	501.60	22.40	0.90	
Springbok Sandstone	67.90		95.16	73.36	59.65	65.87		72.39	148.88	12.20	60.05	60.00
Walloon Coal Measures (Top JCM)	153.10	150.47	156.00	235.37	152.05	152.21		166.53	950.47	30.83	156.67	158.22
Eurombah Formation		563.25	561.70	571.03	561.72	585.70		568.68	84.37	9.19	570.26	560.38
Hutton Sandstone		665.00	631.97					648.49	272.75	16.52	666.97	600.00
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AUS Condabri 9											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover	4.30							4.30	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation			54.98	56.72				55.85	0.76	0.87		
Orallo Formation			154.35	153.97				154.16	0.04	0.19		250.00
Gubberamunda Sandstone			250.65	256.10				253.38	7.43	2.73		289.00
Westbourne Formation	439.44		439.37	346.85	439.27			416.23	1604.65	40.06	438.72	440.00
Springbok Sandstone	566.47		570.96	514.06	516.15	513.39		536.21	707.40	26.60	567.79	568.00
Walloon Coal Measures (Top JCM)	654.15		592.88	653.80	652.23	653.96		641.40	589.11	24.27	653.29	654.00
Eurombah Formation	933.21	933.21	932.25	933.21	932.13	947.15		935.19	28.80	5.37	933.21	947.21
Hutton Sandstone	1004.00		1020.77			1019.65		1014.81	58.60	7.66	1019.79	998.00
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AEL Hopeland 2											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover	0.00							0.00	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation	19.76		19.94					19.85	0.01	0.09	1.20	18.78
Springbok Sandstone	73.02		73.20	56.85	0.00			50.77	903.18	30.05	60.06	43.90
Walloon Coal Measures (Top JCM)	98.93		98.93	99.10	98.77	99.15		98.98	0.02	0.14	99.00	98.16
Eurombah Formation	451.39		451.39	458.13	454.11	455.22		454.05	6.43	2.54	452.38	451.00
Hutton Sandstone	536.51		536.51			536.00		536.34	0.06	0.24	548.31	549.01
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	PAN Duke S1A											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover	0.00							0.00	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone	164.00	163.58	51.86	52.25				107.92	3121.22	55.87		
Westbourne Formation	197.00	196.84	197.22	197.94				197.25	0.18	0.42	197.93	197.00
Springbok Sandstone	350.00	281.74	433.89	349.02		337.17		350.36	2372.37	48.71	336.84	336.00
Walloon Coal Measures (Top JCM)	447.70	450.49	449.00	449.31		449.45		449.19	0.81	0.90	448.86	379.00
Eurombah Formation	790.00	777.39	794.41	795.32		776.89		786.80	65.50	8.09	794.50	782.00
Hutton Sandstone			862.58			849.57		856.08	42.32	6.51	862.65	847.46
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AEL Daandine 23A											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover	0.43							0.43	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone												
Westbourne Formation	20.00		20.04					20.02	0.00	0.02	1.00	0.00
Springbok Sandstone	51.00		51.00	23.49				41.83	168.18	12.97	23.68	30.00
Walloon Coal Measures (Top JCM)	101.00		101.00	102.25	101.20			101.36	0.27	0.52	87.90	102.66
Eurombah Formation	448.02	425.69	445.89	456.21	442.18	447.81		444.30	86.89	9.32	450.67	447.14
Hutton Sandstone	539.00		538.33			537.32		538.22	0.48	0.69	551.77	550.33
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	QGC Teviot 1											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation			116.74					116.74	0.00	0.00		116.94
Gubberamunda Sandstone	4.00	215.45	216.51	26.17				115.53	10151.28	100.75		215.64
Westbourne Formation	320.90	278.13	320.72	275.14	320.62	215.83		288.56	1447.75	38.05	321.04	314.59
Springbok Sandstone	417.30	364.90	475.54	422.78	417.55	419.00		419.51	1023.55	31.99	417.96	418.04
Walloon Coal Measures (Top JCM)	551.42	550.01	550.00	551.42	548.88	549.91		550.27	0.81	0.90	549.83	547.68
Eurombah Formation	829.70	828.80	829.12	841.40	835.71	840.21		834.16	27.57	5.25	829.70	850.00
Hutton Sandstone	910.66		911.32					910.99	0.11	0.33	911.31	905.88
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AUS Gilbert Gully 17											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover												
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone		143.21		20.35				81.78	3773.64	61.43		20.84
Westbourne Formation		232.11	231.41	230.96	231.84			231.58	0.19	0.44	231.27	227.48
Springbok Sandstone		294.28	409.30	353.99	355.04			353.15	1655.69	40.69	353.70	353.00
Walloon Coal Measures (Top JCM)	492.08	492.83	492.00	492.55	491.57			492.21	0.19	0.44	491.82	492.00
Eurombah Formation	792.88	784.61	788.83	817.90	786.62			794.17	148.34	12.18	792.15	792.10
Hutton Sandstone	856.71	838.95	888.81	862.03				861.63	319.38	17.87	861.89	888.68
Evergreen Sandstone												
Precipice Sandstone												

WELL NAME	AUS Zig Zag 7											
	Original Picks (depth, m)	OGIA Picks (depth, m)	Company Re-Picks (depth, m)					Company Statistics			GSQ Picks (depth, m)	
Stratigraphy	Well Completion Report	OGIA	Arrow	Senex	Origin	QGC	Santos	Average	Variance	Std.Dev	Luke	Sally
Cover	1.00							1.00	0.00	0.00		
Wallumbilla Formation												
Bungil Formation												
Mooga Formation												
Orallo Formation												
Gubberamunda Sandstone			4.93	37.25				21.09	261.15	16.16		13.46
Westbourne Formation			40.71	61.86	171.87			91.48	3305.83	57.50	60.20	51.96
Springbok Sandstone	195.77		252.46	199.01	195.77			210.75	581.59	24.12	195.64	195.00
Walloon Coal Measures (Top JCM)	286.75	285.68	286.00	293.03	286.55			287.60	7.51	2.74	286.22	310.00
Eurombah Formation	485.59	476.12	477.73	480.18	476.53			479.23	12.11	3.48	477.45	484.69
Hutton Sandstone	546.49	541.54	545.98	546.41				545.11	4.27	2.07	546.23	539.98
Evergreen Sandstone												
Precipice Sandstone												

Appendix 2 – Regional correlation