Appendix H
Stage 1 groundwater monitoring bore construction

Groundwater Monitoring Bore Drilling Completion Report

Stage 1 Drilling Program

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GROUNDWATER PROJECT

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INTRODUCTION

QGC Pty. Limited ('QGC') - a BG Group business ('BG') is developing an integrated Liquefied Natural Gas (LNG) project in Queensland, Australia. The Queensland Curtis LNG Project ('QCLNG') involves the extraction of coal seam gas (CSG) from deep coal beds in the Surat Basin in South East Queensland from which LNG will be produced for export from a port in Gladstone. In extracting CSG, substantial quantities of associated water must also be extracted.

QGC wishes to implement a comprehensive groundwater monitoring program for the Gas Field Component of the QCLNG Project to ensure that any impacts from the project on the groundwater resources in the region are identified and quantified. The groundwater monitoring program intends to fulfil the statutory, management and environmental requirements for groundwater monitoring.

1.1 Groundwater Monitoring Plan

A major component of QGC's groundwater monitoring program for the QCLNG Project is the Groundwater Monitoring Plan (GWMP), which was developed in 2009 and 2010 and was submitted to the Federal Government (as an appendix to the Stage 1 Water Monitoring and Management Plan) in April 2011. The GWMP is prepared as a working tool to provide monitoring programs for the upstream portion of the QCLNG project and the related reporting requirements. The GWMP is also prepared to satisfy both state and federal government conditions, such as Condition C6 within the Project's Environmental Authority (PEN100020207), and serves as a base for the required Coal Seam Gas Water Monitoring and Management Plan as required in The Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) conditions released in October 2010.

To acceptably monitor the potential impacts to the quality of groundwater and levels caused by CSG activities, groundwater monitoring bores are required across the Project area. Monitoring bores are needed primarily within each of QGC's operational areas, but also up gradient and down gradient of project activities where drawdown impacts are predicted to occur and outside of the predicted impact areas to monitor for background conditions. Monitoring will be required across the range of hydrogeological formations present in the Project area. There are three classes of infrastructure proposed for groundwater monitoring: privately owned bores, vibrating wire piezometers, and multilevel nested well systems (the latter purpose drilled monitoring bores for both water quality and water level sampling).

1.2 This Report

In mid-2010 the QGC Subsurface Development team, in association with the Water Group, instigated Stage 1a of the GWMP drilling program. This involved the drilling and construction of 8 shallow groundwater monitoring bores targeting the Gubberamunda and Springbok aquifers (i.e. the main aquifers located above the Walloon Coal Measures (WCM) that are the target of CSG development), at 4 locations across QGC's Central and Southern Development Areas (CDA and SDA). In early to mid 2011, the Stage 1a drilling program was extended to cover a further 3 monitoring bores in the CDA and also 2 monitoring bores in the Northern Development Area (NDA), again targeting the Gubberamunda and Springbok aquifers. The further 5 bores are known as Stage 1b of the drilling program.

This report documents the findings of the Stage 1 drilling program (i.e. Stage 1a and Stage 1b).

2.0 HYDROGEOLOGICAL SETTING

2.1 Surat Basin Geological Setting

The Surat Basin is a large intracratonic basin of Mesozoic age covering approximately 300,000km2 of southeastern Queensland and northern New South Wales. The basin forms part of the larger Great Australian Basin (Green et al., 1997), and interfingers westward across the Nebine Ridge with the Eromanga Basin, and eastward across the Kumbarilla Ridge with the Clarence-Moreton Basin (Exon, 1976). Basement blocks consisting of the Central West Fold Belt and the New England Fold Belt limit the basin to the south, while in the north the basin has been eroded and unconformably overlies Triassic and Permian sediments of the Bowen Basin.

The Surat Basin contains up to 2,500m of sedimentary rocks deposited during the Latest Triassic to Early Cretaceous periods (Figure 1). The Latest Triassic to Earliest Cretaceous succession in the basin consists of five fining-upwards sedimentary cycles dominated by fluviolacustrine deposits (Exon, 1976; Exon and Burger, 1981; Day et al, 1983). The lower part of each cycle typically comprises coarse-grained mature sandstone, grading up into more labile sandstone and siltstone, with mostly siltstone, mudstone and coal in the upper part. In the Cretaceous, inundation of the land through an increase in sea level led to deposition of predominantly coastal plain and shallow marine sediments in two cycles.

Structurally the Surat Basin is relatively simple, with the area of maximum deposition, the Mimosa Syncline, overlying the thickest Permian-Triassic rocks in the Taroom Trough of the underlying Bowen Basin (Day et al., 1983). Major faulting within the basin predominantly mirrors basinal boundary faults of the underlying Bowen Basin. There is substantial folding across the basin, which is due to compaction and draping, as well as some rejuvenation of older pre-Jurassic structures and faults. Formations outcrop along the northern erosional boundary and dip gently to the south and southwest at less than 5°.

2.2 Shallow Aquifers

The Stage 1 drilling program targets the main aquifers that lie above the Walloon Coal Measures in QGC's tenements, those being the Springbok and Gubberamunda Sandstones. The Springbok and Gubberamunda Sandstones are separated by the Westbourne Formation aquitard.

2.2.1 Springbok Sandstone

The Springbok Sandstone is of late-middle Jurassic age, and sits unconformably on top of the WCM. The unit occurs in small channel/valley structures eroded into the uppermost WCM layers, including the coal seams. The formation consists of feldspathic and lithic sandstones, interbedded carbonaceous siltstones, interbedded mudstone, tuffs, and occasional thin coals. The sandstones display an overall fining upward character, which are fine to coarse grained and found commonly with calcareous cement (calcite) although some areas are friable and display porosity and permeability. Clays, and clay matrix-fill, are common in the typical Springbok Sandstone section, and are likely due to the volcanic sediment sourcing of the material.

The thickness of the Springbok sandstone typically ranges between 50 to 150 m. The depositional environment is believed to be low energy fluvial with gradual infilling with overbank and mire sediments as accommodation space decreased. Sediment sources differ with volcanic lithics and feldspathic rich sediments from the north and east and quartz rich sediments from the south (Green et al., 1997).

Available data suggests that the Springbok aquifer is not widely used within QGC tenements, especially in the SDA and CDA, and there is minimal use in the vicinity of the NDA. This is primarily due to the presence of the shallower Gubberamunda Sandstone aquifer which typically is both better yielding and contains fresher groundwater in the QGC tenements.

2.2.2 Westbourne Formation

The Late Jurassic Westbourne Formation is conformable with the underlying Springbok sandstone. It comprises interbedded with shales, mudstones, siltstones, and fine grained sandstones, with occasional thin coal seams. Sandstones in the section are similar to the Springbok sandstone and could be deposition source related. Thickness of the Westbourne Formation increases to the east up to 200 m. This formation is interpreted to be deposited in a lacustrine (lake environment) environment with deltaic influences. The unit typically forms an effective aquitard separating the Springbok and Gubberamunda Sandstones.

The contact with the Springbok Sandstone is transitional as the Springbok-Westbourne units represent a single fining upwards sequence.

2.2.3 Gubberamunda Sandstone

Conformably overlying the Westbourne Formation is the Gubberamunda Sandstone of late Jurassic age. This sandstone unit consists of medium to coarse grained, poorly sorted, un-cemented, quartz rich sandstones interbedded with fine grained sandstone, siltstone and shale, with occasional conglomeritic layers. Thickness of the Gubberamunda Sandstone increases towards to the south, up to 300 m. Deposition is a high energy, fluvial influenced, mixed continental and shallow marine environment. It includes numerous high permeability lenses and bands which are exploited for their water resources.

The Gubberamunda Sandstone is exposed at the surface across the NDA, and outcrops/subcrops in the CDA and SDA.

The Gubberamunda Sandstone is widely utilised in the CDA and NDA for stock and domestic purposes, where it commonly forms the shallowest aquifer.

2.2.4 Other Shallow Formations

There are several other shallow formations identified regionally as important aquifers, although these for the most part do not occur on QGC tenements or are too shallow (and therefore have limited saturation) to be considered important aquifers.

The Cretaceous-aged Mooga Sandstone, which lies shallower in the Surat sequence than the Gubberamunda Sandstone and is separated from it by the Oralla Sandstone, is utilised to the west of QGC operations for stock and domestic purposes, and also in the southern part of the Wolleebee Creek area of the NDA. The Mooga Sandstone outcrops across parts of the NDA, and subcrops in parts of the CDA and SDA.

Quaternary Alluvium Aquifers and Tertiary sediments are also identified regionally as important aquifers. These typically comprise the surficial unconfined and unconsolidated aquifers associated with the major drainage systems. Directly east of the SDA, the most prevalent Quaternary aquifer is the Condamine River Alluvium (CRA), which is a highly developed and exploited water resource in the region. A great number of extraction bores exist in the CRA, used for multiple purposes such as for stock and domestic uses, irrigation, industrial, and town supply supplies. The Condamine River Alluvium overlies the Surat Basin formations unconformably in some areas, lying in direct contact with many of the aquifers and aquitards of the Surat Basin sequence. Very little CRA is identified on QGC tenements, with only the Harry and Broadwater blocks within the southeastern-most SDA having CRA mapped on them.

3.0 STAGE 1 DRILLING PROGRAM

3.1 Monitoring Well Location – Rationale

As described in Section 1.1, the QGC GWMP outlines a network of groundwater monitoring bores to satisfy some of the groundwater monitoring requirements of the QCLNG Project. Monitoring bores are required to provide sufficient spatial coverage of water levels and water quality monitoring across QGC's operational areas, and in particular areas of potential impact and nearby sensitive receptors. As part of the GWMP development, results of numerical groundwater modelling undertaken as part of QGC's Stage 1 Coal Seam Gas Water Monitoring and Management Plan (WMMP) were used to identify particular areas across QGC's tenements where enhanced groundwater drawdown impacts might be expected. Additionally, the GWMP has been compiled to incorporate the requirements of various other Groundwater Projects including the Connectivity Study and Managed Aquifer Recharge (MAR) projects. That is, some groundwater monitoring locations, well designs and other drilling tasks (e.g. core collection) are specified in the GWMP based on the requirements of these other Groundwater Projects, the details of which are described in the Stage 1 WMMP.

The locations of the monitoring wells in the Stage 1 Drilling Program are a subset of the groundwater monitoring locations identified in the GWMP. The subset was developed based on the following criteria: (i) areas where CSG extraction is currently occurring or scheduled to occur shortly, and (ii) QGC-owned land so that drilling could occur immediately with no delays associated with land access negotiations etc.

3.2 Overview

The aims of the Stage 1 drilling program were to provide:

- Wells to enable accurate and conclusive water level monitoring of the shallow (Gubberamunda and Springbok) aquifers on easily accessible (QGC owned) property in order to satisfy some of the shorter term commitments of the GWMP.
- Intermittent and conclusive water quality monitoring of the shallow (Gubberamunda and Springbok) aquifers on easily accessible (QGC owned) property in order to satisfy commitments of the GWMP.
- Wells of a suitable design and quality that future pumping tests to obtain shallow aquifer hydraulic properties could be undertaken for the target aquifer of each well for input into future groundwater studies.
- Petrophysical logging at each drilling location to ascertain as much shallow geological information as possible, which is typically not an aim of other QGC drilling programs (e.g. CSG well drilling).
- Collection of core in the NDA for laboratory analysis for input into shallow MAR studies for NDA water management option studies.

The Stage 1 drilling program was divided into two parts; Stage 1a and Stage 1b. Stage 1a was instigated by QGC Subsurface Development prior to compilation of the GWMP and involved the drilling of 8 monitoring bores at 4 sites located on QGC owned property. Stage 1b was instigated by Water Group and involved the drilling of a further 5 monitoring bores at 3 sites on QGC owned property, in order to complete the shallow groundwater monitoring network on QGC owned property as outlined in Rev 0 of the GWMP.

Table 1 presents locality information for the Stage 1 drilling program. Note that the coordinates given on Table 1 are derived from a handheld GPS, as surveying is yet to be undertaken. Drilling locations were chosen according to ease of access (i.e. on QGC-owned land) and to minimise land disturbance (i.e. on existing CSG well lease pads or other previously prepared hardstand areas typically used for temporary drilling accommodation camps).

Drilling and well construction operations were undertaken by TCL International Pty Ltd of Albury NSW, using a Schram T685 multipurpose drilling rig, equipped with an 80 HP onboard Worthington Duplex mud pump supported by an ancillary 500 HP OIME Triplex mud pump, a 30 bbl mud system comprising of sand trap, active pit, 2 x 4" desilter cones and a single 800 gpm DFE lineal motion shale shaker.

Drilling operations were overseen by a Queensland Class 2 licensed water bore driller and took place according to the *Minimum Construction Requirements for Water Bores in Australia*. A QGC hydrogeologist was present at all times for wellsite hydrogeological supervision duties.

3.3 Well Drilling

All Stage 1 wells were drilling using mud-rotary methods from ground surface to TD by TCL International Australia Pty Ltd (TCL Drilling).

Drilling was typically undertaken using an 8.5" PDC bit and fresh water based drilling fluid. At the commencement of well drilling, small amounts of PAC-RE polymer were occasionally added to the drilling fluid to enhance viscosity, however, no bentonite was added to the drilling fluid throughout the drilling program as it was found that natural formation clays were sufficient in gelling the drilling fluid to the required density and viscosity. The targeted drilling fluid density was 1.1 g/cc, with the targeted viscosity approximately 40 to 45 seconds on the Marsh funnel. Breakback agents were occasionally added to the drilling fluid as a thinning agent in the event that natural formation clays caused the drilling fluid to exceed the desired viscosity/density.

Table 1: Stage 1 Monitoring Bore Drilling Locality Information

Work Stage	QGC Block	Well Name	Latitude	Longitude	Ground Elevation (mRL)[1,2]	Target Aquifer
Stage 1a	Berwyndale South	Berwyndale South GW1	-26.84696	150.30014	291	Gubberamunda Sandstone
		Berwyndale South GW2	-26.84703	150.30011	291	Springbok Sandstone (mid)
	Lauren	Lauren GW1a	-26.95601	150.35655	321	Gubberamunda Sandstone
		Lauren GW2	-26.95594	150.35651	321	Springbok Sandstone (lower)
	Kenya East	Kenya East GW1	-27.02859	150.54848	317	Gubberamunda Sandstone
		Kenya East GW2	-27.0284	150.54868	317	Springbok Sandstone (mid)
	Poppy	Poppy GW1	-27.17135	150.78246	366	Springbok Sandstone (upper)
		Poppy GW2	-27.17118	150.78229	366	Springbok Sandstone (lower)
Stage 1b	Wolleebee Creek	Wolleebee Creek GW1	-26.28198	149.71487	367	Gubberamunda Sandstone
		Wolleebee Creek GW2	-26.28201	149.71495	367	Springbok Sandstone (lower)
	Kenya East	Kenya East GW3	-27.02253	150.56413	316	Gubberamunda Sandstone
		Kenya East GW4	-27.02247	150.56418	316	Springbok Sandstone (lower)
	Bellevue	Bellevue GW2	-26.69087	150.26704	332	Springbok Sandstone (lower)

Notes: 1. Taken from survey results from adjacent CSG well on the same lease, typically within 50 m.
2. mRL = mAHD.

Penetration rates of around 25 to 30 m/hr were commonly achieved during the drilling program.

Cuttings were logged on site at 2 m intervals by QGC hydrogeologists.

Core collection during drilling of the Woleebee Creek GW1 well (Gubberamunda Sandstone) was specified during the drilling program, in order to provide comprehensive laboratory formation property data for shallow MAR studies. The well was drilled to core depth using a standard PDC bit, after which drilling progressed through the target formation using a conventional 4 7/8” OD x 3” ID core barrel. Core was collected and packed for transport on site by Weatherford Laboratories. The cored section of the drillhole was reamed to 5.5” following coring in preparation for accepting 4” casing.

Drilling summary data cards, inclusive of cuttings logs, are presented as Appendix A. Table 2 presents aquifer information.

3.4 Wireline Logging

In order to confirm screen zones and final well construction designs, wells were petrophysically logged following drilling, to identify the best sand units in which to screen the wells. In order to minimise logging costs and delays in well construction, where possible the deepest well at each site was drilled first so that the shallower well could have its design confirmed at the same time, thus avoiding the need to also petrophysically log the shallower well.

Wireline logging required a minimum 11 m overdrill rathole to allow the logging tools to run to depth, however this was not possible in the later Springbok wells which were designed to monitor the deepest sand unit within the Springbok formation, as this deepest sand unit commonly lay directly on the Walloon Coal Measures, and drilling into the Walloons was to be avoided in order to not breach P&G Regulations. In these situations, wells were designed using additional data sourced from wireline logs from adjacent (on the same lease pad) CSG wells, so that screen settings could still be targeted towards the basal sand units of the Springbok formation.

Wireline logging was undertaken by Weatherford Wireline Services using one of the two logging units on call to QGC. The standard QGC logging suite was run on each drillhole, that being Hole Finder, Induction, Focussed Electric, Density/Caliper, Neutron, and Gamma. On later wells, a CMI tool was also run to obtain well verticality and deviation information.

Wireline logs are presented as Appendix B.

3.5 Well Construction

With the exception of the Wolleebee Creek wells, the Stage 1 monitoring wells were all completed using 5” DN class 18 uPVC bore casing with mechanical (threaded) joints. Solvent-based glues were avoided during well construction due to potential for false water chemistry analyses in the future. Woleebee Creek GW1 was completed with 6” PVC casing to core point (137 m), and then with telescoped 4” PVC casing through the cored section. Due to the Woleebee Creek GW2 well depth exceeding the safe limit for the installation of PVC casing (collapse pressures etc), Woleebee Creek GW2 was completed with 6” PVC casing to 300 m depth with 4” stainless steel casing telescoped below the PVC casing.

All Stage 1 wells were completed with 5 m of stainless steel wedge-wire screens across the target interval as determined from petrophysical logging. Screens were secured to the casing string via mechanical (threaded) joiners. After the drilling of the first well of the program (Kenya East GW1), gravel packing was included in the well construction method due to the presence of fine running sands during development. Stage 1b wells were constructed using pre-packed well screens to avoid problems associated with running gravel packs and bentonite seals to depth after running the casing and screen string.

A minimum 1 m casing sump was run below the well screens to avoid silting of the well screen over time.

Stage 1a wells had their gravel packs sealed with a bentonite plug before cement grout annular plugs were run across selected identified zones (e.g. above gravel pack, and across other identified permeable zones up hole). Initially cement plugs above the screen gravel pack were run utilising a sliding sleeve port run inline with the casing string, with tremi lines run for additional cement plugs up hole. However this

Table 2: Stage 1 Monitoring Bore Aquifer Information

Work Stage	Well Name	Target Aquifer	Aquifer Intersection (m bgl) [1]	Aquifer Lithology [2]
Stage 1a	Berwyndale South GW1	Gubberamunda Sandstone	100 - 110	Coarse to very coarse quartzose sandstone
	Berwyndale South GW2	Springbok Sandstone	224 – 236 (mid)	Fine to medium clayey sandstone
	Lauren GW1a	Gubberamunda Sandstone	170 - 176	Fine to medium grained sandstone
	Lauren GW2	Springbok Sandstone	302 – 314 (lower)	Well sorted fine grained sandstone with some siltstone and clay
	Kenya East GW1	Gubberamunda Sandstone	87 – 107	Medium to coarse sandstone with minor silt
	Kenya East GW2	Springbok Sandstone	242 – 262 (mid)	Medium grained clayey sandstone
	Poppy GW1	Springbok Sandstone	116 – 132 (upper)*	Shale with up to 30% fine to medium sand * Note: petrophysical logs indicate very poor "aquifer"
	Poppy GW2	Springbok Sandstone	162 – 179 (lower)	Fine to medium grained sandstone
Stage 1b	Wolleebee Creek GW1	Gubberamunda Sandstone	135 - 160 166 – 188	Fine to coarse grained sandstone
	Wolleebee Creek GW2	Springbok Sandstone	345 – 362 (mid) 380 – 388 (mid) 400 – 412 (lower) 418 – 434 (lower)	Medium to coarse grained clayey sandstone Fine to medium grained clayey sandstone
	Bellevue GW2	Springbok Sandstone	162 – 173 (lower)	Fine to medium grained sandstone, minor silt and clay
	Kenya East GW3	Gubberamunda Sandstone	72 – 79	Medium to coarse grained clean sandstone
	Kenya East GW4	Springbok Sandstone	269 – 279 (mid) 304 – 322 (lower)	Poorly sorted fine to coarse grained clayey sandstone

Notes: 1. Derived from petrophysical logs – refer Appendix B. Not necessarily formation top/bottom depths
2. Derived from cuttings descriptions

approach proved problematic due to difficulties with the sliding sleeve and multiple tremi lines in the limited annular space, and was abandoned towards the end of Stage 1a, replaced by tremi cementing to surface. Kenya East GW1, which was not gravel packed, had the production interval isolated from the annular cement plug by the use of a flexible rubber packer.

The last three Stage 1b wells were constructed using both pre-packed screens and a secondary gravel pack installed after the casing string was run to depth in the borehole. The reason for the secondary gravel pack was to avoid using flexible rubber packers to isolate the screen section from the annular cement seal, which were considered to be potentially unreliable. Due to the multiple gravel packs, it was then considered that running a (potentially problematic) bentonite seal before grouting was not necessary.

The overdrill rathole was typically backfilled with gravel. Where coal seams were identified within the rathole, the rathole was cemented up to avoid the possibility of gas from the coal seams entering the gravel pack.

Well heads were completed using a 10” steel collar cemented to 1.5 m below ground surface and with a lockable stainless steel cap.

Wells were developed by airlifting from within the well screen until the water produced was clean and fines free to the satisfaction of the supervising hydrogeologist. Occasionally breakback agents were added to the wells in order to clear well screens that had become blocked with bentonitic drilling fluid. Airlift yields and produced water quality were monitored and recorded.

Lauren GW1 had to be abandoned following running of casing when a casing joint failed 71 m downhole during preparation for cementing. The well was then plugged with cement grout from TD to ground surface and Lauren GW1a was successfully drilled as a replacement.

Table 3 presents a summary of the Stage 1 well construction information, and Table 3 presents a summary of the water production information prior to rig release. Due to differing availability of water quality testing equipment during the program, some groundwater salinities were recorded as TDS whilst others were recorded as EC. For Table 4, to allow consistency EC’s were converted to TDS using the formula TDS = EC x 0.6. Note that laboratory analysis of water samples from the Stage 1 wells will be undertaken in late 2011 and early 2012.

Drilling summary data sheets, inclusive of well construction information, are presented as Appendix A. Well construction diagrams are presented as Appendix C.

3.6 Discussion of Drilling Results

3.6.1 Geology

At all Stage 1 drilling locations, with the exception of Poppy in the SDA, the Gubberamunda Sandstone was found to be present. The unit typically consists of a fining upward quartzose sandstone, ranging in grainsize from fine grained to pebbly coarse grained. A coarse grained basal aquifer was commonly located at the base of the Gubberamunda unit in all Stage 1 wells, lying directly on top of the Westbourne Formation. The contact between the Gubberamunda and the Westbourne appears well defined, except for at Woleebee Creek in the NDA. At all locations where it was found, the Gubberamunda unit was interpreted as being overlain by the Orallo Sandstone formation, which consists of fine to medium grained cemented sandstone and shale. However, there did not appear to be any clear distinction between the base of Orallo and the top of the Gubberamunda formation and the boundary is somewhat subjective.

The Westbourne Formation was found to consist of a medium-grey mudstone/shale, with occasional thin sandstone beds. Several thin coal seams were present in the section, and these appeared to be consistent across all Stage 1 drilling locations. The contact with the underlying Springbok Sandstone unit was very diffuse and difficult to pick, with the Westbourne appearing to grade into the Springbok. The Springbok Sandstone commonly consisted of interbedded sandstone and shale, with numerous coal seams, with the sandstone units consisting of a clay rich, lithic fine to medium grained sandstone. In contrast to the Gubberamunda Sandstone, there did not appear to be a consistent aquifer zone across the Stage 1 Springbok wells, with aquifers identified in the upper, mid and lower parts of the formation.

Table 3: Stage 1 Monitoring Bore Drilling Well Construction Information

Work Stage	Well Name	Target Aquifer	Casing Type	Casing Setting (m bgl)	Screen setting (m bgl)	Gravel pack type
Stage 1a	Berwyndale South GW1	Gubberamunda Sandstone	5" DN cl 18 uPVC	0-100	100-105	Unimin 5/2
	Berwyndale South GW2	Springbok Sandstone (mid)	5" DN cl 18 uPVC	0-225	225-230	Unimin 5/2
	Lauren GW1a	Gubberamunda Sandstone	5" DN cl 18 uPVC	0-170	170-175	Unimin 5/2
	Lauren GW2	Springbok Sandstone (lower)	5" DN cl 18 uPVC	0-305	305-310	Unimin 5/2
	Kenya East GW1	Gubberamunda Sandstone	5" DN cl 18 uPVC	0-98	98-103	None
	Kenya East GW2	Springbok Sandstone (mid)	5" DN cl 18 uPVC	0-250	250-255	Unimin 5/2
	Poppy GW1	Springbok Sandstone (upper)	5" DN cl 18 uPVC	0-122	122-127	Unimin 5/2
	Poppy GW2	Springbok Sandstone (lower)	5" DN cl 18 uPVC	0-172	172-177	Unimin 5/2
Stage 1b	Wolleebee Creek GW1	Gubberamunda Sandstone	6" DN cl 18 uPVC 4" DN cl 18 uPVC	0-150 150-178	178 - 183	Pre-pack
	Wolleebee Creek GW2	Springbok Sandstone (lower)	6" DN cl 18 uPVC 6" DN Sch 40 316 SS 4" Sch 40 316 SS	0-300 300-312 312-425	425-430	Pre-pack
	Bellevue GW2	Springbok Sandstone (lower)	5" DN cl 18 uPVC	0-167	167-172	Pre-pack and Unimin 5/2
	Kenya East GW3	Gubberamunda Sandstone	5" DN cl 18 uPVC	0-74	74-79	Pre-pack and Unimin 5/2
	Kenya East GW4	Springbok Sandstone (lower)	5" DN cl 18 uPVC	0-315	315-320	Pre-pack and Unimin 5/2

Table 4: Stage 1 Monitoring Bore Drilling Water Production Information

Work Stage	Well Name	Target Aquifer	Airlift Yield (L/s)	Airlift Groundwater Salinity (field)	Airlift Groundwater pH (field)	Stabilised Standing Water Level (mTOC)
Stage 1a	Berwyndale South GW1	Gubberamunda Sandstone	3 to 4	800 mg/L	Not recorded	21.0
	Berwyndale South GW2	Springbok Sandstone (mid)	0.5 to 1	1400 mg/L	Not recorded	5.6
	Lauren GW1a	Gubberamunda Sandstone	2	800 mg/L	Not recorded	51.8
	Lauren GW2	Springbok Sandstone (lower)	2 to 3	1300 mg/L	Not recorded	11.4
	Kenya East GW1	Gubberamunda Sandstone	3	1000 mg/L	Not recorded	34.8
	Kenya East GW2	Springbok Sandstone (mid)	3	1000 mg/L	Not recorded	8.6
	Poppy GW1	Springbok Sandstone (upper)	Well airlifted dry, little to no continuous yield	1900 mg/L	Not recorded	43.1
	Poppy GW2	Springbok Sandstone (lower)	1.5	2100 mg/L	Not recorded	52.3
Stage 1b	Wolleebee Creek GW1	Gubberamunda Sandstone	1	800 mg/L	9.2	74.7
	Wolleebee Creek GW2	Springbok Sandstone (lower)	Well airlifted dry, little to no continuous yield	7800 mg/L	12.7	77.9 [1]
	Bellevue GW2	Springbok Sandstone (lower)	Well airlifted dry, little to no continuous yield	4.6 mS/cm (~2800 mg/L)	9.3	23.9
	Kenya East GW3	Gubberamunda Sandstone	0.8	700 mg/L	8.8	33.0
	Kenya East GW4	Springbok Sandstone (lower)	0.4	1.9 mS/cm (~1100 mg/L)	9.0	16.3

Note: 1. Still recovering from drilling at approx 5 cm/day at time of reporting (mid-Jan 2012)

3.6.1 Groundwater

In the wells drilled as part of the Stage 1 program, the Gubberamunda aquifer typically showed higher yields during airlifting compared to the Springbok aquifer. Airlift yields from the Gubberamunda aquifer wells averaged 2 L/s, and ranged between 0.8 and 3.5 L/s, whereas airlift yields from the Springbok aquifer averaged only 1 L/s and ranged between no yield and 3 L/s. Three Springbok wells appeared to have very little yield, with a flowrate so small it was unable to be recorded. This is despite the wells screening the most permeable identified section of the formation (based on wireline logs) at the target depth. It is apparent from these results that the hydraulic conductivity of the Springbok aquifer is generally much lower than the Gubberamunda aquifer at the Stage 1 drilling locations.

In the wells drilled as part of the Stage 1 program, the Springbok aquifer typically has elevated groundwater salinities compared to the Gubberamunda aquifer, and the Springbok also shows a larger range of salinities. Field chem kit analysis of airlift water from the Springbok reported salinities of between 1,000 an 7800 mg/L, averaging 2,400 mg/L, whilst reported Gubberamunda aquifer salinities were between 700 and 1,000 mg/L, with an average of 800 mg/L. Although pH wasn't recorded until Stage 1b was undertaken, groundwater pH appears to range around 9 regardless of aquifer.

In the CDA and SDA areas, groundwater pressures were consistently higher in the Springbok aquifer than the Gubberamunda aquifer at each drilling site, with between 15 and 40 m head difference. This suggests that the Westbourne Formation forms an effective aquitard between the two units. Additionally, there appears to be a downwards pressure gradient within the Springbok Sandstone, as shown at Kenya East and Poppy, suggesting that low permeability confining zones within the Springbok separate water bearing zones. The hydrogeologic cause for this anomalous downwards pressure gradient is at this stage unknown.

3.7 Conclusions

It is considered that the Stage 1 groundwater monitoring wells were successful in delivering the objectives of the drilling program, in that:

- Satisfactory 'shallow' (i.e. above Walloon Coal Measures) geological and petrophysical information was collected.
- Hydraulic separation of aquifers was successfully accomplished in the well completions, such that clear hydraulic head and salinity differences were obtained in data from adjacent well pairs.
- Hydraulic heads for each well are easily obtainable for the shallow aquifers by running an electric water level tape, and the wells are suitable for the installation of groundwater level loggers.
- All wells are suitable for future running of electro-submersible pumps for aquifer pumping tests and groundwater quality sampling.

Key information gathered during the Stage 1 drilling program includes:

- Permeable aquifers within Gubberamunda and Springbok Sandstones are typically up to 10 m thick as identified in wireline logs.
- Well defined Gubberamunda-Westbourne contact present in all drillholes.
- No defined Westbourne-Springbok contact in any drillhole, the contact is subjective.
- Basal Gubberamunda coarse grained 'clean' aquifer common in all drillholes.
- No common Springbok aquifer zone across drillholes, there are commonly several aquifer zones separated by low permeability sediments.

- Springbok aquifers are very 'dirty' (i.e. clay rich and lithic) and finer grained, compared to Gubberamunda aquifer.
- Coal seams in the Westbourne and Springbok are common and appear to be consistently present across locations; coal is also present in the Gubberamunda but as rare very thin seams and as formation matrix.
- The Orallo Sandstone formation may be present in the NDA and CDA above the Gubberamunda; however, there is no clear contact with the top of the Gubberamunda.
- The Gubberamunda Sandstone aquifer appears to have better permeability than the Springbok Sandstone aquifer based on airlift yields, with some Springbok Sandstone wells having such low permeability that airlift yields were not able to be recorded.
- The Springbok aquifer potentiometric surface lies 15 to 40 m above the Gubberamunda aquifer potentiometric surface, suggesting the low permeability sediments of the Springbok Sandstone and Westbourne Formation act as aquitards. Additionally there appears to be a downwards vertical head gradient within the Springbok Sandstone although the hydrogeologic cause for this anomalous downwards pressure gradient is at this stage unknown.
- Groundwater salinity in the Gubberamunda aquifer is typically around 800 mg/L, whilst the Springbok aquifer is more saline and variable, averaging 2,400 mg/L but ranging between 1,000 and 7,800 mg/L.

Figure 1 – Locality Plan

Appendix A – Drilling Summary Data Sheets

Appendix B – Wireline Logs