MANAGEMENT PLAN

Groundwater Monitoring Plan

Q-LNG-01-10-MP-0005

Australia Pacific LNG Upstream Project

This plan describes the rationale, scope and methods for monitoring the effects of CSG production on the groundwater system.

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- **Will**, **shall** or **must** indicate a mandatory course of action
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1. Introduction

The purpose of this document is to provide a framework and details of the Australia Pacific (AP) LNG regional groundwater monitoring program. The program has been developed to monitor the potential effects on aquifers of the Great Artesian Basin and potential receptors resulting from depressurisation associated with coal seam gas (CSG) extraction. It encompasses the monitoring of potential secondary effects of changes to the hydrogeological regime such as the effects on springs and surface and subsurface deformation. This regional groundwater monitoring program is intended for the long-term monitoring of these potential effects.

This monitoring plan is intended to satisfy the needs of APLNG's requirements in terms of managing its risks and potential liabilities, and the requirements of both State and Federal regulators.

1.1. Groundwater Monitoring Objectives

The minimum objectives of this plan are to meet State and Federal regulatory requirements for regional groundwater monitoring.

The effects of groundwater pumping (drawdown) to support CSG extraction has the potential for regional scale effects due to the sub-regional (10's of kilometres) to regional (100's of kilometres) scale of CSG development. The APLNG groundwater monitoring program has been developed to effectively monitor the potential effects on receptors at both scales. Therefore, the objectives of this groundwater monitoring program are to:

- Establish an appropriate monitoring regime, both in space and time;
- Provide and early warning of potential impacts from regional-scale activities to enable potential impacts to be managed before mitigation is required;
- Enable detection of long-term trends and potential cumulative effects from current and future CSG operations in the Surat Basin and southern Bowen Basin;
- Identify high risk areas that may require monitoring or enhanced monitoring;
- Gain a better understanding of natural variability in the region;
- Verify and refine understanding of the regional hydrogeology;
- Generate a robust data set against which potential environmental impacts can be adequately assessed; and,
- Support the ongoing improvement of impact prediction tools such as groundwater modelling.

1.2. Groundwater Monitoring Philosophy

The overarching principle of the APLNG groundwater monitoring program is the early detection of any potential impacts resulting from CSG extraction. The base monitoring network originally developed by APLNG assumed a source-pathway-receptor model upon which the potential risk to receptors was assessed. This informed the basis of the monitoring plan design in the following ways:

- Increased density of monitoring in those aquifers and locations where impacts would occur first, e.g. the Springbok Sandstone and Hutton Sandstone, which immediately overlie and underlie the Walloon Coal Measures respectively, and the Bandanna Formation subcrop beneath the Precipice Sandstone to the west of Spring Gully;
- The early commencement of monitoring in already producing gas fields, or in gas fields developed early in the project life;
- Direct monitoring of sensitive receptors to understand actual impacts;
- Data analysis at a frequency allows the early identification of any adverse trends; and

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- Data assessment protocols which allow response prior to any unacceptable impacts being realised at a sensitive receptor.

The Underground Water Impact Report (QWC, 2012) Groundwater Monitoring Strategy was released subsequent to the development of the APLNG groundwater monitoring plan. Where necessary, the pre-existing APLNG Groundwater Monitoring Plan was modified to meet any additional requirements of the UWIR.

Additionally, subsequent interpretation of conditions imposed on the project by the Federal goverment required additional monitoring requirements for EPBC springs which were not part of the original monitoring plan. Due to the potential for these springs to be affected by multiple CSG proponents, the major CSG proponents collaborated to develop an integrated monitoring response with allocated responsibilities. APLNG's Groundwater Monitoring Plan is consistent with this *Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs*, which is discussed further in Section 1.4). In addition to the regional scale program, there are local scale programs which focus on the existing operational gas field at Talinga, and an early development area of Reedy Creek. Reedy Creek is the starting-point for the development of the gas fields in the western portion of APLNG's Walloon Coal Measure tenements. Development in the eastern portion of the fields will extend out from Talinga. These focus sites will contain groundwater monitoring bores in each of the aquifers present and key aquitards, and will also have extensometers, tiltmeters and bores for periodic long term testing of variations in hydraulic characteristics. This plan incorporates the monitoring and assessment previously described in Q-LNG1-10-MP-0018 as Sections 0 and 7.

The groundwater monitoring framework adopted by APLNG is based on the principles of performance assessment and adaptive management. Adaptive management is a structured, iterative process of decision-making with a focus on reducing uncertainty over time via systems monitoring and continuous improvement to achieve the desired environmental and operational outcomes of the project. This will be implemented through a modelling-monitoring-management action approach, where each component of the approach is used to inform the other. Should the monitoring and modelling indicate an increase in risk to potential receptors due to CSG extraction, the adequacy of the monitoring can be reviewed to assist in the management of that risk.

1.3. Applicability of this Plan

This Groundwater Monitoring Plan will be reviewed, and revised as required.

This Groundwater Monitoring Plan is not intended to address groundwater monitoring associated with:

- Aquifer injection trials – these trials are temporary in nature and will be monitored in accordance with their individual management plans and the requirements of their associated Environmental Authorities and Exclusion Decisions;
- Operational aquifer injection – although sub-regional or regional responses in water pressure are expected from large scale aquifer injection schemes, and may be observed in the monitoring bores in the aquifer(s) into which injection is occurring, this plan is not specifically aligned with the monitoring requirements for the injection schemes. Monitoring of operation injection schemes will be in accordance with their individual management plans and the requirements of their associated Environmental Authorities and Exclusion Decisions
- Infrastructure – monitoring associated with operational infrastructure such as ponds or chemical storage facilities that may require monitoring through Environmental Authority conditions or for due diligence purposes;
- Gas injection trials – these trials are temporary in nature and will be monitored in accordance with their individual management plans and the requirements of their associated Environmental Authorities; and,

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- Hydraulic fracture stimulation – these activities will be monitored in accordance with the requirements of the Environmental Authorities associated with the tenure in which the activities are undertaken.

The plan is intended to satisfy the sub-regional to regional scale monitoring requirements to assess the potential effects of CSG production on groundwater systems associated with the following legislation and approvals:

- The Queensland Water Act, 2000;
- The Queensland Petroleum and Gas Act;
- Australia Pacific LNG Project Coordinator-General's report on the environmental impact statement;
- EPBC Act Approval 2009/4974 for the development, construction, operation and decommissioning of the coal seam gas field component of the APLNG project;
- Underground Water Impact Report for the Surat Cumulative Management Area;
- PEN100070307 Spring Gully Environmental Authority;
- PEN100067807 Walloons Environmental Authority;
- PEN101674310 Condabri Environmental Authority;
- PEN101718810 Combabula Environmental Authority;
- PEN100493710 Peat Environmental Authority;
- PEN100395209 Ramyard and Wolleebee Environmental Authority;
- PEN100393309 Gilbert Gully Environmental Authority; and
- PEN100389509 Carinya Environmental Authority.

While the Origin Energy Ironbark project is not part of the APLNG Project, groundwater monitoring associated therewith is included in this plan.

1.4. Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs

The CSG operators in the southern Bowen and Surat Basins, Santos, Origin Energy and Origin Energy on behalf of APLNG, and the Queensland Gas Company (QGC) have developed a Joint Industry Plan (JIP) for a groundwater monitoring and management system to ensure springs protected by the Environment Protection and Biodiversity Conservation Act, 1999 (EPBC Act) are not impacted by coal seam gas (CSG) production. This is a requirement of the Proponent's project approvals under the EPBC Act which require the CSG activities to have "no adverse impacts" to Matters of National Environmental Significance (MNES), which for groundwater relates to discharge from the Great Artesian Basin via springs (EPBC springs). Arrow Energy was been consulted in the preparation of the plan. The JIP is attached as Appendix B.

The plan was developed in accordance with comments received from Geoscience Australia, the Commonwealth Department of the Environment and the Expert Panel for Major Coal Seam Gas Projects (Expert Panel). The plan is also intended to align with spring monitoring and mitigation requirements obligated by the Surat Cumulative Management Area (Surat CMA) Underground Water Impact Report (UWIR)

The principles of the plan are:

- To ensure a consistent approach to springs monitoring and management between the proponents;
- To monitor groundwater so that meaningful responses can be implemented before there is any impact on MNES springs;

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- To use modelling and monitoring to provide an early warning of drawdown approaching EPBC springs to manage increasing levels of risk to MNES;
- To use of the Surat CMA UWIR model to assess potential pressure changes at the springs;
- To clearly define a network of monitoring bores, with specific bores allocated to each of the proponents;
- To allocate responsibility for each EPBC spring to a single proponent, aligning with Surat CMA UWIR Springs Strategy;
- To provide approaches to limit/trigger setting at monitoring bores, accounting for the hydrogeological setting of the spring relative to CSG production; and
- To provide alignment on exceedance response processes and timing between the proponents.

The 2012 UWIR identifies 33 spring vents amongst ten spring complexes and five watercourse springs that are at a higher risk of being affected by CSG activities. The principal risk criterion cited in the UWIR is the prediction of potential to experience more than 0.2 m drawdown in the source aquifer(s) at the spring location at any time. Not all of these higher risk springs are classified as EPBC springs and only five EPBC spring complexes were considered to be in the higher risk category. Drawdown greater than 0.2m is not predicted to occur at any spring until 2017 or later and none of the higher risk watercourse springs contain MNES.

The UWIR assigns responsibility to petroleum tenure holders for specific monitoring and mitigation actions at higher risk springs. Under the JIP, responsibility for the management and mitigation of potential impacts to springs will be in accordance with the responsible tenure holder assignations of the UWIR. On-tenement springs are the responsibility of the tenure holder and off-tenure springs are generally the responsibility of the closest tenure holder. Springs for which the UWIR considers to be at negligible risk (i.e. no underlying drawdown predicted) do not have a responsible tenure holder identified. Should future iterations of the UWIR show an increased level of risk at those springs or should an investigation trigger for those springs be exceeded, responsibility will be assigned in accordance with the UWIR, using the same principle of closest producing tenure holder.

- An early warning system (EWS) has been developed to provide adequate time for assessment and implementation of management measures prior to potential negative effects on MNES. The EWS is built on the following key elements:
- The use of groundwater levels variations as an early warning proxy for impact to the ecosystem supported by the spring. This is conservative as a decrease in pressure does not necessarily result in an impact to MNES;
- A groundwater monitoring network that focuses on the primary source aquifers of EPBC springs (primarily Hutton and Precipice Sandstones). Intervening aquitards will not be monitored because drawdown must first propagate through either of the primary aquifers;
- The use of the regional scale numerical flow model developed for the Surat CMA UWIR to set action trigger, primarily using the 95th percentile prediction (P95) of drawdown.
- The development of drawdown trigger response processes that respond to increasing levels of risk to MNES.
- The ability to use the entire network of monitoring bores to support the assessment of regional scale responses to better understand the source of actual CSG-induced drawdown, and the associated potential risks to MNES.

The early warning system monitoring bore network comprises a total of 14 Hutton and 16 Precipice Sandstone bores that will be monitored between the companies. The JIP identifies the company responsible for the installation and ongoing monitoring of each of the bores. The monitoring bores are scheduled to be completed by the end of 2016, and are a subset of the proponent's wider groundwater monitoring networks. In addition, the Proponents will also be monitoring the CSG reservoirs (Walloon Coal Measures and the Bandanna Formation) to understand the timing and magnitude of drawdown at its source.

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The bores are to be constructed to allow the collection of both water level/pressure and water quality data. Water levels will be collected daily and water quality samples will be collected every six months. Seven samples collected at six monthly intervals will constitute the water quality baseline.

Springs monitoring (water quality, flow/wetted area, etc.) will be undertaken quarterly to match the frequency requested in the UWIR. The first year of quarterly monitoring will constitute the baseline period. In addition to those items above, the baseline monitoring will include assessment of fauna, flora and macro-invertebrates, and collection of groundwater samples for isotope analysis.

A quality plan is associated with the JIP to assure consistency in data collection and analysis methods between the Proponents.

Monitoring bores are distributed closer to CSG production (Early Warning Monitoring Installation – EWMI) and closer to the springs (Trigger Monitoring Point – TMP). Investigation and mitigation triggers apply at both the EWMIs and TMPs, however drawdown limits only apply at TMPs. Triggers and limits are set using the P50 and P95 drawdown predictions of Surat CMA UWIR model. The methodology either defines a fixed value limit or a hydrograph comparison limit depending on the proximity of the spring to production tenure – the former results in limits finer than measurement resolution for on-tenure springs. The JIP identifies investigation triggers, management triggers and drawdown limits for every bore in the EWS network, as appropriate. While water quality investigation triggers will be defined following the establishment of a baseline dataset, no management triggers or limits will be defined for water quality.

The model hydrographis will compared with CSG-induced drawdown only. That is, measured water level responses will be corrected remove non-CSG related effects that may include barometric pressure fluctuations, the effects of earth tides, and the effects of groundwater extraction from the spring source aquifers. If the CSG-induced drawdown exceeds a trigger, the response process will apply.

The JIP defines a response process for the exceedence of triggers, with defined maximum time periods for each step of the response process. The response process includes:

- Verification of exceedence;
- Reporting to the Department of the Environment;
- If a monitoring trigger is exceeded:
    - Review of regional groundwater monitoring data, consideration of model assumptions, and potentially increase monitoring;
    - Provision of assessment to the Department of the Environment
    - Development of preferred management options
- If a mitigation trigger is exceeded:
    - Detailed design of a mitigation plan
    - Implementation of the mitigation plan

Monitoring continues throughout the process to assess the effectiveness of the mitigation measure(s).

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1.5. Plan Preparation

This plan has been prepared and reviewed by the following team

Role	Name	Position	Qualifications	Relevant Experience
Author	Ryan Morris	Senior Hydrogeologist	BSc Hons (Geology) RPGeo (Hydrogeology)	13 years
Author and Reviewer	Andrew Moser	Groundwater Manager	BSc (Applied Geology) RPGeo (Hydrogeology)	24 years

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2. Conceptual Hydrogeological Models

A conceptual hydrogeological model is a succinct, simplified understanding of a groundwater system, and is essential for the development of an appropriate monitoring program.

APLNG has CSG tenements across two geological basins: the Surat Basin and the Bowen Basin. The APLNG tenements included in the APLNG EIS target the Walloon Coal Measures of the Surat Basin, whereas pre-existing operations at Spring Gully and Peat target gas extraction from the Bandanna Coal Measures (or equivalents) in the underlying Bowen Basin.

2.1. Surat Basin and the Walloons Coal Measures

The Surat Basin is an elongated basin that contains a sequence of alternating terrestrial and marginal marine deposits. These deposits reach a maximum thickness of approximately 2500m in the Mimosa Syncline, whose axis is orientated north-south roughly coincident with APLNG's Ramyard and Carinya tenements. The terrestrial units tend to be sandstone-dominated and form regional aquifers, whereas the marine sequences are siltstone- and mudstone dominated and form regionally extensive aquitards.

Although the Surat Basin is geologically bounded by the Kumbarilla Ridge in the east and the Nebine Ridge in the west, it is believed to be hydrogeologically connected to the Clarence-Moreton and Eromanga basins (in the east and west, respectively) and is one of the major constituent basins of the Great Artesian Basin.

For the purposes of simplification, the geology has been grouped into a number of hydrostratigraphic units which include aquifers (saturated permeable strata that supports significant groundwater flows) and aquitards (low permeable strata which retards groundwater flow) on the basis of common characteristics (Figure 1). The aquifers are typically confined by overlying and underlying aquitards with aquifer water pressures elevated above the level of the top of the aquifer unit.

The hydrostratigraphic units are broadly flat-lying; however, uplift and erosion along the eastern and northern margin of the basin has resulted in a south-westerly tilt to the units, exposing most of them along the northern boundary of the basin. These subcropping and outcropping areas represent the intake beds for most recharge to Great Artesian Basin aquifers.

Recharge is predominantly by summer rainfall, either by direct infiltration into the outcropping areas, or indirectly via leakage from streams. Water levels in the Cainozoic Units in particular respond directly to rainfall recharge.

There are over 13,000 groundwater bores in the Surat Basin in Queensland. Most discharge in the basin is from groundwater extraction. The majority of existing groundwater bores, both in terms of extraction/allocation volumes and number of licenses, access groundwater from the non-GAB Cainozoic Units (inclusive of the Condamine River Alluvium, the alluvium of tributaries to the Condamine River, and the Main Range Volcanics). However in terms of the GAB aquifers, most take is from the Gubberamunda Sandstone or equivalents. In the areas where the Springbok Sandstone, Walloon Coal Measures or Hutton Sandstone sub-crop or outcrop, the groundwater take from these aquifers predominates.

Natural discharge occurs from springs, mainly located in the northern parts of the basin. Some of these springs host rare, endangered and threatened species as listed by State and Federal legislation.

The regional groundwater flow direction in most aquifers is to the south-west, and is often locally a subdued reflection of topography. Locally, groundwater flow may be towards surface water features, where these intersect subcropping or outcropping units. Groundwater flow directions in the Hutton and Precipice Sandstones appear to show a distinct divide, with northerly flow to the Dawson River in the north of the basin. In the Cainozoic Units groundwater flow may follow topographic relief, as in the valley of the Condamine River. Estimated flow velocities range from 0.35 metres per year to 5 meters per year.

Most aquifer units in the study area contain groundwater of meteoric origin and are marginally alkaline with median salinities below 1200mg/L as TDS. The dominant water type is generally Na-

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HCO3-Cl (or a close variant). The highest median groundwater salinity (greater than 1400mg/L) is usually associated with the Walloon Coal Measures.

CSG extraction in the Surat Basin is targeted within the Walloon Coal Measures in the north-eastern portion of the basin. This mudstone- and siltstone-dominated unit subcrops in the vicinity of the Warrego Highway and reaches depths in excess of 1600m below ground surface (mbgs) well down-dip of the CSG fields. Thicknesses of these deposits can be in excess of 500m, but are usually between 250m and 300m thick. The total coal thickness rarely exceeds 25m which is comprised of a large number of laterally and vertically discontinuous coal stringers separated by low permeability siltstones, mudstones and minor sandstones.

The Springbok Sandstone aquifer immediately and unconformably overlies the Walloon Coal Measures. This sandstone has traditionally been classified as an aquifer, but testing undertaken in association with CSG activities indicates that it is more generally an aquitard in the central part of the Basin. The finer-grained Upper Walloons interval between the Macalister coal seam and the Springbok Sandstone provides hydraulic separation between the top coal seams and the Springbok Sandstone, however the unconformable contact provides the potential for hydraulic connection in limited areas, notably in the central Condabri area. The Eurombah Formation aquitard immediately underlies the coal measures.

To facilitate CSG extraction, the hydrostatic pressure in the coal seams must be reduced to approximately 50psi above the top coal seam, which is achieved by extracting groundwater (associated water) via production wells. This represents a groundwater level of about 35 m above the top coal seam. Extracting the groundwater propagates a cone of depressurisation which results in a decrease in hydrostatic pressures in the coal measures away from gas production in space and time. Diminished effects may also propagate vertically through the confining aquitard layers to overlying and underlying aquifers. Effective aquitards significantly retard the vertical propagation of depressurisation effects, both in terms of the magnitude of effect and the response time. The retardation potential can be compromised by hydraulically active geological structures (faults, fractures etc) or poorly constructed or deteriorated bores or wells that penetrate the aquitards, should they exist.

Where the Walloon Coal Measures are exposed at ground surface, their low resistance to weathering has resulted in erosion in some places. Up to 100m of Cainozoic-aged sediments have been deposited over the top of the Walloon Coal Measures where it has been deeply eroded in the Condamine River Alluvial area. As the pressure reduction in the coal measures may propagate to the subcrop areas during CSG production, the increased vertical gradient between the coal measures and the alluvium may result in increased downward leakage of groundwater, if hydraulic connection between the coals and alluvial aquifers exist. APLNG tenements are generally removed from the subcrop areas, and separated from them by other operators' tenure. APLNG does not hold tenure in areas where the Condamine Alluvium is used for groundwater supply.

2.2. Bowen Basin and the Bandana Coal Measures at Spring Gully

Spring Gully is situated close to the geographical boundary between the Bowen and Surat Basins. The geological sequences of these basins are separated by a major unconformity, with the Bowen Basin sediments below the contact.

CSG and associated water are produced from the Bandanna Formation of the Bowen Basin sequence. The overlying Surat Basin basal sediments (Precipice Sandstone) dip to the southeast, though the Bowen Basin sediments are more southerly dipping, resulting in a thin subcrop contact between the Bandana Formation and the Precipice Sandstone.

Figure 1 illustrates the hydrostratigraphy at the project site. Apart from subcrop areas, there are generally significant aquitards separating the Precipice Sandstone from the CSG production zone or other aquifers. The potential for natural hydraulic interconnection with the Precipice Sandstone is therefore spatially limited. Although the stratigraphic column includes the Moolayember Formation and Clematis Group Sandstones, these units are not present at the Spring Gully field. The Rewan Formation is in excess of 200m thick in the vicinity of current production.

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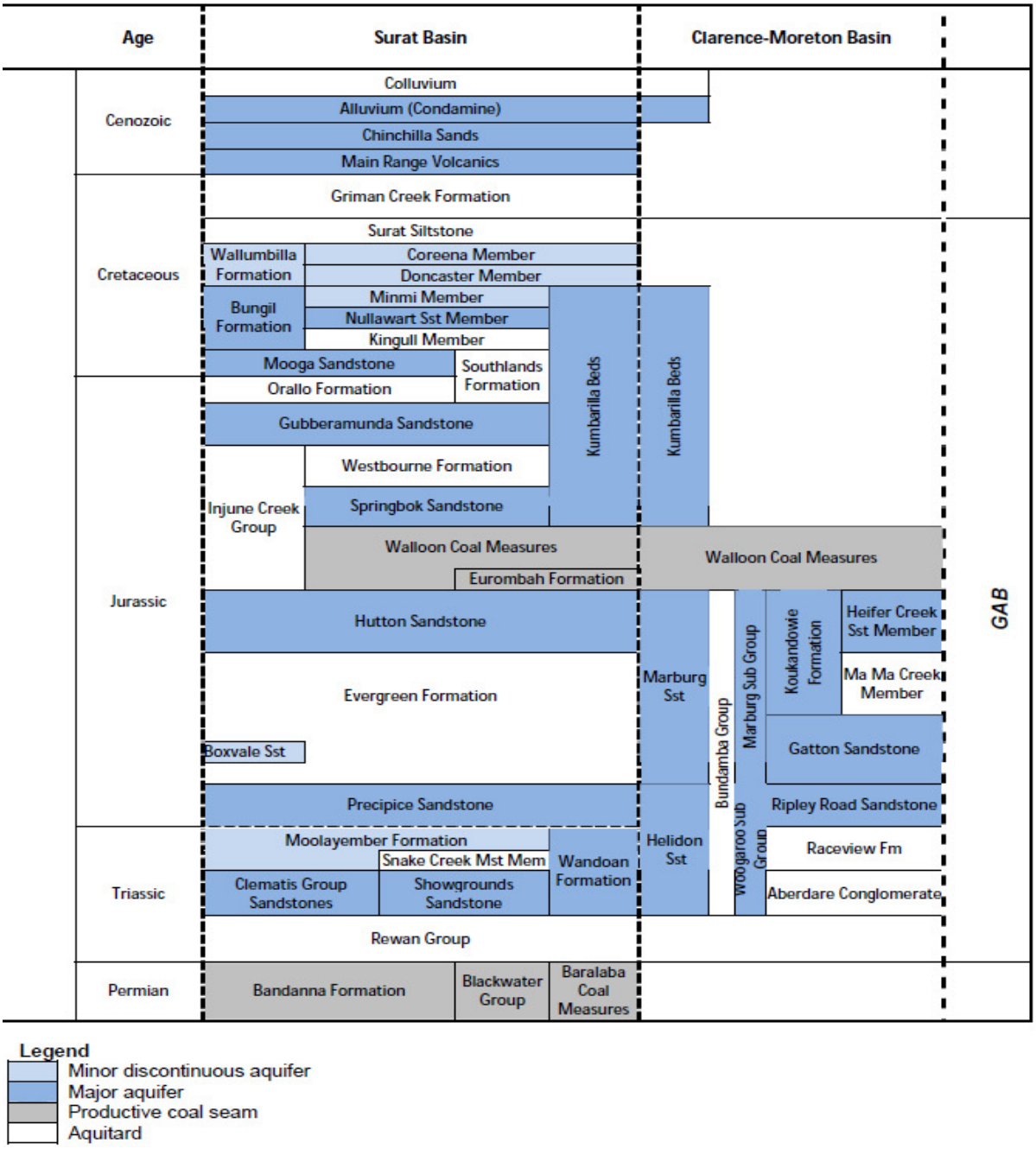
Spring Gully is located on a geological structure known as Comet Ridge, however the Bureau of Mineral Resources has not mapped any large scale regional faults in the area. Numerous small scale faults have been interpreted both at surface and in drillholes. Seismic surveys undertaken across the project area indicate that these structures are not continuous over significant distances in either the horizontal or vertical directions. None have been interpreted to be continuous in a vertical sense from the Precipice Sandstone to any other aquifer.

Figure 1 Hydrostratigraphic Column for APLNG CSG Fields (QWC, 2012)



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3. Groundwater Monitoring

The intention of the monitoring program is to provide adequate lateral and vertical coverage of the gasfields and surrounding potentially impacted areas, considering the conceptual hydrogeological understanding, the APLNG development sequence, other CSG operations, groundwater users and springs. The network is intended to provide an early warning of potential impacts to allow sufficient of time to undertake further assessment and implement management and mitigation options prior to the occurrence of any significant impacts to receptors. Should monitoring indicate an undesirable trend, the requirement for additional monitoring bores, both in other aquifers and laterally away from the Australia Pacific LNG production will be assessed, and actioned if necessary.

3.1. Monitoring Network

3.1.1. Locations and Timing

The monitoring locations and formation intervals have been determined from three primary sources:

- The APLNG base monitoring network – the network developed by APLNG to ensure business and environmental risks could be appropriately managed;
- Surat Cumulative Management Area (CMA) UWIR groundwater monitoring strategy;
- The development of the Early Warning Monitoring System to ensure the protection of EPBC springs (JIP).

Locations for the base APLNG groundwater monitoring network were identified using a risk-based approach. The approach utilised the source-pathway-receptor model, which requires that all three components be present for a risk to exist. By utilising the outputs of the APLNG cumulative effects numerical groundwater flow model, a quantitative estimate of the potential impact on individual (existing) receptors could be made. Receptors included waterbores and springs. Hydrogeological controls affecting potential drawdown were also used to identify areas of potential higher risk. As previously stated, the intention of the monitoring network is to provide early warning of potential impacts, thus monitoring is focussed on the Springbok Sandstone, Hutton Sandstone (Walloon Coal Measures fields) and in the Precipice Sandstone where the Bandanna Formation subcrops beneath it (Spring Gully).

Additional bores were required for compliance with the Surat Cumulative Area Underground Water Impact Report's Water Monitoring Strategy. Where these bores did not correspond with existing or planned APLNG locations and intervals, new bores or appropriate landholder bores were included in the planned network. The objectives/rationale for each of these locations is specified in the UWIR.

The development of the EPBC Springs Early Warning Monitoring system required bores to be specifically located to provide early warning of potential impacts to EPBC springs. The locations for springs monitoring bores were developed in conjunction with Santos and QGC in preparation of the *Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs*. The bores included in the APLNG component of EBPC Spring Protection Early Warning System are identified in Table 4.

The monitoring locations include bores in close proximity to the springs at which limits of drawdown will apply, and bores closer to the development areas, which provide early warning of the propagation of drawdown effects away from the gasfields and in the direction of springs. While the EPBC Springs Early Warning Monitoring system focuses on the areas between the gas fields and the EPBC springs, there is a large network of monitoring on tenure, close to the source of the drawdown in space and time that provides additional early warning.

Groundwater monitoring focuses on the monitoring of *aquifers*, and no monitoring of aquitards is planned with the exception of bores installed for sub-surface deformation monitoring (Section 6.2.2). Monitoring of formations above and below the aquitards will provide early warning of potential effects across or through the aquitards. This is particularly pertinent for the monitoring of

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EPBC springs which have been identified to be sourced from aquitard units (e.g. Birkhead Formation or Evergreen Formation). As monitoring of the aquitard would only be successful if the monitoring bore was installed in that part of the formation that is in direct hydraulic connection with the target spring. However, by their nature, aquitards will have limited lateral continuity to more permeable sub-units. Accordingly, monitoring above and below aquitards provides adequate early warning in these situations.

Target dates for the installation of the monitoring bores are predominantly based on the UWIR requirements, with additional prioritisation given to the APLNG development sequence to ensure monitoring bores are installed as far in advance of new development as practicable. The majority of the monitoring bores, including the bores for the EPBC springs early warning monitoring system are planned to be installed by the end of 2015, with all APLNG monitoring bores scheduled to installed by the end of 2016.

Target dates for installation may be affected by delays to land access/compensation agreement conclusion, environmental/cultural heritage approval delays, rainfall and flooding delays and suitable drilling rig availability, all of which have been encountered to date. The depths of many monitoring bores significantly exceed the depths of the CSG wells and consequently there are fewer drilling rigs with the capacity to drill the deeper holes. The installation of off-tenure monitoring bores required under the UWIR, and for the EPBC springs early warning monitoring system bores are the subject of on-going negotiations with the Department of Natural Resources and Mines, in terms of the ability of CSG companies' ability to access off-tenure locations.

The locations, target installation dates and rationale each monitoring bore location is provided in Appendix A. Maps of the monitoring bores in each of the aquifers are also provided in Appendix A. It is noted that although locations are provided for planned bores, the final locations may vary due to environmental and landholder agreement constraints.

3.1.2. Infrastructure

The APLNG groundwater monitoring network will comprise the following main types of subsurface infrastructure:

- Purpose-drilled groundwater monitoring bores: These bores will be specifically designed and constructed to target a single geological unit and will allow the collection of waterlevel data and water quality samples. The design will ensure isolation from other aquifers;
- Purpose drilled reservoir monitoring wells: The reservoir monitoring wells may target several zones within the CSG target formation (e.g. Upper Juandah Coal Measures, Lower Juandah Coal Measures and Taroom Coal Measures, all within the Walloon Coal Measures). The design will ensure annular isolation and oilfield standard equipment (packers) will be used to ensure intrawell isolation between zones;
- Converted exploration or production wells: These wells will have been assessed with regards to suitability for recompletion as monitoring bores to ensure they are fit for purpose. Daily drilling records, wireline logs and other data will be reviewed in the assessment. The well may be worked over to allow monitoring of the desired zone, e.g. cementing lower zones, or perforating casing at desired depths;
- Existing groundwater bores which may or may not currently be used for water supply. These may be owned by APLNG or by private landholders. If present in the bore, pumping infrastructure will not be removed or modified for ongoing monitoring.
- Vibrating wire piezometers or similar may be used to retain pressure monitoring when bores are decommissioned. The devices will be cemented into the bore.

In general, dedicated monitoring bores targeting aquifers above the Walloon Coal measures will generally be constructed with their open intervals toward the base of the aquifer, whereas those beneath the Walloon Coal Measures will be constructed with the open interval toward the top of the aquifer. Notwithstanding this design, those monitoring bores targeting the Springbok Sandstone will maintain a minimum distance of 30m between the uppermost producing coal and the bottom of the open interval to minimise the risk of the bore producing gas. Bores in the fields that target the

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Bandanna Formation for gas production will be constructed towards the lower portions of the formations.

3.1.2.1. Bore Design and Installation

Groundwater monitoring bores have been designed in accordance with relevant standards, including:

- the Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (NUDLC, 2012);
- the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DERM, 2012); and
- the Code of Practice for constructing and abandoning coal seam gas wells and associated bores in Queensland (DNRM, 2013)

Bores targeting non-gas charged aquifers above the Walloon Coal Measures will be drilled using a water bore drilling rig. Where the target aquifer is the reservoir or below, the bores will be drilled using a fully equipped CSG drilling rig with well-control equipment.

Well Specification Cards (WSC) are developed for every monitoring bore prior to the commencement of drilling. Stratigraphic prognoses are made based on stratigraphic and geophysical interpretations from nearby CSG wells and groundwater bores. The WSC defines preferred bore construction, including casing depths and key installation phases. The WSC are reviewed and approved by two suitably qualified personnel (Senior Hydrogeologists) prior to being issued to the Drilling and Completions team for development into a drilling program which is issued to the drilling contractor and site hydrogeologist.

Four-and-a-half inch (114mm ID) steel threaded casing is generally used for the BMO, Gubberamunda Sandstone and Springbok Sandstone monitoring bores. In the vicinity of Spring Gully, the same size casing will generally be used for the Hutton and Precipice Sandstone Monitoring bores as they lie above the reservoir and can be drilled by a water bore contractor. Those monitoring bores drilled by a CSG rig will typically be cased with API-rated 7” buttress threaded steel casing. Conductor (surface) casing will be of appropriate diameter to allow for a suitable annulus between it and the inner string and be of suitable weight for the design depth and pressure profile, and if necessary installation of a blow out preventer (BOP).

The minimum headworks completion for the monitoring bores is a vertically mounted appropriately pressure rated valve (usually 2000PSI). The valve is installed as a contingency, in case the bore becomes artesian (due to injection) or if the bore produces gas, either at the time of drilling or in the future. Headworks on artesian bores will allow for the safe control of water while allowing the measurement of water pressure.

Bores targeting the Springbok Sandstone or non-reservoir formations known to be gassy will be installed with an A-section (Bradenhead) tying the two casing strings together in a similar manner to CSG wells. This will allow the installation of blow-out protection at a later date should the bores be generating unsafe levels of gas and require work-over.

All casing strings are fully cement grouted from the casing shoe to surface, using either traditional pressure grouting techniques or an external casing packer / annular casing packer. If the cement grout does not return to the surface during the pressure cementing of the casing, a cement bond log (CBL) will be run to assess the integrity of the grout sheath and to ensure aquifers are not connected. If aquifer connection does occur, a remedial cement job is undertaken to rectify the matter. This is undertaken by perforating the casing at the top of the good cement (based on the CBL) and squeezing cement through the perforations to surface. If the remedial cement job is unsuccessful, the bore will be decommissioned. If there are recurring cementing issues in a given area, the cement formula and method will be amended.

Short duration pumping tests (4-8 hours) will be carried out on each bore upon completion. Initial water samples will generally be collected from the bore at the completion of the pumping test.

Should the transmissivity of the formation be too low to allow pumping, a rising head test will be carried out.

The key steps in the installation of groundwater monitoring bores are:

- Development of a WSC using geological and hydrogeological data from offset wells and bores;
- Preparation of a drilling program, which is issued to the drilling contractor and site Hydrogeologist;
- Drilling, installation and pressure cementing of surface casing;
- Drilling, installation and pressure cementing of production casing. Production casing installed to top of target zone. Cuttings are logged by onsite hydrogeologist to prepare a lithological bore log;
- Drilling of target zone and installation of screens;
- Bore development through a combination of flushing with fresh water, airlifting and pumping;
- Installation of bore headworks; and,
- Short duration test pumping.

Bores for monitoring either the Walloon Coal Measures or the Bandanna Formation coals will be fully cased and pressure grouted to total depth. Monitoring intervals will then be perforated through the casing to provide connection with the formation. These monitoring intervals will be separated inside the casing with isolation packers with each zone being individually monitored.

Redundant monitoring bores, bores where aquifer isolation is believed to be compromised, or bores that are to be abandoned for other reasons will be decommissioned in accordance with NUDLC (2012) and DEEDI (2011).

3.1.3. Nomenclature

New monitoring bores will be named using the following convention:

Tenement name – MB tenement bore site number – aquifer code

Aquifer codes are identified in Table 1.

Table 1 Aquifer Codes for Bore Nomenclature

Aquifer Name	Aquifer Code
BMO Grouping	B
Gubberamunda Sandstone	G
Westbourne Formation	Wb
Springbok Sandstone	S
Walloon Coal Measures	W
Hutton Sandstone	H
Evergreen Formation	E
Precipice Sandstone	P
Bandana Formation	B
Clematis Sandstone	C

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For example, the first nested site in Talinga, comprising a Gubberamunda Sandstone and Springbok Sandstone monitoring bore will be named as follows:

- Talinga-MB1-G
- Talinga-MB2-S

Where existing wells are converted into monitoring bores (e.g. Condabri 140), or where existing waterbores are incorporated into the monitoring network, these will be known by their registered names and or common names (e.g. RN10925 Old House bore).

Nests of multiple bores will be named using the following convention:

Tenement name – nested site letter

3.2. Water Level/Pressure Monitoring

Water level/pressure monitoring is the key parameter for assessing changes to the groundwater regime. The 'make good' obligation of the Water Act (2000) is triggered by a water level change (5m in a consolidated aquifer, 2m in an unconsolidated aquifer and 0.2m at a spring), and waterlevel is the primary the trigger mechanism for EPBC springs protection early warning system.

3.2.1. Frequency

Groundwater level or pressure will be recorded on a minimum daily frequency for those bores equipped with automatic pressure monitoring devices. Automated monitoring will commence within six weeks of monitoring bore completion/development.

Waterlevels will be measured with an electronic waterlevel meter (dipmeter) at a minimum of an annual frequency where bore construction allows. Manual waterlevels will be measured from a reference point etched on the wellhead.

Barometric pressure will be monitored at a minimum of three sites: Talinga; Reedy Creek and Spring Gully. The sites provide a roughly even spacing across APLNG tenure. Barometric pressure will be recorded at hourly intervals to allow for different groundwater level recording times through the day.

3.2.2. Instrumentation

Automatic pressure transudcers will be installed in all purpose-drilled groundwater monitoring bores and any additional bores that require monitoring by UWIR and the JIP. Private and government bores included in the monitoring network for other reasons (e.g. a monitoring requirement under a make good agreement; gas seeps monitoring) may not have pressure transducers installed.

Daily groundwater levels will be measured in dedicated groundwater monitoring bores using pressure transducers with on-board temperature sensors. Temperature sensors will allow the correction of waterlevel data for density effects on water column length as the water column in the bore cools after pumping. This is essential for the comparison of vertical hydraulic gradients. Dataloggers will be downloaded at minimum of an annual frequency, or whenever a site is visited for water quality monitoring (e.g quarterly).

Pressure transducers measurements will be unvented (absolute) measurements, requiring barometric pressure corrections to be undertaken where necessary. Situations may arise where vented cables are required.

Where landholder bores are monitored, automatic airline bubblers may be used to measure waterlevels.

Manual waterlevels will be used to correct logger drift through linear interpolation.

It is intended that telemetry will ultimately be installed to automatically download data at all purpose drilled monitoring bores, and all other bores require by the UWIR Monitoring Strategy and

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the JIP. The installation of telemetry at monitoring bores has commenced utilising the UniData Neon platform connected to the online Origin Groundwater Monitoring Portal. This platform will continue to be rolled out.

3.2.3. Quality Assurance/Quality Control

Manual standing water level measurements will be measured every six months in every bore which is mandated by a regulatory requirement (e.g. UWIR or JIP). Standing waterlevels will be measured using an electronic waterlevel meter in accordance with the Origin Energy standard operating procedure Measuring Static Water Level (SWL) (OEUP-Q1000-SOP-OPS-028).

Pressure transducer calibration records shall be provided by the manufacturer.

3.3. Water Quality Monitoring

For natural interaquifer flow to be affected by CSG development there will need to be a relative change in aquifer pressures, which will be evident as a relative change in pre-development groundwater levels if/when the aquifers are drawn down. Water movement would be induced towards the target reservoirs, and since the coal measures tend to contain the poorest water qualities in the sequence, the potential for degradation of commonly used aquifers is considered to be limited. Furthermore, previous studies show few distinguishing characteristics between the formation waters (WorleyParsons, 2012). The similarity in water qualities between the aquifers means that there would be little to differentiate any mixing of water quality as a result of any potential CSG-induced interaquifer flows.

3.3.1. Frequency

Sundaram et al. (2009) provides a framework for the determination of monitoring frequencies for various monitoring applications, e.g. basic resource monitoring, resource monitoring at sensitive sites, measure of aquifer confinement, point or diffuse source contamination. Until groundwater level drawdown due to CSG development is observed, the monitoring program is in a mode of basic resource monitoring. Accordingly, Sundaram et al (2009) indicates:

- groundwater quality indicators (electrical conductivity, temperature, etc) should be monitored at an annual frequency; and,
- groundwater quality parameters are required to be monitored based on assessment of quality indicators and other trends such as groundwater level.

In the subset of bores monitored for groundwater quality, APLNG's minimum monitoring frequency will be six monthly.

Those bores included in the EPBC Spring Protection Early Warning System will be sampled at a six monthly interval, as identified in the JIP.

In accordance with the JIP, a baseline of water quality will be defined after the collection of seven (7) six-monthly water quality samples.

Should drawdown due to CSG activities be recorded which breaches an Early Warning Trigger associated with the EBPC Spring Protection Early Warning System, or otherwise causes a requirement for increased monitoring, an increased frequency of water quality monitoring may be considered as part of response actions (exceptional monitoring).

Water quality monitoring will continue at least until Australia Pacific LNG development in the area has ceased.

3.3.2. Water Quality Parameters

All initial groundwater samples will be analysed for the following parameters to establish baseline characteristics:

- Physio-chemical parameters – pH, electrical conductivity, redox, temperature, total dissolved solids, wellhead methane;

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- Major cations and major anions – calcium, magnesium, sodium, potassium, chloride, sulphate, bicarbonate, carbonate and total alkalinity;
- Minor anions – bromide, fluoride, and iodide;
- Dissolved[1] metals and metalloids – aluminium, arsenic, boron, barium, beryllium, cobalt, iron, manganese, molybdenum, selenium, silver, strontium, tin, arsenic, cadmium, chromium, copper, nickel, lead, lithium, uranium, vanadium, zinc, mercury, and silica;
- Dissolved sulphide;
- Phenols and polycyclic aromatic hydrocarbons (PAHs);
- Total petroleum hydrocarbons (TPH) and benzene, ethylbenzene, toluene and xylenes (BTEX); and,
- Dissolved methane.

For initial samples post bore development, or during landholder bore assessments, the following may be included:

- Stable isotopes of methane and carbon dioxide;

For bores associated with the EPBC Spring Early Warning Monitoring System, the following analytes may be included for the baseline suite.:

- Turbidity;
- Total suspended solids;
- Nutrients – total nitrogen, total Kjeldahl nitrogen, nitrate, nitrate and total phosphorous;
- Carbon – total organic carbon (TOC), dissolved organic carbon (DOC), dissolved inorganic carbon (DIC);
- Ethylene;
- Volatile organic compounds;
- Isotopes – Deuterium, ^{18}Oxygen, Radiogenic ^{14}Carbon, ^{13}Carbon, ^{87}Strontium/^{86}Strontium

It is anticipated that once a better understanding of hydrochemical composition and natural variability has been established, the suite of analytes will be reduced to a number of core parameters (primary indicators). This reduced suite will include:

- Physio-chemical parameters;
- Major cations and major anions;
- Dissolved metals and metalloids;
- Dissolved methane.

3.3.3. Methods

Equipment

Landholder or existing water supply bores that have been incorporated into the monitoring network will be sampled using existing pumping infrastructure.

Initial samples collected from newly drilled monitoring bores will be collected immediately prior to the cessation of test pumping and will therefore be collected by a traditional purge method using an electric submersible pump.

[1] Dissolved concentrations will be analysed as this is representative of the water that flows through the aquifer, rather than analysis of total concentrations which may be affected by in-bore conditions.

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Purpose installed monitoring bores into non-reservoir formations will be equipped with dedicated sampling pumps. These will be air-driven low flow pumps, where the pump inlet is located within the target zone of the monitoring bore. The intake will be at the end of a tube extending below the pump to the target zone. The tube will be of small diameter (1.5" or less) which will effectively reduce the well volume and hence the purge volume. The pump will be operated in accordance with the sampling procedure in Origin Energy Standard Operating Procedure for Low Flow Bladder Pump Operation (OEUP-Q1000-SOP-OPS-027) or a new SOP specific to the system installed. Specifically, drawdown will be maintained at less than 0.1m during purging and sampling. Maximum pumping rates to adhere to this requirement for each of the dedicated installations will be determined during system commissioning.

Those monitoring bores which require fortnightly electrical conductivity (EC) measurements under the Surat CMA UWIR will be equipped with dedicated pumps and automated pump controllers. A flow through cell with EC sensor will be installed on the discharge line. To ensure compliance with UWIR for monitoring by the end of 2012, pressure-temperature-conductivity sensors have been installed in the monitoring bores.

Sampling of Landholder Bores

Water samples from landholder bores will be collected using existing, installed pumps. The bore will generally be purged of three bore volumes or until field parameters have stabilised between successive readings in the discharge water, following which a sample will be collected. If the bore is known to have been in recent regular use, purge volumes may be reduced, particularly if there are no storage or management options for the purged water.

Sample Collection

Samples will be collected in accordance with Origin Energy Standard Operation Procedure Baseline Groundwater Sampling (OEUP-Q1000-SOP-OPS-024). To ensure that samples are not affected by stagnant water within the pumping system, it will be ensured that field parameters have stabilised as per Table 2 (Holmes et al, 2001).

All field water quality parameters will be measured in a flow-through cell.

Table 2 Field Parameter Stabilisation Criteria Prior to Sample Collection

Measurement	Variability	Comparison
pH	+/- 0.1 units	Median of baseline samples
Temperature	+/- 0.2°C	Median of baseline samples
Electrical conductivity	+/- 3%	Median of baseline samples
Dissolved oxygen	+/- 0.3 mg/L	Median of baseline samples
Redox potential (Eh)	+/- 5%	Median of baseline samples

3.3.4. Quality Assurance/Quality Control

Water quality sample quality assurance and quality control will be ensured through adherence with the Joint Industry Early Warning System for EPBC Springs Quality Plan. Adherence with this plan will ensure commonality between methods used by the different operators in the Surat CMA, so that results from different operators can be compared. The main components of the plan include:

- Dedication of water quality sampling equipment to minimise the potential for cross contamination;
- Standardised sampling methods;
- Calibration of field water quality meters;

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- Collection of samples in new, laboratory supplied sample containers, with appropriate preservatives;
- Submission of samples under Chain-of-Custody protocols;
- Submission of samples to laboratories accredited with National Association of Testing Authorities (NATA) for the analyses to be completed (with the exception of isotope samples);
- Collection of the following quality control samples:
    - one duplicate sample for every 10 samples collected;
    - one equipment blank per piece of non-dedicated equipment per day;
    - one field blank per day; and,
    - one trip blank per esky when volatile analyses are requested.
- Laboratory quality control samples including method blank, spike and duplicate analysis.

3.4. Background Monitoring

Due to the regional scale nature of the CSG developments in the Surat Basin, background monitoring for the entire industry is not possible since any location likely to be outside the potential area of influence of the CSG developments is likely to be either outside of the hydrogeological system, or in areas where potential risks to groundwater users, springs and MNES are negligible. Other CSG company's monitoring networks and monitoring requirements under the UWIR Groundwater Monitoring Strategy will provide background monitoring data to assist APLNG in the understanding of off-tenure changes due to CSG production, non-CSG anthropogenic effects and climatic variations.

However, background monitoring is possible on a sub-regional scale. Since the development of the CSG fields is phased, there will be areas that are outside of potential influences of CSG production for many years into the future, particularly in formations separated vertically from the reservoir formations. These locations can be used to understand natural variability in the system and may provide an insight into non-CSG related effects on waterlevels.

3.5. Data Analysis

3.5.1. Waterlevel Reference Point and Calculation of Drawdown

The reference point for drawdown will be the median waterlevel from the period prior to the commencement of gas production proximal to the monitoring bore, with a minimum monitoring period of 3 years. Reference levels for EWS bores will be calculated when one year of data becomes available. Reference values will be identified for each bore, taking cognisance of:

- Water level response over the baseline period;
- Background information for the site and sub-regional setting for the pre-baseline and baseline period, including know extraction from the tapped aquifer; and,
- Underlying water level trends and relationships to climatic variations. If pre-existing trends exits, the reference value may be defined as a time-based function.

Reference points may require periodic re-calculation to make more meaningful assessments to account for long-term climatic events or other non-CSG factors.

Drawdown will be calculated by subtracting the measured waterlevel (daily or weekly average) from the reference point.

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3.5.2. Drawdown Data Corrections

Observed groundwater levels vary through natural and anthropogenic effects not related to CSG extraction. The comparison of measured monitoring data with modelled data requires corrections to the monitoring data for extraneous effects including, but not limited to:

- Logger drift – correction by linear translation to manually measured waterlevels;
- Barometric pressure effects – daily, weekly and seasonal influences that affect measured water levels;
- Earth tides – effects predominantly relating to the gravitational pull of the moon and sun. These occur on a monthly and greater cycle and will be corrected using methods such as the generation of synthetic time series earth tides using TSOFT (Van Camp and Vauterin, 2005);
- Hydrostatic loading or unloading – i.e. the change in weight of the shallow groundwater systems due to infiltration, recharge or evapotranspiration resulting in a greater or lesser load on underlying aquifers;
- Non-CSG groundwater use, including stock and domestic, stock intensive, industrial and town supplies – approaches to remove these effects will depend on the response, but may include the numerical superposition of an injection bore, injecting at the location and rate of the extraction bore, or if the effects are more complex, using the calculated weighted mean drawdown and the removal of the effects of autocorrelation (e.g. Yue et al, 2002)

These data corrections will be undertaken in the stepwise manner described in Appendix D of the JIP. Worked examples are provided therein. The method(s) for trend and statistical analysis may need to be updated following the collection of baseline data and the development of reference values. Where the method for trend and statistical analysis provided in Appendix D of the JIP is no longer suitable, an updated method will be identified in the relevant annual report to the Department of the Environment

Corrected data will be used for the assessment of trends and for comparison with modelled hydrographs. Corrections will only be undertaken if monitoring bore water levels exhibit declining trends, and the drawdown trends are in excess of the UWIR P50 modelled hydrograph for that bore.

3.5.3. EBPC Spring Protection Early Warning System

The development of an effective early warning monitoring system, such as the JIP, must take cognisance of the mechanism(s) by which drawdown is likely to be propagated from the source (CSG production area) to the receptor (EPBC spring), as per the source-pathway-receptor model of assessing hydrogeological risk. The protection of all receptors requires a robust conceptual model to be developed. The vertical and aerial distribution of the springs allows the development of fewer models, with the level of risk relative to the distance from the source of the potential drawdown. Therefore, focussing monitoring efforts on the gasfields in closest proximity to the springs, the formations through which the drawdown must propagate, and the springs closest to the relevant development areas, will be the most effective approach to managing potential risks.

Based on the conceptual hydrogeological models upon which this monitoring plan is based (Section 2), and corroborated by the Surat CMA UWIR model predictions, two primary pathways exist for the transmittal of drawdown to EPBC springs:

- Vertical propagation of pressure reduction from CSG production in the Walloon Coal Measures through the siltstones underlying the coal seams (including the Eurombah Formation) and into the Hutton Sandstone. The vertical permeability of the siltstones will subdue and delay the magnitude of drawdown propagating to the Hutton Sandstone. Due to the relatively higher horizontal permeability of the Hutton Sandstone, the drawdown would then spread laterally from the areas of development outwards over time. Drilling and testing of the Hutton Sandstone (e.g. Reedy Creek-MB3-H, Condabri-INJ1-H) suggests low transmissivities are common and likely to result in a steep drawdown profile within the

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development areas, and a broad, flat profile outward from the gasfields. Higher transmissivity zones within the Hutton Sandstone are likely to attenuate the magnitude of drawdown. Drawdown to the Precipice Sandstone from this mechanism would need to have transmitted through the Evergreen Formation, which would significantly subdue the magnitude of drawdown in the source area.
Drawdown would first be realised at the springs closest in to the Walloon Coal Measure developments and closest to where development commences. For APLNG, this is the Scott's Creek springs, which lie approximately 40km northwest of the Combabula field, due to commence production in 2014. Scotts Creek may also be affected by the QGC Woleebee Creek fields, approximately 55km to the southeast of the springs.
All other Hutton Sandstone sourced EPBC springs are at a greater distance from Walloon Coal Measurement production. While the same mechanism for drawdown would apply, the magnitude of drawdown will be less and the time lag greater.

- Lateral propagation of depressurisation from CSG production from the Bandanna Formation at Spring Gully and Fairview, resulting in underdrainage of the Precipice Sandstone where the Bandanna Formation subcrops approximately 15km to the west of Spring Gully (Santos refers to this area as the Contact Zone). The underdrainage would propagate a cone of depression laterally through the Precipice Sandstone.
  The EPBC springs most at risk from this mechanism are those at Lucky Last, located immediately northwest of the Spring Gully tenements (located on Santos tenement). Extremely high transmissivities observed in the Precipice Sandstone in the vicinity of Spring Gully (e.g. DRP-WI-1 and SG-PB3) suggest a low likelihood of propagating drawdowns of significant magnitude through the Precipice Sandstone. To impact the Hutton Sandstone, the drawdown from the Precipice Sandstone must propagate vertically through the Evergreen Formation.

Analysis of timeseries drawdown data from the UWIR model, confirms these mechanisms as the modelled sources of potential impacts to EPBC springs. The model does not appear to show any propagation of drawdown through intervening Evergreen Formation with the exception of an area between Miles and Dalby. This is of limited lateral extent and magnitude and not in the vicinity of EPBC springs therefore drawdown at an EPBC spring is more likely to be realised via the primary pathway.

As identified in the JIP, monitoring therefore focuses on the spring source aquifer and to provide an early warning of potential impacts to the EPBC springs, it is essential that the monitoring focuses on the source and the pathway to the spring, rather than in the immediate vicinity of the spring itself. Monitoring of the CSG reservoir formation will provide an indication of whether the source of drawdown is likely to be greater or earlier than that modelled and hence provide an indicator of the level of risk to the EPBC springs of concern, however conceptualisation of the reservoirs in the 2012 UWIR model as a single producing layer may make comparisons meaningless

Although KCB (2012) identifies the Evergreen and Birkhead Formations as potential EPBC spring source aquifers, they are typically considered to be aquitards, and should they actually be the source formation, the flow is likely to emanate from a higher permeability intraformational zone (e.g. the Boxvale Sandstone member of the Evergreen Formation), which are commonly recognised to be discontinuous and occurring at a relatively local scale only. Therefore, monitoring within the aquitard would only be successful in the bore were installed within the formation which was in direct hydraulic connection as the potential spring source. Monitoring of the formations above and below the aquitard would provide early warning of potential impacts to aquitard formation sourced EPBC springs, regardless of the primary source of drawdown.

The 2012 UWIR model output (P50 and P95) shows relatively small magnitudes of CSG-production related drawdowns at the EPBC spring and monitoring bores. Maximum predicted drawdowns at each of the EPBC springs are summarised in Table 3. The JIP lists 29 bores that comprise the industry EWMS. Table 4 lists the JIP EWMS monitoring bores for which APLNG is responsible, plus additional bores which APLNG has adopted as part of its early warning monitoring program. The APLNG EWMS therefore exceeds those assigned to APLNG in the JIP. Santos and QGC are responsible for the balance of the industry EWMS monitoring bores.

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T able 4 provides triggers, thresholds and limits applicable to each of the bores. Where sufficient data has been collected, initial reference values from which drawdown will be calculated have been included in Table 4.

Model hydrographs are provided in Appendix 3. Comparison of the UWIR model hydraulic parameterisation and newer data gained from more recent work (APLNG, 2013b), suggest that the leakance of the aquitards is likely to be lower than modelled, the lower transmissivity of the Hutton Sandstone, and the much higher transmissivity of the Precipice Sandstone are likely to result in smaller magnitudes of drawdowns being predicted in future iterations of the UWIR model. Therefore using the previous methods proposed by APLNG (2012) and the JIP whereby limits are based on the magnitude of predicted drawdown will result in a practically unworkable approach as triggers will be within the greater than measurement or method errors (in the millimetre range).

A direct comparison of the actual CSG-production induced drawdown and the modelled drawdown prediction is a simple and practical means of implementing a response mechanism as it does not require statistical analysis of trends, and is the method developed for on-tenure springs in the JIP. Accordingly, this approach will be used to manage the potential risks to EPBC springs for which APLNG is responsible through the JIP. The following thresholds, triggers and limits will apply for the current applicability of the APLNG Stage 2 CSG WMMP (APLNG, 2013a), and is shown schematically as Figure 2:

- Investigation trigger - CSG-production related drawdown greater than the P50 model drawdown prediction at each of the monitoring bores included in the EWMS (both EWMIs and TMPs under the JIP) will initiate an investigative response, which may include review of the monitoring data, review of the model, increase in monitoring and assessment of risks to EPBC springs. It will include a sub-regional scale review to ensure effects are not localised due to other influences not accounted for in the data corrections. Actions will only result if 0.2m or more of CSG-production induced drawdown is observed, as drawdown less than this are within the range of natural variability and method or instrument error; and
- Management / mitigation trigger - CSG-production related drawdown greater than the P95 model drawdown prediction at each of the monitoring bores included in the EWMS (both EWMIs and TMPs under the JIP) will initiate a management response. This response will be in accordance with the APLNG Groundwater Mitigation Plan (APLNG, 2013d). Mitigation triggers will not apply to bores monitoring the CSG reservoirs. Actions will only result if 0.2m or more of CSG-production induced drawdown is observed, as drawdown less than this are within the range of natural variability and method or instrument error.
- The limit of CSG-production related drawdown at which the condition of approval will be breached will be 0.2m drawdown measured in nominated bores in close proximity to the EPBC spring (TMPs in the JIP) as this will be considered to be drawdown that potentially impacts on MNES. The bores to which the limit applies are nominated in Table 4.

In addition to the investigation and mitigation triggers associated with aquifer monitoring bores, comparison of monitoring with modelled drawdown in the CSG reservoir formations will provide an indication of whether the source of the drawdown is realistically represented by the model upon which the early warning system is based. Similarly, by monitoring the spring source aquifers in the development areas will provide an indication of the validity of the model prediction upon which the triggers were based. Mitigation triggers will not apply to reservoir monitoring wells and development area monitoring bores, however exceedence of the P50 hydrograph will trigger the investigation process.

Where APLNG has chosen to include additional monitoring bores in its early warning monitoring system, only the investigation trigger will apply at those bores.

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This system will allow for an increasing level of action commensurate with the increasing level of potential risk to EPBC springs.

3.5.3.1. Nominated Monitoring Bores

Table 4 lists the monitoring bores that are included in the APLNG EPBC Spring protection early warning system. It provides the triggers, thresholds and limits for each of the relevant bores.

Figure 2 Schematic of drawdown exceedence response for the EWM

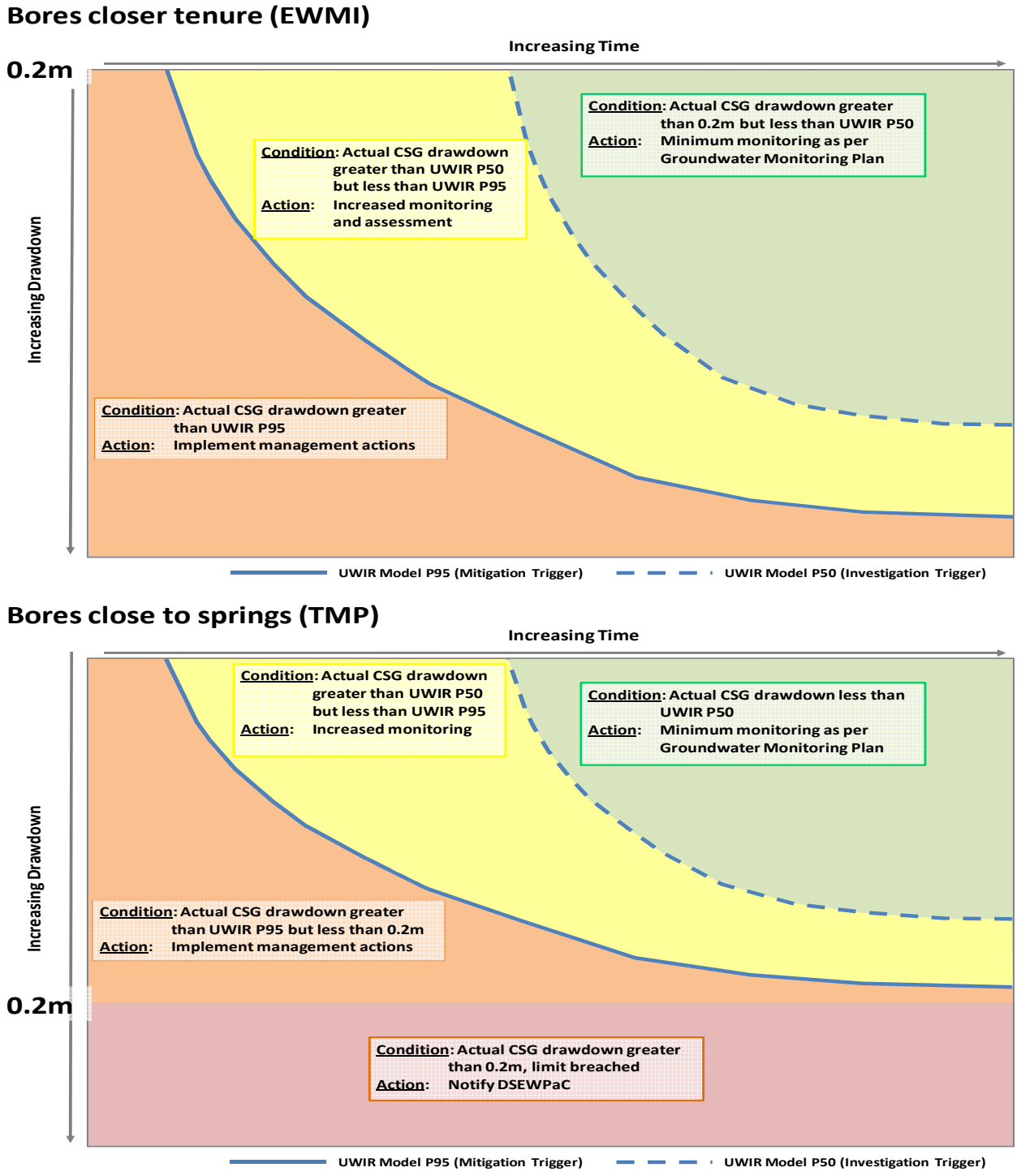

Table 3 UWIR Model Predicted Drawdowns at EPBC Springs

Relevant Spring	Spring Source Formation	First year of modelled drawdown (P95)	First year of modelled drawdown (P50)	P95 Maximum Modelled Drawdown (m)	P95 Year of Maximum Modelled Drawdown
Cockatoo Creek	Precipice Sandstone	NA	NA	NA (0.01)	NA (3895)
Dawson River 2	Precipice Sandstone	NA	NA	NA (0.009)	NA (4095)
Dawson River 6	Precipice Sandstone	NA	NA	NA (0.01)	NA (4295)
Prices	Precipice Sandstone	No drawdown predicted in the source aquifer(s) at the spring location			
Dawson River 8	Hutton Sandstone	2030	2039	0.05	2043
Scotts Creek	Hutton Sandstone	2023	2024	0.25	2039
Yebna 2	Hutton Sandstone	2031	2039	0.15	2165
Lucky Last	Precipice Sandstone	2010	2016	1.3	2079
Elgin 2	Clematis Sandstone	Outside UWIR model domain			
Abyss	Hutton Sandstone	No drawdown predicted in the source aquifer at the spring location			
Carnarvon Gorge	Precipice Sandstone	NA	NA	NA	NA

Table 4 Bores included in the APLNG EPBC spring protection early warning system

EPBC Spring	Spring Source Formation	APLNG Monitoring Bore	Monitored Formation	Bore Target Installation Date	Committed to in JIP	Investigation Trigger[!]	Management Trigger[!]	CSG-induced Drawdown Limit (m)	Reference Water Level
Scotts Creek	Hutton Sandstone	RN14881*	Hutton Sandstone	Existing – not instrumented	Yes	UWIR P50	UWIR P95	0.2	ID
		RN14203*	Hutton Sandstone	Existing – not instrumented	No	UWIR P50	NA	NA	ID
		RN38333 (Scott's Creek Bore)	Hutton Sandstone	Existing	Yes	UWIR P50	UWIR P95	0.2	13.52 mTOC
		RN13946 (House Paddock)	Hutton Sandstone	Existing	No	UWIR P50	NA	NA	-1.62 mTOC
		RN48978 (Lagoon Paddock)	Hutton Sandstone	Existing	Yes	UWIR P50	UWIR P95	NA	ID
		Spring Gully-MB4-H	Hutton Sandstone	Existing	Yes	UWIR P50	UWIR P95	NA	28.45 mTOC – 0.0036*no. Days since 30/8/2012
		Spring Gully-MB17-H	Hutton Sandstone	2014	Yes	UWIR P50	UWIR P95	NA	ID
		Strathblane-WB1-P	Precipice Sandstone	Existing	Yes	UWIR P50	UWIR P95	NA	ID
		Spring Gully MB16-P	Precipice Sandstone	2014	Yes	UWIR P50	UWIR P95	NA	ID

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Dawson River 8	Hutton Sandstone	Kinnoul-MB2-H	Hutton Sandstone	2015	Yes	0.4 m	0.64 m	0.8 m	ID
		Peat-MB3-H	Hutton Sandstone	2014	Yes	0.4 m	0.64 m	NA	ID
Yebna 2	Hutton Sandstone	SG-MB9	Hutton Sandstone	Existing	No¯	UWIR P50	UWIR P95	NA	36.76 mTOC
Abyss	Hutton Sandstone	RN48912	Hutton Sandstone	Existing – not instrumented	Yes	UWIR P50	UWIR P95	NA	ID
Drawdown Source Area	Hutton Sandstone	Reedy Creek-MB3-H	Hutton Sandstone	Existing	No	UWIR P50	NA	NA	82.85 mbgl
		Meeleebee-MB2-H	Hutton Sandstone	2014	No	UWIR P50	NA	NA	ID
		Carinya-MB5-H	Hutton Sandstone	Existing	No	UWIR P50	NA	NA	ID
		Condabri-INJ4-H	Hutton Sandstone	Existing	No	UWIR P50	NA	NA	ID
Development indicators	Hutton Sandstone	Meeleebee-MB3-W	Walloon Coal Measures	2014	Yes	UWIR P50	NA	NA	ID
		Meeleebee-MB4-W	Walloon Coal Measures	2014	No	UWIR P50	NA	NA	ID

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		Combabula-MB3-W	Walloon Coal Measures	Existing	No	UWIR P50	NA	NA	Upper Juandah CM – 480 PSI at gauge Lower Juandah CM – 674 PSI at gauge Taroom CM – 737 PSI at gauge
		Reedy Creek-MB4-W	Walloon Coal Measures	Existing	No	UWIR P50	NA	NA	Upper Juandah CM – 480 PSI at gauge Lower Juandah CM – 674 PSI at gauge Taroom CM – 912 PSI at gauge
		Condabri-MB10-W	Walloon Coal Measures	Existing	No	UWIR P50	NA	NA	Upper Juandah CM – 374 PSI at gauge Lower Juandah CM – 624 PSI at gauge Taroom CM – 806 PSI at gauge
Lucky Last	Precipice Sandstone	SpringGully-PB1	Precipice Sandstone	Existing	Yes	UWIR P50	UWIR P95	NA	62.10 mTOC
		SpringGully-PB3	Precipice Sandstone	Existing	Yes	UWIR P50	UWIR P95	NA	34.10 mTOC -0.002*no. Days since 18/10/2012
		SpringGully-PB5	Precipice Sandstone	2015	Yes (PB2 replacement)	UWIR P50	UWIR P95	NA	ID

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Cockatoo Creek, Dawson River 2, Dawson River 6, Prices, Boggomoss	Precipice Sandstone	Peat MB2-P	Precipice Sandstone	2014	Yes	0.2 m	0.2 m	NA	ID
Development indicators	Precipice Sandstone	Peat MB1-B	Baralaba Coal Measures (Bandanna Formation equiv.)	2014	Yes	UWIR P50	NA	NA	ID
		Durham Ranch 23	Bandanna Formation	Existing	Yes	UWIR P50	NA	NA	CRB1 – 1180 PSI at gauge CRB2 – 1146 PSI at gauge CRB3 – 1132 PSI at gauge
		Spring Gully MB1-B	Bandanna Formation	2014	No	UWIR P50	NA	NA	ID
		Spring Gully MB3-B	Bandanna Formation	2014	No	UWIR P50	NA	NA	ID

[1] Trigger only exceeded if greater than the 0.2 m CSG-production related drawdown is measured
[*] Preferred bore subject to successful Conduct and Compensation Agreement Negotiations
[#] Optional internal compliance bore
[!] Bore exists, monitoring has yet to commence
~ Locations of Spring Gully PB3 and Spring Gully-MB4-H incorrect in JIP. SG-MB09 is at location provided in JIP and will therefore be monitored
NA = Not applicable
ID = To be calculated when sufficient data available. A minimum of one year of data required. Reference values will be reported inthe first annual report following their definition

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3.5.3.2. Water Quality Threshold Values

Approval EPBC 2009/4974 condition requires groundwater quality threshold values to be developed to ensure the protection of MNES.

In accordance with the JIP, a baseline will be defined after the collection of seven (7) six-monthly water quality samples. The approach for identifying a baseline value or trend over the baseline period is:

- Collate water level pressure and hydrochemistry data over the baseline period;
- Collate all background information for the site data over the baseline period; of data. The baseline period data etc.,
- Collate DNRM and other CSG company data;
- Carry out a qualitative and quantitative assessment of the data including simple trends and seasonal variability; and
- Apply the trend analysis method if a baseline value is not readily apparent from simple averages or obvious trends.

For water quality, baseline values will be defined for relevant analytes only and reference values may be set as a range of lower and upper confidence limit. Trigger values will be provided in the first annual report following completion of baseline data collection.

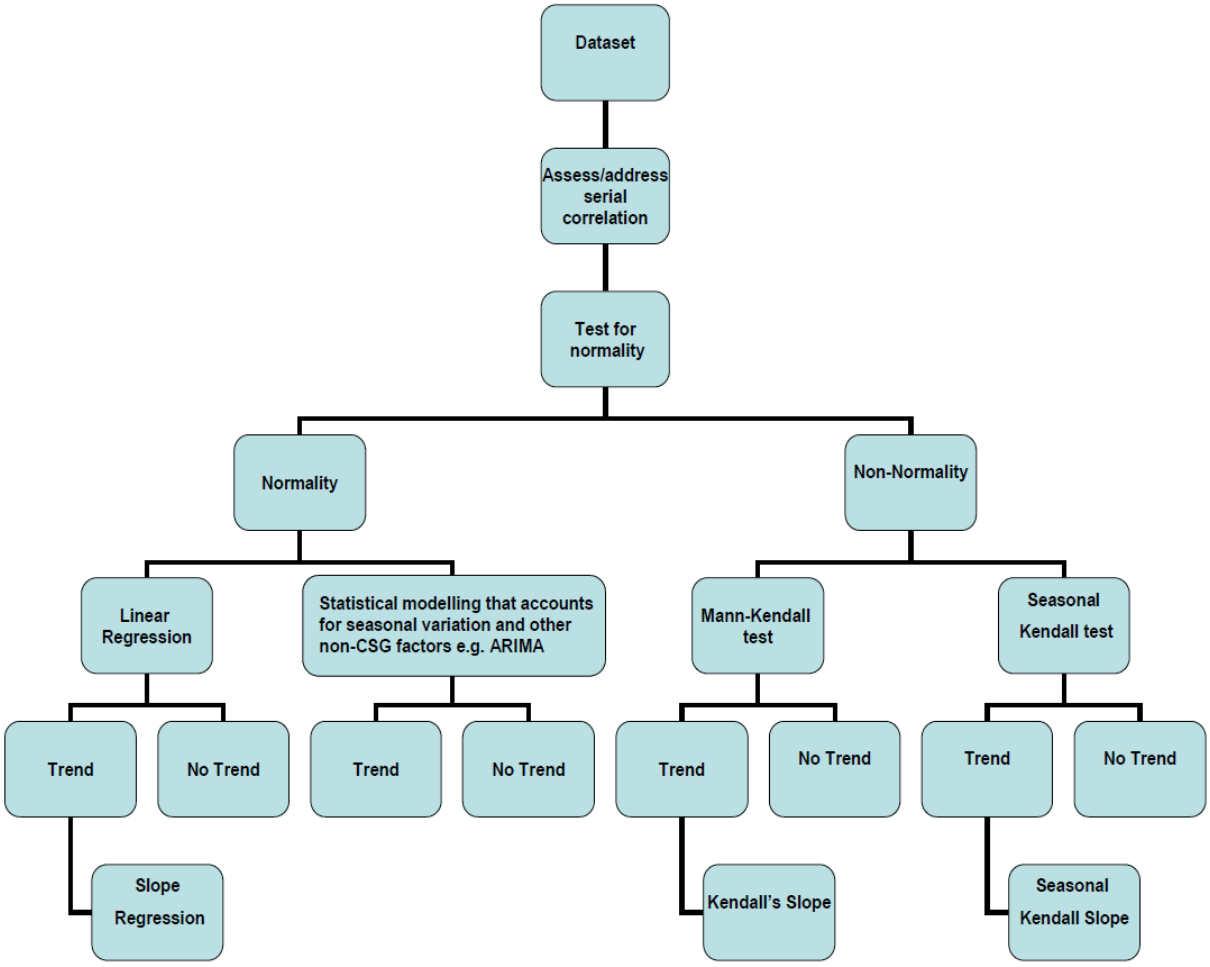
Following establishment of baseline groundwater quality data for the bores included in the EPBC spring protection early warning monitoring system, trend analysis may be undertaken on key water quality parameters. The method for the trend analysis will follow that recommended by Geoscience Australia (GA, 2012) and reproduced schematically as Figure 3. The workflow starts with testing the data for normality and then follows one of two paths depending on whether the data is normally or non-normally distributed. Data is then assessed for seasonal variation, following which the presence or absence of a trend is identified. Should a trend be identified, an indicator of the magnitude of the trend may be determined.

Where a trend is identified, the risk to MNES will be assessed, and should an unacceptable risk to MNES be present, the response plan will be implemented.

Key water quality parameters as indicators of water quality change that will be assessed include:

- Total dissolved solids
- Major cations and major anions

Figure 3 Time-series trend analysis work flow (GA, 2012)



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4. Springs Monitoring

For clarity, this section addresses springs monitoring at the physical spring locations. The monitoring of potential propagation of drawdown effects from production areas towards springs in monitoring bores, and the response mechanisms are presented in previous sections of this plan, and mitigation strategies are contained in the Groundwater Mitigation Plan (APLNG, 2013d). A detailed description of the development of spring investigations is contained in the 2013 Groundwater Assessment (APLNG, 2013a).

Monitoring of springs will be in accordance with the final Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs.

4.1. Identification of springs within 100km extent of drawdown

Validation of springs already included in State and Federal databases within 100km of petroleum lease boundaries in the Surat Cumulative Management Area was completed between January and April 2012 through an assessment of hydrogeological attributes (KCB, 2012) and an Ecological and Botanical Survey (Fensham et al., April 2012).

To satisfy the potentially larger spatial survey requirements of Federal conditions, remote sensing based screening (Phase 1) has been undertaken to identify any potential new springs (Halcrow, Dec 2012) with any potential springs being verified through a helicopter survey (Phase 2). The work was undertaken for Santos on behalf of all major CSG proponents. The survey area covered an area 110km from the Underground Water Impact Report modelled P95 1m drawdown contour. This survey extent was selected due to ongoing issues around defining "...limits of aquifer draw-down...". Comparison of Geoscience Australia's suggested areal extent (based in the north on the extent of potential source aquifers and in the south on the limit of the Surat Cumulative Management Area) indicates that with the exception of the Mulgildie Basin (which is not hydrogeologically connected to the Surat Basin), the Halcrow approach exceeded the GA approach (GA, November 2012) in all but minor areas southwest of St George and Warwick, and south of Blackwater.

Phase 3 Halcrow investigations, constituting field surveys of Phase 2 follow-up targets are scheduled to be undertaken during the second quarter of 2013.

4.2. Locations

The State's delegation of responsibility for spring monitoring is assigned through the Underground Water Impact Report (QWC, 2012) in accordance with the Responsible Tenure Holder rules. Australia Pacific LNG has responsibility for Scott's Creek and Barton Springs.

The JIP also allocates proponent responsibility for each spring complex using the same Responsible Tenure Holder Rules as the UWIR. Accordingly, under the JIP, APLNG is not responsible for any additional springs, however should future UWIRs show increased risk to EPBC springs, APLNG may become responsible for additional springs.

4.3. Parameters, Methods and Frequency

The State's spring monitoring requirements are explicitly detailed in Appendix H4 of the Underground Water Impact Report (QWC, 2012).

Federal requirements for springs classified as belonging to the community of species reliant on outflows from the GAB are specified in project conditions and include:

- *A baseline analysis of four 3-monthly samplings to determine the seasonal presence or absence of all relevant springs, and to establish; the existence, distribution and extent of listed threatened species; aquatic macro-invertebrates; aquatic plants; water quality characteristics; spring physical parameters including seasonal variation, depth, and flow rate; aquifer source including hydrochemical and isotopic analysis, and comparison of water levels with respect to source aquifer potentiometric surface;*

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- *Ongoing monitoring on a 6 monthly basis (to cover high and low rainfall seasons) over the life of the project in the region relevant to each spring.*

State and Federal requirements have been amalgamated into a single monitoring program detailed as follows.

4.3.1. Monitoring Scope and Schedule

The scope for each of the baseline and ongoing monitoring of springs is as follows:

First Quarterly Baseline Visit

An initial visit to characterise each monitoring location:

- Identify safe access procedures and highlight HSSE risks and mitigation;
- Locate a suitable long-term hydrochemistry sampling point and place a permanent marker for future visits;
- Determine how wetted area and physical condition can be monitored;
- Collect first hydrochemical samples;
- Identify feasible methods of measuring water level and flow on a permanent basis. Collect first manual flow (and level) measurements; and
- Prepare a scope of work for establishment of a permanent monitoring measurement station – flow, level & climate (if required).

Second Quarterly Baseline Visit

- Implement scope of work identified in first visit – install flow and level monitoring equipment and climate monitoring, if required; and
- Collect second set of samples and other baseline data.

Remaining Quarterly Baseline Visits (3&4)

- Continue with baseline data collection.

Ongoing monitoring

- 6 monthly for Year two and onwards.

4.3.2. Data Types

The various types of data and observation that will be required are listed in Table 5. Table 6 defines the flow methods and water quality suites that would be employed at the individual vents of the Scotts Creek and Barton Springs (Table 7).

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Table 5 Spring Monitoring Data Types & Observations

Visit	Required Data
Initial visit	Mapping of spring vent location and elevations
All visits	Ground photography to record the appearance of springs and vegetation
	Discharge rates and/or visual flow observations Inundation frequency Wetted area
	Groundwater temperature (where unaffected by surface temperatures)
	Spring sampling for laboratory analyses of water chemistry as per Table 5
	Anecdotal data relating to spring permanency
	Assessment of potential anthropogenic processes (e.g. artesian bores, pumping frequency and rates of nearby bores, flooding conditions through anecdotal evidence and observations
	Any other relevant observations

4.3.3. Specific Data Collection Methodology

Table 6 is based on the UWIR requirements for spring data collection. These procedures will form the initial technical basis for the collection of each spring attribute.

Table 6 Attributes and Methods for Spring Monitoring

Spring attribute	Monitoring Method		
Ambient conditions	Record the total rainfall for the period prior to monitoring. Use observations from the weather station closest to the monitoring site (or a dedicated project climate monitoring station if the nearest BOM site is not suitable)		
Spring flow	**Method A**	Identify a suitable control point. Use a standard low flow hydrology method suitable for the site. Record the method. Use the same control point and method each time the flow is measured. Photograph the control points each time the flow is measured. For watercourse springs measure the flow at the start and finish locations as specified in Table 2. For watercourse springs, comment on the extent of the flow beyond the end location as specified in Table 2.	
	Method B	Assign one of the following classifications to the spring.	
		1	Wetland vegetation, spring pool[1], minor or major flow(s).
		2	Wetland vegetation, no spring pool, surface expression of free water, minor flow(s).
		3	Wetland vegetation, no spring pool, some surface expression of free water.

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Spring attribute	Monitoring Method		
		4	Damp, wetland vegetation, no surface expression of free water.
		5	Dry, no wetland vegetation, no surface expression of free water, no evidence of salt scalding.
Spring Area	**Spring vents**	Use the method described in Fensham & Fairfax 2009 For springs with an area greater than 1.5m^2, use a Differential Global Positioning System. For springs with a total area of less than 1.5m^2, estimate the total area. Using the area, estimate the spring flow using the method described by Fatchen (2001); 10^(((LOG(spring area in m^2) – 3.692)/0.707).	
	Watercourse springs	Estimation of spring area is not required.	
Water chemistry	Measure and where practical, sample water quality in accordance with "Monitoring and Sampling Manual 2009, Environmental Protection (Water) Policy" (DERM 2009). For spring vents, measurements must be taken as close as possible to the vent. Water quality suites are provided in Table 8		
	Suite A	Field water quality measurements.	
	Suite B	Field water quality measurements. Collect a water sample for laboratory analysis.	
Spring physical condition	**Spring vents**	Photograph the spring vent from all aspects. Photograph any significant disturbances noted at the spring. For each photograph record the orientation and describe the features in the photograph. Assign one of the one of the following classification for spring disturbance.	
		1	No evidence of animal disturbance.
		2	Less than 10% of the total spring wetland area shows animal disturbance.
		3	10 – 50% of the total spring wetland area shows animal disturbance.
		4	More than 50% of the total spring wetland area shows animal disturbance.
	Watercourse Springs	A physical condition assessment is not required.	

[1] A spring pool is defined as a body of water with a depth of more than 10cm.

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Table 7 Spring Vent Monitoring Sites

Vent Number	Spring Complex	Location		Flow Measurement Method	Water Quality Suite
		Latitude	Longitude		
189	Scott's Creek	-25.891509	149.285983	A	B
191	Scott's Creek	-25.891755	149.287484	A	B
192	Scott's Creek	-25.888958	149.279041	A	B
192.1	Scott's Creek	-25.888114	149.279189	B	A
702	Barton	-26.270303	149.243285	A	B
703	Barton	-26.285333	149.234459	B	-

4.3.3.1. Flow

At some springs there will be a defined flow channel to allow standard flow measurement techniques to be applied. Other springs have such diffuse discharge that such quantification may not be possible or assessed reliably. In these cases classification as listed in Method B of Table 6 will be required.

Method A of Table 6 presents a general flow monitoring procedure for discrete channels, identified by UWIR. A detailed methodology and implementation plan is required for each location using established techniques such as flumes, weirs or other suitable flow measurement systems.

Technical judgement will be applied to identify the best direct and indirect methods of measuring flow at each site and clearly stating the limits and accuracy of each method and where flow measurement is not possible.

4.3.3.2. Wetted Area

The wetted area of a spring is an important indicator of changes of flow characteristics. Table 6 presents some UWIR recommended methods for determining wetted area. Potential methods may include actual field survey and measurement, consistent photography (ground or air) or other remote sensing techniques.

4.3.3.3. Water Quality Samples

Samples will be collected as close as possible to the actual vent or outlet and at the same location on all visits. Sampling and analysis will be in accordance with the quality assurance protocols described in Section 3.3.4.

The analytes in each suite are listed in Table 8. Following the baseline period, long-term monitoring will consist of a reduced suite of indicator parameters and the suite will be determined following the baseline sampling campaign, but will include as a minimum physiochemical parameter, dissolved metals and major ions.

4.3.3.4. Physical Condition

To include general appearance, disturbance due to animal or anthropogenic activity, slumping and ground collapse and any other changes in condition.

4.3.3.5. Meteorological Conditions

To include collation of records from the nearest climate station over the period since the last visit.

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Table 8 Springs Monitoring Water Quality Suites

Suite A	Parameter
Field Parameters	pH
	Electrical Conductivity (µS/cm @ 25°C)
	Redox (Eh)
	Temperature (°C)
	Free Gas (CH4)

Suite B	Parameter
Field Parameters	pH
	Electrical Conductivity (µS/cm @ 25°C)
	Redox (Eh)
	Temperature (°C)
	Free Gas (CH4)
Laboratory Analytes	Total dissolved solids
	Alkalinity Total Alkalinity as CaCO3 Bicarbonate as CaCO3 Carbonate as CaCO3 Hydroxide as CaCO3
	Sulphate – SO4 by ICPAES
	Chloride
	Major Cations – Calcium, Magnesium, Potassium, Sodium
	Bromide, Iodide, Fluoride
	Total Nitrogen as N (including NOx and TKN)
	Total Phosphorus as P
	Total Organic Carbon (TOC)
	Dissolved Organic Carbon (DOC)
	Metals – As, Ba, Be, Cd, Cr, Co, Cu, Hg, Mn, Ni, Pb, V, Zn.
	Additional dissolved Metals / Metaloids by ICP/MS – Al, B, Fe, Li, Mo, Se, Sr, U.

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4.4. Data Analysis

Analysis of springs monitoring data will include:

- Comparison of time series data of spring flow/wetted area and comparison with meteorological data;
- Presentation of time series photographs and qualitative descriptions of
    - changes to vegetation density and condition;
    - changes in general appearance due to anthropogenic or stock disturbance;
- Assessment in trend of water quality indicator parameters in accordance with Section 3.5.3.2, following the establishment of the baseline dataset.

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5. Water Bore Baseline Assessments

The Water Act 2000 requires baseline assessment to be undertaken prior to the commencement of petroleum activities, or within an otherwise agreed timeframe. The purpose of the baseline assessment is to provide a benchmark against which potential impacts as a result of CSG activities can be assessed. Baseline assessments will be undertaken in accordance with the Baseline Assessment Guidelines (DERM, 2012). The process for the baseline assessment is:

- An Origin Energy Landholder Relationship Advisor (LRA) contacts landowners to determine whether they have bores on their property and the landowner is given a minimum of 10 days written notice of the intention to enter the property to conduct a baseline assessment;
- In conjunction with an Origin Energy hydrogeologist, the LRA arranges a suitable time to visit the landowner;
- On the allocated day, the hydrogeologist meets the landowner and discusses the monitoring program with the landowner;
- Any historical data relating to bore construction, operation, water quality or waterlevels is obtained from the landowner if forthcoming;
- The landowner and hydrogeologist visit each bore on the property to collect the following information where accessible:
    - Accurate location information (GPS);
    - Well head gas concentrations;
    - Standing groundwater level;
    - Details of the bore construction;
    - Details of the pumping system and headworks;
    - A sample for laboratory analysis;
    - A verbal history of the bore.

Following receipt of the laboratory results, the landowner is provided with a copy of the data. The LO is asked to sign an acknowledgment of receipt and that the data contained in the report is correct. Origin is then required to submit the data to the Queensland Water Commission.

The baseline assessments of accessible existing bores have been completed on APLNG operated tenure. Should APLNG become aware of new bores installed on its tenure, these will undergo a baseline assessment.

Data collected in the baseline assessments will be incorporated in the annual report (Section 9.2) and is provided to OGIA (Section 9.3) as a requirement of the *Water Act 2000*.

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6. Aquitard Integrity and Surface Deformation Monitoring

This section equates to and supersedes the aquitard integrity and surface deformation components of the previous standalone Subsidence, Aquitard Integrity and Aquifer Interconnectivity Project Plan (Q-LNG01-10-MP-0018).

6.1. Modelling of Potential Subsurface Deformation

At the water table (in an unconfined aquifer), groundwater is released from storage by gravity drainage. However, in a confined aquifer, groundwater is released from storage due to a reduction in pressure within the pore spaces which accompanies the withdrawal of groundwater from the aquifer. The total load above an aquifer is supported by a combination of the skeletal framework of the aquifer and by the pressure exerted by the associated pore water. Withdrawal of groundwater from the aquifer (such as will occur in CSG production) results in a decline in the pore pressure and subsequently more of the load must be supported by the aquifer skeleton. As a result, the rock particles become distorted and the aquifer skeleton is compressed, leading to a reduction in effective porosity and overall volume. Additionally, the decreased water pressure causes the pore water to expand slightly. Both the compression of the skeleton and expansion of the pore water cause water to be expelled from the aquifer. Compression of the aquifer skeleton can cause subsidence at the ground surface if the overlying rock material is not sufficiently competent to buffer such movement.

To assess the potential risk of aquifer compression and land subsidence associated with the Australia Pacific LNG gas field development, a simple analytical formula was coupled with the numerical groundwater flow model (WorleyParsons, 2010) to calculate the potential compression that may occur.

A simple compaction formula is defined as follows (Edgar and Case, 2000):

$$\partial b = S \partial h$$

Where:

∂b: Level of compaction or change in thickness of the aquifer (m)

S: Storage co-efficient (dimensionless ratio)

∂h: Change in pressure head (m)

The storage co-efficient (S) is the product of the specific storage (Ss) and the aquifer thickness and is a commonly determined value in aquifer testing. In the current study, the specific storage (Ss) for each hydrostratigraphic unit was derived as part of the numerical model calibration, while the change in pressure head value (∂h) was the primary output of the numerical modelling.

Employing the simple compaction formula and the output of the numerical model, the potential compaction of each hydrostratigraphic unit potentially affected by water production during the gas field development was estimated for the APLNG development. The total estimated compaction, as a consequence of the operations, was projected by summing potential deformations in each hydrostratigraphic unit. To minimise the potential for biasing the results through the selection of a single time period only, this analysis was undertaken for ten year time slices from 2019 through to 2079 (beyond the end of gas production in the model). The maximum estimated compaction for each of the seven time slices was then combined to develop a time independent estimate of potential compaction. The highest risk areas equate to less than 0.9m of compaction in that area corresponding to the Mimosa Syncline The low risk areas equate to less than five centimetres of compaction. A comparable exercise was undertaken using the UWIR model P95 drawdown predictions (QWC, 2012), from which a maximum drawdown of less than 0.5m was calculated for APLNG tenure. Santos used alinear elastic theory to calculate potential compaction. Santos estimated compaction of 0.28m for 700m drawdown associated with its Roma Walloons CSG fields (Santos, 2013b).

The risk of compaction is generally correlated with the coal seam elevation and requirements for depressurisation for optimal gas production. The greatest potential for compaction appears to be associated with those areas of comparatively deep coal seams and greater magnitudes of

drawdown. These tenements will not be developed in the first five years of the project. Drawdowns predicted by the UWIR model, tend to be less than that predicted by the APLNG groundwater flow model, therefore based on the methodology used, the risk of compaction has reduced further.

Surface settlement associated with underground coal mining tends to be less than the vertical thickness of coal extracted. The reduction is surface expression of the compaction is dependent several factors, including the depth and width of the extraction zone, which will be discrete compared with the regional effects of CSG depressurisation. Because of the localised source of stress associated with coal mines, the stress redistribution in the overburden during settlement that occurs with that activity may have the potential to induce fractures in the overburden.

CSG development differs from underground coal mining because the depressurisation occurs of a wider area. The stresses on the margins of the gasfields will be significantly less in comparison with an underground coal mine because of the gradients due to the shape of the drawdown associated with depressurisation. It is therefore less likely that CSG depressurisation will lead to fracturing of the overburden. Since the magnitude of compaction is expected to be small, and the likelihood of fracturing the overburden to be remote, APLNG considers the risk of affecting MNES, the hydrology of either the Great Artesian Basin or the Murray Darling Basin river system to be low. In accordance with the APLNG Risk Management Framework (see Section 8.1), low level risks do not require mitigation.

Notwithstanding the low risk, monitoring will be undertaken.

6.2. Monitoring Program

The aquitard integrity and surface deformation monitoring program will be undertaken at two spatial scales: regional and local.

The local scale programs will be focussed on the existing operational gas field at Talinga, and at Reedy Creek. Reedy Creek is the starting-point for the development of the gas fields in the western portion of Australia Pacific LNG's Walloon Coal Measure tenements. Development in the eastern portion of the fields will extend out from Talinga. The purpose of the local scale monitoring is to attempt to understand the mechanisms for deformation (should it occur), and improve the understanding of potential risk such that monitoring can be extended to the wider project area should it be considered necessary.

Regional scale monitoring will extend across the full spatial extent of APLNG tenements.

6.2.1. Regional Scale Monitoring

6.2.1.1. Geodetic Monitoring

APLNG established a geodetic monitoring network across its tenements in 2012. The network comprises 48 pre-existing State permanent survey marks (PSMs). The selection of PSMs was undertaken via the following process:

- General locations for PSMs were identified through risk mapping based on maximum predicted drawdowns in the APLNG EIS numerical groundwater flow model (WorleyParsons, 2010);
- High quality PSMs were selected through a desktop screening process; and
- Field reconnaissance of the proposed PSMs and their appropriateness for inclusion within the regional geodetic monitoring network was completed.

Following finalisation of the network, observations and baseline measurements for each of the nominated survey marks was undertaken.

The field reconnaissance and baseline measurements were performed by Murray and Associates (Qld) Pty Ltd. The methodology used for the survey was a two hour static GPS observation using AUSPOS. AUSPOS is an online service that processes data using the closest 15 International Global Navigation Satellite Systems Service (IGS) Network stations. The IGS is the highest-precision civilian

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GPS community (http://igscb.jpl.nasa.gov/). The precisions were considered to be typically 1-2mm horizontally and 10mm vertically (Murray and Associates, 2012).

The locations and baseline elevations are provided in Appendix B.

Surveying of the geodetic monitoring network will be repeated every two years. Results will be reported in the first annual report following the resurvey. The surveyed data will be compared with InSAR estimates of ground motion for the same location. A linear ground motion trend of greater than 20mm per year (twice the level of precision) will trigger the exceedence response process.

6.2.1.2. InSAR

InSAR (Interferometry for Synthetic Aperture Radar) technology is a measurement method capable of detecting ground motion with millimetric accuracy using data acquired by radar satellites. Measurements are taken from space covering large areas and do not require in-situ inspection for monitoring. The radar satellite images provide an accurate measurement of the distance between the satellite and the ground. "Interferometry" means that there is a superposition of waves from two images in order to detect differences in distance measured in wavelength fractions. To detect ground motion, satellite images taken at different times are compared and for three-dimensional mapping, images taken from different angles are used to measure a stereoscopic effect (Arnaud et. al. 2011).

InSAR was used to establish a baseline of ground motion across the gas fields prior to the advent of significant CSG development, for the period from January 2007 to January 2011 using historical data from the ALOS satellite (Altamira Information, 2012). This period of analysis included CSG extraction at the Spring Gully (Bowen Basin) and Talinga (Surat Basin) gas fields. The intention of the baseline was to provide an initial indication of potential ground motion associated with fields already in production and to provide an understanding of surface deformation relating to non-CSG natural and anthropogenic activities including:

- Landholder groundwater extraction;
- Agricultural practices;
- Erosion or deposition; and,
- Ground movement associated with major rainfall events.

No sub-regional or regional scale effects of CSG production on surface motion were observed in the baseline.

Altamira Information was engaged to continue with InSAR monitoring across APLNG tenements for a period of 2.5 years, with the first acquisitions in July 2012. The current project will utilise Radarsat-2, and will acquire data every 24 days for the first year and then every 48 days thereafter. Average expected precision is expected to be in the order of 5mm and 7mm and the data will be at a spatial resolution of 30 mx30 m. Processed data will be delivered after 1 year and 2.5 years of acquisition.

The processed data provided by Altamira Information will be quantitatively processed in a GIS environment (e.g. ArcGIS). A floating grid methodology will be used to evaluate areas where over 50% of data points exhibit ground motion of greater than 16mm/year over an area of 1,500m by 1,500m. The grid size equates to that of the Surat CMA UWIR model and the approximate distance between any three CSG wells. Sixteen millimetres represents an average annual rate of change twice the magnitude considered stable in the ground motion baseline. Should the analysis indentify such areas, analysis of the cause of the ground motion will be assessed.

In addition to the floating grid methodology, a qualitative assessment of the data will be undertaken. Key considerations in the qualitative assessment will include:

- Sub-regional scale patterns of subsidence centred on active gas fields;
- Localised subsidence centred on pilot production activities;
- Ground motion in the vicinity of EPBC springs; and

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- Ground motion corresponding to the alignment of the Condamine River and tributaries.

The findings of the assessments will be reported in the first annual report following data provision.

6.2.2. Local Scale Monitoring

6.2.2.1. Tiltmeters

Tiltmeters are used to measure oblique ground movement and are designed to accurately measure inclination at the millimetre scale. Ten biaxial tiltmeters have been installed at each of Reedy Creek (PL413) and Talinga (PL226).

Geotechnical Systems Australia (GSA) installed Geokon 6160 biaxial tiltmeters in June 2012. The tiltmeters resolution is ±0.01mm/m and has a range of 15degrees. Each tiltmeter is fixed to a 50 mm steel galvanised post secured into a 2m deep a concrete footing. All of the tiltmeters are orientated with the A axis corresponding to the north (+) – south (-) plane and the B axis corresponding to an east (+) – west (-) plane. The one exception is Tal-TM-9, for which the A axis was set at an azimuth of 30 degrees. GSA aligned as near as possible to a zero degree inclination along both axes. The "zero" measurement, was recorded and will be used as the baseline measurement from with all future movement is calculated.

With the posts being installed to 2 metres, the tiltmeters may be influenced by the movement in the soil profile. At Talinga, the soil is generally silty and sandy. At Reedy Creek, the soil profile is generally a reactive clay type soil, with areas of black soil. This reactive soil is more likely to move due to swelling and shrinking with wet and dry periods which may increase the amount of background noise in the measured response.

Data will be recorded on a minimum daily frequency.

Tiltmeter locations, elevations and zero readings are attached in Appendix B.

6.2.2.2. Extensometers

An extensometer is a geotechnical device that is used to measure small changes across the length over which it is anchored. By measuring the change in length of the formation, the extensometer will provide a direct measurement of the amount of compression/compaction that has occurred within the measured unit. This can be compared with nested monitoring bore water levels and water production/reservoir pressure data to assess the effects of CSG production on aquitard integrity.

Two extensometers, one at both Reedy Creek (PL413) and Talinga (PL226) project areas, were installed between June and July 2012. For each of these extensometers, 5 monitoring depths have been established. At Talinga, the extensometer anchor depths were set at equal spacings (approximately 26 metres) across the Westbourne Formation. The same design was proposed for Reedy Creek, however, the maximum depth achievable was 308 metres below ground level, approximately 17 metres above the bottom of the bore hole. This was likely due to swelling clays causing a reduction in the hole diameter at this depth of the bore hole, which prevented the anchor tool passing through.

Each of the anchors passes through a collar pipe and into the headframe, where they connect to the sensor. Measured movement is both compression and extension and the instruments are designed to have a one metre range of measurement across the length of collar pipe. The design allows for approximately 70% of the available movement via extension and 30% via compression, which equates to 70cm and 30cm respectively. The bore headworks and extensometer headframe have been designed as a sealed unit to facilitate flowing artesian conditions, with a 500 kPa pressure rating.

Sensors record the position of each anchor as a value in millimetres, between 0 and 1000, which must be measured against the baseline or "zero" position established during installation, however the first 3-4 months of data acquisition indicates settling out or stabilisation period for the anchors/wires.

Data will be recorded on a minimum daily frequency.

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Extensometer locations, anchor depths and zero readings are attached in Appendix B.

6.2.2.3. Repeated Hydraulic Tests

Dedicated monitoring bores have been installed at Talinga (Talinga-SC2-Wb) and at Reedy Creek (Reedy Creek-SC2-Wb) for the purpose of periodic hydraulic testing. The bore at Talinga essentially fully penetrates the Westbourne Formation, whereas the Reedy Creek the bore is partially penetrating across approximately 75% of the formation.

The rationale behind this exercise is that significant changes in aquitard integrity may manifest as changes in hydraulic conductivity over time. Hydraulic testing (rising head testing) was conducted on these bores to establish baseline hydraulic conductivities against which future measurements can be compared. Because Reedy Creek-SC2-Wb is artesian, a flow recovery test was also undertaken on this bore as this will be the method used going forward. The baseline values of hydraulic conductivities obtained were:

- Talinga-SC2-Wb: 10^{-3} m/day
- Reedy Creek-SC2-Wb: 10^{-3} m/day (rising head)/ 10^{-3} m/day (flow recovery)

Because of the long period of recovery for these tests (~3 months) and the effect on the extensometer data, hydraulic testing will be repeated every two years.

Changes in aquitard integrity may also result in the groundwater level in the aquitard monitoring bore equilibrating to that of the overlying or underlying aquifer. Pressure transducers with dataloggers have been installed in the Westbourne Formation monitoring bores to monitor for these potential changes.

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7. Aquifer Connectivity Studies

This section describes the activities that will be undertaken to assess the degree of hydraulic connectivity between aquifers. It is predominantly a consolidation and interpretation of data collected throughout the monitoring program. The results of these studies will be presented in the annual reports. This section equates to and supersedes the connectivity component of the previous standalone Subsidence, Aquitard Integrity and Aquifer Interconnectivity Project Plan (Q-LNG01-10-MP-0018).

7.1. Nested Monitoring Bores

By comparing groundwater levels/pressures between bores nested in different aquifers, the degree of connectivity between the aquifers can be assessed. This is particularly pertinent for the monitoring of the Springbok Sandstone since this aquifer directly overlies the Walloon Coal Measures. Due to the relatively short vertical separation between the top producing coals and the Springbok Sandstone, observation of potential drawdown effects will be first realised in the Springbok Sandstone, which will provide an indication of the degree of risk to aquifers with a greater degree of vertical separation. Monitoring of the Hutton Sandstone will provide a similar profile for the aquifers underlying the reservoir. In the Spring Gully area, Precipice Sandstone monitoring bores will provide understanding of the effects of depressurisation in the Bandanna Formation in the vicinity of the subcrop.

APLNG uses the terminaology of co-located for bores drilled on the same drilling lease, and nested for bores grouped together for assessment purposes. Nested bores will be local to eachother and the distance between bores in a nest is generally much less than 2 km. In a large scale CSG development such as the Surat Basin, where the scale of the development is several hundred kilometres across, this approach is considered by APLNG to be suitable as long as there are no known boundaries or baffles in the groundwater system between the bores in the nest. APLNG's monitoring nests are based on current hydrogeological knowledge in their vicinities, and the nests have been selected to ensure aquifer continuity. Should new understanding of the groundwater system in the vicinity of a nest indicate potential for poor horizontal connection, the bores included in the relevant nest(s) will be revised.

All nested monitoring bores will be used in the ongoing assessment and continued monitoring of aquifer interconnectivity. Nested sites and their associated bores are identified in Appendix D, with the map provided in Appendix D showing their locations.

7.2. Springbok Sandstone Detailed Characterisation

Drilling and advanced wireline logging of CSG exploration holes and production wells has suggested that the Springbok Sandstone is not sandstone but rather forms a heterogeneous unit comprising lithologies such as coal, siltstone, shale and sandstone. Since the lithology is highly variable, there is an associated high degree of variability in the permeability/hydraulic conductivity of the formation.

A detailed re-characterisation of the permeability of the Springbok Sandstone is currently being undertaken. The proposed testing program is key in differentiating those intervals of the Springbok with aquifer qualities versus intervals with aquitard characteristics to assist in understanding the variation in hydraulic connectivity between the two formations.

The Springbok Sandstone characterisation studies comprise:

- Laboratory testing of approximately 200 core samples for permeability to both air and brine;
- Applying the Klinkenberg correction to make the results applicable to groundwater;
- Collection of specialised geophysical wireline logs across the majority of CSG exploration and production holes;
- Calibration of horizontal permeability calculated from geophysical log responses, specifically neutron and density logs, to the Klinkenberg-corrected data;

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- Development of vertical profiles of horizontal permeability through the Springbok Sandstone and upper Walloons Coal Measures; and
- Assessment of the profile for aquifer versus aquitard properties.

7.3. Aquitard Laboratory Testing

Because of the low permeability of aquitard material, traditional falling head permeameter tests undertaken by geotechnical laboratories have proved unsuccessful. During early 2011 the University of New South Wales commissioned a centrifuge permeameter, which will overcome the limitations of the traditional falling head permeameter and allow testing of aquitard materials. UNSW has confirmed that the centrifuge permeameter will be available for commercial use, subject to applicability testing.

Fifteen samples have already been analysed from the major aquitards (Westbourne Formation, Eurombah Formation and Evergreen Formation) and the interstitial mudstone and siltstones of the Walloon Coal Measures and the Hutton Sandstone.

More information regarding the centrifuge permeameter can be found at:

(http://www.connectedwaters.unsw.edu.au/news/centrifugepermeametercommissioned.html)

7.4. Field Hydraulic Testing

Laboratory testing of aquitard core material is useful to provide a lower bound of vertical hydraulic conductivity. Field hydraulic testing will be undertaken to assess in-situ structural features or variations that may vary the bulk effectiveness of the aquitard, and assess the spatial extent of these features.

All groundwater monitoring and test bores installed by APLNG are hydraulically assessed by test pumping or rising/falling head tests. This testing ranges from several hours to a number of days, depending on the purpose and characteristics of the bore. Although the testing is short-term, direct connection of the aquifers through fractures or other pathways in the aquitards would manifest as declining water levels in the other bores in the nest.

Analysis of monitoring data from aquifers above or below the aquitard(s) during hydraulic testing will allow vertical hydraulic conductivities to be estimated and therefore the degree of connection to be assessed.

7.5. Isotopic Characterisation of Aquifers and Aquitards

APLNG has entered into a research alliance with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) called the Gas Industry Social and Environmental Research Alliance (GISERA) to support the sustainable development of the CSG industry. A number of GISERA projects relate to groundwater activities.

A specific project has been developed to characterise the individual aquifers, and to a lesser extend the aquitards, in terms of stable and radiogenic isotopes. The purpose of this characterisation is:

- To “fingerprint” each of the aquifers in terms of isotopic composition;
- To determine the source aquifers of springs that support EPBC listed species emanating from Great Artesian Basin sediments; and
- To attempt to quantify any fluid flux across the aquitards.

The suite of isotopes is likely to include:

- Oxygen-18 and deuterium;
- Carbon-13;
- Carbon-14;
- Chlorine-36; and,

- Helium-4.

A novel method called Quartz-Helium Diffusion Testing is being used to estimate the vertical hydraulic conductivity of the Westbourne and Evergreen Formation aquitards.

7.6. Formation Pressure Testing

The petroleum industry uses a number of tools to assess formation pressures in a well prior to casing. These tools include:

- Drill stem tests (DST);
- Modular formation tester (MFT) ; and,
- Modular Formation Dynamics tester (MDT).

In theory, the formation pressure in a vertical wellbore should follow a defined gradient – the hydrostatic pressure gradient. In some cases, formations may be over- or under-pressured relative to the hydrostatic pressure gradient. Deviations from the hydrostatic pressure gradient may be natural, however they are more likely to be anthropogenically induced, either related to pumping (e.g. groundwater use or CSG production) or injection.

In producing CSG gas fields, a pressure profile through the Walloon Coal Measures, with comparison to the hydrostatic pressure gradient will provide an indication of the interconnectivity of the individual coal seams, and other parts of the sequence should they be measured. This profiling only provides a measurement at a single point in time, usually prior to production in a particular gasfield. Temporal pressure profiling will be undertaken in at least ten dedicated Walloon Coal Measure monitoring wells that will be constructed to measure pressures in multiple intervals.

A defined program of pressure profiling *will not* be developed and undertaken, rather data collected for reservoir characterisation during exploration activities will be utilised.

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8. Exceedence Response Process

Should a trigger or threshold be exceeded, the exceedence response process summarised in Figure 4 will be followed. Figure 4 also shows the timing associated with each phase of the process which will ensure actions can be taken to minimise the risk of environmental harm to MNES or other receptors.

If an exceedence is observed in the monitoring record, the exceedence will be confirmed through a sub-regional assessment, and continued monitoring to ensure it is not within the range of natural variability. If a trigger is exceeded, a review of existing data, an increase in the degree of monitoring (exceptional monitoring), review of modelling and risk assessment will be initiated as appropriate to the trigger. Triggers include:

- CSG production induced drawdown, following the removal of non-CSG anthropogenic and natural variation of greater than 0.2m and exceeding the P50 modelled drawdown;
- CSG production induced drawdown, following the removal of non-CSG anthropogenic and natural variation of less than 0.2m, but earlier in time than the P95 modelled drawdown;
- A trend indicating a deterioration in groundwater quality;
- Geodetic survey data showing ground motion in excess of 20mm per year;
- InSAR monitoring identifying 50% of data points exhibiting ground motion of greater than 16mm/year over an area of 1,500m by 1,500m; and
- CSG production induced drawdown in a landholder bore exceeding 5m in a consolidated formation or 2m in an unconsolidated formation.

The exceedence of triggers will be investigated in the regional context, taking cognisance of, but not limited to: the following:

- CSG activities, including production and injection;
- Local, sub-regional and regional groundwater monitoring data;
- Local and sub-regional land-use changes;
- Climatic conditions preceding the trigger exceedence; and/or
- Comparison with predicted drawdowns from the UWIR models, or potential effects, e.g. compaction, associated with predicted drawdown.

Should a trigger exceedence be confirmed, relevant government departments will be notified within 10 days. Further actions undertaken at this stage will include:

- Additional assessment of the risks to potential receptors, including MNES, groundwater and surface water hydrodology, as relevant. This stage may require additional investigations to be undertaken, or an increase in monitoring activities. The activities will be completed within 90 days; and
- Should the risk be considered to be greater than low, the preferred mitigation measure(s) will be identified.

If a mitigation trigger is exceeded management actions will be initiated as the potential environmental risk would be considered greater. A 180 day time period has been allow for this activity, which includes the development of a detailed management and mitigation plan, and may include:

- Confirmation of the concept options;
- Additional field investigations;
- Hydrogeological modelling; and
- Detailed engineering design studies.

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State and Federal (Department of Environment) regulators will be engaged in the development of the mitigation plans. The intention of the response process is to ensure that limits are not exceeded and therefore a condition of approval is not breached. Details of possible mitigation measures and APLNG's intended mitigation measures for springs and groundwater bores are provided in the APLNG Groundwater Mitigation Plan (Q-LNG01-10-MP-0019)

If an investigation trigger is exceeded and found not be as result of CSG-production activities, the trigger mechanisms may be reviewed for appropriateness and changed if necessary. Similarly, the implementation of management measures may render the trigger mechanism inappropriate which may necessitate a review of the trigger mechanism.

Monitoring will continue throughout the exceedence response process and will be used to assess the effectiveness of the implemented management/mitigation measures.

8.1. Risk assessment

Australia Pacific LNG is committed to the continual and effective management of risk and applies a *Risk Policy* (ORG-RISK-POL-001) and *Risk Management Directive* (ORG-RISK-DVE-001) in order to ensure that:

- Appropriate systems are in place to identify all risks to the extent that is reasonably practicable;
- The potential impacts of identified risks are understood and limits set to ensure their appropriate management;
- Responsibilities for risk management are delegated to appropriate persons;
- Assurance is provided as to the effectiveness of the risk management system and its associated risk controls; and
- Any material changes to risk levels are monitored and acted upon accordingly.

To achieve these aims, for all water management activities, Australia Pacific LNG conducts a comprehensive risk assessment that includes the steps outlined in Figure 5, in accordance with International Standard ISO 31000.

For each identified risk, the Australia Pacific LNG risk matrix (Figure 6) is used to assign a consequence and likelihood rating assuming existing controls are in place. These consequence and likelihood ratings are then combined to derive a risk level on a five-point scale from 'Low' to 'Extreme'.

'Low' level risks and some 'Medium' level risks (of acceptably low severity), are considered to be appropriately mitigated by existing controls without the need for further treatment. For all other risks, additional mitigation measures must be considered and treatment plans prepared and approved. For 'Extreme risks', a treatment plan must be prepared and implemented immediately.

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Figure 4 Exceedence Response Flowchart

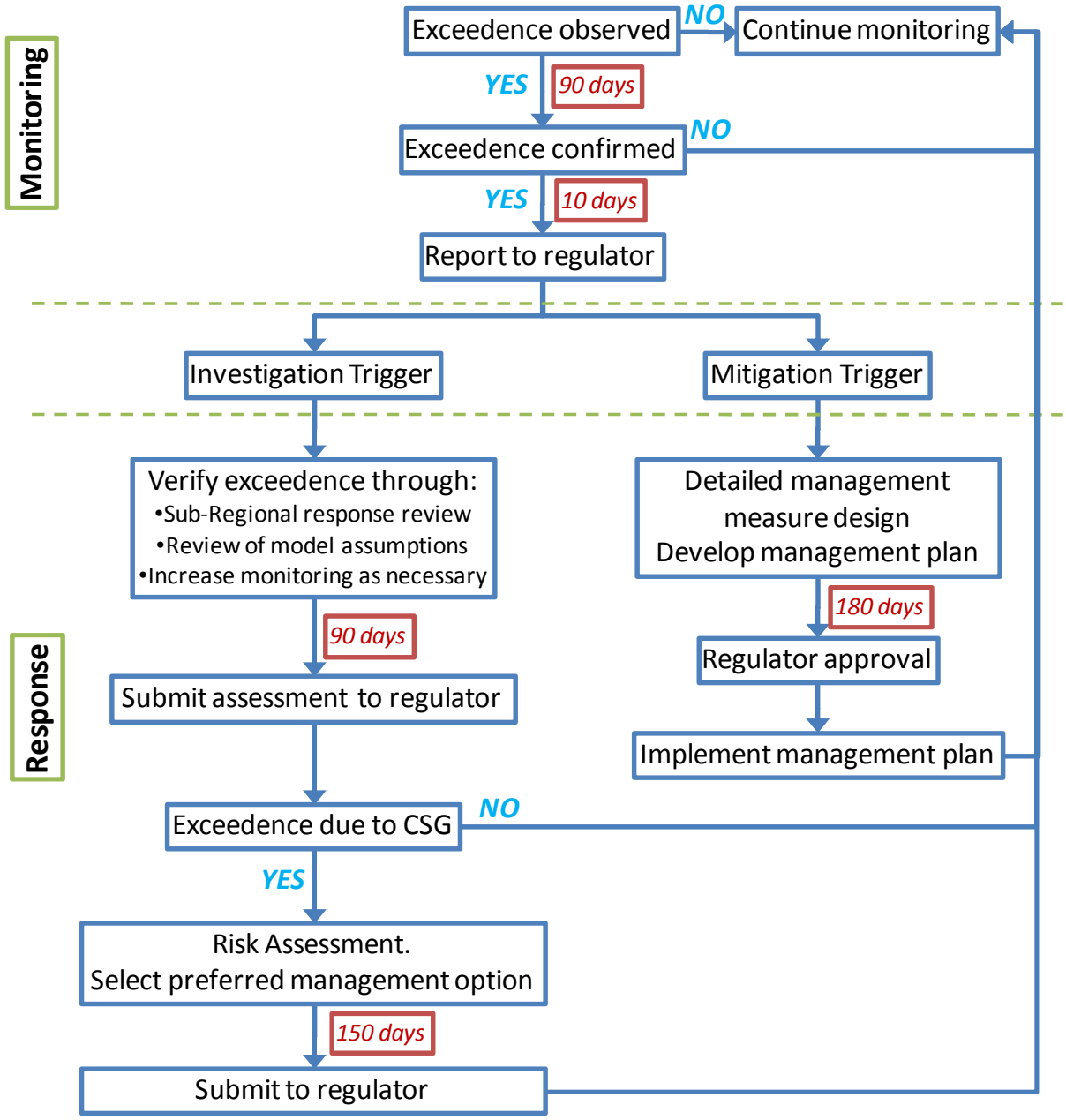

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Figure 5 Risk Assessment Process

Figure 6 Risk Matrix

		LIKELIHOOD RATING					
		1 Remote	2 Highly Unlikely	3 Unlikely	4 Possible	5 Likely	6 Almost Certain
CONSEQUENCE RATING	6 Catastrophic	H	H	S	S	E	E
	5 Critical	M	M	H	S	S	E
	4 Major	M	M	M	H	S	S
	3 Serious	L	M	M	M	H	S
	2 Moderate	L	L	M	M	M	H
	1 Minor	L	L	L	M	M	M

Notes: L = Low, M = Medium, H = High, S = Severe, E = Extreme.

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9. Data Management, Reporting and Data Dissemination

9.1. Data Management

Data collected and compiled as part of the groundwater monitoring program will be stored in appropriate databases.

EsDat is the environmental database currently used by APLNG that can be used to import, validate, store analyse and report the following data:

- Groundwater monitoring data, including:
    - bore construction details;
    - hydraulic data;
    - timeseries waterlevel data (automated and manual measurements);
    - barometric pressure data;
    - water chemistry data, included QA/QC data;
- Groundwater bore baseline assessment data;
- Springs monitoring data including:
    - vent location;
    - weather data;
    - spring flow;
    - wetted area;
    - photographs ;
- Tiltmeter and extensometer timeseries data

Geophysical logs acquired during drilling will be stored in Origin Energy's Geolog database.

InSAR data will be stored in the APLNG geographical information systems database, from which it can be readily interrogated.

9.2. Reporting

Annual reports will be produced to assess and present the results of groundwater monitoring programs. Annual reports will be completed by 30 June each year. These reports will include:

- Changes to the proposed monitoring network from the previous report (for example, new monitoring bores coming online);
- Planned monitoring bore installations for the coming year;
- Differences between the actual development sequence and used in the UWIR model, with specific regard to whether potential impacts may be realised earlier than predicted;
- Presentation of newly acquired hydraulic data;
- Presentation and discussion of uncorrected water level data;
- A description of methods used to correct measured drawdown data and to remove non-CSG effects (barometric, earth tide, non-CSG groundwater extraction, seismic events, hydrostatic loading, etc);
- Presentation and qualitative discussion of corrected drawdown data (where undertaken);
- Comparison of measured water levels or CSG-induced drawdown with triggers, thresholds limits, and predicted drawdowns for that monitoring bore from the UWIR model;
- Presentation of water quality monitoring results, including:

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    - Standard hydrochemical plots (e.g. Piper tri-linear, Durov, Schoeller, or Stiff) of major ion chemistry;
    - Graphs that present the range in variability of other analytes (e.g. box and whisker pre-baseline, timeseries post baseline)
- Water quality data trend analysis (following the completion of baseline sampling only);
- Presentation and discussion of springs monitoring data;
- A summary of bores baseline during the reporting period;
- Presentation and discussion of InSAR and geodetic monitoring results in reports following data collection or provision;
- Presentation of tiltmeter and extensometer data and discussion of the results in the context of CSG-induced drawdowns;
- Presentation of newly acquired hydraulic data;
- Discussion of aquifer connectivity.

9.3. Data Dissemination

Data collected during the bore baseline assessments and routine groundwater monitoring will be provided to the Office of Groundwater Impact Assessment for update and inclusion in its database as required under the Water Act, 2000. Raw data will be provided every six months and the monitoring reporting will be conducted on an annual basis. These anniversaries fall on 1 June and 1 December respectively.

Monitoring reports will be published on the Australia Pacific LNG website (www.aplng.com.au), as required by the Federal project approval (Condition 53ix). Monitoring reports will also be submitted to the Department of Environment.

Data collected from landowner's facilities will be provided to the landowner, including access to live telemetry where available.

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Appendix A: Groundwater Monitoring Bore Network

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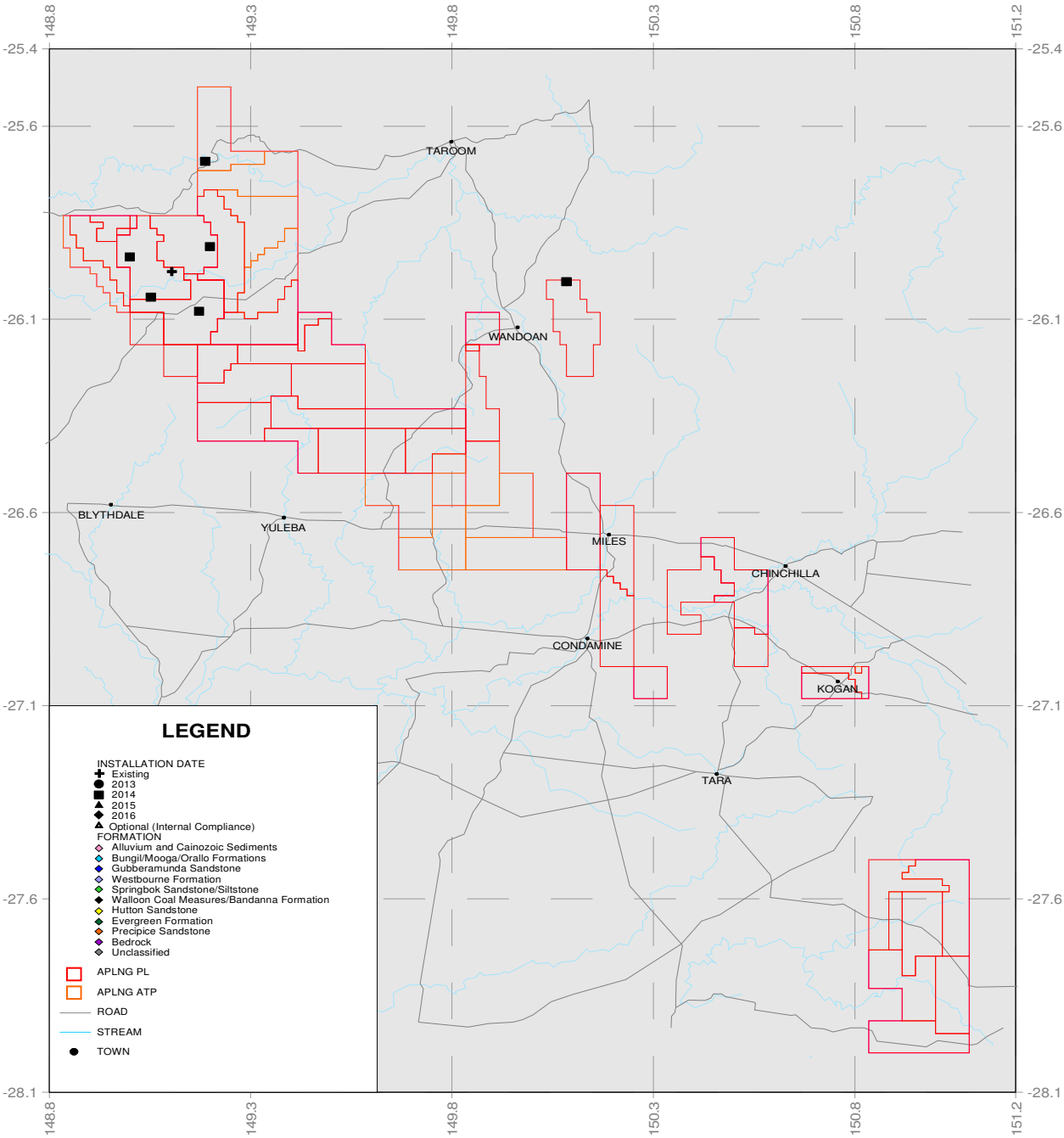

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Bandanna Formation

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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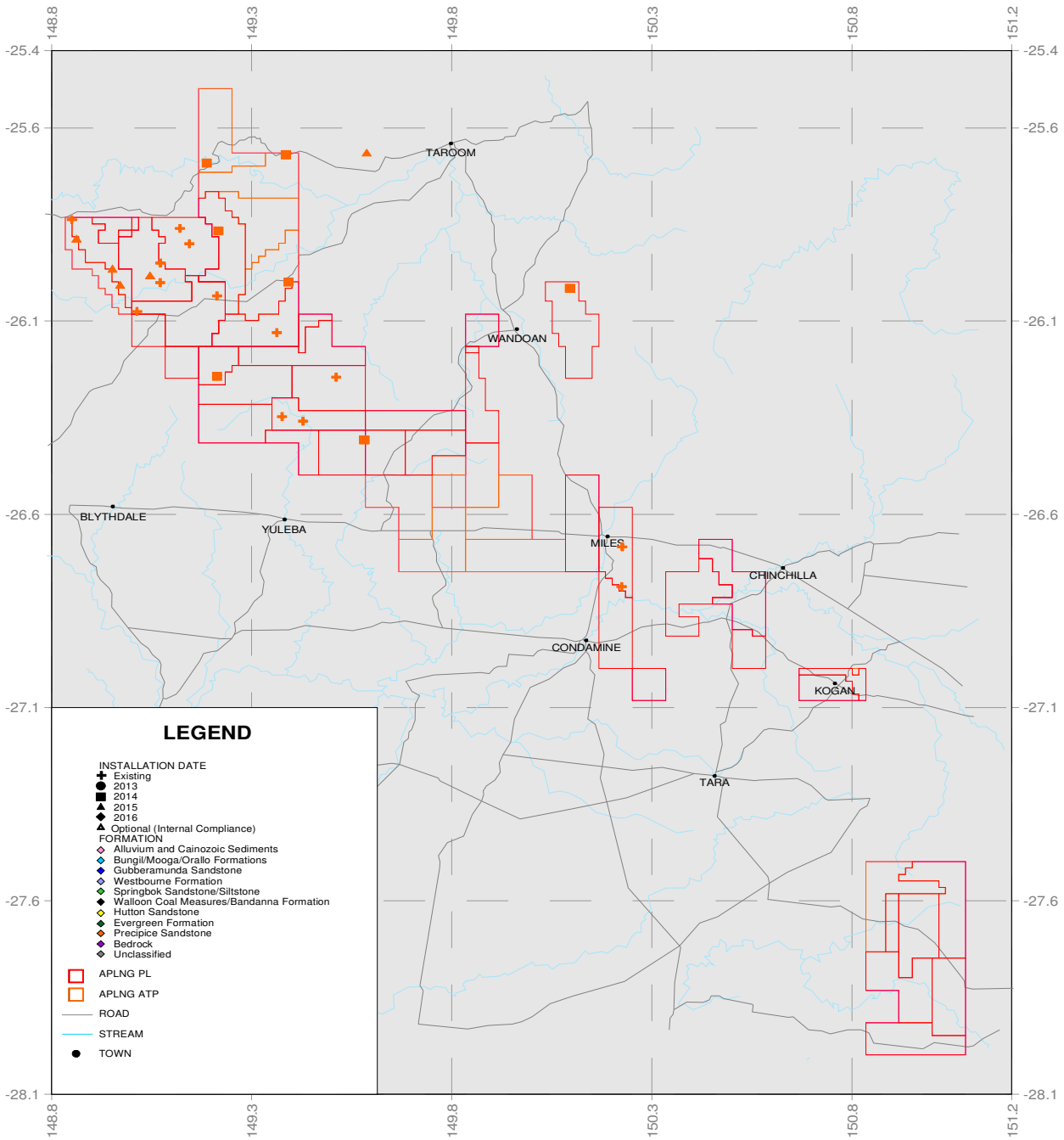

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Precipice Sandstone

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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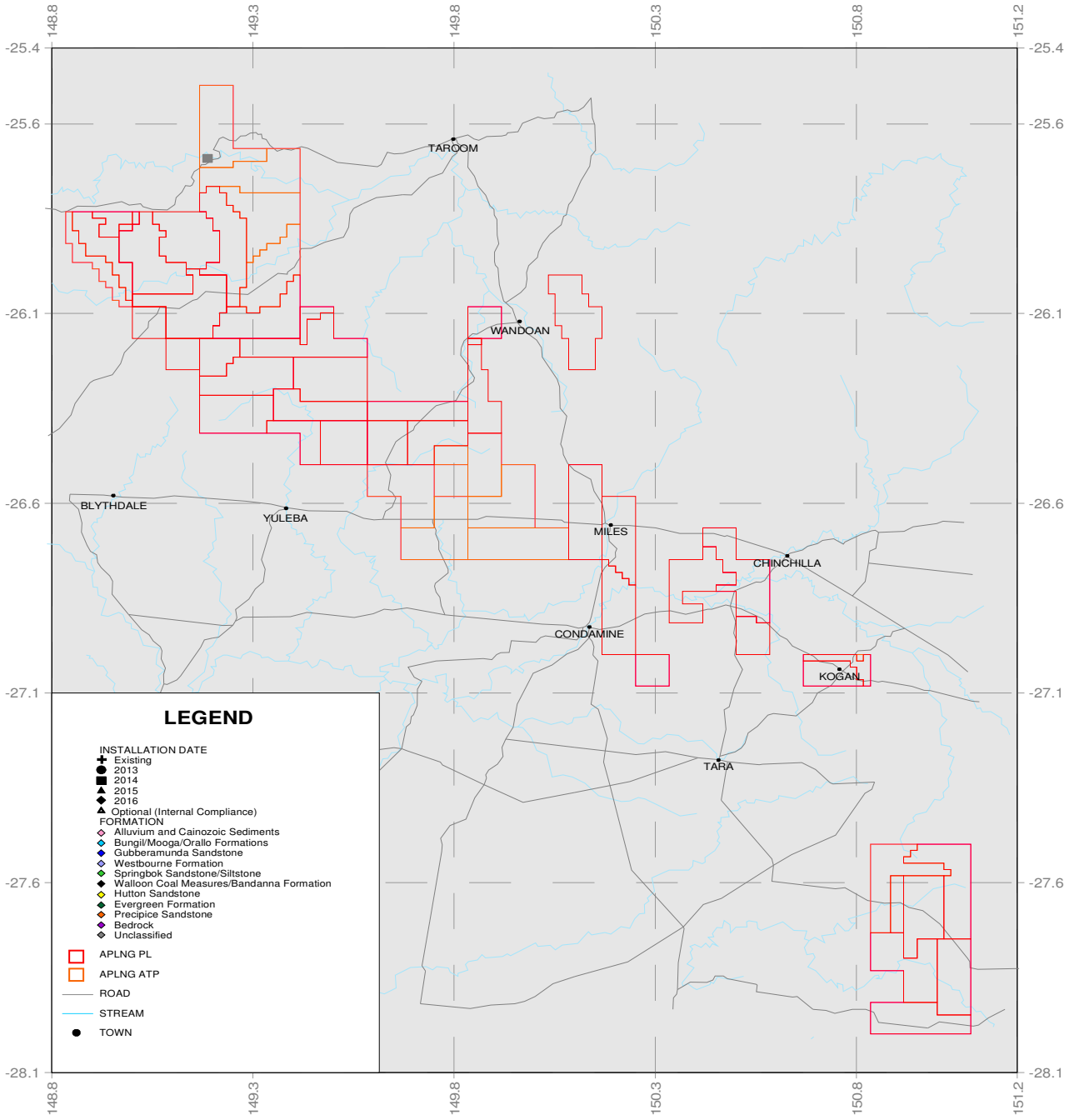

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Evergreen Formation

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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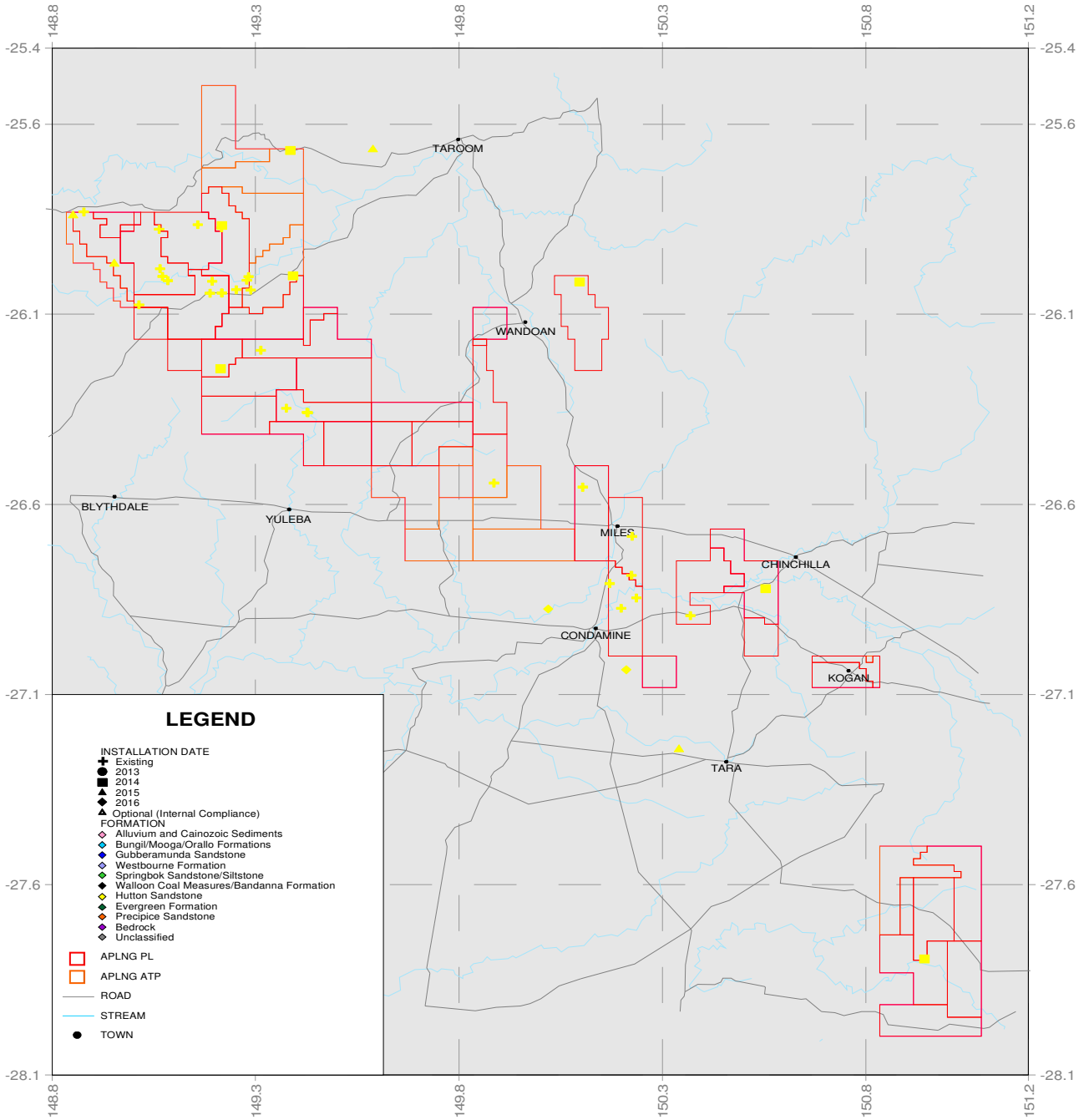

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Hutton Sandstone

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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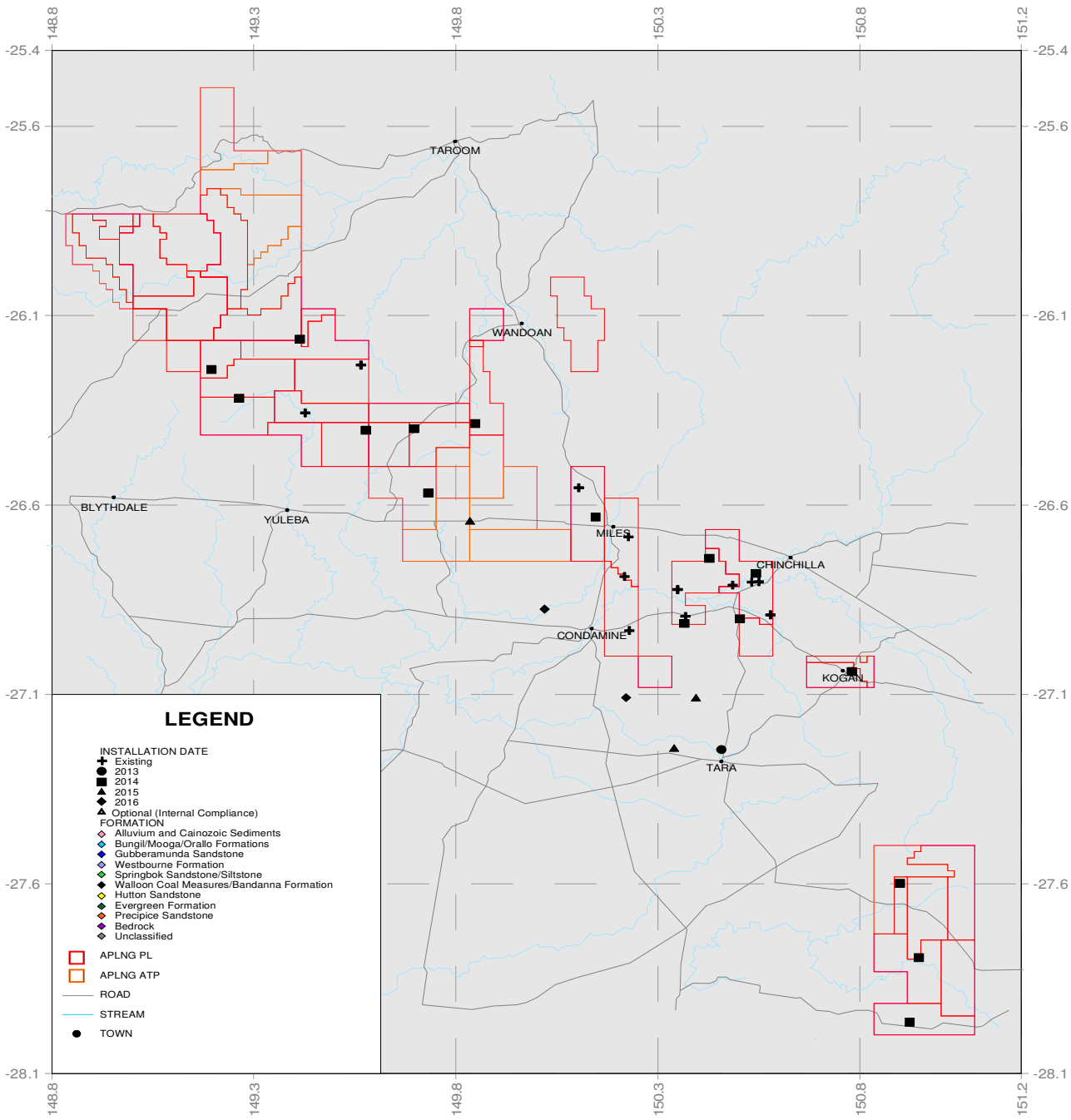

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Walloon Coal Measures

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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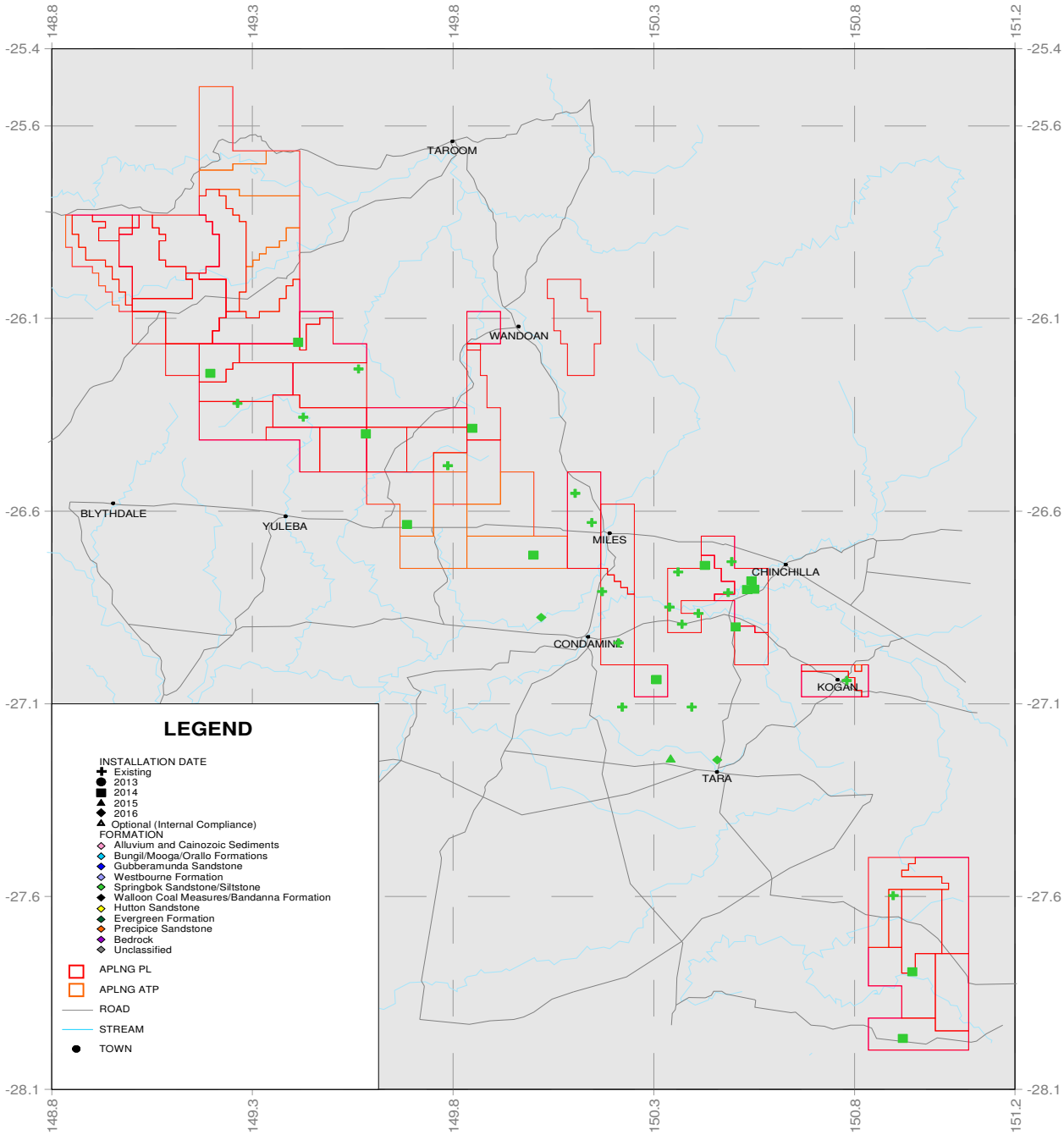

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Springbok Sandstone/Siltstone

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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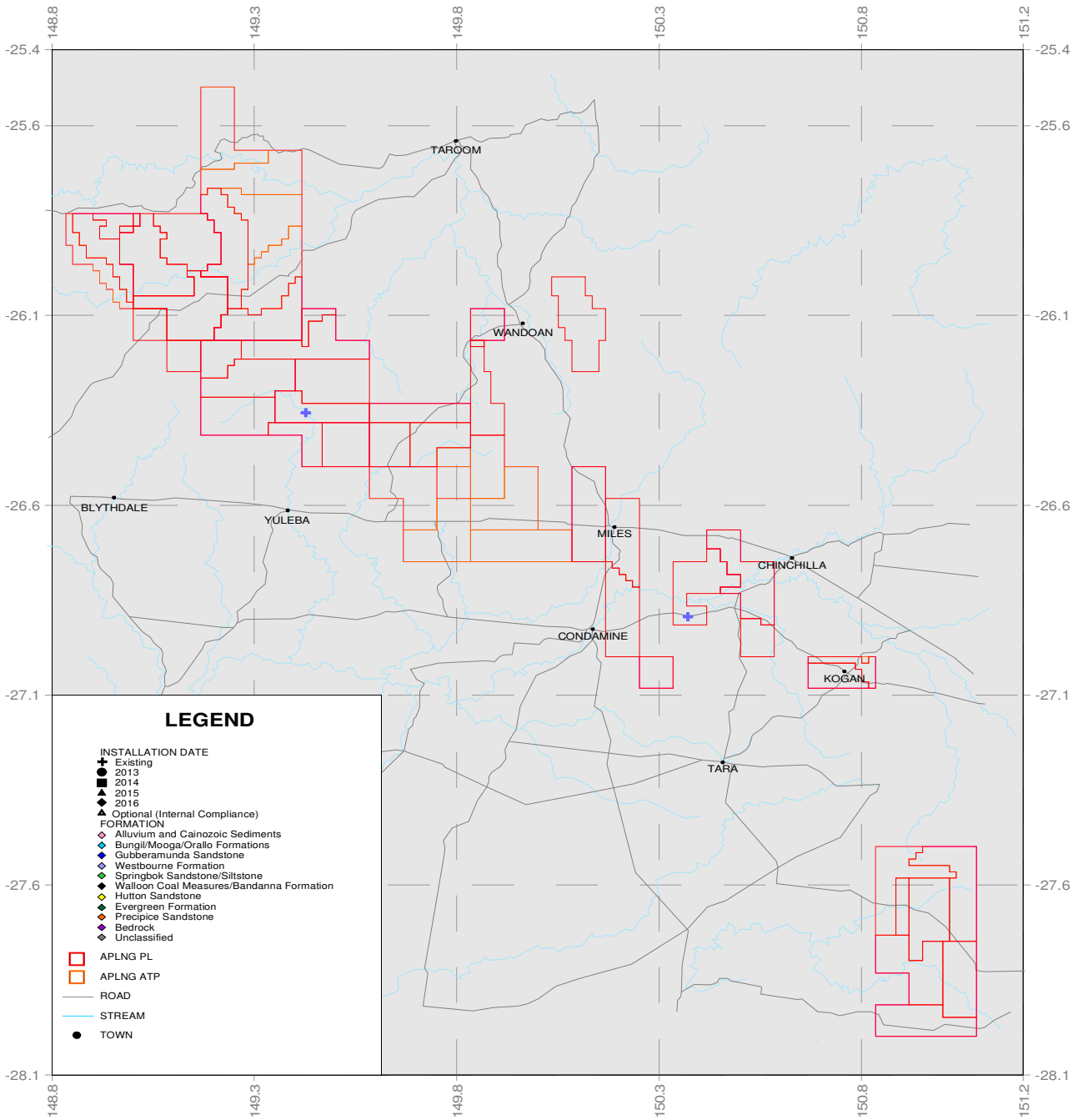

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Westbourne Formation

	Name
Drawn	RM
Rev	A

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Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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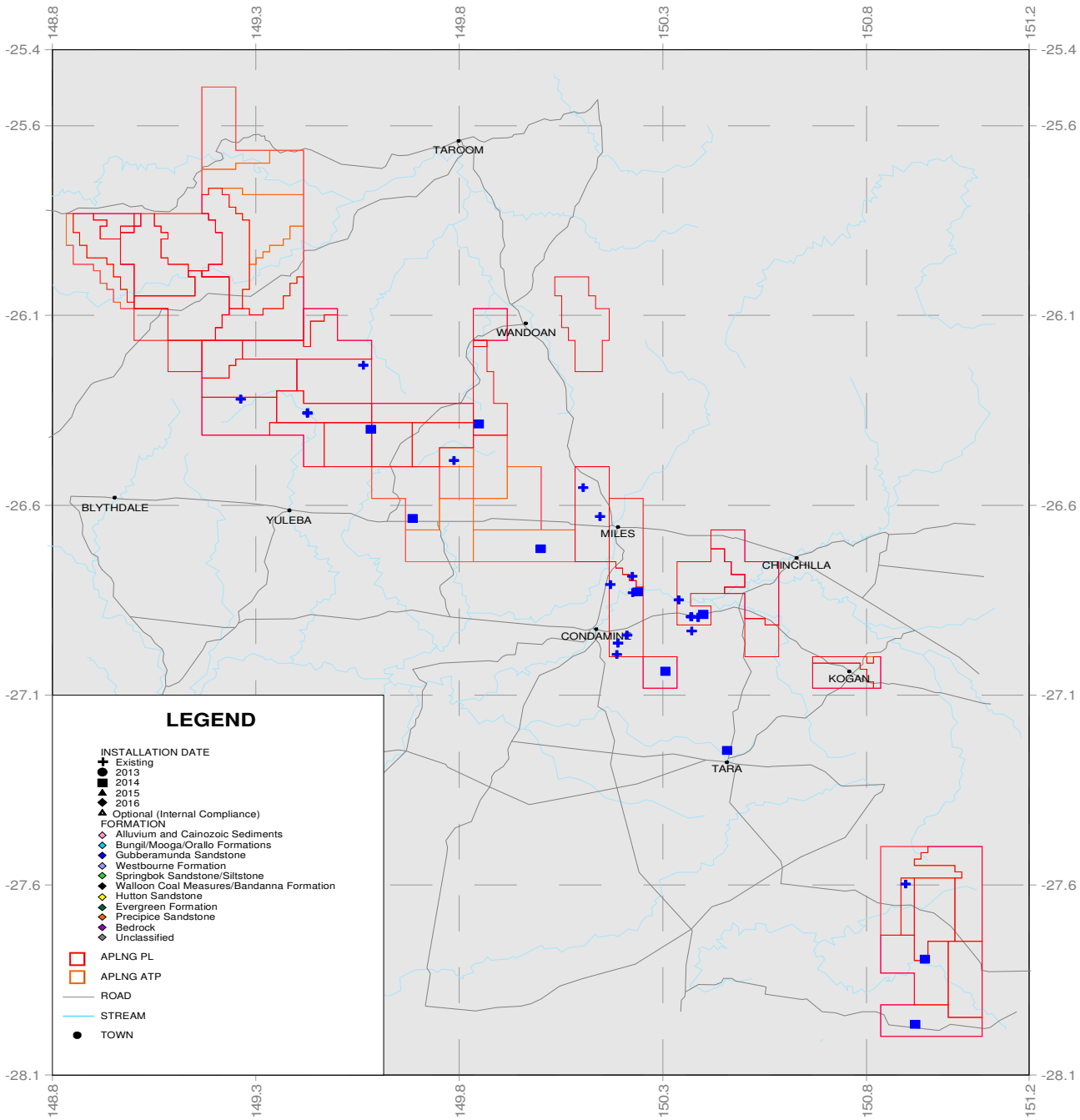

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Gubberamunda Sandstone

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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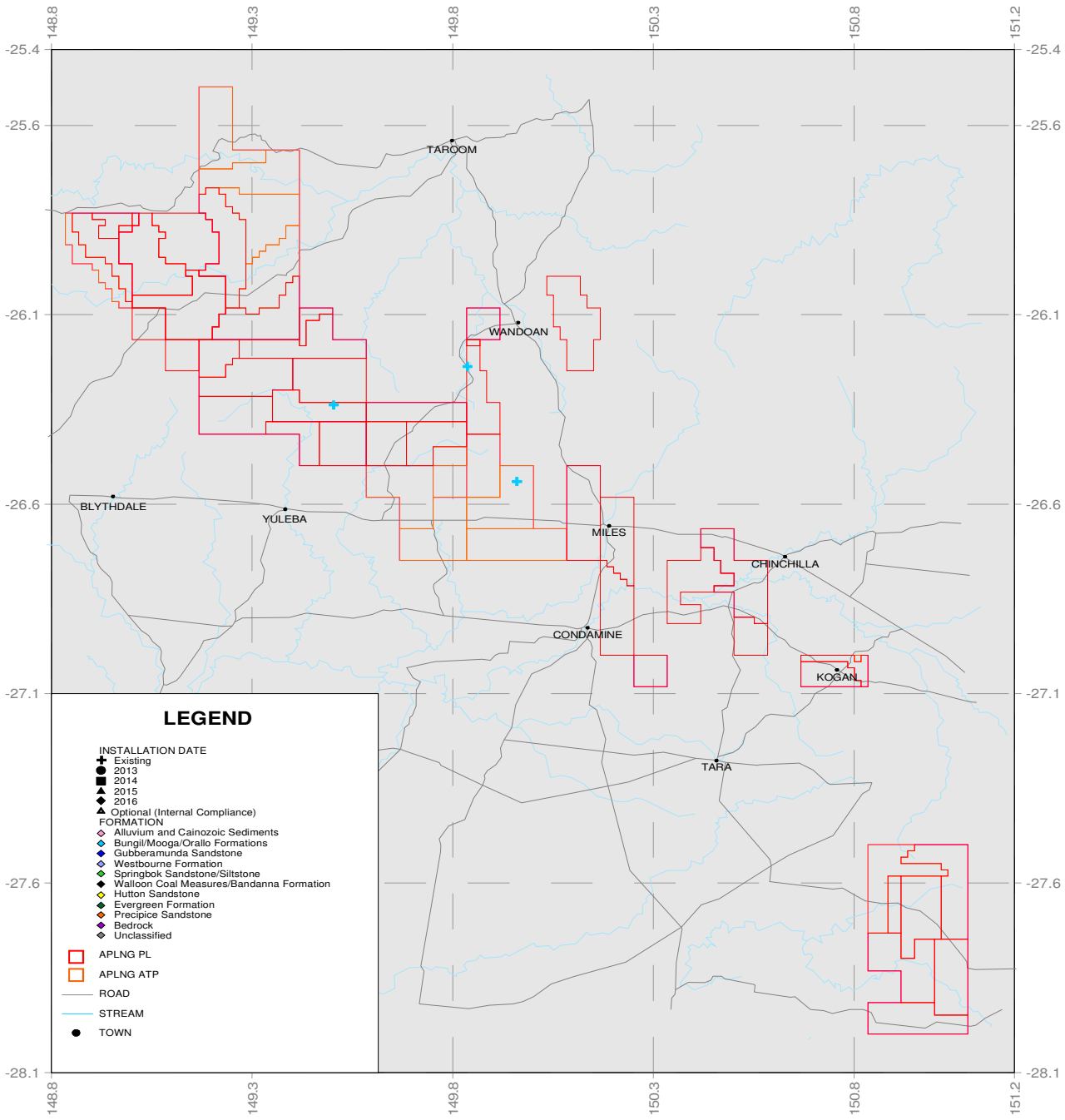

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

BMO Formations

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

N

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Bore Name	RN	Status/Current Commissioing Date	UWIR Location Index	UWIR WQ Monitoring	Jurisdication	Long	Lat	Target Aquifer	Nest ID	Rationale
Bethel BT Roberts Bore 2	123130	Instrumented	281	fortnightly/annual	State and Federal	149.960	-26.540	Mooga		UWIR Requirement
Byme Creek-MB1-W		2015	256, 257, 258	Not required by UWIR	State and Federal	149.835	-26.642	Walloons		Baseline pressures
Carinya-MB1-G		2014		Not UWIR Bore	State and Federal	149.685	-26.635	Gubberamunda	Carinya A	High risk area due to coal depth and high depressurisation requirements Regional coverage
Carinya-MB2-S		2014	250	fortnightly/annual	State and Federal	*149.685*	*-26.635*	Springbok	Carinya A	High risk area due to coal depth and high depressurisation requirements Regional coverage
Carinya-MB3-G		2014	245	fortnightly/annual	State and Federal	150.000	-26.715	Gubberamunda	Carinya B	High risk area due to coal depth and high depressurisation requirements Regional coverage
Carinya-MB4-S		2014	246	fortnightly/annual	State and Federal	150.000	-26.714	Springbok	Carinya B	High risk area due to coal depth and high depressurisation requirements Regional coverage
Carinya-MB5-H		Existing		Not UWIR Bore	State and Federal	149.886	-26.544	Hutton		Fill in large gap in Hutton covereage
Combabula-MB1-G		Existing		Not UWIR Bore	State and Federal	149.564	-26.231	Gubberamunda	Combabula A	Within early development area
Combabula-MB2-S		Existing	382	fortnightly/annual	State and Federal	149.564	-26.231	Springbok	Combabula A	Within early development area
Combabula-MB3-W		Instrumented	283,384, 385	Not UWIR Bore	State and Federal	149.565	-26.231	Walloons	Combabula A	Operational monitoring, within early development area
Combabula-WB1-P		Instrumented		Not UWIR Bore	State and Federal	149.511	-26.245	Precipice		Construction water supply and monitoring
Condabri 140		Instrumented	182,183,184	Not required by UWIR	State and Federal	150.229	-26.931	Walloons	Condabri B	Southern Condabri reservoir monitoring
Condabri-INJ1-H		Instrumented		Not UWIR Bore	State and Federal	150.224	-26.786	Hutton	Condabri C	Injection trial bore, ongoing monitoring
Condabri-INJ2-P		Instrumented		Not UWIR Bore	State and Federal	150.225	-26.787	Precipice	Condabri C	Injection trial bore, ongoing monitoring
Condabri-INJ3-G		Instrumented		Not UWIR Bore	State and Federal	150.225	-26.787	Gubberamunda	Condabri C	Injection trial bore, ongoing monitoring
Condabri-INJ4-H		Existing		Not UWIR Bore	State and Federal	150.226	-26.684	Hutton	Condabri D	Injection monitoring and offset site assessment
Condabri-INJ5-P		Existing	255	fortnightly/annual	State and Federal	150.226	-26.684	Precipice	Condabri D	Injection monitoring and offset site assessment
Condabri-MB10-W		Instrumented	252,253,254	Not required by UWIR	State and Federal	150.227	-26.684	Walloons	Condabri D	Operational monitoring, between Condabri and WCM users, adjacent to QGC Bellevue field
Condabri-MB12-W		Instrumented	211,212,213	Not required by UWIR	State and Federal	150.218	-26.789	Walloons	Condabri C	Operational monitoring in ealry development area. Locate east of Leichardt Fault
Condabri-MB1-G		Instrumented	209	fortnightly/annual	State and Federal	150.171	-26.809	Gubberamunda	Condabri A	High risk area due to thinning/non-existence of Upper Juandah Sandstone,
Condabri-MB2-S		Instrumented	210	fortnightly/annual	State and Federal	150.171	-26.809	Springbok	Condabri A	High risk area due to thinning/non-existence of Upper Juandah Sandstone
Condabri-MB3-G		Instrumented	180	fortnightly/annual	State and Federal	150.212	-26.942	Gubberamunda	Condabri B	Within proposed Southern Condabri to measure potential effects of early operation
Condabri-MB4-S		Instrumented	181	fortnightly/annual	State and Federal	150.212	-26.942	Springbok	Condabri B	Within proposed Southern Condabri to measure potential effects of early operation
Condabri-MB5-G		2014		Not UWIR Bore	State and Federal	150.306	-27.037	Gubberamunda	Condabri E	Close proximity to existing QGC Lauren field Close proximity to Ironbark development
Condabri-MB6-S		2014	168	fortnightly/annual	State and Federal	150.306	-27.037	Springbok	Condabri E	Suspended core hole suitable for retro-fit (Condabri 3) Close proximity to existing QGC Lauren field Close proximity to Ironbark development
Condabri-MB7-G		2014		Not UWIR Bore	State and Federal	150.238	-26.828	Gubberamunda		Close proximity to QGC Berwyndale South field
Condabri-MB9-H		Instrumented	214	fortnightly/annual	State and Federal	150.171	-26.808	Hutton	Condabri A	Regional coverage of APLNG project area Nested site within Springbok and Gubberamunda Sandstone bores On Origin-owned property

Dalwogan 12		2014			State and Federal	150.146	-26.631	Walloons	Dalwogan B	opportunistic workover, operational monitoring
Dalwogan-MB1-G		Instrumented		Not UWIR Bore	State and Federal	150.146	-26.629	Gubberamunda	Dalwogan B	Within existing Dalwogan multi-well pilot - to measure potential effects of early operations Provides suitable regional coverage of central Dalwogan and northern Condabri
Dalwogan-MB2-S		Instrumented	251	fortnightly/annual	State and Federal	150.146	-26.630	Springbok	Dalwogan B	Within existing Dalwogan multi-well pilot - to measure potential effects of early operations Provides suitable regional coverage of central Dalwogan and northern Condabri
Dalwogan-MB3-G		Instrumented		Not UWIR Bore	State and Federal	150.104	-26.554	Gubberamunda	Dalwogan A	High risk area due to thinning/non-existence of Upper Juandah Sandstone, thus no protection to Springbok Sandstone resulting in potential impacts to overlying Gubberamunda Sandstone water bores
Dalwogan-MB4-S		Instrumented	276	fortnightly/annual	State and Federal	150.104	-26.554	Springbok	Dalwogan A	High risk area due to thinning/non-existence of Upper Juandah Sandstone
Dalwogan-MB5-H		Existing	280	Not required by UWIR	State and Federal	150.104	-26.555	Hutton	Dalwogan A	UWIR Requirement
Dalwogan-MB6-W		Existing	277,278,279	Not required by UWIR	State and Federal	150.104	-26.554	Walloons	Dalwogan A	UWIR Requirement
DERM RN13030809	13030809	Instrumented		Not UWIR Bore	State and Federal	149.837	-26.237	BMO		Monitoring commenced during EIS, based on risk mapping
DERM RN42220101	42220101	Instrumented	464	Not required by UWIR	State and Federal	149.503	-26.338	BMO		Monitoring commenced during EIS, based on risk mapping
Duke 25		Non-APLNG - Existing	149	fortnightly/annual	State Only	150.221	-27.108	Springbok	Ironbark A	Suspended exploration coreholes on Ironbark lease. Off-tenure monitoring
Duke 27		Non-APLNG - Existing	145	fortnightly/annual	State Only	150.394	-27.108	Springbok	Ironbark B	Suspended exploration coreholes on Ironbark lease. Off-tenure monitoring
Durham Ranch 23		Instrumented	406	Not required by UWIR	State and Federal	149.104	-25.976	Bandanna	Spring Gully A	operational monitoring Pressures of coals & installed by Pet Engineering - contact Scott Delaney for data
Echo Hills Flowing Bore	58623	Instrumented		Not UWIR Bore	State and Federal	149.214	-26.035	Precipice	Spring Gully F	Spring Gully injection and springs early warning monitoring
Echo Hills House Bore	24696	Existing		Not UWIR Bore	Internal	149.188	-26.045	Hutton		Landholder CCA
Echo Hills Karrajong bore	31521	Existing		Not UWIR Bore	Internal	149.217	-26.044	Hutton		Landholder CCA
Echo Hills Northern Bore	16659	Instrumented	405	Not required by UWIR	State and Federal	149.193	-26.013	Hutton	Spring Gully F	Spring Gully injection and springs early warning monitoring
Echo Hills Sheep Bore	13875	Existing		Not UWIR Bore	Internal	149.217	-26.044	Hutton		Landholder CCA
Gilbert Gully-MB1-G		Existing	20	fortnightly/annual	State and Federal	150.896	-27.597	Gubberamunda	Gilbert Gully A	Within proposed Gilbert Gully multi-well pilot - to measure potential effects of early operations
Gilbert Gully-MB2-S		Existing	20	fortnightly/annual	State and Federal	150.896	-27.597	Springbok	Gilbert Gully A	Within proposed Gilbert Gully multi-well pilot - to measure potential effects of early operations
Gilbert Gully-MB3-W		2014	22,23,24	Not required by UWIR	State and Federal	150.899	-27.598	Walloons	Gilbert Gully A	opportunistic workover of Gilbert Gully 3, operational monitoring
Glen Olive Bore	13518	Existing		Not UWIR Bore	Internal	150.199	-26.873	Hutton		Landholder CCA
Hopelands Wylie House Bore Long	107762	Existing		Not UWIR Bore	State and Federal	150.579	-26.890	Walloons		Shallow WCM, in area of potential ags migration and eraly drawdown effects
Hopelands Wylie House Bore Short	107761	Instrumented		Not UWIR Bore	State and Federal	150.579	-26.890	Walloons		Shallow WCM, in area of potential ags migration and eraly drawdown effects
Ironbark-MB10-H		Non-APLNG 2016	153	Not required by UWIR	State Only	150.211	-27.035	Hutton	Ironbark A	Workover of proposed Condabri South 4
Ironbark-MB11-W		Non-APLNG 2016	150,151,152	Not required by UWIR	State Only	150.221	-27.108	Walloons	Ironbark A	Final location not settled but very likely one of the Duke 3 pilot bores (all within 550 m of UWIR site 36)
Ironbark-MB1-W		Non-APLNG 2015	145,146,147	Not required by UWIR	State Only	150.394	-27.108	Walloons	Ironbark B	UWIR Requirement
Ironbark-MB2-G		Non-APLNG 2015	144	Not required by UWIR	State Only	150.394	-27.108	Gubberamunda	Ironbark B	UWIR Requirement
Ironbark-MB3-S		Non-APLNG 2015	92	fortnightly/annual	State Only	150.342	-27.241	Springbok	Ironbark C	UWIR Requirement
Ironbark-MB4-W		Non-APLNG 2015	93,94,95	Not required by UWIR	State Only	150.340	-27.241	Walloons	Ironbark C	UWIR Requirement
Ironbark-MB5-H		Non-APLNG 2015	96	fortnightly/annual	State Only	150.341	-27.241	Hutton	Ironbark C	UWIR Requirement
Ironbark-MB7-W		Non-APLNG 2015	108,109,110	Not required by UWIR	State Only	150.457	-27.245	Walloons	Ironbark D	UWIR Requirement

Ironbark-MB8-S		Non-ALNG 2016	107	Not required by UWIR	State Only	150.458	-27.245	Springbok	Ironbark D	UWIR Requirement
Ironbark-MB9-G		Non-APLNG 2014	106	Not required by UWIR	State Only	150.458	-27.245	Gubberamunda	Ironbark D	UWIR Requirement
Kainama-MB1-W		2014	158,159,160	Not required by UWIR	State and Federal	150.780	-27.040	Walloons	Kainama A	Sentinel gas monitoring close to WCM water bores
Kainama-MB2-S		Existing	157	fortnightly/annual	State and Federal	150.781	-27.040	Springbok	Kainama A	Regional coverage
Kinnoul-MB1-P		2015		Not UWIR Bore	State and Federal	149.588	-25.664	Precipice	Kinnoul A	Springs monitoring Stage 2
Kinnoul-MB2-H		2015		Not UWIR Bore	State and Federal	149.588	-25.664	Hutton	Kinnoul A	Springs monitoring Stage 2
Lucky Gully-MB1-G		2014	326	fortnightly/annual	State and Federal	*149.583*	*-26.400*	Gubberamunda	Lucky Gully A	Within proposed Lucky Gully multi-well pilot - to measure effects of early operation
Lucky Gully-MB2-S		2014	327	fortnightly/annual	State and Federal	149.583	-26.399	Springbok	Lucky Gully A	Within proposed Lucky Gully multi-well pilot - to measure effects of early operation
Lucky Gully 5		2014		Not UWIR Bore	State and Federal	149.582	-26.408	Precipice	Lucky Gully A	oppourtunistic workover, operational monitoring
Lucky Gully MB3-W		2014	328,329,330	Not required by UWIR	State and Federal	149.577	-26.402	Walloons	Lucky Gully A	Workover of Lucky Gully 8T
Marlan House Bore	7988	Instrumented		Not UWIR Bore	Internal	150.190	-26.963	Gubberamunda		Landholder CCA
Marlan Windmill Bore	11958	Instrumented		Not UWIR Bore	State and Federal	150.187	-26.993	Gubberamunda		Landholder bore - regional monitoring coverage
Meeleebee-MB1-S		2014	386	fortnightly/annual	State and Federal	*149.195*	*-26.242*	Springbok	Meeleebee A	Close proximity to several groundwater users accessing the Springbok Sandstone
Meeleebee-MB2-H		2014	390	fortnightly/annual	State and Federal	*149.214*	*-26.243*	Hutton	Meeleebee A	Potential workover of Meeleebee 5 In vicinity of several private Hutton bores that are projected to be impacted
Meeleebee-MB3-W		2014	387,388,389	Not required by UWIR	State and Federal	149.195	-26.242	Walloons	Meeleebee A	workover of Meleebee 5
Meeleebee-MB4-W		2014	492,493,494	Not required by UWIR	State and Federal	*149.414*	*-26.162*	Walloons	Meeleebee B	UWIR Requirement
Meeleebee-MB5-P		2014	391	Not required by UWIR	State and Federal	*149.214*	*-26.243*	Precipice	Meeleebee A	UWIR Requirement
Meeleebee-MB7-S		2014	491	Not required by UWIR	State and Federal	*149.414*	*-26.162*	Springbok	Meeleebee B	UWIR Requirement
Meeleebee Downs New Clifford House Bore	58726	Instrumented		Not required by UWIR	Internal	*149.363*	*-26.130*	Precipice		Construction water use and injection
Moorabinda Rhodes Grass Bore	31097	Existing		Not UWIR Bore	Internal	149.313	-26.195	Hutton		Springs EWS
Muggleton-MB1-G		Instrumented	358	fortnightly/annual	State and Federal	*149.263*	*-26.321*	Gubberamunda	Muggleton A	Close proximity to existing Pine Hills multi-well pilot Good injection potential - field data to be collected during installation
Muggleton-MB2-S		Existing	359	fortnightly/annual	State and Federal	*149.263*	*-26.321*	Springbok	Muggleton A	Close proximity to existing Pine Hills multi-well pilot Good injection potential - field data to be collected during installation
Noonga Creek 6		2014		Not UWIR Bore	State and Federal	149.732	-26.568	Walloons		oppourtunistic workover, operational monitoring
Norwood Bore	123030	Instrumented		Not UWIR Bore	Internal	149.467	-26.187			Construction water use and injection
Old Hutton Park Bore	48912	Existing		Not UWIR Bore	Federal	148.878	-25.831	Hutton		Springs EWS
Orana-MB10-S		Existing		Not required by UWIR	Optional Internal	150.485	-26.811	Springbok	Orana D	Rock hole seep
Orana-MB11-W		Existing		Not required by UWIR	Optional Internal	150.533	-26.803	Walloon	Orana F	Camping Ground seep
Orana-MB12-S		2014		Not required by UWIR	Optional Internal	150.533	-26.803	Springbok	Orana F	Camping Ground seep
Orana-MB13-W		2014		Not required by UWIR	Optional Internal	150.543	-26.780	Walloon	Orana G	Updip monitoring of seeps and production activities
Orana-MB14-S		2014		Not required by UWIR	Optional Internal	150.543	-26.780	Springbok	Orana G	Updip monitoring of seeps and production activities
Orana-MB15 -S		2014	231	Not required by UWIR	State and Federal	*150.427*	*-26.740*	Springbok	Orana A	UWIR Requirement
Orana-MB1-S		2014		Not UWIR Bore	State and Federal	150.504	-26.900	Springbok	Orana C	BG/QGC production already commenced at Argyle - monitoring of cumulative and effects pre-dating APLNG development. Previously MB1-G and MB2-S, refer to stratigraphy

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Orana-MB3-S		Existing	231	fortnightly/annual	State and Federal	150.494	-26.731	Springbok	Orana A	Regional coverage
Orana-MB4-W		2014		Not UWIR Bore	State and Federal	150.503	-26.900	Walloons	Orana C	Differentiate effects of Kenya/Argyle, operational monitoring
Orana-MB5-W		Existing		Not UWIR Bore	State and Federal	*150.550*	*-26.803*	Walloons	Orana E	Sentinel gas monitoring close to WCM water bores & Condamine gas seep In proximity to existing (producing) QGC and Arrow fields
Orana-MB6-H		2014	215	fortnightly/annual	State and Federal	*150.554*	*-26.822*	Hutton	Orana B	Monitoring of effects of early operations in Hutton Closest to landholder bores in Hutton/Marburg to NE
Orana-MB7-W		2014	232,233,234	Not required by UWIR	State and Federal	*150.427*	*-26.740*	Walloons	Orana A	UWIR Requirement
Orana-MB8-S		2014		Not UWIR Bore	Optional Internal	150.550	-26.803	Springbok	Orana E	Sentinel gas monitoring close to WCM water bores & Condamine gas seep In proximity to existing (producing) QGC and Arrow fields
Orana-MB9-W		Existing		Not required by UWIR	Optional Internal	150.485	-26.811	Walloon	Orana D	rock hole seep
Peat-MB1-B		2014	467	Not required by UWIR	State and Federal	*150.084*	*-26.002*	Bandanna	Peat A	UWIR Requirement
Peat-MB2-P		2014		Not required by UWIR	State and Federal	*150.096*	*-26.015*	Precipice	Peat A	Springs monitoring Stage 2
Peat-MB3-H		2014		Not required by UWIR	State and Federal	*150.096*	*-26.015*	Hutton	Peat A	Springs monitoring Stage 2
Pine Hills South-MB1-S		2016	186	Not required by UWIR	State and Federal	*150.020*	*-26.876*	Springbok	Pine Hills (off-tenure) A	UWIR Requirement
Pine Hills South-MB2-W		2016	187	Not required by UWIR	State and Federal	*150.019*	*-26.875*	Walloons	Pine Hills (off-tenure) A	UWIR Requirement
Pine Hills South-MB3-H		2016	188	Not required by UWIR	State and Federal	*150.020*	*-26.875*	Hutton	Pine Hills (off-tenure) A	UWIR Requirement
Pine Hills-MB1-W		2014	360,361,362	Not required by UWIR	State and Federal	149.264	-26.318	Walloons	Muggleton A	Operational monitoring, between source and springs
Ramyard-MB3-G		Instrumented		Not UWIR Bore	State and Federal	149.787	-26.482	Gubberamunda	Ramyard A	Regional coverage
Ramyard-MB4-S		Instrumented	322	Not required by UWIR	State and Federal	149.787	-26.482	Springbok	Ramyard A	Regional coverage
Ramyard-MB5-W		2014	323,324,325	Not required by UWIR	State and Federal	*149.696*	*-26.399*	Walloons		Baseline pressures
Reedy Ck-INJ1-H		Instrumented		Not UWIR Bore	State and Federal	149.428	-26.359	Hutton	Reedy Creek B	Primary injection trial hole
Reedy Ck-INJ2-P		Instrumented		Not UWIR Bore	State and Federal	149.429	-26.359	Precipice	Reedy Creek B	Primary injection trial hole
Reedy Ck-INJ3-H		Instrumented		Not UWIR Bore	State and Federal	149.376	-26.347	Hutton	Reedy Creek A	Secondary injection trial hole
Reedy Ck-INJ4-P		Instrumented		Not UWIR Bore	State and Federal	149.376	-26.347	Precipice	Reedy Creek A	Secondary injection trial hole
Reedy Ck-INJ5-G		Instrumented		Not UWIR Bore	State and Federal	149.427	-26.358	Gubberamunda	Reedy Creek B	Primary injection trial hole, ongoing monitoring
Reedy Ck-MB1-G		Instrumented		Not UWIR Bore	State and Federal	149.427	-26.356	Gubberamunda	Reedy Creek B	Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations Good injection potential - field data to be collected during installation to confirm
Reedy Ck-MB2-S		Instrumented	351	fortnightly/annual	State and Federal	149.427	-26.356	Springbok	Reedy Creek B	Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations Good injection potential - field data to be collected during installation to confirm
Reedy Ck-MB3-H		Instrumented	355	fortnightly/annual	State and Federal	149.427	-26.358	Hutton	Reedy Creek B	Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations Good injection potential - field data to be collected during installation to confirm Regional coverage of Hutton Sandstone
Reedy Ck-MB4-W		Instrumented	352,353,354	Not required by UWIR	State and Federal	149.427	-26.357	Walloons	Reedy Creek B	operational monitoring

Reedy Ck-SC1-Wb		Instrumented		Not UWIR Bore	State and Federal	149.427	-26.356	Westbourne	Reedy Creek B	Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations Installation of extensometer for aquitard integrity monitoring
Reedy Ck-SC2-Wb		Existing		Not UWIR Bore	State and Federal	149.427	-26.356	Westbourne	Reedy Creek B	Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations Repeated permeability testing
Rockwood Back Bore	30168	Instrumented		Not UWIR Bore	State and Federal	150.371	-26.931	Gubberamunda		Monitoring commenced during EIS, based on risk mapping
Scotts Creek Sawmill Bore	58594	Instrumented		Not UWIR Bore	State and Federal	149.063	-25.877	Hutton		Spring Gully injection and springs early warning monitoring
Spring Gully Camp Bore		Instrumented		Not UWIR Bore	State and Federal	*149.072*	*-25.950*	Precipice	Spring Gully A	Spring Gully injection and springs early warning monitoring
Spring Gully-DMH01		Instrumented		Not UWIR Bore	State and Federal	149.071	-26.000	Hutton	Spring Gully B	Spring Gully injection trial observation bore
Spring Gully-DMP01		Instrumented		Not UWIR Bore	State and Federal	149.071	-26.000	Precipice	Spring Gully B	Spring Gully injection trial observation bore
Spring Gully-MB10-H		2014		Not UWIR Bore	State and Federal	*149.386*	*-25.669*	Hutton	Spring Gully H	Springs monitoring Stage 2
Spring Gully-MB11-P		2014	451	Not required by UWIR	State and Federal	*149.188*	*-25.692*	Precipice	Spring Gully I	UWIR Requirement
Spring Gully-MB12-E		2014	450	Not required by UWIR	State and Federal	*149.187*	*-25.691*	Boxvale	Spring Gully I	UWIR Requirement
Spring Gully-MB13-P		2015		Not UWIR Bore	State and Federal	*149.047*	*-25.982*	Precipice		Stage 2 springs monitoring
Spring Gully-MB14-H		2015		Not required by UWIR	State and Federal	*148.952*	*-25.964*	Hutton	Spring Gully J	JIP
Spring Gully-MB15-H		2015		Not required by UWIR	State and Federal	148.851	-25.838	Hutton	Spring Gully K	JIP
Spring Gully-MB16-P		2014	412	Not required by UWIR	State and Federal	149.217	-25.867	Precipice	Spring Gully L	UWIR requirement and springs early warning
Spring Gully-MB17-H		2014	411	Not required by UWIR	State and Federal	149.217	-25.867	Hutton	Spring Gully L	UWIR requirement and springs early warning
Spring Gully-MB1-B		2014	474	Not required by UWIR	State and Federal	149.000	-25.938	Bandanna		operational monitoring
Spring Gully-MB2-B		2014	396	fortnightly/annual	State and Federal	*149.172*	*-26.079*	Bandanna		Bandanna monitoring for SG Phase 6. Approximate location only.
Spring Gully-MB3-B		2014	472	Not required by UWIR	State and Federal	*149.052*	*-26.043*	Bandanna		UWIR Requirement
Spring Gully-MB4-H		Instrumented		Not UWIR Bore	State and Federal	149.014	-26.075	Hutton	Spring Gully C	Failed attempt at drilling precipice bore SG-PB3 due to lost circulation. Hole completed in Hutton Sandstone
Spring Gully-MB5-B		2014	414	Not required by UWIR	State and Federal	*149.199*	*-25.912*	Bandanna		UWIR Requirement
Spring Gully-MB6-B		2014	452	fortnightly/annual	State and Federal	*149.187*	*-25.692*	Bandanna	Spring Gully I	UWIR Requirement
Spring Gully-MB7-P		2014		Not UWIR Bore	State and Federal	149.392	-25.999	Precipice	Spring Gully G	Springs monitoring Stage 2
Spring Gully-MB8		Instrumented		Not UWIR Bore	Federal	149.084	-26.012	Hutton		Springs EWS
Spring Gully-MB8-H		2014		Not UWIR Bore	State and Federal	149.392	-25.999	Hutton	Spring Gully G	Springs monitoring Stage 2
Spring Gully-MB9		Instrumented		Not UWIR Bore	State and Federal	149.065	-25.980	Hutton		Spring Gully Injection monitoring
Spring Gully-MB9-P		2014		Not UWIR Bore	State and Federal	*149.386*	*-25.670*	Precipice	Spring Gully H	Springs monitoring Stage 2
Spring Gully-PB1		Instrumented	423	fortnightly/annual	State and Federal	148.851	-25.838	Precipice	Spring Gully K	Existing monitoring bore in Bandanna Subcrop
Spring Gully-PB3		Instrumented	471	fortnightly/annual	State and Federal	149.014	-26.075	Precipice	Spring Gully C	Improved coverage of Bandanna Subcrop
Spring Gully-PB4		2015		Not required by UWIR	Optional Internal	*148.863*	*-25.887*	Precipice		Early detection monitoring at Bandana subcrop under Precipice
Spring Gully-PB5		2015	473	fortnightly/annual	State and Federal	148.952	-25.964	Precipice	Spring Gully J	Early detection monitoring at Bandana subcrop under Precipice
Spring Gully-PB6		2015		Not required by UWIR	Optional Internal	*148.971*	*-26.006*	Precipice		Early detection monitoring at Bandana subcrop under Precipice

Strathblane Bullet Hole Gate (old)	58428	Instrumented		Not UWIR Bore	State and Federal	149.121	-25.860	Precipice	Spring Gully D	Spring Gully injection and springs early warning monitoring
Strathblane Scott's Creek Bore	38333	Instrumented	411	Not required by UWIR	State and Federal	149.158	-25.865	Hutton	Spring Gully D	Spring Gully injection and springs early warning monitoring
Strathblane Slip Rails Bore	38334	Existing	411	Not required by UWIR	State and Federal	149.216	-25.873	Hutton		UWIR requirement and springs early warning
Strathblane-WB1-P		Instrumented	414	Not required by UWIR	State and Federal	149.144	-25.900	Precipice	Spring Gully D	Water supply and monitoring
Talinga 15		2014	94, 196, 197, 198	Not required by UWIR	State and Federal	150.365	-26.912	Walloons		Operational monitoring, injection trial monitoring
Talinga 16		Instrumented	220	Not required by UWIR	State and Federal	150.349	-26.823	Walloons		operational monitoring - contact Tristan Renwick-Cook for Data
Talinga-MB10-G		Instrumented		Not UWIR Bore	State and Federal	150.369	-26.893	Gubberamunda	Talinga A	Operational monitoring, injection trial monitoring
Talinga-MB11-S		Existing	219	fortnightly/annual	State and Federal	150.360	-26.758	Springbok		Replacement of Tal17, co located
Talinga-MB1-G		Instrumented		Not UWIR Bore	State and Federal	150.339	-26.849	Gubberamunda	Talinga B	Within existing Talinga operational development
Talinga-MB2-S		Instrumented		Not UWIR Bore	State and Federal	150.339	-26.849	Springbok	Talinga B	Within existing Talinga operational development
Talinga-MB3-H		Instrumented	199	fortnightly/annual	State and Federal	150.369	-26.892	Hutton	Talinga A	Within existing Talinga operational development
Talinga-MB4-G		2014		Not UWIR Bore	State and Federal	*150.399*	*-26.887*	Gubberamunda		Landholder request; injection monitoring
Talinga-MB5-G		Instrumented	190	fortnightly/annual	State and Federal	150.370	-26.893	Gubberamunda	Talinga A	Injection exploration and ongoing monitoring
Talinga-MB7-S		Instrumented	192	fortnightly/annual	State and Federal	150.370	-26.893	Springbok	Talinga A	Injection exploration and ongoing monitoring
Talinga-MB8-W		Instrumented	*193, 195, 197*	Not UWIR Bore	State and Federal	150.368	-26.894	Walloons	Talinga A	Operational monitoring, injection trial monitoring
Talinga-MB9-G		Instrumented		Not UWIR Bore	State and Federal	150.369	-26.893	Gubberamunda	Talinga A	Operational monitoring, injection trial core investigation & monitoring
Talinga-SC1-Wb		Instrumented - extensometer		Not UWIR Bore	State and Federal	150.371	-26.893	Westbourne	Talinga A	Extensometer installation
Talinga-SC2-Wb		Instrumented	191	Not required by UWIR	State and Federal	150.371	-26.893	Westbourne	Talinga A	Ongoing aquitard permeability assessment
Turinga House Bore		Instrumented		Not UWIR Bore	State and Federal	150.370	-26.886		Talinga A	Injection monitoring
Waar Waar-MB1-G		2014		Not UWIR Bore	State and Federal	*150.943*	*-27.795*	Gubberamunda	Waar Waar A	Within proposed Waar Waar multi-well pilot - to measure potential effects of early operations
Waar Waar-MB2-S		2014	6	fortnightly/annual	State and Federal	*150.944*	*-27.795*	Springbok	Waar Waar A	Within proposed Waar Waar multi-well pilot - to measure potential effects of early operations
Waar Waar-MB3-H		2014	10	Not required by UWIR	State and Federal	*150.944*	*-27.795*	Hutton	Waar Waar A	Close to users in Marburg Sandstone, projected to be impacted by CE model Regional coverage of monitoring in Hutton Sandstone
Waar Waar-MB4-W		2014	7,8,9	Not UWIR Bore	State and Federal	150.946	-27.794	Walloons	Waar Waar A	UWIR Requirement
Waikola Bore Pad 1	58073	Existing		Not UWIR Bore	State and Federal	149.283	-26.001	Hutton		Required under CCA
Waikola House Paddock Bore	13946	Instrumented		Not UWIR Bore	State and Federal	149.253	-26.036	Hutton		Required under CCA
Waikola Lagoon Paddock Bore	48978	Instrumented		Not UWIR Bore	State and Federal	149.278	-26.011	Hutton		Required under CCA
Waikola Plains Paddock Bore	17640	Existing		Not UWIR Bore	State and Federal	149.288	-26.036	Hutton		Required under CCA
Wallumba Feedlot bore	58604	Instrumented		Not UWIR Bore	State and Federal	150.236	-26.846	Hutton		Required under CCA
Wallumba House Bore	35916	Instrumented		Not UWIR Bore	State and Federal	150.226	-26.830	Gubberamunda		Required under CCA
Wieambilla Gravel Pit Bore	87755	Instrumented		Not UWIR Bore	State and Federal	150.387	-26.895	Gubberamunda		Monitoring due to landholder concerns
Wieambilla Solar Panel Bore	147358	Instrumented		Not UWIR Bore	State and Federal	150.411	-26.865	Springbok		Monitoring due to landholder concerns
Woleebee-MB1-W		2014	348, 349, 350	Not UWIR Bore	State and Federal	*149.848*	*-26.385*	Walloons	Woleebee A	Sentinel gas monitoring close to WCM water bores

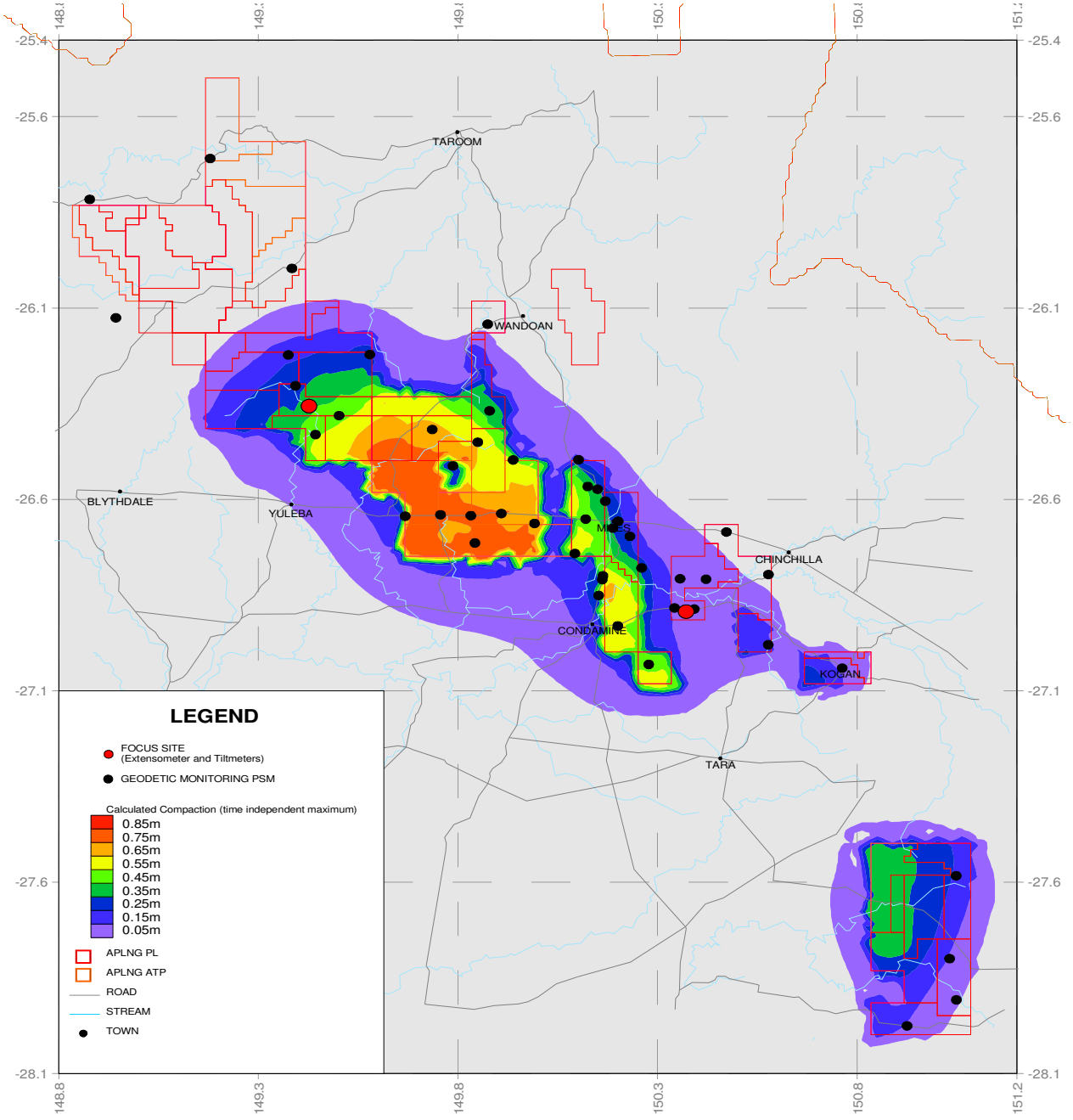
Woleebee-MB2-G		2014		Not UWIR Bore	State and Federal	*149.848*	*-26.386*	Gubberamunda	Woleebee A	Within Woleebee #4 cored hole lease - Originally this bore location was Ramyard MB1-G located 5km to west
Woleebee-MB3-S		2014	347	fortnightly/annual	State and Federal	*149.848*	*-26.385*	Springbok	Woleebee A	
ZigZag-MB1-G		2014	1	fortnightly/annual	State and Federal	150.920	-27.967	Gubberamunda	Zig Zag A	Within proposed Zig Zag multi-well pilot - to measure potential effects of early operations Good injection potential - field data to be collected during installation to confirm
ZigZag-MB4-S		2014	2	fortnightly/annual	State and Federal	150.920	-27.968	Springbok	Zig Zag A	Within proposed Zig Zag multi-well pilot - to measure potential effects of early operations Good injection potential - field data to be collected during installation to confirm
ZigZag-MB3-W		2014	3,4,5	Not required by UWIR	State and Federal	150.923	-27.965	Walloons	Zig Zag A	UWIR Requirement

Appendix B: Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs (30 September 2013)

JIP Provided on CD

Appendix C: Aquitard Integrity and Surface Deformation Monitoring Network

Mark	GDA 94 Easting	GDA 94 Northing	Height (AHD D) - September 2012	Zone
PSM 1415	774378.815	7050462.141	327.719	55
PSM 8240	248463.759	7045937.399	344.364	56
PSM 8620	217037.793	7026879.386	291.341	56
PSM 9706	765571.66	7050224.404	347.832	55
PSM 27113	259182.681	7033827.847	296.283	56
PSM 29917	737251.83	7097489.057	298.272	55
PSM 30370	781953.974	7050029.905	351.967	55
PSM 30371	789557.163	7050478.45	356.867	55
PSM 32884	217817.029	7031509.178	302.475	56
PSM 36000	777790.091	7064539.653	366.227	55
PSM 61546	307306.014	6947426.33	415.216	56
PSM 65636	787378.758	7105375.229	269.967	55
PSM 68160	295882.453	6903765.778	366.705	56
PSM 70746	306057.748	6923395.792	452.334	56
PSM 86008	743625.016	7074300.321	333.942	55
PSM 86711	749641.99	7079692.503	356.483	55
PSM 89145	718647.714	7154699.934	261.959	55
PSM 89358	278037.554	7007060.907	328.346	56
PSM 111710	221378.763	7048469.586	311.433	56
PSM 121898	240909.682	7023467.299	304.193	56
PSM 126914	307924.603	6911494.709	387.72	56
PSM 133510	218071.728	7054253.044	311.519	56
PSM 148138	210823.77	7038917.969	318.052	56
PSM 153189	235988.17	7023686.472	316.619	56
PSM 158500	229919.356	7007192.425	330.601	56
PSM 159921	797779.233	7047400.032	324.831	55
PSM 162615	220138.371	7046482.522	298.287	56
PSM 168619	688199.197	7143347.169	350.693	55
PSM 173572	787289.336	7080291.796	383.176	55
PSM 173645	772846.341	7075201.598	415.447	55
PSM 173646	243670.348	7032168.714	364.44	56
PSM 173647	237197.413	7032169.393	302.451	56
PSM 176255	211123.272	7066089.655	348.043	56
PSM 176256	216070.704	7057632.255	327.497	56
PSM 176658	259522.975	7013483.192	312.591	56
PSM 176688	782771.071	7042100.849	312.736	55
PSM 181319	738632.486	7122534.02	289.568	55
PSM 183532	757678.2	7097224.167	301.092	55
PSM 185010	694269.154	7108945.564	353.254	55
PSM 185050	792861.861	7065930.391	376.848	55
PSM 187251	217954.311	7032596.219	298.331	56
PSM 187253	221986.25	7018174.86	295.077	56
PSM 189029	227551.711	7035090.722	310.56	56
PSM 189236	224444.967	7044189.054	312.854	56
PSM 190826	213284.105	7048928.505	319.852	56
PSM 192739	213603.894	7058376.534	310.638	56
PSM 192750	738908.96	7088531.994	374.006	55
CAR 6 BM2	784143.182	7071272.531	394.488	55



Australia Pacific LNG CSG Stage 2 WMMP

Compaction Risk, Geodetic Monitoring and Focus Site Locations

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

N

Tiltmeters

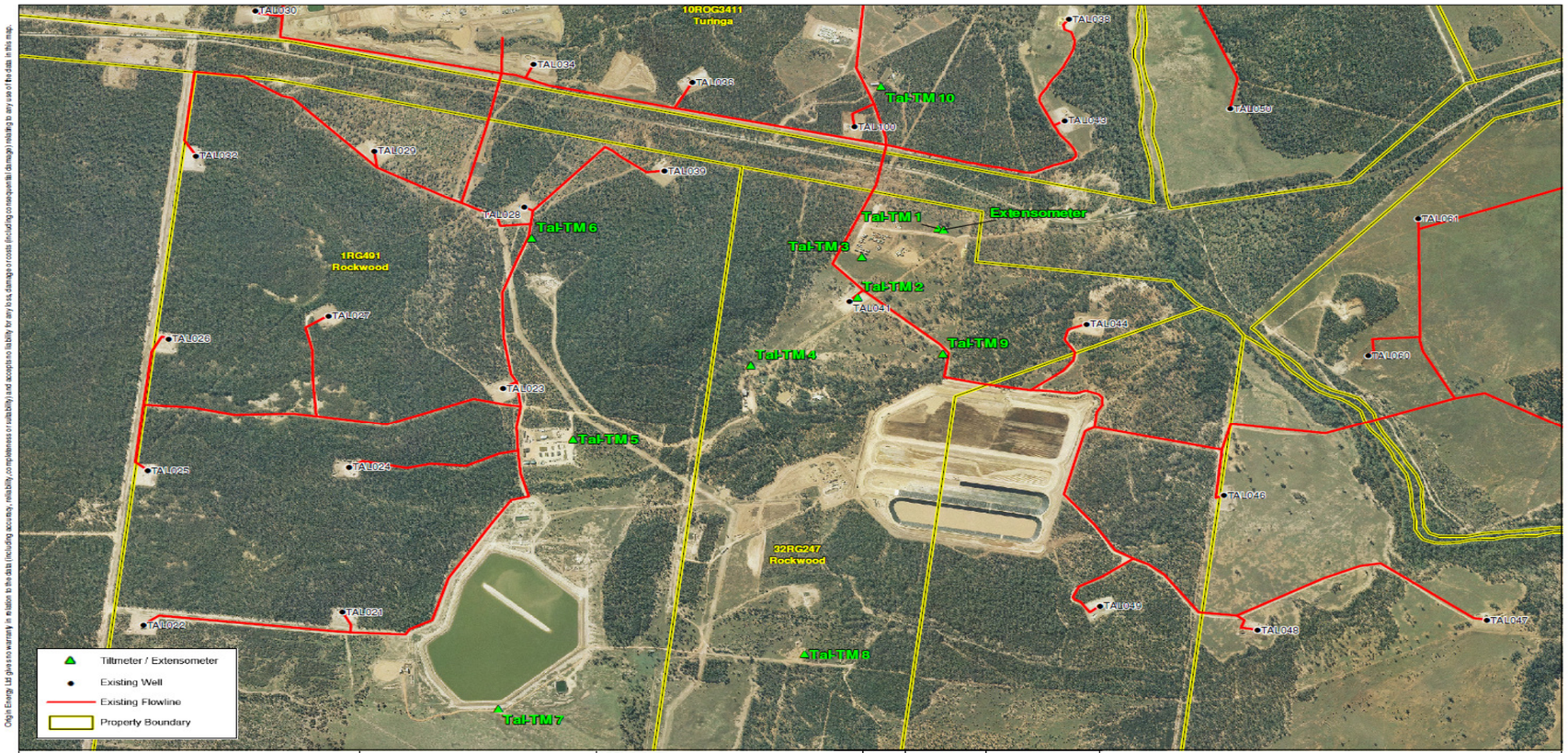
Tiltmeter	Sensor SN	Logger SN	Zero		Location		Elevation
			A axis (N+ S-)	B Axis (E+ W-)	Latitude	Longitude	mAHD
Talinga							
Tal-TM-1	1206770	21456	-0.22	-0.01	-26.893168	150.371222	298.43
Tal-TM-2	1206784	21457	0.1	-0.04	-26.896246	150.367986	306.08
Tal-TM-3	1206766	21449	-0.19	0.11	-26.894401	150.368197	306.21
Tal-TM-4	1206780	21455	0.08	-0.07	-26.899252	150.363748	314.64
Tal-TM-5	1206768	21452	-0.27	-0.03	-26.902501	150.356715	315.28
Tal-TM-6	1206769	21446	0.12	-0.03	-26.893304	150.355298	314.74
Tal-TM-7	1206778	21459	0.11	-0.23	-26.914647	150.353483	313.47
Tal-TM-8	1206783	21464	0.21	0.19	-26.912395	150.365529	316.79
Tal-TM-9*	1206773	21461	-0.22	-0.24	-26.898858	150.37126	297.30
Tal-TM-10	1206771	21444	-0.1	0.03	-26.88667	150.369119	302.25
Reedy Creek							
RC-TM-1	1206775	21458	0.46	-0.12	-26.359884	149.424983	352.33
RC-TM-2	1206774	21460	-0.46	0.37	-26.360135	149.422617	355.52
RC-TM-3	1206785	21144	-0.33	-0.15	-26.358002	149.420329	353.50
RC-TM-4	1206772	21453	-0.01	-0.1	-26.357547	149.422896	352.92
RC-TM-5	1206781	21462	-0.4	-0.18	-26.357128	149.425287	352.69
RC-TM-6	1206782	21465	-0.04	0.26	-26.355682	149.427404	349.96
RC-TM-7	1206767	21445	-0.18	0.25	-26.355968	149.429589	349.08
RC-TM-8	1206776	21450	-0.08	-0.05	-26.353561	149.425969	348.51
RC-TM-9	1206779	21448	-0.65	-0.01	-26.355323	149.424406	354.96
RC-TM-10	1206777	21447	0.27	0.18	-26.352115	149.421989	346.37

* A axis NE-SW; B axis NW-SE

Extensometers

TALINGA					
Extensometer	Sensor SN	Logger SN	Location		Elevation
			Latitude	Longitude	mAHD
Tal-SC-WB1	G11127-1-1	19318	-26.893222	150.371424	304.70
Anchors					
Anchor No.		Depth (mbgl)		Zero (mm)	
1		195		230.62	
2		174		227.13	
3		148		235.44	
4		122		240.26	
5		96		227.94	

REEDY CREEK					
Extensometer	Sensor SN	Logger SN	Location		Elevation
			Latitude	Longitude	mAHD
RC-SC-WB2	G11127-1-2	19448	-26.35633	149.4267	346.10
Anchors					
Anchor No.		Depth (mbgl)		Zero (mm)	
1		308		90.97	
2		295		86.45	
3		280		252.7	
4		265		216.52	
5		250		254.56	


10RGC2411
Turinga
1RG491
Rockwood
32RG247
Rockwood
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Extensometer
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Tiltmeter / Extensometer
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State: Queensland
Project: Australia Pacific LNG
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NAME SIGN.
DRAWN JGW
CHECK
QA
APP
Locations indicative and subject to change
Digital Cadastral Database © The State of Queensland (DNRM) 2012.
GDA
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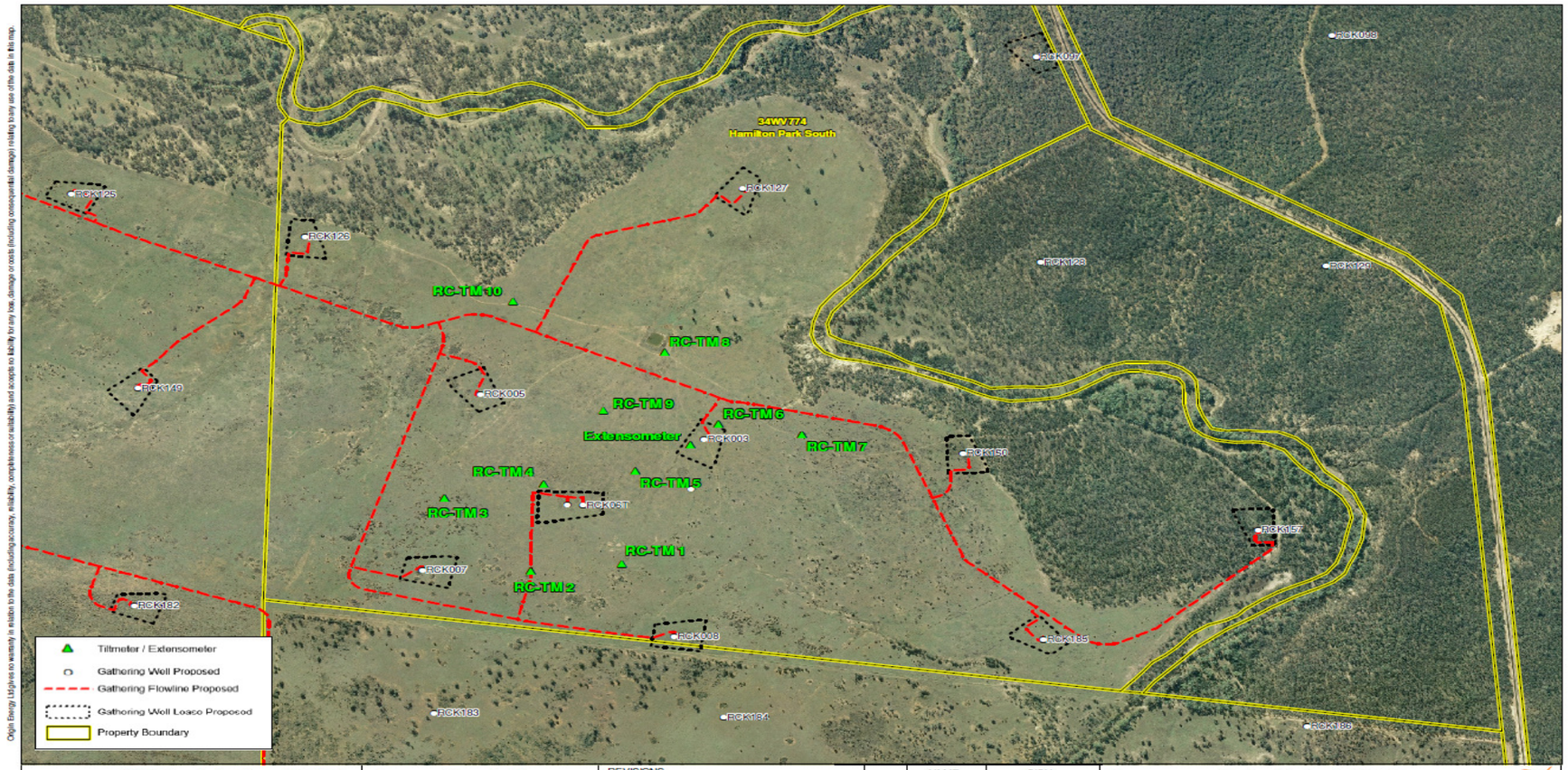
MGA Zone 56 (GDA 94)
Scale 1:15,000 @ A3
Origin Energy Ltd gives no warranty in relation to the data (including accuracy, reliability, completeness or suitability) and accepts no liability for any loss, damage or costs (including consequential damage) relating to any use of the data in this map.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Extensometer
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RCK182
RCK008
RCK185
RCK183
RCK184
RCK186
Tiltmeter / Extensometer
Gathering Well Proposed
Gathering Flowline Proposed
Gathering Well Loaco Proposed
Property Boundary
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GIS Section - Exploration and Production
Geotechnical Instrumentation Monitoring Locations
Date: 13th March 2013
State: Queensland
Project: Australia Pacific LNG
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Map No: 1 of 2
Map ID: GISWR_12900_1_RevA
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GDA
200 0 200 400 600m
MGA Zone 55 (GDA 94)
Scale 1:10,000 @ A3

Appendix D: Monitoring Bore Nested Sites

Nest ID	Nest Longitude	Nest Latitude	Origin Bore Designation	Bore Longitude	Bore Latitude	Target Aquifer
Carinya A	149.685	-26.635	Carinya-MB1-G	149.6853	-26.6348	Gubberamunda
			Carinya-MB2-S	149.685	-26.6346	Springbok
Carinya B	150.000	-26.714	Carinya-MB3-G	150.0002	-26.7145	Gubberamunda
			Carinya-MB4-S	150.0001	-26.7141	Springbok
Combabula A	149.551	-26.234	Combabula-MB1-G	149.5642	-26.231	Gubberamunda
			Combabula-MB2-S	149.5642	-26.231	Springbok
			Combabula-MB3-W	149.5651	-26.2306	Walloons
			Combabula-WB1-P	149.5114	-26.2453	Precipice
Condabri A	150.171	-26.808	Condabri-MB1-G	150.171	-26.8086	Gubberamunda
			Condabri-MB2-S	150.171	-26.8085	Springbok
			Condabri-MB9-H	150.1708	-26.8079	Hutton
Condabri B	150.218	-26.938	Condabri 140	150.2294	-26.9315	Walloons
			Condabri-MB3-G	150.2119	-26.9417	Gubberamunda
			Condabri-MB4-S	150.2119	-26.9417	Springbok
Condabri C	150.223	-26.787	Condabri-INJ1-H	150.2239	-26.7864	Hutton
			Condabri-INJ2-P	150.2245	-26.787	Precipice
			Condabri-INJ3-G	150.2248	-26.7867	Gubberamunda
			Condabri-MB12-W	150.2176	-26.7887	Walloons
Condabri D	150.226	-26.684	Condabri-INJ4-H	150.2256	-26.684	Hutton
			Condabri-INJ5-P	150.2262	-26.684	Precipice
			Condabri-MB10-W	150.2274	-26.684	Walloons
Condabri E	150.306	-27.037	Condabri-MB5-G	150.3063	-27.037	Gubberamunda
			Condabri-MB6-S	150.3062	-27.037	Springbok
Dalwogan A	150.104	-26.554	Dalwogan-MB3-G	150.104	-26.5535	Gubberamunda
			Dalwogan-MB4-S	150.104	-26.5536	Springbok
			Dalwogan-MB5-H	150.1043	-26.5546	Hutton

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Nest ID	Nest Longitude	Nest Latitude	Origin Bore Designation	Bore Longitude	Bore Latitude	Target Aquifer
			Dalwogan-MB6-W	150.1042	-26.5543	Walloons
Dalwogan B	150.146	-26.630	Dalwogan 12	150.146	-26.6315	Walloons
			Dalwogan-MB1-G	150.1455	-26.6295	Gubberamunda
			Dalwogan-MB2-S	150.1455	-26.6295	Springbok
Gilbert Gully A	150.897	-27.598	Gilbert Gully-MB1-G	150.8963	-27.5973	Gubberamunda
			Gilbert Gully-MB2-S	150.8964	-27.5975	Springbok
			Gilbert Gully-MB3-W	150.8988	-27.5983	Walloons
Ironbark A	150.218	-27.084	Duke 25	150.2213	-27.1083	Springbok
			Ironbark-MB10-H	150.2113	-27.0349	Hutton
			Ironbark-MB11-W	150.2213	-27.1083	Walloons
Ironbark B	150.394	-27.108	Duke 27	150.3942	-27.1083	Springbok
			Ironbark-MB1-W	150.3942	-27.1083	Walloons
			Ironbark-MB2-G	150.3942	-27.1083	Gubberamunda
Ironbark C	150.341	-27.241	Ironbark-MB3-S	150.342	-27.2414	Springbok
			Ironbark-MB4-W	150.3404	-27.2412	Walloons
			Ironbark-MB5-H	150.3408	-27.2412	Hutton
Ironbark D	150.458	-27.245	Ironbark-MB7-W	150.4573	-27.2454	Walloons
			Ironbark-MB8-S	150.4577	-27.2454	Springbok
			Ironbark-MB9-G	150.4577	-27.2455	Gubberamunda
Kainama A	150.780	-27.040	Kainama-MB1-W	150.7803	-27.0396	Walloons
			Kainama-MB2-S	150.7806	-27.0395	Springbok
Kinnoul A	149.588	-25.664	Kinnoul-MB1-P	149.5879	-25.6641	Precipice
			Kinnoul-MB2-H	149.5883	-25.6641	Hutton
Lucky Gully A	149.581	-26.402	Lucky Gully 5	149.5817	-26.4076	Precipice
			Lucky Gully MB3-W	149.5772	-26.4024	Walloons
			Lucky Gully-MB1-G	149.5829	-26.3998	Gubberamunda
			Lucky Gully-MB2-S	149.5828	-26.3995	Springbok
Meeleebee A	149.205	-26.243	Meeleebee-MB1-S	149.1953	-26.2422	Springbok

Nest ID	Nest Longitude	Nest Latitude	Origin Bore Designation	Bore Longitude	Bore Latitude	Target Aquifer
			Meeleebee-MB2-H	149.2139	-26.2433	Hutton
			Meeleebee-MB3-W	149.1952	-26.2423	Walloons
			Meeleebee-MB5-P	149.2137	-26.2429	Precipice
Meeleebee B	149.414	-26.162	Meeleebee-MB4-W	149.414	-26.1623	Walloons
			Meeleebee-MB7-S	149.4143	-26.1619	Springbok
Muggleton A	149.263	-26.320	Muggleton-MB1-G	149.263	-26.3206	Gubberamunda
			Muggleton-MB2-S	149.2632	-26.3206	Springbok
			Pine Hills-MB1-W	149.2637	-26.3183	Walloons
Orana A	150.449	-26.737	Orana-MB15 -S	150.4269	-26.7404	Springbok
			Orana-MB3-S	150.4939	-26.7311	Springbok
			Orana-MB7-W	150.4274	-26.7405	Walloons
Orana B	150.503	-26.900	Orana-MB1-S	150.5035	-26.9001	Springbok
			Orana-MB4-W	150.5031	-26.9001	Walloons
Orana C	150.485	-26.811	Orana-MB10-S	150.485	-26.8113	Springbok
			Orana-MB9-W	150.485	-26.8113	Walloons
Orana D	150.550	-26.803	Orana-MB5-W	150.5502	-26.8026	Walloons
			Orana-MB8-S	150.5502	-26.8026	Springbok
Orana E	150.533	-26.803	Orana-MB11-W	150.5326	-26.8033	Walloons
			Orana-MB12-S	150.5326	-26.8033	Springbok
Orana F	150.543	-26.780	Orana-MB13-W	150.543	-26.7803	Walloons
			Orana-MB14-S	150.543	-26.7803	Springbok
Peat A	150.092	-26.011	Peat-MB1-B	150.0841	-26.0022	Bandanna
			Peat-MB2-P	150.0958	-26.0152	Precipice
			Peat-MB3-H	150.0963	-26.0149	Hutton
Pine Hills (off-tenure) A	150.020	-26.875	Pine Hills South-MB1-S	150.0195	-26.876	Springbok
			Pine Hills South-MB2-W	150.0195	-26.8745	Walloons
			Pine Hills South-MB3-H	150.0195	-26.8749	Hutton
Ramyard A	149.787	-26.482	Ramyard-MB3-G	149.7865	-26.4819	Gubberamunda

Nest ID	Nest Longitude	Nest Latitude	Origin Bore Designation	Bore Longitude	Bore Latitude	Target Aquifer
			Ramyard-MB4-S	149.7866	-26.4819	Springbok
Reedy Creek A	149.376	-26.347	Reedy Ck-INJ3-H	149.3758	-26.3472	Hutton
			Reedy Ck-INJ4-P	149.3763	-26.3473	Precipice
Reedy Creek B	149.427	-26.357	Reedy Ck-INJ1-H	149.4283	-26.3588	Hutton
			Reedy Ck-INJ2-P	149.4286	-26.3589	Precipice
			Reedy Ck-INJ5-G	149.4267	-26.3576	Gubberamunda
			Reedy Ck-MB1-G	149.4268	-26.3563	Gubberamunda
			Reedy Ck-MB2-S	149.4267	-26.3563	Springbok
			Reedy Ck-MB3-H	149.4266	-26.3577	Hutton
			Reedy Ck-MB4-W	149.4269	-26.3566	Walloons
			Reedy Ck-SC1-Wb	149.4268	-26.3562	Westbourne
			Reedy Ck-SC2-Wb	149.4267	-26.3563	Westbourne
Spring Gully A	149.088	-25.963	Durham Ranch 23	149.1042	-25.9765	Bandanna
			Spring Gully Camp Bore	149.072	-25.9499	Precipice
Spring Gully B	149.071	-26.000	Spring Gully-DMH01	149.071	-26.0005	Hutton
			Spring Gully-DMP01	149.0714	-26.0004	Precipice
Spring Gully C	149.014	-26.075	Spring Gully-MB4-H	149.0138	-26.075	Hutton
			Spring Gully-PB3	149.0138	-26.0751	Precipice
Spring Gully D	149.141	-25.875	Strathblane Bullet Hole Gate (old)	149.1209	-25.8601	Hutton
			Strathblane Scott's Creek Bore	149.1578	-25.8645	Hutton
			Strathblane-WB1-P	149.1444	-25.9002	Precipice
Spring Gully F	149.203	-26.024	Echo Hills Flowing Bore	149.2137	-26.0348	Precipice
			Echo Hills Northern Bore	149.1933	-26.0132	Hutton
Spring Gully G	149.392	-25.999	Spring Gully-MB7-P	149.3924	-25.9991	Precipice
			Spring Gully-MB8-H	149.3921	-25.9993	Hutton
Spring Gully H	149.386	-25.669	Spring Gully-MB10-H	149.3858	-25.6692	Hutton

Nest ID	Nest Longitude	Nest Latitude	Origin Bore Designation	Bore Longitude	Bore Latitude	Target Aquifer
			Spring Gully-MB9-P	149.3858	-25.6696	Precipice
Spring Gully I	149.187	-25.691	Spring Gully-MB11-P	149.1877	-25.6915	Precipice
			Spring Gully-MB12-E	149.1875	-25.6911	Evergreen
			Spring Gully-MB6-B	149.1872	-25.6916	Bandanna
Spring Gully J	148.952	-25.964	Spring Gully-MB14-H	148.9525	-25.9642	Hutton
			Spring Gully-PB5	148.9525	-25.9642	Precipice
Spring Gully K	148.851	-25.838	Spring Gully-MB15-H	148.8511	-25.8375	Hutton
			Spring Gully-PB1	148.851	-25.8375	Precipice
Spring Gully L	149.217	-25.867	Spring Gully-MB16-P	149.2169	-25.8666	Precipice
			Spring Gully-MB17-H	149.2169	-25.8666	Hutton
Talinga A	150.370	-26.892	Talinga-MB10-G	150.3689	-26.893	Gubberamunda
			Talinga-MB3-H	150.3689	-26.8924	Hutton
			Talinga-MB5-G	150.3703	-26.893	Gubberamunda
			Talinga-MB7-S	150.3703	-26.893	Springbok
			Talinga-MB8-W	150.3683	-26.8937	Walloons
			Talinga-MB9-G	150.3689	-26.8929	Gubberamunda
			Talinga-SC1-Wb	150.3714	-26.8932	Westbourne
			Talinga-SC2-Wb	150.3713	-26.8932	Westbourne
			Turinga House Bore	150.3697	-26.8864	Gubberamunda
Talinga B	150.339	-26.849	Talinga-MB1-G	150.3389	-26.849	Gubberamunda
			Talinga-MB2-S	150.3388	-26.849	Springbok
Waar Waar A	150.944	-27.795	Waar Waar-MB1-G	150.9433	-27.7948	Gubberamunda
			Waar Waar-MB2-S	150.9438	-27.7948	Springbok
			Waar Waar-MB3-H	150.9443	-27.7948	Hutton
			Waar Waar-MB4-W	150.946	-27.7942	Walloons
Woleebee A	149.848	-26.385	Woleebee-MB1-W	149.8476	-26.3853	Walloons
			Woleebee-MB2-G	149.8478	-26.3857	Gubberamunda
			Woleebee-MB3-S	149.8479	-26.3852	Springbok

Nest ID	Nest Longitude	Nest Latitude	Origin Bore Designation	Bore Longitude	Bore Latitude	Target Aquifer
Zig Zag A	150.921	-27.967	ZigZag-MB1-G	150.9196	-27.9667	Gubberamunda
			ZigZag-MB3-W	150.9232	-27.965	Walloons
			ZigZag-MB4-S	150.9203	-27.9681	Springbok

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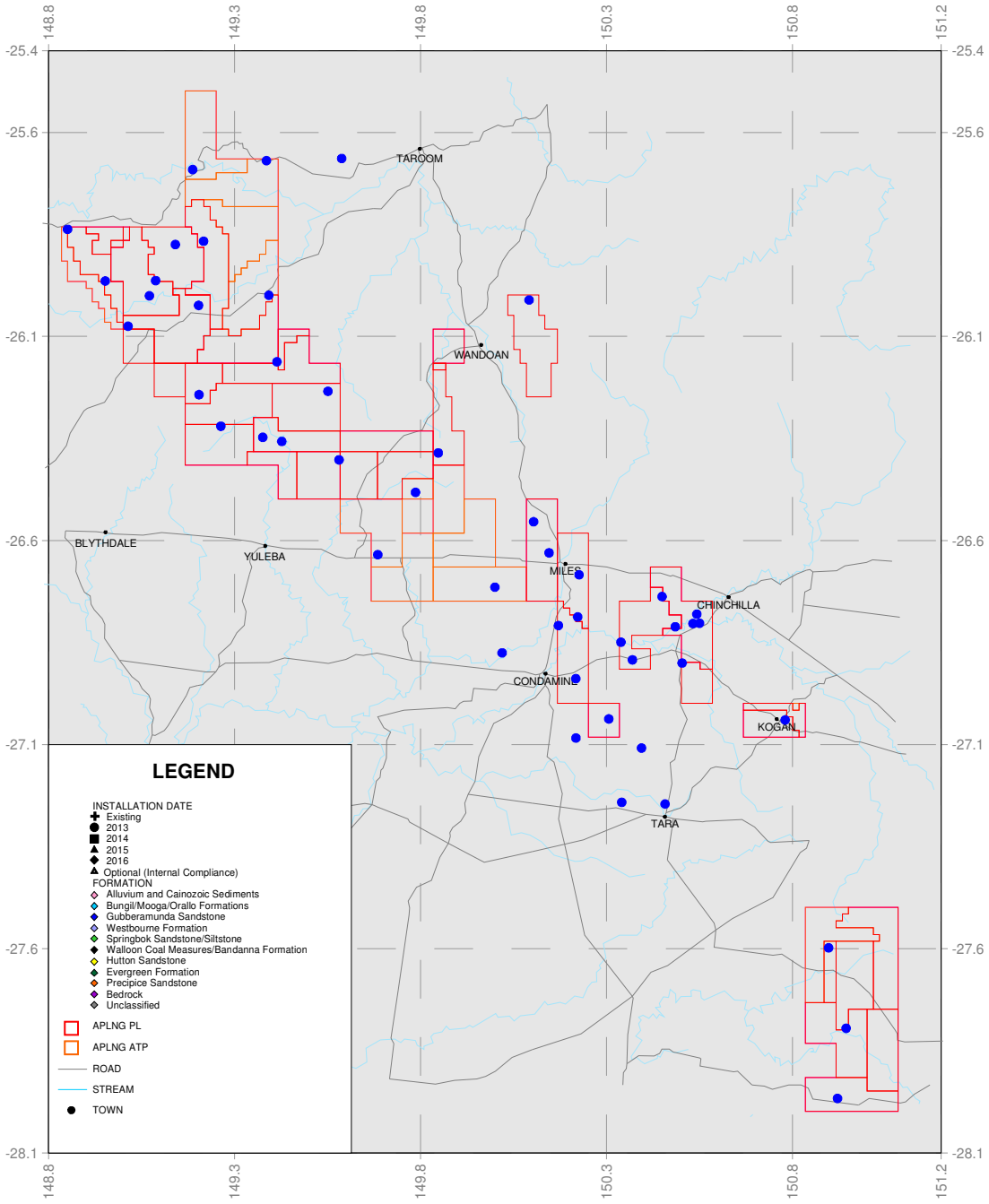

Australia Pacific LNG CSG Stage 2 WMMP

Groundwater Monitoring Bore Locations

Monitoring Bore Nests

	Name
Drawn	RM
Rev	A

Digital Cadastral Database © The State of Queensland (DNRW) 2010

Scale in Kilometers

0 10 20 30 40

1 : 1 350 000 (A4)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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