# Australia Pacific LNG Upstream Phase 1 Groundwater Monitoring Plan

## Q-LNG01-10-MP-0005

| Rev | Date | Details | By | Check | Eng/QA | App |
|---|---|---|---|---|---|---|
| A | 28/5/10 | Initial Draft | RM | | | |
| B | 19/8/10 | Issued for Information | RM | AM | | |
| C | 18/10/10 | Updated | RM | | | |
| D | 16/2/11 | Issued for Information | DW | RM | | |
| E | 13/7/11 | Updated for Review | AM | DW | | |
| 0 | 28/07/11 | Issued for Use | AM | RM | | KJ |
| 1 | 01/02/2012 | Updated | RM | AM | SM | KJ |
| 2 | 19/09/2012 | Updated for St1 CSG WMMP | RM | AM | | |

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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, overlying alluvium and potential receptors resulting from depressurisation associated with coal seam gas extraction. This regional groundwater monitoring program is intended for the long-term monitoring of these potential effects. A plan showing APLNG CSG Fields and Tenements is provided in Figure 1.

This monitoring plan is intended to balance and satisfy the needs of both State and Federal regulators.

It is recognised that, in addition to the regional CSG depressurisation impacts that this plan is designed to monitor, associated CSG activities may affect the groundwater regime in a number of ways, e.g. deterioration of water quality through pond leakage, or increases in pressure and improvements to water quality through re-injection of treated water. Specific monitoring programs have been developed for each site associated with these types of activities and are not included in this plan.

## 1.1 Groundwater Management Framework

The groundwater monitoring framework 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.

The adaptive management process is shown schematically in Figure 2. Monitoring, evaluation and reporting are required to ensure operational and environmental outcomes are being met. If not, a feedback loop into management actions addresses the issues that are preventing the outcomes from being met. Adaptive management principles allow for adjustments in outcomes, indicators and limits, as well as associated monitoring and reporting approaches.



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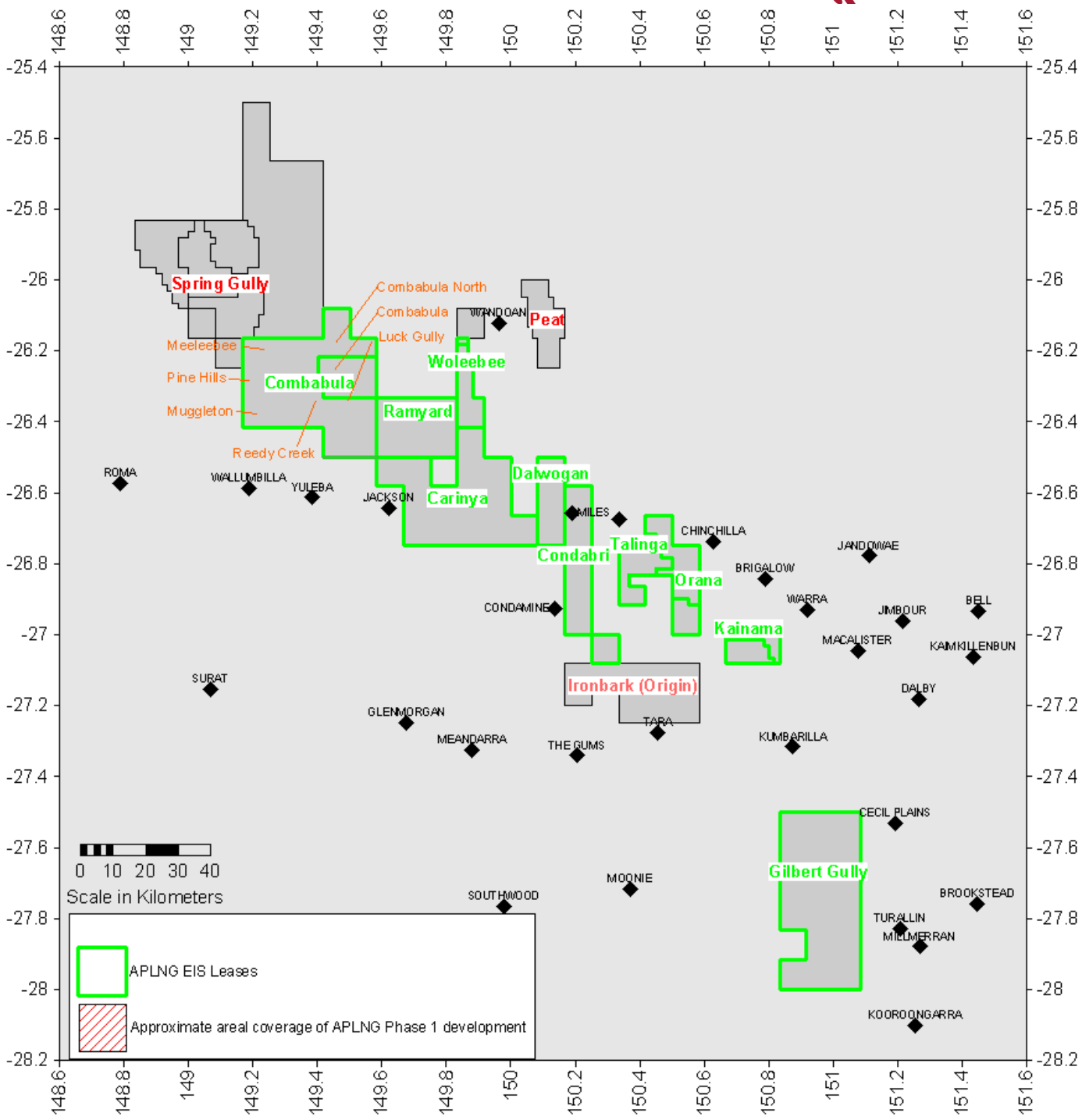


**Figure 1: Location Plan of APLNG Tenements and CSG Fields**



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A number of elements associated with the framework are:

**Outcomes**: the environmental state to be achieved. Outcomes need to reflect project requirements, regulatory requirements and societal values and perceptions. Outcomes must be pragmatic, realistic and measurable (using relevant indicators).

**Indicator:** a measured variable or state of resource condition used to verify that established outcomes are being met.

**Limit (or trigger):** a desired condition or range for a given indicator to be maintained below, above or within. Limits must consider natural variability and background conditions for an aquifer with respect to both quality and quantity.

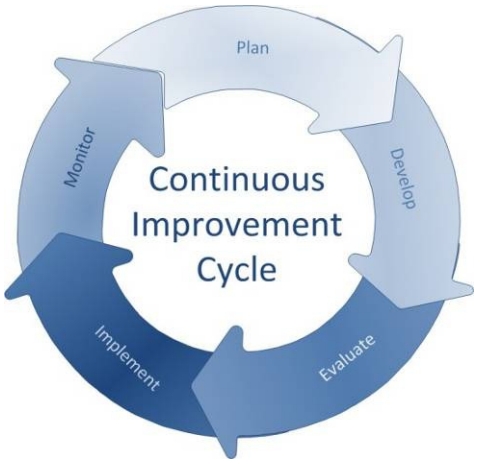
**Threshold:** a value not to be exceeded, such that resource health and associated resources may be maintained (that is, significantly exceeding the established natural variability at a given location or an agreed-upon published criterion).

**Receptor:** a natural discharge point (spring/watercourse) or user (bore) of environment or health value which is interconnected to the groundwater system and is influenced by changes to aquifer physical and chemical characteristics

The development of targets and thresholds for the relevant indicators is discussed further in Section 4.5.

Using adaptive management, as new groundwater quality and quantity knowledge is generated, models can be updated and water management decisions adapted accordingly. This particular framework is therefore a living document and will be updated as required. More frequent during initial implementation, i.e. 1 to 2 years and then less frequent at a later date, i.e. every five years.

**Figure 2: Adaptive Management and Continuous Improvement Process**




# 2. Plan Purpose

## 2.1 Regulatory Compliance

The minimum requirements of this plan are to meet State and Federal regulatory requirements for regional groundwater monitoring (including springs). These requirements are currently detailed in:



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- The State Co-ordinator General's conditions for the project;
- The Federal Government's project approval conditions, specifically the requirements of the Stage 1 and Stage 2 CSG Water Monitoring and Management Plans (CSG WMMP); and,
- The Queensland Water Commission's Underground Water Impact Report, specifically the monitoring strategy therein.

This monitoring plan may be updated in response to various changes in project conditions, e.g. changes in the sequence of development, or through improved understanding of the hydrogeology and risks associated with the project. Any update to the plan will be submitted to relevant State and Federal regulatory agencies for approval where necessary. The most recent version of the plan remains the "point of truth" for monitoring commitments, and may therefore supersede versions of the plan submitted at a point in time. The official version of the plan is the most recent version uploaded to Teambinder.

## 2.2 Exclusions

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 monitoring 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 monitoring in accordance with their individual management plans and the requirements of their associated Environmental Authorities; and,
- Hydraulic fracture stimulation – these activities will be monitoring in accordance with the requirements of the Environmental Authorities associated with the tenure in which the activities are undertaken.

## 2.3 Groundwater Monitoring Objectives

The effects of groundwater pumping (drawdown) to support CSG extraction, and water injection back into aquifers (and associated pressure build-up), will mainly manifest themselves on a regional scale. The monitoring system has been developed to effectively monitor the potential effects on receptors at the regional scale. Understanding the potential pathways and potential effects to sensitive receptors is critical in establishing the level of risk.

Therefore, the objectives of this groundwater monitoring program are to:

- establish an appropriate monitoring regime, both in space and time;
- develop a high quality background dataset against which potential impacts can be assessed;
- identify potential impacts from regional-scale activities with sufficient time to manage these potential impacts before mitigation is required. This will ensure protection of MNES;



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- enable detection of long-term trends and potential cumulative effects from current and future CSG operations;
- 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 data against which predictions made in previous and future environmental impact assessments can be verified; and,
- obtain high quality data to develop limit and threshold values for key indicator parameters and each major aquifer using the adaptive management process.

## 2.4 Monitoring Rationale and Philosophy

The development of groundwater pressure and quality monitoring as detailed in subsequent sections are summarised in Appendix A. In some instances, regulatory requirements override this structured rationale or operate on a different rationale (e.g. UWIR monitoring plan), and some sites, parameters, frequency or schedules have been adopted with varying degrees of alignment to the underlying philosophies.

The 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 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. These focus sites will contain groundwater monitoring bores in each of the aquifers present and key aquitards, and will also have extensometers, tiltmeters and long term hydraulic testing installed. The locations of Talinga and Reedy Creek are shown on Figure 1.

At a regional scale, water level and water quality monitoring will cover the full extent of the Australia Pacific LNG Walloon Coal Measure tenements. Aquitard and surface/ subsurface deformation data acquired in the early development areas will be used to assess potential risks associated with CSG production. Should an increased level of risk be recognised based on the monitoring data from these focus sites, monitoring efforts may be increased in areas that will be developed later in the project.



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# 3. 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.

For more detail regarding the hydrogeological conceptualisation of the Surat Basin, refer to the APLNG EIS Groundwater technical report.

## 3.1 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. 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 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 (Table 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.



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## Table 1 Hydrostratigraphic Column of Surat Basin

| Age | Hydrostratigraphic unit | Stratigraphic units | Aquifer / Aquitard unit |
|---|---|---|---|
| Cainozoic | Cainozoic Units | Alluvium | Aquifer (watertable) |
| | | Colluvium | |
| | | Chinchilla Sands | |
| | | Main Range Volcanics | |
| Cretaceous | Rolling Downs Group | Griman Creek Formation | Aquitard |
| | | Surat Siltstone | |
| | | Wallumbilla Formation | |
| | BMO Grouping | Bungil Formation | Aquifer |
| | | Mooga Sandstone | |
| | | Orallo Formation | |
| Jurassic | Gubberamunda Sandstone | Gubberamunda Sandstone | Aquifer |
| | | Kumbarilla Beds | |
| | | Hooray Sandstone | |
| | | Southlands Formation | |
| | Westbourne Formation | Westbourne Formation | Aquitard |
| | Springbok Sandstone | Springbok Sandstone | Aquifer |
| | | Pilliga Sandstone | |
| | Walloon Coal Measures | Upper Walloons Formation* | Aquitard |
| | | Macalister Coal Seams | Aquifer (coal seams)/ aquitard (siltstones, mudstones) |
| | | Juandah Sandstone | Aquifer |
| | | Lower Juandah Coal Measures | Aquifer (coal seams)/ aquitard (siltstones, mudstones) |
| | | Tangalooma Sandstone | Aquifer |
| | | Taroom Coal Measures | Aquifer (coal seams)/ aquitard(siltstones, mudstones) |
| | Eurombah Formation | Eurombah Formation | Aquitard |
| | Hutton Sandstone | Hutton Sandstone | Aquifer |
| | | Marburg Sandstone | |
| | Evergreen Formation | Upper Evergreen Shale | Aquitard |
| | | Lower Evergreen Shale | |
| | | Basal Evergreen Sandstone | |
| | | Boxvale Sandstone | |
| | Precipice Sandstone | Precipice Sandstone | Aquifer |

* The upper Walloons Formation is defined as that part of the Walloon Coal Measure between its upper surface and the top of the uppermost coal seam.



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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 the Great Artesian Basin aquifers.

Recharge is predominantly by summer rainfall, either by direct infiltration into the outcropping areas, or indirectly via leakage from streams and/or from overlying aquifers. Water levels in the Cainozoic Units in particular respond directly to rainfall recharge, and groundwater abstraction. This, combined with extended periods of below average rainfall over recent times, has resulted in declining water levels in some areas.

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, pump 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. There are over 13,000 groundwater bores in the Surat Basin in Queensland.

The regional groundwater flow direction in most aquifers is to the south-west, and is generally a subdued reflection of topography. Locally, groundwater flow may be towards surface water features, where these intersect subcropping or outcropping units. 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-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 and comprises 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. The Eurombah Formation aquitard immediately underlies the coal measures. The unconformity between the Walloon Coal Measures and the Springbok Sandstone provides the potential for hydraulic connection with the Springbok Sandstone aquifer in limited areas, notably in the central Condabri area. The finer-grained Upper Walloons interval between the Macalister coal seam and the Springbok Sandstone provides some hydraulic separation in the remaining areas.

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



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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. Such 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. Australia Pacific LNG tenements are generally removed from the subcrop areas, and separated from them by other operators' tenure. Australia Pacific LNG does not hold tenure in areas where the Condamine Alluvium is used for groundwater supply.

## 3.2 Bowen Basin and the Bandana Coal Measures at Spring Gully

Spring Gully is situated close to the 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.

Figure 3 shows a geological cross-section through the Spring Gully project area orientated west to east. 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 subcrop contact between the Bandana Formation and the Precipice Sandstone.

Table 2 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 Spring Gully.

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.



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**Figure 3: Spring Gully Geological East - West Cross Section**

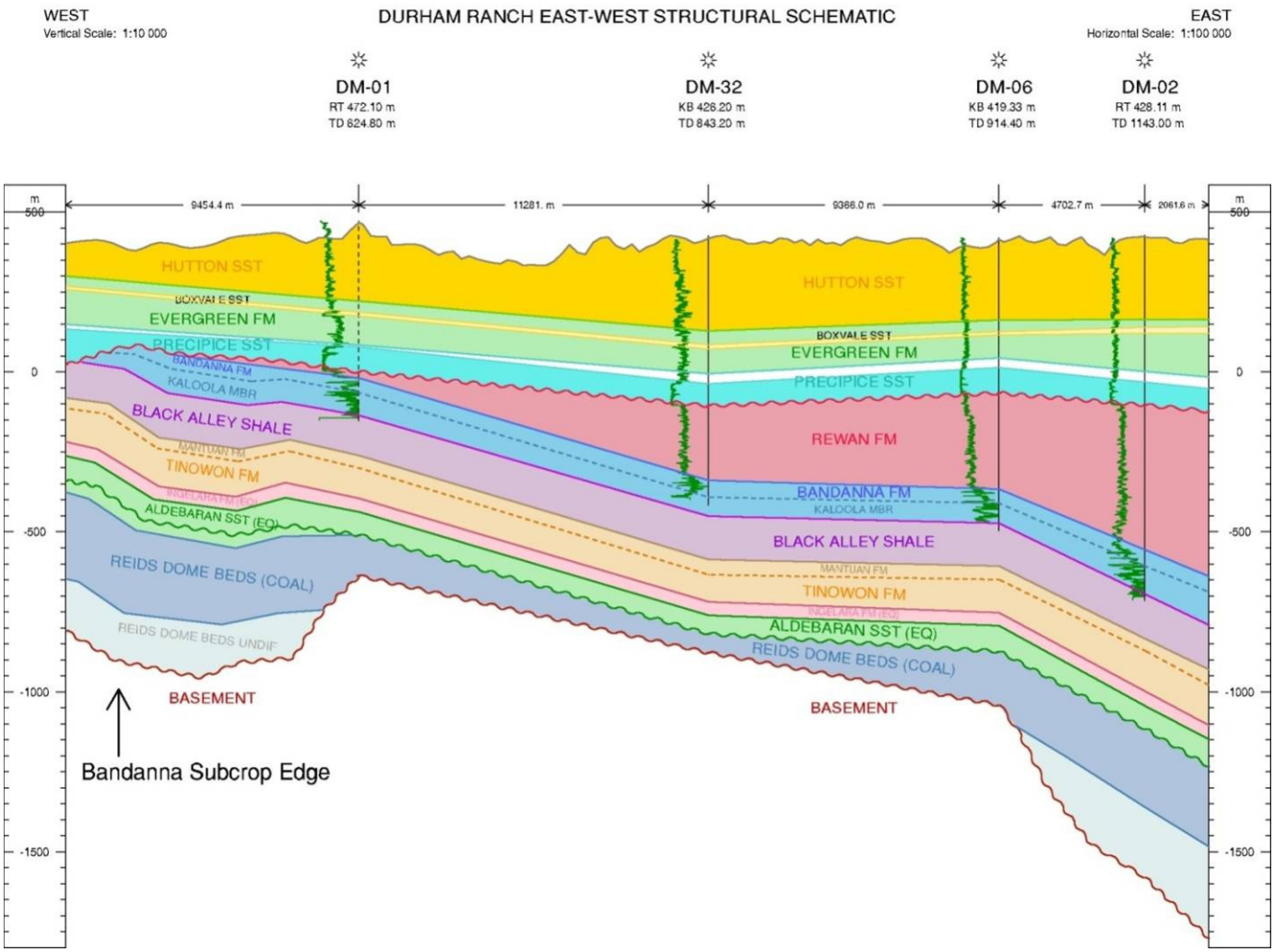




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**Table 2: Hydrostratigraphic Column for Spring Gully – Comet Ridge**

| Province | Age | Spring Gully / Comet Ridge Stratigraphy | | Aquifer /Aquitard |
|---|---|---|---|---|
| Surat Basin | Jurassic | Injune Creek Group | Walloon Coal Measures | Minor coal and sandstone Aquifers with siltstone and mudstone Aquitards (very thin or not present at Spring Gully) |
| | | Bundamba Group | Hutton Sandstone | Major Aquifer - outcropping formation at Spring Gully |
| | | | Evergreen Fm | Aquitard |
| | | | Boxvale Sandstone Mbr | Aquifer |
| | | | Basal Evergreen Fm | Aquitard |
| | | | Precipice Sandstone | Major Aquifer |
| Bowen Basin | Triassic | | Moolayember Formation | Aquitard (not present at Spring Gully) |
| | | | Clematis Group Sandstones | Aquifer (not present at Spring Gully) |
| | | | Rewan Fm | Upper Aquitard underlain by variably developed Aquifer |
| | Permian | Blackwater Group | Bandanna Formation (Coal Measures) | Minor coal and sandstone Aquifers with siltstone and mudstone Aquitards |
| | | | Kaloola Mbr | Aquitard |
| | | Upper Back Ck Group | Black Alley Shale | Aquitard |
| | | | Mantuan Fm | Mixed Aquitards and Marginal Aquifers |
| | | | Upper Tinowon Formation | Aquitard |
| | | | Lower Tinowon Formation | Mixed Aquitards and Marginal Aquifers |
| | | | Ingelara Fm | Aquitard |
| | | Lower Back Ck Group | Aldebaran Sandstone | Minor Aquifer |
| | | | Reids Dome Beds | Aquitard |
| Basement | Devonian | | Timbury Hills Fm | Aquitard |



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# 4. Groundwater Monitoring Program

The objective of the regional monitoring program is to monitor potential effects of the CSG depressurisation on overlying and underlying aquifers, such that informed management decisions can be made.

The intention of the monitoring program design is to provide adequate lateral and vertical coverage of the gasfields and surrounding potentially impacted areas, taking into account the conceptual hydrogeological understanding, other CSG operations and groundwater users. The network must provide an early warning of potential impacts, so that early intervention can minimise the need for mitigation. Should monitoring indicate an undesirable trend, the requirement for additional monitoring bores, both in other aquifers and laterally away from the Australia Pacific LNG tenure will be assessed, and actioned if deemed necessary.

## 4.1 Monitoring Bores

Locations for the groundwater monitoring infrastructure have been 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 (specifically projections of water level decline in individual water bores), a quantitative estimate of the potential impact on individual (existing) receptors could be made. Hydrogeological controls affecting potential drawdown can also be used to identify areas where potential future receptors may be.

To assist in planning the proposed locations of monitoring infrastructure, the following information was used:

- The location, aquifer and projected maximum drawdown of existing water bores, particularly those where projected drawdown is greater than 5m in the consolidated aquifers and 2m in the unconsolidated aquifers (the trigger thresholds set in the amendments to the Water Act 2000);
- The extent and magnitude of projected drawdown in each aquifer based on the cumulative effects model projections (cumulative case, best estimate for 2049), which takes into account the current hydrogeological conceptualisation, particularly the thicknesses of intervening aquitards which control projected drawdowns[1] in overlying and underlying aquifers;
- The structure contour of the upper surface of the Walloon Coal Measures as this will provide an indication of the general direction of up-dip migration of any potential fugitive gas away from the gas fields;
- The potential risk posed by existing water bores and old petroleum exploration and production wells, as a function of their depth and age; and,

[1] As limited information regarding vertical hydraulic conductivity was available, the numerical groundwater flow model was compiled with a single vertical hydraulic conductivity value for each unit, thus the primary control on drawdown in adjacent aquifers was the aquitard thickness



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- The presence of existing and proposed CSG fields in the Surat Basin operated by other proponents.

To ensure early warning of potential drawdown effects, monitoring will initially focus on the Springbok Sandstone aquifer, immediately above the Walloon Coal Measures. Although in the immediate vicinity of the Australia Pacific LNG gas fields this aquifer is relatively under-utilised, monitoring will provide an early indication of pressure effects as a result of CSG activities. A Gubberamunda Sandstone monitoring bore will be co-located at most of the Springbok Sandstone monitoring sites, as this is the aquifer from which most existing (non-CSG) groundwater extraction occurs.

At Spring Gully, early warning of potential impacts on groundwater supply aquifers will be first realised at the sub-crop of the Bandanna Formation beneath the Precipice Sandstone, and monitoring bores have been preferentially located in these areas.

Additional bores are required by the Queensland Water Commission to comply with the Underground Water Impact Report's Water Monitoring Strategy (currently draft). The objectives of each of these locations are specified in the in UWIR.
The rationale for each of the monitoring bores is provided in Appendix A. Maps of the monitoring bores in each of the aquifers are provided in Appendix B.

### 4.1.1 *New Monitoring Bores*

Where existing bores or wells for conversion could not be identified in appropriate locations, new monitoring bores have been and will be installed.

Although co-ordinates are provided for the proposed locations, the intention is for the majority of the nested sites to be co-located on the same drillpad as either existing or proposed production or monitoring bores, or other disturbed areas. The actual locations of these sites will be within the immediate vicinity of the proposed location.

The overarching design requirements for the construction of the new monitoring bores were:

- The ability to continuous monitor groundwater levels/pressures; and,
- The ability to collect a groundwater quality sample.

Alternative technologies such as the Schlumberger Westbay multilevel monitoring system, or cemented vibrating wire piezometers or Welldog monitoring gauges were considered in the development of the plan. With the exception of the monitoring of reservoir intervals (Walloon Coal Measures or Bandanna Formation), groundwater bores have been selected as the standard monitoring design. Alternative designs may be utilised in specific circumstances.

Groundwater bores targeting single aquifers have been selected as the most appropriate design.

Bores targeting aquifers above the Walloon Coal measures will 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 requirement, the design of the 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.



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### *Bore Design and Drilling*

Bores targeting non-gas charged aquifers above the Walloon Coal Measures will be drilled using a water bore drilling rig, with, where appropriate, well-control equipment (e.g. blow-out preventer - BOP) installed. Where the target aquifer is the Walloon Coal Measures or below, the bores will be drilled using a fully equipped CSG rig. Given the shallow depths and proposed locations of some of the monitoring bores, this requirement may be revised subject to further risk assessment.

Groundwater monitoring bores have been designed in accordance with the *Minimum Construction Requirements for Water Bores in Australia, 3rd Edition* (LWBC, 2012) and the *Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland* (DERM, 2012). Particular consideration has been given to casing and annular seal requirements to ensure that no pathway is provided for the transmission of pressure effects associated with CSG water extraction, or movement of water between aquifers.

In a manner analogous to the development of specifications for CSG wells, WSC are developed for every monitoring bore prior to the commencement of drilling. Casing depths and screen/open lengths are specified based on stratigraphic and geophysical interpretations from nearby CSG wells and groundwater bores. These specifications are reviewed by two suitably qualified personnel (Senior Hydrogeologists) prior to being issued to the Drilling and Completions team. The likelihood of artesian or gassy conditions will be assessed during the preparation of the WSC.

Four-and-a-half inch (114mm ID) steel threaded casing is generally used for the BMO, Gubberamunda Sandstone and Springbok Sandstone monitoring bores to ensure a pump can be installed in the bore for sample collection, but also to minimise purge volume during sampling. 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 waterwell contractor. Those monitoring bores drilled by a CSG rig will typically be cased with API-rated 7" K-55 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 of suitable weight for the design depth and pressure profile.

All casing strings are fully cement grouted from the casing shoe to surface, using either traditional pressure grouting techniques or an external casing packer. If the cement grout does not return to the surface during the grouting of the casing, cement bond logs are 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 will be undertaken to rectify the matter. If there are recurring cementing issues in a given area, the cement formula and method will be amended.

Specifically constructed 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 with isolation packers with each zone being individually monitored.

In many cases, the open interval of the monitoring bore will be cored during drilling. This core may be analysed in the laboratory for permeability and mineralogy. These laboratory data will then be used

- Understanding formation variability for water re-injection studies;



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- Directly to refine parameterisation of numerical groundwater flow models; and
- Indirectly to calibrate wireline geophysical logs to further improve model parameterisation and understand variability within the individual units.

Core samples of the intervening aquitards (Westbourne Formation, Upper Walloons sandstone/siltstone/mudstone, Eurombah Formation and Westbourne Formation) will also be collected where practical.

The minimum headworks completion for the monitoring bores will be a vertically mounted appropriately pressure rated valve. 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 deeper 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.

Short duration pumping tests will be carried out on each bore upon completion. Initial water samples are generally 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.



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*Bore Nomenclature*

New monitoring bores will be named using the following convention:

| tenement name – MB tenement bore site number – aquifer code |
|---|

Aquifer Codes are as follows:

| **Aquifer Name** | **Aquifer code** |
|---|---|
| Cainozoic Units | C |
| BMO Grouping | B |
| Gubberamunda Sandstone | G |
| Westbourne Formation | Wb |
| Springbok Sandstone | S |
| Walloon Coal Measures | W |
| Hutton Sandstone | H |
| Precipice Sandstone | P |
| Bandana Formation | B |
| Clematis Sandstone | C |

For example, the first nested site in Talinga, comprising a Gubberamunda Sandstone and Springbok Sandstone monitoring bore will comprise the following:

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

## 4.2 Landholder Bore Baseline Assessments

The *Water Act* (2000) and also introduced a legislative requirement to undertake baseline assessments of water bores. A baseline assessment is an assessment of a water bore undertaken by a petroleum tenure holder to obtain information about the bore.

Table 3 summarises the anticipated number of water bores in each of these tenements based on a search of the DERM groundwater bore database.



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**Table 3: Number of Water Bores on Each Tenement for Baseline Assessment**

| Tenure | Total[1] | Complete | Percentage |
|---|---|---|---|
| ATP592 | 151 | 128 | 85 |
| ATP606 | 157 | 128 | 82 |
| ATP663 | 55 | 47 | 85 |
| ATP692 | 48 | 39 | 81 |
| ATP702 | 4 | 3 | 75 |
| ATP972 | 40 | 32 | 80 |
| ATP973 | 83 | 71 | 86 |
| PL101 | 30 | 29 | 97 |
| PL195 | 12 | 12 | 100 |
| PL200 | 12 | 14 | 100 |
| PL203 | 25 | 25 | 100 |
| PL204 | 8 | 7 | 88 |
| PL209 | 29 | 21 | 72 |
| PL215 | 1 | 1 | 100 |
| PL226 | 4 | 4 | 100 |
| PL265 | 20 | 20 | 100 |
| PL267 | 27 | 26 | 96 |
| Outside | 205 | 147 | 72 |
| **Total** | **911** | **754** | **83** |

! Based on a search of the DERM GWBD

Baseline assessments will be undertaken in accordance with DERM's Baseline Assessment Guidelines. The process for the landholder bore inventory is:

- An Origin Energy landowner liaison officer (LLO) 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 LLO 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;



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- 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.

More detailed assessment is undertaken if there is a likelihood of potential impacts to the bore. Bores accessing the respective aquifers within the Immediately Impacted Area as identified by the Queensland Water Commission Underground Water Impact Report (UWIR) are required to have a rigorous assessment of whether they will be materially impacted by waterlevel drawdown associated with CSG activities. If so, a Make Good Agreement must be entered into with the landowner. In effect, there is a rolling 3-year pro-active assessment of potential impacts and management and mitigation measures. The bore assessment and make good program associated with the release of the draft 2012 UWIR is currently underway.

A secondary purpose of the landholder bore inventory is to identify existing bores suitable for incorporation into the regional monitoring network. Where suitable bores are identified, these will be instrumented and visited on an ongoing basis subject to appropriate resolution of access agreements with the bore owner. Several landowner bores have already been incorporated into the monitoring network (Appendix A).

## 4.3 Springs, Baseflow and Groundwater Dependent Ecosystems

DERM have set a trigger threshold of 0.2m in any aquifer underlying a spring recorded in the Great Artesian Basin Water Resource Plan Spring Register. The register is based on NRM publication Great Artesian Basin Water Resource Plan: Ecological Assessment of GAB springs in Queensland (Fensham and Fairfax, 2005) and the AGE (2005) report on potential river baseflow reaches (subsequently reassessed by DERM resulting in significantly fewer potential baseflow reaches).

Further assessment of springs has been undertaken by the Queensland Water Commission in the preparation of the Underground Water Impact Report (UWIR). The draft UWIR identifies two springs which are predicted to experience greater than 0.2m drawdown and for which Origin/APLNG is the responsible tenure holder:

- Scotts Creek (EPBC listed)
- Barton

The UWIR provides an outline of State monitoring requirements which include:

- Spring flow
- Spring area
- Water chemistry
- Spring physical condition

Different methods or analytical suites may be applicable to each of the springs as indicated in Appendix H of the UWIR.



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Condition 71 of the Federal environmental approval requires monitoring of springs that maintain *The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin*. These requirements include:

- A specific monitoring and remediation program to protect the ecological community
- Quarterly baseline monitoring for 1 year to determine seasonal presence or absence of relevant springs and to understand seasonality of biophysiochemical parameters associated with each of the springs
- Ongoing 6 monthly monitoring of the springs

The preparation of the management plan is contingent on the finalisation of the springs survey required by Condition 70 of the Federal approval. This survey has been undertaken by the QWC and reported through the UWIR and associated documents.

Following the finalisation of the survey, a Springs Monitoring, Management and Mitigation Plan will be prepared that will conform with both State (QWC) and Federal requirements. This plan forms a component of the overall Groundwater Monitoring Program (Appendix C)

## 4.4 Surface and Subsurface Deformation Monitoring

Condition 67 of the Federal environmental approval requires:

- a baseline and ongoing geodetic monitoring program to quantify deformation at the land surface within APLNG tenure;
- modelling to estimate the potential hydrological implications of predicted surface and subsurface deformation; and
- measures for linking surface and sub-surface deformation arising from CSG activities.

Monitoring associated with these conditions is outlined in the Australia Pacific LNG Stage 1 CSG Water Monitoring and Management Plan (Q-LNG01-95-MP-0147), specifically Appendix A – Aquitard Integrity, Subsidence & Interconnectivity Plan (Q-LNG01-10-MP-0018). The Stage 2 CSG WMMP will include a detailed inventory of the recently completed facilities and accompanying monitoring regime and schedule.

## 4.5 CSG Well and Fracture Stimulation Pilot Monitoring

Water quality sampling is undertaken from a large number of existing CSG wells that are currently in production. These samples will be subjected to analysis for a wide range of analytes, including isotopic analysis, which will allow fingerprinting of the gas and waters within the Walloon Coal Measures, and therefore comparison with water from other aquifers.

Hydraulic fracture stimulation has the potential to introduce compounds into the subsurface. Although the majority of the introduced substances will be removed during ongoing production of the fracture stimulated well, a portion may remain that has the potential to affect the quality of the groundwater. A *Hydraulic Fracturing Environmental Assessment* (URS, 2011), which includes a risk assessment has been completed and a program for the assessment of the input fluid and monitoring of the produced water has been undertaken.

Monitoring activities associated with hydraulic fracture stimulation will be undertaken in accordance with Environmental Authority requirements and do not form a component of this plan.



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## 4.6 Background Monitoring

The groundwater monitoring network, as described herein, focuses on monitoring in higher risk aquifers and locations within Australia Pacific LNG tenements in the Surat Basin and Bowen Basins. Although some locations are off-tenure, it is recognised that these sites are still within the potential zone of influence of the project, and may not represent true background response against which trends can be assessed. This issue is further complicated by the presence of other large-scale CSG development in the basins, often directly adjacent to Australia Pacific LNG tenements.

This issue is addressed through the off-site monitoring requirements of the Queensland Water Commission Underground Water Impact Report (UWIR). These bores are not yet presented as part of this monitoring plan, as individual company responsibility for their installation is not established until formal State Government approval of the UWIR. Nevertheless, these off-site monitoring bores will be a legislated requirement and should be considered part of the monitoring network.



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# 5. Minimum Monitoring Requirements

This section describes the minimum monitoring proposed. In accordance with the adaptive management approach, these requirements will be modified on an on-going basis to ensure optimal understanding of the system.

## 5.1 Indicator Parameter Section

Indicators can be used to measure the cause and effect relationship between human activities and the environmental response to those activities. Suitable indicators include those:

- Commonly found in the environment;
- Relatively easy and inexpensive to measure;
- Sensitive to environmental change; and,
- Specific to disturbance impacts.

Indicators can be grouped as condition and development indicators. Condition indicators relate to the physical, chemical and biological aspects of the groundwater system, while development indicators relate to anthropogenic activities.

### 5.1.1 *Water Quantity Indicators*

Changes in quantity of groundwater (or availability of groundwater), flow volumes in aquifers and interaction between groundwater and surface water features are primarily determined based on groundwater level/pressure levels and related changes in these levels. Natural fluctuations in groundwater levels occur in response to daily and seasonal cycles and variability in climatic conditions (that is, precipitation, evaporation and atmospheric pressure). The duration of these fluctuations range from short-term (for example, shallow monitoring bores responding to individual precipitation events) to long-term (multi-year variations in climate and basin water balance).

Development-induced changes in groundwater levels can be caused by removal of groundwater from an aquifer, changes in basin water balances (due to land cover changes including removal of wetlands, construction of ponds etc ) and pressure effects due to injection of water into aquifers. More localised effects can occur as a result of leakage from ponds and dams.

The primary indicator for groundwater quantity is therefore defined as:

- *The temporal change to groundwater level/pressure in a defined aquifer interval at an established monitoring location.*

As a result, water levels at established locations will need to be monitored until sufficient background data have been collected to compare and assess future trends. Characterisation of expected natural fluctuations in groundwater elevation in each specific bore is necessary to establish baseline conditions and variability prior to assessing for development influences. Water level fluctuations related to seasonal effects of annual recharge events and changing climatic conditions must be understood to correctly interpret monitoring trends.



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### 5.1.2 *Water Quality Indicators*

To determine relevant regional groundwater quality indicators, it is necessary to initially sample for a wide range of parameters to gain an understanding of the specific aquifer hydrogeochemistry. Review of these results allows the identification of primary and secondary indicators. Primary indicators are defined as those used to flag situations where conditions fall outside of a well-established range of natural variability or baseline conditions. Secondary indicators are intended to facilitate any follow-up investigation required to better understand a change from baseline conditions. It is noted that both primary and secondary indicators will need to be monitored until sufficient measurements have been collected to demonstrate the range of natural variability at the point of measurement and that background conditions have been sufficiently characterised to compare and assess against future trends. Typically, a minimum of four samples are needed to establish baseline conditions at a given location and begin to track variability. Following the establishment of baseline conditions, only primary parameters need be monitored unless significant variations are observed.

### 5.1.3 *Development Indicators*

Development indicators provide an understanding of changes in activities that may affect recharge and discharge processes. A number of indicators relating to development activities for the Australia Pacific LNG Project within the study area exist. For the purpose of this monitoring program, the most relevant include:

- Extent of CSG fields and associated infrastructure and how they differ, in time and space, in comparison with the development plans used to develop this monitoring program;
- Number of licensed water users or withdrawals in a given area based on the aquifer and the volumes withdrawn or allocated (that is, aquifer-use intensity index);
- Number of injection bores in a given area based on the aquifer priority and volumes injected (water-injection intensity index); and,
- Climatic conditions.

## 5.2 Water Level Monitoring

Water level monitoring is the key parameter for assessing changes to the groundwater regime, particularly as the 'make good' obligation of the *Water Act* (2000) is predicated on a water level change (5m in a consolidated aquifer, 2m in an unconsolidated aquifer and 0.2m at a spring).

### 5.2.1 *Frequency and Duration*

Where possible, water level monitoring will commence prior the start of CSG development, including multi-well extended pilot testing, to ensure that pre-development groundwater levels are characterised, and the range of natural variability is understood prior to any potential effects associated with CSG extraction.

At a minimum, groundwater levels will be manually measured twice yearly. It is intended that the majority of monitoring bores will have permanent water level monitoring devices (e.g pressure transducer and dataloggers) installed. These will log at a minimum of twice daily intervals.



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The Queensland Water Commission Underground Water Impact Report (UWIR - draft) requires fortnightly waterlevel monitoring of those bores indentified in the UWIR. These bores are identified in Appendix A.

Groundwater level monitoring will continue until Australia Pacific LNG development in the area has ceased.

### 5.2.2 *Instrumentation and Control*

Groundwater levels will be measured manually with an electronic water level probe or other measuring device each time a bore is visited.

Permanent water level monitoring devices will be installed in the key monitoring bores. This will comprise a pressure transducer or vibrating wire piezometer for waterlevel measurement, and a datalogger for recording the measurements. Instrumentation Northwest (INW) PT2X pressure/temperature loggers are currently used.

It is intended that telemetry will ultimately be installed to automatically download data at key monitoring locations. 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 implemented

## 5.3 Water Quality Monitoring

### 5.3.1 *Frequency and Duration*

For interaquifer flow to be induced, there will need to be a relative change in aquifer pressures, which will be evident as declining groundwater levels. The coal measures tend to contain the poorest quality waters in the geological sequence. The potential for CSG activities to impact groundwater quality are very limited as any potential inter-aquifer flow induced as a result of CSG depressurisation will be towards the depressurised coal measures. Furthermore, the similarity in water qualities between the aquifers means that there will be little impact to the overall water quality as a result of any potential CSG-induced interaquifer flows.

Using Sundaram et al. (2009) as a guide:

- *groundwater quality indicators* (electrical conductivity, temperature, etc) should be monitored at a 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.

Bores specified in the draft UWIR (identified in Appendix A) require six monthly water quality monitoring. Consideration will be given to the installation of EC/temperature sensors to be deployed in these bores to provide more regulator groundwater quality indicator data.

Australia Pacific LNG's minimum monitoring frequency for groundwater quality parameters will be annually.

Groundwater quality parameters will initially be collected annually for four years to establish baseline conditions, then on a 2-yearly basis unless water quality indicators or groundwater level monitoring indicates changing conditions. Should water level monitoring indicate a declining trend that exceeds the lower control limit for that bore (see Section 4.5), and the investigation indicates that the decline is due to CSG activities, water quality sampling will recommence on an annual basis or as appropriate under the adaptive management regime.



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

### 5.3.2 *Methods*

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 are collected immediately prior to the cessation of test pumping and are therefore collected by a traditional purge method using an electric submersible pump.

However, given the depth of many of the proposed monitoring bores, the purging of 3 bore volumes can equate to several tens of thousands of litres. APLNG has commenced a study to assess alternative groundwater sample collection methods with the specific aim of determining an appropriate method of sample collection for the required suite of analytes, whilst minimising purge volumes and conforming to accepted practises. The results to date of this study have indicated minimal difference between the laboratory results of the alternative methods of sample collection. Contingent on full analysis of the results, APLNG will purse the installation of dedicated low-flow pumps for the ongoing sampling of groundwater monitoring bores.

#### *5.3.2.1 Landholder Bores*

Water samples are to be collected using existing, installed pumps where installed. The bore will be 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 disposal options for the purged water.

If there is no pump installed in a bore, a grab sample will be collected using a bailer (unless the bore has been identified as a high priority quality monitoring site in which case a mobile sampling pump will be employed). The temperature, pH and electrical conductivity of the grab samples will be measured to obtain an initial assessment of water quality, however grab samples will not be submitted for laboratory analysis.

#### *5.3.2.2 Monitoring Bores*

Given the range in depths and diameters of the monitoring bores it is anticipated that several methods of sampling will be required to collect water samples. Sampling methods will be selected to minimise the volume of purge water to manage while ensuring that samples collected are representative of the aquifer water quality. A study is currently underway to assess sampling options, particularly for the deeper monitoring bores. Data to date suggests minimal difference between sampling methods/equipment, thus low-flow sampling is most likely to be pursued. Pumping equipment will be dedicated to each of the monitoring bores.

Where samples are collected through more traditional purging methods (using traditional pumps or low-flow systems), it will be ensured that field parameters have stabilised as per Table 4 (Holmes *et al*, 2001).

**Table 4: Field Parameter Stabilisation Criteria Prior to Sample Collection**

| Measurement | Variability | Recording |
|---|---|---|
| pH | +/- 0.1 units | Previous measurement at time of sampling |
| Temperature | +/- 0.2℃ | Median of 5 previous sampling events |



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| Measurement | Variability | Recording |
|---|---|---|
| Electrical conductivity | +/- 3% | Median of 5 previous sampling events |
| Dissolved oxygen | +/- 0.3 mg/L | Median of 5 previous sampling events |
| Redox potential (Eh) | +/- 5% | Median of 5 previous sampling events |

### 5.3.3 *Parameters*

All initial groundwater samples will be analysed for the following parameters:

- Physical Parameters – pH, total dissolved solids;
- Major Cations and Major Anions – calcium, magnesium, sodium, potassium, chloride, sulphate, bicarbonate, carbonate and total alkalinity;
- Minor Anions – bromide, fluoride, and iodide;
- Dissolved[2] Metals and Metalloids – aluminium, boron, barium, cobalt, iron, manganese, molybdenum, selenium, silver, strontium, tin, arsenic, cadmium, chromium, copper, nickel, lead, 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.

Additional discretionary analyses include:

- Total suspended solids;
- Dissolved organic carbon ;
- Nutrients – nitrate, nitrate and total phosphorous;
- Where samples are visibly degassing or where methane is measured at the wellhead, samples may be analysed for stable isotopes of methane and carbon dioxide;
- Stable and radiogenic isotopes; and,
- At hydraulic fracture stimulation locations, analytes required by the relevant Environmental Authority.

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).

[2] 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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### 5.3.4 *Quality Assurance/Quality Control Sampling*

Field monitoring equipment such as electrical conductivity and pH meters will be calibrated on a daily basis using appropriately ranged and preserved calibration solutions.

Quality assurance/quality control laboratory samples will be collected at 1 duplicate sample for every ten samples collected, or if less than ten samples in a sampling event, one duplicate sample per batch. The duplicate sample will be sent to the primary analytical laboratory.

Duplicate samples will be analysed for the full suite of parameters for which the primary sample is analysed.

## 5.4 Data Management

### 5.4.1 *Data Collation*

All data collected and compiled as part of the groundwater monitoring program will be stored in a relational database. This database will include (but not be limited to):

- Bore location details, aquifer and construction details (including pumping infrastructure and instrumentation);
- Records of landholder bore visits, issues and complaints;
- Water level and chemistry data;
- Geologist and geophysical logs;
- Stratigraphic interpretations; and,
- Relevant CSG production data.

The database will have the ability to check the integrity of laboratory water quality reports, and will be developed for automated statistical analyses as required for the development of control limits, charting and trend determination, as described in Section 4.5.

Origin Energy currently utilises the EsDat environmental database system. The database is currently being customised to ensure compatibility with the data collected and output required. Data is currently

### 5.4.2 *Data Dissemination*

Review and interpretation of the data (see Section 5.6) will be undertaken on minimum annual basis for internal reporting purposes.

Data collected during the bore inventory and monitoring data will be provided to QWC for update and inclusion in the groundwater database as required under the *Water Act, 2000*.

Reporting of monitoring data assessments required to be provided to the QWC on an annual basis following release of the Underground Water Impact Report (UWIR), and raw monitoring data must be submitted every six months.

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

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

## 5.5 Data Analysis

Different methods exist for the assessment of groundwater monitoring data, one of which is the use of statistical tests for the development of indicator parameter limits. It is recognised that alternative methods exist, however statistics honour natural data variability and facilitate tracking of quality and quantity trends. It is also recognised that the regulator may define targets, triggers and thresholds against which monitoring data is to be assessed. Australia Pacific LNG is committed to working with the regulator to define scientifically justified and practical limits.

To facilitate identification circumstances requiring follow-up actions, past approaches have used established generic guidelines to indicate the limit or control condition. These criteria tend to be very conservative and may not take into consideration natural conditions of the area. A more useful approach is to derive screening level values based on data from established monitoring bores. These results are used in combination with other statistical techniques such as control charting and trend analysis to filter spurious data from significant events.

As groundwater data becomes available through the monitoring of the regional network, it will become possible to assess statistical trends for each indicator parameter at each monitoring location. Trends can be identified and follow-up investigations initiated per the established approach outlined in Section 4.5.1. The intent of the investigative follow-up is to identify natural exceptions to established targets and thresholds and facilitate revision of the targets and thresholds as per the adaptive management approach.

Statistical control charting can be utilised for each selected indicator parameter measured at a regional monitoring well. This method honours natural data variability and allows tracking of quality and quantity conditions at each designated location. The technique is commonly used to determine whether or not an observed value within a given set of data, is significantly different from historical values (Gibbons 2009). An Upper Control Limit (UCL) is calculated for each parameter measured at a well where a large number of data points exist. Similarly, a Lower Control Limit (LCL) is calculated to determine the lower bounds on the temporal data set. A data point that exceeds either control limit is an indication of variations outside of natural conditions. Such an excursion can result from a false detection, therefore verification of the data point is required and may be followed by a more in-depth review using more sophisticated techniques of analysis.

An example of the style of data charting, and comparison to established control limits is provided in Figure 5.

In this figure, the action level and initiation of a follow-up response is indicated at the point where a condition moves from the natural range of variability past an established target level or trigger value. The approach uses a green, yellow and red condition to establish the level of action to a particular situation. Thus, changing from a green condition to yellow condition can be defined as exceeding an established trigger level. Subsequently, if conditions move from yellow to red, more stringent controls and/or mitigation may be necessary. This can be further described as follows:

**Green condition**: Groundwater quality and/or quantity results are within the range of natural variability or established baseline conditions.

**Yellow condition**: Evaluation of data indicates a trigger level has been exceeded. As a result, implement the investigation phase of the groundwater management plan.



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Management activities can be invoked as appropriate and must clearly demonstrate trend reversal through their implementation.

**Red condition**: Exceeding a water quality or quantity threshold requires an increased level of groundwater management, risk assessment, remediation and/or mitigation to demonstrate trend reversal and an ultimate return to baseline conditions. The intention is for interventions to be implemented when the trend is in the yellow condition to ensure that the threshold is never exceeded.

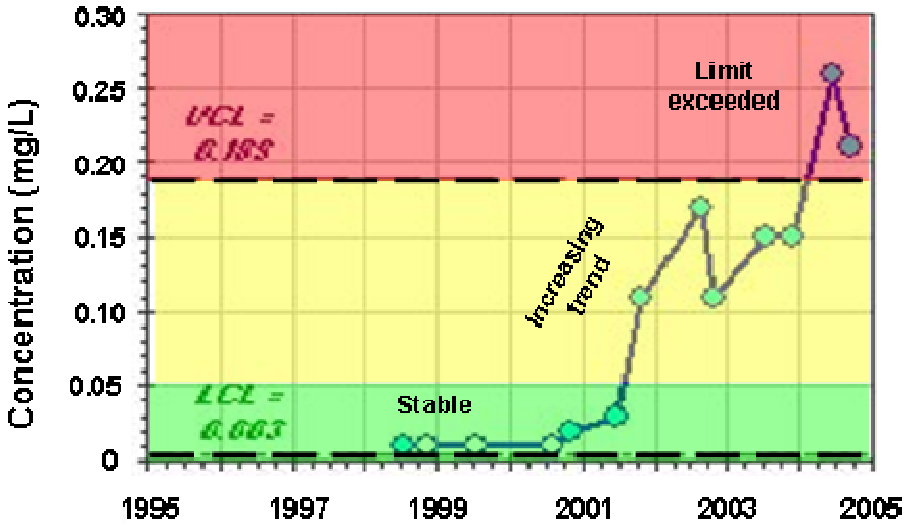
As part of the approach to assessing indicator conditions, trend analysis can be used to assess direction and rate of parameter change such as the non-parametric Mann Kendall test for trend (Mann 1945, Kendall 1975) combined with a modified version of Sen's non parametric slope estimator (Sen 1968).

Trend analysis for selected indicator parameters may incorporate all available data generated from regional monitoring bores. The Mann-Kendall and Sen's slope are evaluated only on data sets where at least four, and no more than 40, data points exist. To indicate potentially significant trends, results can be screened according to the following criteria:

- A slope threshold will be used to screen out high probability trends with very low slopes. A normalised slope threshold of ±10% per year may subsequently be used to screen out small relative trends superimposed on high concentrations. Data will be normalised to a maximum of weekly readings (e.g. every Monday morning's reading on the datalogger).

The overall goal of control charting and trend analysis is to detect situations that may be heading in a direction and at a rate that is outside of natural variability. Therefore, reversal of abnormal trends in water quality or quantity indicators is a fundamental part of achieving the outcomes outlined in Section 1.1.

**Figure 4: Example of Statistical Control Charting**



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### 5.5.1 *EBPC Spring Default Drawdown*

Condition 50 of the Federal Environmental approval (EPBC 2009/4974) requires groundwater drawdown limits for each potentially impacted aquifer to be defined and early warning indicators for when drawdown thresholds are being approached. The purpose of these default drawdown limits is to ensure the protection of *The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin.*

The derivation of the drawdown limits is described in the Australia Pacific LNG Stage 1 CSG Water Monitoring and Management Plan (Q-LNG01-95-MP-0147).

The monitoring strategy will comprise multiple approaches: (1) a trigger limit, i.e. when a specified value is exceeded, a response is initiated, (2) hydrograph comparison trigger and (3) change in trend trigger. This is shown diagrammatically in Figure 5.

(1)This is the default drawdown limit specific for each relevant monitoring bore. The bores to which the default drawdown limits will apply, and their individual limits are provided in Table 5.

**Table 5: Default Drawdown Limits for the Protection of EPBC Springs**

| Monitoring Bore | Monitoring Bore Completion Status | Default Drawdown (m) |
|---|---|---|
| Meeleebee-MB2-H | 2013 | 0.6 |
| Carinya-MB5-H | 2013 | 1.2 |
| Condabri-INJ4-H | Completed | 1.8 |
| Condabri-MB9-H | Completed | 2.5 |
| Reedy Ck-INJ3-H | Completed | 1.0 |
| Reedy Ck-MB3-H | Completed | 1.0 |
| Talinga-MB3-H | Completed | 1.8 |
| Talinga-MB6-H | 2013 | 1.6 |
| Dalwogan-MB5-H | 2013 | 1.6 |
| Orana-MB6-H | 2013 | 1.0 |

(2) Modelled hydrographs are required to be generated for each monitoring bore in order to determine default drawdown values. Actual monitoring bore data can be compared with these modelled hydrographs. If monitored trends exceed modelled trends, an investigation would be triggered. Modelled hydrographs from the APLNG EIS model are included in Appendix C. A hyperlink is provided to the data.

(3) However, it is recognised that if drawdowns were less than modelled in the early period of operations, an increasing drawdown rate may not trigger an action for several years. Therefore, as an extra safeguard, an increase in drawdown trend in excess of 10% over the previous year has also been specified as a trigger for follow-up investigation.

This multi-trigger approach initiates investigations in response to short and long term trends that an average trend for the whole times series would not. The response will be to investigate through the investigation and response process outlined in Figure 6.

Future approaches may be informed by the industry approach being developed for Stage 2 CSG WMMP's.



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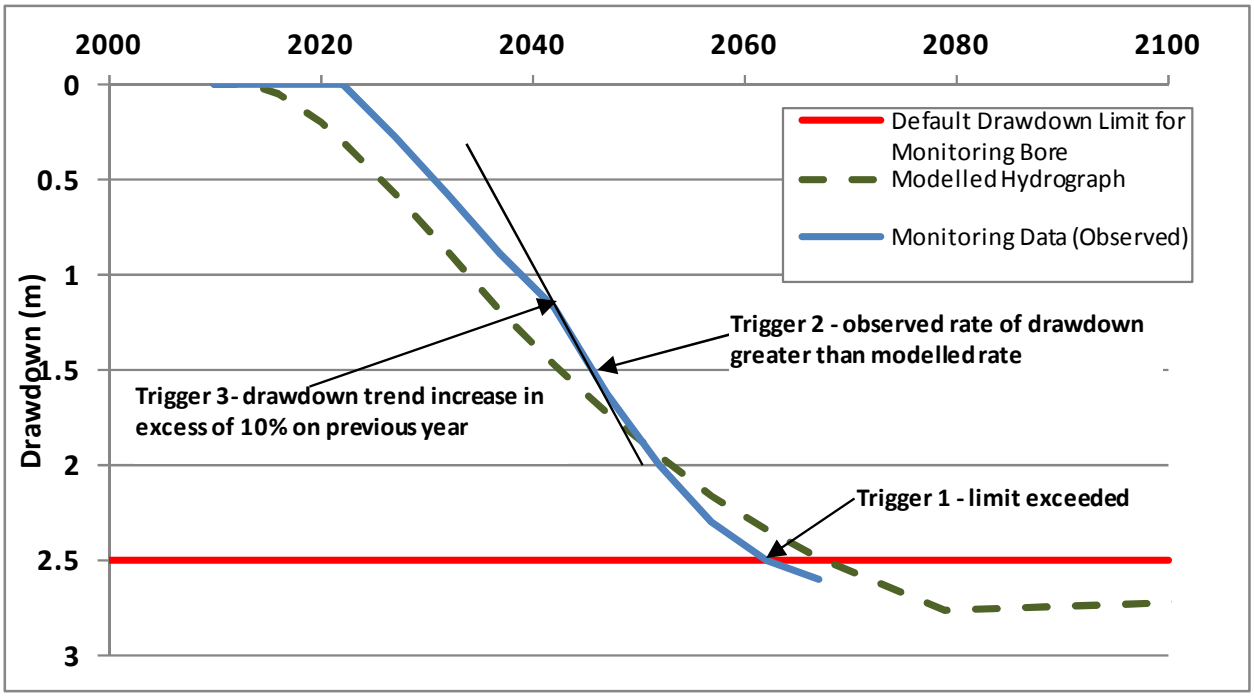
**Figure 5: Schematic of Monitoring Trend Triggers to Initiate a Follow-up Response**




### 5.5.2 *Investigation and Response Process*

A network of regional monitoring bores will be established in the study area, which will include some existing baseline monitoring bores (for example, existing DERM bores), and new monitoring bores to be installed to form the regional network. Depending on sampling frequency and the amount of time for bore conditions to stabilise, it may take more than a year to sufficiently characterise baseline conditions in key regional aquifers, and much longer to establish the range of natural variability.

To help facilitate stabilisation of well conditions (particularly quality) newly installed regional monitoring bores will be assessed more frequently at first to establish a database of values for future comparisons. During this time, monitoring data collected from existing and new regional bores can still be reviewed against preliminary targets and thresholds to roughly assess against regional outcomes. As sufficient data is collected, results from individual monitoring bores that indicate either:

- Deviation from established baseline conditions;
- Levels exceeding statistical control limits; *or* ,
- Identification of a significant trend ;

can then be assessed using an investigative approach.

For example, follow-up to the detection of an indicator parameter excursion, outside of established variability or established criterion, may initiate a phased investigative approach incorporating four basic stages of review. These include:

- Verification;
- Evaluation; and,
- Modification of activities, or management of the effect (e.g. 'make good').

An example flow diagram for follow-up activities during operation of the regional groundwater monitoring network is provided in Figure 6.

Prior to responding to a data excursion using the following investigative approach, it must be clearly demonstrated that the monitoring well(s) has stabilised sufficiently to indicate baseline conditions. Because it can take some time for conditions in a newly installed well to stabilise, it is recommended that at least four measurements for each indicator parameter be collected prior to applying any follow-up response.

The initial step in the process is *verification* of the measurement. This process begins with a check on integrity of the measurement, including a review of the protocol used to collect the measurement and the integrity of the monitoring well itself.

If the original data point is found to be correct, then an investigation of the results is conducted and an *evaluation* phase is initiated to identify the origin or source of the indicator excursion. This phase of investigation is conducted in a phased manner so that all applicable information is accessed and utilised, including the influence of other groundwater users (e.g. increased pumping), changes in climatic conditions, changes in operations, etc. This includes identification of knowledge and/or data gaps and completion of additional characterisation work to fill these gaps and bring the issue into proper context. The goal of the review process is to ensure that any potential effects linked to the indicator change are properly assessed in order to reduce or eliminate consequences. This is achieved by accessing essential information for the decision-making process.

If the *evaluation* phase of the investigation identifies the issue as being a natural aberration, then the result is documented and the area characterisation is updated. This may lead to the revision of a trigger or threshold, or identification of an area as a natural exception to the regional setting. If, however, the results indicate an anthropogenic influence, an assessment of risks is undertaken, and/or use of predictive modelling to assess potential future effects.

If the *evaluation* phase of the investigation indicates a positive result (stabilisation or reversal of unacceptable trend or low risk situation) then a more *in-depth evaluation* or characterisation of the area is updated along with associated trigger and threshold for the associated parameter, and regional monitoring is continued to ensure stabilisation and/or trend reversal. If the result is negative, then *modification* to the identified operation or operations may be required, followed by an *evaluation* phase including risk assessment, or mitigation measures implemented (for example, 'make good'). If a positive result is anticipated, and trends are expected to stabilise or reverse, then the result is documented and a return to regular monitoring occurs. If not, then the continued operation of the identified activity or activities causing the effected may need to be reviewed in consultation with the regulator and other affected parties. Additionally, 'make good' obligations may need to be fulfilled pursuant to the requirements of the *Water Act, 2000*.

## 5.6 Reporting

Monitoring results, both water quantity and water quality, will be verified and stored in the integrated database. At a minimum, these reviews will identify and provide comment on:

- Changes to the proposed monitoring network from the previous report (for example, new monitoring bores coming online);
- Most recent and historical monitoring results, trends, changes in trends in comparison with interim or adopted triggers and thresholds;
- Differences between the actual development sequence and that included in the most recent version of the cumulative effects numerical model;
- Comparisons between the monitoring results and the cumulative effects numerical model predictions;
- Histories of complaints regarding water level drawdown or gas migration in private water bores; and,
- The proposed response plan for investigation of indicator parameters outside the control limits.



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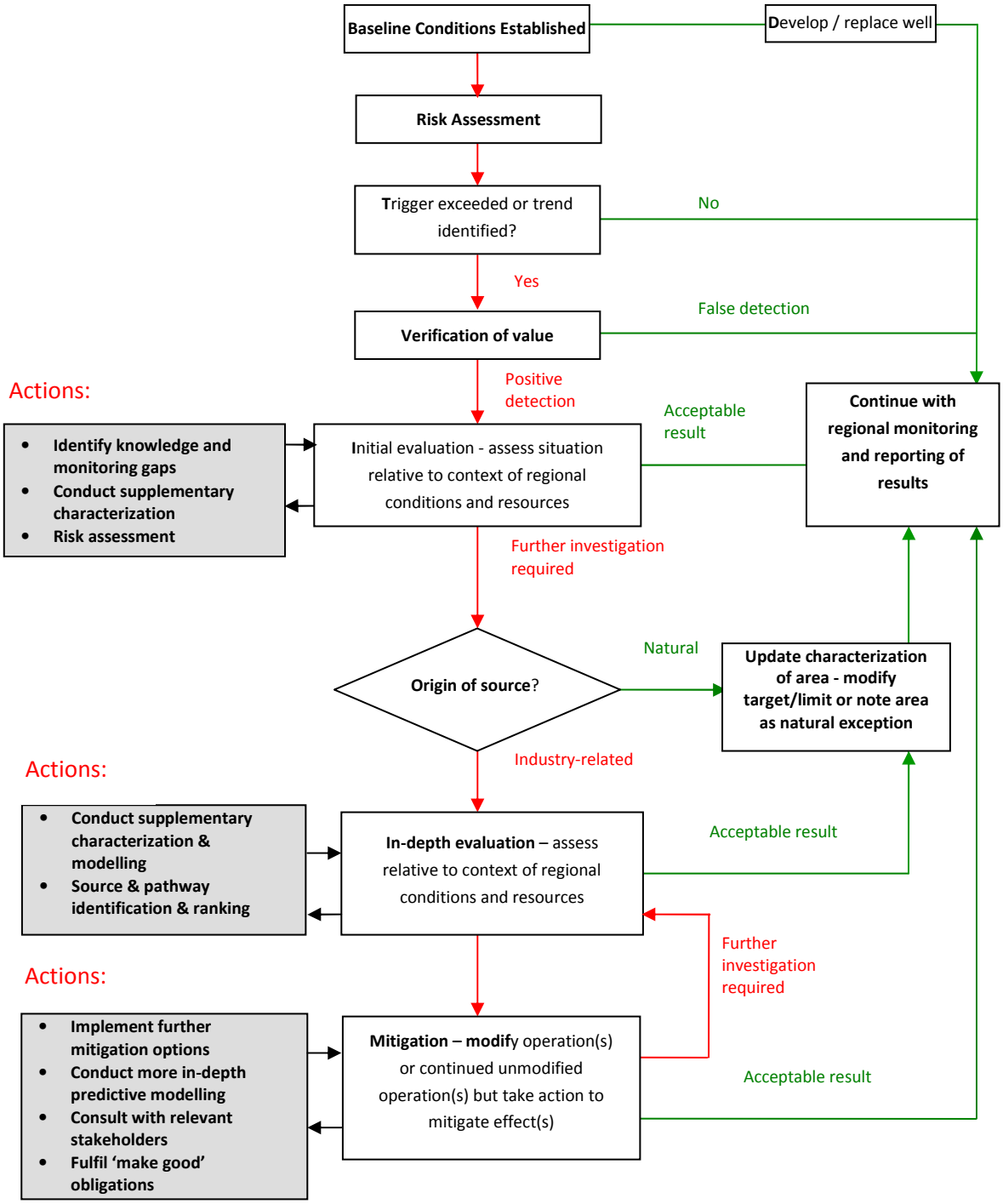
**Figure 6: Investigation and Response Framework**



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# 6. Implementation

## 6.1 Schedule

Where practicable, implementation of the groundwater monitoring program will commence at least one year in advance of the commencement of full-field development. However, in the selection of monitoring sites, extended multi-well pilots have been taken into account, thus potential early effects due to the operation of these pilots can be used to update the conceptual understanding and numerical model to further improve the monitoring network.

The landholder bore survey commenced during 2010 and is expected to be completed by December 2012.

Drilling of dedicated groundwater monitoring bores commenced in August 2010 and has been progressing continuously since. An anticipated date for the installation of each monitoring bore is provided in Appendix A.

The initial water quality sample will be collected immediately following the drilling, completion and development of monitoring bores.

Groundwater level monitoring will commence at the time of individual borehole completion. Pressure transducers will be installed shortly after bore completion.

Existing water bores will be instrumented following the finalisation of appropriate agreements with the owner, and have already commenced. However the majority will be installed after bore selection following the completion of the landholder bore baseline surveys.

Discussions with DERM/QWC and other CSG companies have already commenced to ensure all relevant higher risk off-tenure areas are monitored and that monitoring is undertaken collaboratively in a basin-wide approach.

## 6.2 Contracting Strategy

The proposed contracting strategy for implementation of the groundwater monitoring program is described with the Origin Energy document “APLNG Upstream Phase 1 Contracting and Procurement Strategy for Groundwater Services – Management Plan”. The developed strategy indicates that the design will be undertaken by Origin Energy personnel, with construction supervision and ongoing monitoring to be performed through a combination of Origin Energy hydrogeologists and sub-consultants.

The tendering process for sub-consultants includes a review of proposed personnel qualifications and experience. Only degree qualified personnel will be allowed to undertake technical tasks.

## 6.3 Work Procedures

All field work will be undertaken in accordance with the Origin Energy Groundwater Procedures Manual. This manual includes both safe work procedures and standard operating procedures.



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# 8. Plan Preparation

This plan has been prepared by the following team:

| Role | Name | Position | Qualifications | Relevant Experience |
|---|---|---|---|---|
| Author | Ryan Morris | Senior Hydrogeologist | BScHons (Geology)<br>RPGeo (Hydrogeology) | 12 years |
| Technical Review | Andrew Moser | Groundwater Manager<br>Senior Hydrogeologist | BSc (Applied Geology)<br>RPGeo (Hydrogeology) | 21 years |



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# Appendix A Rationale for Groundwater Monitoring Bore Locations and Construction Schedule



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| Origin Bore Designation | Status/Date Required | Owner | APLNG Development Area | Longitude | Latitude | Total Depth (m) | Target Aquifer | Co-nested bore(s) | Rationale | QWC Location ID | QWC WQ Monitoring |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13030808 | Instrumented | DERM | Woleebee | 149.848 | -26.279 | 10.4 | BMO | - | Monitoring commenced during EIS | - | - |
| 13030809 | Instrumented | DERM | Woleebee | 149.837 | -26.237 | 40 | BMO | - | Monitoring commenced during EIS | - | - |
| 42220004 | Instrumented | DERM | Orana | 150.187 | -26.650 | 31.7 | BMO | - | Monitoring commenced during EIS | - | - |
| 42220101 | Instrumented | DERM | Reedy Creek | 149.503 | -26.338 | 56.4 | BMO | - | Monitoring commenced during EIS | 125 | - |
| 42220127 | Instrumented | DERM | Dalwogan | 150.104 | -26.500 | 79.4 | BMO | - | Monitoring commenced during EIS | - | - |
| 42220205 | Instrumented | DERM | Carinya | 149.921 | -26.560 | 15.4 | BMO | - | Monitoring commenced during EIS | 69 | 6 monthly |
| 42230112 | Instrumented | DERM | ATP663 | 151.274 | -27.517 | 36.8 | Cainozoic | - | Monitoring commenced during EIS | - | - |
| 42230113 | Instrumented | DERM | ATP663 | 151.328 | -27.516 | 56.4 | Cainozoic | - | Monitoring commenced during EIS | - | - |
| 42230203 | Instrumented | DERM | Kainama | 150.979 | -26.899 | 34.4 | Cainozoic | - | Monitoring commenced during EIS | - | - |
| 42230204 | Instrumented | DERM | Orana | 150.668 | -26.816 | 38 | Walloons | - | Monitoring commenced during EIS | - | - |
| 42230208 | Instrumented | DERM | Orana | 150.674 | -26.782 | 49.6 | Cainozoic | - | Monitoring commenced during EIS | - | - |
| 42230629 | Instrumented | DERM | Condabri | 150.149 | -26.869 | 27.7 | Cainozoic | - | Monitoring commenced during EIS | - | - |
| 42231254 | Instrumented | DERM | ATP663 | 151.083 | -27.381 | 26 | Walloons | - | Monitoring commenced during EIS | - | - |
| 42231257 | Instrumented | DERM | Kainama | 150.952 | -27.078 | 49 | Walloons | - | Monitoring commenced during EIS | - | - |
| 42231259 | Instrumented | DERM | Kainama | 151.016 | -26.992 | 27.75 | Cainozoic | - | Monitoring commenced during EIS | - | - |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10925 Rockwood Old House Bore | Instrumented - telemetered | Origin | Talinga | 150.364 | -26.899 | 94 | Gubberamunda | - | Monitoring commenced during EIS. Talinga injection trial monitoring. | - | - |
| 30168 Rockwood Back Bore | Instrumented | Origin | Talinga | 150.371 | -26.931 | 67 | Gubberamunda | - | Monitoring commenced during EIS. Talinga injection trial monitoring. | - | - |
| 42230209A | Instrumented | DERM | Talinga | 150.680 | -26.742 | 36.7 | Cainozoic | - | Monitoring commenced during EIS | - | - |
| 58410 Miles Town Bore | Included | Private | Condabri | 150.184 | -26.666 | 1245 | Precipice | - | Monitoring commenced during EIS. Condabri injection. | - | - |
| 58579 Rockwood Pump Bore | Included | Origin | Talinga | 150.363 | -26.900 | 103 | Gubberamunda | - | Monitoring commenced during EIS. Talinga injection trial monitoring. | - | - |
| Blow Hole | Instrumented | Origin | Spring Gully | 149.135 | -25.870 | 15.82 | Hutton | - | Spring Gully injection and springs early warning monitoring | - | - |
| Bullet Hole Gate (old) | Instrumented | Origin | Spring Gully | 149.121 | -25.860 | 67.5 | Hutton | - | Spring Gully injection and springs early warning monitoring | - | - |
| Byme Creek-MB1-W | 2014 Q4 | Origin | Byme Creek | 149.830 | -26.640 | 1250 | Walloons | - | Baseline pressures | 63 | 6 monthly |
| Camp Bore (Durham 43) | Instrumented | Origin | Spring Gully | 149.071 | -25.951 | 513 | Precipice | - | Spring Gully injection and springs early warning monitoring | - | - |
| Carinya-MB1-G | 2014 Q1 | Origin | Carinya | 149.691 | -26.672 | 630 | Gubberamunda | Carinya-MB2-S | High risk area due to coal depth and high depressurisation requirements Regional coverage | - | - |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Carinya-MB2-S | 2014 Q1 | Origin | Carinya | 149.691 | -26.672 | 900 | Springbok | Carinya-MB1-G | High risk area due to coal depth and high depressurisation requirements<br>Regional coverage | 61 | 6 monthly |
| Carinya-MB3-G | 2014 Q1 | Origin | Carinya | 150.000 | -26.714 | 670 | Gubberamunda | Carinya-MB4-S | High risk area due to coal depth and high depressurisation requirements<br>Regional coverage | 59 | 6 monthly |
| Carinya-MB4-S | 2014 Q1 | Origin | Carinya | 150.000 | -26.714 | 780 | Springbok | Carinya-MB3-G | High risk area due to coal depth and high depressurisation requirements<br>Regional coverage | 59 | 6 monthly |
| Carinya-MB5-H | 2013 Q3 | Origin | Carinya | 149.857 | -26.532 | 1230 | Hutton | - | Hutton bore near area of projected drawdown (project case).<br>Confirm geology for model as no deeper than WCM along axis of Mimosa syncline<br>Regional coverage of Hutton Sandstone | - | - |
| Combabula WB1-P | 2012 Q3 | Origin | Combabula | 149.511 | -26.245 | 1300 | Precipice | - | Situated on Combabula 1 lease | - | - |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Combabula-MB1-G | 2013 Q1 | Origin | ATP606 | 149.564 | -26.231 | 65 | Gubberamunda | Combabula-MB2-S<br>Combabula-MB3-W | Within proposed Combabula multi-well pilot - to measure potential effects of early operations<br>Field data to be collected during installation to assess injection feasibility | - | - |
| Combabula-MB2-S | 2013 Q1 | Origin | ATP606 | 149.564 | -26.231 | 240 | Springbok | Combabula-MB1-G<br>Combabula-MB3-W | Within proposed Combabula multi-well pilot - to measure potential effects of early operations<br>Abandonment of Combabula24 | 92 | - |
| Combabula-MB3-W | 2013 Q1 | Origin | Combabula | 149.564 | -26.231 | 745 | Walloons | Combabula-MB1-G<br>Combabula-MB2-S | operational monitoring, within early multi-well pilot | 92 | - |
| Condabri 140 | 2012 Q2 | Origin | Condabri | 150.228 | -26.932 | | Walloons | Condabri-MB4-S<br>Condabri-MB3-G | Southern Condabri reservoir monitoring | 44 | 6 monthly |
| Condabri Feedlot bore (RN 58604) | Instrumented | Private | Condabri | 150.236 | -26.846 | 1298 | Hutton | - | Required under CCA | - | - |
| Condabri-INJ1-H | Completed | Origin | Condabri | 150.224 | -26.786 | 1200 | Hutton | Condabri-INJ2-P<br>Condabri-INJ3-G | Injection trial bore | - | - |
| Condabri-INJ2-P | Completed | Origin | Condabri | 150.225 | -26.787 | 1250 | Precipice | Condabri-INJ1-H<br>Condabri-INJ3-G | Injection trial bore | - | - |
| Condabri-INJ3-G | 2012 Q3 | Origin | Condabri | 150.225 | -26.787 | 400 | Gubberamunda | Condabri-INJ2-P<br>Condabri-INJ1-H | Injection trial bore | - | - |
| Condabri-INJ4-H | 2012 Q3 | Origin | Condabri North | 150.226 | -26.684 | 880 | Hutton | Condabri-INJ5-P<br>Condabri-MB10-W | Injection monitoring and offset site assessment | - | - |
| Condabri-INJ5-P | 2012 Q3 | Origin | Condabri North | 150.226 | -26.684 | 1155 | Precipice | Condabri-INJ4-H<br>Condabri-MB10-W | Injection monitoring and offset site assessment | 62 | 6 monthly |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Condabri-MB10-W | 2012 Q3 | Origin | Condabri North | 150.227 | -26.684 | 580 | Walloons | Condabri-INJ4-H Condabri-INJ5-P | Operational monitoring, between Condabri and WCM users, adjacent to QGC Bellevue field | 62 | 6 monthly |
| Condabri-MB12-W | 2013 Q1 | Origin | Condabri Central | 150.218 | -26.789 | 734 | Walloons | - | Operational monitoring in ealry development area. Locate east of Leichardt Fault, old Long: 150.204 and Lats: -26.804 | 50 | - |
| Condabri-MB1-G | Instrumented | Origin | Condabri | 150.171 | -26.809 | 409 | Gubberamunda | Condabri-MB2-S Condabri-MB9-H | 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 Reasonably close proximity to Condabri multi-well extended pilot test | 50 | 6 monthly |
| Condabri-MB2-S | Instrumented | Origin | Condabri | 150.171 | -26.809 | 551 | Springbok | Condabri-MB1-G Condabri-MB9-H | High risk area due to thinning/non-existence of Upper Juandah Sandstone | 50 | 6 monthly |
| Condabri-MB3-G | Instrumented | Origin | Condabri | 150.212 | -26.942 | 389.45 | Gubberamunda | Condabri-MB4-S Condabri140 | Within proposed Southern Condabri multi-well pilot - to measure potential effects of early operation | 44 | 6 monthly |



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| Condabri-MB4-S | Instrumented | Origin | Condabri | 150.212 | -26.942 | 580 | Springbok | Condabri-MB3-G<br>Condabri140 | Within proposed Southern Condabri multi-well pilot - to measure potential effects of early operation | 44 | 6 monthly |
| Condabri-MB5-G | 2012 Q4 | Origin | Condabri | 150.317 | -27.022 | 285 | Gubberamunda | Condabri-MB6-S | Close proximity to existing QGC Lauren field<br>Close proximity to Ironbark development | - | - |
| Condabri-MB6-S | 2012 Q4 | Origin | Condabri | 150.317 | -27.022 | 465 | Springbok | Condabri-MB5-G | Suspended core hole suitable for retro-fit (Condabri 3)<br>Close proximity to existing QGC Lauren field<br>Close proximity to Ironbark development | 40 | 6 monthly |
| Condabri-MB7-G | 2013 Q1 | Origin | Condabri | 150.238 | -26.828 | 180 | Gubberamunda | Condabri-MB8-S | Close proximity to QGC Berwyndale South field | - | - |
| Condabri-MB8-S | 2013 Q1 | Origin | Condabri | 150.238 | -26.828 | 365 | Springbok | Condabri-MB7-G | Suspended core hole suitable for retro-fit (Condabri 1)<br>Close proximity to QGC Berwyndale South field | - | - |
| Condabri-MB9-H | Completed | Origin | Condabri | 150.171 | -26.808 | 1100 | Hutton | Condabri-MB1-S<br>Condabri-MB2-G | Regional coverage of APLNG project area<br>Nested site within Springbok and Gubberamunda Sandstone bores<br>On Origin-owned property | 50 | 6 monthly |



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| DALWOGAN 14 | 2013 Q2 | Origin | Dalwogan | 150.146 | -26.631 | 818 | Walloons | Dalwogan-MB1-G<br>Dalwogan-MB2-S | oppourtunistic workover, operational monitoring | - | - |
| Dalwogan MB5 -H | 2013 Q2 | Origin | Dalwogan | 150.106 | -26.545 | | Hutton | - | QWC | 68 | - |
| Dalwogan MB6 -W | 2013 Q2 | Origin | Dalwogan | 150.106 | -26.545 | | Walloons | - | QWC | 68 | - |
| Dalwogan-MB1-G | Instrumented | Origin | Dalwogan | 150.146 | -26.629 | 270 | Gubberamunda | Dalwogan-MB2-S<br>Dalwogan 14 | 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 | Origin | Dalwogan | 150.146 | -26.630 | 470 | Springbok | Dalwogan-MB1-G<br>Dalwogan 14 | Within existing Dalwogan multi-well pilot - to measure potential effects of early operations Provides suitable regional coverage of central Dalwogan and northern Condabri | 62 | 6 monthly |
| Dalwogan-MB3-G | Completed | Origin | Dalwogan | 150.104 | -26.554 | 160 | Gubberamunda | Dalwogan-MB4-S<br>Dalwogan-MB5-H<br>Dalwogan-MB6-W | 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 | - | - |



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| Dalwogan-MB4-S | Completed | Origin | Dalwogan | 150.104 | -26.554 | 230 | Springbok | Dalwogan-MB3-G<br>Dalwogan-MB5-H<br>Dalwogan-MB6-W | High risk area due to thinning/non-existence of Upper Juandah Sandstone | 68 | 6 monthly |
| DMH01 | Instrumented - telemetered | Origin | Spring Gully | 149.071 | -26.000 | 60 | Hutton | DMP01<br>DRP-WI-1 | Spring Gully injection trial observation bore | - | - |
| DMP01 | Instrumented - telemetered | Origin | Spring Gully | 149.071 | -26.000 | 516.5 | Precipice | DMH01<br>DRP-WI-1 | Spring Gully injection trial observation bore | - | - |
| DRP-WI-1 | Instrumented | Origin | Spring Gully | 149.071 | -26.000 | 517.15 | Precipice | DMP01<br>DMH01 | Primary injection trial hole | - | - |
| Duke 25 | Completed | Origin | ATP788 | 150.221 | -27.108 | 750.2 | Springbok | - | Suspended exploration coreholes on Ironbark lease. Off-tenure monitoring | 36 | 6 monthly |
| Duke 26 | Completed | Origin | ATP788 | 150.226 | -27.177 | 840.2 | Springbok | - | Suspended exploration coreholes on Ironbark lease. Off-tenure monitoring | - | - |
| Duke 27 | Completed | Origin | ATP788 | 150.394 | -27.108 | 1020.2 | Springbok | - | Suspended exploration coreholes on Ironbark lease. Off-tenure monitoring | 35 | 6 monthly |
| Durham Ranch 23 | Instrumented | Origin | Spring Gully | 149.104 | -25.976 | | Bandanna | - | operational monitoring Pressures of coals & installed by Pet Engineering - contact Scott Delaney for data | 99 | - |
| Gilbert Gully MB3-W | 2013 Q3 | Origin | ATP663 | 150.900 | -27.598 | 970 | Walloons | GilbertGully-MB1-G<br>GilbertGully-M2-S | opportunistic workover of Gilbert Gully 3, operational monitoring | 6 | - |
| Gilbert Gully-MB4-W | 2014 Q4 | Origin | Gilbert Gully | 150.953 | -27.883 | 150 | Walloons | - | Sentinel gas monitoring close to WCM water bores | 1 & 2 | - |



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| GilbertGully-MB1-G | 2013 Q2 | Origin | ATP663 | 150.900 | -27.598 | 215 | Gubberamunda | GilbertGully-M2-S<br>Gilbert Gully 3 | Within proposed Gilbert Gully multi-well pilot - to measure potential effects of early operations | 6 | 6 monthly |
| GilbertGully-MB2-S | 2013 Q2 | Origin | ATP663 | 150.900 | -27.598 | 440 | Springbok | GilbertGully-MB1-G<br>GilbertGully 3 | Within proposed Gilbert Gully multi-well pilot - to measure potential effects of early operations | 6 | 6 monthly |
| Gravel Pit RN87499 | Instrumented | Private | Talinga | 150.387 | -26.895 | 56 | Gubberamunda | - | Monitoring due to landholder concerns | - | - |
| Kainama-MB1-W | 2013 Q2 | Origin | Kainama | 150.778 | -27.040 | 410 | Walloons | Kainama-MB2-S | Sentinel gas monitoring close to WCM water bores | 38 | 6 monthly |
| Kainama-MB2-S | 2013 Q2 | Origin | Kainama | 150.778 | -27.040 | 140 | Springbok | Kainama-MB1-W | Regional coverage | 38 | 6 monthly |
| LuckGully-MB1-G | 2013 Q3 | Origin | ATP606 | 149.583 | -26.399 | 200 | Gubberamunda | LuckGully-MB2-S<br>LuckyGully5 | Within proposed Lucky Gully multi-well pilot - to measure effects of early operation | 80 | 6 monthly |
| LuckGully-MB2-S | 2013 Q3 | Origin | ATP606 | 149.583 | -26.399 | 575 | Springbok | LuckyGully-MB1-G<br>LuckyGully5 | Within proposed Lucky Gully multi-well pilot - to measure effects of early operation | 80 | 6 monthly |
| LUCKY GULLY 5 | 2013 Q3 | Origin | Lucky Gully | 149.582 | -26.408 | 1581 | Walloons | LuckyGully-MB1-G<br>LuckyGully-MB2-S | oppourtunistic workover, operational monitoring | 80 | - |
| Marlan Windmill Bore (RN11958) | Instrumented | Private | Condabri | 150.187 | -26.993 | 214.3 | Gubberamunda | - | Landholder bore - regional monitoring coverage | - | - |
| Meeleebee-MB1-S | 2013 Q3 | Origin | ATP606 | 149.195 | -26.242 | 50 | Springbok | Meeleebee-MB2-H<br>Meeleebee-MB3-W<br>Meeleebee-MB5-P | Close proximity to several groundwater users accessing the Springbok Sandstone | 93 | 6 monthly |



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| Meeleebee-MB2-H | 2013 Q2 | Origin | ATP606 | 149.195 | -26.242 | 470 | Hutton | Meeleebee-MB1-S<br>Meeleebee-MB3-W<br>Meeleebee-MB5-P | Potential workover of Meeleebee 5<br>In vicinity of several private Hutton bores that are projected to be impacted | 93 | 6 monthly |
| Meeleebee-MB3-W | 2013 Q2 | Origin | ATP606 | 149.195 | -26.242 | 440 | Walloons | Meeleebee-MB1-S<br>Meeleebee-MB2-H<br>Meeleebee-MB5-P | workover of Meleebee 5 | 93 | - |
| Meeleebee-MB4-W | 2013 Q3 | Origin | ATP606 | 149.425 | -26.201 | 800 | Walloons | Meeleebee-MB7-S | QWC | 141 | - |
| Meeleebee-MB5-P | 2013 Q2 | Origin | Meeleebee | 149.195 | -26.242 | 960 | Precipice | Meeleebee-MB1-S<br>Meeleebee-MB3-W<br>Meeleebee-MB2-H | QWC | 93 | - |
| Meeleebee-MB7-S | 2013 Q3 | Origin | ATP606 | 149.425 | -26.201 | 210 | Springbok | Meeleebee-MB4-W | QWC | 141 | - |
| Muggleton-MB1-G | 2013 Q2 | Origin | ATP606 | 149.263 | -26.321 | 120 | Gubberamunda | Muggleton-MB2-S | Close proximity to existing Pine Hills multi-well pilot<br>Good injection potential - field data to be collected during installation | 87 | 6 monthly |
| Muggleton-MB2-S | 2013 Q2 | Origin | ATP606 | 149.263 | -26.321 | 280 | Springbok | Muggleton-MB1-G | Close proximity to existing Pine Hills multi-well pilot<br>Good injection potential - field data to be collected during installation | 87 | 6 monthly |
| NOONGA CREEK 6 | 2014 Q4 | Origin | Noonga Creek | 149.732 | -26.568 | 1321 | Walloons | - | opportunistic workover, operational monitoring | - | - |
| Old Spring Gully Bore | Instrumented | Origin | Spring Gully | 149.081 | -25.953 | 110 | Hutton | - | Spring Gully injection and springs early warning monitoring | - | - |
| Orana MB7 -W | 2013 Q1 | Origin | Orana | 150.493 | -26.731 | | Walloons | Orana-MB1-S | QWC | 56 | 6 monthly |



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| Orana-MB1-Wb | 2013 Q1 | Origin | Orana | -26.900 | 150.504 | 50 | Gubberamunda | Orana-MB7-W | 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 | - | - |
| Orana-MB3-S | Completed - not instrumented | Origin | Orana | 150.494 | -26.731 | 55 | Springbok | - | Regional coverage | 56 | 6 monthly |
| Orana-MB4-W | 2013 Q1 | Origin | Orana | -26.900 | 150.503 | 560 | Walloons | Orana-MB3-S | Differentiate effects of Kenya/Argyle, operational monitoring | - | - |
| Orana-MB5-W | 2013 Q1 | Origin | Orana | 150.575 | -26.824 | 60 | Walloons | Orana-MB6-H | Sentinel gas monitoring close to WCM water bores In proximity to existing (producing) QGC and Arrow fields | - | - |
| Orana-MB6-H | 2013 Q1 | Origin | Orana | 150.575 | -26.824 | 550 | Hutton | Orana-MB5-W | Monitoring of effects of early operations in Hutton Closest to landholder bores in Hutton/Marburg to NE | 51 | 6 monthly |
| Peat MB1-B | 2013 Q3 | Origin | Peat | 150.083 | -26.020 | | Bandanna | - | QWC | 128 | - |
| Pine Hills-MB1-W | 2013 Q3 | Origin | Pine Hills | 149.264 | -26.319 | 641 | Walloons | Muggleton-MB1-G Muggleton-MB2-S | Operational monitoring, between source and springs | 87 | 6 monthly |
| Ramyard-MB3-G | Completed - not developed | Origin | Ramyard | 149.787 | -26.482 | 453 | Gubberamunda | Ramyard-MB4-S | Regional coverage | - | - |
| Ramyard-MB4-S | Completed - not developed | Origin | Ramyard | 149.787 | -26.482 | 688 | Springbok | Ramyard-MB3-G | Regional coverage | 79 | - |



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| Ramyard-MB5-W | 2013 Q3 | Origin | Ramyard | 149.736 | -26.405 | 1000 | Walloons | - | Baseline pressures | 79 | 6 monthly |
| Reedy Ck-MB1-G | Instrumented - telemetered | Origin | ATP606 | 149.427 | -26.356 | 230 | Gubberamunda | ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations<br>Good injection potential - field data to be collected during installation to confirm | - | - |
| Reedy Ck-MB2-S | Instrumented - telemetered | Origin | ATP606 | 149.427 | -26.356 | 430 | Springbok | ReedyCk-MB1-G<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations<br>Good injection potential - field data to be collected during installation to confirm | 85 | 6 monthly |
| Reedy Ck-MB3-H | Instrumented - telemetered | Origin | ATP606 | 149.427 | -26.358 | 1375 | Hutton | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations<br>Good injection potential - field data to be collected during installation to confirm<br>Regional coverage of Hutton Sandstone | 85 | 6 monthly |



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| Reedy Ck-SC1-Wb | Instrumented - telemetered | Origin | Reedy Creek | 149.427 | -26.356 | 375 | Westbourne | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations<br>Installation of extensometer for aquitard integrity monitoring | - | - |
| Reedy Ck-SC2-Wb | Instrumented - extensometer | Origin | Reedy Creek | 149.427 | -26.356 | 375 | Westbourne | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Within proposed Reedy Creek multi-well pilot - to measure potential effects of early operations<br>Repeated permeability testing | - | - |
| Reedy Creek-MB4-W | Completed, surface facilities required | Origin | Reedy Creek | 149.427 | -26.357 | 780 | Walloons | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | operational monitoring | 85 | 6 monthly |
| ReedyCk-INJ5-G | Completed not Instrumented | Origin | ATP606 | 149.427 | -26.358 | 250 | Gubberamunda | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Primary injection trial hole | - | - |



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| ReedyCk-MB5-G | 2012 Q4 | Origin | ATP606 | 149.484 | -26.493 | 250 | Gubberamunda | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H<br>ReedyCk-INJ2-P | Mooga Location | - | - |
| ReedyCreek-INJ1-H | Completed | Origin | Reedy Creek | 149.428 | -26.359 | 1025 | Hutton | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ2-P | Primary injection trial hole | - | - |
| ReedyCreek-INJ2-P | Completed | Origin | Reedy Creek | 149.429 | -26.359 | 1150 | Precipice | ReedyCk-MB1-G<br>ReedyCk-MB2-S<br>ReedyCk-SC1-Wb<br>ReedyCk-SC2-Wb<br>ReedyCk-MB4-W<br>ReedyCk-MB3-H<br>ReedyCk-INJ1-H | Primary injection trial hole | - | - |
| ReedyCreek-INJ3-H | Completed | Origin | Reedy Creek | 149.376 | -26.347 | 1025 | Hutton | ReedyCreek-INJ4-P | Secondary injection trial hole | - | - |
| ReedyCreek-INJ4-P | Instrumented - telemetered | Origin | Reedy Creek | 149.376 | -26.347 | 1150 | Precipice | ReedyCreek-INJ3-H | Secondary injection trial hole | - | - |
| RN 123130 | Completed - not instrumented | Private | Carinya | 149.960 | -26.540 | | Mooga | - | QWC | 69 | 6 monthly |
| Sawmill Bore | Instrumented | Origin | Spring Gully | 149.063 | -25.877 | 58.5 | Hutton | - | Spring Gully injection and springs early warning monitoring | - | - |



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| Scotts Creek Bore | Instrumented | Origin | Spring Gully | 149.158 | -25.865 | 54 | Hutton | - | Spring Gully injection and springs early warning monitoring | 102 | - |
| SG-MB10 | Instrumented | Origin | Spring Gully | 149.061 | -25.992 | 39 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB51 | Instrumented | Origin | Spring Gully | 149.071 | -26.013 | 55.5 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB56A | Instrumented | Origin | Spring Gully | 149.068 | -26.003 | 48.22 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB60A | Instrumented | Origin | Spring Gully | 149.083 | -26.007 | 59.5 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB62A | Instrumented | Origin | Spring Gully | 149.075 | -25.998 | 41 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB63A | Instrumented | Origin | Spring Gully | 149.070 | -25.998 | 59 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB8 | Instrumented | Origin | Spring Gully | 149.084 | -26.012 | 31 | Hutton | - | Spring Gully Injection monitoring | - | - |
| SG-MB9 | Instrumented | Origin | Spring Gully | 149.065 | -25.980 | 43.8 | Hutton | - | Spring Gully Injection monitoring | - | - |
| Solar Panel RN147358 | Instrumented | Private | Talinga | 150.411 | -26.865 | 130 | Springbok | - | Monitoring due to landholder concerns | - | - |
| Spring Gully MB3 - B | 2013 Q3 | Origin | Spring Gully | 149.014 | -26.075 | | Bandanna | - | QWC | 131 | - |
| Spring Gully MB5 - B | 2013 Q3 | Origin | Spring Gully | 149.216 | -25.893 | | Bandanna | - | QWC | 102 | - |
| Spring Gully MB6 - C | 2013 Q3 | Origin | Spring Gully | 149.216 | -25.893 | | Clematis | - | QWC | 102 | - |
| Spring Gully-MB1-B | 2013 Q3 | Origin | Spring Gully | 149.000 | -25.938 | 800 | Bandanna | - | operational monitoring | 132 | - |
| Spring Gully-MB2-B | 2013 Q3 | Origin | Spring Gully South | 149.170 | -26.080 | 1150 | Bandanna | - | Bandanna monitoring for SG Phase 6. Approximate location only. | 95 | 6 monthly |



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| Spring Gully-MB4-H | Instrumented | Origin | Spring Gully | 149.014 | -26.075 | 555 | Hutton | Spring Gully PB3 | Failed attempt at drilling precipice bore SG-PB3 due to lost circulation. Hole completed in Hutton Sandstone | - | - |
| SpringGully-PB1 | Instrumented | Origin | Spring Gully | 148.851 | -25.838 | 199 | Precipice | - | Existing monitoring bore in Bandanna Subcrop | 105 | 6 monthly |
| SpringGully-PB2 | Decommissioned | Origin | Spring Gully | 148.941 | -25.953 | 457 | Precipice | - | Existing monitoring bore in Bandanna Subcrop | 132 | 6 monthly |
| SpringGully-PB3 | Instrumented | Origin | Spring Gully | 149.014 | -26.075 | 555 | Precipice | Spring Gully MB4-H | Improved coverage of Bandanna Subcrop | 131 | 6 monthly |
| Strathblane-WB1-P | 2012 Q3 | Origin | Spring Gully | 149.144 | -25.900 | 500 | Precipice | - | Water supply and monitoring | 102 | - |
| TALINGA 16 | Operational | Origin | Talinga | 150.349 | -26.823 | 571 | Walloons | - | operational monitoring - contact Tristan Renwick-Cook for Data | 53 | - |
| Talinga 17 | Completed not Instrumented | Origin | Talinga | 150.360 | -26.758 | 111 | Springbok | - | Existing reservoir monitoring well | 53 | 6 monthly |
| Talinga-INJ2-G | Instrumented - telemetered | Origin | Talinga | 150.369 | -26.893 | 60 | Gubberamunda | Talinga-SC1-Wb<br>Talinga-SC2-Wb<br>Talinga-MB5-G<br>Talinga-MB7-S<br>Talinga-MB8-W<br>Talinga-MB9-G<br>Talinga-MB10-G<br>Talinga-MB3-H | Primary injection trial hole | - | - |
| Talinga-MB10-G | Instrumented - telemetered | Origin | Talinga | 150.369 | -26.893 | 40 | Gubberamunda | Talinga-SC1-Wb<br>Talinga-SC2-Wb<br>Talinga-MB5-G<br>Talinga-MB7-S<br>Talinga-MB8-W<br>Talinga-MB9-G<br>Talinga-MB3-H<br>Talinga-INJ-2G | Operational monitoring, injection trial monitoring | - | - |



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| Talinga-MB11-S | 2013 Q1 | Origin | Talinga | 150.360 | -26.758 | 111 | Springbok | - | Replacement of Tal17, co located | 53 | 6 monthly |
| Talinga-MB1-G | Instrumented | Origin | Talinga | 150.339 | -26.849 | 66 | Gubberamunda | Talinga-MB2-S | Within existing Talinga operational development Surrounded by currently operating QGC fields. Located on Origin land (Turinga). | - | - |
| Talinga-MB2-S | Instrumented | Origin | Talinga | 150.339 | -26.849 | 261.4 | Springbok | Talinga-MB1-G | Within existing Talinga operational development Surrounded by currently operating QGC fields. Located on Origin land (Turinga). Good injection potential - field data to be collected during installation to confirm | - | - |
| Talinga-MB3-H | Instrumented - telemetered | Origin | Talinga | 150.369 | -26.892 | 940 | Hutton | Talinga-SC1-Wb Talinga-SC2-Wb Talinga-MB5-G Talinga-MB7-S Talinga-MB8-W Talinga-MB9-G Talinga-MB10-G Talinga-INJ-2G | Surrounded by currently operating QGC fields. Located on Origin land (Rockwood). Hutton Sandstone regional monitoring | 46 | 6 monthly |
| Talinga-MB4-G | 2012 Q4 | Origin | Talinga | 150.399 | -26.887 | 20 - 40 | Gubberamunda | - | Landholder request; injection monitoring | - | - |



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|---|---|---|---|---|---|---|---|---|---|---|---|
| Talinga-MB5-G | Instrumented - telemetered | Origin | Talinga | 150.370 | -26.893 | 80.18 | Gubberamunda | Talinga-SC1-Wb<br>Talinga-SC2-Wb<br>Talinga-MB7-S<br>Talinga-MB8-W<br>Talinga-MB9-G<br>Talinga-MB10-G<br>Talinga-INJ-2G | Injection exploration and ongoing monitoring | 46 | 6 monthly |
| Talinga-MB6-H | 2013 Q3 | Origin | Talinga | 150.415 | -26.815 | 840 | Hutton | - | Work-over of existing water supply bore (Bottletree) that is due to be decommissioned | - | - |
| Talinga-MB7-S | Instrumented - telemetered | Origin | Talinga | 150.370 | -26.893 | 222.71 | Springbok | Talinga-SC1-Wb<br>Talinga-SC2-Wb<br>Talinga-MB5-G<br>Talinga-MB8-W<br>Talinga-MB9-G<br>Talinga-MB10-G<br>Talinga-INJ-2G | Injection exploration and ongoing monitoring | 46 | 6 monthly |
| Talinga-MB8-W | Drilled - not completed | Origin | Talinga | 150.368 | -26.894 | 595.7 | Walloons | Talinga-SC1-Wb<br>Talinga-SC2-Wb<br>Talinga-MB5-G<br>Talinga-MB7-S<br>Talinga-MB9-G<br>Talinga-MB10-G<br>Talinga-INJ-2G | Operational monitoring, injection trial monitoring | 46 | - |
| Talinga-MB9-G | Instrumented - telemetered | Origin | Talinga | 150.369 | -26.893 | 88 | Gubberamunda | Talinga-SC1-Wb<br>Talinga-SC2-Wb<br>Talinga-MB5-G<br>Talinga-MB7-S<br>Talinga-MB8-W<br>Talinga-MB10-G<br>Talinga-INJ-2G | Operational monitoring, injection trial core investigation & monitoring | - | - |



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|---|---|---|---|---|---|---|---|---|---|---|---|
| Talinga-SC1-Wb | Instrumented - extensometer | Origin | Talinga | 150.371 | -26.893 | 200.03 | Westbourne | Talinga-SC2-Wb<br>Talinga-MB5-G<br>Talinga-MB7-S<br>Talinga-MB8-W<br>Talinga-MB9-G<br>Talinga-MB10-G<br>Talinga-INJ-2G | Extensometer installation | - | - |
| Talinga-SC2-Wb | Instrumented - telemetered | Origin | Talinga | 150.371 | -26.893 | 200 | Westbourne | Talinga-SC1-Wb<br>Talinga-MB5-G<br>Talinga-MB7-S<br>Talinga-MB8-W<br>Talinga-MB9-G<br>Talinga-MB10-G<br>Talinga-INJ-2G | Ongoing aquitard permeability assessment | 46 | - |
| Thompson Flowing Bore | Instrumented - telemetered | Private | Spring Gully | 149.214 | -26.035 | 570 | Precipice | - | Spring Gully injection and springs early warning monitoring | - | - |
| Thompson Northern Bore | Instrumented | Private | Spring Gully | 149.193 | -26.013 | 92 | Hutton | - | Spring Gully injection and springs early warning monitoring | 98 | - |
| Turinga House Bore | Instrumented - telemetered | Origin | Talinga | 150.370 | -26.886 | | | - | Injection monitoring | - | - |
| Waar Waar-MB3-H | 2014 Q4 | Origin | Gilbert Gully | 150.946 | -27.789 | 790 | Hutton | WaarWaar-MB1-G<br>WaarWaar-MB2-S | Close to users in Marburg Sandstone, projected to be impacted by CE model Regional coverage of monitoring in Hutton Sandstone | 2 | 6 monthly |
| WaarWaar-MB1-G | 2013 Q2 | Origin | ATP663 | 150.946 | -27.789 | 115 | Gubberamunda | WaarWaar-MB2-S<br>WaarWaar-MB3-H | Within proposed Waar Waar multi-well pilot - to measure potential effects of early operations | - | - |



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|---|---|---|---|---|---|---|---|---|---|---|---|
| WaarWaar-MB2-S | 2013 Q2 | Origin | ATP663 | 150.946 | -27.789 | 365 | Springbok | WaarWaar-MB1-G<br>WaarWaar-MB3-H | Within proposed Waar Waar multi-well pilot - to measure potential effects of early operations | 2 | 6 monthly |
| Waikola Bore Pad 1 (RN58073) | Completed not instrumented | Private | Spring Gully | 149.283 | -26.001 | 195.1 | Hutton | - | Required under CCA | - | - |
| Waikola House Paddock (RN13946) | Completed not instrumented | Private | Spring Gully | 149.253 | -26.036 | 103 | Hutton | - | Required under CCA | - | - |
| Waikola Lagoon Paddock (RN48978) | Completed not instrumented | Private | Spring Gully | 149.278 | -26.011 | 176.8 | Hutton | - | Required under CCA | - | - |
| Waikola Plains Paddock (RN17640) | Completed not instrumented | Private | Spring Gully | 149.288 | -26.036 | 198.1 | Hutton | - | Required under CCA | - | - |
| Wallumba House Bore (RN35916) | Instrumented | Private | Condabri | 150.226 | -26.830 | 163 | Gubberamunda | - | Required under CCA | - | - |
| Woleebee MB3-S | 2013 Q2 | Origin | Ramyard | 149.847 | -26.385 | 390 - 410 | Springbok | Woleebee-MB1-W<br>Woleebee-MB2-G | Converted Woleebee #4 cored hole - Originally this bore location was Ramyard MB2-S located 5km to west | 84 | 6 monthly |
| Woleebee-MB1-W | 2013 Q2 | Origin | Ramyard | 149.847 | -26.385 | 575 | Walloons | Woleebee-MB2-G<br>Woleebee-MB3-S | Sentinel gas monitoring close to WCM water bores | 84 | - |
| Woleebee-MB2-G | 2013 Q3 | Origin | Ramyard | 149.847 | -26.385 | 170 | Gubberamunda | Woleebee-MB1-W<br>Woleebee-MB3-S | Within Woleebee #4 cored hole lease - Originally this bore location was Ramyard MB1-G located 5km to west | - | - |
| Wylie House (long) | Instrumented | Private | Orana | 150.579 | -26.890 | 150 | Walloons | - | Shallow WCM, in area of potential ags migration and eraly drawdown effects | - | - |



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|---|---|---|---|---|---|---|---|---|---|---|---|
| ZigZag-MB1-G | 2013 Q4 | Origin | ATP663 | 150.920 | -27.967 | 200 | Gubberamunda | ZigZag-MB2-S | 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 | 1 | 6 monthly |
| ZigZag-MB2-S | 2013 Q4 | Origin | ATP663 | 150.920 | -27.968 | 300 | Springbok | ZigZag-MB1-G | 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 | 1 | 6 monthly |



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# Appendix B Maps of Groundwater Monitoring Bores



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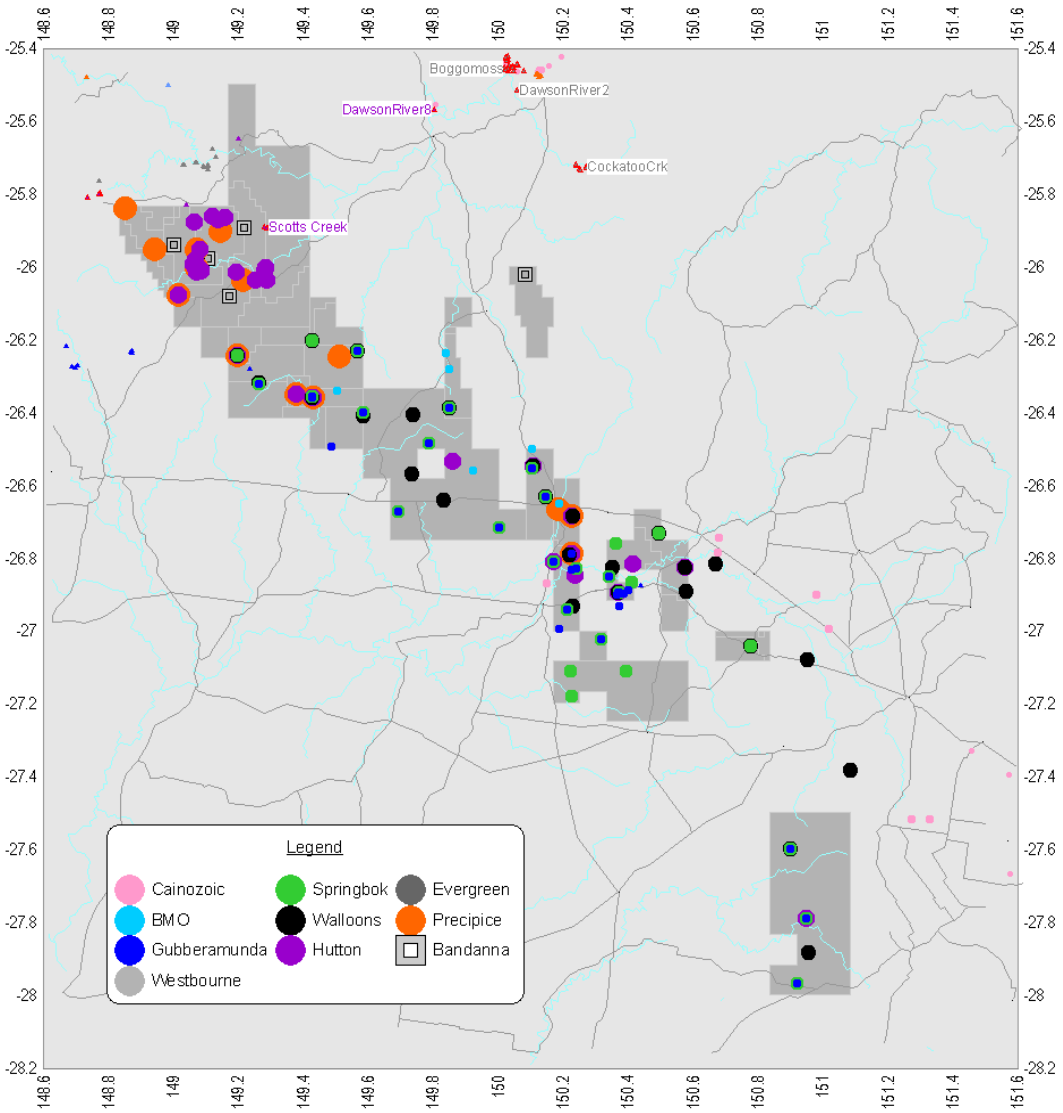
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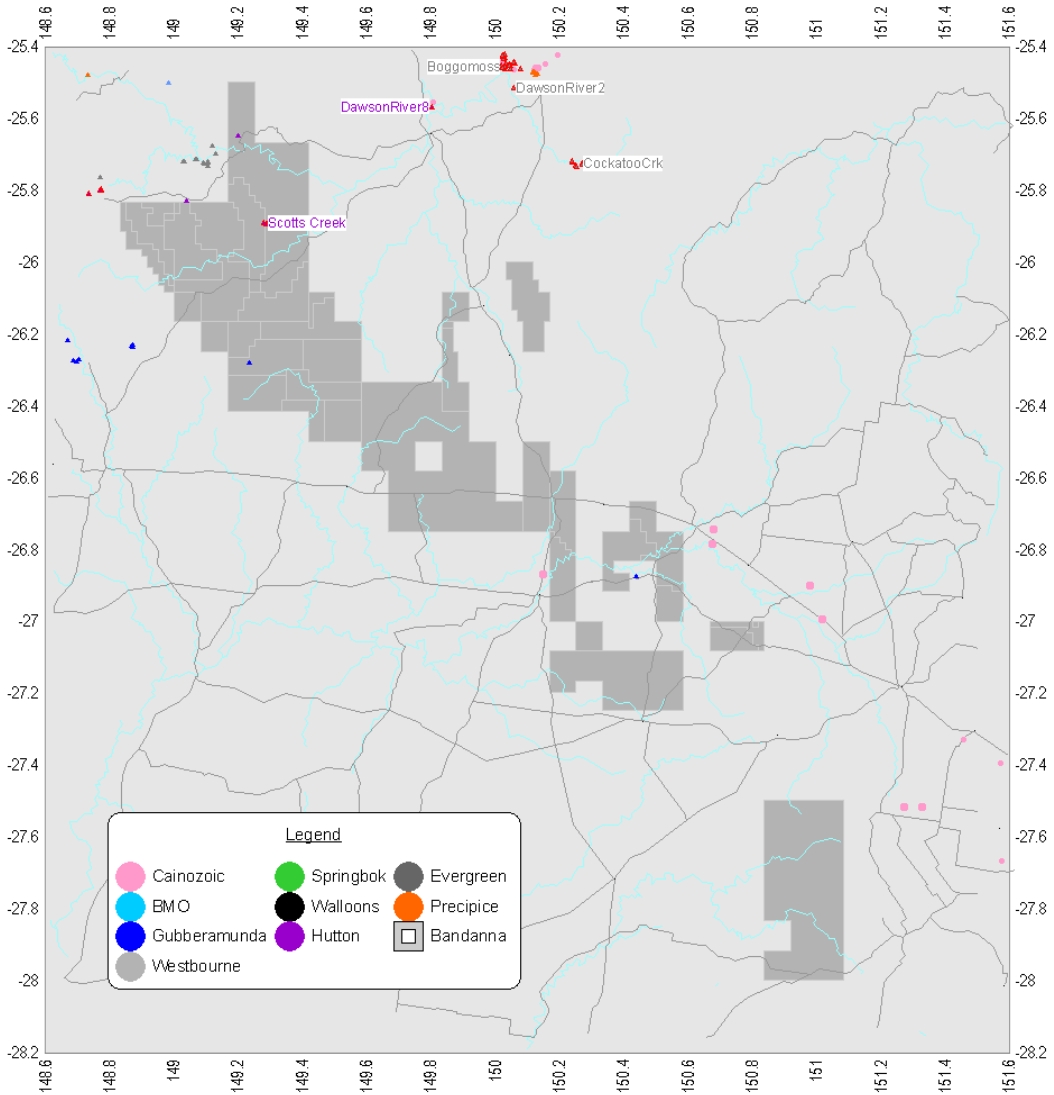
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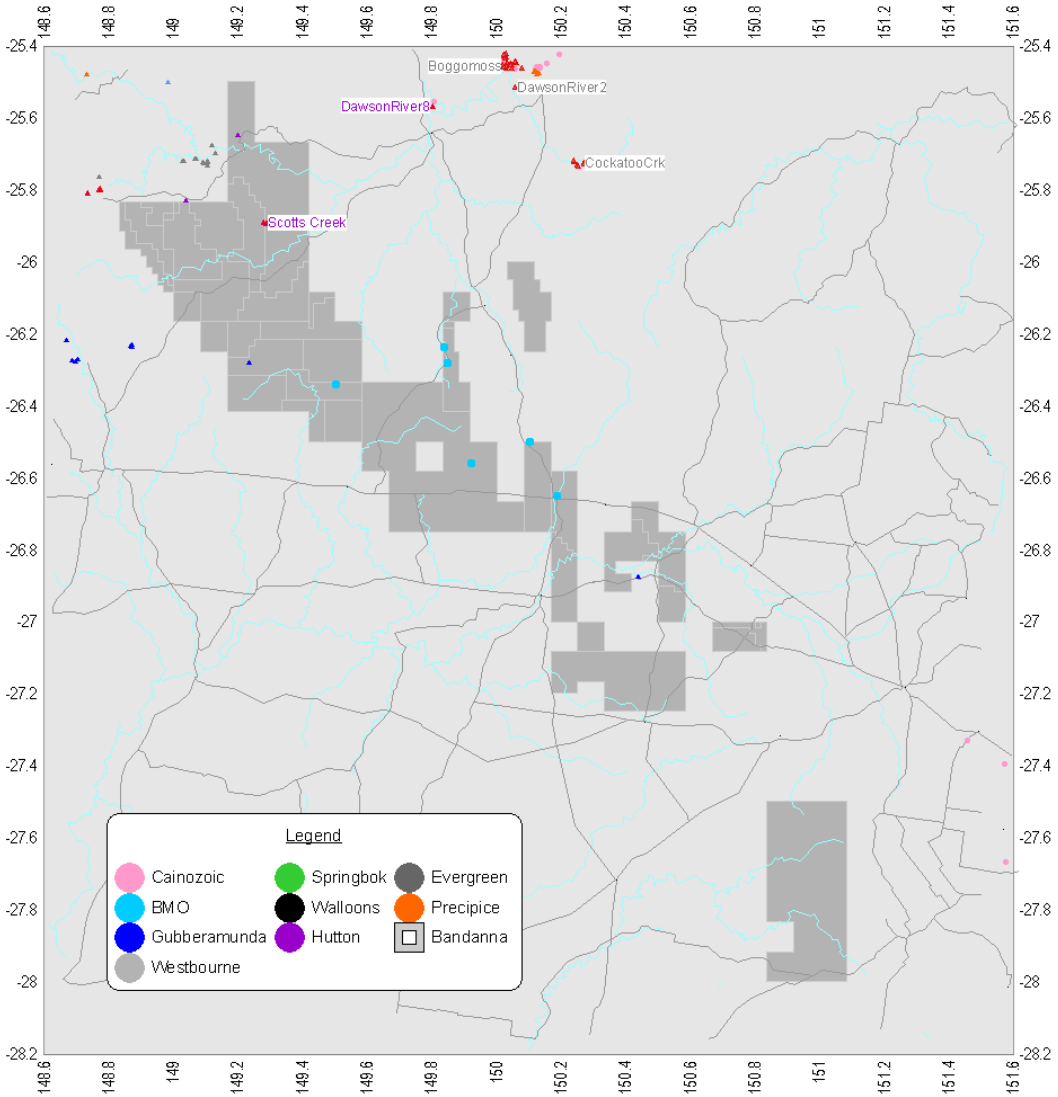
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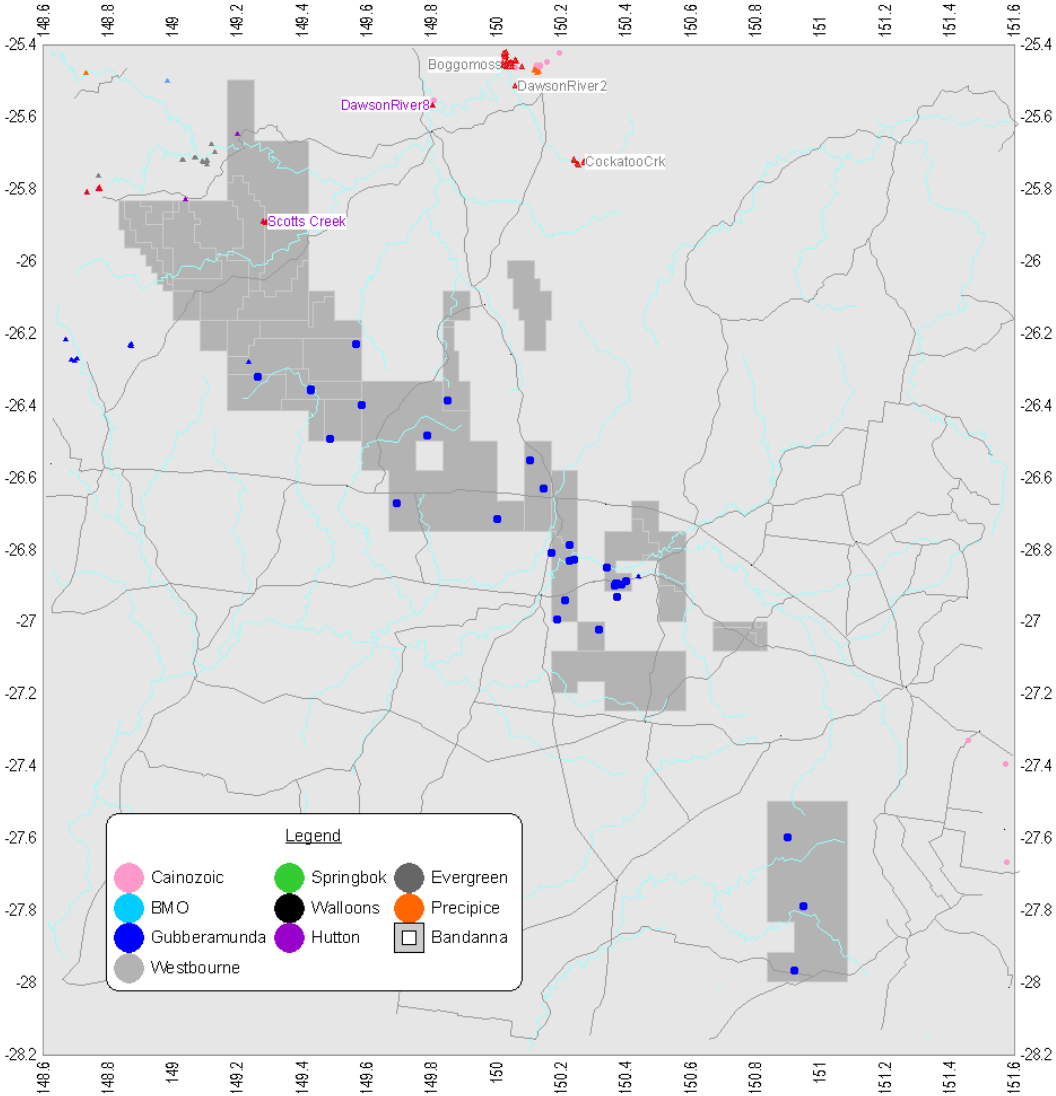
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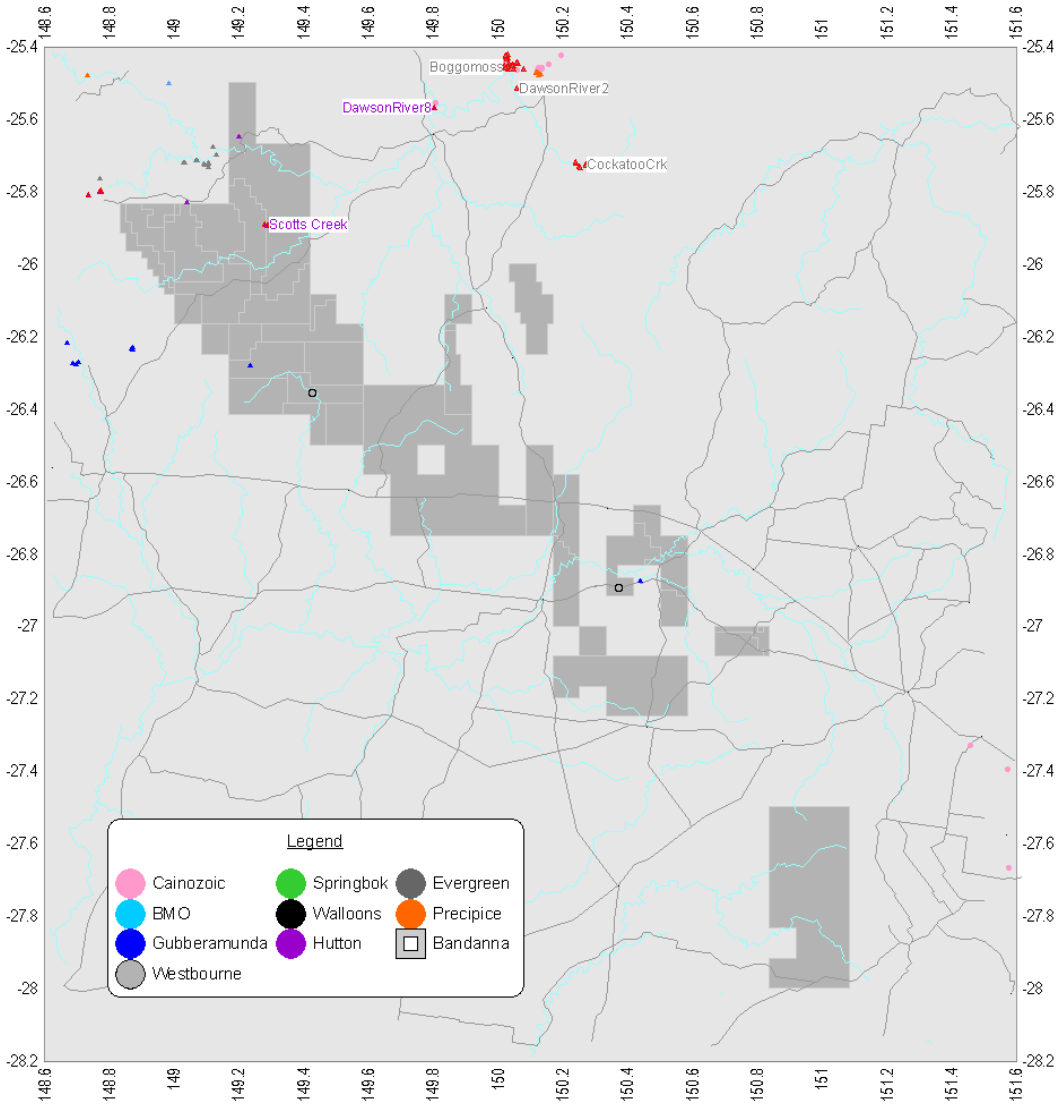
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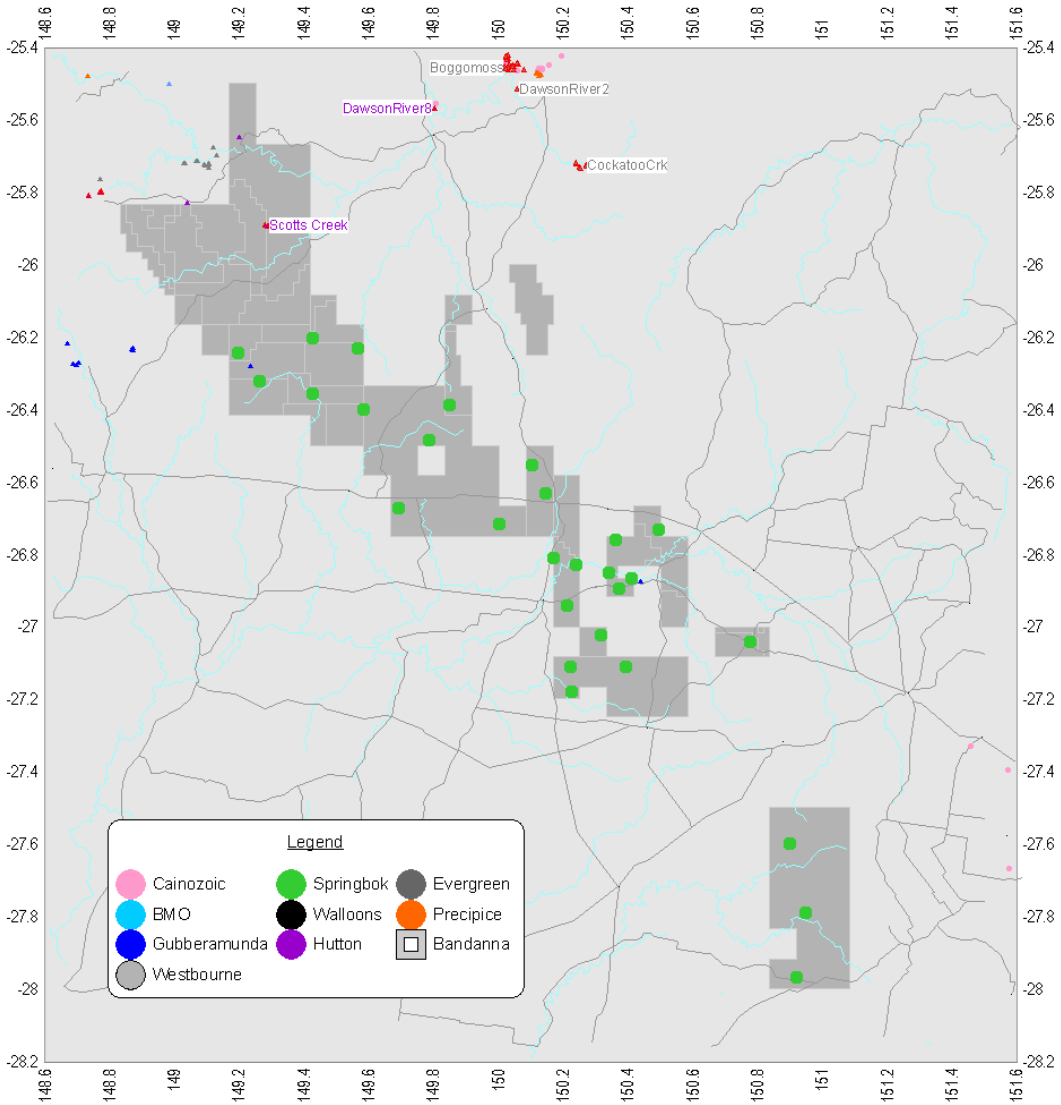
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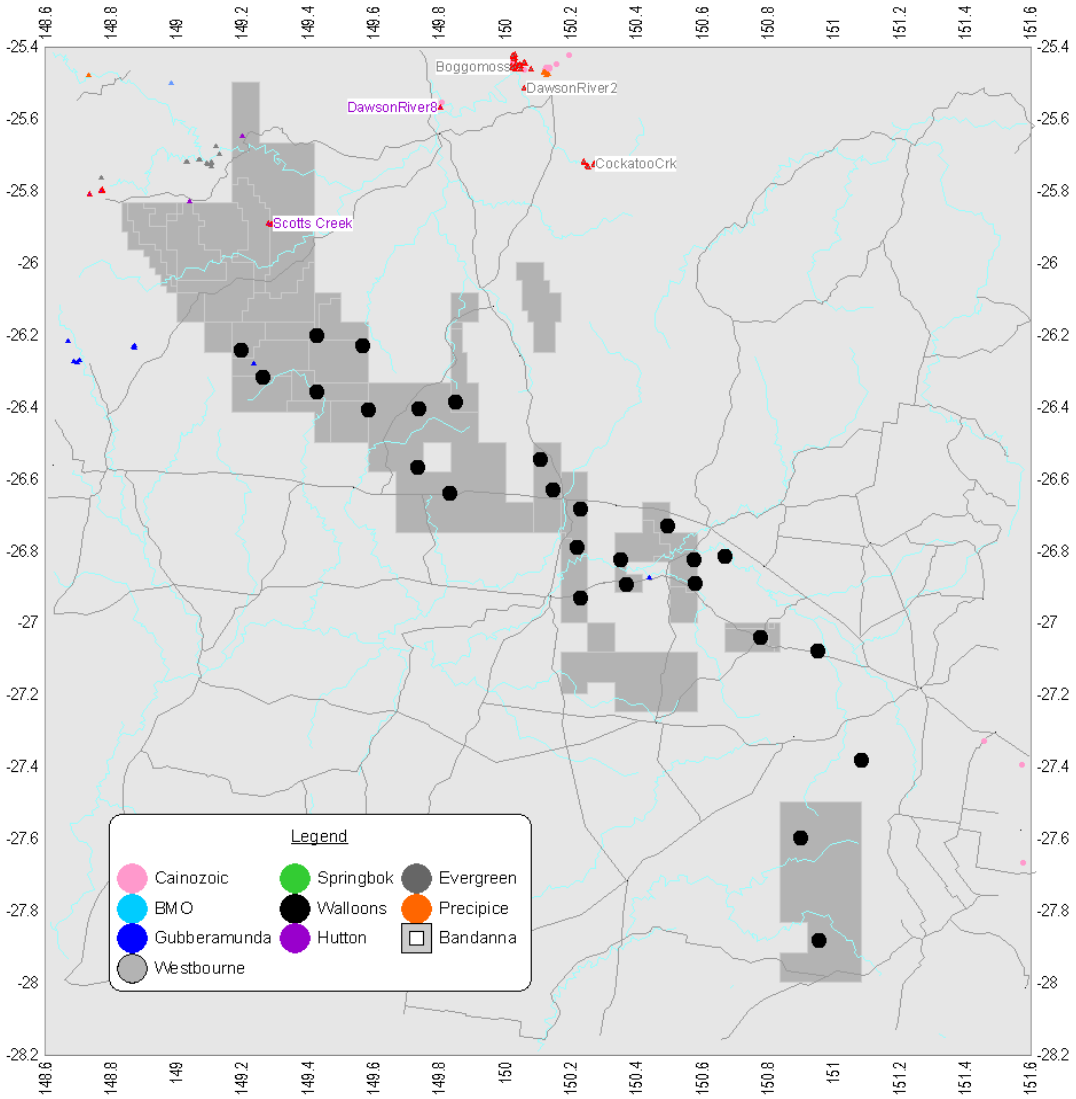
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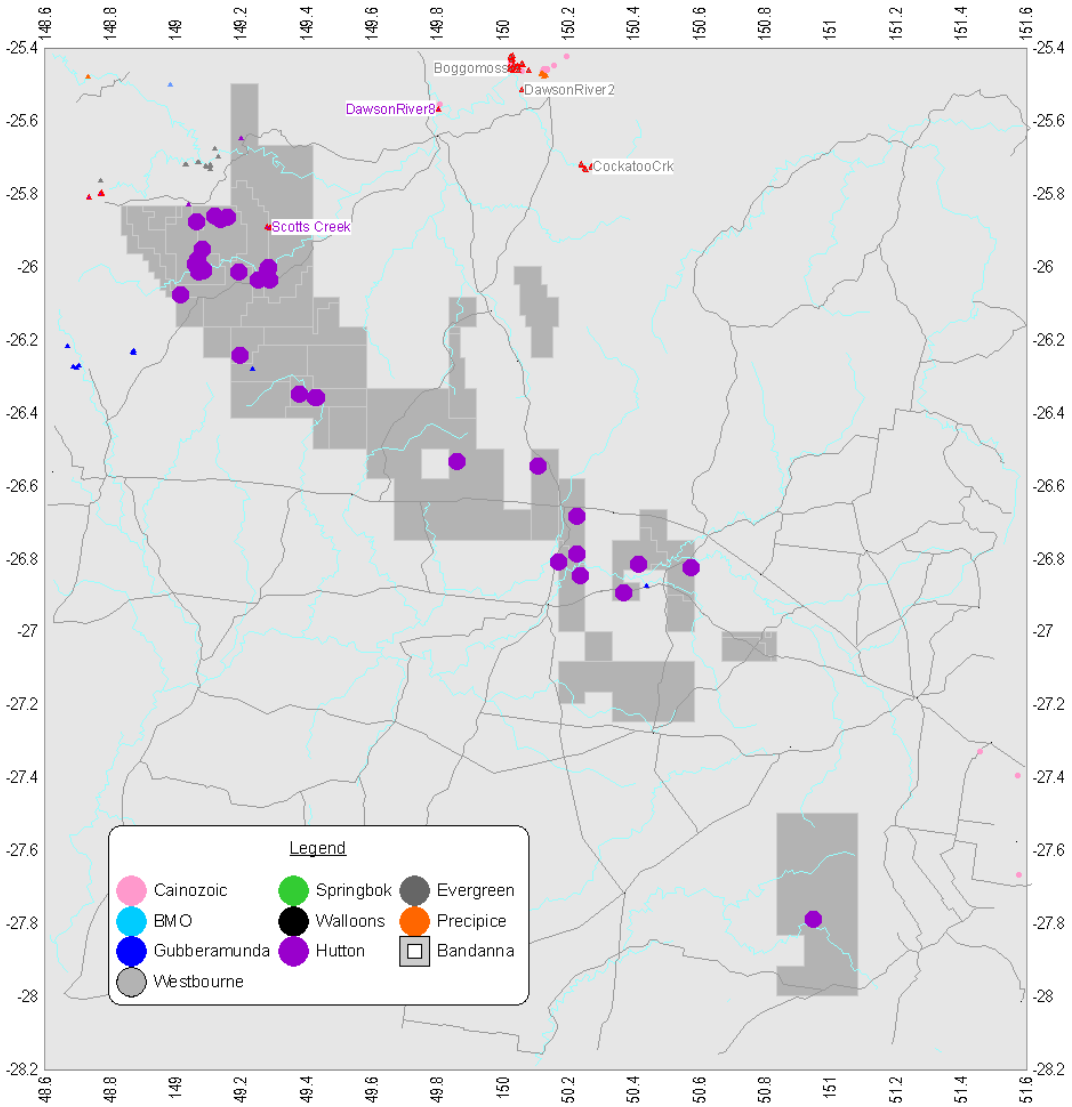
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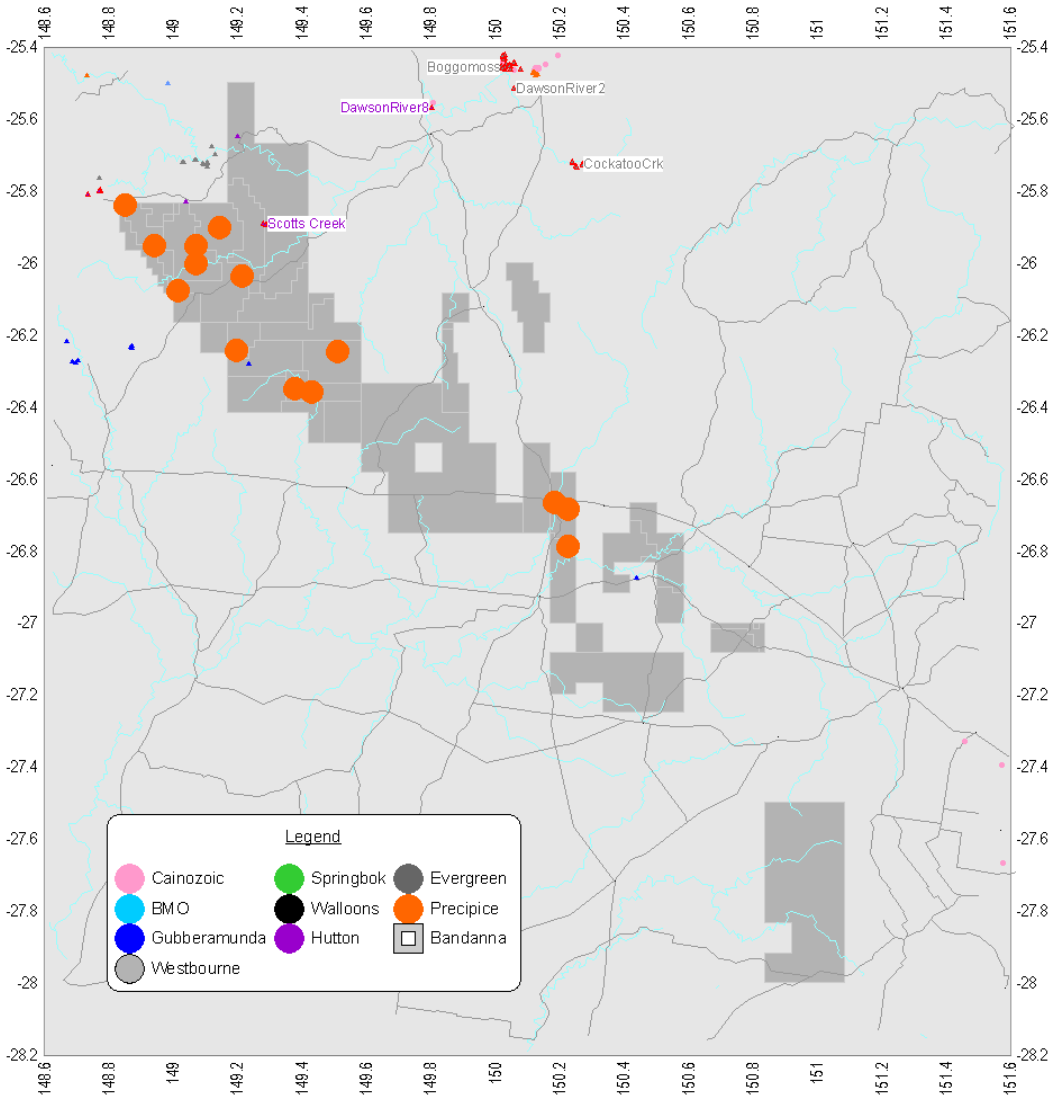
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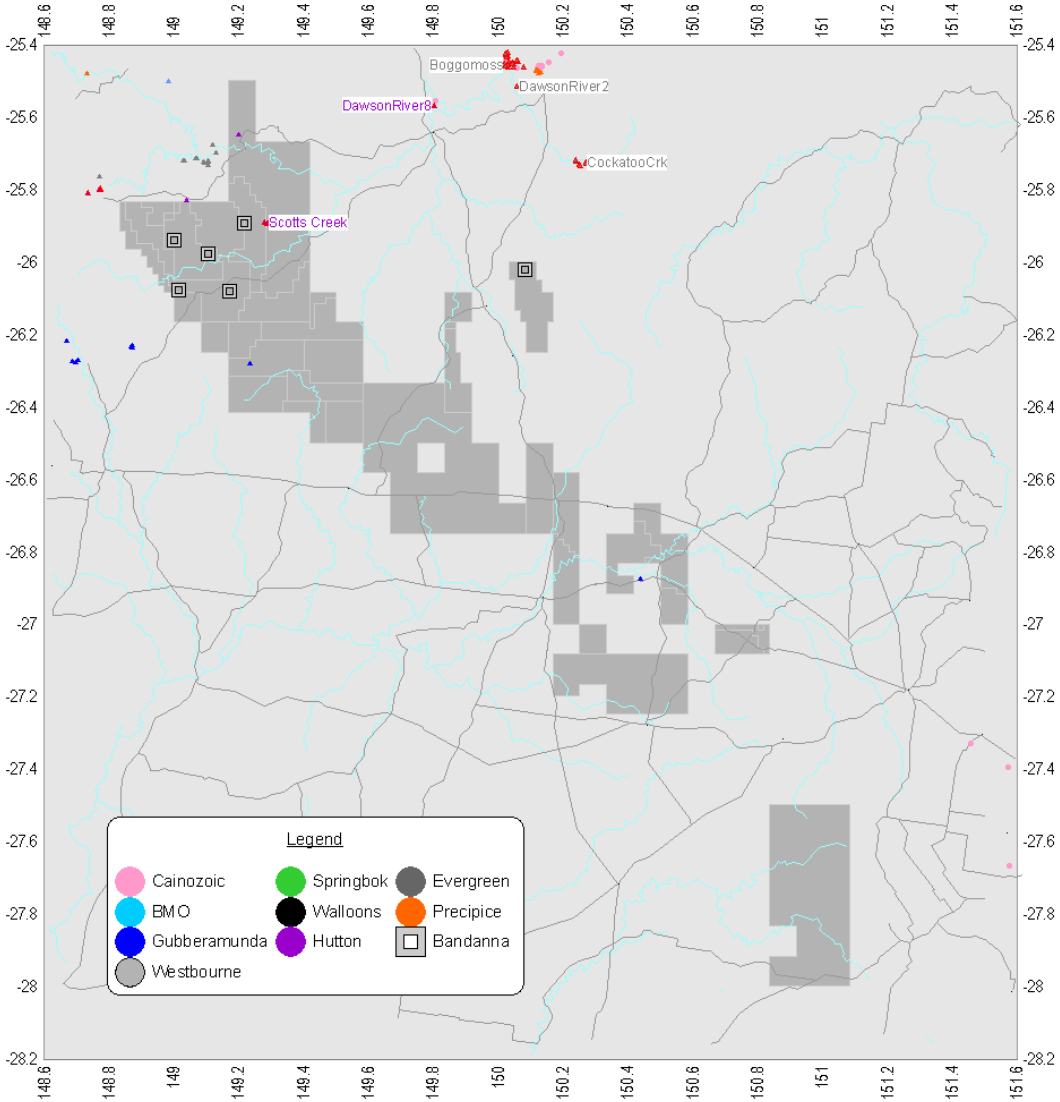
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Scotts Creek
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Gubberamunda
Westbourne
Springbok
Walloons
Hutton
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Precipice
Bandanna

# Appendix C Springs Monitoring, Management and Mitigation Plan (placeholder)



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# Appendix D Modelled Hydrographs for Default Drawdown Trigger Assessment



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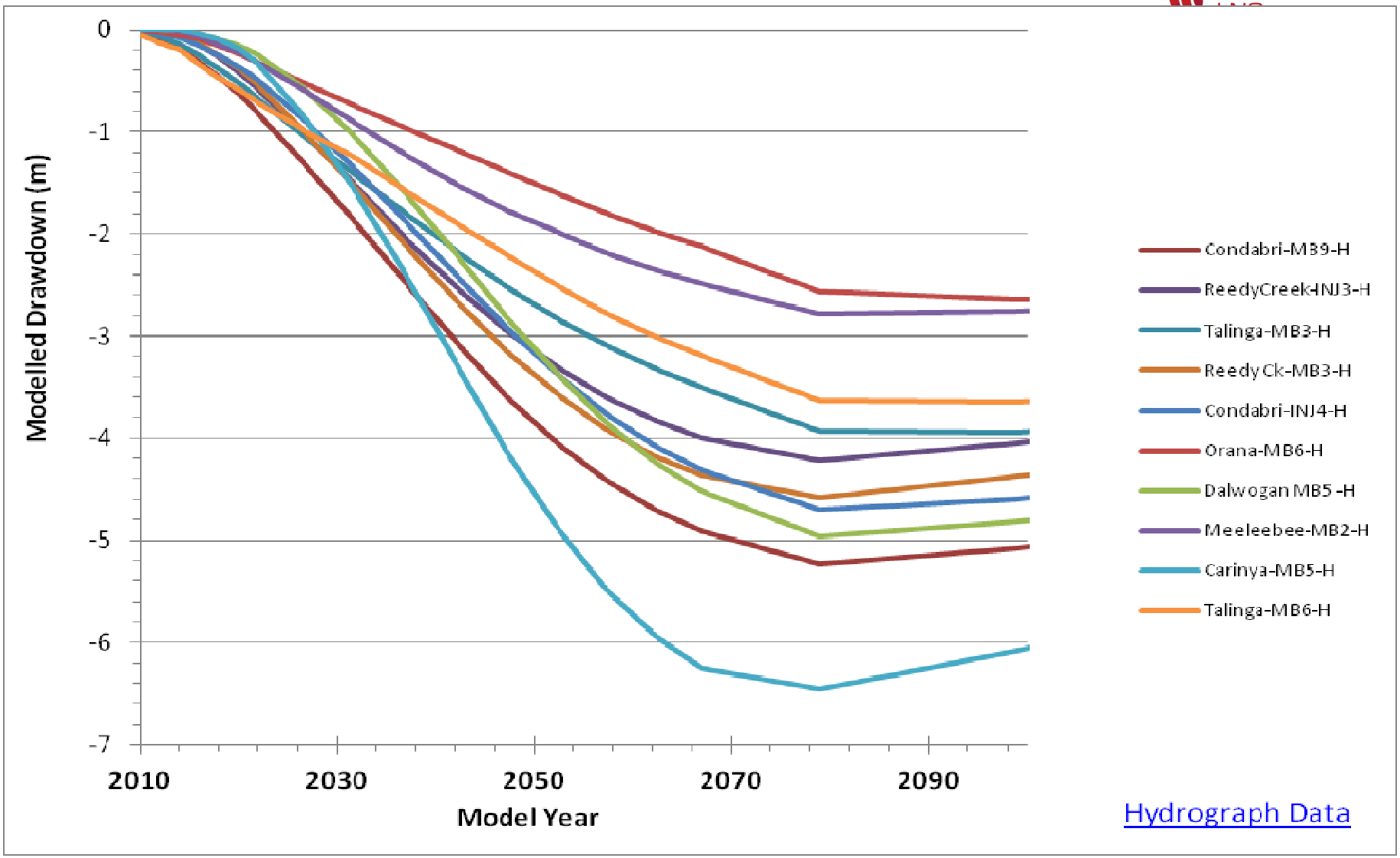




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