Queensland Water Commission

Underground Water Impact Report

for the Surat Cumulative Management Area

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Queensland Water Commission

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Abbreviations

^{o}C	degrees Celsius
3D	three-dimensional
AHD	Australian Height Datum
Arrow	Arrow Energy Ltd
ATP	authority to prospect
CMA	cumulative management area
Commission	Queensland Water Commission
CSG	coal seam gas
dst	drill stem test
EIS	environmental impact statement
EHP	Department of Environment and Heritage Protection
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
DNRM	Department of Natural Resources and Mines
GAB	Great Artesian Basin
km	kilometres
km^2	kilometres squared
m	metres
MDBA	Murray-Darling Basin Authority
MERLIN	Mineral and Energy Resources Location and Information Network
Model	regional groundwater flow model
ML/year	mega litres per year
mm	millimetres
mg/L	milligrams per litre
Origin	Origin Energy Ltd
P&G Acts	*Petroleum and Gas (Production and Safety) Act 2004* and *Petroleum Act 1923*
P&G	petroleum and gas
PEST	Model-Independent Parameter Estimation and Uncertainty Analysis
PH	principal holder

PL	petroleum lease
psi	per square inch
QDEX	Queensland Digital Exploration Reports System
QGC	Queensland Gas Company Pty Ltd
QPED	Queensland Petroleum and Gas Exploration Database
S&D	stock and domestic
Santos	Santos Ltd
SIMS	spring impact management strategy
UWIR	underground water impact report
Water Act	*Water Act 2000*
WMA	water monitoring authority
WMS	water monitoring strategy
WRP	water resource plan

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Overview

Context for this Report

The *Petroleum and Gas (Production and Safety) Act 2004* and *Petroleum Act 1923* authorises petroleum tenure holders to undertake activities related to the exploration for, and production of, petroleum and gas. This authorisation also includes the right to take or interfere with groundwater. However, the *Water Act 2000* establishes responsibilities for petroleum tenure holders to monitor and manage the impacts caused by the exercise of these groundwater rights, including a responsibility to make good impairment of private bore water supplies. Those provisions exist because water is found in association with petroleum and gas and it is not practicable to manage the water separately.

When water is extracted from a gas well, groundwater levels decline in the area surrounding the well. If there are multiple gas fields adjacent to each other, the impacts of water extraction on groundwater levels may overlap. In these situations, a cumulative approach is required for the assessment and management of groundwater level impacts. In Queensland, where this situation exists, a Cumulative Management Area can be established. Within a Cumulative Management Area the Queensland Water Commission is responsible for assessing impacts and establishing integrated management arrangements in an Underground Water Impact Report.

> Petroleum and gas operators have the right to extract groundwater in the process of producing petroleum and gas because the water and the gas are intimately connected. The Surat Underground Water Impact Report forms part of the regulatory framework for managing the impacts of this groundwater extraction.
>
> (see Figure 1.1 on Page 2, Figure 2.2 on Page 6, and Appendix D on Page Apx-11)

In the Surat and southern Bowen Basins, expansion of coal seam gas production is proposed, involving multiple developers adjacent to one another. As a consequence, the Surat Cumulative Management Area was established on 18 March 2011. As required, the Queensland Water Commission has prepared this final Underground Water Impact Report for approval to the Chief Executive of the Department of Environment and Heritage Protection.

On approval, the report becomes a statutory instrument under the *Water Act 2000*. Obligations for individual petroleum tenure holders for activities arising from the Underground Water Impact Report will then become legally enforceable. The Department of Environment and Heritage Protection will be responsible for ensuring petroleum tenure holders comply with their obligations.

Current Groundwater Extraction

Coal seam gas production involves pumping large quantities of groundwater from coal formations to reduce the water pressure in the coal seams, releasing the gas that is attached to the coal. Coal seam gas is produced from the Walloon Coal Measures of the Surat Basin and the Bandanna Formation of the Bowen Basin. These coal bearing formations consist of many thin coal seams separated by low permeability rock. The coal seams collectively make up a small proportion of the total thickness of the coal bearing formations.

The Walloon Coal Measures are a geologic layer of the Great Artesian Basin which comprises layers of lower permeability rocks alternating with aquifers of high economic importance which also feed springs of high ecological and cultural importance.

> The geology of the area consists of multiple layers of rock. Some of the layers transmit water easily and are called aquifers.
>
> (See Figure 6.3 of Page 50)

Much more water is produced during coal seam gas production than during conventional petroleum and gas production. Water production from coal seam gas is currently about 18,000 megalitres per year.

Conventional gas production involves pumping gas from traps in porous rock such as sandstones. Conventional gas operations have reached a mature stage and there are no plans for expansion. Most of the water associated with conventional petroleum and gas production has been extracted from the Great Artesian Basin. Current water extraction is approximately 1,800 megalitres per year and has not significantly exceeded that rate over the past 30 years.

Groundwater in the Cumulative Management Area is primarily used for consumptive purposes such as agriculture, industry, urban, stock and domestic. The total amount extracted for these purposes is some 215,000 megalitres per year. Of this total, about 55,000 megalitres per year is extracted from the Condamine Alluvium, about 85,000 megalitres per year from the Great Artesian Basin aquifers, with the balance extracted from volcanic sediments and deeper formations beneath the Great Artesian Basin.

> Currently water extraction by coal seam producers is approximately 18,000 megalitres per year. This will increase over the life of the industry as outlined in later sections.
>
> Water extraction by non-petroleum and gas users in the Cumulative Management Area is approximately 215,000 megalitres per year.
>
> (see Table 5.1 on Page 40 and Figure 5.2 on Page 43)

Predicted Water Level Impacts

When water is extracted from coal formations, the water from surrounding aquifers will tend to flow into the coal formations. The degree of interconnection between coal bearing formations and surrounding aquifers determines the extent to which water extraction from the coal seams will affect water levels in bores in surrounding aquifers. However, when the water pressure in a coal formation is reduced, the formation is not dewatered but remains saturated. A reduction in water pressure in a confined aquifer will manifest as a decline in the water level in a bore that taps the aquifer.

> When the water pressure in a coal formation is reduced, the formation is not dewatered but remains saturated. A reduction in water pressure in a confined aquifer manifests as a reduction in water level in a bore that taps the aquifer, even though the aquifer remains saturated.
>
> (see Appendix D on Pages Apx-11 to Apx-14)

The Queensland Water Commission developed a regional groundwater flow model to predict the impacts of groundwater extraction by the petroleum and gas activities. The groundwater flow model was developed using existing information about water bores and gas wells and other available information about the way water moves through rocks in the area. The Queensland Water Commission also obtained information from petroleum tenure holders about planned development over the life of the coal seam gas industry as an input to the model. The tenures on which production is planned comprise the 'production area' for the purposes of the report.

The groundwater flow model is large and complex, containing 19 layers and more than three million individual cells. The Queensland Water Commission sought advice from independent experts at key decision points during model construction. The model has been peer reviewed and was found to be a sound model that meets national standards for groundwater flow modelling.

The Immediately Affected Area for an aquifer is the area within which water level impacts are predicted to exceed the trigger threshold within three years.

The Long-term Affected Area for an aquifer is the area within which the impacts are predicted to exceed the trigger threshold at any time in the future.

The trigger thresholds are 5 metres for consolidated aquifers (such as sandstones) and 2 metres for unconsolidated aquifers (such as sand aquifers). A decline in water level in a bore of more than the trigger threshold increases the risk of impairment of water supply from the bore.

Queensland's regulatory framework requires that predicted water level impacts in aquifers be shown as 'Immediately Affected Areas' and 'Long-term Affected Areas'.

The Queensland regulatory framework requires that, for a bore tapping an aquifer in the Immediately Affected Area for the aquifer, a tenure holder enter into a 'make good' agreement with the bore owner on approval of the Underground Water Impact Report.

Immediately Affected Areas

Immediately Affected Areas of any significance will only occur in the coal formations, that is, in the Walloon Coal Measures in the Surat Basin and the Bandanna Formation in the Bowen Basin. There are 85 registered water bores that source water from the Walloon Coal Measures that are located in the Immediately Affected Area for that formation. There are bores that source water from the Bandanna Formation, however, none are located within the Immediately Affected Area for the formation.

There are also very small Immediately Affected Areas in the Precipice Sandstone and Clematis Sandstone caused by conventional petroleum and gas operations. These operations commenced many years ago and maximum impacts in these areas will have essentially already occurred.

In 85 bores it is predicted that the water level decline will exceed the trigger threshold within three years. In total there are 21,000 private water bores in the Cumulative Management Area.

(see Table 6.1 on Page 53 and Figure 6.4 on Page 54)

Long-term Affected Areas

Long-term Affected Areas of significance will exist for the coal formations and for the Springbok Sandstone and the Hutton Sandstone. There are small Long-term Affected Areas for the Precipice Sandstone, Gubberamunda Sandstone and the Clematis Sandstone, including some very small areas associated with long standing conventional petroleum and gas operations.

There are 528 registered water bores that source water from an aquifer within its Long-term Affected Area. Most of the bores tap the Walloon Coal Measures or the Springbok Sandstone, with a small number tapping the Hutton Sandstone.

> In 528 bores it is predicted that the water level decline will exceed the trigger threshold in the long-term. In total, there are 21,000 private water bores in the Cumulative Management Area.
>
> (see Table 6.2 on Page 55 and Figure 6.5 on Page 57)

Further detail about the extent of long-term predicted impacts, in the absence of any reinjection of treated coal seam gas water into aquifers, or similar measures, are as follows:

Walloon Coal Measures

- This is the target coal seam gas formation in the Surat Basin.
- For most of the impacted area, the long-term impact is expected to be less than 150 metres. Within the production area, the magnitude of impact reflects the depth of the top of the coal formation because operational practice for coal seam gas production is to lower the pressure in the coal seams to approximately 35 to 40 metres above the top of the uppermost coal seam. As a result in the more westerly areas, where the coal formation is deep, the pressure reduction is expected to be large.
- There are 400 private water bores that source water from the formation in its Long-term Affected Area. Most of these are located further to the east where the formation is shallow and impacts are smaller. Half of the affected bores are expected to experience an impact of less than 21 metres.

Bandanna Formation

- This is the target coal seam gas formation in the Bowen Basin.
- For most of the impacted area the long-term impact is expected to be less than 200 metres. As for the Walloon Coal Measures pressure reduction will be greater in areas where the coal formation is deep. However in areas where private bores tap the formation the impacts are expected to be much smaller.
- There are no bores that source water from the formation in its Long-term Affected Area.

Springbok Sandstone

- This aquifer overlies the Walloon Coal Measures. For the most part, the aquifer is separated from the productive coal seams by an upper, low permeability layer of the Walloon Coal Measures, although this layer is thin or absent in some areas.
- Over most of the affected area the maximum impact is expected to be less then 20 metres, although there is a small area south of Miles where impacts are expected to reach 90 metres.

- There are 104 bores that source water from the formation in its Long-term Affected Area. It is expected that the impact will not exceed 20 metres in any of those bores and to be less than 10 metres in more than half of them.

Hutton Sandstone

- This aquifer underlies the Walloon Coal Measures. It is separated from the productive coal seams by a low permeability layer of the Walloon Coal Measures.

- Over most of the affected area the maximum impact is expected to be less then 5 metres, although there are small areas where maximum impacts may reach 18 metres.

- There are 23 private bores that source water from the formation in its Long-term Affected Area. The maximum impact in any bore will be 13 metres but more than half of the bores will experience an impact of less than 7 metres.

Precipice Sandstone

- Over most of the Long-term Affected Area the maximum impact is expected to be less than 2 metres. North of Roma where the aquifer is in direct contact with the Bandanna Formation the maximum impact may reach 10 metres. Near Moonie, there are also small areas of local impact where conventional petroleum and gas is currently being produced directly from the formation.

- There are no private bores that source water from the formation in its Long-term Affected Area.

Gubberamunda Sandstone and Mooga Sandstone

- These are shallow aquifers that are not well connected to the coal formations. Generally, impacts will be less then 3 metres and only small areas will be affected.

- There is one bore that sources water from the Gubberamunda Sandstone in its Long-term Affected Area. The impact in that bore is expected to be 5 metres.

Clematis Sandstone

- There are small areas where impacts of up to 2 metres are expected. Near Moonie, there are also very small areas of local impact where conventional petroleum and gas is currently being produced directly from the formation.

- There are no private bores that source water from the formation in its Long-term Affected Area.

Impacts in the Condamine Alluvium

It is predicted that the net change in flow from the Condamine Alluvium to the underlying Walloon Coal Measures will average 1,100 megalitres per year over a 100-year period. In the absence of any measures such as reinjection of treated water into the Alluvium, the maximum impact on water levels is predicted to be 1.2 metres in a small area on the western edge. Over most of the area the maximum impact is predicted to be approximately 0.5 metre. Because predicted impact on water levels does not exceed the trigger threshold of 2 metres, there is no Immediately Affected Area or Long-term Affected Area for the Condamine Alluvium.

It is predicted that there will be some leakage of water from the Condamine Alluvium but the resulting decline in water levels will be less than the trigger threshold of 2 metres. Therefore there is no Immediately Affected Area or Long-term Affected Area for the Condamine Alluvium.

(see Page 56)

Timing of Impacts

For any affected aquifer, maximum impacts will occur at different times depending on the sequence of coal seam gas development and due to the slow movement of water. Maximum impacts in the coal formations will occur toward the end of the life of the industry, and generally between 2030 and 2050. Maximum impacts in the Springbok Sandstone and Condamine Alluvium are expected to occur between 2060 and 2070. In the more remotely connected aquifers, where the predicted impacts are small, impacts will occur later.

In the absence of any re-injection of treated coal seam gas water into affected aquifers, or of similar measures, recovery of water levels will commence after maximum impact occurs, with the recovery rate slowing with time. For the Walloon Coal Measures, the Springbok Sandstone and the Condamine Alluvium, it is predicted there will be 50 per cent recovery, 30 to 80 years after maximum impact.

Predicted Water Extraction

The average volume of water produced by petroleum tenure holders over the life of the industry is predicted to be approximately 95,000 megalitres per year. The volume produced will be larger early in the life of the industry and reduce over time.

Water Monitoring Strategy

The Underground Water Impact Report includes a Water Monitoring Strategy. The Strategy specifies an integrated regional monitoring network for both water pressure and basic water quality. The network of monitoring bores will provide data to verify that impacts are emerging as predicted by the regional groundwater flow model. The monitoring data will also provide information that will contribute to improving the understanding of the way in which water moves through and between aquifers. This information will be incorporated into future generations of the model.

The regional monitoring network incorporates and builds on existing monitoring bore networks. It utilises existing monitoring bores managed by the Department of Natural Resources and Mines as well as monitoring bores that have been established by individual petroleum tenure holders. Petroleum tenure holders are required to establish an additional 392 monitoring points to comprise the regional network of 498 monitoring points at 142 monitoring sites. At many geographic locations (or monitoring sites) monitoring points will be established in several aquifers at different depths. Petroleum tenure holders will construct and operate individual parts of the monitoring network and report results to the Queensland Water Commission.

For the regional monitoring network there will be 142 monitoring sites comprising 498 monitoring points. Of these monitoring points, 106 already exist and 392 will be newly constructed.

(see Table 7.1 on Page 64)

The *Water Act 2000* requires that petroleum tenure holders carry out baseline assessments of private water bores before production commences. The *Water Act 2000* also requires that the Water Monitoring Strategy in the Underground Water Impact Report include a program for carrying out baseline assessments of affected water bores in the Long-term Affected Areas.

Baseline assessments establish details about water bores to assist petroleum tenure holders and bore owners develop agreements about making good impairment of bore supply resulting from water extraction by petroleum and gas operations. These assessments are best carried out close to the time when impairment is expected to begin occurring. As a result, the Water Monitoring Strategy requires petroleum tenure holders to carry out the assessments where impacts of more than 1 metre are predicted within three years. The area covered by baseline assessments will grow each time the Underground Water Impact Report is revised to eventually cover the entire Long-term Affected Areas.

The Water Monitoring Strategy requires petroleum tenure holders to carry out baseline assessments where impacts of more than 1 metre are predicted within three years.

(see Figure 7.4 on page 68)

Spring Impact Management Strategy

The Underground Water Impact Report includes a Spring Impact Management Strategy. Springs with significant cultural and ecological values fed by Great Artesian Basin aquifers exist in the area.

Individual spring vents are often found in close geographic and hydrologic association. Such a group is termed a ‘spring complex’. The Queensland Water Commission carried out a field survey of Great Artesian Basin springs. There are 71 spring complexes comprising 330 individual spring vents within the Surat Cumulative Management Area. Some of these springs contain species listed under the *Environment Protection and Biodiversity Conservation Act 1999* and the *Nature Conservation Act 1992*. There are also 43 ‘watercourse springs’ which are sections of watercourse fed by spring flow.

It is predicted that at five sites, water level impacts in the source aquifer feeding water to the spring will exceed 0.2 metre in the long term. The predicted maximum impact in the source aquifer at any spring location is 1.3 metres. Tenure holders are required to assess mitigation options at the five sites and report these outcomes to the Queensland Water Commission. Options to be assessed include: working with willing landholders to reduce existing bore impacts to offset impacts from coal seam gas water extraction; re-injecting treated water into source aquifers; and managing the water extraction regime to reduce impacts. Appropriate implementation action will be considered after options are evaluated. Tenure holders are also required to monitor conditions in springs.

There are 71 spring complexes in the Cumulative Management Area. It is predicted that in the long term the impact on water levels in the source aquifer for the spring will exceed 0.2 metre at 5 of these sites. Tenure holders are required to assess mitigation options at the 5 sites and report these outcomes to the Queensland Water Commission.

(see Table 8.4 on Page 77)

Responsible Tenure Holders

The *Water Act 2000* establishes obligations for petroleum tenure holders to 'make good' impairment of private bore supplies that result from water extraction. This action might be achieved by making alterations to the bore, by establishing a replacement water supply or by some other measure.

However, within the Cumulative Management Area operations by multiple tenure holders can contribute to the impairment. The Underground Water Impact Report establishes arrangements for an individual petroleum tenure holder to be identified as the responsible tenure holder for these 'make good' obligations.

The Underground Water Impact Report also requires that tenure holders carry out specific activities, such as water monitoring, called 'report obligations'. The Underground Water Impact Report establishes arrangements for an individual petroleum tenure holder to be responsible for specific parts of these integrated programs.

> Individual petroleum tenure holders within the Cumulative Management Area are assigned individual responsibilities for activities such as monitoring.

The general approach taken in assigning these obligations is that within the production area the holder of the petroleum tenure is the responsible tenure holder for the obligations on the land covered by the tenure. For activities outside the production area, the holder of the petroleum tenure within the production area that is closest to the location of the required activity is the responsible tenure holder for the activity.

Reporting and Review

In accordance with Queensland's regulatory framework, the Queensland Water Commission will prepare an annual report on the implementation of the Underground Water Impact Report. These reports will summarise monitoring results and assess if there is any new information that would indicate a significant change to predicted impacts.

The Underground Water Impact Report will be revised every three years. It is intended that the regional groundwater flow model will be updated to incorporate new knowledge as the basis for the revision.

On an ongoing basis the Queensland Water Commission will undertake and promote research to build new knowledge to support the next generation of regional groundwater flow modelling and the next revision of the Underground Water Impact Report. Collaboration is being sought with research bodies, universities and petroleum companies to achieve the best outcomes in an efficient manner.

> The Queensland Water Commission will report annually, continue to undertake and promote research to improve knowledge, and update the model and the Underground Water Impact Report every three years to incorporate new knowledge.

1. Introduction

1.1 Water Rights

Petroleum is a legislative term that includes oil, conventional gas and coal seam gas (CSG). A general term 'petroleum and gas' is used in this report to collectively refer to conventional gas and CSG.

The *Petroleum and Gas (Production and Safety) Act 2004* and the *Petroleum Act 1923* (P&G Acts) authorise petroleum tenure holders to undertake activities related to exploration for and production of petroleum. This authorisation also includes the right to take or interfere with groundwater. However, the *Water Act 2000* (Water Act) establishes responsibilities for petroleum tenure holders to monitor and manage the impacts caused by the exercise of their water rights, including a responsibility to make good impairment of private bore water supplies. Those provisions exist because water is found in association with petroleum and it is not practicable to manage the production of petroleum and water separately.

1.2 Cumulative Management

When water is extracted from a gas well, the groundwater levels fall in the area surrounding the well. Where a petroleum well field is established, the impacts extend laterally beyond the extent of the well field. If there are multiple well fields adjacent to each other, the impacts of water extraction from the fields on water levels will overlap. In these situations, a cumulative approach is required for the assessment and management of water level impacts.

The Queensland regulatory framework provides that an area of concentrated petroleum development where there are likely to be overlapping impacts on water levels from multiple petroleum operations, can be declared a cumulative management area (CMA). In those areas, the Queensland Water Commission (Commission) is responsible for:

- predicting the regional impacts on water levels;
- developing appropriate water monitoring and spring management strategies; and
- assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies.

The regulatory framework provides that the Commission set out these assessments, strategies and responsibilities in an underground water impact report (UWIR).

The Surat CMA was established on 18 March 2011. It covers the area of planned CSG development in the Surat Basin and the southern Bowen Basin. The extent of the Surat CMA is shown in the location map in Figure 1-1. The Commission is responsible for preparing this draft UWIR, seeking public comments on the draft report and finalising the report. The final report must be submitted to the chief executive of the Department of Environment and Heritage Protection (EHP) by 18 July 2012.

1.3 Surat Underground Water Impact Report

The Commission undertook a range of technical investigations and assessments to support the development of the UWIR. These include:

- a compilation of current understanding about the hydrogeology of the area in and around the Surat CMA;
- development of a regional groundwater flow model (the regional model) for making predictions of groundwater impacts from the petroleum and gas activities and for developing the Water Monitoring Strategy (WMS) and the Spring Impact Management Strategy (SIMS);
- a sophisticated analysis of uncertainty in model predictions;

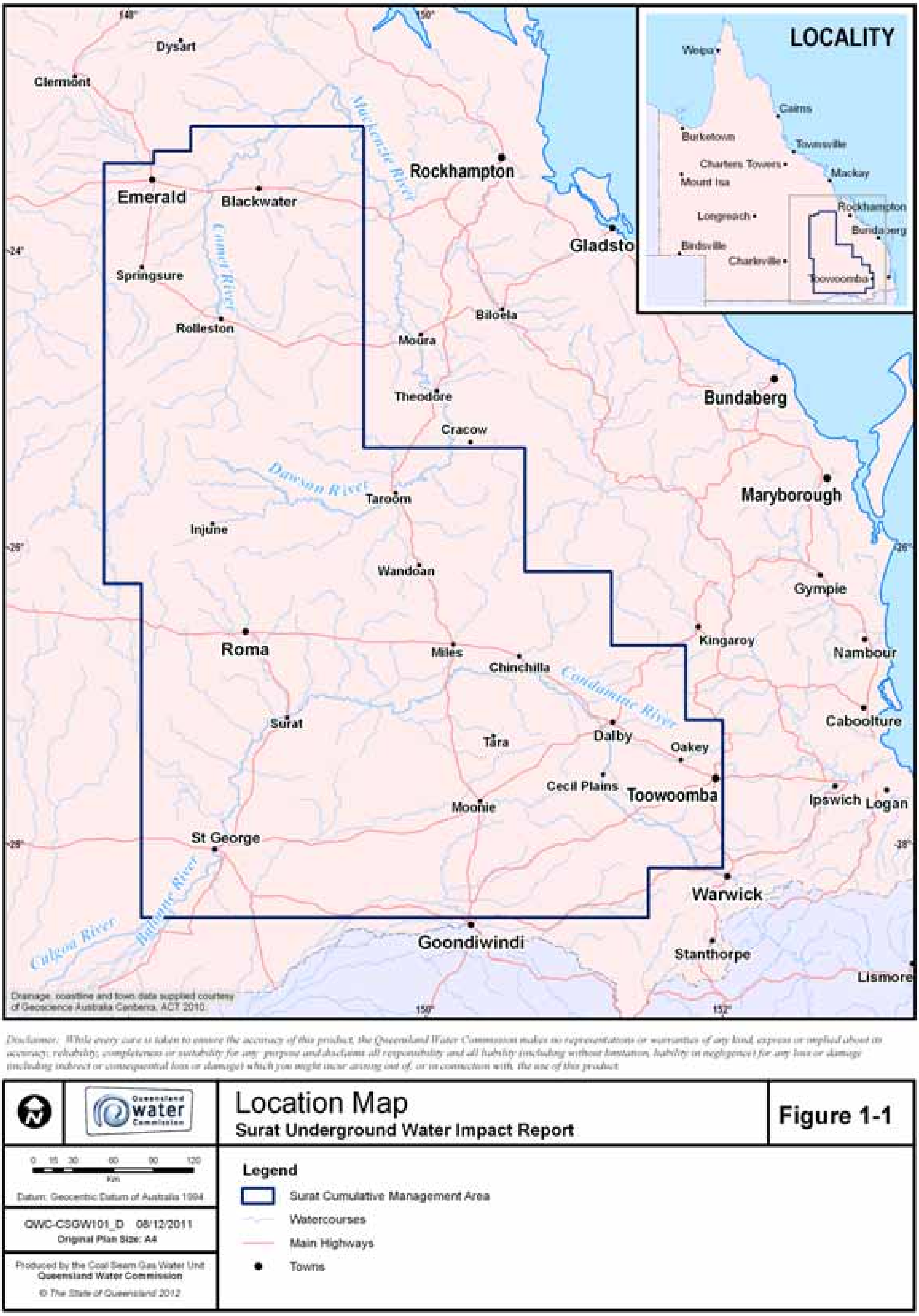

Figure 1-1 Location Map

- a comprehensive survey of the relevant springs in the CMA for their hydrogeological and ecological attributes; and
- an inventory of all existing and proposed monitoring bores and activities in the CMA.

A number of focused technical reports have been prepared to document these investigations. These reports have directly contributed to development of this UWIR and can be made available upon request to the Commission. The UWIR itself has been prepared as a stand-alone report with a view to providing understanding to a broad range of stakeholders.

The initial chapters of the report (Chapters 2 to 5) provide the necessary contextual background. This contextual background was used to construct the regional model, develop the groundwater extraction scenario used for making predictions and to develop the WMS and SIMS. Chapter 2 provides an overview of petroleum and gas tenures and associated activities in the Surat CMA. Chapters 3 and 4 summarise the hydrogeology of the area while Chapter 5 summarises historical and current groundwater extraction.

Chapter 6 describes the techniques and methods used for making groundwater impact predictions and key aspects of the construction of the regional model. It also provides maps showing the areas over which impacts on water levels are predicted to exceed statutory trigger thresholds in the short and long-term.

Chapter 7 specifies the WMS. This strategy outlines the regional monitoring network necessary for on-going assessment of groundwater impacts from CSG activities and for improving our understanding of the groundwater system. The network integrates, wherever possible, existing monitoring works and monitoring works currently proposed by petroleum tenure holders. The strategy requires petroleum tenure holders to implement and maintain the regional monitoring network and regularly report the results to the Commission.

Chapter 8 specifies the SIMS. It explains the work the Commission has undertaken to identify springs and assess the risk to those springs resulting from water extraction. It specifies appropriate spring management actions to be implemented by petroleum tenure holders.

Chapter 9 assigns various responsibilities to individual petroleum tenure holders. The Water Act specifies the circumstances under which petroleum tenure holders need to investigate impairment of private bore supplies and develop make good agreements with bore owners about the impairment. The chapter specifies how a responsible petroleum tenure holder is determined for those obligations. It also specifies the petroleum tenure holders responsible for specified parts of the WMS and the SIMS.

Chapter 10 provides information about reporting and evaluation. The Commission will periodically reassess predicted water level impacts based on emerging knowledge and provide reports accordingly. It will further develop the model and prepare a new UWIR every three years. This chapter also specifies the focus areas for future research that the Commission will lead to improve knowledge in cooperation with research bodies and petroleum tenure holders.

1.4 Implementation of Surat Underground Water Impact Report

Following public submissions on the draft UWIR, the Commission will submit a final report to the chief executive of EHP. On approval, the report becomes a statutory instrument under the Water Act. Obligations for individual petroleum tenure holders, as assigned in Chapter 9, will then become legally enforceable. EHP will be responsible for compliance.

1.5 Inter-jurisdiction Interaction

Some petroleum projects require approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Commission has carried out work supporting the preparation of the UWIR in consultation with relevant Commonwealth agencies, with a view to providing the opportunity for project proponents to use on Commission outputs to meet their obligations to the Commonwealth under their conditions of approval. Compliance with the Commonwealth requirements is ultimately a matter for project proponents and the Commonwealth.

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2. Petroleum and Gas Production

This chapter provides an overview of how petroleum and gas is produced and the different types of petroleum and gas tenures that exist within the CMA. The chapter also provides an overview of existing petroleum and gas activities and the proposed future expansion to other tenures. The Commission has used this information to develop:

- an appropriate approach to modelling;
- a development scenario for making predictions about the CSG water extraction and groundwater level impacts; and
- responsible tenure holder arrangements for the various obligations specified in this report.

2.1 Petroleum and Gas Production and Methods

Historically, petroleum and gas have been produced by conventional production methods from porous rock formations. More recently, gas has been produced from coal seams. Gas produced by conventional methods is referred to as conventional gas, while gas produced from coal seams is referred to as CSG.

There are significant differences between conventional production and CSG production in terms of the water that is extracted. With CSG production, the gas resource is distributed over a relatively large area and the water pressures have to be significantly reduced (referred to as 'depressurisation' of the coal seam) in order to allow the gas to flow towards the production well. Water production peaks early in the life of the production well. The amount of water produced tends to be large in comparison to conventional gas production, and can vary substantially between different gas fields.

2.1.1 Conventional Petroleum and Gas Production

Conventional petroleum and gas is found in porous rock formations such as sandstone. Gas and other petroleum products that form over a long geologic timeframe move through the porous formation, in a generally upward direction, until a trap stops the movement and concentrates the hydrocarbons. The trap could be dome-shaped at the boundary between the permeable rock layer and an overlying impermeable rock layer, or it may be a faulted structure in the rock that has the same effect. As the gas concentrates, the porous rock becomes a gas reservoir. Gas is produced by drilling a well into the reservoir. As there tends to be water in the reservoir under the gas, the production well usually pumps a mixture of water and gas.

The number of production wells is relatively small, as the gas tends to be localised and able to move relatively easily though the porous reservoir rock towards the production well. In addition, although water is produced in association with the gas, there is no need to lower water pressure over large areas to produce the gas. Although the volume of water produced in conventional petroleum and gas production varies, it is generally much smaller than for CSG production.

2.1.2 Coal Seam Gas Production

CSG, comprised mostly of methane, is adsorbed onto the surface of coal particles along fractures and cleats and is held in place by water pressure. The coal then acts as both the source and the reservoir for the gas.

The gas is extracted by drilling a well into the coal formation and pumping water from the well to commence depressurising the coal formation. Initially, just water is produced but as depressurisation is progressively achieved the proportion of gas relative to water slowly increases. Figure 2-1 shows diagrammatically gas and associated water production for a typical CSG well. Water and gas flowing together toward a gas well is known as dual phase flow (Morad et.al. 2008). A typical relationship is demonstrated in Figure 2-2.

Water pressure in the coal formation is typically lowered to within 35 m to 40 m of the uppermost coal seam by pumping water from the gas wells. Typically it takes about three to five years of pumping to gradually lower the water pressure to this level. Water pumping continues at the rate necessary to maintain water pressure at the target level until gas production declines to non-economic levels.

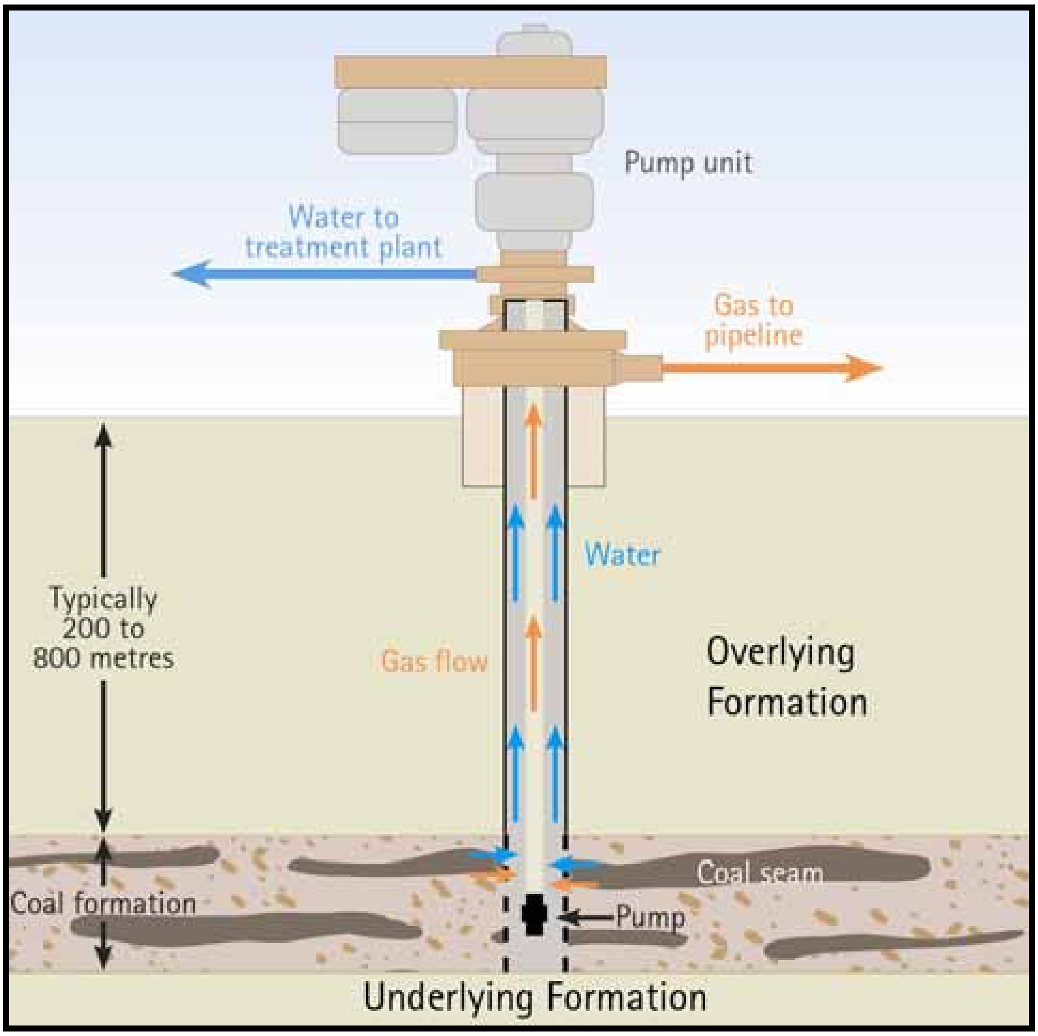

Figure 2-1 Schematic of Coal Seam Gas Well

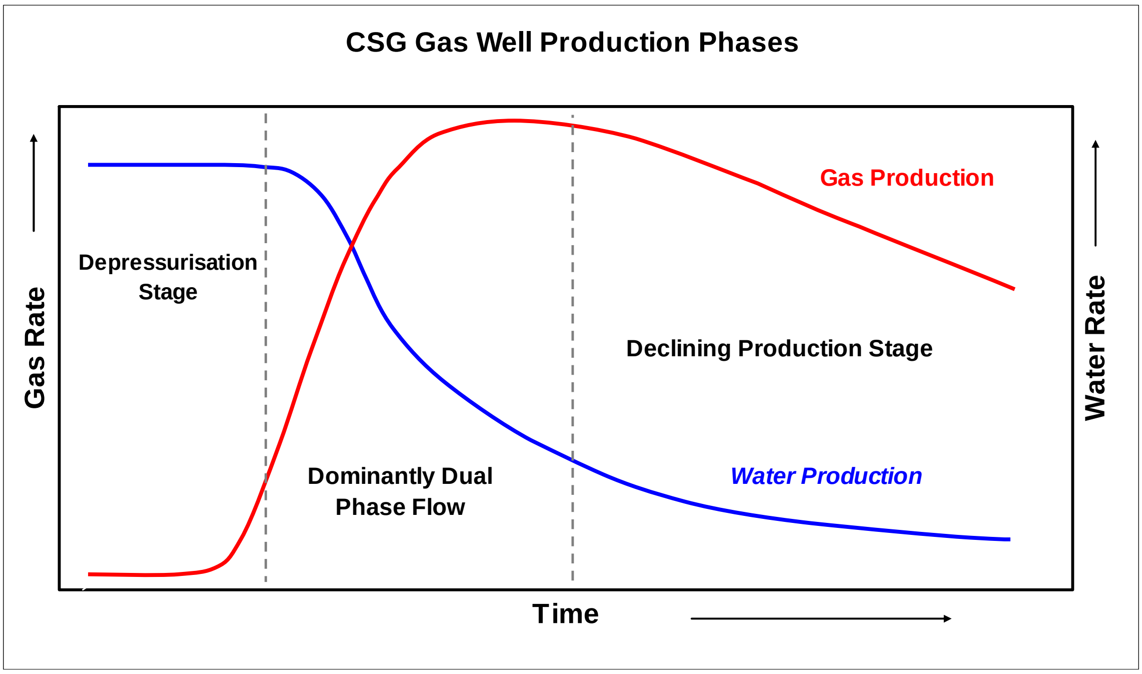

Figure 2-2 A Typical Gas and Water Flow in Coal Seam Gas Production

2.2 Types of Tenures and Authorities

2.2.1 Petroleum Tenures

The P&G Acts specify a number of authorities that can be granted for activities related to the exploration for, and production of, petroleum and gas. The activities of relevance for the UWIR relate to authorities that provide the holder with the right to take or interfere with groundwater during the course of carrying out authorised activities. The relevant authorities are the authority to prospect (ATP) and the petroleum lease (PL).

The P&G Acts refer to ATPs and PLs collectively as petroleum tenures. Petroleum tenures relate to a specific area of land generally described in terms of blocks and sub-blocks. Each block is approximately 75km² and each sub-block is approximately 3km².

An ATP provides the holder with the right to explore for petroleum resources. That right includes drilling test wells to evaluate or test natural underground reservoirs for the petroleum resources; carrying out test production; and taking groundwater in the course of carrying out authorised activities.

The holder of an ATP may apply for a PL if a commercially viable petroleum resource is discovered. The application must be accompanied by a proposed initial development plan. That plan gives detailed information about the nature and extent of activities proposed to be carried out. A PL authorises the holder to: carry out production testing; produce petroleum within the tenure area; and take groundwater in the course of carrying out authorised activities. A PL can be granted for up to 30 years, with potential for renewal. Water extraction must be reported to the Department of Natural Resources and Mines (DNRM).

The P&G Acts provide that a petroleum tenure cannot be granted unless an environmental authority has been issued under the *Environmental Protection Act 1994.*

The entity that holds a petroleum tenure is referred to as a petroleum tenure holder. The entity may be an individual or an entity under the *Corporations Queensland Act (1990)*, or a government owned corporation. As tenures are often held as joint ventures, DNRM assigns a single entity as the 'principal holder' (PH) when it grants an ATP or PL. The PH is the primary contact for the petroleum tenure and is legally responsible for dealing with served notices and other documents. All obligations identified for a petroleum tenure holder under this UWIR are in terms of the PH.

DNRM records all mining and petroleum tenure information in a database called the Mineral and Energy Resources Location and Information Network (MERLIN). General petroleum tenure holder information stored in this database is publicly accessible. Information relating to petroleum test and production wells and water production is recorded in the Queensland Digital Exploration Reports System (QDEX) managed by the Geological Survey of Queensland. The majority of this information is also publicly available.

2.2.2 Water Monitoring Authority

A petroleum tenure holder can have obligations to carry out activities such as monitoring on lands other than those over which that holder has tenure. For example, the WMS specifies monitoring activities for individual tenure holders in areas outside the tenure area.

To deal with these situations the P&G Acts provide that a petroleum tenure holder can apply for a water monitoring authority (WMA). A WMA allows the holder to carry out water monitoring activities in the area to which the WMA relates, which can be land outside the tenure. A WMA ends when the petroleum tenure to which it relates become non-current.

2.3 Petroleum Tenures within the Surat Cumulative Management Area

ATPs cover a large area of Queensland, but PLs are only granted for a small part of that area. Some of the areas covered by ATPs have been identified by their petroleum tenure holders as being part of future development projects in the Surat CMA, but many cover areas that may never be converted into a PL. Figure 2-3 identifies significant groups of relevant petroleum tenures.

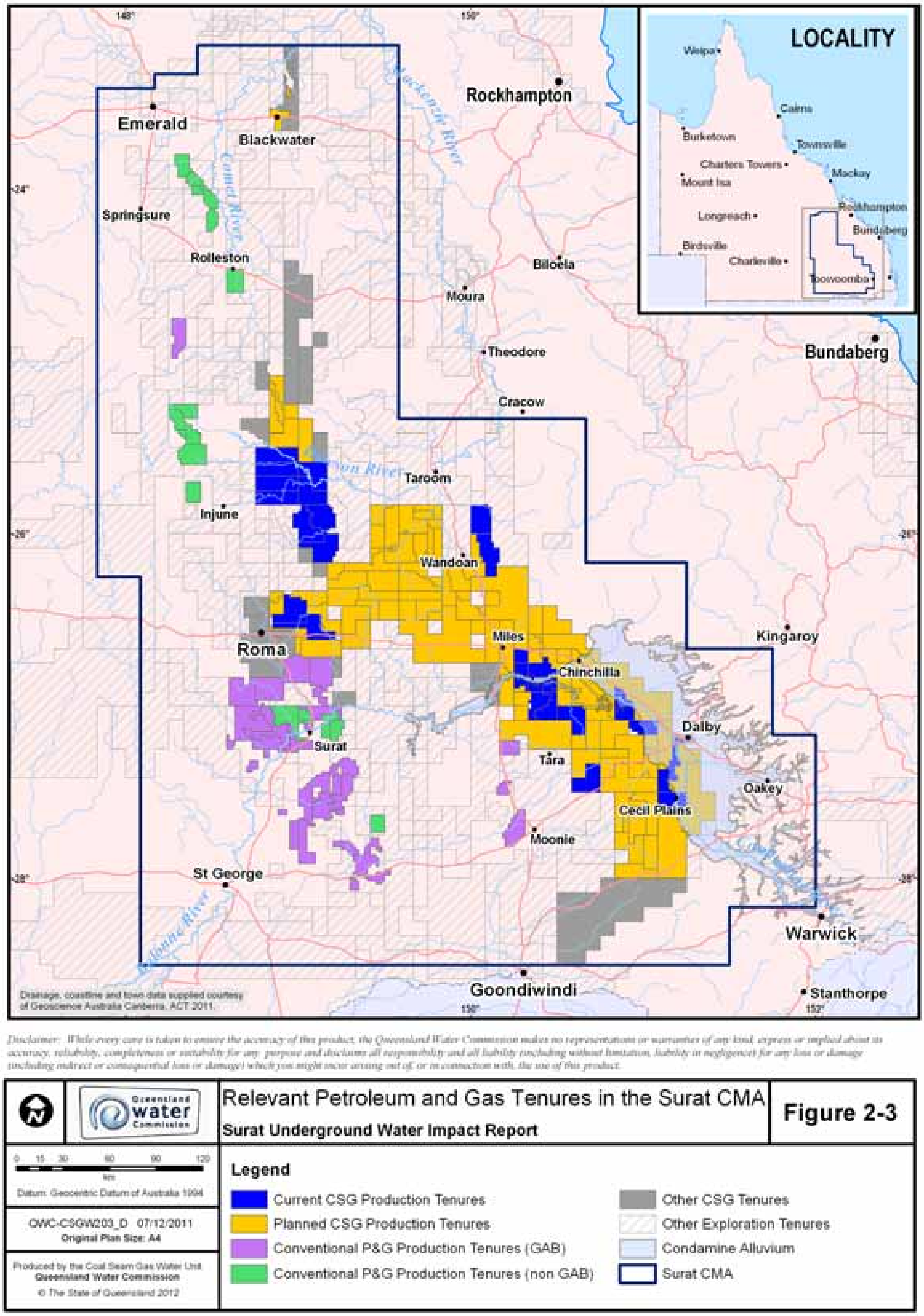

Figure 2-3 Relevant Petroleum and Gas Tenures in the Surat CMA

The Commission has obtained information from DNRM about the existing petroleum and gas production, and from petroleum tenure holders about current plans for the growth and sequencing of future production.

For the purposes of this report, the ***production area*** is the area covered by the following tenures identified in Figure 2.3:

- tenures on which CSG production was occurring at the beginning of 2011 (referred to as 'current CSG production tenures' in this report);
- tenures from which petroleum tenure holders have advised they plan future CSG development (referred to as 'planned CSG production tenures' in this report); and
- tenures from which conventional petroleum and gas operators are extracting water from the geologic formations of the Great Artesian Basin (GAB) (referred to as 'conventional petroleum and gas production tenures' in this report).

There are some petroleum tenures that have been identified in approved environmental impact statements (EIS) or in other public documents as potential development areas, but which are not included in the production area defined above. These tenures are identified as ‘other CSG tenures’ in Figure 2-3, for information purposes.

Figure 2-4 shows the extent of the production area in terms of the four major tenure holders operating in the Bowen Basin and Surat Basin. They are:

- Santos, its subsidiaries and joint venture partners (referred to as 'Santos' in this report);
- Origin Energy, its subsidiaries and joint venture partners, such as Asia Pacific LNG (referred to as 'Origin' in this report);
- Queensland Gas Company, its subsidiaries and joint venture partners (referred to as 'QGC' in this report); and
- Arrow Energy, its subsidiaries and joint venture partners (referred to as ‘Arrow’ in this report).

The petroleum tenures that comprise the production area and the petroleum tenure holders for those tenures are listed in Appendix A.

2.3.1 Existing Coal Seam Gas Production Tenures

The location of the tenures on which there is current CSG production is shown in Figure 2-3 as 'Current CSG Production tenures'. As at June 2012, there existed about 1,700 CSG development wells and about 1,600 CSG appraisal or exploration wells in the CMA as recorded in the DNRM tenure database. However, information obtained about water production indicates that not all of these wells have produced water. For those wells that have produced water, the Commission has used the water production data to classify wells as being either ‘production wells’ or ’test wells’. This classification was carried out on the basis of the length and continuity of water production. Figure 2-5 provides detail about existing gas fields and the distribution of these production and test wells.

The Santos Fairview Field is the oldest field having commenced operation in 1995. It is located approximately 25 km northeast of the town of Injune. While the field lies within the geographic footprint of the Surat Basin, the CSG target formation is the Bandanna Formation of the underlying Bowen Basin. The first well was drilled in 1994 and gas production commenced in 1995.

The Santos Scotia Field is also an established field lying within the extent of the Surat Basin but producing CSG from the Bandanna Formation of the underlying Bowen Basin. The first well was drilled in 1996, but CSG production did not commence until 2002.

The Santos Roma Field is located near the towns of Roma and Wallumbilla. The target formation is the Walloon Coal Measures of the Surat Basin. A pilot operation commenced at the Coxon Creek tenement in mid 2007.

The Origin Talinga Field is located approximately 25 km south-west of the town of Chinchilla and has been in operation since 2005.

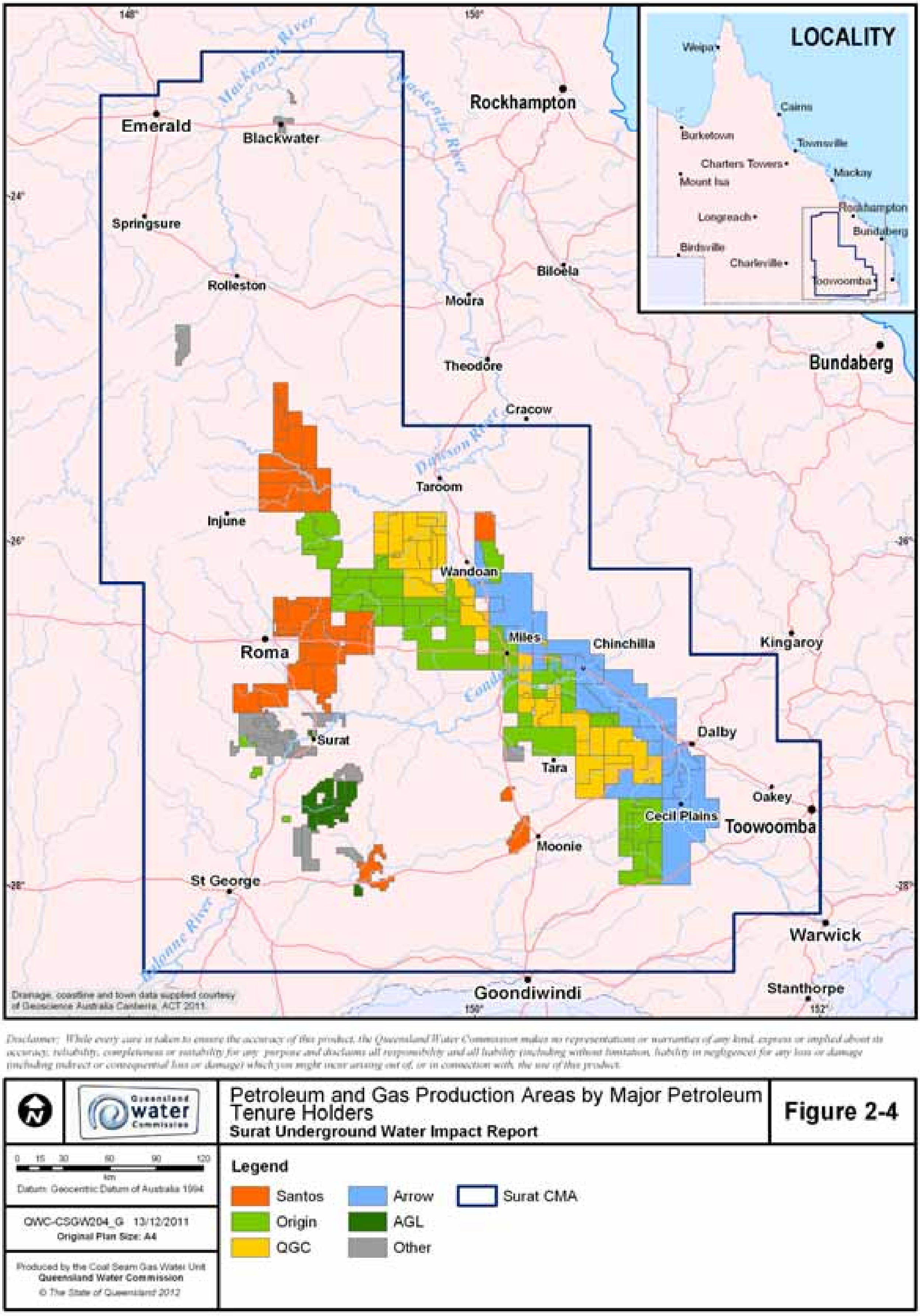

Figure 2-4 Petroleum and Gas Production Areas by Major Tenure Holders

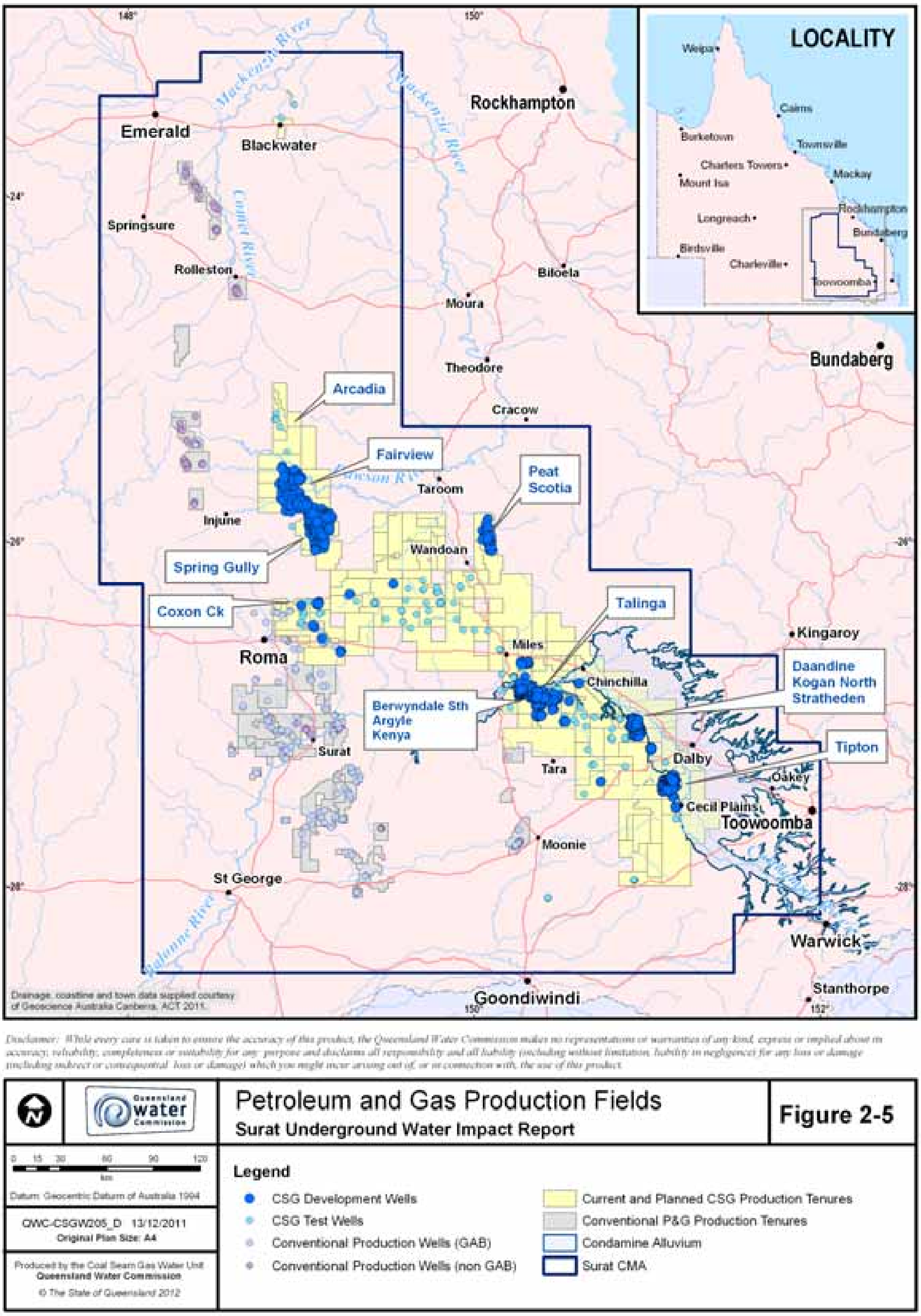

Figure 2-5 Petroleum and Gas Production fields

Origin also operates the Spring Gully Field to the north of Roma and Peat Field to the east of Wandoan. These fields produce CSG from the Bandanna Formation of the Bowen Basin.

QGC has been operating CSG fields in the Surat Basin since mid 2005. The Berwyndale South field has been in operation since mid 2005, the Kenya Field since mid 2007, the Argyle Field since late 2007 and Argyle East Field since late 2008.

Arrow has fields located west of Dalby and near Chinchilla. They include gas fields at Tipton, Daandine, Stratheden and Kogan North, which have been in operation since mid-to-late 2005.

2.3.2 Planned Coal Seam Gas Production Tenures

As previously noted, petroleum tenure holders have provided to the Commission their current plans for CSG development. The relevant petroleum tenures may at this time be PLs or ATPs. The Commission has used the planned development from these petroleum tenures to prepare a water extraction scenario for assessing impacts. The tenures are identified as 'planned CSG production tenures' in Figure 2-3.

Most of the proposed expansion is planned for implementation over the next five to 10 years with a peak in 2014-15. The typical life of a gas field is expected to be around 25 years. It is expected that substantial production will cease around 2050 although logistical limitations and other factors may result in development occurring over a longer period. The following is a broad overview of current planned development.

Santos' proposed Arcadia CSG Field is located directly north of its existing Fairview Field. It will produce from the Bandanna Formation of the Bowen Basin. The field is in the exploration stage. Santos also plans to substantially expand its Roma Field in the near future.

Origin has 14 tenures extending across the eastern part of the Surat Basin from 2012. The target formation for CSG extraction is the Walloon Coal Measures. Origin also plans to develop its Ironbark project near Tara, in south central Queensland.

QGC is further developing its Surat Basin Fields. The future operations are divided into three development areas: the North West Development Area; the Central Development Area; and the South East Development Area.

Arrow is planning to develop its northern Wandoan tenures from 2014, and its tenements near Chinchilla from around 2020. It plans to expand development on its tenures in the area around Dalby in the near future. Development in the Millmerran area will occur at a later stage and is expected to peak at around 2030.

2.3.3 Conventional Petroleum and Gas Production Tenures

Figure 2-5 shows the tenures on which conventional petroleum and gas production is occurring. Some of this production is from the Surat Basin and upper formations of the Bowen Basin that are part of the GAB, but some is from the deep Permian formations well below the Bandanna Formation of the Bowen Basin. Water extraction from the deeper Permian formations is insignificant and is unlikely to have any material impact on the water resources of the Surat and the Bowen Basins. Therefore, impacts from petroleum extraction from those tenures is not considered further in this report.

The Moonie Oil Field, discovered in 1961, is the largest oil accumulation found in the Bowen and Surat Basins. While some small oil accumulations have been identified to the north of Moonie on the same structural trend and on the western flank of the Taroom Trough, the Moonie accumulation appears to be unique and it is likely that any future discoveries of oil in the Bowen and Surat Basins will be small.

The conventional petroleum and gas fields are mature and most are in decline or nearing depletion. Conventional petroleum and gas production is less than five per cent of current gas production in the Surat and Bowen Basins, and the proportion will continue to fall as the CSG industry develops.

3. Regional Landscape and Geology

This chapter describes the physical setting and geology of the region in and around the Surat CMA. It is the basis for assessing the hydrogeology of the area as is set out in Chapter 4 and the conceptual framework for the regional model. The geologic understanding also provided a foundation for spring investigations that the Commission carried out to develop the SIMS.

3.1 Landscape

The Surat CMA straddles the Great Dividing Range (the Range) and falls within a region covering various catchments of both the southern Fitzroy River Basin and the northern Murray-Darling Basin (Figure 3-1).

3.1.1 Topography

The Range rises to approximately 1100 m in the Carnarvon National Park where sandstone outcrops form plateaus and steep escarpments, which are often capped with basalt. The Range becomes subdued between Miles and Inglewood where it is expressed as rolling hills with elevations of less than 300 m. It then rises again to over 1,100 m on the Queensland-New South Wales border in the area south of Warwick, where basalts and granites are exposed at ground level. The topography slopes gently from the Range towards the southwest.

3.1.2 Surface Drainage

The Range divides the Murray-Darling Basin river systems dominated by the Condamine and Balonne Rivers, from the northerly and easterly flowing Nogoa, Comet, Dawson and Boyne River systems. Figure 3-1 shows the extent of the river basins and the location of the major streams.

The Condamine-Balonne River system is the dominant surface drainage system in the south of the region. The Condamine River originates in elevated areas south of Warwick and flows first north-west towards Chinchilla where it then turns westward towards Roma. There are extensive floodplains associated with the upper and central areas of the Condamine River. South of Roma the Condamine River joins the Balonne River and drains south-westerly across the border into the Darling River system.

A local plateau, reaching 400 m AHD, divides the Moonie and the Balonne River catchments, with the tributaries of the Balonne River flowing north and those of the Moonie River flowing south. The Maranoa River lies to the west of the region and flows to the south. In the south of the region, the McIntyre River forms the Queensland–New South Wales border. In the north of the region, the surface drainage is to the north and east into the river systems of the Fitzroy Basin, which drain to the sea at Rockhampton.

Rainfall and runoff are highly variable and evaporation rates are high. Consequently, many of the rivers and streams in the area are ephemeral and characterised by high variations in duration and volume of flows. Intermittency is an important feature of the natural hydrology of the streams and, under natural conditions, prolonged base flows occur only in wetter years in most streams. There are some spring-fed stream sections in the region. For example, the Dawson River is fed in part from the Hutton Sandstones and the Nogoa River in part from the Precipice Sandstone.

3.1.3 Climate

The climate of the area is sub-tropical with summer-dominated rainfall. Much of the area is categorised as semi-arid. The average annual temperature is approximately 20^{o}C with temperatures ranging from 0^{o}C in winter to 35^{o}C in summer.

The highest rainfall generally occurs between November and February and the lowest between April and September, but it is highly variable. Intense cold fronts and low-pressure systems originating in the Southern Ocean result in significant rainfall during winter and spring in some years.

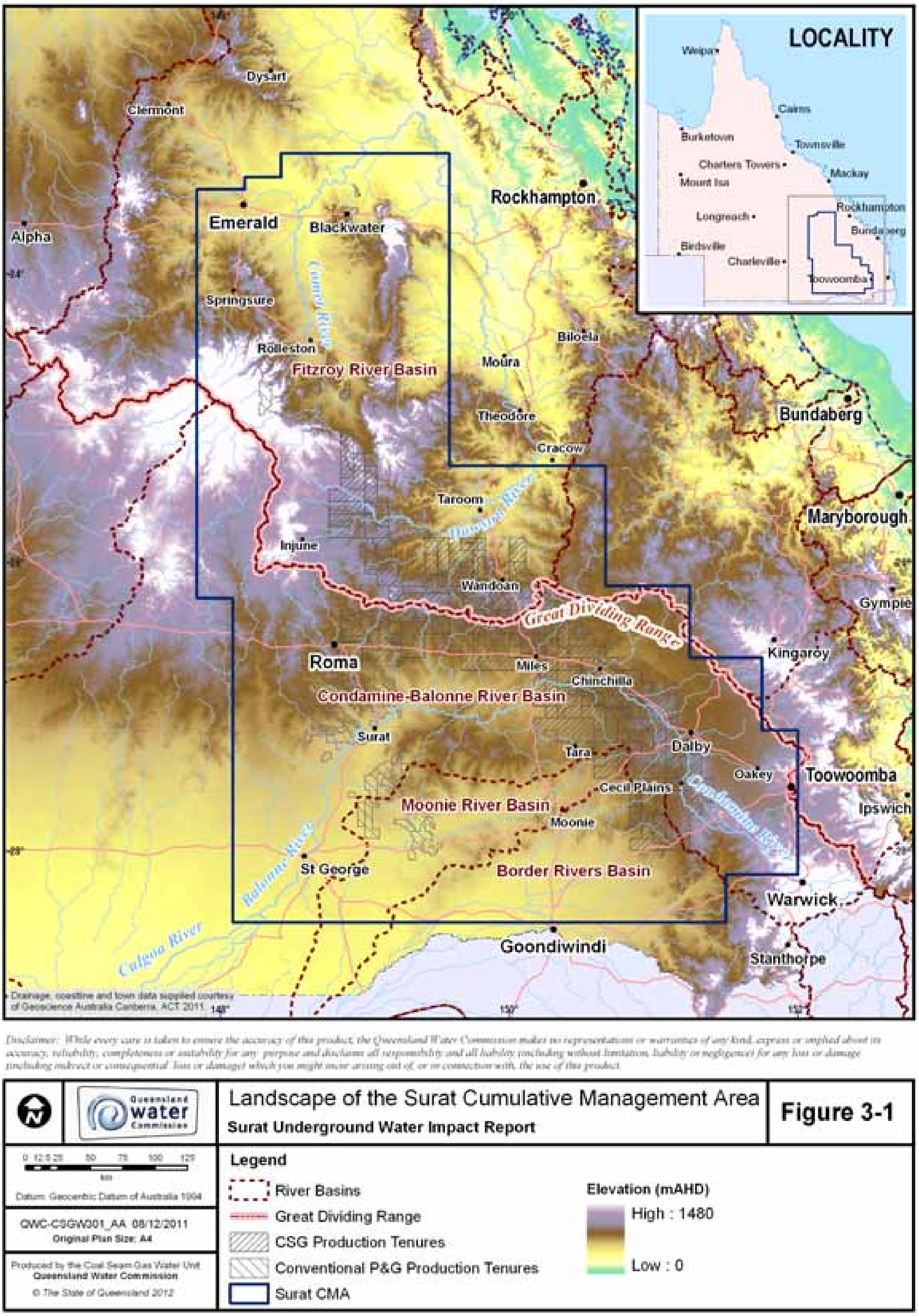

Figure 3-1 Landscape of the Surat Cumulative Management Area

Average annual rainfall varies from over 900 mm per year at Toowoomba in the east, to approximately 500 mm per year at St George in the west. The annual average evaporation ranges between 1,800 and 2,400 mm per year. Prior to the summer of 2010-2011, the rainfall was below the monthly average for 10 years.

3.1.4 Land Use

The predominant land use in the region is agriculture including broad-acre and horticultural cropping, grazing and lot feeding. Other land uses include urban, industrial, CSG and conventional petroleum and gas extraction, mining (dominantly coal) and conservation.

3.2 Geology

The Surat CMA covers part of three geologic basins: the southern Bowen, the northern Surat and the western Clarence-Moreton Basins. Geologic formations within the three basins are mainly comprised of various layers of sandstone, siltstone and mudstone.

The Bowen Basin is the deepest and oldest and runs north-south through the centre of the region. Overlying this is the Surat Basin, which covers most of the central and southern parts of the Surat CMA. The Clarence-Moreton Basin interfingers with the Surat Basin across the Kumbarilla Ridge to the east. Overlying these basins are extensive areas of unconsolidated younger alluvial sediments and volcanics. Figure 3-2 shows the distribution of the basins. More detail on the structures that define the basins is shown in Figure 3-3.

The GAB is not a geologic basin. It is rather a hydrogeological or groundwater basin comprising various parts of other geologic basins. Within the Surat CMA, the GAB includes the Surat Basin, the equivalent formations in the Clarence-Moreton Basin and the upper sedimentary sequences of the Bowen Basin. Chapter 4 describes the hydrogeology of the GAB in more detail.

3.2.1 Bowen Basin

The Bowen Basin is elongated, trending north-south and extends from central Queensland, south beneath the Surat Basin, into New South Wales where it eventually connects with the Gunnedah Basin.

The Bowen Basin contains Permian to Triassic aged sediments with a maximum thickness of approximately 9000 m in the centre of the Mimosa Syncline (Cadman, Pain & Vuckovic 1998). The basin has two main centres of sedimentary deposition, the Taroom Trough to the east and the Denison Trough to the west. The margins of the Bowen Basin are less well defined in the west and southwest. Formations thin to the west across the Nebine Ridge and gently dip towards the Taroom Trough.

Deposition in the basin commenced during the Early Permian with river and deltaic sediments and volcanics in the east and a thick succession of coals and non-marine sedimentary rocks in the west (Geoscience Australia 2008). Figure 3-4 presents a simplified geologic cross-section across the basin. The stratigraphy of the geologic sequences of relevance within the Surat CMA is presented in Appendix B.

The oldest sequence in the Bowen Basin comprises dominantly fine-grained sediments such as mudstone and siltstone of marine origin (Back Creek Group). These are overlain by shale, siltstone, tuff and clayey sandstone. The Bandanna Formation, which includes the CSG producing coal seams, rests on this and comprises dominantly mudstone, siltstone and minor clayey sandstone with a thickness of up to 250 m. The total coal thickness within the Bandanna Formation is generally less than 10 m. The Rewan Formation, a thick sequence of mudstone, siltstone and clayey sandstone, was deposited from rivers and lakes over the Bandanna Formation. This was followed by deposition of the Clematis Group sandstones and finally more mudstones and siltstones of the Moolayember Formation. Due to structural activities and subsidence across the Bowen Basin individual formations are not always laterally extensive. There was widespread erosion prior to deposition of the Surat Basin sediments (Cadman, Pain & Vuckovic 1998).

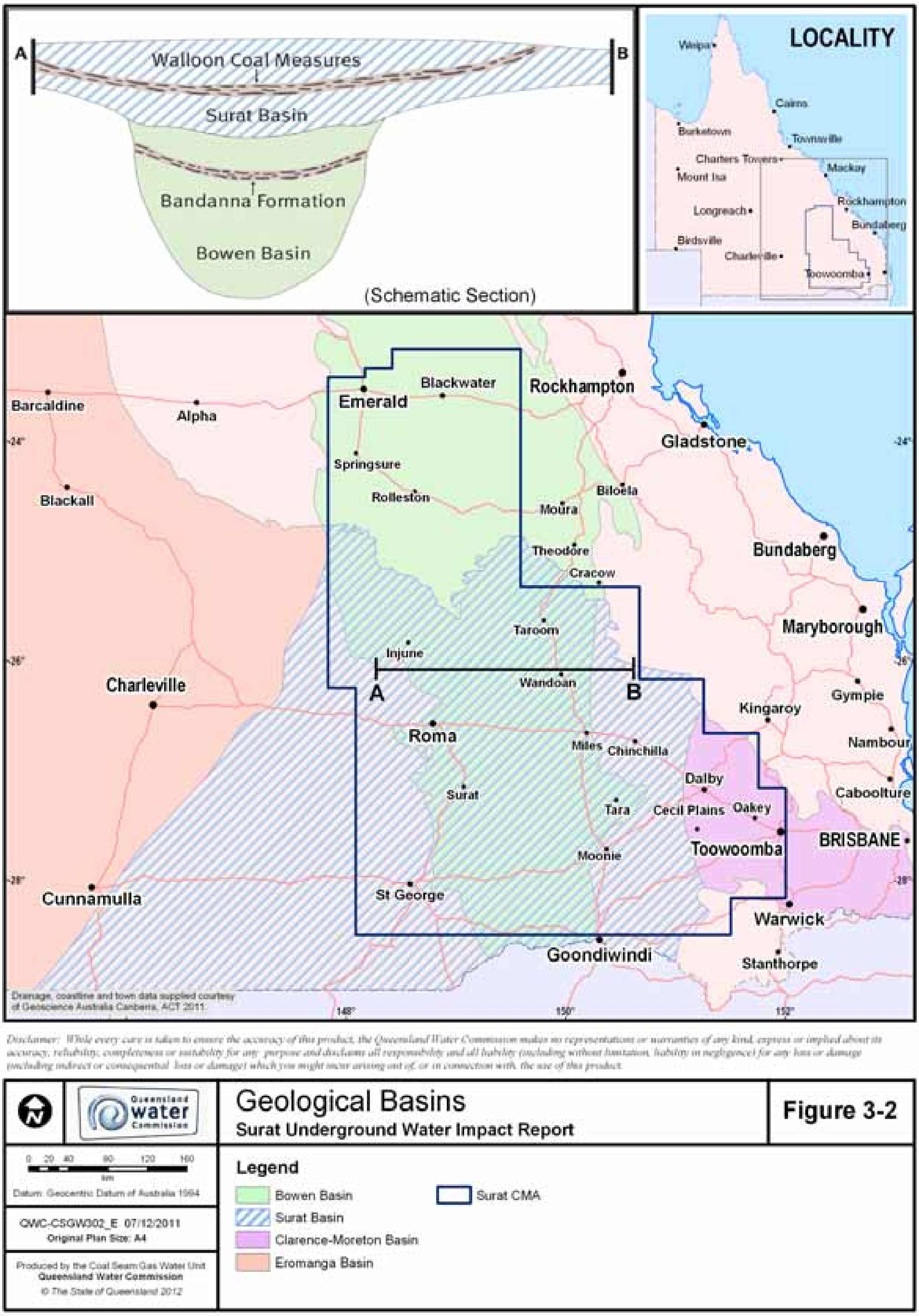

Figure 3-2 Geologic Basins

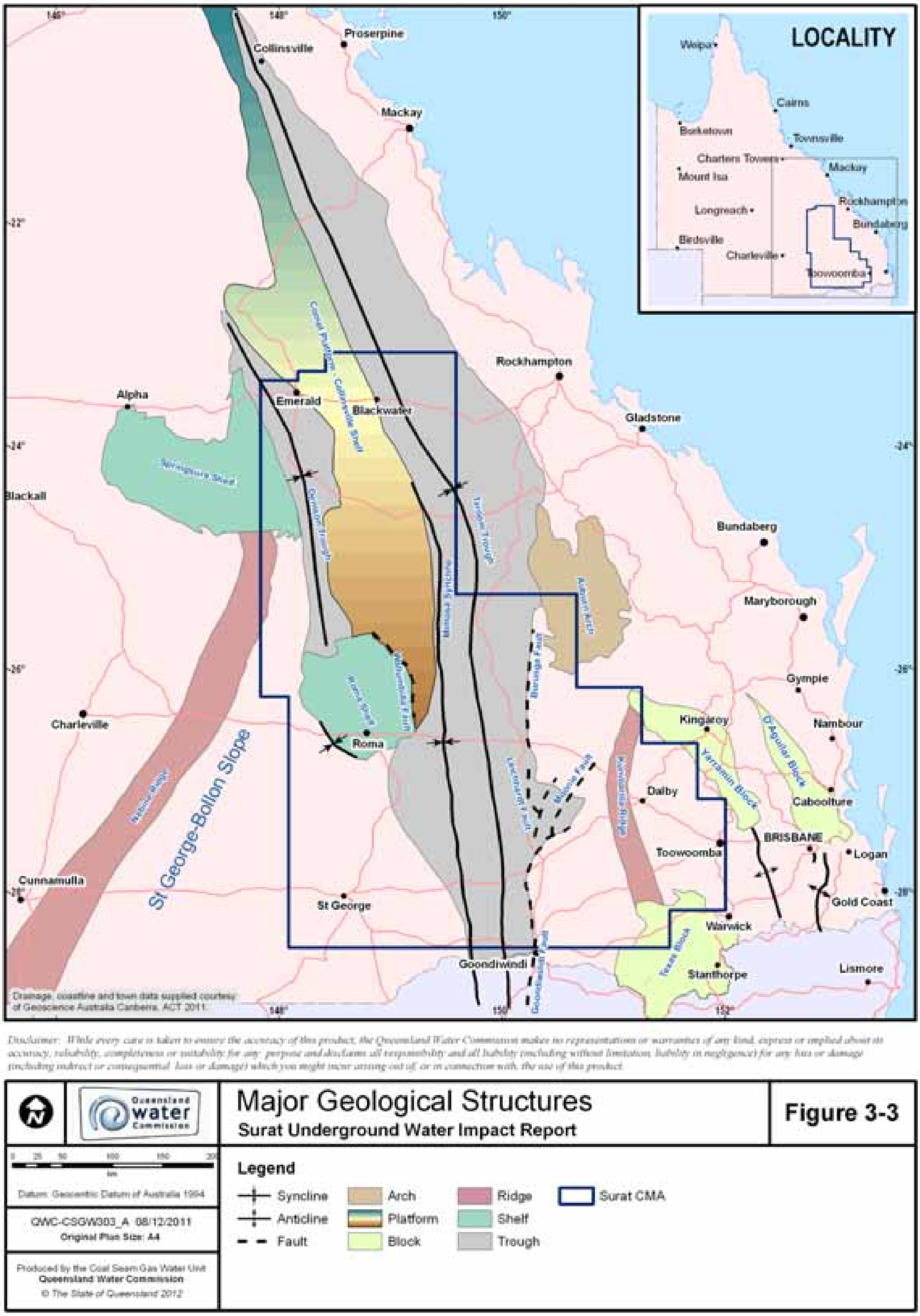

Figure 3-3 Major Geologic Structures

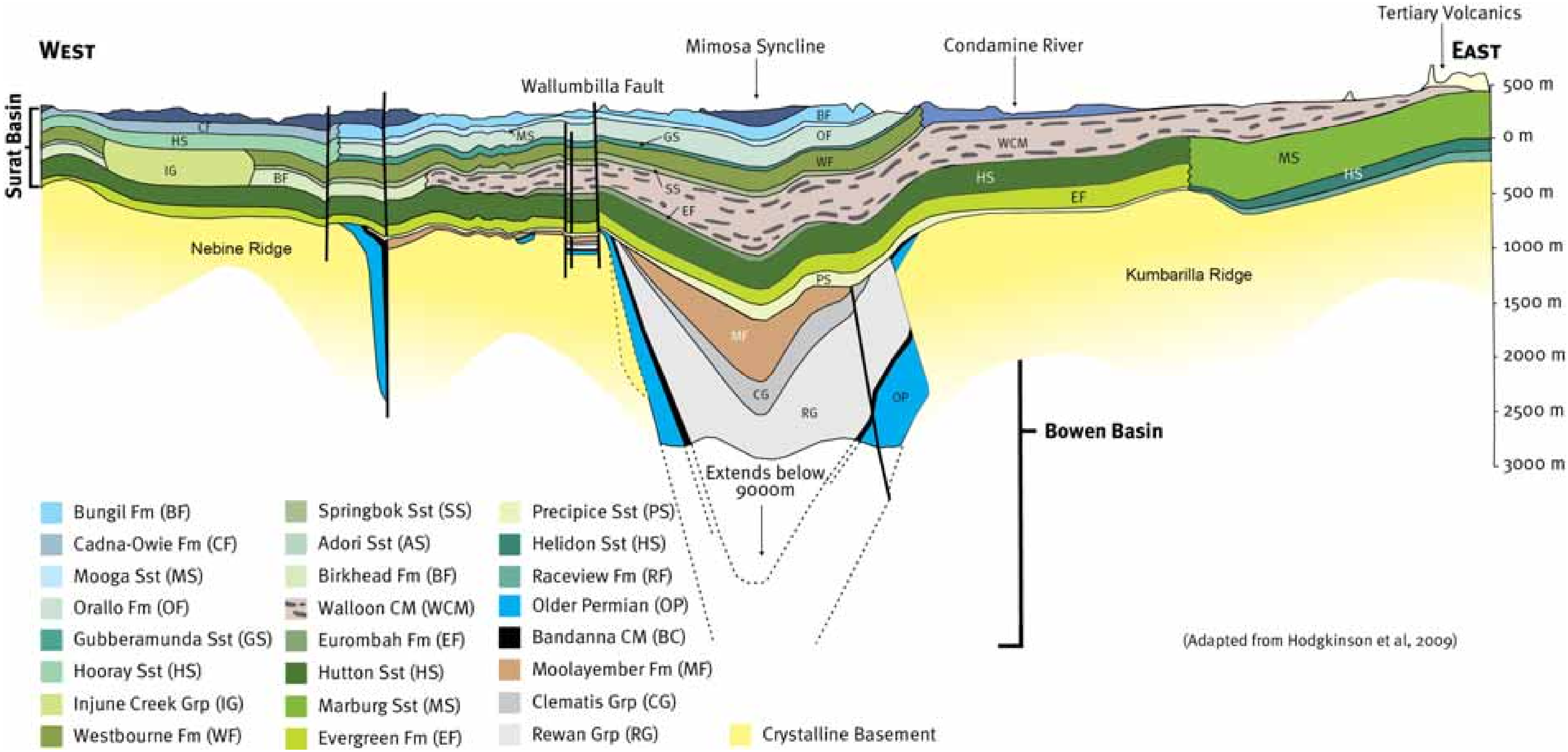

Figure 3-4 Schematic Geologic Cross-section across the Surat Basin and Bowen Basin

3.2.2 Surat Basin

The Surat Basin extends over 180,000 km^2 in southeast Queensland, continuing southwards as the Coonamble Embayment in New South Wales. It overlies the Bowen Basin and is in turn overlain by younger unconsolidated sediments, alluvium and basalts. The sedimentary units of the Surat Basin interfinger with those of the Clarence-Moreton Basin across the Kumbarilla Ridge to the east. To the west, they interfinger with those of the Eromanga Basin across the Nebine Ridge (Goscombe & Coxhead 1995).

The northern margin of the Surat Basin has been exposed and extensively eroded, and the sediments generally dip in a south-westerly direction.

The Surat Basin comprises a Jurassic to Cretaceous aged sequence of alternating layers of sandstones, siltstones and mudstones (Figure 3-4) up to 1500 m thick, which was followed by up to 1200 m of shallow marine mudstones, sandstones and finally sandy units in the Early Cretaceous as the oceans retreated (DNRM 2005). The sediments attain their maximum thickness in the Mimosa Syncline in the north of the basin. Appendix B outlines the stratigraphy of the Surat Basin.

The deepest sediments throughout most of the Surat Basin are the sandstone and siltstones of the Precipice Sandstone. Overlying this formation is the Evergreen Formation, a thick sequence of dominantly siltstone and mudstone that is followed by the Hutton Sandstone, comprising dominantly sandstone, with some siltstone and mudstone.

Overlying the Hutton Sandstone is the Walloon Coal Measures. This is a thick sequence of siltstone, mudstone, fine to medium grained, clayey sandstone, containing the CSG producing coals. While the total thickness of this formation can be up to 650 m, the average thickness is about 300 m. However, the total coal thickness is generally less than 30 m.

The medium to fine grained, often clayey, sandstones, siltstone and mudstones of the Springbok Sandstone overlie the Walloon Coal Measures. This is followed by the Westbourne Formation, which dominantly comprises interbedded siltstone and mudstone and the Gubberamunda Sandstone consisting of fine to coarse grained sandstones. The thinly bedded sandstone, siltstone, mudstone and fossil wood of the Orallo Formation was deposited over the Gubberamunda Sandstone. The Mooga Sandstone was deposited over the Orallo Formation and grades upwards into the interbedded lithic and quartzose sandstone, siltstone and mudstone of the Bungil Formation.

Sedimentation in the Surat Basin ended in the Cretaceous with the interbedded muddy siltstone, fine grained sandstone and mudstone of the Wallumbilla Formation, Surat Siltstone and Griman Creek Formation of the Rolling Downs Group.

3.2.3 Clarence-Moreton Basin

The Clarence-Moreton Basin underlies south-east Queensland and north-eastern New South Wales. The basin contains up to 1300 m of sediments of Late Triassic to Late Jurassic age.

The sedimentary units of the Clarence-Moreton Basin interfinger with those of the Surat Basin across the Kumbarilla Ridge to the west. The majority of the Jurassic and younger Surat Basin stratigraphic sequence is continuous across the Kumbarilla Ridge into the Clarence-Moreton Basin.

The Helidon Sandstone is equivalent to the Precipice Sandstone of the Surat Basin and comprises coarse-grained clayey to quartzose sandstone. The Marburg Sandstone is equivalent to the Hutton Sandstone and comprises sandstone, siltstone, minor mudstone and conglomerate.

The Walloon Coal Measures are continuous between the Surat and Clarence-Moreton Basins across the Kumbarilla Ridge. The formation has been either partly eroded, or exposed, over much of the eastern part of the Clarence-Moreton Basin (Goscombe & Coxhead 1995).

Within the Clarence-Moreton Basin, there are no equivalents of the younger Cretaceous sediments of the Rolling Downs Group.

3.2.4 Cenozoic Formations

Thin accumulations of Cenozoic aged unconsolidated alluvial sediments cover much of the Surat CMA. These typically comprise sand, silt and clay generally deposited along the old and existing streams and drainage lines.

The Condamine Alluvium is one of the more significant accumulations of alluvial sediments within the region. The thickness of alluvium ranges from less than 10 m in headwater areas and along the floodplain margins to 130 m in the central floodplain (up to 20 km wide) near Dalby. The sediments within the central Condamine area are fine to coarse grained gravels and channel sands interbedded with clays. A thick clayey sequence of sheetwash (fan) deposits overlies the floodplain deposits in the east (Huxley 1982; KCB 2010).

The Condamine River has eroded its valley along the strike of the Walloon Coal Measures and the coal measures are the dominant basement geology of the alluvium in the main central plain (Huxley 1982). Basement generally comprises siltstones, sandstone, shales, coals and occasionally basalts on the eastern margin. Towards the western margin, the Hutton and Springbok Sandstones underlie the alluvium.

The Main Range Volcanics comprise mostly of basalt and overlie the eroded surface of Clarence-Moreton Basin and some older basement rocks. Most of the volcanics are extensively eroded, and covered in part with alluvium, including the Condamine Alluvium.

4. Hydrogeology

This chapter builds on the basic geologic understanding provided in the previous chapter to develop an understanding of the hydrogeology of the region. It provides an understanding of the way groundwater moves through and between geologic formations and provides a basis for conceptualisation and construction of the regional groundwater flow model.

4.1 Basic Concept of Groundwater Flow

Groundwater in geologic formations flows from areas of higher water level or water pressure to areas of lower water level or water pressure in much the same way that surface water flows from areas of higher elevation to areas of lower elevation. The difference in water levels is generally referred to as the hydraulic gradient. However, unlike surface water, groundwater tends to flow slowly, through pores and fractures in the formation.

Groundwater flow in confined or pressurised units such as the Walloon Coal Measures is controlled by two primary hydraulic parameters of the material through which it flows: the ***permeability***[1] and the ***storativity***. Permeability represents the ease with which water can flow through the material while storativity represents the material's capacity to store or release water under pressure change. High permeability materials such as sand let the water flow relatively easily resulting in a gentle hydraulic gradient in response to groundwater extraction. In contrast, lower permeability materials such as clay, although yielding relatively small amounts of water, result in much steeper hydraulic gradients. Geologic formations with higher permeability are known as ***aquifers*** while formations with lower permeability are known as ***aquitards***.

Within a geologic formation water typically flows more easily along bedding planes than across them. As a result horizontal permeability is typically two to three orders of magnitude higher than the vertical permeability.

In addition to extraction from bores, water also discharges naturally to surrounding formations, springs and watercourses. At any given point in time, water levels in a geologic formation reflect an imbalance between the amount of water entering the system (i.e. recharge) and flowing out (i.e. discharge) and the formation's hydraulic parameters (i.e. the permeability and the storativity).

4.2 Description of Groundwater Systems in the Surat CMA

CSG exists in the Walloon Coal Measures of the Surat and Clarence-Moreton Basins, and the Bandanna Formation of the underlying Bowen Basin. There are a number of regional aquifers within these basins that are used for water supplies. Overlying the basins are also extensive areas of unconsolidated younger alluvial sediments and volcanics, which contain significant aquifers in localised areas, such as the Condamine Alluvium.

4.2.1 Great Artesian Basin (GAB)

As noted in Chapter 3, the GAB is not a geologic basin. It is a hydrogeological basin comprising various geologic sequences of several geologic basins. Within the CMA the GAB consists of the Surat and Clarence-Moreton Basins, and uppermost aquifer (the Clematis Sandstone and its equivalents) of the Bowen Basin.

The GAB comprises a sequence of alternating layers of permeable sandstone aquifers and lower permeability siltstone and mudstone aquitards, which generally dip in a south-westerly direction. The thickness of the sedimentary sequence reaches nearly 2,500 m in the centre of the Mimosa syncline. The individual sandstone, siltstone and mudstone formations range in thickness between less than 100 m to more than 600 m.

Regionally the main aquifers and aquitards in the GAB approximate the stratigraphic units or geologic formations. Figure 4-1 shows the sequence of the aquifers and aquitards of the basin. At a local level most of the aquifers contain minor interbedded siltstone and mudstone that are reflected in lower bore yields. Similarly, several aquitards contain minor aquifers of permeable sandstones and siltstones that can yield reasonable quantities of water in these otherwise unproductive formations.

[1] For the purpose of this report 'permeability' is taken to be equivalent to 'hydraulic conductivity'

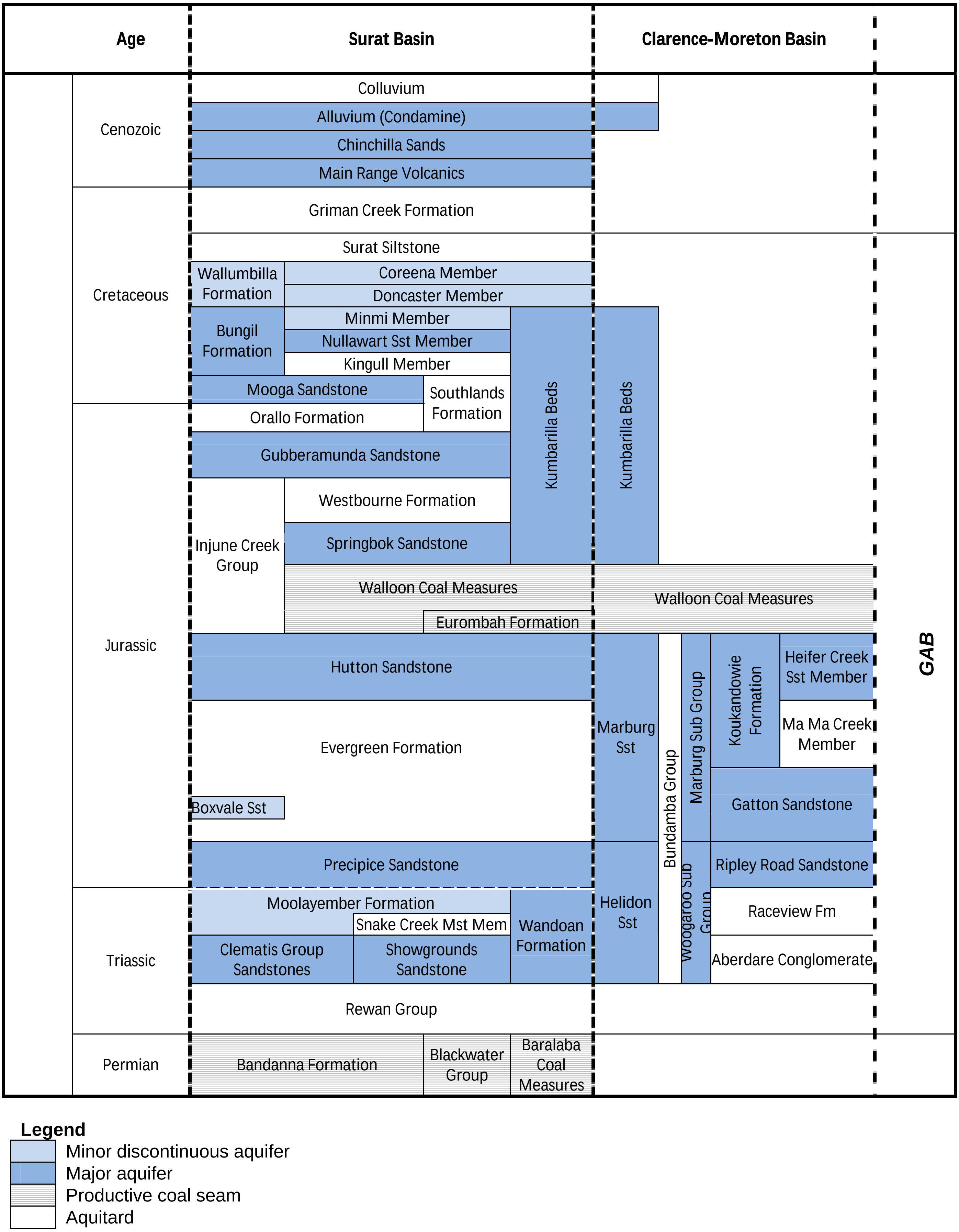

Figure 4-1 Regional Hydrostratigraphy

The main aquifers within the GAB, from the deepest to the shallowest, are the Clematis Sandstone, Precipice Sandstone, Hutton Sandstone, Springbok Sandstone, Gubberamunda Sandstone, Mooga Sandstone and Bungil Formation and their equivalents. These aquifers are laterally continuous, have significant water storage, permeability and porosity and are extensively developed for groundwater use.

The Springbok Sandstone and the Walloon Coal Measures show a very high degree of variability. At many locations the Springbok Sandstone has a very high content of mudstone and siltstone with very low permabilities. This tends to locally isolate groundwater contained in the formation. Similarly the Walloon Coal Measures has thin high permeability coal beds and some sandstones that yield usable quantities of water, particularly close to surface or in outcrop areas where the formation is recharged readily and water is of better quality.

Minor aquifers occur within the Moolayember Formation, the Boxvale Sandstone, and the Doncaster and Coreena Members of the Wallumbilla Formation. These aquifers are not high yielding or laterally continuous, and water quality is often poor.

The major aquitards are the Rewan Group, Moolayember, Evergreen, Birkhead, Westbourne, Orallo, Wallumbilla and Griman Creek Formations and their equivalents. The Westbourne Formation, with its thickness ranging from 100 m to 200 m, separates the Gubberamunda Sandstone from the underlying Springbok Sandstone. The Evergreen Formation is a thick (averaging 300 m) aquitard lying between the overlying Hutton Sandstone and underlying Precipice Sandstone aquifers.

Most recharge occurs along the outcrop areas in the north, northwest, northeast and east along the Range. Recharge occurs predominantly by rainfall, either by direct infiltration into the outcrop areas, or indirectly via leakage from streams or overlying aquifers. It has been identified (Kellett et.al. 2003) that direct rainfall or diffuse recharge rates are generally small, generally less than 2.5 mm per year. However, recharge rates through preferred pathway flow during high intensity rainfall events, and localised recharge from stream or aquifer leakage can be up to 30 mm per year. Calibrated recharge rates from the regional model (see Chapter 6) give recharge rates into the GAB aquifers ranging geographically from 1 to 30 mm per year with a median of 2.8 mm per year.

Recharge water flows primarily along the bedding planes and fractures of aquifers and aquitards from the recharge areas to the south, south-west and west, though there is a minor northward flow component in some aquifers (Hodgkinson et.al. 2009). Groundwater moves very slowly and flow velocities in the GAB have been estimated to range from 1 to 5 m per year (Habermehl 1980). Figure 4-2 shows the location of the recharge areas and the dominant flow directions.

Groundwater movement within the GAB is dominated by subhorizontal flow in the aquifers, with vertical leakage from the aquifers through the low permeability aquitards occurring throughout the basin at a much slower rate.

Natural discharge occurs through springs, rivers, vertical leakage and subsurface flow into adjoining areas.

Water extraction varies across the basin. Aquifers that are relatively shallow and contain good quality water are more heavily used. For example, the Gubberamunda Sandstone exhibits declining water levels due to over 100 years of groundwater development, while the deeper Precipice Sandstone is less developed and has more stable water levels.

Water quality in most aquifers is generally fresh to brackish and suitable for stock, with salinity averaging 1,200 mg/L. However, the Walloon Coal Measures generally have higher salinity, varying from approximately 1,000 mg/L to over 20,000 mg/L. Water quality is spatially variable due to the lateral and vertical variability in the lithology of the formation and variations in groundwater recharge and residence time.

4.2.2 Bowen Basin

The Triassic age sandstone aquifers of the Clematis Group and equivalent formations of the Bowen Basin are recognised as aquifers of the GAB. These aquifers are separated from the Bandanna Formation (from which CSG is produced in the Bowen Basin) by a very thick sequence of fine grained, low permeability siltstones and mudstones of the Rewan Group.

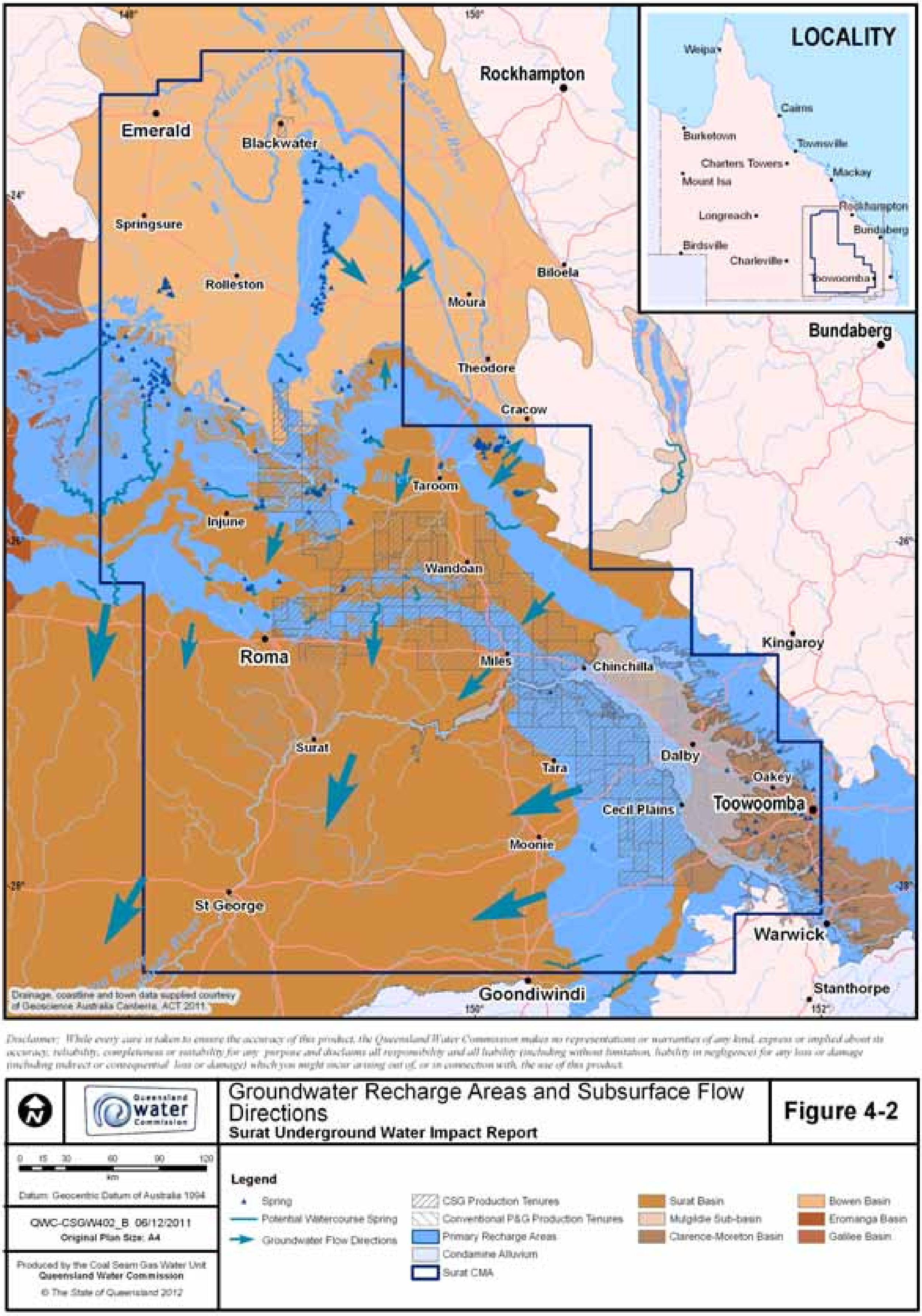

Figure 4-2 Groundwater Recharge Areas and Flow Directions

Limited data is available on the groundwater conditions within the deeper Permian sediments underlying the Bandanna Formation. However, in general these formations are fine-grained, cemented, and have little permeability. As sedimentation was not continuous across the Bowen Basin, the formations are not as laterally extensive as in the GAB. The formations have complex geology and display laterally variable hydraulic properties. Water quality is poor with very high salinities in some places.

4.2.3 Alluvial Systems

Within the Surat CMA there are alluvial systems associated with various river systems. These groundwater systems have been variably developed for irrigation, stock and domestic (S&D) and town water supplies. The most significant and highly developed system occurs within the alluvium associated with the Condamine River.

The Condamine Alluvium is a broad description used for the alluvial and sheetwash deposits of the Condamine River and associated tributaries. The Condamine alluvial aquifer is comprised of gravels and fine to coarse-grained channel sands interbedded with clays. The proportion of clay within the sand and gravel beds increases downstream. The aquifer is generally 30 m to 60 m thick, although it reaches a maximum thickness of 130 m in the central floodplain near Dalby. The individual channel sand and gravel aquifers are less than 20 m thick. Permabilities are higher in the central part of the aquifer and range from 0.5 to 40 m/d.

A thick clayey sequence of sheetwash deposits overlies the productive alluvium in the east, making the aquifer semi-confined in nature. The majority of the sheetwash is composed of low permeability fine-grained material (Huxley 1982; KCB 2010b).

Groundwater levels within the alluvium show almost no difference in water levels with depth. This infers that although the system is made up of many discrete beds, there is significant inter-connectivity in profile within the alluvium, and hydraulically the alluvium acts for the most part as a single aquifer system (KCB 2010b).

Recharge to the aquifer occurs primarily due to infiltration from the Condamine River, with some contribution directly from rainfall and laterally from the surrounding bedrock and tributaries of the Condamine River. The consistent layer of low permeability black soil (up to 10 m thick) over most of the Condamine Alluvium restricts rainfall recharge.

The groundwater quality within the alluvium is generally good but tends to deteriorate and become more saline on the edges of the alluvium and in the down valley direction. The spatial variability in water quality is related to distance from the river, recharge from the river, the permeability of the alluvium, the resulting residence time of groundwater in the aquifer and potentially interactions of alluvium with basement at different points within the system (KCB, 2010b). Salinity in the aquifer throughout the area ranges from approximately 230 mg/L to over 14,200 mg/L, with an average of around 1,000 mg/L.

The Condamine alluvial aquifer is heavily utilised for water supply purposes. Use is predominantly for irrigation and town water supply with minor consumption for domestic, stock watering, industrial, stock intensive and commercial supplies. Bore yields vary between less than 1 L/s and 60 L/s, though yields are mostly less than 10 L/s (DERM 2009; KCB 2010a). Total current water use is approximately 55,000 ML/year.

Groundwater extraction from the Condamine alluvial aquifer has caused considerable decline in groundwater levels as extraction exceeds recharge. Water levels vary from less than 10 m below ground level on the edges of the alluvium, to more than 40 m below ground level in the main extraction area in the centre of the alluvium to the east of Cecil Plains. Water levels have been steadily declining since the 1960s, with no clear response to rainfall events (KCB 2010b). On average, the declines have been approximately 6 m, but can be up to 26 m in areas further away from the Condamine River.

4.2.4 Basalts

The Tertiary aged Main Range Volcanics contain significant aquifers used for irrigation, S&D and town supplies. The aquifers occur at depths ranging from 2 m to 155 m below ground surface; with thickness generally varying from 10 to 30 m. Bore yields are highly variable due to variable aquifer properties. They range from less than 5 L/s to 50 L/s, with an average of approximately 20 L/s. Water quality is generally good with salinity ranging from less than 100 mg/L to approximately 1,100 mg/L. This is because the aquifers respond quickly to recharge from direct infiltration of rainfall, particularly in the elevated areas, and contribute recharge to connected aquifers. Tertiary Basalts also occur in the north of the area overlying the Bowen Basin sediments. In general, the aquifers in these basalts are not as high yielding as that of the Main Range Volcanics.

4.3 Hydrogeology of the Coal Sequences

4.3.1 Walloon Coal Measures

The Walloon Coal Measures comprise siltstone, mudstone, fine-to-medium grained lithic sandstone, and coal deposited over geologic time from rivers and in lakes and swamps across the Surat and Clarence-Moreton Basins (Scott et al. 2004). In the Surat Basin the Walloon Coal Measures have been subdivided into four formations; the Durabilla Formation, Taroom Coal Measures, Tangalooma Sandstone and Juandah Coal Measures.

Figure 4-3 provides a representation of the stratigraphy of the Walloon Coal Measures, although in reality the geology is complex, layers thicken and thin and are not continuous (Scott et.al. 2004).

At the basin scale the Walloon Coal Measures are considered to be an aquitard although in places it functions as an aquifer. The coal seams are generally the more permeable units within a sequence of dominantly low permeability mudstones, siltstones or fine-grained sandstones. Most of the coal seams comprise numerous thin, non-continuous stringers or lenses (up to 45 individual coal seams can be recognised in places) separated by bands of low permeability sediments (Figure 4-3). The coal thickness makes up less than 10 per cent of the total thickness of the Walloon Coal Measures.

Permeability reduces with depth in the Walloon Coal Measures, especially vertical permeability which is very small at depths greater than 800 m (QCGI 2009). In general, the porosity and permeability of sandstones within the formation is limited but there are some sandstones with high porosity and permeability particularly within the Clarence-Moreton Basin (Bradshaw et.al. 2009).

Even though the water quality is generally poor (1,000 mg/L – 20,000 mg/L) and bore yields are low (0.2 L/s to 3 L/s) the Walloon Coal Measures are developed for S&D, stock intensive, industrial and urban purposes where aquifers can be accessed at shallow depths near the outcrop areas (DNR 2005). Groundwater is encountered from 20 m with most supplies being deeper than 30 m (Huxley 1982). Groundwater flow is generally from higher elevations in the north and east toward the west and southwest.

The coal seams within the Walloon Coal Measures do not continue across to the western margin of the basin. The Walloon Coal Measures transgressively grade into the siltstones and sandstones of the Birkhead Formation (USQ 2011). The Birkhead Formation acts primarily as a confining bed in the Surat Basin, providing only small supplies of poor quality water dominantly associated with fine grained sandstones, although the formation characteristics are more similar to an aquifer than a confining bed in the far west outside the CMA.

4.3.2 Bandanna Formation

The Bandanna Formation comprises interbedded coal, mudstone, siltstone and minor clayey sandstone. The thickness of the Bandanna Formation varies from 70 m to 250 m. The Bandanna Formation outcrops on the northern boundary of the Surat CMA. The outcrop area constitutes the primary recharge zone for the formation.

The Bandanna Formation coals are the only sediments with any appreciable permeability within predominantly low permeability sandstones and siltstones. Groundwater flow within the Bandanna Formation is dependent on the permeability of individual coal seams, and their vertical and lateral interconnection. Up to six individual coal seams can be identified. However, the coal seams split and coalesce, do not show persistence and cannot be correlated over any significant distance. The individual coal seams are often thin, averaging less than 2 m, and total coal thickness is generally less than 10 m.

It is likely that the permeability of the coals of the Bandanna Formation within the deepest areas of the Bowen Basin in the Taroom Trough is so low that there is very limited groundwater flow.

There is limited groundwater extraction for agricultural purposes from this formation. Water quality within the Bandanna Formation is variable, with salinity ranging from approximately 500 to 6,000 mg/L. Permian formations underlying the Bandanna Formation are tight and of extremely low permeability.

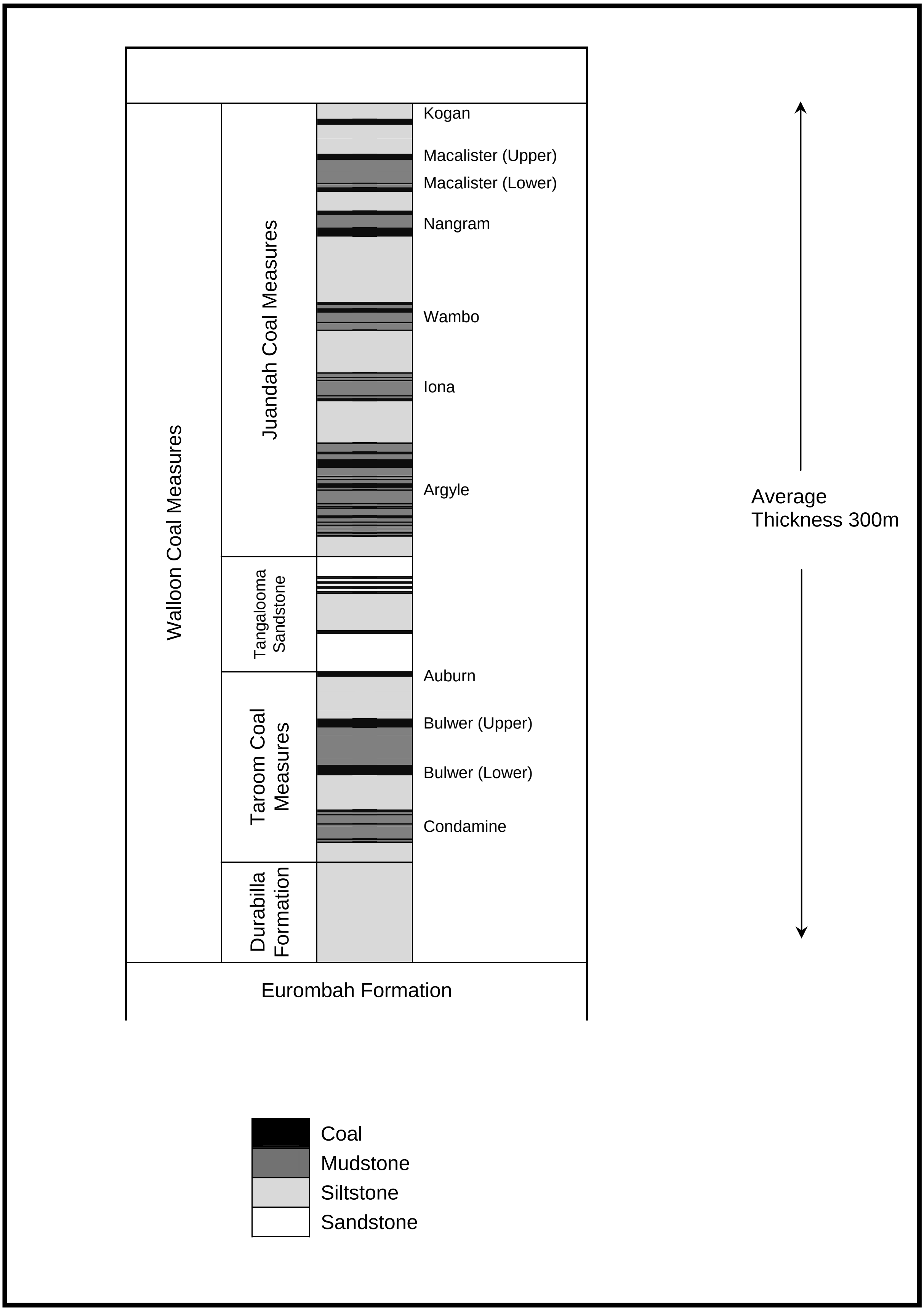

Figure 4-3 Stratigraphy of the Walloon Coal Measures

4.4 Interconnectivity

Interconnectivity between two geologic formations in terms of groundwater movement is the ease or resistance to groundwater flow between the formations. Where there is no discernable thickness of separating material between formations, interconnectivity will depend on the difference in vertical permeability of the two formations. Where there is material separating the two formations, the connectivity will depend on the thickness as well as vertical permeability of separating material. As an example, weathered clay and silt as a separating material will provide more resistance to flow (poor connection) than a gravel bed (good connection). Similarly, a thick layer of silt material will provide a greater resistance to flow than a thin layer of the same material.

All geologic materials are permeable to some extent. For example, clay and mudstone have a very low permeability while coarse sand, gravel and porous sandstone have high permeability. Therefore, all adjacent geologic formations are connected to each other. It is the degree of interconnectivity that varies.

A good hydraulic connection is not in itself sufficient to induce flow of groundwater between two formations. A relative water level (or pressure) difference is needed between the formations, that is, a hydraulic gradient needs to exist. While there will be no flow between well-connected formations if there is no hydraulic gradient between them, there will be flow between even poorly connected formations if there is a large hydraulic gradient between them. However, there could be a significant lag between the time when the gradient is created and the time when the flow rate between the formations reaches a maximum.

4.4.1 Walloon Coal Measures and the Condamine Alluvium

The Walloon Coal Measures represent the main basement unit for most of the central area of the Condamine Alluvium. The alluvium is incised into the Walloon Coal Measures by up to 130 m. A layer of weathered clay and low permeability material exists between the lowermost productive parts of the Condamine Alluvium (the hydraulic Basement) and the uppermost coal beds in the underlying Walloon Coal Measures (Lane 1979). This layer is a combination of low permeability basal alluvial clays of the Condamine Alluvium and the weathered upper part of the Walloon Coal Measures. The two are often indistinguishable from each other and are referred to as the ***transition layer*** for the purpose of this report. Figure 4-4 represents the relationship diagrammatically.

The thickness and permeability of the transition layer influences the degree of connectivity between the Condamine Alluvium and the Walloon Coal Measures. Only a few bores that penetrate through the alluvium into the coal measures have lithological logs that provide information about the thickness, permeability and spatial distribution of this layer. The data suggests that the thickness of this layer averages around 30 m, although in some locations the productive alluvial sands and gravels sit directly on coal seams. Figure 4-5 shows the points where the thicknesses of this layer could be determined based on drilling records. No direct assessment of the permeability of this material is available. However, the nature of the geologic material encountered at these sites suggests that the permeability is likely to range from 8×10^{-6} to 1.5×10^{-1} m/d.

Generally there is a difference in water quality between the Condamine Alluvium and the Walloon Coal Measures. Salinity within the Walloon Coal Measures is high ranging from approximately 1,000 mg/L to over 14,000 mg/L, whereas salinity in the alluvium is lower averaging around 1,000 mg/L. However, as noted in Section 4.2.3 water quality in the alluvium tends to deteriorate and become more saline on the edges of the alluvium and progressively down valley. Interaction with the basement may be a contributing factor to these trends (KCB 2010b).

There is little monitoring data to assist in understanding the interconnectivity between the formations. Recent studies (Hillier 2010; KCB 2010; KCB 2011a) have also reached this conclusion. Monitoring data from the Walloon Coal Measures in the area of the Condamine Alluvium is generally constrained to the area below the margin of the alluvium where the coal measures are shallow and the alluvium is thin, or to the upper weathered zone of the coal measures directly under the alluvium. There is limited water level monitoring of the deeper Walloon Coal Measures under the Condamine Alluvium.

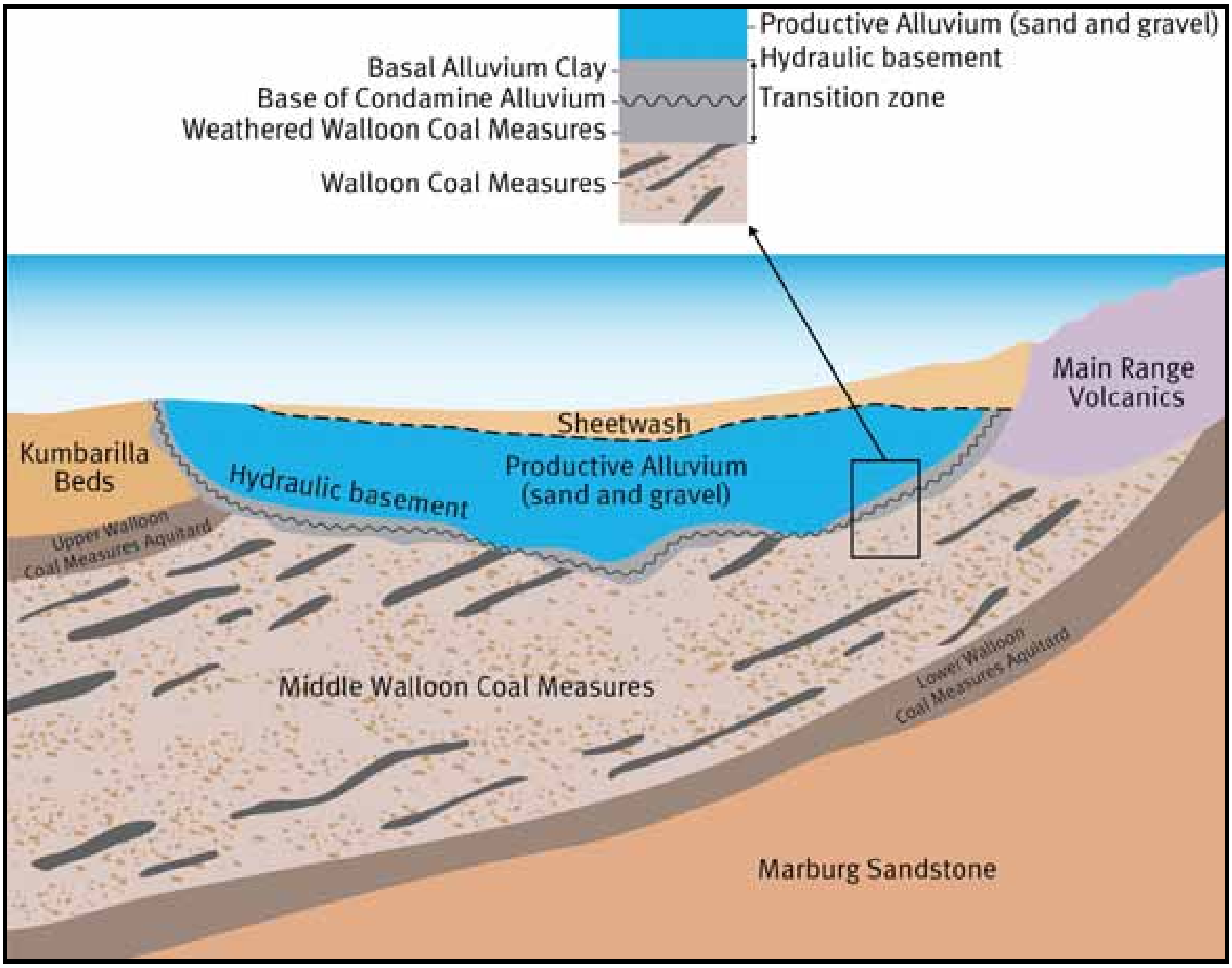

Figure 4-4 Schematic Section across the Condamine Alluvium

There is little long-term monitoring data to clearly define differences in water level between the formations. However, from the available information Hillier (2010) concluded that the water levels in the Condamine Alluvium are generally lower than those in the Walloon Coal Measures by up to 20 m under current conditions, although a reverse gradient could exist at some locations. This would suggest a net flow of water from the Walloon Coal Measures to the Condamine Alluvium. Hillier also concluded that the inferred flow from the Walloon Coal Measures to the Condamine Alluvium is supported by a general decline in water quality downstream in the alluvium and that this is consistent with similar findings elsewhere in the GAB where alluvium acts as a drain for underlying consolidated sediments.

Water levels in the Walloon Coal Measures and the Condamine alluvial aquifer were likely to be similar prior to development of the groundwater resources of the alluvium. However, water levels have been lowered in the alluvium due to water extraction for irrigation, resulting in the water levels in the Walloon Coal Measures now being generally higher than in the alluvium. Although there is a significant amount of monitoring data available from the Condamine Alluvium, there is limited data from the Walloon Coal Measures. There is one area along the western edge of the Condamine Alluvium where a comparison between water level trends in the two formations can be made as shown in Figure 4-6. While water levels have consistently declined in the Condamine Alluvium (RN 42230117) over the past 40 years, the water level in the Walloon Coal Measures (RN 42231214) has remained largely unchanged. A similar but somewhat subdued trend is also observed in the other two bores (RN 42230116 and RN 42231211). The subdued nature of the trend is likely to exist because the bores are screened partly into the transition layer. The figure also shows that the gradient that originally existed from the alluvium to Walloon Coal Measures in that area has been reversed for the past 20 years. However these trends could also be influenced by local factors such as leakage from the watercourse and water extraction.

Differences in water levels and general differences in water quality between the two formations are indicators of the degree of interconnectivity between them. Despite the water level difference, there has not been a widespread deterioration in water quality in the Condamine Alluvium. This suggests a relatively small amount of flow and that the interconnection between the two formations is not strong.

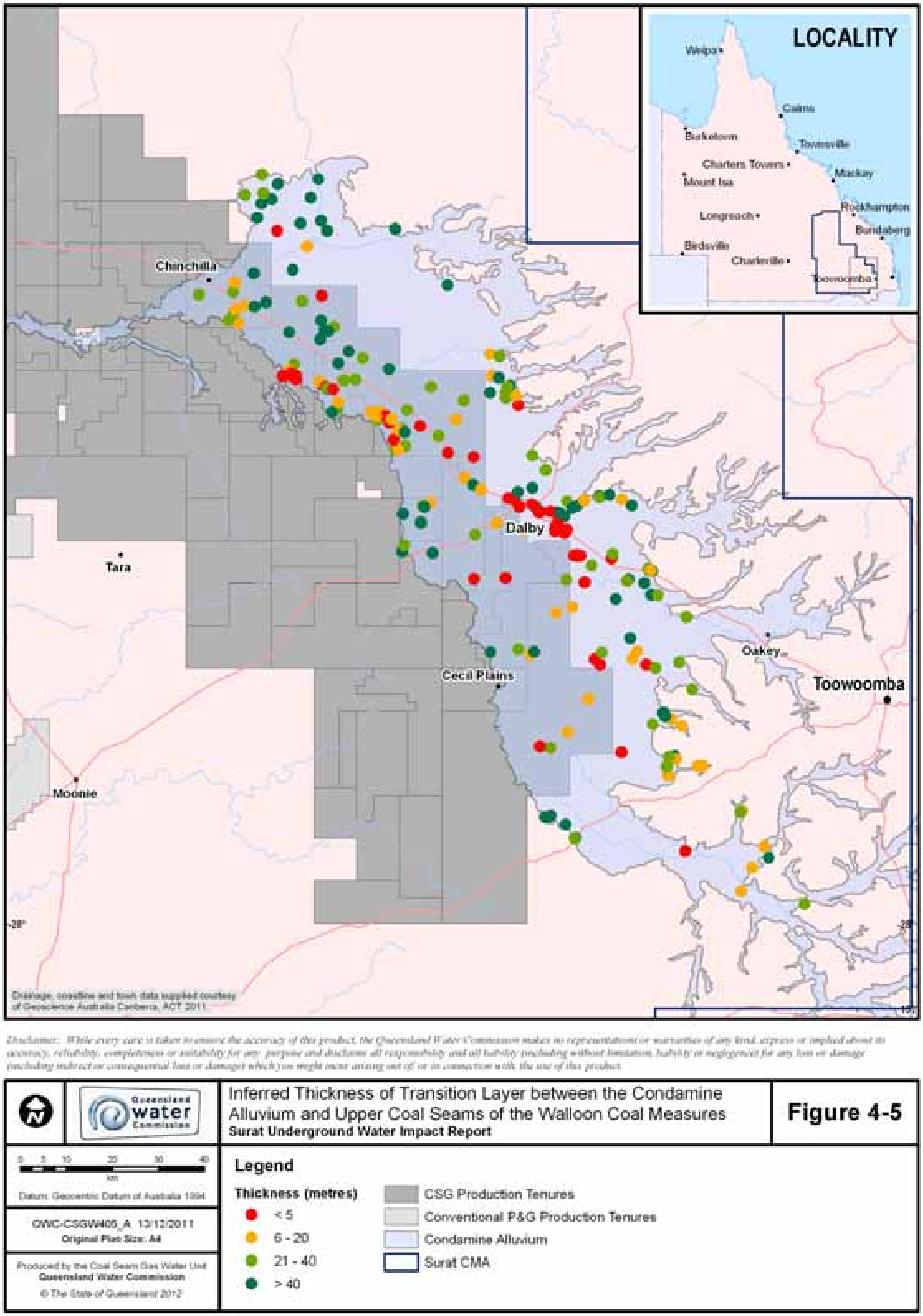

Figure 4-5 Inferred Thickness of Weathered Layer between the Condamine Alluvium and the Walloon Coal Measures

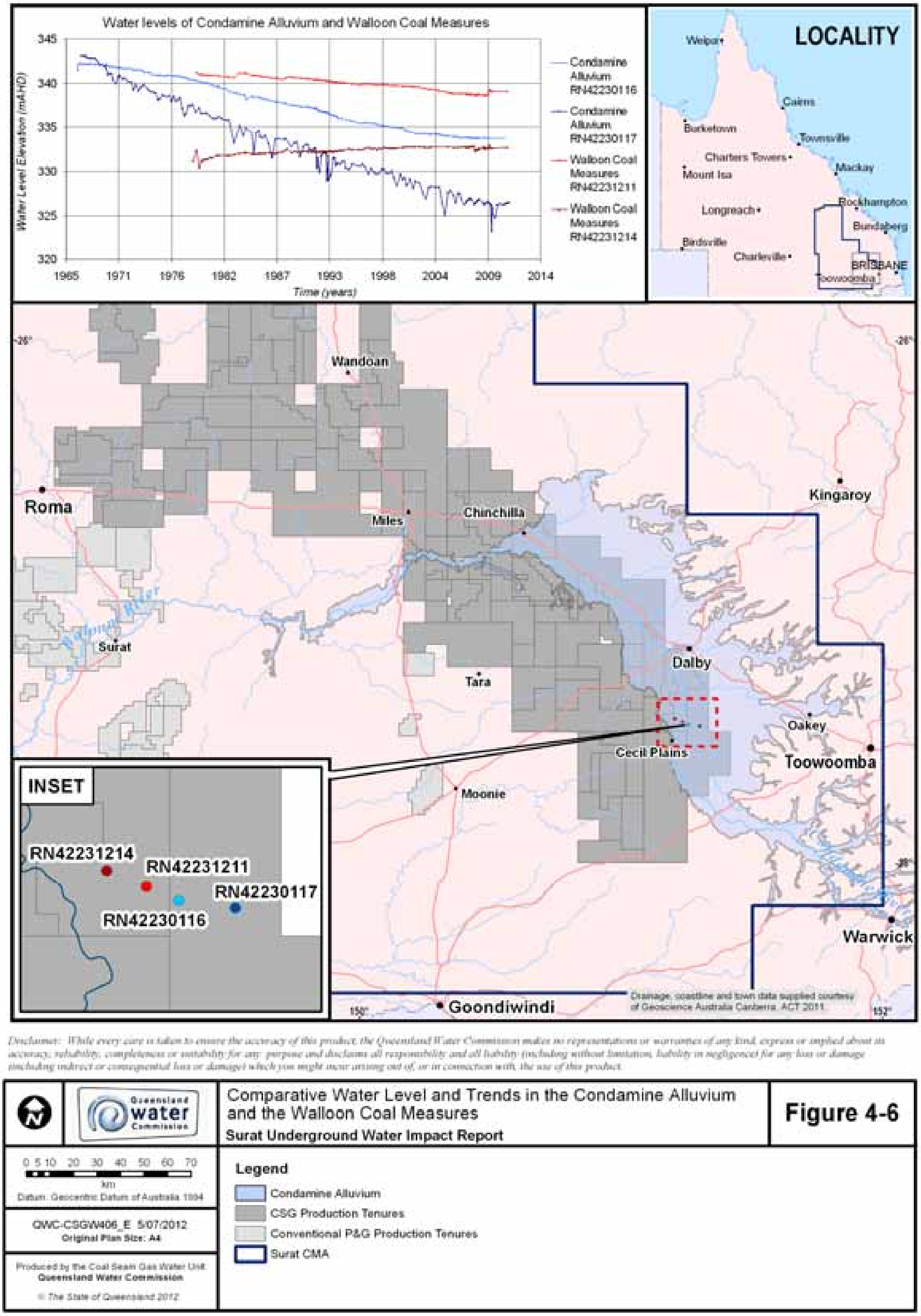

Figure 4-6 Comparative Water Level and Trends in the Condamine Alluvium and the Walloon Coal Measures

In a regional context, the Condamine Alluvium is connected to not only the Walloon Coal Measures but also the Main Range Volcanics along the eastern margins and the Kumbarilla Beds on the west. The way in which the Condamine interacts in a regional setting is not well understood. Previous investigations (Lane 1979; Huxley 1982; Barnett & Muller 2008; KCB 2011b) have made estimates about some of the interactions. They provide estimates of inflow into the eastern side of the alluvium potentially from the Main Range Volcanics ranging from 1,130 ML/year to 3,760 ML/year. Those studies indicate that inflow from the Walloon Coal Measures amounts to a very small component of the total water balance for the Condamine Alluvium.

The long-term water monitoring network specified in Chapter 7 provides for the collection of data from the Condamine Alluvium and surrounding formations. Monitoring data collected when the water level in the Walloon Coal Measures begins to be lowered as a result of CSG development, will improve understanding of the extent and nature of connection between the formations. The interconnectivity between the Condamine Alluvium and the Walloon Coal Measures is a focus area for research that the Commission will pursue in collaboration with other parties. A summary of the Commission's future research focus areas is summarised in Chapter 10.

4.4.2 Walloon Coal Measures and the Aquifers of the GAB

As noted in Section 4.3.1, the coal seams within the Walloon Coal Measures are separated by lower permeability mudstone, siltstone and fine-grained sandstone. For the most part, low permeability siltstones and mudstones are found at the top of the formation, above the uppermost productive coal seams and at the bottom of the formation, below the lowermost productive coal seams. These relatively low permeability layers act as aquitards generally separating the productive coal seams from the Springbok Sandstone aquifer above and the Hutton and Marburg Sandstones aquifers below, except in areas where the upper aquitard has been eroded away.

The thickness of the aquitard layer between the productive coal seams of the Walloon Coal Measures and the Springbok Sandstone is typically about 15 m and it generally has a low permeability, although at some places the aquitard can be absent. Figure 4-7 shows the thickness distribution of this layer.

The Springbok Sandstone is highly variable in nature. At some locations it is an important aquifer but in other places it is highly compacted and has very low permeability. The formation was deposited on the eroded surface of the Walloon Coal Measures. In parts of the north-eastern Surat Basin, the upper aquitard of the Walloon Coal Measures was completely eroded prior to the deposition of the Springbok Sandstone, and the formation is in contact with the productive coal seams (Scott et al, 2007). A higher degree of interconnectivity is expected in these areas.

The aquitard layer of the Walloon Coal Measures separating the lowermost productive coal seams (the Taroom Coal Measures) from the underlying Hutton Sandstone is about 45 m thick (Figure 4-7). This lower aquitard is comprised of dominantly siltstone, mudstone and fine-to-medium grained, poorly sorted sandstones with little permeability.

The lithology of the aquitards is variable and the horizontal permeability is estimated to range from 1.5 m/d to 2.5×10^{-6} m/d, in general averaging 9×10^{-3} m/d. Due to the sedimentary structure of the aquitards the vertical permeability is likely to be at least one to three orders of magnitude lower. These values are based on textbook values for geologic materials and on drill stem tests conducted by petroleum tenure holders that provide local data. There is very little data on the vertical permeability which has a direct influence on connectivity with overlying and underlying aquifers.

There is little historical water level monitoring data in the Walloon Coal Measures and the surrounding aquifers at some locations. Figure 4-8 shows water levels in the surrounding aquifers near the location of the Talinga CSG Field which has been in operation for six years. At this stage the monitoring data, which only covers a few months, does not show evidence of meaningful water level falls in the overlying Gubberamunda Sandstone and Springbok Sandstone as a result of operations at the Talinga Field.

Under the conditions existing before CSG development in the Walloon Coal Measures, a difference in water levels existed between the coal measures and the overlying and underlying aquifers. This suggests limited connection between the formations. However, when depressurisation of the coal measures creates a greater water level difference between the formations, flow could be induced.

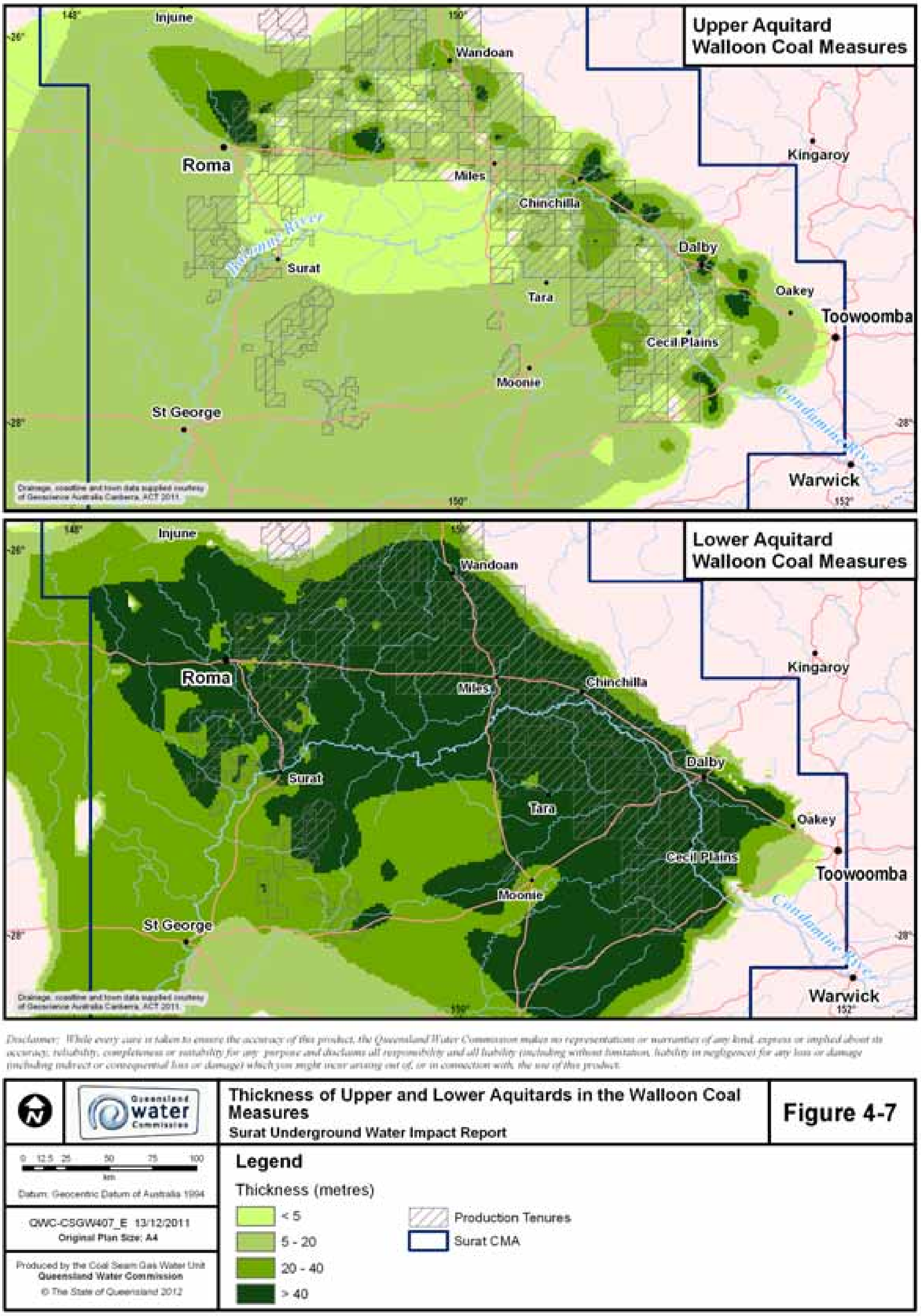

Figure 4-7 Thickness of Upper and Lower Aquitards of the Walloon Coal Measures

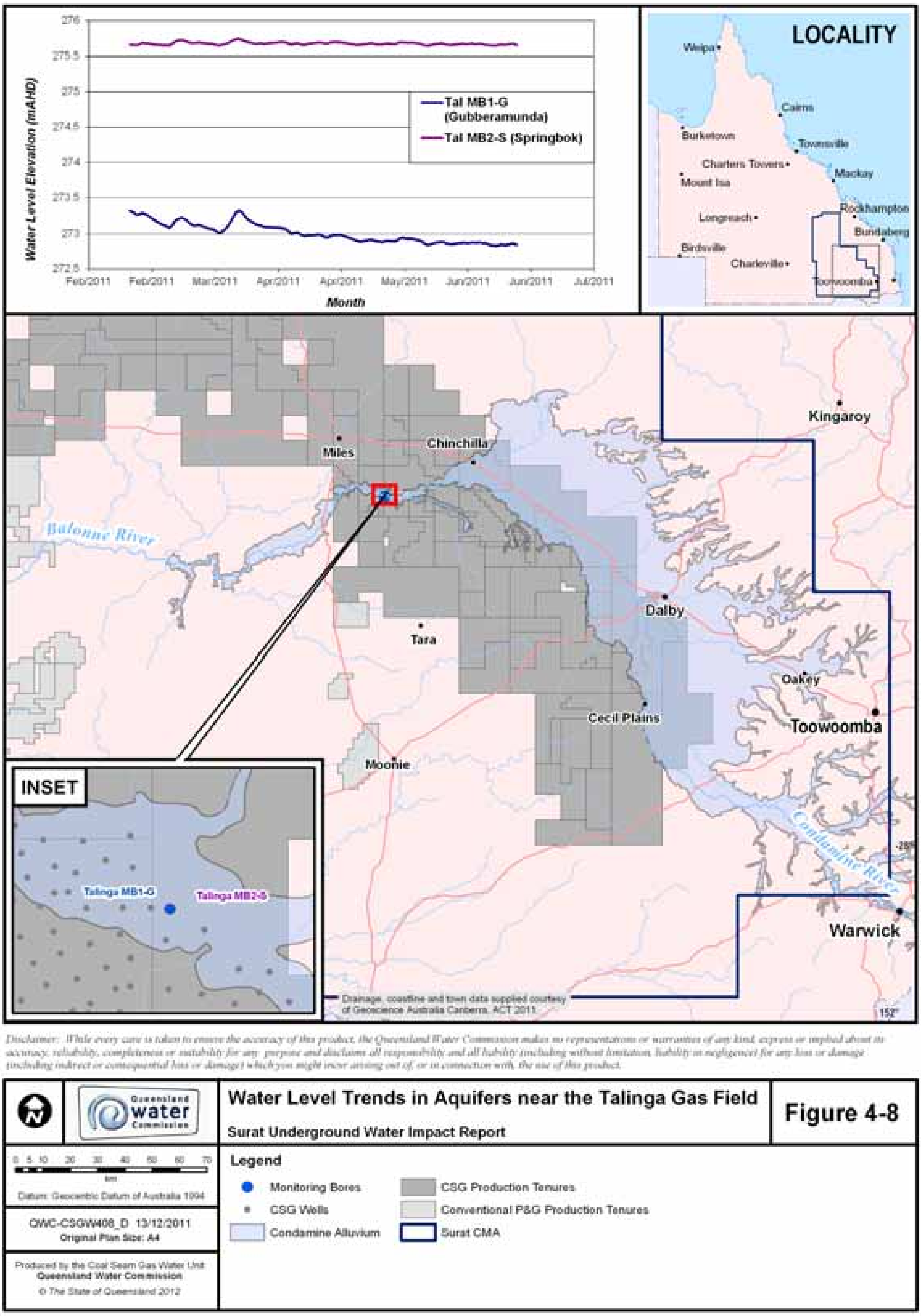

Figure 4-8 Water Level Trends in Aquifers near the Talinga Gas Field

Available information about interconnectivity has been used in the construction and calibration of the model (Section 6.3.2). Initial estimates of permeability values affecting connectivity were refined through the process of model calibration.

The long-term water monitoring network specified in Chapter 7 provides for the collection of data from several layers of the Walloon Coal Measures and aquifers above and below the coal measures, at single geographic locations. Data collected from these bores will provide a basis for future analysis. The interconnectivity between the Walloon Coal Measures is also a focus area for research that the Commission will pursue in collaboration with other parties. A summary of the Commission's plans for future research is summarised in Chapter 10.

4.4.3 Bandanna Formation and Surrounding Aquifers

The Bandanna Formation is the productive CSG formation within the Bowen Basin. It is laterally isolated from its equivalent to the north, the Rangal Coal Measures, by erosion. It is isolated from its equivalent to the east, the Baralaba Coal Measures, by significant faulting. Therefore, depressurisation of the Bandanna Formation is unlikely to affect aquifers in the north around Clermont and in the east around Biloela.

The deeper Permian formations underlying the Bandanna Formation have extremely low permeability. Therefore it is unlikely that depressurisation of the Bandanna Formation will affect the underlying formations.

The Bandanna Formation is generally isolated from the overlying major aquifers by the thick very low permeability mudstones of the Rewan Group. Therefore, for the most part depressurisation of the Bandanna Formation will not affect overlying aquifers. However, there is a narrow, north-south trending zone lying to the east of Injune, close to the existing CSG production fields of Fairview and Spring Gully (Figure 4-9). In this zone the overlying Rewan Group and Clematis Sandstone have been eroded away prior to deposition of the Precipice Sandstone, bringing the Precipice Sandstone into direct contact with Bandanna Formation. This in geologic terms is referred to as an 'unconformity'. Due to this unconformity, there is potentially a high degree of interaction between the Bandanna Formation and the Precipice Sandstone in this area.

The presence of coal within the Bandanna Formation is variable. The more permeable and productive coal bearing horizons are located in the more easterly part of the contact area with the Precipice Sandstone. Within this part of the contact area there is relatively high potential for flow between the productive coal measures of the Bowen Basin and the Precipice Sandstone.

The Precipice Sandstone is separated from the next major aquifer above it, the Hutton Sandstone, by the Evergreen Formation, which is a thick formation of very low permeability. The Evergreen Formation is known to be an effective seal because it forms a cap, trapping gas for conventional petroleum and gas production. It is unlikely that any pressure reduction in the Precipice Sandstone resulting from depressurisation of the Bandanna Formation will affect the Hutton Sandstone.

Some of the earliest CSG fields have been developed in the Bandanna Formation. Fairview was developed in 1996 and Spring Gully in 2005. Monitoring data around the developed area supports the above understanding about connectivity. Water pressures have declined in the Bandanna Formation by over 200 m due to depressurisation for CSG production, with no discernable effect on water levels within the Precipice Sandstone to date (Figure 4-9).

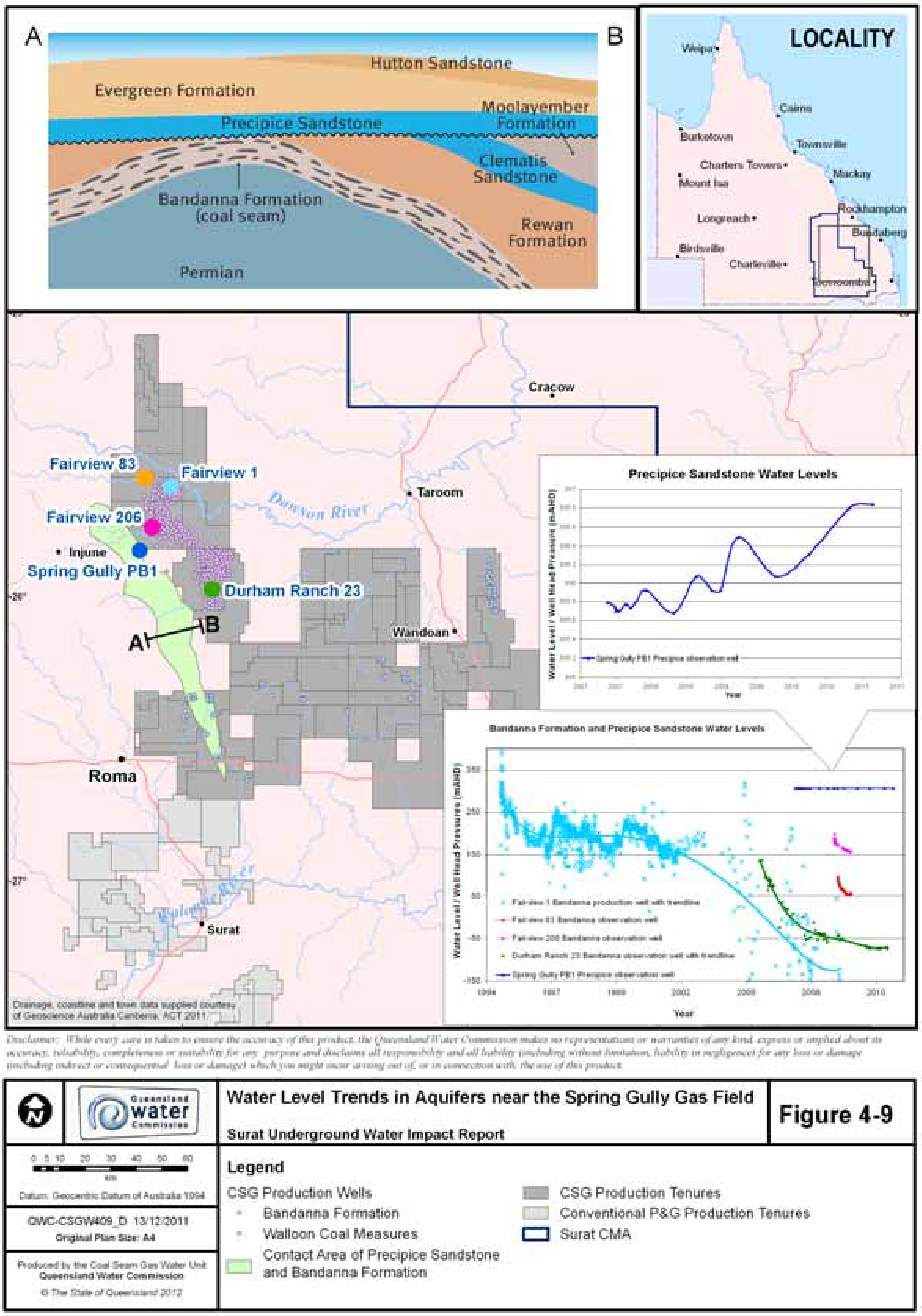

Figure 4-9 Water Level Trends in Aquifers in the Spring Gully Gas Field

4.5 The Influence of Geologic Structures

Geologic structures, such as faults, have potential to influence groundwater flow in two contrasting ways:

- Geologic material in the vicinity of a fault plane can develop fractures and openings that provide additional ***pathways*** for groundwater movement along the fault zones.

- Faults can also serve as hydraulic ***barriers***, where mineralisation and precipitation over time effectively seals the fractures created by faults and thus limits significant movement of groundwater across the structures (Hennig, 2005). Similarly, it is also possible for faults to locally displace or disconnect aquifers and obstruct lateral groundwater flow.

There are some significant regional fault systems within the Bowen and Surat Basins. However, the faults are generally restricted to deeper formations in the Bowen Basin and have less affect on overlying Surat Basin formations. For example, the magnitude of displacement along the Hutton-Wallumbilla fault on the western flank decreases in overlying younger strata (Hodgkinson et.al. 2009).

There are a number of small faults in the GAB with limited strike lengths and there is no significant vertical offset associated with this faulting (QCGI 2009; Hodgkinson et.al. 2009). The Geological Survey of Queensland suggests that fault displacement in the lower formations of the GAB ranges from zero to some tens of metres (Hodgkinson et.al. 2010). Propagation of the faults through to the younger or shallower units is even smaller (QCGI 2009). These smaller faults may potentially be associated with some of the springs in the area.

There are differing views about the overall influence of faults in the Surat and Bowen Basins on regional groundwater flows. Golder Associates (2009) infer that the faults are likely to reduce hydraulic connection across the structures. Hodgkinson et.al. (2010) indicated that the faults are unlikely to present barriers to horizontal groundwater flow and therefore do not affect lateral regional groundwater flow.

The following conclusions can be drawn from current knowledge:

- Any influence of the fault structures on regional groundwater flow, either as pathways or barriers, is likely to be restricted to the Bowen Basin and is unlikely to materially influence majority of the GAB aquifers in the Surat Basin.

- Any regional effect of faults on groundwater flow over long periods of time should be reflected in current observed water levels which are used in calibrating the regional groundwater flow model (see Chapter 6).

- Further targeted research is required to assess the influence of regional structures on groundwater flow if large water level differences occur in the future in and around the structures as a result of CSG development.

The long-term regional monitoring network specified in Chapter 7 provides for the collection of data that will be useful in assessing regional groundwater flow behaviour in relation to regional structures. The potential for structures to influence the movement of groundwater in the area is a focus area for research that the Commission will pursue in collaboration with other parties, as summarised in Chapter 10.

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5. Historic and Current Groundwater Extraction

Groundwater is extensively used in the region. Grazing is the dominant use of groundwater from the GAB aquifers, while irrigation for agriculture is the dominant use from shallow aquifer systems such as the Condamine Alluvium. Groundwater extraction by the petroleum and gas industry is increasing with the expansion of CSG development, although most of this water is of poorer quality.

This chapter provides a summary of water use to date for non-P&G activities and for P&G activities. This provides an understanding of the relative significance of the two water use sectors. The Commission has used the information to calibrate the regional model to make predictions about impacts on groundwater levels.

5.1 Groundwater Extraction Associated with Non-Petroleum and Gas Activities

Non-P&G uses of groundwater in the area are agriculture, industrial, urban and S&D. Under the Water Act, an authorisation is required for extraction of groundwater, other than for P&G activities. The type of authorisation varies depending upon the aquifer system and risk to resource. The following types of authorisation exist in the Surat CMA:

- For GAB aquifers, a water licence is required for taking groundwater from the GAB for all non-P&G activities, including S&D use in most areas. Non-S&D licences have an annual volumetric limit as a condition of the licence.

- For the Condamine Alluvium and Main Range Volcanics, a water licence with a volumetric limit is required for taking of groundwater for all non-S&D use in the areas of significant resource. A statutory authorisation exists for S&D use and a water licence is not required.

- Other groundwater systems in the area are not heavily utilised. A statutory authorisation exists to take groundwater and a water licence is not required for S&D use.

DNRM administers the licensing provisions of the Water Act. Information about water licences, authorised volumetric limit and use is recorded in DNRM's Water Management System, and information about the bores that take water is recorded in DNRM's Groundwater Database. The database may not contain records of all water bores that take water under a statutory authorisation. Many bores with a volumetric limit are metered, but S&D bores are not metered.

The spatial distribution of the water bores in the Surat CMA is shown in Figure 5-1. Table 5-1 provides a summary of all non-P&G water bores and estimated current water extraction. Estimated extraction for volumetric entitlement bores is the maximum authorised under the respective water licence. Actual water use may be less than this. The volume taken from S&D bores has been estimated essentially following the methodology used in the GAB Water Resource Planning process and the Murray-Darling Basin Planning process. The methodology involves estimating use based on the aquifer the bore taps, the property size, whether the property is dominantly rural or urban, and whether groundwater is the likely primary water source. Bore flow rates are used for artesian bores where available.

Table 5-1 shows that there are some 21,200 water bores within the CMA. Less than three per cent of these are artesian, which are mostly S&D bores in the southwest part of the CMA. Total water extraction is about 215,000 ML/year of which about 85,000 ML/year is from the GAB formations and 130,000 ML/year is from other aquifers.

Table 5-1 Non-Petroleum and Gas Groundwater Extraction in the Surat Cumulative Management Area

	Number of Bores			Estimated Groundwater Extraction (ML/year)				
	Non-S&D	S&D	Total	Agriculture	Industrial	Urban	S&D	Total (ML/year)
Non GAB upper formations								
Condamine River Alluvium	896	3,052	**3,948**	41,450	550	4,400	8,600	**55,000***
Other Alluvium	42	715	**757**	5,928	51	-	2,294	**8,273**
Main Range Volcanics & Tertiary Volcanics	1,324	6,314	**7,638**	36,815	2,712	5,924	17,268	**62,719**
Rolling Downs Group	1	209	**210**	100			1,050	**1,150**
Sub Total	*2,263*	*10,290*	***12,553***	*84,293*	*3,313*	*10,324*	*29,212*	***127,142***
GAB								
Bungil Formation & Mooga Sandstone	31	1,068	**1,099**	417	1	239	8,418	**9,075**
Orallo Formation	3	57	**60**	30			300	**330**
Gubberamunda Sandstone	83	825	**908**	2,853	800	1,122	9,047	**13,822**
Westbourne Formation		3	**3**				15	**15**
Springbok Sandstone	10	213	**223**	220		351	1,143	**1,714**
Walloon Coal Measures	251	1,803	**2,054**	7,150	594	143	9,040	**16,927**
Eurombah Formation		18	**18**				381	**381**
Hutton & Marburg Sandstones	358	2,470	**2,828**	8,804	3,698	3,049	12,710	**28,261**
Evergreen Formation	4	298	**302**	108			1,721	**1,829**
Precipice & Helidon Sandstones	32	260	**292**	2,668	3,607	1,523	2,730	**10,528**
Moolayember Formation		86	**86**				433	**433**
Clematis Sandstone		195	**195**				2,123	**2,123**
Sub Total	*772*	*7296*	***8,068***	*22,250*	*8,700*	*6,427*	*48,061*	***85,438***
Non GAB lower formations								
Rewan Group		37	**37**				185	**185**
Bandanna Formation		43	**43**				215	**215**
Bowen Permian		366	**366**				1,830	**1,830**
Basement Rocks	2	123	**125**	16	20		529	**565**
Sub Total	*2*	*569*	***571***	*16*	*20*	*0*	*2,759*	***2,795***
								-
Total	**3,037**	**18,155**	**21,192**	**106,559**	**12,033**	**16,751**	**80,032**	**215,375**

** This is current use under ongoing annual announced allocations administered by DNRM. The total underlying entitlement is approximately 99,000 ML/year*

The following explanations apply in relation to the water use types listed In Table 5-1:

- Agriculture includes irrigation, aquaculture, dairying and intensive stock watering but does not include non-intensive stock or domestic use.
- Industrial includes industrial, commercial and mining.
- Urban is primarily town water supplies but also includes supplies for schools and similar institutions, reticulated domestic supply systems operated by groups of individuals and some commercial and industrial use where the water is delivered through town water reticulation systems.
- Details about other shallow alluvial systems may not be complete but these systems are not well connected from the GAB and are not significant in the context of this report.

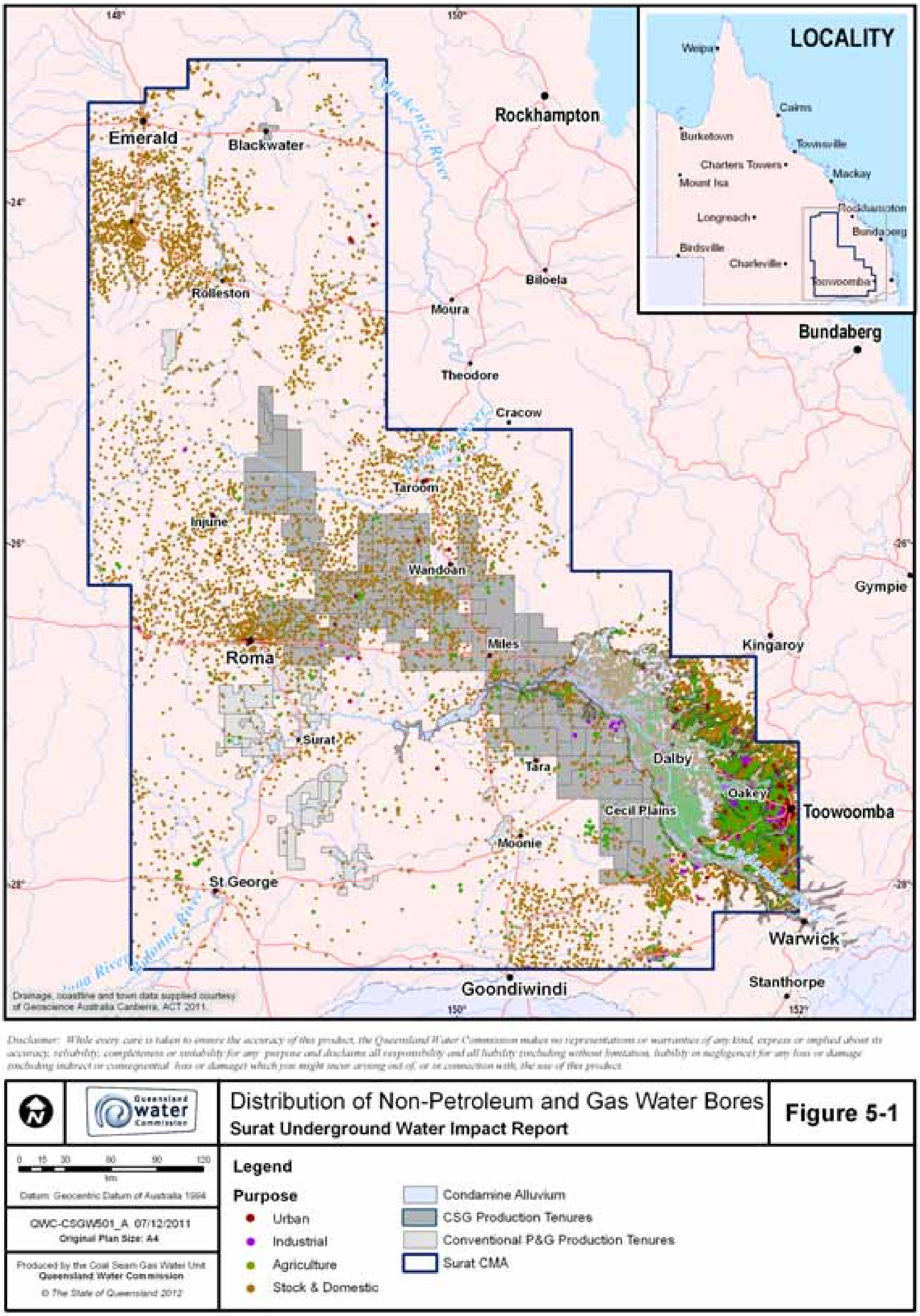

Figure 5-1 Distribution of Non-Petroleum and Gas Water Bores

5.2 Groundwater Extraction Associated with Petroleum and Gas Activities

Petroleum tenure holders have a right to take groundwater under the P&G Acts as described in Chapter 2. There are two types of petroleum and gas activities:

- conventional oil and gas production from dominantly sandstone formations; or
- CSG production from coal formations.

The two types of activities are discussed separately in this section as they have very different water extraction characteristics.

5.2.1 Conventional Petroleum and Gas Water Extraction

Conventional petroleum and gas is recovered from the Bowen and Surat Basins. The most significant extraction has been from the Triassic aged Showgrounds Sandstone of the Bowen Basin and the Jurassic aged Precipice Sandstone and Evergreen Formation of the Surat Basin. The Moonie oil Field, discovered in 1961, is the largest oil accumulation found in the Bowen and Surat Basins. This field is a mature province with the majority of the producing fields in decline or nearing depletion (Cadman, Pain & Vuckovic 1998). The location of these conventional fields is shown in Figure 2-5.

Currently there are 154 conventional oil and gas wells extracting water from GAB formations and 83 extracting water from older Permian and Devonian formations underlying the Bandanna Formation. Most of the water has been produced from the GAB formations where total current water extraction is approximately 1,800 ML/year and has not significantly exceeded that rate over the past 30 years.

Due to the nature of conventional extraction methods, the fields generally have limited numbers of production wells and water production from the individual wells is generally small, averaging less than 2.5 ML/year for most fields.

5.2.2 Coal Seam Gas Water Extraction

Unlike conventional petroleum and gas production, CSG production relies on large-scale depressurisation of coal beds as described in Chapter 2. This process extracts large amounts of water in comparison to conventional operations. While conventional petroleum and gas production has reached a mature stage of development, the CSG industry is at an early stage, with significant growth expected. This growth will result in increased water extraction over time.

CSG field locations are shown in Figure 2-5. There are four major gas fields extracting groundwater from the Bandanna Formation of the Bowen Basin. Some of these are located within the geographic footprint of the Surat Basin but produce CSG from the Bandanna Formation of the underlying Bowen Basin. These Bowen Basin fields are:

- Fairview Field – operated by Santos. The first CSG field in the Surat CMA - commenced operations in 1995.
- Peat Field – operated by Origin since 2001.
- Scotia Field – operated by Santos since 2002.
- Spring Gully Field – operated by Origin since 2005.

The Surat Basin CSG fields commenced development in 2002, later than in the Bowen Basin. The Surat fields extract gas from the Walloon Coal Measures. The major CSG fields in the Surat Basin are as follows:

- Kogan North, Tipton, Daandine, and Stratheden Fields – operated by Arrow since 2006.
- Argyle-Kenya and Berwyndale South Fields – operated by QGC in its Central Development Area near Chinchilla since mid-2005.
- Talinga Field, located approximately 25 km south-west of Chinchilla – operated by Origin since 2005.
- Roma Field (Coxon Creek) – operated by Santos since mid-2007.

Petroleum tenure holders, including coal seam gas explorers and producers, are required under the P&G Acts to report to DNRM on the volume of water they extract during production and testing of their wells. Water extraction from production wells forms part of their six-monthly petroleum production reports. Water extraction from test wells forms part of their production testing reports.

Data about water production obtained by the Commission in early 2011 from DNRM and tenure holders shows that at that time there were 1,160 CSG wells extracting water (as of June 2012, that number is estimated to have increased to about 1400 wells). These include wells that had produced water during the test phase. Total water extraction is approximately 18,000 ML/year. Water extraction during testing is estimated to be less than three per cent of the total current water extracted for CSG production. Historic water production across the CMA from existing conventional and CSG production is shown in Figure 5-2.

Monthly production data received directly by the Commission from tenure holders reaffirms the declining rate of water production from individual wells over time as described in Chapter 2. An example of this relationship developed from reported water production data for some gas wells from the Bowen and Surat Basins is shown in Figure 5-3. There is a significant variation in amount of water that is extracted from these wells reflecting differences in the nature of the coal at the different locations.

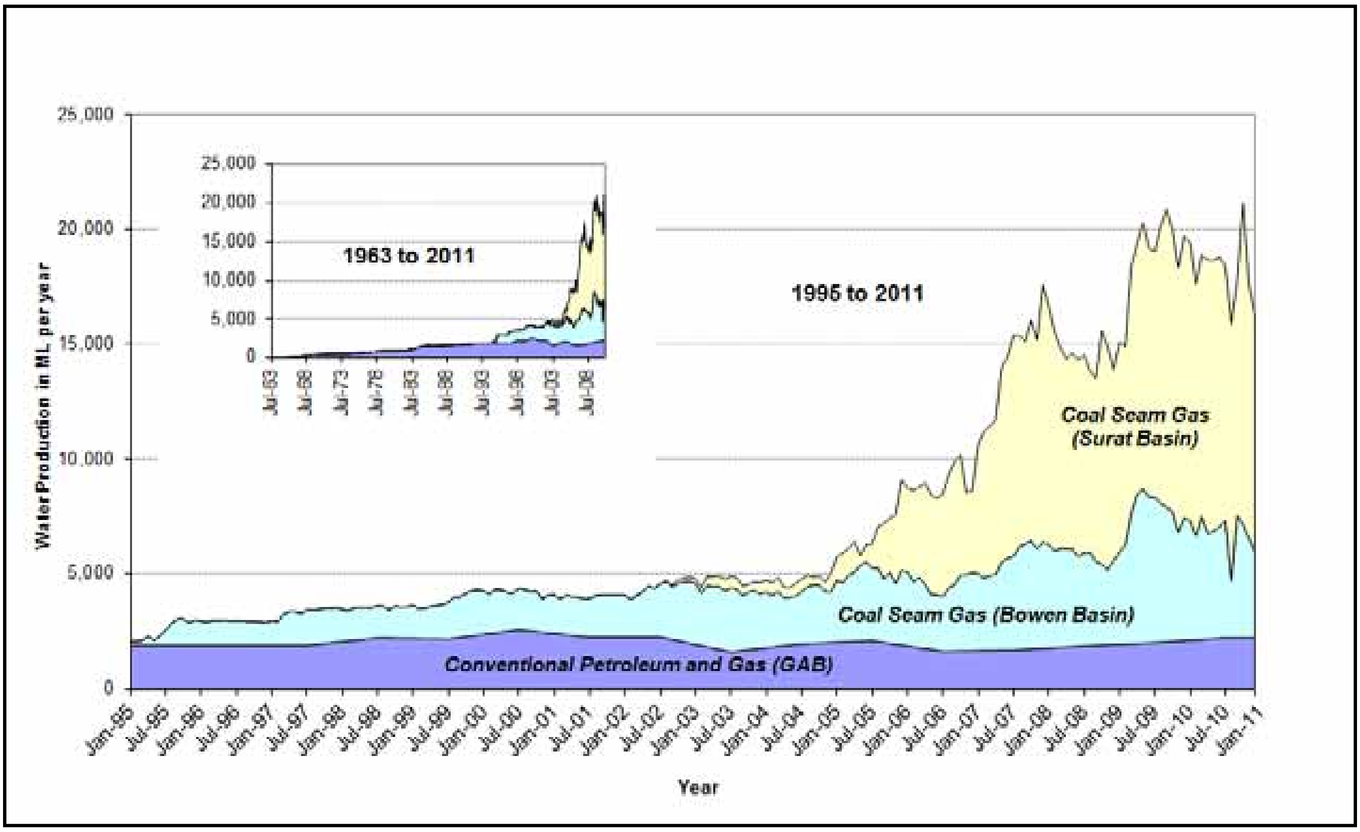

Figure 5-2 Historic Water Production from Petroleum and Gas Wells in the Surat Cumulative Management Area

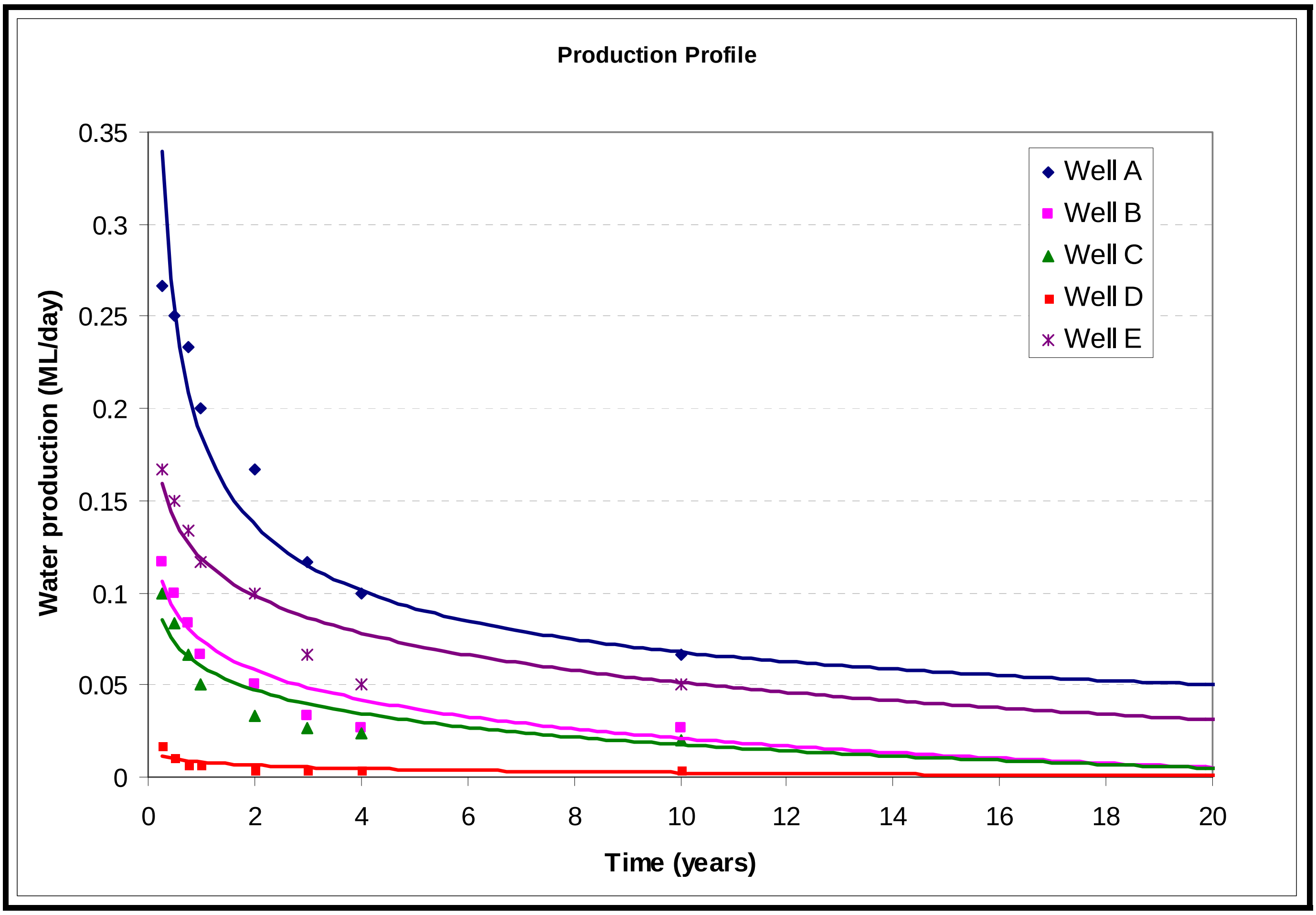

Figure 5-3 Typical Water Production Profiles Derived from Reported Water Production of Coal Seam Gas Wells in the Surat and Bowen Basins

6. Predictions of Groundwater Impacts

This chapter provides an overview of the regional model that the Commission has developed to make predictions about the groundwater impacts. The chapter provides predictions made using the model. The Immediately Affected Area (IAA) and the Long-term Affected Area (LAA) are identified for aquifers in which water level or water pressure impacts are predicted to exceed trigger thresholds. The chapter provides a map of the location of bores and details of the bores in the IAA and LAA.

6.1 Methods and Techniques Used for Groundwater Impact Predictions

There are established mathematical relationships that can be used to predict water pressure changes in a simple homogeneous formation in response to relatively uniform and localised water extraction. Techniques based on these relationships are referred to as ***analytical techniques***. However, in situations where there are spatial variations in hydraulic properties, complex interaction with surrounding formations and spatially distributed and variable groundwater extraction, as is the case in the Surat CMA, analytical techniques are of limited use. In these instances, a numerical ***groundwater flow model*** is a more appropriate tool for predicting water pressure changes.

A groundwater flow model is a computer-based mathematical representation of a groundwater system using the laws of science and mathematics. A modelling code is used to construct a groundwater flow model of a groundwater system in a similar way to that in which a spreadsheet program (such as Microsoft Excel) can be used to carry out relatively simple calculations. However, in the case of a groundwater flow model the designs are complex and consist of a number of input and output files and millions of calculations that can only be carried out by using modern high-performance computers. A model is generally developed for all or part of a groundwater system, with the area referred to as the ***model domain***. A model domain exists in three dimensions. It is divided into a number of building blocks to represent the ground surface and the geologic formations present within the area.

There are three key steps involved in constructing a groundwater flow model:

1. **Conceptualisation** – This involves using available information to translate a complex three-dimensional geologic system, and the understanding of groundwater flow processes in that system, into a simple idealised representation. Numerous assumptions are involved in this process to simplify a complex reality into a relatively simple representation.

2. **Model construction** – The simplified conceptual representation of the system is then converted into a three-dimensional mathematical representation of the physical system and flow processes, which is the groundwater flow model. The model is a series of large computer files representing hydraulic parameters, boundary conditions, groundwater extraction, groundwater recharge, elevation of geologic layers, model grid, and other elements.

3. **Model calibration** – Once constructed, the model is then calibrated based on actual observed groundwater pressures. This calibration process typically involves adjusting the hydraulic parameters of each model layer until the best possible match of predicted to observed water pressures is achieved. Calibration of complex models is carried out using specialised computer programs.

Once constructed and calibrated, the model can then be used to predict changes in water pressure or flow in response to various development scenarios.

There are always uncertainties in model predictions. Some uncertainties are associated with model construction while other uncertainties can arise from the assumptions contained in the development scenario used to make predictions.

Uncertainties are associated with model construction because:

- a groundwater system can be simplified in more than one way depending upon the knowledge available about the system at the time and inaccuracies in field measurements of data (conceptualisation uncertainty); and

- a model can be calibrated to replicate observed water level or water pressure data using quite different sets of hydraulic parameters[2] (calibration uncertainty).

The calibration uncertainty can be assessed by a technique known as ***uncertainty analysis*** which is a recent development applied in more sophisticated groundwater models. Application of the technique requires specialised skills, significant computer capacity and time. The technique involves using multiple sets of parameters, all of which are physically realistic and all of which calibrate the model, to make a large number of predictions. These are then statistically analysed to provide a measure of uncertainty in model prediction. The Commission engaged experts to apply this technique.

It is not practicable to use this type of technique to assess conceptualisation uncertainty in large models. The only approach is to periodically review the conceptualisation as new information about the system becomes available.

Uncertainties in the predictions associated with assumptions about the future groundwater development is not a modelling issue. Any prediction of the impact of CSG development will always be dependent upon the assumptions about how, when and where the development will progress in the future. The Commission will periodically run the model using the current development assumptions as discussed in Chapter 10.

Groundwater systems such as the GAB are complex and our understanding about these systems improves over time, as more information become available. Often a first-generation model helps in identifying key gaps in existing knowledge about the groundwater system and lays the foundation for future monitoring and studies that are required to improve understanding. This process progressively leads to development of later generation models.

6.2 The Regional Model

The Commission developed a groundwater flow model using MODFLOW code. Modflow was developed by USGS (Unites States Geological Survey) in 1988 and has been progressively updated since then. It has become an industry standard for groundwater simulations.

The model domain overlays the entire Surat CMA area and includes coal seam formations and potentially connected aquifers within the Surat, southern Bowen and Clarence-Moreton Basins. Figure 6-1 shows the model domain. The model includes 19 layers to represent the full GAB sequence and alluvial formations within the Surat CMA and the CSG producing Bandanna Formation in the Bowen Basin.

The primary purpose of the model is to predict regional water pressure or water level changes in aquifers within the Surat CMA in response to extraction of CSG water. More specifically, the model is used to:

- define the IAA of consolidated aquifers – that is the areas of the aquifers where water pressures are predicted to decline by more than 5 m within the next three years (to beginning of 2015);
- define the LAA of consolidated aquifers – that is the areas of the aquifers where water pressures are predicted to decline by more than 5 m at any time in the future;
- identify potentially affected springs – springs where the water pressure in aquifers underlying the spring sites is predicted to decline by more than 0.2 m at any time in the future;
- predict the rate of volume of water that will move from the Condamine Alluvium into the Walloon Coal Measures as a result of CSG activities;
- analyse the trends in water pressure changes due to extraction of CSG water; and
- estimate the quantity of CSG water that is expected to be produced.

It should be noted that the model is designed for regional water pressure impact assessment and is not designed to be used to directly predict water pressure or water level variations at a local scale. Therefore, predicted impacts on individual bores or specific locations are of a generalised nature only.

[2] In space and time there can be a number of different distributions of parameters that can result in the same water level pattern. This is mathematically known as the 'non-uniqueness' of a solution.

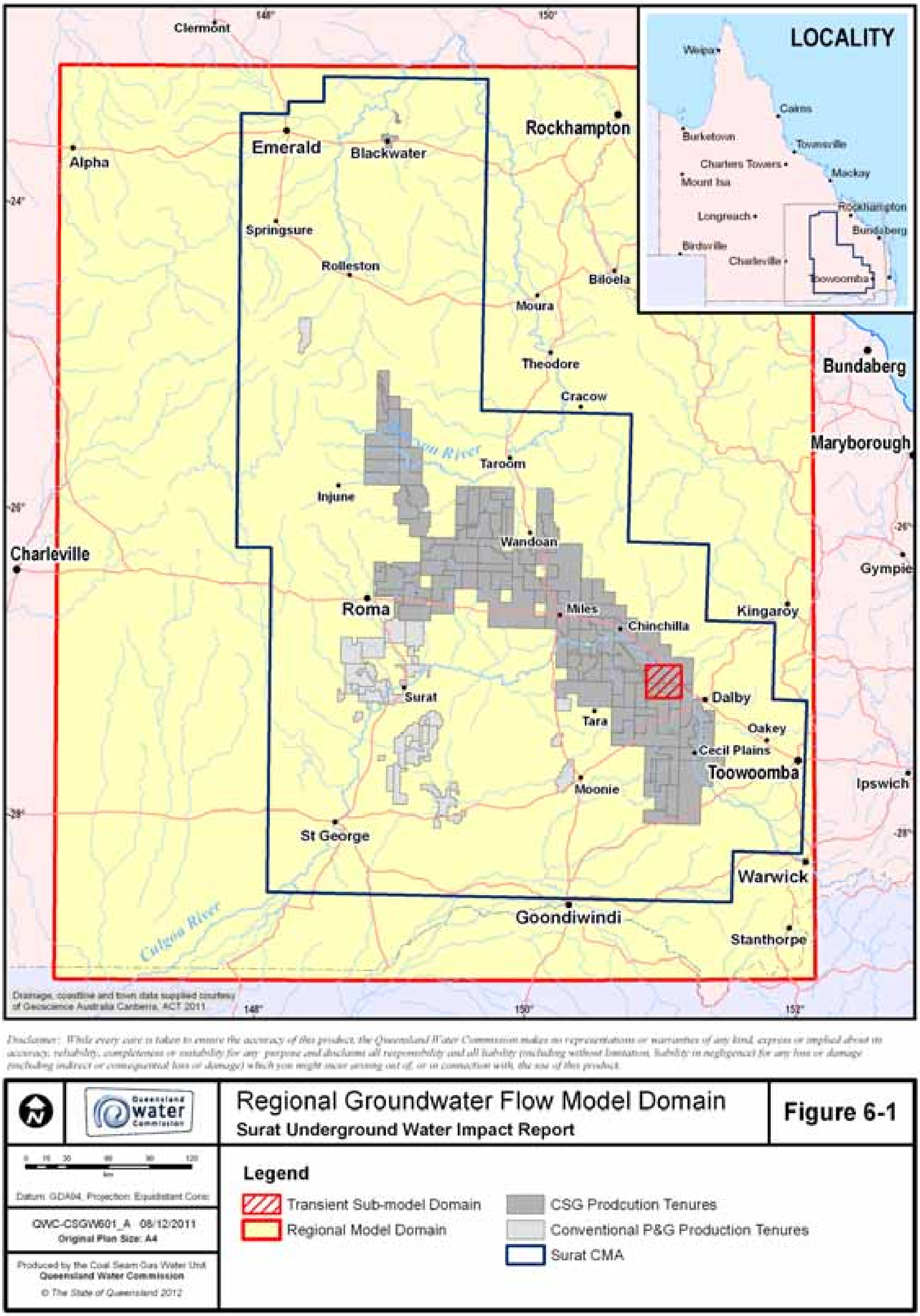

Figure 6-1 Regional Groundwater Flow Model Domain

6.2.1 Conceptual Framework for the Model

The geology and hydrogeology summarised in Chapters 3 and 4 was the basis for developing a conceptual framework for model construction. Information and data used to develop the numerical model include:

- geologic data and interpretation about formation contacts as recorded in the Geological Survey of Queensland's QDEX database and DNRM's Groundwater Database (GWDB);
- distribution and depth of modelled geologic layers for sequences including and underlying the Walloon Coal Measures from a joint study by SRK Consulting and Geological Survey of Queensland of Bowen and Surat Basins and similar surfaces developed initially as part of the Queensland Carbon Geostorage Initiative;
- hydraulic parameter estimates based on primary and interpreted data from pump tests, drill stem tests (DSTs), calibrated parameters from existing models and other reported values in existing reports and literature; and
- estimates of rate of natural groundwater recharge for GAB aquifers from existing reports and literature.

The hydrostratigraphy shown in Figure 4-1 has been simplified into 19 model layers by grouping the various geologic formations present into major aquifers, aquitards, and productive coal measures. The simplified hydrostratigraphy is presented in Figure 6-2. Some formations have been combined as they have similar aquifer properties. The Springbok Sandstone and Walloon Coal Measures have been subdivided into multiple layers because they comprise sediments with different hydraulic parameters.

The regional groundwater flow direction is dominantly from the outcrop or recharge areas in the north, northwest and northeast to the south, south-west and west. Recharge occurs predominantly by direct infiltration of rainfall in the outcrop areas, or indirectly via leakage from streams and/or overlying aquifers. A diagrammatic representation of the groundwater conceptualisation is presented in Figure 6-3. Appendix C shows the range of hydraulic parameters that have been used to guide the model calibration process.

The hydrogeology of the Walloon Coal Measures is particularly complex in that the Walloon Coal Measures actually comprises of a varied sequence of sediments which contain material of high and low permeability. The coal seams are often the main water bearing layers within a sequence of dominantly low permeability mudstones, siltstones or fine-grained sandstones (see Chapter 4).

It is not practical to represent the individual coal seams of Walloon Coal Measures in the regional model as separate layers. This is in part because it is not possible to correlate the coal seams across the area. Therefore, the Walloon Coal Measures is represented in the model by three layers:

- an upper layer representing a generally low permeability mudstone (Layer 9);
- a composite middle layer representing all coal seams from the top of the uppermost productive seam to the base of the lowermost productive seam and the inter-bedded low permeability sediments (Layer 10); and
- a lower layer representing a low permeability formation of dominantly mudstone (Layer 11).

The middle composite layer of the Walloon Coal Measures is therefore a combination of a number of relatively high permeability thin coal seams, separated by thicker predominantly low permeability mudstone, siltstone and sandstone units. The horizontal permeability of this composite model layer in the model represents an average permeability across the whole thickness of the layer.

This simplification is consistent with the general practice of screening gas wells across most of the productive coal seams and the intervening siltstone, mudstone and sandstone to maximise gas extraction. This style of well construction potentially enhances hydraulic connectivity between the coal seams and the inter-bedded sediments.

The representation of the Walloon Coal Measures as a three-layer system is consistent with the current hydrogeological understanding as presented in Chapter 4. The degree of interaction between the coal units which form part of the Walloon Coal Measures and the overlying and underlying aquifers is directly influenced by the vertical permeability and the thickness of the aquitard layers (Layer 9 and 11).

Model Layer	*Formation*	
1	**Alluvium (Condamine) and Main Range Volcanics**	Surat Basin / Clarence - Moreton Basin
2	**Griman Creek / Wallumbilla Formation and Surat Siltstone**	Surat Basin / Clarence - Moreton Basin
3	**Bungil Formation and Mooga Sandstone**	Surat Basin / Clarence - Moreton Basin
4	**Orallo Formation**	Surat Basin / Clarence - Moreton Basin
5	**Gubberamunda Sandstone**	Surat Basin / Clarence - Moreton Basin
6	**Westbourne Formation**	Surat Basin / Clarence - Moreton Basin
7	**Upper Springbok Sandstone**	Surat Basin / Clarence - Moreton Basin
8	**Lower Springbok Sandstone**	Surat Basin / Clarence - Moreton Basin
9	**Walloon Coal Measures (upper aquitard)**	Surat Basin / Clarence - Moreton Basin
10	**Walloon Coal Measures (coal, mudstone, siltstone and sandstone)**	Surat Basin / Clarence - Moreton Basin
11	**Walloon Coal Measures (lower aquitard)**	Surat Basin / Clarence - Moreton Basin
12	**Hutton / Marburg Sandstone**	Surat Basin / Clarence - Moreton Basin
13	**Evergreen Formation**	Surat Basin / Clarence - Moreton Basin
14	**Precipice Sandstone**	Surat Basin / Clarence - Moreton Basin
15	**Moolayember Formation**	Bowen Basin
16	**Clematis / Showground Sandstones**	Bowen Basin
17	**Rewan Group**	Bowen Basin
18	**Bandanna Formation**	Bowen Basin
19	**Permian Sediments**	Bowen Basin

Major aquifers (layers 1, 3, 5, 7, 8, 12, 14, 16)

Productive coal seams (layers 10, 18)

Aquitards/minor aquifers (layers 2, 4, 6, 9, 11, 13, 15, 17, 19)

Figure 6-2 Model Layers and Corresponding Aquifers

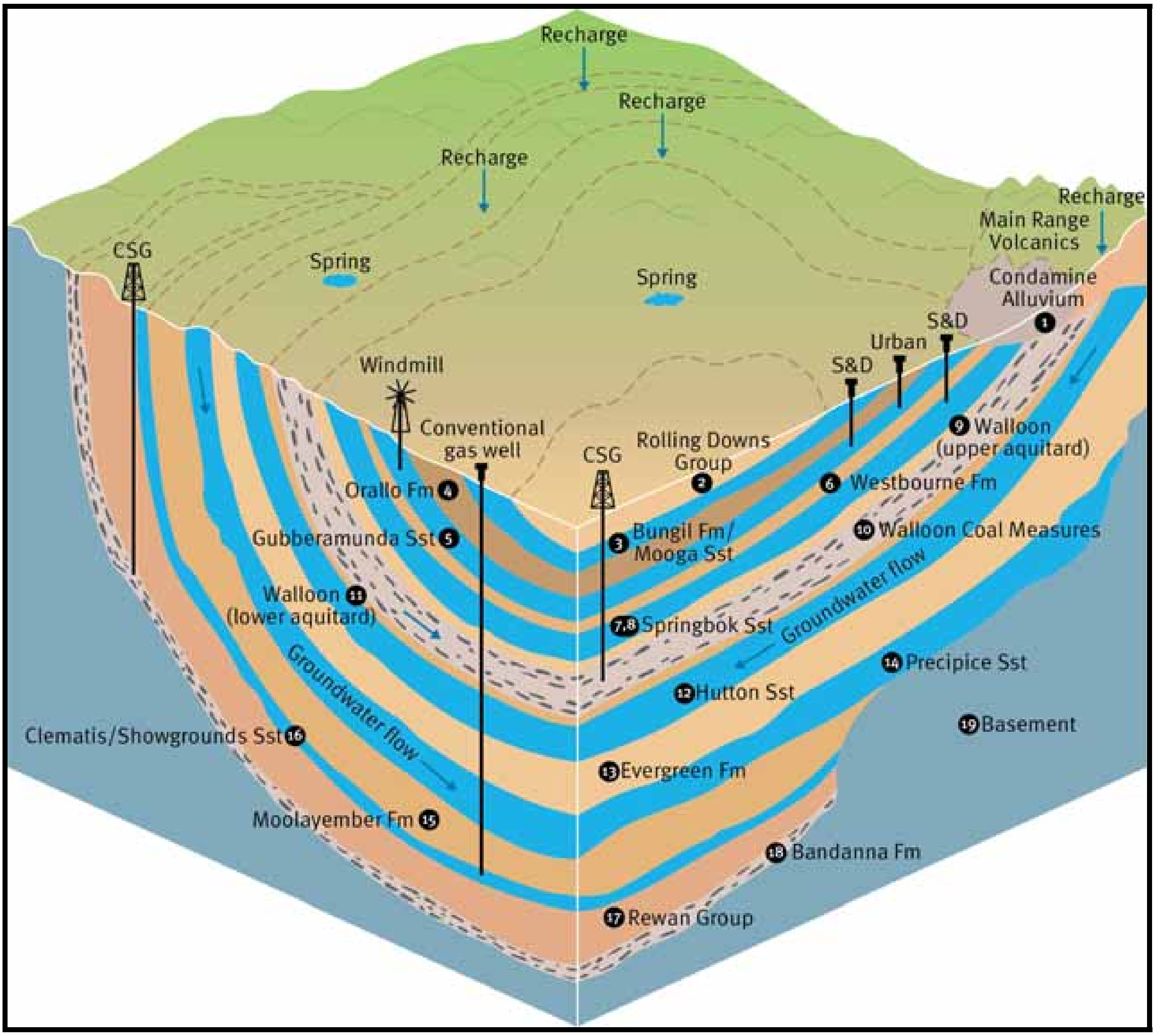

Figure 6-3 Conceptual Model of the Groundwater Systems in the Surat Cumulative Management Area

6.2.2 Groundwater Model Construction and Calibration

The model has been constructed using the MODFLOW 2005 finite difference code developed by the United States Geological Survey.

Model Grid and Parameterisation

The model domain covers an area of around 550 km x 660 km across the southern Bowen Basin and Surat Basin to capture all CSG development areas within the Surat CMA. The model has 19 layers to represent all major aquifers and aquitards each divided into 1.5 km x 1.5 km model cells. This means that geologic formations are collectively represented by more than three million building blocks of 1.5 km x 1.5 km square cells, stacked into 19 layers. The thickness of each layer in each column represents the average formation thickness at that location.

Initial values for hydraulic parameters were based on existing information about the estimated parameters from various sources as outlined in the previous sections. A total of more than 13,000 Drill Stem Tests (DST) data points were used from measurements recorded in the Queensland Petroleum and Gas Exploration Database (QPED) and more than 1,000 pump test records from the DNRM groundwater database.

Model Calibration

Once constructed, the groundwater flow model was calibrated in steady state to replicate pre CSG extraction conditions to 1995 based on the assumption that a reasonable dynamic balance existed at that time. Although the GAB is recognised as a dynamic system, the majority of boreholes show relatively minor trends over the period 1960 to 1995 in the Surat area. Therefore, the assumption about the steady state in 1995 is considered practical for the regional modelling purpose.

The Condamine Aquifer is an exception to the above generalisation. Groundwater levels have continually declined during recent years due to the high levels of extraction from the aquifer. This different behaviour in the Condamine Aquifer has been dealt with by importing groundwater levels from a separate sub-model which has a finer resolution of 500 m x 500 m. This sub-model for the Condamine Alluvium has been in preparation for the water resource planning purpose.

The regional model was calibrated using water levels or water pressure for all bores for which such data was available from DNRM's Groundwater Database and other sources. In total about 1,500 bores were used for calibration of the model.

Estimated groundwater extraction rates from known S&D, licensed entitlement and conventional petroleum and gas production bores were included in the calibration of the model.

Calibration of the model was carried out using specialist automated calibration software (PEST). At the end of the calibration, the overall difference (or residual error) between the observed water levels and predicted water levels was within the acceptable limit as specified in the MDBC modelling guidelines (Middlemis 2000 et.al.). This process resulted in a set of calibrated horizontal and vertical permeabilities.

To assist with the calibration of storage coefficients, a more detailed sub-model was constructed, using 250 m x 250 m model cells, of the existing Daandine CSG production Field west of the Condamine Alluvium (Figure 6-1). The Daandine Field was selected for calibration purposes it has been operational since 2005 and detailed groundwater level data are available for a number of monitoring bores in the immediate vicinity of the well field.

Model Set-up for Interaction with Condamine Alluvium

Over the past 15 years a number of local scale models have been developed for the Condamine Alluvium. These models have been developed to assess the response of the Condamine alluvial groundwater system to use in order to determine a sustainable level of allocation from the system. Most recently, DNRM in collaboration with the National Water Commission has developed a transient groundwater flow model to support water resource management for the Condamine aquifer (the Condamine Model). The Condamine Model was developed by external experts and builds knowledge developed through previous modelling exercises. The model has been calibrated using the latest monitoring data and DNRM is currently reviewing this model internally.

Rather than seek to duplicate the detailed Condamine Model within the regional model, the following integrated approach was adopted:

- Calibrated data from the Condamine Model was used to define the thickness and hydraulic parameters of the relevant layer within the Condamine footprint in the regional model.
- Time-variant water level conditions from the Condamine Model were imported into the regional model.
- The regional model was used to predict the change in flow from the Condamine Alluvium to the Walloon Coal Measures.
- The Condamine Model was then used to estimate impacts on groundwater levels in the Condamine Alluvium that result from the above change in flow.

If the DNRM's review of the Condamine Model results in changes to that model, then predicted change in flow from the Condamine Alluvium to the Walloon Coal Measures from the regional model can be fed back to the revised Condamine Model to update impacts on groundwater levels in the Condamine Alluvium.

6.2.3 Model Set-up for Making Predictions

The model was set up to make predictions starting from 1995. For predictive runs, starting water levels were obtained from the steady state run. The steady state run accounted for the water extraction for S&D and all other use existing in 1995.

The model was set up to run in predictive mode from 1995. Two separate predictive runs were made, a Base Run and a P&G Production Run. The Base Run involved running the model with water extraction from 1995 onward accounting only for non-P&G extraction. In the P&G Production Run, water extraction from current and proposed P&G activities was added to the Base Run water extraction. The difference in predicted water levels between the P&G Production Run and the Base Run provides an estimate of water level impacts that are attributed to P&G activities.

Simulated wells were switched on and off in the model in accordance with the information provided by the tenure holders about the sequencing of development for each of the production tenures. The wells were spaced between 750 to 1,000 m also on the basis of information provided by the tenure holders.

The information about the sequencing of development and well spacing was provided to the Commission by the tenure holders in response to a statutory notice issued by the Commission. Although, the information provided was generally consistent with the information in the EISs prepared by the tenure holders, there were some minor variations. This was mainly because information provided in accordance with the statutory notice was more detailed and up to date than the information in the EISs. Based on the information provided by the tenure holders. Figures A-1 and A-2 in Appendix A present information about the timing of commencement and cessation of production for various parts of production tenures. This information was used in the regional model.

Optimal conditions for the flow of CSG are typically achieved when water pressures in the production well are at around 35 to 40 m above the top of the coal seams. Well fields are generally operated such that water pressure in coal seams are gradually drawn down to, and then maintained at or around this target level. This process typically occurs gradually over a three-to-five-year period and the rate of water extraction declines over the period.

In model simulations, the gas wells initially extract water at a rate based on the relationship between pumping rate and time. The Commission has established this relationship from historical water production data (Figure 5-3) independent of the water production forecasts provided by the tenure holders. The wells were allowed to continue pumping according to this relationship until the target pressure level (35 to 40 m above the top of the coal seams) was reached, after which water extraction was reduced to maintain the target level until the scheduled cessation of production.

6.3 Results of Groundwater Impact Predictions

The uncertainty analysis provided 200 different predictions of drawdown for each of the model cells at different time periods. The 200 predictions were ranked in an increasing order from lowest to highest predicted drawdown. The upper and lower five per cent were discarded as outliers and then the maximum value of the remaining predictions was used in determining the groundwater impacts for the purpose of this report. A reference to impact in this chapter is a reference to drawdown caused by P&G water extraction.

A generic description of depressurisation of aquifers in a multilayered aquifer system (such as the GAB) and how this depressurisation can manifest as a decline in the water level in bores tapping different layers is presented in Appendix D.

In addition to the coal formations from which CSG is produced, the predictions of groundwater impacts were made for the following aquifers: Bungil Formation and Mooga Sandstone, Gubberamunda Sandstone, Springbok Sandstone, Hutton Sandstone, Precipice Sandstone, Clematis Sandstone and the Condamine Alluvium.

6.3.1 Immediately Affected Area (IAA)

The IAA of an aquifer is the area within which water levels are predicted to decline, due to water extraction by petroleum tenure holders, by more than the trigger threshold within three years. The trigger thresholds are specified in the Water Act. They are 5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as sands). Figure 6-4 shows the extent of the IAAs.

Key observations about the IAA are as follows:

- The Walloon Coal Measures and the Bandanna Formation are the only formations that are predicted to experience significant impacts within the next three years. This result is because water is directly extracted from these formations and significant expansion is planned between 2013 and 2014.
- There is a very small IAA in the Springbok Sandstone west of Chinchilla.
- There are very small IAAs in the Precipice and Hutton sandstones and their equivalents. These result from long standing conventional petroleum and gas activities that extract water directly from the sandstone formations. For the most part the impacts will have already occurred.

Table 6-1 provides a summary of the water bores located within the IAA for an aquifer, that extract water from that aquifer. Details of these bores are provided in Appendix E. There may be other private bores that are located within the geographic extent of the IAA for an aquifer, but which extract water from another aquifer. Therefore these bores are not affected bores and are not included in this summary. Information about the purpose, location and target aquifer is compiled from the data obtained from DNRM's GWDB and Water Management System.

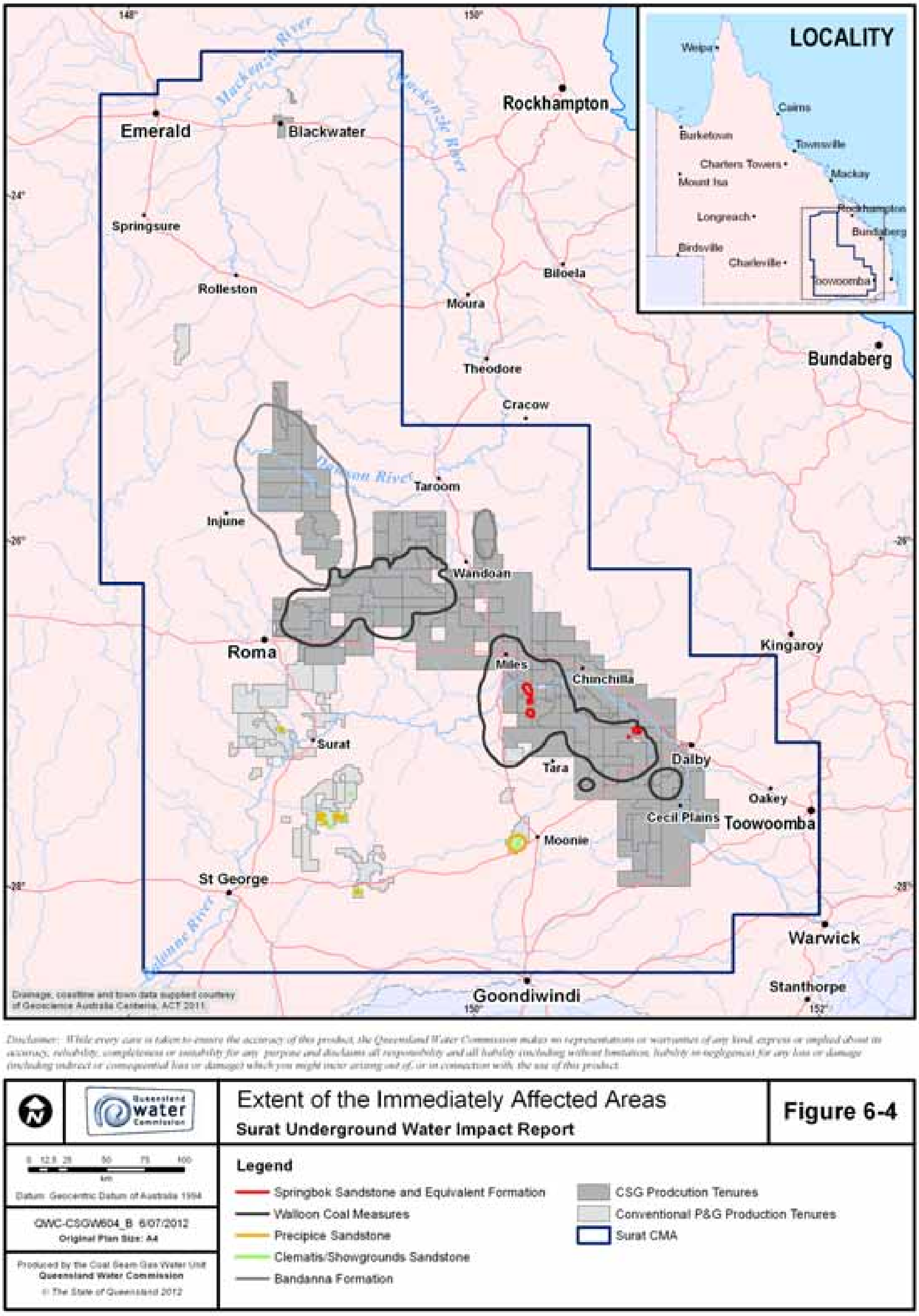

Figure 6-4 Extent of the Immediately Affected Areas

Table 6-1 Water Bores in Immediately Affected Areas

	Agriculture	Industrial	Urban	S&D	Total
Non GAB Upper formations					
Condamine River Alluvium	-	-	-	-	-
Other Alluvium	-	-	-	-	-
Main Range Volcanics & Teritiary Volcanics	-	-	-	-	-
Rolling Downs Group	-	-	-	-	-
Sub Total	-	-	-	-	-
GAB					-
Bungil Formation & Mooga Sandstone	-	-	-	-	-
Orallo Formation	-	-	-	-	-
Gubberamunda Sandstone	-	-	-	-	-
Westbourne Formation	-	-	-	-	-
Springbok Sandstone	-	-	-	-	-
Walloon Coal Measures	5	1	-	79	85
Eurombah Formation	-	-	-	-	-
Hutton & Marburg Sandstones	-	-	-	-	-
Evergreen Formation	-	-	-	-	-
Precipice & Helidon Sandstones	-	-	-	-	-
Moolayember Formation	-	-	-	-	-
Clematis Sandstone	-	-	-	-	-
Sub Total	*5*	*1*	-	*79*	*85*
Non GAB Lower formations					
Rewan Group	-	-	-	-	-
Bandanna Formation	-	-	-	-	-
Bowen Permian	-	-	-	-	-
Basement Rocks	-	-	-	-	-
Sub Total	-	-	-	-	-
Total	**5**	**1**	**-**	**79**	**85**

6.3.2 Long-term Affected Area (LAA)

The LAA of an aquifer is the area within which water levels are predicted to fall, due to water extraction by petroleum tenure holders, by more than the trigger thresholds at any time in the future. The trigger thresholds are specified in the Water Act. They are 5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as sands).

Figure 6-5 Extent of the Long-term Affected Areas shows the extent of the LAAs. The LAAs are significant for the Walloon Coal Measures, the Bandanna Formation, the Springbok Formation, and the Hutton Sandstone. There are very small LAAs for the Precipice Sandstone and Clematis Sandstone.

Table 6-2 provides a summary of the private bores located within the LAA for an aquifer that extract water from that aquifer. There may be other private bores that are located within the geographic extent of the LAA for an aquifer, but which extract water from another aquifer. They are not included in this summary. Information about the purpose, location and target aquifer is compiled from the data obtained from DNRM's GWDB and Water Management System.

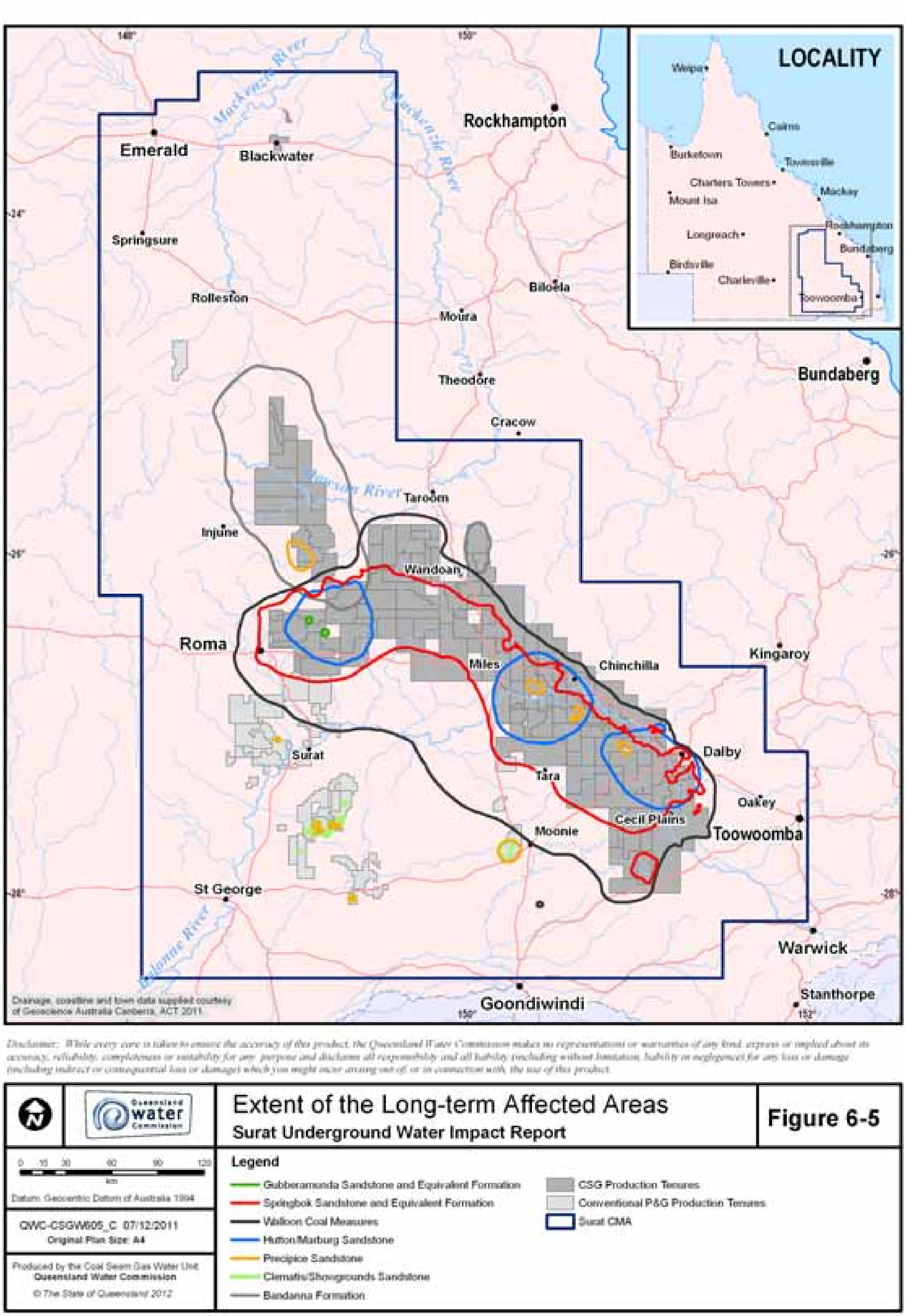

Figure 6-5 Extent of the Long-term Affected Areas

Table 6-2 Water Bores in Long-term Affected Areas

	Agriculture	Industrial	Urban	S&D	Total
Non GAB Upper formations					
Condamine River Alluvium	-	-	-	-	-
Other Alluvium	-	-	-	-	-
Main Range Volcanics & Tertiary Volcanics	-	-	-	-	-
Rolling Downs Group	-	-	-	-	-
Sub Total	-	-	-	-	-
GAB					-
Bungil Formation & Mooga Sandstone	-	-	-	-	-
Orallo Formation	-	-	-	-	-
Gubberamunda Sandstone	-	-	-	1	1
Westbourne Formation	-	-	-	-	-
Springbok Sandstone	2	-	3	99	104
Walloon Coal Measures	27	2	2	369	400
Eurombah Formation	-	-	-	-	-
Hutton & Marburg Sandstones	3	4	-	16	23
Evergreen Formation	-	-	-	-	-
Precipice & Helidon Sandstones	-	-	-	-	-
Moolayember Formation	-	-	-	-	-
Clematis Sandstone	-	-	-	-	-
Sub Total	*32*	*6*	*5*	*485*	528
Non GAB Lower formations					-
Rewan Group	-	-	-	-	-
Bandanna Formation	-	-	-	-	-
Bowen Permian	-	-	-	-	-
Basement Rocks	-	-	-	-	-
Sub Total	-	-	-	-	-
					-
Total	**32**	**6**	**5**	**485**	**528**

The LAAs presented in Figure 6-5 show only the extent of 5 m long-term impacts. Further details about the distribution of long-term impacts are shown on maps provided in Appendix F-1 to F-9. A summary of the long-term impact distribution is provided below.

- *Walloon Coal Measures*: This is the target CSG formation in the Surat Basin. For most of the area the long-term impact is expected to be less than 150 m. Within the production area, the magnitude of impact reflects the depth of the top of the coal formation because operational practice for CSG production is to lower the pressure in coal seams to approximately 35 to 40 m above the top of the uppermost coal seam (refer to Section 2.1.2). As a result, in the more westerly areas, where the coal formation is relatively deep, the impacts are expected to be up to 700 m. There are 400 private water bores that source water from the formation in the affected area. Most of these are located further to the east where the formation is shallow and impacts are smaller. Half of the affected bores are likely to experience an impact of less than 21 m.

- *Bandanna Formation:* This is the target CSG formation in the Bowen Basin. In most of the area the long-term impact is expected to be less than 200 m. For similar operational reasons to the Walloon Coal Measures, impacts in Bandanna Formation are also greater in areas where the coal formation is deep. The impact in these areas is expected to be up to 1,000 m. However in areas where private bores tap the formation the impacts are expected to be much smaller. It is expected that impacts will not exceed 5 m in any bore.

- *Springbok Sandstone:* This aquifer overlies the Walloon Coal Measures. It is separated from the productive coal seams for the most part by the upper aquitard of Walloon Coal Measures (refer to Section 4.4.2). Over most of the affected area the maximum impact is expected to be less than 20 m, although there is a small area south of Miles where impacts are expected to reach 90 m. There are 104 bores that source water from the formation in the affected area. It is expected that the impact will not exceed 20 m in any of those bores and to be less than 10 m in more than half of them.

- *Hutton Sandstone:* This aquifer underlies the Walloon Coal Measures. It is separated from the productive coal seams by the lower aquitard of the Walloon Coal Measures. Over most of the affected area the maximum impact is expected to be less then 5 m, although there are small areas where maximum impacts may reach up to 18 m. There are 23 private bores sourcing water from the formation in the affected area. The maximum impact in any bore will be 13 m, but more than half of the bores will experience an impact of less than 7 m.

- *Precipice Sandstone:* Over most of the affected area the maximum impact is expected to be less than 2 m. West of CSG fields of the Bowen Basin near Injune, the aquifer is in direct contact with the Bandanna Formation and therefore the maximum impact in that area is predicted to reach about 10 m. Near Moonie there are very small areas of local impacts where conventional petroleum and gas is currently being produced directly from the Precipice Sandstone and equivalent formation. However, there are no private bores that tap the Precipice Sandstone in the impact areas of more than 5 m in this formation.

- *Gubberamunda Sandstone and Mooga Sandstone*: These are shallow aquifers that are not well connected to the coal formations. Generally impacts are expected to be less then 3 m and only in relatively small areas. There is one bore that sources water from the Gubberamunda Sandstone in its Long-term Affected Area. The impact in that bore is expected to be 5 m.

- *Clematis Sandstone*: There are small areas where an impact of up to 2 m is expected. Near Moonie there are very small areas of local impact where conventional petroleum and gas is currently being produced directly from the formation.

- *Condamine Alluvium:* The maximum predicted impact is about 1.2 m on the western edge of the alluvium with an average of about 0.5m for most of the area. This is less than the trigger threshold of 2 m for unconsolidated aquifers. Therefore there is no LAA for the Condamine Alluvium. The declining water levels in the Walloon Coal Measures are likely to start affecting the Condamine Alluvium around 2017. The induced leakage will continue long after the cessation of CSG water extraction because a pressure differential between the Walloon Coal Measures and Condamine Alluvium will still exist in some areas due to the slow recovery period. The average estimated net loss from the Condamine Alluvium to the Walloon Coal Measures is expected to be about 1,100 ML/year over the next 100 years.

Maximum impacts in any aquifer will occur at different times at different geographic locations. Maximum impacts in the coal formations will occur towards the end of the life of the industry, generally between 2030 and 2055. Maximum impacts in the Springbok Sandstone and the Condamine Alluvium, are expected to occur between 2060 and 2075. In indirectly connected aquifers where the predicted impacts are comparatively small, such as the Hutton, Precipice, and Gubberamunda Sandstones, there will be a significant time lag before maximum impacts occur.

The total amount of induced flow from the formations overlying and underlying the Walloon Coal Measures is expected to be about 50 per cent of the total water extracted for CSG production from the coal formations.

Impacts in aquifers are expected to persist for long periods in the absence of re-injection of treated CSG water into affected aquifers or similar measures. The rate of recovery will be greatest in the years after water extraction ceases, but will reduce exponentially with time. It is estimated that for the coal measures and the significantly affected aquifers there will be a 50 per cent recovery from maximum impact, 30 to 80 years after maximum impact.

6.3.3 Water Extraction Forecast

The regional model developed by the Commission has provided estimates of CSG water extraction by P&G tenure holders based on the information provided about development plans. It is estimated that over the life of the industry, water extraction will average about 95,000 ML/year. Water production will vary over time and geographically. The effect of dual phase flow, as discussed in Section 2.1.2, is also expected to affect the amount of water extracted.

For the purposes of comparison estimates of water extraction from other sources are given below and summarised in Figure 6-6:

- A tool for estimating water extraction from CSG activities is being developed under research by DNRM as part of the Healthy HeadWaters Coal Seam Gas Water Feasibility Study (HHW). Interim results suggest average water extraction will be approximately 98,000 ML/year under Scenario-1[3].
- Estimates of water extraction from CSG activities have been made by CSG project proponents in their EISs. At the time the UWIR was in preparation, Arrow had not submitted the EIS for the Surat Gas Project, however the Commission has obtained estimates of projected water extraction from Arrow. The estimated average water extraction from these sources suggest is approximately 86,000 ML/year for all four major proponents, although this does not include some expansion projects.
- Industry representatives have advised that they now expect average water production to be approximately 75,000 ML/year.

Water production over the next three years is sensitive to the actual rate of CSG industry expansion. From the Commission's model and the other sources it is estimated that water extraction will be about an average of 125,000 ML/year over the period.

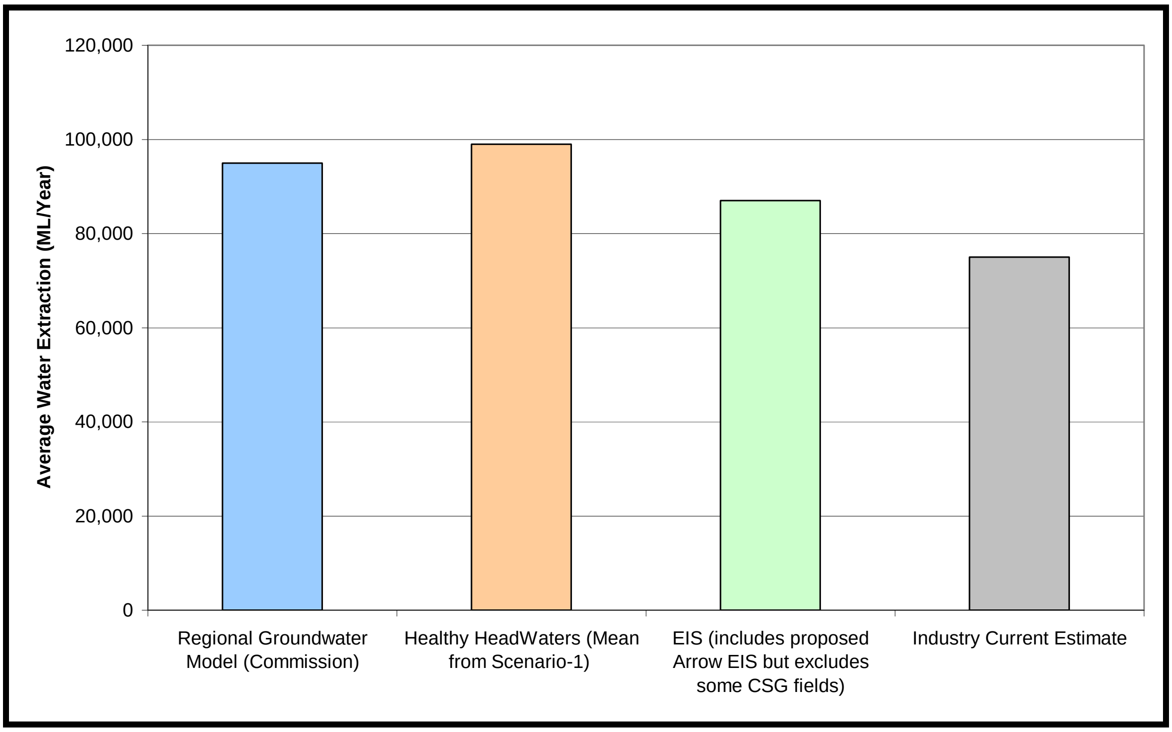

Figure 6-6 Summary of CSG Water Extraction Estimates

[3] Scenario 1 of the HHW project for estimating water production from the CSG development was based on information provided by the proponents to that project on proposed development timelines and inferred information from the publicly available documentations.

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7. Water Monitoring Strategy (WMS)

7.1 Overview

This chapter sets out the WMS for the Surat CMA. The implementation of the WMS will build understanding of the impacts of water extraction by petroleum tenure holders on groundwater and support ongoing improvements in regional groundwater flow modeling.

In this chapter, the term ***monitoring site*** is used to describe a geographic location where a monitoring bore and related works are located. It provides for monitoring at specific geologic sequences or target units (***monitoring points***) at each monitoring site, with many sites requiring monitoring of multiple target units. There are monitoring technologies available that allow a single borehole to be drilled and water pressure to be monitored at a number of monitoring points at a single monitoring bore. Figure 7-1 shows various types of monitoring installations. The term ***monitoring network*** is also used to describe a group of monitoring bores that monitor water level or pressure and water quality in aquifers, to meet specific objectives.

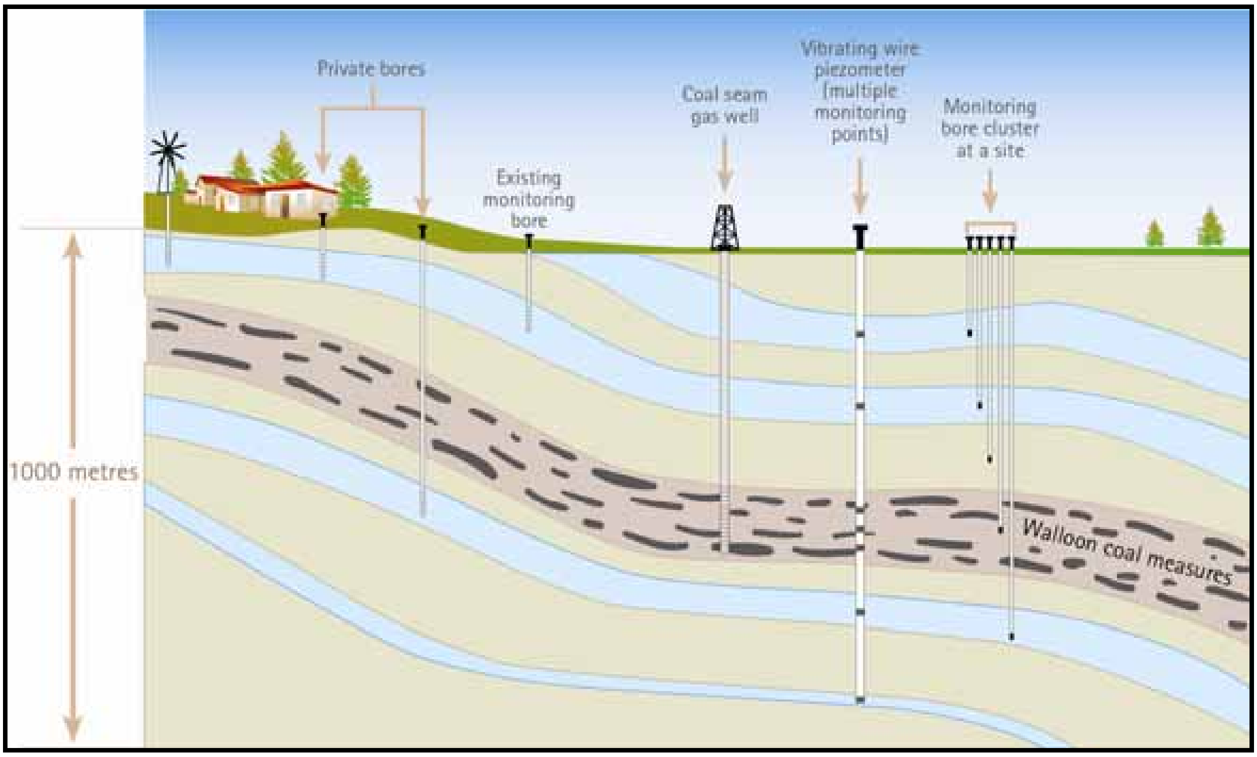

Figure 7-1 Schematic of Groundwater Monitoring Installations

The WMS presented in this chapter includes:

- monitoring of water level or pressure in coal formations and surrounding aquifers;
- monitoring water quality as appropriate to detect quality changes resulting from water extraction by petroleum tenure holders; and
- monitoring the volume of water extracted from petroleum and gas wells.

The WMS is not directed at issues related to the storage and handling of contaminants involved in CSG operations or at groundwater contamination related to CSG activities such as hydraulic fracturing. Any monitoring required in relation to matters such as these is dealt with under environmental authorities issued by EHP or under other authorisations.

There is significant water level or water pressure and water quality monitoring already being undertaken by petroleum tenure holders and DNRM. In addition petroleum tenure holders also have plans for establishing further monitoring works. The Commission has considered these existing and planned works in designing the WMS regional monitoring network (Section 7.3.1). While the WMS regional monitoring network has incorporated some existing and planned monitoring works, it also requires installation of additional monitoring works at some existing monitoring sites and at new sites.

The Commission does not own monitoring works or carry out monitoring. The WMS will be implemented by petroleum tenure holders in accordance with individual responsibilities assigned in Chapter 9. This work involves construction and maintenance of monitoring installations, securing agreement about access to existing bores where necessary, installing monitoring instrumentation and recording and reporting data and progress on implementation to the Commission on a six-monthly basis.

On approval of the UWIR, tenure holders will have a legal obligation to implement their assigned parts of the WMS. EHP is responsible for ensuring that petroleum tenure holders comply with those responsibilities. The Commission will interact with petroleum tenure holders to monitor the progress of monitoring network implementation, analyse monitoring data and provide annual reports assessing trends as discussed in Chapter 10. The Commission will also store and maintain the monitoring data that is received from the tenure holders.

7.2 Rationale for the WMS

The rationale underpinning the design of the WMS is to identify monitoring objectives and select monitoring sites and monitoring points to meet the multiple objectives as efficiently as possible while incorporating existing sites and points where possible. These aspects of the rationale are discussed in the following sections.

7.2.1 Monitoring Objectives

The WMS is designed to meet the following specific objectives.

Objective 1 – Establish background trends

Monitoring is needed to establish background trends in advance of impacts occurring from water extraction by petroleum tenure holders. Identification of these trends is essential to separate the impact of CSG development from other factors such as climate. Background trends also provide useful insight in understanding the functioning of groundwater systems by enabling development of regional water level or pressure surfaces.

Objective 2 – Identify changes in aquifer conditions within and near areas of petroleum development

Monitoring is needed in and around existing and developing gas fields to identify, at an early stage, impacts on water pressure and water quality resulting from CSG water extraction. The amount of water produced, and therefore potential impacts, will be greater for some fields compared to others and the monitoring sites need to be appropriately positioned and installation timed accordingly.

Objective 3 – Identify changes in aquifer conditions near critical groundwater use

There are areas where existing groundwater use is concentrated or of critical importance, for example, towns in the area that rely heavily on groundwater. Water pressure and water quality monitoring sites need to be located to ensure early understanding of any unexpected impacts on water levels or water pressure propagating toward these areas.

Objective 4 – Identify changes in aquifer conditions near springs

Some of the springs fed by aquifers of the GAB are of high ecological value. Chapter 8 establishes a spring monitoring program that identifies the attributes to be monitored in certain springs. The WMS complements the spring monitoring program by establishing water pressure monitoring in aquifers near springs. There is also a need to improve understanding of how the hydrology of springs relate to the conditions in underlying aquifers.

Objective 5 – Improve future groundwater flow modelling

The groundwater flow model is based on a conceptualisation of hydrogeology of the groundwater flow system. As an example, a key matter during construction of the model was identifying the most appropriate representation of the complex Walloon Coal Measures, as discussed in Chapter 4. Monitoring needs to provide information that not only improves understanding of the flow system, but also assists in future updates and calibration of the model.

Objective 6 – *Improve understanding of connectivity between aquifers*

The connectivity between coal formations and surrounding aquifers is a key issue. Monitoring works are needed at multiple sites, with monitoring points established within multiple geologic units at each of those sites, to continue to improve knowledge about connectivity.

7.2.2 Efficiency in Achieving Objectives

A single monitoring installation can improve the overall attainment of more than one objective. For example, a monitoring site selected to provide early warning of water pressure changes at a spring location can also provide information about the propagation of impacts from a nearby gas field. Similarly, a monitoring site installed to establish background trends can become a site that monitors impacts at a later stage when impact areas expand.

Initially a large number of monitoring points were identified to meet the individual objectives. These were then rationalised to ensure that as far as possible multiple objectives are attainted by a single monitoring point. The process involved subjective consideration of: the regional model predictions; anticipated regional hydrogeological processes such as recharge and discharge areas; groundwater flow direction; and geological complexities.

7.2.3 Maximising Benefits from Existing Infrastructure

A number of monitoring sites and monitoring points are already in existence in the area that are operated by individual petroleum tenure holders or DNRM. Although many are located in shallow alluvial systems, some monitor water pressure in the GAB formations and have long-term records. To maximise the benefits from the existing monitoring infrastructure, key existing monitoring points are incorporated in the monitoring network.

In addition to the incorporation of existing monitoring points the WMS also includes collection of a range of water pressure and water quality data from gas wells

Not all existing monitoring points have been included in the monitoring network because data from these points will not substantially add to the attainment of the monitoring objectives. However, the Commission will regularly obtain monitoring data from these points for appropriate analysis. This data collection is identified as an integral part of the water monitoring strategy as stated in Section 7.3. The locations of these existing monitoring points, that are not part of the regional monitoring network, are shown in maps presented in Figures G1 to G9.

7.2.4 Research Project Based Monitoring

The regional monitoring network will be used for the ongoing long-term collection of monitoring data. Separately, the Commission plans to promote a number of research and investigation projects in collaboration with other parties as described in Chapter 10. Some of these projects will involve additional project specific monitoring installations and data collection. These installations will supplement the monitoring network and some of those monitoring points will be added to the network in future.

7.2.5 Staged Installation

The strategy provides for staged implementation of the monitoring network. This prioritises the commencement of monitoring having regard to logistical practicalities associated with site access and installation of deep monitoring bores. The staging also provides opportunity for adjustment of the later stages of installation to address emerging issues.

7.3 Water Monitoring Strategy

The WMS is comprised of the following components:

- a regional groundwater monitoring network required to be implemented and operated by petroleum tenure holders;
- the ongoing collection and reporting of water pressure and water quality data by the petroleum tenure holders;
- the ongoing collection and reporting of water production data from petroleum and gas wells by petroleum tenure holders;
- the ongoing collection and reporting of water quality and bottom hole pressures in selected coal seam gas wells by the petroleum tenure holders; and
- the regular assessment of monitoring results by the Commission, with annual reporting of those assessments as set out in Chapter 10.

7.3.1 Regional Monitoring Network

The regional monitoring network consists of a group of existing and new monitoring bores to monitor water level or water pressure and water quality in aquifers and coal formations. Key attributes include:

- the location of monitoring sites;
- the target geologic units;
- the parameters to be monitored; and
- the frequency of measurement.

The sites and monitoring points of the regional monitoring network are listed in Table G-1 of Appendix G together with other details about their location, status and the rationale for selecting each individual monitoring point and site. Maps showing the locations of monitoring sites for water pressure monitoring and water quality monitoring are presented as Figure 7-2 and Figure 7-3 respectively. Table 7-1 provides a summary of the regional monitoring network. The locations of the monitoring points in each of the main aquifers are shown in Figures G-1 to G-9 in Appendix G.

Some of the monitoring points in the network are at sites where there are existing installations or at sites where installation has been planned by the tenure holders but not yet constructed. These sites have been incorporated in the regional network as far as possible. The Commission has also included a requirement for a large number of new monitoring sites and monitoring points to complete the network for attainment of the monitoring objectives. There are also new monitoring points required at sites where there are existing monitoring points but additional monitoring points are needed to attain the objectives of the regional monitoring network.

There are existing monitoring points that have not been included in the network because data from them will not directly contribute to the attainment of the monitoring objectives. However, the Commission will regularly obtain data from these points for appropriate analysis. This is identified as an integral part of the water monitoring strategy as stated in Section 7.3. For information purpose, the location of these existing monitoring points which are part of the regional monitoring network, are provided in maps presented in Figures G1 to G9.

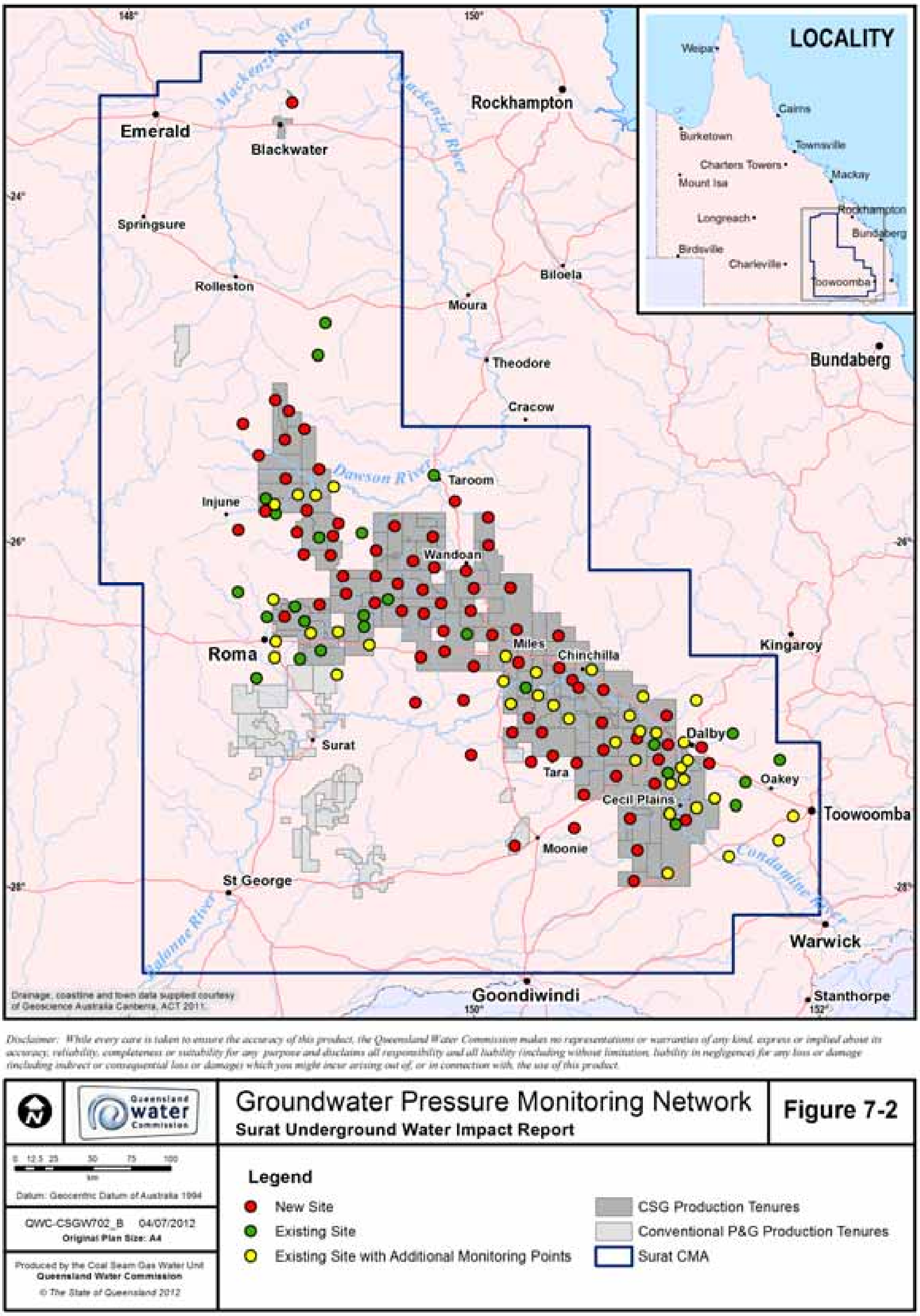

Figure 7-2 Groundwater Pressure Monitoring Network

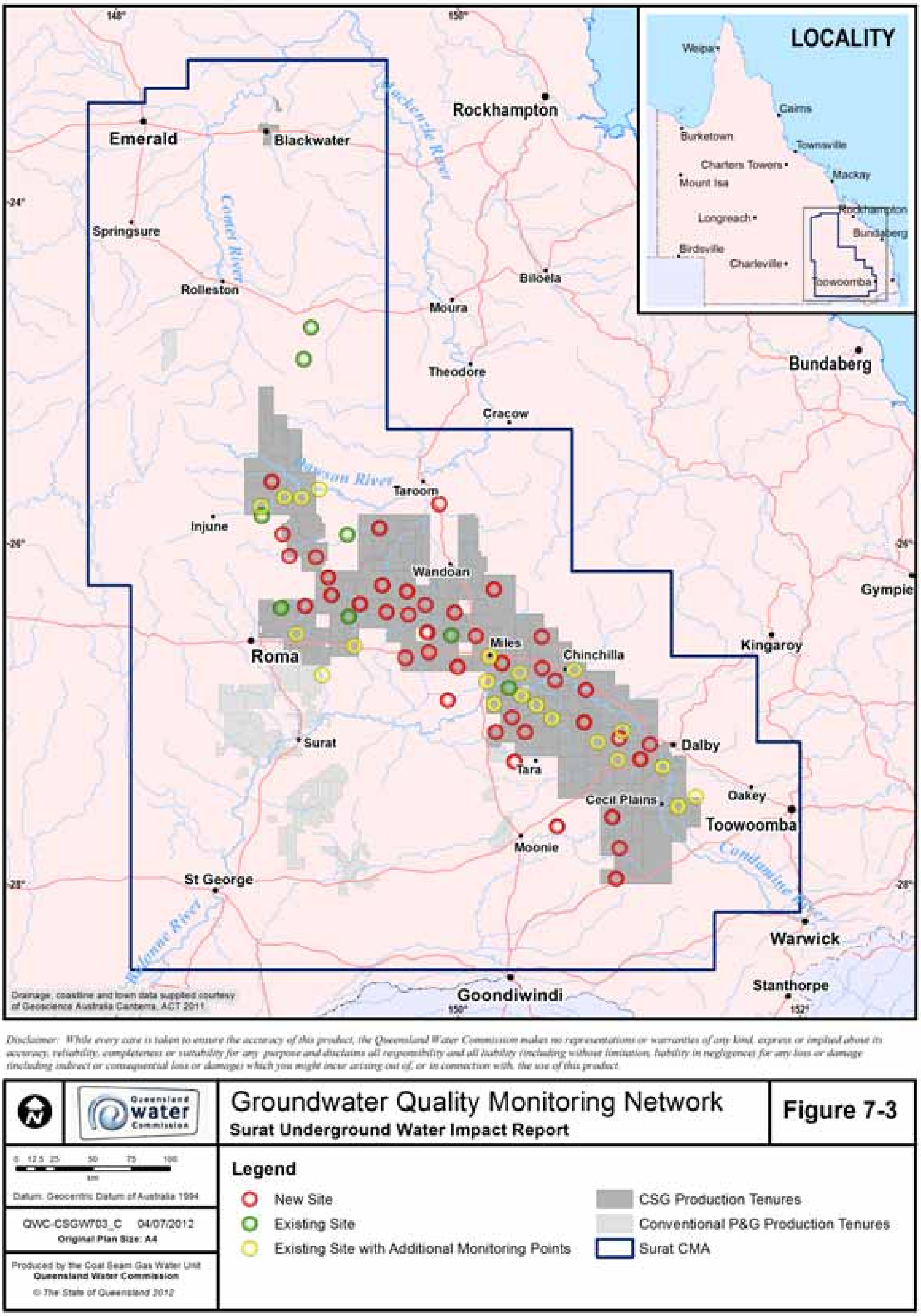

Figure 7-3 Groundwater Quality Monitoring Network

Key features of the regional monitoring network are as follows:

- There are 142 monitoring sites and 498 monitoring points that form the regional monitoring network. At 114 sites, two or more monitoring points will be established.
- Of the 142 monitoring sites, 27 sites are already in existence, 36 are sites where one or more monitoring points exist but additional monitoring points are required at the same sites, and the remaining 79 sites are new sites.
- Of the total 498 monitoring points in the proposed network, 102 are already in existence, 212 are those that are not in existence yet, but are currently planned by petroleum tenure holders, and 184 are completely new monitoring points.
- The Walloon Coal Measures has 103 water level or water pressure monitoring sites with a total of 262 monitoring points that monitor water levels in the different geologic units within the Walloon Coal Measures, including the upper and lower aquitards.
- The Condamine has 18 water pressure monitoring sites with a total of 25 monitoring points. This provides for the monitoring of water pressure differences between the alluvium, the transition layer and the coal seams of the underlying Walloon Coal Measures as described in Chapter 4.
- The regional monitoring network also includes 120 water quality monitoring points.

Table 7-1 Summary of Regional Monitoring Network

Target Unit	Water pressure monitoring points			Water quality monitoring points		
	Existing	New	Total	Existing	New	Total
Condamine Alluvium	10	15	*25*	2	1	*3*
Main Range Volcanics	3	1	*4*	0	0	*0*
Mooga Sandstone	8	0	*8*	4	0	*4*
Orallo Formation	2	0	*2*	1	0	*1*
Gubberamunda Sandstone	17	18	*35*	8	11	*19*
Westbourne Formation	3	2	*5*	0	1	*1*
Springbok Sandstone	10	51	*61*	6	32	*38*
Walloon Coal Measures	36	226	*262*	1	12	*13*
Hutton Sandstone	3	34	*37*	0	18	*18*
Evergreen Formation	1	2	*3*	0	0	*0*
Precipice Sandstone	6	20	*26*	4	11	*15*
Clematis Sandstone	2	6	*8*	2	0	*2*
Bandanna Formation	1	21	*22*	0	6	*6*
All units	**102**	**396**	***498***	**28**	**92**	***120***

Monitoring Parameters and Frequency

Two key parameter sets are required for monitoring: water pressure and water quality. Water quality parameters are required only at key locations, primarily to assist in understanding hydrogeological processes and establishing water quality trends in response to groundwater extraction. The parameters required to be measured for water quality monitoring are set out in Table G-2 of Appendix G.

It is common practice to collect groundwater monitoring data at relatively frequent intervals for the initial monitoring period, often by installing automatic data loggers. This data enables local factors and background trends to be established. After this initial period, less frequent monitoring is usually appropriate.

The WMS requires water level data to be collected at a minimum frequency of once a fortnight. However, it is anticipated that more frequently recorded data will be available to the Commission where it is collected using automatic data loggers.

For water quality installations, field parameters are to be monitored on a fortnightly basis as specified in Table G-1. In addition, annual water quality sampling for detailed laboratory analysis is also required. More frequent water sampling for detailed laboratory analysis may be necessary if analysis of the trends in field parameters or water pressure suggests that a material shift in water quality could occur.

7.3.2 Responsibility of Petroleum Tenure Holders

The WMS will be implemented by petroleum tenure holders in accordance with individual responsibilities assigned in Chapter 9. Table G-1 in Appendix G identifies the responsible tenure holder for each monitoring site.

The responsible tenure holder must construct and maintain monitoring installations, install monitoring equipment and record and report data to the Commission.

Where new monitoring points are required, the tenure holder may:

- modify their plans for constructing monitoring works to align them with the requirements of the regional monitoring network;
- identify a suitable existing bore and negotiate access for monitoring purposes with the bore owner; or
- construct new monitoring works.

Monitoring works and equipment are to be installed, maintained and operated to appropriate regulatory and industry standards.

The petroleum tenure holder responsible for a monitoring site is required to maintain ongoing monitoring capacity at the site. Should a monitoring installation cease to be capable of providing monitoring information then appropriate arrangements for adequate maintenance of the monitoring records will need to be settled with the Commission by the responsible tenure holder. This could mean for example that if a third party water bore is utilised at the site, and the bore owner abandons the bore, then the tenure holder will need to establish a new monitoring installation at the site to maintain the monitoring record.

For their own reasons, petroleum tenure holders may maintain additional monitoring installations to those identified in the regional monitoring network. The Commission will obtain the data from those installations from tenure holders, but will not require that those monitoring installations be maintained as part of the regional monitoring network.

7.3.3 Timing of New Installations

Table G-1 specifies the year by which monitoring needs to commence at each installation. For existing installations the monitoring is to commence as soon as practicable but by the end of 2012 at the latest. If the tenure holder owns the existing installation, then monitoring has commenced. If the existing installation belongs to a third party (for example, DNRM or a land owner), then the responsible tenure holder will need to arrange agreement about access and use of the installation for monitoring purposes, by the end of 2012.

For other installations in Table G-1 of Appendix G there are two commencement times, the end of 2013 and 2016. The installations required by 2013 are at sites where impacts are likely to occur relatively early or where data is needed at an early date for other reasons such as to assist future groundwater flow modelling. If a responsible tenure holder intends to construct other monitoring works in 2013, and for logistical reasons would need to disrupt that program in order to comply with monitoring obligations under the UWIR, then on request the Commission may agree to delay some of the 2013 WMS installation requirement until as early as practicable in 2014. However, the Commission will only agree to rescheduling if it would be in the best overall interest of improving knowledge and understanding of CSG impacts.

The second group is to be installed by 2016. These installations are generally at more remote sites where impacts are not expected for many years. If these installations are established by 2016, they will provide adequate background data in advance of any impacts. Scheduling less urgent installations for 2016 provides the opportunity to revise the network in the 2015 revision of the UWIR, informed by knowledge existing at that time.

7.3.4 Monitoring of CSG Wells

The P&G Acts and associated regulations require that petroleum tenure holders monitor water extraction from petroleum and gas wells. As part of the WMS, total water extraction must be recorded at a suitable scale on a monthly basis and be reported to the Commission every six months.

Bottom hole pressure data and water quality data is generally collected by petroleum tenure holders from CSG production wells for either operational reasons or to meet regulatory requirements. As part of the WMS, CSG tenure holders are required to report this data to the Commission on a six monthly basis.

7.3.5 Implementation and Reporting

This section outlines the program for reporting to the Commission about the implementation of the WMS.

Responsible tenure holders must provide the Commission with a WMS Network Implementation Report every six months. The first such report must be submitted to the Commission within two (2) months of the approval of the final UWIR. These reports will provide details about the installed WMS monitoring works and specify details about planned implementation and issues that may affect timely installation of monitoring works.

The regional monitoring network provides locations for monitoring sites specified in terms of latitude and longitude. Although tenure holders are expected to locate works as close as possible to these locations, it may be impracticable to site the new works exactly at the specified location. For WMS purposes, the new works at some sites will need to be close to the specified location, while for other sites it may be acceptable to locate the works several kilometres from the specified location. If a tenure holder proposes a change to the location of a planned monitoring site, the change is to be specified in the WMS Network Implementation Report. The report should also specify the reasons for the change and how that will affect the attainment of the monitoring objectives identified for the monitoring point, in Table G-1. The Commission will provide guidance to tenure holders for planning purposes. The proposed change will be accepted if the Commission endorses the WMS Network Implementation Report.

There may be potential difficulties associated with water quality sampling from dedicated monitoring bores in the coal formations within or near a production field. Therefore, in a WMS Network Implementation Report, a tenure holder may also propose relocating water quality monitoring points to a nearby, but appropriate CSG well. The proposed change will be accepted if the Commission endorses the WMS Network Implementation Report.

Responsible tenure holders are required to submit all required monitoring data to the Commission every six months in an agreed electronic format.

7.3.6 Baseline Assessment Program

A baseline assessment is an assessment of a private bore by a petroleum tenure holder to obtain information about the bore and information about water levels and quality. The information provides a baseline of bore condition and performance. This information supports the settling of agreements between bore owners and petroleum tenure holders about making good any impairment of bore supply caused by the extraction of groundwater by petroleum tenure holders. The water level and quality information can also assist the Commission in its ongoing assessment of the groundwater system.

The Water Act requires petroleum tenure holders to carry out baseline assessments of water bores on a tenure before production commences on the tenure. These baseline assessments are carried out in accordance with a baseline assessment plan approved by EHP and in accordance with guidelines issued by EHP.

The Water Act also provides that the WMS contain a program for baseline assessments for the LAAs. This program includes land outside the tenures on which production is occurring. Since water level or water pressure impacts in many parts of the LAAs will not occur for a very long time, it is not proposed to undertake the baseline assessment for bores in the entire LAAs. Baseline assessments are best carried out just before the impacts are expected to occur. If they are carried out too early the information collected will be out of date and be of degraded use for assessing changes.

For this reason, the program for carrying out baseline assessments for the LAAs is to progressively expand the area assessed so that assessments are completed soon before impact is predicted to occur. A predicted impact of 1 m within three years has been adopted as the trigger for carrying out a baseline assessment. When a new UWIR is prepared in three years time, a new 1 m impact area will be established.

The baseline assessment program is as follows.

- The baseline assessment area for an aquifer is an area where a water pressure decline of more than 1 m is expected within three years as shown in Figure 7-4.
- Responsible tenure holders must carry out baseline assessments for bores tapping an aquifer within the baseline assessment area for the aquifer.
- If a baseline assessment has already been carried out in accordance with other obligations arising under the Water Act, no further assessment is required.
- The assessments are to be carried out in accordance with the guidelines for baseline assessments issued by EHP.
- The baseline assessment must be completed and the results reported to the Commission within 12 months of the UWIR being approved.
- Each time the UWIR is reviewed, new baseline assessment areas will be established until the baseline assessment areas for an aquifer coincide with the entire LAA for the aquifer.

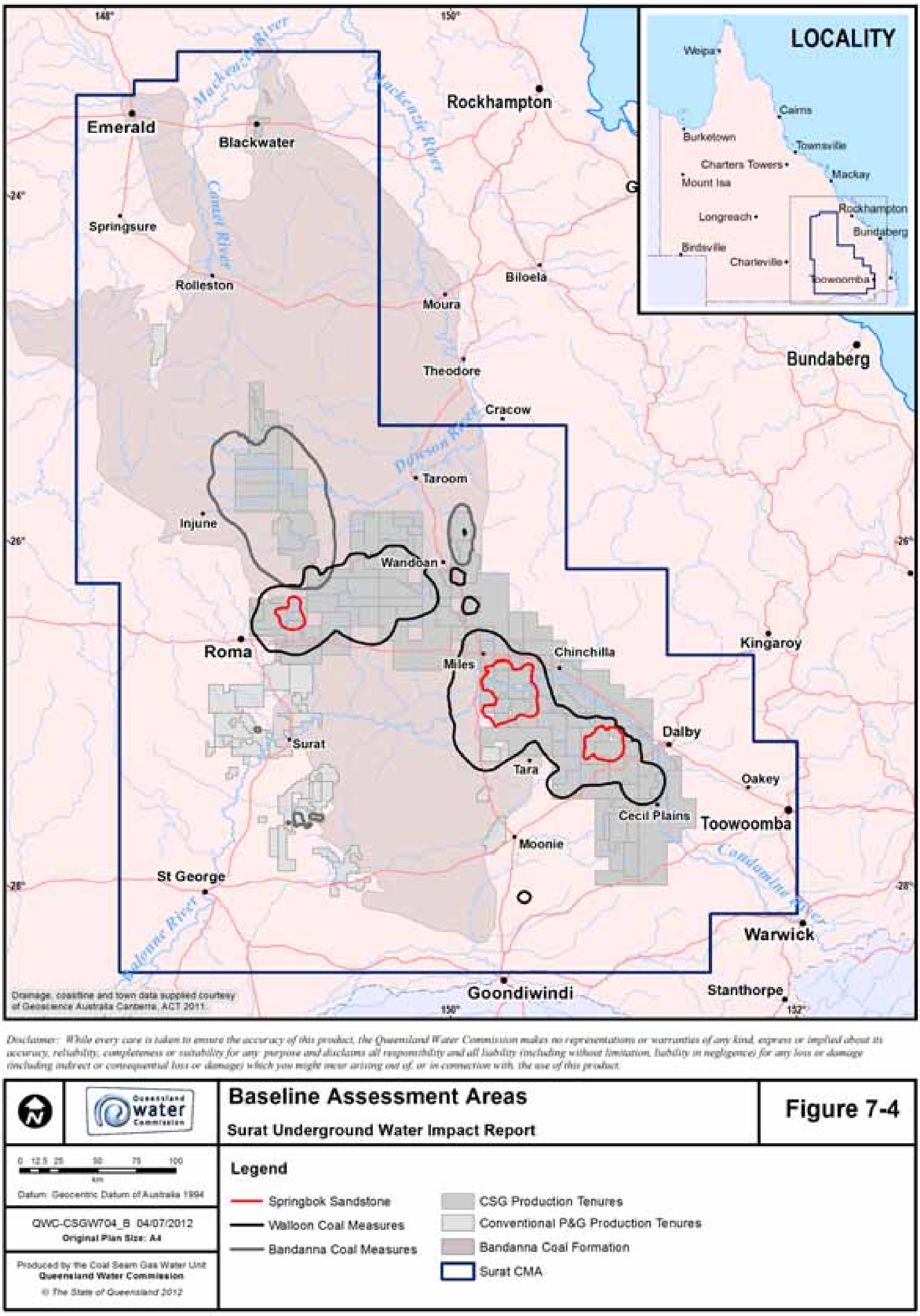

Figure 7-4 Baseline Assessment Areas

8. Spring Impact Management Strategy

8.1 Introduction

Springs are an important part of the landscape in the Surat CMA. They have significant ecological and cultural heritage values. Springs are fed by aquifers. If the water pressure in the aquifer feeding a spring is lowered by water extraction by petroleum tenure holders, then the flow of water to the spring will be reduced to some extent and potentially affect spring values. The Queensland regulatory framework provides that the UWIR include a Spring Impact Management Strategy (SIMS) that considers all potentially affected springs.

This chapter describes the nature of the springs and identifies the potentially affected springs in the Surat CMA. It then describes the way in which the Commission has approached the preparation of the SIMS and specifies the components of the SIMS, which are:

- identification of potentially affected springs;
- an assessment of the connectivity to underlying aquifers and the risks to the springs;
- a spring monitoring program; and
- a spring impact mitigation strategy.

8.2 Springs in the Surat Cumulative Management Area

This section identifies the springs that overly geologic formations in which water pressure are expected to decline by more than 0.2 m because of petroleum tenure holders' water extraction.

8.2.1 Types of Springs

There are six basic types of springs in the CMA, which can be defined by hydrogeological characteristics. Individual springs can display a mixture of these characteristics. The basic spring types are as described below and are represented diagrammatically in Figure 8-1.

(a) A spring can form where there is a change in the geology within the landscape. This type of spring is often referred to as a contact spring. Where a higher permeability formation overlies a lower permeability formation, there is a restriction to flow across the boundary. As a result, water tends to flow laterally and may find expression at the surface as a spring.

(b) Permeability can vary within an individual aquifer. In an aquifer, there can be layers of higher and lower permeability. Water restricted by a lower permeability layer can flow laterally through a higher permeability layer as a perched watertable, and may find expression at the surface as a spring. This type of spring typically occurs within outcropping aquifers and forms in a similar way to a contact spring described under (a).

(c) A geologic structure, such as a fault can provide a path to the surface along which water can flow. If an underlying aquifer is confined by impermeable material and the water pressure in the aquifer is high enough, water can flow to the surface as a spring.

(d) A thinning of a confining layer can provide a path to the surface along which water can flow. If the pressure in the aquifer is high enough, water can flow to the surface as a spring.

(e) Where an aquifer outcrops high in the landscape, such as in Carnarvon Gorge, Expedition Ranges and the Great Dividing Range, a spring can form where there is a change in the slope of the ground surface.

(f) Where an outcropping aquifer has been eroded to create a depression in the surface of sufficient depth to reach the water table, a spring can form. This type of spring is generally associated with creeks and streams, and is referred to as a watercourse spring (also sometimes referred to as baseflow springs) in this report.

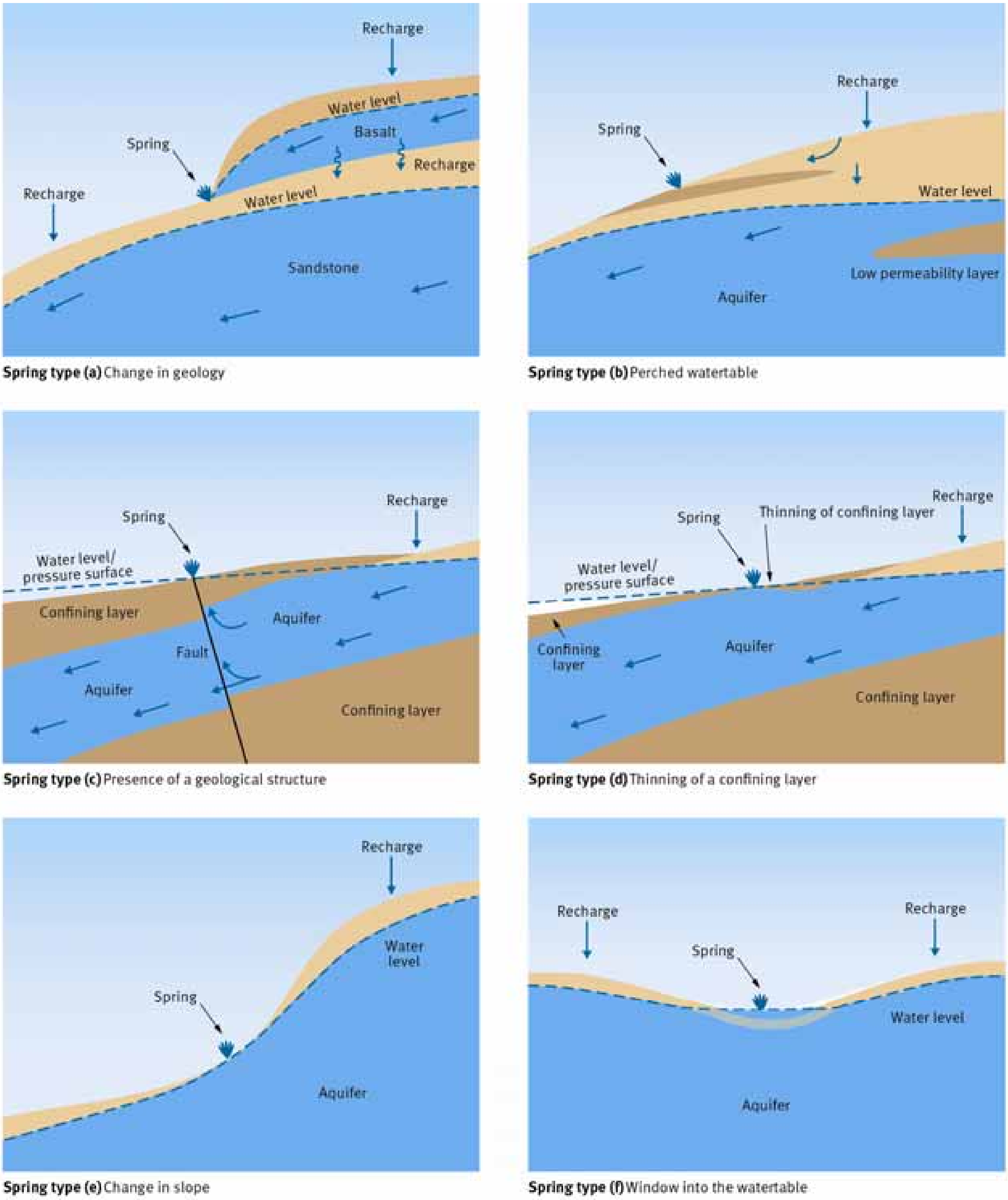

Figure 8-1 Types of Springs in the Surat Cumulative Management Area

8.2.2 Spring Terminology

A range of definitions for springs and groups of springs exist at various geographical scales. This report refers to springs as vents, watercourse springs or spring complexes.

Table 8-1 provides a definition for each term.

Table 8-1 Spring Definitions

Term	Description
Spring vent	A single point in the landscape where groundwater is discharged at the surface. A spring vent can be mounded or flat and can also be represented by wetland vegetation, with no visible water at the location of the spring.
Spring complex	A group of spring vents located in close proximity to each other. The spring vents are located in a similar geology and are fed by the same source aquifer. No adjacent pair of spring vents in the complex are more than 6 km apart.
Watercourse spring	A watercourse spring is a section of a watercourse where groundwater enters the stream from a GAB aquifer through the streambed. This type of spring is also referred to as a baseflow fed watercourse. (Figure 8-1, Spring type (f))

In this report the term ‘springs’, when used alone, refers to spring vents, spring complexes or watercourse springs.

Within the Surat CMA, there are 71 spring complexes (containing 330 spring vents) and 43 watercourse springs.

The data sources that have been used to guide the development of the SIMS has included the Queensland Springs and the Spring Complex datasets held by the Queensland Herbarium; the Queensland GAB Water Resource Plan’s Springs Register (2006) and Wetland Mapping Dataset (2010) held by DNRM; and the GAB Springs Database (2003) held by the Bureau of Rural Sciences.

In addition to the above dataset, the Commission’s spring survey has significantly expanded the knowledge of springs in the Surat CMA. More detail on the spring survey is provided in Section 8.3.1.

8.2.3 Ecological and Cultural Values of Springs

Springs in the GAB, including some springs in the Surat CMA, are of national conservation significance as they provide unique ecological habitats and are often associated with a range of cultural heritage values.

These springs often occur in arid and semi-arid areas and provide habitat for species from wetter environments that would not normally survive in drier conditions. The need to protect the unique species associated with GAB springs has been recognised under two statutes, the EPBC Act and the *Nature Conservation Act 1992*. The statutes recognise and list both individual species and an ecological community associated with GAB springs. The EPBC Act lists both individual species and ecological communities. Table 8-2 provides a summary of the listings under these statutes associated with springs in the Surat CMA (Queensland Herbarium 2012).

In the Surat CMA, the listed ecological community associated with springs is ‘the community of native species dependent on natural discharge of groundwater from the GAB’. The listing includes all discharge springs regardless of the ecological assemblages associated with the spring. A discharge spring is defined as a spring located within an aquitard or confining layer that is fed by flow from an aquifer underlying the confining layer (Figure 8-1, Spring types (c) and (d)).

Table 8-2 Summary of Springs Containing Listed Species or the Ecological Community

Listed species / community	Conservation status		Number of springs associated with the listing in the Surat CMA
	EPBC Act	*Nature Conservation Act 1992*	Spring complexes (Spring vents)*
The community of native species dependent on natural discharge of groundwater from the GAB	Endangered	-	10 (92)
Eriocaulon carsonii	Endangered	Endangered	5 (17)
Myriophyllum artesium	-	Endangered	1 (5)
Arthraxon hispidus	Vulnerable	Vulnerable	2 (17)
Phaius australis	Endangered	Endangered	1 (1)
Thelypteris confluens	-	Vulnerable	1 (2)
Livistona nitida	-	Near Threatened	3 (7)

* *The number in the bracket represents the total number of spring vents within the complexes*

A range of cultural heritage values may also be associated with springs in the Surat CMA. A study in relation to the cultural heritage values associated with springs was carried out in 2005 to support the development of the Queensland GAB water resource plan (CQCHM 2005). The report identified four broad categories of values: mythological associations; ritual and ceremonial associations; economic and subsistence associations: and personal historical events.

The Commission has completed a search of the Aboriginal and Torres Strait Island Cultural Heritage Register (the Register) to identify the registered cultural heritage sites that are in close proximity to potentially affected springs, and which may therefore be linked to the presence of a permanent water source. The entries on the register are far from being a comprehensive assessment of the cultural heritage values associated with springs, as the entries are made as a result of activities such as infrastructure development or mining, rather than as a result of a focused assessment of cultural heritage values associated with springs.

Appendix H-1 provides additional information on the cultural heritage study completed in 2005 (CQCHM, 2005) and the recent search of the Register by the Commission. In Chapter 10, the Commission has also identified a future project to engage with the appropriate Aboriginal Parties and relevant stakeholders to advance the understanding and acknowledgement of cultural and spiritual values associated with the potentially affected springs.

8.2.4 Potentially Affected Springs

A spring is a ***potentially affected spring*** if it overlies a GAB aquifer where the long-term predicted impact on water pressures at the location of the spring resulting from the extraction of water by petroleum tenure holders exceeds 0.2 m. As well as the springs identified using the regional groundwater flow model, the Commission has included high value springs that are located up to 10 km beyond the 0.2 m limit to allow for the limitations associated with modelling very small changes in water pressure.

The Commission has used available knowledge about springs and its regional groundwater flow model to identify potentially affected springs and the risk that they will be impacted. Within the Surat CMA, springs are not known to be fed from the Walloon Coal Measures or the Bandanna Formation, the target formations for P&G production. The majority of springs are fed from the Precipice Sandstone, Hutton Sandstone and the Clematis Group, although springs are also fed from the Basalts, Gubberamunda Sandstone and the Boxvale Sandstone Member of the

Evergreen Formation. These springs could be affected because of interconnectivity between the spring's source aquifer and the target CSG formations.

Springs are also associated with the Basalts to the north, south and west of Toowoomba. These springs are associated with local flow systems and are disconnected from the flow regimes in the underlying GAB formations.

The details of the potentially affected springs are provided in Appendix H-2 and are shown on Figure 8-2. Table 8.3 provides a summary of all springs in the Surat CMA.

Table 8-3 Springs in the Surat Cumulative Management Area

Spring type	Total	Springs associated with an *EPBC Act* listing	Potentially affected springs		
			EPBC Act listed	Non-listed	Total
Spring complexes (Spring vents)*	71 (330)	12 (94)	5 (21)	8 (38)	13 (59)
Watercourse springs	43	-	-	22	22

** The number in the bracket represents the total number of spring vents within the complexes*

8.3 Connectivity and Risk Assessment

The section sets out the following components of the SIMS:

- an assessment of the connectivity of springs to underlying aquifers; and
- an assessment of the risks to the springs.

8.3.1 Spring Survey

In late 2010, the Commission hosted a spring management workshop, attended by botanists, ecologists, spring experts, researchers, petroleum tenure holders and State and Commonwealth Government agency representatives. The purpose of the workshop was to identify critical gaps in the current knowledge of springs and approaches to filling the gaps.

The workshop identified that the spring data set was incomplete in some areas and that the knowledge gaps needed to be filled to adequately identify spring values. A field survey of springs was proposed to fill knowledge gaps in areas of higher likelihood of water pressure decline from P&G activities. It was also recognised that there was significant commonality in the data acquisition required to develop the SIMS and the obligations of individual petroleum tenure holders under the Commonwealth Government conditions of approval under the EPBC Act. It was recommended that data acquisition activities be coordinated.

The Commission built on the guidance provided by the workshop by working with Commonwealth agencies and petroleum tenure holders to develop a coordinated spring survey to fill key knowledge gaps. To guide the design of the survey, the Commission completed a desktop analysis of the available spring databases in early 2011. This involved applying the recommendations from the spring management workshop to the existing datasets to select springs for the survey and to identify the attributes to be measured during the survey. Springs were selected that met the following criteria:

1. Springs that had not previously been fully surveyed, and are located on a petroleum tenure or within 20 km of a petroleum tenure; and

2. Springs known to be associated with EPBC Act listed species and the listed ecological community, 'the community of native species dependent on the discharge of groundwater from the GAB', regardless of their prior survey status.

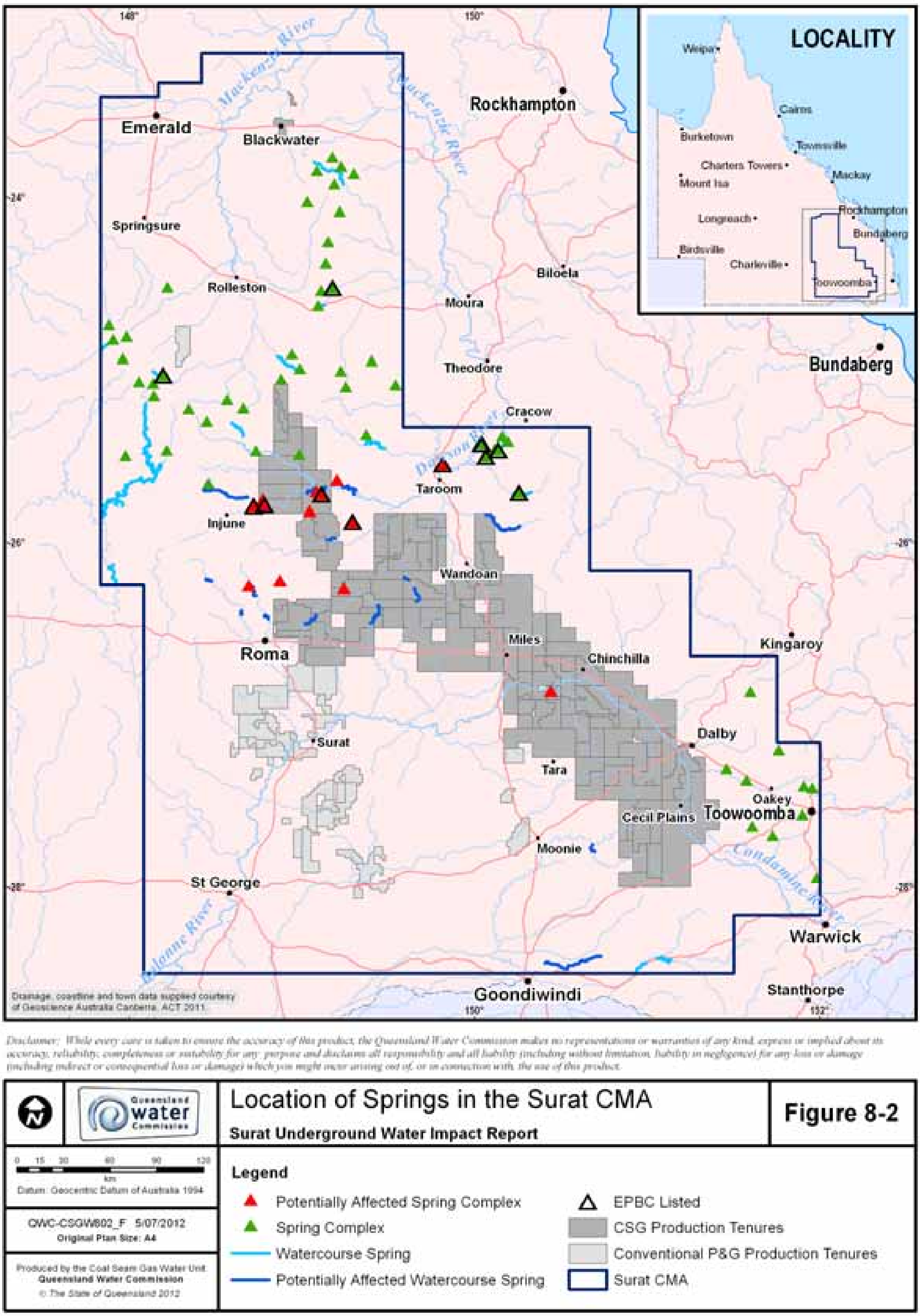

Figure 8-2 Location of Springs in the Surat CMA

Criterion 1 focused the survey on springs overlying aquifers where water pressure impacts were more likely. Criterion 2 ensured that any springs outside the primary survey area that had known high ecological values were included in the survey. The targeted springs were surveyed for ecological, botanical and a specified list of hydrogeological attributes.

The Commission's spring survey, completed in September 2011 was a major undertaking. It has significantly extended the knowledge base about springs in the region. It has provided a foundation for an assessment of the connection of springs to affected aquifers and a subsequent assessment of risk to springs.

8.3.2 Assessing the Connectivity of Springs to Underlying Aquifers

The connectivity between potentially affected springs and aquifer over which it is located has been assessed. For the purpose of this report, the connectivity of springs to underlying aquifers is the assessment of the source aquifer or aquifers that could potentially feed the spring.

The source aquifer assessments used information obtained in existing datasets, new information from the spring survey, and the outcome of a more detailed source aquifer assessment study for selected springs. The results of source aquifer assessment are provided in Appendix H-2 which lists the connected source aquifer for each potentially affected spring and contributed to the subsequent assessment of risks.

Understanding the source aquifer for springs is important in determining the likelihood of impacts occurring. The Commission undertook an assessment of the connectivity for nine spring complexes (KCB 2012). The study followed the current best practice approach that was developed through a recent National Water Commission and DNRM funded project (EHA 2009a, EHA 2009b and PB 2011). The nine complexes were selected having regard to the following:

- areas where water pressures in aquifers are likely to be most affected;
- complexity of their hydrogeological set-up; and
- springs that are representative of other spring sites.

The assignment of spring source aquifers in Table H-2 of Appendix H-2 provides a summary of the findings from the connectivity assessment. Some sites have been identified for additional source aquifer assessments to confirm the connectivity between the spring and underlying aquifers. These investigations will be undertaken by the Commission in 2012 at these additional sites.

8.3.3 Risk Assessment

The knowledge about springs, improved by the Commission's targeted spring survey and further improved by the Commission's connectivity study, enabled a risk assessment of springs. The outcomes from the risk assessment then became the basis for specifying the monitoring and mitigation actions outlined in later sections of this report. The risk assessment was carried out for the 13 spring complexes that contain 59 spring vents identified as potentially affected springs as shown in Figure 8-2 and listed in Table H-2 of Appendix H-2.

For each spring vent, a risk level between 1 (lower) and 5 (higher) has been assigned to each spring on the basis of the ***likelihood*** of there being reductions in the flow of water and the ***consequences*** on spring values if a reduction in flow to the spring was to occur. Details of the risk assessment methodology are provided in Appendix H-3.

Three criteria were used to assess likelihood. They involved use of predicted water pressure impacts in aquifers made using the regional groundwater flow model, the proximity of a spring to P&G development areas, and the stratigraphic separation of a spring's source aquifer from the target P&G formations.

Two criteria were used to assess consequence. They involved the updated conservation ranking for each spring informed by the spring survey and the proximity of the spring to the recharge area of the spring's source aquifer, which is a measure of the resilience of a spring's ecology to changes in availability of water to the spring. Cultural heritage values in springs may align in some cases with ecological values, however cultural heritage values will also exist independently of ecological values. With an estimate of the likelihood of impact now made for springs, future cultural heritage assessments will be focussed accordingly.

The risk assessment score for each spring is shown in Table H-2 of Appendix H-2.

8.4 Spring Monitoring Program

The spring monitoring program is a component of the SIMS. The program is directed at identifying changes in the volume and chemistry of water flowing to a spring, and any changes to the general character of springs. It does not include water pressure monitoring in underlying aquifers as that is provided for in the WMS specified in Chapter 7. It does not include monitoring of flora and fauna, as the identification of ecological assemblages is a matter for further research rather than regular monitoring.

The monitoring program has been designed to collect information on springs above any aquifer that may at some future time be affected by water extraction by petroleum tenure holders. This program, together with data from the WMS will improve understanding of the risk to springs and provide early warning of unexpected impacts on springs.

All springs located within production tenures and springs located off-tenure that were assigned a risk score of 3 or higher were identified as potential sites for monitoring. Not all of those springs were selected because springs tend to occur in groups and the conditions in one spring can represent changes in other springs within a localised area. However the monitoring program includes representative spring vents from each potentially affected spring complex.

Spring sites were selected for monitoring with a view to risk, the representative capacity of a spring, and general site suitability such as the size of the spring and flow rate. A total of 33 spring vents, comprising 10 spring complexes, and five watercourse springs are to be monitored under the program. The locations are shown on Figure 8-3 and individually identified in Tables H-4 and H-5 of Appendix H-4.

Where a different method of measurement of a particular attribute at a spring is required, Table H-6 of Appendix H-4 specifies the method to be used. Tables H-4 and H-5 also specify the responsible tenure holder for each monitoring site.

Table H-6 of Appendix H-4 lists the attributes that are to be measured and describes the monitoring methods that are to be used. In summary, the attributes to be measured are spring flow; spring wetted area; water chemistry; and physical condition. Some of these attributes have to be measured indirectly and these are discussed in the following sections.

Responsible tenure holders must undertake quarterly monitoring and report results to the Commission every six months.

8.4.1 Monitoring Spring Flow

The flow of groundwater to some spring vents is sufficiently great for water to continuously flow away from the spring and drain into a watercourse or other landscape feature. In springs where the flow of groundwater into the spring is relatively small, the spring flow can be completely consumed by evaporation from the pool and evapotranspiration by the vegetation surrounding the pool, resulting in there being no flow away from the spring.

For the monitoring sites where there is flow away from the spring, the flow is to be measured. For some of those springs, the flow is concentrated into a clearly defined channel where it can be measured using a standard hydrological technique. However, if the flow is not sufficiently concentrated there may be many small flows away from the spring with the result that direct measurement is impractical without potentially damaging spring values. In those situations a visual estimate is required.

The area of a spring vent, including the surrounding area of wetland vegetation supported by the spring, is also an important indicator of changes in the flow of groundwater to the spring. This area is required to be monitored at all spring monitoring sites. However it is a difficult attribute to measure and different approaches have been taken in the past. This measure will be required at spring vent monitoring sites identified in Table H-6 of Appendix H-4.

Remote sensing technologies have been applied to spring monitoring in other parts of the GAB. Although the characteristics of the springs in the Surat CMA are significantly different, there is potential to develop similar methods for monitoring springs in the Surat CMA. In Chapter 10, spring monitoring technology is identified as a focus area for the future research.

Table H-6 of Appendix H-4 specifies the monitoring methods required at each monitoring location.

8.4.2 Monitoring Spring Physical Condition

Springs are varied in nature and can be subject to a range of land use pressures. Understanding the changes in spring physical condition at a spring vent will assist in determining if disturbances at the spring are related to reduction in groundwater flow to the spring or other unrelated pressures. This is a difficult attribute to measure in an objective way. A standard methodology is specified in Table H-6 of Appendix H-4.

8.4.3 Monitoring Water Chemistry

The water chemistry of a spring can be influenced by the aquifer feeding the spring and a range of land use pressures. Understanding the changes in water chemistry at the spring will assist in determining if disturbances at the spring are related to water extraction by petroleum and gas development or other factors. Table H-7 lists the chemical parameters that must be measured.

8.5 Spring Impact Mitigation Strategy

The impact mitigation strategy for springs in this section is a component of the overall SIMS.

At this stage, the strategy does not include actions to directly prevent or mitigate predicted impacts on springs. This is because detailed investigations are required before potential options and their effectiveness can be adequately evaluated. Therefore, at this stage the required actions are directed at investigating the potential options to prevent or mitigate predicted impacts at specified sites. The Commission will consider the outcomes from the investigations. Implementation actions can be incorporated through revision to the UWIR.

There is time to implement necessary actions for prevention and mitigation of impacts on springs as it is predicted that impacts will not exceed 0.2 in the source aquifer of any spring for at least 5 years.

Petroleum tenure holders are required to implement a spring mitigation strategy specified in Section 8.5 as well as the spring monitoring program outlined in Section 8.4. Both are part of SIMS. The mitigation strategy is directed at only those springs where an impact of more than 0.2 m is predicted in the source aquifer of the springs.

Five sites containing 38 spring vents and associated watercourse springs are expected to experience impacts of more than 0.2m in their source aquifers. The location of these complexes are shown in Figure 8.3 and summarised in Table 8.4. Details of the individual vents are provided in Appendix H-5.

Table 8-4 Sites for Evaluation of Spring Impact Mitigation Options

Spring Complex	Vent Number	Complex Name	Source aquifer(s)
283	702, 703	Barton	Gubberamunda Sandstone
561	285	Spring Rock Creek	Evergreen Formation, Precipice Sandstone
260	189, 190, 191, 192, 192.1	Scott's Creek	Hutton Sandstone
230	287, 340, 686, 687, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689	Lucky Last	Evergreen Formation, Precipice Sandstone
311/591	534, 535, 536, 693, 704 499, 500, 500.1, 536.1, 536.2, 537, 692, 694, 695, 696, 697, 698, 699	311/Yebna 2	Evergreen Formation, Precipice Sandstone.

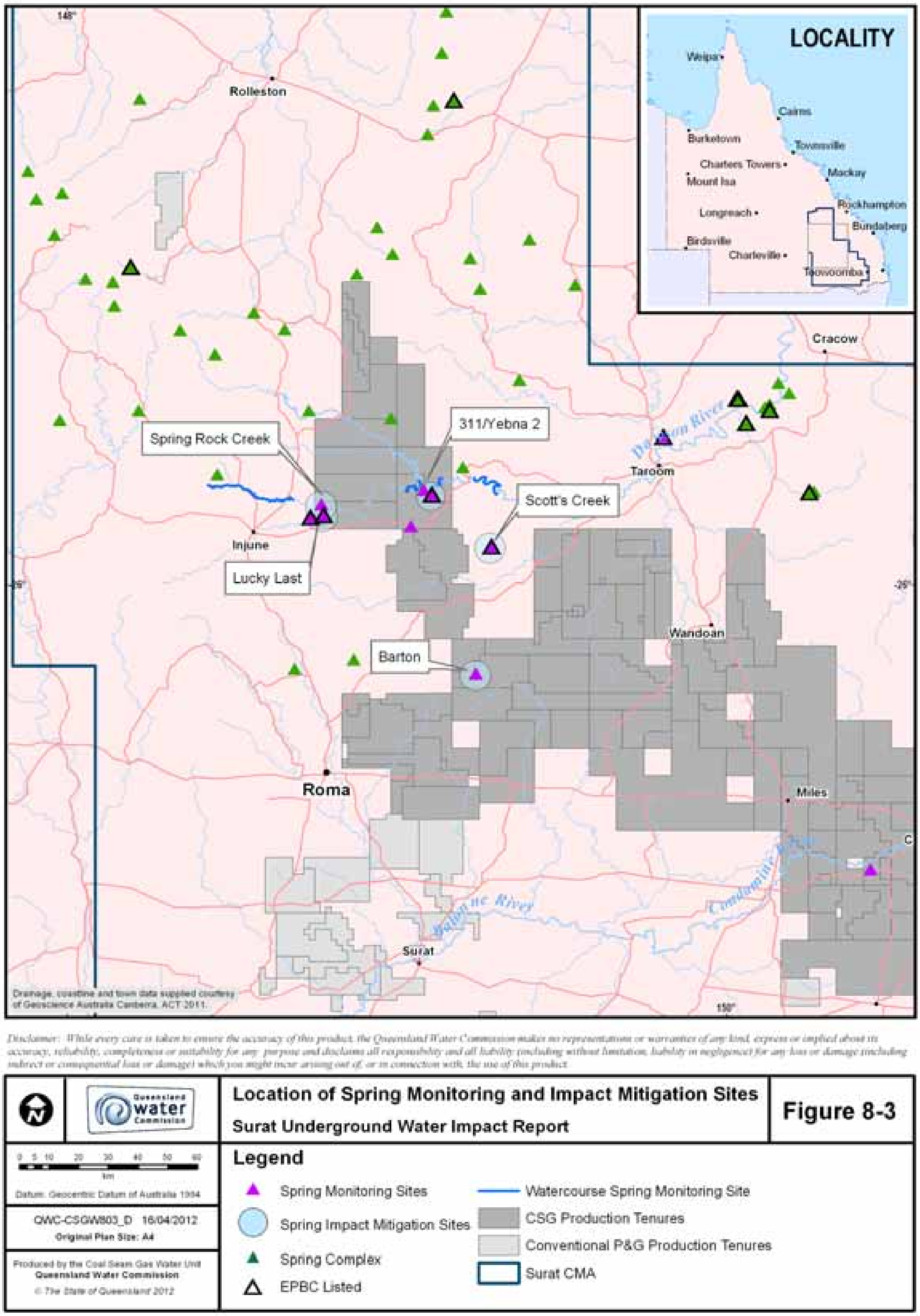

Figure 8-3 Location of Spring Monitoring and Mitigation Sites

The ‘Lucky Last’ spring complex is expected to be the site that is most affected. Impacts in the source aquifer at the location of the spring complex are not expected to exceed more than 0.2 m until 2017 and the maximum impact is expected to be less than 1.3 m. Impacts at the other sites are expected to be smaller and occur later.

8.5.1 Potential Options for Investigation

This section identifies the potential options that are to be considered and investigated before specific actions can be identified for implementation. Individual options will have more or less potential at any one site. Some options are directed at prevention of impacts while others involve offsetting, the impacts of water extraction at a spring due to existing water supply bores, to balance the future impact of CSG operations. Any offset arrangements will need to be voluntarily entered into by bore owners.

Offset impacts by relocating existing water bores

If water extraction from an existing bore is causing some impact at a spring, there may be potential to assist the bore owner to relocate the bore so that it has less impact on the spring but still meets the bore owner’s needs.

Offset impacts through surrender of entitlements that are not needed

There may be situations where an existing water entitlement is not being used, or is being only partially used, and if the entitlement was fully activated there would be an impact at the spring. There may be an opportunity to provide a financial incentive for the bore owner to not use a portion of the entitlement.

Offset impacts though improved water use efficiency

There may be situations where water taken from an existing water bore, that is impacting on a spring, is not being used to maximum efficiency. There may be potential for the petroleum tenure holder to assist the water bore owner to improve the efficiency of their water use and provide a financial incentive to not use the portion of the water entitlement that is no longer needed.

Offset impacts through supply substitution

Where an existing water bore is causing some impact at a spring, it may be possible to assist the bore owner to arrange a supply from another source to reduce impact on the spring, so that the original entitlement or part of the entitlement could be surrendered.

Injection of treated water into spring source aquifers

Injection of treated water into the source aquifer feeding a spring could mitigate impacts at the spring. There would need to be regard to the timing of impacts and the timing of the availability of water for injection and to disturbance at the spring site as a result of injection.

Government is currently establishing policy in relation to the role of injection of treated CSG water into aquifers in the broader context of CSG water management. Simultaneously, petroleum tenure holders are evaluating the potential for injection in their areas of development. Any proposals for injection to mitigate future impacts on springs will need to be developed and evaluated with regard to broader injection plans and government policy.

Managing water extraction

There may be potential to alter the CSG extraction regime to avoid impacts occurring in the spring’s source aquifers. This may include rescheduling of CSG extraction or not extracting CSG from a buffer zone around a mitigation site.

8.5.2 Spring Impact Prevention or Mitigation Actions

This section details the spring impact management strategy and timetable for reporting about its implementation.

For each of the five sites (containing 38 spring vents) listed in Table H-8 (Appendix H-5), a report is to be prepared by the responsible tenure holder evaluating the options for mitigating impacts on water pressures in the source aquifer for the identified spring (Evaluation of Mitigation Options Report).

An Evaluation of Mitigation Options Report will meet the following requirements:

- discuss the advantages and disadvantages of each of the options listed in Section 8.5.1 and any additional options the responsible tenure holder identifies, and their relative viability for the specified spring complex;
- identify the option or combination of options that are the preferred approach for mitigating impacts at the site, including the rationale for the proposed option; and
- identify a program to assess local hydrogeology at the site to provide increased certainty with regard to the spring's source aquifer and improve the understanding of the relationship between reductions in water pressure in the source aquifer and the flow of water to the spring.

These reports are to be provided to the Commission within nine months of the UWIR for the Surat CMA being approved by EHP. The Commission will evaluate these reports in consideration of the other initiatives by the tenure holders in relation to spring impact mitigation (such as implementation of the Queensland Government's CSG Water Management Policy) and advance amendments to the UWIR to require implementation action as appropriate.

A project plan for the preparation of the Evaluation of Mitigations Options Report must be provided to the Commission within two months of the approval of the final UWIR.

8.6 Future Research

The SIMS establishes management arrangements that are to be carried out by responsible tenure holders. Those arrangements are based on current knowledge. However, the Commission intends to promote further research to improve knowledge about springs. This work will be focused on improving our understanding of spring values and improving and further standardising the methodology for spring monitoring. The Commission will work cooperatively with petroleum tenure holders and research bodies to facilitate appropriate research activity.

The Commission's focus areas for research are set out in Chapter 10. Topic areas relevant to springs include:

- improving methods for monitoring flow at springs;
- cultural heritage and fauna assessments at springs to fill knowledge gaps;
- improving understanding of the connectivity of springs to aquifers; and
- improving understanding of the ecophysical relationships of endemic species at springs.

9. Responsible Tenure Holder Obligations

9.1 Meaning of Responsible Tenure Holder

Under Queensland's regulatory framework petroleum tenure holders have the right to take groundwater in the process of producing petroleum and gas. A number of obligations are associated with this right. Petroleum tenure holders have an obligation to make good impairment to the adequacy of water supply from bores resulting from their water extraction. They also have an obligation to monitor water pressure and assess the likely future impacts.

The impacts of water extraction by a petroleum tenure holder on water pressure may extend beyond the tenure. In areas where a number of petroleum tenure holders operate there may be overlapping impacts on water pressure from the separate operations. In such areas, supply from a bore may be impaired because of the cumulative impacts from water extraction by multiple tenure holders. Under Queensland's regulatory framework, the Queensland Government can establish areas of overlapping impact as a CMA.

Within a CMA, individual petroleum tenure holders are identified as the tenure holders responsible for specific activities, even though any individual tenure holder may not be the only entity creating the need for the activity to be carried out. These responsible tenure holder arrangements ensure that there is clear legal responsibility for actions in areas where integrated approaches are needed to manage cumulative impacts.

This chapter assigns responsibilities for specific obligations to individual petroleum tenure holders.

9.2 Underground Water Obligations for Responsible Tenure Holders

The Queensland regulatory framework provides that the underground water obligations comprise make good obligations and report obligations. These are summarised in the following sections.

9.2.1 Make Good Obligations

Make good obligations are specified in the Water Act. The Act provides that IAA for an aquifer is the area within which water pressure are predicted to fall by more than the trigger threshold within three years. The trigger thresholds are set in the Water Act as 5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as sand). Within IAAs there is significant risk that bore supply will be impaired within three years. For the Surat CMA these areas are identified in Chapter 6. Approval of an UWIR by EHP establishes the areas as IAAs.

The Water Act provides that on approval of an underground water impact report the responsible petroleum tenure holder is to carry out a bore assessment and enter into a make good agreement with the owners of bores in the immediately affected area and to then implement the agreement. This enables proactive action before impact occurs to ensure continuity of supply. A bore owner can identify the tenure holder that is responsible for carrying out the bore assessment of a bore in the IAA from Table E-1.

A bore does not need to be recorded on the DNRM's Groundwater Database in order for the make good obligations under the Water Act 2000 to apply. There are some stock watering bores that are not registered on the Groundwater Database for a number of reasons. The owners of such bores should contact their regional DNRM office if they believe the bore is not recorded on the Groundwater Database. This will ensure that the extent of impacts on water supplies is properly represented in future revisions of the UWIR. Registration will also ensure that if a bore is affected at a future date, that there is timely engagement with the relevant tenure holder about make good actions.

Outside an IAA the supply from a bore could be impaired, either because the bore is susceptible to reductions in water pressure that are smaller than the trigger threshold, or because local anomalies cause water pressure impacts to be greater than predicted by the regional groundwater flow model. The Water Act provides that in these areas EHP can direct a tenure holder to carry out a bore assessment and if necessary enter into a make good agreement with the bore owner.

9.2.2 Report Obligations

The report obligations arise from the UWIR itself. The Water Act provides that a report obligation is a requirement with which a responsible tenure holder must comply as specified in an UWIR. The Commission undertakes activities that need to be carried out centrally, such as regional groundwater flow modelling. Any other activities are established as report obligations and assigned to specific petroleum tenure holders. The report obligations are of two types:

1. *Water monitoring activities*: These obligations involve constructing monitoring installations, carrying out baseline assessments and reporting data on an ongoing basis. The activities are specified in Chapter 7.

2. *Spring impact management activities*: These obligations involve implementing a program for monitoring springs and a program to assess options for mitigating the impact of water extraction on springs. The activities are set out in Chapter 8.

9.3 Assignment of Underground Water Obligations

The Commission has developed rules for assigning of responsibilities for make good obligations and report obligations. This section specifies those rules.

9.3.1 Production Area

Chapter 6 provides an assessment of the predicted impact on water pressure from current and planned petroleum production. Plans for development can change over time for a range of reasons. To make its assessment about impacts on water pressure, the Commission has compiled data supplied by petroleum tenure holders on plans for production, as the plans existed at the time the report was prepared.

As described in Chapter 2 the ‘production area’ is the area covered by petroleum leases and authorities to prospect, from which petroleum and gas production is occurring or from which production is planned. The extent of the production area is shown in Figure 2-4. The tenures that comprise the production area and the current principal holders of the tenures are listed in Appendix A.

9.3.2 Assignment Rules for Make Good Obligations

The bores most likely to be affected by water extraction by petroleum tenure holders are bores that are located within the production area. The following rule assigns responsibility for make good obligations in relation to these bores.

Rule 1: The principal holder of a petroleum tenure over land identified in Figure 2-4, is the responsible tenure holder for make good obligations in relation to a bore on the land.

Because water pressure impacts can extend laterally, impact on bore supply could occur in bores outside the lands covered by Rule 1. For bores on those lands, the following rule assigns responsibility for make good obligations to the principal holder of the tenure in the production area that is located closest to the impacted bore.

Rule 2: For a bore on land in the CMA, other than the land to which Rule 1 applies, the principal holder from time to time of a petroleum tenure over the land identified in Figure 2-4 that is closest to the bore, is the responsible tenure holder for make good obligations in relation to the bore.

To apply this rule the relevant distance is the distance from the bore to the nearest point on the boundary of any production area tenure.

Under these rules the responsible tenure holder will change if the ownership of a tenure changes. The responsible tenure holder for a bore can be established at any time by referring to the public access area of the DNRM tenure database. EHP provides a support service for landowners who consider they have an issue with make good obligations, and landowners can establish the identity of the responsible tenure holder through this service if necessary.

9.3.3 Assignment Rules for Report Obligations

The individual activities identified within the WMS and the SIMS, specified in Chapters 7 and 8 respectively, are report obligations. Details of the activities are set out in Appendices G and H. The following rules assign responsibility for those activities. The responsibilities are assigned to tenure holders having regard to the relative contribution of water extraction by tenure holders to the need for the assigned activity, and to the need for simplicity.

Baseline Assessments

Baseline assessments relate to potential future make good obligations. Therefore the same principles apply as for the assigning of responsibilities for make good obligations.

Rule 3: The principal holder, from time to time, of a petroleum tenure over land identified in Figure 2-4, is the responsible tenure holder for carrying out the baseline assessment program identified in Chapter 7 in relation to a bore on the land.

Rule 4: For a bore on land in the CMA, other than the land to which Rule 3 applies, the principal holder from time to time of a petroleum tenure over the land identified in Figure 2-4 that is closest to the bore, is the responsible tenure holder for carrying out the baseline assessment program identified in Chapter 7 in relation to the bore.

To apply this rule the relevant distance is the distance from the bore to the nearest point on the boundary of any production area tenure.

Other Report Obligations

Activities at sites within the production area are to be carried out by the principal holder of the tenure on which the activity is to be carried out. Since the ownership of tenures can change over time, within Chapters 7 and 8 the activities at those sites are noted as being the responsibility of the 'current tenure holder' which is the principal tenure holder at a given point in time.

The following rule deals with those activities.

Rule 5: The principal holder from time to time, of a petroleum tenure over land identified in Figure 2-4, is the responsible tenure holder for the activities identified in Chapters 7 and 8 required to be carried out on the land.

Some of the activities identified in Chapters 7 and 8 are to be carried out outside the production area. The need for these activities arises because of water extraction by tenure holders within the production area. Therefore, responsibility for an activity is assigned to a tenure holder from within the production area. The following rule assigns responsibility in relation to these activities other than the requirement for carrying out of baseline assessments.

Rule 6: For activities other than baseline assessments identified in Chapter 7 and 8, to be carried out outside the area to which Rule 5 applies, the petroleum tenure holder identified in Chapter 7 or 8 as the responsible tenure holder for the activity, is the responsible tenure holder for the activity.

Under these rules, within the production area, the holder of a tenure from time to time will always be the entity responsible for water and spring monitoring on the tenure. If there is a change of tenure ownership responsibility will fall to the new owner.

Outside the production area, a designated tenure holder will be responsible for activities other than the carrying out of baseline assessments irrespective of ownership changes. Only extensive changes to tenure ownership would create a need to change these responsibilities. The appropriateness of the tenure holders identified in Chapter 7 and 8 for specific activities outside the production area will be reviewed when the UWIR is reviewed.

10. Periodic Reporting and Review

10.1 Introduction

The regional groundwater flow model was developed using information available at the time of preparing this report. Information about the geology and hydrogeology of the aquifer system was drawn from published literature and databases, as well as more recent drilling information from P&G companies. Water pressure data was used to calibrate the model. The available water pressure data ranges from a single water pressure measurement in some bores to a series of water pressure measurements in monitoring bores. The knowledge base for future development of the model will improve through the accumulation of data from the regional water monitoring program and through targeted research.

Planned P&G development is described in Chapter 2. The model was used to assess the impact of planned development on the water pressure in aquifers. Planned P&G development will change over time, because of changes in the rate of petroleum and gas development and the sequencing of development of petroleum tenures. These changes will occur for a variety of reasons. In addition, the amount of water taken in the process of producing P&G will depend on the local characteristics of the coal seams. Predictions about water pressure impact depend on the planned development scenario that is used in the model. Therefore, information used to generate these predictions needs to be kept up to date.

Queensland’s regulatory framework provides that the UWIR is to be updated at least every three years. However, arrangements are provided for more frequent reporting about new knowledge or changes to predictions of impacts on water pressure. Arrangements described in this chapter include:

- reporting annually on material changes to predictions of impacts;
- updating the underground water impact report every three years;
- providing access to monitoring data as it is collected; and
- undertaking targeted research to improve knowledge about the aquifer system.

10.2 Annual Reporting and Review

The Commission will adopt a program of annual reporting to EHP and those reports will be published on the Commission's website. The reports will provide the following information.

Petroleum tenure holders have responsibilities under the WMS and SIMS to carry out actions including water pressure monitoring and to submit monitoring data to the Commission. The trends in the monitoring data will reflect the net effect of impacts from petroleum activities along with other causes such as agricultural use or seasonal conditions. On an annual basis, the Commission will summarise and assess monitoring data.

The Commission will obtain from petroleum tenure holders regular updates on changes to their plans for development. On an annual basis, the Commission will run the regional groundwater flow model using the updated estimates of planned production to assess if changes to planned production will cause material change to predicted IAAs and LAAs. Where there is material change, new predictions will be submitted to EHP, along with the summary of monitoring results.

10.3 Replacement of the Surat Underground Water Impact Report

Queensland’s regulatory framework provides that a new UWIR is to be prepared at least every three years. In developing a new underground water impact report, key matters for consideration will be:

1. *Is the regional groundwater flow model still appropriate for its purpose?*

The Commission may update the existing model by incorporating new monitoring data into the model calibration, or alternatively build a new model if that would appropriately incorporate new knowledge and new technologies.

2. *Is the regional water monitoring program still appropriate?*

The Commission will assess if new understanding of the system indicates that the monitoring strategy should be extended or altered.

3. *Is the spring impact management strategy still appropriate?*

The current strategy has identified springs at risk, established monitoring requirements at those springs and required responsible tenure holders to evaluate options for impact mitigation at some sites. At the time of reviewing the underground water impact report, it is expected that new methodologies for monitoring will have been developed, and the need for mitigation strategies and appropriate pathways to implementation will have become clearer.

4. *Are responsible tenure holder arrangements still appropriate?*

Any changes in understanding about predicted impacts, changes to planned petroleum and gas development, and changes in tenure ownership may require revision of the assignment of responsible tenure holder obligations.

10.4 Access to Information

The Commission’s website will become the point of access to information relevant to its underground water management functions. The UWIR will be published on the website along with the annual reports. This will provide access to current output from the regional groundwater flow model.

The Commission will further develop the website in 2012 to provide more extensive access to this information. Areas of development are as follows:

- The Commission will provide access to monitoring data collected from the monitoring network.
- The Commission will provide information about technical studies carried out by the Commission or studies on which the Commission expects to rely for future assessments.

10.5 Research

10.5.1 Approach to Building Knowledge

Knowledge will improve through the accumulation of monitoring data under the WMS and the SIMS. Knowledge will also improve as a result of targeted research.

Research is either underway or is planned by various research bodies that will have relevance to improving the understanding of the hydrogeology of the Surat CMA. Much of this planned research is being, or will be, carried out by petroleum tenure holders and research bodies.

Through the process of building the regional groundwater flow model the Commission has identified the research areas that will be useful for improving knowledge about the groundwater flow system. This has direct relevance to improving the Commission's capacity to make predictions about impacts on water pressure. For these research areas the Commission's approach is to:

- liaise with research bodies and groupings (such as Geoscience Australia, CSIRO, Centre for CSG Technology, Gas Industry Social and Environmental Research Alliance; and the Healthy Headwaters Project) to identify research work that is in progress or is planned that could support the Commission's functions;
- seek to coordinate and influence the design of planned research projects, to meet the Commission’s needs; and

- if necessary, undertake or commission further research to fill any remaining gaps.

10.5.2 Targeted Research Areas

Areas currently targeted for research are briefly summarised as follows:

- interconnectivity between the Condamine Alluvium (CA) and Walloon Coal Measures (WCM);
- influence of geological structures on groundwater flow in the Surat CMA;
- hydrogeology of the Walloon Coal Measures;
- reconceptualisation of the groundwater systems in the Surat and Bowen Basins in Surat CMA;
- second generation regional flow modelling for the Surat CMA; and
- improving knowledge about springs.

Appendix I provides briefs for each of these themes that set out further detail about these research directions.

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12. Glossary

Alluvium: Deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain.

Aquifer: A saturated underground geological formation or group of formations, that can store water and yield it to a bore or spring. A saturated formation that will not yield water in usable quantities is not considered an aquifer.

Artesian Water: Artesian water is water that occurs naturally in, or is introduced artificially into, an aquifer, which if tapped by a bore, would flow naturally to the surface.

Aquitard: A geological formation that prevents significant flow of water, e.g., clay layers or tight deposits of shale; geological material of a lower permeability.

Analytical technique: Mathematical relationships that can be used to forecast water pressure changes in a simple homogenous formation in response to relatively uniform and localised extraction.

Barrier: Physical change by mineralisation and precipitation over a long time period in fissures caused by faults can limit underground water movement.

Basin (Geological): An area in which the rock strata dip from the margins toward a common centre; the site of accumulation of a large thickness of sediments.

Basin (Groundwater or hydrogeological): A groundwater system made up of multiple aquifers, may be equivalent to a geological basin.

Confined aquifer: A saturated aquifer bounded between low permeability materials like clay or dense rock.

Conglomerate: Rock consisting of pebbles or gravel embedded in a finer cemented material; consolidated gravel.

Consolidated aquifer: Water bearing rock aquifer such as sandstone, coal, limestone, granite, etc.

Conventional petroleum and gas: Conventional petroleum and gas is generally found in permeable formations such as sandstone trapped in reservoirs by overlying low permeability rock formation or within geological structures which allow the petroleum and gas to concentrate or pool.

Current tenure holder: See Chapter 9.

Deposition: Is the laying down/settling of material (clay, sand, rock) carried by wind, water, or ice.

Depressurisation: The extraction of groundwater by pumping to decrease pressure in the groundwater system or reduce groundwater head.

Drawdown (n): The difference between the groundwater pressure before and after pumping or depressurisation.

Drawdown (v): The lowering of the water pressure resulting from the extraction of water.

Drill stem test: Is a procedure used to test the surrounding geological formation through the drill stem when a petroleum well is drilled. It is used to estimate the productive capacity, pressure, porosity or permeability of a petroleum producing formation.

Dual phase flow: The flow of two substances through porous media eg both gas and water flowing through a geological formation to a well.

Elevation: Height above a set point usually in relation to a standardised sea level.

Erosion: The wearing down or washing away of the soil and land surface by the action of water, wind, or ice.

Fault: A crack in a geological formation caused up shifting, or tectonic movement and uplift, of the earth's crust, in which adjacent surfaces of the formation are displaced relative to one another and parallel to the plane of fracture.

Formation: A sediment or rock, or group of sediments or rocks. Geologists often group rocks of similar types and ages into named formations, e.g the Hooray Sandstone of the Great Artesian Basin.

Fluvial: Material that is eroded, transported and deposited by river or streams.

Geological formations: See Formation.

Great Artesian Basin Water Resource Plan: Water Resource (Great Artesian Basin) Plan 2006 is a plan which provides a framework for management and use of the groundwater in the Great Artesian Basin in Queensland.

Groundwater: Or underground water, is water found in the cracks, voids or pore spaces or other spaces between particles of clay, silt, sand, gravel or rock within the saturated zone of a geological formation.

Groundwater database (GWDB): A database maintained by DNRM that stores information regarding the location, depth, bore construction, water quality and quantity collected from private, investigation and monitoring bore drilling and monitoring data.

Groundwater flow model: Is a set of equations, which, subject to certain assumptions, quantifies the physical processes active in a groundwater system. While the model itself obviously lacks the detailed reality of the groundwater system, the behaviour of a valid model approximates that of the aquifer and is used to simulate that behaviour.

Homogenous formation: A geological formation which has identical material properties throughout the unit.

Head (groundwater): The groundwater level or pressure.

Hydraulic gradient: Is the difference in water pressure or water level across one or more formation over a unit distance. The hydraulic gradient indicates which direction groundwater will flow, and how rapidly.

Hydraulic parameters: The parameters that describe the material properties that control the flow and storage of water within an aquifer such as permeability and storavitity.

Hydrogeology: The study of groundwater in regard to movement, distribution and interaction of water with rock.

Immediately Affected Area: See Chapter 6.

Input parameters: The initial estimates of the hydraulic parameters of the hydrogeologic units in a model and water balance components such as recharge and groundwater extraction.

Interfinger: Used in relation to sedimentary rocks, interfinger means to change laterally from one type to another where the two types form interpenetrating wedges.

Intake bed: Are areas where sandstone aquifers are exposed or outcrop at the surface or shallowly beneath alluvium, where recharged water can enter.

Interbedded: Beds or layers of geological material of different lithology or properties layered together.

Lacustrine: Formed in lakes or ponds. Lacustrine deposits are stratified materials deposited in lake waters which later become exposed either by the lowering of the water level or by the elevation of the land.

Lithic: Geological deposits or sedimentary rocks that contain abundant fragments of previously-formed rocks.

Licensed entitlement: A water allocation or authority granted under the *Water Act 2000* to access and use groundwater.

Long-term Affected Area: See Chapter 6.

Make good agreement: See *Water Act 2000*.

Measures: A series of coal-bearing rocks.

Model domain: Extent of the groundwater flow model including not only the areal extent but the spatial coverage of the groundwater system ie the geological formations/aquifers included.

Monitoring installation: An individual bore hole equipped to monitor water quality and/or water pressure, potentially at multiple vertical levels.

Mudstone: An extremely fine-grained sedimentary rock consisting of a mixture of clay and silt-sized particles.

Outcrop (n): Geological formation or rock strata exposed at the ground surface.

Permeable: Capable of transmitting water through porous rock, sediment, or soil.

Permeability: The property of a soil, sediment or rock indicating how easily water will be transmitted through it under a gradient.

Petroleum tenure holder: An entity that holds an authority to prospect and/or petroleum lease under the *Petroleum and Gas (Safety and Reliability) Act 2004.*

Platform: Area of geological material, generally igneous or metamorphic basement that is slightly tilted, to relatively flat and overlain by sedimentary material.

Potentially affected spring: See Chapter 8.

Predictive analysis: Using a groundwater flow model to forecast future impacts on a groundwater system from imposed stresses.

Production area: The area from which petroleum and gas is planned to be produced.

Recharge: Is the process of inflow of water to an aquifer.

Regional monitoring network: See Chapter 7.

Responsible tenure holder: Individual petroleum tenure holders identified as the tenure holder responsible for specific activities such as monitoring, spring mitigation, etc.

Basement ridge: A linear elevated feature within the basement rocks (usually of igneous or metamorphic rocks) which defines the boundary between sedimentary basins.

Sediment: The material in suspension in water or deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.

Sedimentary basin: A geological basin containing a sequence of dominantly sedimentary rocks.

Sheetwash (fan): Fluvial material, dominantly fine grained, deposited by extensive overland flow or sheetflood.

Shelf: A narrow surface of basement rock shaped like a shelf.

Siltstone: Fine-grained sedimentary rock consisting of consolidated silt.

Simulation period: The timeframe over which the groundwater predictions are made with the groundwater flow model.

Spring complex: A group of spring vents located in close proximity to each another. The vents are located in a similar geology and are fed by the same source aquifer.

Spring vent: A single point in the landscape where groundwater is present at the surface. The spring vent can be mounded or flat. A spring vent can also be represented by wetland vegetation, with no visible water at the surface of the spring vent.

Storativity: (or storage coefficient) The volume of water that a column of aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Strata: A layer or a series of layers of rock in the ground.

Stratigraphy: The arrangement or layering of rock strata (stratification).

Steady state condition: Conditions representing the long-term 'average' hydrological balance of the groundwater system.

Sub-basin (geology): A smaller depression or accumulation of sediments within a larger basin eg the Surat Basin is a sub-basin of the Great Artesian Basin.

Sub-horizontal flow: Lateral movement of the groundwater.

Syncline: A downward fold in geological strata/material.

Target unit: The geological formation, level or unit targeted for monitoring.

Trough: An elongated, linear structural depression or narrow basin that is not steep walled.

Tenement: A Petroleum Lease or an Authority to Prospect.

Uncertainty analysis: See Chapter 6.

Unconfined aquifer: Is an aquifer with no overlying low permeability layers that restrict water movement into the aquifer. The water level in an unconfined aquifer is known as the water table.

Unconsolidated aquifer: Strata such as sand that has not been turned into rock.

Vertical permeability: The property of a formation indicating how easily or rapidly water will be transmitted vertically.

Watercourse spring: Is a section of a watercourse where groundwater enters the stream from an aquifer. These are also referred to as baseflow fed watercourse.

Water monitoring authority: An authority under the P&G Acts that allow a petroleum tenure holder to carry out water monitoring activities in the area the WMA relates to, which could be outside the actual tenure.

Well field: An area within a petroleum lease with multiple wells used for P&G extraction.

Appendices

Appendix A

Production Tenures and Current Tenure Holders

The Table A-1 below presents relevant details of petroleum and gas tenures in the production area (Section 2.3) and their current tenure holders.

The source data for this information is the MERLIN Database maintained by DNRM as at 23 September 2011. The Commission has further processed the source data to assign a major tenure holder for each of these tenures. The purpose is specified as CSG or conventional petroleum and gas (identified as 'conventional' in the Table), based on the type of wells that are located on the tenure.

Table A-1: Detail of Tenures in Productions Area

Tenure Type	Tenure Number	Status	Principal Holder	Major Tenure Holder	Purpose
EPP	526	Granted	SANTOS TOGA PTY LTD	Santos	CSG
EPP	574	Granted	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
EPP	632	Granted	QGC PTY LIMITED	QGC	CSG
EPP	648	Granted	QGC PTY LIMITED	QGC	CSG
EPP	663	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
EPP	676	Granted	AUSTRALIAN CBM PTY LTD	Arrow	CSG
EPP	683	Granted	ARROW ENERGY PTY LTD	Arrow	CSG
EPP	692	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
EPP	746	Applied	ARROW ENERGY PTY LTD	Arrow	CSG
EPP	747	Granted	ARROW ENERGY PTY LTD	Arrow	CSG
EPP	768	Granted	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
EPP	788	Granted	ORIGIN ENERGY ATP 788P PTY LIMITED	Origin	CSG
EPP	972	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
EPP	973	Granted	AUSTRALIA PACIFIC LNG CSG MARKETING PTY LIMITED	Origin	CSG
PL	1	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	2	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	3	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	7	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	8	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	10	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	11	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	12	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	13	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	14	Granted	OIL INVESTMENTS PTY LIMITED	Origin	Conventional
PL	15	Granted	AGL GAS STORAGE PTY LTD	AGL	Conventional
PL	17	Granted	SOUTHERN CROSS PETROLEUM & EXPLORATION PTY LTD	Southern Cross	Conventional
PL	18	Granted	BRISBANE PETROLEUM LTD	Brisbane Petroleum	Conventional
PL	21	Granted	OIL INVESTMENTS PTY LIMITED	Origin	Conventional
PL	27	Granted	OIL INVESTMENTS PTY LIMITED	Origin	Conventional
PL	28	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	30	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	Conventional
PL	40	Granted	BRISBANE PETROLEUM LTD	Brisbane Petroleum	Conventional
PL	46	Granted	AGL UPSTREAM GAS (MOS) PTY LIMITED	AGL	Conventional
PL	48	Granted	AGL GAS STORAGE PTY LTD	AGL	Conventional
PL	49	Granted	AGL GAS STORAGE PTY LTD	AGL	Conventional
PL	56	Granted	ANGARI PTY LIMITED	Origin	Conventional
PL	64	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	Conventional
PL	66	Granted	AGL GAS STORAGE PTY LTD	AGL	Conventional
PL	69	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	70	Granted	OIL INVESTMENTS PTY LIMITED	Origin	Conventional
PL	71	Granted	ANGARI PTY LIMITED	Origin	Conventional

Tenure Type	Tenure Number	Status	Principal Holder	Major Tenure Holder	Purpose
PL	74	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	Conventional
PL	89	Granted	SANTOS QNT PTY LTD	Santos	Conventional
PL	90	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	91	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	92	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	93	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	99	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	100	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	101	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	119	Granted	AGL UPSTREAM GAS (MOS) PTY LIMITED	AGL	Conventional
PL	171	Granted	ROMA PETROLEUM PTY LIMITED	QGC	CSG
PL	176	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	179	Granted	QGC PTY LIMITED	QGC	CSG
PL	180	Granted	QGC PTY LIMITED	QGC	CSG
PL	185	Applied	AUSTRALIAN CBM PTY LTD	Arrow	CSG
PL	194	Granted	AUSTRALIAN CBM PTY LTD	Arrow	CSG
PL	195	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	198	Granted	ARROW (TIPTON) PTY LTD	Arrow	CSG
PL	201	Granted	QGC PTY LIMITED	QGC	CSG
PL	203	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	204	Granted	AUSTRALIA PACIFIC LNG CSG MARKETING PTY LIMITED	Origin	CSG
PL	209	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	211	Granted	QGC PTY LIMITED	QGC	CSG
PL	212	Applied	QGC PTY LIMITED	QGC	CSG
PL	215	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	216	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	225	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	226	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	227	Granted	OIL INVESTMENTS PTY LIMITED	Origin	Conventional
PL	228	Granted	QGC PTY LIMITED	QGC	CSG
PL	229	Granted	QGC PTY LIMITED	QGC	CSG
PL	230	Granted	ARROW (DAANDINE) PTY LTD	Arrow	CSG
PL	231	Granted	VICTORIA OIL PTY LTD	Victoria Oil	Conventional
PL	232	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	233	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	234	Granted	SANTOS TOGA PTY LTD	Santos	CSG
PL	238	Granted	ARROW (TIPTON) PTY LTD	Arrow	CSG
PL	247	Granted	QGC PTY LIMITED	QGC	CSG
PL	252	Granted	ARROW ENERGY PTY LTD	Arrow	CSG
PL	253	Applied	AUSTRALIAN CBM PTY LTD	Arrow	CSG
PL	257	Applied	QGC PTY LIMITED	QGC	CSG
PL	258	Granted	ARROW (TIPTON) PTY LTD	Arrow	CSG
PL	260	Granted	ARROW (TIPTON) PTY LTD	Arrow	CSG
PL	261	Applied	QGC PTY LIMITED	QGC	CSG
PL	262	Applied	QGC PTY LIMITED	QGC	CSG
PL	263	Applied	QGC PTY LIMITED	QGC	CSG
PL	264	Granted	OIL INVESTMENTS PTY LIMITED	Origin	Conventional
PL	265	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	266	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	267	Granted	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	268	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	272	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	273	Applied	QGC PTY LIMITED	QGC	CSG
PL	274	Granted	QGC PTY LIMITED	QGC	CSG
PL	275	Applied	QGC PTY LIMITED	QGC	CSG

Tenure Type	Tenure Number	Status	Principal Holder	Major Tenure Holder	Purpose
PL	276	Applied	QGC PTY LIMITED	QGC	CSG
PL	277	Applied	QGC PTY LIMITED	QGC	CSG
PL	278	Applied	QGC PTY LIMITED	QGC	CSG
PL	279	Granted	QGC PTY LIMITED	QGC	CSG
PL	280	Granted	BRISBANE PETROLEUM LTD	Brisbane Petroleum	Conventional
PL	281	Applied	BRONCO ENERGY PTY LIMITED	Santos	CSG
PL	282	Applied	BRONCO ENERGY PTY LIMITED	Santos	CSG
PL	289	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	297	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	299	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	304	Applied	ARROW ENERGY PTY LTD	Arrow	CSG
PL	305	Applied	ARROW ENERGY PTY LTD	Arrow	CSG
PL	306	Applied	ARROW ENERGY PTY LTD	Arrow	CSG
PL	307	Applied	ARROW ENERGY PTY LTD	Arrow	CSG
PL	308	Applied	ARROW ENERGY PTY LTD	Arrow	CSG
PL	309	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	310	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	314	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	315	Granted	SANTOS QNT PTY LTD	Santos	CSG
PL	391	Applied	BOW BLACKWATER CSG PL PTY LTD	Bow	CSG
PL	392	Applied	QGC PTY LIMITED	QGC	CSG
PL	393	Applied	QGC PTY LIMITED	QGC	CSG
PL	397	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	398	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	399	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	400	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	401	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	402	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	403	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	404	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	405	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	406	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	407	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	408	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	412	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	413	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	420	Applied	SANTOS TOGA PTY LTD	Santos	CSG
PL	421	Applied	SANTOS TOGA PTY LTD	Santos	CSG
PL	434	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	435	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	436	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	437	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	438	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	439	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	440	Applied	SANTOS TOGA PTY LTD	Santos	CSG
PL	442	Applied	QGC PTY LIMITED	QGC	CSG
PL	443	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	445	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	446	Granted	AGL GAS STORAGE PTY LTD	AGL	Conventional
PL	458	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	459	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	461	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	462	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	463	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	464	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	465	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG

Tenure Type	Tenure Number	Status	Principal Holder	Major Tenure Holder	Purpose
PL	466	Applied	QGC PTY LIMITED	QGC	CSG
PL	467	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	468	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	469	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	470	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	471	Applied	AUSTRALIA PACIFIC LNG PTY LIMITED	Origin	CSG
PL	472	Applied	BG INTERNATIONAL (AUS) PTY LTD	QGC	CSG
PL	474	Applied	QGC PTY LIMITED	QGC	CSG

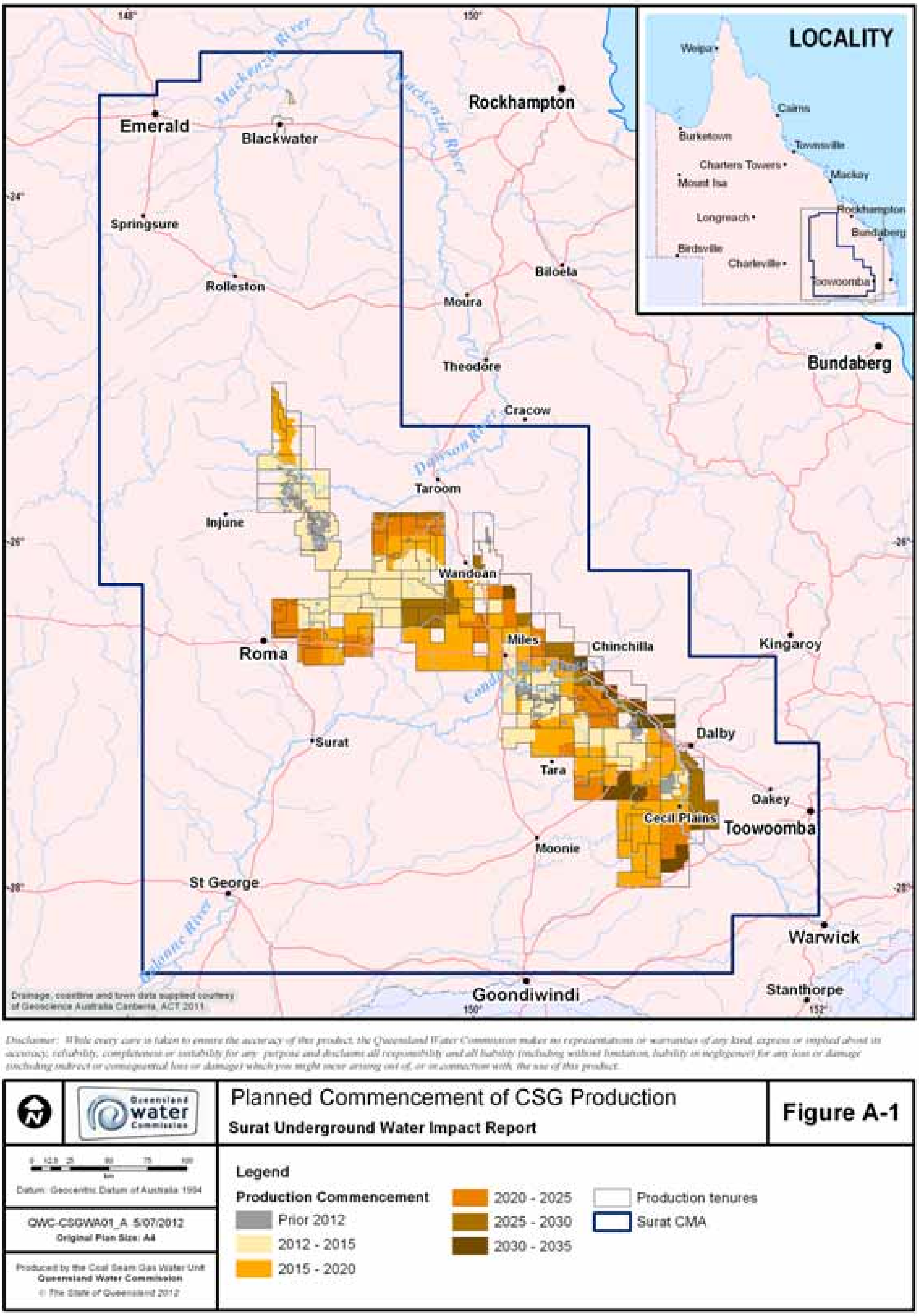


Figure A-1 Planned Commencement of CSG Production

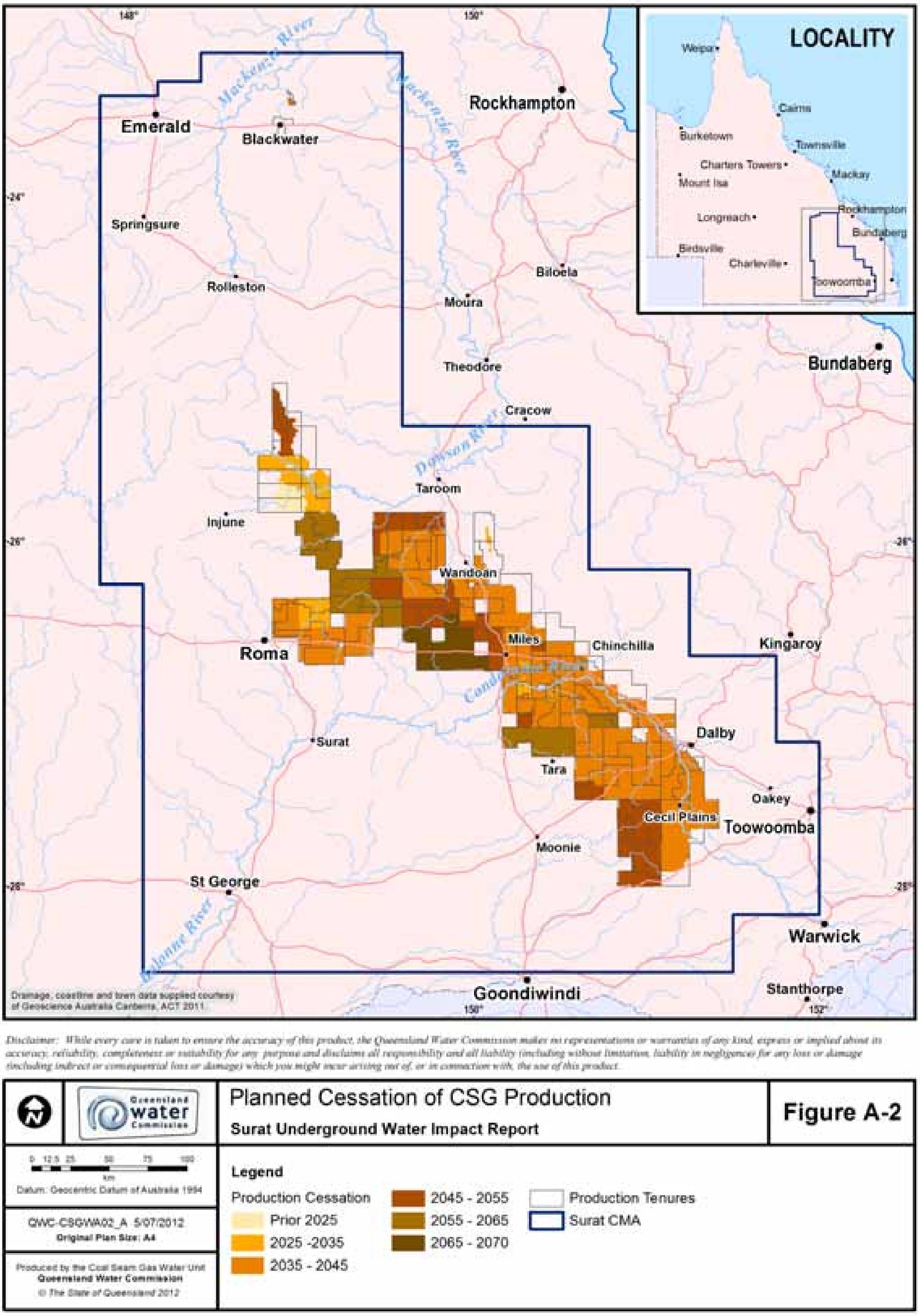
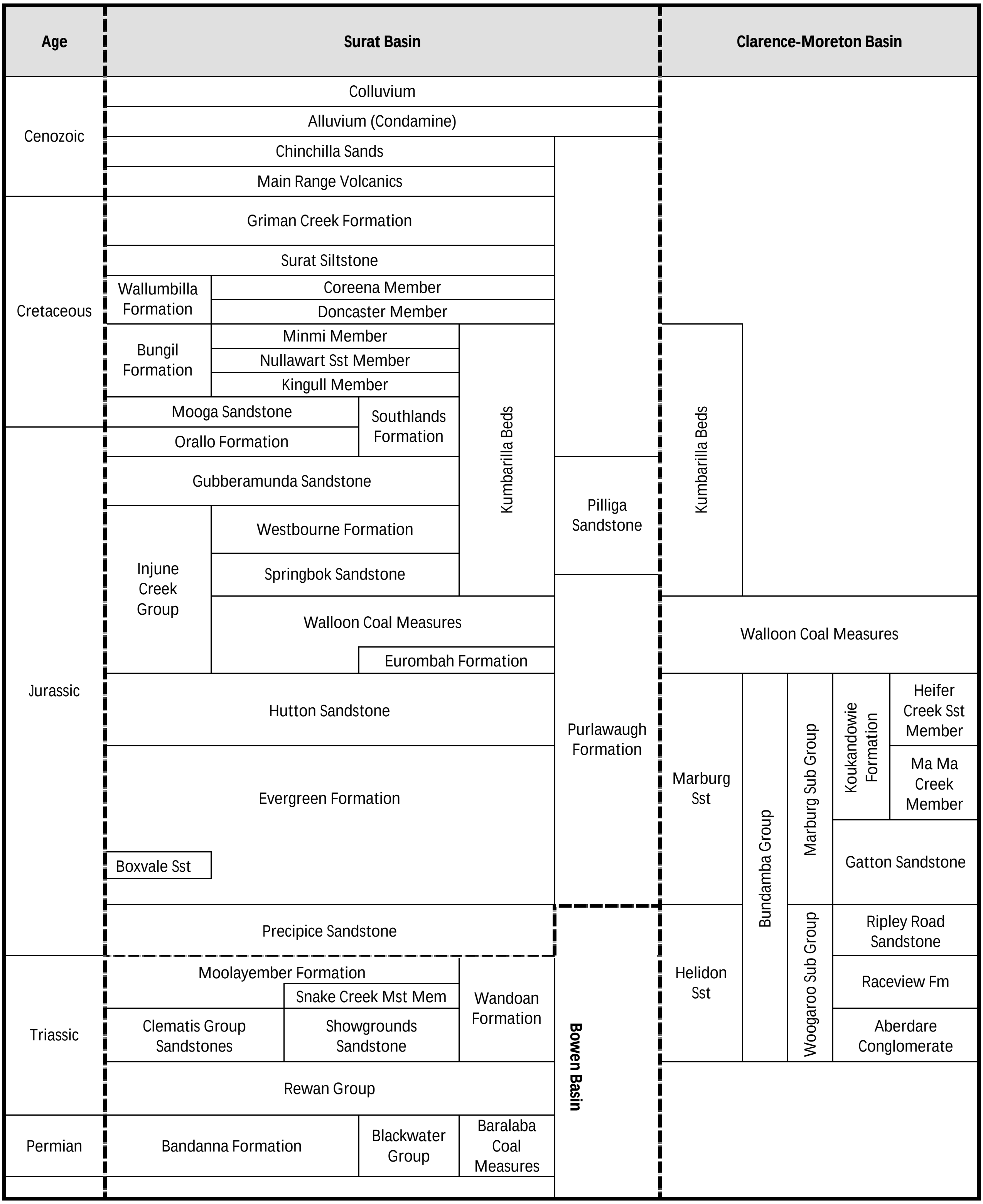


Figure A-2 Planned Cessation of CSG Production

Appendix B

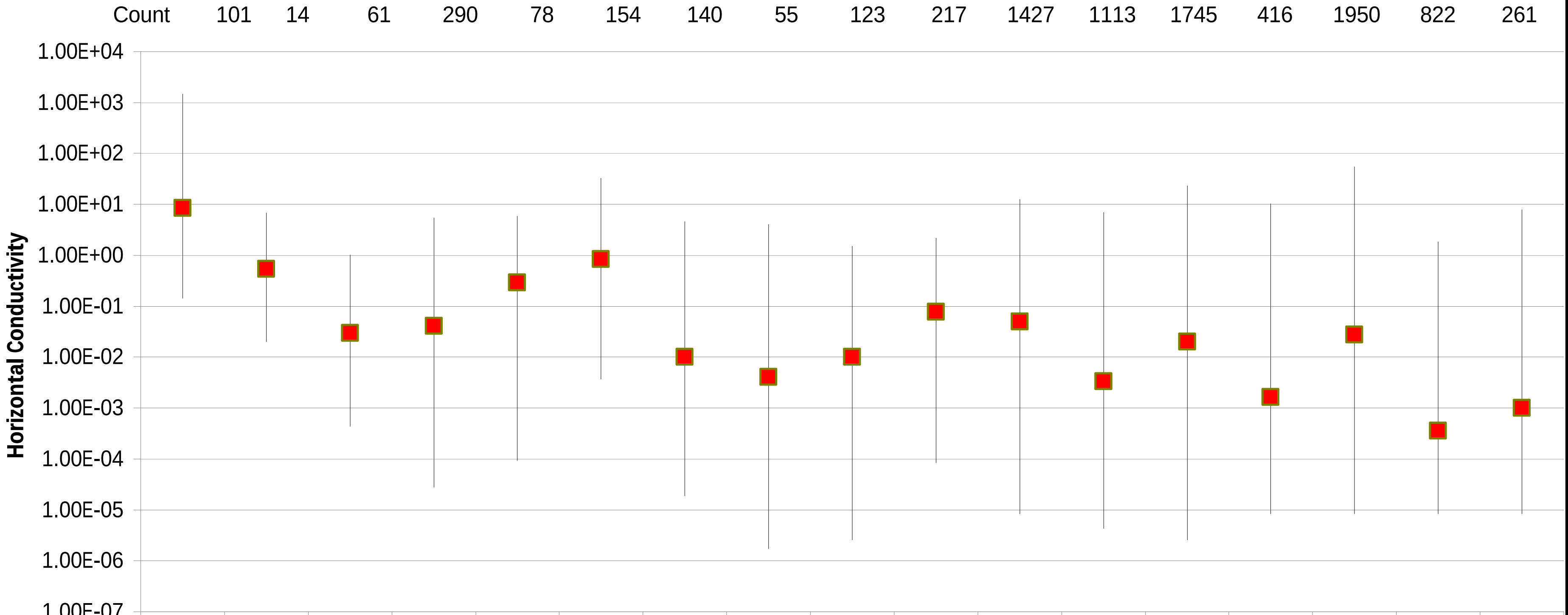
Stratigraphy


Age
Surat Basin
Clarence-Moreton Basin
Cenozoic
Colluvium
Alluvium (Condamine)
Chinchilla Sands
Main Range Volcanics
Cretaceous
Griman Creek Formation
Surat Siltstone
Wallumbilla Formation
Coreena Member
Doncaster Member
Bungil Formation
Minmi Member
Nullawart Sst Member
Kingull Member
Mooga Sandstone
Southlands Formation
Orallo Formation
Kumbarilla Beds
Kumbarilla Beds
Jurassic
Gubberamunda Sandstone
Pilliga Sandstone
Injune Creek Group
Westbourne Formation
Springbok Sandstone
Walloon Coal Measures
Eurombah Formation
Walloon Coal Measures
Hutton Sandstone
Purlawaugh Formation
Marburg Sst
Bundamba Group
Marburg Sub Group
Koukandowie Formation
Heifer Creek Sst Member
Ma Ma Creek Member
Gatton Sandstone
Evergreen Formation
Boxvale Sst
Precipice Sandstone
Helidon Sst
Woogaroo Sub Group
Ripley Road Sandstone
Triassic
Moolayember Formation
Snake Creek Mst Mem
Wandoan Formation
Raceview Fm
Clematis Group Sandstones
Showgrounds Sandstone
Aberdare Conglomerate
Bowen Basin
Rewan Group
Permian
Bandanna Formation
Blackwater Group
Baralaba Coal Measures

Appendix C

Conductivity Data for Geologic Formations

Horizontal Conductivity Values (Pumping Tests, Core Tests, DST)



	Alluvium	Main Range Volcanics	Rolling Downs Group	Bungil / Mooga SST	Orallo FM	Gubberamunda SST	Westbourne FM	Springbok SST	Walloon Aquitards	Walloon Productive Coal	Hutton SST	Evergreen FM	Precipice SST	Moolayember FM	Clematis SST	Rewan Group	Bandana FM
Min Conductivity	1.4E-01	2.0E-02	4.4E-04	2.8E-05	9.3E-05	3.7E-03	1.9E-05	1.7E-06	2.6E-06	8.3E-05	8.3E-06	4.3E-06	2.6E-06	8.3E-06	8.3E-06	8.3E-06	8.3E-06
Max Conductivity	1.5E+03	6.8E+00	1.0E+00	5.4E+00	5.9E+00	3.3E+01	4.6E+00	4.1E+00	1.5E+00	2.2E+00	1.3E+01	6.9E+00	2.3E+01	1.0E+01	5.5E+01	1.9E+00	7.8E+00
Median of Conductivity	8.6E+00	5.4E-01	3.0E-02	4.1E-02	3.0E-01	8.5E-01	1.0E-02	4.1E-03	1.0E-02	7.8E-02	5.0E-02	3.4E-03	2.0E-02	1.6E-03	2.7E-02	3.6E-04	1.0E-03

Appendix D

Understanding Depressurisation in a Multilayered Aquifer System

Types of Aquifers

An ***aquifer*** is a geological formation that largely consists of permeable material such as sand and sandstone, that is capable of storing water in pore spaces and fractures and releasing the water in a reasonable quantity when pumped from a bore that taps the geological formation.

A bore is used to extract water from an aquifer. A bore is constructed by first drilling a borehole. Casing is installed in the bore to stop the bore hole caving in. There are slots near the bottom of the casing to allow water to enter the bore while screening out the entry of sand grains. This section of water entry is called the 'screened' section of the bore. Where needed, a pump is installed, usually just above the screened section.

An ***unconfined aquifer*** is an aquifer that generally occurs at shallower depth or near ground surface (Figure D-1). Pore spaces and fractures are filled with water (i.e. saturated) to some level below the top surface of the aquifer. This upper surface of saturation level is called the water table. Therefore, these aquifers are also known as 'water table aquifers'. Unconfined aquifers receive recharge directly from the infiltration of rainfall and surface water.

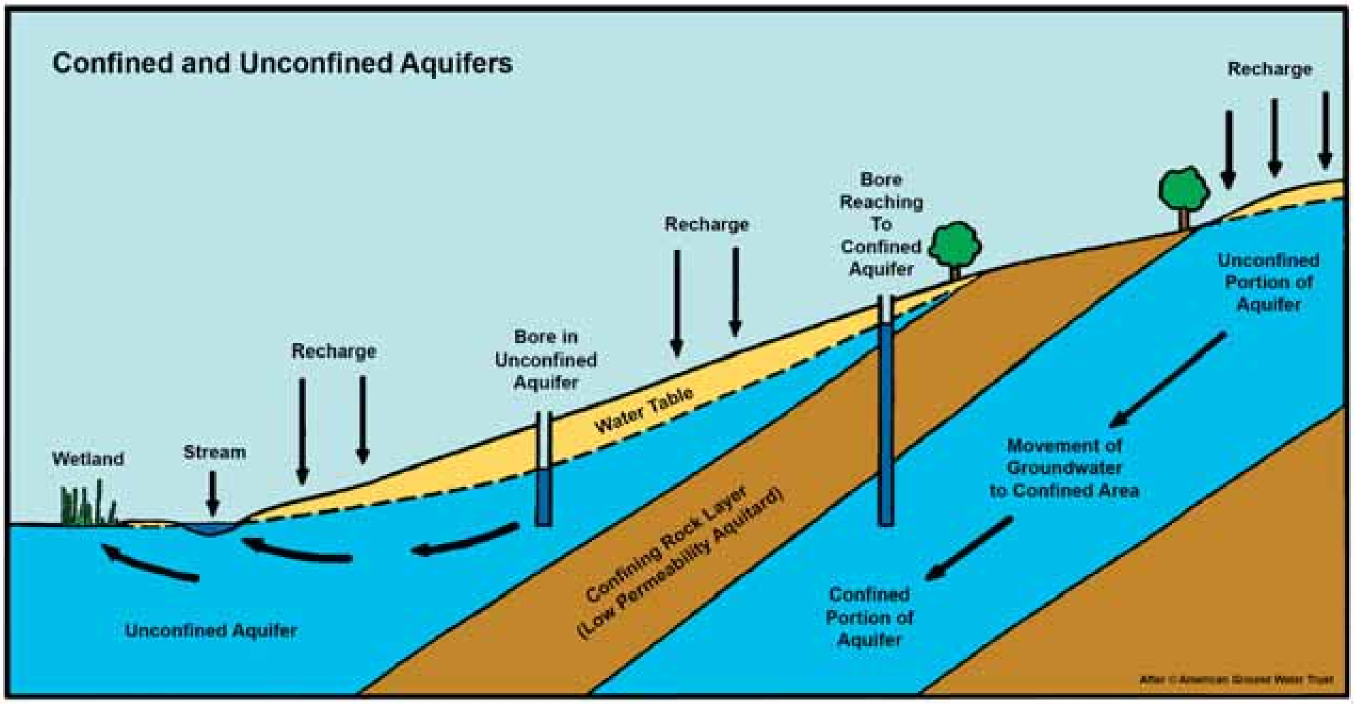


Figure D-1: Confined and Unconfined Aquifers

A bore in an unconfined aquifer is drilled to a depth below the water table and is typically screened in the lower most part of the bore where more permeable material is often encountered. Water enters the bore through the screened section and rises to the water table. When water is pumped of the bore, it is replenished by water flowing from the aquifer through the screen into the bore. The rate of replenishment depends on the permeability of the aquifer, the higher the permeability the faster the rate of replenishment. For this reason, a high pumping rate can be sustained in bores that tap high permeability aquifers.

If the water table declines, then water level in a bore tapping the aquifer will decline to the same level. A decline in the water table may result from a seasonal reduction in recharge or collective storage depletion caused by water extraction by all water users.

The pumping rate of a bore also depends upon the height of the water column above the pump. In comparison to a shallow bore, a deep bore with a deep screened section and a pump set at a deeper level will have a greater height of water column above the pump. This means that a water table decline is likely to affect the pumping rate of shallow bore more than a deep bore, and may even render it dry if the water table declines to near the level of the pump.

Confined aquifers are aquifers that are covered (confined) by an impermeable or semi-permeable layer of rock such as clay, silt or mudstone. These confining layers are referred to as 'aquitards'. Unlike an unconfined aquifer, a confined aquifer remains fully saturated. Water is held in pores and fractures under pressure because it cannot easily escape through the confining aquitards.

Confined aquifers are generally found beneath unconfined aquifers sometimes at great depths. Confined aquifers often occur as multilayered systems where aquifer layers are separated by aquitard layers, as is the case for the aquifers of the Great Artesian Basin (GAB).

Confined aquifers are more readily recharged in areas where confining aquitards are absent or the aquifer is exposed at the land surface, allowing infiltrating rainfall or river flow to enter. However, a confined aquifer can also be recharged by the slow transfer of groundwater into the aquifer through an aquitard.

A bore is constructed to tap a confined aquifer by setting the screened section in the aquifer and sealing the outside of the casing with cement. The water pressure in the aquifer causes the water level in the bore to rise. The level to which water rises is the ***piezometric or pressure level*** of the aquifer although it is also common to refer to this surface as the 'water level' in the aquifer.

The water level in a confined aquifer can be so high that it is above the ground level and water can flow naturally from the bore. Such bores are referred to as ***artesian*** bores.

Aquifer Depressurisation

Where multiple confined aquifers occur at a location, it is a common practice that a water bore will tap only one of the aquifers. Typically, shallower formations are the preferred target because shallower bores cost less to construct. Deeper confined aquifers are only targeted if they contain water of higher quantity or if larger supplies are available.

In a multilayer aquifer system a water level decline in one aquifer does not necessarily affect the other surrounding aquifers to same degree. This is illustrated in Figure D-2 and D-3 which represent conditions in a three layered system with an unconfined aquifer (A) at the top underlain by two confined aquifers (B and C). The aquifers are separated by aquitards. The blue shading represents saturation in the aquifers.

Figure D-2 illustrates ***pre-development*** conditions which exist before bore pumping commences. Bore 1 taps the unconfined aquifer and therefore the water level in the bore is at the same level as the water table. Bores 2 and 3 are tapping the confined aquifers. Because they are under pressure the water levels are above the confining layer and reflects the pressure levels in the aquifers, which are little different to each other.

Figure D-3 illustrates ***post-development*** conditions which exist after pumping from Bore 3 is well established. The water level in the Bore 3 has dropped and pressure in Aquifer C declines to a corresponding level close to the bore and to lesser degree further form the bore. However, the pressure remains above the confining aquitard and therefore the aquifer remains fully saturated. This is sometimes referred to as ***depressurisation***. As the bore is pumped water is instantly released from storage within pores and fractures of the aquifer due to the slight expansion of water that result from the reduction in pressure. At the same time the aquifer material also expands very slightly because of the reduced pressure, 'squeezing' water out of the pores and fractures. The aquifer remains fully saturated.

Because of the pressure difference between Aquifer B and C that has been established, there will be some leakage of water from Aquifer B to C through the aquitard that separates the aquifers. This leakage will reduce the pressure in Aquifer B, although to a much lesser degree because the leakage volume will be smaller than the volume pumped from Aquifer C.

Aquifer Storage Depletion

During depressurisation the confined aquifers remain saturated. In Figure D-3 there will be some leakage from water table Aquifer A to confined Aquifer B because of the change in pressure in Aquifer B. As a result there will be some lowering of the water table in Aquifer A. The decline will be smaller than it would be if Aquifer A was a confined aquifer, because the leakage water comes from draining of the pores at the top of the water table aquifer rather than from the storage of a confined aquifer. A small depth of pore storage from an unconfined aquifer yields the same volume of water as a much larger reduction of pressure in a confined aquifer.

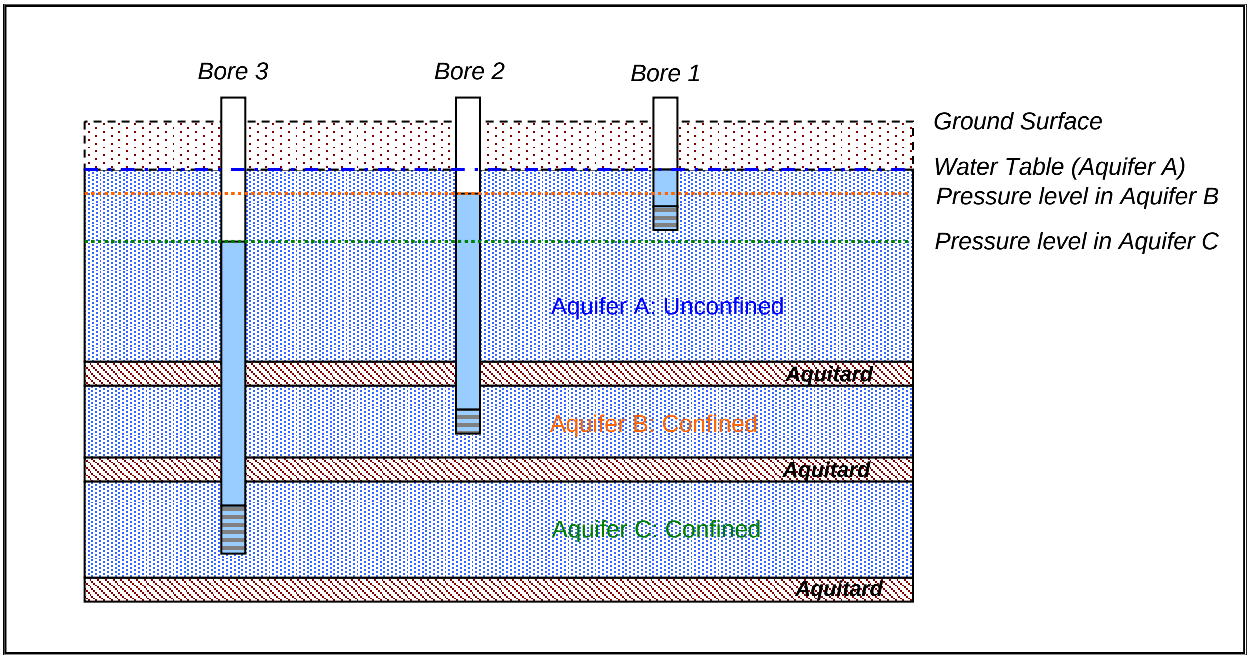


Figure D-2: Aquifer under Pre-Development Conditions

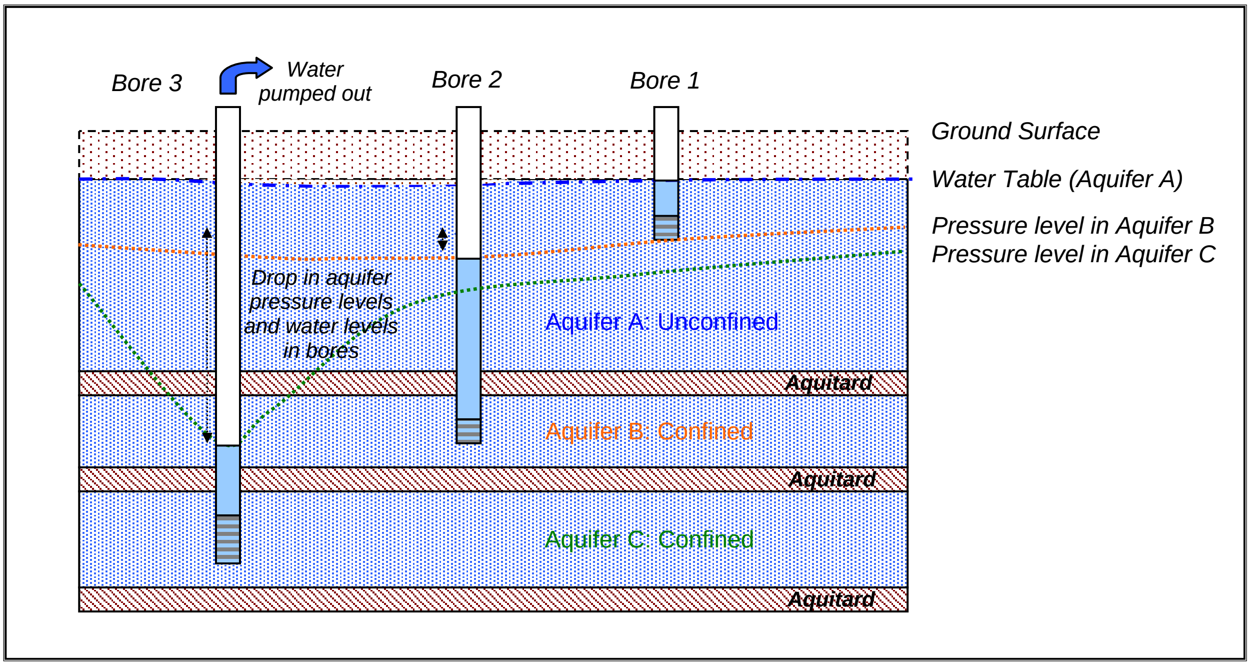


Figure D-3: Aquifer under Post-Development with Depressurisation

Appendix E

Details of Private Bores in Immediately Affected Areas

The Table E-1 below presents details of bores that are within Immediately Affected Area (IAA). A summary of these bores is presented in Table 6-1 of the main report. RN in the first column of the table refers to Registered Number (RN) of bores as recorded in DNRM's Groundwater Database. The last column of the table specifies the responsible tenure holder based on current tenure ownership.

Table E-1: Details of Water Bores in IAA

RN	Latitude	Longitude	Formation	Purpose	Current Responsible Tenure Holder
226	-26.47621	148.892789	Walloon Coal Measures	Stock and Domestic	Santos
5390	-26.82279	150.533441	Walloon Coal Measures	Stock and Domestic	Origin
8425	-26.85677	150.529217	Walloon Coal Measures	Stock and Domestic	Origin
9135	-26.745645	150.417491	Walloon Coal Measures	Stock and Domestic	Arrow
10459	-26.150645	149.813887	Walloon Coal Measures	Stock and Domestic	QGC
10697	-26.737035	150.289715	Walloon Coal Measures	Stock and Domestic	QGC
10725	-26.675646	150.30527	Walloon Coal Measures	Stock and Domestic	QGC
12144	-26.634813	150.228604	Walloon Coal Measures	Stock and Domestic	Origin
12340	-26.735924	150.367769	Walloon Coal Measures	Stock and Domestic	Arrow
12341	-26.79009	150.328326	Walloon Coal Measures	Stock and Domestic	QGC
12646	-27.060041	150.860989	Walloon Coal Measures	Stock and Domestic	Arrow
13117	-26.185927	149.294171	Walloon Coal Measures	Stock and Domestic	Origin
13602	-26.631757	150.288881	Walloon Coal Measures	Stock and Domestic	Arrow
14219	-26.208149	149.29556	Walloon Coal Measures	Stock and Domestic	Origin
14308	-26.763146	150.304993	Walloon Coal Measures	Stock and Domestic	QGC
14745	-26.131083	149.577012	Walloon Coal Measures	Stock and Domestic	QGC
15810	-26.76509	150.344992	Walloon Coal Measures	Stock and Domestic	Origin
16102	-26.193425	149.533057	Walloon Coal Measures	Stock and Domestic	Origin
16135	-26.145923	149.643056	Walloon Coal Measures	Stock and Domestic	QGC
16938	-26.131758	149.463614	Walloon Coal Measures	Stock and Domestic	Origin
16939	-26.134536	149.476113	Walloon Coal Measures	Stock and Domestic	Origin
16940	-26.172036	149.485836	Walloon Coal Measures	Stock and Domestic	Origin
16941	-26.165091	149.49528	Walloon Coal Measures	Stock and Domestic	Origin
16942	-26.14148	149.498335	Walloon Coal Measures	Stock and Domestic	Origin
16943	-26.168611	149.466667	Walloon Coal Measures	Stock and Domestic	Origin
16944	-26.154536	149.473336	Walloon Coal Measures	Stock and Domestic	Origin
16946	-26.170092	149.457225	Walloon Coal Measures	Stock and Domestic	Origin
17414	-27.143896	150.990077	Walloon Coal Measures	Stock and Domestic	Arrow
17631	-27.322959	151.146674	Walloon Coal Measures	Stock and Domestic	Arrow
18230	-26.501206	149.501947	Walloon Coal Measures	Stock and Domestic	Origin
19995	-26.844607	150.533722	Walloon Coal Measures	Stock and Domestic	Origin
22123	-27.084846	150.809814	Walloon Coal Measures	Stock and Domestic	QGC
23386	-27.13342	150.696378	Walloon Coal Measures	Stock and Domestic	QGC
23460	-26.870089	150.42388	Walloon Coal Measures	Stock and Domestic	QGC
23560	-27.291766	150.687808	Walloon Coal Measures	Stock and Domestic	QGC
24278	-27.338159	151.149718	Walloon Coal Measures	Stock and Domestic	Arrow
24280	-27.466386	151.17919	Walloon Coal Measures	Stock and Domestic	Arrow
24288	-27.428965	151.187732	Walloon Coal Measures	Stock and Domestic	Arrow
26063	-26.846004	150.501735	Walloon Coal Measures	Stock and Domestic	Origin
30409	-26.778978	150.436379	Walloon Coal Measures	Stock and Domestic	Origin
30564	-26.228706	149.218339	Walloon Coal Measures	Stock and Domestic	Origin
30997	-27.206961	151.02446	Walloon Coal Measures	Agriculture	Arrow
31995	-26.160924	149.558057	Walloon Coal Measures	Stock and Domestic	QGC

RN	Latitude	Longitude	Formation	Purpose	Current Responsible Tenure Holder
32259	-26.144167	149.563611	Walloon Coal Measures	Stock and Domestic	QGC
33319	-27.06834	150.795815	Walloon Coal Measures	Stock and Domestic	Origin
33821	-26.11509	149.57639	Walloon Coal Measures	Stock and Domestic	QGC
34708	-26.101756	149.665555	Walloon Coal Measures	Stock and Domestic	QGC
35754	-26.187456	149.352654	Walloon Coal Measures	Stock and Domestic	Origin
35842	-26.187313	149.637223	Walloon Coal Measures	Stock and Domestic	QGC
35966	-26.29009	149.826387	Walloon Coal Measures	Agriculture	QGC
37301	-26.176204	149.328615	Walloon Coal Measures	Stock and Domestic	Origin
43660	-26.177593	149.401114	Walloon Coal Measures	Stock and Domestic	Origin
44006	-26.26009	149.843331	Walloon Coal Measures	Stock and Domestic	Origin
44605	-26.077589	149.662222	Walloon Coal Measures	Stock and Domestic	QGC
48806	-26.197313	149.660833	Walloon Coal Measures	Stock and Domestic	QGC
48965	-26.148423	149.66	Walloon Coal Measures	Stock and Domestic	QGC
48981	-26.159814	149.43167	Walloon Coal Measures	Stock and Domestic	Origin
55015	-27.329792	151.127357	Walloon Coal Measures	Stock and Domestic	Arrow
58009	-26.19259	149.759721	Walloon Coal Measures	Stock and Domestic	QGC
58253	-26.216483	149.251394	Walloon Coal Measures	Stock and Domestic	Origin
58288	-26.256761	149.243339	Walloon Coal Measures	Stock and Domestic	Origin
58297	-26.071672	149.687504	Walloon Coal Measures	Stock and Domestic	QGC
58307	-26.356758	149.823887	Walloon Coal Measures	Stock and Domestic	Origin
58402	-26.270373	149.231672	Walloon Coal Measures	Stock and Domestic	Origin
58499	-26.267873	149.199728	Walloon Coal Measures	Stock and Domestic	Origin
58609	-26.189534	149.781665	Walloon Coal Measures	Stock and Domestic	QGC
58646	-26.173426	149.373337	Walloon Coal Measures	Stock and Domestic	Origin
58786	-26.26009	149.843331	Walloon Coal Measures	Stock and Domestic	Origin
61111	-27.092308	150.845542	Walloon Coal Measures	Stock and Domestic	QGC
83510	-27.081483	150.536165	Walloon Coal Measures	Stock and Domestic	QGC
83627	-26.846424	150.521546	Walloon Coal Measures	Agriculture	Origin
87471	-27.155853	151.004612	Walloon Coal Measures	Stock and Domestic	Arrow
87611	-26.765089	150.48499	Walloon Coal Measures	Stock and Domestic	Origin
94052	-27.196111	151.009167	Walloon Coal Measures	Agriculture	Arrow
119170	-26.926811	150.49168	Walloon Coal Measures	Stock and Domestic	QGC
119267	-27.095833	150.929444	Walloon Coal Measures	Industrial	Arrow
119859	-27.334167	151.086667	Walloon Coal Measures	Stock and Domestic	Arrow
123291	-26.637594	150.145753	Walloon Coal Measures	Stock and Domestic	Origin
123292	-26.634917	150.144735	Walloon Coal Measures	Stock and Domestic	Origin
137140	-26.856852	150.445122	Walloon Coal Measures	Stock and Domestic	QGC
137175	-27.119848	150.821865	Walloon Coal Measures	Agriculture	QGC
137552	-27.118611	150.895278	Walloon Coal Measures	Stock and Domestic	QGC
147156	-27.001944	150.67	Walloon Coal Measures	Stock and Domestic	Origin
147170	-26.920556	150.5175	Walloon Coal Measures	Stock and Domestic	Origin
147264	-26.881111	150.512222	Walloon Coal Measures	Stock and Domestic	Origin

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Appendix F

Drawdown Patterns for Long-term Impacts

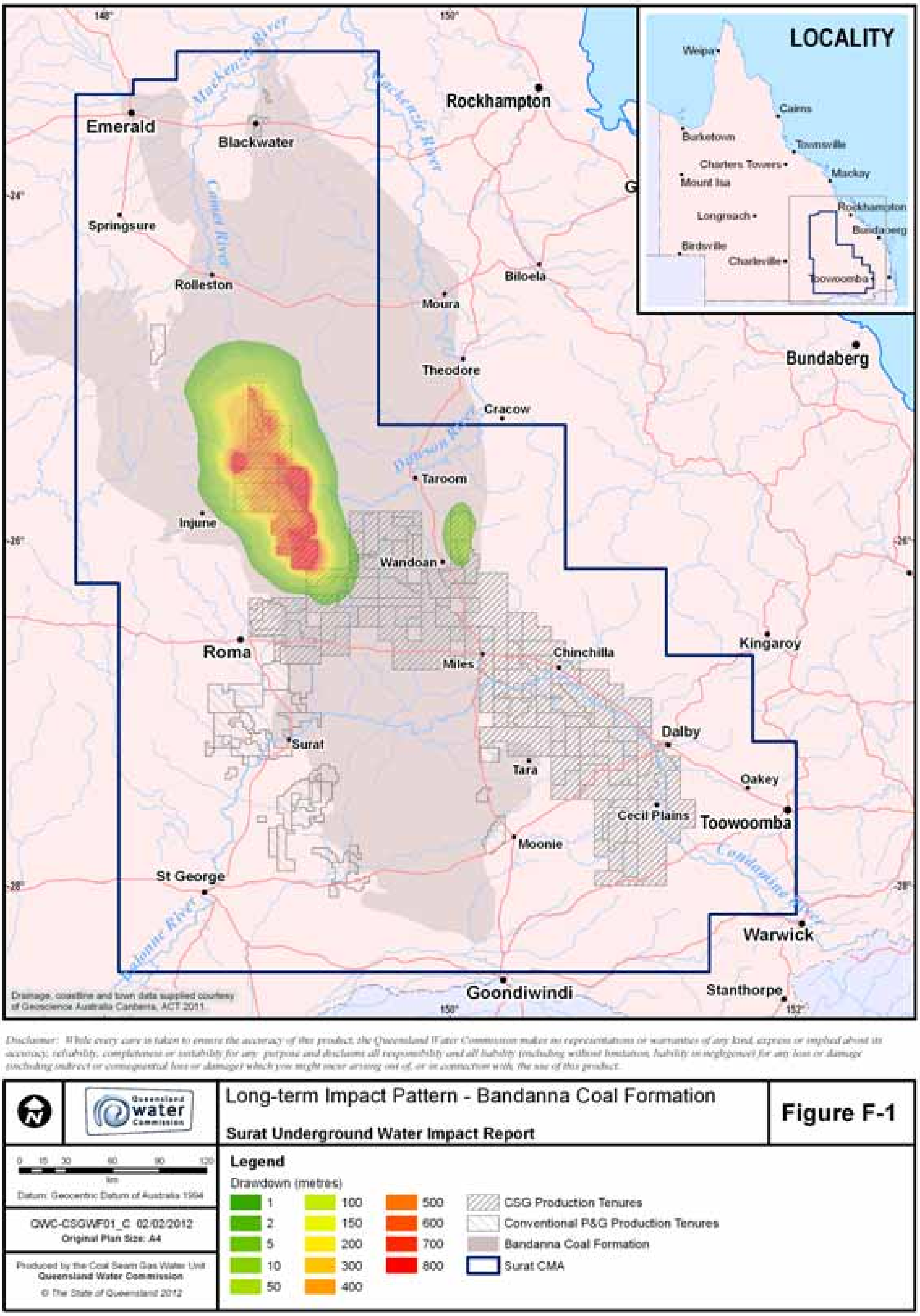


Figure F-1 Long Term Impact Pattern - Bandanna Coal Formation

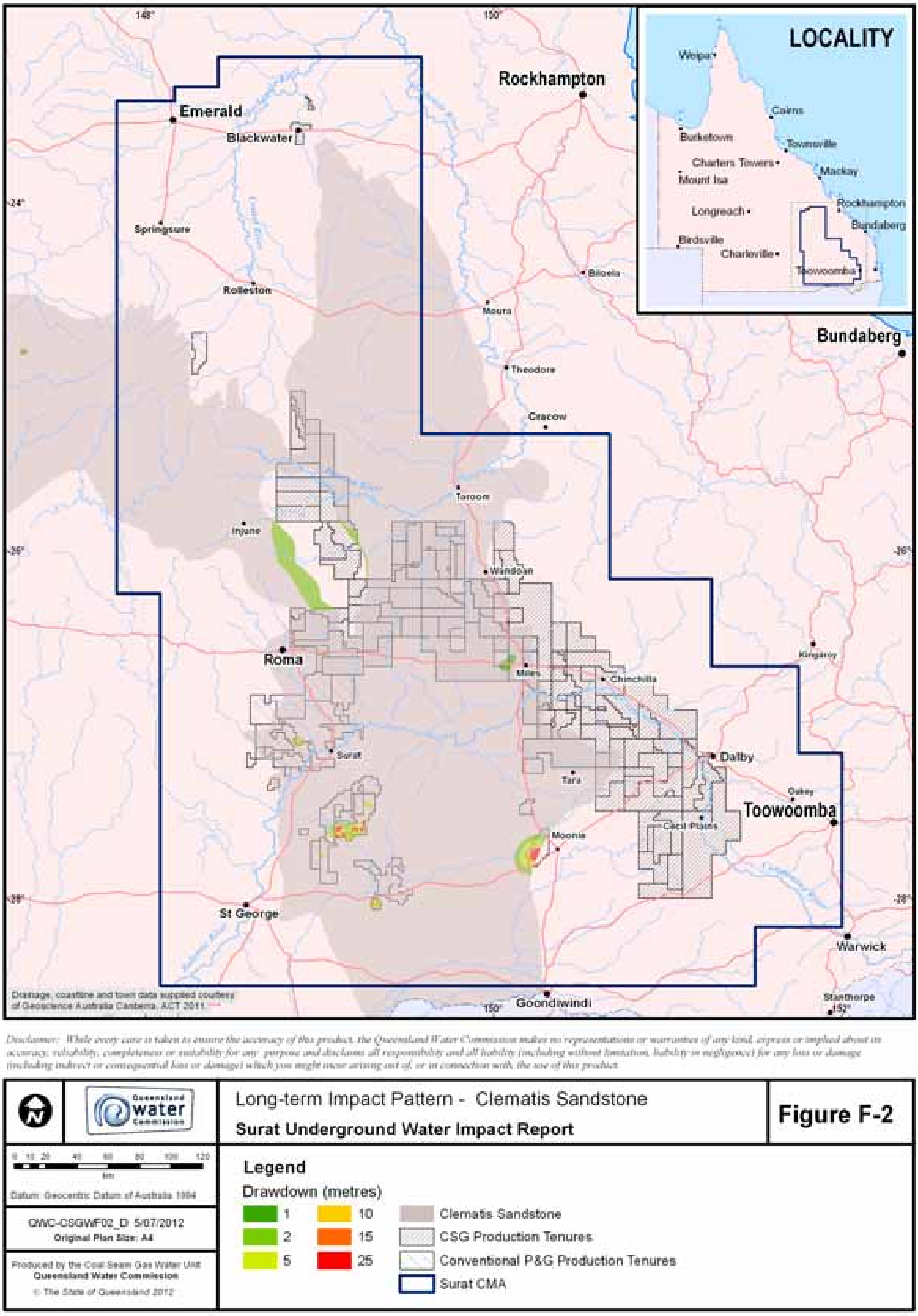
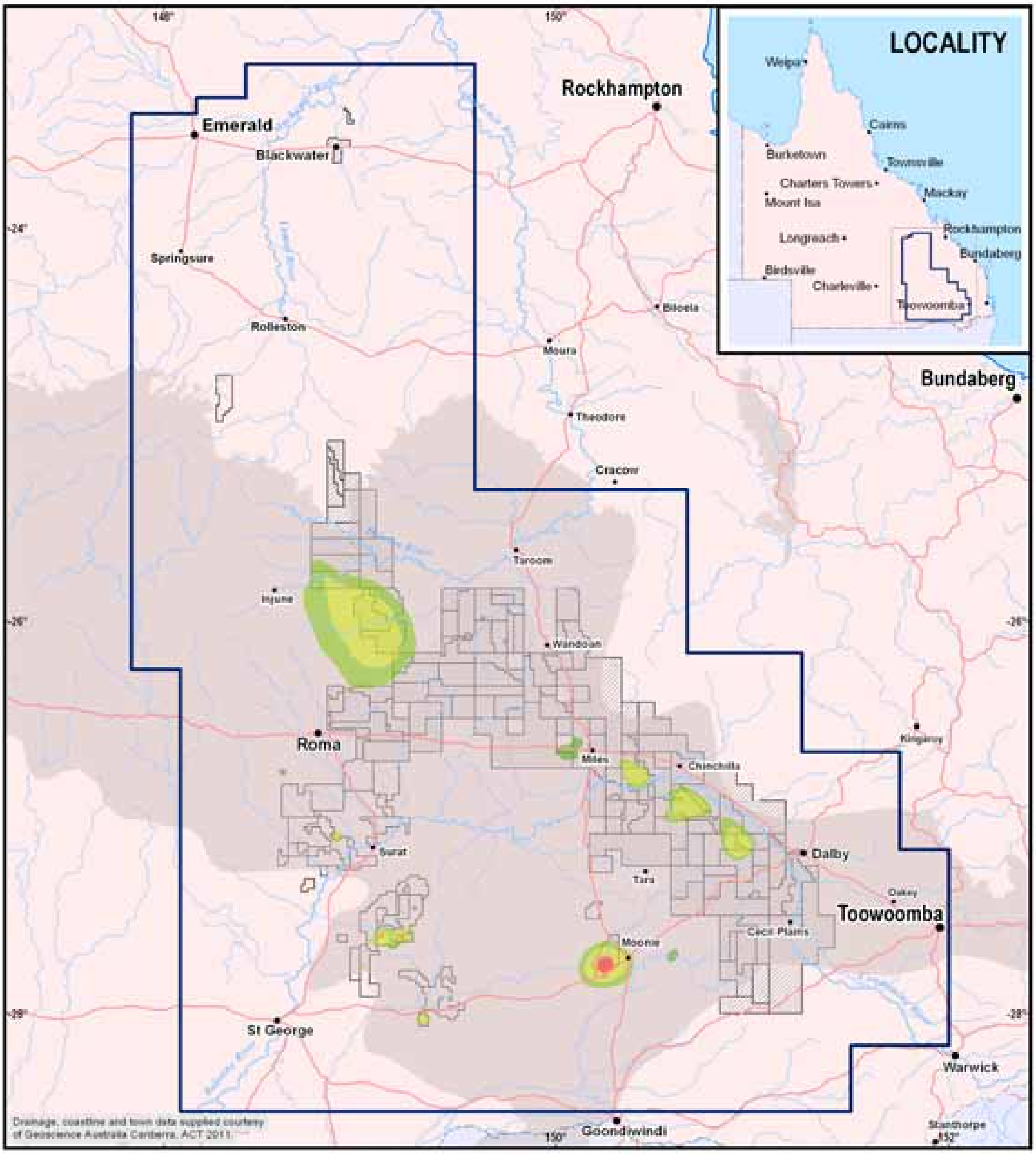


Figure F-2 Long Term Impact Pattern - Clematis Sandstone



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Long-term Impact Pattern - Precipice Sandstone

Surat Underground Water Impact Report

Figure F-3

0 10 20 40 60 80 100 120 km

Datum: Geocentric Datum of Australia 1994

QWC-CSGWF03_E 5/07/2012

Original Plan Size: A4

Produced by the Coal Seam Gas Water Unit
Queensland Water Commission

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Legend

Drawdown (metres)

- 1
- 2
- 5
- 10
- 15
- 25

- Precipice Sandstone
- CSG Production Tenures
- Conventional P&G Production Tenures
- Surat CMA

Figure F-3 Long Term Impact Pattern - Precipice Sandstone

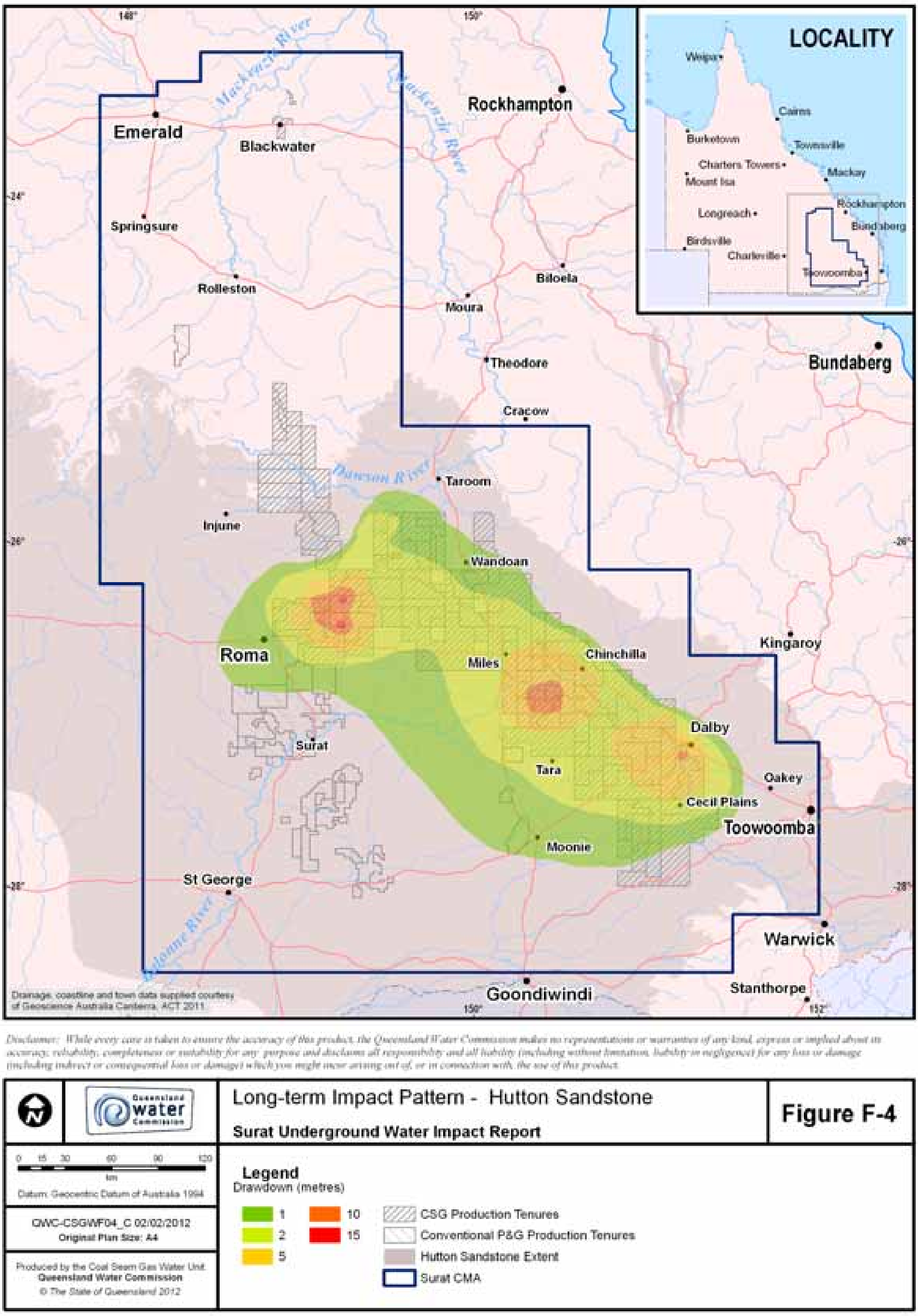

Figure F-4 Long Term Impact Pattern - Hutton Sandstone

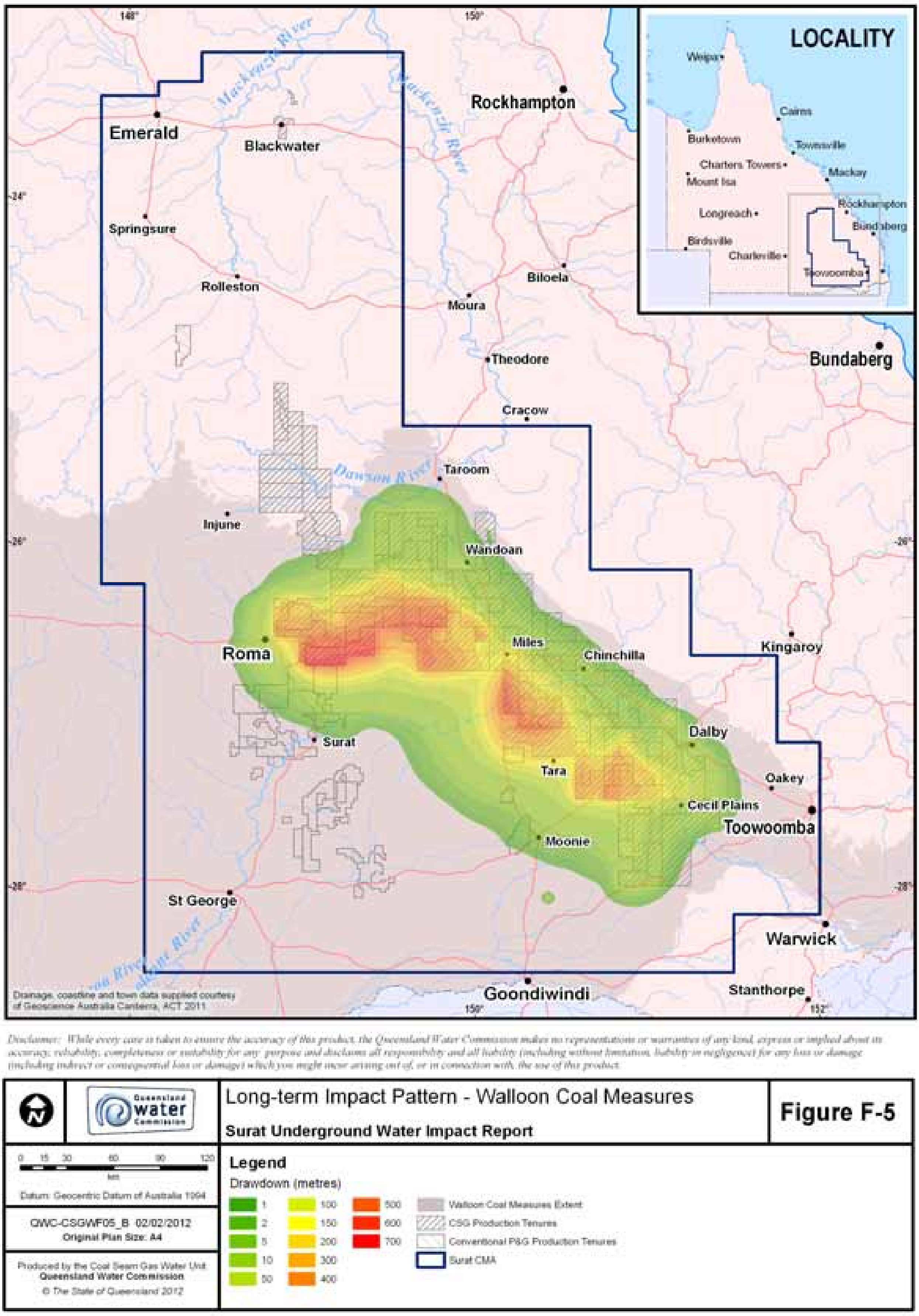

Figure F-5 Long Term Impact Pattern - Walloon Coal Measures

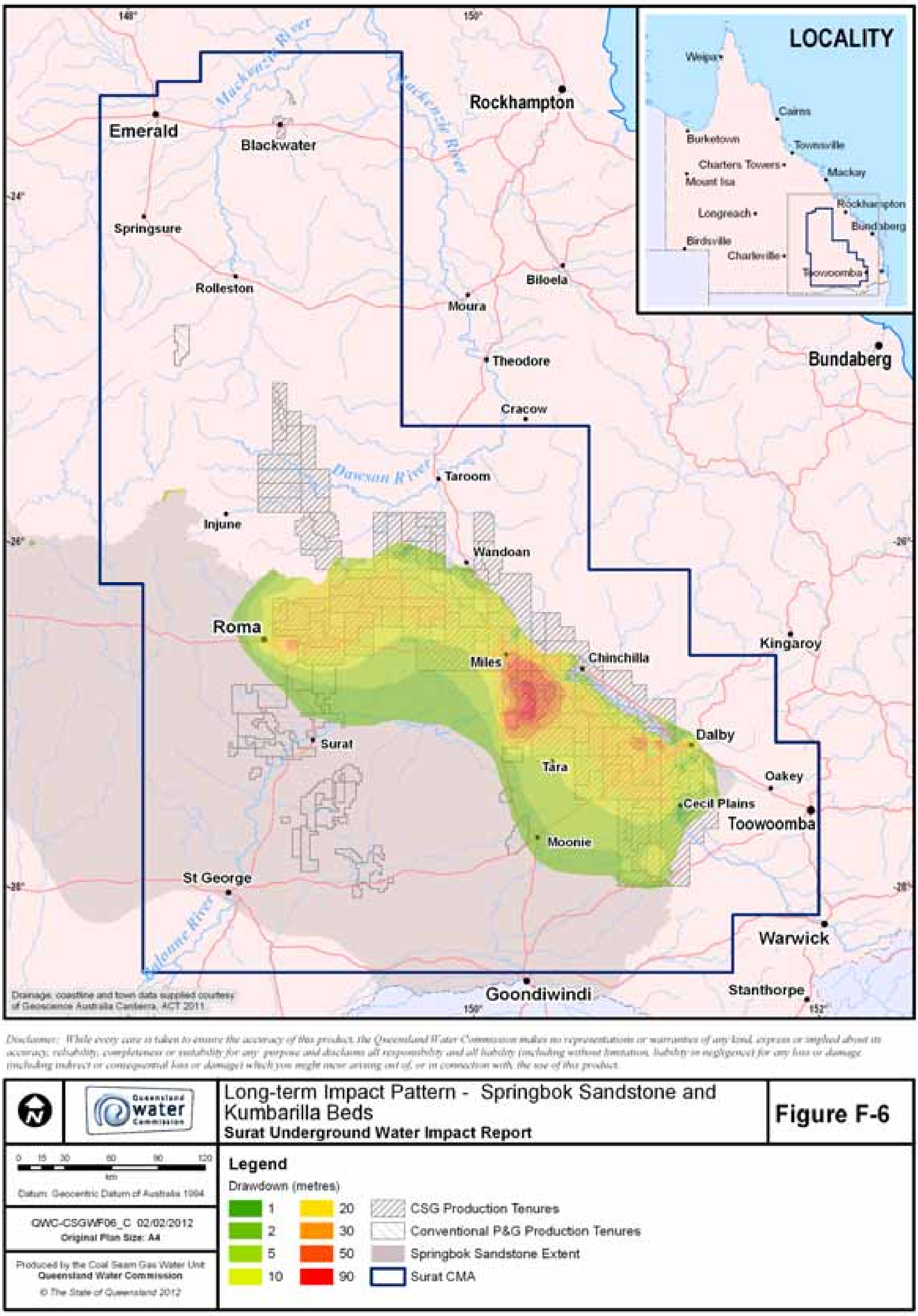

Figure F-6 Long Term Impact Pattern - Springbok Sandstone and Kumbarilla Beds

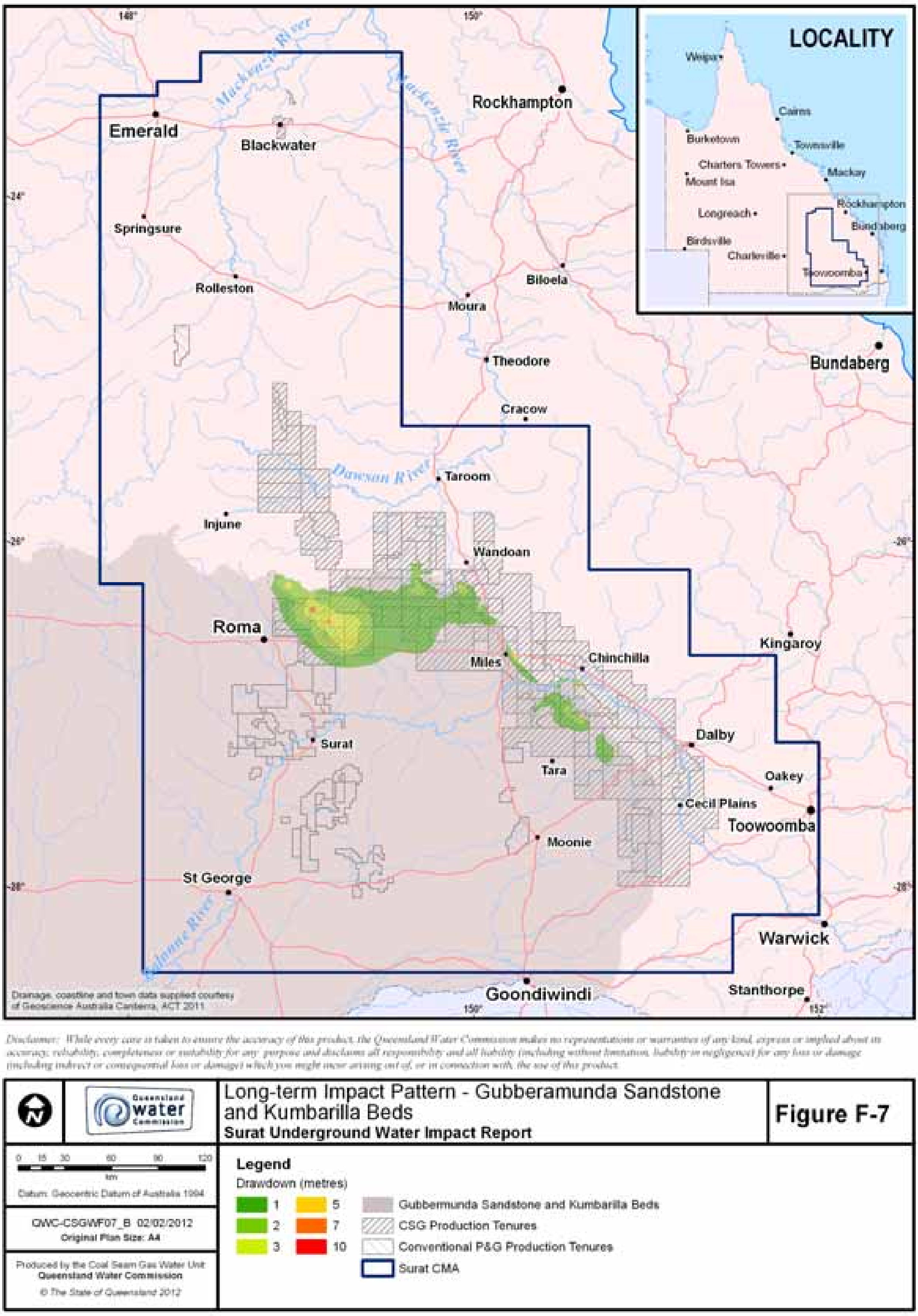

Figure F-7 Long Term Impact Pattern - Gubberamunda Sandstone and Kumbarilla Beds

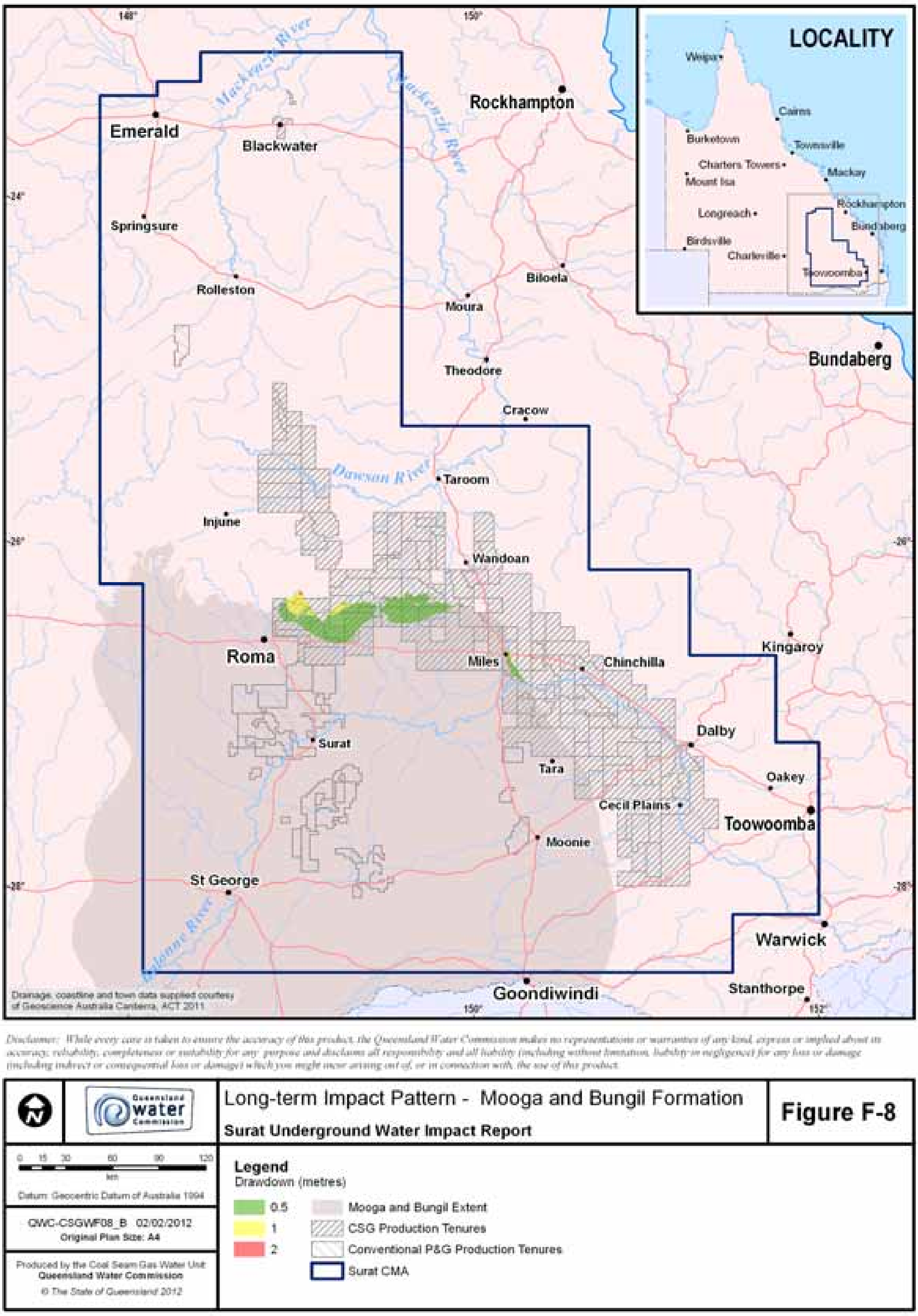

Figure F-8 Long Term Impact Pattern - Mooga and Bungil Formation

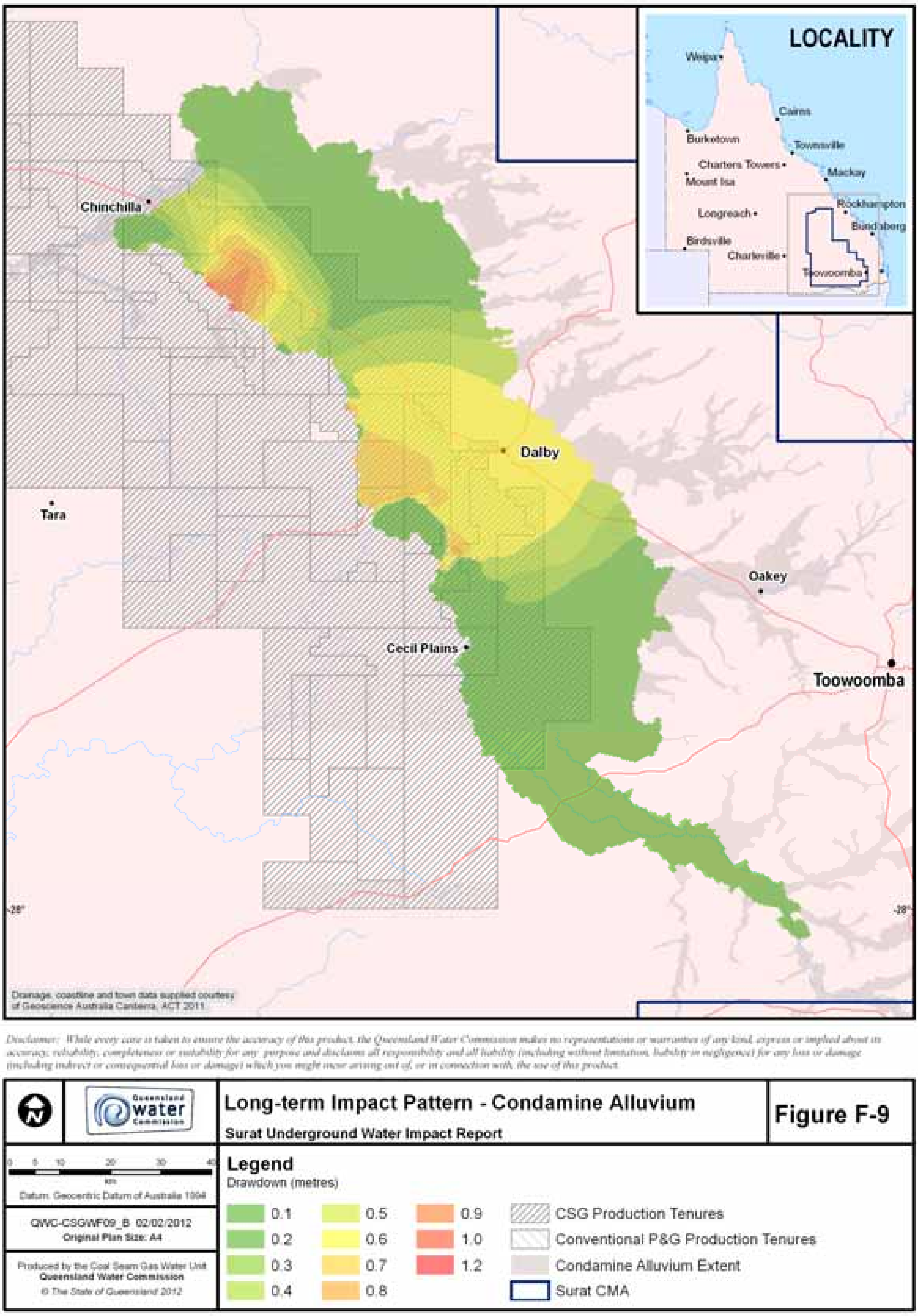

Figure F-9 Long Term Impact Pattern - Condamine Alluvium

Appendix G

Regional Monitoring Network

The Table G-1 below provides detail of the regional monitoring network (Section 7.3.1). The following explanation applies to this table:

Site No: This is the monitoring site number.

Status: 'Existing' means monitoring works physically exist at that location. 'New' means a site where there are no existing works. Tenure holders have already planned monitoring works at some new sites.

Suite: This refers to one of the suites of water quality parameters listed in Table G-2.

Monitoring Point: These are target geologic units where monitoring is required.

Required By: Tenure holders are required to complete installation of monitoring works and commence recording monitoring data by the end of this year.

Objectives: Each monitoring site and monitoring point were selected to fulfil certain monitoring objectives. These are the objectives referred to in Section 7.2 of the UWIR.

Responsible Tenure Holder: This column identifies the responsible tenure holder for the monitoring site. For the sites located in the production area, the responsible tenure holder is identified as 'CTH' as specified in Chapter 9 of the UWIR.

Table G-1: Regional Monitoring Network

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
1	-27.9685	150.9250	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2016		1,2,4,5,6	CTH
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2016		1,2,4,5,6	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,4,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,4,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
2	-27.7894	150.9465	New	Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		1,2,5,6	CTH
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
				Hutton Sandstone	fortnightly			2013		1,2,5,6	
3	-27.6600	150.5800	New	Springbok Sandstone	fortnightly	WQ1	fortnightly	2016		1,2,4,5,6	QGC
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,4,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,4,5,6	
				Hutton Sandstone	fortnightly	WQ1	fortnightly	2016		1,2,4,5,6	
						WQ2	annual				
				Precipice Sandstone	fortnightly	WQ1	fortnightly	2016		1,2,4,5,6	
						WQ2	annual				
4	-27.6390	151.1676	Existing	Juandah Coal Measures	fortnightly			2012	River Road-4	2,5	CTH
5	-27.5898	151.2342	Existing	Condamine Alluvium	fortnightly			2012	RN 42230088A	2,5	CTH
			New	Taroom Coal Measures	fortnightly			2016		2,5	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
6	-27.6049	150.9039	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2013		1,2,4,5,6	CTH
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		1,2,4,5,6	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,4,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,4,5,6	
7	-27.5779	151.1338	Existing	Juandah and Taroom Coal Measures	fortnightly			2012	Meenawarra-5	1,2,5,6	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
8	-27.5464	151.2916	Existing	Condamine Alluvium	fortnightly			2012	RN 42231463A	1,2,5,6	CTH
			New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,4,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
			New	Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
			New	Evergreen Formation	fortnightly			2013		1,2,5,6	
			New	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
9	-27.5318	151.5148	Existing	Condamine Alluvium	fortnightly			2012	RN 42231339A	1,2	Arrow
				Walloon Coal Measures	fortnightly			2012	RN 42231340A	1,2,4	
10	-27.4915	151.3932	Existing	Condamine Alluvium	fortnightly	WQ1 WQ2	fortnightly annual	2012	RN 42231370A	1,4,6	Arrow
			New	Condamine Alluvium - Walloon transition layer / Springbok	fortnightly			2016		1,4,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,4,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,4,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2016		1,4,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
11	-27.424	150.657	New	Gubberamunda Sandstone	fortnightly			2013		1,2,4,5,6	CTH
				Springbok Sandstone	fortnightly			2013		1,2,4,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,4,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,4,5,6	
				Hutton Sandstone	fortnightly			2013		1,2,4,5,6	
				Precipice Sandstone	fortnightly			2013		1,2,4,5,6	
12	-27.4070	151.0469	New	Gubberamunda Sandstone	fortnightly			2013		1,2,5,6	CTH
				Westbourne Formation	fortnightly			2013		1,2,5,6	
				Springbok Sandstone	fortnightly			2013		1,2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
				Hutton Sandstone	fortnightly			2013		1,2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
13	-27.4074	151.1404	Existing	Walloon Coal Measures	fortnightly			2012	Tipton West Pilot-1	2,5	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,5	
14	-27.3984	151.5552	Existing	Condamine Alluvium	fortnightly			2012	RN 42231294A	1,2,4,5,6	Arrow
				Walloon Coal Measures	fortnightly			2012	RN 42231295A	1,2,4,5,6	
15	-27.3810	151.2159	Existing	Juandah Coal Measures	fortnightly			2012	Plainview-1	1,2,5,6	CTH
16	-27.3628	150.8241	New	Gubberamunda Sandstone	fortnightly			2013		1,2,5,6	CTH
				Springbok Sandstone	fortnightly			2013		1,2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
17	-27.3431	151.1242	Existing	Juandah Coal Measures	fortnightly			2012	Long Swamp-1	2,5	CTH

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
18	-27.3134	151.1986	New	Condamine Alluvium	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH
			New	Condamine Alluvium - Walloon transition layer	fortnightly			2013		2,5,6	
			Existing	Walloon Coal Measures	fortnightly			2012	Tipton West-4	2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
19	-27.2885	151.3631	New	Condamine Alluvium	fortnightly			2013		2,5,6	Arrow
				Condamine Alluvium - Walloon transition layer	fortnightly			2013		2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
20	-27.2862	150.5940	New	Gubberamunda Sandstone	fortnightly			2013		2,5,6	CTH
				Springbok Sandstone	fortnightly			2013		2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
21	-27.2673	151.0676	New	Condamine Alluvium	fortnightly			2013		1,2,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
22	-27.2800	150.3300	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	Origin
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
				Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
23	-27.2698	151.2383	Existing	Condamine Alluvium	fortnightly			2012	RN 42230153A	1,2,4	CTH
			New	Springbok Sandstone	fortnightly			2013		1,2,4	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,4	
24	-27.2710	150.9340	Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	JEN_MW001	1,2,5,6	CTH
			New	Springbok Sandstone	fortnightly			2013		1,2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
25	-27.2439	150.4559	New	Gubberamunda Sandstone	fortnightly			2016		1,2,3	CTH
				Springbok Sandstone	fortnightly			2016		1,2,3	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,3	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,3	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,3	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
26	-27.2100	150.7500	New	Springbok Sandstone	fortnightly			2013		1,2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
				Hutton Sandstone	fortnightly			2013		1,2,5,6	
27	-27.1952	151.3179	New	Condamine Alluvium	fortnightly			2016		1,6	Arrow
				Condamine alluvium - Walloon transition layer	fortnightly			2016		1,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality: Suite	Water Quality: Frequency				
28	-27.1793	151.1249	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		1,2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,5,6	
29	-27.1795	151.0439	Existing	Juandah Coal Measures	fortnightly			2012	Stratheden-3	2,5	CTH
30	-27.1656	151.2151	Existing	Condamine Alluvium	fortnightly			2012	RN 42230159A	1,2	CTH
			New	Condamine Alluvium - Walloon transition layer	fortnightly			2013		1,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,6	
31	-27.1660	150.8179	Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	DAV_MW001	1,2	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
32	-27.1434	150.9433	New	Westbourne Formation / Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		1,2,5,6	CTH
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				sandstone or siltstone or mudstone of the Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				Tangalooma Sandstone	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				lower aquitard of the Walloon Coal Measures	fortnightly			2013		2,5,6	
33	-27.1153	151.4978	Existing	Walloon Coal Measures	fortnightly			2012	RN 42231548A	1,2	Arrow
34	-27.1093	151.0539	New	Condamine Alluvium	fortnightly			2013		2,5,6	CTH
			New	Condamine Alluvium - Walloon transition layer	fortnightly			2013		2,5,6	
			Existing	Juandah and Taroom Coal Measures	fortnightly			2012	Daandine-24	2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
35	-27.1083	150.3942	New	Gubberamunda Sandstone	fortnightly			2013		2,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
36	-27.1083	150.2213	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		1,2,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,6	
				Hutton Sandstone	fortnightly			2016		1,2,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
37	-27.1024	150.9614	Existing	Juandah and Taroom Coal Measures	fortnightly			2012	Daandine-2	2,5,6	CTH
			New	Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
38	-27.0500	150.7399	New	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
39	-27.0286	150.5485	Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Kenya East GW1	2,5,6	CTH
			Existing	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Kenya East GW2	2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
			New	Hutton Sandstone	fortnightly			2013		2,5,6	
			New	Precipice Sandstone	fortnightly			2013		2,5,6	
40	-27.0224	150.3171	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
41	-27.0100	151.1140	New	Condamine Alluvium	fortnightly			2016		1,3,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,3,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,3,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,3,6	
42	-27.0093	150.9003	New	Condamine Alluvium	fortnightly			2013		2,3,5,6	CTH
			New	Condamine Alluvium - Walloon transition layer	fortnightly			2013		2,3,5,6	
			Existing	Juandah and Taroom Coal Measures	fortnightly			2012	Kogan North-56	1,2	
43	-26.9492	150.4592	New	Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,4,5,6	CTH
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1	fortnightly	2013		2,4,5,6	
						WQ2	annual				
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,4,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
44	-26.9417	150.2119	Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Condabri-MB3-G	2,5,6	CTH
			Existing	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Condabri-MB4-S	2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
45	-26.9200	149.9400	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		1,2,5,6	Origin
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		1,2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
46	-26.8930	150.3703	Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Talinga MB5-G	2,4,5,6	CTH
			Existing	Westbourne Formation	fortnightly			2012	Talinga-SC2-Wb	2,4,5,6	
			Existing	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Talinga-MB7-S	2,4,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,4,5,6	
			New	sandstone or siltstone or mudstone of the Juandah Coal Measures	fortnightly			2013		2,4,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,4,5,6	
			New	Tangalooma Sandstone	fortnightly			2013		2,4,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,4,5,6	
			New	lower aquitard of the Walloon Coal Measures	fortnightly			2013		2,4,5,6	
			New	Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,4,5,6	
47	-26.8989	150.9792	Existing	Condamine Alluvium	fortnightly			2012	RN 42230203	1,2	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
48	-26.8600	150.7500	New	Condamine Alluvium	fortnightly			2013		1,2,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		1,2,5,6	
				Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,5,6	
49	-26.8470	150.3001	Existing	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Berwyndale South GW2	1,2	CTH
50	-26.8086	150.1710	Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Condabri-MB1-G	2,5,6	CTH
			Existing	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Condabri-MB2-S	2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
			New	Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
51	-26.8035	150.5701	New	Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	CTH

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
52	-26.7922	148.7417	Existing	Gubberamunda Sandstone	fortnightly			2012	Hollyrood 5	2,5,6	Santos
				Lower Juandah Coal Measures	fortnightly			2012	Hollyrood 5	2,5,6	
				Taroom Coal Measures	fortnightly			2012	Hollyrood 5	2,5,6	
53	-26.7578	150.3603	Existing	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Talinga 17	1,2	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	
54	-26.7718	149.2060	New	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		1,2	Santos
				Springbok Sandstone	fortnightly			2016		1,2	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		1,2	
				coal seam of the Taroom Coal Measures	fortnightly			2016		1,2	
				Hutton Sandstone	fortnightly			2016		1,2	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
55	-26.7422	150.6799	Existing	Condamine Alluvium	fortnightly	WQ1	fortnightly	2012	RN 42230209 Pipe A	1,2	CTH
						WQ2	annual				
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		1,2	
56	-26.7310	150.4938	New	Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	CTH
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
57	-26.7030	150.2581	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	CTH
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
58	-26.6833	148.9923	Existing	Mooga Sandstone	fortnightly			2012	Coonardoo 2	2,5,6	CTH
				Gubberamunda Sandstone	fortnightly			2012	Coonardoo 2	2,5,6	
				Upper Juandah Coal Measures	fortnightly			2012	Coonardoo 2	2,5,6	
				Lower Juandah Coal Measures	fortnightly			2012	Coonardoo 2	2,5,6	
				Taroom Coal Measures	fortnightly			2012	Coonardoo 2	2,5,6	
59	-26.7229	149.9994	New	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,5,6	
60	-26.6737	148.8464	Existing	Upper Juandah Coal Measures	fortnightly			2012	Richmond 25	2,5,6	Santos
				Lower Juandah Coal Measures	fortnightly			2012	Richmond 25	2,5,6	
			New	Taroom Coal Measures	fortnightly			2013		2,5,6	
61	-26.6719	149.6919	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,5,6	CTH

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
62	-26.6660	150.1844	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
			New	coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
			New	coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
			Existing	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	RN 58410 Miles Town Bore	1,2	
63	-26.6400	149.8300	New	coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,5,6	CTH
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2,5,6	
64	-26.6366	149.1119	Existing	Gubberamunda Sandstone	fortnightly			2012	Latermore South 2	2,5,6	CTH
				Springbok Sandstone	fortnightly			2012	Latermore South 2	2,5,6	
				Lower Juandah Coal Measures	fortnightly			2012	Latermore South 2	2,5,6	
				Taroom Coal Measures	fortnightly			2012	Latermore South 2	2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
65	-26.6033	149.3932	Existing	Mooga Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	M02	2,5,6	CTH
			Existing	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	G04	2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	
66	-26.5826	148.8511	Existing	Mooga Sandstone	fortnightly			2012	Damper Creek 4	2,4,5,6	Santos
				Gubberamunda Sandstone	fortnightly			2012	Damper Creek 4	2,5,6	
			New	Springbok Sandstone	fortnightly			2016		2,5,6	
			Existing	Upper Juandah Coal Measures	fortnightly			2012	Damper Creek 4	2,5,6	
				Lower Juandah Coal Measures	fortnightly			2012	Damper Creek 4	2,5,6	
				Hutton Sandstone	fortnightly			2012	Damper Creek 4	2,5,6	
67	-26.5500	150.4900	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	QGC
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
68	-26.5448	150.1060	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly			2013		2,5,6	
69	-26.5400	149.9600	Existing	Mooga Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	RN 123130	1,2	CTH
70	-26.5331	149.0543	Existing	Gubberamunda Sandstone	fortnightly			2012	Wingnut 3	2,5,6	CTH
			New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
			Existing	Lower Juandah Coal Measures	fortnightly			2012	Wingnut 3	2,5,6	
			Existing	Taroom Coal Measures	fortnightly			2012	Wingnut 3	2,5,6	
			New	Hutton Sandstone	fortnightly			2013		2,5,6	
			New	Precipice Sandstone	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
71	-26.5268	149.2130	Existing	Mooga Sandstone	fortnightly			2012	Stakeyard East 1	2,5,6	CTH
			Existing	Gubberamunda Sandstone	fortnightly			2012	Stakeyard East 1	2,5,6	
			Existing	Springbok Sandstone	fortnightly			2012	Stakeyard East 1	2,5,6	
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
72	-26.5230	149.8220	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	QGC
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				
				Precipice Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
73	-26.5139	150.2472	New	Springbok Sandstone	fortnightly			2013		2	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2	
74	-26.4948	149.3649	Existing	Gubberamunda Sandstone	fortnightly			2012	Bendemere 1	2,5,6	CTH
				Westbourne Formation	fortnightly			2012	Bendemere 1	2,5,6	
				Springbok Sandstone	fortnightly			2012	Bendemere 1	2,5,6	
				Upper Juandah Coal Measures	fortnightly			2012	Bendemere 1	2,5,6	
				Lower Juandah Coal Measures	fortnightly			2012	Bendemere 1	2,5,6	
				Taroom Coal Measures	fortnightly			2012	Bendemere 1	2,5,6	
75	-26.4650	149.0187	Existing	Orallo Formation	fortnightly			2012	The Bend	2,4,5,6	CTH
				Westbourne Formation	fortnightly			2012	The Bend	2,4,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
76	-26.4387	148.9040	New	Springbok Sandstone	fortnightly			2016		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2,5,6	
77	-26.4391	148.8004	Existing	Gubberamunda Sandstone	fortnightly			2012	Montana 1	2,4,5,6	Santos
				Upper Juandah Coal Measures	fortnightly			2012	Montana 1	2,4,5,6	
				Lower Juandah Coal Measures	fortnightly			2012	Montana 1	2,4,5,6	
				Taroom Coal Measures	fortnightly			2012	Montana 1	2,4,5,6	
78	-26.4302	149.3612	Existing	Mooga Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	Santos Bore ID 1137	2,5,6	CTH
				Orallo Formation	fortnightly	WQ1 WQ2	fortnightly annual	2012	O01	2,5,6	
79	-26.4200	149.7100	New	Springbok Sandstone	fortnightly			2013		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
80	-26.4032	149.5825	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	CTH
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		1,2	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
81	-26.4049	149.9818	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	CTH
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
82	-26.3685	149.1060	New	Gubberamunda Sandstone	fortnightly			2013		2,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				sandstone or siltstone or mudstone of the Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				Tangalooma Sandstone	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				lower aquitard of the Walloon Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
83	-26.3789	148.9636	Existing	Mooga Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	M01	2,4,5,6	CTH
				Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	G01	2,4,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
84	-26.3605	149.8104	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
85	-26.3566	149.4269	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
86	-26.3365	148.8381	Existing	Gubberamunda Sandstone	fortnightly			2012	Navarra 1	2,4,5,6	CTH
			New	Upper Juandah Coal Measures	fortnightly			2013		2,4,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
87	-26.3045	149.2597	New	Gubberamunda Sandstone	fortnightly	WQ1	fortnightly	2013		2,4,5,6	CTH
						WQ2	annual				
				Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,4,5,6	
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1	fortnightly	2013		2,4,5,6	
						WQ2	annual				
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,4,5,6	
88	-26.2952	148.6330	Existing	Upper Juandah Coal Measures	fortnightly			2012	Mt Eden 1	2,5,6	Santos

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
89	-26.2809	149.7024	New	Gubberamunda Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,4,5,6	CTH
				Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,4,5,6	
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,4,5,6	
				sandstone or siltstone or mudstone of the Juandah Coal Measures	fortnightly			2013		2,4,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,4,5,6	
				Tangalooma Sandstone	fortnightly			2013		2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,4,5,6	
				lower aquitard of the Walloon Coal Measures	fortnightly			2013		2,4,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,4,5,6	
90	-26.2732	149.9980	New	Springbok Sandstone	fortnightly			2013		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
91	-26.2700	150.2100	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	CTH
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly	WQ1	fortnightly	2013		2,4,5,6	
						WQ2	annual				
				Precipice Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				
92	-26.2455	149.5571	New	Springbok Sandstone	fortnightly	WQ1	fortnightly	2013		2,5,6	CTH
						WQ2	annual				
				coal seam of the Upper Juandah Coal Measures	fortnightly	WQ1	fortnightly	2013		2,5,6	
						WQ2	annual				
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
93	-26.2007	149.2417	New	Springbok Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,5,6	
				Precipice Sandstone	fortnightly			2013		2,5,6	
94	-26.1711	149.9542	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2	CTH
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2	
				Hutton Sandstone	fortnightly			2016		2	
95	-26.0800	149.1700	New	Bandanna Formation coal seam	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	CTH

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
96	-26.0527	149.4342	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2	QGC
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2	
97	-26.1135	149.6470	New	Springbok Sandstone	fortnightly			2013		2,5,6	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2,5,6	
				Hutton Sandstone	fortnightly			2013		2,4,5,6	
98	-25.9681	149.1842	New	Hutton Sandstone	fortnightly			2013		2,4,5,6	CTH
99	-25.9765	149.1042	Existing	Bandanna Formation	fortnightly			2012	Durham Ranch 23 - CRB1	1,2	CTH
100	-25.9730	149.7599	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	CTH
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
101	-25.9490	149.3514	Existing	Birkhead Formation	fortnightly	WQ1 WQ2	fortnightly annual	2012	RN 30259	1,2	QGC
102	-25.8932	149.2161	New	Hutton Sandstone	fortnightly			2013		2,4,5,6	CTH
				Precipice Sandstone	fortnightly			2013		2,4,5,6	
				Clematis Sandstone	fortnightly			2013		2,4,5,6	
				Bandanna Formation coal seam	fortnightly			2013		2,4,5,6	
103	-25.9099	149.5404	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	CTH
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,4,5,6	
				Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,5,6	
104	-25.8200	149.0314	New	Hutton Sandstone	fortnightly			2013		2,4,5,6	CTH
				Precipice Sandstone	fortnightly			2013		2,4,5,6	
				Bandanna Formation coal seam	fortnightly			2013		2,4,5,6	
105	-25.8375	148.8510	Existing	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	SpringGully-PB1	1,2	Origin

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
106	-25.7863	148.8459	New	Boxvale Sandstone	fortnightly			2013		4	CTH
			Existing	Precipice Sandstone	fortnightly			2012	FV-VW0902	1,2,4	
			New	Bandanna Formation coal seam	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2,4	
107	-25.7700	149.8900	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,4,5,6	QGC
				coal seam of the Lower Juandah Coal Measures	fortnightly			2016		2,4,5,6	
				coal seam of the Taroom Coal Measures	fortnightly			2016		2,4,5,6	
				Hutton Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2016		2,4,5,6	
108	-25.7538	148.7948	Existing	Precipice Sandstone	fortnightly			2012	FV-VW0903	1,2	CTH
109	-25.7347	149.0829	Existing	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	FV-MW0902	2,4,5,6	CTH
			New	Bandanna Formation coal seam	fortnightly	WQ1 WQ2	fortnightly annual	2013		2,4,5,6	
110	-25.7310	148.9810	Existing	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2012	FV-MW0903	2,4,5,6	CTH
			New	Bandanna Formation coal seam	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	
111	-25.6187	149.7682	Existing	Birkhead Formation	fortnightly			2012	RN 9726	1,2	QGC
112	-25.5829	149.1042	New	Clematis Sandstone	fortnightly			2013		2,5,6	CTH
				Bandanna Formation coal seam	fortnightly			2013		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
113	-25.5014	148.7544	New	Clematis Sandstone	fortnightly			2013		2,5,6	CTH
				Bandanna Formation coal seam	fortnightly			2013		2,5,6	
114	-25.4100	148.9052	New	Bandanna Formation coal seam	fortnightly			2013		2,5	CTH
115	-25.3492	149.0188	New	Clematis Sandstone	fortnightly			2013		2,5,6	CTH
				Bandanna Formation coal seam	fortnightly			2013		2,5,6	
116	-25.2420	148.9269	New	Clematis Sandstone	fortnightly			2016		2,5,6	Santos
				Bandanna Formation coal seam	fortnightly			2016		2,5,6	
117	-25.1784	148.8487	New	Clematis Sandstone	fortnightly			2013		2,5,6	CTH
				Bandanna Formation coal seam	fortnightly			2013		2,5,6	
118	-24.9198	149.0980	Existing	Clematis Sandstone	fortnightly	WQ1	fortnightly	2012	Santos Bore ID 1368	1,2	Santos
						WQ2	annual				
119	-24.7348	149.1400	Existing	Clematis Sandstone	fortnightly	WQ1	fortnightly	2012	Santos Bore ID 1349	1,2	Santos
						WQ2	annual				
120	-25.6843	149.1875	Existing	Boxvale Sandstone	fortnightly			2012	RN 58362	1,2,4	Santos
			New	Precipice Sandstone	fortnightly			2013		1,2,4	
			New	Bandanna Formation coal seam	fortnightly	WQ1	fortnightly	2013		1,2,4	
						WQ2	annual				

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
121	-27.2389	149.9842	New	Springbok Sandstone	fortnightly			2013		1,2,5	QGC
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5	
122	-26.9346	149.6603	New	Springbok Sandstone	fortnightly			2013		1,2,5	Santos
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		1,2,5	
123	-25.9325	148.6363	New	Walloon Coal Measures	fortnightly			2016		1,2,5	Santos
				Hutton Sandstone	fortnightly			2016		1,2,5	
				Precipice Sandstone	fortnightly			2016		1,2,5	
				Bandanna Formation coal seam	fortnightly			2016		1,2,5	
124	-27.9222	151.1214	Existing	Springbok Sandstone	fortnightly			2012	RN 41620043	1,2,5	CTH
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	
125	-26.3381	149.5033	Existing	Mooga Sandstone	fortnightly			2012	RN 42220101	2,4,5	CTH
126	-27.7623	150.2355	New	Precipice Sandstone	fortnightly			2013		2,5,6	CTH
127	-25.8580	150.0812	New	Bandanna Formation coal seam	fortnightly			2013		2,5,6	CTH

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
128	-26.0200	150.0830	New	Bandanna Formation coal seam	fortnightly			2013		1,2,4	CTH
129	-25.8250	148.7916	New	Hutton Sandstone	fortnightly			2013		4	CTH
130	-25.6386	148.9103	New	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	CTH
				Bandanna Formation coal seam	fortnightly	WQ1 WQ2	fortnightly annual	2013		1,2	
131	-26.0752	149.0136	New	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2	CTH
				Bandanna Formation coal seam	fortnightly			2013		2	
132	-25.9452	148.9736	New	Precipice Sandstone	fortnightly	WQ1 WQ2	fortnightly annual	2013		2	Origin
				Bandanna Formation coal seam	fortnightly			2013		2	
133	-27.5913	151.8467	Existing	Main Range Volcanics	fortnightly			2012	RN 42231591A	1,2,5,6	Arrow
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		1,2,5,6	
134	-27.7309	151.7628	Existing	Main Range Volcanics	fortnightly			2012	RN 42231597A	1,2,5,6	Arrow
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		1,2,5,6	
135	-27.8251	151.4764	Existing	Condamine alluvium	fortnightly			2012	RN 42231411A	2,5,6	Arrow
			New	coal seam of the Upper Juandah Coal Measures	fortnightly			2016		2,5,6	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality					
						Suite	Frequency				
136	-26.9214	151.2871	New	Main Range Volcanics	fortnightly			2013		1,2,5,6	Arrow
			Existing	Hutton Sandstone	fortnightly			2012	RN 42231553A	1,2,5,6	
137	-27.2681	151.7701	Existing	Main Range Volcanics	fortnightly			2012	RN 42231523A	1,2,5,6	Arrow
				Walloon Coal Measures	fortnightly			2012	RN 42231524A	1,2,5,6	
				Hutton Sandstone	fortnightly			2012	RN 42231590A	1,2,5,6	
138	-23.4558	148.9483	New	Bandanna Formation coal seam	fortnightly			2013		1,2	CTH
139	-25.3170	148.6629	New	Bandanna Formation coal seam	fortnightly			2013		2	Santos
140	-26.1500	149.7690	New	coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2	CTH
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2	
141	-26.2007	149.4317	New	Springbok Sandstone	fortnightly			2013		2	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2	

Site No	Location		Status	Monitoring Points (Target Unit)	Monitoring Parameters and Frequency			Required By	Existing Reference	Objective	Responsible Tenure Holder
	Latitude	Longitude			Water Pressure	Water Quality Suite	Water Quality Frequency				
142	-26.8485	150.6051	New	Springbok Sandstone	fortnightly			2013		2	CTH
				coal seam of the Upper Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Lower Juandah Coal Measures	fortnightly			2013		2	
				coal seam of the Taroom Coal Measures	fortnightly			2013		2	

Table G-2 Regional Groundwater Monitoring Network Water Quality Parameter Suits

Suite		Parameters to be measured as part of suite
Water quality suite 1 (WQ1)	Field parameters	Electrical Conductivity (µS/cm @ 25°C), Temperature (°C)
Water quality suite 2 (WQ2)	Field parameters	Electrical Conductivity (µS/cm @ 25°C), pH, Redox Potential (Eh), Temperature (°C), Free gas at wellhead (CH_4)
	Laboratory analytes	Major cations and anions: Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+), Sodium (Na^+), Bicarbonate(HCO_3^-), Carbonate (CO_3^-), Chloride (Cl^-), Sulphate (SO_4^{2-}), Total Alkalinity
		Metals (dissolved): Arsenic (As), Barium (Ba), Boron (B), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Strontium (Sr^{2+}), Zinc (Zn)
		Fluoride (F^-), Total Dissolved Solids
		Gas (dissolved): Methane (CH_4)

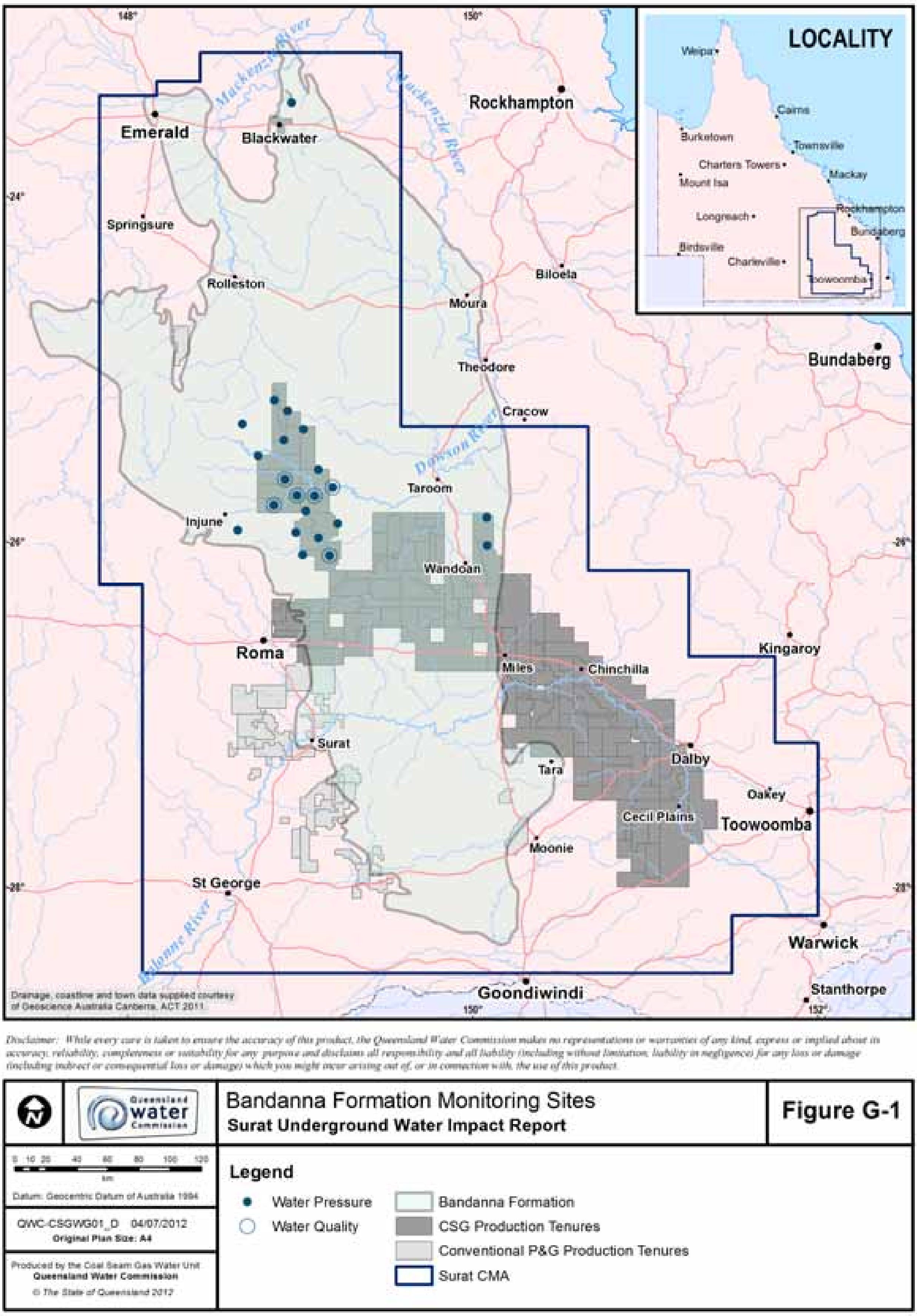

Figure G-1 Bandanna Formation Monitoring Sites

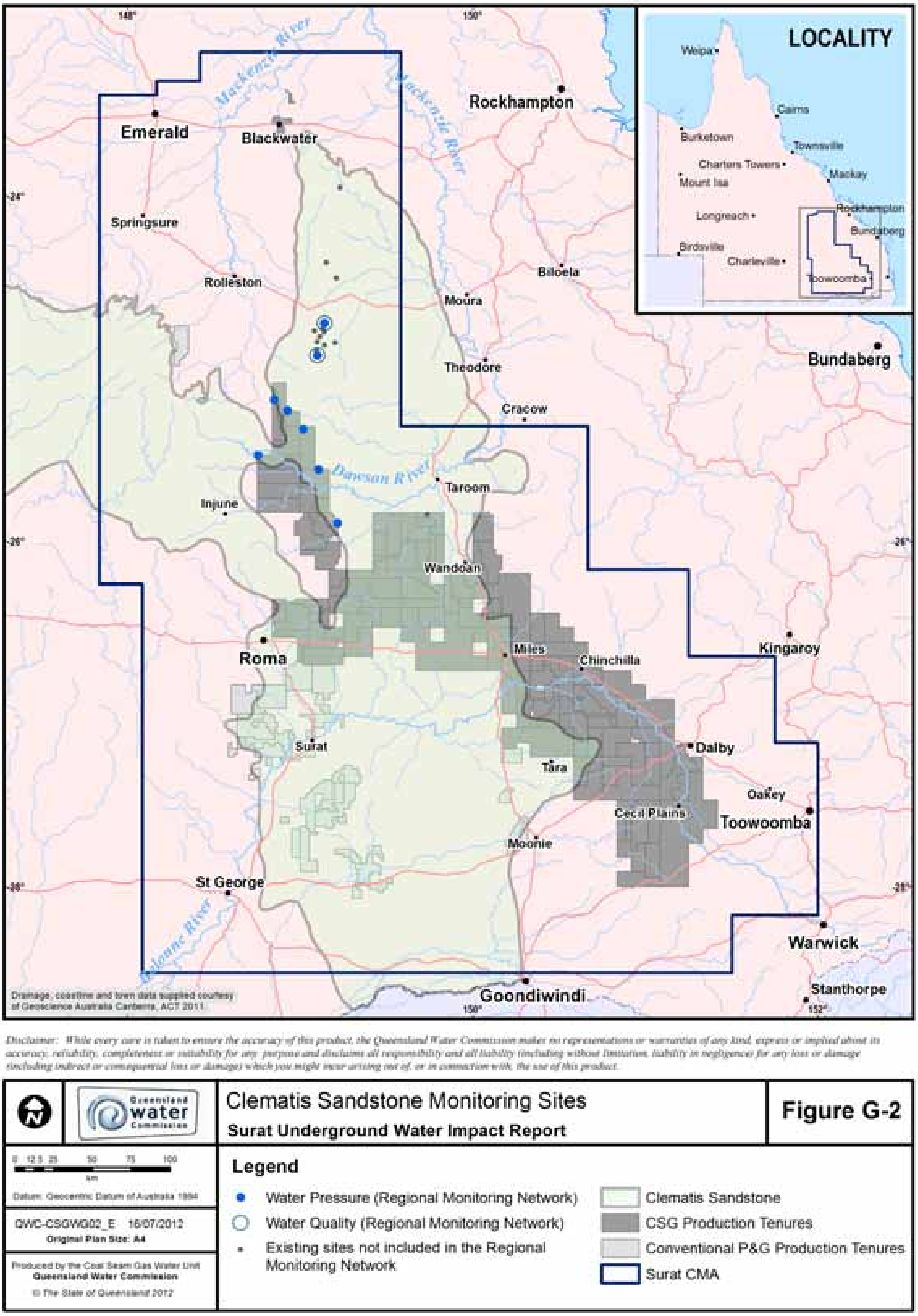

Figure G-2 Clematis Sandstone Monitoring Sites

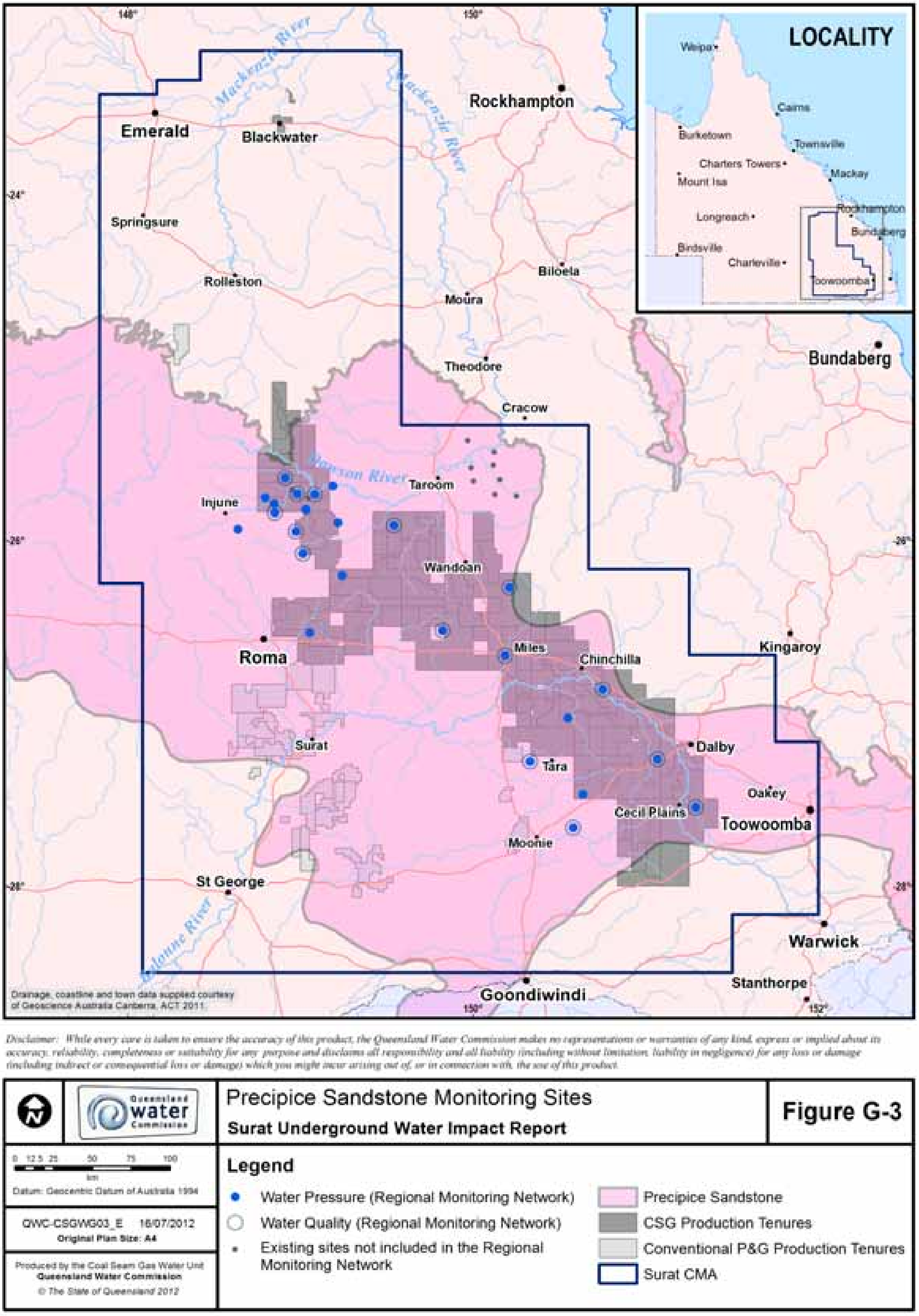

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Figure G-3 Precipice Sandstone Monitoring Sites

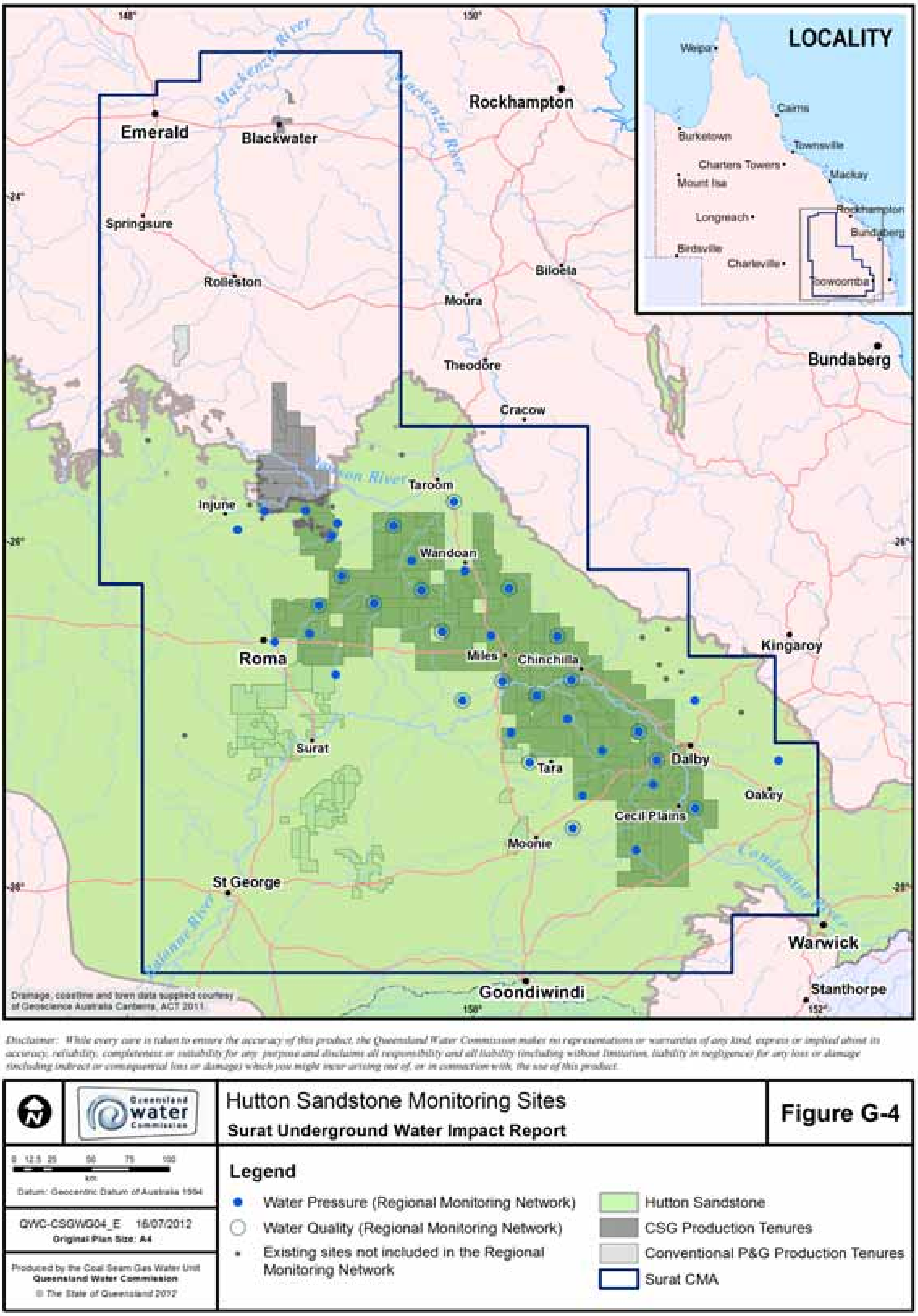


Figure G-4 Hutton Sandstone Monitoring Sites

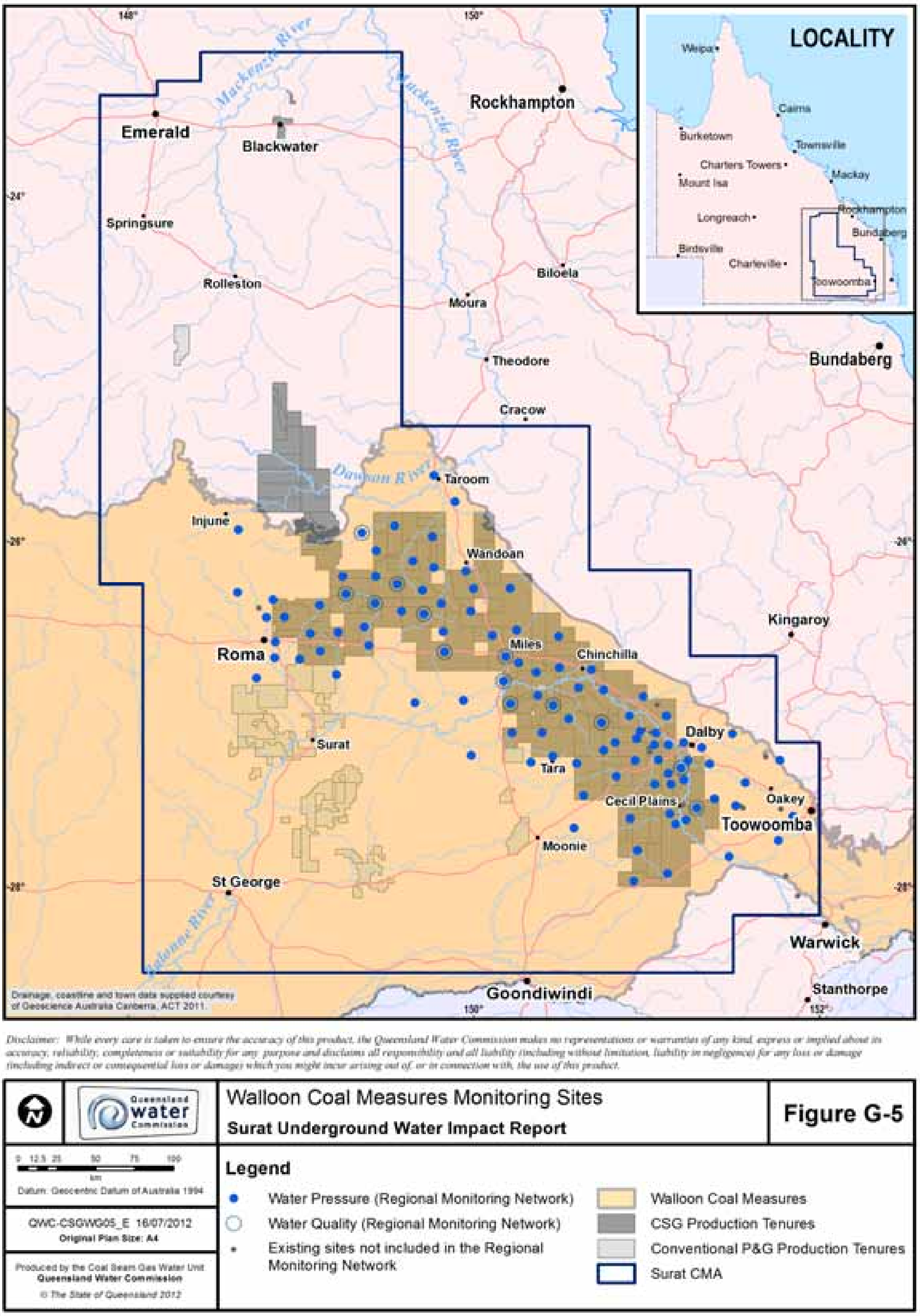
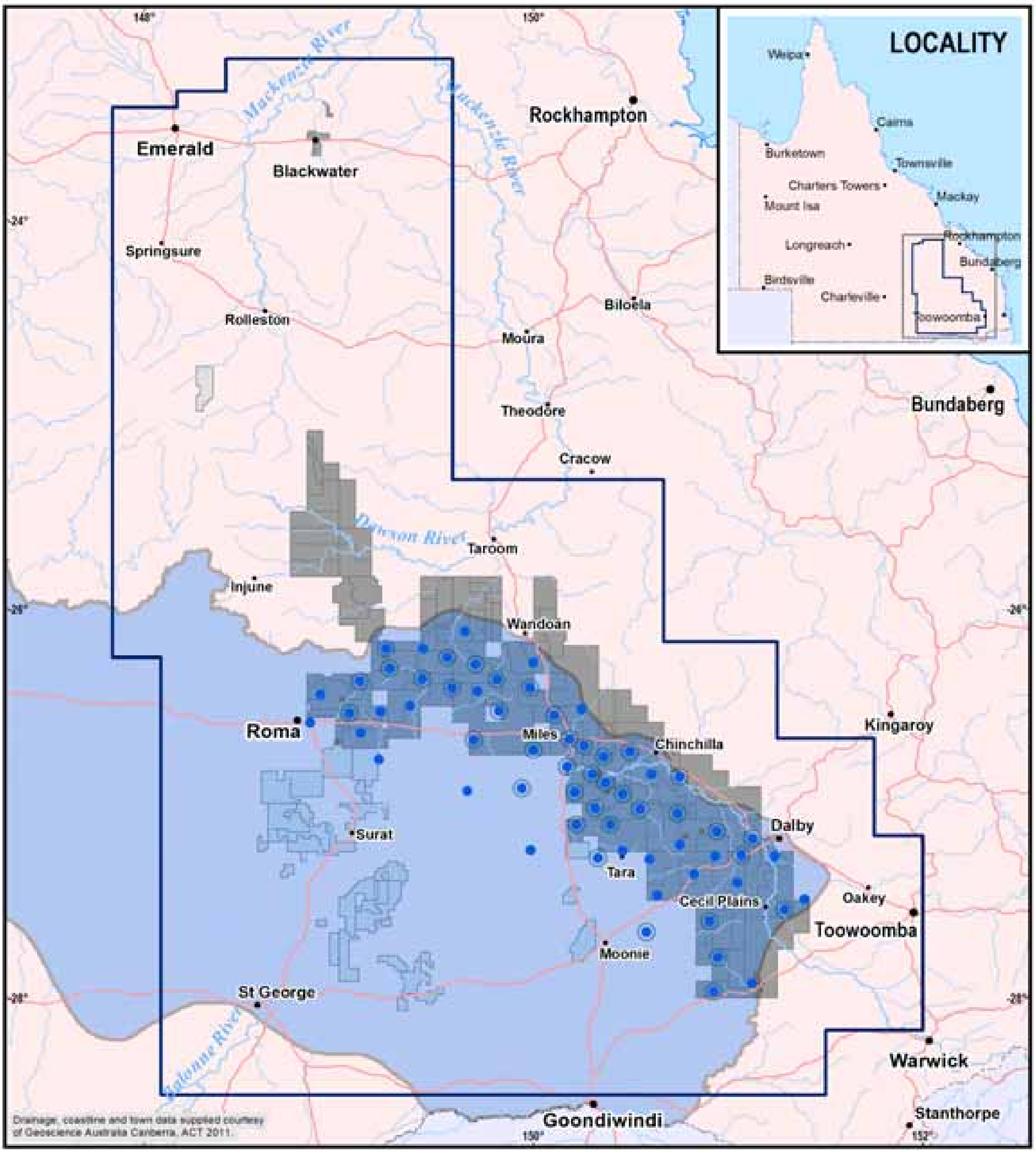


Figure G-5 Walloon Coal Measures Monitoring Sites



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Queensland water Commission

Springbok Sandstone Monitoring Sites

Surat Underground Water Impact Report

Figure G-6

0 12.5 25 50 75 100 km

Datum: Geocentric Datum of Australia 1994

QWC-CSGWG06_E 16/07/2012
Original Plan Size: A4

Produced by the Coal Seam Gas Water Unit
Queensland Water Commission
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Legend

- Water Pressure (Regional Monitoring Network)
- Water Quality (Regional Monitoring Network)
- Existing sites not included in the Regional Monitoring Network
- Springbok Sandstone
- CSG Production Tenures
- Conventional P&G Production Tenures
- Surat CMA

Figure G-6 Springbok Sandstone Monitoring Sites

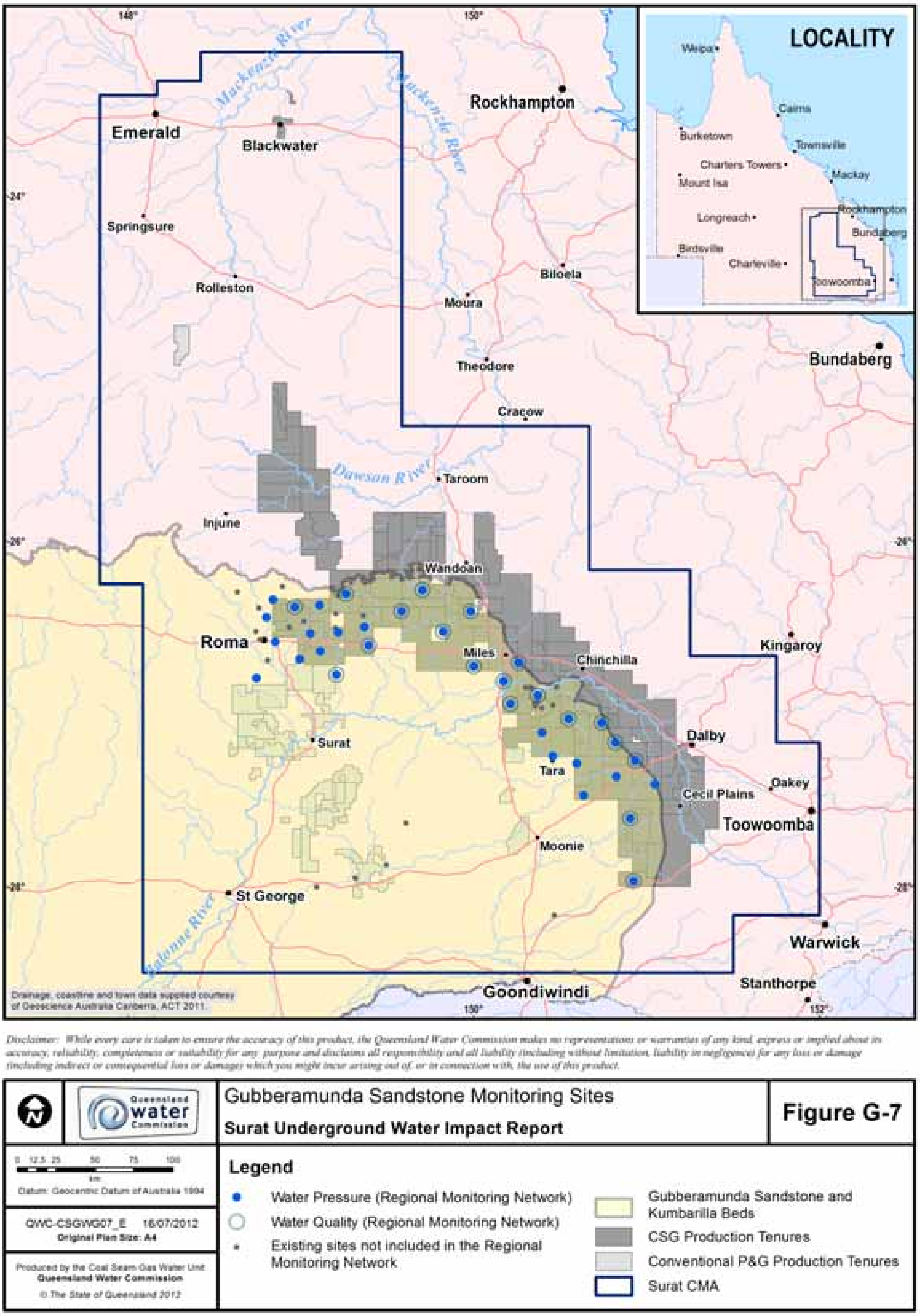

Figure G-7 Gubberamunda Sandstone Monitoring Sites

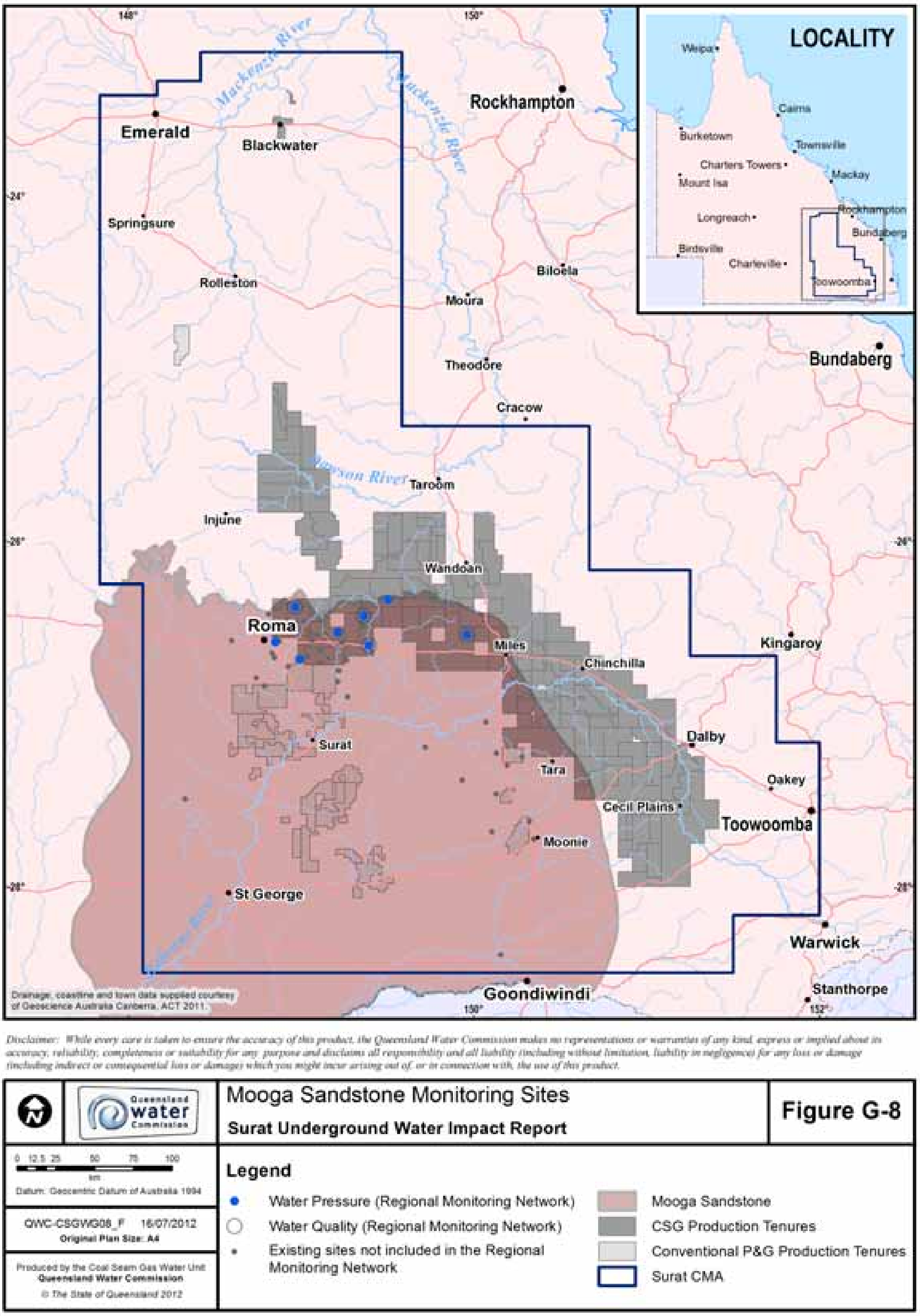

Figure G-8 Mooga Sandstone Monitoring Sites

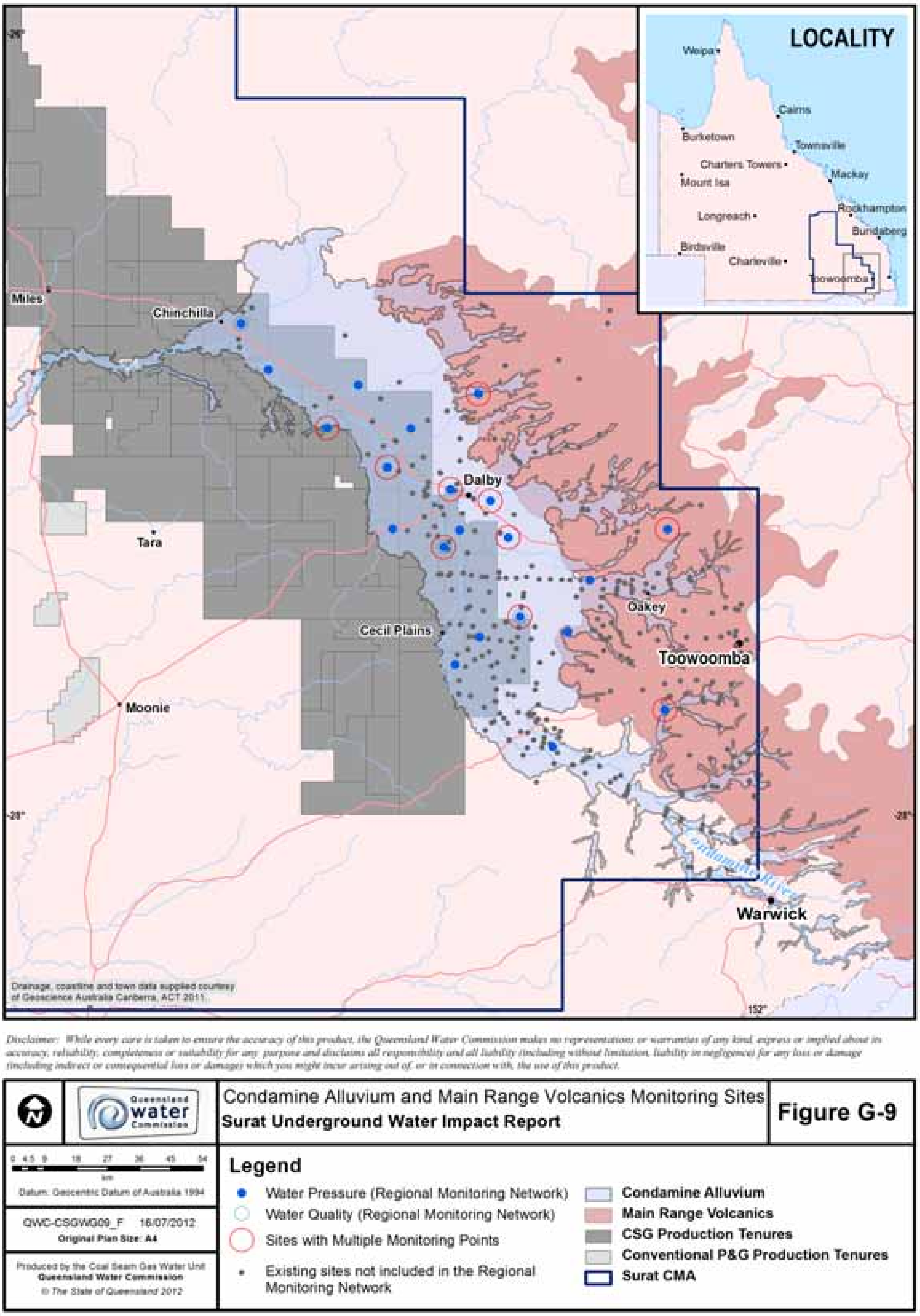

Figure G-9 Condamine Alluvium Monitoring Sites

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Appendix H

Details of Spring Impact Management Strategy

H-1: Cultural and Spiritual Values of Springs

A study in relation to the cultural heritage values associated with springs in the GAB was completed in 2005 to support the development of the *Queensland Water Resource (Great Artesian Basin) Plan 2006* (CQCHM 2005). The study noted that there are a range of cultural heritage values that can be associated with a spring.

The report identified four broad categories of values that are summarised as follows:

- Mythological associations. The linkage between a spring and its water, and mythological events and/or creator beings or other beings.

- Ritual and ceremonial associations. The role that a spring and its water played in the conduct of various ceremonies. This may also be linked to the mythological associations.

- Economic and subsistence associations. The role that a spring or group of springs, and the water available from them, played in the patterns of seasonal, economic and subsistence activities of particular Aboriginal groups.

- Major or personal historical events. This includes event such as births, massacres, and long term camping and habitation.

The Commission carried out a search of the Aboriginal and Torres Strait Island Cultural Heritage Register (the Register) to identify the registered sites that are in close proximity to potentially affected springs and which may therefore be linked to the presence of a permanent water source. Table H-1 provides a summary of the information from the register.

As noted in Chapter 8, the entries on the register are far from being a comprehensive assessment of the cultural heritage values associated with springs, as the entries are made as a result of activities such as infrastructure development or mining, rather than as a result of a focused assessment of cultural heritage values associated with springs.

A future project has been identified by the Commission in Appendix I, to engage with the appropriate traditional stakeholders to advance the understanding and acknowledgement of cultural and spiritual values associated with the potentially affected springs. It is intended that while the focus will be on individual springs, broader linkages between local and regional clusters of springs will be explored as part of this project. This research work will be undertaken in close consultation with the appropriate Aboriginal Parties and relevant bodies.

Table H-1: Summary of records on the Cultural Heritage Register

Type of record	**Number of records**	
	Within 500 m of potentially affected springs	**Within 3 km of potentially affected springs**
Axe grinding grooves	-	1
Paintings and engravings	2	7
Artefacts	11	81
Burial site	-	3
Tree	1	8
Quarry	4	7
Shell midden	4	7

H-2: Details of Potentially Affected Springs

Under the regulatory framework, a spring is a potentially affected spring if it overlies an aquifer where the long-term predicted impact on water levels at the location of the spring resulting from the extraction of water by petroleum tenure holders, exceeds 0.2 m. The Commission has also included high value springs that are located up to 10 km beyond that limit to allow for the uncertainties associated with modelling very small changes in water level at the boundaries of impact areas.

Table H-2 and Table H-3 list the potentially affected spring vents and watercourse springs. The following explanation applies to these tables:

Site number – As defined by the Queensland Springs Dataset held by the Queensland Herbarium. For the watercourse springs the site number is defined in the GAB Springs Register held by DNRM.

Connected Source Aquifer – An assessment of the source aquifer for each spring has been carried out by the Commission (Section 8.3.2). At some spring locations, more than one aquifer may be contributing to the flow. At these sites, more than one aquifer has been identified as a source aquifer.

Estimated years before impacts exceed 0.2 m (from 2012) **–** The time before predicted impact is to exceed 0.2 metre in the source aquifer at the location of the spring. The time is provided as a range to reflect the results of the uncertainty analysis applied when predicting impacts.

Maximum Impact – The estimated maximum impact and the corresponding range of years (from 2012) in the source aquifer at the location of the spring.

Risk Assessment Score – The Commission's risk assessment has assigned each spring vent a risk level between 1 (lower) and 5 (higher) based on the methodology outlined in Section 8.3.3.

Table H-2: Potentially affected spring vents

Complex Number	Site Number	Location		Connected Aquifer (s)	Summary of model predictions			Total Risk Rank
					Estimated years before impacts exceed 0.2 m (from 2012)	Maximum Impact (m)		
		Latitude	Longitude			Magnitude (m)	Timeframe (Years)	
8	26	-25.55242	149.807105	Hutton Sandstone	NA	< 0.2	NA	3
	28	-25.55242	149.807105	Hutton Sandstone				3
	38	-25.56851	149.802111	Hutton Sandstone				3
74	nv329	-25.650000	149.200000	Evergreen Formation Precipice Sandstone Clematis Sandstone	NA	< 0.2	NA	3

Complex Number	Site Number	Location		Connected Aquifer (s)	Summary of model predictions			Total Risk Rank
					Estimated years before impacts exceed 0.2 m (from 2012)	Maximum Impact (m)		
		Latitude	Longitude			Magnitude (m)	Timeframe (Years)	
229*	284	-25.829550	149.041382	Hutton Sandstone	NA	< 0.2	NA	4
230	287	-25.798065	148.775580	Evergreen Formation Precipice Sandstone	5 – 40 years	1 – 1.5	40 – 60 years	5
	340	-25.793992	148.773174	Evergreen Formation Precipice Sandstone				5
	686	-25.794778	148.773408	Evergreen Formation Precipice Sandstone				5
	687	-25.794811	148.773780	Evergreen Formation Precipice Sandstone				5
	687.1	-25.794624	148.773846	Evergreen Formation Precipice Sandstone				5
	687.2	-25.794561	148.773783	Evergreen Formation Precipice Sandstone				5
	687.3	-25.794202	148.773613	Evergreen Formation Precipice Sandstone				5
	687.4	-25.794118	148.773542	Evergreen Formation Precipice Sandstone				5
	687.5	-25.793680	148.773297	Evergreen Formation Precipice Sandstone				5
	687.6	-25.793595	148.773319	Evergreen Formation Precipice Sandstone				5
	688	-25.795114	148.773748	Evergreen Formation Precipice Sandstone				5
	689	-25.793990	148.772839	Evergreen Formation Precipice Sandstone				5

Complex Number	Site Number	Location		Connected Aquifer (s)	Summary of model predictions			Total Risk Rank
					Estimated years before impacts exceed 0.2 m (from 2012)	Maximum Impact (m)		
		Latitude	Longitude			Magnitude (m)	Timeframe (Years)	
260	189	-25.891509	149.285983	Hutton Sandstone	20 – 40 years	0.2 – 0.5	30 – 35 years	5
	190	-25.888437	149.287415	Hutton Sandstone				5
	191	-25.891755	149.287484	Hutton Sandstone				5
	192	-25.888958	149.279041	Hutton Sandstone				5
	192.1	-25.888114	149.279189	Hutton Sandstone				5
283*	702	-26.270303	149.243285	Gubberamunda Sandstone	280 -380 years	0.2 – 0.5	280 -380 years	4
	703	-26.285333	149.234459	Gubberamunda Sandstone				4
311	499	-25.700240	149.128935	Evergreen Formation Precipice Sandstone	40 – 50 years	0.2 – 0.5	50 – 60 years	4
	500	-25.719758	149.104836	Evergreen Formation Precipice Sandstone				4
	500.1	-25.728175	149.100451	Evergreen Formation Precipice Sandstone				4
	535	-25.720200	149.027508	Evergreen Formation Precipice Sandstone				4
	536	-25.714499	149.065431	Evergreen Formation Precipice Sandstone				4
	536.1	-25.713623	149.065391	Evergreen Formation Precipice Sandstone				4
	536.2	-25.715544	149.064819	Evergreen Formation Precipice Sandstone				4
	537	-25.728340	149.093903	Evergreen Formation Precipice Sandstone				4

Complex Number	Site Number	Location		Connected Aquifer (s)	Summary of model predictions			Total Risk Rank
					Estimated years before impacts exceed 0.2 m (from 2012)	Maximum Impact (m)		
		Latitude	Longitude			Magnitude (m)	Timeframe (Years)	
311	692	-25.725986	149.103740	Evergreen Formation Precipice Sandstone	40 – 50 years	0.2 – 0.5	50 - 60 years	4
	693	-25.720666	149.029633	Evergreen Formation Precipice Sandstone				4
	694	-25.712394	149.072622	Evergreen Formation Precipice Sandstone				4
	695	-25.725415	149.086946	Evergreen Formation Precipice Sandstone				4
	696	-25.725471	149.086885	Evergreen Formation Precipice Sandstone				4
	697	-25.725599	149.086748	Evergreen Formation Precipice Sandstone				4
	698	-25.725630	149.086671	Evergreen Formation Precipice Sandstone				4
	699	-25.725790	149.086617	Evergreen Formation Precipice Sandstone				4
	704	-25.679718	149.127267	Evergreen Formation Precipice Sandstone				4
506*	184	-26.233352	148.868584	Gubberamunda Sandstone	40 – 280 years	1 – 1.5	160 - 260 years	2
	185	-26.232091	148.869386	Gubberamunda Sandstone				2
	186	-26.236716	148.868972	Gubberamunda Sandstone				2

* These springs are most likely associated with perched groundwater system and therefore unlikely to be affected by water level changes in the aquifer.

Complex Number	Site Number	Location		Connected Aquifer (s)	Summary of model predictions			Total Risk Rank
					Estimated years before impacts exceed 0.2 m (from 2012)	Maximum Impact (m)		
		Latitude	Longitude			Magnitude (m)	Timeframe (Years)	
507	187	-26.218956	148.670302	Gubberamunda Sandstone	NA	< 0.2	NA	1
	188	-26.269476	148.705438	Gubberamunda Sandstone				1
	679	-26.278483	148.695873	Gubberamunda Sandstone				1
	680	-26.273135	148.686824	Gubberamunda Sandstone				1
	680.1	-26.273627	148.687319	Gubberamunda Sandstone				1
561	285	-25.762677	148.769787	Evergreen Formation, Precipice Sandstone	5 – 60 years	1 – 1.5	30 -50 years	4
584*	711	-26.874195	150.437138	Cainozoic Sediments	NA	< 0.2	NA	3
	711.1	-26.873960	150.437172	Cainozoic Sediments				3
591	534	-25.732642	149.102779	Evergreen Formation, Precipice Sandstone	40 – 50 years	0.2 – 0.5	50 – 60 years	5
592*	286	-25.798174	148.769141	Hutton Sandstone	NA	< 0.2	NA	4
	286.1	-25.798153	148.770287	Hutton Sandstone				4
	286.2	-25.797951	148.770193	Hutton Sandstone				4
	286.3	-25.797621	148.768713	Hutton Sandstone				4
	682	-25.808097	148.734199	Hutton Sandstone				3
	716	-25.807686	148.734000	Hutton Sandstone				3

**These sites will be the subject of additional connectivity investigations in 2012-13*.

Table H-3: Potentially affected watercourse springs

Site Number	River / Reach	Location				Connected Aquifer(s)
		Start		Finish		
		Latitude	Longitude	Latitude	Longitude	
W10	Blyth Creek	-26.424712	149.083838	-26.473330	149.016965	Mooga Sandstone Gubberamunda Sandstone
W122	Murri Murri Creek	-28.442243	150.404080	-28.470820	150.540520	Kumbarilla Beds
W14	Bungaban Creek	-25.836635	150.061238	-25.922420	150.234950	Hutton Sandstone
W15	Bungaban Creek (North)	-25.922420	150.234950	-25.903614	150.261079	Hutton Sandstone
W16	Bungeworgorai Creek	-26.210447	148.442854	-26.228380	148.474480	Gubberamunda Sandstone
W160	Western Creek	-27.752520	150.682180	-27.793570	150.696364	Kumbarilla Beds
W164	Yuleba Creek	-26.364111	149.437886	-26.472280	149.400310	Mooga Sandstone
W17	Bungeworgorai Creek	-26.395378	148.650913	-26.418003	148.643829	Mooga Sandstone
W18	Bungil Creek	-26.255209	148.709508	-26.309723	148.735984	Gubberamunda Sandstone
W19	Bungil Creek	-26.421967	148.787404	-26.450046	148.805048	Mooga Sandstone
W39	Dawson River	-25.725580	149.303075	-25.676722	149.235056	Hutton Sandstone
W40	Dawson River (Central)	-25.679460	149.137341	-25.684793	149.066451	Precipice Sandstone
W59	Eurombah Creek	-25.979855	149.194107	-25.982412	149.145238	Hutton Sandstone
W6	Bethecurriba Creek	-28.470820	150.540520	-28.456342	150.558296	Kumbarilla Beds
W7	Bethecurriba Creek	-28.456342	150.558296	-28.445770	150.584190	Kumbarilla Beds
W76	Horse Creek (East Branch)	-26.201700	149.593600	-26.220195	149.619557	Gubberamunda Sandstone
W77	Horse Creek (East Branch)	-26.264262	149.652155	-26.306200	149.667970	Mooga Sandstone Gubberamunda Sandstone
W78	Horse Creek (East Branch) Tributary	-26.309704	149.674781	-26.344366	149.657824	Mooga Sandstone Gubberamunda Sandstone
W79	Horse Creek (East Branch) Tributary	-26.306200	149.667970	-26.309704	149.674781	Mooga Sandstone Gubberamunda Sandstone
W80	Hutton Creek	-25.743438	148.685682	-25.697695	148.427269	Hutton Sandstone
W81	Hutton Creek	-25.712680	149.083680	-25.715116	149.028281	Hutton Sandstone
W82	Injune Creek	-25.803812	148.779898	-25.811890	148.732691	Hutton Sandstone

Appendix H-3: Risk Assessment of Potentially Affected Springs

This appendix provides details of how the risk assessment of springs referred to in Chapter 8 was carried out.

For each spring vent, a risk level between 1 (lower) and 5 (higher) was assigned on the basis of the ***likelihood*** of there being reductions in the flow of water at the spring and the ***consequences*** on known spring values if a reduction in flow was to occur.

Three equally weighted criteria were used to assess the ***likelihood*** of there being reductions in the flow of water to a spring. The criteria used are as follows:

L1: The magnitude of the predicted impact of groundwater levels

The magnitude of the lowering of groundwater levels in the aquifer feeding the spring was assessed using the Commission’s regional groundwater model.

L2: The distance from the spring to petroleum development

This deals with the possibility that near areas of petroleum and gas development where drawdown in coal measures is large, flow to springs could be controlled by local geological features that are not explicitly reflected in the regional groundwater flow model.

L3: The stratigraphic (vertical) proximity of the source aquifer to the target petroleum formation.

This deals with the interconnectivity between aquifers. A spring with a source aquifer stratigraphically close to a target petroleum and gas formation is more likely to be affected than a spring in an aquifer that is stratigraphically more remote.

Springs are associated with a range of values incorporating ecological, cultural and spiritual components. Many of these values remain difficult to quantify. Two equally weighted criteria have been used which centre on the ***consequence*** that a reduction in spring flow would have on ecological values. Ecological values may reflect some cultural heritage values, however some cultural heritage values will also exist independently. Future work is planned in 2012 on improving knowledge of the cultural and spiritual values at potentially affected springs and is outlined in Appendix I.

The two equally weighted criteria used were to assess ***consequence*** are as follows:

C1: The spring’s conservation ranking

The Commonwealth Recovery Plan (Fensham et al 2010) for ‘The Community of native species dependent on natural discharge of groundwater from the GAB’ provides a conservation ranking for spring complexes. The conservation ranking has been updated using the results of the recent spring survey and has been used in the application of this criterion.

C2: Distance from the recharge area for the spring’s source aquifer

Generally, natural variability in flow at a spring decreases with distance from the source aquifer’s recharge area. Therefore, biota in springs closer to the recharge areas are likely to have developed some capacity to cope with changes in water availability. Biota in springs located far from recharge areas are likely to rely on a steady flow of water and be more vulnerable to water availability. The distance from recharge may therefore be a measure of the resilience of the spring ecology.

The overall risk score was assigned as follows:

Each potentially affected spring was assigned a risk score for each criterion ranging from (lower), 3 (medium) or 5 (high). Total scores for ***likelihood*** and for ***consequences*** of impact were then calculated as follows:

Likelihood of impact (max 15) = L1 + L2 + L3

Consequence of Impact (max 10) = C1 + C2

The scores for each spring were then plotted in the matrix below to assign the overall risk score. The results from the assessment for each spring are provided in Table H-2 of Appendix H-2.

Risk Matrix

		Likelihood		
		Lower (score of 3 to 5)	Medium (score of 6 to 10)	Higher (score of 11 to 15)
Consequence	Lower (2 to 3)	1	2	3
	Medium (4 to 6)	2	3	4
	Higher (7 to 10)	3	4	5

Appendix H-4: Spring Monitoring

The spring monitoring program is described in Section 8.4 of the UWIR. The locations and details of springs that are to be monitored are identified in Table H-4 and Table H-5 below. The following explanation applies to these tables:

Site number – as identified in the Queensland Springs Dataset held by the Queensland Herbarium. For the watercourse springs, the site number is identified in the GAB Springs Register held by DNRM.

Flow Measurement Methods – These are defined in Table H-6.

Water quality Suites – These are defined in are defined in Table H-7.

Responsible Tenure Holder – This column identifies the responsible tenure holder for the monitoring site. For the sites located in the production area, the responsible tenure holder is the current tenure holder (CTH) as specified in Chapter 9 of the UWIR

Table H-4: Spring Vent Monitoring Sites

Site Number	Location		Flow Measurement Method	Water Quality Suite	Responsible Tenure Holder
	Latitude	Longitude			
38	-25.568510	149.802111	B	B	QGC
189	-25.891509	149.285983	A	B	Origin
191	-25.891755	149.287484	A	B	Origin
192	-25.888958	149.279041	A	B	Origin
192.1	-25.888114	149.279189	B	A	Origin
284	-25.829550	149.041382	B	B	CTH
285	-25.762677	148.769787	A	B	CTH
716	-25.807686	148.734000	B	B	Santos
286	-25.798174	148.769141	B	A	CTH
286.1	-25.798153	148.770287	B	-	CTH
286.2	-25.797951	148.770193	B	B	CTH
286.3	-25.797621	148.768713	B	-	CTH
287	-25.798065	148.775579	A	B	CTH
340	-25.793992	148.773174	B	-	CTH
534	-25.732642	149.102779	B	B	CTH
535	-25.720200	149.027508	A	B	CTH
536	-25.714499	149.065431	A	B	CTH
537	-25.728340	149.093903	A	B	CTH
682	-25.808097	148.734199	B	A	Santos
686	-25.794778	148.773408	B	B	CTH
687	-25.794811	148.773780	B	A	CTH
687.1	-25.794624	148.773846	B	-	CTH
687.2	-25.794561	148.773783	B	-	CTH
687.3	-25.794202	148.773613	B	-	CTH
687.4	-25.794118	148.773541	B	-	CTH
687.5	-25.793680	148.773296	B	-	CTH
687.6	-25.793595	148.773319	B	-	CTH
688	-25.795114	148.773748	B	A	CTH
689	-25.793990	148.772839	B	B	CTH
702	-26.270303	149.243285	A	B	Origin
703	-26.285333	149.234459	B	-	Origin
704	-25.679718	149.127267	A	B	CTH
711	-26.874195	150.437137	A	A	CTH

Table H-5: Watercourse Spring Monitoring Sites

Site Number	Location				Flow Measurement Method	Water Quality Suite	Responsible Tenure Holder
	Start		Finish				
	Latitude	Longitude	Latitude	Longitude			
W39	-25.725580	149.303075	-25.676722	149.235056	A	A	Santos
W40	-25.679460	149.137341	-25.684793	149.066451	A	A	CTH
W80	-25.743438	148.685682	-25.697695	148.427269	A	A	Santos
W81	-25.712680	149.083680	-25.715116	149.028281	A	A	CTH
W82	-25.803812	148.779898	-25.811890	148.732691	A	A	CTH

Table H-6: Attributes and Methods for Spring Monitoring

<table>
<tr><th>Spring attribute</th><th colspan="3">Monitoring method</th></tr>
<tr><td>Ambient conditions</td><td colspan="3">Record the total rainfall for the 7-day period prior to monitoring.
Use observations from the weather station closest to the monitoring site.</td></tr>
<tr><td rowspan="7">Spring flow</td><td>Method A</td><td colspan="2">Identify a suitable control point.
Use a standard low flow hydrology method suitable for the site.
Record the method. Use the same control point and method each time the flow is measured.
Photograph the control points each time the flow is measured.
For watercourse springs measure the flow at the start and finish locations as specified in Table H-5.
For watercourse springs, comment on the extent of the flow beyond the end location as specified in Table H-5.</td></tr>
<tr><td rowspan="6">Method B</td><td colspan="2">Assign one of the following classifications to the spring.</td></tr>
<tr><td>1</td><td>Wetland vegetation, spring pool[1], minor or major flow(s).</td></tr>
<tr><td>2</td><td>Wetland vegetation, no spring pool, surface expression of free water, minor flow(s).</td></tr>
<tr><td>3</td><td>Wetland vegetation, no spring pool, some surface expression of free water.</td></tr>
<tr><td>4</td><td>Damp, wetland vegetation, no surface expression of free water.</td></tr>
<tr><td>5</td><td>Dry, no wetland vegetation, no surface expression of free water, no evidence of salt scalding.</td></tr>
<tr><td rowspan="2">Spring area</td><td>Spring vents</td><td colspan="2">Use the method described in Fensham & Fairfax 2009
For springs with an area greater than 1.5m^2, use a Differential Global Positioning System. For springs with a total area of less than 1.5m^2, estimate the total area.
Using the area, estimate the spring flow using the method described by Fatchen (2001); 10^(((LOG(spring area in m^2) – 3.692)/0.707).</td></tr>
<tr><td>Watercourse springs</td><td colspan="2">Estimation of spring area is not required.</td></tr>
</table>

<table>
<tr><td rowspan="3">Water chemistry</td><td colspan="3">Measure and sample water quality in accordance with ‘Monitoring and Sampling Manual 2009, Environmental Protection (Water) Policy’ (DERM 2009).
For spring vents, measurements must be taken as close as possible to the vent.
Water quality suites are provided in Table H-7.</td></tr>
<tr><td>Suite A</td><td colspan="2">Field water quality measurements.</td></tr>
<tr><td>Suite B</td><td colspan="2">Field water quality measurements.
Collect a water sample for laboratory analysis.</td></tr>
<tr><td rowspan="6">Spring physical condition</td><td rowspan="5">Spring vents</td><td colspan="2">Photograph the spring vent from all aspects.
Photograph any significant disturbances noted at the spring
For each photograph record the orientation and describe the features in the photograph.
Assign one of the one of the following classification for spring disturbance.</td></tr>
<tr><td>1</td><td>No evidence of animal disturbance.</td></tr>
<tr><td>2</td><td>Less than 10% of the total spring wetland area shows animal disturbance.</td></tr>
<tr><td>3</td><td>10 – 50% of the total spring wetland area shows animal disturbance.</td></tr>
<tr><td>4</td><td>More than 50% of the total spring wetland area shows animal disturbance.</td></tr>
<tr><td>Watercourse springs</td><td colspan="2">A physical condition assessment is not required.</td></tr>
</table>

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

Table H-7: Water Quality Suites

Suite A	**Parameter**
Field Parameters	pH
	Electrical Conductivity (µS/cm @ 25°C)
	Redox (Eh)
	Temperature (°C)
	Free Gas (CH_4)
Suite B	**Parameter**
Field Parameters	pH
	Electrical Conductivity (µS/cm @ 25°C)
	Redox (Eh)
	Temperature (°C)
	Free Gas (CH_4)
Laboratory Analytes	Total dissolved solids
	Alkalinity Total Alkalinity as $CaCO_3$ Bicarbonate as $CaCO_3$ Carbonate as $CaCO_3$ Hydroxide as $CaCO_3$
	Sulfate – SO_4 by ICPAES
	Chloride
	Major Cations – Calcium, Magnesium, Potassium, Sodium
	Bromide, Iodide, Fluoride
	Total Nitrogen as N (including NOx and TKN)
	Total Phosphorus as P
	Total Organic Carbon (TOC)
	Dissolved Organic Carbon (DOC)
	Metals – As, Ba, Be, Cd, Cr, Co, Cu, Hg, Mn, Ni, Pb, V, Zn.
	Additional dissolved Metals by ICP/MS – Al, B, Fe, Li, Mo, Se, Sr, U.

Appendix H-5: Mitigation of Impacts at Potentially Affected Springs

Section 8.5 of the UWIR describes the program for spring impact mitigation. It requires responsible tenure holders to evaluate options to mitigate impacts for specified spring complexes. Table H-8 provides details of the spring complexes.

Spring Complex – as identified in the Queensland Springs Dataset held by the Queensland Herbarium.

Connected Source Aquifers – An assessment of the source aquifer for each spring has been carried out by the Commission (Section 8.3.2). At some spring locations, more than one aquifer may be contributing to the flow. At these sites, more than one aquifer has been identified as a connected aquifer.

Responsible Tenure Holder – This column identifies the responsible tenure holder for the monitoring site. For the sites located in the production area, the responsible tenure holder is the current tenure holder (CTH) as specified in Chapter 9 of the UWIR

Table H-8: Spring Sites Identified for the Development of Mitigation Measures

Complex Number	Complex Name	Vent Number	Location		Connected Source Aquifer(s)	Responsible Tenure Holder
			Latitude	Longitude		
311 / 591	311 / Yebna 2	534	-25.732642	149.102779	Evergreen Formation Precipice Sandstone	CTH
		535	-25.720200	149.027508	Evergreen Formation Precipice Sandstone	CTH
		536	-25.714499	149.065431	Evergreen Formation Precipice Sandstone	CTH
		693	-25.720666	149.029633	Evergreen Formation Precipice Sandstone	CTH
		704	-25.679718	149.127267	Evergreen Formation Precipice Sandstone	CTH
		499	-25.700240	149.128935	Evergreen Formation Precipice Sandstone	CTH
		500	-25.719758	149.104836	Evergreen Formation Precipice Sandstone	CTH
		500.1	-25.728175	149.100451	Evergreen Formation Precipice Sandstone	CTH
		536.1	-25.713623	149.065391	Evergreen Formation Precipice Sandstone	CTH
		536.2	-25.715544	149.064819	Evergreen Formation Precipice Sandstone	CTH
		537	-25.728340	149.093903	Evergreen Formation Precipice Sandstone	CTH
		692	-25.725986	149.103740	Evergreen Formation Precipice Sandstone	CTH
		694	-25.712394	149.072622	Evergreen Formation Precipice Sandstone	CTH
		695	-25.725415	149.086946	Evergreen Formation Precipice Sandstone	CTH
		696	-25.725471	149.086885	Evergreen Formation Precipice Sandstone	CTH
		697	-25.725599	149.086748	Evergreen Formation Precipice Sandstone	CTH
		698	-25.725630	149.086671	Evergreen Formation Precipice Sandstone	CTH
		699	-25.725790	149.086617	Evergreen Formation Precipice Sandstone	CTH

Complex Number	Complex Name	Vent Number	Location		Connected Source Aquifer(s)	Responsible Tenure Holder
			Latitude	Longitude		
283	Barton	702	-26.270303	149.243285	Gubberamunda Sandstone	Origin
		703	-26.285333	149.234459	Gubberamunda Sandstone	Origin
230	Lucky Last	287	-25.798065	148.775579	Evergreen Formation Precipice Sandstone	CTH
		340	-25.793992	148.773174	Evergreen Formation Precipice Sandstone	CTH
		686	-25.794778	148.773408	Evergreen Formation Precipice Sandstone	CTH
		687	-25.794811	148.773780	Evergreen Formation Precipice Sandstone	CTH
		687.1	-25.794624	148.773846	Evergreen Formation Precipice Sandstone	CTH
		687.2	-25.794561	148.773783	Evergreen Formation Precipice Sandstone	CTH
		687.3	-25.794202	148.773613	Evergreen Formation Precipice Sandstone	CTH
		687.4	-25.794118	148.773541	Evergreen Formation Precipice Sandstone	CTH
		687.5	-25.793680	148.773296	Evergreen Formation Precipice Sandstone	CTH
		687.6	-25.793595	148.773319	Evergreen Formation Precipice Sandstone	CTH
		688	-25.795114	148.773748	Evergreen Formation Precipice Sandstone	CTH
		689	-25.793990	148.772839	Evergreen Formation Precipice Sandstone	CTH
260	Scott's Creek	189	-25.891509	149.285983	Hutton Sandstone	Origin
		191	-25.891755	149.287484	Hutton Sandstone	Origin
		192	-25.888958	149.279041	Hutton Sandstone	Origin
		192.1	-25.888114	149.279189	Hutton Sandstone	Origin
		190	-25.888437	149.287415	Hutton Sandstone	Origin
561	Spring Rock Creek	285	-25.762677	148.769787	Evergreen Formation Precipice Sandstone	CTH

Appendix I

Future Research Directions

This appendix provides details of the Commission's future research directions. Research in these areas will enhance the Commission's capacity to predict water level impacts and prepare future UWIRs.

Reference	**RP 1**
Research Theme	Interconnectivity between the Condamine Alluvium (CA) and Walloon Coal Measures (WCM)
Objective	Improve knowledge about the interconnectivity between the CA and the WCM to support future modelling of water level impacts from CSG water extraction
Background	The Condamine Alluvium is an important water resource overlying the WCM. Current knowledge has been used to characterise the geological and hydrogeological contact between the CA and the WCM (the contact). That knowledge has been used to construct the regional groundwater flow model. Knowledge about the contact can be improved by: ▪ collecting new information about the geological and hydraulic nature of the contact; and ▪ monitoring hydraulic response across of the contact under stressed conditions that simulate CSG development, in local areas.
Key Scope	▪ Synthesise existing data to identify three to four potential sites for detailed investigation. ▪ Drill and install dedicated monitoring and test bores at the selected sites. ▪ Carry out detailed geophysical logging, geologic sampling (coring) and drill stem tests for newly constructed monitoring bores and (to the extent practicable) local existing wells. ▪ Carry out water quality/isotope sampling and analysis to identify hydro-geochemical fingerprints for formation water. ▪ Carry out pump testing for periods long enough to establish hydraulic stress across the contact. ▪ Synthesise information collected to update existing knowledge about the interconnectivity. ▪ Reconceptualise sub-regional groundwater flow system using the new knowledge about connectivity.
Potential partners and linkages	Arrow Energy (supporting field investigations) QGC (providing relevant data and information from investigations in their tenures) Healthy HeadWaters (studies relating to reinjection in the Condamine)

Reference	**RP 2**
Research Theme	Influence of geological structures on groundwater flow in the Surat CMA
Objective	To improve current knowledge about the influence of geological structures on regional groundwater flow to support future modelling of water level impacts from CSG water extraction.
Background	Geologic structures, such as faults have potential to influence groundwater flow either as pathways or barriers to groundwater flow. There are significant regional fault systems within the Bowen and Surat Basins. However, they are generally restricted to deeper formations in the Bowen Basin and do not affect overlying Surat Basin formations to the same extent. The exact nature of influence of faults in the Surat and Bowen Basin on regional groundwater flows is uncertain. There is a need to assess how structures may influence groundwater flow if large water level differences occur in the future in and around the structures as a result of CSG development.
Key Scope	▪ Synthesise relevant information including: o maps and reports containing geologic and geophysical interpretations (including seismic surveys) in the region o lithologic well logs, down hole geophysics and drill stem tests o water quality and geochemical data o water level data o satellite imagery and aerial photo interpretations. ▪ Analyse relevant available data and information develop plans for targeted geochemical and isotope investigation. ▪ Carry out the planned geochemical and isotope field investigation. ▪ Develop conceptual model(s) for groundwater flow in and around geological structures.
Potential partners and linkages	Geosciences Australia Geological Survey of Queensland University of Queensland Great Artesian Basin Water Resource Assessment

Reference	**RP 3**
Research Theme	Hydrogeology of the Walloon Coal Measures
Objective	Improve understanding of the hydrogeology of the Walloon Coal Measures (WCM) to support future modelling of water level impacts from CSG water extraction.
Background	The hydrogeology of the WCM is very complex. The water bearing coal seams comprise numerous thin, non-continuous stringers or lenses separated by bands of low permeability mudstone, siltstone or sandstone. Detailed information on the lithology of the coal measures is only available for producing tenures. There are difficulties in correlating individual coal seams over any significant distance. CSG production involves depressurisation of coal seams by pumping water from the WCM. The flow is predominantly dual phase (water and gas) as described in Chapter 2. The complex stratigraphy of the WCM and the presence of dual phase flow have implications for regional groundwater flow modelling.
Key Scope	Geological and Hydrogeological Characteristics ▪ Synthesise available data pertaining to geology and hydrogeology of the WCM ▪ Identify one or two representative pilot areas for detailed study. ▪ Carry out geochemical and hydro-chemical fingerprinting of the fluid in coal seams and (where practicable) in the matrix between coal seams. ▪ Collect and analyse available monitoring data from the nested piezometric sites in the monitoring network (Chapter 7). ▪ Where practicable use new CSG production activity as a pump test. ▪ Determine new geological and hydrogeological conceptualisations of WCM in the pilot area. Develop a representative groundwater block model for the WCM ▪ Develop a small scale generic block model representing the WCM and the immediately overlying and underlying formations. ▪ Use the block model to test new hydrological conceptualisations. Develop techniques for up-scaling the block model to regional scale ▪ Synthesise the geological and hydrogeological characterisations at a regional scale. ▪ Develop practical approaches to up-scaling block modelling results for application in future regional modelling to support future revisions of the UWIR for the Surat CMA.
Potential partners and linkages	CSIRO in collaboration with industry partners

Reference	**RP 4**
Research Theme	Re-conceptualisation of the groundwater systems in the Surat and Bowen Basins in Surat CMA.
Objective	Improve understanding of the hydrogeology of the groundwater systems in the Surat and Bowen Basins to support future modelling of water level impacts from CSG water extraction.
Background	The aquifer systems in the Surat CMA are complex. The conceptualisation of the groundwater systems used in constructing the regional groundwater flow model is based on information drawn from published literature, departmental databases and petroleum company drilling data that was available at the time. New knowledge that would improve future modelling include: ▪ regional and sub-regional water level/pressure maps for key aquifers to establish groundwater flow patterns and hydraulic gradients between aquifers; ▪ hydrogeological characterisation of aquitards; and ▪ hydraulic connectivity of coal formations with overlying and underlying aquifers.
Key Scope	Collect and synthesis emerging data including: ▪ groundwater level and quality data from bore monitoring; ▪ baseline and bore assessment data; ▪ lithology and hydraulic parameters from drilling and testing of monitoring and production wells; ▪ data generated from local hydrogeological investigations, such as aquifer injection trials; and ▪ regional assessments such as the GAB Water Resource Assessment. This data will be used to build an improved understanding of the hydrogeology of the aquifer systems. Focus areas are: ▪ develop regional and sub-regional water level/pressure maps for key aquifers to establish groundwater flow patterns and hydraulic gradients between aquifers; ▪ assesses cross-formational flow in terms of processes and potential quantities; ▪ assess the assumption of steady state flow in the Surat Basin; ▪ improve understanding of the interconnects within and between formations and basins; ▪ improve quantification of the components of the water balance, including the location, volume and rates of recharge and discharge; ▪ improve understanding of the spatial variation in the hydraulic properties of the aquifers and aquitards; and ▪ improve understanding of the hydraulic response of the groundwater system to stress imposed by CSG development.
Potential partners and linkages	Great Artesian Basin Water Resource Assessment (WRA)

Reference	**RP 5**
Research Theme	Second generation regional flow modelling for the Surat CMA
Objective	To further refine the prediction of water level impacts from CSG water extraction
Background	The current regional groundwater flow model has been built using currently accepted geologic conceptualisations and currently available regional modelling techniques. The modelling process has highlighted a number of areas where improvement may be possible in the next generation of the regional groundwater flow model.
Key Scope	▪ Explore how dual phase flow can be represented in regional groundwater flow modelling for the Surat CMA. ▪ Assess the sensitivity of water level impacts predictions for different conceptual realisations of the hydrogeology. ▪ Assess the potential to use uncertainty analysis techniques to test multiple conceptual realisations of the regional hydrogeology. ▪ Assess the potential to use techniques such as Pareto Analysis to guide reliance on expert knowledge when modelling at a regional scale. ▪ Develop a subregional groundwater flow model to improve understanding of the relationship between the Condamine Alluvium, Walloon Coal Measures and the Main Range Volcanics. ▪ Assess the advantages and disadvantage of using integrated subregional models instead of a single regional model to carry out regional assessments of water level impacts from CSG water extraction.
Potential partners and linkages	CSG companies and research organisations

Reference	**RP 6**
Research Theme	Improving knowledge about springs
Objective	Improve existing knowledge about the springs in the CMA in relation to their hydrology, ecological and cultural values and improve spring monitoring techniques.
Background	The management of potential threats to springs arising from the extraction of groundwater by petroleum tenure holders involves understanding the spring values that could be affected by a reduction in the flow of water to the spring and the interconnection of affected aquifers to springs. The spring survey and connectivity studies carried out by the Commission have largely completed the spring data sets, but some gaps remain. Springs are highly variable in nature and are often in locations that are difficult to access. Remote sensing methods have the potential to improve monitoring efficiency and consistency.
Key Scope	▪ Carry out a survey of the small number of vents springs and watercourse springs that have not yet been fully surveyed. ▪ Carry out further assessments the connectivity of spring vents and watercourse springs to source aquifers. ▪ Assess cultural and spiritual values associated with springs at greater risk of being affected by CSG water extraction. ▪ Assess the response of spring species to changes in water availability and water chemistry. ▪ Assess the potential to use remote sensing techniques to monitoring springs in the Surat CMA.
Potential partners and linkages	Queensland Herbarium Aboriginal Parties Commonwealth agencies

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