Appendix G3

Water monitoring plan

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Narrabri Gas Project

Water Monitoring Plan

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Appendix G3
Narrabri Gas Project
Water Monitoring Plan

November 2016

CDM Smith Australia Pty Ltd
ABN 88 152 082 936
Level 2 / 238 Angas Street
Adelaide
SA 5000
Tel: +61 8 8232 4888
Fax: +61 7 3828 6999

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Glossary of terms and abbreviations

Term	Explanation
Aquifer	A saturated permeable geologic unit that can transmit useful quantities of water
Beneficial use	Beneficial use refers to the use of waters, including produced water from an oil or gas well, for a secondary purpose that has a positive value. Potential beneficial use options for produced water include domestic and livestock supply, industrial supply, irrigation supply, dust suppression and recreation.
Baseline	A starting point used for future comparisons. Water baselines in context of the Narrabri Gas Project have been derived from long term water level and quality data presented in the Narrabri Gas Project Water Baseline Report.
Depressurisation	The extraction of coal seam water to facilitate gas production causes depressurisation of the target coal seams, which has the potential to propagate into surrounding formations.
Discharge spring	Occur where water that has recharged sandstone sediments that outcrop on the margins of the Great Artesian Basin discharges after having travelled underground for relatively large distances and over an extended period of time.
Ecosystem	An interconnected biological community of organisms that interact with each other and their physical environment.
Gaining stream	Streams that gain water from inflow of groundwater through the streambed. This can occur permanently or seasonally.
Groundwater	Water contained in the interconnected pore spaces and voids of the saturated zone of sediments and rocks.
Groundwater dependent ecosystem (GDE)	Ecosystems that have a species composition and natural ecological processes sustained to some extent by groundwater.
Groundwater level (or static / standing water level)	The depth to groundwater from some reference point (usually the natural surface).
Groundwater monitoring network	An arrangement of groundwater monitoring bores that is usually installed to monitor groundwater quantity and quality to inform how a groundwater system is responding to some applied stress, such as irrigation pumping and application, coal seam gas development, municipal water supply and climate variability.
Groundwater quality	A measure of groundwater value expressed in physio-chemical terms, such as acidity / alkalinity, dissolved oxygen, dissolved salts, ions and contaminants like hydrocarbons.

Term	Explanation
Groundwater quantity	A measure of the amount of groundwater held within a groundwater system, usually expressed as groundwater head (elevation or pressure) and flux.
Irrigation scheme	The use of water for agricultural production. In the case of the Narrabri Gas Project, treated water is proposed to be used for irrigation as part of the overall Produced Water Management Plan.
Losing stream	Streams that lose water by outflow through the streambed. This can occur permanently or seasonally.
Managed Release Scheme	In the case of the Narrabri Gas Project, the managed release of treated water into Bohena Creek as part of the overall produced water management plan.
Produced Water	Water that is produced as a by-product of oil and gas exploration and production. In the case of the Narrabri Gas Project, water is pumped from the deep coal seams to depressurise them and allow gas to be released. Produced water is also called "formation water" or, depending on salinity levels, "brine".
Provisional	Elements of the monitoring plan which may be subject to change through development of the project.
Receptor (economic)	Entities that derive a benefit from the water they use, including agricultural and industrial enterprises, and municipalities. These entities may be effected (positively or negatively) to some extent by altered water resource condition (quantity or quality).
Receptor (environment)	Environmental (or ecological) receptors include living organisms or habitats that that may be effected (positively or negatively) to some extent by altered water resource condition (quantity or quality).
Recharge spring	A spring supported by water that recharges sandstone sediments that outcrop on the margins of the Great Artesian Basin and discharge locally after relatively short residence times.
Registered bore	A water bore whose presence has been notified to the New South Wales Department of Primary Industries Water (DPI Water) and included in its registered groundwater bore database. The database typically includes details on bore location, construction and where possible, the source aquifer.
Resilience	The persistence of relationships within an ecosystem and a measure of the ability of the ecosystem (or other sensitive receptor) to absorb changes in external and internal conditions and still persist (adapted from SKM 2011).
Resistance	The ability of an ecosystem (or other sensitive receptor) to return to an equilibrium state after a temporary disturbance. It can involve factors such as constancy (lack of change), persistence (survival times), inertia (ability to resist external perturbations), elasticity (speed with which a system returns to its original state following a perturbation), and amplitude (range over which a system is stable).

Term	Explanation
Spring	A naturally occurring discharge of groundwater flowing out of the ground, often forming a small stream or pool of water. Typically, it represents the point at which the water table intersects the ground level.
Transmissivity	Rate in which water of a given density and viscosity is transmitted through a unit width of aquifer or aquitard under a unit hydraulic gradient.
Unacceptable risk	The level of risk at which mitigation actions are deemed to be warranted.

Abbreviations	Explanation
AIP	Aquifer Interference Policy
BoM	Bureau of Meteorology
DPI Water	New South Wales Department of Primary Industries Water (formerly the NSW Office of Water; NOW)
EC	Electrical conductivity
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
IESC	Independent Expert Scientific Committee
GDE	Groundwater dependent ecosystem
GIA	Groundwater Impact Assessment
ML	Megalitre (1 million litres)
mm	Millimetre
MNES	Matters of National and Environmental Significance
NSW	New South Wales
OCSG	Office of Coal Seam Gas
OMC	Outcome measurement criteria
WBR	Water Baseline Report
WMP	Water Management Plan
y	Year

Section 1 Introduction

1.1 Project description

The proponent is proposing to develop natural gas from coal seams in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri (Figure 1-1). The project area is located within the Narrabri local government area (LGA). The Narrabri Gas Project (the project, NGP) seeks to develop and operate a gas production field sourcing gas from deeply buried coal seams of the Gunnedah-Oxley Basin, which requires the installation of gas wells, gas and water gathering systems, and supporting infrastructure. The natural gas produced will be treated at a central gas processing facility located on Leewood, a local rural property situated approximately 25 km southwest of Narrabri (Figure 1-1).

The project area covers about 950 square kilometres (95,000 hectares) and the footprint of the project infrastructure will encompass about one per cent of that area. The majority of the project area is located within a region known as 'the Pilliga', a forested area designated for forestry, recreation and mineral extraction purposes.

The project is considered a State significant development assessable under Division 4.1 of Part 4 of the *NSW Environmental, Planning and Assessment Act 1979*.

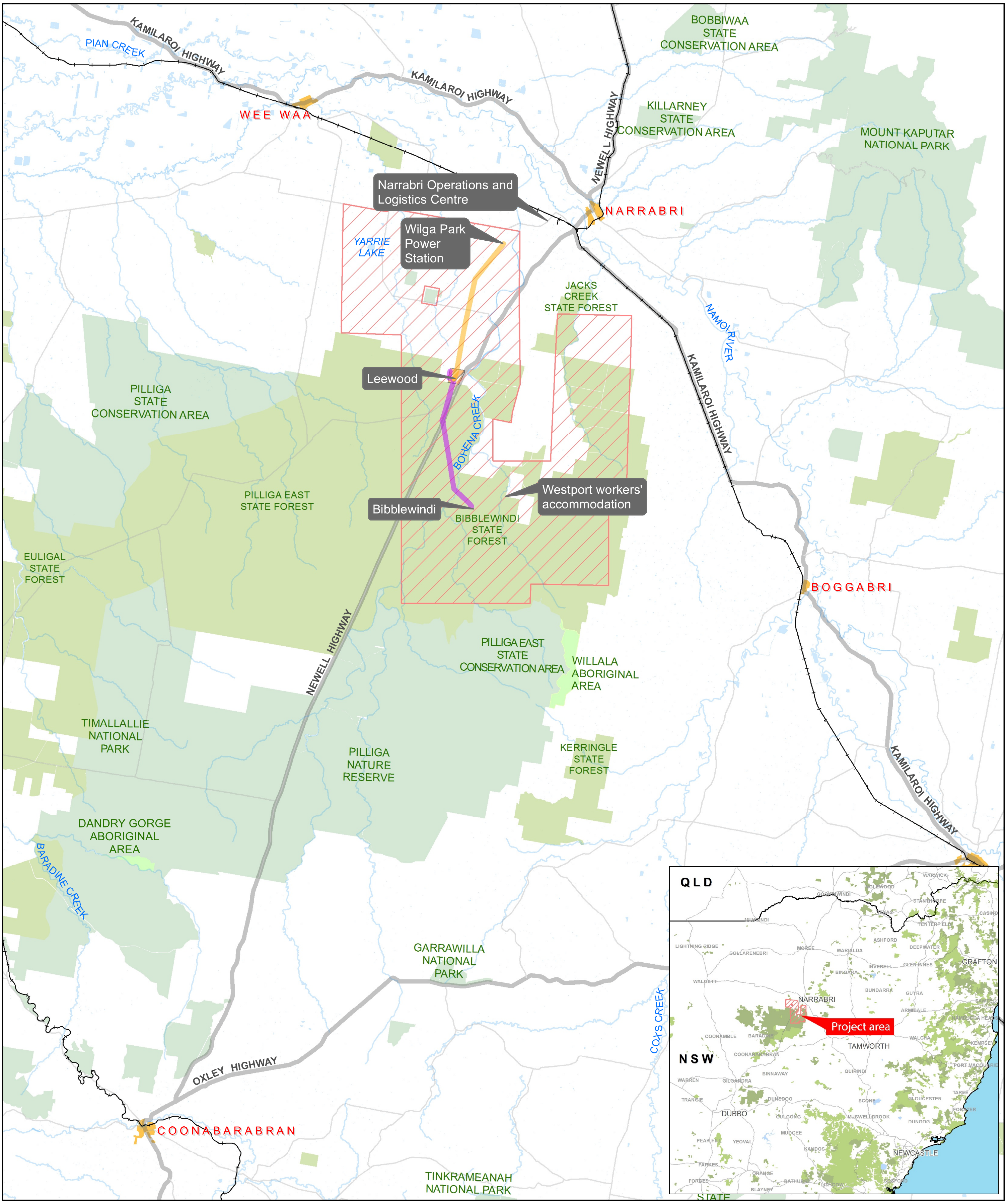
1.2 Water baseline

A water baseline for the project area has been described in the NGP Water Baseline Report (WBR; CDM Smith 2016a). The WBR provides a statement of the groundwater and surface water datasets that constitute the baseline that supports the NGP environmental assessment. The area of baseline monitoring contains eight water sources that are defined in six NSW Water Sharing Plans. The baseline data in the WBR are grouped by water source, with the groundwater baseline also sub-grouped by hydrostratigraphic unit. The baseline has been established using data sourced from fifty groundwater monitoring bores with records of groundwater pressure (head), forty-two groundwater monitoring bores with records of water quality, six streamflow gauging stations and twelve sampling locations for surface water quality. The existing baseline will be complemented by information collected as part of the ongoing monitoring outlined in this plan.

1.3 Relevant legislation and compliance requirements

Surface water and groundwater resources in the project area are managed under NSW's *Water Management Act 2000*. The primary mechanism of the Act that provides for management of the State's water resources are Water Sharing Plans (WSPs). The WSPs establish the rules for the take of water and enable equitable sharing of water between different water users, including the environment.

One of the WSPs that applies to groundwater resources in the project area is the *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater 2011*. This WSP defines and regulates four groundwater sources, including the Gunnedah–Oxley Basin MDB Groundwater Source. The project will extract groundwater directly from the Gunnedah–Oxley Basin MDB Groundwater Source and therefore requires a water access licence to cover the volume of water to be taken.



LEGEND

- Project area
- Leewood
- Urban Areas
- State forest
- Parks and reserves
- Aboriginal areas
- Lakes and dams
- Watercourses
- Highways
- Major Roads
- Train line
- Leewood to Wilga Park infrastructure corridor
- Bibblewindi to Leewood infrastructure corridor

0 5 10 20
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Narrabri Gas Project
Environmental Impact Statement

Job Number 21-22463
Revision A
Date 12 Mar 2015

Regional context and location of key infrastructure

Figure 1-1

C:\Users\AFoddy\Desktop\21_22463_KBM29.mxd [KBM: 235]

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: NSW Department of Lands: DTDB and DCDB - 2012-13. Santos: Operational and Base Data - 2013. Created by: afoddy

At the time of writing of this Water Monitoring Plan (WMP) no proclamation has been made declaring that Part 3 of Chapter 3 of the *Water Management Act 2000* applies in relation to aquifer interference approval. Accordingly, an aquifer interference approval will not be required for the proposed development. The policy intent of the requirements has been addressed through the impact assessment undertaken for the project. Additionally, this WMP is developed having regard to the policy intent and requirements of the overall *NSW Aquifer Interference Policy* (AIP; NSW DPI 2012) including:

- Considering the levels of the risks posed to water resources and users of those resources by the NGP, which are assessed in the Groundwater Impact Assessment (GIA) to be low to very low (CDM Smith 2016b).
- Ensuring minimal impact requirements (Table 1 of the AIP) can be met, noting that the minimal impact considerations include the water needs of dependent ecosystems, culturally significant sites and water users.
- Having appropriate response mechanisms in place should observed changes to water resources (e.g., water table or stream flow decline) be found to exceed the predicted effects or the minimal impact considerations.

1.4 The Water Monitoring Plan

1.4.1 NGP water management

The WMP is one component of the overall NGP water management program. It is designed to support management of the NGP by providing data for ongoing risk assessment of water management strategies and mitigation measures as they relate to the project's water use and the potential effects of the project on other water users.

The WMP is also designed to meet the requirements and expectations of regulatory agencies, as established in the Secretary's Environmental Assessment Requirements for the EIS.

Important aspects of the WMP include the setting of meaningful management objectives against which to assess the environmental performance of the project, and identification of indicators of water resource 'conditions' that are measurable, risk-based and which meet the expectations of the AIP.

1.4.2 Purpose of the WMP

The main purpose of the WMP is to enable potential effects of the project on the condition of water resources to be measured and, if necessary, responded to in a manner that protects the existing water users, including the environment. To achieve this purpose, the WMP includes:

- Design of a monitoring program to support early detection and identification of unexpected impacts from the project should they occur
- Identification of thresholds for observed adverse changes in the condition of water resources at which appropriate actions may be taken to manage and mitigate these effects, taking into account the minimal impact considerations of the AIP
- Validation of the predicted effects of the project on water resources presented in the GIA (CDM Smith 2016b) and adaptive management that will be followed if the predictions are found to be substantially less than observations and need to be revised

- Design of appropriate methods for reporting and analysing data from the monitoring program to identify when adverse changes that were not predicted may be related to the project.

Although the potential effects of the project on groundwater availability to existing users are predicted to be indiscernibly small compared to historical variations in water storage caused by climate and consumptive water-use patterns (CDM Smith 2016b), it is the intention of the WMP that ongoing collection and evaluation of data will be undertaken to identify and respond to adverse changes to water resources when there is reason to believe that the changes may be related to the project.

Should monitoring indicate a trend toward a changing water resource condition that is inconsistent with the magnitude of effect predicted by the GIA, is reasonably attributed to being a potential effect of the project, and which may ultimately reduce water access by users, the early-detection strategy incorporated into the WMP will allow the proponent to take appropriately-scaled management actions to avoid adverse effects, including 'make good' actions if required.

1.4.3 Water management and monitoring objectives

The principal water management objective for the NGP is to not cause adverse change[1] to the existing beneficial uses[2] of groundwater and surface water resources. There are five key components of the management objectives for the WMP that form the basis of the monitoring plan presented in Section 4, addressing the following questions:

- What is to be measured?
- What is the form (or method) of measurement?
- At what location(s) are measurements to be undertaken?
- What constitutes achievement of the monitoring objective?
- What baseline or control data are the monitoring results compared against?

These considerations form the basis for the management objectives in

1.4.4 Structure of the WMP

Section 1, Introduction (this section) – briefly describes the purpose of the WMP and the legislative requirements of the WMP within the context of the NGP.

Section 2, Context – provides an overview of the environmental setting of the NGP, including water-dependent assets and receptors, and describes the potential water-affecting activities of the project.

Section 3, Monitoring plan – sets out the principles of the monitoring plan, describes the monitoring commitments; establishes triggers, thresholds and minimum impact considerations.

Section 4, Implementation and Reporting – outlines the procedures for implementing water monitoring program and reporting the results.

Section 5, References – lists the literature cited in preparation of the WMP.

[1]That would give rise to exceedances of natural resilience and resistance levels of sensitive water receptors (SKM 2011)
[2]In terms of quantity and quality as they relate to ecological, cultural and economic uses of water

Section 2 Context

2.1 Overview

The following provides contextual information for the NGP in relation to the WMP. More detail is provided in the Environmental Impact Statement (EIS) for the project (Santos 2015).

2.2 Climate and topography

The climate of the region is cool to temperate, with hot summers and cool winters. High rates of evaporation are experienced during summer months (November to March) and low rates of evaporation are experienced during winter months (June and July). Mean annual rainfall within the Namoi Catchment is around 630 mm, but ranges from 1,300 mm in the eastern Barwon Highlands to 400 mm in the western part of the catchment. Rainfall data for Narrabri Climate Station 53026 (Mollee) shows that climate variability is significant with rainfall ranging from 280 to 1,002 mm/y over the 89-year rainfall record.

It is recognised that climate variability has the capacity to alter existing beneficial uses of water resources. For example, extended periods of drought may cause surface water to become more saline, water tables to decline (due to consumptive use by irrigators, for example, and reduced rates of recharge), and surface water flows to decline and waterholes to dry up (due to reduced rainfall runoff and consumptive use).

The project is located within the Namoi catchment, to the west of the Great Dividing Range, and the landscape is characterised by steep to undulating, mostly vegetated highlands in the east and south, which slopes toward low relief open floodplain in the west that is associated with the Namoi River. Elevations within the project area range from approximately 400 m Australian Height Datum (AHD) in the southeast down to approximately 250 mAHD in the northwest. Soils are typically clay and sandy- or clayey-loams (Welsh et al. 2014).

The project area itself is located on land where sediments (Orallo Formation and Pilliga Sandstone) of the Great Artesian Basin (GAB) sub-crop or out-crop (see Figure 2-1). The GAB sediments are overlain by alluvial and colluvial sediments associated with the Bohena Creek drainage.

2.3 Land and water use

Table 2-1 presents a summary of the types of land uses in the project area. The majority of the project area comprises woodland vegetation associated with state forest and privately managed land within a forested area known as the 'Pilliga'. The remaining area comprises of agricultural land that primarily supports dryland cropping and pastoral (livestock) grazing activities.

The Namoi catchment accounts for around 2.6% of all surface water diverted for irrigation in the Murray-Darling Basin and 15% of groundwater use in the Basin (MDBA 2016).

Surface water resources are managed under the Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources 2016. In the project area, surface water is used for irrigation, stock and domestic supplies, and for municipal and industrial supply.

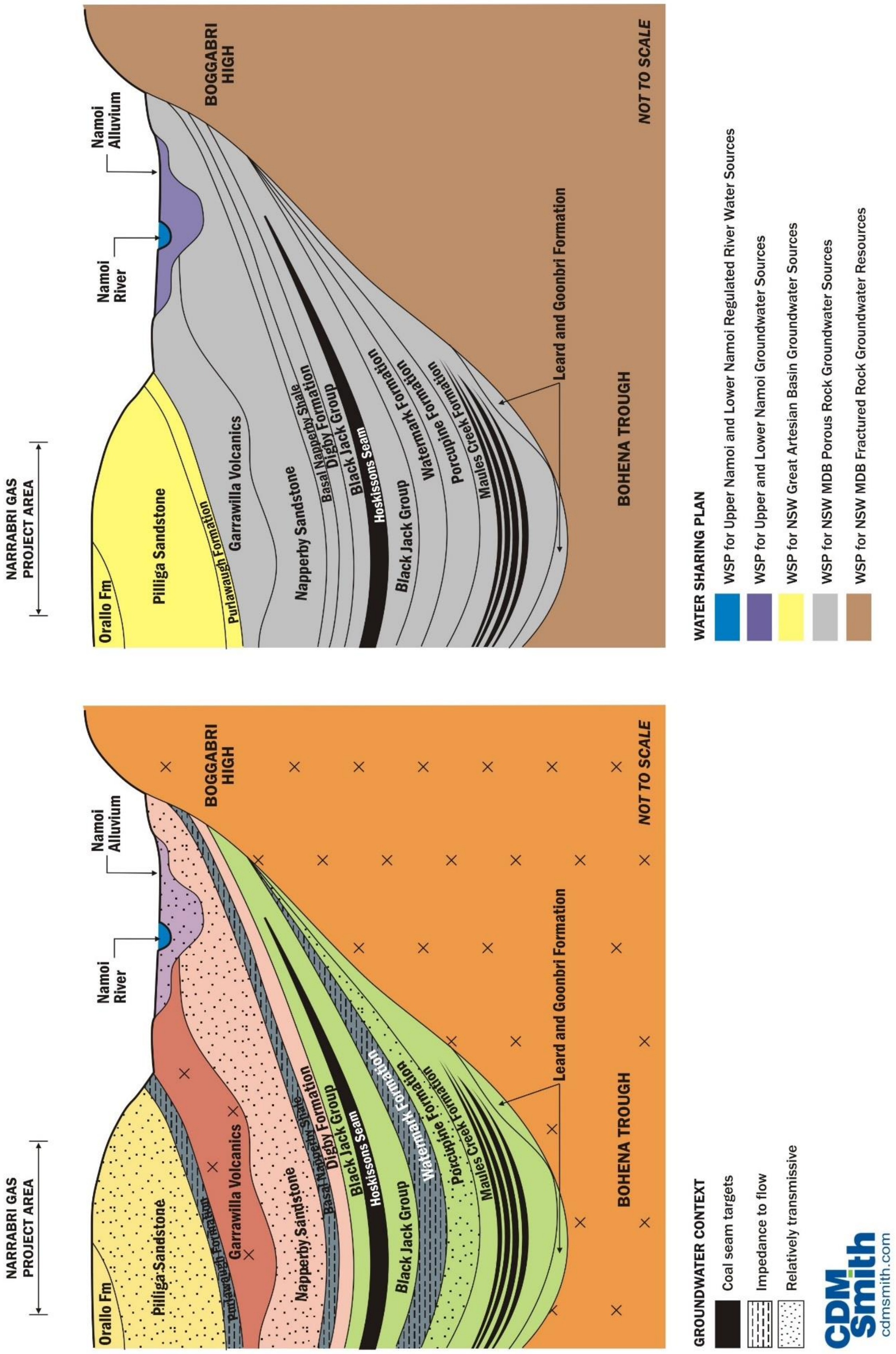


Figure 2-1 Project area schematic showing lithology and WSPs

Table 2-1 Land use in the Namoi Catchment (CDM Smith 2016b)

Namoi Catchment Land Use	Area [km^2]	Proportion of Namoi Catchment [%]
Grazing	4,287	32.6
Dryland cropping and horticulture	1,901	14.4
Forestry	1,881	14.3
Native landscapes	1,858	14.1
Conservation	1,953	14.8
Irrigation	811	6.2
Residential	282	2.1
Industrial	22	0.2
Lakes, rivers, dams	148	1.1
Wetland	10	<0.1
Mining	8	<0.1
Total	13,161	100

Groundwater resources are managed under several WSPs that are discussed in the paragraphs below. Approximately 95% of licensed bores are utilised for irrigation purposes. Groundwater abstractions are concentrated in the alluvial aquifers associated with main rivers and tributaries, although a large number of small scale abstractions also occur from the consolidated (porous) and fractured rock aquifers (CDM Smith 2016b). Local drinking water for Narrabri and Boggabri is supplied from bore fields sourcing alluvial aquifers.

The AIP classifies groundwater assets into 'Highly Productive Groundwater Sources' and 'Less Productive Groundwater Sources'. Groundwater sources in the catchment are covered by a number of groundwater management areas associated with several WSPs, as follows:

- The Highly Productive Groundwater Sources in the area include the alluvial aquifers associated with the Namoi River and the Pilliga Sandstone aquifer of the GAB –
  - The alluvial aquifers are high yielding and produce groundwater that is fresh to slightly brackish and suitable for multiple uses including town drinking supply, stock and domestic use and irrigation. Consequently, alluvial groundwater resources in the catchment are highly developed. These aquifers are managed under the *Upper and Lower Namoi Groundwater Sources* and the Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources 2003 (Figure 2-1).
  - The Pilliga Sandstone forms recharge beds for the GAB sedimentary sequence, it is highly porous and permeable, and produces high yields of good quality groundwater (Radke et al. 2000) that are generally fresh to slightly brackish and suitable for domestic, stock and irrigation purposes (CDM Smith 2016b). The Pilliga Sandstone aquifer is less utilised than the alluvial aquifers due to the availability of better quality water at shallower depths in alluvial sediments. The aquifer is managed under the Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008 (Figure 2-1).

    The Purlawaugh Formation forms an aquitard at the base of the Pilliga Sandstone that effectively isolate the GAB sediments from older and deeper lithology that comprise the Less Productive Groundwater Sources in the project area.
- The Less Productive Groundwater Sources in the area include the fractured and porous rock sequences associated with the
  - Gunnedah-Oxley Basin strata, sedimentary rocks that are the focus of coal mining and CSG exploration within the Namoi catchment. Groundwater associated with these

sediments is managed under the Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 (Figure 2-1). The consolidated sediments are generally low yielding and discontinuous, and so do not form a major water resource in the project area. Extractions from these strata generally only occur at locations where alluvial aquifers are absent (Welsh 2014).

The Basal Napperby Shale and the Watermark Formation (Figure 2-1) form aquitards that effectively isolate the Napperby Sandstone (and the productive alluvial aquifers) from the deeper coal bearing sediments that are targeted by the NGP for gas production.

- Garrawilla Volcanics, where present, separate the GAB sediments from the Gunnedah-Oxley Basin strata. Groundwater in this unit is also managed under the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 (Figure 2-1).
- Deeper Permian volcanic rocks form an effective basement in the project area and are not considered to represent a useable groundwater source.

2.4 Water-dependent assets and receptors

For the Bioregional Assessments, a *water dependent asset* was defined by Barrett et al. (2013) as an "entity contained within a bioregion where the characteristics can be ascribed a defined value (ecological or economic, for example) and which can be clearly linked, either directly or indirectly, to a dependency on groundwater or surface water quantity or quality". Within this context, O'Grady et al. (2015) concluded that water dependent assets can potentially be affected, either positively or negatively, by changes in groundwater or surface water regimes, or both, due to coal resource development.

Barrett et al. (2013) defined a *receptor* as "discrete, identifiable attributes or entities associated with water-dependent assets that (can be) materially impacted by changes in water quality or quantity", and further identified receptors as "the primary mechanism for reporting on the direct, indirect and cumulative impacts…". The WMP adopts a similar philosophy and is designed to monitor possible effects of the project on receptors that are considered potentially sensitive to changes in the quantity and quality of water resources that may occur due to the project.

Table 2-2 links water sources in the project area to ecological water-dependent assets and potential ecological water receptors. Similarly, Table 2-3 links the water sources to economic water-dependent assets and potential economic water receptors.

2.5 Water-affecting activities of the project

Water dependent assets and receptors that are identified as having the potential to be impacted by the NGP are listed in Table 2-2 and Table 2-3. In each case the risks posed to these assets from the project are assessed in the GIA to be low to very low (CDM Smith 2016b).

Table 2-4 and Table 2-5 outline the water-affecting activities of the project that are addressed in this WMP. Potential interactions between the target coal seams for gas production, in which direct depressurisation will be induced, and the shallow high-valued groundwater and surface water sources that host potentially sensitive receptors are assessed in the GIA to be negligible (CDM Smith 2016b).

Monitoring would be undertaken at selected locations within the project area to assist in validating the conclusions of the GIA that negligible impacts from the project are predicted at the locations of water-dependent assets and potentially sensitive receptors (see Section 4).

Table 2-2 Ecological water dependent assets and receptors

Water Source	Asset/value	Potentially sensitive receptors
Surface Water	▪ Rivers, creeks, tributaries, riparian vegetation, wetlands, lagoons, waterholes and billabongs. In particular: o The Namoi River, which forms part of the endangered aquatic ecological community in the natural drainage system of the Darling River lowland catchment (Green et al. 2011). o Lake Goran, a wetland of national significance (Directory of Important Wetlands)	▪ Aquatic ecosystems ▪ Important Bird Areas for migratory species (O'Grady et al. 2015) ▪ Habitats for listed species under the *EPBC Act 1999* *Form of dependence* – permanent or ephemeral flows / inundations
Highly Productive Groundwater Source	▪ Alluvial Water Sources o High yielding alluvial aquifers with good quality water, suitable for maintenance of ecosystem function ▪ Pilliga Sandstone o A GAB aquifer that provides good yields of water, suitable for maintenance of ecosystem function o Represents a GAB recharge bed.	▪ GAB aquifers ▪ Potential low value GDEs: o Type 2 spring ecosystems, where and if they exist o Type 2 baseflow ecosystems, none existing in the project area (see Figure 2-2) o Type 3 forests and woodlands *Form of dependence* – permanent or ephemeral flows / inundations
Less Productive Groundwater Source	▪ Porous and Fractured Rock Water Sources o Low yielding and discontinuous Gunnedah-Oxley Basin o Garrawilla Volcanics	▪ Unknown, if any

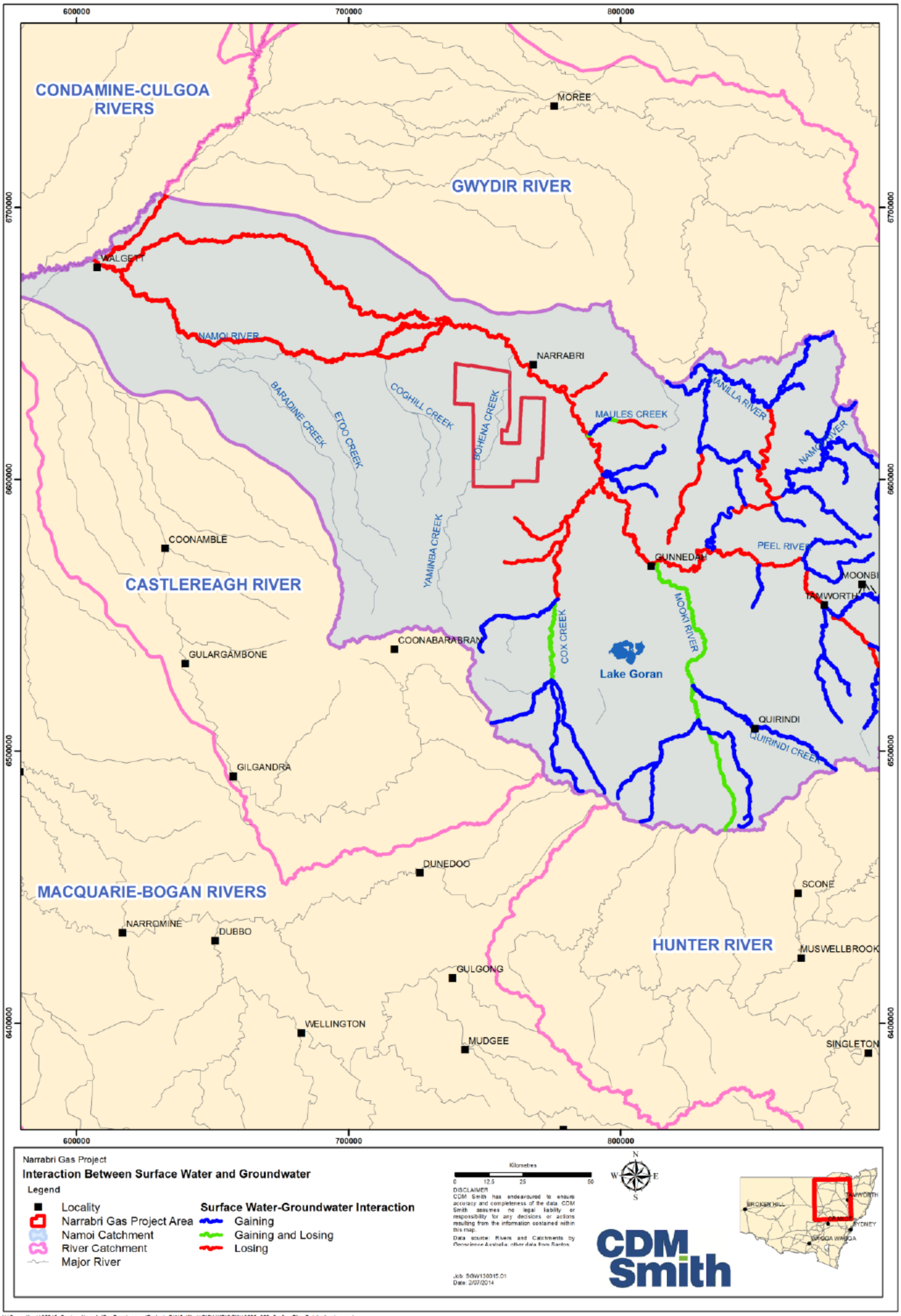


Figure 2-2 Losing and gaining reaches of the Namoi River and some tributaries in the project area (source: CSIRO 2007)

Table 2-3 Economic water dependent assets and receptors

Water Source	Asset/value	Potentially sensitive receptors
Surface Water	▪ Basic landholder rights ▪ Water access rights	▪ Irrigated agriculture ▪ Town potable water supply ▪ Agricultural users ▪ Stock and domestic users ▪ Industry users or other users *Form of dependence* – permanent or ephemeral flows
Highly Productive Groundwater Source	▪ Basic landholder rights (stock and domestic use) ▪ Water access rights to o Alluvial Water Sources ▪ High yielding alluvial aquifers with good quality water, suitable for potable use, stock water, beneficial use, irrigation o Pilliga Sandstone ▪ A GAB aquifer that provides good yields of water suitable for stock and domestic use and irrigation	▪ Primarily alluvial aquifers and Pilliga Sandstone o Irrigated agriculture o Town potable water supply o Agricultural users o Stock and domestic users o Municipal and industrial users ▪ Variable sources o CSG o Mining o Other *Form of dependence* – pressure head / depth to water table, saturated thickness
Less Productive Groundwater Source	▪ Basic landholder rights (stock and domestic use) ▪ Water access rights o Where alluvium is absent, Porous and Fractured Rock Water Sources o Coal seams within Gunnedah-Oxley Basin o Garrawilla Volcanics	▪ Private users (use unknown) ▪ Mining operations (including dewatering) ▪ CSG users *Form of dependence* – pressure head / depth to water table, saturated thickness

Table 2-4 NGP water-affecting activities and potential effects caused to surface water sources addressed by this WMP [1]

Water-affecting activity	Potential effect	Predicted impact	Monitoring detail
Managed release of treated water into Bohena Creek	Changes to surface water quality from discharge of treated water to Bohena Creek	Not measurable	Water quality
	Increased water levels and flows in watercourses due to release of treated water to Bohena Creek (Bohena Creek and Namoi River immediately downstream of confluence with Bohena Creek)	Not measurable	Water quantity (stage height)

Notes: 1. Adapted from CDM Smith (2016b)

Table 2-5 NGP water-affecting activities and potential effects that may be caused to groundwater sources addressed by this WMP [1]

Water-affecting activity	Potential effect	Predicted impact	Monitoring detail
Gas extraction, including: ▪ depressurisation/dewatering of aquifers during operations	Changes to water quality in aquifers supporting sensitive receptors [2] due to induced leakage between aquifers as a result of vertical propagation of depressurisation gradients from the coal measures where gas extraction takes place	Unlikely	Water quality
	Changes to water level / pressures in, and aquifer connectivity between, aquifers supporting sensitive receptors [2] due to induced leakage between aquifers as a result of vertical propagation of depressurisation gradients from the coal measures where gas extraction takes place	Not measurable	Water quantity (level / pressure)
	Compaction at depth due to depressurisation and reduction in the matrix volume of target coal seams, leading to potential subsidence at ground surface due to settlement of the compacted strata and overburden.	Unlikely	InSAR survey
	Changes to groundwater-surface water interactions due to reduction in aquifer pressures	Not measurable	Water quantity and quality (level)
Managed release of treated water into Bohena Creek	Changes to shallow high-valued groundwater quality due to leakage from creek during treated water discharge events [3]	Not measurable	Water quality

Notes:
1. Adapted from CDM Smith (2016b)
2. GDEs and other users
3. Which only occurs during natural creek flow events of at least 100 ML/day
4. Interferometric synthetic aperture radar

Section 3 Monitoring plan

3.1 Key Principles

The WMP is constructed around several key principles. The following description is complimented by the schematic cross section in Figure 3-1, which shows how the key principles of the WMP relate to the key water-dependent assets of the project area.

The key principles of the WMP are as follows:

- Monitoring activities are designed to inform, to the extent possible, an understanding of whether or not the NGP is contributing to changes in water quantity or quality within water assets, particularly the high-valued groundwater sources in the GAB and alluvial aquifers.

- Where possible, leading resource condition indicators (quantity and quality) are used for early warning of potential changes to water resource condition arising from the NGP. Sentinel monitoring locations are nominated at intermediate depths within the Gunnedah-Oxley Basin to detect unexpected change in subsurface condition prior to potential impacts on receptors within shallow high-valued groundwater sources.

- Lagging resource condition indicators (quantity and quality) are nominated to assess trends in water resource conditions associated with non-NGP activities. The nominated monitoring sites are located in the high-valued groundwater sources in the GAB and alluvial aquifers where the project baseline data exhibit historical effects from variations in climate and consumptive water-use patterns.

The nominated groundwater monitoring at intermediate depths within Triassic Age strata of the Gunnedah-Oxley Basin is considered to meet the criteria of a ‘leading resource condition indicator’ because unexpected impacts on groundwater condition at these depths would occur well in advance of adverse impacts occurring in the shallow high-valued groundwater sources.

Adopting this concept of leading and lagging indicators, the nominated monitoring within high-valued groundwater sources in the GAB and alluvial aquifers is considered to be a form of ‘lagging resource condition indicator’ in the sense that unexpected adverse changes observed at these locations would indicate that an impact to the water source has already occurred.

More generally, the purpose of the sentinel monitoring within the Gunnedah-Oxley Basin is to detect potential impacts before they reach high-valued water sources in the GAB and alluvial aquifers, while the purpose of monitoring in the high-valued groundwater sources is to demonstrate that observed changes in resource condition are not an effect of the NGP.

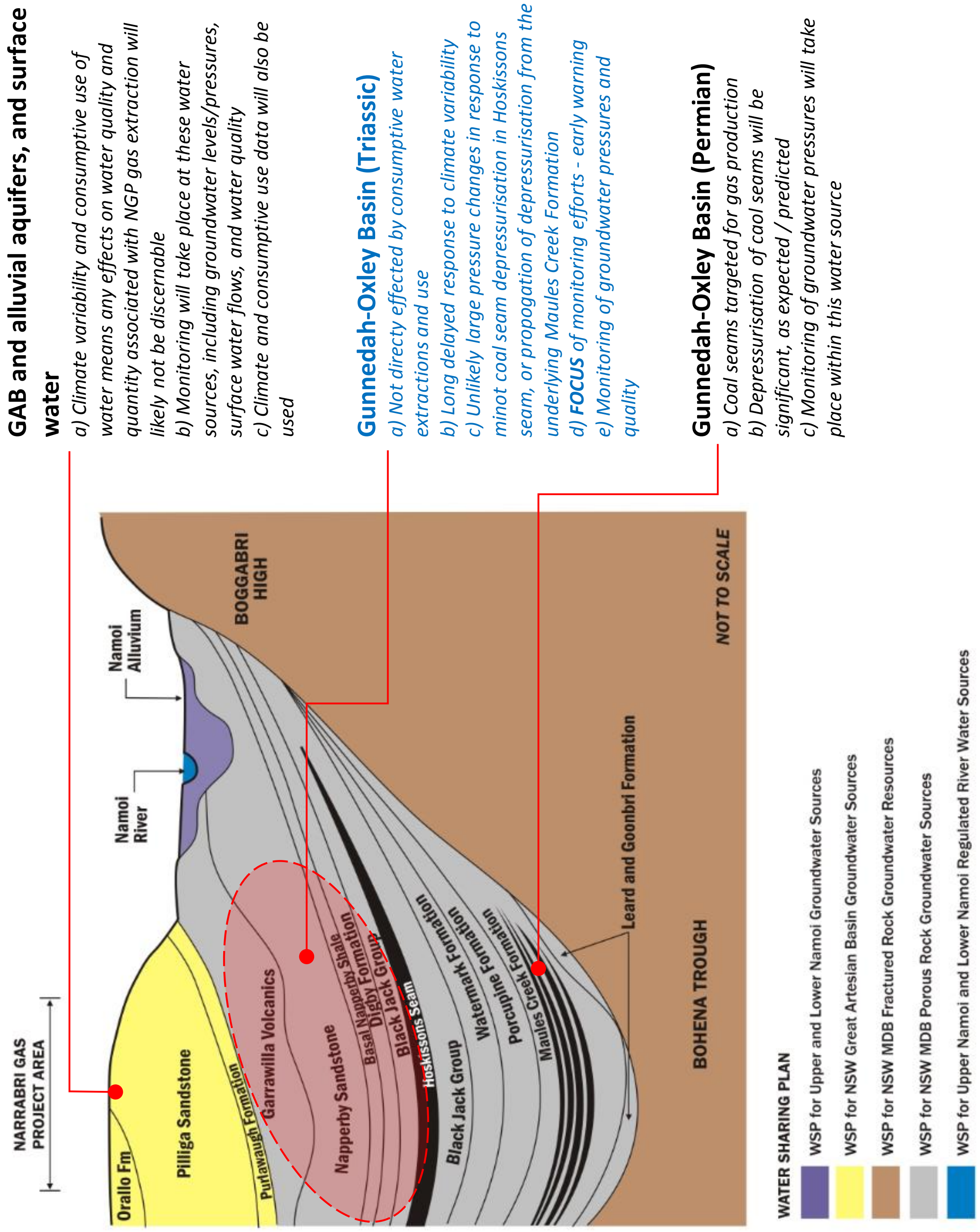


Figure 3-1 Key principles of the Water Monitoring Plan (WMP)

3.2 Groundwater

3.2.1 Overview

The proponent has developed a regional groundwater flow model to assess the potential impact of gas development on the groundwater and surface water resources of the region (CDM Smith 2016b). The model was developed utilising data collected by the proponent (and other parties, including DPI Water) within the region and based on detailed conceptualisation of the regional hydrostratigraphy. Detail on the conceptualisation and construction of the model is presented in the GIA, which is appended to the EIS.

The predictions of the groundwater flow model presented in the GIA show that water sources (groundwater and surface water) utilised for beneficial use are unlikely to be adversely impacted by the project. Table 3-1 presents model predicted drawdowns for key hydrostratigraphic units (HSUs) in the project area.

Table 3-1 Predicted depressurisation and drawdown from the GIA [1]

Hydrostratigraphic unit [2]	Drawdown range (m)	Time at maximum (y)
Water table • Regional • Namoi alluvium	 1 to 1.5 <0.5	300 to 500
Pilliga Sandstone	<0.5 to 0.6	200 to 250
Late Permian coal seams	13 to 16	13 to 400
Early Permian coal seams	93 to 128	3 to 500

Notes: 1. CDM Smith (2016b)

Figure 3-2 is a map showing the predicted maximum extent of drawdown[3] that exceeds 1 m within Late Permian coal seams (CDM Smith 2016b) which occur at mid-depth within the Gunnedah-Oxley Basin and immediately below Triassic Age strata that are the focus for early-detection monitoring (Figure 3-1).

Where groundwater monitoring locations are located outside the area of NGP operations[4], relevant access agreements or permissions will be required to enable the commissioning of new monitoring bores and allow monitoring activities to take place. Where these access agreements or permissions are not granted, alternative monitoring locations will be sought. For the purpose of ongoing monitoring, it is assumed the bores that have historically been monitored and maintained by DPI Water will continue under the same arrangement.

Whilst every effort will be made to undertake the required monitoring at nominated locations, there may be occasions where it is not possible to access these locations due to health and safety considerations. In these circumstances alternative arrangements will be made, where possible.

[3] Assuming 1 m drawdown as the extent boundary
[4] Including existing and proposed monitoring facilities

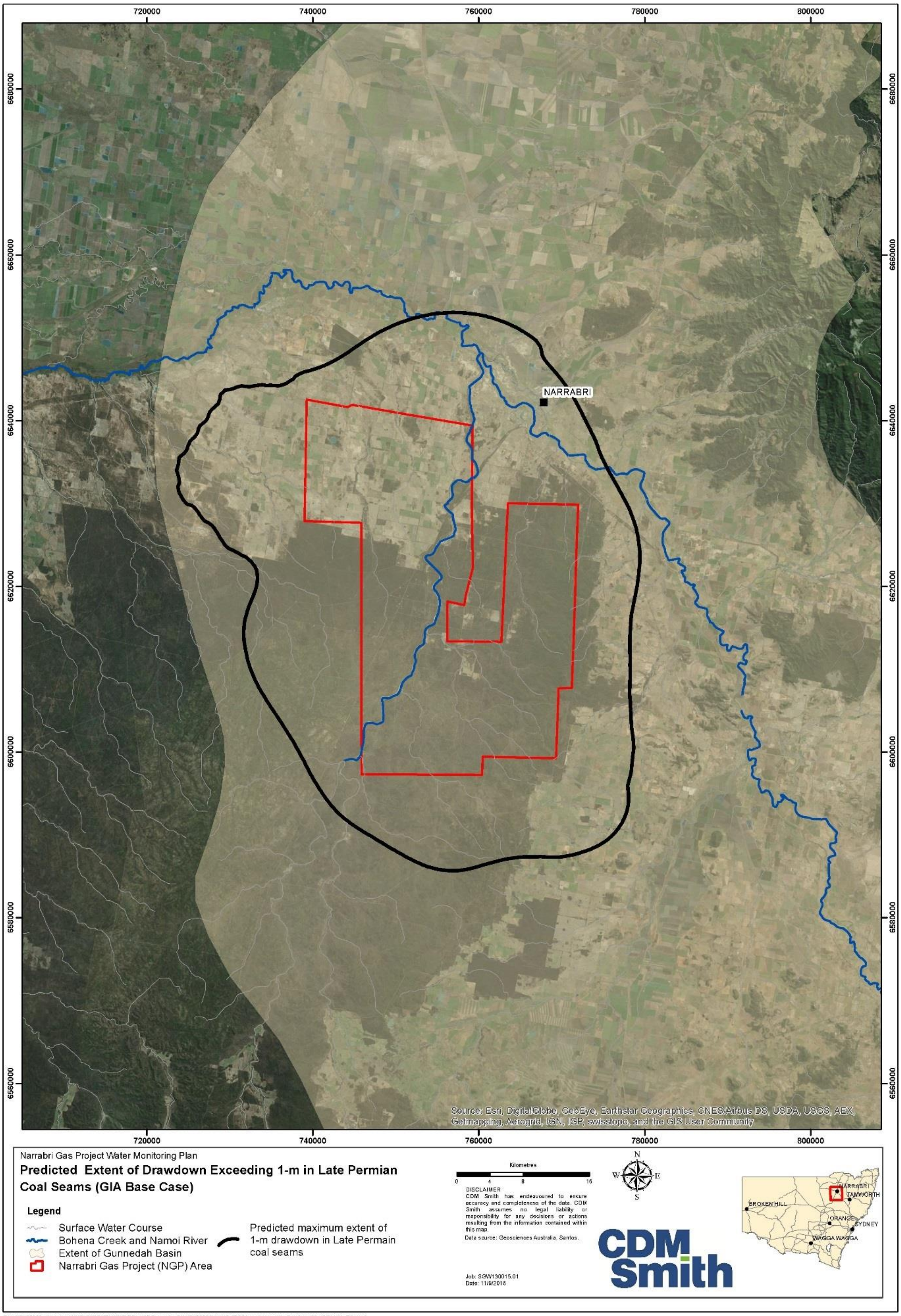


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Figure 3-2 Predicted extent of drawdown exceeding 1 m in Late Permian coal seams

3.2.2 Extractions from groundwater sources

3.2.2.1 Existing users

The proponent has actively engaged with water users in the project area and has collected groundwater-related information from a large number of privately owned bores (Figure 3-3). To the extent that is practical, and at a frequency to be determined, the proponent will continue to measure depth to water in bores and the salinity (as total dissolved solids) of groundwater sampled from individual bores where access is available.

In addition, relevant water use data published by DPI Water will be reviewed and incorporated into the water monitoring program to provide information about:

- Consumptive trends in water demand and use, specifically within the context of trends in climate and consumptive use patterns; and
- Total consumptive groundwater extraction within the project area, specifically within the context of the relative volume of produced water extracted by the proponent for gas production.

Where data are publically available, groundwater extraction associated with mine dewatering and water supply, with potential to affect groundwater pressure in the project area, particularly the Narrabri North Coal Mine, will also be reviewed and incorporated in the water monitoring program. These data will be used to assist in identifying the extent to which water-affecting activities of mines are interacting with the project area groundwater system.

3.2.2.2 The proponent

The approach to gas production involves depressurisation of the coal seams that host the gas resource by extraction of groundwater. The extractions will be licensed, just as other types of groundwater extractions for consumptive uses in NSW are licenced, and the extracted volumes will be recorded for incorporation in the water monitoring program. Table 3-2 presents details of monitoring to be undertaken in regards to groundwater extractions associated with gas production.

Table 3-2 Groundwater extractions monitoring

Parameter	Unit of measurement
Groundwater extraction quantity	ML/day

3.2.3 Groundwater monitoring network

3.2.3.1 Proponent baseline monitoring bores

The proponent has established a network of groundwater monitoring locations within the project area, including multi-level and nested type bore installations. Table B-1 (Appendix B) presents details of the existing groundwater monitoring infrastructure that is maintained by the proponent, and which is being used to collect the project baseline data (CDM Smith 2016a). To the extent that is necessary, the existing network may be supplemented by a number of additional monitoring bores that are designed to complement the existing baseline data and to provide new data at strategic locations prior to or after commissioning of gas production.

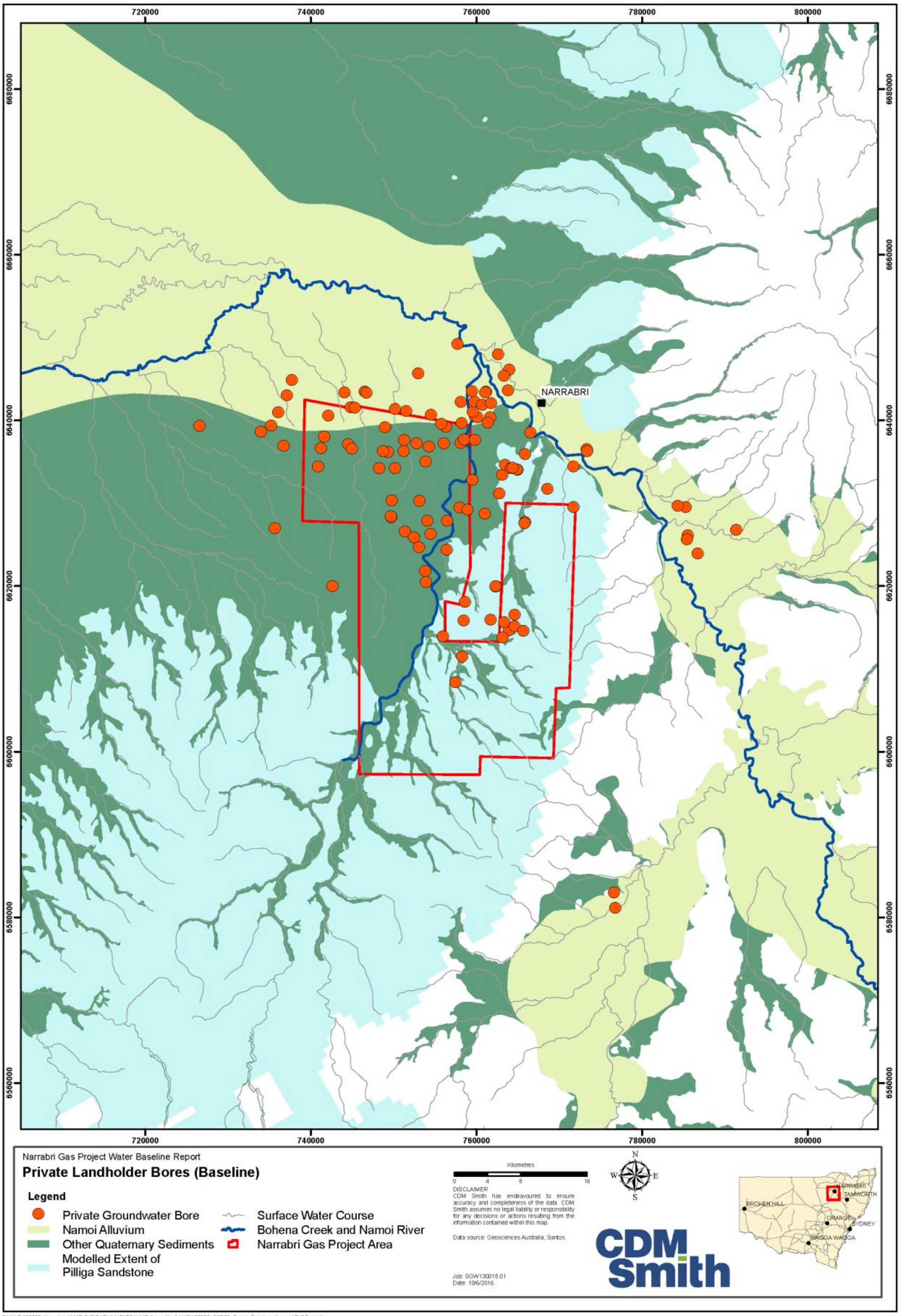

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Figure 3-3 Private landholder bores sampled for the project baseline

3.2.3.2 DPI Water monitoring bores

The proponent has worked with DPI Water to identify bores from the NSW monitoring program that are suitable for inclusion in the NGP groundwater monitoring network. Around thirty DPI Water monitoring bores are nominated to complement the proponent's monitoring locations, and are selected from monitoring bores included in the water baseline. Table B-2 (Appendix B) presents details of DPI Water's groundwater monitoring infrastructure. DPI Water will remain responsible for the monitoring and maintenance of this infrastructure. Future monitoring needs will be assessed during the early stages of gas production based on future development plans (see Section 4.3).

3.2.3.3 Nominated NGP monitoring bores

The locations of groundwater bores nominated in WMP are shown on maps in Figure 3-4 (alluvial aquifers), Figure 3-5 (GAB) and Figure 3-6 (Gunnedah-Oxley Basin). In addition, Figure 3-7 is a schematic to assist with understanding the number and relative depths of nominated monitoring locations within each of the WSP groundwater sources, including the number of additional bores included in the monitoring program that are supplementary to the baseline groundwater bores within the WBR (CDM Smith 2016a).

The nominated monitoring network consists of monitoring bores within the following groundwater sources:

- Lower Namoi Groundwater Sources - 8 Level 1 monitoring bores (7 existing and 1 proposed) and 11 Level 2 monitoring bores (existing) (Figure 3-4)
- Bohena Creek Water Source - 4 Level 1 monitoring bores (existing) (Figure 3-4)
- Southern Recharge and Surat Groundwater Sources of the GAB- 10 Level 1 monitoring bores (existing) and 16 Level 2 monitoring bores (existing) (Figure 3-5)
- Gunnedah–Oxley Basin MDB Groundwater Source - 17 Level 1 monitoring bores (10 existing and 7 proposed).

Table 3-3 to Table 3-6, which accompany Figure 3-4 to Figure 3-6, present details of the groundwater bores nominated in the NGP monitoring network, including the monitoring requirements for each bore, the form of measurement, the management objective to be achieved and the source of baseline data. The tables also distinguish between Level 1 and Level 2 monitoring bores. This designation is based on the level of impact expected at each location, and forms part of the defining of monitoring thresholds in Section 3.7.

3.2.3.4 Expanded Rationale for groundwater monitoring

In broadest terms, the nominated water monitoring program is focussed on demonstrating that the NGP is not affecting the beneficial use status of water sources occurring within the project area, and specifically within the context of the minimal impact considerations of the AIP (NSW DPI 2011). Of primary importance is the protection of the beneficial use of high-valued groundwater sources in GAB and alluvial aquifers that are used for stock, domestic, municipal and irrigation purposes.

Numerical groundwater modelling in the GIA (CDM Smith 2016b) shows that transfer of depressurisation from deep coal seams to the shallow high-valued groundwater sources will be impeded by thick aquitard sequences, resulting in small (if measurable) drawdowns in the high-valued groundwater sources many years after gas production ceases (see Table 3-1). The GIA concludes that the project will not cause an adverse reduction in the amount of water available in high-valued groundwater sources, both for anthropogenic uses and maintenance of ecosystem function. No potential for deterioration of groundwater quality in the shallow high-valued groundwater sources exists because the direction of vertical groundwater flow induced by depressurisation in deeper coal seams is always downward toward the seams.

Nominated monitoring bores in the Gunnedah-Oxley Basin, within sediments of Triassic Age, are located with existing bores that are screened in deeper Permian-Age coal seams or with existing shallow bores screened in the GAB and alluvial aquifers. The intention of this strategy is to supplement the monitoring depths at existing locations with measurements at intervening depths that will support detection and monitoring of vertical propagation of depressurisation from the target coal seams into overlying strata and water sources.

Thirteen of the nominated monitoring bores within the GAB are screened in Pilliga Sandstone, either within the area of outcrop of the Pilliga Sandstone or immediately down-gradient of that area with respect to the direction of regional groundwater flow. The area of outcrop of the Pilliga Sandstone forms the recharge bed for the GAB within the project area and is the key target for monitoring by these bores.

In assessing changes to groundwater conditions that are observable in data from the groundwater monitoring program, consideration will need to be given to the relatively high level of groundwater extractions by other users from the shallow high-valued aquifers in the project area, particularly groundwater extractions for irrigation. Additionally, the levels of groundwater storage in the alluvial aquifers and GAB are subject to changes induced by climate variability, such as drought cycles, and anthropogenic and ecological responses to these varying climate stresses. For example, historical groundwater pumping from the Upper and Lower Namoi Groundwater Sources has affected storage levels in the alluvial aquifers in the past, to the extent that those changes would exceed the minimal impact considerations of the AIP. Such effects can be seen in hydrographs for the baseline groundwater monitoring bores presented in the WBR (CDM Smith 2016a). Larger effects are anticipated during extended dry periods when groundwater recharge is less, surface water sources are less available and groundwater pumping for irrigation is likely to be greater.

It is also possible that changes in water quality could occur in the shallow high-valued aquifers that are unrelated to the project. For example, long-term use of groundwater for irrigated agriculture can over time cause higher salinity to develop in shallow water table aquifers. This effect is caused by repeated cycling of groundwater past the root zone of crops and resultant concentration of salts at the water table.

Monitoring of groundwater pressure in the coal seams from which water and gas will be extracted will show depressurisation over time and then slow recovery of pressure following decommissioning of the gas field. Because these data will be available at depths considerably below the shallow high-valued groundwater sources in the GAB and alluvial aquifers they are not considered to be useful for the purpose of identifying potential unexpected effects in the shallow water sources. The WMP therefore has a specific focus on monitoring groundwater pressure at intermediate depths within the aquitard sequences between the deep coal seams and the shallow water sources. The key targets for this 'sentinel' monitoring are Triassic Age strata in the Gunnedah-Oxley Basin (typically the Napperby and Digby Formations). Monitoring at these intermediate depths will also assist in ongoing validation of the GIA groundwater flow model and its predictions.

Induced downward flow gradients during and following gas production will prevent the potential for adverse change in the quality of shallow high-valued groundwater sources (as discussed above). Groundwater that is present within the alluvial aquifers, GAB and Gunnedah-Oxley Basin typically has distinctive chemical compositions ('signatures') at different depths within different strata (Jacobs 2014, refer Appendix C). These chemical signatures may be useful to assess whether unexpected inter-aquifer water transfers are occurring; however, it is noted that these potential changes in water quality are expected to be very small and are likely to be indiscernible. The nominated water quality monitoring program reflects this situation.

Whilst monitoring within the different aquifers occurring in each WSPs is planned under the WMP, a key focus is the monitoring of groundwater pressure in Triassic Age strata of the Gunnedah-Oxley Basin, immediately above the Late Permian coal seams, to acquire leading resource condition data. Typically, the nominated monitoring of shallow high-valued groundwater sources in the GAB and alluvial aquifers will form a basis for collecting lagging indicator data.

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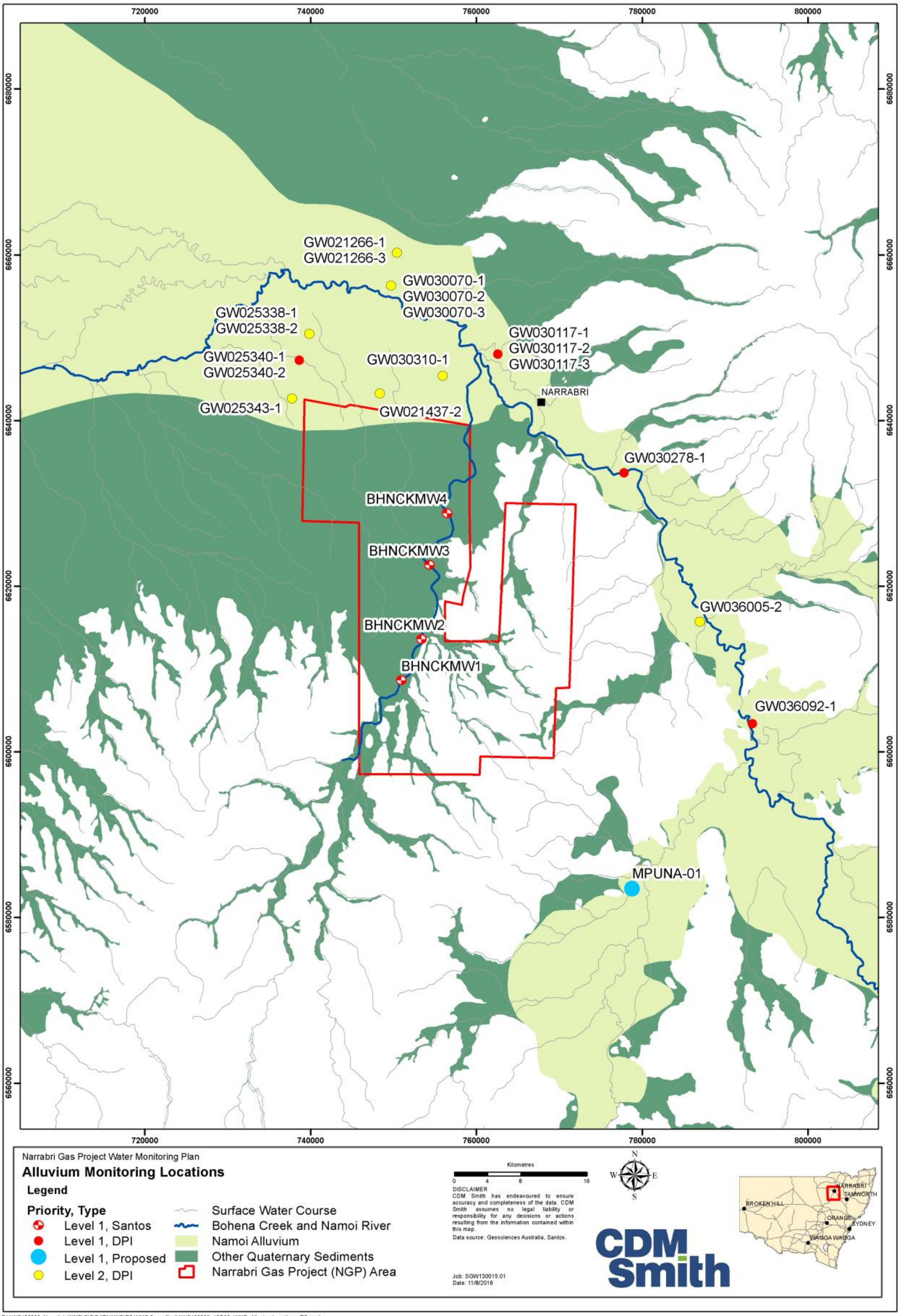

Figure 3-4 Nominated alluvial aquifer groundwater monitoring bores

Table 3-3 Monitoring program details - WSP for Upper and Lower Namoi Groundwater Sources

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Bore category</th><th colspan="2">Form of measurement</th><th rowspan="2">Management Objective [1]</th><th rowspan="2">Baseline / control data</th></tr>
<tr><th>Water quantity</th><th>Water quality</th></tr>
<tr><td>GW036092-1
GW030278-1
GW030117-1
GW030117-2
GW030117-3
GW025340-1
GW025340-2
MPUNA-01</td><td>Level 1</td><td>▪ Field measured
⇒ water level (reduced to mAHD), using calibrated pressure transducers
▪ Frequency
⇒ Continuous (recording interval set to 24 hrs)</td><td>▪ Field measured
⇒ EC, pH, DO, Eh
▪ Frequency
⇒ Quarterly
▪ Laboratory
⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate
▪ Frequency
⇒ Biennial</td><td rowspan="3">Quantity
a) No adverse change to water table in alluvial aquifers [3]
Quality
a) No adverse change to existing beneficial use of groundwater sourced from alluvial aquifers [3]</td><td rowspan="3">WBR data [2]</td></tr>
<tr><td rowspan="2">GW030310-1
GW021266-1
GW021266-3
GW025343-1
GW025338-1
GW025338-2
GW021437-2
GW030070-1
GW030070-2
GW030070-3
GW036005-2</td><td rowspan="2">Level 2</td><td rowspan="2">▪ Field measured
⇒ water level (reduced to mAHD), using manual techniques
▪ Frequency
⇒ Biannual (unless equipped with pressure transducers)</td><td>▪ Field measured
⇒ EC, pH, DO, Eh
▪ Frequency
⇒ Biannual</td></tr>
<tr><td>▪ Laboratory
⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate
▪ Frequency
⇒ Biannual, but only if and when pressure declines attributed to NGP are observed</td></tr>
</table>

Notes:
1. Refer Section 3.2
2. CDM Smith (2016a and 2016b)
3. Other than those attributed to climate variability (seasonal and inter-annual), irrigation, mining and other anthropogenic influences

Table 3-4 Monitoring program details - WSP for Namoi Unregulated and Alluvial Water Sources

Location	Bore category	Form of measurement		Management Objective [1]	Baseline / control data
		Water quantity	Water quality		
BHNCKMW1 BHNCKMW2 BHNCKMW3 BHNCKMW4	Level 1	▪ *Field measured* ⇒ water level (reduced to mAHD), using calibrated pressure transducers ▪ *Frequency* ⇒ Continuous (recording interval set to 24 hrs)	▪ *Field measured* ⇒ EC, pH, DO, Eh ▪ *Frequency* ⇒ *Quarterly* ▪ *Laboratory* ⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate ▪ *Frequency* ⇒ *Biennial*	*Quantity* a) No adverse change to water table in alluvial aquifers [3] *Quality* a) No adverse change to existing beneficial use of groundwater sourced from alluvial aquifers [3]	WBR data [2]

Notes:
1. Refer Section 3.2
2. CDM Smith (2016a and 2016b)
3. Other than those attributed to climate variability (seasonal and inter-annual), irrigation, mining and other anthropogenic influences

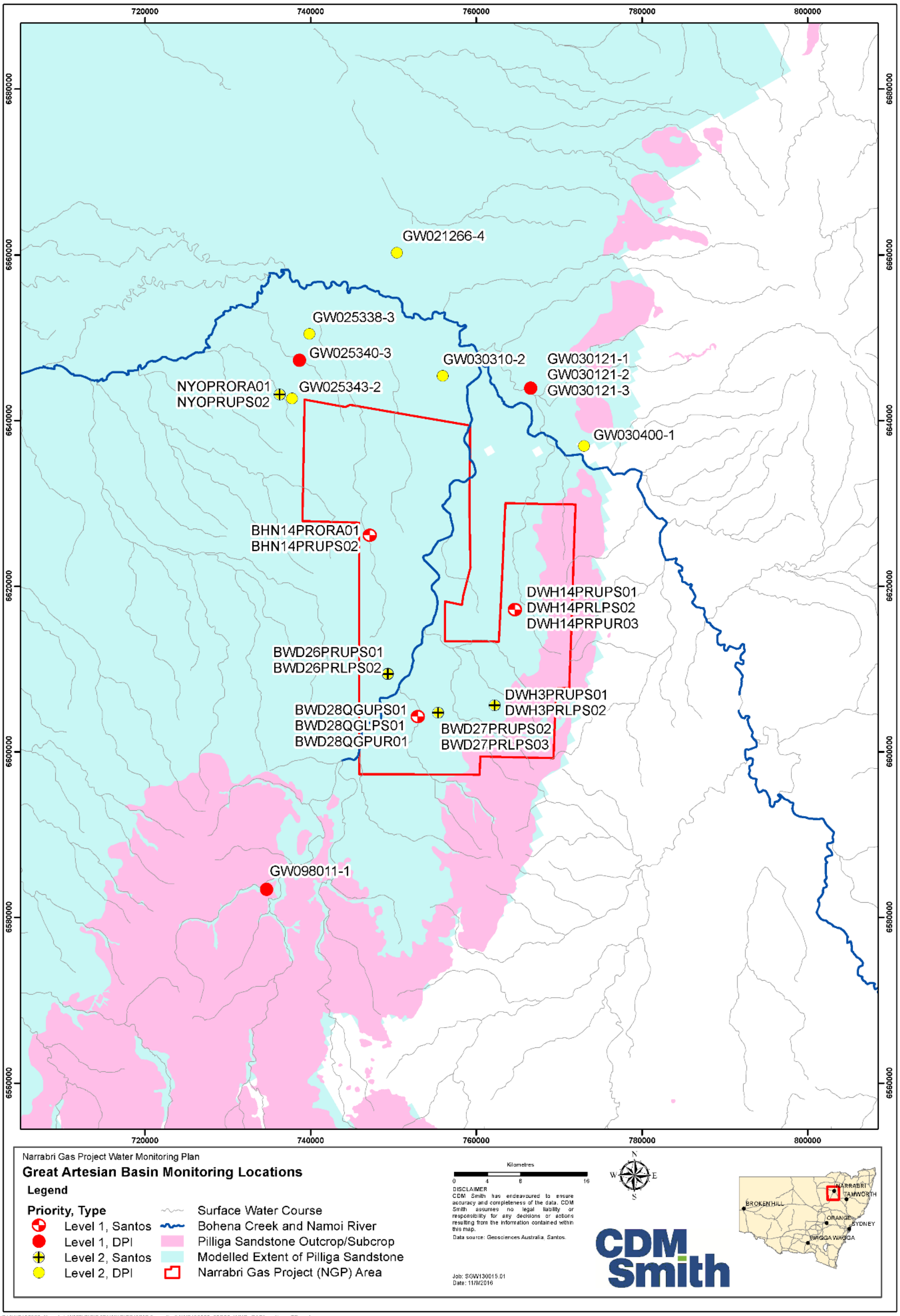

Figure 3-5 Nominated GAB groundwater monitoring bores

Table 3-5 Monitoring program details - WSP for NSW Great Artesian Basin Groundwater Sources

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Bore category</th><th colspan="2">Form of measurement</th><th rowspan="2">Management Objective [1]</th><th rowspan="2">Baseline / control data</th></tr>
<tr><th>Water quantity</th><th>Water quality</th></tr>
<tr><td>BHN14PRORA01
BHN14PRUPS02
DWH14PRUPS01
DWH14PRLPS02
DWH14PRPUR03
GW025340-3</td><td rowspan="2">Level 1</td><td rowspan="2">▪ Field measured
⇒ water level (reduced to mAHD), using calibrated pressure transducers
▪ Frequency
⇒ Continuous (recording interval set to 24 hrs)</td><td>▪ Field measured
⇒ EC, pH, DO, Eh
▪ Frequency
⇒ Quarterly
▪ Laboratory
⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate
▪ Frequency
⇒ Biennial</td><td>Quantity
a) No adverse change to spring discharges or wetted areas [3]
b) No adverse change to pressure heads in GAB aquifers [3]
Quality
a) No adverse change to existing beneficial use of groundwater sourced from GAB aquifers [3]</td><td rowspan="2">WBR data [2]</td></tr>
<tr><td>GW030121-1
GW030121-2
GW030121-3
GW098011-1</td><td>(bores not equipped for water quality sampling)</td><td>Quantity
As above</td></tr>
</table>

Notes:
1. Refer Section 3.2
2. CDM Smith (2016a and 2016b)
3. Other than those attributed to climate variability (seasonal and inter-annual), irrigation, mining and other anthropogenic influences

Table 3-5 Monitoring program details – WSP for NSW Great Artesian Basin Groundwater Sources (cont.)

Location	Bore category	Form of measurement		Management objective [1]	Baseline / control data
		Water quantity	**Water quality**		
BWD26PRUPS01 BWD26PRLPS02 BWD27PRUPS02 BWD27PRLPS03 BWD28QGLPS01 BWD28QGUPS01 BWD28QGPUR01 DWH3PRUPS01 DWH3PRLPS02 NYOPRORA01 NYOPRUPS02	Level 2	▪ *Field measured* ⇒ water level (reduced to mAHD), using manual techniques ▪ *Frequency* ⇒ Biannual (unless equipped with pressure transducers)	▪ *Field measured* ⇒ EC, pH, DO, Eh ▪ *Frequency* ⇒ *Biannual* ▪ *Laboratory* ⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate ▪ *Frequency* ⇒ *Biannual, but only if and when pressure declines attributed to NGP are observed*	*Quantity* a) No adverse change to spring discharges or wetted areas [3] b) No adverse change to pressure heads in GAB aquifers [3] *Quality* a) No adverse change to existing beneficial use of groundwater sourced from GAB aquifers [3]	WBR data [2]
GW030310-2 GW030400-1 GW021266-4 GW025343-2 GW025338-3			(bores not equipped for water quality sampling)	*Quantity* As above	

Notes:
1. Refer Section 3.2
2. CDM Smith (2016a and 2016b)
3. Other than those attributed to climate variability (seasonal and inter-annual), irrigation, mining and other anthropogenic influences

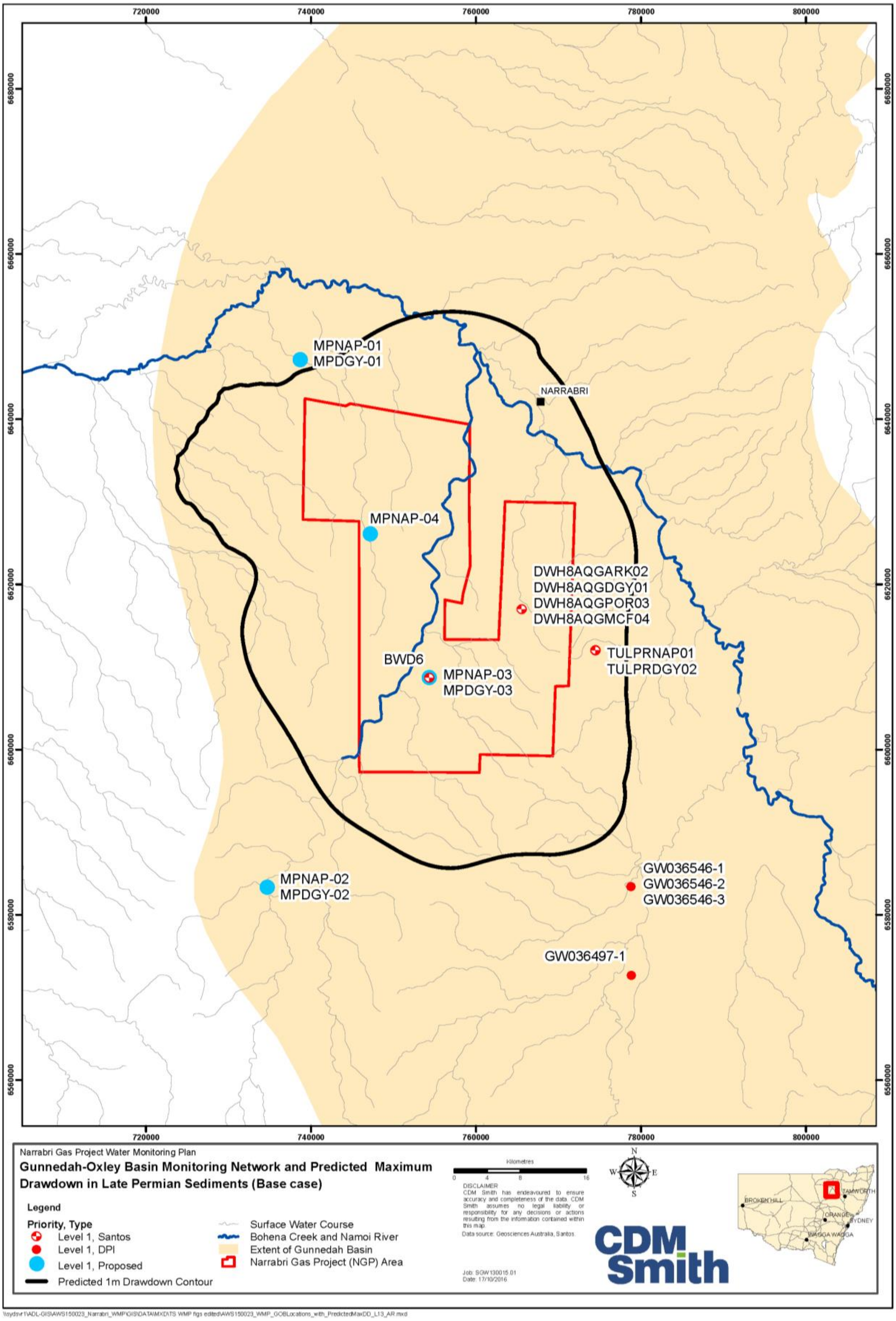

Figure 3-6 Nominated Gunnedah-Oxley Basin groundwater monitoring bores

Table 3-6 Monitoring program details - WSP for NSW Porous Rock Groundwater Sources

Location	Bore category	Form of measurement		Management objective [1]	Baseline / control data
		Water quantity	Water quality		
TULPRDGY02 TULPRNAP01 MPDGY-01 MPNAP-01 MPDGY-02 MPNAP-02 MPDGY-03 MPNAP-03 MPNAP-04	Level 1	▪ *Field measured* ⇒ water level (reduced to mAHD), using calibrated pressure transducers ▪ *Frequency* ⇒ Continuous (recording interval set to 24 hrs)	▪ *Field measured* ⇒ EC, pH, DO, Eh ▪ *Frequency* ⇒ *Quarterly* ▪ *Laboratory* ⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate ▪ *Frequency* ⇒ *Biennial*	*Quantity* d) No unexpected change in water pressure in the Gunnedah-Oxley Basin *Quality* d) No unexpected change in water quality in the Gunnedah-Oxley Basin	WBR data [2]
BWD6 DWH8AQGDGY01 DWH8AQGPOR03 DWH8AQGMCF04 GW036546-1 GW036546-2 GW036546-3 GW036497-1			(bores not equipped for water quality sampling)	*Quantity* As above	

Notes: 1. Refer Section 3.2
2. CDM Smith (2016a and 2016b)

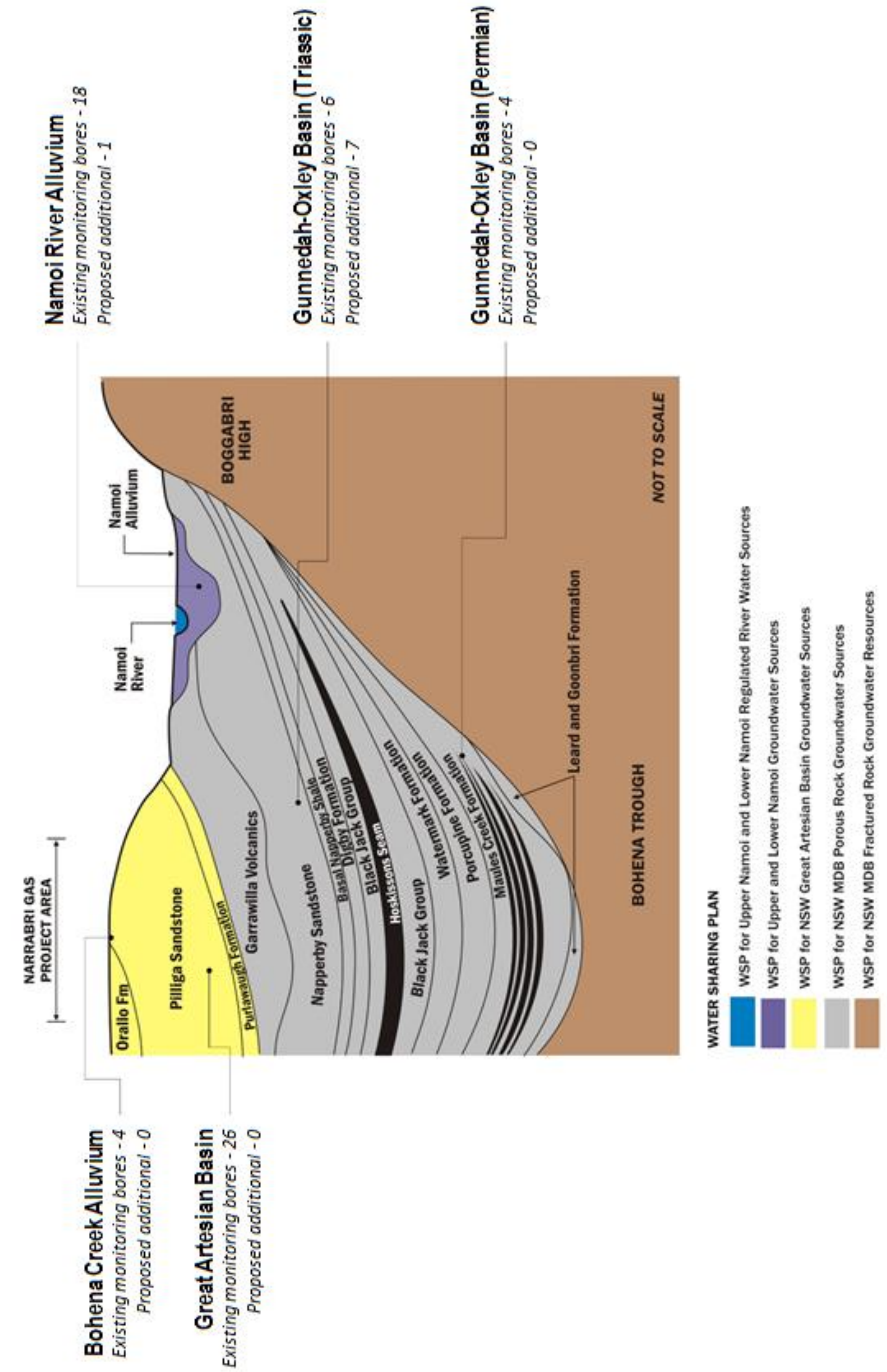

Figure 3-7 Comparison of nominated groundwater monitoring network against baseline monitoring

3.3 Surface water

3.3.1 Overview

Where surface water monitoring sites are located outside the area of the NGP operations, relevant access agreements or permissions will be required to enable monitoring activities to take place. Where these access agreements or permissions are not granted, alternative monitoring locations will be sought, if appropriate. For the purpose of ongoing monitoring, it is assumed the surface water facilities that have historically been monitored and maintained by DPI Water will continue under the same arrangement.

Whilst every effort will be made to undertake the required monitoring at nominated locations, there may be occasions where it is not possible to access these locations due to health and safety considerations. In these circumstances alternative arrangements will be made, where possible.

3.3.2 Diversions of surface water

Surface water diversion data collected annually by DPI Water, will be reviewed and incorporated in the water monitoring program for the following purposes:

- Assessing consumptive use trends within the context of trends in climate and stream flow, and to assist in assessing the status of watercourse reaches identified as being losing reaches (see Figure 2-2)
- Assessing the volumes managed releases to Bohena Creek from the proponent's water treatment plant within the context of the volumes of water diverted for consumptive use, particularly downstream from the confluence of Namoi River and Bohena Creek confluence.

3.3.3 Surface water monitoring network

3.3.3.1 DPI Water monitoring sites

Three stream flow-gauging stations maintained by DPI Water are nominated for incorporation into the NGP regional surface water monitoring program. One station is located on Bohena Creek and two stations are located on the Namoi River (see Figure 3-8)Figure 3-8.

A total of six water quality monitoring sites maintained by DPI Water are also nominated as part of the regional surface water monitoring program. Four of the nominated water quality sites are located on Bohena Creek and two are located on the Namoi River.

The rationale for selecting these locations is provided in the next section.

3.3.3.2 Nominated NGP surface water monitoring

The purpose of the surface water monitoring network is to identify potential adverse impacts to surface water flows and water quality that may be an effect of the NGP.

Table 3-7 presents details of the nominated surface water monitoring locations for the NGP. Listed in the table are the monitoring requirements for each location, the parameter to be measured, the form of measurement, the management objective to be achieved and the source of baseline data for each site. All nine of the nominated monitoring locations are maintained by DPI Water.

The following rationale is applied in selecting the surface water monitoring locations:

- Flow gauging –
  - one station on Bohena Creek to measure flows downstream of the proposed location for managed releases
  - two stations on the Namoi River, immediately upstream and downstream of the confluence with Bohena Creek, to assess potential effects of flow in Bohena Creek on flow in the Namoi River
- Water quality –
  - four stations on Bohena Creek, one immediately upstream and three downstream of the proposed managed release, to assess potential changes in water quality immediately downstream of the proposed managed release and prior to mixing of Bohena Creek water with Namoi River water (one of these stations is location with the flow gauging station on Bohena Creek)
  - two stations on Namoi River at the same locations as the nominated flow gauging stations, to assess potential changes in water quality immediately upstream and downstream of the confluence with Bohena Creek.

Table 3-7 Monitoring program details - surface water

Location	Parameter	Form of measurement	Management Objective [1]	Baseline / control data
419003 419039 419905	Stage height and discharge	▪ *Field measured* ⇒ stream gauge (reduced to mAHD), using calibrated loggers, converted to discharge rate ▪ *Frequency* ⇒ Continuous (recording interval set to 6 hrs)	*Quantity* a) No adverse change to stream flow regimes (timing, frequency and duration) [3] b) No adverse change to water body stage heights [3]	WBR data [2]
7103 7506 7510 7512 419003 419039	Water quality	▪ *Field measured –* ⇒ EC, pH, DO, Eh ▪ *Laboratory* ⇒ pH, salinity (as EC and TDS), major ions, and other analytes as appropriate ▪ *Frequency* ⇒ At end of discharge event to Bohena Creek, and within 5 to 7 days after end of discharge event to Bohena Creek	*Quality* a) No adverse change to existing beneficial use of surface water assets [3]	WBR data [2]

Notes:
1. Refer Section 3.2
2. CDM Smith (2016a and 2016b)
3. Other than those attributable to climate variability, treated water releases, irrigation, mining and other anthropogenic influences

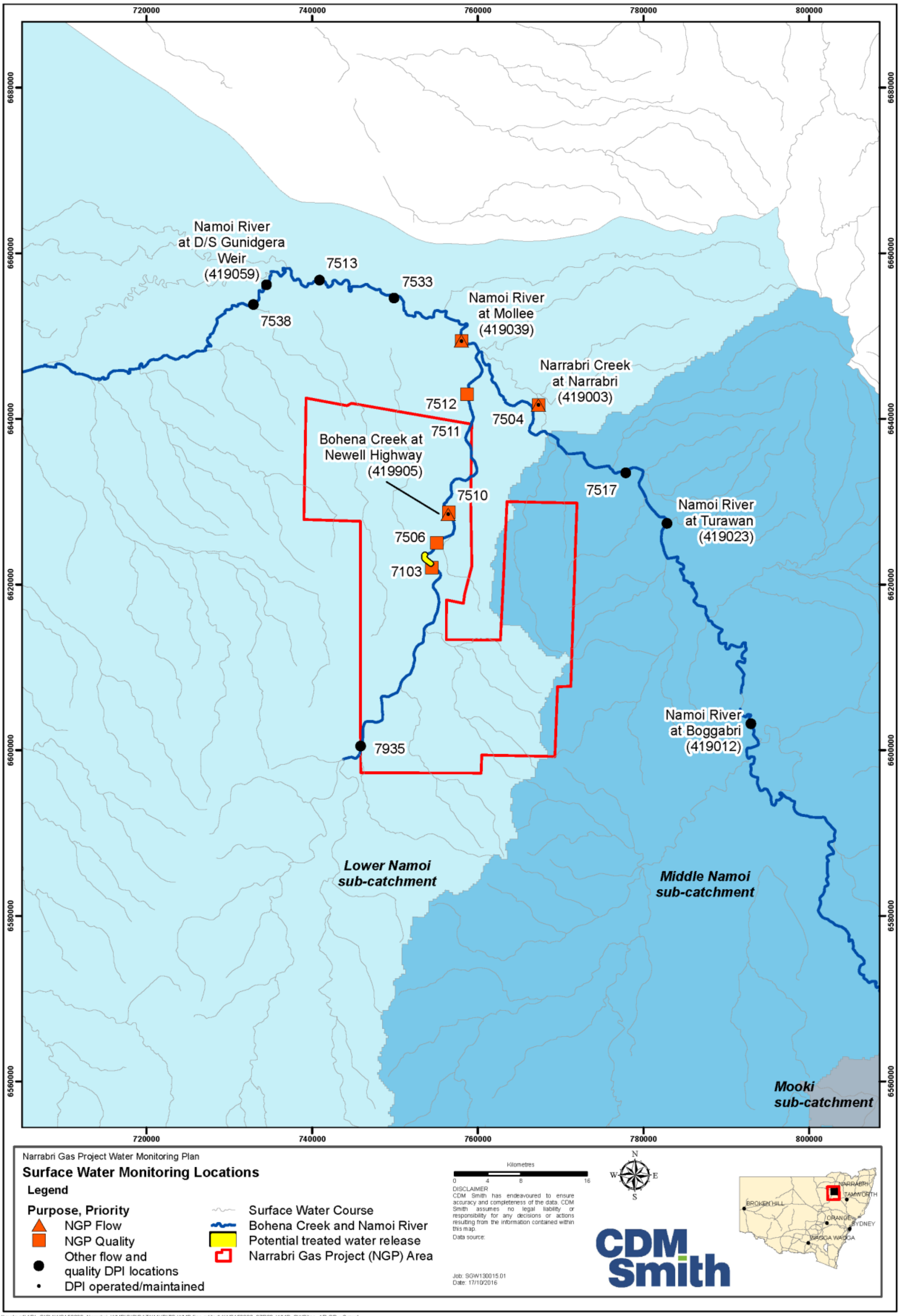

Figure 3-8 Surface water monitoring locations

3.4 GDEs

The GDE Impact Assessment (CDM Smith 2016c) concludes that the risks posed to GDEs by the project are low (CDM Smith 2016c). Specific conclusions from the GDE Impact Assessment that inform the WMP include the following:

- No potential Type 1 GDEs (aquifers and stygofauna) are identified within the GDE study area
- Potential Type 2 GDEs (springs and base flow) –
  - No protected groundwater-dependent species or habitats are found in the study area
  - No potential Type 2 GDEs meet the definition of a high-priority GDE in NSW, and none support Matters of National Environmental Significance (MNES) defined under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
  - Maximum drawdown of the water table elevation and hydraulic head in the source aquifers for potential Type 2 GDEs is predicted to be less than 0.5 m
  - All potential Type 2 GDEs have water sources derived from either the Pilliga Sandstone aquifer or alluvial aquifers
  - The overall risk assessment score for potential Type 2 GDEs identified in the study area is low, based on low ecological values but low likelihoods of potential impacts
- Potential Type 3 GDEs (terrestrial vegetation) –
  - Two vegetation communities listed as endangered under the *NSW Threatened Species Conservation Act 1995* (TSC Act) are identified as potential Type 3 GDEs within the project area
  - Potential Type 3 GDEs source groundwater predominantly from the water table
  - Predicted drawdowns in the source aquifers due to the project are less than 0.5 m
  - The overall risk assessment score for potential Type 3 GDEs is low, based on high ecological values but low likelihoods of potential impacts.

For GDEs assessed to have low risk, the GDE risk assessment guidelines (Serov et al. 2012) recommend continued long-term monitoring.

Within this context, monitoring of potential impacts on GDEs will be accomplished through the nominated groundwater monitoring of shallow high-valued groundwater sources. Figure 3-9 presents a map of the locations of these monitoring bores. Water table elevation and groundwater pressure data collected at these locations will be used to identify potential impacts to GDEs. The monitoring program for nominated groundwater monitoring bores is outlined in Section 3.2.

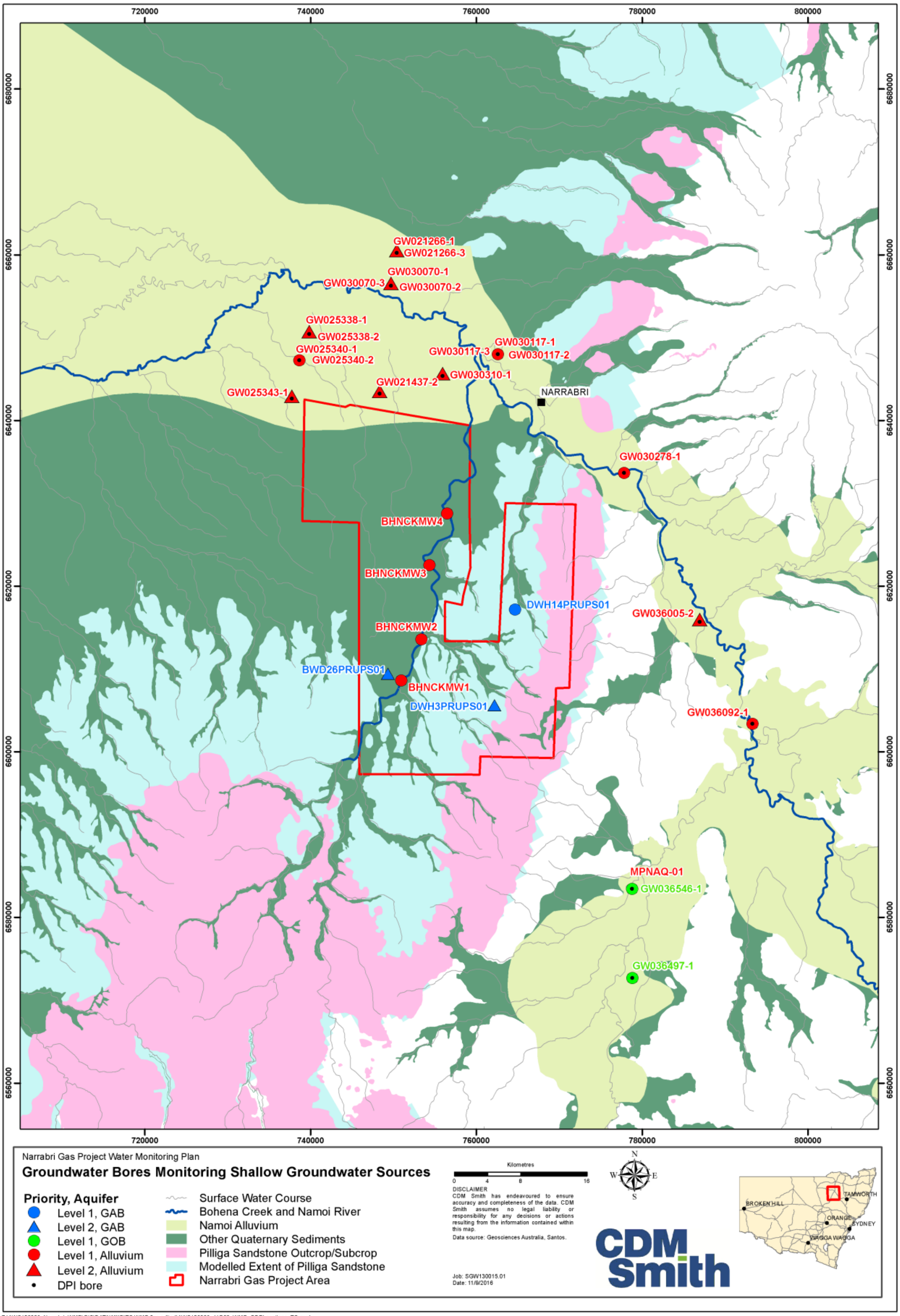

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Figure 3-9 Groundwater bores monitoring shallow groundwater sources

3.5 Land subsidence

The proponent has conducted a baseline monitoring program to quantify existing rates of deformation at the land surface within the project area using interferometric synthetic aperture radar (inSAR[5]) and has undertaken an assessment of the potential for subsidence to arise from the NGP. The subsidence assessment and associated risk assessment form part of the GIA.

The processes of compaction at depth and associated settlement of overburden are expected to take many years to become measurable at ground surface, and potential effects are predicted to be very small. The probable worst-case range of subsidence at depth within the target coal seams and their hosting strata due to depressurisation of the coal seams is predicted to be 137 mm to 205 mm of vertical compaction within the project area (CDM Smith 2016b). This magnitude of compaction at depth is likely to cause negligible settlement and subsidence at ground surface due to the large depth below ground surface of the target coal seams and the presence and thickness of structurally competent rock formations within the overburden.

The nominated monitoring of subsidence for the WMP involves continued use of inSAR as detailed in Table 3-8.

Table 3-8 Land subsidence monitoring program

Method	Measurement
Interferometric synthetic aperture radar (InSAR) survey	Every 48 days

3.6 Climate

Rainfall and temperature data sourced from the Bureau of Meteorology (BoM) will be collated for the water monitoring program to provide a climate context to groundwater recharge potential, consumptive water-use patterns and trends in aquifer storage levels observed in the hydrographs of groundwater monitoring bores.

Table 3-9 lists the parameters and the form of measurement for the nominated climate monitoring.

Table 3-9 Climate data required to complement the water monitoring program

Climate parameter	Measurement
Temperature	Average daily for each month [1]
Rainfall	Monthly [2]

Notes:
1. BoM climate station 054038 (Narrabri Airport)
2. BoM climate stations 054120 (Narrabri Bowling Club), 053030 (Narrabri West Post Office), BoM climate station 054038 (Narrabri Airport) and 054026 (Narrabri Mollee), or other stations as appropriate

[5] A radar technology used in geodesy and remote sensing to assess motion of ground surface over time

3.7 Thresholds for management action

3.7.1 NSW Aquifer Interference Policy

The AIP (NSW DPI 2012) defines impact-assessment criteria that are presented as a set of 'minimal impact considerations'. NSW has classified all WSP groundwater sources as Highly Productive or Less Productive Groundwater Sources, and the AIP sets different minimal impact considerations for these two water source types.

Within the project area the Upper and Lower Namoi Groundwater Sources and the Southern Recharge and Surat Groundwater Sources (GAB) are classified as Highly Productive Groundwater Sources. The Gunnedah–Oxley Basin MDB Groundwater Source is classified as a Less Productive Groundwater Source.

The minimal impact considerations of the AIP define acceptable and potentially unacceptable changes in water table elevation, groundwater pressure and water quality, according to the following definitions of these terms:

- The water table assessment of the AIP examines the height of groundwater in parts of groundwater sources that are not confined by overlying rocks or sediments
- The water pressure assessment of the AIP describes the pressure of the groundwater in parts of groundwater sources that are confined by overlying rocks or sediments
- The water quality assessment of the AIP examines whether a change to any water quality parameter would change the water quality enough to potentially impact on current and future uses.

The 'NSW Aquifer Interference Policy Fact Sheet 4: Assessing the impact' provides an explanation of the minimal impact considerations in the AIP, including cartoons illustrating these concepts, and sets out guidance on how to apply the minimal impact considerations to evaluate the potential impacts of an aquifer interference activity.

3.7.2 NGP impact assessment criteria

Within the context of setting impact assessment criteria for the NGP, it is relevant to note that the minimal impact considerations of the AIP provide valuable guidance but are not straightforward to apply to the NGP. The objective of the monitoring program is to assist with achieving no adverse impacts on the shallow high-valued groundwater sources within the project area; however, the baseline data within the WBR (CDM Smith 2016a) already exhibit historical variations in water table elevation and groundwater pressure that exceed the AIP minimum impact considerations for Highly Productive Groundwater Sources. For example, most hydrographs within the WBR exhibit historical cumulative variations of water table elevation or groundwater pressure that exceed 2 m, and in many bores the fluctuations in levels are 5 m to more than 20 m. These historical responses are attributable to variations in climate and consumptive water-use patterns, including groundwater extractions for irrigation and municipal supply.

Consequently, application of the AIP minimum impact considerations is unable to provide a reasonable approach to assessing the potential effects from the NGP on shallow high-valued groundwater sources. Alternative thresholds for management action have been developed for this WMP that meet the intent of the AIP and are appropriate for assessment of potential impacts in the receiving environment.

3.7.2.1 Impact level assessment

The outcome of an assessment of potential impact under the AIP is either a Level 1 impact, which is considered to be acceptable, or a Level 2 impact that requires further investigation to assess the significance of the potential impact and need for mitigation actions.

Although groundwater modelling conducted for the GIA (CDM Smith 2016b) predicts that there will be no Level 2 impacts to high-valued groundwater sources in the project area, the concept of Level 1 and Level 2 impacts is adopted for setting impact considerations for the NGP. Thus, the WMP is designed to detect the threat of unexpected Level 2 impacts should they occur, noting again that none are predicted. This approach is considered to address uncertainty in the modelling predictions and provides a safeguard against unexpected effects from the project on water assets.

Consistent with the AIP's concepts of impact levels, the groundwater monitoring network has the following focus:

- Level 1 monitoring locations provide a basis for early detection of possible effects arising from the NGP that may propagate to high-valued water resources utilised by potentially sensitive receptors. They are designated as Level 1 monitoring locations in the sense that Level 1 impacts are predicted at these locations -
  - higher frequency monitoring will occur at Level 1 monitoring locations
- Level 2 monitoring locations, in association with Level 1 locations, provide a basis for further studies to assess situations in which the condition of a water resource utilised by a potentially sensitive receptor is likely to be adversely affected by the NGP. These locations are designated as Level 2 in the sense that monitoring data are to assist with evaluating if a Level 2 impact has or is likely to occur –
  - lower frequency monitoring will normally occur at Level 2 monitoring locations
  - more frequent monitoring may be considered if unexpected trends are observed at Level 1 monitoring locations.

The surface water monitoring network has not been separated into Level 1 and 2 categories.

3.7.2.2 NGP impact considerations

The nominated response triggers and threshold levels for management actions for the NGP are listed in Table 3-10 and Table 3-11. The intent of the WMP is to use response triggers and threshold levels that as far as possible are consistent with the concept of Level 1 and Level 2 impacts in the AIP.

The response triggers in Table 3-10 are summarised as follows:

- Level 1 monitoring is the default situation in all groundwater sources
- The nominated Level 1 response trigger for Highly Productive Groundwater Sources is based on exceedance of the water production volume published in the EIS, and occurs if the realised cumulative water production exceeds the cumulative water production simulated in the GIA for three or more consecutive years –
  - the Level 1 response trigger defined by the cumulative water production simulated in the GIA is therefore a set of fixed values for the life of project (see Table 3-12)

- the Level 1 trigger is designed to accommodate year-to-year departures in water production relative to the published water curve in the EIS by permitting up to two consecutive years of cumulative exceedance
- response triggers are not defined for the water table and groundwater pressure in Highly Productive Groundwater Sources (as they are in the AIP) due to expected large variations in these quantities that are unrelated to the project (see Section 3.7.2)

- Level 2 monitoring is triggered in all groundwater sources if a Level 2 trigger is exceeded in the Triassic Age strata of the Gunnedah-Oxley Basin (Upper Black Jack Group, Digby Formation and Napperby Formation)
- The nominated Level 2 response trigger in the Gunnedah-Oxley Basin is based on exceedance or likely exceedance of the maximum drawdown for these strata predicted in the GIA –
  - the Level 2 response trigger defined by exceedance of maximum drawdown simulated in the GIA is therefore a set fixed values for the life of project (see Table 3-13)
  - the predicted maximum drawdown at some monitoring locations is less than 0.5 m (the adopted predictive precision of the modelling) in which case a trigger value of 0.5 m is proposed.

Table 3-10 Minimum impact considerations for NGP

Water Sharing Plan	Monitoring target	Response triggers	
		Water table	**Water pressure**
NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 (Gunnedah-Oxley Basin MDB Groundwater Source)	Gunnedah Oxley Basin Triassic Age sedimentary rocks	N.A.	**Level 1** – three or more consecutive years in which cumulative water production exceeds cumulative water production published in the EIS **Level 2** – pressure decline in Triassic Age strata exceeding or likely to exceed the predicted maximum drawdown [1]
Upper and Lower Namoi Groundwater Sources 2003 (Upper and Lower Namoi Groundwater Sources)	Namoi Alluvium	**Level 1** – three or more consecutive years in which cumulative water production exceeds cumulative water production published in the EIS **Level 2** – none defined for water table or groundwater pressure, but initiated if Level 2 response is triggered for GOB Triassic Age strata	N.A.
NSW Great Artesian Basin Groundwater Sources 2008 (Southern Recharge and Surat Groundwater Sources)	Pilliga Sandstone	**Level 1** – three or more consecutive years in which cumulative water production exceeds cumulative water production published in the EIS **Level 2** – none defined for water table or groundwater pressure, but initiated if Level 2 response is triggered for GOB Triassic Age strata	

Notes: 1. Predicted using the Gunnedah Basin Regional Groundwater model in the GIA (see Table 3-13)

The nominated management actions in Table 3-11 are summarised as follows:

- If the Level 1 and Level 2 response triggers are not exceeded, then the project is on track and it follows that the magnitude of observed effects from the project is consistent with, or less than the approved magnitude of effects predicted in the EIS; this is the expected situation for the project
- The management action for the Level 1 response trigger involves updating of the groundwater modelling predictions in the GIA based on the realised volume of water production to that point in time, and an updated projection of future water production until project completion –
  - mitigation and make good actions may be required if unacceptable impacts are predicted in the high-valued groundwater sources
  - no management response will be required if the realised volume of water production does not exceed the published water curve in the manner described by the Level 1 response trigger
- Exceedance of the Level 2 response trigger would indicate that an unexpected impact has, or is likely to occur in the Triassic Age strata of the Gunnedah-Oxley Basin, thereby requiring additional investigations to ascertain if this impact is likely to propagate to the shallower high-valued groundwater sources in the project area
  - mitigation and make good actions may be required if unacceptable impacts occur in the high-valued groundwater sources.

No threshold levels for water quality are nominated as the project does not pose a risk to water quality in high-valued water sources in the GAB and alluvial aquifers (see Section 3.2.3.4). Notwithstanding this lack of potential to cause an impact, the WMP includes water quality monitoring in aquifers to assist with interpretation of water table and groundwater pressure information.

Table 3-11 refers to Steps 1 to 11 of the WMP implementation. This procedure and the eleven steps are described in Section 4.2.

Table 3-11 Level 1 and 2 management actions

Threshold level	Purpose	Action
Level 1	Update groundwater impact predictions	▪ Update the modelling predictions in the GIA based on the realised volume of water production and an updated forecast of water production until project completion ▪ Document the updated modelling predictions, refer to regulators and review water licensing requirements ▪ Review the significance and acceptability of predicted impacts ▪ Consider implementation of make good provisions [2] if necessary ▪ Review the adequacy of monitoring program, revise and update the WMP if necessary
Level 2	Early detection and initiation of further investigations and possible make good provisions	▪ Undertake targeted studies (which may include field investigations, data analysis and modelling) to identify potential causes of variance from the predicted response ▪ Identify requirement for implementation of management strategies ▪ Consider implementation of make good provisions [2] if necessary ▪ Document and report the new findings ▪ Review the adequacy of monitoring program, revise and update the WMP if necessary ▪ Follow the WMP implementation Steps 1 to 11 (see Section 4)

Notes:
1. Gunnedah Basin Regional Groundwater model developed for the GIA
2. Make good provisions for existing bore owners may involve:
   - Lowering the pump setting in the bore
   - Increasing the water column above the pump
   - Improving the pressure at the bore head, if the bore is artesian (e.g. new headworks and piping)
   - Changing the type of pump to suit the lower water level in the bore
   - Deepening the bore to allow it to draw groundwater from a deeper part of the aquifer
   - Bore reconditioning to improve hydraulic efficiency
   - Drilling a new bore
   - Other modification to the bore that will mitigate the impairment
   - Providing an alternate water supply
   - Providing compensation, which could be monetary, for impairment of the water supply

Table 3-12 Nominated Level 1 response trigger

Year of field development plan	Simulated cumulative water production [GL] not to be exceeded in three or more consecutive years
1	2.6
2	5.9
3	9.4
4	12.4
5	14.2
6	15.9
7	17.3
8	18.8
9	20.1
10	21.5
11	23.3
12	25.0
13	26.7
14	28.4
15	29.9
16	31.3
17	32.7
18	34.0
19	35.2
20	36.2
21	36.7
22	37.0
23	37.2
24	37.3
25	37.5

Table 3-13 Nominated Level 2 response trigger in Triassic Age strata of the Gunnedah-Oxley Basin

Monitoring bore	Formation	Predicted maximum drawdown [m]	Predicted time of maximum drawdown [y]
GW036546-3	Upper Black Jack Group	< 0.5	571
DWH8AQGDGY01	Digby Formation	2.4	191
GW036546-1	Digby Formation	< 0.5	571
MPDGY-01	Digby Formation	< 0.5	371
MPDGY-02	Digby Formation	< 0.5	821
MPDGY-03	Digby Formation	3.2	161
TULPRDGY02	Digby Formation	1.2	201
GW036497-1	Napperby Formation	< 0.5	1021
GW036546-2	Napperby Formation	< 0.5	621
MPNAP-01	Napperby Formation	< 0.5	371
MPNAP-02	Napperby Formation	< 0.5	821
MPNAP-03	Napperby Formation	1.9	191
MPNAP-04	Napperby Formation	1.5	151
TULPRNAP01	Napperby Formation	0.7	221

3.8 Data Management and Quality Control

The proponent uses EQuIS to manage the quality and integrity of hydrological data collected for the NGP. EQuIS is recognised as the world's most widely used software for environmental data management.

An overview of the proponent's data management system is presented as Appendix D. The management system will guide the implementation of the WMP, covering all stages of data management from planning through to data collection and evaluation to archiving.

Key steps in these procedures include:

- Setting of objectives for data collection
- Planning and scheduling of sampling activities
- Definition of field and laboratory protocols
- Data entry and automated completeness checking
- Data verification, validation and corrective action procedures
- Data storage, backup and retrieval
- Notification of threshold exceedances

Section 4 Implementation and Reporting

The nominated monitoring program is focused on water assets and receptors that are likely to be most sensitive to changes in water quantity and quality. The monitoring effort is commensurate with the low level of risk identified in the GIA and aims to provide early detection of potentially adverse changes in water resource condition.

Implementation of the WMP involves collecting data and information to inform assessment of whether management objectives are being achieved, and triggering higher-level responses if management objectives are not being achieved.

4.1 Trend analysis

The implementation procedure for the WMP is based on the concept of identifying trends in the monitoring data as a method for assessing cause and effect, more specifically, attributing observed changes in water resource conditions to their likely causes (e.g., climate, consumptive groundwater extractions, mine dewatering, coal seam gas production or a combination of these stressors).

Within the context of the WMP, the term trend is used in its normal sense to mean the general direction in which a monitored quantity is developing or changing over time. More formally, mathematical techniques can be applied to 'fit' trends to data and to evaluate the statistical significance of the fitted trend, which can vary from not significant to highly significant. For example, fitting a straight line to a series of groundwater pressures taken over time is known as fitting a linear trend to the data, where the slope of the line indicates the rate at which pressure has been changing. If the same procedure is applied to other data sources, such as rainfall and consumptive water use, then matching trends in those data sets may suggest a causal link, while an absence of matching trends might suggest some other factor is affecting the groundwater pressure.

Trend analysis over the life of the WMP will assist in understanding the baseline conditions for the project as well as understanding groundwater system responses to coal seam gas production.

4.2 Implementation steps

There are eleven steps involved in implementing the monitoring program. A flowchart of the implementation steps is shown in Figure 4-1 and further description of each step is provided in the sections below.

Data acquisition occurs in Step1, analysis and evaluation of acquired data occurs in Steps 2 to 6, and adaptive management is achieved in Steps 6 to 11.

Step 1. Monitoring event

Undertake the monitoring event (see Section 3) including recording of field observations and data, and following appropriate sampling procedures and protocols.

Step 2. Data analysis and evaluation

As soon as practicable following the monitoring event and receipt of laboratory or other testing data:

- Complete and document quality assurance (QA) and quality control (QC) and, if an issue is identified with regard to QA/QC, undertake the monitoring event again
- Collate leading indicator data and information for monitoring in Triassic Age strata within the Gunnedah-Oxley Basin (Figure 4-1) and evaluate trends in resource condition (quantity and quality). Evaluate propagation of reduced groundwater pressures in units located vertically between the target coal seams for gas production and high-valued groundwater sources in the GAB and alluvial aquifers.
- Collate lagging indicator data and information in the shallow high-valued groundwater sources and evaluate trends in resource condition (quantity and quality).

Step 3. Possible adverse trend identification

Analyse acquired datasets for evidence of significant trends.

If there are no significant data trends that indicate the NGP impact considerations have been, or are likely to be exceeded then the monitoring program continues as scheduled (i.e., return to Step 1). Otherwise, if there is a trend toward a possible future exceedance then proceed to Step 4.

Step 4. Possible adverse trend confirmation

Review possible causes of the observed trend. If reasons for the observed trend are not apparent, undertake an additional round of monitoring (Step 1), followed by data analysis and evaluation (Step 2) and trend analysis (Step 3) to confirm whether or not the observed trend is attributable to the NGP. It may be that a number of additional rounds of monitoring will be required to confirm a data trend exists that requires further attention.

If necessary, data collected from the nominated Level 1 monitoring network (see Section 3.7) can be supplemented by monitoring at Level 2 groundwater monitoring location to provide additional data to assist in trend confirmation.

Step 5. Assess trend impacts

Assess the confirmed trend, together with other relevant information, to identify whether the level of threat posed by the change in resource condition poses an unacceptable risk.

Step 6. Analysis of new information

If the Step 5 assessment concludes that the observed trend does not pose an unacceptable risk to water-dependent assets or receptors then the WMP will need to be revised accordingly (Step 9), otherwise Step 7 will need to be addressed.

Step 7. Identify and implement additional investigations

Depending on the assessment outcomes, it may be necessary to implement further works, such as groundwater or surface water modelling, on-ground investigations (e.g., establishing additional monitoring infrastructure), collection of additional climate and consumptive use data, detailed risk assessment, receptor exposure assessment or any combination of these. The investigation would be used to identify the level of risk posed by the trend.

Step 8. Analysis of new information

If analysis of the data and information arising from the additional investigations (Step 7) identifies the level of risk posed to water assets and potential GDEs by the observed change in water resource or land condition (quantity, quality, subsidence) are acceptable then the WMP will need to be revised (Step 9). If, however, the level of risk posed by the observed change in condition is considered unacceptable then additional work will be required to address the situation (Step 10).

Step 9. Update WMP

If necessary (e.g., additional monitoring infrastructure is commissioned) update the WMP to be consistent with changes in the monitoring requirements associated with additional assessments undertaken as part of Steps 5 and 7, or new management strategies implemented as part of Step 11.

Step 10. Inform regulators

In the unlikely event that analysis of the data and information arising from the implementation procedure (Steps 5 and 7) identifies that the level of risk posed to water-dependent assets or receptors by the observed change in resource condition is unacceptable, inform the appropriate regulatory agencies of the nature of the potential adverse effect. Confer on potential management strategies to remove or mitigate the level of risk posed by the change in resource condition.

Step 11. Implement agreed management strategy

Implement the agreed management strategy, which may involve make good provisions (e.g., engineering solutions, operational solutions or both). Following implementation of the agreed management strategy, and undertaking additional investigations (Step 7) update the WMP to be consistent with these changes.

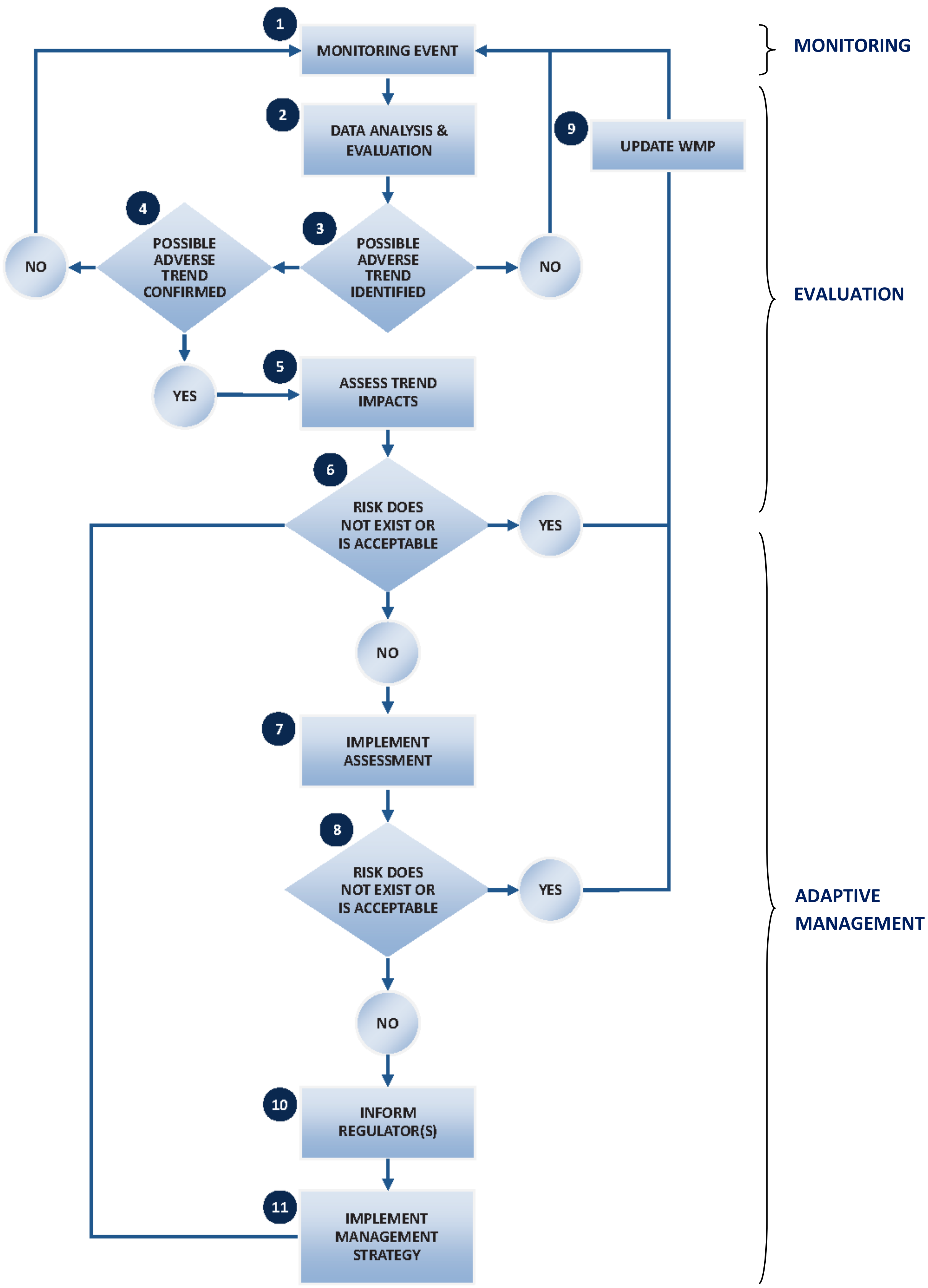

Figure 4-1 WMP implementation procedure

4.3 Reporting

4.3.1 Annual reporting

Each year a concise report will be prepared that outlines the details of the monitoring completed during the preceding year, including all measurements undertaken for the monitoring program, synthesis of water sampling and analytical results and an evaluation of these data. The purpose of the report will be to catalogue the monitoring results and review observed changes in the condition of water sources, if discernible, against those predicted in the GIA (CDM Smith 2016b). The Level 1 trigger will be checked at the time of each annual report. Thus, a Level 1 exceedance could be triggered in any year that has two preceding years of cumulative water production exceeding the water curve published in the EIS (see Section 3.7.2.2).

4.3.2 Periodical reporting

Periodically, following the timing proposed below, the annual reports will be collated for additional review. If there is an identified trend in the observed groundwater responses that indicate a Level 2 trigger is, or is likely to be exceeded, then a more detailed report will be prepared, which may involve updating of the numerical model with data from the field development program (e.g. realised well locations and water production volumes) and further predictive simulations to assess trends.

It is proposed that the first periodical report will be prepared after the first three years of operations, and then subsequent reports will be prepared every five years following (i.e. periodical reporting after 3 y, 8y, 13y, 18 y and 23y).

An important component of the periodical reviews, if appropriate, will be assessing the sufficiency of monitoring and identifying whether additional monitoring infrastructure is required. The WMP will be updated to reflect changes in the monitoring program that result from the periodical reviews.

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Appendix A – Disclaimer and limitations

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If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.

Appendix B - Baseline groundwater monitoring

Table B-1 Santos groundwater monitoring bore details

Bore	Parameter [1]		Lithological unit	WSP [1]	Screened interval (mBGL) [2] Top	Screened interval (mBGL) [2] Bottom
DWH8AQGMCF04	Pressure	●	Maules Ck Fm	Murray-Darling Basin Porous Rock Groundwater Sources	855 [3]	
	Quality					
DWH8AQGPOR03	Pressure	●	Porcupine Fm	Murray-Darling Basin Porous Rock Groundwater Sources	780 [3]	
	Quality					
BWD6	Pressure	●	Porcupine Fm	Murray-Darling Basin Porous Rock Groundwater Sources	648 [3]	
	Quality					
DWH8AQGDGY01	Pressure	●	Digby Fm	Murray-Darling Basin Porous Rock Groundwater Sources	505 [3]	
	Quality					
TULPRDGY02	Pressure	●	Digby Fm	Murray-Darling Basin Porous Rock Groundwater Sources	214	217
	Quality	●				
TULPRNAP01	Pressure		Napperby Sst	Murray-Darling Basin Porous Rock Groundwater Sources	124	130
	Quality	●				
GW036546-1	Pressure	●	Digby Fm	Murray-Darling Basin Porous Rock Groundwater Sources	80	82.5
	Quality					
BWD28QGPUR01	Pressure	●	Purlawaugh Fm	Great Artesian Basin Groundwater Sources	293 [3]	
	Quality					
DWH14PRPUR03	Pressure	●	Purlawaugh Fm	Great Artesian Basin Groundwater Sources	263	269
	Quality	●				
BHN14PRUPS02	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	212	218
	Quality	●				
BWD26PRLPS02	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	140	146
	Quality	●				
BWD26PRUPS01	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	95	101
	Quality	●				
BWD27PRLPS03	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	198	204
	Quality	●				
BWD27PRUPS02	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	94	100
	Quality	●				
BWD28QGLPS01	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	247 [3]	
	Quality	●				
BWD28QGUPS01	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	81 [3]	
	Quality	●				
DWH14PRLPS02	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	213	219
	Quality	●				
DWH14PRUPS01	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	63	69
	Quality	●				
DWH3PRLPS02	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	150	156
	Quality	●				
DWH3PRUPS01	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	77	83
	Quality	●				
NYOPRUPS02	Pressure	●	Pilliga Sst	Great Artesian Basin Groundwater Sources	207	213
	Quality	●				
BHN14PRORA01	Pressure	●	Orallo Fm	Great Artesian Basin Groundwater Sources	109	115
	Quality	●				
NYOPRORA01	Pressure	●	Orallo Fm	Great Artesian Basin Groundwater Sources	147	153
	Quality	●				

Notes:
1. ● represents groundwater pressure (head) monitoring, ● represents groundwater quality monitoring
2. Metres below ground level
3. Installed as vibrating wire piezometers

Table B-2 Proponent groundwater monitoring bore details (cont.)

Bore	Parameter [1]		Lithological unit	WSP [1]	Screened interval (mBGL) [2]	
					Top	Bottom
BHNCKMW1	Pressure		Bohena Creek Alluvium	Upper Namoi Unregulated and Alluvial Water Sources	1.8	2.3
	Quality	●				
BHNCKMW2	Pressure				1.8	2.3
	Quality	●				
BHNCKMW3	Pressure				1.5	20
	Quality	●				
BHNCKMW4	Pressure				1.5	1.7
	Quality	●				

Notes:
1. ● represents groundwater pressure (head) monitoring, ● represents groundwater quality monitoring
2. Metres below ground level
3. Installed as vibrating wire piezometers

Table B-3 DPI Water groundwater monitoring bore details[1]

Bore	Parameter [2]		Lithological unit	WSP	Screened interval (mBGL) [3]	
					Min	Max
GW036546-3	Pressure	●	Black Jack	MDB Porous Rock Groundwater Sources	87	91
	Quality					
GW036546-2	Pressure	●	Napperby Fm		27	29
	Quality					
GW036497-1	Pressure	●			18	20
	Quality					
GW030310-2	Pressure	●	Pilliga Sst		100.5	106.6
	Quality					
GW030121-3	Pressure	●			106.7	112.8
	Quality					
GW030400-1	Pressure	●			60.6	61.8
	Quality					
GW030889-1	Pressure	●			n/a	n/a
	Quality					
GW098011-1	Pressure	●			n/a	n/a
	Quality					
GW021266-4	Pressure	●	Orallo Fm		107.3	113.4
	Quality					
GW025343-2	Pressure	●	Mooga Sst		45.1	50
	Quality					
GW025338-3	Pressure	●			65.5	70.1
	Quality					
GW025340-3	Pressure	●			62.2	65.9
	Quality					
GW021266-3	Pressure	●	Namoi Alluvium	Upper and Lower Namoi Groundwater Sources	60	70.1
	Quality					
GW021437-2	Pressure	●			47.9	49.4
	Quality	●				
GW025338-1	Pressure	●			25.9	30.5
	Quality	●				
GW025338-2	Pressure	●			46.9	50.6
	Quality					
GW025340-1	Pressure	●			25.6	31.7
	Quality					
GW025340-2	Pressure	●			35.4	41.5
	Quality					

Notes:
1. Bolded bore names are located within the project area, unbolded bore names occur regionally
2. ● represents groundwater pressure (head) monitoring, ● represents groundwater quality monitoring
3. Metres below ground level

Table B-3 DPI Water groundwater monitoring bore details (cont.)

Bore	Parameter [1]		Lithological unit	WSP	Screened interval (mBGL) [2]	
					Min	Max
GW025343-1	Pressure	●	Namoi Alluvium	Upper and Lower Namoi Groundwater Sources	35.1	38.1
	Quality	●				
GW030070-1	Pressure	●			12.2	18.3
	Quality	●				
GW030070-2	Pressure	●			38.1	44.2
	Quality	●				
GW030070-3	Pressure	●			57.9	64
	Quality	●				
GW030310-1	Pressure	●			34.1	40.2
	Quality	●				
GW030117-1	Pressure	●			15.2	21.3
	Quality	●				
GW030117-2	Pressure	●			36.6	39.3
	Quality	●				
GW030278-1	Pressure	●			24.7	27.7
	Quality	●				
GW036005-2	Pressure	●			76	78
	Quality	●				
GW036092-1	Pressure	●			19.8	22.8
	Quality					
GW021266-1	Pressure				n/a	n/a
	Quality	●				
GW030117-3	Pressure				n/a	n/a
	Quality	●				

Notes: 1. ● represents groundwater pressure (head) monitoring, ● represents groundwater quality monitoring
2. Metres below ground level

Appendix C – Hydrogeochemical data ranges

Table C-1 Monitoring program – groundwater signatures

Constituents	Groundwater source indicative values					
	Quaternary		Triassic-Cretaceous		Permian	
	Bohena Alluvium	Namoi Alluvium	Orallo	Pilliga	Black Jack	Maules Creek
F (mg/L)	<0.1	<1	<0.5	<1	3	5-10
K (mg/L)	<3	<8	<20	~30	57	50-300
Ba (mg/L)	0.5	<0.1	0.2	0.2	6	na
B (mg/L)	<0.1	<0.2	0.05	0.1	0.4	0.4
Li (mg/L)	<0.2	<0.02	0.04	0.07	2.2	3.6
Sr (mg/L)	<0.5	<0.3	0.1	0.2	4	0.5 - 5
Mn (mg/L)	0.5	<0.1	<0.1	<0.1	<0.01	<0.01
SO_4 (mg/L)	<1	<60	<1	<3	<25	<1-800
EC (µS/cm)	100-500	400-3000	1300	300	6000	12000
SAR (mol ratio)	1-2	1-2	3-35	4-30	12-500	140-380
HCO_3:Cl (mol ratio)	<2	2-15	1-8	1-12	1-16	1-6

Appendix D – Proponent data management system